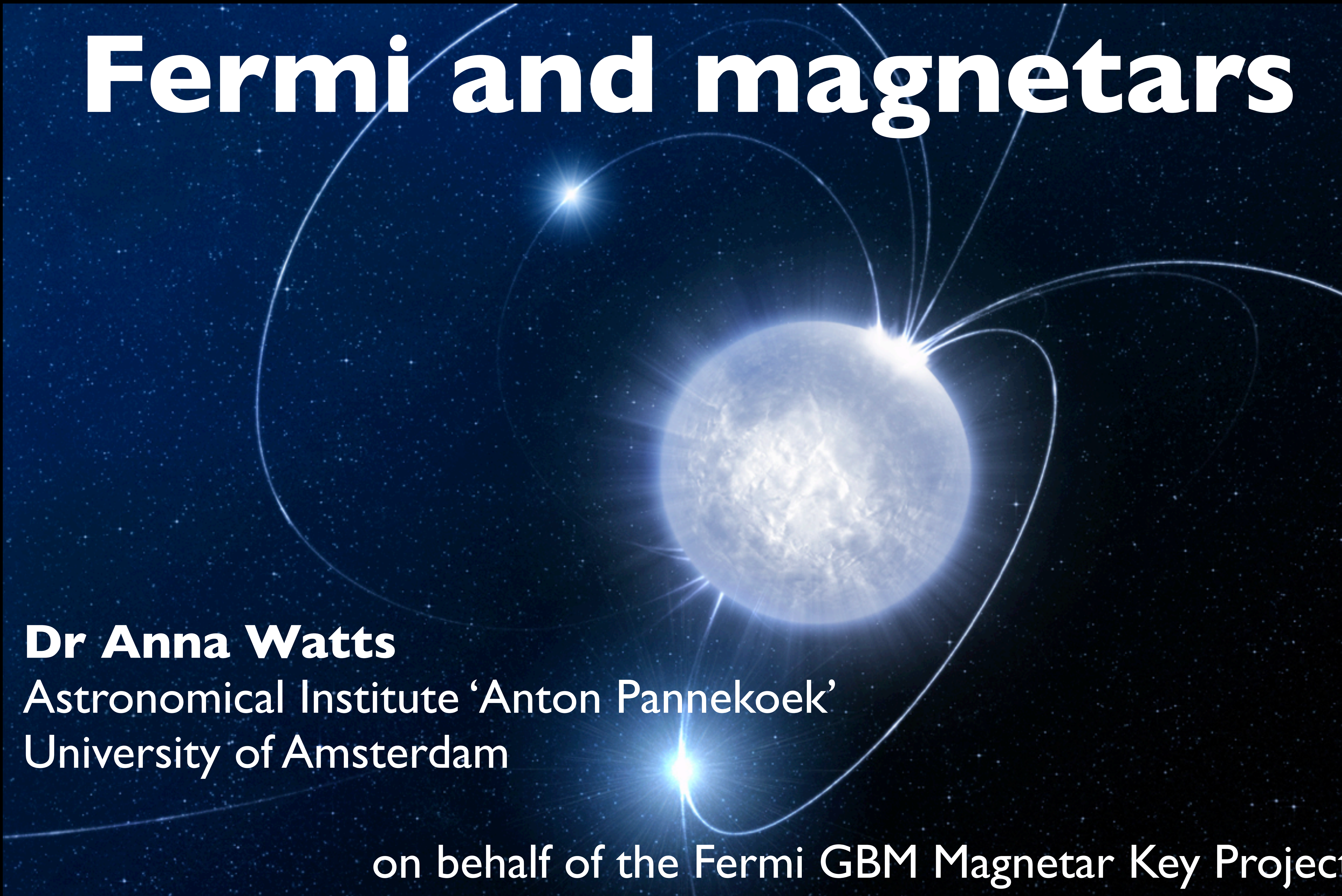
Fermi and magnetars



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on behalf of the Fermi GBM Magnetar Key Project

Image: ESO/L.Calçada

Magnetars

- ~20 isolated neutron stars (NS) with
  - Slow spin periods (2-12s)
  - Rapid spin-down
  - Regular gamma-ray bursts
    (Soft Gamma Repeaters, SGRs)
- Some located in supernova remnants
- Young neutron stars with ultra-strong magnetic fields

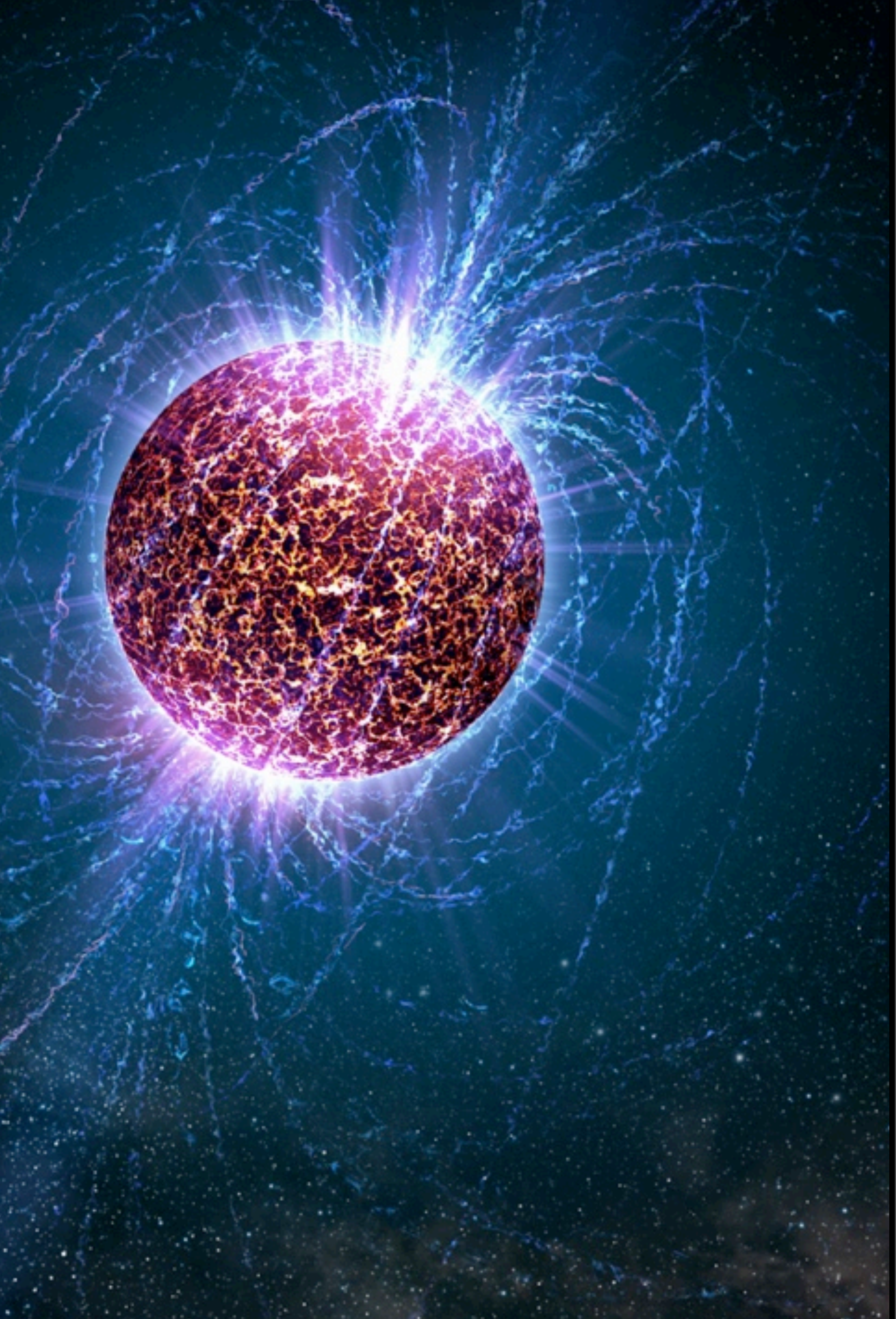


Image: Casey Reed/Penn State U

GBM SGR activity

Source	Active period	Triggered bursts
SGR 0501+4516	Aug-Sep 2008	26
SGR 1806-20	Nov 2008	1
SGR 1550-5418	Oct 2008 Jan-Feb 2009 Mar-Apr 2009	7 117 14
SGR 0418+5729	June 2009	2
1E 1841-045	Feb 2011	3

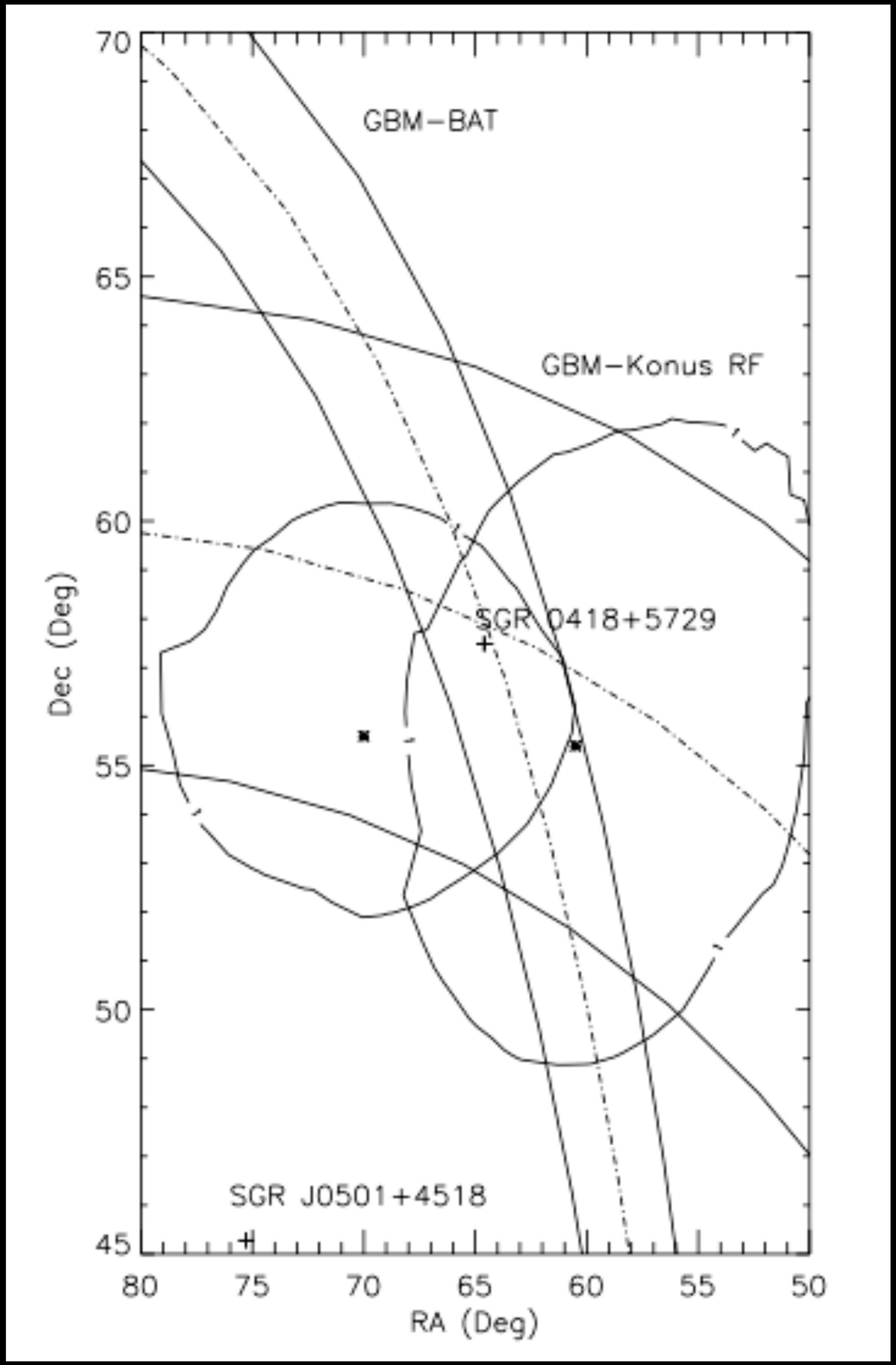
Many untriggered bursts also detected (e.g. Kaneko et al. 2010)

Key questions

- What are the general properties of the NS population?
  - How many magnetars are there?
  - Where do they come from, where do they go?
- What is the dense matter equation of state?
  - Can we constrain this using magnetars?
- How does magnetic field evolution proceed in NS?
  - What triggers bursting activity in magnetars?
- What physical processes occur for magnetic fields above the QED limit?
  - How do strong fields affect radiative processes in bursts?

Magnetar population

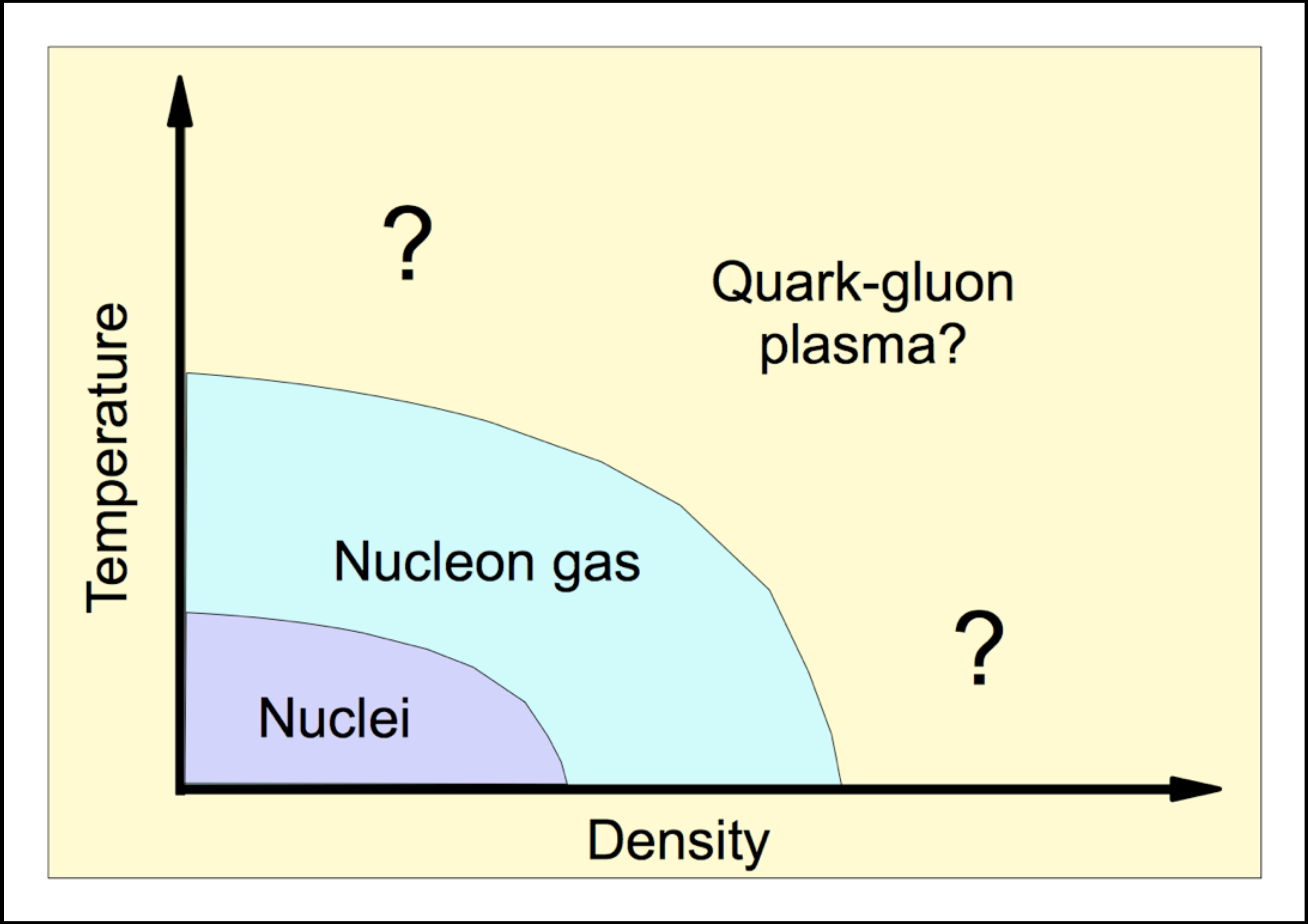
- GBM has seen 2 new and 3 previously-known SGRs.
- The new sources appear to be close (~2kpc). SGR 0418+5729 would not have been detected if only 1.5 times further away.
- Is there a population of 'dim' SGRs?
- Mark and recapture method: galactic SGR population estimated to be 9 (+17.3/-1.6)*, assuming membership fixed and bursting behaviour homogenous.



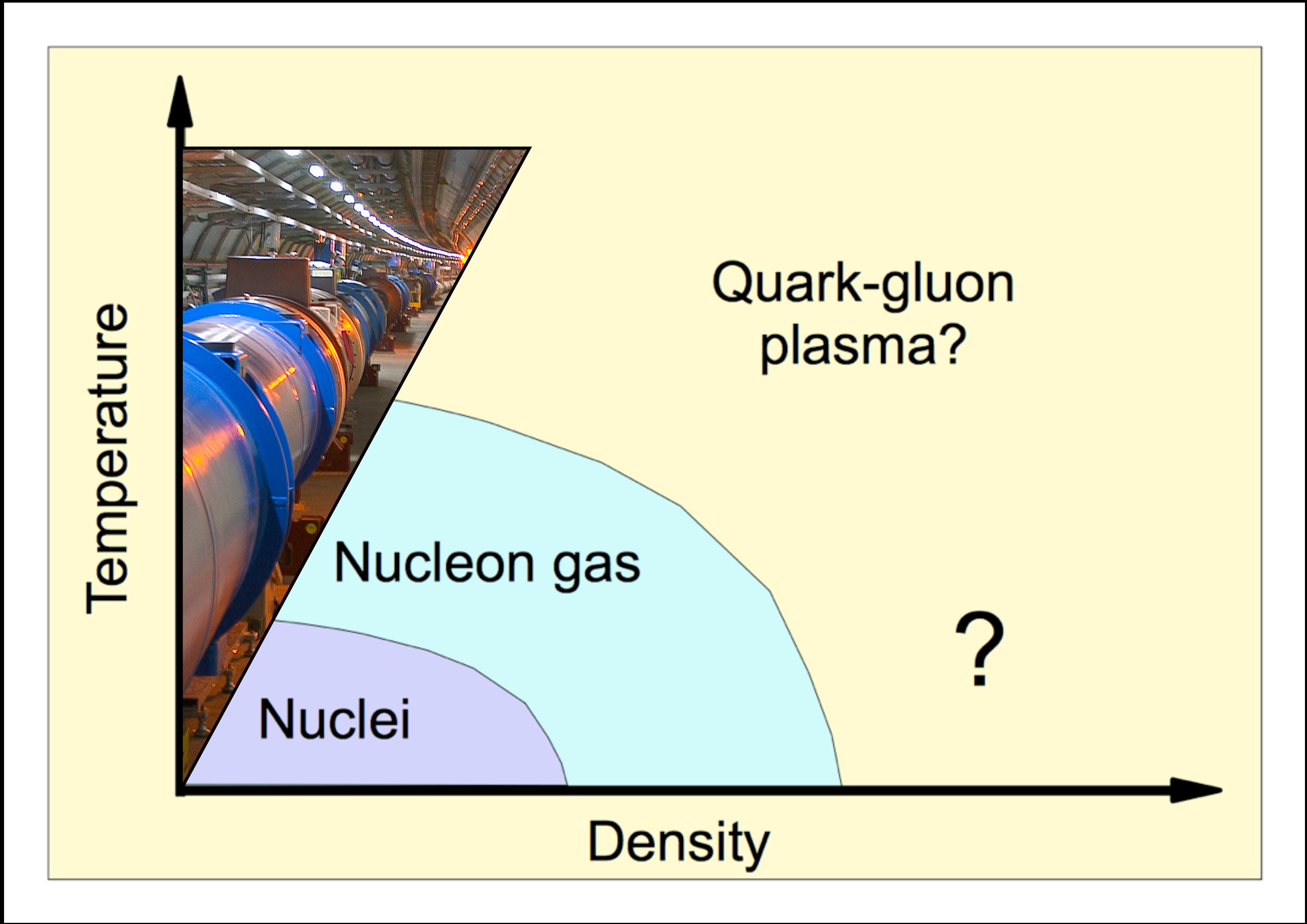
SGR 0418+4729, discovered by GBM (van der Horst et al. 2010)

* not including new bursts from 1E1841-045

Equation of state (EoS)

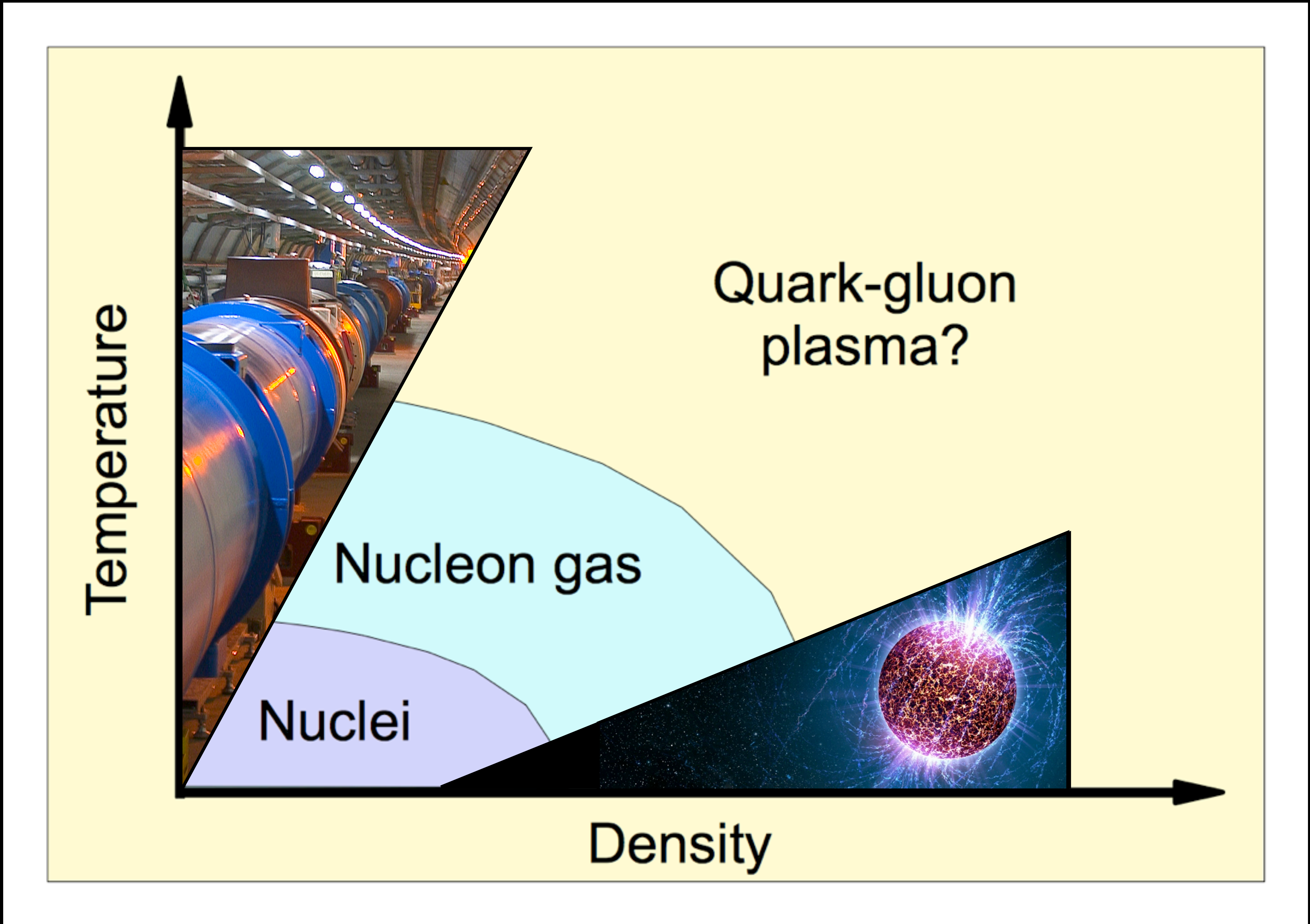


Equation of state (EoS)



LHC image: CERN

Equation of state (EoS)

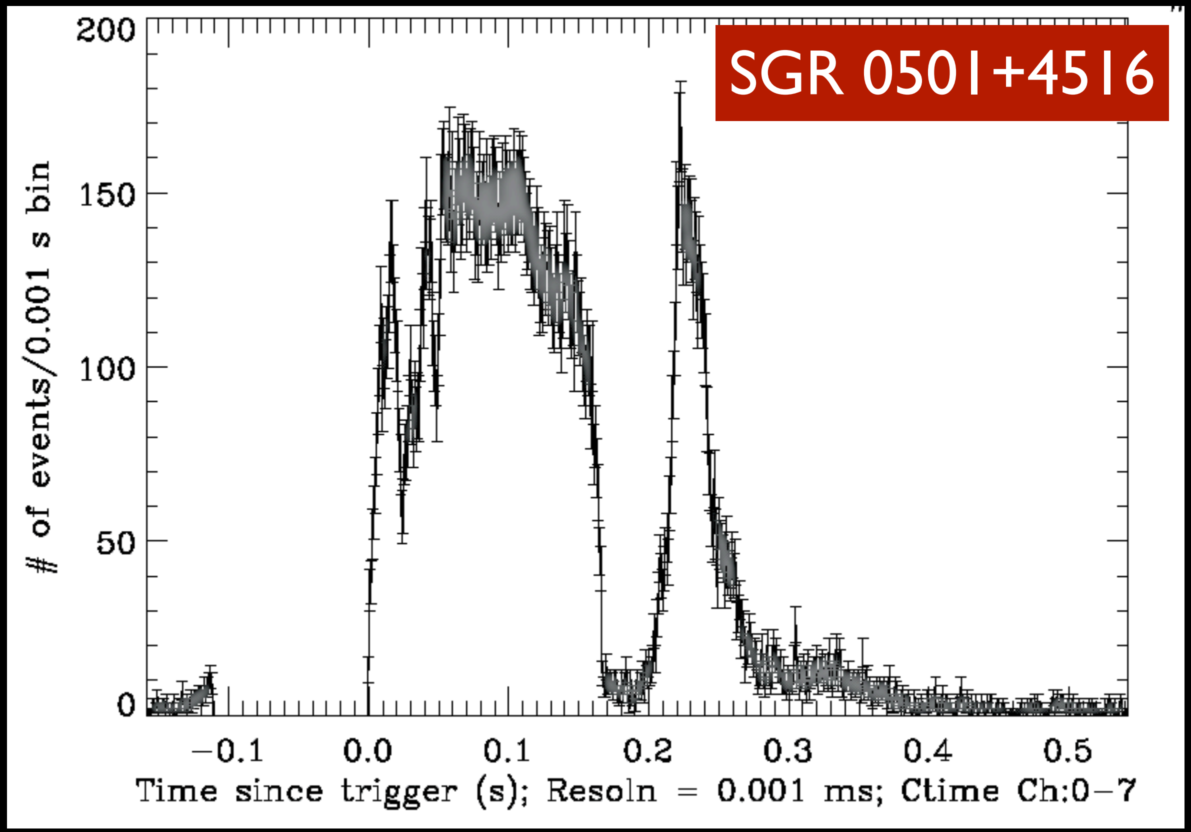


LHC image: CERN

Photospheric radius expansion

- Thermonuclear bursts on accreting NS often reach the Eddington limit and show Photospheric Radius Expansion (PRE).

- Can be used to constrain EoS.

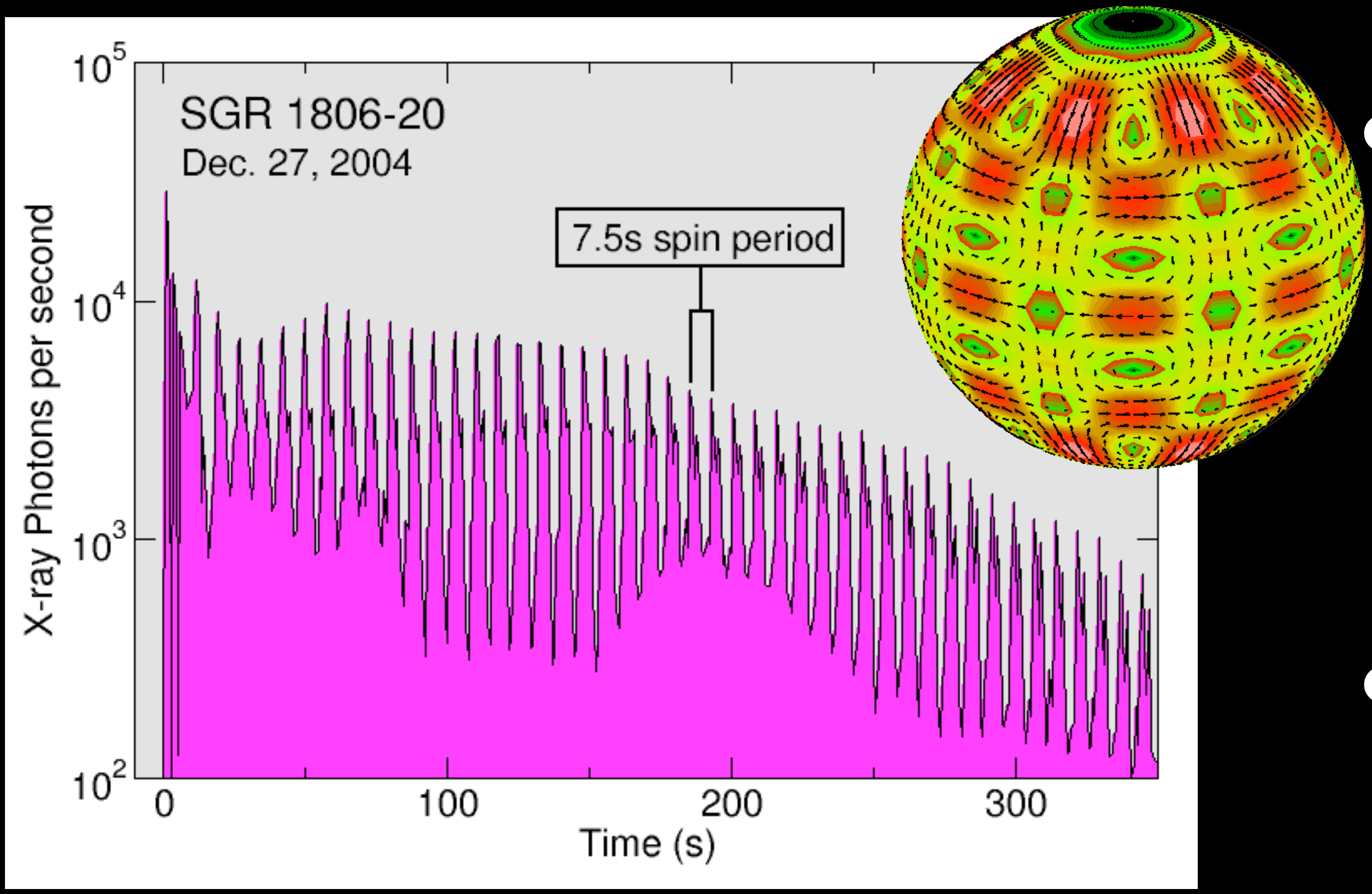


- Could magnetar bursts also show PRE? Would be a new way of studying EoS and magnetic field.

- Four baseline conditions can be met (Watts et al. 2010).

- Detailed studies of photospheric stability and emission signature now underway (Poster 39, Thijs van Putten).

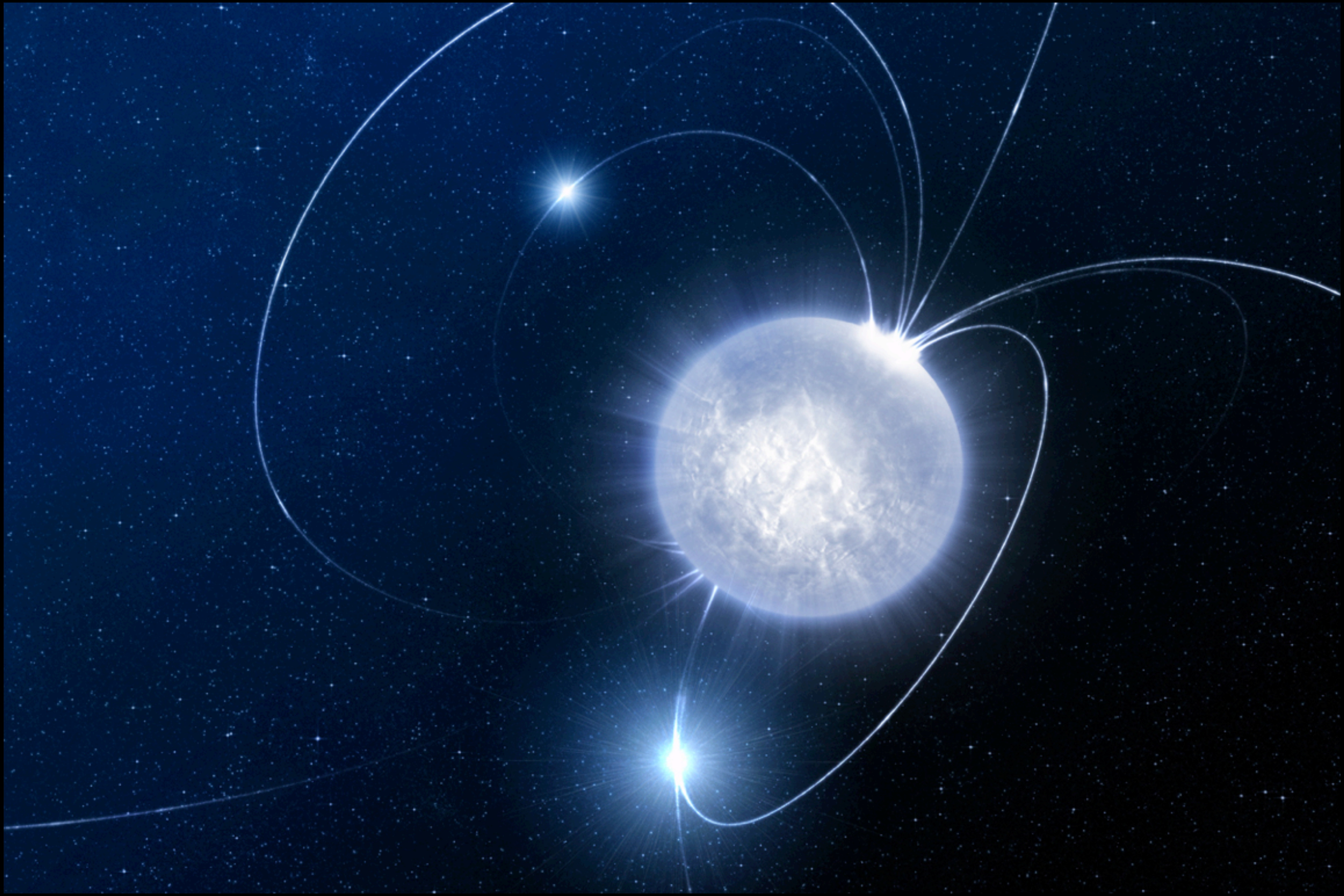
Seismology



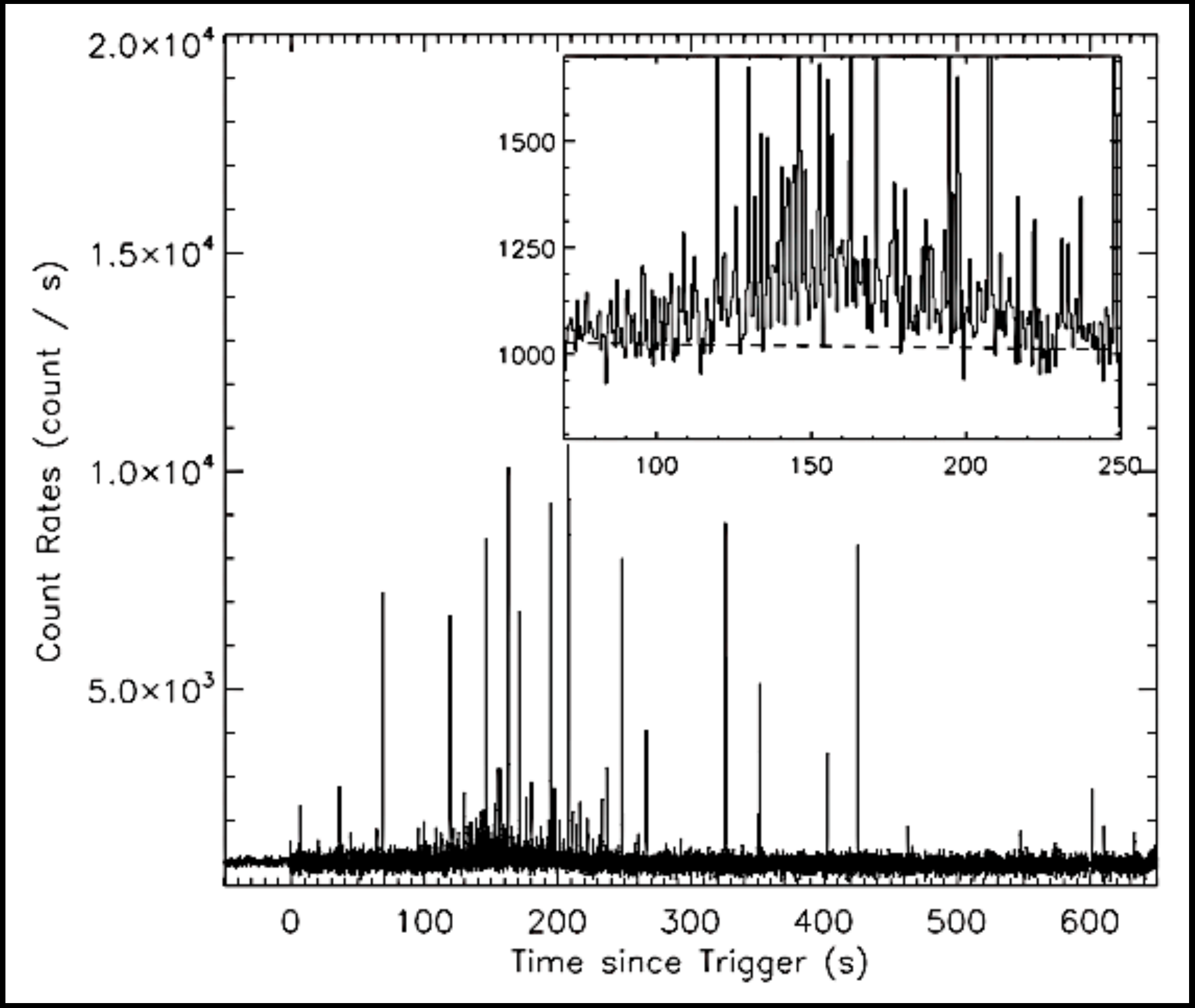
- Giant flares trigger seismic vibrations of magnetars (Israel et al. 2005, Strohmayer & Watts 2005,6, WS 2006).
- Seismic models can constrain EoS and field.

- Searching for seismic vibrations triggered by GBM bursts.
- Upper limits only so far (SGR 1550-5418 - Kaneko et al. 2010; Poster 26 by Daniela Huppenkothen on SGR 0501+4516).
- Nevertheless constraining for models of excitation/emission.

Magnetic evolution



Burst trigger mechanism

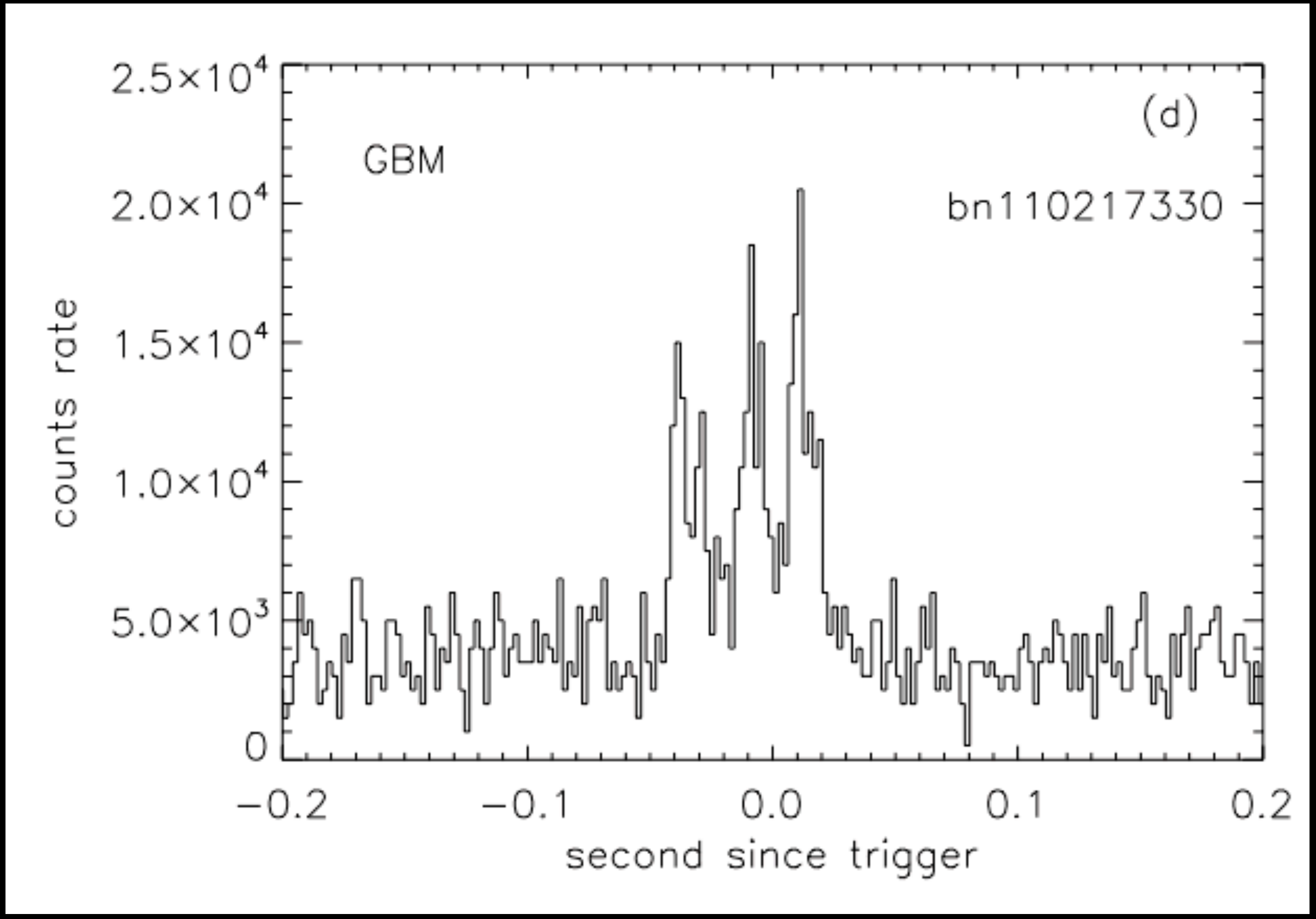


- What size of region is involved in the bursts?
  - Spectral fitting of GBM data during a 'burst storm' from SGR 1550-5418 reveals smallest hotspot ever recorded for a magnetar, radius ~100m, ~10^{-5} x NS surface area (Kaneko et al. 2010).

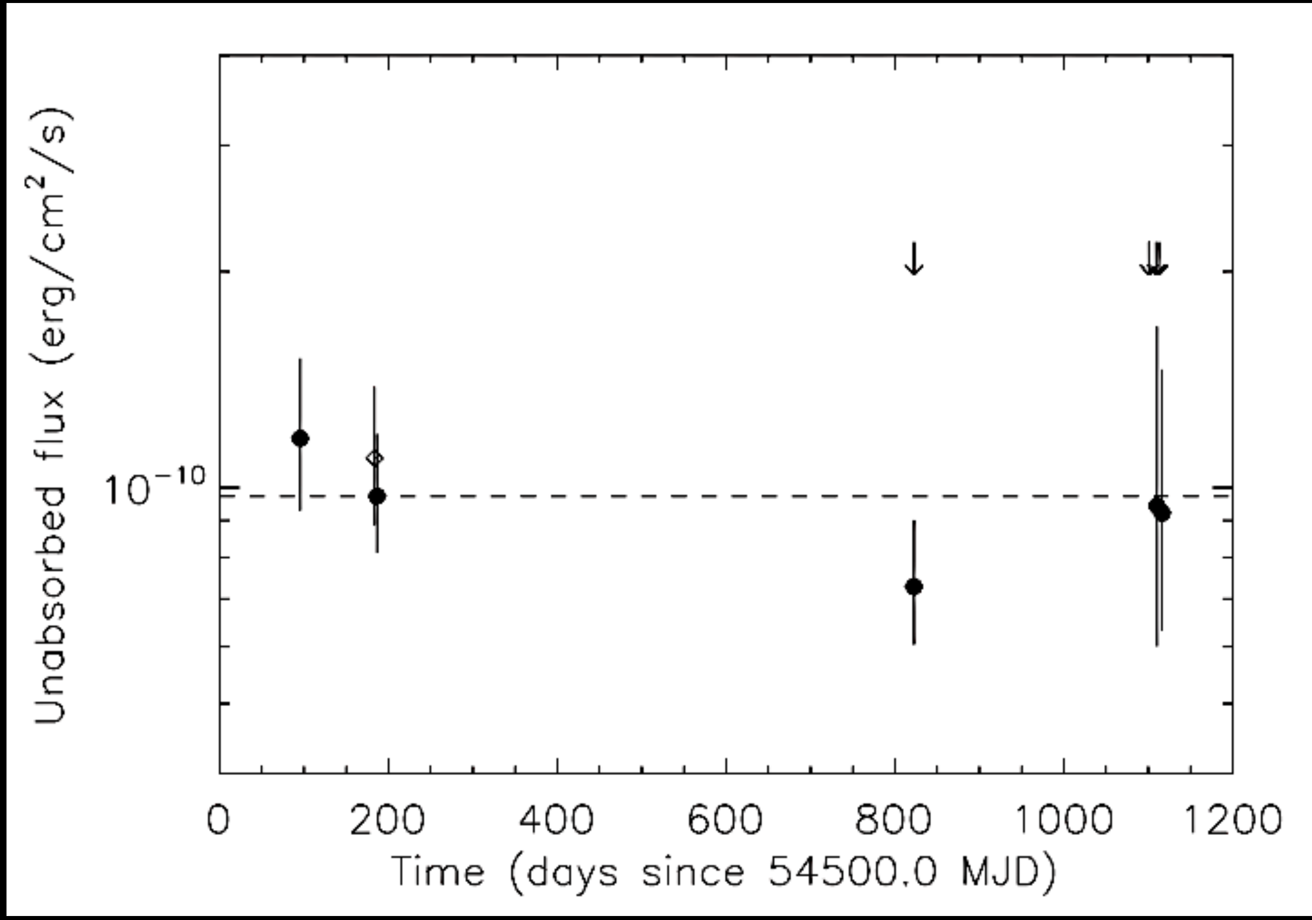
- What is the minimum field strength required for bursting?
  - SGR 0418+5729 shows standard bursts (van der Horst et al. 2010) despite low dipole field (< 10^{13} G, Rea et al. 2010).

Bursts and persistent emission

- Bursting behaviour results from release of magnetic stress, and is expected to lead to changes in persistent emission.
- No changes observed after burst active period from 1E 1841-045 (Lin et al. 2011b).

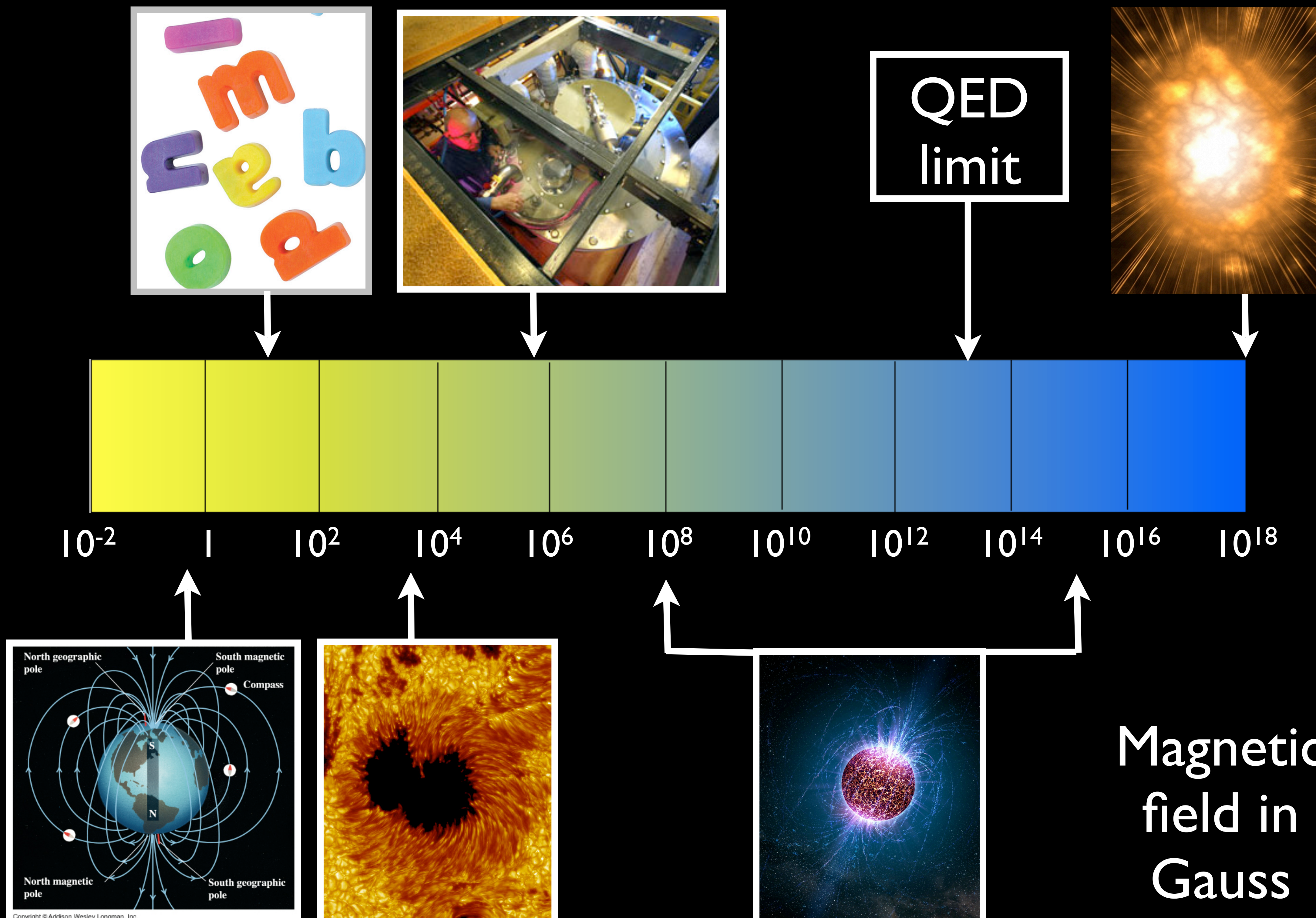


Bursting in 2011



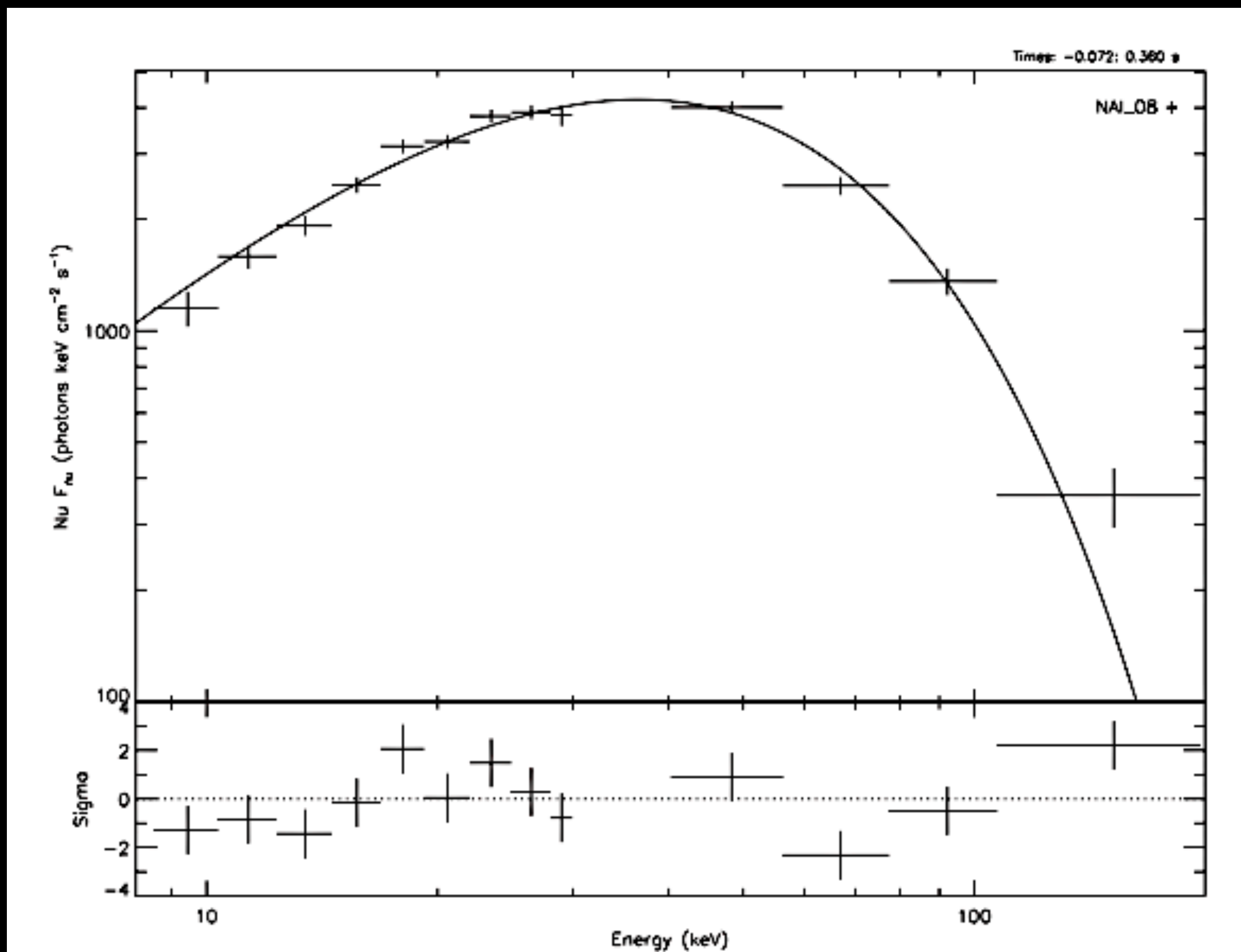
Persistent flux unchanged

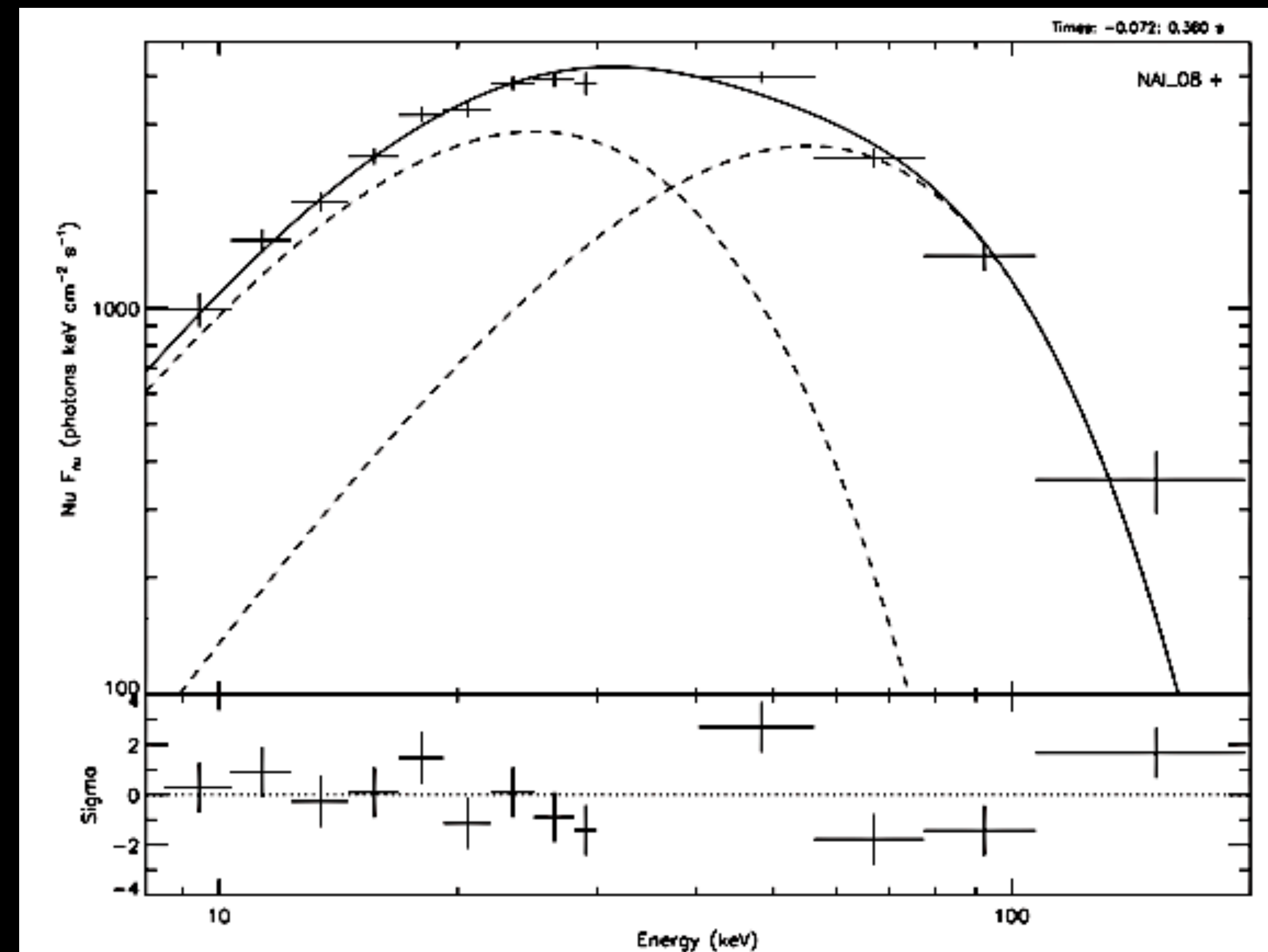
High magnetic field physics



Magnetic field in Gauss

Burst spectra





- For SGR 0501+5416, bursts are best fit by COMPT or 2BB models (Lin et al. 2011a).
- Are these models physically motivated, and can we use them to diagnose strong field physics?

Summary

- NS population - new sources being discovered, hinting at a population of nearby dim SGRs.
- Dense matter EoS - new techniques being developed as a direct result of GBM data.
- Magnetic field evolution - unexpected results on burst triggering and effects.
- High magnetic field physics - burst spectra are well fit by models that do not incorporate these effects.

Magnetar key project team

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