Cataclysmic Variables as Astrophysical Laboratories

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Cataclysmic Variables (CV) are wonderful laboratories to study quite a number of basic physical and astrophysical processes, such as the MHD origin of the large viscosities observed in otherwise inviscid accretion disks, a variety of thermal and dynamical instabilities in the accretion disks, the coupling of the accretion streams with the magnetic field of the white dwarf primary, thermal and non-thermal radiative emission mechanisms, the magnetic dynamos generated in the solar-type secondaries, the physics of nova TNR's, and the structures of the mass-changing components of close binary systems.
A systematic study of CVs started at the Observatories of Padova and Asiago in the 50's and was mainly performed by Prof. L. Rosino. Taking advantage of this heritage, around mid 70's, I started several observational programs, initially using only the Asiago telescopes, and successively with IUE, ESO and WIRO telescopes.
In the last two decades, my work has been also aimed to discuss evolutionary models of CVs. In addition to the study of CVs, another research project has also been carried out in collaboration with colleagues of the University of Lecce: the study of magnetic winds from AeBe Herbig (pre.main sequence) stars.
Some important achievements of my research have been:

- **i)** the study of systems that exhibit behaviours that characterize different sub-classes of CVs, like the old nova GK Per (Bianchini et al. 1986, A&A,160, 367),
- **ii)** the discovery of solar-type cycles in the secondary components of CVs (Bianchini, 1990, AJ. 99, 1941),
- **iii)** the study of a dynamo model capable to produce the magnetic braking mechanism responsible for the observed secular evolution of close binary system (Zangrilli, Tout & Bianchini, 1997, MNRAS, 289, 59),
- **iv)** the discovery of two populations of novae (Della Valle, Bianchini, Livio, & Orio, 1992, A&A 266, 232; Della Valle, Bianchini, Rosino, & Livio, 1994, A&A 287, 403.),
- **v)** a spectroscopic survey of LMXB's (low mass X-ray binaries) and Black Hole candidate binaries that showed a variety of disk instability phenomena (Masetti , Bianchini & Della Valle,1996, A&A, 317, 769; Bianchini, Della Valle, Masetti & Margoni, 1997,A&A, 321,477; Della Valle, Masetti & Bianchini, 1998, A&A 329, 606. S\'anchez-Fernandez et al. , 1999, A\&A Letters 348, 9.).
- **vi)** a model of magnetic winds from from AeBe Herbig stars (Strafella et al. 1998, ApJ, 505, 299).

In the last five years I have tried to improve and extend my research program establishing collaborations with colleagues of the Astronomy Department (University of Padova) and the Observatory of Padova (INAF) as well as with colleagues from other national and international organizations like the University of Lecce, ESO, the University of Wyoming (Laramie, USA), the University of Wisconsin (Madison, USA). The main goals of these researches are here summarized.

1) The search and study of objects that may contribute understanding evolutionary links amongst different sub-types of CVs.
2) The study of luminous post-novae and their connection with Super Soft X-ray sources.
3) The study of the properties of the two nova populations (disk and bulge) and the determination of their distribution in the Galaxy ;
4) The search for very evolved novae in the Galaxy that should appear intrinsically very faint at minimum and present large amplitude outbursts.
5) A better definition of the dynamo model operating in the secondary components of CVs , in particular in the overshoot region.
6) Analysis of the physical nature of the viscosity inside accretion disks.
7) Spectropolarimetry of agnetic winds from AeBe stars.

Project 1. ***ACCRETION AND WINDS FROM HOT POST-NOVAE***

We have focused our attention on magnetic old novae that exhibit Intermediate Polar behaviours. In particular, we have studied:

- **a)** the effects of the WD magnetic field that may stop the accretion process in the old nova intermediate polar GK Per (Bianchini et al. 2003, A&A *Collaboration with the University of Wyoming*);
- **b)** young post-novae that still appear 2-4 mag brighter than the pre-outburst state and that present photometric multiperiodicities typical of intermediate polars. The case of RW UMi is important because it shows a quite interesting evolution of the observed photometric frequences that might be related to the

increasing effect of the WD magnetic field against a decreasing mass transfer rate from the secondary (Bianchini et al. 2003, PASP. *Collaboration with University of Wyoming*);

- **c)** the mechanism of the wind formation in the old nova Q Cyg (Kafka et al. 2003)

as compared to that of other CVs.

- **d)** the complex accretion geometry in the intermediate-polar old nova DQ Her (Bianchini et al., A&A, 2004).

Project 2. VARIABLE SUPER SOFT X-RAY SOURCES IN M31 AS HOT CVs OR POST-NOVA CANDIDATES

From a list of Chandra and XMM-Newton supersoft X-ray sources in M31 compiled by Marina Orio (in preparation) we select possible classical and recurrent novae and black-hole candidates. Using the digitized images of M31 taken with the 180cm and stored in the Asiago Archives we are trying to detect long term variability that might cast some light on the nature of these sources. We have recently identified the source r-3 115 as a possible transient optical object (work in progress, *collaboration with Marina Orio (Wisconsin) and Paul Johnson (Wyoming)*).

Project 3. VLTI OBSERVATIONS OF NOVAE IN OUTBURST.

Williams (1992) discovered that the emission spectra of novae immediately after light maximum can be divided into two classes based on the relative strength of Fe II lines and He+N lines. Fe II novae are slow novae while the evolution of He/N novae is very rapid. A fraction of both types of novae may eventually evolve into the subclass of 'neon novae', thus revealing the presence of a chemically evolved WD.

About 3.5 mag below the light maximum, the leading expanding shell becomes transparent in the continuum and the nebular lines appear. This evolutionary stage is called *the transition phase* which is characterized in the optical lightcurve by a plateau, by oscillations or by a deep minimum. In particular, the presence of an optical dip is accompained by a brightening of the IR emission that keeps the bolometric luminosity unchanged. The interpretation is that, in some cases, the outer edge of the ejecta are cool enough to form dust particles. A nova that originates from a CO WD may become a 'dusty' nova, while an ONeMg WD, a neon nova, does not form much dust.

At visual maximum the pseudo photosphere roughly mimics that of an F-type supergiant. Bath & Shaviv (1976) calculated photospheric radii in the range 10**12-10**13 cm, assuming an optically-thick wind model. The dimensions of the dust shells during the transition phase are considerably larger than the optical photospheres at light maximum and may reach 10**15 cm (Shore & Gehrz 2004).

We have recently proposed (*collaboration with R.E. Williams, Piero Rafanelli, Stefano Ciroi, Francesco Di Mille, DavideFedele, Veronica Roccatagliata*) VLTI observations of outbursting galactic novae brighter than mag 10 to perform time resolved VISIR N-band LR spectroscopy to detect mid-IR radiation during the early phases of post-nova evolution and thus select dust-forming objects. Spectroscopy in the N-band would in fact provide information about SIV, PAH, SiC, NeII abundances and the way matter is ejected by the WD (shells + winds). We then proposed to observe only *dusty novae* during their transition phase if they have reached maximum optical magnitude brighter than 7.5 mag so to be detectable by VLTI/MIDI. This will allow estimate of the size of their dust nebula. Detection of dust forming events in the early phases of a post-outburst nova evolution is important to define the conditions for grains formation.

A direct measure of the radii of dust shells formed during the transition phase would help understanding the structure and the physics of the ejecta and test theoretical models (*ESO proposal, period 76*).

Project 4. *NOVA POPULATIONS IN THE GALAXY*

The existence of two nova populations (disk and bulge) has been discovered by us (Della Valle et al. 1992, 1994). We wish now to determine their distribution in the Galaxy. This has also been the thesis work of Lucia Pavan who developed a new program to determine interstellar absorption which is critical for nova distances.
This work is in collaboration with Sergio Ortolani and Massimo Della Valle.
The first results are interesting. *However, we are still trying to reach a higher resolution and precision in the determination of the interstellar absorption law for any l,b. Actually, this will be the first scientific output of our research project.*

Project 5. SEARCH FOR EVOLVED NOVA SYSTEMS

Some CVs possess evolved secondaries. The study of their properties may help understanding the evolution of their parent stars during CV formation.
We have recently found that the old nova V840 Oph actually contains an evolved carbon-rich secondary star and is probably a magnetic system (Schmidtobreick et al. 2003). The search for evolved secondaries is still in its beginning.
In addition, it is believed that 99% of all galactic CVs are already very short period (1.5 h) evolved, faint systems. Classical novae should also follow the same evolution.
Very evolved nova systems should then appear as tremendous outburst novae (TONs). Their existence could also strengthen the so-called hibernation scenario which proposes an evolutionary bond between several CV subclasses. Previous results from aour spectroscopic survey of TONs candidates (Schmidtobreick et al. 2005, A&A) are non conclusive about the existence of TONs but seem to contradict the hibernation scenario.

Project 6. THE DYNAMO MECHANISM IN THE SECONDARIES OF CVs

This project is for the moment in a stand-by state, but the basic idea to improve our previous model is to evaluate how the depth of the overshoot region increases with the decreasing mass of the secondary during CV evolution.
This is crucial to calibrate the increase of the efficiency of the boundary layer dynamo before it is suppresed as soon as the star becomes fully convective. This is important because connected to the value of the upper limit of the period gap.
I have recently started a new collaboration with Luca Zangrilli (*Osservatorio Astronomico di Firenze INAF*) to address this problem.

Project 7. THE VISCOSITY AND STABILITY OF ACCRETION DISKS

In collaboration with Fabrizio Tamburini (*Dept. Padova*), we have analyzed the dynamical stability of hydrodynamical flows in the midplane of thin axisymmetric Keplerian accretion disks in close binary systems. We used Floquet theory to study a particularly simple model - namely inviscid, thin accretion disks - in relation to the the primary mass, the orbital period, the disk radius and polytropic index, for a specific normalized Fourier mode of the radial motion in cartesian coordinates We constrained our parameters by using typical physical parameters of Cataclysmic Variables, while thermodynamical quantities were provided by the Shakura-Sunyaev alpha-disk solution. We have discussed the onset of superhumps during the superoutbursts of dwarf novae as due to the coupling between velocity and enthalpy perturbations for each Fourier mode, at the r(3:2) orbital resonance (Tamburini & Bianchini 2002). Our goal is now to improve our code in order to account for all relevant Fourier modes and compare our semi-analytical results with the existing N-body numerical simulations. This will ultimately be a test of the Floquet analysis adopted.

Project 8. THE STABILITY OF DYNAMICALLY UNSTABLE CVs

We have recently suggested (paper submitted to A&A, *collaboration with the University of Wyoming*) that some apparently dynamically unstable CVs may possess magnetic secondaries in which the spin down of their outer convective layers produce Coriolis forces that change the Roche geometry and stabilize the mass transfer within the binary system. These CVs mainly cluster above the period gap and tend to select masses of the secondaries between 0.3-0.7 Mo together with low mass WDs.
Since the perturbing acceleration produced by Coriolis forces would be seen as an increase of the gravitational acceleration at the stellar surface, we are wondering whether this might also represent a cause for a misclassification of the
luminosity class of secondaries. However, more quantitative conclusions will require the accurate mass determination of a larger number of CVs and a more realistic dynamo model that predicts the intensity and the geometry of the magnetic field inside the convective layers of the cool components.

Project 9*. SPECTROPOLARIMETRY OF MAGNETIC WINDS FROM AeBe HERBIG STARS*
In collaboration with Enrico Giro (*INAF*), Fabrizio Tamburini (Dip. Astronomia) and F.Strafella (*Università di Lecce*), we have obtained and analysed spectropolarimetric observations of the H-alpha Pcyg profile of AB Aur. We found that the the variations of the polarization degree and angle through the PCyg profile appear different at different epochs. This suggests that the line forming region varies with time and that this is probably connected with the rotation period and the inclined rotator model of the star (work in progress).
Still using spectropolarimetry, we have also studied the peculiar outburst of 838 Mon
And, in particular, its light echo across the circumstellar medium uncovering its dipole-like structure (Desidera et al. 2004).

Collaborations:
Francesco Strafella, University of Lecce
Massimo Della Valle, Osservatorio Astronomico di Firenze (INAF).
Bob Williams, STScI
Paul Johnson, University of Wyoming
Ron Canterna, University of Wyoming
Marina Orio, Osservatorio Torino (INAF) and University of Wisconsin
Claus Tappert, ESO
Linda Schmidtobreick, ESO
Elena Mason, ESO
Enrico Giro, INAF (PD)
Franco Sabbadin, INAF (PD)

Research Products :
2000:papers with referee: 2
papers without referee: 5
2001:papers with referee: 3
papers without referee: 0
2002:papers with referee: 1
papers without referee:5
2003:papers with referee: 5
papers without referee:3
2004:papers with referee: 3
papers without referee: 4

TOTAL: papers with referee:14
papers without referee:17

In total, the 31 papers published in the last five years have received 22 citations (by May 18, 2005, ADS source).

List of 5 most relevant publications:

1) Bianchini, A., Skidmore, W., Bailey, J. M., Howell, S., Canterna, R., 2000, *The dwarf nova binary system BV Puppis,* A&A, 367, 588.
2) Bianchini, Antonio, Alford, Brian, Canterna, Ronald, Della Valle, Massimo, 2001, *The recovery of the old nova RS Car (1895),* MNRAS, 321, 625.
3) Bianchini, A., Canterna, R., Desidera, S., Garcia, C., 2003, *Evidence for Magnetic Accretion during the 2002 Optical Outburst of the Old Nova GK Persei (1901)*, PASP, 115, 474.
4) Bianchini, A., Tappert, C., Canterna, R., Tamburini, F., Osborne, H., Cantrell, K., 2003*, RW Ursae Minoris (1956): An Evolving Postnova System*, PASP, 115,811.
5) Bianchini, A., Mastrantonio, E., Canterna, R., Stute, J., Cantrell, K., 2004, *The old nova DQ Her (1934). The eclipse of the triple-peaked H_{alpha} profile*, A&A, 426, 669.