SPECTRAL EVOLUTION OF MAGNETAR BRIGHT BURSTS

George A. Younes — GWU

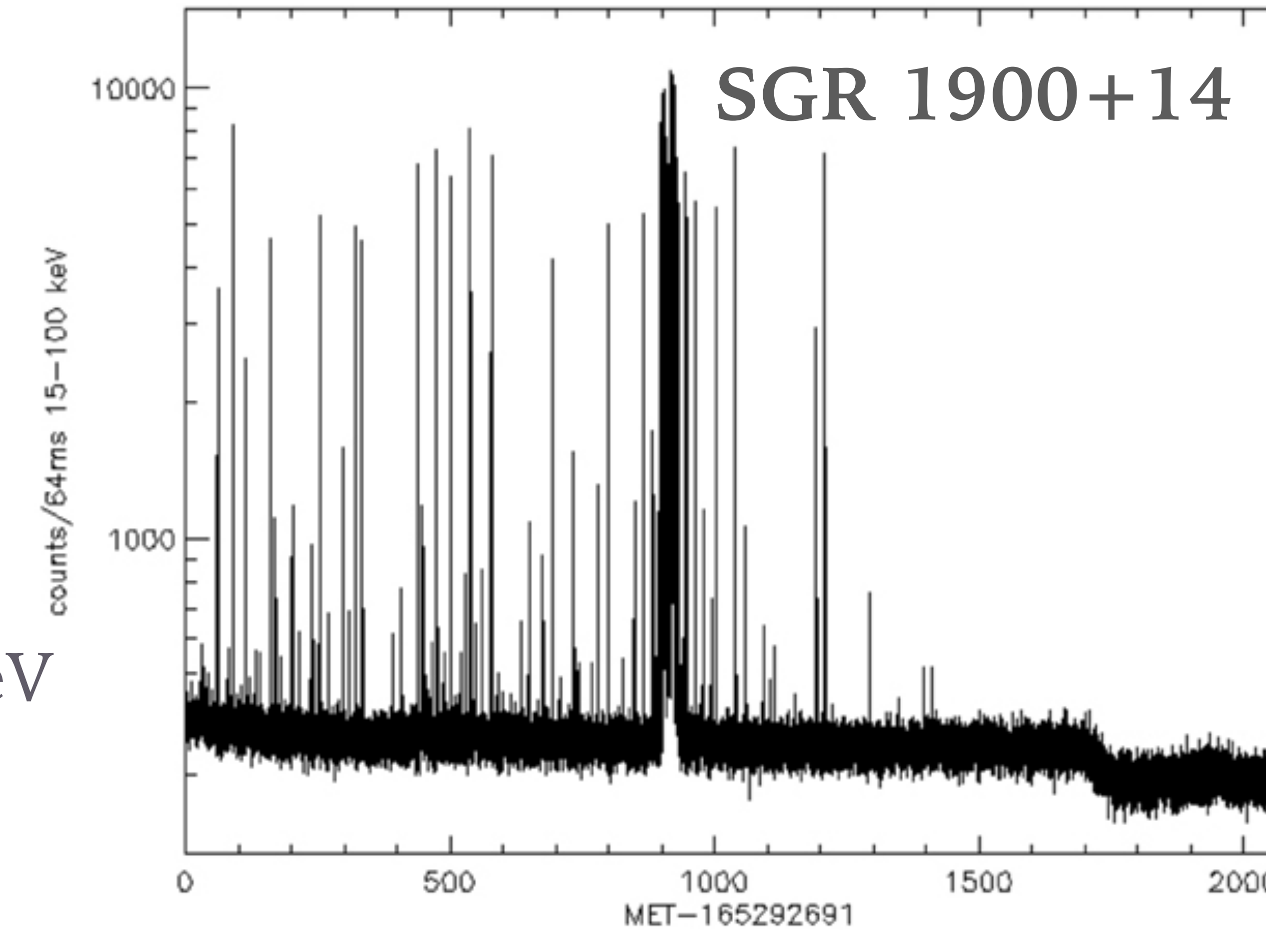
On behalf of the FERMI GBM magnetar team (PI: C. Kouveliotou)

Sixth International Fermi Symposium

DC - November 2015

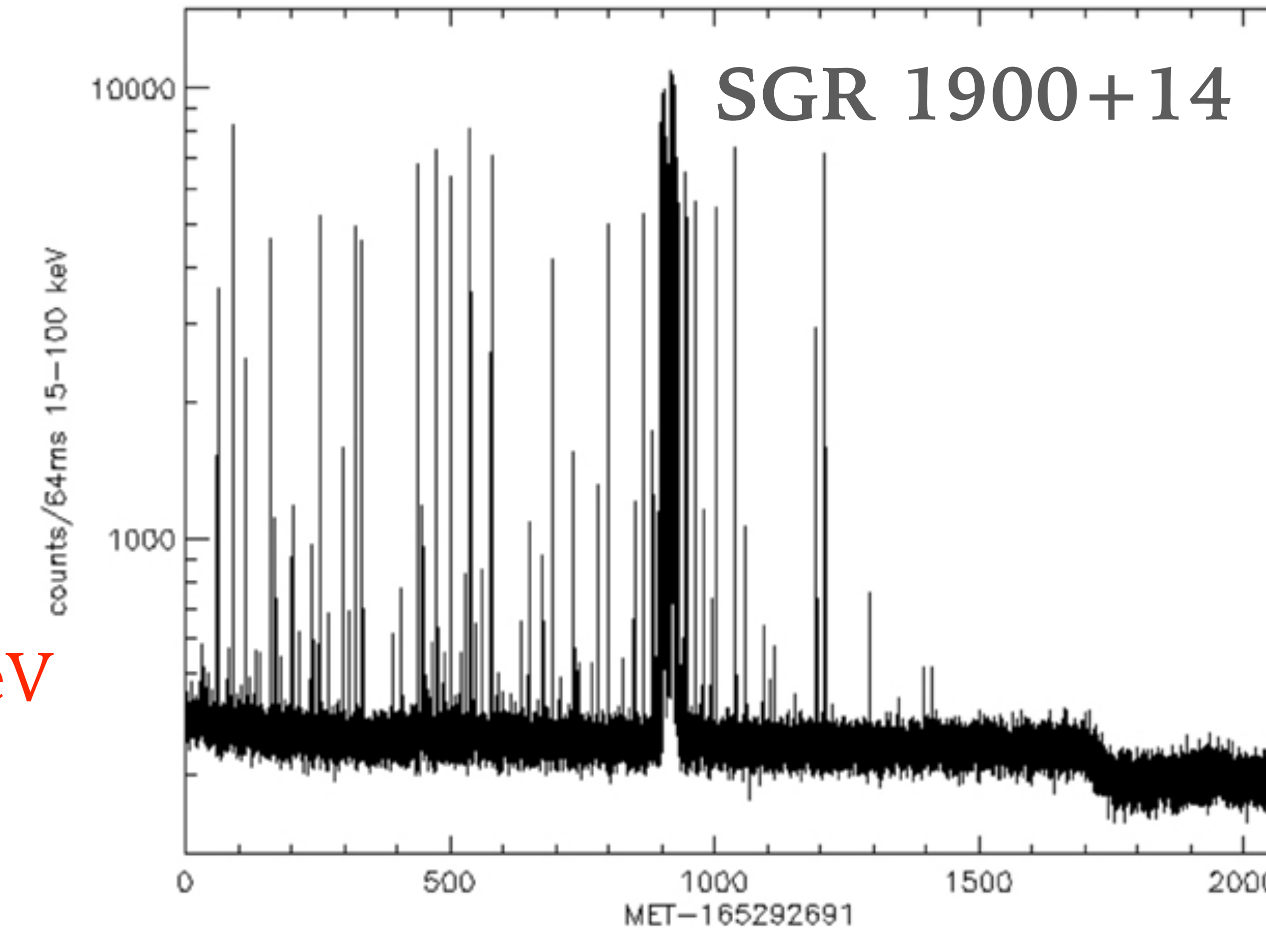
MAGNETARS

- Isolated neutron stars
- L_X ~ 1.0E32 - 1.0E36 erg/s
- P~1-12 s, Pdot~1.0E-14-1.0E-11s/s
- B ~ 1.0E13-1.0E15 G
- X-/Gamma-ray bursts
  - Between 1-100 keV. Peak @ tens of keV
  - Mostly: 0.1 s, E~1.0E37-1.0E41 erg
  - Rarely GF(3): 400 s, E~1.0E46 erg
- Long outbursts
- Timing noise and glitches
- **23 confirmed magnetars!**



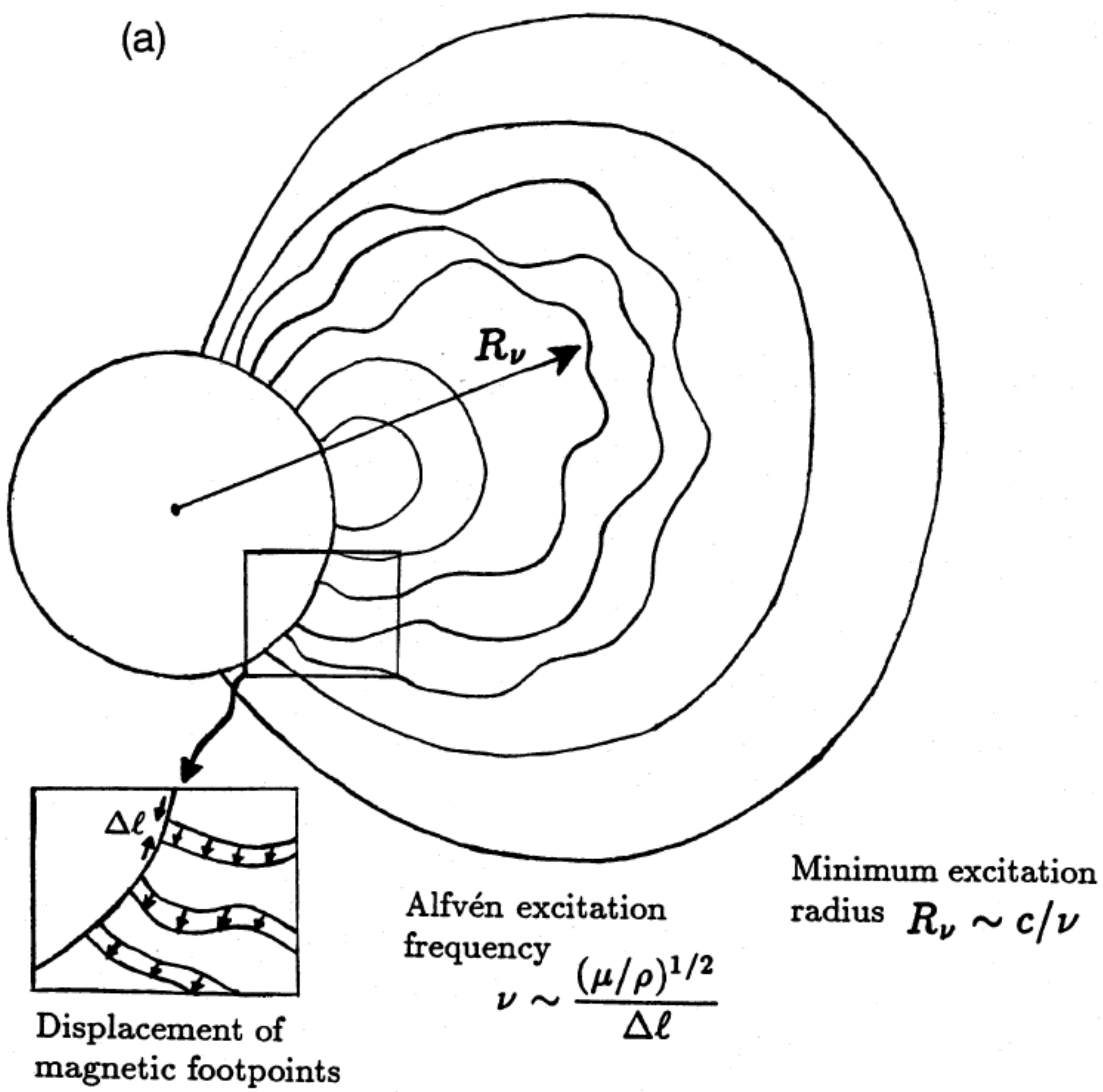
MAGNETARS

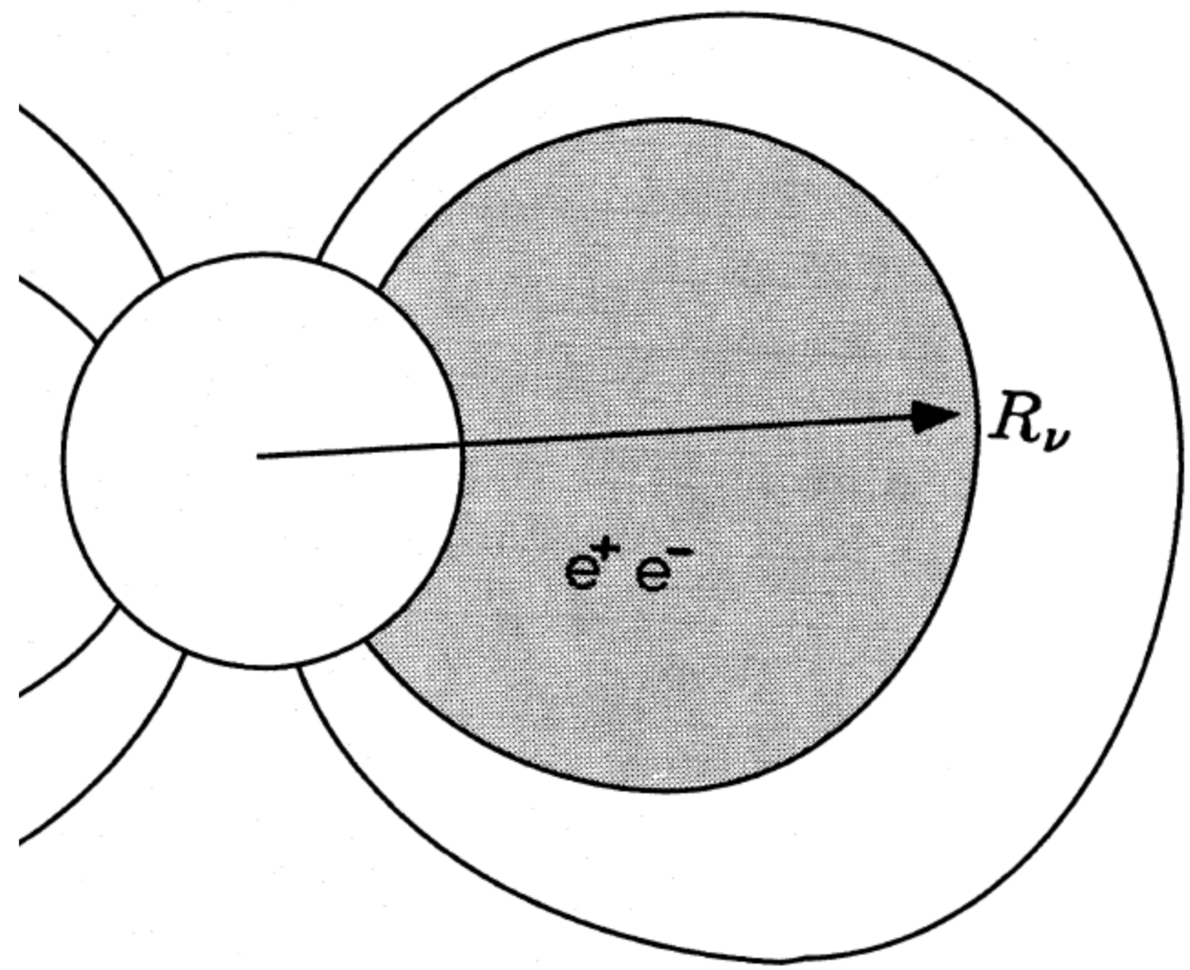
- Isolated neutron stars
- L_X ~ 1.0E32 - 1.0E36 erg/s
- P~1-12 s, Pdot~1.0E-14-1.0E-11s/s
- B ~ 1.0E13-1.0E15 G
- X-/Gamma-ray bursts
  - Between 1-100 keV. Peak @ tens of keV
  - Mostly: 0.1 s, E~1.0E37-1.0E41 erg
  - Rarely GF(3): 400 s, E~1.0E46 erg
- Long outbursts
- Timing noise and glitches
- **23 confirmed magnetars!**



MAGNETARS — BURST THEORY

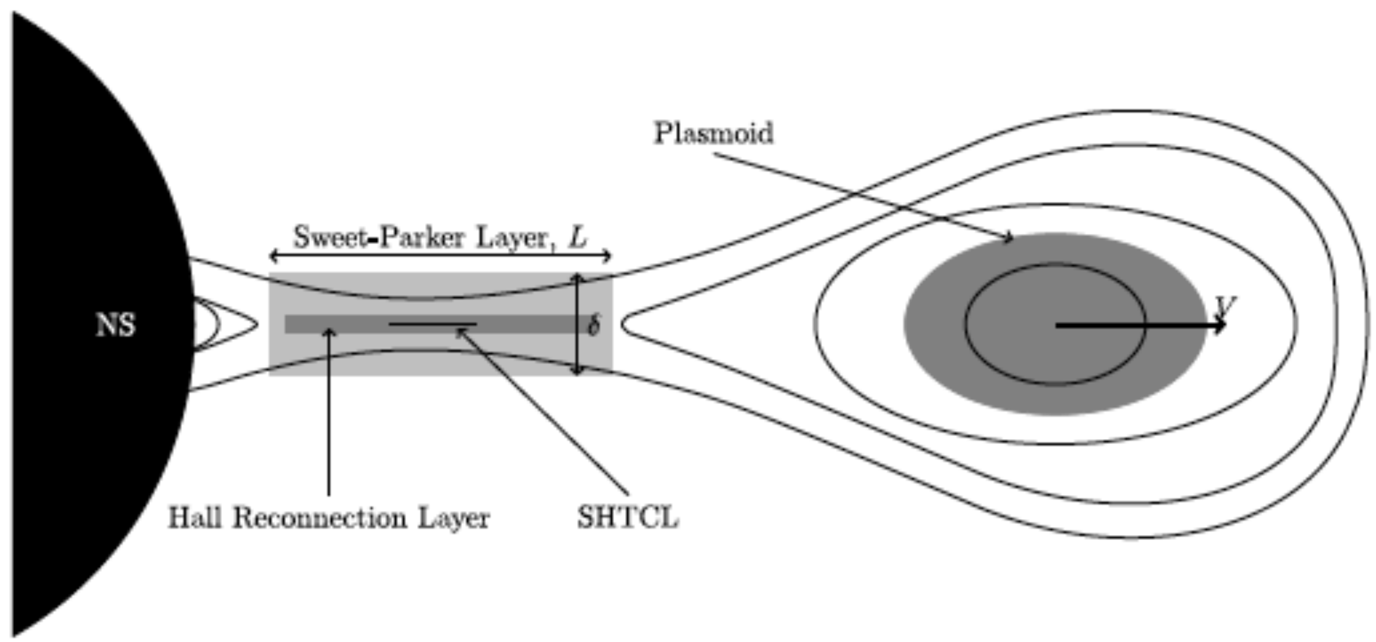
Thompson & Duncan 1995
Heyl & Hernquist 2005





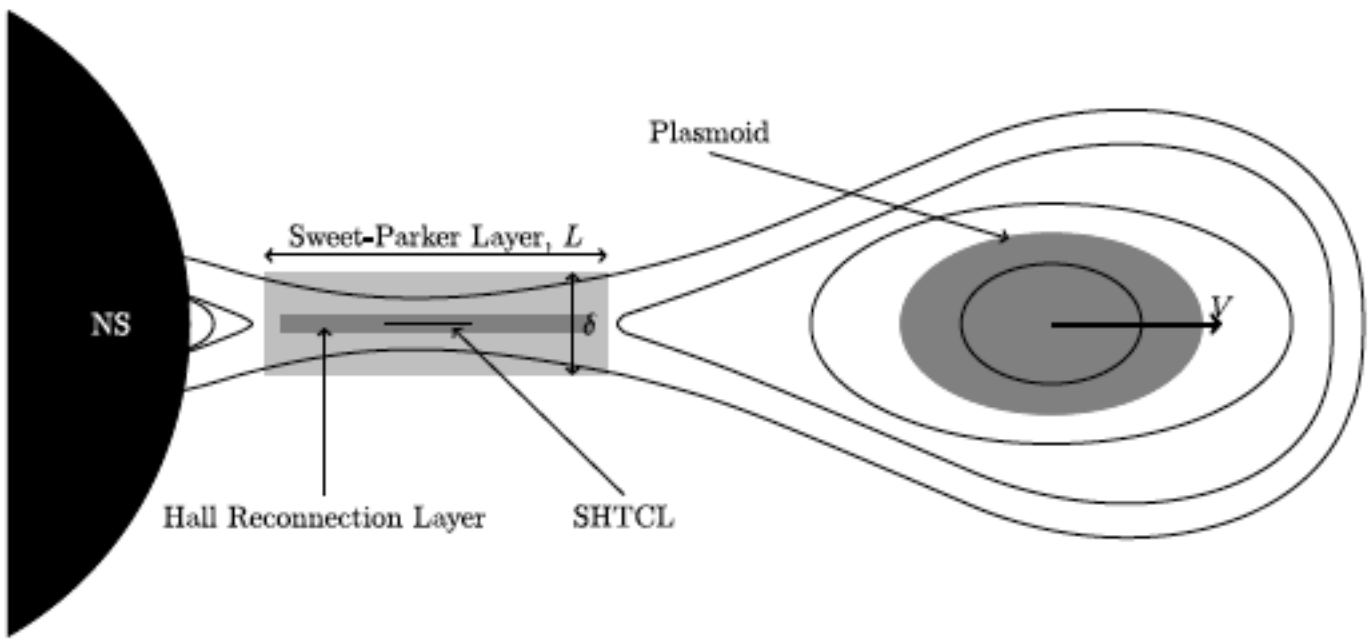
MAGNETARS — BURST THEORY

Lyutikov 2003, 2006, 2014
Gill & Heyl 2005

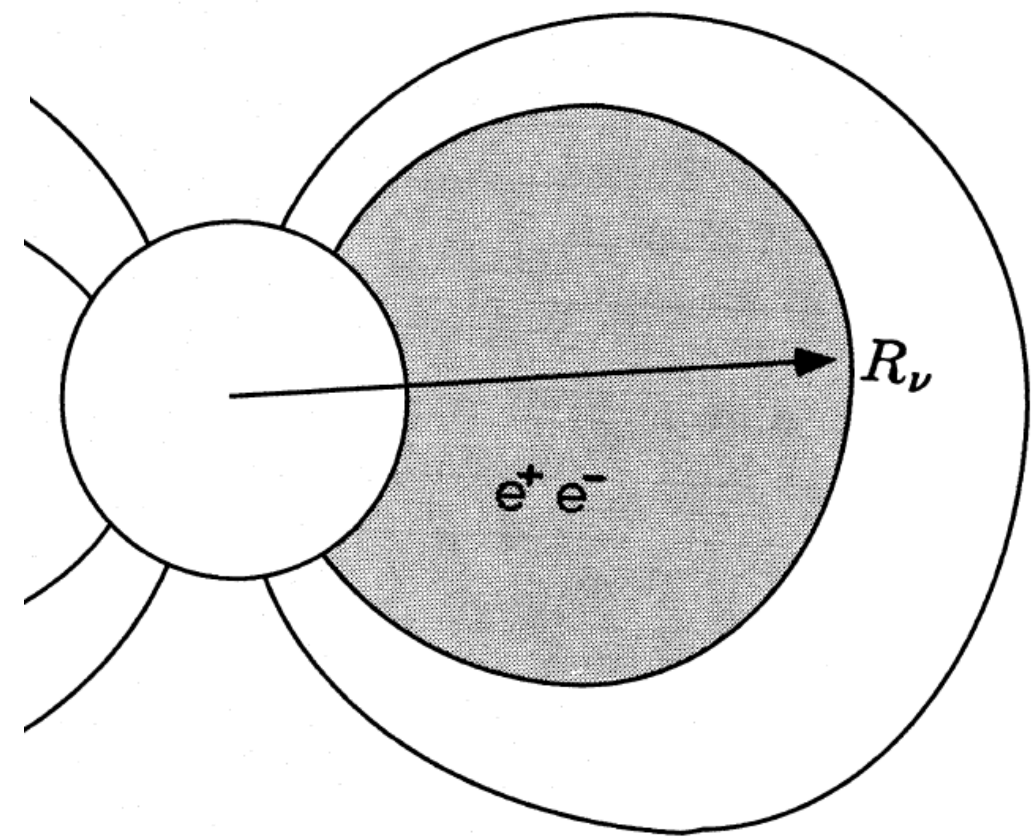


Magnetic reconnection in upper magnetosphere
Also predicts the formation of photon-pair plasma fireballs in closed flux lines

MAGNETARS — BURST THEORY



Radiative mechanism: cooling of hot, optically thick plasma, confined in ultra-strong B (>B_QED)



Thompson & Duncan 1995
Lyubarski 2003
POSTER Barchas and Baring

MAGNETAR — 5 YEARS GBM CATALOG

Table 1
Summary of GBM Magnetar Bursts

Source	Burst Active Periods	Number of Bursts with TTE data
SGR J1550–5418	2008 Oct–2009 Apr	386
SGR J0501+4516	2008 Aug/Sep	29
1E 1841–045	2011 Feb–Jul	6
SGR J0418+5729	2009 Jun	2
SGR 1806–20	2010 Mar	1
SGR J1822.3–1606	2011 Jul	1
AXP 4U 0142+61	2011 Jul	1
AXP 1E 2259+586	2011 Aug	1
Unknown	…	19

5 yr magnetar burst catalog, Collazzi et al. 2015

MAGNETAR — 5 YEARS GBM CATALOG

Table 1
Summary of GBM Magnetar Bursts

Source	Burst Active Periods	Number of Bursts with TTE data
SGR J1550–5418	2008 Oct–2009 Apr	386
SGR J0501+4516	2008 Aug/Sep	29
1E 1841–045	2011 Feb–Jul	6
SGR J0418+5729	2009 Jun	2
SGR 1806–20	2010 Mar	1
SGR J1822.3–1606	2011 Jul	1
AXP 4U 0142+61	2011 Jul	1
AXP 1E 2259+586	2011 Aug	1
Unknown	…	19

5 yr magnetar burst catalog, Collazzi et al. 2015

SGR 1935+2154	2015 Feb-March	>20
4U 0142+61	2015 Feb	~10
1E 1841—045	Scattered	~10

MAGNETAR — 5 YEARS GBM CATALOG

Table 1
Summary of GBM Magnetar Bursts

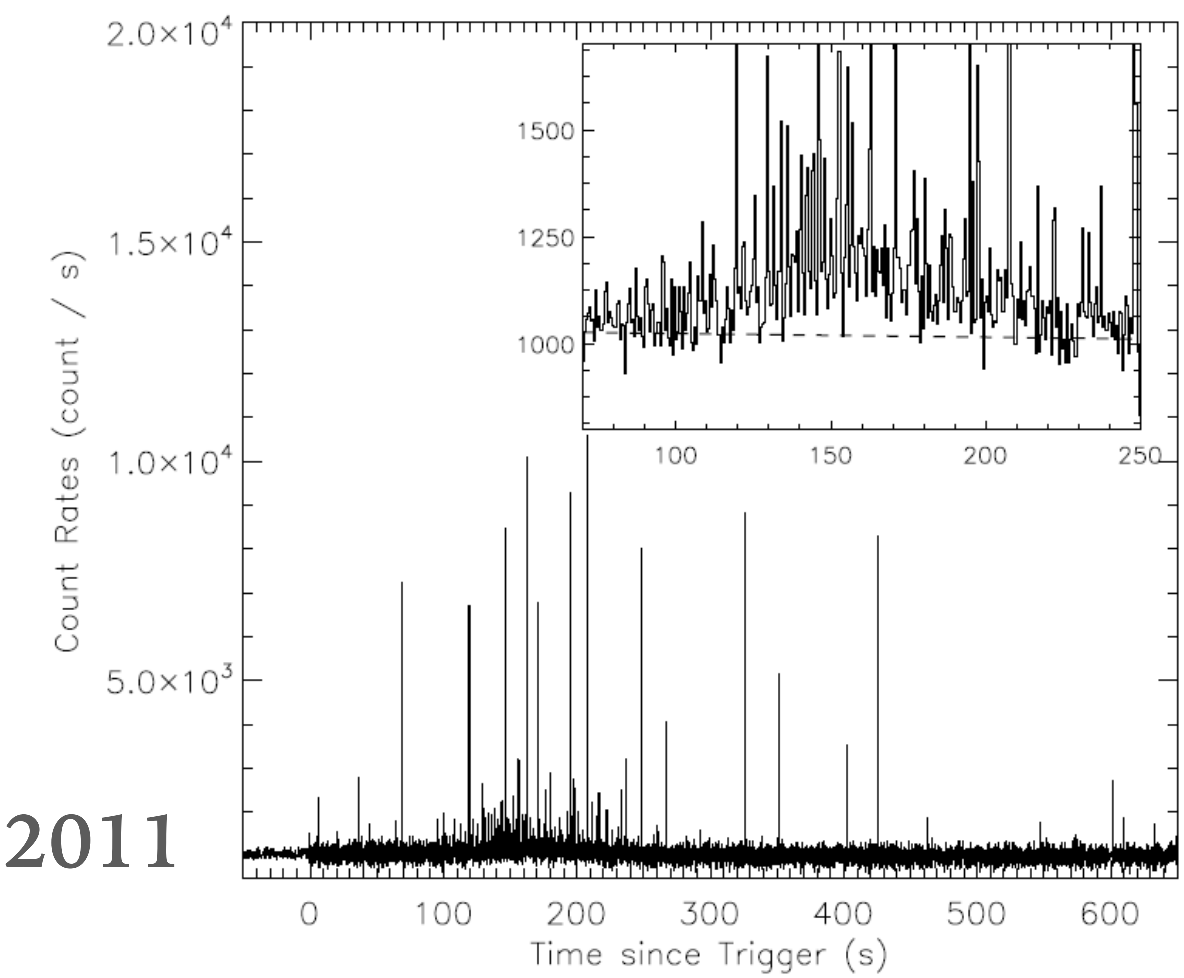
Source	Burst Active Periods	Number of Bursts with TTE data
SGR J1550–5418	2008 Oct–2009 Apr	386
SGR J0501+4516	2008 Aug/Sep	29
1E 1841–045	2011 Feb–Jul	6
SGR J0418+5729	2009 Jun	2
SGR 1806–20	2010 Mar	1
SGR J1822.3–1606	2011 Jul	1
AXP 4U 0142+61	2011 Jul	1
AXP 1E 2259+586	2011 Aug	1
Unknown	…	19

5 yr magnetar burst catalog, Collazzi et al. 2015

SGR 1935+2154	2015 Feb-March	>20
4U 0142+61	2015 Feb	~10
1E 1841—045	Scattered	~10

SGR J1550–5418 – GENERAL PROPERTIES

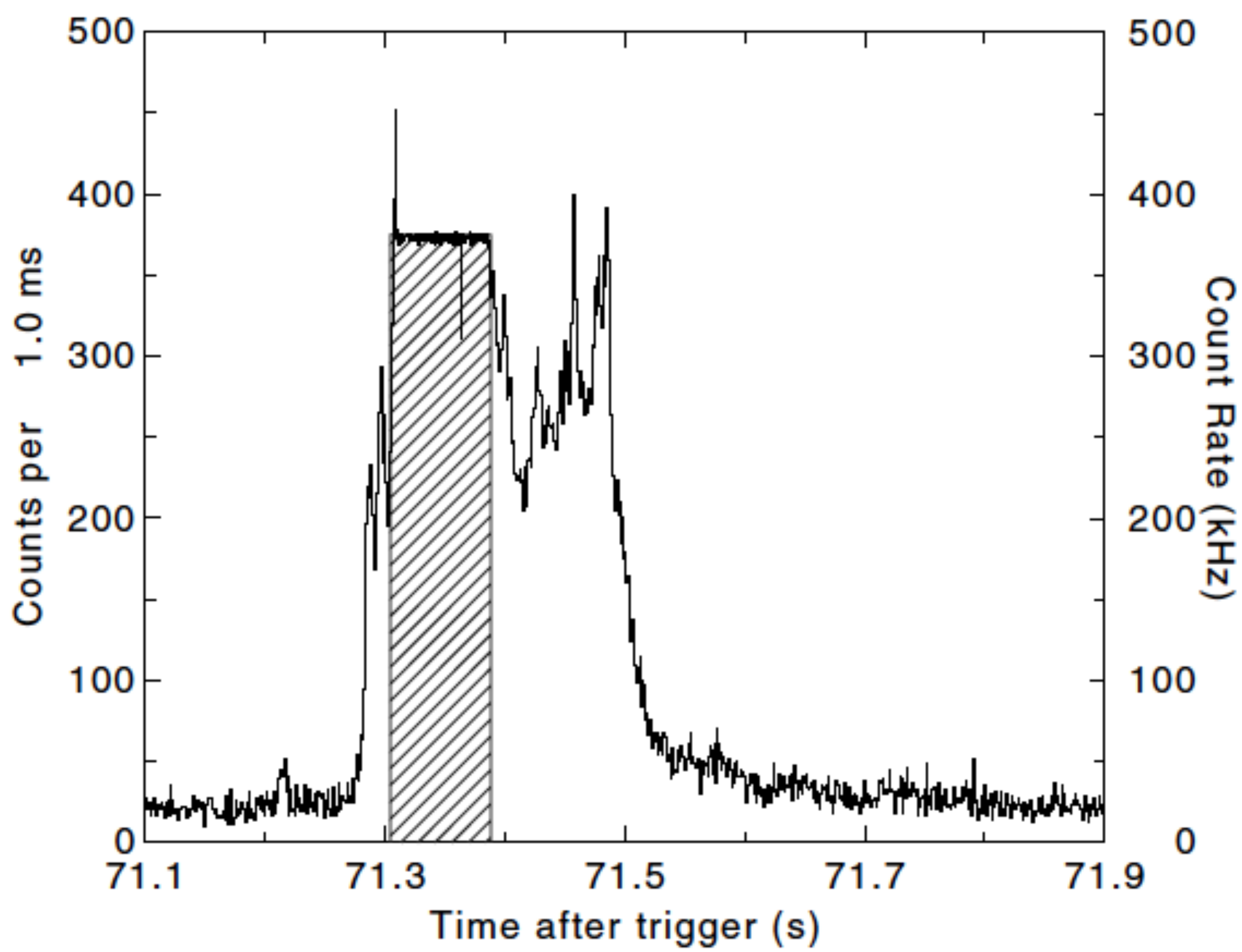
- P = 2.1 s, Pdot = 2.32E-11 s/s, B ~ 2.1E14 G.
- Entered high level of activity in 2008-2009.
  - Hundreds of bursts on 22 January 2009 seen with many high energy instruments — GBM most complete sample (**van der Horst et al. 2012**).



Kaneko et al. 2011

SGR J1550-5418 - GBM BURST EXAMPLE

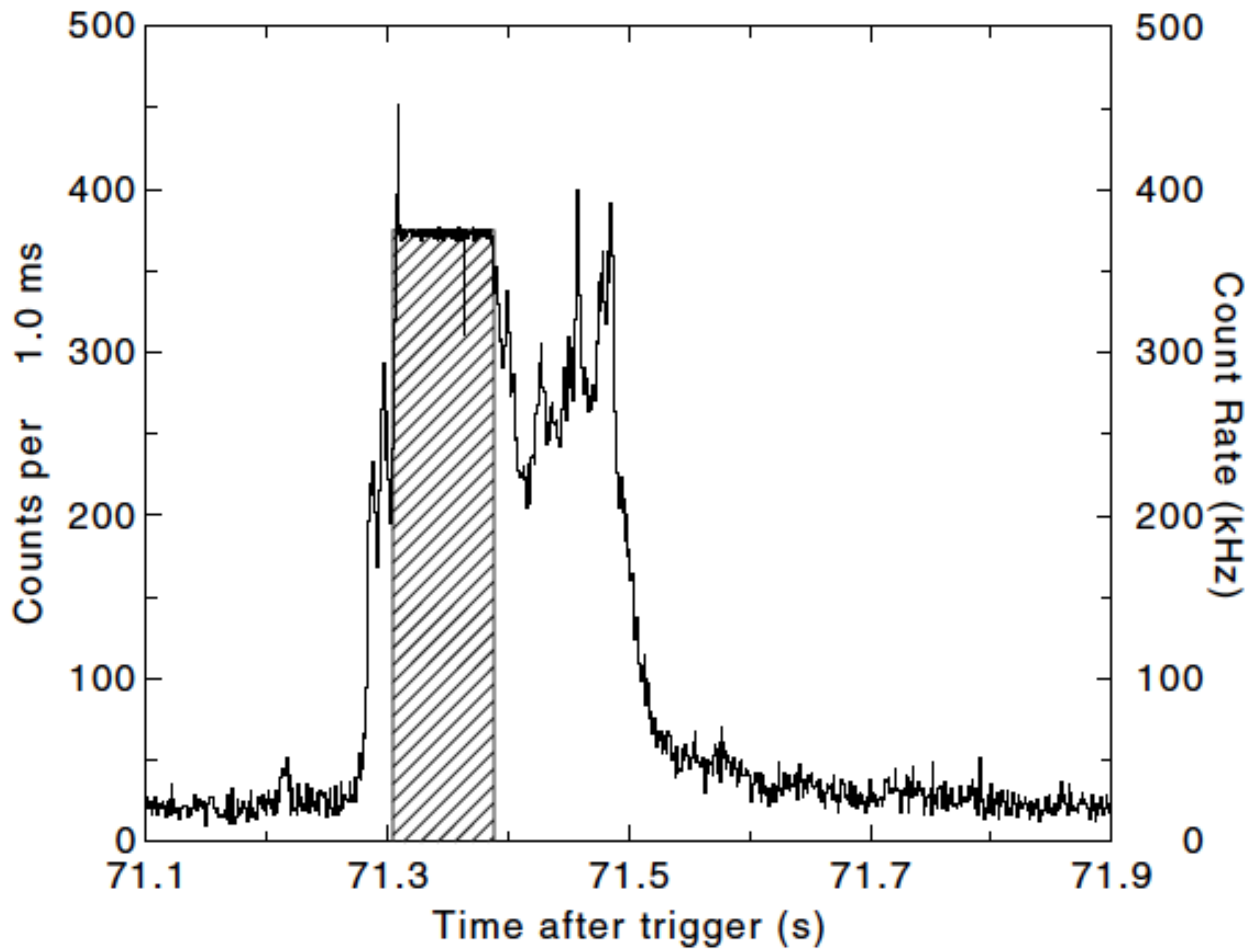
GBM light curve



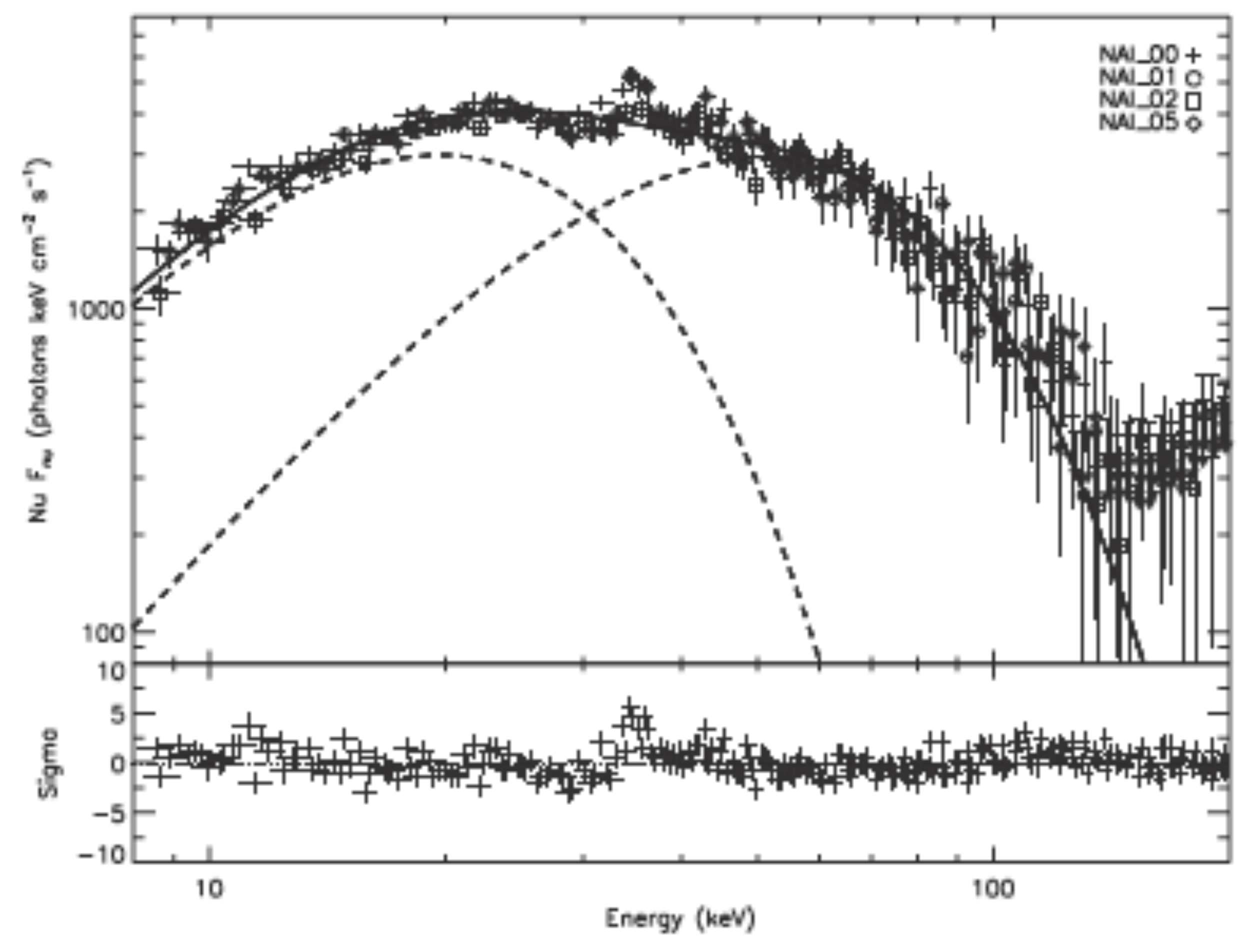
van der Horst et al. 2012

SGR J1550-5418 - GBM BURST EXAMPLE

GBM light curve



Corresponding spectrum
Usually 2 BB thermal model

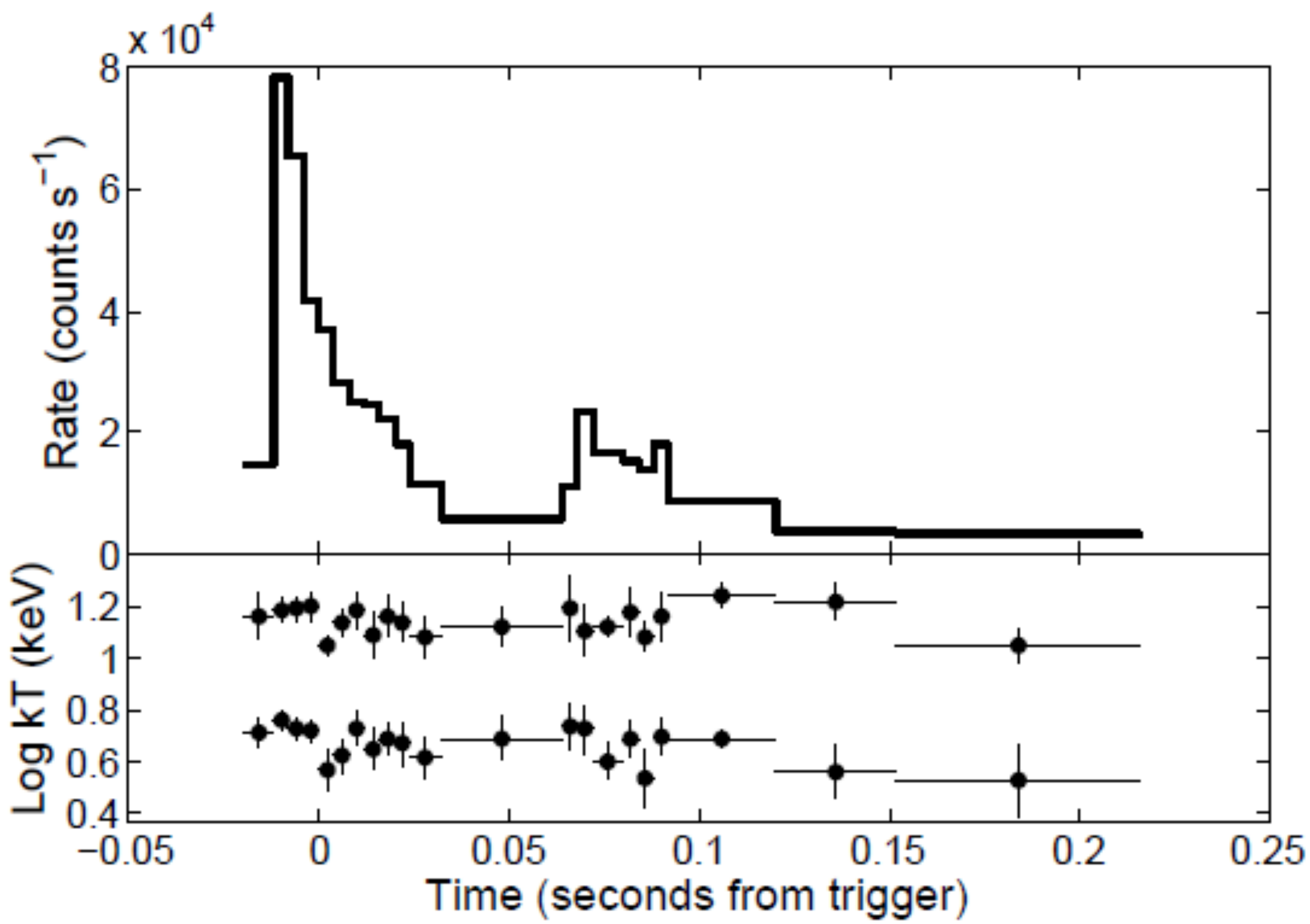


van der Horst et al. 2012, Lin et al. 2012

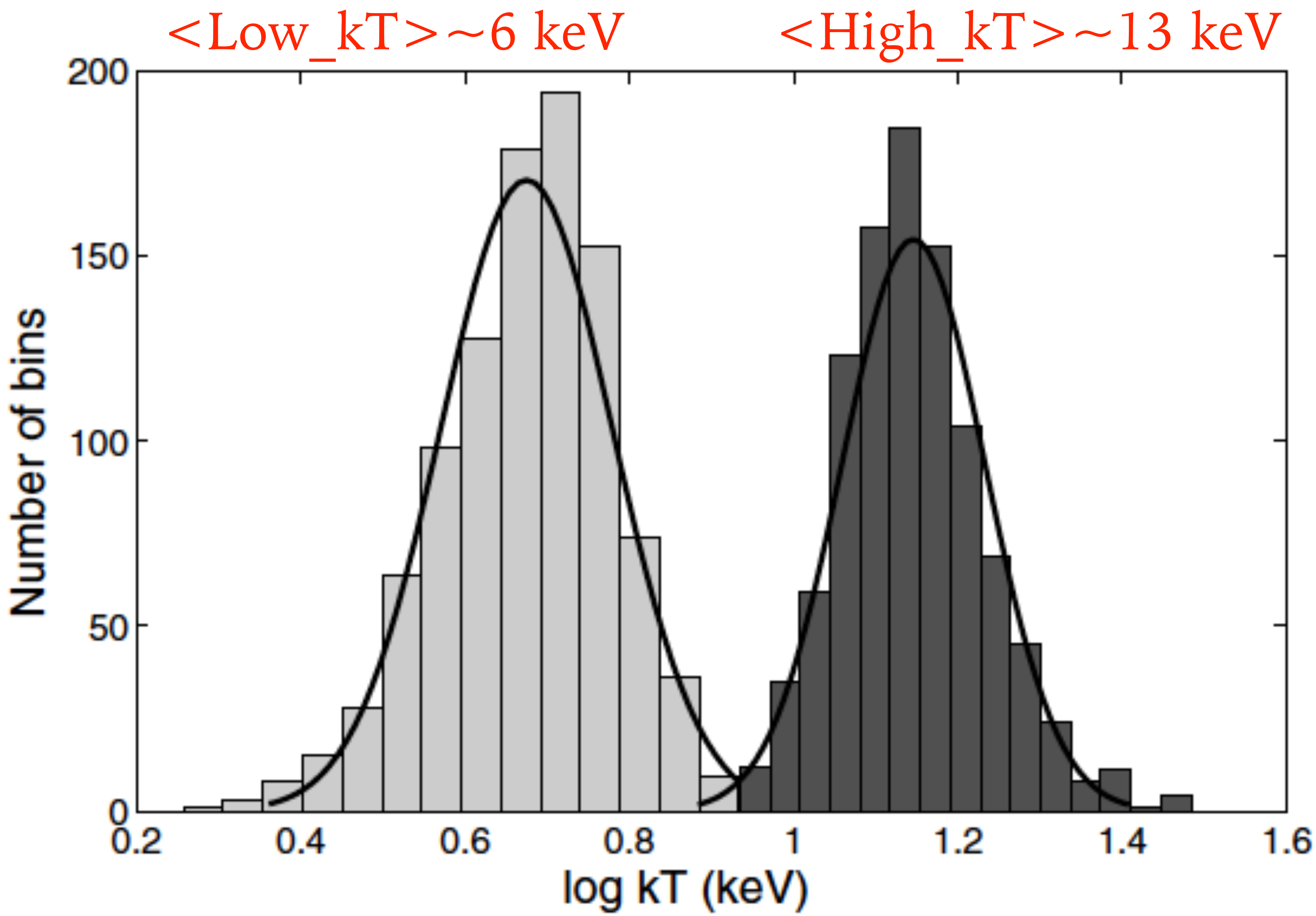
SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY

Time resolved spectroscopy of 60 brightest bursts

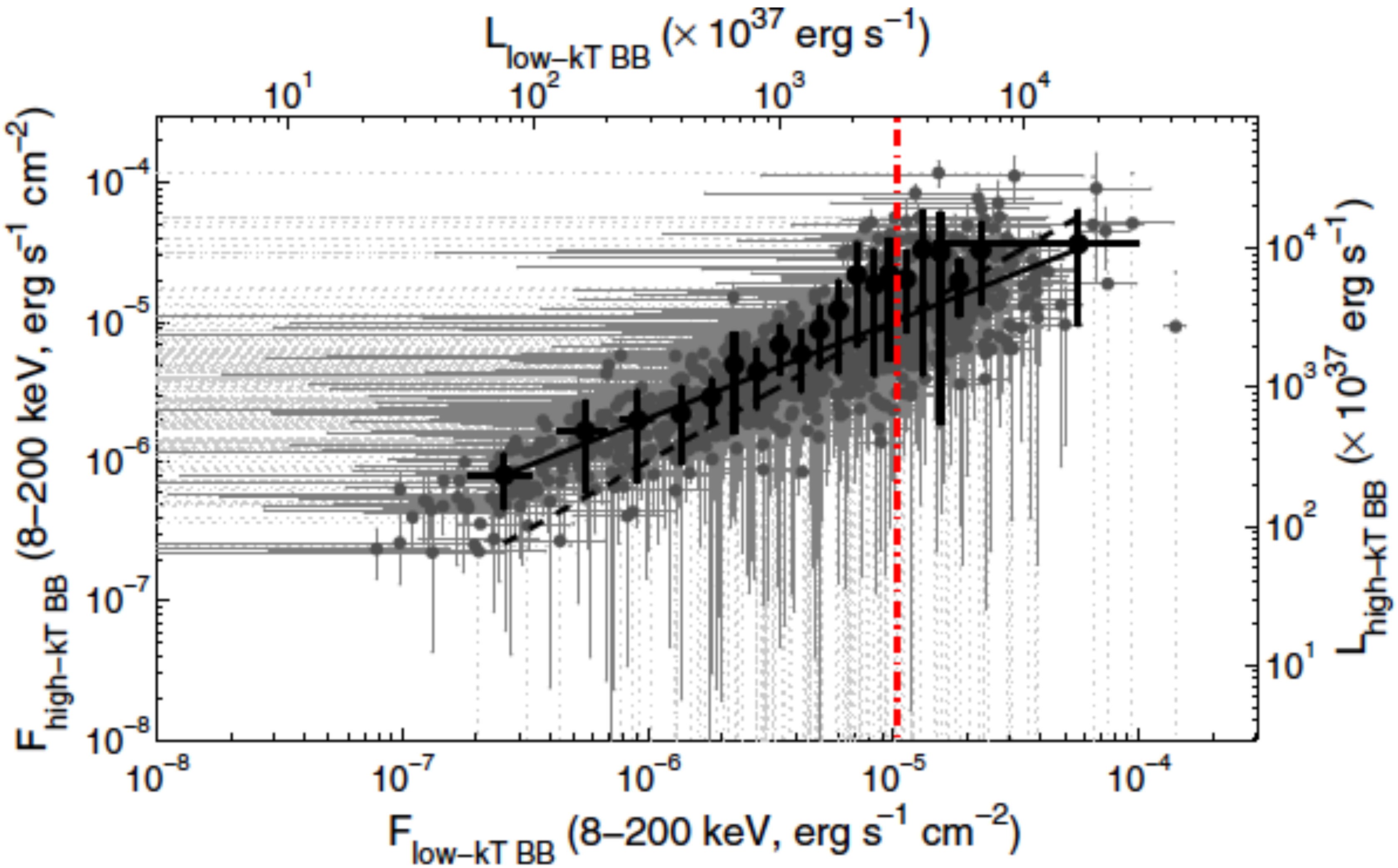
- Bin at >=4ms (achieve 3sigma constraint on kT)
- Fit each bin with 2BB model
- Follow evolution of fit parameters



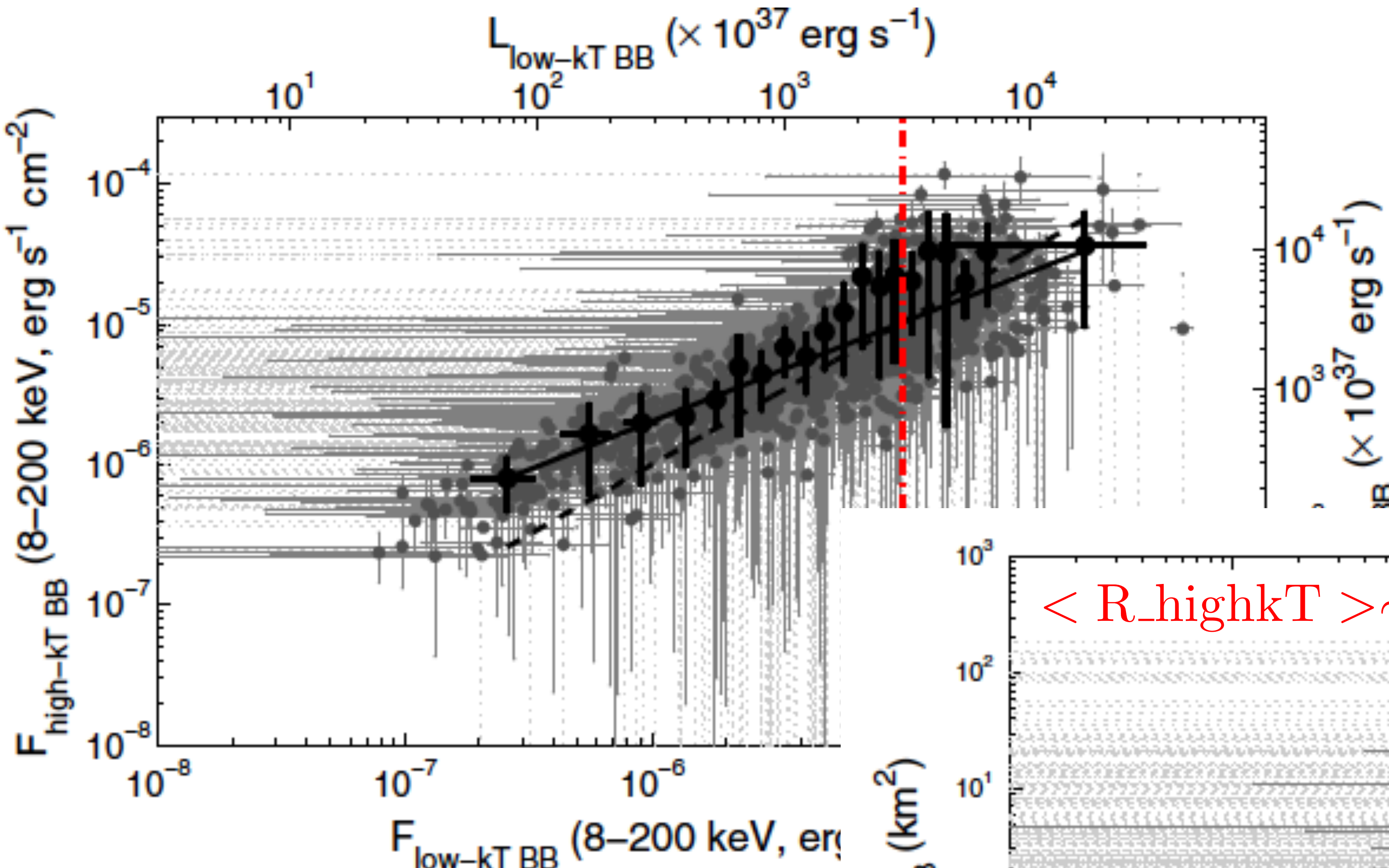
SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY

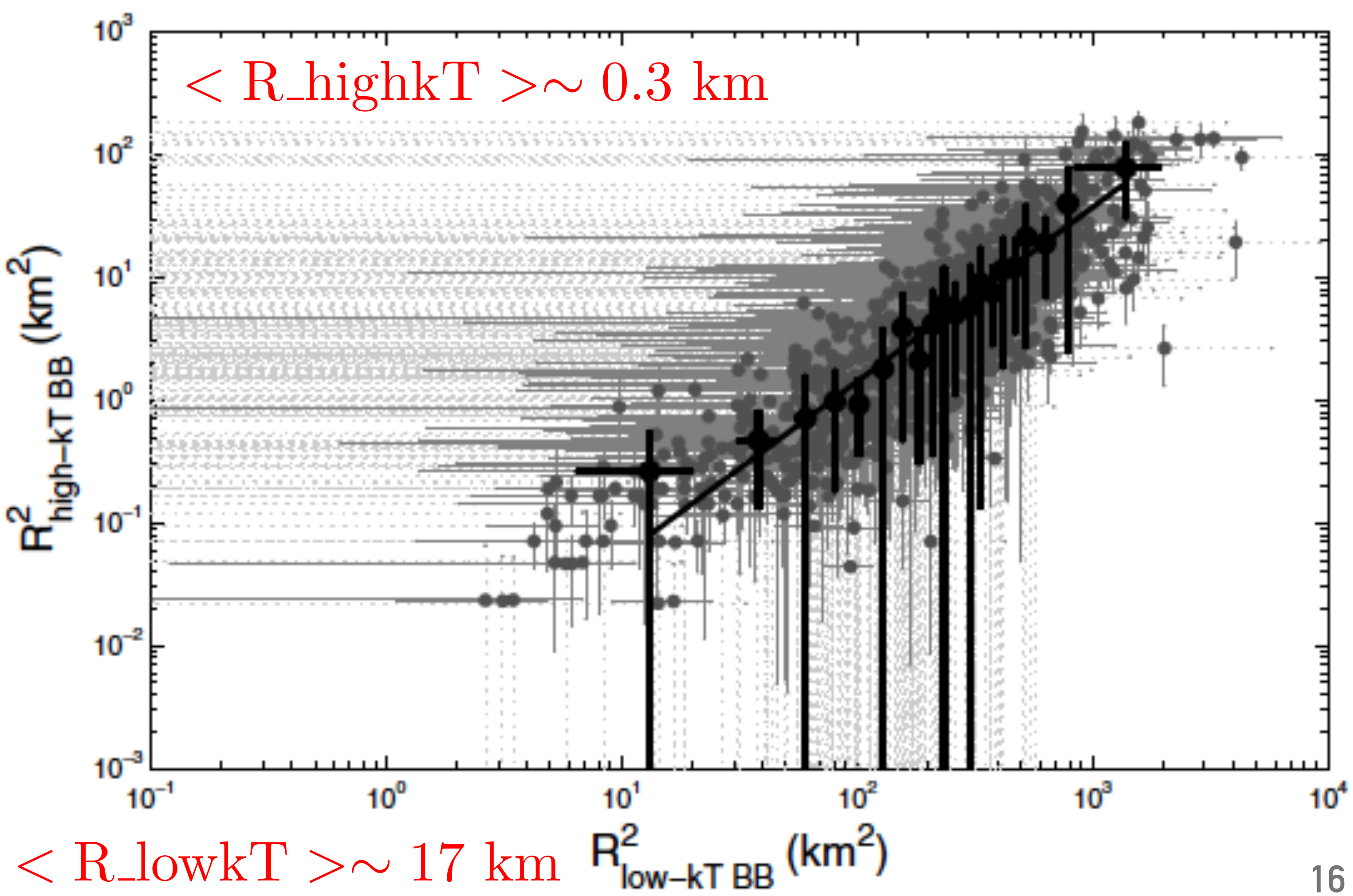


SGR J1550–5418 – TIME RESOLVED SPECTROSCOPY

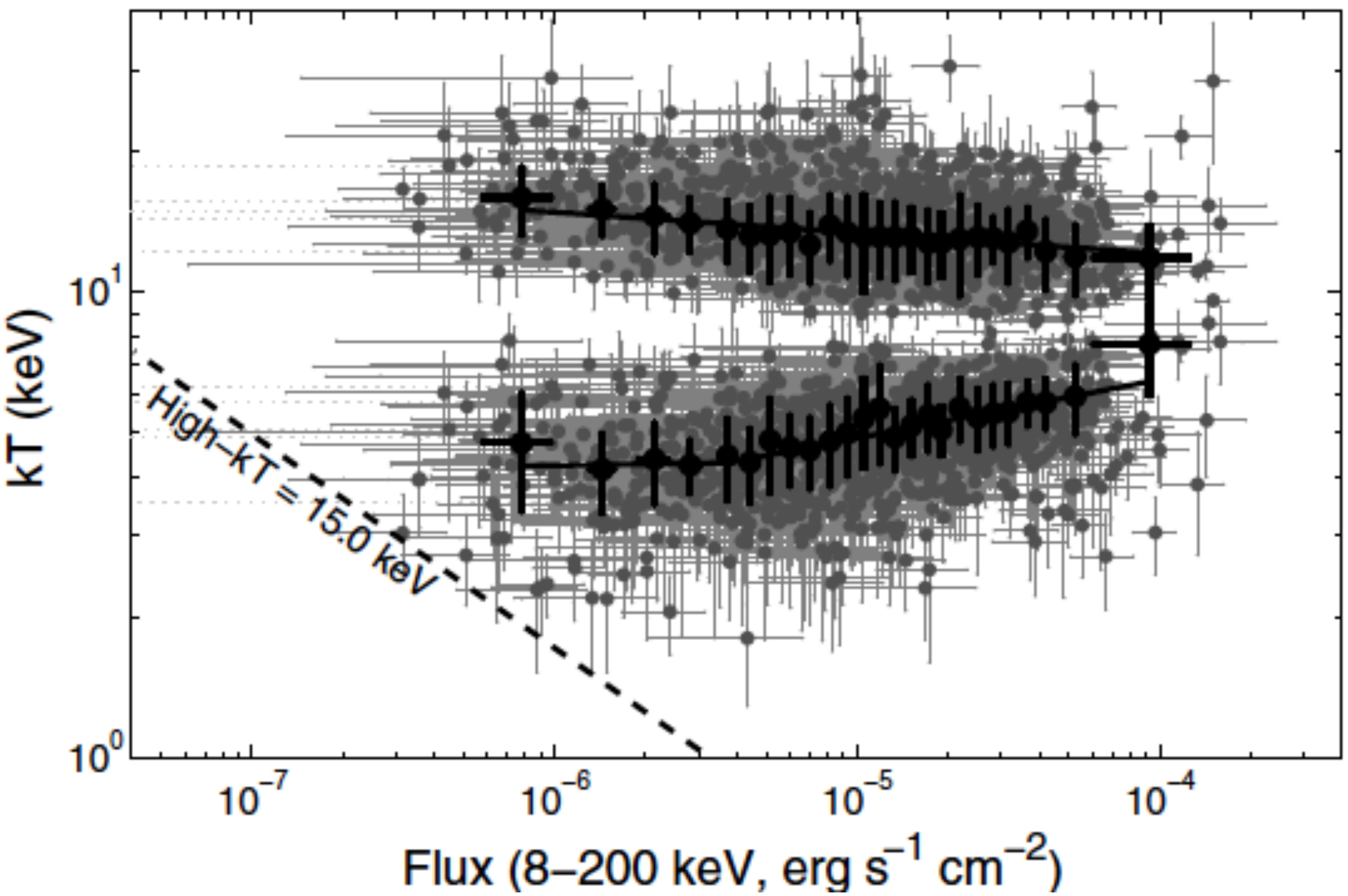


SGR J1550–5418 – TIME RESOLVED SPECTROSCOPY





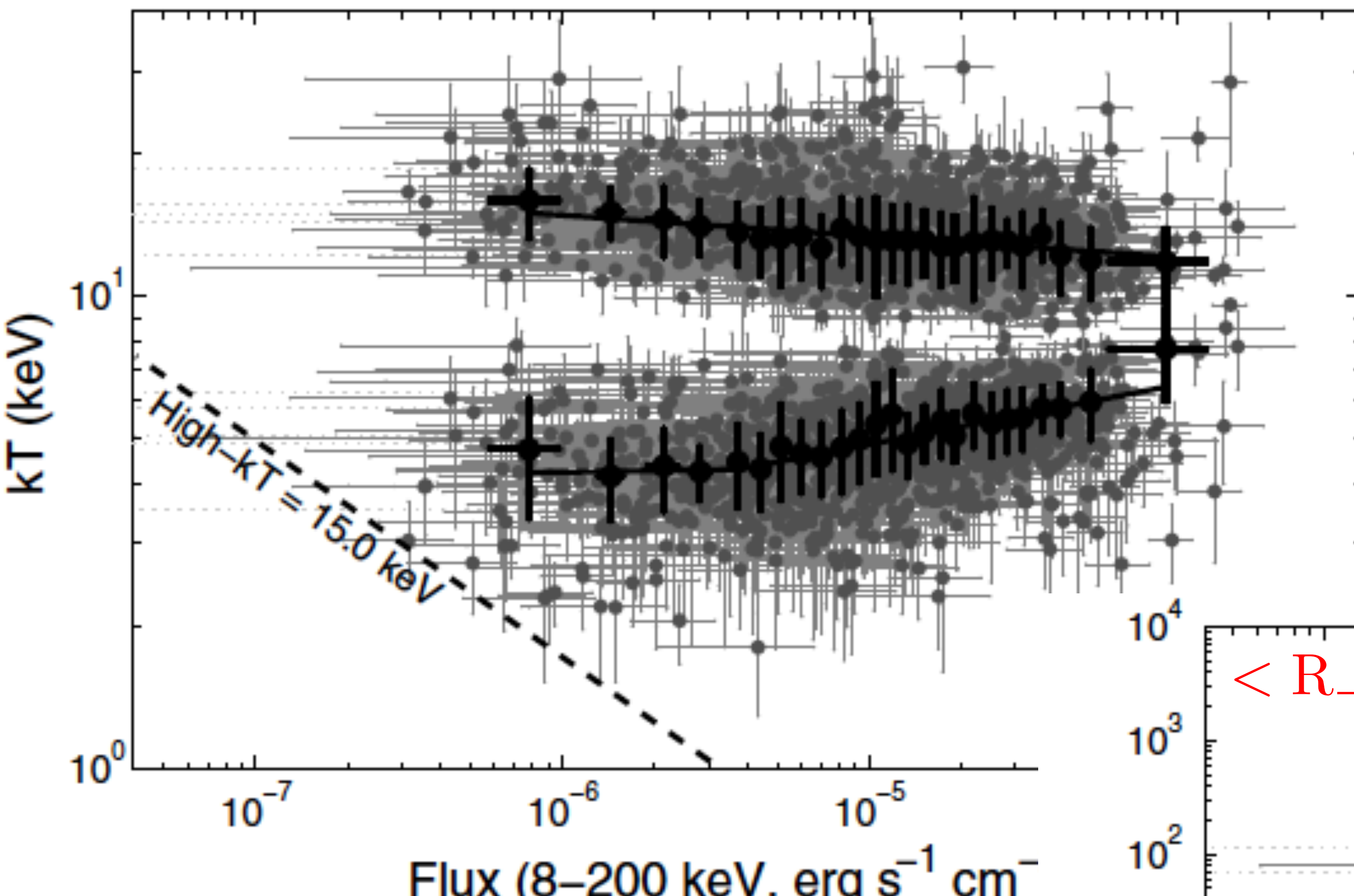
SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY



<High_kT>~13 keV

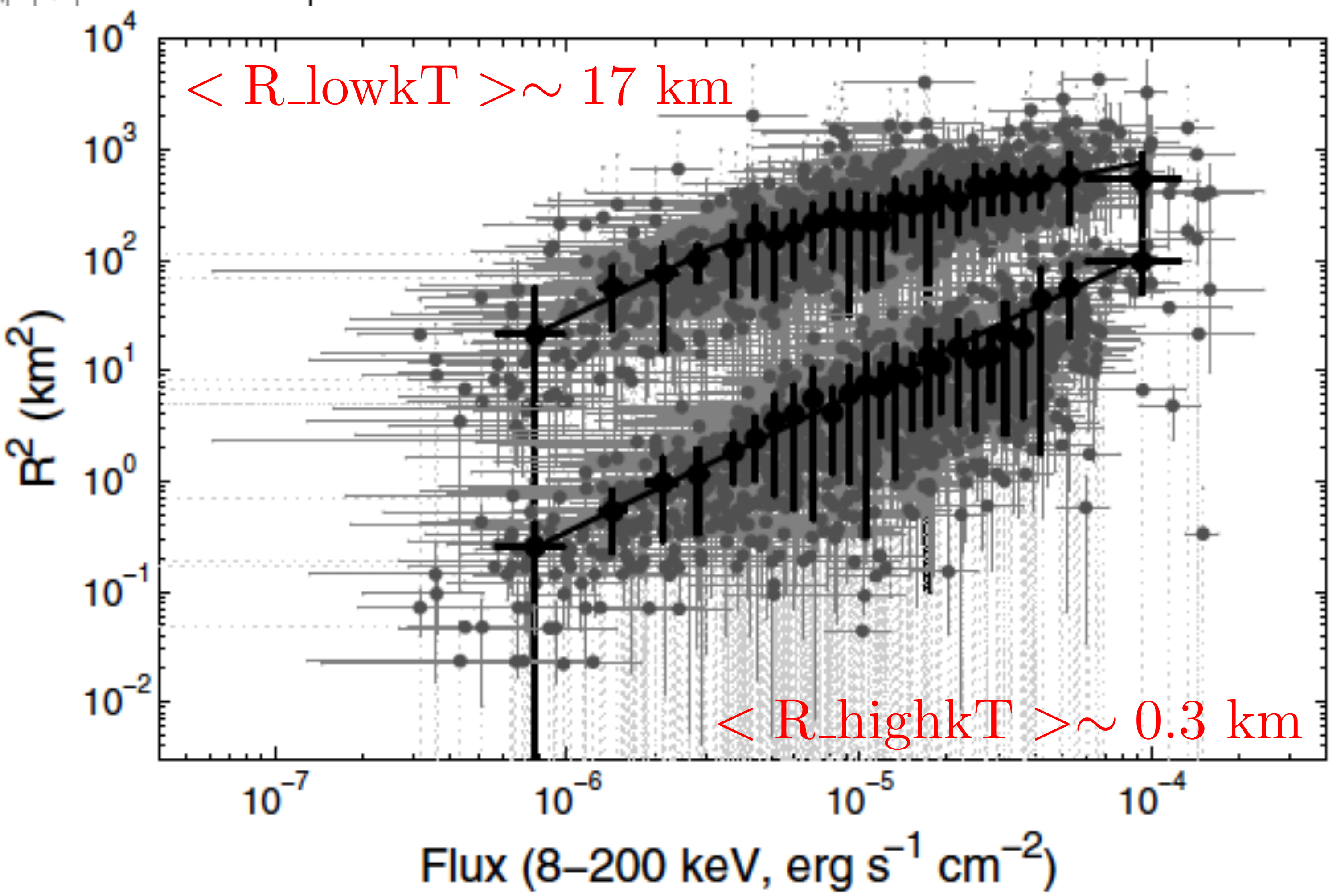
<Low_kT>~6 keV

SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY

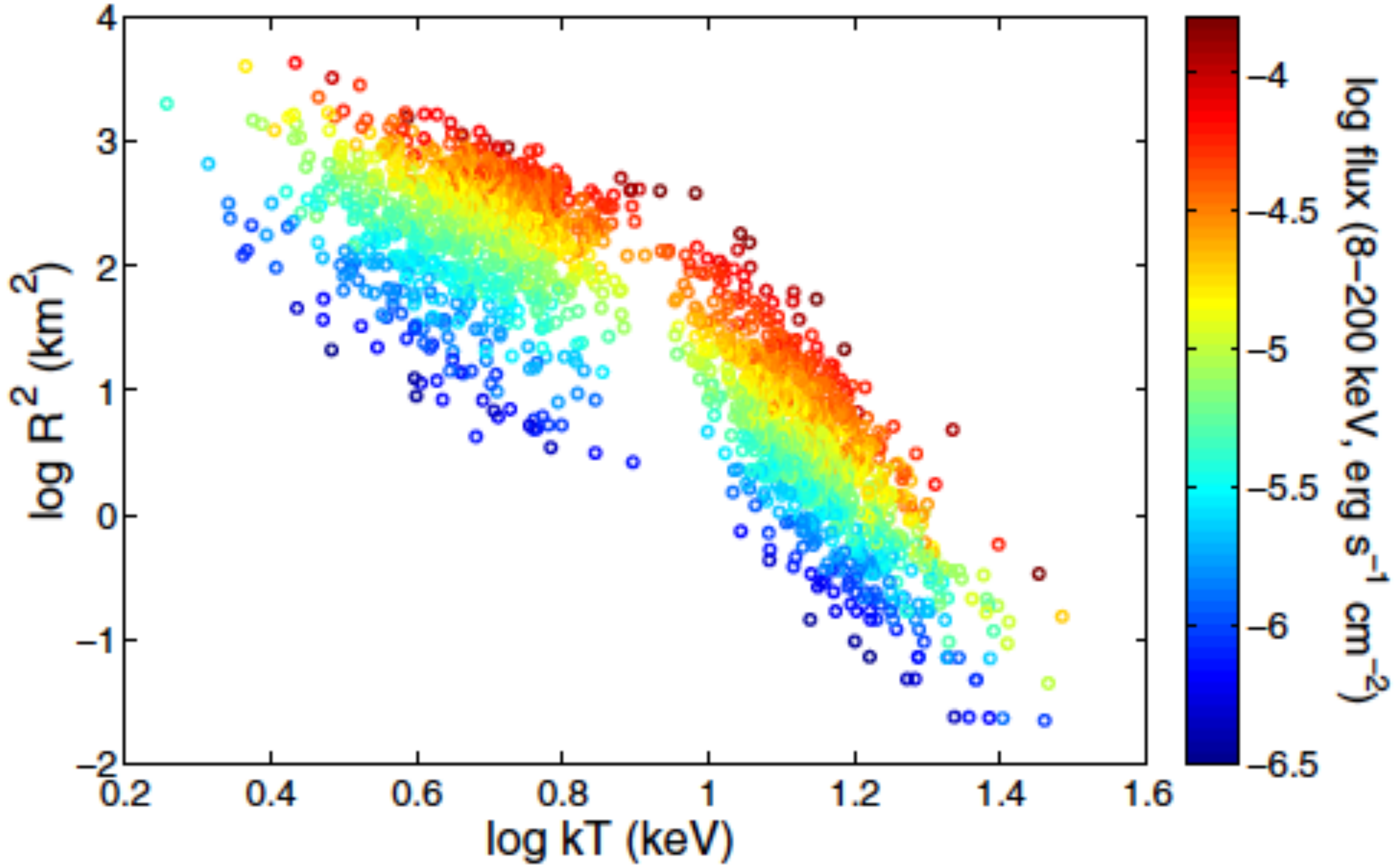


<High_kT>~13 keV

<Low_kT>~6 keV

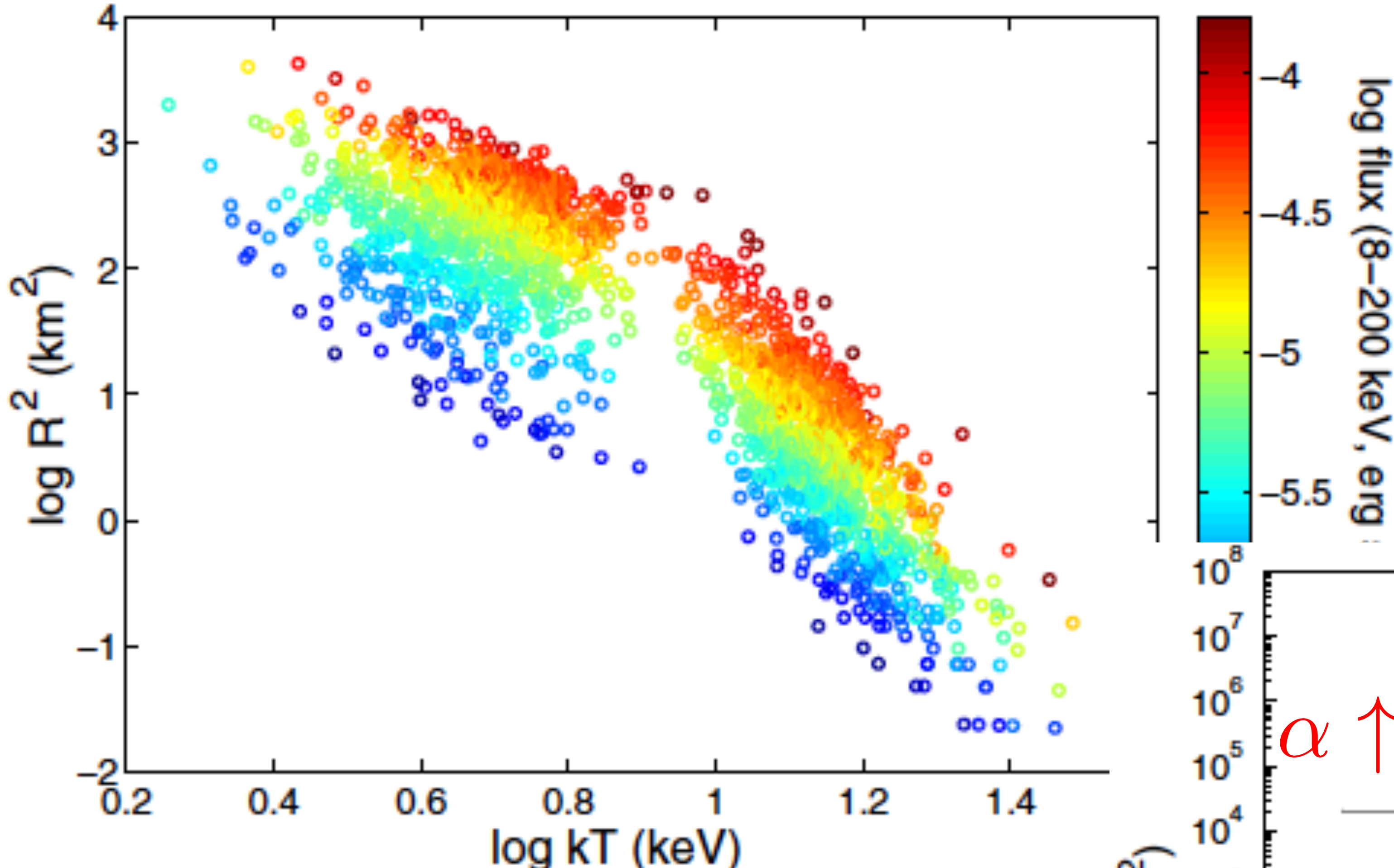


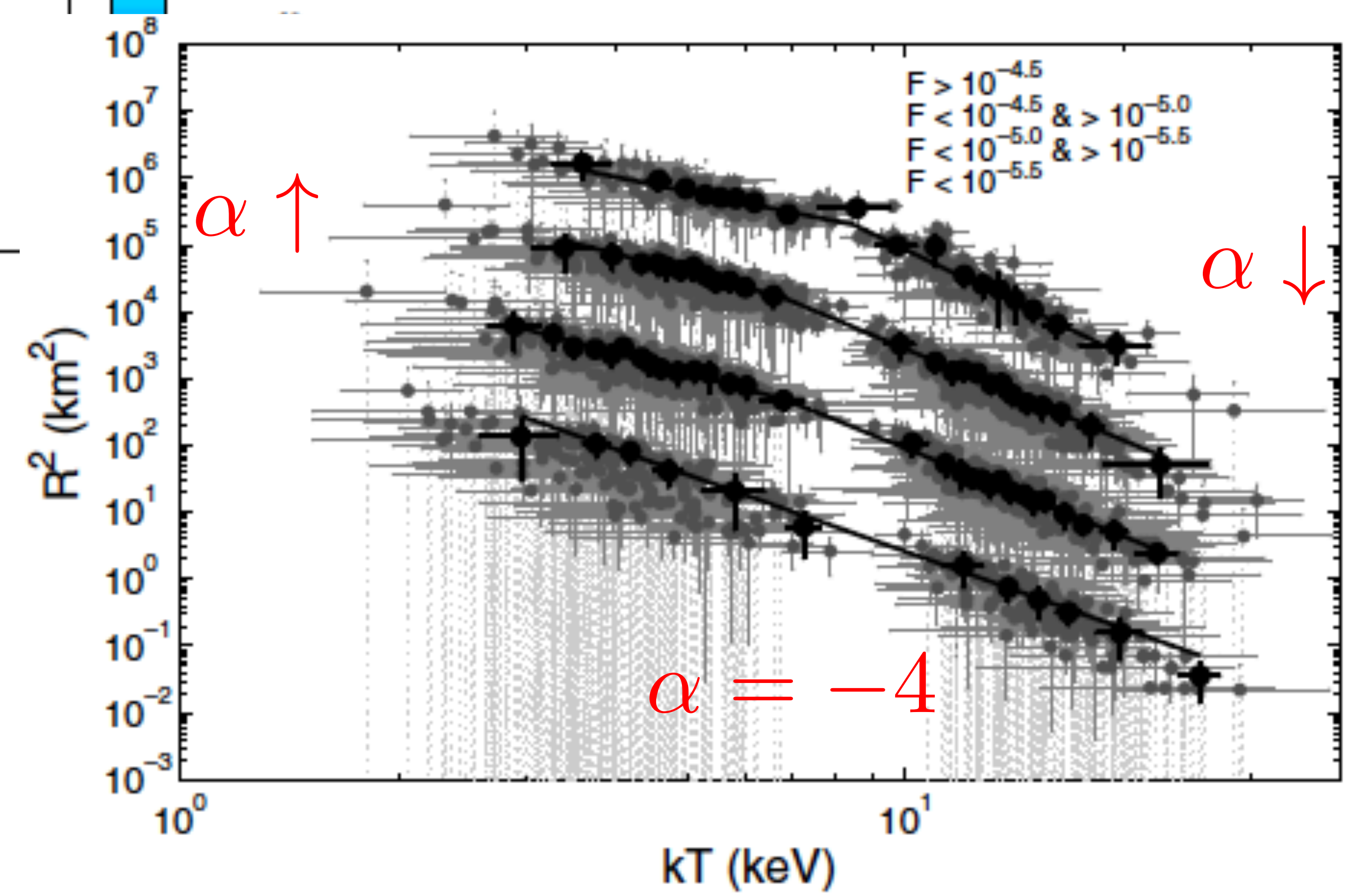
SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY



Younes et al. 2014

SGR J1550-5418 - TIME RESOLVED SPECTROSCOPY



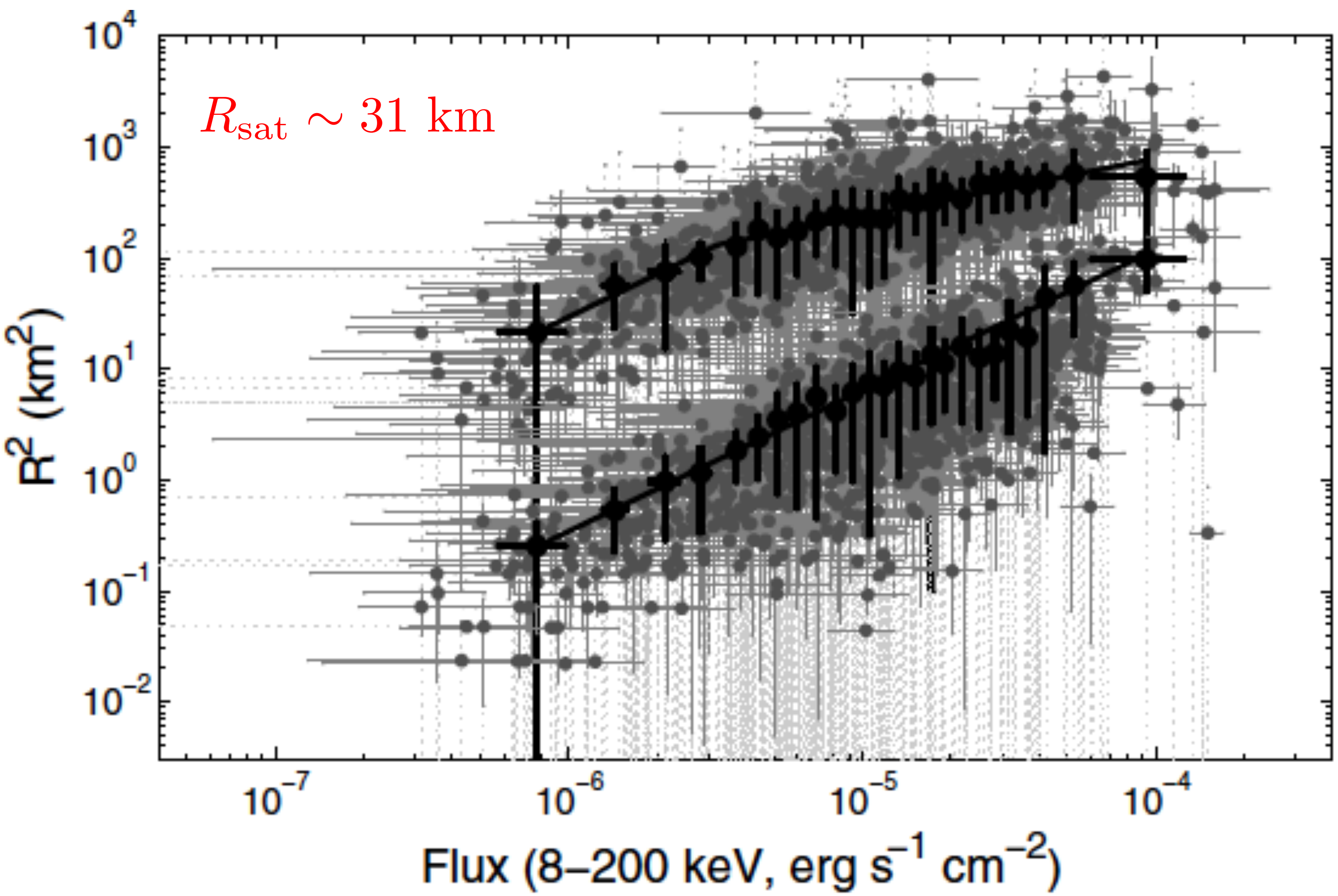


Younes et al. 2014

SGR J1550–5418 – TIME RESOLVED SPECTROSCOPY

- **Correlations seen in individual bursts**
  - Radiative region developing, subsequently cooling, in similar fashion for all bursts for this magnetar.
- **2 thermally emitting regions during bursts**
  - Highly coupled with energy equipartition between them
  - Hotter region — smaller volume: adiabatically expanding / contracting region, footpoints of plasma fireball?!
  - Cooler region — larger volume: more complicated to interpret, outer surface layer of plasma?!
  - $R^2 - kT^4$ relation: places plasma close to the NS surface

SGR J1550–5418 - TIME RESOLVED SPECTROSCOPY



Internal B field strength:

$B \gtrsim 4.5 \times 10^{15}$ G

Younes et al. 2014, Thompson & Duncan 1995

CONCLUSION

- Strength of high time-resolution study of magnetar bursts (thank you FERMI/GBM)
  - Track evolution of emitting regions
  - Put to test the emission from a photon-pair fireball
  - Prediction of intrinsic parameter of the system.

FUTURE PROSPECTS

- Similar analysis to all GBM detected outbursts — comparison between different magnetars (keep CTTE running).
- Motivation for a more in depth theoretical calculation of emergent spectrum of magnetar bursts, with the many physical and geometrical effects (POSTER BARCHAS & BARING).