XMM-NEWTON AND CHANDRA LETGS X-RAY SPECTROSCOPY OF SUPERSOFT X-RAY BINARIES

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ABSTRACT

With current generation X-ray observatories, detailed diagnostics of the high-temperature environment of white dwarf binaries accreting close to the Eddington limit (supersoft X-ray binaries, SSXBs) and of the nuclear burning region on their photospheres have become possible. High-resolution X-ray spectroscopy of SSXBs with the Chandra LETGS and the XMM-Newton RGS has revealed complex absorption and emission line spectra which probably reflect a combination of high-gravity stellar atmospheres, dynamical processes in the atmosphere, patchy absorption structures, X-ray scattering, and coronal-like emission from the wind.

Key words: stars: novae, cataclysmic variables; X-rays: spectroscopy; X-rays: stars.

1. INTRODUCTION

Luminous supersoft stellar X-ray sources (SSXBs) have been established as a population of accreting binaries by the discovery of several systems during the ROSAT All-Sky Survey (Trümper et al., 1991) and follow-up multi-wavelength studies. They are observationally distinguished by their very soft X-ray spectra with blackbody temperatures from 10 to 80 eV and luminosities of $10^{36} - 10^{38}$ erg/s (Kahabka & van den Heuvel, 1997).

Several SSXBs have been identified as accreting close binaries with orbital periods of ~ 1 day or less. They are interpreted as white dwarfs which accrete matter from a more massive main-sequence secondary at a rate $\dot{M}_{\rm acc}$ just sufficient to permit (quasi-) stable nuclear burning near its surface (van den Heuvel et al., 1992). This implies that the luminosity must be close to the Eddington limit of a solar mass object. Stable burning stops below $\sim 10^{-7} M_{\odot}$/yr, giving place to shell flashes. The conventional model predicts that at $\dot{M}_{\rm acc} > 4 \times 10^{-7} M_{\odot}$/yr, a red-giant envelope develops and X-ray emission is temporarily quenched. Hachisu et al. (1996), however, have shown that no static envelope solution on the white dwarf exists for $\dot{M}_{\rm acc} > 10^{-6} M_{\odot}$/yr. Instead, excess matter should be expelled by a strong wind providing a potential channel to grow the white dwarf mass to near the Chandrasekhar limit.

With high-resolution X-ray spectroscopy detailed diagnostics of the high-temperature environment of white dwarf binaries accreting close to the Eddington limit and of the nuclear burning region on their photospheres have become possible. Here, we summarize the first results of our recent X-ray observations of selected SSXBs.

2. ANALYSIS OF INDIVIDUAL SYSTEMS

2.1. QR And (RX J0019.8+2156)

The brightest galactic SSXB, QR And, has been observed at persistent X-ray luminosity since its discovery during the ROSAT All-Sky Survey. The XMM-Newton EPIC pn spectrum can be reasonably well fitted with a blackbody with $kT_{\rm bb}$ = 20 eV and $nH = 6.910^{20}$ cm^{-2} (reduced χ^2 = 3.8 for 57 degrees of freedom) (Fig. 1). This temperature is quite low compared to other SSXBs. The lack of dips in the orbital soft X-ray light curve suggests that either the orbital inclination of QR And is lower than 75^o previously anticipated, or the X-ray emission is not confined to the surface of the white dwarf, but comes from an extended structure, e. g. a corona or a wind.

2.2. RX J0439.8-6809

During a 40 ks observation with the Chandra LETGS source photons of RX J0439.8-6809 have been detected in the narrow 40–70 Å wavelength interval, only (Fig. 2). A white-dwarf LTE atmosphere fit to the data yields an effective temperature of $T_{\rm eff} = (3.15 \pm 0.10)\ 10^5$ K and a neutral hydrogen column density $n_{\rm H} = (3.2 {\pm} 0.4)\ 10^{20}$ cm^{-2}. The latter is compatible with $n_{\rm H} = (4.0 \pm$

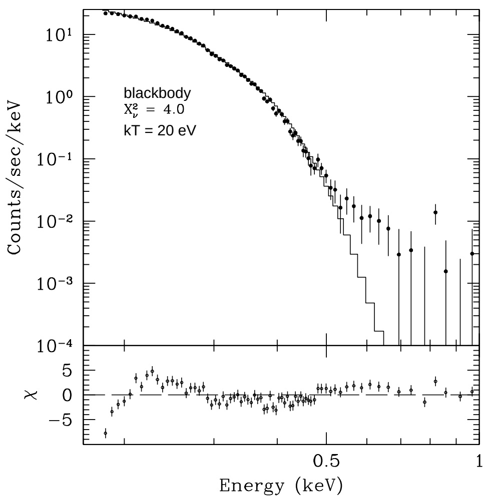

Figure 1. XMM-Newton EPIC pn spectrum of QR And.

1.0) 10^{20} cm^{-2} obtained with the HST Imaging Spectrograph (van Teeseling et al., 1999). The significant residuals indicate that the X-ray spectrum of RX J0439.8-6809 is far more complex than this simple model.

2.3. RX J0513.9-6951

High-resolution X-ray spectra of the transient SSXB RX J0513.9-6951 obtained during two target of opportunity campaigns with the Chandra LETGS show a very complex structure and deviate strongly from simple Planckian distributions (Fig. 2). Probably, the spectra are a combination of absorption features of a hot white dwarf atmosphere and of emission line features, most likely originating in a corona or wind above the accretion disk. A more detailed discussion of this data is presented in an accompanying paper (Burwitz et al., 2005).

3. CONCLUSIONS

With the advent of high-resolution X-ray spectroscopy using the Chandra LETGS and the XMM-Newton RGS a detailed study of the physical conditions in white dwarf binaries accreting close to the Eddington limit has become possible. Their soft X-ray spectra reflect the complex emission and absorption processes involved by the hot high-gravity stellar atmosphere, its structure and dynamics, and the interaction of the emitted photons with the expected strong wind emerging from the system. Currently, we are still at the beginning to fully explore the diagnostic information available from the wealth of absorption and emission features seen in the spectra. Their interpretation requires the extension of NLTE-modeling to soft X-ray wavelengths (see e.g. Lanz et al. (2005); Petz et al. (2005); Rauch et al. (2005)) as well as further exploration of the underlying atomic data.

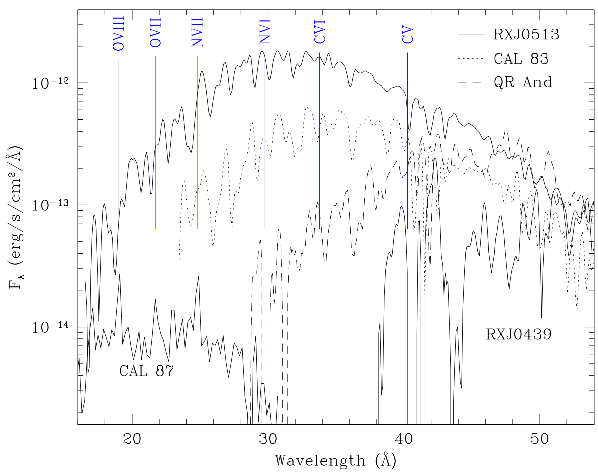

Figure 2. Chandra LETGS spectra of bright SSXBs. From top to bottom: RX J0513.9-6951 (Burwitz et al., 2005), CAL 83 (Paerels et al., 2001; Lanz et al., 2005), QR And, RX J0439.8-6809 (Reinsch et al., 2001), CAL 87 (shifted down by own decade, Greiner et al. (2004)).

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