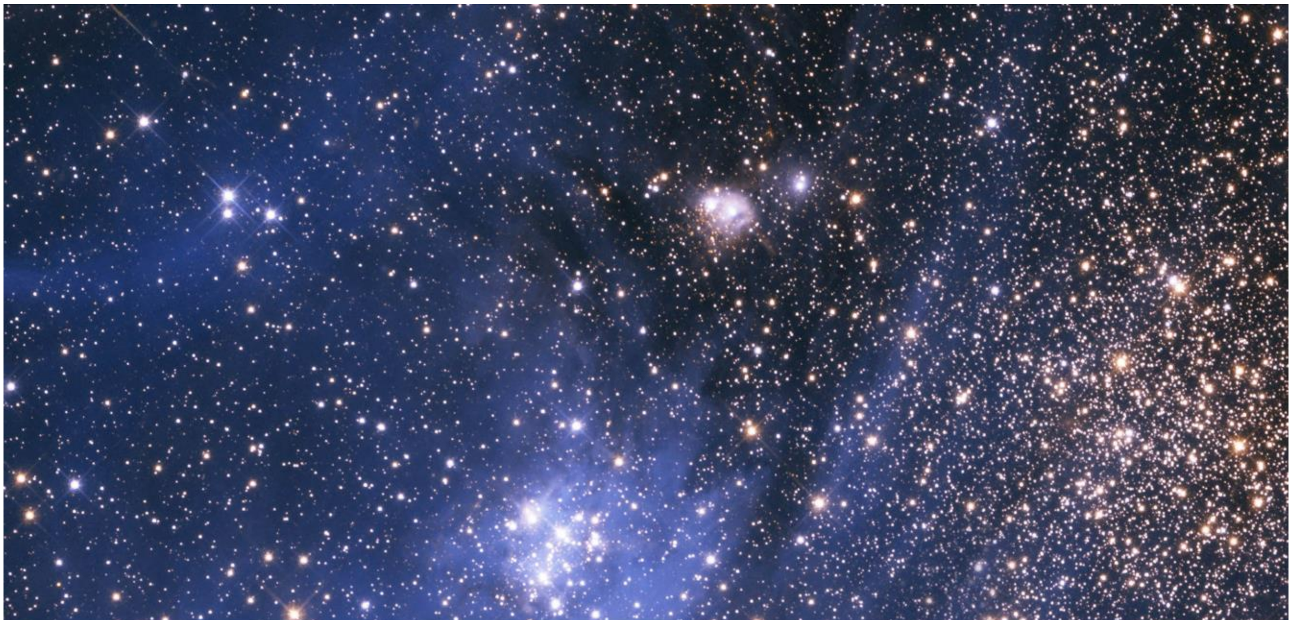

Self-Study for the 2017 External Review of the Department of Astronomy and McDonald Observatory at The University of Texas at Austin

DEPARTMENT OF ASTRONOMY AND MCDONALD OBSERVATORY
SELF-STUDY FOR THE 2017 EXTERNAL REVIEW
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Section I. Executive Summary of Self-Study

The Astronomy program at UT Austin, comprised of the Department of Astronomy and McDonald Observatory, plays a central role in the University's mission to achieve excellence in research, education, and public outreach. We advance frontier research that is revolutionizing our understanding of the Universe and our place in it. We are among the best programs in the nation, and we aspire to become the top US public university for Astronomy and to rank amongst the top several elite institutions globally.

We present this self-study as part of the external review of the Astronomy program scheduled in March 2017. It provides an opportunity to present our strategic vision plan (Section III), and an assessment of our strengths, weaknesses, and opportunities (Section IV). Our strategic goals include the following:

- Hire the best new faculty members, at an average rate of one per year over the next decade, to counter the large wave of ongoing retirements. Grow in frontier research areas that build on our unique strengths, while being open to new/interdisciplinary areas of great potential.
- Recruit the best graduate students and postdocs to maintain a thriving research program and compete with top Astronomy departments in the nation.
- Continue to provide researchers with access to cutting-edge research facilities: McDonald Observatory, the Texas Advanced Computing Center, and the Giant Magellan Telescope (GMT), one of the world's largest future optical/infrared telescopes.
- Support the GMT toward a successful completion and leverage its transformational potential to attract world-class faculty, researchers, and students.
- Explore research initiatives that give us a scientific edge over other GMT partners, such as complementary theoretical work and far-infrared/sub-millimeter observations.
- Constrain the evolution of dark energy with implications for fundamental physics and the fate of the Universe.
- Develop cutting-edge instrumentation for the Hobby-Eberly Telescope, GMT, and McDonald Observatory.
- Offer a research-centered experiential undergraduate program that engages students in STEM and transforms them into scientists, innovators, and leaders.
- Lead a high-impact education and public outreach program that impacts millions of people annually, brings scientific ideas to society and draws diverse young people into STEM fields.
- Foster a climate of inclusion and excellence that promotes the broader participation of women and other under-represented groups in science.
- Leverage philanthropy, external relations, and support groups to advance our mission.

With the implementation of these goals, we will be a major player in the quest to answer the oldest and deepest of questions: How did the Universe begin in a Big Bang and what came before? When and how did the first stars, planets, galaxies, and black holes form? How did they evolve into their present-day state? How do stars evolve and die, producing neutron stars, black holes, and the chemical elements necessary to form planets and life? What are the demographics of exoplanets and what are the opportunities for life outside our Solar System? What is the nature of the dark matter and dark energy that make up most of the Universe? What is the ultimate fate of the Universe?

Section II. Introduction

II.A. The University and College of Natural Sciences

The University of Texas at Austin (UT Austin), founded in 1883, is the flagship institution of the University of Texas System and is ranked among the largest and best research universities in the country. It has a vibrant community of more than 51,000 students and and 3,090 teaching faculty within 18 colleges and schools. UT Austin is one of the top 20 public universities according to US News & World Report, with more than 15 undergraduate programs and more than 40 graduate programs ranked in the top 10 nationally.

Established in 1970, the College of Natural Sciences (CNS) is the largest college at UT-Austin and one of the largest colleges of science in the United States. As of fall 2016, CNS is home to 10,975 undergraduates, 1,229 graduate students, 700 tenure and non-tenure track faculty members, and 1,200 staff. It hosts 12 departments (Astronomy, Chemistry, Computer Science, Human Development and Family Sciences, Integrative Biology, Marine Science, Mathematics, Molecular Biosciences, Neuroscience, Nutritional Sciences, Physics, and Statistics and Data Sciences). The College has an average annual extramural funding of $116 million (average of 2011-14) and hosts 12 Top-Ten Ranked Programs according to US News & World Report 2015. CNS is committed to providing its students with world-class, research-based science education, to discovering important new knowledge through research, and to creating an environment that fosters the economic and technological development of Texas and the US.

II.B. The Astronomy Department and McDonald Observatory

The Department of Astronomy and McDonald Observatory are distinct, but complementary units within the College of Natural Sciences of The University of Texas at Austin. The Department and Observatory work synergistically to promote excellence in research, education, and public outreach. We will use the shorthand term “Astronomy program" to refer to the combination of the two units.

The Astronomy Department was initiated in 1962 with the arrival of Harlan Smith, and it had five founding faculty members by 1963. The Department grew rapidly in the 1970s and early 1980s, but then suffered a prolonged hiring drought that ended in 2000. Over the last 16 years, the Department has hired ten additional top-tier faculty members, but also experienced significant attrition, and is currently facing a large wave of retirements (Section IV.A). As of December 2016, the Astronomy Department comprises over 200 members, including 19.5 tenured/tenure-track (TTT) faculty members (with one faculty member on 50% phased retirement), two research professors (holding a joint appointment with the Observatory), four Emeritus faculty members, one lecturer, 13 postdocs, 35 graduate students, 129 undergraduate majors, and four main support personnel.

McDonald Observatory staff is comprised of ten PhDs with responsibilities for Observatory work, eleven PhDs performing independent research, 96 support personnel, both in Austin and at the Observatory site in west Texas, and a number of research associates and affiliates with less than 25% time appointments.

Figure IV-1: In September 2016, faculty, research scientists, and the graduate student and postdoc representatives attended our first strategic retreat in the last nine years. The retreat was organized jointly by the Department of Astronomy and McDonald Observatory, and allowed us to brainstorm on ways to bolster our standing as one of the best Astronomy programs in the nation and build a stronger sense of community. *(Photo credit: Lara Eakins)*

The Department and Observatory jointly lead a top-tier research program which spans nearly every area of modern astronomy, including cosmology, galaxy formation and evolution, black holes, dark matter, dark energy, star formation and stellar evolution, chemical evolution, planetary systems, and instrumentation. Research led by the Astronomy program contributes to UT Austin's 2017 ranking in space science as #6 among US public universities by US News & World Report (Table III-1). Research highlights from faculty and research scientists are presented in Section V, and their curriculum vitae are provided in the Appendix (Section XII).

We aspire to become the top state university for Astronomy in the country. To move toward that goal, we need to recruit the very best intellectual capital exemplified by world-class faculty, research staff, graduate students, and postdocs, and provide them with the resources and facilities they need to excel. We outline our strategic plan in Section III.

Our faculty members and research staff regularly secure observing time on a wide array of competitive public facilities, including optical/infrared telescopes, such as Keck, Gemini, Hubble, Spitzer, Kepler, as well as far-infrared/radio facilities, such as Herschel, Atacama Large Millimeter/submillimeter Array (ALMA), and the Karl G. Jansky Very Large Array (VLA). Many of our researchers play a leading role in high-impact international science collaborations, which are conducting large observational surveys, such as galaxy evolution surveys with NASA's Hubble Space Telescope (e.g., GOODS, GEMS, STAGES, the HST Treasury Survey of Coma, CANDELS); NASA's Kepler/K2 missions to explore the structure and diversity of planetary systems; NASA's c2d Spitzer legacy program to probe the evolutionary sequence ranging from molecular gas cores to planet-forming disks. Some researchers are also playing key roles in shaping future NASA observatories (e.g., JWST, WFIRST, LUVOIR, and the Origins Space Telescope). Eight of our faculty members are theorists, exploring everything from planets to the furthest reaches of the Universe. Many of them make active use of supercomputer facilities.

The UT Astronomy program also has unique in-house resources and strengths, which give us a competitive advantage over many other departments. Our researchers have generous access to UT's McDonald Observatory and the Texas Advanced Computing Center (TACC), as well as guaranteed future access to the next-generation Giant Magellan Telescope (GMT). Our program also benefits from the strong synergy between our observational and theoretical efforts.

McDonald Observatory is responsible for providing cutting-edge observational facilities and instrumentation (Section IX). It hosts the upgraded 10-m Hobby-Eberly Telescope, the 2.7-m Harlan J. Smith Telescope, the 2.1-m Otto Struve Telescope, and several smaller telescopes; and innovative new instrumentation, such as the Visible Integral-field Replicable Unit Spectrograph (VIRUS) and the Immersion Grating INfrared Spectrometer (IGRINS). Through its role as a node host, UT also has access to the Las Cumbres Observatory (LCO) network. The upgrade of the HET to a wide-field telescope with highly capable instrumentation that is aligned with frontier science questions is an important and ongoing development that is discussed further in Section IX. The Observatory is committed to offering observing facilities that enable cutting-edge research and attract excellent faculty, students, and research staff to the UT Astronomy program.

TACC designs and operates some of the world's most powerful computing resources (Section IV.C). UT astronomers can secure significant computational resources on TACC by using allocation channels available only to UT scientists, in addition to securing resources through open competitive applications. Theorists use TACC to run, analyze, and visualize state-of-the-art simulations while observers use TACC for data-intensive projects, taking advantage of its large (more than 100 petabytes) dedicated user storage and advanced computing technologies.

The Astronomy program is proud to be a major founding partner in the consortium to design, construct, and operate the GMT (Section IV.C), which will be the world's largest (25.4-m) optical/infrared telescope when it begins commissioning in 2023. GMT will allow UT Astronomy to lead transformational science and attract top-level faculty and students. GMT's exquisite sensitivity and spatial resolution, coupled with its large field of view, will catalyze breakthroughs on fundamental questions concerning the formation and evolution of stars, galaxies, and black holes; the opportunity for life outside our Solar System; the nature of dark energy and dark matter, and the ultimate origin and fate of the observable Universe. UT Austin has set a goal to contribute 10 percent of the construction costs (roughly $100 million) of GMT. We also contribute scientific expertise, instrumentation in the form of the high-resolution IR Echelle Spectrograph GMTNIRS, and representation on the GMT Organization Board of Directors and Science Advisory Committee.

In addition to leading a top-tier research program, the Astronomy Department also oversees the educational program for undergraduate non-science majors, astronomy majors, and graduate students. We share the beauty of science and astronomy with over 3,500 non-science majors each year, preparing them to be informed citizens for the greater benefit of society. We offer a research-centered experiential undergraduate program for our majors and believe that involvement in research is key for engaging students in STEM and transforming them into scientists, innovators, and leaders (Sections IV.E and VI). Three of our faculty members are part of the prestigious UT Academy of Distinguished Teachers. Graduate students and postdocs are vital for advancing our research and teaching mission, and we strive to provide them with broader training and mentoring to prepare them as future leaders with high scholarly, societal, and economic impact (Sections IV.B, VII, and VIII). We are committed to promoting a department culture that values inclusion and diversity (Section IV.F).

McDonald Observatory and the Astronomy Department have a far-reaching education and public outreach program. We use the immense appeal of astronomy to bring scientific literacy to society at large and draw diverse young people into STEM fields. The McDonald Observatory Visitor Center welcomes around 90,000 visitors each year and 2.3 million listeners tune into StarDate Radio daily. Annual K-12 teacher professional development workshops train 300 teachers, each of whom impacts 100 students per year. Star parties with two telescope on the UT Austin campus host 5,000 visitors a year, are designated as one of the “Gems of the University” in Signature Courses, and have won past Austin Chronicle "Best of Austin" Critics Choice Awards. The Undergraduate Astronomy Students Association provides daytime viewing opportunities with H-alpha and solar telescopes on campus and in the city. The Astronomy on Tap event, led by postdocs and graduate students, draws about 3,500 people per year in Austin to hear informal astronomy talks.

The Astronomy program benefits immensely from the support of the McDonald Observatory and Department of Astronomy Board of Visitors, and an emerging network of alumni (Section IV.H). With 240 members, our Board of Visitors is arguably the largest Astronomy Board of Visitors in the nation. It has provided invaluable advocacy and support for our program over the past forty years. In the next decade, philanthropic support from the Board of Visitors will be critical for advancing our standing as one of the top astronomy programs in the nation.

II.C. Rankings of the Astronomy Program

The Astronomy program at The University of Texas at Austin is one of the top-ranked programs in the nation based on available rankings of Astronomy and Astrophysics programs. In the 1995 National Research Council (NRC) survey, we were ranked 4th among public universities and 10th overall in the country for faculty quality and program effectiveness. The subsequent 2010 NRC survey (http://www.phds.org/rankings/astronomy) of Astrophysics and Astronomy graduate programs measured overall program quality based on 20 key variables, such as the characteristics of the faculty (number of publications and citations, number of awards) and the students (GRE scores, percent with fellowships), as well as broader features of the doctoral programs (average time to complete a degree, measures of ethnic and gender diversity). The survey produced two sets of rankings based on survey-based weights and regression-based weights. To account for uncertainties in the data, the measurements and the weights were both randomly perturbed and resampled some hundreds of times, yielding ranges of ranks rather than specific rankings. While the wide range of ranks makes the results hard to interpret, one can nonetheless see that UT fares comparably to many top public universities. For example, the standard rankings based on survey-based weights and regression-based weights were respectively 5-26 and 8-22 for UT Austin Astronomy, compared to 5-16 and 5-17 for the University of Arizona, 1-6 and 3-11 for UC Berkeley, 12-26 and 4 -17 for UC Santa Cruz.

Since 2015, US News and World Report (USNWR) has produced a ranking of the "Best Global Universities for Space Science," based on their research related to a number of topics in the field of space science, including astronomy and astrophysics, celestial bodies and other subjects related to the study of the Universe. The Report's methodology is focused on research performance, bibliometric indicators, such as publications and citations, and assessments of the global reputation of an institution. The UT Astronomy program leads research that has contributed to the USNWR 2017 ranking of UT Austin in space science as #6 among US state universities, #13 in the nation, #18 on the world stage (Table III-1).

In addition to the above rankings, we are using common metrics (publications, citations), as well as other factors, such as the quality of our faculty and educational program, the diversity of our program, and our leadership in next-generation facilities to measure our progress (Section IV). Ultimately, one lasting measure of success is our ability to lead transformational science and develop leaders who reshape our understanding of the Universe and our place in it.

Section III. Astronomy Program Strategic Plan

Advances in astronomy continue to revolutionize our understanding of the Universe. Astronomers have confirmed the basic predictions of inflationary Big Bang theory, firmed up our understanding of the age and geometry of the Universe, and established that an amazing 95% of the Universe is dark, with 25% as dark matter and the remaining 70% in the form of a mysterious dark energy. Last year, the first detection of gravitational waves, believed to be caused by the collision of two black holes 1.3 billion light-years away, validated Einstein's theory of general relativity and opened a new astrophysical window to the Universe. We are now uncovering some of the youngest generation of galaxies formed when the Universe was merely a few percent of its current age, and using theoretical models to explore the growth of stars, galaxies, and black holes. Stars in all their complexity, from newly formed to aging red giants to compact remnants in the form of white dwarfs, neutron stars, and black holes, remain frontier laboratories of physics. Low metallicity stars are important tools for near-field cosmology, while gamma-ray bursts and superluminous supernovae can be seen at redshifts of 10 or greater, directly probing the early Universe. In less than two decades, we have gone from knowing only our Solar System to studying hundreds of widely diverse planetary systems that challenge planet formation models and raise new questions about life in the Universe. Recent reports show an Earth-sized planet, Proxima b, orbiting in the habitable zone of Proxima Centauri, our nearby neighboring star: this may be the nearest possible abode for life outside our Solar System.

Table III-1: US News & World Report 2017 Relative Ranking in Space Science for US Universities

Relative Rank	Institution
1	California Institute of Technology
2	Harvard University
3	University of California, Berkeley
4	University of California, Santa Cruz
5	Princeton University
6	University of Arizona
7	Stanford University
8	University of California Santa Barbara
9	Yale University
10	University of Chicago
11	Ohio State University – Columbus
12	Johns Hopkins University
13	The University of Texas at Austin
14	Pennsylvania State University – University Park
15	Massachusetts Institute of Technology

Notes to Table: The table shows the 2017 US News and World Report relative ranking in space science among US Universities. Public universities are shown in green. Details can be found at www.usnews.com/education/best-global-universities/space-science

The Astronomy program at UT Austin is an integral part of this astronomical revolution and is poised to further advance the frontiers of human knowledge. We are one of the top programs in the nation and contribute to UT Austin's 2017 ranking in space science as #6 among US public universities by US News & World Report (Table III-1). We aspire to become the top state university for Astronomy in the country and to rank amongst the top several elite institutions globally.

To be a program of the first class, we need to recruit the very best intellectual capital exemplified by world-class faculty, researchers, graduate students, and postdocs, and provide them with the resources and research infrastructure they need to excel. We aim to continue the quest to answer the oldest and deepest of questions: How did the Universe begin in a Big Bang and what came before? When and how did the first stars, planets, galaxies, and black holes form? How did they evolve into their present-day state? What is the origin of chemical elements and how are they spread throughout space to form new stars, planets, and life? What are the demographics of exoplanets and what are the opportunities for life outside our Solar System? What is the nature of the dark matter and dark energy that make up most of the Universe? What is the ultimate fate of the Universe?

We outline our strategic goals for the next decade under points A to H below. We denote points of particular importance in blue. For each of these strategic goals, we also present a parallel analysis of our strengths, weaknesses, and opportunities in Sections IV.A to IV.H.

A) Recruitment of World-Class Faculty and Growth of our Research Program: Over the last four years we have hired four new excellent faculty members with leading expertise in early galaxy evolution, the formation of stars and planetary systems, obscured star-forming galaxies, and near-field cosmology. However, *nearly half of our faculty will be retiring in the next decade, and it is imperative that we hire rapidly (~1 hire per year over the next decade) to maintain our research and education mission*. In particular, we need to rebuild our faculty in a timely way so that UT Astronomy is in a position to lead scientific breakthroughs in the golden era (2017-2023) where we will have an unprecedented number of transformational facilities, such as ALMA, JWST, GAIA, LSST, SKA, and GMT (see Section IV.A for details).

Our hiring plan takes into account frontier areas of astronomy highlighted by the National Academy of Sciences 2010 decadal survey of Astronomy and Astrophysics (New Worlds, New Horizons). We envision a hiring plan that offers us the flexibility to hire outstanding superstar faculty members in any area of astronomy. However, when selecting between candidates of comparable excellence, we will prioritize *hiring in frontier areas where we can have maximal impact through our unique strengths:* our present access to McDonald Observatory and the Texas Advanced Computing Center, our future access to the Giant Magellan Telescope, and the strong synergy between our observational and theoretical efforts. With this hiring strategy, we envision the following evolution in our program's research areas:

- After factoring upcoming retirements, we estimate that we will still have a significant number of faculty members leading science in the following frontier areas: first light and reionization, the evolution of galaxies and black holes, extragalactic star formation, dark matter, and dark energy.
- Conversely, we expect the wave of upcoming retirements to produce a loss of expertise in some critical fields. To offset this loss, we will hire in the research areas of *observational near-field cosmology, chemical evolution, and the formation and evolution of stars and planets.* These research areas are highlighted in the decadal survey and inform important work being conducted by other faculty members (see IV.A for details).
- We put a high priority on hiring faculty members in *planetary systems science* to build a planetary science program, that will explore exoplanetary systems and opportunities for life, and can lead to a *Center for the Exploration of Life in the Universe.* The planetary science program will benefit from the high-resolution capability of GMT for exploring exoplanet atmospheres and will help us build important bridges with the Jackson School of Geological Sciences, the Department of Biology, and other UT divisions. We are exploring this interdisciplinary initiative through discussions of the Astronomy Department leadership with several UT divisions, as well as through the submission of concept papers by individual researchers to the "Bridging Barriers" initiative launched in 2016 by the Office (https://research.utexas.edu/vpr-initiatives/bridging-barriers/) of the Vice President for Research (VPR).

- We are interested in faculty members who can develop *interdisciplinary initiatives* within UT Austin or with the private sector. Such initiatives can catalyze research breakthroughs and external funding. In addition to the aforementioned planetary science program, we are particularly interested in joint hires in *big data science* with the Department of Computer Science, the Texas Advanced Computing Center, and the Cockrell School of Engineering. In the same vein, we aim to promote *collaborations with the Physics Department* in the areas of gravitational waves, fundamental physics, and cosmology.

B) Advancing Excellence with Top-Tier Graduate Students and Postdocs: Graduate students and postdocs are vital for advancing our research and teaching mission. In the last four years, we have made headway in recruiting top students and improving diversity through a multi-pronged approach, which includes holistic admission criteria, an inclusive department climate, cutting-edge research projects, and improved recruiting packages. In order to better compete with other top US public universities, the next step is to explore ways to offer full multi-year graduate fellowships, while maintaining the quality, breadth, and critical mass of our graduate research program.

One of the most serious challenges for our research program is that many research-active Associate and Full Professors are struggling to recruit graduate students and postdocs. This situation is caused by the high-and-rising costs of graduate student or postdoc support, coupled with the limited funds available from federal grants, CNS, and the Department, and a recently proposed policy to limit the number of semesters a student may TA (Section IV.B). We are committed to addressing this challenge to maintain a thriving research program and compete with top departments. We are exploring numerous solutions, including requesting more flexibility from CNS, enhanced philanthropic efforts, assessing our graduate program size and redirecting more of our existing endowments toward graduate student support (while still allowing resources for faculty startup packages). We also aim to establish an unrestricted prize postdoctoral fellowship, which would complement the existing Harlan J. Smith and W. J. McDonald prize fellowships, which have had a focus on observational astronomy.

Our graduate program produces outstanding PhD graduates who have a broad spectrum of interests and continue as future leaders in research, education, and the private sector, particularly in the area of big data. We have made important headway and will continue our efforts to provide our graduate students and postdocs with broader training and mentoring to prepare them as future leaders with high scholarly, societal, and economic impact.

UT Astronomy postdocs make critical contributions to our department by conducting research, supervising undergraduate students, mentoring graduate students, and leading outreach events. We have made significant improvements in mentoring, supporting, and communicating with our postdocs. Steps taken include setting up a newly revitalized postdoc mentoring committee; establishing a department website (www.as.utexas.edu/astronomy/education/postdocs.html) of postdoc resources, such as mentoring and professional development resources, funding and research opportunities, resources for advising and mentoring undergraduates, and the Astronomy program code of conduct; holding a departmental colloquium each semester to showcase the work of postdocs; setting up a network of Informal mentors for graduate students and postdocs (http://www.as.utexas.edu/astronomy/education/mentors.html); and making the salary of the

Harlan J. Smith and J.W. McDonald prize postdoctoral fellowship competitive with named fellowships at peer institutions. Every two years, we also give postdocs generous financial resources to organize the Frank N. Bash Symposium "New Horizons in Astronomy." Moving forward, it is important to sustain these efforts and promote better interaction between postdocs and the rest of the Astronomy program community.

C) Access to Forefront Research Facilities- McDonald Observatory, TACC, GMT: Researchers in the UT Astronomy program regularly win observing time on a wide range of competitive public observational facilities (e.g., Keck, Gemini, Hubble, Spitzer, Kepler, Herschel, ALMA, VLA), and many have a leadership role in science collaborations conducting large observational surveys on some of these facilities. Some researchers are also playing key roles in shaping future NASA public observatories (e.g., JWST, WFIRST, LUVOIR, and the Origins Space Telescope). In addition to having access to public facilities, researchers in the UT Astronomy program have a competitive advantage over many other departments thanks to their generous access to McDonald Observatory, the Texas Advanced Computing Center, the future Giant Magellan Telescope.

McDonald Observatory provides access to a wide array of telescopes, including the upgraded 10-m Hobby-Eberly Telescope and cutting-edge instrumentation, such as the Visible Integral-Field Replicable Unit Spectrograph (VIRUS) integral field spectrograph and the Immersion Grating INfrared Spectrometer (IGRINS). Important improvements over the last two years include the deployment of the upgraded Low-Resolution Spectrograph (LRS2) on the 10-m Hobby-Eberly Telescope and the first light of the upgraded Hobby-Eberly Telescope with a highly expanded field of view of 22 arcminutes. The queue-scheduled operation of the Hobby-Eberly Telescope makes it a powerful tool for time-domain and synoptic observations. McDonald Observatory also hosts a node in the Las Cumbres Observatory global array of robotic telescopes, another key tool for time-domain astronomy.

The TACC designs and operates some of the world's most powerful computing resources. UT astronomers can secure significant computational resources on TACC by using allocation channels available only to UT scientists, in addition to securing resources through open competitive applications. Theorists use TACC to run, analyze, and visualize state-of-the-art simulations that explore how stars, galaxies, black holes, and large-scale structure evolve across cosmic time. Observers are using TACC for data-intensive projects; taking advantage of its large (more than 100 petabytes) dedicated user storage and advanced computing technologies.

UT Astronomy is a major founding partner in the next-generation Giant Magellan Telescope (GMT), which will be the world's largest (25.4-m) optical/infrared telescope when it begins commissioning in 2023. GMT will allow UT Astronomy to lead transformational science and attract top-level faculty and students. Membership in GMT is a necessary but not sufficient condition for advancing our national standing. *We must, therefore, strive to support GMT and make it highly successful while supporting other excellent research initiatives that make us stand apart relative to other GMT or Thirty Meter Telescope (TMT) partners.*

We give high priority to two such research initiatives. The first initiative is the development of the theoretical framework for addressing frontier science questions that will be tackled by frontier facilities, such as ALMA, GAIA, GMT, JWST, LSST, and SKA. Observations produce discoveries, but understanding requires theory. The UT Astronomy theory group is world-class and would benefit from resources, such as students or a prize postdoctoral fellowship (Section IV.B).

The second initiative is to secure complementary data at long (far-infrared, sub-millimeter, radio) wavelengths and thereby gather crucial information that is missing from optical/infrared surveys with JWST, GMT, and LSST. We note that only half of the extragalactic background radiation reaching us today is at UV/optical wavelengths, while the other half is at far-infrared/ sub-millimeter wavelengths. We are currently exploring participation in the NSF-funded TolTEC Public Legacy Surveys on the 50-m Toltec Large Millimeter Telescope (LMT) in Mexico. In the longer term, we will evaluate a possible future partnership in the LMT. We will explore how to advance these initiatives through opportunities provided by ConTex, a partnership formed in late 2016 between the University of Texas System and Mexico's National Council of Science and Technology (CONACYT) to support bilateral efforts that enhance academic and research cooperation between Texas and Mexico (https://research.utexas.edu/find-funding/contex-programs/).

D) Pushing New Frontiers with HETDEX: The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey designed to measure the evolution of dark energy via the power spectrum of around 0.8 million Lyman-alpha emitting galaxies (LAEs) in the redshift range $1.9 < z < 3.5$. HETDEX aims to measure the expansion rate of the universe to sub-percent accuracy at an average redshift around 2.5. This measurement, when combined with the currently available nearby measures, will produce the most accurate measure of any potential evolution in dark energy. This is an important project as the nature of dark energy has implications for fundamental physics and the fate of the Universe.

The HETDEX data will also allow a large number of other important science projects, such as mapping the cosmic web, exploring galaxy evolution in different environments at redshift $z>2$, understanding the escape of Lyman alpha photons from galaxies, searching for the most metal-poor stars in the Milky-Way Galaxy, discovering supernovae via novel means, studying dark matter and star formation distributions in nearby galaxies, and measuring the total mass of neutrinos.

The project has received $37 million in funding to date. Important milestones have been achieved, including the first light of the upgraded HET with a large increase in field of view in 2015. To date, 16 of the 78 planned integral field unit (IFU) spectrographs have been installed, resulting in the largest spectrograph in the world.

HETDEX will provide the most accurate measure of the expansion rate of the Universe at high redshift (Fig. IV-8) compared to other dark energy surveys. The only major survey with similar accuracy to HETDEX at high redshift is MS-DESI, which is expected to deliver results around 2026. HETDEX is significantly late due to a variety of issues with the ambitious telescope upgrade and massive instrument build. The team expects a full complement of spectrographs in early 2018 and results on dark energy by 2022. Under this timeline, HETDEX can have a significant impact by delivering results before MS-DESI and providing the most accurate measure of the expansion rate at high redshift, where this measurement can set strong constraints on the possible evolution of dark energy.

E) Growing Leaders in our Undergraduate Program: Our Astronomy program will continue to offer a research-centered experiential undergraduate program. We believe that early and sustained involvement in research is key for engaging students in STEM and transforming them into scientists, innovators, and leaders. Our undergraduate curriculum equips students with core skills needed for starting research. Over 60% of astronomy majors are involved in research, and over 70% of our faculty have supervised UG research in recent years. Many freshmen join the Astronomy Freshman Research Initiative stream (www.as.utexas.edu/~mikemon/FRI/ast2.html), which gives first-year students the opportunity to engage in research experience. Our stream is part of the CNS FRI program, which has become a national model for science education (https://cns.utexas.edu/fri). Other freshmen and senior students also have the opportunity to conduct individual research projects with faculty, postdocs, and research scientists.

The size of our Astronomy Undergraduate Program has nearly doubled over the last five years, and we are now one of the largest programs in the nation, with 129 astronomy majors and a diverse student body. We need a commensurate increase of resources and have started a major initiative to double the capacity of our Undergraduate Research Computer Laboratory. We are committed to providing our students with a 21st-century education that prepares them not only for graduate school and academic careers, but also for non-academic careers in the public and private sector. We are exploring interdisciplinary courses and the establishment of networking groups on LinkedIn and other platforms.

F) Fostering a Climate of Inclusion and Excellence: We are committed to fostering a climate that promotes the broader participation of women and other under-represented groups in science. In the last four years, we have made important progress in improving diversity among our graduate students (Table IV-2). As of 2016, our graduate students include 11 (31%) female, 3 African American/Black, and 3 Hispanic students. On the faculty side, we are working to increase the percentage of women (currently at 15%) and to rectify the lack of representation from the African-American/Black, Hispanic/Latinx, and Native American communities on our faculty. For the first time in its history, the department elected a female professor as Department Chair, effective fall 2015.

Following the AAS recommendation on the Physics GRE Subject Exam (PGRE) and the advocacy effort led by our junior faculty, UT Astronomy was one of the early programs to eliminate the PGRE from its graduate admissions process. The UT Astronomy Department Chair also led a discussion among 30 other department chairs to encourage more programs to drop the PGRE requirement and shared the findings (www.as.utexas.edu/~sj/PGRE/PGRE-Landscape-Final.pdf) in a public report. As of December 2016, 13 or 48% of the 27 astronomy programs participating in the survey no longer require the PGRE: 9 have made the PGRE optional, and four have eliminated it.

A more inclusive climate in the department is promoted by numerous initiatives associated with the Equity and Inclusion Group, the Association of Women in Astronomy Research and Education (AWARE), and the Texas Astronomy Undergraduate Research experience for Under-represented Students (TAURUS).

G) Leading a High-Impact Education and Public Outreach Program: McDonald Observatory and the Astronomy Department are committed to continuing a far-reaching education and public outreach program that leverages the immense appeal of astronomy to bring scientific ideas to society at large, and draw diverse young people into STEM fields.

Approximately 90,000 visitors tour the McDonald Observatory Visitor Center each year and 2.3 million listeners tune into StarDate Radio daily. Annual K-12 teacher professional development workshops train 300 teachers, each of whom impacts 100 students per year. Viewing nights on the UT Austin campus host 5,000 visitors a year, are designated as one of the "Gems of the University" in Signature Courses, and have won past Austin Chronicle "Best of Austin" Critics Choice Awards. The Undergraduate Astronomy Students Association provides daytime viewing opportunities with H-alpha and solar telescopes on campus and in the city. The Astronomy on Tap (AoT) event, led by postdocs and graduate students, draws about 3,500 people per year in Austin to hear informal astronomy talks.

We are engaged in addressing challenges related to staffing, and the aging infrastructure of the McDonald Observatory visitor center, and the campus telescopes. The relatively recent withdrawal of NASA as a provider of small and supplemental educational grants has been felt and we are seeking new creative opportunities for non-government funding.

H) Leveraging Philanthropy, External Relations and Support Groups (Section IV.H): We plan to leverage our 40-year history with fundraising and external relations to advance excellence in our research program. Most of our philanthropic support currently comes through the UT McDonald Observatory and Department of Astronomy Board of Visitors (BoV). With 240 members, our BoV is arguably the largest Astronomy Board of Visitors in the country. Our BoV has accomplished great things for the Texas Astronomy program, including funding chairs, professorships, and fellowships to support faculty and students; supporting HETDEX; funding the biennial Frank N. Bash Symposium for young researchers (Figure IV-5); supporting our visitor programs (Section X) for distinguished scientists (including Nobel Prize winners); and much more.

The main development priorities for the coming three to five years will be fundraising for our partnership in the Giant Magellan Telescope (IV.C) and the support of graduate students and postdocs (IV.B).

We currently have to fundraise $46.1 M to reach our target goal of $100 M for a 10% partnership in GMT. This amount will supplement the $50 M award from the University of Texas at Austin, and the $3.9 M fundraised to date primarily through gifts from BoV members. In 2016-2017, we are looking into eight additional prospects for asks of $1 million in support of the GMT, as well as opportunities among the University community for asks of $8-10 million.

We also aim to create a multi-million dollar level endowment (the Astronomy Research Excellence Fund) to support research, with a focus on support for graduate students and postdocs. We will continue our recent efforts to greatly extend our group of alumni and friends, experiment with alumni newsletters, and increase our social media activity. In 2017 we are also restructuring our

Astronomy program websites to improve our communications with donors, alumni, faculty, and the scientific community.

Section IV. Analysis of the Astronomy Program's Strengths, Weaknesses, and Opportunities

For each of the strategic goals (A to H) in our strategic plan, we present here an analysis of our strengths, weaknesses, and opportunities. We denote points of particular importance in blue.

IV.A. Recruitment of World-Class Faculty and Growth of Our Research Program

In order to advance our standing as a top-tier program, it is vital for us to recruit and support the best intellectual capital in the form of world-class faculty.

Current Strengths

The UT Astronomy program currently has an excellent group of faculty members and research scientists who are engaged in a wide range of research activity, spanning cosmology, galaxy formation and evolution, black holes, dark matter, dark energy, stellar evolution and star formation, planetary systems, and instrumentation. Many of our faculty members are considered to be leaders in their research area, based on their record of publications, invited talks at conferences, and leadership roles in high-impact science collaborations (Section V).

At the time of the last external review in 2009, there were 20 tenured/tenure-track teaching faculty in the Astronomy program. Since then, we have lost three faculty members: Eiichiro Komatsu (theoretical cosmology), Jenny Greene (nearby galaxies and black holes), and Sally Dodson-Robinson (planetary systems science). We made a successful counter-offer to Eiichiro Komatsu in 2009 by providing him with resources to set up the Texas Center for Cosmology, but he subsequently accepted a directorship at the Max-Planck-Institute for Astrophysics in 2012. Two of our female faculty members, Jenny Greene and Sally Dodson-Robinson, left due in part to the lack of a permanent solution for their dual career spousal problems.

Fortunately, from 2012 to 2016, we have hired four outstanding faculty members who have bolstered our research program. Steve Finkelstein, a former Hubble Fellow with leading expertise in galaxy evolution at very high redshifts, joined us in 2012. He was followed in 2013 by Adam Kraus, a former Hubble Fellow and Harvard-Smithsonian CfA Clay Fellow, whose cutting-edge research focuses on the formation of stars and planetary systems. Caitlin Casey, a former Hubble Fellow and UC Irvine McCue Fellow who leads research on obscured star-forming galaxies (Fig. IV-2) joined us in 2015. We have also strengthened our theory group in 2015 by recruiting Professor Mike Boylan-Kolchin, a leading expert on near-field cosmology and dark matter, from the University of Maryland. In near-field cosmology, detailed observed properties of nearby galaxies are compared with sophisticated cosmological simulations to better understand the build-up of these galaxies from early times to the present day (Fig. IV-3).

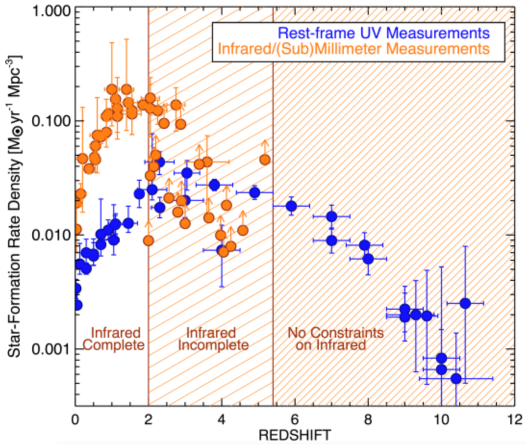


Figure IV-2: This figure illustrates the research of recently hired faculty member, Caitlin Casey. It shows the cosmic star-formation history of the Universe, as measured at rest-frame ultraviolet (blue points, e.g. Ellis et al., 2013), and longer infrared or (sub)millimeter (Casey et al., 2012, 2013; Gruppioni et al., 2013). Our current understanding of star formation in the early Universe is severely limited by the lack of long-wavelength constraints, particularly beyond z~4. *(Courtesy: Caitlin Casey)*

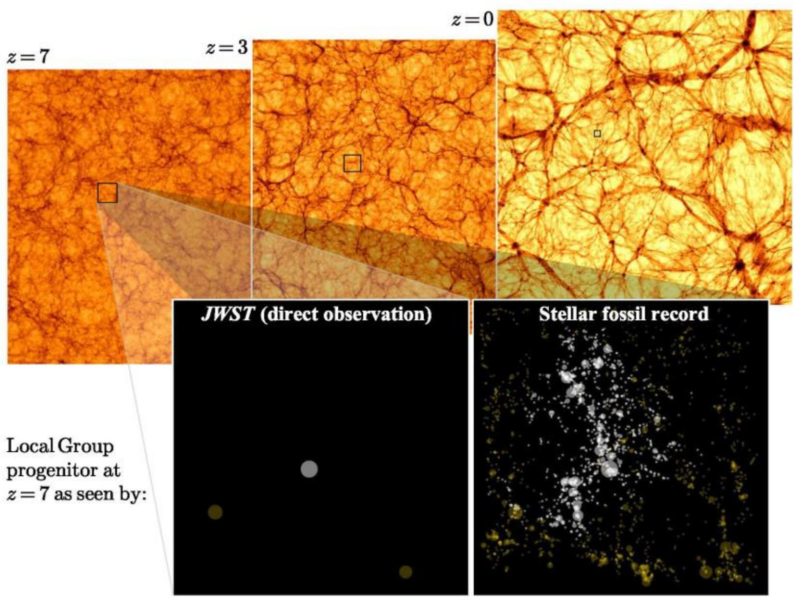


Figure IV-3: This figure illustrates the research on near-field cosmology by a recently hired faculty member, Mike Boylan-Kolchin. The stellar fossil record in the Local Group traces the cosmic evolution of dwarf galaxies over a region that is cosmologically representative at high redshift (upper panels). Near-field cosmology, therefore, provides a unique and powerful complement to direct observation of low-mass galaxies in the high-redshift Universe (lower panels). *(Adapted from Boylan-Kolchin et al. 2016, MNRAS, 452, L51.*

Challenges and Opportunities

1) The UT Astronomy Department is at a critical point in its history. As of 2015, over 65% of the faculty members were at least 60 years old. From 2016 to 2021, 7 (32%) of the tenured/tenure-track (TTT) faculty are formally retiring, some after more than 45 distinguished years of research, service, and teaching (Table IV-1). We benefit from the continued engagement of many of our Emeritus faculty members. Beyond these seven committed faculty members, ongoing discussions of other faculty with the Department Chair suggest that we will have a total of 10 retirements by 2026, resulting in nearly half of our current faculty retiring over the coming decade.

Table IV-1: Astronomy Tenured/Tenure-Track Faculty

Academic Year	# of New TTT Faculty Hired	# of TTT Faculty Retiring or Separating	Total # of TTT Faculty
2014-15	0	0	21
2015-16	2	-0.5	22.5
2016-17	0	-3	19.5
2017-18	2 approved	-1.5	20.0
2018-19	0 (TBD)	-1.5	18.5
2019-20	0 (TBD)	0	18.5
2020-21	0 (TBD)	-1.5	17.0

2) We are grateful that the Dean of the UT College of Natural Sciences, Linda Hicke, plans to keep the size of our tenured/tenure-track faculty to 22. However, we are concerned that there is no formal commitment from CNS on the timescale of future hires and a multi-year hiring plan. Such a multi-year hiring plan would provide a golden opportunity for our department to plan its growth strategically and build critical mass in new high-impact areas. We have secured two new tenure-track faculty positions (for which we are currently recruiting) to start in fall 2017. With nearly half of our faculty retiring in the next decade, it is imperative that we continue to hire in a timely way (~1 hire per year over the next decade) to maintain our research and education mission, and advance our goal of becoming a top public university astronomy department.

Without additional timely hires, we will be unable to offer the required array of courses (graduate courses, undergraduate majors courses, and service courses) central to our program. A reduction in the number of large-format introductory astronomy service courses, which provide the teaching assistantships for supporting our graduate students, would exacerbate the daunting challenges we face in supporting students who advance our research mission (Section IV.B).

It is also imperative that we rebuild our faculty rapidly so that we do not miss out on upcoming opportunities to lead scientific breakthroughs in the golden era (2017-2023) of transformational observational facilities, such as the James Webb Space Telescope (JWST; 2018), NASA's premier infrared space telescope; the Large Synoptic Survey Telescope (LSST; 2022) providing a thousand-fold increase in survey power in time-volume; the Square Kilometer Array (SKA; 2022), the world's largest array of radio telescopes; and the Giant Magellan Telescope (GMT; 2023), the world's largest optical telescope.

3) **Hiring Plan:** As recommended by the previous visiting committee, we outline here the considerations guiding our hiring plan. Our hiring plan is shaped by three overarching principles:

i. Our faculty hiring plan needs to be flexible enough to allow us to take advantage of targets of opportunity and to hire outstanding superstar faculty members in any area of astronomy.
ii. When selecting between candidates of comparable excellence, we need to prioritize hiring in certain areas (outlined below) where we can have maximal impact through existing strengths and new opportunities unique to our program.

iii. We need to actively recruit women and minorities to extend our recent improvements in diversity (Section IV.F).

Following points (i) and (ii) above, our faculty hiring ads state that we are open to all fields of astronomy, while concurrently mentioning some areas of particular interest to us, as outlined below:

a) *Decadal survey areas where UT Astronomy can have maximal impact*: While we remain open to all science areas highlighted by the National Academy of Sciences 2010 decadal survey of Astronomy and Astrophysics (New Worlds, New Horizons), we are focusing on the subset of frontier areas where we can maximize our scientific impact through our *unique* resources: our present access to McDonald Observatory and TACC, our future access to the Giant Magellan Telescope, and the strong synergy between our observational and theoretical efforts. These frontier areas include first light and reionization; the formation and evolution of stars, black holes, and galaxies across cosmic time; stellar birth, evolution, and death, and the production of chemical elements essential for life; near-field cosmology and stellar archeology as probes of galaxy assembly; the formation of stars and planetary systems, and opportunities for life outside our Solar System; dark matter, dark energy, and fundamental physics; and transient phenomena.

   Some of the aforementioned frontier areas are not prime targets for hire as we will continue to have leading expertise from multiple faculty members, even after upcoming retirements. These areas include first light and reionization (Bromm, Finkelstein, Shapiro, Boylan-Kolchin, Milosavljevic), the evolution of galaxies and black holes across cosmic time (Bromm, Casey, Finkelstein, Gebhardt, Jogee, Milosavljevic), star formation in distant galaxies (Casey, Finkelstein, Jogee), stellar evolution (Bromm, Milosavljevic, Winget), high energy astrophysics (Kumar), dark matter, dark energy, and fundamental physics (Boylan-Kolchin, Gebhardt, Hill, Kumar, Shapiro).

   Conversely, we need to hire in certain critical frontier areas, such as observational near-field cosmology, chemical evolution, the formation of stars and planets, and time domain astronomy where upcoming retirements will produce a loss of expertise. For example, the retirements of David Lambert (2016) and Chris Sneden (2018) require us to fill a gap in *observational stellar archeology, near-field cosmology, and chemical evolution*, three areas that garner immense benefit from the high-resolution spectroscopic capabilities of McDonald Observatory and GMT, and complement the ongoing theoretical work in near-field cosmology by faculty member Boylan-Kolchin. The recent retirement of Neal Evans (2016) leaves a void in *observational research on star formation and proto-stellar disks in the nearby Universe.* This area of research is instrumental in shaping important work being conducted by our faculty members on star formation at higher redshift (e.g., by Bromm, Casey, Finkelstein, Jogee, Milosavljevic, Shapiro), and on stars and planetary systems (e.g., by Adam Kraus). Expertise is also likely to be lost in binary star evolution including stellar-mass black holes and in the end points of stellar evolution and associated aspects of time-domain astronomy.

A high priority for us is to hire in the areas of *planetary systems science* to build a planetary science program that will explore exoplanetary systems and opportunities for life, and can lead to a Center for the Exploration of Life in the Universe. At the TTT faculty level, we only have one junior tenure-track faculty member (Kraus) who is working in this area. This planetary science program will benefit in the short term from the Habitable Planet Finder at McDonald Observatory, and in the long term, from the high-resolution capability of GMT for exploring exoplanet atmospheres. It will also help us build important interdisciplinary bridges with the CNS Departments of Biology, Computer Science, and Statistics; the Jackson School of Geological Sciences; the Applied Research Laboratories (ARL); and the Center for Space Research (CSR). We are exploring this interdisciplinary initiative through discussions of the Astronomy Department leadership with several UT divisions, as well as through the submission of concept papers by individual researchers to the "Bridging Barriers" initiative (https://research.utexas.edu/vpr-initiatives/bridging-barriers/) launched in 2016 by the Office of the Vice President for Research.

Interdisciplinary hires: We live in a time when research breakthroughs and external funding are increasingly focused on interdisciplinary initiatives. We aim to hire faculty members who can catalyze interdisciplinary initiatives within UT Austin or with the private sector.

The aforementioned hire in planetary systems science can be an interdisciplinary faculty hire conducted jointly by the Astronomy program, the Jackson School of Geological Sciences, and the Department of Biology. While astronomers tend to be experts on the detection of planetary systems, the latter two units could bring in expertise in planetary atmospheres and astrobiology.

We are also considering a faculty hire in *big data science* who can catalyze new research initiatives (particularly in the data-intensive era of LSST, SKA) and build bridges between the Astronomy program, the private sector, and UT Austin entities, such as the Department of Computer Science, the Institute for Computational Engineering and Sciences (ICES), the Texas Advanced Computing Center (TACC), and the Cockrell School of Engineering. Such a faculty hire would ideally involve a joint hiring committee comprising members of the Astronomy program and one of the other units.

We also aim to hire faculty members who can enhance collaborations with the Physics Department and ICES in the areas of cosmology, dark matter, dark energy, gravitational waves, and fundamental physics.

IV.B. Advancing Excellence with Top-Tier Graduate Students and Postdocs

Graduate students and postdocs constitute a fundamental pillar of the Astronomy program: they conduct frontier research, publish papers in top-ranked scientific journals, educate thousands of undergraduates, lead outreach programs, and improve our inclusive community. In order to advance our standing as one of the best programs in the nation, we need to recruit top-tier graduate students and postdocs, endow them with resources to excel, and shape them into scientific leaders with high scholarly, societal, and economic impact.

Figure IV-4: UT Astronomy Graduate Students. *(Photo credit: Lara Eakins)*

Current Strengths

1) Our graduate program is one of the best in the nation. We contribute to US News & World Report's 2017 ranking of UT Austin in space science as #6 among US state universities, and #18 in the world (Section II.C).

2) Our graduate (Section VII) and postdoctoral (Section VIII) programs currently consists of 35 graduate students and 13 postdoctoral fellows, many of whom hold named prize fellowships. From 2013 to 2016, approximately 20% of our graduate students have held NASA, National Science Foundation (NSF), UT Graduate School, or CNS graduate fellowships each year. On average, around 27% of our postdocs hold prestigious postdoctoral prize fellowships, including the NASA-funded Hubble postdoctoral fellowship, NSF postdoctoral fellowship, NASA-funded Sagan fellowship, Harlan J. Smith and W. J. McDonald prize postdoctoral fellowships, and prize fellowships from their home countries. We discuss further changes in our program size in the next section under point (3).

3) Our graduate program produces outstanding PhDs with a broad spectrum of interests. Upon graduation, our students have won highly prestigious postdoctoral fellowships, including Hubble Fellowships, Sagan Fellowships, the Enrico Fermi Postdoctoral Fellowship, NASA fellowships, and the University of Arizona Prize Postdoctoral Fellowship. Our students take faculty positions at research universities, key technical roles at observatories, positions as educators at undergraduate serving institutions, and positions in the private sector, particularly in the area of big data.

4) After years of stagnant graduate research assistantship (GRA) stipends, we raised our GRA stipends by over 30% as of 2015-16 to $28K/year to be more competitive with peer institutions and deal with the rising cost of living in Austin. CNS raised its teaching assistantship (TA) salaries to $24K/year effective Fall 2015. This has helped us be more competitive and provide better support for our students. We discuss recently announced changes in the TA stipend effective 2017-18 in the next section under point 2(d).

5) We have made headway in providing our graduate students and postdocs with broader training and mentoring to prepare them as future leaders for research, education, and the private sector.

a) In the last four years, we have added courses on Planetary Astrophysics, Galaxy Evolution at High Redshift, Computational Astrophysics, and Data Science with a focus on Big Data to the graduate curriculum.
b) We have connected our students and postdocs to the resources and professional development opportunities provided by CNS. These include panel discussions from experts in academia and industry, as well as one-to-one career advice from a career development specialist (https://cns.utexas.edu/postdocs/professional-development-and-career-support). We have also started to extend our astronomy alumni network and invite alumni in academic and non-academic jobs to present seminars.
c) In addition to the formal mentoring provided by the PhD research committee, the graduate advisor, and the Graduate Studies Committee (GSC), we have recently set up a network of Informal mentors (www.as.utexas.edu/astronomy/education/mentors.html) for graduate students and postdocs. Mentors participate in informal discussions on professional development (e.g., feedback on applications for jobs, observing time, grants; bouncing research ideas; guidance for giving good talks and being effective teachers); perspectives on different career paths; advice on work-family-life balance; and help in overcoming diverse challenges. Mentors take part in a department-supported mentoring lunch each semester and are also available for individual discussions.

6) In the last four years, we have made headway in recruiting top students and improving diversity (Section IV.F) through a multi-pronged approach, which includes holistic admission criteria, focused recruiting efforts, cluster visits, a department climate of inclusion, cutting-edge research projects, and improved recruiting packages. We now have 11 (31%) female students, 3 (8.6%) African American/Black, 4 (11.4%) Hispanic, and 1 (2.9%) Asian students (Table IV-2).

7) UT Astronomy postdocs make critical contributions to our department by conducting research, supervising undergraduate students, mentoring graduate students and leading outreach events, such as Astronomy on Tap (Section IV.G). In addition to the mentoring resources outlined in (5), we have set up a new postdoc mentoring committee in 2015 (Section VIII). We have also set up a departmental website (www.as.utexas.edu/astronomy/education/postdocs.html) of resources for postdocs, such as professional development resources, funding/research opportunities, resources for advising and mentoring undergraduates, resources for traveling and inviting research collaborators, and the Astronomy program code of conduct. To promote better interaction, our departmental emails include welcoming informational messages on new postdocs, and one colloquium spot each semester has been allocated to showcase postdoctoral research. We also invite the postdoctoral representative to faculty meetings and strategic retreats. Every two years, we give postdocs generous financial resources to organize the Frank N. Bash Symposium "New Horizons in Astronomy," which brings together young researchers from around the world. The symposium is funded primarily through the generous support of our Board of Visitors (Section IV.H).

8) We have recently increased the stipend of the Harlan J. Smith and W. J. McDonald prize postdoctoral fellowships to $62,000, placing it more in line with compensation of named fellowships at peer institutions. At the university level, the minimum salary for a postdoc is now approximately $47,000, though most grant-funded postdocs in the department are paid higher salaries.

Figure IV-5: UT Astronomy postdocs have the opportunity to organize the biennial Frank N. Bash Symposium, "New Horizons in Astronomy," which brings together young researchers from around the world. *(Photo credit: Lara Eakins)*

Challenges and Opportunities

1) Our main peer competitors among US public universities are UC Berkeley, UC Santa Cruz, UC Santa Barbara, the University of Arizona, and Ohio State University, while higher-ranked private universities include Harvard, Princeton, and Caltech (Table III-1). To effectively compete against our main rivals, we need to be able to offer full 5-year graduate fellowships, competitive postdoctoral fellowships, and/or a program that offers unique advantages. The breadth and excellence of our research program, as well as our inclusive climate, is appealing to many candidates, but we are only able to offer very few multi-year fellowships.

2) One of the largest current challenges for our research program is that many research-active Associate and Full Professors are struggling to recruit graduate students and postdocs. This situation is caused by several factors:

a) *Challenges of External Funding*: Our Astronomy program, like many other competitive programs, makes offers to new graduate students, guaranteeing five years of support through a mix of Graduate Research Assistantships (GRAs), Teaching Assistantships (TAs), fellowships, and departmental support. However, federal grants have a low success rate of 15% to 21%, and their award period is only three years. Therefore, even faculty members with grants can typically support a student *for only three out of the five years* for which we commit to fund students.

b) *Faculty hires:* Currently, the department uses its endowments to supplement the CNS start-up funds in order to build competitive packages to recruit top-tier faculty candidates. We typically add in $50 to $100K per faculty hire. This currently leaves us with endowed funds of about $130K to $150K per year for graduate student support (Section VII).

c) *Summer support:* Providing summer support ($10.3K per student without indirect cost) is the most challenging problem in the support of graduate students. Summer support comes entirely from GRAs or department funds since our department does not offer summer courses and receives no summer TAs since 2014. At the present time, the department is able to provide summer support for 4-5 students from endowed and discretionary funds, but it does not have the means to support a large number of students over the summer. In the near future, we are planning to redirect additional resources from our endowments toward graduate student support.

d) *TA top-off and Maximum Number of Semester TAs*:

Two recent changes were announced in Spring 2017: the CNS TA stipend will be raised to $27K/year as of 2017-18 and CNS will ask the department to limit the number of semesters a student may TA during their first 5 years. Discussions are ongoing between the Department and the Dean's office to finalize the TA semester limit. We greatly appreciate the increased CNS TA stipend, which will reduce the TA top-off burden for the department's 40 TA slots. We are concerned that a policy to limit the number of semesters a student can TA to any number well below 10 semesters will reduce the size, quality, and ranking of our graduate and research program. We believe that the best students and faculty join UT Astronomy because of the quality, breadth, and critical mass of our research program.

e) *Choosing between postdocs and graduate students:* Typical NSF or NASA Astronomy grants are not large enough to support both graduate students and postdocs. Postdocs with a $55-60K salary typically cost a grant $100K per year after folding in indirect costs and benefits. The corresponding cost for graduate students is $65K per year. Thus, even faculty members with funds are increasingly having to hire either a graduate student or postdoc, but not both.

3) We have started an active fundraising effort (section IV.H) to set up an Astronomy Research Excellence Endowment to cover the summer support of additional students (with a $250K endowment per summer fellowship). We are also encouraging faculty to co-advise students and set up external collaborations where students can benefit from summer research internships (e.g., at SANDIA, STScI, Max Planck Institutes, Astronomy institutes in Mexico taking advantage of fellowships from ConTex, the new research and education collaboration between The University of Texas System and CONACYT).

4) While the increase in GRA stipend to $28K/year in 2015 was helpful to graduate students, the cost of living in Austin is rising by a few percent annually. Therefore, it behooves us to raise the GRA regularly, while grappling with the challenges outlined above.

5) Many frontier science and funding opportunities are at interdisciplinary boundaries, and national reports advocate a broader interdisciplinary training. We are exploring the viability offering inter-disciplinary courses, such as planetary science courses offered by Astronomy/Geology, astrobiology courses offered by Astronomy/Biology, and big data courses offered by Astronomy/Computer Science/TACC.

6) We have made significant improvements in mentoring, supporting, and communicating with our postdocs. Moving forward, it is important to sustain these efforts and promote better interaction between postdocs and the rest of the Astronomy program community.

7) UT Astronomy is one of the few top-ranked programs that does not have *an unrestricted prize postdoc or a theory prize postdoc.* This puts us at a competitive disadvantage relative to our main competitors who do (e.g., University of Arizona, UC Berkeley, UC Santa Cruz, Ohio State University among state universities, and Harvard, Caltech, Chicago, Stanford, Princeton among private institutions).

Our Harlan J. Smith and J.W. McDonald prize postdoctoral fellowships are restricted to new PhD graduates. While they can currently be offered to candidates with observational or theoretical interests, the application pool is heavily biased toward observational candidates. Furthermore, newly hired faculty members are given priority to use this postdoctoral fellowship as a way to complement the CNS start-up funds, and this limits its use as true prize postdoctoral fellowship.

If we want to advance in our ranking, we need to set up an unrestricted prize postdoctoral fellowship. However, there are significant financial challenges toward setting up a postdoctoral endowment (of order $2 million) due to other competing fundraising priorities. In particular, as outlined in Section IV.C under "Challenges and Opportunities," our philanthropic effort currently focuses on securing the remaining $46 M for our goal of a 10% share in GMT, along with funds to address the serious problems of graduate student support.

IV.C. Access to Forefront Research Facilities: McDonald Observatory, Texas Advanced Computing Center, Giant Magellan Telescope

Current Strengths

Members of the UT Astronomy program regularly secure observing time on numerous public competitive observing facilities including optical/infrared facilities, such as Keck, Gemini, Hubble, Spitzer, Kepler, as well as far-infrared/radio facilities, such as Herschel, ALMA, and the VLA. Numerous researchers are also science leads in international collaborations, which conduct large surveys on some of these facilities. Some members of our program are also helping to shape future NASA observatories (e.g., JWST, WFIRST, LUVOIR, and the Origins Space Telescope).

In addition to having access to public facilities, researchers in the UT Astronomy program benefit from unique in-house resources, which give them a competitive advantage. These resources include generous access to McDonald Observatory and the Texas Advanced Computing Center (TACC), guaranteed future access to the next-generation Giant Magellan Telescope (GMT), and the strong synergy between our observational and theoretical efforts.

McDonald Observatory: Researchers in the Astronomy program benefit from access to McDonald Observatory (Section IX) in west Texas, the home of the upgraded 10-m Hobby-Eberly Telescope, the 2.7-m Harlan J. Smith Telescope, the 2.1-m Otto Struve Telescope, 0.9-m, and 0.8-m telescopes, telescopes of the Las Cumbres Observatory (LCO) network of robotic telescopes, and cutting-edge instrumentation, such as the Visible Integral-Field Replicable Unit Spectrograph (VIRUS) integral field spectrograph and the Immersion Grating INfrared Spectrometer (IGRINS). Important upgrades of telescopes and instrumentation at McDonald Observatory in the last two years include the deployment of the upgraded Low Resolution Spectrograph (LRS2) on the 10-m Hobby-Eberly Telescope, and the first light of the upgraded Hobby-Eberly Telescope with a five-fold increase in diameter to 22 arcminutes, and the installation of 16 of the 78 Visible Integral-Field Replicable Unit Spectrograph (VIRUS) units -- an important milestone for the HETDEX survey (Section IV.D). In progress are the completion of the remaining VIRUS units, the completion and deployment of HET’s upgraded High-Resolution Spectrograph, and the completion of the HET’s Habitable Planet Finder (by our partner Penn State).

Texas Advanced Computing Center (TACC): UT astronomers have access to TACC, which designs and operates some of the world's most powerful computing resources, and is known for its leadership in high-performance computing, scientific visualization, and big data analysis and management. TACC is part of the NSF-funded Extreme Science and Engineering Discovery Environment (XSEDE), the most advanced, powerful, and robust collection of integrated advanced digital resources and services in the world. In addition to open applications through XSEDE for supercomputing resources, UT astronomers can secure significant additional computational resources on TACC by using allocation channels available only to UT scientists. For example, it is not uncommon for theorists to receive several additional million core hours each year through TACC. Theorists in the UT Astronomy program use TACC to run, analyze, and visualize simulations exploring how stars, galaxies, black holes, and large-scale structure evolve across cosmic time, and how stars evolve and die. Observers are using TACC for data-intensive projects, taking advantage of its large (more than 100 petabytes) dedicated user storage and advanced computing technologies. The spectroscopic data of HETDEX are being stored and processed on TACC systems. The related SHELA/HETDEX project on galaxy evolution in the cosmic web uses TACC to store the extensive photometric data from five surveys and analyze over a million galaxies.

The Giant Magellan Telescope (GMT): The playing field in astronomy will change radically over the next decade. While presently each country or institution has access to numerous medium-sized public optical/infrared telescopes, the frontier questions we must address in the next decade require such expensive next-generation facilities that only a mere handful of such facilities will exist worldwide. Many of these facilities will be privately funded and therefore only be accessible to partner institutions, giving them an unfettered advantage to lead scientific breakthroughs.

Motivated by these considerations, the UT Astronomy program has become a major founding partner in the next-generation Giant Magellan Telescope, which will be the world's largest (25.4-m) optical/infrared telescope, when it begins commissioning in 2023. GMT will allow UT Astronomy to lead transformational science, attract top-level faculty and students, and move closer to its goal of being the top public research university in the country.

The GMT consortium consists of 11 founding partners, including seven US institutions (Carnegie, Harvard, Smithsonian Institution, Texas A&M, UT Austin, U. Arizona, U. Chicago) and four international partners (Astronomy Australia Ltd (AAL), Australian National University (ANU), Korea Astronomy and Space Sciences Institute (KASI), and the Brazilian Sao Paulo Research Foundation (FAPESP)). UT Austin has set a goal to contribute 10 percent of the construction costs (roughly $100 million) of GMT, the largest goal in the consortium after the University of Arizona. In addition to capital costs, we contribute to the GMT consortium in terms of instrumentation in the form of the near-infrared spectrograph GMTNIRS.

GMT instrument development is being staged to match the technical development of the telescope and its adaptive optics (AO) system. Stage 1 (2023) will provide first light with four mirrors and two instruments (the GCLEF highly-stable visible echelle high-resolution spectrograph and the GMACS wide field visible multi-object spectrograph). Stage 2 will provide a full aperture (seven mirrors) and another instrument, while stage 3 (2025) will unleash the full AO capability and the remainder of the approved instruments. Under development are the GMTIFS Near-IR IFU and Adaptive Optics Imager, the GMTNIRS high-resolution IR Echelle Spectrograph, which both utilize the AO system, and the Facility Fiber Optics Positioner MANIFEST. UT leads GMTNIRS and is a key player in the wide field capability enabled by MANIFEST.

GMT’s exquisite sensitivity, spatial resolution, and field of view will catalyze breakthroughs on fundamental questions: When and how did first stars, planets, galaxies, and black holes form? How did they evolve over time? How do stars die, forge new elements, and distribute them throughout the Universe? What are the demographics of exoplanets and how many are habitable? What is the nature of dark energy, dark matter, and the ultimate fate of the Universe? The ultra-high spatial resolution of GMT will allow first direct observations of giant planet formation inside the "snow line” (2-4 AU; Figure IV-6), a detailed look at the atmospheres and bulk weather patterns in giant planets; and the characterization of potentially habitable planets. Another example shown in Figure IV-7 illustrates how the simultaneous high sensitivity and large field of view of GMT will enable a transformative leap in our ability to study the first generation of galaxies.

The period of 2018 to 2024 will be a golden era where we will benefit from the synergy between GMT and other transformational facilities coming online: JWST (2018), LSST (2022), SKA (2022), and GMT (2023). LSST will map over 18,000 square degrees of sky and uncover tens of billions of objects for the first time, and the most interesting ones can be followed up with GMT to obtain visible and near-infrared spectra, even for exceptionally faint objects. SKA and ALMA will provide the census of cold gas and star formation for thousands of galaxies at $z>>1$, complementing the info from GMT on stellar populations, chemical evolution, and the intergalactic medium.

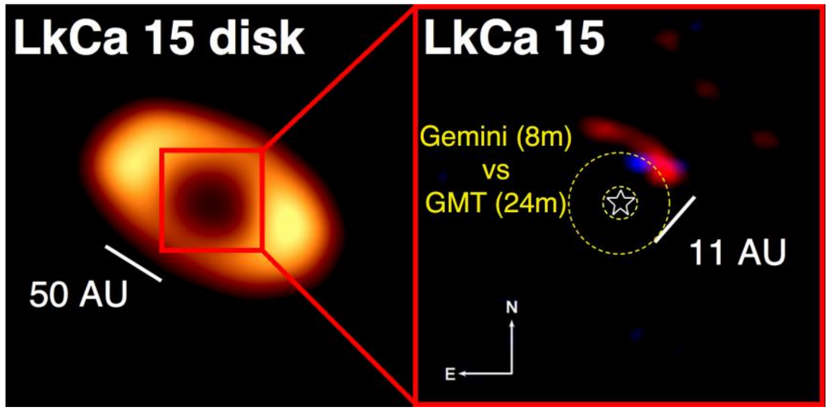


Figure IV-6: The submm image (left) of LkCa15 shows the gapped protoplanetary disk, while the near-infrared image with non-redundant aperture masking (right) reveals the planet and extended material surrounding it. The circles show the relative resolution when observing at 2 microns with the present-day 8-m Gemini telescope (outer circle) versus the future GMT (inner circle of radius 21 mas). GMT will allow us to directly observe Jovian/Saturnian planet formation in the snow line (at radii of 2-4 AU) where it should commonly occur, while current technology on 8-m class telescopes only allows us to probe the outer Solar System (10 AU and beyond). (*Courtesy: Adam Kraus)*

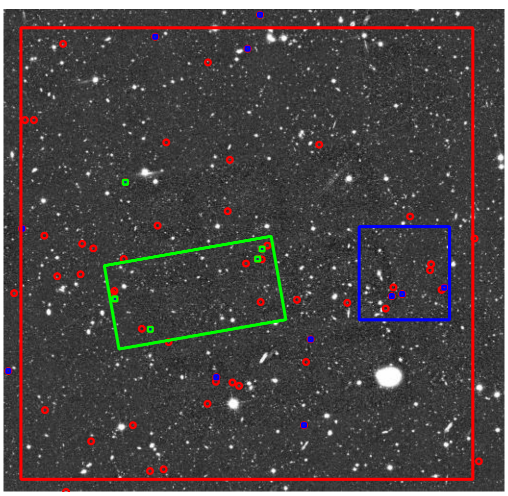


Figure IV-7: Colored symbols denote the position of known extremely distant galaxies. Those in green, blue, and red can be seen respectively by the current Keck 10-m telescope, the future 6.5-m JWST and the GMT. Colored boxes represent the corresponding field of view. GMT will observe ~50 very faint distant (e.g., z >9) galaxies at once, while Keck and JWST can only observe 3-4 moderately faint galaxies. GMT will thus allow a transformative leap in our ability to study the first generation of galaxies. *(Courtesy: Steve Finkelstein)*

Challenges and Opportunities

1) A major challenge for UT Astronomy is to complete fundraising for our target contribution of $100 M for a 10% partnership in GMT. In 2014, thanks to the support of the UT leadership, particularly CNS Dean Linda Hicke, and former UT President Bill Powers, the University of Texas System Board of Regents authorized UT Austin to spend $50 M to participate in building the GMT. Efforts to fundraise the remaining $50 M have yielded $3.9 M as of January 2017. However, in 2016-2017, there are eight additional GMT prospects for asks of $1 million, as well as opportunities among the University community for asks of $8-10 million. In 2017, the GMT Organization (GMTO) is positioned to make a major push in philanthropy as well (Section IV.H).

One factor that mitigates the impact of fundraising delays for GMT is that the telescope's 3-stage deployment strategy will enable competitive science even with the partially completed GMT.

2) Membership in GMT is a necessary but not a sufficient condition to advance our standing because competing top public state Universities (e.g., UC Berkeley, UC Santa Cruz, University of Arizona), and private institutions (e.g., Harvard, Caltech, Chicago) are also partners in GMT or the Thirty Meter Telescope (TMT). We must strive to support GMT so it is highly successful while developing additional forward-looking initiatives that make us stand apart, such as those outlined below:

a. Hiring faculty who can lead world-class science.

b. *Conducting complementary surveys at long wavelengths (far-infrared, sub-millimeter, radio)* to gather information that is crucial for our understanding of the Universe, but is missing from optical/infrared surveys with JWST, GMT, and LSST. In particular, only half of the extragalactic background radiation reaching us today is at UV/optical wavelengths, while the other half is at far-infrared/ sub-millimeter wavelengths and is likely dominated by thermal emission from dust heated by young stars and nuclear activity in galaxies. ALMA can map targeted objects, but its very small field of view limits large surveys. Prior to 2016, the Astronomy Department was exploring partnership in the 25-m submillimeter Cerro Chajnantor Atacama Telescope (CCAT), which was ranked the highest priority among medium scale, ground-based projects by the Astro2010 Decadal Survey. However, the lack of funding from the 2016 NSF Mid-Scale Innovations Program (MSIP) has led to a significant downscaling of CCAT. We are no longer considering CCAT. Instead, we are exploring participation in the NSF-funded TolTEC Public Legacy Surveys on the 50-m Toltec Large Millimeter Telescope (LMT) in Mexico and possible future partnership in the LMT. We will explore how to advance these initiatives through opportunities provided by ConTex (https://research.utexas.edu/find-funding/contex-programs/), a partnership formed in late 2016 between the University of Texas System and Mexico's National Council of Science and Technology (CONACYT) to enhance academic and research cooperation between Texas and Mexico.

c. *Development of the theoretical framework for frontier science questions*: UT Astronomy has a very strong theory group with expertise in many fields, including cosmology, first stars and galaxies, dark matter, supernovae, time-domain astronomy, high-energy physics, and near-field cosmology. We need a stronger effort to synergize existing theoretical expertise and build the theoretical framework for frontier science questions that will be addressed by next-generation facilities, such as GMT, JWST, LSST, and SKA. Resources, such as students, postdocs, or a UT Astronomy prize postdoc in theory (Section IV.B) would help. We are exploring some modest internal seed funding to support these initiatives, but a large investment in resources is challenging for the reasons outlined in point (e).

d. *Building Synergistic collaborations*: We need to build more synergistic collaborations with institutions with common interests to maximize our impact. One example is a stronger collaboration with Texas A&M University (a 5% partner in GMT) to plan Texas-led science with GMT. Examples of recent successful partnerships include the collaboration with the Korea Astronomy and Space Sciences Institute (KASI) on IGRINS and other instrumentation; the new partnership with other GMT institutions on developing the wide-field survey capability (Section IX.E); the international UT-led HETDEX collaboration on dark energy (Section IV.D); the recently NSF-funded SHELA/HETDEX collaboration on galaxy evolution between UT Austin, Texas A&M University, and Penn State University; and the Kepler/K2 missions. We are also exploring the possibility of a Z Astrophysical Plasma Properties (ZAPP) center associated with a five-university consortium hosted in Texas, with the potential of garnering significant funding from DOE, NSA, and NSF.

e. *Addressing financial challenges*: At this time, it is challenging for the Astronomy program to allocate significant financial resources toward the initiatives in (b) and (c), as we are focusing our philanthropic effort (Section IV.H) on fundraising the remaining $46 M for our goal of a 10% share in GMT, and fundraising endowments to address the serious challenges of graduate student support (Section IV.B). If the funding challenges remain, it will be important for our Astronomy program to do a comprehensive analysis of the best way forward.

IV.D. Pushing New Frontiers with Hobby-Eberly Telescope Dark Energy Experiment

Current Strengths

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey designed to measure the evolution of dark energy via the power spectrum of around 0.8 million Lyman-alpha emitting galaxies (LAEs) in the redshift range $1.9 < z < 3.5$.

HETDEX aims to measure the expansion rate of the universe to sub-percent accuracy at an average redshift around 2.5. This measurement, when combined with the currently available nearby measures, will produce the most accurate measure of any potential evolution in dark energy. It will also provide the tightest constraint on the curvature of the universe. The target specification is to measure the effect of dark energy at a redshift $z=2.5$ assuming it is the cosmological constant, which is about a 1% accuracy in the distance. This specification leads to all instrument and telescope designs. By adhering to this goal, HETDEX can be one of the most important experiments to study the evolution of dark energy.

The HETDEX team is led by Gary Hill (PI) and Karl Gebhardt (Project Scientist) from UT Austin, and includes members from UT Austin, Pennsylvania State University, Leibniz-Institut für Astrophysik Potsdam (AIP), Texas A&M University, Ludwig-Maximilians-Universität Munich, Institut für Astrophysik Göttingen, University of Oxford, Max-Planck-Institut für Astrophysik (MPA), and The University of Tokyo. The project received $37 million in funding through philanthropy, McDonald Observatory, the Department of Astronomy, in-kind contributions from the HETDEX consortium, and NSF grants to conduct the survey and analyze the data to constrain the nature of dark energy. Technical details and a description of the survey are provided in section IX.

To enable HETDEX, the top-end of the 10-m class Hobby-Eberly Telescope (HET) at McDonald Observatory has been equipped with a new wide-field corrector (Section IX). The first light of the upgraded HET with a highly expanded diameter field of view (from 4 to 22 arcminutes) occurred in 2015, marking an important milestone. To date, 16 of the 78 planned integral field unit (IFU) spectrographs have been installed. Each IFU feeds a low-resolution spectrograph unit of the Visible Integral-field Replicable Unit Spectrographs (VIRUS, Section IX). VIRUS gathers spectra from 35,000 fibers, simultaneously.

While HETDEX was designed to make significant advancement to the understanding of dark energy, it will also allow a large number of other science projects, such as mapping the cosmic web, exploring galaxy evolution in different environments at redshift $z>2$, understanding the escape of Lyman alpha photons from galaxies, searching for the most metal-poor stars in the Milky-Way Galaxy, discovering supernovae via novel means, studying dark matter and star formation distributions in nearby galaxies, and measuring the total mass of neutrinos. To enable this broad impact, the goal is to produce calibrated data as soon as they come off the telescope and distribute them to the HETDEX community.
An example of a powerful NSF-funded ancillary project (UT PI: Jogee, Co-I: Finkelstein) that leverages HETDEX is the study of galaxy evolution as a function of stellar mass and environment during the important cosmic epoch ($1.9 < z < 3.5$) when star formation and black hole accretion peaked, and massive proto-clusters collapsed into existence. This study focuses on a 24 square degree field within the full HETDEX survey area and uses a powerful combination of five existing photometric surveys from UV to far-infrared wavelengths (DECam ugriz, NEWFIRM K-band, Spitzer IRAC, and Herschel-SPIRE) with future HETDEX spectroscopy.

The HETDEX team has achieved the major accomplishment of building the largest spectrograph in the world in regards to area coverage, placed it on an essentially new 10-m class telescope, and planned a very large observational campaign. No other instrument-telescope combination can come close to the area coverage for spectroscopic redshifts. The main HETDEX program aims to produce 0.6 billion spectra. With a parallel program, there will be an additional 2-3x that amount, of which a significant fraction will be useable for cosmology and galaxy studies. Thus, we expect about one billion spectra of high quality.

Challenges and Opportunities

HETDEX is significantly late due to a variety of issues with the ambitious telescope upgrade and massive instrument build. The HET is now in science operations, and the final hurdle is getting all spectrographs on the telescope. The most important next step is acquiring replacement detectors for VIRUS, followed by the final assembly of the spectrographs. The HETDEX team expects a full complement of spectrographs in early 2018, with a steady build-up of units until then (see Section IX for more details).

Data are being taken now with 20% of VIRUS and observations will continue; these early observations serve to confirm the observational design and software and provide experience operating and maintaining the instrument. Multiple papers will come from these ongoing observations. HETDEX will formally start when there is a nearly full complement of spectrographs and will take approximately four years. Thus, final results from HETDEX are expected in 2022. This very significant delay compared to the original design is a serious setback for the HETDEX project. However, the project has not compromised on performance and final cosmological constraints, and there is no other competing project that can achieve sub-percent accuracy for the distance measures.

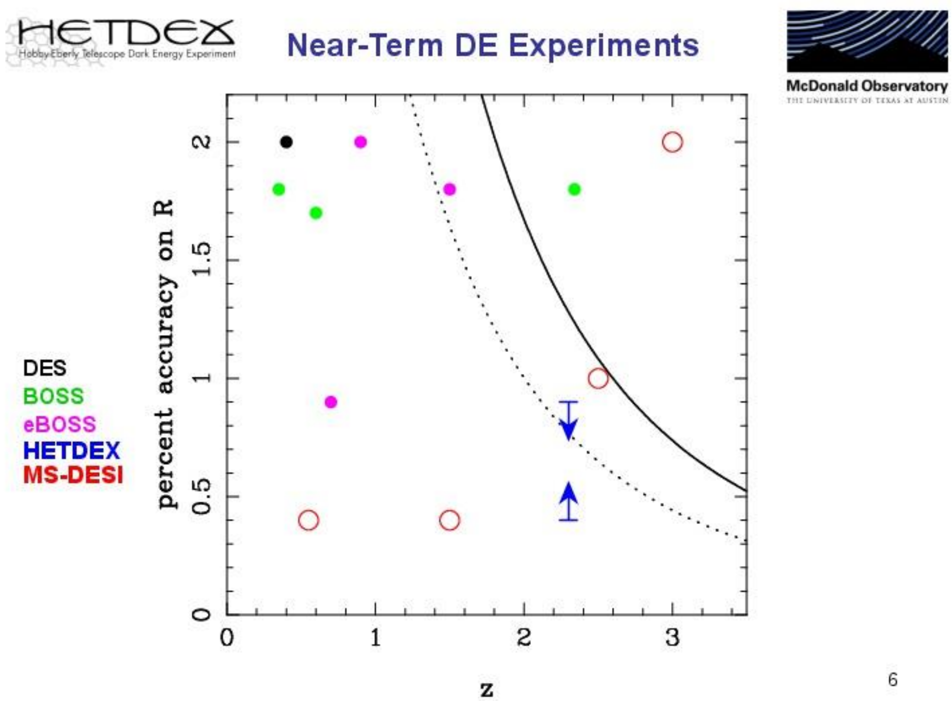


Figure IV-8: This figure summarizes the percentage accuracy expected on the measurements of the expansion rate from all significant ongoing and near-term dark energy surveys. The upper limit for HETDEX represents the baseline survey, while the lower represents the lower limit from an extended survey. *(Courtesy: Karl Gebhardt)*

The HET Board has allocated to the HETDEX Team about 50% of the observing time estimated for completing the project. While the HET Board has been very supportive and there are strong expectations that this support will continue, we need to continue to cultivate engagement and support of HETDEX over the full HET partnership. We will also work to retain the attention of the many talented scientists, engineers, and software experts contributing to HETDEX.

Moving forward it is important for the team to construct a multi-layered plan with an assessment of contingences and resources needed under different scenarios, not only for completing the delivery of the hardware, but also for the execution and management of the survey, and the analysis of the data to deliver the dark energy science.

Most dark energy surveys are focused on improving the expansion accuracy at low redshifts, where it was originally discovered. HETDEX will provide the most accurate measure of the expansion rate of the Universe at high redshift (Fig. IV-8) compared to other dark energy surveys. The only major survey that can obtain a similar accuracy to HETDEX at high redshift is MS-DESI. They are expected to start in 2020-2021 and require a 5-year survey to reach a similar accuracy to HETDEX. They span a larger redshift range, going from 0.6 to 3.2. The combination of dark energy constraints from HETDEX, MS-DESI, and all the nearby studies will provide the ultimate constraint on the evolution of dark energy. HETDEX can have a significant impact by delivering results before MS-DESI and having the best accuracy on the expansion rate at the cosmic epoch where this measurement can set strong constraints on the possible evolution of dark energy.

IV.E. Growing Leaders in our Undergraduate Program

Numerous reports indicate that for our nation to excel, we need to produce one million additional Science Technology Engineering & Mathematics (STEM) graduates over the next decade than expected under current assumptions (e.g., President's Council of Advisors on Science and Technology, 2012). Yet fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. The UT Astronomy program is dedicated to improving engagement, retention, and graduation rate of students in STEM by offering a research-centered experiential undergraduate program (Section VI). A hallmark of our program is early and sustained engagement in research, which we believe is key for transforming our students into scientists, innovators, and leaders.

Figure IV-9: UT Astronomy Undergraduate Students *(Photo credit: Lara Eakins)*

Current Strengths

The size of our Astronomy Undergraduate Program has nearly doubled over the last five years, and we are now one of the largest programs in the nation with 129 astronomy majors. We have a diverse student body: in 2015-16, our majors consist of 38% women, 62% men and 54% White, 9% Asian, 6% African-American/Hispanic, and 31% in other categories. We also share the beauty of science and astronomy with over 3,500 non-science majors each year, preparing them to be informed citizens for the greater benefit of society.

Our undergraduate curriculum promotes early involvement in research. Each year, we offer an astronomy research seminar (AST 104) to introduce students to UG research opportunities in the Astronomy Department. We also teach a Research Methods class (AST 376R) to equip students from freshman to junior years with some of the core skills needed for starting research. Our lower and upper division courses teach our students to think critically, develop leadership traits, and master quantitative, analytical, and programming skills.

The Astronomy Department has a thriving UG research community where over 60% of astronomy majors are involved in research, and over 70% of our faculty members have supervised UG research in recent years. Many freshmen join our currently active Astronomy Freshman Research Initiative (FRI) Stream (www.as.utexas.edu/~mikemon/FRI/ast2.html), entitled `Exploring the Physics of the Universe with White Dwarf Stars', which gives first-year students the opportunity to engage in research experience. This stream engages them over three semesters, starting in the spring of their freshman year. Our stream is part of the CNS FRI program, which has become a national model for science education (https://cns.utexas.edu/fri). Freshmen and students in sophomore to senior years also have the opportunity to conduct individual research projects with faculty, postdocs, and research scientists. Many of them travel to McDonald Observatory to obtain their data and experience the forefront of astronomical research. The Department supports UG astronomy majors conducting research (in the form of stipends, travel funds to conferences, observing trips, etc.) and offers prizes for excellence in research.

Many of our instructors are adopting student-centered, experiential teaching techniques. These include learner-centered instruction, small group discussions, peer collaboration, low-stakes testing, and flipped courses. Faculty members train in workshops led by the CNS Texas Institute for Discovery Education in Science (TIDES). A few faculty members have tried out new CNS teaching spaces, which became available in 2016 and are designed for improved learning and student interaction. We are also exploring curriculum reform to make our courses more effective for our majors. Three of our faculty members are part of the prestigious UT Academy of Distinguished Teachers.

We have traditionally offered a Bachelor of Science in Astronomy (BS) degree with an honors option and a Bachelor of Arts in Astronomy (BA) degree. In 2014-15, we added a Bachelor of Science and Arts in Astronomy (BSA) degree. These three degree options allow us to accommodate different academic choices and ensure on-time graduation in four years (Section VI).

Challenges and Opportunities

1) The Astronomy Undergraduate Research Computer Lab is central to our goal of providing a research-centered education. It provides not only the required computers with specialized software and licenses but also the space for fostering peer interaction and supportive STEM communities. The lab also hosts our Research Methods course, Freshman Research Initiative steams, and vertically integrated research teams. Unfortunately, our current lab accommodates only 18 students or 13% of our majors at a given time, leading to overcrowding and inadequate access. We have started a major initiative to double the capacity of our Undergraduate Research Computer Lab from 18 to 37 seats. We aim to cover the cost ($220K) through requests to CNS, one-time use of department endowments, and philanthropic efforts aided by our fundraising video (https://youtu.be/i2qOmYnK3mg).

2) While about one-third of our students pursue graduate school and academic careers, a large number are headed for non-academic positions, which require them to apply science to broader arenas of society (e.g., private sector, defense, medicine, engineering, government, science policy, outreach). We are exploring ways to better prepare students for 21st-century interdisciplinary careers in academia and beyond. One possible initiative is to offer more inter-disciplinary courses, such as courses in planetary science offered by Astronomy/Geology, astrobiology by Astronomy/Integrative Biology, and Big Data by Astronomy/ Computer Science/TACC. We are also starting to build an alumni and friend network and aim to create networking groups on LinkedIn and other platforms.

3) In addition to the currently active FRI stream on white dwarfs, the Astronomy program also used to host a second complementary FRI stream, "Cosmic Dawn," which focused on scientific research in cosmology using state-of-the-art supercomputer simulations run on the Texas Advanced Computing Center (Section VI). This stream was active until 2014 but was terminated due to lack of CNS FRI funding, despite being in high demand with students from a wide range of majors. The several dozens of FRI streams currently funded by CNS cannot accommodate a large fraction of CNS Freshmen and efforts are underway to secure more funding. If future calls for new FRI streams are made, our faculty members will explore new complementary Astronomy FRI streams.

IV.F. Fostering a Climate of Excellence and Inclusion

The Astronomy program is vested in fostering a climate that promotes the inclusion and broader participation of women and other under-represented groups in science. An inclusive program is essential for tapping into the full pool of excellence of our diverse nation and for promoting a just and equitable environment where everyone can be part of the scientific journey. We are committed to providing a workplace that is free of harassment and discrimination on the basis of race color, creed, religion, gender, citizenship, age, disability, veteran status and sexual orientation.

Strengths

1) In the last four years, we have made important progress in improving diversity among our graduate students (Table IV-2) through a multi-pronged approach, which includes holistic admission criteria, focused recruiting efforts, cluster visits, an inclusive department climate, cutting-edge research projects, and improved recruiting packages. In 2016-17, our graduate students include 11 (31%) female, 3 African American/Black, and 3 Hispanic students.

2) Over 2012-2014, the Department lost two junior female faculty members (Jenny Greene and Sally Dodson-Robinson) due in part to two-body problems, leaving the department with only two (9%) female faculty members (Harriet Dinerstein and Shardha Jogee). With the recent hire (2015) of Caitlin Casey, who brings expertise in the study of dusty obscured galaxies, we have increased the percentage of women on the faculty to 15%. For the first time in its history, the department elected a female professor as department chair, effective fall 2015.

Table IV-2: Demographics of Astronomy Students and Tenured/Tenure-Track Faculty

Group	Years	Total No.	Gender			Race and/or Ethnicity					
			Male	Female	Other	White	Black African American	Hispanic	Asian	Native American	Other
UG Students	2016-17	129	64.4%	35.7%	0.0%	51.9%	2.3%	5.4%	10.8%	0.0%	29.5%
	2015-16	99	61.6%	38.4%	0.0%	54.6%	1.0%	5.1%	9.1%	0.0%	30.3%
Group	Years	Total No.	Gender			Race and/or Ethnicity					
			Male	Female	Other	White	Black African American	Hispanic	Asian	Native American	Other
	2014-15	92	68.5%	31.5%	0.0%	57.6%	1.1%	6.5%	6.5%	0.0%	28.3%
Graduate Students	2016-17	35	68.6%	31.4%	0.0%	57.1%	8.6% (3)	11.4%	2.9%	0.0%	20.0%
	2015-16	39	76.9%	23.1%	0.0%	51.3%	2.6% (1)	15.4%	5.1%	0.0%	25.6%
	2014-15	35	80.0%	20.0%	0.0%	54.3%	0.0%	14.3%	5.7%	0.0%	25.7%
TTT Faculty	2016-17	19.5	84.6%	15.4% (3)	0.0%	89.7%	0.0%	0.0%	10.3%	0.0%	0.0%
	2015-16	22.5	86.7%	13.3% (3)	0.0%	91.1%	0.0%	0.0%	8.9%	0.0%	0.0%
	2014-15	21	90.5%	9.5% (2)	0.0%	90.5%	0.0%	0.0%	9.5%	0.0%	0.0%

3) The AAS recommendation (https://aas.org/governance/council-resolutions#GRE) on the Physics Subject Exam (PGRE) and other recent studies (e.g., Levesque et al. 2015) show that the PGRE does not strongly correlate with long-term success in research and has a disproportionately large negative impact on under-represented groups. Our faculty voted to eliminate the use of the PGRE in our graduate admissions process, effective fall 2016. Our junior faculty (Adam Kraus, Caitlin Casey, Mike Boylan-Kolchin, and Steven Finkelstein) played an important part in this decision through their advocacy and analysis of our internal data.

4) To promote policy changes on the PGRE broadly across the astronomical community, the UT Astronomy Department Chair, Shardha Jogee, led a survey and discussion among ~30 astronomy department chairs to encourage departments to make the PGRE optional or eliminate it from the admissions process. As of December 8, 2016, 13 or 48% of the 27 responding astronomy programs no longer require the PGRE: 9 have made the PGRE optional, and four have eliminated it. While the movement is encouraging, we still have a long way to go. The report is now public and is being circulated by Department Chairs and by the AAS leadership to encourage more change. An article in the AAS digest is forthcoming. (www.as.utexas.edu/~sj/PGRE/PGRE-Landscape-Final.pdf)

5) The department and CNS now have an accommodation policy for graduate student parents, allowing extensions of academic responsibilities. This aims at reducing the ``pipeline leak'' of

women leaving the sciences due to family formation (e.g., Charbonneau et al. 2013; Mason, Goulden, & Frasch 2011).
6) The Association of Women in Astronomy Research and Education (AWARE) was created in 2014 to support the broader participation of under-represented groups in STEM. It brings together women at different career levels to provide support and vertical mentorship. AWARE has hosted discussions on equity, sexual harassment and Title IX policies, and professional development. It has also organized events to educate our community on equity issues, including a 2014 CNS-wide talk on the under-representation of women in science by Dr. Meg Urry, a 2015 presentation on "Unconscious Bias in Hiring, Promotions, and Tenure" by Dr. Joan Schmelz (then chair of the AAS Committee on the Status of Women in Astronomy), a 2016 discussion forum for women from social sciences, engineering, and natural sciences, and representation at the 2015 "Inclusive Astronomy" conference. Spearheaded by graduate student Raquel Martinez, AWARE now participates in "Girl Day," an annual event that brings more than 5,000 K-8 girls to the UT campus.

Figure IV-10: Left: Participation of the Association of Women in Astronomy Research and Education (AWARE) and other members of the Astronomy program in Girl Day, an annual event which brings 5,000 K-8 girls to the UT Austin campus. *(Photo credit: Raquel Martinez).*

7) The Texas Astronomy Undergraduate Research experience for Under-represented Students (TAURUS) was launched by Assistant Professor Caitlin Casey in 2016, with support from the Department and Observatory. We welcomed 5 TAURUS scholars to UT Austin for nine weeks in the summer, where they worked with graduate student mentors and professional astronomers, and participated in bi-weekly seminars on topics ranging from the latest in astrophysics to social justice in STEM. A strong highlight of the TAURUS summer experience was a trip to McDonald Observatory, giving many TAURUS scholars their first opportunity to visit an observatory. The pilot year of TAURUS was funded by discretionary funds from the Department, and it is expected that the program will continue by seeking external funding independently (e.g., as part of a CAREER or NSF AAG grant), as part of the department's NSF REU proposal, or through philanthropy.

8) The Equity and Inclusion Group, newly founded by Raquel Martinez, Brandon Bozek, and Caitlin Casey has organized events to support our diverse community, including supportive meetings after

the recent presidential elections, and Allyship Toolkit workshops to make the campus safer and more welcoming for all LGBTQA+ people.

Challenges and Opportunities

We have no representation from the African-American/Black, Hispanic/Latinx, or Native American (Table IV-2) communities on our faculty. Across the nation as a whole, only about 2.2% of Physics and Astronomy faculty members are Hispanic or African American. A major challenge in recruiting faculty from under-represented groups is the limited application pool: only about 3.5% of the Astronomy PhD pipeline is made of URMs. We are making progress on this issue by encouraging qualified candidates to apply, contacting senior mentors, scouting scientific conferences, and consulting organizations catering to under-represented groups (e.g., the AAS Committee on the Status of Minorities in Astronomy (CSMA), the AAS Committee on the Status of Women in Astronomy (CSWA), postdocs in bridge programs, and the national online directory of minority postdocs).

We will continue to adopt best practices to limit bias in our faculty hiring and student admissions process. These include carefully phrasing the job ad, training members of the hiring/admissions committee, discussing the pitfalls of recommendation letters, and using pre-set carefully defined criteria when evaluating applications.

IV.G. Leading a High-Impact Education and Public Outreach Program

Perhaps more than any other science, astronomy awakens curiosity and evokes questions about the largest, farthest, oldest, and deepest of mysteries. McDonald Observatory and the Astronomy Department lead a vibrant education and public outreach program that leverages the immense appeal of astronomy to bring scientific ideas to society at large and draw diverse young people into STEM fields. We seek to:

- Enhance public and student understanding of
    - The scale, natural phenomena, and evolution of the Universe
    - Science itself as process and practice
    - The night sky, and how to preserve it
- Improve the effectiveness and reach of science teaching and free-choice learning
- Inform the science-interested public and key stakeholders about the capabilities and achievements of the UT Astronomy program's activities
- Contribute to positive and fruitful relationships between McDonald Observatory and its west Texas neighbors

In pursuit of these goals, we carry out a range of activities at the Observatory site, on the UT Austin campus, and in the city of Austin. Many are almost entirely self-supporting, funded by fees, sponsorships, grants, and donations.

Current Strengths

StarDate: StarDate is the longest-running natural science radio feature in the US. The show's two-minute modules play daily on nearly 400 radio stations nationwide, reaching some 2.3 million listeners. Nearly half a million podcast files are downloaded annually from the stardate.org server; the associated website provides additional written and graphical information about astronomy and the night sky and serves over seven million page views per year. StarDate radio broadcasts also reach a number of under-served audiences in the US including more than fifty thousand American Indians and tens of thousands of Pacific Islanders. Sample radio audiences include Hawaii Public Radio, the Turtle Mountain community (Belcourt ND), Alamo Navajo School Board (Magdalena NM), Native American Sioux Tipi History (McLaughlin SD), the Jicarilla Apache Reservation (Dulce NM), and Hoopa Valley Tribally-Owned Community Radio (Hoopa CA). StarDate is also heard by a large Hispanic audience on radio stations such as KMBH and KHID in the Rio Grande Valley of TX. StarDate also reaches throughout the world to millions of people on the Armed Forces Radio and Television Services. The bi-monthly StarDate magazine, which reaches over 18,000 readers, offers detailed sky-watching information, topical feature articles, and the latest astronomy news.

Public Visits to the McDonald Observatory Visitor Center: The McDonald Observatory Visitor Center in west Texas draws about 90,000 visitors annually. During the daytime, visitors can enjoy interpretive exhibits and other media, tour the site, safely view a filtered and magnified image of the Sun, and gaze in awe at the great research telescopes. During hundreds of evenings each year (three nights per week, every week) the site comes alive with star parties and special viewing opportunities that let visitors, guided by experts, encounter celestial wonders through large telescopes with their own eyes.

Student Field Trips to McDonald Observatory: Nearly ten thousand K-12 students, mostly from Texas and many from economically disadvantaged communities, visit the Observatory each year, where our education team offers inspiring, interactive learning experiences that align with state and national teaching standards. Our Live from the McDonald Observatory program uses videoconferencing technology to reach students who cannot visit in person. Over 8,000 participants engaged with us in this way last year.

Professional Development for K-12 Teachers: A single teacher can affect thousands of students across a career. By improving even modest numbers of such teachers' ability to teach science well, we can enhance the education of millions of students. UT Astronomy faculty, who are themselves gifted teachers, team with McDonald Observatory education staff to offer astronomy-themed teacher workshops to hundreds of teachers annually. In these residential, multi-day workshops, conducted at the Observatory, teachers learn both astronomy content basics and engaging curriculum support activities that can help make science come alive in classrooms far from research facilities. The curriculum activities align to Next Generation Science Standards and Texas Essential Knowledge and Skills requirements.

UT Astronomy faculty and McDonald Observatory staff also present workshops annually at the Conference for the Advancement of Science Teaching, the annual meeting of the Science Teacher's Association of Texas. This conference reaches 5000+ science teachers per year, and the McDonald

Observatory education team typically directly interact with and present to 200-300 teachers at this meeting each year. In total, through workshops and other professional development offerings, the McDonald Observatory EPO team directly trains and reaches more than 300 teachers per year. The impact on K-12 students is leveraged through these teacher trainings (Fig. IV-12).

Figure IV-11: Teacher Workshop group from the 2015 GMT Teacher Workshop in front of the 2.1-m Otto Struve Telescope at McDonald Observatory. *(Photo credit: Keely Finkelstein)*

Astronomy Department Star Parties and Outreach Programs In Austin: The Astronomy Department host several programs in Austin to serve local schools and the public. These include field trips for local schools, which reach 750 students (mostly 2nd to 5th grades) a year, and three nighttime public viewing opportunities on our two campus telescopes that host approximately 5,000 visitors a year combined. The field trip program is also offered in the summer for groups from local science-themed summer camps from The Thinkery, the Austin Nature and Science Center, and other organizations. The star parties (Figure IV-13) are considered one of the "Gems of the University" highlighted for students in Signature Courses and have won two Austin Chronicle "Best of Austin" Critics Choice Awards (2010 and 2013).

The Astronomy Department also participates in Explore UT, the university-wide open house, where we host hundreds of families and dozens of school groups. Under the leadership of astronomy graduate student Raquel Martinez, the Association of Women in Astronomy Research and Education (AWARE) participates in "Girl Day," an annual event that brings more than 5,000 K-8 girls to UT campus, and promotes participation of girls in STEM (Figure IV-10).

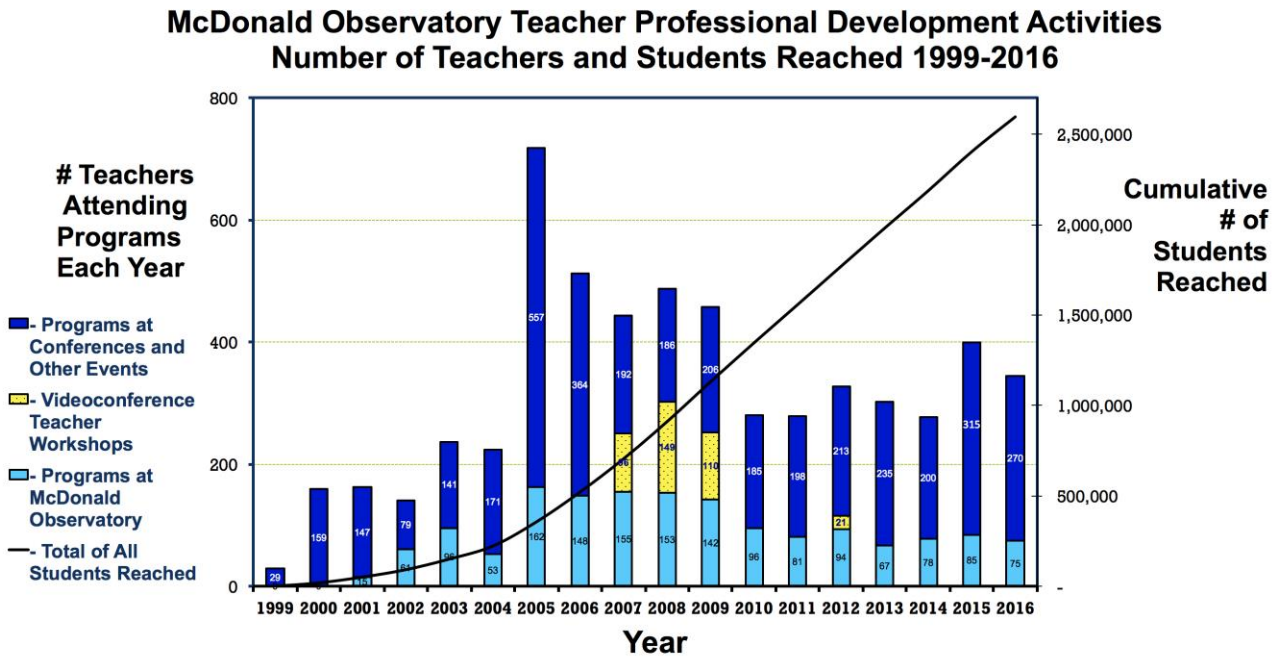


Figure IV-12: Impact of McDonald Observatory Teacher Professional Development activities on a number of teachers and students reached. Calculated number of students reached assumes each teacher served sees an average of 100 students per year with a 15% loss per year of teachers who continue to use the materials. *(Courtesy: Keely Finkelstein)*

Figure IV-13: Students and the general public regularly attend the Astronomy Department "star parties" at the 16-inch telescope on the roof of the RLM building. *(Photo credit: UT Communications)*

The Undergraduate Astronomy Students Association (ASA) holds numerous outreach activities and has recently launched "Telescopes by the Tower" where they bring telescopes with solar filters and an H-alpha telescope to engage with the public on the UT campus. They have also expanded this to include other parts of Austin on the second Saturday of each month (Fig. IV-14).

Astronomy on Tap: A new popular outreach event is the Austin chapter of the Astronomy on Tap (AoT) lecture series, started by postdoctoral fellows Rachael Livermore and Jeffrey Silverman in 2014. The AoT Committee is now led by postdoc Brandon Bozek and graduate student Raquel Martinez and draws about 3,500 people each year to hear astronomy talks in an informal setting.

Open House for Texas legislative staff: In 2016, we hosted the first Open House for Texas legislative staffers and their families in the department to share with them the mission of the Astronomy program. The evening featured talks by the Astronomy Department Chair and McDonald Observatory Director, a lively poster session by our students, and a tour of the VIRUS instrumentation lab. Attendees included representation from Governor Abbot's office, Lt. Governor Patrick's office, the Office of the Speaker, the House Appropriations Committee, the Senate Higher Education Committee and the Senate Finance Committee. They were enthusiastic about what they saw and expressed support for our mission.

Fig. IV-14: Members of the Astronomy Students Association (ASA) bring telescopes with solar filters and an H-alpha telescope to engage with the public in various locations in Austin.

JWST Booth at SXSW in Austin: Another featured program aimed at the public was the UT Astronomy Department's participation with NASA, STScI, and Northrop Grumman as part of their annual exhibits, displays and booths at SXSW over the last four years, featuring a full-scale model of the James Webb Space Telescope (JWST). In 2013, the event reached an estimated 20,000 people over three days.

Challenges and Opportunities

McDonald Observatory Education & Outreach activities are almost totally dependent upon fee revenue supplemented by donations, sponsorships, and grants. The relatively recent withdrawal of NASA as a provider of small and supplemental educational grants has been felt and we are seeking new creative opportunities for non-government funding.

The team that plans, writes, commissions, and edits content for our daily StarDate radio program and bimonthly StarDate magazine is very small (less than 2 FTE). The loss of either of those persons would pose a major challenge in the short-term, as StarDate has paying subscribers, scheduled air slots, and an audience in the millions: "The show must go on." We are beginning a process of succession planning that will likely entail shoring-up revenue for StarDate so that we can improve upon the present staffing situation.

Demand for admission to McDonald Observatory star parties is outstripping our capacity at three nights per week so that we are increasingly turning people away. This is a great problem to have and testifies to the perceived value of the program. We are looking into ways to expand our capacity while maintaining a positive cash flow. We will also be pursuing ways to make the Observatory Visitor Center and daytime tour program a more appealing option and to more effectively market this to visitors in west Texas. Another challenge associated with the large crowds that come to star parties is what to do with them when inclement weather prevents telescope viewing. The Visitor Center is not currently configured to enable a satisfying alternative. We are investigating ways in which the largest spaces in that building, the exhibit hall, and auditorium, can be redesigned to provide a fulfilling mass visitor experience on cloudy nights, as well as a conventional visitor experience for daytime visitors. The Visitor Center's aging building infrastructure (lighting, fire alarm system, sidewalks) also requires non-trivial attention.

A very positive upcoming opportunity is found in the potential for education and outreach partnerships for the upcoming GMT. With its extensive experience in astronomy education and public communication, including the operation of a major public visitor complex, UT is positioned to serve the GMT community in a leadership role. We have already started this locally by offering GMT-oriented teacher professional development workshops (summers 2014-2015), as well as three mini GMT workshops at the Conference for the Advancement of Science Teaching (CAST) during the last three years. McDonald Observatory education team members have participated in Chile-US astronomy education summits during 2015 and 2016 in Chile.

Although we have numerous volunteers for our departmental outreach activities on campus, most are conducted and overseen by single department staff member (Lara Eakins), who has many other responsibilities, including administrative duties, maintaining the demonstration equipment for our undergraduate courses, and maintaining both campus telescopes. We need more resources to maintain a responsive and high-impact outreach program. Both of the telescopes on campus are operational in their current state but are in need of maintenance and renovation. The 16-inch telescope on RLM has suffered past water damage on its walls and flooring, and the drive system has aging computer equipment. The Painter Hall telescope has components dating from the late 19th century and would benefit greatly from a complete renovation. This would be a major project that would require a specific fundraising effort.

IV.H. Leveraging Philanthropy, External Relations, and Support

The Department of Astronomy and the McDonald Observatory have a long history of fundraising and external relations activity. Since the 1970's, our administration has worked to establish relationships with key members of the public to voice support for the program. The Department of Astronomy is highly ranked, and we have established strong donor relationships to support research through endowments. Our StarDate radio program and magazine, award-winning star parties in Austin, as well as the 90,000 visitors we receive each year at the Observatory, are a testament to the quality of our far-reaching public outreach programs.

Current Strengths

The fraction of higher education costs funded by the public coffers has fallen dramatically over the past two decades. Many entities in our State have struggled to build a base of support from private sources. However, because of our 40-year history with fundraising and external relations, the outlook for philanthropic support in the future is promising.
As outlined in the other sections of this self-study, the UT Astronomy program is well positioned to be on the cutting-edge of scientific discovery in the next decade. And because we have built a development program, we can more easily build upon this strength to continue funding research and propel us forward.

The hallmark of our philanthropic support comes through a 240-person Board of Visitors. This external body commits to an annual gift, and many have founded endowments to support faculty and students over the years as well. Many have also made significant specific additional gifts to help support priorities of the Astronomy program. The Board also includes public officials and those we recognize as honorary members. Additionally, StarDate radio and magazine have a membership base that includes thousands of people all over the country who make donations beyond their annual subscription.

Finally, while we are a component of The University of Texas at Austin, McDonald Observatory is fortunate to receive a direct appropriation from the State of Texas. That allocation in the State Budget facilitates the operation of the Observatory. Over the years, many State officials have visited the Observatory, and we will continue to foster those relationships in the future.

Challenges and Opportunities

In 2017, we are at a crossroads. The University's partnership in the Giant Magellan Telescope remains a large financial commitment and a dominant funding priority. Additionally, our strategic plan highlights how critical it is to support graduate students and postdocs, the essential human capital for advancing our research program. These two priorities will dominate development priorities for the coming 3 to 5 years.

In support of the GMT, we have primarily secured gifts to date from our Board of Visitors members. In 2016-2017, there are eight additional prospects for asks of $1 million in support of the GMT, as well as opportunities among the University community for asks of $8-10 million. In 2017, the GMTO (the non-profit organization that represents the coalition partners) is positioned to make a major push in philanthropy as well. GMTO recently completed a self-study on creating and maintaining a functioning development operation in support of existing partners.

In support of research in the Department of Astronomy, our goal is to create a $1 to $3 million endowment to support excellence in research, with a focus on fellowships for graduate students and postdocs. This endowment will be named the Astronomy Research Excellence Fund. It will incorporate smaller, named endowments with common terms of use. Excellence Funds are available for donor naming opportunities to recognize philanthropic leadership. This campaign will complement GMT fundraising and allow participation from philanthropists interested in funding excellence and talent within the Department. There are prospects for an initial four Excellence Funds for a total of $250,000 to fund one graduate summer fellowship.

A parallel strategy for the Department of Astronomy is to increase our reach among the public and with our alumni. We know that engaging our students while they are in Austin will result in stronger long-term relationships when they have reached the peak of their career. Given that our program is high-ranking and also sizeable, engagement of this key constituency is a key to our long-term development success.

Our education and outreach programs at the McDonald Observatory and Star Date radio provide a very strong base within the larger public audience. If we capitalize on media opportunities and expand our conversion of visitors to subscribers to donors, that reach will be exponentially increased. This is an area of opportunity for us to expand the reach and to dramatically increase awareness and support.

In 2016 we have begun to experiment with alumni newsletters and with increasing our social media activity. We have also dedicated resources to reaching out to older alumni to update their contact information and poll for their preferred level of ongoing engagement. Initial response has been very positive. We hope to expand the participation of our alumni in giving and also in sharing their career experience with current students.

Additionally, we have created a campaign on LinkedIn and social media to engage University of Texas alumni who took an astronomy class from our Department. We believe this large group of alumni is an untapped resource. UT alumni who are interested in scientific advancement have proven to be supportive through our "Friends" program and also through the Board of Visitors. Cultivating this base will expand our constituency in the years to come.

Finally, we are undergoing a restructuring of our websites across the Department of Astronomy and McDonald Observatory. Fiscal years 2017 and 2018 will see an overhaul of those web platforms and a better alignment with our social media and traditional media presence. Professionalizing these platforms will improve our communications with donors, alumni, faculty, and the scientific community.

Section V. Faculty and Research Staff

V.A. Overview of Faculty and Research Staff

The Astronomy Department currently includes over 200 members, including 19.5 tenured/tenure-track (TTT) faculty members (with one faculty member on 50% phased retirement), two research professors (holding a joint appointment with the Observatory), four Emeritus faculty members, one lecturer, 13 postdocs, 35 graduate students, 129 undergraduate majors, and four main support personnel.

McDonald Observatory staff is comprised of ten PhDs with responsibilities for Observatory work, eleven PhDs performing independent research, 96 support personnel, both in Austin and at the Observatory site in west Texas, and a number of research associates and affiliates with less than 25% time appointments. The McDonald scientific staff play key roles in instrumentation development for McDonald, HET, and GMT; the upgrade of the HET; maintenance and more modest upgrades of the McDonald telescopes; and telescope time allocation and scheduling.

Our faculty members and research scientists are engaged in a wide range of research activities, spanning cosmology, galaxy formation and evolution, black holes, dark matter, dark energy, stellar evolution and star formation, planetary systems, and instrumentation. Tables V-1 and V-2 show, respectively, the diverse research interests of faculty members and research scientists, along with the research group(s) they are affiliated with. Research in the Astronomy program is loosely divided into five research groups designated as the Extragalactic, Interstellar, Planetary Systems, Stars, and Theory groups. These groups hold weekly seminars and receive research funds from the Department and Observatory (see Section XI.A).

Over the last five years, faculty members have secured an average of $4 M per year in extramural funding. The publication record of faculty members at different stages of careers is shown in Table V-3. The curriculum vitae provided the Appendix (Section XII) illustrates the publication records, invited talks, grant records, and leadership role of individual researchers.

Table V-1: Department of Astronomy Faculty and Their Research

Faculty Name	Year of PhD	Research Interests	Research Group
Lecturers (Non-Tenure Track)			
Finkelstein, Keely	2008	Galaxy Formation and Evolution; Studies of star-forming galaxies at intermediate redshifts; Observations of lensed galaxies and Lyman Alpha Emitters; Astronomy Education and Public Outreach.	Extragalactic
Assistant Professors			

Faculty Name	Year of PhD	Research Interests	Research Group
Boylan-Kolchin, Michael	2006	Dark matter; cosmological structure formation; galaxy formation and dynamics; near-field cosmology; cosmic reionization.	Theory
Casey, Caitlin M.	2010	Dusty Starburst Galaxies, Infrared and Submillimeter Observations, Galaxy Mergers, Star Formation across cosmic time, Black Hole Growth, Large Scale Structure, Formation of Massive Galaxy Clusters	Extragalactic
Finkelstein, Steven L.	2008	Observations of the High-Redshift Universe; Galaxy Formation and Evolution; Reionization; Chemical Evolution of the Universe.	Extragalactic
Kraus, Adam	2009	Star and planet formation, exoplanets, fundamental properties of stars, nearby star clusters and associations, multiple star systems, high-resolution imaging, and interferometry.	Interstellar and Planetary Systems
Associate Professors			
Milosavljevic, Milos	2002	Formation of stars, galaxies, and massive black holes in the early universe; computational astrophysics; radiation transport; chemical enrichment of the universe; machine learning with astronomical big data.	Theory
Full Professors			
Armandroff, Taft (100% Administrative)	1988	Dwarf spheroidal galaxies, stellar populations in the Galaxy and nearby galaxies, globular clusters, and astronomical instrumentation.	Extragalactic and Stars
Full Professors			
Bromm, Volker	2000	Formation of the first stars and quasars; high-redshift supernovae and metal enrichment; supermassive black hole formation; gamma-ray bursts; reionization of the intergalactic medium; present-day star formation; computational astrophysics.	Theory
Dinerstein, Harriet	1980	Planetary nebulae and interstellar matter; analysis of infrared, optical, and ultraviolet spectra; interpretation of nebular emission lines; elemental abundances in planetary nebulae in the context of stellar and galactic chemical evolution; physics of H2 in photodissociation regions; interstellar and circumstellar dust	Interstellar and Stars
Gebhardt, Karl	1994	Formation and evolution of galaxies; dynamics of stellar systems; study of supermassive black holes.	Extragalactic
Jaffe, Daniel (100% Administrative)	1981	Infrared spectroscopy of young stars, protostars, young planetary systems, and star-forming clouds; physics of the dense interstellar medium; observations of young brown dwarfs. Instrumentation for infrared spectroscopy. Fabrication of diffractive devices for ground and space based spectroscopy of astronomical objects and greenhouse gasses in the Earth's atmosphere.	Interstellar

Faculty Name	Year of PhD	Research Interests	Research Group
Jogee, Shardha	1999	Galaxy Formation and Evolution as a Function of Cosmic Epoch and Environment; Structural Archeology as a Probe of Galaxy Assembly; Galaxy Assembly Modes (Mergers, Secular Processes, Gas Accretion); Quenching and Feedback Processes; Star Formation; Evolution of Black Holes; Galactic Bars and Mergers.	Extragalactic
Kormendy, John	1976	Supermassive black holes in galactic nuclei; structure and dynamics of galaxies; secular evolution of galaxies; dark matter; galaxy formation and evolution.	Extragalactic
Kumar, Pawan	1988	Gamma-ray bursts; helioseismology; binary stars; tidal interaction; accretion disks; cosmology.	Theory
Robinson, Edward	1973	Observational studies of white dwarfs, neutron stars, and black holes; cataclysmic variables, low-mass X-ray binaries, X-ray transients; pulsating white dwarfs, data analysis, and astrostatistics.	Stars
Scalo, John	1974	Star formation; interstellar medium; turbulence; galaxy evolution; complex systems; astrobiology.	Planetary Systems and Theory
Shapiro, Paul	1978	Theoretical astrophysics: cosmology, galaxy formation, the interstellar medium, the intergalactic medium, interstellar dust grains, astrophysical hydrodynamics.	Theory
Sneden, Christopher	1973	Chemical composition of stars; stellar evolution; galactic nucleosynthesis.	Stars
Full Professors			
Weinberg, Steven	1957	Elementary particle physics and cosmology.	Theory
Wheeler, J. Craig	1969	Stellar evolution; supernovae; accretion disks; gamma-ray bursts; black holes; magnetic fields; astrobiology; the technological future of humanity.	Theory
Winget, Donald	1982	Theory and observation: cosmochronology; assembly history and evolution of the Milky Way; late stages of stellar evolution; stellar pulsations and asteroseismology; exploring crystallization in a dense Coulomb plasma, plasmon neutrinos, dark matter and other extreme physics with white dwarf stars; dark stars; experimental astrophysics with white dwarf photospheres in the laboratory.	Stars and Theory
Research Professors			
Cochran, William,	1976	Detection and characterization of extrasolar planetary systems. Kepler andK2 mission follow-up observations. High precision radial velocity measurements of stellar radial velocity variations. Exoplanet atmospheres. Planetary and stellar populations.	Planetary Systems
Hill, Gary	1988	Observational cosmology; radio galaxies and quasars; galaxy clusters; innovative astronomical instrumentation.	Extragalactic

Professors on Phased Retirement			
Lacy, John (In 2nd year of 3-year phased retirement)	1979	Infrared astronomical spectroscopy; infrared studies of interstellar molecules; studies of ionized gas in the Galactic Center; development of high-resolution infrared spectrographs.	Interstellar
Emeritus Professors			
Bash, Frank N.	1967	Large-scale structure of spiral galaxies; star formation on large scales.	Interstellar
Evans, Neal	1973	Molecular clouds; star formation; millimeter, submillimeter, and infrared astronomy.	Interstellar
Jeffries, William	1965	Astrometry, celestial mechanics, statistics	Stars
Lambert, David L.	1965	Stellar atmospheres; chemical composition of stars; chemical evolution of the universe.	Stars
Wills, Derek	1967	Statistical properties of quasars	Extragalactic

Table V-2: McDonald Observatory Research Staff and Their Research

Researcher Name	Year of PhD	Research Interests	Research Group
Benedict, George	1972	Space astrometry; search for extrasolar planetary systems; surface photometry of galaxies; barred galaxies	Planetary Systems and Stars
Brooks, Cynthia	1995	Astronomical instrumentation; silicon diffractive optics	Interstellar
Caldwell, John	1979	Gravitational microlensing, Cepheid variable stars, Photometry, standards & transformations	Stars
Cochran, Anita	1982	Primitive bodies in the Solar System; Composition of Comets.	Planetary Systems
Drory, Niv	2002	Structure, dynamics, and formation history of galaxies, Observational cosmology, Astronomical instrumentation and data analysis	Extragalactic
Dupuy, Trent	2010	star and planet formation and evolution, brown dwarfs, ultracool atmospheres, and high-precision astrometry	Planetary Systems and Stars
Endl, Michael	2001	Detection of extrasolar planets and brown dwarf companions. Search for extremely low-mass planets around M dwarf stars. High precision stellar radial velocity measurements. Astrobiology.	Planetary Systems
Froning, Cynthia	1999	Stellar astrophysics, exoplanet radiation environments, X-ray binaries, accretion disk physics, astronomical instrumentation	Stars
Lee, Hanshin	2008	Astronomical instrumentation; focal-plane wide-field wavefront sensing; active alignment control of imaging systems; adaptive image compensation/recovery; phase-retrieval.	Extragalactic

Researcher Name	Year of PhD	Research Interests	Research Group
Mace, Greg	2014	Low-mass stars and brown dwarfs, spectroscopic and visual binaries, infrared spectroscopy and instrumentation	Planetary Systems and Stars
Macqueen, Phillip	1986	Instrumentation, CCD detectors, exoplanets, the Galaxy halo.	Planetary Systems and Stars
McQuinn, Kristen	2010	Galaxy Formation and Evolution, Structure and Evolution of Low-mass Galaxies, Chemical Evolution of Galaxies.	Extragalactic
Montgomery, Michael	1998	Pulsation and seismology of white dwarf stars, nonlinear light curve modeling, numerical and theoretical studies of convection, evolution of white dwarf stars, constitutive physics of white dwarfs (crystallization, diffusion), Science Director of Whole Earth Telescope.	Stars and Theory
Noyola, Eva	2006	Globular cluster dynamics, intermediate mass black holes, compact objects in globular clusters, dwarf galaxies, dark matter, and astronomical instrumentation	Extragalactic
Odewahn, Stephen	1989	Automated image classification for sky surveys and automated morphological classification of galaxies.	Extragalactic
Rostopchin, Sergey	1990, MSc	Night operation software programming, binary stars abundances, parameters	Stars
Shetrone, Matthew	1996	Observational techniques; queue scheduled telescopes; galactic nucleosynthesis; stellar evolution.	Stars
Trafton, Laurence	1965	Planetary atmospheres; volatile transport; evolution of the Solar System.	Planetary Systems

Table V-3: Faculty Publication Metrics

Title		N_ref_tot ‘(1)	N_ref_3yr (2)	N_cite_tot (3)	N_cite_3yr (4)	Cite_rate_3yr _avg (5)
Associate & Full Professor[a] 1+16 members	Median	118	12	8444	165	522
	Average	143	14	13428	225	737
	Min	46	0[b]	3447	0[b]	108
	Max	355	36	58574	1105	2329
Research Professor 2 members	Median	156	20	10180	918	1241
	Average	156	20	10180	918	1241
	Min	83	11	4796	598	384
	Max	228	29	15563	1237	2097

Title		N_ref_tot ‘(1)	N_ref_3yr (2)	N_cite_tot (3)	N_cite_3yr (4)	Cite_rate_3yr _avg (5)
Assistant Professor 4 members	Median	77	32	4102	760	669
	Average	76	35	3871	856	640
	Min	55	25	1861	587	329
	Max	96	51	5421	1319	894
Professor Emeritus[c] 3 members	Median	294	17	19523	84	1021
	Average	293	18	17411	171	871
	Min	83	0	4899	0	93
	Max	503	37	27811	428	1499

Notes to Table: (a) The Table Includes Prof. S. Weinberg who has a joint appointment with the Astronomy and Physics Departments. (b) Includes professors who have taken an administrative position. (c) Includes only Prof. Emeritus who retired in 2016. (1) N ref_tot: The total number of refereed papers. (2) N_ref_3yr: The number of refereed papers over the past three years. (3) N_cite_tot: The total number of citations (from both referred and un-refereed papers). (4) N_cite_3yr: The “3 year cites” or total number of citations for papers written in the last three years. (5) Cite_rate_3_avg: The average of citation rate (number of citations per year) in the past three full calendar years (2013-15), taken directly from the ADS metric tool.

V.B. Major Research and Teaching Awards

Major research prizes won by faculty members include:

- 1 National Science Foundation Early Career Development Grant Award
- 7 Alfred P. Sloan Fellowships
- 1 Packard Fellowship for Science and Engineering
- 1 Edith and Peter O’Donnell Award
- 1 Henry Norris Russell Lectureship
- 2 National Science Foundation Young Investigator Awards
- 1 Annie Jump Cannon Award (AAS)
- 2 Heineman Prizes (AAS)
- 2 Newton Lacy Pierce Prizes
- 2 Astronomical Society of the Pacific Maria and Eric Muhlmann Prizes
- 2 Trumpler Awards
- 1 Nobel Prize in Physics
- 1 National Medal of Science

Major teaching prizes won by faculty members include:

- Induction of three faculty members to the UT Academy of Distinguished Teachers
- Numerous College of Natural Sciences Teaching Awards
- Numerous Board of Visitors Excellence in Teaching Awards

V.C. Leadership Role in Research

Faculty and research staff in the UT Astronomy program have made important contributions to many frontier areas of astronomy highlighted by the National Academy of Sciences 2010 decadal survey of Astronomy and Astrophysics (New Worlds, New Horizons), including cosmology; first light and reionization; the evolution of galaxies and black holes; the formation and evolution of stars and planetary systems; stellar evolution and chemical evolution; near-field cosmology; and the nature of dark matter and dark energy. Research led by the Astronomy program contributes to UT Austin's 2017 ranking in space science as #6 among US public universities by US News & World Report (Table III-1).

Research staff and faculty members develop cutting-edge observational facilities and instrumentation for McDonald Observatory, such as the upgraded 10-m Hobby-Eberly Telescope (HET), the VIRUS integral field unit, and the Immersion Grating INfrared Spectrometer (IGRINS). Other efforts include the completion and deployment of HET's upgraded High-Resolution Spectrograph, and the completion of the HET's Habitable Planet Finder (by our partner Penn State). Our researchers are also leading the development of the GMTNIRS high-resolution IR Echelle Spectrograph for the next-generation Giant Magellan Telescope.

Many of our researchers are also key players in large science collaborations and surveys, such as the galaxy evolution surveys with NASA's Hubble Space Telescope (e.g., Jogee in GOODS, GEMS, STAGES, and the HST Treasury Survey of Coma; Finkelstein in CANDELS and the Hubble Frontier Fields); NASA's Kepler and K2 mission (B. Cochran and Endl) to explore the structure and diversity of planetary systems; the NASA's Spitzer c2d Legacy program to probe the evolutionary sequence ranging from molecular gas cores to planet-forming disks (Evans); the NASA/ESA Euclid mission (Bromm) ; and the SDSS MaNGA survey (Drory). Our researchers (e.g., Bromm, Jaffe, Finkelstein) are also helping to shape future NASA observatories (e.g., JWST, WFIRST, LUVOIR, and the Origins Space Telescope).

Highlights of UT-led Projects

We provide below a few examples of important projects led by UT Astronomy faculty and research staff. The list is in alphabetical order. More examples can be found in the curriculum vitae of members of the Astronomy program provided the Appendix (Section XII).

- Mike Boylan-Kolchin is the PI of the Millennium-II Simulation Project, one of the most-used set of simulations of cosmological structure formation. He is also leading work on dwarf galaxy simulations within the Feedback In Realistic Environments (FIRE) project (PI: Phil Hopkins), which aims to perform realistic simulations of galaxy formation in a cosmological context across the entire range of observed galaxy masses, from ultra-faint galaxies around the Milky Way to massive central cluster galaxies.
- Using the supercomputers at TACC, Volker Bromm and Milos Milosavljevic have built one of the leading groups in the world to simulate the formation of the first galaxies from ab-initio cosmological initial conditions. One key result is the prediction that galaxies were already substantially metal-enriched very early in cosmic history. Indeed, this is a robust

conclusion of ΛCDM structure formation and can be used to test this scenario with JWST and GMT deep-field campaigns at the hitherto inaccessible small-scale end of the model.

- David Lambert and collaborators have explored the evolution of stars and of the Galaxy by providing elemental and isotopic abundances of stellar atmospheres and the diffuse interstellar medium. Such explorations have been based on high-resolution spectra from the ultraviolet to the infrared with McDonald Observatory's facilities playing a prime role. Recently, focus has been on hydrogen-deficient stars such as the R CrB supergiants, luminous stars in which refractory elements (e.g., Ca and Ti) are grossly underabundant relative to volatiles (e.g., Na), and compositions of open clusters in the Milky Way.
- Niv Drory leads the Instrument development and build in MaNGA and serves as the Instrument Scientist for the project (Drory et al. 2015, AJ, 149, 77). MaNGA (Bundy et al. 2015, ApJ, 798, 7) is a 10,000 galaxy, 6-year, Integral Field Spectroscopy (IFU) survey within the current generation Sloan Digital Sky Survey (SDSS-IV). This is the first truly statistical IFU survey of galaxies at the present epoch, where spectra are taken across the full face of each galaxy as opposed to along a single axis (long-slit) or only in the very center (single fiber). The survey has thus far observed around 4,000 galaxies and has published more than 30 papers among them two papers in Nature (Cheung et al. 2016, Nature, 533, 504; Chen et al. 2016, Nature Communications, 7, 13269).
- Gary Hill (PI) and Karl Gebhardt (Project Scientist) are leading the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), a blind optical spectroscopic survey that aims to measure the evolution of dark energy via the power spectrum of Lyman-alpha emitting galaxies (LAEs) in the redshift range $1.9 < z < 3.5$. It will also allow a large number of other science projects, such as mapping the cosmic web, exploring galaxy evolution in different environments at redshift $z>2$, understanding the escape of Lyman alpha photons from galaxies, searching for the most metal-poor stars in the Milky-Way Galaxy, discovering new supernovae, studying dark matter and star formation distributions in nearby galaxies, and measuring the total mass of neutrinos.
- Dan Jaffe leads numerous projects focusing on the development of state-of-the-art instrumentation. At Texas, he developed the first 800 GHz system for the Caltech Submillimeter Observatory (CSO) and devised an optical system that permitted large-scale submillimeter mapping in unused daytime hours. For more than a decade, Jaffe worked with PI John Lacy to develop high-resolution spectrographs for the mid-IR, TEXES, and EXES. He now serves as PI for a high-resolution near-IR spectrometer (IGRINS, now in service on the McDonald 2.7-m telescope) and a 1-5 micron high-resolution spectrometer for the Giant Magellan Telescope. As a result of his grating work, he is also a member of the science teams for the FORCAST grism facility, for NIRCam on JWST, and for ISHELL on the NASA-IRTF
- Shardha Jogee (PI) and Steven Finkelstein (Co-I) are UT lead investigators for the SHELA/HETDEX project, which is an unprecedented study of how galaxies grow across different environments during the important cosmic epoch ($1.9 < z < 3.5$) when star formation and black hole accretion peaked, and massive proto-clusters collapsed into existence. It targets about 0.8 million massive galaxies via a powerful combination of five existing photometric surveys from UV to far-infrared wavelengths (DECam ugriz, NEWFIRM

K-band, Spitzer IRAC, and Herschel-SPIRE) with future HETDEX spectroscopy. The project is a collaboration between UT Austin, Texas A&M University, and Penn State University, and was recently awarded $0.9 M by NSF.

- Kristen McQuinn is leading the panchromatic STARBurst IRregular Dwarf Survey (STARBIRDS), a comprehensive program to understand the lifecycle and impact of starbursts in low-mass galaxies. The survey combines an impressive scope of observations on 20 galaxies in the X-ray, Ultraviolet, Halpha, Optical, Infrared, and Radio regimes obtained from NASA space telescopes (Chandra, GALEX, HST, Spitzer) and ground-based facilities (KPNO, GBT, Parkes). The science goals include characterizing the temporal and spatial properties of the star formation activity, identifying the trigger mechanisms for the bursts, and measuring the impact of starburst-driven galactic winds on the star formation efficiency and chemical evolution of the galaxies.
- Don Winget, Mike Montgomery, and their collaborators have created the field of “Experimental Laboratory Astrophysics” by developing an experimental platform using the massive Z- machine at the Sandia National Laboratories (SNL), which produces laboratory plasmas that have the same properties as those in white dwarf stars. This allows us for the first time to study "star matter” in the laboratory, thereby allowing world-class fundamental science that would otherwise not be possible.

Highlights of UT-led Research Papers

We list below a few examples of key scientific results led by UT Astronomy faculty and research staff. The list is in alphabetical order. More research highlights can be found in the curriculum vitae of members of the Astronomy program provided the Appendix (Section XII).

- Mike Boylan-Kolchin and collaborators have shown that the masses of dwarf satellites of the Milky Way, the most dark-matter-dominated galaxies known, are substantially lower than predictions of the ΛCDM model. This discrepancy is now known as the “too-big-to-fail” problem (Boylan-Kolchin et al. 2011, MNRAS, 415, L40).
- Volker Bromm has written some of the foundational papers on the formation of the first stars, making the key prediction that they were typically very massive (Bromm & Larson 2004, ARAA, 42, 79).
- Volker Bromm and Avi Loeb have originated the idea of "direct-collapse black holes," a novel class of seed black holes that could only have formed under the peculiar conditions of the early, primordial universe (Bromm & Loeb 2003, ApJ, 596, 34), and that could account for a series of recent observations, such as the tight correlation between the unresolved cosmic infrared and X-ray backgrounds, and the discovery of the most luminous Lyman-alpha emitter ever observed, the so-called CR7 source (2015).
- The census of star-formation over cosmic time has largely been carried out at optical and near-infrared wavelengths, neglecting the contribution of emission from cold dust. Dust in galaxies’ interstellar medium absorb starlight and re-radiates it at long wavelengths, and large spectroscopic surveys of $z>1$ obscured galaxies reveal that dust obscures the majority of cosmic star-formation beyond $z\sim2$. The work of Caitlin Casey and collaborators has increased the number of obscured galaxies known over tenfold (Casey et al. 2012, ApJ, 761,

139; Casey et al. 2012, ApJ, 761, 140) and pushed their detections to higher redshift regimes, using observations to constrain dust formation scenarios in the early Universe.

- William Cochran is a co-Investigator on the NASA Kepler mission and worked with Kepler PI Bill Borucki to define and develop the mission. He also worked with the Kepler team to define the occurrence rate of small Earth-size planets in the solar neighborhood (Howard et al. 2012, ApJS, 201, 14; Mullally et al. 2015, ApJS, 217, 31).
- Harriet Dinerstein is spearheading an observational program to measure enrichments of trans-iron elements made by slow neutron capture reactions in AGB stars, by investigating their abundances in planetary nebulae (Dinerstein 2001, ApJL, 550, L223; Sterling et al. 2015, ApJS, 218, 25). She and her collaborators are using the IGRINS spectrometer to discover and measure near-infrared emission lines of species such as Se (element 34) and Kr (element 36). Recent advances have included first detections of emission lines of Ge, Rb, and Cd, and measurements of planetary nebulae in the Magellanic Clouds (Sterling et al. 2016 ApJL, 819, L9; Mashburn et al. 2016, ApJ, 831, L3).
- Harriet Dinerstein has developed and implemented a method for directly measuring abundances of iron-group elements in planetary nebulae, using the least refractory member of the group, Zn (Dinerstein & Geballe 2001, ApJ, 562, 515). She is finding that the majority of planetary nebulae have sub-solar Zn abundances (hence also Fe), in spite of having solar or nearly solar abundances of O and other alpha species. This casts an entirely new light on the overall chemical composition of the progenitor stars. It also affects operation of the s-process, since Fe itself is the seed nucleus that captures most of the neutrons.
- Harriet Dinerstein has been studying the excitation and emission spectrum of molecular hydrogen (H2) in the vicinity of hot stars such as young, high-mass stars and the central stars of planetary nebulae. Decades ago, she was the first to recognize the role of UV radiation in exciting fluorescent emission in planetary nebulae, based on observations at McDonald Observatory (Dinerstein et al. 1988, ApJL, 327, L27). Under supervision by Dinerstein and co-Advisor Dan Jaffe, graduate student Kyle Kaplan is using IGRINS to obtain vastly improved data. A paper on the Orion Bar photodissociation region, led by Kaplan, has just been accepted for publication in ApJ (Kaplan et al., 2017).
- Niv Drory was among the first to work on the galaxy stellar mass function at high redshift (Drory et al., 2004, ApJ, 608, 742) and has written a number of seminal papers in the field, including the first very wide redshift study ranging from redshift 0 to 5 (Drory et al., 2005, ApJL, 619, 131).
- In collaboration with D.B. Fisher, Niv Drory has worked on the structure of bulges in the local universe and published a series of well-regarded papers detailing the observational methods of recognizing different morphological, kinematic, and stellar population structures in the centers of disk galaxies and their connection to both the disk and the bulge (e.g. Drory & Fisher, 2007, ApJ, 664, 660; Fisher & Drory, 2008, AJ, 136, 773; Fisher & Drory 2011, ApJL, 733, 47).
- Michael Endl and collaborators discovered an Earth-sized planet, Proxima b, orbiting in the habitable zone of Proxima Centauri, our nearby neighboring star. This may be the nearest

potentially habitable planet to our Solar System. (Anglada-Escudé, G. et al. 2016, Nature 536, 437).

- Neal Evans led a Legacy Program on the Spitzer Space Telescope and an Open Time Key Project on the Herschel Space Observatory. These projects led to over 100 publications. The summary of the Legacy Program results on nearby clouds has accumulated 706 citations since publication (Evans et al. 2009, ApJS, 181, 321).
- Neal Evans co-authored a review with R. Kennicutt combining research on Galactic and extra-galactic star formation that has garnered 622 citations since publication (Kennicutt & Evans 2012, ARA&A, 50, 531).
- Neal Evans used the Atacama Large Millimeter/Submillimeter Array to conclusively demonstrate infall of material to form a protostar (Evans et al. 2015, ApJ, 814, 22).
- Steve Finkelstein and collaborators have made several important discoveries over the past few years, including the discovery of the then most-distant spectroscopically confirmed galaxy at a redshift of 7.51 (Finkelstein et al. 2013, Nature, 502, 524); the measurement of the evolution of the galaxy UV luminosity function over the first billion years (Finkelstein et al. 2015, ApJ, 810, 71); the first robust measure of the evolution of the stellar mass function at high redshift (Song, Finkelstein et al. 2016, ApJ, 825, 5); the first measurement of potential quenching and bulge formation in the centers of massive galaxies at z~4 (Jung, Finkelstein et al. 2017, ApJ, 834, 81); the discovery, through gravitational lensing, of the faintest galaxies at high redshift, observationally confirming that the Galaxy UV luminosity function maintains its steep faint-end slope a factor of 100 fainter in luminosity than previous observations (Livermore, Finkelstein, & Lotz 2017, ApJ, in press).
- Karl Gebhardt and collaborators have reported the important relationship between nuclear black hole mass and galaxy velocity dispersion (Gebhardt et al. 2000, ApJL, 539, L13).
- Shardha Jogee is a co-Investigator on five international science collaborations (GEMS, STAGES, GOODS, The Hubble ACS Treasury Survey of Coma, GOODS-NICMOS Survey (GNS) of Massive Galaxies) that have conducted some of the largest or deepest galaxy surveys to date. In these collaborations, Jogee and members of her research group (Marinova, Heiderman, Weinzirl, Barazza) have led ten papers on the structure, merger, and assembly history of galaxies that garnered ~750 citations to date.
- While earlier work suggested a dearth of barred galaxies at earlier times, Shardha Jogee and collaborators first demonstrated that strong stellar bars are common in massive disk galaxies over the last eight billion years, a period long enough for bars to drive significant secular evolution of galaxies (Jogee et al. 2004, ApJL, 615, L105).
- Shardha Jogee and collaborators showed that contrary to common lore, only at most 30% of the cosmic star formation rate density can be assigned to visible major mergers over half of the age of the Universe. They also set the first empirical constraints on the minor merger rate of galaxies over that epoch (Jogee et al. 2009, ApJ, 697, 1971).
- Graduate student Weinzirl, working with Shardha Jogee, showed that when the Universe was merely a few billion years old, the majority (>60%) of massive galaxies were disk-dominated and over a third were ultra-compact (Weinzirl et al. 2011, ApJ, 696, 411). This result poses serious challenges to current state-of-the-art theoretical models.

- John Kormendy has led the development of a major new paradigm on galaxy evolution that complements our picture of hierarchical clustering and galaxy merging. This is the slow ("secular") evolution of galaxy disks that results when global non-axisymmetries such as bars rearrange disk angular momentum and hence disk structure. These processes build (among other features) outer rings at 2.2 bar radii, inner rings around the ends of bars, and high-density but disky central components of galaxies called "pseudobulges." Most regular features seen in (e. g., de Vaucouleurs') galaxy classification schemes are explained by these secular processes (Kormendy & Kennicutt 2004, ARA&A, 42, 603).
- John Kormendy and Luis Ho have analyzed all supermassive black hole (BH) masses and host galaxy properties and rederived BH-host-galaxy correlations in ARA&A, 51, 511 (2013). Many new results are revealed; e. g., that BH masses correlate well with elliptical-galaxy-like "classical bulges" but do not correlate with pseudobulges or with galaxy disks or (beyond implications of the correlation with bulges) with galaxy dark halos.
- Pawan Kumar and collaborators predicted pulsations of stars in close binary systems by tidal forces almost 20 years before these oscillations were discovered by the Kepler satellite (Kumar, Ao, & Quataert, 1995, ApJ, 449, 294).
- Pawan Kumar and collaborators determined several key parameters for gamma-ray bursts and showed that the prevailing paradigm for how gamma-rays are produced in these enigmatic explosions is incorrect (Panaitescu & Kumar 2002, ApJ, 571, 779; Kumar & McMahon 2008, MNRAS, 384, 33).
- Pawan Kumar and collaborators solved a major, puzzling, discovery by the Fermi satellite regarding high-energy radiation (>100 MeV) from gamma-ray bursts (Kumar & Barniol Duran 2009, MNRAS, 400, L75).
- Several members of Adam Kraus's group have pioneered the field of observational planet formation, placing direct constraints on the locations and timescales of planet assembly. Their results include observations of newly formed (or forming) planets via direct imaging (e.g., LkCa15 b; Kraus & Ireland 2012, ApJ, 745, 5) and transits (e.g., K2-33 b; Mann et al. 2016, AJ, 152, 61), as well as by observing mass accretion (Zhou et al. 2014 ApJ, 783, 17) and protolunar disks (Kraus et al. 2015, ApJ, 798, 23) in the circumplanetary environment.
- Kristen McQuinn and collaborators have shown from the star formation histories of galaxies that intense periods of star formation (or starbursts) in low-mass galaxies, previously thought to last only 10 Myr, actually last hundreds of Myr and have a correspondingly larger impact on the evolution of the host galaxy (McQuinn et al. 2010, ApJ, 721, 297).
- Milos Milosavljevic co-wrote foundational papers on the detection of electromagnetic transients from coalescing massive black holes, a key objective in the new era of gravitational wave astronomy (MacFadyen & Milosavljevic 2008, ApJ, 672, 83).
- Milos Milosavljevic and collaborators wrote foundational papers on radiative self-regulation during accretion onto black holes, deriving limits on how fast black hole remnants of the first stars can grow (Milosavljevic et al. 2009, ApJ, 698, 766; Milosavljevic, et al. 2009, ApJL 696, L146).

- Milos Milosavljevic and members of his research group performed the first cosmological simulations resolving the formation of individual heavy-element-enriched second generation stars that survive until present to be discovered in the nearby universe (Safranek-Shrader et al. 2014, MNRAS, 440, L76; Safranek-Shrader et al. 2016, MNRAS, 455, 3288).
- Milos Milosavljevic and members of his research group performed the first simulations resolving chemical heterogeneity in the formation of second-generation stars in the universe (e.g., Ritter et al. 2015, MNRAS, 451, 1190; Sluder et al. 2016, MNRAS, 456, 1410).
- Paul Shapiro and collaborators have made major contributions to radiation hydrodynamic models of the re-ionization era of the early Universe (e.g., Ocvirk et al. 2016, MNRAS, 463, 1462). This project has critically involved undergraduate students in the Cosmic Dawn Freshman Research Initiative and won a college prize for visualization.
- Chris Sneden is exploring the production of Fe-group elements in the early galaxy, via detailed chemical composition analyses of very metal-poor stars. Supported by NSF and HST STIS grants, he has gathered high-resolution spectra in wavelength domains spanning the vacuum-UV to the IR, producing the most precise abundances of the Sc ... Zn group and his team is interpreting these data regarding the onset of Galactic element production (Sneden et al. 2016, ApJ, 817, 53; Afsar et al. 2016, ApJ, 819, 103).
- Chris Sneden is studying the chemical compositions of RR Lyrae stars in several collaborative efforts with astronomers at Carnegie and Rome Observatories. The goals are to map out the metallicity dependence of pulsational properties of these stars, with a view to significantly increasing the accuracy of RR Lyrae stars as fundamental distance indicators in Galactic and extragalactic stellar populations (Chadid et al. 2017, ApJ, in press arXiv:1611.02368).
- Craig Wheeler and collaborators pioneered the field of spectropolarimetry of supernovae at McDonald Observatory, a new window into supernova that provides the only information on the chemistry- dependent morphology of distant supernovae. They continue to play a leadership role in the field using the facilities of the European Southern Observatory Very Large Telescopes (Wang & Wheeler 2008, ARA&A, 46, 433; Stevance et al. 2016, MNRAS, 461, 2019).
- Members of Craig Wheeler's group discovered the new class of superluminous supernovae, established two fundamental categories, hydrogen rich and hydrogen deficient, and have contributed to theoretical modeling of these events that could be seen at z ~10 with JWST (Quimby et al. 2007, ApJL, 688, 99; Chatzopoulos et al. 2011, ApJ, 729, 143; Chatzopoulos et al. 2016, ApJ, 828, 94).
- Graduate student Chatzopoulos, working with Craig Wheeler, produced the first rotating models of pair-instability supernovae that may dominate the first stars and showed that rotation may substantially lower the ZAMS mass that produces these still hypothetical events (Chatzopoulos et al. ApJ, 2013, 776, 129).
- Craig Wheeler, Sean Couch, and collaborators were among the first to explore the supernova/gamma-ray burst connection, to argue for the role of magnetic jets in shaping core-collapse supernovae, to argue that the magnetorotational instability (MRI) plays a

natural role in iron-core-collapse, and to explore the role of the MRI in producing the ambient magnetic field in the progenitor star (Wheeler et al. 2000, ApJ, 537, 810; Akiyama et al. 2003, ApJ, 584, 954; Couch et al. 2011, ApJ, 727, 104; Wheeler et al. 2015, ApJ, 799, 85).

Section VI. Undergraduate Program

Overview: The UT Astronomy program offers a research-centered experiential undergraduate program and supportive peer communities to improve the engagement, retention, and graduation rate of students in Science Technology Engineering & Mathematics (STEM). We believe that active learning techniques and sustained involvement in research is key for engaging students in STEM and transforming them into scientists, innovators, and leaders. Our undergraduate curriculum equips students with core skills needed for starting research. A large fraction of astronomy majors are involved in research and many start research in the freshman year through the Astronomy Freshman Research Initiative stream.

The size of our Astronomy Undergraduate Program has nearly doubled over the last five years, and we are now one of the largest programs in the nation with 129 astronomy majors in 2016-17. We have a diverse student body: in 2015-16, our majors consist of 38% women, 62% men and 54% White, 9% Asian, 6% African-American and/or Hispanic, and 31% in other categories. We also share the beauty of science and astronomy with over 3,500 non-science majors each year, preparing them to be informed citizens for the greater benefit of society. We are committed to providing our students with a 21st-century education that prepares them not only for graduate school and academic careers but also for non-academic careers in the public and private sector.

VI.A. Undergraduate Program

Figure VI-1: UT Astronomy Undergraduate Students. *(Photo credit: Lara Eakins)*

1) Undergraduate Curriculum (degree options)

The undergraduate program provides two semesters of introductory coursework in Astronomy for students majoring outside of the College of Natural Sciences. These courses serve to fulfill the Natural Science and Technology, Part I Core Requirements. The first-semester general introductory course, Astronomy 301, is followed by a more specialized course:

- Astronomy 309C: Birth of Stars and Planets
- Astronomy 309G: Current Topics in Astronomy; Popular Astronomy
- Astronomy 309L: Search for Extraterrestrial Life; Planets and Life
- Astronomy 309N: Lives and Deaths of Stars; Cosmic Catastrophes, Astronomy Bizarre
- Astronomy 309R: Galaxies, Quasars, and the Universe

We also offer an upper division course:

- Astronomy 321: Future of Humanity

The undergraduate program provides three-degree options: **Bachelor of Science in Astronomy (BS), Bachelor of Arts in Astronomy (BA**), and **Bachelor of Science and Arts in Astronomy (BSA).** Please see the supporting documentation:

- Bachelor of Science in Astronomy: Sample 4-Year Plan
- Bachelor of Science and Arts in Astronomy: Sample 4-Year Plan
- Bachelor of Science & Arts (BSA) 2016-18 Checklist

The **BS degree** is designed to give students an understanding of the universe and to prepare them to participate in the advancement of research in astronomy. Two options are available: Astronomy and Astronomy Honors. Students who plan to follow Option II, Astronomy Honors, must be admitted to the Dean's Scholars Honors Program. Students must receive credit for the following mandatory coursework:

- Mathematics 408C: Differential and Integral Calculus
- Mathematics 408D: Sequences, Series, and Multivariable Calculus
- Mathematics 427J: Differential Equations with Linear Algebra
- Mathematics 427K: Advanced Calculus for Applications I
- Mathematics 427L: Advanced Calculus for Applications II
- Mathematics 340L: Matrices and Matrix Calculations
- Physics 301: Mechanics
- Physics 101L: Laboratory for Physics 301
- Physics 316: Electricity and Magnetism
- Physics 116L: Laboratory for Physics 316
- Physics 315: Wave Motion and Optics
- Physics 115L: Laboratory for Physics 315
- Physics 336K: Classical Dynamics
- Physics 352K: Classical Electrodynamics
- Physics 353L: Modern Physics Laboratory

- Physics 355: Modern Physics and Thermodynamics
- Physics 373: Quantum Physics I: Foundations
- Physics 362K: Quantum Physics II: Atoms and Molecules
- Physics 369: Thermodynamics and Statistical Mechanics
- Astronomy 352K: Stellar Astronomy ("A junior/senior-level introduction to stellar astronomy and astrophysics, with emphasis on observational and empirical methods for studying stars via the light they emit. Devoted to astrometry, basic radiation quantities, magnitudes, and luminosities, low and high resolution spectroscopy, the Hertzsprung-Russell Diagram, statistical physics, variable stars, star clusters, and stellar atmospheres.")
- Astronomy 353: Astrophysics ("Introduces astronomy, physics, and other science and engineering majors to fundamental astrophysical concepts and principles and their applications. The concepts are developed from first principles, thus linking the elementary physics curriculum—classical and quantum mechanics, electromagnetism, thermodynamics—to a variety of astrophysical phenomena. The material is introduced rigorously and/or with order-of-magnitude and dimensional analysis techniques. The lectures are interactive and are designed to foster proficiency in independent physical reasoning and mathematical modeling. Where possible, connections to current research problems are highlighted.")
- Astronomy 358: Galaxies and the Universe ("Addresses the properties, contents, origin, and evolution of galaxies; their interaction and mass assembly history; the properties of their central black holes and starbursts; and the characteristics of the early Universe. The emphasis will be on using the laws of physics to interpret observations and understand how galaxies form and evolve. Discusses some of the current/upcoming exciting science from observations conducted or planned with current/next-generation telescopes. Explores the evolution of galaxies over a wide range of epochs, from the present-day out to epochs when the Universe was a mere few percent of its present age.")

Students must also take 9 additional semester hours of required upper division Astronomy or Physics Coursework, and must receive at least one additional elective credit from:

- Astronomy 351: Astronomical Instrumentation ("Teaches the fundamentals of the design and construction of experimental apparatus using astronomical instruments as the model for the process. Covers key aspects of some of the most important topics in the field: optics and optical design, mechanical design and machining, electronics design and fabrication, real-time computer control, project planning, and performance analysis. Gives concrete knowledge of many of the essentials of instrumentation. Students plan out, schedule, and organize an instrumentation project and have some idea of what goes into a project budget. They understand the steps involved in the mechanical, optical, software, and electronics design.")
- Astronomy 364: Planetary Systems ("Covers three main topics: identification of planetary systems around other stars, characterization and interior/atmospheric properties of planets, and formation and evolution of stars and their planetary systems. The emphasis is

on establishing a quantitative framework for understanding and implementing methods currently used in the study of planetary systems. Incorporates in-class discussions of current scientific literature, either through direct studies of current astronomical literature, or reading of derived products like press releases, news articles, and blog posts.")

- Astronomy 376C: Cosmology ("Applies the laws of physics to address the fundamental questions: What are our origins? What is our place in the overall cosmic scene? What is time? What is dark energy, and what the dark matter?")
- Astronomy 376R: Practical Introduction to Research ("Gives students the skills to become excellent researchers. It focuses on data analysis, making presentations and plots, good coding practices, using on-line material, and data mining. Coming out of the class, the students are attractive to researchers in the university as well as have learned important skills for non-academic paths. Much of the coding is in Python.")

Before beginning upper division coursework, students may elect:

- Astronomy 307: Introductory Astronomy ("This is an introductory overview course for science majors, and is often taken by astronomy majors during their first year. This makes use of pre-calculus concepts and covers fundamentals of astronomy, stars, planets, galaxies, and basic cosmology. This course is sometimes taken by non-CNS majors to fulfill the "quantitative reasoning" portion of their degree requirement").

The minimum grade point average for all mathematics and science courses required by degree, as well as for all courses taken at The University of Texas at Austin, is 2.0, and the minimum grade in each required mathematics and science course is C−.

The requirements to graduate in Astronomy with honors are:

- Take the AST 379H Honors Tutorial Course, in which the student completes a supervised research project
- Maintain a final GPA of at least 3.00 and a GPA in physics and astronomy of at least 3.50.
- Deliver a written report and an oral or poster presentation of the research project, approved by the research supervisor and the honors adviser.
- Complete at the University at least sixty semester hours of coursework counted toward the degree.

A large fraction of students receiving a BS in Astronomy are also receiving a BS in Physics as double major.

The **BSA degree** offers a cross-disciplinary experience for students who want to combine a strong core science experience with coursework in areas such as business, communications, fine arts, and the liberal arts. Students choose a major comprised of 48 hours of science and mathematics. Students choose either a transcript-recognized minor outside of the sciences, 15 hours in a field of study outside of sciences, or an 18 to 24-hour transcript-recognized certificate.

The **BA degree** is shared with the College of Liberal Arts.

2) Number of Majors and Graduates (five-year history)

Table VI-1 provides a 5-year history of the Astronomy major degree program enrollment and degrees awarded. The number of majors enrolled in the program has increased steadily since 2012. The years-to-graduation do not count the transfer students' years completed outside of the University of Texas at Austin. BSA is a new degree, and the first BSA in Astronomy was awarded in 2014-15.

Around 22 students (in their freshman to senior years) delve into research projects annually during the Research Methods course. About 30 freshmen participate in the Astronomy Freshman Research Initiative stream (see point 4 below), starting from the spring semester of their freshman year. Additionally, a significant fraction of our undergraduate majors pursues at least one research project that involves substantial one-on-one interaction with the faculty and research scientists in our department. Over the past five years, there have typically been 15-20 active research projects at any given time; the most recent semester (fall 2016) saw this number jump to 28 active research projects. These research opportunities prepare our students for national-level competitions. The Astronomy Department encourages undergraduate research by supporting travel funding (for travel to conferences, McDonald Observatory, etc.) and with summer research funding (which supported six different researchers during the most recent summer).

3) Trends in Undergraduate Enrollment and Seats Taught (five-year history)

Table VI-3 provides seats taught for every Astronomy course in the period 2011-15.The scheduling of courses strikes a balance between the service courses (teaching about 3,500 undergraduate non-majors per year), undergraduate major courses, and graduate courses (described elsewhere). The department typically offers 8 to 9 class sections intended for non-science students each semester, each with about 200 available seats and divided roughly evenly between Astronomy 301 (Introduction to Astronomy) and AST 309x (topical courses in subfields of astronomy). AST 307 (Introductory Astronomy for Science Majors) is typically offered with one section per semester, with 70-90 seats, and serves our majors as well as majors from other departments within the College of Natural Sciences. All upper-division major courses are currently offered once per year, typically capping at 45 seats, with some caps increased to 60 seats to meet growing demand.

In the past year, most courses at all levels have reached the enrollment cap; all upper-division courses in spring 2017 have wait lists. Our upper division courses typically see significant demand from other departments (especially Physics, Aerospace Engineering, and Geology) for which our courses serve as upper-division technical electives. To ensure that our majors receive sufficient priority, we have now begun reserving a set fraction of the seats in each course specifically for Astronomy majors.

Table VI-1: Astronomy Major Enrollment and Degrees Awarded

	2016-17	2015-16	2014-15	2013-14	2012-13	2011-12
Total majors	129	99	92	76	70	72
Graduated in <= 4 Years at UT	2*	12	5	6	4	7
Graduated in >= 5 Years at UT	9*	4	4	7	6	5
Graduated with BS Degree	5*	11	6	11	6	12
Graduated with BA Degree	1*	2	2	2	4	0
Graduated with BSA Degree	5*	3	1	n/a	n/a	n/a
AST / PHY Double Majors	48	45	44	38	26	29
AST / non-PHY Double Majors	14	5	5	7	9	11
GPA in Major 3.0+	75	70	62	54	53	58
Transfer Student	28	17	20	23	25	24

Notes to table: *2016-17 graduation numbers only include those graduating in fall 2016.

Table VI-2 provides a summary of self-reported demographic data for Astronomy majors.

Table VI-2: Self-Reported Demographics of Astronomy Majors

	2016-17	2015-16	2014-15	2013-14	2012-13	2011-12
Total	129	99	92	76	70	72
Female	46	38	29	23	16	22
Male	83	61	63	53	54	50
White	67	54	53	43	40	48
Black or African American	3	1	1	0	1	1
Hispanic	7	5	6	11	10	13
Asian	13	9	6	4	5	3
Native American	0	0	0	0	0	0
Other - Multiple	29	21	21	14	10	4
Other – Foreign	10	9	5	4	4	3

Table VI-3: Course Enrollment Statistics

	2011 Fall	2012 Spr.	2012 Sum.	2012 Fall	2013 Spr.	2013 Sum.	2013 Fall	2014 Spr.	2014 Sum.	2014 Fall	2015 Spr.	2015 Sum.	2015 Fall	2016 Spr.	2016 Sum
AST 301 (INTRO. TO ASTRON.)	1,127	691	39	1,053	649	63	987	820	28	1,069	760	0	1,248	839	0
AST 103L (ASTRON. OBS.)	57	63	0	56	57	0	52	59	0	50	52	0	37	53	0
AST 104 (UG ASTRON. SEM.)	24	0	0	33	0	0	34	0	0	20	0	0	20	0	0
AST 307 (INTRO. ASTRON.)	88	79	0	123	76	0	69	80	0	82	65	0	152	59	0
AST 309 (BIRTH STARS & PLAN.)	0	0	0	63	0	0	0	0	0	148	111	0	0	0	0
AST 309 (CUR. TOP. ASTRON.)	150	0	0	0	0	0	298	0	0	0	0	0	0	0	0
AST 309 (POP. ASTRON.)	0	0	0	0	209	0	0	201	0	0	0	0	0	0	0
AST 309C (BIRTH STAR. PLAN.)	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0
AST 309G (POP. ASTRON. NONSCI.)	0	0	0	0	0	0	0	0	0	196	0	0	0	0	0
AST 309G (POP ASTRO NONSCI.)	0	0	0	0	0	0	0	0	0	0	0	0	206	203	0
AST 309L (SEARCH EXTRATER. LIFE)	0	63	42	0	88	36	0	80	32	0	185	0	0	105	0
AST 309N (LIVES & DEATHS STARS)	207	302	0	170	0	0	151	182	0	0	205	0	0	467	0
AST 309R (GALAX., QUAS., & UNIV.)	0	180	0	154	208	0	0	89	0	0	0	0	138	0	0
AST 309S (THE SOLAR SYSTEM)	91	121	0	0	0	0	0	0	0	84	93	0	0	0	0
AST 210C (CONF. COURSE ASTRON.)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AST 110K (CONF. COURSE)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AST 210K (CONF. COURSE-FRI)	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
AST 210K (CONF. COURSE)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

	2011 Fall	2012 Spr.	2012 Sum.	2012 Fall	2013 Spr.	2013 Sum.	2013 Fall	2014 Spr.	2014 Sum.	2014 Fall	2015 Spr.	2015 Sum.	2015 Fall	2016 Spr.	2016 Sum
AST 210K (COSMIC DAWN-FRI)	0	5	0	0	7	0	0	4	0	0	0	0	0	0	0
AST 210K (WHITE DWARFS-FRI)	0	0	0	0	25	0	0	25	0	0	31	0	0	28	0

4) Undergraduate Educational Opportunities (e.g., Freshman Research Initiative)

The University of Texas College of Natural Sciences Freshman Research Initiative (FRI) program (https://cns.utexas.edu/fri) has become a national model for science education. It consists of many discovery-based research courses or course-based undergraduate research experiences (CUREs). Its goal is to get freshmen out of routine lab courses and into research experiences in which they can do actual front-line research directed by a faculty member and a Research Educator (RE). The RE position is a postdoc-like position that is supported from the CNS instructional budget, and this position is designed to be 50:50 in terms of teaching and research responsibilities. The program also provides for undergraduate student mentors, usually former members of the stream to assist in the leadership of the cohort. To date, the Astronomy program has led two very successful FRI streams over the past eight years.

The first FRI stream in Astronomy, "Exploring the Physics of the Universe with White Dwarf Stars" (http://www.as.utexas.edu/~mikemon/FRI/ast2.html), was developed and run by Don Winget and Mike Montgomery. This stream began in spring 2009 and was initially supported by the Norman Hackerman Advanced Research Program (funded by the State of Texas Coordinating Board), with the Department of Astronomy providing support for student travel to McDonald Observatory. Starting in 2012, this stream became a "full" FRI stream, with CNS supporting both the RE and the student travel. Currently, this stream has undergraduates at all levels, graduate students, postdocs, research scientists, and faculty members interacting through a "layered mentoring"

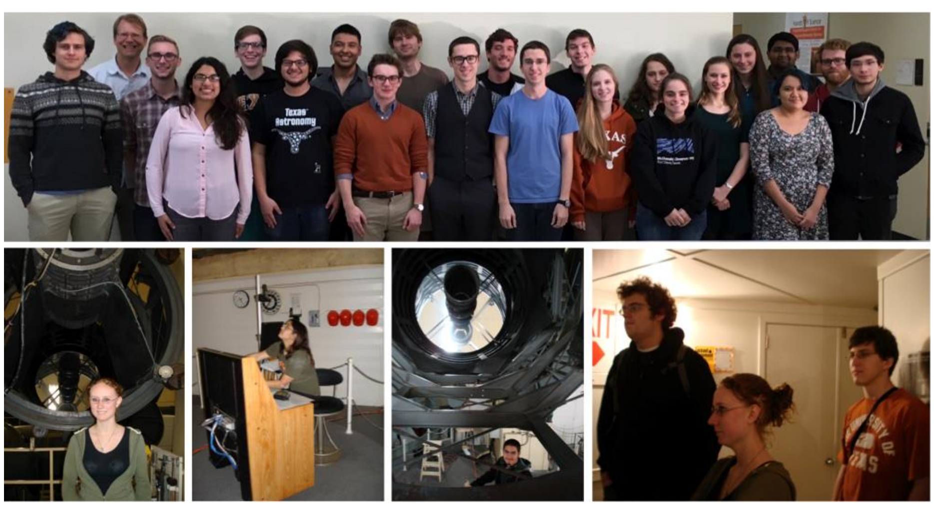


Figure VI-2: Fall 2015 students, mentors, and RE for the White Dwarf Stream (upper picture), and students at the 2.1-m Otto Struve Telescope at McDonald Observatory (lower pictures).

concept that has been refined for this stream. In this stream, students learn in the spring semester the basic concepts involved in the research, such as time series aperture photometry, basic stellar evolution (using the MESA stellar evolution code), and the Python language, and these are explored in labs. During the spring break and the following summer session, they travel to McDonald Observatory to obtain data for one of the many projects, and they begin the reduction and analysis of these data. In the following fall semester, they finish this analysis and place the data in the larger context of the ongoing research programs. Some students also do theory related projects, involving numerical modeling of stars. Still, other students work on experimental astrophysics. This involves data modeling and analysis of experimental data from work at Sandia National Labs on the Z-machine—the largest x-ray source on Earth. These experiments create stellar plasmas, or "star stuff," in the laboratory. As appropriate, results are readied for publication.

The second Astronomy FRI stream was created in 2011 by Professor Paul Shapiro. "Cosmic Dawn" (http://www.as.utexas.edu/~gfigm/fri) was the first FRI stream in theoretical cosmology. It is the only one of its kind in the US to engage students on this frontier. The largest, fastest, massively-paralleled supercomputers in the world – including those at UT's Texas Advanced Computing Center – are used to simulate these processes with gravitational N-body and numerical hydrodynamics methods, including radiation transport, and predict observable consequences of this "epoch of reionization" (EOR).

Freshman members of the "Cosmic Dawn" FRI stream are taught cosmology and the gravitational dynamics of galaxy formation, in which dark matter and atomic gas collapse into

Figure VI-3: Spring 2013 students of the *Cosmic Dawn* Freshman Research Initiative, with Prof. Shapiro (sitting), Research Educator D'Aloisio (far left) and Graduate Teaching Assistant Park (far right), in front of poster papers presenting results of their analysis of frontier cosmological simulations of galaxy formation using the UT TACC supercomputer lumps in gravitational equilibrium, called galactic halos, where luminous galaxies occur. They learn computer programming to analyze and visualize large-scale simulations of the Cold Dark Matter (CDM) universe, to characterize galactic halos and correlate their properties with the environment in which they form. Each spring semester, a class-wide research question is posed, with a class-wide plan to answer it. Students work in four-member teams and present their results for that semester. Summer scholars continue this. The returning fall semester class learns more about the subject and computer programming, to advance the project towards publication. Each spring semester, a new cycle begins, with new simulations to analyze and new science questions to answer.

While the FRI streams are primarily supported by funds from the College of Natural Sciences budget, PI Shapiro and RE Anson D'Aloisio, in collaboration with Oliver Dore (Jet Propulsion Laboratory), were awarded an annual grant, renewable for 3-years, through the NASA Jet Propulsion Laboratory Strategic University Research Partnership (SURP) program entitled, "Simulating Reionization and Its Observable Consequences with the Cosmic Dawn Freshman Research Initiative at The University of Texas." This grant was used to provide summer salary for both Graduate Research Assistants and an FRI alumnus and mentor as an Undergraduate Research Assistant during the summer.

Examples of the outcomes of the FRI streams include numerous publications, posters, and other scientific products. For example, student George Miller of the White Dwarf stream was the point-of-contact for an international team of observers looking for planets in binary systems containing white dwarf stars. George's contribution was significant: not only did he make some of the observations at McDonald Observatory, but he reduced these (and other) data, in the process redesigning our data reduction pipeline for a new telescope (the MONET telescope) with its observing software. This work resulted in two refereed journal papers, four conference proceedings, and was the basis for his grand prize in the 2012 George H. Mitchell Student Awards for Academic Excellence ($20,000).

Furthermore, the Cosmic Dawn students have produced state-of-the-art movies and images of cosmological N-body simulations on Stallion (a wall consisting of 16x5 tiles of 30-inch Dell high-resolution monitors, a total resolution of 328 million pixels), Mustang (a "3D" stereoscopic display), and Lasso (a large, 12.4 megapixel interactive multi-touch display). These visualizations are on public display at the VisLab, and they have been used for multiple outreach presentations, including a presentation for the Astronomy Department Board of Visitors, two presentations for UT's Astronomy Student Association, three recruitment presentations for prospective Astronomy graduate students, and four presentations for the FRI High School Summer Academy.
Direct involvement in research allows the students to experience the joy and satisfaction of knowing something about the universe that no one who has ever lived has ever known before. Many go on to do a research project with someone else in the department, or other departments if their core interest is in another science discipline; a few continue as mentors in the FRI program.

For the overall statistics of FRI students in CNS, Rodenbusch, Hernandez, Simmons, & Dolan (2016) found that when compared to a matched control group, for every 100 students who enter college, 17 more will graduate if they complete the FRI, and for every 100 students who graduate, 23 more will earn a STEM degree if they complete the FRI. These effects of the FRI were consistent for students regardless of background, showing that FRI improves diverse students' persistence in science.

While we do not have separate statistics on all the students who have passed through our stream, many of our students have gone on to win awards and be admitted to top graduate programs in a variety of fields. Below is a small representation of recent FRI student members:

- George Miller: grand prize winner of the 2012 George H. Mitchell Student Awards for Academic Excellence ($20,000 prize), currently at Harvard (Astronomy)
- Jennifer Ellis: 3-year NSF Graduate Fellowship, currently at UC-Boulder (Physics)
- Kevin Luecke: Student Employee of the Year at UT-Austin for 2012-2013, currently at Microsoft Kinect Division
- Julie C. Gerzina: winner of a student internship program through the Science of Environments Research Institute (SEERI) sub-program, currently a PhD Student at Princeton University (Geosciences).
- Jacob L. Schmelz was awarded a summer research internship in the summer of 2013 by the University of Tokyo Research Internship Program where he spent six weeks at the University of Tokyo Hongo Campus working on X-ray clusters of galaxies. Jacob is currently a medical student at the University of Texas McGovern School of Medicine.

Anecdotally, many students have remarked that the concepts in the stream are being introduced in some of their other classes and that they find the concepts much easier to understand—as well as more relevant—in the context of their application in the research stream. We see this as a validation of the FRI concept and also as a demonstration of the deep resonance of the stream with the Physics and Astronomy curriculum.

Unfortunately, the College of Natural Sciences was not able to renew funding for the "Cosmic Dawn" stream beyond fall of 2014 due to limited financial resources, so we currently offer just one FRI stream at this time. One goal for the continuing White Dwarfs stream is to include more opportunities for students to observe remotely, using a computer linked with a robotic telescope. This is vital since there are insufficient resources for each student to travel to McDonald Observatory. This is possible using the MONET telescope at McDonald Observatory, as well as the PJMO telescope operated by the Central Texas Astronomical Society, with whom we have an agreement.

The students for this stream do nearly all of their work in the computer lab on the 15th floor of RLM. While it currently contains 18 computers, a larger capacity is needed. The FRI course, along with several other groups, is competing for this space, and we have begun to exceed its capacity. Our growing enrollment combined with the large increase in astronomy majors in recent years has led to serious overcrowding. This space has become the single most important workspace for the undergraduates; addressing this need is of the utmost importance for the Department of Astronomy and the College of Natural Sciences.

5) Curriculum Reform

A number of faculty members have taken on curriculum reform and best practices in teaching undergraduate classes. Specific examples of curriculum reform include transforming an introductory astronomy course (Astronomy 301) taught by Daniel Jaffe into a flipped course. This was done over semesters spring 2013 and fall 2013. Other courses such as our interactive, computer-based research methods course, Astronomy 376R: A Practical Introduction to Research (developed by Shardha Jogee), employ in-class interactive teaching strategies and hands-on research for our majors, many of them freshmen. This course takes place in our computer lab, and students work in small teams (2-3) with each student having their own station, and get trained on research methods, and practical applications to astronomy data reduction and analysis. Since this is a limited-enrollment course, steps are being taken to increase the frequency it is offered and to use the course to introduce students to programming in Python.

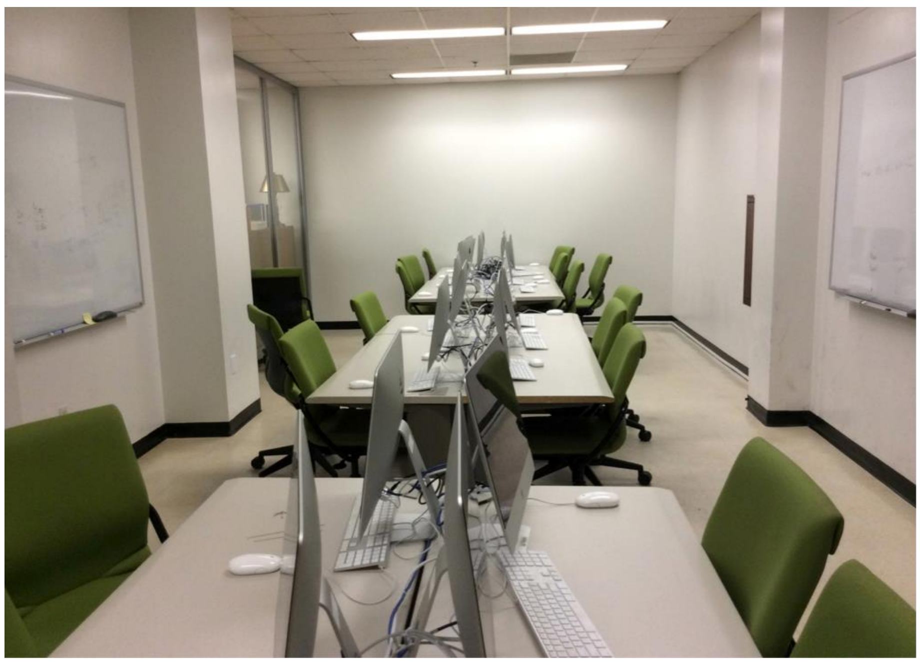


Figure VI-3: Astronomy Undergraduate Computer Lab in RLM. Currently seats only 18 or 13% of our current Astronomy majors at any given time. This is the primary space used for research by all of the students, from freshman to senior year, conducting research with Astronomy faculty and research staff. (Photo credit: Paul Shapiro)

Many faculty members and lecturers also make use of research-proven teaching strategies such as lecture tutorials, think-pair-share, and more for large introductory astronomy classes (e.g., Caitlin Casey, Keely Finkelstein, Steven Finkelstein, Judit Ries). A final example is faculty members being able to use new teaching spaces that are designed for improved learning, course design, and student interaction. These classrooms are available through the College of Natural Sciences, but are small in number. A number of faculty members have been able to make use of them (Caitlin Casey and Steven Finkelstein). These rooms move away from the traditional lecture hall, and contain group tables (6-8 seating) that are moveable and have the ability to be written on; the rooms also allow for multiple wall space for group work, problem solving, and sharing / projecting material around the room. Multiple faculty members also take advantage of the teaching professional development opportunities provided through the College of Natural Sciences and the Texas Institute for Discovery Education in Science (TIDES; https://cns.utexas.edu/tides). Specific examples include the TIDES faculty workshops, CNS New Faculty Orientation and Trainings, CNS Teaching Discovery Days. Two faculty members (Steven Finkelstein and Caitlin Casey) are present on college-wide committees representing Astronomy. These committees have been formed related to the 21st Century Undergraduate Education initiatives: Faculty Curriculum Vision Group (Casey) and Establishment of Experiential Learning Curriculum in Undergraduate Education Group (Finkelstein).

6) Instructional Staffing and Budget Management

Table VI-5 illustrates the CNS approved workload for Astronomy Tenured/Tenure Track Faculty members during the academic year. Teaching assignments are modified when faculty are on approved leave or are elected/assigned to an administrative role.

Table VI-5: Astronomy Workload

			Classes by Semester
AST	1	New Faculty – Year 1 or 2	1-0
	2	Active Research	1-1
	3	Minimal Activity	2-2
	4	Research Inactive	2-3

To maintain the level of courses necessary to meet the CNS core curriculum offerings in the sciences, the Department of Astronomy occasionally requests a minimal number (1-2) of non-tenure track appointments each semester. In addition, our Astronomy graduate students are supported as Teaching Assistants, and we hire undergraduate graders to assist with the large service courses that have 200+ student enrollments.

The Department's 2016-17 instructional budget allocations include $29,705 for non-tenured faculty (NTT) and $407,880 for 42 teaching assistants (TA) and 16 undergraduate graders ($18,540).

7) Advising, Scheduling and Enrollment Infrastructure

The Astronomy department has two Undergraduate Advisor positions, currently held by Professor Adam Kraus and Dr. Keely Finkelstein. Each semester, every undergraduate Astronomy major is required to meet with one of the advisors before the student is cleared to enroll for the next semester's classes. These meetings are intended not just to check that the student's planned course load is appropriate, but also to discuss the student's participation in other aspects of the program such as research, the long-term plan for degree completion, and the ongoing preparation for various career options after graduation. The logistical capability to engage with every student at least twice a year is seen as offering a clear advantage for our students.

VI.B: White Paper by Undergraduate Students

Introduction

The undergraduate astronomy major at The University of Texas at Austin provides a unique experience for students due to the access to participation in world-class research, facilities at the cutting-edge of astronomical research (in particular the McDonald Observatory), and an exemplary faculty of instructors who are leaders in their field and care about undergraduate education. The experience of astronomy undergraduates at UT is overall a great one. Students, in general, feel they are being challenged by their education, they feel included as members of the department and feel privileged to have opportunities to make meaningful contributions to the field of astronomy through participation in professional research. Students also appreciate the opportunity to have their voices heard in the external review through this paper.

This paper reports on the opinions of undergraduate astronomy students and offers their suggestions for how to continue to improve the already excellent undergraduate experience at UT astronomy.

Curriculum

The students feel that the size of the department is beneficial, in that it is small enough to allow a sense of camaraderie and membership in the department, and that they can develop a rapport with some faculty and graduate students as well as other undergrads. The students have a sense that faculty genuinely care about their education, about providing challenging opportunities both inside and outside the classroom, and are willing to provide necessary support to enable their success. The students feel that there are several faculty who are excellent lecturers, who give engaging lectures and challenging assignments, without being so challenging as to be unattainable. The students appreciate the structure of some classes that are more focused on professional astronomical practice and habits of mind than on grades and exams. Some students feel that some instructors rely overmuch on PowerPoint in their lectures, which can decrease engagement and interactivity. They feel that PowerPoint use could be decreased or, if still used, could be modified to make it more interactive or engaging.

Some students do not like that there is no recommended order for the astronomy classes to be taken in, as this leads to portions of each class to be spent on review of topics. Additionally, there is some overlap of material in upper division classes. Having required pre-requisite classes or prescribed order would ensure students enter the class with a similar base knowledge and can help avoid overlap. Perhaps AST 307 could be made to be a required class for the major and replace one required upper division class, like physics. The students recognize that non-astro majors take the classes as well, which necessitates the review, however, for astro majors, this problem feels cumbersome, and detracts from the quality of the class.

Some students have observed that there is a lack of consistency within the same class taught in different semesters by different instructors. They suggest a departmentally created “scope and sequence” for each course (if it does not already exist) which outlines exactly what topics will be taught in each class. This can also help avoid course overlap, and allow the whole department to know and have input into what is taught in each class. It would be just a broad outline, and so still allow each instructor to have their style and lessons.

There can sometimes be some difficulty in astronomy majors getting into required astronomy courses before they fill up. The students recognize that this is attempting to be addressed by reserving some seats for astro majors. However, this semester ran into the difficulty in that not all astro majors filled out the survey that was sent. They recommend perhaps collecting information through the advising cards prior to registration to determine what classes students intend to take, and reserving more seats than requested by students, any extra of which can then be opened later to non-majors.

The students feel there is a greater need for programming experience than is typically gained through astro coursework. They offer several suggestions. First, they feel the research methods class should be better publicized beyond FRI students. Some students even suggest making it a required course. This would mean expanding the seating in the class, and the available computers, as well as further reduction in requirements elsewhere in the curriculum, however, the students feel that the gain of more programming experience is beneficial. Secondly, the students suggest replacing a general science requirement with a computer science class, particularly an intro to programming class, such as the intro to python, or a statistics and data science class targeting big data skills. Third, the students suggest Python or big data workshops, if there is not room to add these classes to schedules. These workshops could be student-led, either grad student or fellow undergrad student with familiarity with a language. Fourth, the students recommend adding more programming tasks to astronomy coursework, to force students to gain familiarity with some languages and how they are used in professional astronomy. While some instructors already do this, they feel it could be added to more courses, and more of it could be done in courses already doing it.

The students are highly in favor of adding the option of specialization to the astronomy degree. While retaining the basic astro degree plan option, other options could be added such as astrobiology, astrogeology, instrumentation or computer science, similar to how the Physics

Department offers specializations such as radiation physics. These would entail slightly different course plans while remaining an astronomy degree plan. For example, if a student wished to specialize in astrogeology, perhaps an upper division geology course could replace the Quantum II requirement, among others, as a detailed understanding of quantum isn't as vital to geology as it is to, say, astrophysics. Adding these formal degree plan options allows for greater flexibility and interests within the astronomy field. The students feel only a few options is best, not a large number. Alternatively, the students wondered about allowing enough flexibility in required courses to allow the advisors to be able to tailor the degree slightly to a student's interest if formal degree options aren't viable.

The students understand that this program is designed to prepare students for graduate studies in astronomy, not necessarily for careers outside of pursuing a graduate degree. Most students feel that the program curriculum does not necessarily need to be modified with non-academic career paths in mind and that the program does, for the most part, provide useful skills for other career paths. However, students feel that non-academic career options could be better advertised and discussed by the department, and how to turn astronomy degree skills into skills marketable on resumes and job interviews, and what sorts of non-academic careers astronomy alumni typically seek out and are successful with.

Some students have suggested a required 1 hour per week seminar course for first semester students (freshmen or transfer students) as a way to disseminate information about the astronomy department, the degree, expectations for astronomy students, professional astronomy careers, scholarships and grants, research opportunities, summer opportunities and how to find them, professional astronomy norms students can participate in like AAS, how to search astronomy papers (NASA ADS), and academic and non-academic career options.

Research

The many opportunities available for undergraduate students to participate in research with faculty is one of the things that makes the Astronomy Department so effective at preparing undergraduates for graduate school. Students involved in research feel that faculty genuinely care about their success on their project and their growth as scientists. Through weekly meetings, students feel that involvement in department research helps them to be more connected and welcome within the department and gives them a taste of what it would be like to continue in academia.

Some students feel that the process of getting involved in research with faculty can be difficult and intimidating. While the department has attempted to make getting involved in research easier for undergraduates, their means for doing so are not well maintained. On the department website is a list of faculty who are welcoming undergraduate researchers. While, in concept, this is a great way to aid undergraduates in finding a suitable research project, the list is not kept up to date. As a result, undergraduates wind up contacting many unavailable faculty before finding a project they can work on. Students also feel that some faculty can be difficult to get into contact with, either by not responding to emails or by not being easy to find in their offices.

One way that the CNS is helping students get involved in research is through the Freshman Research Initiative. Currently, there is one astronomy stream in the FRI, the 'Exploring the Universe with White Dwarf Stars' stream. Students feel that it would be beneficial to have an additional astronomy stream in a different field so that freshman who may not be interested in stellar astronomy have a choice of what stream to join.

Students appreciate the availability of department and CNS funding for research because it enables students needing a source of income to not have to sacrifice research experience to a part-time job. Students feel that sources of funding in the department should be better advertised, both to them and to their advisors so that students in need can get the funding necessary to enable them to do their research.

The students recognize the need to expand the undergraduate research computer lab, and the efforts the department is undertaking to address it. Most students fully support the expansion and have willingly participated in efforts to secure funding for the project.

Department Outreach

The astronomy department is fairly strongly engaged in public outreach, and there are a couple of opportunities for students to get involved. However, most outreach done by undergraduates is affiliated with the Astronomy Students Association (ASA), not the Astronomy Department. This is fine for most students, but those that prefer not to be a part of the ASA are lacking in opportunity to get involved with the Austin community.

The two main types of events that the department advertises to undergraduates are events on the roof of the RLM, and the South by Southwest booth that showcases the James Webb Space Telescope. The former happens 2-3 times a year when there is some special event happening that the public would be interested in viewings, such as transits, solar and lunar eclipses, and various planetary events like alignments. The later happens once a year at the SXSW festival, and students can sign up to work a shift at the JWST booth. Both of these are valuable opportunities to get involved in astronomy, and undergraduates appreciate the experience and the opportunity to join the department in outreach. However, some students feel that it would benefit them more if there were more outreach events offered to them from the department, beyond just ASA-led.

Awards and Recognition

Another important opportunity for undergraduate students in the department is scholarships, recognition, and other awards. Some students have expressed frustration over a lack of communication in regards to what awards are available, and what they might be eligible for. The department awards multiple students every year for outstanding research or academic achievement, but not very many students even know that this is a potential opportunity for them. In addition, students are confused about deadlines and rules for the Cox research fund consistently and feel like they are not prepared for the application. Our suggestion for the improvement of this aspect of the department is to advertise the scholarships and awards offered by the department more frequently. Another idea is to specifically contact the faculty and researchers that have undergraduates working with them and tell them about the various awards their students may be eligible for.

Freshman/Transfer Student Orientation

The transition from either high school to college or another college to UT astronomy is often a confusing process. For many students attempting to enter the Astronomy program here, there is seemingly little information on what exactly they will find in the astronomy department. Many students upon entering the Astronomy program as an incoming freshman felt out of the loop with the department because there is no astronomy specific orientation offered. Those that join the ASA or go to the ASA organized Prospective Students Day have slightly more knowledge about navigating their first year here, but many do not get these chances. Similarly, transfer students are also left confused about what exactly they need to do as an astronomy major, as they do not attend the same orientation to the department.

An astronomy-specific orientation would help with some of the following: how to get access to the computer lab, the undergraduate lounge, and the department lounge; how to join the departmental email list; how to navigate RLM; how to navigate the departmental website and degree plans; how to find and access undergraduate resources; meeting some faculty and staff.

Students have mandatory meetings with a faculty advisor before registration, but an introductory meeting at the beginning of their first year would be helpful as well, either during the astronomy-specific orientation or as a required advising appointment similar to at registration time. This would allow them to ask questions early on and give them more time to figure out how they want to plan out their degree plan. This would also help acquaint them with at least one faculty member, which will give them a person to talk to about finding research or just what research is going on in the department.

In past years there had been a mentorship program that is no longer in place. Many students feel strongly they would benefit from a structured, departmentally organized mentorship program with more senior undergraduate students, graduate students, or faculty. This would greatly improve the orientation, and communications problems addressed earlier, improve student involvement and engagement in the department, and enrich students' experiences as astronomy majors. Some students responded very positively to the idea of a mentorship program, indicating a strong desire for such a program.

Inclusion in the Department

The students feel that the astronomy department makes a significant effort to include the undergraduates in the community. Examples of this are inviting us to Astronomy on Tap, department holiday parties and events, and the few outreach events that we are asked to participate in. Students here appreciate these efforts, and most feel that the astronomy department goes above and beyond other departments in the College of Natural Sciences in this respect. However, there have been a few suggestions on improving the undergraduate environment.

The first suggestion posed is to schedule the annual holiday party so it does not coincide with any final exams, as this has been a problem this year and in years past; perhaps the holiday party could be held on the two "dead days" between the last day of class and finals. Another suggestion is to have more department parties or social events that give the students a chance to familiarize themselves with the rest of the department.

Astronomy Students Association

The students recognize that the single largest reason this department has an active undergraduate community is due to the efforts of the Astronomy Students Association (ASA). It has already been mentioned in this report several times due to its overarching ability to connect students to resources they need. The ASA is an organization that has weekly meetings that feature professors and researchers talking about their research and experiences (a great way for undergraduates to find and get involved in a research group). In addition to their weekly meetings, they host star parties, actively involve students in outreach at elementary schools, nature preserves, and public spaces in and around Austin, have social events like parties and group camping and plan and run Prospective Students Day. This combines into a source of community for the undergraduates in the department and works to build connections between its members. Many students find their friends, their study groups, and their research entirely from the ASA. This is an amazing resource, but it is not department sponsored. This means that students who don't want to join the ASA are not getting these same resources.

The department has relied on the ASA in the past to relay information to the students, coordinate a town hall to talk about the state of the department, and inform the astronomy students of possible opportunities. This leaves out students who do not attend ASA meetings or get their emails.

Undergraduate Representatives

The department has started to address this with the appointment of undergraduate representatives, who can act as a go-between for the students and the department, but there are still things that ASA does that possibly shouldn't be their responsibility. The students recognize and appreciate the value of the undergraduate representatives, and would like the position to exist beyond this review process, and to be advertised to the department - both faculty and students - so everyone can make use of this resource to facilitate communication. The undergrad reps are considering employing an "office hour" type structure, in which they are available to either faculty or students to drop by and express thoughts or concerns. The undergrad reps would appreciate formal departmental support for their position, in the form of advertising their services, utilizing them in their formal capacities, and relying on them as a facilitation of communication between faculty and students.

Conclusion:

Across the board, students feel a genuine appreciation for the department efforts in their education. Students enjoy their experience here. We value the opportunity to provide input into the course of the astronomy department at UT. We recognize and appreciate the efforts of the department chair, Dr. Jogee, in reaching out to and including the undergraduates, such as: spearheading the overhaul of the computer lab to support undergraduate research, reaching out to ASA to have a "town hall" meeting to hear students' opinions, creating the undergraduate representative position and actively seeking undergraduate input into the department. We would like to thank Dr. Jogee and the astronomy department for the opportunity to have our voices heard.

Evaluation Committee Members:

Anna McGilvray
Logan Pearce
Richard Seifert

Section VII. Graduate Program

VII.A. Graduate Program

Overview: Graduate students are vital members of the Astronomy program: they conduct innovative research, publish papers in peer-reviewed scientific journals, educate thousands of undergraduates, lead outreach programs, and improve our inclusive community. Our graduate program is one of the best in the nation. We contribute to US News & World Report's 2017 ranking of UT Austin in space science as #6 among US state universities.

In the last four years, we have made headway in recruiting top students and improving diversity through a multi-pronged approach, which includes holistic admission criteria, an inclusive department climate, cutting-edge research projects, and improved recruiting packages. In order to better compete with other top US public universities, we are now exploring ways to offer full multi-year graduate fellowships, while maintaining the quality, breadth, and critical mass of our research program.

One of the largest obstacles to our research program is that many research-active tenured faculty members face difficulties in recruiting graduate students and postdocs, due to the rising cost of graduate student support and the limited funds available from federal grants, CNS, and the Department.

Figure VII-1: UT Astronomy Graduate Students. *(Photo credit: Lara Eakins)*

Our graduate program produces outstanding PhD graduates who continue as future leaders in research, education, and the private sector, particularly in the area of big data. We will continue our efforts to provide our graduate students and postdocs with broader training and mentoring to prepare them as future leaders with high scholarly, societal, and economic impact.

1) Degree Requirements (core courses, qualifying exams, candidacy, etc.)

Students admitted to our graduate program are expected to pursue a PhD degree; thus, we consider the MA degree as optional, “en route” to the PhD, which can be picked up after a student has passed his/her second-year qualifying exam (also known and the “Second-Year Defense”). We, therefore, here focus on the requirements for the PhD degree.

During their first two years in the program, our graduate students are required to take a total of nine courses. Seven of them must be selected from the following list of classes, offered by the astronomy department once in every two-year cycle: Radiative Processes, Gravitational Dynamics, Gas Dynamics, Galaxies, Interstellar Medium, Cosmology, Stellar Structure and Evolution, Instrumentation, Planetary Astrophysics, Data Analysis, and Computational Astrophysics. For the remaining two courses, our students have the flexibility to also take them in the astronomy department, or in related departments (e.g., physics, computer science, statistics).
If taken within the astronomy department, our students can select from an augmented list that now also includes additional courses, offered less frequently than the standard two-year cycle: Stellar Atmospheres, Nucleosynthesis, Asteroseismology, Galaxy Evolution at High Redshift, Mathematical Methods, Physics of Compact Objects, High Energy Astrophysics, and Galaxy Formation. Whereas we make every effort to offer the courses in the former list every two years, so that every student has the chance to take them, these latter courses are offered less frequently, because of faculty availability and student demand. Popular courses taken outside the astronomy department have recently been: Bayesian Statistical Methods, Scientific and Technical Computing, Parallel Computing, Quantum Mechanics, and Quantum Field Theory (all graduate level). We provide specific course offerings over the three-year period 2013-16 in Table VII-1.

In addition to their course work, our students begin doing research right away. They are required to report on their research project as part of our second-year qualifying exam. Ideally, students have a paper submitted by the end of their second-year, or have a “proto-paper” draft, soon to be submitted; barring that, they have to submit a detailed written report on their project.

Our second-year qualifying exam consists of two parts: (i) the student’s presentation, by way of a seminar talk, of their research project (see above); and (ii) an oral examination, in a closed-door meeting with the members of their research committee (typically four to five faculty members). The oral exam, in turn, has two parts, the first focused on the student’s general knowledge of astrophysics, based on the courses taken (specifically, each student picks three of his/her courses); and the second on questions related to the respective research project.

If they pass the qualifying exam, typically by the end of the spring semester in Year 2, our students are expected to prepare their PhD proposal over the summer, where they make a case for their PhD project, and where they have to argue that this work can be accomplished in another three years (or at most four years), so that they can realistically graduate by the end of (total program) Year 5 (or at most Year 6). Once, they have reached convergence with the members of their research committee, they apply for PhD candidacy, typically by the beginning of Year 3 (fall semester).

Table VII-1: Graduate Courses in the Astronomy Program

2015-16	Fall	
	AST 381 PLANETARY ASTROPHYSICS	KRAUS, A
	AST 381C GRAVITATIONAL DYNAMICS	SHAPIRO, P
	AST 383 ASTRONOMICAL DATA ANALYSIS	MILOSAVLJEVIC, M
	AST 383D STELLAR STRUCTURE AND EVOLUTN	BROMM, V
	Spring	
	AST 380E RADIATV PROCS & RADIATV TRANSF	MILOSAVLJEVIC, M
	AST 383 NUCLEOSYNTHESIS	LAMBERT, D
	AST 392J ASTRONOMICAL INSTRUMENTATION	FRONING, C

2014-15	Fall	
	AST 381 COMPUTATIONAL ASTROPHYSICS	MILOSAVLJEVIC, M
	AST 386C PROPERTIES OF GALAXIES	JOGEE, S
	AST 393F SURVEY OF INTERSTELLAR MEDIUM	EVANS, N
	AST 396C ELEMENTS OF COSMOLOGY	SHAPIRO, P
	Spring	
	AST 381 PHYSICS OF COMPACT OBJECTS	ROBINSON, E
	AST 382C ASTROPHYSICAL GAS DYNAMICS	BROMM, V
	AST 386 GALAXY EVOL AT HIGH REDSHIFT	FINKELSTEIN, S
	AST 392J ASTRONOMICAL INSTRUMENTATION	JAFFE, D
2013-14	Fall	
	AST 380E RADIATV PROCS & RADIATV TRANSF	MILOSAVLJEVIC, M
	AST 381 PLANETARY ASTROPHYSICS	COCHRAN, W
	AST 381C GRAVITATIONAL DYNAMICS	BROMM, V
	Spring	
	AST 383 ASTRONOMICAL DATA ANALYSIS	ROBINSON, E
	AST 383D STELLAR STRUCTURE AND EVOLUTN	WINGET, D
	AST 392J ASTRONOMICAL INSTRUMENTATION	LACY, J

Most popular courses outside the Astronomy Department taken by our students:

SDS 384 Bayesian Statistical Methods
SDS 394 Scientific and Technical Computing
(1st semester of a sequence)
SDS 394C Parallel Computing for Scientists &
Engineers (2nd semester of sequence)
PHY 389K Quantum Mechanics
PHY 396K Quantum Field Theory

Once in candidacy, our students have to meet with their research advisory committee at least once a year, to report on their progress and challenges. As part of these annual meetings, the timeline, and expected research accomplishments are reviewed, so that the student has a clear understanding of what the expectations for earning the PhD degree are. Typically by the end of Year 5 or 6, our students defend their PhD thesis.

2) Available Financial Support (Teaching Assistants, Graduate Research Assistants, Fellowships)

To recruit top-tier graduate students, we need to provide cutting-edge research opportunities and offer competitive support packages, while maintaining the quality, breadth, and critical mass of our graduate research program. The department guarantees financial support for five years (five academic years and five summers) for all admitted students. The support package consists of a mix of Fellowships, Graduate Research Assistantships (GRAs), and Teaching Assistantships (TAs). We discuss each of these sources of support below.

Fellowships: We have a mix of fellowships, including UT (Graduate School, University, and CNS) one-year fellowships, a few summer fellowships allocated by the Department from its endowments, and external competitive, multi-year national fellowships, typically from NASA and NSF. Our students have been very successful in obtaining NASA and NSF fellowships (four awards during the three-year period 2013-16, roughly 10% of our total student population). Another 10% of our students have held UT Graduate School or CNS graduate fellowships each year (Table VII-2).

Table VII-2: Financial Support (TAs, Fellowships) for Graduate Students

	Number of Semester-Based Teaching Assistantships (TAs) from CNS	Number of Graduate Students	Number of Graduate Students on External or UT Graduate School (GS) Fellowships	New Students Enrolled
2015-16	43	36	9 (1 NASA, 3 NSF, 5 GS)	9
2014-15	42	36	9 (1 NASA, 3 NSF, 5 GS)	5
2013-14	41	37	5 (2 NASA, 2 NSF, 1 GS)	7

Graduate Research Assistantships: After years of stagnation, we raised our GRA stipends by over 30% in 2015 to $28K/year to be more competitive with peer institutions and deal with the rising cost of living in Austin. In AY 2016-17, the cost of funding a student with GRAs is $45.1K without indirect costs and $64.8K with indirect costs at the rate of 56.5%. The cost includes the GRA stipend ($28K/year), tuition (around $4.3K in the fall and spring semesters, and $1.6K in the summer) and fringe benefits.

Teaching Assistantships: CNS typically allocates the Astronomy Department approximately 42 Teaching Assistantships distributed between the fall and spring semesters (Table VII-2), based on the enrollment in the courses we offer. Over the last five years, we have typically supported 60% of our 35 graduate students with Teaching Assistantships during the 9-month academic year.

Two recent changes were announced in Spring 2017: the CNS TA stipend will be raised to $27K/year as of 2017-18 and CNS will ask the department to limit the number of semesters a student may TA during their first 5 years. Discussions are ongoing between the Department and the Dean's office to finalize the TA semester limit. We greatly appreciate the increased CNS TA stipend, which will reduce the TA top-off burden for the department's 40 TA slots. We are concerned that a policy to limit the number of semesters a student can TA to any number well below 10 semesters will reduce the size, quality, and ranking of our graduate and research program. We believe that the best students and faculty join UT Astronomy because of the quality, breadth, and critical mass of our research program.

Summer Support: Providing summer support ($10.3K per student without indirect cost) is the most challenging problem in the support of graduate students. Summer support must come entirely from GRAs or department funds because our department has not received any summer Teaching Assistantships since 2014. At the present time, the department is able to provide summer support for 4-5 students from endowed and discretionary funds, but it does not have the means to support a large number of students over the summer.

Table VII-3: TA Usage in Astronomy Graduating Cohorts

Graduation Year	# of Graduating Students	Minimum # of Semester TAs	Maximum # of Semester TAs	Average # of Semester TAs	Percent holding 8 or more semesters of TA	Average Time to Degree	# of TAs allocated to Astronomy by CNS
2011-12	6	2	11	5	17%	5.6	40
2012-13	9	1	13	6	33%	5.3	40
2013-14	5	0	9	6	40%	5.2	41
2014-15	6	0	10	5	33%	5.2	42
2015-16	8	2	14	8	50%	5.6	43

Table VII-4: TA Usage and Post-Graduation Placement of Astronomy Graduating Cohorts

NAME	Graduation Semester	# of Semester TA-ships	Fellowships	First Post-Graduation Placement
2011 – 2012 Graduates				
Stacy, Athena	Fall	11		Prize Post Doc- NASA Goddard Space Flight Center
Shoji, Masatoshi	Fall	4		Business Consultant at ABeam Consulting
Deen, Casey	Fall	2	NASA	Post Doc- Max Planck Institute
Ludwig, Randi	Summer	7		Postdoc UT Austin Physics
Chiang, Chi-Ting	Summer	5		Prize Postdoc at University of Chicago FLASH center
Murphy, Jeremy	Summer	2	Continuing, Benfield	Prize Postdoc at Princeton
2012 – 2013 Graduates				
Heiderman, Amanda	Fall	4		Post Doc- Max Planck Institute
Kim, Hyo Jeong	Fall	1		Postdoc at Chosun University
Chatzopoulos, Emmanouil	Spring	6	NASA, Powers, Benfield	Prize Postdoc at University of Chicago FLASH center
Barentine, John	Spring	4		Program Manager: International Dark-Sky Association (IDA) Non-Profit
Kagan, Daniel	Summer	13		Postdoc at Tel Aviv/ Hebrew U. of Jerusalem
Hermes, James "JJ"	Summer	8	Goetting, Benfield	Postdoc at University of Warwick; currently a Hubble Fellow
Robertson, Paul	Summer	8	Continuing	Postdoc at Penn State; currently a Sagan Fellow
Weinzirl, Timothy	Summer	6		Postdoc at UT Austin Astronomy/ Now post doc at U of Nottingham
Jee, Inh	Summer	3		PhD Student at Max Planck Inst.
2013 – 2014 Graduates				
Jardel, John	Spring	9		Data Scientist at Square Root Inc
Hollek, Julie (Krugler)	Summer	9		Data Scientist at Twitter
Falcon, Ross	Summer	5	Diversity Recruiting, NPSC	Postdoc-Sandia National Lab
Safranek-Shrader, Chalence	Summer	5	NASA, Continuing, Goetting	Postdoc-UC Santa Cruz
Merello, Manuel	Summer	0		Postdoc-Istituto di Astrofisica e Planetologia Spazial
2014 – 2015 Graduates				
Brugamyer, Erik	Fall	8	Continuing, Goetting	Offered post-doc at U of Delaware but declined for Cost Accountant at The Whitley Group
Lindner, Christopher	Fall	7	NSF	Data Scientist at Civitas Learning
Gully-Santiago, Michael	Spring	0	NASA, Benfield	Kavli postdoc at Peking University
Park, Hyun-bae	Summer	10	Summer fellowship from Japan Society for the	K-GMT Postdoc at Korea Astronomy and Space Science Institute

NAME	Graduation Semester	# of Semester TA-ships	Fellowships	First Post-Graduation Placement
			Promotion of Science	
Vutisalchavakul, Nalin	Summer	3		CNS Specialist for Astronomy Courses.
Chonis, Taylor	Summer	0	NSF	Currently Systems Engineer at Ball Aerospace
2015 – 2016 Graduates				
Jeon, Myoungwon	Fall	12		Prize postdoc U of Arizona Steward Observatory
Santana, Rodolfo	Fall	11	Diversity Recruiting, Continuing, Goetting	Data Scientist in California
Hummel, Jacob	Spring	14		Data Scientist at overstock.com
Gullikson, Kevin	Spring	5	Continuing, Hutchinston	Data Scientist at Spark Cognition
Chiang, Yi-Kuan	Spring	3	Continuing	JSPS Fellow at University of Tokyo; currently postdoc at Johns Hopkins University
Sluder, Alan	Summer	14		Research Affiliate Postdoctoral Fellow – University of Texas at Austin
Song, Mimi	Summer	3	Continuing	Prize postdoc at NASA's Goddard Space Flight Center
Johnson, Marshall	Summer	2	NASA	Columbus Prize Fellowship at Ohio State

Funds Available for Graduate Student Support: Department and CNS funds available to us for graduate student support (recruitment of new students and support of existing students) are listed below

a) CNS recurring funds: $38,040 per year
b) CNS bridge funds: $22,380 (2017-18), $17,380 (2018-19), $12,380 (2019-20), 0 thereafter.
c) Department Cox Endowment recurring funds: $50,000 per year
d) Department Cox Endowment funds dedicated to travel support for graduate students (through the Cox Graduate Excellence Funds and Cox funds awarded to the five departmental research groups): $30,000 per year
e) Department summer fellowships: We currently award two summer fellowships (Goetting Endowed Presidential Scholarship and Benfield Memorial Scholarship) each year totaling $20,000
f) Department discretionary and reserve funds (from the Cox endowment, the Board of Visitors funds, the Blumberg endowment, the Lambert endowment, etc.) contribute $30,000 to $50,000 per year. The available recurring department funds amount to $130K to $150K a year and these funds are also used toward startup packages for new faculty hires.

<u>3) Program Size (current and planned, relationship with financial support)</u>

We are working on reducing the graduate program size to a target size that the Department can support using the currently available resources resources. Through reallocation of resources, we hope to reduce our program size only by a modest amount. We note that with a faculty target size of 22, the current graduate program size of 35 already yields a conservative average of 1.6 students per faculty. A much smaller program size is not practical since most of our faculty members are research-active and the Department is actively hiring junior tenure-track faculty members who typically recruit several students from startup funds to build a competitive research group.

4) Admissions Process (quality of applicants, selectivity, and yield)

Over the past several years, we have been increasingly proactive to address the diversity of students in our graduate program, recognizing that this diversity is crucial for growth and creativity, as the insight brought by people from different socio-demographic backgrounds leads to a richer propagation of ideas and a better growth of our student population as a whole.

Our methods for this have been to take a holistic approach, with a number of cross-checks. The cross checks involve a discussion of implicit biases at the start of the committee and examining the applicant pool at each step to ensure the demographics are roughly constant. The holistic approach means that we take all information available together, and do not make, for example, hard cuts on numbers on either GPA or GRE scores. We have placed emphasis on “grit,” in that we are looking for students who have shown a passion for astronomy and research, as well as shown the ability to overcome obstacles in their lives. Studies, as well as our experience, have shown that this grittiness, rather than GRE scores or undergraduate GPA, are the best indicator for future success in graduate school.

Along these lines, we have recently made the decision to no longer accept Physics GRE (PGRE) subject test scores as part of our admissions process. Recent evidence has demonstrated that there is a significant lack of correspondence between students’ performance on the PGRE and their success in graduate school and beyond. Rather, student performance on the PGRE (and the general GRE) is more closely correlated with race and gender than long-term career success. By using it as a consideration in graduate admissions, the PGRE is harmful to students belonging to underrepresented groups. Additionally, there is no evidence that comparable PhD programs which do not require the PGRE are comprised of less skilled cohorts, and a separate study using self-reported data from the past five years of postdoctoral prize fellows in the United States indicate no correlation between number of first-author papers published and PGRE performance. This will take effect for the incoming class of 2017.

Our attempts to improve the demographics of our graduate student population have proven successful. This is illustrated in Tables VII-5 and VII-6. In 2012, we had a population of about 40 graduate students, consisting of four women and zero African Americans (in fact, UT Astronomy has never granted a PhD to an African-American). In 2016-17, we now have 11 (31%) female students, 3 (8.6%) African American/Black, 4 (11.4%) Hispanic, and 1 (2.9%) Asian American students (Table VII-5 and Table VII-6).

Defining the selectivity of our admissions process as admitted students per total number of applicants results in 19% (2015), 16% (2014), and 21% (2013). Thus, our typical selectivity is 20%.

Defining our admissions yield as a number of enrolled students per total number of admitted ones, we have 32% (2015), 23% (2014), and 24% (2013). Here, we see the impact of small-number statistics, resulting in considerable year-to-year variation. But typically, a quarter of the admitted student pool accepts our offer.

Table VII-5: Admissions Statistics for Under-represented Minorities

Entering Year	Applied			Admitted and Offered Visits			Enrolled		
	Black / Afr. Am.	Hisp.	B+H	Black / Afr. Am.	Hisp.	B+H	Black / Afr. Am.	Hisp.	B+H
Fall 2015	4	9	13 (9%)	4	3	7 (25%)	1	2	3 (33%)
Fall 2014	2	11	13 (9%)	1	4	5 (33%)	0	2	2 (40%)
Fall 2013	1	6	7 (5%)	1	2	3 (10%)	0	0	0 (0%)

Notes to Table 3: a) "B" denotes Black/African American students who self-identify as Black and Black/White; b) "H" denotes Hispanic students who self-identify as Hispanic and Hispanic/White. As explained below, we judge the quality of our applicants with a holistic set of criteria, including non-quantifiable ones such as "grit." Keeping this caveat in mind, the average undergraduate GPA of our applicant pool has been about 3.6 (over the three recruiting years 2013, 2014, and 2015).

Table VII-6: Graduate Student Demographics

	Total Students	**Male**	**Female**	**White**	**Black / African American**	**Hispanic**	**Asian American**	**International or Other**
2016-2017	35	68.6%	31.4%	57.1%	8.6%	11.4%	2.9%	20.0%
2015-2016	36	77.8%	22.2%	58.3%	2.8%	13.9%	2.8%	22.2%
2014-2015	36	80.6%	19.4%	55.6%	0.0%	13.9%	2.8%	27.8%
2013-2014	37	86.5%	13.5%	56.8%	0.0%	10.8%	8.1%	24.3%

As of late Fall 2016, CNS has instituted a new policy assigning Department Chairs the responsibility to approve the acceptance of new graduate students by faculty members in their department. As per our implementation of this policy and associated best practices, Astronomy faculty members can typically admit a new student only if they can provide a minimum level of support (of order two summers) for their new student, as well as support their current students. (http://www.as.utexas.edu/~sj/sign-off/CNS-Chair-Signoff-Policy-Final-2016.pdf),

5) Degree Completion Rates and Time to Degree

We have been quite successful in selecting our students for their ability to do research. This is reflected in a high PhD degree completion rate, with only ~10% dropping out before the PhD (typically close to the second-year qualifying process, at which point they typically still pick up a Masters degree). Over the three-year period of 2013-16, the average time to the PhD degree was 5.3 years. For further details, see Table VII-8.

Table VII-8: Average Time to Degree

	Total Students	Total Graduated Fall/Spring/Summer	Average Time to Degree
2015-16	36	8	5.6
2014-15	36	6	5.2
2013-14	37	5	5.2

6) TA Workload Policies

Almost all our graduate students act as Teaching Assistants for a few semesters, even if they are otherwise supported with GRAs and/or fellowships. We believe that such exposure to teaching is a vital part of the professional preparation of our students. When they are supported by Teaching Assistantships, our students typically have a 20-hour (per week) appointment, and we are making every effort to not exceed this time limit. In addition, we try to circulate teaching assignments between the different levels (large-format intro, signature classes, smaller format upper-division courses). We do expect our students to conscientiously fulfill their teaching assistant duties; if they don't, we individually follow up with them until their performance is up to our standards.

7) Graduate Student Professional Development Opportunities

Our graduate program produces outstanding PhD graduates who have a broad spectrum of interests and continue as future leaders in research, education, and the private sector, particularly in the area of big data (Table VII-4).

All our students are exposed to cutting-edge computational techniques and resources, in most cases provided by UT's Texas Advanced Computing Center (TACC). This exposure is frequently enhanced through classes taken in the departments of statistics and computer science. In the last four years, we have added graduate courses on frontier science areas, such as Planetary Astrophysics, Galaxy Evolution at High Redshift, Computational Astrophysics, and Data Science with a focus on Big Data to the graduate curriculum.

Many frontier science and funding opportunities are at interdisciplinary boundaries, and national reports advocate a broader interdisciplinary training. We are exploring the viability offering inter-disciplinary courses, such as planetary science courses offered by Astronomy/Geology, astrobiology courses offered by Astronomy/Biology, and Big Data courses offered by Astronomy/Computer Science/TACC. Our students are embedded in a comprehensive professional mentoring structure, ranging from an entry-level seminar to departmental mentor relations. We have recently set up a network of Informal mentors for graduate students and postdocs (www.as.utexas.edu/astronomy/education/mentors.html). The informal mentors complement the formal mentoring provided by the PhD research committee, the graduate advisor, and the Graduate Studies Committee, and provide informal advice on a host of professional development issues. Mentors take part in a department-supported mentoring lunch each semester and are also available for individual discussions. They provide advice on job applications, observing and grant proposals, oral presentations, teaching techniques, work-family-life balance, imposter syndrome, different career paths, and more. They bounce research ideas and provide help for overcoming diverse challenges.

We have connected our students to the professional development opportunities provided by CNS (https://cns.utexas.edu/postdocs/professional-development-and-career-support). These include panel discussions from experts in academia and industry, as well as one-to-one career advice from a career development specialist. We have also started to extend our astronomy alumni network and to invite alumni, particularly those in the data science industry.

For students who wish to prepare for careers in teaching and outreach, we are ideally placed by our partnership with the McDonald Observatory Outreach and Education Division, and the multiple initiatives available at UT, such as the Texas Institute for Discovery Education in Science (TIDES; https://cns.utexas.edu/tides) and UTeach, a dedicated program to prepare teachers in the STEM fields.

We expect to significantly strengthen our professional development opportunities further in the near future, as a result of the ongoing CNS effort to implement the 21st Century Graduate Education roadmap. One focus of this roadmap is to enhance the student's ability to take classes beyond CNS, say in UT's School of Business. Such courses would allow our students to systematically develop substantive skills in management and leadership, which in turn would enhance their career prospects in non-academic fields.

VII.B. White Paper by the Graduate Students

Introduction

As one of the largest astronomy departments in the country, the Department of Astronomy at The University of Texas at Austin is home to a dynamic and energetic research program. The reputation of the department is not lost on the graduate students, and we are very proud of the many successes the Department's graduates achieve. The graduate students of the Department of Astronomy at The University of Texas at Austin appreciate the opportunity to participate in the Department's External Review process. We have prepared this review from the graduate student perspective, highlighting strengths of the department and also detailing concerns when necessary.

A small committee of graduate students wrote this review: Intae Jung (4th Year), Rebecca Larson (1st Year), Raquel Martinez (3rd Year, Current Graduate Student Representative), Jacob McLane (2nd Year), and Brian Mulligan (6th Year, Graduate Student Representative 2014-2015). The entire graduate student body provided input for this document through a "Town Hall"-style meeting.

The Graduate Program

Research

The Graduate Program wants its students to begin research as soon as they are ready. It is not until the beginning of the second semester of the first year that a student is required to identify a Research Advisor that will supervise their Second-Year Project. By the end of their first year, the student forms a Research Committee and develops a proposal that details the research plan for the Second-Year Project. This research project culminates in the Second-Year Defense by the end of the fourth semester, which consists of an hour-long public talk, then a closed-door oral exam and defense of the project. After a successful defense, students then apply for and obtain PhD candidacy by the beginning of the fifth semester. Advancing to candidacy involves the student forming a Dissertation Committee and submitting a Dissertation proposal outlining the research plan and timeline toward the PhD. The time between passing the Second-Year Defense and PhD candidacy is an opportunity for students to change their research focus or advisor, though few students exercise this option. After the student advances to candidacy, a yearly meeting with their Dissertation Committee is required to discuss the student's progress toward their PhD. The students' ability to conduct research almost immediately is a very attractive aspect of the Department. Also, the opportunity to embark on small, short-term projects at first before committing to an advisor or research focus for the PhD is beneficial for those students that do not come into the program with a set research direction in mind.

The Second-Year Defense

The completely oral format of the Second-Year Defense is considered to be a most positive component of the Department's Graduate Program. The graduate students recognize that the ability to think on one's feet and speak in detail about one's research or work is crucial to success in any career. Thus, the nature of Second-Year Defense is by far preferred over a more traditional written qualifying exam. Even so, the graduate students feel that some aspects could be improved to ensure everyone finds the Second-Year Defense experience, while stressful, still truly worthwhile.

The Graduate Program A-to-Z handbook describes the content and format of the Second-Year Defense, yet this can vary widely depending on the makeup of the student's committee. Attempts have been made to standardize the exam to some extent. For example, professors are asked to provide students with detailed syllabi and/or question lists for any graduate course they teach so that students may use these in preparation for the Second Year Defense. Then, when students choose three courses (of the 9 required by the Graduate Program) to be responsible for, the syllabi and questions lists provide guidance in preparation and questioning by the student's committee. Unfortunately, some professors do not provide question lists, or the lists are ignored during the exam. Another stipulation that seeks to promote uniformity among the exams is the requirement that two Graduate Studies Executive Committee (GSEC) members preside over the exam. The GSEC member would be the one that would make sure the Research Committee adheres to the A-to-Z guidelines, but in practice that varies widely among the students. Because of these failures, students feel that after their closed-door session, no amount of studying could have prepared them for the questions they received. While we recognize and understand that perfection is not possible nor the goal, students would still like to feel as if they did well on this exam.

Curriculum

Graduate students are required to take nine academic courses during the first four semesters. Seven of these must come from a selection of "core" courses deemed by the faculty as major subject areas in astrophysics. The remaining two courses are elective courses that can be satisfied with non-core courses or courses offered outside of the Department (e.g. Physics, Geosciences, Statistics).

The biggest complaint from the graduate students regarding the curriculum is the quality of graduate course instruction. It is not apparent whether our course evaluation forms are taken seriously or used by the department at all. The same negatively reviewed instructors are tapped to teach important core courses time and time again -- to the detriment of the student's overall astronomy learning. Students feel this time is wasted and should instead be devoted to research. We urge the Department to develop a system that incorporates the student's feedback into course assignments and incentivizes sound teaching practices.

A minor complaint from the graduate students is that of course scheduling. Graduate students would like some input into what courses are offered and hope that the actual course schedule can be made and disseminated more than one semester in advance. This would help entering students in planning their first two years in the program to optimally achieve academic and research goals.

Student Advocacy

While the Research Advisor is typically the primary point of contact for a student to go to with any issues and concerns, there are times when the Advisor cannot, will not, or should not be the person to serve as the student's advocate. Though uncommon, these situations do occur and students feel as if they have no one to go to in the Department for support or be a strong voice for their interests and well-being. Nominally, this person has been the Graduate Advisor, who has in the recent past been more of a logistical point of contact to ensure the graduate students are adequately progressing through the milestones of the program. There has been much turnover of faculty in this position (three in the past three years), so the time to develop the relationship necessary for students to feel comfortable enough to go to them with issues has not been there. We hope that the Department recognizes the importance and necessity of a tenured faculty member to have such a role by either emphasizing this component of the Graduate Advisor's duties, or introducing an official Student Advocate to separate program logistics from student issues, concerns, and well-being.

Facilities

McDonald Observatory

UT graduate students have direct access to all UT telescopes at McDonald Observatory, including the Hobby-Eberly Telescope, the 2.7-m Harlan J. Smith Telescope, the 2.1-m Otto Struve Telescope, and the 0.8-m Telescope. For each of these telescopes, graduate students can apply for time directly through the internal Telescope Allocation Committee (TAC), which look favorably upon proposals with graduate students as the Primary Investigator (PI). This is useful as it grants students experience in writing proposals and reasonable student requests for observing time are almost never rejected by the TAC, especially if the data are to be used towards their thesis. There is ample opportunity for the graduate students who have proposed for time to go out to the observatory and take their data. Many of the graduate students, who can use these facilities for their dissertation projects, will gain personal experience with the entire process of proposing for time, taking data, processing and data analysis, and producing scientific results. Access to these observing facilities is a huge draw for potential graduate students and is a top selling point in recruitment efforts.

While McDonald Observatory is a great resource for the students whose science can be achieved using its capabilities, there are many graduate students whose work cannot be done with the facilities at McDonald. Many students are able to go on observing runs for other projects to get the observing experience they seek, but there is no official way to receive this kind of experience. Many graduate students have expressed the desire for an Observational Astronomy course that would teach all of the required knowledge about proposing, observing, and data reduction that goes into using professional telescopes, and which they will need in order to be successful in their careers. McDonald Observatory would be an invaluable resource to use as part of this course, if we could get time and resources allocated to it. This would provide an opportunity for interested graduate students to gain this experience even if their dissertation work cannot be completed using McDonald Observatory.

UT has recently bought into the Giant Magellan Telescope, which will be another valuable resource for graduate students in the future. Funding and gaining guaranteed time in the next generation of big observatories will place UT in a very prestigious position, and will undoubtedly aid in recruitment efforts.

Department Building

The Astronomy Department is located in the Robert Lee Moore (RLM) Building on the UT campus. This building has 17 stories, as well as a rooftop, domed telescope that is used for outreach and education. The Astronomy Department is located on the 15th through 17th floors with some more offices and a break room on the 13th floor. Graduate students are given a designated office location, with their own personal desk and computer in a room with no more than 4 other graduate students. Graduate students have access to the building itself at all hours and can use their own office space, or any of the meeting and conference rooms. While graduate students are grateful for their provided spaces, RLM itself has many ADA compliance violations and ventilation issues. The graduate students feel that some money and investment should be made in bringing our spaces up to code.

Computing

There are three primary hardware computational resources available to graduate students: desktop workstations provided by the department, machines owned or operated by individual professors, and the resources available at the Texas Advanced Computing Center (TACC). In addition to hardware, a number of software resources useful for astrophysics are available to graduate students. These resources as a whole contribute to a rich computing environment within the department.

All incoming graduate students are given a choice of a desktop Macintosh (Mac) or a machine running Red Hat Enterprise Linux (RHEL) when they accept their offer to join the department. The majority of students choose Mac; a few, mostly those who focus on computational astrophysics, choose RHEL. Neither operating system works perfectly with all software required for the variety of research that is being performed - specifically major updates to the Mac OS tend to require sometimes substantial work by the IT staff to ensure that astronomical codes such as IRAF and IDL continue to work, and thus the OS on student machines may lag behind official releases, which have potentially negative implications for security and installation of newly available research related software; for RHEL, the underlying operating system and associated tools such as compilers are based on those available in 2009 (for RHEL 6) or 2013 (for RHEL 7), and are sometimes inadequate for using the most up-to-date astrophysical codes. Additionally, there is no stable version of Microsoft Office available for RHEL; most students instead use OpenOffice, which is not completely compatible with Microsoft Office documents, leading to problems when trying to develop presentations that will be shown using Microsoft PowerPoint or when trading or printing documents created in Microsoft Word. There are workarounds that users may use to overcome these problems with RHEL, namely using PDF instead of Microsoft data file formats and manually installing more up-to-date tools. Use of Microsoft Windows instead of Mac or RHEL could overcome some of these issues, but Windows is not well supported for most astrophysical codes, so this is not considered an effective solution.

Apart from the issues with the operating system, the hardware provided is generally useful for all scientific applications. There is some interest among the graduate students to instead receive a laptop instead of a desktop system. Most students have a personal laptop that they use for giving talks and when traveling. Some students spend a substantial quantity of time outside of the office due to the need to be at McDonald or other observatories, and having a laptop would allow them easier access to their personal computational resource. Modern laptops are effectively comparable to desktops in terms of computational performance, at least for the applications for which graduate students desktops are used, would not be detrimental to scientific output, and would provide a more reasonable single resource for all requirements and expectations of graduate students. We understand that there are concerns over theft (especially if the laptops are used for storing student data) and damage. We note that for the latter, this is just as much a concern for students' personal laptops, which students already must personally replace in the event of damage. Requiring use of encryption and strong passwords on any department provided laptops could alleviate the former concern of theft.

For the desktop systems, the department provides a useful set of licensed software for graduate student and other departmental users, including IDL, Mathematica, and Matlab. The licenses for these products tend to be prohibitively expensive for graduate students to purchase on their own and thus the availability of this software through the department is extremely helpful to graduate students for their research. While IDL is not being actively developed for new astrophysical codes, there remains a large code base that relies upon it. Some of this code base is being slowly translated into the Python language, which has the advantage of being open source and under a GPL or GPL-compatible license. IDL is likely to persist as a required tool for the foreseeable future. Mathematica and Matlab are not used as heavily by most students but are still critical resources for the few who do use them. Continued access to these suites of software is necessary.

In addition to the desktop systems, slightly higher performance computers are also available to many students through their advisor or research group. Machines with 8 or more cores, larger memory, or larger storage systems are often in use, which can serve as a bridge to the massively parallel systems available at the Texas Advanced Computer Center (TACC), or can provide slightly higher performance systems for serial or smaller parallel problems without the overhead of conforming to the particular programming requirements of the TACC machines and avoiding the wait times that often occur on TACC machines due to demand.

Finally, TACC provides a major resource for graduate student computing. The current set of TACC machines includes Stampede, Lonestar 5, and Maverick for high-performance visualization and processing, and other systems capable of large data storage. TACC is a strong asset for the department and the graduate students and is often mentioned by current graduate students as part of their motivation for choosing The University of Texas at Austin as their graduate school. The ease of acquiring computing time in addition to easy access to consultants, computing classes, and computing workshops held in Austin are useful resources to assist graduate students in accomplishing their research and expanding their skill sets while in graduate school.

Overall, the computing resources available to the department are valuable assets for research and recruiting. Ongoing investment by the department and university are important to ensure that the computational capability remains up-to-date with the needs of the users. Investment in laptops rather than desktops will improve the value of the systems that are provided to students.

Networking and Collaboration

Graduate students at UT are provided with many opportunities for interaction with astronomers at other institutions. Through the Department Colloquium, a visiting scientist is brought in every week. Faculty, post-docs, and students are given the opportunity to sign up for individual meetings during the visitor’s stay. Additionally, a group of graduate students takes the colloquium speaker out to lunch off campus. The environment for colloquium lunches is more informal and a great opportunity for graduate students to discuss not only research, but also the academic job market, outreach, or non-academic career paths. Each research group invites a Tinsley Scholar each year for a special colloquium and research seminar talk. The Tinsley program is another excellent opportunity for graduate students to interact with young, up-and-coming astronomers. During faculty hiring, candidates are also treated as colloquium visitors and taken out to lunch by the graduate students. Often the visiting astronomers participate in discussions on equity and inclusion, or provide mentoring to our graduate students. All of these events are financially sponsored by the Department and are important experiences and interactions for the graduate students.

The department also offers funding from several sources for travel to scientific conferences, workshops, observatories, and meetings. This funding is typically split three ways between the student’s Research Advisor, the research group they belong to, and the Graduate Advisor. This funding is crucial to the student’s ability to network and collaborate with researchers at other institutions and is generally awarded for all reasonable requests.

In addition to visiting speakers and travel to visit collaborators, each graduate student must have an outside member on their Dissertation Committee. This member typically collaborates on the student’s work and provides a much-needed outside letter of recommendation when the student graduates and is looking for employment. The department’s effort in establishing routes for the students to network and collaborate is much appreciated and should be continued.

Graduate Student Recruiting

Admissions

Our program currently aims to recruit 5-6 students per year so as to maintain a graduate population on the order of 30 students. We admit students with the intent of seeing them receive a PhD and practice no weed out process beyond the qualifying exam that takes place at the end of a student's second year.

Admissions applications are due on December 15th, after which the admissions committee meets and narrows down the pool of candidates. Candidates are then asked to participate in an interview, generally over Skype or a similar service, during January before the final decisions are made. Admission offers are sent out in late January or early February. After being offered admission, prospective students are strongly encouraged to visit the Department during one of our two graduate student weekends, an offer which most students accept. Student decisions are due April 15th.

Recent admissions committees have put greater emphasis on recruiting women and underrepresented minorities (URMs), which has begun to have a positive impact on the diversity of the department. Of the 20 students recruited in the last three years, ten have been female, and seven have been URMs. To help facilitate this goal, beginning this year, the Department will no longer accept the physics GRE score as part of a student's application material, given its well-measured bias against women and URMs.

Prospective Student Recruiting Weekends

The Department holds two prospective student recruiting weekends, at the beginning and end of March, which students are invited to attend. Students are flown in Wednesday night and taken to an informal dinner where they can meet the graduate students in the department as well as fellow visiting prospective students. Flights are booked and paid for by the department so as to minimize the hassle for visiting prospective students. Students spend Thursday and Friday meeting with various faculty members they have expressed interest in working with as well as receiving introductions to various UT facilities at their disposal (TACC, McDonald, GMT). Thursday night, students will have dinner with one of the research groups and Friday night one of the faculty members will host the entire department at their home for dinner so that everyone may interact with the perspectives. Students are then flown home on Saturday.

During their visit, prospective students stay with a graduate student host who is also responsible for chaperoning the student to their various functions and to and from the airport. Graduate students are also responsible for organizing activities outside of the ones put on by the department. Examples of activities include going bowling, going to Zilker Park, visiting the State Capitol, and taking the perspectives to 6th Street on a Friday night.

Positives

The graduate student population, in general, enjoys having the opportunity to interact and shape the students that eventually come here. Serving as a host allows us to answer questions and speak plainly about the department's merits and faults to the visiting perspectives. The extracurricular events put on by the grad students also serve as an important introduction to our department's culture, allowing students to determine if they're going to enjoy it here. This “personal touch'' to proceedings is the leading non-academic reason many of us came here and is one of the strengths, we feel, of our recruiting process.

Negatives

The biggest complaint among graduate students is a perceived lack of appreciation by the department of the time, energy, and funds that we put into the recruiting process. We generate a list of hosts for the visiting students, match the perspectives with the best possible host by research interest whilst taking into account pet allergies and dietary concerns, arrange transportation to all their events, make sure that they get to all their meetings, and organize activities for them, all without department oversight or recognition. As hosts we give up a significant amount of time and productivity during the visiting weeks, and incur costs, some of which we can't recoup from the Department. For example, it is tradition to take students to 6th Street of Friday night during their visit and, as hosts, we pay for their drinks; we cannot be reimbursed for these costs as grad students as it is against Department policy to pay for alcohol. Timely reimbursement has also been an issue over the past few years. Additionally, many hosts are first or second year students that are still expected to complete and turn in course work while conducting their hosting duties.

We undertake these tasks because we care about who is joining our cohort and we want them to have the best, most authentic experience possible while here. That being said, we would appreciate if the department would: a) Push assignment due dates to non-visit days so that we can be the best hosts possible and b) acknowledge the work we put into helping them recruit future students. A thank you would be appreciated.

Student Representation in the Department

Graduate students have several organized positions to provide input to and keep abreast of issues occurring at the departmental, college, and university level. There are six graduate student positions that are directly involved in committees or other governing bodies: Graduate Representative, Recruiting Officer, GSA Representative, CNS Dean's Council Representative, Computer Officer, and Lunch Officer. The graduate students elect each officer or representative for a term of one year. Nominations and voting for these positions usually occur each April, with the newly elected officers taking their position at the end of spring semester.
The Graduate Representative attends departmental faculty meetings and is the primary official point of contact between the faculty and graduate students. The Graduate Representative also sits on the admission committee for graduate students. The position greatly helps alleviate concerns of transparency in the decision-making process for departmental decisions and issues, and to ensure that the faculty hear of graduate student concerns or viewpoints. The inclusion of the Graduate Representative in the admission committee ensures that the admission committee can be informed of issues that may not be otherwise apparent to someone who may not have been an undergraduate for several decades. In addition to being a voice for the graduate students, the Graduate Representative gains valuable experience in the administration of the department and how candidates for graduate students and faculty are evaluated.

The Recruiting Officer is involved in the recruitment of prospective graduate students. Their responsibilities include planning of activities for the two weeks in which prospective students are visiting campus during March of each year, as well as organizing graduate student hosts for each of the prospective students. The Recruiting Officer works closely with the Department Chair's office and the Program Coordinator to organize the recruiting week events.

The other positions have a more obvious role for specific committees from a university-wide to the departmental level. The GSA Representative sits on the Graduate Student Assembly, an advisory body at the university level. The GSA consists of one or more representatives from each department in the university. The CNS Dean's Council Representative sit on the recently created Council that meets with and advises the Dean at the College level. The Computer Officer sits on the departmental computing committee, which infrequently meets to consider and address computational issues and needs within the department. Finally, the Lunch Officer organizes lunches between the graduate students and departmental visitors.

Each of these positions is helpful for advancing the interests of the department as well as graduate students within the department. The positions also give a subset of the graduate students experience in administration in an academic environment, and insight into the operation of an academic department. The graduate students greatly appreciate these opportunities and consider them to be an important component of this department.

Faculty Involvement

While it is the consensus that faculty members are engaged in the overall professional success of the graduate students, this seems to the graduate students to be an area in which the Department needs to make some improvements. While there is a decisive effort on the part of a small subset of the (normally more junior) faculty members to be involved in more informal and social events, there is a significant lack of faculty interaction in many department sponsored social events, such as the yearly happy hour to welcome new students, and the weekly astro-ph lunch. Other events, such as the Equity & Inclusion meetings, have only a small representation from the faculty.

There is a healthy social environment among the graduate students and postdocs, most notably in the healthy attendance at weekly happy hours. Many graduate students also participate in sporting events and activities with each other. Bi-weekly Graduate Student and Postdoc Seminar (GSPS) meetings bring together graduate students and postdocs for personal and professional development talks and activities.

There are several departmental talks each week hosted by the different research groups that are typically poorly attended by faculty members. Each graduate student is required to give a talk each year in one of these seminars for practice and gain input on their research from others in the department. Due to this, the postdocs recently advocated for taking one of the colloquium slots (that are usually much more attended by faculty) each semester to split up among a few researchers for short talks. The first of these Postdoc Colloquiums provided the opportunity for our young scientists to speak in front of an audience that included a diverse faculty presence. The need for three of our young scientists to take one of the colloquium spots in order to gain an audience with the majority of our faculty speaks volumes about the problem of a lack of faculty attendance at student talks and regular seminars.

Non-Research Career Paths

Teaching Opportunities

There is no formal requirement in the program for teaching experience for graduate students before graduation. The experience that students have in teaching thus varies across the spectrum

for graduating students, depending on the funding available to them throughout their graduate career. Students who are on NSF or other fellowships, or whose advisor has substantial funding available, tend to have little or no experience in teaching prior to graduation. On the other hand, students whose advisors have no or little funding tend to have more extensive teaching experience. There is concern that these latter students may be at a disadvantage for accomplishing research over the course of their time in graduate school, whereas the former may not be as competitive when applying for jobs that have a substantial teaching component.
The experiences available to graduate students within the department are limited to teaching assistants (TAs). The department of astronomy does not offer assistant instructor (AI) positions to graduate students. There are typically about 25 TA positions (20h appointments) available each semester, half of which are for introductory courses (e.g., AST 301, 307, 309) and the remainder for lab courses, upper division courses, and signature courses.

The TA positions for introductory courses tend to be limited to grading and office hours, and as such are representative of typical TAs. The upper division course TAs are largely similar to the introductory course but are for smaller classes, offer more opportunities to interact with students, and typically require grading of more advanced, quantitative material. There are 2-3 TA positions each semester for University of Texas signature courses, although with the recent retirement of Neal Evans it is unclear whether there will continue to be a spring semester signature course offered within the department. The signature course TA provides a more extensive experience for the graduate students, requiring the TA to manage 3 hourly discussion sections each week and doing associated lesson plan development that supplements the lecture component of the class. Finally, there are lab sections that graduate students may TA. Three of the lab sections each semester are for an introductory lab that is loosely supplementary to Astronomy 301 / 307. During fall semester there is an additional upper division lab section that is supplementary to Stellar Astronomy (AST 352K). These lab courses allow for more direct control by the graduate students on the curriculum, grading, and lesson plan development. While the graduate students are officially considered only TAs to these lab courses, there is little to no input from the principal instructors for these labs. The labs have been largely developed by past graduate students, but may require editing or small revision, depending on the interests or intent of the TA each semester.

The lab courses and signature courses provide additional experience in teaching that most courses do not offer, though this comes with an additional workload that can interfere with a student's ability to accomplish research. This effect may be minor for a single semester, but can be detrimental to the time required for a student to graduate if they are tapped to TA these courses for many consecutive semesters. In the past, there have been graduate students that have been assigned to signature courses for 3 or more consecutive semesters, or for alternating semesters for several years. While the faculty member responsible for assigning TA positions is generally accommodating to requests from professors or students for most classes, there is often pressure from the signature course professor to select specific TAs. A policy was put in place in 2012 to ensure that students get a break from being a TA for the signature courses at least once a year; this policy does not also consider TA workload in the non-signature course semesters.

There are a variety of options for TA positions to fit a graduate student's interest in receiving teaching experience, although the lack of AI opportunities can be detrimental to those who are interested in a teaching-track academic position after graduate school. Some students in the past have elected to find teaching positions outside of the university, sometimes without the knowledge of their advisors, in order to gain this teaching experience. We encourage the department to make AI positions available in order to accommodate these students within the department rather than externally. The lab courses are already student run and thus offer easy opportunities to create AI positions. The addition of one or more AI position for Astronomy 301 may allow the department to expand course offerings for undergraduates and by extension allow expansion of graduate student course offerings.
The department has also started a program called Texas Astronomy: a University Research experience for Undergraduate Students (TAURUS), an REU-like program targeting ``underserved and traditionally marginalized groups''. This REU utilizes volunteer graduate students to act as mentors and instructors in aspects of research for the undergraduate students who enter the program. The first TAURUS was held during summer of 2016. We look forward to the continuance of this program.

The TA positions available to graduate students are commensurate with those offered at other institutions. The requirements range from only grading and office hours, up to lesson plan and curriculum development as well as classroom management. Students have opportunities to request specific classes, based on their interest in subject as well as desired workload. The lack of AI positions may discourage some applicants to the program who have an interest in teaching, and may be detrimental to the careers of graduating students who have interest in teaching.

Outreach Opportunities

There are a wide variety of opportunities for those students who are interested in public outreach, both through the Department and McDonald Observatory. Public outreach is expected of astronomers for funding such as NSF fellowships and is required to promote the field of astronomy, especially in light of the current climate of funding for basic research.

Public observing using the Painter Hall 9" telescope occurs on Friday and Saturday nights when school is in session. In the past, the public observing has been run by graduate students compensating with a 10 hour TA appointment, though with the dearth of astronomy graduate students requesting a TA in the last couple of years, this position has been taken over by undergraduate volunteers. In addition to public observing, requests to the department from external entities are forwarded to all members of the department by Lara Eakins. Graduate students occasionally conduct these talks.

Other outreach efforts are organized directly by the post-docs and graduate students in the department. One notable case is Astronomy on Tap ATX (AoTATX), a production originally organized by post-docs Rachael Livermore and Jeffrey Silverman with no departmental support and now run by a committee consisting of research associates, post-docs, graduate students, and undergraduate students. AoTATX events are held monthly and offer graduate students an opportunity to give a short public talk in a casual venue. About 1/4 of current graduate students have given a talk at AoTATX during the two years of its existence.

In the 2008 review, it was noted that the public outreach office of McDonald Observatory had hired graduate students to assist with their outreach programs. We are not aware of this happening since that time, though it is possible such opportunities were available, but the graduate students were unaware. It was also noted in the previous review that an organized listing of outreach opportunities through the department would be beneficial to making graduate students aware of these opportunities. We continue to encourage the department to develop such a list and advertise its existence.

Compensation and Benefits

Students admitted to the PhD program at UT Austin receive a promise of 5 years of full support either through a TA, GRA, or some combination thereof. There are concerns within the department that the push for a 5-year graduation timeline is counterproductive to student development, but those concerns will be addressed elsewhere in this report.

Salaries

Salaries for graduate students holding a TA or a GRA prior to the 2015-2016 academic year were $24,000 per year. General consensus in the department was that this salary was insufficient given the cost of living in Austin, and thus the TA and GRA salaries were increased to $28,000 a year beginning in the 2015-2016 academic year. This amount is sufficient enough to allow a student to rent an apartment, pay utilities, pay insurance, etc. whilst still having money left over to spend as they wish at the end of the month. It is also worth noting that the state of Texas does not have an income tax, allowing students to keep a larger portion of their paychecks than similarly appointed students at other institutions.

The largest point of student concern with regards to salaries is the fact that Austin is continually ranked as one of the fastest growing cities in the US (with Forbes ranking it as the fastest growing this Year[1]). As such, cost of living is always steadily increasing for graduate students with the most immediate effect being an increase in rent of ~$50-100 per month year after year. If costs of living continue to rise in such a fashion, students are likely to find themselves once again in a situation where they experience diminished buying power. The Graduate Students are pleased to know that the issue of salary will be re-visited every three years, but encourage the Department to make assessments and adjustments more frequently.

Health Insurance

All students supported through either a TA or GRA receive full health insurance benefits from the university in the form of UT SELECT. This insurance plan is essentially the same plan that all Texas

[1] http://www.forbes.com/sites/erincarlyle/2016/03/08/americas-fastest-growing-cities-2016

state employees receive and provides excellent coverage with affordable copays. This health plan is further augmented by the excellent, and conveniently located, University Health Services (UHS) and Forty-Acre Pharmacy which can accommodate all of a student's general medical needs. Given that the University has invested significant time and money into the creation of the new Dell Medical School, it seems a safe assumption that the University will continue to maintain a high standard of medical care for employees and students. Dental and vision plans, whilst not part of the standard graduate student package, are available at a nominal monthly rate to students.

Students that are supported through fellowships have had issues obtaining the same benefits afforded to those funded through TA or GRA. For example, fellowships provided through the Graduate School usually come with an extra amount of money for the fellow to purchase the student health insurance plan. This involves the fellow paying for a year's worth of premiums upfront (~$2,000; which itself can be a burden) and then being reimbursed after the purchase has been made. The student health insurance plan, while a reasonable plan for a healthy person in their low- to mid-20s, is not as good as the UT SELECT plan that the vast majority of the department enjoys. Should the fellow want UT SELECT, they must pay the ~$600 monthly premium and then be reimbursed. After some complaint, the Department has adjusted this so that the fellow is paid the amount of the premium first and does not incur an out-of-pocket expense. We urge the Department to determine whether another way exists so that the health insurance premium transaction does not have to involve the student.

Gender and Racial/Ethnic Diversity

As mentioned above, targeted recruitment of women and underrepresented minorities has positively impacted the diversity of the graduate student population. Of the current 34 graduate students, the past three entering cohorts consist of 10 out of the 11 women graduate students and 6 out of the 7 African-American or Hispanic/Latinx students. The reasons for the lack of diverse recruiting prior to these cohorts could be the result of small number statistics, but we hope to not slide back into complacency and continue the recruitment efforts and maintenance of support mechanisms for our marginalized student population to thrive and succeed.

The graduate students would like to see the progress made in diversifying our population reflected in the hiring of new faculty. With two new faculty lines being filled this spring and potential for more in the near future, we are very excited for a group of bright, energetic, and diverse junior faculty to join the Department. We urge the Department to take measures to ensure best practices are followed to limit bias in hiring. We hope that not only will more women be hired, but also persons of color. Additionally, we hope that efforts are made to ensure that the fantastic faculty that are already here, stay here.

International Student Concerns

International students make up over ⅕ of the Graduate Students in the Department. However, the past three cohorts have been predominantly US citizens, with only one international student among the more junior graduate students. This has raised some concern about the Department's commitment to fostering a diverse graduate student pool, especially with respect to international students. We recognize the importance of bringing people from all walks of life into the Department, as it increases our creativity and productivity. We hope that strides made in some areas (i.e. increased matriculation of URMs) are not at the expense of others. In addition to this, there are several small concerns addressed below that could be improved with some action, although in most aspects, international students are treated the same as US students.

English Requirement

Upon the acceptance to the PhD program, all international students are required to provide TOEFL scores that satisfy the level of proficiency in both written and spoken English. If they are going to be a TA, international students must pass an additional English proficiency test if they were not exempted. Currently, the Department equally provides opportunities for both international and native students to become TAs. Since English proficiencies can vary individually, it is crucial for international students to improve their scientific English skills, allowing them to give professional presentations and interact with collaborators.

The University provides graduate-division English as a Second Language (ESL) courses for international students for oral communication and academic writing at basic and advanced levels. Even if students pass the English proficiency test, taking advanced-level ESL courses are still beneficial for those who want to develop their English. These ESL courses open every spring and fall semester as regular course work. Thus if it is made known to the international students, and the Department is supportive, they can take advantage of the ESL courses. These courses would be essential to helping those who need to improve their communication and writing skills in academic discourse.

Dissemination of Information

The Department informs international students that they must prepare for living costs for the first two months before they receive their first monthly paycheck from their TA/GRA positions. This is very critical and useful but it could be better if more detailed information was delivered to international students, including other settlement fees such as purchasing furniture and vehicles. Most apartment units near campus do not come furnished, and in most residential areas students need a car to go grocery shopping. This is huge and unexpected expense for international students, because in many foreign countries built-in accommodations are more common, and public transportation is suitable enough to not require a car.

International students are not very familiar with the financial aid available to them upon their arrival; therefore the Department should provide more practical information about financial aid or subsidies if there are available financing sources. Especially since, in most cases, international students live by themselves without family or friends who can help them and barely have any other source of money in the case of financial trouble.

The International Students and Scholar Services (ISSS) in the University International Office offers general financial aid for international students who are in need, which is up to $2,500 per semester towards a student’s tuition and fee bill. This benefit is incredibly helpful if the student suffers from financial issues. However, this subsidy is not useful for international students in

Astronomy program because, even in the case that the ISSS subsidy can partially cover the tuition fee, the Department does not provides any option to deliver the extra money from the ISSS to the student, or to add the extra money onto one's salary paycheck. This financial aid from the ISSS is the most popular and easy-to-access way for international students across the campus to receive financial support when they are in need. Therefore, the Department should find the way to deliver the subsidy from the ISSS to international Astronomy Graduate Students.

Conclusions

The Graduate Students in The University of Texas at Austin Astronomy Department are again grateful to have been asked to prepare this review of our program, from our perspective. We greatly value our access to fantastic facilities, bright and forward-thinking researchers, and all the other resources UT, and the City of Austin have to offer. We feel that successfully addressing the issues mentioned above will enhance the academic, research, and social atmosphere of the Department, raising its general quality and excellence for many years to come.

Evaluation Committee Members:

Intae Jung
Rebecca Larson
Raquel Martinez
Jacob McLane
Brian Mulligan

Section VIII. Postdoctoral Program

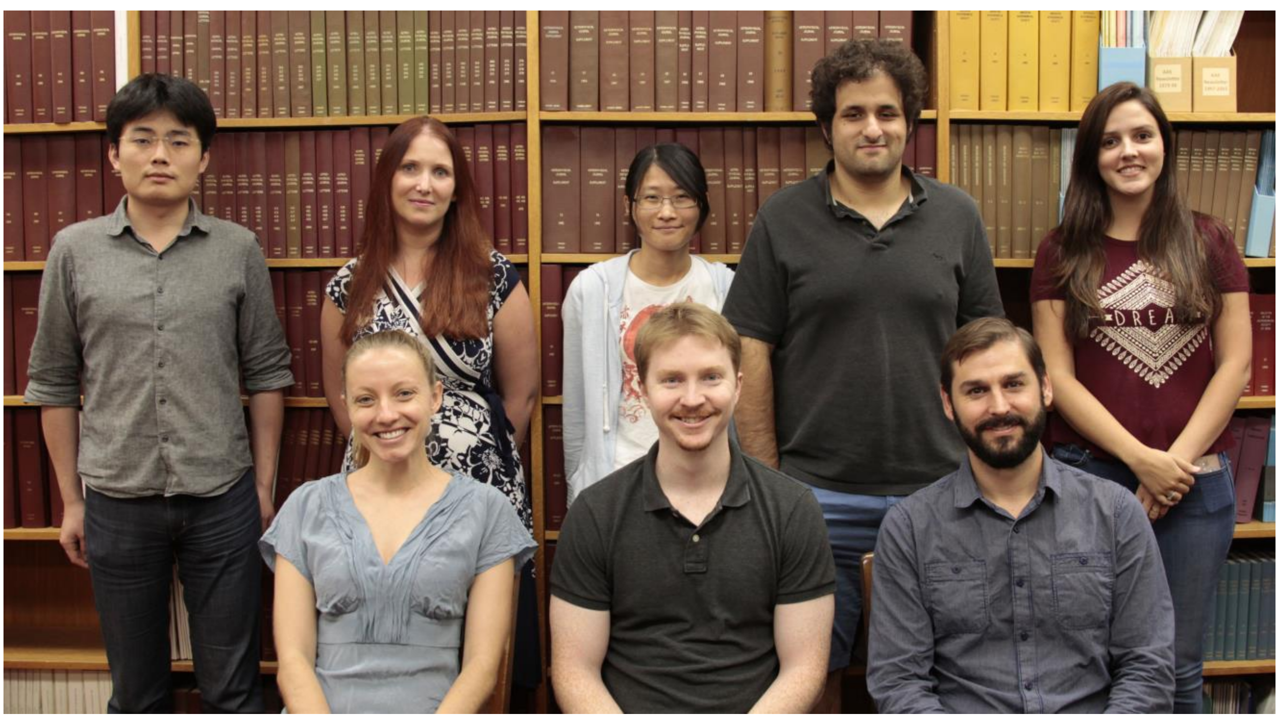


Figure VIII-1: A small group of our Postdoctoral Fellows**. Back Row: L-R:** Dr. Shingo Hirano, Dr. Rachael Livermore, Dr. Chao-Ling Hung, Dr. Aaron Rizzuto, Dr. Fabiola Campos, **Front Row: L-R**: Dr. Kimberly Sokal, Dr. Gregory Zeimann, Dr. Brendan Bowler *(Photo credit: Lara Eakins)*

VIII.A: Postdoctoral Fellows and Their Research

The postdocs within the Department of Astronomy and McDonald Observatory play an essential role in research and outreach efforts. The Observatory has two prize postdoctoral fellowship programs, Harlan J. Smith and W. J. McDonald fellows, offered in alternating years. Unlike many prize fellowships, only graduating PhD students are eligible to become Smith and McDonald fellows, meaning the program is focused on early career development and recognizing/fostering outstanding talent directly out of graduate school. In addition, we have additional postdocs supported by grants plus various other prize fellows (Hubble, Sagan, NSF) most years.

VIII.B. Postdoc Mentoring and Resources

The Postdoc Mentoring Committee (PMC) had formally existed, but was essentially dormant for several years. With an eye to postdocs' well-being and to better address the concerns of postdocs, the committee was re-formed in 2015 with Chris Sneden as chair and with Mike Boylan-Kolchin, Anita Cochran, Mike Montgomery, and Shardha Jogee (ex officio) as members. Department Chair Jogee met with postdoc representatives in the Winter of 2015-2016 to learn about some of the concerns and issues that postdocs face; the committee then met with the postdocs in the spring to have a longer and wider-ranging discussion. Several concrete "action items" emerged from those meetings and are being pursued by the current committee (now chaired by Boylan-Kolchin). Below, we detail some of the issues relevant for postdocs as well as current and future steps being taken to ensure that postdocs can be happy and productive members of the department / observatory. A common theme is that a centralized repository of knowledge about procedures at various levels is essential.

Integration in the Department: A common concern — and one that goes beyond postdocs is that of integration into the department. Unlike graduate students, who arrive with a natural cohort of their incoming class, postdocs often arrive at different points throughout the year and have only one point-of-contact in the department (their official supervisor). This is sub-optimal both for the postdoc, who may not know who to talk with about various standard issues, and for members of the department, who will not realize that a new researcher is around.

Our departmental emails now include welcoming informational messages on new postdocs. One colloquium spot each semester has also been allocated to showcase postdoctoral research. The first such colloquium took place in October, with three postdocs presenting their work to the department. The postdoc colloquium provides another way to increase interactions between postdocs and the broader (beyond their research group) department.

The department has also set up a website of resources for postdocs, such as professional development resources, funding/research opportunities, resources for advising and mentoring undergraduates, resources for traveling and inviting research collaborators, and the Astronomy program code of conduct (http://www.as.utexas.edu/astronomy/education/postdocs.html).

Every two years, postdocs are given generous financial resources ($30K) and staff support to organize the Frank N. Bash Symposium "New Horizons in Astronomy," which brings together young researchers from around the world. The symposium is funded primarily through the generous support of our Board of Visitors (Section IV.H).

Career Development: Every postdoctoral position is transitory. Career development and career management are two crucial pieces of the postdoc experience; these are also areas where the department can play a major and positive role. The PMC has taken the lead on this through a number of initiatives. First, we have hosted two events on career development and applying for academic jobs / fellowships. The first was in the spring semester and was open to both postdocs and grad students. In it, PMC members presented thoughts from their perspective (newly-hired faculty, long-tenured faculty, grant-funded research scientist) and then took questions / moderated a subsequent discussion. The PMC hosted a similar event early in the fall semester, at the outset of the academic job season, for postdocs alone. This was somewhat more focused and covered much more about faculty jobs. These events have several benefits: postdocs can ask questions to faculty and research scientists at a variety of career stages and with a variety of backgrounds; they can hear questions that others have; and they see that senior members of the department may have differing opinions on various issues. We plan to continue to have these meetings once per semester.

The Department has recently set up a network of Informal mentors for graduate students and postdocs (www.as.utexas.edu/astronomy/education/mentors.html). The informal mentors provide advice on a host of professional development issues. Mentors take part in a department-supported mentoring lunch each semester and are also available for individual discussions through a system of "office hours". They brainstorm on research ideas and provide advice on job applications, observing and grant proposals, oral presentations, teaching techniques, work-family-life balance, imposter syndrome, different career paths, and more. All PMC members are part of this network and have further made themselves available for the explicit purpose of reviewing job and grant applications. We have emphasized to the students that getting the opinion of someone outside of their area of expertise can be particularly valuable for applications, making the informal mentoring system very valuable. Anecdotally, the system is working (postdocs are contacting PMC members with questions).

Not all postdocs decide to continue with careers in academia. For these postdocs, faculty and research scientists are often of little direct help, as they usually have been exclusively within academia throughout their careers. The College of Natural Sciences (CNS) has several resources (https://cns.utexas.edu/postdocs/postdoc-resources) for postdocs interested in non-academic careers, however, ranging from a full-time career advisor specializing in such jobs to panels to CV workshops. The department and PMC have organized or hosted events on non-academic careers and have notified the postdocs of relevant events hosted by CNS as well. This is one area where alumni can play an important role (both in terms of perspective and forging connections); the department's efforts to maintain complete and up-to-date records on alumni therefore should be invaluable moving forward.

Compensation: The department and observatory have been successful at attracting high-quality postdocs both on individual grants and on national fellowships. An important recent development with the department/observatory and university more broadly has been the realization that postdoc salaries were insufficient to be competitive with other prize postdocs (for the Smith and McDonald fellowships) or to have a reasonable standard of living (university-wide). Accordingly, Director Armandroff recently announced the decision to increase the salary of Smith and McDonald fellows to $62,000, placing it more in line with compensation of named fellowships at peer institutions. At the university level, the minimum salary for a postdoc is now approximately $47,000 (though many grant-funded postdocs in the department are paid higher salaries).
In summary, the department and observatory jointly enjoy the benefits of an active and involved group of postdocs who contribute substantially to the research and departmental culture. It is incumbent on the faculty and research staff to place the postdocs in the best possible positions to succeed. Through ongoing initiatives originating from the Postdoc Mentoring committee, Department Chair and McDonald Observatory Director, we are working hard to ensure that the Astronomy program provides an inclusive, welcoming, and intellectually vibrant setting where postdocs can thrive and grow as scientists.

Table VIII-1: Department of Astronomy Postdoctoral Fellows and Their Research

Postdoc Name	PhD Year	PhD Institution	Research Interests	External Fellowships Held at UT
Monika Adamow	2014	Nicolaus Copernicus University	Evolved stars; chemical composition of stars; stellar evolution; exoplanets	Mobility+III (Poland)
ABS Reddy	2015	Indian Institute of Astrophysics	Galactic Archaeology, in particular, the student of kinematics, dynamics	
Brendan Bowler	2013	University of Hawaii	High-contrast imaging of exoplanets; exoplanet atmospheres; brown dwarfs	Hubble Fellow
Brandon Bozek	2009	UC Davis	Near-field cosmology; the nature of dark matter; numerical simulations; galaxy formation and evolution	
Fabiola Campos	2013	UFRGS (Brazil)	Stellar astrophysics, white dwarf stars, globular clusters	CNPq/Science Without Borders
Sungryong Hong	2011	UMass Amherst	Galaxy Formation and Evolution: Stellar Feedback, Interstellar Medium, Galactic Outflows, Lyα Emitting Galaxies, Galaxy Clustering, Large Scale Structure	
Chao-Ling Hung	2015	University of Hawaii	Extragalactic astronomy	

Rachael Livermore	2013	Durham University	Galaxy evolution; gravitational lensing; reionization	
Andrew Mann	2013	University of Hawaii	Late-type stars; exoplanets; star and planet formation; chemical abundances	Hubble Fellow
Aaron Rizzuto	2015	Macquarie University	pre-main sequence stars; young exoplanets; star formation; interferometry	
Kimberly Sokal	2016	University of Virginia	Observational Astronomy; spectroscopy; YSOs; Stellar formation and evolution	
Isak Wold	2014	UW-Madison	Galaxy evolution	
Greg Zeimann	2012	UC Davis	Galaxy Evolution and cosmology	

VIII.C. White Paper by Postdocs

White Paper on the Postdoctoral Community by the Postdocs

The postdoctoral researcher community in the Department of Astronomy and McDonald Observatory at The University of Texas at Austin is a lively group of professional astronomers with expertise in a range of fields. We represent a range of experience levels from having just left graduate school to many years removed from our doctorate with multiple postdoctoral positions. Our community is made up traditional postdocs, W.J. McDonald and H.J. Smith Fellows, and national prize fellowships. Beyond carrying out our research programs, we are active members in the department and astronomical community having founded (or co-founded), organized and run: the Graduate Student-Postdoc Seminar, a departmental seminar to foster postdoc-graduate student interaction; the UT Astronomy Equity and Inclusion Group; Astronomy on Tap ATX, the largest public outreach event of its kind; and more. We have a strong desire to see the department thrive and improve, so we are sharing our views with Department here in a white paper. These views, both positive and negative, are discussed below.

Positive Steps Forward

The UT astronomy department has made several positive strides to improve the postdoc environment within the astronomy department over the past year. We are grateful for these needed steps and detail their benefit below.

Postdoc Mentoring Committee and Postdoc Colloquium

The Postdoc Mentoring Committee (PMC) had been inactive for many years but held meetings in spring 2016 at the request of postdocs. There was a desire for greater mentorship resources outside of a traditional advisor to provide multiple perspectives on performance and greater advocacy within the department. The postdoc mentoring committee consists of junior and senior faculty and research scientists. The aim of the PMC is to provide the postdoc community with guidance and support to promote success locally within the department and in the future. The PMC has led several efforts on those fronts. The members have offered to informally mentor postdocs and review CVs, cover letters, research and teaching statements during this job season. In line with this effort, the PMC held an academic jobs roundtable in the fall of 2016 to discuss the faculty application process. The PMC also organized and hosted (with the postdoc representative) a Postdoc Colloquium for three postdocs to present their research to the department. The postdoc colloquium was proposed by the postdocs in the spring of 2016 as a means of fostering greater engagement with faculty within the department, which could be improved. Another Postdoc Colloquium will be held in the spring of 2017 and is planned to be a recurring event each semester.

Informal Mentorships

A network of informal mentorship (www.as.utexas.edu/astronomy/education/mentors.html) was started in spring 2016 by the department as a result of a call for greater mentorship from graduate students. The informal mentors consist of research scientists and faculty members. The aim of the informal mentors is to provide a supportive environment for graduate students and postdocs through informal discussions on professional development and general help in overcoming any particular challenge. The informal mentors are tasked with holding one hour each month where they offer an open door policy to meet with mentees. The goal is to complement the more formal research-centered mentoring that already exists for both postdocs and graduate students by their immediate supervisors and within research groups. The graduate students and postdocs held a lunch meeting with several of the informal mentors in summer 2016 and plan to repeat this practice each semester. This program is still new and has not been fully utilized. There is a need for more top-down and bottom-up promotion and engagement if it is to be successful.

Raise in salary for W. J. McDonald and H. J. Smith Fellows

The starting postdoc salary is below the 2012 median in astronomy and is not keeping pace with the rising cost of living in Austin, which is 11% higher than the national average. This was particularly problematic for McDonald and Smith fellow pay that was well below other national prize fellowships. The initial request for a salary raise was made by a former McDonald Fellow Natalie Gosnell in spring 2015. This resulted in a $2,000 raise of the Fellow salary from $51,000 to $53,000. In March 2016, former and current McDonald/Smith Fellows Gosnell, Andrew Mann, and Chao-Ling Hung initiated a meeting with the McDonald Director, Taft Armandroff. The Fellows suggested that the McDonald Fellow salary should match the median salary ($62,000) of a list of 28 institutional postdoc fellow salaries in the US Several junior faculty members also voiced their support on this matter. In August 2016, Hung was notified by Armandroff that the request of a salary raise (to $62,000) was approved at the University level and applies to all future fellows.

Department Webpage

A department webpage for the postdocs was constructed in July 2016. The website is meant (www.as.utexas.edu/astronomy/education/postdocs.html) to be a living document that should be added to and improved over time and is intended to function as a centralized source of information on mentoring resources, university funding rules and opportunities, travel policies, and other miscellaneous resources. The postdocs will contribute to some future changes. One planned development is the creation of a guide for incoming postdocs on how to start their new position in the department, which is sorely needed.

Postdoc Contributions to Department Culture

In the recent past, there has been substantial engagement among postdocs, graduate students, and junior faculty members through various bottom-up initiatives that significantly contribute to department culture and community. We are grateful to the Department for support that has been given on these fronts. However, they could all benefit from greater and more regular faculty engagement, particularly from senior faculty.

In the fall of 2016, an Equity and Inclusion (E&I) group was created as a forum to address the structural and cultural marginalization of underrepresented groups in our professional community. This safe space meets monthly and includes primarily graduate students, postdocs, junior faculty, and research scientists. Additionally, in the fall of 2016 two Allyship Toolkit Workshops run by the UT Gender and Sexuality Center were held in the department. Both the Allyship Workshops and E&I groups were co-founded and currently organized by a graduate student, postdoc, and junior faculty member as a joint initiative.

The Texas Astronomy Undergraduate Research experience for Underrepresented Students (TAURUS) is a 9-week summer undergraduate research program for highly-motivated students from underserved and traditionally marginalized groups. The TAURUS program provides hands-on professional science-experience to prepare students for entering graduate school, professional development, and community support beyond the end of the program. We view this program as of vital importance to address the equal access problem that exists in astronomy for underrepresented minorities and of great benefit to the community of the UT astronomy department. As a secondary benefit, the TAURUS program has offered an excellent avenue for postdocs to gain mentoring experience. Four of the five mentors of undergraduates during the summer of 2016 were postdocs who each contributed $4500 of their grant money to support a TAURUS scholar (the remaining costs were subsidized by seed funds of $30,000 allocated by the Department from its Cox Endowment). Sustained financial and structural support for TAURUS is of critical importance.

A former postdoc, Jeffrey Silverman, started a bi-weekly Graduate Student and Postdoc Seminar (GSPS) series in the spring of 2014, which continues to be run jointly by graduate students and postdocs. This series provides an opportunity for graduate students and postdocs to practice research talks and share other information and skills that are not formally taught. Topics have included writing telescope proposals, applying for postdocs, giving research and public talks, and presentations on careers outside academia by former students who have left the field. A modest amount of Department discretionary funds goes to support the GSPS series.

Other events that have facilitated interactions and community growth in the department include a weekly astro-ph discussion group (started and long run by a junior faculty member) and weekly Friday happy hour gatherings off campus— all of which are well attended by postdocs and graduate students and have helped generate a positive culture in the department. Postdocs have the opportunity to frequently give talks in the department both through group seminars (Stellar, ISM & Planetary, Extragalactic, Theory) and, more recently, a new initiative to devote a colloquium for internal postdocs to present their research each semester.

The postdocs are very active in public outreach activities. Two postdocs, Rachael Livermore and Jeffrey Silverman, founded the Austin chapter of Astronomy on Tap (AoT) in the fall of 2014. Astronomy on Tap ATX puts on free monthly professional astronomy talks in a pub and is one of a constellation of similar events that began in New York City. Under Jeff and Rachael's guidance, the Astronomy on Tap ATX event grew to be the largest of its kind in the world, regularly attracting an audience that averages 300 people each month. Astronomy on Tap ATX regularly invites local organizations, like the Austin Public Library, and advertises other local events, like Not So Math (an AoT-like math themed event) to build bridges within the Austin community. It is designed to be an accessible and welcoming event; the Austin chapter is one of only a few to have an all-ages admission policy, and it has a code of conduct that is explicitly highlighted from the stage at the start of every event. The exceptional success of Astronomy on Tap ATX is due to the hard work of Jeff and Rachael, who created an incredibly professional program in their spare time and at great personal expense. Rachael and Jeff initially self-funded the significant cost of the venture after the department declined to participate officially. Departmental support is unofficial in the form of graduate student, postdoc, research scientist, and staff volunteers that run the event and give professional astronomy talks. Supportive faculty members have given talks and patronized the event, for which we are very grateful. In the summer of 2016, Rachael and Jeff handed over organizing to a committee consisting of postdocs, graduate students, staff and research scientists. Astronomy on Tap ATX recently held a fundraising event at the November 2016 show for the TAURUS program illustrating its versatile benefit to the UT astronomy community.
Postdocs have participated in a variety of other outreach events. Multiple postdocs volunteered at the Association of Women in Astronomy Research and Education (AWARE) booth at the UT's Girl Day STEM Festival, where over 5000 elementary and middle school students from across the state came to UT to learn about opportunities in STEM careers. Postdocs have also volunteered their free time at NASA/JWST booth at SXSW and have answered Department requests to volunteer for school visits and a variety of other astronomy events around town.

Next Steps

Code of Conduct

Following incidents with former staff and students in the department and the widely reported harassment cases at other institutions, the postdocs have requested that the Department adopts a Code of Conduct to be specifically agreed to by every incoming staff member, student, and visitor. The postdocs are willing to lead the writing of this but require a commitment from the faculty that it will be adopted and enforced.

Faculty Hires

During the faculty search in spring 2015, each candidate had lunch with the postdocs. However, the number of spots was limited to only three postdocs per candidate. As a result, no postdoc was able to meet with all or even most of the candidates, and this resulted in a lack of feedback provided by postdocs to the search committee. Postdocs benefit from meeting candidates as it provides an opportunity to learn from them about how to prepare for the faculty job search or interviews. We understand that budget may be an issue, so we have suggested the department organize a brown bag type lunch or pizza lunch to make it available to more postdocs.

Communication with incoming postdocs

The communication within the department and between the department and the postdocs is poor. The postdocs, and department at large are currently not made aware of new arrivals. This makes it difficult to provide any sort of welcome to new postdocs or to integrate them into the department. Timeliness and a lack of communication on acceptance of paperwork requirements has led to delays in being paid and employee status for many new arrivals. We have requested that the postdoc representative is notified of new arrivals and that an email is sent to the department introducing the new postdoc. We note, that although late, an email was sent around announcing the arrival of the two new postdocs. We would also like to see some form of welcome event for new arrivals, which could be as simple as alerting people to attend the regular daily tea and cookies on when a new postdoc arrives to meet them.

Poor accessibility for those with physical disabilities

Most of the Department of Astronomy is located on the 15th-17th floors of the Robert Lee Moore building, which has men's and women's bathrooms alternating every half floor between floors 7 and 17. To reach nearly all bathrooms, one must ascend or descend a half flight of stairs. One standard accessible bathroom is located on floor 13, and one single accessible stall is located on floor 14. Currently, this places an additional burden on students, researchers, and staff with physical disabilities, so expanding the range of accessible bathrooms throughout the building should be a priority for UT.

Alumni List

We would like to see a list of graduate student and postdoc alumni to provide networking opportunities inside and outside of academia. This currently exists only in an informal manner, and the rapid turnover of postdocs means that former postdocs can be forgotten. The postdoc representative has touched base with the new Director of Development Keary Kinch about building a list, and we are pleased that the list is under construction.

Greater Faculty Engagement

Overall faculty participation in departmental functions is poor. This includes research-related meetings (e.g., astro-ph discussion and TAURUS talks), initiatives related to departmental culture (e.g., the Equity and Inclusion discussion group), informal gatherings (e.g., Beer and Bull) and PhD defenses. Many of these meetings/initiatives are vital to improving departmental culture and instilling a sense of community. Although there are a few notable exceptions who regularly attend many of these, the vast majority of the faculty are never or almost never seen at such events. The postdoc colloquium is one positive step towards building greater faculty-postdoc interaction. Other avenues should be pursued to improve faculty-postdoc interaction outside of the various research groups.

Administrative Issues

Multiple postdocs have reported the loss of health care, mishandling of immigration documents and slow reimbursement of travel funding during their time at UT. This is indicative that significant improvement can be made by the departmental administration in maintaining postdocs' employment status. Some of these issues have begun to be addressed. Based on interviews with current postdocs, the postdoc representative concluded that the incidents of losing health care occurred during a transition in position (including the start of a postdoc position) or a change in funding source. There is also a pattern of miscommunication (or lack of communication) between departmental administration and HR at CNS. The postdoc representative and the Department Chair met in late September 2016 to discuss these issues and decided to arrange a future meeting with Human Resources to understand the source of the problem and explore preventative steps in the future. Possible steps include (1) advance notice from HR to the postdoc of the impending renewal of position, (2) advance notice to incoming postdocs for completing necessary employment documents, and (3) possible revisions on handling the reimbursement system for externally funded postdocs.

Postdoc Professional Development, PI Status, and Service

Our postdoc community shares some concerns about the professional development opportunities provided by the department/UT. As mentioned above, postdocs contribute to a significant mentor body for the TAURUS program. However, postdocs feel that there is a lack of opportunity to (1) serve as primary mentors for UT undergraduate/graduate students, and (2) serve as instructors of record for formal courses. We feel such teaching, and mentoring opportunities are critical for postdocs as they are learning to be successful teachers and mentors for the next generations.

In line with this goal, it is concerning that postdocs are disqualified for PI status of external grants. Currently, postdocs must work through faculty for externally funded grants, which creates unnecessary work for the faculty member and makes it difficult to track/utilize the grants for the postdoc. Exceptions have been made in a few specific cases, but this required asking for PI rights for each individual award/grant, and not all requests are granted. An ideal scenario would be for all postdocs to have automatic PI rights. Short of that, a uniform and clear policy, with a simpler path to gain PI status would significantly improve the situation.

Committee participation is also important for postdoc training and development. Postdocs appreciate that we are allowed to serve on the McDonald TAC. We would prefer if this continued for future TAC member rotations. No postdoc sits on the graduate admissions committee, which we would like changed.

The Frank N. Bash Symposium

The Frank N. Bash Symposium (BashFest) is a bi-annual two-day symposium started in 2005. It is organized by the University of Texas postdocs and funded by the Astronomy program Board of Visitors (BoV), the Department of Astronomy and McDonald Observatory. We carefully select 13 postdocs in various research fields including observational and theoretical astrophysics and invite them to give review talks in their fields. The symposium also features posters presented by postdocs and graduate students at UT-Austin and other institutions. After the symposium the invited speakers and poster presenters submit proceedings, which the organizing committee review and publish on the Proceedings of Science website indexed by the Astrophysics Data System (ADS). The organizing committee of Bashfest 2015 introduced a specific code of conduct for the meeting, which was well received and has acted as a template for other meetings throughout the US astronomical community.

We have had six successful symposia to date. There are several positive outcomes from this postdoc-led symposium, including bringing active junior researchers to UT Austin for networking opportunities among postdocs and graduate students and providing conference organizing and proceedings editing experience to postdocs. The invited speakers from other institutes have praised the well-organized symposium and the idea of a postdoc-led event at the department level. The postdocs greatly appreciate this great experience supported by the BoV and the department administration and recognize it as a rare opportunity that does not exist at many other institutions.

However, there are several issues relating to the running of BashFest that were raised by the 2015 organizing committee. While the postdocs are given responsibility for managing the budget, we were not given the information necessary to do so. In general, the committee felt a lack of trust from the administrative staff to run the symposium, and the resulting withholding of information limited their ability to manage the symposium adequately. If BashFest is to continue, there needs to be better communication so that the committee can manage the budget effectively. In addition, the faculty attendance (especially senior-level faculty) in 2015 was poor. The invited speakers - who are all future faculty candidates - expect active communication and interactions with the faculty members at UT, not just with postdocs and graduate students, when they accept the invitation. The department can also use this opportunity as a pre-faculty search. We request that the Department strongly encourages the participation of faculty members.

Sustainability of Postdoc Mentoring Committee

While the postdocs appreciate the positive steps that the Postdoc Mentoring Committee has taken, we note that it has only begun to meet in the last six months after several years of being inactive. We would like to see a commitment from the department to keeping this committee active for the benefit of postdocs on a long-term basis.

Evaluation Committee Members

Brandon Bozek (Postdoctoral Representative)
Brendan Bowler
Chao-Ling Hung
Hwihyun Kim
Rachael Livermore
Andrew Mann

Section IX. McDonald Observatory

IX.A. Introduction

McDonald Observatory's primary mission is to provide highly capable telescopes and instrumentation to members of the UT Astronomy program to support leading research and educational programs. This section describes our Observatory in west Texas and our instrumentation development activities. The upgrade of the Hobby-Eberly Telescope (HET) to a wide-field telescope with world-leading spectroscopic capabilities is a significant recent outcome that will advance scientific frontiers in several areas, and that has a meaningful impact on the research programs that UT astronomers can undertake. Also noteworthy is work on the development of new instrumentation for McDonald Observatory and GMT. The observing capabilities and activities of McDonald Observatory are an asset in attracting and retaining faculty, students and researchers in the UT Astronomy program.

IX.B Hobby-Eberly and McDonald Observatory Telescopes, and Instruments

McDonald Observatory's telescopes are spread across two mountains, Mt. Locke and Mt. Fowlkes, 16 miles outside the town of Ft. Davis, Texas. Mt. Locke is the original mountain and houses the older telescopes; Mt. Fowlkes is the site of the HET. The site is as dark as any professional observatory in North America.

The Hobby-Eberly Telescope

The Hobby-Eberly Telescope (HET) is an innovative 10-m telescope sited at the McDonald Observatory. The HET operates with a fixed segmented primary of 11-m size and has a tracker, which moves the four-mirror Wide Field Corrector (WFC) and prime focus instrument package (PFIP) to track the sidereal and non-sidereal motions of objects. We have completed a major multi-year wide-field upgrade (WFU) of the HET that has substantially increased the pupil size to 10-meters and the field of view (FOV) to 22 arcminutes diameter (previously was 9.2-m and four arcminutes) by replacing the corrector, tracker, and PFIP and adding new metrology systems. This is the largest FOV of any 10-m class telescope. The new wide-field HET feeds the revolutionary integral field spectrograph (VIRUS), fed by 35,000 fibers, in support of the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), a new low-resolution spectrograph (LRS2), the upgraded high-resolution spectrograph (HRS), and later the Habitable-Zone Planet Finder (HPF).

The upgraded HET and its new instrumentation provide state-of-the-art observing capability to members of the UT Astronomy program. It aligns well with the research interests of Faculty and Research Scientists in cosmology, galaxy evolution, Galactic archeology, and exoplanets. McDonald Observatory operates the HET and is entitled to 68% of the observing time. HET partners Pennsylvania State University, Ludwig-Maximilians-Universität München, and Georg August Universität Göttingen are entitled to 25%, 6%, and 1% of the observing opportunities, respectively, based on resources paid into HET. The collaboration of the four universities on HET is organized via the HET Board of Directors.
The HET was the first fully queue-scheduled ground-based optical telescope. Queue scheduling of the HET was an integral part of the HET design, allowing the HET to execute temporal projects, targets of opportunity, and surveys as part of normal operations. The queue operates with several dozen programs submitted from the Telescope Allocation Committees (TACs) from each of the partners. Program completion rates for P1, P2, and P3 priority bands have historically been 95%, 92%, and 75%, respectively. The HET has produced 366 journal publications with 20,243 citations, with a median of 30 per paper and an H-number of 77. Wide angle surveys account for 28% of papers and 38% of citations while synoptic (e.g. planet searches) and Target of Opportunity (e.g., supernovae and gamma-ray bursts) programs have produced 46% of the papers and 44% of the citations. Areas of significant broader impact from before the HET Wide Field Upgrade (see below) were in the follow-up of very high redshift SDSS quasars, planet verification from the Kepler mission, supernova typing from the SDSS SN program, and the construction of very large catalogs of elliptical and spheroidal galaxies. In summary, the vast majority of the HET's impact has come from exactly where the designers intended: spectroscopic surveys over wide parts of the sky and time domain science.

HET Wide Field Upgrade

The primary motivation for the WFU and VIRUS is to execute the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), but the upgrade also improves telescope performance for all science applications. The $37M HETDEX project encompasses the HET WFU, the development of VIRUS, and the execution of the multi-year survey. The science requirements of HETDEX led us to design the ambitious new WFC, employing meter-scale aspheric mirrors and covering a 22-arcmin diameter FOV. The WFC is optimized to feed fibers. The new tracker was needed to accommodate the size and five-fold weight increase of the new PFIP and WFC, and the new metrology systems (specifically wavefront sensors) are needed to provide feedback on all axes to meet our performance requirements. The WFC was contracted to the University of Arizona (UA) College of Optical Sciences (OSC), the WFC reflective coatings to JDSU and Zecoat, the tracker, was built by the UT Center for Electro-Mechanics (CEM) and McDonald, and the new metrology systems were developed in-house by McDonald.

The WFC is one of the largest, most complex optical assemblies deployed to date in astronomy. It presented challenges in mirror figuring, alignment, handling, and testing. The project started in 2009. McDonald provided expertise in optics testing and analysis to support UA OSC in this project. In the large optic figuring, OSC encountered problems in measuring the mirror figures that led to two mirrors being mis-figured. This led to changes in the prescription and the addition of an aspheric corrector plate, which McDonald diagnosed using optical tests that we designed and added to OSC's plan. The alignment scheme developed by OSC also ran into problems when the optical references drifted in tilt. This led to the repurposing of interferometric tests developed by OSC for alignment rather than testing, and McDonald added an important conjugate test with sensitivity to field aberrations to break degeneracies in the alignment that might have crept into the new scheme.

We organized several formal and informal reviews during the production of the WFC to provide technical input as problems were encountered and to provide final approval to ship the WFC. Upon completion of the alignment and tests, there remained a possibility that the WFC could produce a tilted focal surface that would cause it to fail our requirements for imaging over the wide field. However, at that point, there were no further tests that could be executed at UA, and we instead elected to ship and install the WFC. We designed small deployable wavefront sensors that could be used to test the image quality and alignment of the WFC over the full field of view, in conjunction with the HET primary mirror (PM). McDonald organized the careful shipment of the WFC and undertook the acceptance testing at the HET to confirm that the alignment had not been disturbed. The WFC was installed in July 2015, it was aligned to the primary mirror frame of reference, and first light was achieved on July 29, 2015, with good on-axis image quality. The subsequent wavefront testing over the field, using geostationary satellites, was an exacting exercise and demonstrated that the system meets our requirements and produces images in line with specifications over the full 22 arcminute FOV. In this effort, McDonald expertise in optomechanical design, optics testing and analysis, and optics handling all played a key role in ensuring the successful outcome to the construction of the new HET, and in particular the excellent final performance of the WFC, albeit with a substantial delay in delivery.

The new HET PFIP, telescope control system (TCS) and metrology systems were all developed by McDonald. The HET has no natural axes and relies on feedback from six metrology instruments to control the motion of the tracker and maintain the WFC in alignment with the PM and the sky. Together, these systems provide the feedback to maintain the attitude of the WFC within tight constraints as we track, and also maintain the radius of curvature of the PM, which otherwise evolves with temperature during the night (since it is on a steel truss). The new TCS integrates the tracker motion control system, PFIP control system, payload alignment system, VIRUS and LRS2 data acquisition systems and centralized logging. The system is complete in its functions with the commissioning of focus and PM control in late 2016 and is now being refined to optimize efficiency for science operations.

The HET WFU started early science operations in February 2016 with the delivery of the new facility low-resolution spectrograph (LRS2) and entered scheduled science operations with LRS2 on December 1, 2016. Setup time on targets with LRS2 is already typically 5-7 minutes, half what it was with the old system, and the accuracy of the setups is much better. The frames of reference of the system, projected on sky, are mapped such that we can place an object onto the LRS2 IFUs, blind, so setup time is independent of the brightness of the target. Having focus under control improves the quality of data obtained and guiding residuals are small. The performance of the new telescope is already significantly better than the old HET, meeting requirements in almost all respects. Table IX-1 summarizes the current performance of the upgraded HET compared to the old HET and the requirements for the upgrade.

Table IX-1: High-level performance requirements for HET upgrade

Performance area	Requirement	"old" HET	Upgraded HET	Comment
Pupil diameter	10-m class	9.2-m	10.0 m	At center of track
Field of view	22 arcmin diameter	4 arcmin	22 arcmin	70 times larger area at same level of field vignetting
Median on-axis image quality EE(50%)	1.25 arcsec EE(50%)	1.7 arcsec	1.3 arcsec	In median 1.0 arcsec site seeing
Open-loop pointing (rms)	25 arcsec (goal 9 arcsec)	30 arcsec	5-15 arcsec	Achieving 5 arcsec within central half of track range
Setup time (end of exposure to start of next)	< 5 minutes 90% of the time	7-20 mins	4-7 minutes	Upgrade can set up blind on invisible targets in same time
Setup accuracy (rms)	0.25 arcsec (0.1 arcsec goal)	0.5 arcsec	0.25 arcsec	Ability to center target on fiber, slit, or IFU; measured on old LRS and new LRS2
Metrology System	full sensing of all degrees of freedom	only guiding	All degrees	Wavefront sensing feedback completes all degrees of freedom, particularly focus
Guiding residuals	0.25 arcsec rms	0.5 arcsec	*0.15 arcsec*	Guiding drift on some long tracks traced to transform error in tracker motion control; being remedied

Notes to Table: As compared to performance of the "old" HET and current performance of the HET WFU (characteristics in *italics* are based on limited data)

VIRUS

The Visible Integral-field Replicable Unit Spectrograph (VIRUS) is an innovative, highly multiplexed (replicated) spectrograph that will place 35,000 fibers (each 1.5 arcsec diameter) on sky, simultaneously, to open up the emission-line universe to systematic surveys for the first time. It covers a fixed wavelength range of 350-550 nm and resolving power R~750, and is designed to detect LAEs efficiently, while also uncovering populations of objects selected by their line emission rather than by their continuum emission properties. The 3-year HETDEX survey will provide a rich and unique resource in astronomy well beyond the principal aims of HETDEX. VIRUS is the first highly replicated optical spectrograph, a concept that we have pioneered. It consists of 156 individual spectrograph channels arranged as 78 unit pairs, fed by 78 fiber integral field units (IFUs) each with 448 fibers. Each IFU has 1/3 fill-factor for the fibers and covers 50x50 arcsec^2. The on-sky position is dithered between three exposures to fill in the full area of each IFU. The IFUs are deployed at the focus of the HET in a ¼ fill-factor pattern except for a central hole where other instruments are deployed. VIRUS on the upgraded HET is designed to provide an order of magnitude increase in grasp (AΩ) over any existing survey spectrograph.

VIRUS is a joint project of The University of Texas at Austin (UT), Leibniz-Institut für Astrophysik Potsdam (AIP), Texas A&M University (TAMU), Max-Planck-Institut für Extraterrestriche-Physik (MPE), University of Oxford, Ludwig-Maximilians-Universität München (LMU), Pennsylvania State University, Institut für Astrophysik Göttingen, and Max-Planck-Institut für Astrophysik (MPA). UT leads the project and is responsible for the construction of the cameras, integration of the instrument, characterization, and deployment. AIP spearheads the IFU production with partial funding from MPE and MPA, TAMU has provided the collimators and the enclosures, and Oxford many mass-produced machined parts. MPE/LMU is leading the development of the data reduction and analysis pipeline (called Cure), and researchers at all the institutions are taking part in the exploitation of the resulting dataset.

Prior to embarking on the mass-production of spectrographs we constructed a prototype of a single VIRUS spectral channel and deployed the instrument (VIRUS-P/Mitchell Spectrograph) on the McDonald Harlan J. Smith 2.7-m telescope. The instrument has been used for a Pilot Survey that proved the concept of using wide-field integral field spectroscopy to detect emission-line objects in a blind survey and to aid in the development of software pipelines. The instrument has also been used for a wide variety of science especially on local galaxies for studies of dark matter, galaxy structure and stellar populations (e.g. the VENGA survey).

The CCDs for VIRUS have a nominal 2Kx2K format and are read out in parallel in 20 seconds. The VIRUS system will be 665 Mpixel, which is comparable to the largest imaging mosaics yet deployed. The data volume from the full VIRUS array is about 2.5 GB per observation. Observation times per field are 20 minutes for the HETDEX survey, split into three exposures, and we expect to generate 40 TB of raw data over the course of the survey.

The integrated detector system for VIRUS was supplied by Astronomical Research Cameras, Inc., with the University of Arizona Imaging Technology Laboratory (ITL) providing thinned backside illuminated CCDs with AR coatings optimized for the VIRUS bandpass. The design is highly customized to the VIRUS application. In 2015 we noticed instances of CCDs showing blemishes that were not present at delivery. Following an extensive investigation, we identified two contamination sources: one within the storage boxes supplied by ITL and the other within the cryostats themselves. The response of a given CCD to these contaminants is highly variable, which made diagnosis difficult, but many of the 50 assembled cameras have at least one CCD that is affected. This issue took a long time to diagnose and set back deployment of VIRUS quite significantly. We have elected to replace all the CCDs with an updated design from ITL and have determined how to ensure the cryostat environment is extremely clean.

Through characterization, we identified 16 units from the initial build with two CCDs that are affected only mildly by the contamination and we have deployed these units (a 20% microcosm of the full instrument) at HET in order to test the cryogenic and readout infrastructure fully and start training of HET personnel in the maintenance of the system. The infrastructure for VIRUS at HET is on a large scale. The units are housed in two large enclosures either side of the telescope structure, and the detectors are cooled by liquid nitrogen (LN) supplied from an 11,000-gallon external dewar that is replenished approximately twice per month. The enclosures are essentially sealed clean-rooms with a heat removal system to avoid degradation of the seeing by heat generated by the detector controllers and electronics escaping to the dome by convection or air leaks.

This initial deployment also allows instrument commissioning to start and provides a flow of data to begin testing of the data processing and quality control. Such a staged deployment is an enormous advantage of a replicated instrument like VIRUS. The IFUs are deployed in a 4x4 pattern with extent of nearly 8 arcminutes. The 7000 fibers on sky already make it the largest fiber-fed instrument and widest-field integral field spectrograph. The HET system has been commissioned to the point where we can place the IFUs to better than 2 arcsec, and we have used VIRUS to confirm the quality of the images over the radial extent of the field of view. Early science

commissioning has focused on the GOODS-N, COSMOS, and SHELA fields, where there is significant ancillary data for comparison. These data are aiding in the completion of the development of the Cure data reduction pipeline and providing verification of performance of the system (see more details in Section IX.D.). Throughput and sensitivity are in line with predictions.
Construction, characterization, and deployment of the full complement of 78 VIRUS units, outfitted with new CCDs from ITL, is scheduled to take the balance of 2017. The goal is to reach at least 50 IFUs on sky in time to commence HETDEX observing on the main North Galactic Cap field before the end of 2017. We have sufficient funding and staff to support this effort, including the replacement of the CCDs.

LRS2

The previous HET Low-Resolution Spectrograph was the first facility instrument delivered to HET and resulted in 216 publications with 14,671 citations over the 15 years it was in service. It was, however, incompatible with the WFU and has been replaced with a more capable broad-band fiber-fed instrument called LRS2, based on VIRUS. It takes advantage of the fact that the VIRUS spectrograph unit was designed to be easily adapted to other applications. LRS2 is fed by a pair of 7x10 $arcsec^2$ lenslet coupled fiber IFUs, covers 350-1100 nm, at a fixed resolving power of R~1200-1800, with the wavelength range split with dichroics into four channels shared between two VIRUS units, one for the blue and orange wavelength range (370 - 630 nm) and the other for the red and far-red range (630-1050 nm). The units operate independently, but one unit can record sky data while the other is exposing on a target. LRS2 uses the multiplex power of VIRUS to cover wavelength, rather than wide area. It utilizes the infrastructure provided for VIRUS at HET. Only minimal modification from the base VIRUS design in optics (grisms for both units and minor modifications to optics for the red unit) and the detectors (thicker CCDs with optimized AR coatings) were required. LRS2 utilizes a unique and innovative input feed for the IFU that includes multiplet microlens arrays and dichroic beamsplitters. We have been developing these technologies as a way to couple instruments to large telescopes, and LRS2 provided the first opportunity to test on sky. It is working very well, and this success is being leveraged for future instruments for McDonald and GMT.

LRS2 was the first facility instrument to be deployed on the upgraded HET, and it is now in queue-scheduled science operations. LRS2 was delivered in early 2016, entered shared risk science observations in July, and has been utilized for scheduled queue observations since December. LRS2 is a powerful instrument serving the HET strengths in survey follow-up, synoptic observations, and transient events. It will be particularly useful for following up emission-line objects detected with VIRUS at higher resolution and can be used in parallel with VIRUS.

The HET High-Resolution Spectrograph (HRS)

The HET High-Resolution Spectrograph (HRS) has been one of the two primary HET instruments since its commissioning in mid-2001. HRS is fiber fed, and optical bench mounted, with an unfolded, 200 mm diameter white pupil design, an R4 echelle grating, and has had two reflective grating cross dispersers. HRS offered multiple configurations, including 2.0 and 3.0 arcsecond fibers, resolving powers of R=17,000, 30,000, 60,000, and 120,000, a dozen different cross disperser settings, and an iodine cell for precision radial velocity observations. A primary science mission of HRS has been general stellar abundance work for studies of the nucleosynthesis of the elements and the chemical evolution of the Galaxy and nearby galaxies. The other primary science mission has been precision radial velocity (PRV) observations for exoplanet discovery and characterization.

The HET High-Resolution Spectrograph (HRS) was in service for 12 years up until the takedown of the HET for the Wide Field Upgrade project in August 2013. The HRS was used for about 50% of HET observing time, has about 160 published papers, and approximately 8000 citations of those papers. HRS produced good quality data. However, competitiveness was unsatisfactory in a number of important areas. Throughput was poor, providing performance equivalent to an R=60,000 spectrograph on a 4-m telescope. HRS had no useful spectral coverage below 420 nm. Therefore it missed a significant fraction of the heavy metal spectral lines frequently used in stellar abundance research. Radial velocity precision was lower than expected compared to similar spectrographs. Long-term observations of one particular RV standard star saw HRS performance of 2.7-m/s compared to about 1.7 m/s elsewhere. HRS had limited or no sky subtraction capability in the blue at resolving powers above 30,000. The R=120,000 mode was less than Nyquist sampled in the blue half of each diffraction order. In response to these deficiencies, McDonald Observatory, aided by additional funding from HET partner Penn State, is currently upgrading the HRS to enhance its capabilities and competitiveness. Initial funding came in late 2011, and the project received engineering resources in 2012. Much of the upgrade is complete, and HRS will return to science operation in 2017. Throughput will improve by a factor of 4.5x at R=70,000 in the 480-680 nm spectral region, and by a factor of up to 6x in the violet and near IR. A factor of 3x comes from image slicing the output of the optical fibers, and a factor of 1.5x or more comes from replacing reflective surface relief cross dispersers with volume phase holographic gratings. At R=105,000, the gain in throughput will be 8x in the visual spectral region, and up to 11x in the violet and near IR due to a 5x gain from image slicing. Stability and radial velocity precision will improve via mechanical design including kinematic mounting of moving parts, and optical stabilization via octagonal optical fibers, fiber modal scrambling, and optical double scrambling. Sky subtraction options are available for all wavelengths and resolving powers. The four new cross dispersers are designed to provide the cross-dispersion necessary for this capability. A two-channel exposure meter with object & sky channels will aid observing efficiency and allow calculation of flux-weighted barycentric corrections for PRVs. A new monolithic CCD eliminates the previous mosaic gap, offers improved quantum efficiency and cosmetics, and has higher quality silicon in support of better PRVs.

A second arm for the spectrograph, known as the blue arm, is designed into the HRS upgrade and will be implemented as a second phase of the upgrade. The blue arm has a single configuration with spectral coverage from 362 nm to 479 nm. The existing pupil relay mirror, cross disperser, camera, and detector are now known as the red arm. The red arm offers simultaneous coverage with the blue arm, using one of the red arm spectral regions (479 nm to 675 nm, 614 nm to 933 nm, and 791 nm to 1095 nm).

The HET Habitable-zone Planet Finder Spectrograph (HPF)

HET partner Penn State is building a near-infrared spectrograph called the Habitable-zone Planet Finder Spectrograph (HPF). HPF is designed to deliver 1 m/s precision radial velocities working at a resolving power of 50,000 with spectral coverage from 800 nm to 1300 nm. The start of commissioning is anticipated at the HET in late 2017.

The powerful combination of the 10-m aperture HET, the HPF, and HET queue scheduling will be used to find and study exoplanets around M dwarfs. A statistically significant survey of M dwarfs will be undertaken with an emphasis on finding the nearest exoplanets to Earth. Questions involving planet formation and evolution will be addressed, along with understanding how common planets are in M dwarf habitable zones and identifying potentially habitable planets. A goal is an atmospheric characterization of exoplanets with an emphasis on potential biosignatures.

HPF is a folded, classical white-pupil, R4 echelle spectrograph, with a volume phase holographic grism cross disperser, and an HAWAII-2RG, 1.7 micron cutoff, HgCdTe 2Kx2K detector. HPF is highly stabilized in pressure, temperature, optical illumination of its optics, and calibration light to achieve ~ 1 m/s radial velocities. Specifically, HPF operates at a pressure of 10^{-10} atmospheres with fluctuations of ~10^{-9} atmospheres, has long term temperature stability less than 1 mK rms, uses octagonal optical fibers with modal scrambling and double scrambling, and has a simultaneous calibration fiber carrying light from a laser frequency comb. The spectrograph is cooled radiatively to ~180 K with liquid nitrogen as the cooling source, and electrical heating of the radiation shield as the temperature control mechanism.

HPF will have competition at or near its first light from capabilities such as carmenes, espresso, Subaru-IRD, and iLocater. Nevertheless, it will be among the first of its class of instruments, will be fed by one of the largest telescopes in the group, plus it will have the added benefits of queue scheduling and an HET exoplanet consortium that historically have won significant amounts of HET time. It is anticipated that HPF will have a significant impact in the field of M dwarf exoplanet research.

HET Returns to Science Operations

HET has been undertaking shared-risk science operations with LRS2 since July 2016, while we complete the telescope commissioning. As of December 1, 2016, we have entered the first trimester of queue-based observing when science observations scheduled through the partner Time Allocation Committees (TAC's) were resumed. During the shared-risk phase, diverse science programs were undertaken with LRS2 that tested its capabilities, including: follow-up of supernova targets from McDonald, Lick, and iPTF, extremely metal-poor star candidates, black-hole mass correlations in galaxies, confirmation of z~4 galaxies and z~1-2 clusters from the HETDEX/SHELA survey, and measurements of exoplanetary atmospheres. Now that we have returned to science operations during dark time, the programs are similarly diverse. For the first period of normal science operations, Texas has 15 science programs with 67, 66 and 65 hours allocated in the P1, P2, and P3 priority bands, respectively. There are also ten hours of lowest priority, P4, filler hours allocated. One program, led by Karl Gebhardt, is a collaborative project to start preliminary exploration for the HETDEX project with ten additional high priority hours contributed from the other HET partners.

Table IX-2. HET Operations Team

Engineering Staff:		**Night Operations Staff:**	
Electrical Engineers (one is also the facility manager)	3	Resident Astronomers	4
Electromechanical Technician	1	Telescope Operators	4
Mechanical Engineer	1		
Mechanical Technicians	2	**Administrative Staff:**	
Optomechanical Technicians	3	Office and Procurement Administrator	1
Software Engineers	3		
Network Administrator	1		
The HET has an operation staff of 23 people.			

Mirror Coating Facility

The HET started planning a mirror coating facility located in the HET building late in 2009. Before this project, HET primary mirror segments were being re-aluminized at the 2.7-m telescope. We sought higher reflectivity over the entire wavelength range of the HET instrumentation with particular emphasis on the UV band in preparation for the HETDEX project. HET also wanted to explore more durable coatings, particularly multilayer silver coatings. A lot of upfront effort went into specifying and selecting the vacuum coating equipment. A small company specializing in custom coatings and coating equipment was selected to design and build the coating system. The system turned out very well with high-end vacuum pumping equipment and the capability to deposit six different materials in one coating run. Currently, the HET mirror segments are still being coated with only high purity aluminum, but the long-term goal is to deposit multilayer silver coatings, possibly by obtaining the rights to use an existing coating recipe under license.

Thermal Management Project

In 2012, HET Operations started a project, administered and contracted via UT Project Management and Construction Services (PMCS), to move heat sources further away from the telescope enclosure/building and to dump heat, extracted from various sources inside the telescope dome, in the so-called Remote Thermal Area. Since the telescope upgrade introduced more heat sources, the extraction of the heat was very effectively integrated with the thermal management project that was already underway.

UT-Owned Telescopes on Mt. Locke

UT owns four research-class telescopes on Mt. Locke: the 2.7-m Harlan J. Smith Telescope, the 2.1-m Otto Struve Telescope, the 0.9-m Telescope and the 0.8-m Telescope. The 2.7-m is used for research all nights of the year (except during aluminizing). The 2.1-m is used most nights of the year, with 20+ nights a year dedicated to outreach programs for visitors. The 0.9-m is primarily used for outreach, though it is sometimes used for research by our Freshman Research Initiative class. All three of these telescopes are used only on-site. The 0.8-m telescope is used many nights and can be used remotely via the web.

Harlan J. Smith 2.7-m Telescope

The Harlan J. Smith 2.7-m Telescope has three foci: f/33 coude, f/18 Cassegrain and f/9 Cassegrain. Currently, there are no instruments that use the f/18 focus. There are three instruments that are used at dark time at the f/9 focus. These include The George and Cynthia Mitchell Spectrograph (formerly VIRUS-P), an IFU-fed low-resolution spectrograph that was the prototype for the VIRUS spectrographs for the HETDEX project, VIRUS-W, a different IFU-fed spectrograph similar to VIRUS-P but with higher spectral and spatial resolution, and DIAFI (Direct Imaging Auxiliary Functions Instrument), a widish-field camera system with 42 filter slots. There are two instruments in use for bright time at the 2.7-m telescope. IGRINS (Immersion Grating Infrared Spectrograph) is a high-resolution spectrograph that provides coverage of the whole H and K bands at R=40,000 in a single observation. It is used at the f/9 focus. Alternatively, the Tull 2DCoude high-resolution spectrograph can be used with the f/33 focus. This spectrograph has two modes of operation with R=60,000 and R=200,000. Additional instruments are available for use at the 2.7-m telescope, but their usage is low. (http://www.as.utexas.edu/mcdonald/facilities/2.7-m/2.7.html)

Otto Struve 2.1-m Telescope

The Otto Struve 2.1-m Telescope has three foci: f/23 coude, f/13.6 Cassegrain, and f/3.9 Prime. Currently, all of the available instruments use the f/13.6 focus, though work is underway to deploy one instrument (ProEM) to f/3.9. There are no instruments using the f/23 focus. Principal instruments include a high-speed small-field CCD camera (ProEM) optimized for high-speed photometry and Camera for QUasars in EArly uNiverse **(**CQUEAN), with a deep depletion CCD optimized for the red, Electronic Spectrograph 2 (ES2), a long-slit CCD spectrograph, and the Sandiford Echelle Spectrograph (SES), a high-resolution spectrograph. Additional instruments (http://www.as.utexas.edu/mcdonald/facilities/2.1-m/2.1.html) are available for use at the 2.7-m telescope, but their usage is low.

0.8-m Telescope

The 0.8-m Telescope is dedicated to an f/3.0 Prime Focus Corrector (PFC) CCD camera providing a 1.1 degree field of view with 1.4 arcsec pixels. Generally used with UBVRI filters, additional filters can be used. The telescope was recently upgraded to a computer-controlled mount and electronics using funds provided via Rice University and Houston Community College from NSF. The new mount enables remote, web-based access to the telescope and camera so that users can use this telescope from off-site.

Other Telescopes Sited at McDonald Observatory

There are other telescopes sited at McDonald Observatory, many of which are available to our astronomers to use. McDonald is a node of the Las Cumbres Observatory (lco.global) network, currently hosting a 1m telescope. As host, we are allowed access to the complete network (currently ten 1m telescopes, two 2m telescopes and many 0.4m telescopes and growing). Another 1m telescope, along with a high-resolution spectrograph, are expected in the next year or so. Also, we might be the site of multiple 0.4m telescopes. The existing telescope resides on Mt. Fowlkes. Sited near the LCO telescope is the McDonald Laser Ranging Station a project of the UT (http://www.csr.utexas.edu/mlrs/), Center for Space Research that shoots a laser through a 30-inch telescope to range from the Moon and satellites. In addition, Mt. Fowlkes is home to a node of the Robotic Optical Telescope Search Experiment an 18-inch telescope which has been (ROTSE, http://www.rotse.net/), used by UT astronomers to search for supernovae.

Two additional telescopes are sited on Mt. Locke. These are the MONET/North telescope (Monitoring Network of Telescopes, a project of Georg Augustus Universitat). This is a 1.2m telescope that can be used robotically for imaging with filters. The other telescope in the network is at SAAO in Sutherland. UT astronomers may access either telescope. In addition, Boston University has a 20-inch telescope that they use for monitoring atmospheres of planets.

IX.C. Telescope Usage

McDonald Observatory is a resource for the whole Astronomy program. Access to the original McDonald Observatory telescopes on Mt. Locke are prioritized for programs from The University of Texas astronomers, but we accept proposals from other astronomers around the world. The collaboration of UT with KASI to build the IGRINS instrument has resulted in a large cadre of Korean users of the 2.7-m telescope. Other non-UT users come from other institutions in the state of Texas (Rice, A&M, A&M Commerce, TCU, Texas Tech, UTEP) and outside the state and the country. Access to the UT share of the Hobby-Eberly Telescope (HET) is restricted to astronomers at The University of Texas, with some of that share being purchased by Texas A&M.
Figures IX-1 and IX-2 show the UT use of the HET and 2.7-m telescopes by category, where “Other UT” includes Post-Docs and researchers between Post-Doc and Research Scientist. Figure IX-3 shows the oversubscription rate for both telescopes.

Figure IX-1: The use of the HET by category of PI. The telescope was down for upgrades during the gap in the plot.

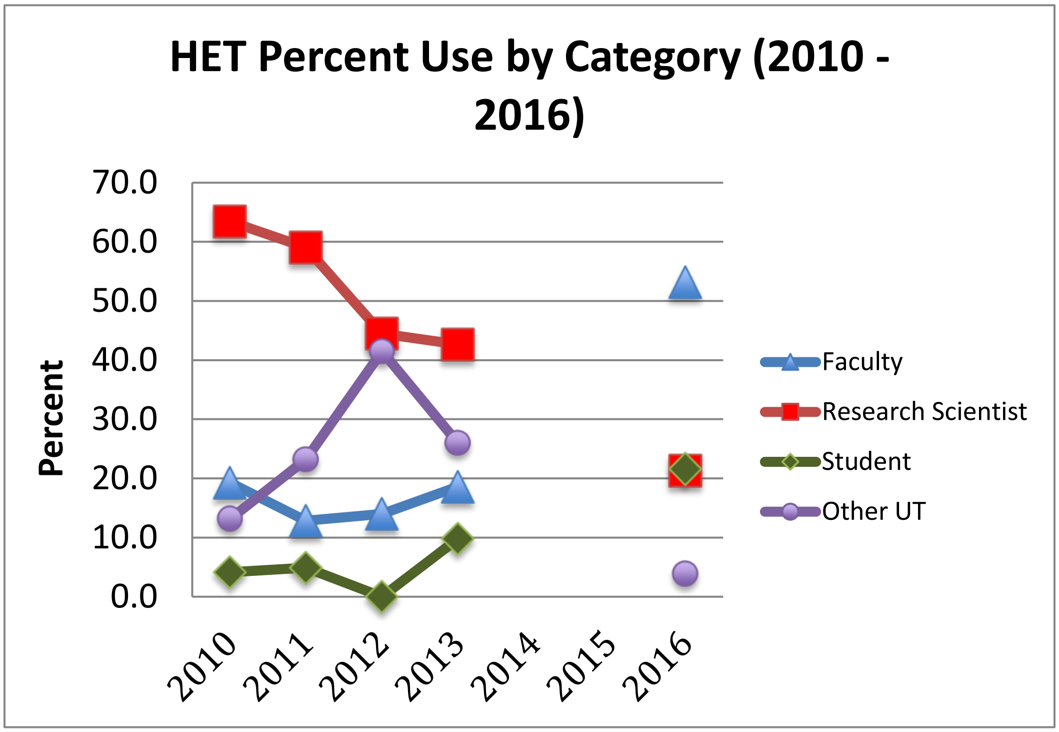


Figure IX-2: The use of the 2.7-m by category of PI. The drop of Research Scientist percentage in 2015 reflects William Cochran being reclassified from Research Scientist to Faculty (Research Professor).

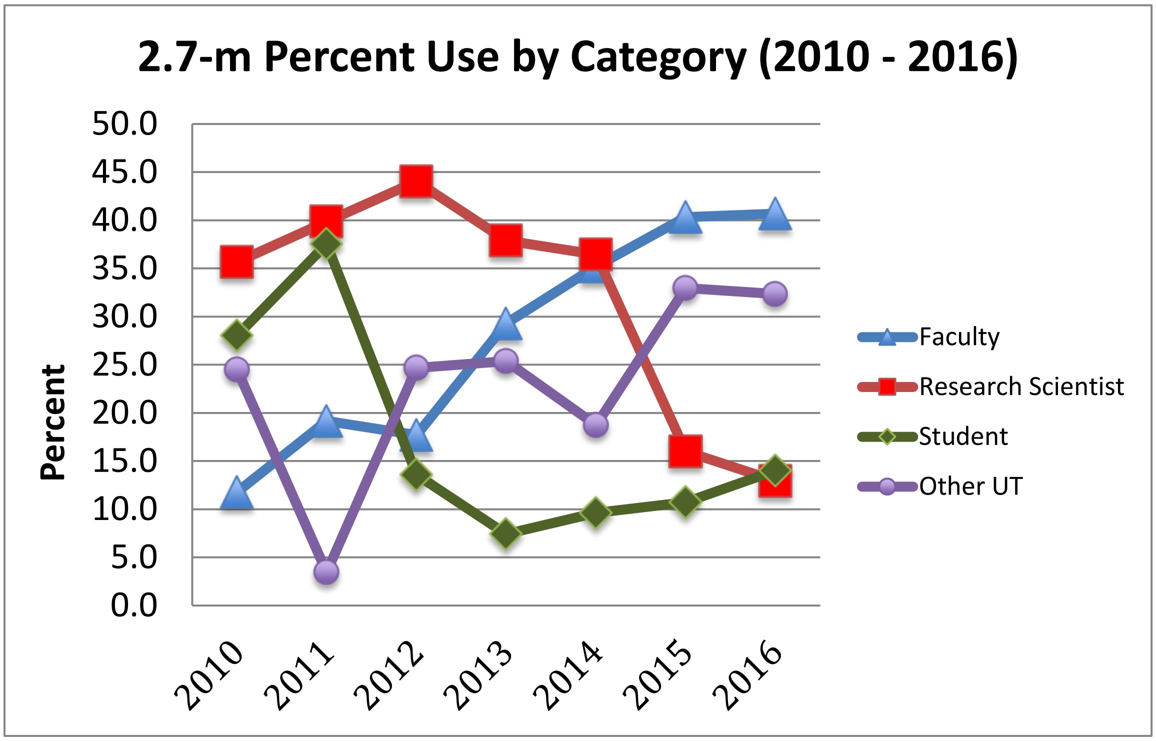
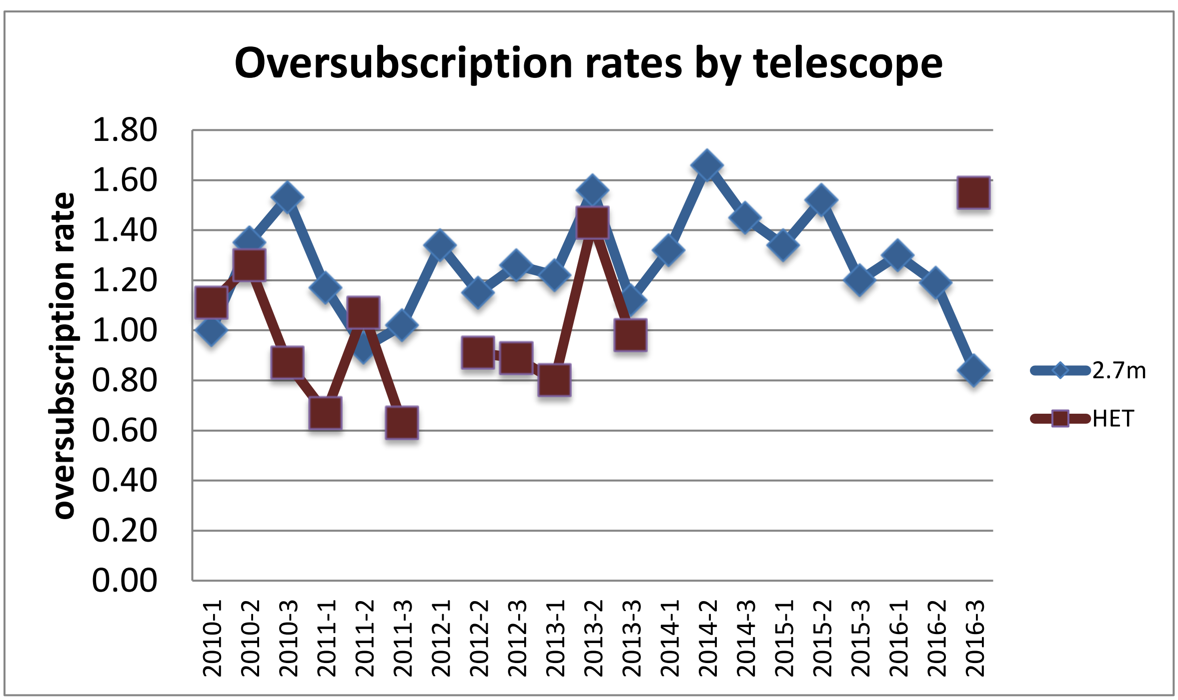


Figure IX-3: The oversubscription rates for HET and the 2.7-m. These are the rates at the proposal deadline. Undersubscribed time gets distributed in an additional call for proposals or as discretionary time.



In the following tables, we note the UT PIs of telescope proposals, PI status, proposal title and number of nights or hours (HET) assigned. The PI status is denoted as follows: F=Faculty, RS=Research Scientist, Res=Researchers between postdoc and Research Scientist, PD=Postdoc and GS=Grad Students. For Grad Students, their faculty advisor is listed in parentheses under their name.

Table IX-3 – University of Texas Personnel Telescope Time

University of Texas at Austin HET Programs			
1 July 2016 through 30 November 2016 LRS2 Shared Risk Time			
PI	**Status**	**Proposal Title**	**Hours**
Castenheira, Barbara	Res	Spectroscopy of Extremely-Low Mass White Dwarfs	2.7
Endl, Michael	RS	Exoplanetary Atmospheres with LRS2	6.4
Gebhardt, Karl	F	Exploration of the Host Galaxy Extremes in the Black-Hole Mass Correlations	16
Martinez, Raquel (Kraus)	GS	Spectroscopic Observations of Two Young Planetary-Mass Companions on Wide Orbits in Taurus	4.7
Shetrone, Matthew	RS	Spectroscopic follow-up of extremely metal-poor star candidates	7.4
Shetrone, Matthew	RS	Confirmation of Li-rich M dwarfs	0.7
Stevans, Matthew (S. Finkelstein)	GS	Spectroscopic Confirmation of the Brightest Galaxies at z~4	10
Wheeler, Craig	F	HET Follow-up of DIAFI Supernova Targets	6.7
Wheeler, Craig	F	HET Follow-up of Supernova Discoveries	13.5
1 December 2016 through 31 March 2017			
Casey, Caitlin	F	Spectroscopic Confirmation for an Extremely Rare Giant Radio Galaxy	4.5
Casey, Caitlin	F	The Circum-Galactic Medium of Dusty Star-Forming Galaxies at z>2	5
Finkelstein, Steven	F	Confirmation of the Brightest Known Lyman-Alpha Blob in the Universe	2.25
Gebhardt, Karl	F	Addressing a Bias in the Relation Between Galaxies and Their Central Black Holes	15
Gebhardt, Karl	F	HETDEX Observation	54
Hill, Gary	RS/F	Spectroscopic confirmation of high-redshift radio galaxy candidates	8.2
Jung, Intae (S. Finkelstein)	GS	A spectroscopic search for galaxies in the epoch of reionization	15
Larson, Rebecca (S. Finkelstein)	GS	Confirmation of Ly-a Emission in Galaxies at the End of Reionization	13
Martinez, Raquel (Kraus)	GS	Searching for the Elusive Photospheric Continuum of the Wide-Orbit, Planetary-Mass Companion, FW Tau b	10.7
McQuinn, Kristen	RS	Measuring Stellar Abundances with LRS2	4.4
Stevens, Matthew (S. Finkelstein)	GS	Spectroscopic Confirmation of the Brightest Galaxies at z~4	14
Wheeler, Craig	F	HET LRS2 Observations of Halpha in Old Hydrogen-deficient Supernovae	9

University of Texas at Austin HET Programs			
1 July 2016 through 30 November 2016 LRS2 Shared Risk Time			
Wheeler, Craig	F	HET LRS2 Follow-up of Supernova Discoveries	21

University of Texas at Austin 2.7-m Programs			
1 December 2014 through 31 March 2015			
PI	**Status**	**Proposal Title**	**Nights**
Barnes, Thomas	RS	A multi-satellite, ground-based study of pulsating variables in NGC2264	4
Cochran, William	RS/F	Kepler Extended Mission Ground-Based Follow-Up Observing	3
Endl, Michael	RS	McDonald Observatory Planet Search	17.5
Gosnell, Natalie	PD	Constraining Blue Straggler Formation Mechanisms with IGRINS	1.5
Gullikson, Kevin (Kraus)	GS	A Search for Companions to A and B stars	3
Jaffe, Daniel	F	Tests of Pre-Main Sequence Evolution Models Using Stars of Known Mass	3
Jaffe, Daniel	F	Phased Spectroscopic Detection of Non-Transiting Planets: IGRINS Observations of Tau Boo b	3
Juarez, Aaron (Jaffe)	GS	The IGRINS Survey of Taurus and Ophiucus YSOs	4
Kidder, Benjamin (Jaffe)	GS	IGRINS Survey of Class I and Transition Disk YSOs	3
Lacy, John	F	The H_2:CO Ratio in Molecular Clouds	1.5
Lambert, David	F	IGRINS and H-deficient stars	1
Lambert, David	F	Chemical compositions of SRd variables	3
Livermore, Rachael	PD	The Faint End of the Lyman alpha Luminosity Function at $2 < z < 3.8$	4
Mace, Gregory	PD	IGRINS Substellar Boundary Survey	4
Mann, Andrew	PD	A Method to Measure Detailed Abundances in Cool Dwarfs	3
McKay, Adam	PD	High Spectral Resolution Observations of Comet C/2014 Q2 (Lovejoy)	1.5
Noyola, Eva	Res	Medido: Dark matter in Low Dispersion Systems	10
Odewahn, Steve	RS	What powers the nuclei of early-type galaxies with H_2 emission?	1
Ramirez, Ivan	PD	Starspot models and the IGRINS solution to the O and Fe abundance problems in K dwarfs	2
Ramirez, Ivan	PD	The O and Fe abundance problems in K dwarfs	3
Riddle, Andrew (Kraus)	GS	Stellar Parameters of Low-Mass Eclipsing Binaries	2
Sneden, Chris	F	Infrared Spectroscopy of Field Red Horizontal Branch Stars	2
Sneden, Chris	F	An Infrared Spectroscopic Study of M67	2
Wheeler, Craig	F	Catching up to the Hydrogen Envelope: Late-time Halpha Observations of Type I SNe	3
1 April 2015 through 31 July 2015			
Ramirez, Ivan	PD	High-precision abundances of F-type dwarfs: a star with a debris disk and a solar sibling	3

University of Texas at Austin 2.7-m Programs			
1 December 2014 through 31 March 2015			
Riddle, Andrew (Kraus)	GS	Stellar Parameters of Low-Mass Eclipsing Binaries II	1
Sneden, Chris	F	Exploiting the first Gaia Data Release	3
Sneden, Chris	F	An Infrared Spectroscopic Study of NGC 6940	2
Wheeler, Craig	F	Catching up to the Hydrogen Envelope: Late-time Halpha Observations of Type I SNe	3
1 August 2015 through 30 November 2015			
Cochran, William	RS/F	PICK2 - Planets in Clusters with K2 - TS23 follow-up	5.5
Cochran, William	RS/F	Kepler Mission Follow-up Observations	12.5
Dinerstein, Harriet	F	Chemical Enrichment in Planetary Nebulae from IGRINS Observations	2
Endl, Michael	RS	Probing Exoplanet Occurrence Rates at 5 AU: The 2.7-m Harlan J. Smith Telescope Legacy Survey	8
IGRINS Mini-Queue		IGRINS Mini-Queue	4
Jaffe, Daniel	F	Internal Shocks in the Extended Jets from Protostars	2
Jaffe, Daniel	F	Young Brown Dwarfs in Taurus - Stellar and Disk Properties	4
Jaffe, Daniel	F	The Effect of Variability on YSO Parameter Determination	5
Juarez, Aaron (Jaffe)	GS	Coevality of Binary Systems in Taurus	2
Kaplan, Kyle (Dinerstein)	GS	Deep IGRINS Spectra of Photo-Dissociation Regions	2
Kraus, Adam	F	The Newly-Formed Transiting Planets of Scorpius-Centaurus	2
Lacy, John	F	The H_2 abundance in molecular clouds	3
Lambert, David	F	Chemical compositions of SRd variables	3
Lambert, David	F	Heavy elements in very young open clusters	3
Livermore, Rachael	PD	The Faint End of the Lyman alpha Luminosity Function at $2 < z < 3.8$	4
Mace, Gregory	PD	Deciphering the Substellar Boundary in Taurus	4
Mace, Gregory	PD	Characterizing Nearby Young Low-Mass Stars and Brown Dwarfs with IGRINS	6
Mann, Andrew	PD	A Method to Measure Detailed Abundances in Cool Dwarfs	2
Rizzuto, Aaron	PD	Unveiling the Greater Taurus Ecosystem and Star Formation History	2
Sneden, Chris	F	Exploiting the first Gaia Data Release	5
Wheeler, Craig	F	Catching up to the Hydrogen Envelope: Late-time Halpha Observations of Type I SNe	4
1 December 2015 through 31 March 2016			
Barnes, Thomas	RS	Probing the instability regions of pre-main sequence stars in NGC 2264	4
Bowler, Brendan	PD	Characterizing Nearby Young Low-Mass Stars and Brown Dwarfs with IGRINS	4
Cochran, William	RS/F	PICK2 - Planets in Clusters with K2 - TS23 follow-up	6
Endl, Michael	RS	The Harlan J. Smith 2.7-m Telescope Exoplanet Survey	9
IGRINS Mini-Queue		IGRINS Mini Queue	4

University of Texas at Austin 2.7-m Programs			
1 December 2014 through 31 March 2015			
Indahl, Briana (Hill)	GS	VIRUS-P Pilot Survey of Galactic Outflows in Local Galaxies	6
Jaffe, Daniel	F	Young Brown Dwarfs in Taurus - Stellar and Disk Properties	6
Jaffe, Daniel	F	Protostars and Disks in Ophiuchus, a Test of Environment	4
Kaplan, Kyle (Dinerstein)	GS	Anatomy of a Bullet Bow Shock In Orion	4
Kidder, Benjamin (Jaffe)	GS	IGRINS Survey of Class I YSOs in Taurus-Auriga	2
Kim, Hwihyun	PD	Kinematic Study of Ionized and Molecular Gas in Monoceros R2	2.5
Kim, Hwihyun	PD	Study of Stellar Populations and Gas Kinematics in the Nuclear Region of M82	2.5
Lambert, David	F	Heavy elements in young open clusters	3
Livermore, Rachael	PD	The Faint End of the Lyman alpha Luminosity Function at $2 < z < 3.8$	4
Luna, Jessica (Jaffe)	GS	Phased Spectroscopic Detection of Non-Transiting, Planets: IGRINS Observations of Tau Boo b	4
Mace, Gregory	PD	Faint Substellar Objects with IGRINS	4
McKay, Adam	PD	High Spectral Resolution Observations of Comets C/2013 US10 (Catalina) and C/2013 X1 (PanSTARRS)	5.5
McLane, Jacob (Jaffe)	GS	Tests of Pre-Main Sequence Evolution Models Using Stars of Known Mass	3
Noyola, Eva	Res	Medido: Dark matter in Low Dispersion Systems	5
Ramirez, Ivan	PD	High precision spectroscopy of twin stars	3
Rizzuto, Aaron	PD	Calibrating Young Stellar Models: Dynamical Masses and Magnetic Fields	2
Sneden, Chris	F	High-Resolution Infrared Spectroscopy of Open Clusters	1
Sneden, Chris	F	Exploiting the first Gaia Data Release	5
Wheeler, Craig	F	Catching up to the Hydrogen Envelope: Late-time Halpha Observations of Type I SNe	3
1 April 2016 through 31 July 2016			
Bowler, Brendan	PD	Characterizing Nearby Young Low-Mass Stars and Brown Dwarfs with IGRINS	4
Cochran, William	RS/F	K2 Follow-up Observations	6
Dinerstein, Harriet	F	Neutron-Capture Element Enrichments in Planetary Nebulae with IGRINS	4
Endl, Michael	RS	The McDonald Observatory Exoplanet Legacy Survey	7.25
Indahl, Briana (Hill)	GS	VIRUS-P Pilot Survey of Galactic Outflows in Local Galaxies	7
Jaffe, Daniel	F	Surveying the Edges of the L1688 Core in Ophiuchus	8
Jaffe, Daniel	F	Young Brown Dwarfs in Ophiuchus - Stellar and Disk Properties	3
Johnson, M. (W. Cochran)	GS	Measuring the Spin-Orbit Misalignment of a Long-Period Eclipsing Binary	1
Johnson, M. (W. Cochran)	GS	Measuring the Spin-Orbit Misalignment of a Young Binary Brown Dwarf	1.5

University of Texas at Austin 2.7-m Programs			
1 December 2014 through 31 March 2015			
Kidder, B. (Jaffe)	GS	IGRINS Study of Class I YSOs in Ophiuchus	4
Kraus, Adam	F	The Mass-Radius Relation of Young Stars	4
Lacy, John	F	Gas Motions in the Central Parsec of the Milky Way Galaxy	3
Lambert, David	F	Fluorine in Globular Clusters	2
Lambert, David	F	Search for Li-rich giants among K giants with infrared excess.	3
Mace, Gregory	PD	Unearthing Ophiuchus Binaries for GAIA to Appraise	3
Mann, Andrew	PD	Candidate Planets in the Upper Scorpius Star Forming Region	2
McKay, Adam	PD	High Spectral Resolution Observations of Comet C/2013 X1 (PanSTARRS)	0.75
McLane, Jacob (Jaffe)	GS	Using Young Stellar Objects as a Test for Pre-Main Sequence Stellar Evolution	3
Noyola, Eva	Res	Medido: Dark matter in Low Dispersion Systems	6
Rizzuto, Aaron	PD	Calibrating Young Stellar Models: Dynamical Masses and Magnetic Fields	1
Sneden, Chris	F	High-Resolution Infrared Spectroscopy of Giants in the Inner Bulge	6
Sneden, Chris	F	Carbon Isotopic Ratios in Red Giants with High Lithium Abundances	2
Wheeler, Chris	F	Late-time Halpha Observations of Type I Supernovae	4
1 August 2016 through 30 November 2016			
Cochran, William	RS/F	K2 Follow-up Observations	10
Endl, Michael	RS	The McDonald Observatory Exoplanet Legacy Survey	12
Johnson, Marshall (W. Cochran)	GS	Confirmation of KELT Transiting Planet Candidates using Doppler Tomography and Constraining the Mass-Radius Relation for M Dwarfs	5
Kraus, Adam	F	Is there a Columba Moving Group?	7
Lambert, David	F	Heavy elements in very young open clusters	4
Lambert, David	F	Search for Li-rich giants among K giants with infrared excess	4
Livermore, Rachael	PD	The Faint End of the Lyman alpha Luminosity Function at 2 < z < 3.8	6
McQuinn, Kristen	RS	McDonald Observatory: Characterizing a New Population: Blue Diffuse Dwarf Galaxies	5
Ramirez, Ivan	PD	The TAURUS Program	2
Rizzuto, Aaron	PD	Unveiling the Kinematic Substructure of the Taurus Star-Forming Region	14
Wheeler, Craig	F	Late-time Halpha Observations of Type I Supernovae	7

University of Texas at Austin 2.1-m Programs			
1 December 2014 through 31 March 2015			
PI	**Status**	**Proposal Title**	**Nights**
Robinson, Edward	F	Optical Photometry of X-Ray Binary Stars	7
Gyorgey Ries, Judit	Res	Small Near-Earth Object Follow-up and confirmation	14
Bell, Keaton	GS	Detailed Time Series Photometric Study of Variable White Dwarf	27

(Winget)		Systems	
Barnes, Thomas	RS	Investigations of Possible Binary RR Lyrae Variables	6
1 April 2015 through 31 July 2015			
Robinson, Edward	F	Optical Photometry of X-Ray Binary Stars	7
Rizzuto, Aaron	PD	New Young Stars in the Upper Scorpius K2 Field	10
Bell, Keaton (Winget)	GS	Time Series Photometry of Pulsating, Extremely Low-mass White Dwarfs	29
Gyorgey Ries, Judit	Res	Small NEO astrometric confirmation and follow-up	14
Barnes, Thomas	RS	Investigations of Possible Binary RR Lyrae Variables	3
1 August 2015 through 30 November 2015			
Bell, Keaton (Winget)	GS	Asteroseismic Survey of Low-Mass White Dwarfs	28
Gyorgey Ries, Judit	Res	Small Near-Earth Object Follow-up and confirmation	14
1 December 2015 through 31 March 2016			
Barnes, Thomas	RS	Investigations of Possible Binary RR Lyrae Variables	6
Winget, Don	F	Asteroseismic Survey of Extreme Mass White Dwarfs	28
Gyorgey Ries, Judit	Res	Small Near-Earth Object Follow-up and confirmation	16
1 April 2016 through 31 July 2016			
Winget, Don	F	Asteroseismic Survey of Extreme Mass White Dwarfs	26
1 August 2016 through 30 November 2016			
Bell, Keaton (Winget)	GS	Probing New Physical Domains with Time-Series Photometry of Pulsating White Dwarf Stars	28
Vanderbosch, Z. (Winget)	GS	Adding a filter wheel to the McDonald ProEM System	4

IX.D. Hobby-Eberly Telescope Dark Energy Experiment (HETDEX)

The new HET facility and VIRUS combine to provide a survey facility an order of magnitude more powerful than any in existence and a unique capability of executing blind spectroscopic surveys over large areas of sky. This capability has been developed, and its specifications flowed down from the requirements of the HETDEX project to detect on the order of a million LAEs in the epoch of maximum star formation activity in the Universe, to measure their large-scale structure distribution, and to analyze the resulting data to measure the expansion rate and angular diameter distance to sub-percent accuracy at z~2.5.

The resulting instrument properties and status of the hardware deployment are described above. The HETDEX survey has a primary spring field of 300 sq. degrees and an equatorial fall field of 150 sq. degrees. Observed with a 1/4.5 fill factor the total area observed will be 100 sq. degrees. The sensitivity of $3\text{-}4\times10^{-17}$ erg/cm^2/s in achieved in each 20-minute observation of three exposures and data from the early deployment of VIRUS units shows that this requirement is being met. The baseline survey is expected to take four years, with extensions possible beyond that. The HET Board has already allocated 1100 dark hours, about half the required total, and has committed that the survey will be completed. The DEX Coordination Committee (DCC), with members from each HETDEX participating institution, provides the partners with a voice in how the observations are planned and the data exploited. Fields can be observed for 10-months out of the year, and the HETDEX observations will dominate dark time when conditions are suitable. The transparency and image quality requirements for HETDEX observations are modest, and as a result, we expect to utilize large blocks of observing time leading to high efficiency.

The replicated nature of VIRUS and the resulting parallel data stream from the 156 spectral channels has enabled data analysis software to be developed over the last decade, starting with the single channel VIRUS prototype, which was used for the HETDEX Pilot Survey on the Harlan J. Smith Telescope. That software has evolved into the Cure reduction package, which is now being used as the basis for the analysis of early science data from the limited VIRUS already deployed. Since there is no *a-priori* knowledge of the location of the emission lines in wavelength or on the sky, we have to understand the noise characteristics of the data extremely well and object detection is based on a Bayesian approach that incorporates that knowledge to test whether the distribution of light between fibers is consistent with a source at a particular redshift and position on sky, given exterior information on photometric conditions and image size from the HET guiding system. Most of the fibers are observing sky, most of the time, which provides continuous measurement of the noise characteristics of all 15 million resolution elements in a single VIRUS exposure. Stars within the field of view provide simultaneous spectrophotometric calibration of each observation. Repeat observations of several calibration fields will aid in evaluating uniformity over the area and timeframe of the survey.
The survey will contain a million [OII]3727 emitters, and they will be separated from the LAEs based on deep, broad band imaging that is being obtained at the Subaru Telescope. Equivalent width is the primary criterion used for separation. The methodology has been demonstrated in the Pilot Survey. There is adequate imaging in place already to support the first year of HETDEX, being provided by the University of Tokyo, plus the extensive UV to far-infrared imaging obtained for the more limited SHELA area.

The [OII] population will provide an unprecedented dataset for studying the evolution of star formation at $z < 0.5$, particularly for the lowest mass galaxies. There is considerable synergy with the upcoming Westerbork APERTIF HI surveys. The Medium Deep Survey has been targeted to overlap half of the HETDEX Spring Field, and the intent is to use [OII] emitters from the HETDEX survey to stack the radio data and extend gas and star formation indicators to much fainter limits. Simulations of the baseline survey, compared to SDSS catalogs, indicate that ~50K stars and ~50K galaxies with $g<22$ will have spectra at $S/N>3$ per resolution element in HETDEX, along with ~10K nearby galaxies where there will be sufficient signal to resolve the galaxies, particularly in emission lines. HETDEX will be particularly powerful in selecting ~10K AGN at $z>2$ without the biases of color selection. In addition to the core science of the evolution of dark energy, measurement of the growth factor, and measurement of the curvature of the Universe, HETDEX will provide a tight upper limit on the total neutrino mass. Being a unique, blind spectroscopic survey, we expect serendipitous discoveries such as extremely metal-poor stars in our Galaxy.

IX.E. Instrumentation for Giant Magellan Telescope

The Giant Magellan Telescope will be the apex of the observing capabilities used by UT Astronomy program scientists (Sec. IV). GMT instrument development is being staged to match the technical development of the telescope and its adaptive optics (AO) system. Instruments selected for the first phase of GMT include the GCLEF highly-stable visible echelle high-resolution spectrograph and the GMACS wide field visible multi-object spectrograph. Also under development are the GMTIFS Near-IR IFU and Adaptive Optics Imager, the GMTNIRS high-resolution IR Echelle Spectrograph, which both utilize the AO system, and the Facility Fiber Optics Positioner MANIFEST. A Commissioning Camera, ComCam, will be used to validate the telescope instrument quality and the Ground-Layer AO performance. UT leads GMTNIRS and is a key player in the wide field capability enabled by MANIFEST. Engagement of UT faculty, researchers, students, and technical staff in developing instrumentation for GMT helps GMT to succeed by providing experienced instrument development resources and, in many cases, proven design concepts already deployed at McDonald Observatory. Engagement in GMT work enables our instrument developers to work on a frontier facility to address world-class scientific questions.

GMTNIRS

The GMT Near-IR spectrometer (GMTNIRS) is a 1.2 – 5 micron echelle optimized for studies of young stellar objects, debris disks, and protoplanetary systems. The GMTNIRS team is composed of scientists and engineers at the University of Texas, the Korea Astronomy and Space Science Institute, and Kyung Hee University. It will use Silicon immersion gratings to achieve high spectral resolution in a compact format. GMTNIRS makes use of the GMT AO system for all bands. Using a common 65 mas slit, GMTNIRS will deliver R = 60K (JHK) and 90K (LM) spectra over 5 (JHKLM) atmospheric windows. The whole JHKLM spectral range will be covered in a single observation leading to a single, fixed optical configuration. This combination of high spectral resolution and broad wavelength coverage represents an enormous gain in observing efficiency compared to current spectrographs that sample only a fraction of a band in a single setting.

The core technology of silicon immersion gratings for GMTNIRS has been demonstrated very successfully in the IGRINS spectrograph that has seen extensive use at the McDonald Observatory Harlan J. Smith Telescope. Work on GMTNIRS is focused currently on the development of the optomechanical design and development and testing of the silicon immersion gratings. Immersion gratings are prism-shaped reflection gratings in which the incident light is diffracted on the grating surface inside a medium like silicon. The high refractive index of silicon makes the effective wavelength inside the grating shorter by a factor of 3.4, boosting the resolving power by this factor (or alternately shrinking the size of the spectrograph needed to attain high resolving power). The gratings can also be ruled coarsely enough to permit continuous wavelength coverage at high resolution on 2K detectors, even at long wavelengths. We are manufacturing 10 cm R3 immersion gratings for IGRINS through conventional contact lithography, and are scaling the grating size up to that required for GMTNIRS (20 cm for LM bands).

GMTNIRS will permit GMT to make significant and unique contributions to studies of many aspects of the formation, evolution, and nature of stars and planetary systems, and the abundances and aspects of stellar evolution in our own and nearby galaxies. IGRINS has proven quite revolutionary in providing both high spectral resolution and broad wavelength coverage, and having an equivalent capability on an ELT will offer unique science opportunities to the GMT community. The greatest challenge for the project is the long timeframe and drawn-out funding stream from GMTO. Having sufficient funds to keep the team together is a problem, and we are seeking alternate funding models to advance this instrument.

GMT Wide-Field Multi-Object Spectroscopy

We are interested in advancing the wide field capabilities of the GMT since it will have the largest field of the ELTs at 20 arcminutes. There is considerable interest in having an early wide field natural seeing capability for GMT during its first phase, and we have formed a working group with members from the Australian community, Korea, UT Austin and TAMU. The aim of this initiative is to develop the concepts for a Wide Field (WF) Facility that includes the corrector, the fiber positioner, and early instrumentation. It is expected that the WF Facility will complement the GMACS moderate-field imaging spectrograph being developed by TAMU, by providing a wider field of view, higher spectral resolution through image slicing, and adaptability to different wavelength ranges and resolutions.

Parts of this system are being developed and prototyped. The Australian community has proposed the MANIFEST system for fiber positioning over this field of view, based on the “starbug” concept. They are deploying a prototype system on the UK Schmidt called TAIPAN, as a demonstrator. At UT, we have proposed a novel segmented corrector concept, the Arrayed Wide-Areal Correction System (AWACS), that could reduce the cost of the wide field corrector for GMT by a factor of ten, and make it technically feasible. This novel concept harnesses our experience in replicated optics to provide ~400 arrayed correctors each utilizing small optics and a single astigmatic element to give ~60% fill factor over the full 20 arcminute field. The 5 arcminute imaging field of GMACS would sit in a hole in the center of AWACS and would not need correction. We have a proposal submitted to the Air Force for the development of the concept and an NSF ATI proposal pending to deploy a first AWACS system on the 2.7-m McDonald Harlan J. Smith Telescope. Once the design is proven, it can be adapted to GMT with little additional design work.

The other potential UT contribution to the GMT WF Facility is the replicated unit spectrograph VIRUS2. We have obtained an NSF MRI grant for this next generation modular replicated spectrograph that will provide a fully-filled integral field of 2.5 arcminutes, with 2.6 arcsecond spatial resolution and coverage from 370 to 950 nm for the Harlan J. Smith Telescope. VIRUS2 is fed by 1641 fibers split into three buttable IFUs with near 100% fill factor. The VIRUS2 spectrograph consists of 9 spectrograph units, fed by a novel dichroic beam splitting switchyard, which is part of the fiber feed. This switchyard builds on our fiber optics experience from LRS2 and VIRUS. Development of VIRUS2 will put it on the telescope in 2019. It will also support a multi-fiber feed from 75 19-element deployable-IFUs (dIFUs) as part of the AWACS initiative. The dIFU feed can be added with modest additional effort due to our in-house expertise in fiber cable construction.

The novel doublet microlens array (MLA) input for VIRUS2 is adaptable to any telescope with a focal ratio between f/8 and f/10, so it could also be coupled directly to GMT without any changes. The large grasp of VIRUS2, facilitated by this MLA design and the replicated units, already qualifies it as an ELT class instrument. The lens elements would be 0.3 arcsec on GMT, ideally sampling the native site seeing, and the IFU would have a ~15 arcsecond field of view. Alternatively, VIRUS2 could be fed by a multi-object feed with ~200 small 7-element dIFUs of 1 arcsec diameter that would slice the images of small objects to maintain spectral resolution. Coupled with MANIFEST, this mode would provide an early wide field multi-object capability for GMT with a resolving power, R~2300, and wide wavelength coverage. VIRUS2 will have been used at McDonald for several years before GMT first light and could be moved relatively easily due to its modular design.

The GMT WF working group will meet in February 2017 in Australia to examine the science case and to develop a proposal to GMT. There is particular interest at UT in red coverage for follow-up of high redshift galaxies from JWST, ALMA, and the SKA pathfinder surveys and in utilizing a broad-band integral field spectrograph to detect exoplanet atmospheres. With 2023 first light for GMT, we have time to develop the WF facility by leveraging ongoing initiatives (TAIPAN, AWACS, VIRUS2), so that a first phase could be deployed potentially without significant direct funding from GMT.

IX.F Instrument Development

McDonald Observatory has extensive facilities and skilled personnel with great experience in developing innovative telescopes and instrumentation for optical and near-infrared observing. The Astronomy program is a recognized leader in instrumentation development and training in observing and instrumentation.
In Austin, we have more than five thousand square feet of machine shop, clean room, electronics benches, mechanical assembly and optical test facilities. The large well-equipped machine shop has two 3-axis computer numerical control (CNC) mills, a CNC lathe, and wire electrical-discharge machine (EDM), which allow complex parts to be manufactured, together with a number of manual machines. We have a FARO coordinate measuring machine (CMM) arm with 25 micron accuracy for evaluating the alignment of assemblies and for checks, and a Laser Tracker (LT) with 10-micron precision. For optical testing, commercial cameras, Video Alignment Telescopes and Shack Hartmann Wavefront sensors with complete control and analysis software are available as needed. Fully equipped electronics test benches are available with test equipment appropriate for both digital and analog circuit testing. A detector lab with a 120 square foot class-100 clean room, electrostatic discharge protection and complete vacuum and cryogenics facilities is available. Additional class 1000 clean rooms, vacuum ovens, a plasma cleaner, and large ultrasonic cleaners have been installed for the IGRINS and VIRUS projects. We also have a major technology facility for construction and test of fiber optics, integral field units and VPH gratings, developed as part of the VIRUS and LRS2 projects. It is in a large, clean environment of 30-m length.

We have often used the McDonald telescopes, and the Harlan J. Smith Telescope in particular, as a test bed for innovative and powerful instruments and technologies with application to larger facilities. These initiatives have included IGI (one of the first applications of volume phase holographic grisms), The Mitchell Spectrograph (aka VIRUS-P, the VIRUS replicated spectrograph prototype), IGRINS (prototype immersed echelle NIR high resolution spectrograph), 2dCoude (an efficient white pupil cross-dispersed echelle high resolution spectrograph), and in the future VIRUS2 (which can also have application on GMT and is described more extensively above). These initiatives have provided the Harlan J. Smith Telescope with forefront instrumentation and kept it competitive with other facilities. The Harlan J. Smith Telescope gives us the ability to develop new instrumentation concepts at lower cost and to have access to significant amounts of telescope time for demonstration and science applications. It also provides a valuable training platform for the next generation of observers and instrumentalists.

Student training is also an integral part of our instrumentation program. Currently, we have two graduate students and five undergraduates involved directly in instrumentation from component testing, through assembly and commissioning, and this has been typical of the past 20 years. As an example of how graduate students are given leadership roles in forefront instrumentation projects, HET LRS2 formed the centerpiece of the PhD Thesis of Taylor Chonis, who graduated in 2015. The project allowed Taylor to obtain a comprehensive training in all aspects of modern instrument development. It is rare in most programs that a student can play a central role in building a facility class instrument for a large telescope. Taylor has now joined Ball Aerospace as a Systems Engineer (his dream job) and is working on the final testing of JWST. Taylor's experience is quite typical of a student who gained great practical experience as a result of our instrument programs, and who went on to a strong career in astronomy or industry. Other graduate students include Marsha Wolf (UW-Madison), Joe Tufts (STA), Josh Adams (ASML), Guillermo Blanc (U. Chile), Jeremy Murphy (Princeton), and earlier Richard Stover (UCO), Steve Vogt (UCSC), Chuck Claver (LSST), and Anjum Mukadim (UW).

Table IX-4

Person and Title	Years with McDonald	Tools & Skills	Major Projects
Bruce Campbell (CNC Machinist)	6	Program and operate CNC mills, lathe, and wire EDM (Electrical Discharge Machining), and manual machines to fabricate custom high precision parts from solid models and drawings	HETDEX, VIRUS, HET HRS, IGRINS, DIAFI
Niv Drory (Research Scientist)	3	Project planning, management, Software: C/C++/Python, Scientific Data Analysis; Instrument/Telescope Control Systems; Instrument science: design, verification, validation of instrumentation concepts in the science context. Hardware: Fiber and IFU systems for astronomy	VIRUS, VIRUS2, HET WFU Telescope control system (TCS), Cure reduction pipeline for VIRUS; SDSS-IV/MaNGA
Doug Edmonston (Tech Staff Asst V)	34	Electronic schematic and PCB CAD, PCB assembly, electronics and cable construction, lab computing, (OrCAD, SMD workstation, E-tech workbench, Windows)	HRS, DIAFI, VIRUS-P, VIRUS, CCDs, TS2
John Goertz (Tech Staff Asst V)	11	Fabricate parts, maintain public telescopes on campus, maintain drawings, generate drawings and designs, interfaces with outside shops	VIRUS-P, VIRUS, HRS, Public Telescopes

Person and Title	Years with McDonald	Tools & Skills	Major Projects
John Good PE (Engineering Scientist, Mechanical Eng.	28	3D design, FEA, CMM, laser tracker, optics handling, project management (SoW, specifications, budgets, schedules, reviews)	2D Coude, HET enclosure, coating facility, tracker, WFC, EXES, VIRUS-P, VIRUS, IGRINS DCT
Gary Hill (Research Professor)	28	Instrument conceptualization, science flow-down, optomechanical design, photonic components, project management and fundraising; student supervision	IGI, IGP, ROKCAM, CoolSpec, LRS, VIRUS-P, VIRUS, LRS2, HET WFU
Kenneth Hope (CNC Machinist)	3	Program and operate CNC mills, lathe, and wire EDM (Electrical Discharge Machining), and manual machines to fabricate custom high precision parts from solid models and drawings	HETDEX, VIRUS, HET HRS, IGRINS, DIAFI
Ron Leck (Senior Software Engineer)	9	Software development (C/C++, Matlab/Simulink, dSPACE, Python, Linux, TCL, QT Gui)	2.1-m Argos, HET louver automation, HET WFU tracker motion control system
Hanshin Lee (Research Scientist)	8	Optical engineering. Optical design and analysis (Zemax, MATLAB), data reduction, simulation (C++, Python); photonic components; alignment of optomechanical assemblies and testing	HET WFC, HET WFU, VIRUS, LRS2, VIRUS2, IGRINS, GMTNIRS, AWACS
Phillip MacQueen (Sr. Research Scientist)	30	Spectroscopic and imaging observer, instrument design, electronic engineering, optical design, mechanical design, control software, simulation software, vacuum, and cryogenics	TS2, CCDs, HET 1, HET WFC, HET WFU, VIRUS-P, VIRUS, HRS, DIAFI
Rupert Ruiz (Scientific Instrument Maker II)	8	Program and operate CNC mills, lathe, and wire EDM (Electrical Discharge Machining), and manual machines to fabricate custom high precision parts from solid models and drawings	HETDEX, VIRUS, HET HRS, IGRINS, DIAFI
Sam Odoms (Senior Software Engineer)	38	Telescope, guider, instrument, & detector control software (includes C, Python, Linux, assembler, TCL)	CCDs, HRS, TS2, DIAFI, GUIDERS
Trent Peterson (RESA II, Lab Manager)	4	Cryogenic and vacuum systems, data acquisition, optical alignment, task management	VIRUS, CHILI, LRS2, VIRUS2
Jason Ramsey (Engineering Scientist, Software Engineer)	4	Software definition and development, instrument control (C++, Python, Linux, SVN, Matlab, ZMQ)	HET WFU, HET TCS, VIRUS, LRS2, VIRUS2
Brian South (RESA III, Mechanical Engineer)	8	CAD optomechanical design, FEA, electromechanical design, optical fibers (Inventor, Solid Works, CMM, CFD)	HRS, TS2, CCDs
Joe Strubhar (Mechanical Engineer)	10	CAD optomechanical design, FEA, electromechanical design, optical fibers (Inventor, Solid Works, CMM)	HRS, DIAFI, IGRINS, GMTNIRS, VIRUS-P

Person and Title	Years with McDonald	Tools & Skills	Major Projects
Brain Vattiat (RESA V, Mechanical Engineer)	8	CAD design and instrument control (Solidworks, Labview, Laser Tracker, Faro CMM)	VIRUS-P, VIRUS, HETDEX, CHILI, LRS2, VIRUS2
Gordon Wesley (RESA V, Mechanical Engineer)	23	Mechanical and electrical design, controller programming, supervise machine shop, maintain CAD software (Inventor and Solid Works) and design file vaults, support Mt. Locke staff and telescopes	HETDEX, VIRUS, HRS, DIAFI, VIRUS-P, Machine Shop Upgrades, HET MI Segment Jack

Section X. Organization and Governance

X.A. Organizational Structure

The Department of Astronomy and McDonald Observatory constitute the pillars of the UT Astronomy program, and they work synergistically to promote excellence in research, education, and public outreach.

The Astronomy Department comprises over 200 members, including 19.5 tenured/tenure-track (TTT) faculty members (with one faculty member on 50% phased retirement), two research professors (holding a joint appointment with the Observatory), four Emeritus faculty members, one lecturer, 13 postdocs, 35 graduate students, 129 undergraduate majors, and four main support personnel.

McDonald Observatory staff is comprised of ten PhDs with responsibilities for Observatory work, eleven PhDs performing independent research, 96 support personnel, both in Austin and at the Observatory site in west Texas, and a number of research associates and affiliates with less than 25% time appointments.

The Department of Astronomy and the administrative offices of McDonald Observatory at The University of Texas at Austin are located on the 13th, 15th, 16th, and 17th floors in the Robert Lee Moore Building (RLM) on the UT Austin campus. The Chair of the Department of Astronomy (Dr. Shardha Jogee) and the Director of McDonald Observatory (Dr. Taft Armandroff) hold offices located on the 15th floor of RLM. Both the department and the observatory are under the College of Natural Sciences.

The Department and Observatory jointly lead a top-tier research program in frontier areas of astronomy, including cosmology, galaxy formation and evolution, black holes, dark matter, dark energy, star formation and stellar evolution, chemical evolution, planetary systems, and instrumentation. The Astronomy Department is responsible for advancing our research program and overseeing the undergraduate (Section VI) and graduate (Section VII) educational programs. McDonald Observatory provides cutting-edge observational facilities and instrumentation (Section IX) and works with the Astronomy Department to lead a far-reaching education and public outreach program (Section IV.G). Our Astronomy program benefits immensely from the support, advocacy, and insights of our remarkable Board of Visitors (Section IV.H).

As shown by the Astronomy Department organizational chart (Figure X-1), all faculty members report to the Department Chair. Postdocs and researchers employed by faculty members report both to the faculty and Department Chair. Research scientists, associates, fellows, and affiliates, as well as other observatory staff report to the McDonald Observatory Director (Figure X-5 and X-18). Many of the administrative staff are shared by the Astronomy Department and McDonald Observatory (Sections X.E and X.F).

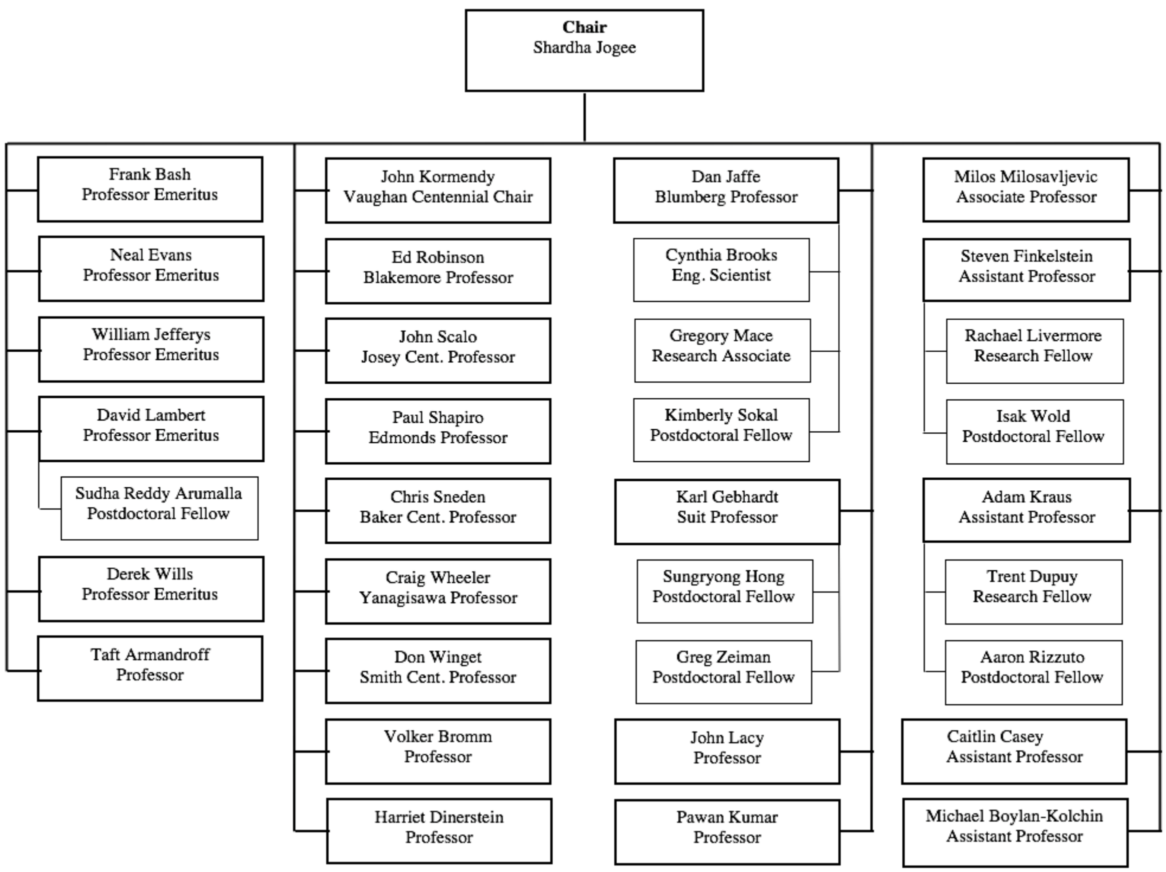


Figure X-1: Faculty Organization Chart for the Department of Astronomy. All faculty members report to the Department Chair. Postdocs and researchers employed by the faculty report to the faculty and Department Chair

X.B. Governance Policies and Procedures

Department of Astronomy Governance Policies and Procedures

The governance structure of the Department of Astronomy outlined below conforms with the Rules and Regulations of the Board of Regents of The University of Texas at Austin, the Handbook of Operating Procedure of The University of Texas at Austin, and the Policies of the College of Natural Sciences.

The Voting Faculty votes on important matters, including the strategic plan of the department, research initiatives, faculty hires, allocation of resources, and matters related to the graduate and undergraduate programs. The Voting Faculty consists of all persons officially appointed to the faculty as Professors, Associate Professors, Assistant Professors, and Lecturers, with at least 50% appointment, who are tenured or receiving probationary credit toward tenure. Faculty with less than 50% appointment, as well as Research Professors of all ranks, and Emeritus, Retired, Visiting, and Adjunct Faculty, shall be accorded voice but not vote at faculty meetings.

The Budget Council consists of all members of the Voting Faculty with tenure. The Senior Budget Council consists of all members of the Voting Faculty who are Full Professors. The Budget Council votes on promotion to tenure, the Senior Budget Council votes on promotion to Full Professor.

The Endowment Holders comprise all members of the Voting Faculty who hold endowed Chairs or Professorships.

The Graduate Studies Committee (GSC) consists of all Voting Faculty and research staff members who have an interest in co-supervising graduate student research.

The Undergraduate Studies Committee (UGSC) consists of all Voting Faculty and research staff members who have an interest in co-supervising undergraduate student research.

The Department Chair: The Voting Faculty recommends to the Dean a faculty member who is a Full Professor for appointment as Chair. The candidate is selected based on an election by a simple majority of the Voting Faculty. The election is administered by current Chair unless the current Chair is a candidate, in which case the election is administered by the Chair of the Faculty Evaluation Committee (defined below). Only Full Professors are eligible for this office.

The Faculty Evaluation Committee consists of five tenured members of the Voting Faculty who are elected by all members of the Voting Faculty. The committee provides the annual performance reviews and the category ratings of each faculty member to the Department Chair. It also recommends to the Department Chair merit raises for all faculty members, except those who report directly to the Dean. It also provides advice on workloads, Third Year Reviews, promotions, prizes, faculty leaves, Chair's Fellowships, and any similar matters identified by the Chair.

Astronomy Program Committees: The Department Chair appoints the Associate Chair and members of all departmental committees, except the Faculty Evaluation Committee. Some joint Department/Observatory committees are assigned by the Department Chair and the McDonald Observatory Director. A partial list of committees is provided below, and a full list can be found at http://www.as.utexas.edu/astronomy/2016-17Committees.pdf

- **The Graduate Studies Executive Committee (GSEC**) consists of the Chair of Graduate Studies, a Graduate Advisor, and at least two other members, one of whom may be the Assistant Graduate Advisor. The Department Chair and Associate Chair are ex-officio members of the GSEC.
- **The Undergraduate Studies Executive Committee (UGSEC)** consist of the Chair of the UGSC, the Undergraduate Advisor, and at least two other members, one of whom may be the Assistant Undergraduate Advisor. The Department Chair and Associate Chair are ex-officio members of the UGSEC.
- **The Graduate Admission Committee** recommends the admission of graduate students and helps recruit them.
- **The Teaching Peer Review and Awards Committee** reviews teaching performance of all faculty members periodically and recommends faculty members for teaching awards.
- **The Cox Committee** makes advisory recommendations to the Department Chair on the allocation of Research funds from the Cox Endowment if such funds are deemed to be available by the Department Chair.
- **The Office Space Committee** advises the Department Chair on office space needs of the various groups in the department.
- **The Postdoc Mentoring Committee** mentors postdoctoral fellows and provides advice on career and professional development.

McDonald Observatory Governance Policies and Procedures

The McDonald Observatory Director constituted the McDonald Observatory Research Scientist Evaluation Committee in February 2016. The Committee assists the Director in the evaluation of the Research Scientists, Senior Research Scientists, Research Fellows, and Research Associates. The Committee is particularly important in the evaluation of candidates for promotion to Research Scientist and Senior Research Scientist. In addition, the Committee assists the Director in the annual process to evaluate requests for zero-percent time appointments. The Committee members are Anita Cochran, Gary Hill, Matthew Shetrone, and Chris Sneden; it is Chaired by William Cochran.

The McDonald Observatory Director also constituted the McDonald Observatory Faculty Advisory Committee. The Committee assists the Director in engaging the faculty and research scientists in the use of McDonald Observatory and GMT. The Committee also assists in the scientific prioritization of McDonald Observatory activities. The Committee members are Caitlin Casey, Steven Finkelstein, Karl Gebhardt, Adam Kraus, and Chris Sneden.

The HET also has a Users' Committee that has representation from all of the HET institutions. UT members of the HET Users' Committee are William Cochran, Steven Finkelstein, Karl Gebhardt, Gary Hill (ex officio for VIRUS), Hanshin Lee (ex officio for LRS2), Phillip MacQueen (ex officio for HRS), and Matthew Shetrone (ex officio as Lead Resident Astronomer).

X.C. Faculty Endowments and Allocation Process

The Astronomy Department has nine endowed Professorships and three endowed Chairs (Table X-1). Only faculty members at Full Professor level are eligible for Endowed Professorships and Endowed Chairs. Decisions on the recipient of an endowed Professorship are made through votes of the current endowment holders, defined as all members of the Voting Faculty who hold endowed Chairs or Professorships. Decisions on the recipient of an endowed Chair are made through votes of the Senior Budget Council.

Table X-1: Department of Astronomy Endowed Chairs and Professorships

Faculty Name	Rank	Endowed Chair/Professorship
Armandroff, Taft	Director, Professor	Frank and Susan Bash Endowed Chair
Gebhardt, Karl	Professor	Herman and Joan Suit Professorship in Astrophysics
Jaffe, Daniel	Professor, Vice President for Research	Jane and Roland Blumberg Centennial Professor in Astronomy
Kormendy, John	Professor	Curtis T. Vaughan, Jr. Centennial Chair in Astronomy
Robinson, Edward	Professor	William B. Blakemore Professor in Astronomy
Scalo, John	Professor	Jack S. Josey Centennial Professor in Astronomy
Shapiro, Paul	Professor	Frank N. Edmonds, Jr. Regents Professor in Astronomy
Sneden, Christopher	Professor	Rex G. Baker, Jr. and McDonald Observatory Centennial Research Professor in Astronomy
Weinberg, Steven	Professor (0% Appointment)	Jack S. Josey-Welch Foundation Chair in Science and Regental Professor
Wheeler, J. Craig	Professor	Samuel T. and Fern Yanagisawa Regents Professor in Astronomy
Winget, Donald	Professor	Harlan J. Smith Centennial Professor in Astronomy
Vacant	Professor	Edward Randall Jr. M.D. Centennial Professor in Astronomy
Vacant	Professor	Isabel McCutcheon Harte Centennial Chair in Astronomy
Emeritus Endowed Chairs and Professorships		
Evans, Neal	Professor Emeritus	Emeritus Edward Randall Jr. M.D. Centennial Professor in Astronomy
Lambert, David L.	Professor Emeritus	Isabel McCutcheon Harte Centennial Chair in Astronomy

X.D. Colloquia, Lecture Series, Seminars

Antoinette de Vaucouleurs Lectureship and Medal

This memorial lectureship was established in 1990-91 to honor the late University of Texas Astronomy Department Research Scientist Associate Antoinette de Vaucouleurs. The prize was endowed by private gifts and matching funds from the Board of Regents of the University of Texas and is awarded annually to an "outstanding astronomer (Figure X-2) in recognition of a lifetime of dedication to astronomy". The recipient visits the Astronomy Department for a few days and gives both a science seminar as well as a public-level talk and receives a $5000 honorarium and medal. A list of recent recipients is shown in Table X-2.

Figure X-2: Dr. Adam Riess, winner of the 2011 Nobel Prize in Physics, receives the 2015-2016 Antoinette de Vaucouleurs Medal from the Astronomy Department Chair, Shardha Jogee. *(Photo credit: Lara Eakins)*

Beatrice M. Tinsley Centennial Visiting Professorship

The Tinsley Visiting Professorship (Table X-2) was created in honor of the late Beatrice M. Tinsley who received her PhD in Astronomy from the University of Texas in 1967 and passed away at the young age of 40. The Visiting Professorship was created through private donations and a matching grant from The University of Texas at Austin in 1982-83. The Professorship allows the Astronomy Department to invite eminent astronomers to visit and work with our faculty and research scientists for approximately a month to facilitate longer and more productive collaborations. The recipient receives a $1000/week honorarium and has their travel and lodging covered.

Tinsley Scholars

The Tinsley Scholars program was created in 2007-08 as an addition to the Tinsley Visitor Program and invites early-career scientists (Table X-2) to visit the department for approximately a week. They receive an honorarium of $1000, and their travel and lodging are covered. Each of the research groups in the Astronomy program chooses a visitor in their field, so we usually host up to six Tinsley Scholars a year. The Tinsley scholars typically give the weekly colloquium talk and often an additional seminar presentation during their visit.

Colloquium Program

The Department of Astronomy hosts a weekly colloquium during the academic long semesters that invites a guest speaker to meet with faculty, researchers, postdocs, and graduate students and give a talk on their current research in their field of expertise. A typical colloquium speaker visits

Austin for one or two days and has their travel and lodging covered. In the 2014-15 academic year, we hosted a total of 31 colloquium speakers, 29% of whom were women and 71% male. In 2015-16, we hosted 27 speakers and got closer to gender parity with 44% women speakers and 56% male.

Table X-2: Recent Distinguished Lecturers

Antoinette de Vaucouleurs Medalist				
Date	**Name**	**Affiliation (at time of award)**	**Title (at time of award)**	**Research Area**
Mar. 2011	Robert P. Kraft	University of California, Santa Cruz	Professor Emeritus (UC Santa Cruz) and Astronomer Emeritus, UC Observatories/Lick Observatory	Metal-poor stars, Novae
Apr. 2012	Wendy L. Freedman	Carnegie Institution for Science	Crawford H. Greenewalt Chair and Director of Carnegie Observatories	Observational cosmology, Hubble Constant
Feb. 2014	Robert C. Kennicutt, Jr.	Institute of Astronomy at the University of Cambridge, England	Plumian Professor of Astronomy and Experimental Philosophy and Head of the School of Physical Sciences	Extragalactic Astronomy, Cosmology, Galaxy formation and evolution
Dec. 2014	Claudia Megan Urry	Yale University	Israel Munson Professor of Physics and Astronomy, Director - Yale Center for Astronomy and Physics, President - American Astronomical Society	Galaxy Evolution, AGN
Dec. 2015	Adam Riess	Johns Hopkins University and the Space Telescope Science Institute	Bloomberg Distinguished Professor, the Thomas J. Barber Professor in Space Studies at the Krieger School of Arts and Sciences, the Krieger Eisenhower Professor of Physics and Astronomy (Johns Hopkins), Senior Science Staff (STScI), Nobel Laureate	Cosmology, Dark Energy
Tinsley Visiting Professor				
2011	Lars Bildsten	Kavli Institute for Theoretical Astrophysics, University of California - Santa Barbara	Wayne Rosing, Simon and Diana Raab Chair in Theoretical Astrophysics	White dwarf stars, Type Ia Supernovae

2011	Charles Steidel	California Institute of Technology	Lee A. DuBridge Professor of Astronomy	Observational cosmology, Galaxy formation

Tinsley Visiting Professor				
2012	Andrea Ferrara	Scuola Normale Superiore, Pisa, Italy	Professor	Observational cosmology
2014	Mark Dickinson	National Optical Astronomy Observatory (NOAO)	Associate Astronomer	Galaxy formation and evolution, AGN, High-Z galaxies
2015	Sera Markoff	University of Amsterdam	Associate Professor	Accretion and jet production of black holes, High energy astrophysics
Tinsley Scholars				
Fall 2011	Ilaria Pascucci	Lunar and Planetary Laboratory, University of Arizona	Assistant Professor	Formation and evolution of planetary systems, Exoplanets, Astrobiology
Fall 2011	Marc Sarzi	University of Hertfordshire	STFC Advanced Fellow and Senior Lecturer	Early-type galaxies
Fall 2011	Naveen Reddy	University of California, Riverside	Assistant Professor	Galaxy formation and evolution, Star formation, High-Z galaxies
Spring 2012	Amanda Karakas	Australian National University	ARC Future Fellow	Stellar Astronomy and Planetary Systems
Spring 2012	Katrien Kolenberg	Harvard-Smithsonian Center for Astrophysics	Marie Curie Fellow	RR Lyrae stars, Asteroseismology
Spring 2012	Daniel Apai	University of Arizona	Assistant Professor	Exoplanets, Astrobiology
Fall 2012	Brian Siana	University of California, Riverside	Assistant Professor	Galaxy formation in the early universe
Fall 2012	Gregory Sloan	Cornell University	Senior Research Associate	ISM, Atmospheres of cool stars, Star formation
Fall 2012	Casey Papovich	Texas A&M University	Associate Professor	Galaxy evolution and formation, Large-scale structure, Cosmology

Spring 2013	Gerald Handler	Nicolaus Copernicus Astronomical Center, Warsaw, Poland	Assistant Professor	Asteroseismology
Tinsley Scholars				
Spring 2013	Masami Ouchi	University of Tokyo, Japan	Associate Professor	Reionization, High-z galaxies, Large-scale structure
Spring 2013	Luisa Rebull	California Institute of Technology	Associate Research Scientist	Star formation and early evolution, Circumstellar disks
Fall 2013	Seth L. Redfield	Wesleyan University	Assistant Professor	ISM, Circumstellar disks, Stellar Atmospheres
Spring 2014	Klaus Pontoppidan	Space Telescope Science Institute	Associate Astronomer	Observational planet formation, ISM, Hi-res spectroscopy
Spring 2014	Anna Frebel	MIT	Assistant Professor	First generation stars and galaxies, Metal-poor stars
Spring 2014	Kevin Bundy	University of Tokyo	Assistant Professor	Galaxy formation and evolution, High-Z galaxies, AGN
Spring 2014	Gaspar Bakos	Princeton University	Assistant Professor	Exoplanets, Instrumentation
Spring 2014	Eugene Oks	Auburn University	Professor	Theoretical Atomic, Laser and Plasma Physics
Spring 2015	Stijn Wuyts	Max Planck Institute fur Extraterrestriche Physik	Junior Scientist	Formation and evolution of galaxies
Spring 2015	Rory Barnes	University of Washington	Assistant Professor	Habitability of Exoplanets
Spring 2015	Raffaele Gratton	Padua Astronomical Observatory, Instituto Nazionale di Astrofisica in Padova, Italy	Full Astronomer	Metal-poor stars, globular clusters
Fall 2015	Stella Offner	University of Massachusetts Amherst	Assistant Professor	Star formation

Fall 2015	Ethan Vishniac	Johns Hopkins University	Research Professor	Dynamics of magnetic fields in the accretion disks, stars, and galaxies
Tinsley Scholars				
Spring 2016	David Yong	Australian National University	Astronomer	Chemical evolution of star clusters and stellar populations
Spring 2016	William Bottke	Southwest Research Institute, Boulder	Senior Research Scientist	Formation and history of planetesimals, planets, and moons, Solar System small bodies
Spring 2016	Tiantian Yuan	Australian National University	Research Fellow	Galaxy formation and evolution, High-Z galaxies
Spring 2016	Kaitlin Kratter	University of Arizona and Steward Observatory	Assistant Professor	Star and planet formation

Research Seminars

Research in the Astronomy program is loosely divided into five research groups designated as the Extragalactic, Interstellar, Planetary Systems, Stars, and Theory groups. These groups each hold weekly seminars and receive research funds from the Department and Observatory, primarily designed to support research-related travel of graduate students.

To promote interaction between different research groups, some groups (e.g., Planetary Systems and Interstellar) hold joint seminars, and only a few research groups offer their seminar for credit each semester (e.g. Extragalactic and Theory in the fall semesters, Stars and Interstellar/Planetary Systems in the spring semester). We have also set up the Cosmos Seminar for interdisciplinary talks that cut across the interest of many research groups.

X.E. Staff, Space, and Budget for the Astronomy Department

Staff

The Department of Astronomy employs four full-time employees (FTE) and contributes partial funding to several McDonald Observatory staff positions that total 1 FTE. These administrative staff positions ultimately report to the Department Chair and Associate Chair, as shown in the Astronomy staff organization chart (Figure X-3). The solid lines represent direct reporting under the Department while the dotted lines represent indirect support from McDonald Observatory staff. The executive assistant (EA) maintains the overall operation of the Department and supervises three administrative support staff.

The purposes for each administrative position including the EA is as follows:

- **Executive Assistant:** Assist the Department Chair in daily operations, long-term planning, budget monitoring, correspondence, faculty liaison, and special events.
- **Administrative Program Coordinator:** Manages the visiting scholar and colloquium programs and is the initial point of contact for the all departmental constituents including, faculty, staff, students, and visitors.
- **Senior Administrative Associate:** Provides administrative support for the faculty and researchers and serves as the back-up assisting the Department Chair.
- **Academic Program Coordinator:** Coordinates all operations of the departmental academic programs and events, including supporting the undergraduate and graduate students.
- **Director of Development:** Evaluates cultivates, solicits and stewards major gifts for the McDonald Observatory and Department of Astronomy to advance the strategic fundraising goals.

While each of these staff members oversees specific job duties and constituencies, being a small department we must be flexible in assignments and work to cross-train our staff to step in and assist faculty and students in the absence of the assigned staff member. To be more proactive in staff assignments and managing deadlines, we are in the process of developing detailed guidelines and a master calendar for each position.

The Department advances educational services with 1 FTE and funds this service through the Instructional Resource Fees (IRF). The research associate reports to the Chair and provides support for undergraduate teaching, maintaining relationships with the K-12 teaching community within the State of Texas and maintains relationships with the astronomy education and public outreach community nation-wide. A technical staff assistant V under the engineering shop, and reporting to the Observatory, provide .1250 FTE to support the design, fabrication, and maintenance of the instruments used by the Department (Figure X-3).

The Department uses its indirect cost/overhead recovery funds to support 0.40 FTE towards the salary of our Director of Development who reports to both the Director of McDonald Observatory and the Chair. This position assists with the strategic fundraising program for the Department.

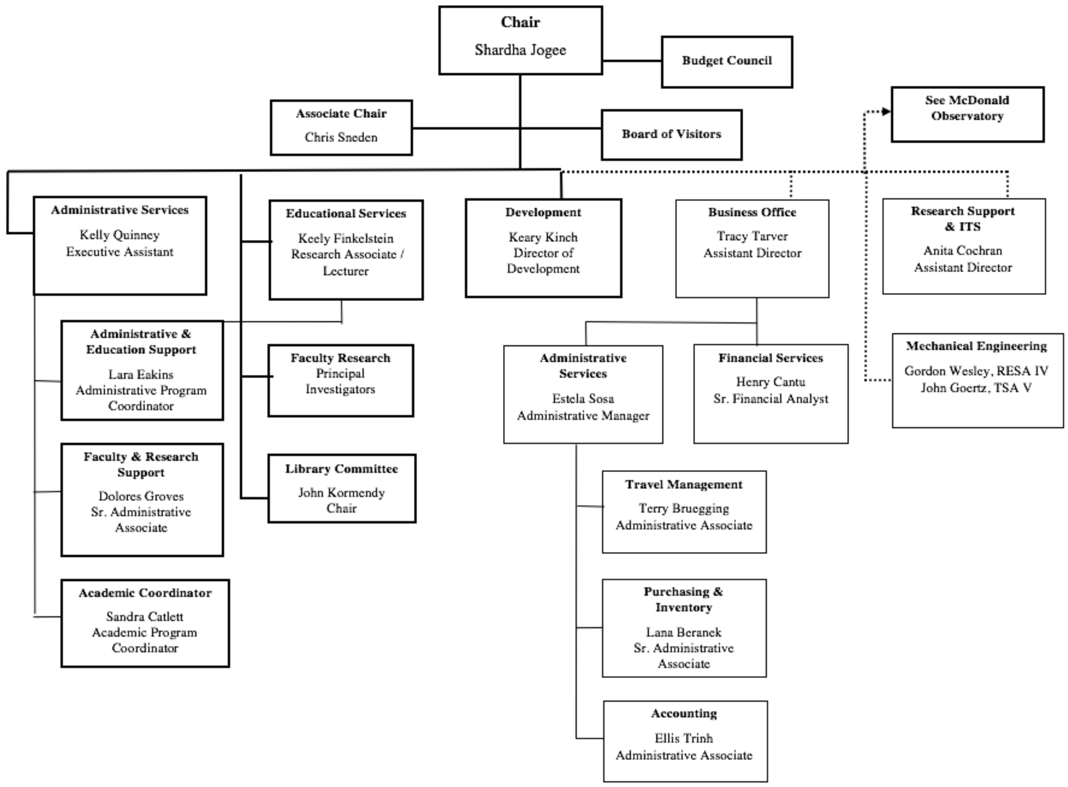


Figure X-3: Staff Organization Chart for the Department of Astronomy**.**

The Department further benefits from the availability of the Observatory's business office that provides services such as accounting, personnel, payroll, purchasing, and travel support. The Department pays for an additional .43 FTEs by contributing to the salaries of the financial analyst and the human resources and payroll administrator, whose supervisor reporting structure lies within the Observatory (Figure X-5).

Space

The administrative staff of both the department and observatory work closely together for both organizations – the Department of Astronomy and McDonald Observatory -Austin are co-located in Robert Lee Moore Hall (RLM). They occupy floors 15 – 17 and about 25% of the 13th floor. We also have some space on the second floor of RLM. In addition, McDonald Observatory occupies space in another building on University Avenue (UA9) for the Education and Outreach (E&O) office.

The Astronomy Department Chair's office and the McDonald Observatory Director's office occupy one wing of the 15th floor. The Chair's component includes the office of the Chair, the Chair's Executive Assistant, one Senior Administrative Assistant, an Administrative Program Coordinator and an Academic Program Coordinator. The Director's component includes the Director, the Director's EA, the Assistant Director for Research and the Austin office of the McDonald Superintendent. The development office occupies four offices on the 15th floor and works on development causes for the GMT, the Department and the Observatory.

The 15th floor also includes a general-purpose classroom used for classes and seminars, two conference rooms, an undergraduate research computer lab and the Peridier Library. We plan to replace the library with an expanded undergraduate research computer lab. The rest of the 15th floor contains the computer group and the computer server closet (part of the group reports to the College of Natural Sciences but are housed in RLM), faculty, postdoc and student offices.

The 16th floor includes many faculty, research scientist, postdoc and graduate student offices. In addition, it includes various labs including labs for the assembly of VIRUS and IGRINS and their successors, a clean room, a classroom for the instrumentation class, and a printer room. The computer switches and many compute nodes are also located on 16. There is a small, glass-walled conference room available for impromptu meetings.

The 17th floor is a mixture of academic and engineering purposes. It houses more faculty, research scientists, graduate students, and postdocs but it also includes our engineering group. This includes offices for the engineers plus several machine shops. The CCD lab is also contained in a lab on 17. In addition, Dan Jaffe's silicon immersion grating lab is on 17.

The 13th floor is to be the new home of the E&O office. In addition, there is the Observatory business office, which also serves the Department. This includes the Assistant Director for Administration, HR, accounting, travel, purchasing, and accounts payable. The mailroom is on the 13th floor, as is the break room. There is a classroom for the introductory lab class and school groups. A heliostat on the roof (14th floor) can project an image of the Sun in this classroom. One of the offices is currently being used by TAs but will be the office for an emeritus faculty member in the future.

Dedicated visitor offices can be found on the 16th and 17th floors and are used on a temporary basis to house our colloquium and seminar visitors. Long-term visitors are assigned offices based on availability during the time they visit and consist of a shared office.
The "optical tunnel" is located on the 2nd floor. This space has an optically isolated bench for aligning and testing instruments in a long, skinny space. We also have some workspaces with the welding shop on 2.

The UA9 space is a few blocks from RLM and houses the E&O office, though personnel should be moving to RLM in early 2017 so that they are in closer contact with the researchers and faculty. We will maintain the space at UA9 for now for storage of the overflow E&O materials.

Space is managed and assigned by the Department Chair after consultation with the Office Space Committee which is made up of the following representatives:

- Department Chair
- Department Executive Assistant
- Faculty Member appointed by the Chair
- Assistant Director for Research, McDonald Observatory
- Assistant Director for Administration, McDonald Observatory

- Research Engineer/Scientist Associate
- Graduate Student Representative
- Postdoc Representative

Each spring a call is made to the Astronomy program for office space requests. This call includes permanent office space for active faculty members, research staff, postdocs, and staff members. The graduate student representative manages the assignment of graduate student offices using an allocation provided by the Chair's Office. We also ask that any long-term visitor requests be made at this time so that we may allocate temporary visitor space for collaborators who will be visiting for an extended period. The space committee reviews all requests and makes recommendations of how to assign the office space to the Chair before the semester ends in May each year.

Budget

The Department of Astronomy's academic core funds come from the State of Texas' general revenue (consisting of state tax dollars appropriated to the University by the Legislature), and indirect cost (state funds) returned to the Department from income on contracts and grants. These state funds along with student fees are used to support the University's general educational and research operations. Together, these sources provided approximately $2.8M for the current year.

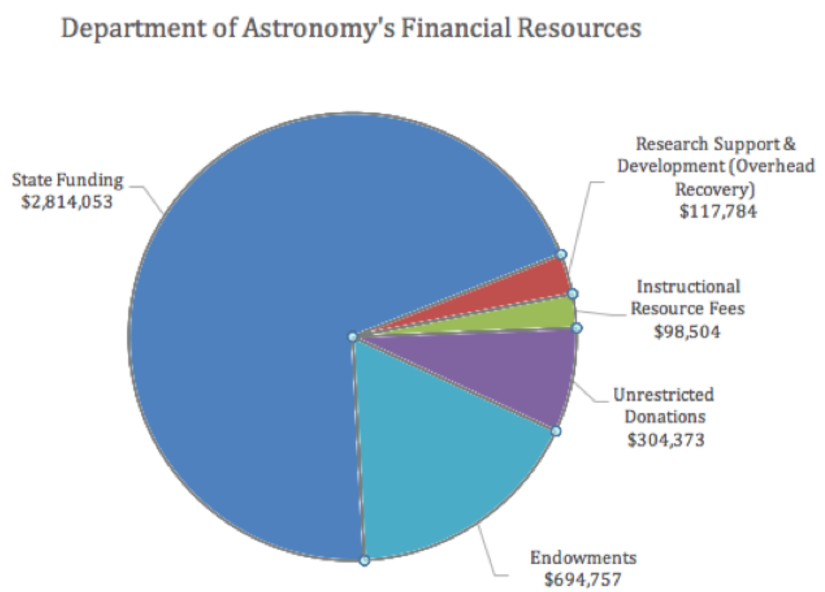


Figure X-4: Department of Astronomy's Financial Resources

Another substantial portion of our budget consists of funds that come from endowments and unrestricted donations. Typically, endowments are used to support salary supplements for endowed chairs and professorships, enhance operations, and provide for lectureships and scholarships. Unrestricted donations provide the Astronomy program with a pool of available funds used to promote excellence and provide for academic support. Together, these sources provided an income of approximately $1M. Figure X-4 illustrates our annual sources of income.

X.F. Staff, Space, and Budget for McDonald Observatory

Staff

In June 2014, Dr. Taft Armandroff began serving as Director of the McDonald Observatory, succeeding Dr. David Lambert. Dr. Armandroff's management team assists him with the management of the Observatory. Figure X-5 illustrates the management team in the highlighted boxes.

The Director and his management team, except for the Superintendent and the HET Facility Manager, primarily operate from The University of Texas at Austin central campus. The Superintendent and the HET Facility Manager live onsite at the Observatory in the Davis Mountains, Fort Davis, Texas. The Observatory currently employs the equivalent of 117 full-time employees (FTE) with 72 FTEs at the Observatory in west Texas and 45 FTEs in Austin. In addition to FTEs, the Observatory employs casual/hourly employees and students.

The following describes the functions of the Director's management team:

- **Director of Development**: There are two directors for development: one shared with the Department of Astronomy and the other dedicated to the Giant Magellan Telescope (GMT). These positions solicit, secure, and steward major gifts for the McDonald Observatory to advance strategic fundraising goals. The Observatory employs two full-time development assistants who focus on relations, memberships, and development. See Figure X-6, Director of Development.
- **Assistant Director for Research Support:** This position acts as the liaison with the scientific community, chairs the Telescope Allocation Committee, advises the director on astronomical issues such as telescope and instrument improvements and prepares various reports. Three named postdoctoral fellows report to this position. This person is also responsible for the supervision of the systems architecture and coordinates with the Center for Space Research. See Figure X-7, Assistant Director for Research Support.
- **Assistant Director for Administration**: This position acts as the liaison with all University administrative offices. This person advises the director on all administrative and financial matters for the Observatory and supervises a centralized Business Office consisting of 5 FTEs. See Figure X-8. This centralized office provides services to the Observatory as well as to the Department of Astronomy, and a few of the salaries are shared between both organizations. Services provided by the Business Office include human resources, payroll, compliance, legal agreements, accounts receivable and payable, procurement, travel management, contract and grant reporting, financial planning, reporting, and budgeting.
- **Assistant Director for Education and Outreach:** This position oversees McDonald Observatory's education and public outreach programs. This person is responsible for a total personnel and operational budget of approximately $2M a year including production

and distribution of the syndicated radio program StarDate and the bi-monthly, StarDate magazine; the operation of the Frank N. Bash Visitors' Center in Fort Davis, Texas serving ~90K people annually; publications, media relations, memberships and grant funding for public outreach and education program. See Figure X-9, Assistant Director for Education & Outreach, and Figure X-14, Frank N. Bash Visitor Center.

- **Chief Astronomer:** This position advises the Director on future major instrumentation and telescope projects as well as astronomical issues and directs major research. The Chief Astronomer is a key player and devotes a majority of his time to the HETDEX and VIRUS projects. This person works closely with the Chief Scientist and the Engineering Shop. See Figure X-10, Chief Astronomer, and Figure X-17, Hobby-Eberly Telescope Dark Energy Experiment (HETDEX).
- **Chief Scientist:** This position advises the Director on future major instrumentation and telescope projects as well as astronomical issues, leads the Observatory's activities in detectors (CCD Group) with 4 FTEs, and assist in managing the HET improvements and enhancements. See Figure X-11. Chief Scientist. This person works closely with the Engineering Shop (see Figure X-12) and the Chief Astronomer.
- **Superintendent:** This position is responsible for managing the daily operations of our remote facility (excluding the HET) in the Davis Mountains approximately 450 miles from central campus. The Superintendent's support team includes Administration (6 FTEs), Astronomers Lodge (4 FTEs), Observing Support (8 FTEs), Physical Plant (14 FTEs), Safety Office (2 FTEs), and the Visitor's Center (16 FTEs). The Superintendent further leads the Observatory's Tenant's Council, assists the Director with V.I.P. visits and preparations for the July Board of Visitors' meeting, acts as an ambassador for McDonald to west Texas, and maintains the west Texas operational budget. The Superintendent reports directly to the Director and coordinates all matters and decisions with the Director's respective Assistant Directors. See Figure X-13, West Texas Operations, Figure X-14, Frank N. Bash Visitors Center, and Figure X-15, Physical Plant.
- **HET Facility Manager:** This position leads the Hobby-Eberly Telescope operations and maintenance effort for the HET and participates in the telescope's on-going development in support of the science mission of the telescope. This person works closely with the Chief Astronomer and Chief Scientist and the engineering shop supervisor. The Facility Manager has two support staff (systems engineer and an administrative associate) and three operating groups: Computer Group (4 FTEs), Engineering Group (9 FTEs), and Night Operations (8 FTEs) for a total of 23 FTE staff (including the Facility Manager). See Figure X-16, HET.

McDonald Observatory oversees GMTNIRs and employs independent researchers. For reporting purposes, these researchers report to the Director of the McDonald Observatory and are responsible for raising 100% of their salary and the salary of any support staff from contracts and grants. They may co-supervise graduate students and sit on departmental committees. The McDonald researchers are funded 100% by the Observatory and provide essential services to the Observatory's operations. In return, they can spend up to 25% of their time on independent research projects. See Figure X-18, Non-Faculty Researchers. Appended on the following pages are the organizational charts for McDonald Observatory.

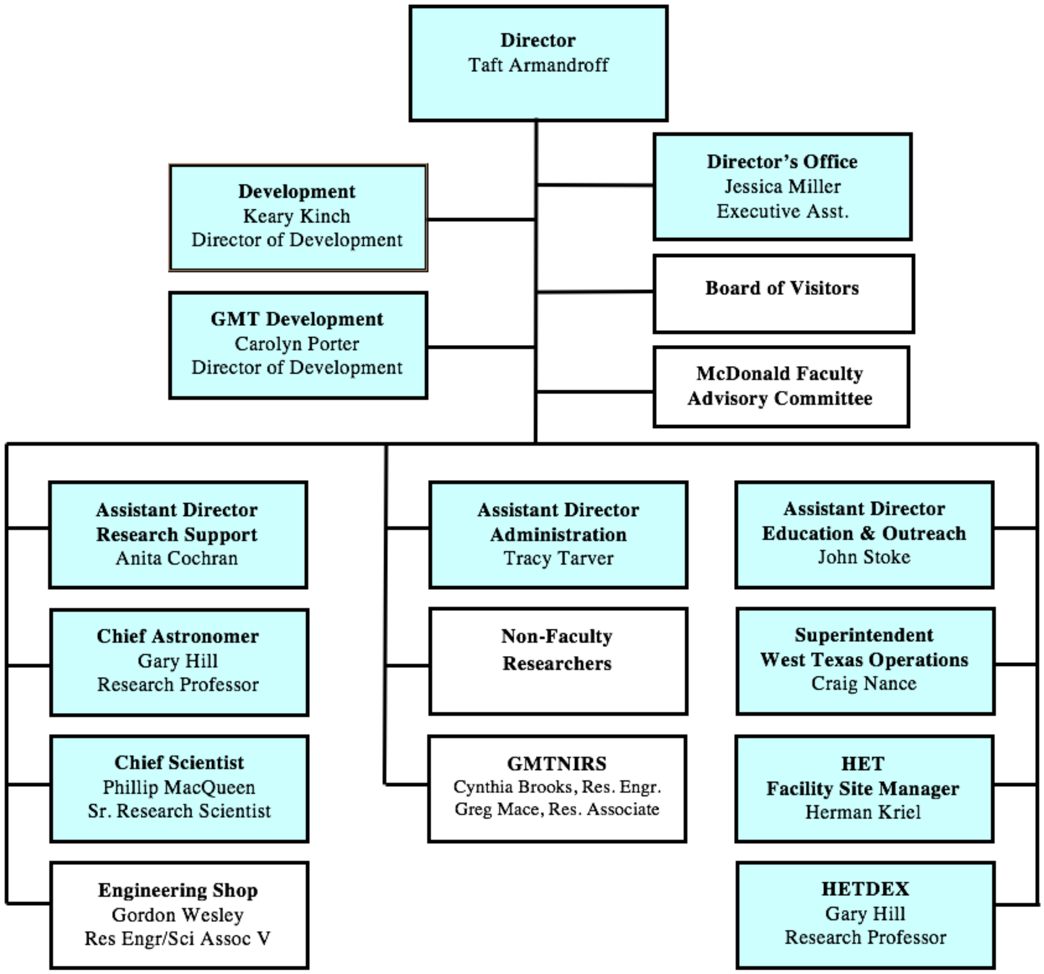


Figure X-5. Director, McDonald Observatory

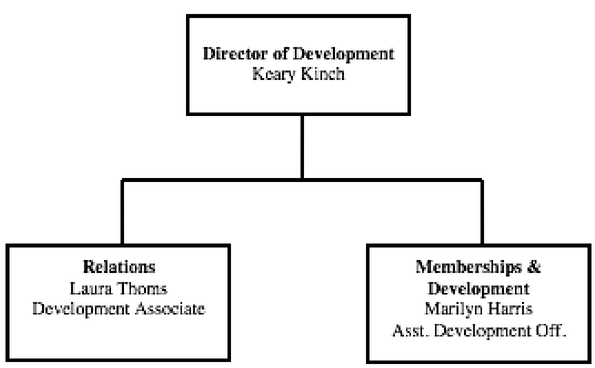


Figure X-6. Director of Development

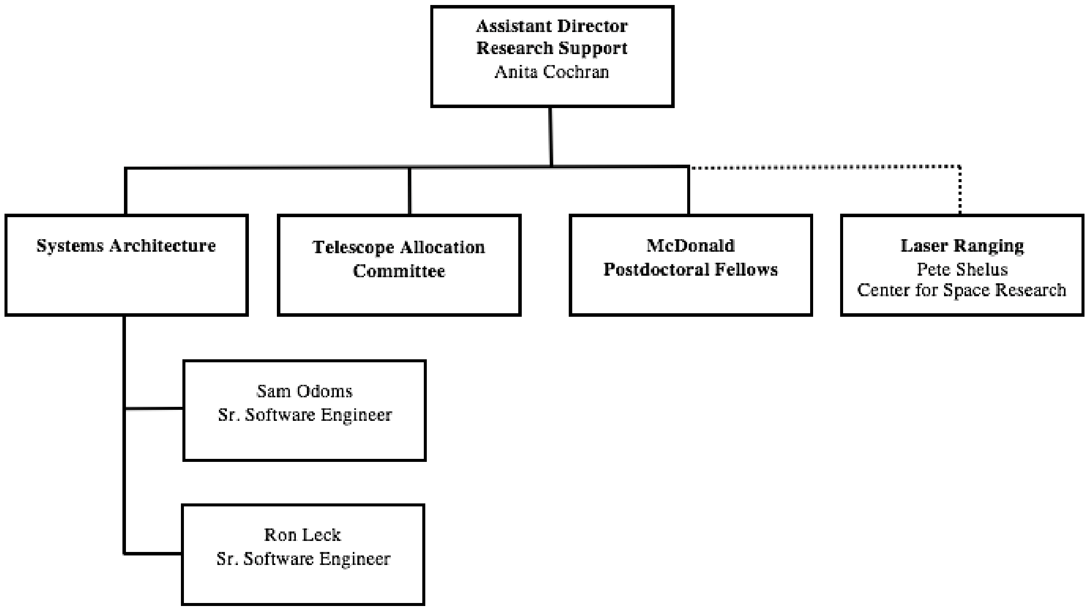


Figure X-7. Assistant Director for Research Support

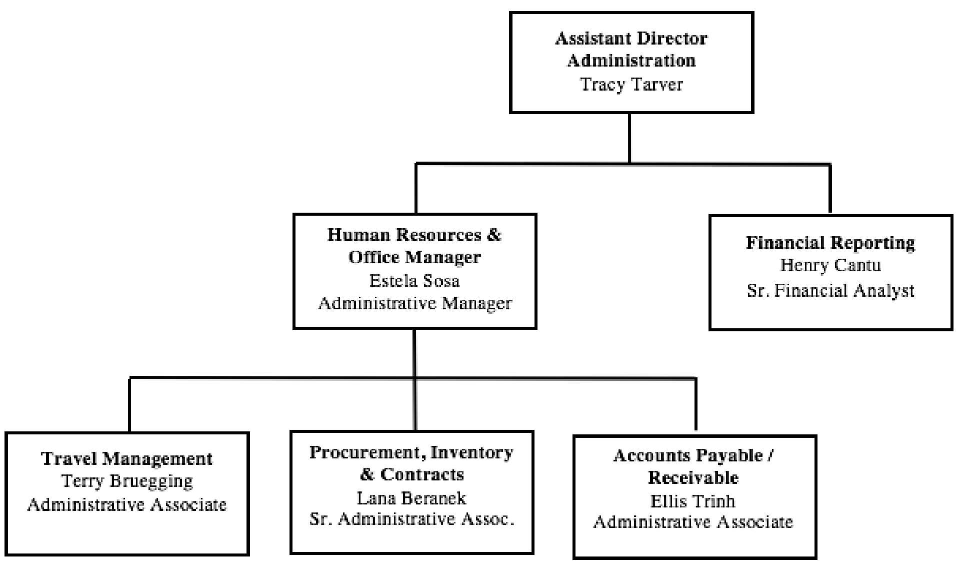


Figure X-8. Assistant Director for Administration

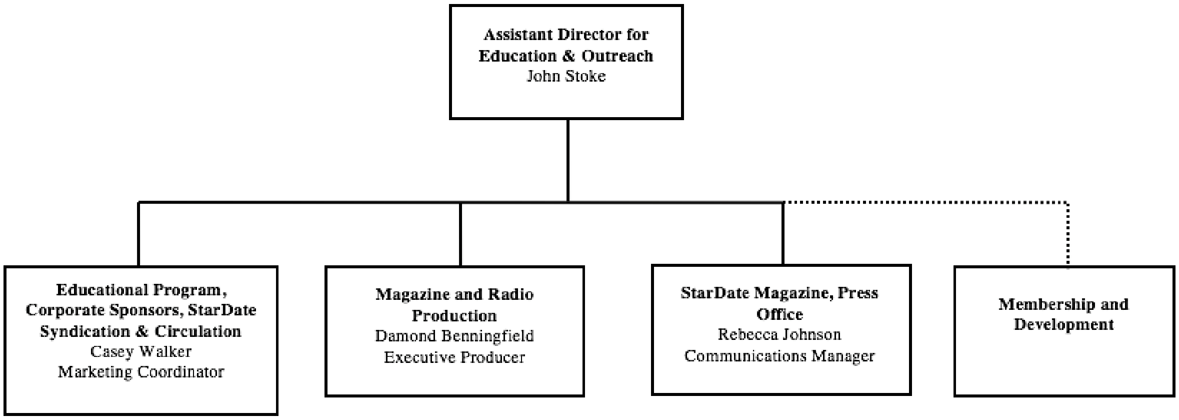


Figure X-9. Assistant Director for Education & Outreach

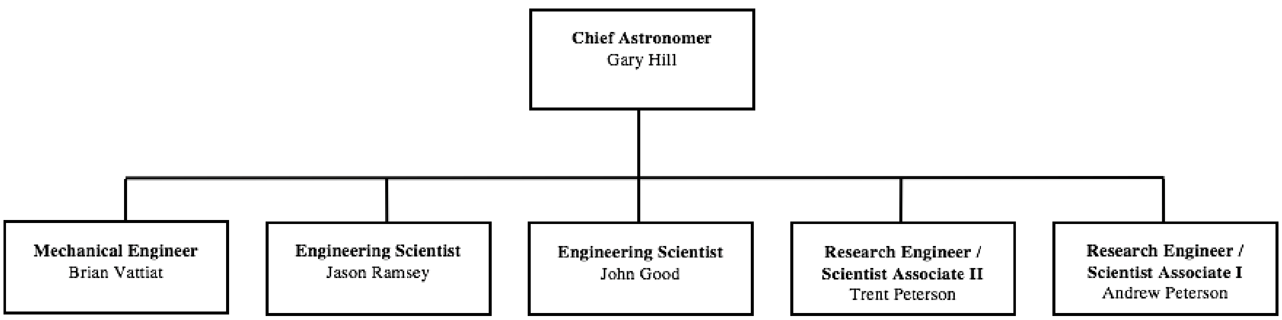


Figure X-10. Chief Astronomer

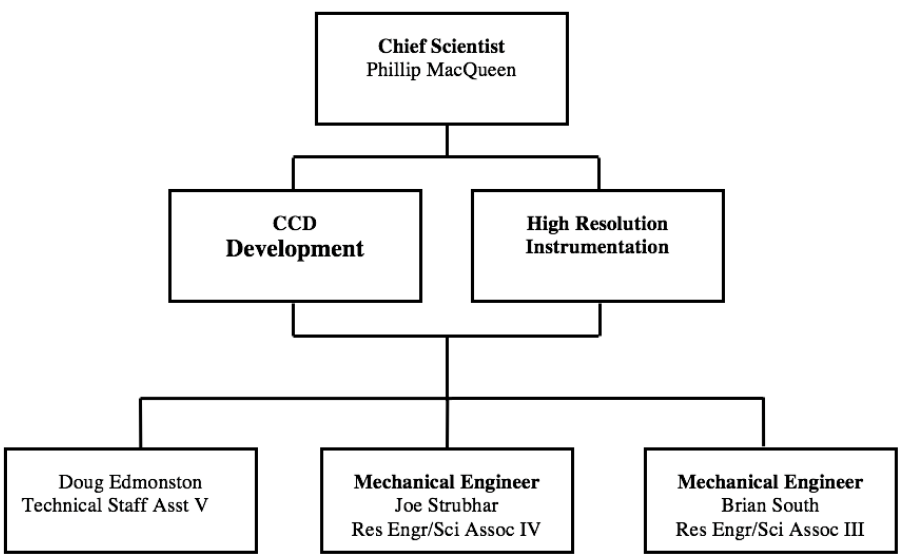


Figure X-11. Chief Scientist

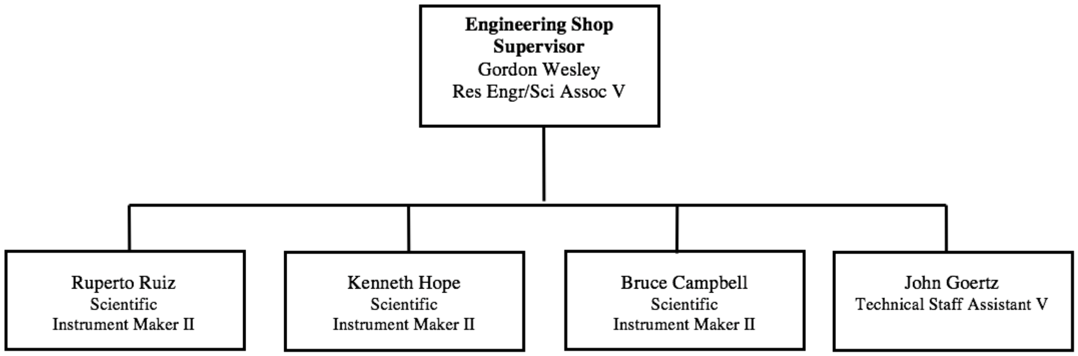


Figure X-12. Engineering Shop

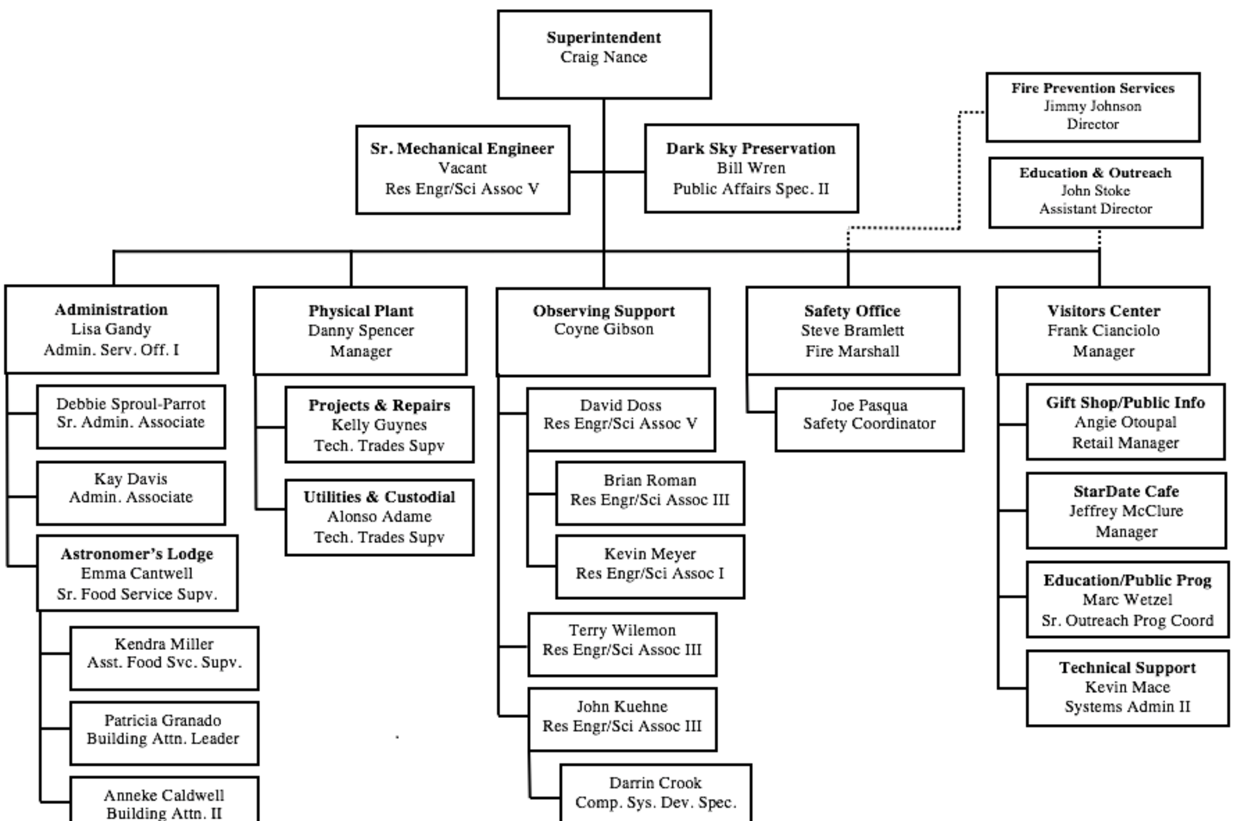


Figure X-13. West Texas Operation

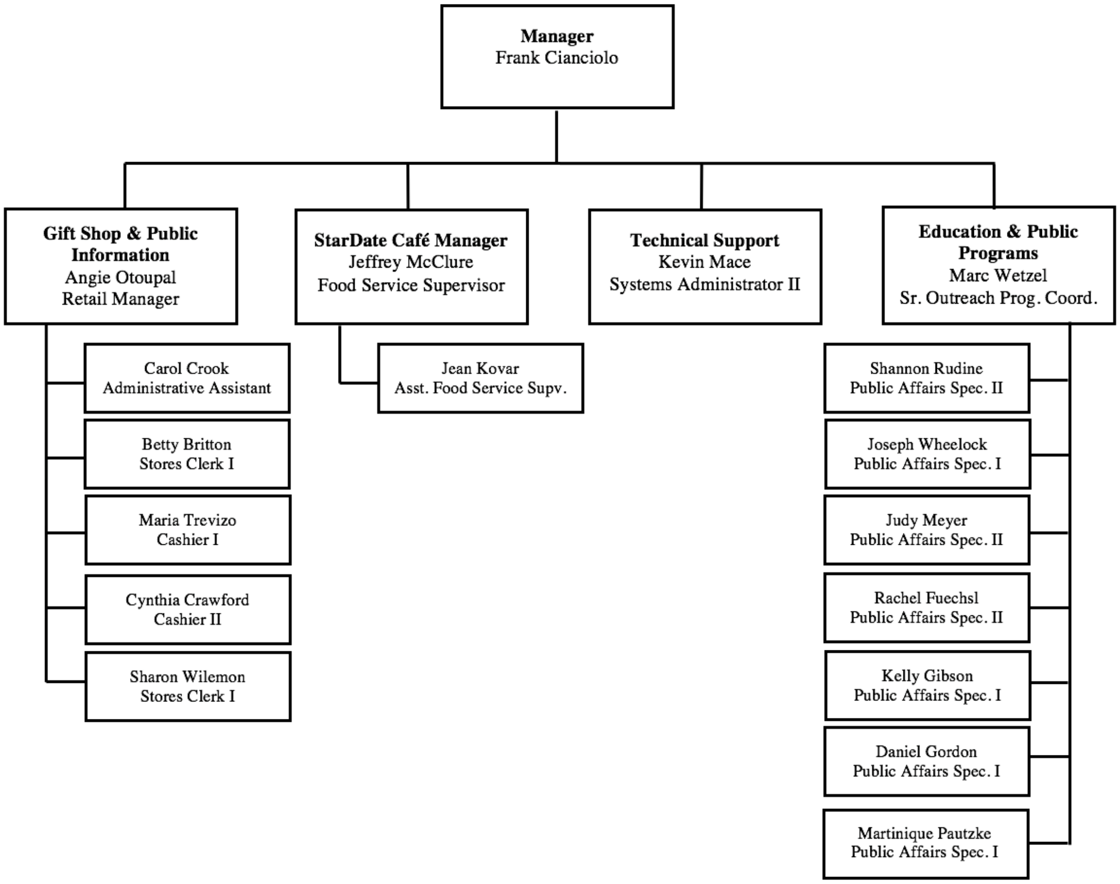


Figure X-14. Frank N. Bash Visitors Center

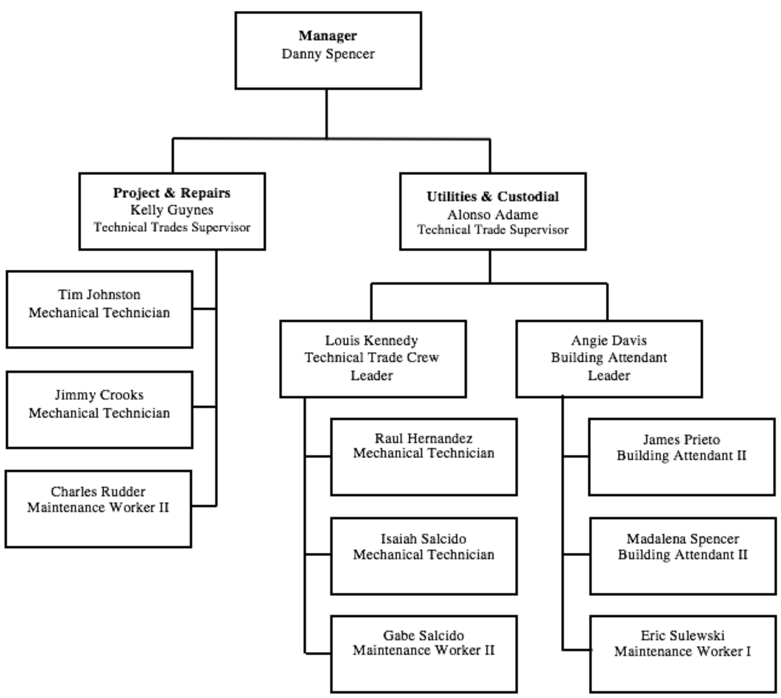


Figure X-15. Physical Plant

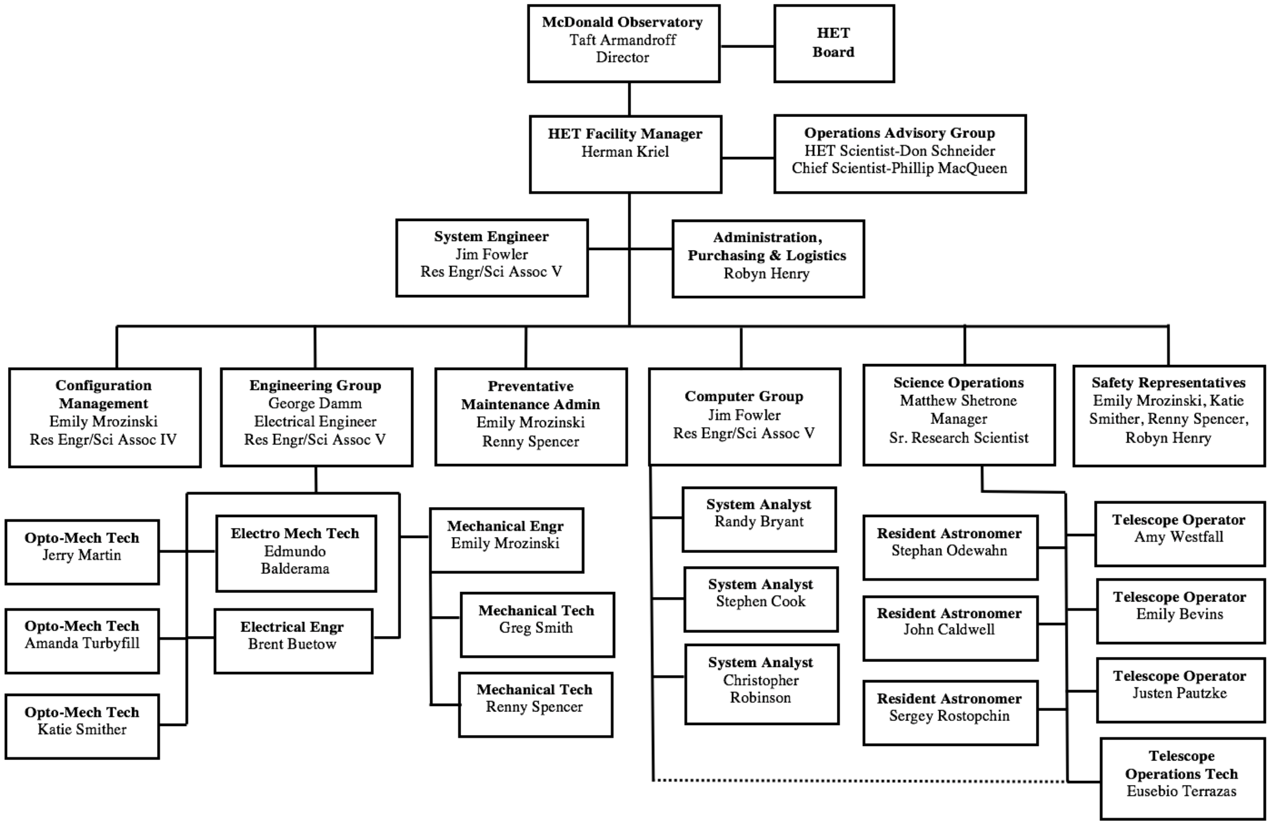


Figure X-16. Hobby-Eberly Telescope (HET)

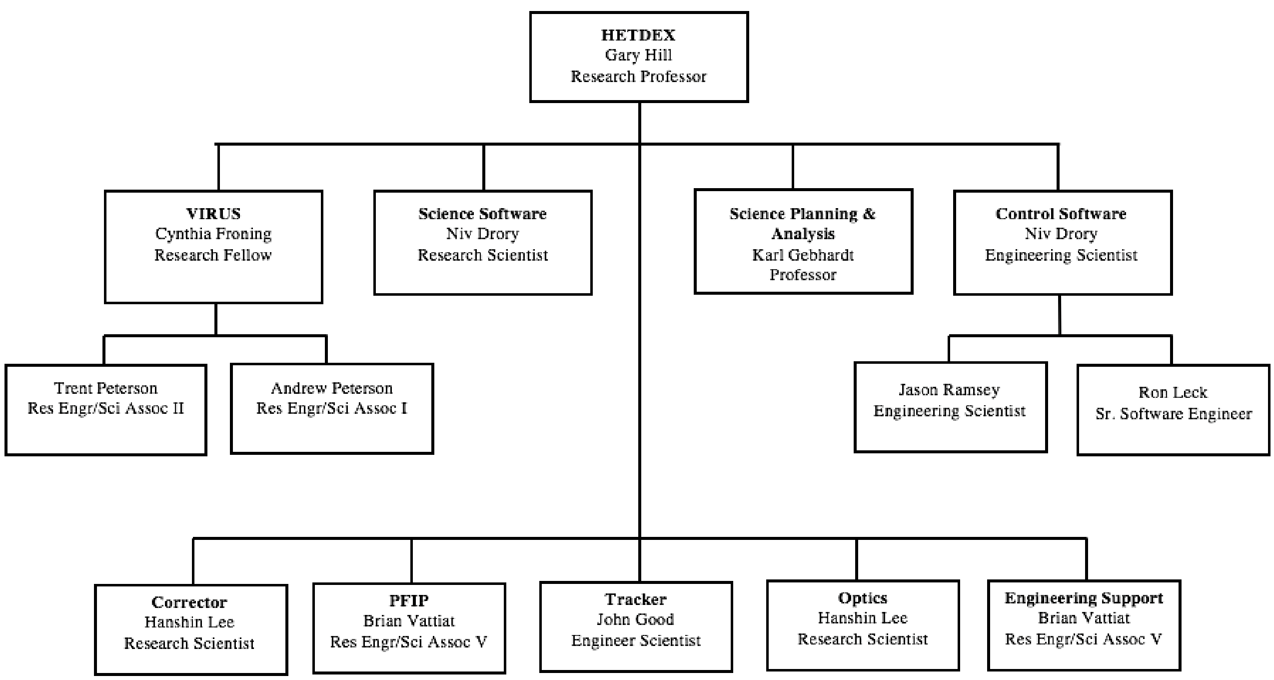


Figure X-17. Hobby-Eberly Telescope Dark Energy Experiment (HETDEX)

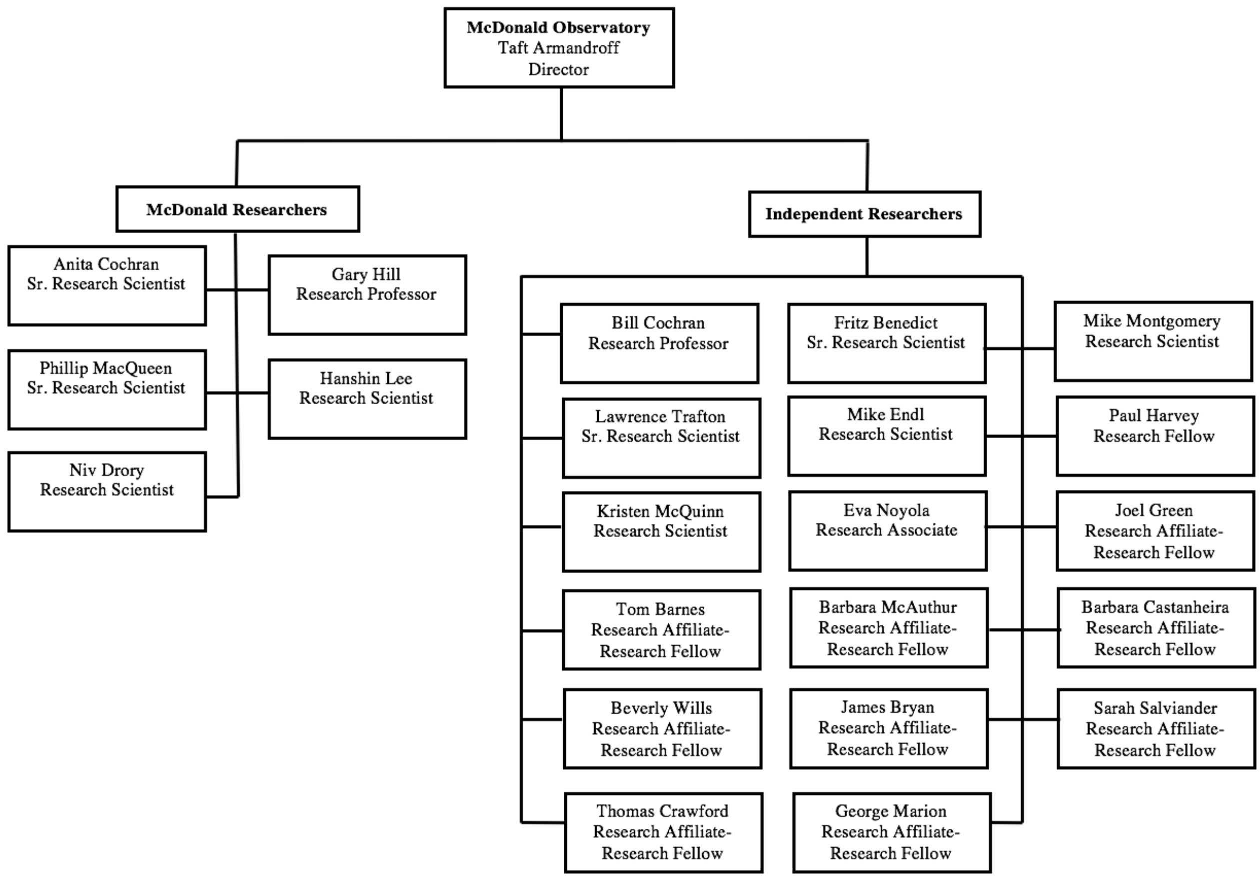


Figure X-18. Non-Faculty Researchers

Space

The Astronomy Department and McDonald Observatory-Austin are co-located in Robert Lee Moore Hall in Austin, Texas. The Austin space is described in Section X.E. The McDonald Observatory facilities in west Texas are located approximately 450 miles west of Austin in the Davis Mountains. The site hosts research telescopes (Section IX.B) as well as education and outreach facilities, and related infrastructure.

The McDonald Observatory site is approximately 800-acres in extent and administratively part of The University of Texas at Austin. It consists of two moderate peaks, Mount Locke and Mount Fowlkes, with a valley in-between. The original McDonald Telescopes (2.1-m Otto Struve, 2.7-m Harlan Smith, 0.9-m, and 0.8-m) are on Mount Locke with the Hobby-Eberly Telescope on Mount Fowlkes. In the valley is the Visitor's Center as well as the majority of staff housing.

The Frank N. Bask Visitors Center (FNBVC) is host to ~90,000 visitors per year. It consists of an interpretive exhibit hall, theater, gift shop, café, and support offices. Integral to the main building is the 'telescope park' consisting of three telescopes of the 0.5-m class used to give the guest views of celestial objects. Adjacent to the telescope Park is a large outdoor amphitheater where sky shows are given to share with large crowds the constellations, celestial motions, and other information about the night sky.

Adjacent to the FNBVC is the prior visitors' center building (formerly the Moody Visitors' Center) which is presently used for office space and storage. In that vicinity is the roll-off roof solar telescope which is used to safely transmit electronic images of the Sun to the new center as part of the public programs. Also in the Moody Center is a broadcast studio used by education staff to conduct education programs with school classes in distant locations.

The community fire hall is adjacent to the residential area. The fire hall has four large fire trucks in it so that staff can react in the event of a fire, either wildfires or a fire in a building or residence. The fire hall also serves as the offices for Physical Plant, which can be thought of as the utilities and community services organization. Physical Plant has a large outdoor yard for equipment adjacent to the fire hall, as well as covered storage for equipment.

Located on Mount Locke is the Astronomers' Lodge, a 16-room lodge which operates as a hotel for guests of the Observatory. The Lodge also has a 2-room studio and also offers a stand-alone cottage adjacent to the 2.1-m for lodging. The Lodge serves cooked lunches and dinners daily, as well as self-serve continental breakfast.

The Center for Space Research operates a laser ranging facility from Mount Fowlkes, and have entered into an agreement to expand that into a facility for geodetic science in the coming few years. This will include the addition of new geodetic equipment, as well as a radio dish adjacent to the existing Visitors' Center.

Housing:

There are 39 domiciles at the McDonald site. These are provided primarily for emergency response, but also for the necessity of each staff members' respective jobs.

Ten houses are located on Mount Locke. These include the Director's House, the Superintendent's house, and several others. For the most part, these are older houses that in some cases date back to the 1930's. These are kept modern through occasional upgrades.

Twenty houses are located in the housing area in the valley. Fifteen of these are 4-bedroom houses built coincident with the construction of the 2.7-m telescope. An additional five 3-bedroom houses were built at the same time as the construction of the HET. There are six mobile homes for Visitors' Center staff, as well as two RV spots and a small trailer.

In the valley area are a number of community amenities, such as a swimming pool, tennis court, playground equipment, and cookout area.

Utilities:

The site is served by a collection of utilities and operates as a de-facto small town. A description of these utilities follows.

Power is provided to the site via overhead lines from Alpine Electric and Power (AEP). McDonald Observatory buys its power as part of a consortium called the University of Texas Aggregation Group (UTAG). All servicing and repairs to the electric utilities are by AEP. In the event of power outages, supplemental emergency generators are used in select locations.

The major roads on the site are owned and maintained by the Texas Department of Transportation. The minor roads are the responsibility of the Observatory.

Water is the sole responsibility of the Observatory. Water is pumped from two wells located on an adjacent ranch ~7 miles away. On the site are a series of holding tanks and pumps which store and distribute the water. The Observatory water system is licensed by the Texas Commission on Environmental Quality (TCEQ), and several staff are licensed water plant operators. The water system is in the middle of a multi-million-dollar upgrade to add additional capacity, to include two on-site wells, and increased water pumping capacity to Mount Fowlkes.

All wastewater is gravity fed to a new (circa 2014) wastewater plant owned and operated by the Observatory. The wastewater system is located downhill from the residential area. The system is licensed by the TCEQ, and several of the staff are licensed wastewater operators.

Network connectivity is provided by an OC3 line at 155MB/sec. There is existing infrastructure to greatly increase the bandwidth if future needs require.

Budget

The operation of the McDonald Observatory in Austin and west Texas is supported by a variety of funding sources. The principal funding sources include:

Special Item Support in the State's Legislative Appropriations Budget Under UT Austin:

McDonald Observatory's special item support includes two lines of approximately 15 such special items under the UT Austin's state appropriations. The McDonald Observatory item is one of the largest items while the Center for Advanced Studies in Astronomy (CASA) is one of the smaller items.

The McDonald line item goes back to 1933. The CASA line item was introduced in 1991 to get limited funding for the construction of the Hobby-Eberly Telescope (HET). It now provides partial support for the HET upgrade and operations.

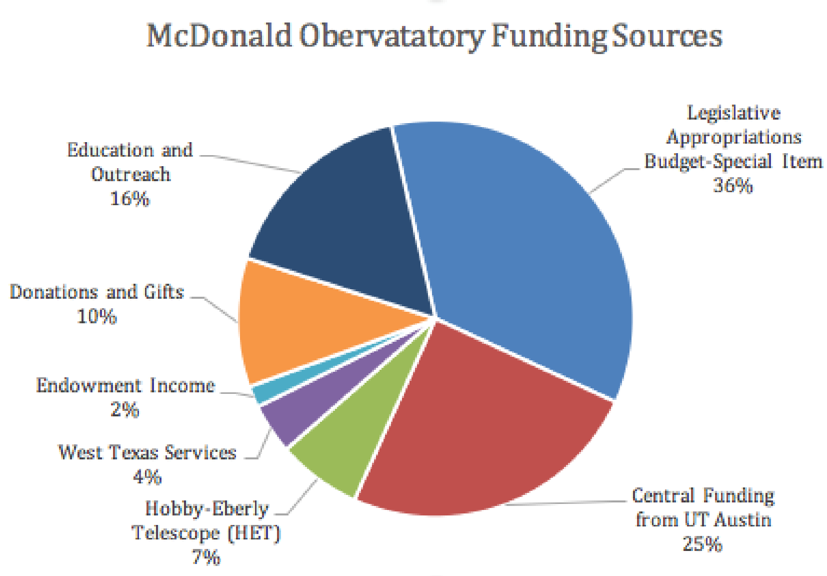


Figure X-19: McDonald Observatory Funding Sources

The State budget is set by the Legislature every two years. The Texas Legislature convenes in regular session at noon on the second Tuesday of January of every odd-numbered year for no more than 140 days. Special items are entered in the draft budgets at the levels approved in the previous biennium. During the session, special items are treated uniformly for the most part (i.e., all are cut or increased by a fixed percentage) but at a late date and during conferences between the House and Senate individual items may be given individual treatment. The approved funding is subject to fluctuations on a two-year cycle, and every line item is vulnerable to a veto by the Governor after the Legislature has sent up a budget. The 84th Legislative Session yielded $3,765,190 for the McDonald Observatory and $432,006 for CASA for a total of $4,197,196 each year of the biennium.

UT Austin Direct Funding:

UT Austin has augmented the line items, largely to account for contributions to merit raises, through appropriated general funds and institutional funding. The UT augmentation has not only helped to smooth out the fluctuations of the special line items but has been essential in helping with the total overall budget for the operation of McDonald Observatory.

Most of our special item state appropriations and UT direct funding are allocated to salaries and wages. Salaries for west Texas operations, including the Hobby-Eberly Telescope (HET), are approximately $3.67M. Austin salaries are about $3.62M. The Observatory allocates the remaining share of its state appropriations for operations such as: observing support – $267K; instrument repair and maintenance – $81K; research groups/postdocs – $41K; advanced studies/special projects – $154K; and supplies, phones, computer needs, and general operating – $120K.

The Center for Advanced Studies in Astronomy funds salaries at $273K, and research support in the areas of spectroscopy and comets at a rate of $80K and $10K respectively. In addition, we provide a modest amount of research support for the HET Resident Astronomers at $5K per scientist for a total of $20K.

The West Texas Physical Plant is funded by the University with an annual operating budget around $753K. Seventy-eight percent of Physical Plant's $754K operating budget is spent on salaries for a total of $589,781. The remaining 22% supports general services ($48K), building maintenance ($27K), telephone services ($32K), custodial services ($6K), grounds maintenance ($27K), and water and wastewater treatment ($24K). In addition, we receive about $277K for utilities.

The Observatory benefited from major repair funded and managed by the University's campus Office of Project Management and Construction Services. Within the last few years, the observatory suffered from a severe hailstorm that resulted in new roofs for our housing.

The development of the Safety and Security department began in 2004 as the result of visits by the UT Police Chief and Fire Marshall. The result of their finding brought additional support from the University which includes the purchase of a fire truck and two safety positions with an annual operating budget of $24K matched from the Observatory's West Texas revolving funds.

A portion of the indirect costs collected by the University on grants and contracts is returned to the contributing units via the College of Natural Sciences Dean's office. We are receiving approximately 25% of the indirect cost that our PI's are generating. The funds are transferred to the Astronomy program and split 50/50 between the Observatory and the Department of Astronomy. Our annual allocation fluctuates, and for FY 15-16, the Observatory's allocation was $52K. In addition, the Cockrell School of Engineering transfers to the Observatory a portion of the IDC generated from the Laser Ranging Station at McDonald operated by the Center for Space Research, which is being negotiated for this fiscal year but has ranged around $24K/year.

The Observatory often retains funds from one fiscal year to the next to supplement large research projects, instrumentation upgrades, computer upgrades, telephones and OC3 lines, safety and security, and minor building renovations.

Hobby-Eberly Telescope (HET):

McDonald operates the HET on behalf of the consortium (UT, Penn State, Munich, Göttingen). The annual operations budget for the HET is $2.5M. The Observatory is responsible for 67.58%, or $1,689,342 of the operations budget and the other partners contribute ~32% or $810,658.

The operations budget does not include funds for new instruments and upgrades to existing instruments. McDonald is financing the upgrade to the High-Resolution Spectrograph (HRS) with some help from Penn State. McDonald has led the HETDEX project with assistance from Munich on the data reduction software. McDonald has also financed and led the construction of the replacement for the Low-Resolution Spectrograph (LRS).

West Texas Services:

The Astronomer's Lodge (AL) is a 16-room lodging facility operated as an auxiliary enterprise and is completely self-sufficient. Income is generated from the sale of services at a current nightly of $94 for meals and lodging for single occupancy and $150 for double occupancy. AL expenses include salaries, wages, and fringe benefits for four FTEs as well as the utilities, maintenance, and operations costs. The annual operating budget is under $267K.

The availability of on-site residential housing at McDonald Observatory is essential to the operations of our remote research facility that is approximately 450 miles from central campus and without the amenities, emergency response, and support of a nearby incorporated city. The on-site housing provides the necessary infrastructure needed to support the Observatory operations and safety. Essential personnel, who are required as a condition of their employment, to reside on-site, occupy the houses and are charged a rental rate that is deducted from their paycheck. The current annual operating budget is approximately $200K. A portion of the funds is used to pay off two long-term notes; one for the construction of new housing in 1997 and the other for the replacement of fire-resistant siding on the new homes. Both notes will be paid by the end of the fiscal year 2020. Additionally, $100K has been allocated to home lightning protection for all the 1970's era houses.

Endowment Income:

The Director has three unrestricted endowments for the general support of the Observatories operations:

W.J. McDonald Endowment (1926): This is what remains of Mr. McDonald's original bequest that founded the Observatory and built the 82-inch telescope. Current annual income is about $45K.

Robert Lumb Endowment, endowed in 1999: This endowment was created by the Lumb Estate for the support of the McDonald Observatory at the discretion of the Director. The endowment corpus at $870K provides an annual income of $45K.

Frank & Susan Bash Endowed Chair for the McDonald Observatory Director, endowed in 2003: This $2M chair was funded by private donations at the retirement of Frank Bash. Current annual income is around $106K.

The annual income generated from these endowments total approximately $205K and is used to support a few activities such as development, special events, travel, recruiting, and research projects. Dr. Taft Armandroff, Director of McDonald Observatory, holds the Frank & Susan Bash Endowed Chair.

Two endowments provide postdoc and student support:

Harlan J. Smith Postdoctoral Fellowship: The $95K endowment was created in 1992 and provides an annual income of $4.8K for the research support of a postdoctoral fellow at the McDonald Observatory. The fellowship if funded out of the observatory's general budget.

Walton, Jr. Memorial Fund: Created in 2005 from a donation by the wife and friends of the late C. Lee Walton, Jr. The endowment generates an annual income of $4.3K and is used to support student travel to the Observatory or for other purposes to benefit the Observatory at the discretion of the director.

Donations and Gifts:

A regular but non-steady stream is provided by private gifts. Much of this comes as a result of dedicated efforts at funding particular goals.

Ongoing development goals (not including those supporting Education and Outreach) include:
Board of Visitors (BoV) Funding. Annual dues by the approximately 240 BoV members provides about $240,000 in total funding. Part of this funding is used to cover the expenses of holding the winter and summer meetings. After a division of the BoV income between the Department and Observatory and the subtraction of essential expenses (Development office support, staff awards, bi-annual postdoc fest, etc.), the income provides about $30K/year for the Director's Excellence funds.

Giant Magellan Telescope (GMT) funding. Our goal is to raise $50 million to match the contribution from the University to secure a 10% investment in the GMT.

Education and Outreach:

Education and Outreach (E&O) supports activities in Austin and McDonald Observatory. Staff in Austin including freelancers produce the nationally recognized and syndicated StarDate radio program and the bi-monthly StarDate magazine. Educational activities originating in Austin include preparation of material for K-12 students and teachers. One of the E&O staff members serves as the Communication Manager for the Astronomy program. The Friends of McDonald Observatory is managed in coordination with the development office.
With the exception of a couple of partial salaries, support from the business and development offices, and occasional emergency funding, E&O activities are funded by an amalgam of subscriptions, ticket sales for visitor center programs, E&O supplements to research grants, grants from Foundations and individuals, endowments supporting the E&O activities (presently, the endowment income is approximately $44.8K/year) and subscriptions from the Friends of McDonald.

A summary of aspects of E&O finances include:

StarDate radio: This daily two-minute program costs approximately $200K to produce with about half this amount recouped by sales to radio stations. StarDate magazine subscription income is estimated at $150K and does not cover production cost. Grants – research supplements and foundation gifts – are sought to complete the financing.

Friends of McDonald and Orion Society: Memberships are possible at multiple levels. Total income is over $100K and, after administrative costs, the memberships provide a net income of about half. Educational activities: The majority of funding is devoted to teachers' workshops. Principal sources of income are grants, gifts and endowment income average around $50K. These activities are self-sufficient.

At the Observatory, the principal financial stability is fueled by the roughly 90,000 visitors per year paying admissions, gift shop and StarDate café sales, and the programs. A major component of the educational activities at the Observatory is the video-conferencing of programs into schools. Total income from all sources is about $1.5 million and pays the VC's expenses, primarily salaries, wages, and fringe benefits.

The E&O activities are diverse and well recognized by visitors and individuals on and off campus and are largely responsible for the widely held positive impression of the McDonald Observatory.

Section XI. Research Space and Facilities

XI.A. Research Support

External Support

Contracts and grants (the great majority from the federal government) provide our primary source of research support. The Astronomy program faculty, including two Research Professors, brought in $5.8M in new research funding during the 2015-2016 academic year.

We obtain the majority of our contract and grant funding from the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). Direct contracts and grants from NASA accounted for $1.36 M and NSF accounted for $3.6M last year.

Academic Year	Total External Grant Funding Received
2015 – 2016	$ 5,869,966.67
2014 – 2015	$ 2,994,478.75
2013 – 2014	$ 3,287,172.02
2012 – 2013	$ 2,285,347.47
2011 – 2012	$ 5,023,721.51

Table XI-1: This table represents the amount of annual funding secured by the Astronomy Faculty over the past five years.

Internal Support

Astronomy faculty, research staff, postdocs, and students are fortunate to have a variety of opportunities to have their research funded internally. In addition to Endowed Professorships and Chairs that are awarded to distinguished faculty members, the Astronomy program has additional resources that are available to support it's research and education mission. Some of these include:

Cox Endowment for Advanced Studies Astronomy Scholarships and Fellowships: The purpose of the Cox Endowment is to support research and programs in the Department of Astronomy. These funds are allocated by the Department Chair and awarded for a number of specific purposes as outlined below.

Graduate Student Support: The Department allocates recurring funds of to $130K to $150 K each year for graduate student support (recruitment of new students and support of existing students) as listed below.

a) Department Cox Endowment recurring funds: $50,000 per year
b) Department Cox Endowment funds dedicated to travel support for graduate students (through the Cox Graduate Excellence Funds and Cox funds awarded to the five departmental research groups): $30,000 per year
c) Department summer fellowships: We currently award two summer fellowships (Goetting Endowed Presidential Scholarship and Benfield Memorial Scholarship) each year totaling $20,000
d) Department discretionary and reserve funds (from the Cox endowment, the Board of Visitors funds, the Blumberg endowment, the Lambert endowment, etc.) contribute $30,000 to $50,000 per year. These discretionary funds are very limited over the next few years as they are committed toward start-up packages for new faculty hires.

The total recurring funds from CNS are $38,040 per year. The combined total recurring amount ($168K to $188K) from the department and CNS is over a factor of eight smaller than the yearly cost of supporting our 35 graduate students ($1.6 M without indirect costs). External fellowships (e.g., from NASA and NSF) and internal CNS/Graduate School fellowships provide only limited help as they typically support only a modest fraction (~20%) of students. Therefore, most of the funds for graduate student support need to come from TAs or GRAs offered by the research advisor. The Department Chair is working on philanthropic initiatives to set up additional endowed funds for graduate student support.

Research Group Funding: Research in the Astronomy program is loosely divided into five research groups designated as the Extragalactic, Interstellar, Planetary Systems, Stars, and Theory groups. These groups receive research funds from the Department and Observatory, primarily designed to support research-related travel of graduate students. The Department typically contributes a total of $20K, which is matched by the Observatory. The groups manage their allocation and process requests for travel and research assistance from their members. Priority is given to student requests whenever possible.

Annual Faculty Professorships through Cox Endowment: Faculty members who do not hold an Endowed Chair or Professorship receive a small (currently $2,000) annual professorship through the Cox Endowment. These funds are available to be used for travel or other research opportunities. It should be noted that Assistant Professors who have start-up funds do not receive these professorships.

Faculty Travel Grants: Eligible faculty may receive as much as $1,200 per academic year for travel expenses to present original papers at scholarly and professional meetings. Administered through University of Texas Graduate School, these grants are open to all tenured, tenure-track, and emeritus faculty.

Rom Rhome Travel Grants: Through an endowment started by Mr. Rom Rhome, a longstanding member of the College of Natural Sciences Advisory Council, faculty members presenting at an international meeting during the academic year are eligible to receive funds to assist with travel expenses. The Rom Rhome International Professional Development Fund is administered through the College of Natural Sciences on an annual basis. Nominations are submitted by the department chairs and awarded each fall.

Board of Visitors Excellence Funds – Conference/Meeting Support:

The Astronomy program has used the Board of Visitor Excellence Funds to host numerous scientific conferences and meetings to further advance cutting-edge research by bringing together scientists from around the world to collaborate. Notable meetings funded by this endowment over the past five years include:

Cosmological Radiative Transfer Comparison Project Workshop IV: The Cosmological Radiative Transfer Comparison Project (CRTCP) was organized to guide and promote progress on the new frontier in computational cosmology, incorporating radiation transport algorithms in the simulation of cosmic structure formation and evolution. Organized by Professor Paul Shapiro, this intensive three day scientific symposium focused on the progress that has been made in the CRTCP and the future directions of the Comparison Project.

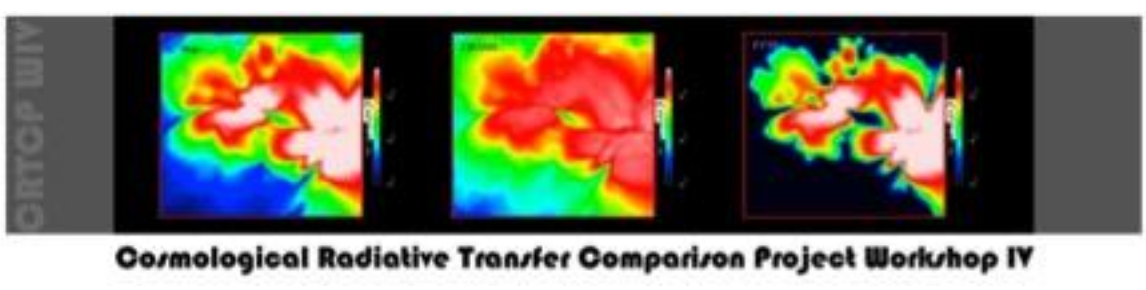


Figure XI-4: CRTCP Workshop IV gathered leading experts on radiative transfer and gas dynamics in computational cosmology, UT Austin, December 12 – 14, 2012.

Frank N. Bash Symposium: New Horizons in Astronomy: This biennial meeting brings together young researchers on the cutting edge of astronomy and astrophysics, to promote the exchange of research ideas and visions of the future of astronomy. Organized by the UT Austin postdoctoral fellows, the symposium focuses on invited review talks and includes participants from around the world. BashFest 2015 was held on October 19-20, 2015 and BashFest 2013 was held on October 8-9, 2013.

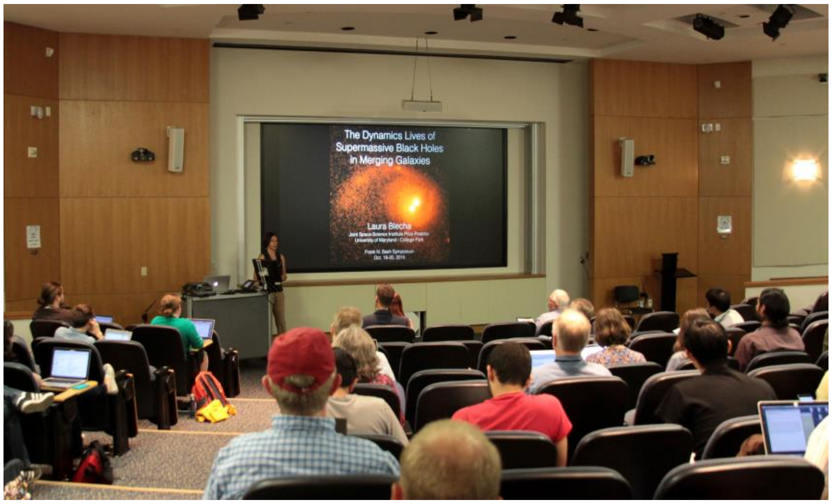


Figure XI-1: Dr. Laura Blecha, from the University of Maryland presents an invited review talk at Bash'15 held on the UT Austin campus. (*Photo credit: Lara Eakins)*

South By High Redshift (SXHZ): The first "South by High Redshift" conference was held on April 1-3, 2015. Assistant Professor Steven Finkelstein led the Scientific Organizing Committee to a successful three-day scientific meeting focusing on a variety of topics concerning the formation and evolution of galaxies, covering the first two billion years after the Big Bang.

Figure XI-2: More than 100 researchers from around the world participated in the South by High Redshift Conference held at the AT&T Executive Conference Center on the UT Campus. *(Photo credit: AT&T staff)*

NealFest Observing the Universe from Molecules to Galaxies: Professor Neal J. Evans, II has been a pioneer in the study of how stars form within this galaxy and others. To recognize his outstanding and distinguished career, his colleagues and former students came together to discuss the numerous advances he has made, placing them in context with our current understanding of star formation in the Universe. The meeting was held on April 25-26, 2013.

Figure XI-3: Professor Neal J. Evans, II, shown here with his former graduate students who celebrated with him during NealFest. *(Photo credit: Lara Eakins)*

XI.B. Relationships with Organized Research Units (ORUs)

As discussed in Section II.B., the Department of Astronomy and McDonald Observatory are distinct, but complementary, units within the College of Natural Sciences. McDonald Observatory functions as an Organized Research Unit (ORU). The Department and Observatory work synergistically to create the UT Astronomy program. The other ORU that we have a significant relationship with is the Center for Space Research (CSR), an ORU in UT's Cockrell School of Engineering. CSR operates a laser ranging facility for geodetic science at McDonald Observatory.