Archived Colloquia 2024-2025

From General Relativity to General Partner in a Venture Capital Fund

Andrew Ray
Friday 13 September 2024

How I went from studying Astrophysics at Saint Mary's to building spacecraft and startups. A survey by the American Institute of Physics found that 46% of recent physics PhD grads wanted to work in academia, yet less than 5% ended up doing so. Are physicists really that bad at math or is something else going on? In this session we'll talk about maximizing the value that physicists can provide to the world and to themselves. It will cover my career spanning real world applications of General Relativity, my transition to startup founder (x3), and then to a science focused Venture Capital investor (where the math gets even simpler). It will touch on my experiences with startups and how they can maximize the impact of scientific discoveries for the world while also positioning scientists to share in the economic value created.

Machine learning: A new data analysis paradigm for astrophysical data analysis

Dr Yashar Hezaveh
Canada Research Chair in Astrophysical Data Analysis and Machine Learning at Université de Montréal
Friday 20 September 2024

In this talk I will share our research in analyzing strong gravitational lensing data for the inference of cosmological parameters. In particular I will discuss the shortcomings of traditional closed-form approaches to likelihoods and priors and show how machine learning can be used to perform significantly more accurate inference. I will discuss topics related to diffusion models, out-of-distribution issues, quantification of model accuracy and show how machine learning can be used within a rigorous Bayesian framework for the analysis of astrophysical data.

The SCALES project: Stirring up the ISM with clustered feedback

Dr Marta Reina-Campos
(CITA National Fellow at the Canadian Institute for Theoretical Astrophysics (CITA) and McMaster University)
Date: Friday 27 September 2024

Stellar clusters are critical constituents within galaxies. Gravitationally-bound stellar systems are the result of intense star formation, and they regulate the baryonic lifecycle of their host galaxy through their clustered stellar feedback. However, current modern simulations of galaxy formation lack a holistic view of the role of star clusters in galaxy evolution, and how they are shaped by their host galactic environment.

In this seminar, I will review current numerical approaches to model the intertwined evolution of star clusters and galaxies, and I will discuss their perks and caveats. As an alternative approach, I will present a novel method to model individual star clusters within galaxies within the hydrodynamical code GIZMO. By employing sink particles, I can represent stellar clusters built via gas accretion and hierarchical merging with sub-clusters. Using a large grid of turbulent clouds, I will discuss the impact of a variety of numerical choices, and the consequences on the most massive star cluster of assuming different physical setups for the clouds. I will demonstrate that this prescription leads to molecular clouds being shorter lived due to more destructive feedback, and I will discuss what physics are required to reproduce the formation of star cluster populations.

Galaxy Simulations in the Era of Exascale

Dr Evan Schneider
(University of Pittsburgh)
Friday 4 October 2024

Over the last several decades, galaxy formation theory has adopted "feedback" as an essential process affecting galaxy evolution. Winds generated by supernova explosions of massive stars are predicted to eject large quantities of mass and energy from the interstellar medium over cosmic time, regulating galaxy growth rates and polluting the CGM and IGM with heavy elements. However, our current observational and theoretical constraints on the amount of mass and energy ejected by these winds are uncertain by orders of magnitude. In this talk, I will describe our group’s efforts to better understand the physics of supernova-driven outflows using extremely high resolution simulations. Employing the GPU-based code Cholla on the world’s fastest computers, we can capture the effects of individual explosions on galaxy scales, allowing us to link predictions made by small-scale idealized simulations to halo-scale zooms with a cosmological context.

Simulating Cosmic Reionization

Rahul Kannan
(Center for Astrophysics | Harvard & Smithsonian)
Friday 18 October 2024

The study of primitive stars and galaxies is an exciting new frontier in astrophysics and cosmology. They form within the first gigayear after the Big Bang and significantly impact their surroundings by emitting a lot of high-energy radiation that transforms the surrounding cold neutral gas into a hot and ionized medium. This process, called reionization, is initially patchy, with ionized bubbles surrounding the most energetic sources. These bubbles eventually grow bigger and more numerous as the ionizing radiation output from galaxies increases and eventually overlap, ionizing the low-density gas in the entire Universe. Understanding this early epoch is important because it forms an important evolutionary link between the smooth matter distribution at early times and the complex structures we see today. Fortunately, a wide array of instruments that have been specifically designed to study the high redshift Universe, such as JWST, ALMA, HERA, and others, are unleashing a flood of observational data that is ushering the study of reionization into a new high-precision era. It is, therefore, imperative that theoretical/numerical models achieve sufficient accuracy and physical fidelity to meaningfully interpret these new results. In this talk, I will review the recent THESAN simulation project, which aims to self-consistently model the reionization process and the sources responsible for it.

Experimental Methods for Nuclear Astrophysics

Dr Ben Reed
(TRIUMF & St Mary’s University)
Friday 25 October 2024

Understanding the origins of elements and the processes governing astrophysical environments requires precise knowledge of nuclear reaction rates. This talk explores both direct and indirect experimental methods used to study key nuclear reactions relevant to astrophysical phenomena. It highlights direct measurements conducted at TRIUMF with DRAGON and the development of the DEMAND Array, which introduces a novel experimental method for probing nuclear physics in core-collapse supernovae. Additionally, studies using Gammasphere for gamma-ray spectroscopy are discussed, offering crucial insights when direct measurements are not feasible. Together, these methods help refine models of stellar environments, contributing to a deeper understanding of nucleosynthesis and the evolution of the cosmos.

From Physics to Finance – Riding the Wave of Adventure

Alyson Bailey-Flynn
(Royal Bank of Canada)
Friday 1 November 2024

As SVP, Capital Markets, Wealth Management, Insurance, APAC & Europe, Internal Audit at RBC Alyson has had a distinguished career in financial services across the multiple lines of defence, continents, and financial institutions. What started with a single physics class at Saint Mary's, to a BSc Honours in Physics & Math, and eventually a Masters of Mathematical Finance, Alyson will share her journey and insights for success across her career.

Material innovations for stable efficient photovoltaics

Dr Ghada Koleilat
(Canada Research Chair in Advanced Materials for Energy Application,
Dalhousie University)
Date: Friday 8 November 2024

Solution processed semiconductors offer the advantage of low cost large scale applications such as in photovoltaics. To enable wider adoption, efficiency, reliability and stability of these new material systems need to be improved. The Koleilat group works in advanced materials innovation to accelerate adoption of alternative technologies. Dr. Koleilat will be presenting various material systems her group is working on and their applications in photovoltaics.

What the Variability of Embedded Protostars Tells Us about Accretion: Past, Present, and Future

Doug Johnstone
National Research Council Canada - Herzberg Astronomy and Astrophysics Research Centre, President's Science Advisor
Friday 29 November 2024

The James Clerk Maxwell Telescope (JCMT) has been monitoring eight nearby low-mass star-forming regions in the Gould Belt at submillimetre wavelengths for over seven years to search for and quantify the time dependent brightness variability of the resident deeply embedded protostars. Secular variability is common among these protostars; greater than 25% of the sample show measurable long-term brightness changes and 10% show burst behaviour lasting months to years. We interpret this secular variability as reflecting changes in the mass accretion rate from the disk to the protostar, as predicted by theoretical models of (proto)stellar assembly. For a subset of our sample we have contemporaneous mid-IR light-curves which allow additional constraints on the conditions responsible for the brightness variations, confirming that the submillimetre variability is driven by changes in the dust temperature profile of the envelope. Furthermore, we have combined, for one source, single dish and interferometric sub-mm monitoring, which has allowed us to unambiguously recover a time lag in the variability at larger angular scales and use the results to confirm the envelope structure surrounding the embedded protostar.

How Galaxies Evolve Over Time: Insights from the Middle-Aged Universe

Dr Ivana Damjanov
Saint Mary’s University
Friday 17 January 2025

Recent images from the James Webb Space Telescope (JWST) confirm that galaxies have been undergoing morphological transformations for more than 12 billion years. By combining high-resolution ground-based imaging with extensive spectroscopic surveys, we are able to trace the evolution of galaxy structure and stellar populations during the latter half of the cosmic history. In this presentation, I will show how we use state-of-the-art spectro-photometric surveys to investigate the growth in size of galaxies that ceased star formation prior to the observed cosmic time. Additionally, I will explore the connection between size evolution and the broader history of star formation in these galaxies. The studies I will present serve as crucial tests for various processes proposed to drive galaxy mass assembly over the past 6 billion years. Moreover, they provide key insights into the connection between the evolved galaxy populations we observe in the local universe and those from very early cosmic epochs now revealed by the JWST.

An update on tidal energy in the Bay of Fundy

Dr Richard Karsten
Department of Mathematics and Statistics
Acadia University
Friday 17 January 2025

For over 100 years, Acadia researchers have studied how to extract energy from the Bay of Fundy tides. In this talk, we will review where we are in developing Nova Scotia tidal energy projects from a physics point of view. We examine the Bay of Fundy tidal system and how much energy can be extracted from the tides. Then, we look at the challenges in extracting the energy from the fast-moving tidal currents, as well as the technology that has been developed in response. Finally, we examine more recent efforts to determine the impacts of tidal turbines on endangered fish populations.

Identifying galaxy mergers in observational data and the impact of mergers on galaxy evolution

Dr Kiyoaki Omori
Saint Mary's University
Friday 7 February 2025

In the currently accepted cosmological framework, one of the main pathways of galaxy growth and evolution is through galaxy interactions and mergers, where multiple galaxies merge to become one larger galaxy. Not only are galaxy interactions and mergers a main pathway for galaxy growth, they are related to numerous processes pertaining to galaxy evolution, such as star formation, galaxy chemical evolution, and active galactic nuclei (AGN) activity. As such, galaxy interactions and mergers are a unique laboratory to study galaxy evolution. However, the relative role of galaxy interactions and mergers on galaxy evolution-related processes is still under debate, and quantitative conclusions are contested. One reason for this is the difficulty in identifying galaxy mergers in observational data. In this talk, we present a machine-learning based method for merger identification. Our merger classifier is built upon Zoobot (Walmsley et al. 2023) - a deep representation learning model trained on observational images and citizen science labels. We present the fine-tuning of Zoobot using both observational and simulational based images. Using our trained model and obtained merger probabilities, we investigate within HSC-SSP observational data a) the relationship between galaxy mergers and environment, and b) the relationship between galaxy mergers and AGN activity. We present our findings.

High-spectral-resolution view of ultra-fast outflows in active galactic nuclei

Dr Yerong Xu
Saint Mary's University
Friday 28 February 2025

Ultra-fast outflows (UFOs) are an extreme subclass of winds in active galactic nuclei (AGN), characterized by mildly relativistic speeds and high ionization states. They are considered one of the most promising candidates to drive AGN feedback and potentially regulate the co-evolution of supermassive black holes (SMBHs) and their host galaxies. However, several key questions about UFOs remain unresolved: 1) What is the mechanism for accelerating winds up to relativistic speeds? 2) Do they affect the accretion process and SMBH growth? 3) Are UFOs powerful enough to drive AGN feedback? In this talk, I will review the state-of-art progress in these questions, and present results from the performance verification (PV) observation of the recently launched high-resolution X-ray mission, XRISM, targeting the prototype UFO source, PDS 456.

Probing the Star Formation Main Sequence in low-mass galaxies at cosmic noon with HST and GTC

Dr Rosi Gonzalez
Saint Mary's University
Friday 7 March 2025

The Star Formation Main Sequence (SFMS) is a fundamental scaling relation that links the star formation rate of galaxies with their stellar mass. The normalization, scatter, and slope of this relation provide important constraints on the evolution and mass assembly of galaxies over cosmic time. Over the past decades, numerous studies have investigated the evolution of the SFMS from the times of the local Universe to the Epoch of Reionization. However, most efforts so far have focused on the study of bright, massive galaxies (>10^9-10 Msun) due to typical mass-completeness limits. The general picture connecting the low- and high-mass galaxy regimes is not yet fully elucidated and extrapolations from our understanding of high-mass galaxies may not apply. The star formation histories of low-mass objects have been found to be more stochastic and burstier compared to the steady, smooth trajectories followed by more massive galaxies. In my recent work, I combined data from the GTC/SHARDS and HST/GOODS-CANDELS surveys to explore the evolution of the SFMS properties at 1 < z < 3 using a sample of ~34,000 newly discovered galaxies, which allows us to push mass-completeness down to 10^8 Msun. Our SFMS is overall compatible with previous findings based on the analysis of more massive galaxies, albeit suggesting hints of a possible steepening in the low-mass regime, specially at z > 2.

Connecting Compact Object Dynamics with Multi-Messenger Observations in Dense Star Clusters

Dr. Claire Ye
University of Toronto
Friday 14 March 2025

Frequent dynamical encounters in globular clusters significantly enhance the production of multi-messenger phenomena. It is now well established that globular clusters host robust populations of compact objects, including low-mass X-ray binaries, millisecond pulsars, and gravitational wave sources. The evolution of these compact objects is intricately linked within dense star clusters. Black holes impact the dynamics of neutron stars and white dwarfs. In turn, the collapse of white dwarfs and neutron stars through accretion or mergers plays a crucial role in explaining various observations of more massive compact objects. In this talk, I will use binary black hole mergers and millisecond pulsar observations as examples to illustrate the dynamical evolution of black holes, neutron stars, and white dwarfs in dense star clusters. I will demonstrate how we can connect these dynamics with rich observational data to understand compact object formation and evolution.

Hot off the press: new cosmology results from the Atacama Cosmology Telescope

Dr. Renee Hlozek
University of Toronto
Friday 21 March 2025

I will present the brand new maps and images from the Data Release 6 of the Atacama Cosmology Telescope (ACT) in both temperature and polarization. The ACT telescope was operational from 2007 - 2022 and was built 17000ft (5200 m) up in the Atacama desert of Northern Chile These are the clearest and most precise images yet of the universe's infancy, a few hundred thousand years after the big bang. I will also discuss how these maps and power spectra constrain our cosmological model beyond the standard "LambdaCDM" picture, paying special attention to what ACT tells us about models of dark matter, and the initial fluctuations of inflation.

AI-Driven Astronomy: Merging Data-driven Insights with Physics-Based Modeling

Dr. Cecilia Garraffo
AstroAI, Center for Astrophysics, Harvard & Smithsonian
Friday 28 March 2025

Astronomy is on the cusp of a data revolution, propelled by next-generation observatories like the Vera C. Rubin Observatory and NASA's Roman Space Telescope. Traditional analysis methods have struggled with large scale and complex datasets, opening the door to artificial intelligence (AI) as a powerful tool. Yet harnessing AI effectively in astronomy requires more than raw data processing: we must also embed physical principles and modeling to ensure that AI-driven insights remain grounded in science.
In this talk, I will discuss emerging techniques that bring together advanced AI methods with physics-based simulations, helping us reveal intricate patterns and phenomena—from exoplanet surveys to cosmic structure—with physical accuracy. Ultimately, I will emphasize the importance of community readiness and collaboration as we transition from a data revolution to an AI-driven discovery revolution in astronomy.

Atomic masses and exotic elements. What can they tell us about the nucleus?

Dr. Marilena Lykiardopoulou
LTA Applicant
Tuesday 20 May 2025

Since its discovery in 1911, the atomic nucleus has been under intense study due to its vast complexity and the number of different elements and isotopes that exist around us. One particularly puzzling aspect in the early days of nuclear physics, was that some nuclei appeared to be more strongly bound than others, which led scientists to refer to them as magic. In 1949, a groundbreaking work finally explained how and why some nuclei have this advantage over other ones, but shortly after the first inconsistencies between experiment and theory were found. Today, more than 75 years since that ground breaking work by Mayer and Jensen, that we refer to as the Nuclear Shell Model, we are still trying to understand this exciting and highly complex system: the nucleus. To do so, we have to go beyond what we can find around us in nature and make our own nuclei in accelerators.
In this talk I will discuss some of the open questions regarding Nuclear Structure, the discipline that studies the structure of the atomic nucleus, the nuclei that we need to answer them and how we can produce and study these nuclei in accelerator facilities. More specifically, in the first part of the talk I will discuss about a group of unstable neutron-rich magnesium and sodium isotopes that defy the Nuclear Shell Model and how we used atomic masses to better understand them at TRIUMF, in Vancouver, Canada. In the second part of the talk, I will focus on superheavy elements, how we produce and detect them, the outlook for new element discoveries at Berkeley Lab and how that helps us understand the properties of the atomic nucleus.

Nuclear Physics Techniques: From Fundamental Studies to Practical Applications

Dr. Fatima Garcia
LTA Applicant
Thursday 22 May 2025

The field of nuclear science plays a pivotal role in our understanding of the universe. Its impact can be seen in a wide range of areas, from the production of the elements in stellar environments to the treatment of the most aggressive types of cancer. In this three-part talk, I will discuss production, study and applications of radioactive isotopes. First, I will describe the radioactive isotope beam production mechanisms at TRIUMF and how I built a predictive tool for experiment planning. I will then describe how we can study isotopes once they are produced, using the GRIFFIN spectrometer. Finally I will mention an interesting application of traditional nuclear physics techniques to study the chemistry of exotic elements, discussing work done at Lawrence Berkeley National Laboratory. Together, these topics highlight how nuclear science drives discovery across the sciences and beyond.

Using the Atomic Nucleus as a Probe for Beyond the Standard Model Physics

Dr. Antione Belley
LTA Applicant
Monday 26 May 2025

At the heart of particle physics lies the Standard Model, one of the most (if not the most) successful theories of all of science, which describes the fundamental building blocks of the Universe and how they interact with each other. However, even with all the successes of this theory, mounting evidence tells us that it is at best incomplete. Nonetheless, after years of searches at particle accelerators, direct observation of any process Beyond the Standard Model still eludes us. In this talk, I will present how developments in nuclear theory can allow another, less expensive, avenue to become competitive in those searches: the high-precision measurement of low-energy processes inside the atomic nucleus. I will present a unified framework utilizing machine learning emulators to obtain robust uncertainty quantification of nuclear theory inputs required to interpret results of experimental searches. Furthermore, I will show how these emulators can be used to tackle multiple other problems in nuclear physics and expand our understanding of the underlying nuclear forces.

How Stars Die and Elements are Born: The Role of Nuclear Reactions in Supernova Explosions

Dr. Thanassis Psaltis
LTA Applicant
Wednesday 28 May 2025

The origin of the elements is a fundamental question that bridges astrophysics, nuclear physics, and cosmochemistry. From the oxygen in the air we breathe to the gold in your jewelry, nearly every atom in our bodies and on Earth was forged in the fiery hearts of stars and the explosions that mark their death. In this colloquium, I will give an overview of the different processes that stars undergo to synthesize elements, and I will focus on core-collapse supernovae. In particular, I will discuss how by reducing uncertainties in nuclear reaction rates and using spectroscopic information from the oldest stars in the Milky Way, we can constrain the astrophysical conditions of these explosions and explain the origin of the elements between strontium and silver. I will also present a recent experimental study aimed to reduce the uncertainty in the production of the important radioisotopes 56-Ni and 44-Ti and the astrophysical origin of rare presolar stardust grains. Throughout the colloquium I will discuss plans for the current and next generation of radioactive ion beam facilities around the world, which will lead to a better understanding of the origin of the elements in the Cosmos.