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NSF Fellowship Application

Previous Research Experience

My first research experience was as an undergraduate, beginning the summer after my sophomore year and continuing through my junior year. I did research in the Haverford physics department with Professor Jerry Gollub, in the field of fluid dynamics. I had the primary responsibility for an experiment on fluid mixing – we studied the patterns which form when fluids are mixed in a roughly two-dimensional layer, half of which is initially covered with a fluorescent dye. The purpose of the work was to learn something about the fundamental properties of fluid flow in a simple, controlled setting. The fluid was mixed by suspending it over magnets and running an alternating current through it; we obtained digital images of the flow once per forcing period. The images were used to measure various statistical properties of the fluid, which gave information about the rate of fluid transport, the development of thin striations of dye, the degree of diffusion and the extent to which the mixing reached a steady state. One of the main results of the study, which we published in *Nature*, was that if the flow was non-turbulent, the fluid field exhibited a steady pattern which recurred after each period of mixing. I mainly worked on this project independently, though I consulted regularly with more experienced people in the lab. My contribution involved fine-tuning and improving the preexisting experimental procedure (I primarily revamped the system of electronics that we had set up to drive and monitor the flow), performing most of the experimental runs, writing a large portion of the computer programs that we used to analyze the data, preparing the results for presentation and suggesting new areas in which to take the project.

The summer after my junior year, I worked as an intern at the Harvard-Smithsonian Center for Astrophysics with Mark Gurwell and Paul Ho on a project to search for brown dwarfs orbiting nearby stars. I also worked on this project during my senior year at Haverford (using it to write my senior thesis – for which Professor Bruce Partridge was my advisor) and returned to Harvard the following summer to continue the research. The project consisted of analyzing images of nearby stars that were obtained with the Keck Telescope and looking for evidence of faint companions which may have been obscured by the point-spread functions of the bright stars. I began this project by learning basic image processing techniques and went on to develop sophisticated computer algorithms of my own, designed to subtract out artifacts from the images that were due to diffracted light from the primary star, while leaving the flux from any potential companions unchanged. Most of my work on this project involved designing and testing specific algorithms and applying them to the images in our data set. I worked independently, but consulted with my advisors on a regular basis to discuss new ideas and techniques. My work led to the detection of a definite, close companion to one of the stars (though it appears to be an M star companion rather than a brown dwarf) and the detection of an extremely faint, apparent companion to another star. By analyzing images of this latter object taken in the J and K_{short} bands, as well as through a methane filter, I determined that its colors are not indicative of a brown dwarf and that instead, it is most likely a background object. In addition to being published in my senior thesis, this work was presented as a poster at the January 2000 meeting of the American Astronomical Society, as well as in a talk I gave at a Keck Northeast Astronomy Consortium undergraduate research symposium at Wesleyan University in October 1999.

Upon arriving at Cornell as a graduate student in fall 2000, I began work on a small research project with Professor Yervant Terzian at Cornell and Murray Lewis at Arecibo Observatory. We used Arecibo to obtain 21-cm line profiles of spiral galaxies; the widths of these lines can be measured and used as a distance indicator via the Tully-Fisher relation (Tully & Fisher, 1977). In my work, I observed nearby galaxies (recessional velocities less than 30,000 km/sec), many of which have been previously measured, but not necessarily with instruments as sensitive as the recently upgraded Arecibo telescope. This work was intended as a preliminary effort in a long term project to extend the Tully-Fisher relation to high redshift galaxies – particularly those for which distances have been obtained via Type Ia supernovae measurements, so that the two techniques can be compared. My responsibilities for this project involved generating a list of potential galaxies to observe and traveling to Arecibo in December 2000 to obtain measurements. After being trained in the use of the telescope, I performed several sets of observations on my own and obtained a preliminary database of measurements to work with. Upon returning to Cornell, I worked on writing fast, flexible computer algorithms in IDL to analyze the data and measure line widths –

the previous software used for this project was written in the 1970's-era language Analyz, as well as in C, and my goal was to rewrite the algorithms in a modern language, making some improvements to them along the way, so that they could be used in the future for quick analysis of large quantities of data. My contribution to this project is mostly complete, though I still have some work left to do in debugging the computer programs I wrote.

Since May 2001, I have been working with Professor Stephen Eikenberry at Cornell on multiwavelength observations of microquasars – black hole or neutron star binary systems in the Galaxy with evidence of relativistic jets. (I plan to pursue this work for my Ph.D. thesis, and it is discussed further in my Proposed Plan of Research.) The work that I have done so far falls into several categories.

First, I have been reanalyzing data obtained in 1997 and published by Eikenberry, et al. (1998ab, 2000) which consists of simultaneous infrared and x-ray measurements of the microquasar GRS 1915+105. As published, these data show that the system underwent large infrared flares on time scales of around 30 minutes (evidence for the formation of jets), accompanied by emptying and refilling of the inner accretion disk as seen in the x-rays. However, the infrared light curves also contain evidence for smaller, faster infrared flares whose origin and relationship to the x-ray flux is unclear. I have been working on detecting and measuring the properties of these flares (which are often small "bumps" superimposed on the large flares), and especially on writing computer algorithms to reprocess the infrared images in our data set and regenerate the light curves with as many sources of systematic error removed as possible, so that higher signal-to-noise measurements of the small flares can be made. I have also worked on modeling the x-ray spectra obtained during these observations at fast (one second) time resolution, so as to track the properties of the accretion disk during the jet formation process and determine their relationship to the small flares.

In August 2001, I traveled to Palomar Observatory with Professor Eikenberry and obtained additional infrared photometry and spectroscopy of GRS 1915+105 at a time when simultaneous measurements in the radio and x-ray were being made. (Preliminary analysis suggests that no jet formation took place during this observation run.) Also, I spent some time during the summer working with a team of undergraduate research students hired by Professor Eikenberry to monitor GRS 1915+105 and other black hole candidates using a small telescope near the Cornell campus. We obtained important evidence showing that GRS 1915+105 can be quiet in the infrared even while it is undergoing large flares in the radio which correspond to jet formation.

Finally, I have written proposals for a new round of observations of GRS 1915+105 as well as Cygnus X-3 (another microquasar) next summer, using Palomar and the Rossi X-ray Timing Explorer (RXTE). The addition of Cygnus X-3 to the proposal was an idea I came up with independently. It is a less active source than GRS 1915+105, but extremely interesting to observe if we can catch it during a period of jet formation; therefore, we proposed to observe it with RXTE as a target of opportunity observation, so that we can restrict our observations to GRS 1915+105 unless Cygnus X-3 shows evidence for impending jet formation.

Publications and Presentations:

Rothstein, D., E. Henry & J.P. Gollub, 1999. "Persistent patterns in transient chaotic fluid mixing." *Nature*, 401, 770

Rothstein, D.M., 1999. "Searching for companions to nearby stars using methane-band imaging." Oral presentation at the Keck Northeast Astronomy Consortium undergraduate research symposium, Wesleyan University, Middletown, CT

Rothstein, D.M., M.A. Gurwell & P.T.P. Ho, 2000. "Searching for companions to nearby stars using methane-band imaging." Poster presentation at the 195th Meeting of the AAS, Atlanta, GA. B.A.A.S. 31, No. 5, 1534

References (in this essay):

Eikenberry, S.S., et al., 1998a, *Astrophysical Journal*, 494, L61
Eikenberry, S.S., et al., 1998b, *Astrophysical Journal*, 506, L31
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