Origin of the Galactic Ridge X-ray Emission (GRXE) unresolved

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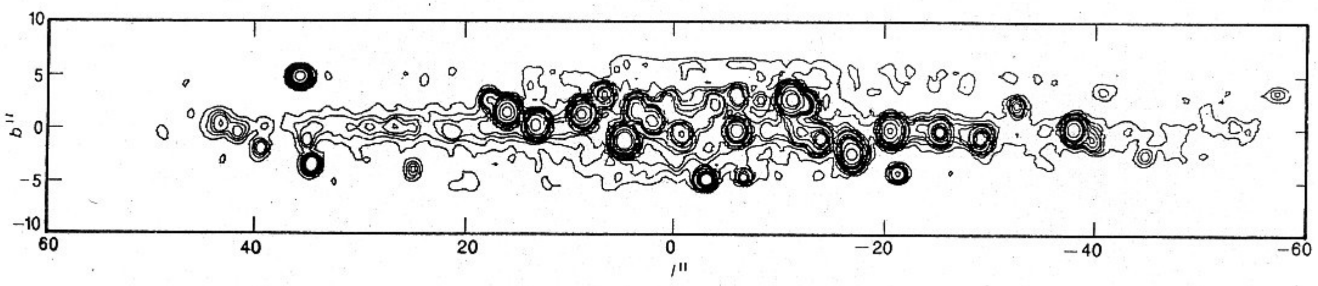
Contents

Contents

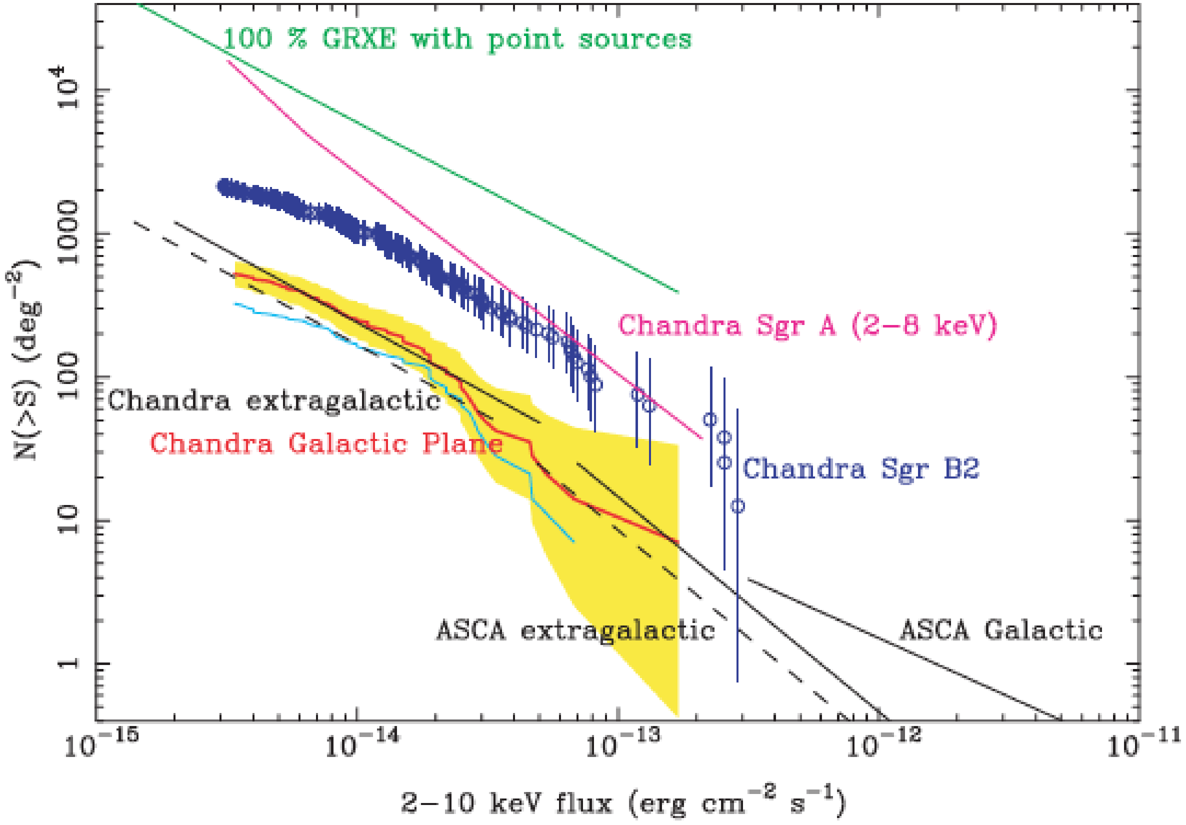
1. Introduction and Summary
2. Diffuse emission in the GRXE
3. Origin of the point sources constituting GRXE

• Galactic “Ridge” X-ray emission

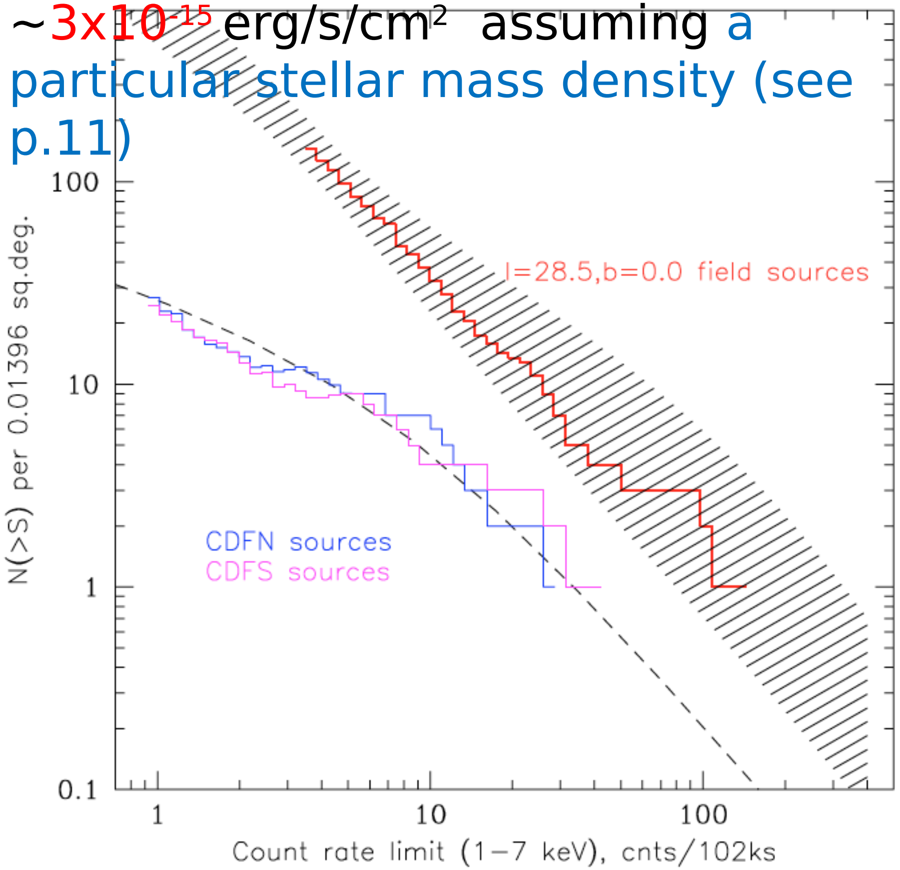


Warwick et al. (1985)

- Ebisawa et al. (2001, 2005)
  ~100 ksec Chandra observation
  at (l,b)=(28.5, 0)
- Resolved ~ 10 % of the emission into point sources with at ~3×10^{-15} erg/s/cm^2 (2-10 keV)

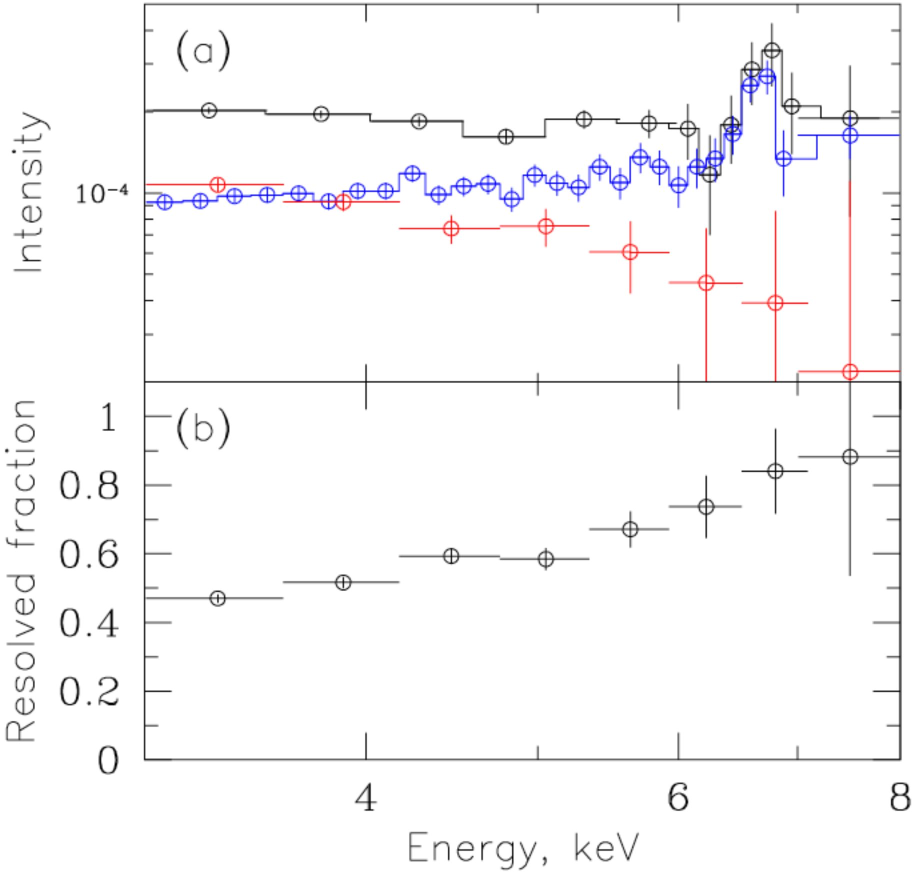


Using the same data,
Revnivtsev and Sazonov (2007) claimed
that Galactic log N-log S steepens below
~3x10^{-15} erg/s/cm^2 assuming a particular stellar mass density (see p.11)



Revnivtsev et al (2009)
carried out ~900 ksec Chandra observation at (l,b)=(0.08, -1.42)

At ~10^{-16} erg/s/cm^2 (0.5-7 keV) ~80% of the GRXE is resolved into point sources



Much more dimmer Galactic point sources?

Is 100 % of the GRXE due to point sources?

Bottom-line

1. Majority of the GRXE is resolved into point sources
2. There is diffuse emission in the GRXE
   - Absolute flux of the GRXE and stellar density still controversial
   - The 6.4 keV line emission is due to cosmic-rays
3. Origin of the point sources unknown yet
   - Most hard X-ray sources exhibit near-infrared absorption lines
   - Likely to be a new class of the Galactic X-ray sources

Contents

Contents

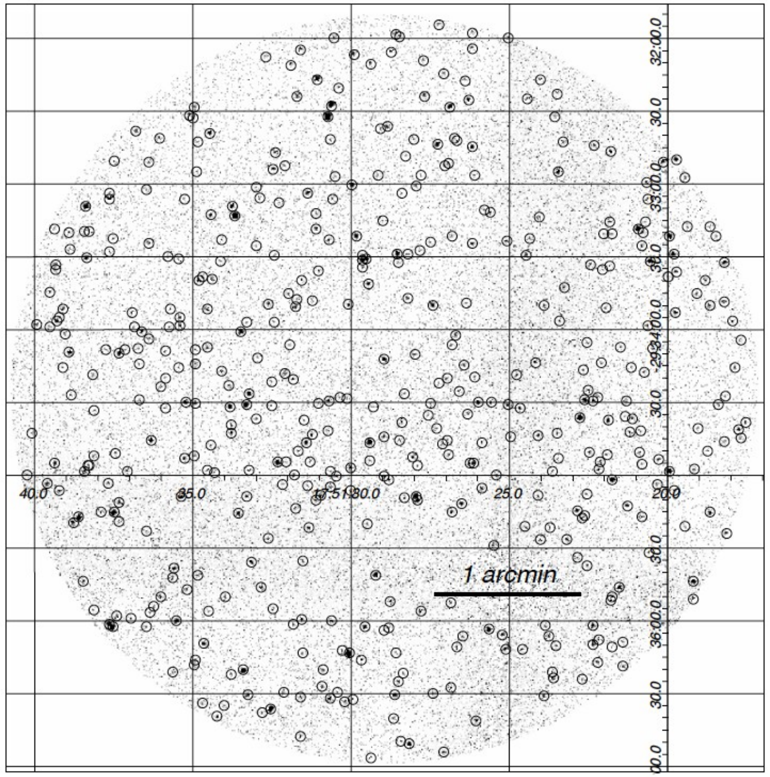
2. Diffuse emission in the GRXE

- 2-1: Uncertainty of absolute flux of the GRXE and Galactic star number densities

- 2-2: 6.4 keV line emission due to Cosmic-ray

Uncertainty of absolute flux of the GRXE

- The GRXE flux may be underestimated



Revnivtsev et al. (2009)

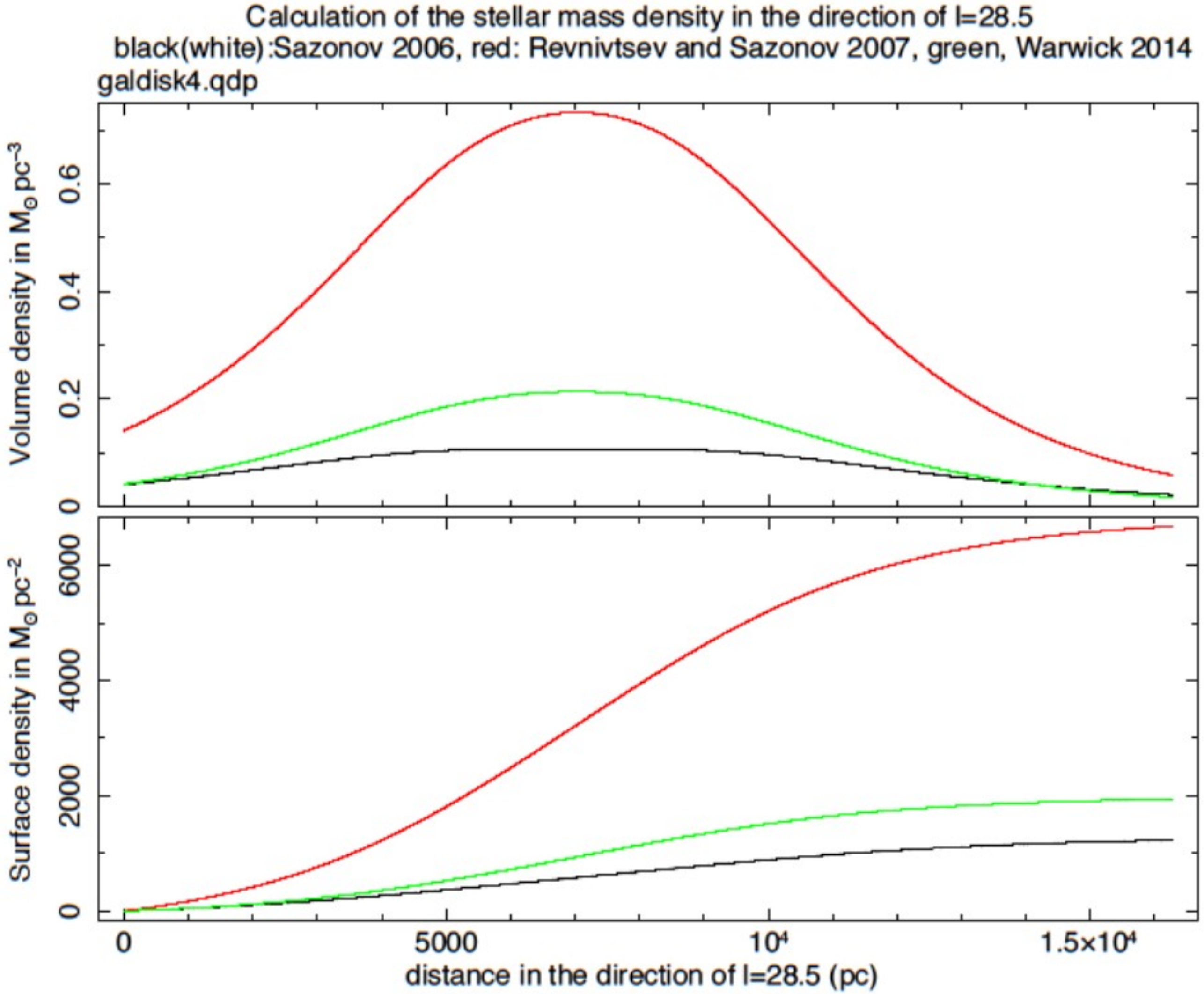
We estimated the GRXE flux subtracting NXB and CXB, compared with Suzaku at the Revnivtsev field

	Surface brightness (erg s^{-1} cm^{-2} deg^{-2})	Contribution of point sources
Suzaku	$(1.09\pm0.02)\times10^{-10}$	49%
Chandra	$(1.01\pm0.01)\times10^{-10}$	53%
Chandra point sources	$(5.32\pm0.07)\times10^{-11}$	—
Revnivtsev et al. 2009	$(7.1\pm0.5)\times10^{-11}$	75%

Suzaku and Chandra GRXE fluxes are consistent.
Point source fraction is ~50%.

Iso, Ebisawa, Tsujimoto (2012)

Galactic stellar number density may be overestimated



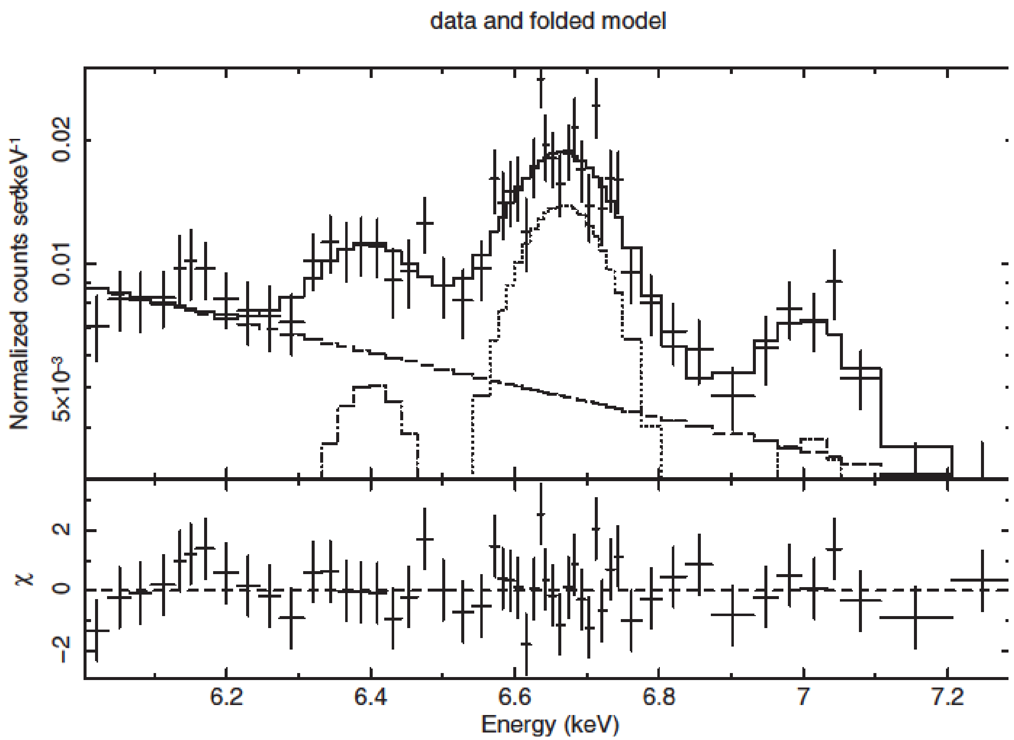
Toward (l,b)=(28.5, 0), very different stellar mass density is assumed by Sazonov (2006), Revnivtsev and Sazonov (2007) and Warwick (2014)

Revnivtsed and Sazonov (2007) adopts the largest stellar density

Depending assumption, >100 % of the GRXE emission maybe explained by point sources!

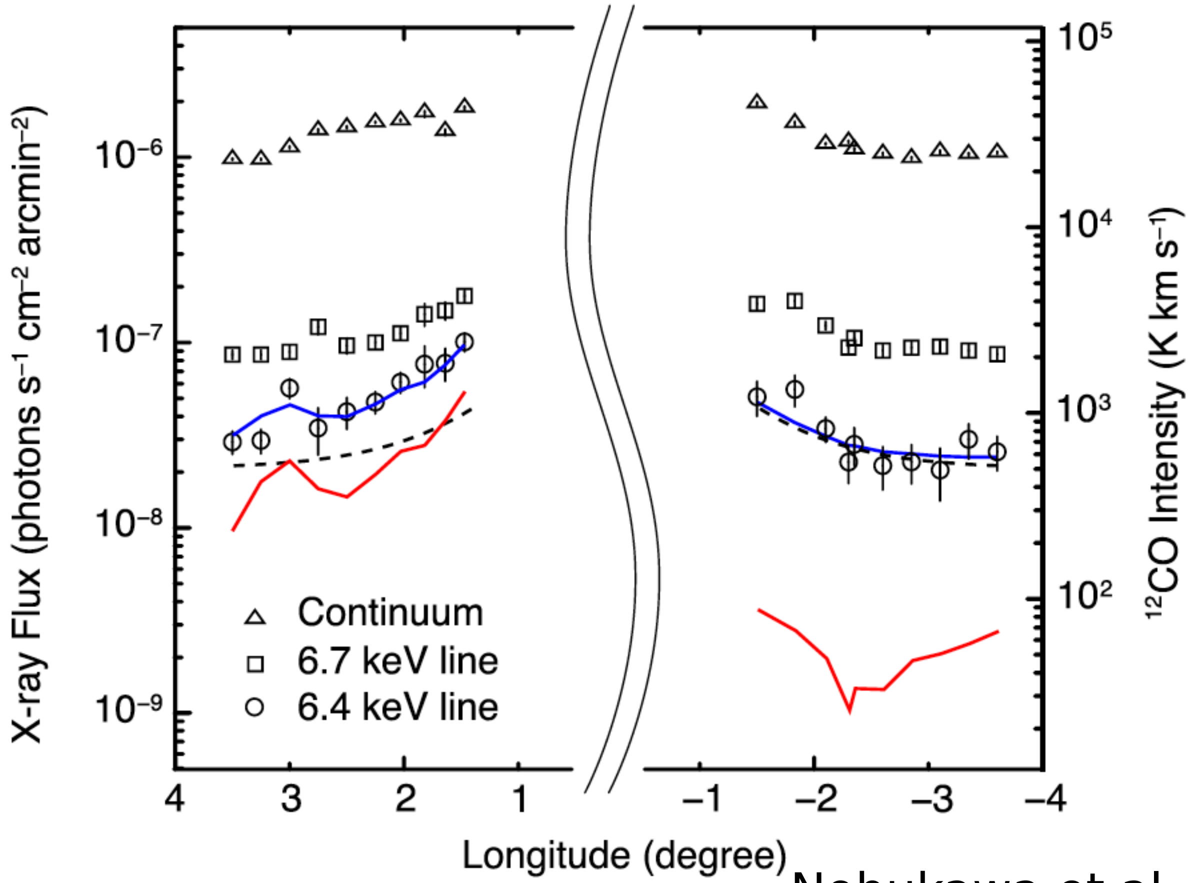
Eze, Saitou, Ebisawa (2015)

2-2: 6.4 keV line emission due to Cosmic rays



Suzaku spectra at (l,b)=(28.5, 0.0) field

Ebisawa et al. (2008)

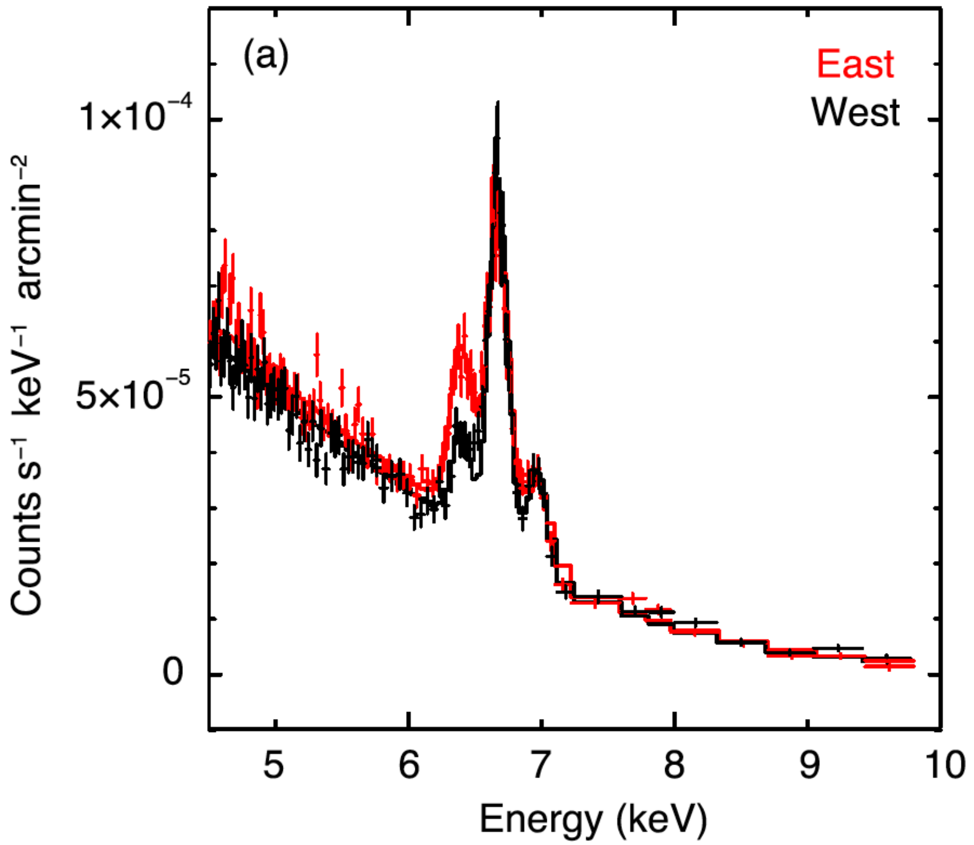


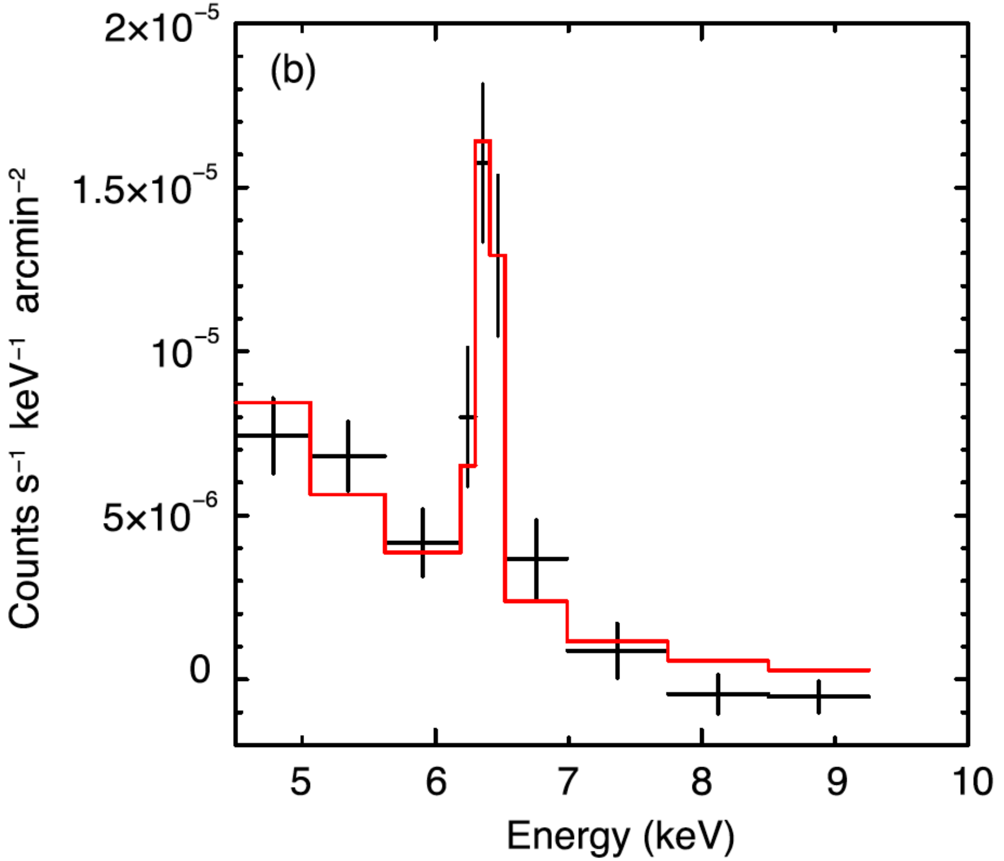
Nobukawa et al. (2015)

Significant asymmetry only in the 6.4 keV line

Correlated with Molecular cloud distribution

Subtract west from east





Nobukawa et al. (2015)

Interaction of molecular clouds and high energetic cosmic-rays can explain the 6.4 keV line flux
Contribution to the continuum not estimated well

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- We have carried out Near-infrared (NIR) spectroscopy of the point sources at both (l,b)=(28.5, 0) and (0.08, -1.42) fields
- If hard X-ray sources are CVs, we should expect NIR emission lines from the irradiated accretion disk
- However, most of the hard X-ray sources exhibited NIR absorption lines (characteristics of late-type stars).
- They are likely to be detached binaries of white-dwarfs and late-type companions

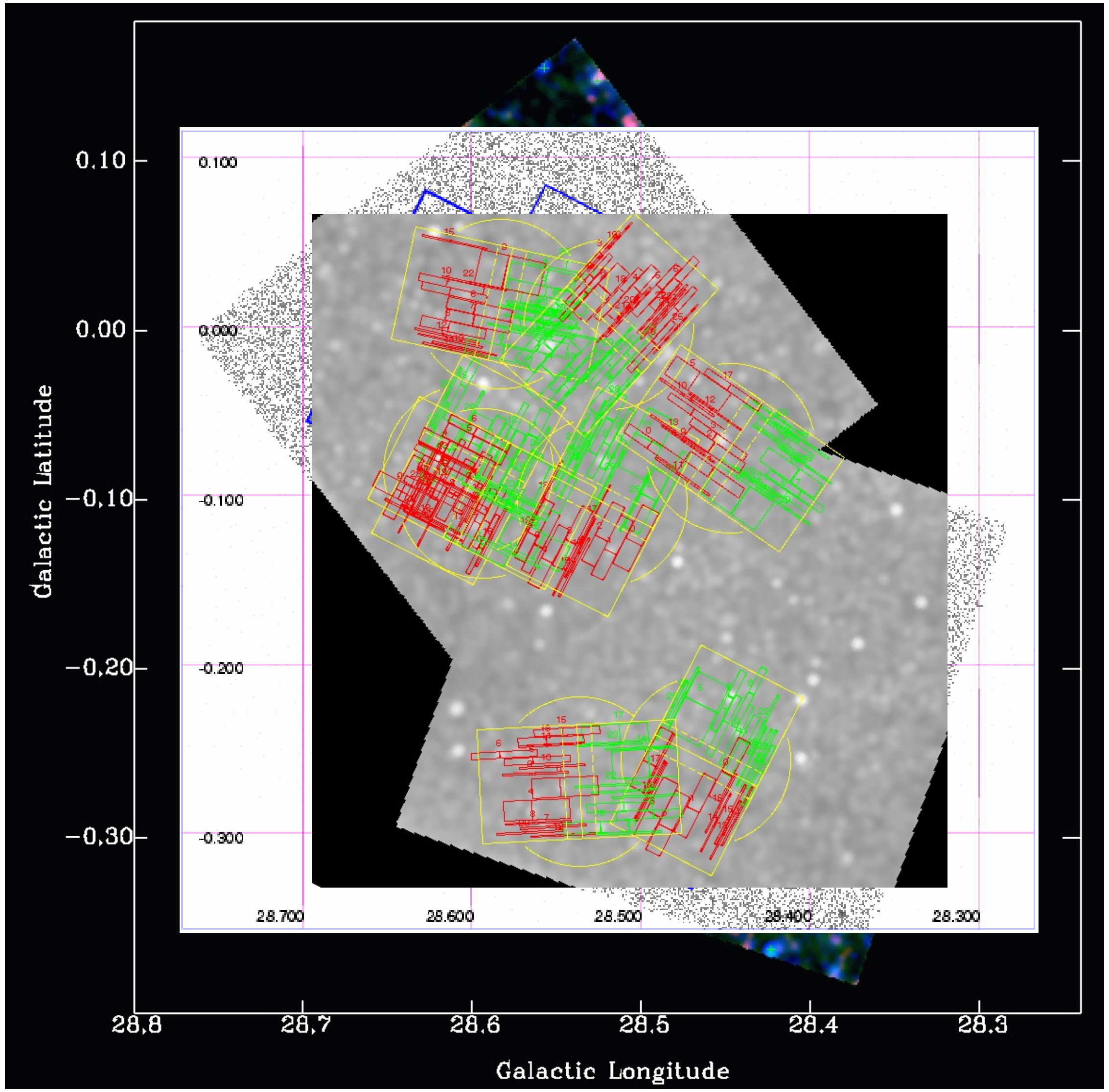
Morihana et al. (2016)

Ebisawa field (l,b)=(28.5°,0.0°)

X-ray image (*Chandra*)
274 X-ray sources
(down to ~10^{-15} erg/cm^2/s, Ebisawa et al., 2005)

ESO, NTT/SofI
142 sources Ided
down to Ks~15 mag
(Ebisawa et al., 2005)

Subaru/MOIRCS
Well-exposed
42 spectra

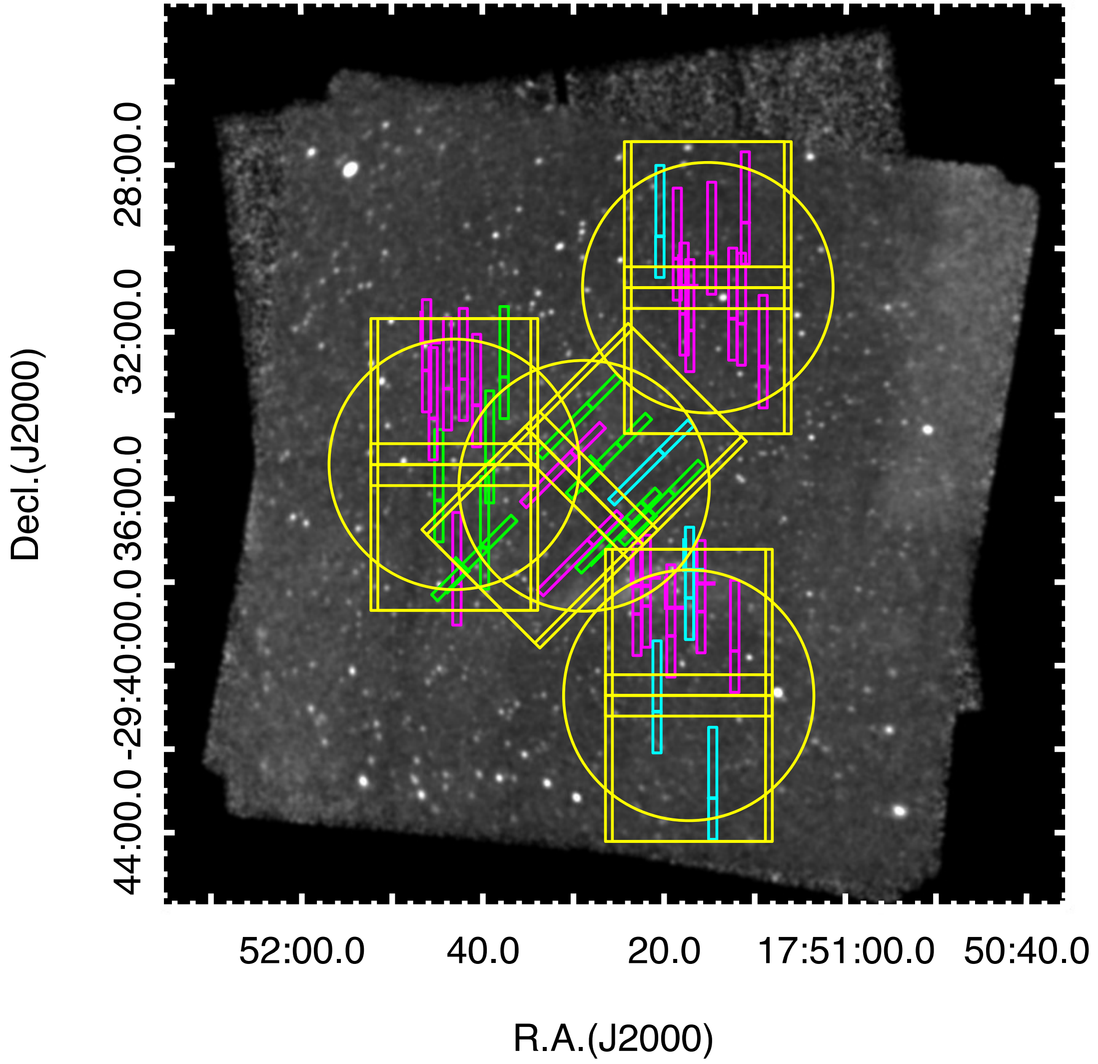


Chandra Bulge Field (l,b)=(0.0°,-1.4°)

X-ray image
(*Chandra*)
2002 X-ray sources
(down to ~10^{-16} erg/cm^2/s,
Morihana et al., 2013)

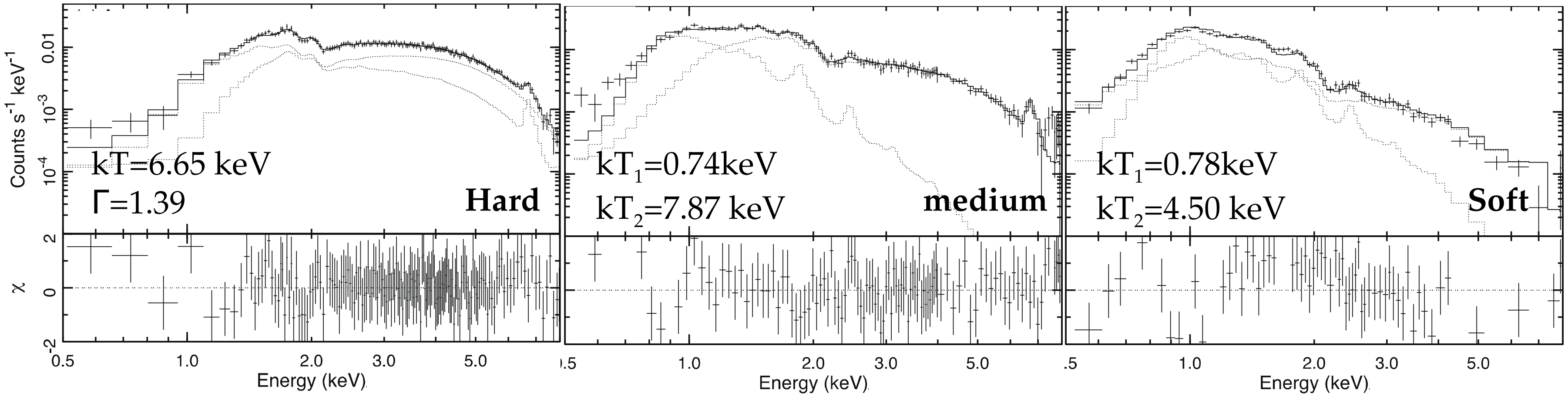
IRSF/SIRIUS
222 sources Ided
down to Ks~16 mag
(Morihana et al., 2016)

Subaru/MOIRCS
Well-exposed
23 spectra



X-ray Results

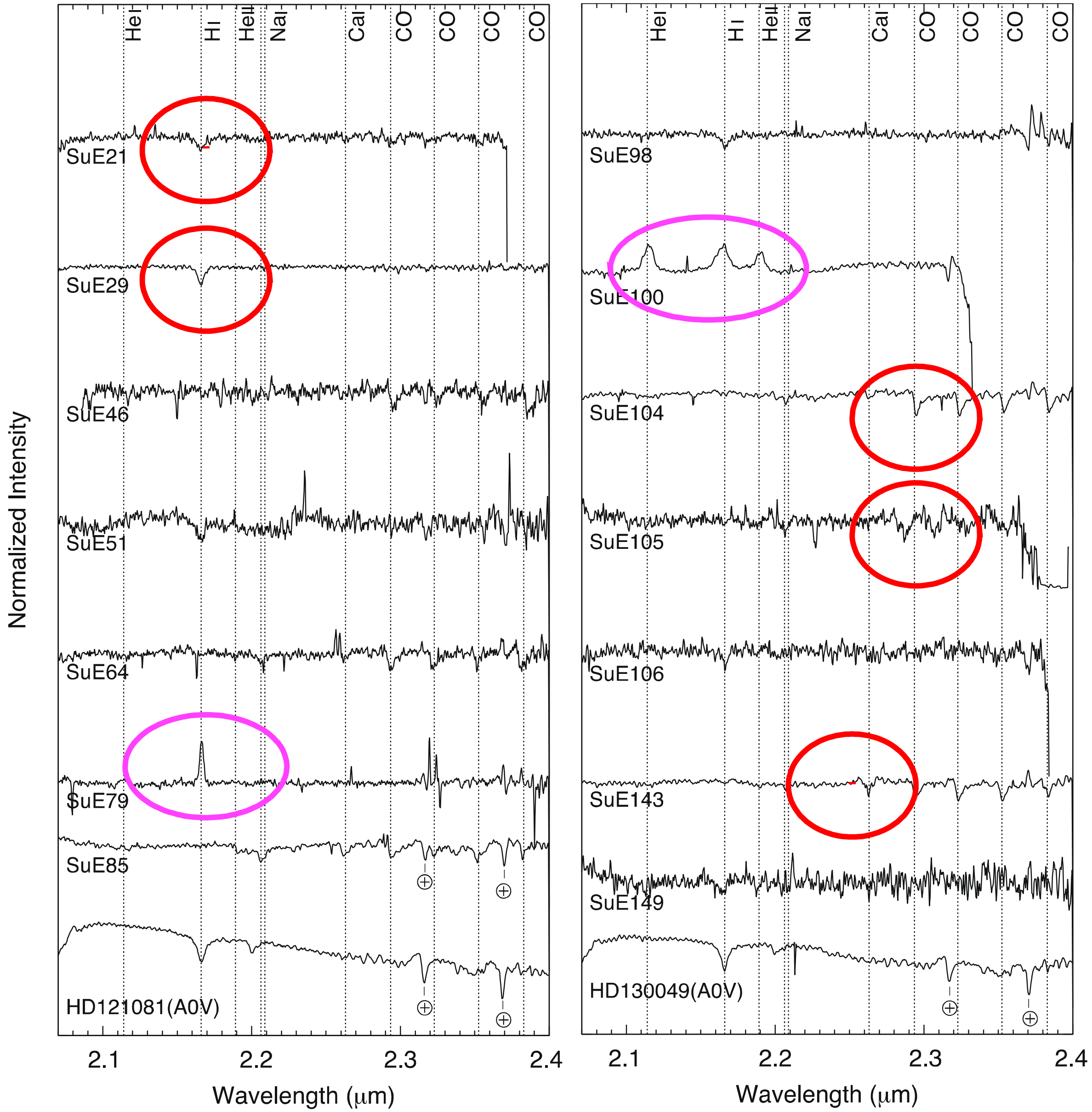
- We classified X-ray sources into three groups (hard, medium, soft) based on X-ray hardness and made composite X-ray spectrum of each group.



(Morihana et al., 2013)

- High temperature plasma with the Fe K lines
- Medium temperature plasma with the Fe K lines
- Low temperature plasma with weak Fe K lines

NIR spectra



- We obtained 65 well-exposed NIR spectra (R~1400) in both fields
- We divided NIR spectra into two types:
  - absorption lines such as H I, Na I, Ca I, and CO bandhead features
    →Late-type stars
  - emission lines such as HI, HeI, and HeII
    →Cataclysmic Variables (CVs)

(Morihana et al.,2016)

Source Classification

We further classify target sources based on X-ray and NIR features

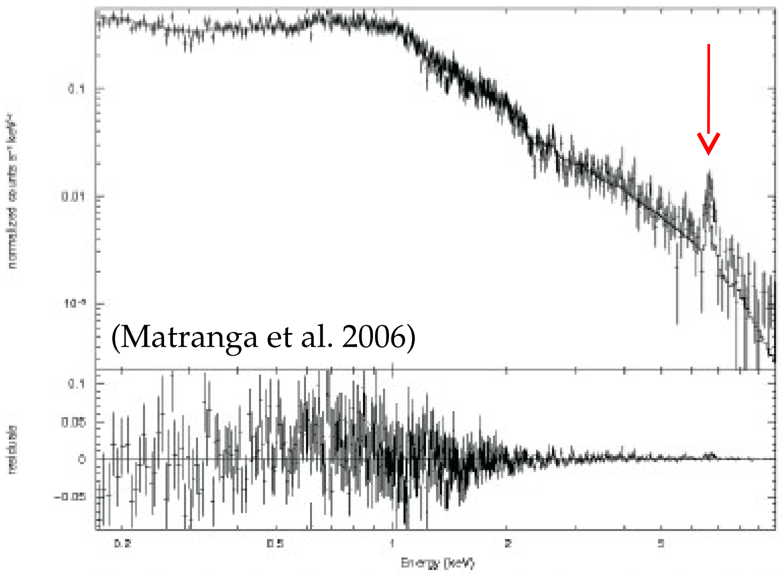
X-ray	NIR	
hard	Emission lines (HI, HeI, HeII)	→ CVs (class A), 2 sources
	Absorption lines (HI, NaI, CO)	→ New type (class B), 17 sources
medium	Absorption lines (HI, NaI, CO)	→ Late-type stars on flare (class C) } 46 sources
soft	Absorption lines (HI, NaI, CO)	→ Late-type stars on quiescence (class C) } 46 sources

- CVs and **late-type stars** are predicted populations
- Only two hard sources are considered to be CVs
- **Most X-ray hard sources (17 of 19) do not have NIR spectra with emission lines, but absorption lines**
- **These had sources are "new class", presumably, detached binaries of white dwarfs and low-mass companins**

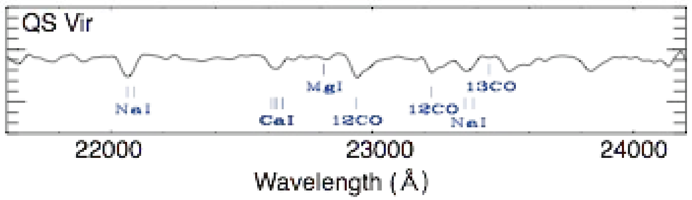
Candidates of New class of hard X-ray sources

Pre Cataclysmic Variables

- detached binaries including white dwarf and dwarfs

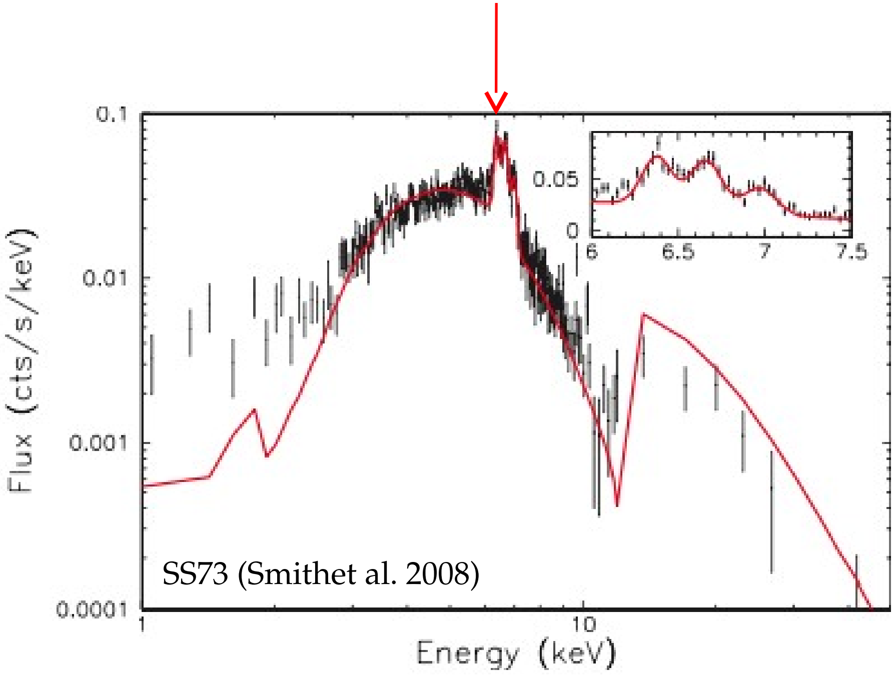


(Matranga et al. 2006)



Symbiotic binary

- detached binaries composed of white dwarf and red giants



SS73 (Smithet al. 2008)

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