Cornell University
REU Program in Astronomy and Astrophysics
2012 Research Projects

Please rank these projects by mentor name on the back of your application

1. Prof. Joseph Burns

The Nature and Cause(s) of Unusual Features in Saturn's Rings

This project will investigate uncommon ring structures (e.g., inclined or non-circular rings, gaps, impact clouds, time-variable "propellers") that have been identified in visual and infrared images taken by the Cassini spacecraft since it arrived at Saturn in 2004. We now have sufficient data taken at various times and in different viewing geometries to begin to better understand the three-dimensional nature and histories of these objects. Our ultimate goal is to develop models of disk-moon interactions. Possible subjects include i) an inclined dusty ringlet that seems to be getting pushed about by sunlight; ii) rings that are very close to the planet and may have been kicked onto inclined, elliptical orbits by the crash of a cometary cloud; and iii) spiral density and bending waves in the main ring system, where one can infer local ring properties (surface density and viscosity). As our understanding of the nature of such features improves, we will then try to simulate the causes of the features. This research would be done with Cornell's planetary rings group, containing representatives from Cassini's imaging and infrared teams.

2. Prof. James Cordes

Project 1: Searching for Transient Radio Bursts Faster than One Second

The study of the time-domain radio sky is a priority for future radio astronomical facilities. We are developing algorithms that take into account distortions of radio bursts as they propagate through the interstellar medium. These algorithms will then be applied to high-time-resolution data that we are obtaining with the Arecibo telescope in Puerto Rico. The project involves development of the algorithms, writing code to implement them within an existing processing pipeline, and interpreting results with respect to their statistical significance and astrophysical meaning. Part of the project will also involved application to data obtained with a small, wide-field radio telescope on the roof of the Space Sciences Building. A student working on this project will learn about and apply techniques in statistics using tools developed with computational tools based on C programs, Python, and MySQL.

Project 2: Detecting Gravitational Waves Using Pulsar Timing

A multi-institution project we are involved with is to use the fastest spinning radio pulsars (those spinning with millisecond periods) to detect long-wavelength gravitational waves. While several sources of such waves exist, the most likely is the large number of merging super-massive black holes at cosmological distances. We are developing algorithms for improving the basic raw data (arrival times of pulses) and for detecting gravitational waves in a collection of such arrival times from multiple pulsars. Part of the project involves simulation of pulsar data and testing detection algorithms. Another part is to simulate the effects of the interstellar medium on the arrival times. A third part extends detection algorithms to bursts of gravitational waves that are expected in the final plunge phase of a merger of two black holes. This too needs to be simulated so that we can optimize the chances of detection. A fourth part of the project involves characterization of actual pulsar data with respect to sources of error and contributions from processes occurring in each pulsar.

3. Prof. Riccardo Giovanelli

ALFALFA is a spectro-photometric survey of the z=0 universe. It uses the HI spectral line of 21cm wavelength to estimate the atomic gas content of cosmic sources. Survey observations will cover 7000 square degrees of sky with the 305m radio telescope of Arecibo, Puerto Rico. Observations for the survey are nearly (>90%) complete. REU students would be involved in activities of data reduction, follow-up observations of interesting sources and overall involvement with a group of faculty and students working on topics of galaxy properties and evolution.

4. Prof. Terry Herter

Participation in SOFIA Science

Our team at Cornell has constructed FORCAST, an astronomy instrument for use with SOFIA (the Stratospheric Observatory For Infrared Astronomy). SOFIA is a modified Boeing 747SP airplane housed a 2.5-meter telescope. FORCAST has been used for both observatory characterization and science observations. We are looking for someone to participate in analysis of the science data obtained with FORCAST. There may also be an opportunity to join in flight preparation and fly on SOFIA when FORCAST has commissioning flights in summer 2012. SOFIA flies out of the NASA Dryden Airborne Operations Facility (DAOF) which is located in Palmdale, CA.

5. Prof. Jonathan Lunine

Jonathan Lunine works on a variety of spacecraft missions and their data, on the outer solar system and on exoplanets. Here are some projects that REU students can do with Prof. Lunine:

Perrier pockets on Enceladus: Working with colleagues at JPL, Prof. Lunine is making a model of how geysers on Saturn's moon Enceladus might work. Cassini data show that water, carbon dioxide and other substances are shooting out of surface fractures on Enceladus, and modeling the processes involved will help determine whether the subsurface reservoirs might be habitable. Some understanding of thermal physics is helpful for this project.

Land o' lakes on Titan: Saturn's moon Titan has hundreds of lakes its the northern hemisphere, filled with liquid methane and ethane in a bedrock of water ice. We will examine radar images and make comparisons with terrestrial environments containing lakes, to decide what is the most likely geological setting for the lakes. Are they part of a landscape of karst topography, or has a form of ice volcanism played a role? Some knowledge of geology and an interest in remote sensing are helpful.

Graphite planets: Carbon-rich planets have been discovered around other stars, and now there is some evidence (described in a paper by Prof. Lunine and colleagues) that Jupiter might have a ratio of carbon-to-oxygen in its deep interior different from the value in the Sun. We will use a simple model of the protoplanetary disk from which the Sun and planets formed to investigate ways in which Jupiter might have acquired this odd composition. A good understanding of classical mechanics and thermal physics is helpful for this project.

Other projects are potentially available as well depending on most recent results from the various missions on which Prof. Lunine is working.

6. Senior Research Associate Dr. Gregory Sloan

We are investigating the final stages of stages of stellar evolution, when stars are stripping their outer envelopes, ejecting dust, and seeding the interstellar medium with the products of fusion in their cores. Our work combines data from a wide variety of telescopes, including the Spitzer Space Telescope, the Wide-Field Infrared Survey Experiment (WISE), and the Canada-France-Hawaii Telescope, to study dying stars in a range of environments, including Galactic globular clusters and nearby galaxies in the Local Group. Summer students joining our group will get involved with the analysis of imaging data to identify targets, place them on optical and near-infrared color-magnitude diagrams, and study their variability. Our students generally have the opportunity to co-author peer-reviewed papers and present their results at a scientific meeting. They also gain experience with basic data reduction and analysis techniques in astronomy.

7. Prof. Gordon Stacey

Star Formation Through Cosmic Time

The Stacey research group is focused on the study of star formation in galaxies over cosmic time. Our primary probes are the bright far-IR fine structure lines from abundant atoms and ions such as C+, O++, N+ and O. These lines cool molecular clouds in galaxies and enable their collapse to form stars. We have detected these lines from galaxies at redshifts between 1 to 4 -- looking back in time to withing 1.5 billion years of the Big Bang, and probing the epoch when the star formation rate per unit co-moving volume of the Universe peaked -- about 12 to 8 billion years ago. We build state of the art spectrometers to detect these lines and use our spectrometers on the world's largest submillimeter telescopes such as the 12 meter Caltech Submillimeter Observatory (CSO) on Mauna Kea in Hawaii. This means that in addition to studying the astrophysics of distant galaxies we build and improve our spectrometers in the lab. Building such spectrometers involves low temperature physics (our detectors operate at ~80 milli-Kelvins), optics, electronics, semi-conductor and super-conductor physics, mechanical engineering, and software development.

REU students are involved in the on going research in the lab and can pick a particular sub-project of interest. In the past, students have built cryogenic Fabry-Perot interferometers, electronic boxes that control Helium-3 refrigerators, designed optics, created data reduction software, as well as participated in the science of galaxies in the early Universe and traveled to the CSO to participate in observing runs. We are also obtaining complementary extragalactic science with the 3.5 m submillimeter European Space Agencies Hershel Space Telescope and beginning the design phase of a large format submillimeter camera for the 25 CCAT submillimeter telescope. CCAT is a Cornell-led telescope to be build on the 5600 meter high summit of Cerro Cajnantor in Chile. There will be science and software opportunities linked with these programs as well.

8. Prof. Saul Teukolsky

Computer Visualization of Black Holes from Supercomputer Simulations

The work of the undergraduate in this project will involve numerical computations, color graphics and video animation. The project will focus on forefront problems in Theoretical Astrophysics and General Relativity, such as black holes, gravitational waves, relativistic neutron stars, and fluid flows. In particular, the undergraduate will build graphics software for the visualization of binary black holes in orbit about each other. The research group at Cornell is involved in calculating the inspiral and coalescence of two black holes in such a system as they lose energy by emitting gravitational waves. Such events are likely to be detectable by the LIGO gravitational wave detector. The undergraduate will develop software to help study the output of these large-scale computer calculations.

Candidates for this position should be majoring in astronomy, physics or engineering physics and have a strong background in fundamental physics and mathematics. In addition, experience with computing is highly desirable. Students should be interested in continuing this research during the remainder of their undergraduate careers after the conclusion of the summer.

9. Prof. Joseph Veverka

Surface Processes on Comets

We now have spacecraft images of five different comet nuclei. At least two of these (Wild 2 and Tempel 1) display enigmatic pitted terrain which almost certainly is not the result of impact cratering. We will compare the detailed morphology of the "pits" on the two comets using high resolution stereo images and compare the results with the predictions of several models that have been suggested for the production of pitted terrains. We will also look into possible reasons for the absence of pitted terrains on some comet nuclei.

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Thanks!