Harvard-Smithsonian Center for Astrophysics

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

28 August 2016

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,
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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. John ZuHone john.zuhone@cfa.harvard.edu

My work involves the study of the "intracluster medium" (ICM) of galaxy clusters, a hot magnetized plasma that makes up most of the baryonic matter of clusters. Using magnetohydrodynamic simulations and X-ray observations, we can study the effects of cluster mergers on the ICM, including the formation of cold fronts, shock fronts, turbulence, and effects on relativistic cosmic rays. I also participate heavily in the development of scientific software for astrophysics, both for simulation and observational analysis.

Projects that need working on:
1. MHD simulations of cluster mergers, including the Bullet cluster. This would also include simulations with viscosity and thermal conduction.
2. Extending the capabilities of my software for creating mock X-ray observations from 3D simulations of astrophysical objects.
3. Studying the properties of turbulence in galaxy clusters formed in an MHD cosmological simulation.
4. Improving and extending the Galaxy Cluster Merger Catalog (http://gcmc.hub.yt) by either adding new simulations or new data products. This may be appealing for someone with web programming experience.

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. Blakesley Burkhart blakesley.burkhart@cfa.harvard.edu

Turbulence and magnetics 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 and 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 Alfven 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).

Dr. John Kovac jmkovac@cfa.harvard.edu

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.

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.

Dr. Karin Oberg koberg@cfa.harvard.edu

Star and planet forming regions present a rich chemistry, which regulates which kind of planets are formed where, including the likelihood delivering prebiotic material to rocky planets. Molecules 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 in laboratory astrochemistry, exploring the physics and chemistry of interstellar ices.

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, and I am preparing for use of the Dark Energy Spectroscopic Instrument, the James Webb Space Telescope, and the Euclid satellite. 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. 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.

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 ~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 (~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 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 ~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. Kelly Chance kchance@cfa.harvard.edu

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) 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.

Dr. Michael Dunham mdunham@cfa.harvard.edu

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.

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. Eugene Avrett avrett@cfa.harvard.edu

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.

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 and stellar cluster formation using high-resolution radio and sub-millimeter interferometers as well as infrared telescopes. Possible projects for undergraduate research involve processing and analyzing data taken from the Submillimeter Array (SMA), Atacama Large Millimeter/Submillimeter Array (ALMA), Karl Jansky Very Large Array (VLA), and Herschel Space Telescope. Depending on time availability, these projects can be tailored to fit the time frame of summer research, junior tutorial or senior thesis. If schedule permits, the student will travel to Mauna Kea, Hawaii for one-week observing.

Dr. Randall Smith rsmith@cfa.harvard.edu

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.

Dr. Dan Schwartz dschwartz@head.cfa.harvard.edu

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 effect: 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.

Dr. Jun-Hui Zhao jzhao@cfa.harvard.edu

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.

Dr. Jim Babb jbabb@cfa.harvard.edu

Models of astrophysical environments as varied as planetary atmospheres and the interstellar medium can be enhanced with reliable descriptions of collisional processes involving, for example, atoms and ions. Theoretical quantum mechanical approaches are applied to describe the collisions of relevant atoms. A recent effort that focused on radiative collisions of Si and O that enter models of supernova ejecta can be extended to other heavy atoms involving C.

Dr. Ryan Allured rallured@cfa.harvard.edu

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.

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 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.

Dr. Aneta Siemiginowska asiemiginowska@cfa.harvard.edu

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.

Dr. Joseph Hora jhora@cfa.harvard.edu

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.

Dr. Scott Randall srandall@cfa.harvard.edu

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.

Dr. Akos Bogdan abogdan@cfa.harvard.edu

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.

Dr. Charlie Conry cconroy@cfa.harvard.edu

My research group studies the evolution of stars and galaxies in a cosmological context. I have several research opportunities related to understanding to what extent the properties of stars (their masses, ages, and composition) can shed light on the formation and evolution of the Milky Way. The projects would involve hands-on experience with some combination of 1) large observational datasets, 2) new state-of-the art models for stars that our group is developing, and 3) a variety of tools and techniques for data analysis.

Dr. Dan Milisavljevic dmilisavljevic@cfa.harvard.edu

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 of reverse engineering supernovae is unraveling the complicated final stages of stellar evolution, and providing exciting new ways to understand how stars explode and evolve into remnants that seed interstellar space with the raw materials needed for new stars, planets -- and potentially life. Students will gain hands-on experience and acquire an interdisciplinary, widely applicable skill set analyzing data obtained by premier space-borne and ground-based facilities (including the Hubble Space Telescope, Chandra X-ray Observatory, and the 6.5m Magellan and MMT telescopes). Projects involving development of the new Open Supernova Catalog (sne.space) and analysis of its contents are also available for students with abilities in computer programming. Please feel free to contact me: let's brainstorm and tailor a project that leverages your unique interests and strengths.

Dr. Xingang Chen xingang.chen@cfa.harvard.edu

I am a visiting assistant professor from UT Dallas. I am a theoretical cosmologist specializing in early universe models and their observational consequences in the cosmic microwave background and large scale structures. Recent years of astrophysical observations have revealed some secrets of the distributions of light and matter in the largest scales of our Universe. We find that these structures all evolved from some special initial conditions at the beginning of Big Bang. Our research projects include the early universe model-building and data analyses that allow us to understand these secrets in terms of fundamental physics, and to make new proposals for theoretical model building and predictions for future experiments. Some of the projects are accessible to undergraduate students, which at the same time will provide introductions to the more advanced subjects in cosmology and high-energy physics. Interested students are encouraged to talk to me.

Dr. Eric Chaisson ejchaisson@cfa.harvard.edu

Although semi-retired, I am still actively engaged in the research and teaching of “cosmic evolution” — an interdisciplinary, 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. My most recently published paper on the subject is found in the journal*Entropy*, downloaded as a PDF here:
http://www.mdpi.com/1099-4300/17/12/7857
A longer review of the subject is published here: http://dx.doi.org/10.1155/2014/384912
Both of these recent papers serve to undergird my course, Astro E8 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
A recent talk I gave on cosmic evolution can be found here:

https://www.youtube.com/watch?v=uLtJyg_f3B0
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. Hossein Sadeghpour hsadeghpour@cfa.harvard.edu

Simulations of dynamics of precursor organic and prebiotic molecule formation in interstellar medium:

There's convincing evidence that much of the terrestrial water was delivered to Earth during the Late Heavy Bombardment approximately 3.8-4.1 Gyr ago. A crucially sensitive indicator of extra-terrestrial origin of water on Earth is the deuterium-to-hydrogen ratio (D/H). The (D/H) in carbonaceous chondrites has been measured in accord with the Vienna Standard Mean Ocean Water (D/H) (todays oceans).

Reactive and quantum molecular dynamics of carbon and hydrogen bonds in the gas phase, near carbonaceous surfaces, under impact of UV radiation and cation interaction, can be simulated to investigate the synthesis of large carbon-bearing chains, filaments, cages, and chemical dynamics of PAH (Polycyclic aromatic hydrocarbon) reactions (for instance benzene and o-benzyne forming naphthalene, or benzene and o-C_10H_6 forming anthracene), as precursor to prebiotic chemistry. The following two references may be helpful:

1. N. Patra, P. Král, and H. R. Sadeghpour, "Nucleation and Stabilization of Carbon-rich Structures in Interstellar Media", Astrophysical Journal, Volume 785(2014); 10.1088/0004-637X/785/1/6.
2. D. W. Marshall, and H. R. Sadeghpour, "Simulating the formation of carbon-rich molecules on an idealized graphitic surface", Monthly Notices of the Royal Astronomical Society, Volume 455, Issue 3, p.2889-2900 (2016); 10.1093/mnras/stv2524.

Dr. Jaesub Hong jhong@cfa.harvard.edu
Dr. Suzanne Romaine

We are developing miniature lightweight Wolter Optics for future X-ray telescopes for astrophysics and planetary science. Through a hybrid approach that combines thin NiCo shells with lightweight ceramic substrate, the miniature X-ray optics will finally enable true focusing X-ray imaging in planetary science. X-ray telescopes using MiXO on future large planetary missions can be used to unveil surface elemental composition of airless planetary objects such as asteroids, comets, and moons. Small X-ray telescopes using MiXO can be launched as free-fliers like CubeSAT. We are looking for a motivated student who will work with us in fabricating thin films for X-ray optics, conducting optical/X-ray measurements to characterize optics, and/or performing ray-tracing simulations to optimize X-ray optics configuration, depending on his or her preference and skill sets.

Dr. Edward Tong etong@cfa.harvard.edu

Instrumentation Development at Receiver Lab: At the receiver lab, we are at the forefront of instrumentation development for radio-telescopes. Our work spans from designing RF/microwave low noise amplifiers, to cryogenic ultra-sensitive detectors for the Submillimeter Array and sub-100mK wideband spectrometers, and development of automatic control of astronomical instrumentation. We would like to involve undergraduate students in our lab. If you would like to work with instrumentation development for radio-astronomy, we will be happy to get you on board in our team. There is no need of prior experience in hardware, just a motivation to work with and explore instrumentation work.

Dr. Gongjie Li gli@cfa.harvard.edu

I mainly focus on the dynamics of astrophysical systems, which is essential in explaining a wide range of astrophysical phenomena, from the high-energy regime on the interactions of black holes and stars to the low-energy range on the formation and evolution of planetary systems. The relevance and the popularity of systems in these two regimes have been greatly enhanced lately due to the recent detections, such as the observations of tidal disruption events of stars shredded by supermassive black holes, the gravitational wave radiations produced by the mergers of the black hole binaries, the discoveries of extrasolar planetary systems and the unexpected structure of the Kuiper Belt in our own Solar System. Possible projects for undergraduate research involve numerical simulations of the dynamical interactions between the stars and supermassive black holes or tests of dynamical stability in planetary systems.

Dr. Philip Sadler psadler@cfa.harvard.edu

The CfA has a large and active Science Education Department that conducts educational research in STEM fields. My own 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. This year's effort will closely examine the high school chemistry concepts covered in the Next Generation Science Standards which will impact curricula developed nationally over the next decade. I am also examining the impact of prior knowledge on the completion of MOOCs, how prior coursework and experiences impact success in introductory CS courses, and the role of out-of-school-time activities, engaged in prior to college, lead to an interest in pursuing a STEM career. Students will have the opportunity to investigate their own research question using large, nationally-representaive datasets that have previously been collected, learn and apply statistics pertinent to the social sciences, and author a paper to be submitted to a peer-reviewed journal in education (often in conjunction with a junior or senior thesis).

Dr. Antony A. Stark astark@cfa.harvard.edu

The South Pole Telescope (SPT; Carlstrom et al. 2011 PASP 123:568) and the Parallel Imager for Southern Cosmology Observations (PISCO , PI: A. Stark; Stalder, et al. 2014 SPIE Conf. Series 9147) are being used by collaborators at the CfA and other Magellan partner institutions in pursuit of the “cluster method” of observational cosmology in a multi-year program that will be achieving full sensitivity in the coming year. The SPT is surveyin large areas of the southern sky (4000 square degrees) at millimeter wavelengths with sensitivities ~ 3 mK antenna temperature per one arcminute beam — significantly deeper than any other survey, including Planck and ACT. Clusters of galaxies are detected in these data with high completeness and purity as statistically-significant Sunyev-Zel’dovich signatures. Follow-up observations at optical and X-ray wavelengths confirm the existence of the clusters and determine their properties. The some of the world’s largest telescopes and space observatories, including HST, the VLT, Southern Gemini, Spitzer, ALMA, ATCA, Chandra, and XMM-Newton are being employed in the follow-up effort. The first images with PISCO on the Magellan telescopes will be used to determine the history of Dark Energy and the nature and mass of neutrino species.

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. Nia Imara nia.imara@cfa.harvard.edu

Giant molecular clouds (GMCs) set the stage for the formation of stars in our Galaxy and beyond. Since GMCs are the reservoirs of star-forming fuel, understanding their origins and evolution is crucial for a comprehensive view of galaxy evolution. I am interested in characterizing and understanding the properties of GMCs from both observational and theoretical points of view. GMCs in dwarf galaxies are of particular interest, since the environments of dwarfs are expected to be relatively “primordial” compared to the interstellar medium of the Milky Way. Thus, by studying GMCs in dwarfs, we learn about star formation in environments dramatically different from our own...and perhaps even get a glimpse into the nature of star formation in the early Universe.

I currently have new radio observations of dwarf galaxies from the Atacama Large Millimeter Array (ALMA), the world's leading interferometer. The goal of this project is to identify GMCs in the data sets, using a contouring algorithm, and to characterize their properties (e.g., size, mass, luminosity, kinematics). We will discover how GMCs in these galaxies may differ from those in Milky Way-type galaxies. The student working on this project will take a proactive role in learning how to reduce interferometric data. The project will involve imaging the data, analyzing the data, and interpreting the results in light of theoretical models of GMC properties. It will also involve statistics and programming skills.

Dr. Brian McLeod bmcleod@cfa.harvard.edu

Instrumentation: The CfA is a partner in the 25m Giant Magellan Telescope. Comprised of seven 8.4m diameter primary mirror segments and seven 1m diameter secondary mirror segments, the GMT will be the world's largest optical telescope when it sees first light in a few years. I am leading the design of the telescope's active optics sensor systems. Using light from stars in the outer parts of the telescope field of view, these sensors will determine the corrective forces and motions needed to bring the telescope optics into the correct shape and position. Possible student projects could include simulations of the performance of the system, as well as involvement in prototyping activities in the laboratory and at the existing Magellan Clay telescope.

Dr. Matt Nicholl matt.nicholl@cfa.harvard.edu

I study supernovae: the luminous and violent death throes of massive stars. I am involved in a search for the brightest and rarest supernovae from the Pan-STARRS Survey for Transients, and carry out follow-up observations using an array of optical telescopes. Many of the most interesting explosions occur in dwarf galaxies, where conditions may be very different from those in large spirals like our Milky Way. One crucial question across many areas of astrophysics is the impact of metallicity (the fractional content of nuclei heavier than hydrogen and helium) on stellar evolution. An interested student is encouraged to work with me on analysing the spectra of supernovae in faint galaxies to infer the metal content in the stellar envelope. This could lead in a number of interesting directions including comparisons with supernova models, measurements of other physical properties from our spectra and Pan-STARRS data, statistical analysis and possibly a publishable paper. The student will also learn about the physics of supernovae and improve their computing skills.

Dr. Ian Stephens ian.stephens@cfa.harvard.edu

I am interested in understanding the star formation process for solar-type stars. My group has engaged on a very large project using the Submillimeter Array telescope on Mauna Kea called MASSES (the Mass Assembly of Stellar Systems and their Evolution with the SMA). In the Perseus Molecular Cloud, we have commenced a high-resolution survey that maps molecular gas about 72 protostars. These observations represent the largest molecular line survey in a single star-forming region to date, allowing for robust statistical constraints on the star formation process. I have a number of undergraduate projects that can use these data. Specifically, the student will analyze the dense gas kinematics, the energetics of protostellar outflows, protostellar and outflow evolution, and/or angular momentum profiles. Such studies will help us understand how young stars evolve into stars like our sun.

Dr. Martin Elvis melvis@cfa.harvard.edu

The space rubble that is the asteroids is important to us on Earth because they: carry clues to the formation and history of the Solar System, contain mineral that cannot be made on Earth that may have important new properties, are rich in materials that are valuable either on Earth or in space, and because one of them could wipe out the human race. (Note: We don't know of any that would do this, yet.)
I have been working on many projects that address each of these problems and always have projects suitable for junior or senior thesis projects.

Dr. Aneta Siemiginowska asiemiginowska@cfa.harvard.edu

My work involves theory, observations and statistics and focuses on understanding nature of quasar jets. Large scale relativistic jets extend out to hundred kiloparsec distances and transfer the energy generated by the central supermassive black hole to these outermost regions. Interactions between jets and the environment play important role in the evolution of the Universe, but we still do not understand the nature of these interactions, or the emission processes responsible for the jet 's emission. There are several aspect of the studies that can be taken by a student. In particular a project to study X-ray properties of quasars at different redshift, including quasars with known jets can be a primary focus for a student this year. The project involves analysis of Chandra X-ray data, statistics and computations using Python.