Observational population studies of cataclysmic variables -
The golden era of surveys

B. T. G"ansicke

Department of Physics, University of Warwick, CV4 7AL Coventry, UK

Abstract. We review the properties of the currently known CV population from an accountants point of view. In particular, it is examined to what extent different selection mechanisms (variability, X-ray emission, colours, spectroscopic properties) affect the observed CV orbital period distribution. Large-scale surveys provide homogeneously selected CV samples, for which observational biases can in principle be modelled. Such samples will eventually provide the essential observational input for an improved understanding of CV evolution, and we highlight the impact of several completed and on-going surveys.

1. Introduction

Historically, cataclysmic variables (CVs) were discovered because of their variability, predominantly being large-amplitude variables such as dwarf novae or classical novae, e.g. U Geminorum (Hind 1856), but also some irregular low-amplitude systems such as the polar prototype AM Herculis (Wolf 1924). In 20th century, the rate of discovery of CVs was rather slow until the mid-seventies, Warner (1976) discussed the properties of some 27 systems with known orbital periods, and noted the following points: a strong preference for short-period CVs and a deficiency of CVs in the orbital period range 1.5 – 3.25 h. It became rapidly clear that the orbital period distribution of CVs is closely related to the evolution of these systems, more specifically to the rate at which CVs lose orbital angular momentum (e.g. Eggleton 1976). To our knowledge, the first orbital period histogram was published by Whyte & Eggleton (1980), based on data for 33 CVs, clearly showing the presence of a “period gap” between 2 – 3 h. Both the number of discovered CVs and the amount of detailed follow-up studies have rapidly increased since 1980, stimulating growing activity on the topic of CV evolution. Disrupted magnetic braking became the standard scenario of CV evolution explaining the presence of the period gap in the context of an abrupt change in the rate of orbital angular momentum loss at $P_{\text{orb}} \approx 3$ h (Rappaport et al. 1983; Paczyński & Sienkiewicz 1983; Spruit & Ritter 1983; see also King 1988; Howell et al. 2001).

While no globally accepted alternative to the standard model exists so far, it has been criticised on the base that (a) many of its predictions are in disagreement with the observations and (b) it is based on an ad-hoc assumption about the mechanism of orbital angular momentum loss. The unset-tled nature of the field of CV evolution is reflected in the number of alternatives/modifications to the standard model that have been published in the recent years (e.g. Clemens et al. 1998; McCormick & Frank 1998; Schenker et al. 1998;
Figure 1.  Left: The distribution of the known CVs from Downes et al. (2001) in galactic coordinates. The galactic centre wraps around at the right/left edge of the plot; the solid line indicates declination $\delta = 0$. CVs with a known orbital period are shown as black dots, those without as grey dots. Right: The period distribution of the 531 CVs listed by Ritter & Kolb (2003), V7.3. The 2 – 3 h period gap is indicated in grey.

Kolb & Baraffe 1999; Spruit & Taam 2001; Taam & Spruit 2001; Kolb et al. 2001; King et al. 2002; King & Schenker 2002; Schenker & King 2002; Schenker et al. 2002; Andronov et al. 2003; Barker & Kolb 2003; Taam et al. 2003; Ivanova & Taam 2004).

The purpose of this paper is to review the properties of the known CV population that currently provides the observational input for CV evolution theory, and to assess the impact that several large-scale surveys had/have on this field.

2. The known population of CVs

The known population of CVs comprises 531 systems with a known orbital period (Ritter & Kolb 2003, V7.3). Qualitatively, the main features of this period distribution (Fig. 1) are a sharp cut-off at $\simeq 80$ min$^4$, a deficit of systems in the gap ($\sim 10\%$ of all CV are have orbital periods in the gap), and a steady drop-off in numbers towards longer orbital periods.

The importance of observational selection effects became apparent, at the latest, with the advent of X-ray satellites. Until the mid-seventies CVs were divided into dwarf novae, novae, and nova-like variables. The discovery of the variable star AM Herculis being both a strong X-ray source and a strongly magnetic star (Hearn et al. 1976; Berg & Duthie 1977; Tapia 1977) added a whole new aspect to CV research. This illustrates that using the properties of ob-

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1 Only two CVs with hydrogen-rich donors are known at shorter orbital periods (EIPsc, $P_{orb} = 64.2$ min, Thorstensen et al. 2002; V485 Cen, $P_{orb} = 59.0$ min, Augusteijn et al. 1994), which are likely to have evolved through a phase of thermal-timescale mass transfer (Gänsicke et al. 2003) – the other ultrashort-period systems have degenerate helium-donors (AM CVn stars, see Nelemans this volume).
served CVs to develop the theory of CV evolution is a risky business unless the observational biases are fully understood.

Practically all CVs have been discovered using one of the four following criteria: variability, X-ray emission, peculiar colours (usually meaning blue), and spectroscopic properties (composite spectra, emission lines). Dividing the known CVs into four subclasses according to the method of their discovery results in Fig. 2. In numbers, 270 CVs were discovered by variability, 121 by X-ray emission, 91 by colour, and 43 by spectroscopy. The variable CVs are predominantly (86%) dwarf/classical novae, the X-ray CVs comprise 57% magnetic systems, 43% of the colour-selected CVs are novalike variables, and the spectroscopically selected CVs show no preference for CV subtype. It is comforting to see that the defining features of CV evolution, period gap and period minimum, are apparently present in all four subsamples. Interesting features are the double-peaked distribution of short-period variable CVs, and the “spike” near four hours in the period distribution of colour-selected CVs. However, great care has to be taken when interpreting such features, compare e.g. Hameury et al.’s (1990) prediction with the present-day period distribution of polars with Fig. 2.

Figure 3 shows the period distribution divided by the degree of white dwarf magnetism. It has been thoroughly discussed whether magnetic/non-magnetic CVs evolve in the same way (e.g. Wickramasinghe & Wu 1994), and differences in their evolution are expected to result in different period distributions. Judging by eye, one would be prone to suggest that the period gap is most clearly pronounced for the non-magnetic dwarf novae/novalike variables, and that the presence of a gap is not clearly evident for the magnetic CVs. However, comparing the cumulative distributions of different CV sub-samples based on a two-sided Kolmogorov-Smirnov test gives a significantly low probability for identical
parent CV populations (0.5%) only if SW Sex stars are included in the category of magnetic CVs. All other reasonable permutations of CV subclasses result in probabilities for identical parent populations of 16% to 48%. It is hence of great importance to answer the question whether SW Sex stars are magnetic or not (e.g. Rodríguez-Gil et al. 2001; Hameury & Lasota 2002).

In summary, the interpretation of the overall CV period distribution and those of different subpopulations in terms of CV evolution is tempting, but despite the substantial observational efforts invested over the last three decades, the number of known and well-studied systems is still too small for a solid statistical assessment.

3. The Palomar-Green survey

The photographic $U$ and $B$ Palomar-Green (PG) survey was carried out using the Palomar 18′′ (46 cm) Schmidt telescope and covered 10714 deg$^2$ at galactic latitudes $|b| > 30^\circ$ and declinations $\delta > -10^\circ$ with a limiting magnitude $15.5 \lesssim B \lesssim 16.7$ (Green et al. 1986). Classification spectroscopy was obtained for 1878 blue objects with $U - B < -0.46$, resulting in a list of $\approx 80$ CV candidates. Intensive follow-up studies resulted in the identification of 31 new CVs (see Ringwald 1993, 1996, and references therein). In addition to these new discoveries, the PG CV sample contains 4 previously known CVs. The distribution of the PG CVs in galactic coordinates, as well as their orbital period distribution are shown in Fig. 4. Overall, the PG CV period distribution is similar to that of the entire observed CV population (Fig. 1).

Closer inspection of the PG CVs revealed a group of stars that Thorstensen et al. (1991) coined as a class of cataclysmic binaries with mysterious, but consistent, behaviour: the SW Sextantis stars, with famous founding members being SW Sex, DW UMa, PX And, and V1315 Aql. Among the defining characteristics of these objects are that the vast majority of them have orbital periods in the...
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Figure 4. **Left:** The distribution of CVs (black dots) from the Palomar Green survey in galactic coordinates. The area covered by the survey is indicated in grey. **Right:** Orbital period distribution of the PG CVs. The period gap is indicated in light grey, previously known systems are shown in dark grey, new discoveries in white. Tick marks above the histogram indicate the individual periods of the PG CVs.

range $3 - 4\,\text{h}$, they all have high inclinations$^2$, they display single-peaked Balmer and He I emission lines which suffer from transient orbital phase-dependent absorption in the line cores, moderately strong emission of He II $\lambda 4686$, and the radial velocities measured from the emission lines are offset by large degrees with respect to the expected motion of the white dwarf. All these features are very difficult to understand within the “standard” cartoon of disc-accreting CVs. Despite intensive efforts, most of the SW Sex behaviour is still mysterious, and the growing number of these systems (see Sect. 6 below) strongly suggests that these objects represent rather the norm than the exception in the $3 - 4\,\text{h}$ period range.

Another species of CVs firstly identified in the PG survey are a number of short-period SU UMa dwarf novae that have very short and coherent super-cycle periods, such as RZ LMi, ER UMa and V1159 Ori (Robertson et al. 1995). The frequent outbursts suggest that these systems have, despite their short orbital periods, rather high mass transfer rates.

4. CVs discovered by ROSAT

The ROSAT/PSPC all sky survey was the first imaging survey in soft X-rays ($0.1 - 2.4\,\text{keV}$), and resulted in the identification of 105 924 X-ray sources (Voges et al. 1999, 2000). Additional X-ray sources were detected in the WFC survey (Pounds et al. 1993; Pye et al. 1995), as well as in pointed PSPC and HRI observations. As already outlined in Sect. 2, polars and intermediate polars (IPs) are the most prominent X-ray emitters amongst CVs, and consequently the ROSAT mission

$^2$In fact, 75% are eclipsing. This is obviously a selection effect, implying that a substantial number of CVs with intrinsically similar properties, but low inclinations have not yet been recognised as SW Sex stars.
has had a huge impact on the statistics of magnetic CVs, doubling the number of known systems (Haberl & Motch 1995; Beuermann et al. 1999; Thomas et al. 1998). However, also a substantial number of non-magnetic CVs were identified during follow-up studies of ROSAT sources, such as the optically very bright \((V \simeq 12.6)\) CV RX J1643.7+3402 (Mickaelian et al. 2002), with the total of ROSAT-lead CV discoveries exceeding 100. Figure 5 shows the orbital period distribution of 69 ROSAT CVs for which follow-up studies have been carried out.

Among the potentially most important discoveries made by ROSAT are the two ultra-short period systems RX J0806.3+1527 (\(P_{\text{orb}} = 321\) s, Burwitz & Reinsch 2001; Ramsay et al. 2002) and V407 Vul = RX J1914.4+2456 (\(P_{\text{orb}} = 569\) s, Haberl & Motch 1995; Cropper et al. 1998), which are thought to be double-degenerate CVs. If these periods should be confirmed to be the orbital periods, these systems would be the shortest period binaries known, and represent excellent candidates for the detection of gravitational waves.

5. The Edinburgh-Cape survey

The Edinburgh-Cape survey has been very similar to the Palomar-Green survey (Sect. 3) in scope and specifications. The imaging survey was carried out using the 1.2 m UK Schmidt telescope at the AAO, obtaining \(U\) and \(B\) photographic plates with a limiting magnitude of \(B \simeq 18\) and covering \(|b| > 30^\circ, \delta < 0^\circ\); spectroscopic and photometric follow-up observations have been obtained at SAAO for objects with \(U - B < -0.4\) and \(B \lesssim 16.5\) (Stobie et al. 1997; Kilkenny et al. 1997). A total of 27 CVs are contained in the EC survey, of which 15 new discoveries (Chen et al. 2001). Period determinations exist so far for about half of the new systems (Fig. 6).

It is intriguing that most of the EC CVs with a measured orbital period are found near \(3 - 4\) h, i.e. the range where the PG survey established SW Sextantis stars as a homogeneous class of objects (Sect. 3). It is not yet clear how many of the EC CVs may share the defining properties of the SW Sex stars.
An object of particular interest that has emerged from the EC survey is the eclipsing detached white dwarf/red dwarf binary EC13471–1258. O’Donoghue et al. (2003) presented a very detailed follow-up analysis of this object, which suggests that its donor star is very close to being Roche-lobe filling, and that the white dwarf is rotating fairly rapidly. Combining both pieces of evidence, O’Donoghue et al. (2003) suggested that EC13471–1258 may be a hibernating CV. Confirming this hypothesis would be extremely important in the context of Shara et al.’s (1986) nova hibernation scenario.

6. The Hamburg Quasar Survey

The Hamburg Quasar Survey (HQS) is an objective prism Schmidt survey carried out with the 80 cm Schmidt telescope at Calar Alto, covering $\approx 13,600$ deg$^2$ at $|b| > 20^\circ$ and $\delta > 0^\circ$ with a limiting magnitude of $17.5 \lesssim B \lesssim 18.5$ (Hagen et al. 1995). The spectral range covered by the photographic plates is $\approx 3400 – 5400$ Å, and all fields were observed at least twice to allow the investigation of variability. Gänsicke et al. (2002a) selected CV candidates from the HQS based on (1) the detection of Balmer line emission and (2) blue colour plus variability. Identification spectroscopy of these candidates, primarily carried out using the Calar Alto 2.2 m telescope, led to the identification of 53 new CVs. Gänsicke et al. (2002a) carefully investigated the CV detection efficiency of the HQS as well as possible selection effects using 84 previously known CVs contained in the survey, and found that the applied selection criteria recover $\approx 90\%$ of the known short-period ($P_{\text{orb}} < 2$ h) CVs. This fraction drops to $\approx 40\%$ above the period gap, as many disc-dominated long-period CVs have weak or no Balmer emission. A conservative estimate of the completeness is that the HQS allows to identify all CVs with $B \lesssim 16.5$ and an H$_\beta$ equivalent width $\gtrsim 10$ Å. So far the periods of 40 new HQS CVs have been measured (Fig. 7), follow-up studies of the remaining 13 systems are underway. Whereas the period distri-
Figure 7. Left: Galactic distribution of CVs from the Hamburg Quasar Survey. Right: Orbital period distribution of the HQS CVs. See Fig. 4 for details.

bution of the HQS CVs is still somewhat preliminary, with 25% of the new CVs lacking a $P_{\text{orb}}$ measurement, it is worth to note the following points.

1. Only relatively few new CVs have been found below the gap, despite the fact that Gänscike et al. (2002a) convincingly demonstrated that the applied selection criteria are most efficient for short-period CVs. This clearly implies that most of the short-period CVs in the parameter space covered by the HQS (sky area, magnitude range, Balmer line equivalent width) have been previously identified, either because of their outbursts (dwarf novae) or their X-ray emission (polars). In fact, most of the new dwarf novae discovered in the HQS have rather long outburst intervals, e.g. the SU UMa systems KV Dra = HS 1449+6415 (Nogami et al. 2000), HS 2219+1824 (Rodríguez-Gil et al. 2004c), or the deeply eclipsing $P_{\text{orb}} = 4.2$ h dwarf nova GY Cnc = HS 0907 +1902 (Gänscike et al. 2000). The shortest-period CV from the HQS, HS 2331 +3905, had no recorded outburst so far, resembling in many other aspects the (in)famous WZ Sge (Araujo-Betancor et al. 2004).

2. A very large number of CVs is found with orbital periods in the range 3 – 4 h (Aungwerojwit et al. this volume; Rodríguez-Gil this volume), of which a large fraction are SW Sextantis stars. This includes four previously known systems (PX And, BH Lyn, WX Ari, and LX Ser), and 7 new discoveries, HS 0357 +0614 = KUV 03580+0614 (Szokody et al. 2001), HS 0455+8315 (Gänscike et al. 2002c), HS 0551+7241 (Dobrzycka et al. 1998), HS 0728+6738 (Rodríguez-Gil et al. 2004b), HS 0129+2933, HS 0220+0603, and HS 1813+6122 (Rodríguez-Gil, this volume). The large number of new SW Sex stars found in the HQS (25% of the whole class) is compatible with the properties of these objects: while they have relatively strong emission lines, they are weak X-ray emitters, and exhibit only moderate variability, making them inconspicuous for the two most widely used discovery mechanisms. Whereas the PG survey already suggested that SW Sex stars may be fairly common, our follow-up work on HQS CVs clearly demonstrates that SW Sex stars are the dominant species of systems in the 3 – 4 h period range. The nature of the SW Sex stars is still intensively debated (e.g. Hoard et al. 2003). A number of arguments indicate that these systems have mass transfer rates well in excess of those predicted by angular momen-
tum loss through magnetic braking (e.g., the very hot white dwarf primaries found in SW Sex stars, Araújo-Betancor et al. 2003b), and it has been proposed that they may contain weakly magnetic white dwarfs (Rodríguez-Gil et al. 2001; Hameury & Lasota 2002). Investigating in detail the properties of all CVs in the 3–4 h period range appears now to be a key project for our overall understanding of CV evolution.

The HQS has turned out to be efficient in adding new members to the small class of IPs, too, which also do not display large-amplitude variability. Specifically, we have identified HS 0618+7336 = 1RXS J062518.2+733433 as a rather “normal” IP \((P_{\text{orb}} = 283 \text{ min}, P_{\text{spin}} = 19.8 \text{ min})\); Araújo-Betancor et al. 2003a), HS 0756+1624 = DW Cnc as one of the few short-period IPs, very similar to V1025 Cen \((P_{\text{orb}} = 86.1 \text{ min}, P_{\text{spin}} = 38.6 \text{ min})\); Rodríguez-Gil et al. 2004a), and an unusual long-period IP \((P_{\text{orb}} = 265 \text{ min}, P_{\text{spin}} = 69.2 \text{ min})\); Rodríguez-Gil et al. in prep).

As with the other surveys mentioned so far, also the HQS has unearthed a peculiar group of systems, the magnetic white dwarf/red dwarf binaries HS 1023 +3900 = WXLMi (Reimers et al. 1999) and HS 0922+1333 (Reimers & Hager 2000). Spectroscopically, these systems are characterised by a very cold white dwarf, a late-type stellar companion, and extremely strong and sharp cyclotron emission lines arising from an accretion shock close to the white dwarf surface. Contrary to all other known polars, these systems have never been found in a state of high mass transfer, and were consequently named low accretion rate polars. Additional systems of this kind were identified in the SDSS (Sect. 5), and it may well be that these objects are not CVs, but pre-polars, with the white dwarf accreting from the wind of the donor star (see Schmidt this volume; Webbing this volume).

Finally, two extremely interesting objects have recently been discovered in the HQS. The detached white dwarf/red dwarf binary HS 2237+8154 resembles EC 13471–1258 discussed in Sect. 5 in that its donor star is almost Roche-lobe filling. In addition, it contains a very cold/old white dwarf, and its orbital period is 178 min, just at the upper edge of the period gap. Gansicke et al. (2004) suggest three alternative evolutionary states for the system, being a pre-CV
shortly before the start of mass transfer, a CV that has stopped mass transfer and is entering the period gap, or, in analogy to EC 13471–1258, a hibernating nova. HS 2331+3905 is probably the most complex CV found to date (Araujo-Betancor et al. 2004). It contains a cold white dwarf and most likely a brown dwarf donor, and shows all signs of an extremely low mass transfer rate. The system is eclipsing with a period of 81 min, but also displays a photometric period of 83.4 min which we interpret as a permanent superhump. HS 2331+3905 is the brightest CV where a pulsating white dwarf, which is also very likely a rapid rotator, was found. Most exotically, however, is the presence of a large-amplitude radial velocity variation in the emission line wings with a period of 3.5 h, which is in no way commensurate with the orbital period, and which may be related to a precessing warped inner disc.

7. The 2dF Quasar Survey

The 2dF Quasar Survey (2QZ) is a spectroscopic survey of colour-selected quasar candidates with $18.4 < B < 20.9$ using the AAT/2dF and covering $740 \, \text{deg}^2$. The candidates were selected by $U - B < 0.36$ on UKST photographic plates, cutting out the main sequence (Boyle et al. 2000). The total spectroscopic data base comprises some 48 000 spectra. 21 new CVs were identified so far, and Marsh et al. (2002) reported first follow-up studies (see Fig. 8). The 2QZ CVs represent the faintest CV sample obtained so far.

8. The Sloan Digital Sky Survey

The Sloan Digital Sky Survey (SDSS) is by far the largest of the surveys described in this paper. It is carried out using a purpose-built 2.5 m telescope in New Mexico, and has been designed to obtain deep ($g < 23$) imaging in five broad-band filters and spectroscopy of $\sim 10^6$ colour-selected objects with a limiting magnitude of $g \simeq 20$ at $|b| > 30^\circ$ (York et al. 2000). The main purpose of the SDSS is to obtain an enormous photometric and spectroscopic data base of galaxies and quasars. QSO candidates for the spectroscopy are selected by excluding main sequence stars, white dwarfs, and white dwarf/red dwarf binaries in the four-dimensional ($u - g$, $g - r$, $r - i$, $i - z$) colour space (Richards et al. 2002). For the discovery of CVs, this broad selection represents an enormous progress over the earlier “blue-only” surveys, such as the PG survey (Sect. 3), and the SDSS CVs will represent the most unbiased sample obtained so far. At the time of writing, the third data release (DR3) has been made public, which provides imaging data for $5282 \, \text{deg}^2$ and spectroscopy for $528640$ objects (Abazajian et al. 2004). SDSS up to DR3 has resulted in the spectroscopic identification of 131 CVs, of which 113 are new discoveries (Szkody et al. 2002, 2003, 2004, Szkody priv. comm.)\(^3\). The broad colour range covered by SDSS is reflected in the very broad variety of subtypes among the SDSS CVs.

\(^3\)Two further SDSS data releases are planned, and the total number of SDSS CVs is expected to be $\simeq 200$. Alas, by the time that the funding for SDSS ends (July 2005), the covered survey area will substantially fall short of the planned $10000 \, \text{deg}^2$.\(^2\)
So far, period measurements are available only for $\sim 30\%$ of the new SDSS CVs (Fig. 9), and no firm conclusions should be drawn at this point, but it appears that the period distribution of the SDSS CV sample differs dramatically from that of the presently known mixed bag of CVs (Fig. 1) – it is strongly concentrated towards periods below the gap, and the gap itself is not very pronounced. This dominant number of short-period CVs is likely to prevail when more periods are determined, as the faint end of the SDSS CV sample has not yet been explored, and these systems are most likely intrinsically faint low-mass transfer systems. A substantial number of the SDSS CVs clearly exhibit the Balmer lines of the white dwarf accretor, and fitting those spectra with model atmospheres suggests low effective temperatures around 11,000 K (Fig. 10), implying very low secular mean mass transfer rates (Townsley & Bildsten 2002). Whereas in CVs white dwarf temperature determinations from optical data alone are prone to some uncertainties (because of the contamination by the disc/hot spot), low white dwarf temperatures are independently suggested by the fact that several of the SDSS CVs have been found to contain pulsating ZZ Ceti white dwarfs (e.g. Woudt & Warner 2004). Low mass transfer rates are also indicated by the absence of observed outbursts in most of the white dwarf dominated systems. Combining all available evidence, it appears that SDSS may be finding the missing population of old, low-luminosity short period CVs. Establishing the properties of the complete SDSS CV sample is of outmost importance for testing and improving our understanding of CV evolution, but will require massive observational effort. A first step towards this goal has been the award

\footnote{In fact, these low-luminosity SDSS CVs may represent just the tip of the iceberg. The sample of single white dwarfs for which SDSS spectroscopy has been obtained shows a sharp cut-off for $T_{\text{eff}} \lesssim 10,000$ K (Kleinman et al. 2004), which is a clear bias in the target selection of the SDSS spectroscopy. If the majority of CVs are post-period minimum systems, accretion heating may not be sufficient to keep their white dwarfs hot enough to be targeted by SDSS. It is important to realise that while the SDSS discovered low-luminosity CVs seem to match the predicted properties for old CVs near the minimum period, their number still falls significantly short with respect to the predicted space density: none of them is within $d \lesssim 100$ pc.}
of the International Time 2004/5 on La Palma for follow-up studies of SDSS CVs (PI Gänsicke).

9. Other surveys of interest

A number of additional surveys have led to the discovery of CVs, and we can give here merely a brief and incomplete list. The First and Second Byurakan Survey (Stepanian et al. 1999) were objective prism surveys similar to the HQS (Sect. 6.), resulting in the discovery of \( \sim 20 \) CVs and CV candidates. However, almost no detailed follow-up studies have been carried out with the exception of the IP DW Cnc, independently discovered in the HQS (Rodríguez-Gil et al. 2004a). The Calán-Tololo survey has been another objective prism survey, carried out in the southern hemisphere, leading to the identification of 16 new CVs, with the first follow-up results just being published (Tappert et al. 2004). Finally, the Hamburg-ESO survey (Wisotzki et al. 1996), a southern twin of the HQS, could potentially lead to the discovery of a substantial number of new southern declination CVs, but so far just a single new system has been reported BW Scl = HE2350–3950 (Augusteijn & Wisotzki 1997).

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Figure 10. A substantial number of the SDSS CVs are low mass transfer systems where the white dwarf is detected in the optical spectrum. Fitting the SDSS spectra with white dwarf models (Gänsicke et al. 1995) results in \( T_{\text{eff}} \approx 10500 \text{K} \). Four examples are shown on the left, from top to bottom: SDSS1238–0339, SDSS0131–0901, SDSS0904+0355, and SDSS1610+4459.
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