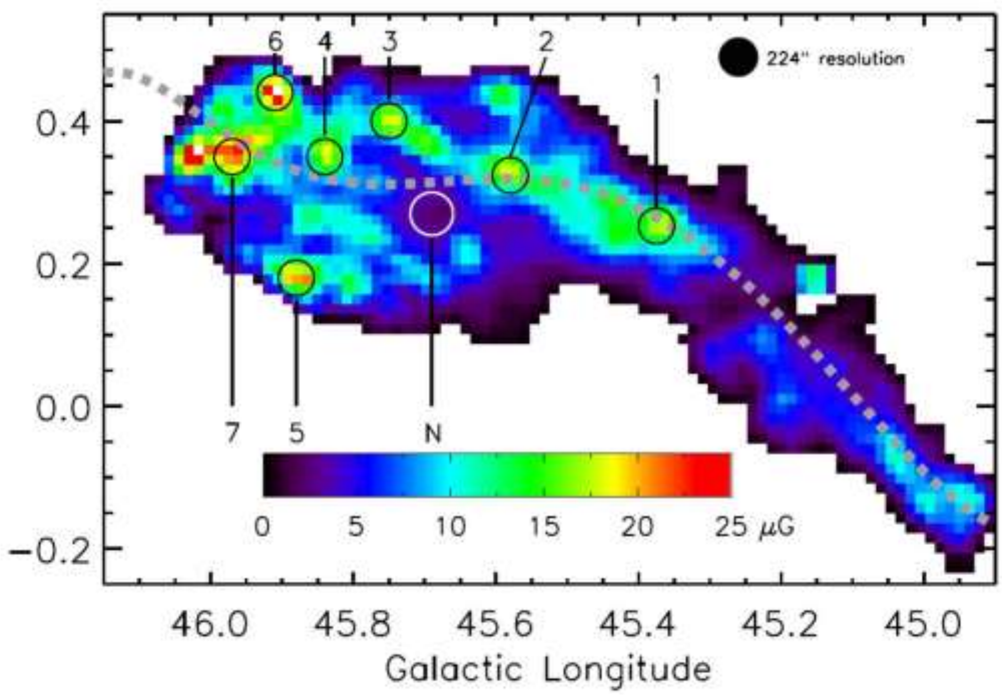
Boston University

Institute for Astrophysical Research



Map of the magnetic field strength of a molecular cloud, from Marchwinski et al. (2012). The cloud extent is about 120 x 30 light years and resides some 5000 light years from us. Seven 'magnetic cores' that were discovered are indicated by circles and numbers. See the discussion of research activities by Professor Clemens' research group.

Annual Report

June 2013

Overview

Introduction

The mission of the Institute for Astrophysical Research (IAR) is to promote and facilitate research and education in astrophysics at Boston University. The IAR accomplishes this mission by administering research grants, enhancing the visibility of IAR members with funding agencies, coordinating the use of Boston University astrophysics facilities, promoting the design, development, and operation of Boston University instruments and telescopes, sponsoring regular seminars and occasional professional meetings, and actively engaging students of all levels in research. The primary research fields in which IAR astronomers are involved include blazars and other active nuclei of galaxies, clusters of galaxies, the formation of stars, the gaseous and ionized interstellar medium, the physical properties, evolution, and magnetic activity of stars, extrasolar planets, magnetic fields, high-energy phenomena, dark matter, and the large-scale structure of the universe.

Executive Summary

FY13 marked a highly successful 15th year in the IAR's mission to foster research in astrophysics at Boston University. The scientific productivity of IAR astronomers remained at a high level this year, resulting in the publication of 45 scientific papers in the peer-reviewed literature and garnering significant interest in the popular media. In FY13 the IAR managed 25 active research grants, the total funding for which was $5.56M awarded to date. This represents an increase of 21% over the previous year.

The IAR manages the use of Boston University's share in observing time at the 1.83-meter-diameter Perkins Telescope of Lowell Observatory in Flagstaff, Arizona. This telescope is vital to the research of a number of IAR faculty, scientific staff, and students. The IAR also plays a key role in instrument development and astronomical research carried out with the Discovery Channel Telescope (DCT) operated by Lowell Observatory with Boston University as a permanent partner. Early scientific observations with the DCT were initiated in 2013.

Faculty, Staff and Leadership

Size and Organization

In FY13, the IAR personnel included 5 full professors (Thomas Bania, Kenneth Brecher, Dan Clemens, James Jackson, and Alan Marscher), 3 associate professors (Elizabeth Blanton, Tereasa Brainerd, and Merav Opher), 1 assistant professor (Andrew West), 1 professor *emeritus* (Kenneth Janes), 2 senior research scientists (Dr. Svetlana Jorstad and Brian Taylor), 1 senior postdoctoral associate (Dr. Manasvita Joshi), 2 postdoctoral associates (Dr. Jonathan Foster, and Dr. Saurav Dhital), a new Postdoctoral Fellow (Joseph Neilsen), 2 visiting researchers (Iván Agudo and Kathleen Kraemer), and a full-time fiscal administrator (Alyson Savoie). In addition, 21 graduate students (3 of which earned their PhD degrees) and 8 undergraduate students were actively involved in IAR research programs.

Leadership

The IAR has a director, who reports to the Dean of the College of Arts and Sciences. Professor Alan Marscher is the current IAR Director, appointed through June 2016.

Changes in Appointments and Staffing

Professors Blanton and Opher were awarded tenure in May 2013. There were a number of changes in research appointments. Dr. Manasvita Joshi was promoted from Visiting Researcher to Senior Postdoctoral Associate. Dr. Saurav Dhital was promoted from Visiting Researcher to Postdoctoral Associate for a short term at the end of FY13. Dr. Jonathan Foster vacated his position as Postdoctoral Associate to accept a prize postdoctoral fellowship at Yale University. Dr. Joseph Neilsen, who was awarded a two-year (extendable to 3 years) Einstein Fellowship in high-energy astrophysics, selected Boston University as his host institution. He joined the IAR as a Postdoctoral Fellow on December 1, 2012. There were no changes in administrative staffing in FY13.

Related Professional Activities and Accomplishments

Professor Blanton began a three-year term (2012-15) on the Nominating Committee of the American Astronomical Society. This committee selects a slate of candidates for the various officers of the society, which is the primary professional association of astronomers in North America.

Professor Clemens completed his second year as Chair of the Board of Directors of the Associated Universities for Research in Astronomy (AURA), and was elected to a third and final one-year term as Chair of the AURA Board for 2013-14 and for a second and final three-year term as a member of that Board. AURA manages the National Optical Astronomy Observatories (NOAO), the National Solar Observatory (NSO), the Gemini International Observatory, the Space Telescope Science Institute (STScI), and the construction of the Large Synodic Survey Telescope (LSST) on behalf of the National Science Foundation and NASA. This major commitment of effort by Prof. Clemens represents a key national leadership role serving the entire US professional astronomical community.

Prof. West was recently elected to be a co-chair of the LSST Galactic Structure and Interstellar Medium sub-group. The LSST is a major new telescope initiative, dedicated to deep, repeated surveys of the sky. "With a light-gathering power among the largest in the world, it can detect faint objects with short exposures. Its uniquely wide field of view allows it to observe large areas of the sky at once; compact and nimble, it can move quickly between images. Taking more than 800 panoramic images each night, it can cover the sky twice each week." (From the LSST website)

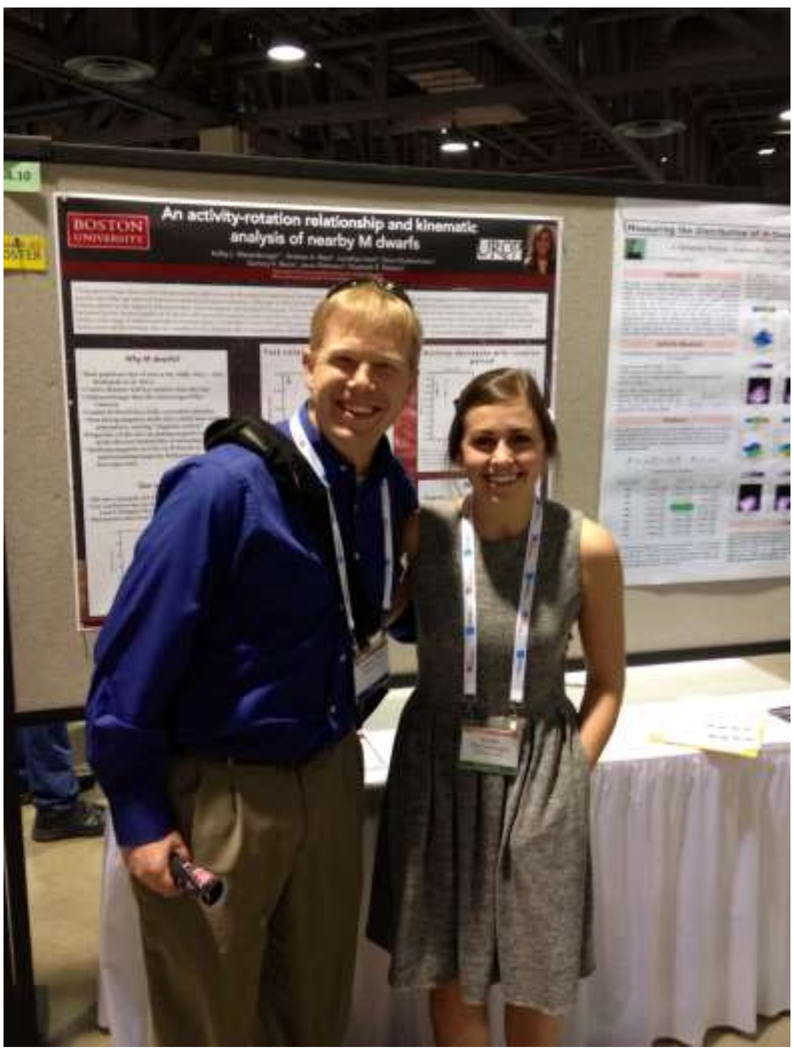
IAR members played a number of other important roles in service to the profession. These include reviewing proposals for observing time on telescopes, papers submitted to scientific journals, and funding proposals, serving as members on the scientific organizing committees of, and as session chairs at, scientific conferences, and providing data or training to colleagues and their students at other institutions around the world.

Honors and Awards

Professor West was awarded a 5-year National Science Foundation CAREER grant, one of only five such grants in the field of Astronomy in 2013. He was also awarded a Cottrell grant from the Research Corporation for Scientific Advancement. Both very prestigious awards support highly promising young faculty members. In addition, Professor West had an asteroid named after him for his work on the Sloan Digital Sky Survey: http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=173872.

Graduate Student Sadia Hoq (advisor: Professor Clemens) was awarded one of 11 Chambliss Astronomy Achievement Student Awards in the graduate student category for her January 2013 poster paper at the American Astronomical Society Meeting in Long Beach, CA. The paper was entitled "Using Open Star Clusters to Probe the Small-Scale Characteristics of the Galactic Magnetic Field."

Kolby Weisenberger (advisor: Professor West) was awarded a Chambliss Astronomy Achievement Student Award at the same meeting in the undergraduate student category. Her paper was entitled "An Activity-Rotation Relationship and Kinematic Analysis of Nearby M Dwarfs."



Professor West and Kolby Weisenberger in front of Kolby's award-winning poster presentation at the January 2013 American Astronomical Society Meeting in Long Beach, California

Facilities

The Perkins Telescope at Lowell Observatory

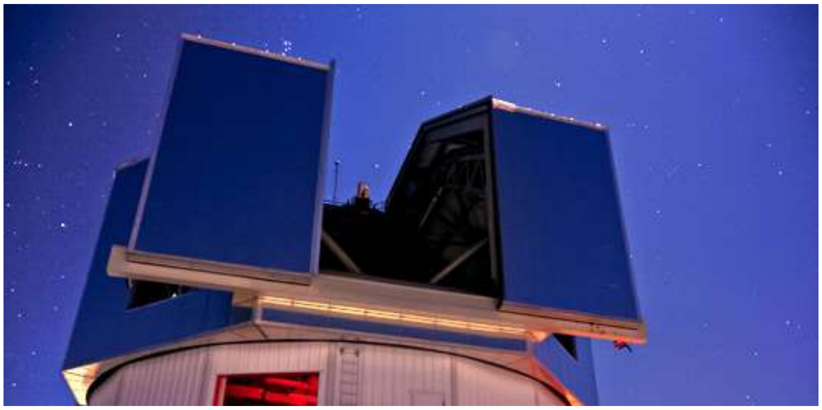
The IAR manages Boston University's share of observing time on the Perkins Telescope, a 1.83 meter (6 feet) diameter reflecting telescope. The IAR director solicits proposals for observing time from members of the Boston University astronomical community on a quarterly basis. The proposals are reviewed, with those that are approved being recommended to Lowell Observatory, where the schedule is drafted. There are often negotiations when multiple observers request overlapping time periods on the telescope.

Senior Research Scientist Jorstad serves as the Boston University representative on the Lowell Observatory Mesa Advisory Board, which met for the first time in May. This committee represents partner interests to Lowell Observatory for issues and operations of astronomical facilities on Anderson Mesa, where the Perkins Telescope is located.

The Discovery Channel Telescope

The agreement for Boston University to become a permanent partner with Lowell Observatory to operate the new Discovery Channel Telescope (DCT) provides Boston University astronomers with guaranteed observing time on this world-class scientific facility. The Department of Astronomy will administer Boston University's role in the DCT. The IAR will be the primary unit for external funding of research projects that use the DCT. The DCT is a reflecting telescope with a diameter of 4.3 meters, located at Happy Jack, Arizona, on National Forest Service land. This is a very dark site, which, in combination with the large light-collecting area of the telescope, will allow ultra-high-sensitivity observations of faint cosmic objects such as distant stars and galaxies.

Professor Clemens serves as the BU representative on the DCT Advisory Board, which met for the first time in May. This committee represents partner interests to Lowell Observatory for issues and operations involving the DCT. Other Board members include representatives from the Univerity of Maryland/Goddard Space Flight Center, and the University of Toledo, as well as an observer from Georgia State University.



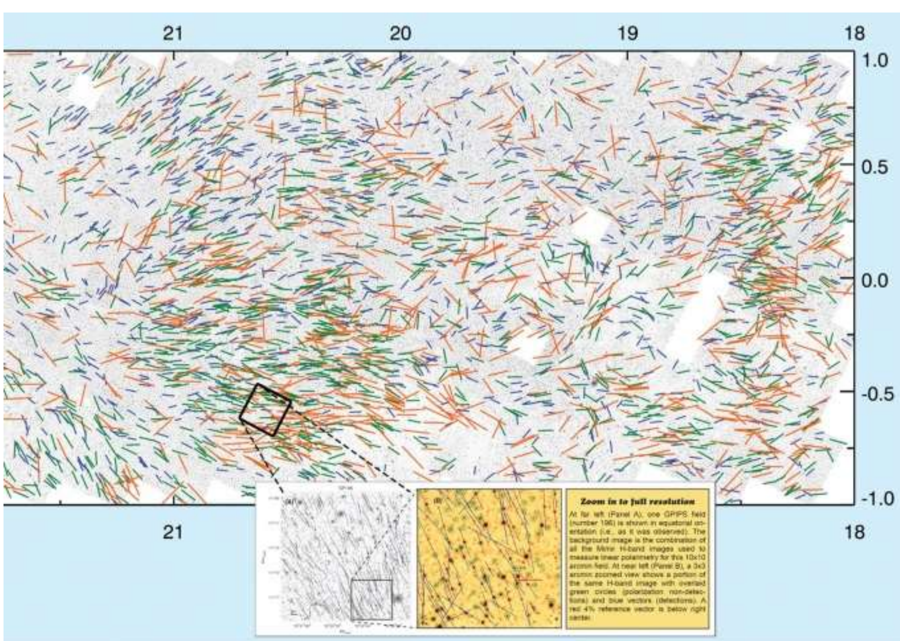
Top left: Dome housing the DCT, with the Pleides star cluster above the left flap. Top right: the DCT. Bottom: Image of the Sombrero galaxy obtained with the DCT. (Photo credit: P. Massey, Lowell Observatory)

Research & Scholarship: Selected New Results from IAR Research

Mapping of the Milky Way's Magnetic Field by Professor Clemens' Group

The Galactic Plane Infrared Polarization Survey (GPIPS) conducted by Professor Clemens' group using the Mimir instrument on the Perkins Telescope saw several key milestones this past year. In August 2012, the first public release of a portion of the GPIPS data went live on the web, hosted by BU fileservers. In January 2013, the GPIPS team became a formal meeting exhibitor at the American Astronomical Society meeting in Long Beach, CA, displaying a 40×3 foot banner of the GPIPS stellar polarization and image data. Even with the 40-foot format, only 10% of GPIPS data could be displayed, as otherwise the density of information would have rendered the banner black! The GPIPS banner was exhibited and seen by AAS attendees throughout the 5-day meeting. The banner and the GPIPS project were featured in a *Sky & Telescope* article ("Mapping the Milky Way" authored by Dr. Monica Young (BU PhD 2010); see http://www.skyandtelescope.com/news/Mapping-the-Milky-Way-187458841.html).

Graduate students Jordan Montgomery, Lauren Cashman, and Sadia Hoq (L to R) in front of the GPIPS banner at the January 2013 AAS meeting.

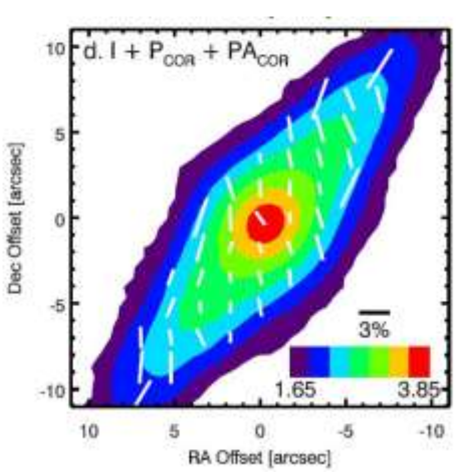


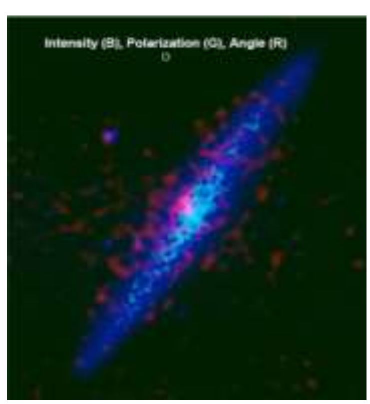
Zoom of a portion of the banner

The collection of data for GPIPS finished in June 2013 on the Perkins Telescope. Since its beginning in June 2006, GPIPS members have conducted 24 observing runs, spanning approximately 350 nights, collecting well over 2 million images with the Mimir instrument. Data processing and analyses have kept pace, allowing all of the science-quality catalogs, deep images, and other products to be fully released to the astronomical community for correlative studies before the end of 2013. In its scope, unique polarization insight into the magnetic field in the Milky Way, and its accurate calibration, GPIPS is a substantial contribution to astronomical knowledge, on par with small NASA missions. It could not have been performed at any national or international facility, because of both instrumentation and telescope access limitations, and is a prime example of the type of unique, large projects that are well-matched to university teams and university-provided resources leveraging Federal science support.

As GPIPS observations phase out, GPIPS science analyses will take center stage. This has already begun, as undergraduate (now Penn State graduate student) Rob Marchwinski, graduate student (now U. Texas postdoc) Mike Pavel, and Professor Clemens used early GPIPS data, combined with Galactic Ring Survey (J. Jackson et al. 2006) data, to produce the first resolved magnetic field map of a molecular cloud. In the past, only select, small regions of star formation in clouds could be so studied. GPIPS reveals the entire context of the magnetic field, and in the case of this cloud, uncovered seven "magnetic cores" - regions of higher gas density and higher magnetic fields. These cores would normally go on to collapse and form stars, but here the magnetic field provides key support resisting that collapse. That the magnetic field might be an important agent in regulating the rate of star formation has been suggested before, but never previously observed. The *Astrophysical Journal* paper presenting these results (Marchwinski et al. 2012) was also featured in a BU press release that was picked up by national and international web sites, including NSF.gov, leading to over 180,000 Google hits at last check. A figure from this work appears on the cover page of this report.

The Future: While GPIPS offers an unprecedented view of the magnetic field structure of the disk of our Milky Way Galaxy, even larger-scale information may be missed. To better understand our own Galaxy, Milky Way "analog" galaxies, especially those that present edge-on profiles, are being examined using Mimir on the Perkins. The first of these was found by accident in deep exposures of the Taurus constellation, yet revealed magnetic field structure very similar to those seen in other galaxies at radio wavelengths. The left figure below shows a false color image of that "T-Galaxy" and the polarization vectors measured by Mimir. Graduate student Jordan Montgomery has begun a project to examine and analyze the Mimir-traced infrared polarization in a sample of edge-on large galaxies, already studied by others using the *Spitzer Space Telescope* and *HST*, including NGC5775, shown below at right.



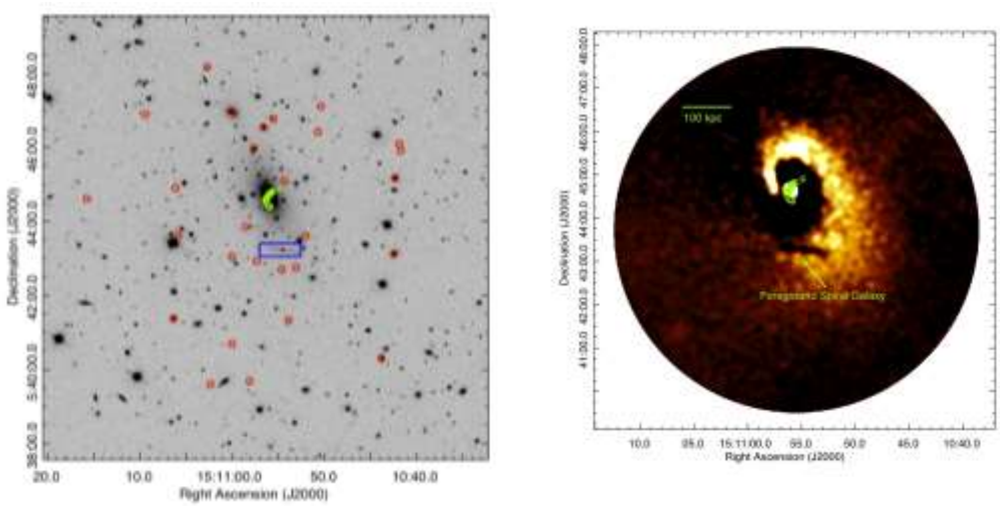


(Left) False-color representation of the infrared brightness of the nearly edge-on T-Galaxy, overlaid with white polarization vectors revealing the magnetic field direction in this 150 million light-year distant Milky Way analog galaxy. (Right) Mimir image, and polarization information, for the edge-on galaxy NGC5775 at 85 million light-years distance.

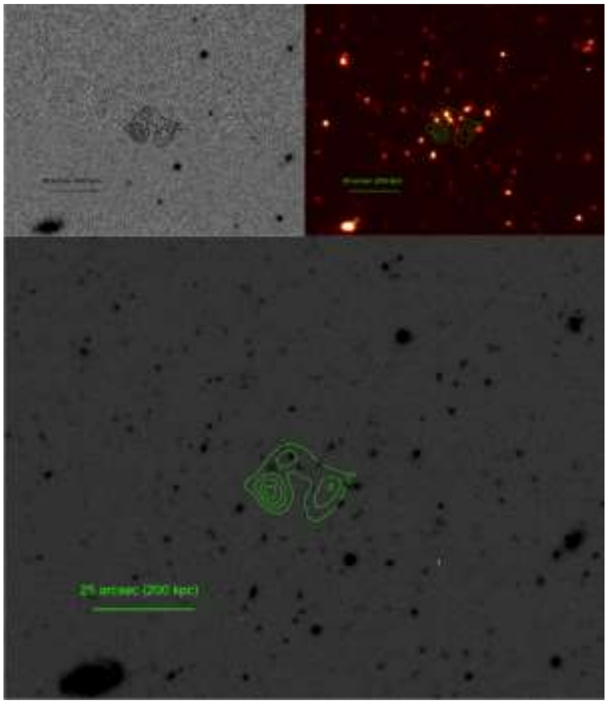
Studies of Clusters of Galaxies by Professor Blanton and Collaborators

Abell 2029 is the poster child for massive, relaxed, nearby cool core clusters of galaxies. There is no significant substructure seen in the distribution of the individual galaxies, and the hot, intracluster medium (ICM) has a smooth and regular appearance as seen in X-ray light. However, subtracting a symmetric model from the X-ray emission reveals a faint, extended spiral structure. These types of features are likely due to the sloshing of the hot gas in the cluster after an off-axis merger with a sub-cluster or group or galaxies. With an extent of approximately 400 kpc as observed in the X-ray with *Chandra*, the sloshing spiral in A2029 is the largest continuous such structure observed to date in any cluster. Sloshing of the cluster gas (which is cooler in the center than the outskirts) may significantly affect the thermal structure of the ICM. It provides another source of heating in addition to active galactic nucleus (AGN) feedback. The central galaxy in A2029 is host to a radio-emitting AGN with a power insufficient to offset the cooling in the central regions of the cluster. In addition, this radio source has a bent appearance, and it is probable that the radio lobes are being distorted by the sloshing gas. In a new paper, (Paterno-Mahler et al. 2013), the group estimates that the merger that produced the sloshing feature occurred 2-3 Gyr ago.

New Research Direction: Professor Blanton and collaborators are conducting a large survey of distant clusters of galaxies. They are using bent, double-lobed radio sources (AGN) as signposts for these high-redshift systems since radio sources with these morphologies usually reside in clusters and the radio emission is easy to see to large distances. The group is following up 653 of these sources that were not detected optically to the limit of the Sloan Digital Sky Survey in infrared light using the *Spitzer* Space Telescope. Deep, follow-up observations in optical light with the Discovery Channel Telescope have begun and will be crucial for estimating the photometric redshifts (to obtain distances) of the potential clusters and studying the galaxies they contain in more detail.



Left: Optical r-band image of Abell 2029 with radio contours (green) superposed. The red circles indicate point sources detected in X-ray light (many are background active galactic nuclei, although some are associated with galaxies in the cluster). *Right:* Model-subtracted *Chandra* X-ray image of the sloshing spiral in A2029 with radio contours of the AGN superposed. In addition, a linear feature in X-ray light resulting from absorption from an unrelated, foreground edge-on spiral galaxy is indicated. (Both figures are from Paterno-Mahler et al. 2013.)

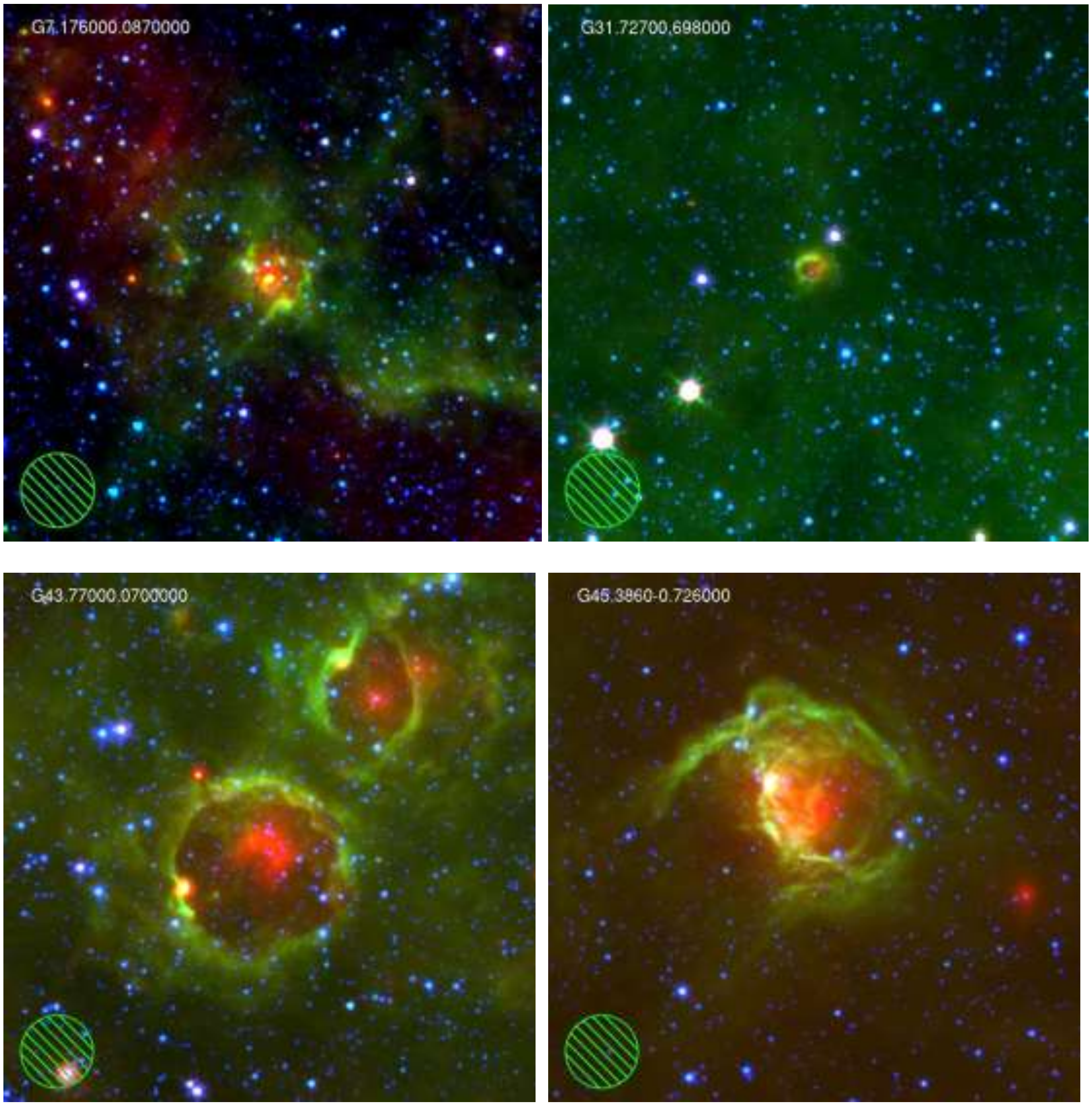


Top left: Sloan Digital Sky Survey r-band image with 1.4 GHz radio contours superposed. Cluster galaxies are not detected to the limit of the SDSS. *Top right:* Infrared 3.6 um image of the same field from the Spitzer Snapshot program. The cluster is easily visible. *Bottom:* R-band visible-light image from the LMI at the Discovery Channel Telescope of the same field. The total exposure was 30 minutes, and the seeing was approximately 0.7 arcseconds. Visible-light observations combined with those in the infrared are important for estimating the redshifts, and therefore distances, of the clusters in our survey, as well as for studying the galaxy populations in detail. The cluster shown is at a redshift of 0.96.

Finding Distant Ionized Gas Clouds and Using them to Explore our Milky Way Galaxy by Professor Bania and Collaborators

Stars with masses greater than ten times that of our Sun shine for only about 10 million years before they detonate in titanic supernova explosions that spew into space heavy elements forged by nuclear reactions in their cores. During their lives, massive stars ionize the gas that surrounds them, creating an ionized hydrogen (H II) region. Professor Thomas Bania, former BU graduate students Loren Anderson (an assistant professor at West Virginia University) and Dana Balser (a staff scientist at NRAO), and Robert Rood (University of Virginia, deceased) have used the Green Bank Telescope (GBT, operated by the National Radio Astronomy Observatory, NRAO), to discover previously unknown H II regions in distant locations inside our Milky Way Galaxy. During FY13, Professor Bania and collaborators have extended the survey to search for HII regions in the newly discoverd Outer Scutum-Centarus (OSC) Arm.

In order to detect fainter H II regions, Prof. Bania's team migrated the H II Region Discovery Survey (HRDS) to the Arecibo Observatory (operated by the National Astronomy and Ionospheric Center), the largest radio telescope in the world (1000 feet in diameter). The technique that they employ is to search for hydrogen-recombination lines in the spectra of candidate H II regions that were beyond the reach of the GBT. Professor Bania's team has discovered more than 600 regions in the Milky Way where massive stars form, more than doubling the number of such known regions. The newly discovered regions include the most distant sites of massive-star formation known in the Milky Way. Future generations of stars and planets form from massive stars. This census changes our view of how the chemical elements that massive stars produce enrich interstellar space. This new census provides targets for observational studies of galactic chemical evolution that will be made by NSF-supported instruments such as the Karl Jansky Very Large Array (VLA) and the Atacama Large Millimeter Array (ALMA).

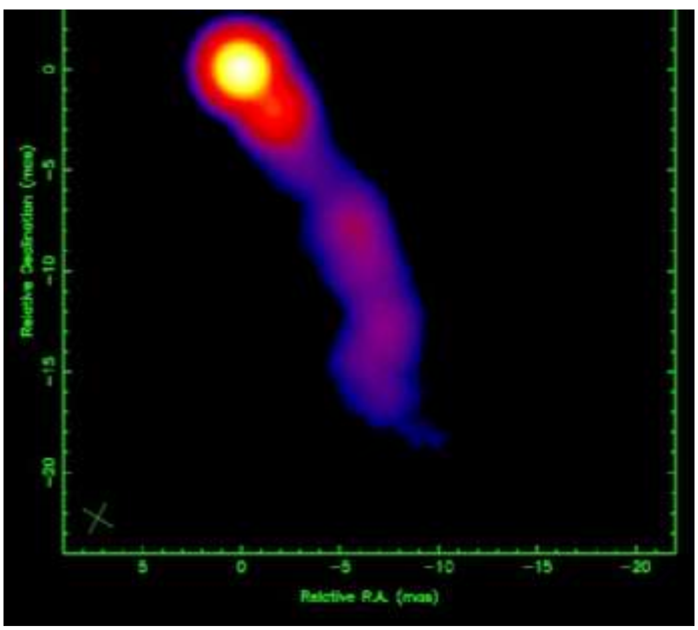


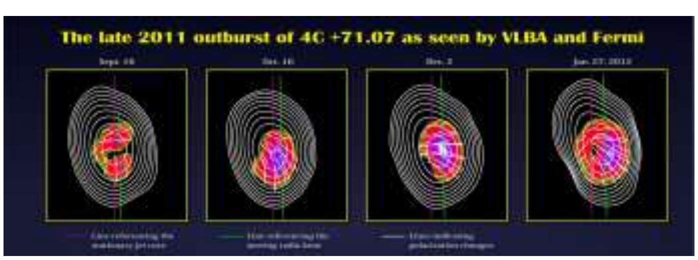
These images show massive star formation regions (HII regions) discovered using NRAO's Green Bank Telescope as part of the HII Region Discovery Survey led by Professor Bania. The data in the images are from the Spitzer Space Telescope. The red channel shows emission from hot dust at a wavelength of 24 µm, the green channel shows the interface between the star forming region and the interstellar medium at 8 µm, and the blue channel primarily traces stellar emission at 3.6 µm. The circle in the lower left shows the resolution of the Green Bank Telescope. The object name is given in the top left corner.

Probing the Ultra-high-energy Jets of Blazars across the Electromagnetic Spectrum by Professor Marscher, Senior Research Scientist Jorstad, and their Research Group

Blazars – the most extreme class of active nuclei of galaxies – are the most luminous long-lived objects in the universe. They contain supermassive (up to 20 billion times the mass of the Sun) black holes that accrete gas from the central regions of the host galaxy. Jets stream out of the nucleus at near-light speeds and emit radiation profusely across the entire electromagnetic spectrum. In order to probe the jets, Professor Marscher and Senior Research Scientist Jorstad have developed a comprehensive program to monitor changes in their brightness and polarization at microwave, infrared, visible, ultra-violet, X-ray, and gamma-ray frequencies. Their project involves monthly radio frequency observations with the Very Long Baseline Array (which produces images of the jets of blazars with angular resolution 1000 times finer than that of the Hubble Space Telescope) of a sample of 35 blazars, as well as optical polarimetric and photometric observations with PRISM and Mimir on the Perkins Telescope. Graduate students Michael Malmrose, Nicholas MacDonald, Terri Scott, and Karen Williamson, and undergraduates Adi Foord, Claudio DeMutiis, and Vishal Bala participated in the analysis of the data from these extensive observations. The data collected by the group are combined with observations by collaborators using numerous other space- and ground-based telescopes around the world.

In FY13, the group reported at the January 2013 American Astronomical Society meeting their new finding that associates an outburst of gamma-rays with a bright "knot" of high-energy plasma ejected from the nucleus of the quasar 4C+71.07 at a speed of 99.875% the speed of light.





Top: radio image of the jet of quasar 4C+71.07; yellow denotes brightest region (from Lister et al.). *Bottom:* Time sequence of microwave images by Jorstad and Marscher of the bright "core" region jet of the jet (which is yellow in the upper image). The color, which represents intensity of polarized emission, accentuates the new knot of high-energy plasma that strongly emits gamma-rays as it speeds away from the core. The ability of the Boston University group to use polarization and changes in brightness at microwave, visible, and gamma-ray frequencies to locate the gamma-ray outburst in the core out to 70 light-years away from the black hole (which cannot be seen, but lies to the upper left in the lower images), represents a major breakthrough in the field.

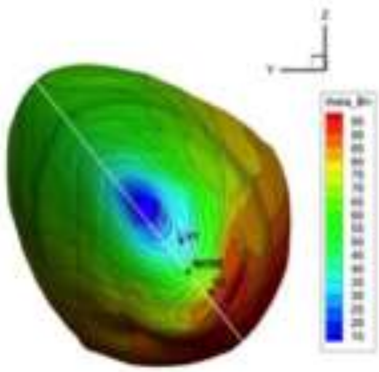
Such comprehensive observations of blazars have provided extremely rich data sets that reveal both complexities and patterns that challenge current theoretical models. Professor Marscher, Senior Postdoctoral Associate Joshi, and graduate students Michael Valdez and Nicholas MacDonald are developing new theoretical paradigms and numerical codes that are potentially capable of explaining the observational results. Professor Marscher has completed a 3-year project to create the Turbulent Extreme Multi-Zone computer model that calculates the time variations of radiation emitted when turbulent high-energy plasma crosses a standing cone-shaped shock wave in a blazar jet. Graduate student Valdez has translated the code to the C++ language and will optimize and parallelize it to run on a supercomputer, after which he will develop the code further. Dr. Joshi is modifying her own time-dependent code to take into account various sources of photons in the nucleus of an active galaxy that can be scattered to gamma-ray energies. Graduate student MacDonald is calculating the time-dependent emission from an energetic plasma passing through photons from a slower sheath of a jet.

Finding Planets around Other Stars by Emiritus Professor Janes and Collaborators

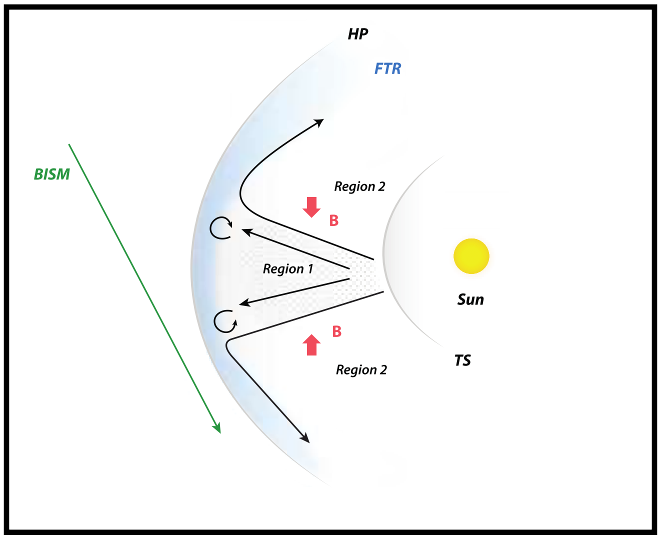
NASA's Kepler Mission is a space telescope that has been staring at one spot in the sky continuously for over four years to search about 150,000 stars for signs of orbiting extra-solar planets. Emeritus Professor Kenneth Janes has been working with members of the Kepler team to study several star clusters located in the field of view of the Kepler telescope. In addition to searching for planets around cluster stars (they have found two planets thus far), they are finding how fast stars of different ages spin, by monitoring the subtle brightness variations as starspots rotate across their surfaces. In a supporting ground-based study using the PRISM camera on the Perkins Telescope, he has developed a new Bayesian statistical procedure for finding the overall properties of the star clusters.

A New Description of the Outer Boundary of the Solar System by Professor Opher's Group

Professor Opher and her group study the boundary between our solar system and the interstellar medium of the Milky Way Galaxy. Recent models had indicated that under the expected conditions of the interstellar magnetic field (ISMF) there should be no bow shock ahead of the heliosphere. In FY13 the group discovered (work led by Dr. B. Zieger) that even though a *fast* bow shock might be ruled out, the conditions in the local interstellar medium are such that a *slow* bow shock will be present, most likely along NASA's Voyager 1 probe's trajectory. This means that Voyager 1 will encounter ISM conditions mediated by the slow bow shock while Voyager 2 should not. The work was featured as an AGU Research Spotlight in EOS ("The solar system has a bow shock after all, it's just slow").



3-D view of the slow magnetosonic surface with the prospective crossing locations of Voyager 1 (V1) and Voyager 2 (V2). The angle between the interstellar magnetic field (B_ISMF) and the normal to this isosurface (θ_Bn) is plotted as contour lines on the surface. The slow bow shock is restricted to the quasi-parallel region of blueish colors north-west of the nose. The white line indicates the intersection of the isosurface with the B_ISMF–v_ISMF plane.



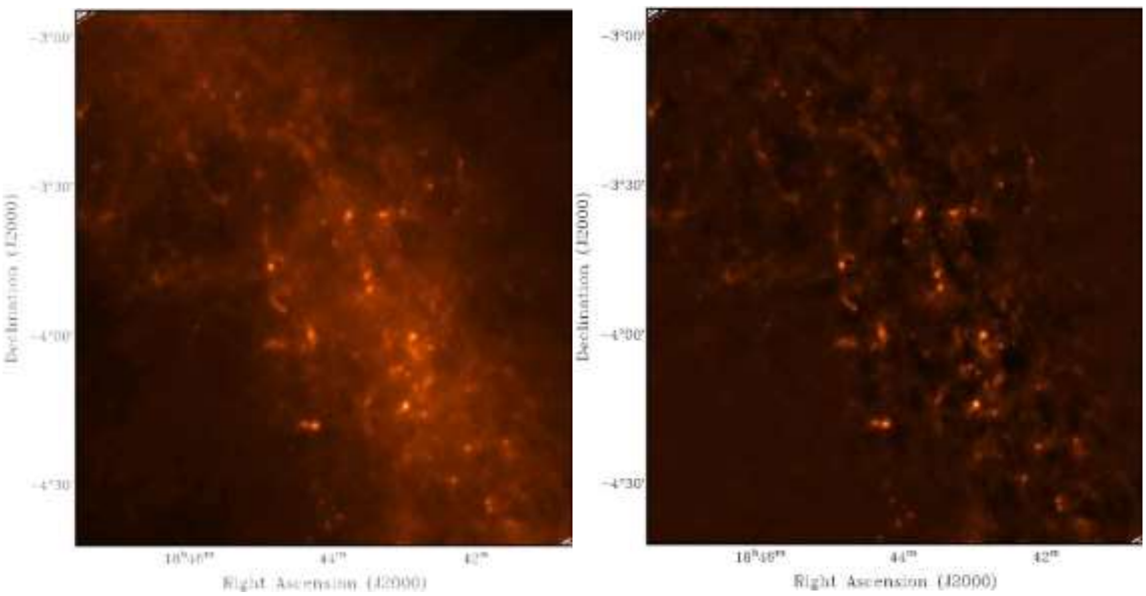
The sector region separates two flows in the heliosheath. One inside the sector, in region 1, filled with disconnected magnetic structures, is un-magnetized; and the second, in region 2, is magnetized.

Professor Opher's group has developed a 3D magneto-hydrodynamic (MHD) model including time-dependent solar cycle conditions to describe the heliosheath (project lead by PhD student Elena Provornikova). They compared the results with the data from Voyager 1 (V1) and 2 (V2) out to 30 time the Earth's orbital distance. The main conclusions are that time dependent effects alone cannot explain the vastly different behavior of the flows in the heliosheath seen by V1 and V2. This has the implication that the standard 3D MHD models need to include additional physical effects to explain the shape and behavior of the flows in the heliosheath. The group also developed a model of the flows in the heliosheath as modified by the presence of a reconnected "sector region," a region where the solar magnetic field reconnects. They have shown that the heliosheath flows are separated into two regions: the region within the reconnected sector fields behaves as a un-magnetized hydrodynamic flow collimated by the un-reconnected plasma outside of it. This scenario can explain the V1 measurements indicating that the spacecraft is immersed in a "quasi-stagnation region," where the solar wind speeds are close to zero. The collimation of the flows within the sector region creates such a quasi-stagnation region ahead of the heliopause.

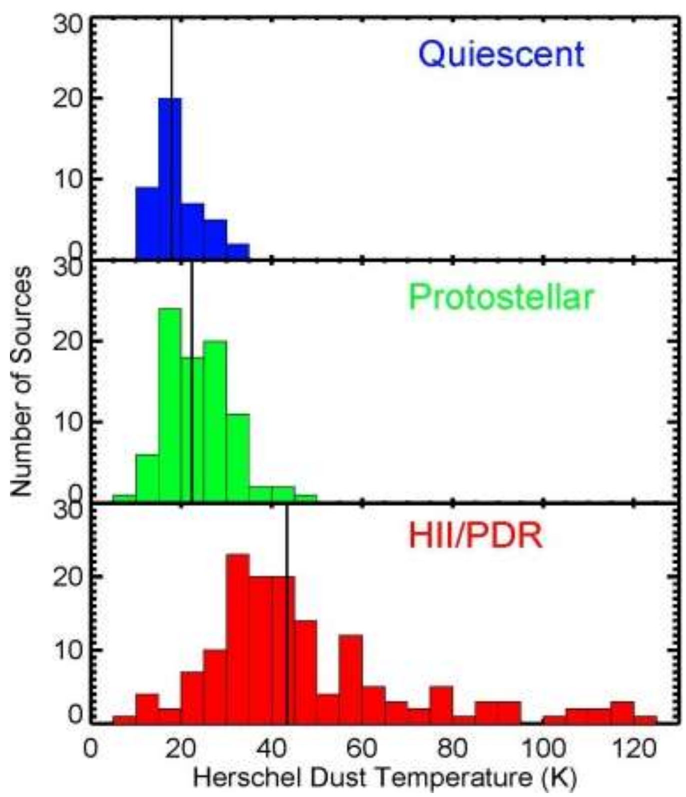
Professor Opher and PhD student Christina Kay investigated the deflection of coronal mass ejections (CMEs). They developed a model, called ForeCAT, that is able to follow the trajectory and deflections of CMEs owing to magnetic forces along their trajectory to Earth. The main result is the importance of the magnetic field background; especially in the low corona (1-4 solar radii). Global MHD codes predict a very quick decrease in the magnetic field intensity, much more rapid than is consistent with radio observations. If one allows a slower decrease, the deflection is strongly affected. This work is the first step toward a prediction of where CMEs will ultimately end up in their trajectory. Future research will extend this work to study CME deflections in M stars as well.

Studies of Massive Star Formation in the Milky Way Galaxy by Professor Jackson's Group

Professor Jackson, his students, and collaborators have developed a median-filter subtraction technique to suppress unrelated foreground and background emission along the line of sight through the Milky Way Galaxy in order to isolate emission from star-forming cores. Using this method with the *Herschel* Space Telescope, they have shown that the dust temperatures correlate in the expected way with the evolutionary state of the star-forming cores. Based on the morphology in *Spitzer* Space Telescope infrared images, they classify clumps as “pre-stellar” (dark at all mid-IR wavelengths), “protostellar” (IR dark except for point sources at wavelengths of roughly 24 μm or longer; coupled with “green fuzzy” or “extended green object” emission at 4.5 μm that indicates outflows), and “H II regions” (bright extended 8 μm emission from PAHs and extended emission at about 24 μm and longer). The pre-stellar clumps are the coldest, the protostellar clumps are warmer, and the H II region clumps are the warmest. The group has produced robust maps of dust temperatures, column densities, and submillimeter-wave/far-infrared luminosities for every core in their survey.



Herschel Hi-GAL 500 μm images toward a region in the Galactic plane. *Left:* Original data before background/foreground removal (*Right*)

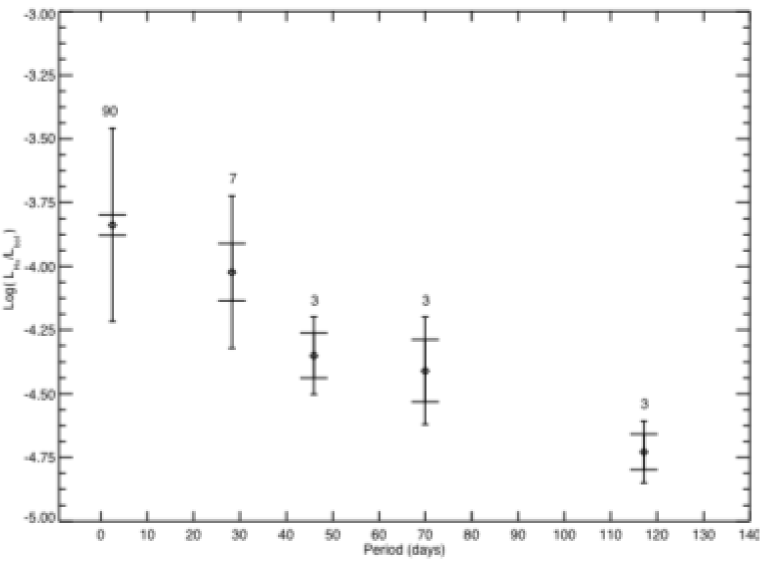


Dust temperature distributions for (*top*) pre-stellar or “quiescent” cores, (*middle*) protostellar cores, and (*bottom*) H II regions. As expected based on earlier findings, the temperatures increase for each phase.

A preliminary determination of the Galactic distribution of the roughly 300 clumps of molecular gas studied in the survey shows that (1) the star-forming clumps are much more tightly confined to particular loci in position-velocity space than the more diffuse molecular gas traced by CO; the simplest interpretation is that the high-mass star-forming clumps are tightly confined to spiral arms; and (2) the map of the Galactic distribution of clumps appears to trace Galactic spiral arms. In particular, the far side of the Scutum-Centaurus arm appears to have been detected by the survey for the first time.

Low-mass Stars by Professor West and his Research Group

Boston University undergraduate Kolby Weisenburger has been working with Prof. Andrew West and a team of researchers at Harvard University to study how stellar rotations may affect the production of magnetic fields (and the associated atmospheric heating) in the lowest mass stars. Their research has a profound impact on the study of habitability of extrasolar planets orbiting low-mass stars and puts important constraints on the physics of magnetic field generation in fully convective, low-mass environments. The team has found for the first time that there is a correlation between the rotation rate of low-mass stars and their magnetic activity, the latter of which is a good indicator of magnetic field strength. By examining the 3D kinematics of the stars, the study also confirmed that the least active and slowest rotating stars are also those that are most likely the oldest stars (they move the fastest owing to billions of years of dynamical interactions with other stars).

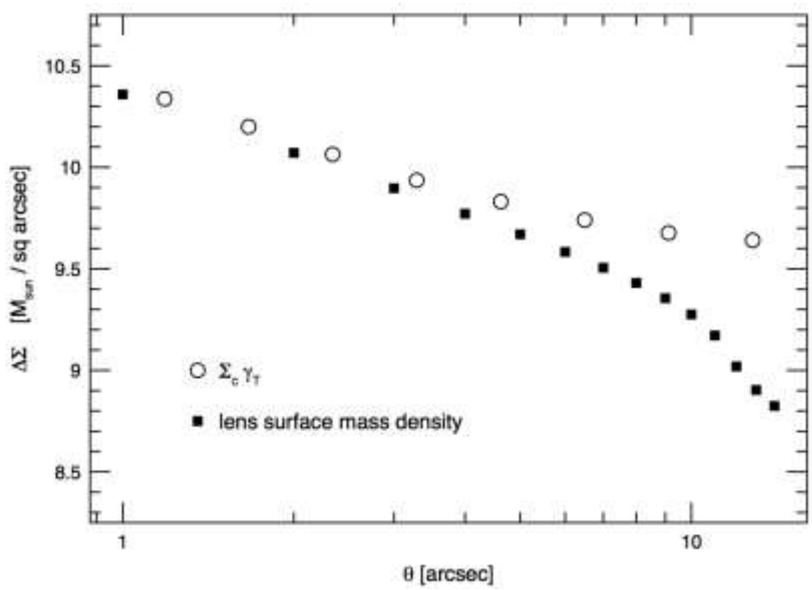


Ratio of hydrogen emission-line to total luminosity (an indicator of the level of magnetic activity) of low-mass stars, plotted against the period of rotation of the star. Faster spinning stars are more magnetically active. (A. West et al., submitted for publication)

Professor West has begun conducting a census of nearby very low-mass (VLM) stars/brown dwarfs and will be measuring their parallaxes in order to determine their distances. With these data, plus measurements of their brightness, he will build a VLM luminosity function. This will allow him and his research team to place constraints on, and help differentiate among, various models of low-mass star formation.

Mapping Dark Matter via Weak Gravitational Lensing by Professor Brainerd

Professor Brainerd continued her research on the use of observations of weak gravitational lensing as a method for directly mapping the dark matter of the universe. In a preliminary theoretical study of weak galaxy-galaxy lensing in the region of the Hubble Deep Field (North), she found that the standard method used to infer the dark matter density field from an observed gravitational lensing signal is incorrect. The standard method is based on the assumption that the observed lensing signal is simply related to the density field by a multiplicative constant. While this assumption is strictly true for single, massive, isolated gravitational lenses such as galaxy clusters, it is not true for the galaxy population as a whole. The reason for this is that, due to the very wide range of galaxy masses that exists in the universe, and the fact that galaxies are broadly distributed in distance from the observer, all extremely distant galaxies are typically lensed at a weak (but nevertheless important) level by two or more foreground galaxies. Therefore, the typical weak lensing that occurs is properly thought of as a "compound" effect due to many independent galaxy lenses, not a single isolated galaxy lens. As a result, if the standard theory is used to convert the observed weak lensing signal around galaxies into a corresponding dark matter mass density, the inferred dark matter mass density significantly exceeds the actual dark matter mass density on large angular scales.

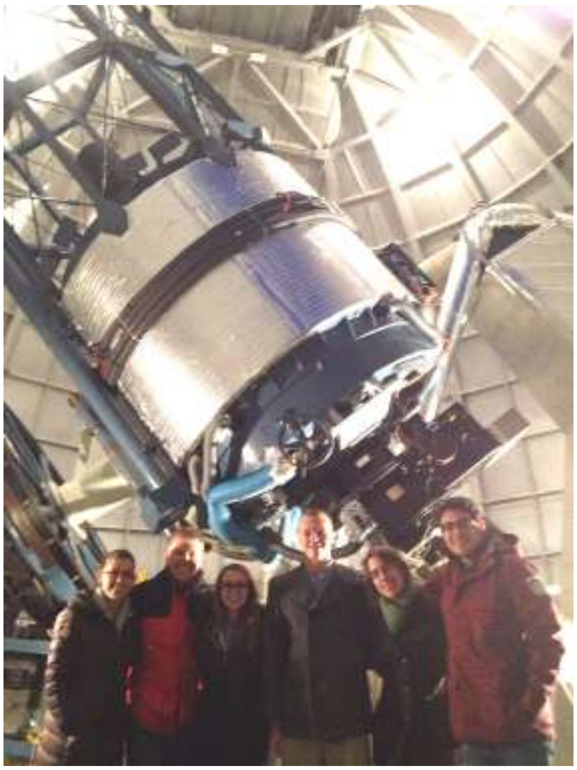


The actual dark matter density surrounding a set of theoretical galaxy lenses (squares) compared to the dark matter density that is inferred from the weak gravitational lensing signal that is measured around the galaxy lenses (circles). On large angular scales the standard method of converting an observation of weak galaxy lensing into a measurement of the amount of dark matter fails due to the fact that most distant galaxies have been weakly lensed by two or more foreground galaxies.

Professor Brainerd used the DCT for two half-nights in February 2013 to acquire deep, multi-color images of 6 clusters of galaxies from the maxBCG cluster catalog. Over the next several years, she intends to acquire similar observations of an additional 45 clusters in order to carry out a number of projects: (i) a measurement of the total dark matter content of the clusters, (ii) a measurement of the degree to which the dark matter content of the clusters deviates from spherical symmetry, (iii) an assessment of the degree to which the dark matter mass, the optical light from the cluster galaxies, and the X-ray light from the hot intercluster gas share the same shape and orientation, and (iv) a measurement of the optical light in the cluster that is not directly associated with the galaxies. These studies will help inform our understanding of the formation and evolution of clusters of galaxies, which are the largest gravitationally-bound structures in the universe.

Undergraduate Education

The use of the Perkins Telescope for professional-quality observations is an important part of our educational mission. To date, over 100 undergraduates have traveled to Flagstaff to observe with the Perkins Telescope. These include undergraduate non-science concentrators (CAS AS102HP and CAS AS102), soon-to-be astronomy majors, undergraduate science concentrators in the honors program (CAS AS203HP), observational astronomy students (CAS AS441), and senior undergraduate students who use their observations as part of their Senior Work For Distinction (CAS AS491/AS492).



Professor West and students from the Pre-Major in Astronomy Program (PreMAP) visited the Perkins Telescope of Lowell Observatory in Flagstaff, Arizona

For the past 9 spring semesters, all of the students enrolled in AS441 have participated in field trips to the Perkins Telescope to use either Mimir or PRISM to collect data for their class projects. Organized into groups of 2-4, AS441 students have each spent 2 to 3 nights operating the Perkins Telescope (weather permitting). This capstone event in the training of our undergraduate astronomy students is extremely popular, and it has 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 Boston University and its undergraduate students. In addition to using the Perkins Telescope to acquire data for their course work, AS441 students are also encouraged to experience some of the unique features of northern Arizona, including one- or two-day trips to Meteor Crater and/or the Grand Canyon. From 2004 to 2008 the AS441 field trip was sponsored by the National Science Foundation (PREST grant, PI: Kenneth Janes). Since 2009, the AS441 field trip has been sponsored by the Department of Astronomy.

During FY11, eight undergraduate CAS students were engaged in research under the direction of faculty supervisors in the IAR. The IAR faculty considers this to be a very important component to the undergraduate majors program. Experience in world-class research is key to comprehensive preparation of our students for graduate school or post-graduation employment in the field. In return, undergraduate students support the research programs by helping to analyze the voluminous data obtained in the course of our research.

Graduate Education

During FY13, 21 graduate students carried out research in the IAR. Three of the IAR graduate students - Michael Pavel (advisor: Clemens), Antonia Savcheva (West), and Joshua Wing (Blanton) successfully defended their PhD dissertations in FY13.

The IAR sponsors weekly astrophysics colloquia during the academic year. Associated with the seminar series are a pair of 2-credit graduate seminar courses, GRS AS850 and AS851. In these seminar courses, the graduate students learn to read and critically evaluate manuscripts that have been published in the peer-reviewed literature.

As is the case for undergraduate education, the use of the Perkins Telescope figures prominently in the Astronomy graduate education mission. To date, approximately 45 graduate students have traveled to Flagstaff to observe with the Perkins Telescope. These include students enrolled in GRS AS710 (Observational Astronomy), and students who have used the telescope to acquire the data for their oral comprehensive exam projects and PhD dissertations.

Community Life

The IAR is a vibrant, collegial community within BU that is engaged in a wide variety of astrophysical research projects. The IAR members believe that in order to build the strongest research program, it is extremely important to foster personal interactions, both within the IAR itself and within the broader community of astronomers. The most direct method by which the IAR accomplishes this is through the sponsorship of a colloquium series. During FY13, the IAR hosted 26 professional colloquia, 22 of which were delivered by astrophysicists from outside Boston University. Graduate students are encouraged to interact directly with the colloquium speakers by attending lunch with the speaker, having their own private question-and-answer session with the speaker after the colloquium, and joining all members of the IAR at the BU Pub after the colloquium for lively exchanges of ideas. Senior members of the IAR interact directly with the colloquium speakers through private and "group" meetings during the visit, as well as joining some of the speakers for dinner.

Together with the Department of Astronomy, the IAR also sponsors refreshments after the Friday afternoon graduate Journal Club meetings. This provides a good opportunity for all graduate students in the Department (not just IAR students) to interact with each other and with their professors in a casual setting.

The IAR co-sponsors two annual musical events on Friday evenings that further foster a sense of community among the faculty, staff, and students. The first, dubbed "Astronomy Unplugged" and organized by IAR Director Marscher, features a party with live popular-style music performed by members of the Boston University astronomy and space physics community and friends. The second is a formal program of classical music, performed in the Tsai Auditorium by members of the Boston University astronomy and space physics community and friends, as well as by members of the Cognitive & Neural Systems Department, followed by a reception.

Outreach Activities

As an AAS exhibitor, Professor Clemens' GPIPS team was offered the opportunity to participate in an organized outreach to Los Angeles area middle and high schools, predominantly from disadvantaged or minority communities. Pupils came to the AAS meeting and were treated to a set of short talks and hands-on exercises linked to the exhibit booth science contents. The GPIPS team ran one of these talk/exercise stations, meeting with some 50 students and helping them gain familiarity with terrestrial magnetism (by their making take-home electromagnets) and Galactic magnetism (by a detailed explanation of the GPIPS banner).

The GPIPS EPO table, with compasses and materials to make electromagnets. (NB: photographing pupil participants was discouraged by the AAS, as releases would have been required).

Groups of young members of the Hopi Indian community in Arizona visit the Perkins Telescope at Lowell Observatory on a regular basis. This often occurs when a Boston University astronomer is observing at the telescope, as was the case multiple times in FY13. The participants are provided with an explanation of the observing program and view images being constructed from the current observations with the telescope.

Professor Marscher has written a textbook on cosmology, *From Nothing to Everything: The Story of Our Universe*, an e-book that is available for free download from his research group's website, www.bu.edu/blazars. The website also contains mp3 recordings of his songs with science themes that he sometimes performs for his classes and at public lectures. Prof. Marscher and Dr. Jorstad also mentored an undergraduate student (from SUNY Plattsburgh) participating in the NSF-sponsored Maria Mitchell Observatory summer student program. They provided the student with an observational research project and guided the student through the data analysis, interpretation, and presentation as a poster paper at the winter meeting of the American Astronomical Society.

Professor West remains active in the Astronomy & Astrophysics Section of the National Society of Black Physicists (NSBP), the American Astronomical Society Committee for the Status of Minorities in Astronomy, and Boston University's Multicultural Advisory Committee.

In addition to the activities listed above, IAR members engage in numerous other forms of outreach. These include, for example, talking to school children, responding to email communications from school students, and providing information to the media seeking advice on news items relating to astronomy.

Professor Marscher wrote an article, “What Produces Cosmic Jets?” for a special issue of *Sky & Telescope* magazine entitled “Astronomy’s 60 Greatest Mysteries.” The special issue presents the latest research findings on many topics of current interest in the study of the cosmos.

Press Releases

Members of the IAR are involved in a variety of activities that enrich the lives of people outside the profession of astronomy. Some of this occurs via press releases and other interactions with the popular media. Members of the IAR faculty participated in several press releases during FY13 that garnered substantial national and international attention.

8/21/12 "Why Aren’t There More Stars?" BU press release about paper by undergraduate Robert Marchwinski, graduate student Michael Pavel, and Professor Clemens:

http://www.bu.edu/cas/2012/08/21/bu-researchers-suggest-answer-to-universal-question-why-aren’t-there-more-stars/

12/3/12 "Construction on ATST site begins following formal blessing" with Professor Clemens in photo: http://www.aura-astronomy.org/news/news.asp?newsID=311&newsType=0

1/7/13 “The Gamma-Ray Activity of a High-Redshift Quasar,” Professor Marscher, at the American Astronomical Society meeting in Long Beach, California

1/9/13 “The Arecibo & Green Bank Telescope H II Region Discovery Surveys,” Professor Bania, at the American Astronomical Society meeting in Long Beach, California

Professor Bania’s research findings were also displayed on the National Science Foundation’s website under the title “Scientists Discover Hundreds of Massive Star-Forming Regions in Milky Way”: NSF research highlights

Professor Opher was featured in a number of public forums:
1. Interview with Sara Rimer, BU: http://www.youtube.com/watch?v=n28VxvPp3p8

2. Speaker at the “*Big Ideas for Busy People”,* Cambridge Science Festival, 2013 - http://www.youtube.com/watch?v=Np78sHrjAx4

3. “Reshaping the Solar System, Research Magazine 2012”, BU, http://www.bu.edu/research/magazine/2012/dialogues/reshaping-the-solar-system/index.shtml”

4. Bild der Wissenschaft ,“Die Selstsame Grenze des Sonnensystems”, January 2012

5. WGBH “Voyager's Merav Opher on Touching the Edge of Our Solar System” http://wgbhnews.org/post/voyagers-merav-opher-touching-edge-our-solar-system, September 14, 2012; http://people.bu.edu/mopher/WGBH_Opher.mp3

Sponsored Grants and Contracts

In FY13 the IAR managed 25 active research grants, for which the funding awarded to date totaled $5.58M. During FY13, 20 new proposals were submitted, with requested funding totaling $6,998,632 ($2,210,358 requested during the proposed first year.). Seven new grants were awarded through the IAR totaling $811,186 in terms of funds that arrived in FY13. Including the out-year funding committed by the agencies for these grants, the total is $1,412,626. Funds in IAR grants awarded previously and continued into FY13 totaled $4,747,477. The total of new funds that actually were disbursed to Boston University in FY13 plus previous grant funding continuing into FY13 is $5,558,663. This represents an increase of $965,122 (almost 21%) over the same statistic reported in the FY12 IAR Annual Report. That this increase occurred during a year when federal funding was its most stringent in recent years implies that the research programs fostered by the IAR are extremely competitive on the national scale.

Major New Grant Activity

New grants awarded to faculty through the IAR in FY13 include substantial funding for theoretical studies. Professor Brainerd secured a 3-year grant through the NASA Astrophysical Theory Program to study weak gravitational lensing, which is recognized as an excellent probe of the structure of the universe. Two 2-year NASA Fermi Guest Investigator grants to Professor Marscher support the development of theoretical models to explain the ultra-luminous, time-variable gamma-ray emission from the relativistic jets of blazars. This supports an ongoing comprehensive observational program that is also supported by NASA through continuing grants and a new grant to Senior Research Scientist Jorstad. Professor Jackson was awarded a major NSF grant to study massive star formation through a survey of molecular line emission in the Milky Way Galaxy. Postdoctoral Fellow Joseph Neilsen was awarded a prestigious 2-year (+ 1-year renewable) Einstein Fellowship, which he chose to carry out at Boston University, working with two research advisors, Professors Marscher and Blanton.

Two major awards to Professor West were announced but the funds not yet received at the time of this report. These are a 5-year NSF CAREER grant and a Cottrell grant from the Research Corporation for Scientific Advancement, both very prestigious awards for highly promising young faculty members. Professor West will use the funds to advance his ground-breaking research on low-mass stars.

New grants in FY13 (TOTAL = $1.41M)

PI	Award Title	Sponsor	Project Start Date	Project End Date	FY13 Funding	Total Award
Brainerd, Tereasa	Theoretical Studies of Weak Gravitational Lensing	NASA	02/15/2013	02/14/2016	57,917.00	297,225.00
Jackson James	Student Support for Observing Project on the Green Bank Telescope	National Radio Astronomy Observatory	09/01/2012	08/31/2013	35,000.00	35,000.00
Jackson James	MALT 90: A Molecular Line Survey of Massive Star Formation	National Science Foundation	08/15/2012	07/31/2015	328,960.00	499,270.00

Jorstad Svetlana	Multi-frequency Campaigns to Study Rapid Variability in Gamma-ray Blazars	NASA	12/01/2012	11/30/2013	99,998.00	99,998.00
Marscher Alan	Tracking the Evolution of Multi-waveband Outbursts in Fermi Blazars	NASA	09/01/2012	08/31/2014	99,999.00	199,953.00
Marscher Alan	Turbulent Extreme Multi-Zone Model for Blazar Variability	NASA	09/01/2012	08/31/2014	87,882.00	179,750.00
Marscher Alan	Heart of Darkness: High-resolution X-ray Spectra of Outflows (Einstein Fellowship, Joseph Neilsen)	Smithsonian Astrophyscial Observatory	12/01/2012	11/30/2014	101,430.00	101,430.00

Continuing Grants in FY13 (TOTAL = $5.08M)

PI	Award Title	Sponsor	Project Start Date	Project End Date	Total Award Amount ($)
Bania Thomas	Galactic Chemical Evolution: The 3-Helium Project	National Science Foundation	09/01/2007	08/31/2012	318,603.00
Bania Thomas	Deep GLIMPSE: Exploring the Far Side of the Galaxy	Jet Propulsion Laboratory	08/22/2011	09/30/2014	10,000.00
Blanton Elizabeth	X-ray Cluster Environments of Radio Sources	NASA	01/01/2010	12/31/2013	328,470.00
Blanton Elizabeth	A Targeted, Distant (Z>0.7) Cluster Survey, Using Bent, Double Radio Sources	Jet Propulsion Laboratory	08/19/2011	09/30/2014	67,060.00
Clemens Dan	Completing the Galactic Plane Infrared Polarization Survey	National Science Foundation	08/01/2009	07/31/2013	906,060.00
Jackson James	Infrared Dark Clouds	National Science Foundation	08/01/2008	07/31/2013	649,151.00
Jackson James	Galactic Structures Using 2MASS Data	NASA	01/01/2009	03/31/2013	326,002.00
Jackson James	HERSCHEL Dust Temperatures of High-mass Star Forming Cores	NASA	01/19/2012	01/18/2015	315,130.00

Jorstad Svetlana	Probing Blazar Physics through Variability across the Electro-magnetic Spectrum	NASA	08/01/2010	07/31/2012	34,990.00
Jorstad Svetlana	Searching for the Site of Gamma-ray Emission in Blazar Jets	NASA	11/01/2010	10/31/2012	99,962.00
Jorstad Svetlana	Exploration of Gamma-ray Blazars across the Electro-magnetic Spectrum	NASA	08/01/2011	07/31/2013	96,962.00
Jorstad Svetlana	Identifying the Mechanisms of High Energy Photon Production in Gamma-ray Blazars	NASA	01/27/2012	01/26/2013	19,000.00
Marscher Alan	The Most Compact Regions of Relativistic Jets in Active Galactic Nuclei	National Science Foundation	07/01/2009	06/30/2013	602,138.00
Marscher Alan	Thermal Emission from Hot Dust as a Source of Seed Photons for Producing Gamma Rays in Blazars	NASA	08/01/2011	07/31/2013	200,000.00
Marscher Alan	Continued Comprehensive Monitoring of Gamma-ray Bright Blazars	NASA	09/01/2011	08/31/2014	600,000.00
Marscher Alan	Correspondence of X-ray and Sub-millimeter Variations in Bright Gamma-ray Blazars	NASA	04/25/2012	04/24/2013	19,000.00
West Andrew	Wide Low-mass Binaries: Coeval Laboratories for Testing the Formation and Evolution of Stars	National Science Foundation	08/15/2009	07/31/2012	54,753.00
West Andrew	Using White Dwarf-M Dwarf Pairs to Probe the Magnetic Activity and Angular Momentum Evolution of Low-mass Stars	National Science Foundation	09/01/2011	08/31/2014	429,710.00

List of Scientific Publications by IAR Members

Papers Published in Peer-Reviewed Scientific Journals
(IAR members when research was carried out are indicated in bold-face type)

1. Ahn, C. P., . . ., **West, A. A.**, et al., “The Ninth Data Release of the Sloan Digital Sky Survey: First Spectro-scopic Data from the SDSS-III Baryon Oscillation Spectroscopic Survey,” *Astrophysical Journal Supplement,* Vol. **203, article id. 21** (2012).

2. Anderson, L. D., **Bania, T. M.**, Balser, D. S., & Rood, R. T., “The Green Bank Telescope H II Region Discovery Survey. III. Kinematic Distances,” *Astrophysical Journal,* Vol. **754, Issue 1, article id. 62** (2012).

3. Andrews, J. J., Agüeros, M. A., Belczynski, K., **Dhital, S.**, Kleinman, S. J., & **West, A. A.**, “Common Proper-motion Wide White Dwarf Binaries Selected from the Sloan Digital Sky Survey,” *Astrophysical Journal*, Vol. **757, article id. 170** (2012).

4. Arlen T., ..., **Jorstad, S. G., MacDonald, N. R., Marscher, A. P.**, et al., “Rapid TeV Gamma-Ray Flaring of BL Lacertae”, *Astrophysical Journal,* Vol. **762, article id. 92** (2013).

5. **Bania, T. M.**, Anderson, L. D., & Balser, D. S., “The Arecibo H II Region Discovery Survey,” *Astrophysical Journal*, Volume **759, Issue 2, article id. 96** (2012).

6. Bochanski, J. J., **Savcheva, A., West, A. A.,** & Hawley, S. L., “Mapping the Local Halo: Statistical Parallax Analysis of SDSS Low-Mass Subdwarfs,” *Astronomical Journal*, Vol. **145**, **article id. 40** (2013).

7. Burgasser, A. J., Luk, C., Dhital, S., Bardalez Gagliuffi, D., Nicholls, C. P., Prato, L., **West, A. A.**, & Lépine, S., “Discovery of a Very Low Mass Triple with Late-M and T Dwarf Components: LP 704-48/SDSS J0006-0852AB,” *Astrophysical Journal*, Vol. **757, article id. 110** (2012).

8. Cawthorne, T. V., **Jorstad, S. G., & Marscher, A. P.** “Polarization structure in the core of 1803+784: a signature of recollimation shocks?” arXiv:1305.5356, *Astrophysical Journal*, in press (2013).

9. Clarke, T. E., Randall, S. W., Sarazin, C. L., **Blanton, E. L.**, & Giacintucci, S., “Chandra View of the Ultra-Steep Spectrum Radio Source in Abell 2443: Merger Shock-Induced Compression of Fossil Radio Plasma?” arXiv:1306.3879, *Astrophysical Journal*, in press (2013).

10. **Clemens, D. P.**, **Pavel, M. D.**, & **Cashman, L. R.**, “Near-infrared polarimetry of a normal spiral galaxy viewed through the Taurus Molecular Cloud Complex,” *Astronomical Journal*, Vol. **145, article id. 74** (2013).

11. Davenport, J. R. A., Becker, A. C., **West, A. A.**, et al., “The Very Short Period M Dwarf Binary SDSS J001641−0009252,” *Astrophysical Journal*, Vol. **764, article id. 62** (2013).

12. Dawson, K. S., . . ., **West, A. A.**, et al., “The Baryon Oscillation Spectroscopic Survey of SDSS-III,” *Astronomical Journal*, Vol. **145, article id. 145** (2013).

13. Evans, R., **Opher, M.**, Oran, R., van der Holst, B., Sokolov, I. V., Frazin, R., Gombosi, T. I., & Vásquez, A., "Coronal Heating by Surface Alfven Wave Damping: Implementation in a Global Magnetohydrodynamics Model of the Solar Wind" *Astrophysical Journal*, Vol. **756, article id. 155** (2012).

14. **Finn, S. C., Jackson, J. M.,** Rathborne, J. M., **Chambers, E. T.**, & Simon, R. "The Distribution of Dark Clouds in the First Galactic Quadrant," *Astrophysical Journal*, Vol. **764, article id. 102** (2013).

15. **Foster, J.B.**, Rathborne, J.M., **Sanhueza, P., Claysmith, C.**, Whitaker, J.S., **Jackson, J.M.**, **Mascoop, J.L.**, Wienen, M., Breen, S.L., … **Hoq, S.**, Brooks, K.J., & Longmore, S.N., "Characterization of the MALT90 Survey and the Mopra Telescope at 90 GHz," *eprint arXiv:1306.0560 , Publications of the Astronomical Society of Australia*, in press (2013).

16. Hayashida, M., ..., **Agudo, I.**, ..., **Blumenthal, K.,** ... , **Jorstad, S. G.**, **Joshi, M.**, ..., **Marscher, A. P.**, ..., **Taylor, B.**, et al. "The Structure and Emission Model of the Relativistic Jet in the Quasar 3C 279 Inferred from Radio to High-energy γ-Ray Observations in 2008-2010," *Astrophysical Journal*, Vol**. 754, article id. 114** (2012).

17. Hoare, M. G., . . ., **Jackson, J. M.**, et al. "The Coordinated Radio and Infrared Survey for High-Mass Star Formation (The CORNISH Survey). I. Survey Design," *Publications of the Astronomical Society of the Pacific*, Vol. **124**, pp. 939-955 (2012).

18. **Janes, K.**, Barnes, S. A., Meibom, S., & **Hoq, S**., "NGC 6811: An Intermediate-age Cluster in the Kepler Field", *The Astrophysics Journal*, **article id. 145** (2013).

19. Larionov, V.M., **Jorstad, S.G.**, **Marscher, A.P.**, Morozova, D.A., Blinov, D.A., Hagen-Thorn, V A., Konstantinova, T.S., Kopatskaya, E.N., Larionova, L.V., Larionova, E.G., Troitsky, I.S., "The Outburst of the Blazar S5 0716+71 in 2011 October: Shock in a Helical Jet," *Astrophysical Journal*, Vol. **768, article id. 40** (2013).

20. Lico, R., Giroletti, M., Orienti, M., Giovannini, G,; Cotton, W., Edwards, P.G,; Fuhrmann, L., Krichbaum, T.P., Sokolovsky, K.V., Kovalev, Y.Y., **Jorstad, S.**, **Marscher, A.**, Kino, M,; Paneque, D., Perez-Torres, M.A., & Piner, G., "VLBA monitoring of Mrk 421 at 15 GHz and 24 GHz during 2011," *Astronomy & Astrophysics*, Vol. **545, article id. A117** (2012).

21. Lohfink, A. M., Reynolds, C. S., **Jorstad, S. G., Marscher, A. P.**, Miller, E. D., Aller, H., Aller, M. F., Brenneman, L. W., Fabian, A. C., Miller, J. M., Mishotzky, R. F., Nowak, M. A., & Tombesi, F. "An X-Ray View of the Jet-Cycle in the Radio Loud AGN 3C120," arXiv:1305.4937, *Astrophysical Journal*, in press (2013).

22. Lu, R.-S., . . ., **Jorstad, S. G.,** . . ., **Marscher, A. P.,** et al., "Fine-scale structure of the quasar 3C 279 Measured with 1.3 mm very long baseline interferometry," arXiv:1305.3359, *Astrophysical Journal*, in press (2013).

23. **Marchwinski, R. C.**, **Pavel, M. D.**, & **Clemens, D. P.**, "Resolved Magnetic Field Mapping of a Molecular Cloud Using GPIPS," *Astrophysical Journal*, Vol. **755, article id. 130** (2012).

24. Meibom, S., . . ., **Janes, K.**, et al., "Planet occurrence unaffected by stellar environment in open clusters," *Nature*, in press (2013).

25. **Morgan, D. P., West, A. A.**, Garcés, A., Catalán, S., **Dhital, S.**, Fuchs, M., & Silvestri, N. M., "The Effects of Close Companions (and Rotation) on the Magnetic Activity of M Dwarfs," *Astronomical Journal*, Vol. **144, article id. 93** (2012).

26. Nichols, J. D., Burleigh, M. R., Casewell, S. L., Clarke, J. T., Cowley, S. W. H., **West, A. A.**, & Wynn, G. A., "Origin of electron cyclotron maser-induced radio emissions at ultra-cool dwarfs: magnetosphere-ionosphere coupling currents," *Astrophysical Journal*, Vol. **760, article id. 59** (2012).

27. Nowak, M. A., **Neilsen, J.**, Markoff, S. B., Baganoff, F. K., Porquet, D., Grosso, N., Levin, U., Houck, J., Eckart, A., Falcke, H., Ji, L., Miller, J. M., Wang, Q. D., "Chandra/HETGS Observations of the Brightest Flare Seen from Sgr A*," *Astrophysical Journal*, Vol. **759, article id. 95** (2012).

28. Ott, J., Stilp, A. M., Warren, S. R., Skillman, E. D., Dalcanton, J. J., Walter, F., de Blok, W. J. G., Koribalski, B., & **West, A. A.**, "VLA-ANGST: A High-resolution H I Survey of Nearby Dwarf Galaxies," *Astronomical Journal*, Vol. **144, article id. 1230** (2012).

29. **Paterno-Mahler, R.**, **Blanton, E. L.**, Randall, S. W., & Clarke, T. E., "Deep Chandra Observations of the Extended Gas Sloshing Spiral in A2029," arXiv:1306.3520, *Astrophysical Journal*, in press (2013).

30. **Pavel, M. D, & Clemens, D. P.** "H II Region Driven Galactic Bubbles and Their Relationship to the Galactic Magnetic Field," *Astrophysical Journal*, Vol. **760, article id. 150** (2012).

31. **Pavel, M.D., & Clemens, D. P.** "A Lack of Resolved Near-infrared Polarization across the Face of M51," *Astrophysical Journal*, Vol. **761, article id. L28** (2012).

32. **Provornikova, E., Opher, M.**, Izmodenov, V., & Toth, G., "Do Corotating Interaction Region Associated Shocks Survive When They Propagate into the Heliosheath?" *Astrophysical Journal Letters*, Vol. **756, article id. L37** (2012).

33. **Provornikova, E., Opher, M.**, Izmodenov, V., & Toth, G., "Propagation into the heliosheath of a large-scale solar wind disturbance bounded by a pair of shocks," *Astronomy & Astrophysics*, Vol. **552**, **article ID A99** (2013).

34. Purcell, C.R., Hoare, M.G., Cotton, W.D., Lumsden, S.L., Urquhart, J.S., Chandler, C., Churchwell, E.B., …, **Jackson, J. M.**, …, Umana, G.; Zijlstra, A.A., "The Coordinated Radio and Infrared Survey for High-mass Star Formation. II. Source Catalog," *Astrophysical Journal Supplement*, Vol. **205, article id. 1** (2013).

35. Raiteri, C. M., Villata, M., Smith, P. S., Larionov, V. M., Acosta-Pulido, J. A., Aller, M. F., D'Ammando, F., Gurwell, M. A., **Jorstad, S., Joshi, M.,** ..., **Agudo, I.,** ..., **Blumenthal, K.,** ... , **Marscher, A. P.,** ..., **Taylor, B.,** et al., "Variability of the blazar 4C 38.41 (B3 1633+382) from GHz frequencies to GeV energies," *Astronomy & Astrophysics*, Vol. **545, article id. A48** (2012).

36. Richardson, N. D., Schaefer, G. H., Gies, D. R., Chesneau, O., Monnier, J. D., Baron, F., Che, X., Parks, J. R., Matson, R. A., Touhami, Y., **Clemens, D. P.**, Aldoretta, E. J., Morrison, N. D., Brummelaar, T. A., McAlister, H. A., Kraus, S., Ridgway, S. T., Sturmann, J., Sturmann, L., **Taylor, B.**, Turner, N. H., Farrington, C. D., & Goldfinger, P.J., "The H-band Emitting Region of the Luminous Blue Variable P Cygni: Spectrophotometry and Interferometry of the Wind," *Astrophysical Journal*, Vol. **769, article id. 118** (2012).

37. Richardson, J. D., Burlaga, L. F., Decker, R. B., Drake, J. F., Ness, N. F., & **Opher, M.**, "Magnetic Flux Conservation in the Heliosheath," *Astrophysical Journal Letters*, Vol. **762, article id. L14** (2013).

38. **Sanhueza, P.**, **Jackson, J. M.**, Foster, J.B., Garay, G., Silva, A., Finn, S.C., "Chemistry in Infrared Dark Cloud Clumps: A Molecular Line Survey at 3 mm," Astrophysical Journal, Vol. **756, Issue 1, article id. 60,** (2012).

39. Tombesi, F., Sambruna, R. M., **Marscher, A. P.**, **Jorstad, S. G**., Reynolds, C. S., Markowitz, A., "Comparison of ejection events in the jet and accretion disc outflows in 3C 111," *Monthly Notices of the Royal Astronomical Society*, Vol. **424,** pp. 754-761 (2012).

40. Vidotto, A. A., Fares, R., Jardine, M., Donati, J.-F., **Opher, M.,** Moutou, C., Catala, C., Gombosi, T. I., "The stellar wind cycles and planetary radio emission of the τ Boo system" *Monthly Notices of the Royal Astronomical Society*, Vol. **423,** pp. 3285-3298 (2012).

41. Warren, S. R., Skillman, E. D., Stilp, A. M., Dalcanton, J. J., Ott, J., Walter, F., Petersen, E. A., Koribalski, B., & **West, A. A.**, "Tracing Cold HI Gas in Nearby Low-Mass Galaxies," *Astrophysical Journal*, Vol. **757, article id. 110** (2012).

42. Wehrle, A. E., **Marscher, A. P.**, **Jorstad, S. G.**, Gurwell, M. A., **Joshi, M.**, **MacDonald, N. R.**, **Williamson, K. E.**, **Agudo, I.,** & Grupe, D., "Multiwavelength Variations of 3C 454.3 during the 2010 November to 2011 January Outburst," *Astrophysical Journal,* Vol. **758, article id. 72** (2012).

43. **Wenger, T.V.**, **Bania, T. M.,** Balser, D .S., & Anderson, L. D., "The Green Bank Telescope H II Region Discovery Survey. IV. Helium and Carbon Recombination Lines," *Astrophysical Journal*, Volume **764, Issue 1, article id. 34** (2013).

44. **Wing, J. D., & Blanton, E. L.**, "An Examination of the Optical Substructure of Galaxy Clusters Hosting Radio Sources," *Astrophysical Journal*, Vol. **767, article id. 102** (2013).

45. **Zieger, B., Opher, M.,** Schwadron, N. A., McComas, D. J., & Toth, G. "A slow bow shock ahead of the heliosphere", *Geophysics Research Letters*, in press (2013).

Papers Published in Proceedings of Conferences

1. **Agudo, I.**, **Marscher, A. P., Jorstad, S. G.**, & Gómez, J. L., "Discerning the location of the gamma-ray emission region in blazars from multi-messenger observations", *Highlights of Spanish Astrophysics VII, Proceedings of the X Scientific Meeting of the Spanish Astronomical Society (SEA)*, ed. J.C. Guirado, L.M. Lara, V. Quilis, & J. Gorgas, pp.152-157 (2013).

2. **Agudo, I., Marscher, A. P., Jorstad, S. G.**, Larionov, V. M. , Gomez, J. L., Lahteenmaki, A., Smith, P. S., Nilsson, K., Readhead, A. C. S., Aller, M. F. , Heidt, J., Gurwell, M. , Thum, C., Wehrle, A. E., & Kurtanidze, O., "Locating the Gamma-ray Flaring Emission of Blazar AO 0235+164 in the Jet at Parsec Scales Through Multi Spectral Range Monitoring", *Fermi Symposium Proceedings*, ed. N. Omodel, T. Brandt, & C. Wilson-Hodge, eConf C121028 (2012).

3. **Blanton, E. L.**, Randall, S., Clarke, T., Sarazin, C., McNamara, B., Douglass, E. M., Wing, J., **Paterno-Mahler, R.**, Brodwin, M., Ashby, M., "AGN in Clusters of Galaxies: feedback, sloshing, and lobe bending," in *Half a Century of X-ray Astronomy*, **Article id. 63** (2012).

4. Bochanski, J., Hawley, S. Covey, K., Agüeros, M., Baraffe, I., Catalán, S., Mohanty, S., Rice, E. & **West, A.**, "Measuring the Ages of Low Mass Stars & Brown Dwarfs," *Astronomische Nachrichten*, Vol. **334**, p. 44 (2013).

5. Burgasser, A. J., Faherty, J. K., Schmidt, S., **West, A. A.**, Rosa Zapatero Osorio, M., Pineda, J. S., Burningham, B., Nicholls, C., Sanderson, R., Shkolnik, E., Rodriguez, D., Riedel, A. & Joergens, V., "The kinematics of very low mass dwarfs: splinter session summary," *Astronomische Nachrichten*, Vol. **334**, p. 93 (2013).

6. **Dhital, S., West, A. A.**, Stassun, K. G. & Law, N. M., "The SLoWPoKES Catalog of Low-mass Ultra-wide Binaries: A Cool Stars Resource for Testing Fundamental Properties and for Constraining Binary Formation Theory," *Astronomische Nachrichten*, Vol. **334**, p. 14 (2013).

7. **Foster, J. B.**, Rathborne, J. M**.; Jackson, J. M.**, Longmore, S. N., Whitaker, S., & **Hoq, S.**, "The Millimeter Astronomy Legacy Team 90 GHz Survey (MALT90) and ALMA," *eprint arXiv:1303.3007*, in *New Trends in Radio Astronomy in the ALMA Era, Astronomical Society of the Pacific Conference Series*, in press (2013).

8. Krichbaum, T. P., . . ., **Marscher, A. P., Jorstad, S. G.,** et al. "Zooming towards the Event Horizon - mm-VLBI today and tomorrow," *arXiv:1305.2811*, in 11th European VLBI Network Symposium, ed. P. Charlot et al., in press (2013).

9. **Marscher, A. P.**, "Turbulent Extreme Multi-Zone Model for Multi-Waveband Variations of Blazars," *Fermi Symposium Proceedings*, ed. N. Omodel, T. Brandt, & C. Wilson-Hodge, eConf C121028 (2012).

10. **Neilsen, J., "**The Case for Massive, Evolving Winds in Black Hole X-ray Binaries," *arXiv:1304.6091*, in *Advances in Space Research*, in press (2013).

11. Randall, S. W., Nulsen, P., Forman, W., Clarke, T., Donahue, M., Giacintucci, S., Jones, C., Sun, M., Churazov, E., Kraft, R., **Blanton, E. L.**, Simionescu, A., David, L., & Werner, N. 2012, "Shock Heating in AGN Feedback from a Very Deep Chandra Observation of the Galaxy Group NGC 5813," in *Half a Century of X-ray Astronomy*, **Article id. 64** (2012).

12. Randall, S. W., Nulsen, P., Zuhone, J., Clarke, T., Forman, W., Jones, C., & **Blanton, E.**, "Initial Results from a Very Deep Chandra Observation of the Galaxy Group NGC 5813," in *Galaxy Clusters as Giant Cosmic Laboratories*, p. 47 (2012).

Abstracts of Papers Presented at Meetings

1. Anderson, L. D., Balser, D.S., **Bania, T. M.**, & **Wenger, T.**, "A WISE Extension of the GBT HRDS," *American Astronomical Society,* AAS Meeting #221, #413.01 (2013).

2. Balser, D. S., Anderson, L.D., **Bania, T. M.**, & **Wenger, T.**, "Probing Metallicity Across the Galactic Disk with the GBT," *American Astronomical Society,* AAS Meeting #221, #413.03 (2013).

3. **Bania, T. M.**, Anderson, L. D., & Balser, D. S., "The Arecibo H II Region Discovery Survey," *American Astronomical Society,* AAS Meeting #221, #413.04 (2013).

4. **Blanton, E. L.,** 2012, "AGN in Clusters of Galaxies: feedback, sloshing, and lobe bending," *Black Hole Feedback 2012*, p. 41 (2012).

5. Bochanski, John J., Willman, B., & **West, A. A.**, "Mapping the Milky Way's Halo out to 500 kpc: New M Giants selected from UKIDSS," *American Astronomical Society*, AAS Meeting #221, #254.26 (2013).

6. Bowshire, E. C., Agueros, M. A., Covey, K. R., Hartman, J. D., Lopez-Morales, M., Pooley, D. A., Saar, S., & **West, A. A.**, "Deep Imaging of M37, A Better Hyades," *American Astronomical Society*, AAS Meeting #221, #252.07 (2013).

7. **Brainerd, T. G.**, **Wenger, T. V.**, & **Agustsson, I.**, "Cosmic Magnification in the Sloan Digital Sky Survey," *American Astronomical Society*, AAS Meeting #221, #152.05 (2013).

8. **Brecher, K.**, "On the Late Development and Possible Astronomical Origin of the Gyroscope," *American Astronomical Society*, AAS Meeting #221, #208.02 (2013).

9. **Brecher, K.**, **Zastrow, M.**, "Development and Preliminary Testing of a Physical Optics Concept Inventory," *American Astronomical Society,* AAS Meeting #221, #211.05 (2013).

10. **Cashman, L. R.**, **Clemens, D. P.**, & **Pavel, M. D.**, "The Galactic Plane Infrared Polarization Survey (GPIPS): Data Release 1," *American Astronomical Society*, AAS Meeting #221, #352.16 (2013).

11. **Clemens, D.P.**, **Cashman, L.R.**, **Hoq, S.**, **Montgomery, J.**, **& Pavel, M.D.**, "The Galactic Plane Infrared Polarization Survey (GPIPS): The Full Poster," *American Astronomical Society*, *AAS Meeting* #221, #352.15 (2013).

12. **Dhital, S.**, **West, A. A.**, Stassun, K., Schluns, K., & Massey, A. P., "SLoWPoKES-II: Identifying Ultra-wide Binaries to the Late-M and L Spectral Types," *American Astronomical Society*, AAS Meeting #221, #423.07 (2013).

13. Drake, J., **Opher, M.**, Swisdak, M., & Schoeffler, K., "Magnetic reconnection in the heliosheath and its signatures and consequences," 39th COSPAR Scientific Assembly, Abstract E1.8-13-12, p. 479 (2012).

14. Drake, J., **Opher, M.**, Swisdak, M., & Schoeffler, K., "A reconnection mechanism for the generation of anomalous cosmic rays," 39th COSPAR Scientific Assembly, Abstract D1.1-15-12, p. 480 (2012).

15. Fuchs, M., Bochanski, J. J., Willman, B., Dotter, A. L., & **West, A. A.**, "Using HST Globular Clusters to Derive an Empirical Photometric Metallicity Relation for Low-mass Stars," *American Astronomical Society, AAS Meeting* #221, #158.06 (2013).

16. Guzmann, A., Smith, H. A. Hora, J. L. Zhang, Q., **Jackson, J.M.**, Myers, P. C.; Tolls, V.; Martinez-Galarza, J.; & Jimenez-Serra, I., "Multiband IR Study of the Earliest Stages of Star Formation Within Infrared Dark Filaments," *American Astronomical Society, AAS Meeting* #221, #312.03 (2013).

17. **Hoq, S.**, **Cashman, L. R.**, & **Clemens, D. P.**, "Using Open Star Clusters to Probe the Small-Scale Characteristics of the Galactic Magnetic Field," *American Astronomical Society*, AAS Meeting #221, #250.30 (2013).

18. **Janes, K**., Meibom, S., Barnes, S., **Hoq, S.**, "Baysesian Analysis of Star Cluster Color-Magnitude Diagrams", AAS Meeting, 221, 250.15 (2013).

19. **Jorstad, S. G.**, & **Marscher, A. P.**, "The Gamma-ray Activity of the high-z Quasar 0836+710," *American Astronomical Society*, AAS Meeting #221, #430.05 (2013).

20. **Joshi, M., Marscher, A. P., Jorstad, S. G.,** Boettcher, M., **Agudo, I.,** Larionov, V. M., Aller, M., & Gurwell, M., "Multiwavelength Spectral Studies Of Blazars," 39th COSPAR Scientific Assembly, Abstract F4.2-1-12, p. 848 (2012).

21. **Kraemer, K. E.**, Sloan, G.C., Lagadec, E., Devost, D., **Clemens, D. P., Cashman, L. R**., McDonald, I., Boyer, M. L., & Zijlstra, A. A. "Evolved Stars and Variability in the M5 and M15 Globular Clusters," *American Astronomical Society*, AAS Meeting #221, #250.23 (2013).

22. Lu, R., Fish, V. L., Weintroub, J., Doeleman, S., Bower, G. C., Freund, R., Fribert, P., Ho, P. T., Honma, M., Inoue, M., **Jorstad, S. G.,** Krichbaum, T., Marrone, D. P., **Marscher, A. P.,** et al., "Fine Scale Structure of AGN Jets with 1.3 mm VLBI," *American Astronomical Society*, AAS Meeting #221, #143.05 (2013).

23. **Marscher, A. P.**, "Modeling Millimeter-wave to Gamma-ray Variations of Blazars as Turbulent Plasma Crossing a Standing Shock," *American Astronomical Society*, AAS Meeting #221, #339.53 (2013).

24. **Montgomery, J.**, **Cashman, L. R.**, **Clemens, D. P.**, & **Pavel, M. D.**, "Near-Infrared Polarization Observations of NGC891,"*American Astronomical Society*, AAS Meeting #221, #146.12 (2013).

25. **Opher, M.**, Toth, G., Drake, J., & Swisdak, M., "3D Global Structure of the Heliosheath with the Sector Region," 39th COSPAR Scientific Assembly, Abstract D1.1-19-12, p. 1406 (2012).

26. **Opher, M.**, **Provornikova, E.,** Toth, G., Drake, J., Swisdak, M., & Izmodenov, V., "What did we learn about the 3D Global Structure of the Heliosphere with Voyager and IBEX," 39th COSPAR Scientific Assembly, Abstract D1.1-20-12, p. 1407 (2012).

27. **Paterno-Mahler, R.**, **Blanton, E. L.**, Randall, S. W., Clarke, T. E., **Wing, J. D.**, Ashby, M. N., & Brodwin, M., "Sloshing in Clusters of Galaxies" (poster), American Astronomical Society Meeting #221, #243.13 (2013).

28. Pineda, J. S., **West, A. A.**, Bochanski, J. J., & Burgasser, A. J., "Measuring the Distribution of Active M Dwarfs in the Galaxy," *American Astronomical Society*, AAS Meeting #221, #158.09 (2013).

29. **Schluns, K., West, A. A., Dhital, S., & Massey, A. P.**, "Investigating the Properties of Low-Mass Stars Using Spectra of Wide Binaries," AAS Meeting #221, #158.05 (2013).

30. Schmidt, S. J., Hawley, S. L., Davenport, J. R., **West, A. A.**, & Bochanski, J. J. "First Results From The BOSS Ultracool Dwarf (BUD) Sample," *American Astronomical Society*, AAS Meeting #221, #158.21 (2013).

31. Schultz, B., **Jorstad, S. G.**, **Marscher, A. P.**, **Williamson, K. E.**, & Walker, G. E., "Comparison of Optical and Multi-Waveband Variations of Selected Gamma-ray Bright Blazars in 2012," *American Astronomical Society*, AAS Meeting #221, #339.50 (2013).

32. **Weisenberger, K., West, A. A.**, Irwin, J., Charbonneau, D., Berta, Z. K., Dittmann, J., & Newton, E. R., "An Activity-Rotation Relationship and Kinematic Analysis of Nearby M Dwarfs," *American Astronomical Society*, AAS Meeting #221, #158.10 (2013).

33. **Wenger, T. V.**, **Bania, T. M.,** Balser, D. S., & Anderson, L. D., "The Green Bank Telescope H II Region Discovery Survey. IV. Helium and Carbon Recombination Lines," *American Astronomical Society*, AAS Meeting #221, #413.02 (2013).

34. **West, A. A.**, Bochanski, J. J., Pineda, J., **Dhital, S., Savcheva, A., Jones, D.**, **Schluns, K.,** & **Massey, A. P.**, "Science Highlights from the SDSS DR7 Spectroscopic M Dwarf Catalog," *American Astronomical Society*, AAS Meeting #221, #158.04 (2013).

35. **Williamson, K. E.**, **Jorstad, S. G.**, & **Marscher, A. P.**, "Analysis of Spectral Energy Distributions of Gamma-Ray Emitting Blazars," *American Astronomical Society*, AAS Meeting #221, #339.40 (2013).

Miscellaneous Scientific Publications

1. **Clemens, D. P.,** Heckman, T., Hammel, H. B, & the AURA Board of Directors. "AURA's Response to the NSF Portfolio Review," http://www.aura-astronomy.org/news/NSFPortfolioReview/ AURA_Response_NSF_Portfolio_Review_121102_V3.pdf (white paper) (2012).

2. Larionov, V. M., Blinov, D., & **Jorstad, S. G., "**An unprecedented optical outburst of the blazar CTA 102," *The Astronomer's Telegram, **#4397** (*2012).

3. **Marscher, A. P.**, "What produces cosmic jets?" in *Astronomy's 60 Greatest Mysteries*, special issue of *Sky & Telescope*, ed. R. Naeye, p. 62 (2013).

4. Wehrle, A. E., Grupe, D., Gurwell, M. A., **Jorstad, S. G.**, **& Marscher, A. P., "**Gamma-Ray Blazar BL Lacertae at historic high brightness in millimeter, X-ray and far-infrared bands," *The Astronomer's Telegram, **#4557** (*2012).