24 September 2008

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 300 scientists and powerful astronomical observatories worldwide and in space. The following is only 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://www.seo.harvard.edu/resprog/index.html.

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

David Charbonneau

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By targeting nearby stars smaller than 0.3 solar radii, a transit search using modest equipment is capable of discovering planets as small as 2 Earth radii in the habitable zones of their host stars. The discovery of such planets is important for two reasons: First, their transiting geometries permit direct estimates of the planetary masses and radii, and hence provide fundamental constraints on the physical structure of planets that are primarily rock and ice in composition. Second, by differencing spectra gathered when the planet is in view from those when it is occulted by the star, we can study the atmospheric chemistry of potentially habitable worlds. The MEarth Project consists of 8 identical, automated 16-inch telescopes in a single enclosure at Mt Hopkins, Arizona. Students are invited to join in the fun of analyzing MEarth data and hunting for these elusive worlds.

Dr. Daniel Fabrycky  
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Dynamics of Transiting Extrasolar Planets: The CfA is the leader in the subfield of extrasolar planets which pass in front of their host stars, a happy circumstance that allows very precise measurements of the properties of close-in planets. I have a number of manageable projects (a) theorizing how the orbits (semi-major axis, eccentricity, inclination) of close-in planets evolve over time and (b) proposing new observational effects or interpreting old observational results that shed light on such evolution.

Dr. Gabor Furesz  
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We'll be working mostly on instrumentation and data reduction. We're getting ready for Kepler with TRES. However, the dynamical studies of open cluster will continue, and I have lots of data to work with. We took H-alpha, Li and Mg band spectra in ONC, as well as H-alpha an Li in the Rosette. For the latter we have Spitzer photometry and some collaborators at U. of Arizona. We're about to write up a very detailed photometric and spectroscopic survey result on the Rosette cloud, including 13CO data as well. Kinematics of the cloud and the small cluster cores, and the effect of the birth of NGC 2244 on the rest of the cloud is under investigation.

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As part of a curriculum for high-school astronomy courses, our group is developing a series of activities in which students and their teachers detect transiting exoplanets, using the CfA's
MicroObservatory network of small, educational telescopes. We are addressing a variety of questions about how students will gather and interpret their data, and about the feasibility of combining multiple data sets from many high-schools nationwide.

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Opportunity for software development for balloon-borne ProtoEXIST: The first balloon flight of Harvard's "ProtoEXIST" telescope, a wide-field hard X-ray imaging telescope and predecessor of a future proposed NASA satellite (EXIST) is scheduled for May, 2009, from the NASA balloon base in Ft. Sumner, NM. TWO students are sought to help on the development of this experiment and possibly to participate in the launch campaign (which MIGHT be after finals!):

a) a student very proficient in C++ to help with software development for the real-time data display and commanding system (partially written but needing significant additions and innovative new features). Here's an opportunity to joystick a "space telescope" (well, almost).

b) a student with computer AND electronics/mechanical skills (e.g. someone who enjoyed taking things apart AND putting them back together, no parts left over!). There is significant hardware assembly and "integration" of the detectors and telescope in our lab at the CfA over the Nov. - Feb. period before shipping to NASA in March for testing with the balloon gondola (spring break?).

Sophomores or juniors preferred, who might then be able to carry on next summer and help with prep. for a follow-on flight in Spring 2010. Junior/Senior thesis opportunities... Work Study eligibility desirable but not required... Need 8-10h/week schedule (flexible).

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The Spitzer Cygnus-X Legacy Survey: The Cygnus-X region contains a massive star formation complex with the richest known concentration of massive protostars and the largest OB associations in the nearest 2 kpc. This unbiased survey of 24 sq degrees in Cygnus-X with the IRAC and MIPS instruments will have the sensitivity to detect young stars to a limit of 0.5 Msolar. The Cygnus-X survey will be an important step in constructing one of Spitzer's greatest legacies: surveying with high sensitivity and spatial resolution a representative sample of Galactic star forming regions, from Bok globules to complexes containing millions of solar masses of gas and hundreds of O-stars. See the project web page at http://www.cfa.harvard.edu/cygnusX for more information. We currently have the full MIPS data set and the remainder of the IRAC data were taken a couple weeks ago. A first pass at
the data reduction has been performed, producing images and source catalogs. We have optical r', i',
and Halpha photometry from the IPHAS survey for the region, and deeper JHKs photometry in the
DR21 region and on S106.

The undergraduate project would consist of helping to run the data pipeline needed to generate higher
quality data products from the IRAC survey, including flagging and correcting image artifacts. A
research project on star formation in one of the clusters of young stars in the Cygnus-X region
could also be carried out.

Dr. Christine Jones, Dr. William Forman, & Dr. Ryan Hickox
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1. Building a Database for Cutting-Edge Astronomical Surveys: The Chandra XBootes group seeks to
better understand the cosmic evolution of galaxies and supermassive black holes through the use of
large multiwavelength astronomical surveys. We are seeking a motivated undergraduate to help design
and build a database to synthesize multiwavelength data sets from a number of the world's most
advanced observatories, including Chandra and Spitzer as well as ground-based optical and radio
facilities. The final database will be placed online for use by the greater astronomical community.
Strong computing skills are required, experience with databases is a plus.

2. A New Computational Tool for X-Ray Studies of Black Holes, Neutron Stars, and Galaxy Clusters:
The Chandra XBootes group uses X-ray observations from advanced space telescopes such as Chandra
and XMM-Newton to explore black holes, neutron stars, and clusters of galaxies. We are seeking a
motivated undergraduate to help develop STACKFAST, a new computing tool for advanced analysis
of X-ray data, that will allow us to extend the limits of the world's most sensitive X-ray observatories.
The goal is to create and release a public version of the STACKFAST code for use by the greater
astronomical community. Computer programming skills are required, familiarity with IDL is a plus.

Dr. Robert Kirshner
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The CfA supernova program is an ongoing project to study supernovae and to apply them to
cosmology. The dark energy that makes up 70% of the universe was found this way. We would be
delighted to engage another Harvard undergraduate in this work. There have been several who've gone
on to be graduate students in astronomy and other fields.

Dr. David Latham
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I am actively involved in spectroscopic and photometric follow-up observations of transiting-planet candidates identified by photometric surveys. This is a chance to join in the fun.

Dr. Julia Lee  
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Research on topics related to neutron star and energetic black hole systems, big and small. Spectral studies using data from X-ray satellites to determine accretion physics and system geometry. Topics of interest range from measuring black hole spin to jet physics to determining plasma conditions in these systems and interstellar space.

Dr. Dimitar Sasselov  
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Projects include working with astro-comb data to obtain precise measurements of the radial velocities of nearby stars, which in turn will enable the hunt for SuperEarth exoplanets orbiting them, and theoretical investigations into the geochemical cycles that may operate on SuperEarth exoplanets.

Dr. Patrick Slane  
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1. Research on X-ray Emission from Supernova Remnants: As the outgoing blast wave from a supernova explosion sweeps up and heats the surrounding circumstellar material, the extremely high temperatures that result lead to bright thermal X-ray emission. This emission provides characteristics of the underlying explosion, including estimates of the energy and age as well as evidence of the ejecta material that was synthesized in the cataclysmic event.

This project entails the investigation of the X-ray emission from a bright, but poorly-studied, Galactic supernova remnant using observations from the XMM-Newton Observatory. The student will gain an introduction to the physics of supernova remnants and their evolution, including an investigation of the ionization properties of the shocked gas - topics with broad application to high energy astrophysics. The research will include work on data reduction, image processing, and spectral modeling. A background with unix-based computing environments would be helpful.

2. Stop for Science! A Science Enrichment Program for Elementary School Students: Broad scientific awareness and literacy is the cornerstone required to support efforts aimed at improving the quality of science learning. While direct efforts to supplement the curriculum in our schools are crucial, a
parallel need is to create an environment that fosters enthusiasm and encourages inquiry outside of the classroom. The "Stop for Science!" program provides large-format posters on a variety of science themes intended for prominent display in schools. The posters are accompanied by a series of questions that are used to engage students in the process of extracting science from their surroundings.

This project involves help with the design and production of posters for the "Stop for Science!" program, along with development of resource materials that provide teachers with suggestions for related topics, demonstrations, and extended activities. These materials will be developed for existing prototype posters from an initial pilot program. The natural enthusiasm that students display for astronomy-related themes makes the application of this program to topics in astronomy and space science particularly appropriate. The participating student will use graphics software to produce final versions of existing prototype posters along with supporting educational materials, and also help generate outlines for additional posters in the series. Experience with Macintosh-based software would be helpful, and the project would benefit from a creative flair, but the most important requirement is an interest in engaging young students in science.

Dr. Howard Smith

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I have a modest sized and very interesting program using a brand new set of excellent Spitzer data to examine 114 regions of high mass star formation in the Milky Way. We have an emphasis on the very earliest stages of star formation - embedded submm cores in an early stage. We can see that the prime objects are in fact part of clusters of young stars that have been resolved by Spitzer, and we can now study the whole clusters as well as the brightest (most massive) one or two prime objects. A talented senior or maybe a junior who is interested in making infrared observations of star forming regions into a thesis or similar project would be able to work closely with me to reduce and analyze these data -- my preference is for 2 semesters of effort. This project is part of a larger program using both SMA and soon-to-be-obtained Herschel Space Telescope far infrared data to study these objects, and so our results will have immediate applications beyond the Spitzer data. Although we do also have a large set of theoretical models to use in explaining our results, and some spectroscopic data also, the primary need at the moment is for someone to work with me on the beautiful IRAC+MIPS data. I'll be happy to talk with anyone further.

Dr. Andrew Szentgyorgyi

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1. Using tunable lasers to observer 240 stars at a time with a multiobject spectrograph (Hectochelle) at the MMT. The job would consist of developing software to analyze spectroscopic data to study
structure in open clusters and globular clusters.

2. Using femtosecond comb lasers to search for low mass exoplanets. The job will also be to develop software and reduce data from the TRES spectrograph at the FLWO observatory to improve radial velocity measurement precision.

Both projects potentially involve observing at Mt. Hopkins.

Dr. Ronald Walsworth
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1. Star noise: The astro-comb wavelength calibrator should provide improved precision in astrophysical spectroscopy. However, some of the planned applications of this new device -- such as searches for Earth-mass planets around Sun-like stars -- may be limited by "star noise", i.e., motion in the stellar photosphere (turbulence, convection, etc.) that could mask small radial velocity changes induced by a light planet. An undergrad project could be to go learn what is known and not known about such noise in various types of stars; and then teach my group of physicists, which is beginning to become exoplanet astrophysicists (at least part-time). This project would significantly impact our exoplanet work with astro-comb.

2. M-dwarf phenomenology: Similarly to the project above, my group of physicists needs to better understand M-dwarf phenomenology (i.e., everything known about M-dwarf stars) to work effectively in the field of exoplanet research. An undergrad could go learn what is known and then teach us. This project would significantly impact our M-dwarf work with astro-comb.

3. Echelle spectrographs: We also need to better understand how real echelle spectrographs function. We have a basic understanding, and our collaborators (Andy S., HAPRS team, etc.) are world experts. But my group will also need a thorough understanding to allow us to maximally exploit the capabilities of the astro-comb. Our collaborators are too busy to teach us in detail; so I would like to assign a smart undergrad to go learn the details and then teach us. This project would significantly impact all our work with astro-comb.

4. Diamond magnetometer for brain science: We recently began the development of a new precision measurement technology - Nitrogen Vacancy (NV) diamond magnetometers - which should provide combined magnetic field sensitivity and spatial resolution better than any existing technology (SQUIDs, Hall probes, magnetic resonance force microscopy, etc.). A paper on our work has just appeared in Nature Physics; and a second paper is in press at Nature. One application we are pursuing is a "magnetic field imager", which we will apply to real-time mapping of magnetic fields created by neural circuits (i.e., network of neurons in a petri dish). A project for an undergrad would be to model...
what we will be able to detect with this "magnetic field imager", once it is developed, given the expected sensitivity of the device and existing knowledge about the magnetic field patterns created by neurons when they fire.

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The young star GQ Lup has received considerable attention since the detection by direct imaging of a substellar/planetary companion at projected separation of 0.7 arcsec, about 100 AU. Such wide separation high mass ratio companions appear to be very difficult to form in current models. In this project, we will analyze data from the Smithsonian's Submillimeter Array that locates dust emission around GQ Lup, to determine if the bulk of the raw material for companions is associated with the primary star, the substellar companion, or resides in a circumbinary disk, to shed light on possible formation scenarios.

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To work with hi resolution X-ray (Chandra) and/or IR (Spitzer) data to better understand star formation in clusters. Specific goals include: combining the data to create full cluster census, understanding cluster properties, understanding the impact of X-rays and X-ray flares on star/planet forming disks. Projects start with data reduction, move through basic to advanced analysis and are targeted towards teaching the student how to document their work.

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How to Build Big Stars: As one of the building blocks in the visible universe, massive stars dominate the appearance and the evolution of galaxies. However, their formation is not well understood. My research focuses on studying different evolutionary stages of massive star formation using high resolution radio and sub-millimeter interferometers. Possible projects for undergraduate research involve processing and analysis of data, including data taken from the world's first sub-millimeter interferometer, the Submillimeter Array.