HOW AMATEUR ASTRONOMERS ARE HELPING DISCOVER THE TRUE NATURE OF CATACLYSMIC VARIABLES

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Abstract

A long-term monitoring program designed to study certain cataclysmic variables in outburst has been started. Amateur astronomers have provided significant help in this program through their timely observations and reports of outbursting stars. Eight CVs were studied at outburst in the past year.

1. Introduction

Cataclysmic variables (CVs) (novae, recurrent novae, dwarf novae, and novalike systems; see Table 1) are close binaries containing white dwarf primaries and late-type main-sequence secondary stars filling their Roche lobes (see Figure 1). The secondary loses mass through the inner Lagrangian point and, in order to conserve angular momentum, the transferred material usually forms an accretion disk around the white dwarf component. A hot spot originates at the place where the mass-transfer stream impacts the disk. For the systems in which the primaries have strong magnetic fields, the process of forming the accretion disk is disturbed. The transferred material is forced to follow the field lines and creates accretion columns near one or both of the white dwarf's magnetic poles.

Generally, the orbital periods of CVs range from a little over 1 hour to about 12 hours, with a characteristic gap between about 2 and 3 hours. The shortest orbital periods imply typical dimensions for the systems to be on the order of a solar diameter. The spectra of CVs are very complicated. The accretion disk usually dominates the spectrum in the visible, producing a blue continuum and typically broad emission lines of hydrogen, helium, and sometimes other elements. A contribution to the visible spectrum by the secondary late-type star is usually seen if the orbital period is more than about 6 hours, while the absorption lines of the white dwarf primary are rarely seen. Comprehensive reviews of cataclysmic variables can be found in Robinson 1976, Warner 1976, Patterson 1984, and Wade and Ward 1985.

The purpose of this paper is to discuss a scientific project I have undertaken for the last five or so years, and to discuss how this project has benefited from the help of amateur astronomers from the AAVSO and the RASNZ.

2. Scientific Goals

The project under study here is an observational program to determine if CVs in the Milky Way's halo are similar to those in the galactic disk. There was a real dearth of knowledge about any of these stars until this project was started. For example, the *General Catalogue of Variable Stars* (Kholopov *et al.* 1985)(GCVS) lists 426 CVs, of which only 14% have galactic latitudes >30 degrees. Patterson (1984) listed 113 CVs which at that time had known orbital periods. Of these, only 8% were possible galactic halo objects. Even large high latitude surveys such as the Palomar-Green

(PG) survey (Green *et al.* 1982), which covered 200 square degrees of the sky, had less than 4 objects with possible halo membership due to its bright limiting magnitude ($B \approx 16$).

Table 1. Types of Cataclysmic Variables

Type	*Designations*	*Description*
Classical Novae	N, CN, Na, Nb, Nc	Show large, infrequent outbursts (>9 magnitudes)
Recurrent Novae	RN	A mixed group of binaries with some observational similarities to N and DN
Dwarf Novae	DN, UG	Show 2-10 magnitude outbursts with periods from weeks to years
Nova-like	NL	Appear to be DN, but no outbursts yet observed
Z Cam	ZC	Similar to DN but show "standstills" in light curve
SU UMa	SU, UGSU	DN with orbital periods <0.1 day
DQ Her, AM Her	DQ, AM	Highly magnetic CVs
Low Mass X-ray Binaries	LMXRB	Similar properties to CVs but have a neutron star or black hole for the primary

See the GCVS or the references listed in the introduction for more complete descriptions.

Table 2. Observational Data Collection

Type	*Description*	*Equipment Needed (other than telescope)*	*Who*
Photometry	Light curves at minimum	CCD	P, A
	Monitoring at minimum	CCD	A, (P)
	Outbursts	eye, PMT, CCD	A
Spectroscopy	Spectra at minimum	All require large	(P)
	Radial velocities	telescope with	(P)
	Outbursts	spectrograph	A, (P)
Multi-wavelength studies	At minimum	Require space-based	(P)
	At outburst	telescopes such as IUE or ROSAT	A, (P)

A = Amateur Astronomer
P = Professional Astronomer
() = Very hard to impossible to do at all with today's telescopes and equipment

So the project was clearly defined and the tools of study laid out. I planned to gather observational evidence on approximately 100 known or suspected CVs which were likely members of the galactic halo (see Howell and Szkody 1990). It was clear from the start that most of the past and current information of any monitoring of these stars was performed by amateurs, so their help was crucial to the project. Various technical papers detail the project to date (Szkody and Howell 1992 and references therein) but here I will lay out the types of observations needed and show exactly how important amateur involvement is to the success of this project.

There are basically three types of information needed for these objects: photometry, spectroscopy, and multi-wavelength observations. These can be broken down as shown in Table 2.

You will notice from Table 2 that the amateur astronomer contribution to this project is not only large, but in many cases the only information available. I should explain my distinction between amateur and professional. Generally professional astronomers get very little telescope time per year both on ground-based and space-based telescopes. Therefore, I have based my distinction on amount of telescope time and instrument availability. For example, not many amateurs, I would guess, have 2+ meter telescopes with spectrographs or their own orbiting X-ray satellite!

Unfortunately, no telescope allocation committee will grant months of telescope time to monitor CVs every night; too bad, but a good policy. So the real work in this project, that of monitoring, watching for outbursts, following outbursts, etc., falls on the amateurs. Some professionals, such as myself, do however have target-of-opportunity programs at telescopes both on the ground and in space. So this project can and has benefited tremendously from rapid communication from amateurs.

3. Examples from the Past Year of this Project

Table 3 shows the progress made in just this past year. All of these observational studies were prompted by outburst reports from amateurs involved in monitoring projects, either directly to the AAVSO or RASNZ (then transmitted to me), or directly to me.

Table 3. Results from Amateur Outburst Reports for 1991

Star	*Observations Made*
WW Cet	Studied during outburst with ground-based telescopes at CTIO
KK Tel	Spectra obtained at outburst at CITO
Tombaugh CV (1217-18)	Studied with ground-based telescopes at KPNO and IUE. Spectrum obtained at outburst (see Levy *et al.* 1990)
TT Ind	Studied with ground-based telescopes at CTIO
VZ Tuc	False alarm, but candidate star now identified
SW UMa	Ground-based photometry obtained during outburst
EF Peg	Ground-based PMT and CCD photometry obtained by amateurs and professionals. CCD spectra also obtained. (See Howell and Fried 1991.)
VZ Aqr	Visual and PMT photometry obtained by amateurs and professionals

Figures 2-4 show examples of the type of data collected. To put these observations in perspective, these are more data obtained on these types of objects during outburst in one year than probably all that have been obtained in the past combined! There is no doubt about it, amateurs have made the difference.

4. Why this Project Presents Observational Challenges

This particular project is aimed at CVs with faint minimum magnitudes (16-24), a very hard regime to work in. Outburst magnitudes are from 3 to 6 (for novae) to 10 to 16 for the others. It is obvious why most of our detailed studies have to be done during outburst.

The other reasons for this being a difficult project are:

1) Generally, there are no reliable coordinates or charts for these stars. Recent work on this project by myself and collaborators is beginning to change this.
2) Outbursts are rare, maybe one every year or so.
3) Outbursts (when magnitude is >15) last only a few days.

The outburst properties of these stars make timely amateur reports extremely important.

Figure 5 shows a recent result from this project (see Howell and Szkody 1990). This result came mostly from the beginning data collection process, based on many nights of CCD photometric data. The contribution from amateurs has recently started to become much larger (see Table 3), and will no doubt make an impact on this project.

I would like to thank my collaborators on this project and in particular the help, friendship, and perseverance of the members of the AAVSO and the RASNZ. Also my sincere thanks and appreciation to Janet Mattei and Frank Bateson for their support of this project. Robert Fried at Braeside Observatory has made many contributions to this and other projects. His efforts and contributions are warmly acknowledged.

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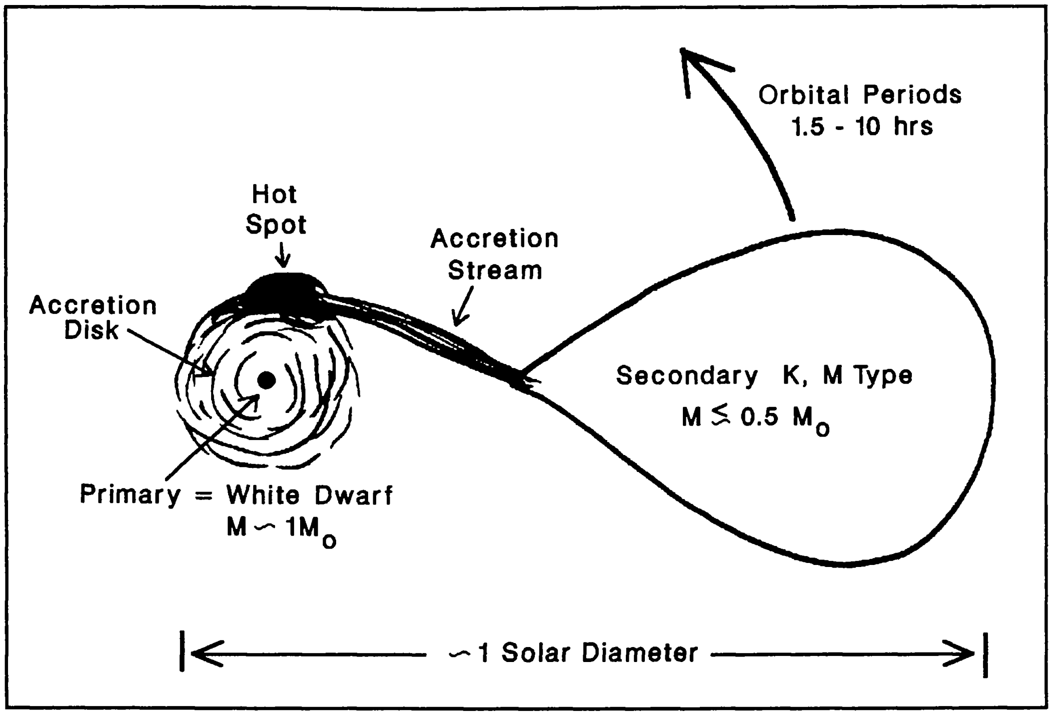

Figure 1. Basic CV model (looking down on the orbital plane).

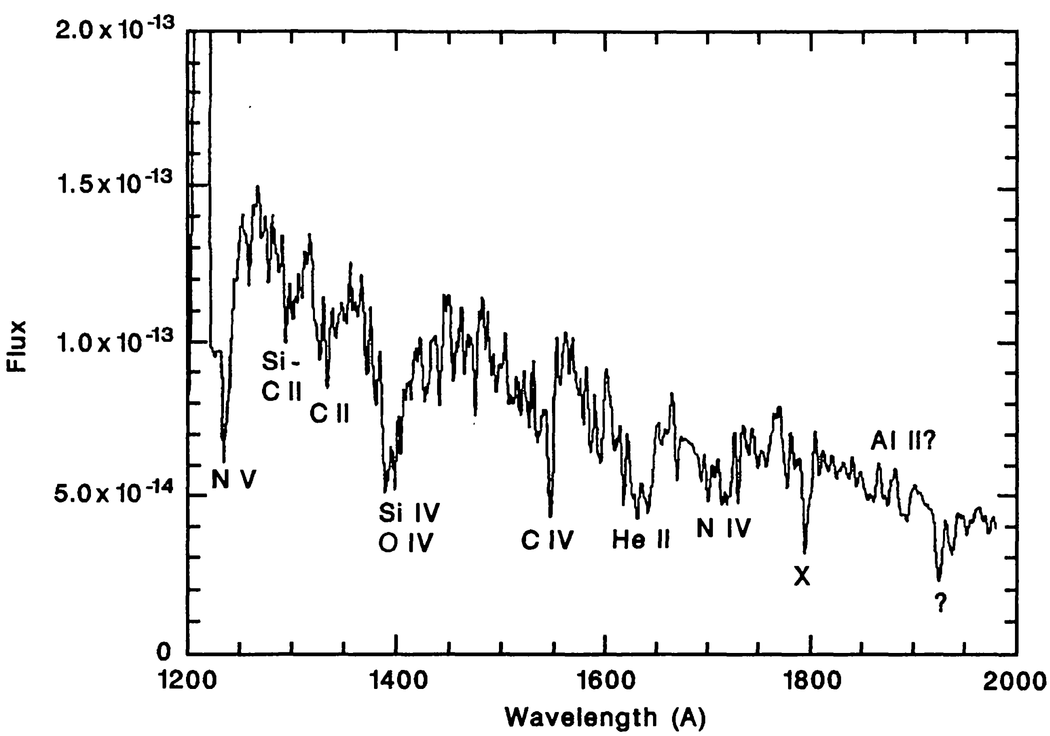

Figure 2. IUE outburst spectrum of 1217-18 (Tombaugh's CV).

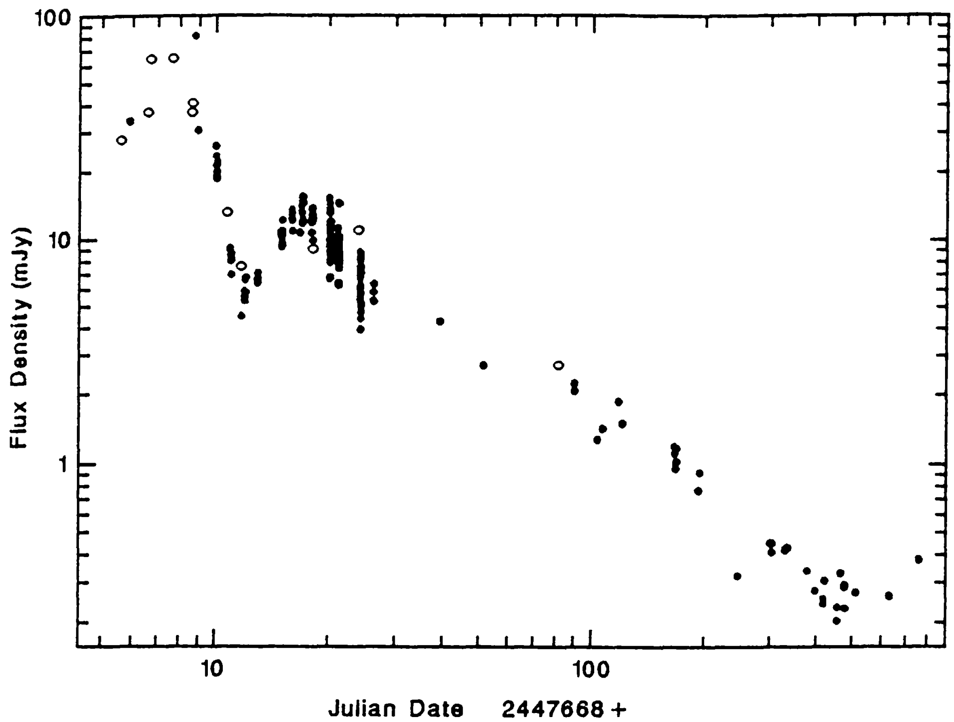

Figure 3. V404 Cygni, May 1989 to November 1990. Open circles are data from Braeside Observatory.

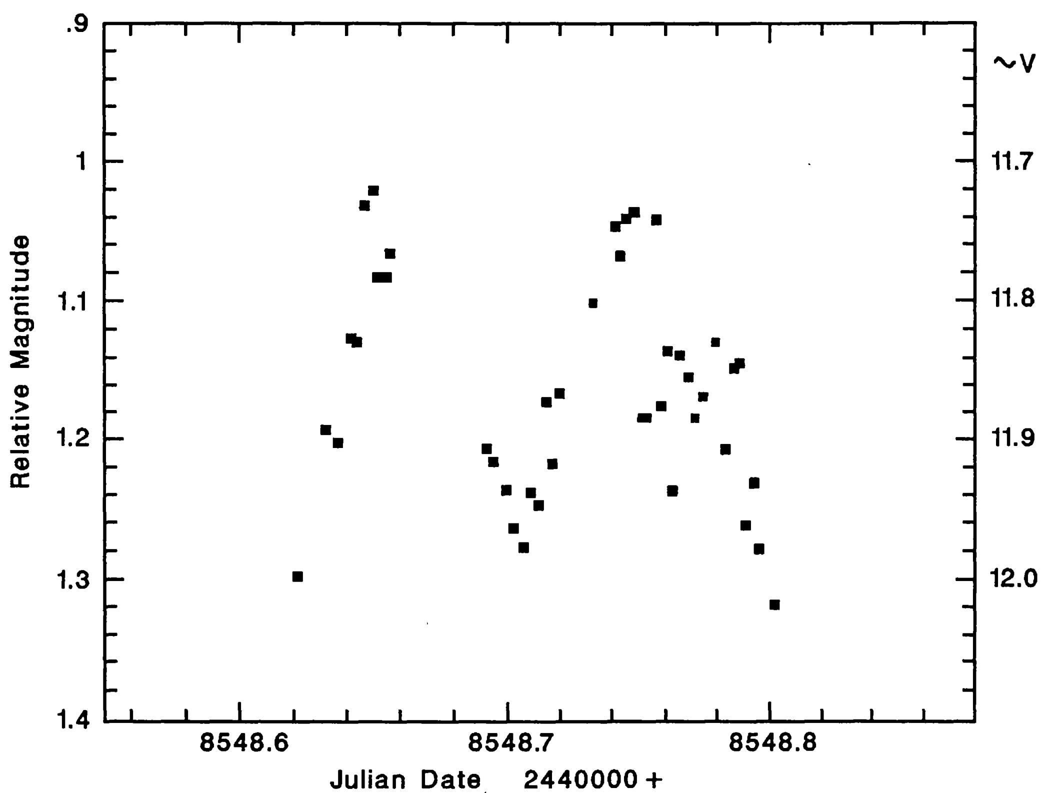

Figure 4. EF Peg, October 19, 1991 UT. Data are from Braeside Observatory during outburst.

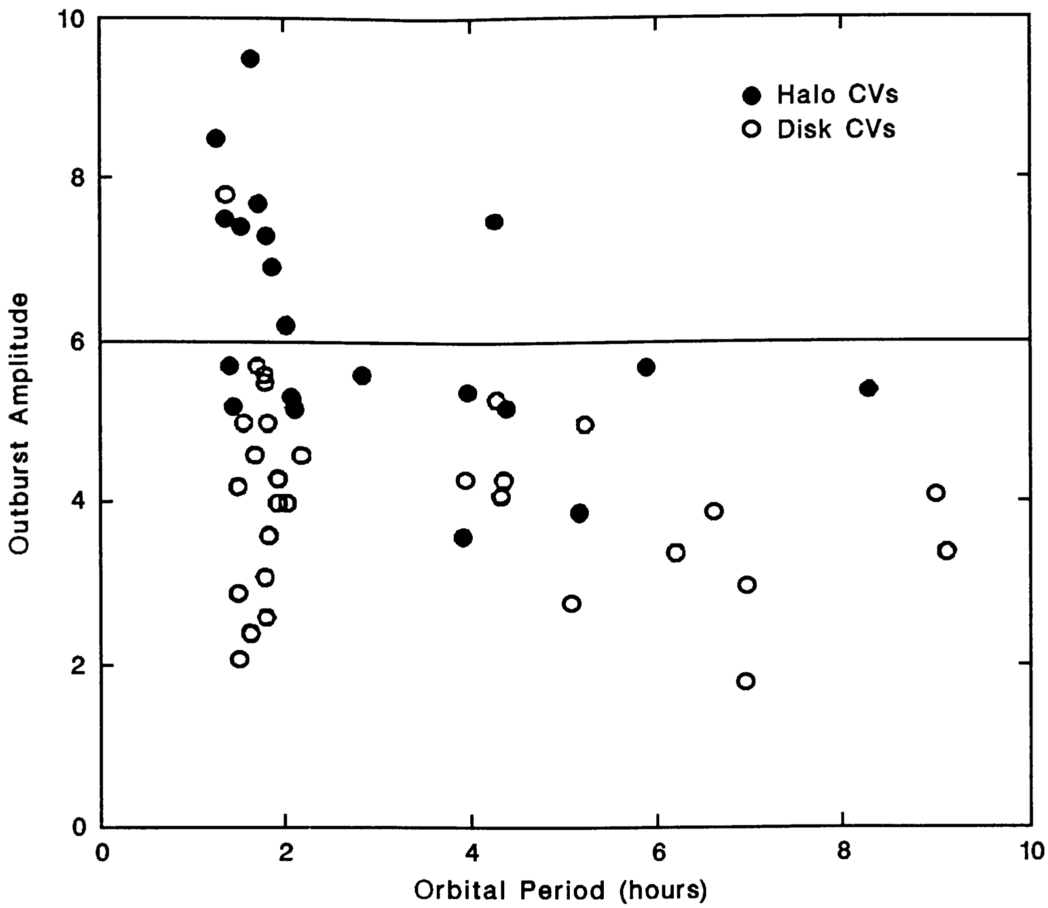

Figure 5. The relation between orbital period and outburst amplitude for the sample of galactic disk dwarf novae from Patterson 1984; (open circles) and our current sample of high-latitude dwarf novae (filled circles).