Wide-Band Spectral Studies of Magnetar Burst and Persistent Emissions

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1. University of Tokyo, 2. Sanford University,
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8.ISAS/JAXA, 8. Saitama Universisty, 9. Tokyo Institute of Technology

Current Understanding and Future Study of Magnetars:
Research Strategy in the ASTRO-H era
1 September 2012

Highly Magnetized Neutron Star “Magnetar”

Characteristics

- Magnetic Field : $B \sim 10^{14}$ G
- Dissipation of Magnetic Energy

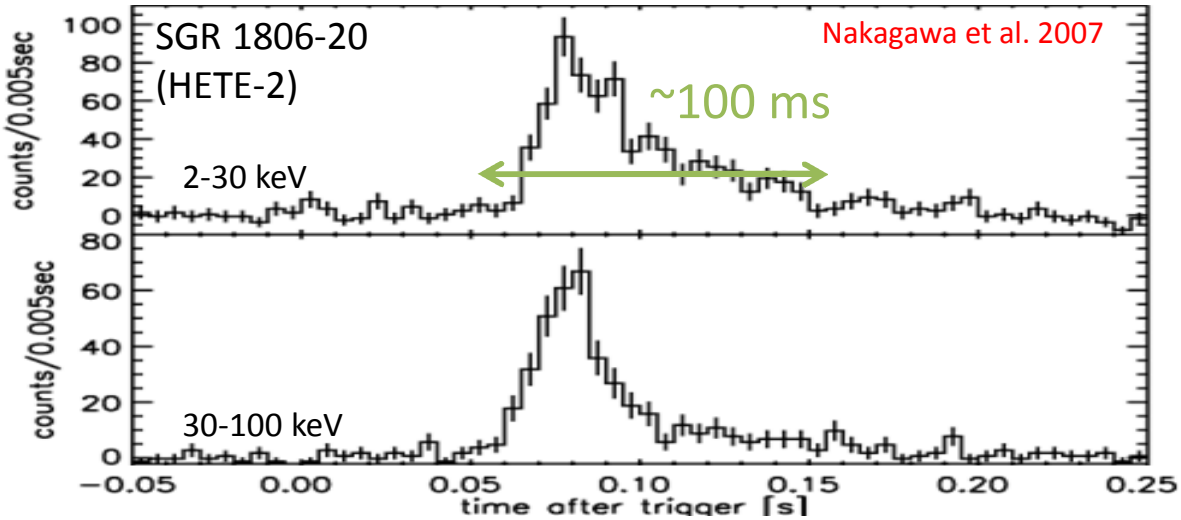
Thompson & Duncan 1995

X-ray Counterparts

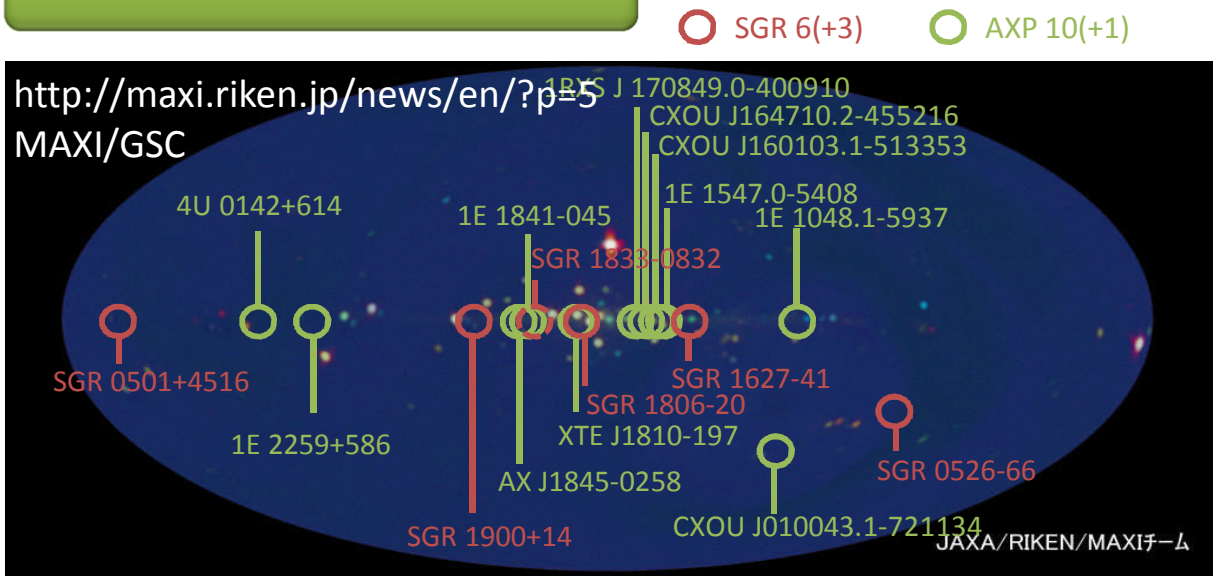
1. Soft Gamma Repeater (SGR)
   6(+3) Objects
2. Anomalous X-ray Pulsar (AXP)
   10(+1) Objects

- Pulse Periods : $P \sim 2$-12 s
- X-ray Persistent Emission
- Sporadic Burst Activities
- Location : Galactic Plane

Typical Light Curves of The Short Burst



A Distribution of SGRs and AXPs



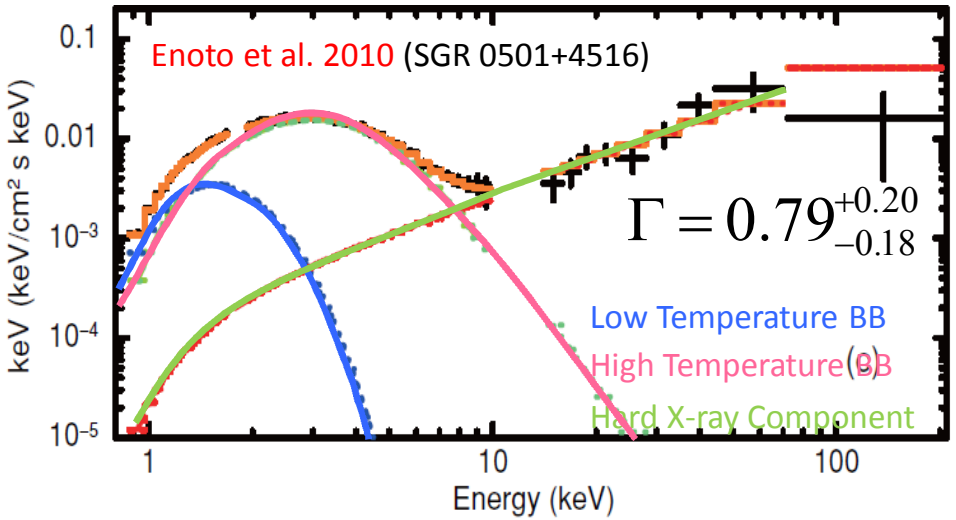
Typical Energy Spectrum of Magnetar

Phenomenological Studies

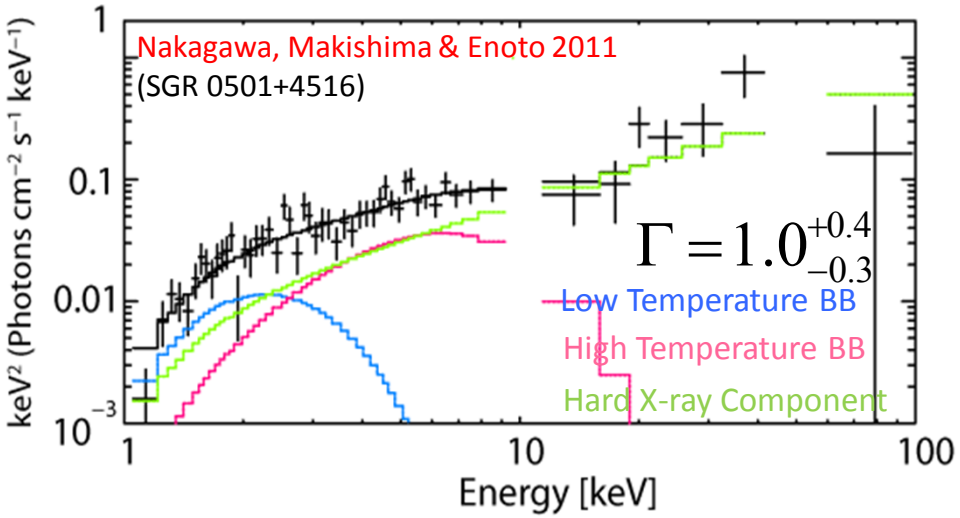
2BB : Two-Blackbody Model,
BB+PL : Blackbody+Powerlaw, PL : Powerlaw

	Persistent Emission $\sim 10^{-11}$ erg cm^{-2} s^{-1}	Small SGR/AXP Bursts $\sim 10^{-8}$ erg cm^{-2} s^{-1}	Bright SGR Bursts $10^{-7} \sim 10^{-6}$ erg cm^{-2} s^{-1}
Soft Comp.	e.g., 2BB or BB+PL e.g., Marsden & White 2001; Tiengo et al. 2008; Nakagawa et al. 2009; Enoto 2010	2BB	2BB e.g., Olive et al. 2004, Nakagawa et al. 2007
Hard Comp.	PL (Hard X-ray Component) e.g., Kuiper et al. 2006; Enoto et al. 2010	PL (Hard X-ray Component) Nakagawa, Makishima & Enoto 2011; Enoto et al. 2012 Submitted	???

Persistent Emission

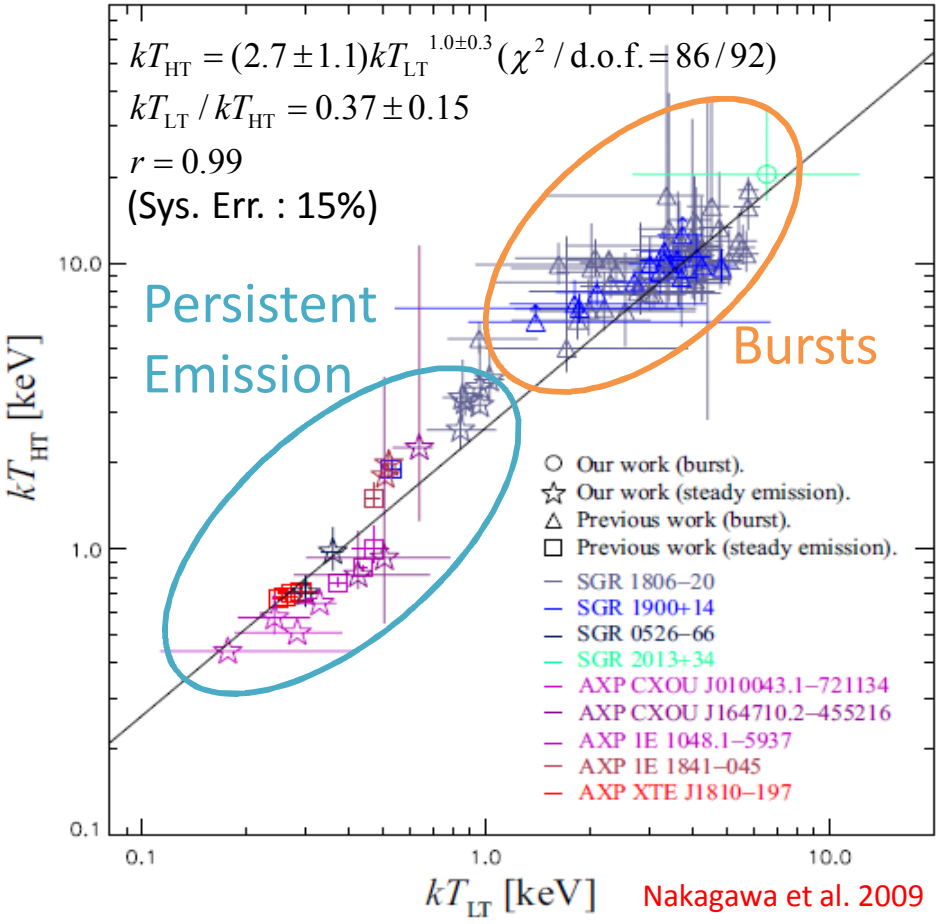


Small SGR Bursts



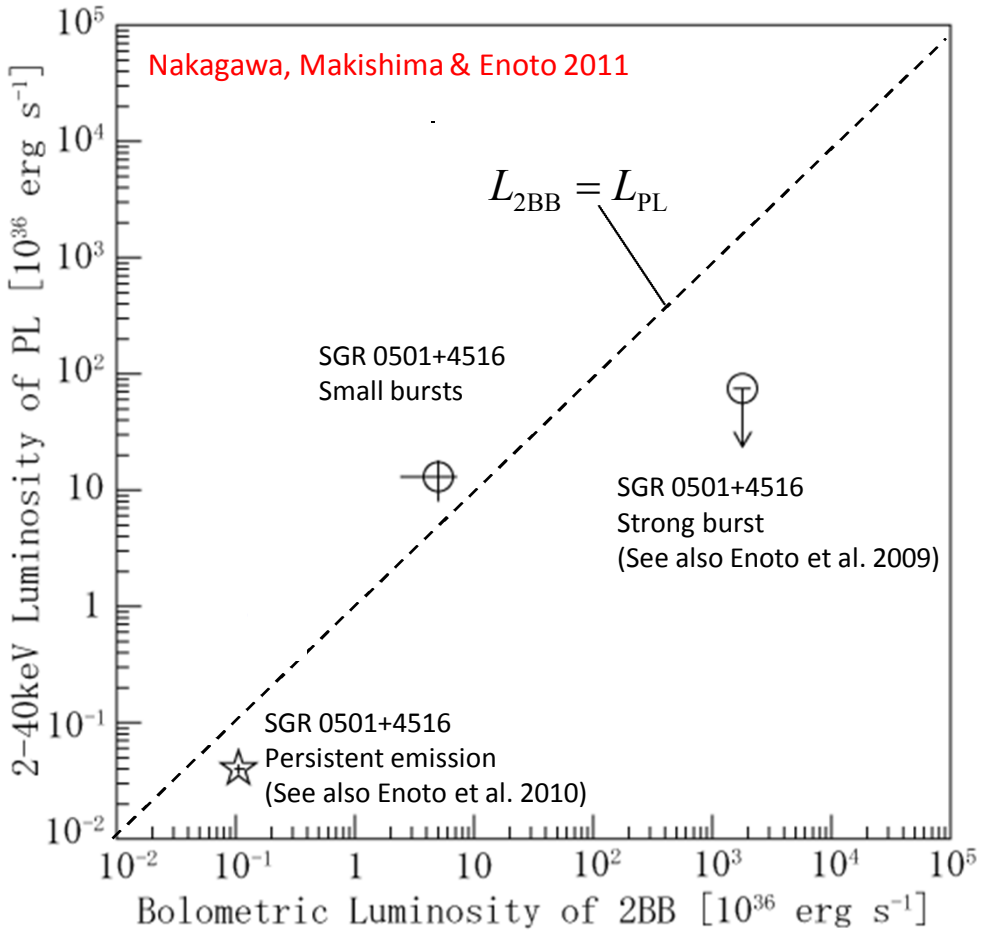
Spectral Correlations

kT_{LT}-kT_{HT} Correlation



Nakagawa et al. 2009

L_{2BB}-L_{PL} Correlation



- A common radiation mechanism between the bursts and persistent emission.
- A possibility that the persistent X-ray emission may consist of numerous micro bursts.

Nakagawa et al. 2009; Nakagawa, Makishima & Enoto 2011

Topics of My Talk

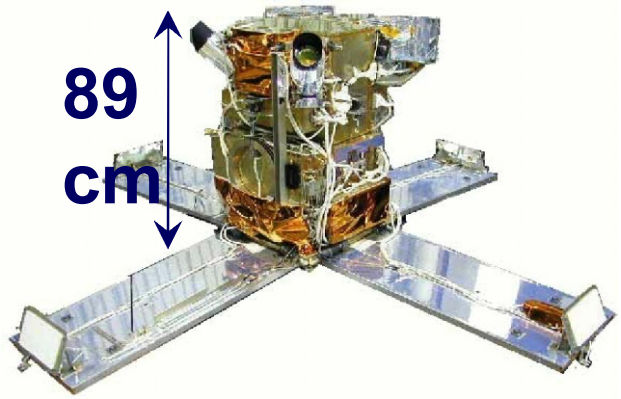
1. HETE-2 X-ray Observations of Bright bursts from SGR 1806-20.
   Contributions of hard X-ray components in bright SGR bursts.

2. Suzaku X-ray Observations of AXP 4U 0142+614
   Comparisons of persistent emission
   in active phase and quiescent phase.

HETE-2 Observations of Bursts from SGR 1806-20

HETE-2 Satellite

- High Energy Transient Explorer 2 (HETE-2)
- Launched on 9 October 2000
- Gamma-Ray Bursts, SGR Bursts, X-ray Bursts



Mass : 124 kg
Height : 89 cm
Width : 66 cm
Altitude : 625 km
Inclination : 0-2 degree (Equatorial Orbit)
Attitude : Anti-Solar Pointing

Observations of SGR Bursts

181 Events (18 June 2001 – 7 August 2005)

SGR 1806-20	:	62 Events --> 50 Bursts
SGR 1900+14	:	6 Events --> 5 Bursts
Out of Filed of View	:	113 Events

Same Data Sets with Nakagawa et al. 2007.

SGR Bursts – Analyses of Individual Spectra

➢We re-analyzed SGR bursts with the following spectral model individually.

XSPEC Spectral Model

$N_{\mathrm{H}} \times (\mathrm{Blackbody} + \mathrm{Blackbody} + \mathrm{Powerlaw})$

$N_{\mathrm{H}} = 7.8 \times 10^{22}\ [\mathrm{cm}^{-2}]$ fixed (Nakagawa et al. 2009)

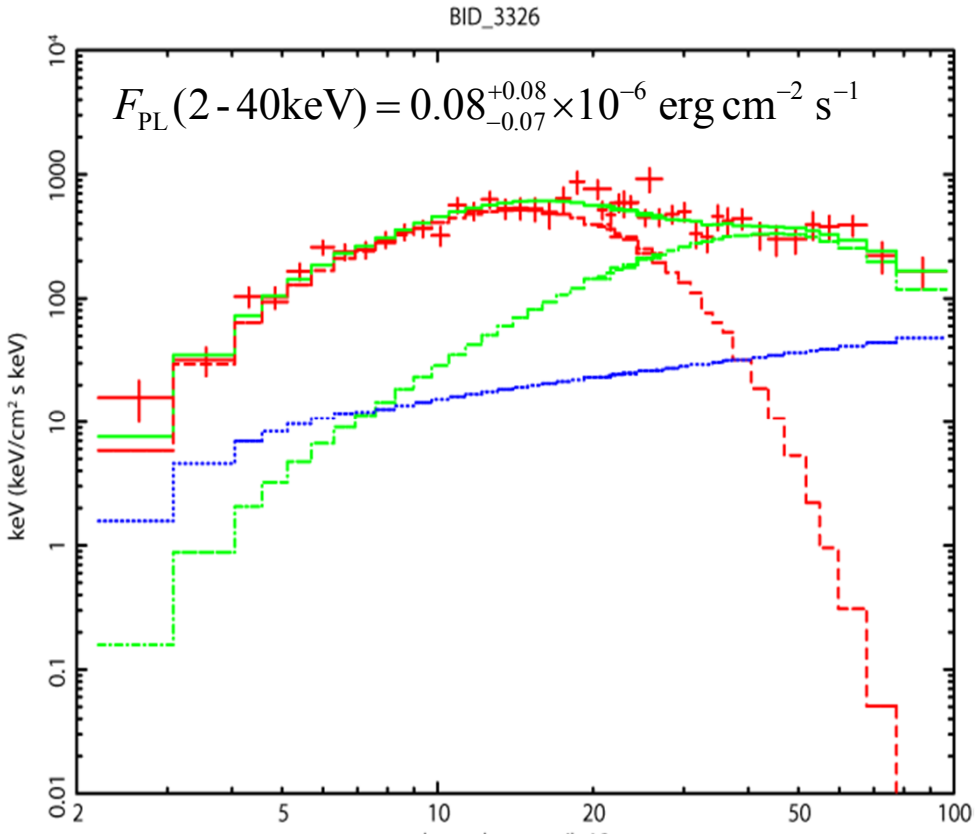
$\Gamma = 1.5$ (SGR 1806−20) fixed (Enoto et al. 2011)

Flux of Hard X-ray Component

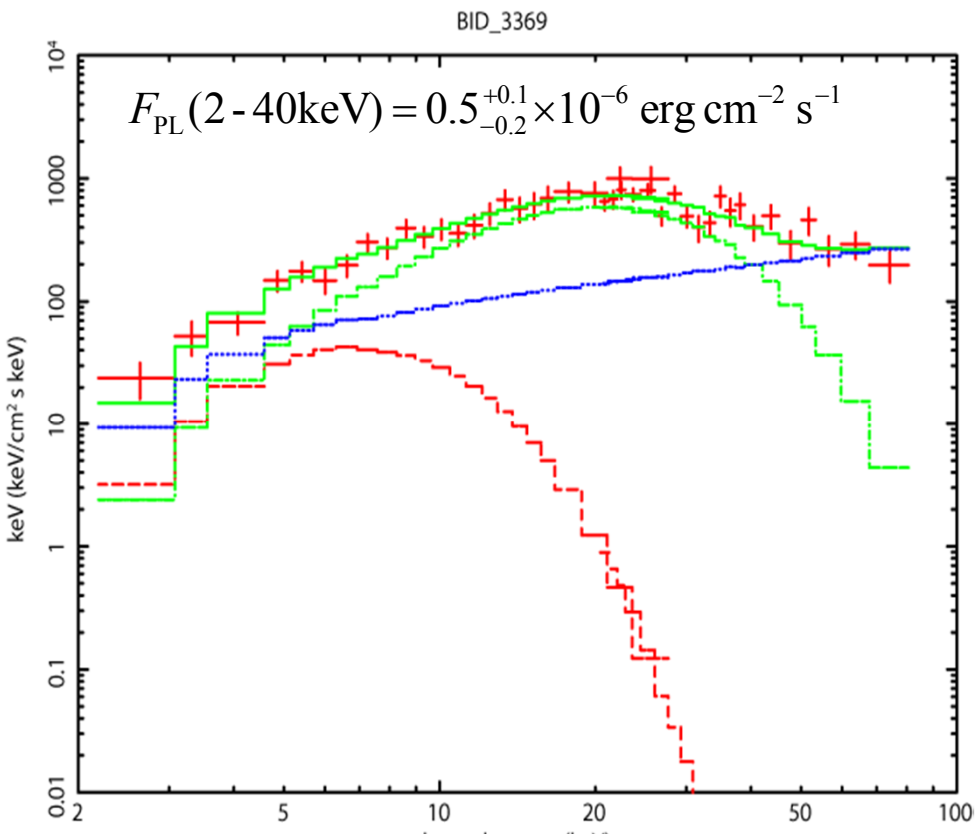
28 Bursts : Estimated with Errors

22 Bursts : Upper Limits

BID 3326 BID : Burst ID



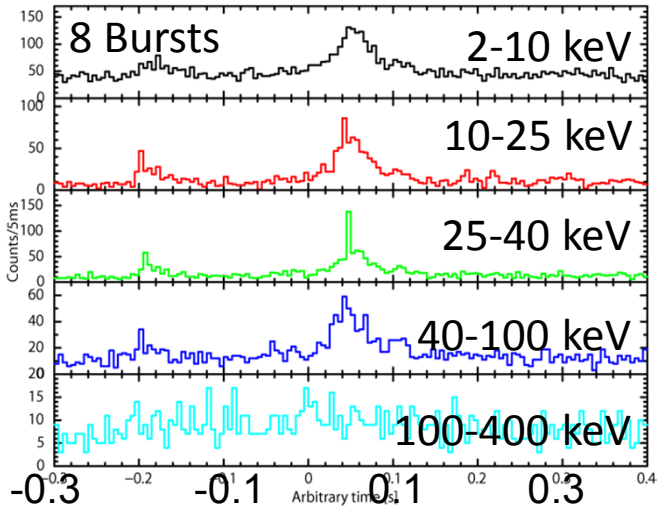
BID 3369 BID : Burst ID



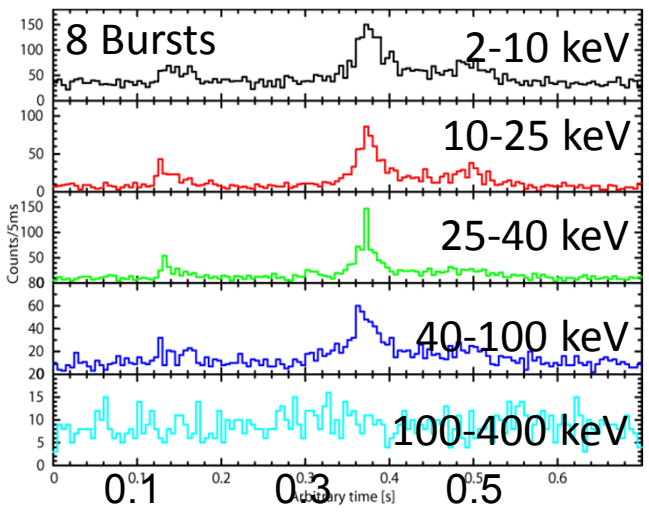
SGR Bursts – Summed Light Curves

- The BB temperatures of the SGR bright bursts are almost constant.
- We divided 50 SGR bursts into the following 6 groups and re-analyzed them individually.

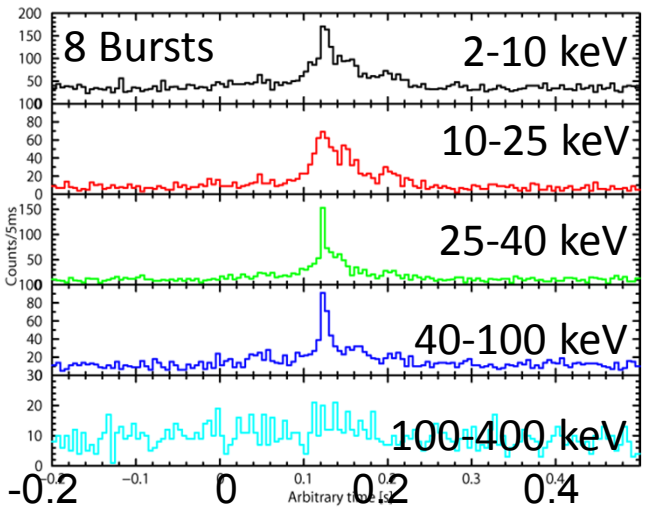
GROUP1 (0.32--0.75 [10^{-6} erg cm^{-2} s^{-1}])



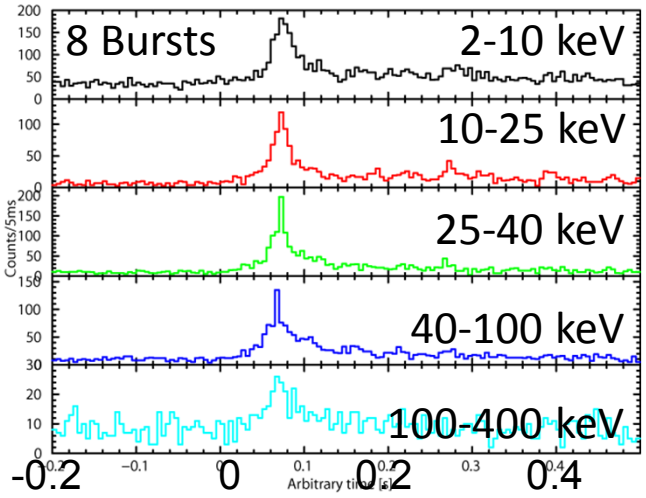
GROUP2 (0.75--1.03 [10^{-6} erg cm^{-2} s^{-1}])



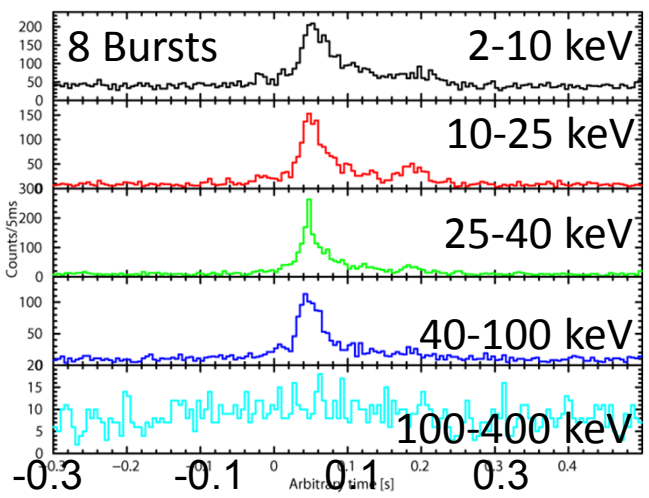
GROUP3 (1.03--1.32 [10^{-6} erg cm^{-2} s^{-1}])



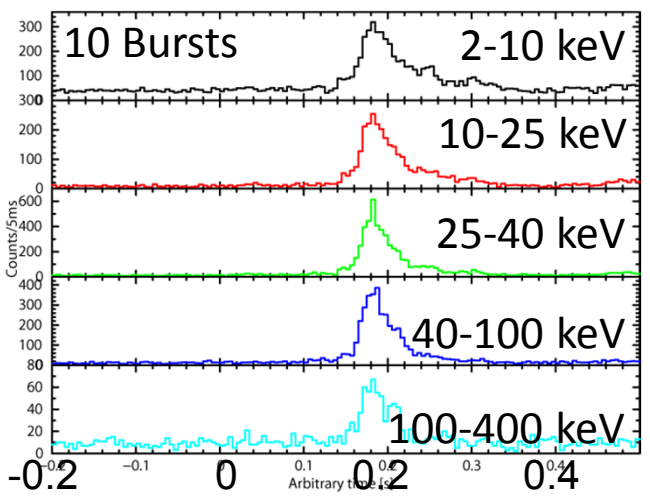
GROUP4 (1.35--1.58 [10^{-6} erg cm^{-2} s^{-1}])



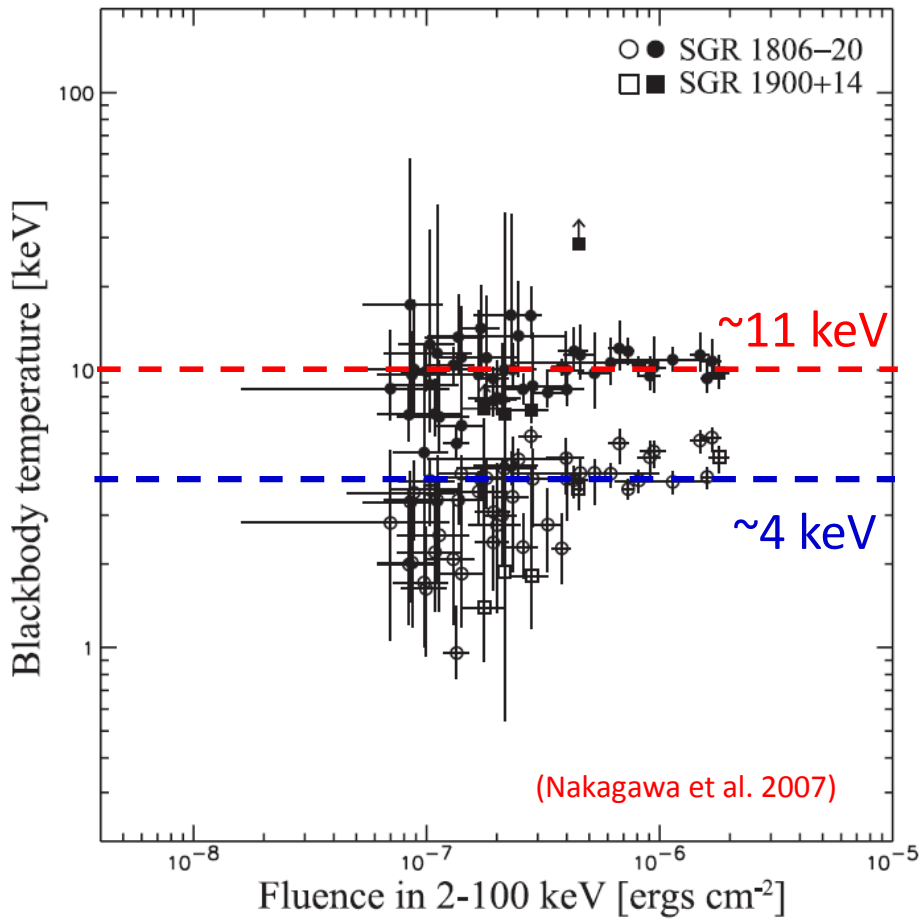
GROUP5 (1.68--2.53 [10^{-6} erg cm^{-2} s^{-1}])



GROUP6 (2.82--7.98 [10^{-6} erg cm^{-2} s^{-1}])



SGR Bursts – 2BB Temperatures



XSPEC Spectral Model

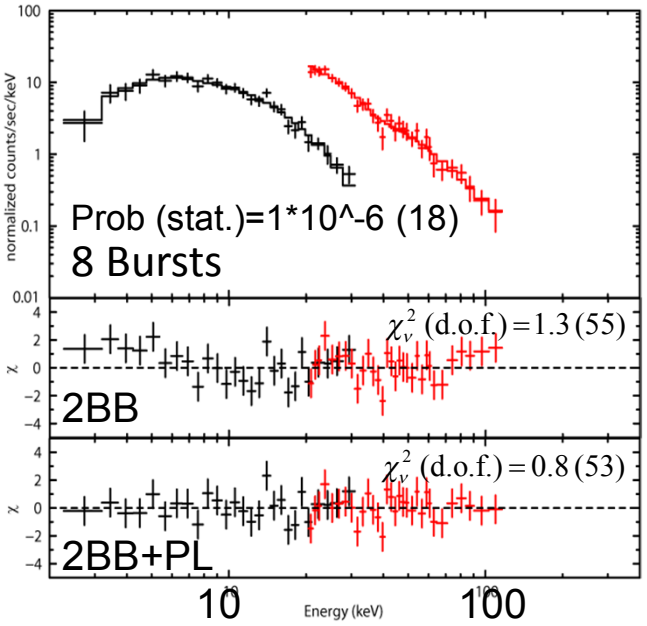
$$N_{\mathrm{H}} \times (\mathrm{Blackbody} + \mathrm{Blackbody} + \mathrm{Powerlaw})$$

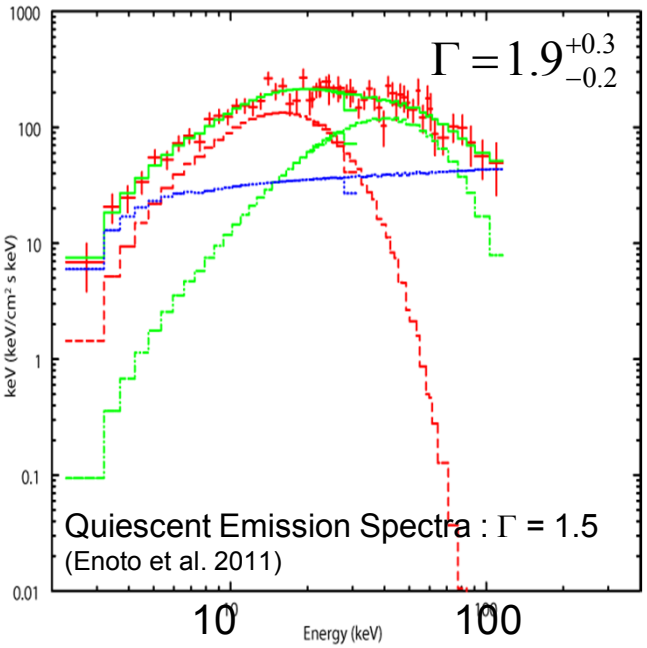
$N_{\mathrm{H}} = 7.8 \times 10^{22}\ [\mathrm{cm}^{-2}]$ fixed (Nakagawa et al. 2009)

$\Gamma = \mathrm{free\ parameter}$

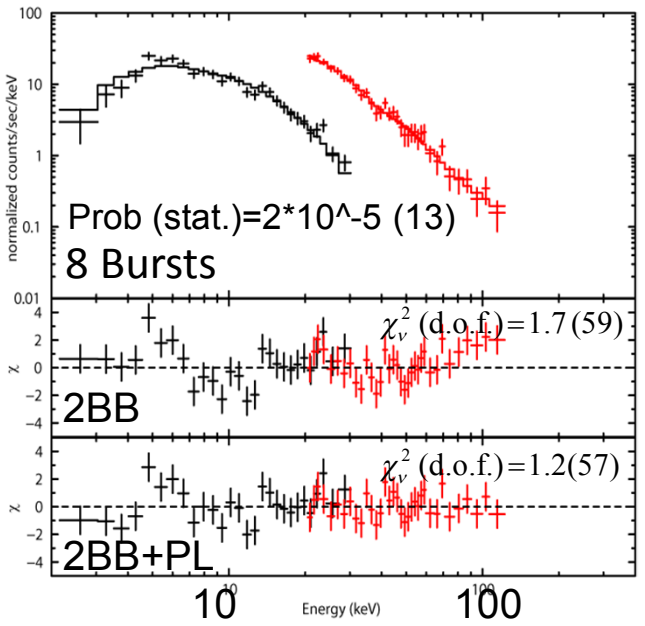
SGR Bursts – Summed Spectra (1)

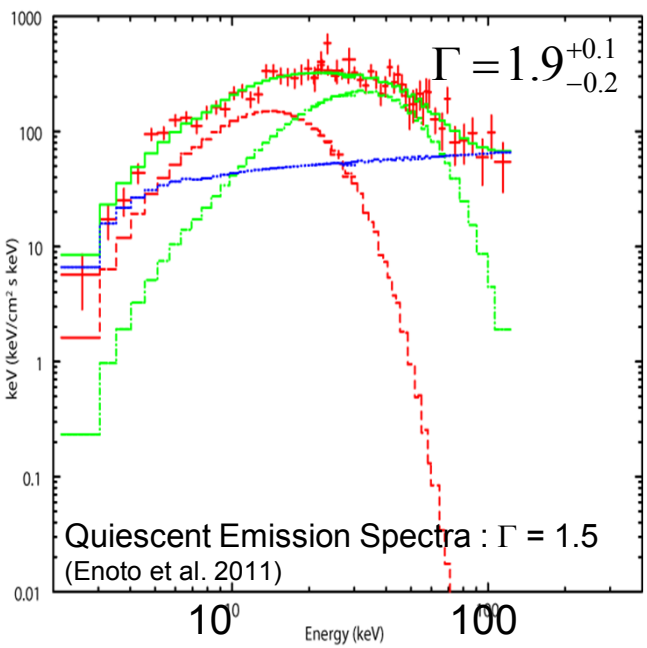
GROUP1 (0.32--0.75 [10^{-6} erg cm^{-2} s^{-1}])



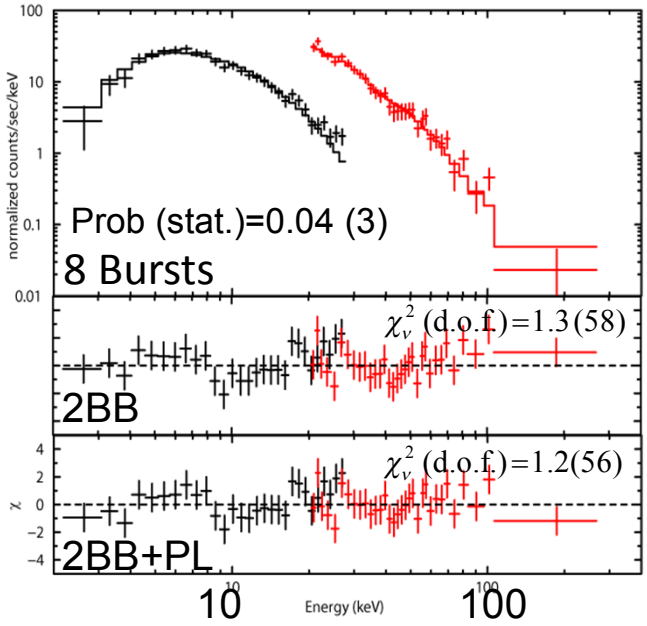


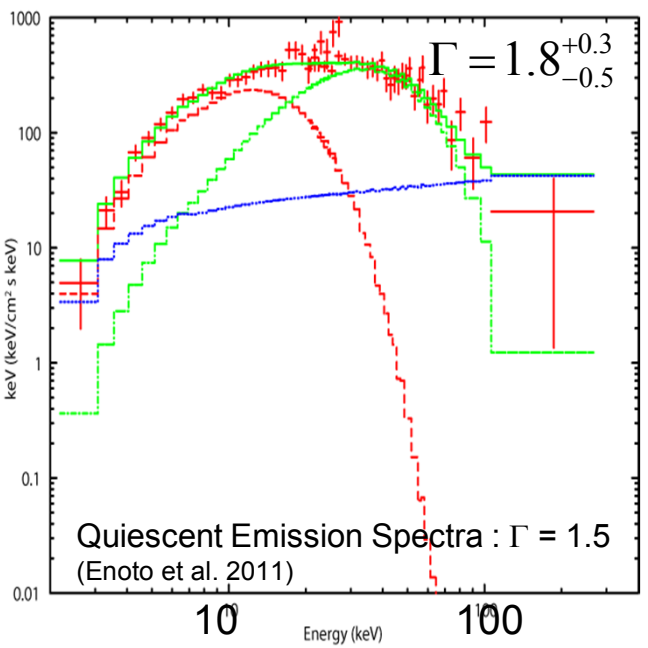
GROUP2 (0.75--1.03 [10^{-6} erg cm^{-2} s^{-1}])





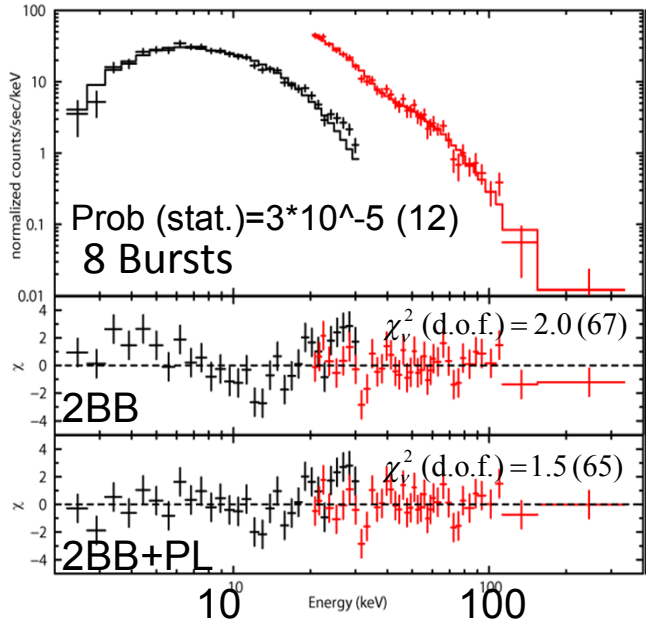
GROUP3 (1.03--1.32 [10^{-6} erg cm^{-2} s^{-1}])

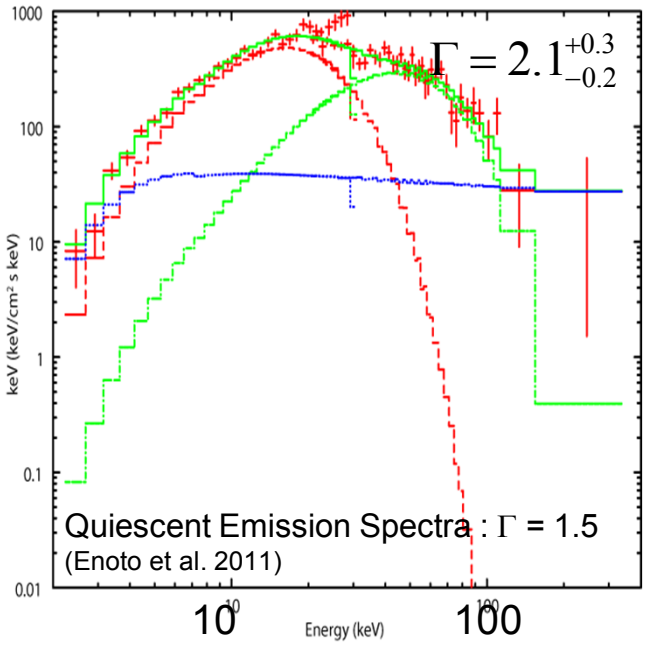




SGR Bursts – Summed Spectra (2)

GROUP4 (1.35--1.58 [10^{-6} erg cm^{-2} s^{-1}])





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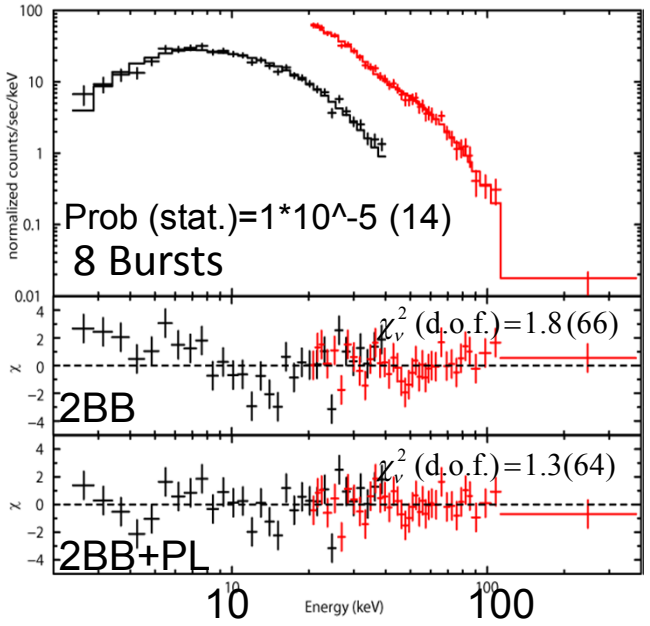

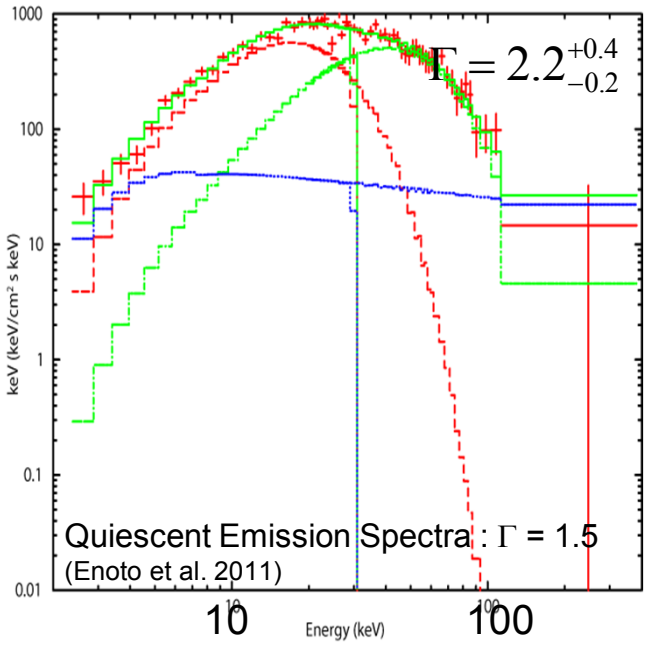

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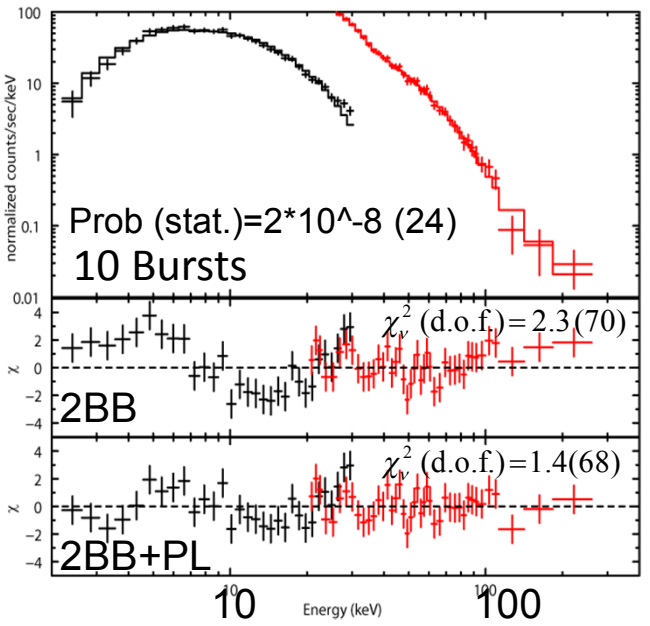
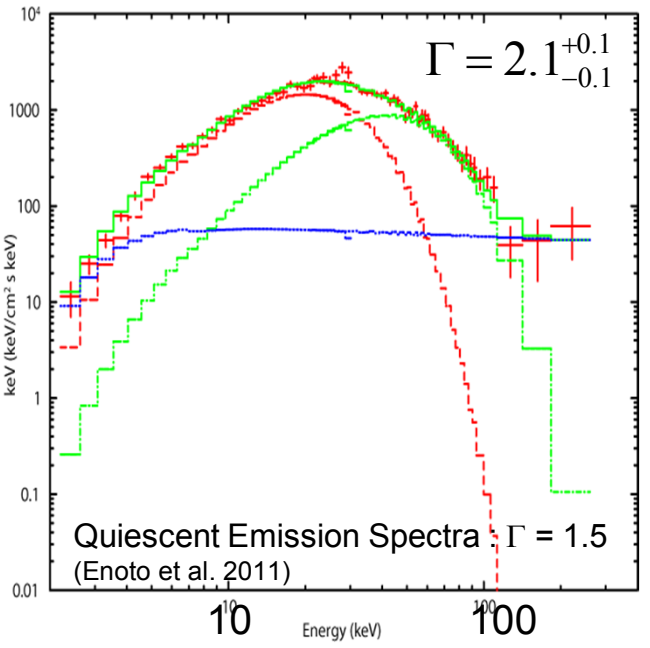


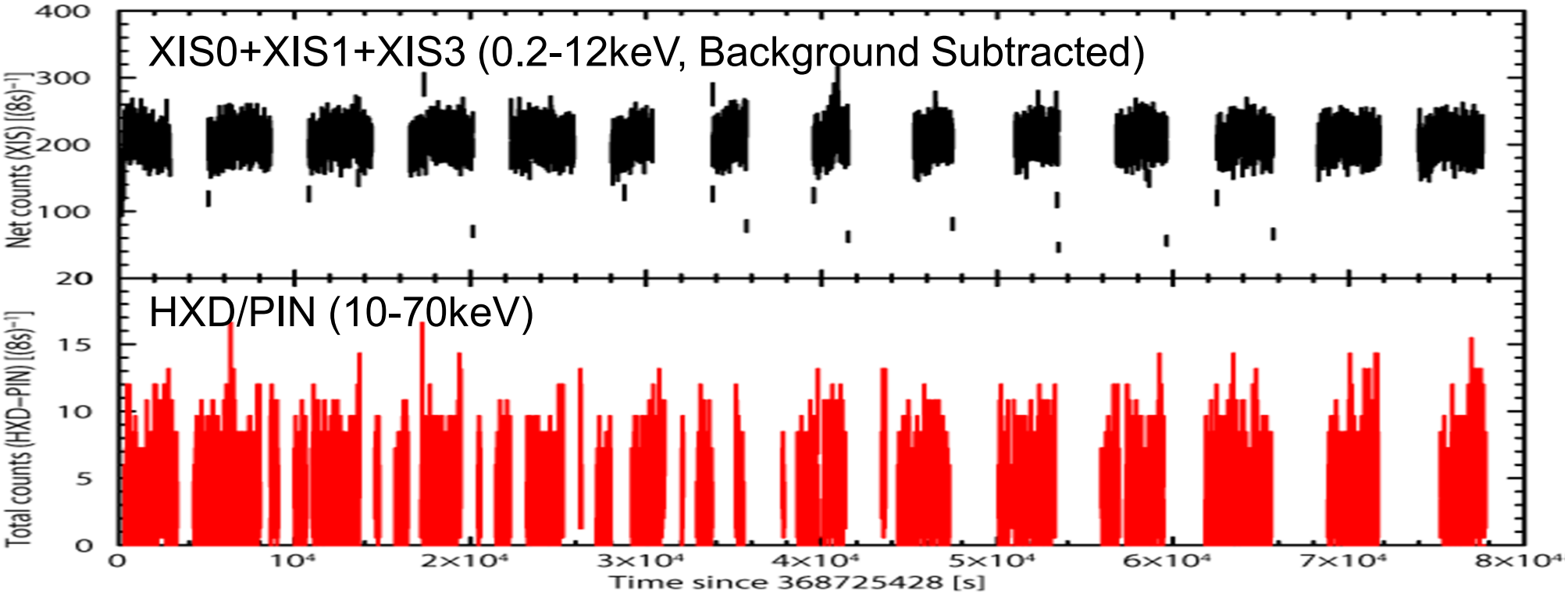


Suzaku ToO Observation of AXP 4U 0142+614

Observation during Active Interval

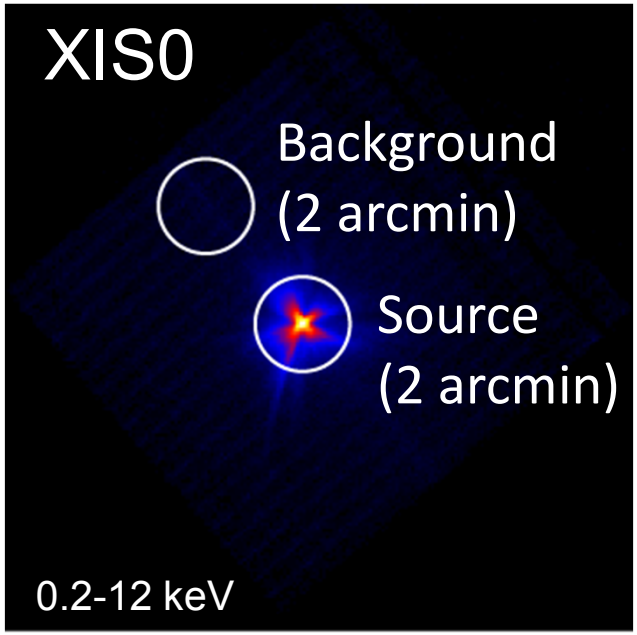
- ObsID : 406031010 (AO-6)
- Date : 2011-09-07 15:44:36 -- 2011-09-08 13:46:21
- Nominal Position : XIS
- XIS Mode : XIS0&XIS1-->Normal, XIS3-->1/4Window

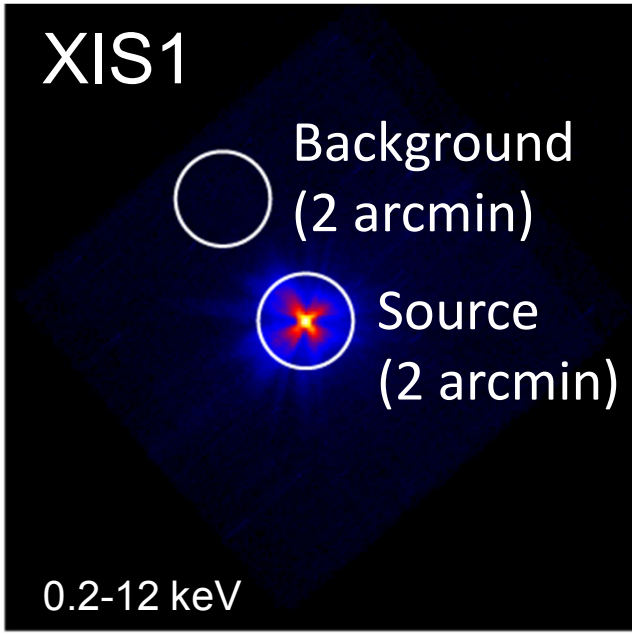
- Net Exposure : XIS-->41ks, HXD/PIN-->42ks
- No obvious bursts.

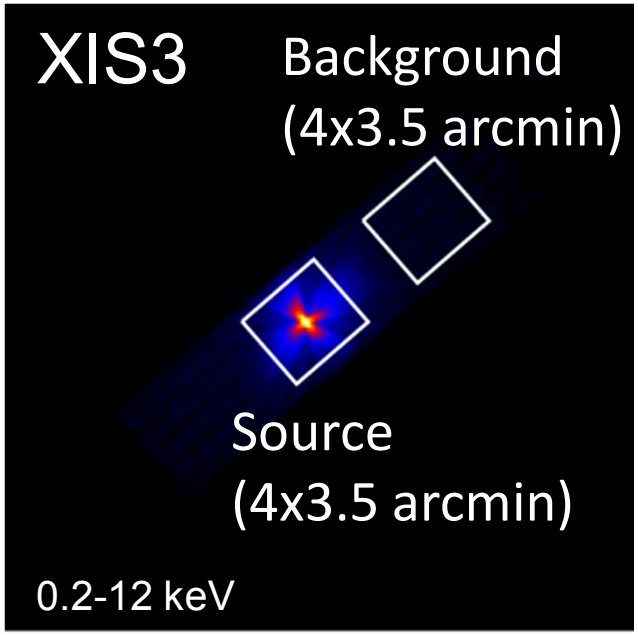


AXP 4U 0142+614 – Source and Background Regions

Source and Background Regions

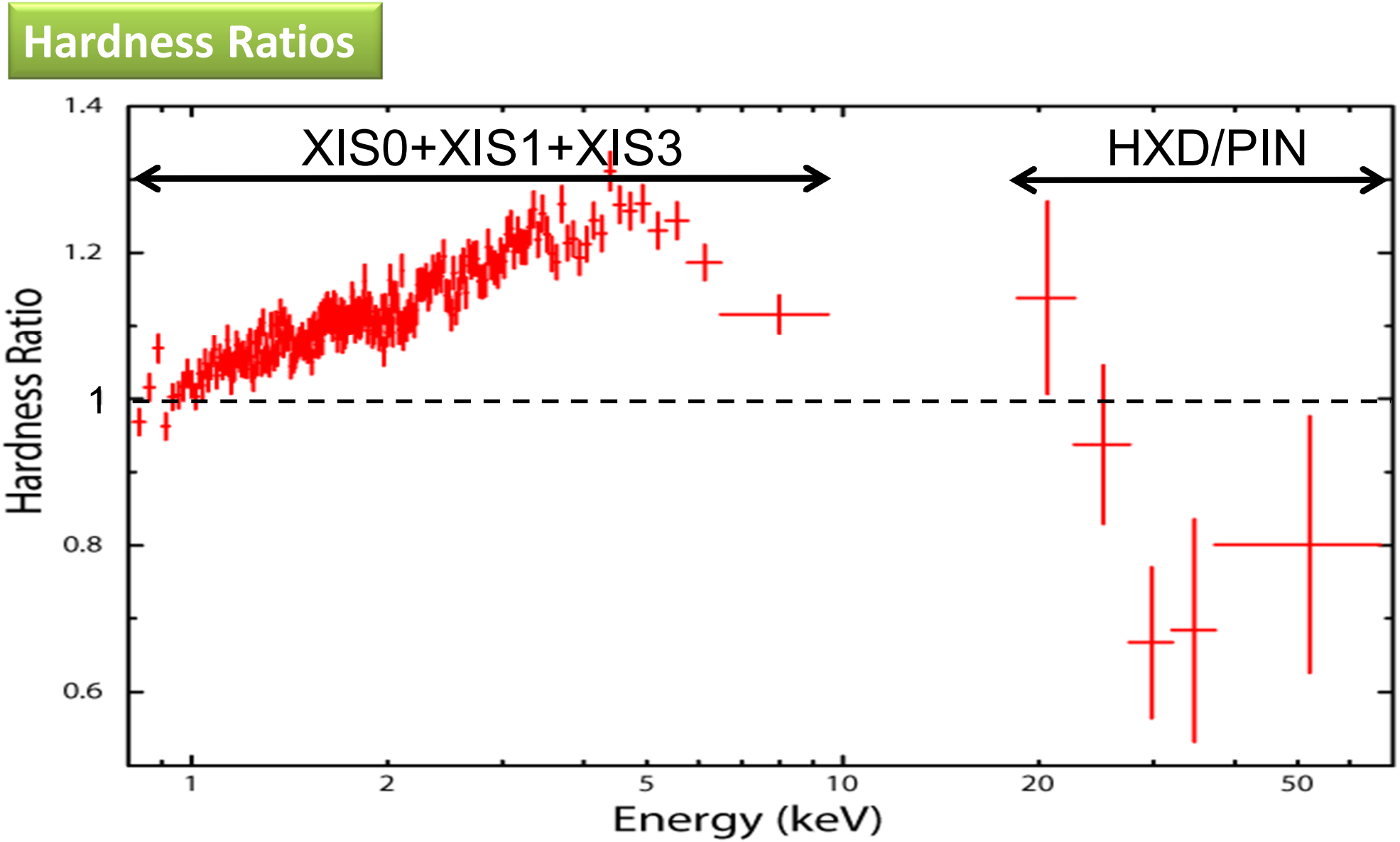






AXP 4U 0142+614 – Hardness Ratios

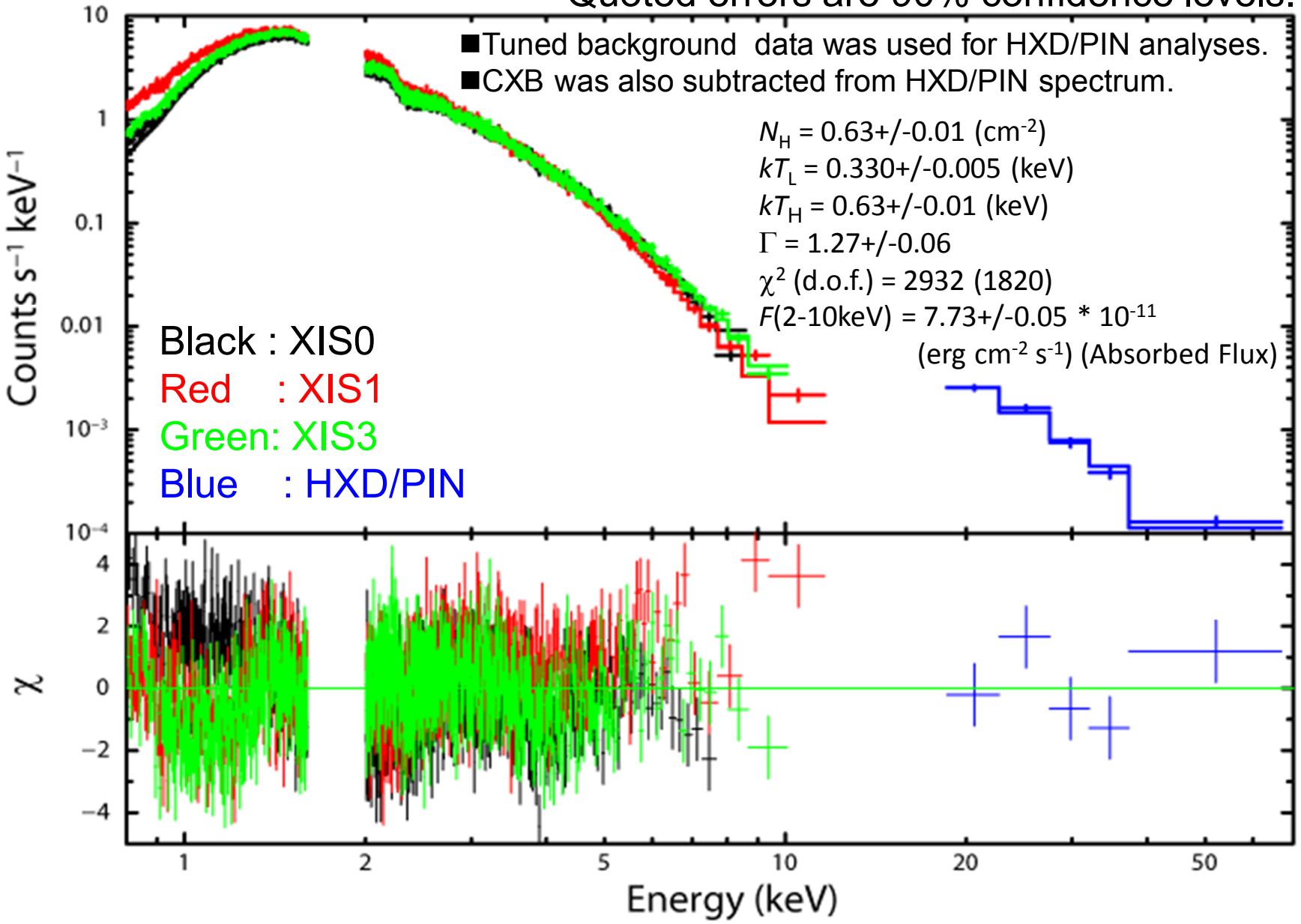
■Ratio of active and quiescent phase spectra.



AXP 4U 0142+614 – Spectra

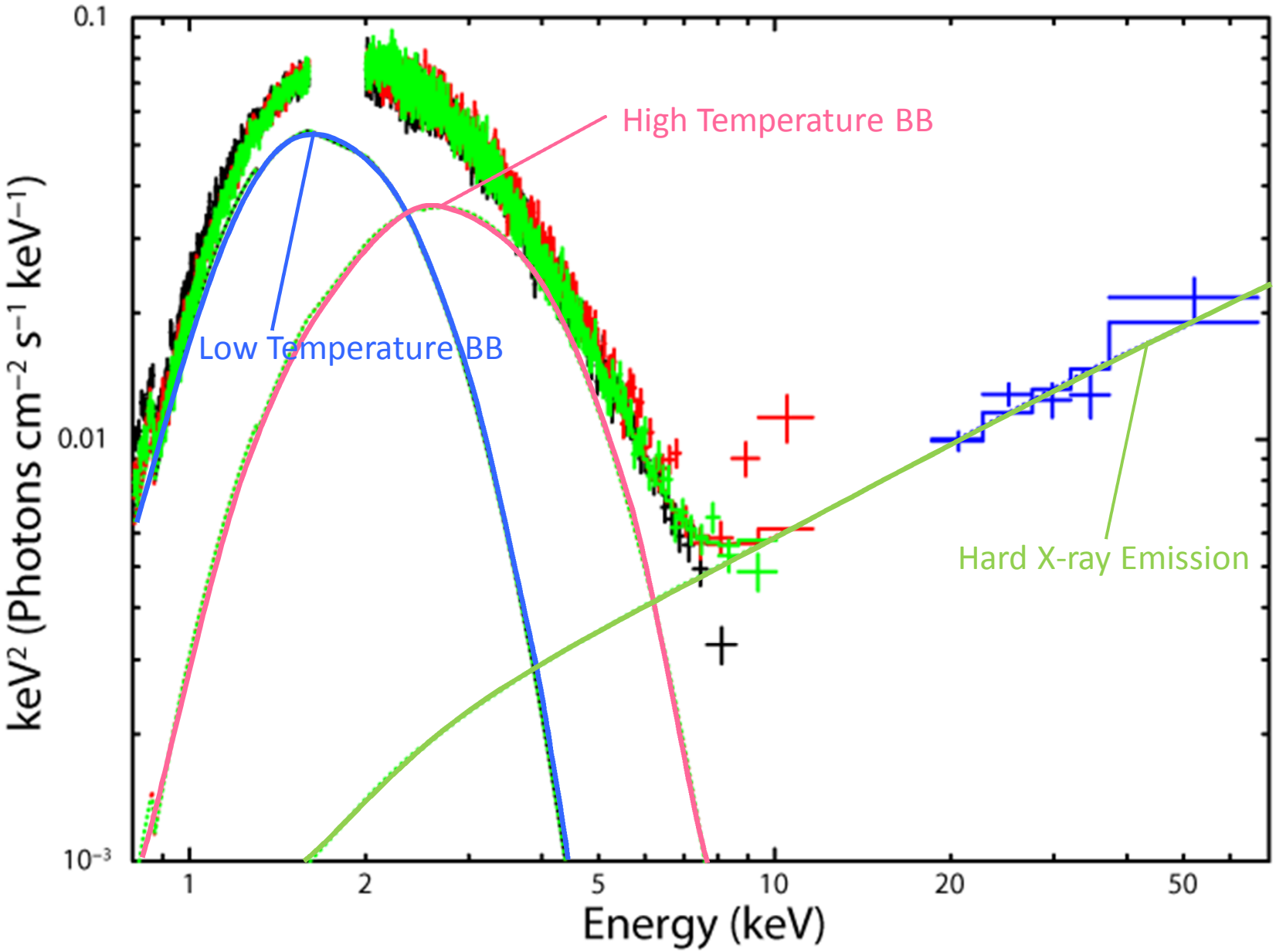
Spectrum

Quoted errors are 90% confidence levels.



AXP 4U 0142+614 – νF_ν Spectra

νF_ν Spectrum



AXP 4U 0142+614 – Spectral Parameters

Spectral Parameters in Active Phase and Quiescent Phase

■Quoted errors are 90% confidence levels.

	Active Phase	Quiescent Phase (*)	
N_H (cm^{-2})	0.63+/-0.01	0.627+/-0.007	
kT_L (keV)	0.330+/-0.005	0.331+/-0.004	
kT_H (keV)	0.63+/-0.01	0.60+/-0.01	
Γ	1.27+/-0.06	1.53+/-0.11	
L_{2BB} (10^{36} erg s^{-1})	0.452 (-0.10, +0.12)	0.431+/-0.008	~5%
L_{PL} (10^{36} erg s^{-1})	0.102 (-0.006, +0.007)	0.086 (-0.009, +0.010)	~19%
χ^2 (d.o.f.)	2932 (1820)	3386 (2508)	

(*) See Enoto et al. 2011 for detailed analyses.

Summary

Bright Bursts of SGR 1806-20

■We re-analyzed 50 bright bursts from SGR 1806-20 detected by HETE-2, in order to examine effects of the hard X-ray component on them.

■Some bright bursts are well fitted by the two-blackbody model plus the power-law model.

Persistent Emission of AXP 4U 0142+614

■The Suzaku ToO (AO-6) observation of AXP 4U 0142+614 was performed on 7 September 2011 in active phase.

■The spectra during the active phase might be harder than that during the quiescent phase.