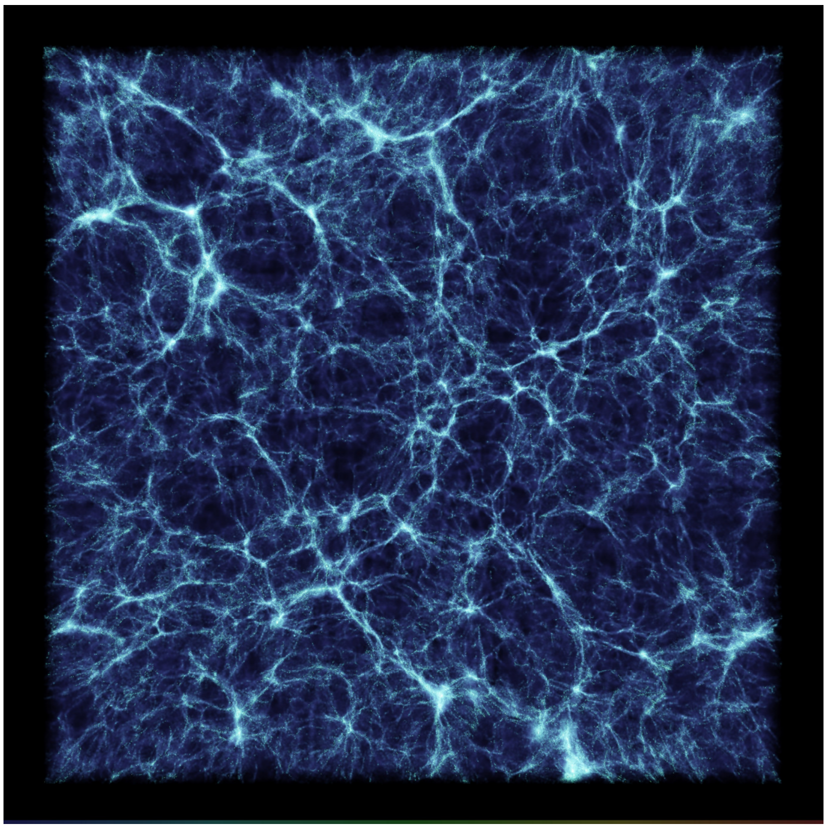
Institute for Computational Astrophysics ICA

ANNUAL REPORT 2008



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(Cover Art by Rob Thacker and Mark Richardson)

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Institute for Computational Astrophysics

Saint Mary's University

Annual Report 2008

Introduction

The Institute for Computational Astrophysics (ICA) was formed in late 2001 by Saint Mary's University in response to a proposal by Drs. David Clarke and David Guenther to promote research into astrophysical problems using high performance computing. Saint Mary’s dedicated two of its Canada Research Chairs (CRC) allotment to the Institute in addition to creating a third new position from University funds. These first hires were completed in 2003. Since then effort has been spent in recruiting both graduate students and post doctoral fellows and on obtaining the resources necessary to perform and comprehend numerical solutions of astrophysical problems. The ICA has played a very prominent role in the establishment of ACEnet, the regional high performance computing consortium for Atlantic Canada. The local ACEnet facilities and staff are supported administratively by the ICA. The current ICA faculty members are Drs. Robert Deupree (Director), David Clarke, David Guenther, Ian Short, and Rob Thacker. Ms. Florence Woolaver is just about to complete her second year as the ICA Administrator.

This year saw the completion of the first Ph. D. in the ICA and the Department of Astronomy and Physics (and in any arts or science discipline at Saint Mary’s). Dr. Catherine Lovekin, working with supervisor Dr. Deupree, studied the effects of rapid rotation on the structure, pulsation frequencies, and the ratios of pulsation amplitudes in different wavelength intervals. Her thesis defense was in August, and Dr. Arthur Cox served as the external appraiser. Dr. Lovekin began a post doctoral position at the Paris Observatory in Meudon in September. In addition, Mr. Nick MacDonald completed his Master’s work on numerical simulations of extragalactic jets and defended his thesis in August. He and his wife are spending a year teaching English as a second language in Greece. Dr. Nathalie Toqué completed her post doctoral position with Dr. Deupree in February and accepted a post doctoral position with Dr. Günther Rüdiger in Potsdam. Dr. Joris van Bever finished his post doctoral fellowship at the end of September and took up a position at the Free University of Brussels. Dr. Chris Cameron joined the ICA as a post doc (and CITA National Fellow) in September to work with Dr. David Guenther on asteroseismology. Drs. Alex Razoumov and Eduard Vorobyov are continuing ACEnet post doctoral fellows. Ph. D. student, Mr. James Wurster began in September and is working with Dr. Thacker on modeling active galactic nuclei. Ms. Jenna Hurry joined the ICA in September in a one year Research Associate position working with Dr. Thacker. Current ACEnet technical staff members Mr. Phil Romkey and Dr. Sergiy Khan are supported administratively by the ICA.

Events in 2008

This year saw the purchase and installation of a Canada Foundation for Innovation and Nova Scotia Research Investment Trust funded computer cluster to be dedicated to Dr. Thacker's numerical work. The cluster is built up of what are called "fat nodes", 9 16-way SMP nodes with 32 GB memory and 2.0 GHz AMD Opteron CPUs, 4 32-way SMP nodes with 64 GB memory and 2.2 GHz AMD Opteron CPUs and one final 32-way SMP with 128 GB memory and 2.0 GHz CPUs for conducting large data analysis jobs. The cluster thus has a total of 304 CPU cores and 672 GB of memory. The nodes are interconnected via single data rate Infiniband to enable high performance data transfers, and all nodes are attached to a 16TB central file server. This equipment is located in the recently remodeled Science Building and gives the ICA two "in house" computer clusters (the other is a 42 node cluster used for MPI code development) in addition to the facilities provided by ACEnet. The ACEnet facilities include serial, MPI, and SMP clusters.

The ACEnet Graphics Workroom opened this past spring. This room contains four computers with high quality graphics cards and two 30" monitors per computer. The ICA also hosts the ACEnet Data Cave and the Research Collaboration Room (a multi-site, video teleconferencing facility) and is responsible for scheduling these facilities.

The Data Cave Grand Opening was held on June 10, with various funding agencies, media outlets, and ACEnet and Saint Mary members in attendance. Photos of some aspects of the event are shown in Figures 1-3.

Figure 1: Speakers of the Data Cave Opening Ceremony. From left to right: Dr. Colin Dodds, President, SMU; Dr. Robert Deupree, Principal Investigator, ACEnet and Director, Institute for Computational Astrophysics, SMU; Dr. Mark Whitmore, Dean of Science, University of Manitoba; Dr. Chris Loomis, Vice President Research, MUN; Ms. Lynne Zucker, Director of Education and Research Markets, SUN Microsystems Canada

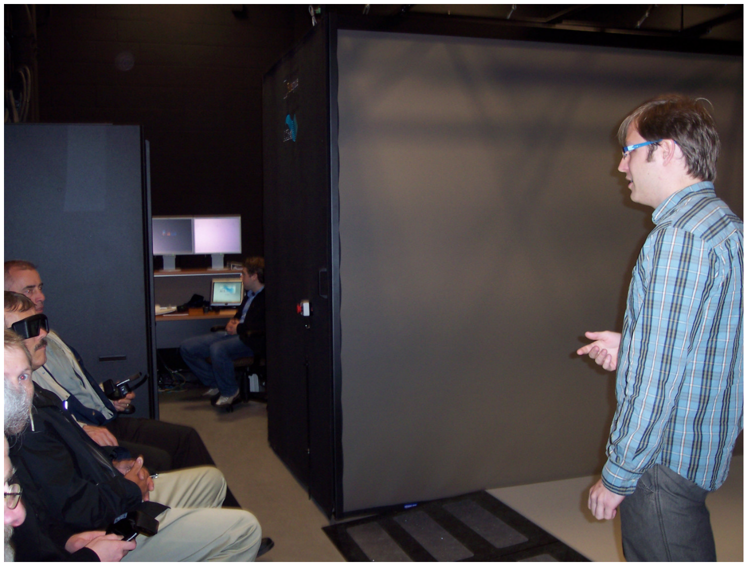

Figure 2: Chris Geroux, Ph. D. student gives a tour to guests in the Data Cave.

Figure 3: Jon Ramsey, Ph. D. student, and Mark Richardson, undergraduate honours student, operate the consoles of the Data Cave.

Usage of these facilities is comparatively intensive during the summer research season, averaging about 30 hours per month for the Data Cave (despite some down time to equipment failure after a power shutdown in the Science Building), 60 hours per month for the Graphics Workroom, and 15 hours per month for the Remote Collaboration Room.

The ICA will be hosting a conference on numerical astrophysics in October, 2009, and planning is under way. The Local and Scientific Organizing Committees (LOC and SOC) have been created and some funding has been raised. The SOC members hope to have the first announcement released in the next few weeks. In addition, members of the ICA, particularly Dr. Thacker, are working with other members of the Department of Astronomy and Physics in organizing the Canadian Astronomical Society (CASCA) meeting which will be held in Halifax in June, 2010.

Individual ICA members are also participating with other members of the Astronomy and Physics Department and the Halifax chapter of the Royal Astronomical Society of Canada in designing International Year of Astronomy (IYA) activities for 2009. Again, Dr. Thacker is taking one of the lead roles. Several ICA faculty members will be giving public lectures as part of this activity.

ICA faculty members continue to serve the astronomical community in a variety of ways. Several members have served of various proposal review panels or as external reviewers. Dr. Thacker serves on both the CITA Council and the CASCA Board of Governors. Dr. Deupree was reappointed for a second term as ICA Director and continues as a member of the Hertzberg Institute of Astrophysics Advisory Board. Dr. Deupree continues to serve as the ACEnet Principal Investigator, and Dr. Thacker serves as a member of the ACEnet Research Directorate and as the ACEnet representative on Compute Canada's National Initiative Committee. All of the ICA faculty and post doctoral fellows Alex Razoumov and Eduard Vorobyov are serving on the LOC for the upcoming ICA conference.

David Guenther joined the BRITE Constellation consortium to work on red giant stars. The BRITE Constellation is a proposed set of four nano-satellites designed to observe oscillations on the brightest stars in the sky. The project represents a joint collaboration of Canadian and Austrian asteroseismologists. The first two satellites are scheduled for launch in 2009.

Undergraduate Researchers

Three undergraduates worked with ICA faculty members on research this past summer. Mr. Mark Richardson, funded by an NSERC USRA, worked with Dr. Thacker and was an extensive user of the ACEnet Graphics Workroom and the Data Cave. Ms. Heather Pickup and Mr. Joey Richard worked with Dr. Guenther on asteroseismology.

Research

Ph. D. student Jon Ramsey and Dr. Clarke continue to develop AZEuS, the adaptive-mesh version of ZEUS3D. AZEuS (the Adaptive Zone Eulerian Scheme) is designed to solve the equations of astrophysical fluid dynamics with essentially arbitrary resolution. Much of the code is now working to within tolerances, and their first application is to follow the development of a stellar jet from its launch site at the scale of 0.05 AU to where it can be observed at an appreciable fraction of a parsec. Figure 4 shows the early stages of such a jet, with the dashed lines indicating nested grids, inside of which the numerical resolution is double that outside. Aside from the scientific content of this simulation, still being coaxed from the ACEnet machines, the technical accomplishments it represents are considerable, including the ability to pass all MHD signals (shocks, rarefactions, contacts, etc) across grid boundaries with essentially zero reflections while maintaining critical numerical and physical constraints, including all conservation laws and the solenoidal condition ($\nabla \bullet B = 0$). Mr. Ramsey is using this code to study jets launched from Keplerian disks by creating simulations to compare with observations of the jets.

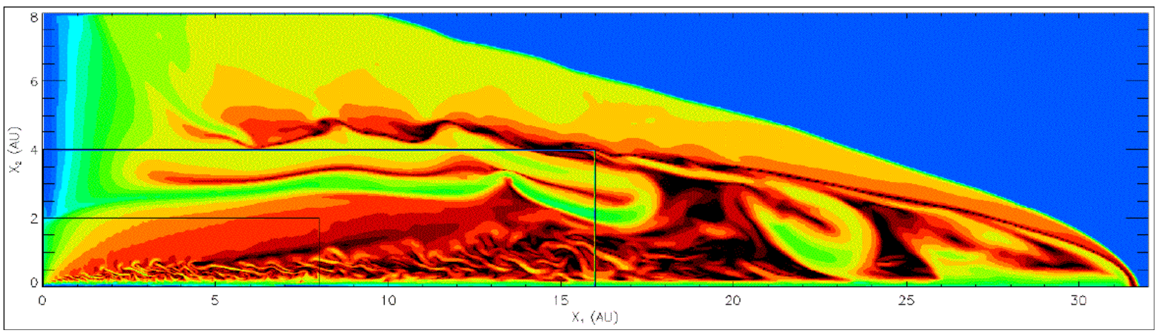

Figure 4: Very early stages of an stellar jet being launched from a Keplerian (rotating) disc, maintained as boundary conditions on the left. Dashed lines indicate nested grids, where each inner grid has twice the resolution of the grid containing it. Grids are fixed, though AZEuS is capable of adaptively adding, modifying, and eliminating grids should that be required. In this image, the jet is launched along the left boundary inside $0.05 < r < 0.25$, barely visible in the figure. The jet quickly expands to its observed width, and excites a bow shock as it advances supersonically into the putative stellar atmosphere.

Mr. Nick MacDonald's M.Sc. thesis entitled "Bridging the gap: Synthetic Radio Observations of Numerical Simulations of Extragalactic Jets" outlines a method to track the effective "age" of the relativistic electron population thought to co-exist within the diffuse gas of extragalactic jets, and responsible for the synchrotron emission we see. This allows the rendering of simulations much like radio telescopes can observe actual extragalactic jets, thereby giving a more realistic probe into the physics of such objects.

Dr. Clarke has demonstrated that the algorithms used in ZEUS-3D are capable of simulating super-Alfv'enic turbulence, a state widely believed to describe the interstellar medium (diffuse gas permeating the stars in the galaxy, and from which new stars are born). This is a difficult numerical problem because it requires particular attention to be paid to how the velocity and magnetic vector fields interact, and few codes in the world are capable of such simulations without gross numerical instabilities destroying the integrity of the solution. Figure 5 is a still from a simulation of super-Alfv'enic turbulence.

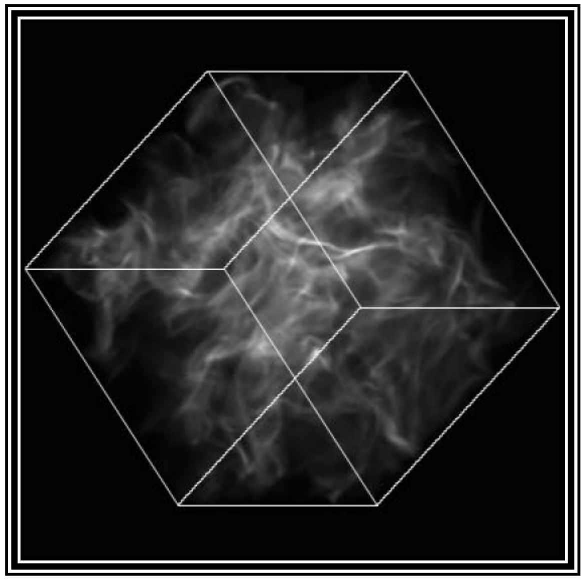

Figure 5: Simulation of a super-Alfv'enic turbulent fluid using ZEUS-3D on ACEnet's "Fundy" computer cluster. Shown is the magnetic "pressure", where white indicates regions of strong magnetic field, black weak. The arrangement of the magnetic field into "bundles" or "filaments" is a harbinger of super-Alfv'enic turbulent motion.

Dr. Clarke has established a web site (http://ica.smu.ca/zeus3d) from which his research code dzeus35 can be downloaded, including user manual, installation instructions, and numerous support libraries, etc This site was "officially" launched in March, 2008, though a preliminary version has been available since December 2007. To date, about 50 astrophysicists from around the world including graduate students, post doctoral fellows, and senior researchers have downloaded the software.

Dr. Deupree expanded his efforts in studying what features may be gleaned about a rapidly rotating star's internal angular momentum distribution. Dr. Catherine Lovekin, in her Ph. D. thesis work, examined how uniform and differential rotation affect both the periods and the horizontal character of linearized pulsational perturbations. She found that uniform rotation decreased the frequencies of all the modes she examined (the four lowest radial and four lowest horizontal order p modes). Higher order radial modes tended to be affected more than lower order ones, with the result that the large separation, given by the difference of the frequencies with consecutive numbers of radial nodes and the same horizontal configuration, decreased as rotation increased.

The small separation, on the other hand, increased to the extent that at large rotation rates the small and large separations were about the same value. Differential rotation in which the rotation rate was constant on cylindrical surfaces but increased with decreasing distance from the rotation axis did not appreciably modify the frequencies from the model uniformly rotating with the same equatorial surface velocity.

Using these results, Dr. Lovekin examined how the perturbations would change the pulsational amplitude ratios in different colors. This is a common way of determining the horizontal mode, usually identified by the ℓ associated with spherical harmonics. The ℓ is no longer a valid quantum number for rotating stars, but a single value may be the primary constituent unless the star is rotating quite rapidly. Dr. Lovekin found that the amplitude ratio as a function of color depended not only on the horizontal mode, but also on the inclination between the observer and the rotation axis. In particular the horizontal mode associated with $\ell = 2$ showed larger variations than the other modes, possibly leading to confusion in this photometric mode identification.

Dr. Deupree extended the results of Mr. Aaron Gillich, who completed his Master's degree in 2007, to examining whether individual line equivalent widths in rotating models are consistent with the effective temperatures determined for the same models. These calculations assumed that the emergent intensity distribution at any location on the model surface could be modeled with a plane parallel model atmosphere and that the spectral energy distribution was a weighted integral of this intensity over the model surface in the direction of the observer. While work is continuing, it appears that the He lines and the metal lines can yield different results.

Dr. Deupree devoted significant effort to solving numerical problems associated with secular time scale flows in the outer layers of rotating stars. These are not so much of interest in themselves, but rather obstacles to allowing the solution of the secular motion in the interior of the models. The numerical problems associated with the surface appear to be overcome, and numerical studies are being conducted to determine the reliability of the secular flows in the interior.

Ph. D. student, Mr. Chris Geroux is working with Dr. Deupree performing 3D radiation hydrodynamic simulations of the interaction of convection and pulsation in RR Lyrae stars. He intends to explore how convection affects both edges of the instability strip and the full amplitude solutions.

Dr. David Guenther continued to analyze the data coming from Canada's first space telescope, MOST. He shares responsibility with the other 7 science team members for the stellar modeling, oscillation modeling, and interpretation of the data obtained from the satellite. He participated in the MOST science team meetings: December 2007 in Halifax and July 2008 in Vienna. Guenther hosted the MOST Science Team meeting in Halifax.

Dr. Guenther spent 3 weeks during the summer 2008 at the University of Vienna where he worked on oscillations in giants with Ph. D. candidate Mr. Thomas Kallinger. He worked on oscillations in Procyon, alpha Cen A and other solar type stars with undergraduate Mr. Daniel Huber, on oscillations in pre-main-sequence stars with post doctoral fellow Dr. Konstanze Zwintz, and on Bayesian analysis techniques with M.Sc. candidate, Mr. Michael Gruberbauer.

Dr. Guenther continued his work with the Yale Convection Group (Dr. P. Demarque, P.I.) on calculating three-dimensional stellar convection zones.

With Drs. Pierre Demarque and Christian Straka (Yale University) Dr. Short has begun a collaboration to model the outer boundary condition of M dwarf interior structure models more realistically by accounting for hydrodynamic atmospheric turbulence. He will be calculating mean radiative opacities suitable for radiation hydrodynamic simulations. The goal is to resolve the discrepancy between the observed and computed mass-radius relation among M dwarf stars.

The relatively cool barely evolved standard star Procyon (α Canis Minoris) has been the subject of much interest recently. It has been the target of a recent interferometric study in the near IR band that has provided unprecedented information of the variation of the visibility with wavelength tantalizingly close to the visible band. This is a major step toward imaging the surface of a dwarf star other than the Sun at optical wavelengths. Moreover, Procyon was a target of the Canadian MOST satellite and was found to have significantly lower amplitude oscillations than expected for a star of its parameters. However, previous analyses of the star's spectrum and spectroscopic determinations of its atmospheric properties were based on LTE modeling. Dr. Short has begun a program to model the high resolution Griffin atlas of Procyon with the same type of massively Non-LTE modeling that he recently applied to the Sun and metal poor red giants to investigate how the inferred atmospheric properties are affected when more realistic modeling is applied.

Dr. Thacker's 2007 ORION award winning research on Active Galactic Nuclei (AGN), conducted in collaboration with Drs. Scannapieco and Couchman (McMaster), has culminated in a series of three papers on the evolution and clustering of these unique systems. Current observational research is focused on understanding the evolution of these systems, both in terms of their underlying clustering, population statistics and the dependence of physical properties on the relative brightness of the AGN. This work has been able to show that a simple theoretical model of feedback as a heating process on the gas surrounding these AGN is able to broadly explain many of the observations of these systems including their luminosity function and clustering behaviour (as measured in the Sloan and 2df quasar surveys). At the same time this feedback also increases the gas density around large elliptical galaxies, and cross-correlating with measurements of the cosmic microwave background allows us to directly measure the level of feedback on these galaxies.

With graduate student Mr. Pascal Elhai (Queen's) and his co-supervisor, Dr. Widrow (Queen's), Dr. Thacker has continued research into gravitational clustering in the very early universe. Their tool for this research has been large scale simulations in so-called "scale-free" universes, which are theoretically simple to model and are a comparatively accurate representation of the first Gyr of cosmic evolution. They have been able to show that current simulations of "first star" formation are probably grossly inaccurate in terms of their gravitational modelling, and solving these problems is extremely difficult because of some fundamental issues in gravitational clustering theory. This work has implications not only on the formation of the first stars, but also on the relative amount of gamma-rays expected from annihilation of dark matter in the galactic centre.

In collaboration with Dr. Stephane Courteau and co-supervised M.Sc. student, Ms. Kelly Foyle, Dr. Thacker investigated the evolution of breaks in the luminosity profiles of galaxies using a large catalogue of numerical models. While the ubiquitous single exponential profile is used extensively in galaxy modeling, the reality is that most galaxies show a "break" with the luminosity profile showing one slope up to this break, and another after it. This research showed that this evolution is a natural product of star formation and dynamical effects within the disk, with bars tending to resonantly scatter stars and change the interior luminosity profile. The outer edges of the galaxy remain much more stable over time. Future research will need to use higher resolution since many of the resonant processes we are modeling are quite sensitive to particle resolution.

With Ph. D. student Mr. David Williamson, Dr. Thacker has recently started investigating the evolution of galactic disk collapses at high resolution. The computing cluster Dr. Thacker purchased with his CFI funds is designed specifically for conducting this research as many hundreds of thousands of time steps will be required to complete these simulations. The main focus of the project is to understand the impact of star formation on the intergalactic medium and then to be able to parameterize this physics as a function of scale, thereby allowing low resolution simulations to be able to capture at least some of the physics below the resolution scale of the simulation.

Through his collaboration with Drs. Scannapieco and Windhorst at Arizona State University, Dr. Thacker has become involved in a number of projects focusing on high redshift (z=5-10) galaxy formation. The main motivation for these projects is the prediction of galaxy luminosity functions for the upcoming Wide Field Camera 3 (WFC3) to be installed on the Hubble Space Telescope during HST servicing mission 4. Dr. Thacker's research associate, Ms. Jenna Hurry is now dedicated to this project and making excellent progress on creating the mock observations. A secondary project is to look at "stacked" images (i.e.

multiple images combined together to reduce the signal-to-noise ratio) and whether the resultant light curve can be fit be current models of gas/stellar accretion and mergers.

Dr. Thacker is part of a collaborative project on weak lensing of the Cosmic Microwave Background (CMB) lead by Dr Diego Saez (Universidad de Valencia, Spain). Saez and collaborators developed a numerical analysis tool for predicting the impact of weak lensing by foreground galaxy clusters on measurements of the CMB. Dr. Thacker provided a parallel version of the simulation code they have been using and together they are now running a series of simulations to make predictions for the Planck satellite. The overall impact of weak lensing on the CMB is actually comparatively small and restricted to small scales ("high l's"). However, Planck will be the first space-borne experiment capable of measuring the impact of weak lensing. The primary motivation for making these measurements is that accurate estimation of cosmological parameters is dependent upon being able to disentangle the impact of weak lensing on the primary CMB signal.

Mr. James Wurster intends to study the interaction of AGN with their surroundings. He proposes to examine the nonrelativistic MHD process to just below the Bondi radius using an adaptive mesh refinement (AMR) code, AZEuS. He will use the mass accretion history from a smoothed particle hydrodynamics (SPH) simulation of a minor merger as an incoming mass flux boundary condition; previous studies have shown how to apply the mass injection boundary conditions, as well as how to impose magnetic field lines on the incoming flow. The behaviour of the unresolved inner accretion region will be modelled by imposing an inner boundary condition with an outgoing jet or wind solution. The long term goal of this project is to calculate the heating rate from AGN on the interstellar and intergalactic media and couple this back to the SPH simulation. Then, he plans to extend the model to an entire galaxy using AMR.

Dr. Chris Cameron joined the ICA as a CITA National Fellow working with Dr. Guenther. His research focuses on modeling stellar oscillations and using those models to interpret data from missions like MOST. In particular, he is developing models of stars with very strong magnetic fields (roAp stars) and stars that rotate very rapidly (Be and SPBe stars). Dr. Cameron is also involved in observational research associated with the MOST mission with special focus on frequency analysis and error estimation techniques.

Dr. Alexei Razoumov focused on high-resolution models of feedback in young (z=2-4) galaxies. To resolve the scale of large star-forming clouds and hot bubbles created by individual supernova explosions in the interstellar medium, he ran isolated disk models of such galaxies at 5-10 pc spatial resolution. These models showed the onset of high-velocity gas outflows following starbursts, producing neutral gas velocity dispersion of ~100 km/s typical of damped Lyman-alpha absorbers which are thought to be associated with forming galaxies.

Currently, Dr. Razoumov is working to include such outflows into cosmological galaxy formation models.

Dr. Razoumov continued his collaboration with Peter Laursen (Copenhagen) and Dr. Jesper Sommer-Larsen (Munich) on Ly-alpha and Ly-continuum emission from high-redshift galaxies. Solving radiative transfer equations for Ly-alpha resonant scattering on adaptive meshes, they showed that the surface brightness and the total flux from the same z=3 galaxy can vary by up to an order of magnitude depending on the orientation. This finding demonstrates that one must be extremely cautious when using Ly-alpha emission to infer star formation rates. Moreover, the same galaxy can be detected either as a Lyman-break galaxy or as a Ly-alpha emitter when viewed from different angles. With LyC emission, they extended their earlier work to z=4-10 galaxies, finding very large escape fraction of ionizing photons favouring cosmological reionization by stellar sources.

Merging their radiative transfer and hydrodynamical solvers, Dr. Razoumov and Dr. Eduard Vorobyov wrote a new coupled radiation hydrodynamics code which they intend to use to model dwarf galaxies during the epoch of reionization.

Dr. E. Vorobyov continued to study numerically the dynamics and evolution of circumstellar disks around low-mass protostars. He uses a specifically designed numerical hydrodynamics code in the thin-disk approximation that can follow the evolution of a pre-stellar cloud core from a gravitationally unstable stage to the formation of a protostar/disk system and can evolve the resultant disk for up to 5 Myr. This code allows investigating the physical properties of circumstellar disks along the three main stages of disk evolution: Class 0, Class I, and Class II phases. Dr. Vorobyov has constructed a theoretical diagram "disk mass – stellar mass" for low-mass protostars, which can be directly compared to the observationally derived diagrams. Dr. Vorobyov and Dr. Basu (University of Western Ontario) have also investigated the relative importance of viscous and gravitational torques in viscous and self-gravitating circumstellar disks around low-mass protostars. It is found that the early disk evolution is dominated by self-gravity, and the late evolution by viscosity. The Shakura & Sunyaev α-parameter is estimated to most likely lie in the 0.001-0.01 range, with a preference for lower values. It is shown that gravitational torques in self-gravitating circumstellar disks can drive mass accretion rates on to protostars that are in good agreement with those measured for T Tauri stars. A near-linear dependence between the disk mass and the mass accretion rate was predicted.

In collaboration with Dr. E. Vasiliev from the South Federal University, Dr. Vorobyov has developed a numerical hydrodynamics code that includes an extensive network of chemical reactions in the primordial gas and is used to study explosive phenomena in first protogalaxies at $z = 10 - 15$. It is demonstrated that the dynamics of a shell created by energetic explosions of the first supernovae is distinct in rotating and non-rotating protogalaxies. Dwarf protogalaxies with total (dark matter plus baryonic) mass $10^7\ M_\odot$ are unlikely to form stars as a result of the shell fragmentation.

Dr. Vorobyov has begun a collaboration with Drs. J. Dettmar and D. Bomans (both from Ruhr-Universitat Bochum) and Prof. Yu. Shchekinov (South Federal University) to investigate numerically the secular evolution of oxygen abundance in low surface brightness (LSB) galaxies. It is demonstrated that a pronounced anticorrelation between the mean oxygen abundance and radial abundance fluctuations, complemented by synthesized Hα equivalent widths and broad-band optical colors, can be used to constrain the minimum age of LSB galaxies.

With Drs. D. Mayya and R. Romano, Dr. Vorobyov continued to work on the interpretation of optical and near-infrared broadband imaging data of 15 candidate ring galaxies. It was shown that only 9 out of 15 ring galaxies in their sample have multiband morphologies that are expected from the classical collisional formation scenario, indicating the high degree of contamination of the ring galaxy sample by galaxies without a clear ring morphology. It is also found that the rings are located preferentially at around half-way through the stellar disk.

Dr. Vorobyov continued his collaboration with Dr. Ch. Theis (Vienna University) to study numerically the stellar velocity distribution in disk galaxies with a well-developed spiral structure. Dr. Vorobyov has developed a stellar dynamics code that solves the Boltzmann moment equations up to second order and is suitable to study the shape and orientation of the stellar velocity ellipsoids in disk galaxies. It is demonstrated that that the ratio of smallest versus largest principal axes of the stellar velocity ellipsoid becomes abnormally small near the outer edges of the stellar spiral arms. The extent to which the stellar velocity ellipsoid is elongated (as compared to the unperturbed value typical for the axisymmetric disk) increases with the strength of the spiral density wave. The abnormally small values of the velocity ellipsoid axis ratio can potentially be used to track the position of stellar spiral density waves.

Refereed Publications

Cameron, C., Saio, H., Kuschnig, R., Walker, G. A. H., Matthews, J. M., **Guenther, D. B.**, Moffat, A. F. J., Rucinski, S. M., Sasselov, D., Weiss, W.W., "MOST detects SPBe pulsations in HD 127756 & HD 217543: Asteroseismic rotation rates independent of vsini", 2008, ApJ, 685, 489 -507

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Thacker, Robert, "Two Easy Pieces: Radial Profile Breaks in Disk Galaxies & the Variability of Substructure in Dark Matter Halos", Arizona State University, USA, 21 February 2008

Razoumov, Alexei, "High-redshift galaxies in absorption: can our models reproduce observations?", Munich University Observatory, Germany, March 2008

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Thacker, Robert, "A New Technique to Understand the Impact of Black Holes on Galaxy Formation", Queen's University, 25 March 2008

Vorobyov, Eduard, "The early and late phases of evolution of circumstellar disks around low-mass protostars", Saint Mary's University, 28 March 2008

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Thacker, Robert, "Top Ten Events in the International Year of Astronomy 2009", AST Teachers conference, 24 October 2008

Poster Presentations

MacDonald, N. R. & Clarke, D. A., "Bridging the Gap: Synthetic Radio Observations of Numerical Simulations of Extragalactic Jets'', CASCA, University of Victoria, 20-23 May 2008

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