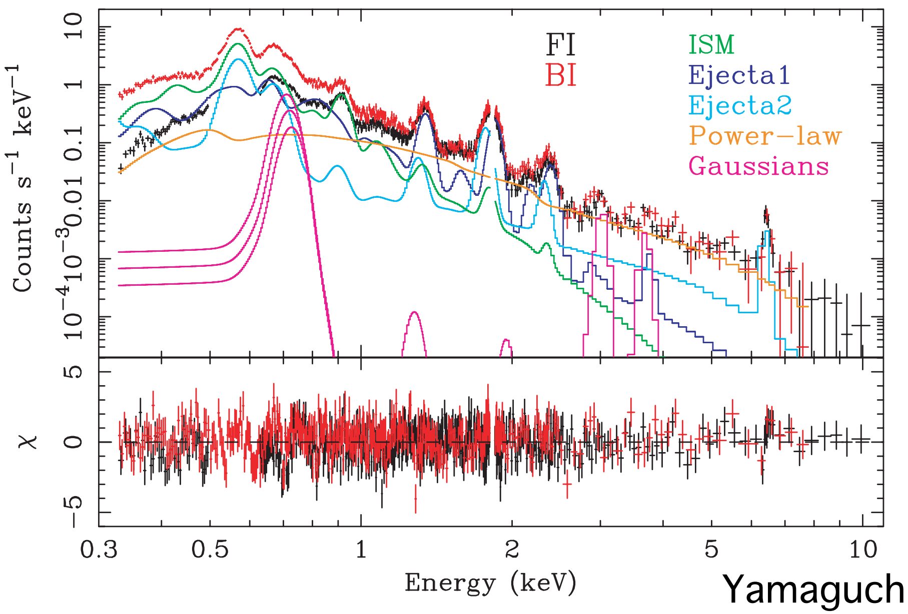
A deep Suzaku observation of the Galactic Ia supernova remnant G306.3−0.9

Katsuhiro Tachibana (Kyoto Univ.)

H. Uchida, H. Matsumura, T. G. Tsuru, T. Tanaka (Kyoto Univ.),
M. Sawada, Y. Itoh (Aoyama Univ.), A. Bamba (Univ. of Tokyo)

Stratified Structure of Type Ia SNR

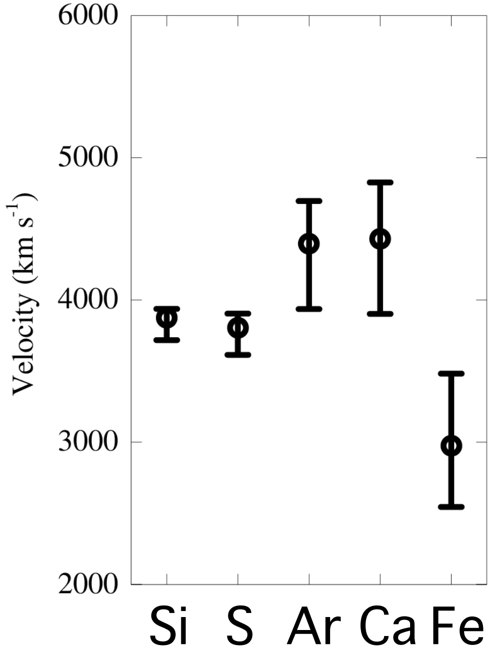
SN1006

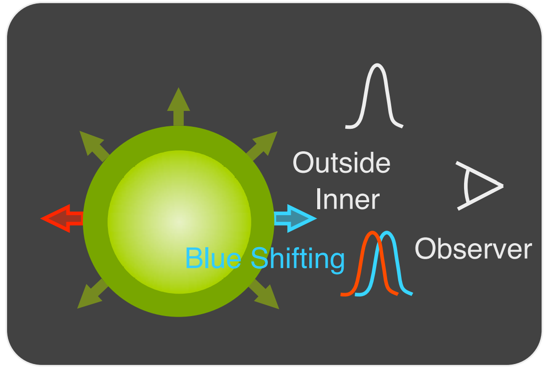


Yamaguchi+08

lower ionization Fe-K emission

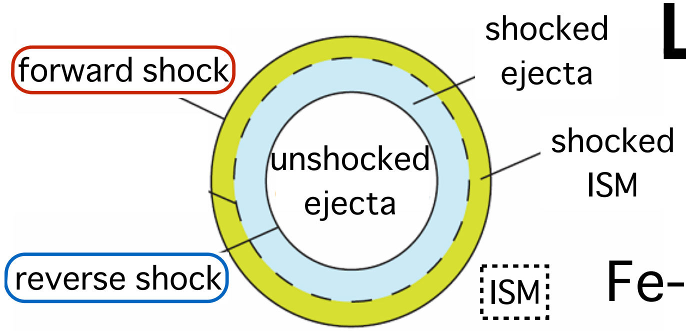
Tycho





A. Hayato

slower expansion velocity of Fe



H. Yamaguchi modified

Fe-centered structure is maintained, and Fe are shock-heated later by reverse shock.

Fe-K traces the distribution of the nuclear-burning product.

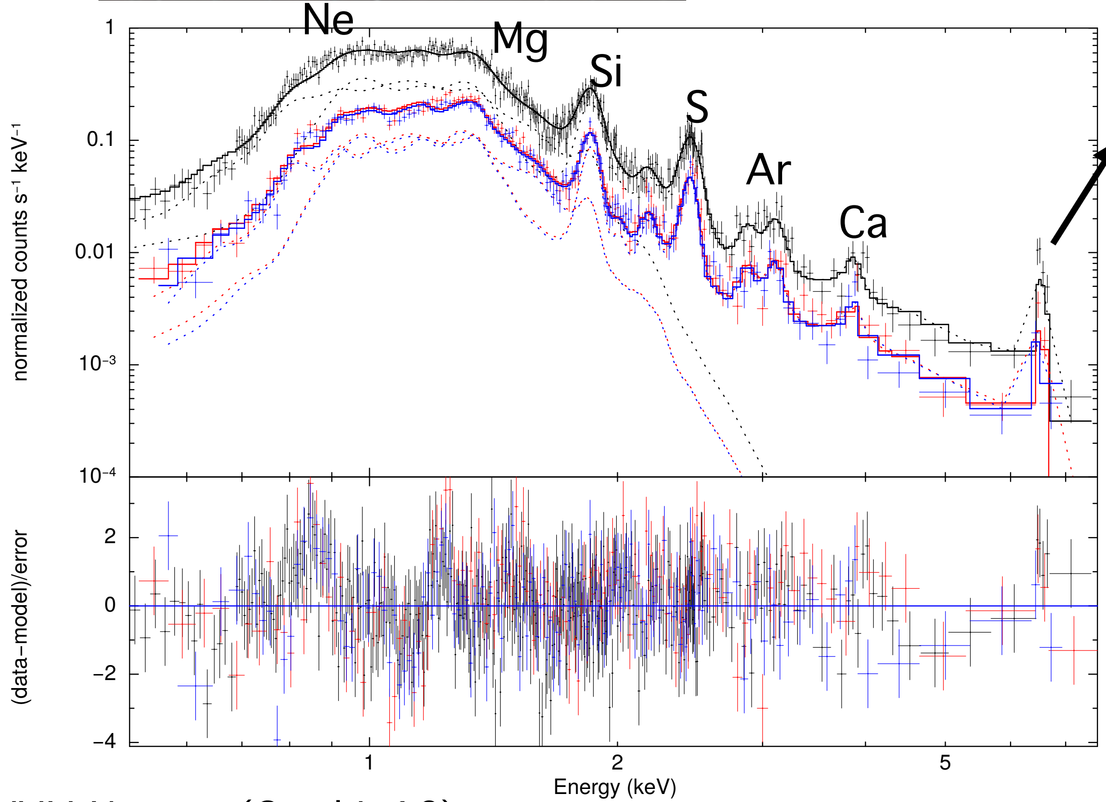
Only 14 samples have been identified as Type Ia SNRs with the Fe-K emission.

SNR G306.3−0.9

- Discovered with the Swift Galactic plane survey (Miller+11)
- a 5 ks follow-up observation with Chandra (Reynolds +13)

→ 110" radius => age ~ 2500 yr (assuming 8 kpc)

Age is still unknown



XMM-Newton (Combi+16)

<u>Strong low-ionized Fe-K</u>

⇒ Type Ia origin

XMM-Newton (Combi+16), Suzaku (Sezer+17)

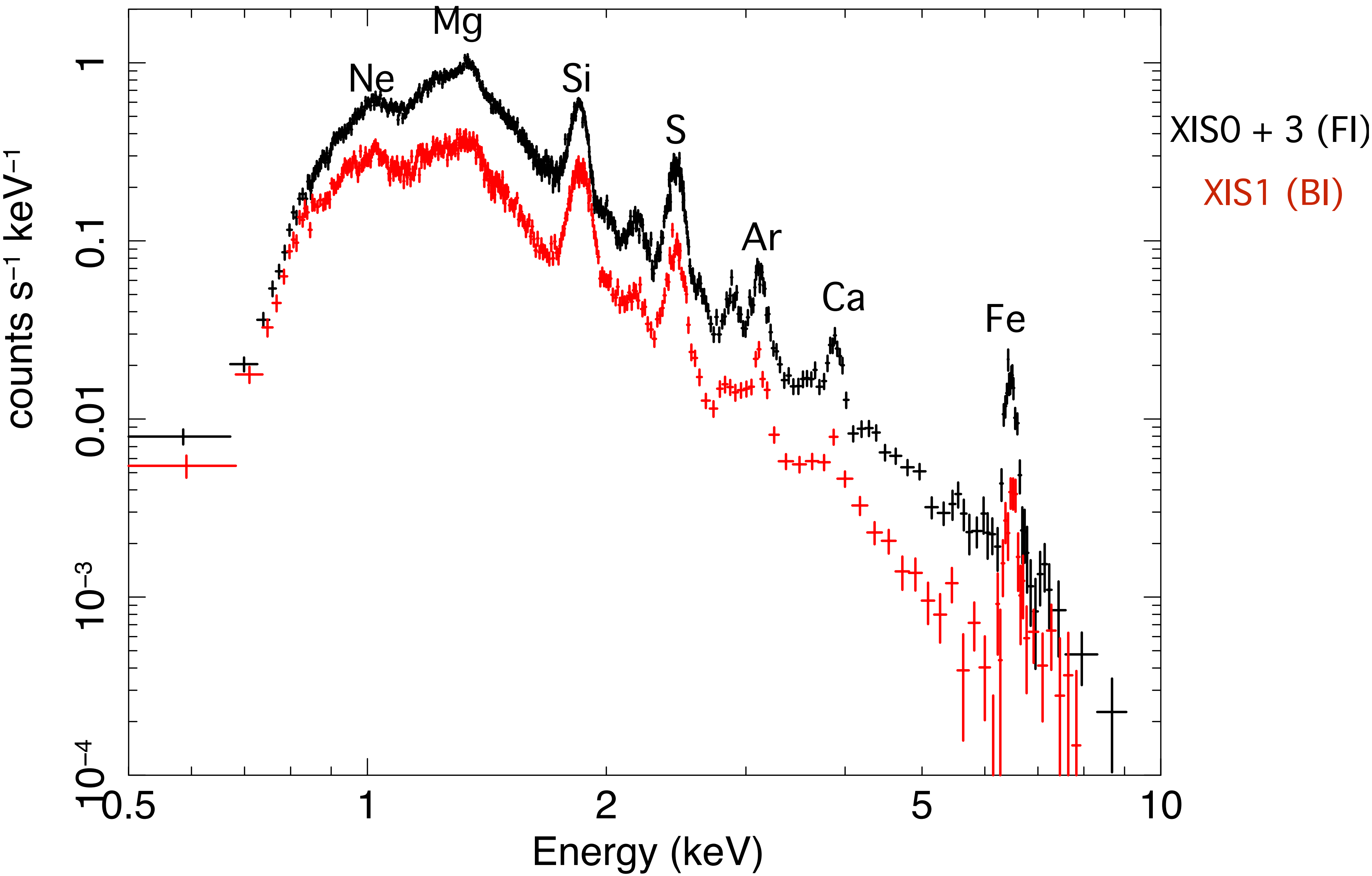
CIE plasma for intersteller medium

+

Single-NEI plasma for ejecta

- explore the nature of Fe ejecta
- determine the age

Suzaku Spectrum



Estimate the Systematic Error of Fe-K Centroid Energy

Mesure a gain shift

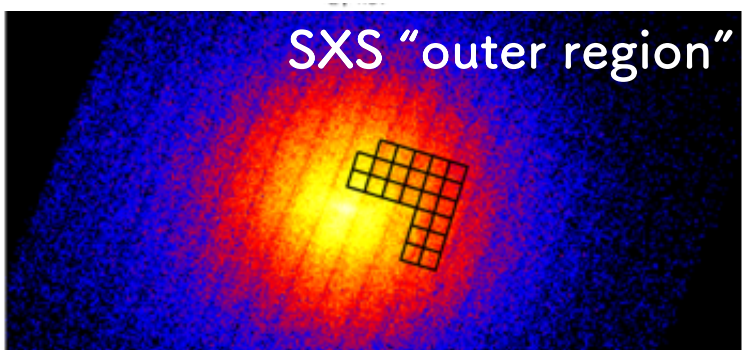
- the Perseus cluster was observed with XIS one week after the G306.3−0.9
- Measured with Hitomi SXS (energy resolution of 5 eV).

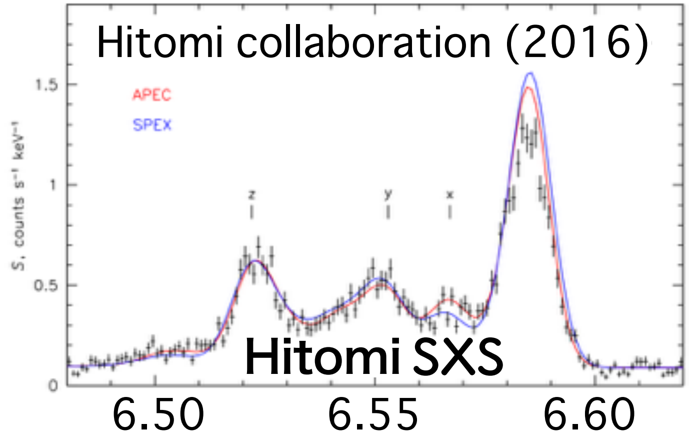
  → CIE plasma $kT_e = 4.1 \pm 0.1$ keV, z=0.01756
- compare XIS to SXS

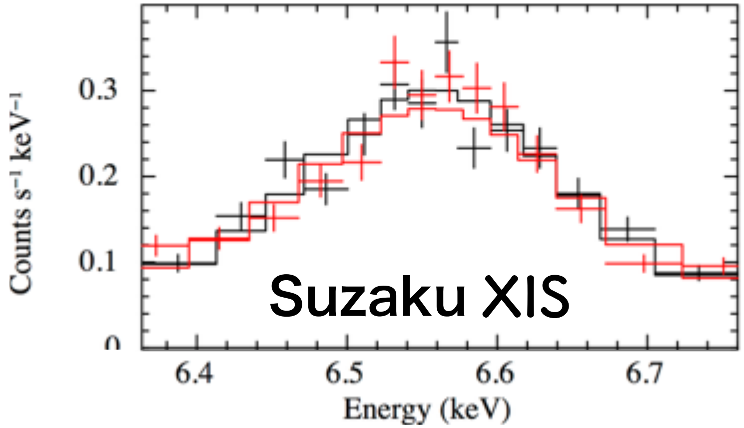
  ⇒ measure a gain shift ΔE.

⇒ $\Delta E = -2 \pm 5$ eV

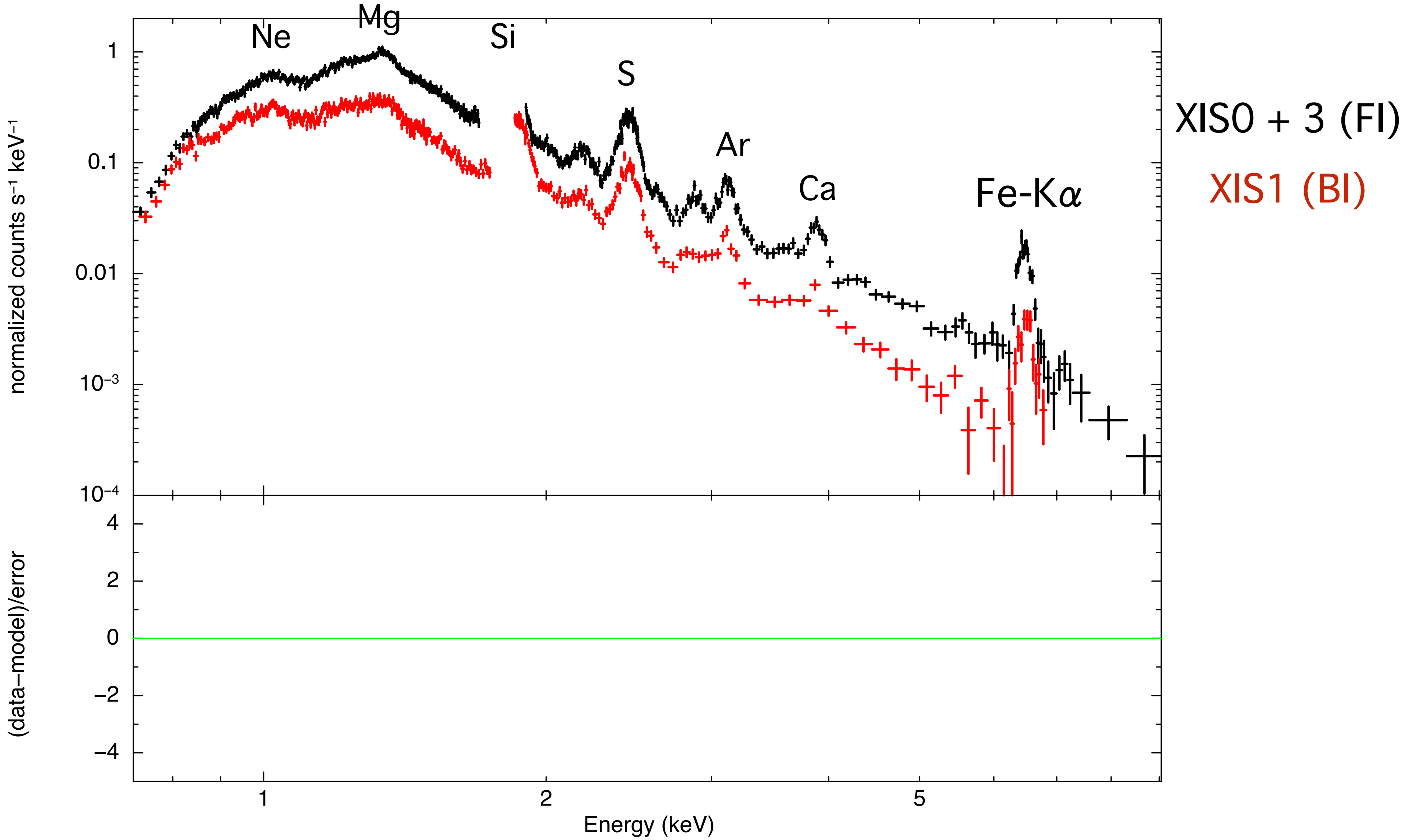
XIS energy scale at Fe-K is highly reliable at a level of ≤ 7 eV



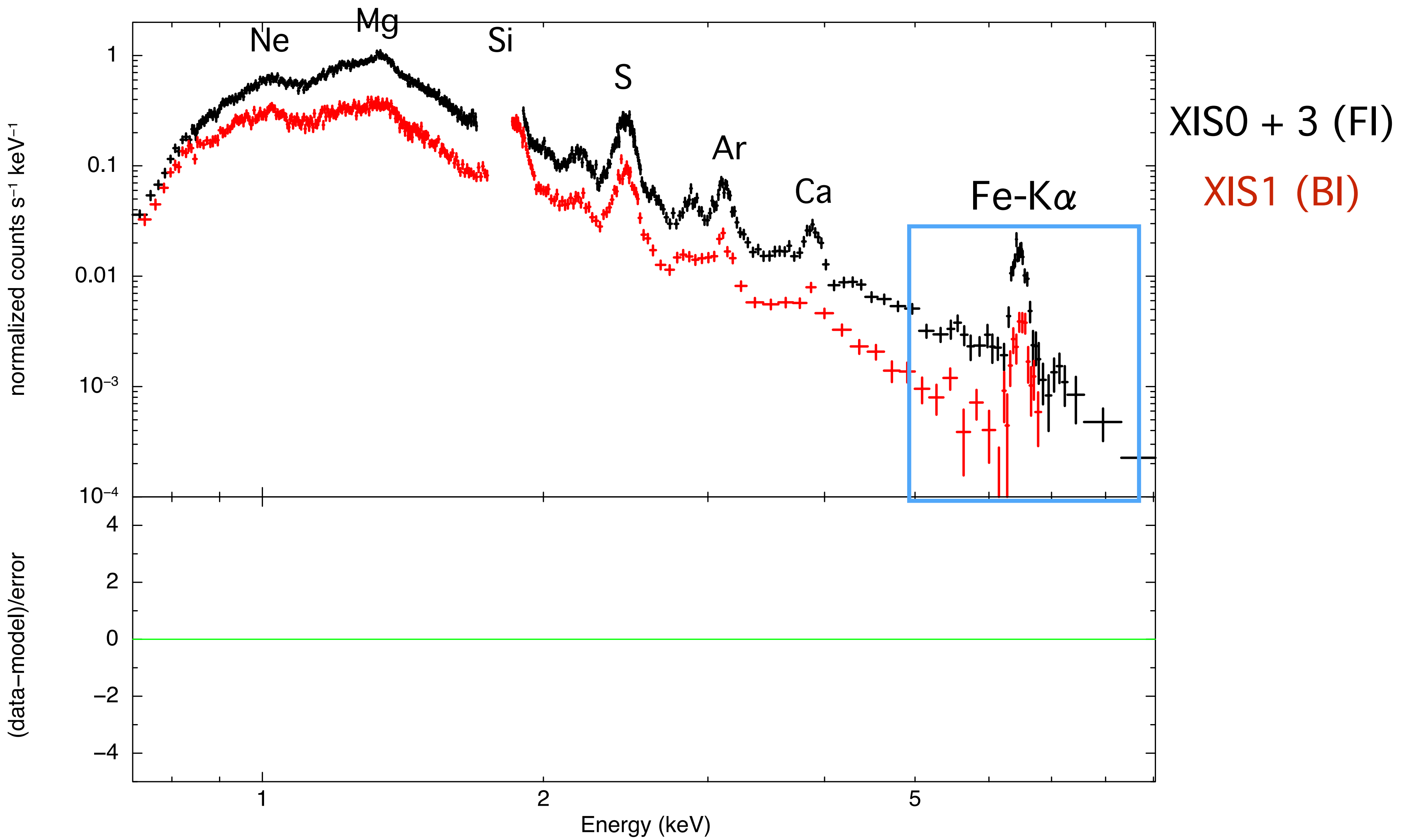




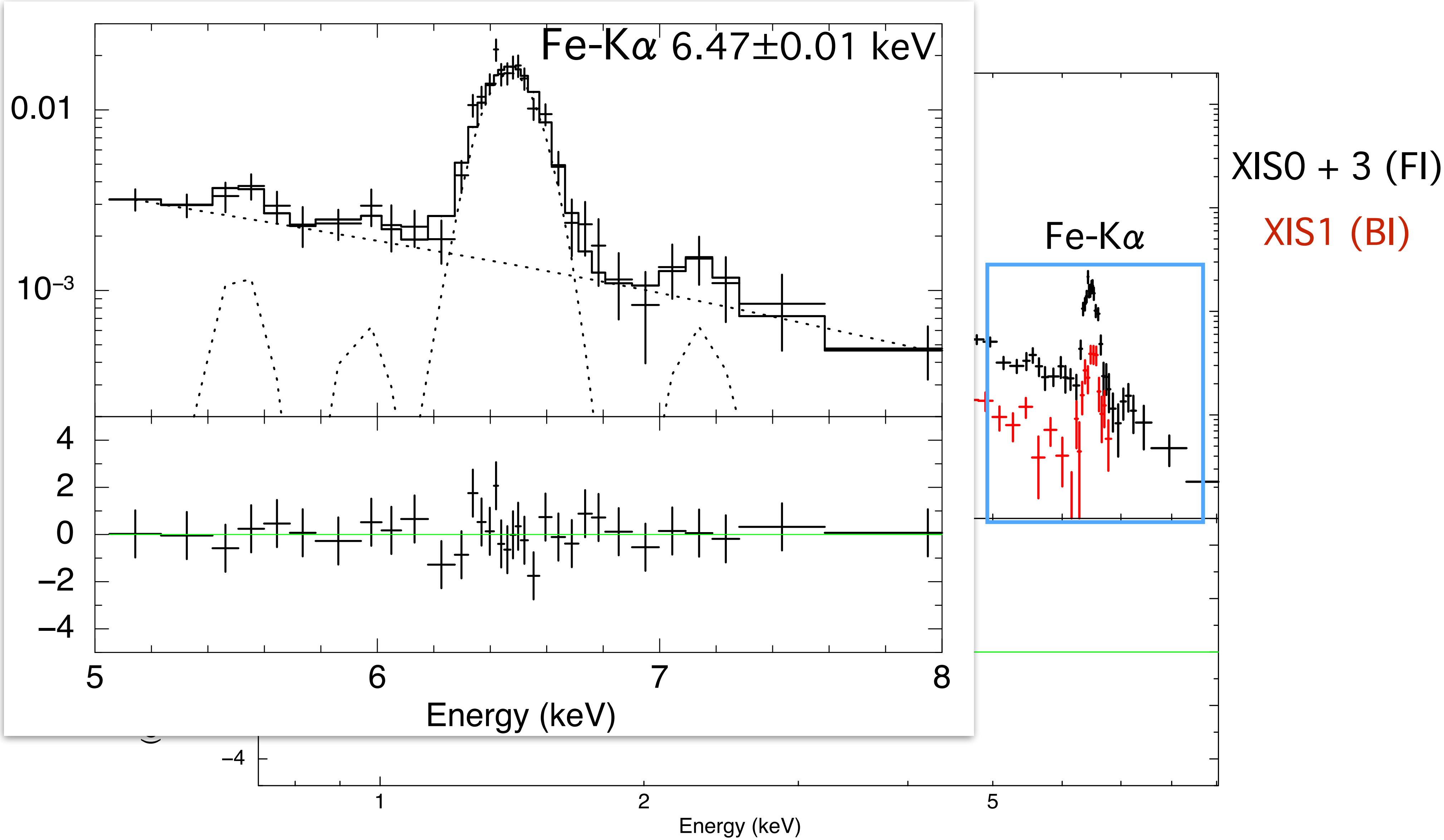
Suzaku Spectrum



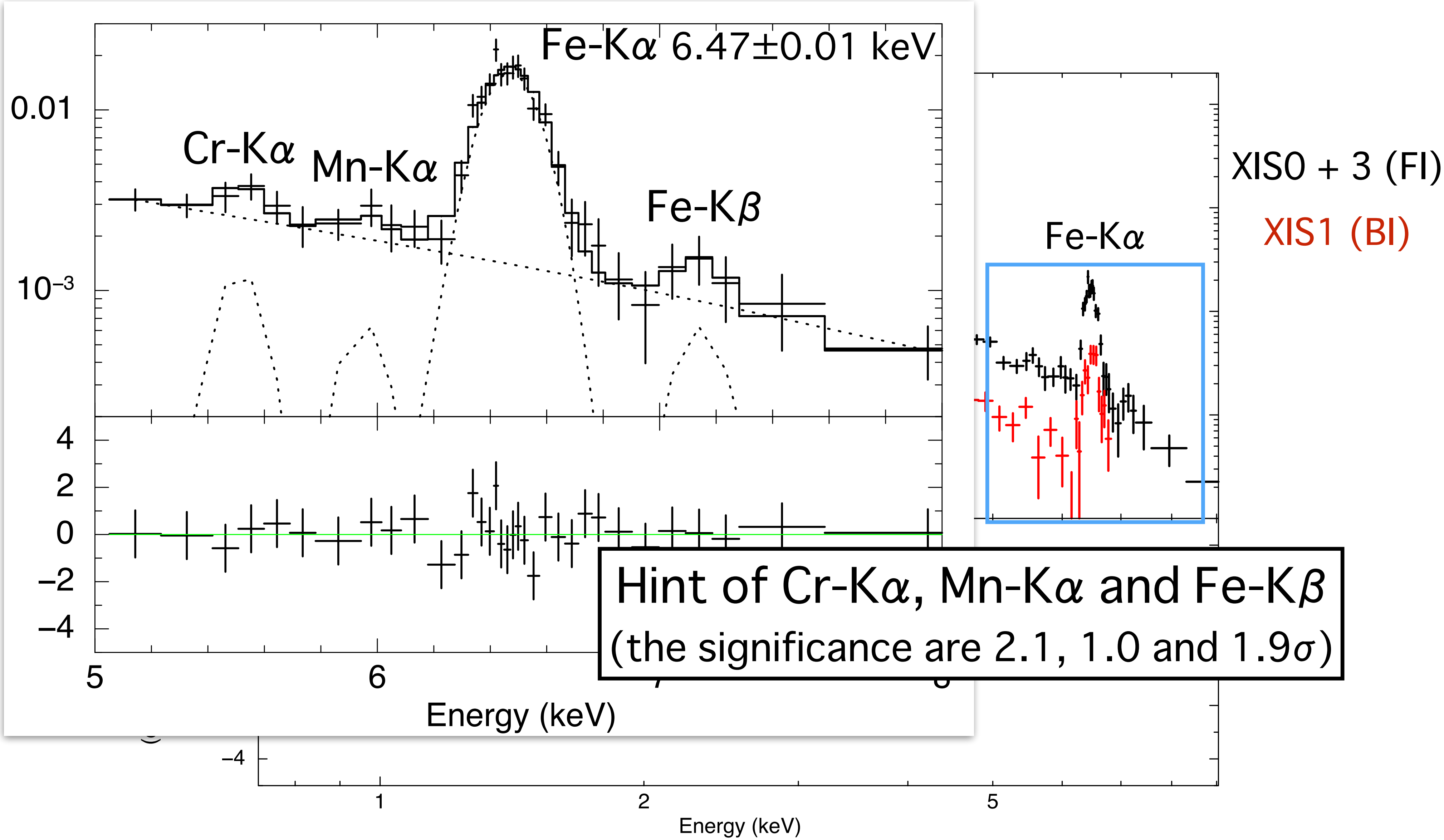
Suzaku Spectrum



Suzaku Spectrum



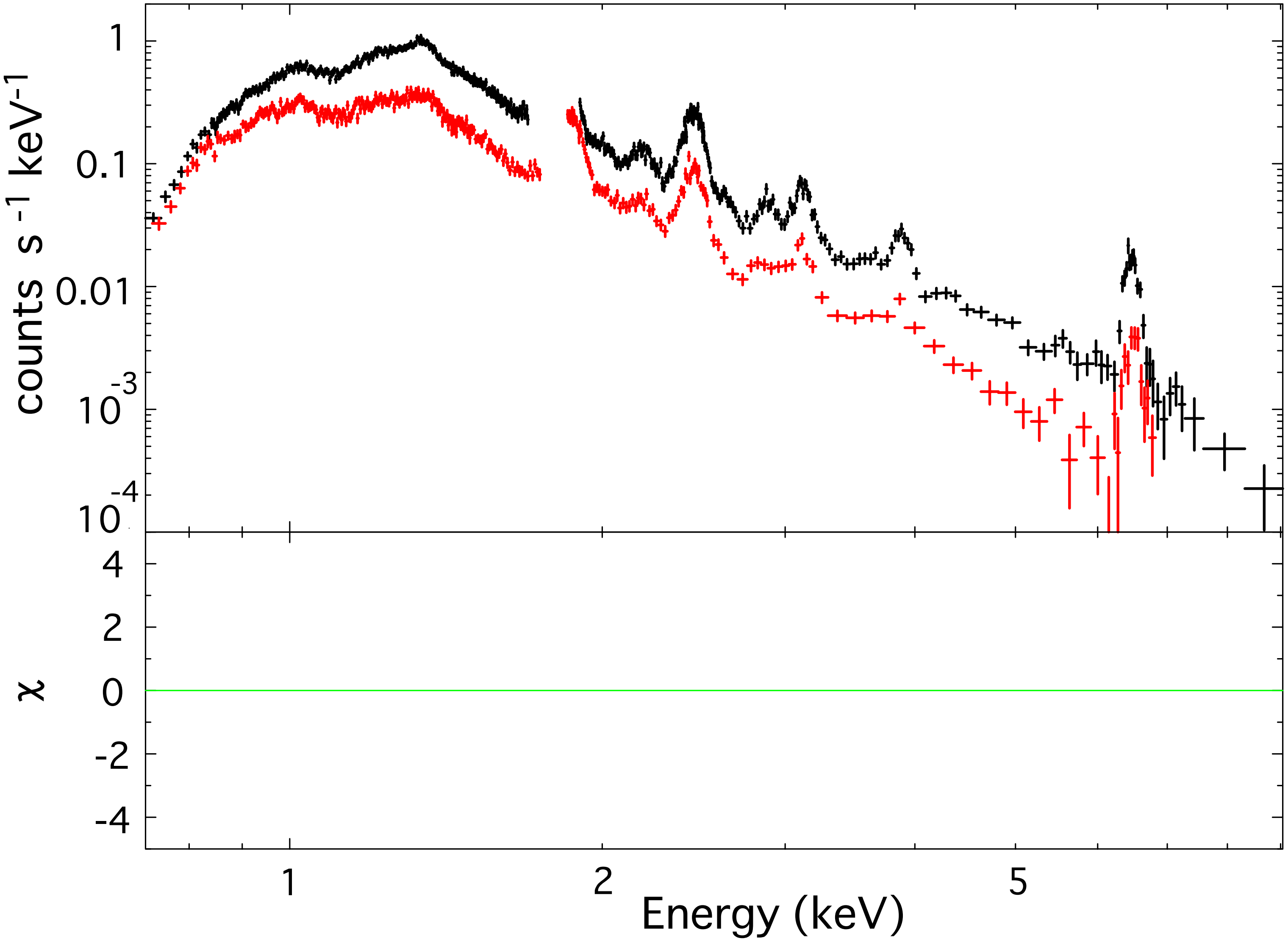
Suzaku Spectrum



Hint of Cr-Kα, Mn-Kα and Fe-Kβ
(the significance are 2.1, 1.0 and 1.9σ)

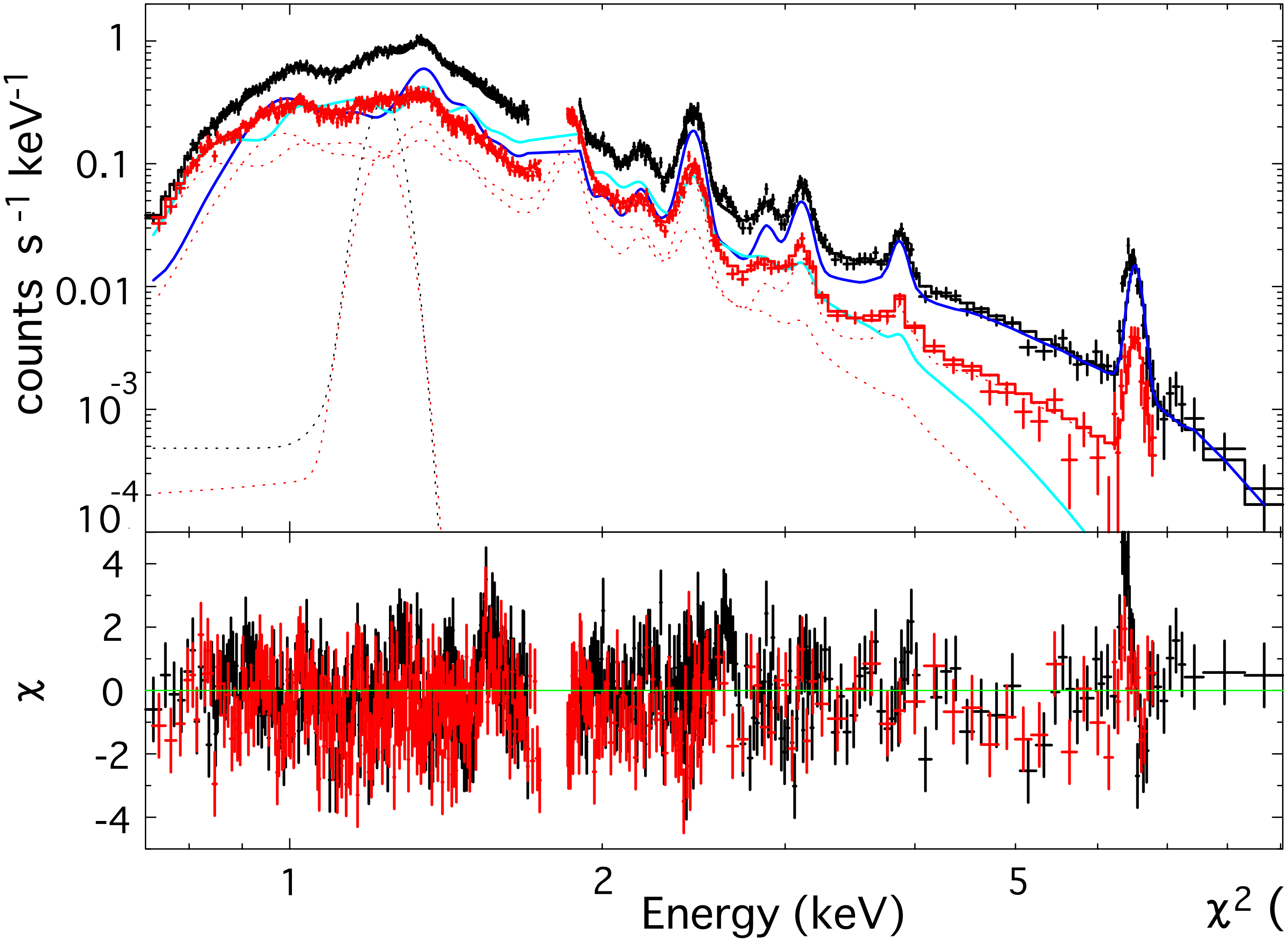
Single-Ejecta Model (same as the previous works)

CIE (ISM) + NEI (ejecta)



Single-Ejecta Model (same as the previous works)

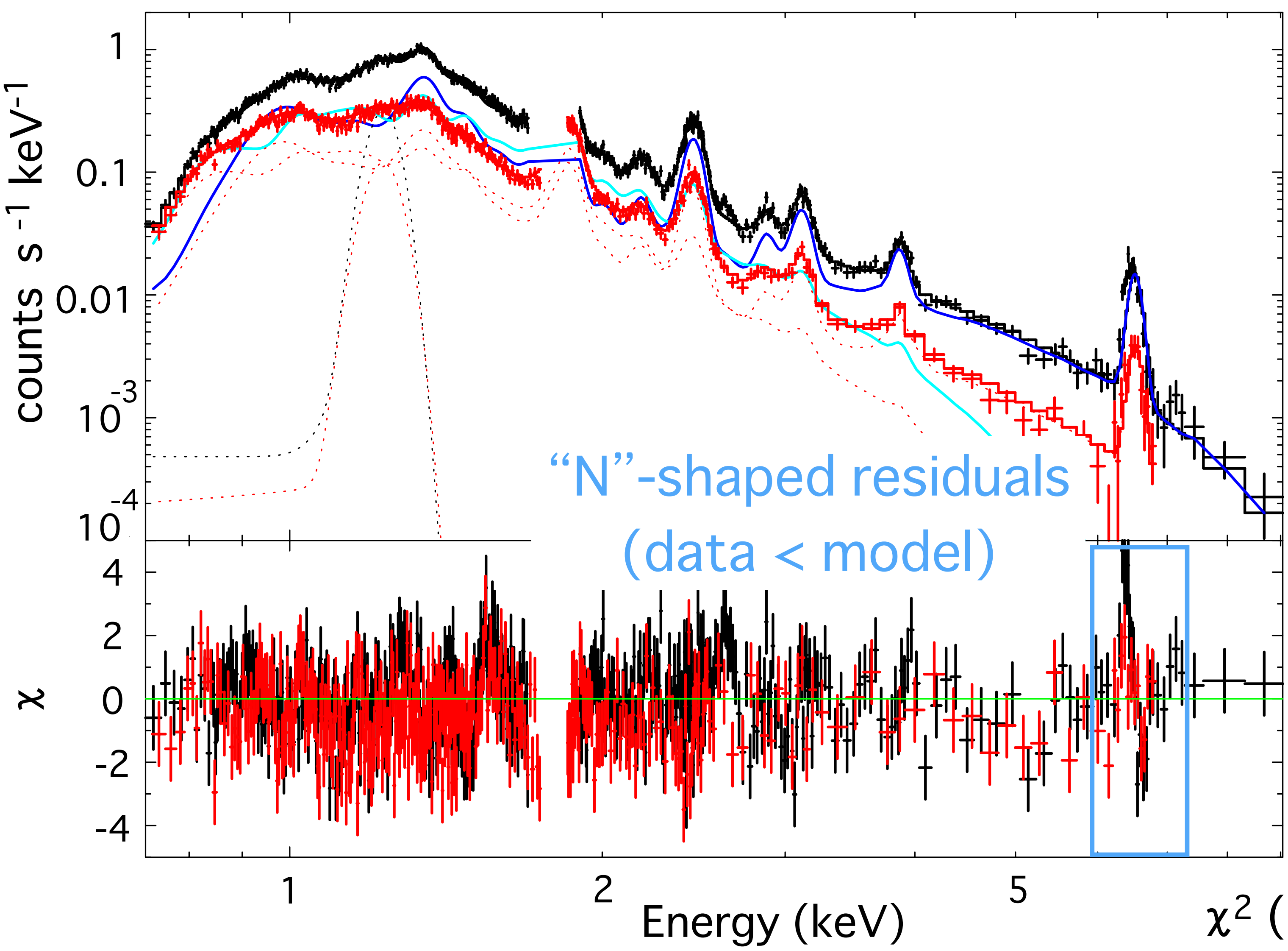
CIE (ISM) + NEI (ejecta)



χ^2 (d.o.f.)=1.335 (773)

Single-Ejecta Model (same as the previous works)

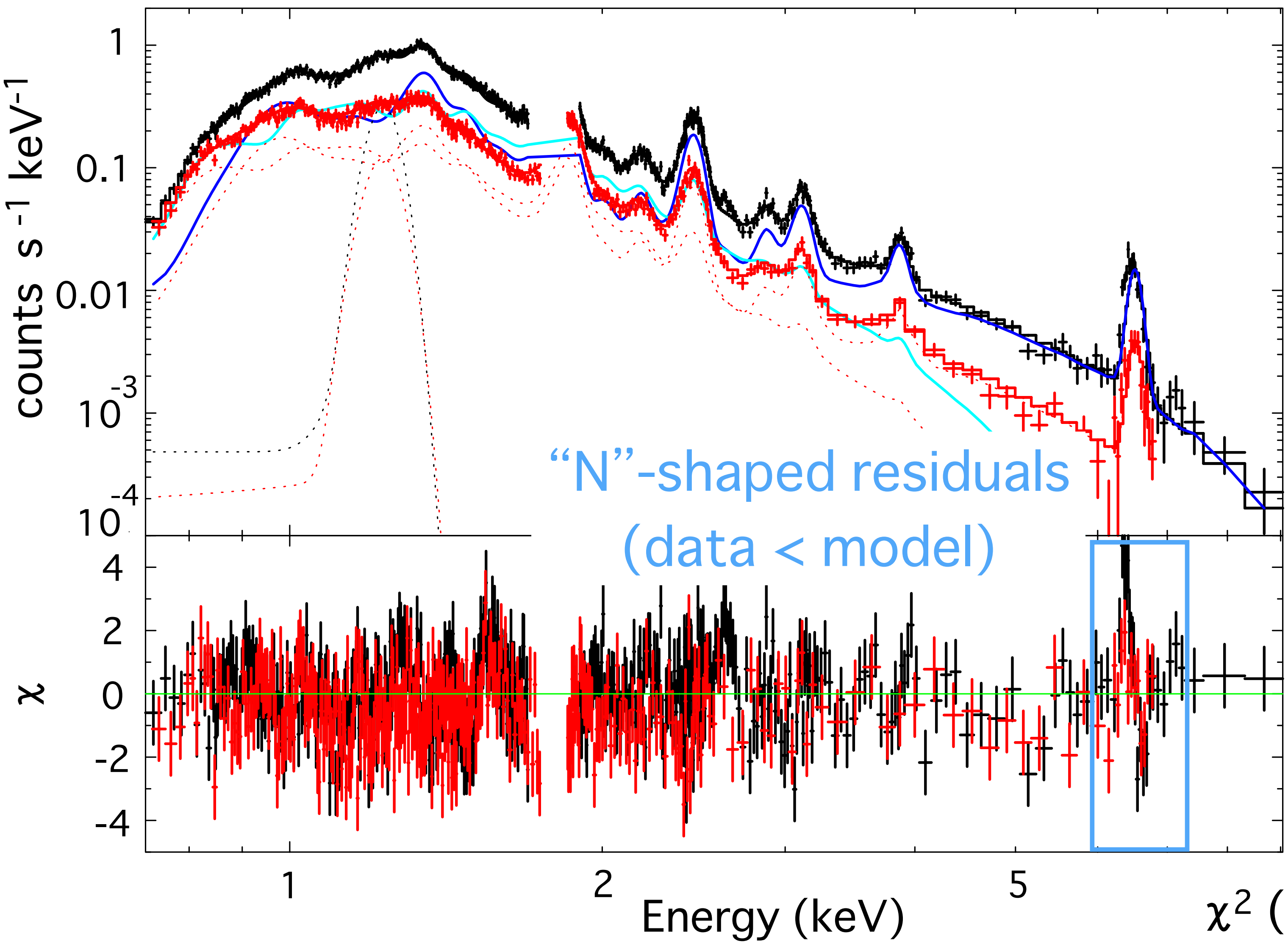
CIE (ISM) + NEI (ejecta)



χ^2 (d.o.f.)=1.335 (773)

Single-Ejecta Model (same as the previous works)

CIE (ISM) + NEI (ejecta)

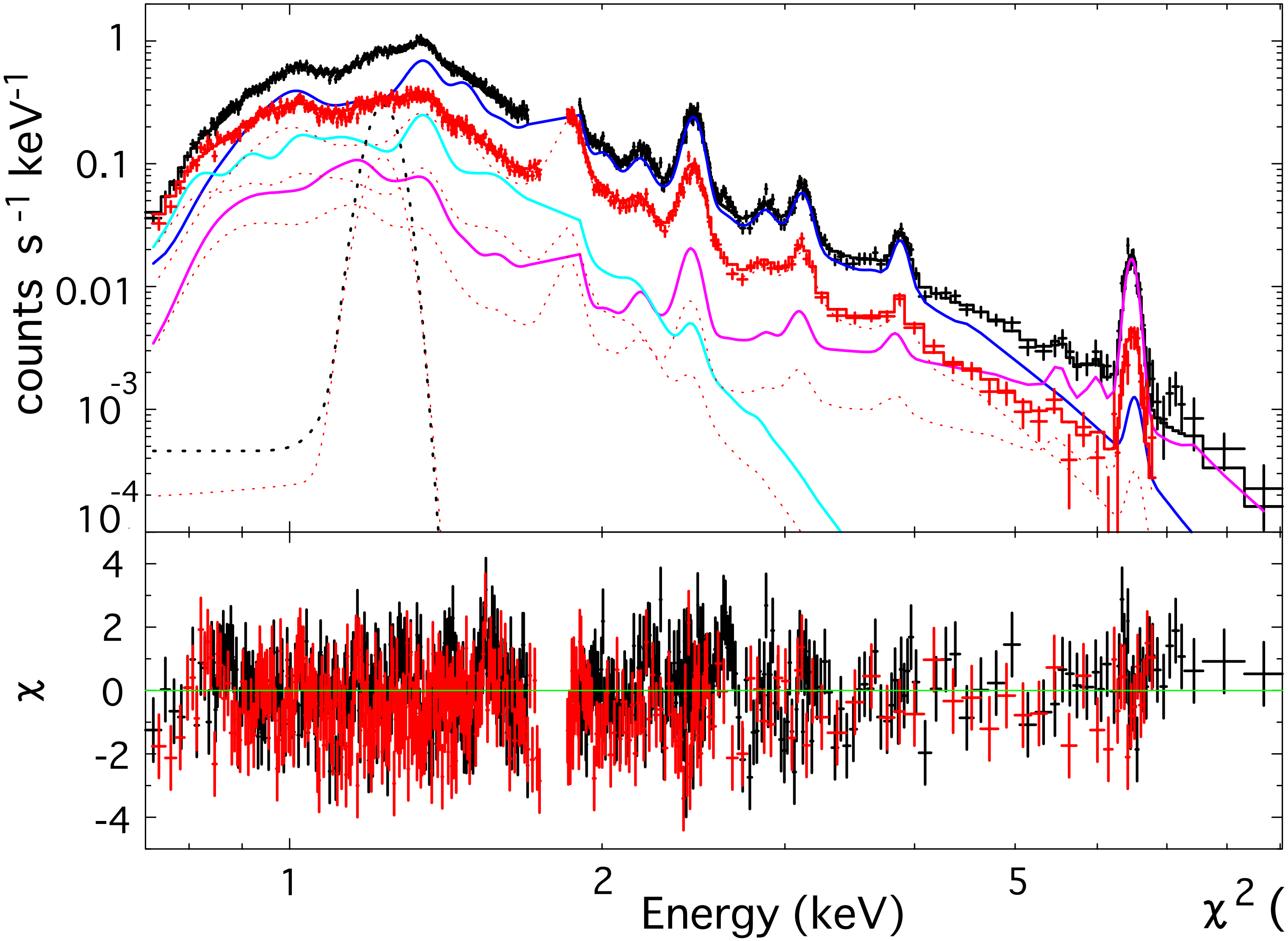


χ^2 (d.o.f.)=1.335 (773)

→different ionization timescale between IME and Fe

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)



N_H=1.3×10^{22} cm^{-2}

(ISM)

kT_e= 0.28 keV

(IME ejecta)

kT_e= 0.98 keV

n_et= 1.5×10^{11} cm^{-3}s

(Fe ejecta)

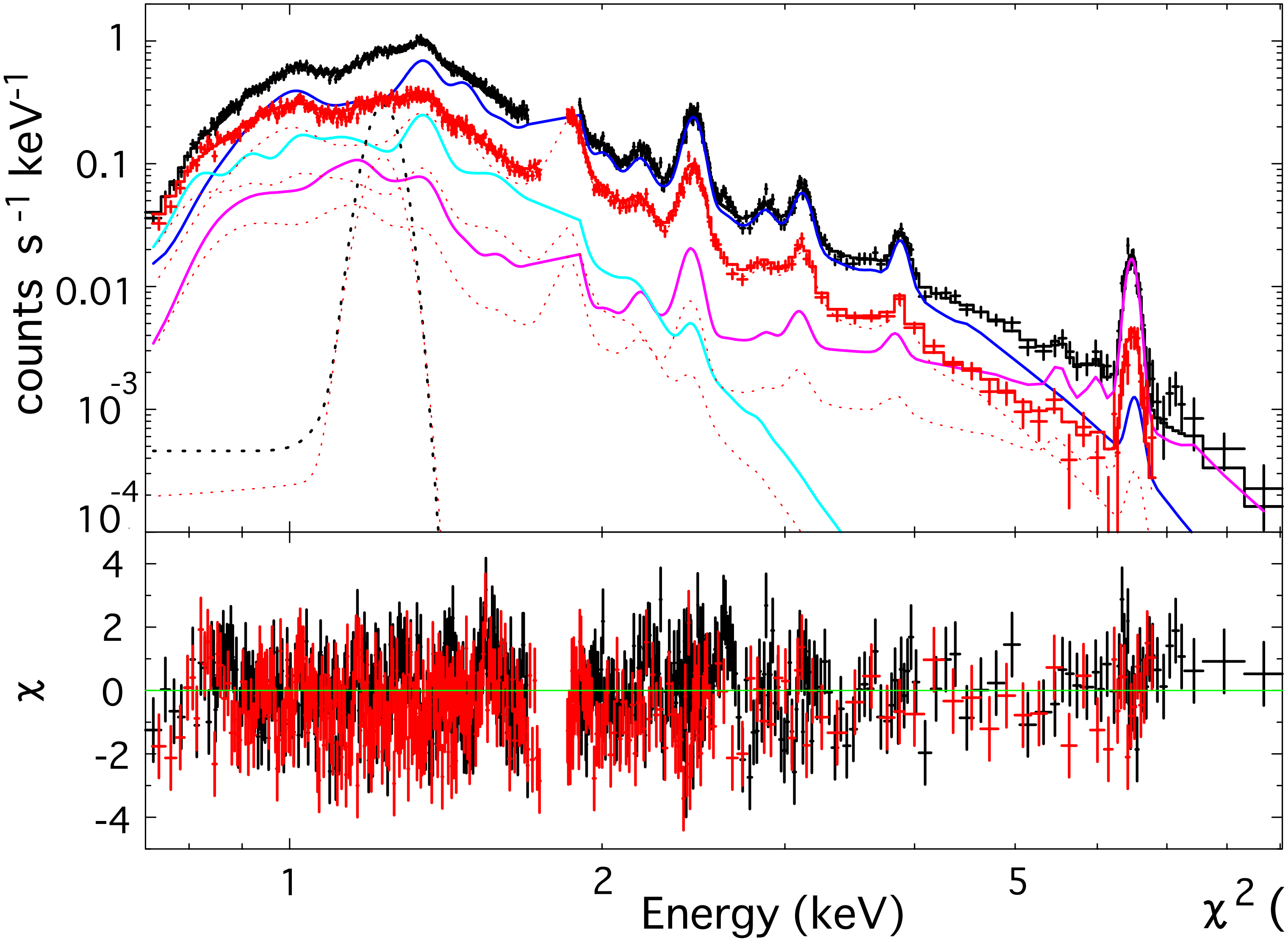
kT_e= 5 keV (fix)

n_et= 1.5×10^{10} cm^{-3} s

χ^2 (d.o.f.)=1.149 (768)

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)



$N_H = 1.3\times10^{22}$ cm^{-2}

(ISM)

kT_e = 0.28 keV

(IME ejecta)

kT_e = 0.98 keV

n_et = 1.5×10^{11} cm^{-3}s

(Fe ejecta)

kT_e = 5 keV (fix)

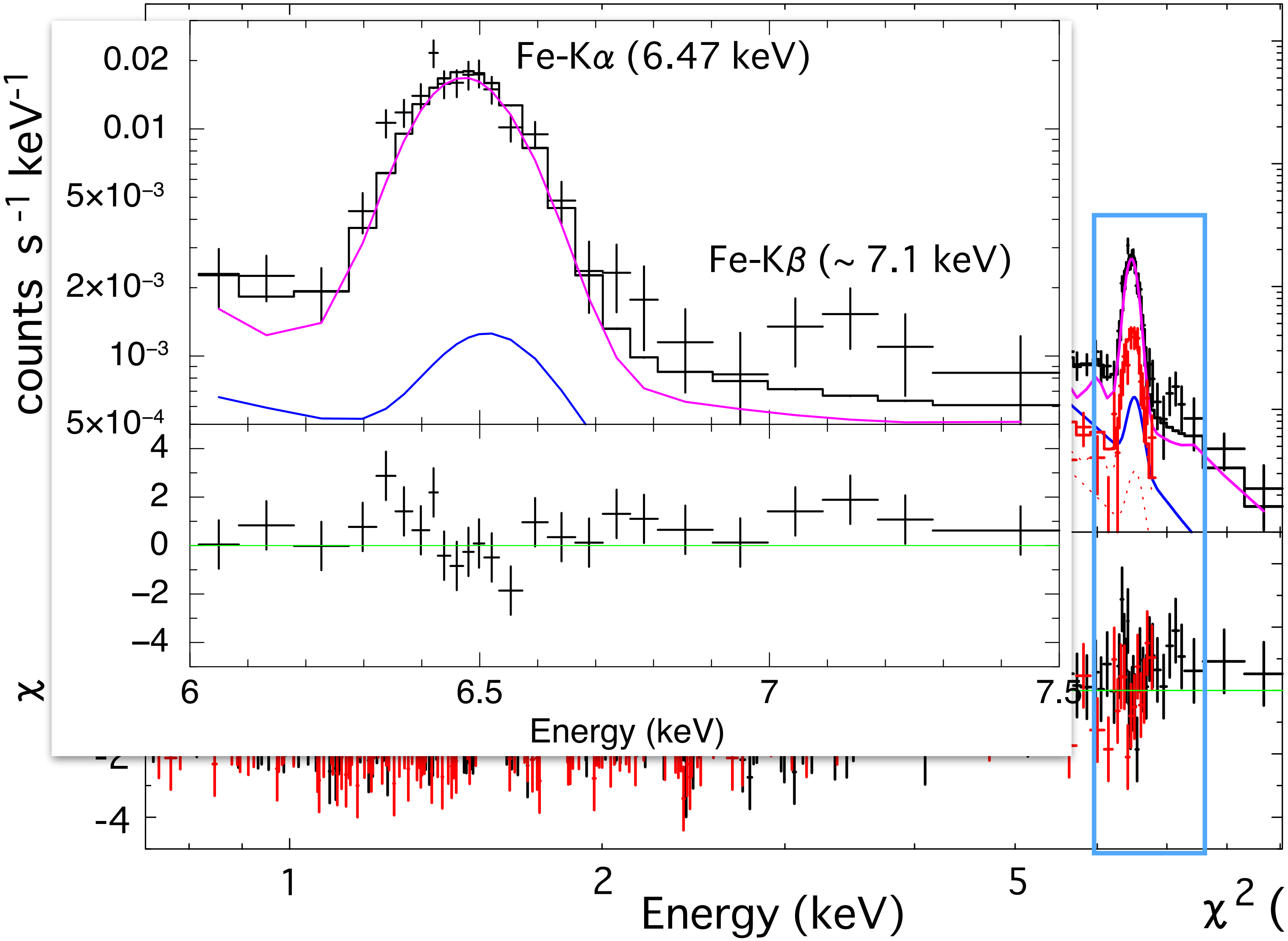
n_et = 1.5×10^{10} cm^{-3} s

χ^2 (d.o.f.)=1.149 (768)

Fe has one order of magnitude lower n_et than IME

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)



N_H=1.3x10^{22} cm^{-2}

(ISM)

kT_e= 0.28 keV

(IME ejecta)

kT_e= 0.98 keV

n_et= 1.5x10^{11} cm^{-3}s

(Fe ejecta)

kT_e= 5 keV (fix)

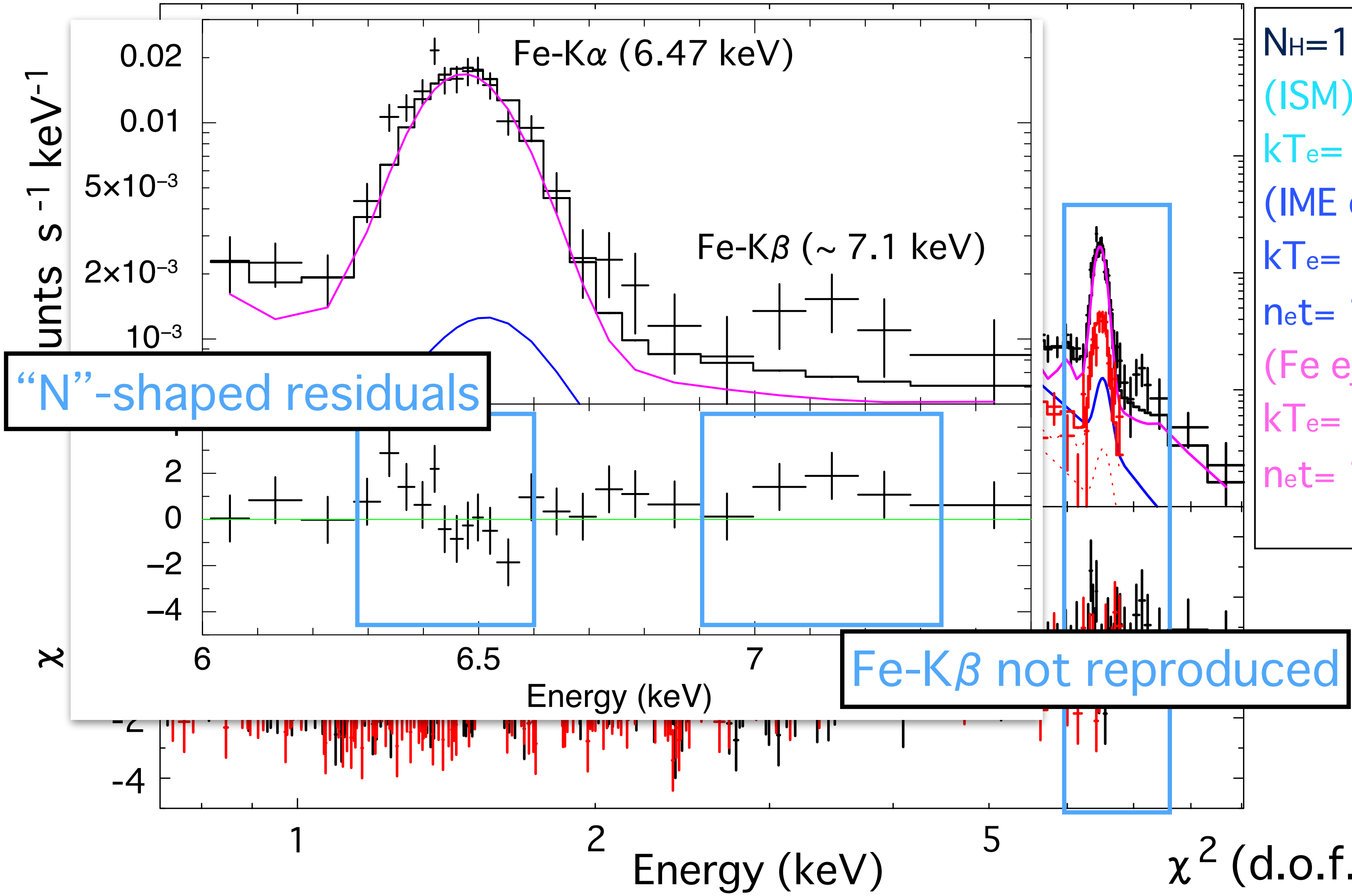
n_et= 1.5x10^{10} cm^{-3} s

χ^2 (d.o.f.)=1.149 (768)

Fe has one order of magnitude lower n_et than IME

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)



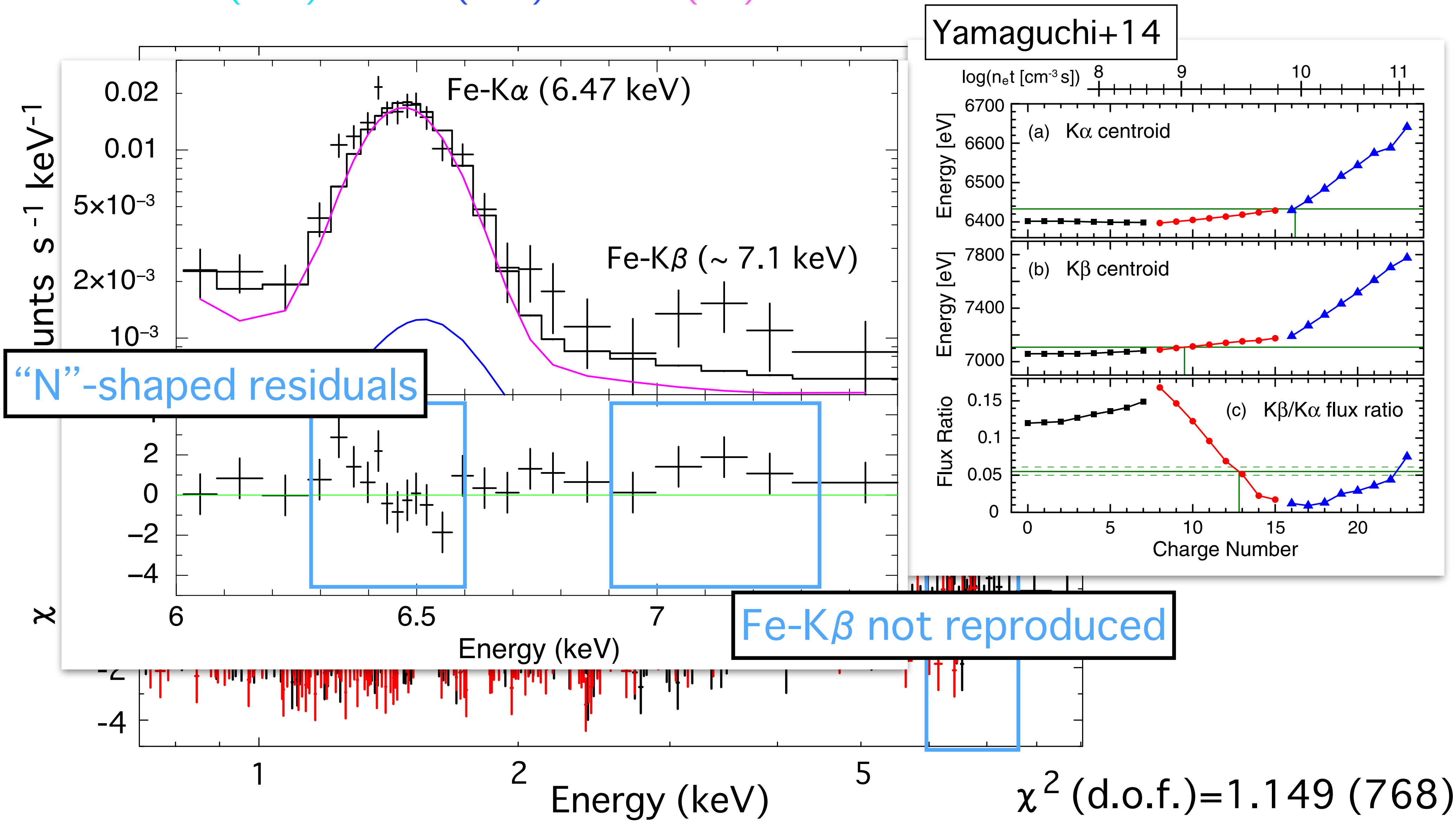
N_H=1.3x10^{22} cm^{-2}
(ISM)
kT_e= 0.28 keV
(IME ejecta)
kT_e= 0.98 keV
n_et= 1.5x10^{11} cm^{-3}s
(Fe ejecta)
kT_e= 5 keV (fix)
n_et= 1.5x10^{10} cm^{-3} s

χ^2 (d.o.f.)=1.149 (768)

Fe has one order of magnitude lower n_et than IME

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)

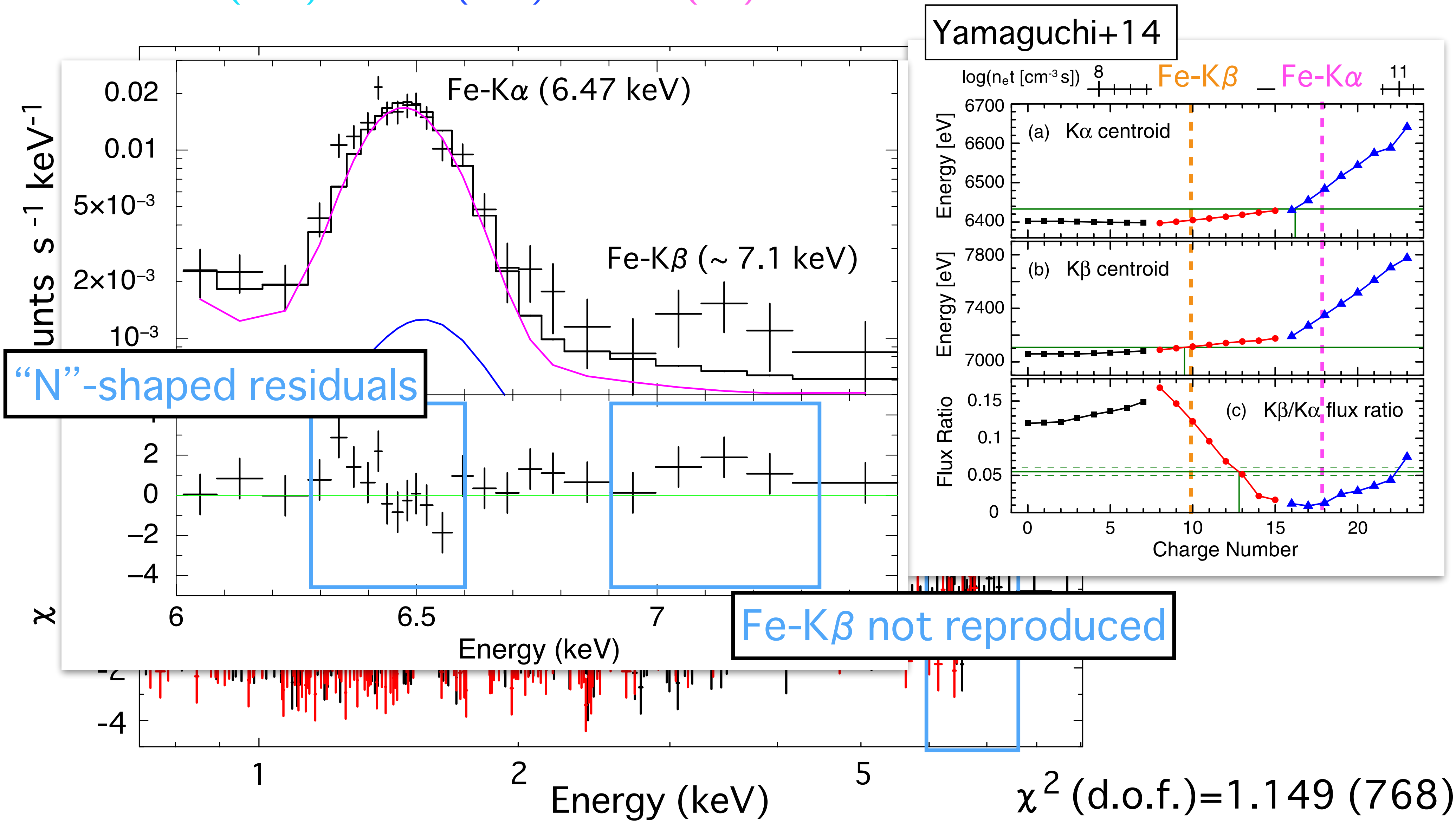


χ^2 (d.o.f.)=1.149 (768)

Fe has one order of magnitude lower $n_e t$ than IME

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)

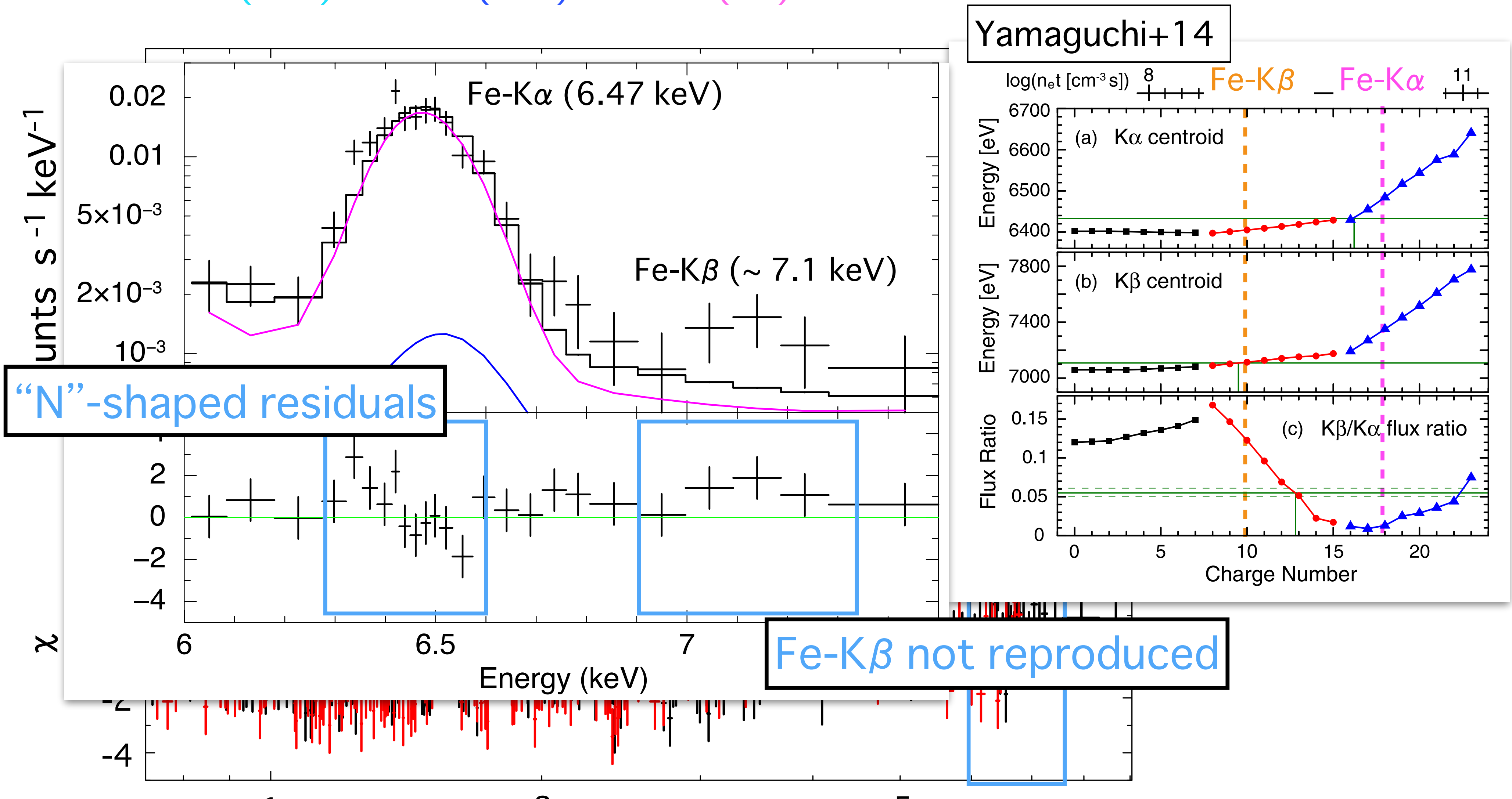


χ^2 (d.o.f.)=1.149 (768)

Fe has one order of magnitude lower $n_e t$ than IME

Two-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (Fe)

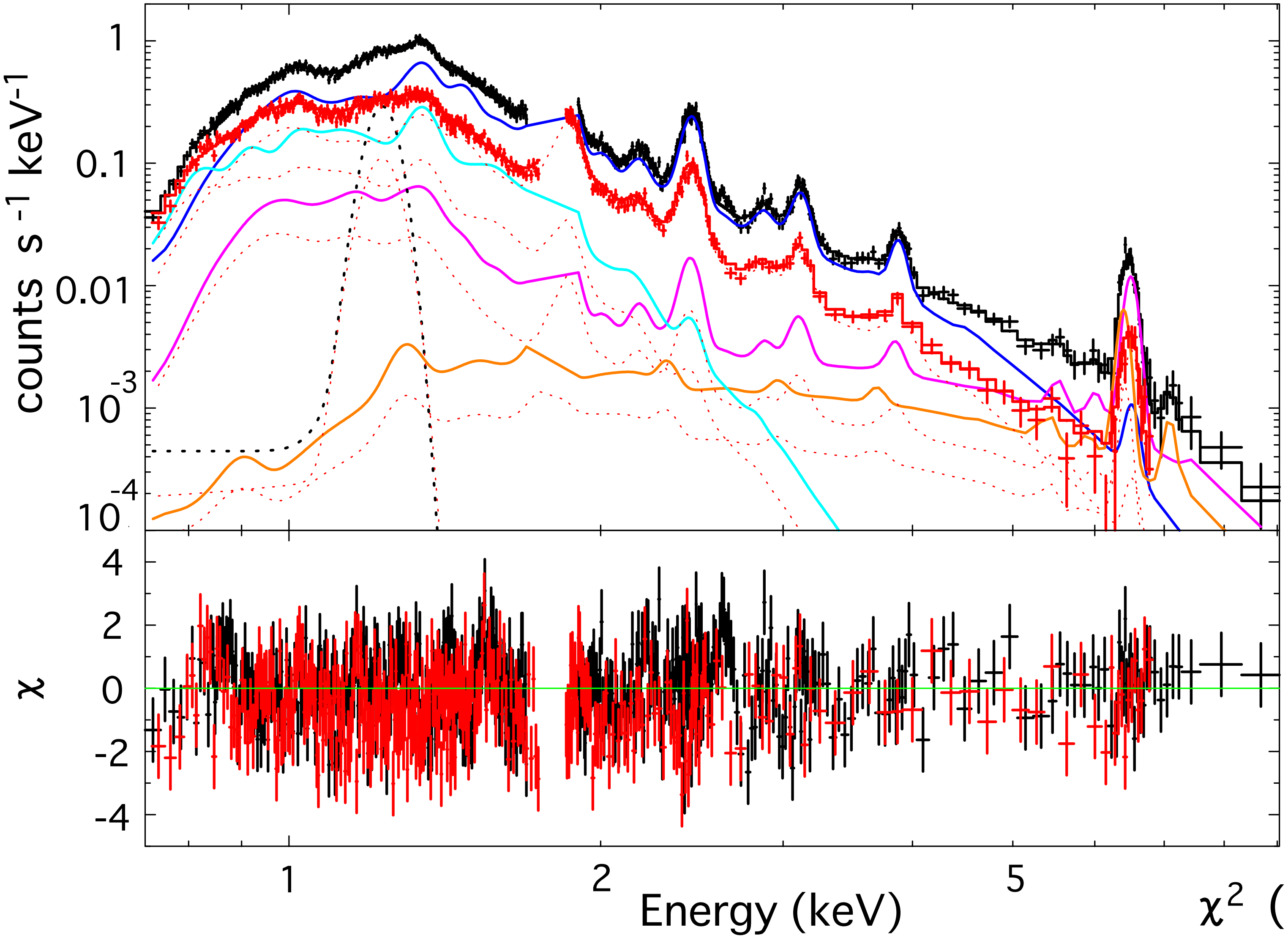


χ^2 (d.o.f.)=1.149 (768)

→indicates the presence of lower-$n_e t$ Fe

Three-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (high-n_et Fe) + NEI (low-n_et Fe)



N_H=1.3x10^{22} cm^{-2}

(ISM)

kT_e= 0.27 keV

(IME ejecta)

kT_e= 0.93 keV

n_et= 1.8x10^{11} cm^{-3}s

(Fe ejecta)

kT_e= 5 keV (fix)

n_et= 2.1x10^{10} cm^{-3} s

(low-nt Fe)

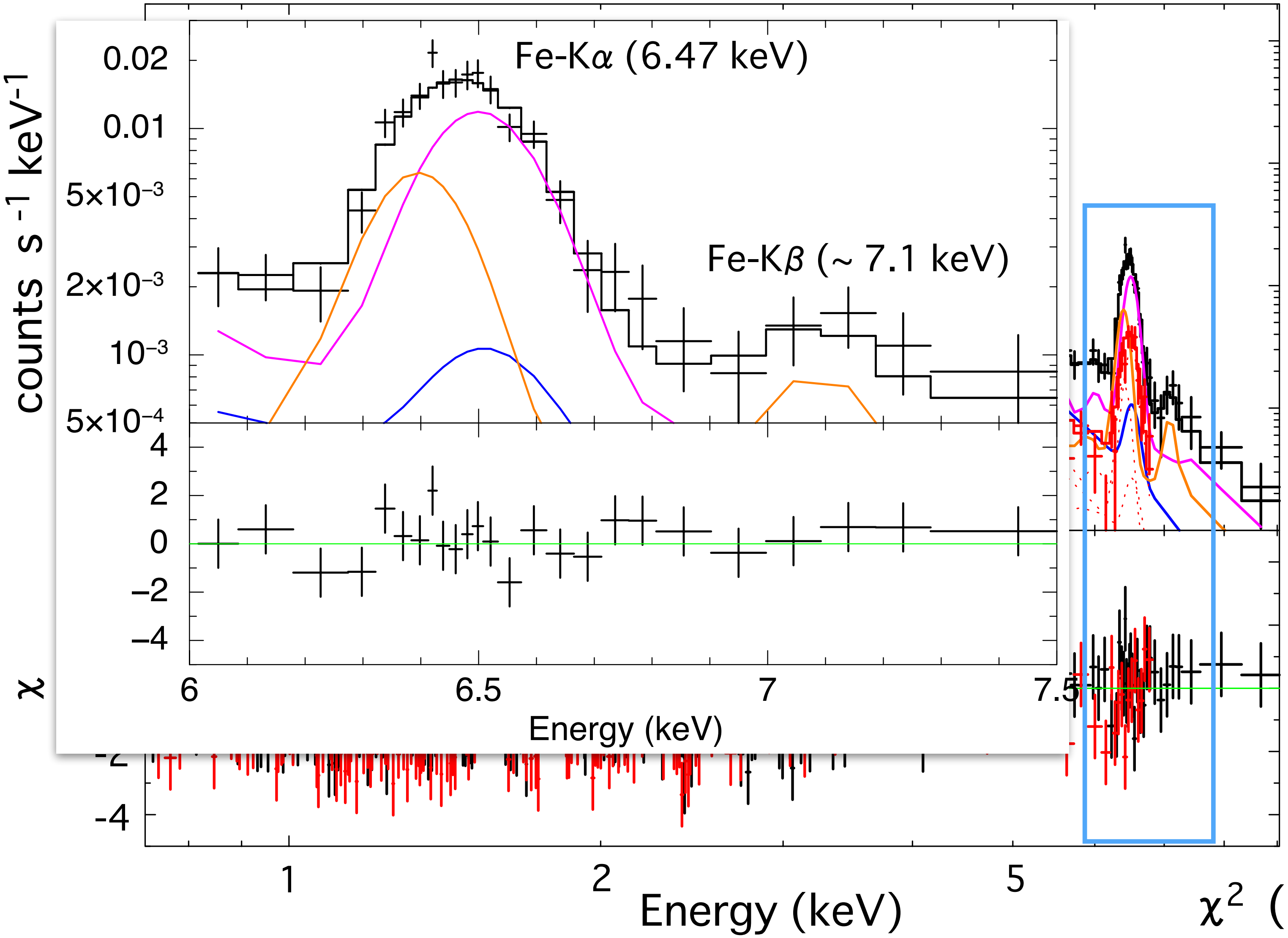
kT_e= 5 keV (fix)

n_et= 7.5x10^{9} cm $^{-3}$s

χ^2 (d.o.f.)=1.126 (766)

Three-Ejecta Model

CIE (ISM) + NEI (IME) + NEI (high-net Fe) + NEI (low-net Fe)



N_H=1.3x10^{22} cm^{-2}

(ISM)

kT_e= 0.27 keV

(IME ejecta)

kT_e= 0.93 keV

n_et= 1.8x10^{11} cm^{-3}s

(Fe ejecta)

kT_e= 5 keV (fix)

n_et= 2.1x10^{10} cm^{-3} s

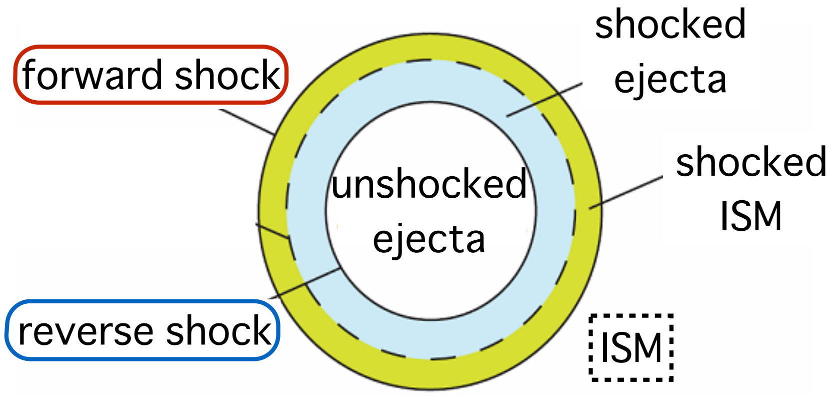
(low-nt Fe)

kT_e= 5 keV (fix)

n_et= 7.5x10^9 cm $^{-3}$s

χ^2 (d.o.f.)=1.126 (766)

Discussion① Nature of Fe ejecta



H. Yamaguchi modified

	Fe		IME
$n_e t$	2.1×10^{10} cm^{-3}s	<	1.8×10^{11} cm^{-3}s
$k_e T$	> 3 keV	>	0.93 keV

Fe-dominated ejecta has

- one-order-of-magnitude lower $n_e t$
- higher temperature

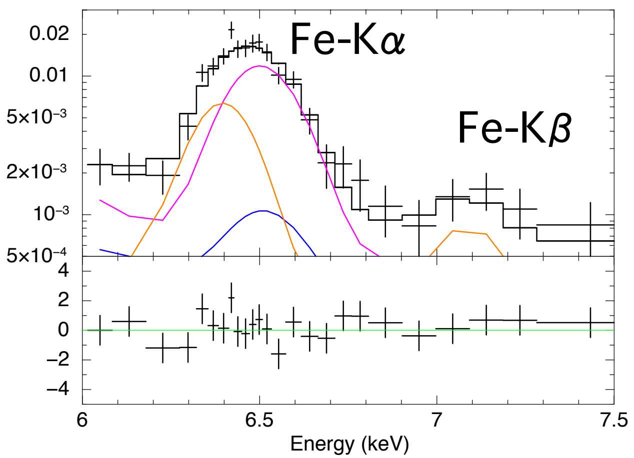
→ Fe has recently shock-heated by reverse shock.

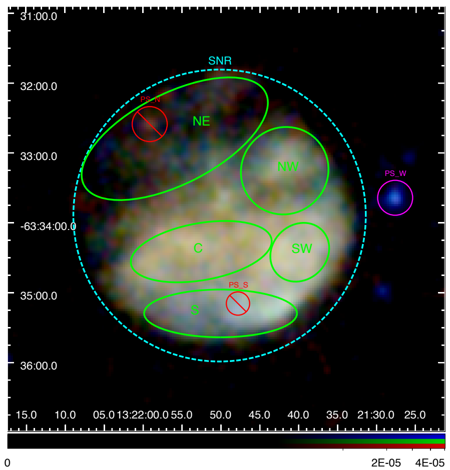
the ejecta stratification is still maintained.

---

additional "lower-ionized Fe ejecta" component

G306.3−0.9



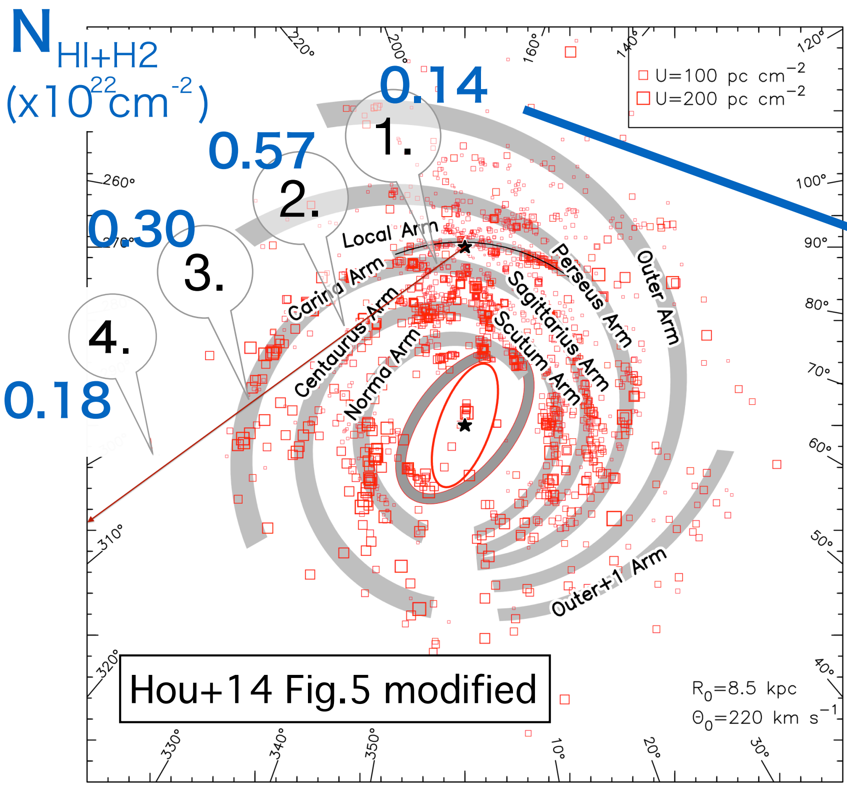


XMM-Newton (Combi+16)

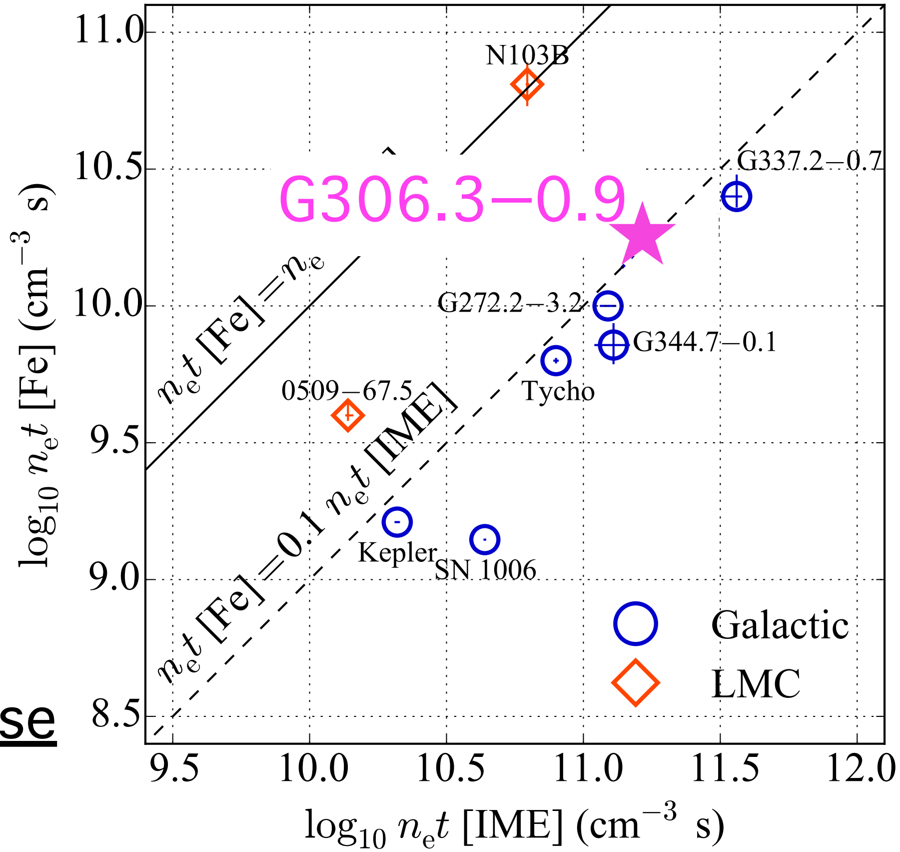
the possibilities of

- anisotropy of reverse-shock
- non uniformity of ejecta

Discussion② Distance and Age



- Distance
  (fit result) N_H =1.2-1.3 x 10^{22} cm^{-2}
  (Galactic total) ΣN_{HI+H2} ~1.18 x $10^{22}cm^{-2}$
  → likely on the edge of the Galaxy (d ~ 20 kpc)
- Forward shock-velocity (from kT_e of ISM)
  → v ~ 490 km s^{-1}



- t_{sedov} = 0.4R/v ~ 8500 yr
- one of the most thermally evolved Type Ia SNRs.
- mixing of ejecta is not so effective in a relatively later stage of the Sedov phase

Summary

- We analyzed the Suzaku data of the SNR G306.3−0.9
- Spectrum analysis showed the Fe-Kα centroid is 6.47±0.01 keV.
- Fe-dominated ejecta has
  - one-order-of-magnitude lower $n_e t$ = 2.1 x 10^{10} cm^{-3} s
  - higher kT_e > 3 keV

  than IME-dominated ejecta, indicating Fe has recently shock-heated by reverse shock.
- To explain Fe-Kβ, additional "lower-ionized Fe ejecta" component is needed.
- The Hydrogen absorption column density 1.2-1.3 x 10^{22} cm^{-2} leads to the conclusion that the SNR age is ~ 8.5 kyr.

  Mixing of ejecta is not so effective in a relatively later stage of the Sedov phase.