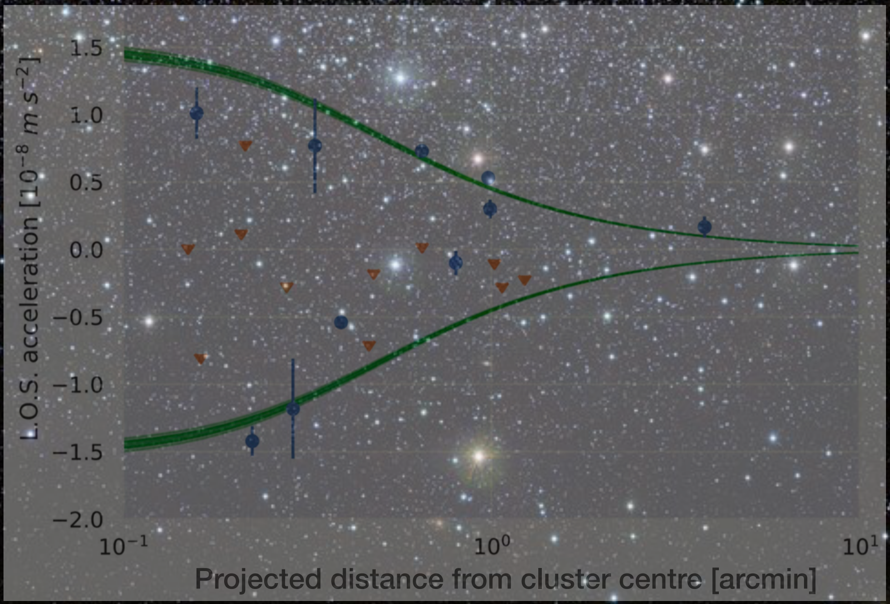
Institute for Computational Astrophysics
Annual Report
Academic Year 2019-20



ICA Annual report, compiled by Marcin Sawicki, Acting Director

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ON THE COVER

Globular clusters, such as 47 Tucanae pictured in this image taken with ESO's VISTA telescope, constitute some of the oldest components of galaxies, including our home the Milky Way. Having formed when the Universe was a fraction of its present age, globular clusters thus hold important clues for understanding the earliest phases of galaxy formation.

The ICA's Dr. Vincent Hénault-Brunet uses observations of globular clusters and detailed dynamical models that he builds to probe the masses of globular clusters and constrain the number of black holes that they contain. The inset plot — from a recent paper led by Dr. Hénault-Brunet — shows the line-of-sight accelerations of binary pulsars (blue circles) and upper limits on the accelerations of isolated pulsars (orange triangles) found in the globular cluster 47 Tucanae, and compares these observational data to the maximum acceleration contours (shown in green) of the best-fitting dynamical model of the cluster.

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. Throughout the past decade, the ICA has acquired access, through ACEnet and Compute Canada (organizations in which several ICA members have played very significant roles), to significant high performance computing resources required for these simulations and analysis. More recently, the ICA has also engaged in the processing and analysis of large astrophysical datasets and in the development of software in support of new astronomical instruments. A number of graduate students have been part of the ICA, and to date fifteen MSc degrees and eight PhD degrees were awarded to students supervised by ICA faculty members. In addition, the ICA has enriched the environment of the Department of Astronomy and Physics and of the University by hosting twelve postdoctoral fellows to date as well as numerous short- and long-term research visitors.

As of August 2020, the ICA has six full-time faculty members, each of whom is also a faculty member in the Department of Astronomy and Physics. These are Dr. David Clarke, Dr. Ivana Damjanov, Dr. Vincent Hénault-Brunet, Dr. Marcin Sawicki (Acting ICA Director), Dr. Ian Short, and Dr. Robert Thacker. Notably, Drs. Damjanov and Hénault-Brunet joined the Institute this year. Additionally, two emeritus faculty members, Dr. Robert Deupree and Dr. David Guenther, continue their affiliation with the ICA, while Dr. Ralph Pudritz (McMaster) and Dr. Richard Henriksen (Queen's) serve as external members of the Institute in which role they provide invaluable advice to the Institute.

There were nine research students working with ICA faculty during AY 2019-20: four graduate students (Lingjian Chen, Angelo George, Kamalpreet Kaur, Paresh Mungara) and five undergraduates (Remy Arsenault, Abigail Battson, Ophélie Leste, Peter Smith, Harrison Soucherau). One postdoctoral fellow, Dr. Gaël Noirot, was affiliated with ICA faculty, and two new postdoctoral fellows are scheduled to start their appointments in the fall of 2020.

Ms. Florence Woolaver served as the ICA Assistant for a 13th year, splitting her support roles between the Department of Astronomy and Physics (70%) and the ICA (30%). Ms. Woolaver retired in late 2019, and Ms. Shannon Rhode replaced her in early 2020 under a similar split arrangement. Finally, connected to the ICA are two ACEnet employees located at Saint Mary's: Mr. Phil Romkey and Dr. Sergiy Khan.

At present, the ICA is in a period of renewal that follows the retirements of two key members, Dr. Bob Deupree (inaugural ICA Director) and Dr. David Guenther (founding ICA member). Their retirement has resulted in a decrease of faculty-level ICA members to four in recent years, along with an associated decrease in research activity and in the number of students and post-doctoral fellows being supervised. Time-consuming administrative roles held by ICA faculty — e.g., Dr. Short is the Department Chair and Dr. Thacker the SMU Science Outreach Centre Director, President of the Canadian Astronomical Society (CASCA), and SMUFU Chief Negotiator — have taken a further toll on research activity. However, two recent Astronomy & Physics faculty hires, Drs. Ivana Damjanov and Vincent Hénault-Brunet, joined the ICA during this reporting period, and their presence is already rejuvenating the Institute and will continue to do so as the research programs and teams of these new faculty members grow over the coming years.

During AY 2019-20 the ICA carried out a self-study as part of the Senate-mandate periodic review. This activity has charted a new direction for the Institute, namely that of growing the ICA's activity in the direction of Astrophysical Data Analytics (for details, see the ICA's 2020 Self-study Report). This direction is closely aligned with, and indeed drives key elements of the strategic plan of the Department of Astronomy and Physics. In particular, in addition to the envisaged expansion in research scope, there is a related initiative to introduce formal, course-based training in astrophysical data analytics for both undergraduate and graduate students in SMU's Astronomy/Astrophysics degree programs. In this regard, we note that in AY 2020-21, the Department is trialling two courses on astrophysical data analytics, taught by ICA members Drs. Damjanov and Hénault-Brunet.

2. Research

ICA members engage in research in a number of areas of astrophysics and using numerous techniques. These range from computational models to the analysis of complex datasets, and tackle topics from the atmospheres of stars to the evolution of galaxies.

2.1. Stellar atmospheres

During AY 2019-20, Dr. Ian Short has continued to develop novel codes for the computational modelling and visualization of stellar atmospheres and spectra, and related observables, in effectively platform-independent or web-oriented programming languages such as Python, Java, and Javascript (the Chroma+ suite). In 2019 he collaborated with Honours student Jason Bayer (now an MSc student at UWO) to improve the Chroma+ suite in three ways: (1) The treatment of how partition functions are appoimated; these allow the code to quickly calculate the fraction of many chemical elements that are in each ionization stage, and are necessary to compute the strength of spectral lines in stellar spectra. (2) The treatment of spectral lines based on species-wise model atoms rather than the traditional line list – this allows for a more complete inclusion of the physical mechanisms that broaden spectral lines. (3) The ability to compute limb darkening curves that describe the variation of brightness across the resolved projected disk of a star through a variety of photometric filters. This is an important first step toward generating transit light curves of extra-solar planets for arbitrary star/planet combinations.

Dr. Short also collaborated with Dr. Philip Bennett (Saint Mary's University, Dalhousie University, and Eureka Scientific) to implement a major improvement to how the Chroma+ suite computes the chemical and ionization equilibrium, and the equation of state relating the gas pressure, density, and temperature, throughout a stellar atmosphere. This involved porting a FORTRAN code (GAS) developed by Dr. Bennett, and related linear algebra library (BLAS and LINPACK) routines to Python, Java, and Javascript, and integrating it into the Chroma+ codes. The spectacular result is that these codes can now quickly compute the partial pressures of 105 chemical species self-consistently, including many diatomic and polyatomic molecules, for cool stellar atmospheres. Users of ChromaStar and ChromaStarServer can very quickly visualize these partial pressures versus depth in a web browser on demand. A related improvement was to increase the number of TiO bands included in the computed spectra – these are the most important bands determining the appearance of the stellar spectra of late-types stars (red dwarfs and giants) in the visible band. See www.ap.smu.ca/OpenStars for additional information.

2.2. Magnetohydrodynamics of jets

Dr. David Clarke's principal research interests include performing magnetohydrodynamical (MHD) simulations to investigate open problems in astrophysics, as well as maintaining and providing the astrophysical community with the widely-used MHD code ZEUS-3D. Dr. Clarke continues to work on the problem of stellar jets, a phenomenon associated with very early star formation. Jets are supersonic, narrow beams of magnetised gas that "proto-stars" launch along their rotation axes to very great distances (several million times their own diameters). They have profound influence both on how the proto-star evolves to a "main-sequence star" (the bulk of those we see in the night sky), and the environment in which the young stars are formed. Without jets, for example, stars as we know them could not exist, and we would not be here to discuss them

When gases attain a high enough temperature (e.g., stellar coronae), the atoms become ionised and the fluid — now known as a plasma — becomes an ensemble of charged particles. As such, a plasma is capable of generating and sustaining a magnetic field that permeates the gas, and this same magnetic field confines the charged particles in a way that particles in an ordinary gas like our atmosphere are not. The prominences from our own sun are an excellent example of this phenomenon. Ambipolar diffusion (AD) is a process by which charged matter can escape the confines of a magnetic field, and can have profound implications in astrophysics. It can mitigate how stars form, and how stellar jets — Dr. Clarke's particular focus — evolve and influence their environment. Dr. Clarke's former Honours students — Michael Power and Chris MacMackin — made significant progress on the theoretical aspect of AD, and Dr. Clarke continues working on a manuscript to report these findings.

While ZEUS-3D is a mature code that can be downloaded from its own website (www.ap.smu.ca/~dclarke/zeus3d) complete with installation and user's manuals, a distributable version of its successor, AZEuS (with adaptive mesh refinement) is still under development. Dr. Clarke continues to work on the development of AZEuS.

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.

Some of the research topics pursued during the reporting period include:

A survey of the stellar kinematics in the outer regions of globular clusters. A series of collaborative workshops led by Dr. Hénault-Brunet in 2017-2018 resulted in two successful observing proposals in 2018-2019 (using the 2dF/AAOmega instrument on the Anglo- Australian Telescope, and the FLAMES instrument on the VLT) to obtain spectroscopy of hundreds of stars in the outskirts of several Milky Way globular clusters. This unique dataset wouldn't have been possible just a few years ago before Gaia proper motions enabled accurate membership selection of spectroscopic targets in the low-density outskirts of clusters (where contaminants otherwise dominate). The kinematics of stars in these external regions of globular clusters can reveal crucial information about their interaction with the Milky Way, including possible traces of dark matter around clusters. The final observations for this survey have been obtained in early 2020 and the analysis is ongoing. A first paper (led by PhD student Zhen Wan; University of Sydney) introducing the survey and presenting a detailed analysis of a first cluster (NGC 3201) is currently being finalized and expected to be submitted shortly. The study identifies the signature of stars escaping from the cluster, casting doubts on a recent suggestion that NGC 3201 is surrounded by a small dark matter halo. SMU undergraduate student Tashveena Surdha will contribute to the analysis of another cluster recently observed as part of this survey in the context her Honours thesis (starting September 2020).

Work has continued to investigate ways to better constrain the size of present-day black hole populations in Milky Way globular clusters by using observations of the velocities and spatial distribution of visible stars, which are affected by the presence of black holes. A study was published (Hénault-Brunet et al. 2020) illustrating the significant constraints achievable when comparing equilibrium dynamical models capturing the effect of mass segregation to commonly available observations (using the cluster 47 Tuc as a test case). Undergraduate research assistant Peter Smith has been developing tools to explore how the precise timing of pulsars in the core of globular clusters (probing their acceleration in the cluster's gravitational potential) can improve those constraints, with a publication in preparation. Collaborations have been initiated with Dr. H. Baumgardt (University of Queensland) and Dr. M Giersz (Warsaw) to combine the strengths of different dynamical modelling approaches (equilibrium models, evolutionary Monte Carlo models and N-body models) to hone in on the dynamical evolution of black hole populations in individual clusters. Further work on this topic will form part of the M.Sc. thesis of Nolan Dickson (starting September 2020).

Finally, Dr. Hénault-Brunet is continuing to collaborate to projects pushing to obtain increasingly precise velocity measurements for stars near the centre of globular clusters, using adaptive optics (AO) on the 8-m class Gemini (NIFS and GeMS instruments) and VLT (MUSE instrument) telescopes. A successful proposal to uncover the black hole population in young and intermediate age massive clusters (PI: N. Bastian, LJMU) was recently awarded 20 hours (rank A) of observing time on the VLT-MUSE instrument.

2.4. The evolution of galaxies

Several ICA researchers study the evolution of galaxies, including faculty members Drs. Ivana Damjanov, Marcin Sawicki, and Rob Thacker, as well as post-doctoral fellow Dr. Gaël Noirot and several graduate students.

Dr. Sawicki's research interests are in the formation and evolution of galaxies, with a specific interest in their earlier 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. Dr. Sawicki's current focus in related to obtaining, processing, and analysing the large data sets ("Big Data") created in massive surveys of distant galaxies. Over the past several years much of his research time has been spent in relation to the CLAUDS survey (a major Canada-France-China observing collaboration that he leads) done with the Canada-France-Hawaii Telescope (CFHT), and its combination with the HyperSuprime-Cam Subaru Strategic Program (HSC-SSP) being taken on Japan's national Subaru Telescope by a large team of Japanese, Taiwanese, and American astronomers. Together, these two surveys probe the distant Universe to an unprecedented combination of area and depth that will be unmatched until at least the next decade. The merged CLAUDS+HSC-SSP catalogs of galaxies and stars, which were recently finalized and validated, form the foundation of a number of scientific investigations; they will also be released publicly world-wide, where they will enable many more investigations by the community. Indeed, many leading research teams from the US, Europe, and Japan have already contacted the CLAUDS team seeking early access to these data. For more information on the CLAUDS project see https://www.ap.smu.ca/~sawicki/sawicki/CLAUDS.html.

A number of projects based on the merged CLAUDS and HSC-SSP datasets is now being led by ICA members (and many more by external collaborators). These including the study of massive galaxy environments led by PhD student Lingjian Chen (paper submitted to MNRAS) and studies of galaxy morphologies led by graduate student Angelo George (2020 MSc thesis, and since September 2020 PhD thesis, both co-supervised by Drs. Damjanov and Sawicki) and undergraduate student Harrison Souchereau (2020 honours thesis supervised by Dr. Damjanov); both these projects are described in more detail further down. Additionally, working with Dr. Sawicki, PhD candidate Anneya Golob continues her research on the CLAUDS project part-time as she works full-time as Data Scientist at RubiCloud. Her paper that describes the machine learning code for distinguishing stars from galaxies in deep images is under review by MNRAS, and she is finalizing her research on the evolution of the galaxy stellar mass function in the CLAUDS+HSC-SSP dataset. Meanwhile, former post-doctoral fellow Dr. Thibaud Moutard used the CLAUDS+HSC-SSP dataset to publish the most-detailed yet study of the evolution of the UV luminosity density of the Universe. ICA members and students are also involved in several published or ongoing studies based on the CLAUDS data, including investigations of the ionizing radiation escaping from distant quasars (led by recent ICA sabbatical visitor Dr. Ikuru Iwata and Dr. Sawicki) and galaxies; the nature of distant quasars; and studies of galaxy luminosity functions at extreme wavelengths.

Turning to the study of ultra-massive galaxies, recent graduate students Dr. Liz Arcila-Osejo and Gurpreet Cheema, and Dr. Sawicki published a series of three papers on the nature of extremely massive quiescent galaxies seen at high redshift ($z \sim 1.6$). The first of these studies, published in the previous reporting period, presented the basic characteristics of this population. During the present reporting period, a paper led by Ms. Cheema analyzed the clustering of these "dead monsters" to conclude that they are likely to be the direct progenitors of some of the ultra-massive central galaxies of the most massive present-day galaxy clusters. Meanwhile, an analysis of their environments led by Drs. Sawicki and Arcila-Osejo, shows that these monsters must have formed through major mergers at early epochs (redshifts $z>1.6$) and are likely to continue to grow slowly through minor mergers to the present day. Separately, but at similar redshifts, Dr. Gaël Noirot is a key member of a large international project that studies the properties of distant galaxy clusters selected at the locations of high-z Active Galactic Nuclei (AGN). There, he leads the analysis of HST grim spectra of cluster member galaxies.

Dr. Noirot, as well as recent ICA alumnus Dr. Moutard, have been working to understand the processes that result in the dramatic quenching of star formation in many galaxies. Working with Dr. Sawicki, in this reporting period Dr. Moutard published a paper on the connection between the quenching of star formation and the presence of an Active Galactic Nucleus at the centre of the galaxy; instead of supporting the conventional picture where AGNs are expected to induce quenching, this work suggests an alternative explanation, where the AGN is only triggered during the final phases of a galaxy-galaxy merger that triggered the shut-down of star formation in the first place. In ongoing work, Dr. Noirot, together with Drs. Sawicki and Moutard, is tackling the mysteries of the quenching process by investigating the properties of quenching galaxies using HST grim spectroscopy. In addition to yielding immediate scientific insights, this work is also developing techniques that these researchers will use to analyze data from the upcoming Guaranteed Time Observer program on the James Webb Space Telescope (JWST).

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 (i.e, 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 and CLAUDS imaging surveys mentioned earlier, and the HectoMap survey, which is a dense spectroscopic survey of 52 square degrees within the HSC SSP footprint.

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 modeling of galaxy light profiles that is optimized for 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, (until recently MSc and now) PhD candidate Angelo George has been modeling the two-dimensional galaxy light profiles in the CLAUDS+HSC-SSP data, as well as galaxy light profiles in in the cores of clusters from the Hubble Space Telescope CLASH survey. Some of Mr. George's most intriguing results (published in his MSc thesis in August 2020) are (a) that the evolution in the relation between the size and mass of galaxies depends on galaxy mass, and (b) that the most massive galaxies in cluster cores are smaller in size than their massive counterparts in the “field”. Undergraduate student Harrison Souchereau has developed and tested a versatile algorithm for the extraction of one-dimensional radial profiles of galaxies in the CLAUDS+HSC-SSP fields (2019/20 honours thesis under Dr. Damjanov’s supervision) and is continuing to work with Drs. Damjanov and Sawicki to extract the 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.

As a senior participant in the 2019 Kavli Summer Program in Astrophysics at the University of California Santa Cruz, Dr. Damjanov became a research advisor for the project to investigate the performance of machine learning algorithms in the identification and classification of galaxy tidal features in the HSC-SSP imaging survey, led by a PhD student Connor Bottrell (University of Victoria) and postdoctoral fellow Dr. Helena Domínguez Sánchez (Institute of Space Sciences, Barcelona). These features, shells and streams in otherwise undisturbed galaxy light profiles, point towards major merging events in the assembly history of host galaxies. Although their frequency is not well understood, merging events are considered to be one of the main mechanisms that drive the observed evolution in properties of individual galaxies and their populations. In related work, Undergraduate student Ophélie Karishma Leste has been working with Dr. Damjanov on the classification of galaxies with tidal features in deep imaging surveys such as HSC-SSP, first improving previous classifications and creating the optimal galaxy samples for training machine learning algorithms and then datamining the Sloan Digital Sky Survey (SDSS) spectroscopic database and comparing spectroscopic measurements (average stellar population age, metallicity, dynamics, stellar mass) of galaxies harbouring tidal features with the general galaxy population. Ms. Leste is now extending this work to include her own measurements based on spectroscopic and imaging dataset, as a part of her undergraduate honours thesis.

Taking advantage of the volume covered by Hectomap and the number of objects with measured spectroscopic redshifts (~100,000), Dr Damjanov will use these measurements to examine in detail the connections between the observed morphological transformations of galaxies and their internal spectroscopic properties and environments, tracing the evolutionary trends in these relations over 7 billion years of cosmic time. The HectoMap survey includes several hundred galaxy clusters. The most massive clusters in the survey display arcs surrounding the most massive galaxies in them. 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. By measuring the shapes of and distances to the lensed galaxies it is possible to model the distribution of dark matter within these massive galaxy clusters.

Dr. Damjanov has established a collaboration with staff astronomers at the W. M. Keck Observatory which hosts the largest-mirror telescopes on Earth. Using Keck spectrographs, she is now leading a survey of the most massive lensing clusters identified in the HectoMap region of the HSC SSP. The first target, a spectacular supercluster that showcases two brightest cluster galaxies surrounded by a number of strong lensing arcs, was observed in June 2020. The goal of this survey is to provide dynamical models for distant clusters, precursors of the most massive galaxy clusters observed in the local volume, and to follow the evolution of the most massive galaxies residing in the cores of these clusters.

Working towards a MSc degree under Dr. Damjanov's supervision, Kamalpreet Kaur is selecting and characterizing the population of post-starbursts galaxies, a key link between galaxies that actively form stars and systems in which the star formation ceased more than a billion years before they are observed. She has been using the large-area spectroscopic galaxy sample (SHELS) to measure the properties of emission and absorption lines in galaxy spectra and construct the poststarburst sample. With a number of these rare systems now in hand, Ms. Kaur will take advantage of deep HSC imaging available for SHELS galaxies to explore the structure of light profiles in poststarburst systems and trace the relation between their structural properties and environments.

On the theoretical side, Dr. Rob Thacker and graduate student Paresh Mungara have been working on understanding the role of chaos in simulations of galaxy formation. Perhaps more commonly known as the "Butterfly effect", simulations of galaxy formation show sensitivity to small changes in their initial conditions, but determining the exact level of this sensitivity is important to understanding how robust results are from simulation work. Results derived with previous graduate student Tiffany Fields (MSc, 2019) have shown that a precise methodology for classifying the level of chaos is not possible within current simulation frameworks essentially because the simulations simply run out of resolution in many regions within the simulation volume. Consequently, simulations conducted with Mr. Mungara have focused on trying to quantify whether these variations can be related back to physical quantities in the simulations. The simplest idea along these lines is whether density, which largely determines how many time-steps a simulation requires in a given region, is related to the local variations observed in solution variances. This research is challenging conceptually since while variations in solutions are described in a global context, specifically in terms of their "phase space" evolution, the issues that lead to these variations arise in a local context. Consequently, this research is targeted at trying to build a bridge between these scales to help better understand robustness of simulation work. One can do this by relating how the local variations contribute to the global differences by analyzing the complete distribution of variations across all regions. The implications of these studies are significant because we are not yet fully able to describe how the variations in quantities calculated from simulations are the result of physical effects versus numerical ones. Furthermore, with enormous surveys of galaxies coming in the next few years, the precise nature of statistical variances will become increasingly important, rendering understanding this in simulations increasingly valuable.

2.5. Development of new tools

ICA astronomers are participating in the CFI-funded GIRMOS instrument which is now under construction by a consortium of Canadian institutions and is to be deployed on the 8-metre Gemini North Telescope later this decade. When coupled with Gemini's new NSF-funded Adaptive Optics (AO) system now under construction, GIRMOS will enable detailed spectroscopic studies of distant objects and will be complementary in that regard to the soon-to-be-launched JWST. Drs. Damjanov, Hénault-Brunet, and Sawicki are all members of the GIRMOS Science Team. Moreover, Dr. Sawicki leads the development of GIRMOS's observing and data reduction software (OBSW), and this effort will soon move into a new phase with the arrival of post-doctoral fellow Dr. Johannes Zabl who will take on the design and implementation of GIRMOS-OBSW starting in late 2020.

Postdoctoral fellow Dr. Gaël Noirot and Dr. Sawicki are preparing some of the software tools that will be needed for the analysis of slit-less grim spectroscopy that will come from the James Webb Space Telescope (JWST), Hubble's much more capable successor. In addition to (and as part of) this work, Dr. Noirot has been analysing archival Hubble Space Telescope (HST) grism spectra of $z>1$ galaxies that are in the process of quenching their star-formation activity. Incoming post-doctoral fellow Dr. Nicholas Martis, a galaxy evolution expert, will be joining the JWST project in the fall of 2020.

3. 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.

3.1. Saint Mary's

Dr. Short has served as Department Chair for the Department of Astronomy & Physics. Dr. Thacker served as Director of the Saint Mary's Science Outreach Centre, as Acting Dean of Science for Student Affairs, and on the University Pension Committee (where he Chairs the Investment Subcommittee). Dr. Clarke has chaired the Department's 16th annual undergraduate summer research mini-symposium in September 2019, served as the science representative to the University's Copyright Committee; served as the Department's Science Atlantic representative; organized the Department's student participation in the 2020 Atlantic Universities Physics and Astronomy Conference. Additionally, Drs. Damjanov, Sawicki and Short contributed to the Department's Graduate Program Review, and all regular ICA faculty contributed to developing and implementing changes to the Department's Undergraduate Program that follow that Program's review. Dr. Thacker served as the Director of the SMU Outreach Centre. He coordinated Faculty open houses, student visits to the Faculty of Science, MacLennan lecture etc, and Chaired of Faculty of Science Community Engagement & Outreach Committee. He conducted numerous outreach events – 103 in total, including above two lectures; 46 episodes of Science Files on the Rick Howe Show (News 95.7); 39 episodes of Ottawa Today (1310 News); 6 CTV anchor interviews; 9 other various interviews, plus one presentation to a group of mixed students visiting SMU (grades 5-9). Finally, a large fraction of Dr. Thacker's time over the summer has been devoted to issues related to being SMUFU Chief Negotiator due to COVID-19 financial situation.

3.2. National

On the national scene, Dr. Thacker served as President of the Canadian Astronomical Society (CASCA) — completing his term in June 2020 — which entailed an extensive amount of travel and consultation with government and industry; in this role he also co-Chaired the Coalition for Canadian Astronomy and served on the Longer Range Plan Implementation Committee for Canadian astronomy, on the CASCA-ACURA Thirty Metre Telescope (TMT) Advisory Committee, and on the CASCA-Canadian Space Agency's Joint Committee on Space Astronomy and is CASCA's representative to NDRIO. Dr. Thacker is also a Board member of the Association of Canadian Universities for Research in Astronomy (ACURA) and the SMU institutional representative to the ACURA Council. Finally, Dr. Thacker is a Director of the Royal Astronomical Society of Canada, the premier amateur association in the country. Dr. Thacker served on the ACEnet Research Directorate until May 2020, at which point the role was taken on by Dr. Hénault-Brunet. Dr. Hénault-Brunet also serves on the CASCA Sustainability Committee, and NSERC's selection committee for the prestigious Vanier Scholarship. Dr. Damjanov is a member of CASCA's Board of Directors and serves on several CASCA committees. She also serves on the Canadian Time Allocation Committee (CanTAC), the body appointed to assess Canadian observing-time proposals for the CFHT and Gemini telescopes. Dr. Damjanov has also been a member of the multidisciplinary review panel for the application stage of the Frontier Fields in Research Fund since its inaugural competition in 2019. Dr. Sawicki serves on the Science Management Committee of the Canadian Advanced Network for Astronomy Research (CANFAR) and on the Management Committee of the CFI-funded GIRMOS instrument project. Drs. Damjanov, Hénault-Brunet, and Sawicki all serve on the GIRMOS Science Team.

3.3. International

On the international level, Dr. Sawicki serves on the Board of Director's of the Gemini Observatory, one of the premier world observatories with 8-metre-class telescopes located in Chile and Hawaii and served on a US National Science Foundation major facility funding review panel.

4. Upcoming ICA Activities

The Institute has recently undergone a strategic planning exercise and submitted its result to the SMU Senate. We are now proceeding with implementing the first steps of our new strategic plan, which focuses on increasing our strength in the area of astrophysical data analytics. In parallel — and indeed in connection to that plan — we are pursuing infrastructure funding through a major role in a multi-institutional CFI Innovation Fund proposal (now under review) and a CFI JELF computing hardware proposal (under development).

5. Financial Statement

There was no spending in the ICA budget in AY 2019-20. At the start of September 2020, the ICA fund contains $12,223.

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 $1,510,000.

6. Peer-reviewed Publications

ICA members publish papers 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), and Monthly Notices of the Royal Astronomical Society (MNRAS, IF = 5.2). Nineteen peer-reviewed papers by current ICA members or recent alumni (based on work performed at the ICA) were published in AY 2019-20. A list of these publications is given in a separate section at the end of this report.

Papers published in peer-reviewed journals by ICA members and associated students and post-docs during AY 2019-20 are listed below. Names of ICA faculty and associated personnel are highlighted in boldface.

1. *A Rapidly Declining Transient Discovered with the Subaru/Hyper Suprime-Cam*, Tominaga, N., Morokuma, T., Tanaka, M., Yasuda, N., Furusawa, H., Tanaka, M., Jiang, J.-A., Tolstov, A., Blinnikov, S., Doi, M., **Iwata, I.**, Kuncarayakti, H., Moriya, T. J., Nagao, T., Nomoto, K., Noumaru, J., Takata, T., 2019, ApJ, 885,13

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