



Revealing the X-ray emission processes of old rotation-powered pulsars: XMM-Newton observations of PSR B0950+08, B0823+26 and J2043+27



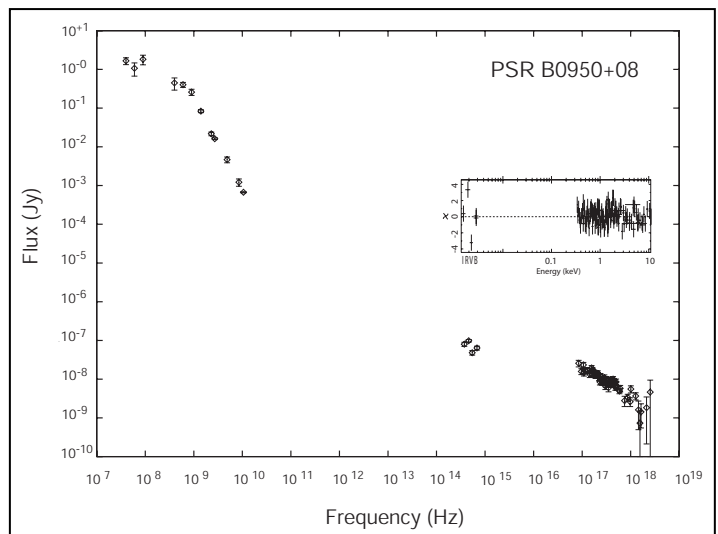
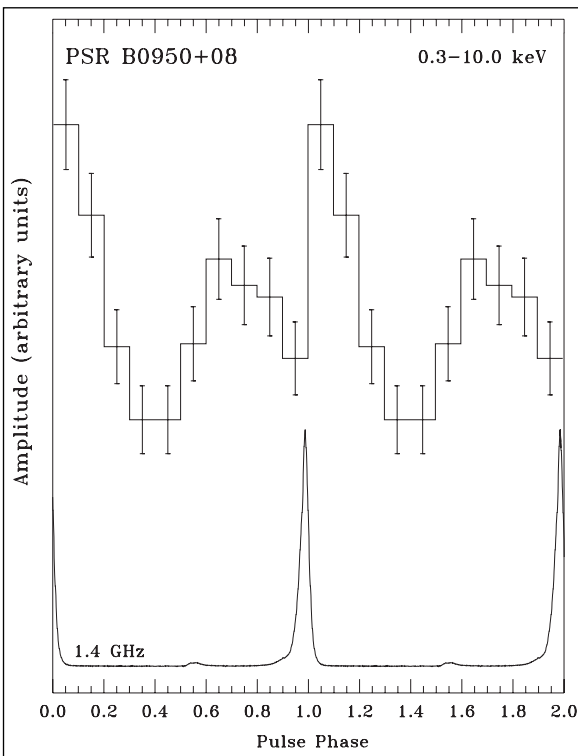
The X-ray emission of old rotation-powered pulsars is largely dominated by non-thermal processes

We have completed part of a program to study the X-ray emission properties of old rotation-powered pulsars with XMM-Newton in order to probe and identify the origin of their X-radiation. Only XMM-Newton has enough sensitivity to allow to study these old and relatively faint pulsars. As it turns out, their X-ray emission is largely dominated by non-thermal processes. Although thermal polar caps were expected, none of the observed spectra required adding a thermal component consisting of either a hot polar cap or surface cooling emission to model the data.

The X-ray spectrum of PSR B0950+08 is best described by a single power law of photon-index $\alpha = 1.93_{-0.12}^{+0.14}$. Taking optical data from the VLT FORS1 into account, a broken power law model with the break point $E_{\text{break}} = 0.67_{-0.41}^{+0.18}$ keV and the photon-index $\alpha_1 = 1.27_{-0.01}^{+0.02}$ and $\alpha_2 = 1.88_{-0.11}^{+0.14}$ for $E < E_{\text{break}}$ and $E > E_{\text{break}}$, respectively, is found to describe the pulsar's broadband spectrum from the optical to the X-ray band.

We also find that the X-ray emission from PSR B0950+08 is pulsed with two peaks per rotation period. The phase separation between the two X-ray peaks is $\sim 144^\circ$ (maximum to maximum) which is similar to the pulse peak separation observed in the radio band at 1.4 GHz. The main radio peak and the trailing X-ray peak are almost phase aligned. The fraction of X-ray pulsed photons is $\sim 30\%$. A phase-resolved spectral analysis confirms the non-thermal nature of the pulsed emission and finds no spectral variations as a function of pulse phase.

The spectral emission properties observed for PSR B0823+26 and PSR J2043+27 are similar to those of PSR B0950+08 (Becker et al., 2004, ApJ, in press).



Left: Integrated pulse profiles of PSR B0950+08 as observed with the EPIC-PN aboard XMM-Newton (top) and at 1.4 GHz with the Effelsberg radio telescope (bottom). **Right:** Combined radio, optical and X-ray spectral data of PSR B0950+08. The inset shows the contribution to the χ^2 fit statistic for a broken power law model fitted to the optical and X-ray data.