Boston University
Institute for Astrophysical Research
Annual Report
June 2006

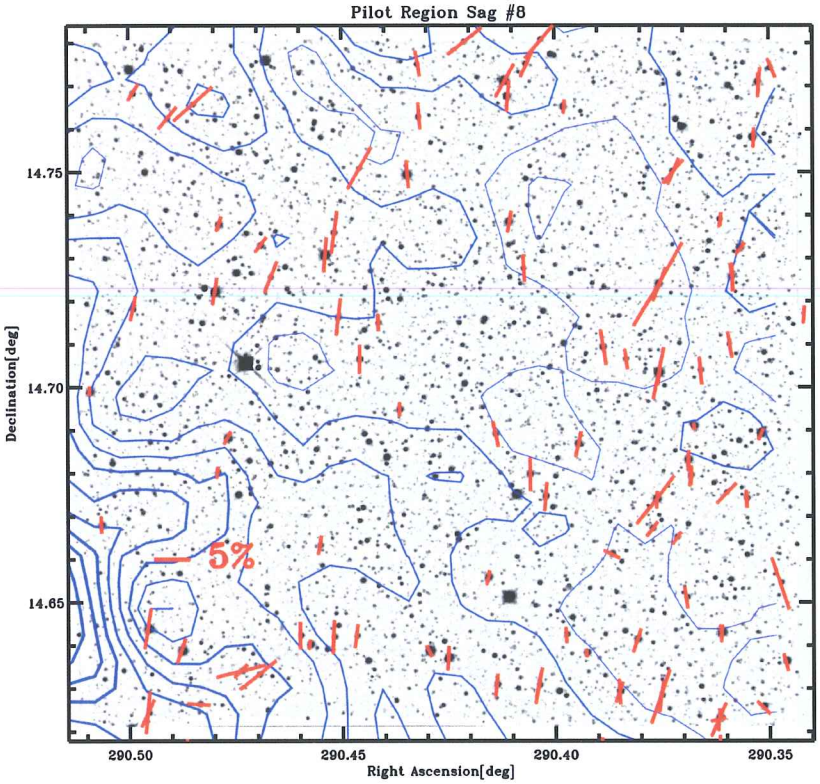


Figure : (grayscale image) Mimir coadded photometric image of one field (#8) of the 21 fields in the Saggitarius region, overlaid with red vectors showing the locations and Mimir-measured polarization properties of stars in the field. A P=5% reference vector is at lower left. Blue contours indicate GRS ^{13}CO integrated intensity distribution, bold contours denote higher column densities.

Tereasa Brainerd, Director
Kimberly Paci, Fiscal Administrator

Table of Contents

Summary

The Institute for Astrophysical Research marked a very successful 8th year in its mission to foster research at Boston University. All three of our state-of-the-art instruments (Mimir and PRISM at Lowell Observatory, and MIRSI at NASA's Infrared Telescope Facility) continue to operate beautifully and are returning exciting science results.

The IAR continues its vigorous research program. In the past year, IAR members published thirty-four scientific papers in refereed journals. Among our scientific highlights for the year are: (1) the discovery of a Jupiter-like planet orbiting a sun-like star, (2) the completion of the Galactic Ring Survey, and the completion of the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire.

In FY2006, total IAR grant expenditures, including new and continuing grants, was $1,002,592. IAR members submitted twenty-two new funding proposals totaling over $3.6M in requests. The IAR received a total of $1,260,364 in grant income, including 12 new awards totaling $754,994.

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

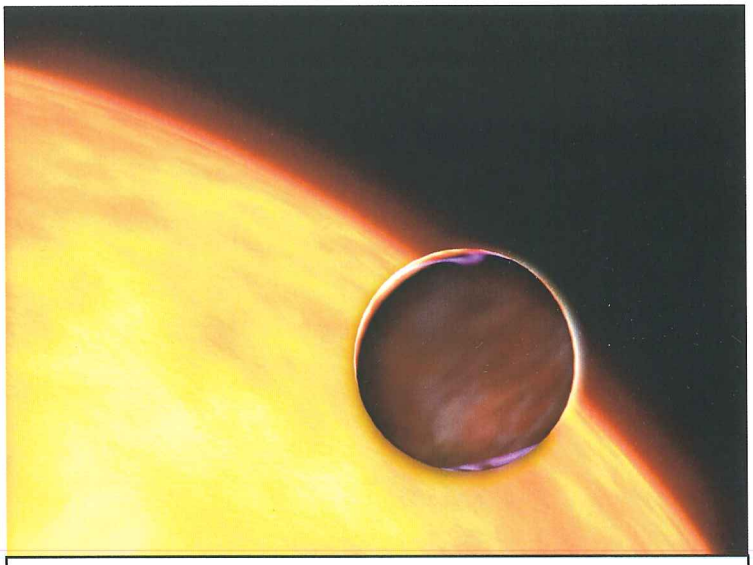
During the past year, the IAR membership consisted of faculty, staff, and students who were involved in research. Faculty members included Professors Thomas Bania, Dan Clemens, James Jackson, Kenneth Janes, and Alan Marscher, Associate Professor Tereasa Brainerd, and Assistant Professor Elizabeth Blanton. Research Associates affiliated with the IAR included Senior Research Associate Dr. Svetlana Jorstad, Research Associates Drs. Jill Rathborne and Ronak Shah, and Research Fellow Dr. Kathleen Kraemer. IAR staff members included Senior Research Associate Amanda Bosh, stationed in Flagstaff, Arizona at the Lowell Observatory site on Mars Hill, and IAR Fiscal Administrator Ms Kimberly Paci.

Graduate students conducting astrophysical research with IAR faculty members during the past year included Ingolfur Agustsson, Loren Anderson, Nina Bonaventura, Edward Chambers, Ritaban Chatterjee, Francesca D'Arcangelo, Edmund Douglass, Susanna Finn, Paul Howell, Alexis Johnson, Amber Kendall, Emily Mercer, Suwicha Wannawichian, and Monica Young.

Undergraduate students working within the IAR included Brett Chizinsky, Michael Dormandy, Nicholas McConnell, Haruki Oh, Joshua Schiode, Andrew Sorkin, and Elizabeth Taber.

Scientific Highlights

Discovery of Extrasolar Planet X0-1b

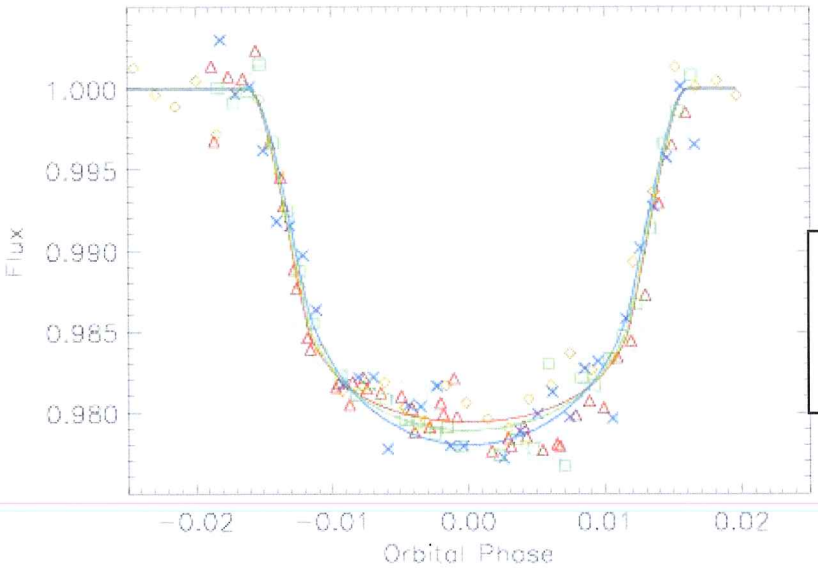


Astist's conception of extrasolar planet X0-1b transiting its sun.

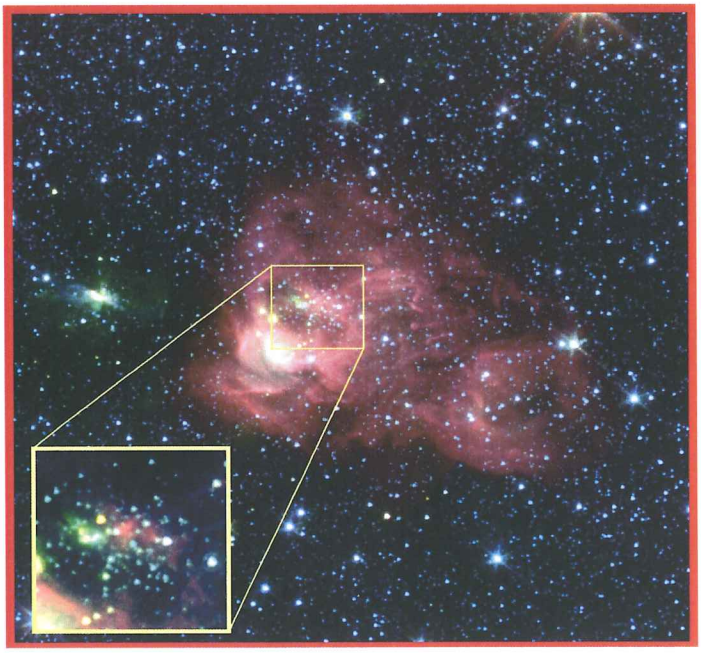
On May 18, 2006, the Space Telescope Science Institute (STScI), Boston University and several other institutions announced the discovery of a new extrasolar planet. The planed is called XO-1b and it orbits a sun-like star that is located 600 light years from the earth. The mass of XO-1b is about 90% that of the planet Jupiter, and it is somewhat larger in radius than is Jupiter. The discovery team was led by Dr. Peter McCullough of STScI and included BU Professor Kenneth Janes and BU graduate students April Pinnick and Paul Howell.

X0-1b is an example of a "transiting" extrasolar planet; that is, in the course of its 3.9 day orbit X0-1b passes directly in front of its sun. Although X0-1b cannot (yet) be imaged directly, it is possible to detect the dimming that occurs when X0-1b passes in front of its sun and blocks a small portion of its light. The discovery process began with images taken by a small camera in Hawaii that scans the sky night after night, searching for small variations in brightness that could be caused by a planet transiting in front of its sun. These images were analysed with software written in part by Professor Janes. Candidate targets were supplied to a team of mostly amateur astronomers, including Paul Howell, who used their own backyard telescopes to cull red herrings from the list. Spectroscopy of a few of the best candidates was obtained with a large telescope in Texas and this was used to eliminate all of the candidates except XO-1b. In order to refine the characteristics of the planet, April Pinnick used the PRISM instrument on the 1.8-m Perkins telescope at Lowell Observatory to obtain precise meaurements of the light curve that resulted as X0-1b transited its sun. BU undergraduate students Joshua Shiode and Danielle Best assisted with some of the observations at the Perkins telescope.

The discovery of X0-1b is a good example of the fundamental discoveries that can be made when long-time professional astronomers combine their research efforts with graduate students and a large base of dedicated amateur astronomers. Paul Howell and April Pinnick, in particular, have received a considerable amount of notice for their work on this project. Paul was featured in an article in the Portland, Maine Press-Herald on May 19, 2006 and both of these students were featured in the June 5, 2006 issue of BU Today. A profile of April and Paul will appear in the June 25 Boston Globe magazine.



Light Curve of extrasolar planet X0-1b transiting its sun. The light curve was obtained by BU graduate student April Pinnick using PRISM on the 1.8-meter Perkins telescope at Lowell Observatory.



Galactic Legacy Infrared Mid-Plane Survey Extraordinare

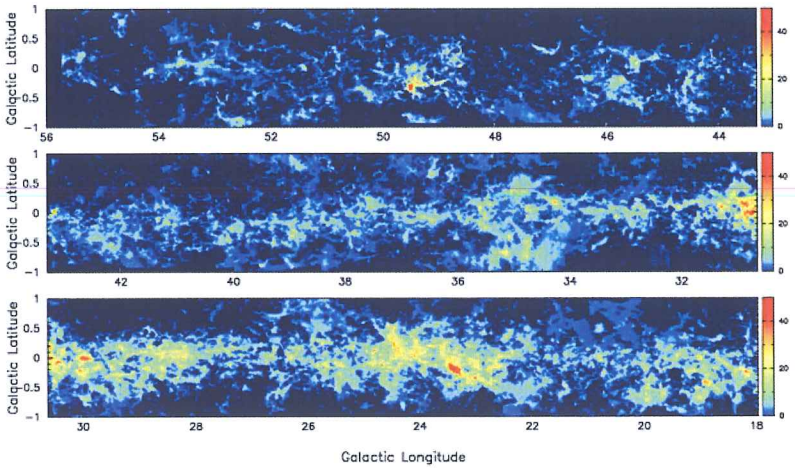
During the past year the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) project completed all observations with the Spitzer Space Telescope and released data products to the astronomical community, including a catalog of some 50 million stellar objects found in the survey. BU members of the

A new star cluster in the Milky Way discovered with the Glimpse survey. The cluster is located in a star-forming cloud, shown by diffuse red emission. The inset shows the cluster itself, where green indicates the presence of hot hydrogen gas and blue indicates older, normal stars. A massive new star is believed to be forming in the white arc that is to the lower left of the central star cluster.

GLIMPSE team include Professors Clemens, Bania and Jackson, as well graduate student Emily Mercer. Emily Mercer has led an effort to combine GLIMPSE data with Galactic Ring Survey (GRS) data to try to ascertain the "horizon" for GLIMPSE when looking into the deep, dark interior of the Milky Way. Emily has also recently published the discovery of almost 100 previously unknown star clusters in the inner Milky Way, which she found largely by sophisticated computer sifting of GLIMPSE data.

Galactic Ring Survey

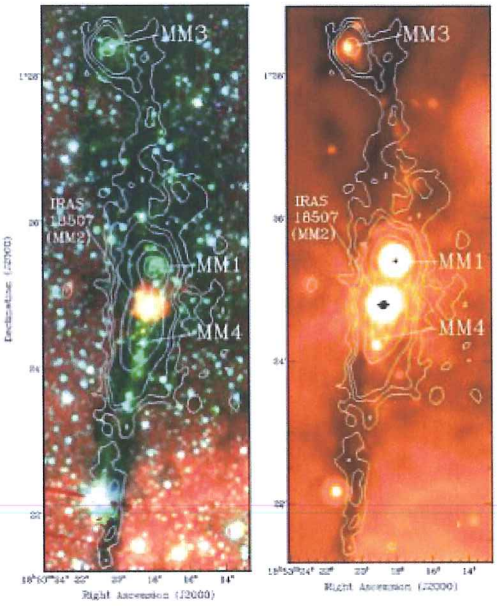
The Galactic Ring Survey (GRS) is a new ^{13}CO 2.6mm survey of a large portion of the Galactic plane that has been Professor James Jackson's main research project over the past several years. This eight-year, $3 million project was carried out with the 14 meter FCRAO telescope and provides the best images of the Galaxy's molecular clouds to date. The survey was completed in the past year, and the paper describing the survey was published recently. Professor Jackson's group is now engaged in an analysis of Galactic structure, molecular cloud structure, and molecular cloud properties using the data they obtained in the GRS.



Integrated intensity image of ^{13}CO (1-0) emission from the BU-FCRAO Galactic Ring Survey. The emission is integrated over all velocities (V_{lsr} = -5 to 135 km/s for l < 40 degs and V_{lsr} = -5 to 85 km/s for l > 40 degs). A striking aspect of the image is the abundance of filamentary and linear structures and the complex morphology of the individual gas clouds. The brightest regions, shown in red and yellow, are the birthplaces of stars and star clusters.

A particularly exciting result from the GRS was the detection in ^{13}CO of a large number of Infrared Dark Clouds (IRDCs). These objects, discovered as mid-IR extinction features by the MSX and ISO satellites, had remained mostly curiosities because their distances, and hence their physical properties, were unknown. With the ^{13}CO detections, Professor Jackson's group could establish kinematic distances, and for the first time deduce the sizes and masses of IRDCs. Remarkably, IRDCs have the same sizes (a few pc) and masses (a few thousand times the mass of the sun) as do molecular clumps such as Orion or Rho Ophioucus that are known to be forming star clusters. Millimeter continuum imaging of a sample of 38 clouds of known distance reveals that IRDCs contain cold, dense cores with a characteristic mass of order 100 times the mass of the sun. Because these cores are very similar to "hot cores" associated with high mass protostars, Professor Jackson's group suggests that they are the cold precursors to massive stars. Indeed, follow-up

observations have indicated that about one third of the cores show signs of active star formation. Some of these cores are extremely luminous, with luminosities greater than 10,000 times the luminosity of the sun. These high-luminosity cores are almost certainly high-mass protostars. IRDCs may well be the birthplaces of all high-mass stars and star clusters, and their quiescent cores the elusive high-mass "pre-stellar cores".



The infrared dark cloud G034.43+00.24. Left: Spitzer Space Telescope/IRAC three-color image overlaid with contours of 1.2 mm continuum emission obtained with the IRAM 30m telescope. Right: Spitzer Space Telescope/MIPS 24 micron image with the same contours of 1.2 mm continuum emission. The morphology of the millimeter continuum emission traces the extinction in the IR extrememly well. Labeled on the image (MM1, etc.) are three compact, cold cores as traced by the millimeter continuum emission. These three cores show extended emission in the Spitzer/IRAC image (left) and are very bright at 24 microns (right), suggesting that they harbor high-mass protostars.

Instrumentation Program

IAR members are actively engaged in building state-of-the art astronomical instrumentation and have delivered three major 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, 2005 to June 30, 2006, Mimir was scheduled on the Perkins telescope for a total of 146 nights, or 41% of the total available nights for the year. The distribution of nights scheduled for Mimir use was 73 nights for BU scientists and students, 59 nights for Lowell scientists, 8 nights for outside visitors, and 6 nights for BU undergraduate education (CAS AS441 observing trip). The remaining nights on the Perkins telescope were scheduled for PRISM (39% of the total available nights), the Kron Photometer (10% of the total available nights), and the refurbished DeVeny Spectrograph (10% of the total available nights). Hence Mimir has now joined PRISM as being one of the two most heavily used science instruments on the Perkins telescope.

During Summer 2005, the Mimir helium refrigerator compressor was moved out of its temporary location in the telescope dome to its permanent home in the "helium shed"outbuilding located outside the dome. Since the compressor generates 6 kW of heat, its relocation to the new shed has helped improve telescope seeing and general Mimir operations. This work was funded under the Lowell Observatory portion of the collaborative PREST NSF grants to BU (PI: Kenneth Janes) and Lowell (PI: Marc Buie).

Also in Summer 2005, significant in-cryostat work was performed on Mimir to solve some outstanding problems and to boost operational robustness. These included solving a nagging problem with the camera selection motion stage. Users can now easily switch between the wide-field camera, the high-resolution camera, and the pupil viewer while Mimir is on the telescope. The filter wheel encoder systems were fully redesigned and replaced the older, problematic systems. The mechanical parts for the new encoder system were designed by Professor Clemens while in Flagstaff, the electronic drawings were emailed to the Scientific Instrument Facility (SIF) at BU where the parts were fabricated and then sent to Flagstaff for installation. In this crucial way, the SIF was able to support BU faculty research, in real-time, from two thousand miles away.

A Mimir engineering run in Fall 2005 resulted in an increase in the detector well depths by a factor of about 3 to 4, as well as much improved cosmetics (i.e., reduction of the number "hot" or bad pixels in the array detector). Since then a program of continous study and improvement has wrung more latent dwell times out of the data collection system to try to achieve the highest ratio of "open shutter" efficiency possible.

In Spring 2005, an extensive period of Mimir operation was devoted to performing a pilot study to demonstrate methods and potential science for a Galactic Plane Infrared Polarization Survey (GPIPS). The pilot study surveyed about 0.5 square degrees of the galactic plane using Mimir's wide-field imaging polarimetry mode. These data were analyzed and shown to produce a spectacular increase in sensitivity to the weak magnetic field pervading the disk of the Milky Way. The methodology and results from the pilot survey featured prominently in a proposal submitted to the NSF in November 2005, and it has just recently been designated for full funding ($660,000 over three years). The GPIPS project was the key science goal used to draw the attention and funding of the W. M. Keck foundation to the Mimir instrument development project.

Mimir has been used in the past year for the Marscher/Jorstad blazar polarimetry monitoring program, Professor Blanton's distant galaxy cluster discovery program, BU graduate student April Pinnick's stellar cluster polarization survey, numerous Lowell science projects, as well as outside user groups' science. These include a comet polarimetry study (M. Kelley et al., UMinn), a program to study weather and clouds on Venus (E. Young et al., SWRI), and a spectroscopic study of the giant star - disk system epsilon aurigae (R. Stencel et al, U. Denver).

The Mimir website is people.bu.edu/clemens/mimir.

CAS AS441 students Ann Douglas, Elizabeth Taber, Joshua Shiode, and Anthony Falsetti (left to right) prepare to begin a night of observing using Mimir on the Perkins telescope. AS441 students performed IR spectroscopy observations of planetary nebulae, emission nebulae, as well as normal and giant stars. Two groups of four students each (the entire class) were able to take four-day, three-night field trips in March 2006, partially supported by an NSF PREST grant (PI: Kenneth Janes).

PRISM

The Perkins Re-Imaging SysteM (PRISM) instrument was designed and constructed at Boston University and is a key component of the collaboration between BU and Lowell Observatory to operate the Perkins telescope. PRISM is a facility-class instrument for optical imaging, spectroscopy, and polarimetry. As mentioned above, PRISM and Mimir are now on the telescope for roughly 80% of the available nights per year, with demand for these two instruments being split roughly equally. PRISM has now entered into its third year of use; over 45,000 images have been obtained to date, including a sequence of images tracking a transit of the planet XO-1b in front of its sun. The light curve obtained with PRISM for this transiting planet is one of our most exciting science highlights of the year. About 20 observers have used PRISM so far, including BU graduate and undergraduate students, Lowell Observatory staff members, and outside visitors. Almost $1 million in grants that require PRISM observations have now come to the IAR.

PRISM is used primarily in support of major long-term observing campaigns, including the study of stellar activity in solar-type stars by Professor Kenneth Janes, blazer variability programs by the Marscher/Jorstad group and Richard Miller at Georgia State Univeristy, 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. More recently, Professor Elizabeth Blanton has begun to use PRISM observations of wide-angle tail radio soures as part of her program to identify very distant galaxy clusters. A half-dozen BU undergraduates and two graduate students have undertaken directed research projects using PRISM, supported in part through the NSF PREST program that is discussed elsewhere in this report.

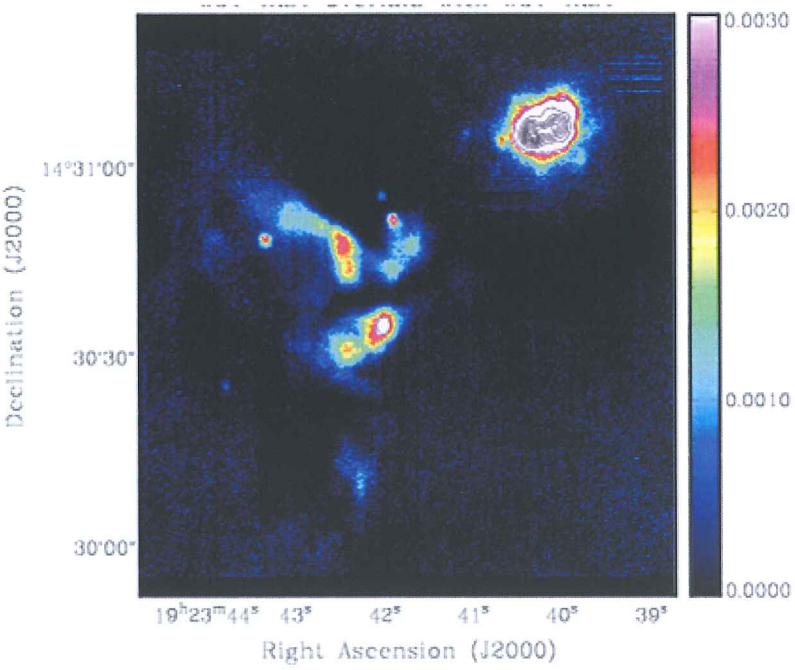
PRISM has encountered very few problems since operations began. The polarimetric mode has been put into operation within the past year, which has made it possible for the Marscher/Jorstad blazar group to begin a major new observing program, funded by the NSF. Low-resolution spectroscopy is also now fully enabled.

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. IAR members are using MIRSI to image infrared dark clouds (IRDCs) in order to obtain constraints on the sizes of the central cores that are thought to harbor massive star formation. Narrow-band imaging of other, known star forming regions is being 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 to spectroscopic mode. 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 20-25% of 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 VLT for mapping large regions of star formation, such as W5, 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 dim and bright emission. In the W51 image, the dynamic range, or ratio between dimmest and brightest regions of emission is 200:1. Such capabilities allow MIRSI users to detect even very faint sources.



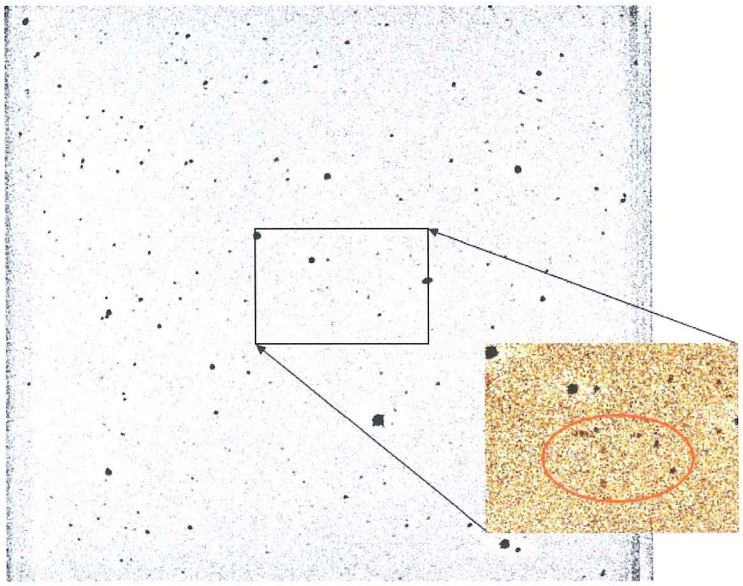
A 10 micron image of the W51 massive star forming region obtained with MIRSI on the IRTF. The image scale is 1.5x1.5 arcminutes. The colour scale (blue to white) separates dim and bright regions of emission from dust grains, organic molecules, and line emission. Images such as these allow astronomers to improve their understanding of massive star formation.

Scientific Programs

The IAR hosts a number of different scientific programs. A few 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 continues his efforts to determine the cosmic abundance of ^{3}He in a variety of astrophysical environments and to use the ^{3}He abundance to constrain Galactic chemical evolution. During the past year Professor Bania's team made the first ever ^{3}He observations with the 305 meter Arecibo telescope, they continued their experimental campaign at the Green Bank Telescope, and they published a new detection of ^{3}He in the planetary nebula J320. The J320 detection is particularly important since it is only the second planetary nebula known definitely to have ^{3}He. Professor Bania also continues working with the Haystack Observatory team led by Alan Rogers who are measuring the hyperfine spin-flip transition of deuterium at 327 MHz. The discovery of the D I line after 50 years of futile searches was made possible by a state of the art low-frequency array pioneered by the Haystack team.

Professor Blanton is investigating the interactions of radio sources with the intracluster medium (ICM) in clusters of galaxies. Two BU graduate students, Loren Anderson and Ned Douglass, have worked with Professor Blanton this year. Loren Anderson studied the interaction of a radio source with the ICM in the cluster Abell 262. A new X-ray "tunnel" was found coincident with low-frequency radio emission and, on larger scales, a "ripple" was found in the X-ray emission, corresponding to the propagation of a shock or sound wave from a previous radio outburst. Ned Douglass has been studying the interaction of a wide-angle tail (WAT) radio source with the ICM in the cluster Abell 1446. Along with BU undergraduate Elizabeth Taber, Professor Blanton performed observations of a sample of WAT radio sources using PRISM on the Perkins telescope. Since WAT sources



Mimir image, centered on a wide-angle tail (WAT) radio source. The inset shows 7 or 8 galaxies that may constitute an extremely distant cluster of galaxies. Combining near-IR imaging from Mimir with optical imaging from PRISM is an efficient way to discover distant galaxy clusters that contain WATs.

are usually found in clusters, they can be used to discover extremely distant galaxy clusters. Near infrared (NIR) imaging with Mimir on the Perkins telescope is currently being performed for these objects since they are expected to be bright in the NIR compared to other objects in the field. Professor Blanton has identified tens of very distant cluster candidates and, if they are confirmed, they will greatly increase the number of known distant galaxy clusters and they will also be very useful for fundamental studies of galaxy evolution and cosmology.

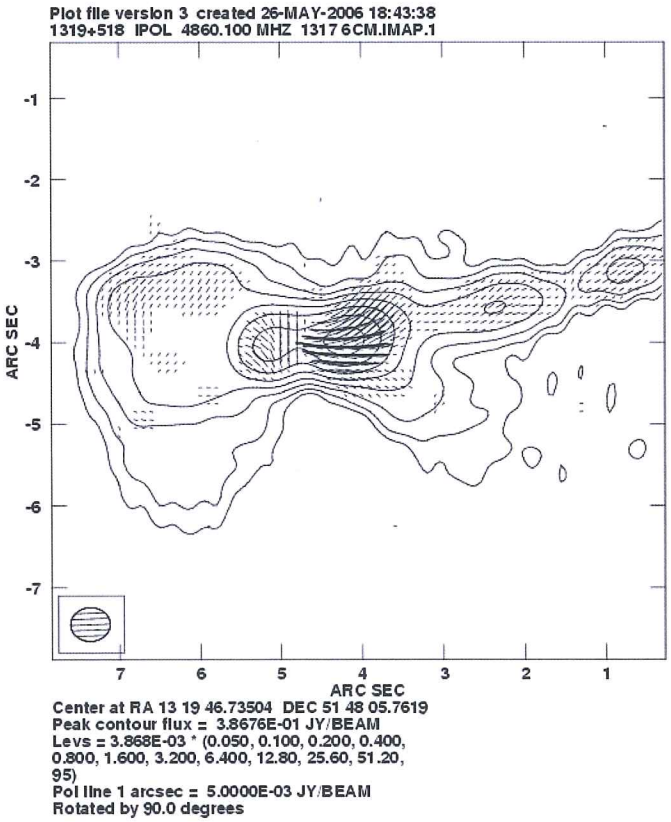
Professor Brainerd has been studying the interactions of small, dwarf satellite galaxies that are in orbit about large spiral galaxies. These satellite galaxies are similar in size and nature to the Magellanic Clouds that orbit our own Milky Way galaxy. Over the past year Professor Brainerd and BU graduate student Ingolfur Agustsson have concentrated on a sample of about 2000 satellite galaxies that were obtained from the Sloan Digital Sky Survey. They have shown that the satellite galaxies are being greatly distorted by gravitational tides exerted by the large galaxies which they orbit. The distortion of the shapes of the satellite galaxies has important implications for the analysis of weak gravitational lensing studies in which it is assumed a priori that tidal distortions are non-existent. Brainerd and Agustsson's work has shown that between 10% and 15% of all galaxies in weak galaxy-galaxy lensing studies are distorted by gravitational tides. This reduces the gravitational lensing signal compared to what would be obtained if the tidal distortions were absent and, if the tidal distortions are not accounted for, it results in the masses of lens galaxies being underestimated by about 30%.

A large spiral galaxy in the Sloan Digital Sky Survey and its satellite galaxy (above and to the left of the spiral galaxy). Note that the images of the spiral galaxy and its satellite are quite well aligned, indicating a gravitational interaction between the two galaxies.

Under the supervision of Professor Clemens, BU graduate student Nina Bonaventura used both PRISM and Mimir on the Perkins telescope to search for brown dwarf stars that are evaporating from the Praesepe star cluster. In addition, Professor Clemens and R. Stencel (University of Denver) have used Mimir on the Perkins telescope to obtain spectra of the nearby binary star system Epsilon Aurigae, which is an F-type supergiant being orbited by a small hot star with an enormous circumstellar disk. The spectra show a combination of normal hydrogen absorption lines, as would be formed in a stellar atmosphere, plus some strong hydrogen line emission, thought to arise from the hot disk. In addition, Professor Clemens performed a pilot IR polarization survey using Mimir in Summer 2005. This was a proof-of-concept for a large, multi-year

survey to be carried out with the Perkins telescope. The survey, known as the Galactic Plane Infrared Polarization Survey or GPIPS, was recommended for full funding by the NSF in June 2006.

The group led by Professor Alan Marscher and Senior Research Associate Dr. Svetlana Jorstad continued their multi-waveband studies of relativistic plasma jets in quasars and radio galaxies. Their program consists of regular monitoring of the time-variable brightness, polarization, and structure of blazars, which are the most extreme class of quasars. The instruments that they use include Mimir and PRISM on the Perkins telescope, the Very Long Baseline Array (VLA), the Rossi X-ray Timing Explorer and the Spitzer Space Telescope. Collaborators around the world contribute data from a variety of other telescopes. The group organized two 10-day campaigns of simultaneous multifrequency polarization observations to reveal connections between the emitting regions at different wavelengths and the structure of the jet as close as a few light months from the supermassive black hole at the heart of the nucleus. The group found that the electric vector position angle for the quasar 3C 454.3 showed a very fast rotation and a dramatic decrease of the fractional polarization at both optical and IR wavelengths. This implies that the polarized regions are cospatial and have a similar size, less or about 1 light day. This places the regions in the innermost section of the jet. In addition, the group measures the polarization and brightness of several blazars monthly to connect polarization variability with changes in X-ray brightness. Theoretical research includes modeling the emission pattern of the region where the jet flow first accelerates, probably through magnetic and gas dynamical forces. BU graduate students Francesca D'Arcangelo, Ritaban Chatterjee, and Suwicha Wannawichian, as well as BU undergraduate students Brett Chizinsky, Haruki Oh, and Andrew Sorkin, participated in the research.



Jorstad and Marscher also used the Spitzer Space Telescope to detect IR emission in the jet of quasar 1317+520 at distance of 10" from the core, which is cospatial with bright radio and X-ray emission. The spectral energy distribution indicates that the emission is synchrotron radiation from radio up to X-ray frequencies by electrons with energies up to at least 100 TeV. This requires extremely efficient particle acceleration out to about 100 kiloparsecs from the nucleus of the quasar.

Polarization(sticks) and radio emission (countours) from the jet of quasar 1317+520.

Polarization observations with the VLA suggest that this occurs where a large cloud rams into the jet, forming an oblique shock in the northern part of the jet that causes a velocity shear to develop within the jet flow, leading to ordering of the magnetic field along the jet.

Jorstad, Marscher and their collaborators also completed a detailed study of time sequences of radio images of blazar jets. By comparing the measured sizes of moving bright spots in the jets with the sizes derived from the time required for the brightness to decrease, a new method was developed to determine the velocity at which plasma flows down each jet as well as the angle that the jet axis makes with the line of sight. This breakthrough allows the group to gain a true picture of each jet, as opposed to a mere projection on the sky.

Professor Janes continued his investigations of star clusters in order to study stellar activity and galactic evolution. It is generally accepted that stellar activity (i.e., starspots and related phenomena) declines with the age of the star, however we cannot directly measure the age of an individual star. Activity is well-established in young cluster stars, up to an age of about 700 million years, and the activity level of our 4.7 billion year old Sun is also known. The Sun's luminosity varies by about 0.1% over the 11-year solar cycle, and about 2-3 times that much with the passage of large spots. However, we do not know whether the Sun is typical of 5 billion year old stars, and we do not know whether our period in history is typical of the Sun's long-term behavior. To explore these issues, Professor Janes has been searching for low-amplitude variability using several old open clusters, whose ages can be directly determined. Preliminary results for several clusters show that activity is ubiquitous in clusters up to the age of the Sun, but stars in the oldest cluster show essentially no signs of activity. The data indicate that, in general, stars similar in age to the sun have higher levels of activity than the Sun. Therefore the Sun is either an unusually quiet star, or we are seeing it at an unusual moment in its history.

Star clusters are important astrophysical targets because their physical properties can be determined with considerable confidence. Furthermore, they are ubiquitous throughout our galaxy. They are important tracers of galactic evolution and they are essential for testing stellar evolution problems. Roughly a thousand clusters are known in our galaxy, but we know very little about most of them. Most clusters survive for only a short time, but it is the much smaller number of clusters which survive for a large fraction of the lifetime of the galaxy that are useful for studies of galactic evolution. In a continuing program supported by the NSF, Professor Janes plus BU students and collaborators from other institutions are using the Perkins telescope, along with other telescopes, to search through the cluster catalogs to identify more old clusters. Because the observations require telescopes of only modest aperture and the analysis is rather straightforward, this is an ideal project for the Perkins telescope and for student involvement.

Lowell Observatory Partnership

The IAR continues its partnership with Lowell Observatory to share the operation of the 1.8-m Perkins telescope on Anderson Mesa, near Flagstaff, Arizona. Our current Memorandum of Understanding extends through July, 2008. As part of this partnership 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 now in routine use as the primary science instruments on the telescope. Together, Mimir and PRISM were scheduled to be used for 80% of the total nights on the Perkins telescope last year. 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. In addition, the IAR is actively engaged in seeking support to join Lowell in the building and operation of the new Discovery Channel Telescope. A summary of our work towards this is outlined in the Discovery Channel Telescope section of this report.

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 our program began in early 2005.

In the past year, we have completed the first phase of the image improvement program. New duct work and fans have been installed to pull warm air from the control room and computer room to a vent about 50 feet from the telescope dome. Additional fans and ducting have been added to the telescope itself to pull ambient air across the mirror surface. The goal is to keep the telescope and surroundings as close as possible to the outside air temperature to minimize the refractive effects of thermal fluctuations along the light path from the star to the telescope. Other improvements in the past year include the addition of a set of "enable/abort" buttons outside the control room, so that the observer is required to go out to the dome and watch the telescope when it slews over large distances. This is an important safety improvement to prevent damage to the telescope or instruments due to passage near the support pier or observatory floor. Finally, as mentioned in the Instrumentation section, PREST funds were used in the past year to build the helium compressor shed for Mimir.

Over the past year, more than a dozen BU undergraduate students visited the telescope, supported in part by the PREST grant. Several honors students from CAS AS202, the entire CAS AS441 class, as well as several other students working on directed study projects joined BU astronomers at the telescope. Most of these students obtained observations for their own projects using Mimir or PRISM. BU undergraduate student Joshua Shiode, who will be a senior in the fall, began an ambitious project under Professor Clemens' direction to search for planetary nebulae that are hidden in the galactic plane. Josh has already spent more than a week at the telescope and made an initial report on his work at an international meeting on planetary nebulae in Hawaii. 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 two students were fully-funded under the PREST program.

As part of the PREST grant, the NSF has requested that BU and Lowell have a visiting astronomer program at the Perkins telescope. For a number of years prior to this, Lowell has scheduled visitors at the telescope; however through our PREST funding we have now 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 six outside groups have been awarded time on the telescope. Five of the six outside groups used a BU instrument (i.e., Mimir or PRISM) for their observations.

DISCOVERY CHANNEL TELESCOPE

In order to continue to thrive, the IAR requires guaranteed access to a state-of-the-art telescope. We have identified the Discovery Channel Telescope (DCT) as the telescope that would be ideal for us. The DCT is a 4-meter telescope that is currently being built by Lowell Observatory with partial funding from the Discovery Channel. The telescope will be located at Happy Jack, Arizona and it is expected to see first light in 2009 or 2010. As of this report, much of the construction on the site has been completed, including most of the main telescope building, as well as an auxiliary building. The primary mirror blank has been completed and will undergo final figuring and polishing over the next two years. An official ground breaking ceremony was held on July 12, 2005, and Professor Jackson attended the ceremony as a representative of the IAR. Also in attendance at the ceremony was John Hendricks, founder and CEO of Discovery Communications Inc., who has personally invested $1 million in the DCT. To date, Mr. Hendricks and Discovery Communications have invested a total of $10 million in this project.

John Hendricks (right), founder and CEO of Discovery Communications, Inc. and Carrie Passmore (left), VP of Public Partnerships for Discovery Communications, Inc. at the July 12, 2005 groundbreaking ceremony for the DCT.

The IAR wishes to become a partner with Lowell Observatory and the Discovery Channel in the operation of the DCT in order to foster not only our research mission, but our education mission as well. In terms of research, the IAR has identified four key projects that are very well-suited to the capabilities of the DCT as well as the scientific interests of the IAR members. These key projects are (i) a determination of the detailed kinematics of the Milky Way, (ii) to constrain the nature of dark matter on galaxy scales through the interactions between companion galaxies, (iii) to carry out an extensive census of blazars, and (iv) to probe the nature of dark energy using distant clusters of galaxies. In order to carry out these studies the IAR would require one new near-infrared instrument that would combine narrow and wide field imaging with an integral field spectrometer. Professor Clemens has recently developed a conceptual design for this instrument, which would be built at BU.

The education and public outreach possibilities that will result from the DCT are simply unparalleled. Access to the DCT would, of course, provide outstanding opportunities for undergraduate and graduate research and training. In addition, Discovery Communications owns multiple television stations with millions of subscribers and it also has a strong educational mission. Educational material produced by Discovery Communications currently reaches over 60,000 K-12 classrooms in the USA. Part of the

agreement between Lowell Observatory and Discovery Communications is that Lowell must partner with at least one university that has professional educators. The university's professional educators would assist Discovery staff with the development of K-12 classroom materials as well as the transition from televison-based classroom materials to interactive broadband classroom materials. The National Science Foundation (NSF) is keenly aware of the DCT and its potential for broad impact on science education, and the NSF is supportive of the project. Becoming involved with the DCT presents an excellent opportunity to foster interdisciplinary activity within the broader BU community, a priority that has been called out by President Brown. Over the past 6 months the IAR has held numerous meetings with members of the BU School of Education and College of Communications, all of whom are very enthusiastic about joining the DCT project.

Crew from Discovery Communications filming construction of the main telescope building for the DCT in January, 2006. Film footage will ultimately air on the Discovery Channel as part of a documentary on the building of the DCT.

President Brown and Provost Campbell have encouraged the IAR to investigate the possibility of forming a consortium of universities that could partner with Lowell Observatory in the operation of the DCT. In response to this encouragement, the IAR invited representatives of Vanderbilt University and the Keck Northeast Astronomy Consortium (KNAC; Colgate University, Middlebury College, Vassar College, Wesleyan University, Haverford College, Swarthmore College, Wellesley College, and Williams College) to attend a meeting on March 13, 2006 at BU to discuss the possibility of forming a consortium. The outcome of the meeting was that the KNAC members were unlikely to be able to join the consortium, but that a partnership between Vanderbilt University and BU would be especially fruitful. In addition to complementary science goals amongst the astronomers from these two institutions, Vanderbilt has a new graduate program designed to increase the number of underrepresented minorities in astrophysics. Vanderbilt's program is already filled to capacity, and the IAR would be pleased to take on additional outstanding minority graduate students who have been identified through Vanderbilt's program but who cannot be accommodated by Vanderbilt. To follow through on our initial meeting, IAR members intend to travel to Vanderbilt University in summer 2006 to learn more about the astronomical research that is being done at Vanderbilt, as well as the step program that is successfully attracting underrepresented minority students to pursue PhDs in astrophysics. We note that Vanderbilt's interest in the DCT is extremely strong, and their administration has already committed $400,000 in annual operating costs, in perpetuity, should Vanderbilt become a DCT partner.

CAS AS441 (Observational Astronomy) students visit the DCT site in spring 2006. The students are standing in front of the central pier that will ultimately support the telescope.

Joining the DCT would be tremendously beneficial to the IAR, as well as to a broad community within BU. It would build upon our current partnership with Lowell Observatory and our very successful astronomical instrumentation program. Having guaranteed access to this state-of-the-art facility would provide excellent leverage with funding agencies, particularly the NSF. The connection with Discovery Communications would greatly raise the visibility of BU, placing a spotlight on BU as a world leader in science research and education

IAR Advisory Board Meeting

The IAR held a meeting with its advisory board November 17 and 18, 2005. The advisory board consists of three highly respected astrophysicists: Drs. Charles Lada (Smithsonian Astrophsical Observatory), Richard Miller (Georgia State Universtiy), and Robert Ghetz (University of Minnesota). 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 advisory board was very pleased with the current status of the IAR, noting that the IAR members showed an extremely high level of morale and enthusiasm that is driving an increase in scientific productivity. The board was also very pleased that the IAR has successfully addressed two major concerns that had been noted in the October 2003 advisory board report: (1) IAR members have now secured external grant funding to support the operation of BU instrumentation on the Perkins telescope and (2) the MIRSI instrument is well-supported and is being fully utilized at the Infrared Telescope Facility (IRTF) in Hawaii. The November 2005 advisory board report strongly recommends that at least one new astrophysics faculty member be added to the Department of Astronomy and that Boston University continue its partnership with Lowell Observatory to operate the Perkins telescope beyond July 2008. This will allow BU to maximize the scientific return from PRISM and Mimir.

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-two astrophysicists from across the nation. Students prepare for upcoming seminars through the Astrophysics Journal Club, which meets Friday afternoons. The seminar schedule is shown in Appendix B.

Accounts, Funding, Expenditures

Accounts supervised by the IAR during the past year include a total of twenty-nine grants and contracts, the Lowell Operations account (20-341), the IDC return account for the IAR (20-351-1648-9), the IAR MIRSI bridge funding account (20-351) and Professor James Jackson's retention account (20 201 1588-9).

Grant and contract accounts supervised by the IAR include twelve new sponsored grants and contracts, five existing grants which received further income, and fifteen other continuing sponsored grants and contracts within the IAR. A total of five of these sponsored grants and contracts were closed out during the past year.
Twenty-two new funding proposals were submitted to federal and other agencies, totaling over $3.6M.

Lowell Operations (20-341)
The Lowell Operations account is funded through the College of Arts and Sciences and is used to cover the cost of the annual usage fee to Lowell Observatory, the salary for the BU Researcher at Lowell and auto insurance on the BU vehicle kept out in Arizona for use by BU personnel when they go there to observe. Due to the ability of Professor Alan Marscher and Dr. Svetlana Jorstad to cover costs for Brian Skiff from external funding, and to the resignation of Amanda Bosh effective May 1, 2006,the IAR was able to reimburse an unused portion of 020 341 Lowell funds to the college. This totaled $6820. The expenses to be recorded against this account for FY06 are as indicated in the following table.

Category	Cost
Usage fee paid to Lowell Observatory	$136,841
Dr. Amanda Bosh (part time salary)	$25,133
Auto Insurance	$1750
AAS Job Ad for New Res. Assoc	$248
Computer System for New Res. Assoc.	$4074
Returned to College of Arts and Sciences	$6821
Total	$174,867

IAR Dept. Account (020-351)
The IAR Unrestricted Departmental account is generally not used. It was initially set up with $25k by the College of Arts and Sciences in 1998 as a start-up account for the IAR. Once the start-up funding was expended the account remained dormant until this year when the College provided funding for 6 months of Research Associate salary to continue working with the IAR's MIRSI instrument.

A total of $22,619 was spent on the Research Associate's salary from January '06 - June '06 and $1,500 on miscellaneous expenses.

IAR IDC Return (20-351-1648-9)
This account was used to meet IAR expenses throughout the year. Expenditures, as of this report, totaled $83,933 and income totaled $92,725. In managing IAR activities utilizing this account, we internally track expenses in nine categories, some of which have Object Code equivalents, but others of which either combine or split Object Codes. These expense categories are broken down in the following table.

IAR FY2006 Expenditures

Category	Cost	Percent of FY06 Expenditures
Basic Operations	$55,447	66%
Proposal Development	$1,183	1%
Infrastructure	$6,433	8%
Seminar Series	$10,793	13%
Social	$100	0%
Cost Sharing	$4,178	5%
General Research	$1,500	2%
Educational Etc.	$1,599	2%
Advisory Council	$2,700	3%
Total Expended	$83,933	100%

Basic Operations, the largest expense category, covers fixed costs such as Fiscal Administrator Paci's salary, the director's stipend, and benefits for both.

The Seminar Series makes up the 2nd largest expense category for the IAR this year. Seminar costs include travel, meals and accommodations for our guest speakers. Thirteen seminars were held during the Fall 2005 semester, and nine were held during the Spring 2006 semester. The schedules are shown in appendix B.

Infrastructure expenses make up the 3rd largest expense category. Included in the infrastructure category are minor costs such as telephone lines and minor computer equipment.

Cost sharing is the 4th largest expense category. Cost share expenses hit the account early this fiscal year and were made up of cost overruns from the highly successful Milky Way Surveys Conference held in June 2003. These charges occurred well after the conference was held due to the timing of the grant closing process and grant end dates.
The Advisory Board meeting held this year was the 5th largest expense for the IAR and well worth the cost. For more details on the meeting see page 21.

Sponsored Grants and Contracts

The IAR managed a total of thirty-two grants during this fiscal year. There are twelve new grants, which have been awarded to the Institute, five existing grants that were awarded further funding, and fifteen other continuing grants. This year, the IAR closed out a total of five awards.

A summary of the FY2006 sponsored grant income and expenditures are contained in the following tables.

FY2006 Grant Income – Institute for Astrophysical Research (7/2005-6/2006)

P.I.	Agency	Title	FY2006 Award
*Bania	NASA	Mapping the Distribution of Hot Gas in the Inner Milky Way	$56,600
*Blanton	NASA	Chandra General Observer Progam, Cycle 6-Bubbles and B-Flats: A Deep Observation of Abell 2052	$58,792
Blanton	Foundations	Clare Boothe Luce Professorship	$109,724
Bosh	NASA	Planetary Ring Studies using Stellar Occultation	$45,392
Clemens	JPL	The SIRTF Galactic Plane Survey	$58,706
*Jackson	NSF	Release and Analysis of the Galactic Ring Survey	$175,000
Jackson	NASA	The MSX Dark Cloud Catalog	$87,975
*Janes	NSF	REU Supplement: Collaborative Research: BU/LowellObservatory Partnership-Bringing the Perkins Telescope into the 21ST Century	$8,171
*Janes	NSF	Old Star Clusters: Stellar Activity and Galactic Structure	$217,841
*Jorstad	JPL	Spitzer Space Telescope: Deep Imaging of Quasar Jets with IRAC	$22,318
Marscher (8514-5)	NSF	Multifrequency Probes of Blazar Jets	$203,653
*Marscher	NASA	Positrons in AGN Jets: Search for Annihilation Line Radiation	$56,903
*Marscher	NASA	Mapping the Variable X-Ray Emission in Blazars	$28,009
*Marscher	NASA Sub	Studies of Winds in Quasars	$23,088

*Marscher	NASA	Relation Between X-Ray State and Energy Flow in Jets or Radio Galaxies	$30,496
*Marscher	NASA	NGC1052: The Key to Explore the Disk-Jet Connection in AGN	$30,278
*Marscher	JPL	Spitzer Space Telescope: Comparison of Time-Variable IR and X-Ray Continuum Spectra in Four Blazars	$47,498

***New Awards**

Summary of IAR Grant Income

Origin of Award	Total Current Year Funding (7/05-6/06)
Institute for Astrophysical Research (20-351)	$1,260,364

FY2006 Grant Expenditures – Institute for Astrophysical Research (7/2005– 6/2006)

P.I.	Agency	Title	FY2006 Expense
Bania	NSF	Collaborative Research: The 3-Helium Problem	$26,155
*Bania	NASA	Mapping the Distribution of Hot Gas in the Inner Milky Way	$27,913
Blanton	Foundations	Clare Boothe Luce Professorship	$116,517
*Blanton	NASA	Chandra General Observer Progam, Cycle 6-Bubbles and B-Flats: A Deep Observation of Abell 2052	$3,486
Blanton	NASA	The Formation of Wide-angle Tailed Radio Sources	$15,075
Bosh	NASA	Planetary Ring Studies Using Stellar Occultation	$10,846
Brainerd	NSF	Dynamics of Satellite Galaxies	$47,484
Clemens	JPL	The SIRTF Galactic Plane Survey	$68,788
*Jackson	NSF	Release and Analysis of the Galactic Ring Survey	$935
Jackson	NASA	The MSX Dark Cloud Catalog	$108,240

Jackson	NSF	The Galactic Ring Survey	$362
Jackson	JPL	Spitzer Space Telescope: 24 Micron Survey of the Galactic Plane	$41,171
Jackson	JPL	Spitzer Space Telescope: The Small Magellanic Cloud	$62,639
Jackson	JPL	Spitzer Space Telescope: The Small Scale Structure of Cluster Forming Infrared Dark Clouds	$12,458
Jackson	NASA	Infrared Studies of Star Forming Regions in the Galactic Ring Survey	$37,708
Jackson	NASA	The Mid-Course Space Experiment Extended Source Catalog	$54,311
Janes	NSF	Collaborative Research: Boston University/Lowell Obs. Partnership	$46,219
*Janes	NSF	REU Supplement: Collaborative Research: BU/LowellObservatory Partnership-Bringing the Perkins Telescope into the 21ST Century	$2,721
*Janes	NSF	Old Star Clusters: Stellar Activity and Galactic Structure	$5,226
*Jorstad	NASA	Spitzer Space Telescope: Deep Imaging of Quasar Jets with IRAC	$16,274
Marscher	NSF	Multifrequency Probes of Blazar Jets	$164,316
*Marscher (9007-5)	NASA	Positrons in AGN Jets: Search for Annihilation Line Radiation	$43,061
*Marscher	NASA	Mapping the Variable X-Ray Emission in Blazars	$31,718
*Marscher	NASA Sub	Studies of Winds in Quasars	$22,937
*Marscher	NASA	Relation Between X-Ray State and Energy Flow in Jets or Radio Galaxies	$22,943

*Marscher	JPL	Spitzer Space Telescope: Comparison of Time-Variable IR and X-Ray Continuum Spectra in Four Blazars	$3,759
Marscher	NASA	Connection between X-Ray Dips and Superluminal Ejections in the Radio Galaxy 3C 120	$485
Marscher	NASA	High Energy Variable & Particle Acceleration in the Quasar 3C273	$10,025

Summary of IAR Sponsored Funding Expenditures

Origin of Award	**Total Current Year Expenditures (7/05-6/06)**
Institute for Astrophysical Research (20-351)	$1,002,592

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 in the next several years. Having guaranteed access to these instruments has begun to pay off with successful proposals to federal funding agencies, and we expect this trend to continue in the future. In order to optimize the science return from our investment in PRISM and Mimir, we wish to continue our partnership with Lowell Observatory beyond the end date of the current MOU.

We will continue to promote the Discovery Channel Telescope as our first priority for a new telescope facility. The DCT offers us the ability to carry out cutting-edge science in combination with an unparalled program of education and outreach, and provides a unique opportunity to foster interdisciplinary work amongst three Boston University colleges and schools (CAS, SED, COM). Becoming a partner with Lowell Observatory and Discovery Communications, Inc. in the operation of the DCT will help to propel us to the next tier of front-line research institutions and will provide important exposure of Boston University and the IAR to the general public.

Finally, in order to secure the rise in our scientific stature, the IAR needs to add at least one new, young astrophysics faculty member who will use our instruments and telescopes to conduct world-class research. This person should be sought and hired within the next two years.

Appendix A: Publications

Articles in Referred Journals

Agustsson, I. & Brainerd, T. G., "The Orientation of Satellite Galaxies: Evidence for Elongation in the Direction of the Host", ApJ, 644, L25-L28, 2005

Agudo, I., Gomez, J.L., Gabuzda, D.C., Marscher, A., Jorstad, S.G., and Alberdi, A. "The Milliarcsecond-Scale Jet of PKS 0735+178 during Quiescence", 2006, Astronomy & Astrophysics, in press

Bach, U., Villata, M., Raiteri, C.M., Agudo, I., Aller, H.D., Aller, M.F., Denn, G., G'omez, J.L., Jorstad, S., Marscher, A., Mutel, R.L., and Ter"asranta, H. "Structure and Flux Variability in the VLBI Jet of BL Lacertae during the WEBT Campaigns (1995--2004)", 2006, Astronomy & Astrophysics, in press

Balser, D.S., Goss, W.M., Bania, T.M., & Rood, R.T., "Detection of hep3 in a Planetary Nebula Using the VLA", ApJ, 640, 360—368, 2006

Benjamin, R. A., Churchwell, E., Babler, B.L., Indebetouw, R., Meade, M.R., Whitney, B.A., Watson, C., Wolfire, M.G., Wolff, M.J., Ignace, R., Bania, T.M., Bracker, S., Clemens, D.P., Chomiuk, L., Cohen, M., Dickey, J.M., Jackson, J.M., Kobulnicky, H.A., Mercer, E.P., Mathis, J.S., Stolovy, S.R., Uzpen, B.,"First GLIMPSE Results on the Stellar Structure of the Galaxy", ApJ, 630, L149--L152, 2005

Brainerd, T. G., "Anisotropic Distribution of SDSS Satellite Galaxies: Planar (not Polar) Alignment", ApJ, 628, L101-L104, 2005

Carraro, G., Janes, K.A., Eastman, J.D., "Photometry of Neglected Open Clusters in the First and Fourth Galactic Quadrants," MNRAS, 364, 179, 2005

Carraro, G., Subramanian, A., Janes, K.A. 2006, "Preliminary Parameters of Six Neglected Old Open Clusters," submitted to MNRAS, 2006

Carraro, G., Janes, K.A., Costa, E., Mendez, R.A., "Photometry of Seven Overlooked Open Clusters in the First and Fourth Galactic Quadrants," MNRAS, 368, 1078, 2006

Carraro, G., Subramanian, A., Janes, K.A. 2006, "Preliminary Parameters of Six Neglected Old Open Clusters," submitted to MNRAS.

Clarke, T. E.; Sarazin, C. L.; Blanton, E. L.; Kassim, N. E.; Neumann, D., "Low Frequency Radio Observations of Interactions in Cooling Core Clusters", AAS 177.05, 2005

Gómez, J. L., Marscher, A. P., Jorstad, S. G., Agudo, I. "The jet in the radio galaxy 3C120: Jet/cloud interactions at parsec scales", Astronomische Nachrichten, 327, 223-226, 2006

Jackson, J.M., Rathborne, J. M., Shah, R. Y., Simon, R., Bania, T. M., Clemens, D. P., Chambers, E. T., Johnson, A. M., Dormody, M., Lavoie, R., and Heyer, M. H., "The Boston University-Five College Radio Astronomy Observatory - Galactic Ring Survey", ApJS, 163, 145-159, 2006

Janes, K.A., Buie, M.W., Bosh, A.S., Clemens, D.P., Jackson, J.M., "The Perkins Telescope in the 21st Century: An NSF PREST Project," AAS, 207.17311, 2005

Jorstad, S., Marscher, A., McHardy, I., Markowitz, A., Clemens, D., Janes, K. 2005 "Multifrequency Observations of the Exotic Behavior of the Quasar 3C 454.3 in Spring-Autumn 2005," AAS, 207.141014

Jorstad, S. G., Marscher, A. P, Lister, M. L., et al., "Polarimetric Observations of 15 Active Galactic Nuclei at High Frequencies: Jet Kinematics from Bimonthly Monitoring with Very Long Baseline Array", AJ, 130, 1418—1465, 2005

Jorstad, S. G. & Marscher, A. P., "The X-ray and radio jets of quasars on kiloparsec scales", Astronomische Nachrichten, 327, 227—230, 2006

Kassis, M., Adams, J.D., Campbell, M.F., Deutsch, L.K., Hora, J.L., Jackson, J.M., Tollestrup, E.T., "Mid-Infrared Emission at Photodissociation Regions in Orion Nebula", ApJ, 637...823K, 2006

McCullough, P.R., Stys, J.E., Valenti, J.A., Fleming, S.W., Janes, K.A., Heasley, J.N., "The XO Project: Searching for Transiting Extrasolar Planet Candidates," PASP, 117, 783, 2005

McCullough, P.R., Stys, J.E., Valenti, J.A., Johns-Krull, C.M., Janes, K.A., Heasley, J.N., Bye, B.A., Dodd, C., Fleming, S.W., Pinnick, A., Bissinger, R., Gary, B.L., Howell, P.J., Vanmunster, T. 2006, "A Transiting Planet of a Sun-like Star," ApJ, in press, September 1, 2006

Mercer, E.P., Clemens, D.P., Meade, M.R., Babler, B. L., Indebetouw, R., Whitney, B. A., Watson, C., Wolfire, M.G., Wolff, M.J., Bania, T. M., Benjamin, R. A., Cohen, M., Dickey, J. M., Jackson, J. M., Kobulnicky, H. A., Mathis, J. S., Stauffer, J.R., Stolovy, S. R., Uzpen, B., and Churchwell, E.B., "New Star Clusters Discovered in the GLIMPSE Survey", ApJ, 635, 560—569, 2005

Quierza, C., Rood, R.T., Balser, D.S., & Bania, T.M., "Radio Recombination Lines in Galactic hii Regions", ApJ, in press: 2006

Raiteri, C. M., ... Jorstad, S. G., et al., "The WEBT campaign to observe AO 0235+16 in

the 2003-2004 observing season. Results from radio-to-optical monitoring and XMM Newton observations", A&A, 438, 39—53, 2005

Rathborne, J.M., Jackson, J.M., Simon, R., "Infrared Dark Clouds: Precursors to Star Clusters", ApJ, 641...389R, 2006

Rathborne, J.M., Jackson, J.M., Simon, R., Shipman, R., Frieswijk, W., "Massive Protostars in the Infrared Dark Cloud MSXDC G034.43+00.24", Apj, 630L.181R, 2005

Rogers, A.E.E., Dudevoir, K.A., Carter, J.C., Fanous, B.J., Kratzenberg, E., Bania, T.M., "Deuterium Abundance in the Interstellar Gas of the Galactic Anticenter from the 327 MHz Line", ApJ, 630, L41--L44, 2005

Shiode, J., Clemens, D.P., Janes, K.A., Pinnick, A., 2006, "Missing Galactic PNe: [S III] Imaging Survey," in Proc. IAU Symp. 234, Planetary Nebulae in our Galaxy and Beyond (3-7 April 2006), eds. M. J. Barlow & R. H. Mendez, 2006, Cambridge Univ. Press, in press

Simon, R., Jackson, J.M., Rathborne, J.M., Chambers, E.T., "A Catalog of Midcourse Space Experiment Infrared Dark Cloud Candidates", ApJ, 639...227S, 2006

Sivakoff, G. R.; Sarazin, C. L.; Blanton, E. L.; Juett, A. M.; HST ACS Virgo Cluster Survey Team, "The Low Mass X-ray Binary - Globular Connection in the HST ACS Virgo Cluster Survey", AAS 202.05, 2005

Sokolov, A., and Marscher, A.P.,"External Compton Radiation from Rapid Nonthermal Flares in Blazars", Astrophysical Journal, 629, 52-60, 2005

Stanimirovic, S., Bolatto, A.D., Sandstrom, K., Leroy, A.K., Simon, J.D., Gaensler, B.M., Shah, R.Y., Jackson, J.M, "Spitzer Space Telescope Detection of the Young Supernova Remnant 1E 0102.2-7219", ApJ, 632L.103S, 2005

Turler, M., Chernyakova, M., Courvoisier, T.J.-L., Foellmi, C., Aller, M.F., Aller, H.D., Kraus, A., Krichbaum, T.P., Lahteenmaki, A., Marscher, A., McHardy, I.M., O'Brien, P.T., Page, K.L., Popescu, L., Robson, E.I., Tornikoski, M., & Ungerechts, H. "A Historic Jet-Emission Minimum Reveals Hidden Spectral Features in 3C 273",2006, Astronomy & Astrophysics, in press

Uzpen, B., Kobulnicky, H.A., Olsen, K.A.G., Clemens, D.P., Laurance, T.L., Meade, M.R., Babler, B.L., Indebetouw, R., Whitney, B.A., Watson, C., Wolfire, M.G., Wolff, M.J., Benjamin, R.A., Bania, T.M., Cohen, M., Devine, K.E., Dickey, J.M., Heitsch, F., Jackson, J.M., Marston, A.P., Mathis, J.S., Mercer, E.P., Stauffer, J.R., Stolovy, S.R., Backman, D.E., & Churchwell, E., "Identification of Main-Sequence Stars with Mid-Infrared Excesses Using GLIMPSE: beta Pictoris Analogs?", ApJ, 629, 512—525, 2005

Wong, K.-W.; Sarazin, C. L.; Blanton, E. L.; Reiprich, T. H., "XMM-Newton and Chandra Observations of Abell 2626", AAS 177.06, 2005

Seminars and Colloquia

Bania, T. Invited Paper at international conference: "Local Late Galactic Evolution", held at the International Space Science Institute (ISSI) in Bern, Switzerland, 20-21 October 2005: "New Determinations of the D and he3 Abundance in the Galactic Interstellar Medium"

Bania, T. Colloquium at University of Massachusetts, Amherst, MA, 30 March 2006: "The 3-Helium Problem: Constraining the Chemical Evolution of the Milky Way", Invited talk at University of Michigan, Dept. of Physics, April 2006

Blanton, E., "Radio Sources in Clusters of Galaxies: Impact On the X-ray-Emitting ICM and Probes of High-z Systems"

Brainerd, T.G., "Supernovae Under the Gravitational Lens", invited lecture in conjunction with PhD defense by Christofer Gunnarsson, Stockholm University, Stockholm Sweden, September 23, 2005

Brainerd, T.G., "Satellite Galaxies and CDM Halos", Michigan State University astronomy colloquium, East Lansing, Michigan, January 18, 2006

Brainerd, T.G., "New Constraints on CDM Halos from Satellite Galaxies and Weak Lensing: the view from CAS 514B", Boston University astronomy colloquium, Boston, MA, February 7, 2006

Brainerd, T.G., "Satellite Galaxies and CDM Halos", invited lecture at the American Association of Physics Teachers annual meeting, Boston, MA, March 13, 2006

Brainerd, T.G., Contributed conference talk: "Flattening of Field Galaxy Halos", presented at the XXIst IAP meeting: Mass Profiles and Shapes of Cosmological Structures, July 7, 2005, Paris, France

Jackson, J.M., Astronomy Dept. Colloquium, University of Maryland, "Infrared Dark Clouds", November, 2005

Jackson, J.M., Astronomy Dept. Colloquium, University of California, Berkeley, "Infrared Dark Clouds", May, 2006

Jackson, J.M., Astrophysics Colloquium, Lawrence Livermore National Laboratories, "Infrared Dark Clouds", May, 2006

Jorstad, S.G., American Astronomical Society Meeting 207, 8-12 January 2006,Washington, DC, poster #141.04, "Multifrequency Observations of the Exotic Behavior of the Quasar 3C 454.3 in Spring-Autumn 2005."

Jorstad, S.G., "Apparent Speed as a Probe of the Parsec Scale Jet Physics,"oral presentation at meeting "The Common Physics of AGN, Microquasars, and Gamma-ray Bursts," Dec. 14-17, 2005, Ann Arbor, MI.

Jorstad, S.G., The 16th New England Regional Quasar/AGN Meeting, 30 May, 2006, MIT, Boston, oral presentation "The Kiloparsec Scale Jet of the Quasar 1317+520."

Marscher, A. & Jorstad, S.G., "The Exotic World of Quasars," at the Science LiteracyWorkshop for Public Radio Reporters, Oct. 16, 2005, Cambridge, MA

Marscher, A., "Jets in Active Galactic Nuclei," invited talk at meeting "The Common Physics of AGN, Microquasars, and Gamma-ray Bursts," Dec. 14-17, 2005, Ann Arbor, MI

Marscher, A., "Exploring Blazar Jets through Multiwaveband Monitoring with RXTE, the VLBA, and other Instruments," poster paper at American Astronomical Society Meeting, Washington, DC, Jan. 9-12, 2006 (author list: Marscher, A.P., Jorstad, S.J., Aller, M.F., and McHardy, I.M.; abstract published in 2005, Bulletin of the American Astronomical Society, 37, 1399)

Marscher, A., "X-ray Light Curves as Probes of Relativistic Jets in Radio-Loud AGN," invited talk at meeting "RXTE: A Decade of Exploring the Extreme Universe," Jan. 13, 2006, Greenbelt, MD

Marscher, A., "Sites of Particle Acceleration in Quasar Jets," invited talk, New England Space Science Consortium solar physics workshop, March 1, 2006, Cambridge, MA

Marscher, A., "Upper Limit to the Positron Content of the 3C 120 Jet," contributed talk at the New England Regional Quasar/AGN Meeting, May 30, 2006, Cambridge, MA

Marscher, A., "Active Galactic Nuclei," invited talk (in Russian) at Astronomy 2006: Tradition, Present, and Future, June 26-30, 2006, St. Petersburg, Russia

Conference Proceedings and Abstracts

Anderson, L., Blanton, E. L., Clarke, T. E., Sarazin, C. L. 2005, Six Years of Science with Chandra Symposium, "Chandra Observation of the Cooling Flow Cluster A262", 2005

Bolatto, A.D., Stanimirovic, S., Leroy, A.K., Sandstrom, K., Simon, J.D., Shah, R., Jackson, J.M., et al., "Spitzer Observations of the Magellanic Clouds", AAS, 20714504B, 2005

Chambers, E.T., Rathborne, J.M., Jackson, J.M., Simon, R., "Active and Quiescent Cores in Infrared Dark Clouds", AAS, 20718412C, 2005

Clarke, T., Sarazin, C., Blanton, E., Kassim, N. 2005, Six Years of Science with Chandra Symposium, "Ghost Cavities in Cluster Cores Viewed with Chandra and the VLA", 2005

Clemens, D.P., Pinnick, A., Bonaventura, N., Sarcia, D.S., Grabau, A., Tollestrup, E.V., Buie, M., Taylor, B., & Dunham, E., "Galactic Plane Infrared Polarization Survey: Calibration and Pilot Surveys", BAAS, 207, 133.06, 2006

Douglass, E. M., Blanton, E. L., Clarke T. E., Sarazin, C. L., Wise, M. W., Six Years of Science with Chandra Symposium, "Chandra Observation of the Cluster Environment of a WAT Radio Source in Abell 1446", 2005

Jackson, J.M., Rathborne, J.M., Shah, R.Y., Simon, R., Bania, T.M., Clemens, D.P., Chambers, E.T., Johnson, A.M., Dormody, M., Lavoie, R., & Heyer, M., "The Boston University-Five College Radio Astronomy Observatory Galactic Ring Survey", BAAS, 207, 81.20, 2006

Janes, K.A., Buie, M.W., Bosh, A.S., Clemens, D.P., & Jackson, J.M., "The Perkins Telescope in the 21st Century: An NSF PREST Project", BAAS, 207, 173.11, 2006

Johnson, A.M., Rathborne, J.M., Jackson, J.M., Shah, R.Y., Simon, R., "Molecular Clouds in the Boston University—Five College Radio Astronomy Observatory Galactic Ring Survey", AAS, 207.8121J, 2005

Jorstad, S.G., Marscher, A.P., Stevens, J., Robson, I., Lister, M., Stirling, A., Cawthorne, T., Smith, P., Gomez, J.L., Gabuzda, D., and Gear, W. "Polarimetric Observations of 15 AGNs at High Frequencies", in Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed. J.D. Romney and M.J. Reid, Astronomical Soc. Pacific Conf. Ser., 340, 183-185, 2005

Jorstad, S., Marscher, A., McHardy, I., Markowitz, A., Clemens, D., & Janes, K., "Multifrequency Observations of Exotic Behavior of the Quasar 3C 454.3 in Spring-Autumn 2005", BAAS, 207, 141.04, 2006

Jorstad, S.G., and Marscher, A.P. "The X-ray and Radio Jets of Quasars on Kiloparsec Scales", in High-z Radio Galaxies, ed. M. Villar Martin et al., Astronomische Nachrichten, 327, 227-230, 2006

Jorstad, S.G., Marscher, A.P., et al. "Multi-frequency Polarization Properties of Blazars", in Astronomical Polarimetry: Current Status and Future Directions, ed. A. Adamson, C. Aspin, and C.J. Davis, Astronomical Soc. Pacific Conf. Ser., 343, 469—473, 2005

Jorstad, S. G., Marscher, A. P., Stevens, J. A. et al., "Multi-frequency Polarization Properties of Blazars," in Astronomical Polarimetry: Current Status and Future Directions, ed. A. Adamson, C. Aspin, C. J. Davis, Astronomical Soc. Pacific Conf. Ser., 343, 469—474, 2005

Jorstad, S.G., and Marscher, A.P. "Jet Kinematics of AGNs at High Radio Frequencies", in Variability of Blazars II: Entering the GLAST Era, ed. H.R. Miller et al., Astron. Soc. Pacific Conf. Ser., 350, 149—154, 2006

Jorstad, S.G., Marscher, A.P., Aller, M.F., and Balonek, T.J. "X-ray, Optical, and Radio Monitoring of Gamma-Ray Blazars", 2006, in AGN Variability from Radio to X-ray, ed. C.M. Gaskell et al., Astronomical Soc. Pacific Conf. Ser., in press

Jorstad, S. G., Marscher, A. P., Stevens, J., et al., "Polarimetric Observations of 15 AGNs at High Frequencies", in Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed. J. Romney & M. Reid, Astronomical Soc. Pacific Conf. Ser., 340, 183—184, 2005

Jorstad, S. G., Marscher, A. P., Lister, J., et al., "Jet Kinematics of AGNs at High Radio Frequencies", in Blazar Variability Workshop II: Entering the GLAST Era, ed. H. R. Miller, K. Marshall, J. R. Webb, and M. F. Aller, Astronomical Soc. Pacific Conf. Ser., 350, 149—154, 2005

Jorstad, S., Marscher, A., Stevens, J., Smith, P., Forster, J., Lister, M., Stirling, A., Gomez, J., Cawthorne, T., Gear, W., and Robson, I. "Multifrequency Polarization Properties of Blazars", 2006, in Multifrequency Behaviour of High Energy Cosmic Sources, ed. F. Giovanelli and L. Sabau-Graziati, Chinese J. Physics, in press

Marscher, A.P. "Are 3C~120 and Other Active Galactic Nuclei Overweight Microquasars?" in From X-ray Binaries to Quasars: Black Hole Accretion on All Mass Scales, ed. T. Maccarone, Astrophysics & Space Science, 300, 39-44, 2005

Marscher, A.P. "Relationship between High-Frequency Emission and the Radio Jet in Blazars", in Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed. J.D. Romney and M.J. Reid, Astronomical Soc. Pacific Conf. Ser., 340, 25-29, 2005

Marscher, A.P. "X-ray and Radio Emission in the Nuclei of Radio Galaxies and the Disk-Jet Connectiom", in High-z Radio Galaxies, ed. M. Villar Martin et al., Astronomische Nachrichten, 327, 217-222, 2006

Marscher, A.P., and Jorstad, S.G. "Polarization Monitoring as a Probe of Blazar

Jets on the Finest Scales", in Astronomical Polarimetry: Current Status and Future Directions, ed. A. Adamson, C. Aspin, and C.J. Davis, Astronomical Soc. Pacific Conf. Ser., 343, 480-484, 2005

Marscher, A.P. "Probing the Compact Jets of Blazars with Light Curves, Images, and Polarization", in Variability of Blazars II: Entering the GLAST Era, ed. H.R. Miller et al., Astron. Soc. Pacific Conf. Ser., 155—162, 2006

Marscher, A.P., and Jorstad, S.G. "3C 120 and the Disk-Jet Connection", 2006, in AGN Variability from Radio to X-rays, ed. C.M. Gaskell et al., Astronomical Soc. Pacific Conf. Ser., in press

Marscher, A.P. "The Intimate Connection between High and Low Frequency Emission in Blazars", 2006, in Multifrequency Behaviour of High Energy Cosmic Sources, ed. F. Giovanelli and L. Sabau-Graziati, Chinese J. Physics, in press

Marscher, A.P. "Relativistic Jets in Active Galactic Nuclei", in Relativistic Jets: The Common Physics of AGN, Microquasars and Gamma-Ray Bursts, ed. P.A. Hughes, AIP Conf. Proc., in press

Marscher, A. P. & Jorstad, S. G., "Polarization Monitoring as a Probe of Blazar Jets on the Finest Scales", in Astronomical Polarimetry: Current Status and Future Directions, ed. A. Adamson, C. Aspin, C. J. Davis, Astronomical Soc. Pacific Conf. Ser., 343, 480—485, 2005

Mercer, E.P., Clemens, D.P., Jackson, J.M., Bania, T.M., Rathborne, J.M., Shay, R.Y., & the GLIMPSE Team, "GLIMPSing the Galactic Horizon", BAAS, 207, 133.07, 2006

Pyatunina, T. B., Kudryavtseva, N. A., Gabuzda, D. C., Jorstad, S.G., et al., "Analysis of Strong Outbursts in Selected Blazars from the Metsahovi and UMRAO Monitoring Databases," in Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed. J. Romney & M. Reid, Astronomical Soc. Pacific Conf. Ser., 340, 113—114, 2005

Pyatunina, T. B., Gabuzda, D. C., Jorstad, S. G., et al., "Multi-Frequency Polarization Imaging of Blazars with Cyclic Activity," in Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed. J. Romney & M. Reid, Astronomical Soc. Pacific Conf. Ser., 340, 198—199, 2005

Rathborne, J.M., Chambers, E.T., Jackson, J.M., Simon, R., "High-resolution millimeter imaging of Infrared Dark Cloud cores", AAS, 20718418R, 2005

Shah, R.Y., Jackson, J.M., "Spitzer/MIPS Pilot Survey of the Galactic Plane", AAS, 207.6350S, 2005

Shiode, J., Clemens, D.P., Janes, K.A., Pinnick, A. 2006, "Missing Galactic

PNe: [S III] Imaging Survey," in Proc. IAU Symp. 234, Planetary Nebulae in our Galaxy and Beyond (3-7 April 2006), eds. M. J. Barlow & R. H. Mendez (Cambridge Univ. Press), in press.

Simon, R., Jackson, J., Bania, T.M., Clemens, D.P. & Heyer, M.H., Astronomische Nachrichtten, vol 326, 668: "The Distibution of MSX Infrared Dark Clouds in the inner Milky Way", 2005

Sivakoff, G., Sarazin, C., Jordan, A., Blanton, E., Cote, P., Ferrarese, L., Irwin, J., Juett, A., Six Years of Science with Chandra Symposium, "The Low-Mass X-ray Binary - Globular Connection in the HST ACS Virgo Cluster Survey", 2005

Appendix B: Seminar Series Schedules

Institute for Astrophysical Research Seminar Series
Fall 2005

Sept 13 - Heidi Newberg, RPI, *Will the real stellar halo please stand up?*

Sept 20 - Robert Simon, Univ. of Cologne, *Submillimeter and far-infrared Astronomy at KOSMA: Preparing for Herschel and SOFIA*

Sept 27 - Igor Drozdovsky, Instituto de Astrofisica de Canarias, *The stellar structures around disk galaxies*

Oct 4 - Nathan Smith, Univ. of Colorado, *Eta Carinae and the LBVs: Extreme Mass Loss from Luminous Evolved Stars*

Oct 18 - Peter McCullough, Space Telescope Science Institute, *The XO Planet Finding System*

*Oct 21 - 3pm (note special day and time) Joao Yun, University of Lisbon, *Building an Astronomy Research Group from Scratch: Tale of a Portugese BU Alumnus*

Oct 25 - Beth Willman, New York Univ., *A Little Light, A Lot of Relevance: the least luminous galaxies*

*Oct 28 - 3pm (note special day and time) Greg Sivakoff, UVA, *Low Mass X-ray binaries in galaxies*

Nov 1 - Eric Gawiser, Yale Univ., *The MUSYC census of Protogalaxies at z = 3*

*Nov 4 – Freeman Dyson, Professor Emeritus Institute for Advanced Study at Princeton *Gravitons*

Nov 8 - Jill Rathborne, BU/IAR, *Infrared Dark Clouds: precursors to star clusters*

Nov 29 - Robert Zinn, Yale Univ., *The QUEST RR Lyrae Survey and the New Virgo Stellar Stream*

Dec 6 - Eileen Friel, NSF

Institute for Astrophysical Research Seminar Series
Spring 2006

Jan 31 - Charles Lada, CFA, *Origins of Star Formation Research from Aristotle to Ambartsumian*

Feb 7 - Tereasa Brainerd, BU, *New constraints on CDM halos from satellite galaxies and weak lensing: the view from room 514B*

Feb 28 - David DeVorkin, NASM, *Beyond Stardrek – Women who changed the Universe*

March 7 - Spring Break

March 14 - Jonathan McKinney, *General Relativistic Magnetohydrodynamic Simulations of Jet Formation and Large-Scale Propagation from Black Hole Accretion Systems*

March 20 - George Jacoby, NOAO, *The Luminosity of Type Ia SNe and the Future of the Sun*

March 28 - Mike Cushing, U of Arizona, *Clouds and Chemistry: Probing the Atmospheres of Ultracool Dwarfs with Spitzer*

April 4 - Philip Myers, CFA, *Observations and Models of Young Stellar Clusters*

April 11 - David Soderblom, STScI, *The Sun at 1,000 Light Years: Can we see our future in the stars?*

April 18 - Rick Pogge, Ohio State U., *Measuring supermassive black holes in AGN – A progress report*