4U 1909+07: a well-hidden pearl

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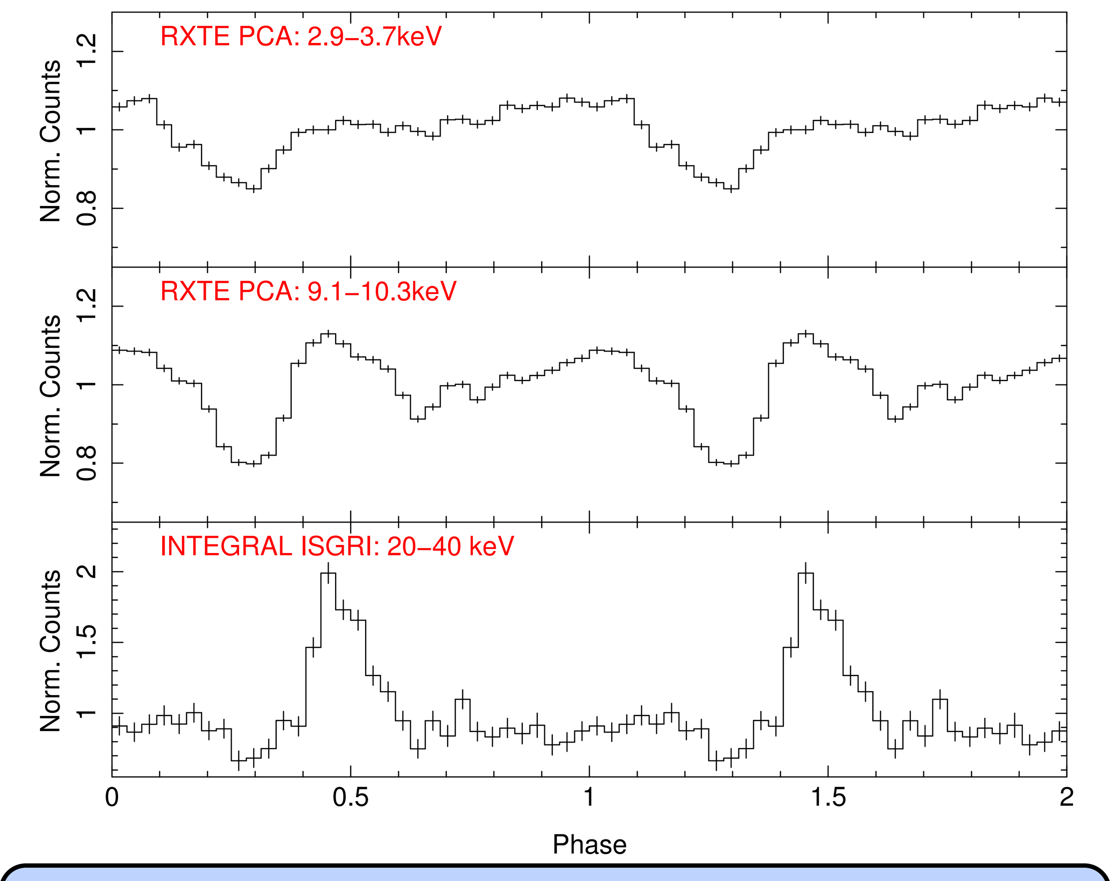
Abstract

We present the first detailed spectral and timing analysis of the HMXB 4U 1909+07 with *INTEGRAL* and *RXTE*. 4U 1909+07 is detected with an average of 2.4 cps in ISGRI, but shows flares with up to ~50 cps. We found that the pulse period of the neutron star is changing erratically around 605 sec, in a manner consistent with a random walk. The pulse profile is extremely energy dependent. It shows a double peaked structure at low energies. The secondary pulse, however, decreases rapidly with increasing engery and above 20 keV only the primary pulse is visible, with an extended phase range of low count rates following afterwards. This evolution is consistent between PCA, HEXTE and ISGRI. Performing phase resolved spectral analysis allowed us to investigate this behavior more closely. We find that the spectrum can be fitted with a power law with a Fermi-Dirac cutoff and a blackbody component. A change in the folding energy is required to fit the different pulse phases.

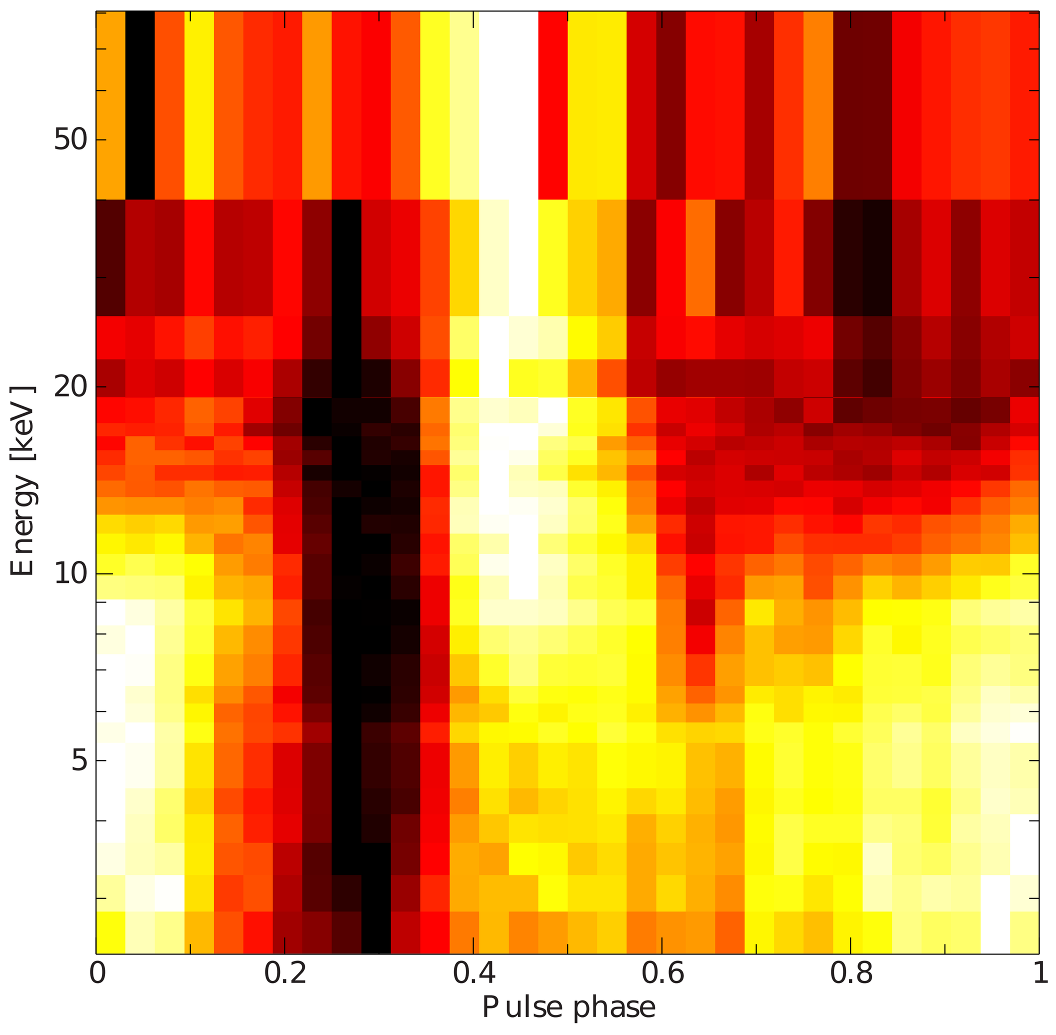
The 4U 1909+07 system

Detected with the *Uhuru* satellite (Giacconi et al., 1974) as 3U 1912+07 and filed in the fourth *Uhuru* catalog as 4U 1909+07 (Forman et al., 1978), the source was seen with most instruments ever since. The exact nature of the system was, however, not clear for almost 30 years. Wen et al. (2000) analyzed *RXTE* ASM data and found a stable 4.4 days period, which was interpreted as the orbital period of a binary orbit. Due to the high absorption, however, no optical counterpart could be identified. Using *RXTE* PCA data, Levine et al. (2004) found a second shorter period of 605s in the X-ray flux, easily explained by the pulse period of a slowly rotating neutron star. Using the Doppler delay curve they could refine the binary orbit parameters. One year later Morel & Grosdidier (2005) could make a detection in the near infrared of a OB star at the location of the X-ray source, thus finally placing the system in the class of High Mass X-ray Binaries (HMXB).

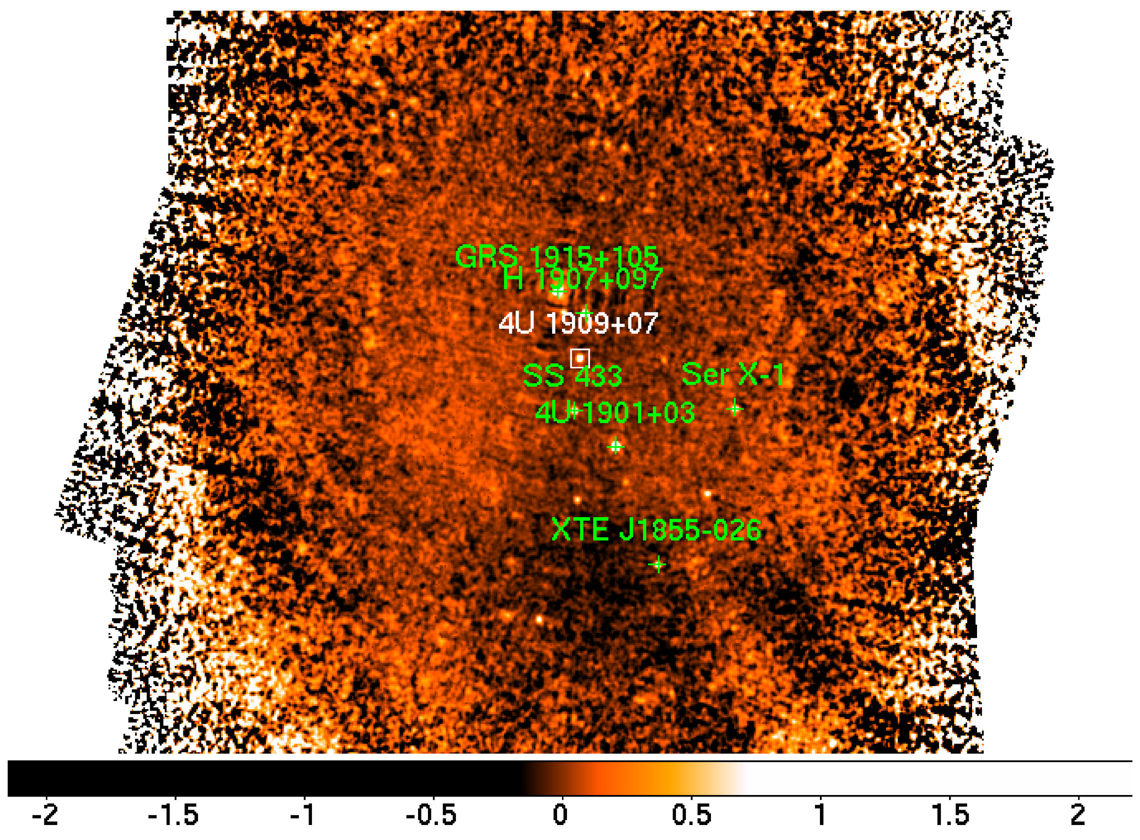
Pulse profiles



The pulse profile of 4U 1909+07 shows a very peculiar energy dependent behavior:
2-4 keV: long plateau, with the second half of the plateau brighter than the first. Individual pulses are seperated by a rather steep dip (see *top panel* in the *plot above*).
4-15 keV: two peaked structure, the first (primary) pulse is slimmer than the secondary. The peaks are seperated by a dip in which the countrate drops by ~30%.
above 20 keV: only primary peak is visible (*bottom panel* in the *plot above*). At these very high energies the pulse separating dip is no longer as deep compared to the average countrate than at lower energies.
In the plot below this behavior is represented in a *landscape plot*, where the *y*-axis shows energy, the *x*-axis the pulse phase and color coded is the relative countrate. To enhance the contrast every pulse profile was normalized. The two broad energy bands at the highest energies are HEXTE data, the others PCA data. A simpler pulse profile at higher energies is typical for many HMXB.

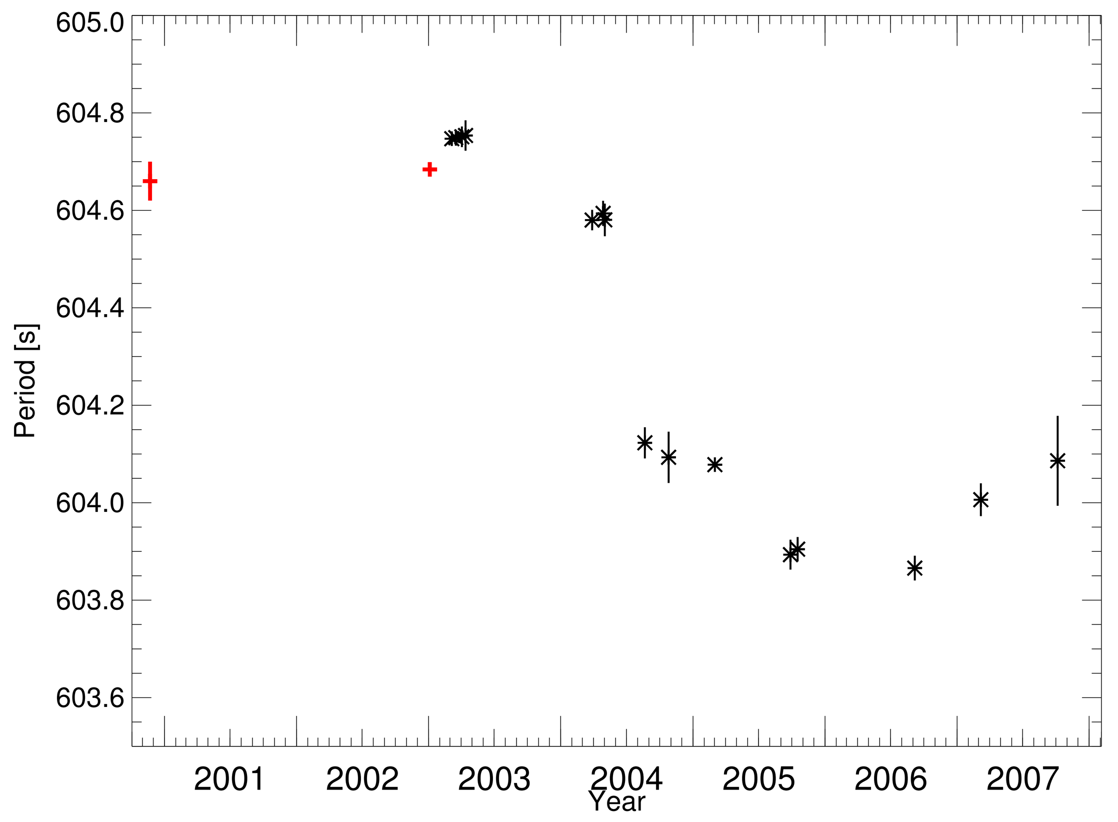


Data and pulse period

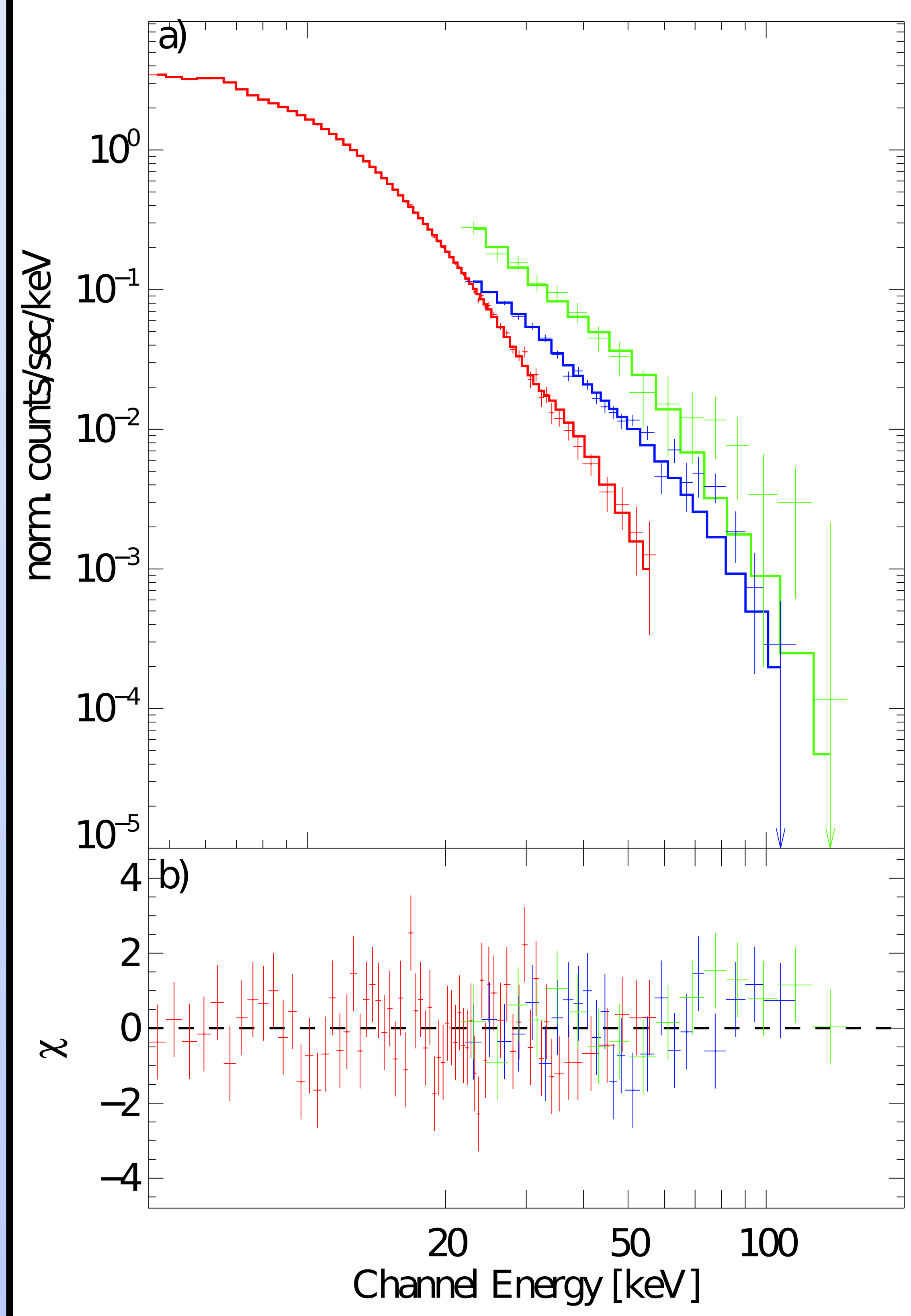


4U 1909+07 lies very close to the black hole binary GRS 1915+105 (see *image above*), which is covered in a key programme with *INTEGRAL*. This way, almost 6 Msec of data exist for 4U 1909+07, although a large part only at large off-axis angles.

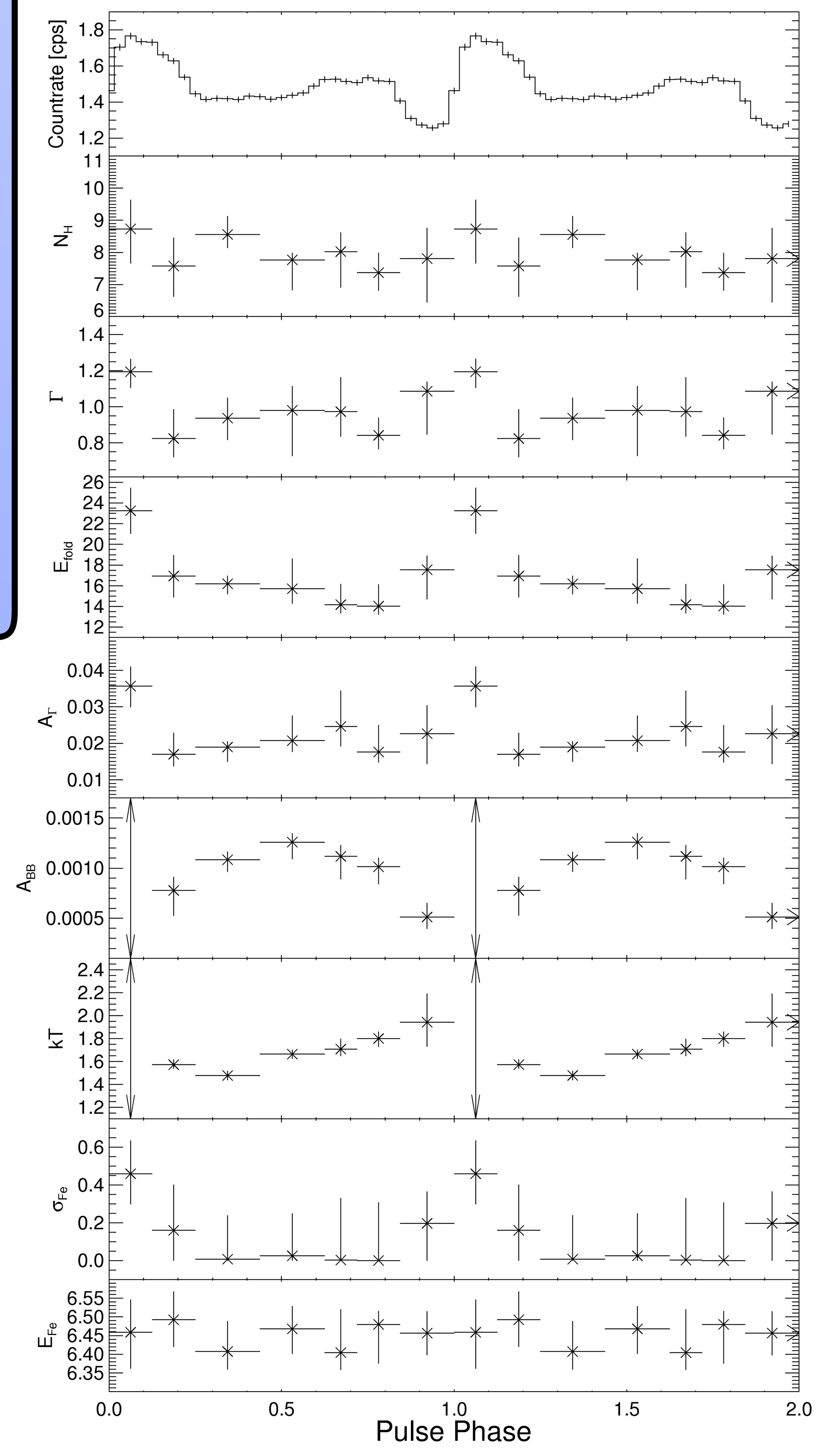
We analyzed all available IBIS/ISGRI data up to Dec 2007 in order to follow the pulse period evolution. Prior to our analysis only two measurements of the pulse period were performed (Levine et al., 2004). These data points are plotted in red in the pulse period *plot below*. The ISGRI data range from 2003 to 2007 and are shown in black. The evolution is consistent with a random-walk like behavior, typical for windfed HXMB without a persistent accretion disk (see, e.g, Deeter et al., 1989).



Phase averaged spectrum



Phase resolved spectrum



Spectrum

The phase averaged spectrum from the 2003 ISGRI data was fitted simultaneously with the 2003 *RXTE* PCA and HEXTE data. The spectrum was fitted with a standard powerlaw attenuated by a Fermi-Dirac-cutoff and photo absorption, as well as a strong iron line at 6.4 keV. No evidence for a cyclotron line could be found. The spectrum is shown in the *upper plot* on the *right hand side*, together with the best fit model and its residuals

Pulse phase resolved spectral analysis was carried out for PCA and HEXTE data. We fitted spectra for 7 phase bins, see the *lower plot* on the *right hand side*. For most of the phase spectra an additional blackbody component is necessary to achieve satisfying fits. The most drastic spectral changes happen at the onset of the primary pulse, where almost all parameters change. Additionally, the blackbody component vanishes completely in this phase bin. This is also the brightest phase bin and thus dominating the phase averaged spectrum, explaining why no blackbody component was needed there. The blackbody could be an indicator of a visible hot spot on the neutron star surface, moving in and out of sight with the rotation of the neutron star.

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