Bull. Astr. Soc. India (1996) **24,** 669–673

Cataclysmic variables : interclass connections

G.C. Anupama

Indian Institute of Astrophysics, Bangalore 560 034, India

Abstract. The observational properties of the subclasses of the Cataclysmic Variables; classical and recurrent novae, dwarf novae, intermediate polars and the polars are described here. An interclass connection based on the properties and the theoretical cyclic evolution scenario is also presented.

1. The system

A cataclysmic variable star (CV) is a semi-detached binary system consisting of a degenerate white dwarf primary and a mass donating companion (secondary) usually a late type star on or near the main sequence. These systems are short period binaries, with periods in the range of 1-15 hrs. The separation of the binary components is small enough that a combination of gravitational and centrifugal forces causes of flow of hydrogen-rich gas from the secondary, through the inner Lagrangian point, onto the white dwarf. This transferred material has a high specific angular momentum and hence does not strike the primary directly but forms an accretion disc around it. Further material when accreted from the secondary strikes this disc at its outer edge causing a luminosity enhancement, or a bright spot. In some CVs the white dwarf has a strong magnetic field which guides the accretion flow along the dipolar field lines.

The principal subclasses of CVs are the classical and recurrent novae, dwarf novae, nova-like variables, polars (AM Her types) and intermediate polars and the DQ Her types. In the latter three subclasses the white dwarf has a magnetic field strong enough to either disrupt the accretion disc completely, or just the boundary layer between the disc and the surface of the white dwarf.

2. Outburst

The non-magnetic CVs show outburst activity of varying degrees. In a classical nova outburst the system increases in brightness from its mean quiescence level by ~ 9 – 15 mag in $\lesssim 1-2$ days, followed by a relatively slow decline. The outburst is accompanied by mass ejection ($10^{-4} - 10^{-5}\, M_{\odot}$) at high velocities (100 – 1000 km s^{-1}). Recurrent novae are those systems which show two or more classical novalike outbursts. The outburst magnitude is in the range $\Delta m \sim 7-9$ mag and the outburst interval is of the order of decades.

Dwarf novae, in contrast to the novae have frequent, small, short outburst with recurrence periods of a few days/months/years and outburst ranges of $\Delta m \sim 2$–5 mag. Based on the type of outburst these systems are subdivided into the U Gem, SU Uma and Z Cam types. The U Gem types show normal outbursts comprising of short, long and anamolous durations. The SU Uma types, in addition to the normal outburst show super outbursts lasting for periods longer than the normal ones, while the Z Cam types have extended periods of standstill outbursts.

The AM Her stars do not show outbursts, but show high and low states lasting for months to years. The nova-like do not show any outburst.

The outburst in the classical and recurrent novae is powered by thermonuclear runaway reactions in the accreted material on the surface of the white dwarf, while in the dwarf novae the outbursts are due to instabilities in discs. The outburst mechanism depends on the mass of the white dwarf and the accretion rate. Nova systems have more massive white dwarfs ($M_{wd} \gtrsim 0.6\ M_{O}$) and higher mass accretion rates $M \gtrsim$ 10-8 $M_{\odot}$ yr^{-1}). Dwarf novae have less massive white dwarfs and lower mass accretion rates ($M \sim 10^{-10}\ M_{\odot}$ yr^{-1}).

3. Quiescence

The UV/Optical spectrum of CVs at quiescence is an accretion disc spectrum, with a blue continuum and strong emission lines due to the hydrogen Balmer series, high excitation lines like HeII, CIV, NV etc. The total luminosity of the system is determined by $\dot{M}$. CVs are strong X-ray sources, emitting in both the hard and soft X-rays. The origin of the X-ray emission is the matter falling radially onto the white dwarf.

A characteristic property of CVs is their flickering at almost all wavelength regions, with timescales of the order of minutes and amplitude of the order of 0.1–1 mag. This is a consequence of the mass transfer and accretion process. The nature of flickering is however poorly understood. White light high-speed photometry of the optical eclipses of several systems indicates that flickering originates in different locations in different objects. Flickering may originate either from the bright spot, the region near the white dwarf, or from the entire disc.

4. Interconnection

The subclasses of CVs were originally thought to be mutually exclusive. Observations over the past couple of decades or so have however shown that an object may be classified differently at different epochs. Several novae show dwarf novalike outbursts before and after a nova outburst, while some novae have been detected to have a magnetic white dwarf. For example the classical nova GK Per began showing dwarf nova activity ~ 50 yrs after the nova outburst in 1901. These dwarf nova outbursts occur with a recurrence period of 3 years and have an amplitude of ~ 3-4 mag. This object has also been recently discovered to be an intermediate polar. The discovery of optical circular polarization from the fast nova V1500 Cyg (1975) implies this system was likely to have a synchronized AM Her star before its classical nova outburst. The behaviour of the nova CP Puppis is also similar to V1500 Cyg, and also has a magnetic white dwarf. The intermediate polar EX Hya also shows dwarf novalike outbursts, while the quasiperiodic oscillations seen in the polar EF Eri is similar to that observed in the dwarf nova U Gem.

The examples cited above and observations several other CVs (not cited here) imply an interconnection between the subclasses, and it is also likely that all CVs have magnetic white dwarfs, with different values of the magnetic field strength. The cyclic evolution scenario (Livio 1990) blends the CV subclasses. The elements of this scenario as well as the evidences in its favour are presented below.

4.1 Cyclic Evolution

According to the cyclic evolution scenario, the dwarf novae and classical novae are the same systems observed at different epochs in their cyclic evolution.

4.1.1 Scenario Elements

Following outbursts, novae remain bright due to the presence of a hot white dwarf. The mass loss rate from secondary at this phase is enhanced due to irradiation of the secondary by the hot white dwarf. Also, radiation from the white dwarf is reprocessed in the disc and the secondary during this phase, which lasts for about a few decades to a few hundred years.

As the white dwarf cools, $\dot{M}$ decreases towards a secular mean value.

Dwarf nova activity begins when $\dot{M} \sim 10^{-10} M_{\odot}\ \mathrm{yr}^{-1}$ due to fluctuations in $\dot{M}$ about the mean.

There is an increase in $\dot{M}$ once again before a nova outburst occurs.

4.1.2 Basis

Dwarf nova activity is not expected in nova systems since for the deduced accretion rates discs in these systems are expected to be stable. Further, some of the old, recovered novae show low states of $\dot{M}$. These points suggest that $\dot{M}$ changes as a function of time in nova systems.

In dwarf novae the white dwarf accretes mass both during outburst and also at quiescence. If the white dwarf is sufficiently massive, once some critical envelope mass is accreted, the system should undergo a nova outburst.

Theoretical predictions of similar period distribution in the dwarf nova and classical nova systems have been made.

4.1.3 Evidences

Several novae (V1229 Aql, IV Cep, HR Del, FH Ser, V1500 Cyg, CP Pup) did not return to their pre-outburst brightness for a long time.

An analysis of a long time series of magnitudes in several novae show a mean rate of decline of (2.1 ± 1.4) x 10^{-5} mag/day (Vogt 1990, Duerbeck 1992).

V - J colours of several novae got redder with time, consistent with the suggestion of a slow decrease in $\dot{M}$, with the secondary becoming more visible (Szkody 1992).

Dwarf nova activity has been observed in several novae before and after outburst.

Variations in $\dot{M}$ about a secular mean have been observed in several systems.

All the above mentioned evidences point to a change in $\dot{M}$ over time. What brings about this change is however not obvious. It could either be due to magnetic braking in the secondary, or due to long-term solar type activity in the secondary, which has in fact been observed in several systems (Bianchini 1990).

5. Final remarks

Some observational properties are presented in this talk with a view to establish the connection between the subclasses among the CVs, the studies of which are very vital in understanding several important astrophysical processes like accretion onto compact objects, dust formation and binary evolution, to name a few.

Some critical observations are required, like

Monitoring of novae for decades after outburst, especially with multiwavelength observations,

Search for dwarf nova activity in pre/post novae,

Detection of white dwarf pulsations in fast nova systems like V1500 Cyg and CP Pup,

Search for a long-term activity related to the secondary and

Estimation of orbita! periods in as many CV systems as possible.

References

Bianchini A. 1990 AJ 99, 1941.

Duerbeck H.W. 1992 MNRAS 258, 629.

Livio M. 1990 in Cassatella A., Voitti R., eds, The Physics of Classical Novae, Springer-Verlag, Heidelber p.342.

Szkody P. 1992 Astr. Soc. Pacific Conf. Ser. 29, 326.

Reviews on the recent developments in this field can be obtained from the monograph Cataclysmic Variable Stars (B. Warner 1995 : Cambridge Astrophysics Series), the conference proceedings Accretion-Powered Compact Binaries (ed. C.W. Mauche, 1990, Cambridge University Press) and Cataclysmic Variables (ed. A. Bianchini *et al.*, 1995, Kluwer Academic Publishers), and the review by F. Cordova (in X-Ray Binaries ed. W.H.G. Lewin *et al.* (1995), Cambridge Astrophysics Series). Reviews on novae can be found in the book Classical Novae (eds. M.F. Bode & A. Evans) (1989, John Wiley and Sons), and the conference proceedings Physics of Classical Novae (ed. A. Casatella & R. Viotti, 1990, Springer-Verlag).