The hard X-ray emission of the pulsar wind nebula G21.5-0.9

F. Bocchino[1], L. Sidoli[2], A. Paizis[2], S. Mereghetti[2], R. Bandiera[3]

[1]INAF-Osservatorio Astronomico di Palermo, Italy

[2]INAF-Istituto di Astrofisica Spaziale e Fisica Cosmica, Milano, Italy

[3]INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy

Abstract: G21.5-0.9 is a pulsar wind nebula (PWN) with an intriguing X-ray halo, explained in terms of dust scattered emission from the core. Recently, the pulsar has been detected in radio, after a long search. We have combined the XMM-Newton and INTEGRAL data to study the spectrum of the nebula between 1 and 100 keV. Our preliminary result seems to indicate that the spectrum is well described by single power-law with γ=1.74+/-0.06, and a flux of 4.4 10^{-11} erg cm^{-2} s^{-1} in the 10-100 keV. Considering the uncertainties in the data points, a Vela-like strong break @ E<20-30 keV keV may be discarded, unlike smoother Crab-like breaks.

Hard X-ray tails in the spectra of pulsar wind nebulae

- In general, the present knowledge of the hard X-ray (E>10 keV) spectrum of pulsar wind nebulae (PWNe) is rather poor. Notable exceptions are the Crab (Massaro et al. 2000: Kuiper et al. 2001), Vela (Mangano et al. 2005) and B1509-58 (Forot et al 2006).
- Above 10 keV, the shape of the PWN (unpulsed) spectrum (and in particular **the detection of a break**) may reveal the details of the electron acceleration process (de Jager et al. 1996; Sefako & de Jager 2003)

The pulsar wind nebula G21.5-0.9:

- The PWN G21.5-0.9 has been extensively studied in radio (Bock et al. 2001 and references therein) and in the X-ray band up to 10 keV (e.g. Slane et al. 2000; Warwick et al. 2001; Safi-Harb et al. 2001. Bocchino et al. 2005 and reference therein). After a long quest (La Palombara et al. 2000), a pulsar has been finally detected (Gupta et al. 2005; Camilo et al. 2006).
- In literature, previous observations of G21.5-0.9 at above 10 keV have been reported by Malizia et al. (2004) with BeppoSAX/PDS. The data were contaminated by the outburst of the transient source IGRJ18325-0756; after correcting for this, the spectrum was fitted with a single power-law with a resulting photon index of 2.6 and a 20-100 keV flux of 4-5 10^{-11} erg cm^{-2} s^{-1} (Malizia et al. 2004). A very preliminary IBIS/ISGRI spectrum have been reported by Terrier et al. 2004, (3 bins, 15-60 keV). They obtain a flux of 3.6 10^{-11} erg cm^{-2} s^{-1} (15-60 keV) and suggest a steepening of the source spectrum at high energies, w.r.t the extrapolation of the 0.5-10 keV flux reported by Safi-Harb et al. (2001).

INTEGRAL observations of G21.5-0.9

- We analysed public archival observations of the source made with IBIS (Ubertini et al., 2003) on board INTEGRAL (Winkler et al., 2003). The source is detected only in the low-energy CdTe detector (ISGRI, energy range 15-1000 keV; Lebrun et al. 2003).
- Public observations pointed within 10 degrees from the source were used, resulting in **489 individual pointings** performed in 2003 and 2004), for **a total of about 934 ksec**. All the data have been processed using version 5.1 of the OSA analysis software.
- The average IBIS/ISGRI spectrum of G21.5-0.9 was extracted from the mosaic. To do so we ran the imaging step in four energy bands (20-30, 30-40, 40-60 and 60-100 keV) for all the pointings and then built one mosaic image per energy range in the standard way. The spectrum was finally extracted using the source flux from each energy map. The spectral analysis has been performed with the corresponding rebinned response matrices.

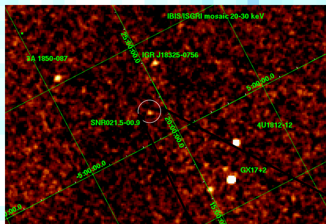


Fig. 1: INTEGRAL/IBIS image of the region around the pulsar wind nebula G21.5-0.9. The figure shows the significancee map in the 20-30 keV band, and it has been constructed by a subset of SCWs used for spectral analysis.

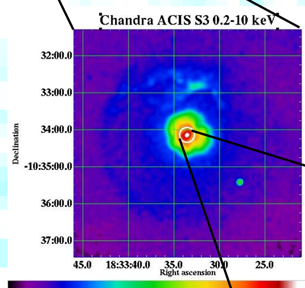


Fig. 2: Chandra ACIS image of the pulsar wind nebula G21.5-0.9. The figure shows the prominent X-ray halo around the bright PWN. Bocchino et al. (2005) argue that the halo is in part due to interstellar dust scattering and part due to a limb brightened X-ray shell. For this work, we have collected the spectrum from the 12" circle centered on the X-ray peak and shown in the figure.

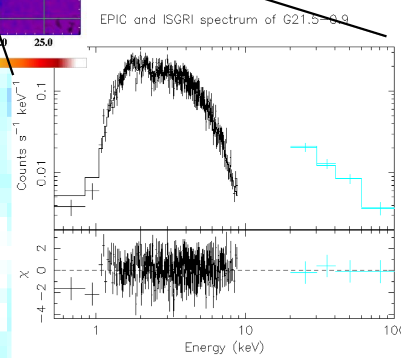


Fig. 3: XMM-Newton and INTEGRAL spectrum of the PWN G21.5-0.9. In this figure we have used the MOS spectrum extracted from the 12" circle of Fig. 1, which covers the 0.5-10 keV band, and the ISGRI spectrum extracted as specified in the left panel, extending up to 100 keV. We also show the best fit power law and residual (N_H=2.5+/-0.1 10^{22} cm^{-2}, γ=1.74+/-0.06). The ISGRI/MOS normalization factor is 1.8+/-0.1, fully consistent with the expected value of 1.78+/-0.06 (Kirsch et al. 2005). The 10-100 keV flux is 4.4 10^{-11} erg cm^{-2} s^{-1}.

DETECTING THE BREAK IN THE HARD X-RAY SPECTRUM

Fig. 1 shows that a single power-law is a good fit to the data. However, when carefully considering all the uncertainties, this does not imply that a break is >100 keV. By fitting the spectrum with a broken power law, we have derived the statistical constraints on the position of the break (Fig. 3). The results depends on the ISGRI/MOS normalization factor, and we have used the value 1.78+/-0.06 in deriving the χ^2 contours.

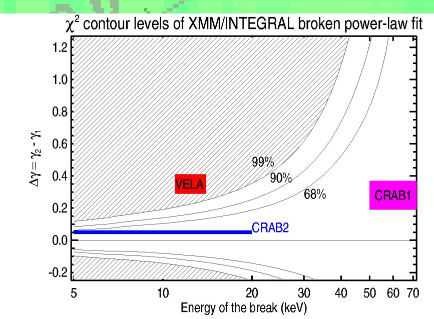
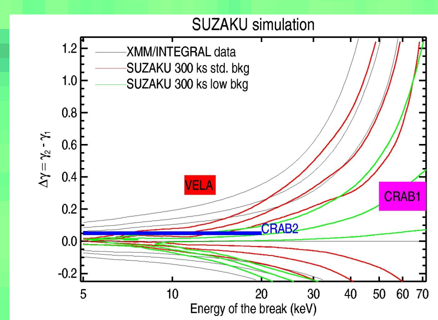


Fig. 4 (LEFT): Constraints on the shape of the spectrum from the XMM/INTEGRAL data. The forbidden region in the $\Delta\gamma$-E_b space is hatched. $\Delta\gamma$ is the difference between the index before (γ_1) and after (γ_2) the break. We also mark the position of the breaks detected in other PWNe, namely the Vela PWN (Mangano et al. (2005), the Crab nebula according to de Jager et al. (1996, "CRAB1") and Massaro et al. (2000, "CRAB2"). Out data allow us to discard "strong" breaks like the one of the Vela PWN, but smoother break are possible. We stress that the broken power-law model is an ideal representation of a more realistic situation in which the spectrum has a smooth curvature spanning a large bandwidth.

Fig. 5 (RIGHT): SUZAKU constraints on the shape of the spectrum of G21.5-0.9. Thanks to the 1-600 keV bandwidth of the XIS+HXD combination, a 500 ks observation may lead to substantial improvement on the localization of the break, especially in the case of low background (-3% PIN, -5% GSO), provided that accurate instrument intercalibration is provided. Unlike the real data (fig. 4), the presence of a smooth Crab-like break ("CRAB2") would be successfully addressed.



CONCLUSIONS

- The joint spectral analysis of XMM-Newton and INTERAL /ISGRI data on the pulsar wind nebula G21.5-0.9 strongly suggests that the hard X-ray emission comes from the 12" central region of the bright X-ray plerion.
- A fit with a power-law with γ=1.74 gives a good fit to the data up to 100 keV. However, a detailed spectral analysis with a broken power-law indicates that relatively "smooth" breaks like the ones observed in the Crab are consistent with the data, while Vela-like breaks are not (Fig. 4). Further observations in the hard X-ray (e.g. Suzaku HXD) band would lead to a better characterization of the spectrum of the nebula (Fig.5).
- The position of the break and the slope after it may be compared with models of electron acceleration and propagation in PWNe. Work is in progress to develop a detailed model of the synchrotron spectrum of this nebula, including a possible break below 100 keV.