

**REU Project Abstracts for Summer 2005  
(Current List of April 27)**

**NUCLEAR PHYSICS**

**Title: Production of Rare Isotopes**

**Supervisor: Prof. Betty Tsang**

**Abstract:**

Projectile fragmentation is one of the means to produce rare isotopes in the *Coupled Cyclotron Facility* (CCF) at the National Superconducting Cyclotron Laboratory at MSU. To understand the mechanisms of producing extremely neutron rich isotopes, we have carried out comprehensive cross-section measurements in the projectile fragmentation of Ca40, Ca48, Ni58 and Ni64. While the Ni64 data is being analyzed, we found that by adding 8 neutrons to the projectile of Ca40, fragmentation of Ca48 produces nearly twice as many (~200) isotopes as the fragmentation of Ca40 (~100 isotopes). Currently configuration of the A1900 fragment separator does not allow similar measurements of fragments cross-sections produced by heavier projectiles such as Kr86 or Xe136 easily. Thus we want to look into the design of detection systems that allow us to make measurements with heavier beams. We also expect that there will be opportunities to participate in experiments with our research group in June when two of our experiments are scheduled to run.

See for example:

<http://meetings.nscl.msu.edu/userworkshop2003/Presentation%20files/tsang.pdf>

**Title: Survey of single particle structure in nuclei**

**Supervisor: Prof. Betty Tsang**

**Abstract:**

The 1963 Nobel Prize in Physics was awarded to Maria Goeppert Mayer and Hans Jensen for their explanation of the structure of nuclei. The success of the Shell Model to explain the existence of the magic numbers of 2, 8, 20, 28, 50, 82 and 128 in neutron and protons has prompted the speculations that the closed shell can be treated as an inert core and the valence nucleons outside this core can be treated as independent particles. Such simple model allows the understanding of many observed nuclear properties. It also prompted many studies in the past four decades to describe the configuration of single particle orbits.

Recent advance in radioactive beams by using nuclei far away from stability has revived interest in measuring single particle structure in nuclei. There is evidence that the traditional view of the simple shell models will be modified for these exotic nuclei. Currently the only technique to study the single particle configuration of rare isotopes is to use transfer reactions. Thus it is important to establish reference points in the stable nuclei region allowing reliable extrapolations to rare isotopes.

The objective of this project is to use a consistent analysis procedure that our group has developed to analyze the past transfer reaction data published in the literature [see for example, [http://groups.nscl.msu.edu/hira/poster/poster\\_lee.ppt](http://groups.nscl.msu.edu/hira/poster/poster_lee.ppt)]. The extracted data will be invaluable for nuclear model development. In June, two experiments on transfer

reactions are scheduled to run at the National Superconducting Cyclotron Laboratory.. The REU student is encouraged to participate in these runs

**Title: Polarization sensitivity of segmented Germanium detectors at the NSCL**

**Supervisor: Prof. Krzysztof Starosta**

**Abstract:**

Segmented Germanium detectors are used at the National Superconducting Cyclotron Laboratory to measure properties of gamma-rays emitted during the deexcitation of unstable exotic nuclei. One of the advantages of the segmentation is in the fact that the detectors become sensitive to the polarization of gamma-rays which Compton scatter inside the detector. The information about gamma-ray polarization provides an experimental tool for determination of spins and parities of excited nuclear states. The scope of the project is to use gamma-rays with well known degrees of polarization to measure the polarization sensitivity of segmented detectors from the asymmetry of Compton scattering. A data set with significant statistics is available for the polarization sensitivity analysis from an experiment completed at the NSCL in April 2005.

**Title: Doppler Shift Attenuation method for nuclear lifetime measurements**

**Supervisor: Prof. Krzysztof Starosta**

**Abstract:**

Energies of gamma-rays emitted from a moving source are subject to Doppler shift which depends on the velocity of the source and the angle of observation. This fact is the basis of the Doppler Shift Attenuation (DSAM) method for nuclear lifetime measurements. In the DSAM method nuclei produced in a target as a result of a fusion-evaporation reaction are implanted and stopped in the target backing. Gamma-rays emitted during the stopping process differ in the Doppler shift depending on the lifetime of the initial state; for very short lifetimes the energies are fully shifted while for lifetimes longer than the stopping time there is effectively no shift since the gamma rays are emitted from the source at rest. The scope of the project is to measure lifetimes of excited states in  $^{134}\text{Pr}$  using the DSAM method. The project involves Monte-Carlo computer simulations of nuclear stopping for reconstruction of the gamma-ray line shapes extracted from available data.

**Title: LEBIT - Trapping of rare isotopes (experimental)**

**Supervisors: Prof. G. Bollen, Dr. S. Schwarz**

**Abstract:**

A physicist's dream - place a single particle freely in space and study it. Such a dream has become reality at LEBIT at the NSCL (<http://groups.nscl.msu.edu/lebit/>). LEBIT - the Low Energy Beam and Ion Trap facility - will allow us to capture single rare isotopes in devices called ion traps. First experiments aim at the precise determination of the mass of the trapped ions. This allows us to determine nuclear binding energies, an important and basic information. Penning traps, which employ a strong magnetic field for the ion storage, are ideal for this kind of measurement. The construction of LEBIT is completed and an exciting commissioning phase with beams of stable and unstable isotopes has started.

We are looking for a highly motivated and experimentally skilled student who wants to get hands-on experience at a high-tech precision instrument. Themes for individual

projects range from the design, building and test of dedicated electronics components, development work for the computer-based control system, ion optics simulations and their comparison with measurements, to systematic investigations of the properties of LEBIT components.

**Title: Production and Study of Neutron-Rich Nuclei**  
(available for 2 students)

**Supervisor: Prof. Michael Thoennessen and Dr. Thomas Baumann**

**Abstract:**

Last year we completed the construction of two major devices necessary to study the decay very neutron-rich nuclei. The combination of the superconducting 4 T sweeper magnet and the Modular Neutron Detector Array (MoNA) allows us to detect charged fragments and neutrons in coincidence. We are scheduled to run a major experiment to measure the decay of  $^{250}\text{O}$  in July. This run offers a unique opportunity for the REU students because they can get involved in all of the final preparations, including scintillation detectors, gas detectors, electronics, data acquisition and data analysis. Within these areas there several different opportunities for REU projects which the students can choose from depending on their interest.

## **NUCLEAR ASTROPHYSICS**

**Title: Nucleosynthesis in Thermonuclear (type Ia) Supernovae**

**Supervisor: Prof. Edward Brown**

**Abstract:**

Multidimensional simulations of thermonuclear (type Ia) supernovae can now capture much of the relevant behavior of the deflagration. These simulations do not, however, study the isotopes synthesized in the explosion, and it is necessary to post-process the output of the simulation with a nuclear reaction network that includes all relevant nuclear reactions. In this project, the REU student will perform, and assist in interpreting, nucleosynthesis calculations for type Ia supernovae using a modern, object-oriented reaction network. In doing this project, the student will learn about type Ia supernovae and how they are being modeled with state-of-the-art simulations. The student will interact with members of the Joint Institute for Nuclear Astrophysics. A knowledge of programming is useful.

**Title: Experiments for Nuclear Astrophysics**

**Supervisor: Prof. Hendrik Schatz**

**Abstract:**

To be announced

## **THEORETICAL PHYSICS**

**Title: Partitioning of Large Structures**

(available for 2 students)

**Supervisors: Profs. Scott Pratt and Wolfgang Bauer**

**Abstract:**

We will look at the size distribution of genes in genomes of different species and try to formulate constraints on evolutionary models that result from these observations. Other systems that we will compare are random partitions of atomic nuclei, the frequency distribution of words in the English language, and random fluctuations of the stock market. All of these systems have common statistical features, and we will try to figure out why. If you would like to take part in this project, you must be able to write (fairly simple) programs in C or in Java or in another high-level programming language. It would help to have some understanding of molecular biology, but is not required. A basic familiarity with statistical concepts is useful, but this does not need to exceed what's usually taught in an undergraduate statistical mechanics course.

**Title: Testing Excitation with a Simple Adiabatic Model**

**Supervisors: Prof. Filomena Nunes and Dr. Neil Summers**

**Abstract:**

Light exotic nuclei are mainly probed through reactions with stable targets. Although most of the reaction models developed so far assume that the constituents of the exotic nucleus remain inert throughout the reaction process, there are indications that this assumption may not be valid. We propose to include excitation in a simple adiabatic reaction model to probe the importance of this effect. The project will involve an analytical evaluation of the problem followed by numerical computation of the resulting integrals.

**Title: Structure of Nuclei**

**Supervisors: Profs. Alex Brown and Vladimir Zelevinsky**

**Abstract:**

To be detailed later

## **CONDENSED MATTER PHYSICS**

**Title: Giant Magnetoresistance in Magnetic Multilayers**

**Supervisors: Profs. Jack Bass and William Pratt**

**Abstract:**

Giant Magnetoresistance (GMR) in Magnetic Multilayers is of interest both for the underlying physics and for technology--the read heads in modern computer hard drives are now GMR multilayers. The MSU group pioneered measurements of Giant Magnetoresistance in Metallic Magnetic Multilayers with Current Flow Perpendicular to the Layer Planes, a geometry that usually gives more direct access to the physics underlying GMR. A specific project will be chosen after discussion with the REU student. The project will involve sample preparation (using a state-of-the-art sputtering system), sample characterization, and measurement of magnetoresistance. The project might also involve optical and electron-beam lithography in collaboration with a Ph.D. student or Postdoc.

**Title: Femtosecond Electron Spectroscopy**

**Supervisor: Prof. Chong-Yu Ruan**

**Abstract:**

Reaction and function at the nanometer scale are the new frontier of materials research. Fundamental understanding of these processes requires the structures and dynamics to be resolved at the atomic scale. The femtosecond electron crystallography and spectroscopy currently implemented in our laboratory aim to provide sufficient resolution and sensitivity to determine at the elementary space and time scale the atom-charge correlations leading to novel ultrafast material transformation and reaction. The REU project will involve the characterization of femtosecond electron pulse in space, time, and energy domains which is central to calibrate our experiments, especially in the development of time-resolved electron spectroscopy.

**Title: Seeing is Believing: the Nanoscale World of Scanning Probe Microscopy**

**Supervisor: Prof. Stuart Tessmer**

**Abstract:**

We study the physics of electrons inside metals and semiconductors. To measure the properties of the charges on nanometer length scales, we use incredibly sensitive tools called scanning probe microscopes. In addition to observing the local electronic structure, we can actually create pictures of the individual atoms on the surface. Surprisingly, the microscopes are relatively small: the entire system fits easily on a desktop. The plan for the REU student for this project is to (1) learn how to operate a scanning probe microscope, and (2) use it to characterize nanostructured semiconductor materials. To see more about the group, you can find us on the web at <http://www.pa.msu.edu/~tessmer/NanoGroup.htm>

**Title: Local structure and superconducting properties across the phase diagram of high-Tc La<sub>2</sub>-xSrxCuO<sub>4</sub>**

**Supervisor: Prof. Simon Billinge**

**Abstract:**

La<sub>2</sub>-xSrxCuO<sub>4</sub> copper-oxide belongs to a class of high-T<sub>c</sub> superconductors. It exhibits superconductivity at low temperature for a wide range of Sr concentrations. As temperature is increased above T<sub>c</sub>, superconducting properties are lost. Crystal structure of this class of materials plays an important role for the physical properties. Local structure of materials is often different than their average crystal structure. The atomic pair distribution function (PDF) technique based on neutron or x-ray scattering experiments is providing local structural information of materials. This challenging project is designed to address the relationship between the local structure of La<sub>2</sub>-xSrxCuO<sub>4</sub> and its superconducting properties. It is based on detailed analysis of a uniquely rich set of existing PDFs from neutron scattering data. The project involves structural modeling using the program PDFFIT, extracting structural parameters, detailed PDF data analysis and postprocessing, and collation of these results in a skillful manner in order to establish relationship between the local structure and superconductivity. The project offers an opportunity to gain skills of applying a local structural technique in acquiring insight into a possible relationship between the local structure and high temperature superconductivity.

This project involves extensive computer analysis of data. No programming or data analysis prior knowledge is required, but a masochistic enjoyment of using computers is a useful trait for this project.

**Title: Development of an image-plate x-ray camera for studying of the structure nano-materials**

**Supervisor: Prof. Simon Billinge**

**Abstract:**

Nanoscience and nanotechnology are two current "buzz-words" in physics that refer to the development of materials that take advantage of special properties associated with their small size, where small here refers to the nanometer length-scale. A major stumbling block in this endeavor is to study the atomic-scale structure of materials of this dimension since conventional approaches to structure solution fail for these materials. In my group we are developing novel methods using advanced x-ray and neutron scattering to do this. The REU project will be to develop and commission an x-ray camera for collecting data using recent image-plate technology. The camera has been designed and built by us, but has to be configured and tested and then data from the camera have to be extracted and analyzed. The project will be a mixture of hands-on work to configure and commission the camera, experimental work in the form of data collection, and computer analysis, including some code writing, to extract and process the data. No specific experience is needed except some experimental aptitude and interest and basic confidence in using computers. Some straightforward programming skills will also get you going more quickly with that aspect of the project.

**Title: Mesoscopic Physics**

**Supervisor: Prof. Norman Birge**

**Abstract:**

The electronic properties of small metallic samples are full of surprises. In the 1980's we learned that electrons in metals maintain quantum-mechanical phase coherence over large distances at low temperature. In the 1990's, we learned how electron pair correlations induced in a superconductor propagate in a normal metal. In the past few years, we have learned how a spin-polarized current propagates in a nonmagnetic metal. Now, we are struggling to understand the rich behavior that occurs when a ferromagnetic metal is placed in contact with a superconductor. An REU student could work in any one of these areas, or, if he or she is ambitious, could start a new project to study the electronic properties of graphene. Graphene is the name given to a single two-dimensional sheet of graphitic carbon. Within the past year, it was discovered that graphene is stable at room temperature, and has remarkable electronic properties. (See the article by Novoselov et al., Science 306, 666 (2004).) For example, the density of electrons or holes in graphene can be controlled by a gate, and the mobility of the charge carriers is very high. Graphene is promising as a material for future ultra-small electrical circuits.

## **ASTRONOMY**

**Title: Photometry of Pulsating Stars**

**Supervisor: Prof. Horace Smith**

**Abstract:**

Pulsating stars are keys to the galactic and extragalactic distance scales, and also important probes for understanding the structure and evolution of stars. In this project,

we will use old and new CCD observations of pulsating stars to determine their brightnesses. The new observations will be obtained with the CCD camera on the telescope of the campus observatory. Some of these stars may be multimode pulsators, unusual stars that are simultaneously pulsating in more than one mode and that are not well understood. Others are type II Cepheid variable stars in the globular star clusters of our Galaxy. Those Cepheids are far older than our Sun and are lacking in heavy elements compared to our own star.

**Title: Globular Clusters and X-ray binaries**

**Supervisor: Prof. Steve Zepf**

**Abstract:**

A possible project with Prof Zepf and his group is to use combinations of data from the Hubble Space Telescope on extragalactic globular clusters and data from the Chandra X-ray observatory on X-ray binaries to learn what properties of globular clusters help form X-ray binaries. While ordinarily stars never collide, the central regions of globular clusters have such high stellar densities that collisions and near collisions can help create X-ray binaries in which a neutron star or black hole accretes matter from an ordinary star. We are trying to learn more about how these processes work by determining what properties of a globular cluster make it more likely to host an X-ray binary.

There are also possibly theory projects on the formation of globular clusters early in the universe for students comfortable writing their own computer code.

**Title: Search for distant clusters of galaxies**

**Supervisor: Prof. Megan Donahue**

**Abstract:**

We're searching for distant (redshift  $z > 1$ ) clusters of galaxies, using new ground-based near-IR imaging obtained at the Kitt Peak 4-meter by Professor Donahue April 19-25, 2005. Her targets are extended X-ray sources that have no optical (I-band) counterparts. So they are either redshift  $z > 0.9$  clusters of galaxies or they are falsely classified as being extended, and are really just constellations of unrelated X-ray point sources. At this flux level in the X-ray survey used to select the infrared targets, we expect about a 50% contamination rate, so we expect to discover  $\sim 6$  high- $z$  clusters with 12 candidates. These clusters would be a significant enhancement to the number of X-ray clusters known already at these redshifts. There is a larger tie-in for that project, because if we discover a rich high- $z$  cluster, it may become a candidate for Hubble Space Telescope monitoring for supernovae by Saul Perlmutter's large HST project (219 90-minute orbits). At the same time, that HST project will accumulate fantastically detailed HST images of distant clusters. We will need someone willing to work with IRAF, learn a little bit about scripting; but mainly we need someone who is conscientious and organized, and who would be excited to discover new astronomical sources of cosmological importance.

**Title: Photometry of Metal-Poor Stars in the Galaxy**

**Supervisor: Prof. Tim Beers**

**Abstract:**

For several years we have been obtaining broadband UBV and BVRI photometry for large samples of candidate low-metallicity stars in the halo of the Galaxy. Such studies

are useful for refining the list of objects that ultimately will have spectroscopic observations obtained with SOAR and other telescopes. This summer, I would plan on working with Julie Krugler to guide her in the reduction and analysis of data which will be obtained during a two week observing run in May at Kitt Peak National Observatory, and a three week observing run (at nearly the same time) at Cerro Tololo Interamerican Observatory.

## **BIOPHYSICS**

**Title: Study of Protein Folding Using Optical Methods**

**Supervisor: Prof. Lisa Lapidus**

**Abstract:**

Proteins are part of all processes of life, such as photosynthesis, respiration and reproduction. Within the cell, proteins are continuously constructed from amino acid building blocks strung together like beads on a necklace using a gene as a template for the sequence. But a protein does nothing until this necklace folds into the native structure necessary for performing its particular function. The process of folding a protein into its native structure is spontaneous and depends in detail on the physical interactions between different residues of the polypeptide chain and with the surrounding water.

In my lab we study protein folding using optical methods. We have recently developed an ultra-rapid mixer to start observing the folding process after only 10 microseconds using fluorescence. An REU student would use this mixer to study the folding of apomyoglobin, a muscle protein. This protein has a fast folding step that has never been observed before. Lab duties would include some simple biochemical preparation of the protein for study, optical observation of the protein during folding and data analysis of the folding process. A background in biology is **not** required.

## **ACOUSTICS**

**Title: Studies in Acoustics and Perception of Sound**

*(available for 2 students)*

**Supervisor: Prof. William Hartmann**

**Abstract:**

The acoustics group has REU openings in two areas. The first measures the acoustical properties of various rooms on campus with particular reference to binaural properties and the implications of room reflections for sound localization by human listeners. The second project develops new materials and demonstrations for the teaching of musical acoustics at the elementary university level. All students working in the acoustics program are involved, at least as listeners, in current experiments run by graduate students - experiments on the detection of binaural incoherence, and virtual reality experiments on localization in the vertical plane.