Undergraduate Research Opportunities (including senior theses)

Adviser	Field	Topics - for detailed project description see page #	Page #
Prof. Davor Balzar	Condensed matter physics	directly contact Dr. Balzar: balzar@du.edu	-
Prof. Mercedes Calbi	Condensed matter physics	directly contact Dr. Calbi: mcalbi@du.edu	-
Prof. Kingshuk Ghosh	Biophysics	directly contact Dr. Ghosh: kingshuk.ghosh@du.edu	-
Prof. Jennifer Hoffman	Astrophysics	• What makes the "winking star" wink? • Learn to use a telescope, and help bring an astronomical instrument back to life! • A supernova on your desktop • 3-D simulations of hot star winds	2
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Prof. Robert Stencel	Astrophysics	• Adventures in Interferometry of evolved stars • Archival Analysis of the extreme binary Epsilon Aurigae • Automating the Student Astronomy Lab telescope	5
Prof. Sean Shaheen	Condensed matter physics	directly contact Dr. Shaheen: Sean.Shaheen@du.edu	-
Prof. Toshiya Ueta	Astrophysics	• Search for H alpha emission from possible wind-ISM shock cases using data from Wyoming Infrared Observatory (WIRO) • Verifying the Dust-Gas Coupling in an evolved star using data from the Hubble Space Telescope • Differential Proper-Motion Study of the Enigmatic Concentric Arcs of the Cygnus Egg Nebula with Imaging-Polarimetry	6
Prof. Barry Zink	Condensed matter physics	directly contact Dr. Zink: Barry.Zink@du.edu	-

Prof. Jennifer Hoffman (contact Dr. Hoffman: jennifer.hoffman@du.edu)

- **What makes the "winking star" wink?**

KH 15D, sometimes called the "winking star," is a young binary star surrounded by a thick wobbling disk that causes peridioc and variable eclipses. I am looking for a student to help analyze data from the McDonald Observatory's 2.7 m telescope that will help us learn more about the characteristics of the disk. For more background on this project, see my KH 15D page. This project would be good for a student with some computing experience and an interest in stellar astronomy.

- **Learn to use a telescope, and help bring an astronomical instrument back to life!**

I am working with colleagues nationwide to move an instrument called the HPOL spectropolarimeter from Wisconsin to Arizona, where it will be installed on the Mt. Lemmon Observing Facility. We are interested in training undergraduates in conducting observations with the instrument at the new telescope. Some of these observations will be used to calibrate the instrument and others will be scientific observations of stars and supernovae. This project is best suited for students who would like hands-on experience with astronomical equipment, can travel frequently, and don't mind staying up all night! Travel expenses will be covered.

- **A supernova on your desktop**

Students in my computational astrophysics group create 3-D models of the spectral and spectropolarimetric signatures created when light from a supernova explosion interacts with the surrounding gas thrown off by the pre-supernova massive star. No programming experience is required for participation in this group; the work is collaborative and ongoing.

- **3-D simulations of hot star winds**

I am beginning a project with a colleague at East Tennessee State University to create three-dimensional computer models of the structure of the stellar winds of very hot, active stars. The shapes these winds create in the circumstellar material surrounding their stars give us clues to the stars' subsequent evolution and ultimate explosion as supernovae. A student with good visualization and programming skills could join this project and learn to create models of different stellar wind geometries.

Prof. Dinah Loerke (contact Dr. Loerke: dinah.loerke@du.edu)

Modern fluorescence microscopy techniques can reveal the dynamics of specific proteins and intracellular structures with high resolution in space and time, and quantitative analysis of these - often very heterogeneous - dynamics provides unprecedented mechanistic insight into cellular processes. The scales of measurement can range from the dynamics of whole cell populations (e.g. scattering of adherent cell clusters in response to growth factors, or tissue remodeling during development) to the spatiotemporal dynamics of tiny subcellular particles (e.g. clathrin-coated pits on the cell membrane, or chromatin in the cell nucleus during replication). We perform quantitative image analysis of live-cell microscopy data, data analysis, and modeling in MatLab; students with experimental interests may also be able to do some additional cell and microscopy work. Possible projects include:

- **Remodeling dynamics in the fly embryo:**

This project will look at the dynamic reorganization of the epithelial sheet in the drosophila embryo during formation of the elongated body axis (in collaboration with Prof. JT Blankenship, Department of Biology). Building on some already established methods for segmentation of 4-D live cell movies, the goal of the project is to (a) develop a quantitative description of elongation process, and (b) formulate a (preliminary) testable mechanistic model for dynamic reorganization.

- **Lifetime analysis in biology:**

In engineering, lifetime analysis of mechanical components (such as sensors, batteries, etc.) has been used to study various aspects of the survival or failure process, and the goal of this project is to extend some of these principles to lifetime analysis in biology on subcellular particles. This will first require a solid estimation of experimental error in biological lifetime measurement (i.e. the relationship between measured vs. actual lifetimes), and will then be followed by developing survival models for one or more biological systems.

Prof. Mark Siemens (contact Dr. Siemens: msiemens@du.edu)

We use ultrafast laser pulses to excite and observe the dynamics of energy transport in nanostructures. Students will learn optics techniques and LabView programming for automated system control and data acquisition, and might do some numerical modeling in MatLab/C++. Possible thesis projects include:

- **Ultrafast laser pulse measurement and characterization:**

This project will require building various setups to explore the various techniques for measuring a short laser pulse's duration. A possible extension of this project is optimization of the pulse duration by dispersion compensation with a prism pair.

- **Photoacoustic measurements of thin films:**

One of the responses of a material to an ultrafast laser pulse is the generation of acoustic (vibrational) waves, which are then free to propagate in the material. A second, timedelayed "probe" laser pulse can be used to observe the propagating acoustic waves. Depending on the nature of the excitation, acoustic waves with depth or surface sensitivity can be generated, which are useful for characterizing nanostructured surfaces.

- **Ultrafast measurement of "thermal lensing":**

The optical energy deposited when a material absorbs an ultrafast laser pulse causes thermal expansion of the material, forming a bump on the surface. This can be measured by looking at a second ultrafast pulse reflected off of the material's surface, since the thermal bump acts as a curved mirror. The dynamics of the defocusing can be used to determine the thermal conductivity and expansion coefficient in the surface material.

- **Nano-bulk heat sinking modeling:**

The transport of thermal energy from a nanostructure into a bulk material depends not only on the heat-sinking capabilities of the bulk material, but also on the nanostructure size. Obtaining physical insight from experiments requires comparison with numerical models. The primary objective of this project is to implement numerical models in 4D (3 spatial dimensions + time) for diffusive Fourier transport and/or ballistic transport. This project will require much less experiment and more computational work.

Prof. Robert Stencel (contact Dr. Stencel: rstencel@du.edu)

With access to DU's fine telescopes (Chamberlin, Student Astronomy Lab and Mt. Evans) plus any number of additional telescopes on earth and in space, projects that span a wide range of stellar astrophysics are underway, creating multiple opportunities for senior thesis research.

Prospective senior thesis topics include:

- **Adventures in Interferometry of evolved stars**

We have been making use of the Center for High Angular Resolution Astronomy interferometric array of near-infrared telescopes at Mt.Wilson CA to study an eclipsing binary, but see opportunities to expand this work to a wider class of interacting binaries and evolved stars. In addition, the Magdalena Ridge Optical Interferometer near Socorro NM is about to come on line and provide additional research capabilities.

- **Archival Analysis of the extreme binary Epsilon Aurigae**

Using the CHARA array, we have imaged the solar system-sized dark disk in this system, and in parallel with Hubble, Gemini, IRTF and many other data sources, are poised to make a complete model for the structure in the disk, including radiative transfer calculations. The interested student can participate in any or all of the continuing effort.

- **Automating the Student Astronomy Lab telescope**

Sandwiched between the historic but cranky old Chamberlin 20 inch refractor telescope, and the modern but hard to access Mt. Evans twin 28 inch reflector telescopes is the Student Astronomy Lab, featuring the 30 inch Montgomery telescope. This is a work in progress, and interested students can participate in developing LabView control software, new mechanism and pursuing new observations - photometric and spectroscopic with this accessible research equipment.

Prof. Toshiya Ueta (contact Dr. Ueta: Toshiya.Ueta@du.edu)

- **Search for H alpha emission from possible wind-ISM shock cases using data from Wyoming Infrared Observatory (WIRO)**

3-night worth of data exists which needs to be reduced carefully in order to determine detection/non-detection of H alpha emission from possible wind-ISM shock cases. This project involves careful reduction of ground-based astronomical data and subsequent analysis, because we attempt to detect faint emission in the close vicinity of a star which is very bright. This project may involve additional trips to WIRO observations for follow-up observations.

- **Verifying the Dust-Gas Coupling in an evolved star using data from the Hubble Space Telescope**

A well-known evolved star IRC +10 216 has multiple shells of dust which are supposedly expanding due to radiation pressure from the star impinging upon dust particles and these dust particles transferring outward momentum to the gas component of the shell. We will be obtaining new HST data using the WFC3 camera to address one of the outstanding questions concerning stellar mass loss, "Does the gas component really move with the dust component as we postulate as the cause of the dusty mass loss processes?" This project requires straightforward optical HST data reduction and comparison of the data taken at two different time epochs to detect expansion of the circumstellar shells of IRC +10 216. Besides HST data reduction, you will learn how to program in IDL.

- **Differential Proper-Motion Study of the Enigmatic Concentric Arcs of the Cygnus Egg Nebula with Imaging-Polarimetry**

This ambitious project aims at solving the enigma of the Egg Nebula, that is, the issue in which this object possess the bipolar circumstellar lobes that are superposed with multiple concentric shells - how can axisymmetric structure and spherical structure co-exist in the circumstellar environment? We will address this question by reducing data taken from different time epochs with different instrument. Because of the complexity of the data set, this project will benefit from participation by those who have some prior knowledge in computation/astronomical data reduction, but should be doable by any level. You will need to learn how to reduce HST data from multiple instruments and multiple observations modes, and post-reduction analysis that requires IDL programming. While the learning curve for this project is high, after completing this project you will be versatile in HST data reduction and ready to apply Space Telescope Summer Student Internship Program or any other highly competitive astronomy REU opportunities.