YY Draconis and V709 Cassiopeiae: two intermediate polars with weak magnetic fields

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1. Spin pulse profiles

We present data from long *ROSAT* HRI observations of the intermediate polars YY Dra and V709 Cas. As seen in earlier observations, the pulse profile of YY Dra (Figure 1) is clearly double-peaked with two similar peaks per cycle separated by about 0.5 in phase. We argue that the pulse profile of V709 Cas (Figure 2) is also 'double-peaked' but its two maxima are separated by only about one-third of the pulse cycle. The secondary minimum in the V709 Cas pulse profile is therefore 'filled-in' somewhat by the proximity of the two peaks. Whilst the power spectrum of YY Dra is dominated by the first harmonic of the spin frequency (ie. $2/P_{\rm spin}$), that of V709 Cas is dominated by the fundamental and the second harmonic (ie. $1/P_{\rm spin}$ and $3/P_{\rm spin}$). The power spectra of both systems show no evidence for X-ray beat period or orbital modulation, so both must be disc-fed accretors seen at low inclination angles.

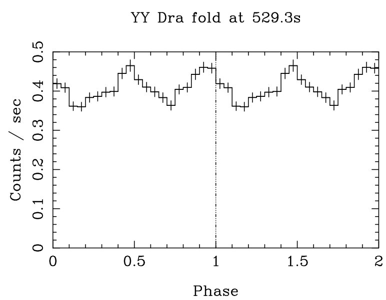

Fig. 1. The *ROSAT* HRI lightcurve of YY Dra folded at a period of 529.3 s.

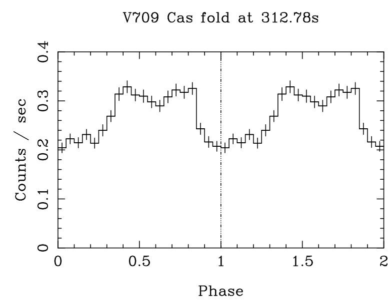

Fig. 2. The *ROSAT* HRI lightcurve of V709 Cas folded at a period of 312.78 s.

Two-pole disc-fed accretion is the 'normal' mode of behaviour in intermediate polars as material attaches to the field lines from the inner edge of the accretion disc, yet both single-peaked and double-peaked pulse profiles are seen in different systems. It is important that the paradigm which states 'single-peaked profile equals one-pole accretion; double-peaked profile equals two-pole accretion' is put to rest for intermediate polars. Double-peaked pulse profiles *are not* a unique indicator of two pole accretion. Instead we argue that double-peaked pulse profiles are the result of a weak magnetic field, and single-peaked pulse profiles are the result of a strong magnetic field.

[1] A postscript version of the full paper can be obtained from: http://physics.open.ac.uk/~ajnorton/papers/yydra_v709cas.ps

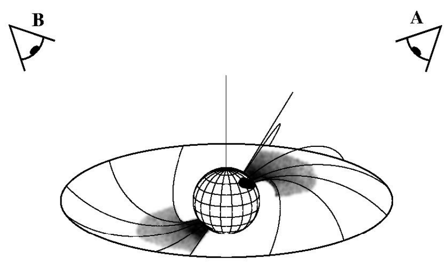

Fig. 3. Two-pole disc-fed accretion in an intermediate polar with a relatively weak magnetic field – a fast rotator.

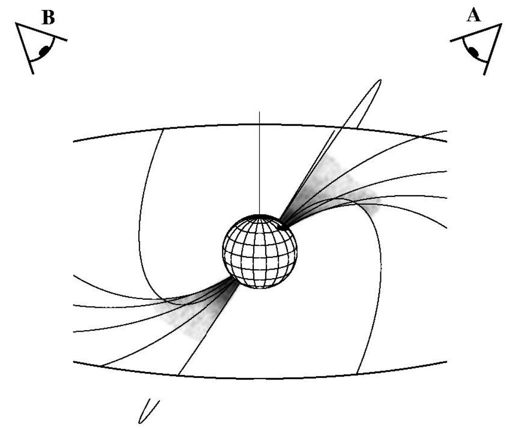

Fig. 4. Two-pole disc-fed accretion in an intermediate polar with a relatively strong magnetic field – a slow rotator.

2. Fast rotator = weak field = double-peaked pulse profile

All intermediate polars with 'fast rotating' white dwarfs ($P_{\rm spin} \leq 700$s) exhibit double peaked pulse profiles: namely AE Aqr (33 s), DQ Her (142 s), XY Ari (206 s), V709 Cas (313 s), GK Per (351 s), YY Dra (529 s) and V405 Aur (545 s). If they are in a state of equilibrium rotation (i.e. the accretion disc is disrupted at the radius where the Keplerian period of the disc is equal to the rotation period of the white dwarf), then the magnetic moment $\mu \propto P_{\rm spin}^{7/6}$. So fast rotators have relatively small magnetospheres and material threads onto the field lines when relatively close to the white dwarf, as shown in Figure 3. This results in *large* emission regions, whose 'vertical' optical depth (along the magnetic field lines) is *less* than their 'horizontal' optical depth (parallel to the white dwarf surface). In this case minimum attenuation of the X-ray flux occurs when the emission region is seen from above. So when the upper pole points towards the observer, maximum flux is seen from it, so giving the first peak in the pulse profile (Figure 3, viewpoint A). The contribution to the modulation from the lower pole is *in anti-phase* with that from the upper pole since, when the upper pole is pointing towards the observer, the lower pole will generally be occulted, and when the upper pole is pointing away from the observer, the lower pole is at its most visible, so giving a second peak in the pulse profile (Figure 3, viewpoint B). So in this case **a double-peaked X-ray pulse profile is seen**.

3. Slow rotator = strong field = single-peaked pulse profile

With a relatively *strong* magnetic field, the accreting material attaches to the field lines whilst still quite distant from the white dwarf, as shown in Figure 4. This results in *small* emission regions, whose 'vertical' optical depth (along the magnetic field lines) is *greater* than their 'horizontal' optical depth (parallel to the white dwarf surface). In this case minimum attenuation of the X-ray flux occurs when the emission region is seen from the side. Hence, when the 'upper pole' points away from the observer, then pulse maximum is seen (Figure 4, viewpoint B), and when it points towards the observer, pulse minimum is seen (Figure 4, viewpoint A). The contribution to the modulation from the lower pole is *in phase* with that from the upper pole, since when the upper pole is pointing towards the observer, the lower pole will generally be occulted. Conversely, when the upper pole is pointing away from the observer, the lower pole is viewed essentially from the side too, and so its flux adds to the pulse giving a maximum. So in this case **a single-peaked X-ray pulse profile is seen**.