The broad-band X-ray spectrum of RE 0751+14 (PQ Gem)

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RE 0751+14 is a member of the class of Soft Intermediate Polars. Unlike classical Intermediate Polars, they are characterized by the presence of a soft component in their X-ray spectra, in addition to the hard component typical of these systems. The broad-band coverage of the Narrow-Field instruments on board BeppoSAX is ideal for the study of such objects. Here we report the preliminary results of the analysis of a BeppoSAX pointing to RE 0751+14. Both components are clearly detected, and their temperature determined (∼50 eV and ∼40 keV), enabling the possibility of studying them simultaneously.

1. INTRODUCTION

Intermediate Polars (IPs) are a subclass of cataclysmic variables in which the magnetic field of the white dwarf strongly influences the accretion flow, channeling the material onto the magnetic poles. Contrary to the class of Polars, these systems are not synchronized, i.e. the white dwarf rotation period is shorter than the orbital period of the binary. An accretion disk might be present, but disrupted by the magnetic field before reaching the white dwarf surface. As the accreting gas reaches the white dwarf, a strong shock is formed, resulting in the emission of X-rays (see \cite{1} for a review).

Differently from Polars, IPs do not generally show detectable polarized radiation in the optical/IR bands, suggesting that they possess lower magnetic fields, although the detection of polarized radiation in a few systems has raised the question of whether IPs have similar magnetic fields to Polars but are still asynchronized because of their longer orbital periods \cite{2}.

Coherent X-ray pulsations, ranging from a few tens to a few thousands of seconds, are a signature of channeled accretion towards the magnetic poles of the white dwarf. While in the optical this periodicity $P_{\omega}$ appears as a large-amplitude quas sinusoidal modulation, in the X-rays it is quite complex \cite{3}. The X-ray spin pulse amplitude is strongly energy dependent, being greater (∼50%) at low energies. This suggests that the modulation is at least partly due to phase-dependent photoelectric absorption. Besides the spin, variations at the orbital $P_{\Omega}$ (∼ hours) and beat $P_{\omega-\Omega}$ periods are also observed.

IP’s are harder than polars in that they gen-
erally do not have visible soft X-ray components, which could be consistent with the idea that high field magnetic accreting white dwarfs tend to suppress hard X-ray emission \cite{4}. On the other hand, the possible presence of large additional absorption is likely to make such a component unobservable. Observations made with the *Ginga* satellite showed that for some systems a good fit is obtained with a double bremsstrahlung model in which the two components have the same temperature but different intrinsic absorption \cite{5,6}. An obvious interpretation for this is that the absorbing material is spatially or temporally inhomogeneous.

Recently, an substantial soft X-ray component has been discovered in a few sources of the IP class. Four of these sources were discovered with *ROSAT* \cite{7,8}. Based on the similarity of their energy distribution with that of Polars, and on evolutionary considerations \cite{10}, it is thought that these soft IPs are the actual progenitors of Polars. Indeed, their soft component has been modeled as a blackbody with temperatures between 40 and 60 eV, slightly higher than the typical values for Polars. In the two systems which were bright enough to allow a more detailed spectral analysis, an additional weaker hard component has been observed \cite{11}.

It is thus crucial to properly determine the energy distribution at low and high energies in order
Table 1  
Preliminary best fit parameters corresponding to the model described in the text.

| Parameter   | Best fit value |
|-------------|----------------|
| \(N_H\)    | \(1.1 \times 10^{20}\text{cm}^{-2}\) |
| \(kT_{bb}\)  | \(51 \pm 11\text{ eV}\) |
| \(R_{bb}\)  | \(16\text{ (d/260 pc) km}\) |
| \(L_{bol_{bb}}\) | \(2.5 \times 10^{32}\text{ (d/260 pc)}^2\text{ erg/s}\) |
| \(kT_{br}\)  | \(43 \pm 13\text{ keV}\) |
| \(L_{br}\)  | \(5.8 \times 10^{31}\text{ (d/260 pc)}^2\text{ erg/s}\) |
| \(E_{line}\) | \(6.62\text{ keV}\) |
| \(\sigma_{line}\) | \(0.38\text{ keV}\) |
| \(N_H\)    | \(7.6 \times 10^{22}\text{ cm}^{-2}\) |
| cov. frac. | 0.46 |

To evaluate the influence of the magnetic field, of the accretion rate and of the inferred accretion geometry on the existence of a strong soft component. With this goal in mind, we have started a campaign to observe three of these systems (RE 0751+14, RX J0558.0+5333 and FO Aqr) with BeppoSAX: the unique broad band coverage of the Narrow Field Instruments on board BeppoSAX is ideal for the study outlined above.

2. RE 0751+14

RE 0751+14 (PQ Gem) has been discovered as a bright EUV source in the ROSAT WFC All-sky survey [1]. It is the second IP ever detected in the EUV (the first being EX Hya) and the first EUV-selected. In common with classical IPs the system has an asynchronously rotating white dwarf (\(P_\omega=13.9\text{ min}\)), much shorter than the orbital period \(P_{12}\)=5.2 hr [13,14], a strong hard X-ray modulation at \(P_\omega\) [12] and optical modulation at the beat frequency [3]. The spin-modulated polarization and a photometric orbital variation in the red [13,14,15] and of course the presence of a strong soft X-ray component modulated at \(P_\omega\) are features which link RE 0751+14 to Polars, indicating a magnetic field stronger than classical IPs. Recently, Mason [7] reported large variations of \(P_\omega\). The white dwarf spins down with \(P = 1.1 \times 10^{-10}\text{s/s}\), the largest spin variation observed in an IP.

Its X-ray spectrum, as observed in two separate observations with ROSAT and Ginga has been modeled with a soft blackbody \((kT=46\text{ eV})\) and a partially-absorbed hard bremsstrahlung \((kT\sim 20\text{ keV})\). Additionally, a narrow iron line at 6.7 keV is also required to fit the data [12]. No time variations in the parameters of the partial-covering model were detected within the errors. A phase-resolved spectral analysis of both the soft and the hard components has also been performed, but the non-simultaneity of the data makes the results uncertain [12].

3. BEPPOSAX OBSERVATIONS

We observed RE 0751+14 with the Narrow Field Instruments on board BeppoSAX in 1996 between Nov. 9th 16:48 UT and Nov 12th 6:24 UT. The total exposure time is 105 ksec for MECS, HPGSPC and PDS, but only 24 ksec for the LECS, because of additional observational constraints. For a description of the satellite and its instruments see [18–21].

The source has been detected in all four instruments. Our preliminary analysis is limited to LECS, MECS and PDS, ensuring a coverage between 0.1 and 200 keV with a gap between 10 and 14 keV.

Data preparation and linearization was performed using the SAXDAS v1.0 package under FTOOLS environment. For LECS and MECS, source photons have been extracted from a circle centered on the source with radius 4′. The standard background has been used for background subtraction.

4. THE BROAD-BAND SPECTRUM

The 0.1–200 keV spectrum of RE 0751+14 obtained combining all three instruments is shown in Figure 1. The source is clearly detected from 0.2 to 40 keV. The net count rates in the different instruments are 0.13 cts/s (LECS), 0.30 cts/s (MECS, 3 units) and 0.26 cts/s (PDS). In order to fit the data we adopted a model consisting of interstellar absorption, a soft blackbody, a hard bremsstrahlung, a gaussian line around 6...
keV and a partial covering absorption model (see [12]). In order to account for differences in the cross-calibration, the normalizations for the single instruments have been left free and corrected for calibration effects after the fit. The best fit parameters are shown in Table 1 (reduced $\chi^2 \sim 1.0$). Given the preliminary status of the analysis, only the $1\sigma$ errors on the two temperatures are reported.

Thanks to the high-energy response provided by the PDS, it is for the first time possible to determine the temperature of both the hard and soft components simultaneously. Notice that they are roughly three orders of magnitude apart. The values are compatible with the results of [12]. The ratio of the soft to hard flux is $\sim 4.3$, also consistent with what found by [12]. At variance with what observed with Ginga, the iron line is rather broad and centered at lower energies. This is likely to be the result of the blending of multiple narrow lines such as seen in the IP AO Psc by [22]. The derived size of the emission area for the blackbody component is consistent with what derived by [11], corresponding to a fractional area of the white dwarf $f \sim 1 \times 10^{-5}$.

5. DISCUSSION

These results show that the soft X-ray emission in PQ Gem originates from a very small area which could be related to the footprints on the white dwarf surface of an arc-shaped accretion curtain [22]. On the other hand, the blackbody temperature derived here, consistent with the ROSAT results, falls into the high value range for Polars, while the thermal plasma temperature is close to the standard IPs. Interestingly, the derived soft-to-hard X-ray flux ratio is more appropriate to a Polar system.

We have compared the observed flux ratio (computed in the ROSAT band 0.1–2.4 keV) to those observed in Polar systems (see Fig 8. in [24]). From this we can estimate a magnetic field strength of $\sim 10$ G. This value is compatible with the estimates by [18].

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