Course: AST 375 or CS 378: Cosmic Dawn II -- FRI

Semester: Fall 2014

Unique No.: 48615 (AST 375 -- FRI), 53136 (CS 378 -- FRI)

Hours: M & W 2-3 pm

Location: RLM 15.201 (computer lab) or
RLM 15.216A (Edmonds Lounge) on days TBD

Prerequisites: FRI Intro. to Research Methods (including AST 376) and Cosmic Dawn I,

Textbook: (Optional) 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: M, W 3-5pm, RLM 15.201

Lab Access: RLM 15.201 is reserved for Cosmic Dawn on Mondays and Wednesdays from 1:00-4:00pm, Tuesdays from 2:00-3:30pm, and Thursdays from 2:00-3:00pm. You may also access the RLM 15.201 any time that is not booked for exclusive use by another class (see http://www.as.utexas.edu/meeting/ or schedule posted outside RLM 15.201).

Help sessions: M 1:00-2:00pm (Doss) and 3:00-5:00pm (Saito) in RLM 15.201
T 2:00-3:30pm in RLM 15.201 (Park)
W 1:00-2:00pm (Doss) and 3:00-5:00pm (Saito) in RLM 15.201
Th 2:00-3:00pm (Choi) in RLM 15.201
F 3:00-4:00 in RLM 15.201 (Doss)

Overview: As a returning 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. As in Spring 2014, 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, physics, astronomy, and mathematical techniques. You will interact with experienced researchers in a team effort to break new ground in this exciting field.

Exams: None.

Homework: Conduct your ongoing research assignments.

Presentations: At the end of the semester you will give an oral presentation to the class on the research conducted over the course of the semester.

Grading: A letter grade (without plus/minus system) will be assigned based on the effort and progress you made in your research project(s), including the final oral presentation.

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.

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 Prof. Shapiro and/or the T. A., Mr. Park, ahead of time. You are responsible for the missed material and completing your work within the allowed time frame. 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 will 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.

Our Spring 2014 FRI class began just as our team's newest frontier simulation of the epoch of reionization (EOR) was finishing its run on the U.S. Dept. of Energy's world-leading massively-paralleled supercomputer, Titan. This ground-breaking simulation, which took 80 million CPU hours, calculated the gravitational N-body dynamics of galaxy and large-scale structure formation fully coupled to the calculation of the hydrodynamics of the atomic hydrogen gas and the transport of UV starlight through it, as it ionized and heated the gas. The simulation centered on a cosmologically-expanding box which is today 300 million light-years across, chosen to simulate the formation and impact of reionization on our Local Group comprised of the Milky Way galaxy, its neighbor The Great Galaxy in Andromeda, and other satellite dwarf galaxies. The class

analyzed and visualized the results, focusing on several science questions. Students were grouped into 6 teams of 4 students each, each addressing one of the three basic science questions: (1) Is there a correlation between the timing of the reionization of a given patch of the universe with the over-density of matter in that patch relative to the mean density over all space? (2) Does reionization of the local patch of intergalactic gas surrounding a galaxy suppress the atomic gas contents of that galaxy and how does this suppression vary with galaxy mass and the timing of reionization of that patch? (3) What does computer animation of the simulation results reveal about the evolving structure of the spread of reionization and its correlation with the cosmic web of galaxies and large-scale structure in the universe? Our results were presented in power-point slide presentations at the end of the semester, including 3D movies on the stereoscopic display Mustang at the TACC VisLab, as well as final class poster papers and individual student LaTeX'd research papers. Our 4 FRI summer fellows continued this work, pushing further in their analysis, to study the simulated galaxies' star formation histories and advance the computer visualizations and animations of the Local Group and other "zoomed-in" regions of the full box.

This Fall 2014 class will pick up where our Spring and Summer 2014 work left off. Students will learn FORTRAN 90 so they can program at a more advanced level. For example, fly-thru movies of the 3D simulation results require that the trajectories of flight be programmed. Programming also allows us to compute new combinations of the simulation results for further study and visualization.

Schedule

	Date	Location
Orientation: Reactivation of computer accounts, lab access, assignment #1 (with Fortran 90 tutorial).	8/27	RLM 15.201