

# Uniting Quiescent and Burst Emission Mechanisms of Magnetar Candidates

Yujin E. Nakagawa

Institute of Physical and Chemical Research (RIKEN)  
Japan

Atsumasa Yoshida<sup>1</sup>, Kazutaka Yamaoka<sup>1</sup>, Shibasaki Noriaki<sup>2</sup>

1. Aoyama Gakuin University; 2. Rikkyo University

Nakagawa et al. 2009, PASJ, 61, 109

# Introduction

## Magnetar

- Highly Magnetized NS :  $B \sim 10^{15}$  G
- Dissipation of Magnetic Energy
  - I. Soft Gamma Repeaters (SGRs; 5)
  - II. Anomalous X-ray Pulsars (AXPs; 10)

## Spectral Shapes

### Quiescent Emission

It is still unclear which model (2BB/BB+PL) is more reliable or physically suitable.

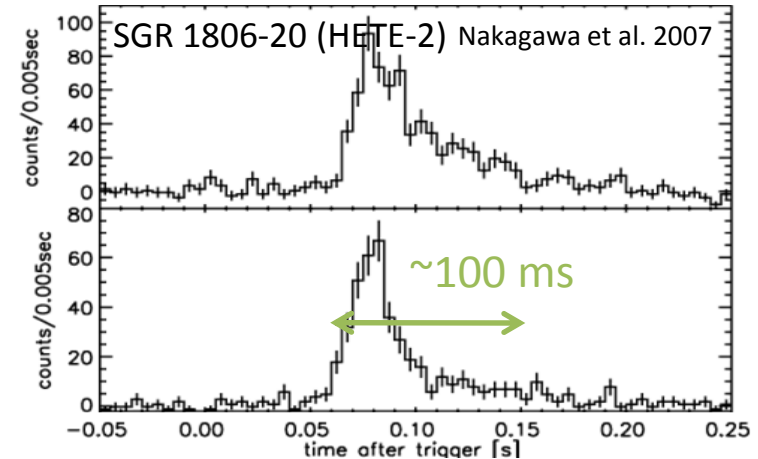
### SGR Short Bursts

Nakagawa et al. 2007

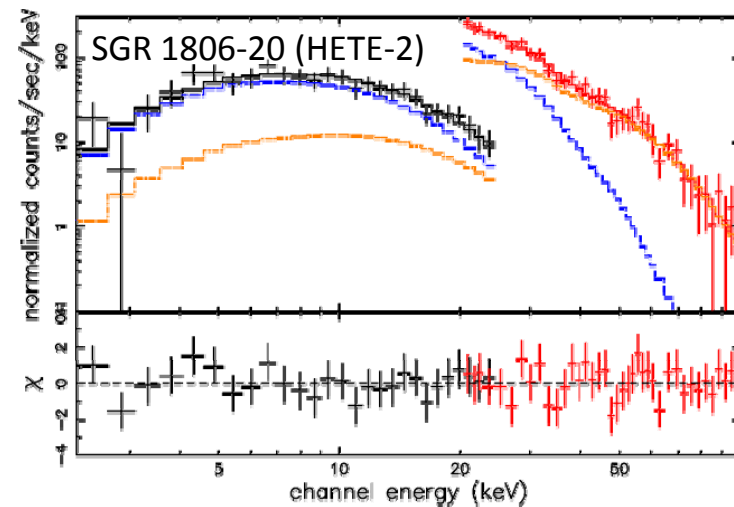
The 2BB model is the most acceptable.

Energy Band	Quiescent Emission	SGR Short Burst
Soft	2BB or BB+PL	2BB
Hard	PL (Hard Tail)	???

## Short Burst Light Curve



## Short Burst Spectrum



# Motivation and Samples of Our Study

## Motivation

Energy Source : Magnetic Energy

- A similar physical process?
- The spectra emerge alike?

It would be preferred to represent **spectra of quiescent emissions by 2BB** rather than BB+PL for SGRs, and even for AXPs if it is **the same class of object**.

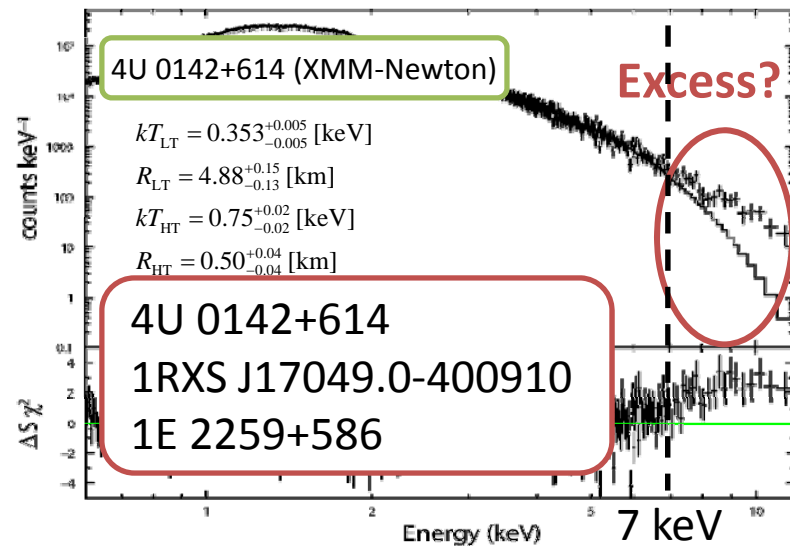
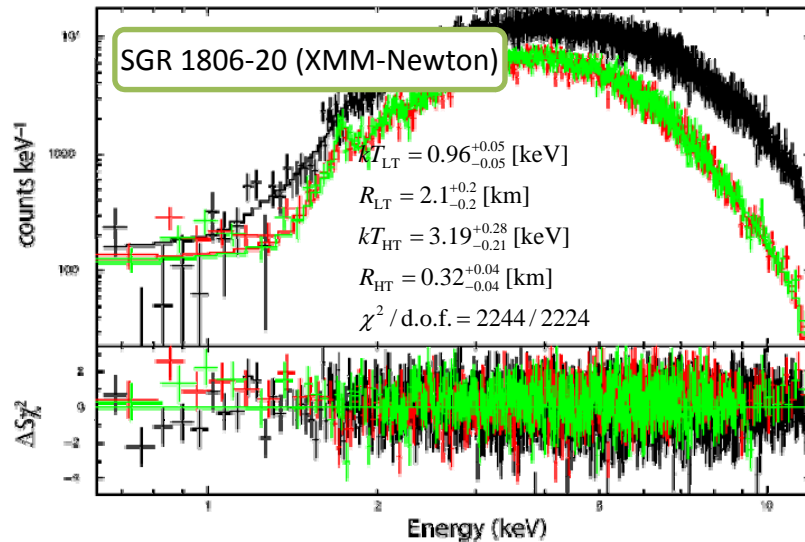
## Samples

Objects	Detectors/Satellites	Periods	References
SGR 0526-66	<i>ACIS/Chandra</i>	2000-2001	(1)
SGR 1627-41	<i>EPIC/XMM-Newton, ACIS/Chandra</i>	2001-2005	(2), (3), (4)
SGR 1806-20	<i>EPIC/XMM-Newton, ACIS/Chandra</i>	2000-2005	(5), (6)
SGR 2013+34 (GRB 050925)	<i>BAT/Swift</i>	2005	(7), (8)
AXP CXOU J010043.1-721134	<i>EPIC/XMM-Newton, ACIS/Chandra</i>	2000-2005	(9), (10)
AXP 4U 0142+614	<i>EPIC/XMM-Newton</i>	2002-2004	(11)
AXP CXOU J164710.2-455216	<i>BAT/Swift, XRT/Swift, ACIS/Chandra</i>	2005-2007	(12), (13), (14), (15)
AXP 1RXS J170849.0-400910	<i>EPIC/XMM-Newton</i>	2003	(16), (17)
AXP 1E 1841-045	<i>EPIC/XMM-Newton</i>	2002	
AXP 1E 2259+586	<i>EPIC/XMM-Newton</i>	2002-2005	(18)

(1) Kurkarni et al. (2003); (2) Kouveliotou et al. (2003); (3) Wachter et al. (2004); (4) Mereghetti et al. (2006b); (5) Kaplan et al. (2002); (6) Mereghetti et al. (2005); (7) Holland et al. (2005); (8) Markwardt et al. (2005); (9) Lamb et al. (2002); (10) Majid, Lamb & Macomb (2004); (11) Guver, Ozel & Gogus (2007); (12) Krimm et al. (2006); (13) Campana & Israel (2006); (14) Muno et al. (2006); (15) Muno et al. (2007); (16) Oosterbroek et al. (2004); (17) Rea et al. (2007); (18) Woods et al. (2004)

# Spectral Analyses (1)

## 2BB Spectra



## Possibility of > 7 keV Excess

Hard Component (>20 keV) by INTEGRAL

Molkov et al. 2005; Gotz et al. 2006b; Kuiper et al. 2006

Is the excess associated with this?

To investigate our idea, a power law model related to the hard component (HPL) reported by Kuiper et al. (2006) was added to the 2BB and BB+PL spectral fits.

## 2BB+HPL/BB+PL+HPL Spectra

4U 0142+614

$p = 1.05$ ,  $N_{20 \text{ keV}} = 2.3 * 10^{-5}$  photons  $\text{cm}^{-2} \text{s}^{-1} \text{keV}$

2BB+HPL :  $\chi^2 / \text{d.o.f.} = 876 / 819$ ,  $P = 0.08$

BB+PL+HPL :  $\chi^2 / \text{d.o.f.} = 1086 / 819$ ,  $P = 1 \times 10^{-8}$

1RXS J170849.0-400910

$p = 1.44$ ,  $N_{20 \text{ keV}} = 8.8 * 10^{-6}$  photons  $\text{cm}^{-2} \text{s}^{-1} \text{keV}$

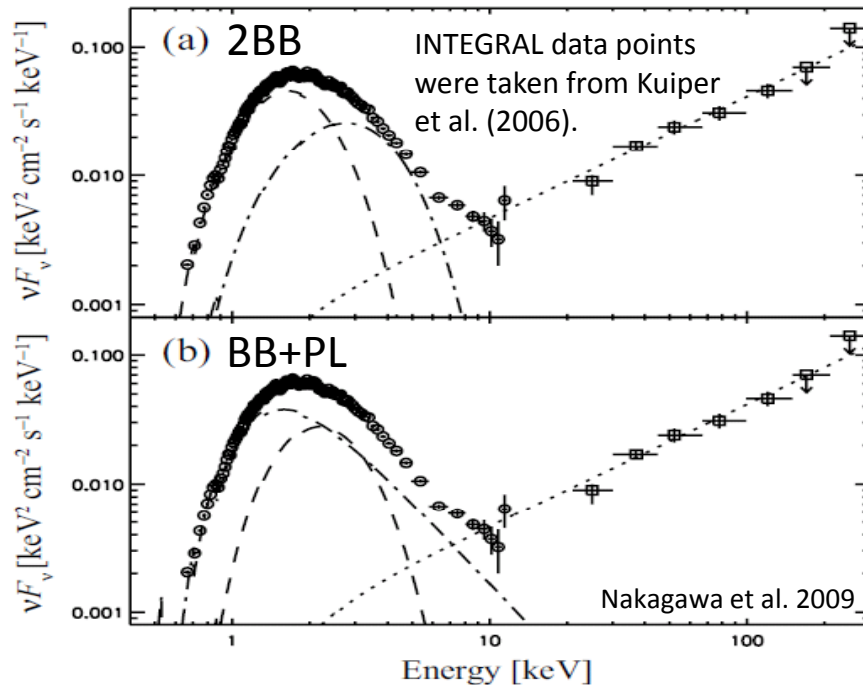
2BB+HPL :  $\chi^2 / \text{d.o.f.} = 1438 / 1232$ ,  $P = 4 \times 10^{-5}$

BB+PL+HPL :  $\chi^2 / \text{d.o.f.} = 1270 / 1232$ ,  $P = 0.22$

# Spectral Analyses (2)

## Schematic View

4U 0142+614 (XMM-Newton+INTEGRAL)



A distinctive hard component is required for **either case** to represent hard component seen by INTEGRAL separately from the higher temperature blackbody or secondary steep power law model.

- ◆ The non-thermal hard component can affect the low energy spectra (< 12 keV).
- ◆ The apparent disagreement between the quiescent emission spectra and 2BB for the three AXPs (1E2259+586, 4U0142+614 and 1RXS J170849.0–400910) might be due to a narrow observational energy band (<12 keV).
- ◆ One must not reject 2BB just using the data of the X-ray band.

## 2BB/BB+PL Comparison

SGR 1806-20 (XMM-Newton)

2BB :  $\chi^2 / \text{d.o.f.} = 2244 / 2224, P = 0.38$

BB+PL :  $\chi^2 / \text{d.o.f.} = 2274 / 2224, P = 0.23$

Both Acceptable

AXP 4U 0142+614 (XMM-Newton)

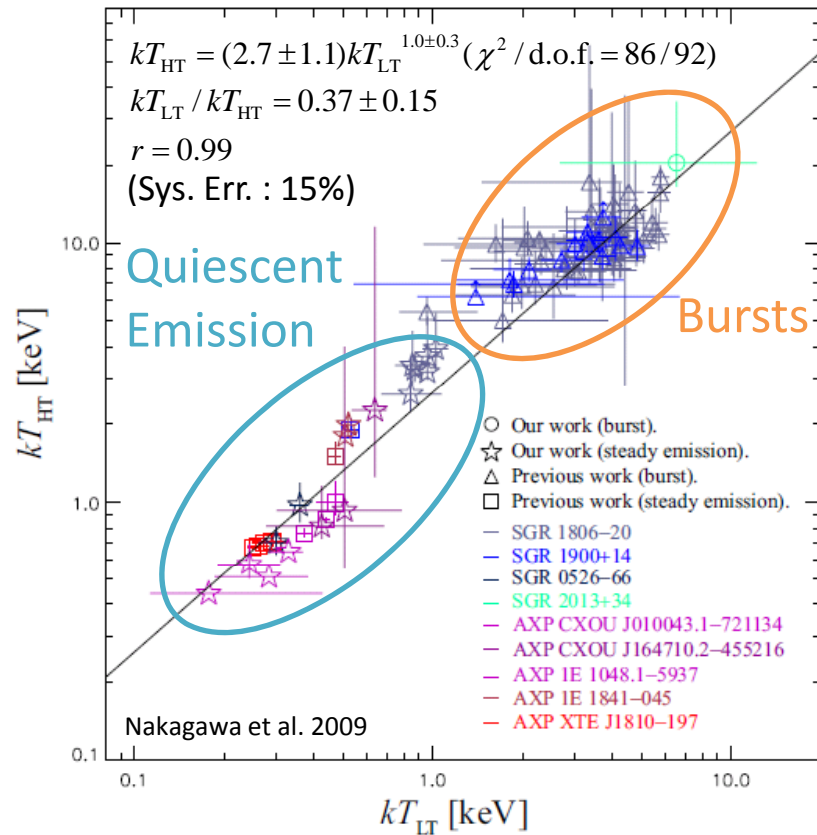
2BB :  $\chi^2 / \text{d.o.f.} = 1086 / 819, P = 10^{-10}$

BB+PL :  $\chi^2 / \text{d.o.f.} = 978 / 819, P = 10^{-5}$

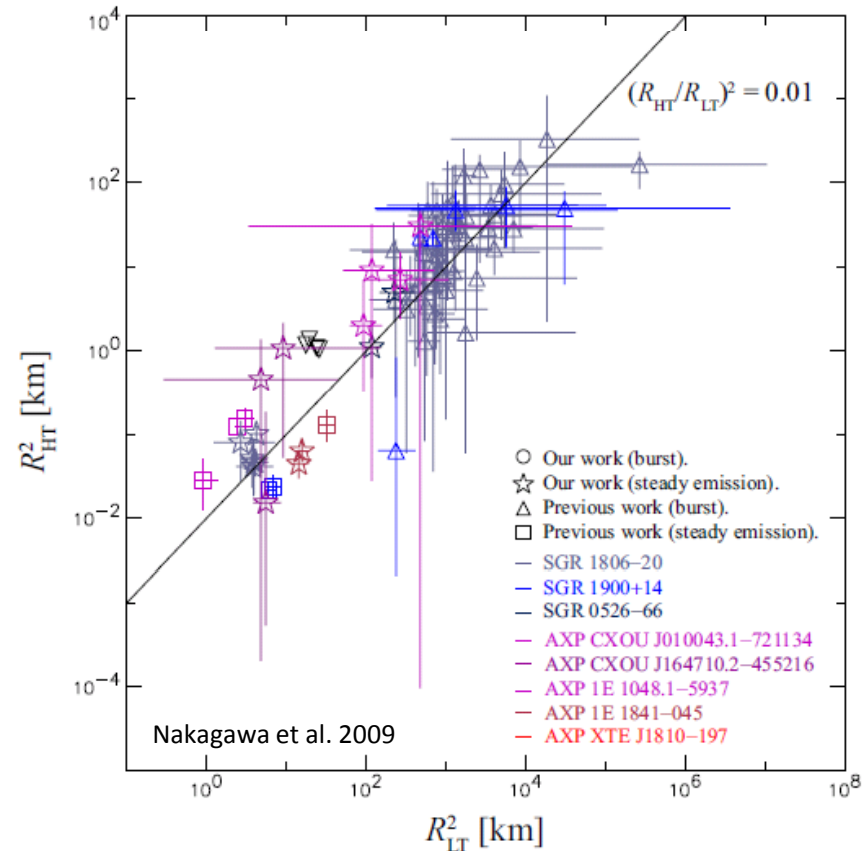
Both Unacceptable

# 2BB Spectral Parameters (1)

## $kT_{LT}$ - $kT_{HT}$ Correlation



## $R_{LT}^2$ - $R_{HT}^2$ Correlation



It is remarkable that the correlation seems to be independent of the objects and/or the emission types (the quiescent emission or the burst).

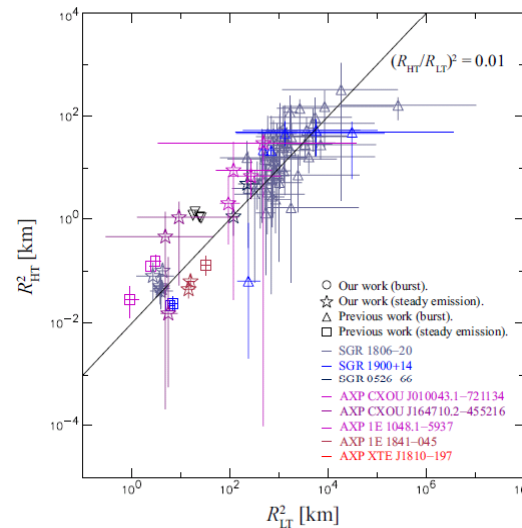
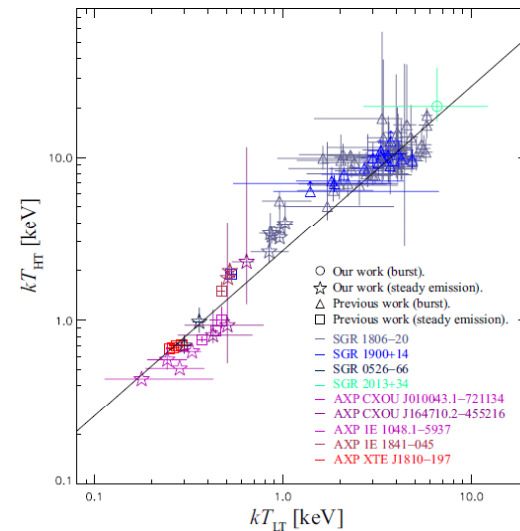
References : Morii et al. 2003; Feroci et al. 2004; Olive et al. 2004; Gotthelf et al. 2004; Gotthelf & Halpern 2005; Tiengo et al. 2005; Gotz et al. 2006a; Mereghetti et al. 2006a; Nakagawa et al. 2007

# 2BB Spectral Parameters (2)

## Implications

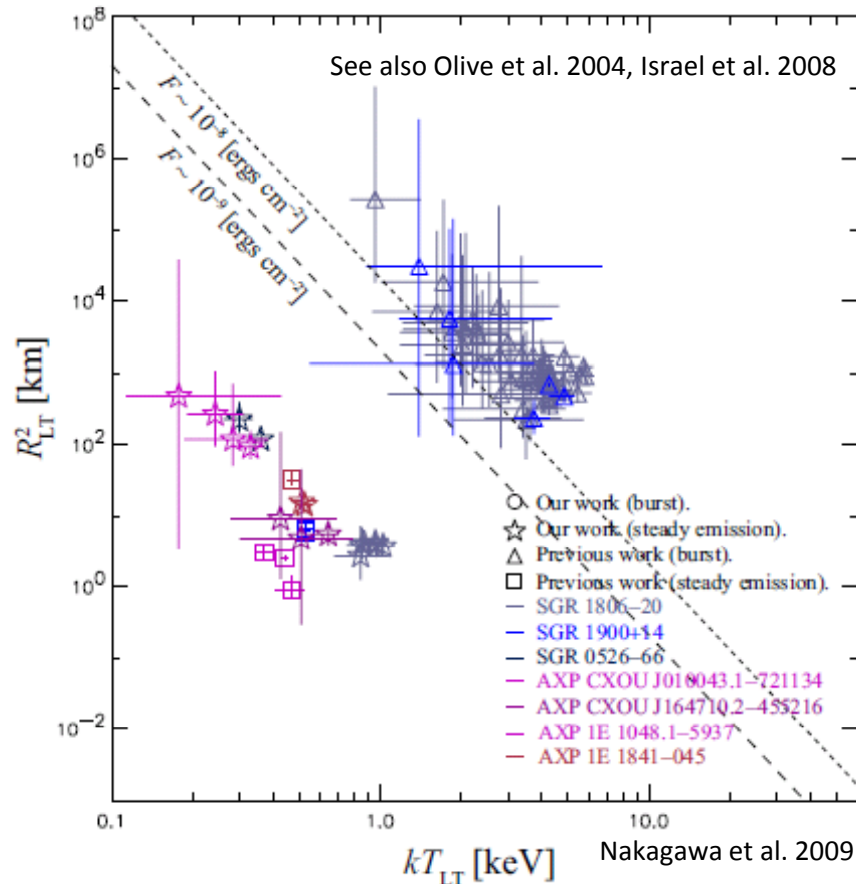
- A **common emission mechanism** among the magnetar candidates, and in both the quiescent emission and the bursts?
- The relation between the quiescent emission and the bursts might be analogous to a relation between microflares and solar flares of the sun.
- The **quiescent emission** might be due to **very frequent small bursts** similar to the microflares, while the **burst** might be due to a **relatively large burst** similar to the ordinary solar flare.

## $kT_{LT} - kT_{HT} / R_{LT}^2 - R_{HT}^2$ Correlations



# 2BB Spectral Parameters (3)

## $kT_{LT}-R_{LT}^2$ Relation



\* The  $kT_{HT}-R_{HT}^2$  relation also has a similar distribution.

- One may see that data points of the quiescent emission and the burst are apparently clustering in separate areas.
- It is obvious to consider the detectability for the burst with such as WXM/HETE-2.
- Since most of the short bursts localized by the WXM/HETE-2 have fluences greater than  $10^{-8}$  ergs  $\text{cm}^{-2}$ , dim bursts are not detectable. Such dim bursts may fall on a gap between the burst population and the quiescent emission population.



# Summary

- The spectra of both the quiescent emission and the bursts for most magnetar candidates are reproduced by a photoelectrically absorbed two blackbody function (2BB).
- There is a strong correlation between lower and higher temperatures of 2BB ( $kT_{\text{LT}}$  and  $kT_{\text{HT}}$ ) for the magnetar candidates of which the spectra are well reproduced by 2BB.
- A square of radius for  $kT_{\text{LT}}$  ( $R_{\text{LT}}^2$ ) is well correlated with that for  $kT_{\text{HT}}$  ( $R_{\text{HT}}^2$ ).
- A ratio  $kT_{\text{LT}}/kT_{\text{HT}} \sim 0.4$  is nearly constant irrespective of objects and/or emission types (i.e., the quiescent emission and the bursts).
- A common emission mechanism among the magnetar candidates, and in both the quiescent emission and the bursts..
- The relation between the quiescent emission and the bursts might be analogous to a relation between microflares and solar flares of the sun. The quiescent emission might be due to very frequent small bursts similar to the microflares, while the burst might be due to a relatively large burst similar to the ordinary solar flare.