Boston University
Institute for Astrophysical Research
Annual Report
June 2004

PRISM "First Light" Image November 2, 2003
The spiral galaxy M74

James M. Jackson, Director
Kimberly Paci, Fiscal Administrator

IN MEMORIUM

Professor Lynne K. Deutsch
November 26, 1956 - April 2, 2004

The IAR notes with great sadness the untimely passing of Prof. Lynne K. Deutsch after a long illness. Prof. Deutsch, a superb instrumentalist, leaves a lasting legacy to the IAR and the astronomical community with MIRSI, the Mid-Infrared Spectrometer and Imager. The great demand for MIRSI at NASA's Infrared Telescope Facility in Hawaii is a testament to Lynne's skill and scientific vision. Lynne was an inspiration to both her students and her colleagues. She will be sorely missed.

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Summary

The Institute for Astrophysical Research marked a very successful 6th year in its mission to foster research in astrophysics at Boston University. Especially noteworthy are the success of the IAR's three instrument programs. MIRSI (the Mid-InfraRed Spectrometer and Imager) continued its scientific observations on NASA's Infrared Telescope Facility. Its spectacular images and spectra demonstrate that MIRSI is the world's premier mid-infrared camera. On November 2, 2003, PRISM (the Perkins ReImaging SysteM) performed its first observations ("first light") at the Perkins 72 inch telescope at Lowell Observatory, and is now a productive facility instrument. Mimir, an infrared camera, spectrometer, and polarimeter, nears completion and will be deployed to Lowell Observatory in July 2004.

The IAR continues a vigorous research program. In FY2004, total IAR grant expenditures, including new and continuing grants, was $672,808. IAR members submitted twenty new funding proposals totaling over $23M in requests. The IAR received a total of $750,585 in grant income, including five new awards totaling $362,225. IAR members published twenty scientific papers in refereed journals and twenty-six conference proceedings. The scientific proceedings of the Milky Way Surveys conference hosted by the IAR last year will soon be published as volume number 317 in the Conference Series of the Astronomical Society of the Pacific.

Institute Mission

The mission of the IAR is to promote and facilitate research and education in astrophysics at Boston University. The IAR accomplishes this mission by: (1) administering research grants, (2) enhancing the visibility of IAR members with funding agencies and in the astrophysics community, (3) coordinating the use of Boston University astrophysics facilities, and (4) promoting the design, development, and operation of Boston University instruments and telescopes.

Faculty, Staff and Students

During this past year, the IAR membership consisted of faculty, staff, and students engaged in astrophysical research. Faculty members included Professors Thomas Bania, Dan Clemens, James Jackson, Kenneth Janes, and Alan Marscher, Associate Professor Tereasa Brainerd, and the late Assistant Professor Lynne Deutsch. IAR Research Associates included Senior Research Associate Dr. Svetlana Jorstad, Research Associates Drs. Jill Rathborne and Ronak Shah, and Research Fellow Dr. Kathleen Kraemer. IAR staff members included Senior Research Associate Dr. Amanda Bosh, stationed in Flagstaff, Arizona at Lowell Observatory, Senior Research Technician Alexander Grabau, and IAR Fiscal Administrator Ms. Kimberly Paci.

Graduate students conducting astrophysical research with IAR faculty during the past year included Mr. Loren Anderson, Mr. Edward Chambers, Mr. Ritaban Chaterjee, Ms. Francesca D'arcangelo, Dr. Melissa Hayes-Gehrke, Mr. Edmund Douglass, Mr. Paul Howell, Ms. Alexis Johnson, Dr. Marc Kassis, Ms. Emily Mercer and Mr. Andrei Sokolov. Undergraduate students working within the IAR included Ms. Amy Caluori, Ms. Wendy Chan, Mr. Michael Dormody, Mr. Jason Eastman, Mr. Richard Lavoie, Mr. Michael Martin, Mr. Daniel Salem and Mr. Joshua Shiode.

Dr. Marc Kassis defended his PhD dissertation, entitled "Mid-Infrared Observations of Photodissociation Regions and MIRSI: A Mid-Infrared Spectrometer and Imager Developed for Ground Based Observing" and received his degree in September 2003. Dr. Kassis now works at the Keck Observatory in Hawaii as an instrument support scientist.

Dr. Melissa Hayes-Gherke defended her PhD dissertation entitled "Ultra High Precision Photometry of Open Clusters: A Study of Stellar Activity in Old Stars" and received her degree in April 2004. Dr. Hayes-Gherke has accepted a teaching position with the University of Maryland.

Scientific Publications

Over the past year IAR members published a number of significant scientific papers, including twenty papers in refereed journals and twenty-six conference proceedings. A complete list of all of last year's IAR publications is presented in Appendix A.

Instruments and Telescopes

IAR members are actively engaged in three major technical programs: (1) the development of new instruments, (2) the Lowell Observatory Partnership, and (3) Antarctic infrared astronomy.

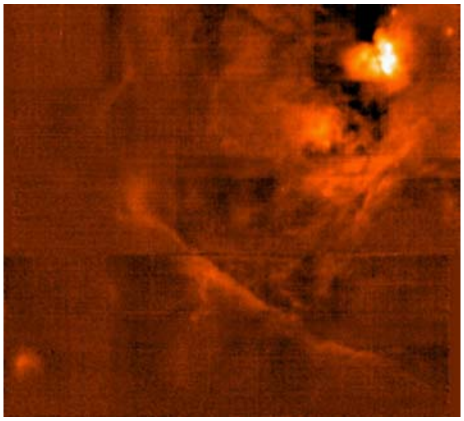
Instrumentation Program

Instrumental building is an important IAR strategic priority, and we are pleased to report that the IAR instrument development program reached new heights in 2003/2004. Three IAR instruments, MIRSI, PRISM, and Mimir are now complete. Two (MIRSI and PRISM) are successfully deployed to telescopes, and the third will be deployed in July 2004.

MIRSI

The late Prof. Lynne Deutsch's instrument MIRSI (Mid-InfraRed Spectrometer and Imager) is a state-of-the-art mid-infrared (8-26 μm wavelength) imager and spectrograph using a 240x320 pixel detector array. MIRSI had its first scientific observations at NASA's Infrared Telescope Facility on Mauna Kea, Hawaii in 2002 and continues to be a popular instrument there. Indeed, about 1/6 of all of the IRTF telescope time is devoted to MIRSI. IAR astronomers have established long-term, ongoing scientific projects with MIRSI.

MIRSI images and spectroscopy formed the basis of Dr. Marc Kassis Ph. D. thesis. His observations of the Orion star-forming region reveal the warm dust heated by nascent, embedded young stars. Kassis found that the transition between the ionized gas in the immediate vicinity of the hot young stars and the more distant neutral gas is extremely sharp, much sharper than theory predicts.



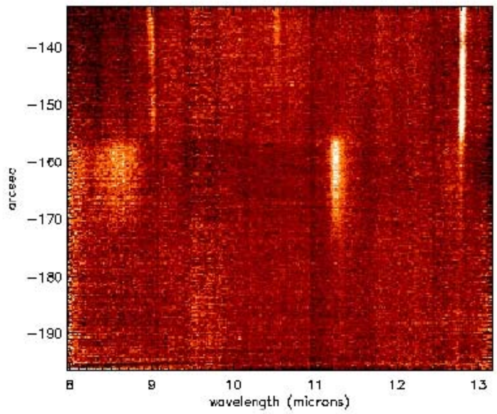


Figure 1. (left) A mid-infrared MIRSI image of the Orion star forming region. (right) a spectral image of the transition region showing a sharp boundary between ionized gas and illuminated dust.

PRISM

PRISM, the Perkins Reimaging System, is a wide-field optical camera designed and constructed at Boston University by Prof. Ken Janes, engineer Dominic Sarcia and undergraduate Jason Eastman. Financial support for the project has come from the University, the IAR, the NSF and Lowell Observatory. After a brief commissioning period, PRISM has now gone into routine operations at Lowell Observatory's Perkins telescope near Flagstaff, Arizona. Some of the initial results include the discovery of a comet (C/2004 A1), the recovery of a lost Kuiper-Belt Object (2003 WU188), investigation of an open star cluster, Berkeley 20, that has been claimed to be associated with tidal debris from a dwarf galaxy captured by the Milky Way (PRISM found no evidence to support this idea), and continued monitoring of blazars and star clusters. PRISM is shared by Lowell Observatory and IAR astronomers.

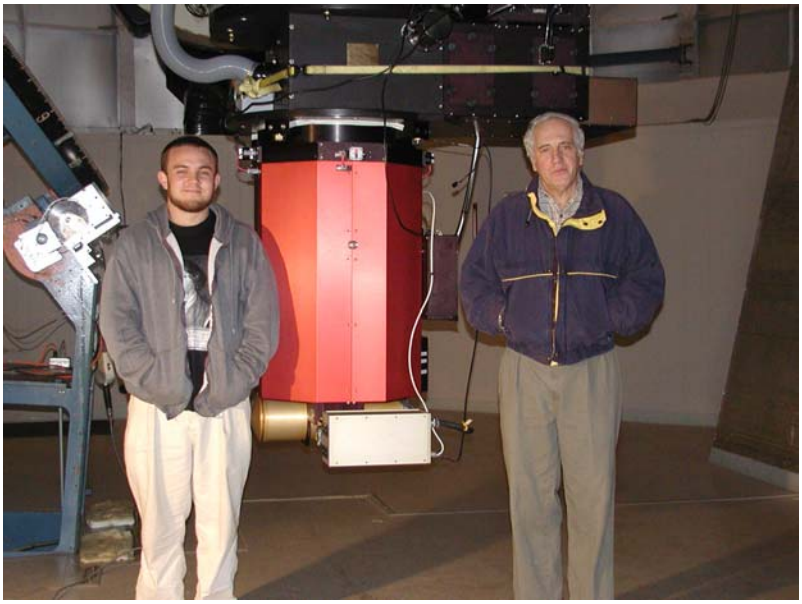


Figure 2. *The PRISM instrument installed at Lowell Observatory. Prof. Janes is on the right, and Jason Eastman on the left.*

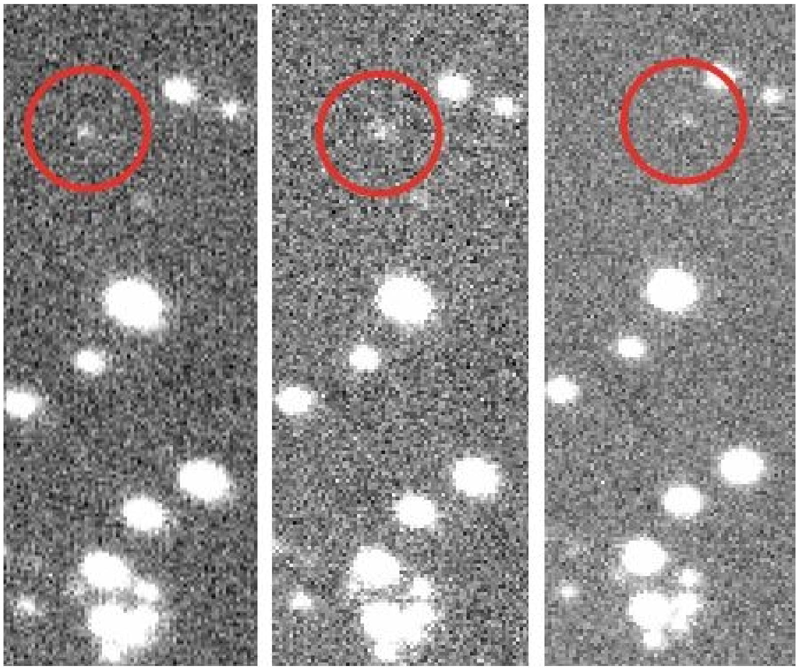


Figure 3. *PRISM observations reveal a "lost" Kuiper Belt Object 2003 WU188. This object (circled in red), a small solid, icy object in the outskirts of the solar system, was found because it moves with respect to background stars. These three images were taken over the course of a few hours.*

Mimir

The Mimir near-infrared imaging spectrometer and polarimeter achieved several successes over the past year, culminating in its imminent departure from IAR laboratories to the Perkins telescope in the next few days. During the summer of 2003, the crystalline optics – lenses and filters – were installed into their individually engineered high-precision mounts and then integrated into the two main optical assemblies, the collimator and the camera block. Around forty such delicate optical elements were installed, with only one fatality. This was quickly replaced with the rapid and diligent efforts of our optical element supplier, Lambda Optics in California. -

The science-grade ($250k) detector array was delivered to us by Raytheon and its location in its mount was measured to a few microns in the lab of Professor Bennett Goldberg of the Physics Department. The detector array and mount unit was installed into Mimir for the first time in the fall. With the installation of the optical elements and the science-grade detector, the first full cold run of Mimir was begun in October of 2003. During this cold run, the first images were obtained, confirming the operation of the detector array and the optics. The image quality was surprisingly good and the optics appeared to be well aligned and located properly. This cold run extended over 102 days, showing that Mimir is capable of long-term operation at the telescope, and was ended only when all testing was completed. During this run, the first spectra were obtained, also confirming that the design parameters were being met.

A number of problems were uncovered in the cold run, including camera block motion and thermal control. These were solved during the spring of 2004, leading up to a second, more complete cold run during the month of June. For this run, all filters and grisms were installed, as well as all of the polarization optics. All modes were tested and found to be operable. The first polarization data were obtained, thus certifying Mimir as a working polarimeter. High-resolution spectra were obtained, spanning wavelengths from 1 to 5 microns, also certifying the spectrometer mode. The detector array temperature was found to be controllable from 26 to more than 40 K, allowing for great flexibility in selecting optimal operating conditions for the different imaging and spectrometer modes.

Mimir is currently being disassembled and readied for shipment to the Perkins telescope and should be reassembled and tested on the telescope, achieving “first light,” this fall. Routine operations by BU and Lowell scientists should begin as early as the spring of 2005.

Figure 4. *The Mimir instrument in the IAR infrared lab.*

Lowell Observatory Partnership

Boston University and Lowell Observatory are partners in the operation of the 72-inch Perkins telescope on the Andersen Mesa, near Flagstaff, Arizona. Boston University scientists and students regularly used the telescope in the past year. The Boston University and Lowell Observatory have agreed to a new five-year term for joint use of the Perkins telescope. This new agreement is vital to reap the scientific benefits of the Mimir and PRISM instruments.

The Antarctic Infrared Observatory (AIRO)

Prof. James Jackson is leading a team that is proposing to the NSF Office of Polar Programs to build AIRO (the Antarctic InfraRed Observatory). A 2-m class infrared telescope, AIRO will initially be equipped with a 2-color (K and L band) camera. AIRO would be deployed to Antarctica after a five-year construction and testing period in Boston and at Lowell Observatory. It would be optimized for an efficient, relentless wide-field imaging survey in the thermal infrared. These wavelengths, from 3 to 5 μm, provide a unique window on very low-mass stars (brown dwarfs), protoplanetary disks, very old stars, and star-forming regions. The AIRO team includes members from both Boston University and Lowell Observatory. Telescope Technologies, Limited, a firm specializing in the manufacture of robotic, research-grade, 2 meter class telescopes, performed an important preliminary telescope design, and they conclude that there are no significant technical hurdles to the AIRO telescope.

The IAR supports AIRO as its top priority among potential new projects. The IAR welcomes the College and University to help seek foundation or donor funds to help support AIRO. A proposal to the National Science Foundation to fund the construction and deployment of AIRO was submitted in June 2004.

Scientific Programs

In addition to instrument development, the IAR hosts a number of scientific programs, including studies of blazars, star formation, cosmology, stellar activity, and the interstellar medium.

The blazar research group consists of Professor Alan Marscher, Senior Research Associate Svetlana Jorstad, graduate students Andrei Sokolov, Francesca D'Arcangelo Ritaban Chatterjee, and Suwicha Wannawichian, and undergraduate students Kristopher Makrides and Daniel Salem. During FY04, Marscher and Jorstad carried out extensive multi-epoch observations of quasars, BL Lacertae objects, and radio galaxies with the 10-antenna Very Long Baseline Array (VLBA) and the 27-antenna Very Large Array (VLA) of the National Radio Astronomy Observatory, NASA's Rossi X-ray Timing Explorer, and Lowell Observatory's Perkins Telescope. In addition, they analyzed their X-ray images of five quasars obtained with the Chandra X-ray Observatory and an optical image of one of these from the Hubble Space Telescope (HST) archive. The main goal of the observational program is to use multiwaveband analysis to derive the physical properties of the jets, including how the velocity (actually, the relativistic Lorentz factor), magnetic field, electron density, and electron energies change with time and position in the jet. This was done in detail with the VLA, Chandra, and HST images for the quasar 0827+243. In a paper accepted for publication in the Astrophysical Journal, Jorstad and Marscher demonstrate that the flow speed of the jet must remain extremely relativistic out to at least 800 kiloparsecs from the nucleus. The magnetic field in this jet is very low (1-3 microGauss) within several kiloparsecs of the nucleus, where X-rays are generated by inverse Compton scattering of cosmic microwave background photons.

The combined X-ray and radio monitoring of the radio galaxy 3C 120 by Marscher and Jorstad revealed a prolonged dip in summer 2003 followed by the appearance of very bright, apparently superluminally moving radio knots, confirming a pattern reported previously (Marscher et al. 2002, Nature). The X-rays are thought to be emitted by very hot plasma close to a 30-million solar-mass black hole, with the dips corresponding to a change from a turbulent to an ordered magnetic field in the inner disk of accreting gas. The long-term light curves (brightness vs. time) of three quasars demonstrates that the X-ray, optical, and infrared emission arises from the radio-emitting portion of the jet, which is probed by the VLBA images. There is a preliminary indication that the patterns of variability are affected by changes in the direction of the jet, since this alters the magnitude of the effects of special relativity when the flow speeds are extremely close to the speed of light. Jorstad, Marscher, and co-authors, reported changes in the direction and apparent velocity of the jet in the quasar 3C 279 in a paper published in the Astronomical Journal in June 2004. In support of the monitoring program, Sokolov and Marscher developed a theoretical model that can explain the close correlation between the variations in X-ray flux and those at lower frequencies. The study, accepted for publication in the Astrophysical Journal, proposes that the observed frequency-dependent time delays between the peaks of flares arise from a combination of gradients in electron energy and light-travel effects. Both Jorstad and Marscher reported on multiwaveband polarization observations of active galactic nuclei at a conference on polarimetry in Kona, Hawaii, in March 2004. They find some similarities in millimeter-wave and optical polarization in a number of blazars and plan to study this in depth with a new project funded with a large grant from the National Science Foundation and making use of the new MIMIR and PRISM instruments on the Perkins Telescope.

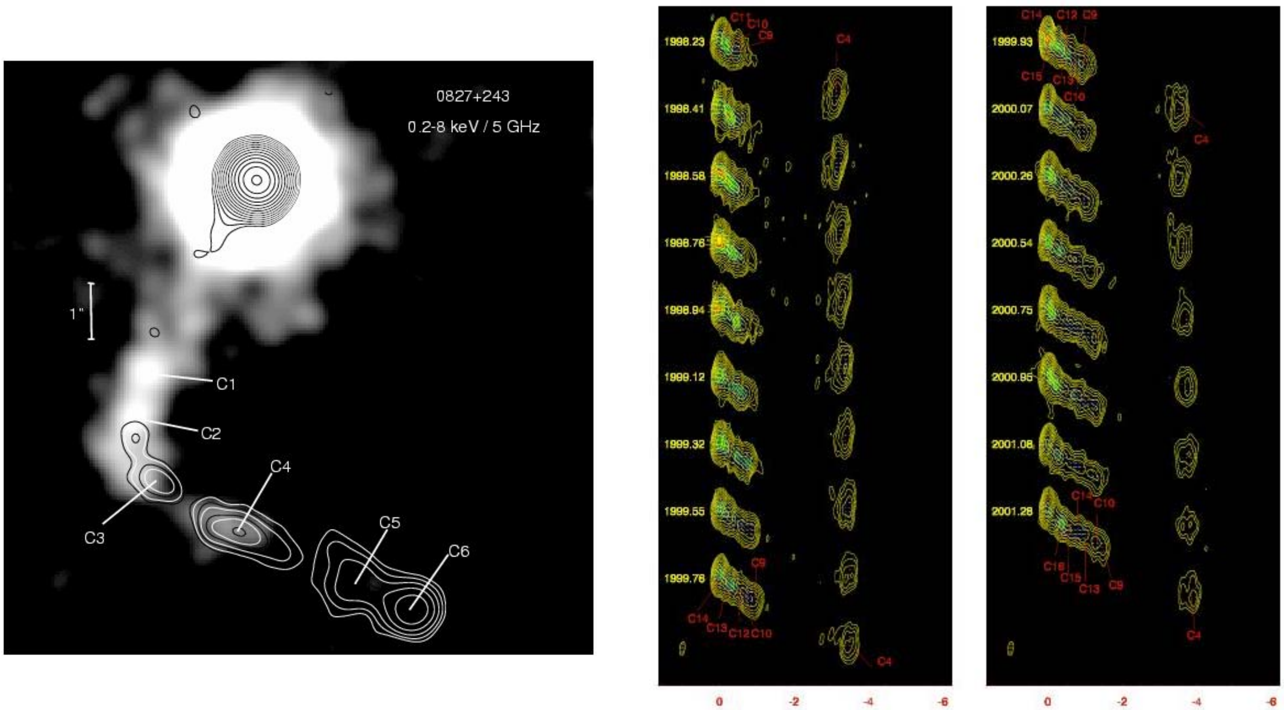


Figure 5. *(Left) An X-ray image of the central regions of the quasar 0827+243 (gray-scale) superposed on a radio image (contours). The central black hole (bright region at the top) is emitting a jet of energetic particles that takes a sharp turn near radio knot C3. (Right) Radio images of the quasar 3C 279 taken at 43 GHz frequency with the VLBI interferometer at a frequency of 43 GHz. The number to the left of the each image represents the year. The sequence shows that knots of plasma in the innermost jet are propagating away from the central core at very fast speeds, close to the speed of light.*

Prof. Tereasa Brainerd investigated the weak lensing properties of massive clusters of galaxies in a Lambda-CDM universe in order to determine the degree to which substructure in clusters at moderate to high redshift affects weak lensing estimates of the total cluster mass. Using direct raytracing techniques, we find that the substantial amounts of substructure in the cluster lenses make relatively little difference to the tangential shear profiles (i.e., compared to a smooth lens). In particular, on scales larger than about 200 kpc, the shear profiles are well-fitted by standard NFW models. However, the virial radii and concentration parameters that are inferred from analyses of the weak lensing signal differ somewhat from the expectations of the NFW theory. The weak lensing analysis leads to cluster mass estimates that are generally within 15% of the true cluster masses (68% confidence bounds), where the variance is caused by projection effects.

Prof. Brainerd also used the July 2003, full data release of the Two Degree Field Galaxy Redshift Survey (2dFGRS) to investigate the velocity dispersion of satellite galaxies about large host galaxies. In good agreement with the expectations of the Cold Dark Matter model, we find clear evidence for a decrease in the velocity dispersion of satellite galaxies as a function of projected radius from the host. When "host" and "satellite" galaxies are selected from a Lambda-CDM simulation in a manner that is identical to that used for the 2dFGRS, we find a remarkable agreement between the dynamics of the simulated galaxies and the real galaxies. In particular, the amplitude and shape of the velocity dispersion profiles are nearly indistinguishable. Further, we find clear differences between the dynamics of satellites that surround early-type hosts and those that surround late-type hosts. The amplitude of the velocity dispersion profile is much higher for satellites of early-type hosts than it is for satellites of late-type hosts, and the slope of the velocity dispersion profile is much steeper for satellites of early-type hosts than it is for satellites of late-type hosts. Finally, we find that the velocity dispersion of satellites with projected radii < 120 kpc scales with the luminosity as the square root of L. This is steeper than what would be expected based on the Tully-Fisher or Faber-Jackson law, but it is consistent with the predictions of a Lambda-CDM universe.

The stellar group consists of Prof. Janes and graduate student Melissa Hayes-Gehrke, who finished her PhD dissertation in April on the subject of stellar activity (i.e., starspots and related phenomena) in old open cluster stars. Although it is generally accepted that activity in stars declines with the age of the star, we cannot directly measure the age of an individual star; hence the age-activity relation is at best indirectly known. Activity is well-established in young cluster stars, up to the age of the Hyades (about 700 Myr), and of course we know the activity level of the Sun, at an age of 4.7 Gy. We know that the Sun varies by about 0.1% (about 0.001 magnitude,or one millimag) over the solar cycle, and about 2-3 times that much with the passage of large spots. But we do not know whether the Sun is typical for stars its age, and for that matter, we do not know whether our instant in history is typical of the Sun's long-term behavior.

To explore these issues, Janes and Hayes-Gehrke have been following several old open clusters, whose ages can be directly determined. For the past 8 years we have been monitoring several old open clusters, to search for low-amplitude variability resulting from activity cycles in the cluster stars. They have just submitted a paper to the Astronomical Journal (Hayes-Gehrke, Janes and Yoss, 2004) which demonstrates that many, if not most, of the stars in the youngest of our old open clusters, NGC 7789, (age about 1.6 Gyr) are indeed variable on a variety of timescales, in a manner consistent with the activity that can be found in many nearby field stars. Preliminary results for the other clusters show that activity is ubiquitous in clusters up to the age of the Sun, but in the oldest cluster in the sample, NGC 188, there are essentially no signs of activity. Because the activity level in M67 stars (the cluster nearest the Sun in age) is higher than that in the

Sun, either the Sun is an unusually quiet star, or we are seeing it at an unusual moment in it history.

Professor Thomas Bania (on sabbatical leave during the Spring 2003 semester), along with collaborators Prof. Rood at Virginia and Dr. Balser at NRAO (and formerly of Boston University), are engaged in a long-term project to measure the abundance of the rare 3-helium isotope via observations of its radio spin-flip transition. Because 3-helium was produced in the very early Universe, its abundance provides key cosmological constraints. Bania used the new NRAO Green Bank telescope (GBT) and the recently upgraded Arecibo telescope to continue his long-standing, NSF supported, 3-helium research program.

In 2004 the National Astronomy and Ionospheric Center (NAIC) will begin to operate a new state-of-the-art instrument, the Arecibo L-band Feed Array (ALFA), at its Arecibo Observatory in Puerto Rico. The ALFA instrument will revolutionize Arecibo's ability to map the skies rapidly and with unprecedented sensitivity. During his sabbatical Professor Bania assumed a leadership role in the formation of an international, multi-institution consortium that will use ALFA to conduct a wide range of research programs to study our own Milky Way Galaxy. This GALFA consortium has had two workshops and has produced a report to NAIC that describes the scientific goals and the logistical requirements. Professor Bania is a co-author of this document and he hosted the second GALFA workshop at Boston University in June, 2003. Over 50 scientists from 12 countries attended.

The Galactic Ring Survey (GRS) is a multi-year effort, led by Prof. James Jackson, to map the distribution of the ^{13}CO molecular line in the inner part of the Milky Way galaxy. The GRS team includes Profs. Bania and Clemens, Research Associates Dr. Rathborne and Dr. Shah, graduate students Anderson, Chambers, and Johnson, undergraduates Dormody, Lavoie, and Martin, and collaborator Dr. Mark Heyer at the Five College Radio Astronomy Observatory. Last year, the GRS covered over 16 square degrees, bringing the total area mapped up to 58 square degrees. Observations for the GRS will be completed in the 2004/2005 season.

BU investigators Clemens, Bania, and Jackson participate in the GLIMPSE Legacy-class project on the Spitzer Space Telescope. They were thrilled by the successful launch of the Spitzer observatory in August of 2003. Spitzer is the last of the great observatories, and the most capable infrared telescope launched to date. It will revolutionize our understanding of the cosmos through conducting deep areal surveys, pointed observations, and spectroscopy. The first GLIMPSE data collected by Spitzer in December were rapidly analyzed by the BU team (graduate student Emily Mercer and Profs. Clemens, Jackson, and Bania) to produce one of three GLIMPSE team articles in a special edition of the Astrophysical Journal devoted to first observations by the Spitzer Space Telescope. Those papers are due to be published this September.

Our BU GLIMPSE team has also worked on GLIMPSE data and publications that resulted in a NASA press release and three submitted peer-reviewed articles. These cover the nature of star formation in the RCW49 molecular cloud as well as the best determination of the nature of infrared extinction by dust performed to date. All of these publications resulted from the earliest, small portions of the GLIMPSE data collection that took place in the December to February time periods. Larger, more complete GLIMPSE data collection periods by the Spitzer Space Telescope have taken place and will continue to do so over the upcoming year. The complete data set of the GLIMPSE survey of the galactic plane are being publicly released as quickly as they are obtained, in order to aid the astronomical community in extracting the maximum science from the Spitzer mission. Our BU team is taking lead responsibility for science investigations into the structure of the Milky Way and the nature of star formation in the inner galaxy.

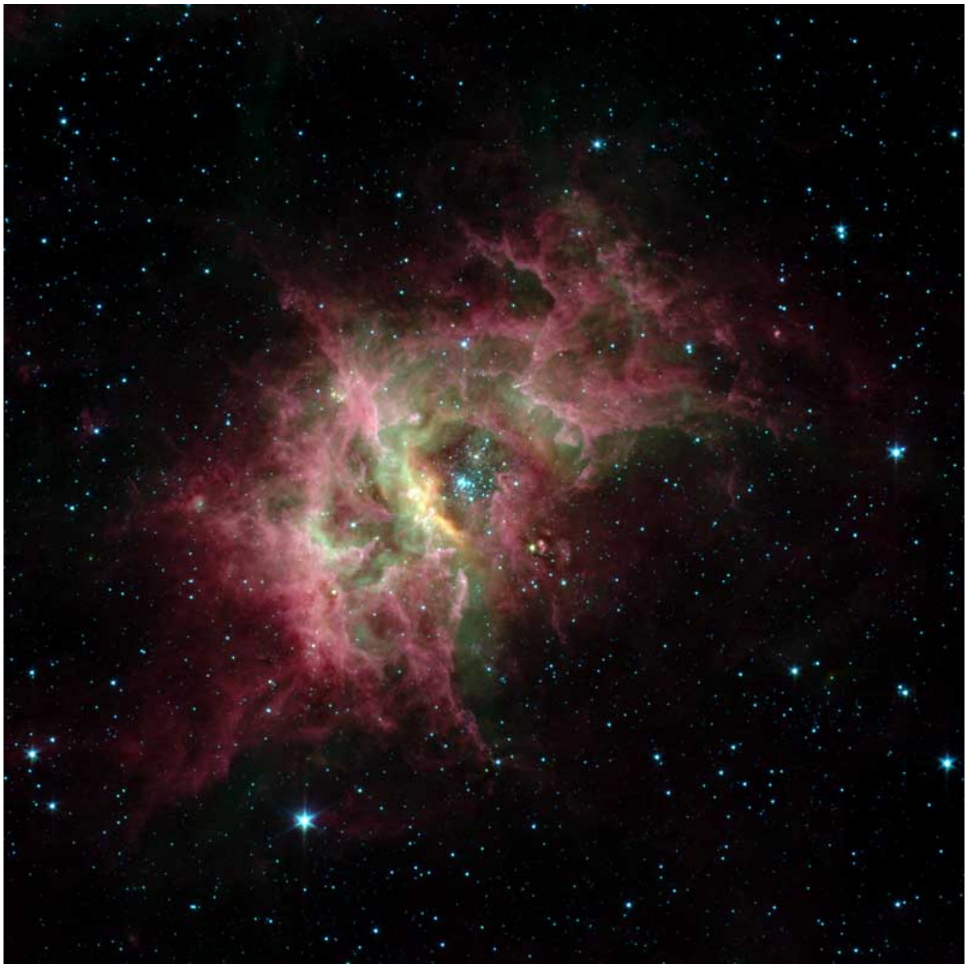


Figure 6. *The RCW49 star-forming cloud, as imaged at infrared wavelengths by the Spitzer space telescope. IAR astronomers are participating in the GLIMPSE survey, for which this image is taken. The false-color image shows that the central star cluster is illuminating and carving a cavity into the surrounding gas, and that many more planetary systems than expected are forming in this region.*

Seminar Series

The IAR Astrophysics Seminar Series on Tuesday afternoons brings external astrophysicists from the local area as well as from across the nation to Boston University to present their recent work and to consult with IAR faculty and students. During the past year, the IAR sponsored seminars by nineteen astrophysicists from across the nation. Students prepare for upcoming seminars through the Astrophysics Journal Club, which meets Friday afternoons. The seminar schedule is shown in Appendix B.

Future Activities

During the upcoming year, we will continue the Perkins telescope partnership with Lowell Observatory. MIRSI will continue to be deployed to the Infrared Telescope Facility, and Mimir and PRISM will be operating at the Perkins telescope. For the first time, IAR astronomers will have guaranteed access to a suite of state-of-the-art optical and infrared instruments. These instruments will greatly improve the quantity, quality, and stature of our scientific publications in the next few years.

We will continue to promote the Antarctic Infrared Observatory project as our first priority for a new telescope facility. We applaud University efforts to secure private funds to help develop AIRO.

As our new instruments and telescopes (MIRSI, Mimir, PRISM, and AIRO) come become productive, we need to position ourselves to make the new discoveries that these unique capabilities will make possible. The IAR is actively seeking funds for collaborative efforts to manage and improve IAR facilities. We are especially interested in improving the seeing characteristics of the Lowell Observatory. We have also entered into a long-term agreement with the IRTF to continue MIRSI's use there for the next several years.

We are pleased to announce that a new IAR faculty member, Dr. Elizabeth Blanton, will be joining us in August 2005. Prof. Blanton, an expert in galaxy clusters, uses radio, optical, and X-ray observations to understand the gas between cluster galaxies. She brings an exciting extragalactic research program that will certainly strengthen the IAR.

Appendix A: Publications

Articles in Referred Journals

Benjamin, R. A., Churchwell, E., Babler, B. L., Bania, T. M., Clemens, D. P., Cohen, M., Dickey, J. M., Indebetouw, R., Jackson, J. M., Kobulnicky, H. A., Lazarian, A., Marston, A. P., Mathis, J. S., Meade, M. R., Seager, S., Stolovy, S. R., Watson, C., Whitney, B. A., Wolff, M. J., & Wolfire, M. G., "GLIMPSE. I. An SIRTF Legacy Project to Map the Inner Galaxy", Publications of the Astronomical Society of the Pacific v. 115, P.953-964 (2003)

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Bottcher, M., Marscher, A.P., Ravasio, M. et al. "Coordinated Multiwavelength Observations of BL Lac in 2000", ApJ, 596, 847-859 (2003)

Boumlttcher, M., et al., "Coordinated Multiwavelength Observations of BL Lacertae in 2000", Astrophysical Journal v. 596, P.847-859 (2003)

Brainerd, T. G. & Specian, M. A., "Mass-to-Light Ratios of 2dF Galaxies", Astrophysical Journal v. 593, P.L7-L10 (2003)

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Hodge, T. M., Kraemer, K. E., Price, S. D., & Walker, H. J., "Classification of Spectra from the Infrared Space Observatory PHT-S Database", Astrophysical Journal Supplement Series v. 151, P.299-312 (2004)

Hutchison, K. D. & Jackson, J. M., "Cloud detection over desert regions using the 412 nanometer MODIS channel", Geophysical Research Letters v. 30, P.2-1 (2003)

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Appendix B: Seminar Series Schedules

Institute for Astrophysical Research Seminar Series
Fall 2003

Sept. 8	F. Peter Schloerb (FCRAO/Univ. of Mass.–Amherst) "The Large Millimeter Telescope"
Sept. 15	Jim Jackson (IAR) "The Galactic Ring Survey"
Sept. 25	Leslie Sage (*Nature*) "How to Get Published in *Nature*"
Sept. 29	Tom Bania (IAR) "The He3 Project"
Oct. 14	Dan Clemens (IAR) "The Mimir Instrument: Science, Capabilities & Status"
Nov. 10	James Moran (Harvard-Smithsonian CFA) "First Scientific Results with the Submillimeter Array"
Nov. 17	Ronak Shah (IAR) "The Boston University-Five College Radio Astronomy Observatory Galactic Ring Survey: ^{13}CO Survey of the Inner Galaxy"
Dec. 1	Jessica Rosenburg (Univ. of Colorado) "The Connections Between Galaxies & the Intergalactic Medium"
Dec. 8	Tereasa Brainerd, (IAR) "Mass-to-Light Ratios of Galaxies in the Two Degree Field Redshift Survey (2dFGRS)"
Dec. 15	Rafael Guzman (Univ. of Fl) "A Multiwavelength Survey of Luminous Compact Blue Calaxies from z =3 to z = 0"

Institute for Astrophysical Research Seminar Series
Spring 2004

Jan. 13 Alan Marscher (IAR)
"Relativistic Jets in Blazars: Tales of Multiwaveband Variability"

Jan. 20 Svetlana Jorstad (IAR)
"Extended X-Ray/ Radio Jets in Quasars"

Jan. 27 Herman Marshall (MIT)
"X-ray Imaging and Spectroscopy of Relativistic Jets from Black Holes"

Feb. 3 Dimitar Sasselov (Harvard/CfA)
"The Exoplanet OGLE-TR-56b: Small Orbit, Large Radius"

Feb. 10 Ken Janes (IAR)
"Stellar Activity and Other PRISM Science"

Feb. 27 Richard Binzel (MIT)
"Asteroids Come of Age"

Mar. 2 Deepto Chakrabarty (MIT)
"Clocking Millisecond X-Ray Pulsars: A Speed Limit for the Fastest Spinning Stars in the Universe"

Mar. 16 Sally Oey (Lowell Observatory)
"Consequences of Massive Star Feedback in Star-Forming Galaxies"

Mar. 23 Amanda Bosh (IAR/Lowell Observatory)
"Planetary Rings: Saturn and Uranus"

Mar. 30 Stephen Levine (US Naval Observatory)
"Asymmetric Galaxies and a Look at the LMC"

Apr. 6 Don Backer (UC Berkeley)
"Observations and Model of the PSRJ0737-3039 Double Pulsar System

Apr. 13 Ben Lane (MIT)
"High-precision astrometry for finding planets"

Apr. 26 Lisa Prato (UCLA)
"Young Low-mass Star & Brown Dwarf Binaries: Dynamical Mass Ratios and Masses"

Apr. 27. Lynn Matthews (CfA)
"Extraplanar Gas in Low Surface Brightness Galaxies"

May 3 Christopher Conselice (Calif. Inst. of Technology)
"Galaxy Formation: Stars, Dark Matter and Morphology"

May 6 Elizabeth Blanton (U. Virginia)
"Radio Sources in Clusters of Galaxies: Impact On the X-ray-Emitting ICM and Probes of High-z Systems"