SGR 0418+5729: a Waning Magnetar ?

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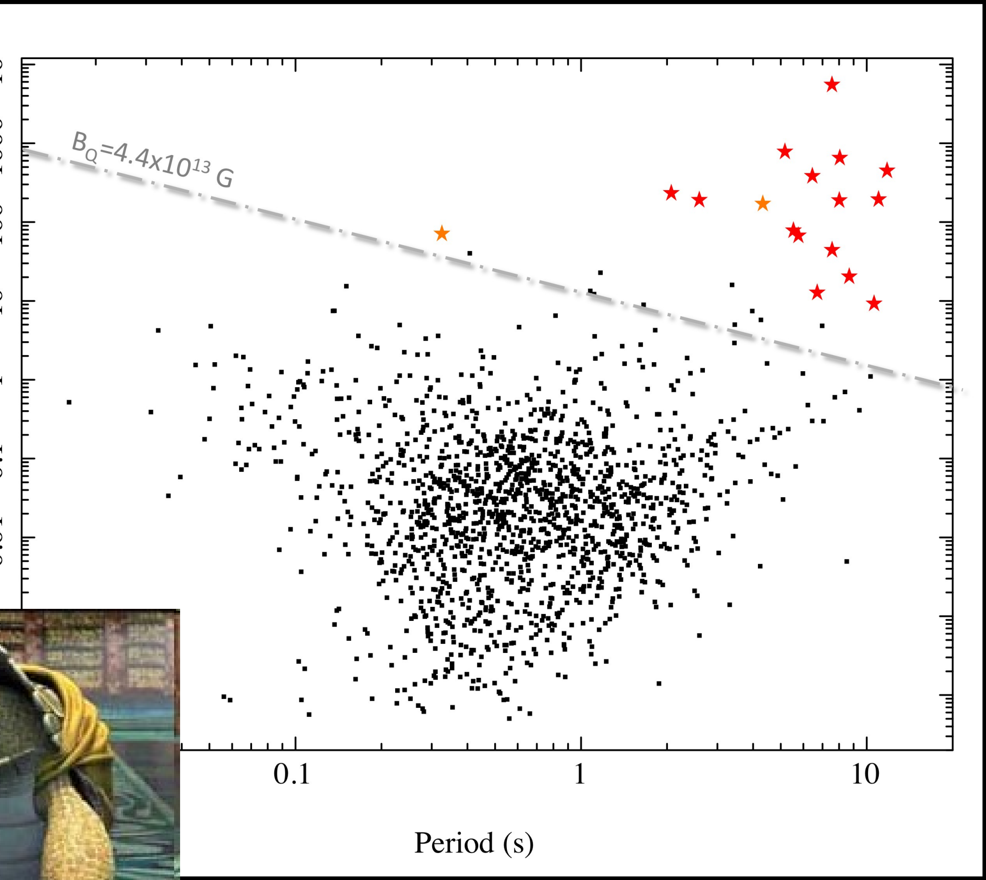
SGRs, AXPs and the Like

"Magnetar activity" (bursts, outbursts) detected so far only in high-B sources ($B_p > 5\times10^{13}$ G) : AXPs+SGRs (☆) and PSR J1846-0258, PSR J1622-4950 (☆)

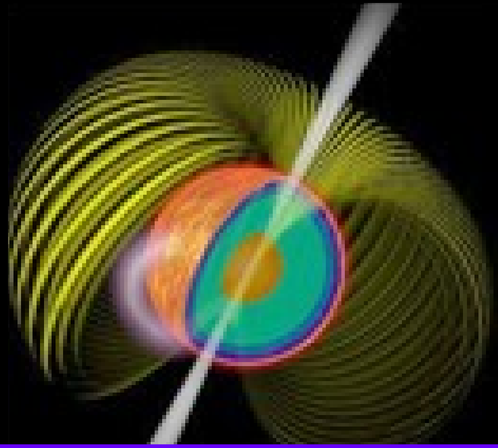
The ATNF Catalogue lists 18 PSRs with $B > 5\times10^{13}$ G (HBPSRs)



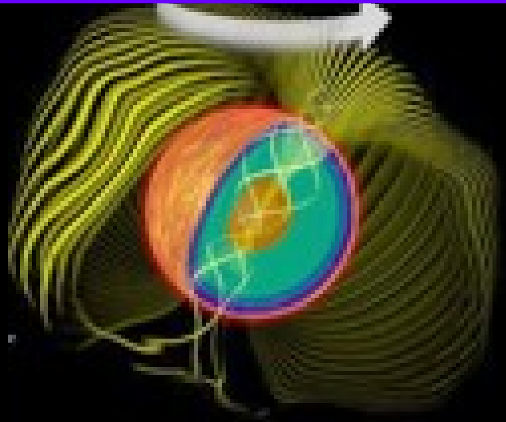
"A high dipole field does not always make a magnetar, but a magnetar has necessary a high dipole field !"
Wise Oogway

A Magnetar at Work

- What really matters is the internal toroidal field B_φ
- A large B_φ induces a rotation of the surface layers
- Deformation of the crust ⇨ fractures ⇨ bursts/twist of the external field



Wise Oogway says “To have a large enough B_φ also the dipole field must very high !” (it figures…)



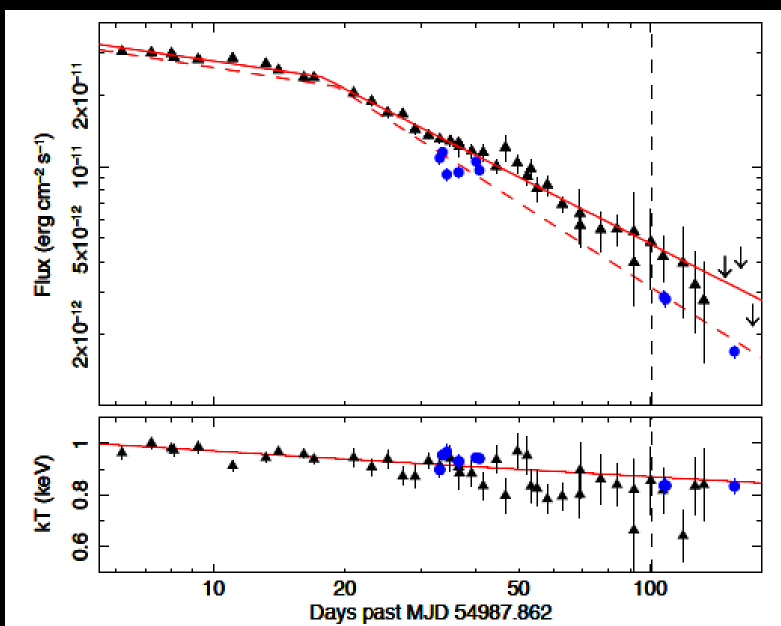
SGR 0418+5729

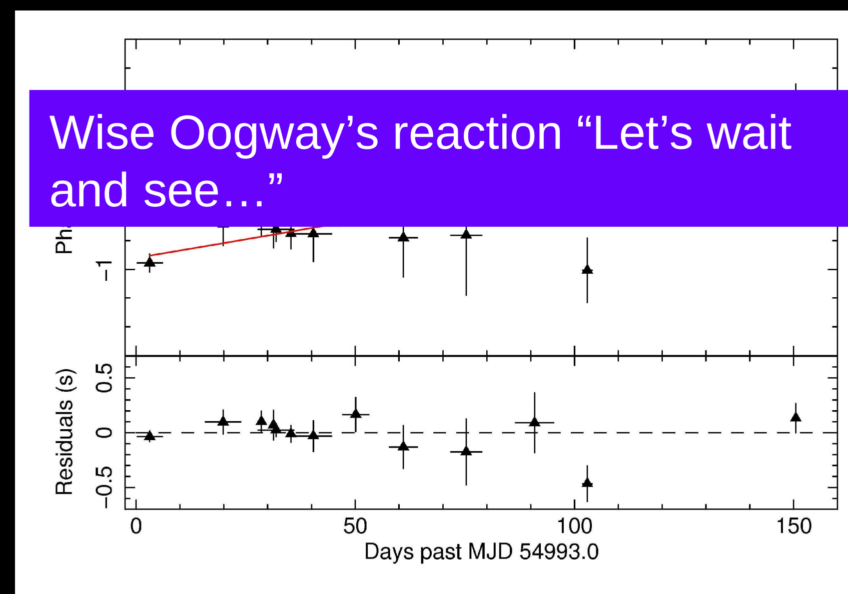
- 2 bursts detected on 2009 June 05 with Fermi/GBM, spin period of 9.1 s with RXTE within days (van der Horst et al. 2010)
- All the features of a (transient) magnetar
  - Rapid, large flux increase and decay
  - Emission of bursts
  - Period in the right range (~2 – 12 s)
  - Period derivative ?

Hunting for $\dot{P}$ - I

SGR 0418+5729 was monitored for ~ 160 d with RXTE and Swift (Esposito et al. 2010)

No positive detection of $\dot{P}$. Upper limit ~ 1.1×10^{-13} s/s, $B_p < 3 \times 10^{13}$ G, weakest ever (AXP 1E 2259+586 has $B_p \sim 6 \times 10^{13}$ G)





Wise Oogway's reaction "Let's wait and see…"

Hunting for $\dot{P}$ - II

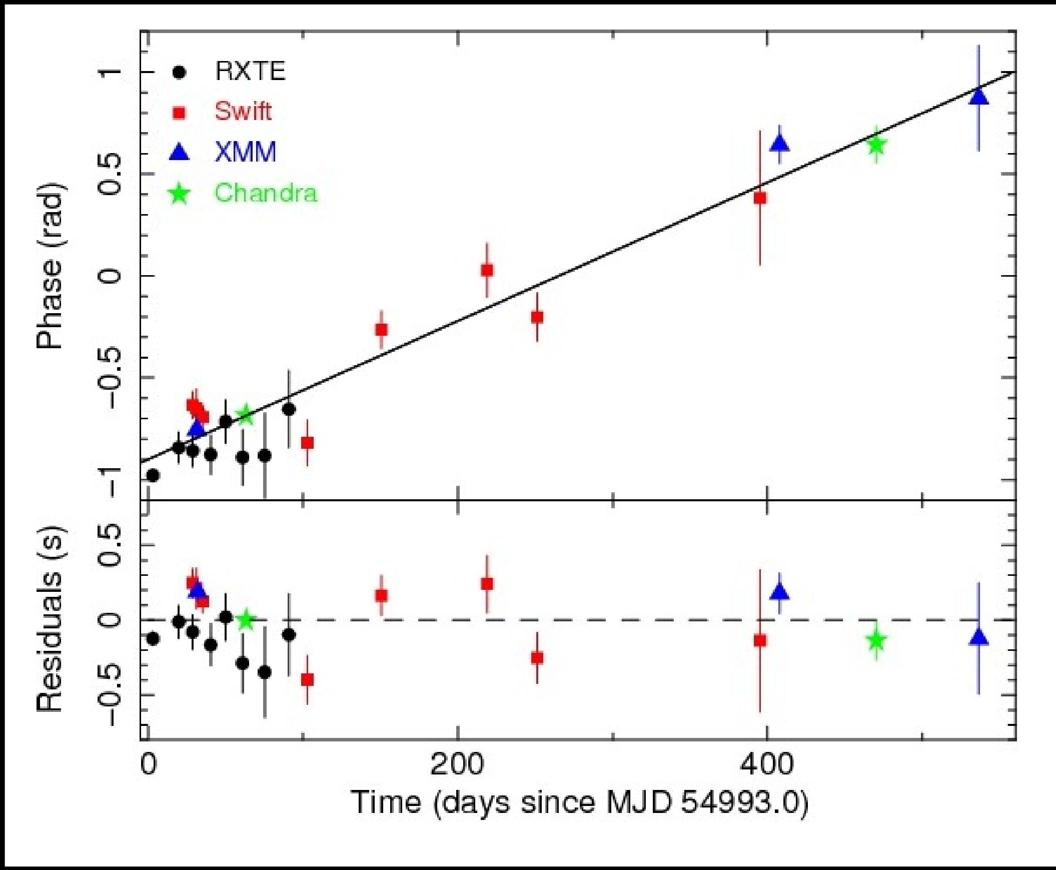
Visibility constraints prevented new observations until 2010 July

New pointings with Swift, XMM-Newton and Chandra

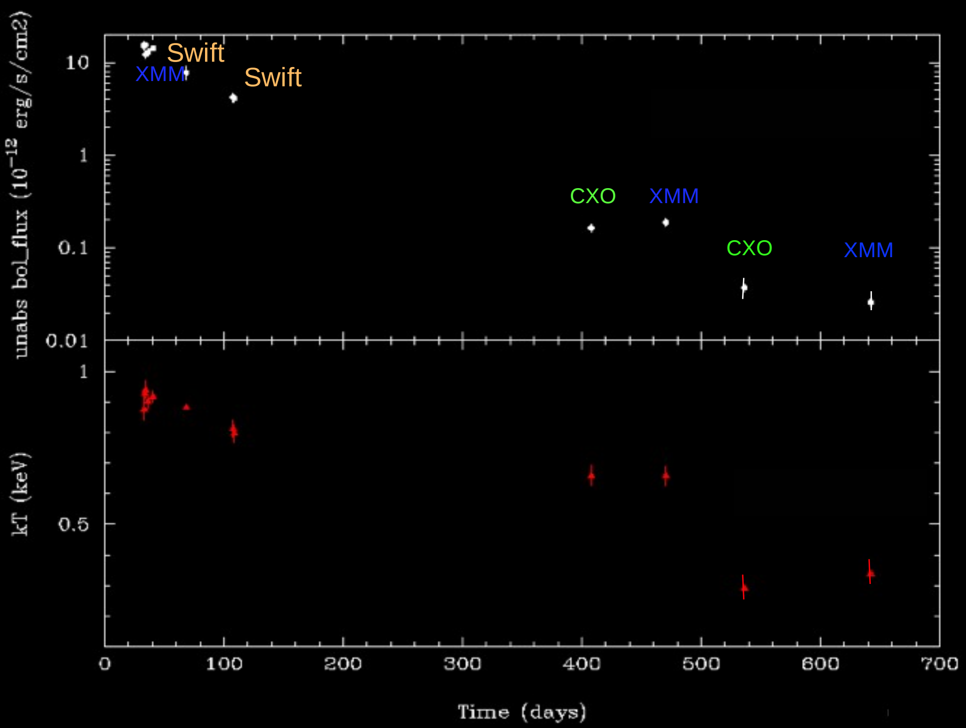
Phase-coherent timing solution covering ~ 500 d (Rea et al. 2010)

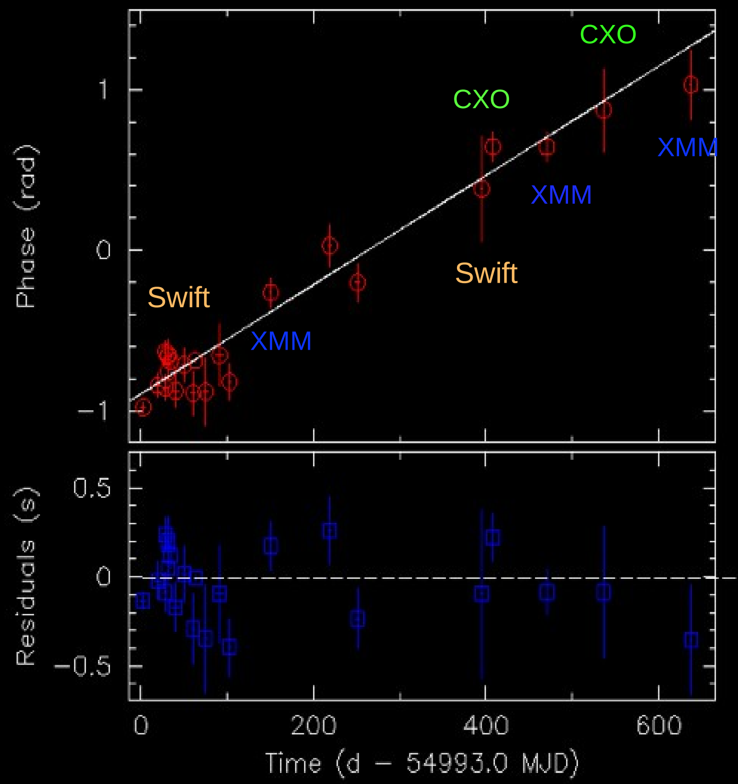
$\dot{P}$ < 6x10   s/s (90% cl)
B < 7.5x10   G
SGR 0418+5729 is a low-(dipole) field magnetar

Wise Oogway says "Ouch…."



... and the Chase Goes On





SGR 0418+5729 now monitored for ~ 650 d

$\dot{P}$ < 4.7x10 s/s, B < 6.6x10 G (Rea et al. 2011)

Is SGR 0418+5729 an Old Magnetar ?

- Clues (Rea et al. 2010)
  - Large characteristic age (> 24 Myr)
  - Weak bursting activity (only 2 faint bursts)
  - Low dipole field ($B < 7.5 \times 10^{12}$ G)
- Main issues (Turolla et al. 2011)
  - P, $\dot{P}$ and B from magneto-rotational evolution
  - capacity of producing bursts
  - spectrum of the persistent emission

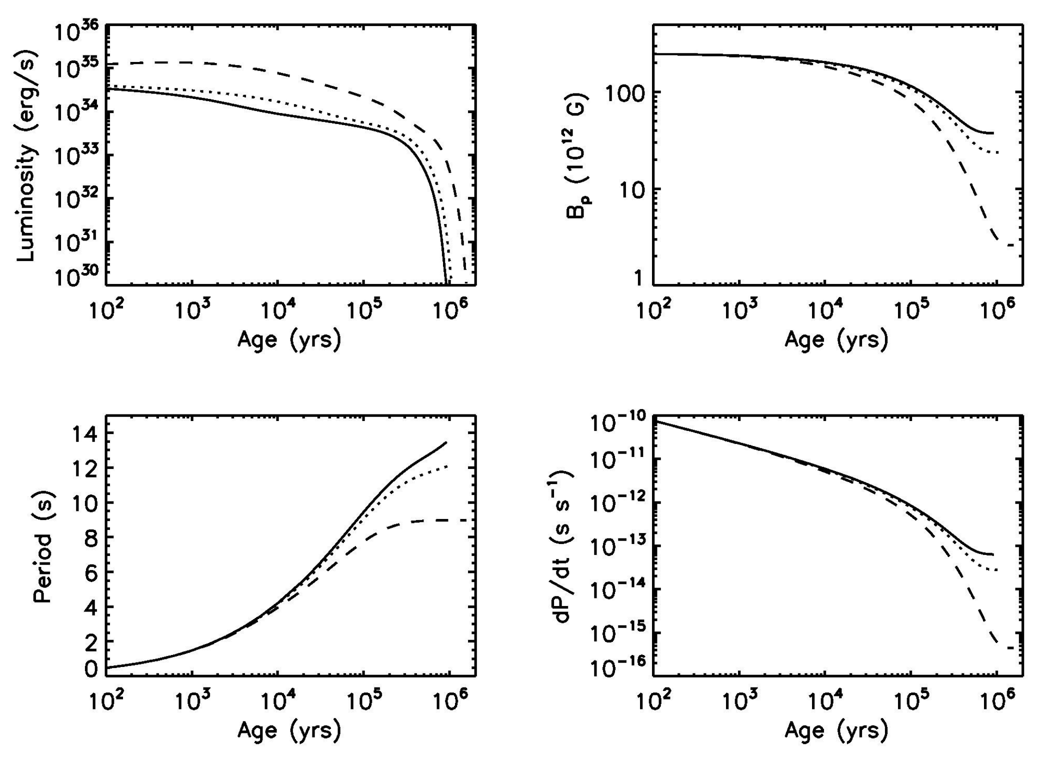
Magneto-rotational Evolution

Coupled magnetic and thermal evolution (Pons, Miralles & Geppert 2009)

Standard cooling scenario (Page et al. 2004), M=1.4 M_{-} , toroidal+ poloidal crustal field, external dipole

P_0 = 10 ms, $B_{p,0}$ = 2.5x10^{14} G,
$B_{pol,0}$ = 10 $B_{p,0}$, $B_{tor,0}$ = 0 (Æ) ,
4x10^{15} (···), 4x10^{16} G (- - -)

P ~ 9 s, $\dot{P}$ ~ 4x10^{-16} s/s,
B_p ~ 2x10^{12} G, L_X ~ 10^{31} erg/s
for an age ~ 1.5 Myr



Wear and Tear

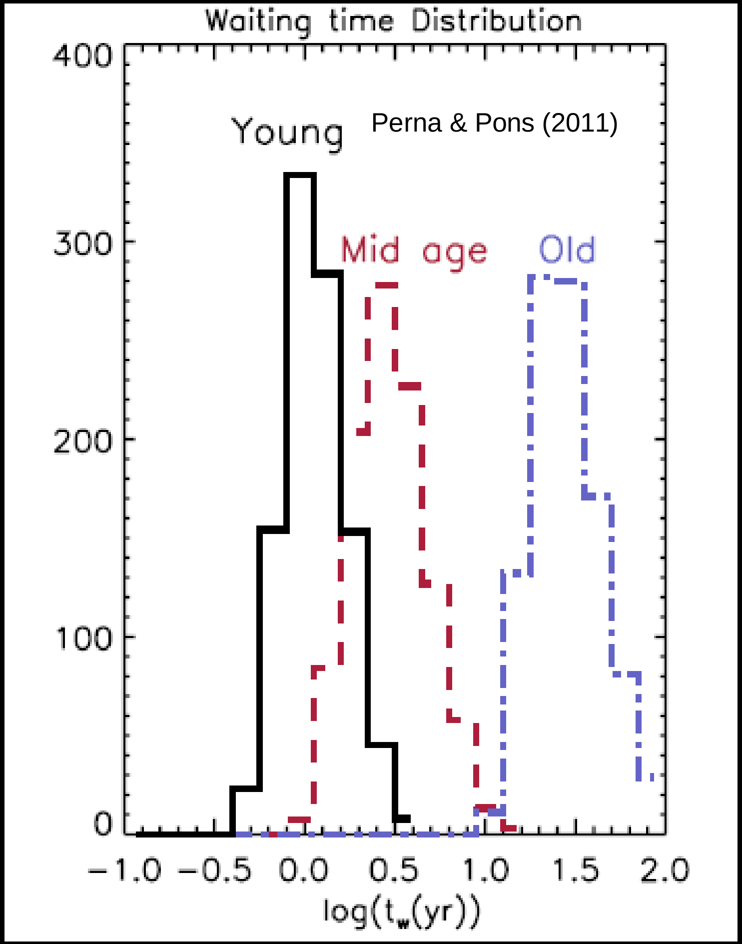
Calculation of magnetic stresses acting on the NS crust at different times (Perna & Pons 2011)

Crustal fractures possible also at late evolutionary phases (≈ 10^5 – 10^6 yr)

Burst energetics decreases and recurrence time increases as the NS ages

For $B_{p,0} = 2\times10^{14}$ G and $B_{tor,0} = 10^{15}$ G, $\Delta t \approx 10 - 100$ yr

Fiducial model for SGR 0418+5729 has similar $B_{p,0}$ and larger $B_{tor,0}$ ⇨ comparable (at least) bursting properties



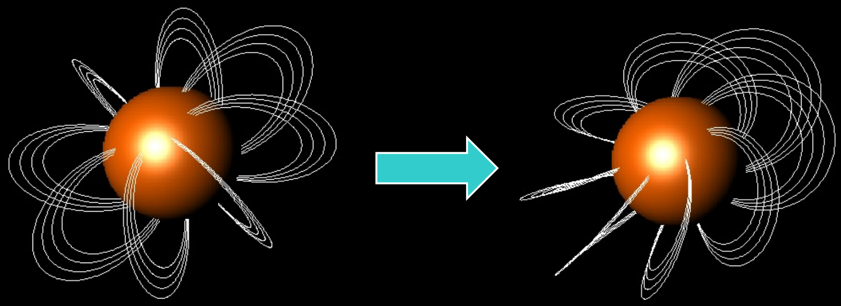
Magnetars Persistent Emission

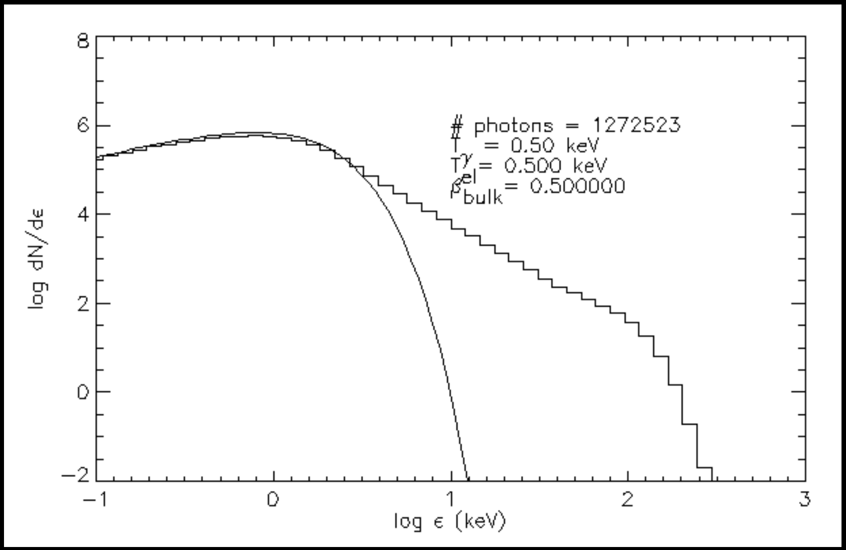
In the twisted magnetosphere model currents flow along closed field lines

Resonant cyclotron scattering of thermal photons and heating of the star surface (Thompson, Lyutikov & Kulkarni 2002)

Thermal (BB) plus high-energy tail (PL) (Lyutikov & Gavriil 2006; Fernandez & Thompson 2007; Nobili, Turolla & Zane 2008a,b)

RCS models quite successful in fitting SGR/AXP spectra (Rea et al. 2008; Zane et al. 2009)



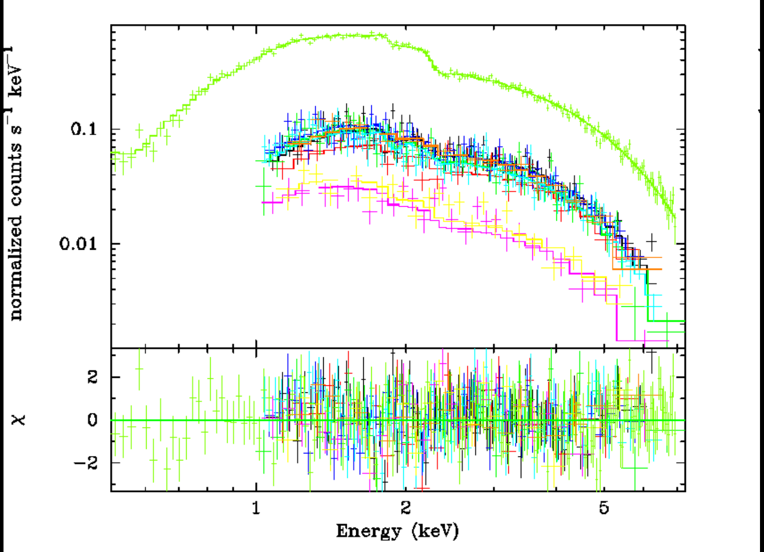


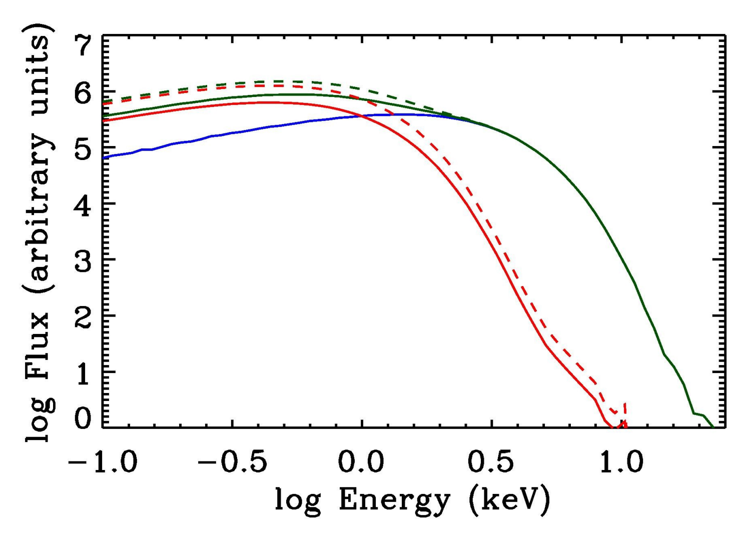
SGR 0418+5729 X-ray Spectrum

X-ray spectra (1 – 10 keV) during outburst decay best fit by BB+BB: kT_c ~ 0.3 keV, kT_h ~ 0.9 keV and A_c/A_h = 5□30

Superposition of two RCS spectra with kT_c ~ 0.3 keV and kT_h ~ 0.9 keV, A_c/A_h = 15 – 30, B_p = 5x10^{12} G and $\Delta\varphi$ = 0.4 rad

RCS spectrum consistent with BB+BB in the 1 – 10 keV range (no tail)





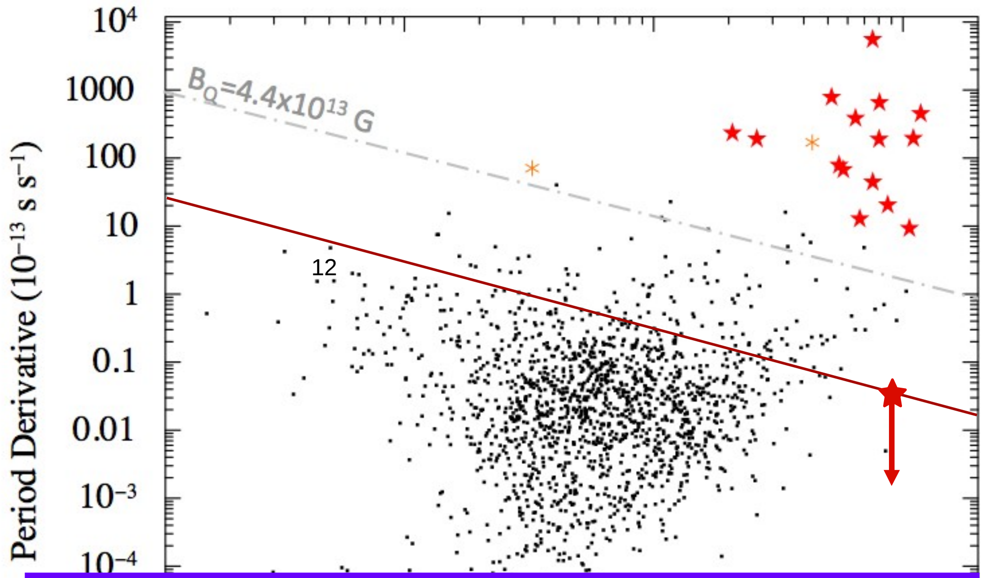
Conclusions

SGR 0418+5729 is a low-B source: more than 20% of known radio PSRs have a stronger B_p

SGR 0418+5729 properties compatible with an aged magnetar ≈ 1Myr old

A continuum of magnetar-like activity across the P-$\dot{P}$ diagram

No need for a super-critical field



Wise Oogway says “That necessary B_p > B_{crit} in “magnetars” is a long-perpetuated myth”