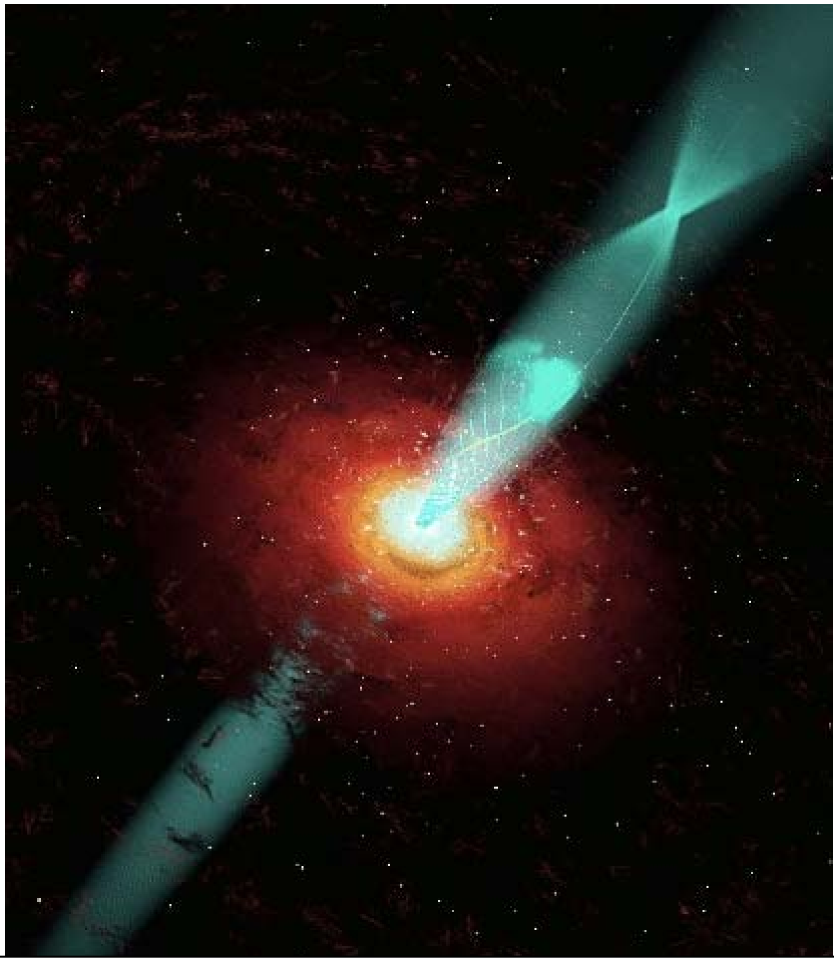
Boston University
Institute for Astrophysical Research
Annual Report
June 2008



A still frame at high resolution from a movie of the inner region of an active galaxy. The image is a conceptual interpretation of data and shows a disk of material that is being accreted by a supermassive black hole, as well as powerful jets that are collimated and accelerated by a twisted magnetic field. The movie was made by Cosmovision, a group led by Dr. Wolfgang Steffen of the Instituto de Astronomia (UNAM) in Ensenada, Mexico.

Tereasa Brainerd, Director
Kimberly Paci, Administrator

Table of Contents

Introduction 3
- Summary 3
- Institute Mission 3
- Faculty, Staff and Students 3

Science Highlights 4
- Black Holes at the Centers of Blazars 4
- Infrared Dark Clouds and the Births of High-Mass Stars 6

Instrumentation Program 7
- Mimir 7
- PRISM 8
- MIRSI 9

Science Programs 10

Lowell Observatory Partnership 21
- PREST 22
- Impact on Education 23
- Impact on Research and Instrumentation Programs 24
- Funding for Instrumentation and Science at the Perkins Telescope 26

IAR Advisory Board Review 26

Future Activities 26

Seminar Series 29

Appendices 35
- Appendix A: Publications and Presentations 35
  - Articles in Refereed Journals 35
  - Professional Seminars, Colloquia and Conference Talks 37
  - Conference Proceedings, Abstracts and Poster Papers 38
  - Electronic Publications 42

- Appendix B: Seminar Series Schedules 43

Introduction

Summary

The Institute for Astrophysical Research marked a successful 10th year in its mission to foster research at Boston University. All of our state-of-the-art astronomical instruments (Mimir and PRISM at Lowell Observatory, and MIRSI at NASA's Infrared Telescope Facility) continue to operate well and are returning exciting science results.

The IAR continues its vigorous research program. In the past year, IAR members published sixteen scientific papers in refereed journals, including one paper in the prestigious journal Nature. Among our scientific highlights for the year are: (1) a report of strong observational evidence in support of the idea that the powerful jets associated with active galaxies originate with twisted magnetic fields nearby to supermassive black holes and (2) the discovery that all infrared dark clouds contain protostellar corses that will eventually form massive stars.

In FY2008, total IAR grant expenditures, including new and continuing grants, was $1.16M. IAR members submitted twenty one new funding proposals totaling over $3.1M in requests. The IAR received a total of $1.14M in grant income, including fourteen new awards totaling $775,028.

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 within 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

In FY2008, IAR members included Professors Thomas Bania, Dan Clemens, James Jackson, Kenneth Janes, and Alan Marscher, Associate Professor Tereasa Brainerd, Assistant Professor Elizabeth Blanton, and Senior Research Associate Dr. Svetlana Jorstad. Other personnel associated with the IAR included Research Associate Dr. Irena Stojimirovich, Research Fellow Dr. Kathleen Kraemer, Research Associate Brian Taylor (the IAR’s Telescope Support Scientist stationed in Flagstaff, Arizona at Lowell Observatory), Senior Research Associate Dr. Amanda Bosch, and IAR Fiscal Administrator Ms Kimberly Paci.

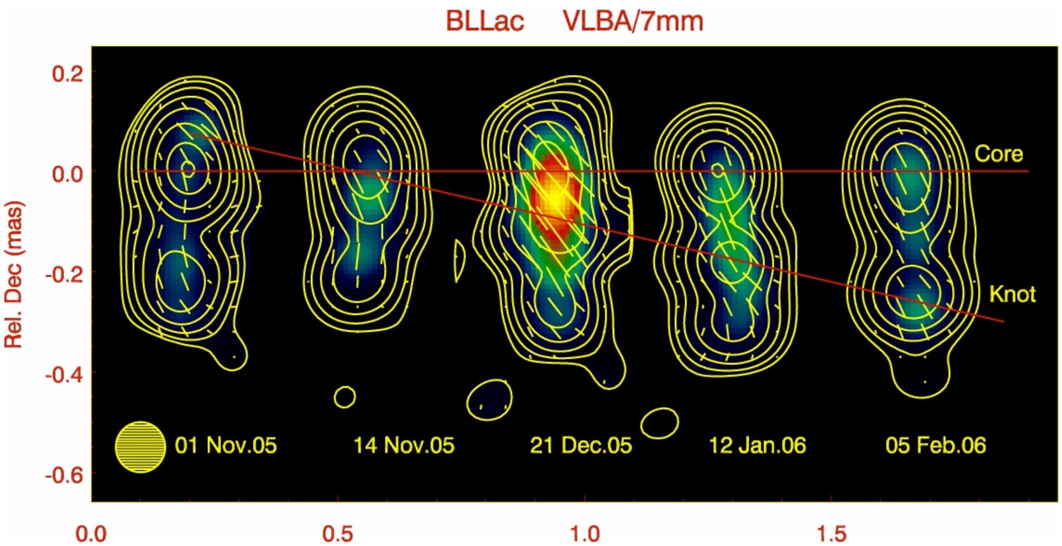
BU graduate students conducting astrophysical research with IAR members during the past year included Ingolfur Agustsson, Loren Anderson, Cara Battersby, Carol Carveth, Edward Chambers, Ritaban Chatterjee, Benjamin Chicka (STH Science & Religion MA student), Francesca D'Arcangelo, Edmund Douglass, Julia Duval, Susanna Finn, Paul

Howell, Ji Hyun Kim, Nicholas Lee, Neil Lender, Michael Pavel, April Pinnick, Joshua Wing, and Monica Young. BU undergraduate students working within the IAR included Jessica Donaldson, Sadia Hoq, Katherine Jameson, Anthony Lollo, Alice Olmstead, Catilin O'Nan, Mary MacDonald, Chad Madsen, and Julie Moreau.

Science Highlights

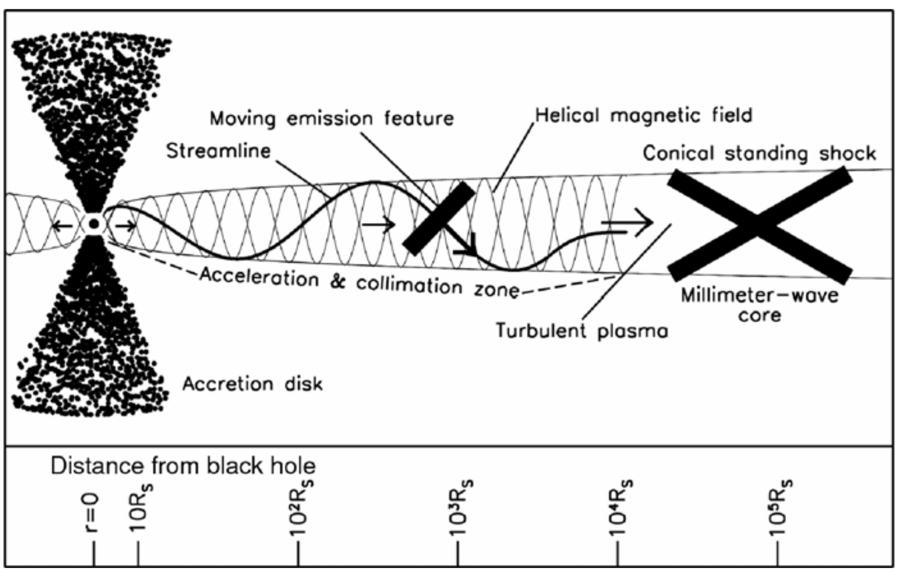
Black Holes at the Centers of Blazars

A holy grail of research in the field of active galaxies is the observation of phenomena that can directly test the hypothesis that accretion of material onto a supermassive black hole is responsible for the enormous amounts of energy that are produced by these objects. Blazars are the most extreme examples of active galactic nuclei, and they are the primary research topic being studied by the blazar research group at Boston University. The group is led by Professor Alan Marscher, and in April 2008 the group published a tremendously exciting paper in the prestigious journal Nature that shows direct observational evidence for the presence of a supermassive black hole at the center of the blazar known as BL Lacertae.



Sequence of Very Long Baseline Array images of the active galactic nucleus BL Lacertae. The angular resolution of 0.0001 arcseconds corresponds to about 0.4 light-years. The contours are in factors of 2 and correspond to total intensity, while the false colors indicate the polarized intensity. The yellow sticks are perpendicular to the magnetic field. In the first image, a new "knot" of emission, identified by its oblique polarization direction, appears upstream of the stationary core. In subsequent images, it moves southward (down) past the core at an apparent speed of 5 times that of light (an illusion caused by its motion at 98% the speed of light). The 2nd flare occurred as the disturbance passed through the core.

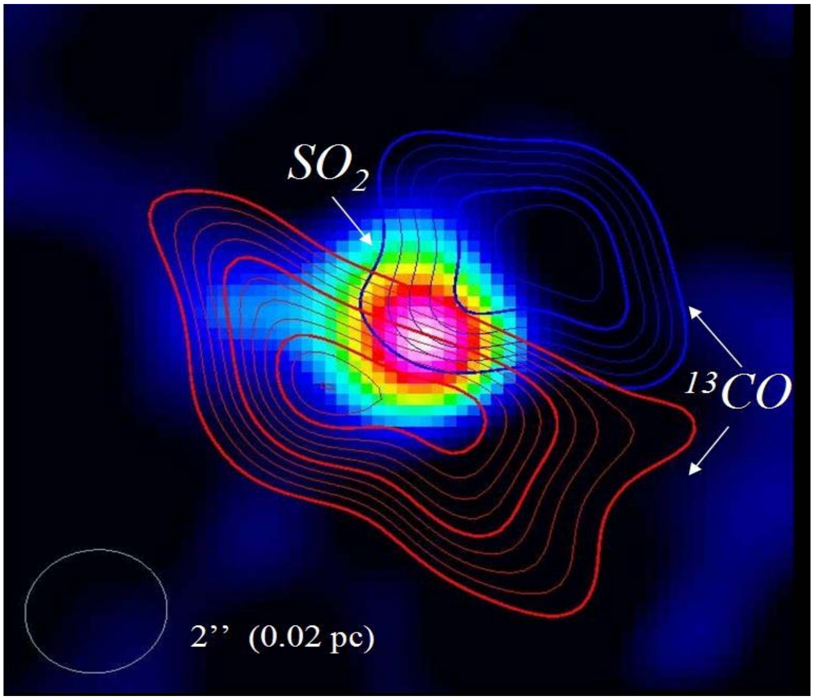
Oppositely-directed jets of plasma are observed to emanate from the centers of active galaxies at speeds very close to the speed of light. According to theory, the jets are propelled by tightly-twisted magnetic fields that collimate and accelerate the jet. Prior to the study done by the BU blazar group, however, it was not possible to test this theory of jet formation directly. In their Nature paper, the BU blazar group reports a series of high-resolution radio images and optical polarization measurements of a bright feature in a jet that caused a double flare of radiation. Optical flux density measurements of the double flare were obtained with a number of telescopes, including the 1.8 m Perkins telescope at Lowell Observatory. The BU blazar group concludes that the event started in a helical magnetic field, consistent with the collimation and acceleration zone that is present in standard theoretical models in which active galaxies are powered by accretion of material by supermassive black holes. These observations are the closest look yet at the inner regions of the jets of active galaxies, and the BU blazar group's work has made a significant impact on our understanding of the role of supermassive black holes in powering the jets.



Sketch of a relativistic plasma jet in an active galactic nucleus, based on the Marscher et al. (2008, Nature) observations of a double flare in BL Lacertae. The first flare occurred as the emission feature made its last loop in the acceleration and collimation zone. The second flare coincided with passage of the disturbance (by this time a moving shock wave) through the millimeter-wave core, which is modeled here as a standing recollimation "X-shaped" (nose-to-nose cones in three dimensions) shock system.

Infrared Dark Clouds and the Births of High-Mass Stars

Infrared dark clouds are cold, dense interstellar gas clouds that are identified as dark patches of obscuration against the bright emission from the Milky Way Galaxy at infrared wavelengths. Observations by Professor Jackson's research group, and others, have shown that infrared dark clouds host the very earliest stages of the formation of high-mass stars (i.e., stars that are at least 8 times more massive than the sun). In the past year, Professor Jackson's group found that all infrared dark clouds contain protostellar "cores", dense globs of molecular gas that will eventually spawn a star. About one third of these cores have already formed a young star, as evidenced by warm, compact embedded infrared sources revealed by the Spitzer Space Telescope. The remaining two thirds are probably "pre-protostellar" cores that have not yet formed a warm, young star. When the smallest scale molecular structures in these cores are observed, many of the cores are found to contain multiple young stars. This is expected since young stars tend to form in clusters. One of the high-mass stars observed by Professor Jackson's group shows evidence for a proto-planetary disk, which may be the first such disk found around a high-mass star.



An image of a young, high-mass protostar taken with the Submillimeter Array telescope at Mauna Kea, Hawaii. The central region shows emission from sulfur dioxide molecules (SO_2; white contours), which traces the warm, dense gas immediately surrounding the warm, young star. Surrounding the young star is a much more extended structure traced by emission from ^{13}CO molecules. This structure may well be a circumstellar disk that will eventually form planets. The eastern half is moving away from the earth (blue contours) and the western half toward the earth (red contours), exactly as expected for a rotating disk. The size of the disk is approximately 20,000 astronomical units, or roughly the size of the "Oort cloud" of comets that marks the extreme edges of our own solar system.

Instrumentation Program

IAR members have designed and built three state-of-the-art astronomical instruments to date: Mimir and PRISM which operate on the Perkins Telescope at Lowell Observatory, and MIRSI which operates on NASA's Infrared Telescope Facility in Hawaii. The combination of these instruments allows IAR astronomers to carry out investigations over wavelengths that span the optical, near-infrared, and mid-infrared regions of the electromagnetic spectrum.

Mimir

Mimir is a facility-class instrument for near infrared imaging, spectroscopy, and polarimetry. For the period of July 1, 2007 to June 30, 2008, Mimir was scheduled on the Perkins Telescope for a total of 88 nights, supporting seven distinct projects/groups.

Mimir continues to work well, although it did require some repairs over the past year. These included swapping out the refrigerator cold head, installation and integration of the new helium compressor, reworking of cryogenic interfaces, and minor internal repairs and tunings. These changes have allowed Mimir to remain cold and sealed for 245 days, besting its previous record by more than a factor of three and returning Mimir to a state of low-maintenance, continuous operation.

Brian Taylor completing installion of Mimir on the Perkins Telescope. The carrier cart is being wheeled away from the stainless steel cryostat; the electronics box is mounted in the upper left. The two metallic cables leaving the cryostat below the electronics are high-pressure helium lines that are part of the closed-cycle refrigeration system that keeps the optics and detector cold.

For the upcoming year, warm engineering work is scheduled for late July into early August 2008. This will include modifications to the telescope mounting ring at the front of Mimir to allow easier cold head replacement, removal of the internal liquid nitrogen ring, installation of the new "HK" spectroscopy filters, repairs to failed position and temperature sensors, cleaning and inspections of all moving parts, and other preventative maintenance. It is expected that after Mimir returns to cold service in early September 2008 it will then run continuously until July 2009.

In support of continuous operation, and in order to reduce risk to the expensive optics and detector in the event of a power failure, Professor Clemens and Brian Taylor are continuing their efforts to design and implement a backup power generation system for Mimir. This system would keep Mimir's cooling system working for up to 48 hours in the event that a snow storm or lightning storm interrupts power to the telescope.

Mimir is being used most extensively in support of Professor Clemens' GPIPS project (discussed in the Science Programs section). It has also been used recently for the BU blazar group's monitoring program, Professor Blanton's distant galaxy cluster discovery program, a study of interstellar bubbles by BU graduate student Mike Pavel, a study of two large molecular clouds by BU undergraduate student Katie Jameson, a study of galactic star clusters by BU graduate student April Pinnick, numerous Lowell science projects, as well as outside user groups' science. In addition, every spring semester undergraduate students enrolled in AS441 (Observational Astronomy) travel to Lowell Observatory to obtain data with Mimir as part of their course work.
The Mimir website is people.bu.edu/clemens/mimir.

PRISM

The Perkins Re-Imaging SysteM (PRISM) instrument is a key component of the partnership between BU and Lowell Observatory to operate the Perkins Telescope. PRISM is a facility-class instrument for optical imaging, spectroscopy, and polarimetry. PRISM has now entered into its fifth year of use. As of June 1, 2008 over 100,000 images have been obtained with PRISM, including sequences of images tracking the transits of a number of exoplanets in front of their stars. Roughly 30 observers have used PRISM so far, including BU graduate and undergraduate students, Lowell Observatory staff members, and outside visitors.

The Perkins Re-Imaging SysteM (PRISM) instrument mounted on the Perkins telescope.

PRISM is used primarily in support of major long-term observing campaigns, including the study of stellar activity in solar-type stars by Professor Ken Janes, blazar variability programs by the blazar research group, as well as tracking of Kuiper-belt objects (the most distant observable objects in our solar system) by Larry Wasserman and Robert Millis at Lowell Observatory, determining the rotation senses of large spiral galaxies by BU graduate student Paul Howell, and searching for distant galaxy clusters by Professor Elizabeth Blanton.

PRISM has encountered very few problems since operations began, and it continues to operate smoothly. PRISM was scheduled for use by 13 different observers on 159 nights in the past year. All three PRISM modes (imaging, spectroscopy, and polarimetry) were in full use during the year. Paul Howell, who was observing for his PhD dissertation work, was one of the heavier users of PRISM this year. In addition, 14 graduate students (members of AS710 - Observational Astronomy) spent several nights at the Perkins Telescope obtaining data for class projects.

The PRISM website is www.bu.edu/prism.

MIRSI

MIRSI, the Mid-Infrared Spectrometer and Imager, has been a facility instrument at NASA's Infrared Telescope Facility (IRTF) in Hawaii since late 2002 and continues to be a highly-sought after instrument. MIRSI was built by the late Professor Lynne Deutsch and is primarily used by the general astronomical community to study asteroids and planets. IAR members have used MIRSI to image infrared dark clouds in order to obtain constraints on the sizes of the central cores that harbor massive star formation. Narrow-band imaging of other, known star forming regions has also been carried out in order to determine the composition of gas and dust toward star-forming regions.

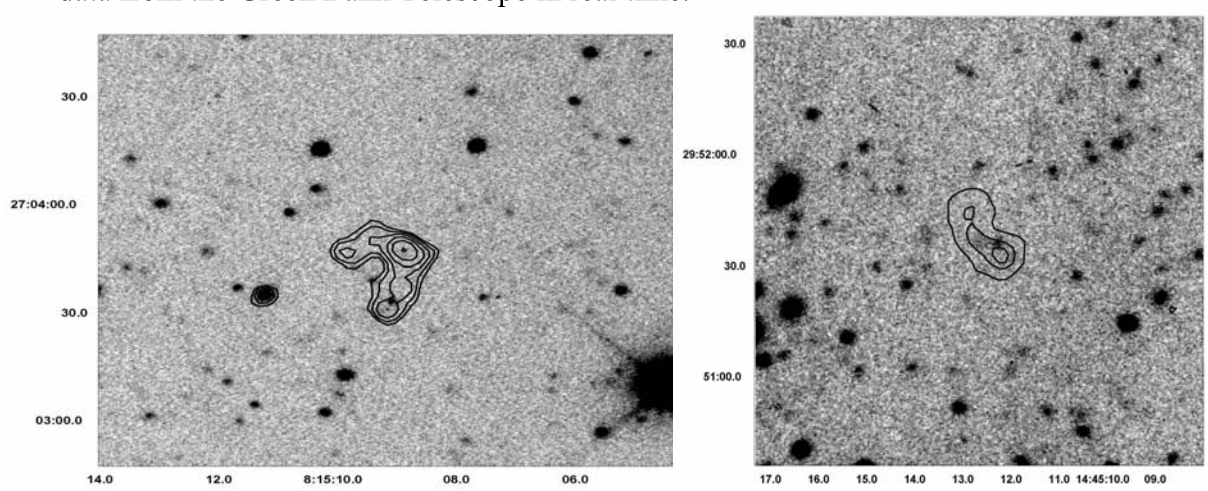
MIRSI provides both imaging and spectroscopy across the mid-infrared band, from 7 to 25 microns. A number of different combinations of filters and grisms are available to users, allowing them to quickly and efficiently switch between imaging and spectroscopic modes. This is advantageous because it allows users to maximize the time spent studying astronomical sources instead of dealing with complex instrument changes. On a per semester basis (approximately 180 nights), MIRSI continues to be regularly scheduled for 20-25% of the available observing nights. The community interest in MIRSI is driven by its high-quality wide-field imaging capabilities. This makes MIRSI and the smaller aperture NASA IRTF competitive with mid-infrared instruments on most of the world's largest telescopes such as Keck, Gemini, and the VLT for mapping large regions of star formation and solar system phenomena such as comets. Unlike the mid-infrared instruments on larger aperture telescopes, MIRSI can capture variations in spectral line, dust, and PAH emission throughout a star forming region, providing valuable diagnostic tools. Furthermore, MIRSI provides images with high contrast between bright and dim emission, enabling MIRSI users to detect very faint sources.

In return for contributing MIRSI to the IRTF, Boston University astronomers are guaranteed observing time on the telescope. MIRSI is currently unsupported financially by Boston University.

Science Programs

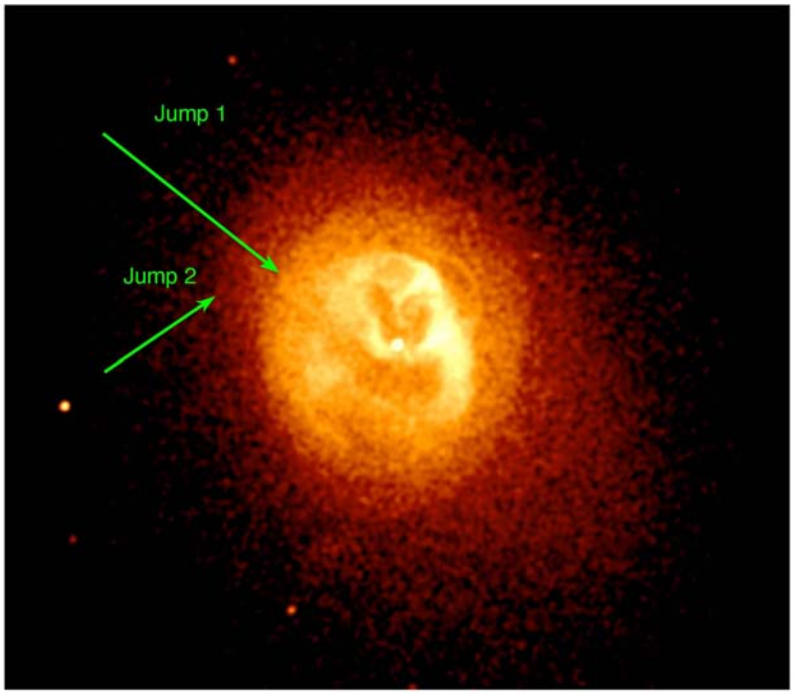
The IAR hosts many different science programs. Two of the particularly noteworthy results from the past year are outlined in the Science Highlights section, and below are updates on other ongoing investigations.

Professor Bania and his collaborators are working to confirm the stellar production of ^{3}He by planetary nebulae. They are using radio recombination lines to measure the nebular electron temperature (a proxy for the source metallicity) and have now made measurements for a sample of 125 H II regions whose locations span the entire disk of our Galaxy. This is an unprecedentedly large, uniform, and sensitive sample, with observations coming from the Green Bank Telescope and the Arecibo Observatory. In addition, Professor Bania has worked to develop a software package (TMBIDL) for the analysis of single dish radio astronomy data. Major enhancements that were implemented in TMBIDL over the past year are: (1) the ability to analyze any spectral line data obtained with the NRAO 140-foot telescope's Model IV Autocorrelator, (2) the ability to archive the history of the data reduction process for each data unit in a variety of ways, and (3) the ability to analyze simultaneously both spectral line and continuum data from the Green Bank Telescope in real time.



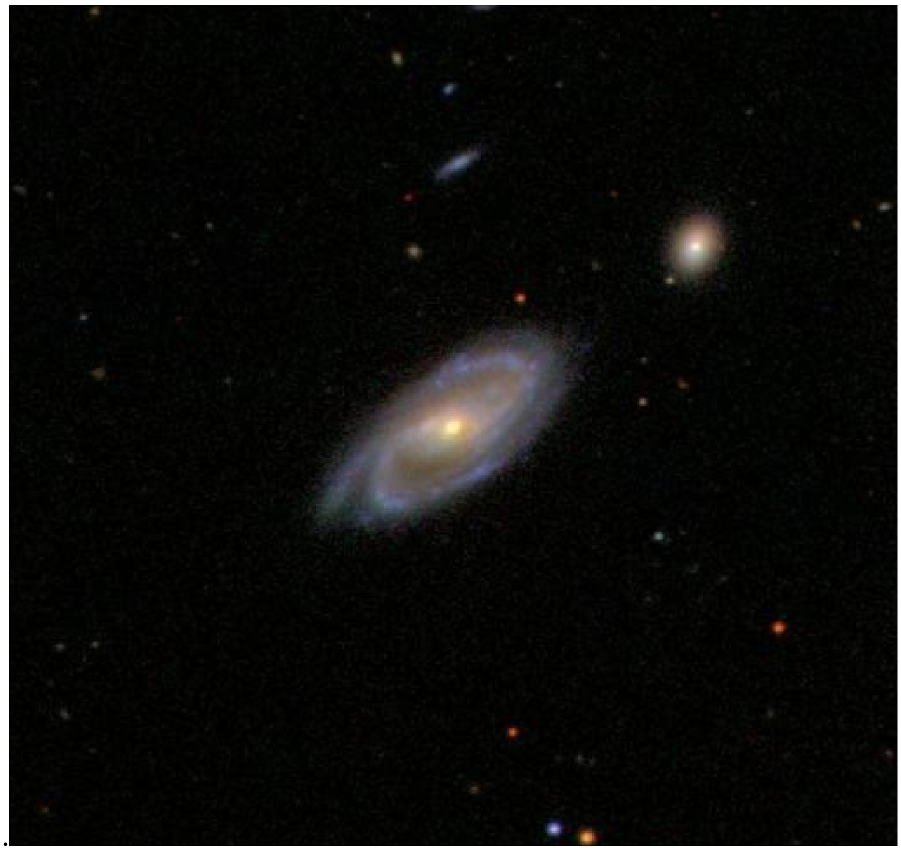
Radio source contours overlaid onto R-band optical images that were obtained with PRISM on the Perkins telescope. The radio sources have no identifications in the SDSS, and faint identifications in the Perkins images. These are most likely to be distant galaxy clusters.

Professor Blanton and her research group have been studying clusters of galaxies, particularly topics related to radio source interactions in clusters of galaxies. Graduate student Josh Wing has been working with Professor Blanton to correlate radio sources from the FIRST survey with optical sources from the Sloan Digital Sky Survey (SDSS). They have found hundreds of galaxy clusters in the SDSS that are associated with radio sources.



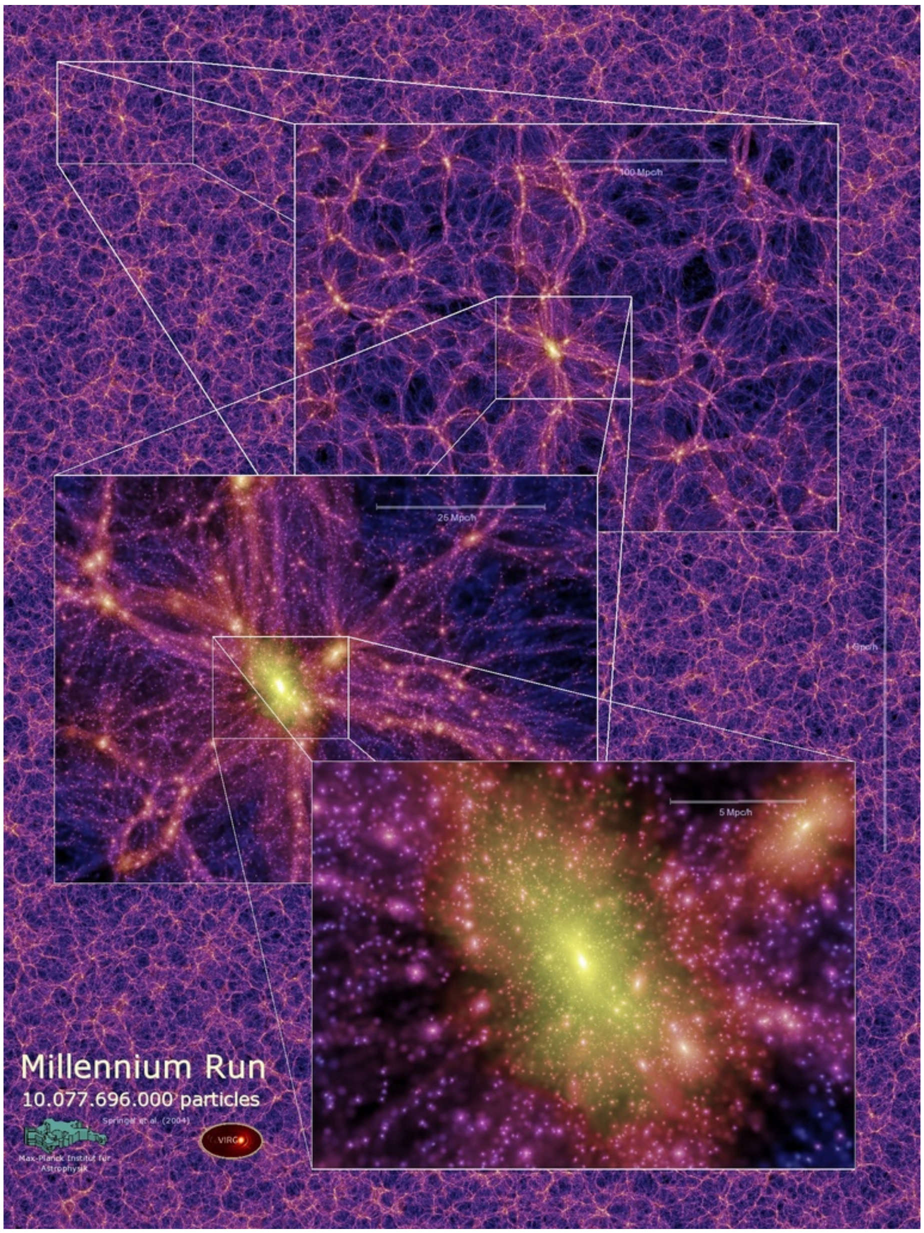
Deep Chandra observation of the central region of the cool core of galaxy cluster Abell 2052. The image shows bubbles blown out by the AGN to the north and south, as well as shock features to the northeast. These jumps in surface brightness are consistent with shocks with Mach numbers of 1.8 and 1.2 for the inner and outer shocks, respectively.

Additionally, they have found that bent, double-lobed radio sources are associated with galaxy clusters roughly 85% of the time. Hundreds more of these types of radio sources have host galaxies that are too faint to be detected with the SDSS, and most of them are expected to be in distant galaxy clusters with redshifts greater than about 0.8. Josh Wing was given an Honorable Mention Chambliss award at the January 2008 AAS meeting for this work. Graduate student Ned Douglass has been working with Professor Blanton on the interaction of wide-angle tail radio sources with the intracluster medium using X-ray observations from Chandra. These types of sources are often associated with merging clusters, but not unambiguously. It is important to study these low-redshift objects in detail in order to better understand high redshift clusters. Also, Professor Blanton's group obtained a deep Chandra X-ray observation of the cool core of galaxy cluster Abell 2052, discovering two shocks in the inner region of the cluster that are associated with outbursts from the central AGN. A long Chandra observation of galaxy cluster Abell 262, along with multi-frequency radio observations, has shown several episodes of outbursts from the AGN. This allows the determination of the radio source duty cycle and the energy input into the cluster.



A large spiral galaxy in the Sloan Digital Sky Survey and two small satellite galaxies that are in orbit about the spiral galaxy.

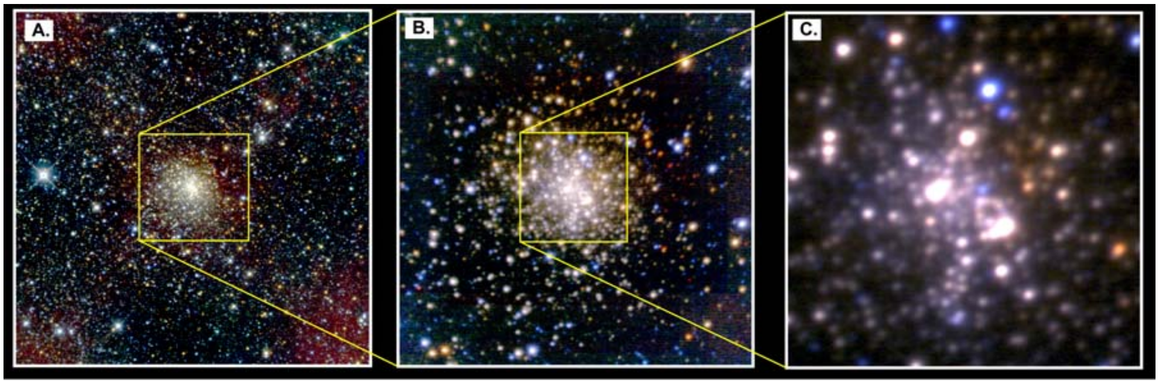
Professor Brainerd and graduate student Paul Howell began a campaign with the Perkins telescope to measure the rotation senses of the disks of approximately 600 large spiral galaxies. Good data on roughly 150 spiral galaxies were acquired this year. The galaxies were selected from the Sloan Digital Sky Survey and all are known to be orbited by at least one small satellite galaxy. The rotation senses of the disks will be compared to the directions in which the satellites orbit about those disks.   This will lead to a strong constraint on whether satellite galaxy orbits are preferentially prograde or retrograde with respect to the disks that they orbit, and the result could provide an important clue to the way in which spiral galaxies acquire their angular momentum. One of the outstanding problems in the popular Cold Dark Matter (CDM) model is that computer simulations of disk galaxy formation within CDM halos rarely result in the formation of disk galaxies that are spinning as fast as the majority of spiral galaxies in our Universe. If, however, satellite galaxies move about their host spiral galaxies on orbits that are preferentially prograde, we would then expect the eventual accretion of the satellites by the spiral galaxies to "spin up" the disks. Since, to date, the accretion of satellite galaxies by large disk galaxies has not been simulated with particularly high resolution or realistic initial conditions, this could help to ease the current tension between the predictions of CDM and the observed properties of large spiral galaxies.



A slice through the Millennium Run Simulation, the largest Cold Dark Matter simulation ever to be released to the public. The simulation was run by astrophysicists at the Max Planck Institute for Astrophysics in Garching, Germany and used more than 10 billion particles. The color scale shows the density of matter along the line of sight. The slice is 15 Mpc/h thick and represents the "present day" universe. Each of the overlaid panels zoom into the simulation by factors of 4, enlarging the regions shown in the white rectangles.

Professor Brainerd and graduate student Ingolfur Agustsson continued their investigations into the locations and velocities of satellite galaxies with respect to their host galaxies, focusing primarily on host-satellite systems that were obtained from the Millennium Run Simulation. The Millennium Run Simulation was designed and run by astrophysicists at the Max Planck Institute for Astrophysics (MPIA) in Garching, Germany and is the largest computer simulation of a CDM universe that has ever been publicly-released in catalog form. Its extraordinarily high resolution, combined with a semi-analytic model of galaxy formation, makes this simulation ideal for the investigation. The shear size of the simulation (10 billion particles), however, makes it impossible for the full data set (i.e., positions and velocities of the individual particles) to be available to the public. Because of the work that Ingo and Professor Brainerd had done previously with the simulation, Dr. Simon White (the Director of MPIA) invited Ingo to spend 3 weeks in Germany this year in order to be able to work with the full Millennium Run data set on the MPIA supercomputers. As a result of this generous invitation, it was possible to confirm that the locations of satellite galaxies around their host galaxies provide reasonably accurate tracers of the shapes of the dark matter halos that surround the host galaxies. In addition, it was found that it is extraordinarily difficult to use the motions of satellites around their hosts as a measure of the mass of the host galaxies. When analyzing the motions of satellite galaxies in a large redshift survey, it is commonly assumed that the velocity dispersion profile can be fit by a combination of a Gaussian distribution plus a constant ("DC") offset. This is supposed to account for "false satellites" in a realistic data set. Results from the Millennium Run Simulation, however, show that this basic assumption is incorrect. This calls into serious question all published results for the velocity dispersions of satellite galaxies, including some rather famous results that claimed the observed velocities of satellites galaxies were a perfect match to the predictions of CDM.

Over the past year Professor Clemens and his research group continued to obtain observations for the Galactic Plane Infrared Polarization Survey (GPIPS), a large project involving hundreds of nights of observing on the Perkins telescope with the Mimir instrument. Mimir was specifically designed and developed to conduct the GPIPS project, and Mimir continues to be the premier wide-field infrared imaging polarimeter in the world. The GPIPS project and Mimir's capabilities have received widespread attention over the past year, largely due to the group's participation at meetings and conferences. GPIPS utilized nearly 50 nights on the Perkins telescope over the past year, obtaining infrared polarimetric data on 550 of the 3,214 "fields" that make up the GPIPS survey region. This is by far the largest number of fields that the group has observed in any one year, and it came about through the combined efforts of the Lowell Observatory staff and Brian Taylor, the IAR’s Telescope Support Scientist, who squeezed out the remaining time overheads in the data collection system.

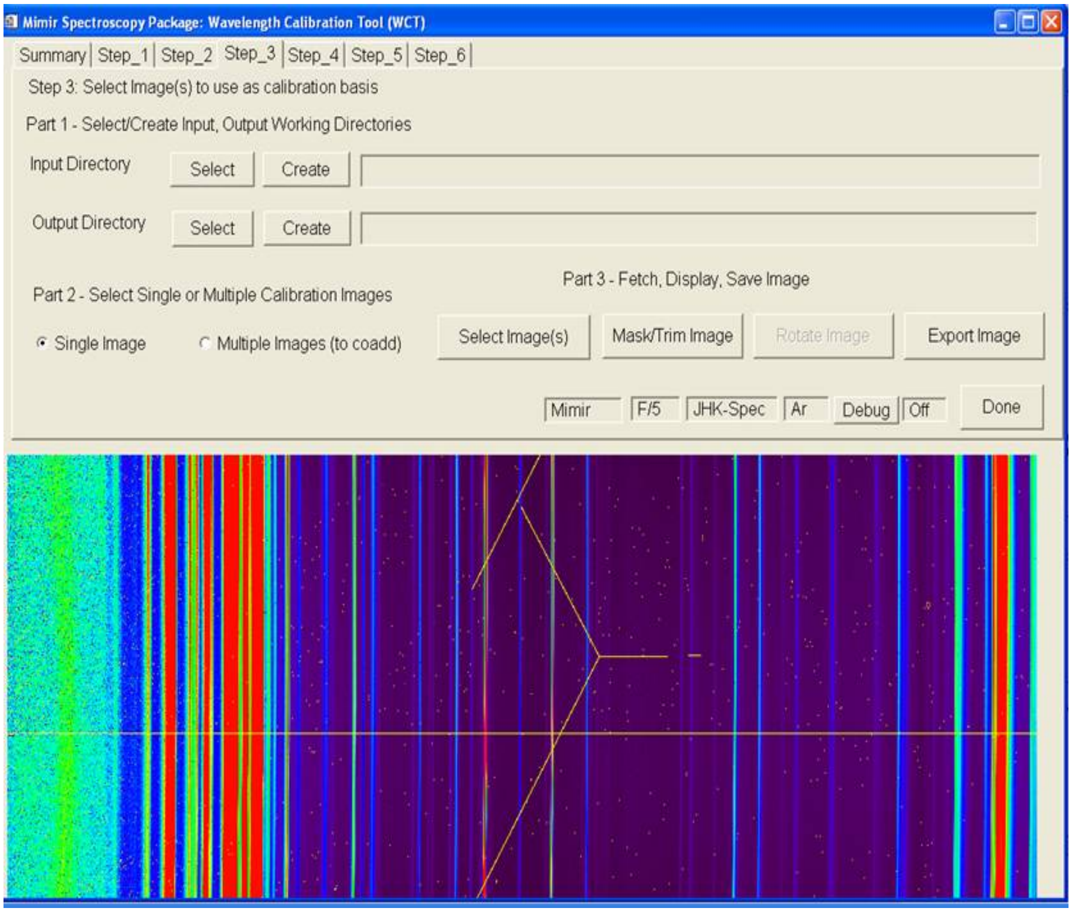


Mimir infrared images of the field containing the globular star cluster GC01. (A) Three-color composite of images taken in the J (1.2 micron - blue), H (1.6 micron - green), and K (2.2 micron - red) wavelength bands. The field is the 10x10 arcminute instantaneous field of view of Mimir. (B) A zoomed version of the center of the image in (A), showing the cluster center. (C) Mimir image using its narrow-field, high angular resolution mode, with 0.18 arcsecond pixels. This resolves the cluster center into individual stars.

At the time of this writing (shortly into the 2008 "season"), the group has obtained another 220 fields and is on track to meet or exceed last season's record. At the end of Professor Clemens' initial 3-year NSF grant to start GPIPS, the group will have obtained data for about 50% of the full 72 square degrees of the sky that GPIPS is hoped to cover. More importantly, the data collection rate is now such that completion of GPIPS observing over the full 72 square degrees can be accomplished in 3 more seasons.

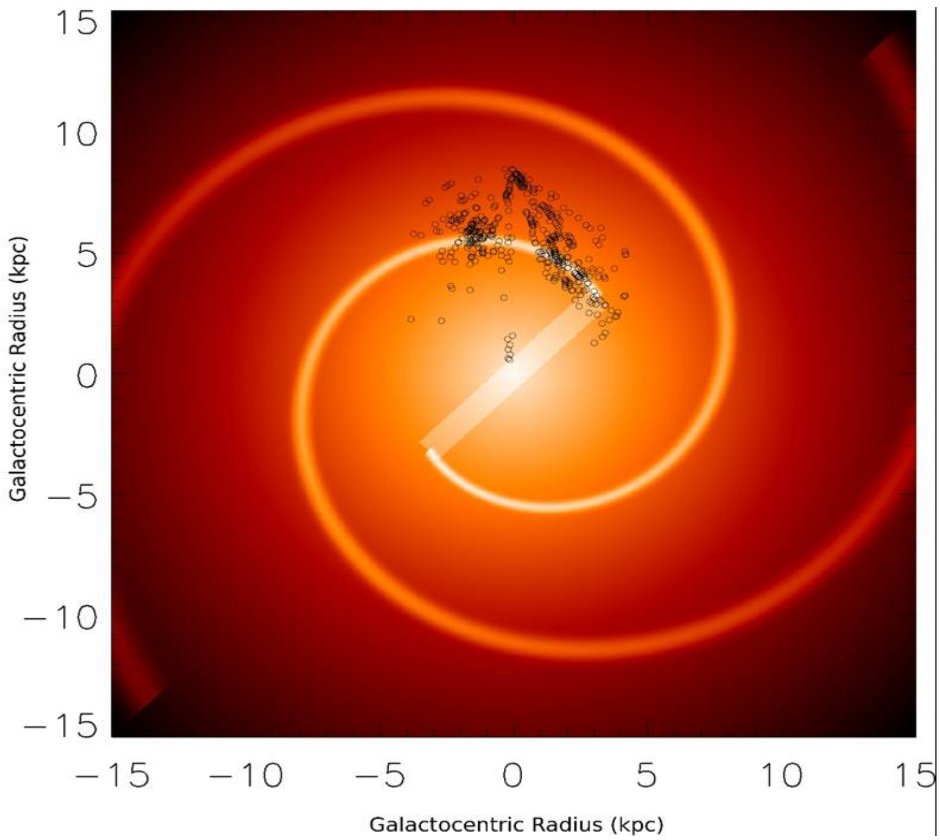
GPIPS observations have been biased to "skim the cream" scientifically by prioritizing the regions being studied. In the first GPIPS season, all galactic star cluster directions were surveyed, and these will form the PhD dissertation research project for graduate student April Pinnick. Similarly, all known interstellar bubbles were observed in the second GPIPS season and these will form the PhD dissertation work of Mike Pavel. In the current observing season undergraduate student Katie Jameson is conducting GPIPS observations of two large molecular clouds and these data will form the basis of her Senior Distinction Thesis. Graduate student Carol Carveth created the GPIPS Web Portal to allow other scientists in the broader astronomical community to access GPIPS data without a proprietary period.

Screen shot of one page of the Mimir Software Package - Wavelength Calibration Tool (WCT) used to obtain accurate wavelengths for spectra obtained using Mimir or Prism. Shown in the color window is a spectral image of the argon spectral line lamp. The WCT is a critical tool in the reduction and analysis of Mimir spectra and will be used by a wide variety of scientists at BU, Lowell, and elsewhere.



Professor Clemens' group has also invested a great deal of time in software development to allow quick calibration and analysis of GPIPS and other Mimir-obtained data. In the past year, two large Mimir software packages, the Basic Data Processor and the Wavelength Calibration Tool, have been written, tested, and released to the community via the Mimir web site. These IDL-based tools are "point and click" graphical user interface packages that collect numerous programs and procedures into simple-to-use, intuitive formats that perform all critical calculations and data bookkeeping. Over the next year, a point-source-photometry tool and a polarimetric analysis tool will be publicly released and will be used to analyze Mimir-obtained GPIPS data.

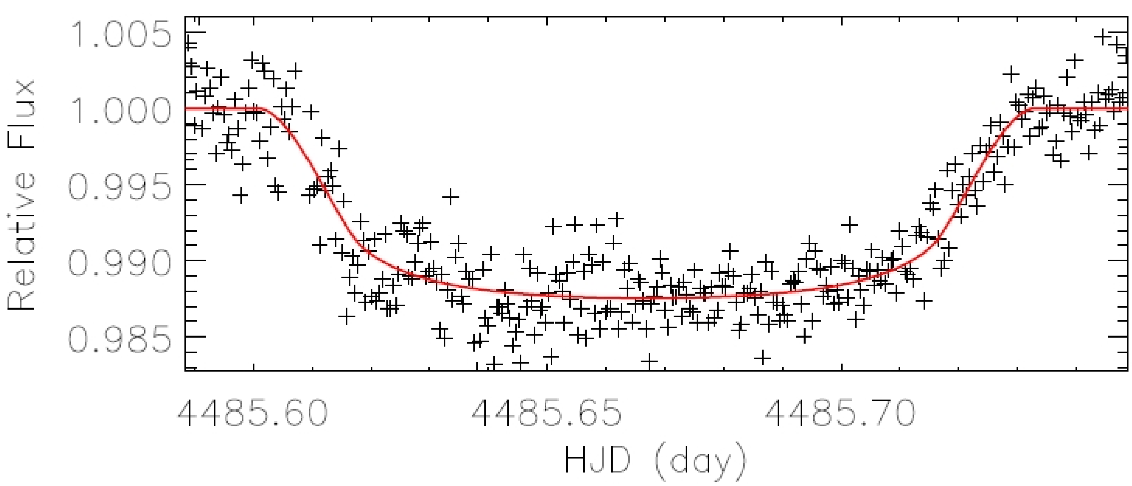
Locations of infrared dark clouds (circles) superposed on a 2-armed barred spiral model for the Milky Way Galaxy.



In addition to their work on the role of infrared dark clouds in star formation, Professor Jackson's group has also been working to map the structure of the Milky Way Galaxy. Remarkably, although the sun is one of the stars within the Milky Way Galaxy, the structure of our home galaxy is poorly understood because we live deep within the galaxy. Nevertheless, progress on understanding the structure of our Galaxy is being made. By measuring the velocities of the molecular clouds identified with the Galactic Ring Survey, the distances to these clouds can be estimated because the orbital speeds of the clouds around the center of the Galaxy are known. Graduate student Julia Duval and collaborators have used this technique to find the unmistakable sign of spiral structure in the Milky Way. This spiral structure is also confirmed by the spatial distribution of the infrared dark clouds. The new map of the Milky Way made by Professor Jackson's group does not, however, agree with previous models of the Milky Way that suggested that our Galaxy has four major arms. Instead, Professor Jackson's group finds that the Milky Way has two major spiral arms, the nearest of which (known as the "Scutum-Crux" arm) stands out as a major feature in maps of molecular gas.

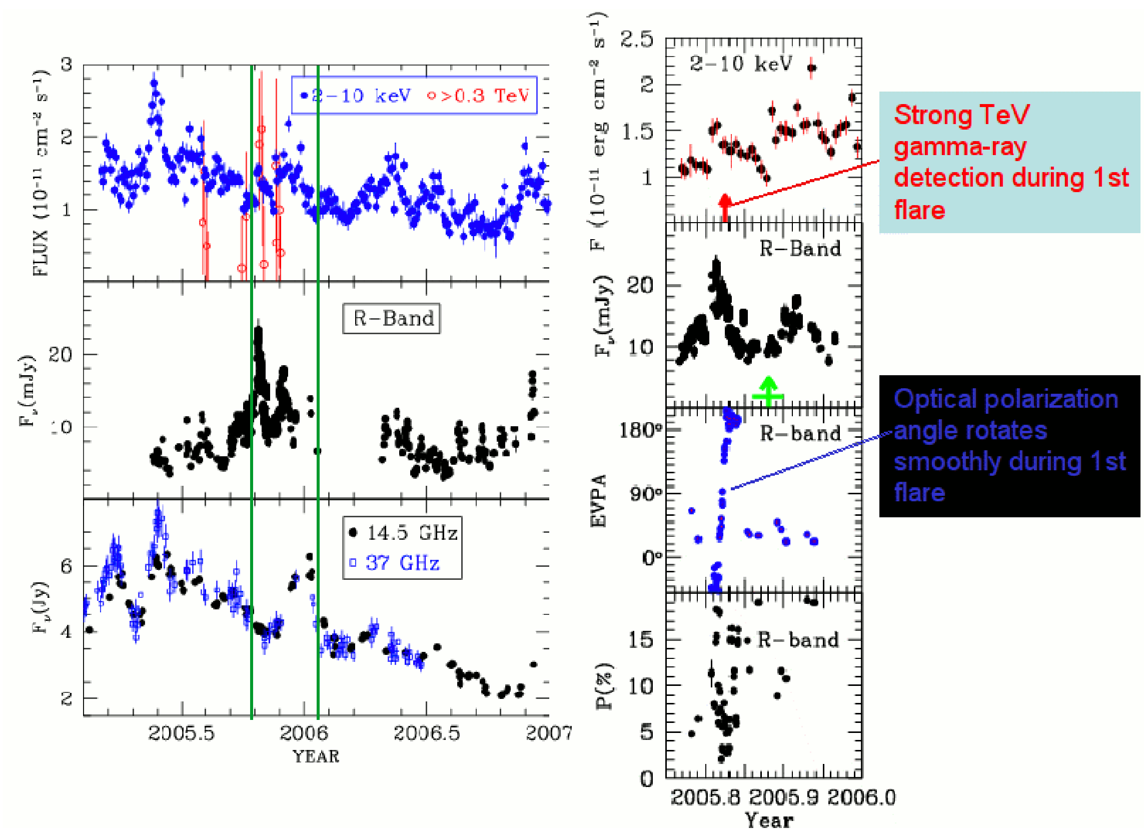
Professor Janes has continued his collaboration with Dr. Peter McCullough of the Space Telescope Science Institute as part of the XO project. This project searches the skies for extrasolar planets (planets outside our own solar system) that transit in front of their host stars. When these planets pass in front of their stars, the light from the star is dimmed very slightly for a few hours. The XO project discovered its first transiting exoplanet a few years ago and they have recently submitted papers to the ApJ detailing the discovery of their fourth and fifth expolanets (XO-4 and XO-5, respectively). Both of these exoplanets are similar in mass to the planet Jupiter (1.72 and 1.15 times the mass of Jupiter, respectively). Observations of the light curves of XO-4 and XO-5 were obtained using PRISM on the Perkins Telescope. These observations were important to the confirmation of these objects as genuine exoplanets, as well as allowing measurements of the radii of the exoplanets (1.34 and 1.15 times the radius of Jupiter, respectively).

Light curve showing the transit of exoplanent X0-5 in front of its star. The light curve was obtained in R-band using PRISM on the Perkins Telescope. Also shown is the best-fitting transit model (red line).



In addition to his work with the XO collaboration, Professor Janes has recently wrapped up his long-running study of the micro-variability of stars that reside in old open star clusters. As part of this, Professor Janes has produced an on-line archive of all of the photometry and most of the images for 4 old open clusters that he obtained over the past 12 years. Using a simple period-search procedure, Professor Janes has searched the photometric data from the clusters for the presence of transiting exoplanets. To date, no convincing candidates have been found, but Professor Janes intends to repeat the analysis with a more robust algorithm in the near future.

The blazar research group, led Professor Marscher, uses multifrequency observations to identify sites of emission at different wavebands and explore the physics of highly relativistic jets. Multifrequency observations include: (i) total and polarized intensity imaging of 29 gamma-ray bright blazers and radio galaxies with the Very Long Baseline Array (VLBA) at 43 GHz to study jet kinematics and structure of the magnetic field with a resolution of about 100 microarcseconds; (ii) optical and infrared polarization measurements with the Perkins telescope, a 1.5 m telescope at Steward Observatory, a 2.2 m telescope at Calar Alto Observatory, Spain, and a 70 cm telescope at the Crimean Astrophysical Observatory; (iii) X-ray monitoring 2-3 times per week of 5 blazars with NASA's Rossi X-ray Timing Explorer (RXTE); (iv) far-infrared observations of several blazars with the Spitzer Space Telescope; (v) optical and radio light curves of a sample of blazars and radio galaxies using data from telescopes around the world; (vi) high-resolution observations of more extended jets of blazars with the Chandra X-ray Observatory, the Hubble Space Telescope, the Spitzer Space Telescope (infrared), and the Very Large Array (radio).



Multi-waveband light curves of BL Lac. Right panel corresponds to time interval delineated by the green vertical lines in the left panel.

The blazar group's recent results provide strong evidence that the optical polarized emission in blazars originates in shocks, most likely situated between the core of the jet on 3 mm and 7 mm VLBI images. They also support the idea that the core at a wavelength of 1 mm lies at the edge of the transition zone between electromagnetically dominated and turbulent hydrodynamical sections of the jet. Their study of radio galaxies, which possess radio properties of blazars and X-ray behavior similar to Seyfert galaxies, indicates that appearances of superluminal knots in the jet follow low-hard X-ray states, reminiscent of the behavior of microquasars. This challenges models that relate the accretion state to the geometry of the magnetic field. The models must explain how the transition back to a radiative inner disk releases an ultra-fast moving energetic disturbance into the jet.

Lowell Observatory Partnership

BU undergraduate students Amanda Robison, Caitlin O'Nan, Dave Tooley, Eric O'Dea, and Dan Tran (left to right) on an AS441 field trip to operate Mimir on the Perkins Telescope in Spring 2008.

For the past 10 years, the IAR has partnered with Lowell Observatory to share the operation of the 1.8-m Perkins Telescope on Anderson Mesa, near Flagstaff, Arizona. Renewal of this partnership for an additional 5 years (starting August 1, 2008) was strongly recommended by the IAR Advisory Board and, as of this writing, negotiations for the renewal of the agreement are underway. We fully expect that a new Memorandum of Understanding will be signed by BU and Lowell in July, 2008. This will extend our partnership through July, 2013. As in the previous 10 years, IAR astronomers will be entitled to 50% of the nights on the telescope, distributed equally over all phases of the moon.

As part of our partnership with Lowell Observatory, the IAR developed two new instruments for the Perkins Telescope: Mimir, which operates at near-IR wavelengths, and PRISM, which operates at optical wavelengths. As detailed in the Instrumentation section, these two instruments are in routine use as the primary science instruments on the telescope. The IAR and Lowell have continued to improve the Perkins Telescope facility over the past year, an effort which is primarily funded through the NSF PREST program discussed below.

PREST

In the fall of 2004, the IAR (PI: Kenneth Janes) and Lowell Observatory (PI: Marc Buie) received a collaborative research grant from a new NSF initiative called "Program for Research and Education with Small Telescopes" (PREST). The grant includes funds for upgrades to the Perkins Telescope and dome to improve the image quality, as well as funds for student involvement in the operation of the telescope. Full operation of the program began in early 2005, and the grant will expire in December 2008. Currently there are few funds remaining in BU's part of the PREST grant, and we intend to use those funds to complete renovations on the computer room later this summer.

In order to improve the image quality it is necessary to remove as many sources of heat as possible from the dome and to ventilate both the dome and the telescope. To date, ventilation fans have been installed to help remove warm air from the dome, ventilation has been added to the primary telescope mirror, and the helium compressor for Mimir has been moved outside of the dome to a separate enclosure. By far the largest source of heat in the dome is the computer room, and this was moved downstairs and away from the telescope during the past year. Brian Taylor was largely responsible for completing this daunting task. To do accomplish the job, some of the downstairs walls had to be moved, air conditioning had to be installed, and much of the wiring connecting the computers to the telescope and control room had to be rerouted. This was a massive effort, but the result is a nice, compact, organized, and cool computer room that is away from the telescope. In addition, Brian installed a seeing monitor that now resides outside the Perkins dome and delivers a continuous record of the seeing at the site.

During the past year PREST funds were used to conduct an engineering study of the stability of the Perkins dome to see if it would be possible to install a ventilation system in the dome in order to further improve the seeing. The study concluded that there would be no structural weaknesses if 6 to 8 holes were cut in the dome between the ribs in order to install louvers or doors. This would allow wind to blow through the dome at night and reduce what is known as "dome seeing". At the present, we are investigating ways in which we could proceed with the dome ventilation that are both viable and affordable.

The PREST grant provides funds for the support of a graduate student in residence in Flagstaff and for travel funds for students to participate in the observational programs at the telescope. During FY06, two BU graduate students, Nina Bonaventura and April Pinnick spent a semester each as "graduate students in residence", living in Flagstaff, helping out at the telescope and beginning work for their own research. These students were fully-funded under the PREST program. During FY07 most of the graduate students who were interested in participating in the residency program were completing course work at BU and were preparing for their written comprehensive exam, so the graduate student residency program was put on hold temporarily.

In FY08 PREST funds were used to support two graduate students (Michael Pavel, who was a graduate student in residence in Flagstaff for the fall semester, and Ji Hyun Kim who was supported for two semesters while attending classes at BU). Mike did a lot of observing during his time at Lowell Observatory, both for himself and for others. In addition, Mike updated the PRISM operating manual and he helped Brian Taylor in a variety of tasks, mostly relating to Mimir maintenance. Mike had rather more interaction with the Lowell staff than most of our previous students students in residence, and the Lowell staff members were very pleased by this.

Ji Hyun used optical imaging data to perform a complete study of the seeing at the Perkins. She used the FWHM image size measurements that come from CCD photometry output files to compile the statistics. Some improvement over the earlier values that we used for the PREST grant were found, but not as much as we had hoped for. However, Ji Hyun completed her study prior to the computer room being moved downstairs, and observers who have used the telescope since have reported a substantial improvement in the seeing following the move. Lastly, Ji Hyun found that in general the seeing at the telescope itself is correlated with, but usually substantially higher than, the seeing recorded by the new seeing monitor. This is an argument in favor of proceeding with the ventilation of dome; i.e., the seeing outside the dome is substantially better than inside the dome.

Over the past year, 8 BU undergraduate students and 14 BU graduate students visited the Perkins Telescope, supported in large part by the PREST grant. In particular, the entire entire CAS AS441 (Observational Astronomy) and GRS AS710 (Observational Astronomy) classes joined BU astronomers at the telescope. All of these students obtained observations for their class projects using Mimir or PRISM. Over the past several years, a total of 32 BU undergraduate students and 15 BU graduate students have received PREST funding to travel to the Perkins Telescope to conduct observations as part of their education. This has become an important part of the educational program of the Department of Astronomy, but we are now at the point where PREST funding will no longer be able to support student trips.

As part of the PREST grant, the NSF requested that BU and Lowell have a visiting astronomer program at the Perkins Telescope. For a number of years prior to this, Lowell had scheduled visitors at the telescope; however through our PREST funding we instituted a more formal visitor program. Visitor applications for time on the Perkins Telescope are evaluated on a quarterly basis by a joint IAR-Lowell committee, and in past year a total of 59 nights were scheduled for visiting observers. All but one of the visiting observers used a BU instrument (PRISM or Mimir) for their observations.

Impact on Education

The availability of the Perkins Telescope for professional-quality observations has become an important part of our educational mission. In the 10 years of our partnership, approximately 50 undergraduates and 30 graduate students have traveled to Flagstaff to observe. These include undergraduate honors students (AS102 and AS203), observational astronomy students (AS441 and AS710), senior undergraduate students who use their observations as part of their Senior Work for Distinction, and graduate students who use their observations for their oral comprehensive exam projects and PhD theses. Of special note is that for the past 4 spring semesters all of the students enrolled in AS441 have participated in field trips to the Perkins Telescope to use Mimir to conduct near-infrared imaging and spectroscopy. Organized into groups of 3 to 4, AS441 students have each spent 2 to 3 nights operating Mimir and the Perkins Telescope. This capstone event in the training of our undergraduate astronomy students has been extremely popular, and it has also been highly effective for aiding the scientific and personal maturation of the students. This unique field trip experience has become a distinguishing high mark for BU and its undergraduate students. PREST funds will no longer be able to support these trips but, because of the high degree to which they reflect positively on the Department of Astronomy, the College of Arts and Sciences, and Boston University as a whole, we intend to submit a proposal to the College later this year to request funding (on the order of $10,000) to continue this program in the 2008/2009 academic year.

Impact on Research and Instrumentation Programs

Having guaranteed access to the Perkins Telescope allows IAR members to carry out large, long-term projects that would be difficult or impossible to carry out using shared national facilities. This is because the oversubscription rate for these facilities is simply too high for IAR members to obtain as many observing nights as are necessary to complete these projects. It is the access to the Perkins Telescope that places the BU blazar research group at the very forefront of the study of gamma-ray bright jets in quasars and active galactic nuclei, and has allowed GPIPS, the unique investigation of the Milky Way's magnetic field, to be carried out.

The blazar research group maps the emission from blazar jets across the full electromagnetic spectrum, which is the key to truly understanding the nature of the jets. In particular, the cores of the jets are located within a few light-years of central, supermassive black holes, and the jets emit radiation from microwave wavelengths through gamma-ray wavelengths. Short wavelength (gamma-ray and X-ray) radiation is observed from space observatories, and long wavelength (radio and microwave) radiation is observed with radio telescopes. The blazar research group depends on the Perkins Telescope for observations of the optical and near-IR emission. In order to map the emission at visible wavelengths, the group matches the linear polarization features on radio images with those observed at optical wavelengths, where the angular resolution is too crude to make images of the desired ultra-fine scale. Also, since the emission of the jets is variable at all wavelengths of interest, the group uses cross-wavelength correlations of the variations in brightness to determine the relationship between the optical emission and the X-ray. If the comparison of the polarization angle pinpoints the location of the optical emission on the radio image, then the emission at all wavelengths can be mapped.

The blazar group plans a long-term study of the 40 brightest gamma-ray blazars, and completion will take several years (which is the time scale over which a typical blazar changes its brightness, structure, and polarization to a sufficient degree that a careful analysis can be accomplished and firm conclusions can be drawn). No other similar study is planned by any other blazar groups around the world since they cannot match the scope of the BU blazar group's program.

GPIPS represents an increase of 5 orders of magnitude in Galactic magnetic field information over previous studies. Completing the full GPIPS survey, some 72 square degrees of sky located along the galactic equator in the northern hemisphere, will require about 150-200 clear nights on the Perkins Telescope. Given that the survey region is only visible for a limited time every year (due to the earth's revolution about the sun), and given that not all nights during the visibility time frame will have suitable conditions for observing, completion of GPIPS will take a considerable amount of time. Professor Clemens' research group has invested considerable energy into enhancing the efficiency of data collection, including tracking down and eliminating many unnecessary sources of overhead time. This has greatly improved the efficiency with which data are being collected, and the survey is on track to being completed in 2011.

Recently, studies have revealed that polarimetry conducted within spectral features (absorption bands of water ice) in the longer wavelength L-band (3.1 microns wavelength) offer the unique opportunity to trace magnetic fields deep inside dark molecular clouds, without the confusion generated by surface fields and tracers. Mimir is uniquely suited to conducting studies of magnetic fields in these dense cloud cores using L-band ice polarimetry. Additional wavelength filters and an L-band polarimetric half-wave plate are necessary, and both would be reasonable cost elements in a new NSF proposal to pursue this intriguing new science area. The unique combination of Mimir on the Perkins, in infrared imaging polarimetric mode, would allow this new science to be performed, and would do so uniquely since no other instrument can do this. In addition, Lowell scientists are eager to exploit Mimir's longer wavelength (L- and M-band) capabilities for studying young stars and binaries. Some software work is needed to make this happen, but is well within Mimir's design capabilities. Turning on these capabilities could go far to revitalize use of the Perkins Telescope by Lowell scientists and help ensure a robust future for this telescope and our instruments.

Finally, ongoing instrumentation development projects are made possible by having access to the Perkins Telescope. Adaptive optics (AO), which allow much of the distorting effects of the earth's atmosphere to be removed from astronomical images, are rapidly becoming a standard capability at many observatories. AO is not currently implemented on the Perkins Telescope, and this would be a natural new direction for our instrument development teams. The Mimir F/17 high resolution camera is already capable of exploiting the higher angular resolution imaging and spectroscopy that AO would deliver. Science that would be enabled by an AO system includes planetary astronomy, imaging and spectroscopy in dense star fields such as star clusters, as well as starburst galaxies and star-forming regions in our Galaxy.

Funding for Instrumentation and Science at the Perkins Telescope

IAR members have obtained substantial funding from multiple agencies in order to build PRISM and Mimir, and to support the science that is being carried out with these instruments. To date, instrumentation development for the Perkins Telescope has been funded at a level of $1.5M, and funding for scientific investigations that include observations with the Perkins Telescope totals $2.6M. Major, grant-funded projects that are currently being carried out on Perkins Telescope include a study of old star clusters (PI: Janes), the Galactic Plane Infrared Polarization Study (PI: Clemens), a study of the rotation senses of the disks of spiral galaxies (PI: Brainerd), and studies of blazar variablitiy (PIs: Marscher and Jorstad).

IAR Advisory Board Review

The IAR held a meeting with its advisory board on March 20 and 21, 2008. The advisory board consisted of three highly respected astrophysicists: Dr. Charles Lada (Harvard-Smithsonian Center for Astrophysics), Professor Roberta Humphries (University of Minnesota), and Professor Hugh Aller (University of Michigan; Chair of the Advisory Board).   The meeting consisted of a one-day mini science symposium and one day of round-table discussions between the IAR members and the board. The report of the advisory board is strongly positive, reflecting an overall impression strength in all aspects of the IAR's mission. The report calls out the importance and impact of our Lowell Observatory partnership to our programs of forefront astronomical research, as well as to our educational efforts through the Department of Astronomy. The advisory board strongly recommends the renewal of the IAR's charter, as well as the renewal of our partnership with Lowell Observatory for an additional 5 years. In addition, because of the pending retirement of Professor Janes and an overall sense that the IAR faculty are spread too thinly to maintain a strong instrument development program, the advisory board recommends hiring two new faculty members: one in the field of stellar astronomy and one in the field of astronomical instrumentation.

Future Activities

During the upcoming year we will continue the operation of the Perkins telescope in partnership with Lowell Observatory. MIRSI will remain at the Infrared Telescope Facility. The availability of PRISM, Mimir, and MIRSI will continue to improve the quantity, quality, and stature of our scientific publications. Having guaranteed access to these instruments is paying off with successful proposals to federal funding agencies, and we expect this trend will continue in the future. In order to compensate for the retirement of Professor Ken Janes (who will be at half-time for the next two years, followed by full retirement), the IAR needs to hire a new, young faculty member immediately. Ideally, that faculty member should be a specialist in stellar astrophysics so that we do not lose this fundamental line of research within the IAR. In addition, within the next two years the IAR should hire a new astrophysicist who specializes in the building of instruments in order to revitalize our instrument program. Such a revitalization could allow us access to new, large telescopes in exchange for providing state-of-the-art, facility-class instruments.

In order to maximize the science return from our substantial investments in PRISM and Mimir, it is vital that we continue our partnership with Lowell Observatory for another 5 years. Mimir was specifically designed and built to carry out the GPIPS project, which will be about 50% complete by the end of this summer. No other instrument/telescope combination is capable of performing this particular survey. Further, the blazar group's current large project depends critically on long-term monitoring of blazers with PRISM and Mimir on the Perkins telescope. Without guaranteed access to optical and near-IR observations, their efforts will founder.

In addition to the obvious scientific return arguments, there are other important reasons to continue our partnership with Lowell Observatory. Through our partnership with Lowell, we gain depth and visibility. Lowell has a high visibility in many communities, and this enhances our visibility in those areas. We also gain opportunities for growth and enhanced telescope access via our partnership. Also, it is not merely the faculty members of the IAR who have benefited from our partnership with Lowell over the past 10 years; students of all levels (undergraduate astronomy majors, undergraduate non-science majors, and graduate students) have enjoyed important, practical educational experiences with a telescope that is of sufficient quality for professional astronomical research to be done. This is a far cry from the sorts of very basic amateur astronomy that can be done with the small telescopes in the Coit Observatory (located on the roof of the CAS building). Undergraduate student training in the hands-on use of large telescopes and modern instruments is hard to come by at most US institutions, and such training gives our students competitive advantages in job searches, career choices, and graduate school applications. We will, therefore, continue to bring BU students to the Perkins Telescope in order to enrich their academic experience.

In order to remain competitive with funding agencies and to attract the strongest young astronomers to our faculty, it is vital that the IAR have access to high-quality research-grade telescopes. Although the Perkins Telescope has been a tremendous boon to our science effort, it is not a modern telescope and at 1.8m in diameter its aperture is, to say the least, rather modest. In order to maintain the vitality of our research effort, it is critical that IAR start to look beyond the Perkins Telescope, even as we renew our partnership with Lowell Observatory this summer.

The funding for national astronomical observatories continues to shrink at an alarming rate. Therefore, in order to guarantee the ability to carry out cutting-edge astronomy, the majority of US universities have access to large privately-owned telescopes. The building and operation of such telescopes is often funded through consortia of partners from multiple universities. All of our US peer departments (and even some lower-tiered departments) already have guaranteed access to telescope facilities that are far superior to the Perkins. Of order 30 US astronomy departments have regular access to privately-owned telescopes that have at least twice the collecting area of the Perkins Telescope. For astronomers, not having our own state-of-the art telescope with which to carry out observations is akin to biologists, chemists, or physicists not having their own state-of-the art laboratories. Simply put, the astronomical laboratory is the observatory, and the experiment is the universe itself.

Without guaranteed access to a larger, more modern telescope than the Perkins in the near future, the IAR will not continue to thrive. IAR members will find it increasingly difficult to compete for funding to carry out their research and to build new astronomical instrumentation. At present, a number of new telescopes are being considered by the IAR. As these telescope projects develop and head toward completion, we are weighing the advantages and disadvantages of each.

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 twenty-three astrophysicists. Graduate students prepare for upcoming seminars through the Astrophysics Journal Club, which meets on Friday afternoons. The seminar schedule is shown in Appendix B.

Appendix A: Publications and Presentations

Articles in Referred Journals

Agudo, I.; Bach, U.; Krichbaum, T.P.; Marscher, A.; Gonidakis, I.; Diamond, P. J.; Perucho, M.; Alef, W.; Graham, D.A.; Witzel, A.; Zensus, J.A.; Bremer, M.; Acosta-Pulido, J.A.; and Barrena, R.; "Superluminal Non-ballistic Jet Swing in the Quasar NRAO 150 Revealed by mm-VLBI," 2007, Astronomy and Astrophysics, 476, L17-20

Balser, D. S.; Rood, R. T.; and Bania, T. M.; Comment on "Deep Mixing of 3He: Reconciling Big Bang and Stellar Nucleosynthesis", 2007, Science, 317, pp. 1171

Bania, T. M.; Balser, D. S.; Rood, R. T.; Wilson, T. L.; LaRocque, J.M.; "^{3}He in the Milky Way Interstellar Medium: Ionization Structure ", 2007, Astrophysical Journal, 664, pp. 915-927

Burke, C. J.; McCullough, P. R.; Valenti, J. A.; Long, D.; Johns-Krull, C. M.; Machalek, P.; Janes, K. A.; Taylor, B.; Fleenor, M. L.; Foote, C. N.; and 4 coauthors, "XO-5b: A Transiting Jupiter-sized Planet With A Four Day Period," Submitted to Astrophysical Journal, 05/2008: Astro-ph, 2008arXiv0805.2399.

Burke, C. J.; McCullough, P. R.; Valenti, J. A.; Johns-Krull, C. M.; Janes, K. A.; Heasley, J. N.; Summers, F. J.; Stys, J. E.; Bissinger, R.; Fleenor, M. L.; and 8 coauthors, "XO-2b: Transiting Hot Jupiter in a Metal-rich Common Proper Motion Binary," 2007, Astrophysical Journal, 671, pp. 2115-2128

Chatterjee, R.; Marscher, A.P.; Jorstad, S.G.; Oh, H.; McHardy, I.M.; Aller, M.F.; Aller, H.D.; Balonek, T.J.; Miller, H.R.; Ryle, W.T.; Tosti, G.; Kurtanidze, O.; Nikolashvili, M.; Larionov, V.M.; and Hagen-Thorn, V.A.; "Correlated Multi-Waveband Variability in the Blazar 3C 279 from 1996 to 2007," 2008, Astrophysical Journal, submitted

Clemens, D. P.; Sarcia, D.; Grabau, A.; Tollestrup, E. V.; Buie, M. W.; Dunham, E.; and Taylor, B.; "Mimir: A Near-Infrared Wide-Field Imager, Spectrometer and Polarimeter," 2007, PASP, 119, pp. 1385-1402

Douglass, E. M.; Blanton, E. L.; Clarke, T. E.; Sarazin, C. L.; Wise, M.; "Chandra Observation of the Cluster Environment of a WAT Radio Source in Abell 1446", 2008, Astrophysical Journal, 673, pp. 763-777

Gomez, J.L; Marscher, A.P.; Jorstad, S.G.; Agudo, I.; and Roca-Sogorb, M.; "Faraday Rotation and Polarization Gradients in the Jet of 3C 120: Interaction with the External Medium and a Helical Magnetic Field," 2008, Astrophysical Journal Letters, in press

Hagen-Thorn, V.A.; Larionov, V.M.; Jorstad, S.G.; Arkharov, A.A.; Hagen-Thorn, E.I.; Efimova, N.V.; Larionova, L.V.,; and Marscher, A.P.; "The Outburst of the Blazar AO 0235+164 in 2006 December: Shock-in-Jet Interpretation," 2008, Astrophysical Journal, 672, pp. 40-47

Jackson, J.M.; Finn, S. C.; Rathborne, J. M.; Chambers, E. T.; Simon, R.; "The Galactic Distribution of Infrared Dark Clouds" 2008, Astrophysical Journal, 680, pp. 349-361

Johns-Krull, C. M.; McCullough, P.R.; Burke, C. J.; Valenti, J. A.; Janes, K. A.; Heasley, J. N.; Prato, L.; Bissinger, R.; Fleenor, M.; Foote, C. N.; and 6 coauthors, "XO-3b: A Massive Planet in an Eccentric Orbit Transiting an F5 V Star," 2008, Astrophysical Journal, 677, pp. 657-670

Jones, T. J.; Stark, D.; Woodward, C. E.; Kelley, M. S.; Kolokolova, L.; Clemens, D.; and Pinnick, A.; "Evidence of Fragmenting Dust Particles from Near-Simultaneous Optical and Near-Infrared Photometry and Polarimetry of Comet 73P/SCHWASSMANN WACHMANN 3," 2008, Astronomical Journal, 135, pp. 1318-1327

Jorstad, S.G.; Marscher, A.P.; Stevens, J.A.; Smith, P.S.; Forster, J.R.; Gear, W.K.; Cawthorne, T.V.; Lister, M.L.; Stirling, A.M.; Gomez, J.L.; Greaves, J.S.; and Robson, E.I.; "Multiwaveband Polarimetric Observations of 15 Active Galactic Nuclei at High Frequencies: Correlated Polarization Behavior", 2007, Astronomical Journal, 134, pp. 799-824

Marscher, A.P.; Jorstad, S.G.; Gomez, J.L.; McHardy, I.M.; Krichbaum, T.P.; and Agudo, I.; "Search for Electron-Positron Annihilation Radiation from the Jet in 3C 120", 2007, Astrophysical Journal, 665, pp. 232-236

Marscher, A.P.; Jorstad, S.G.; D'Arcangelo, F.D.; Smith, P.S.; Williams, G.G.; Larionov, V.M.; Oh, H.; Olmstead, A.R.; Aller, M.F.; Aller, H.D.; McHardy, I.M.; Lahteenmaki, A.; Tornikoski, M.; Valtaoja, E.; Hagen-Thorn, V.A.; Kopatskaya. E.N.; Gear, W.K.; Tosti, G.; Kurtanidze, O.; Nikolashvili, M.; Sigua, L.; Miller, H.R.; and Ryle, W.T.; "The Inner Jet of an Active Galactic Nucleus as Revealed by a Radio to Gamma-ray Outburst," 2008, Nature, 452, pp. 966-969

McCullough, P. R.; Burke, C. J.; Valenti, J. A.; Long, D.; Johns-Krull, C. M.; Machalek, P.; Janes, K. A.; Taylor, B.; Gregorio, J.; Foote, C. N.; and 4 coauthors; "XO-4b: An Extrasolar Planet Transiting an F5V Star," Astrophysical Journal in press, 5/2008: Astro-ph, 2008arXiv0805.2921.

Wong, Ka-Wah; Sarazin, C. L.; Blanton, E. L.; Reiprich, T. H; "XMM-Newton and Chandra Observations of Abell 2626: Interacting Radio Jets and Cooling Core with Jet Precession?", 2008, Astrophysical Journal, in press

Professional Seminars, Colloquia and Conference Talks

Blanton, E. L.; “AGN Interactions and Feedback in Clusters of Galaxies”, NERQUAM (New England Regional Quasar Meeting), 2008

D’Arcangelo, F.D.; New England Regional Quasar and AGN Meeting, 2008 30 May, Harvard University; contributed talk: “Correlated Multiwavelength Polarization in a Survey of Blazars”

Jorstad, S.G.; Meeting on Approaching Micro-Arcsecond Resolution with VSOP-2: Astrophysics and Technology, 2007 December 3-7, Institute of Space and Aeronautical Science, Sagamihara Japan; invited talk: “Polarization Properties of AGN at High Frequencies”

Jorstad, S.G.; Astronomical Institute, St. Petersburg State University, Russia, 2008 March 27, invited seminar: “Physics of Compact Jets in Blazars”

Jorstad, S.G.; Workshop on Blazar Variability across the Electromagnetic Spectrum, Paris, France, 2008 April 22-25; invited talk: “VLBI Observations of Blazars”

Marscher, A.P.; Meeting on Approaching Micro-Arcsecond Resolution with VSOP-2: Astrophysics and Technology, 2007 December 3-7, Institute of Space and Aeronautical Science, Sagamihara Japan; invited talk: “The Compact Structure of Blazars at High Frequencies”

Marscher, A.P.; Max-Planck-Institut fur Radioastronomie, Bonn, Germany, 2008 April 18, invited seminar: “Digging Deeper into the Inner Jets of Blazars”

Marscher, A.P.; Workshop on Blazar Variability across the Electromagnetic Spectrum, Paris, France, 2008 April 22-25; invited talk: “Long-term X-ray Variability in Blazars and its Multiwaveband Context”

Marscher, A.P.; Instituto de Astrofisica de Andalucia, Granada, Spain, 2008 April 28, invited seminar: “Digging Deeper into the Inner Jets of Blazars”

Marscher, A.P.; Maria Mitchell Observatory, 2008 May 27; invited seminar: “Active Galactic Nuclei”

Marscher, A.P.; Getting Involved with GLAST Workshop, 2007 June 21, Harvard University; invited talk: “GLAST and Multiwaveband Monitoring as Probes of Bright Blazars”

Marscher, A.P.; Maria Mitchell Observatory, 2007 August 7; invited seminar “Blazars: Rapid Variability from Jets Powered by Black Holes”

Marscher, A.P.; 2nd Multiwavelength Workshop for Next-Generation Gamma-ray Experiments, 2007 August 9-10, Adler Planetarium, Chicago, IL; invited talk: "Multiwaveband Behavior of Blazars"

Marscher, A.P.; New England Regional Quasar and AGN Meeting, 2008 30 May, Harvard University; contributed talk: "The Locations of High-energy Flares in Blazar Jets"

Marscher, A.P.; Meeting of Amateur Telescope Makers of Boston, 2008 June 12, Harvard University; invited lecture: "Jets from Black Holes in Active Galactic Nuclei"

Young, M.; New England Regional Quasar and AGN Meeting, 2008 30 May, Harvard University; contributed talk: "The SDSS/XMM-Newton Quasar Survey and the alpha(OX)-luminosity(UV) Correlation"

Conference Proceedings, Abstracts and Poster Papers

Agustsson, I., & Brainerd, T.; "Anisotropic Locations of Satellite Galaxies", 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #09.01

Anderson, L. D. and Bania, T. M.; "Resolution of the Distance Ambiguity for Inner Galaxy H II Regions", 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #18.02

Bania, T., & Anderson, L.; "Milky Way HII Regions: From A GLIMPSE To A Stare", 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #18.01

Blanton, E. L.; Randall, S. W.; Douglass, E. M.; Clarke, T. E.; Anderson, L. A.; Sarazin, C. L.; McNamara, B. R; "Deep Chandra Observations of the Cool Core Clusters A2052 and A262", 2008, Bulletin of the American Astronomical Society, HEAD meeting #10, #9.06

Blanton, E. L.; Douglass, E. M.; Wing, J.; Sarazin, C. L.; Clarke, T. E.; Poster Presentation: "X-ray Observations of Clusters with Wide-Angle Tail Radio Galaxies", 2007, Rodos, Greece, X-ray Surveys: Evolution of Accretion, Star Formation, and Large Scale Structure

Carveth, C.; Clemens, D. P.; Pinnick, A.; Pavel, M.; Jameson, K.; and Taylor, B.; "Magnetic Fields for All: The GPIPS Community Web-Access Portal," 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #14.12

Chambers, E.T.; Jackson, J. M.; Rathborne, J. M.; Simon, R.; "Ammonia in Infrared Dark Cloud Cores", 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #06.09

Clemens, D. P.; Pinnick, A.; Pavel, M.; Jameson, K.; Carveth, C.; and Taylor, B.; "Stalking the Milky Way Magnetic Field: GPIPS Season Two," 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #14.11

D'Arcangelo, F.D.; Marscher, A. P.; Jorstad, S. G.; Smith, P. S.; Larionov, V. M.; Hagen-Thorn, V. A.; Kopatskaya, E. N.; Williams, G. G.; and Gear, G. K.; "Correlated Rapid Optical and Radio Polarization Variability in a Sample of Blazars", 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #04.08

D'Arcangelo, F.D.; Marscher, A. P.; Jorstad, S. G.; Smith, P. S.; Larionov, V. M.; Hagen-Thorn, V. A.; Kopatskaya, E. N.; and Williams, G. G.; "Correlated Multiwavelength Polarization Variability in OJ287 and Other Blazars" [Winner of one of two Chambliss Student Achievement Awards for the most outstanding poster presentations by graduate students], 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #20.02

Donaldson, J.; Walker, G;, Strelnitski, V.; Jorstad, S; and Marscher, A. P.; "Optical Monitoring of a Sample of Gamma-ray Blazars at the Maria Mitchell Observatory" [Honorable mention for Chambliss Student Achievement Awards for the most outstanding poster presentations by undergraduate students], 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #04.06

Douglass, E.; Blanton, E. L.; Clarke, T. E.; Sarazin, C. L.; Poster Presentation: "X-ray Properties of Clusters with Wide-Angle Tail Radio Sources: Abell 562 and Abell 1446", 2007, Eight Years of Science with Chandra Symposium

Duval, J.; Jackson, J. M.; Johnson, A.; Rathborne, J. M.; Heyer, M. H.; Simon, R.; Shah, R.; "Distances and Properties of Molecular Clouds identified in the Galactic Ring Survey", 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #18.03

Finn, S. C., & Jackson, J. M.; "Infrared Star Counts Do Not Indicate Distances to Galactic Molecular Clouds", 2008, Bulletin of the American Astronomical Society, AAS Meeting #212, #18.06

Finn, S.; Jackson, J. M.; Rathborne, J. M.; Simon, R.; Chambers, E. T.; "The Galactic Distribution of Infrared Dark Clouds", 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #92.09

Ingalls, J. G.; Reach W. T.; Bania, T. M.; and Carpenter, J. M.; "Molecular Cloud Structure from a CO Spectral Line: Interferometric Observations of MBM-12", 2007, in proceedings of SINS – Small Ionized and Neutral Structures in the Diffuse Interstellar Medium, ASP Conference Series, Vol. 365, Edited by M. Haverkorn and W. M. Gross, p. 201

Jackson, J. M.; Chambers, E. T.; Rathborne, J. M.; Simon, R.; Zhang, Q.; "Infrared Dark Clouds Massive Star Formation: Observations Confront Theory", ASP Conference Series, Vol. 387, proceedings of the conference held 10-14 September 2007 at Heidelberg Convention Center, Heidelberg, Germany. Edited by Henrik Beuther, Hendrik Linz, and Thomas Henning. San Francisco: Astronomical Society of the Pacific, 2008, p.44

Jackson, J. M.; Finn, S.; Rathborne, J.; Chambers, E.; Simon, R.; "The Galactic Distribution of Infrared Dark Clouds", 2007, Bulletin of the American Astronomical Society, AAS Meeting #212, #86.03

Jameson, K.; Clemens, D. P.; Pinnick, A.; and Pavel, M.; "NIR Spectroscopy and Imaging of the Massive Star Cluster Mercer 23," 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #58.37

Janes, K., & Kim, J.; "Why have no Transiting Planets been found in Star Clusters?" in "Transiting Planets," IAU Symposium 253, F. Pont, D. Queloz and D. Sasselov, eds., Cambridge U. Press, in press

Janes, K.; Hoq, S.; Lollo, A.; MacDonald, M.; "Separating The Wheat from the Chaff: Finding the Properties of Distant Old Open Clusters," 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #58.13

Jorstad, S.G., & Marscher, A.P.; "The Quasar 1317+520: A Laboratory for Particle Acceleration," 2008, in Extragalactic Jets: Theory and Observation from Radio to Gamma Ray, ed. T.A. Rector and D.S. De Young, Astron. Soc. Pacific Conf. Ser., vol. 386, pp. 219-226

Jorstad, S.G.; "Polarization Properties of AGN at High Frequencies," 2008, in Approaching Micro-Arcsecond Resolution with VSOP-2: Astrophysics and Technology, ed. Y.Hagiwara, E.Fomalont, M.Tsuboi, and Y.Murata, Astron. Soc. Pacific Conf. Ser., vol. TBD, in press

Leroy, A.; Bolatto, A. D.; Stanimirovic, S.; Sandstrom, K.; Simon, J. D.; Bot, C.; Shah, R.; Jackson, J. M.; "Dust, Atomic, and Molecular Gas in the Nearest Primitive Environment The Second Annual Spitzer Science Center Conference: Infrared Diagnostics of Galaxy Evolution", ASP Conference Series, Vol. 381, proceedings of the conference held 14-16 November, 2005 in Pasadena, California, USA. Edited by Ranga-Ram Chary, Harry I. Teplitz and Kartik Sheth. San Francisco: Astronomical Society of the Pacific, 2008, p.173

Marscher, A.P., & Jorstad, S.G.; "View of Active Galactic Nuclei from the Past and Present", 2007, in Astronomy 2006: Tradition, Present, and Future", proceedings of the conference held 21-16 June, 2006 at St. Petersburg State University, Russia, eds. V. Orlov, V. Reshetnikov, and N. Sotnikova, pp. 116-139 (in Russian)

Marscher, A.P.; "The Core of a Blazar Jet," 2008, in Extragalactic Jets: Theory and

Observation from Radio to Gamma Ray, ed. T.A. Rector and D.S. De Young, Astron. Soc. Pacific Conf. Ser., vol. 386, pp. 437-443

Marscher, A.P.; “The Compact Structure of Blazars at High Frequencies,” 2008, in Approaching Micro-Arcsecond Resolution with VSOP-2: Astrophysics and Technology, ed. Y.Hagiwara, E.Fomalont, M.Tsuboi, and Y.Murata, Astron. Soc. Pacific Conf. Ser., vol. TBD, in press

Pavel, M. D.; Pinnick, A.; Clemens, D. P.; and Taylor, B.; “Latitude Survey of the Outer Galaxy Magnetic Field”, Bulletin of the American Astronomical Society, AAS Meeting #211, #14.14

Pinnick, A., & Clemens, D. P.; “Probing the Galactic Magnetic Field toward 12 Open Clusters,” 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #14.13

Rood, R. T.; Quireza, C.; Bania, T. M.; Balser, D. S.; and Maciel, W. J.; “The Abundance Gradient in Galactic H II Regions”, 2007, in From Stars to Galaxies: Building the Pieces to Build up the Universe”, ASP Conference Series, Vol. 374, Edited by Antonella Vallenari, Rosaria Tantalo, Laura Portinari, and Alessia Moretti, p. 169

Stanimirović, S.; Bolatto, A. D.; Sandstrom, K.; Leroy, A.; Simon, J. D.; Gaensler, B. M.; Shah, R.; Jackson, J. M.; “The Young SNR 1E 0102.2-7219: Testing Dust Formation in Primordial Galaxies The Second Annual Spitzer Science Center Conference: Infrared Diagnostics of Galaxy Evolution”, ASP Conference Series, Vol. 381, proceedings of the conference held 14-16 November, 2005 in Pasadena, California, USA. Edited by Ranga-Ram Chary, Harry I. Teplitz and Kartik Sheth. San Francisco: Astronomical Society of the Pacific, 2008, p.65

Wing, J. & Blanton, E.; “Distant Clusters Associated with Radio Sources”, 2007, Bulletin of the American Astronomical Society, AAS Meeting #211, #96.07

Wong, Ka-Wah; Sarazin, C. L.; Blanton, E. L.; Reiprich, T. H; “XMM-Newton and Chandra Observations of Abell 2626: Interacting Radio Jets and Cooling Core with Jet Precession?”, 2008, Bulletin of the American Astronomical Society, HEAD meeting #10, #9.05

Electronic Publications:

Carveth, C.; Clemens; D. P.; Pinnick, A.; Pavel, M.; Jameson, K.; and Taylor, B.; “Magnetic Fields for All: The GPIPS Community Web-Access Portal,” poster presentation at the conference “The Cosmic Agitator - Magnetic Fields in the Galaxy”,

March 2008, Lexington, KY. Web link at:
http://thunder.pa.uky.edu/magnetic/MeetingPhotosTalksPosters/Posters/Carveth_Poster.pdf

Clemens, D. P.; “The Galactic Plane Infrared Polarization Survey (GPIPS),” proceedings of the conference “The Cosmic Agitator - Magnetic Fields in the Galaxy”, March 2008, Lexington, KY. Web link at:
http://thunder.pa.uky.edu/magnetic/MeetingPhotosTalksPosters/March26Session1_Troland/3_Clemens/Clemens_WM.pdf

Clemens, D. P.; “Mimir, a Near-Infrared Wide-Field Imager, Spectrometer, and Polarimeter,” poster presentation at the conference “The Cosmic Agitator - Magnetic Fields in the Galaxy”, March 2008, Lexington, KY. Web link at:
http://thunder.pa.uky.edu/magnetic/MeetingPhotosTalksPosters/Posters/Clemens_Poster.pdf

Pavel, M.; Pinnick, A.; Clemens, D. P.; and Taylor, B.; “Latitude Survey of the Outer Galaxy Magnetic Field,” poster presentation at the conference “The Cosmic Agitator - Magnetic Fields in the Galaxy”, March 2008, Lexington, KY. Web link at:
http://thunder.pa.uky.edu/magnetic/MeetingPhotosTalksPosters/Posters/Pavel_Poster.pdf

Pavel, M.; Pinnick, A.; Carveth, C.; Jameson, K.; and Clemens, D.P.; “Polarimetry of Galactic Bubbles,” proceedings of the conference “The Evolving ISM in the Milky Way and Nearby Galaxies”, December 2007, Pasadena, CA. Web link at:
http://web.ipac.caltech.edu/staff/ismevol/proceedings/pavelm_v1.pdf

Pinnick, A., & Clemens, D. P.; “Probing the Galactic Magnetic Field Towards 12 Open Clusters,” poster presentation at the conference “The Cosmic Agitator - Magnetic Fields in the Galaxy”, March 2008, Lexington, KY. Web link at:
http://thunder.pa.uky.edu/magnetic/MeetingPhotosTalksPosters/Posters/Pinnick_Poster.pdf

Appendix B: Seminar Series Schedules

Institute for Astrophysical Research Seminar Series
Fall 2007

Sept. 18 Jay Lockman, NRAO
"The ongoing formation of the Milky Way: High Velocity clouds plunging into the Galaxy "

Sept. 25 Alberto Bolatto, University of Maryland
"The Primitive Universe, Near and Far"

Oct. 2 Giles Novak, Northwestern University
"The Galactic Magnetic Field and its Role in Star Formation"

Oct. 9 No Seminar Monday schedule for classes

Oct. 16 Kelsey Johnson, University of Virginia
"Are Super Star Clusters Actually Super?"

Oct. 23 Irena Stojimirovic, BU/IAR
"Parsec-scale Outflows from Low-Mass YSOs"

Oct. 30 James Jackson, BU/IAR
"Infrared Dark Clouds: The Birth of Star Clusters"

Nov. 6 Amalia Hicks, University of Virginia
"Missing Baryons: Recent Results from X-ray Observations of High-Redshift Clusters"

Nov. 13 Ian Dell'Antonio, Brown University
"Lensing/Dark Matter"

Nov. 20 Keivan Stassun, Vanderbilt University
"A Synthesis of Fundamental Issues in the Formation and Early Evolution of Low Mass Stars and Brown Dwarfs"

Nov. 27 Daniela Calzetti, University of Massachusetts
"Star Formation in the Mid-Infrared, and implications for the high redshift Universe"

Dec. 4 Josh Winn, MIT
"The Transits of Exoplanets"

Institute for Astrophysical Research Seminar Series
Spring 2008

Jan. 29 Michael Meyer, University of Arizona
"Two Tails of a Distribution Function: The Initial Mass Functions of Extreme Star Formation"

Feb. 5 Paul Ho, Sinica Institute of Astronomy and Astrophysics, Taipei Harvard-Smithsonian Center for Astrophysics, Cambridge, MA
"From the SMA to ALMA"

Feb. 12 Paul Green, University of Arizona
"Factory Trawling the X-ray Sky: The Chandra Multiwavelength Project (ChaMP)"

Feb. 26 Steve Longmore, Harvard-Smithsonian CfA
"The Evolutionary Sequence of Protostellar Cores"

Mar. 18 Sara Seager, MIT
"Exoplanets: Interiors, Atmospheres, and the Search for Habitable Worlds"

April 1 James Slavin, NASA/GSFC
"MESSENGER Mission"

April 8 Hans Zinnecker, Astrophysical Institute of Potsdam (AIP)
"Do all (massive) stars form in clusters?"

April 15 Ned Wright, UCLA
"IR Cosmology"

April 22 Robert Mathieu, University of Wisconsin
"Open Clusters: Open Windows on Stellar Dynamics"

April 29 Julio Navarro, University of Massachusetts
"Dark Matter"

May 6 Bruno Guidordoni, Observatory of Lyon, France
"Simulating Galaxy Formation"