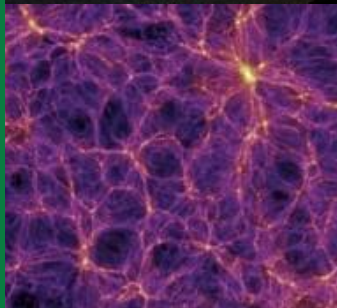
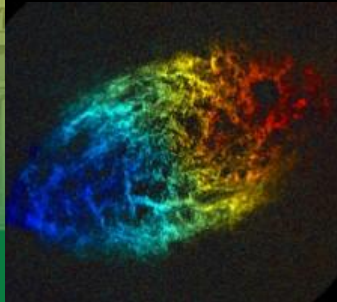


# UNIVERSITY OF ALBERTA DEPARTMENT OF PHYSICS RESEARCH AREAS



# ASTROPHYSICS & GRAVITY



UALBERTA  
PHYSICS

*From the births of stars ...  
through their deaths and beyond ...  
to the edge of the Universe*

The astrophysics faculty explore questions such as:

- How did the universe form?
- How did structures form in the early universe?
- How do clouds of gas form stars and planets?
- What happens when stars collide & merge?
- How do stars explode as supernovae?
- How do black holes accrete gas and create relativistic jets?
- What are neutron stars made out of?
- What happens inside of black holes?



**Rodrigo Fernández, Professor**  
*Supernovae and Neutron Star Mergers*

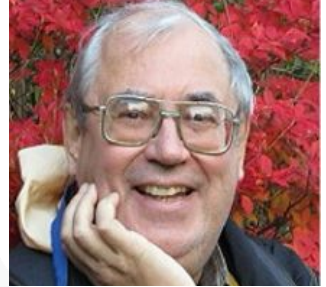
Fernández and his group study neutron star mergers, supernovae, and other transient systems. These events are the formation sites of black holes, neutron stars, and of most elements heavier than helium. The complexity of these phenomena requires the use of numerical simulations on large supercomputers to make reliable predictions that can be tested with observations.

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**Valeri Frolov, Professor**  
*Black Holes*

Classical and quantum gravity; Black hole physics; Large extra dimensions; Hidden symmetries and higher dimensional black holes; Problem of black hole entropy; Models of a black hole's interior; Quantum field theory in a curved spacetime; Quantum effects in accelerated frames; Cosmological defects; Interaction of strings and branes with a black hole; Wormholes and time machine problem.

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**Craig Heinke, Professor**  
*High-Energy Astrophysics*

Heinke's research group uses a range of X-ray and other telescopes to study high-energy astrophysical systems, especially compact objects (the dense remnants of dead stars; white dwarfs, neutron stars, and black holes). Key questions include how compact objects accrete matter from companion stars, the composition and cooling of neutron stars, and how interactions in dense star clusters affect binary stars.

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**Natalia Ivanova, Professor**  
*Evolution of Binary Stars*

Ivanova and her group are working on understanding the physics of stable and unstable stellar interactions -- from violent mergers to stable mass transfer -- and their effects on the lives of close binary stars, using supercomputers to model these interactions, and the behavior of stellar populations. Ivanova is looking for new students with interests in theoretical and computational astrophysics, high-performance computing and data analysis.

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[www.ualberta.ca/~ivanova/](http://www.ualberta.ca/~ivanova/)

**Sharon Morsink, Professor**  
*Neutron Stars and Relativity*

Dr. Morsink and her group study neutron stars, the highest density objects in the universe, using the effects of special and general relativity. Using analytical and numerical calculations, they identify how relativistic effects change the appearance of light (especially X-rays) from fast-spinning, dense neutron stars, and how we can use this to understand the behavior of matter at extreme densities in the cores of neutron stars.

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**Don Page, Professor**  
*Black Holes and Cosmology*

Page's research group works at the confluence of general relativity and quantum mechanics, applying both to understand black holes and the origin and nature of the universe. Current questions include the evaporation of black holes, whether information is destroyed when it falls into a black hole, and whether the universe is one realization of a "multiverse".

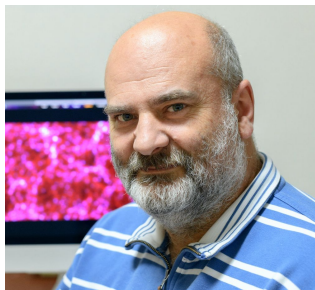
[dpage@ualberta.ca](mailto:dpage@ualberta.ca)



**Dmitri Pogosyan, Professor**  
*Evolution and Structure of the Universe*

Pogosyan's research interests span the range from the theory of the early Universe, to theory and analysis of initial perturbations to the Cosmic Microwave Background, to the modeling of the observed large-scale structure at low and high redshifts, to the statistical study of the galactic turbulence.

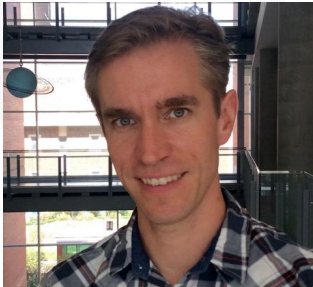
[pogosyan@ualberta.ca](mailto:pogosyan@ualberta.ca) | [www.ualberta.ca/~pogosyan](http://www.ualberta.ca/~pogosyan)



**Saeed Rastgoo, Assistant Professor**  
*Quantum Gravity, Black Holes, Gravitational Waves*

Rastgoo's research group studies classical and quantum gravity, including the study of the interior and exterior of quantum black holes, the fundamental and fine structure of spacetime, and the very early and quantum cosmology. They also use phenomenological approaches to connect quantum gravity theory with modern experiments, including the use of multimessengers, particularly gravitational waves, to probe new and fundamental physics of black holes, spacetime, and cosmology.

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**Erik Rosolowsky, Professor**  
*Star Formation*

Rosolowsky's research group uses multi-wavelength observations of star formation and the interstellar medium to study the connections between stellar generations. In this work, they use surveys of nearby galaxies from facilities like the Atacama Large Millimetre/submillimetre Array and the Hubble Space Telescope. Dr. Rosolowsky is recruiting new students with interests in observational astronomy, machine learning and big data analysis to tackle some of the pressing questions in galaxy evolution.

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**Gregory Sivakoff, Professor**  
*Relativistic Jets and Accretion*

Sivakoff's research group studies the stellar undead (white dwarfs, neutron stars, and stellar-mass black holes that return to life by eating a nearby star) and supermassive black holes. Using observations across the electromagnetic spectrum, they are learning how these objects produce highly-focused very-fast outflows (relativistic jets) and how jets affect their environment

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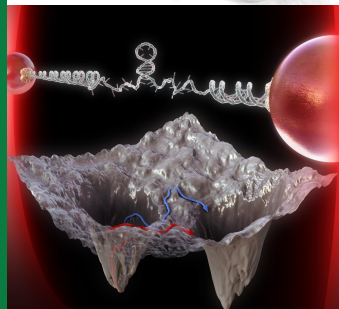
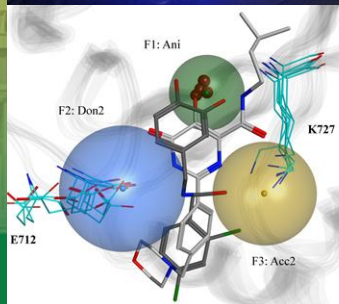
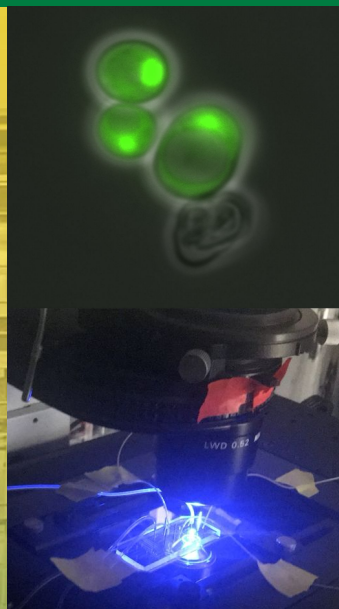


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**ASTROPHYSICS & GRAVITY**

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# BIOPHYSICS



UALBERTA  
PHYSICS

# probing the physical basis of life

Biological physics uses the concepts and tools of physics to elucidate the principles and mechanisms underlying living systems, from the behaviour of biological molecules like proteins to the functioning of cells and organisms.

Research in Biophysics at the University of Alberta explores a range of theoretical, computational, and experimental problems, including how protein and RNA structures fold, mechanisms of neurodegeneration and cancer, function and evolution of gene networks, the role of quantum effects in biology, and improved methods discovering new drugs and mitigating drug resistance. These studies take advantage of tools like advanced single-molecule force spectroscopy, flow cytometry, live-cell imaging and microfluidic devices, THz laser sources, and high-performance computing facilities. Group members also collaborate extensively with colleagues in the life sciences and medicine.



**Daniel Charlebois, Assistant Professor**  
*Computational & Experimental Biophysics*

Dr. Charlebois' lab is part of a cutting-edge research program that combines computation and experiment at the interface of physics and biology. He is developing spatial cell population simulation algorithms, investigating the effects of the physico-chemical environment on synthetic gene networks, and mitigating drug resistance in pathogens.

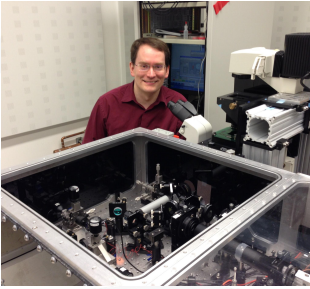
[dcharleb@ualberta.ca](mailto:dcharleb@ualberta.ca) |  
[www.ualberta.ca/~dcharleb](http://www.ualberta.ca/~dcharleb)

**Jack Tuszyński, Professor**  
*Theoretical & Computational Biophysics*

Dr. Tuszyński studies diverse theoretical and computational problems in biophysics, from drug design and discovery in cancer and neurodegeneration to electrical signaling in cells and quantum biology.



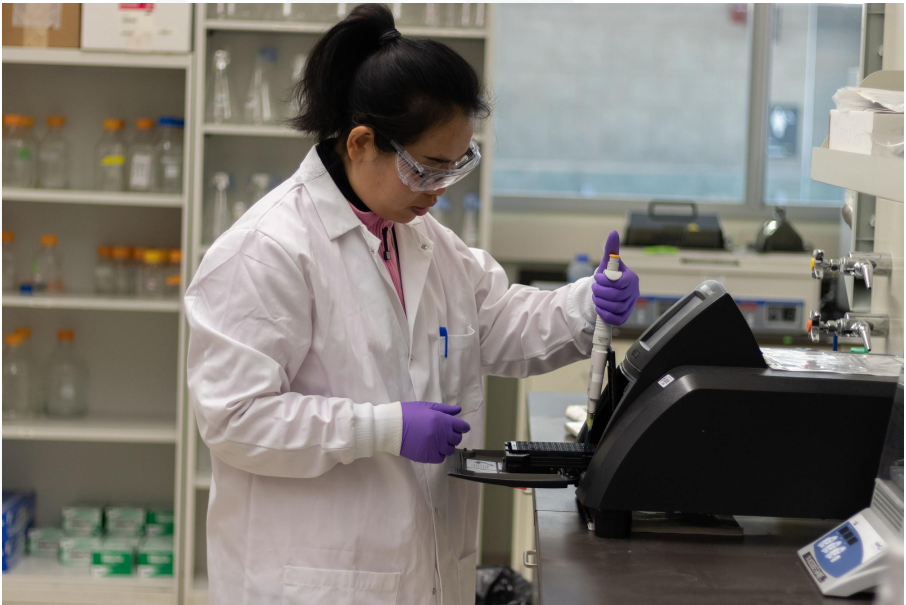
[jackt@ualberta.ca](mailto:jackt@ualberta.ca) |  
[www.pharmamatrix.com](http://www.pharmamatrix.com)



**Michael Woodside, Professor**  
*Experimental Biophysics*

Dr. Woodside explores how the folding of proteins, and DNA/RNA relates to biological function and disease. Using state-of-the-art laser tweezers and fluorescence assays combined with ensemble biophysical and biochemical approaches, his lab explores the fundamental physics of folding and test theory, how evolution shapes folding via *de novo* protein design and ancestral protein reconstruction, probes viral RNA structures that recode gene expression, and studies misfolding mechanisms in neurodegeneration and tests possible drugs.

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[spaces.facsci.ualberta.ca/woodside](https://spaces.facsci.ualberta.ca/woodside)



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**Additional researchers in Biophysics include:**

- **Frank Hegmann, Professor**  
*Experimental Biophysics*  
*Ultrafast terahertz science and nanophysics*  
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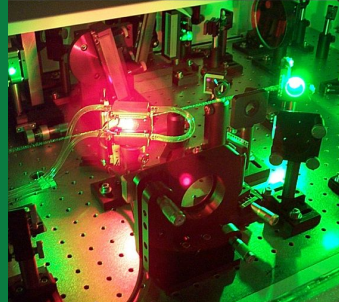
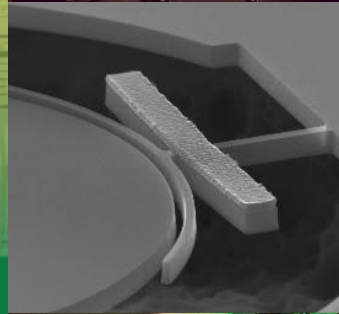
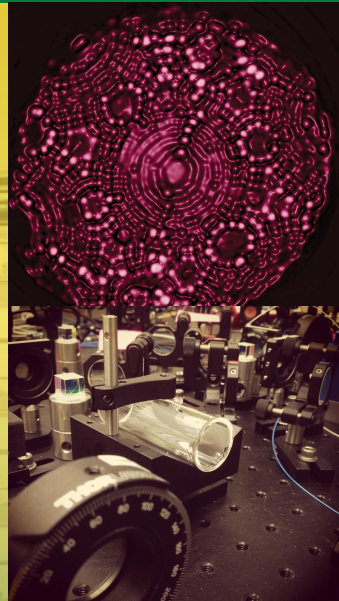


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## **BIOPHYSICS**

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# CONDENSED MATTER PHYSICS ATOMIC, MOLECULAR & OPTICAL PHYSICS



UALBERTA  
PHYSICS

# uncovering the nature of matter from the macroscale to the nanoscale

Researchers in Condensed Matter Physics and Atomic, Molecular & Optical Physics at the University of Alberta use advanced computational resources, state-of-the-art experimental facilities in CCIS and the nanoFAB explore a wide range of topics, including: magnetism, photonics, optomechanics, quantum technologies, scanning probe microscopy, strongly correlated electrons, superconductivity, superfluidity, topological phases of matter, ultracold quantum gases, ultrafast laser spectroscopy.

## **Igor Boettcher, Assistant Professor,** *Condensed Matter Theory*

The Boettcher group studies quantum many-body systems on a wide range of platforms, including topological semimetals, ultracold quantum gases, circuit quantum electrodynamics, and novel superconductors. This is achieved by applying techniques from quantum field theory and the renormalization group.

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## **John P. Davis, Associate Professor** *Cavity Optomechanics & Confined Superfluids*

Combining state-of-the-art nanofabrication, cavity optomechanics, and ultra-low temperatures, the Davis lab explores the interface between the classical world and the quantum one, while developing next-generation quantum technology. His lab has also developed Canada's only cryogenic system capable of cooling below 1 mK, in order to study exotic states of superfluid  $^3\text{He}$ .

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## **Mark Freeman, Professor** *Experimental Hybrid Nanosystems*

Facilitated by the UofA's outstanding nanofabrication infrastructure, Dr. Freeman's lab studies the physics of nanosystems incorporating magnetic, mechanical, and optical degrees of freedom - such as gaining new insights into magnetism through the use of nanomechanical signatures of spin resonance.

[mark.freeman@ualberta.ca](mailto:mark.freeman@ualberta.ca) | [www.ualberta.ca/~freemamm](https://www.ualberta.ca/~freemamm)



**Frank Hegmann, Professor**  
*Experimental Condensed Matter Physics*

Dr. Hegmann explores ultrafast phenomena in materials on the nanoscale using time-resolved terahertz spectroscopy and terahertz scanning tunneling microscopy (THz-STM). His state-of-the-art Ultrafast Nanotools Lab and Ultrafast Spectroscopy Lab use amplified femtosecond laser sources and picosecond-duration terahertz pulses to probe ultrafast excitation dynamics and carrier transport in nanomaterials.

[hegmann@ualberta.ca](mailto:hegmann@ualberta.ca) | [www.hegmannthz.wordpress.com](http://www.hegmannthz.wordpress.com)



**Lindsay LeBlanc, Associate Professor**  
*Experimental Atomic and Optical Physics*

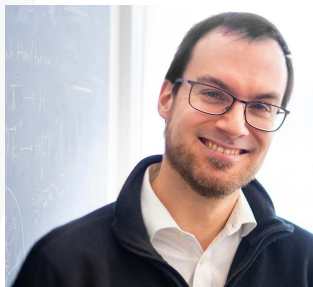
Dr. LeBlanc uses atomic systems, including warm vapours, laser-cooled ensembles, and ultracold quantum gases (Bose-Einstein condensates) to study and exploit the quantum nature of matter. Applications include quantum memory, quantum computing, and sensing. This research has applications in quantum information and involves developing cutting-edge quantum technologies in her state-of-the-art lab.

[lindsay.leblanc@ualberta.ca](mailto:lindsay.leblanc@ualberta.ca) |  
[sites.google.com/ualberta.ca/ultracold](https://sites.google.com/ualberta.ca/ultracold)

**Joseph Maciejko, Associate Professor**  
*Condensed Matter Theory*

Dr. Maciejko researches emergent phenomena in quantum many-body systems. Areas of current interest include the topology and geometry of quantum matter, strongly correlated electrons, and quantum criticality.

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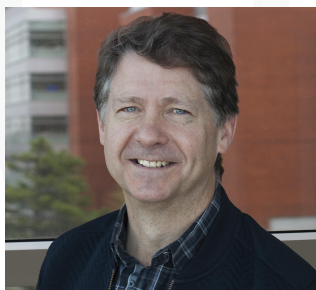
**Frank Marsiglio, Professor**  
*Condensed Matter Theory*

The Marsiglio lab studies various aspects of many-body electron systems, including superconductivity, polaronic effects, spin-orbit coupling in trapped ions, and impacts of external fields and stimuli.

**Al Meldrum, Professor**  
*Optics and Photonics*

Dr. Meldrum's work focuses on optical materials development, applications-driven optical sensing technologies, and optical devices. His lab offers the opportunity for multidisciplinary training, with students interacting closely with chemists and engineers, as well as physicists and potentially industry as well.

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**Robert Wolkow, Professor**  
*Atom-Defined Quantum Circuitry*

Dr. Wolkow's research offers the opportunity to build, explore, and commercially deploy their lab's newly discovered atom scale circuitry. Smaller, dramatically less energy consuming and enormously faster than CMOS, these atomic electric machines open the door to a near term classical computing revolution while pointing to a scalable approach to quantum circuitry.

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**Additional researchers in CMP/AMOP include:**

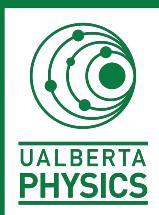
**Paul Barclay, Adjunct Professor**  
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<http://barclaylab.ucalgary.ca/pbarclay>

**Wayne Hiebert, Adjunct Professor**  
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**Marek Malac, Adjunct Professor**  
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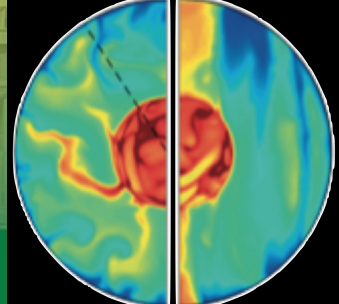
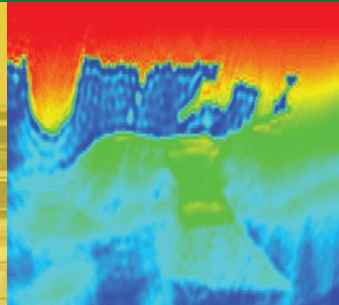
**Kim Chow, Professor**  
[khchow@ualberta.ca](mailto:khchow@ualberta.ca)  
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# GEOPHYSICS



UALBERTA  
PHYSICS

# *advancing our understanding of Earth's structure and evolution*

The wide variety of research in Geophysics at the University of Alberta includes both fundamental and more applied geophysical science projects. Current research focuses on the field of geophysical data processing, theoretical and applied seismology, earthquake studies, geodynamics, geomagnetism and paleomagnetism, magnetotellurics, environmental geophysics, geothermal energy, climatology and planetary geophysics.



**Claire Currie, Professor**  
*Geophysics & Geodynamics*

Geophysics – geodynamics; convergent plate margins: subduction zones and mountain belts; continental structure, strength, and dynamics; numerical modelling of lithosphere and upper mantle dynamics; controls on earthquake distribution.

[claire.currie@ualberta.ca](mailto:claire.currie@ualberta.ca) |  
<https://sites.ualberta.ca/~ccurrie1>

**Mathieu Dumberry, Professor**  
*Physics of Planetary Interiors*

Dr. Dumberry's research focuses on the physics of planetary interiors, including the study of flows in the fluid core of planets, the generation and evolution of planetary magnetic fields, the rotational dynamics of planetary bodies and fluid-solid interactions at interior boundaries. His work is mainly theoretical, including numerical simulations, with an emphasis on relating specific observations to simple models of the dynamics.

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**Jeff Gu, Professor**  
*Crust and Mantle Seismic Structure*

Dr. Gu's main research area is earthquake seismology, including regional crust and mantle seismic structure analysis, induced earthquakes, and global seismic imaging.

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**Moritz Heimpel, Associate Professor**  
*Dynamics of Planetary Interiors*

Dr. Heimpel's main research interest is dynamics of planetary interiors. This involves theoretical and numerical modelling of fluid dynamics and magnetohydrodynamics applied to planetary atmospheres and interiors. Work on planetary dynamos have implications for the dynamical evolution of several of the solar system planets, particularly Mercury, Earth, Jupiter, Saturn, Uranus and Neptune, as well as exoplanets.

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**Vadim Kravchinsky, Professor**  
*Paleomagnetism & Petromagnetism*

Dr. Kravchinsky uses paleomagnetism and petromagnetism as tools (1) to reconstruct past climate and environmental changes, (2) to perform plate tectonic reconstructions, (3) to study evolution of Earth and mass extinctions, and (4) to determine ages of geological and archeological objects.

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**David Potter, Professor**  
*Petrophysical & Geophysical Techniques*

Dr. Potter studies petrophysical and geophysical techniques: both fundamental research and applied studies for the oil and gas industry.

[dkpotter@ualberta.ca](mailto:dkpotter@ualberta.ca)



**Mauricio Sacchi, Professor**  
*Seismic Data Processing and Imaging*

Dr. Sacchi's lab conducts research in the area of statistical and transform methods for seismic data processing, waveform imaging and inversion with an application to applied and global seismology. His group has become recognized for the development of algorithms for multi-dimensional seismic data reconstruction, de-noising and the application of sparsity promoting and dimensionality reduction methods to seismic data processing.

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**Bruce Sutherland, Professor**  
*Geophysics & Fluid Dynamics*

Atmospheric, oceanic and environmental fluid dynamics; stratified flows, internal waves, plumes and gravity currents; particle-bearing and particle-laden flows.

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<http://sites.ualberta.ca/~bsuthe>

**Martyn Unsworth, Professor**  
*Electromagnetic Geophysics*

Dr. Unsworth's research is in the field of electromagnetic geophysics, primarily using the magnetotelluric method to image Earth structure in 3-D. His research includes using magnetotellurics in (1) exploration for mineral and geothermal resources (2) studying plate tectonic processes and earthquakes and (3) imaging magma beneath active volcanos to better understand eruptions and hazards.

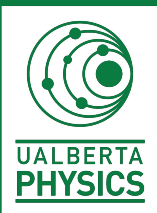
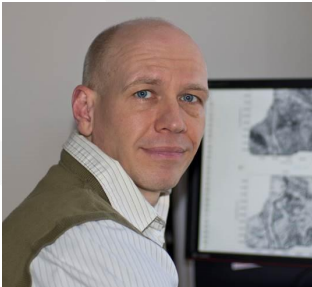
[unsworth@ualberta.ca](mailto:unsworth@ualberta.ca) |  
<https://sites.ualberta.ca/~unsworth>



**Mirko van der Baan, Professor**  
*Seismic Wave Propagation & Geomechanics*

My research interests span signal processing, seismic wave propagation, geomechanics and microseismicity. Some research questions my students and I are tackling: Does fracking cause earthquakes? How can we mitigate human-induced seismicity? Can we model rock deformation during hydraulic fracturing treatments? How can we enhance data quality and resolution to detect weak events and features? Can machine learning algorithms predict failure? I collaborate extensively with the hydrocarbon industry and many of my students have found positions there.

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## GEOPHYSICS

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# PARTICLE PHYSICS



UALBERTA  
PHYSICS



# uncovering the mysteries of our universe

*The particle physics group at University of Alberta studies the fundamental nature of matter and force. Our work tries to answer some of the most fundamental questions in nature, such as: what is the nature of dark matter? why is the Universe full of matter and not anti-matter? how do neutrinos change flavour and are they their own anti-particle?*

*Our group plays major roles in large international collaborations around the globe at CERN (Switzerland), SNOLAB (Ontario) and the South Pole.*

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## Nassim Bozorgnia, Assistant Professor

Dr. Bozorgnia's research is focused on dark matter phenomenology, especially the nature and detection of dark matter, the Galactic dark matter distribution, and dark substructures. The goal of her research is to identify the particle nature of dark matter, through distinct signatures on the Galactic dark matter distribution. Her group uses various approaches to probe the dark matter distribution in the Milky Way, taking advantage of state-of-the-art high resolution cosmological simulations and recent high precision astronomical data.

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## Andrzej Czarnecki, Professor

Dr. Czarnecki studies phenomenology of gauge interactions and searches for new physics.

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<https://sites.ualberta.ca/~andrzejc>

## Doug Gingrich, Professor ATLAS

Dr. Gingrich's research focuses on experimental high energy particle physics using the ATLAS detector at the CERN laboratory in Geneva, as well as phenomenology and searches for quantum gravity and superstring theory.

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### **Aksel Hallin, Professor**

#### *Dark Matter & Neutrino Physics*

Dr. Hallin's research focuses on two high priority areas of astroparticle physics: the nature of the neutrino and the search for dark matter. Based on the SNO+ neutrino detector at SNOLAB, the Hallin group studies the measurement of neutrino properties, solar neutrinos and geoneutrinos. As part of the DEAP-3600 experiment at SNOLAB, Dr. Hallin also explores direct detection of galactic dark matter.

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### **Carsten Krauss, Associate Professor**

#### *Dark Matter & Neutrino Physics*

Finding dark matter particles and neutrinos from sources far away from earth has been Dr. Krauss' research focus for some time. He is leading the search for dark matter with the PICO bubble chambers at SNOLAB, is involved in the SNO+ experiment, and is also working on a new neutrino telescope in the Pacific Ocean to measure neutrinos from very distant sources.

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### **Roger Moore, Professor**

#### *Neutrino & Beyond the Standard Model Physics*

Dr. Moore's research focuses on supersymmetry, dark matter and neutrinos. He is a member of the IceCube experiment at the South Pole which measures the interactions of high energy neutrinos in the ice 2 km below the surface of Antarctica. The energy of some of these neutrinos exceeds the highest energies ever obtained by an accelerator making them an excellent place to search for evidence new physics. He is also working on a new neutrino detector in the Pacific Ocean off the west coast of Vancouver Island.

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### **Alexander Penin, Professor**

#### *Perturbative Quantum Field Theory*

Dr. Penin studies perturbative quantum field theory and its application to particle and condensed matter physics.

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**James Pinfold, Professor**  
*ATLAS, MoEDAL*

Dr. Pinfold is working on the ATLAS and MoEDAL experiments at the LHC at CERN. He is involved in the search for magnetic charge, extra dimensions, new symmetries of nature, candidates for dark matter and other avatars of new physics. He is currently involved in the design, construction and testing of a new MoEDAL sub-detector (MAPP) for the detection of fractionally charged particles and new long-lived particles at the LHC. In addition, Pinfold is also contributing to the upgrade of the ATLAS LUCID-luminometer and AFP, ATLAS' latest detector.

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**Marie-Cécile Piro, Assistant Professor**  
*Dark Matter Physics & Beyond*

Marie-Cécile Piro and her group focus on developing dark matter direct detection techniques, understanding their response by analyzing the data and simulating their backgrounds in order to extract the interesting signal. They work to improve detector's performance and test the feasibility in laboratory. Dr. Piro is also exploring new horizons focusing on theory and phenomenology of dark matter.

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**Juan Pablo Yáñez, Assistant Professor**  
*Neutrino Physics*

Dr. Yáñez's main research interest is neutrino physics, in particular neutrino oscillations and the origin of neutrino masses. He is currently involved in the IceCube, SNO+ and P-ONE experiments, as well as in modeling atmospheric neutrino production and the development of novel photodetectors for large particle physics experiments.

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