Harvard-Smithsonian Center for Astrophysics

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

26 August 2014

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
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Dr. Warren Brown wbrown@cfa.harvard.edu

Stellar Dynamics: I use the technique of optical spectroscopy to measure the nature and motions of stars. I'm best known for the discovery of "hypervelocity stars," stars escaping the Milky Way. I have a couple of open projects on measuring the distribution of runaway stars ejected from the Galactic disk, and using stellar motions to measure the dark matter distribution of the Milky Way halo. I also have a discovery program for ultra-compact binaries that are strong gravitational wave sources and possible supernova progenitors, and we could ramp-up a project to obtain time-series photometry to find eclipsing and tidally distorted binary systems.

Dr. David W. Latham dlatham@cfa.harvard.edu

My group is actively involved in follow-up observations of candidate transiting planets, both from ground-based surveys such as the Hungarian Automated Telescope Network (HATNet), the Kilodegree Extremely Little Telescopes (KELT), the Qatar Exoplanet Survey (QES), and from NASA's Kepler mission. We use KeplerCam on the 1.2-m telescope at the Whipple Observatory for high-quality light curves, the Tillinghast Reflector Echelle Spectrograph (TRES) on the 1.5-m telescope, also on Mount Hopkins, for spectroscopic determinations of host star parameters and for orbital solutions and mass determinations for giant planets, and the High Accuracy Radial velocity Planet Searcher for the Northern hemisphere (HARPS-N) on the Telescopio Nazionale Galileo on La Palma to determine masses of small planets. This is an opportunity to learn about astronomical photometry and/or spectroscopy while working on exoplanet candidates of current interest.

Dr. David Charbonneau dcharbonneau@cfa.harvard.edu

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.

Dr. Qizhou Zhang qzhang@cfa.harvard.edu

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.

Dr. Philip M. Sadler psadler@cfa.harvard.edu

The CfA has a large and active Science Education Department that conducts educational research. My efforts focus on developing standardized tests that gauge science teacher knowledge and changes in student understanding at the pre-college level, particularly measuring scientific misconceptions. I am also examining the impact of prior knowledge in the completion of MOOCs, how prior coursework and experiences impact success in introductory college science, calculus, and CS courses, and the role of out-of-school-time activities prior to college lead to an interest in pursuing a STEM career.

Dr. Gerhard Sonnert gsonnert@cfa.harvard.edu

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.

Dr. Karin Oberg koberg@cfa.harvard.edu

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.

Dr. Belinda Wilkes bwilkes@cfa.harvard.edu

Multiwavelength Studies of Powerful 3CR Radio Sources: Along with a large, international team, Belinda Wilkes is investigating the radio-to-X-ray spectral energy distributions (SED) of high-redshift ($z>0.5$), 3CR radio-loud active galaxies (AGN). These sources are amongst the most luminous in the Universe, with central super-massive black holes hosted by massive galaxies and relativistic jets which emanate along the poles of the accretion disk and result in complex radio-emitting structures often extending over tens of thousands of light years. The team is in the midst of analyzing recent Herschel far-infra-red data, collecting high signal-to-noise optical spectra and obtaining Chandra (new and archival) X-ray snapshots of the full 3CR sample in the redshift range 0.5-2. Our primary motivation is to study the properties of the central AGN as a function of its orientation in this complete, orientation unbiased sample. Other projects include the search for high-redshift clusters, for which luminous radio sources may be a sign-post, study of the non-thermal radio and X-ray emission related to the jets and lobes and geometric and physical modeling of the central obscuring material. A student could become involved in any aspects of this project, either as research experience or for a thesis project.

Dr. Edo Berger eberger@cfa.harvard.edu

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. More information is available from: https://www.cfa.harvard.edu/~eberger.

Dr. John Johnson jjohnson@cfa.harvard.edu

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.

Dr. Edward Deluca edeluca@cfa.harvard.edu

The Solar & Stellar X-Ray Group has ongoing research programs in solar coronal physics, solar and stellar dynamo models and heliospheric physics. Scientists are working on both theory and modeling of observations from Chandra, IRIS, Hinode, SDO, STEREO, Wind, ACE and LRO. We currently have a major hardware program: the SWEAP instrumentation package for the Solar Probe Plus mission. We have had good experience with previous Harvard undergraduate students and would be willing to consider an interested student, preferably a sophomore or junior as the learning curve is fairly steep. Our group consists of 18 PhD scientists with interests outlined below:

Thermal structure of the solar atmosphere: Alisdair Davey, Vinay Kashyap, Steve Saar, Paola Testa, Mark Weber, Trae Winter, Hui Tian

Magnetic structure of the solar atmosphere: Ed DeLuca, Kathy Reeves, Yingna Su, Mah Asgari-Targhi, Antonia Savcheva

Mass and energy flow in the solar atmosphere: Leon Golub, Kelly Korreck, Paola Testa, Hui Tian

Solar flares, CMEs and particle acceleration: Bin Chen, Justin Kasper, Kelly Korreck, Kathy Reeves, Yingna Su, Trae Winter

Solar wind structure and acceleration: Justin Kasper, Kelly Korreck, Mike Stevens, Kamen Kozarev, Hui Tian

Cosmic ray physics: Tony Case, Justin Kasper, Kelly Korreck

Solar and Stellar Activity: Steve Saar, Paola Testa

Dr. August (Gus) Muench gmuench@cfa.harvard.edu

Our group is utilizing an informatics approach for studying the basic properties of young stars and their circumstellar/protoplanetary disks in nearby star forming regions of our local Galaxy. An informatics approach combines the construction and maintenance of large databases of source properties with the application of statistical tools that mine these databases, characterize individual sources and infer source properties through comparison to models. Data mining and information science are already or will soon become dominant aspects of astronomical research and we welcome students of any computational science background who are interested in engaging in these challenges now. We are also an open science research group, utilizing web based notebooks and social media to document and disseminate our results and perform outreach to the general public about how panchromatic observations are used in concert to deduce the properties of distant stars and their planetary systems.

Dr. Scott Randall srandall@cfa.harvard.edu

My work focuses on the study of various aspects of clusters and groups of galaxies. Galaxy clusters are the largest virialized structures in the Universe, and as such are important to the study of cosmology and large-scale structure. I currently have several projects involving data analysis of Chandra and Suzaku X-ray observations that a motivated undergraduate could be involved with. These projects include an analysis of the (to date, poorly studied) extended gas atmospheres in merging galaxy clusters to look for signatures associated with large scale cosmological structure, a search for emission from the warm-hot intergalactic medium (WHIM) in large scale structure filaments that is thought to contain the bulk of the "missing baryons" in the local universe, and studies of the feedback mechanism between the central super-massive black hole and diffuse gas in the cores of galaxy clusters that regulates gas cooling and thereby star formation and galaxy evolution.

Dr. Aneta Siemiginowska aneta@head.cfa.harvard.edu

(1) Characterization of gamma-ray time-variability seen in quasars and blazars. The observed flux variations in quasars happen on many timescales with some large amplitude changes identified as flares. We will apply stochastic variability models to gamma-ray light curves. This project involves statistics and computations using Python.

Studies of X-ray morphology and X-ray spectral properties of young radio galaxies observed with Chandra. The main goal is to understand the activity state of the central black hole and properties of ISM in the vicinity of a young and compact radio source. The project involves analysis of Chandra data, including statistics and Python programming.
(2) Measurement of a black hole mass in high redshift quasars. We will use a high redshift sample of quasars to study the mass measurements and issues related to the standard methods. The project involves spectral modeling, computations and Python programming.

Dr. Sayan Chakraborti schakraborti@cfa.harvard.edu

Massive stars end their lives in supernovae. These powerful explosions drive fast shock waves into the slowly moving wind from the original star. Such strong shocks can produce plasma at a billion Kelvin and accelerate cosmic rays. The radio and X-ray emission, resulting from this interaction, traces the history of mass loss from these stars. Thus, powerful observatories operating at these wavelengths provide us an unique window into the final moments of stellar evolution. I would like to involve students in either observational, theoretical or both aspects of these investigations.

Dr. Sheperd Doeleman sdoeleman@cfa.harvard.edu

Work in my group is focused on building the Event Horizon Telescope (EHT): a global array of mm and submm wavelength dishes that form an Earth-sized network. When phased together using the Very Long Baseline Interferometry (VLBI) technique, the EHT achieves an angular resolution of 10's of micro arcseconds, the sharpest of any astronomical technique. With just a few networked dishes, our group has resolved event horizon scale structure in SgrA*, the 4 million solar mass black hole at the Galactic Center, and in the much more luminous and massive black hole at the center of the giant elliptical galaxy M87. Over the next 2-3 years, this international project will add new sites and increase observing bandwidth to focus on astrophysics at the black hole boundary with the ultimate goal of imaging an event horizon. We are interested in working with students on instrumentation (primarily digital signal processing to enhance observing bandwidths) and on processing and analysis of ever richer data sets. There are opportunities for observing in exotic (and some not-so-exotic) locations around the Globe. EHT data products will soon have an unprecedented combination of sensitivity and resolution with excellent prospects for imaging strong-field General Relativity signatures, detecting magnetic field structures through full polarization observations, time-resolving black hole orbits, new tests of GR, and modeling black hole accretion, outflow and jet production.

Dr. Daniel Eisenstein deisenstein@cfa.harvard.edu

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.

Dr. Alyssa Goodman agoodman@cfa.harvard.edu

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.

Dr. Patricia Udomprasert pudomprasert@cfa.harvard.edu

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 who can help:

--create interactive multimedia presentations ("Tours") about astronomy topics
--develop new curricular materials for use in local schools
--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

Dr. Mari Paz Miralles mmiralles@cfa.harvard.edu

There are still many mysteries to unveil regarding our closest star, the Sun. In particular, there is not consensus on how the solar corona is able to generate, accelerate, and heat plasmas. In my research, I study both dynamic and steady phenomena that take place in the atmosphere of the Sun and its wind. By studying the physical properties of the plasma we can provide constraints to theoretical models and test different mechanisms. Possible projects for undergraduate research involve the analysis and interpretation of data from polar jets, solar flares, coronal mass ejections, coronal cavities, and fast/slow wind coronal-source regions. Students involved in these projects will have the opportunity to work with spectral and imaging data from space-based instruments aboard the Hinode, SDO, SOHO, and STEREO spacecraft. Undergraduate participation in any of these projects is welcomed and will result in a publication.

Dr. Eric Chaisson ejchaisson@cfa.harvard.edu

Although semi-retired, I am still actively engaged in the research and teaching of “cosmic evolution” — a grand cosmological worldview that attempts to quantitatively unify all complex systems observed in Nature, including galaxies, stars, planets, life, and society, from big bang to humankind. A recent review of the subject is published here: http://dx.doi.org/10.1155/2014/384912 And a sequel, also just published, that attempts to examine potential practical applications of cosmology to civilization is here: http://dx.doi.org/10.4236/ns.2014.610077 Both of these recent papers serve to undergird my teaching in Harvard Extension, which might also intrigue students interested in undergraduate education, and whose multi-media web site runs parallel Introductory and Advanced Tracks for non-science students and technical colleagues, respectively: https://www.cfa.harvard.edu/~ejchaisson/cosmic_evolution/docs/splash.html. I do not have any research funds of my own currently, but that should not deter passionate students who have the persistent curiosity needed to explore Nature writ large.

Dr. Michael McCarthy mmccarthy@cfa.harvard.edu

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.

Dr. Martin Elvis melvis@cfa.harvard.edu

Whether for scientific investigations, human exploration or mining it is a billion dollar class decision which asteroid to go to with a space mission. For 30 years a simple algorithm has been used - the Shoemaker-Helin formula - to sift through the many thousands of possible mission targets among the near-Earth asteroids. But NASA is rightly worried that this 1970s approach may not be good enough, and so has initiated the NHATS program which takes over a major climate-modeling computer at NASA-Goddard to brute-force calculate every possible trajectory for every near-Earth asteroid every few hours for 30 years into the future. As thousands more near-Earth asteroids are found every year - and the rate is increasing - it would be really helpful to know if Shoemaker-Helin is a good first step, or if we can find a better algorithm to replace it. This would be your job. You won't start from scratch: We already have the NHATS data and need to compare the NASA results with Shoemaker-Helin. We also have a new algorithm (from Jonathan McDowell) that looks like it should do better. We are pretty confident that, whatever the result, we will get a publishable paper out of this.

Dr. Lincoln Greenhill lgreenhill@cfa.harvard.edu

Exploring the radio sky: The sky we observe varies dramatically as a function of wavelength: radio, infrared, visible and x-ray all offer unique views through the universe. At meter wavelengths, radio interferometers collect data from which the entire hemisphere of the sky can be imaged instantaneously and in real-time. As the observed sky changes with both time and frequency, animations can be made by varying either. However, there are currently no suitable visualization tools for interactively viewing all-sky data sets such as these. In this project, the student will work toward creating an interactive visualization system for all-sky data from the LEDA radio telescope. LEDA is a 256-element radio interferometer in Owens Valley, California, that makes all-sky images every few seconds. The student will use NVIDIA graphics cards along with OpenGL and CUDA programming languages, to create an interface that allows users to explore LEDA datasets. By doing so, the student will gain valuable familiarity and experience with parallel programming techniques and data visualization while gaining a fresh perspective on the sky. Supervisors: Lincoln Greenhill, Ben Barsdell.

High performance, low power computing: Radio interferometer telescopes combine the signals of many antennas in a process called correlation. A correlator computes the cross multiplication of signals from all antenna pairs; as more antennas are added to an array to increase signal to noise, the computational requirements increase quadratically – in proportion to the number of unique antenna pairs. As such, the cost to both design and run correlators limits the achievable size and performance of radio interferometer arrays. In this project, the student will design and implement a cross correlator on the new energy efficient, high performance Parallella signal processing platform (www.parallela.org). The aims of this green computing project are to evaluate the power efficiency that can be achieved for cross-correlation algorithms running on the Ephiphany microprocessor that powers the Parallella board. Showing that high performance can be achieved in a small power envelope would motivate further research into the platform for radio astronomy applications. This project offers a good introduction to high performance parallel computing in C/C++; the experience and skills learned are broadly applicable in physics and computing. Supervisors: Lincoln Greenhill, Ben Barsdell, Danny Price.

Dr. Roy Gould rgould@cfa.harvard.edu

Our group is developing an online laboratory for the study of exoplanets, designed specifically for education rather than scientific research. The lab focuses on developing and understanding of the core practices of science, including model-building, data-gathering (using small, automated telescopes), and model-fitting and data analysis. There is a strong emphasis on developing innovative scientific visualizations.

Dr. Cara Battersby cbattersby@cfa.harvard.edu

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.

Dr. Josh Grindlay jgrindlay@cfa.harvard.edu

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.

Search for “missing” black hole X-ray binaries: Why is the bright X-ray source Cyg X-1 the only confirmed black hole in a high mass X-ray binary (BH-HMXB) in our Galaxy when there are at least 20 black holes in low mass X-ray binaries? The missing BH-HMXBs might be found as faint hard X-ray sources in young massive clusters (YMCs), where the BHs are born, accreting from the stellar winds of massive binary companions (e.g. O or B stars) at larger separations and longer binary periods than for Cyg X-1. A systematic search for single-line spectroscopic binaries (SB1’s) that are already detected as faint X-ray sources (e.g. by ROSAT, Chandra or XMM) can be observed with NuSTAR. A few targets will be observed this year to address this fundamental question so that initial data will be available for analysis.

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 ~1month 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.

Dr. John Raymond jraymond@cfa.harvard.edu

Ion Temperatures in a Shock Wave: Collisionless shock waves in low density plasmas do not bring the plasma into thermal equilibrium. The particle velocity distributions can be far from Maxwellian, and each particle species can have a different temperature. Shock waves in the solar wind preferentially heat higher mass ions, and the electrons are heated less than protons. The shock waves are much stronger in supernova remnants, but less is known about the relative temperatures of the particles. In shocks above about 1500 km/s, the electrons are only heated to about 10% of the ion temperatures, and in the one case where we have good observations, the temperatures of H, He, C, N and O are roughly proportional to their masses. The shocks in the Cygnus Loop supernova remnant are slower, about 400 km/s, and there the electron and ion temperatures are about equal. We have gotten observing time on HST to see whether the He and C kinetic temperatures are also about equal to the proton temperature. The project is to measure the instrument profile of the COS spectrograph from an observation we obtained of a planetary nebula, then analyse a spectrum that will be obtained in November to determine the He and C line widths and compare with the H temperature we measured from an optical spectrum. It should lead to a short, straightforward paper.