Old novae and the SW Sex phenomenon

Linda Schmidtobreick and Claus Tappert

1 European Southern Observatory, Casilla 19001, Santiago 19, Chile
2 Departamento de Física y Astronomía, Universidad de Valparaíso, Avda. Gran Bretaña 1112, Valparaíso, Chile

Abstract. From a large observing campaign, we found that nearly all non- or weakly magnetic cataclysmic variables (CVs) in the orbital period range between 2.8 and 4 hours are of SW Sex type and as such experience very high mass transfer rates. The exceptions seem to be some old novae that have periods around 3.5 h. Their spectra do not show the typical SW Sex characteristics but rather resemble those of dwarf novae with low mass transfer rates.

The presence of old novae in this period range of SW Sex stars that do not follow the trend but show instead rather low mass transfer rates is interpreted as evidence for an effect of the nova eruption on the mass transfer rate of the underlying CV similar to the hibernation scenario.

1. SW Sextantis stars

The sub-class of SW Sextantis stars were originally defined by Thorstensen et al. (1991) as eclipsing nova-like stars which however show single-peak emission lines with high velocity line wings, strong He II emission but no polarisation, and transient absorption features in the emission lines at an orbital phase of $\phi = 0.5$. A distinctive feature that was later attributed to SW Sex stars is the orbital phase offset of 0.2 cycles of the radial velocity curves with respect to the photometric ephemeris. In general, SW Sex stars are considered novalikes with an extremely high mass transfer rate (see e.g. Rodríguez-Gil et al. 2007a). This idea is supported by the temperature of the white dwarfs in these systems which exceed the the expected value for accretion governed by an angular momentum loss from standard magnetic braking (Townsley & Gänsicke 2009).

At the beginning, few SW Sex stars were known and they were considered as strange objects with unusual behaviour. However, Gänsicke (2005) compared the results of various CV surveys and showed that SW Sex stars are common in the orbital period range between 2.8 and 4 h which is right at the upper edge of the period gap. He found that in particular all the eclipsing nova-like systems in this period range belong to the sub-class of SW Sex stars.

Since being an eclipsing system is no intrinsic physical property of the star but rather depends on the angle under which the binary is seen, it is entirely plausible that all non- or weakly-magnetic CVs just above the period gap are physically similar to the SW Sex stars, and in particular experience a very high mass transfer rate. We have thus conducted a survey to test this idea by performing time-series spectroscopy for non-
Figure 1. Optical spectra of the four low mass system candidates among our old nova sample: a) V842 Cen, b) V2109 Oph, c) V728 Sco, d) XX Tau. The plots have been taken from Schmidtobreick et al. (2005) (a,d) and Tappert et al. (2012) (b,c).

eclipsing CVs in the 2.8–4 h period range (Rodríguez-Gil et al. 2007b, Schmidtobreick et al. in preparation). We checked for the presence of defining SW Sex characteristics like broad line wings with large-amplitude radial velocity variations, single-peaked line profiles with phase-dependent central absorption, and phase lags between the radial velocity modulation in the line cores and wings. Our main result is that indeed the majority of the observed CVs in the 2.8–4 h period range are of SW Sex type and can thus be considered as high mass transfer systems. This suggests that SW Sex stars actually represent a stage in the secular evolution of CVs and that CVs reaching the 2.8–4 h period range will then share the SW Sex characteristics (Schmidtobreick et al. in preparation).

2. Old novae with low mass transfer rates

Nova eruptions can occur for every CV assuming that the mass-transfer rate is high enough to accumulate the necessary amount of material on the surface of the white dwarf (Iben et al. 1992). As the effects of the nova eruption disappear, the behaviour of the CV depends once again on its properties like orbital period, mass-transfer rate, and magnetic field that also determine its position among the various subtypes of CVs.

In addition, the hibernation model predicts changes of the mass transfer rate in the evolution of the pre- and post-nova, i.e. a long state of low mass transfer once the white dwarf has cooled down and irradiation ceases to push the secondary out of thermal equilibrium (Shara et al. 1986, Prialnik & Shara 1986). It was originally invoked
Table 1. The four low mass transfer candidates among the old novae and possible values for their orbital period.

| System      | $P_{\text{orb}}$ [h] | comments                                                                 |
|-------------|-----------------------|--------------------------------------------------------------------------|
| V842 Cen    | 3.94 or 3.79          | two possible values from high-speed photometry (Woudt et al. 2009)       |
|             | 3.51                  | periodicity in x-ray photometry (Luna et al. 2012)                       |
| V2109 Oph   | -                     | eclipse measurements (Tappert et al. 2013)                              |
| V728 Sco    | 3.32                  | orbital or superhump period from time-resolved photometry (Rodríguez-Gil & Torres 2005) |
| XX Tau      | 3.26                  |                                                                          |

to explain the missing CV population at minimum orbital period. However, recent surveys like SDSS and CSS have shown that this is an observational bias, so in principle, hibernation is no longer needed. Still, the theoretical arguments for the occurrence of hibernation are valid and it thus seems likely that some kind of hibernation occurs. Unambiguous observational evidence, however, is still missing.

Some new input to the discussion on old novae with low mass transfer rates came from the discovery of nova shells around Z Cam (Shara et al. 2007) and AT Cnc (Shara et al. 2012), both CVs that were known as dwarf novae with no nova outburst recorded. While the existence of such systems could be taken as evidence for hibernation, it could also be interpreted in the way that all type of CVs (including low mass transfer dwarf novae) can experience the one or other nova explosion during their lifetime without necessarily undergoing cyclic changes of CV-class.

Several years ago, we conducted a project investigating old novae which had experienced large outburst amplitudes (Schmidtobreick et al. 2005, 2003). The idea behind this was that since the absolute magnitude of a nova explosion depends mainly on the mass of the white dwarf (Livio 1992) and thus differs only slightly for different systems, novae with large outburst amplitudes are intrinsically faint CVs and therefore likely candidates for low mass transfer systems. Spectroscopic observations seemed to confirm the low mass transfer status of two of the systems from our sample: V842 Cen and XX Tau. A recent approach by Tappert et al. (2012) to re-discover lost old novae revealed two more candidates: V2109 Oph and V728 Sco. In particular V728 Sco which has also been observed photometrically can be considered a low mass transfer system which shows frequent stunted dwarf novae outbursts (Tappert et al. 2013, and also this conference). The various attempts to determine the orbital periods of these low mass transfer candidates are listed in Table 1.

3. Combining the information of SW Sex and old novae

In Fig. 2, the orbital period distribution of CVs is given for different classes of non- or weakly magnetic CVs as defined in Ritter & Kolb (2003) (update RKcat7.18, 2012). The position of the period gap and the location of the SW Sex regime are indicated. The lack of dwarf novae below 3.8 h and the peak of high mass transfer systems in the same area are evident.

In this context, it appears interesting that the possible orbital periods of the three low mass transfer old novae with confirmed periodicities (see Table 1) seem to lie in
the 2.8-4 h period range which is the regime of the SW Sex stars. It is not particularly surprising to find the majority of the old novae clustered in this period range since due to the high mass transfer rate of the CVs in this range their recurrence time is lower and therefore they are more likely to be observed as a novae (Iben et al. 1992). However, these three old novae are observed as low mass transfer systems!

The observations therefore seem to indicate that these three systems are indeed SW Sex stars which due to the nova explosion in the recent past were pushed into a low state and thus experience low mass transfer rates at the moment. This scenario is supported by the likeliness of the eclipse light curve of V728 Sco during an outburst with the eclipse lightcurves of SW Sex stars as was pointed out by C. Knigge during the discussion of C. Tappert’s talk of this conference.

4. Conclusions

The finding of several old novae with currently low mass transfers in a period range that is generally populated by high mass transfer systems is interpreted as evidence that the nova eruption has some effect on the mass transfer rate similar to what Shara et al. proposed for the hibernation scenario. Whether the mass transfer in these hibernating systems will completely cease or just remains on a low level before rising up again remains to be investigated.

In any case, the few low mass transfer systems in the 2.8-4 h period range (see Fig. 2) that were not observed as novae but are classified as dwarf novae, seem to be
Old novae and the SW Sex phenomenon

good candidates to search for indications of nova eruptions in the past, i.e. shells as
observed around Z Cam and AT Cnc.

Acknowledgments. This research was supported by FONDECYT Regular grant
1120338 (CT). We gratefully acknowledge the use of the SIMBAD database, operated
at CDS, Strasbourg, France, and of NASA’s Astrophysics Data System Bibliographic
Services.

References

Gänsicke, B. T. 2005, in The Astrophysics of Cataclysmic Variables and Related Objects, edited
by J.-M. Hameury, & J.-P. Lasota, ASP Conf. Ser. 330, 3.
Iben, J., I., Fujimoto, M. Y., & Macdonald, J. 1992, ApJ, 388, 521.
Livio, M. 1992, in Vina del Mar Workshop on Cataclysmic Variable Stars, edited by N. Vogt,
ASP Conf. Ser. 29, 4.
Luna, G. J. M., Diaz, M. P., Brickhouse, N. S., & Moraes, M. 2012, MNRAS, 423, L75.
Prialnik, D., & Shara, M. M. 1986, ApJ, 311, 172.
Ritter, H., & Kolb, U. 2003, A&A, 404, 301.
Rodríguez-Gil, P., Gänsicke, B. T., Hagen, H.-J., Araujo-Betancor, S., Aungwerojwit, A., & et
al. 2007a, MNRAS, 377, 1747
Rodríguez-Gil, P., Schmidtobreick, L., & Gänsicke, B. T. 2007b, MNRAS, 374, 1359.
Rodríguez-Gil, P., & Torres, M. A. P. 2005, A&A, 431, 289
Schmidtobreick, L., Tappert, C., Bianchini, A., & Mennickent, R. E. 2003, A&A, 410, 943.
— 2005, A&A, 432, 199.
Shara, M. M., Livio, M., Moffat, A. F. J., & Orio, M. 1986, ApJ, 311, 163.
Shara, M. M., Martin, C. D., Seibert, M., Rich, R. M., Salim, S., Reitzel, D., Schiminovich, D.,
Deliyannis, C. P., Sarrazine, A. R., Kulkarni, S. R., Ofek, E. O., Brosch, N., Lépine, S.,
Zurek, D., De Marco, O., & Jacoby, G. 2007, Nat, 446, 159
Shara, M. M., Mizusawa, T., Wehinger, P., Zurek, D., Martin, C. D., Neill, J. D., Forster, K., &
Seibert, M. 2012, ApJ, 758, 121.
Tappert, C., Ederoclite, A., Mennickent, R. E., Schmidtobreick, L., & Vogt, N. 2012, MNRAS,
423, 2476.
Tappert, C., Vogt, N., Schmidtobreick, L., Ederoclite, A., & Vanderbeke, J. 2013, MNRAS in
press, ArXiv e-prints. [1302.5570]
Thorstensen, J. R., Ringwald, F. A., Wade, R. A., Schmidt, G. D., & Norsworthy, J. E. 1991,
AJ, 102, 272.
Townsley, D. M., & Gänsicke, B. T. 2009, ApJ, 693, 1007
Woudt, P. A., Warner, B., Osborne, J., & Page, K. 2009, MNRAS, 395, 2177.