On the X-ray Emission Mechanisms of the Persistent Source and Very Low Fluence Bursts of SGR J0501+4516

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Persistent Emission v.s. Short Bursts

- Focus on very low fluence bursts

X-ray emission from Magnetar

$10^{33} \sim 10^{35}$ | $\sim 10^{37}$ | $\sim 10^{41}$ | $\sim 10^{45}$

Luminosity (erg s^{-1})

Persistent Emission ($10^{33} \sim 10^{35}$)

Short Bursts ($\sim 10^{37}$)

- ~ 0.1 s
- Up to 200 keV
- Unpredictable from SGRs and AXPs (18/23 magnetars*)

Intermediate Flare ($\sim 10^{41}$)

Giant Flare ($\sim 10^{45}$)

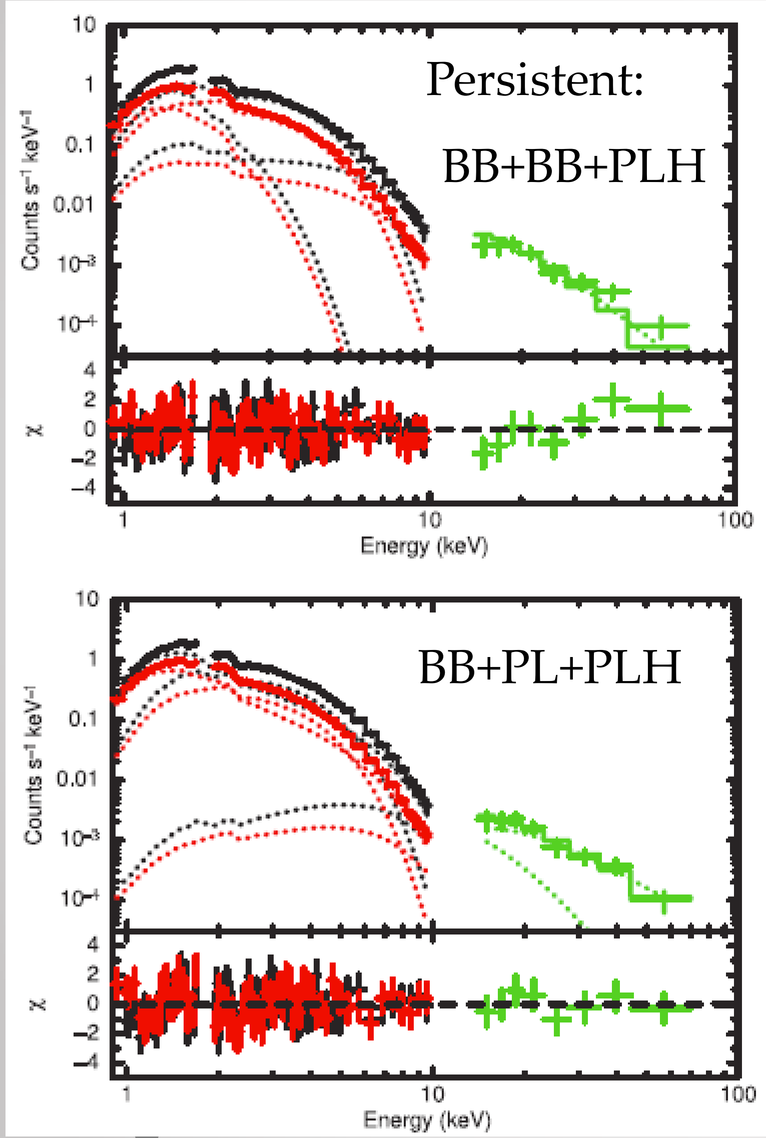
- Short hard spike + long soft periodic tail
- Only 3 : SGRs 0526-66, 1900+14, 1806-20

* From McGill SGR/AXP Online Catalog

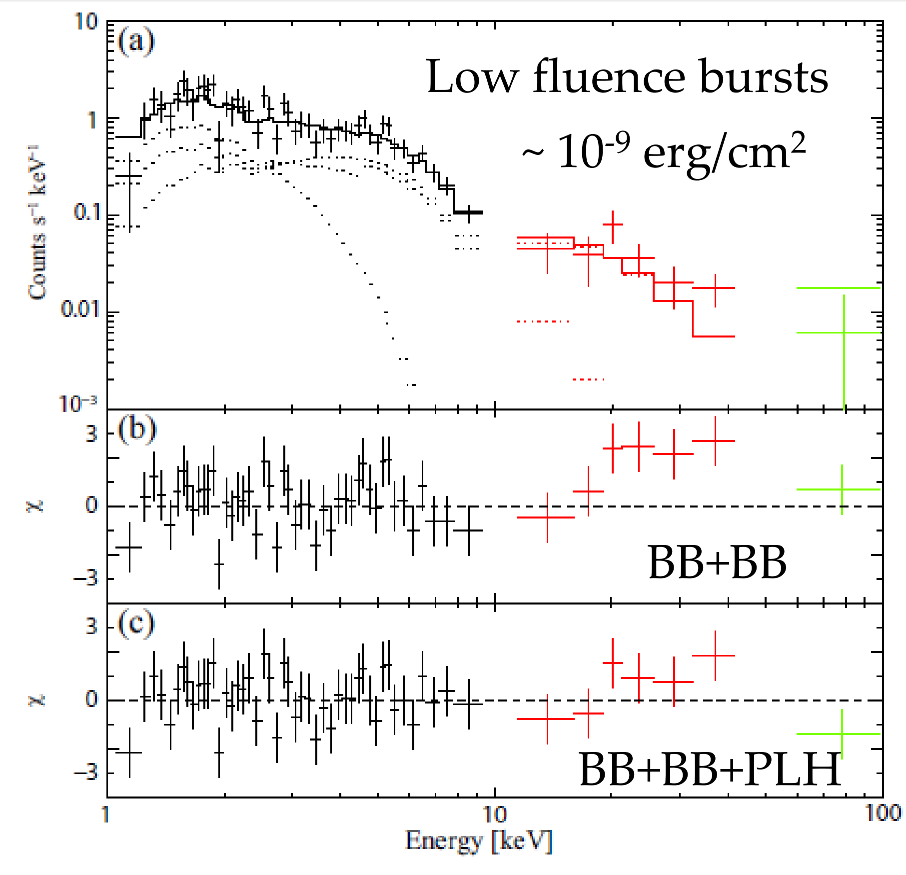
Persistent Emission v.s. Short Bursts

- Focus on very low fluence bursts
- Idealized physical models for both persistent emission and bursts spectra

Phenomenological models

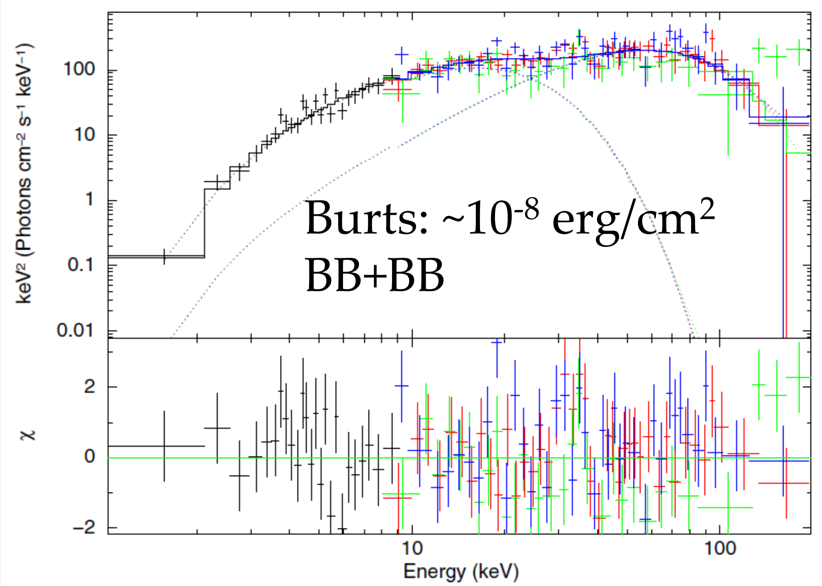


Enoto et al. (2010)



Nakagawa et al. (2011)

- Persistent : (BB+BB or BB+PL) + PL hard band
- Bursts : BB+BB
- Low fluence bursts: BB+BB (+ PL hard band)



Lin et al. (2012)

Idealized physical models

Surface emission transport through atmosphere: harder than Planck shape

kT & B

Zane et al. (2001), Ozel(2001,2003), Ho & Lai (2001, 2003)

The sudden magnetic energy release → hot pair plasma → trapped by magnetosphere formed a bubble: modified BB (MBB)

kT

Thompson & Duncan (1995), Lyubarsky (2002)

Magnetosphere: Resonant cyclotron scattering (RCS) by a non-relativistic warm plasma in an in homogeneous magnetic field

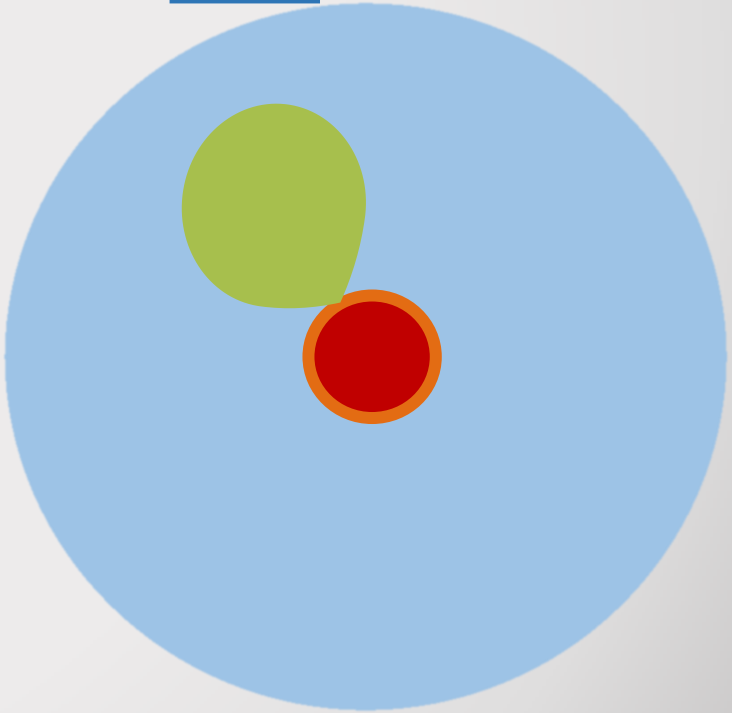
β & τ

Lyutikov & Gavriil (2006)

Persistent emission: STEMS

Burst emission: MBB + RCS

Guver et al. (2007, 2008)



Persistent Emission v.s. Short Bursts

- Focus on very low fluence bursts
- Idealized physical models for both persistent emission and bursts spectra
- Proper source to study both spectra together

SGR J0501+4516

- $P = 5.762\text{s}$ $\qquad \dot{P} = 5.8\times10^{-12}\,\text{s/s}$ $\qquad B_{dipol} = 2\times10^{14}\,\text{G}$
- Anti-Galaxy center direction, most likely at the Perseus arm (~2 kpc)

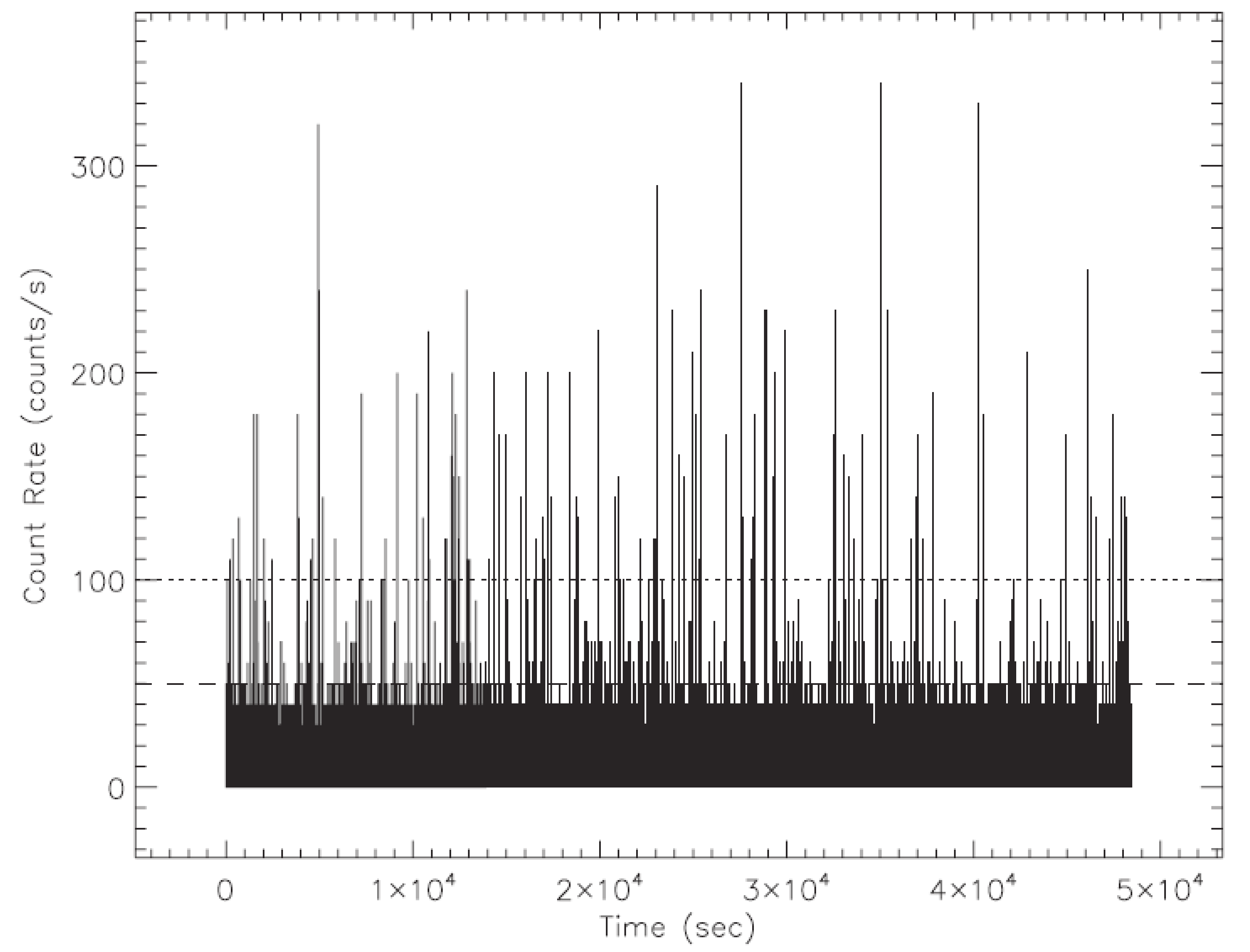
$$\text{R.A.} = 05^{\text{h}}01^{\text{m}}06^{\text{s}}.76 \quad \text{decl.} = +45^{\circ}16'33''.92$$

- Burst active period

  ~ 2 weeks after 2008 August 22
- XMM-Newton observation: 0560191501
  - 2008 August 23 (the most burst active day)
  - Exposure 48.9 ks
  - Study the spectra of burst and underlying persistent emission at the same time

Persistent and bursts selection

- 100 ms binned lightcurve
- Persistent emission: ~5.5 counts per bin; total exposure of 32.7 ks
- Bursts: 2σ over persistent level, ~10 counts per bin, 129 burst bins with total exposure of 8.7 s

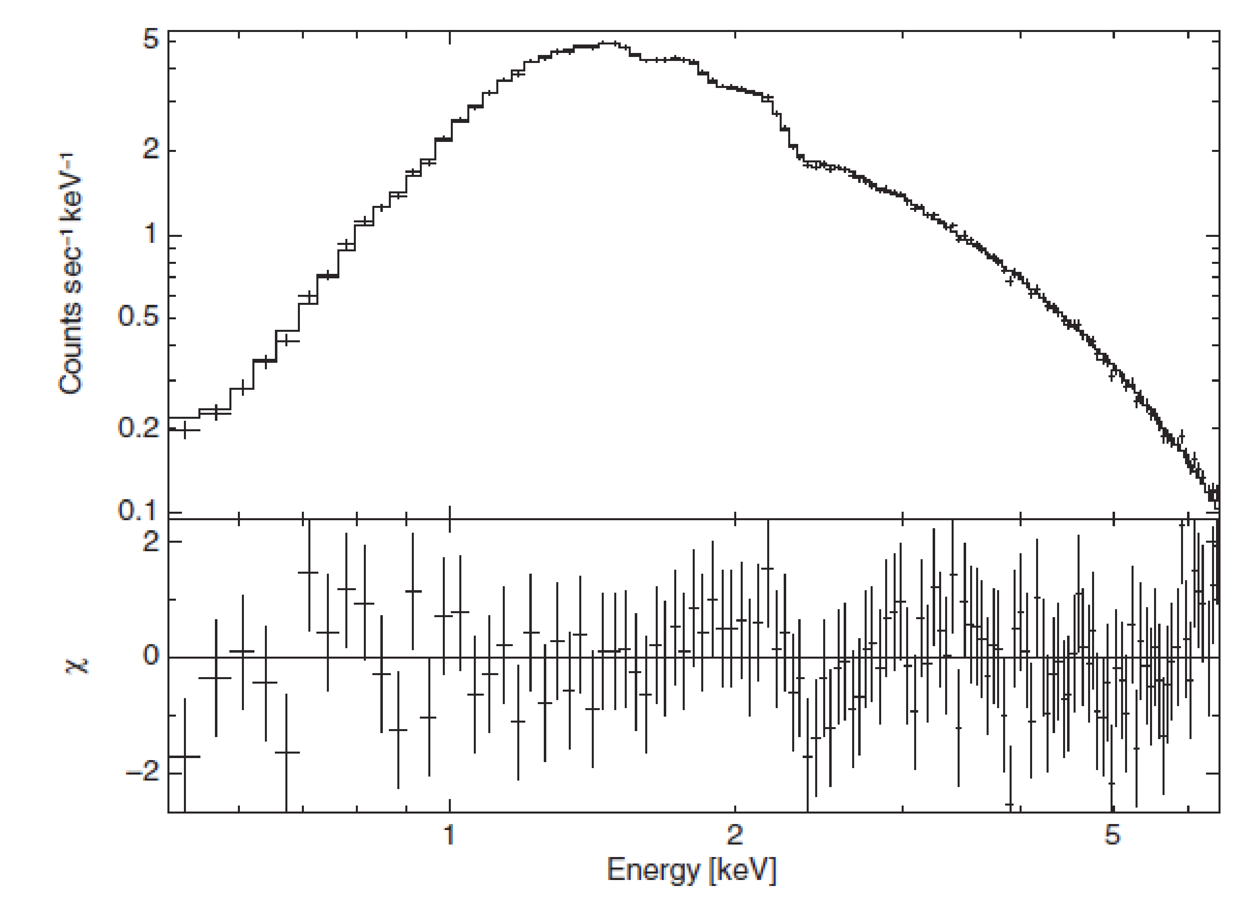


Model	N_{H} (10^{22} cm^{-2})	B (10^{14} G)	kT[a] (keV)	Index	β	τ	χ^2_ν/dof
BB+PL	0.91 ± 0.01	...	0.70 ± 0.01	2.79 ± 0.04	...	...	0.7657/117
STEMS	0.67 ± 0.02	2.21 ± 0.07	0.38 ± 0.02	...	0.37 ± 0.01	5.0 ± 0.2	0.7615/116

Persistent emission spectrum

- Galactic N_{H} towards the direction of the source
  $(0.62\ or\ 0.52) \times 10^{22}$ cm^{-2}

- Unabsorbed flux (0.5-6.5 keV)
  $(5.88 \pm 0.02) \times 10^{-11}$ erg/s/cm^2
- Hot-spot surface area
  131 ± 27 km^2

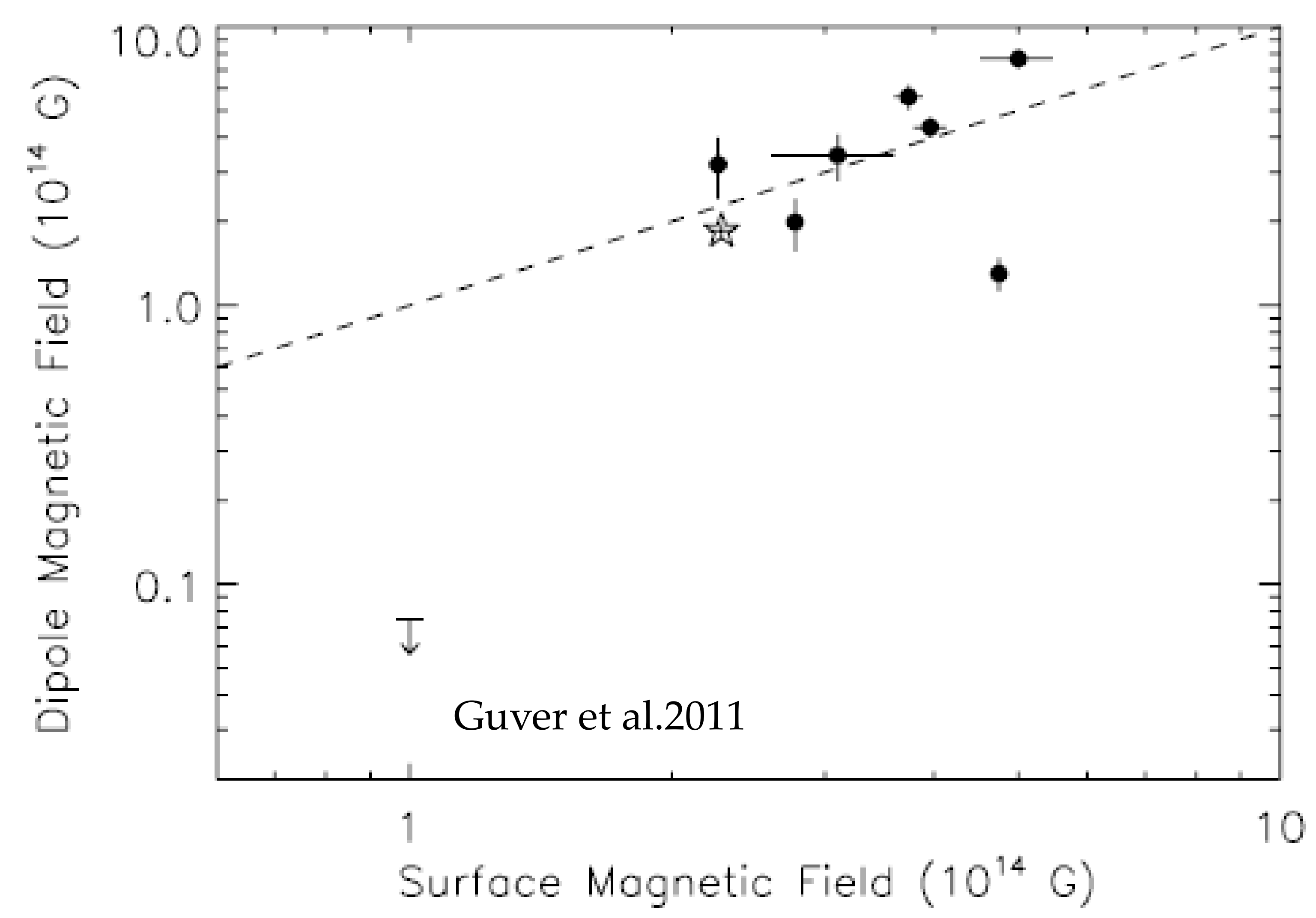


B-field

For SGR J0501+4516

$B_{stem} \sim B_{dipo}$

Its surface magnetic field is close to a dipole



Weak bursts stacked spectrum

- combine 129 burst bins into one stack spectrum
- Adopt N_{H} , β & τ from the persistent spectrum fit with STEM

➢ MBB+RCS

$kT_b = 1.16 \pm 0.04$ keV

➢ The emission area

93 ± 10 km^2,

~7.4% of magnetar surface

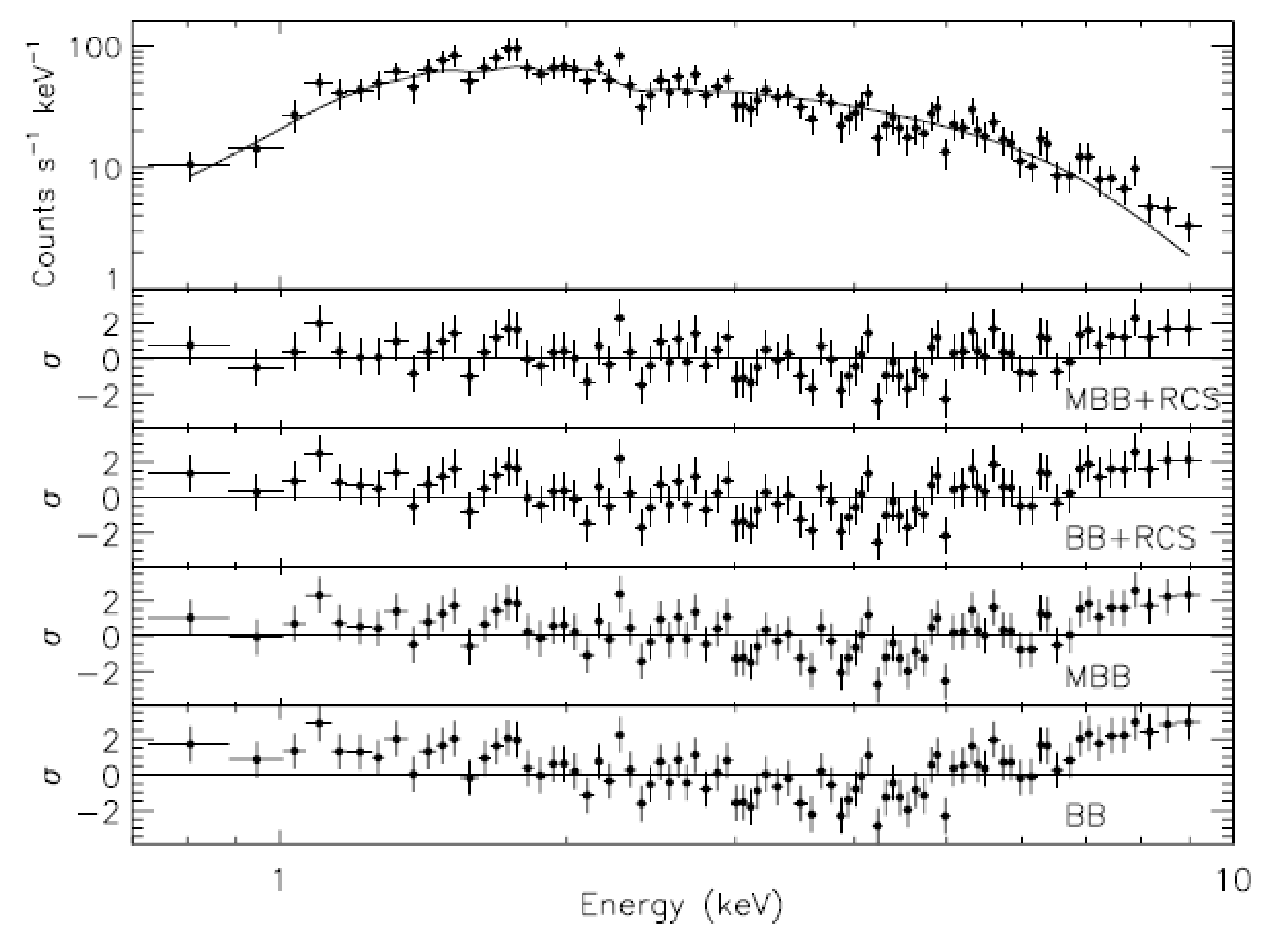
➢ Average unabsorbed flux

$(1.8 \pm 0.05) \times 10^{-9}$ erg/s/cm^2

over 30 times of the persistent flux level

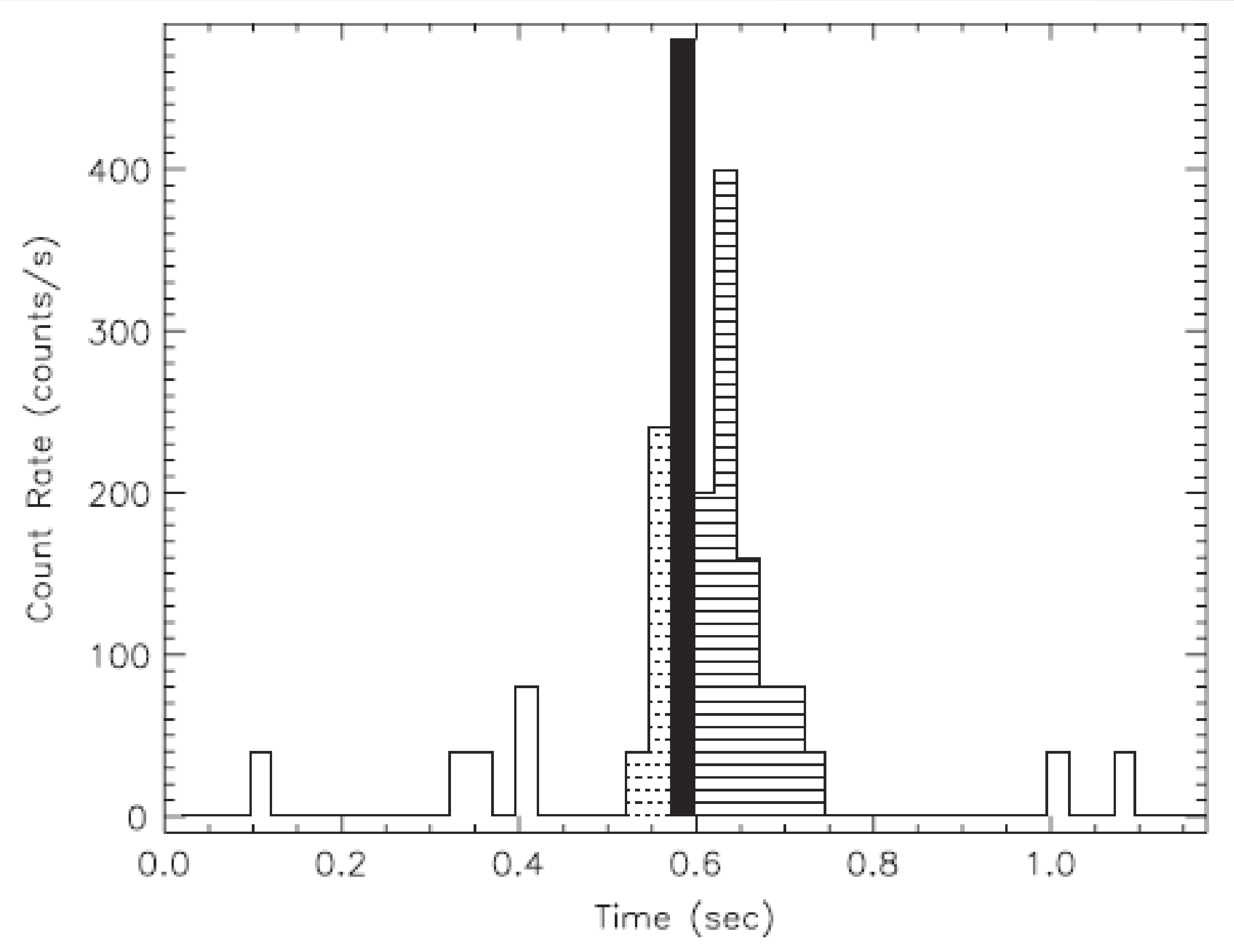
➢ Average luminosity

$\sim 10^{36}$erg/s

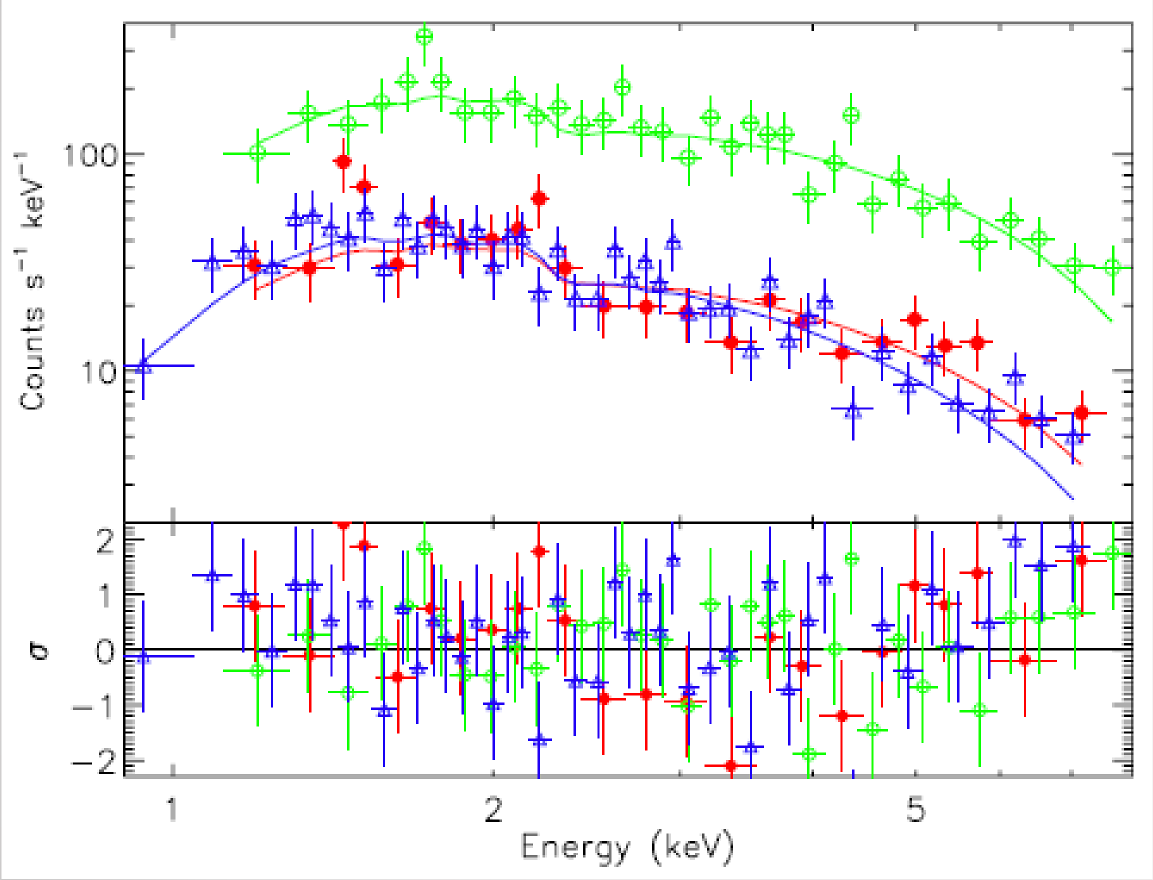


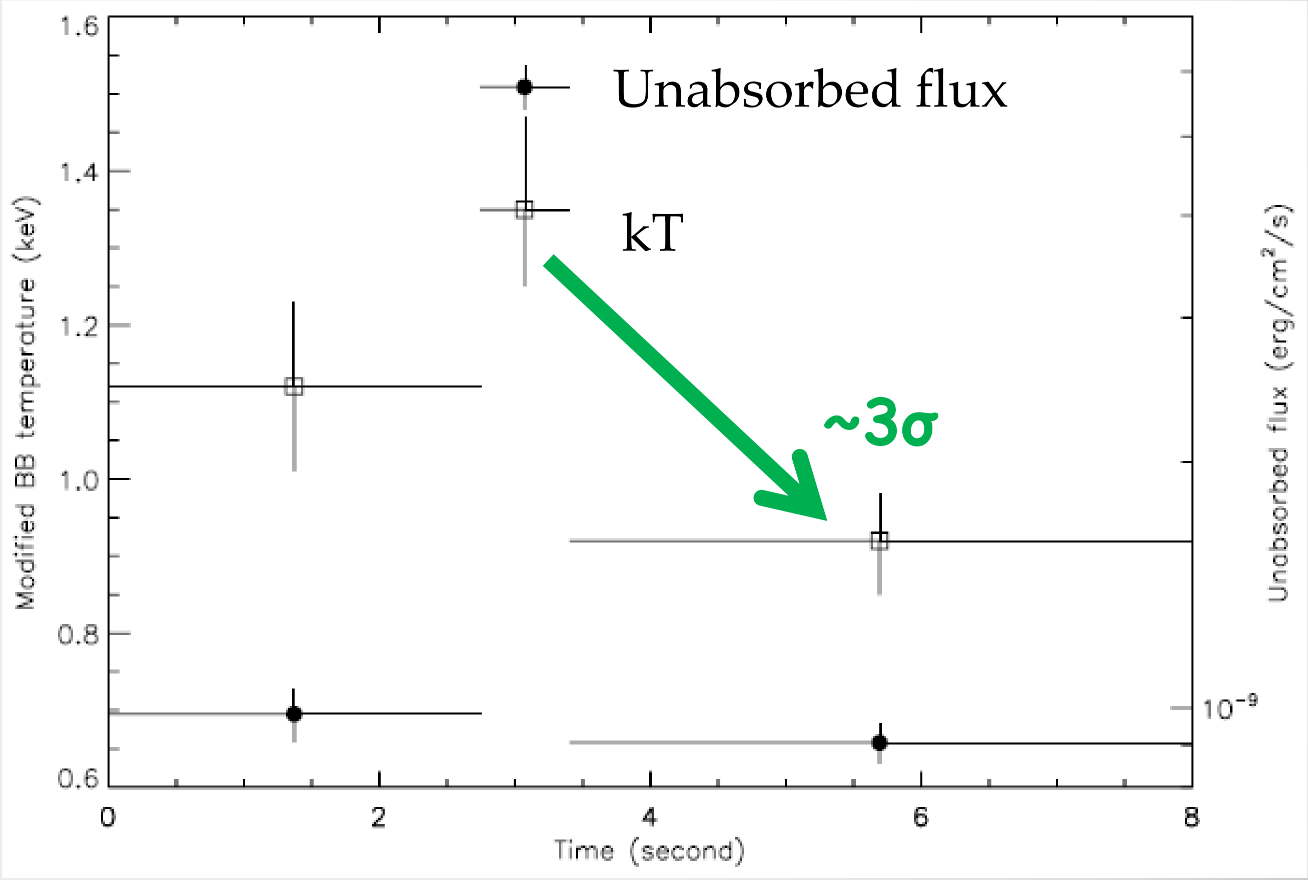
Time resolved burst stacked spectra

- Select 47 relatively stronger bursts, and separate each one into three parts
  - rise
  - 25 ms peak
  - decay
- Fit 3 stacked spectra with MBB+RCS model



Time resolved burst stacked spectra





Emission areas for rise, peak and decay parts are:

$58 \pm 19, 160 \pm 41, 118 \pm 29\ \mathrm{km}^2$

Summary

- Study X-ray spectra from magnetar with idealized physical models

  Persistent - STEMS

  Bursts - MBB+RCS

- Any the connection between the persistent emission and bursts?

  Persistent emission and weak bursts (~2σ) have different spectral shape, hence different origin