XMM-NEWTON OBSERVATIONS OF THE TWO ANOMALOUS X-RAY PULSARS 1RXS J170849.0-400910 AND 1E 1048.1-5937

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ABSTRACT

We report the results of *XMM-Newton* observations of the two Anomalous X-ray pulsars 1RXS J170849.0-400910 and 1E 1048.1-5937. We discuss their long term evolution and the existence of correlations between X-ray flux, spectral hardness and pulsed fraction.

Key words: X-rays; Neutron Stars; magnetars.

1. 1RXS J170849.0-400910

The Anomalous X-ray pulsar (AXP) 1RXS J170849.0-400910 is a particularly interesting source, for at least two reasons. First, although early data suggested it was a fairly stable rotator (Israel et al., 1999), in the last four years it experienced at least two glitches (Kaspi et al. 2000, Kaspi et al. 2003, Dall'Osso et al. 2003) with different post-glitch recoveries. Second, an absorption line at ~ 8keV has been detected at 4σ confidence level (CL; Rea et al. 2003), in the phase-resolved spectrum taken with BeppoSax in 2001. This was the longest observation ever performed for this AXP, and it was taken when the source was not totally recovered from its second glitch.

We observed the source with *XMM-Newton* during the post-glitch epoch, for 50ks on 28-29 Aug 2003 (see Rea et al. 2005 for more details). By comparing these data with those collected over the past five years, we found a clear correlation between the spectral index Γ and the luminosity L: the spectrum became harder as the flux rose in correspondence of the two glitches and then softened as the luminosity dropped, following the glitch recovery (see Fig.1). However, we found no evidence for absorption features in the *XMM-Newton*. In particular, for a line

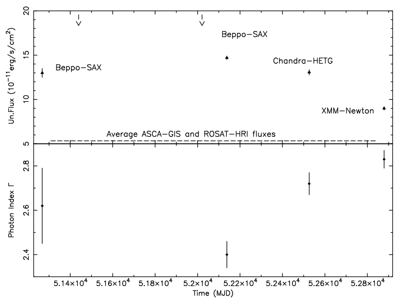

Figure 1. Flux and spectral hardening evolution of 1RXS J170849.0-400910. The dashed line is the average flux measured with Asca and Rosat. The two arrows mark the time of the two glitches. During the second BeppoSax observations, taken shortly after the second glitch, an absorption line at ~ 8keV has been detected (Rea et al., 2003). Taken from (Rea et al., 2005).

at ~ 8keV we derived a 95% upper limit for the depth of 0.15. For comparison, the depth of the line observed with BeppoSax at this energy was 0.8 ± 0.4 at 90% CL.

Quite interestingly all the observed phenomenological features including the glitching activity, the observed $\Gamma - L$ correlation, and, possibly, the transient appearance of a cyclotron line may be explained by the onset of a twist in the external magnetosphere. As suggested by Thompson et al. (2002), "magnetars" (AXPs and SGRs) may differ from radio pulsars in the fact that their internal magnetic field is highly twisted, up to 10 times the external dipole. At intervals, it can twist up the external field, leading to the build up of stresses in the star crust, crustal fractures and possibly glitches. Twisted magnetospheres can also support current flows. In turn, the pres-

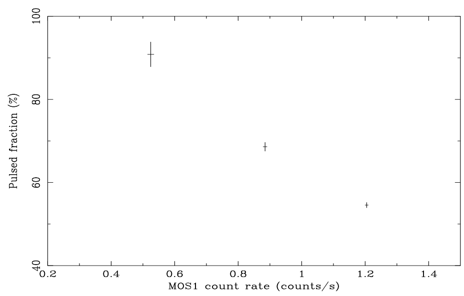

Figure 2. Correlation between PF and count rate, as measured by XMM-Newton. From Tiengo et al. (2005).

ence of charged particles (e^- and ions) produces both a large resonant scattering depth and an extra heating of the star surface (by returning currents). However, since i) the e^- distribution is spatially extended and ii) the resonant frequency for e^--cyclotron depends on the local value of the magnetic field, repeated scatterings onto e^- could lead to the formation of a high energy tail instead of a narrow line. Both e^- scattering depth and released luminosity increase with the twist angle, and, since the spectral hardness increases with depth, this implies a positive $\Gamma - L$ correlation (as observed). Finally, this scenario may explain the transient appearance of a cyclotron line during the epoch in which the twist was substantial. In fact, magnetospheric charges also provide a substantial depth to the resonant proton scattering. When the X-ray luminosity at the resonant frequency exceeds the luminosity produced by the returning currents, ions are effectively confined in a thin layer close to the surface leading to the appearance of a spectral line instead of a power law tail.

2. 1E1048.1-5937

Among other AXPs, 1E1048.1-5937 is particularly important for understanding the connection between AXPs and SGRs. It is the first AXP for which X-ray bursts have been discovered and it is one of those with hardest spectrum and most variable period evolution (both characteristics are typical of SGRs). Long term variations in its X-ray flux have been reported in the past using data from different satellites (Oosterbroek et al., 1998) and have recently more firmly established by Mereghetti et al. (2004), and by the RXTE monitoring programme (Gavriil & Kaspi, 2004). Here we present results based on 3 *XMM-Newton* observations taken in 2000, 2003 and 2004, which allow a systematic study of long terms changes based on a homogeneous dataset (see Tiengo et al. 2005 for a more detailed discussion).

We find that the canonical AXPs model, consisting of an absorbed blackbody plus a power law component, can reproduce all spectra, while a two blackbodies model is rejected by the high quality spectrum taken with a 50ks observation in 2003. In the attempt to establish a more physical link between the thermal and the power law components, we also fitted the 3 spectra with a simple Comptonization model (CBB = Comptonized Black Body). The basic idea is that soft thermal photons (emitted, e.g., at the star surface) are upscattered by a population of relativistic e^- with small optical depth and mean Lorentz factor $\langle\gamma\rangle$. If the soft photon input is a blackbody at T_{BB}, the emerging photon spectrum is given by $\mathrm{CE}^{-\alpha}\int_0^{\mathrm{E}} \mathrm{dE}'\,\mathrm{E}'^{1+\alpha}/[\exp(\mathrm{E}'/\mathrm{kT_{BB}})-1]$, where $\alpha = 1 - \ln\tau^B_{\mathrm{es}}/\ln \mathrm{A}$, τ^B_{es} is the scattering depth in a magnetized medium, $\mathrm{A} \sim 4\langle\gamma^2\rangle/3$ is the mean energy amplification factor per scattering, and C is a normalization factor. We have found that a two component model made of a CBB and a colder blackbody successfully reproduces all observations. In this case the radius of the colder blackbody is consistent with the star radius, while a smaller area is associated with the hotter thermal component. This may suggest that a magnetically active hot region is present at the star surface: accelerated high energies particle heat the region and upscatter soft photons, producing the comptonized spectrum.

XMM-Newton data clearly revealed a spectral difference between the three observations, with spectral changes not monotonically related with the X-ray luminosity (when the flux is at the highest level, in 2003, the spectral hardness is intermediate). However, we find a coherent pattern between flux and pulsed fraction (PF) (shown in Fig.2). The reality of this correlation is quite robust, since in Fig.2 we are comparing PFs and fluxes measured with the same detector operating in the same mode in the three observations (0.6-10 keV, MOS1). Accounting for the existence of an empirical anti-correlation between flux and PF is crucial when the source energetics is inferred by measurements of the pulsed flux. For instance, we estimated that the total energy release of the RXTE flares peaking in Nov. 2000 and June 2001 can be at least double (2 and 20×10^{40} ergs) the value derived assuming a constant PF = 0.94 (Gavriil & Kaspi, 2004).

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