SGR J1935+2154

Timing and Spectral Analysis

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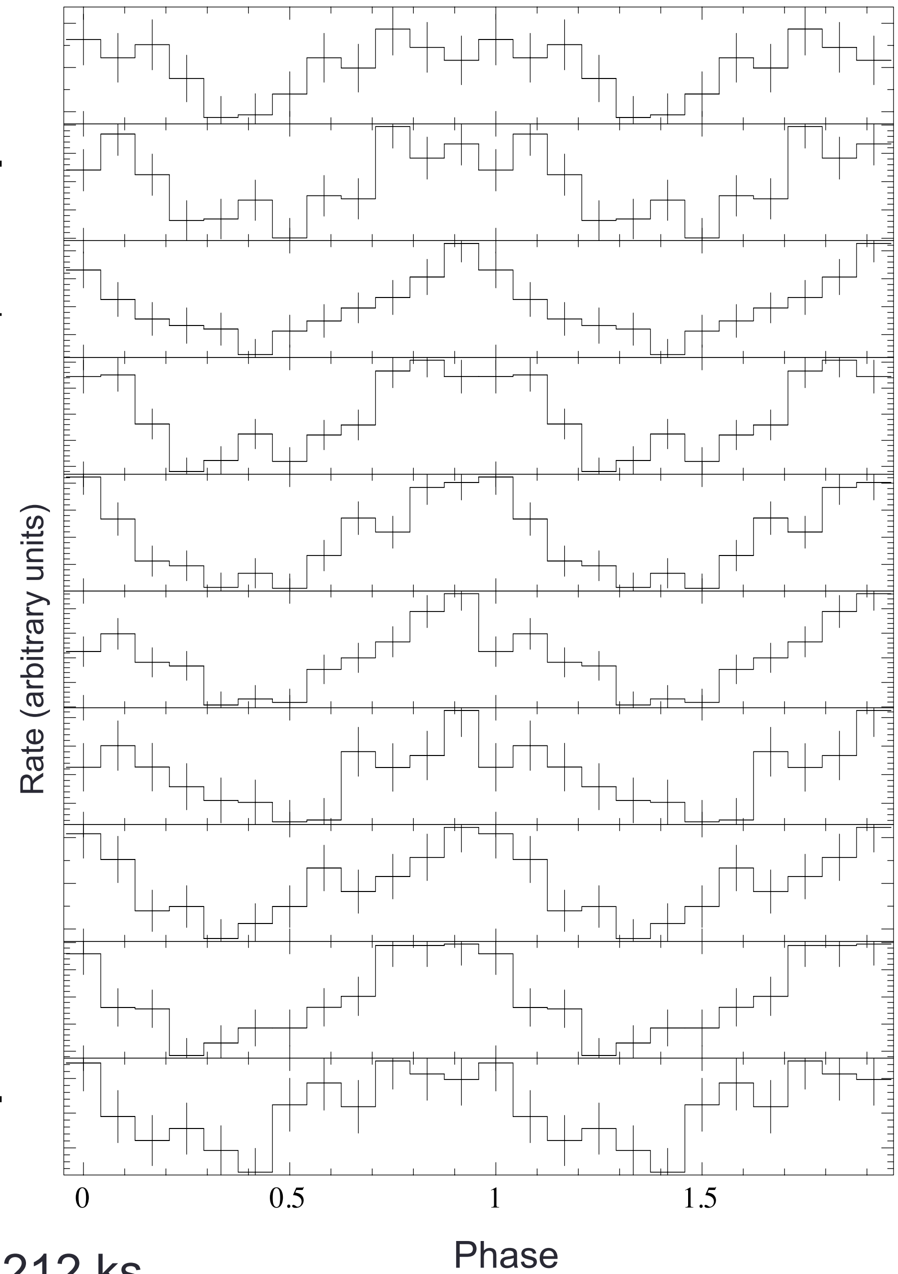
Discovery

- Detected first in July 14 (2014) with Swift BAT thanks to a short burst
- Association with SNR G57.2+0.8 (no known age and ~9 kpc distance)
- First period estimate P=3.25 s with Chandra observations (15, 28 July)

Observations

	Obs. Id.	Instr.	Exp. (ks)	Date (2014)	Epoch (TJD)
Chandra	15874	ACIS-S	10.1	Jul 15	16853.0
	15875	ACIS	75.4	Jul 28	16886.0
	17314	ACIS	29.2	Aug 31	16900.0
XMM	0722412501	EPIC	19.0	Sep 26	16926.0
	0722412601	EPIC	20.0	Sep 28	16928.0
	0722412701	EPIC	18.0	Oct 04	16934.0
	0722412801	EPIC	9.7	Oct 16	16946.0
	0722412901	EPIC	7.3	Oct 24	16954.0
	0722413001	EPIC	12.6	Oct 27	16957.0
	0748390801	EPIC	10.8	Nov 15	16976.0

Chandra ~0.1 cts/s XMM ~0.2 cts/s

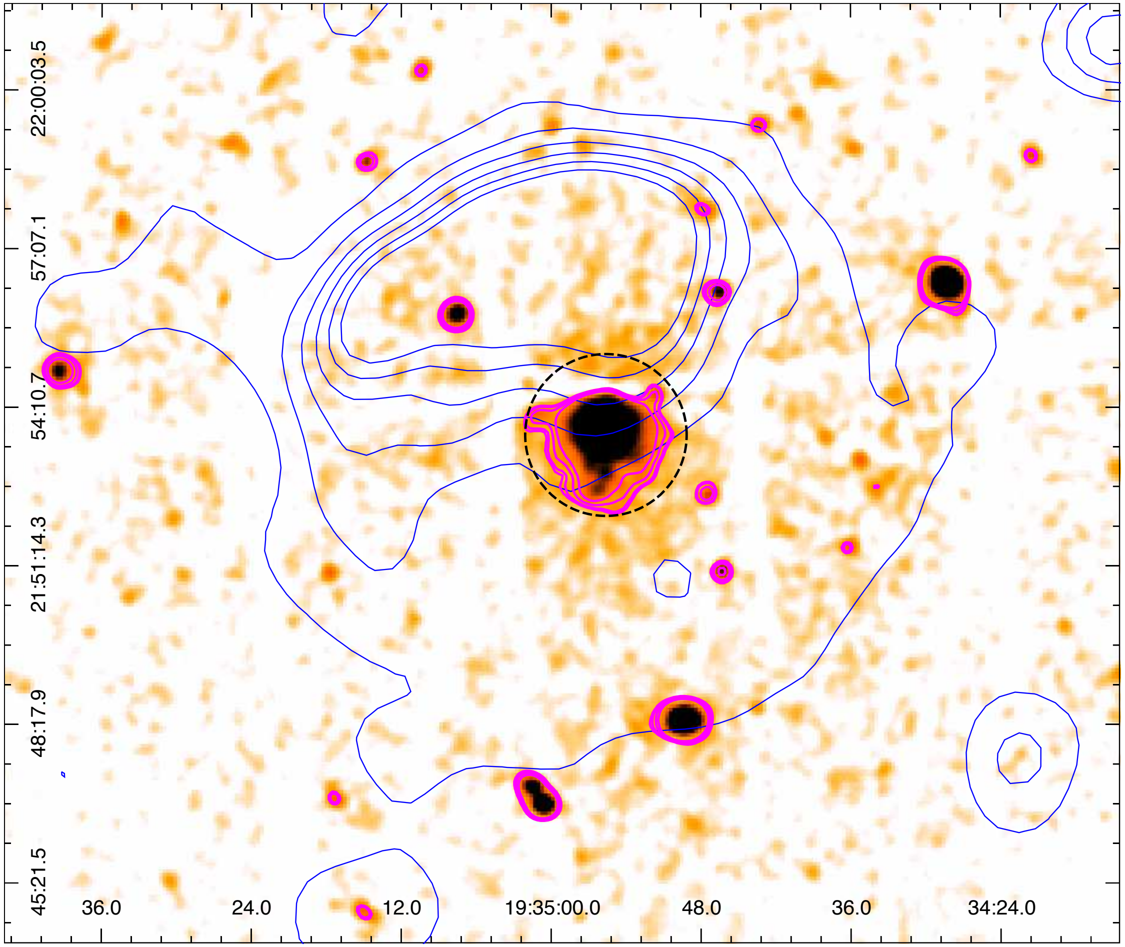


10 observations, >120 days, total exposure ~ 212 ks

Data Reduction

Diffuse emission!

→ Annulus background region (47'' – 110'')



98 ks pn image. From Israel et al. (2015)

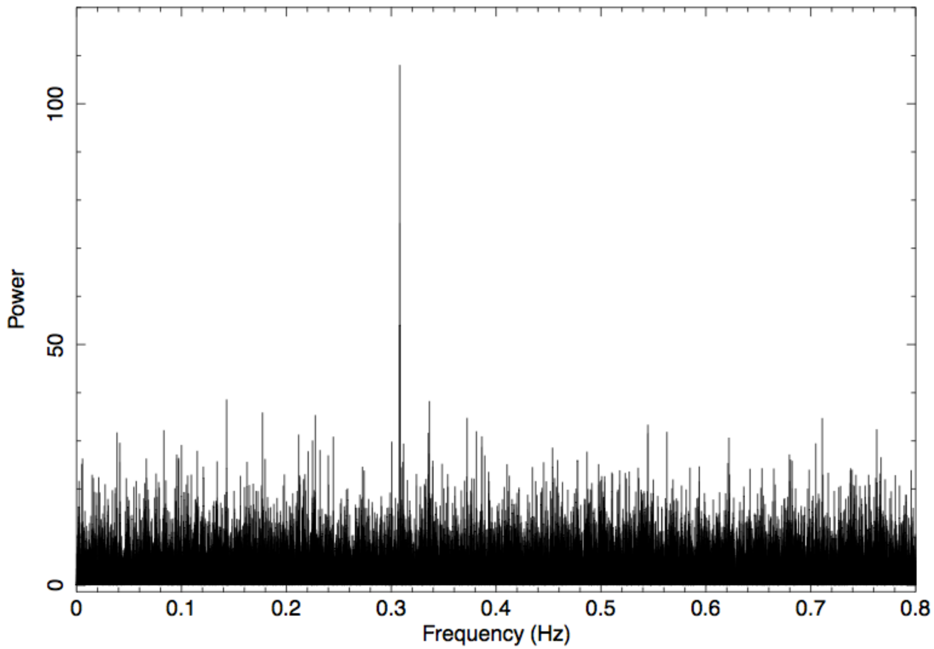
Blue contours:
radio emission (1.4 GHz)

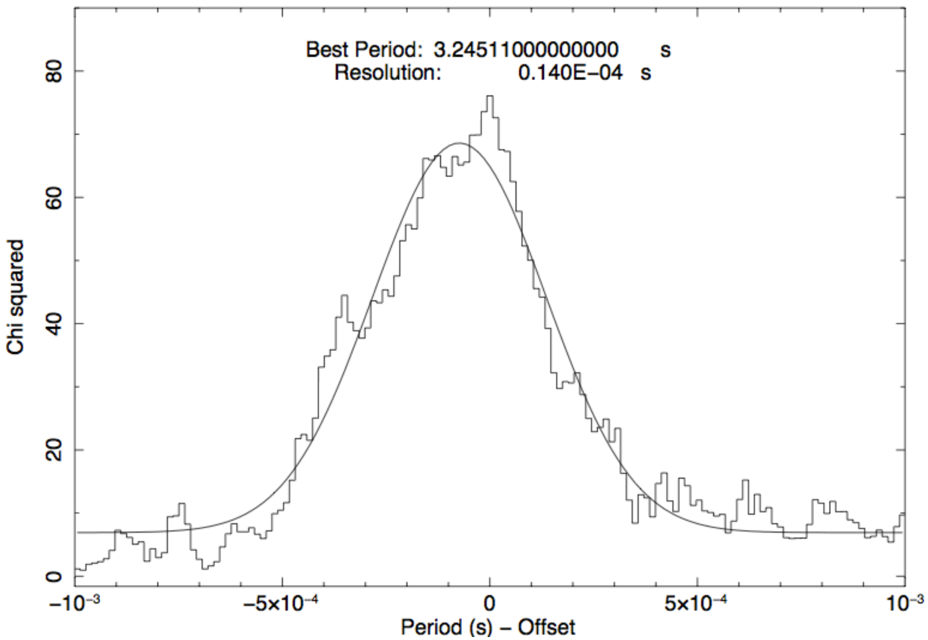
Magenta contours:
X-ray diffuse emission

Black circle:
90'' from the source position

Timing Analysis

- Starting point: observation XMM – 0722412501 (16926 TJDs)





Power spectrum + `efsearch`

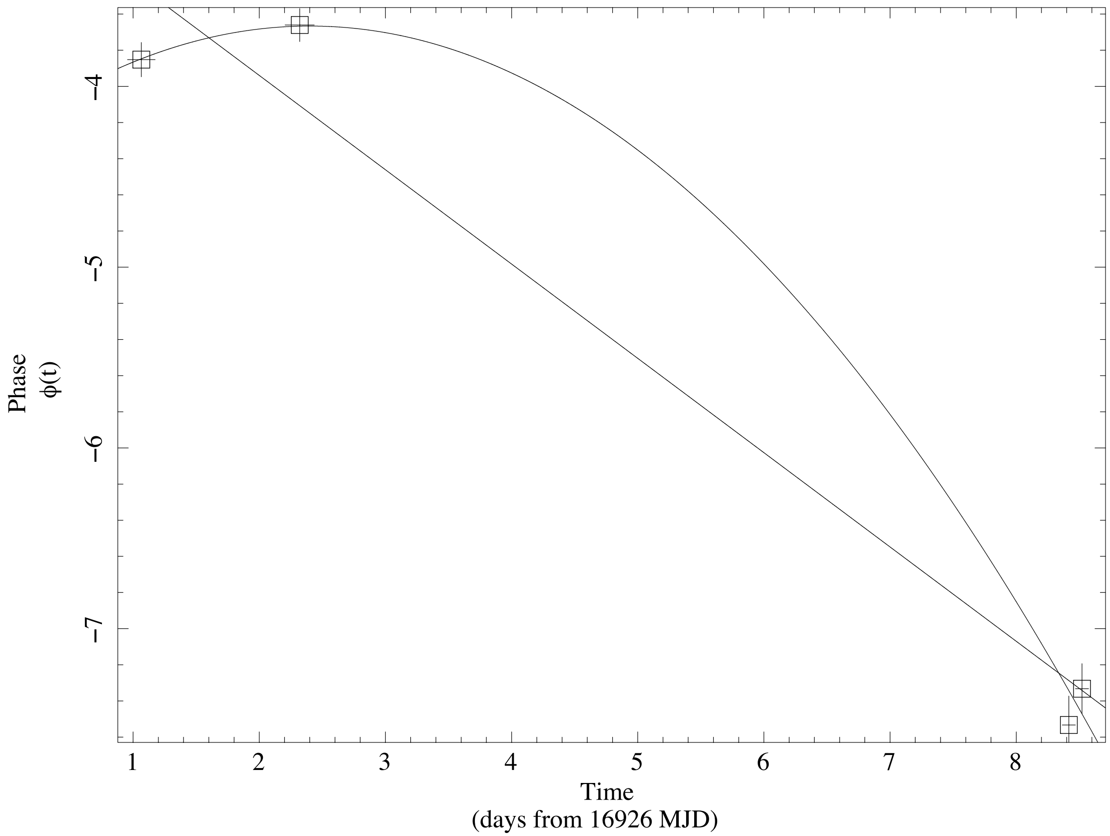
P=3.2451(1) s

Now we can start the phase fitting!

Timing Analysis – phase fitting

- quadratic term necessary from the third observation (16926 TJD)

$$\dot{P} = (4.38898 \pm 0.00002) \times 10^{-6} s/s$$

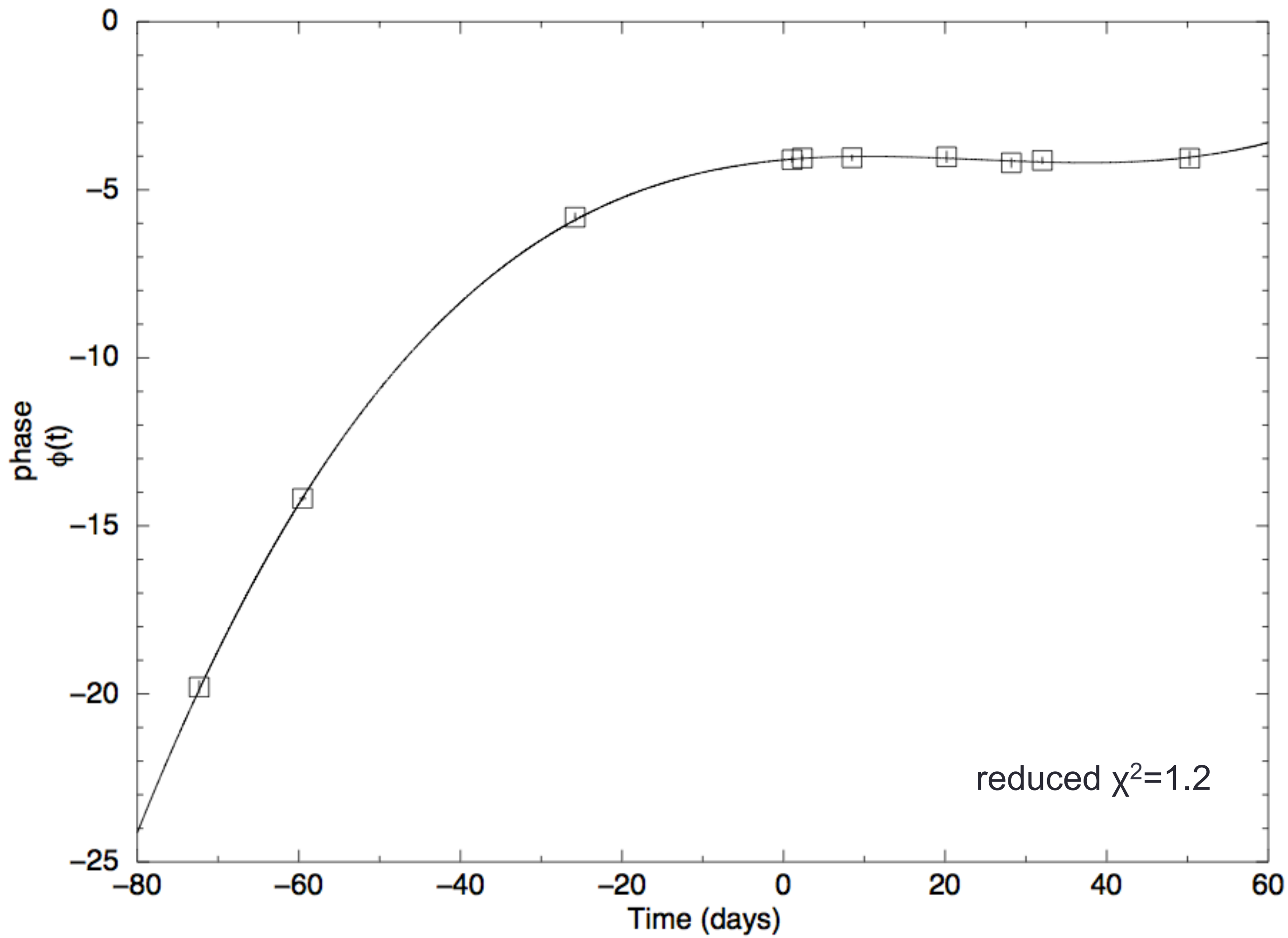


linear:
chi-sq. 43

Quadratic:
chi-sq. 2.5

Timing Analysis – phase fitting

- All 7 XMM observations described by linear + quadratic.
- Adding the three Chandra Obs. we find a **cubic term!**

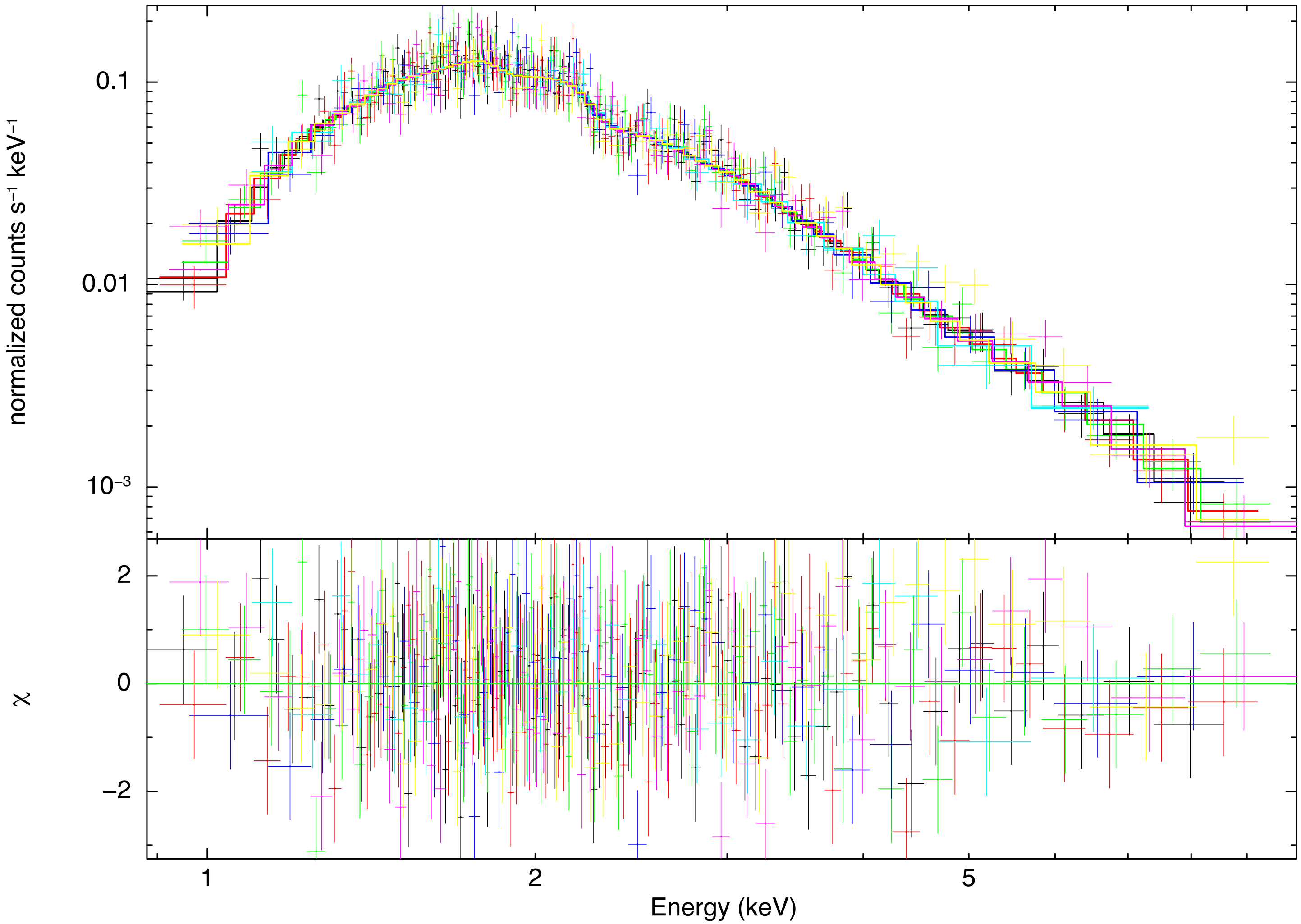


Timing Analysis – results

$P = 3.24506504 \pm 1.2$	s
$\dot{P} = (1.4317 \pm 0.0031) \times 10^{-11}$	s/s
$\ddot{P} = (-3.4 \pm 0.7) \times 10^{-19}$	s/s^2
$\nu = 0.308160233 \pm 0.000000011$	Hz
$\dot{\nu} = (-1.3596 \pm 0.0029) \times 10^{-12}$	Hz/s
$\ddot{\nu} = (3.3 \pm 0.7) \times 10^{-20}$	Hz/s^2
$B_p \simeq 2.04 \times 10^{14}$	Gauss
$\tau_{char} \simeq 3600$	years
$L_{sd} \simeq 1.65 \times 10^{34}$	erg s^{-1}

Timing results with 1σ uncertainities

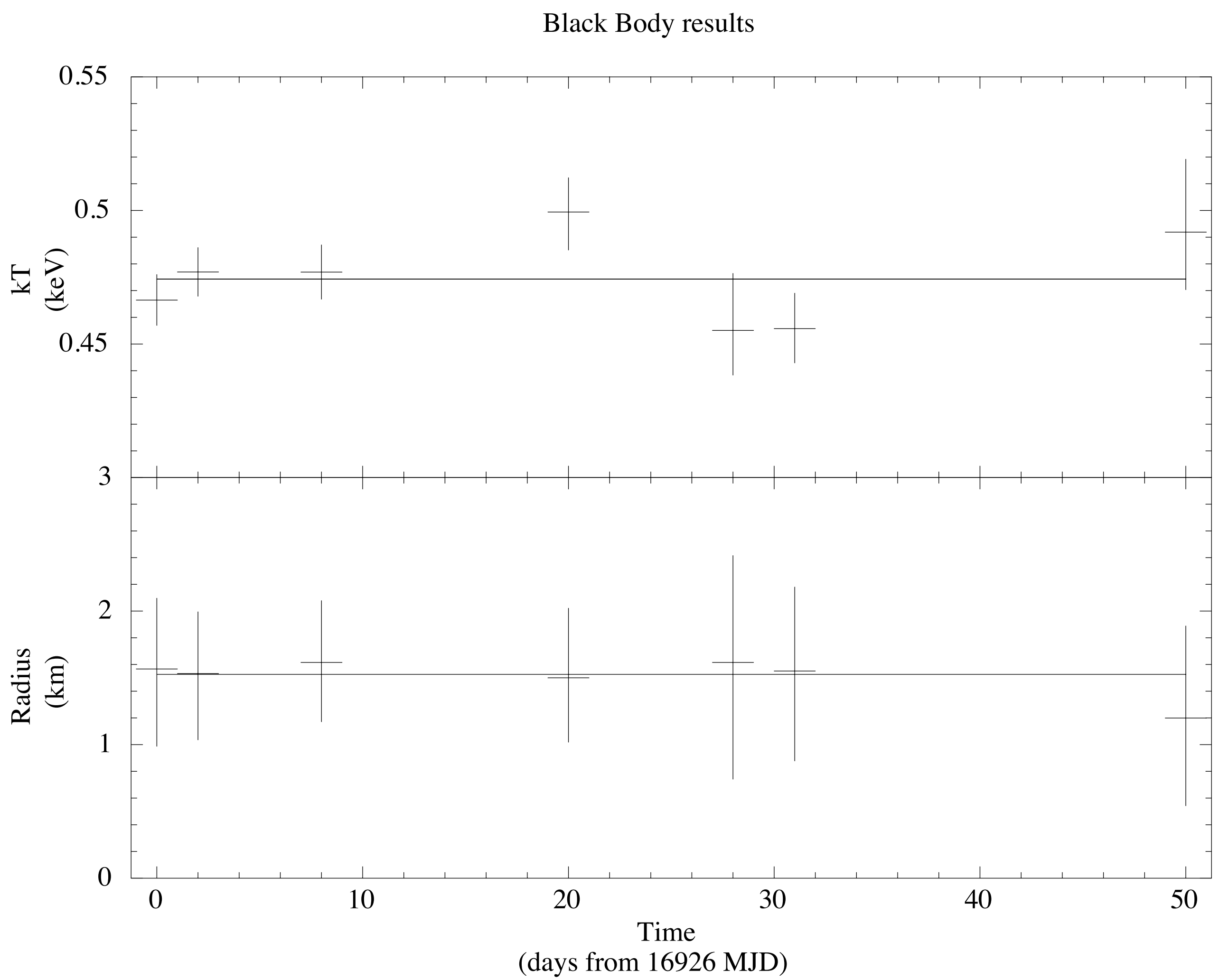
Spectral Analysis – phase averaged



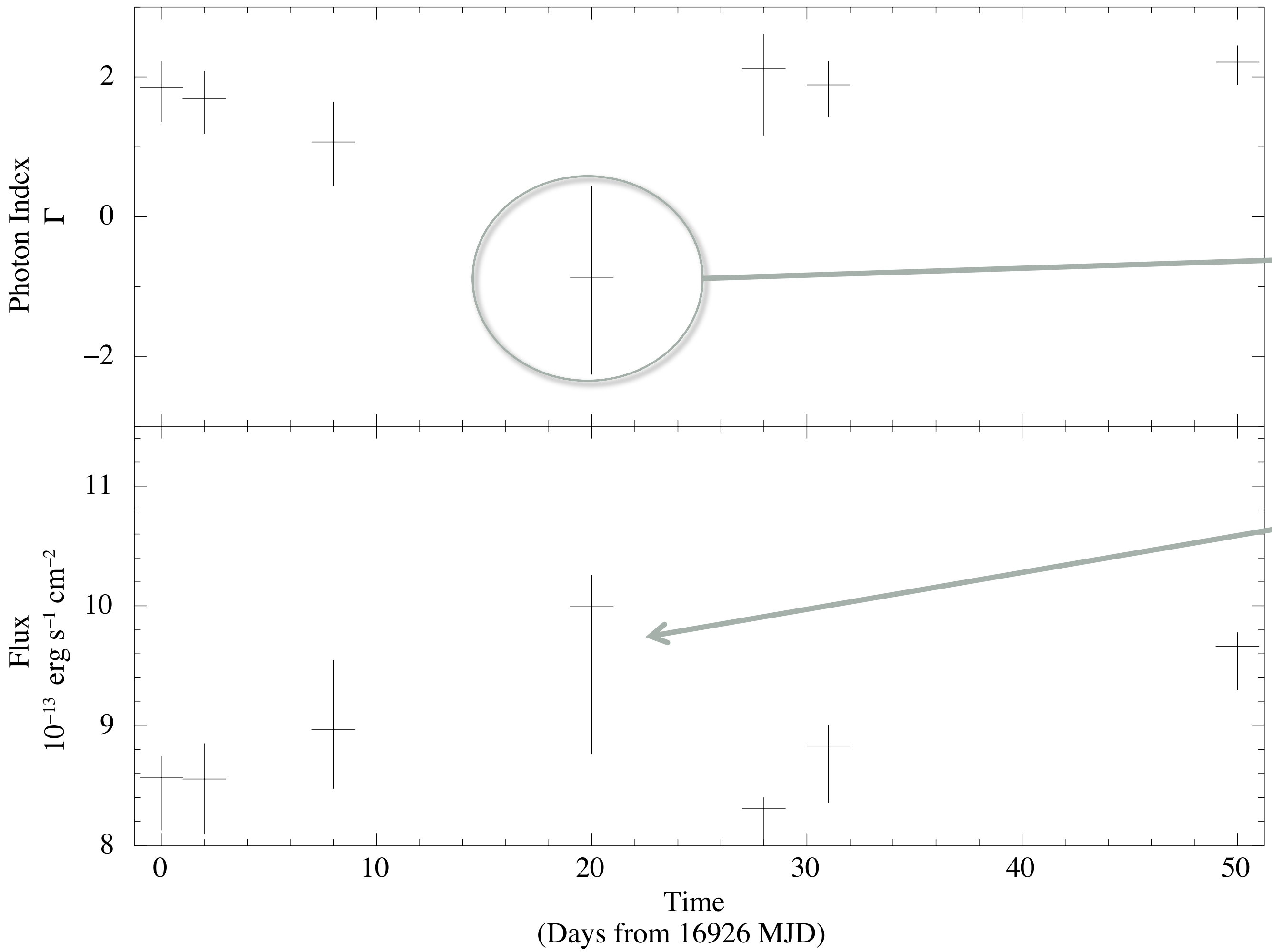
N_H (10^{22} cm^{-2})	Γ	kT (keV)	BB-Radius (km)	Flux (10^{-13} erg cm^{-2} s^{-1})	reduced χ^2 erg s^{-1}	L_X
1.57 ± 0.07	1.9 ± 0.3	0.47 ± 0.01	1.53 ± 0.49	8.7 ± 0.2	1.08	$\sim 1.8 \times 10^{34}$

Spectral analysis – phase averaged

- 7 XMM observations analyzed separately (absorption fixed)



Spectral analysis – phase averaged

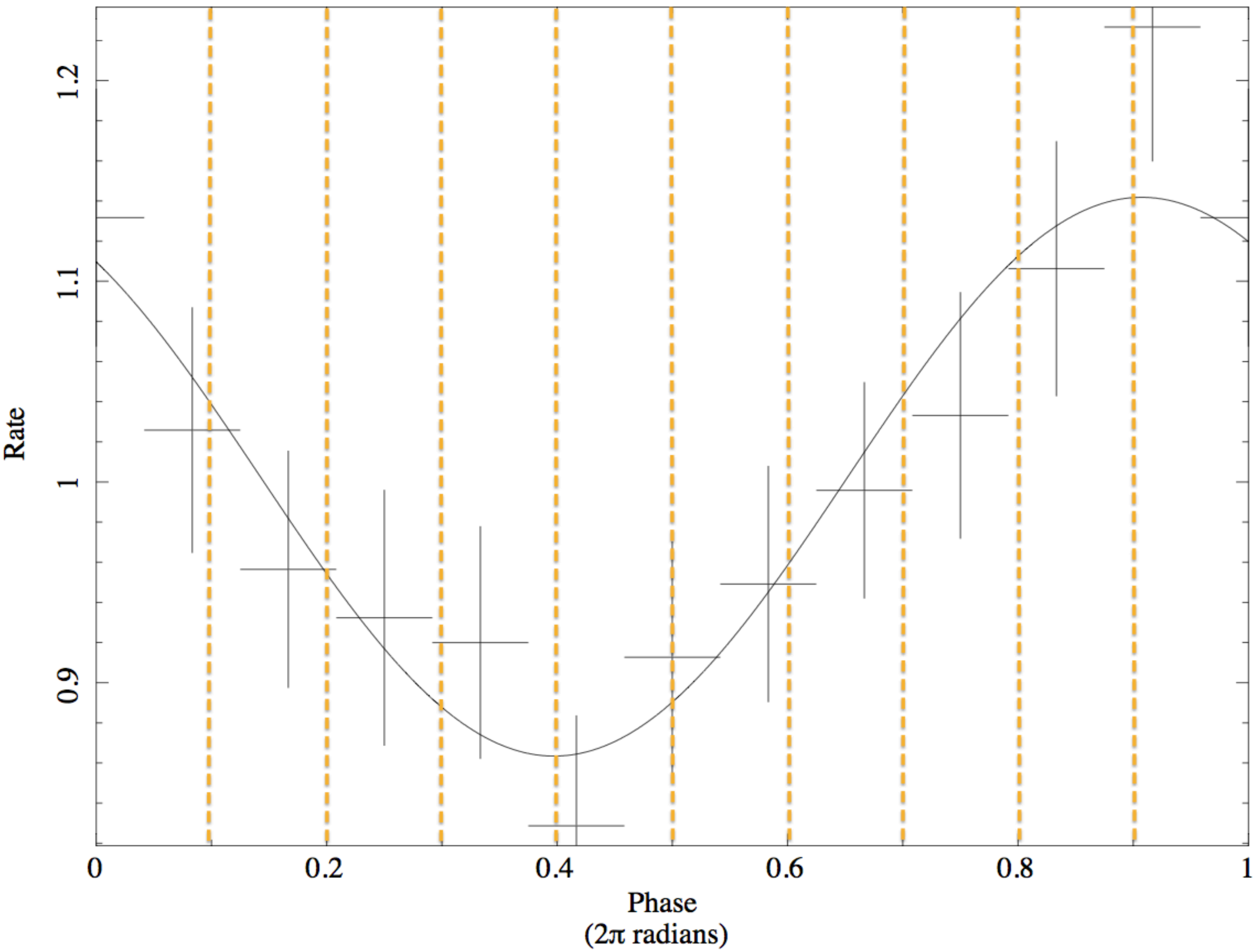


$\Gamma \sim -0.87$
due to low statistics
(exp~ 9.7 ks,
second lowest)

Corresponding flux
overestimated

Spectral analysis – PPS

Thanks to the complete timing solution a PPS is possible

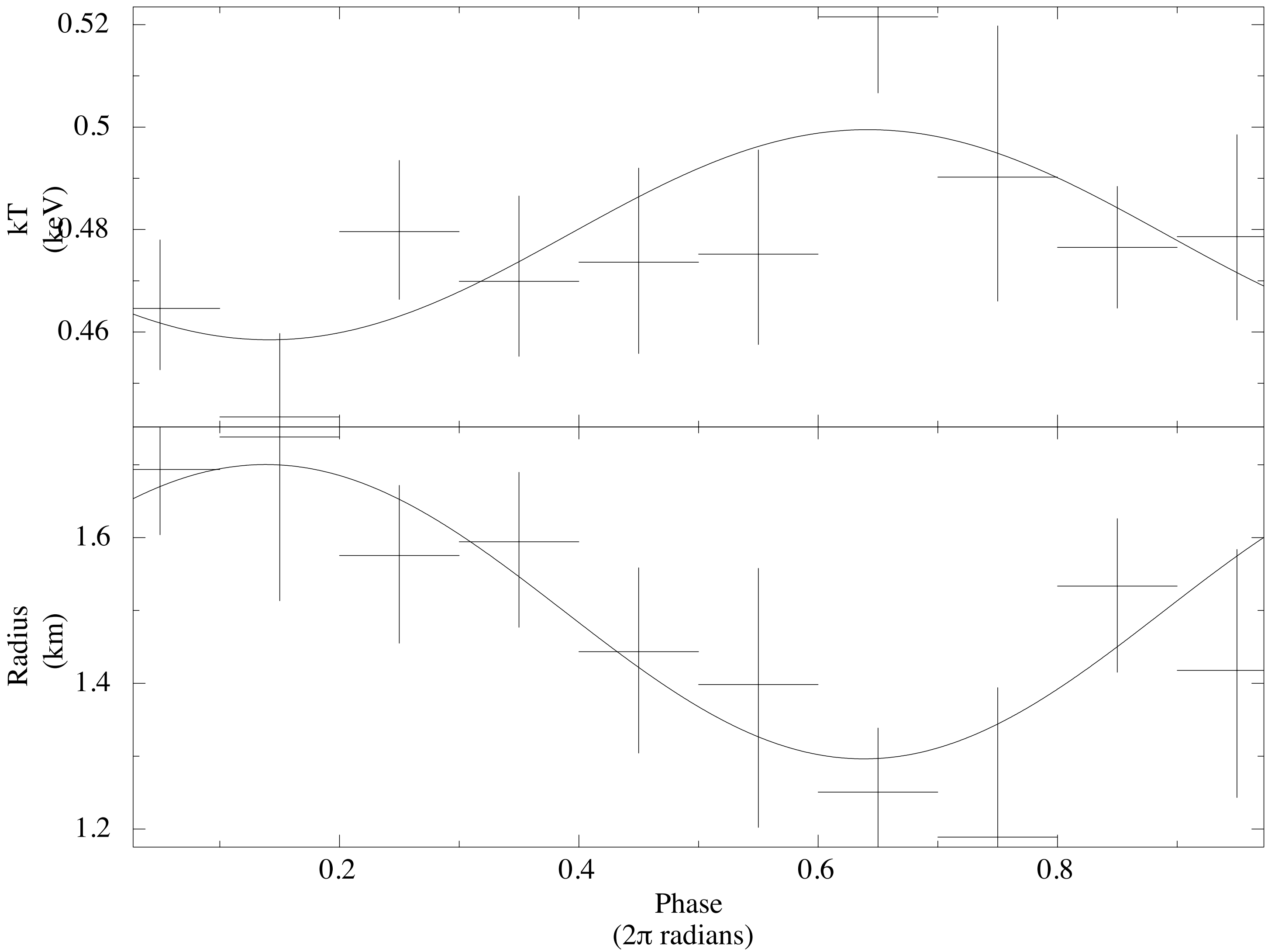


Divided in 10 phase intervals

Combine for 7 XMM obs.

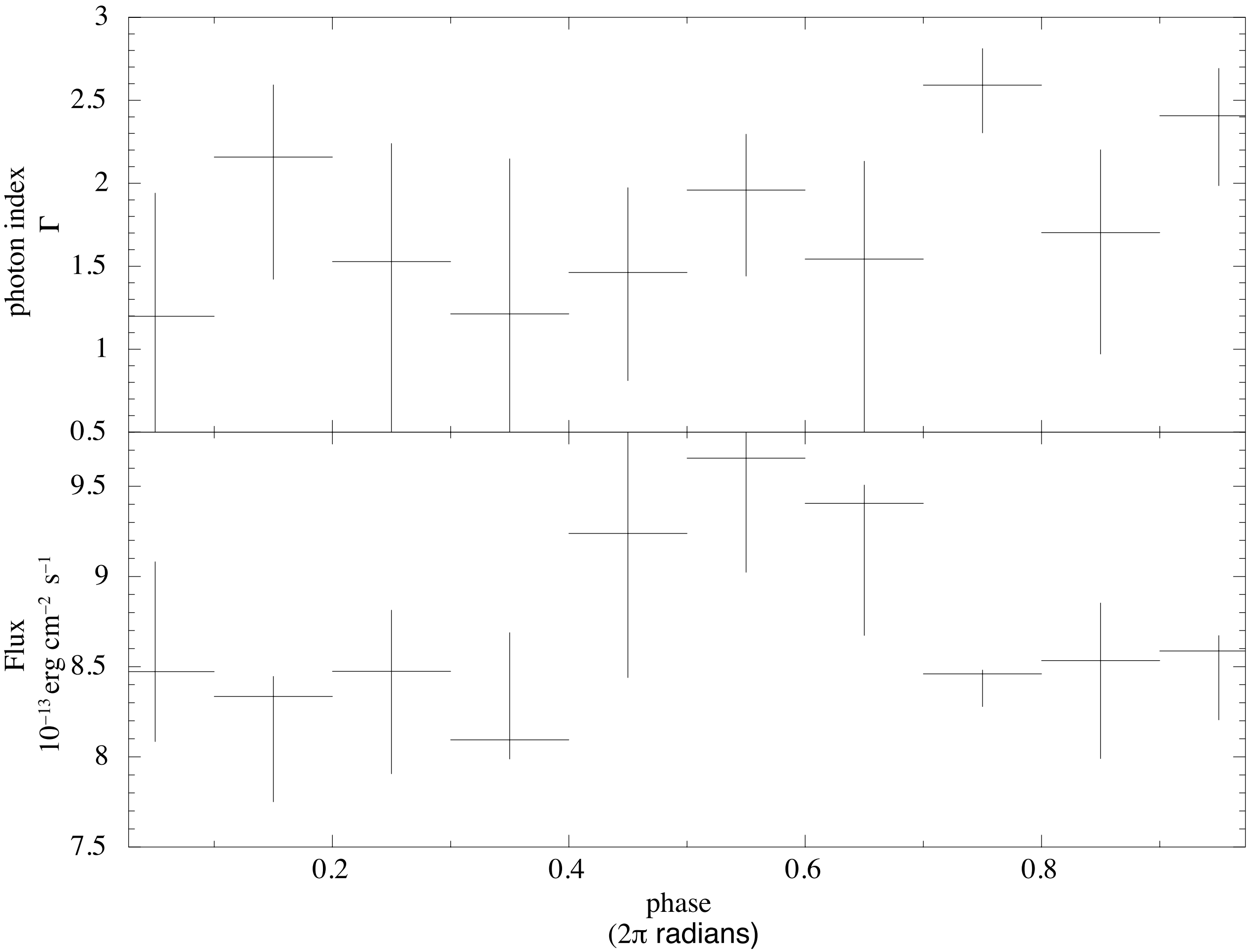
20 counts per bin

Spectral analysis – PPS



Clear modulation due to the orbital motion of the emitting hotspot

Spectral analysis – PPS



no clear behaviour for the photon index

Modulation similar to that of the BB temperature (phase shifted ~ 0.1(2π) rad)

Discussion

- Spectral parameters in range for the typical SGR

  (kT~0.5 keV, R_{hs}~1.5 km, Γ~ 2)

- No significant flux decay in 50 days of XMM observation, no phase dependence of spectral parameters

- L_X/L_{sd}~1 (in outburst)! Magnetars with L_X/L_{sd}<1 (in quiescence) are expected to emit in the radio band

- Up to now no significant radio pulsation detected (after the discovery): 0.5 mJy limiting flux

- Low outburst peak luminosity (missed the outburst or incorrect distance)

  Swift pre-outburst estimates: $L_{X,qui} \sim 5 \times 10^{33}\, erg\, s^{-1}$ $Ł_X/L_{sd} \sim 0.25$

What to do

- Follow up of observations to detect flux decay and quiescent emission

- Dedicated radio observations

Thank you!

References

1. G. L. Israel et al. *"SGR J1935+2154: its discovery, monitoring and environment"* – 2015 (work in progress)

2. M. Stamatikos et al., *"GRB 140705A: Swift detection of a short burst. GRB Coordinates Network"*, 16520, 1 - 2014;

3. G. L. Israel et al., *"Chandra discovery of 3.2s X-ray pulsations from SGR 1935+2154."* Astronomer's Telegram 6370 - 2014;

4. M. Z. Pavlovic et al., *"The Radio Surface-brightness-to-Diameter Relation for Galactic Supernova Remnants: Sample Selection and Robust Analysis with Various Fitting Offsets."* Ap.JS. 204:4 – 2013;

5. N. Rea et al., "The Fundamental Plane for Radio Magnetars." Ap.JL. 748: L12 – 2012.

Radio Magnetars

XTE J1810−197 (B_p~2.1×10^{14}G)

For many months the strongest PSR at 20 GHz, variable radio emission in intensity and morphology. Started ~1 yr after the X-ray outburst and declined in a few years

1E 1547−5408 (B_p~2.2×10^{14}G)

Between two X-ray outbursts radio emission declined and then rised again

PSR 1622−4950 (B_p~2.8×10^{14}G)

Discovered in the radio and afterwards in the X-ray

- Delay of the radio with respect to the X-ray outburst
- Decay of the radio flux as the X-ray outburst decays

Radio active magnetars could behave like Pulsars, but

- Pulsars dominated by dipolar component
- Magnetars have important multipolar + toroidal components

Radio Magnetars

Radio magnetars may have lower toroidal component (responsible for X-ray emission – twisting magnetosphere)
In fact high B_{tor} = possibility of sustaining long lasting twist that inhibit the pair cascade