Institute for Computational Astrophysics
Annual Report
2023-24

ICA Annual report, compiled by Marcin Sawicki, Interim Director

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ON THE COVER

A panoramic view of the Horsehead Nebula, a star-forming region in the constellation of Orion, taken by the European Space Agency's Euclid space telescope. Euclid launched on 1 July 2023 and began science operations later that year. This image is among the first released by Euclid to the public and showcases the power of this new, wide-field space observatory.

ICA faculty Ivana Damjanov and Marcin Sawicki, along with several ICA students and post-docs, are members of the Euclid Consortium.

1. Overview

The ICA's mission is to promote the study of complex astrophysical phenomena by numerical simulation, a remit which also includes 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 eight 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 sixteen postdoctoral fellows to date as well as numerous short- and long-term research visitors.

As of August 2023, 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 AY2023-24 were 21 early-career researchers:

- Five postdoctoral fellows: Dr. Guillaume Desprez, Dr. Vince Estrada-Carpenter, Dr. Nick Martis, Dr. Gaël Noirot, and Dr. Michele Pizzardo.
- Ten graduate students (including one long-term visiting PhD student): Yoshihisa Asada, Abigail Battson, Lingjian Chen, Maigan Devries, Nolan Dickson, Angelo George, Fraser Smith, Peter Smith, Shannon MacFarland, Devin Williams.
- Six undergraduates: Starling Cox, Noha Hoque, Katherine Myers, Joyo Smit and Samuel Willis, and Clara Wrightman-Dillon.

The ICA also has three external members: Dr. Ralph Pudritz (McMaster University) Dr. Richard Henriksen (Queen's University), and Harrison Souchereau (Yale University). Ms. Shannon Rhode provides administrative support as ICA Assistant, splitting her support duties between the ICA (30%) and the Department of Astronomy and Physics (70%).

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. These are described in the following sections (Sec. 2.1-2.5), with a focus on progress in AY2021-22. Notably, this research has resulted in XXX papers published or submitted to journals in AY2021-22 (see Section 6).

2.1. Stellar atmospheres

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 reads the VALD3 atomic line list in the near UV to near IR range containing 600,000 lines (34 Mbytes), and provides a much improved fit to the solar flux distribution. The spectrum synthesis calculation has now been automatically parallelized on the Compute Canada cluster Graham using the slurm ArrayJob facility. He has made significant progress in a noval approach to automatic continuum rectification (normalization) of observed spectroscopic data for meaningful comparison to synthetic spectra using the ELODIE archive. See www.ap.smu.ca/OpenStars for additional information.

2.2. Magnetohydrodynamics

Dr. David Clarke, whose retirement took effect at the end of August, 2023, is primarily interested in performing magnetohydrodynamical (MHD) simulations to investigate open problems in astrophysics including astrophysical jets and the non-ideal effects of ambipolar diffusion. In addition, he maintains and provides the astrophysical community with the widely-used MHD code ZEUS-3D which has enabled numerous other investigators to do research in their areas of interest. Details of these activities have been given in previous ICA reports.

ZEUS-3D is a mature code that can be downloaded from www.ap.smu.ca/~dclarke/zeus3d complete with installation and user's manuals, and to date some 850 unique downloads of the code have been recorded. A user-friendly version of ZEUS-3D's successor, AZEuS (that incorporates adaptive mesh technology), remains under development and is of Dr. Clarke's "retirement projects". On a related note, Dr. Clarke is also working on completing his senior undergraduate level textbook entitled "A First Course in Magnetohydrodynamics".

2.3. Star clusters

Dr. Hénault-Brunet's research programme 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 of globular clusters and their contribution to rate of gravitational wave events, (2) the evolution of the stellar mass function of globular clusters and constraints on their initial mass function, (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 new constraints on the dark remnant content of globular clusters (including black holes). PhD student Nolan Dickson has been fitting multi-component equilibrium “mass models” that were recently developed by Hénault-Brunet and collaborators to a wide range of data, for a sample of ~40 Milky Way globular clusters. These models were previously used to constrain the initial mass function (IMF) of stars up to ~8 $M_\odot$ (locked in white dwarfs at the present day) by fitting them to detailed observations of visible tracer stars. One key finding was that the IMF above 1 $M_\odot$ is generally consistent with the canonical Salpeter slope (Dickson, Hénault-Brunet et al., 2023), with no obvious indication of the shallower slopes at lower metallicities suggested by some star formation theories. In a companion study (Baumgardt, Hénault-Brunet et al., 2023), constraints on the global present-day stellar mass function within globular clusters to show that the IMF of globular clusters below of 1 $M_\odot$ was likely more bottom-light (i.e. lacking low-mass stars) than the commonly assumed canonical Kroupa or Chabrier IMF. This has significant implications for the evolution of GCs, the number of black holes initially formed per unit cluster mass (and thus the rates of black hole-black hole mergers), the self-enrichment of globular clusters from massive star ejecta (and the problem of multiple populations), and the interpretation of the properties of distant globular clusters in the early Universe as probed by the James Webb Space Telescope.

The most recent results from this project led to new improved and independent constraints on the size of present-day black hole populations in a significant sample of globular clusters (Dickson, Smith, Hénault-Brunet et al., 2024). Direct constraints on both the total and visible mass components provided by several observables allowed the models to accurately determine the distribution of the dark mass (including black holes) within clusters. This was also demonstrated in a proof-of-concept fitting of the models to mock observations extracted from Monte Carlo cluster models, a part of the project led by MSc student Peter Smith. Mass fractions in black holes ranging from 0 to 1% of the total mass of the cluster were found to be typically required to explain the observations, in agreement with previous works, but this time comparing the models simultaneously to many more observables for the first time, and demonstrating the robustness of the method.

In parallel, MSc student Peter Smith developed a new method to combine multimass equilibrium dynamical models and pulsar timing data to constrain the mass distribution and remnant populations of Milky Way globular clusters (Smith, Hénault-Brunet et al. 2024). The method 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. It demonstrated 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. The models favour a small population of stellar-mass black holes in this cluster (with a total mass of ~500 $M_\odot$), arguing against the need for a large (>2000 $M_\odot$) central intermediate-mass black hole. The method was then applied to Terzan 5, a heavily obscured bulge cluster that hosts the largest population of millisecond pulsars of any Milky Way GC and for which the collection of conventional stellar kinematic data is very limited. It allowed to improve existing constraints on the mass distribution and structural parameters of this cluster and place stringent constraints on its black hole content, finding an upper limit on the mass in black holes of ~4000 M ⊙. This new 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. Honours thesis student Noha Hoque is now applying it to the cluster M62 and investigating the potential of future pulsar surveys.

MSc student Abigail Battson is looking at other implications of the presence of compact stellar remnants in globular clusters. 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. She has recently identified an intriguing excess of high-velocity star candidates in the cluster NGC 3201, which is much more significant than expected based on the ejection rate of such stars in current dynamical models of clusters, and which a priori cannot explained by contamination (Battson, Hénault-Brunet et al., to be submitted).

One of the main limitations in understanding the co-evolution of black holes and globular clusters is the unknown initial density of globular clusters at the time of their formation ~12 Gyr ago. Present-day populations of binaries (in particular their period distribution) can be used to constrain the initial density of clusters. Binaries are dynamically affected by their interactions within the cluster, potentially resulting in their disruption. Disruption (or ionization) occurs preferentially for binaries with a binding energy smaller than the average kinetic energy of a star in the cluster. As the average kinetic energy is related to the density of the cluster, denser globular clusters result in higher ionization rates and more effective destruction of long-period binaries. Since the majority of binary disruptions occur early on in the clusters evolution when a cluster is at its densest, the current population of binaries and their period disruption may be used to infer back to the initial density of the globular cluster. Using this idea, a novel hierarchical Bayesian method was previously developed by former MSc student Maigan Devries to use multi-epoch radial velocity measurements in the cluster NGC 3201 (from the VLT-MUSE integral field unit spectrograph) to place constraints on the intrinsic binary period distribution in this cluster, with a particular emphasis on understanding the long period tail of the distribution. In this reporting period, work on this topic has continued with the calculation of new dynamical models by Dr. Hénault-Brunet and his team. These models include more realistic binary populations and varying initial conditions, and will be important for interpreting the results of the hierarchical Bayesian method based on multi-epoch radial velocity surveys.

2.4. The evolution of galaxies

Many 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. Guillaume Desprez, Vince Estrada-Carpenter, Nick Martis, Gaël Noirot, Michele Pizzardo, along with several students.

Dr. Sawicki studies the formation and evolution of galaxies, with a specific interest in 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 at present following the spectacularly successful lauch of the James Webb Space Telescope (JWST) in December 2022. Several ICA researchers, led by Dr. Sawicki and including post-docs Dr. Desprez, Dr. Estrada-Carpenter, Dr. Martis and Dr. Noirot, along with students Yoshihisa Asada, Shannon MacFarland, and Katherine Myers are at the forefront of this work internationally as key members of the CANUCS survey that uses 200 hours of guaranteed JWST observing time, they are leading Canada's exploration of the distant Universe with JWST.

ICA researchers have been making full use of the CANUCS JWST data: Graduate student Yoshi Asada has led a paper on the ubiquity of low-mass interacting galaxies in the early universe, and how these interactions trigger rapid and intense bursts of star formation before ending in galaxy-galaxy mergers through which larger galaxies, such as our own Milky Way, eventually form. Post-doctoral fellow Vince Estrada-Carpenter led a study of a highly magnified interacting galaxy system at cosmic noon using data from JWST's made-in-Canada NIRISS spectrograph, which allowed the resolution of star-forming ragions in this galaxy and a better understanding of the timescales on which they evolve; these results were accepted for publication by the Monthly Notices of the Royal Astronomical Society and were scheduled to feature as a NASA press release in fall 2024. And post-doc Dr. Guillaume Desprez led a study (also published in the same journal) which put into question early JWST results by other researchers that resulted in highly-publicized - but apparently erroneous - claims that JWST has discovered ultramassive galaxies inconsistent with our current understanding of the age of the universe.

ICA researchers have also participating vigorously in the exploitation of early-release science observations by the JWST, particularly focusing on working with the imaging and spectroscopy of the SMACS 0723 dataset (the first JWST science data released to the community in mid-2022 and dubbed “Webb’s First Deep Field” for its depth and image clarity. With these, ICA postdoc Dr. Gaël Noirot has led a project - published in this AY - that uses observation of this field made with JWST’s made-in-Canada NIRISS instrument to measure more than a hundred new redshifts to galaxies that were previously unknown. These data were made world-public and described in a related peer reviewed paper published in the Monthly Notices of the Royal Astronomical Society.

The successful launch, on Canada Day, 1 July 2023, of the European Space Agency’s flagship *Euclid* mission paves the way for science that will be highly complementary to that which JWST enables. While JWST can observe extremely faint and distant objects, Euclid specializes is 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 by a consortium of fifty Canadian and French astronomers, including ICA’s faculty Dr. Ivana Damjanov, postdocs Drs. Desprez, Estrada-Carpenter, and Noirot, and students Lingjian Chen, Angelo George, and Devin Williams. DEUS paves the way for the exploitation of the deep data from *Euclid* space telescope, and we look forward to using these combined datasets to study the distant Universe when the first internal (to the *Euclid* team) data release happens in late 2024.

The Euclid/DEUS project builds on its older sibling, the CLAUDS survey (a major Canada-France-China observing collaboration that he Dr. Sawicki continues to lead), which was undertaken with the Canada-France-Hawaii Telescope (CFHT), and its combination with the HyperSuprime-Cam Subaru Strategic Program (HSC-SSP) on Japan’s national Subaru Telescope Together, these two surveys probe the distant Universe to an unprecedented combination of area and depth that will be unmatched until the next decade. The merged CLAUDS+HSC-SSP catalogs of galaxies and stars, which were recently finalized and validated by the SMU-based team, form the foundation of a number of scientific publications (for a full list, see the CLAUDS project see the CLAUDS Project Website). These include a major study of the evolution of galaxy sizes led by ICA PhD student Angelo George published in this academic year (see also below) A number of projects based on the merged CLAUDS and HSC-SSP datasets is being led by ICA members and are expected to be submitted for publication in late 2024 or early 2025. These including the study of galaxy stellar mass functions and massive galaxy environments led by PhD student Chen, and studies of the evolution of galaxy morphologies led by students George and Williams co-supervised by Dr.s Sawicki and Damjanov; these projects are described in more detail further down. Altogether, 32 peer-reviewed papers based on CLAUDS data have been published to date, 4 more are undergoing peer review, and are in preparation by ICA members and external collaborators.

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 physARCical 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, and DEUS imaging surveys mentioned earlier, as well as the HectoMap survey (a dense spectroscopic survey of 52 square degrees within the HSC-SSP footprint). Using measured structural and spectroscopic properties of non-star forming (i.e., quiescent) galaxies in HectoMap, Dr

Damjanov has led the study that, for the first time, separates *and* quantifies the impact on the average quiescent size growth of (a) galaxies joining the quiescent population with time and (b) galaxies that are evolving after reaching quiescence within this population (Damjanov et al. 2023). The follow-up study explores 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. 2024, accepted for publication in the AAS Journals). 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 is developing the optimal strategy for measuring sizes and shapes of galaxies in the CLAUDS+HSC-SSP using a combination of existing software and custom-built algorithm for the modelling of galaxy light profiles in large-area high-quality images obtained with a ground-based telescope. Two student-led projects are underway as part of this effort: working with Dr. Damjanov and Dr. Sawicki, PhD student Angelo George has been modeling the two-dimensional galaxy light profiles in the CLAUDS+HSC-SSP data. After publishing their first work showing that over 6 billion years of cosmic time star spatial distribution of older stars in galaxies broadens with time, and pushes the remaining star forming regions to the outskirts (George et al. 2024), the student has completed a follow-up project to explore these effects in the densest regions of the cosmic large scale structure, galaxy clusters. In a manuscript that will be submitted to the AAS Journals in December 20204, they show, for the first time, clear evidence that cluster galaxies are smaller than their field counterparts and that this difference is more prominent if galaxy size is measured at shorter 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, 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 (to be submitted to the AAS Journals in December 2024), 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.

Using the funding for student researchers from the New Technologies for Canadian Observatories (NTCO) program[1], Dr. Damjanov started a project to develop deep (machine-) learning (DL) approach to the identification of galaxies that show signatures of (recent) past merger activities in deep HSC-SSP images (e.g., shells and/or streams). The lead of the program is a SMU undergraduate student Joyo Smit, and it is being developed in collaboration with DL experts Drs. Helena Domínguez Sánchez and Jesús Vega-Ferrero (Centro de Estudios de Física del Cosmos de Aragón and Universidad de Valladolid, Spain). From the fall semester of 2023 until the end of summer 2024 the student explored unsupervised DL method, so-called contrastive learning, and its adaptation to the classification of galaxy images. The initial results are promising and generated considerable interest during the student's visit to the University of Victoria for the NTCO Student Symposium.

The HectoMap survey includes several hundred galaxy clusters. The most massive clusters in the survey display arcs surrounding their most massive galaxies. These arcs are light profiles of background galaxies (i.e., galaxies more distant than the cluster) which are bent (lensed) due to the effect that the gravity of both luminous and dark matter along the line of sight has on the light as it travels from observed distant galaxy. Measurements of the

[1] https://www.uvic.ca/research/centres/arc/create/index.php

shapes of and distances to the lensed galaxies enable modelling of the distribution of dark matter within massive galaxy clusters. Dr. Damjanov has developed observing proposals to target these clusters in collaboration with staff astronomers at the W. M. Keck Observatory, the host of the largest-mirror telescopes on Earth. The first massive lensing cluster target was observed in June 2020, and the team was successful in securing observing time through 2024. Dr. Damjanov has been co-advising a graduate student at the Seoul National University, Lael Shin (working in the group of Dr. Jubee Sohn) on reducing and interpreting data that show how kinematics of the brightest cluster galaxy in this massive cluster connects to the light and dark matter distribution in its immediate environment .

Post-doctoral fellow Dr. Michele Pizzardo, who joined Dr. Damjanov's group in November 2022, has been very successful in exploring dynamical properties of galaxy clusters in IllustrisTNG simulations. In a series of publications , Dr. Pizzardo explores the reach of observational techniques based on spectroscopic surveys to probe underlying distribution of galaxies in clusters in the 6 dimensional phase space and thus trace the growth of structure in the aging universe. In the latest publication, they used dynamics of galaxies in simulated galaxy clusters to relate the “splashback radius”, observable based on galaxy cluster density profile, to the true inner boundary of the cluster infall region (Pizzardo et al. 2024b). The series of published results offers clear interpretations of observation-based measurements in relation to the true dynamical properties of galaxies in clusters.

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.

For the evolution of galaxies there is agreement that individual galaxy evolution is not truly ergodic, but the exact departure from this assumption has not been estimated, and neither has the impact of different physics within the galaxy formation process been considered as a part of this process. In particular one outstanding issue is whether there might be a mass dependence in the amount of variation seen, i.e. "partial ergodicity." The goal of this research is to put some constraints on the maximum evolution by considering the different physics at play in galaxy formation in a systematic fashion. Of course, it is challenging to recreate a precise sample of galaxies, so rather than simulating a larger volume, statistical modelling of selected Sloan survey galaxies has been used to create model galaxies with parameters drawn from distributions determined by the observed catalogue. While this does introduce the possibility of creating galaxies that are not allowed physically in nature, since the exact parameters are drawn from modelled distributions in practice the sampled galaxy parameters are reviewed to ensure physical plausibility. By the nature of their construction, they are statistically appropriate. These galaxies were created using the “make galaxy” code provided to us by Dr Volker Springel, augmented to include additional components such as substructure and a hot gas halo. To calculate evolution of the galaxies the GIZMO code was used, but in a step-by-step approach of adding different physics processes, including feedback and winds. The key outcome of this work, as defended in Smith's MSc thesis in August 2023, is that there is fairly strong evidence for a mass dependence in the level of ergodicity shown, i.e. partial ergodicity. We believe this to be the first time such a result has been demonstrated in the astrophysics literature, which is now published as MNRAS, 532, 4774, (2024).

Research is now continuing with the FIRE-2 collaboration (PI Hopkins, Caltech) on extending this analysis to simulated galaxies with more accurate merger trees. Smith has been given full access to the data created by the collaboration, which includes over 20 high resolution galaxy simulations. 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. Initial analysis, which has taken some time due to the larger size of the data, and the need to analyze it remotely, shows that there is indeed a stronger tendency towards ergodicity in this data set. The analysis will also examine high redshift behaviours which are expected tend further toward ergodicity due to the high supply of gas in these early systems.

With honours thesis student Samuel Willis, Dr. Thacker is investigating the transfer of angular momentum from dark matter to 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. Although heavily simplified as compared to evolution in the actual universe, these modelled mergers allow the precise exchange of angular momentum to be evaluated under controlled conditions. While studies like this were conducted in the early 1990s, few attempts have been made to study the mergers at higher resolution. In general the transfer of angular momentum is a product of the torques between the dark matter and the gas. The research will examine how this changes in terms of individual particle distribution properties, as well as the three dimensional breakdown of the internal angular momentum distribution.

2.5. Development of new research tools

ICA scientists are involved in the development of new astronomy research tools.

2.5.1. GIRMOS

ICA astronomers Drs. Damjanov, Hénault-Brunet, and Sawicki, participate in the CFI-funded GIRMOS project to build a multi-unit 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 detailed spectroscopic studies of distant objects and will be complementary in that regard to the recently-launched JWST. All three of these ICA faculty are members of the GIRMOS Science Team, where they help guide the development of the instrument's capabilities with reference to science goals. Dr. also Sawicki leads the development of the GIRMOS data reduction software suite which will be vital for all users of GIRMOS in processing the instrument's raw data into science-ready products.

2.5.2. 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. 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, and continued through the subsequent years with contributions from ICA sabbatical visitor Dr. Ikuru Iwata, postdocs Drs. Thibaud Moutard, Robert Sorba, and Gaël Noirot, and students Martin Hellmich, Rebecca Hemel, and Nolan Dickson.

ICA's Dr. Hénault-Brunet is the Lead of the CASTOR's Near-Field Cosmology Science Working Group (SWG). This involves coordinating a group of near-field cosmology experts to provide feedback on mission requirement, updating and designing proposed legacy surveys for the mission, and assessing and optimizing surveys for astrometric programs (proper motions and parallaxes). Drs. Damjanov and Sawicki are senior members of CASTOR's Galaxy Evolution SWG, and Dr. Sawicki is also a senior member of the Cosmology SWG.

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

The first annual ICA Research Symposium was held over the course of a full day on 2 February 2024. Approximately 35 participants attended and heard 20 research presentations on a variety of topics, including two invited presentations from external speakers (Dr. Tyrone Woods from the University of

Manitoba, and Dr. Catherine Lovekin from Mount Allison University). Given the success of this (first) ICA Research Symposium, we have decided to make it an annual event, with the 2nd Annual ICA Symposium to be held in January 2025.

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 strenght 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.

A new initiative -- ICA Firesides -- has been inaugurated in AY2024-25: the first annual ICA Research Symposium and the bi-montly "Un-Seminar" seminars. For more detail see Sec 5.

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.

4.1. Saint Mary's

Dr. Short presented a colloquium at Saint Mary's University and a contributed talk at the ICA Symposium on the latest developments with the Chroma+ stellar atmospheric and spectrum modelling code. He served on the University's Appointments Committee. 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 Dr. Sawicki continued to serve for the fifth year as the ICA's Acting Director.

As Director of the SMU Science Outreach Centre, Dr. Thacker coordinated Faculty open houses, student visits to the Faculty of Science, and Chaired of Faculty of Science Community Engagement & Outreach Committee. He conducted numerous interviews – 97 in total, including 47 episodes of Science Files on the Todd Veinotte Show (CityNews Halifax); 42 episodes of CFRA Live! (580 CFRA Ottawa); 8 CTV interviews. Dr Thacker has also taken over as the departments Graduate Coordinator, and returned to sit on the university pension committee. He officially stepped down as the SMUFU Lead Negotiator in July of 2024. Dr. Hénault-Brunet served as the Department's Science Atlantic representative. He also coordinated the Department of Astronomy & Physics colloquium series and serves as the Director of the Burke-Gaffney Observatory, a role in which 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 appointed to the NSERC Banting Postdoctoral Fellowship review panel in July of 2024, as well as providing Discovery Grant reviews. He also gave an invited keynote talk in the computational astrophysics symposium at the Canadian Association of Physicists annual congress.

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 serves on the ACEnet Research Directorate, and chaired the CASCA Awards Committee in 2022-2024. He also served on NSERC's PromoScience review committee, as an external reviewer for the Meritorious Service Decorations of the Governor General of Canada, is the SMU institutional representative to the ACURA council, and a member of the Nominating Committee for this council. He was an external reviewer for Executive Committee proposals for HST Cycle 32, an external reviewer for the Canadian Time Allocation Committee (CanTAC), and a reviewer for JWST Cycle 2 AO proposals for the Canadian Space Agency. Dr. Hénault-Brunet led the Near-Field Cosmology Science Working Group for the CASTOR mission. He was a member of the

Scientific Organizing Committee member for the workshop "Globular Clusters and their Tidal Tails" in Toronto in May 2024.

Dr. Damjanov currently chairs CASCA's Equity and Inclusivity Committee. During 2023-2024 reporting period she was also a co-chair of the CASCA committee tasked to review the use of the optical and infrared (OIR) facilities available to Canadian astronomers and provide recommendations for (near-)future strategies in that domain. The OIR Review Committee delivered their final report to the community in September 2024. In addition, Dr. Damjanov serves a three-year term (2023-2026) on the NSERC Review Committee for Doctoral Scholarships and Postdoctoral Fellowships.

Dr. Sawicki served as the Chair of the Astrophysics and Cosmology Panel of NSERC Discovery Grants allocation process, and on the search committee for the next Director of the Gemini International Observatory.

4.3. International

Dr. Damjanov serves as one of two Canadian representatives 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. Sawicki conitnues to serve on the Management Committee of the CFI-funded GIRMOS instrument project and on the Steering Committee for the HSC Multi-Wavelength Consortium.

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 intitiaitve that are CASTOR and GIRMOS (see Section 2.5).

Following the resounding success of the (first) ICA Research Symposium held in February 2024, the Institute will make this an annual event, with the 2nd annual Symposium planned for 2025 January 29.

The ICA has also recently begun a series of "ICA Firesides", which are a series of discussions/panels/seminars, to be held every ~2 months, on a variety of topics related to the mission and focus of the ICA. The first of these Firesides was held in September 2024 and was a panel discussion on the subject of posdoc applications that was attended by about 25 participants. A second is scheduled for late November 2024 on the topic of scientific journal publishing process. Further Firesides will be held on a bi-monthly cadance and we look forward to reporting on these in the AY2024-25 Report.

6. Finances

Research at the ICA is supported through grants from NSERC, Canada Foundation for Innovation (CFI), Research Nova Scotia Trust (RNST), and the Canadian Space Agency. As of the end of the present reporting period, the total amount of research funding for which ICA members are lead grand-holders is ~C$1.5M.

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 $11,732.

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 quality, high-impact 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), and Nature Astronomy (Nat. Astron., IF = 15.6).

Papers published or submitted by ICA members and associated students and post-docs during AY 2023-24 are listed below.

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