XMM-Newton and *INTEGRAL* observations of Soft Gamma-ray Repeaters

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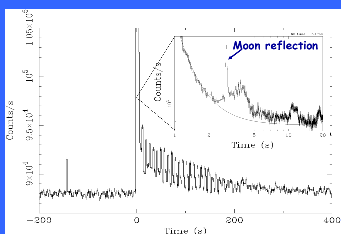
ABSTRACT

All the currently known Soft Gamma-ray Repeaters (SGRs) have now been observed with the *XMM-Newton* satellite, allowing us to describe with unprecedented details the soft X-ray emission from these objects. Moreover, the *INTEGRAL* satellite has allowed us to study for the first time the persistent hard (>20 keV) X-ray emission from the two brightest SGRs, SGR 1806-20 and SGR 1900+14.

In particular, SGR 1806-20, which displayed exceptional activity in the last few years, culminating with the Giant Flare of 2004 December 27, was observed several times by *XMM-Newton* and frequently monitored by *INTEGRAL* between 2003 and 2005, showing different spectral and intensity states. On the other hand, SGR 1900+14 and SGR 1627-41 have been observed in a non-bursting state, allowing us to study the persistent emission of SGRs when the source activity level is low.

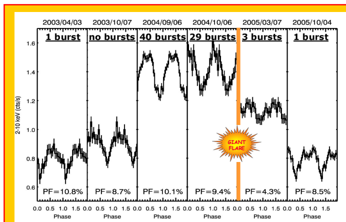
The results can be interpreted within the *magnetar* scenario, where the SGR energy is provided by the decay of the extremely high magnetic field (B~10^{14}-10^{15} G) of these peculiar neutron stars, and compared with those obtained for the Anomalous X-ray Pulsars (AXPs), that are also believed to be *magnetars* and have been extensively observed with *XMM-Newton* and *INTEGRAL*.

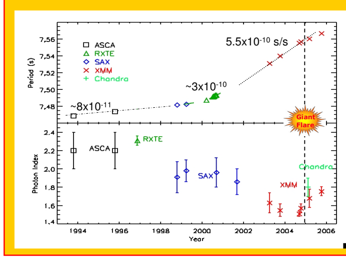
The Giant Flare of SGR 1806-20



On 2004 December 27, the anticoincidence of the SPI instrument on *INTEGRAL* was saturated by a huge spike followed by a tail pulsating at a period of 7.56 s, that allowed to identify the source of a Giant Flare from SGR 1806-20 *(Borkowski, Götz, Mereghetti et al., 2004, GCN 2920).* The initial spike was the strongest cosmic signal ever detected by a γ-ray instrument and saturated almost all the in-orbit satellites. It was so bright to be detected also through its reflection on the Moon surface.

XMM-Newton monitoring of SGR 1806-20

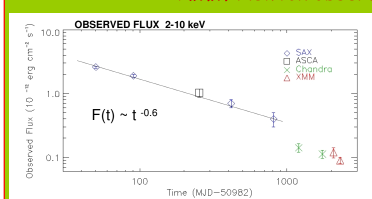




SGR 1806-20 has been observed by *XMM-Newton* 7 times (the data of the last observation, performed on 2006 April 4, are not yet available). The source flux increased from 2003 to 2004, but then decreased after the Giant Flare. This flux variability can be directly related to the burst activity, that was very high in the months preceding the Giant Flare (see, at the top of each panel, the number of bursts detected by *XMM-Newton*). This behavior can be explained in the framework of the *magnetar* model, where the increase in the flux and burst frequency is caused by the twisting of the magnetosphere, and a Giant Flare is due to a sudden reconfiguration of the magnetosphere to a more relaxed state (*Thompson, Lyutikov & Kulkarni 2002, ApJ, 574, 332*).
An additional indication of a global magnetospheric reconfiguration connected to the Giant Flare comes from the pulsation profiles of the 6 observations: in addition to some changes in the shape, we note that the pulsed fraction (reported at the bottom of each panel) has significantly decreased in the first observation after the Giant Flare.

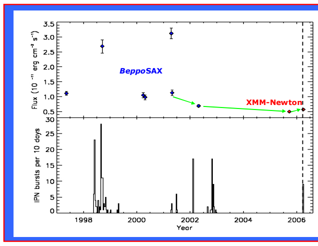
The upper panel shows how the spin-down trend of SGR 1806-20 increased after 2000, to decrease again to an intermediate value after the Giant Flare. As shown in the lower panel, where the photon indexes of a power-law fit to the X-ray spectra are plotted, the spin-down rate is well correlated to the spectral hardness, that increases when the spin-down rate is higher. This correlation is the same observed by *Marsden & White (2001, ApJ, 551, L155)* comparing the hardness and spin-down of different AXPs and SGRs, and can also be interpreted within the *magnetar* model. In fact, the spectral hardening might be caused by the cyclotron resonant scattering produced by the magnetospheric currents induced by the magnetic field twisting, that might be also responsible for the higher spin-down rate, because, for a fixed dipole field, the fraction of field lines that open out at the speed-of-light cylinder grows as the field twisting increases.

XMM-Newton observations of SGR 1627-41



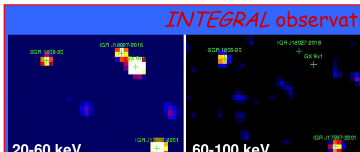
SGR 1627-41 was detected by *XMM-Newton* at a very low flux level, corresponding to the lowest luminosity (~3×10^{33} erg/s, for d=11 kpc) ever observed for an SGR. As foreseen by the *magnetar* model, the lack of bursts from this source since 1998 might be the reason for the low X-ray luminosity reached in recent years. However, the ~10^{36} erg/s luminosity still observed in SGR 0526-66 after more than 20 years of bursting inactivity, is a puzzling exception to this prediction.

XMM observations of SGR 1900+14

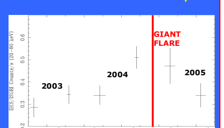


The relation between luminosity and bursting activity is also confirmed by the comparison between the two available *XMM-Newton* observations of SGR 1900+14: the first one, taken after a long quiescent period, confirmed a decreasing trend in luminosity already visible in the last *BeppoSAX* observation performed 3.5 years earlier, but the most recent one shows an increase associated to the burst reactivation of March 2006.
See the poster of Esposito et al. for details.

INTEGRAL observations of SGR 1806-20

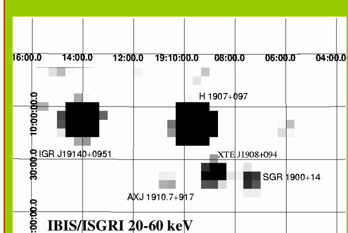


Thanks to very long observations with the γ-ray imager IBIS-ISGRI on board the *INTEGRAL* satellite, SGR 1806-20 was the first SGR to be detected as persistent source of hard X-rays.



Note how the flux of the hard X-ray tail is well correlated with that observed by *XMM-Newton*. It means that also the hard tail can be related, as explained for the soft X-ray emission, to the cyclotron scattering mechanism induced by the magnetospheric twisting.

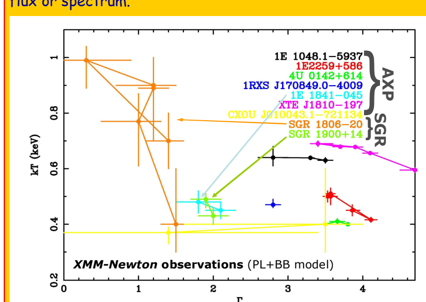
INTEGRAL discovery of persistent hard X-rays from SGR 1900+14

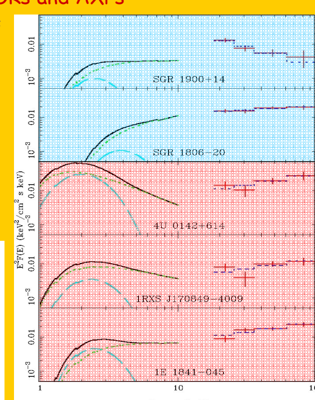


INTEGRAL has also allowed us to discover persistent hard X-ray emission from the other moderately active SGR: SGR 1900+14. The *INTEGRAL* observations were taken in a period preceding the bursting reactivation of March 2006, making SGR 1900+14 the first *quiet* SGR detected at high energies. This might be the reason for the steep spectrum of its hard tail: a power-law with Γ~3, to be compared to Γ~2 found in SGR 1806-20. The much harder spectra (Γ~1, *Kuiper et al. 2006, astro-ph/0603467*) observed in the AXP spectra above 20 keV, instead, do not follow this possible correlation.

Comparison between SGRs and AXPs

The *XMM-Newton* spectra of SGR 1900+14 and the ones of SGR 1806-20 with the best statistics are not well fit by an absorbed power-law model, but require the addition of a blackbody component. The same model is adequate also for all the AXPs, that have been observed in several occasions by *XMM-Newton*. The blackbody temperatures are similar for all the *magnetar* candidates, while the photon index is typically softer for the AXPs. It is however worth to note that SGR 1900+14 have spectral parameters very similar to those of the AXP 1E 1841-045, that is one of the quietest AXPs, never being observed to emit bursts and/or vary in flux or spectrum.





The INTEGRAL spectra show instead that the AXPs are harder than SGRs, with the broad-band spectra of AXPs requiring a positive break in the power-law at ~15 keV. Note also the very different slopes of the hard tails of 1E 1841-045 and SGR 1900+14.

These results are widely discussed in our recent papers:

- S. Mereghetti, D. Götz, et al., *INTEGRAL discovery of persistent hard X-ray emission from the Soft Gamma-ray Repeater SGR 1806-20*, 2005, A&A 433, L9
- S. Mereghetti, D. Götz, et al., *The First Giant Flare from SGR 1806-20: Observations Using the Anticoincidence Shield of the Spectrometer on INTEGRAL*, 2005, ApJ 624, L105
- S. Mereghetti, A. Tiengo, P. Esposito, D. Götz, et al., *An XMM-Newton view of the Soft Gamma Repeater SGR 1806-20: long-term variability in the pre-Giant Flare epoch*, 2005, ApJ, 628, 938
- N. Rea, A. Tiengo, S. Mereghetti, et al., *A First Look with Chandra at SGR 1806-20 after the Giant Flare: Significant Spectral Softening and Rapid Flux Decay*, 2005, ApJ, 627, L133
- A. Tiengo, P. Esposito, S. Mereghetti, et al., *The calm after the storm: XMM-Newton observation of SGR 1806-20 two months after the Giant Flare of 2004 December 27*, 2005, A&A, 440, L63
- D. Götz, S. Mereghetti, A. Tiengo, P. Esposito, *Magnetars as persistent hard X-ray sources: INTEGRAL discovery of a hard tail in SGR 1900+14*, 2006, A&A, 449, L31
- S. Mereghetti, P. Esposito, A. Tiengo, R. Turolla, et al., *XMM-Newton observation of the Soft Gamma Ray Repeater SGR 1627-41 in a low luminosity state*, 2006, A&A, 450, 759