Institute for Computational Astrophysics ICA

2005 ANNUAL REPORT

Compiled by:
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Institute for Computational Astrophysics

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Institute for Computational Astrophysics
Annual Report
2005

The Institute for Computational Astrophysics (ICA) was formed by an act of the Saint Mary's University Faculty Senate in December 2002 on the basis of a proposal generated by Drs. David Clarke and David Guenther. In July 2005, Dr. Terry Murphy, Vice President Academic and Research submitted the amended ICA Constitution to Senate, on behalf of the ICA. Senate unanimously passed the amended ICA Constitution in July, 2005. The Institute at date of submission consists of the following members: Director, Secretary, five full-time Faculty members, two Canada Research Chairs, and two Post Doctoral Fellows.

In 2005, ICA Post Doctoral Research Associate Dr. Amanda Karakas left the ICA to begin a Post Doctoral position at McMaster University. Dr. Sasha Men'shchikov will be leaving for a position at the Service d'Astrophysique in France in January, 2006. In October, 2005, Dr. Joris Van Bever from Brussels, Belgium joined us as an ICA Post Doctoral Research Associate. The ICA will have two new post doctoral fellow arriving in 2006: Dr. Nathalie Toqué in March and Dr. Alex Razoumov in July, and will be submitting Dr. Rob Thacker for a Canada Research Chair position as Dr. Joseph Hahn will be returning to Texas as of July, 2006.

EVENTS IN 2005

Dr. Deupree continues to serve as the CASCA representative on the CITA board, attending board meetings both in October and in the first week of 2006. He has been asked to serve on the Advisory Board of the Herzberg Institute for Astrophysics and will attend his first board meeting in early 2006. He continues to serve as the ACEnet Principal Investigator, and as such serves as a member on the National Initiatives Committee (NIC), an organization made up of the Principal Investigators (or designees) of the seven regional computing consortia such as ACEnet. The task of the NIC is to develop a CFI proposal for funding computational hardware for the consortia and for developing a model for the consortia to work together to provide computational needs on a national scale. The proposal is expected to be completed by the end of May, although it is expected that the governance issues will require more time. In addition, Dr. Deupree continues to serve as a referee for academic journals and as a member of the CFI College of Reviewers.

The Department had a good recruiting year. The ICA participated by giving colloquia and meeting students from Atlantic Canada, fielding booths at undergraduate events, and soliciting undergraduates from fellow researchers. Among new students working with Faculty: Aaron Gillich being supervised by Bob Deupree; Chris Geroux and Joel Tanner being supervised by Dr. Deupree while completing Master's with either Dr. Deupree or Dr. David Guenther.

In 2005, Catherine Lovekin (student supervised by Dr. Deupree) completed her Master's and is continuing in her Ph.D. research. Jonathan Ramsey (student supervised by Dr. David Clarke) is nearing completion of his Master's. Both Catherine and Jonathan have past their comprehensive exams fulfilling the entry requirement for the Ph.D. program.

The ICA has consistently played a major role in the initial formation of ACEnet (Atlantic Computational Excellence Network). ACEnet will be hosting HPCS 2006 (High Performance Computing Symposium), the 20th International Computing Symposium on High Performance Computing Systems and Applications, in St. John's, Newfoundland May 14 – 17th , 2006, and Dr. Deupree, as Principal Investigator of ACEnet, has assumed the role of Conference Chair. Ms. Julee Adams, ICA Secretary, has the role of Project Manager. The ICA is sponsoring the Division of Dynamical Astronomy (DDA) of the American Astronomical Society conference with Dr. Joseph Hahn, ICA Canada Research Chair as head of the Local Organizing Committee. The DDA conference will be held on-campus June 25 – 29, 2006. The ICA is working with Dr. David Guenther in making preparations to host the MOST conference on-campus in 2006 (dates finalized: June 16 – 19, 2006).

Included here are discussions on resources, summer students, visitors to the ICA, seminars presented by ICA members at other institutions, publications by ICA members, and brief statements of research progress for the ICA members.

Resources

The funding for the ACEnet project is expected to be finalized by the end of 2005. ACEnet is one of seven regional consortia to provide high quality computational capability to academic researchers. ACEnet serves the entirety of Atlantic Canada, and the ICA is expected to be a major user of the ACEnet resources. Construction has started on an expansion to the Science Building which will house much of the ACEnet infrastructure on the Saint Mary's campus. The construction of the ACEnet space is expected to be complete by the end of August, 2006. Some of the infrastructure will be located in the basement of the McNally Building, and the construction of this part is nearly complete. Key components of the ACEnet architecture to be located at Saint Mary's include a (128 node initially) Opteron cluster with Myranet interconnects, an Access Grid facility, and a data cave for high quality visualization of computed results (most particularly useful for three dimensional calculations). The cluster will be installed in the spring of 2006.

Summer Students

Faculty within the ICA employed summer students during 2005. They are as follows:

Faculty	Student
Dr. Robert G. Deupree	Patrick Rogers, Chris Geroux
Dr. David Guenther	Joel Tanner
Dr. C. Ian Short	James Sherar
Dr. Joseph Hahn	Yannick Poirier

ICA Visitors

January 31st – April 30, 2005
Birgit Fuhrmeister
Hamburg Observatory and University of Hamburg, Germany

Seminars Presented Elsewhere by ICA Personnel

November, 2005 University of Vienna, Vienna, Austria
Understanding eta Boo
Dr. David Guenther

November 10, 2005 Dalhousie University
Stellar Atmospheric Modelling and the problem of stellar composition
Dr. Ian Short

October 28, 2005 University of Western Ontario, London, ON
Stellar Atmospheric Modelling and the problem of stellar composition" (with an introduction to the ICA)
Dr. Ian Short

April 28, 2005 Herzberg Institute of Astrophysics, Vancouver, BC
Modeling Nonspherical Stars
Dr. Robert G. Deupree

April 27, 2005 BC.NET, Simon Fraser University Harbour Centre, Vancouver, BC
Technology and Fulfilling the ACEnet Vision
Dr. Robert G. Deupree

April 25, 2005 University of British Columbia
Modeling Nonspherical Stars

Dr. Robert G. Deupree

March 31, 2005 University of New Brunsiwick
Modeling Stars
Dr. Robert G. Deupree

January 26, 2005 Memorial University of Newfoundland, St. Johns, NL
Modeling Stars
Dr. Robert G. Deupree

January 6, 2005 McMaster University, Hamilton, ON
Nucleosynthesis in AGB Stars
Dr. Amanda Karakas

Refereed Publications

Jonathan Ramsey and David Clarke

(SMUICA-05-101)Ramsey, J.P.; Clarke, D.A., "The Role of The Equation of State in Simulations of Astrophysical Fluids", ApJ submitted.

Robert Deupree and Amanda Karakas

(SMUICA-05-110)Deupree, R.G.; Karakas, A.I., "The Structure of Close Binaries in Two Dimensions", 2005ApJ…633..418D.

David Guenther

Walker, G.A.H., Kuschnig, R., Matthews, J.M., Cameron, C., Saio, H., Lee, U., Kambe, E., Masuda, S., Guenther, D. B., Moffat, A.F.J., Rucinski, S.M., Sasselov, D. and Weiss, W.W., "MOST Detects G-Modes in the Be Star HD 163868," 2005ApJ…635L..77W.

Lefevre, L., Marchenko, S.V., Moffat, A.F.J., Chene, A.N., Smith, S.R., St-Louis, N., Matthews, J.M., Kuschnig, R., Guenther, D.B., Poteet, C.A., Rucinski, S.M.,. Sasselov, D, Walker, G.A.H., and Weiss, W.W., "Oscillations in the Massive Wolf-Rayet Star WR123 with the MOST Satellite," 2005ApJ…634L..109L.

(SMUICA-05-118) Kallinger, Th.; Zwintz, K.; Guenther, D.B.; Pamyatnykh, A.A.; Weiss, W.W., "Pulsation of the K 2.5 giant star GSC 09137-03505?" 2005 A&A...433..267-273.

(SMUICA-05-117) Randall, S.K.; Matthews, J.M.; Fontaine, G.; Rowe, J.; Kushnig, R.; Green, E.M.; Brassard, P.; Chayer, P.; Guenther, D.B.; Kuschnig, R.; Moffat, A.F.J.; Rucinski, S.M.; Sasselov, D.; Walker, G.A.H.; Weiss, W.W., "Detection of Long-Period Variations in the Subdwarf B start PG 0101+039 on the Basis of MOST Photometry", 2005ApJ…633..460R.

(SMUICA-05-116) Guenther, D.B.; Kallinger, T.; Reegen, P.; Weiss, W.W.; Matthews, J.M.; Kuschnig, R.; Marchenko, S.; Moffat, A.F.J.; Rucinski, S.M.; Saselove, D.; Walker, G.A.H., "Stellar Model Analysis of the Oscillation Spectrum of ETA Bootis Obtained from MOST" 2005 ApJ, 635, 547.

(SMUICA-05-115) Straka, C.W.; Demarque, P.; Guenther, D.B.; Li. L.& Robinson, F.J."Space and Ground Based Pulsation Data of ETA Bootis Explained with Stellar Models Including Turbulence", 2006ApJ…636..1078S.
(SMUICA-05-112) Robinson, F.J.; Demarque, P.; Guenther, D.B.; Kim, Y.C.; Chan, K.L., "Simulating the outer layers of Procyon A: a comparison with the Sun", MNRAS - 362, 1031.

(SMUICA-05-103) Walker, G.A.H.; Kushing, R.; Matthews, J.M.; Reegen, P.; Kallinger, T.; Kambe, E.; Saio, H.; Harmanec, P.; Guenther, D.B.; Marchenko, S.; Moffat, A.F.J.; Ruchinski, S.M.; Sasselov, D.; Weiss, W.W.; Bohlender, D.A.; Bozic, H.; Hashimoto, O.; Koubsky, P.; Mann, R.; Ruzdjak, D.; Skoda, P.; Slecht, M.; Sudar, D.; Wolf, M.; Yang, S., "The Radial and Nonradial Pulsations of the Be Star zeta Ophiuchi from MOST Satellite Photometry and Ground-based Spectroscopy", 2005 ApJ...623, L145-148 .

(SMUICA-05-102) Straka, C.W.; Demarque, P.; Guenther, D.B., "An Improved Treatment and Constraints from Procyon A", 2005 ApJ...629..1075.

Joseph Hahn

(SMUICA-05-113) Hahn, J. and Malhotra, R., "Neptune's Migration into a Stirred-Up Kuiper Belt: A Detailed Comparison of Simulations to Observations", 2005, AJ Vol. 130, pg 2392.

Ian Short

(SMUICA-05-114) Short, C.I. and Hauschildt, P.H., "A Non-LTE Line-Blanketed Model of a Solar-Type Star", 2005ApJ...618, 926.

Short, C.I., 2005, “NLTE Ba and Sr in metal poor red giant stars”, 2006ApJ…641..494S.

Fuhrmeister, B., Short, C.I., & Hauschildt, P.H., 2005, “Influence of NLTE calculation on the hydrogen lines in chromospheric models”, ApJ accepted, December 2005.

Amanda Karakas

(SMUICA-05-108) Renda, A.; Fenner, Y.; Gibson, B.K.; Karakas, A.I.; Lattanzio, J.C.; Campbell, S.W.; Chieffi, A.; Cunha, K.; Smith, V.V., "On the Origin of Fluorine in the Milky Way", 2005, Nucleau Physics A, Vol 758, pg. 324.

(SMUICA-05-107) Campbell, S.W.; Fenner, Y.; Karakas, A.I.; Lattanzio, J.C.; Gibson, B.K., "Abundance Anomalies in NGC 6752 - Do AGB Stars Have a Role to Play?", 2005, Nuclear Physics A, Vol 758, pg 272.

(SMUICA-05-106) Lugaro, M.A.; Pols, O.R.; Karakas, A.I.; Tout, C.A., "HR4049: Signature of Nova Nucleosynthesis?", 2005, Nuclear Physics A, Vol 758, pg. 725.

(SMUICA-05-105)Stancliffe, R.J.; Lugaro, M.A.; Tout, C.A.; Karakas, A.I., "Nucleosynthesis on the Asymptotic Giant Branch: A comparison between codes", 2005, Nuclear Physics A, Vol. 758, pg. 569.
(SMUICA-05-104) Karakas, A.I.; Lugaro, M., "The Uncertainties in the 22Ne + alpha-capture reactions and Mg production in intermediate-mass AGB stars", 2005, Nuclear Physics A, Vol. 758, pg. 489.

Alexander Men'shchikov

(SMUICA-05-119)Men'shchikov, A.B.; Miroshnichenko, A.S., Properties of galactic B[e] supergiants. V. Two-dimensional radiative transfer model of RY Sct and its dusty disc. A&A, 2005, vol. 443, pg. 211-222.

(SMUICA-05-109) Riechers, D.; Balega, Y.; Driebe, T.; Hofmann, K.H.; Men'shchikov, A.B.; Shenavrin, V.I.; Weigelt, G., "A quasi-time dependent radiative transfer model of OH 104.9+2.4, 2005, ApJ...436..925-931.

Men’shchikov, A.B.; Balega, Y.Y.; Berger, M.; Driebe, T.; Hofmann, K.H.; Maximov, A.F.; Schertl, D.; Shenavrin, V.I.; Weigelt, G., Near-infrared speckle interferometry and radiative transfer modeling of the carbon star LP Andromedae, 2006 A&A…448..271M.

Catherine Lovekin and Robert Deupree

Lovekin, C.C.; and Deupree, R.G.; Testing von Zeipel’s Law Using 2D Stellar Evolution, to appear in the Proceedings of Stellar Pulsation and Evolution 2005.

Catherine Lovekin, Robert Deupree, and Ian Short

(SMUICA-05-120) Lovekin, C.C., Deupree, R.G., and Short, C.I; Surface Temperature and Synthetic Spectral Energy Distributions for Rotationally Deformed Stars. 2005, ApJ in press

Conference Presentations

May 14 – 18, 2005, Oral Presentations at the Annual CASCA conference held in Montreal.

1. Modeling Circumbinary Dusty Disc around B[e] Supergiant RY Set by A. Men’shchikov
2. Nonspherical Effects in the Evolution of Close Binary Stars by R. G. Deupree
3. MOST, Modes and Models by D. Guenther

May 14 – 16, 2005, Poster Presentations at the Annual CASCA conference held in Montreal.

1. Chiaroscuro: From Pericenter Glow to Apocenter Enhancement – Illuminating the Secular Structure of Dusty Planetary Systems by C. Capobianco and J. Hahn
2. The Long Term Evolution of Saturn's Ring-satellite System by J. Hahn
3. Low-metallicity Super-AGB Stars by A. Karakas
4. Testing von Zeipel's law by C. Lovekin
5. The role of the equation of state in the simulation of astrophysical fluids by J. Ramsey and D. Clarke
6. NLTE Strontium and Barium in metal poor red giants by I. Short

Scientific Research

Here we present summaries of ICA faculty research performed over the past year.

Dr. Alexander Men'shchikov has been working with Dr. Clarke on the development of the 3D MHD code ZEUS-3D and an adaptive mesh refinement (AMR) version (called AZEUS) of the same code. Very good progress has been made in the last months. The main achievement is that the code works now for two problems -- collapse of rotating protostellar cloud and spherical explosion -- although considerable work and polishing is expected to make it work in the general case and publish first results.

Dr. Men'shchikov has also been working on 2D radiative transfer modeling of dusty envelopes of stars in collaboration with German colleagues (Bonn: Gerd Weigelt, Thomas Driebe, Dominik Riechers) and an American colleague (Greensboro, NC: Anatoly Miroshnichenko). They modeled the B[e] supergiant RY Sct and its dusty disk and improved their model of the OH/IR star OH 104.9+2.4. Such modeling is very important for understanding the properties and for the derivation of correct physical parameters of these stars.

Dr. Joris Van Bever's research is situated in understanding the evolution of and modeling the observable properties of young, massive starbursts and their populations of massive stars and compact remnants. He plans to develop spectral synthesis models of starbursts that incorporate the important effects of both binary stars and dynamics in dense super star clusters, by coupling his spectral synthesis code to a self-written N-body code.

There is growing evidence that most massive stars are formed in clusters and, therefore, young starbursts play a key role for testing our theoretical understanding of processes such as star formation, the evolution of massive stars (including the formation of objects such as Wolf-Rayet stars, red supergiants, high-mass X-ray binaries, young pulsars, stellar-mass black holes, ultraluminous X-ray sources, etc.), and the chemical evolution of galaxies (massive stars lose large amounts of mass through stellar winds and supernovae, providing feedback to the interstellar gas). Young starburst regions are important for our understanding of a wide range of phenomena including galaxy mergers, Wolf-Rayet galaxies, ultraluminous infrared galaxies, blue compact dwarf galaxies, active galactic nuclei, and Giant HII regions. They have become an extensively studied scientific topic by many research groups all over the world.

The main goal of the proposed research is to include (besides detailed and accurate treatments of binaries) stellar dynamics in the theoretical modeling of starbursts. Recent N-body simulations have shown that --- within the short lifetime of massive stars --- collisions between stars in dense clusters occur and drastically affect their evolution, as well as the overall dynamical evolution of the cluster. Massive stars in particular, collide often (especially if primordial binaries are present), producing all sorts of exotic merger products. These dynamical processes could therefore significantly affect the conclusions of traditional population- and spectral synthesis models.

Mr. Ramsey is still studying the effects of the equation of state on numerical simulations of protostellar jets launched from Keplerian discs with Dr. Clarke. He is also exploring the protostellar jet launching mechanism in an effort to ascertain what the fundamental parameters controlling jet morphology are. Mr. Ramsey and Dr. Clarke will shortly be embarking on an exploration of large-scale simulations of protostellar jets designed to be directly comparable to current observations of jets in star formation regions. Due to computational demands, high-resolution simulations of protostellar jets on this scale have never been attempted. With access to the computational resources of ACEnet, and with some modification to Dr. Clarke's ZEUS hydrodynamics code, these simulations can be completed in weeks instead of years.

This year David Guenther worked almost exclusively on trying to understand the steroseismic observations obtained from the MOST satellite (Microvariability on Stars, Jaymie Matthews, UBC, P.I.). A member of the MOST science team, he is responsible for the astrophysical interpretation of the observations of Sun-like stars, which to date include Procyon, eta Boo, and eps Eri. He was unable to interpret the data on Procyon owing to a significant noise component in the data coming from sunlight scattered off of the earth's surface. Although the data for eta Boo were also contaminated by a large stray light component, he was able to identify a sequence of radial p-modes and carry out an analysis. His analysis of the data for the third star, eps Eri, is in progress.

Motivated by the existence of a large non-stellar signal (noise) in the MOST data, University of Vienna graduate student Thomas Kallinger and David Guenther investigated ways to remove it from the data. They have successfully developed a model of the stray light component and in tests on the background signal from MOST are able to filter out all the white noise and identify all the stray light signal.

Using only the oscillation data on eta Boo obtained from MOST Guenther determined the age, mass, and composition of the star. Combining MOST results with ground-based results he showed there is a small discrepancy between the oscillation spectrum of the models and the observations. Because the discrepancy is confined to the higher frequencies he suggested that the discrepancy is caused by inadequacies in the model of convection, which is based on the mixing length approximation.

David Guenther is collaborating with the Yale convection group (Pierre Demarque, Yale University, P.I.) to develop an improved model of convection for stellar modeling. Their long term goal is to replace the mixing length approximation, currently used to model convection, with the results of detailed three-dimensional hydrodynamical numerical simulations of stellar convection. To test their calculations they have used the seismic data obtained from the Sun and stars. For the Sun they were successful in removing the small discrepancy that exists between the oscillation spectrum of the solar model and the observed oscillation spectrum. They are currently computing a convective model of eta Boo to see if models based on it will remove his recently discovered discrepancy in the oscillation spectrum. The computation, which has already been running for approximately one year, is not yet completed. In the meantime they scaled their simulations for the Sun's convective envelope to match eta Boo and incorporated them into their model of eta Boo to see if the oscillation discrepancy is eliminated. Encouragingly, it is.

David Guenther has expanded his extensive and dense grid of stellar models and oscillation spectra (approximately one million models) that he uses to analyze stellar oscillations. The grid is used by an optimized search program, based on DNA sequence matching techniques, that looks for the best matches between the observed oscillation spectrum and the model spectra. With the assistance of Saint Mary's University graduate student Joel Tanner, the grids are being expanded to include pre-main-sequence models.

Undergraduate student Chris Geroux and David Guenther used the recently updated chemical abundances for the Sun to see how they affect the age of the Sun determined from seismology. With the old abundances the asteroseismic age agrees with the independently derived meteoritic age of the Sun within the uncertainties of the model physics. With the new abundances, the asteroseismic age is more than four sigma away from the meteoritic age.

Thomas Kallinger and David Guenther, while examining the oscillation data obtained from MOST for eta Boo and Procyon, discovered tentative evidence for short life-time modes. The short life-times could explain, in part, why it has proven so difficult to identify individual frequencies in the oscillation spectrum of Procyon and eta Boo.

With P.H. Hauschildt (Hamburg Observatory), Dr. Ian Short has used the PHOENIX model atmosphere and spectrum synthesis computer code on the ICA parallel computer (Pluto) to created new computational models of the atmospheres and spectra of stars that are like the Sun. In these models the thermodynamic state of the gas and radiation is treated with an unprecedented degree of realism, with tens of thousands of the most important spectral lines being allowed to depart from the simplifying approximation of local thermodynamic equilibrium (LTE). These models show that Iron and Iron-group elements are by far the most important ones to treat realistically for accurate simulation of the star's atmospheric structure and the overall stellar spectrum. Another important result is that the opacity of the atmosphere of the Sun and of other cool stars in the violet and near UV spectral bands is still poorly understood.

With P.H. Hauschildt (Hamburg Observatory), Short has computationally simulated with the PHOENIX code the spectrum of the astrophysically importantelements Strontium and Barium with atmospheric models of very old Red Giant stars in our galaxy with the goal of determining more accurate chemical compositions for these stars. The concentrations of Strontium and Barium in these ancient stars provide clues as to the origin of chemical elements heavier than Helium. Short and Hauschildt have shown that more realistic modelling of the spectrum changes the inferred concentration of these elements by as much as a third of their value.

With Birgit Fuhrmeister and P.H. Hauschildt (Hamburg Observatory), Short has computationally modelled with the PHOENIX code the Hydrogen spectrum of stars like the Sun that have a temperature inversion in their outer atmosphere (the chromosphere). The physical process that heats the chromosphere is not well understood and indicates gaps in our knowledge of gas and radiation physics in stellar environments. By adjusting atmospheric models until the computed spectrum matches the observed one, investigators infer the detailed temperature structure of the chromosphere, which provides constraints on theories of chromospheric heating. We have shown that the computed spectrum, and, thus, the inferred temperature structure, depends on the detailed treatment of the equilibrium state of chemical elements that have spectral lines that overlap with transitions of Hydrogen.

Dr. Hahn is examining Neptune's migration into the Kuiper Belt, which is the vast swarm of comets that inhabit the outer edge of our Solar System. This bulk of this activity has been the analysis of hundreds of N body simulations of the Solar System's 4.5 billion--year history; these simulations consumed a total of about two years worth of CPU time, but were executed in only a week of `real time' on the ICA's Beowulf cluster. These simulations are in very good agreement with astronomical observations of the Kuiper Belt, and the results are also providing some new insight into the early evolution of the outer Solar System.

Dr. Hahn is assessing the role of the Yarkovsky Effect in the Kuiper Belt. This project is being explored by Mr. Daniel Majaess, who will be reporting his results in his Honor's thesis with Dr. Hahn. The Yarkovsky effect is the very weak acceleration that a small asteroid or comet experiences due to the anisotropic re-radiation of incident sunlight. This effect is known to cause asteroid orbits to drift slowly over time, and Mr. Majaess' task is to determine whether this effect is of any consequence in the Kuiper Belt. In particular, Mr. Majaess will determine whether the Yarkovsky effect plays a role in the delivery of comets into the inner Solar System from the Kuiper Belt. To study this phenomena, Mr. Majaess is using an N body integrator to simulate the evolution of cometary orbits on CITA's McKenzie computer cluster, which is one of the largest computer clusters of its kind in Canada.

Dr. Hahn is also working with honors student Mr. Adam Chaffey to use an N body integrator to simulate the spiral density waves that a satellite can launch in a gravitating particle disk. This work is also being done on the ICA's Beowulf cluster. This is a rather challenging task since the computer must follow the motions of a very large number of interacting particles in order to resolve any wave action. This project is also quite timely, since the Cassini spacecraft has just arrived at Saturn, and is now returning many images of the spiral density waves that Saturn's satellites are launching in that planet's rings. A long-term goal of Mr. Chaffey's project is to apply our N body simulations to these spacecraft observations in order to study these ring-satellite interactions.

Dr. Hahn is also studying the disk around the star Beta Pictoris with honors student Mr. Gary Hubertise, who is analyzing optical and infrared observations of this system. These telescopic images have been provided by Dr. Sara Heap (NASA Goddard Space Flight Center), who used the Hubble Space Telescope to observed this dust disk at optical wavelengths, and by Dr. Zahhad Wahhaj (University of Pennsylvania) who used the Keck 10m telescope to observe this system in the infrared. The well-known warp that has been observed in this dust disk is usually attributed to perturbations from unseen planets that are suspected to orbit within. Mr. Hubertise's task is to characterize the disk's radial variations and its perturbed appearance. The results of his data analysis will then be used by Master's student Mr. Chris Capobianco in his effort to model this system.

To better characterize this unseen planetary system, Mr. Capobianco is developing a model of a dust disk that is perturbed by embedded planets. Mr. Capobianco will then attempt to fit simulated images of this dust disk to the telescopic observations of this system. Mr. Capobianco will then scan the available parameter space to determine the range of planetary systems (i.e., the number of planets, their masses, and their orbits) that might account for the warp that is observed in the Beta Pictoris dust disk.

Drs. Deupree and Karakas completed their two dimensional study of the structure and evolution of stars in close binary systems. This assumed that the orbits of the stars were circular and that the azimuthal effects were negligible. The gravitational potential affecting each binary member was the sum of its self potential, which may be nonspherical, and a point source potential assumed for the companion. The evolution was followed for each binary member. Deupree and Karakas considered the cases of a binary system of 8 and 5 solar mass stars with separations of 10, 14, and 20 solar radii. The 10 solar radius separation case has Roche lobe overflow occurring very close to the ZAMS. The 14 solar radius separation has Roche lobe overflow about halfway through core hydrogen burning, while the third case does not overflow the Roche lobe until the beginning of hydrogen shell burning. The results of these calculations showed that traditional one dimensional stellar evolution models follow the evolution well up until the time when of Roche lobe overflow. This is because the nonspherical effects are too small in the deep interior where the evolution is determined. However, the formal boundary of the convective core becomes slightly elongated as Roche lobe overflow is approached. This work was followed up by Mr. Patrick Rogers who examined the possible errors associated with assumption that the companion had a point mass by evaluating the total potential on spheres just outside each component assuming that both stars had the mass distribution found by Deupree and Karakas. He found the departures of the potential of each companion on the sphere surrounding the other star was never greater than 0.4%.

Dr. Deupree and several students began investigating how one might decouple the rotational velocity from the inclination of the observer to the polar axis by comparing theoretical results and observational data. Mr. Chris Geroux is examining how this might show up in the H-R diagrams of galactic clusters, and Mr. Aaron Gillich is studying the deduced observational properties of a rapidly rotating star as a function of the inclination. Mr. Joel Tanner is performing two dimensional stellar evolution sequences. Both he and Ms. Catherine Lovekin are calculating pulsation periods of rotating stars to see if they can be used to constrain the rotation and inclination for rapidly rotating stars.

Ms. Catherine Lovekin has been studying synthetic spectra of rapidly rotating stars. The air of this research was to look for indications of the oblate ness and inclination of the star in the macroscopic features of the spectral energy distribution. Ms. Lovekin has also started two new projects this year involving stellar pulsations. One project involves calculating the radial pulsations of multimodes Cepheids to see how rotation early in a stars lifetime can affect its subsequent evolution and structure. The other project looks at the non-radial modes in rotating stars. The characteristics of these modes are not well understood, and the aim of this project is to generate a better characterization. Ms. Lovekin is currently enrolled in our Ph.D. program and in 2005, received the Senior Women Academic Administrators of Canada (SWAAC) Graduate Student Award of Merit.

In the other collaboration, Drs. Clarke and Hahn intend to use Dr. Clarke's Zeus hydrodynamic code to simulate the spiral density waves that a satellite can launch in a planetary ring. The intent is to simulate the spiral waves in Saturn's rings that are being monitored by the Cassini spacecraft that is presently in orbit about Saturn. Spiral waves play a major role in shaping that planet's rings, and the goal is use these simulations to address some of the outstanding questions about this system, namely, how old are these rings, and what is the nature of their origin? It is anticipated that these simulations will be executed on the ICA Beowulf cluster during the summer of 2005 by an undergraduate Honors student.

Other Activities

Last summer Dr. Adam Sarty of the Astronomy and Physics Department and Dr. Hahn organized the Astronomy and Physics Summer Undergraduate Research Conference. This gave the summer undergraduate students supporting faculty research the opportunity to present papers to the faculty and their peers on their research project much as is done at professional meetings. Six of these students were working for ICA faculty members.

CONCLUDING REMARKS

The ICA is progressively gaining recognition amongst its peer groups as evidenced by the facts that 1) ICA members are in demand to give talks elsewhere, 2) external visitors want to come here, often at their own expense, 3) researchers wish to send their current graduate students to visit over several weeks to several months timescales, 4) the ICA is beginning to host international conferences. This recognition has come despite the need for some ICA members to spend a good deal of time bringing ACEnet to fruition. It is hoped that these gains can be accelerated as ACEnet makes the transition from a system on paper to a system in reality.

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