



## Harvard-Smithsonian Center for Astrophysics

60 Garden St., MS-19, Cambridge, MA 02138



17 August 2015

Dear Harvard Students,

The Harvard-Smithsonian Center for Astrophysics (CfA, <http://www.cfa.harvard.edu/>), located at 60 Garden Street opposite the Quadrangle, is one of the world's great centers for research in astrophysics, with over 300 scientists and access to powerful astronomical observatories worldwide and in space. The following is a partial list of CfA research opportunities for undergraduates. I encourage students to contact these scientists directly to inquire about these opportunities. Harvard has several programs to provide partial support for student research, described at:

<http://uraf.harvard.edu/>

If you have questions about getting involved in research at the CfA, please do not hesitate to contact me.

Best regards,

Edo Berger,  
Director of Undergraduate Studies, Astrophysics  
Professor of Astronomy  
Harvard University  
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P-320

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Dr. Gerhard Sonnert

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Gerhard Sonnert works on large-scale survey studies in the area of science and mathematics education. Current projects include an examination of the factors influencing students' success in college calculus, a study of what predicts beginning college students' career interests, and an investigation of the extent to which professional development institutes for middle school life science teachers actually improve their scientific knowledge and pedagogical skills. He is particularly interested in the gender aspects of science careers.

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Dr. David Charbonneau

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I would welcome working with undergraduate students on a variety of observational or instrumentation projects related to exoplanets. My primary activities are as follows:

(1) The MEarth Project consists of two arrays, one in Arizona and the other in Chile, each comprising 8 robotic telescopes, photometrically surveying 4000 nearby, small stars to search for small planets near the habitable zone. Due to their proximity to us and the small stature of their parent stars, the atmospheres of such planets are observationally accessible.

(2) The HARPS-N Project is an ultra-stable, high-resolution spectrograph located on the Italian National Galileo Telescope in the Canary Islands. Our international team is gathering data to measure the masses and hence learn something about the composition of small planets identified by the NASA Kepler Mission.

(3) My team is conducting a census of nearby M-dwarfs to deduce their fundamental properties and develop methods to facilitate their characterization. M-dwarfs outnumber Sun-like stars 10:1, and so if they too host habitable planets, then likely the closest and most observationally accessible Earth-like planets orbit M-dwarfs in our census.

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Blakesley Burkhart

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Turbulence and magnetic fields are ubiquitous in the interstellar medium of galaxies as well as the intercluster and intergalactic medium. Magnetohydrodynamic (MHD) turbulence is interrelated to important and basic physical processes such as cosmic ray acceleration, dust polarization, magnetic reconnection, star formation, heat transport in galaxy clusters (i.e. the cooling flow problem), and diffuse structure in the ISM. It is important therefore to understand MHD turbulence from an observational as well as theoretical/numerical basis. Several projects touching on different aspects of MHD turbulence are available and can suit students interesting in numerics/theory, observations, or both. Projects include:

1) Dust polarization models and measuring the alignment of magnetic field lines relative to the density in filamentary structure and comparison with Planck data. (Student will work with numerics and observations).

2) Rotation measure vs. column density in simulations and observations to understand the role magnetic fields play in dense structures (student will work with numerical simulations).

3) Theoretical tests of MHD turbulence Fast, Slow and Alfvén wave behaviour in MHD simulations (student will work with numerical simulations and test theoretical predictions).

- 4) Tests of anisotropy (i.e. statistical methods of determining magnetic fields) in observational data (student will work with observations).
- 5) Tests of magnetic reconnection in simulations of star formation (numerical project with application to theory).

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John Kovac

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The Cosmic Microwave Background (CMB) group at the CfA works to design, build, operate, and analyze data from some of the most sensitive microwave telescopes ever built, currently including BICEP3, the Keck Array, and BICEP4. Our telescopes observe the CMB from the South Pole, searching for signatures of Inflation that may be imprinted as a specific pattern of polarization in the CMB, while also using the maps we make to study gravitational lensing, dark matter, and our own galaxy. This year, we are gearing up for another season at the South Pole and running a full telescope-testing program here at Harvard.

We have current projects potentially suited to committed undergraduates ranging from design, development, and construction of instrumentation for CMB telescopes operating at the South Pole to analysis of data returned by these telescopes to constrain inflationary observables and simulation of CMB lensing observations. Visit the group website (<http://www.cfa.harvard.edu/CMB/>) to see a little more about what we do or contact us to come by and check out what is going on in the lab.

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Edo Berger

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The Dynamic Universe: The universe is a highly dynamic place teeming with the explosions and eruptions of massive stars, neutron stars, and black holes. In this context my research group is focused on two exciting areas:

[1] The study of gamma-ray bursts and the search for their mysterious progenitors – GRBs are the most energetic explosions known in the universe and their study requires observations from gamma rays to radio wavelengths.

[2] We are leading a search for never before seen transients using the PanSTARRS survey, the most ambitious all-sky optical survey ever undertaken.

Students involved in these projects will have an opportunity to work with data from observatories around the world (including the 6.5m Magellan and MMT telescopes), and to be involved in perhaps the most fast-paced branch of astronomy.

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Dr. Karin Oberg

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Star and planet forming regions present a rich chemistry, which regulates important aspects of planet formation, including delivery of prebiotic material to Earth analogs. The presence of molecules in these regions can also be used to trace the star and planet formation process through observations of molecular lines that are sensitive to e.g. the details of the radiation fields, temperature and density profiles. In the astrochemistry group we combine laboratory experiments and radio observations of protostars and protoplanetary disks to characterize this often exotic chemistry that results in the formation of molecular probes and prebiotic molecules. Undergraduate projects are available in the areas of spatially resolved molecular line observations ('astrochemical imaging') of

different astronomical objects, interpretation of radio astrochemical spectra, and, starting in the fall of 2014, in laboratory astrochemistry, focused on the physics and chemistry of analogs to interstellar icy grain mantles.

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Dr. John Johnson

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My research interests are focused on the detection and characterization of planets around stars other than the Sun, commonly known as exoplanets. Thus far, exoplanetary scientists have discovered more than 800 confirmed planets outside of our Solar System, with roughly 2000 additional planet candidates from the highly successful NASA *Kepler* Mission. Beyond discovering new planets, I am interested in the statistical correlations between exoplanet properties and the physical characteristics of their host stars. For this reason, much of my research is concentrated on measuring the properties of stars, ranging from low-mass red dwarfs up to A-type stars like Vega and giant stars like Pollux. The varying properties of planets in these different stellar environments provide vital clues about the conditions and mechanisms of planet formation. Students in my group are encouraged to hone their computer programming skills; expand their knowledge and understanding of Bayesian statistics; and gain hand-on experience at various telescopes around the world.

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Dr. Daniel Eisenstein

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I work on cosmology and galaxy evolution, using both theoretical and observational tools. My primary focus has been on the use of large-scale structure to determine the composition of the Universe. I use sound waves that propagate in the first million years after the Big Bang to infer the expansion history of the Universe and the properties of dark energy. Much of my work uses data from the Sloan Digital Sky Survey III, of which I am Director. My group is also actively developing a new code for enormous cosmological simulations. I would be happy to meet with interested undergraduates to consider projects.

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Dr. Alyssa Goodman

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Project 1: Milky Way Star Forming Regions. Recently, it has become possible to map out the distribution of star-forming molecular clouds in nearby galaxies. But, meanwhile, we do not yet have a full catalog of all the star-forming regions in our own Milky Way! Our vantage point on Earth, buried within the disk of the Milky Way, makes it hard to understand the 3D positions of distant star-forming regions, but new software tools are allowing us to decompose maps of molecular gas into a 3D catalog of Milky Way clouds.

Project 2: ADS All-Sky Survey. We have begun to create a map of all of astrophysical literature on the sky. An undergraduate interested in using either the map of "why and how the sky is/was studied where", or in extracting historical images of objects or classes of objects from the literature should come talk with us about joint astronomy--history of science--information science options for research. (<http://arxiv.org/abs/1111.3983>)

Project 3: The Spiral Structure of the Milky Way as seen in Infrared Dark Clouds. Thanks to the Sun's position slightly "above" the Galactic plane, it is possible to map out evidence for the Milky Way's spiral arms using the dust distribution as seen projected onto the sky.

Project 4: Data Visualization with Glue. Astronomical data has become more and more three-dimensional as spectrally-resolved imaging becomes more pervasive (see <http://astrobites.com/2012/05/24/data-overload-how-to-deal-with-multidimensionaldata->

sets/). In a joint effort with Prof. Hanspeter Pfister in SEAS, our group is developing a Python-based visualization environment intended to link views into multi-dimensional data. Students interested in combining CS and Astronomy research should contact us to learn more, and visit <http://projects.iq.harvard.edu/seamlessastronomy/software/glue> to learn more about the software effort.

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Dr. Josh Grindlay

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**Stellar variability with DASCH:** Our DASCH project (<http://dasch.rc.fas.harvard.edu>) provides a unique dataset on variability of stars and quasars on timescales from hours to days to decades to a century. Scanning and data processing is “complete” for Data Releases DR1 – DR3 (and DR4, by October). Much of the Sloan Survey (SDSS) is covered, and together with pending release of DR8 for the APASS photometric survey, there are well defined stellar samples to study. Junior paper or Senior Thesis projects can be done on several key projects: flare size distribution for M dwarfs (of interest for habitability of planets around these stars), outbursts from B stars (including Be stars with neutron star companions), long-term variability of K giants (already discovered by DASCH to have ~100y variability), and more.

**Enhanced analysis code development for DASCH:** Although DASCH photometry is already “good” (rms ~0.1mag) it can be further improved, particularly with expanded use of the DR8 APASS survey, with greatly increased coverage and colors that enable better local calibrations. This, in turn, enables variability studies of more objects as rms photometric errors are decreased. Development of improved algorithms for optimizing the photometry pipeline for DASCH is an excellent topic for students with interest in pipeline code development. A related project for a CS-Astro concentrator is to work on script development for further automation of the extensive DASCH data processing pipeline. This could enable “customized” data processing for a given (limited) field. Yet another area for code development, not yet implemented, are analysis techniques for galaxy photometry of the digitized photographic data. This would enable new archival studies of supernovae in Virgo galaxies for new determinations of the SN rate.

**Measuring/constraining the size distribution of Blazar/Quasar flares:** Why do Blazars undergo extreme flares more often than do quasars? And what is the size distribution (number of flares vs. peak flux) for each of these classes of active galactic nuclei (AGN)? And how do these distributions compare with those found for stellar flares from active stars? These questions can be answered by using data from our DASCH project, which provides ready access to ~100y light curves of AGN and stars over a broad magnitude range (B ~9-17) and with cadence between observations of ~days - months. The long-term duration enables the rarest/largest flares to be seen, which in turn enables the (likely) power law distribution of flare sizes to be measured. A similar study can be made of stellar flares from magnetically active M dwarfs (“flare stars”) and K giants (RSCVn binary systems) to test the idea that despite their luminosities differing by ~15 orders of magnitude, both are triggered by magnetic field reconnection events.

**Searching for the missing Black Hole High Mass X-ray Binary Population:** Stellar mass black holes (~5-20solar masses) are the remnants of ~20-40 solar mass stars and become “visible” when they accrete matter from close binary companions. Neutron stars (~1.5-2 solar masses) are the remnants of ~10-20 solar mass stars and similarly are visible (as luminous X-ray sources) when they accrete from either lower mass companion

stars (typically  $\sim 0.5$  solar mass K dwarfs) in close binary orbits (as low mass X-ray binaries, LMXBs) or from the strong winds of higher mass ( $\sim 20$  solar masses) binary companions (HMXBs). Although their lifetimes as HMXBs are short ( $< 10^6$  y),  $> 10X$  more NS-HMXBs than BH-HMXBs are found than expected by both their stellar formation ratios and retention in binaries. Our Galaxy has only one confirmed BH-HMXB (and 2 other likely ones), vs.  $> 20$  NS-HMXBs. The missing "reservoir" of BH-HXMBs might be found in the population of single-lined spectroscopic binaries (SB1's) with suitably short ( $< 10$ - $30d$ ) binary periods. This project would entail a literature search for SB1 candidate systems and proceed with both higher resolution (Echelle) optical/nIR spectra to better rule out unseen stellar companions as well as NuSTAR observations to search for the expected hard X-ray spectral signature of a wind-accreting black hole.

**Initial development of REXIS data processing pipeline:** Harvard and MIT are developing the first "student experiment" on a major NASA mission: the Regolith Imaging X-ray Spectrometer (REXIS) to be included on the NASA mission OSIRIS-REx to be launched in 2016 for a 2019 sample return from the asteroid Bennu. REXIS will provide a map of the asteroid in X-rays from fluorescent line emission from key elements (Fe, Mg, S, Si) that will part of the overall survey to select the sample return site. The ground-based data analysis software (to be run during the mission at Harvard and MIT) is in need of significant development. A student with C and Python or IDL software experience can play a key role in designing and writing the initial implementation of the data processing pipeline that will incorporate data files describing the spacecraft and asteroid position and instrument calibration vs. time so that X-ray spectral line maps can be continuously created as the  $\sim 1$ month survey phase of the asteroid takes place. Key parts of the code have already been written but integration into an overall pipeline is now needed.

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Kelly Chance

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My group's research is principally the making and analysis of measurements of the Earth's atmosphere using spectroscopy. The atmospheric issues includes air pollution, ozone layer chemistry and the greenhouse effect. Measurements are in the ultraviolet, visible, and infrared. They are obtained from ground-based and airplane-based spectrometers and, especially, from satellites. We are involved in the analysis of spectra from six existing satellites making global measurements and we lead the implementation of the TEMPO instrument ([tempo.si.edu](http://tempo.si.edu)) for measuring North American air pollution from geostationary orbit. Our research includes the making of measurements, the development of algorithm physics and algorithms, detailed analysis of spectra, and global, regional, and local atmospheric process studies. There are opportunities in all of these for undergraduates to make significant contribution.

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Michael Dunham

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Stars like the sun form from the gravitational collapse of dense condensations of dust and molecular gas. Many details related to how exactly stars form and how they gain their mass remain poorly understood. The mass of a star, its most fundamental parameter, determines its luminosity, surface temperature, and even how long it lives. I am leading a large survey of the youngest protostellar systems with the Submillimeter Array (SMA) in Hawaii in order to study the physical processes that regulate accretion of mass onto stars

and ultimately determine how stars gain their mass. There are many opportunities for students to become involved with observing, data reduction, and scientific analysis.

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Dr. Michael McCarthy

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Many of the more than 160 molecules now known in space are highly reactive or unstable species, generally unknown or unfamiliar on Earth, such as radicals, carbenes, and molecular ions. Unambiguous astronomical detection of these reactive intermediates frequently requires highly accurate laboratory measurements of their rotational spectra. Using highly sensitive instrumentation and production techniques developed at the CfA, measurements of this kind are undertaken, yielding precise rest frequencies to guide dedicated radio astronomical searches for exotic new species. This research program has resulted in the astronomical detection of a significant number of these so-called "non-terrestrial" molecules; a recent highlight of our work is detection of molecular anions in space.

The laboratory astrophysics group at the CfA has a long tradition of involving students in research in a setting that provides an excellent vehicle for integrating research and education because the research is collaborative and interdisciplinary, at the nexus of chemistry, molecular physics, and observational radio astronomy. Students will receive hands-on training in the production of chemically unstable molecules using electrical discharges and molecular beam sources. They will also have the opportunity to learn about state-of-the-art laboratory instrumentation operating in the radio band by which the rotational spectra of new molecules is observed and analyzed, and to use this equipment first hand.

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Dr. Eugene Avrett

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PANDORA is a computer program that is used to calculate stellar spectra (including solar spectra) given the properties of the atmosphere, and to determine such properties from observations. The temperature distribution can be determined by the assumption of radiative equilibrium, or determined empirically in the case of emission lines formed in chromospheric regions. The optically thick non-LTE statistical-equilibrium and radiative-transfer equations are solved for all important atoms and ions to determine the profiles of spectral lines (in emission or absorption) and the overall continuum energy distribution. An application of the program is the determination of stellar abundances from available observations.

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Dr. Qizhou Zhang

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As one of the building blocks in the visible universe, massive stars dominate the appearance and the evolution of galaxies. However, their formation is not well understood. My research focuses on studying different evolutionary stages of massive star formation using high-resolution radio and sub-millimeter interferometers. Possible projects for undergraduate research involve processing and analyzing data taken from the Submillimeter Array, Karl Jansky Very Large Array, and Herschel Space Telescope.

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Dr. Randall Smith

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My group works at the interface of atomic physics and EUV/X-ray astrophysics, as the maintainers of the primary database of atomic data for modeling X-ray emitting and absorbing plasmas. We collect and verify atomic data, using it to create plasma emission

models, and we will soon be making laboratory astrophysics measurements using the CfA Electron-Beam Ion Trap (EBIT). We test our data by trying to understand complex astrophysical plasmas, such as those found in supernova remnant shock fronts, symbiotic stars, and clusters of galaxies. Opportunities exist for both short-term and long-term projects of an observational, theoretical, or experimental nature. Note that due to US law, experimental work may be restricted to US citizens or green card holders, although we will attempt to accommodate anyone.

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Dr. Dan Schwartz

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Search for X-ray jets from (high redshift) Quasars: Powerful radio quasars have radio and X-ray jets extending 100's of kpc from the supermassive black hole core. These jets can be travelling with bulk relativistic velocities approaching the speed of light. When oriented within roughly 10 degrees of our line of sight, relativistic beaming can greatly enhance the apparent brightness of the jets. Remarkably, since the X-rays are emitted via inverse Compton scattering of the cosmic microwave background, their surface brightness is constant no matter what their redshift. Such systems may be "hiding" among X-ray sources already found in sky surveys. There are two effects: Because the radio brightness does fade, some X-ray sources will not be recognized as radio sources. More significantly, Chandra is the only X-ray observatory ever launched (or currently planned to be launched) which has the angular resolution necessary to separate a jet from the point source core emission. Therefore: this project will start with catalogs of X-ray surveys and examine: 1) Quasars which have been identified, 2) Unidentified X-ray sources, and in both cases assess the possibility of jet emission based on serendipitous observations. The null result can place an upper limit on the surface density of such sources. There is a very exciting, but highly speculative, possibility that a quasar with an X-ray jet will be found at a very large redshift. The student might propose further Chandra observations, or might examine also Fermi gamma ray data, at their initiative.

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Dr. Cara Battersby

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Massive stars light up the universe around us, shape galaxies, and they explode as supernovae that create the heavy elements of which we are made, yet we understand very little about where they come from. From detailed observations of star-forming regions to expansive surveys of the entire Galaxy, I study how massive stars are born. There are many opportunities for a student to become involved with this research. A few potential projects are:

1) The center of our Galaxy hosts a supermassive black hole and the densest reservoir of cold, molecular gas in the Galaxy. The best measurements to date suggest that the Galactic center is breaking star formation laws and under-producing stars by about an order of magnitude. Whether we are missing embedded cores and signatures of star formation or there are greater forces at work (e.g. shocks from infalling gas) remains an open question that can only be addressed by looking deep into the Galactic center clouds at high-resolution in long-wavelengths. We are performing a survey of this region to search for young, embedded cores. How many we find, and what their nature is, will have a tremendous impact on our overall understanding of how stars form in such an extreme environment.

2) Massive stars are born in clusters, and recent work suggests that rather than being static gas structures while forming, these massive clusters may be the culmination of dynamic accretion processes from large scales. We can test this hypothesis in massive

star-forming regions throughout the Galaxy and determine how important the potentially large effect of global accretion is on the formation of massive stars.

3) Despite having lived here all of our collective lives, we still know very little about the structure of the Galaxy we are in. Using archival data, we can search for long, filamentary gas clouds which may trace the densest part of our spiral arms: the skeleton of our Milky Way, and revolutionize our picture of the Galaxy. We have already found a handful of these "Bones of the Milky Way" and expect there are more to be uncovered.

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Dr. Jun-Hui Zhao

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Research projects: (1) Formation of super star clusters in blue-compact-dwarf galaxies and low-metallicity galaxies from nearby and distant systems. (2) Star formation history and nuclear activities at the Galactic center as well as their feedback to the interstellar medium.

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Dr. Jim Babb

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Theoretical atomic and molecular physics has wide applications in astrophysics. Related topics in modeling details of collisions between atoms and molecules and their interaction with light might be of interest to a student with experience in scientific computation wondering about practical applications of quantum mechanics.

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Dr. Ryan Allured

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Adjustable X-ray Optics: The X-ray optics group at SAO is developing technology to achieve lightweight, sub-arcsecond X-ray telescopes. This work is in support of the X-ray Surveyor mission concept, a hopeful successor to the Chandra Observatory. We deposit piezoelectric material on the back of thin, glass mirrors in order to electronically control the mirror figure. The potential undergraduate student would learn about optical theory as it applies to modern X-ray telescopes, the design and use of laser metrology systems featuring interferometers and wavefront sensors, and general data acquisition and data analysis programming primarily in the Python language.

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Dr. Patricia Udomprasert

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Do you enjoy helping others understand how the Universe works? Are you interested in helping to improve science education? The WorldWide Telescope Ambassadors Program is looking for undergraduate students to help with new education research projects funded by the National Science Foundation and the Templeton Foundation:

- Create interactive multimedia presentations ("Tours") about astronomy topics
- Develop new curricular materials for use in local schools and after school programs
- Curate existing tours, tutorials, and educational resources on our website
- Tally and analyze results from student surveys
- Score and code student assessments for education research projects
- Run demo stations at local public science festivals and teach others how to use WWT.

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Dr. Aneta Siemiginowska

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**Studies of X-ray morphology and X-ray spectral properties of radio galaxies** observed with Chandra. The projects involves analysis of Chandra X-ray images, which are the highest resolution X-ray images available to date. The data analysis will involve working with CIAO tools, statistics and methodology for Poisson data, including some Python programming. The main goal of the project is to understand the activity state of the central black hole and the impact of the radio source onto the ISM in more general sense of the feedback and the galaxy evolution.

**Studies of X-ray jets** using archival data. This project will involve application of the new algorithms for analysis of Poisson images. The relativistic quasar jets are being resolved with Chandra X-ray Observatory. The question about the X-ray emission process remains unresolved. We will study the properties of the large-scale jets associated with radio-loud quasars and their relation to the central black hole at high redshift.

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Dr. Joseph Hora

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Most stars in our Galaxy form in massive clusters, yet the processes that produce high-mass stars is not well understood. Their formation is enshrouded in gas and dust, and the timescales of formation are fairly short, making them more difficult to study. Recently, a wealth of data has become available from surveys using the Spitzer Space Telescope (e.g., <https://www.cfa.harvard.edu/cygnusX/>) and the Herschel mission that is making it possible to learn much more about the processes that form high-mass stars. Here are two possible projects in this area of study:

1. Infrared Dark Clouds (IRDCs) are dense clouds of gas and dust that are at the earliest stages of massive star formation. We have recently surveyed ~75 regions containing IRDCs with Spitzer that have existing far-IR and deep near-IR observations. The project will involve using Spitzer color/color diagrams, SED fitting techniques, and searches for molecular outflows to identify massive young stellar objects and learn about how they are forming. We will also study the clusters of low-mass stars associated with the IRDCs to learn about how massive clusters are assembled.

2. The emission from young stellar objects (YSOs) is often variable, and their near-IR emission and variability can tell us about the stellar rotation and conditions in the disk surrounding the YSO such as hot spots, warps, and dust clouds. We have obtained multiple epochs of near-IR photometry in several star-forming regions using a robotic telescope that SAO operated recently at the Whipple Observatory. The project will involve assembling the near-IR dataset and analyzing the time series data to look for periodic and non-periodic variability in the YSOs, and inferring the properties of the stars and surrounding disks from the observations.

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Dr. Scott Randall

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One of the major outstanding problems of modern astrophysics is finding the so-called "missing baryons" in the local universe. Cosmological and higher redshift observations indicate that these baryons should be present, yet they have not yet been conclusively observed. A leading theory is that they are contained in a warm-hot intergalactic medium (WHIM) gas phase in enormous large-scale structure filaments, which are difficult to observe directly due to the very low density of this gas. Modern X-ray observatories allow us to look at the outskirts of galaxy clusters for the first time, where the hot gas in clusters is expected to interface with the hotter, denser (and therefore more easily detected) part of

the WHIM, since galaxy clusters form at the intersections of large scale structure filaments. Students involved in this project will have the opportunity to work with data from world class X-ray observatories such as Chandra, XMM-Newton, and Suzaku, to study the outskirts of galaxy clusters, extended filaments between galaxy clusters, and the dense end of the WHIM.

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Dr. Akos Bogdan

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Exploring the evolution of galaxies throughout Cosmic time is paramount in modern astrophysics. It is believed that the evolution of galaxies hinges on three major components: the central supermassive black hole (BH), the stellar body, and the dark matter halo. The specific symbiosis of these components likely results in the demography of galaxies observed across the Universe. The coalescence of two galaxies, and their dark matter halos, results in the formation of an elliptical galaxy. It is envisioned that during this pivotal evolutionary phase, energetic feedback from a rapidly growing BH (also known as an active galactic nucleus) heats and expels the galaxy-wide gas supply, thereby quenching on-going star formation and truncating the growth of the BH. However, despite the critical importance of BHs to provide the necessary feedback in galaxy evolution, there is still no consensus on whether the triggering and growth of massive BHs is primarily driven by the properties of the stellar spheroid or the larger-scale dark matter halo. I would like to involve interested students in this work, who could utilize multi-wavelength observational data to probe whether BHs located in galaxies exhibit a tighter correlation with the dark matter halo or with the bulge mass. This will allow to explore if BHs co-evolve with their dark matter halos or with their stellar bulges.

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Dr. Charlie Conroy

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My research group focuses on problems related to stars, stellar populations, and galaxies. There are a variety of projects available for undergraduates including: analysis of a new generation of advanced stellar evolution models, understanding the information content of observational data, both at the stellar and galaxy level, and designing next generation observational surveys.

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Dr. Dan Milisavljevic

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Reverse Engineering Supernovae: I'm seeking motivated and enthusiastic students to join my team of supernova sleuths actively investigating the catastrophic deaths of massive stars. Our comprehensive multi-wavelength, multi-phase approach is unraveling the complicated final stages of stellar evolution, and providing exciting new ways to understand how stars explode and evolve into supernova remnants that seed interstellar space with the raw materials needed for new stars and planets. Ultraviolet, optical, and near-infrared data come from many ground-based and space facilities including the Hubble Space Telescope. The projects I have in mind are mostly related to supernova tomography, but I'm always open to discuss alternative project ideas.

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