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A time-variable, phase-dependent emission line in the isolated neutron star RX J0822–4300

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Abstract. RX J0822–4300 is the central compact object (CCO) associated with Puppis A. X-ray observations suggested it to be a young neutron star (NS) with a weak dipole field and a peculiar surface temperature distribution dominated by two antipodal spots with different temperatures and sizes. An emission line at 0.8 keV was also detected. Our 130 ks observation with *XMM–Newton* allowed us to study in detail its phase-resolved properties, confirming the existence of a narrow emission line, only seen in the "soft" phase interval – when the cooler region is aligned to the line of sight. We found evidence for a variation in this component, a decrease in the central energy from ∼0.8 keV in 2001 to ∼0.73 keV in 2009–10. The line could be generated via cyclotron scattering of thermal photons in an optically-thin layer of gas or it could originate in low-rate accretion by a debris disc. In any case, a variation in energy, pointing to a variation of the magnetic field in the line-emitting region, cannot be easily accounted for.

Key words. stars: neutron – pulsars: general – X-rays: individual: RX J0822–4300.

1. Introduction

RX J0822–4300, the CCO in Puppis A SNR (3.7 kyr), shows a peculiar timing behaviour with a 112 ms pulsation and a 180° shift in the phase of the pulse peaks occurring abruptly at ∼1.2 keV (Gotthelf & Halpern 2009). This is due to the existence of 2 antipodal spots on the surface, with different temperatures ("warm" and "hot") (Hui & Becker 2006) . The star rotation makes the spectrum to change from a soft phase (alignment with the warm spot), with evidence for an emission line at ∼0.8 keV, to a hard one (alignment with the hot spot). The upper limit to the period derivative points to a

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dipole magnetic field $B < 2 \times 10^{11}$ G, and to a characteristic age $\tau > 5$ Myr (Gotthelf et al. 2010). Thus, RX J08224300 can be included in the anti-magnetar family (De Luca 2008).

2. Results

We performed a phase-resolved spectral analysis on 2 different combined EPIC-pn event lists, one from the data collected in 2009–10 (∼130 ks), one from archival observations (∼50 ks, 2001). We selected 4 phase intervals and performed a simultaneous fit to the 4 phase resolved spectra for each epoch. A double blackbody (2BB) model resulted in structured residuals in the 0.6–0.9 keV range only in the soft phase, clearly pointing to a missing component. Moreover, the parameters did not change between the epochs, but residuals did. The addition of a gaussian emission line gave a much better fit with no structured residuals. Then we linked the 2BB parameters between the two epochs, leaving the parameters of the line free to vary in time. The line component varies as a function of time, its central energy being higher in the first epoch (∼0.80 keV) than in the second one (∼0.73 keV) (Fig. 1). For details see De Luca et al. (2012).

The most natural interpretation of the variable emission line is that of a cyclotron feature produced by electrons in a very compact region. A variation of the central energy of the feature would require a change either in the position of the emitting plasma within a non-variable magnetic field, or in the intensity of the magnetic field itself. Another possibility is the cyclotron scattering of surface thermal photons by a geometrically- and optically-thin layer of plasma. However, one might invoke a spatially limited scattering medium, possibly some distance away from the star surface. To ease the problem, an energy source unrelated to the surface thermal emission should be invoked to excite the electrons, e.g. low rate accretion endowed with magnetic fields of 10^{11-13} G.

3. Conclusions

The time-evolution of the spectral feature we found is model-independent and represents the first evidence for variability in an "antimagnetar" candidate. Likely, such activity is related to a variation in the magnetic field of the star. A ∼10% decrease in ∼8 yr seems unlikely to be attributed to the large-scale dipole field. Possibly, we are witnessing evolution of a localized multipole component, dominating close to the star surface. This would hint at the presence of a large internal field, as proposed to explain the anisotropic thermal map of the star. Precise X-ray timing and further sensitive phase-resolved spectroscopy to monitor variability could help to solve this puzzle. Our result would have important implications for the understanding of CCOs and of their relations with other families of NS.

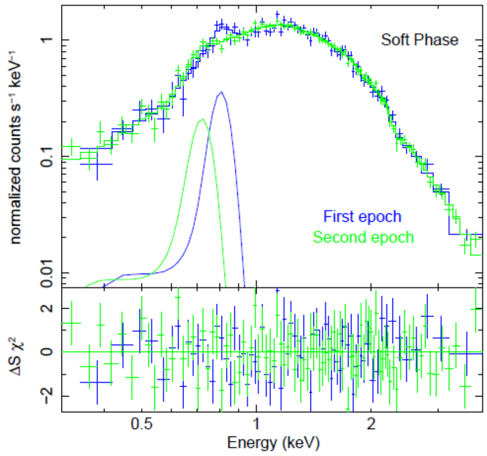

Fig. 1. Soft-phase spectra for the two epochs. The best-fitting model (2BB+Gauss) is superimposed and the line component at both epochs is also shown. The continuum components do not change as a function of time. The model yields a good description of the spectra (χ^2_ν=1.02, 154 d.o.f.).

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