Department of Physics: Advertised USRA/SUPRE Projects for Summer 2026

1 Machine Learning for Planetary Space Physics (Multiple Projects)

Planetary science and space physics are increasingly data rich areas of research, requiring the use of machine learning and other automated methods for analysis. However, while plentiful, these data are still sparsely sampled over vast regions of space, and require the use of physics knowledge, and uncertainty quantification, to advance our understanding. The following are projects that will use machine learning with scientific information, to further our understanding of planetary space physics.

1) Reinforcement Learning for Planetary Exploration: Scientific sensors flown or operated on spacecraft are often bandwidth limited and require prioritizing data to send back to Earth. Several projects ranging from extreme event identification in solar wind detection to novelty detection for Mars rovers are available to interested undergraduates. Students on this project will implement reinforcement learning based systems as proof of concepts for space weather alerts and data prioritization with publicly available data. This project is benefitted from students with prior physics and computational training (e.g. CMPUT 365) but I encourage motivated students to reach out.

2) Emulation of Magnetohydrodynamic Models with Probabilistic Machine Learning: Physics based models are computationally expensive but are required for interpretation of planetary datasets. Comparisons of these models and data sets are benefited through the use simulation based inference, or the use of machine learning models to emulate physics based solutions. Students on this project will simulate planetary space environments for comparisons to current, or future, datasets. This project is benefitted from students with prior physics or statistics training (e.g. ECE 342, PHYS 467) but I encourage motivated students to reach out.

Contact

Dr. Abigail Azari (aazari@ualberta.ca)

2 Biological Physics

1) Predicting microbial evolution. This research investigates the evolution of drug resistance within communities of pathogenic yeasts. The project involves assisting senior researchers to develop mathematical/computational models and to perform microbiology laboratory experiments on Candida species. The objective is to establish a quantitative and predictive understanding of resistance evolution in multispecies pathogen communities to inform better treatment strategies against drug-resistant infections.

2) Microbial magnetobiology. This research involves engineering magnetic field devices to characterize the effects of magnetic fields on the growth, pattern formation, and gene expression of genetically engineered budding yeast (*S. cerevisiae*). The goal of this research is to advance our fundamental understanding of the magnetobiology of microorganisms.

Contact

Dr. Daniel Charlebois (dcharleb@ualberta.ca)

3 Rotating Neutron Stars

Neutron stars are tiny stars with ultra-strong magnetic and gravitational fields and densities larger than nuclear. Their small size and large average densities allow them to spin at very rapid rates, with surface velocities that are a large fraction of the speed of light. The strong gravitational fields and relativistic rotation rates make it necessary to use Einstein's theory of general relativity to compute the properties of these stars.

The student will make use of an existing computer program (written in the C programming language) that solves the Einstein field equations for a rapidly rotating neutron star. The student will investigate some of the properties of the neutron star (for instance, the moment of inertia) and will write new functions in C and/or Python to analyse the results.

Contact

Dr. Sharon Morsink (morsink@ualberta.ca) by January 12, 2026, with a resume and up-to-date unofficial transcripts.

4 The Dynamic Radio Universe

We are entering the era of time-domain astronomy, where repeated observations of the sky reveal the dynamic Universe are performed at many different parts of the electromagnetic spectrum. We already expect to find exciting sources like the cataclysmic ends of massive stars (supernovae and gamma-ray bursts) and transient emission from neutron star and stellar-mass black holes that steal (accrete) material from a nearby star (X-ray binaries). However, we will undoubtedly reveal unknown sources (perhaps the electromagnetic counterparts to the sources of detectable gravitational waves and astrophysical neutrinos). The Very Large Array All Sky-Survey (VLASS) is an exciting survey being performed at radio wavelengths that will be made over several years, stitching together a relatively deep image of the entire sky visible from New Mexico, where the radio array is located. Three passes will be made providing information about transients. By the summer of 2021, VLASS will have started the second half of its second pass over the whole sky. Together, we will use data from the first two epochs to identify and classify transient radio sources.

Contact

Dr. Gregory Sivakoff (sivakoff@ualberta.ca)

5 Analysis of data from the PICO-40L dark matter detector at SNOLAB

Finding direct evidence of the particle nature of dark matter is one of the principle goals of particle physics with activities related to this at pretty much every lab around the world. The Canadian SNOLAB is an ideal site for such research as it is one of the deepest labs in the world, providing excellent shielding from cosmic radiation backgrounds. PICO is an international collaboration operating a large particle detector underground in SNOLAB aiming to detect dark matter by seeing bubbles in the boiling liquid of the PICO-40L bubble chamber. A student can contribute to this team effort by helping to analyze data, using tools such as machine learning, acoustic waveform analysis and optical pattern matching. Other projects to develop components for the new, larger PICO-500 detector are also available.

Contact

Dr Carsten B. Krauss (carsten.krauss@ualberta.ca)

6 Development of the P-ONE neutrino telescope in the Pacific Ocean

Neutrino events with energies above 1 PeV have been observed in the IceCube detector located in the ice of the South Pole glacier. In order to utilize such events for extracting particle physics we will need a new, large detector in the Pacific Ocean. We are in the process of developing a new such detector to be deployed in the Cascadia Basin already instrumented by Ocean Networks Canada. Students will use the existing framework of (python) programs to simulate and reconstruct how neutrinos in such a detector will been observed and what precision can be reached. We are also working on the development of a trigger system of distributed single board computers that is planned to be deployed in the ocean. Students will work on programming the computers to implement and performance test different trigger algorithms.

Contact

Dr Carsten B. Krauss (carsten.krauss@ualberta.ca)

7 Space mission data analysis & space plasma physics

The Earth's magnetosphere, ionosphere, and atmosphere form a tightly coupled space plasma environment that protects our planet. Yet, this coupling also causes space weather events that harm satellites and astronauts, disrupt GNSS-based navigation and communication, and even damage power grids and pipelines. What makes space plasma physics especially exciting is that, unlike distant astrophysics, near-Earth space can be directly measured by spacecraft. NASA and Canadian missions allow us to fly instruments through space plasmas and observe fundamental physical processes---such as particle acceleration, plasma waves, and turbulence---in real time.

1) Project 1 focuses on analyzing *in-situ* measurements from the NASA THEMIS and MMS spacecraft missions to study the fundamental nonlinear plasma phenomenon called nonlinear time domain structures (TDSs). These are tiny but powerful electrostatic structures ubiquitously observed in the plasma universe. The student will analyze high-resolution spacecraft data to identify TDSs events and build the first large statistical database of these structures in the magnetosphere. This work helps us understand and predict the impacts of TDSs in producing auroras and space weather effects that disrupt communications.

2) Project 2 focuses on analyzing *in-situ* measurements from the NASA ELFIN CubeSats to study how energetic electrons are lost from Earth's radiation environment. When these particles precipitate into the atmosphere, they can affect radio communication, atmospheric chemistry, and space weather conditions. The student will investigate how different physical mechanism---such as magnetic field geometry and wave-particle interactions---control where and how energetic electrons are lost. This project directly connects CubeSats observations with space weather applications (modeling and prediction).

Students in both projects will gain experience in signal processing techniques (e.g., FFT and wavelet), numerical modeling, and spacecraft data analyses. Students will collaborate with national and international spacecraft mission teams to conduct high-impact, discovery-driven research.

Contact:

Dr. Yangyang Shen (yangyang.shen@ualberta.ca)

8 Elastic field numerical modeling and Imaging

This project focuses on utilizing the Devito package, a specialized tool for solving partial differential equations (PDEs), to conduct elastic forward Born modeling and inversion. Our primary objective is to explore and analyze numerical parameter cross-talk issues. We aim to investigate whether introducing new parameterizations in the inverse problem can effectively reduce parameter crosstalk. A key requirement for participants is either existing proficiency in Python or a strong commitment to develop this skill within the first month of the internship. Preference will be given to students who have taken GEOPH 110, GEOPH 325, GEOPH 326 and PHYS 234.

Contact

Dr. Mauricio Sacchi (msacchi@ualberta.ca)

9 Scattering in real time in two dimensions

Scattering is typically described in a time-independent fashion, with an eye on measuring the outcome well away from the target, and in a "steady-state" type of scenario. We have recently examined the detailed time-resolved one-dimensional scattering case, where the two outcomes are transmission and reflection. Preliminary work has been done in two dimensions, but so far, we have not attained definitive results for well-known geometries. This work would seek to attain this goal and then explore the scattering consequences for previously unexplored geometries.

Contact

Dr. Frank Marsiglio (fm3@ualberta.ca)

10 Surface vs Bulk Superconductivity

The theory of superconductivity (BCS) is best understood in wave vector space, where use is made of the translational invariance in the problem. Many experiments (e.g. tunneling via the STM (scanning tunneling microscope), only probe the surface; this region can look very different compared to the bulk. We wish to explore the key differences, including essential differences in the symmetry of the order parameter, and assess how faithfully so-called surface probes can determine the bulk properties of a superconductor.

Contact

Dr Frank Marsiglio (fm3@ualberta.ca)

11 Ultrasound imaging of long bones

The cortex of long bone is a hard tissue layer bounded above and below by soft tissue and marrow, resulting in high impedance contrast interfaces, and therefore is a natural waveguide for ultrasonic energy to propagate. The velocities of the guided modes are different and sensitive to the cortical thickness and the elasticity of the propagating medium. We are a research team to use ultrasound to study bone tissues. The research involves multi-disciplines involving signal/image processing techniques, numerical simulation, and machine learning. This is joint work with Professor Mauricio Sacchi. I am looking for a student who has good signal processing skills to analyze the data. Knowledge with machine learning is an asset. It is possible for qualified candidate to apply for NSERC summer internship.

Contact

Dr. Lawrence Le (lawrence.le@ualberta.ca)

12 Molecular Biophysics (Various Topics)

1) Protein aggregation mechanisms: we are studying how proteins aggregate to cause disease, aiming to determine the molecular mechanisms of aggregation and discern which steps are most important to stop it. We use single-molecule mass photometry to 'weigh' molecules with light and monitor how populations of aggregates change over time, then we model the aggregation kinetics mathematically to find the mechanism that best fits the data. Projects that are primarily experimental or primarily theoretical/computational are both possible.

2) Mechanism of propagated misfolding in neurodegeneration: we are studying how misfolding can propagate between protein molecules in disease, looking specifically at the protein SOD1 linked to ALS. We aim to find compounds that bind to different parts of the SOD1 protein, then test if they are able to inhibit propagation of misfolding, to identify which parts of the protein are involved in the conversion process. Primarily experimental.

3) Identifying targets for drugs in viral RNAs: we developed an information-theoretic approach for assessing if an RNA sequence is druggable. We aim to use this method to scan through the genomes of prominent viruses to find structures in the viral RNA that can be targeted with drugs. Primarily computational/theoretical.

4) Molecular dynamics simulations of protein folding: we are studying the folding of unusual proteins that can switch between different structures (known as 'fold-switching' proteins). Molecular dynamics simulations of fold-switching proteins will help interpret upcoming single-molecule laser tweezers measurements of their folding dynamics. Primarily computational.

5) Machine learning (ML) in drug discovery: we are looking at how to use active learning to predict new drug candidates when given only a limited amount of experimental data on possible drugs, such that training of ML models must use sparse information. Active learning will be applied to regression of simulated data as proof of principle, exploring which ML architecture works best. Primarily computational.

Contact

Dr Michael Woodside (mwoodsid@ualberta.ca)

13 Plan and design a nuclear magnetic resonance (NMR) detector

Spin-polarized noble gases are used in magnetometric applications such as magnetic resonance imaging (MRI) and chemical analysis via NMR. Our lab is developing a novel nuclear spin polarizer. NMR detection will be used to characterize the polarizer’s performance. The project will aim to plan and design an NMR detector for this purpose. The student will design the coil system, estimate the magnetic field strength and uniformity through theoretical and numerical models (e.g. in COMSOL), and choose the detection scheme (e.g. adiabatic fast passage or free induction decay). The student will also design any necessary mechanical supports for custom fabrication and plan for the driving electronics. If time allows, the student will carry out experimental component fabrication and characterization.

Contact

Dr. Gil Porat (gporat@ualberta.ca)

14 Greybody factors and quasinormal mode calculations of black holes

Black holes left in isolation may emit radiation by two mechanisms. Either by Hawking evaporation or as a result of its ringdown after being formed, or due to some other perturbation. Both types of radiation are characteristics of the black hole and, in principle, allow a determination of its properties. Recent and future gravitational wave detectors aim to measure the characteristic quasinormal modes. These measures could allow alternative theories of gravity, that incorporate aspects of quantum gravity, to be tested. The two most popular approaches to investing possible quantum aspects of gravity included loop quantum gravity and superstrings.

The student will perform numerical calculations of radiation transmission (greybody factors) and complex frequencies of the radiation (quasinormal modes) for different black hole spacetimes. A knowledge of general relativity is desirable but not essential. A strong background in mathematical physics and computing would be an asset.

Contact

Dr Doug Gingrich (gingrich@ualberta.ca)

15 How likely are damaging earthquakes?

Natural earthquakes occur all over the world, some with devastating effects. In the last decade it has become clear that human activities may also trigger earthquakes, for instance due to saltwater disposal or fracking. In this project we will investigate the seismic hazard in Northeast British Columbia in the Montney play, an unconventional hydrocarbon reservoir.

Contact

Dr Mirko van der Baan (mirko.vanderbaan@ualberta.ca)

16 Antimatter in atoms

What is the probability of finding a positron in the hydrogen atom? This project will determine it using the Dirac equation and elements of Quantum Field Theory. In addition, it will be an opportunity to hone your computing skills, both numerical and symbolic. The outcome is expected to be published in the Physical Review.

Contact

Dr Andrzej Czarnecki (andrzejc@ualberta.ca)