UW Physics REU 2010 Project List

Projects are offered from the following physics subfields:

- Cosmology and astrophysics
- Elementary particle physics
- Nuclear physics and astrophysics
- Atomic physics
- Physics education
- Condensed matter and nanostructure physics
- Numerical modeling and simulations

If you have a special interest not represented in the list below, feel free to contact either Subhadeep Gupta or Alejandro Garcia for help. They may be able to design new projects that align with your interests.

Experimental Projects

Nano-Optics of Nano-Solids
Markus Raschke

We use the optical antenna properties of metallic nanostructures to spatially confine light on nanometer length scales for the spectroscopic investigation of nano-solids. In combination with scanning probe microscopy this allows for microscopy in the optical near-field of a tip providing ultrahigh spatial resolution with spectroscopic sensitivity down to the single molecule level. The implementation of coherent nonlinear and ultrafast optical techniques gives access to the study of electron and lattice dynamics on the nanoscale, symmetry properties as defined my magnetic and ferroelectric order, and molecular self-assembly of polymers or biomolecules. We are furthermore interested in fundamental optical phenomena in the optical near-field and the ability to control optical fields on the nanoscale. REU students participate in different experiments working alongside graduate students. They gain experience in basic optics and solid-state spectroscopy and both in femtosecond laser techniques and atomic-force and scanning-tunneling microscopy.

Laser trapping of 6He
Alejandro Garcia

This project aims at determining the angular correlation between the electron and the neutrino in the decay of 6He. We plan to use a Magneto-Optical laser trap to hold the 6He atoms so that the decay particles can be observed with minimal interference. The student will participate in on-going trials to improve production of 6He via nuclear reactions and on setting up the Magneto-Optical laser trap.

Development of new tests of Einstein's Equivalence Principle
Eric Adelberger, Frank Fleischer, Blayne Heckel, Stephan Schlamminger and William Terrano

The Eot-Wash group has the made the best tests of the universality of free fall, the most precisely tested (2 parts in 10^{13}) consequence of Einstein's Equivalence Principle. We are currently pursuing 2 paths aimed at improving this precision by a factor of 10--the first by increasing the power of our tests by making the test-body pair more sensitive to Equivalence Principle violation, the second by reducing the noise in our differential acceleration measurements. Both of these have REU projects. Specifically, the first REU project involves design and testing work on a prototype torsion pendulum that contains both neutron-rich (Be) and proton-rich (CH2) test bodies. The other project deals with a new cryogenic torsion balance designed to study the ultimate limits of the classical technique. Both projects require hands-on hardware work, computer modeling, and data analysis.

Research and Development for Gravity Wave Detectors
Stephan Schlamminger, Jens Gundlach, Blayne Heckel and Eric Adelberger

The Eot-Wash group is involved with the Laser Interferometer Gravitational Wave Observatory (LIGO) and the planned, space-based Laser Interferometer Space Antenna (LISA). One of the technological challenges in LIGO as well as in LISA is to avoid spurious forces acting on the interferometer mirrors. We have built ultra sensitive torsion balances to study such weak forces that may arise due to charge accumulation, surface potentials, residual gas molecules or gravity itself. The REU student working with us will learn about torsion balances to investigate such forces. The student will gain hardware experience in designing and building other instrumentation for LISA and LIGO. An example of a specific project is the development and characterization of an optical angle meter with nano-radian resolution.

Search for Dark Matter
Leslie Rosenberg

Our group is operating the Axion Dark Matter eXperiment (ADMX), a detector to search for the axion, a hypothetical particle that may form the dark matter in our galaxy. We recently commissioned a new data channel that looks for axions that have recently fallen into our galactic dark-matter halo. Also, we're in the process of rebuilding the detector for its next and more sensitive phase. We welcome someone with computing and mechanical skills who can join our group and who has an interest in experimental cosmology.

Quantum Computing with Trapped Ions
Boris Blinov

In the trapped ion quantum computing lab at the University of Washington we experimentally investigate the techniques for building a conceptually new type of computational device. A quantum computer will be extremely fast at solving some important computational problems, such as the factoring and the database search. While days of practical quantum computing may be quite far in the future, we are developing the main building blocks of such a device – the quantum bits ("qubits"), the basic logic operations, the qubit readout... The physical implementation of the qubit in our lab is the hyperfine spin of a single, trapped barium ion. Students in this REU project will participate in experiments with laser-cooled, RF-trapped single ions, will help develop techniques for single- and multi-qubit manipulation via microwave-induced hyperfine transitions and ultrafast laser-driven excitations. They will gain valuable hands-on experience with lasers and optics, RF and digital electronics, and ultrahigh vacuum technology.

Next generation neutrino detectors
Nikolai Tolich

Our group is involved in a number of experiments to detect neutrinos. Neutrinos are elusive particles that pass through matter almost completely unhindered, which makes them excellent probes of the physics occurring deep inside objects such as the earth and the sun, but also makes them extremely difficult to detect. We are currently working on ides for two different neutrino detectors, which both use liquid scintillator as the detection medium. One detector, around 1 kton in mass, could be used to measure neutrinos coming from the earth. This would allow us to measure the main source of heat within the Earth, which is thought to power mantle convection, earthquakes, and plate tectonics. The other detector, around 50 to 100 kton in mass, could measure neutrino oscillations from a man-made neutrino source. This would allow us to understand the nature of neutrinos. An REU student could help us simulate new detector designs, or could help us make measurements of the optical properties of the liquid scintillator to see if such detectors would be possible. For more information on our research group, see: http://www.phys.washington.edu/users/ntolich/

Neutrinos and Dark Matter
Michael Miller

We have an opening for an REU student in our neutrino/ dark-matter group at CENPA. I am one of four professors in the group and am working primarily on the MAJORANA project (*), although my interests are increasingly towards using the same technology to also search for Dark Matter interactions in the lab (**). This summer we have multiple projects that are well suited for a 10-week program. I include a few below:

1) Hardware: we have a large, fully constructed detector that holds 1 ton of liquid Argon. The goal is to use liquid Ar as an active "shield" for neutrino/Dark Matter detectors. When charged particles traverse the Ar light is produced and collected in photo multiplier tubes. The goal for the summer would be to play the lead role in operating and calibrating this device. It is a rare chance to play a leading role in an expensive (~$1M) device.

2) Software: we have multiple project choices involving simulations of neutrino detectors. These include learning how to write custom, high performance c++ code, as well as using standard tools of particle physics: the GEANT4 and ROOT c++ libraries.

3) Analysis: We have a rich set of data currently being collected at the Soudan deep underground laboratory that is probing terra incognita in the search for direct detection of Dark Matter. Data analysis would include in situ measurement of various background sources that are critical to fully utilizing the discovery potential of the Majorana prototype dark matter detector.

(*) Majorana home:
http://majorana.npl.washington.edu/

(**) Big picture description:
We are developing and building novel detector technologies to probe some of the most compelling questions of physics beyond the standard model: (i) the absolute neutrino mass scale, (ii) the Dirac/Majorana character of neutrinos, (iii) lepton-number conservation and its implications for the matter/anti-matter asymmetry, and (iv) general searches for dark matter interactions. The prospective student would join an active group based at University of Washington and be expected to contribute to both hardware and software tasks.

WALTA

R.J. Wilkes, T.H. Burnett, A. Goussiou

WALTA (Washington Large Area Time Coincidence Array) is a project to investigate the highest energy cosmic rays with the participation of middle and high school students and teachers throughout the Seattle area. Particle detectors and front-end electronics are sited at high schools and linked to UW via the schools' internet connections. The school network forms an extensive air shower (EAS) array suitable for detection of extremely high energy cosmic ray showers. During summer 2010 we will hold our annual one-week workshop for teachers in August. REU students will assist with detector development and installation, preparation of materials for the summer workshop, developing and documenting tools and materials for classroom use, and maintaining contact with teachers and students.

Research-based Instructional Strategies for Teaching Physics

Lillian C. McDermott, Paula Heron, Peter Shaffer

The Physics Education Group conducts research on student understanding of physics and uses the results to guide the design of instructional materials, which are intended for national distribution. The effectiveness of these curricula is assessed at the University of Washington and at many other institutions. REU students will have the opportunity to participate in programs shaped by the group's research, such as the summer program for K-12 teachers and the tutorials for the introductory physics course. In addition to taking part in classroom activities, previous REU participants assisted in investigations of the effect of different instructional strategies on student understanding of important fundamental concepts.

Electronic Phenomena in Nanowires

David Cobden

A huge variety of nanowires and nanotubes of many materials can now be synthesized. They allow us to explore numerous physical phenomena that are either new or significantly different from those seen in the bulk. These include phase transitions in reduced effective dimensionality and coupling of electronic and namomechanical properties. One possible summer project in our lab is to study the coupling of the metal-insulator phase transition in vanadium oxide nanowires to their mechanical distortion, induced either by micromanipulation or by electric field. Another project is to try to detect the predicted but never seen chiral photomotive force, by studying chiral nanowires of selenium and tellurium in a circularly polarized laser beam.

Semiconductor Nanostructures (tentative)
Marjorie Olmstead

We are investigating growth and properties of novel electronic materials compatible with silicon. The materials we are currently investigating are chalcogenides and oxides, which are of interest for as high-dielectric constant insulators, non-volatile phase change memory, and/or spin electronics (spintronics) that will add functionality to silicon technologies. We study the interplay between nanoscale kinetics and thermodynamics while forming an interface between two dissimilar materials, and the impact of the growth process on the structural, optical, magnetic, and electronic properties of the resultant nanostructure. Our primary experimental tools are in situ scanning probe microscopy, photoelectron spectroscopy and diffraction and ion scattering spectroscopy. This interdisciplinary research involves collaborators from physics, chemistry, and materials science.

X-ray Optics, Nonlinear Spectral Signatures, and Economics
Jerry Seidler

The Linac Coherent Light Source (LCLS), recently completed and commissioned at SLAC, is the world's first hard x-ray laser. It will allow measurements with unprecedented spatial and time resolution across multiple disciplines of science. Specific endstations are under construction to focus on: nonlinear x-ray optics in atomic physics, correlated electron physics in solid state and nanophase materials, pump-probe studies of biological and synthetic photochemistry, and plasma physics relevant for astrophysical nebula and planetary and stellar interiors. Science at the LCLS will, however, be constrained by a fundamental limit: it costs approximately $100,000 per hour to operate the light source, and therefore beam time is a scarce resource and high-efficiency experimental methods become precious. Our group has recently developed a new type of x-ray optic which promises to greatly decrease the measurement time for x-ray emission spectroscopy at the LCLS. Several summer projects are possible, including taking lead responsibility for modeling and designing an x-ray spectrometer for one of several applications at the LCLS. A successful project may enable new and important science while also saving the scientific community millions of dollars. Students involved in this project will get an in-depth experience in experimental instrument design, including both a broad introduction to modern x-ray techniques and also complete training in multiple aspects of instrument design. These students will also participation in one of my group’s trips to a synchrotron light source for characterization of, and experimental measurements with, the instruments that we design and build.

Theory/Numerical Modeling Projects

Neutrino Mass and Dark Energy (tentative)
Ann Nelson

Two of the most dramatic developments of the past five years have been the discovery that neutrinos oscillate, or quantum-mechanically change from one type to another due to a non-zero mass, and that 70% of the energy density of the universe exists in the form a mysterious, smooth, negative pressure fluid which has been dubbed "dark energy." Recently, a group of UW theorists have linked these two developments, by introducing theories in which neutrino masses depend significantly on the matter and neutrino densities in the local environment, as a result of new neutrino interactions. Such theories of mass varying neutrinos (MaVaNs) can explain the origin of the cosmological dark energy density and why its magnitude is apparently coincidental with that of neutrino mass splittings. An undergraduate with good familiarity with upper division quantum mechanics and some computer skills would be able to assist with studies of how the matter density dependence of neutrino masses affects the interpretation of neutrino oscillation experiments.

Light Front Quantum Mechanics
Jerry Miller

In 1947 Dirac introduced a new form of relativistic quantum mechanics in which the variable ct +z acts as a “time” coordinate and ct-z acts as a “space” coordinate. This so-called light front formalism was largely forgotten until the 1970's, when it turned out to be useful in analyzing a variety of high energy experiments. Despite the phenomenological success of this formalism, it has enjoyed only limited use in computing wave functions of particles and atomic nuclei. The present project is devoted to using the light front formalism to solve quantum mechanics problems involving bound and scattering states. A mathematically strong REU student would learn about relativistic quantum mechanics through the process of solving the relevant relativistic equations. This project would involve working on interesting and timely topics and could provide great preparation for graduate school quantum mechanics, field theory or even string theory. A full year of quantum mechanics is a necessary prerequisite.

Charge Symmetry Breaking in Quantum Chromodynamics
Jerry Miller, Daniel Bolton

One interesting aspect of the strong nuclear force is that it doesn't distinguish between the proton and the neutron, a fact referred to as charge symmetry. However, because the neutron is slightly more massive than the proton, we know this symmetry is broken (at the level of less than a percent). One of the two sources of this mass difference is the mass difference between the up and down quarks which make up the nucleons themselves. This project involves solving quantum mechanics problems which connect the quark mass difference to a real, observable charge symmetry breaking effect which was measured at a particle accelerator in 2003. A student could expect to learn about scattering theory and develop skills solving differential equations with a computer.

Planetesimal Dynamics
Tom Quinn

Comets provide unique constraints on the formation of the Solar System, however their evolution from "planetesimals" in the proto-planetary nebula involves a combination of orbital, collisional and even galactic dynamcs. This project will perform simulations of these processes using clusters of workstations, and analysis of the results to compare with the observed comet distribution in our Solar System and the observation of disks around other stars.

Cosmology
Tom Quinn

Groups and clusters of galaxies are the largest bound objects in the Universe, containing more than a third of the hot diffuse gas and a significant fraction of the galaxies in the Universe. Therefore, understanding the physical processes that occur in group and cluster environments, including the interactions between the dark matter, hot diffuse gas, galaxies, and the Active Galactic Nuclei, is key to gaining insights into the evolution of baryons and galaxies across the age of the Universe. This project will analyze large N-body simulations of galaxy clusters formation in order to understand the role these interactions play in establishing the observed cluster properties across cosmic time.

Computational Condensed Matter Theory and Response Functions: Real-time Time-Dependent Density Functional Theory
John J. Rehr

Real-time, time-dependent density functional theory (RT-TDDFT) is a powerful numerical method for computing linear and non-linear response functions in condensed matter physics. This work goes beyond ground-state calculations to calculate excited-state properties, for example as measured in electron and photon spectroscopies. Interest in theoretical or mathematical physics, scientific programming, and high-performance computing is desirable.

Theory project on diffusive and localized electron states (tentative)
David Thouless

In 1958 P. W. Anderson wrote a paper on “Absence of diffusion in certain random lattices", for which he was subsequently awarded the Nobel Prize. Physicists had been taught to expect electrons to propagate as waves in uniform lattice, and that the motion would become diffusive in the presence of disorder. We found Anderson's argument for the localizing effect of strong disorder counterintuitive. However, a rigorous proof of Anderson localization was obtained in 1985, but there is no comparable proof that weak disorder produces diffusive motion in three dimensions. It is known that any disorder in one dimension localizes all states, and there are reasons to think the same may be true in two dimensions.

I am starting to explore a new approach to this problem. The work involves numerical simulation of a single electron started at one point in a weakly disordered lattice, and following its subsequent motion, by mapping the lattice onto a one-dimensional lattice. The results of this simulation can guide the probabilistic arguments that are needed to get deeper understanding of the diffusive motion that we all believe in. The summer project would involve both aspects of this work.