

Smithsonian Astrophysical Observatory (SAO)

Charles Alcock, Director

The Smithsonian Astrophysical Observatory (SAO) was established in 1890 as a research unit of the Smithsonian Institution concentrating on studies of solar radiance. Sixty-five years later, SAO assumed responsibility for establishing an optical network for tracking the first artificial satellites. From this pioneering effort, the size and scope of SAO grew with the international space program to include major research in virtually all branches of astrophysics, as well as in areas of earth and planetary sciences.

Since 1955, when its headquarters moved to Cambridge, Massachusetts, SAO has pursued such research in close collaboration with the Harvard College Observatory (HCO) and the Harvard University Department of Astronomy. On July 1, 1973, the Smithsonian Institution and Harvard University formalized their collaboration as the Harvard-Smithsonian Center for Astrophysics (CfA) to coordinate the related research activities of the two observatories under a single director. Today the observatories retain their separate identities, each responsible to its parent organization; however, the joint venture draws on the coordinated strengths of the two organizations and the combined staffs in six research divisions: Atomic and Molecular Physics; High Energy Astrophysics; Optical and Infrared Astronomy; Radio and Geoastronomy; Solar, Stellar, and Planetary Sciences; and Theoretical Astrophysics. In addition, the CfA has a Science Education Department.

Facilities

Observational facilities include the multipurpose Fred Lawrence Whipple Observatory (FLWO) on Mt. Hopkins in Arizona and the Submillimeter Array Telescope (SMA) on Mauna Kea, Hawaii, the latter a collaboration with the Academia Sinica's Institute of Astronomy and Astrophysics of Taiwan. The major instrument on Mt. Hopkins is the 6.5-m-diameter optical telescope of the MMT Observatory, a facility operated jointly with the University of Arizona. SAO scientists have developed and deployed a suite of advanced wide-field imagers and spectrographs for the MMT including the Hectospec/Hectochelle fiber-fed optical spectrographs, the Megacam imager, and MMIRS, an infrared spectrograph and imager. VERITAS, the Very Energetic Radiation Imaging Telescope Array System, is a major ground-based gamma-ray observatory at FLWO with an array of four 12-m optical reflectors for gamma-ray astronomy in the GeV – TeV energy range. Also located at the FLWO are: the MINIature Exoplanet Radial Velocity Array (MINERVA), the MEarth planet hunter, a 1.2-m imaging optical/infrared telescope, and the 1.5-m Tillinghast spectroscopic telescope. FLWO is also home to HAT, the Hungarian Automated Telescope, a completely automated set of small aperture telescopes that search for transiting extra-solar planets; four HAT-Net telescopes are at FLWO, and two are at the SMA site in Hawaii.

In addition to these SAO-operated facilities, the Center for Astrophysics has a 20% share of the twin 6.5-m Magellan telescopes in Chile, operated by a five-institution consortium headed by the Observatories of the Carnegie Institution of Washington. A set of $f/5$ wide-field optics, identical to those at the MMT, have been installed at the Magellan Clay Telescope. These new Magellan optics allow the operation of Megacam and MMIRS in the Southern Hemisphere. Not least, SAO/CfA is involved in the development of both the 25-m Giant Magellan Telescope, with its partners in the Magellan consortium and others, and the Large Synoptic Survey Telescope.

Special laboratories are maintained for the development of telescope instrumentation and for the spectroscopy of atoms and molecules. A 1.2-m radio telescope on the roof of the Observatory in Cambridge is used for the study of molecular clouds and the structure of the Milky Way through the spectral lines of CO and other molecules.

SAO instrumentation is also operating in space. The Chandra X-ray Observatory, the third of the National Aeronautics and Space Administration's (NASA) Great Observatories, carries the SAO-designed High Resolution Mirror Assembly X-ray telescope and the SAO-designed and -built High Resolution Camera (HRC). Chandra, which

SAO operates for NASA, is used to study X rays from high-energy regions of the Universe. The Spitzer Space Telescope uses SAO's Infrared Array Camera (IRAC) as its 3-to-10 micron camera for the study of both the very deep, early universe and the formation of stars and planets locally. NASA's Solar Dynamics Observatory (SDO) provides better-than-high-definition views of the Sun using SAO's Atmospheric Imaging Assembly telescope. SAO's Ultraviolet Coronagraph Spectrometer (UVCS) is one of a suite of instruments onboard the International Solar and Heliospheric Observatory (SOHO) spacecraft. The SAO-designed and -built X-Ray Telescope (XRT) is a high-resolution grazing-incidence telescope on board the Japanese Hinode satellite, which is designed to observe the generation, transport, and emergence of solar magnetic fields in the sun. SAO instruments are also onboard NASA's Transition Region and Coronal Explorer (TRACE) spacecraft to study the sun.

Numerous facilities serving the general scientific community are located at the CfA in Cambridge. The Institute for Theoretical Atomic, Molecular and Optical Physics, established in 1988 to attract and encourage talented graduate students to enter this field, emphasizes theoretical study of fundamental questions in atomic and molecular physics, hosts many visitors, both long- and short-term, and conducts conferences and workshops. The Center for X-ray Technology, established in 2003 as a collaborative effort with other institutions, promotes the development of detectors and optics leading to space telescope applications, including X-ray interferometers. The Institute for Theory and Computation (ITC), also hosted by the CfA, is dedicated to research in high-end astrophysical computing. The ITC consists of members of the Harvard Department of Astronomy, Smithsonian astrophysicists, postdoctoral researchers, graduate students, and associates at other institutions.

Other services at SAO include the Minor Planet Center, which disseminates information on asteroid and comet discoveries worldwide. The United States' gateway for SIMBAD, an international astronomical computer database, is also located at the Cambridge site, as is Harvard's extensive collection of astronomical photographic plates, the largest in the world. In addition, SAO conceived, developed, and now operates the Astrophysics Data System (ADS), funded by NASA. This service includes on-line access to more than 11 million abstracts of articles in the fields of astronomy, astrophysics, space instrumentation, and space physics. Full-text on-line journals are also available. The HITRAN database of molecular parameters for transmission through and emission from planetary atmospheres is maintained at SAO for more than 5000 users worldwide. SAO participates in the National Virtual Observatory (NVO) and the International Virtual Observatory (IVOA) collaborations, whose aims are to implement improved connectivity between the various astronomical data archives in the world.

SAO, on behalf of NASA, serves as the site of both the Chandra X-ray Observatory Science Center (CXC) and the Chandra Operations and Control Center, the latter of which conducts Chandra flight operations on an around-the-clock basis. The CXC develops and oversees the General Observer program for this mission, as well as calibrates, manages, and distributes data received from Chandra.

The CfA's library, which includes the SAO collection as well as that of HCO, is available to the staff and to visitors. Located near the center of a community of universities, government agencies, and corporate scientific enterprises, SAO investigators enjoy access to a variety of facilities and counsel, and they may avail themselves of opportunities to pursue academic interests within the community. Smithsonian staff and their Harvard colleagues at the CfA publish more than 500 papers each year in internationally known journals.

Office of the Director

RESEARCH STAFF

ALCOCK, Charles Roger, Director, Harvard-Smithsonian Center for Astrophysics; Professor of Astronomy, Harvard University. B.Sc. (1972) Auckland University, New Zealand; Ph.D. (1977) California Institute of Technology. Research specialties: Large astronomical surveys; outer solar system; cosmic dark matter; astronomical data mining; virtual observatory technologies. Contact: CALcock@cfa.harvard.edu

BRICKHOUSE, Nancy Susan, Astrophysicist; Senior Science Advisor, Harvard-Smithsonian Center for Astrophysics. B.S. (1977) University of North Carolina; Ph.D. (1984) University of Wisconsin. Research specialties: Plasma physics;

solar and stellar coronae; plasma emission line spectroscopy; ultraviolet and X-ray spectroscopy of astrophysical sources; laboratory astrophysics. Contact: NBrickhouse@cfa.harvard.edu

RESEARCH PROGRAMS

The scientific objectives of the CfA are intentionally flexible so that response to new research opportunities can be prompt and effective. By design, the research programs reflect the strongest areas of the two observatories and concentrate in fields where the contribution to national goals and scientific excellence can best be realized. These broad objectives are pursued by the six major divisions as follows:

- Atomic and Molecular Physics
- High Energy Astrophysics
- Optical and Infrared Astronomy
- Radio and Geoastronomy
- Solar, Stellar, and Planetary Sciences
- Theoretical Astrophysics
- Science Education Department

Atomic and Molecular Physics

Quantitative information about atomic and molecular processes required for interpreting astronomical observations is obtained from combinations of laboratory and theoretical studies. Laboratory research includes millimeter-wave through ultraviolet spectroscopy (millimeter-wave spectroscopy of molecules including anions that have recently been detected in space, long carbon chains and rings), and stored light experiments in quantum optics. Fundamental precision measurements to test time-reversal symmetry-violating phenomena and applications of new magnetic resonance imaging techniques using spin-polarized noble gases are pursued. Tests of general relativity and the underlying equivalence principle use laboratory experimental techniques as well as radio observations of solar-system objects, spacecraft, and quasars and measurements of the round-trip timing of laser pulses sent to the moon. The application of the laser frequency comb to astrophysical measurements has been developed and is being refined. The development of precise laser-based distance measurement techniques supports both the equivalence principle work and future space missions. Measurements of trace gases (primarily atmospheric pollutants and greenhouse gases) and other atmospheric constituents are made from satellite-based spectrometers operating in the ultraviolet, visible, and infrared.

Theoretical research with applications to astrophysics includes calculations of atomic and molecular structure, cross-sections for recombination and molecular collisional processes, photoionization, photodissociation, charge transfer, and the interactions between matter and anti-matter. These studies are used in the Atomic and Molecular Physics (AMP) division to explain the characteristics of X rays stemming from interactions of comets with the flux of ions and electrons streaming from the Sun (the solar wind), to examine the distributions of energetic atoms in atmospheres of the terrestrial planets, to develop new radiative transfer tools for the modeling of planetary atmospheres, and to measure and model photochemistry and pollution in the Earth's atmosphere. AMP is a worldwide center for the development and archiving of fundamental spectroscopic parameters of molecular gases. These data are employed for calculations of transmittance and radiance for the Earth's atmosphere and for astrophysics. The Institute for Theoretical Atomic, Molecular and Optical Physics, funded primarily by the National Science Foundation and situated in the AMP division, has now been in existence for twenty-two years. The main goals of the Institute are to educate both students and postdoctoral fellows in theoretical AMO Physics, to maintain a world-class visitor program, and to organize and support workshops in forefront areas of AMO Physics research.

RESEARCH STAFF

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CHANCE, Kelly V., Senior Physicist; Associate Director, Atomic and Molecular Physics Division, Harvard-Smithsonian Center for Astrophysics. B.S. (1970) University of Hawaii; A.M. (1972), Ph.D. (1977) Harvard University. Research specialties: Molecular spectroscopy, structure, and dynamics and their application to atmospheric studies; laboratory spectroscopy and satellite-based measurements of the Earth's atmosphere, particularly of atmospheric pollutants and greenhouse gases; atmospheric composition and radiative transfer. Contact: KChance@cfa.harvard.edu

DALGARNO, Alexander, Senior Physicist; Phillips Professor of Astronomy, Harvard University. B.Sc. (1947), B.S. Advanced Studies (1948), Ph.D. (1951) University College, London; D.Sc. (1982) Queen's University of Belfast; D.Sc. (2000) York University, Canada. Research specialties: Theoretical atomic and molecular physics; ultracold gases; chemical physics; interstellar medium; astrophysical plasmas; early universe; atmospheric physics.

KHARCHENKO, Vasili A., Physicist. M.Sc. (1974) Politechnic Institute (Leningrad); Ph.D. (1978), D.Sc. (1988) Ioffe Physico-Technical Institute (St. Petersburg). Research specialties: Atmospheric physics; atomic collision theory.

LIU, Xiong, Research Scientist, Smithsonian Astrophysical Observatory. B.S. (1995) Nankai University; M.A. (1998) Research Center for Eco-environmental Sciences, Chinese Academy of Sciences; M.S. (2002) University of Alabama in Huntsville; Ph.D. (2002) University of Alabama in Huntsville. Research specialties: Remote sensing of atmospheric trace gases, aerosols, and clouds; Atmospheric radiative transfer modeling and instrument calibration; Tropospheric chemistry studies integrating satellite measurements, chemical transport models, and in situ observations. Contact: XLiu@cfa.harvard.edu

McCARTHY, Michael C., Senior Physicist. B.Sc. (1986) University of Alaska; Ph.D. (1992) Massachusetts Institute of Technology. Research specialties: Astrochemistry; laboratory astrophysics of reactive molecules; microwave and laser spectroscopy. Contact: MMcCarthy@cfa.harvard.edu

PHILLIPS, David Forrest, Physicist. B.S. (1988) California Institute of Technology; Ph.D. (1996) Harvard University. Research specialties: Development and applications of atomic clocks; precise tests of fundamental physical laws; quantum optics. Contact: DPhillips@cfa.harvard.edu

REASENBERG, Robert D., Physicist. B.S. (1963) Polytechnic University (Brooklyn); Ph.D. (1970) Brown University. Research specialties: Tests of general relativity, especially laboratory and space-based experiments to test the equivalence principle; solar-system dynamics and solar-system-based tests of general relativity; terrestrial and celestial applications of laser distance measurement.

ROTHMAN, Laurence S., Senior Physicist. B.S. (1961) Massachusetts Institute of Technology; A.M. (1964), Ph.D. (1971) Boston University. Research specialties: Molecular spectroscopy; HITRAN (high-resolution transmission) database compilation. Contact: LRothman@cfa.harvard.edu

SADEGHPOUR, Hossein R., ITAMP Director. B.S. (1981), M.S. (1983), Ph.D. (1990) Louisiana State University. Research specialties: Atomic and molecular collisions and spectroscopy; formation and collision of cold antihydrogen and protonic atoms, quantum mechanical interference effects; rydberg collisions; absorption and scattering of light for astrophysical applications, recombination and reionization, and two-photon processes, coherent control and manipulation on the nanoscale, coherent light interaction with nanotubes, ultracold collision of dipolar systems. Contact: HSadeghpour@cfa.harvard.edu

WALSWORTH, Ronald L., Senior Physicist. B.S. (1984) Duke University; Ph.D. (1991) Harvard University. Research specialties: Development of atomic clocks and precision measurement tools; precise tests of fundamental physical laws; bioimaging and brain science; searches for extrasolar planets. Contact: RWalsworth@cfa.harvard.edu

WANG, Huiqun, Physicist. B.S. (1997) University of Science and Technology, China; Ph.D. (2004) California Institute of Technology. Research specialties: Martian atmospheric chemistry and meteorology; planetary science; chemical transport models; General Circulation Models. Contact: Hwang@cfa.harvard.edu

AFFILIATED RESEARCH STAFF

MARTIN, Randall V., Research Associate, Dalhousie University. B.A. (1996) Cornell University; M.Sc. (1998) Oxford University; M.S. (2001), Ph.D. (2002) Harvard University. Research specialties: atmospheric chemistry; satellite remote sensing; global modelling of atmospheric composition.

PHILLIPS, James D., Research Associate. B.S. (1975) University of Michigan; Ph.D (1983) Stanford University. Research specialties: Laboratory and space-based experiments on gravity; space-based astronomical optical instruments; measuring glacier motion with laser ranging.

High Energy Astrophysics

Research in the High Energy Astrophysics Division focuses on astronomical objects and processes that emit and absorb energy as X-rays, which include planets, all types of stars, neutron stars, supernova remnants, supermassive and stellar-mass black holes, galaxies, and galaxy clusters. Observations are made from spacecraft, notably the Earth-orbiting Chandra X-ray Observatory, one of NASA's Great Observatories, as well as other space-based X-ray telescopes. The division's scientific studies are directed at a broad range of topics, including cosmology, the structure, interactions, and evolution of astronomical objects, and processes that generate X-ray radiation. In support of their scientific studies, members of the division use telescopes at all major observatories covering all available wavelengths. Division scientists are working to develop novel X-ray optics and detectors, funded in part by grants from the Gordon and Betty Moore Foundation and NASA. In addition, the Division operates the NASA Astrophysics Data System, the premier digital library of astrophysics publications. Staff members participate in planning and developing major new X-ray missions, and currently operate the Chandra X-ray Center, which conducts flight operations and science activities for the Chandra X-ray Observatory. In solar physics, the Division participated in developing an X-ray telescope for the Japanese Hinode mission and now operates a data center for analyzing Hinode data. Division solar researchers are major participants in the Atmospheric Imaging Assembly investigation on NASA's Solar Dynamics Observatory, launched in February 2010, and in the IRIS satellite to study the solar atmosphere, while Division scientists are principals in the Solar Wind Electrons Alphas and Protons (SWEAP) investigation for NASA's future Solar Probe Plus mission to the Sun. In support of its research and educational goals, the Division funds approximately 30 postdoctoral fellows, hosts many visiting scientists, runs two NSF summer intern programs – one, in its 17th year, with a broad focus on astrophysics and a second, in its 3rd year, targeted on solar physics – and conducts extensive education and public outreach activities.

RESEARCH STAFF

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ALDCROFT, Thomas L., Astrophysicist. B.S. (1987) California Institute of Technology; Ph.D. (1993) Stanford University. Research specialties: X-ray constraints on the intergalactic medium; quasar absorption line systems; quasar multiwavelength spectral energy distribution. Contact: TALdcroft@cfa.harvard.edu

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BURKE, Douglas, Astrophysicist. B.Sc. (1992), M.Sc. (1993) Imperial College of Science, Technology and Medicine (London); Ph.D. (1997) University of Durham. Research specialties: Galaxy clusters; observational cosmology; extragalactic astronomy; Astroinformatics; Semantic Web. Contact: DBurke@cfa.harvard.edu

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DAVID, Laurence P., Astrophysicist. B.A. (1980) Drexel University; M.A. (1983), Ph.D. (1985) Indiana University. Research specialties: Early-Type Galaxies; Groups of Galaxies; Clusters of Galaxies; Cosmology. Contact: LDavid@cfa.harvard.edu

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DRAKE, Jeremy J., Astrophysicist. B.Sc. (1985) University of Newcastle-Upon-Tyne; D.Phil. (1989) Brasenose College, Oxford University. Research specialties: Star and planet formation; protoplanetary disks, stellar atmospheres; stellar magnetic activity; element abundances and stellar evolution; novae; extreme ultraviolet and X-ray astronomy. Contact: JDrake@cfa.harvard.edu

EDGAR, Richard J., Research Astrophysicist. B.A. (1976) University of Colorado; M.S. (1983), Ph.D. (1985) University of Wisconsin. Research specialties: X-ray astronomy; spectroscopy; diffuse soft X-ray background; hot interstellar medium supernova remnants; nonequilibrium ionization solar wind, x-ray instrument calibration. Contact: REdgar@cfa.harvard.edu

EDMONDS, Peter D., Astrophysicist. B.S. (1988), Ph.D. (1994) University of Sydney. Research specialties: Globular clusters; compact binaries, especially accreting systems; HST studies of globulars; optical identifications of X-ray sources; X-ray studies of compact binaries; millisecond pulsars; stellar pulsations. Contact: PEdmonds@cfa.harvard.edu

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EVANS, Ian N., Astrophysicist. B.Sc. (1982) University of Western Australia; Ph.D. (1987) Australian National University. Research specialties: Physics of active galactic nuclei, including the impact of nuclear activity on the host galaxy; HII region abundances and physics of the interstellar medium; image-processing algorithms. Contact: IEvans@cfa.harvard.edu

EVANS, Nancy R., Astrophysicist. B.A. (1966) Wellesley College; M.Sc. (1969), Ph.D. (1974) University of Toronto. Research specialties: Cepheid masses and luminosities; binary stars (star formation); visual and ultraviolet observations of intermediate mass stars; X-ray observations of star clusters.

FABBIANO, Giuseppina, Senior Astrophysicist. Ph.D. (1973) University of Palermo. Research specialties: X-ray astronomy; normal galaxies; populations of X-ray sources in galaxies; silent supermassive black holes; multiwavelength astrophysics archives and data analysis in the Virtual Observatory. Contact: GFabbiano@cfa.harvard.edu

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GRAESSLE, Dale E., Astrophysicist. B.S. (1981) University of Missouri, Columbia; Ph.D. (1989) University of Wisconsin. Research specialties: X-ray astronomy; high-energy astrophysics; AGN spectra; instrument calibration; synchrotron radiation. Contact: DGraessle@cfa.harvard.edu

GREEN, Paul J., Astrophysicist. B.A. (1981) Oberlin; Ph.D. (1992) University of Washington, Seattle. Research specialties: Extragalactic X-ray astronomy; quasars and AGN; quasar variability; X-ray survey multiwavelength followup; wide separation quasar pairs or lenses; quasar emission and absorption lines; galactic faint halo carbon stars; S stars.

HARRIS, Daniel E., Astrophysicist. B.A. (1956) Haverford College; M.A. (1957), Ph.D. (1961) California Institute of Technology. Research specialties: Nonthermal processes in extragalactic sources: clusters of galaxies, radio galaxies, and quasars with a particular emphasis on relativistic jets.

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MACHACEK, Marie Esther, Astrophysicist. B.A. (1969) Coe College; M.S. (1970) University of Michigan; Ph.D. (1973) University of Iowa. Research specialties: Galaxy interactions and evolution; X-ray studies of hot gas in galaxies, clusters, and groups. Contact: MMachacek@cfa.harvard.edu

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ROTS, Arnold H., Astrophysicist. B.Sc. (1967), M.Sc. (1971), Ph.D. (1974) University of Groningen, Netherlands. Research specialties: Interstellar medium in extended galaxies; dynamics of galaxies; study of pulsars, in particular timing; data analysis algorithms; time keeping; data archives; Virtual Observatory. Contact: ARots@cfa.harvard.edu

SAAR, Steven H., Astrophysicist. B.A. (1980) Northwestern University; Ph.D. (1987) University of Colorado. Research specialties: Solar/stellar magnetic fields, dynamos, and related activity; stellar rotation, convection, and surface features; detection of extrasolar planets. Contact: SSaar@cfa.harvard.edu

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SLAVIN, Jonathan David, Astrophysicist. B.S. (1984) Georgetown University; Ph.D. (1990) University of Wisconsin. Research specialties: Theories of the interstellar medium (ISM), especially local ISM (including our local interstellar cloud) and interactions of hot gas and cooler gas; supernova remnant (SNR) evolution; interstellar dust; X-ray, ultraviolet and infrared observations of SNRs and the hot ISM; intracluster medium in rich clusters. Contact: JSlavin@cfa.harvard.edu

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WEBER, Mark, Astrophysicist. B.S. (1991) Harvey Mudd College; M.S. (1995), Ph.D. (1999) Montana State University. Research specialties: Coronal differential rotation; large-scale structure of corona; magnetic loop models; variation of solar neutrino flux. Contact: MWeber@cfa.harvard.edu

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GAENSLER, Bryan M., Research Associate, Smithsonian Astrophysical Observatory. B.Sc. (1993), Hons Class I (1994), Ph.D. (1998) University of Sydney. Research specialties: Neutron stars; supernova remnants; supernovae; the interstellar medium; magnetic fields; shocks; turbulence; the Magellanic Clouds; radio polarimetry; interferometry; high energy astrophysics; history of astronomy.

GRINDLAY, Jonathan E., Robert Treat Paine Professor of Astronomy, Harvard University. A.B. (1966) Dartmouth College; A.M. (1969), Ph.D. (1971) Harvard University. Research specialties: High energy astrophysics; X-ray observations and models of compact Objects in binaries in globular clusters; active galaxies; gamma-ray bursts; development of hard X-ray imaging detectors and telescopes; time domain astrophysics and surveys. Contact: JGrindlay@cfa.harvard.edu

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SEWARD, Frederick D., Astrophysicist. AB (1953) Princeton University; PhD (1958) University of Rochester. Research specialties: X-ray astronomy; Supernova remnants; Neutron Stars.

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Optical and Infrared Astronomy

Research in this division spans extragalactic and galactic astronomy, with special emphases on cosmology, the large-scale structure of the universe, cosmic gamma-ray sources, clusters of galaxies, clusters of stars, the halo of our galaxy, and the formation and evolution of stars and galaxies. Observations are made from orbiting observatories including the Hubble Space Telescope and the Spitzer Space Telescope, as well as from ground-based observatories such as the MMT, Magellan, and FLWO. SAO/CfA astronomers were the first to uncover the large-scale structure of the distribution of galaxies in space and the acceleration of the Universe. Division scientists have also led the exploration of the very high energy (TeV) gamma-ray universe using atmospheric Cerenkov telescopes. OIR scientists are heavily involved in the analysis of Spitzer data and led the development of the Infrared Array Camera (IRAC) for Spitzer. They are active in the development of both advanced optical and infrared instruments for existing ground-based facilities, and concepts for the next generation of large optical/infrared telescopes and instruments, including the Giant Magellan Telescope (GMT), a 25-m telescope made up of seven 8.4-m segments, three of which have been fabricated so far.

RESEARCH STAFF

ASHBY, Matthew L. N., Astrophysicist. B.A. (1988) University of Colorado; M.S. (1991), Ph.D. (1995) Cornell University. Research specialties: Infrared properties of nearby and distant galaxies; active galactic nuclei; galaxy evolution; radiative transfer. Contact: MAshby@cfa.harvard.edu

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FALCO-ACOSTA, Emilio, Astronomer. B.S., M.S. (1983), Ph.D. (1986) Massachusetts Institute of Technology. Research specialties: Observational cosmology; estimation of cosmological parameters and studies of galaxy evolution; searches for and studies of gravitational lenses in all-sky surveys; searches for extrasolar planets. Contact: Falco-AcostaE@si.edu

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LATHAM, David W., Senior Astronomer. B.S. (1961) Massachusetts Institute of Technology; Ph.D. (1970) Harvard University. Research specialties: Searches for and characterization of extrasolar planets; the formation and early history of the Milky Way Galaxy; the frequency and orbital characteristics of binaries in various stellar populations. Contact: DLatham@cfa.harvard.edu

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TOLLS, Volker, Astronomer. Diploma (1988), Ph.D. (1992) University of Cologne. Research specialties: Design and test of radio telescope instrumentation, ground-based and spaceborne, millimeter-to-infrared astronomy; interstellar chemistry; planet detection and imaging; coronagraphic techniques. Contact: VTolls@cfa.harvard.edu

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Radio and Geoastronomy

Research in the SAO Radio and Geoastronomy Division includes studies of a wide range of astrophysical phenomena. Division staff operate the Submillimeter Array (SMA), an eight-element interferometer used for high-resolution observations of celestial objects at submillimeter wavelengths. Other facilities include a small millimeter wavelength telescope dedicated to mapping emission from molecular clouds in the Milky Way. Astronomical observations are also carried out with major national and international radio telescopes, including the Atacama Large Millimeter/submillimeter Array, the NRAO Very Large Array and Very Long Baseline Array, the IRAM 30-m Telescope and Plateau de Bure interferometer, and the South Pole Telescope. Astronomical research programs involve investigations of the structure of the Milky Way, the evolution of galaxies, the formation of stars, the formation of planets in circumstellar disks, the physics and chemistry of the interstellar medium, circumstellar and interstellar masers, planetary and cometary atmospheres, and the epoch of reionization. In addition, Division astronomers are leading the development of the Event Horizon Telescope, to directly image the immediate environment of a black hole, taking advantage of technological advances in very long baseline interferometry at millimeter and submillimeter wavelengths

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PAINE, Scott N., Astrophysicist. B.S. (1984) California Institute of Technology; Ph.D. (1992) Massachusetts Institute of Technology. Research specialties: Millimeter-wave and submillimeter-wave optics and instrumentation; Fourier transform spectroscopy; Atmospheric radiometry and radiative transfer modeling. Contact: SPaine@cfa.harvard.edu

PATEL, Nimesh A., Radio Astronomer and General Engineer. M.Sc. (1984) Bombay University; Ph.D. (1990) Indian Institute of Science, Bangalore. Research specialties: Evolved stars; Molecular spectroscopy; Star formation; Astrophysical masers; Radio interferometry; Antenna pointing and metrology; instrumentation and software. Contact: NPatel@cfa.harvard.edu

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WILNER, David James, Associate Director, Radio and Geoastronomy Division, Harvard Smithsonian Center for Astrophysics. A.B. (1987) Princeton University; Ph.D. (1993) University of California, Berkeley. Research specialties: Star and planet formation; protoplanetary disks and debris disks; aperture synthesis observations and interferometry techniques. DWilner@cfa.harvard.edu

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Solar, Stellar, and Planetary Sciences

Research in the SSP Division is directed toward understanding star and planet formation and the physical processes in the Sun, stars, and stellar systems. Division research on the Sun addresses its basic stellar properties, its atmosphere and corona, and its effects on the Earth. Studies of other stars seek to measure the age and chemical composition and to understand the structure of surrounding disks, magnetic fields, and winds. Searches for objects in our own solar system and for extra-solar planets inform theoretical investigations of star and planet formation and evolution. Observational data are obtained from ground-based observatories (such as the MMT Observatory, Magellan, and the Whipple Observatory) and from satellites including the Solar and Heliospheric Observatory, the Transition Region and Coronal Explorer, the Far Ultraviolet Spectrographic Explorer, the Hubble Space Telescope, the Chandra X-ray Observatory, and the Spitzer Space Telescope.

RESEARCH STAFF

AVRETT, Eugene H., Senior Physicist. B.S. (1957) Georgia Institute of Technology; Ph.D. (1962) Harvard University. Research specialties: Theory of stellar atmospheres and spectra; models of solar and stellar atmospheres; computer simulation of solar, stellar, and nebular spectra. Contact: EAvrett@cfa.harvard.edu

CRANMER, Steven R., Astrophysicist. B.S. (1990) Drexel University; M.S. (1991) Ohio State University; Ph.D. (1996) University of Delaware. Research specialties: Heating of the solar corona and acceleration of the solar wind; Plasma physics and kinetic theory of waves and turbulence; Rotating hot stars (O, B, Wolf-Rayet) and circumstellar fluid dynamics; Radiative transfer and spectroscopy.

DUPREE, Andrea K., Senior Astrophysicist. B.A. (1960) Wellesley College; Ph.D. (1968) Harvard University. Research specialties: Astronomical spectroscopy; theory of solar and stellar atmospheres and spectra; stellar chromospheres and coronae; mass loss and stellar winds. Contact: ADupree@cfa.harvard.edu

GINGERICH, Owen, Senior Astronomer Emeritus; Professor of Astronomy and the History of Science Emeritus, Harvard University. B.A. (1951) Goshen College; M.A. (1953), Ph.D. (1962) Harvard University. Research specialties: History of astronomy, especially the sixteenth to twentieth centuries.

IRWIN, Jonathan M., Astronomer. B.A., M.Sci. (2004); M.A., Ph.D. (2007) University of Cambridge. Research specialties: Robotic telescope operations; very low-mass eclipsing binaries; rotational evolution of low-mass stars. Contact: JIrwin@cfa.harvard.edu

KALKOFEN, Wolfgang, Astrophysicist. Vordiplom (1956) Goethe University, Germany; M.A. (1961), Ph.D. (1963) Harvard University. Research specialties: Radiative transfer in continua and in spectral lines through static and moving media; radiative gas dynamics; propagation and dissipation of shock waves in stellar atmospheres.

KENYON, Scott J., Senior Astrophysicist. B.S. (1978) Arizona State University; M.S. (1979), Ph.D. (1983) University of Illinois. Research specialties: Numerical calculations of planet formation; structure of debris disks; the formation and evolution of single and multiple stars; accretion disks. Contact: SKenyon@cfa.harvard.edu

KORZENNIK, Sylvain G., Physicist. Degree of Engineering (1977) Free University of Brussels; Ph.D. (1990) University of California, Los Angeles. Research specialties: Astronomy; solar physics; helioseismology; astroseismology; extrasolar planets. Contact: SKorzennik@cfa.harvard.edu

LATHAM, David W., S.B. Massachusetts Institute of Technology (1961), Ph.D. Harvard University (1970); The search for and characterization of exoplanets, binary and multiple star characteristics of various stellar populations in the Galaxy, the chemical and kinematical history of the Galaxy, telescopes and instrumentation, NASA's Kepler mission, NASA's Transiting Exoplanet Survey Satellite. Contact: DLatham@cfa.harvard.edu

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MEIBOM, Søren, Astronomer. M.S. (1999) University of Copenhagen; Ph.D. (2005) University of Wisconsin. Research specialties: Observational studies of the rotation of stars as a function of mass and age with a special focus on members of open clusters with known ages; searches for transiting planets in open clusters; surveys of open clusters to determine membership and binarity. SMeibom@cfa.harvard.edu

MIRALLES, Mari Paz, Astrophysicist. M.Sc. (1989), Ph.D. (1993) Complutense University of Madrid. Research specialties: Solar physics: solar corona, ultraviolet spectroscopy of solar-wind source regions; star formation: radio astronomy, molecular clouds, OB stars, ultracompact H II regions, infrared imaging and spectroscopy. Contact: MMiralles@cfa.harvard.edu

NOYES, Robert W., Astrophysicist; Professor of Astronomy, Harvard University. B.A. (1957) Haverford College; Ph.D. (1963) California Institute of Technology. Research specialties: Solar and stellar physics; solar structure and dynamics; detection and characterization of planets around other stars; origin and evolution of planetary systems. Contact: Rnoyes@cfa.harvard.edu

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PETAEV, Michail, Senior Geologist. M.A. (1979) Moscow State University; Ph.D. (1985) Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow. Research specialties: Experimental and theoretical cosmochemistry; petrologic and chemical studies of the meteoritic record of events and processes in the primordial solar nebula; thermodynamic and kinetic modeling of nebular condensation and igneous and aqueous processes on asteroids. Contact: MPetaev@cfa.harvard.edu

RAYMOND, John C., Astrophysicist. B.A. (1970), Ph.D. (1976) University of Wisconsin, Madison. Research specialties: Supernova remnants; solar physics; cataclysmic variables. Contact: JRaymond@cfa.harvard.edu

SOON, Willie, Astrophysicist. B.Sc. (1985), M.Sc. (1987), Ph.D. (1991)[with distinction] University of Southern California. Research specialties: Observational analysis and physical modeling of phenomena relevant to the Sun, Sun-like stars, and the Earth. Contact: WSoon@cfa.harvard.edu

SPAHR, Timothy, Astronomer. B.S. (1993) University of Arizona; Ph.D. (1998) University of Florida. Research specialties: Distribution of asteroids; sky surveys for near-Earth objects; determination of orbits.

SZENTGYORGYI, Andrew H., Associate Director, B.S. (1979) S.U.N.Y. at Stony Brook, M.S. (1983), Ph.D. (1986) University of Wisconsin, Madison. Research specialties: exoplanets, stellar astronomy, precision radial velocity surveys; high dispersion spectroscopy; instrumentation. Contact: ASzentgyorgyi@cfa.harvard.edu

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AFFILIATED RESEARCH STAFF

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FRANKLIN, Fred A., Astronomer and Physicist. B.A. (1954) Harvard College; M.A. (1956), Ph.D. (1962) Harvard University. Research specialties: Planetary photometry; stability problems; investigations of concentration and scattering properties of small particles in the solar system; techniques and instrumentation to measure the Earth's albedo.

JOHNSON, John A., Professor of Astronomy, Harvard University. B.S. (2000) Physics Missouri University of Science and Technology, M.A. (2002) Astronomy UC Berkeley, Ph.D. (2007) Astronomy UC Berkeley. Research specialties: detection and characterization of planets orbiting nearby stars; stellar astrophysics; design and implementation of robotic telescopes for highly precise radial velocity monitoring of bright stars.

KURUCZ, Robert L., Research Associate. A.B. (1966) Harvard College; Ph.D. (1973) Harvard University. Research specialties: Radiative transfer; stellar atmospheres; solar physics; atomic and molecular spectroscopy. Contact: RKurucz@cfa.harvard.edu

ÖBERG, Karin I., Assistant Professor of Astronomy, Harvard University. B.Sc. (2005) California Institute of Technology, Ph.D. (2009) Leiden University. Research specialties: Astrochemistry; laboratory astrophysics; molecular processes during star and planet formation. Contact: KOberg@cfa.harvard.edu

SASSELOV, Dimitar, Professor, Harvard University. M.Sc. (1986), Ph.D. (1988) University of Sofia; Ph.D. (1990) University of Toronto. Research specialties: Stellar pulsation; radiation hydrodynamics; stellar spectroscopy; extrasolar planets.

STRACHAN, Leonard, Research Associate. S.B. (1982) Massachusetts Institute of Technology; A.M.(1987), Ph.D. (1990) Harvard University. Research specialties: Solar physics; ultraviolet spectroscopy; development of space-based instruments. Contact: StrachanL22@si.edu

Theoretical Astrophysics

Research in the Theoretical Astrophysics division utilizes both physical analysis and mathematical modeling to understand astronomical systems. A broad range of topics is investigated, including the formation, structure, and evolution of stars, the properties of atoms and molecules in interstellar space, the structure and properties of accretion systems, high-temperature plasmas, the formation and evolution of planetary systems, both solar and extrasolar, the formation of galaxies, clusters, and quasars in the universe, and theories of the early universe.

RESEARCH STAFF

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AFFILIATED RESEARCH STAFF

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Science Education Department

The Science Education Department (SED) conducts several programs designed to improve the teaching of precollege science, mathematics and technology, partly through the use of examples from astronomy and space science. These programs include the development of curriculum materials and standardized tests, the integration of its robotic telescopes into classroom projects, the production of films and videos, research on the effect of pre-

college science courses on students' college science success, and the training of pre-college educators. Areas of interest include the development of innovative educational technologies, scientific visualizations, and research methodologies.

RESEARCH STAFF

GOULD, Roy R., Education Analyst, SAO Education Forum. A.B. (1968) Cornell University; Ph.D. (1974) Harvard University. Research specialties: Science education; technology-based tools for science and math education; integration of contemporary science into school curricula; public understanding of science. GouldR@si.edu

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