Harvard-Smithsonian Center for Astrophysics

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

27 August 2018

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
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P-309

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. 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 the BICEP Array which is under construction now. 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

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/). Our group has created the Python-based linked-view visualization environment for high-dimensional data known as "glue." We have several computationally-oriented projects related to statistical algorithms, visualization and human-computer interaction challenges and glue. Projects include new approaches to augmented reality (e.g. Hololens) visualization in science. Students interested in combining CS and Astronomy research should contact us to learn more, and visit http://glueviz.org 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 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. James 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. Past efforts focused on radiative collisions of Si with O and C with S, which enter models of supernova ejecta. The methodology can be extended to other interesting atoms. Collisions related to several ionic fine structure emission lines that serve as tracers of high energy sources in galaxies and measures of gas densities in star formation are also of interest.

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

We are using the recently available wealth of infrared data from the Spitzer, Herschel, and WISE missions to perform a study of star formation in the outer Galaxy. There have been many observational studies of star formation in regions in the solar neighborhood,and massive regions in the inner parts of the Galaxy. However, the outer Galaxy, which is intermediate in metallicity between the inner Galactic disk and the Magellanic Clouds, and at much lower volume densities, has not been as extensively studied. The extension of the Spitzer and Herschel Galactic surveys to the outer Galaxy has now made this possible. We are using techniques developed in studies of nearby star formation and massive regions such as Cygnus-X to locate young stellar objects in the outer Galaxy, use modelfitting to determine their properties such as luminosity and mass, and study their clustering properties. Comparing the results to star formation regions in other parts of the Galaxy will provide information on how dynamical processes can affect the mechanisms that influence the fragmentation of molecular clouds and star formation efficiency. The results will have applications to the study of star formation in other galaxies, where global properties can be observed but we cannot resolve individual clusters or stars in the infrared. This study will provide a database of outer Galaxy star formation which we will use to select objects to follow up with JWST. Possible student projects could consist of a detailed study of the star-forming clusters discovered in this survey and comparing them to previously-studied regions in the inner Galaxy, or a study of the infrared dark clouds (IRDCs) in the outer Galaxy.

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

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 have 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 will provide for undergraduate students introductions to 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.

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. 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. 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

1. Can Gaia stop us losing Near-Earth Asteroids and measure their masses? Asteroids send us unique information about the origin, and violent history, of the Solar System. Among the millions of asteroids a relatively small group are the near-Earth asteroids. As their name suggests, the orbits of near-Earth asteroids bring them close enough to Earth that many can be quite readily visited with spacecraft for science or resources; some also come too close and pose a threat of impact with Earth. Surprisingly, a large fraction of these near- Earth asteroids have poorly known orbits, complicating their use, and leaving their threat level ill-determined. We want to take advantage of the newly available highly accurate star positions from the Gaia satellite, in combination with a specialized instrument, “PISCO”, on the large Magellan-Clay telescope in Chile. Our goal is to determine precisely where near-Earth asteroids will be well into the future. Last year an undergraduate, Anthony Taylor, was able to obtain 3X better astrometry than existing asteroid surveys and to show that this improvement made a dramatic difference to how well an asteroid was located on its next pass near Earth (its next "apparition"). He's about to submit a paper on this topic. The next phase would be to improve the accuracy by making a distortion map of the PISCO camera images. Then we may be able to use super-precise orbits to measure the otherwise elusive masses of asteroids using the Yarkovsky effect. The first exercise would be to see if Gaia accuracy is enough to measure the Yarkovsky effect. Both parts of the project should lead to publishable papers.

2. How many asteroids could be profitable to mine? Back in 2014 I published a paper "How many ore-bearing asteroids?" (arXiv:1312.4450)which came to the uninspiring conclusion that the number was 10. But that was then. Now we have more asteroids

known, and better models of the whole population. Plus we have better rockets - see Falcon Heavy "red Tesla in space". Combining these improvements there may be 100X as many ore-bearing (i.e. profitable) asteroids compared with a few years ago. The project would use the new model of Mikael Granvik (arXiv:1804.10265) to go from a single number to plot of how the number of ore-bearing asteroid depends on delta-v (a measure of the energy needed to reach an asteroid) and how complete our surveys are. The project should lead to a publishable paper.

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.

Dr. Dong-Woo Kim dkim@cfa.harvard.edu

Over the past 20 years, X-ray observations have revoluntionized our understanding of the galaxy population by allowing us to study in depth their high energy content. The hot gaseous halo in galaxies plays a crucial role in the galaxy formation and evolution. As the hot gas is often extended to the outskirts beyond the optical size, the large scale structural features identified by Chandra and XMM-Newton (including jets, cavities, cold fronts, filaments and tails) point to key evolutionary mechanisms, e.g., AGN feedback, merging history, accretion/stripping and star formation and its quenching. In our project, the X-ray Galaxy Atlas (XGA), we systematically analyze the archival Chandra and XMM-Newton data of ~100 galaxies to study the hot gaseous halo. Using uniformly derived data products with spatially resolved spectral information, we investigate gas morphology, scaling relations, dark matter profiles, circumnuclear gas in relation to AGN and X-ray binaries. Our projects properly suited to undergraduates include:

- X-ray image processing to optimally display high dynamic range data and to search for otherwise hidden features (e.g., by subtracting smooth 2D model, unsharp masking).
- design and develop s/w tools to analyze Chandra and XMM-data in specific purposes (e.g., for low s/n point sources, diffuse emission) either standalone or by combining with existing tools (CIAO for Chandra and SAS for XMM-Newton).
- analyze XGA data products for specific goals, including correlation studies, mass profiles, circum-nuclear gas, circum-galactic medium (CGM) and X-ray binaries.

Dr. Howard Smith hsmith@cfa.harvard.edu

Colliding galaxies trigger massive bursts of star formation as well as accretion onto the supermassive black hole nuclei. This emission heats the dust, and so is particularly bright at infrared wavelengths. My program emphasize observations of the full range of infrared observations from a few microns to the submillimeter, particularly those from space mission like Spitzer and Herschel, and combine them with UV and optical data to obtain complete spectral energy distributions (SEDs) of merging galaxies. We model these SED to obtain star formation rates, AGN activity, masses, and many other properties. We combine these results with infrared spectroscopic data as well. We examine possible differences in the star formation processes underway. These mergers are bright, and so we more can readily sample conditions in the early universe via these bright systems. Our increased understanding of the SEDs of local mergers enables us to unravel the nature of galaxies and galaxy evolution in the high-z universe. Opportunities exist for students in data reduction and analysis (many space missions), and for coding and performing related computational tasks.

Dr. Warren Brown wbrown@cfa.harvard.edu

Projects relating to stellar motions and using them to probe the Milky Way. I have begun searching for hypervelocity stars in the southern hemisphere; forthcoming proper motion measurements will allow us to explore their trajectories and origin, and perhaps constrain the distribution of dark matter surrounding the Galaxy. The same survey also finds extremely low mass white dwarfs in binaries that are strong gravitational wave sources and possibly supernova progenitors. The failed targets are distant halo stars, and we can use those to measure the velocity dispersion profile and mass profile of the Milky Way halo. The choice of project depends on interest and experience.

Dr. Benedikt Diemer benedikt.diemer@cfa.harvard.edu

My research focuses on structure formation, the process by which matter in the universe collapses into the objects we observe (such as galaxies) and those that are hidden (such as dark matter halos). This evolution is extremely complex and non-linear, meaning that it must be understood using large supercomputer simulations rather than pure math. I run and analyze such simulations, both N-body (dark matter only) and hydrodynamical simulations.

Possible projects for undergraduate students include the density profiles of dark matter halos in self-similar universes, building a predictive framework of galaxy evolution based on log-normal star formation histories, and a number of projects related to the splashback radius, a recently proposed definition of the boundary of dark matter halos. This list is incomplete though, and I would be happy to meet and discuss these ideas in more detail. Due to the heavily numerical nature of my work, you would need good computational and programming skills, preferrably in python and/or C/C++.

Dr. Or Graur or.graur@cfa.harvard.edu

Different types of stars end up exploding as various kinds of supernovae. If we could connect between each type of star and each type of supernova we would gain a deeper understanding of how stars evolve and die, how heavy elements are produced and dispersed into space, and how galaxies change over time. I have two projects to offer students, both of which involve analyzing Hubble Space Telescope images of nearby supernovae. In one, we will conduct the first-ever comparison of Type Ia supernovae in the near-infrared. In the other project, we will take a close look at the Type Ia supernova SN 2014J, which exploded in the nearby galaxy M82. We will use these images to probe what the star that exploded as this supernova was up to thousands of years before the explosion. The answer to this question will determine the nature of the star and allow us to place one more piece in this exciting cosmic puzzle. For more information about my research, visit my website (www.cfa.harvard.edu/~orgraur).

Dr. Sergi Blanco-Cuaresma sblancocuaresma@cfa.harvard.edu
Dr. Alberto Accomazzi aaccomazzi@cfa.harvard.edu

The SAO/NASA ADS is a core component of the scholarly infrastructure of Astronomy, and also finds substantial use in the Physics and Geophysics communities. The ADS's bibliographic dataset currently consists of over twelve million documents, and is growing at a rate of several thousand per month. Nearly every Physics, Astronomy, and Geophysics article refereed in the past 20 years is fully indexed and served by the ADS. 50,000 scientists and librarians use the ADS daily. The ADS bibliographic database, full-text corpus, citation network and usage logs provide a unique dataset for people interested in data science.
The current ADS processing pipeline identifies citations between papers but it does not distinguishes where the citations are located. The student will define and develop a strategy to automatically extract the context in which a citation is provided in a paper and characterize its use. This could involve running an existing text extraction/data mining/tagging system (such as Grobid), as well as developing a specific post-processing pipeline (python programming skills are required). A possible approach is to first limit the scope to the introduction section, which is typically used to provide the fundamental background to understand the research results. Articles with a high number of citations coming from the introduction section may be reference review/introductory papers worth highlighting. The student will verify if this number correlates with the global number of citations or if it provides a new valuable independent measure of the paper's content.

Dr. Luca Matra luca.matra@cfa.harvard.edu

Planetesimal belts (or 'debris disks') are rings of asteroids and comets such as our own asteroid and Kuiper belt in the Solar System, and are present around at least 20% of nearby stars. These planetesimals are the most untouched relics of the building blocks that went to form planets in our own and other planetary systems. Observations of their structure tell us whether any planets may be present in these systems and help us understand their formation. In addition, observations of gas released as comets collide within these belts give us access to the exo-cometary ice content and its composition. This is important as these comets may later impact planets such as young Earth analogs potentially delivering water and other basic ingredients for the development of life.
I am leading observational surveys with millimeter-wavelength telescopes such as the Atacama Pathfinder Experiment (APEX), the Nobeyama 45m, the Submillimeter Array (SMA) and the Atacama Large Millimeter/submillimeter Array (ALMA) to both 1) detect carbon monoxide (CO) and atomic carbon (C) gas released within these belts, and 2) image the structure of these belts. I would be more than happy to welcome a student to get involved with any of these projects, which would mainly involve analysis and interpretation of millimetre-wavelength spectra and/or images, and understanding of their significance in the broader context of the origin and composition of these belts and the general architecture of planetary systems.

Dr. Huiqun Wang hwang@cfa.harvard.edu

Mars Daily Global Map (MDGM) is an unique dataset suitable for studying clouds, dust storms, polar caps and surface albedo features on Mars. Each MDGM is a mosiac on a regular latitude / longitude grid for the whole planet. We have been creating MDGMs using wide-angle images taken by the Mars Reconnaissance Orbiter (MRO) Mars Color Imager (MARCI) and archiving the product on NASA's Planetary Data Systems (PDS). Student involved in this project will get experience on planetary image processing, as well as Martian atmospheric and surface phenomena.

Dr. Igor Pikovski igor.pikovski@cfa.harvard.edu

I work in quantum optics and study the effects of gravity on quantum phenomena. The main goal of my research is to study what novel quantum effects may arise when gravity is taken into account, and what low-energy experiments one can design to probe the interplay between gravity and quantum theory. Many of the projects are accessible to undergraduate students that are familiar with quantum mechanics. If you are interested in learning more about this research field and possible projects, please don't hesitate to reach out.

Dr. Sarah Sadavoy sarah.sadavoy@cfa.harvard.edu

I study the formation of low-mass stars like our sun through observations with radio telescopes. Star formation occurs in molecular clouds, which are large clouds of gas and dust that collapse and form new stars. My work tackles a variety of stages in the star formation process, from the initial fragmentation stages of the cloud to the properties of planet-forming disks around young stars. I have a number of data sets in hand and also forthcoming that will make great projects for interested undergraduate students. These projects include: (1) studying the gas chemistry in a very young star-forming region to understand how different molecules form and become depleted at early stages, (2) exploring the evolution dust across a large survey of molecular clouds to better trace how dust grains go from the sizes of nanometers to the sizes of astreroids and planets, (3) characterizing the gas temperatures and densities around several young star systems to determine how stars themselves evolve and shape their immediate environments, and (4) probing for high density structures on the scales of disks in a large ALMA survey to identify new disk candidates and new binary star systems.Through these projects, undergraduate students will gain new insights into the physical processes that relegate star formation and learn about data reduction and data analysis with new observations from telescopes all over the world.

Dr. Belinda Wilkes bwilkes@cfa.harvard.edu

Studies indicate that deep in the heart of every large galaxy there is a very massive black hole that is roughly a million to a billion times more massive than our Sun. The impact of these massive objects on the evolution of the galaxies is one of the important questions that astronomers are trying to address.

The strong gravitational force from a supermassive black hole drags the nearby gas and stars into the very center of the galaxy. This process releases a great amount of energy which makes the central part of the galaxies radiate across all wavelengths. In some cases, relativistic jets emerge from the vicinity of the supermassive black holes and result in complex radio-emitting structures often extending over tens of thousands of light years. These classes of active supermassive black holes are indeed among the most luminous objects in the Universe.

Dr. Belinda Wilkes, along with collaborators at the Harvard-Smithsonian Center for Astrophysics investigates the properties of active supermassive black holes with extended radio structures. Her team are currently analyzing the observational data obtained by several telescopes at various wavelengths. Using this analysis they estimate the physical properties of the supermassive black holes (e.g. mass, the rate of the growth) and the galaxy they live in (e.g rate of formation of stars, age). The primary motivation is to investigate whether there is a relationship between the properties of the supermassive black holes and the properties of the host galaxies.
A student could become involved in any aspects of this project, either as research experience or for a thesis project. Some of the potential projects are investigating the images obtained by the Hubble space telescope for this sample and clarifying whether they are going through a merging process with another galaxy, or investigating the relationship between the host galaxies structure and the radio structures extending from the supermassive black hole.

Dr. Michael Stevens mstevens@cfa.harvard.edu

One of the major goals of the *Parker Solar Probe* mission is to understand how the Sun's atmosphere and solar wind are heated to temperatures almost one thousand times hotter than the surface of the Sun itself. The phase-space distributions of ions and electrons in the plasma hold the keys to this understanding, because they contain lasting signatures of energy exchanged with magnetic waves. In this project, the objective is to combine measurements from two different instruments, both of which are accommodated on the *Wind* and *Parker Solar Probe* spacecraft missions. One of those devices (the electrostatic analyzer) makes very fast measurements of ion phase-space distributions at a low resolution, while the other (the Faraday Cup) makes very slow measurements at a high resolution. In the past, these experiments have been operated separately and compared only for calibration purposes, but we will endeavor to treat them jointly in order to make deductions that neither could support independently. The student will contribute to ground software that jointly analyzes specific types of measurements from the two classes of instrument, and then he/she will apply it to measure wave storms upstream of the earth with *Wind*.
Potential outcome: If highly successful, this project will produce a useful tool for interpreting atypical measurements of the solar wind in space, as in the unstable or strongly non-equilibrium environments the *Parker Solar Probe*will visit. The Parker Solar Probe will launch in summer 2018.
Developmental value: The student will gain functional knowledge and hands-on experience in the disciplines of statistical physics, plasma astrophysics, numerical methods, and space instrumentation, while having an opportunity to make a useful contribution to a high-profile upcoming mission.

Ms. Kiranjyot Gill kiranjyot.gill@cfa.harvard.edu

Recent two- and three-dimensional numerical simulations of core-collapse supernovae typically predict gravitational wave emission in two main frequency ranges. These two signal components encode some of the properties of the explosion mechanism and high-density physics. Due to the fact that simulations are very numerical expensive, only a handful of sophisticated simulations exist today. This means that the space of possible physical conditions of the explosion has been poorly sampled. The goal of the project would be to explore this space and use analytical formulas to produce predictions of the

behavior of the two main signal component as a function of a few key parameters. The project could consist of three distinct parts:
• 1) General understanding of the core-collapse scenario.
• 2) Determine the important physical parameters that determine the frequency of the gravitational waves.
• 3) Write a code to create signals. It will be necessary to allow for some degree of randomness in the strength and duration of the two components. It could be a good idea to first implement the two components separately and then merge them. Python should be more than fast enough, but a faster language like C++ or Fortran might have some benefits too.

Dr. Sandro Tacchella sandro.tacchella@cfa.harvard.edu

My research focuses on the formation and evolution of galaxies. I'm curious to understand how the first galaxies in the early universe form, the bulge and disk components in galaxies buildup, and star formation in massive galaxies ceases. I'm using both observational and theoretical tools, including the Hubble Space Telescope, the 6.5m MMT telescope, cosmological simulations, and empirical models.

I would be happy to welcome undergraduate students on a variety of observational or theoretical projects related to galaxies. Specifically, projects include:

(i) Studying recently obtained spectra of distant galaxies in order to determine their metallicity content;
(ii) Working with a state-of-the-art cosmological simulation (IllustrisTNG) to constrain the equilibrium growth of galaxies;
(iii) Comparing sizes and ages of today's galaxies in order to assess the physics that drives the diversity of morphology;
(iv) Making clustering predictions of the first galaxies for the upcoming James Webb Space Telescope using a newly developed empirical model.

Dr. Maciej Wielgus maciej.wielgus@cfa.harvard.edu

I work with the Event Horizon Telescope project on imaging compact astrophysical objects with VLBI (Very Long Baseline Interferometry) data. Our primary scientific targets are Sgr A* (supermassive black hole in the center of our own Milky Way galaxy) and M87 (largest black hole in the local Universe), and the main aim of the project is to deliver first images of black hole sources with sub-event horizon resolution scale. So far our efforts in software development were focused primarily on reconstructions of total intensity images. Improving our framework for polarimetric imaging is a crucial next step that will allow us to investigate, among other things, structure of magnetic fields in a supermassive black hole vicinity. I'm particularly interested in:

- developing new software tools for time variability studies of polarimetric quantities and relating the estimated variability to source properties
- advancing the development of imaging techniques using polarimetric quantities, developing robust algorithms for imaging with polarimetric closure quantities, exploring implications of non-Gaussian distributions of errors and implementing proper statistical tests to deal with them.

Dr. Antonija Oklopčić antonija.oklopcic@cfa.harvard.edu

A significant fraction of exoplanets discovered to date orbit their host stars at much closer separations than any of the Solar System planets. These close-in exoplanets are subject to intense stellar radiation, which can have dramatic effects on their atmospheres. The upper layer of a planetary atmosphere, called the thermosphere, can get heated by stellar X-ray and UV radiation to temperatures of several thousand degrees, creating pressure gradients that drive a supersonic planetary outflow. This process, called photoevaporation or hydrodynamic escape, is much more efficient at removing planetary gas than the mass-loss mechanisms operating in Solar System planets. Atmospheric escape and mass loss in close-in exoplanets can have a profound influence on the extent, composition, and evolution of their atmospheres, and consequently, on demographics of planetary systems. I am interested in how we can observe and characterize planetary mass loss through spectroscopic observations of exoplanet transits. My research involves theoretical modeling of atomic (hydrogen/helium) level populations in exoplanet thermospheres, as well as data analysis. I would be happy to meet with interested undergraduates to discuss possible projects.

Dr. Mislav Balokovic mislav.balokovic@cfa.harvard.edu

Although quasars have been discovered more than 50 years ago, many details of the structure of the material surrounding their central supermassive black holes are still unknown. The textbook picture in which all active galactic nuclei (AGN) are the same, and the observed differences are due to different viewing angles with respect to the axis of symmetry of the system, is known to be deficient and overly simplistic. The innermost regions of the gas flow around the black holes generally cannot be resolved directly except in a few extreme cases, but we learn about their structure through characterization of spectra and their evolution over time. My work is at an intersection of theoretical modeling of broadband X-ray spectra of AGN and interpretation of observational data from X-ray telescopes such as NuSTAR, Chandra, XMM-Newton, and Swift. I am interested in working with undergraduate students on new, more realistic models for AGN, studies of the impact of geometry on their X-ray spectra, analyses of spectra of particular AGN using multi-epoch archival data, and combining the observational constraints from the X-ray band with those from optical, infrared and radio observations. Projects can be entirely theoretical, entirely observational, or at the intersection of both, and can be tailored to fit within any student's research time frame.

Ms. Ashley Villar vvillar@cfa.harvard.edu

If a star passes too close to a supermassive black hole's event horizon, the star can be pulled apart by tidal forces, resulting in a bright electromagnetic transient. This rare phenomenon is called a tidal disruption event (TDE). To date, astronomers have only discovered approximately 100 TDEs, and many questions about their physical properties remain uncertain. In 2023, the new 8.4-meter Large Synoptic Survey Telescope (LSST) will begin a decade-long, wide-field survey of the southern sky. Rough estimates indicate that LSST will discovery hundreds of TDEs per year; however, there has not been a systematic study of the observational quality and expected properties of detected TDEs. In this project, a student will simulate TDEs observed with LSST, analyze their light curves, and explore challenges we might face when optimizing the scientific return of LSST. In addition to authoring a publishable paper, the student will learn about the physics of TDEs, astrophysical modeling, and Python coding.