OBSERVATIONAL STUDIES OF CATAclySMic VARIABLE EVOLUTION:
OF SAMPLES, BIASES AND SURPRISES

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1. INTRODUCTION

The essential idea of the standard model of cataclysmic variable (CV) evolution (disrupted magnetic braking, King 1988) is that CVs evolve towards shorter periods due to a combination of angular momentum losses: magnetic braking (dominating in systems with orbital periods $P_{\text{orb}} > 3\,\text{h}$) and the less efficient gravitational radiation (dominating in systems with orbital periods $P_{\text{orb}} \lesssim 2\,\text{h}$). The standard paradigm of CV evolution successfully explains the 2–3h gap in the observed CV period distribution. However, most other predictions made by this model are in strong contrast with the properties of the known CV population. Recently, a number of far-reaching modifications for the standard scenario have been proposed (see Spruit & Taam 2001, King & Schenker 2002, Schenker & King 2002 and Andronov et al. 2003). Unfortunately, none of them has been completely successful in tuning the predictions so that they fully agree with the observations. It is apparent that the disturbing disagreements between theory and observations have a common denominator: the possible impact of selection effects on the currently known population of CVs. In order to quantitatively test any theory of CV evolution it is necessary to establish a large and unbiased sample of CVs as well as of their progenitors, (pre-CVs, detached white dwarf/late type main sequence stars).

Such an observational data base will also serve for future improvements of the theory of CV evolution.

2. CVS FROM THE HQS

Most CVs have been discovered through one of the following three channels: variability, blue colour, or X-ray emission. We are currently pursuing a large search for CVs based primarily on their spectroscopic properties, using the Hamburg Quasar Survey (HQS; Hagen et al. 1995) as target sample (Gänsicke et al. 2002). The HQS provides an efficient means of discovering CVs that are so far under-represented in the currently known sample of CVs, i.e. weak X-ray emitters, not particularly blue objects, and CVs that show variability with low amplitudes or long recurrence times. A careful study of the CV discovering efficiency of the HQS concluded that this survey is especially sensitive to short period systems, such as SU UMa dwarf novae (Gänsicke et al. 2002).

So far, we have discovered 53 new CVs, including a number of fascinating systems (Araujo-Betancor et al. 2004, Gänsicke et al. 2004), and doubling the number of known CVs in the sky area/magnitude range covered by the survey, and measured orbital periods for 29 of these systems (Fig. 1). The simple fact that we do not detect a large number of short orbital period systems implies that either they do not exist in the quantity predicted by the theories, or that they look very different from the short period CVs we know (e.g. have weak emission lines). Another striking feature of the HQS CV population is...
Fig. 1. The period distribution of 29 new CVs from the HQS. An additional 24 HQS CVs are awaiting their period measurement. Shown in gray is the 2 – 3 h period gap. Note the concentration of systems in the 3 – 4 h period range.

the large number systems in the 3–4 h orbital period range, most of which (at least 6) are new SW Sex stars (Rodrguez-Gil et al. 2004). Whereas SW Sex stars initially appeared to be the “freaks” among the CVs, they now turn out to be a significant sub-class, and understanding their relation to the global population of CVs is likely to be closely related to a major improvement of our understanding of CV evolution as a whole.

3. PRE-CVS FROM SLOAN/UKST

Whereas far more than 1000 CVs are listed by Downes et al. (2001), only a shocking small number of pre-CVs is currently known. Schreiber & Gansicke (2003) have analysed in detail the properties of all (30) pre-CVs for which both the orbital period and the white dwarf temperature have been measured, and showed that this population is heavily biased towards binaries containing rather hot (young) white dwarfs (T_{wd} > 15000 K) and low-mass/late-type (M_{sec} < 0.4 M_\odot) secondary stars. An important consequence of this bias is that we currently know only a single progenitor for CVs with periods > 4 h: V471 Tau. Schreiber & Gansicke also showed that this bias is a natural result of the way that most pre-CVs were discovered – as a white dwarf in the first place, with some evidence (weak emission lines, eclipses, or ellipsoidal modulation) for a faint companion cropping up later. Among the exceptions is V471 Tau, which was indeed discovered as a spectroscopic binary. Schreiber & Gansicke conclude that there ought to be a large population of pre-CVs containing cold (old) and/or early-type secondary stars. We have initiated a large search for pre-CVs with the aim to produce a large and (largely) unbiased sample of pre-CVs.

4. POST-SUPERSOFT CVS = FAILED SNIA?

Supersoft X-ray binaries are one likely channel for producing supernovae of type Ia (e.g. Langer et al. 2000). In these systems, contrary to “normal” CVs, the donor star is more massive than the white dwarf, and mass transfer occurs on the thermal time scale of the donor star (Schenker et al. 2002). If the white dwarf fails to grow over the Chandrasekhar limit, the mass ratio will eventually change over (M_{wd} > M_{donor}), and the system will appear as an apparently “normal” CV – with the difference that the donor star is not a main sequence star, but the exposed core of a previously more massive star. Post-supersoft X-ray binaries can, hence, be considered failed SN Ia, and their observational hallmark should be abundances typical of CNO burning.

Testing the abundances of the donor star in a CV is equivalent to testing the abundances of the material that it is transferring onto the white dwarf, i.e. the abundances of the accretion disc/flow. The natural wavelength range to carry out this test is the far-ultraviolet (FUV), which contains the N V \lambda 1240 and C IV \lambda 1550 resonance lines. We are currently carrying out a HST/STIS FUV spectroscopic survey of a large number of CVs, and Gansicke et al. (2003) presented the strong evidence that EY Cyg, BZ UMa, EI Psc (1RXS J232953.9+062814) and V396 Hya (CE 315) are post-supersoft X-ray binaries. Since the publication of these results, our
HST/STIS survey has unveiled three additional systems with significantly enhanced N/C emission line flux ratios: QZ Ser, GSPav, and CW1045+525. The fraction of likely failed SN Ia in the HST/STIS survey is $\sim 12\%$, which is within the range predicted by the evolutionary models. However, considering the still rather small total number of systems observed in this survey, the statistical significance of this fraction is too low for a definite conclusion.

Apart from the systems mentioned here, AE Aqr, V1309 Ori, TX Col, BY Cam, MN Hya, and GP Com have been shown to exhibit strong N/C enhancement. The 14 post-supersoft CVs known so far span a large range in orbital periods (47–661 min) and CV subclasses (dwarf novae, nova-like variables, polars, intermediate polars, AM CVn systems). This underlines the fact that the observed abundance anomalies are likely to be related to a general evolutionary effect rather than to the specific properties of a small subgroup of CVs.

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