remain to be addressed. What is the origin and nature of the short-duration bursts? Do they produce afterglows, like the long bursts? Are all GRBs associated with a supernova, and if so, why do we rarely observe it? Is this related to the difference in collimation of the γ-rays with respect to the optical light? Are GRBs preferentially found in galaxies undergoing a starburst?

The number of GRBs with optical counterparts roughly corresponds to the number of supernovae observed before 1934, when Baade and Zwicky suggested that supernovae might be powered by the gravitational collapse to a neutron star. The collapsar model, a massive star collapsing to a black hole, has now become widely accepted to explain GRBs. But, just as Baade and Zwicky failed to anticipate Type Ia supernovae, the collapsar model, even if correct, may be incomplete. A challenging future lies ahead.

We would like to acknowledge the support which our collaboration has received from the staff at several observatories.

References

Akerlof, C., Balsano, R., Berthelemy, S., et al. 1999, *Nature* **398**, 400.
Andersen, M.I., Hjorth, J., Pedersen, H., et al. 2000, *A&A* **364**, L54.
Andersen, M.I., Hjorth, J., Gorosabel, J., et al. 2002, *A&A*, submitted.
Berger, E., Kulkarni, S.R., Frail, D.A. 2001, *ApJ* **560**, 652.
Castro Cerón, J.M., Castro-Tirado, A.J., Gorosabel, J., et al. 2002, *A&A*, in press.
Costa, E., Frontera, F., Heise, J., et al. 1997, *Nature* **387**, 783.
Eichler, D., Livio, M., Piran, T., et al. 1989, *Nature* **340**, 126.
Fynbo, J.U., Jensen, B.L., Gorosabel, J., et al. 2001, *A&A* **369**, 373.
Frail, D.A., Kulkarni, S.R., Sari, R., et al. 2001, *ApJ* **562**, L55.
Galama, T.J., Vreeswijk, P.M., Van Paradijs, J., et al. 1998, *Nature* **395**, 670.
Gorosabel, J., et al. 2002a, *A&A* **384**, 11.
Gorosabel, J., et al. 2002b, in preparation.
Greiner, J., Klose, S., Zeh, A., et al. 2001, *GCN* **1166**.
Iwamoto, K., Mazzali, P.A., Nomoto, K., et al. 1998, *Nature* **395**, 672.
Lattimer, J.M., Schramm, D.N. 1974, *ApJ* **192**, L145.
Klebesadel, R.W., Strong, I.B., Olson, R.A. 1973, *ApJ* **182**, L85.
Kouveliotou, C., Meegan, C.A., Fishman, G.J., et al. 1993, *ApJ* **413**, L101.
MacFadyen, A.I., Woosley, S.E. 1999, *ApJ* **524**, 262.
Meegan, C.A., Fishman, G.J., Wilson, R.B., et al. 1992, *Nature* **355**, 143.
Metzger, M.R., Djorgovski, S.G., Kulkarni, S.R., et al. 1997, *Nature* **387**, 878.
Paciesas, W.S., Meegan, C.A., Pendleton, G.N., et al. 1999, *ApJS* **122**, 465.
Paczynski, B. 1998, *ApJ* **454**, L45.
Pedersen, H., et al. 2000, *The Messenger* **100**, p. 32.
Salamanca, I., et al. 2002, *GCN* **1443**.
Van Paradijs, J.A., Groot, P.J., Galama, T., et al. 1997, *Nature* **386**, 686.
Vreeswijk, P.M., Fruchter, A.S., Kaper, L., et al. 2001, *ApJ* **546**, 672.
Woosley, S.E. 1993, *ApJ* **405**, 273.

Cataclysmic Variables: Gladiators in the Arena

R.E. MENNICKENT[1]*, C. TAPPERT*[1]*, M. DIAZ*[2]

[1]*Departamento de Física, Universidad de Concepción, Chile*
[2]*Instituto Astronomico e Geofisico, Universidade de São Paulo, Brazil*

1. Warriors and weapons

Life can be different for individuals growing up alone or closely interacting with members of their community. The same is true for stars, which present interesting phenomena when they are forced to evolve together in close interaction. This is the case for cataclysmic variables (CVs, Fig. 1), consisting of a red dwarf filling its Roche lobe and transferring matter onto a white-dwarf (WD) companion. If the white dwarf is a non-magnetic one, the orbiting gas interacts with itself dissipating energy by viscous forces, forming a luminous accretion disc around the white dwarf. The WD reacts by emitting X-rays and UV radiation from the region where the inner disc reaches its surface. As a result, part of the red dwarf atmosphere is irradiated and mildly heated, and possibly the upper accretion disc layers evaporated. It has been suggested that after a long-time of having accreted matter, the outer layers of the white dwarf eventually undergo a thermonuclear runaway in a so-called nova explosion.

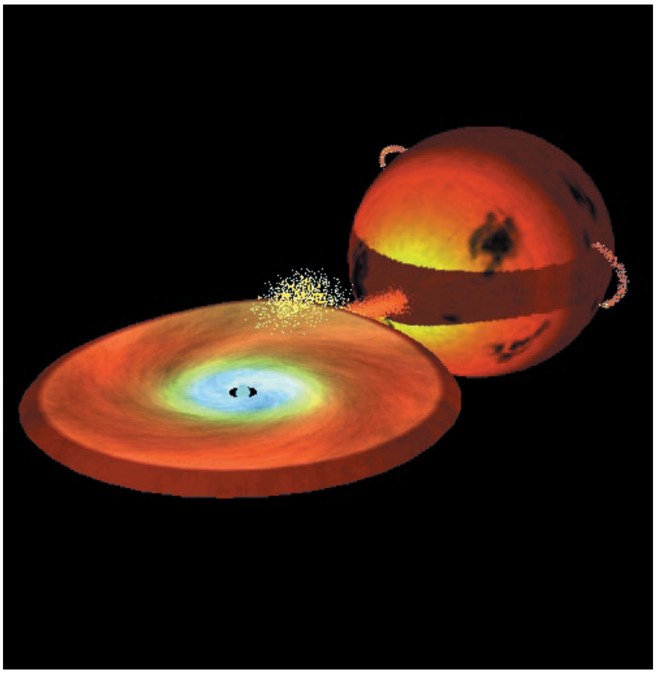

Figure 1: Computer-generated view of a cataclysmic variable star by Andrew Beardmore. The donor, usually a M-type star, transfers matter onto a white dwarf. Due to viscous forces, an accretion disc is formed. Colours represent different temperatures, from the higher (white) to the lower ones (red-black). Irradiation of the donor by the white dwarf and disc shading are also shown, as well as the hotspot in the region where the gas stream impacts the disc.

Here we present some results of our recent research in the area of dwarf novae, a subclass of cataclysmic variables showing semi-regular outbursts in time scales of days to years with typical amplitudes of 2–6 mags. The origin of these dwarf-nova outbursts is not a thermonuclear runaway as in the case of a nova outburst, but a sudden jump in disc viscosity and mass transfer rate as a result of the hydrogen ionization. In this article we do not go into deep details. Instead, we will illustrate the application of some standard techniques in the field of CVs aimed to explore disc dynamics and also to reveal the nature of the donor star. The latter point is especially important to constrain theories of CV evolution.

A typical spectrum of a dwarf nova in quiescence is shown in Figure 2. It is characterized by H I and He I emission lines. Flanking the strong Balmer emission lines we observe the gravity broadened absorption profiles typical of a white dwarf. The $H\alpha$ emission is double peaked, reflecting an origin in a rotating disc, with an equivalent width of –110 Å and half peak separation 560 km s^{-1}, whereas their full width at zero intensity is 2950 km s^{-1}. These velocities are typical for dwarf nova accretion discs and reflect the rotation of the outer and inner disc regions, respectively. The steep emission decrement suggests an origin in an optically thin accretion disc. The fact that we can observe the WD in this system suggests that the disc has a low luminosity, which should be related to a low-mass accretion rate. There is evidence that radial velocities (RVs) of the emission lines in CVs do not reflect the orbital motion too well, so most of the mass determinations for short orbital period dwarf novae available in the literature could be heavily biased. Therefore, the possibility of measuring the WD absorption RVs is very interesting, since it could be the only source of reliable stellar masses for these systems. As an example, we show in Figure 2 the radial velocities for the emission and absorption components of 1RXSJ105010.3-140431. It is clear that, whereas the emission RV reflects the large amplitude motion of the hotspot around the centre of mass, the white dwarf RVs have almost zero amplitude. This result has been interpreted as evidence for an undermassive donor star, likely in the realm of brown dwarf stars (Mennickent et al. 2001). Figure 2 also illustrates that high resolution spectrography is needed to measure the subtle motion of a white dwarf gravitationally linked to an undermassive secondary star. According to the standard CV evolution scenario (see below), we should expect many short orbital period CVs hosting brown-dwarf like secondaries. We are currently conducting a project aimed to determine the secondary mass of a sample of short orbital period CVs showing white dwarf absorptions. We will obtain radial velocities using cross-correlation in high-resolution UVES spectra.

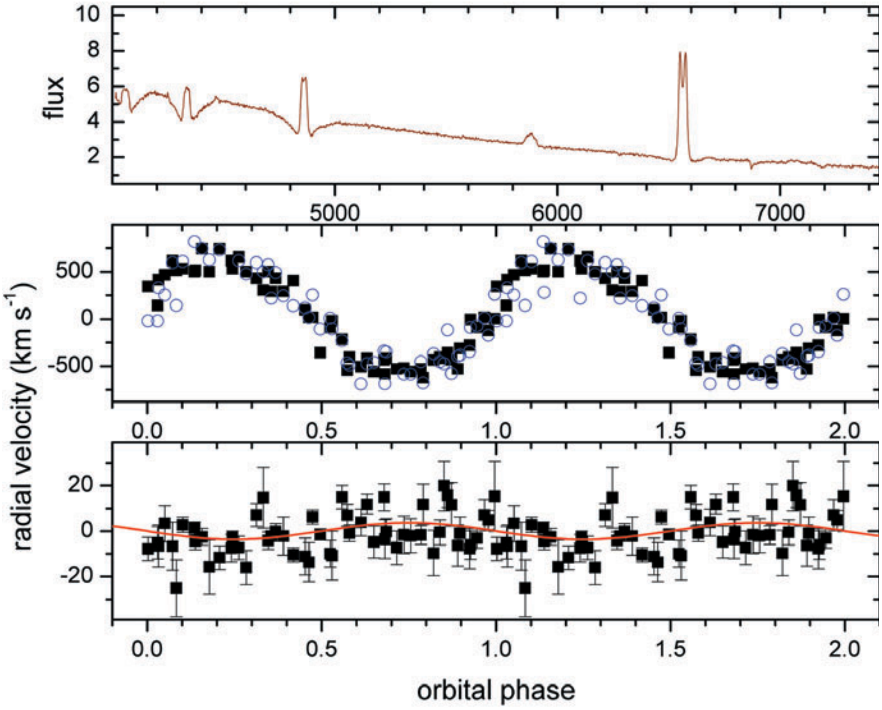

Figure 2: Upper panel: Spectrum of 1RXSJ105010.3-140431, a cataclysmic variable with a low mass accretion rate (Mennickent et al. 2001). The double emission lines in the Balmer series are formed in the accretion disc and hotspot. The flux is given in units of 10^{-16} erg s^{-1} cm^{-2} Å^{-1}, the horizontal units are in Å. Middle panel: The $H\beta$ (squares) and $H\gamma$ (circles) hotspot velocity folded with the ephemeris given by Mennickent et al. (2001). Bottom panel: The $H\gamma$ absorption line velocity (squares) obtained by cross correlation and the best sine fit. Note the different amplitude for the emission and absorption components.

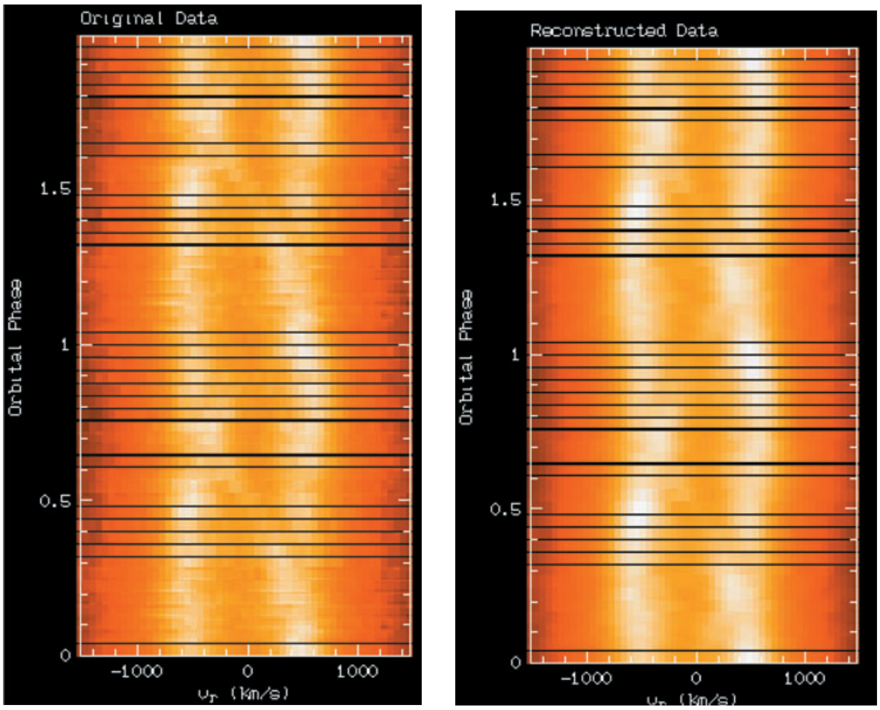

Figure 3: Left: $H\alpha$ trailed spectra of the cataclysmic variable VW Hyi. The sinusoids followed by the double emission peaks reflect the orbital motion of the disc around the binary centre of mass. The s-wave indicates the presence of an additional emission component in the system. Right: Reconstructed data from the Doppler map of Figure 4.

2. Imaging the invisible arena

In CVs, accretion onto a white dwarf releases a considerable amount of energy. This makes the accretion discs luminous, and visible at large astronomical distances, and they can be studied in some detail. CVs are ideal laboratories to study accretion-related phenomena, since their binarity and the time scales involved (much shorter than in other astronomical objects), make it possible to obtain insights into the accretion processes that drive some of the most energetic objects in the Universe.

The angular diameter of a typical CV accretion disc as seen from Earth is of the order of 10^{-4} arcseconds, too small to be resolved from Earth even with modern interferometers. It is possible however, to use indirect imaging techniques to image the accretion disc and the processes taking place in the CV.

The technique of Doppler tomography was introduced by Marsh & Horne (1988) to the realm of interacting binaries. A nice analogy useful to under-

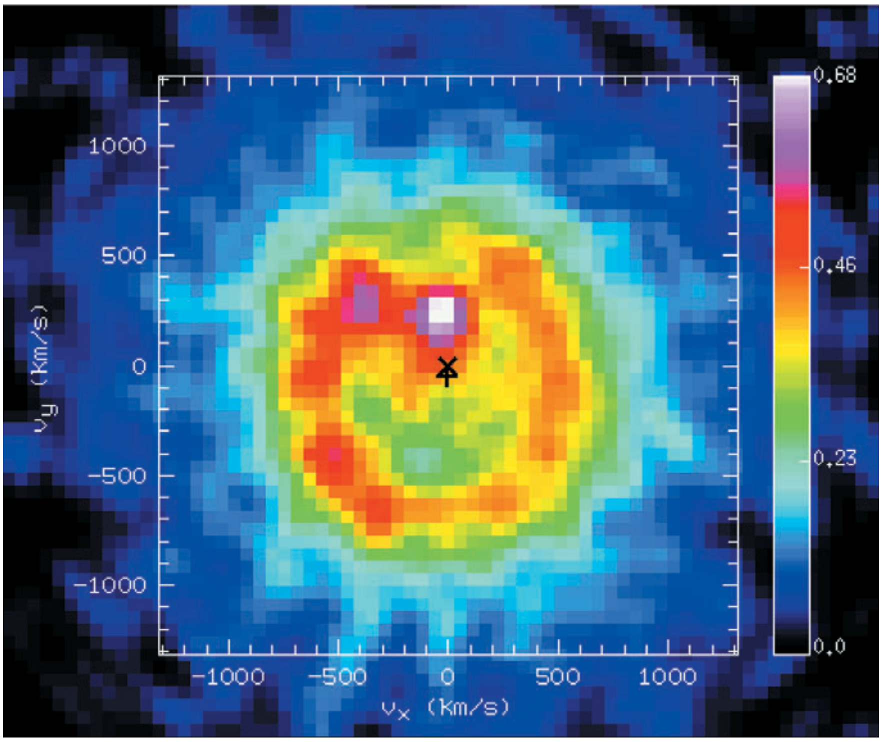

Figure 4: Doppler map of VW Hyi obtained from the data shown in Figure 3. The cross and the plus signs indicate the position of the white dwarf and the system centre of mass, respectively. The accretion disc is revealed in the donut-shaped emissivity region. The central bright spot in the upper region represents emission from the secondary star. The hotspot is also revealed in the upper left quadrant, as well as the gas stream connecting the donor and the hotspot.

stand Doppler imaging as applied in CVs comes from the field of medical diagnostics. In computer tomography, a 3-D image is reconstructed from 2-D slices obtained at different angular positions around the body. In astronomy, we cannot move the telescope around the CV, but the spinning binary does the job for us. We simply take spectra of the system at several binary phases, and then combine them in a 2-D image of the emitting region in velocity space. This can be done since optically thin accretion discs are strong line emitters, and the emission line contains information on disc emissivity projected into the line of sight. Doppler maps can be obtained for different spectral lines, yielding useful probes for the physical conditions inside the accretion disc. Doppler tomography has been successfully applied to a large number of CVs (e.g. Kaitchuck et al., 1994), and now is widely used in the area of CVs, Algols, X-ray binaries and isolated rotating stars (see a recent review in Marsh 2001). As a reminder, we list the facts regarding the interpretation of the resulting maps:

- The coordinates of the white dwarf in the map are $(v_x, v_y) = (0,-K_1)$, those of the secondary $(0,-K_2)$, with K_1 and K_2 being the respective semi-amplitudes of the radial velocity curves.
- The velocity image of the accretion disc is inverted with respect to the spatial one, as the material near the primary has high rotational velocities, and material at the outer parts of the disc rotates with lower velocities.
- A transformation of the resulting map into a spatial coordinate system is only possible if the valid velocity law is known. This is not necessarily always the case, since also emission from non-Keplerian sources is possible.

In this work, the implementation of Spruit (astro-ph/9806141) has been used to perform the Doppler tomography. We have replaced the original IDL routines by a corresponding MIDAS interface, but still use the FORTRAN core program (version 2.3.1), to run the computation on a Linux PC.

We show in Figure 3 the Hα trailed spectra of the cataclysmic variable VW Hyi. This is a rather bright southern SU UMa star with a large photometric database. However, the spectroscopic record is rather poor. The outburst recurrence time is about 27 d. We obtained 44 spectra with the EMMI spectrograph mounted at the ESO 3.5-m NTT at La Silla Observatory, on August 29, 1998. The spectra had a wavelength range of 4475–7040 Å and a spectral resolution of 2.5 Å. The sinusoids traced by the Hα double emission peaks reflect the orbital motion of the disc around the binary centre of mass. The s-wave indicates the presence of an additional emission component in the system. In Figure 4 we show the Doppler map of VW Hyi obtained from the data shown in Figure 3. The accretion disc is revealed in the donut-shaped emissivity region. The central bright spot in the upper region represents emission from the secondary star. The hotspot is detected as the second maximum in the upper left quadrant, as well as the gas stream connecting the donor and the hotspot. This is one of the few maps showing emission from all of these four components. We must keep in mind, however, that these emissions are highly variable, and different components may be visible at different times, depending on the luminosity state of the CV.

Figure 5 shows the Doppler map of another cataclysmic variable star of the dwarf nova type, RZ Leo, which is characterized by a relatively long recurrence time and short orbital period. The data presented here have been discussed by Mennickent & Tappert (2001) in the context of a search for the orbital period, but they did not construct Doppler maps from these data. Contrary to that seen in VW Hyi, the map reveals the existence of two isolated emission maxima on roughly opposite sides of the disc. The feature in the $(-v_x,\pm v_y)$ quadrant is the more dominant one and could be related to the classical hotspot. Up to now, no convincing theory can explain isolated emission-line sources like the one observed in the $(+v_x,+v_y)$ quadrant of RZ Leo, although emission in this quadrant has been observed in roughly 32% of the CVs (Tappert & Hanuschik 2001).

Doppler imaging is already well established, but it has an even more promising future in CV research. The method is being improved in several ways. Steeghs (2001) describes a modification which allows orbital variability to be included in Doppler reconstructions. Bobinger et al. (1999) describe a method to simultaneously fit spectra and light-curves of emission lines. Skidmore et al. (2000) introduced the method of ratio maps between reconstructions obtained at different wavelengths. Using this method, Mennickent et al. (2001) determined a steady-state $(T \sim r^{-3/4})$ accretion disk mainly emitting in Hα and an optically thicker hotspot with a strong contribution to the higher-order Balmer lines and He I 5875 in 1RXSJ105010.3-140431.

3. Looking for signatures of the red warrior

The determination of the secondary mass in CVs is the key to understanding the secular evolution of these objects. Cataclysmic variables are found with orbital periods between 78 minutes and 10 hours, with an abrupt drop in the number of systems in the range 2–3 hours, the so-called “period gap”. Current theories state that the process of mass transfer becomes linked with the loss of orbital momentum, so the bi-

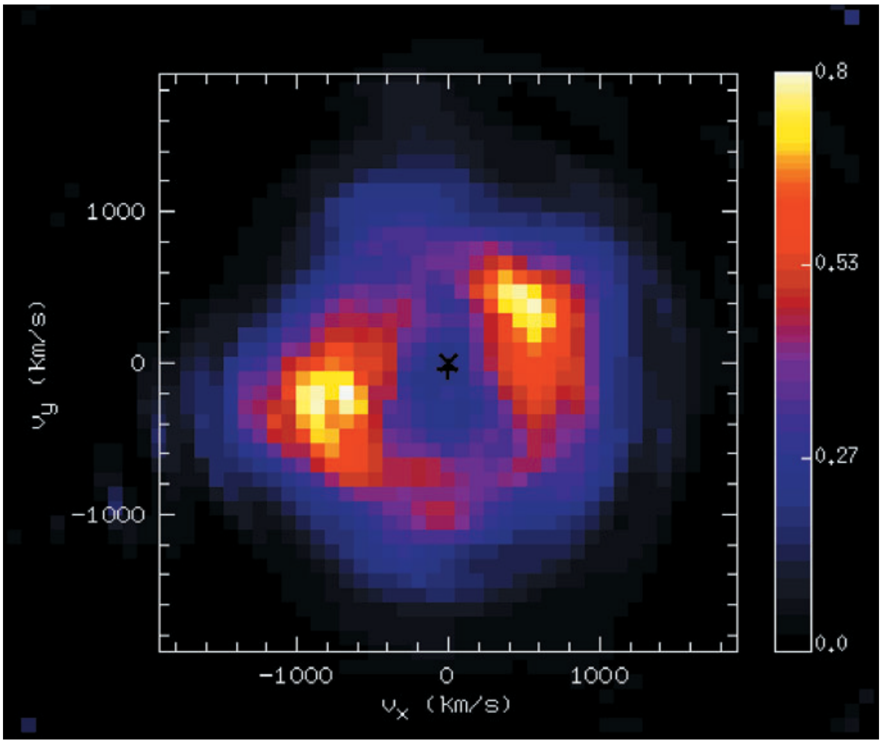

Figure 5: Doppler map of RZ Leo. The spot on the left side could be associated with the disc-stream interacting region.

nary spins faster whereas the secondary becomes less and less massive, eventually being eroded by the process, resulting in a kind of brown dwarf star when the orbital period approaches 80 minutes (e.g. Howell et al. 2001), which is consistent with our finding for 1RXSJ105010.3-140431 (see above). While above the gap CV evolution is likely driven by loss of angular momentum due to magnetic-braking (MB), below the gap the responsible mechanism is thought to be gravitational radiation (GR). Since the efficiency for removing angular momentum by GR is much smaller than for MB, a pile-up of systems is expected below the orbital period gap. Some of them should be systems with normal secondary stars approaching the orbital period minimum at 80 minutes, others should be systems which have "bounced" near P_{min} and now are receding towards the longer period area. These systems should have degenerated secondaries. The period gap is understood as an interruption of the mass transfer rate when the secondary becomes detached from its Roche-lobe, probably due to the onset of convection at $M_2 \sim 0.3\ M_\odot$.

At present, four methods have been used to search for undermassive secondary stars in cataclysmic variable stars: (1) analysis of the spectral energy distribution using multi-wave-band observations through the ultraviolet, optical, and infrared spectral regions (Ciardi et al. 1998; Mason 2001), (2) looking for signatures of the secondary star (Steeghs et al. 2001, Littlefair et al. 2000, Dhillon & Marsh 1995), (3) "weighting" the secondary star, possible in systems which develop an elliptical accretion disc during certain luminosity states (e.g., Patterson 2001), and (4) by spectroscopic diagnostic of the stellar masses in systems where the white dwarf is revealed through its optical absorption wings (Mennickent et al. 2001).

While the IR spectra of bright CVs have been measured and modelled in the past years, there are only a few spectrophotometric observations of low-luminosity systems in J, H and K band. In order to investigate the relatively unexplored infrared region of short period CVs, we have initiated a programme with ISAAC aimed to find evidence for undermassive secondary stars.

VY Aqr is a cataclysmic variable showing one of the largest outburst amplitudes among dwarf novae (Downes et al. 2001). Accordingly to current models for dwarf nova outburst (Osaki 1996), this is consistent with a very low mass transfer rate system. Spectroscopic studies in the optical region have revealed the orbital period (0.06309(4) d, Thorstensen 1997), but not the stellar masses, likely due to the distorted nature of the emission-line radial velocities (e.g. Augusteijn 1994). J-band spectroscopy by Littlefair et al. (2000) revealed spectral features of the secondary star, but too weak to make an estimate of the spectral type. According to the current CV evolution scenario (e.g. Howell et al. 2001), the orbital period and the low mass transfer rate of VY Aqr should suggest a system beyond the orbital period minimum, probably containing an undermassive secondary star. This has also been supported by the application of Method 3 (Patterson 2001). We have found direct evidence for this scenario, based on the unambiguous detection of the secondary star in the spectrum of VY Aqr (Mennickent & Diaz 2002).

The ISAAC infrared spectrum of VY Aqr shown in Figure 6 reveals Bracket and Paschen emission lines. We also observe the K I doublets at 1.169-1.177 and 1.244-1.253 and the Na I line at 1.141, which are signatures of a cool secondary star, confirming previous indications found by Littlefair et al. (2000).

When fitting the spectral energy distribution (SED) we observed that spectral types earlier than M7 fail to reproduce the depth of K I lines in the J band and the continuum in the K band. On the other hand, spectral types later than L3 do not fit well the H and K band continuum shape. These cool types present a well-defined CO band head at 2.29 μm which is not seen in our data. Our fit with a M9.5 type secondary plus power-law continuum is slightly better than that for M7 and L3 type templates, giving a χ^2 parameter about 15% lower. If such a spectral contribution is in fact due to the emission of the secondary star in the system one may estimate its temperature. Using the effective temperatures for L type dwarfs derived by Leggett et al. (2001) using structural models, we find $T_2 = 2300 \pm 100\ K$ for the secondary star in VY Aqr. The best fit with a M9.5 companion is shown for illustration in Figure 7. Representative fits using types between M7 and L3 indicate that the secondary star may contribute with 45% to 55% to the flux at 2.17 μm, depending on the spectral type. Later types yield better fits for smaller flux fractions. Using the distance values for our templates from M7 to L2 (LHS3003 and LHS429 by van Altena et al. 1995 and Kelu-1 from Dahn et al. 2000) and the flux fractions derived from the spectral fitting we were able to derive a distance estimate for the system between 80 and 120 pc, with a most likely value of 100 ± 10 pc. The spectroscopic parallax given above is in agreement with the distance of 110 pc found by Augusteijn (1994) using the average absolute magnitude value for dwarf novae in outburst.

We have applied the method outlined above to a sample of cataclysmic variables which are candidates to host brown-dwarf like secondaries (Mennickent & Diaz, 2002). The SED fitting for RZ Leo and CU Vel suggests M5 type dwarf companions, and distances of 340 ± 110 and 150 ± 50 pc, respectively. We find no evidence of a secondary star in the IR spectra of WZ Sge and 1RXSJ105010.3-140431. The infrared SED in these objects is dominated by the accretion disc, and it can be well modelled by a simple power-law continuum.

Figure 8 shows a comparison of the $T_{eff} - P_{orb}$ CV evolutionary tracks near the orbital period minimum with our data and some additional data taken from the literature. From this figure we conclude the following: (1) HV Vir, WZ Sge, EF Eri, WX Cet, LL And and SW UMa seem to be post-orbital period minimum systems. (2) It is difficult to reconcile the positions of VY Aqr in the diagram with the code's predictions. (3) In the same context, RZ Leo and CU Vel should be evolving toward the orbital period minimum.

The fact that the predicted density of short orbital period CVs is at least a factor 10 higher than observed (e.g. Patterson 1998) and that the observed orbital period minimum is slightly, but significantly longer than the theoretical one, has motivated the entrance of two new theoretical models. Both explain the absence of the spike at P_{min} as an age effect, i.e. that CVs have not yet evolved down to P_{min}. While Taam & Spruit (2001) invoke a circumbinary disc as braking mechanism for the evolutionary process, King & Schenker (2002) propose a reduced duration of the CE phase, leading to a much longer lifetime of the pre-CV state. This approach additionally solves the space density problem. In this picture, most systems around the orbital period minimum in Figure 8 could be systems born with this mass-period configuration, not the remnants of the evolution of longer-period systems born with more massive secondaries.

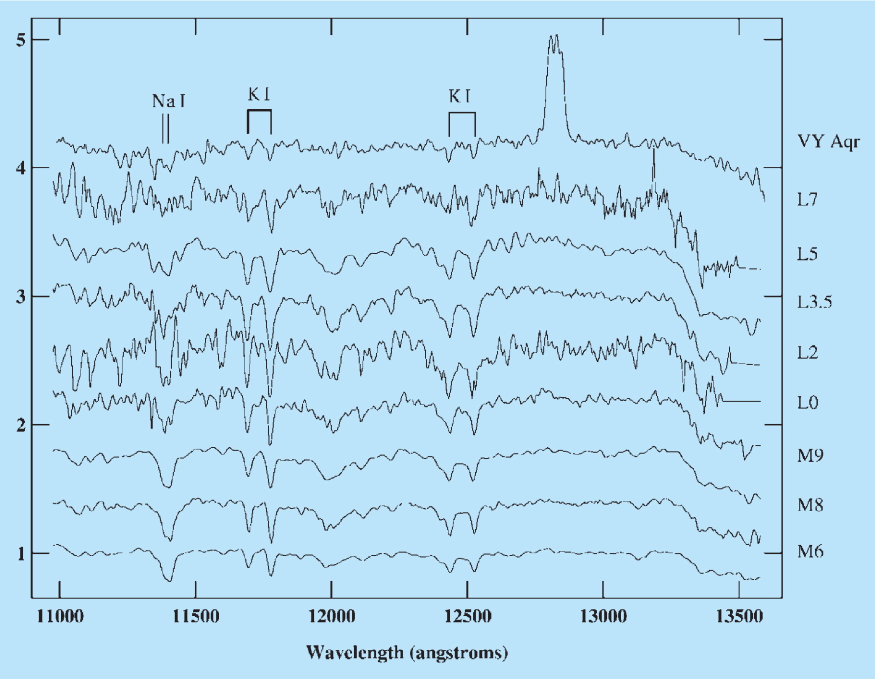

Figure 6: Comparison of the normalized spectrum of VY Aqr with late-type templates.

The results from the application of the spectral fitting procedure described above suggests that the infrared continuum shape in short-period cataclysmic variables may be a useful indicator of the companion spectral type. This point is especially important if we consider that, due to the limitation imposed by the spectrum S/N in such faint systems, it is not always possible to detect the individual lines of the secondary star, but nevertheless to determine the shape of its continuum. Also, the method has the advantage of avoiding the uncertainties associated with non-simultaneous multi-wavelength observations, although their predictive power clearly is inferior to the ideal case of modelling of simultaneous multi-waveband observations. We are currently analyzing ISAAC data of a larger sample of CVs which are candidates for harbouring brown dwarf like secondaries in order to provide constraints on the proposed evolutionary models.

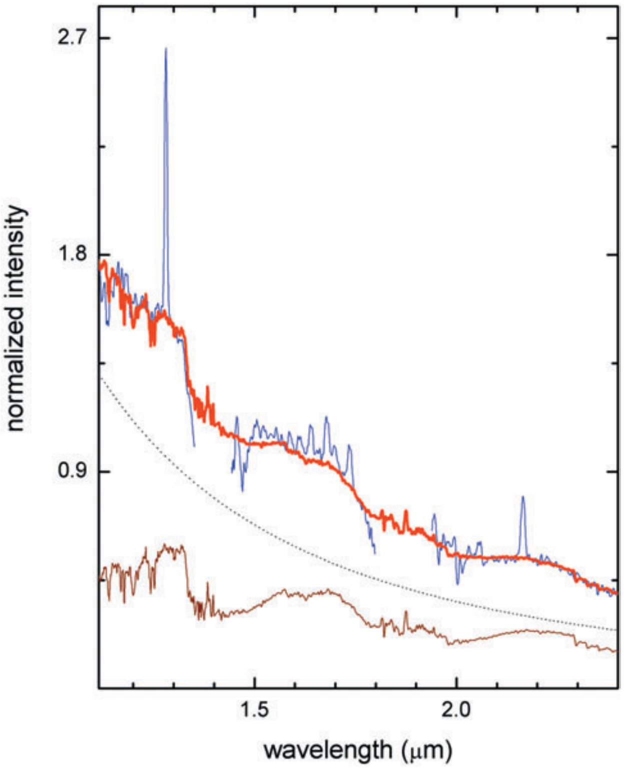

Figure 7: ISAAC spectrum of VY Aqr and the best composite SED fit (red line). The individual M 9.5 type template spectrum and power law continuum are shown. The spectra are normalized to 29.7 × 10^{-17} erg cm^{-2} s^{-1} Å^{-1}.

Acknowledgements

We thank Sandy Leggett who provided the IR digital spectra of low-mass red objects used in our SED models. We also thank Steve Howell and Elena Mason for providing digitalized versions of the CV evolution tracks shown in Figure 8. This work was supported by Grant Fondecyt 1000324, DI UdeC 99.11.28-1, CNPq 301029 and FAPESP 99-06261. We also acknowledge support by grant Fundación Andes C-13600/5.

References

Allen 2000, *Allens Astrophysical Quantities*, Arthur N. Cox (ed), AIP Press, Springer.

Augusteijn, T., 1994, *A&A* **292**, 481.

Bobinger, A. et al., 1999, *A&A* **348**, 145.

Ciardi, D.R., Howell, S.B., Hauschildt, P.H., & Allard, F., 1998, *ApJ* **504**, 450.

Dahn, C. et al., 2000, Giant Planets to Cool Stars, ASP Conf. Ser. C. Griffith and M. Marley eds.

Dhillon, V.S., Littlefair, S.P., Howell, S.B., Ciardi, D.R., Harrop-Allin, M.K., & Marsh, T.R., 2000, *MNRAS* **314**, 826.

Dhillon, V.S., Marsh, T.R., 1995, *MNRAS* **275**, 89.

Downes, R.A., Webbink, R.F., Shara, M.M., et al.,2001 astro-ph/0102302 (see also http://icarus.stsci.edu/ downes/cvcat

Howell, S.B., Nelson, L.A., & Rappaport, S., 2001, *ApJ* **550**, 897.

Howell, S.B., Ciardi, D.R., 2001, *ApJ* 550, L57.

Ishioka, R.et al. 2001, *PASJ* **53**, 905.

Kaitchuck, R.H., Schlegel, E.M., Honeycutt, R.K., et al., 1994, *ApJS* **93**, 519.

King, A.R., Schenker, K., 2002, in *The Physics of Cataclysmic Variables and Related Objects*, Gansicke et al. eds. ASP Conf. Ser., Vol. **261**, p. 233.

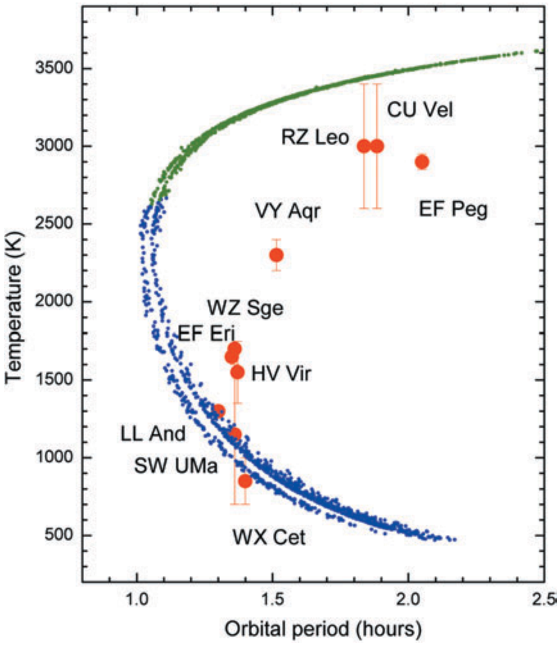

Figure 8: Cataclysmic variables close to the orbital period minimum. Observations are compared with results of the CV population synthesis code by Howell et al. (2001). Normal and degenerate stars are represented by green and blue dots respectively. The evolution of a particular system is from longer periods to shorter periods, eventually passing by the minimum around 80 minutes. We have used spectral type – temperature calibrations based on data of M-L dwarfs by Leggett et. al. (2000, 2001). Data for LL And and EF Eri are from Howell & Ciardi (2001), for WX Cet, EF Peg and SW UMa from Mason (2001) and for WZ Sge (a temperature upper limit) from Ciardi et al. (1998). All others are from Mennickent & Diaz (2002).

Leggett, S.K., Allard, F., Dahn, C., Hauschildt, P.H., Kerr, T.H., & Ryner, J. 2000, *ApJ* **535**, 965.

Leggett, S.K., Allard, F., Geballe, T.R., Hauschildt, P.H., & Schweitzer, A. 2001, *ApJ* **548**, 908.

Littlefair, S.P., Dhillon, V.S., Howell, S.B., & Ciardi, D.R., 2000, *MNRAS*, **313**, 117.

Marsh, T.R., 2001, in "Astrotomography", *Lect. Notes on Phys*. **573**, Eds. H.M.J. Boffin, D. Steeghs and J. Cuypers, Springer, p. 1.

Marsh, T.R., Home, K., 1988, *MNRAS* **235**, 269.

Mason, E., 2001, PhD thesis, Department of Physics & Astronomy, University of Wyoming.

Mennickent, R.E., & Diaz, M., 2002, *MNRAS*, in press (astro-ph/0206343).

Mennickent, R.E., Tappert, C., 2001, *A&A* **372**, 563.

Mennickent, R.E., Diaz, M., Skidmore, W., Sterken, C., 2001, *A&A*, **376**, 448.

Osaki, Y., 1996, *PASP*, **108**, 39.

Patterson, J., 1998, *PASP*, **110**, 1132.

Patterson, J., 2001, ***PASP***, 113, 736.

Skidmore, W., Mason, E., Howell, S.B., Ciardi, D.R., Littlefair, S., & Dhillon, V.S., 2000, *MNRAS*, **318**, 429.

Steeghs, D., Marsh, T., Knigge, C., Maxted, P.F.L., Kuulkers, E., & Skidmore, W., 2001, *ApJ*, **562**L, 145.

Steeghs, D., 2001, in "Astrotomography", *Lect. Notes on Phys*. **573**, Eds. H.M.J. Boffin, D. Steeghs and J. Cuypers, Springer, p. 45.

Taam, R.E., Spruit, H.C., 2001*, ApJ* **561**, 329.

Tappert, C., Hanuschik, R.W., 2001, in "Astrotomography", *Lect. Notes on Phys.* **573**, Eds. H.M.J. Boffin, D. Steeghs and J. Cuypers, Springer, p. 119.

Thorstensen, J.R., & Taylor, C.J., 1997, *PASP*, **109**, 1359.

van Altena, W.F., Lee, J.T., & Hoffleit, E.D., 1994, The General Catalogue of Trigonometric Parallaxes (New Haven: Yale University Observatory).

Reproduction of a colour-composite image of the nearby spiral galaxy NGC 300, obtained in 1999 and 2000 with the Wide-Field Imager on the MPG/ESO 2.2-m telescope at the La Silla Observatory. For more details see http://www.eso.org/outreach/press-rel/pr-2002/phot-18-02.html