Institute for Computational Astrophysics
Annual Report
2024-25

ICA Annual report, compiled by Marcin Sawicki, Interim Director

CONTENTS

ON THE COVER

A view of the gravitationally-lensing galaxy cluster MACS J1423 obtained with the James Webb Space Telescope by the CANUCS team. MACS J1423 is one of five massive galaxy clusters observed as part of the CANUCS project. Just to the lower left of the cluster lies a very distant galaxy, dubbed Firefly Sparkle, a young system whose star-forming clusters are magnified into a line of bright "sparks" by a foreground galaxy cluster. These staggered-age clusters show that Firefly Sparkle is actively assembling itself 600 million years after the Big Bang, much like the Milky Way Galaxy in its youth. Several current and former ICA members were involved in the Nature paper describing Firefly Sparkle, including Yoshi Asada, Guillaume Desprez, Marcin Sawicki, Vince Estrada-Carpenter, Gaël Noirot, and Johannes Zabl.

Image credit: NASA, ESA, CSA, STScI, Chris Willott, Lamiya Mowla, Kartheik Iyer and the CANUCS Team

1. Overview

The ICA's mission is to promote the study of complex astrophysical phenomena by numerical simulation and large-scale astrophysical data analytics. In addition to core faculty, postdoctoral fellows, graduate and undergraduate students have been and continue to be vital members of the ICA. To date more than twenty MSc degrees and ten PhD degrees were awarded to students supervised by ICA faculty, and several more theses are in progress. In addition, the ICA has enriched the environment of the Department of Astronomy and Physics and of the University by hosting nineteen postdoctoral fellows to date as well as numerous short- and long-term research visitors.

As of August 2025, the ICA has five full-time faculty members: Dr. Ivana Damjanov, Dr. Vincent Hénault-Brunet, Dr. Marcin Sawicki (Acting ICA Director), Dr. Ian Short, and Dr. Robert Thacker.. Three emeritus faculty members, Dr. David Clarke, Dr. Robert Deupree and Dr. David Guenther, continue their affiliation with the ICA.

Working with ICA faculty during AY2024-25 were seventeen early-career researchers:

- Four **post-doctoral fellows**: Dr. Gaia Gaspar, Dr. Kiyoaki Omori, Dr. Rosa María Mérida, and Dr. Michele Pizzardo.

- Seven **graduate students** (including one long-term visiting PhD student): Yoshihisa Asada, Abigail Battson, Lingjian Chen, Nolan Dickson, Angelo George, Fraser Smith, Devin Williams.

- Seven **undergraduate researchers**: Emily Fisher, Mackenzie Hayduk, Noha Hoque, Ella Jackson, Jorge Meza, Darra Stewart, Katie Saunders.

Several recent ICA alumni are affiliate members, including Dr. Guillaume Desprez (now at University of Groningen), Dr. Gaël Noirot (NASA's Space Telescope Science Institute), and Dr. Vince Estrada-Carpenter (Arizona State University).

The ICA's website provides up-to-date information about the Institute and its people.

2. Research

Astrophysical research is the primary goal of the ICA. Institute members engage in research in a number of areas of astrophysics using a range of research techniques. These range from numerical modelling to the analysis of complex datasets and development of new instruments and techniques; they tackle a broad spectrum of topics from the atmospheres of stars to the formation of galaxies soon after the Big Bang, and also include the development of future research facilities. This work is described in the following sections, with a focus on progress in AY2024-25. Notably, this research has resulted in 44 papers published top-tier peer-reviewed astrophysics journals in AY2024-25 (see Section 7).

2.1. Star clusters

Research on star clusters is led by Dr Hénault-Brunet, whose group uses a combination of dynamical models, statistical methods, and observations (spectroscopic, photometric, and astrometric) to tackle open questions about the dynamics of globular star clusters and related astrophysical implications, in particular: (1) the black hole content (both stellar-mass and intermediate-mass black holes) of globular clusters and their contribution to rate of gravitational wave events, (2) the formation and evolution of globular clusters, their initial conditions, stellar initial mass function and the evolution of their stellar mass function over time, (3) the dynamical interaction between globular clusters and the Milky Way and how this informs scenarios for the formation and evolution of these systems.

In the reporting period, Dr. Hénault-Brunet's group continued to work on dynamical modelling of globular clusters to provide improved constraints on the dark remnant content of globular clusters (including black holes) and on their initial conditions in the early universe. Populations of stellar-mass black holes in globular clusters strongly influence their dynamical evolution and lifetimes.

Previously, we (Hénault-Brunet and graduate students Nolan Dickson and Peter Smith) used multimass equilibrium models of Milky Way globular clusters to explore the present-day black-

hole populations of a large sample of clusters, based on several observables (Dickson et al. 2024, Smith et al. 2024). We have now combined these equilibrium models with new rapid, semi-analytical cluster evolutionary models, which simulate the bulk properties of clusters and their black-hole subsystems over time. These coupled models allow us to place constraints on the initial conditions of Milky Way globular clusters based on their observable present-day conditions (Dickson et al., in prep). These models also provide a framework for probing the highly uncertain physics surrounding the formation of black holes, such as their natal kicks, by experimenting with flexible prescriptions and common assumptions and analyzing the impacts on the initial conditions, evolution and present-day structure of Milky Way globular clusters.

Work also continued to demonstrate the use of pulsar timing data to constrain the mass distribution of globular clusters (Smith et al. 2024). The method we recently developed was first applied to 47 Tuc, a cluster for which there exists an abundance of stellar kinematic data and which is also host to a large population of millisecond pulsars. We showed that the pulsar timing data can be used place strong constraints on the overall mass distribution and remnant populations even without fitting on stellar kinematics. This method can be easily applied to other cluster with pulsar timing data, for which data sets will continue to grow with the next generation of radio telescopes. This formed the basis of Noha Hoque's Honours thesis who applied it to the globular cluster M62, showing that it is likely not a core-collapsed cluster and instead probably contains a small population of black holes. She also investigated the potential of future pulsar surveys in globular clusters by fitting multimass models to mock observations (including mock pulsar timing observations for different pulsar sample sizes) extracted from dynamical Monte Carlo cluster models

MSc student Abigail Battson completed her thesis. Using Gaia DR3 data, she performed a systematic search for high-velocity stars ejected from three-body interactions (between a single object and a binary) in Milky Way globular clusters, possibly involving a "bully" black hole (Battson et al., in prep). She computed new Monte Carlo dynamical models to try to interpret an intriguing excess of high-velocity star candidates around the cluster

NGC 3201, which is much more significant than expected based on the nominal ejection rate of such stars and a priori cannot be explained by contamination. The high-velocity star candidates identified will warrant further investigation when Gaia DR4 and its higher precision proper motions becomes available in late 2026.

Undergraduate summer research student Ella Jackson studied the globular cluster Palomar 5 to understand its initial BH population. Palomar 5 is one of the rare globular clusters that is also identified as the (not yet disrupted) progenitor of a large-scale stellar tidal stream. With its extended tidal tails, it is a Rosetta Stone for understanding the formation of stellar streams and the role that black holes may have in promoting cluster expansion and generating streams. N-body simulations previously showed that two cluster models with different initial conditions (one with a higher initial density and a significant population of black holes, the other with a larger initial radius but fewer black holes) can explain Palomar 5 in its current state, in particular its long tidal tails and large half-mass radius (Gieles et al. 2021). The two models predict different present-day velocity dispersions and stellar-mass black hole mass fractions, providing means to discern between these models. In a preliminary analysis of proprietary multi-epoch VLT-FLAMES spectroscopic data, we were able to determine the line-of-sight velocity dispersion of the cluster estimate its binary fraction. We found these results tentatively favour the model with a higher initial density containing significant population of black holes. This points to the importance of black holes for accelerating the expansion and mass loss of globular clusters and producing stellar streams.

Undergraduate summer research student Mackenzie Hayduk performed orbital modelling of fast-moving stars near the centre of the massive globular cluster Omega Centauri (ω Cen) to improve constraints on a possible intermediate-mass black hole in this system. Intermediate-mass black holes (IMBHs), with masses between 10^2 and 10^5 $M_\odot$, could be the missing link between stellar and supermassive black holes. Proving their existence and understanding their demographics is key to understanding the evolution of galactic centres and analysing future gravitational wave signals detectable with LISA. Recently, Haberle et al. (2024) suggested an IMBH in ω Cen by analysing several stars near the cluster's centre that exceed the central escape

velocity, constraining the IMBH mass to be $>8,200$ M$_\odot$. We strengthened the case for an IMBH by fitting the full orbits of the fast-moving stars using and all available astrometric data, and we found a more stringent lower mass limit for the IMBH. We also make predictions for the orbital parameters and line-of-sight velocities of the fast-moving stars that will refine this analysis when compared with upcoming JWST data.

2.2. Stellar atmospheres

Stellar atmospheres are the visible layers where a star's light and spectra originate, making them essential laboratories for understanding the physical processes that govern stellar structure and evolution. The modeling of these atmospheres underpins much of modern astrophysics, from determining stellar ages, masses, and chemical compositions to calibrating cosmic distance scales and interpreting the light of galaxies across cosmic time.

During AY 2023-24, Dr. Ian Short continued development of the Chroma+ suite of stellar atmospheric and spectrum modelling codes written in Python and Java. The code now computes the emergent intensity distribution assuming a spherical atmosphere rather than a planar one, and now produces more realistic exoplanet transit light curves. This work is described in Short, C.I., "Chroma+ model stellar surface intensities: Spherical formal solution", 2025, arXiv:2510.05035v2, and was presented at the ICA Symposium in January 2025 and at the EASA annual meeting in May 2025. See www.ap.smu.ca/OpenStars for additional information.

2.3. The evolution of galaxies

Several ICA researchers study the evolution of galaxies. These are faculty members Drs. Ivana Damjanov, Marcin Sawicki, and Rob Thacker, as well as post-doctoral fellows Drs. Rosa Maria Merida, Kiyoaki Omori, Gaia Gaspar, and Michele Pizzardo, along with several students.

Dr. Sawicki studies the formation and evolution of galaxies, with a specific interest in the early stages of their evolution, the so-called "high redshift Universe." This research allows us to look back in time to when the Universe and its content were only a fraction of their present age. This research area is making enormous advances following the spectacularly successful launch of the James Webb Space Telescope (JWST) in December 2022.

Several ICA researchers, including Dr. Sawicki, Dr. Rosa Mérida, Dr. Kiyoaki Omori, and Dr. Gaia Gaspar, graduate student Yoshihisa Asada, and ICA alumni Dr. Vince Estrada-Carpenter, Dr. Guillaume Desprez, and Dr. Gael Noirot, are members of the JWST CANUCS Guaranteed Time Observations program that uses 200 hours of JWST time to study very distant galaxies behind massive, gravitationally lensing galaxy clusters. These researchers have published 9 peer-reviewed papers in this reporting period based on JWST CANUCS data. Highlights include: the first published report (led by post-doc Dr. Rosa Mérida) of an interacting pair of Little Red Dots (LRDs are a mysterious class of objects discovered in the distant universe by JWST), and the determination of the transmitivity of intergalactic gas at high redshift led by PhD student Yoshihisa Asada. Asada and ICA alumnus Dr. Guillaume Desprez were key contributors to a Nature paper (Mowla et al. 2025) that describes the CANUCS observations of the early stages in the assembly of a Milky Way-like galaxy just 600 million years after the Big Bang; these results were featured in a NASA press release and appeared in several media outlets including the BBC, CBC, and Globe and Mail. Meanwhile, the results of a paper on an unusual gravitational lens system, led by then-ICA postdoc Dr. Estrada-Carpenter and published just before the start of this reporting period, were the subject of a September 2024 NASA press release and covered by several outlets, including the Washington Post and People magazine.

The successful launch, on 1 July 2023, of the European Space Agency's flagship *Euclid* mission has paved the way for science that will be highly complementary to that being done with JWST. While JWST can observe extremely faint and distant objects, *Euclid* specializes in studies of the more nearby (but still very distant) Universe but over much larger areas of the sky than is possible with JWST. Building on the continuing success of the CLAUDS survey (see below), Dr. Sawicki co-leads (with S. Arnouts of France) the Deep Euclid U-band Survey (DEUS) that is being carried out with CFHT by a consortium of fifty Canadian and

French astronomers, including ICA's faculty Dr. Ivana Damjanov, former ICA postdocs Drs. Desprez, Estrada-Carpenter, and Noirot, and students Lingjian Chen, Angelo George, and Devin Williams. These U-band data are essential for enabling the measurements of distances to millions of remote galaxies through the technique of photometric redshifts. DEUS thus paves the way for the exploitation of the deep data from the *Euclid* space telescope as part of a multi-wavelength joint dataset now being assembled. DEUS observations are expected to be completed at CFHT in 2025 and will be combined with Euclid and other datasets in 2026 in preparation for scientific exploitation by the community.

The DEUS project builds on its older sibling, the CLAUDS survey (a major Canada-France-China CFHT observing collaboration that Dr. Sawicki continues to lead), and its combination with the HyperSuprime-Cam Subaru Strategic Program (HSC-SSP) on Japan's national Subaru Telescope. Together, CLAUDS and HSC-SSP probe the distant Universe to an unprecedented combination of area and depth that will be unmatched until the coming decade. The merged CLAUDS+HSC-SSP catalogs of galaxies and stars, which were recently finalized and validated by the ICA-based team, form the foundation of 39 peer-reviewed publications to date (see the CLAUDS Project Website). In this reporting period, they include papers on the evolution of galaxy sizes led by PhD students Angelo George and Devin Williams (co-supervised by Drs. Danjanov and Sawicki — see farther below for more detail). Three further CLAUDS+HSC-SSP papers led by ICA researchers are in preparation with several more led by external collaborators also in the works.

ICA faculty member Dr. Ivana Damjanov utilizes large-area imaging and spectroscopic surveys to study the evolution of galaxies in the last 7 billion years, which corresponds to the second half of cosmic history. These studies provide crucially important constrains for the physical processes responsible for triggering, regulating, and halting star formation in galaxies and for the mechanisms that promote galaxy morphological transformation and growth after the cessation of star formation. Dr. Damjanov is actively involved in the HSC-SSP + CLAUDS survey and Euclid space mission (mentioned earlier), as well as the HectoMap survey (a dense spectroscopic survey of 52 square degrees

within the HSC-SSP footprint). Using measured spectroscopic properties of non-star forming (i.e., quiescent) galaxies in HectoMap, Dr Damjanov led the study to explore the changes in stellar population properties of quiescent galaxies (i.e., average age and metallicity) with stellar mass using a new approach based on the full-spectrum fitting performed on median HectoMAP spectra of galaxies segregated by stellar mass (Damjanov et al. 2025). This work demonstrates that individual galaxy spectra of moderate signal-to-noise can be effectively utilized to tracing star formation histories of some of the oldest galaxies at the universe.

Dr. Damjanov has been developing the optimal strategy for measuring sizes and shapes of galaxies in the CLAUDS+HSC-SSP using a combination of existing software and a custom-built algorithm for the modelling of galaxy light profiles in large-area high-quality images obtained with a ground-based telescope. Two sets of student-led projects have been included in this effort: working with Dr. Damjanov and Dr. Sawicki, PhD student Angelo George has been modelling the two-dimensional galaxy light profiles in the CLAUDS+HSC-SSP data. During the 2024-2025 reporting period, the student published a study that explored the structural properties of galaxies in the densest regions of the cosmic large-scale structure, galaxy clusters (George et al., 2025). They show, for the first time, clear evidence that non-star-forming (i.e., quiescent) cluster galaxies are smaller than their field counterparts and that this difference is more prominent if galaxy size is measured at shorter wavelengths. In the final study of their PhD thesis (defended in August 2025), the student performed a decomposition of galaxy light profiles from the CLAUDS+HSC-SSP survey into bulges and disks and investigated, for the first time, the evolution of these components at two rest-frame wavelengths.

Starting as a summer undergraduate research assistant in 2018, Harrison Souchereau has been developing a versatile algorithm for the extraction of one-dimensional radial profiles of galaxies in the CLAUDS+HSC-SSP fields. After completing the undergraduate degree in April 2020 (with honours thesis project overseen by Dr. Damjanov) and joining the graduate program in Astronomy at Yale University, this student has continued to collaborate with Drs. Damjanov and Sawicki. The team is preparing a publication that will provide the

technical overview of the code and accompany its public release (Souchereau et al. 2025, in prep). Devin Williams, a second-year PhD student under the supervision of Drs. Damjanov and Sawicki, has been using the software to measure radial profiles of several million CLAUDS+HSC SSP galaxies and examine the change in their outer regions as a function of galaxy mass, distance, star formation activity, and environment. The highlight of this work is a clear picture that favours mergers with low-mass satellites as the main mechanisms behind the observed growth of outskirts in massive galaxies, regardless of the current (global) level of star formation in them (Williams et al. 2025). The student is now following up this study with the exploration of the effects that galaxy environments (e.g., dense cluster regions) have on the observed stellar halo growth.

Postdoctoral fellow Dr. Michele Pizzardo, who was a member of Dr. Damjanov's group from November 2022 to May 2025, has been very successful in exploring dynamical properties of galaxy clusters in IllustrisTNG simulations. In a series of publications, Dr. Pizzardo explored the reach of observational techniques based on spectroscopic surveys to probe the underlying distribution of galaxies in clusters in the 6-dimensional phase space and thus trace the growth of structure in the aging universe. In their last study, before moving to a new postdoctoral position, Dr. Pizzardo switched gears and developed expertise in measuring structural properties of galaxies. Using the spectro-photometric sample of quiescent galaxies from the HectoMAP survey, they show that in the last 7 billion years of cosmic time, quiescent galaxies show a systematic decline in size and a rise in central concentration of light profiles at redder rest-frame wavelengths. These structural variations are stronger for galaxies that recently joined the quiescent population than for the descendants of galaxies that were already quiescent 7 billion years ago. The combined evidence supports inside-out quenching as the dominant mechanism halting star formation during this epoch. Their findings link newcomers to their direct progenitors in the star-forming population. For the aging quiescent population, the results suggest minor mergers with progressively redder satellites at lower redshifts as the primary driver of quiescent galaxy evolution. This work is now accepted for publication in the Astronomy & Astrophysics journal.

Dr. Damjanov is an active member of the Euclid Consortium. In the last year, she has been heavily involved in the publication that explores morphological properties of galaxies in the first (quick) data release (Q1), comparing the measurements performed in the visible (VIS) filter and in the near-infrared (NISP) filters (Euclid Consortium: Quilley, Damjanov et al. 2025, accepted for the special issue of the Astronomy and Astrophysics). In addition, she is the core member of the team that performed the decomposition of galaxy light profiles in Euclid's Early Release Observations (ERO) into bulges and disks (Euclid Consortium: Quilley et al. 2025, accepted for publication in the Astronomy and Astrophysics. This pilot ERO study is now being extended to the first full data release from Euclid to provide the largest sample of decomposed galaxy light profiles in visible and near-infrared wavelengths to date.

During the summer of 2025, two undergraduate students joined Dr. Damjanov's research group. Darra Stewart has been working on the (scaling) relation between galaxy size and stellar mass, exploring the differences that arise when structural parameters are measured in images taken at different wavelengths. In addition, the student is using a spectroscopic sample of cluster galaxies at low redshift to incorporate the effects of environment in their investigations of the scaling relations. Katie Sanders has been using the first photometric dataset from the Euclid mission and combining it with ground-based spectroscopy to conduct a census of the most compact galaxy population found in Euclid data and their specro-photometric properties. The student is currently quantifying the limitations of Euclid imaging and data reduction/analysis pipeline in identifying these compact systems.

On the theoretical side, Dr. Rob Thacker and graduate student Fraser Smith have been working to understand galactic star formation on a more statistical footing. Specifically, for theoretical modelling of star formation it is useful to be able relate the overall time variation in star formation within an individual galaxy to the overall statistical variation observed in a sample of galaxies of similar size. The root concept behind this is ergodicity, namely the idea that a single system will, over time, occupy all possible states available to it, or in the case of restricted freedom to create so-called "partial ergodicity." This is a significant

simplification of evolutionary behaviour but for certain systems, such as gas contained within a box, it is actually an accurate description.

Building on their earlier published work on idealized simulations, research is now continuing with the FIRE-2 collaboration (PI Hopkins, Caltech) on extending this analysis to simulated galaxies with more accurate merger trees and detailed physics. Smith has been given full access to the data created by the collaboration, which includes over 20 high resolution galaxy simulations.The 120 TB of data is now likely to be hoeted at SMU to enable more rapid analysis. The star formation approach used in this work is arguably the most accurate to-date in the field, and has considerably more variation than the algorithms used in the initial study. This makes the probability of ergodicity higher, but there are also changes in star formation behaviour with mass, such that at higher masses the overall star formation for the galaxy becomes smoother.

The new analysis shows that these simulations do indeed show behaviour that is closer to ergodic. The precise way of measuring this is with via a statistic known as the "TM-metric" which has been used extensively in condensed-matter physics. However, our work has highlighted that the precise nature of the system being studied, specifically how variable it is with time, gives an impression of strong ergodicity at late times, while statistically we can show via a "block scramble" technique that there is a dependence on the ordering of the blocks. This has pinpointed a problem with the statistic that is not widely appreciated and in fact suggests that while we do have systems that look more ergodic in practice the regime that this happens in may be limited. This work is essentially complete and will be submitted to collaborators for review shortly.

With honours thesis students Emily Fisher and Jorge Mexa, Dr. Thacker is investigating the behaviour of shock processes and statistics for measuring mixing of gas in large scale simulations of collisions of clouds of dark matter and gas. This work is an extension of previous investigations on energy transfer by honours student Starling Cox and Samuel Willis. Although heavily simplified as compared to evolution in the actual universe, these modelled mergers allow straightforward analysis. For the work with Emily Fisher, the focus is on understanding whether unevenness in shock fronts

("rugosity") plays any role in increasing the level of turbulence post shock passage. This draws on issues such as inhomogeneities in the medium as well as processes like the Richtmeyer-Meshkov instabilitiy. The work is now moving towards developing detailed analysis codes that calculate the fields needed for these measurements. With student Jorge Meza, the focus has been on how under-resolved mixing is represented by various statistical measurement techniques. This is of value in understanding how "coarse-grained" approaches to measurements may actually hide additional structure and results. This work also has completed a series of simulations and is now working towards developing the statistical analysis tools needed. Both these studies are comparatively new in terms of their conceptual background, so it will be interesting to see how results play out! Measuring rugosity has not been attempted in the literature much at all, and most measurements of mixing tend to rely on one statistic alone without considering other possibilities. While appearing somewhat academic, both of these studies speak to the fundamental processes inherent in the evolution of astrophysical systems that are often challenging to measure.

2.4. Development of future research tools

With an eye to the future, ICA scientists are involved in the development of new astronomy research tools.

2.4.1. GIRMOS

ICA faculty Drs. Damjanov, Hénault-Brunet, and Sawicki, and post-doc Dr. Gaia Gaspar participate in the CFI-funded GIRMOS project to build a multi-unit integral field spectrograph for the giant 8-metre Gemini telescope in Hawaii. When coupled with Gemini's new NSF-funded Adaptive Optics (AO) system now also under construction, GIRMOS will enable efficient yet highly detailed spectroscopic studies of distant galaxies and AGN.

In this academic year, GIRMOS successfully passed its peer-reviewed Critical Design Review (CDR) and is now proceeding towards construction. Dr. Sawicki is a founding member of the GIRMOS project consortium, serves on the project's Management Group, and also oversees the

development of the GIRMOS data reduction software suite, the implementation of which is being led by Dr. Gaspar.

Drs. Damjanov, Gaspar, Hénault-Brunet, and Sawicki are members of the GIRMOS Science Team which helps guide the development of the instrument's capabilities with reference to its science goals. During this reporting period, the Science Team has been developing the plans for a massive GIRMOS Guaranteed Time Observations program to make maximum use of the instrument when it goes on the sky. As part of this, Dr. Damjanov is the co-lead of G4, the high-redshift galaxy survey proposal for 900 h of Guarantied Time Observations with GIRMOS on the Gemini North telescope. Meanwhile, Dr. Gaspar co-leads a proposed program that aims to use GIRMOS to study the nature of ring galaxies and their Active Galactic Nuclei.

2.4.2. CASTOR

CASTOR is the #1 priority for space astronomy in Canada (source: Canadian Astronomy Long Range Plan 2020-2030) and is moving forward with development funding from the Canadian Space Agency, aiming for launch in the late 2020s. The project is being led by Canada in partnership with the UK and US.

CASTOR is a project that has long-standing ICA connections that started in 2010 when Dr. Sawicki and then-graduate student Robert Sorba provided the first studies of CASTOR precursor's expected performance for measuring the Dark Energy equation of state. Over the years, many ICA members, including faculty, postdocs, and students, have contributed to the development of CASTOR. Most recently, SMU, via ICA, has held the largest university-based science development contract in CASTOR's CSA-funded Phase 0 study. This included contributions from ICA faculty Drs. Damjanov, Henault-Brunet, and Sawicki and their students and postdocs. To put this work in context, the recently-published refereed paper[1] that describes the CASTOR mission lists 99 co-authors from 28 institutions in 11 countries… nine, or nearly 10%, of these authors are ICA members.

Having recently completed its CSA-funded Phase-0 development, CASTOR is now awaiting federal government funding to begin the construction phase of its lifecycle. The ICA looks forward to continuing its role and increasing its involvement in CASTOR.

3. ICA Seminars and Meetings

Following the success of the first annual ICA Research Symposium in 2024, the 2nd Symposium was held over the course of a full day on 31 January 2025. Approximately 30 participants attended and heard 20 research presentations on a variety of astrophysics research topics. The 3rd Annual ICA Symposium to be held in winter 2026.

ICA Firesides, a new 'un-seminar seminar' series, has been inaugurated in FY 2024-25. Three Firesides were held in this academic year (on scientific publishing, on AI in astronomy, and on the mysteries of the post-doc application process). This series has proven to be very popular and continues in 2025-26, with two Firesides scheduled in the fall of 2025 and more planned for 2026.

Finally, the Galaxy Evolution Discussions Series meets regularly (twice-weekly) to provide a regular forum for researchers interested in studies of the formation and evolution of galaxies. This field is an area of particular strength in the ICA with much observational and theoretical research This discussion series regularly attract a dozen attendees, including 3 faculty members, with the rest split roughly evenly between postdocs and graduate and undergraduate students.

4. Service

Members of the ICA play significant roles in service to the University and the community on local, national, and international levels. Some of these activities are summarized here.

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[1] The CASTOR Mission, https://www.spiedigitallibrary.org/journals/Journal-of-Astronomical-Telescopes-Instruments-and-Systems/volume-11/issue-4/042202/The-CASTOR-mission/10.1117/1.JATIS.11.4.042202.full

4.1. Saint Mary's

Dr. Short presented contributed talks at the ICA Symposium and at the annual meeting of the Eastern Association of Stellar Astronomers (EASA) on the latest developments with the Chroma+ stellar atmospheric and spectrum modelling code. He served on the University's Appointments Committee and the CASCA 2025 AGM LOC, and coordinated the Astronomy and Physics undergraduate programs. Dr. Thacker served as Director of the Saint Mary's Science Outreach Centre. Dr. Hénault-Brunet serves as the Director of the Burke-Gaffney Observatory and coordinator "Star Finder - The David Lane Astronomy Outreach Program", and Dr. Sawicki continued to serve for the fifth year as the ICA's Acting Director.

As Director (until July 2025) of the SMU Science Outreach Centre, Dr. Thacker coordinated Faculty open houses, student visits to the Faculty of Science, and chaired the Faculty of Science Community Engagement & Outreach Committee. He conducted numerous interviews – 90 in total, including 41 episodes of Science Files on the Todd Veinotte Show (CityNews Halifax); 42 episodes of CFRA Live! (580 CFRA Ottawa); 3 CTV interviews. Dr. Thacker also did double duty as the department's Graduate Coordinator, and continued to serve on the university pension committee. He officially stepped down as the SMUFU Lead Negotiator in July of 2024, but is part of the 2025 negotiations team. He also gave two public lectures, one at Acadia University, and another at the Dartmouth Probus Chapter, along with a keynote talk at the Atlantic AI Summit.

Dr. Hénault-Brunet served as the Department's Science Atlantic representative and as Saint Mary's representative on the ACENET Research Directorate. In his role as Director of the Burke-Gaffney Observatory, he led the organization of the first Star Finder Teachers' Workshop in August 2025, and he gives frequent interviews on astronomy-related news (CBC/Radio-Canada radio and TV, for stations in Nova Scotia, PEI, Newfoundland, and New Brunswick).

4.2. National

On the national scene, Dr. Thacker is serving as the Chair of the Local Organizing Committee for the CASCA Annual General Meeting in 2025. He was also a reviewer on the NSERC Banting Postdoctoral Fellowship review panel in December 2025, as well as providing Discovery Grant reviews.

Dr. Short gave an invited public lecture at a hybrid meeting of the Halifax Centre of the RASC and a contributed talk at a hybrid annual meeting of the Eastern Association of Stellar Astronomers (EASA), both on the remote-access low-resolution spectrograph at the BGO. He gave an invited public lecture remotely at a meeting of the DDO Defenders in Richmond Hill, ON, on defining and measuring the basic properties of stars. He served as a reviewer for national funding agencies.

Dr. Hénault-Brunet served on the ACEnet Research Directorate. He also served on NSERC's PromoScience review committee, is the SMU institutional representative to the ACURA council, and chairs the Nominating Committee for this council. He was an external reviewer for the Canadian Time Allocation Committee (CanTAC). Dr. Hénault-Brunet led the Near-Field Cosmology Science Working Group for the CASTOR mission. He led the Scientific and Local Organizing Committee for the workshop ""Globular Clusters: From the Milky Way to High-Redshift Galaxies"" in Halifax in June 2025, and co-chaired the Scientific Organizing Committee for the CASCA 2025 Annual General Meeting at Saint Mary's in June 2025.

Dr. Damjanov was the chair of CASCA's Equity and Inclusivity Committee from June 2022 to June 2025 and is currently leading the team analyzing the data from the first climate survey targeting the broad astronomical community in Canada. The survey includes responses from undergraduate and graduate students, postdocs, and astronomers in tenure-track or tenured positions at research institutes and universities across the country. During the 2024-2025 reporting period, she started a two-year term as the Vice President of CASCA. In addition, Dr. Damjanov serves a three-year term (2023-2026) on the NSERC Review Committee for Doctoral Scholarships and Postdoctoral Fellowships.

4.3. International

Dr. Damjanov serves as one of two Canadian representatives and the Deputy Chair on the Gemini Science and Technology Advisory Committee that

advises Gemini International Observatory's Board of Directors on policy matters of long-range scientific and technological importance to the Observatory. Dr. Damjanov is active in the Euclid Consortium, an organization that includes more than 2,500 scientists from 18 countries running the Euclid Dark Universe space mission. In the summer of 2025, Dr. Damjanov was appointed a coordinator for the key project DR1-KP-JL-2 - a group of key publications related to galaxy mergers and morphology based on the first full data release from Euclid.

Dr. Sawicki continues to serve on the Management Committee of the CFI-funded GIRMOS instrument project and on the Steering Committee for the HSC Multi-Wavelength Consortium. Dr. Sawicki served in the NASA process for selecting observing projects for the James Webb Space Telescope and on the search committee for the Executive Director of the Gemini International Observatory.

5. Upcoming Activities

ICA members continue with the implementation of the ICA's strategic plan, which focuses on increasing the institute's strength in the area of astrophysical big data and data analytics. As part of this, Institute members play key roles in the development of future research tools that will both fuel and benefit from this effort, including major national/international-scale initiatives that are CASTOR and GIRMOS (see Section 2.4).

Supporting its research activity as well as HQP training, in FY 2025-26, the ICA is expanding its series of ICA Firesides "un-seminar seminars", and will again - for the 3rd time - host its annual ICA Research Symposium (see Section 3).

6. Finances

The Institute does not receive operating funds but has a small residual fund in its account. At the start of November 2024, the ICA fund contains $8326.00.

Research at the ICA is supported through grants to its members from NSERC, Canada Foundation for Innovation (CFI), Research Nova Scotia Trust (RNST), and the Canadian Space Agency (CSA).

The ICA welcomes external funding for its research from interested donors and would like to engage potential donors with the help of SMU Advancement.

7. Publications

ICA members primarily publish their research in high-impact specialist refereed journals, including Astrophysical Journal (ApJ, with Impact Factor, IF = 8.4), Astronomical Journal (AJ, IF = 5.5), Astronomy & Astrophysics (A&A, IF = 6.2), Monthly Notices of the Royal Astronomical Society (MNRAS, IF = 5.2).

Papers published by ICA members and associated students and post-docs during AY 2024-25 are listed below.

1. The Growth of Galaxy Stellar Haloes over $0.2 \leq z \leq 1.1$ Williams, Damjanov, Sawicki, Souchereau, Chen, Desprez, George, Annunziatella, Arnouts, Gwyn, Marchesini, and Sajina (2025) The Astrophysical Journal 989 107

2. The Connection between Galaxy Mergers, Star Formation, and Active Galactic Nuclei Activity in the HSC-SSP Omori, Bottrell, Bellstedt, Robotham, Yesuf, Goulding, Sawicki, Nagao, and Takeuchi (2025) The Astrophysical Journal 989 73

3. Binarity at LOw Metallicity (BLOeM): Bayesian inference of natal kicks from inert black hole binaries Willcox, Marchant, Vigna-Gómez, Sana, Bodensteiner, Deshmukh, Esseldeurs, Fabry, Hénault-Brunet, Janssens, Mahy, Patrick, Pauli, Renzo, Sander, Shenar, van Son, and Stoop (2025) Astronomy and Astrophysics 700 A59

4. RIDEN pilot survey: broad-band selection of candidate quasars with extended Lyman-α nebulae using CLAUDS–HSC-SSP–DUNES^2 joint data Shimakawa, Kikuta, Kusakabe, Sawicki, Liang, Momose, Gwyn, and Desprez (2025) Monthly Notices of the Royal Astronomical Society 540 3565

5. In Search of the First Stars: An Ultra-compact and Very-low-metallicity Lyα Emitter Deep within the Epoch of Reionization Willott, Asada, Iyer, Judež, Rihtaršič, Martis, Sarrouh, Desprez, Harshan, Mowla, Noirot, Felicioni, Bradač, Brammer, Muzzin, Sawicki, Antwi-Danso, Markov, and Tripodi (2025) The Astrophysical Journal 988 26

6. Effects of Environment on the Size Evolution of Quiescent Galaxies: Comparing Galaxies in Clusters and in the Field at Two Rest-frame Wavelengths George, Damjanov, Sawicki, Williams, Chen, Desprez, Annunziatella, Arnouts, Gwyn, Marchesini, Moutard, and Sajina (2025) The Astrophysical Journal 987 45

7. A Holistic Exploration of the Potentially Recoverable Redshift Information of Stage IV Galaxy Surveys Scott, Malz, and Sorba (2025) The Astrophysical Journal 985 227

8. Possible environmental quenching in an interacting little red dot pair at z ~ 7 Mérida, Gaspar, Sawicki, Asada, Desprez, Rihtaršič, Antwi-Danso, Tripodi, Willott, Bradač, Brammer, Iyer, Martis, Muzzin, Noirot, Sarrouh, and Markov (2025) Astronomy and Astrophysics 698 A317

9. Selection of high-redshift Lyman-Break Galaxies from broadband and wide photometric surveys Payerne, d'Assignies Doumerg, Yèche, Ruhlmann-Kleider, Raichoor, Lang, Aguilar, Ahlen, Arnouts, Bianchi, Brooks, Claybaugh, Cole, de la Macorra, Dey, Dey, Doel, Font-Ribera, Forero-Romero, Gontcho, Gutierrez, Gwyn, Honscheid, Juneau, Lambert, Landriau, Guillou, Levi, Magneville, Manera, Meisner, Miquel, Moustakas, Newman, Palanque-Delabrouille, Percival, Picouet, Prada, Pérez-Ràfols, Rossi, Sanchez, Sawicki, Schlegel, Schubnell, Sprayberry, Tarlé, Weaver, and Zou (2025) Journal of Cosmology and Astroparticle Physics 2025 031

10. Euclid: V. The Flagship galaxy mock catalogue: A comprehensive simulation for the Euclid mission Euclid Collaboration, Castander, et al. (2025) Astronomy and Astrophysics 697 A5

11. Euclid: IV. The NISP Calibration Unit Euclid Collaboration, Hormuth, et al. (2025) Astronomy and Astrophysics 697 A4

12. Euclid: III. The NISP Instrument Euclid Collaboration, Jahnke et al. (2025) Astronomy and Astrophysics 697 A3

13. Euclid: II. The VIS instrument Euclid Collaboration, Cropper, et al. (2025) Astronomy and Astrophysics 697 A2

14. Euclid: I. Overview of the Euclid mission Euclid Collaboration, Mellier, et al. (2025) Astronomy and Astrophysics 697 A1

15. Improving Photometric Redshifts of Epoch of Reionization Galaxies: A New Empirical Transmission Curve with Neutral Hydrogen Damping Wing Lyα Absorption Asada, Desprez, Willott, Sawicki, Bradač, Brammer, Dubath, Iyer, Martis, Muzzin, Noirot, Paltani, Sarrouh, Harshan, and Markov (2025) The Astrophysical Journal 983 L2

16. The Average Stellar Population Age and Metallicity of Intermediate-redshift Quiescent Galaxies Damjanov, Geller, and Sohn (2025) The Astrophysical Journal 982 178

17. CANUCS: Constraining the MACS J0416.1-2403 strong lensing model with JWST NIRISS, NIRSpec, and NIRCam Rihtaršič, Bradač, Desprez, Harshan, Noirot, Estrada-Carpenter, Martis, Abraham, Asada, Brammer, Iyer, Matharu, Mowla, Muzzin, Sarrouh, Sawicki, Strait, Willott, Gledhill, Markov, and Tripodi (2025) Astronomy and Astrophysics 696 A15

18. Galaxy properties from the outskirts to the core of a protocluster at z = 3.70 Toshikawa, Wuyts, Kashikawa, Uchiyama, Bremer, Sawicki, Ono, Kubo, Ito, and Ali (2025) Monthly Notices of the Royal Astronomical Society 537 3561

19. Euclid preparation: LXIV. The Cosmic Dawn Survey (DAWN) of the Euclid Deep and Auxiliary Fields Euclid Collaboration, McPartland, et al. (2025) Astronomy and Astrophysics 695 A259

20. Euclid preparation: LXI. Cosmic Dawn Survey: 'Pre-launch' multiwavelength catalogues for Euclid Deep Field North and Euclid Deep Field Fornax Euclid Collaboration, Zalesky, et al. (2025) Astronomy and Astrophysics 695 A229

21. JWST, ALMA, and Keck Spectroscopic Constraints on the UV Luminosity Functions at z ~ 7–14: Clumpiness and Compactness of the

Brightest Galaxies in the Early Universe Harikane, Inoue, Ellis, Ouchi, Nakazato, Yoshida, Ono, Sun, Sato, Ferrami, Fujimoto, Kashikawa, McLeod, Pérez-González, Sawicki, Sugahara, Xu, Yamanaka, Carnall, Cullen, Dunlop, Egami, Grogin, Isobe, Koekemoer, Laporte, Lee, Magee, Matsuo, Matsuoka, Mawatari, Nakajima, Nakane, Tamura, Umeda, and Yanagisawa (2025) The Astrophysical Journal 980 138

22. Cluster Candidates with Massive Quiescent Galaxies at z ~ 2 Kiyota, Ando, Tanaka, Finoguenov, Ali, Coupon, Desprez, Gwyn, Sawicki, and Shimakawa (2025) The Astrophysical Journal 980 104

23. Euclid preparation: LVIII. Detecting extragalactic globular clusters in the Euclid survey Euclid Collaboration, Voggel, et al. (2025) Astronomy and Astrophysics 693 A251

24. Euclid preparation: LVII. Observational expectations for redshift z < 7 active galactic nuclei in the Euclid Wide and Deep surveys Euclid Collaboration, Selwood et al. (2025) Astronomy and Astrophysics 693 A250

25. Euclid preparation: LVI. Sensitivity to non-standard particle dark matter models Euclid Collaboration, Lesgourgues et al. (2025) Astronomy and Astrophysics 693 A249

26. Euclid preparation: LV. Exploring the properties of proto-clusters in the Simulated Euclid Wide Survey Euclid Collaboration, Böhringer, et al. (2025) Astronomy and Astrophysics 693 A59

27. Euclid preparation: LIV. Sensitivity to neutrino parameters Euclid Collaboration, Archidiacono, et al. (2025) Astronomy and Astrophysics 693 A58

28. Formation of a low-mass galaxy from star clusters in a 600-million-year-old Universe Mowla, Iyer, Asada, Desprez, Tan, Martis, Sarrouh, Strait, Abraham, Bradač, Brammer, Muzzin, Pacifici, Ravindranath, Sawicki, Willott, Estrada-Carpenter, Jahan, Noirot, Matharu, Rihtaršič, and Zabl (2024) Nature 636 332

29. Detailed Study of Stars and Gas in a z = 8.3 Massive Merger with Extreme Dust Conditions Harshan, Tripodi, Martis, Rihtaršič, Bradač, Asada, Brammer, Desprez, Estrada-Carpenter, Matharu, Markov, Muzzin, Mowla, Noirot, Sarrouh, Sawicki, Strait, and Willott (2024) The Astrophysical Journal 977 L36

30. Probing Populations of Dark Stellar Remnants in the Globular Clusters 47 Tuc and Terzan 5 Using Pulsar Timing Smith, Hénault-Brunet, Dickson, Gieles, and Baumgardt (2024) The Astrophysical Journal 975 268

31. Modeling and Subtracting Diffuse Cluster Light in JWST Images: A Relation between the Spatial Distribution of Globular Clusters, Dwarf Galaxies, and Intracluster Light in the Lensing Cluster SMACS 0723 Martis, Sarrouh, Willott, Abraham, Asada, Bradač, Brammer, Desprez, Harshan, Muzzin, Noirot, Rihtaršič, Sawicki, and Strait (2024) The Astrophysical Journal 975 76

32. Euclid preparation: LIII. LensMC, weak lensing cosmic shear measurement with forward modelling and Markov Chain Monte Carlo sampling Euclid Collaboration, Congedo, et al. (2024) Astronomy and Astrophysics 691 A319

33. Euclid preparation: LII. Forecast impact of super-sample covariance on 3×2pt analysis with Euclid. Euclid Collaboration, Sciotti, et al. (2024) Astronomy and Astrophysics 691 A318

34. Euclid preparation: LI. Forecasting the recovery of galaxy physical properties and their relations with template-fitting and machine-learning methods Euclid Collaboration, Enia, et al. (2024) Astronomy and Astrophysics 691 A175

35. Major merger fraction along the massive galaxy-quenching channel at 0.2 < z < 0.7 Inoue, Ohta, Asada, Sawicki, Desprez, Gwyn, and Picouet (2024) Publications of the Astronomical Society of Japan 76 950

36. The GLEAMing of the first supermassive black holes: III. Radio sources with ultra-faint host galaxies Broderick, Seymour, Drouart, Knight, Afonso, De Breuck, Galvin, Hedge, Lehnert, Noirot, Shabala, Turner, and Vernet (2024) Publications of the Astronomical Society of Australia 41 e071

37. ODIN: Improved Narrowband Lyα Emitter Selection Techniques for z = 2.4, 3.1, and 4.5 Firestone, Gawiser, Ramakrishnan, Lee, Valdes, Park, Yang, Ciardullo, Artale, Benda,

Broussard, Eid, Farooq, Gronwall, Guaita, Gwyn, Hwang, Im, Jeong, Karthikeyan, Lang, Moon, Padilla, Sawicki, Seo, Singh, Song, and Troncoso Iribarren (2024) The Astrophysical Journal 974 217

38. CANUCS: An Updated Mass and Magnification Model of A370 with JWST Gledhill, Strait, Desprez, Rihtaršič, Bradač, Brammer, Willott, Martis, Sawicki, Noirot, Sarrouh, and Muzzin (2024) The Astrophysical Journal 973 77

39. Binarity at LOw Metallicity (BLOeM): A spectroscopic VLT monitoring survey of massive stars in the SMC Shenar, Bodensteiner, Sana, Crowther, Lennon, Abdul-Masih, Almeida, Backs, Berlanas, Bernini-Peron, Bestenlehner, Bowman, Bronner, Britavskiy, de Koter, de Mink, Deshmukh, Evans, Fabry, Gieles, Gilkis, González-Torà, Gräfener, Götberg, Hawcroft, Hénault-Brunet, Herrero, Holgado, Janssens, Johnston, Josiek, Justham, Kalari, Katabi, Keszthelyi, Klencki, Kubát, Kubátová, Langer, Lefever, Ludwig, Mackey, Mahy, Maíz Apellániz, Mandel, Maravelias, Marchant, Menon, Najarro, Oskinova, O'Grady, Ovadia, Patrick, Pauli, Pawlak, Ramachandran, Renzo, Rocha, Sander, Sayada, Schneider, Schootemeijer, Schösser, Schürmann, Sen, Shahaf, Simón-Díaz, Stoop, Toonen, Tramper, van Loon, Valli, van Son, Vigna-Gómez, Villaseñor, Vink, Wang, and Willcox (2024) Astronomy and Astrophysics 690 A289

40. Euclid preparation. XLVIII. The pre-launch Science Ground Segment simulation framework Euclid Collaboration, Serrano, et al. (2024) Astronomy and Astrophysics 690 A103

41. Euclid preparation. XLVII. Improving cosmological constraints using a new multi-tracer method with the spectroscopic and photometric samples Euclid Collaboration, Dournac, et al. (2024) Astronomy and Astrophysics 690 A30

42. Environments around Quasars at z ~ 3 Revealed by Wide-field Imaging with Subaru HSC and CFHT Suzuki, Uchiyama, Matsuoka, Toshikawa, Gwyn, Imanishi, Liu, Noboriguchi, Sawicki, and Toba (2024) The Astrophysical Journal 972 82

43. Euclid preparation: XLVI. The near-infrared background dipole experiment with Euclid. Euclid Collaboration, Kashlinsky, et al. (2024) Astronomy and Astrophysics 689 A294

44. Euclid preparation: XLV. Optical emission-line predictions of intermediate-z galaxy populations in GAEA for the Euclid Deep and Wide Surveys Euclid Collaboration, Scharré, et al. (2024) Astronomy and Astrophysics 689 A276