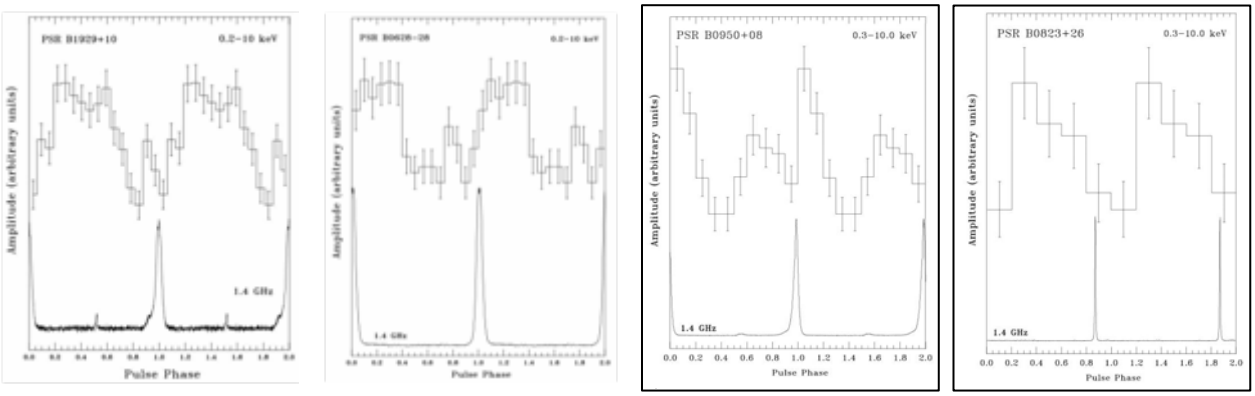
X-ray emission properties of old rotation-powered pulsars

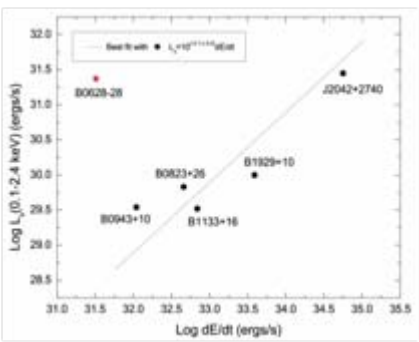
Werner Becker

Max-Planck Institut für extraterrestrische Physik, Giessenbachstrassse 1, 85741 Garching, Germany

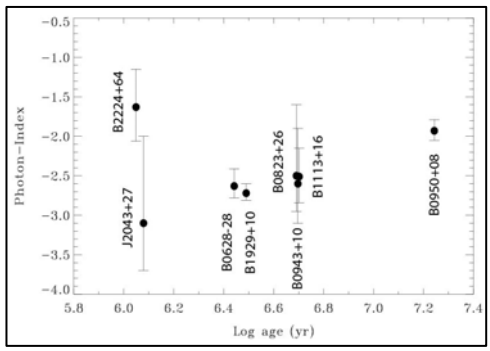
Results: We have studied the X-ray emission properties of old rotation-powered pulsars with XMM-Newton in order to probe and identify the origin of their X-radiation. The X-ray emission from these old pulsars is found to be largely dominated by non-thermal processes. All spectra are best fitted by a simple power law model. None of the observed spectra required adding a thermal component (representing either a hot polar cap or surface cooling emission) to model the data. For PSR B1929+10 -- which in X-rays is the brightest among the old rotation-powered pulsars -- the contribution from thermal emission of heated polar caps is inferred to be at most ~ 7%. The new results invalidate the ROSAT based picture in which old pulsars emit X-rays from heated polar caps and show sinusoidal pulse profiles. All lightcurves are markedly different from broad sinusoidal pulse profiles but show two or more peaks and/or narrow distinct features.



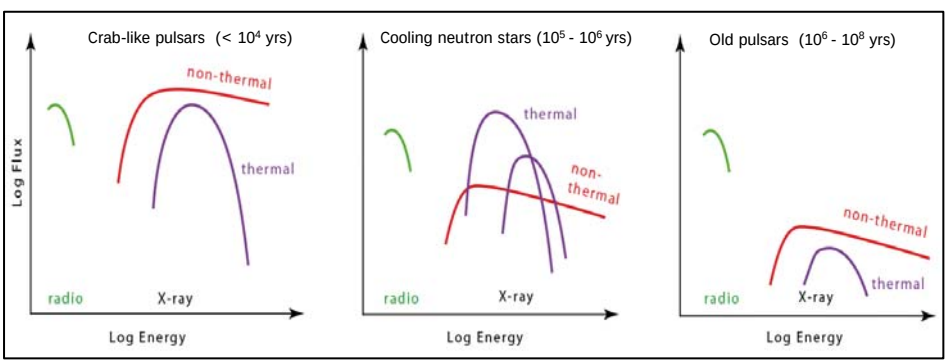
Integrated pulse profiles of the old pulsars PSR B1929+10, B0628-28, B0950+08 and B0823+26 as observed with the EPIC-PN aboard XMM-Newton (top) and at 1.4 GHz with the Effelsberg radio telescope (Becker et al. 2004, 2005, 2006). X-ray and radio profiles are phase aligned. Two phase cycles are shown for clarity. All pulsars which are detected with sufficient photon statistics show narrow pulse components. All lightcurves are markedly different from broad sinusoidal pulse profiles which are expected for thermal hot polar cap emitters! Pulsed fractions are in the range 30-50 %. Small energy dependences in the profiles are observed for B1929+10 and B0950+08.



X-ray luminosity vs. spin-down energy within 0.1-2.4 keV. The X-ray efficiency for all pulsars but B0628-28 is in agreement with Lx ~ 10^{-3} Edot (Becker & Trümper 1997). For B0628-18 the radio dispersion measure based distance in the Cordes & Lazio (002) Galactic free electron model might be to large by a factor of few, resulting in a to larger distance and hence to large X-ray luminosity (c.f. Becker et al. 2005, ApJ 633, 367).



Photon-Index vs. spin-down age for old rotation-powered pulsars. The energy spectrum of all old pulsars is best fitted by single power laws, identifying their emission to be non-thermal. No evidence forspectral softening with increasing spin-down age is seen for old pulsars.



Emission properties of rotation-powered pulsars are varying with age. There is no doubt that magnetospheric emission dominates in old pulsars. Their pulse profiles are not sinusoidal as concluded from ROSAT observations of B1929+10.

The hot polar caps in cooling neutron stars may be formed by internal anisotropic heat flow rather than from high energy particles bombarding the polar caps. Hot polar cap emission may then decreases along with the cooling surface component so that old (cooled down) neutron stars have no observable heated polar caps.

For references and more details see: Becker et al. 2006, ApJ, 645, 1421