MAGNETIC ACCRETION IN AN EXTREME ENVIRONMENT: THE CASE OF THE LOW-ACCRETION RATE POLAR WX LMI

J. Vogel, A. Schwope, R. Schwarz, and A. Staude

Astrophysikalisches Institut Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany

ABSTRACT

The class of low-accretion rate polars was uncovered recently in optical spectroscopic surveys (HQS, SDSS). Contrary to their high-accretion rate cousins which were discovered numerously in the RASS, they did not show up as prominent X-ray emitters. They were identified on the basis of highly peculiar optical spectra with broad cyclotron harmonics in emission mimicing quasar emission lines. They could form an important part of the population of close interacting binaries, being either normal CVs in extended low states of accretion or pre-CVs on their track towards Roche-lobe overflow. Here we present preliminary results of a multiwavelength study of the prototypical system WX LMi (HS1023+3900) involving X-ray spectroscopy, ultraviolet, optical and IR-photometry, and optical low-resolution spectroscopy.

1. INTRODUCTION

Polars are magnetic cataclysmic binaries consisting of a late-type main-sequence star and a strongly magnetic white dwarf locked in synchronous rotation. In normal polars accretion happens via Roche-lobe overflow and accretion streams towards the magnetic poles where the accretion energy is released mainly as X-ray thermal radiation, optical cyclotron radiation and a prominent soft X-ray component. The energy balance between those components is of debate since the days of discovery of the very first systems. The soft component makes them prominent sources in the soft X-ray sky and they were found numerously in the ROSAT all-sky survey. The detection bias is large and the true space density highly uncertain. Recently a few systems with very low accretion rate (a factor 100 – 1000 below the canonical values for Roche-lobe overflow) were uncovered in optical spectroscopic surveys (HQS, SDSS). They offer the opportunity to study the physics of accretion in an environment of extreme low-accretion rate/high magnetic field. They might serve as tracers to uncover the unbiased sample of magnetic CVs. Establishing their detailed properties is the first important step in understanding their role in close binary evolution. To this end we initiated an in-depth study of WX LMi, the brigthest of the currently known 6 systems. XMM-Newton observations were performed to test the bombardement accretion scenario, to measure the white dwarf's temperature and to constrain the magnetic activity of the secondary star.

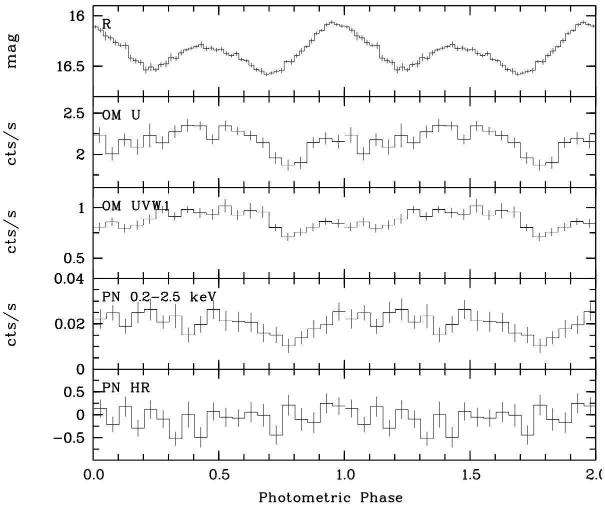

Figure 1. The phase-folded light-curves of WX LMi, obtained with XMM (PN and OM) and with the AIP 70cm-telescope (R). The data shown here are binned in phase, 200s for the top panel, 500s for the lower four. The hardness ratio is for the energy bands 200 - 700 eV and 700 - 2500 eV. The R band lighcurve clarifies the two accretion spots, which are visible alternatively.

2. THE DATA

WX LMi was discovered during follow-up of quasar candidates from the Hamburg Quasar Survey (HQS, Reimers et al. 1999). Phase-resolved low-resolution spectroscopy of WX LMi (Reimers et al. 1999, Schwope et al. 2002) clearly reveals the presence of two accretion spots on the southern hemisphere emitting strongly beamed optical cyclotron radiation. Detailed modeling allowed the magnetic field strength and the plasma temperature to be determined (61 and 69 MG, 1 – 2 keV, respectively). At such high field strengths and low temperatures probably no accretion shock forms. Accretion heating rather happens via particle bombardement of the atmosphere (Fischer & Beuermann 2001), just as the plasma cooling happens mainly via cyclotron radiation instead of bremsstrahlung in the hard X-ray regime. In order to test the predictions of the bombardement model XMM-Newton observations with a full phase coverage of three orbits (30 ksec) were performed in March 2004.

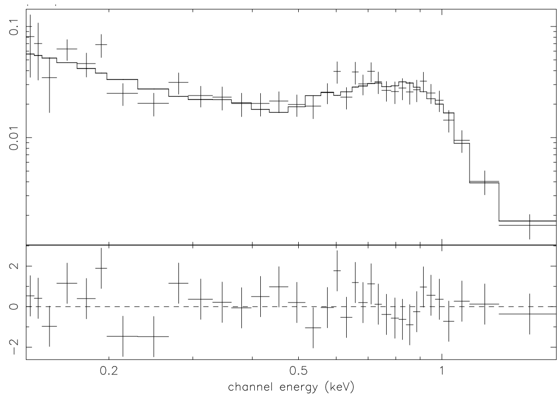

Figure 2. The EPIC-PN spectrum and the fit with an absorbed multi-temperature plasma emission model, yielding a plasma temperature T_{max} of 1.09(±0.24) keV and a hydrogen column density $N_H = 8 \cdot 10^{19} cm^{-2}$. The energy channels are binned with a minimum of 20 counts in each bin. Above 2 keV no significant X-ray emission was detected.

Figure 2 shows the EPIC-PN spectrum. There is no significant X-ray detection in the energy range above 2 keV. The spectrum can be fitted well with an absorbed T_{max} = 1.23(±0.28) keV multi-temperature MEKAL model. This plasma temperature lies within the regime for a coronal source as well as in the domain one expects for the plasma being accreted. The comparison of the phase-folded PN lightcurve (Figure 1) with the R-band lightcurve suggests a correlation of the X-ray emission with the visibility of the two spots. At optical flux minimum around phase 0.75 when both spots are self-eclipsed there is 50% residual X-ray flux. This can be attributed to the active secondary ($L_{x,M_2} \sim 1 \times 10^{29}$ ergs/s). The luminosities in the cyclotron ($L_{1/2,cyc} \sim 7.0/3.6 \times 10^{28}$ ergs/s) and X-ray spectra are comparable, which supports the bombardement scenario by Fischer & Beuermann.
The OM lightcurves (see Figure 1) are likewise affected by the visibility of the two accretion spots due to the emission from the heated white dwarf atmosphere. Those regions are not seen in the soft X-ray spectrum, which sets certain constraints on the maximum temperature and size of the heated atmosphere.

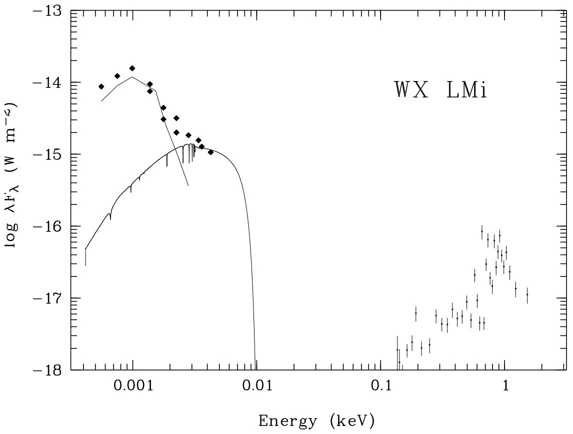

Figure 3. Broad-band spectral energy distribution of WX LMi (two points at the same energy mark minimum and maximum measurements): JHK from 2MASS catalog, UBVRI obtained with the AIP 70 cm telescope, OM U, OM UVW1 and EPIC PN spectrum. Overplotted are the spectrum of a M4.5 star and a model spectrum for a nonmagnetic white dwarf with a temperature of 8000 Kelvin.

The OM flux in the U and UVW1 filter around phase 0.75 shows a very cold white dwarf. With model spectra for nonmagnetic white dwarfs no satisfying fit can be achieved. But assuming a white dwarf radius of R_{WD} = $8.7 \cdot 10^8$ cm and a distance of 100 pc (Schwarz 2001) a white dwarf temperature of 8000 Kelvin is most likely. This gives a lower limit for the white dwarf age of $\sim$ 1 Gyr and possibly means that WX LMi has never been accreting at a rate normally expected for CVs and is a pre-CV at the onset of accretion.

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