Chandra Observations of Anomalous X-ray Pulsar J170849.0-400910

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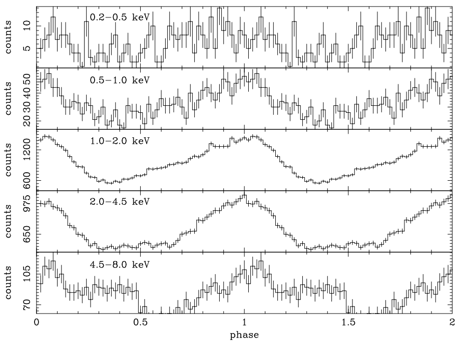
We present the results of Chandra continuous clocking mode observations of the Anomalous X-ray pulsar J1708-4009, made on March 4, 2004 (MJD 53189). The 0.3-10.0 keV spectrum is well fitted by a power-law plus blackbody model, as seen in earlier *Beppo*SAX and XMM-Newton observations. We find that the spectral properties are indeed variable, with the 0.5-10.0 keV unabsorbed source flux $f_x = 1.1 \times 10^{-10}$ ergs cm^{-2} s^{-1}, having increased since previous XMM-Newton observation (on MJD 52879). The trend towards spectral softening has reversed, with a harder $\Gamma = 2.61^{+0.13}_{-0.15}$ and higher $kT = 0.473^{+0.003}_{-0.003}$ keV. We present analysis of the phase resolved spectra, including fits to a two component black-body model. Our data do not reveal the 8.1 keV absorption feature as seen in the previous *Beppo*SAX observation, in either the phase-integrated, or in the phase-resolved spectra. Timing analysis of our data shows that the period is consistent with spin-down ephemeris determined for the post 2nd glitch era, from earlier RXTE/PCA observations.

Timing Analysis



Evolution of pulse morphology with energy, for 0.2–0.5, 0.5–1.0, 1.0–2.0, 2.0–4.5 and 4.5–8.0 keV bands. Plotted on the y-axis are counts/bin for a bin width of $2\pi/50$ radians.

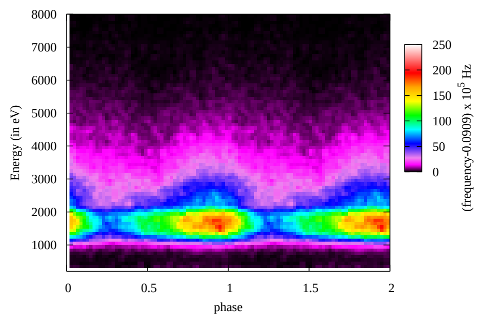
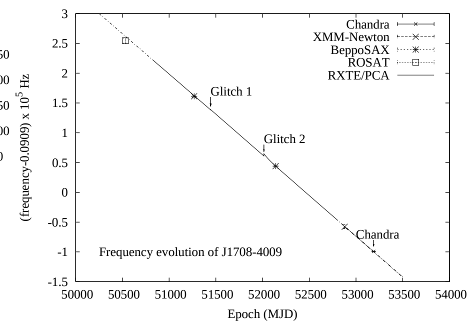


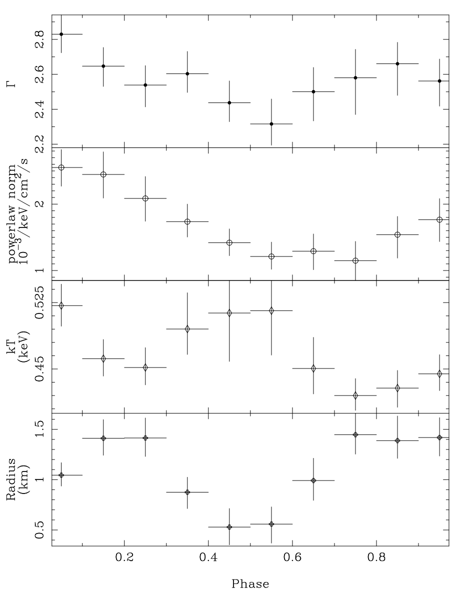
Figure maps the number of counts as a function of energy and phase, for a pulse profile divided in to 50 phase bins, and the 0.2-8.0 keV spectra distributed into 78 energy bins of 100 eV each.



Frequency evolution of J1708, including results from earlier *Beppo*SAX, ROSAT, XMM-Newton[5] and $\simeq 5.4$ years long monitoring observations with RXTE/PCA (solid line)[3]. See [6] for references.

Timing analysis of the 29.18 ks exposure was carried out using the Bayesian approach[1], as well as with the Z_1^2 method. The frequency evolution is seen to be consistent with that predicted from extrapolation of the spin ephemeris from the 2^{nd} glitch [3] on MJD 52014. The $0.3 - 8.0$ keV pulsed fraction varies between 35% to 45%, and approaches $\simeq 100\%$ at $E > 20$ keV (RXTE/HEXTE, RXTE/PCA and ISGRI observations)[4]. The pulse morphology evolves from a single peaked structure at $E < 4.5$ keV to a double-peaked structure at $4.5 \leq E \leq 10.0$ keV, with the “new” peak dominating at $E > 20$ keV.

Phase Resolved Spectroscopy & The Multiwaveband Spectra



Best fit parameters from powerlaw + black body fits to the phase resolved spectra of J1708. $N_H = 1.44 \times 10^{22}$ cm^{-2} (from phase integrated spectral fit) constant for all fits.

Time evolution of spectral parameters, for an absorbed powerlaw plus blackbody fit to the phase integrated spectrum.

MJD	Unabsorbed Flux ($\times 10^{-10}$ ergs cm^{-2} s^{-1})	Γ	kT keV	Reference
50329	1.68	$2.92^{+0.3}_{-0.3}$	$0.41^{+0.03}_{-0.03}$	Sugizaki et al., 1997
51268	1.3	$2.6^{+0.2}_{-0.2}$	$0.46^{+0.03}_{-0.03}$	Israel et al., 2001
52140	1.87	$2.40^{+0.06}_{-0.06}$	$0.44^{+0.01}_{-0.01}$	Rea et al., 2003
52879	0.91	$2.83^{+0.03}_{-0.08}$	$0.456^{+0.009}_{-0.009}$	Rea et al., 2005
53189	1.11	$2.61^{+0.14}_{-0.13}$	$0.473^{+0.008}_{-0.008}$	present work

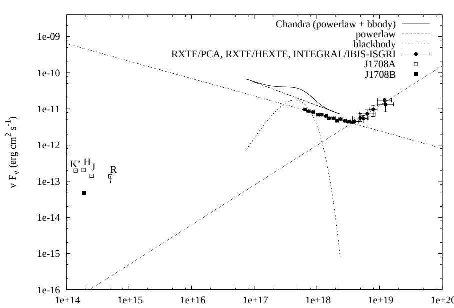


Figure shows multiband observations of J1708. Plotted are the pulsed, unabsorbed fluxes from RXTE/HEXTE, RXTE/PCA and INTEGRAL/ IBIS-ISGRI, alongwith the best fit powerlaws (dotted lines) to the high ($E > 15$ keV) and low (2.4-15 keV) energy components[4]. The de-reddened optical fluxes are for the two objects detected within $0.8''$ of the Chandra HRI position[2] – J1708A (J,H,K' and R), and J1708B (H). The total, as well as the powerlaw and blackbody components of the unabsorbed X-ray 0.3-10.0 keV (Chandra) flux are also shown.

The 0.3-10 keV unabsorbed flux is the sum of a powerlaw and blackbody ($(8.68 + 2.43) \times 10^{-11}$ ergs cm^{-2} s^{-1} respectively) components. This black body temperature is seen to remain unchanged (within statistical limits) when the powerlaw is replaced by a “hard” black body component. A possible explanation is that the thermal emission occurs from a hot spot on the NS surface, while the hard component orginates from reprocessing of the $E > 20$ keV spectrum.

References:
(1) Gregory P.C. and Loredo T. J., 1992, ApJ, 389, 146-168
(2) Israel G. L., Covino, S., Perna E. et al., 2003, ApJ 589, L93.
(3) Kaspi V. M. and Gavril F. P., 2003, ApJ, 596, L71-L74.
(4) Kuiper L., Hermsen W. et al. 2006, astro-ph/0603467
(5) Rea N. et al., 2005, MNRAS, 361, 710.
(6) Sutaria F. K., Pavlov G., et al., 2006, in preparation.