White dwarfs with jets as non-relativistic analogues of quasars and microquasars?

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Abstract. We explore the similarities between accreting white dwarfs (CH Cyg and MWC 560) and the much more energetic jet sources - quasars and microquasars. To-date we have identified several common attributes: (1) they exhibit collimated outflows (jets); (2) the jets are precessing; (3) these two symbiotic stars exhibit quasar-like emission line spectra; (4) there is a disk-jet connection like that observed in microquasars. Additionally they may have a similar energy source (extraction of rotational energy from the accreting object). Study of the low energy analogues could have important implications for our understanding of their higher energy cousins.

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EMISSION LINE SIMILARITIES

As illustrated in Zamanov and Marziani (2002), there are striking similarities between the optical spectra of Active Galactic Nuclei (AGNs) and two accreting white dwarfs. Almost every emission line visible in the AGN spectrum of I Zw 1 shows a corresponding feature in the spectra of CH Cyg and MWC 560. The similarity between the UV spectrum of CH Cyg and I Zw 1 is demonstrated in Fig.1.

In AGN, hydrogen and FeII emission lines are emitted from the so-called Broad Line Region. This region is thought to lie within $<$1 pc of the central black hole. Its structure is still poorly understood. The clear similarity between the emission lines suggests that we are observing a scaled down version of the quasar Broad Line Region in galactic objects like MWC560 and CH Cyg (see also Zamanov and Marziani, 2002).

DISK-JET CONNECTION

Comparison of the flickering behaviour of T CrB (February 28, 1995) and MWC 560 (March 05, 1990) is shown on Fig. 2. In the case of MWC 560, the short term variability (on a time scale of minutes) is missing. Only smooth, hour-timescale variations are present. This indicates disruption of the inner part of the accretion disk during the time of jet ejection. A disruption of the inner disk (disk-jet) connection is also observed in CH Cyg (Sokoloski and Kenyon 2003). The behaviour is closely analogous to that of

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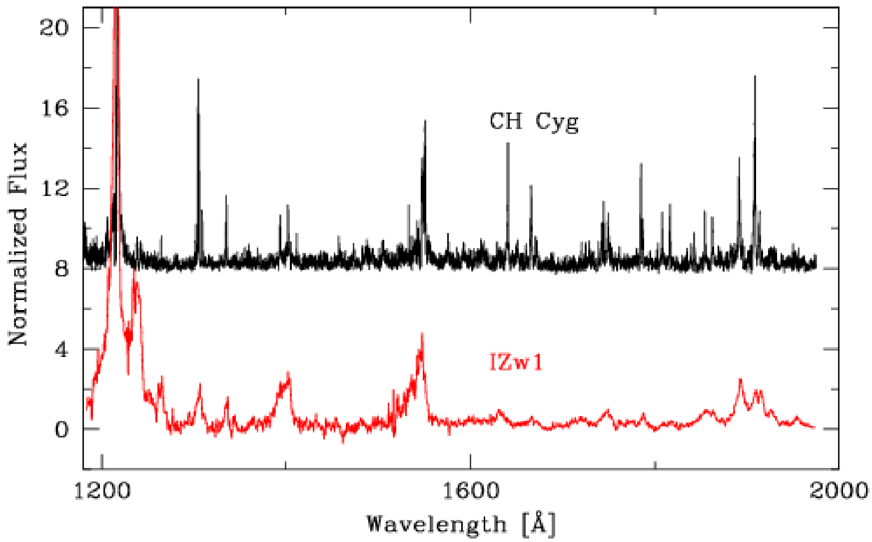

FIGURE 1. The UV spectra of symbiotic star CH Cyg and Narrow Line Seyfert 1 galaxy I Zw 1. Clear similarity in the emission lines is visible.

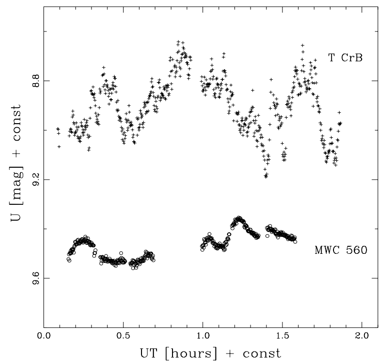

FIGURE 2. The flickering behaviour of MWC 560 and T CrB.

the microquasar GRS1915+105. This supports the view that there may be a common mechanism for jets in quasars, microquasars and symbiotic stars (see also Livio, Pringle and King 2003).

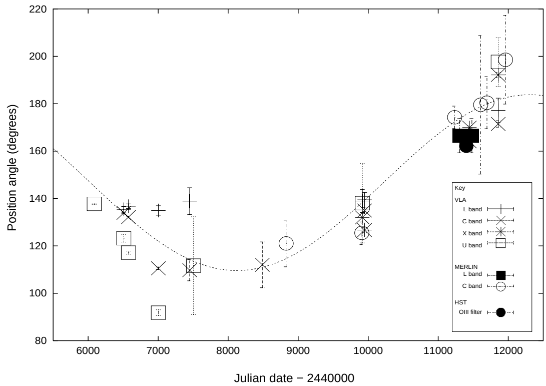

FIGURE 3. Variation of the position angle of the extended emission in the central region of CH Cyg between 1985 and 2000, along with a curve representing the precessing jet model, adapted from that for the high-velocity jets of SS 433.

PRECESSING JETS

The best known precessing jets in astrophysics are probably those of SS 433. In recent years precessing jets have been identified in two symbiotic stars: CH Cyg (on the basis of radio imaging by Crocker et al. 2002) and MWC 560 (from optical spectroscopy by Iijima 2002). In both cases the model of the jets of the microquasar SS 433 has been adopted to fit the evolution of the morphology of the outflows (using velocities appropriate for white dwarfs).

ENERGY SOURCE OF JETS

It is worth noting that interacting binaries, where a white dwarf accretes material from the wind of a red giant (usually classified as symbiotic stars), are strongly variable objects. We show above that the spectra of CH Cyg and MWC 560 are similar to low-redshift quasars around the times when jet activity is detected (CH Cyg - July 1984, MWC 560 - November 1990).

Jets are detected in systems quite different from those harboring black holes (for a review see Livio, 2001): young stellar objects (velocity v$\sim$200 km s^{-1}), planetary nebulae (v$\sim$200-1000 km s-1), supersoft X-ray sources (v$\sim$1000 km s^{-1}). The jet velocities observed in the accreting white dwarfs (we call them *"nanoquasars"*) are $\sim$1000 km s^{-1} in CH Cyg (Taylor et al. 1986) and 1000-6000 km s^{-1} in MWC 560 (Tomov et al. 1992). They are consistent with an overall picture in which the jet velocity is of the same order as the escape velocity from the accretor (Livio 2001).

The luminosities of MWC 560 and CH Cyg are considerably less than the Eddington limit. The mass accretion rate is about $M_{acc} \sim 0.05\ M_{Edd}$. At such mass accretion rates the most probable jet energy source involves extraction of rotational energy from the compact object. In the case of nano-quasars the extraction is probably occurring via the propeller action of a magnetic white dwarf (Mikolajewski et al. 1996). The most probable source of jet formation in quasars is the extraction of energy and angular momentum via the Blandford and Znajek (1977) mechanism. In this sense the jets in the “nanoquasars” probably represent a low energy (non-relativistic) analogue of the jets in quasars and microquasars. They involve a similar energy source - the extraction of rotational energy from the central compact object.

CONCLUSIONS

We think it is appropriate to call the two accreting white dwarfs discussed here "nanoquasars" because they represent the very low energy analogue of quasars and microquasars. The name is chosen by analogy with the quasar and microquasar denominations, and also because $\nu\alpha\nu o\varsigma$ (ancient greek) = nano (ital.) = dwarf(engl.).

We suggest that the "nanoquasars" could be an important link in our understanding of a broad range of accreting sources. They could help us to create a unified picture of accreting objects from cataclysmic variables and stellar-mass black holes up to the most powerful quasars.

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