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FRESIP Project Observations of Cataclysmic Variables - A Unique Opportunity

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Abstract. FRESIP Project observations of cataclysmic variables would provide unique data sets. In the study of known cataclysmic variables they would provide extended, well sampled temporal photometric information and in addition, they would provide a large area deep survey; obtaining a complete magnitude limited sample of the galaxy in the volume cone defined by the FRESIP field of view.

1. Introduction

If one reviews the many leaps of understanding that have been made in observational astronomy, it becomes clear that most of these have come about through many year efforts and dedicated observational programs. The classification of stellar spectra, the National Geographic/ Palomar Observatory Sky Survey, long term records of certain variable stars collected by the AAVSO, objective prism surveys for QSO's, and the Hubble guide star catalogue are but a few examples.

The FRESIP Project can provide astronomers with another leap into the understanding of planetary systems and could potentially provide humankind with much understanding about our existence, as well as simultaneously giving us a better view and understanding of our own galaxy and the universe beyond.

One of the unique opportunities available from the FRESIP Project is in the observational study of cataclysmic variables. These binary systems consist of a low mass red main sequence star in orbit about a white dwarf primary. The red star fills its Roche lobe and material flows through the inner Lagrangian point to usually form an accretion disk about the white dwarf. Some of these systems have highly magnetic white dwarfs in which the associated magnetic fields are so strong that the flow of material is interrupted and only an inner disk or even no disk at all is permitted to form.

Three basic types of CV exist. These are the dwarf novae (DN) which have fairly regular outbursts due to disk instabilities. These outbursts have amplitudes of usually 2-5 magnitudes but a larger amplitude group (with outburst amplitudes up to 10 magnitudes) exists. Novalike systems (NL) are similar to DN but are essentially always in outburst as they have a high rate of mass transfer. Finally there are the Novae (N) which undergo thermonuclear outbursts with long temporal spacing. Mass transfer rates from the secondary to the primary and the orbital period of the system are the basic causes for the different types of CV.

Low mass X-ray binaries (LMXRBS) are related systems in which the sec-

ondary can be a subgiant or giant and the primary is a neutron star or black hole.

In both cataclysmic variables and LMRXBs, there is a poor understanding of any temporal process. These systems are usually faint enough that they can not be monitored by amateur groups, are not easy to perform detailed studies on as they require large telescope time, and they spend most of their time in quiescence. Except for a few bright, somewhat well studied, probably nontypical systems, we are at a loss at understanding their behavior and evolution. This is unfortunate for astronomy, as CVs are very good laboratories for accretion studies. They undergo changes on minute to hour to daily to longer timescales, accretion and accretion disks are important for our understanding not only of CVs, but also our understanding of accretion processes in other astrophysical objects such as AGNs and newly forming solar systems.

In the following paper, I emphasize the need and value of essentially complete temporal monitoring of CVs that the FRESIP telescope could provide. The types of data sets which would be available divide up into two major areas; 1) A well sampled temporal study of known or newly discovered CVs within the FRESIP field of view (FOV) and 2) A deep survey conducted in some test areas within the FRESIP FOV. This second dataset would be of use to persons wishing to obtain deep surveys of extragalactic objects, studies of other possibly yet unknown faint or transient phenomena, and studies that would help our understanding of CCDs as instruments capable of observing low S/N objects and long-term operation in a space environment.

2. Temporal Studies of Cataclysmic Variables

The best long term time series data sets that are available for CVs to date, are visual and photoelectric measurements of CVs. These lightcurves are mostly obtained by amateurs belonging to the AAVSO or other equivalent organizations. These, of course, have a number of flaws such as 24-hour aliasing, large uncertainties, and the limiting magnitude is usually brighter than about 12th magnitude.

Cannizzo and Mattei (1992) for example, have presented the entire almost 100 year lightcurve of SS Cygni. Even though this represents a milestone in the study of CVs, it still is incomplete in two ways. It represents only one CV, and possibly a non-typical one at that, there are gaps in the data of days (> 10 days at times), and at particularly important places, such as the fast rise to outburst. These problems are in addition to those already stated above.

Richter (1992) shows outburst lightcurves for a few large amplitude DN. These lightcurves are from Sonneburg Observatory plates but are typical of data of this sort from any of the observatory plate collections; they are missing data for various reasons, have uncalibrated plate materials, and as above, the limiting magnitude is usually not very faint (about 16-17th magnitude). In his work, Richter discusses some interesting features seen in the outburst decline lightcurves. Interpretation of these gaps is very important to our understanding of the outburst physics, yet it is very difficult due to lack of contiguous data points.

We do not have complete coverage of the entire outburst of many kinds of

CVs, and Howell (1993) has shown that there are many faint CVs with large amplitude outbursts for which we have just a single datum. These same stars have essentially NO information during minimum light due to their faintness and there is evidence (Howell et. al. 1990) that many such systems have large variations during quiescence as their mass transfer rate changes with time. Only a long-term, well sampled data set can answer all the above questions.

Photometric studies of CVs can be roughly divided up into four regimes: 1) quiescence, 2) the outburst cycle (rise-maximum-decline), 3) the longer term cycle to cycle variations, and 4) quasi-periodic oscillations (QPOs). We have a fairly good understanding for some systems of regime 2 but only sketchy information on various systems in the others. No complete picture exists and it is unlikely it will without data from the FRESIP project.

To demonstrate what can be accomplished with a long-term photometric study, I will use an example based on a 4-year ongoing project to study an LMXRB. The star V404 Cygni underwent an outburst in May 1989. It had been listed as a classical novae since its last outburst in 1938. Wagner et al. (1992) showed the system to have an orbital period near 6.5 days and a black hole primary of 8-12 solar masses. Photometric information was collected over many nights by myself and my colleagues.

Using nearby stars within the same FOV, and pooling all the data, nearly 3000 data frames, we were able to detect the 0.2 mag full amplitude in the lightcurve orbital modulation and are finally beginning to understand the many other detailed photometric variations within this system. Quasi-periodic oscillations have been a source of confusion and frustration for CV workers for many years. Data from a single night or even many nights observation can produce spurious frequencies within a power spectrum to fool the observer. The papers of Patterson and Thomas (1993) bear testimony to the observational difficulties of QPO studies.

The origin of these quasi-periodic oscillations is of great importance to theoretical studies. The origin and nature of why certain frequencies are preferred in certain systems is a complete mystery. The large stumbling block to date has been the need for finding and positively identifying QPOs.

Figure 1 shows sample frequency spectra for constant comparison stars and our current frequency spectrum on V404 Cyg in which we can clearly identify the many QPOs that exist in the system. Remember that this frequency spectrum is based on more than 4 years of ground-based photometric data and is marred by daytime data losses and weather interruptions. We are now able to provide, for this one system, the data needed for better models of accretion mechanisms and binary structures in black hole systems.

The current targeted FOV of the FRESIP telescope contains 6 known CVs (Downes and Shara 1993). Photometric information of these objects in 'white light' will reveal much needed new information of the nature of CVs. The study of these stars alone with data taken every hour for many years would dramatically improve the data-base for CV research.

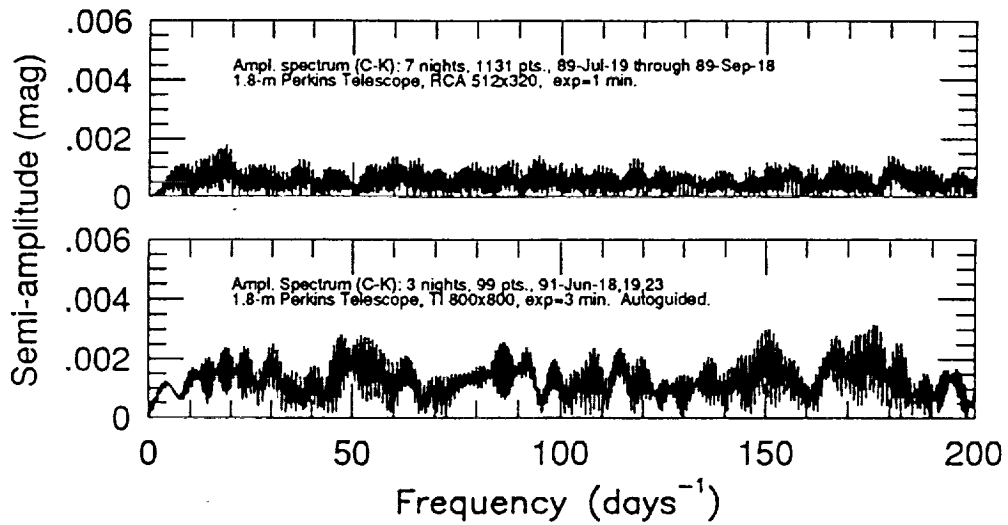


Figure 1A. Frequency Spectrum of assumed constant comparison stars used in the study of V404 Cygni. The two comparison stars C and K used in the bottom panel are about 3 magnitudes fainter than those in the top panel. Note that the number of observations used and time coverage are not the same. Adapted from Kreidl (1992).

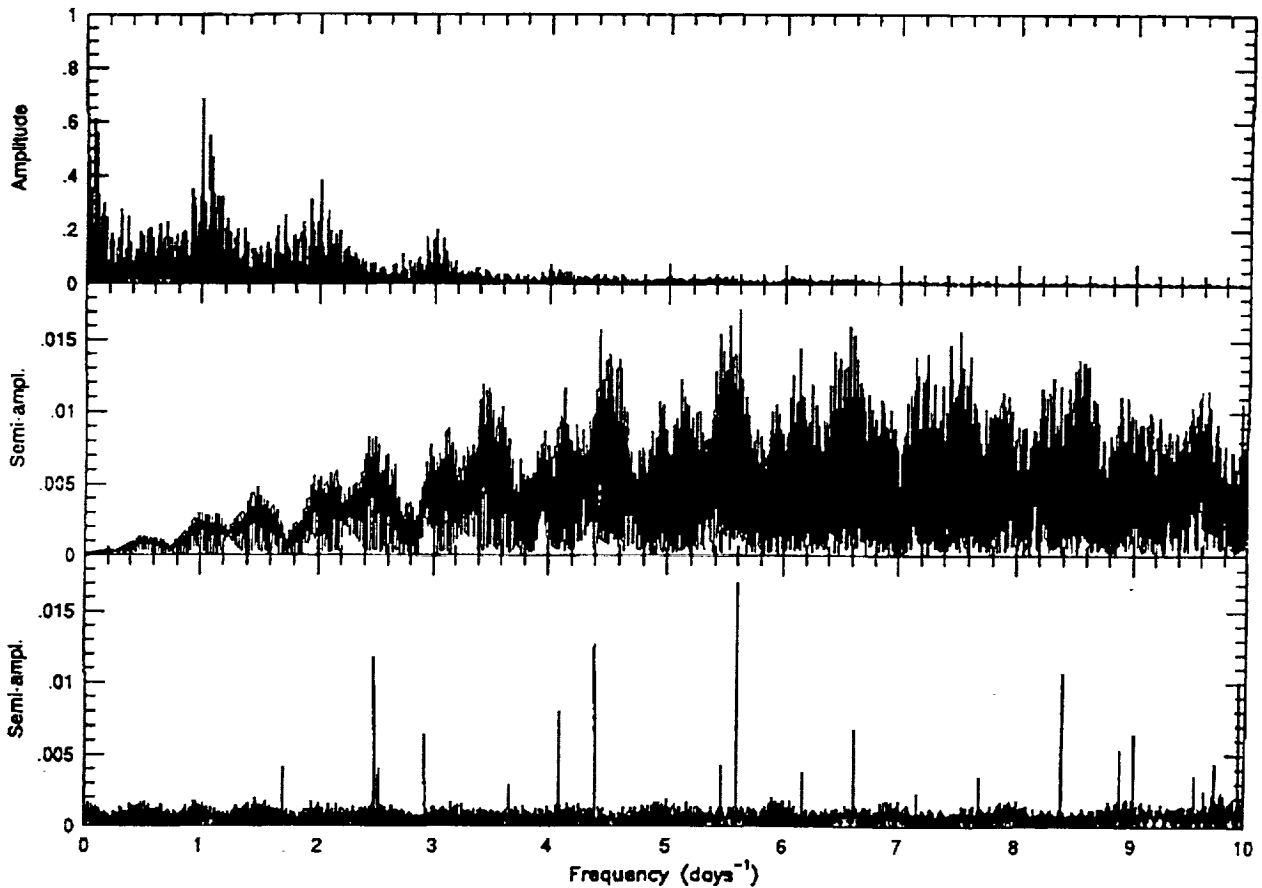


Figure 1B. Frequency Spectrum for the Black Hole LMRXB V404 Cygni. The top panel shows the spectral window, the middle panel is the raw spectrum and the bottom panel in the cleaned spectrum. Note the presence of many significant periods.

3. The FRESIP Deep Cataclysmic Variable Survey

The study of CVs, since their "discovery" as a class of star in the mid-fifties, has led to a list of ~ 500 known systems. Of these, only about 1/4 have a known orbital period and any other associated detailed information. It has become apparent in recent years (Howell and Szkody 1990, Howell 1993) that the well known and well studied systems, the brightest and closest ones, are likely to be atypical of the entire population of CVs. Howell (1993) has provided evidence which suggests that there may be an entire population of low luminosity CVs which have very faint minimum magnitudes (18-22+), and are rarely observed due to their infrequent, yet large, outbursts.

The collected information on the current well studied systems may be leading us to a false conclusion about the entire population of CVs in general. Surveys to find these fainter systems have been limited to very small areas of the sky and single epochs. They usually employ 2-color techniques (looking for blue objects) in an attempt to isolate candidates. Other methods have been literature searches for randomly seen outbursting systems and then attempted follow-up studies to try to identify the candidate stars.

Long-term, deep survey data is badly needed. Many CVs are NOT blue most of the time. Most CVs spend the majority of their time at (faint) minimum, and single epoch snapshots will miss any indication of orbital variation or other photometric signatures. The long-term luminosity of these stars is also of interest as they are likely to have their mass transfer start and stop stochastically. Studies of the nature of mass transfer will provide information on how binaries evolve, the thermal evolution of the secondary star, and binary dynamics.

If these fainter systems exist in abundance as appears likely from recent clues (Shara et al. 1993), then the current beliefs on the space density of CVs must be revised. This large increase in numbers of binary systems would have important implications to CV evolution, binary star formation rates, and the evolutionary status of stellar systems in our galaxy.

In order to determine how the FRESIP Project could be used for such a deep survey, I have run simulations for the FRESIP telescope based on a 1m aperture and use of a broadband filter. A larger telescope using unfiltered light will give higher S/N values for a given integration time. These are shown in Figure 2. Figure 2A shows the predicted S/N obtainable for four sample magnitudes in a 1 hour exposure. We see that stars of even 20th magnitude are easily detectable and their variability deduced. Figure 2B shows the same information but for a single 24-hour period. We are now able to begin to detect 24th magnitude sources. Over only a small time span compared to the mission lifetime, variable objects at quite faint magnitudes will be easily detectable. Detection of serendipitous CVs and supernovae in background galaxies should also occur. Over many years, FRESIP will provide us with a complete sample of variable sources such as CVs, to a limiting magnitude which should detect all unobscured CVs in the volume cone, defined by the FOV, within our entire galaxy.

The FRESIP Project will provide photometric information showing orbital modulations and other variations for many CVs. These would be the first such data sets and be of a unique nature.

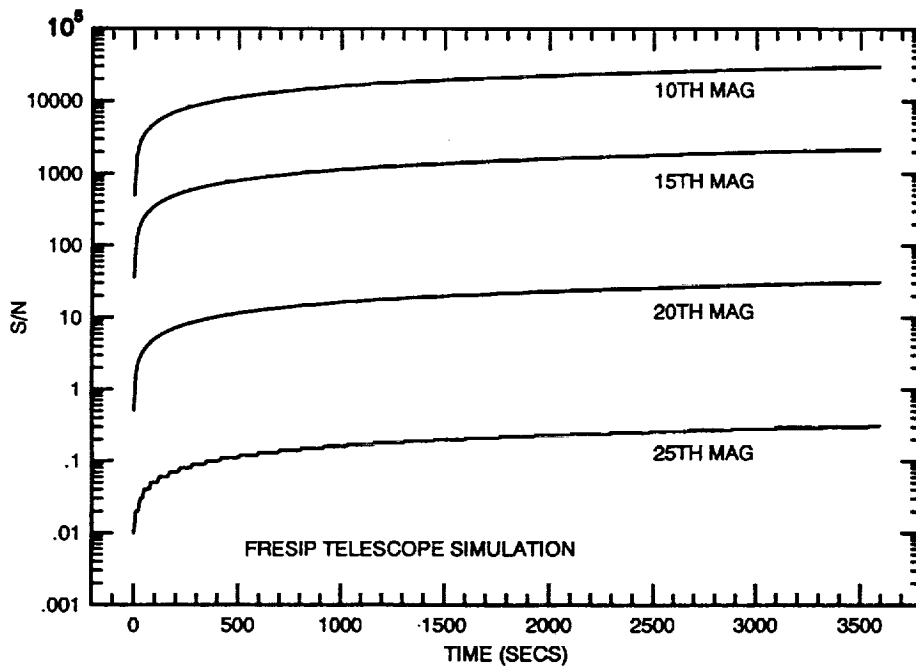


Figure 2A. Simulations of the S/N obtainable with the FRESIP telescope during one hour of observation.

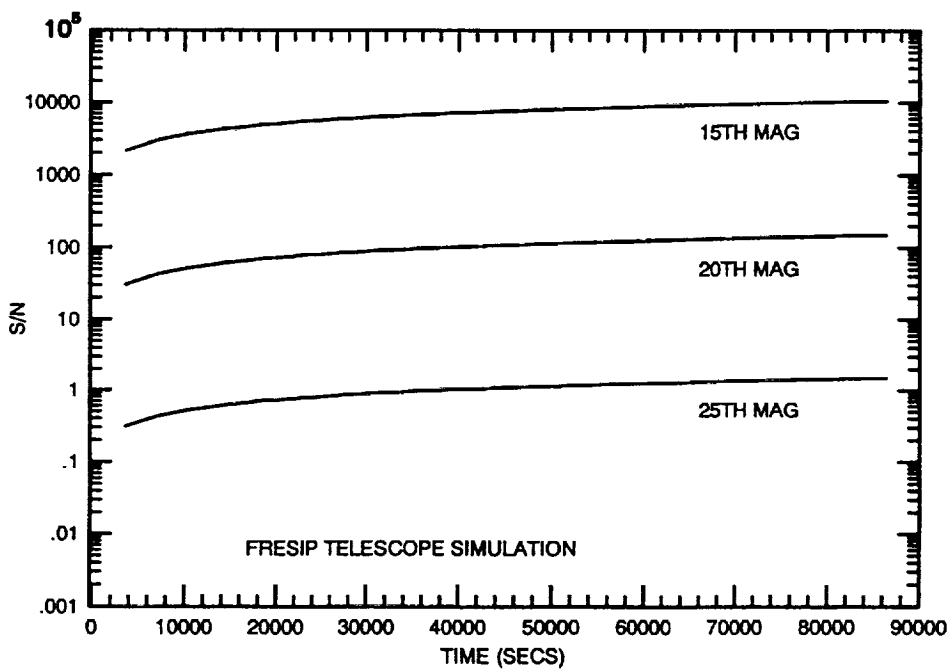


Figure 2B. Simulations of the S/N obtainable with the FRESIP telescope during one day of observation.

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