Our distorted view of magnetars:

Applications of the Resonant Cyclotron Scattering Model to AXPs and SGRs

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Introduction: Anomalous X-ray Pulsars (AXPs) are a small class of slowly rotating (5-12 s) pulsars the emission of which highly differs from the rest of the known X-ray pulsars. Their high X-ray luminosity (10^{34} - 10^{36} erg/s) is thought to be powered by the decay of the strong magnetic field they are believed to have (10^{14} - 10^{15} G, according to the magnetic dipole loss formula), although other models, e.g. invoking a fossil disk, are still open and largely plausible. The X-ray spectrum of these sources has been all along empirical fit by two components (besides the absorption): a thermal black-body with kT ~ 0.3-0.4 keV and a non-thermal steep power-law with Γ ~ 2-4 (see Woods & Thompson for a recent review). However, the physical interpretation of these two components is still not clear and the discovery of infrared and γ-ray emission from most of these objects made an overall picture of their spectral distribution even more complicate and unclear.

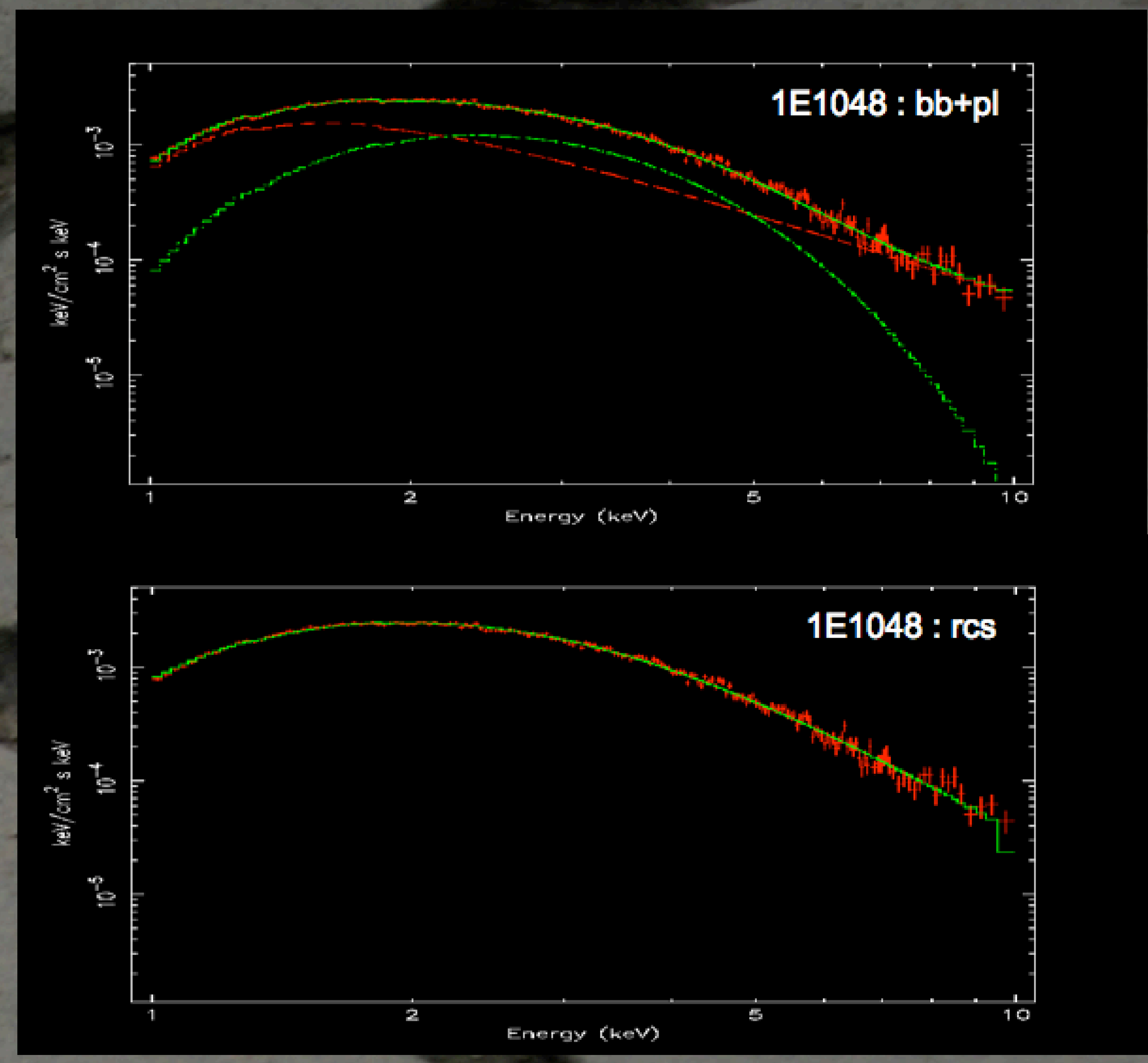

Figure 1: 1E 1048-5937. XMM-Newton spectrum fit with an absorbed power-law plus a blackbody and with the RCS model, first and second panels, respectively.

	N_H (10^{22} cm^{-2})	kT (keV)	BB norm / β	Γ / τ	PL norm / RCS norm	$\chi_\nu 2$	Flux$_{(2\text{-}10\ \text{kev})}$ erg s^{-1}cm^{-2}
BB + PL	1.12	0.64	1.03e-4	3.3	1.09e-2	0.99	7.9e-12
RCS	0.49	0.52	0.41	1.9	0.22	1.09	7.9e-12

Table 1: 1E 1048-5937. XMM-Newton spectral parameters for the BB+PL model and the RCS model (for info on this observation see Tiengo et al. 2005). Note that the derived RCS values differ from those fixed in Lyutikov & Gavriil 2005 for the Chandra observation, in fact their preliminary model was not an XSPEC interpolating model hence they had to fix β, τ and T and fitting only the normallization.

The Resonant Cyclotron Scattering Model.
Magnetospheres of magnetars may be filled with dense plasma, with densities well in excess of the minimum expected value (Goldreich-Julian density). Since in the soft X-rays the resonant cyclotron cross-section is about five orders larger than the Thompson cross-section, a relatively small amount of plasma suspended in the magnetospheres of neutron stars may considerably modify the emergent spectra. Multiple resonant cyclotron scattering by a non-relativistic w in an inhomogeneous magnetic field will on average Compton-up the transmitted radiation resulting in a formation of a non-thermal spectrum. This model is intended to explain the black-body plus power-law modelling of the X-ray spectra of AXPs, interpreting the AXPs' spectrum as this transmitted radiation, where the thermal surface emission was modified by the resonant compton scattering process (see Lyutikov & Gavriil 2006).

In practice: Intensity tables, through a Monte-Carlo, were created for this analytical model for different values of β (thermal velocity in terms of velocity of light: ranging between 0.1-0.5), τ (resonant optical depth; in the 1-10 range) and T (surface black body temperature; in the 0.1-3 keV range). We then built an XSPEC atable model with four parameters: β, τ, T and normalization. We then fit the model with XSPEC to the XMM-Newton and Chandra spectra of a large number of AXPs and SGRs (1RXS J1708-4009, 1E 2259+586, 1E 1048-56, XTE J1810-197, 4U 0142+61, SGR 1806-20, SGR 1900+14). See Fig.1, 2 and 3.

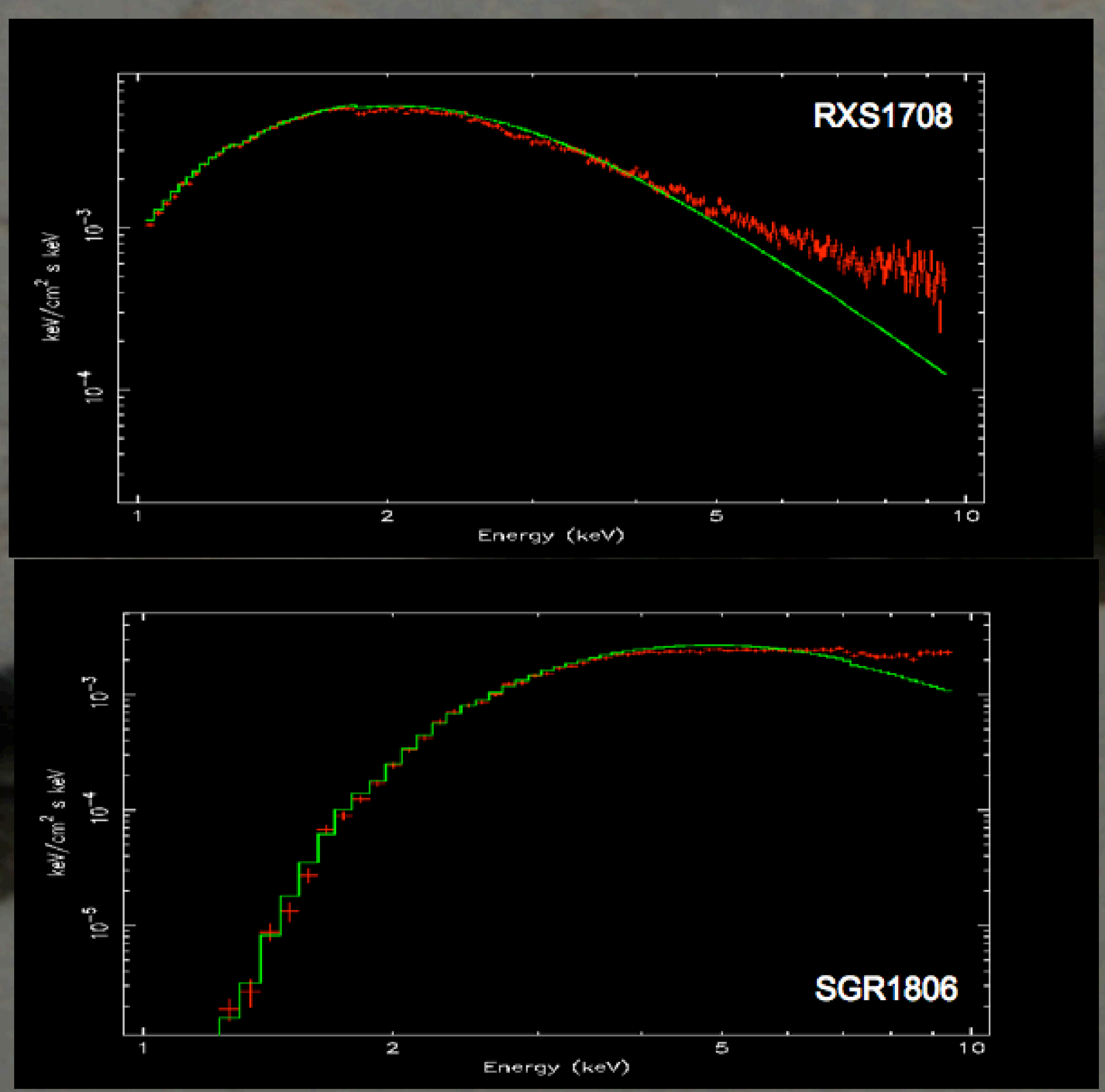

Figure 2: 1RXS J1708-4009 and SGR1806-20 . XMM-Newton spectra fitted with he RCS model, first and second panels, respectively (the black-body plus power-law fits might be found in Rea et al. 2005b and Mereghetti et al. 2005b) .

Conclusions: For the softer sources, as 1E 1048-5937, the Resonant Cyclotron Scattering model can explain their X-ray emission as well as the black-body plus power-law model, with the advantage of a clear physical explanation (see Fig. 1). However, for the AXPs and SGRs with a much harder X-ray spectral emission, with feasible values of τ and β, the model drops too fast to explain their emission at higher energies (see Fig. 2 and 3). This apparent discrepancies might be explained as a different contribution in the 6-10 keV range of the hard tail these sources are known to have (Kuiper et al. 2006). We fitted with this model all AXPs and SGRs, inferring many information on the characteristics of this plasma which is possibly present in the magnetosphere of some of these sources (see Tab. 1). A detailed discussion is in progress (Rea et al. 2006, in prep.)

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