Biophotonics: Shedding Light on Biosensory Disorders and Age-Related Degenerative Diseases

CAP lecture

Ozzy Mermut (York University)
Date: Friday 1 April 2022
Time: 3:00 PM
Location:
Zoom https://us02web.zoom.us/j/83744069484?pwd=RWN0cVNrOUZKNGRUczhuajREZHh4UT09

Vision disorders such as age-related macular degeneration, affect over 200 million people world-wide. There is an urgent need to develop better approaches for the early diagnosis of tissue degeneration, and improve therapies to treat, eliminate or reverse disease pathogenesis. Biophotonic technologies are emerging as powerful methods, offering inherent specificity and sensitivity for early identification of biomarkers of disease progression, with phototherapy providing precise tissue targeting, and advances in fast laser methods offering more precise and confined treatments. However, these treatments still require innovations in laser-based approaches to improve control, precise energy delivery, and dose confinement in complex tissues such as the retina. Our long-term goal is to identify tissue specific biomarkers for diagnosis of early-stage vision disorders to permit the development of novel photonic techniques for targeted and minimally invasive phototherapeutics for macular degeneration producing optimal reactions limited to specific regions, and designing new biomimetic models that recapitulate the bio-realistic environment of the natural retina with accurate dose measures that provide molecular-scale chemical information during laser treatment. This will advance our understanding of the pathogenesis of disorders, and enable development of personalized phototherapeutics for debilitating vision diseases as well as other biosensory dysfunctions and cancer.

Short bio

Ozzy Mermut is an Assistant Professor of Physics and Astronomy at York University and Chair of the Division of Physics in Medicine and Biology in the Canadian Association of Physicists. As a core and steering member of the Centre for Vision Research and Vision: Science to Applications, her interests span both medical and biological physics through development of photonic approaches towards optimalizing health outcomes in age-related diseases, from early diagnosis, effective treatment, to high precision dosimetry.

Measuring cosmological evolution and growth of structure with galaxy surveys

Will Percival (University of Waterloo)

Date: Friday 25 March 2022
Time: 3:00 – 4:00 PM (ADT)
Location: Zoom or AT101

Maps of the 3D positions of galaxies in the Universe allow us to constrain the evolution of the Universe and the growth of cosmological structure within it. The present-day energy-density in the Universe is dominated by an unknown component called Dark Energy that gives rise to acceleration of the cosmological scale. Using maps of galaxies we can measure this expansion and structure growth within it. We do this using various physical features including Baryon Acoustic Oscillations, Redshift-Space Distortions and Voids. I will explain how these cosmological probes work, and present recent measurements from the Sloan Digital Sky Survey. Finally, I will look ahead to the future, reviewing the Dark Energy Spectroscopic Instrument and Euclid experiments, showing how they will transform our understanding of Dark Energy.

The TRIUMF Storage Ring Project

Iris Dillman (TRIUMF)
Date: Friday 18 March 2022
Time: 3:00 – 4:00 PM (ADT)
Location: Zoom or AT101

Heavy-ion storage rings connected to radioactive beam facilities offer a unique environment for nuclear physics experiments. So far, storage rings have been only coupled to in-flight fragmentation facilities, for example the ESR and the CRYRING at GSI Darmstadt/ Germany, the CSRe at HIRF in Lanzhou/ China, and the Rare RI Ring at RIKEN Nishina Center in Japan. Neutron capture reactions play a crucial role for the understanding of the synthesis of elements heavier than iron in stars and stellar explosions. The majority of the neutron captures on stable or long-lived nuclei have been experimentally constrained in the past decades, but direct neutron capture cross sections of short-lived nuclides (half-life << 1 year) have been so far out of reach and led to large uncertainties in theoretical predictions of very neutron-rich nuclei.

A new project at TRIUMF proposes to use for the first time a new concept coupling a high-intensity neutron generator to a storage ring fed by the existing ISAC facility. I will introduce the TRISR project and outline some measurements that would become possible, especially with the availability of clean, intense radioisotope beams from the new ARIEL facility.

Probing Convection with Asteroseismology

Catherine Lovekin (Mount Allison University)
Date: Friday 11 March 2022
Time: 3:00 – 4:00 PM (AST)
Venue**:** AT101, please follow SMU masking and social distancing policy. For more information, please consult smu.ca/covidinfo/

Asteroseismology gives us an unprecedented ability to probe the internal structure of stars. This includes studying the effects of convection, in particular the behaviour of the convective boundary region and associated convective overshoot. Observations from satellite missions like Kepler and TESS give us long time series, which allows us to identify pulsation frequencies with very high accuracy. In this talk, I will discuss ways we can constrain the extent of the convective overshoot region in main sequence stars using asteroseismology, and what we have learned about stellar convection as a result.

Accessing nuclear structure beyond the proton dripline

Kyle Brown (Michigan State University)
Date: Friday 4 March 2022
Time: 3:00 - 4:00 PM (AST)
Location: AT 101 or Zoom

Two-nucleon decay is the most recently discovered nuclear-decay mode. For protonrich nuclei, most multi-proton decays occur via sequential steps of one-proton emission. Direct two-proton (2p) decay was believed to occur only in even-Z nuclei beyond the proton-drip line where one-proton decay is energy forbidden. This has been observed for the ground states of around a dozen nuclei including 6Be, the lightest case, and 54Zn, the heaviest case. Direct 2p decay has also recently been observed for isobaric-analog states where all possible 1p intermediates are either isospin allowed and energy forbidden, or energy allowed and isospin forbidden.

For light proton emitters (A < ~30), the lifetimes are short enough that the invariantmass technique is ideal for measuring the decay energy, intrinsic width, and, for multiproton decays, the momentum correlations between the fragments. I will describe recent measurements of proton emitters using the invariant-mass technique with the silicon arrays like the High-Resolution Array (HiRA). I will present a new, high-statistics measurement on the decay of the ground and excited states in 12O and 19Mg. By measuring the momentum correlations between the decay fragments, one can observe how the decay transitions from direct to sequential as the decay energy increases. I will also present the first observation of 11O, the mirror of the well-known halo nucleus 11Li, as well as the first observation of 18Mg.

Exploring Strange New Worlds: Kepler’s Circumbinary Planets

William Welsh (San Diego State University)
Date: Friday 18 February 2022
Time: 3:00 - 4:00 PM (AST)
Location: AT 101 or Zoom

NASA's *Kepler* Mission was spectacularly successful: its discovery of nearly 3000 exoplanets has revolutionized our understanding of the architectures of planetary systems. Among the most fascinating of these systems are the "circumbinary planets": planets that orbit two stars. Like the fictional planet "Tatooine" from the Star Wars movies, these worlds have two suns in their skies. We currently know of a dozen such planets, and each system has revealed an important new facet and challenge (headache!) to solve. In this talk, I will give an overview of how we find exoplanets, present the main results of the Kepler Mission, and discuss the rich phenomenology the circumbinary planets exhibit that is both fascinating and astrophysically important.

What can we learn about early galaxies before JWST?

Victoria Strait (University of Copenhagen)
Date: Friday 11 February 2022
Time: 3:00 - 4:00 pm
Venue: Atrium 101 or Zoom

Constraints on physical properties of early galaxies in the redshift range z ~ 6-10 (just a few million years after the Big Bang) are key for a full understanding of the process of reionisation and early galaxy evolution, including the onset of star formation. I will present results on the highlights from my study of ~200 z ~ 6-10 galaxy candidates from the Reionisation Lensing Cluster Survey (RELICS) survey which utilises galaxy clusters as comic lenses to magnify faint sources. This will include a variety of results about specific exciting galaxies using data from the Hubble Space Telescope, Spitzer Space Telescope, and the Keck Telescopes. Additionally, I will discuss some exciting prospects for the recently launched James Webb Space Telescope.

The Kinematic and Chemical Transformation of Galaxies Over the Past 11 Billion Years

Raymond Simons (Space Telescope Science Institute)
Date: Friday 4 February 2022
Time: 3:00 - 4:00 PM (AST)
Location: AT 101 or Zoom

In this talk, I will discuss our emerging picture of galaxy formation in the early universe. Early galaxies evolve in a lively ecosystem, assembling through action that re-shape galaxies on short timescales (e.g., mergers and the evolution of young stars). I will show how this bears out in observations. Using the Hubble Space Telescope and the Keck Observatories, I will show that the resolved kinematics and chemical abundances of the ionized gas inside galaxies in the early universe favor a disruptive and inhospitable mode of early galaxy assembly. I will show how these galaxy properties evolve to the present day for different galaxy populations, revealing that thin rotationally-supported galaxy disks develop only at late cosmic times on average. Finally, I will show how we are using hydrodynamical simulations of galaxies to interpret these observations, to make forecasts for our next generation of observatories, and to probe the detailed structure and kinematics of the circumgalactic gas around galaxies.

New results from LIGO and Virgo

Jess McIver (University of British Columbia)
Date: Friday 28 January 2022
Time: 2:00 - 3:00 PM (AST) ***** note the unusual time *****
Location: Atrium 101 or Zoom

In less than five years, the field of gravitational wave astronomy has grown from a ground-breaking first discovery to revealing new populations of stellar remnants through distant cosmic collisions. I'll summarize recent results from LIGO-Virgo and their wide-reaching implications, give an overview of the instrumentation of the current Advanced LIGO detectors, and discuss prospects for the future of multimessenger astrophysics with gravitational wave detectors on Earth and in space.

Neutron-upscattering enhancement of the triple-alpha process

Dr. Jack Bishop (Cyclotron Institute, Texas A&M)
Date: Friday 14 January 2022
Time: 3:00 -4:00 PM (AST)
Location: Zoom

The triple-alpha process fuses three alpha-particles into carbon-12. Through the presence of a resonance (known as the Hoyle state) in carbon-12, this reaction process is enhanced by several orders of magnitude. The speed of this reaction is driven by the balance of how the Hoyle state decays, either via sequential alphadecay back into three alpha-particles (alpha-width), or via sequential gamma-decay and pair-production (radiative width). The decay via alpha-particles is dominant and therefore the reaction rate is almost directly proportional to the radiative width.

In stellar environments with a high density of neutrons (~1e6 g/cm3), the interaction of the neutrons with the Hoyle state before it decays has long been thought to allow for an additional decay path. This enhancement was predicted to enhance the triple-alpha reaction rate by a factor of ~100 based on theoretical models. This mechanism is known as neutron-upscattering.

The pertinent cross-sections that drive this upscattering process have never been measured however due to the extreme difficulty of the measurement involved. Recent experimental developments have now made this experiment possible by studying the time-reverse process using the Texas Active Target Time Projection Chamber (TexAT TPC) using a beam of neutrons at Ohio University Edwards Accelerator Laboratory to measure the neutron inelastic scattering to populate the Hoyle state.

This talk will discuss the impact of neutron-upscattering to the triple-alpha process, how TPCs work, and present the results of this new and exciting measurement.

An Introduction to (Dynamic) Nested Sampling

Institute for Computational Astrophysics (ICA)
Data Analytics Seminar Series

Joshua Speagle (University of Toronto)
Date: Thursday 18 November 2021
Time: 2:30 - 3:30 PM (AST)
Recording: https://youtu.be/pdBvz9TEW1M

I will present a brief introduction to Nested Sampling, a complementary framework to Markov Chain Monte Carlo approaches that is designed to estimate marginal likelihoods (i.e. Bayesian evidences) and posterior distributions. This will include some discussion on the philosophical distinctions and motivations of Nested Sampling, a few ways of understanding why/how it works, some of its pros and cons, and more recent extensions such as Dynamic Nested Sampling. I will also highlight how this can work in practice using the public Python package dynesty.

Mapping the z ~ 2.5 Universe with Lyman-alpha Tomography

Dr. Andrew Newman (Carnegie Institution for Science)
Date: Friday 3 December 2021
Time: 3:00 -4:00 PM (AST)
Location: Atrium 101 or Zoom

Among the main questions in galaxy evolution is the role that galaxies' masses and environments have in determining their properties over time. The "cosmic noon" era around z~1.5-3 is recognized as pivotal, but it has been observationally challenging to connect early galaxies' properties to the large-scale structures in which they are growing. An exciting new method to chart the z~2.5 universe is to map the intergalactic medium (IGM) in 3D by measuring Lyman-alpha absorption in the spectra of many faint galaxies. This technique, known as Lyman-alpha tomography, produces "dark matter maps" that uniquely enable the detection of structures independent of their galaxy content. The maps are particularly suitable for the detection of protoclusters, the ancestors of today's galaxy clusters. We are now mapping the z=2.2-2.8 universe over 1.7 sq. deg. in several extragalactic survey fields via the Lyman-alpha Tomography IMACS Survey (LATIS) at Magellan. I will describe the survey and initial results, including a novel population of "optically dim" protoclusters that are clearly seen in the IGM maps but are missed by galaxy surveys, most likely due to their unusual galaxy populations.

A new elementary particle is being born

Attila Krasznahorkay (Atomki, Hungary)
Date: Friday 26 November 2021
Time: 3:00 -4:00 PM (AST)
Location: Atrium 101 or Zoom

An anomaly indicating the formation and decay of a new light particle was observed in the study of high-energy transitions in the 8Be nucleus at our institute ATOMKI in Debrecen, already in 2016. It turned out that this could be a first hint for a new mXc2=17 MeV boson, called X17 in the literature. The possible relation of the X17 to the Dark Matter problem triggered great theoretical and experimental interest in the particle, hadron, nuclear and atomic physics communities. We obtained a similar anomaly in 4He, which also supports the existence of the X17 particle. Many experiments were performed in several different cases, but the anomaly remained, which could not be reproduced by even the latest (ab initio) calculations for 4He. These results support the existence of the new particle which may also play a significant role in the interpretation of dark matter. They also suggest the vector nature of this particle, necessitating the introduction of a new 5-th interaction.

Shocking tales of structure formation: Evolving galaxies and black holes in evolving environments

Andra Stroe (Center for Astrophysics | Harvard & Smithsonian)
Date: Friday 19 November 2021
Time: 3:00 -4:00 PM (AST)
Location: Atrium 101 or Zoom

Understanding the interplay between galaxy evolution, star formation, and black hole activity from the perspective of structure formation remains one of the most fascinating challenges in modern astrophysics. On the largest scales, pairs of galaxy clusters colliding drive the growth of structure. Cluster mergers are the most energetic events since the Big Bang, which release 1064 ergs over 1-2 billion years and produce dramatic, long-lasting effects. By bringing together panchromatic observations, I will discuss how the merger of galaxy clusters can trigger star formation and black hole activity in cluster galaxies, shape the evolution of cluster galaxies, and reverse typical environmental trends observed in relaxed clusters at low redshift.
With approximately half the galaxy clusters in the local Universe undergoing mergers, this recent work has revealed gaps in our understanding of the growth of structure in the Universe and showed the potential for discovery in this understudied field. I will draw parallels between the fundamental drivers of galaxy and black hole evolution in low-redshift clusters and the processes relevant in the context of proto-clusters and high-redshift clusters, where mergers and associated non-thermal phenomena were far more common than in the nearby Universe. A treasure trove of cluster samples at increasingly large redshifts will be delivered by a new generation of instruments, including eROSITA, GMT, ELT, ATHENA, Lynx, and SKA. The detail with which we can study clusters in the nearby Universe provides us the calibration

for the physics of high redshift events and helps guide discoveries in the field of galaxy and black hole evolution at the epoch when structures first formed.

Teaching a machine to learn to extract stellar properties from sky surveys

Institute for Computational Astrophysics (ICA)
Data Analytics Seminar Series

Sébastien Fabbro (NRC Herzberg – Canadian Astronomy Data Centre)
Date: Thursday 18 November 2021
Time: 2:30 - 3:30 PM (AST)
Recording: https://www.youtube.com/watch?v=NOsI1YggJJ4

Astronomical surveys can enable us to trace the evolutionary history of the local Universe. The ever growing data size and complexity accompanying the surveys have motivated many of us to revisit traditional methods to extract the stellar properties efficiently. I will present some of recent developments guided by deep learning that can alleviate bottlenecks in the analysis of galactic archaeology surveys. In particular, I will discuss how we can exploit feedback loops between physical modelling and data-driven approaches to face the interpretability and the uncertainty quantification challenges.

The Cosmic Life Cycle of Massive Galaxies

Katherine Whitaker (University of Massachusetts)
Date: Friday 29 October 2021
Time: 3:00 -4:00 PM (ADT)
Location: Atrium 101 or Zoom

Over the last few decades, we have uncovered billions of years of cosmic growth that present new challenges to galaxy formation theories. In this talk, I will review the recent innovative techniques developed to probe the distant universe, and the key observations constraining the formation histories of galaxies over the past 11 billion years. We have discovered a population of surprisingly compact and massive “red and dead” (quiescent) galaxies that are no longer actively forming stars. The physical mechanisms responsible for shutting down star formation and the subsequent buildup of this quiescent population at such early times is one of the most outstanding questions in astrophysics today. I will present promising paths forward towards solving this puzzle that leverage strong gravitational lensing and the capabilities of the Hubble Space Telescope and ALMA, as
well as a look toward the future with exciting upcoming public facilities.

Probing Dynamic Intracluster Medium: Insights from X-ray Surface Brightness Fluctuations

Irina Zhuravleva (University of Chicago)
Date: Friday 22 October 2021
Time: 3:00 -4:00 PM (ADT)
Location: Loyola 173 or Zoom

Clusters of galaxies are mainly filled with dark matter and hot, Xray emitting gas. They evolve through matter accretion along cosmic filaments, violent mergers, feedback from active galactic nuclei (AGN). Despite being very dynamic environments, the processes that drive gas motions in the intracluster medium (ICM), the properties of turbulence and relevant plasma physics remain poorly explored. In this talk, I will mainly focus on observational efforts to probe these physics. A recent analysis of X-ray surface brightness fluctuations in the central regions of bright, nearby galaxy clusters provided constraints on velocity power spectra, effective equation of state of small-scale perturbations produced by AGN feedback, and directly probed how magnetic fields modify small-scale density perturbations of the gas, affecting its transport properties. At the end of the talk, exciting possibilities to probe gas motions and plasma physics in the ICM with near-future XRISM observatory will be discussed.

Stellar Populations and Formation Histories of Massive Galaxies Derived from Deep Hubble Space Telescope Grism Data

Vicente Estrada-Carpenter (Saint Mary's University)
Date: 15 October 2021
Time:3:00 - 4:00 PM (ADT)
Location: Atrium 101, in-person (Zoom available only upon request, contact s.rhode@smu.ca)

A key question in the field of galaxy evolution is: How do massive quiescent galaxies form in the early universe? Many works have shown the existence of massive quiescent galaxies up to redshifts of $z > 3$ (when the age of the universe was < 2.2 Gyr). These galaxies are puzzling because they have been able to form massive amounts of stellar mass ($\log(M/M_\odot) > 10$) in a relatively rapid fashion, even simulations have struggled to recreate these galaxies. Therefore we are lacking some knowledge about the formation of massive galaxies. My research has focused on understanding the star-formation, chemical, morphological, and quenching histories of high redshift ($0.7 < z < 2.5$) massive quiescent galaxies using HST WFC3 grism spectra + photometry from the CLEAR (CANDELS Lyman-α Emission at Reionization) survey. By studying these massive quiescent galaxies at high redshift we can better constrain their star-formation histories as the uncertainty on age constraints is ~ logarithmic. My work has touched upon topics such as the mass - stellar metallicity relationship (showing that this relationship does not evolve with redshift up a $z = 1.7$), the link between a galaxies formation redshift and its morphology (providing evidence that the most compact galaxies get their compact morphologies from having formed in the early universe), and the evolution of galaxies as they cross the green valley (showing that galaxies form more rapidly at high redshift and that fast quenching occurs more in high mass galaxies).

The Virtual Universe (Galaxy outflows and their circumgalactic signatures in the IllustrisTNG simulations)

Dylan Nelson (Heidelberg University)
Date: 8 October 2021
Time: 1:00-2:00 pm (ADT)
Location: Zoom

Recently it has become possible to numerically simulate large, representative volumes of the Universe. These cosmological (magneto)hydrodynamical simulations solve for the coupled evolution of gas, dark matter, stars, and supermassive black holes interacting via the coupled equations of self-gravity and fluid dynamics, all within the context of an expanding spacetime. We can use these 'virtual universes' to study, theoretically, how galaxies form and evolve within the large-scale structure.

In particular, I will discuss our investigations into galaxy evolution, galactic-scale outflows, and the circumgalactic medium in the IllustrisTNG simulations. I will show how outflows sculpt the surrounding CGM, imprinting observable signatures in the gas, as well as in nearby satellite galaxy populations. I will highlight recent results from the high-resolution TNG50 simulation, which provides a unique look at the small-scale structure of cold, circumgalactic gas.

Learning on the Birth of the Stars with SITELLE

Laurie Rousseau-Nepton (Canada-France-Hawaii Telescope)
Date: 1 October 2021
Time: 3:00-4:00 PM (ADT)
Location: Zoom

October 2018 marked the beginning of a new large program at the Canada-France-Hawaii Telescope: SIGNALS, the Star-formation, Ionized Gas, and Nebular Abundances Legacy Survey. During the next four years and with 60 nights of telescope time in hands, our collaboration is observing more than 50,000 extragalactic star-forming regions located in different galactic environments using the instrument SITELLE, an Imaging Fourier Transform Spectrograph. In order to build this sample, we cover 40 galaxies that are actively forming stars within a distance of 10 Mpc. SITELLE was built in Canada and is the perfect instrument to survey these often extended objects.

With SIGNALS, we are seeking to increase our knowledge on how stars form in galaxies, how their birthplace affects their properties, and how multiple generations of stars transform galaxies. Stars continuously affect their environment by returning new elements to the interstellar gas.

These new elements are then recycled to form new stars. Stars form in a wide variety of environments. These can be different galaxy to galaxy, location to location. The result is that each star has its own story. By studying 50,000 regions where stars actively form, we will understand what triggers their formation, how efficiently stars form, and how each generation transforms the gas around them. This will also help researchers to understand the star-formation history of the whole Universe since the Big Bang. During this presentation, I will introduce this ambitious project and the instrument SITELLE as well as show some preliminary results.

Nuclear Physics in Stellar Environments: The Case of Radioactive 26Al in the Galaxy

Sergio Almaraz-Calderon (Florida State University)
Date: 24 September2021
Time: 3:00-4:00 PM (ADT)
Location: Zoom

The satellite-based observation of the long-lived radioisotope aluminum-26, the first of its kind made in space via the detection of its characteristic 1.809 γ-ray line, has long been recognized as direct evidence of ongoing stellar nucleosynthesis processes in the Galaxy. This observation also explains the excess of 26Mg found in presolar dust grains and meteorites. In this talk, I'll describe recent experimental efforts to understand the nucleosynthesis of this important radioisotope by studying nuclear reactions in the laboratory relevant for the production and destruction of 26Al in the stars.

The Growth & Transformation of Galaxies Over Cosmic Time

Dr. Wren Suess (University of California, Santa Cruz)
Date: Friday 17 September 2021
Time: 3:00 - 4:00 PM (ADT)

Deep surveys have allowed us to chart the evolution of galaxies from billions of years ago through to the present day with unprecedented precision. We've learned that the properties of both star-forming and quiescent galaxies — including stellar masses, structures, star formation rates, gas content, and kinematics — change dramatically with redshift. Despite this progress, several key questions remain unsolved in our current view of galaxy evolution. We still don't understand how galaxies grow over cosmic time, or what physical mechanisms are responsible for shutting down star formation and creating the bimodality between star-forming and quiescent galaxies. In this talk, I'll discuss how new insights from color gradients and half-mass radii have changed our view of galaxy growth, provide insights into how galaxies quench, and show the need to move beyond a bimodal picture of galaxy evolution. Finally, I'll show that studying the molecular gas reservoirs and star-formation histories of recently-quenched galaxies can provide clues to the mechanisms responsible for quenching star formation in galaxies.