**Title:** Short Period Photometric Time Series in H-α of CVs Using Small Aperture Telescopes:

**Project Summary:**

Observe and record unfiltered and H-alpha photometric variations of CVs using a network of amateur astronomers with small aperture telescopes and medium format CCD imagers.

The goal is to observe CVs between outbursts when the larger professional telescopes are busy with other projects. Even a modest sized network will be able to perform comprehensive observations of target systems for extended periods. In the process, this project will result in both the acquisition of new scientific insights related to the life cycle of cataclysmic variable, and encourage and nurture an attitude of inclusion among students, citizen scientists, and the professional community.

**Project Description:**

There are already networks of amateur astronomers collecting photometric data from CVs, and from this data, much has been inferred about the nature of the accretion disk around the White Dwarf (WD) primaries of these Cataclysmic Variable (CV) binary systems. This is particularly so if the orbital plane of the binary is closely in line with the observer. (e.g. HT Cas, Nov. 2010). On the occasion that observers find a CV in nova, such as the U Sco nova in 1999 (Iijima, J. 2002) and again in 2010, spectroscopic measurements of the events have been very illuminating, revealing much about the composition of the CV as it tears itself apart. And because of an existing network of amateur astronomers monitoring U Sco, its predicted 2010 outburst was discovered within a day of its onset; with over 2300 magnitudes recorded during the nova event (Schaefer, B. 2010).

Between nova outbursts, many CVs continue to exhibit considerable variation in magnitude. Many nearby CVs, for example TT Ari (Stanishev, V. 2004), have very short orbital periods, and even shorter variations in luminosity during quiescence. They often demonstrate periodic and non-periodic variations that are not consistent with the orbital period of the binary pair. Presumably, there are multiple sources contributing to this changing luminosity. Hopefully, the interplay of these sources will be evident in the changing ratio of total luminosity to H-alpha band luminosity; changes that occur over the period of just minutes. I propose that this data can be collect by amateur astronomers and made available for analyze.

By taking a series of photometric observations, alternating between an unfiltered exposure and an exposure using a narrow band (5-7nm) Hydrogen-alpha filter (657nm), near simultaneous data can be collected with a single telescope. As each image would include the data of the target star system and the necessary comparison star data, accurate light curves can then be plotted that show visible light luminosity changes, H-alpha luminosity changes, and the difference between them. Using only the small telescopes (20 cm to 30 cm aperture) commonly available to amateur astronomers, CVs down to $14^{th}$ magnitude can be observed and recorded in this way. And even with spectrographic resolution of only 9 to 10 angstroms per pixel, it should be possible to use the spectrographs to track the changes in the larger absorption and emission bands (typically Hα band).

Taking these time series observations will require a great deal of observation time. And observation time is hard to come by at professional observatories. But by utilizing a network of citizen scientists, many star systems can be observed and monitored in detail. This effort will also require the construction of an automated web site and data base to store and make available the data. In this way, both raw and processed data can be easily shared, and the accumulated data can be used by amateurs and professional alike to better understand the dynamics of CVs, and to design more detailed observations to explore specific behaviors of the observed systems. Members of existing networks of amateur astronomers (AAVSO, CBA, etc.) can be approached to do these selective photometric time series observations as. There are also numerous amateur spectroscopy groups (e.g. Yahoo Group / amateur_spectroscopy) whose members may be interested in contributing.

**Goals of the Project:**

1. Select and observe several typical CVs in the $7^{th}$ to $14^{th}$ magnitude range. Observation alerts from CBA and AAVSO are always good candidates and using them will insure that there is plenty of concurrent data. Individual exposure time should be less than 15 min. per image to provide adequate time series resolution; typically unfiltered exposures of 90sec and H- α exposures of 10-15 min. Determine the limitations of this technique and the best candidate stars for continued observations.
2. Proceed to make photometric and observations of suitable CVs, collecting observations from multiple observers to obtain continuous coverage of the observed systems through multiple orbital cycles.
3. Establish the communications infrastructure (e.g. web sites, on-line networks, mailing lists) to encourage and support other citizen scientists to participate in and contribute to this research.
4. Through web content, publications, and personal presentations, increase the awareness among amateur astronomers and the general public of the contributions that common people can and do make to science.

**Limitations of the Project:**

The long term goals of this research is to better understand the nature of the fluctuations in luminosity of CV systems during quiescence, and possibly the mechanisms of angular momentum transfer in the gases of the WD accretion disk. The immediate and limited goal of this project is to acquire initial observational information, refine the observation techniques based on evaluation of the initial data. Equally important will be creating a network of citizen scientists to continue the observations. Subsequent observations and analysis will be part of an ongoing use of this network, but more detailed observations and analysis would be the subject of future proposals.

**Data Management Plan**

Raw data will consist of CCD images stored in FITS (Flexible Image Transport System) format. Individual observers will be responsible for long term storage of raw data. FITS header data will

include as a minimum; target star designation, time/date stamp, location data, sensor data (type, size, and pixel size) and exposure data.

Processed photometric data will be compiled and submitted as text files in American Association of Variable Star Observers (AAVSO) data format. It will be stored on the project's web site (www.cbastro.info), with copies submitted to the AAVSO. Processed photometric data will be available for download to any interested parties.

Profile information of individual contributors will be stored as a single xml file. This can include equipment, location, and observer information. Profile information will not be stored online and will only be distributed with the permission of the participants. Optional observation data from individual contributors, such as equipment calibration data, will be stored on line only with participant's permission.

**Resources:**

Alan A. Bedard , Primary Investigator (PI)

Charles Bedard, Consulting Mathematician

Digital-SF Observatory Foundation, a non-profit corporation with observatory facilities located near Cle Elum, Washington. Facilities include:

- Observatory building with 10ft dome, attached control room and adjoining outbuilding.
- 203mm f/6.3 Schmidt-Cassegrain Telescope with 80mm f/6.3 Guide scope and computer guided mount.
- Kodak KAF 0400 based CCD imager with regulated thermoelectric cooling, and an uncooled CCD imager for auto guiding.
- Software and computers for telescope control, auto guiding, camera control, image processing (photometry), and spectrographic measurements.

Existing Internet Infrastructure, including:

- Digital-SF.com (primary domain)
- Yahoo Group / digital-sf_photometry

**Current Budget:**

The current facilities are leased to the Digital-SF Observatory Foundation for $1 a year. This includes all utilities and maintenance costs. Travel expenses incurred by the PI on local trips to promote amateur astronomer involvement are defrayed by the PI. There is no current budget for out of state trips or capital improvements.

**Project Budget:** $2600.00

The proposed project budget is based on the stated goals, and will provide support for at least a calendar year.

- Travel (Line E) – Attend Society for Astronomical Sciences Symposium, Big Bear, CA. Promote involvement with project by other astronomers and astronomy groups. Present initial findings and analysis for peer review. $1000
  – Attend regional Amateur Astronomical Society events to create interest in, and promote participation in this project. $500
- Consultant Services (Line G3) – Hire web site programmer to create script to automate collection and distribution of data for existing website (www.cbastro.info). $1000
- Computer Services (Line G4) – Annual fees for increased data at existing web site. $100

**References:**

Iijima, J. 2002. The spectrum of the recurrent nova U Scorpii during the 1990 outburst. Astronomy & Astrophysics 387, 1013-1021.

V. Stanishev, V. Zamanov, R. Tomov, N. and Marziani, P. 2004. Hα variability of the recurrent nova T Coronae Borealis. Astronomy & Astrophysics 415, 609-616.

Schaefer, B 2010. Summary of 2010 U Sco nova observing campaign. http://www.phys.lsu.edu/newwebsite/downloads/Schaefer_U_Sco_July2010.pdf

**Biographical Sketches:**

Alan Bedard

- Associate of Arts and Science, Technical Communications
- Project Management Certificate
- Nuclear Physics: Navy Nuclear Power Program
- Ten years observational astronomy
- Twenty years Technical Writer
- President of Board, 501c non-profit corporation
- Director, Digital-SF Observatory Foundation (a 501c non-profit), founder

D. Charles Bedard

Master of Science, Statistical Mathematics