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NSF Fellowship Application

Proposed Plan of Research

My proposed research project is to study the multiwavelength properties of microquasars – black hole or neutron star binary systems in the Galaxy with evidence of relativistic jets. I will do this work in conjunction with Professor Stephen Eikenberry at Cornell. I plan to obtain simultaneous, high time resolution light curves and spectra in the infrared and x-ray (and perhaps the radio) of at least several microquasars and construct as large a database as possible of observations of these objects. I will analyze and interpret whatever data I obtain in order to study the jet formation process. The primary question I would like to answer is: "What is the physical process that underlies jet formation in microquasars, and how does it relate to changes in the inner accretion disk of the system?"

It is important to note that very few high time resolution, multiwavelength observations of microquasars have been published. The few that have are primarily of one object (GRS 1915+105; e.g. Eikenberry, et al., 1998a, 2000), though there have been rare attempts involving Cygnus X-3 (Mason, Cordova & White, 1986) and XTE J1118+480 (Kanbach, et al., 2001). Multiwavelength studies are extremely important because the different regions of the electromagnetic spectrum probe emission from different parts of the microquasar – the radio comes from synchrotron emission in the jets, the infrared probes the companion to the compact object as well as the accretion disk and jet, and the x-ray comes from thermal emission in the inner part of the accretion disk and perhaps nonthermal emission from the jet or a corona of relativistic electrons. It is only by observing at different wavelengths simultaneously that one can learn about the interaction between different parts of the microquasar system. Long-term multiwavelength studies are helpful, and many have been performed, but observations at high time resolution are particularly useful because they probe processes happening in the inner part of the system, close to the compact object and the ultimate source of the jets.

Because of the current paucity of high time resolution, multiwavelength observations of more than one microquasar, one of the goals of my project will be to see how ubiquitous the processes that have been observed in GRS 1915+105 are, and whether microquasars in systems with different physical characteristics exhibit different types of jet formation. For example, Cygnus X-3 is a microquasar which shows evidence of a binary orbit, exhibiting a regular variation of period 4.8 hours in x-rays and the infrared (e.g. Mason, Cordova & White, 1986). In GRS 1915+105, by contrast, no evidence of the binary orbital period has been observed. This raises the possibility that observations of Cygnus X-3 could be used to determine whether properties of the orbit have any relationship to jet formation in microquasars. One previous multiwavelength monitoring campaign of Cygnus X-3 showed that the source exhibited infrared flaring over a single orbital period, during which no corresponding x-ray disruptions were observed (Mason, Cordova & White, 1986) – in GRS 1915+105, infrared flares always appear to be associated with disruptions in the x-ray flux that correspond to emptying and refilling of the inner accretion disk. The origin of the infrared flares in Cygnus X-3 is unclear, but explanations including synchrotron radiation from the jets (Mason, Cordova & White, 1986) and thermal free-free emission from the inner regions of the system (Fender, et al., 1996) have been proposed. Further multiwavelength monitoring over several orbital periods is essential to determine the origin of the infrared flares and their relationship to the binary orbit, as well as how they are related to the inner accretion disk of the system.

Though there are only a few "classic" microquasars in the Galaxy – objects in which high spatial resolution maps have shown jets forming and moving away from the system – there are many more x-ray binaries for which radio emission has been observed, strong circumstantial evidence for the presence of jets (Fender, 2001). I plan to focus my observational efforts on GRS 1915+105 (probably the most active microquasar known today) and Cygnus X-3, but it is likely that I will expand the project to include other microquasars or microquasar candidates. As discussed in my Previous Research Experience Form, I have already observed GRS 1915+105 last summer at Palomar Observatory and written a proposal to conduct joint observations of GRS 1915+105 and Cygnus X-3 next summer, using Palomar and the Proportional Counter Array (PCA) aboard the Rossi X-ray Timing Explorer (RXTE).

One of the key issues I face in carrying out this project is figuring out how to maximize the chance of observing jet formation in a microquasar during a given period of telescope time. Even one night of such observations could produce enough interesting data for a thesis, but our current procedure for observing GRS 1915+105 relies almost entirely on chance – we schedule telescope time months in advance and hope that the source will be doing something interesting when we observe it. The difficulty is that multiwavelength observations require coordination between different astronomical facilities, and also that we need to use telescopes with large collecting area (which are often oversubscribed) if we want to observe features on the fastest time scales.

I am looking at several different ways to alleviate this problem. One simple technique is to schedule simultaneous measurements of more than one microquasar (such as those of GRS 1915+105 and Cygnus X-3 discussed above), so that we can switch between the two depending on which is undergoing more interesting emission. Another key effort is a program that Professor Eikenberry runs every summer, during which he hires undergraduate research assistants to use the Hartung-Boothroyd Observatory (HBO) 0.6 meter telescope, located near the Cornell campus, to monitor black hole candidates and microquasars. This telescope is capable of observing medium to large infrared flares, such as those of duration roughly 30 minutes in GRS 1915+105 observed by Eikenberry, et al. (1998a) at Palomar. Our unlimited access to this telescope allows us to perform long-term monitoring that can be coupled with publicly available x-ray measurements from the All Sky Monitor on RXTE and be analyzed for clues that would allow us to better predict upcoming episodes of jet formation. I helped out with this project on occasion last summer, but in the future, I plan to be more closely involved and ensure that we coordinate our observations as much as possible with ongoing, high time resolution programs to monitor microquasars, being conducted with the RXTE PCA or other x-ray instruments. In addition, I may pursue an instrumentation project which would involve upgrading the HBO infrared camera so that it can perform simultaneous imaging in the H and K bands, which would allow us to obtain rudimentary spectral information of infrared flares without sacrificing time resolution or signal-to-noise. This would allow us to measure infrared colors of the flares and therefore constrain the physical processes which are responsible for them, as in Fender, et al. (1996). Furthermore, Palomar (the largest telescope to which we have easy access) does not currently have an instrument capable of performing simultaneous H and K imaging, so an upgraded version of the HBO camera could perhaps be useful at Palomar as well.

Regardless of what new data I obtain, a large portion of my thesis will consist of in-depth analysis of data originally published by Eikenberry, et al. (1998ab, 2000), among the first measurements showing the connection between infrared jet formation and emptying and refilling of the x-ray inner accretion disk in GRS 1915+105. As discussed in my Previous Research Experience Form, I am currently analyzing several aspects of this data, including small, low signal-to-noise flares present in the infrared and their relationship to the x-ray emission, as well as modeling the x-ray spectra at one second time resolution to track the properties of the accretion disk and jet during the formation process. I will continue this work, and repeat it on further observations, in order to answer questions such as "When in the x-ray cycle does the ejection of particles actually occur?", "How much of the x-ray emission is due to each of the system's various components: accretion disk, jet and corona?", "What is the composition of material in the ejecta?" and "What is the physical difference between the flares which occur at different time scales?" Further observations of GRS 1915+105 will help us answer these questions, as well as map out how the many different x-ray states that this source exhibits affect the infrared emission in different ways.

**References:**

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