Course: AST 210K/PHY 101L or AST 375 or CS 378: Cosmic Dawn FRI Stream

Semester: Spring 2014

Unique No.: AST 210K/PHYS 101L: 48715/58200 or AST 375: 48760 or CS 378: 53940

Hours: M & W 2-3 pm

Locations: RLM 7.116 (practicum)
RLM 5.118 (lectures)
RLM 15.201 (additional lab for assignments and research)

Prerequisites: FRI Intro. to Research Methods (including AST 376) or by permission

Textbook: (Required) Duncan, T & Tyler, C. *Your Cosmic Context: An Introduction to Modern Cosmology* (Pearson Addison-Wesley) ISBN: 978-0-13-240010-7

Website: http://www.as.utexas.edu/~gfigm/fri/

Instructors: Prof. Paul Shapiro (Principal Investigator)
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Office Hours: immediately following class or by appointment

Dr. Anson D'Aloisio (Research Educator)
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Office Hours: W 3:00-4:00pm (immediately following class, see help sessions section) in RLM 7.116 or by appointment

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Mentors: Joel Doss (jodo94@utexas.edu), Office Hours: M 3-4pm
Andrew Miculka (andrewmiculka@utexas.edu), Office Hours: F 2:30-3:30pm
Sae Saito (saepiusa@hide-factory.com), Office Hours: M 3-4pm
Jacob Schmelz (jschmelz@utexas.edu), Office Hours: M and W 1-2 pm

Lab access: RLM 7.116, W 3:00-4:00pm
RLM 15.201, M 3:00-4:00pm, T 2:00-3:30pm, F 2:30-3:30pm, or any hour which is not booked for exclusive use by another class

Help sessions: M 1:00-2:00pm (Schmelz) and 3:00-4:00pm (Saito and Doss) in RLM 15.201
T 2:00-3:30pm in RLM 15.201 (Park)
W 1:00-2:00pm (Schmelz) in RLM 15.201 and 3:00-4:00pm in RLM 7.116 (D'Aloisio)
F 2:30-3:30 in RLM 15.201 (Miculka)

Overview: As a student in the Cosmic Dawn research stream, you will get to analyze and visualize new cosmological simulations. These simulations will utilize the computational resources of the Texas Advanced Computing Center, and will be among the most advanced in the world. We will provide you with the necessary background to participate in original scientific research in Cosmology and Astrophysics. This includes (but is not limited to) elements of computer programming, an introduction to supercomputing, scientific visualization, physics, astronomy, and mathematical techniques. You will interact with experienced researchers in a team effort to break new ground in this exciting field. A tentative course schedule is provided as an attachment to this syllabus. Note that the schedule is subject to change as we adjust material to meet the research goals for the course. More detailed information, including reading material and homework assignments, will be provided separately. The grade breakdown for the course is as follows: 5% participation, 15% lab notebook, 30% homework and research assignments, 15% group oral presentation,10% group poster paper, 25% final paper. More details on these grading criteria are described below.

Exams: None.

Homework: Homework and research assignments are worth 30% of your grade and will generally be due a week after they are assigned at the beginning of class. Late homework will be not be accepted. We will drop your lowest two homework/research assignment grades.

Grading: Your letter grade will be assigned on the plus-minus system.

Notebook: Keeping a record of the steps you take to find a result is a critical part of being a good scientist. As such, you are required to maintain a clear and legible lab notebook. As a guideline for keeping a good lab notebook, someone should be able to reproduce your result independently simply by following your notebook, without additional input from you. We will randomly check notebooks periodically throughout the semester. Your lab notebook will be worth 15% of your grade.

Final Paper: At the end of the semester, you will hand in a final write-up of the work you did in Cosmic Dawn, including the scientific motivation, your methods, the results, and the scientific implications of the results. This will be worth 25% of your final grade.

Oral and Poster Presentations: At the end of the semester you and a group of your fellow students will give an oral presentation to the class on the research conducted over the course of the semester, and prepare a poster paper on it. You will need to give scientific motivation for your topic, and describe what you found clearly and within the given time limits. This will be worth 25% of your grade.

Academic Dishonesty: We have a zero tolerance policy regarding cheating and plagiarism. All students involved in either of these acts will receive zero credit for the work in question and may be subject to further disciplinary action by the University of Texas.

Absences: If you must miss class for any reason (i.e. illness, family emergency, etc...), please notify Dr. D'Aloisio ahead of time. You are responsible for the missed material and completing your work within the allowed time frame (see above). In the event of an absence, please feel free to come to office hours for assistance.

According to UT Austin policy, you must notify us of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, you will be given an opportunity to complete the missed work within a reasonable time after the absence.

Disabilities: Students with disabilities can request necessary accommodations from the Division of Diversity and Community Engagement, Services for Students with Disabilities (512-471-6259 or www.utexas.edu/diversity/ddce/ssd/)

Cosmic Dawn: How the first galaxies formed, ended the dark ages, and reionized the Universe

What are the differences between galaxies born and raised in regions of space that were either crowded or sparse, and how did their build-up over time by the collision and merger of smaller progenitors affect their ability to emit the light that reionized the Universe?

Prof. Shapiro's group studies the first billion years of cosmic time when the first galaxies and stars were born, the last window of cosmic time accessible to direct observation. To test current theory, they use supercomputers to simulate the formation of galaxies and large-scale structure in the expanding universe. When these galaxies formed stars, starlight escaped into the surrounding gas, heating and ionizing it. This "feedback" impacted future galaxy and star formation and left observable imprints on the universe which astronomers are just now beginning to detect. Students will help make new discoveries with the most advanced simulations in the world, performed at the Texas Advanced Computing Center at UT.

In spring 2012, we studied the results of a cosmological N-body simulation of galaxy and large-scale structure formation in the LCDM model of the Universe, during the first billion years of cosmic time. We focused on the galactic halos that formed and analyzed the internal properties of individual halos and the correlations between different properties. Our results were presented in a class poster paper. Our summer fellows and continuing students in fall 2012 refined these results and helped lay the groundwork for the next step, in which we studied the environmental dependences of these halo properties, in spring 2013. In the summer of 2013, a new generation of summer fellows came to grips with the discovery that the N-body simulation results needed to be improved by a more accurate calculation of the gravitational force with finer length resolution. In fall 2013, the returning Cosmic Dawn class demonstrated that the halo properties produced by a new simulation with finer length resolution were sufficiently accurate and rederived the results of the spring 2013 class with this more accurate simulation.

This spring 2014 semester, we will explore the phenomenon of the merger history of the galactic halos for the first time. In the LCDM model of the Universe, structure formation is hierarchical, with small objects forming first and merging together over time to build larger objects, in a continuous sequence of ever-larger structures. We will use a new cosmological N-body simulation of this process that keeps track of which halos a given N-body particle belongs to at each moment of time after it collapses out of the expanding Universe into its first galactic halo. This merger history is an important influence on the star formation history of these galactic halos. For example, mergers of colliding galaxies are believed to trigger bursts of star formation which can be extremely luminous.

Tentative Course Schedule (up to the week of 3/24/2014)

	Date	Location
Introduction/Overview	1/13	RLM 5.118
Lab 1: Cosmic overview, First computer login, Texas Advanced Computer Center sign-up	1/15	RLM 7.116
No class: M.L.K. Jr. holiday	1/20	
Lab 2: Introduction to Unix	1/22	RLM 7.116
Lecture 1: Cosmic overview continued, mechanics and gravitation	1/27	RLM 5.118
Lab 3: Introduction to Unix part 2 and the Texas Advanced Computing Center	1/29	RLM 7.116
Lecture 2: Mechanics continued, 1D projectile motion in a gravitational field	2/3	RLM 5.118
Lab 4: Introduction to scientific data visualization with VisIt	2/5	RLM 7.116
Lecture 3: 1D projectile motion continued, cosmic redshift and the expanding Universe	2/10	RLM 5.118
Lab 5: Scientific data visualization 2	2/12	RLM 7.116
Lecture 4: The expanding Universe 2, the Friedmann equations	2/17	RLM 5.118
Lab 6: Overview of ACES VisLab resources	2/19	ACES Vis. Lab.
Lecture 5: The Friedmann equations continued	2/24	RLM 5.118
Lab 7: Basics of IDL	2/26	RLM 7.116
Lecture 6: Cosmic epochs, the fate and age of the Universe, gravitational collapse	3/3	RLM 5.118
Lab 8: Basics of IDL 2: writing and executing scripts	3/5	RLM 7.116
Lecture 7: Structure formation in the Universe	3/17	RLM 5.118
Lab 9: Manipulating our cosmological simulation data with IDL	3/19	RLM 7.116