Graduate Studies in Astronomy and Astrophysics at Boston University
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The Astronomy Department

The Astronomy Department, as it exists today, was formed in 1966 by Professor Gerald Hawkins and included only two full-time faculty positions. Since that time over 40 years ago, it has grown steadily. Research has expanded into the Center for Space Physics, a unit devoted to research in solar system atmospheres, planetary magnetospheres, the heliosphere, and solar physics, the Institute for Astrophysical Research, a unit devoted to research in a wide range of astrophysical topics, and the Center for Integrated Space Weather Modeling, a unit devoted to creating a physics-based numerical simulation that describes the space environment from the Sun to the Earth. B.U. is now a nationally renowned center for space physics research, and has a first-rate program in astrophysical research.

The Department offers a PhD program in astronomy for students interested in research and academic careers in astrophysics and space physics, and an MA program in astronomy for those interested in careers in scientific applications, scientific computing, and other related fields. The Center for Space Physics, the Institute for Astrophysical Research, and the Center for Integrated Space Weather Modeling are affiliated with the department. The faculty and graduate students in the department are typically members of these units, too.

Research

All faculty members hold Ph.D. degrees in astronomy or physics from first-rate universities. Faculty research interests include observational and theoretical studies in galactic and extragalactic astrophysics, magnetospheric and ionospheric physics, planetary atmospheres, solar and heliospheric physics, star formation and galactic structure, variable stars and star clusters, active galaxies and quasars, high-energy astrophysics, cosmology and relativity, science education, and the search for
extraterrestrial life. Faculty and graduate students carry out observational programs under the BU-Lowell Observatory partnership on the 72” Perkins telescope in Flagstaff, AZ, and as guest investigators at facilities such as the Arecibo Radio Observatory in Puerto Rico; the Cerro Tololo Inter-American Observatory in Chile; the James Clerk Maxwell Telescope, NASA's Infrared Telescope Facility, and other international telescope facilities on Mauna Kea in Hawaii; the Millstone Hill/Haystack Observatory in Massachusetts; and the National Optical and Radio Astronomy Observatories in Arizona, New Mexico, and West Virginia. Members of the department also actively make observations on space-based facilities, such as NASA's Hubble Space Telescope, the Compton Gamma Ray Observatory, the Rossi X-ray Timing Explorer, the POLAR satellite, the Cluster suite of four satellites, the Chandra X-Ray Observatory, the Spitzer satellite and telescope, and the Combined Release and Radiation Effects satellite (CRRES). Department members are also actively involved in research programs developing instruments for and analyzing data from those instruments on upcoming scientific satellites (IBEX, LRO, RBSP, MMS, DSX, TGE, Maven, etc.), as well as Boston University's Planetary Environment Imaging Spectrograph and Monochromatic Imager (located in Texas) and Mobile Ionospheric Observatory. The Center for Space Physics has two active NASA-sponsored sounding rocket programs, which present graduate students with the opportunity to develop an instrument for spaceflight within the period of a PhD program.

**Research Instrumentation and Facilities**

Members of the Department of Astronomy-faculty, staff, and students - use a wide range of instrumentation and facilities in their scientific research. Some of this instrumentation is developed locally and is used at a variety of locations, including the Boston University campus. In many cases, however, the researcher needs to use the unique instrumentation available at national and international centers for research in astronomy, atmospheric physics, and space physics.

Facilities for student instruction are maintained at the Coit Observatory on the roof of the College of Arts and Sciences building. The facilities now include a 6½” refractor, a 12” reflector, a robotic 14” Celestron telescope, four 8” reflectors, a solar telescope and spectrograph, CCD cameras, and a photographic darkroom. The Solar Telescope has been upgraded to allow spectroscopic observations and CCD imaging of bright stars and planets as well. The two sounding rocket labs also maintain high-vacuum spaceflight calibration facilities. The Department maintains a comprehensive astronomical research library that includes many books for research and general reading, sky atlases, and subscriptions to over 50 scientific and popular journals in astronomy and space science. For data analysis and for general purpose computing, each graduate student is provided with a Windows desktop computer. For certain graduate-level and undergraduate-level coursework, there is a computer lab containing PCs running Windows and Linux. The University maintains several computing facilities and systems, the newest and most powerful of which is the IBM Blue Gene supercomputer.
Research Projects and Equipment

Sounding Rocket Program in Planetary Atmospheres
One sounding rocket program in BU's Center for Space Physics is a UV telescope and echelle spectrograph for the measurement of emission line profiles from planetary atmospheres. This experiment is part of NASA's Planetary Rocket program. The instrument is assembled and tested in a laboratory in the CAS building at BU, then launched periodically from the White Sands Missile Range in New Mexico. The Principal Investigator is John T. Clarke, and the project scientist is Dr. Chris Sweeney. This experiment is available for graduate student training, and it is one of the few programs in the US in which grad. students can develop and work with an instrument which is flown into space as part of their thesis. The CSP also runs a sounding rocket program in astrophysics, headed by Tim Cook and Supriya Chakrabarti. The astrophysics program is developing cutting edge instruments to address some of the most challenging scientific problems of our time. One recent experiment, SCARI, studied the shock waves created by the motion of our sun through the Galaxy. A second, SPINR, recently completed three flights to study the properties of dust in reflection nebulae and ultimately how the dust effects the structure of the Galaxy.

CEDAR Imager (Coupling, Energetics, and Dynamics of Atmospheric Regions)
A National Science Foundation-sponsored facility, the CEDAR program's Class-1 CCD Imager was designed and built at Boston University. Class-1 images now operate at the Haystack Observatory/Millstone Hill complex in Westford, Massachusetts (approximately 60 miles from campus) and at several other sites. The imager operates in all-sky (180-degree field of view) mode to record emissions from the ionosphere associated with solar-terrestrial disturbances.

Hancock VLBA Site (Very Long Baseline Array)
One of the ten stations of the VLBA transcontinental radio interferometer array operated by the National Radio Astronomy Observatory (NRAO) is located at Boston University's Sargent Camp near Hancock, New Hampshire. Each station has a 25-meter diameter radiotelescope and associated computers and electronics. The array operates at centimeter wavelengths and produces images of quasars and other compact objects with resolutions as fine as 0.0002 arcseconds.

CISM
In September 2002, the National Science Foundation awarded BU a $20 million 5-year grant to create a Center for Integrated Space Weather Modeling, recently renewed through 2012. CISM’s main goal is to create and couple physics-based numerical simulation models that describe the space environment from the Sun to the Earth. Analogous to the models used to predict the Earth's weather, CISM intends to create models that can be used to predict the ‘weather’ in space around the Earth. These models will be able to provide advance warning of potentially harmful space weather events that could put astronauts at risk, disable satellites, disrupt communications, or cause costly damage on Earth. Jeffrey Hughes directs this exciting new endeavor.
The Galactic Ring Survey

Professor Jim Jackson’s main project is the *Galactic Ring Survey*, a long-term project designed to map a portion of the inner Milky Way Galaxy. The survey looks at the distribution of star-forming molecular clouds by imaging their carbon monoxide emission. Eventually the project will map over 60 square degrees of sky. The Galactic Ring Survey uses the FCRAO radio telescope near Amherst. B.U. gets about 10-15 observing shifts on the radio telescope every month.

POLAR

Professor Ted Fritz is Principal Investigator of the CAMMICE and CEPPAD investigations of the NASA *POLAR* mission; Professor Harlan Spence is co-Investigator on both. This spacecraft launched in 1996 with the purpose of examining the polar regions of the Earth’s magnetosphere by studying energetic particles, magnetic and electric fields, and imaging auroral regions from high above the north pole. Recently, scientists using the POLAR spacecraft captured the first-ever movie of auroras dancing simultaneously around both of Earth’s polar regions. The images confirm the three-century old theory that auroras in the northern and southern hemispheres are nearly mirror images -- conjugates - of each other.

MACCS

Professor Jeffrey Hughes is also running the *MACCS* (Magnetometer Array for Cusp and Cleft Studies) project, an array of ground-based magnetometers in Arctic Canada that monitor the electric currents associated with the aurora in the high latitude ionosphere. MACCS is a joint venture between the Augsburg College Physics Department and BU’s Astronomy Department. Since 1991, faculty and students at the two colleges have worked together to build, calibrate and install magnetometers and computer-based recording systems at eight villages at the northern end of Hudson Bay, on Baffin Island and on the shores of the Arctic Ocean.

AIRO

AIRO aims to exploit the unique conditions at the South Pole by establishing a new permanent national facility, the Antarctic Infrared Observatory. Because the South Pole’s enormous advantage in thermal background translates directly into increased sensitivity and observing speed, a small, inexpensive telescope at the South Pole can outperform larger telescopes at other sites. AIRO will be optimized for wide-field imaging in the thermal infrared. The project will answer key questions about the nature of high redshift galaxies, the evolution of stars and galaxies, the formation of stars, and the physics of the interstellar medium.
**CLUSTER**
The Cluster mission, consisting of four identical spacecraft flying in formation between 25000 and 125000 km above the Earth, will study the planet’s magnetic field and electric surroundings in three dimensions. In particular, it will be looking at the effects of the solar wind, the hot wave of energy produced by the Sun, which buffets Earth's protective magnetosphere. This wind often breaks through at the poles, producing auroras. Cluster will examine this phenomenon, along with several others associated with the solar wind. Professor Ted Fritz currently administers this project.

**CRaTER (Cosmic Ray Telescope for the Effects of Radiation)**
Professor Harlan Spence Principal Investigator of the CRaTER project. CRaTER’s objective is to measure and characterize the potential biological effects of radiation that occur in deep space. The project’s goal is to gather the data needed to develop equipment and materials that will ensure human safety in the lunar environment. Consisting of a novel cosmic ray sensor system coupled with proven analog and digital electronics, CRaTER will relay its data back to Earth through the LRO spacecraft’s communication system. LRO instruments will gather data on the lunar environment, a vital first step in NASA’s preparation for what President Bush announced will be a series of human and robotic missions to the moon starting in 2008.

**Mimir and PRISM (The Perkins Re-Imaging SysteM)**
Boston University and Lowell Observatory are partners in the operation of the Perkins telescope on Anderson Mesa, a dark site outside Flagstaff, Arizona. The telescope has been enhanced by the addition of two modern light analysis instruments that were developed in IAR laboratories. The first, PRISM, achieves three goals: It reimages the long-focus Perkins telescope to a much shorter effective focal length, making it possible to image a wide field of view; it can do high-precision multi-object polarimetry, and it can do low-resolution multi-object spectroscopy. The second, Mimir, is a near-infrared wide- and narrow-field imager, spectrometer, and imaging polarimeter that operates from 1 to 5 microns wavelength across fields up to 10x10 arcmin. Both of these instruments are used by Boston University researchers to conduct extensive surveys and time-critical investigations.
Meteor Radar Project
Professor Meers Oppenheim and his collaborators study the millions of small particles that rain down upon the Earth each day. Large radars and wide-field cameras generate detailed measurements of some of these particles. Their group builds physics based models and perform supercomputer simulations to understand these measurements. The results of this work allow scientists to better characterize the particle environment of the solar system and the effects of particles on the atmosphere.

EMMREM
We are preparing to return humans to the Moon and setting the stage for exploration to Mars and beyond. However, it is unclear if long missions outside of Low-Earth Orbit (LEO) can be accomplished with acceptable risk. The Earth-Moon-Mars Radiation Exposure Module (EMMREM) will develop and validate a numerical module for completely characterizing time-dependent radiation exposure in the Earth-Moon-Mars and Interplanetary space environments. The results of EMMREM will improve risk assessment models so that future human exploration missions can be adequately planned for. Prof. N. Schwadron is the Principal Investigator for the EMMREM project.

IBEX
The Interstellar Boundary Explorer (IBEX) is a small explorer mission with the sole objective to discover the interaction between the solar wind and the interstellar medium. IBEX provides the first global observations of the interstellar interaction – disclosing its fundamental nature and providing the observations needed for detailed modeling and in-depth understanding. IBEX will be launched around June of 2008, and we are currently preparing for the scientific analysis of IBEX data. The first global views of the heliosphere will be generated around January of 2009, and the baseline mission will be completed two years after launch. An extended mission would occur two years after the baseline mission. Prof. Schwadron at BU is the Science Analysis Lead for the IBEX Mission.
**RBSP-ECT**

BU was selected by NASA to lead the Radiation Belts Storm Probe (RBSP) – Energetic particle, Composition, and Thermal plasma (ECT) instrument suite in late 2006. The RBSP mission and the ECT suite will provide the measurements needed to characterize and quantify the plasma processes that produce very energetic ions and relativistic electrons in Earth’s damaging radiation belts. The ECT suite consists of three instrument packages, measuring electrons and ions with energies from a few electronvolts up to relativistic energies. The mission consists of two satellites passing continuously through the hearts of the radiation belts. The ECT team, led by BU, is comprised of top radiation belt scientists from around the US. Professor Harlan Spence is Principal Investigator of the RBSP-ECT instrument suite which is slated for launch in 2012.
The Graduate Program

Degree Programs
The graduate program consists of formal courses in astronomy and original research work conducted under the guidance of a faculty advisor. During the first academic year, students generally concentrate on foundation coursework; a thesis research area is usually chosen during the second year. Original research, the most important part of the graduate program, occupies much of the student's time after the first year. Formal admission to PhD candidacy is based on satisfactory performance in coursework and on the Comprehensive Examination, which is administered to ensure that students have mastered the basic physics and astronomy necessary for research in astronomy and space science. Graduate students are supported through University Fellowships or Department of Astronomy scholarships, teaching fellowships, and research assistantships. The normal procedure is for students to receive a fellowship in the first year or two and to be supported with research assistantships when they begin working closely with individual faculty members in their research.

Seminars and Colloquia
Faculty, visiting scientists, and graduate students present their research work and review current topics of interest in two regular colloquium and seminar series - one in astrophysics and one in space physics. Graduate students may receive course credit for work done in seminars; all graduate students are expected to attend colloquia and those seminars that are relevant to their general research areas.

Admission Tests and Prerequisites
Applicants to the graduate program should have a strong physics background implied by a bachelor's degree in either physics or astronomy. Undergraduate credits in physics should include upper-level courses in mechanics, electromagnetism, quantum mechanics, optics, and thermodynamics/statistical mechanics. Mathematics through differential equations is required, and courses in introductory astronomy and/or astrophysics are highly recommended. Applicants should have a cumulative GPA equivalent to B or higher as a minimum requirement; admission is competitive, based on a number of factors including grades, letters of recommendation, and scores on the GRE examinations.

To be considered for admission it is necessary to submit the Application for Graduate Admission (available from the Graduate School of Arts and Sciences) and three letters of recommendation. All applicants are required to submit Graduate Record Examination (GRE) scores, including the Subject Test in Physics. Applicants whose native language is not English must have a TOEFL exam score or must demonstrate equivalent proficiency in the English language.

Further information on graduate programs and financial aid may be obtained from:
MA in Astronomy

The MA in Astronomy requires completion of a total of eight graduate courses in astronomy and physics with a grade of B - or higher. At least six of these must be astronomy courses numbered 700 - 799. In addition, the candidate must either pass the written Astronomy Comprehensive Examination or write a formal thesis describing a research project carried out by the student and directed by a faculty member. The master's thesis must give evidence of the candidate's ability to understand, evaluate critically, and carry forward competently previous scientific investigation. This is achieved by an advancement in an experimental technique, an extension in the application of a physical theory, or the accumulation of new data or observational material. A thesis is required to demonstrate the candidate's ability to present the results of his or her work in a logical and coherent manner. The thesis is judged in an oral examination administered by a committee of three faculty members, including the student's advisor. A prospectus of the thesis must be approved by the committee at least six months prior to the oral examination. The Comprehensive Exam is given in May each year and is normally taken in the student's second year of graduate school. See the following "PhD in Astronomy" section for details.

PhD in Astronomy

Admission into the PhD program follows upon completion of the requirements for the master's degree, but well-prepared candidates holding a bachelor's degree may be admitted directly into the PhD program. Requirements for the PhD degree are as follows:

• Coursework - Students entering the program without a master's degree must pass a total of 16 courses in graduate-level astronomy and physics with a grade of B - or higher. Of these, eight must be astronomy courses numbered 701 - 749, three must be astronomy courses numbered 750 - 799 or physics courses numbered 500 - 849, and one must be the combination of two 2-credit astronomy seminar courses: GRS AS 850, 851 or AS 865, 866. No more than four of the sixteen courses may be numbered 900 - 919. Students entering with a master's degree must take a minimum of eight graduate level courses in astronomy or physics. Of these eight, at least three must be numbered 701 - 749, three must be astronomy courses numbered 750 - 799, and one must be the combination of two 2-credit astronomy seminar courses: GRS AS 850, 851, or AS 865, 866. No more than one of the eight courses may be numbered 900 - 919.

• Written Comprehensive Examination - A student must pass the written Astronomy Comprehensive Examination (by the end of the second year of study) and the Oral Qualifying Examination (see below) in order to be admitted to PhD candidacy.

• Oral Qualifying Examination - After passing the Comprehensive Examination, a student must take the Oral Qualifying Examination within the subsequent academic year.

• PhD Dissertation - The PhD dissertation can be on any topic in astronomy, astrophysics, or space physics. The dissertation must represent original scientific research that contributes substantially to the advancement of the field.

• Final Oral Examination - Candidates must defend their dissertations as worthy contributions to scientific knowledge and demonstrate mastery of related fields of physics.
Graduate Course Descriptions

GRS AS 701 -- Introduction to Astrophysics
Introduction to astronomical and astrophysical nomenclature and concepts. Coordinate systems, celestial orbits, radiation, stars, stellar structure, stellar evolution, clusters of stars, galactic components, galactic structure, galaxy types, active galaxies, cosmology. Brecher, Jackson, Janes. 4 cr.

GRS AS 703 -- Introduction to Space Physics
Survey of physical phenomena in the sun, solar wind, and magnetospheres, ionospheres, and upper atmospheres of objects in the solar system. Introduction to the physical processes governing space plasmas, solar-terrestrial interactions, and ionized and neutral media surrounding the Earth and other solar system bodies. Hughes, Oppenheim, Spence. 4 cr.

GRS AS 710 -- Observational Techniques

GRS AS 712 -- Radiative Processes in Astrophysics

GRS AS 713 -- Astronomical Spectroscopy

GRS AS 725 -- Gravitational Astrophysics

GRS AS 726 -- Cosmic Gas Dynamics

GRS AS 727 -- Cosmic Plasma Physics
Physics of astrophysical and space plasmas. Magnetohydrodynamic waves and instabilities. Magnetoionic theory, electron waves, ion waves. Kinetic theory of waves in
_Hughes, Oppenheim, Spence_. 4 cr.

**GRS AS 751 -- Galactic Astronomy and the Interstellar Medium**

Prereq: GRS AS 712, 713, 726, or consent of instructor. Physical processes in interstellar 
clouds, ionized hydrogen regions, planetary nebulae, supernova remnants. Dust and 
extinction. Cosmic rays and the galactic magnetic field. _Bania, Clemens, Jackson_. 4 cr.

**GRS AS 753 -- Stars and Stellar Systems**

Prereq: GRS AS 712, 713, 725, 726, or consent of instructor. Stellar interiors and 
atmospheres. Determination of physical properties of stars through observations. Binary 
and multiple stars. Star clusters. Novae and supernovae. Stellar evolution and the 
chemical evolution of the galaxy. _Janes, Brecher_. 4 cr.

**GRS AS 757 -- High-Energy Astrophysics**

Prereq: GRS AS 712, 725, 726, 727, or consent of instructor. Physics of interactions 
between high-energy particles and photons. Compton scattering. Nuclear collisions. 
Acceleration and energy losses of high-energy particles. Neutrino production. Physics of 
cosmic rays. Pulsars. Accretion onto compact objects. Active galactic nuclei and other 
high-energy phenomena. _Brecher, Marscher_. 4 cr.

**GRS AS 759 -- Galaxies and Cosmology**

Prereq: GRS AS 712, 713, 725, 726, or consent of instructor. Appearance, content, and 
physical properties of galaxies. Distances to galaxies and the Hubble Law. Active 
galaxies and quasars. Geometrical and physical cosmology --- the Big Bang model and 
the early universe. Formation of galaxies and large-scale structure. Alternative 
cosmologies. _Brainerd, Brecher, Marscher_. 4 cr.

**GRS AS 781 -- Planetary Atmospheres**

Prereq: GRS AS 726 or consent of instructor. Planetary and cometary atmospheres; 
atmospheric vertical mixing; radiative processes; catalytic ozone destruction; aurorae and 
airglow; planetary ionospheres; energy budgets. Planetary evolution: solar nebula, 
outgassing, water loss on Venus and Mars, escape of light gases, greenhouse effect, 
isotope fractionation, impact theory. _Clarke, Chakrabarti_. 4 cr.

**GRS AS 783 -- Ionospheres**

Prereq: GRS AS 712, 713, 726, 727, or consent of instructor. The formation of the 
ionosphere. The structure and dynamics of the ionosphere and thermosphere. Aeronomy. 
Thermosphere/ionosphere coupling. Ionospheric electric fields and current systems. 
Ionospheric storms. Ionospheric waves and irregularities. Active experiments in space. 
Radio and optical ionospheric diagnostics. _Mendillo, Chakrabarti_. 4 cr.

**GRS AS 785 -- Magnetospheres**

Prereq: GRS AS 712, 713, 726, 727, or consent of instructor. Solar wind/magnetosphere 
interaction. Magnetospheric dynamics and substorms. Magnetospheric electric fields and 
current systems. Ionosphere/magnetosphere coupling. The aurora. Magnetospheric 
plasma waves and instabilities. _In situ_ plasma and field diagnostics. _Hughes, Fritz_, 


Spence. 4 cr.

**GRS AS 786 – Heliosphere**

Prereq: GRS AS 712, 713, 726, 727, or consent of instructor. Fundamentals of Solar and Heliospheric Physics, including observational methods and theory from the Sun’s interior through interplanetary space and into the local interstellar medium. The Sun as a star. Relation of our heliosphere to astrospheres surrounding other stars. *Schwadron.* 4 cr.

**GRS AS 850, 851 -- Astrophysics Seminar**

Weekly seminar offering graduate students and advanced undergraduates discussions of current research topics in astrophysics with staff and visiting scientists. *Staff.* 2 credits each semester.

**GRS AS 865, 866 -- Space Physics Seminar**

Weekly seminar offering graduate students and advanced undergraduates discussions of current research topics in space physics with staff and visiting scientists. *Staff.* 2 credits each semester.

**GRS AS 901,902 -- Research in Astronomy**

*Aaron, Bania, Basu, Blanton, Brainerd, Brecher, Chakrabarti, Chen, Clarke, Clemens, Cook, Crooker, Fritz, Goodrich, Hughes, Jackson, Janes, Lyon, Marscher, Mendillo, Oppenheim, Schwadron, Siscoe, Spence.* Variable cr, 1st & 2nd sem.

**GRS AS 911,912 -- Directed Study in Astronomy**

*Aaron, Bania, Basu, Blanton, Brainerd, Brecher, Chakrabarti, Chen, Clarke, Clemens, Cook, Crooker, Fritz, Goodrich, Hughes, Jackson, Janes, Lyon, Marscher, Mendillo, Oppenheim, Schwadron, Siscoe.*
Astronomy Department Faculty

Jules Aarons, Professor Emeritus. Ph.D. University of Paris. Professor Aarons studies the effects of the earth’s ionosphere on radio wave transmissions from satellites. The deterioration of signals is seen primarily in the high latitude region both in the auroral zone and the polar cap and in the region near the earth’s magnetic equator. Recently he used the transmissions from the Global Positioning System series of satellites to study latitude, longitude and local time effects of magnetic storms. The database is continuous GPS data from a large number of stations throughout the world.

Recent Publications:

Thomas Bania, Professor. Ph.D. University of Virginia. Professor Thomas M. Bania studies the interstellar medium of the Milky Way and other galaxies primarily using the techniques of radio spectroscopy. He led the Boston University effort to construct and operate the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) at the geographic South Pole. AST/RO was a collaboration between Boston University and the SAO Center for Astrophysics. He also studies promordial nucleosynthesis during the Big Bang, primarily with measurements of the light isotope of helium, 3-He. Bania collaborates with Professors Jackson and Clemens in studies of the structure of the Milky Way ISM using the on-going Galactic Ring Survey which is being conducted by Boston University and the Five College Radio Astronomy Observatory. This same team has recently proposed to build a 2-meter infrared telescope, AIRO, which is to be sited in Antarctica and which will survey the Southern sky at mid-infrared wavelengths.

Recent Publications:

Elizabeth Blanton, Assistant Professor. Ph.D. Columbia University. Professor Blanton's primary field of research is clusters of galaxies. In particular, using the Chandra X-ray Observatory, she studies the X-ray emission from the hot, intracluster medium (ICM), and the mutual effect that the ICM and central galaxy radio sources have on one another. These central radio sources are powered by supermassive black holes and inject large quantities of energy into the ICM, along with magnetic fields, and are an important piece of the puzzle of "cooling flow" systems. Professor Blanton takes a multi-wavelength approach to studying clusters, and uses data at optical and near-infrared wavelengths, as well as in the X-ray and radio regimes. She is also interested in using radio sources as tracers of clusters of galaxies at high redshifts which can be
used for cosmological studies.

Recent Publications:

Teresa Brainerd, Associate Professor, Director of Institute Astrophysical Research. Ph.D. The Ohio State University. Professor Brainerd is a cosmologist whose interests include weak gravitational lensing, galactic dynamics, and simulations of the formation of large-scale structure in the universe. Her recent work has focused on the use of satellite galaxies and weak gravitational lensing to probe the underlying mass distribution of the dark matter halos that surround large galaxies. Currently, she is working with graduate students on investigations of the velocity fields of satellite galaxies and on the intrinsic alignments of galaxies over large distances in the universe.
Recent Publications:

Kenneth Brecher, Professor. Ph.D. Massachusetts Institute of Technology. Kenneth Brecher is Professor of Astronomy and Physics and Director of the B. U. Science and Mathematics Education Center. His astrophysical research interests center on a range of topics in theoretical high-energy astrophysics including neutron stars, pulsars, x-ray binary sources, supernovae and gamma-ray bursters. He is currently engaged in several materials, software, hardware and curriculum development projects for use in K - 12, undergraduate and informal science education. He is the Principal Investigator on "Project LITE: Light Inquiry Through Experiments", which is developing materials about light, optics, color and perception (cf. http://www.bu.edu/sme/lite, http://www.bu.edu/sme/lite/vision and http://www.bu.edu/sme/lite/spex). He is co-initiator and Project Scientist on the "MicroObservatory Project" which has developed a network of automated astronomical telescopes for student use (http://mo-www.harvard.edu/MicroObservatory/). He has also worked on the history of astronomy, archaeoastronomy and the application of early astronomical records to modern astrophysical problems.
Recent Publications:
Supriya Chakrabarti, Professor, Director, Center for Space Physics. PhD Berkeley. Professor Supriya Chakrabarti's research interest spans experimental studies of astrophysical phenomena from atmospheres and ionospheres of the Earth and planets to the Interplanetary, Interstellar and Intergalactic media. The measurements are carried out by ground and space based observations using instruments and techniques that his group developed over the years. His current research program includes the development of novel detectors for ultraviolet imaging and spectroscopy and ground based high resolution studies of terrestrial airglow and aurora. Recently his group was awarded a sounding rocket project to take an image of a planet around Epsilon Eridani.

Recent Publications:

Jiasheng Chen, Assistant Research Professor. Jiasheng Chen studies the dynamics of the magnetosphere by analyzing multiple spacecraft (particular the POLAR satellite) data. The POLAR satellite has observed a new magnetospheric phenomenon called the CUSP ENERGETIC PARTICLE (CEP) event (Chen et al., GRL, 24, 1447, 1997; JGR, 103, 69, 1998). This discovery has been written into the web-based Space Physics Text Book (see http://www.oulu.fi/~spaceweb/textbook/cusp.html). After three year debate, this new phenomenon has finally been reported to NASA Headquarters as one of the most important discoveries (http://www-istp.gsfc.nasa.gov/istp/polar/2001jan.html) of the POLAR project. New observations suggest that (1) the high-altitude cusp is the extremely dynamic region in geospace; (2) the solar plasma and ionospheric particles are two seed populations for the CEPs; and (3) some of them are energized in the cusp to energies up to 10 MeV. These cusp energetic particles may drift into the nightside plasma sheet along the closed magnetic field lines, may move into the magnetopause boundary layer along the closed/open field lines, and may leak into the downstream or upstream regions along the open field lines. These results may be shedding light on the long-standing unsolved issue about the origins of the energetic particles in the radiation belt and in upstream events.

Recent Publications:

John Clarke, Professor. PhD Johns Hopkins University. Professor John T. Clarke works in the area of planetary atmospheres, with particular interests in planetary aurora and the escape of the atmospheres of Venus and Mars. He has been an active observer using the Hubble Space Telescope since its launch, with programs to study the atmospheres of Venus, Mars, Jupiter, Saturn, and Uranus, and the interplanetary hydrogen. He is best known for recent work on Jupiter's and Saturn's aurora, with programs since 1994 using HST to study these ultraviolet
emissions. This work has included campaigns to study Jupiter's aurora while Cassini measured the solar wind conditions as it flew past Jupiter in early 2000, and a recent similar campaign with HST as Cassini approached Saturn in Jan. 2004.

Recent Publications:

Dan Clemens, Professor. Professor Dan Clemens investigates the nature of star formation and the structure of the Milky Way galaxy using ground and space-based observatories at millimeter, infrared, and optical wavelengths. He is also an instrumentalist, having recently built Mimir, a multi-function near-infrared imager, spectrometer, and polarimeter for the Perkins telescope in Flagstaff, Arizona. With Mimir, he and his students are conducting a large-scale survey of the magnetic field of the Milky Way called GPIPS, an acronym for the Galactic Plane Infrared Polarization Survey. He was a member of the team that conducted the Galactic Ring Survey (GRS) using the 14 meter Five College Radio Astronomy Observatory, under the direction of Professor Jackson. Clemens also led the Boston University component of the GLIMPSE Legacy-class survey of the Milky Way's disk, conducted by the Spitzer Space Telescope.

Recent Publications:

Timothy Cook, Research Associate Professor. PhD University of Colorado. Professor Timothy Cook specializes in developing novel instrumentation and data analysis techniques for use in ultraviolet astronomy and space physics. His current research includes sounding rockets and satellites such as SCARI. SCARI is an interferometric echelle spectrograph designed to measure emission from hydrogen moving through the solar system in order to learn about conditions in interstellar space around the sun.

Recent Publications:

Nancy Crooker, Research Professor. Ph.D. University of California, L.A. Professor Nancy Crooker works in the area of heliospheric and solar-terrestrial physics, with particular interests in
coronal mass ejections, the hurricanes of space, and in the structure of the heliospheric current sheet, a global boundary which separates magnetic fields of opposite polarity. She leads an effort supported by NASA and NSF to determine the magnetic topology of heliospheric structures using in situ electron and magnetic field data from a number of spacecraft. She is best known for her early work in developing the concept of antiparallel merging, a process of coupling between the solar wind and the magnetosphere, and for her recent work in revealing the extent to which the solar wind consists of transient as opposed to steady-state structures.

**Recent Publications:**


**Theodore Fritz, Professor.** Ph.D. University of Iowa. Professor Theodore A. Fritz works in the area of planetary magnetospheres and possible Sun-Earth relations. His particular research interests include energetic charged particles, their composition, and the mechanisms by which they are transported and energized within magnetospheres. His present focus has been on the role of the Earth’s magnetospheric cusp region as an entry point for solar wind plasma into the magnetosphere and its probable energization there to energies associated with the extraterrestrial ring current. He has participated either as a Principal Investigator or Co-Investigator in about 18 spaceflight projects such as the Application Technology Satellite (ATS-6), the International Sun-Earth Explorer 1&2 (ISEE 1&2), the NASA Galileo mission orbiting Jupiter, the NASA Global Geospace Science (GGS) Polar satellite mission, and the joint European Space Agency/NASA four satellite Cluster mission. In addition to these ongoing data analysis efforts, he is involved in the development of instrumentation for use in space to measure these energetic charged particles. Professor Fritz has joint appointments in the Department of Electrical and Computer Engineering and the Department of Aerospace and Mechanical Engineering. Presently Professor Fritz is leading a group of engineering faculty, graduate, and undergraduate students designing and fabricating a Loss Cone Imager for a US Air Force scientific satellite project know as the Demonstration and Science Experiment (DSX).

**Recent Publications:**


**Charles Goodrich, Research Professor.** Ph.D. Massachusetts Institute of Technology. Professor Goodrich studies the global interactions of the solar terrestrial system. As Co-Director for research integration of code coupling for the Center for Integrated Space Weather Modeling he works with modelers of the solar corona, interplanetary space, and the magnetosphere and the ionized and neutral upper atmosphere of the earth to understand the causes and impacts of space weather. He follows the development of the codes and knits them into a comprehensive computational model. He is also known for his work in visualizing the solar-terrestrial
environment, most recently contributing to the feature articles on the Sun and Space Weather in the July 2004 edition of National Geographic Magazine.

Recent Publications:

W. Jeffrey Hughes, Professor, Director, Center for Integrated Space Weather Modeling (CISM). Ph.D. University of London. Professor Jeffrey Hughes works in magnetospheric physics with particular interest in the dynamics of the magnetosphere and its coupling to the solar wind and to the ionosphere. He is director of CISM, a multi-institutional NSF Science and Technology Center led by Boston University whose goal is to build a physics based computer simulation model of the space environment from the Sun to the Earth, that will both help us understand the complex coupling between regions in geospace and provide tools useful for predicting conditions in space. He is also PI of the MACCS magnetometer network in arctic Canada that monitors currents in the auroral and polar cap ionosphere.

Recent Publications:

James Jackson, Professor, Department Chair. Ph.D. Massachusetts Institute of Technology. Prof. Jackson studies star formation, galactic structure, and the interstellar medium in both the Milky Way and other galaxies using radio, submm, mm, and infrared astronomy. He is PI of the Boston University-Five College Radio Astronomy Observatory Galactic Ring Survey (GRS) http://www.bu.edu/grs. The GRS team is mapping a large portion of the Milky Way's molecular gas in order to study its dominant structure, the 5 kpc molecular ring. Recent results include: (1) the study of the structure of molecular clouds, in which we find that all molecular clouds have the same structure independent of star-formation activity; (2) a new technique to determine the distances to clouds, which resolves a long-standing problem called the "near-far kinematic distance ambiguity"; and (3) a comparison of maps of CS, a dense gas tracer, and 13CO, a column density tracer, which surprisingly shows that 13CO is just as effective in identifying star-forming cloud cores as CS. Jackson also leads the effort to place a new infrared telescope called the Antarctic Infrared Observatory (AIRO) at the South Pole. Because the thermal background is so low in Antarctica, a small telescope there can outperform huge telescopes in Hawaii and Chile. AIRO's first mission will be to survey the southern skies in the thermal infrared at 3 microns.

Recent Publications:
Kenneth Janes, Professor, Director of Undergraduate Studies. Ph.D. Yale University. Professor Kenneth Janes' primary research field is the study of the stellar populations of the galaxy. By learning the ages and compositions of star clusters, the development of the galaxy can be mapped out from the time of the formation of the first stars to the present. Currently he is also studying stellar activity (starspots) and searching for planetary transits using highly precise photometric measurements of stars in clusters. He is part of a team of professional and amateur astronomers that recently discovered a Jupiter-sized planet orbiting a nearby star much like the Sun.

Recent Publications:

John Lyon, Research Professor. PhD University of Maryland. Professor Lyon is a member of the CISM research team. His primary research interests include space plasma physics and magnetospheric physics; numerical simulation and computational physics. He divides his time between Boston University and Dartmouth University, where he is a full-time faculty member. As a member of the CISM research team, Professor Lyon works with Mary K. Hudson and other professors at Dartmouth on 3D global magneto- hydrodynamic (MHD) simulations of the solar wind interacting with the earth's magnetosphere, and hybrid simulations on a finer scale of processes associated with the flow of the solar wind around the magnetosphere.

Recent Publications:

Alan Marscher, Professor. Ph.D. University of Virginia. Professor Marscher's group concentrates on observational and theoretical studies of relativistic jets of high-energy plasma that flow out of the cores of quasars and other types of active galactic nuclei. The main focus is on the most violently variable objects, nicknamed "blazars." The observational studies involve: (1) Compilation of light curves (brightness vs. time) from radio to X-ray and
gamma-ray frequencies in order to draw inferences concerning the exotic emission processes that occur in the jets. Various telescopes are used, including NASA's Rossi X-ray Timing Explorer and, in the future, the Gamma Ray Large Area Space Telescope (GLAST). (2) Imaging of the jets with NRAO's Very Long Baseline Array (VLBA, resolution as fine as 0.0001 arcseconds) and Very Large Array (VLA), as well as NASA's Chandra X-ray observatory. In the case of the VLBA, images are obtained at different times in order to construct "movies" of the changing structure of each jet. (3) Theoretical modeling of the time-variable multifrequency spectra of synchrotron and inverse Compton radiation from the jets. The models involve, for example, emission induced by shock waves and variations caused by swings in the direction of the jet. The blazar group currently consists of Professor Marscher, senior research associate Dr. Svetlana Jorstad, graduate students Francesca D'Arcangelo, Ritaban Chatterjee, Nicholas Lee, and Monica Young, and two undergraduate students.

Recent Publications:

Michael Mendillo, Professor. PhD, Boston University. As Professor of Astronomy and Professor of Electrical and Computer Engineering, Professor Mendillo leads a research group in space physics that has developed new low-light-level imaging techniques for observations of emissions from the atmospheres of the Earth, Planets and Moons in the Solar System. At Earth, studies of atmospheric waves, "space weather storms" and plasma instabilities in the ionosphere are conducted using all-sky cameras at several sites in North and South America, radar observatories, satellite data, and the global network of global positioning system (GPS) receiving stations. Current emphasis is on understanding the role of coupling from above and below in both observational and modeling studies. In areas of Planetary Astronomy, Professor Mendillo’s group studies the very large-scale, though tenuous, escaping atmospheres (called "exospheres") associated with Jupiter's moons Io and Europa, our Moon, and the planet Mercury. Imaging at sodium wavelengths is used to trace the more abundant species in each of those bodies. A new observing technique, called high definition imaging (HDI) has been developed on campus to study the sources of Io's sodium clouds, and the spatial distribution of sodium gas in Mercury's atmosphere. In support of the NASA/ESA Cassini Mission to Saturn and its moon Titan, modeling studies of their upper atmospheres and ionospheres are conducted using general circulation model (GCM) methods, as well as 1- and 2-dimensional sub-models for high resolution studies. The joint investigation of atmospheres (Comparative Aeronomy) is done between Earth and Mars using Mars Global Surveyor (MGS) observations of the martian ionosphere together with simultaneous terrestrial data from a network of radio observatories.
Recent Publications:
Meers Oppenheim, Associate Professor, Director of Graduate Studies. Ph.D. Cornell University. Professor Oppenheim studies space plasma physics using supercomputer simulations, theory, and data. Recently, he has been studying the physics of meteors. Every day, many tons of material hits the Earth's atmosphere moving faster than 11 km/s, mostly in the form of particles smaller than a grain of sand. While larger particles create visible meteors, the more common small ones appear only on radar screens. These particles tell us about the distribution of small particle both within and outside our solar system. Further, they add metals and dust to our upper atmosphere modifying atmospheric chemistry and create a threat to spacecraft. We are developing theories of meteor evolution from their ablation through their turbulent diffusion into the atmosphere and using these theories to study meteoroids and the atmosphere. Dr. Oppenheim also studies fields, waves, and turbulence in the ionosphere and auroral magnetosphere. Improving our understanding of these systems enables us to better characterize energy flows in the upper atmosphere.

Recent Publications:

Jack Quinn, Research Professor. Ph.D. University of California, San Diego. Professor Quinn works in magnetospheric physics with a focus on plasma transport, energization, source and loss processes. He has developed instrumentation for several space missions, including CRRES, Equator-S, and Cluster, and served as Co-Principal Investigator for the Electron Drift Instrument, which measures plasma drifts using a weak electron beam. Professor Quinn is currently Executive Director for the Center for Integrated Space Weather Modeling (CISM).

Recent Publications:

Nathan Schwadron, Associate Professor. Ph.D. University of Michigan. Dr. Schwadron is engaged in broad research topics covering (1) the composition and origin of solar wind, solar wind acceleration and coronal heating, (2) the structure of the coronal and heliospheric magnetic field, (3) the structure of the large-scale heliosphere, (4) the sources, propagation and acceleration of pickup ions, energetic particles, and cosmic rays, and (5) the sources and implications of solar and cometary X-rays.
Recent publications:

George Siscoe, Research Professor. Ph.D. Massachusetts Institute of Technology. Professor Siscoe’s areas of research include space plasma physics, geospace environment modeling, and space weather. He is currently interested in increasing understanding of magnetospheric structure and behavior through numerical simulations.

Recent publications:

Harlan E. Spence, Professor. PhD UCLA. Professor Harlan E. Spence leads a research group that studies the physics of cosmic plasmas, from the Sun’s corona to interplanetary space to Earth’s upper atmosphere, using experimental and modeling techniques. Several fundamental themes unify Spence’s research projects: energy conversion processes, including magnetic reconnection; plasma turbulence and structuring, and their roles in various plasma environments; charged particle acceleration, transport, and losses, both in explosive solar phenomena and at interplanetary shocks as well as in Earth’s radiation belts; and solar cosmic ray production and galactic cosmic ray modulation. As co-Director for Validation and Metrics of BU’s Center for Integrated Space Weather Modeling, Spence and his research team develop and use physics-based, numerical models to understand the powerful dynamics of interacting solar and planetary plasmas (“space weather”) and the resultant deleterious effects on space technologies and astronauts. Professor Spence complements these modeling efforts with the development of instruments on NASA spacecraft and the analysis of the new observations needed to fuel understanding. He is co-Investigator on two energetic particle instrument packages in orbit on the POLAR satellite since 1996 and co-Investigator on a suite of particle instruments on the upcoming Magnetospheric Multiscale Mission. He is Principal Investigator on a cosmic ray sensor that will launch on the Lunar Reconnaissance Orbiter in late 2008, and is Principal Investigator on a recently selected instrument suite that will provide the key measurements for the NASA’s Radiation Belt Storm Probes mission. Spence serves on several national committees that advise NASA and NSF on future space missions and research programs.

Recent Publications:
Huang, C.-L., H. E Spence, J. G. Lyon, F. Toffoletto, H. J. Singer, S. Sazykin, Storm-time Configuration of the Inner Magnetosphere: LFM MHD Simulations, Tsyganenko Model, and
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