Report of the 2017 External Review Committee, Astronomy Department and McDonald Observatory, The University of Texas at Austin

Dear Dean Hicke,

The External Review Committee, comprising Matthew Bershady, David Charbonneau, Martha Haynes, and Piero Madau, met from the evening of March 19 to the afternoon of March 22, at the University of Texas at Austin to review the state of the Astronomy program. Over these days, we met with you, Shelley Payne (Associate Dean for Faculty Affairs), Dean Appling (Associate Dean for Research and Facilities), David Vanden Bout (Associate Dean for Undergraduate Education), Dan Knopf (Associate Dean for Graduate Education), Shardha Jogee (Chair), Taft Armandroff (McDonald Observatory Director), as well as with faculty, postdocs, graduate students and undergrads. The Committee was asked to address the current stature of the Astronomy program, alongside its aspirations.

Attached please find our written response to your questions and a summary of our evaluation. We were very impressed with the vibrant and scientifically productive Astronomy program and very optimistic about its future. We would like to thank you and your staff, particularly Kathy Bartsch, for the warm hospitality. We would also like to thank and commend the Astronomy department for all the hard work that went into preparing for this review and assembling the self-study. The efficient organization and gracious hospitality of the department are also acknowledged. We are grateful to the McDonald staff for the time and effort spent on showing one of us the Observatory facilities.

Sincerely,
Matthew Bershady, David Charbonneau, Martha Haynes, and Piero Madau

Responses to the following questions for the Astronomy Program:

What areas of strength in the Astronomy department should we continue to invest in and build over the next decade? What are your recommendations of areas that should be de-emphasized in terms of faculty recruitment and programmatic development?

> The Department and Observatory jointly lead a high-level research program that spans many areas of modern astronomy. Its customary position is in the top tier of US astronomy departments - no more than a dozen in number, and its strength lies mostly in optical astronomy, construed broadly to include everything from innovative instrumentation to observation to theoretical modeling and supercomputer simulations. Faculty members and research staff regularly secure observing time on a wide array of competitive public facilities, bring extramural funding to UT, and play a leading role in high-impact international science collaborations that are conducting large observational surveys. The research highlights called out in the self-study are all first rate. The current research program encompasses many fields and is at or near the forefront, internationally, in many of them. The Department has an outstanding cohort of junior faculty members, and is eagerly moving into new/interdisciplinary areas of research. The Chair and Department deserve credit for exciting hires, particularly with regards to diversity, and for fostering an environment that is friendly, positive, and inclusive. Active steps may need to be taken in order to retain the younger faculty. To advance its research and education mission, improve its ranking among peer institutions, and lead US Astronomy in the LSST and GMT era, the Department must be allowed to recruit new faculty at a rate of roughly one/yr over the next decade as required to counter the large wave of ongoing retirements. Priority should be given to users of Observatory facilities, observers with interests in GMT science, instrumentalists, and theorists that interface well with observers.

Please comment on the quality of facilities available to members of the department.

- *Observing facilities:* McDonald Observatory (MDO) is among the top-two continental facilities in the United States (competing with Steward) and arguably has the best outreach program of any observatory in the world. Remote observing capabilities would benefit scientists and students in the program.
- *Computing facilities:* Generally excellent. Researchers in the Astronomy have generous access to the Texas Advanced Computing Center, which designs and operates some of the world's most powerful computing resources.
- *Instructional facilities:* The Astronomy Undergraduate Computer Lab is excellent, and we endorse the plan to expand its size and capacity. While the classroom in RLM needs updating, we suggest the top priorities outside of the computer lab area (i) ensuring access to MDO for instructional purposes via remote observing and (ii) maintaining student laboratory experience in instrumentation.
- *Laboratory facilities:* These are extensive and state-of-the art (machining, instrument assembly, clean-rooms) and in several instances powerfully unique (silicon-immersion grating fabrication). It is important to maintain the proximity and spatial integration of these facilities and MDO staff offices with the astronomy department.
- *General condition of building and office in forming a collegial and interactive program:* The vertical structure of the program across three floors is not ideal but preferable to separate buildings. Making these three floors contiguous would be beneficial. The building is due for renovation but renovation should retain laboratory space and integration as well as enhance instructional and communal space.

What do you view as the strengths and weaknesses of the current undergraduate program, in terms of curriculum, course options and requirements, and degree programs?

Overall, we are extremely impressed with the undergraduate program, both in terms of its large number of majors, the commitment of the faculty and the breadth of preparation (courses, access to research etc). The undergraduate students with whom we spoke were extremely enthusiastic as well as accomplished. The Astronomy Students Association provides them with a mechanism for self-identification, outreach and peer mentoring.The increase in enrollment in upper level classes due to their popularity however has created some stress with classes becoming filled before students can enroll. A balance should be struck between making classes accessible to large numbers of students and keeping them sufficiently challenging for those ready to tackle more advanced material; this balance could be achieved by requiring prerequisites for some upper level classes. Taking advantage of the connection to the McDonald Observatory would also benefit the program, especially offering remote observing capabilities for students who have been appropriately trained and probably had been to the McDonald site at least once. Concern was also raised that undergraduates had some difficulty enrolling in appropriate computer science courses due to overcrowding. There is a perceived need from the students for more programming classes and more programming tasks in astronomy coursework. Workshops/classes on big data science and Python programming are becoming essential in a modern undergraduate education.

How can we improve the Astronomy graduate program without significant additional financial investment? Are the programs optimally structured? What is the standard in the field for graduate student stipends and expectations for participation as teaching assistants? Are the training components of the graduate program appropriate to provide a strong foundation in skills and experiences to prepare students for future careers inside and outside the academy?

The strongest testament to the quality of the graduate program is that 23/34 of the new PhDs obtained post-doctoral positions. many of them as “prize” fellows. All of the remainder have found excellent jobs outside academia, often as data scientists in tech companies, demonstrating that graduate training in astrophysics opens the door to a broad range of careers. Over the past several years, the department has been more and more proactive in increasing student diversity through a holistic review approach that no longer accepts Physics GRE subject test scores as part of the application process. The demographics of the student population appears to have dramatically improved since 2012.

GRA stipends have been raised in 2015 to be more competitive with peer institutions, and in the same year the admission yield has exceeded 30%. The average time to PhD, 5.2-5.6 years, is normal in astronomy. There were concerns about the quality of some graduate course instruction, and the students urged the department to take the course evaluation forms more seriously. The ratio of students per faculty member is also normal for astronomy. It is hard to see how a significantly larger number could be supported by UT Astronomy through GRAs, internal scholarships, and federal funding; a decrease in number would also be a mistake. The department is allocating $200K/yr for graduate student support, and yet students hold TA-ships for 6 semesters in their first five years on the average, a number that appears higher than in other astronomy departments (e.g., UCSC astronomy students typically hold TA-ships for only 2-3 quarters over five-six years). To improve the competitiveness and ranking of UT Astronomy, less reliance on TA-ships is advisable. Possibilities worth exploring in the short term include some creative use of endowment funds.

What is the optimal strategy for taking advantage of UT Austin's participation in the GMT project?

The University is well positioned to play a leading role in the GMT both because of the currently committed funding and because of the strategic development of GMTNIRS. The NSF-funded VIRUS-2 instrument is also an adroit and technically appealing opportunity for future GMT instrumentation that plays to GMT's strength as the only wide-field 30m-class telescope in the world. An ideal strategy would leverage the committed funding to raise the additional funding to achieve a 10% share and at the same time establish UT-Austin as the host of the GMT Science Center. Toward this end, the success of HETDEX is critical to establishing UT-Austin as an overall leader of GMT. Continued recruitment and retention of faculty for whom GMT will be a tremendous asset and who will engage in GMT development activities will enable the University to capitalize on its investment.

What is the optimal strategy for taking advantage of the resources at McDonald Observatory and the HETDEX project?

McDonald Observatory (MDO) is thriving. We recommend the College ensures HETDEX succeeds (discussed specifically in response to the following question); continues to encourage integration of MDO with the Astronomy department (fostering the positive dynamic between MDO and the department, also discussed below); and finally ensures MDO continues to prosper in the era of GMT. Given the enormous cost of GMT there will be pressure to curtail funding for MDO, but maintaining MDO will be a strategic master-stroke that leverages large dividends in science exploration, training, and outreach for marginal costs.

There have been substantial delays and other challenges in the HETDEX upgrade project. Have these delays seriously reduced the ability of the project to have a large impact? Are there actions we can take to avoid these types of problems in the future?

HETDEX and the HET telescope upgrade project are each enormous undertakings and each the first of their kind. We applaud the technical and scientific ambitions, but caution that their scopes were under-estimated, the projects remain under-managed, and the staffing for the scientific analysis that ensures UT-Austin's recognition is not yet in place. Moving forward, the key is to act on these lessons learned to implement sufficient management, oversight, and staffing for science analysis that will ensure success in the overall program. This success will demonstrate the ability of the Astronomy program to be leaders in "big science" enterprises, such as GMT.

Our view is that while HETDEX is late, it is not too late. Competing experiments may also face similar delays. HETDEX still holds promise for cosmological discoveries regarding the nature of dark energy that may be of Nobel Prize-winning caliber. However, the success of HETDEX should not be measured on this basis alone because HETDEX is more than a cosmology experiment. HETDEX is the path finder for a new generation of astronomical instrumentation that uses replicated spectrographs to cut costs and achieve unparalleled acquisition of spectroscopic data. The VIRUS instrument is an paradigm-changing concept that, with success, will demonstrate UT-Austin as a

pioneer in the field. Further, VIRUS will be applied broadly to a wide range of fundamental astronomical questions in Galactic and extragalactic astronomy.

Achieving success: The telescope upgrade, while substantially delayed, now appears to be well in hand. HETDEX instrumentation (VIRUS) is close, with the CCD system still at risk. After lengthy discussion with the MDO staff, we see no silver bullet, and recommend supporting their decision to stay with current vendor since other options will incur significant additional cost and further delays. Nonetheless it remains critical to monitor progress and the degree of success of the final CCD system; this will determine the impact on, and observational strategy for, optimizing science returns with VIRUS. The most important action we recommend moving forward concerns project management and oversight of the HETDEX science program. While excellent, the team is small and competing with huge international collaborations and DOE-funded national laboratories with 100's of technical and science staff. We did not see an adequate plan for analysis and science publications; these need to be articulated in written form, fully scoped, and properly managed.. We recommend specifically that there is a review of the HETDEX survey within 6 months time that ensures (a) there is sufficient management and staffing moving forward to complete the survey observations, analysis, and science publications; and (b) that the flagship HETDEX science is led by, and identified with, science staff and faculty at UT-Austin.

Please comment on what works well in the relationship between the Astronomy department and McDonald Observatory. What could be improved?

McDonald Observatory (MDO) is one of the greatest assets of the Astronomy program, offering access to state-of-the-art observing facilities; opportunities for student training in observations and instrumentation; and an unparalleled outreach program second to none. Historically, the converse has also been true: The investment of scientific interest of the department faculty in developing MDO facilities has led to unique and world-competitive facilities. Regenerating and growing this dynamic is critical for future success. Maintaining physical proximity of department and MDO staff in one integrated and updated building is necessary, but not sufficient. Greater operational integration of MDO science staff and department faculty is paramount for further leveraging MDO--department synergies. This integration likely should include greater (and formal) involvement of MDO science staff on department selection and recruitment of students, postdocs, and faculty (and vice versa); broadening the base (number) of research professors; and cross-appointment of science staff and department faculty with splitting of duties. The undergraduate and graduate curriculum and research should have broader components in observations and instrumentation. These components should be tightly coupled with the resources at MDO and a well-coupled science staff and faculty. Remote observing (e.g., for the 2.7m) would be a useful and important addition that augments a deepened suite of hands-on experience at the observatory and in the laboratories on campus. The formidable MDO outreach program should be integrated with the department and used as basis for developing a parallel outreach program in Austin, ultimately coupled to the GMT science and operations center that we hope your program is able to secure.

Should Astronomy enhance interactions/collaborations with other units in the university, including the Jackson School of Geosciences? If so, how?

While exoplanetary studies should provide a natural link to the Jackson School, the collaborations are not yet established. We suggest that exoplanets is a future direction worth fostering, perhaps through a joint seminar series on astro/geobiology and/or an educational initiative including undergraduate course offerings. We were somewhat surprised that there was no apparent (to us) involvement of members of the physics department in HETDEX dark energy science. Similarly, one of the biggest challenges of the HETDEX survey is data collection and analysis (200 GB per night over a 3 yr survey). Another connection worth fostering is then with Computer Science/Statistics.

What is the single most important change we can make to enhance the international reputation of the program?

We strongly recommend that the University fulfill its 10% commitment to the GMT and use that commitment as leverage to site the GMT Science Center in Austin. The success of HETDEX, a flagship projects for McDonald Observatory and one of the first major experiments to search for dark energy, may be crucial to securing more private and federal funding for UT Astronomy.

Information Required by the Graduate School

1. Overall impression of the graduate program
   Very positive overall. The department atmosphere is friendly, supportive and to a large extent lively.

2. Quality of faculty and graduate students.
   High on both counts. The recent faculty hires are truly outstanding. The graduate student body is exceptionally diverse.

3. Satisfaction and esprit de corps of faculty and graduate students
   The atmosphere seems generally positive. There seems to be some weariness among the senior faculty.
   Strengths: The junior faculty present themselves as a vibrant, congenial cohort, and the graduate students are enthusiastic and engaged.
   Weaknesses: There appears to be some fatigue among the senior faculty. The graduate students have some concerns about teaching (some courses, taught by some faculty, could be improved).

4. Accuracy and comprehensiveness of the Self-Study (what other information should we have provided?)
   The self-study was very comprehensive, fair and clearly thoughtful. The inclusion of white papers (e.g. grad students, ugrad students) was a great idea (the students greatly appreciated the opportunity to contribute).

5. Ranking among peer institutions.
   Competitive. The Department aspires to rank higher and has the potential to rise.

6. Competition: Programs that represent greatest competition for top quality students
   Ohio State, Michigan, Virginia, Yale, Johns Hopkins, Penn State

7. Competitive Advantage: Points of effective program strength vs. competition
   Involvement in GMT; affiliation with McDonald Observatory; intellectual and research breadth of faculty; leadership in diversity and inclusion, access to state-of-the-art computing facilities.

8. Competitive Disadvantage: Points over which program loses top quality students
   Funding model for graduate students; graduate students spend too much time supported on TA-ships compared to grad students at peer institutions, meaning that they have less time to do research.

9. Effective use of resources
   Creative use of endowed chair funds to support graduate students (rather than as TAs) will help the graduate students to be more productive and also to recruit Increasing the capability to observe with McDonald telescopes remotely would enable the graduate students to get more hands-on experience in observing and to devise observing programs that make use of the McDonald access advantage (e.g. time domain science, follow-up observations).

10. How well are students supported financially?
    Monetary amount is typical of other programs but the method of support should emphasize more research assistantships/fellowship support and less reliance on TA-ships, especially in later years.

11. Effective admissions process
    Very effective (Bravo!). The department has been a leader in eliminating the GRE subject (physics) test and addressing unconscious bias. The result is a very diverse graduate student cohort.

12. Enhancement: Requirements for program to improve competitiveness and rank
    We believe that the department should rely less for graduate support on TA-ships. Rather, there should be more external funding for RA-ships (requires higher rate of external faculty funding) or fellowships.

13. Would you send your very best undergrads to this program?
    Competition for the best graduate students is fierce. At this stage we would send our very best undergrads to this program only if the students were clearly interested in developing optical/IR instrumentation and/or participating in large optical surveys.

14. Would you hire one of the program's graduates?
    Absolutely.

15. Is this program "cutting edge?" If not, why? If yes, why?
    UT Astronomy program is clearly cutting-edge. Strengths: excellent junior and senior faculty; excellent track record; leadership in GMT program; graduate students given opportunities to be PIs of McDonald programs, excellent computing facilities.