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# The origin of the Galactic Ridge X-ray Emission


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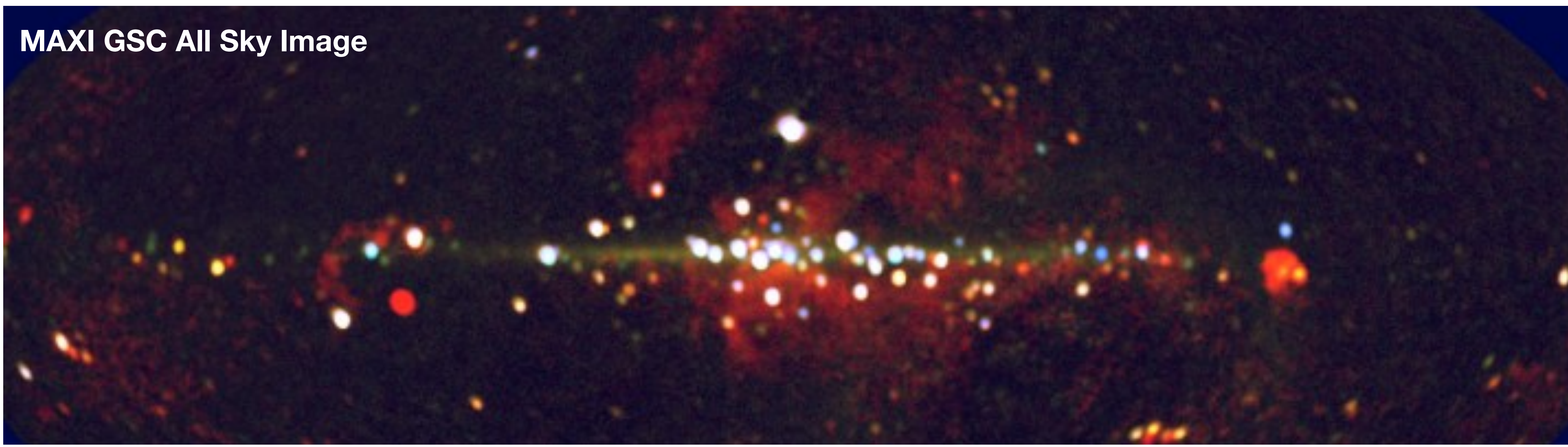


Related publications:
- Yuasa et al. 2010, A&A, 520, A25
- Yuasa et al. 2012, ApJ, 753, 129
- Yuasa, Springer Theses Series, January 2013

EAYAM 2015, Taipei, Taiwan

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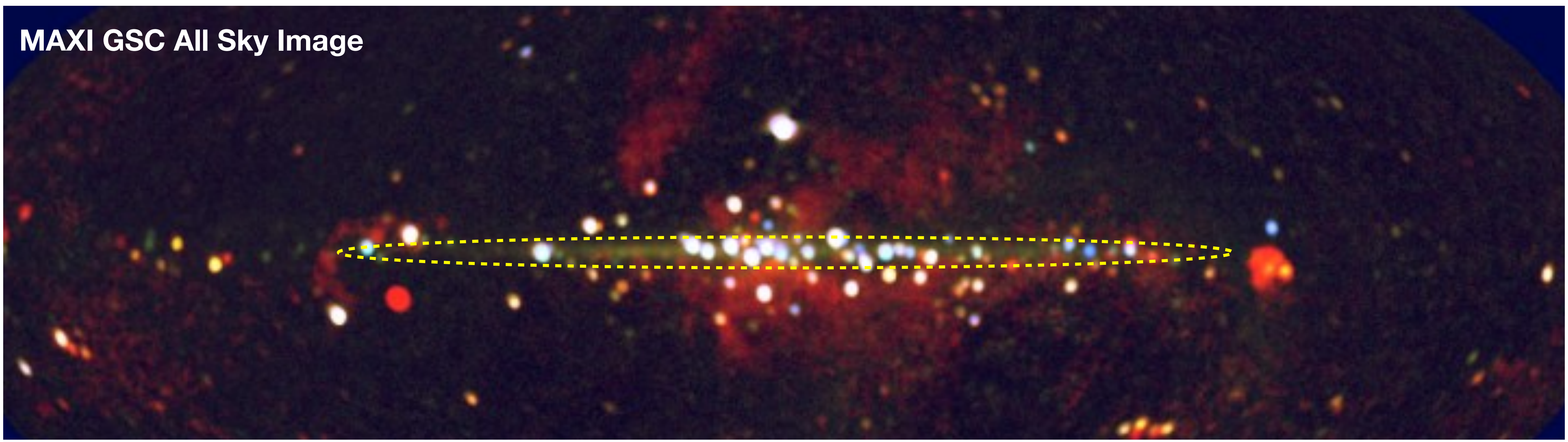


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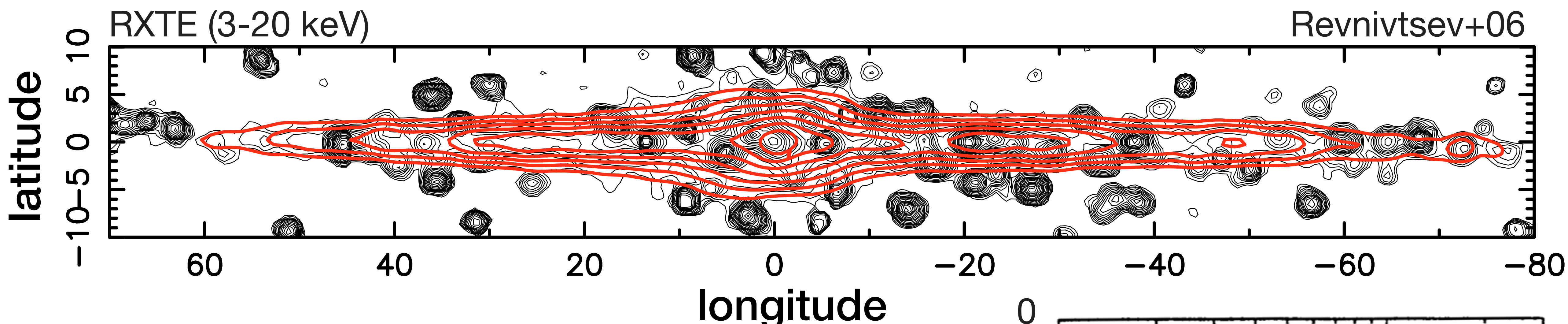
# Galactic Ridge X-ray Emission (GRXE)

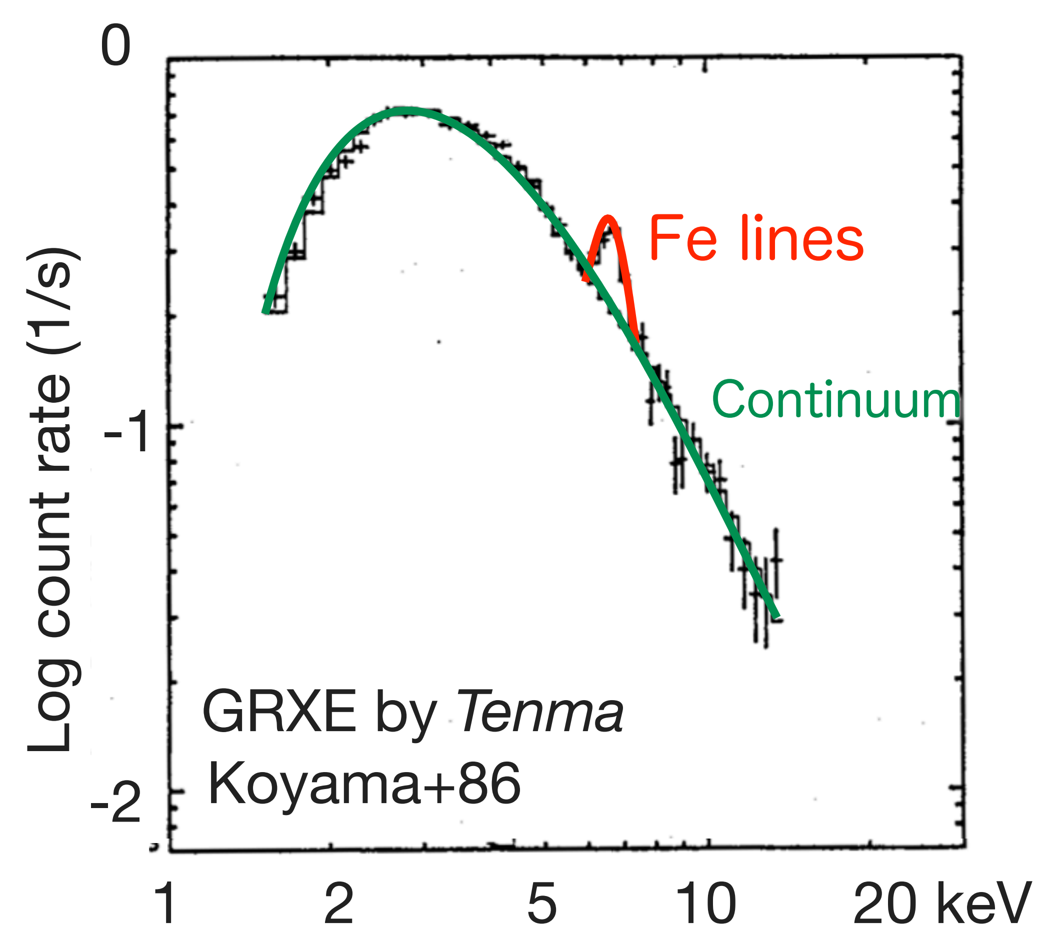
X-ray background emission observed along with the Galactic disk and the Galactic bulge. Total luminosity is $\sim 10^{38}$ erg/s in 2-10 keV.

The origin of the GRXE has been one of great mysteries in X-ray astrophysics over 40 years (e.g. Cooke et al. 1969).




**Spectral feature**

- Continuum + Emission lines.
- Coexistence of lines from light (Si/S) and heavy (Fe) elements.
    - Multi-temperature plasma?




**Two major scenarios of the GRXE origin**

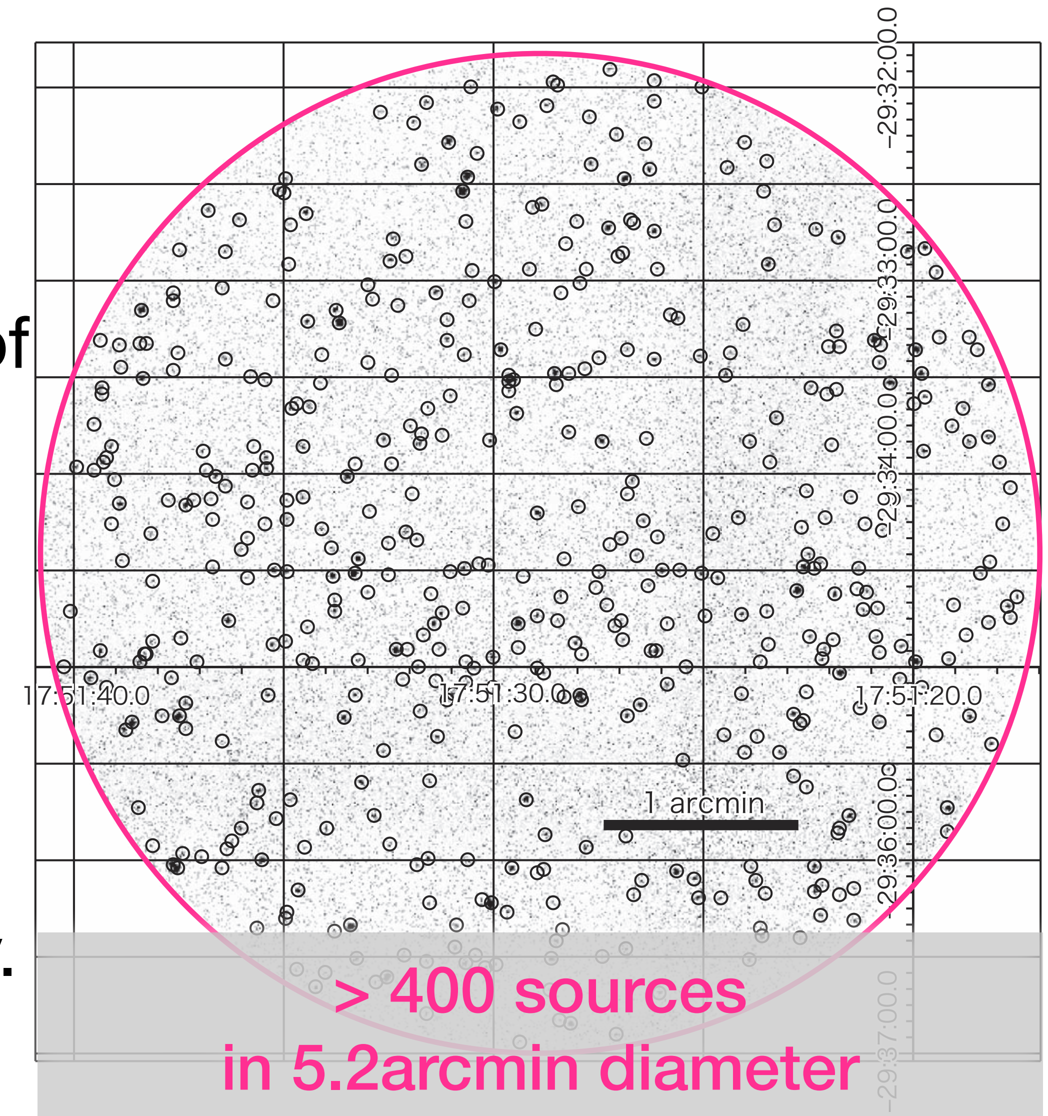
- Diffuse plasma scenario
- Point source scenario

# Imaging decomposition

**Revnivtsev+09 - Chandra 1-Ms imaging**

- 80% of GRXE was resolved as point sources.
- Based on solar neighborhood population, GRXE can be considered as a superposition of numerous dim point sources, mostly **coronal X-ray sources** and **accreting WDs**.

soft X-ray band | hard X-ray band




**Remaining problem**

- Source types not confirmed spectroscopically.
- Spectral decomposition requires broadband energy coverage.

**Our approach**

1. Use Suzaku X-ray telescope for broader energy coverage.
2. Construct a spectral model of **accreting WDs**, especially magnetic CVs.
3. Validate the spectral model using nearby CVs.
4. Use the CV model to **fit the broadband GRXE spectrum**.

# Modeling X-ray spectrum of magnetic CVs

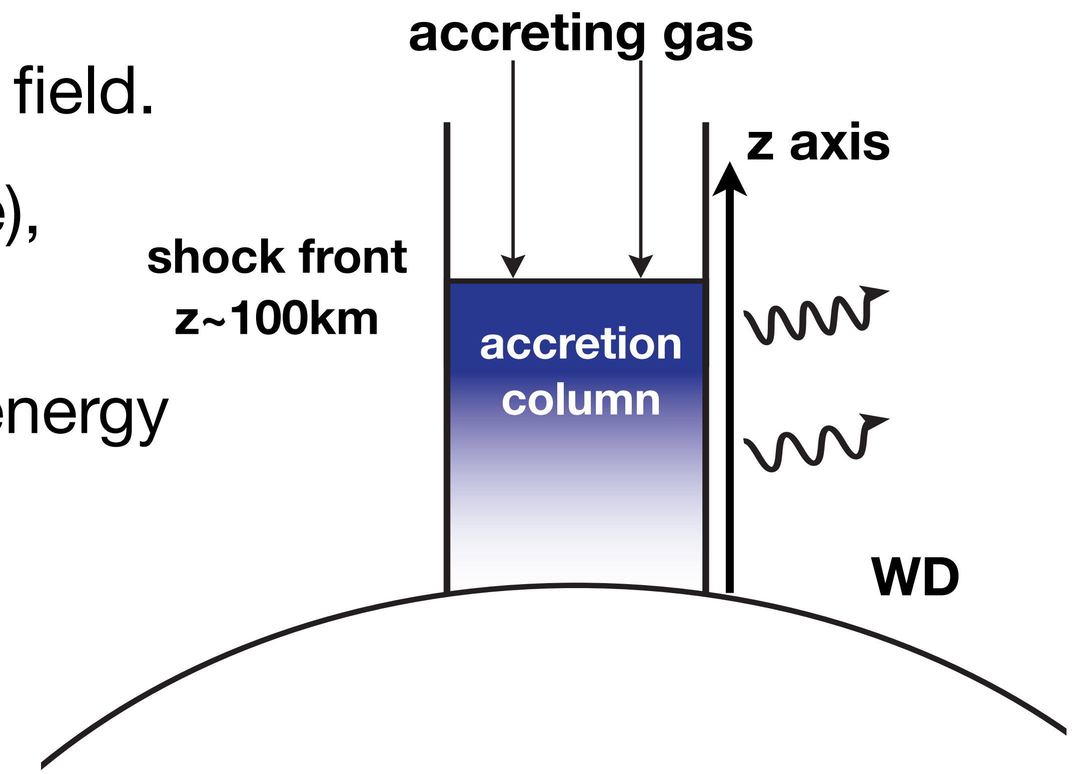
- Accretion column formed by the strong magnetic field.
- Near the WD surface (~100 km above the surface), gas bulk velocity exceeds the sound velocity.
- A shock is formed, and converts bulk kinematic energy into thermal energy (kT > 10 keV).
- The heated gas cools via X-ray radiation.
- Density, temperature, and velocity can be calculated based on conservation laws.

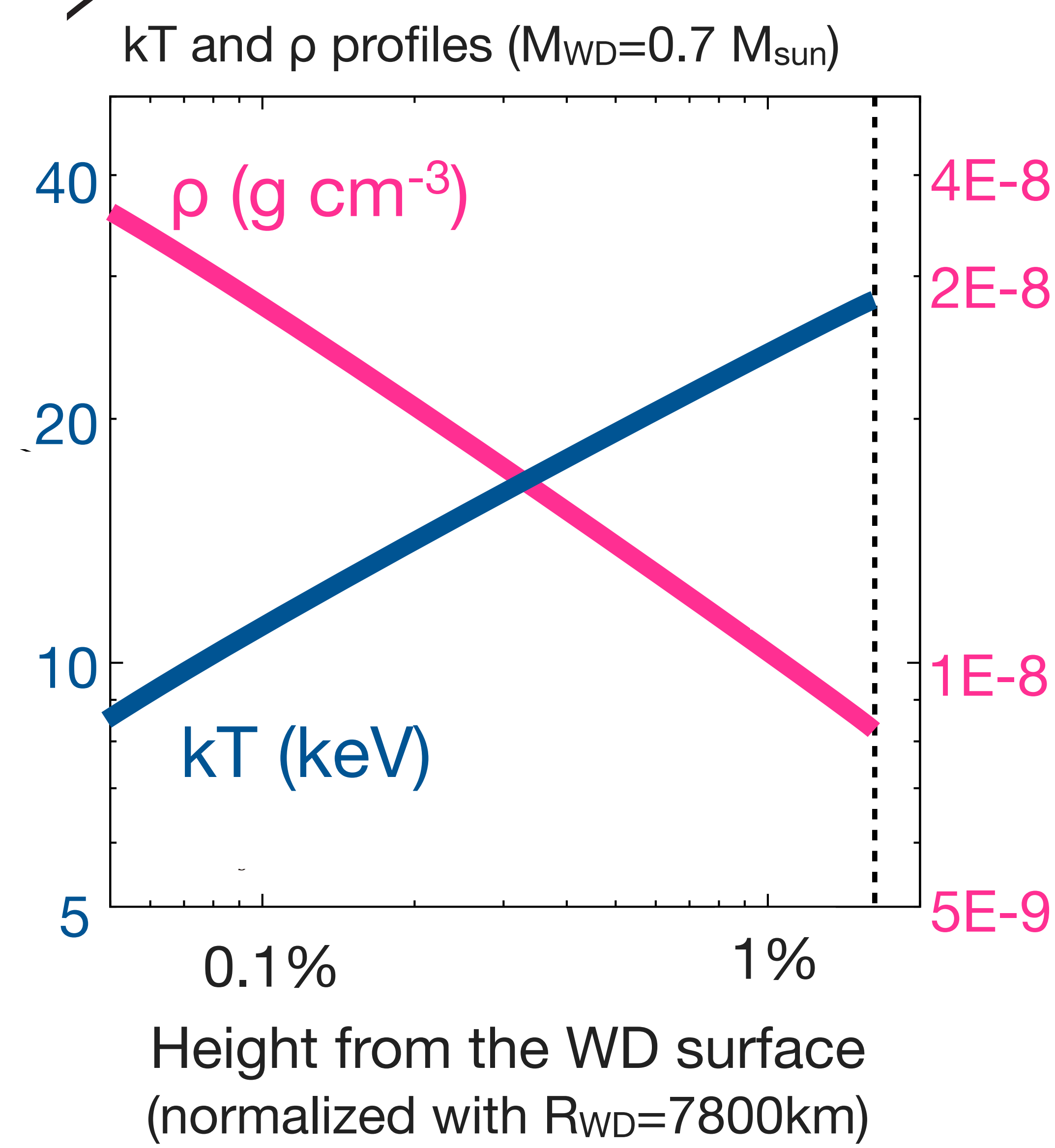
$$\frac{\mathrm{d}}{\mathrm{d}z}(\rho v) = 0, \qquad \frac{\mathrm{d}}{\mathrm{d}z}(\rho v^2 + P) = -\frac{G M_{\mathrm{WD}}}{z^2}\rho,$$

$$v\frac{\mathrm{d}P}{\mathrm{d}z} + \gamma P \frac{\mathrm{d}v}{\mathrm{d}z} = -(\gamma-1)\underline{\Lambda n^2}$$

plasma thermal cooling function (e.g. Schure+09)

- These reduces to an initial value problem of ODEs (Cropper+99, Suleimanov+05).
- **WD mass** and **Fe abundance** are main free parameters of this spectral model.



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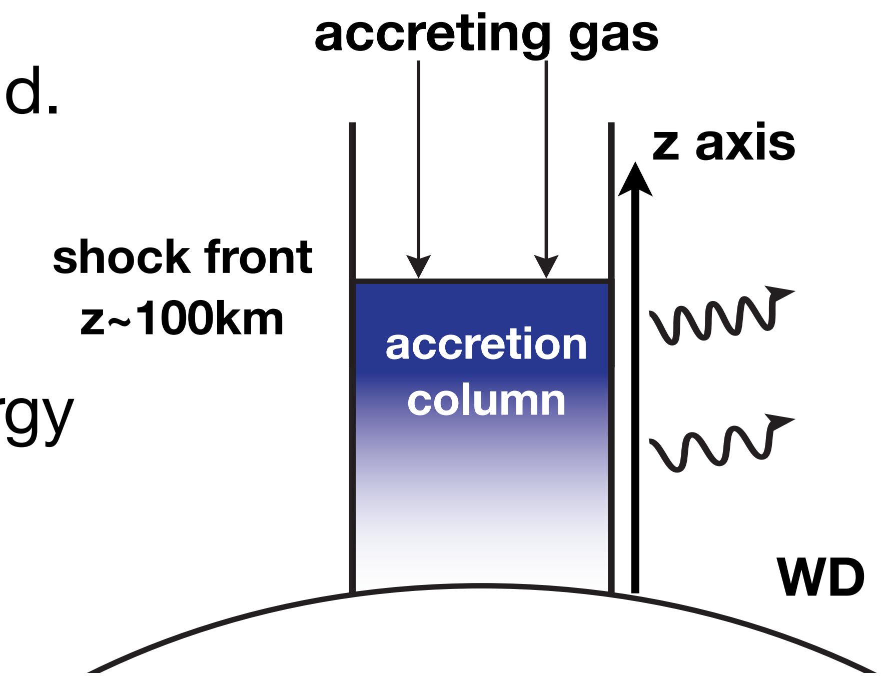


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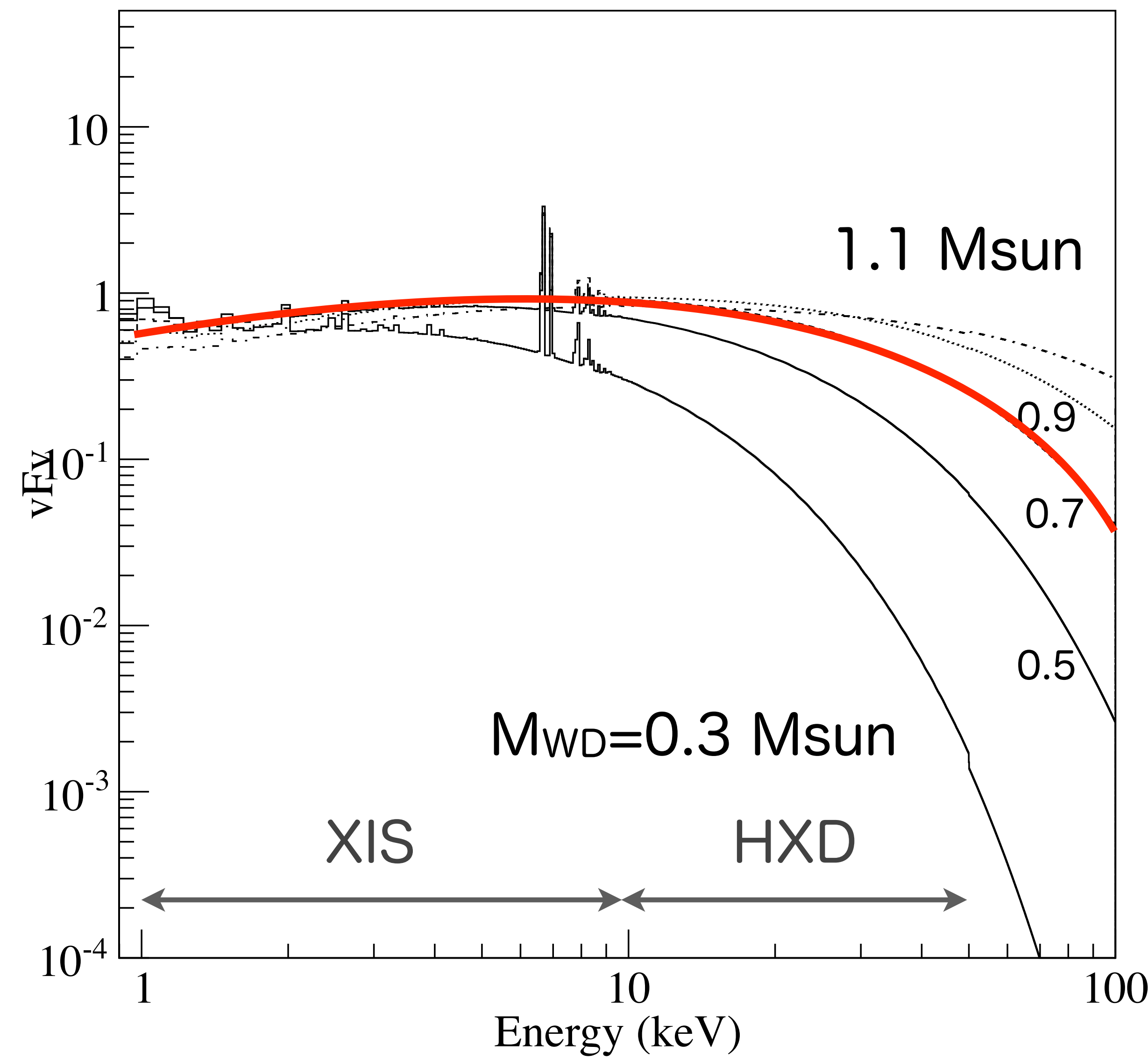
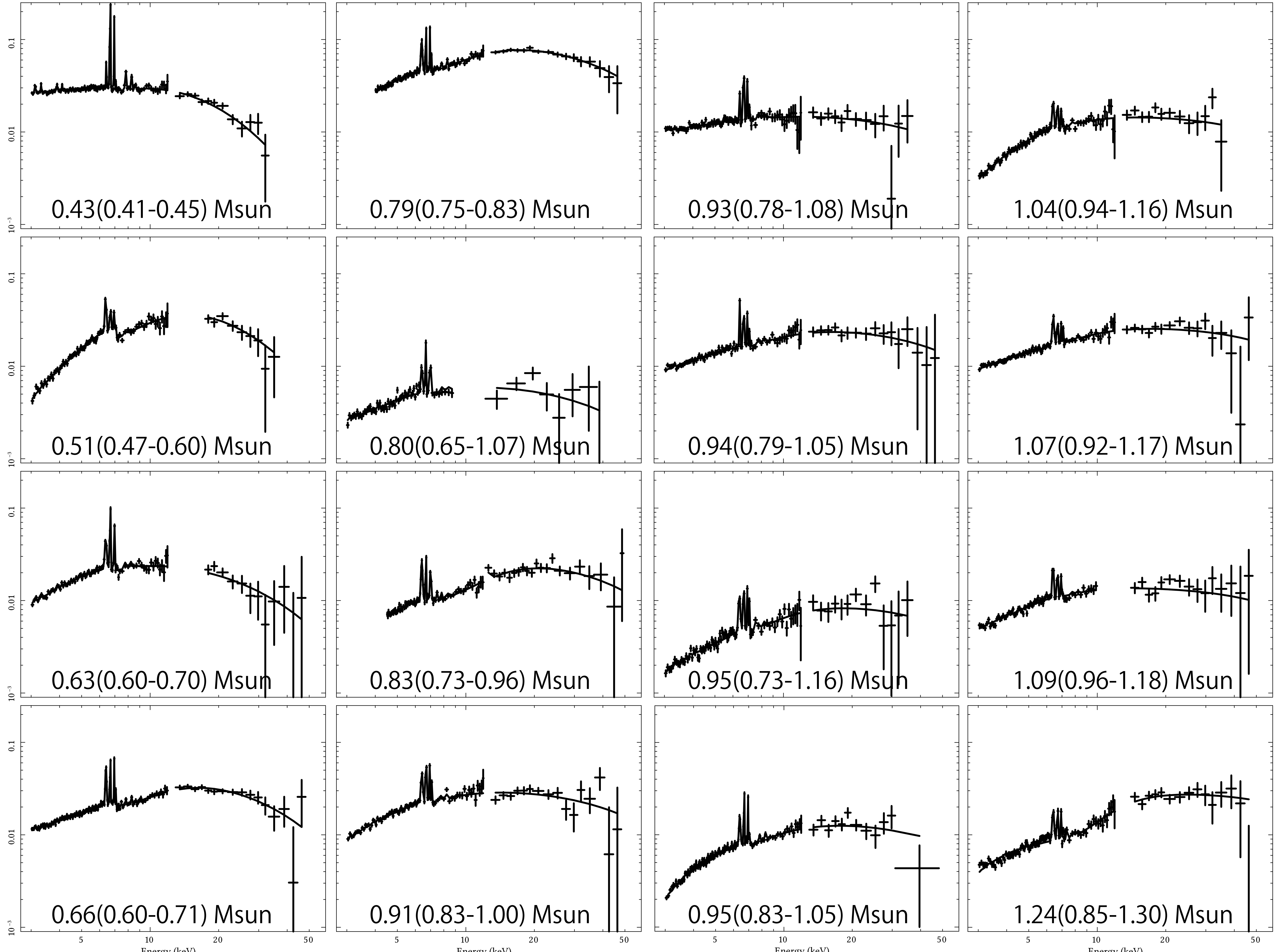
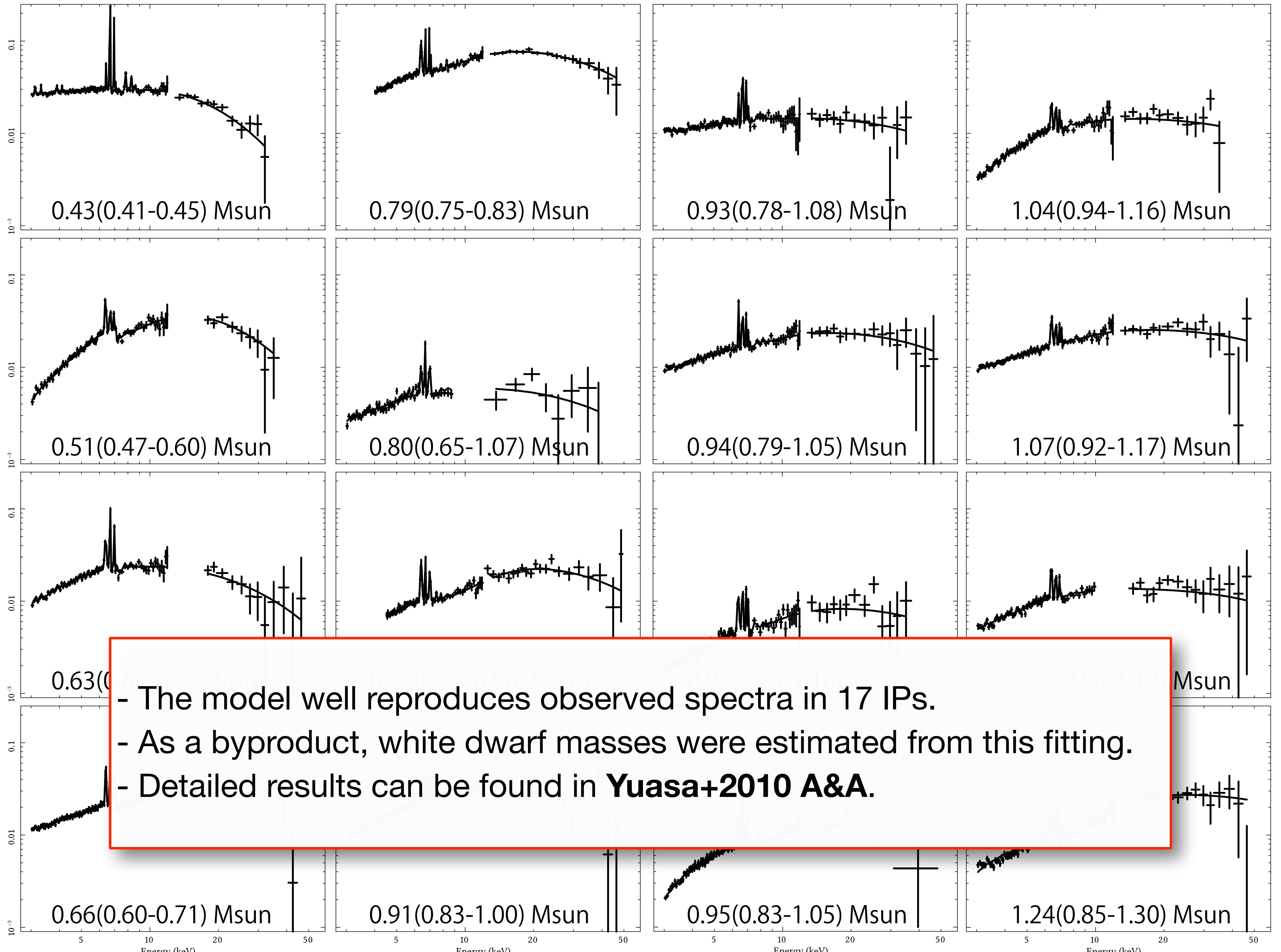


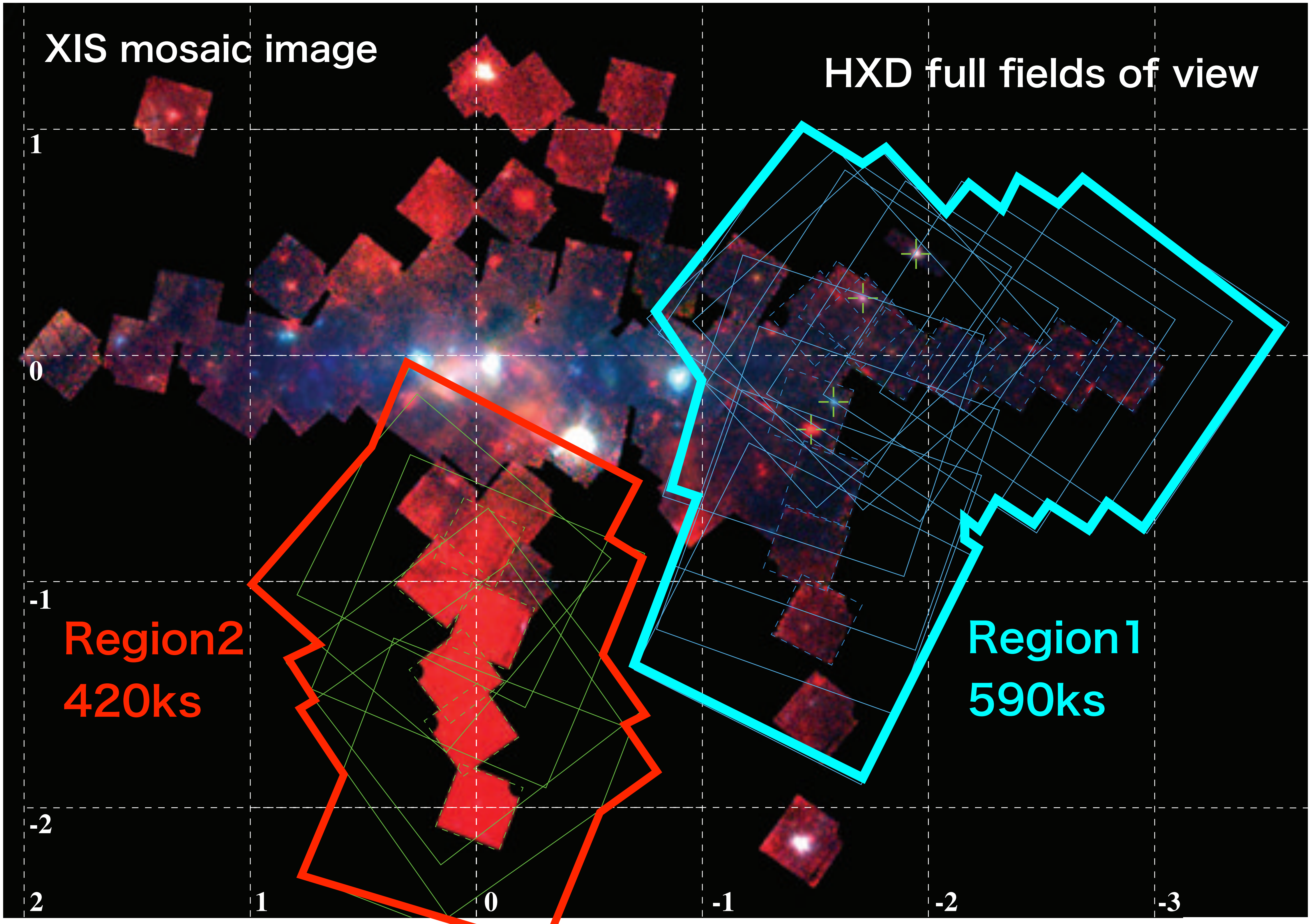

0.43(0.41-0.45) Msun
0.79(0.75-0.83) Msun
0.93(0.78-1.08) Msun
1.04(0.94-1.16) Msun
0.51(0.47-0.60) Msun
0.80(0.65-1.07) Msun
0.94(0.79-1.05) Msun
1.07(0.92-1.17) Msun
0.63(0.60-0.70) Msun
0.83(0.73-0.96) Msun
0.95(0.73-1.16) Msun
1.09(0.96-1.18) Msun
0.66(0.60-0.71) Msun
0.91(0.83-1.00) Msun
0.95(0.83-1.05) Msun
1.24(0.85-1.30) Msun
0.1
0.01
$10^{-3}$
5
10
20
50
Energy (keV)




- The model well reproduces observed spectra in 17 IPs.
- As a byproduct, white dwarf masses were estimated from this fitting.
- Detailed results can be found in **Yuasa+2010 A&A**.

# Suzaku GRXE observations

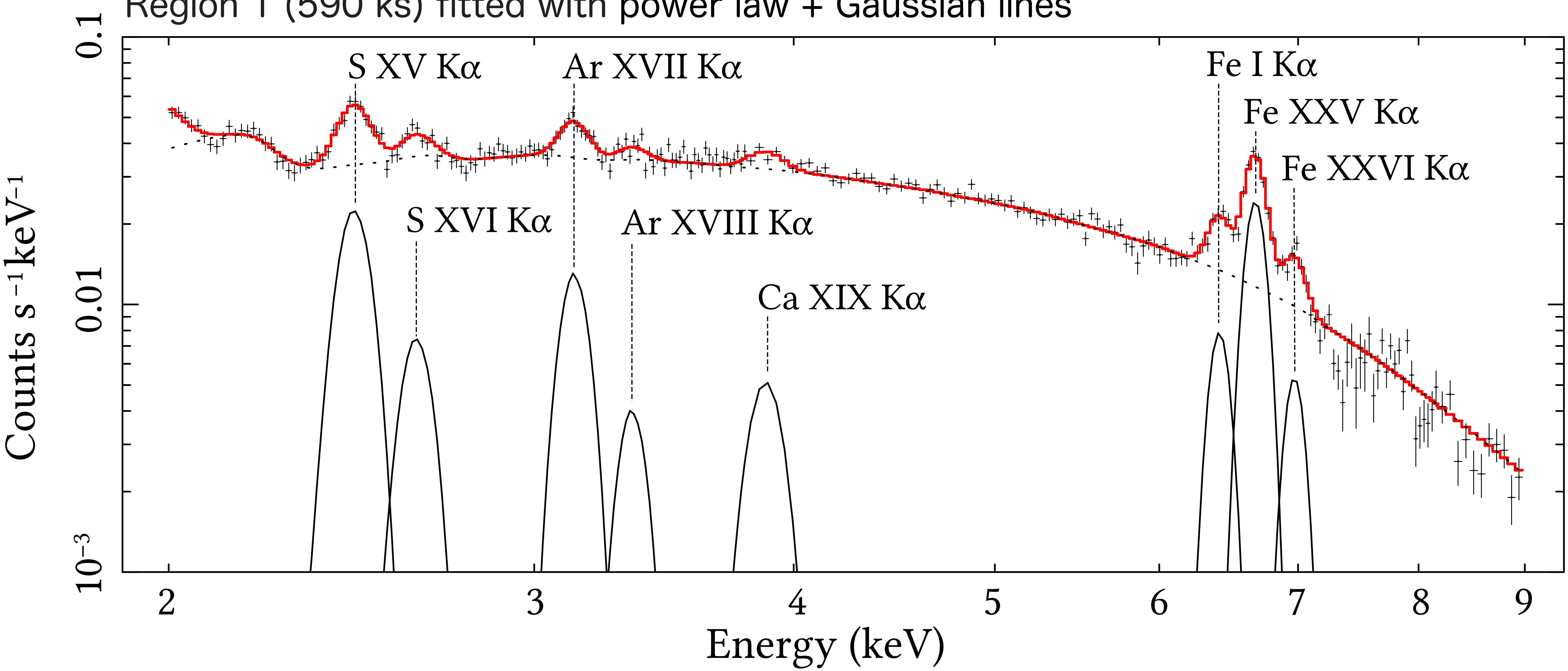
- Suzaku's Galactic center and Galactic bulge observations were summed to produce a data set of the GRXE (avoiding known bright X-ray sources).
- Region 1 = 590 ks; Region 2 = 420 ks → Total exposure = 1Ms



# Close-up view of the XIS spectrum

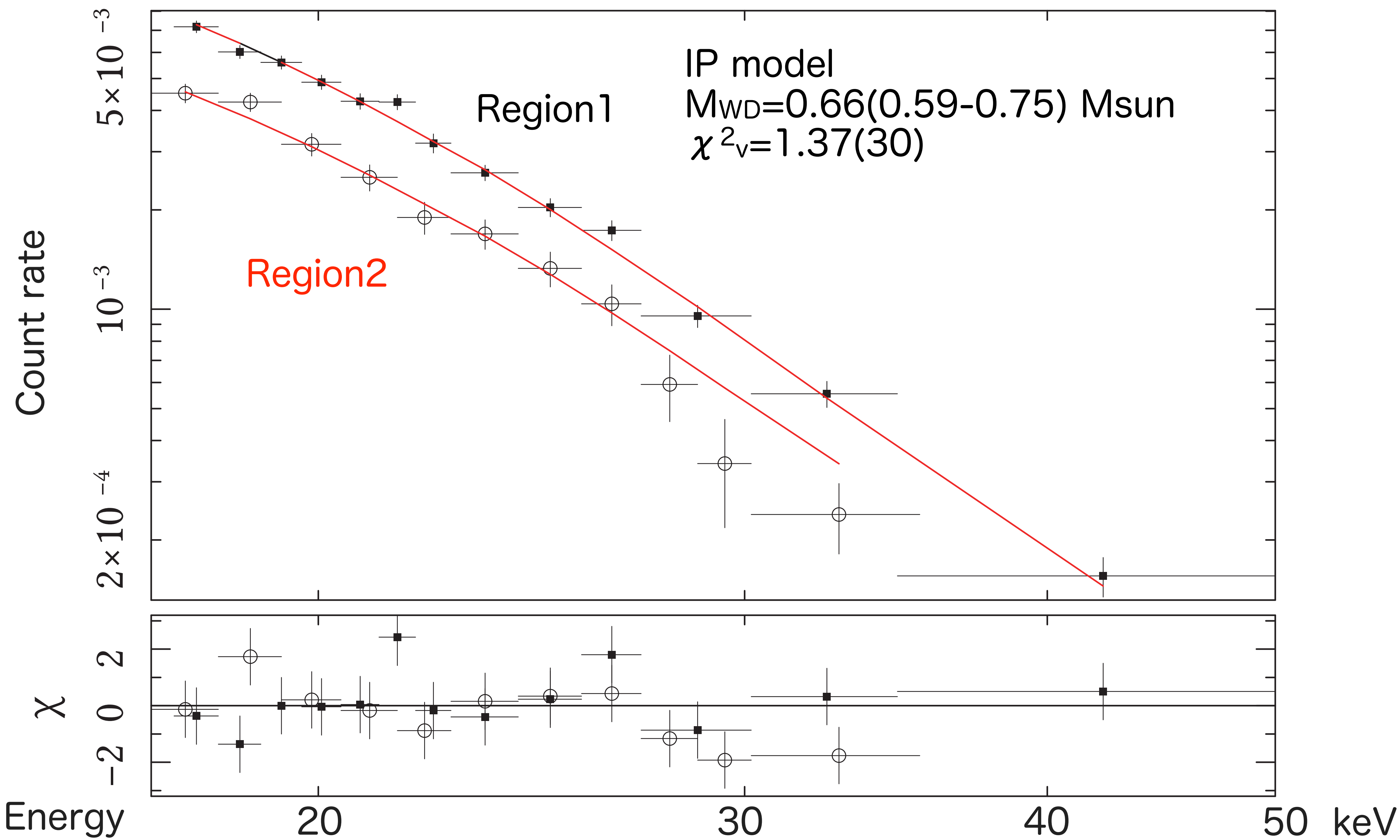
- Lines from lighter (S/Ar/Ca) elements coexist with those from Fe.
- This indicates contributions from plasmas with very different temperatures.
- At least two plasma components are necessary to explain the spectrum.

Region 1 (590 ks) fitted with power law + Gaussian lines



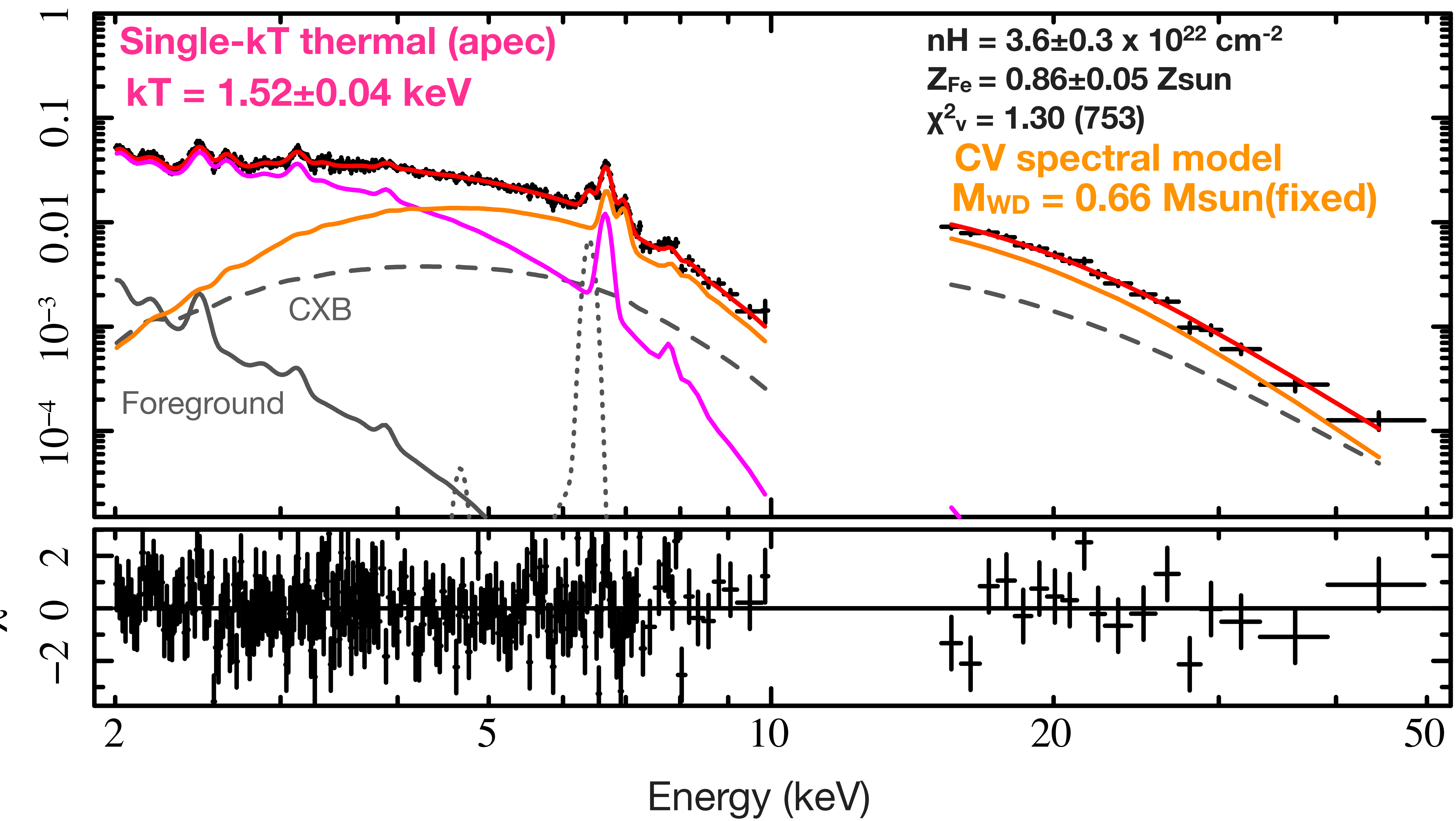
# Fitting the GRXE in the hard X-ray band

- Single-temperature thermal model gave the best fit at **kT=15.7 (13.7-18.4) keV**.
- The IP spectral model well reproduced the data with **$M_{WD}$=0.66 (0.59-0.75) $M_{Sun}$.**
  - This could be interpreted as a representative WD mass of IPs in the Galaxy. (c.f. ～0.5 $M_{Sun}$ by Krivonos+07 with INTEGRAL data)



# Broad-band GRXE spectral fitting

- Hard X-ray spectral fit with the CV model extrapolated below 10 keV.
- Another lower temperature component is required.



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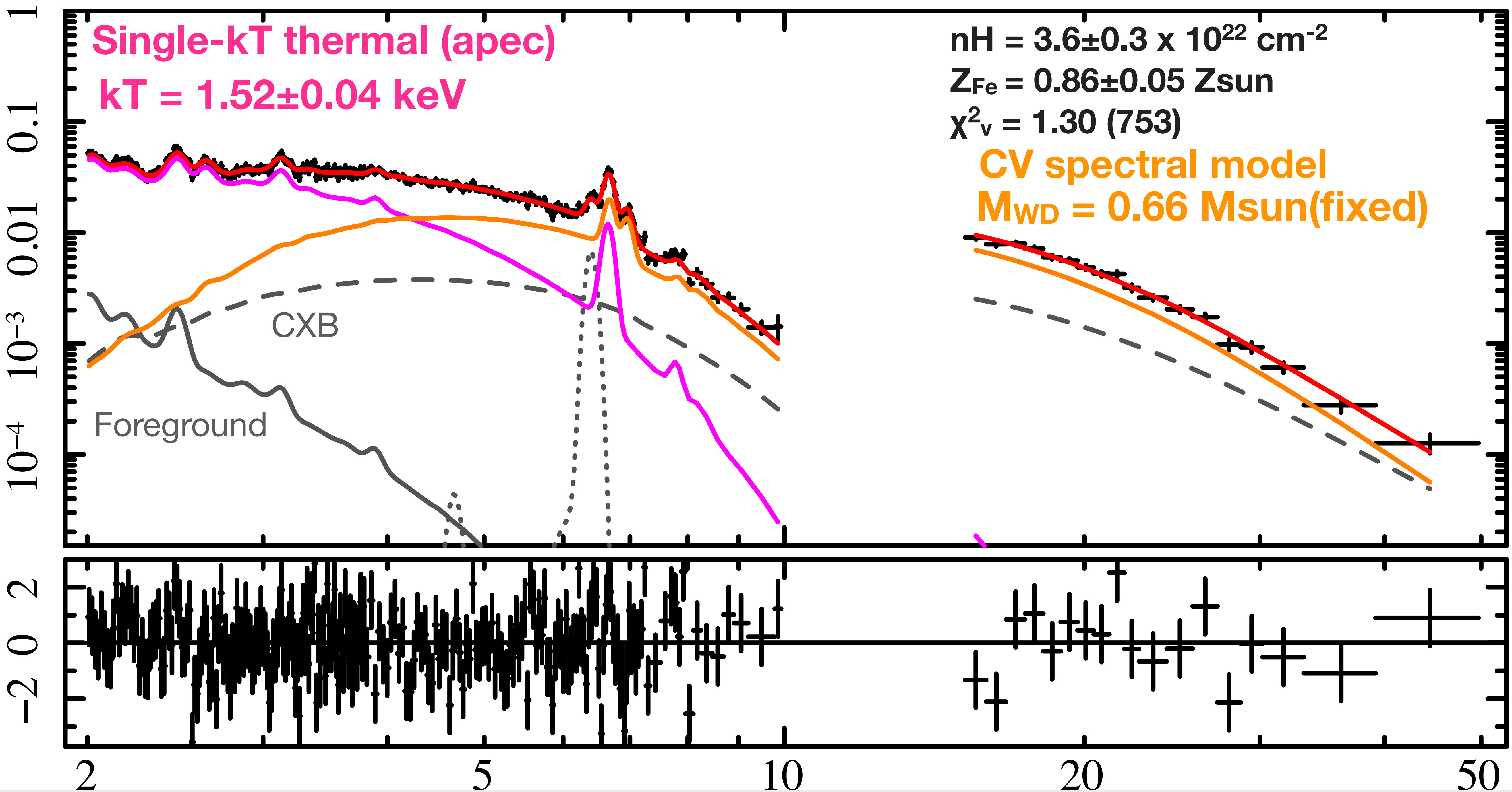


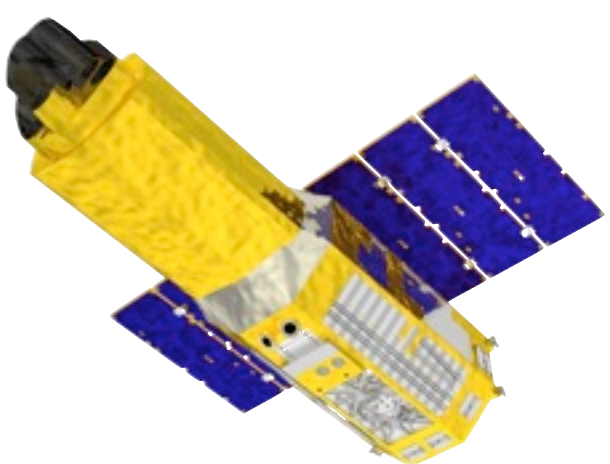

The broadband GRXE spectrum is decomposed into two components for the first time.

**low-kT component 1-1.5 keV** → typical **coronal active star**

**high-kT component >10 keV** → reproduce by **the magnetic CV model**

# Summary and conclusion

- Constructed X-ray spectral model of magnetic CV.
- Validity confirmed by analyses of 17 nearby CVs observed by Suzaku.
- Broadband GRXE spectrum was measured with the highest precision.
- Spectral fitting suggested two distinctive components which correspond to properties of **coronal active stars** and **accreting WD binaries**.
- Our spectroscopy result also supports the “Point Source Scenario” as the origin of the GRXE.



Suzaku (2005-)

I am now involved in ASTRO-H.
If you are interested in it, lets discuss on it.

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