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Broadband spectroscopy of persistent low luminosity X–ray pulsars

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Abstract. We present the results we have recently obtained, based on *XMM–Newton* observations, by investigating the soft X–ray emission of X Persei and RX J0146.9+6121, two low–luminosity and long–period Be/NS binary X–ray pulsars; moreover, we investigate the capability of *Simbol–X* to detect a cyclotron absorption feature in their spectrum.

1. Introduction

Most Be/NS binary X–ray pulsars are transient sources with $L_X \geq 10^{36}$ erg s^{-1} and orbital eccentricity $e > 0.3$. On the other hand, a small group of these pulsars are persistent sources, with $L_X \leq 10^{35}$ erg s^{-1}, $e < 0.2$ and long pulsation periods (P > 100 s) (Pfahl et al. 2002; Reig et al. 2007). Recent studies of X Persei, the prototype of this class of sources, have shown that a single power–law component cannot describe its X–ray spectrum, and that an additional thermal component is necessary; it can be modelled with a hot (kT > 1 keV) and small (R < 1 km) black–body, which suggests a polar cap emission. Moreover, also a *cyclotron resonant scattering feature* (*CRSF*) has been detected in its high–energy spectrum (Coburn et al. 2001). Its centroid energy is given by $E_c = 11.6 \times B/(10^{12}$ G) keV, therefore the detection of such a feature in the spectrum of a pulsar provides a powerful tool to estimate its magnetic field strength B.

Here we present the results obtained for X Persei and RX J0146.9+6121(another source of the same class), based on *XMM–Newton* observations; moreover, we investigate the capability of *Simbol–X* to detect a cyclotron absorption feature in their spectrum.

2. XMM–Newton observations

We used archival data of *XMM–Newton* to perform a spectral analysis of the two sources (La Palombara & Mereghetti 2006, 2007). In both cases the spectral fit with a simple power–law component left a significant data excess, which could be modeled with a black–body component. The best–fit results are reported in Table 1. They show that this thermal component is characterized by a high temperature and a small size, and contributes ~ 30–40 % to the total source flux. The derived luminosities confirm that these sources are at the low luminosity end of the Be/NS X–ray binaries.

If we assume that the source is in the 'accretor' status, with matter accretion on the NS surface, we can estimate the radius of the accretion column. Considering $B_{NS} = 10^{12}$ G, $M_{NS} = 1.4\ M_{\odot}$ and $R_{NS} = 10^6$ cm, from the source luminosity we can derive the accretion rate and the magnetospheric radius R_m (Campana et al. 1998); then, we can use the relation $R_{col} \sim R_{NS} (R_{NS}/R_m)^{0.5}$ (Hickox et al. 2004) to obtain the column radius, which is also reported in Table 1. For both sources its value is in good agreement with the black–body radius; therefore we can confirm the polar–cap origin of this component.

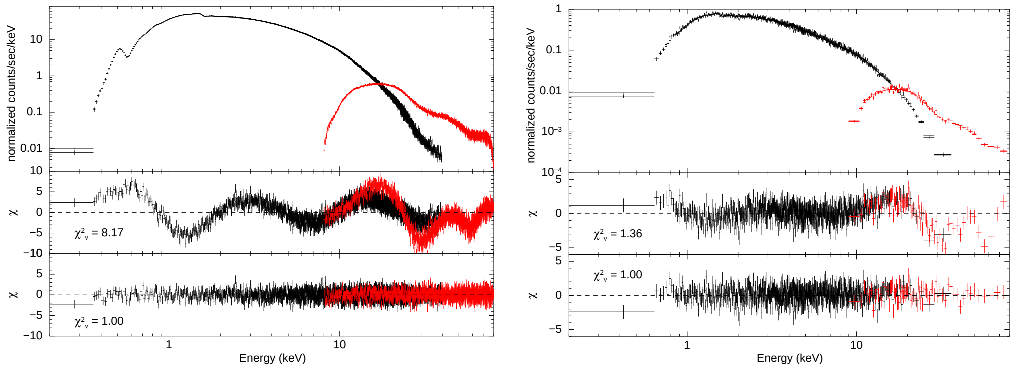

Fig. 1. *Top panel*: simulated *Simbol–X* spectrum of X Persei (*left*) and RX J0146.9+6121 (*right*). The spectra of the MPD and of the CZT detectors are shown in black and red, respectively. *Middle panel*: data-model residuals (in units of σ) when no CRSF is considered. *Bottom panel*: residuals when also a CRSF is considered.

Table 1. Best–fit spectral parameters (in 0.3–10 keV) for X Persei and RX J0146.9+6121.

Source	X Persei	RX J0146.9+6121
N_H (10^{21} cm^{-2})	$2.86^{+0.10}_{-0.10}$	$5.09^{+0.24}_{-0.23}$
Γ	$1.35^{+0.05}_{-0.05}$	$1.34^{+0.05}_{-0.06}$
kT_{BB} (keV)	$1.35^{+0.03}_{-0.03}$	$1.11^{+0.07}_{-0.06}$
R_{BB} (m)	392^{+11}_{-10}	140^{+17}_{-14}
f^a_{TOT}	1.2×10^{-9}	2.0×10^{-11}
f^a_{PL}	7.3×10^{-10}	1.5×10^{-11}
f^a_{BB}	4.7×10^{-10}	0.5×10^{-11}
χ^2_ν	1.052	1.036
d (kpc)	1	2.5
L^b_X	1.4×10^{35}	1.5×10^{34}
R_{col} (m)	345	200

[a] Unabsorbed flux in units of erg cm^{-2} s^{-1}
[b] Total luminosity in units of erg s^{-1}

3. Simbol–X simulations.

Based on observations taken with *RossiXTE*, Coburn et al. (2001) found that the fit of the of X Persei spectrum is improved by the addition of a *CRSF* at 28.6 keV. Prompted by this result, we investigated the capability of *Simbol–X* to detect this type of feature both in X Persei itself and in RX J0146.9+6121.

We generated in XSPEC the expected count spectra of the two sources using the script *sx_ws2.tcl* provided by the *Simbol–X* team, which assumes the current reference configuration: a telescope with multi–layer mirrors of Wolter–I type, with FL = 20 m, FOV = 12' and HEW = 18" at 30 keV; a Macro–Pixel and a CZT detector for the low and high energy bands, respectively, with 128x128 pixels each. For both detectors two relevant response files were used, i.e. one ARF and one RMF file.

For each source we considered its *XMM–Newton* best–fit model (Table 1), corrected by a CYCLABS component (Makishima et al. 1990) with a cyclotron energy of 28.6 keV. We generated the spectra of both sources considering an observation time of 50 ks, then each spectrum was fitted both without and with the CYCLABS component; the spectra and the data-model residuals are reported in Fig. 1. It clearly shows that the first solution is rejected by the data, thus proving the capability of *Simbol–X* of detecting a *CRSF* also in faint sources like RX J0146.9+6121.

Based on the above results, we consider the broadband study of long period Be/NS pulsars a primary scientific topic for this mission.

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