

Breaking news

(Tiengo et al. submitted)

A phase-variable absorption feature in the X-ray spectrum of a magnetar

Andrea Tiengo

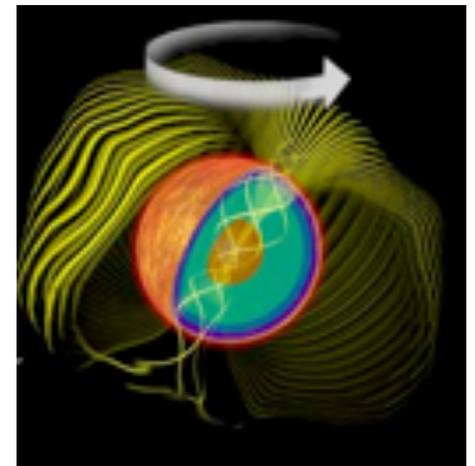
IUSS Pavia, INAF-IASF Milano

P. Esposito, S. Mereghetti, R. Turolla, L. Nobili,
S. Zane, N. Rea, L. Stella, G.L. Israel,
F. Gastaldello, D. Götz, G.F. Bignami

ESAC – 2013 May 23

SGR 0418+5729

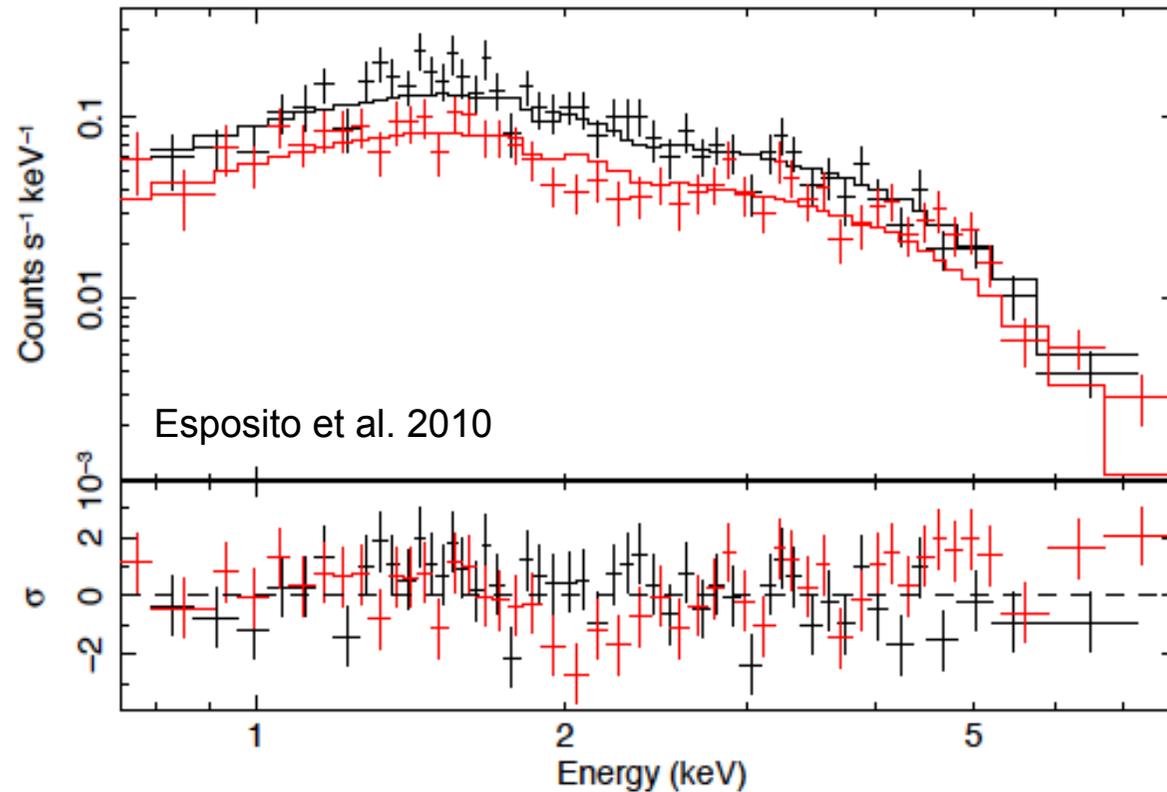
- Two **BURSTS** detected on 2009 June 05, spin **PERIOD** of 9.1 s (van der Horst et al. 2010)
- Apparently all the features of a (transient) **SGR**
 - Rapid, large flux increase and decay
 - Emission of bursts
 - Period in the right range ($\sim 2 - 12$ s)
- Unexpectedly low **PERIOD DERIVATIVE** ($4 \times 10^{-15} \text{ s s}^{-1}$, Rea et al. 2013)
 - $\Rightarrow B_{\text{dip}} \approx 6 \times 10^{12} \text{ G} \Rightarrow$ a **LOW MAGNETIC FIELD** magnetar?
- Consistent with magnetar model if **INTERNAL** (crustal) magnetic field $B > 10^{14} \text{ G}$ (Rea et al. 2010; Turolla et al. 2011)
- Strong **MULTIPOLAR** field components on the surface from spectral analysis (Güver et al. 2011)



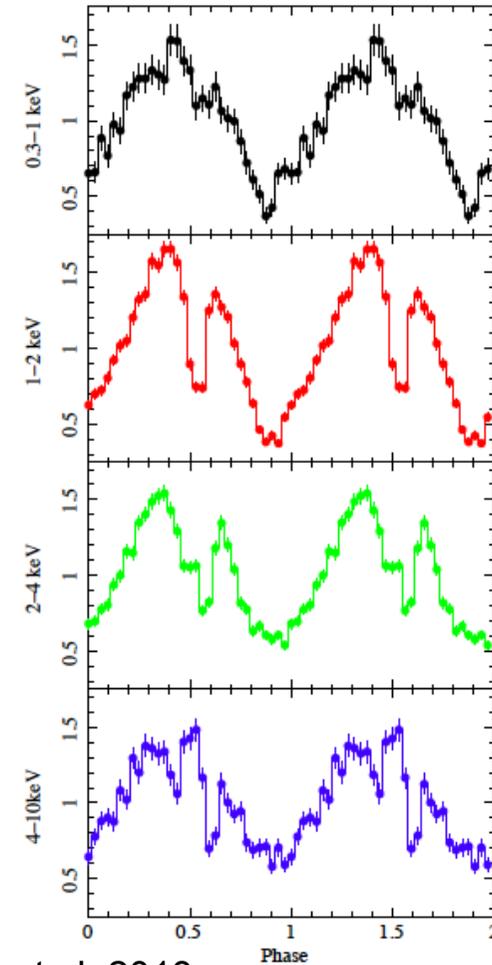
Another “anomaly” of SGR 0418+5729

Swift/XRT
(2009 July 12-16)

Spectra from adjacent phase intervals:
ABSORPTION LINE at ~2 keV?

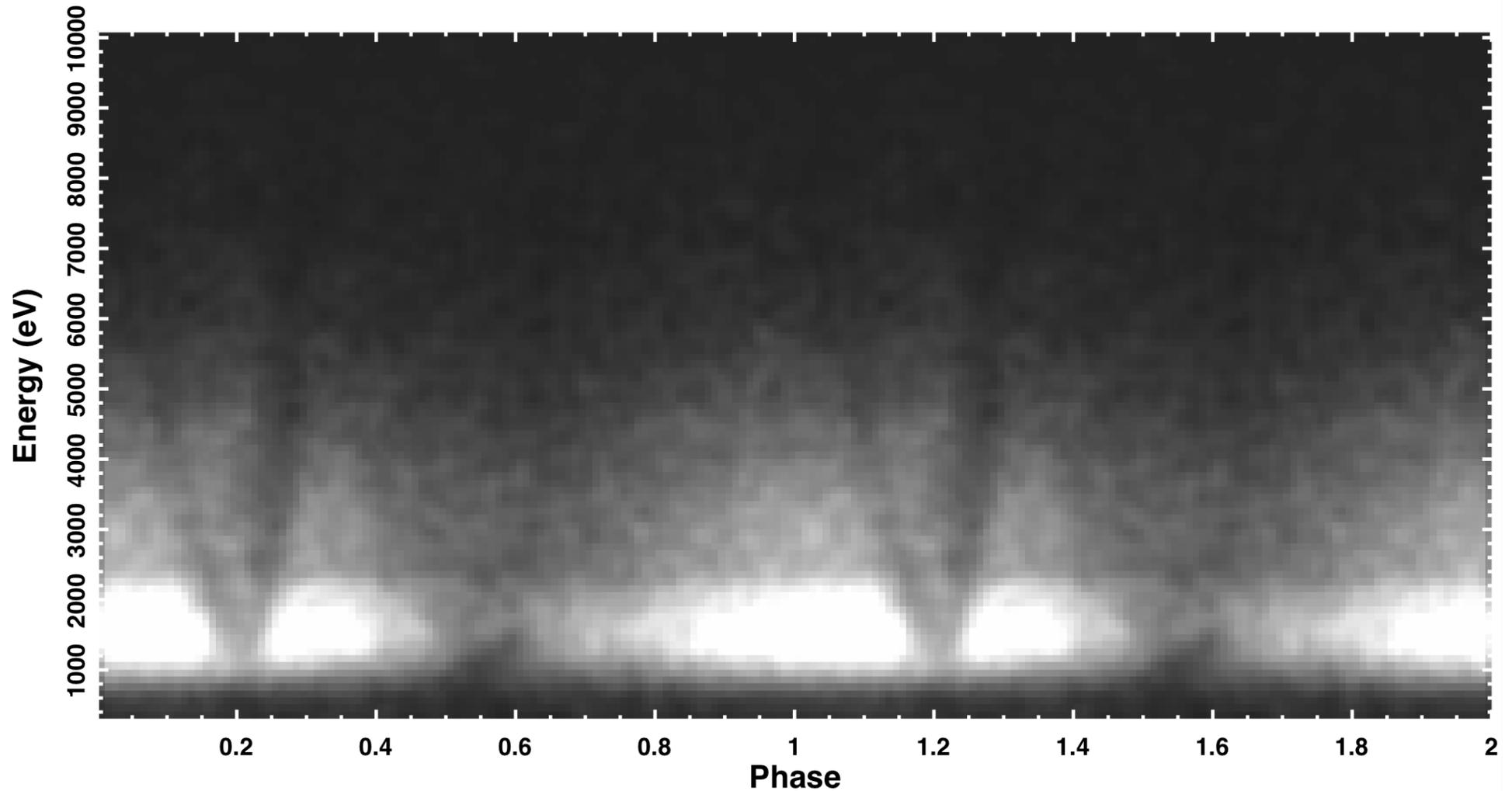


XMM-Newton/EPIC
(2009 August 12)



A strongly **VARIABLE** feature in the phase-resolved spectrum?

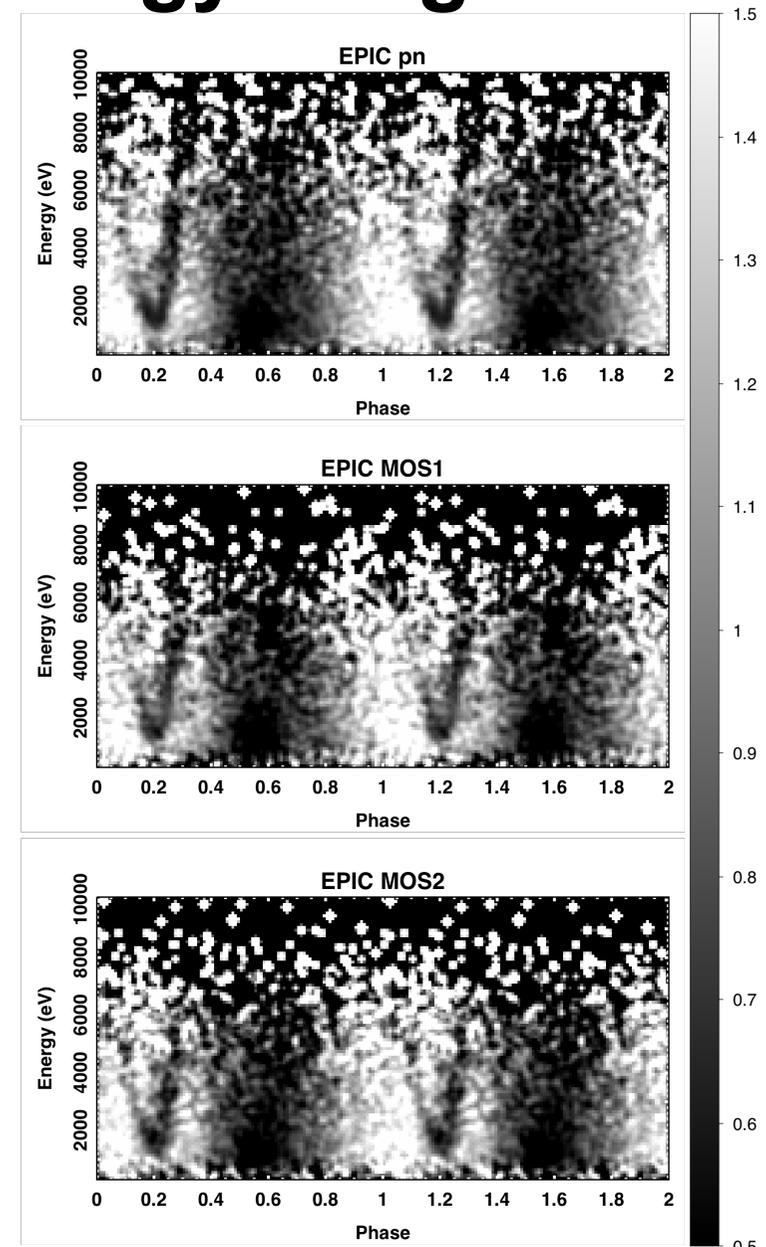
EPIC phase-energy image



An absorption line at a phase-variable energy?

Normalized phase-energy image

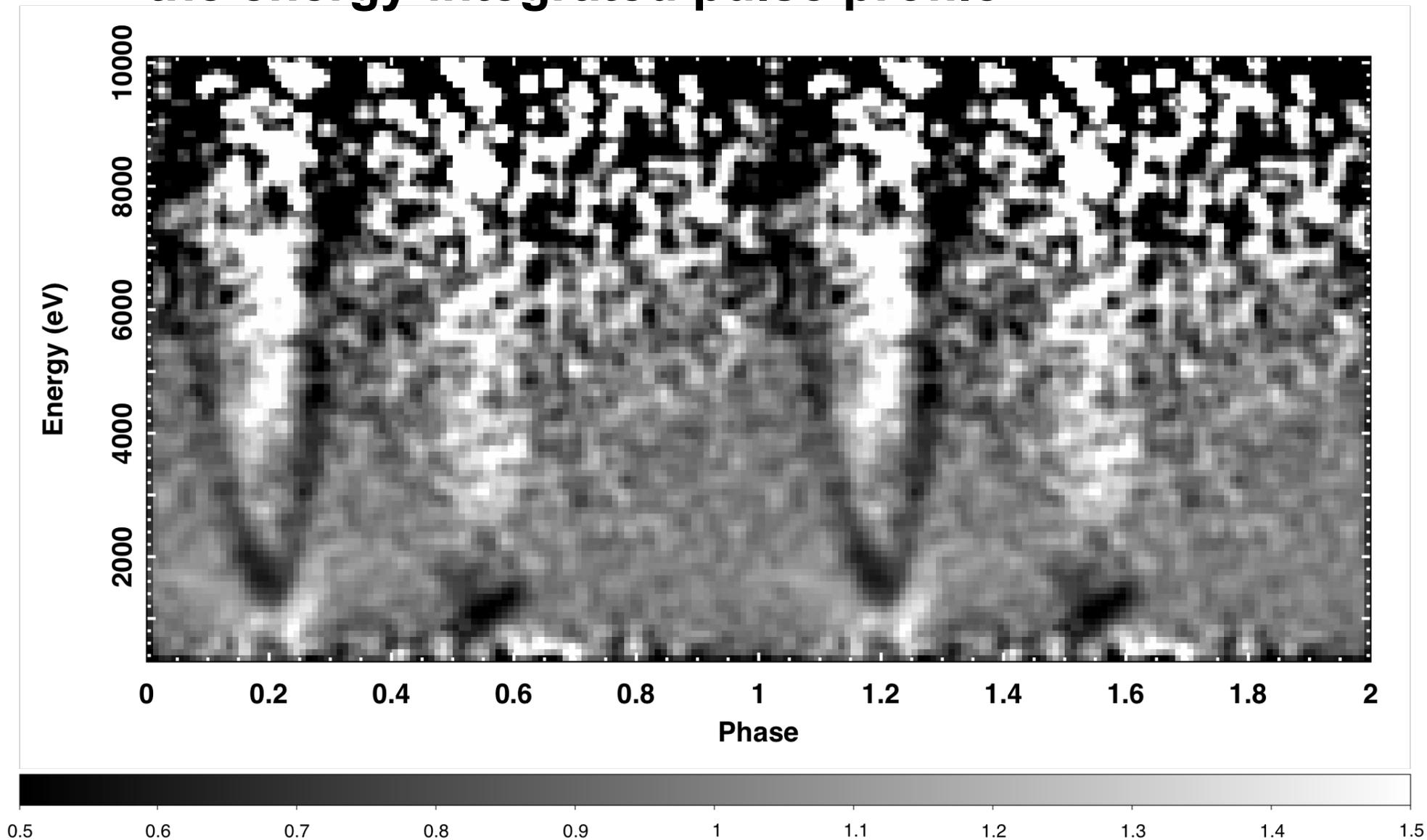
- Effective area and source spectrum decrease with energy
⇒ we normalize the image to the phase-averaged spectrum
- Same behavior in PN, MOS1 and MOS2 data ⇒ not due to statistical fluctuations or instrumental effects



An absorption line at a phase-variable energy!

Phase-energy image

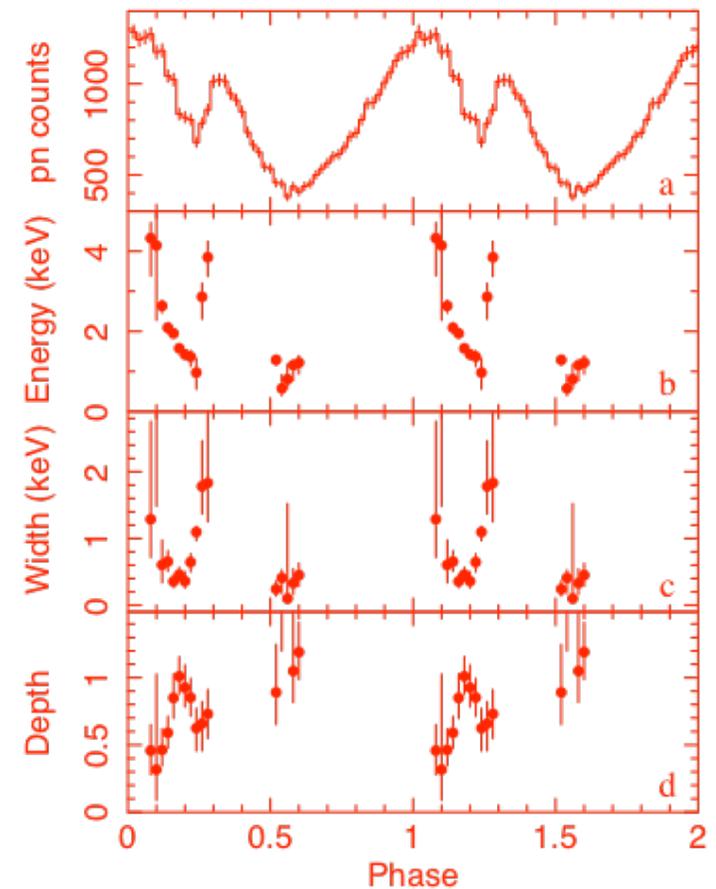
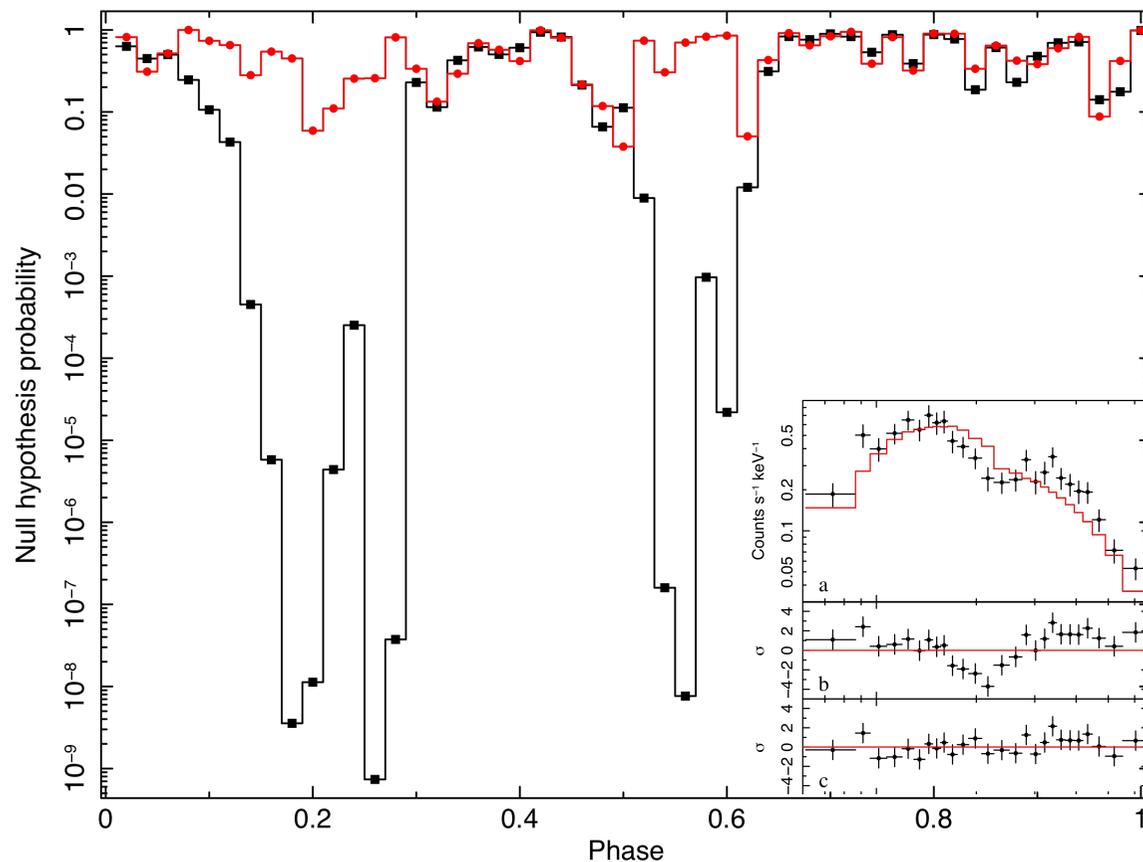
Normalized to the phase-averaged spectrum AND
the energy-integrated pulse profile



Phase-resolved spectral analysis

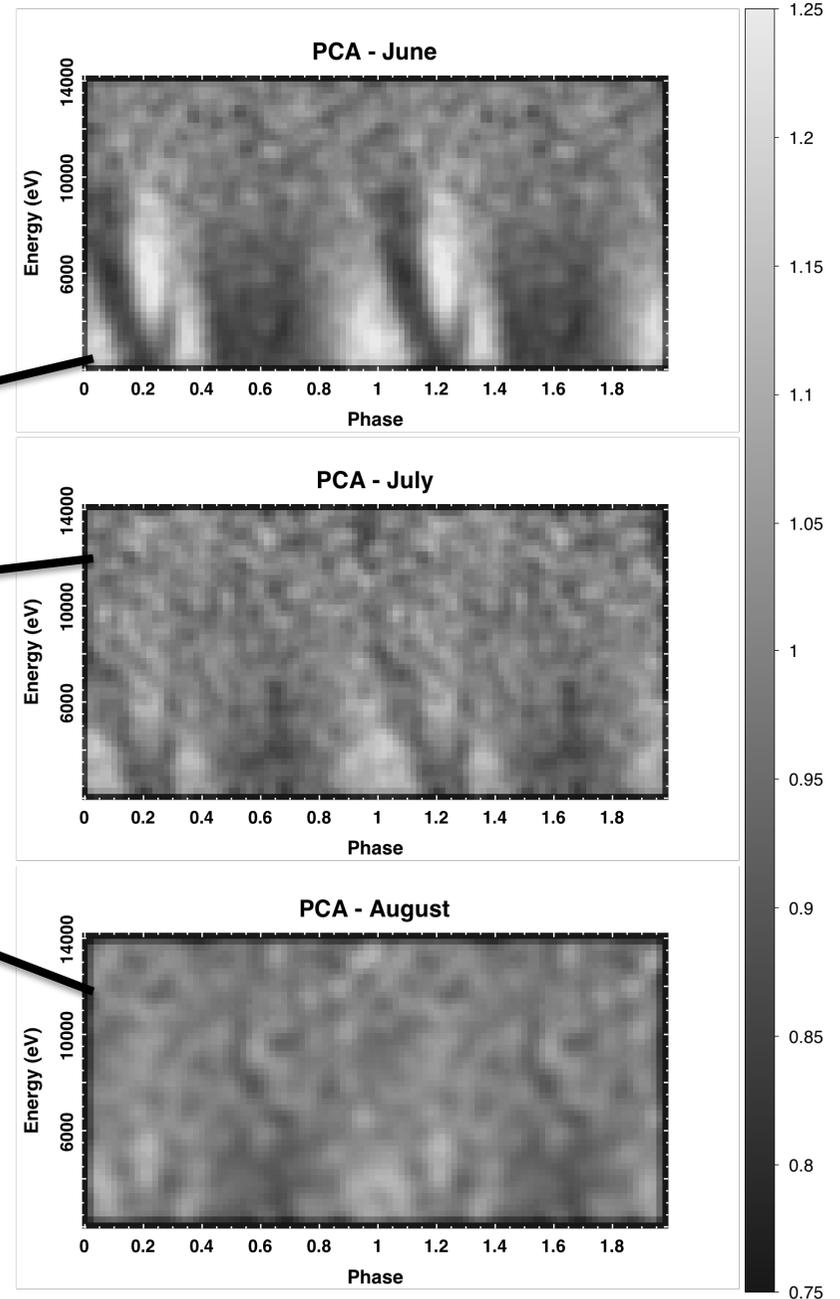
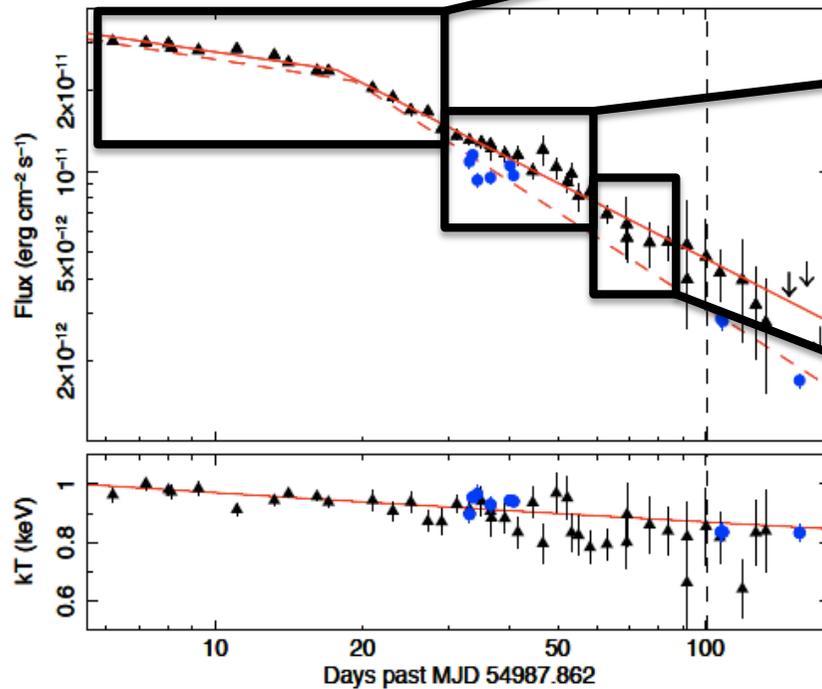
50 PHASE RESOLVED SPECTRA

- At most phases: acceptable fits by rescaling the model of the phase-averaged spectrum (e.g., $phabs*(bbody+powerlaw)$; **black**)
- At phases $\sim 0.1-0.3$ and $\sim 0.5-0.6$: acceptable fits with the addition of an absorption line (e.g., $cyclabs$; **red**)



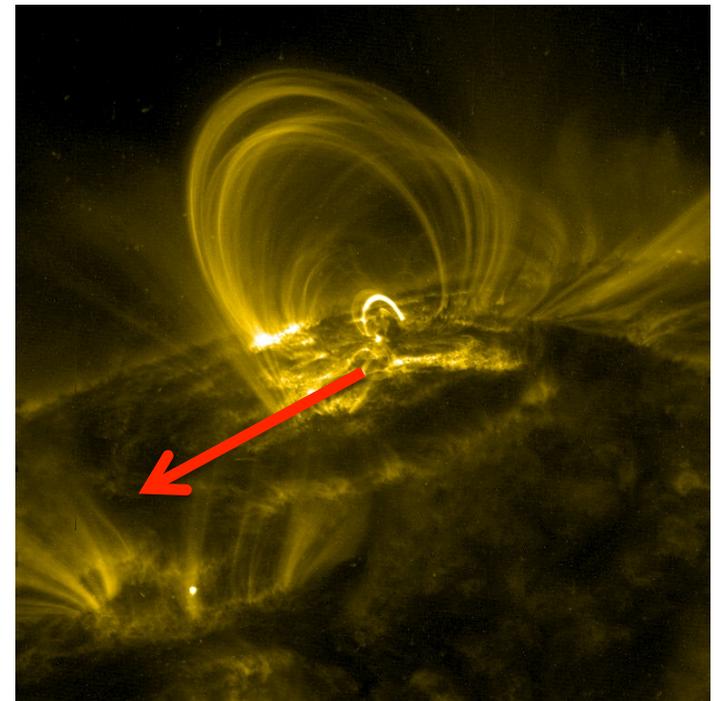
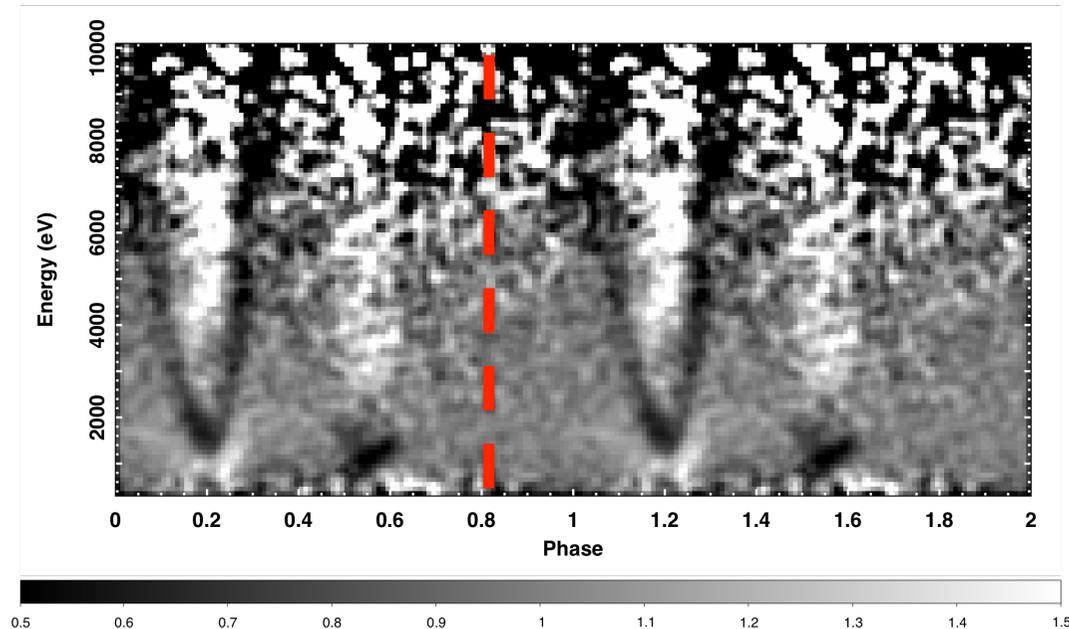
Is the line visible in other observations?

- **Clearly detected in RXTE data!**
 - line visible up to ~ 8 keV
 - line was already present at the onset of the outburst



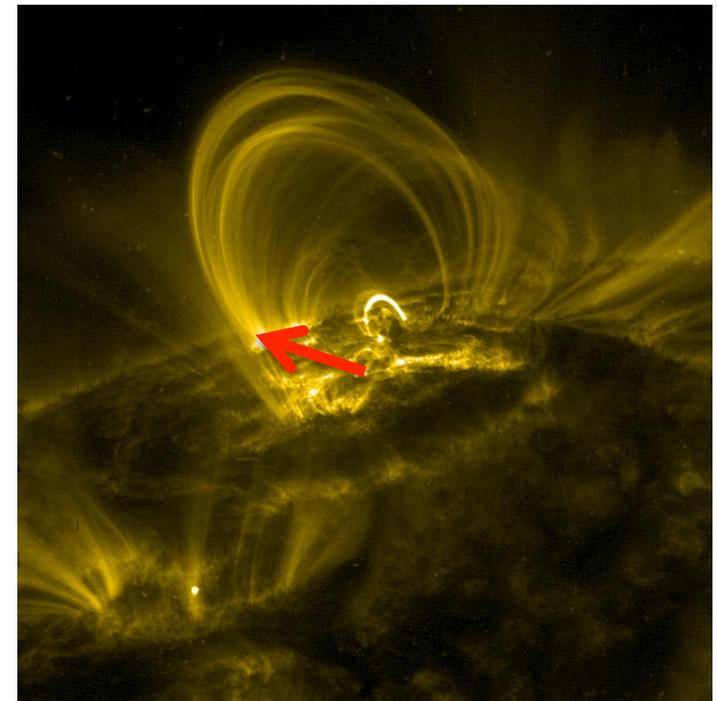
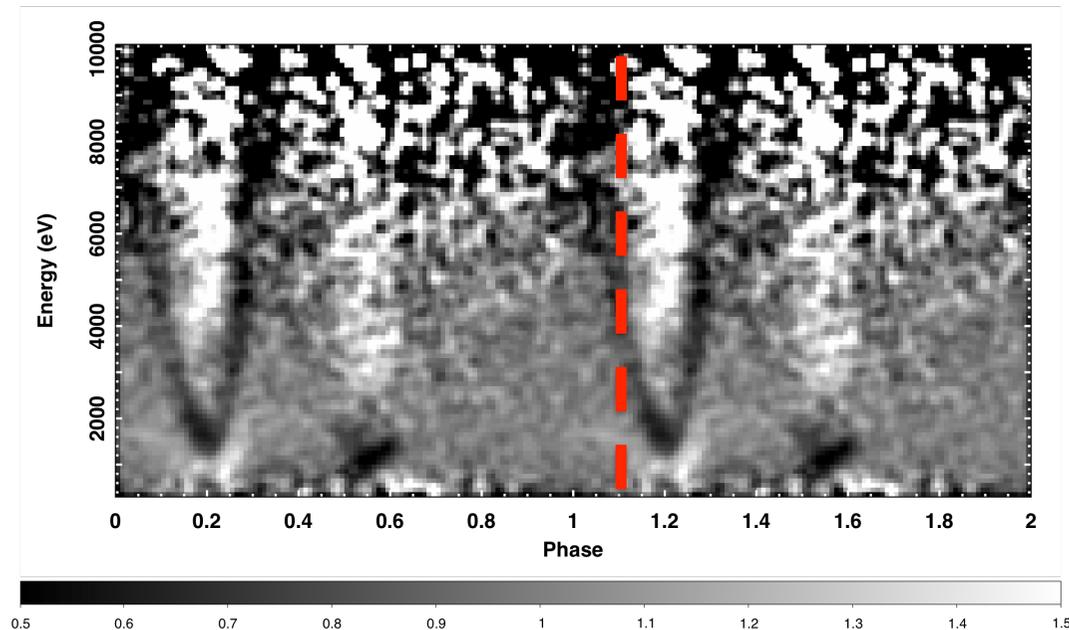
What is the origin of this variable line?

- $E \sim 1-5$ corresponds to $E_{\text{cyc,proton}} \sim (2-10) \times 10^{14}$ G
⇒ **MAGNETAR-like magnetic field**
- If proton cyclotron line, we need a **STRONGLY VARIABLE B**, that might vary:
 - along the **SURFACE** (small-scale multipolar B components) **OR**
 - along a **VERTICAL** plasma structure emerging from the surface (coronal loop/solar flare analogy; e.g., Beloborodov & Thompson 2007; Masada et al. 2010)



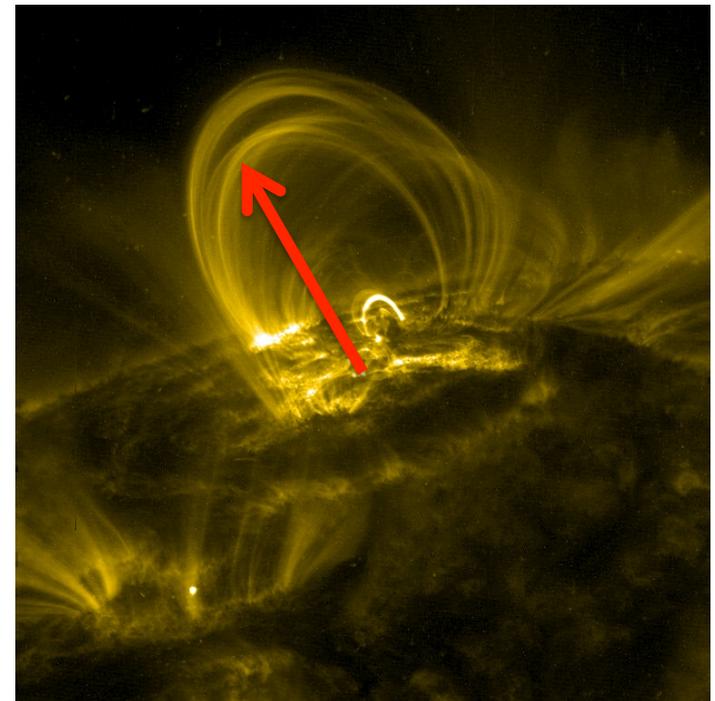
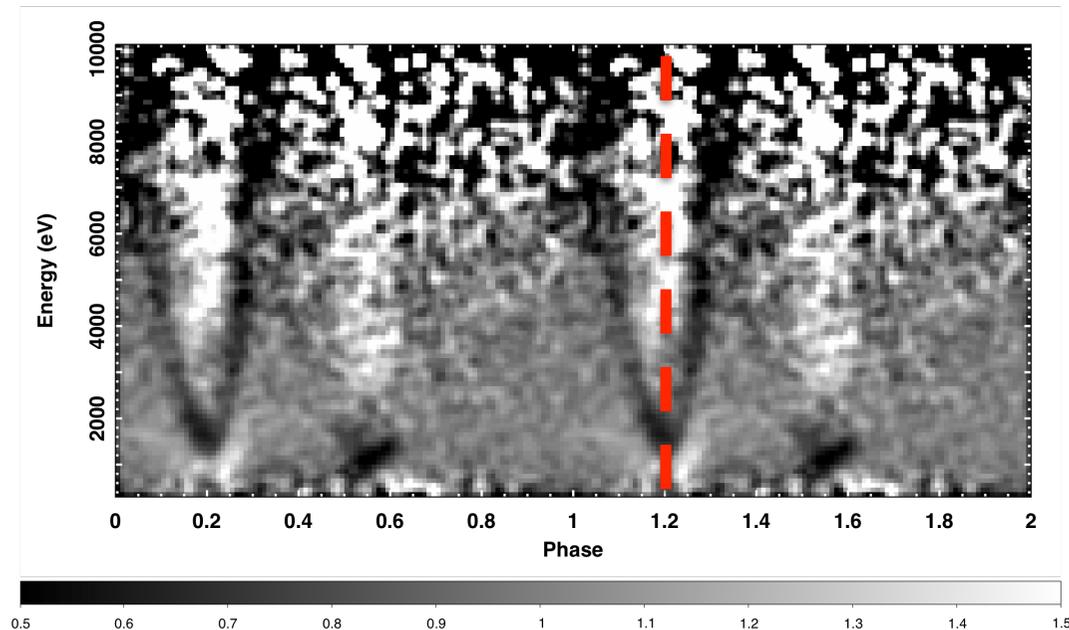
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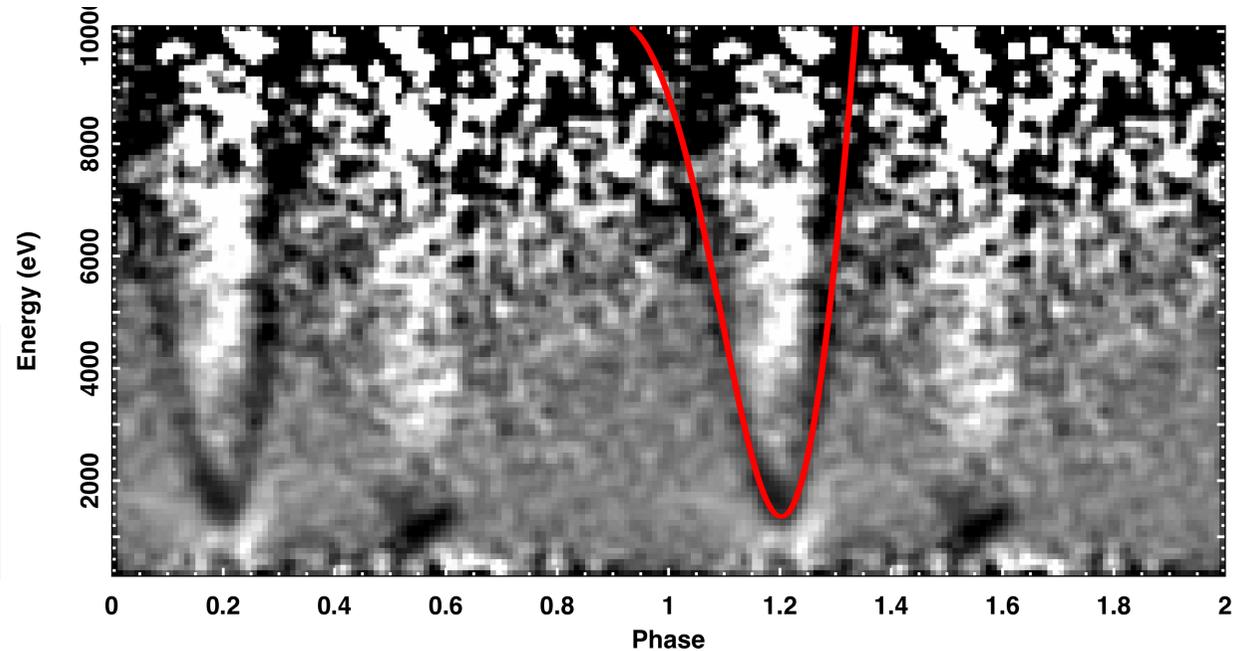
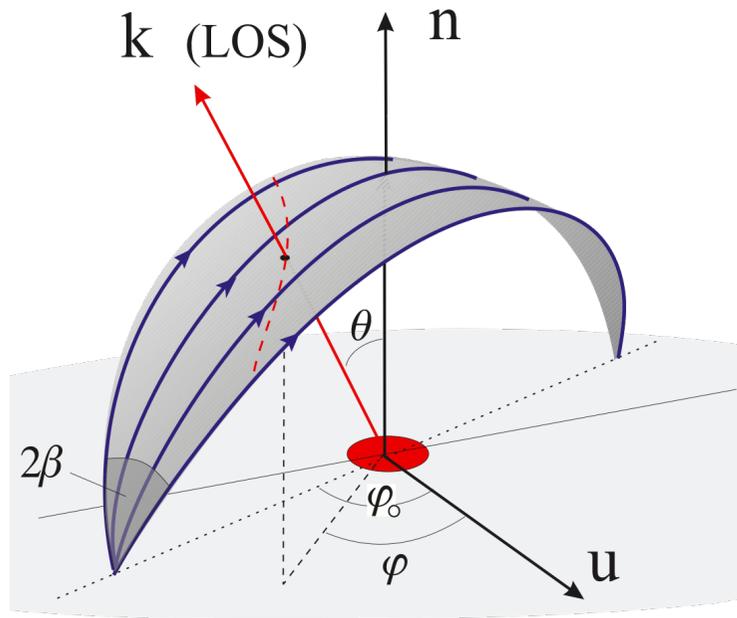


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A simple proton cyclotron model



- Different geometries can be envisaged, but our toy-model shows that the hypothesis of **PROTON CYCLOTRON** resonant scattering in a **MAGNETAR LOOP** is a viable scenario

Conclusions

- The X-ray spectrum of SGR 0418+5729 shows an **ABSORPTION LINE** with strong energy **VARIABILITY** with phase, **UNPRECEDENTED** among neutron stars (including accreting pulsars)
- A natural interpretation as **PROTON CYCLOTRON** line implies magnetic fields $>2 \times 10^{14}$ G \Rightarrow additional confirmation of magnetar nature of SGR 0418+5729 and of the overall **MAGNETAR MODEL**
- The much lower dipolar component of the magnetic field inferred from low spin-down rate and the line phase variability can be explained only with strong **MULTIPOLAR** magnetic field components, which are also predicted by the **MAGNETAR MODEL**