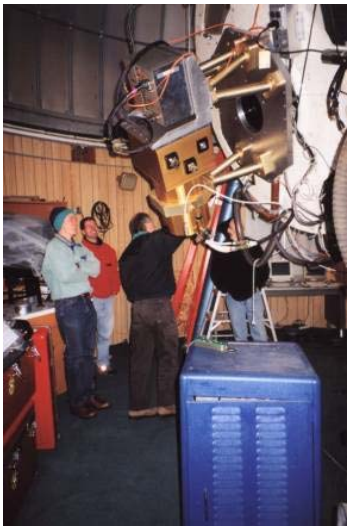
The PRISM optical spectrograph is nearly complete. Here MIT professor James Elliot is seen with the instrument.
An "first light" image from MIRSI's commissioning run at Mt. Lemmon, showing the Moon from the lunar surface.

Boston University
Institute for Astrophysical Research
Annual Report
August 2002



The IAR's MIRSI mid-infrared camera achieves first light.

James M. Jackson, Acting Director
Kimberly Paci, Fiscal Administrator

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Summary

The Institute for Astrophysical Research marked a very successful 4th year in its mission to foster research in astrophysics at Boston University. Three instrumentation projects: MIRSI (the Mid-InfraRed Spectrometer and Imager), Mimir (named after a Norse god), and PRISM (the Perkins ReImaging SysteM) are underway. MIRSI, a new mid-infrared camera built under the direction of Prof. Lynne Deutsch, passed its "first light" milestone in December 2001 on the Mt. Lemmon Observing Facility. Mimir, a 2 – 5 mm infrared imager, spectrometer, and polarimeter being built by PI Dan Clemens, Eric Tollestrup, and Domenic Sarcia, is nearly complete and will have its first run on the Perkins telescope at Lowell Observatory in Fall 2002. PRISM, a wide-field optical imaging spectrograph (PI: Prof. Kenneth Janes), is also near completion, with an anticipated first run in Fall 2002. Two scientific papers from the Institute were published in *Nature*: "The Cosmological Density of Baryons from Observations of 3-He^+ in the Milky Way" by T.M. Bania, R.T. Rood, and D.M. Balser, and "Observational Evidence for the Accretion-Disk Origin for a Radio Jet in an Active Galaxy" by A.P. Marscher *et al*. The Institute hosted an international workshop, "Infrared Astronomy from Antarctica," in March 2002.

The IAR continues a vigorous research program. Ten new funding proposals totaling about $2,000,000 in requests were submitted by IAR members, and three new awards totaling $261,556 were made. Including these new awards, a total of 27 grants amounting to a total of $1,010,004 in funding were administered by the IAR.

Our partnership with Lowell Observatory continues to be successful, and Mimir's and PRISM's deployment on the Perkins 72 inch telescope at Lowell this fall will represent a major upgrade in IAR facilities.

The IAR Advisory Board met on January 28 and 29, 2002 to review the institute's progress. In May 2002 the IAR members held a very successful retreat in Falmouth, Massachusetts.

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 involved in astrophysical research. Faculty members included Professors Alan Marscher, Thomas Bania, James Jackson, and Kenneth Janes, Associate Professors Dan Clemens and Tereasa Brainerd, and Assistant Professor Lynne Deutsch. Research Associates affiliated with the IAR included Senior Research Associates Drs. Svetlana Jorstad and Eric Tollestrup, Research Associates Drs. Robert Simon, Joseph Adams and Ronak Shah, Research Fellow Dr. Kathleen Kraemer, and Senior Mechanical Engineer Domenic Sarcia. IAR staff members included Senior Research Associate Dr. Amanda Bosh, stationed in Flagstaff, Arizona at the Lowell Observatory site on Mars Hill, and IAR Fiscal Administrator Ms. Kimberly Paci.

Professor Brainerd was promoted in August 2001 from Assistant to tenured Associate Professor of Astronomy.

Professor Jackson was promoted in January 2002 from Associate Professor to full Professor.

Professor Clemens will be promoted on September 1, 2002 from Associate Professor to full Professor.

Graduate students conducting astrophysical research with IAR faculty during the past year included Dr. Candace Wright, Ms. Melissa Hayes-Gehrke, Mr. Marc Kassis, Mr. Andrei Sokolov, Mr. Michal Kolpak, and Ms. Alexis Johnson. Undergraduate students working within the IAR included Ms. Emily Flynn, Mr. Todd Veach, Mr. Kris Makrides, Mr. Michael Specian and Mr. Ori Fox.

Dr. Candace Wright defended her PhD dissertation, entitled "Applications of Weak Gravitational Lensing: Constraining the Dark Matter in Clusters and Galaxies," and took up a postdoctoral position at Hanscom Air Force base. Dr. Wright is the institute's third PhD.

Dr. Amanda Bosh was hired as Senior Research Associate based at the Lowell Observatory in Flagstaff, Arizona, where she serves as the liaison between Lowell and the IAR. She takes over from Dr. John Noble, who left the position in October 2001 to take another position at Lowell.

During the past year, Professor Deutsch has been on leave of absence at the Harvard-Smithsonian Center for Astrophysics working with the team that developed the IRAC (Infrared Array Camera) for the SIRTF (Space InfraRed Telescope Facility) mission.

Professor Brainerd was on sabbatical during the entire academic year. Professor Janes was on sabbatical for Fall 2001. Professor Clemens, the IAR director, was on sabbatical for the 2002 Spring semester and will continue his sabbatical in the 2002 Fall semester. From June to December 2002, Prof. Jackson will serve as the IAR's Acting Director.

Scientific Highlights

Over the past year IAR members published a number of significant scientific papers. Two of these, published in *Nature*, are particularly noteworthy. The first, "The Cosmological Density of Baryons from Observations of 3-He^+ in the Milky Way" by T.M. Bania, R.T. Rood, and D.M. Balser, uses observations of the radio spin-flip transition of the helium-3 ion to estimate the bayonic mass density in the early Universe. The standard cosmological theory makes specific predictions about the amount of 3-helium produced in the first few minutes after the Big Bang. These observations show that the observed amount of helium-3 strongly constrains the amount of normal matter in the Universe, and that this amount agrees well with the currently favored value. This paper was deemed so important that a commentary on it appeared in the prestigious "News and Views" section of *Nature*. The second paper, "Observational Evidence for the Accretion-Disk Origin for a Radio Jet in an Active Galaxy," by Marscher et al., establishes the first direct observational link between a supermassive black hole and its jet. The team established this link by monitoring the X-ray and radio emission from the active galaxy 3C120. The observations show that the accretion disk surrounding this supermassive black hole periodically collapse and emits radio-loud blobs into its jet.

In addition to these papers, IAR members have published 23 papers in refereed journals, 24 abstracts at conferences, and presented 17 invited talks. A complete list of all of last year's IAR publications and invited talks is presented in Appendix B.

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

The IAR instrument development program reached new heights in 2001/2002. One instrument (MIRSI) has been fabricated and tested; two are currently under development (Mimir and PRISM); and one loaned instrument (IRCAM) is partially supported by our efforts. This fall should see the first use of both Mimir and PRISM on the Perkins telescope. IRCAM, on loan from the Naval Observatory, is used as a facility instrument on the Perkins telescope.

MIRSI

Professor Lynne Deutsch's instrument MIRSI (Mid-InfraRed Spectrometer and Imager) is a state-of-the-art mid-infrared (8-26 microns wavelength) imager and spectrograph using a 240x320 pixel detector array. MIRSI had its "first light" on the Mount Lemmon Observing Facility in December 2001. The successful observing run demonstrated that the camera is working properly. Several mid-infrared images of Orion, Jupiter, and the Moon were obtained. MIRSI will be deployed to NASA's Infrared Telescope Facility (IRTF) in November for use by BU and outside scientists.

Mimir

The Mimir cryostat assembly is scrutinized by Eric Tollestrup.

Professor Clemens leads an IAR team including Dr. Tollestrup and Mr. Sarcia, in designing and fabricating the Mimir near-infrared (1-5 microns wavelength) imaging spectrometer and polarimeter for use on the Perkins 72" telescope. This project is co-lead by Dr. Marc Buie at Lowell Observatory. During the past year, the IAR team designed and fabricated the filter wheel and other mechanical mechanisms. The 1024x1024 InSb array is purchased and will be accepted this summer. Mimir's optical design is complete and lenses are being ordered and installed. In Fall 2002, Mimir will be integrated, tested, and delivered to Lowell Observatory. Professor Clemens will accompany Mimir to Arizona and will take part in testing and installation at the Perkins telescope. Once commissioned, Mimir will remain at the Perkins telescope for general use. Because Mimir will greatly eclipse IRCAM's performance, we plan to return IRCAM to USNO once Mimir is commissioned on the Perkins.

To visit the Mimir site, click here.

PRISM

Professor Ken Janes, along with Domenic Sarcia and graduate student Melissa Hayes-Gehrke, has designed and partially fabricated the PRISM (Perkins ReImaging SysteM) wide-field optical (0.3-1 microns wavelength) imaging spectrograph for use on the Perkins telescope. Mechanical fabrications are underway at Boston University's Scientific Instrument Facility. The PRISM cryostat has been assembled, its optics have been designed and ordered, and final fabrication and testing should be complete in late summer. PRISM is expected to arrive for testing and commissioning at the Perkins telescope in the fall of 2002. It will join Mimir as an IAR instrument available for routine use by all Lowell Observatory, BU, and outside collaborative scientists.

To visit the PRISM site, click here.

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/Lowell partnership is entering the final year of its initial five-year agreement. The IAR considers a renewal of this partnership an absolute necessity for the success of the IAR's instrumentation program.

Dr. Amanda Bosh was hired as a Senior Research Associate to be the IAR's representative at Lowell University. Dr. Bosh has many years experience using the Lowell facilities and comes with a strong research record in planetary astronomy. In the past year, she has contributed significantly to the testing of Lowell's LOIS telescope operations software.

The Antarctic Infrared Observatory (AIRO)

Professor 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 initially equipped with a 2-color (K and L band), wide-field imaging survey 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 efficient, relentless observing of large fields of view. The thermal infrared spectrum, from 2.4 to 5 microns wavelength, provides a unique window on very low-mass stars (brown dwarfs), protoplanetary disks, very old stars, and the star-forming Universe. The AIRO team includes members from both Boston University and Lowell Observatory.

Significant NSF support ($100,000) for the AIRO design and for the "Infrared Astronomy from Antarctica" workshop was awarded to Boston University from the NSF via CARA (the Center for Astrophysics Research in Antarctica).

Professor Jackson briefed the NSF Office of Polar Programs on the AIRO project in Washington on May 2, 2002.

The IAR supports AIRO as its top priority among potential new projects.

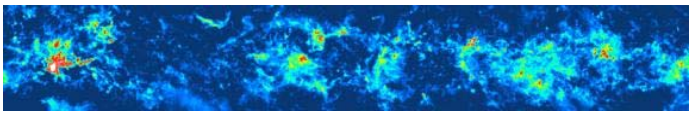
Scientific Programs

In addition to instrument development, the IAR hosts a number of scientific programs. Prof. Marscher, Dr. Jorstad, and graduate student Sokolov form a vigorous team studying blazers, especially through time-variability studies at radio, optical, and X-ray wavelengths. Their *Nature* paper has been described above.

Prof. Bania, 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. Their *Nature* paper has also been described above.

Prof. Brainerd, along with her recently-graduated PhD student Candace Oaxaca Wright, are studying the weak lensing of distant galaxies by more nearby galaxies. The cause of this phenomenon is the gravitational deflection of light by the massive dark matter halos which surround the foreground galaxies. Their work on this so-called "galaxy-galaxy" lensing has shown that if normal galaxies have flattened dark matter halos, there will be a measurable anisotropy in the lensing signal. They have also shown that there will be a marked correlation in the final image shapes of lens-source pairs which are separated in redshift by $\Delta z < 0.5$. This is due to multiple weak lensing events caused by foreground galaxies, and this effect must be taken into account in order to interpret galaxy-galaxy lensing signals correctly.

The Galactic Ring Survey (GRS) is a multi-year effort to map the distribution of the ^{13}CO molecular line in the inner part of the Milky Way galaxy. Prof. Jackson leads the GRS in collaboration with Profs. Bania and Clemens, post-docs Dr. Simon and Dr. Shah, graduate students Johnson and Kolpak, undergraduates Fox, Veach, Flynn, and Nero, and collaborator Dr. Mark Heyer at the Five College Radio Astronomy Observatory. With the implementation of 16 new pixels in the FCRAO SEQUOIA receiver, the "on-the-fly" mapping scheme, and a new correlator system with twice the bandwidth, the GRS has improved its mapping speed over previous years by about an order of magnitude. Last year, the GRS covered over 11.5 square degrees, bringing the total area mapped up to 31.4 square degrees. The GRS passed a significant milestone in mapping a complete strip along the Galactic plane from a longitude of 15 to 52 degrees.

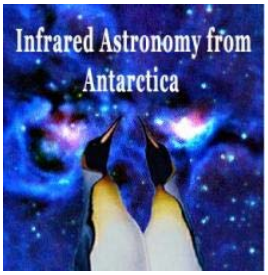


An image of ^{13}CO emission along the Galactic plane from the BU-FCRAO Galactic Ring Survey reveals star-forming molecular clouds in the inner Milky Way galaxy. The image

covers ~16 square degrees of the Galactic Plane from 40 to 51 degrees in galactic longitude and -1 to 0.5 degrees in latitude.

"Infrared Astronomy from Antarctica" Workshop

On March 5 and 6, 2002, the IAR hosted the workshop "Infrared Astronomy from Antarctica." Fifty-six astronomers from 5 continents attended the meeting, which presented the scientific and technical case for a 2-meter class telescope on the Antarctic Plateau. Because of the extreme cold there, such a telescope would have an enormous advantage in sensitivity due to the extraordinarily low thermal backgrounds. The workshop members agreed that wide-field imaging in the thermal infrared from Antarctica would be an important new technique to study a number of diverse astrophysical phenomena, such as brown dwarfs, protoplanetary disks, star-forming regions, and evolved stars. The conferees heartily endorsed the construction of a new Antarctic infrared telescope. See http://www.bu.edu/irafa for details.



Seminar Series

The IAR Astrophysics Seminar Series on Monday 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 24 astrophysicists. Student preparation for upcoming seminars is through the Astrophysics Journal Club, which meets Wednesday afternoons. The seminar schedule is shown in Appendix A.

IAR Advisory Board

The Advisory Board consists of Professor Robert Gherz of the University of Minnesota, Professor H. Richard Miller of Georgia State University, Dr. Charles Lada of the Harvard-Smithsonian Center for Astrophysics, Associate Dean W. Scott Whitaker, and Astronomy Department Chairman Professor W. Jeffrey Hughes. The Board provides advice to the IAR Director and the Dean of the College of Arts and Sciences regarding the execution of the institute's programs and fulfillment of its mission. The Council met on January 28 and 29, 2002 and issued a report to the dean that listed suggestions to foster the institute's progress.

IAR Retreat

On May 4 and 5, 2002, the institute held a retreat on Cape Cod in Falmouth, Massachusetts. The nine senior members of the institute discussed the IAR's goals, both individually and collectively. The retreat re-invigorated the membership, and a consensus was reached about the IAR's short- and medium-term priorities.

Future Activities

During the upcoming year, we will continue the Perkins telescope partnership with Lowell Observatory. We will deploy MIRSI to the Infrared Telescope Facility, and Mimir and PRISM to the Perkins telescope. These instruments will no doubt increase the quantity, quality, and stature of our scientific publications over the next few years.

We will carry out negotiations with Lowell Observatory to develop an MOU to renew our partnership of the Perkins telescope and instrumentation for a second five-year period.

We are planning to hold an IAR-hosted scientific topical meeting on Galactic surveys in July 2003. This meeting will highlight new data from the SIRTF Legacy-class GLIMPSE project (PI: Ed Churchwell, Wisconsin), on which several IAR members participate, and the Galactic Ring Survey.

We will continue to promote the Antarctic Infrared Observatory project as our first priority for a new telescope facility.

As our new instruments and telescopes (MIRSI, IRCAM, Mimir, PRISM, and AIRO) come on-line in the next few years, we need to be positioned to make the new discoveries these unique capabilities will provide. However, as our instrumentation programs have grown and prospered, we have fewer faculty devoted to observing and analysis. A new, young astrophysicist who will utilize our instruments and telescopes to conduct front-line research and discoveries is needed to secure our rise in scientific stature. That person should be sought and hired over the next 1-3 years.

When AIRO comes on line, we will be poised to build new infrared instruments, and to seek out even larger, more sophisticated telescope and instrument opportunities. Several initiatives, such as the Lowell Next Generation Telescope and the Cornell large infrared telescope, are actively under consideration.

Appendix A: Seminar Series Schedules

Institute for Astrophysical Research Seminar Series
Fall 2001

September 24	Charles Lada	Harvard-Smithsonian Center for Astrophysics	*Seeing Through the Dark: Infrared Extinction, The Nature of Dark Clouds*
October 1	Jerry Sellwood	Rutgers University	*Maximum Disks and Their Implications*
October 15	Michael Pahre	Harvard-Smithsonian Center for Astrophysics	*The Luminosity, Velocity and Mass Functions of Galaxies*
October 22	Butler Burton	University of Leiden and National Radio Astronomy Observatory	*The Continuing Enigma of the High-Velocity Clouds*
October 29	Frank Bash	University of Texas	*The Hobby-Eberly Telescope, The South African Large Telescope, The Extremely Large Telescope and the Large Atacama Telescope*
November 5	Mark Reid	Harvard-Smithsonian Center for Astrophysics	*What Lurks at the Galactic Center*
November 20	Alan Tokunaga	University of Hawaii Institute for Astronomy	*Construction of a Facility Instrument for the 8.2-m Subaru Telescope and Some Recent Results*
December 3	John Huchra	Harvard-Smithsonian Center for Astrophysics	*Two Extragalactic Globular Cluster Systems*

Institute for Astophysical Research Seminar Series
Spring 2002

February 4	Larry Marshall	Gettysburg College	*The EVO: A Virtual Educational Observatory*
February 25	John Arabadjis	MIT	*Marco Polo and Galaxy Clusters: Stalking Dark Matter*
March 25	Richard French	Wellesley College	*Space Telescope Images of Rings of Saturn*
April 1	Bruce Carney	University of North Carolina	*Why Do Some Halo Red Giants Rotate Rapidly? Is It Something They Ate?*
April 8	Wes Lockwood	Lowell Observatory	*Sunspots, Starspots, Tomorrow's Weather*
April 17	Mordecai-Mark Mac Low	American Museum of Natural History	*Central Star Formation by Supersonic Turbulence*
April 22	Neal Evans	University of Texas, Austin	*From Molecular Cores to Planet-forming Disks with SIRTF*
April 29	Letizia Stanghellini	Space Telescope Institute	*Planetary Nebulae in the Magellanic Clouds*

Appendix B: Publications, Etc.

Articles in Refereed Journals

Agudo, I., Gomez, J.L., Marti, J.M., Ibanez, J.M., Marscher, A.P., Alberdi, A., & Hardee, P.E., "Jet Stability and the Generation of Superluminal and Stationary Components", 2001, Astrophysical Journal Letters, 549, L183-186.

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"Dust Characteristics of Massive Star-forming Sites in the Mid-Infrared",
2001, Astrophysical Journal, 561, 282.

Marengo, M., Karovska, M., Fazio, G.G., Hora, J.L., Hoffmann, W.F., Dayal, A., and Deutsch, L.K., "Mid-Infrared Observations of the Mira Circumstellar Environment", 2001, Astrophysical Journal Letters, 556, L47.

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Colloquium, MIT, Space Sciences, 12 Feb. 2002

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Jackson, J. M., "The Antarctic Infrared Observatory", Astrophysics at Dome Concordia, Hobart, Australia, June 28-29, 2001

Jackson, J. M., "The Galactic Ring Survey", Tufts University Astrophysics Lunch Talk, November 8, 2001

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Jorstad, S., "VLBI Images of Blazars", International Workshop on Blazar Astrophysics with BeppoSAX and Other Observatories, Frascati, Italy, 10-11 December 2001

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Marscher, A., "Relationship between X-ray Flares, Synchrotron Flares, and Ejections of Superluminal Components in Blazars", International Workshop on Blazar Astrophysics with BeppoSAX and Other Observatories, Frascati, Italy, 10-11 December 2001

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