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Polarization studies of magnetic cataclysmic variables

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Abstract

I discuss methods and results in the use of photo-polarimetry and spectro-polarimetry in the studies of magnetic cataclysmic variables. In particular I show how polarimetry can be used to derive the geometry of the accretion region on the surface of the white dwarf, the accreting geometry of the system as a whole and how polarimetry aides in the interpretation of X-ray/optical photometry and spectroscopy. I finish by describing the high speed spectro-polarimetric capabilities of SALT (Southern African Large Telescope) due for completion in 2005.

Keywords: Accretion; Accretion discs – methods; Analytical – techniques; Polarimetric – binaries; Close – novae; Cataclysmic variables – X-rays; Stars

1. Introduction

Polars (AM Herculis systems) are a sub-class of magnetic cataclysmic variables (mCVs). They are short period binaries that contain a white dwarf (the primary) and a red dwarf companion star (the secondary) that overflows its Roche lobe. The magnetic field of the white dwarf is sufficiently strong to lock the system into synchronous rotation and to prevent an accretion disc from forming. Instead, the overflowing material from the secondary initially continues on a ballistic trajectory until, at some distance from the white dwarf, the magnetic pressure overwhelms the ram pressure of the ballistic stream. From this point onwards the accretion flow is confined to follow the magnetic field lines of the white dwarf, see e.g. Cropper (1990) or Warner (1995) for a review of magnetic cataclysmic variables (mCVs).

Eventually the magnetically confined accreting material will impact on the surface of the white dwarf. At this point a stand-off shock will form giving rise to X-ray Bremsstrahlung and optical cyclotron radiation as the shocked material cools and settles onto the surface of the white dwarf (see Fig. 1 and the review of Wu, 2000). Some of the X-ray emission is in turn reprocessed by the photosphere of the white dwarf and re-emitted as soft X-rays or ultra-violet radiation. X-rays are also reprocessed by the accretion column/stream and the irradiated face of the secondary star which is seen as variable optical line emission over the binary orbit (see e.g. Schwope et al., 2000).

2. Photo-polarimetry

Since the discovery of polarized emission from AM Her (Tapia, 1976) many mCVs have been observed photo-polarimetrically. Fig. 2 shows an example of photo-polarimetric observations of the polar V834 Cen (from Potter et al., 2004). The light curves display the typical features of accretion onto a single region close to the magnetic pole of the white dwarf namely the presence of positive circular polarization throughout the orbit and a single bright and faint phase. There is also a linearly polarized pulse as the accretion region is viewed perpendicular to its magnetic field lines as it rotates over the limb of the white dwarf.

The shapes of the phase-resolved photo-polarimetric curves depends on the geometry of the accretion shock itself. In particular the gross features of the photo-polarimetry depends on the shape, size and location of the

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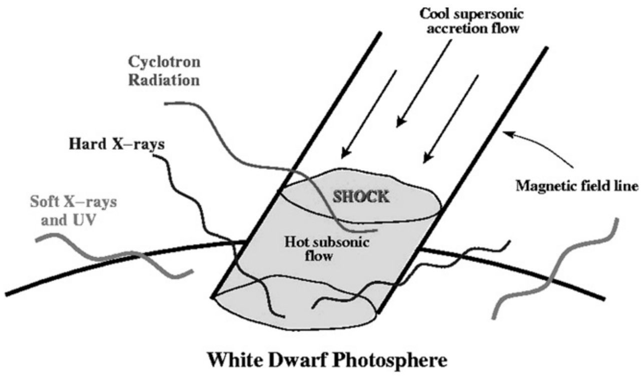

Fig. 1. Diagram of the accretion region on the surface of the white dwarf.

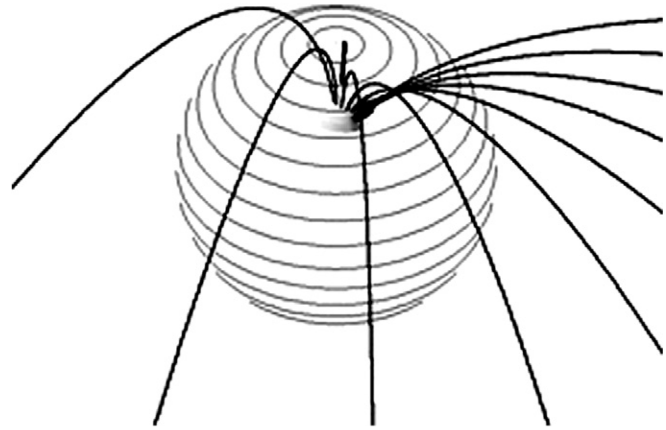

Fig. 3. The prediction for the shape, size and location of the upper accretion region (grey shaded area). The globe represents the surface of the white dwarf with latitudes marked every 10°. The upper magnetic pole is indicated by a vertical straight line. The remaining solid curves represent magnetic field lines. The white dwarf rotates in a anti-clockwise direction as seen from above the upper spin axis.

accretion region on the surface of the white dwarf. Many authors (e.g. Bailey et al., 1995 and Potter et al., 1998) have modelled the variations in the photo-polarimetry and have been able to reconstruct the accretion region in terms of these parameters. The solid curves of Fig. 2 are the model fits from Potter et al. (2004) and Fig. 3 shows the prediction for the shape size and location of the accretion region on the surface of the white dwarf.

Modelling of the photo-polarimetry can be a powerful tool when combined with other indirect imaging techniques such as Doppler tomography (Marsh and Horne, 1988) and Roche tomography (Dhillon and Watson, 2001). This is because, for example, most of the observed optical emission lines arise as a result of reprocessing of the X-ray emission from the accretion region. Therefore the interpretation of Doppler maps and Roche tomograms is greatly aided by knowing the location of the accretion region and can lead to a better understanding of the overall emission and accretion geometries of polars.

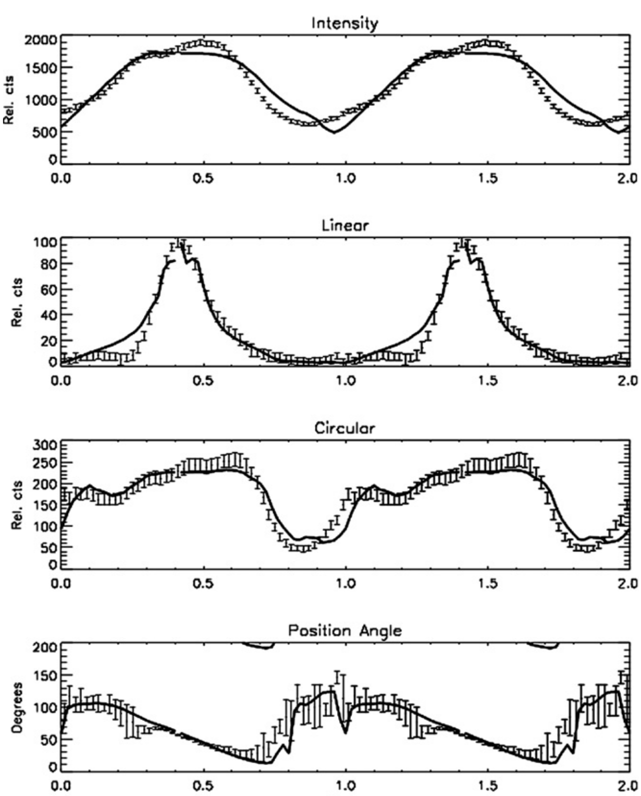

Fig. 2. Photo-polarimetric observations of the polar V834 Cen (from Potter et al., 2004). Solid curves are a model fit (see text).

3. Spectro-polarimetry

Phase resolved spectroscopic observations of the emission lines provide a useful diagnostic of the overall emission and accretion dynamics in polars particularly

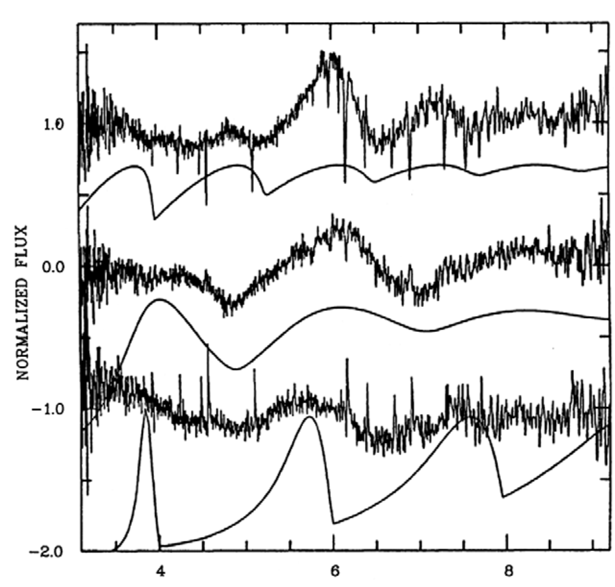

Fig. 4. An example of phase resolved (three phase bins) spectroscopic observations of the polar QS Tel from Schwope et al. (1995).