Discovery of a recombination dominant plasma: a relic of a giant flare of Sgr A*?

Shinya Nakashima (Kyoto Univ.)

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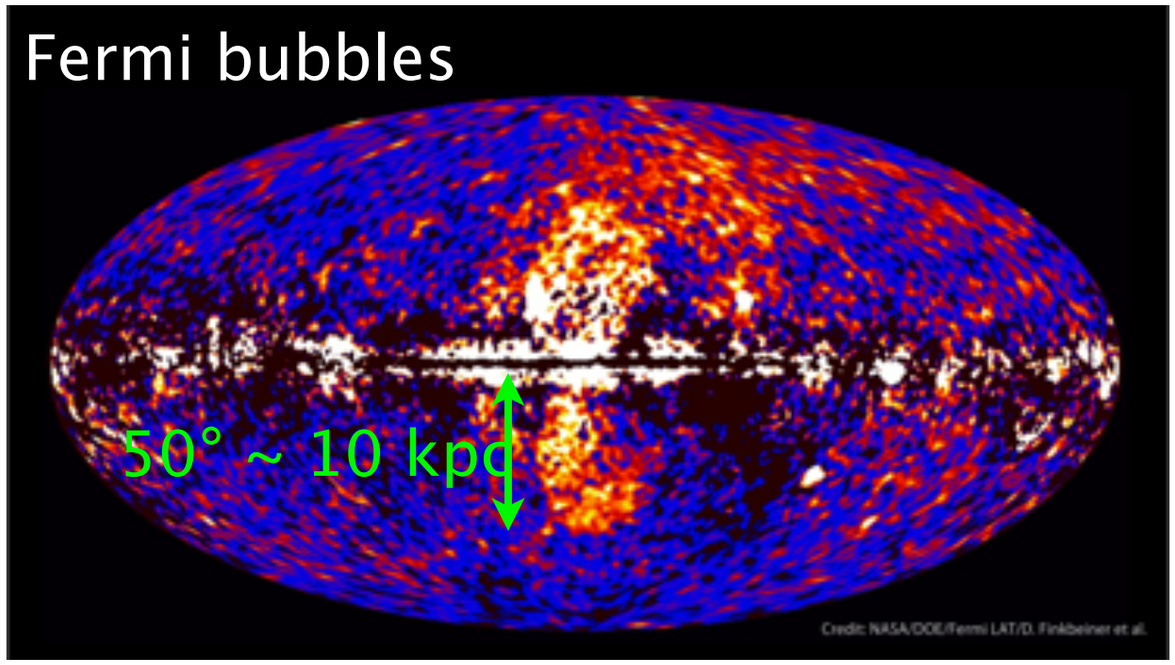
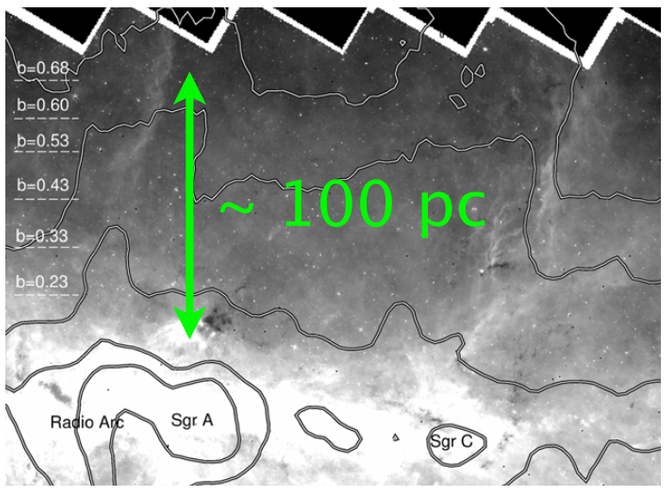
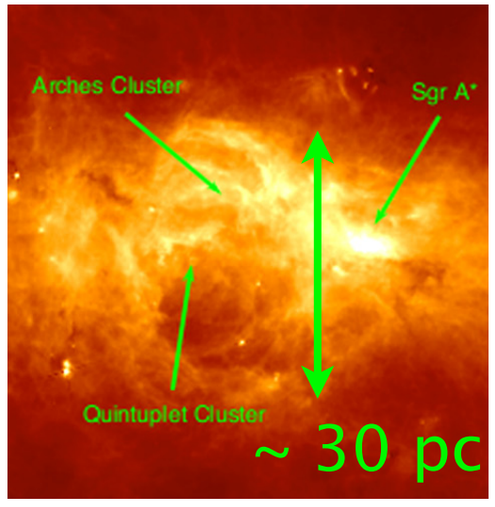
H. Uchiyama[3], H. Murakami[4]

Outflows from GC in various



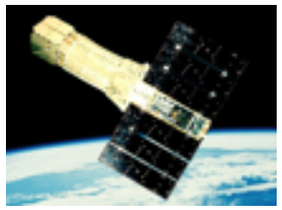
- 10 kpc outflows
  - Fermi bubbles (Su+10)
  - Magnetized radio outflows (Carrett +13)
- 100 pc scale outflows
  - Galactic center lobe (Sofue+84, Lav +10)
  - IR galactic center bubble (Molinari

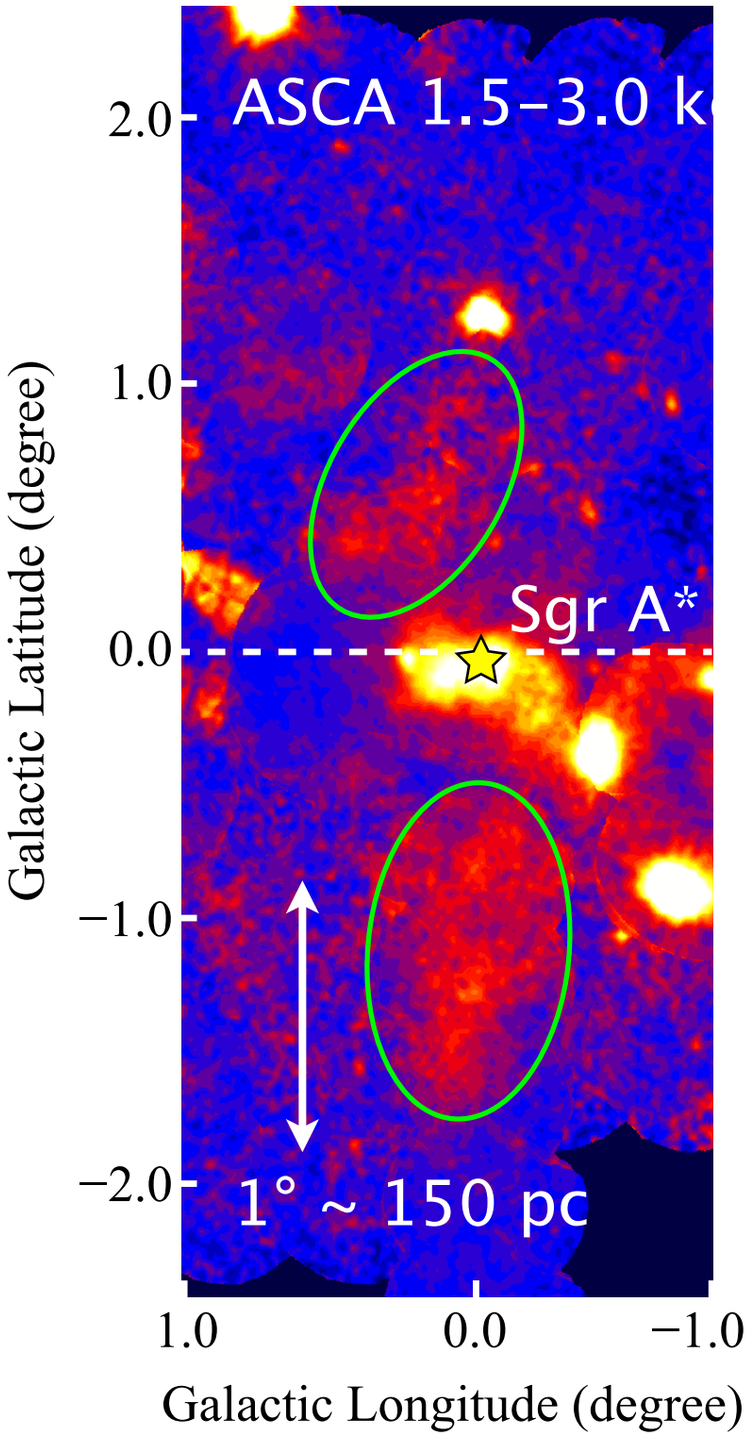




Is there any hot gas outflows ?
-> We have searched outflows in X-ray band.

Outflow-like emissions in X-ray band





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  - ~150 pc scale.
  - photon statistics are limited and detailed nature is not clear.

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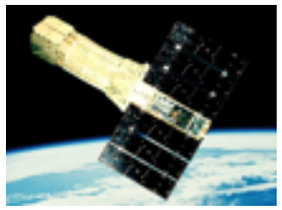

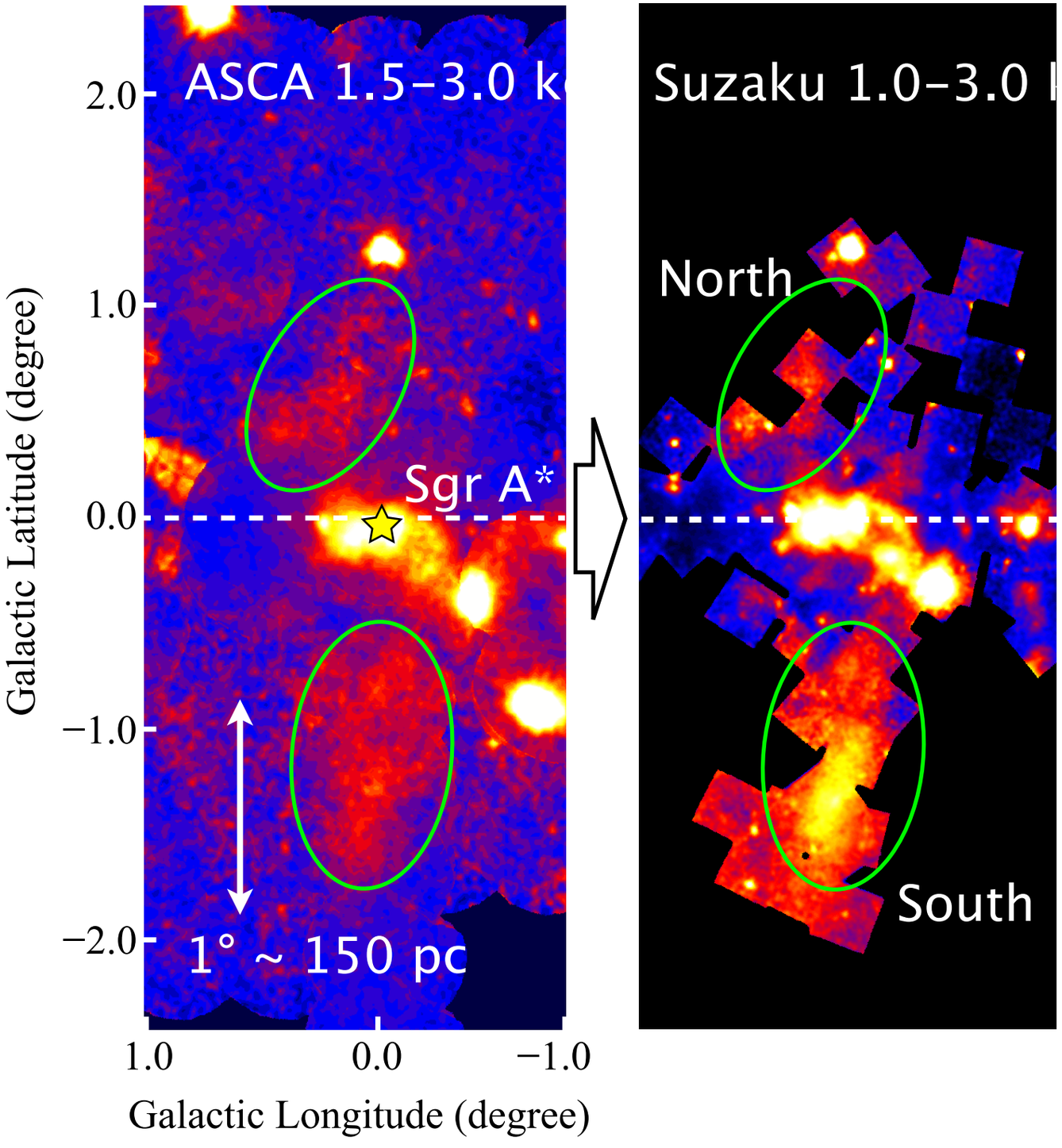

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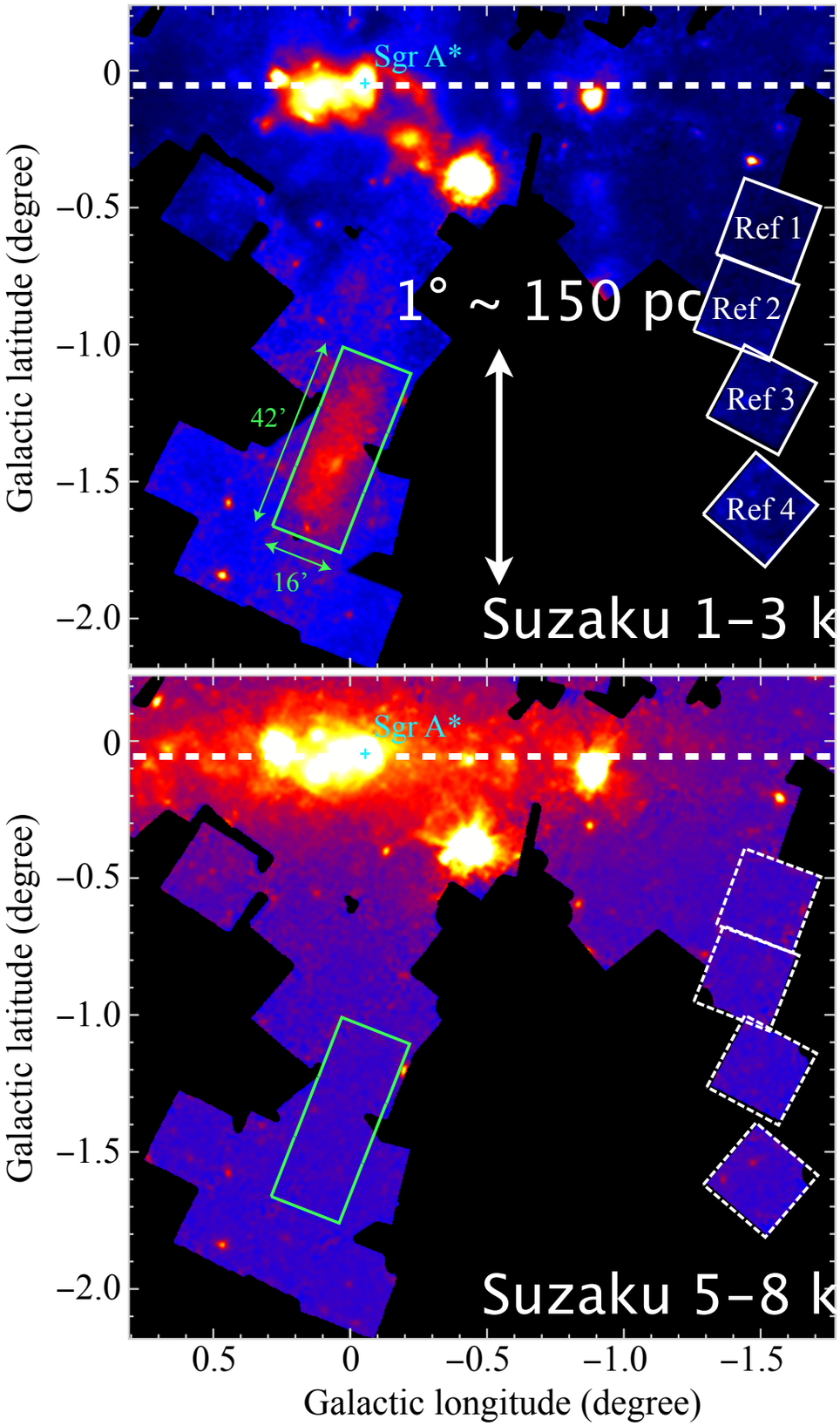
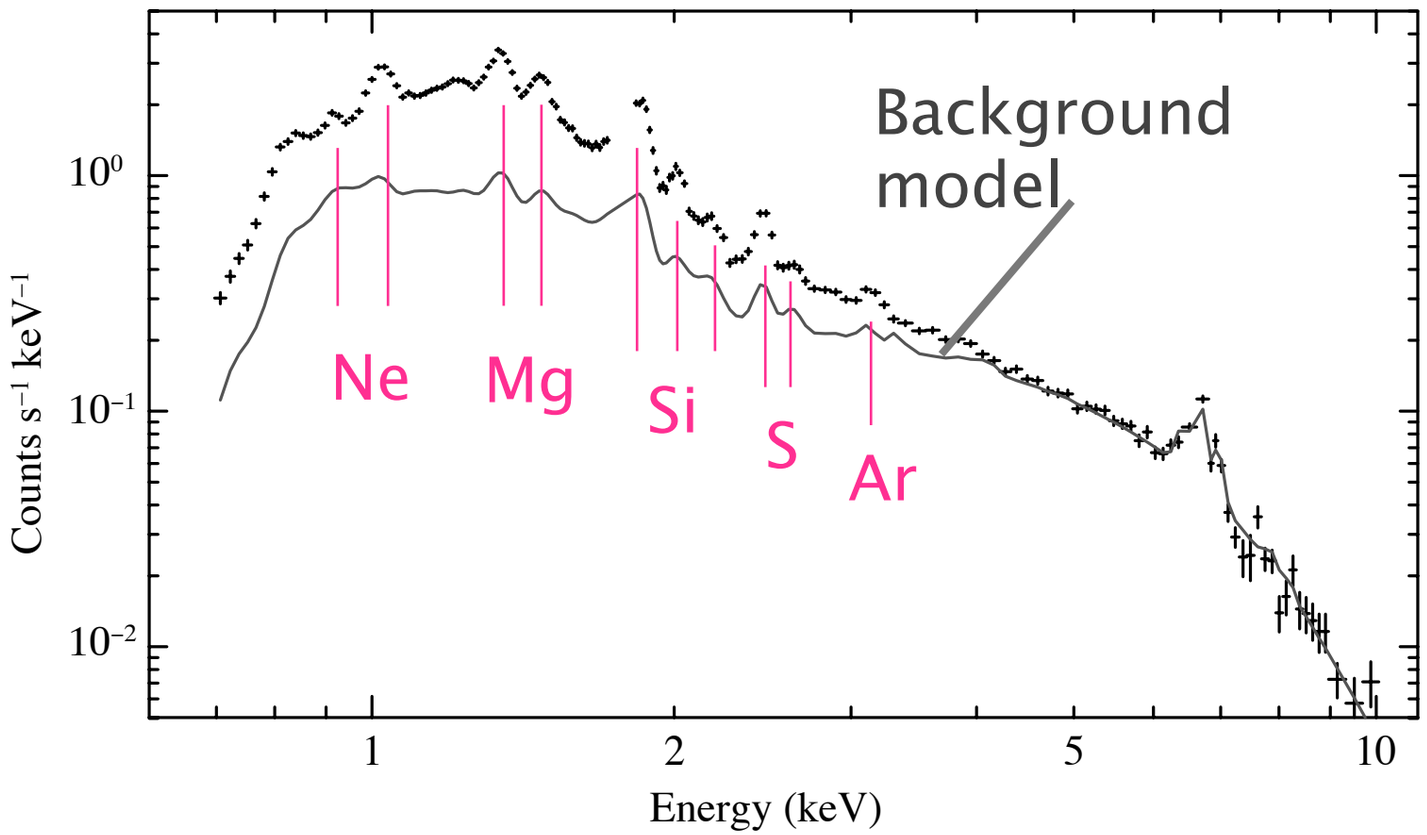
- We confirmed the emissions with Suzaku.
  - Not all the region have been covered by Suzaku yet.
  - good photon statistics and high contrast image.
- We investigated detailed nature of the emissions with Suzaku data.

Spectrum of the south emission (Nakashima +13)

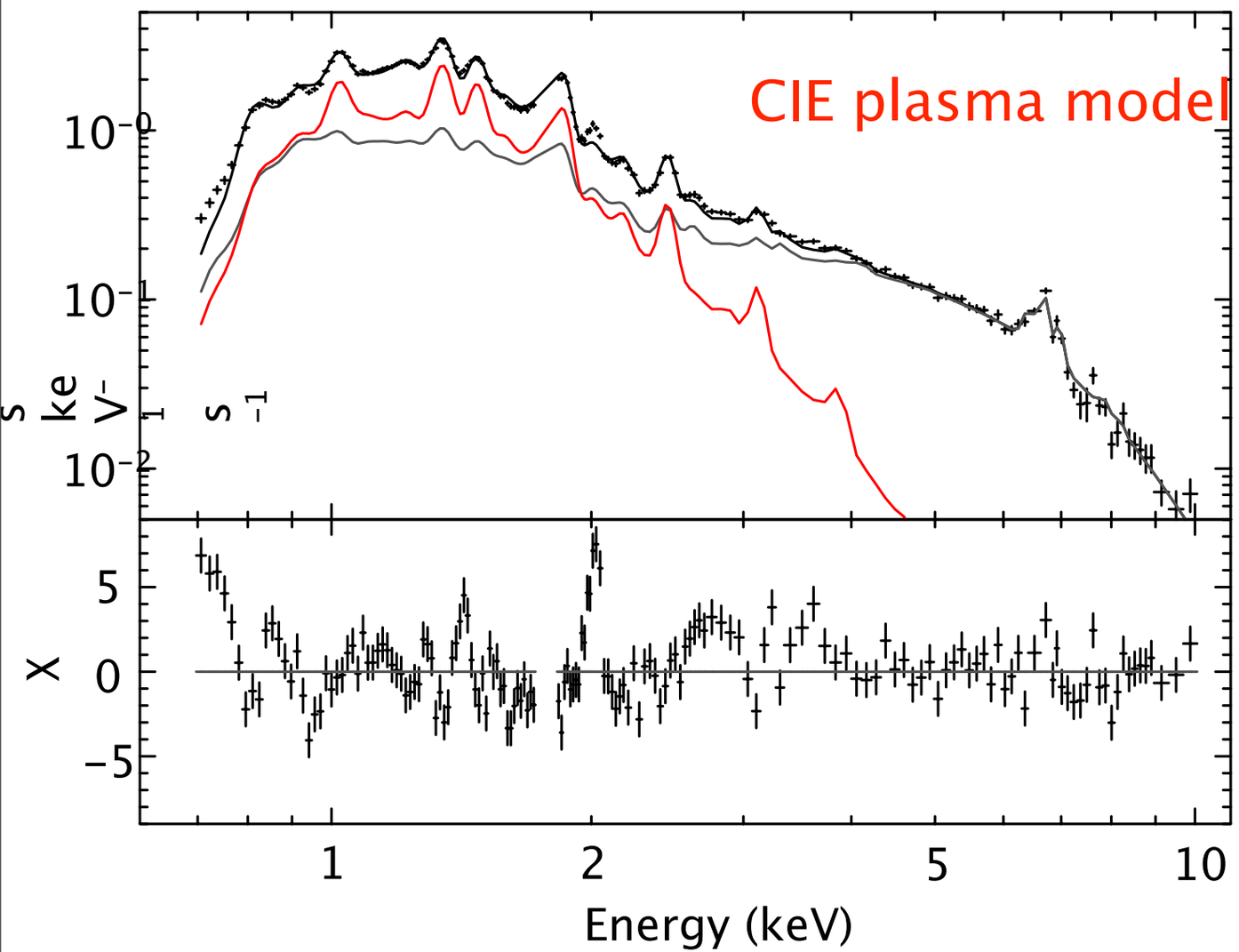




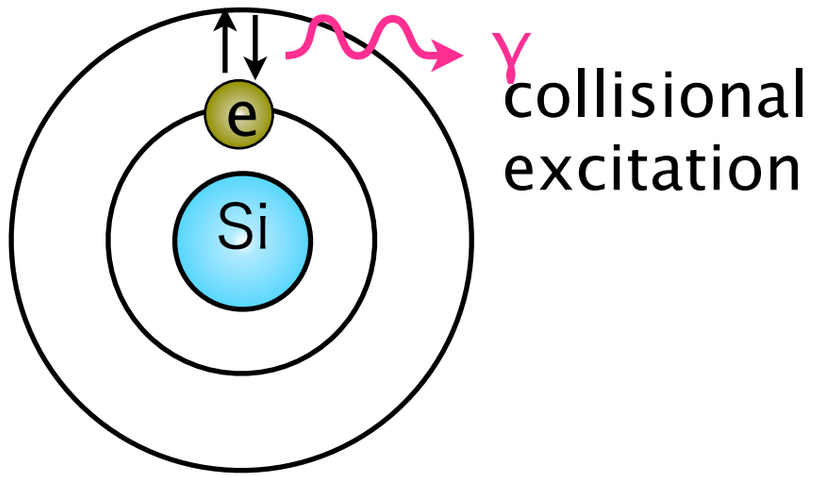
- There is no excess in the hard X-ray band.
- We obtained a spectrum from the brightest part of the south emission.
- Background level is estimated from nearby fields.
- Detect emission lines from highly ionized atoms -> emission from plasma (~10^7 K).

South emission is over-ionized plasma

Compared the data with physical plasma models



Not Collisional Ionization Equilibrium (CIE) plasma



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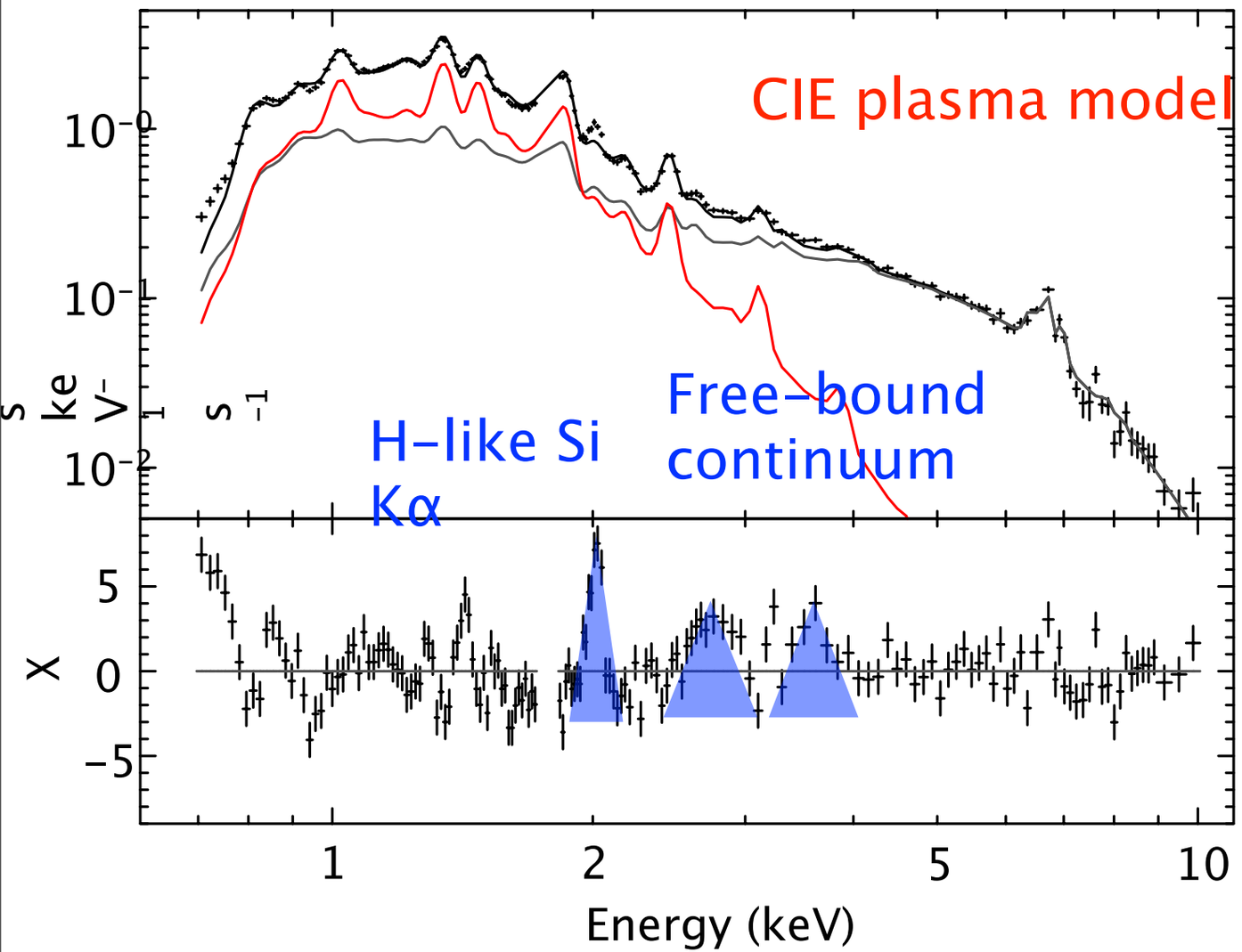

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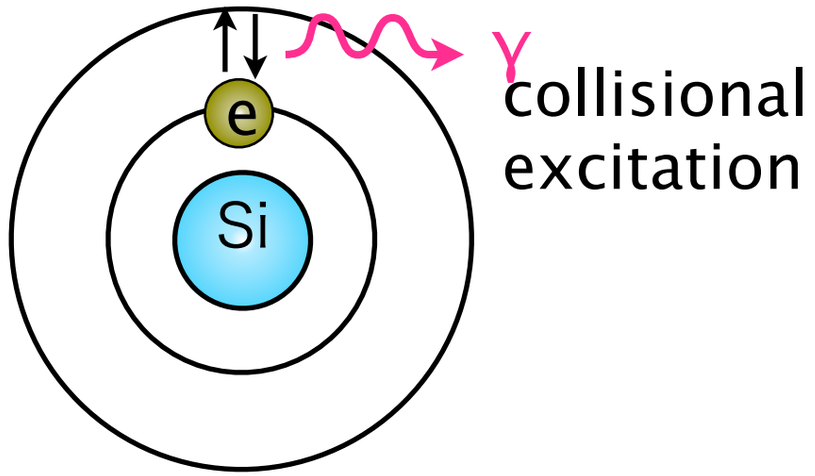

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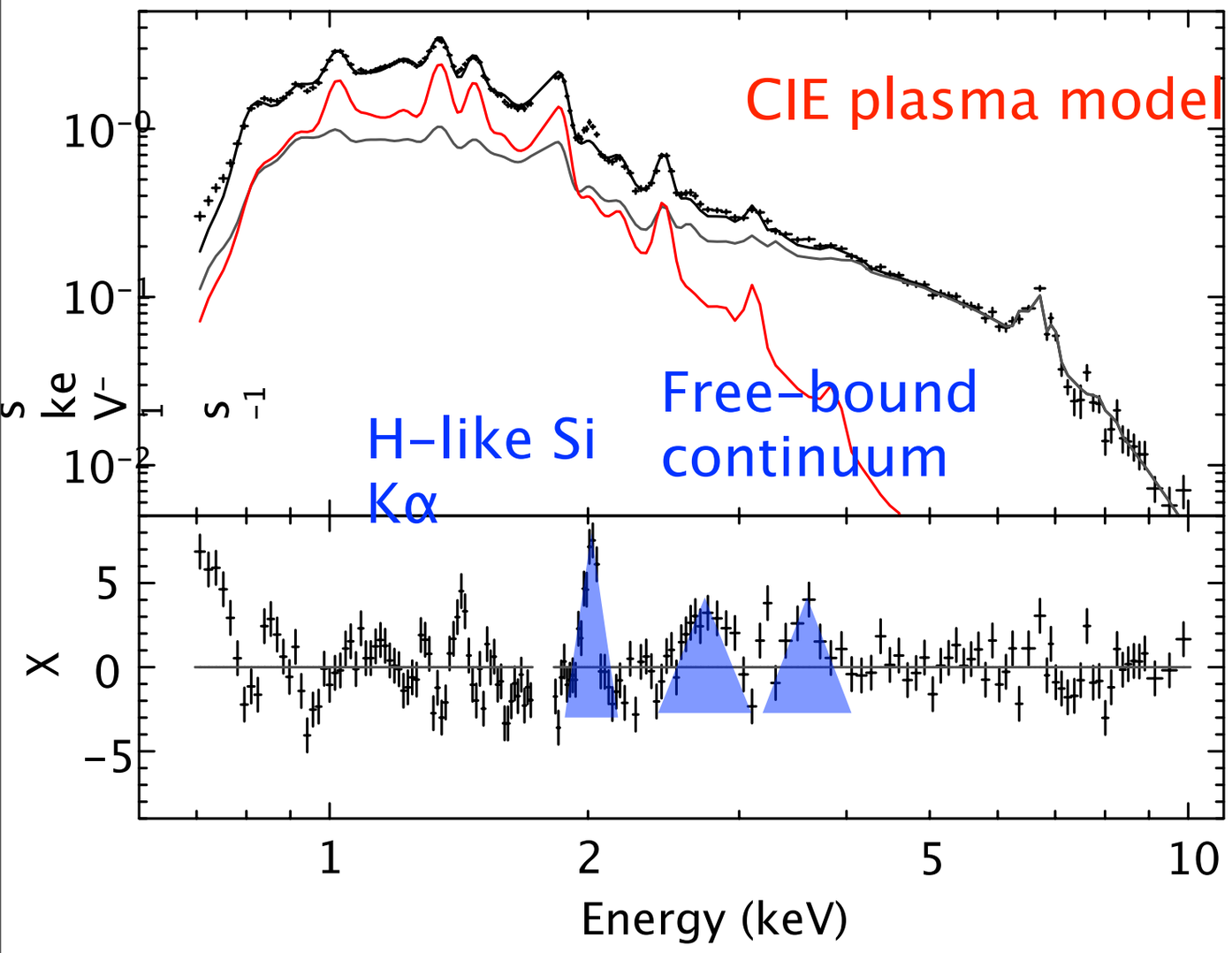

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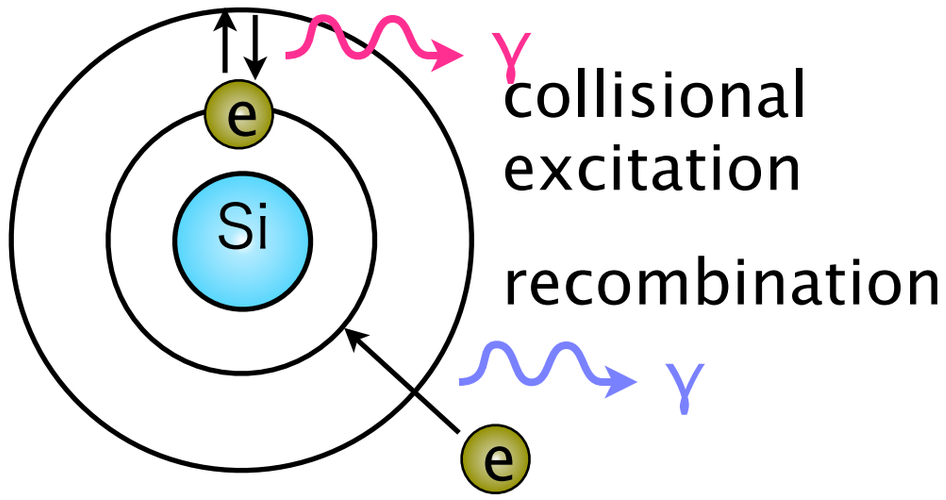

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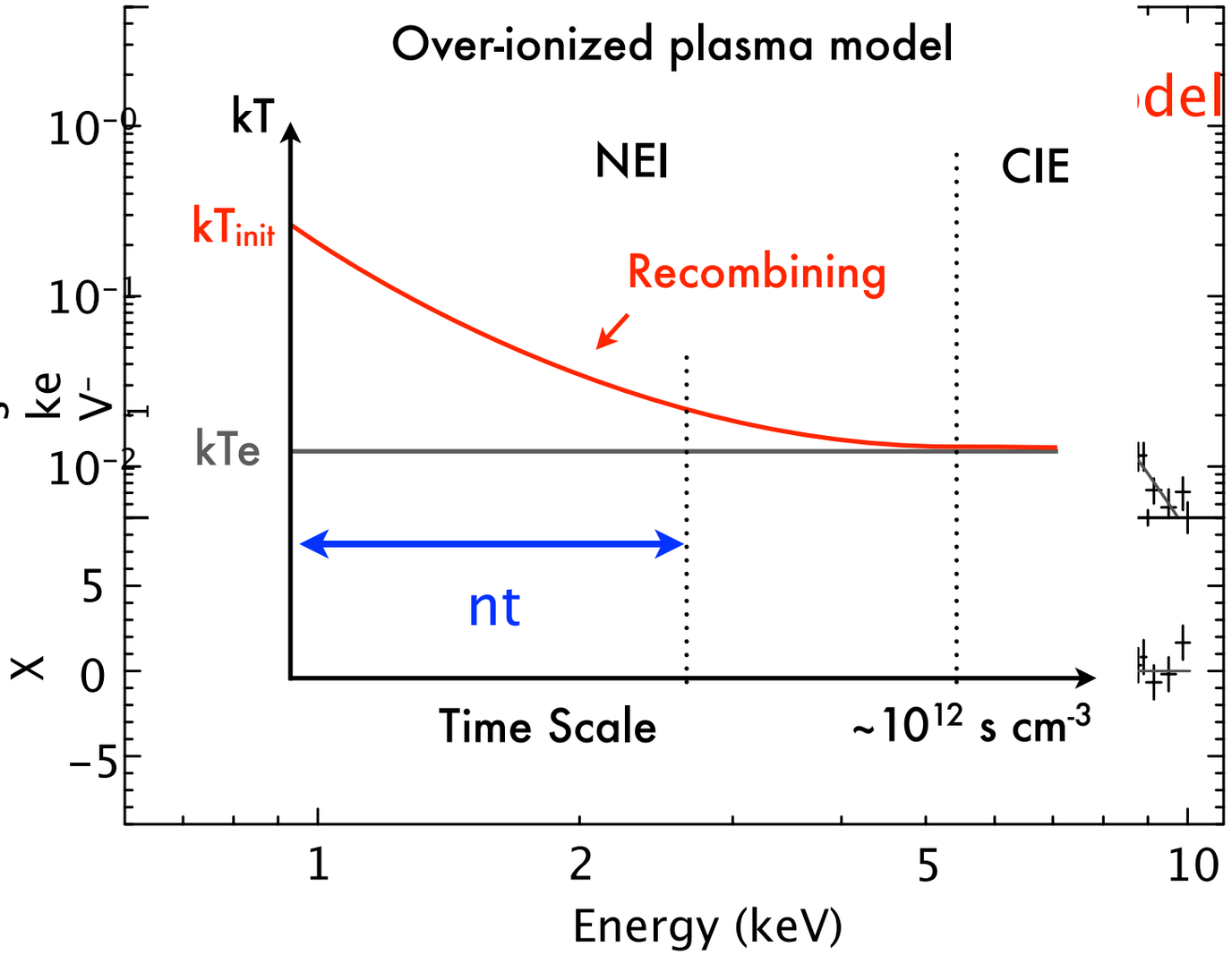

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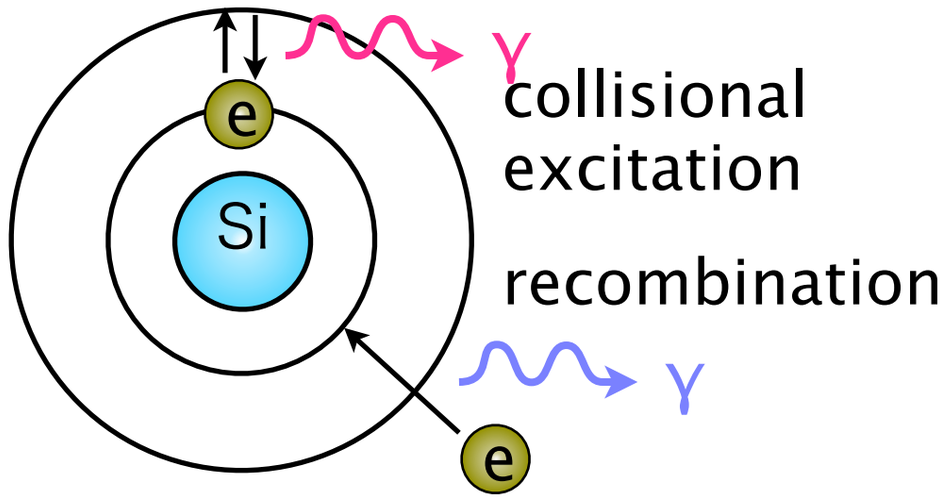

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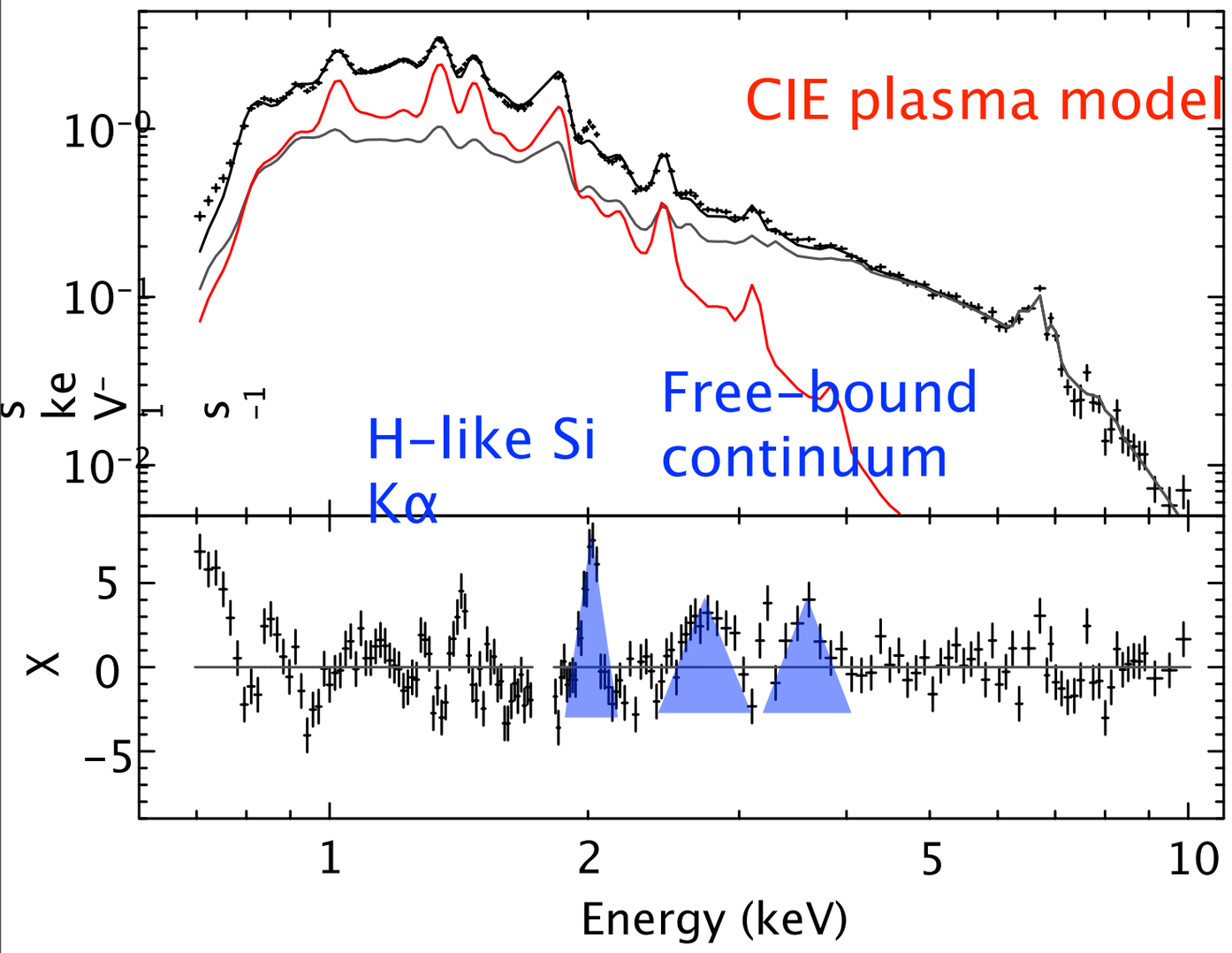

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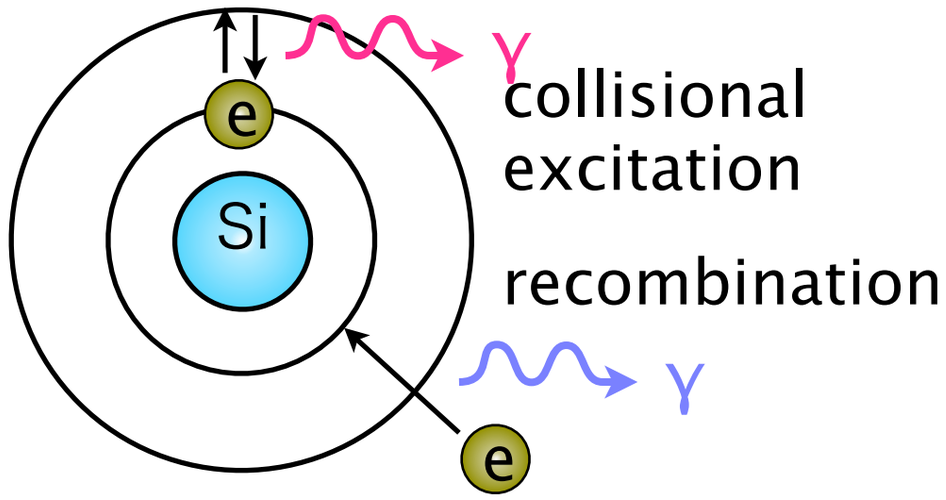

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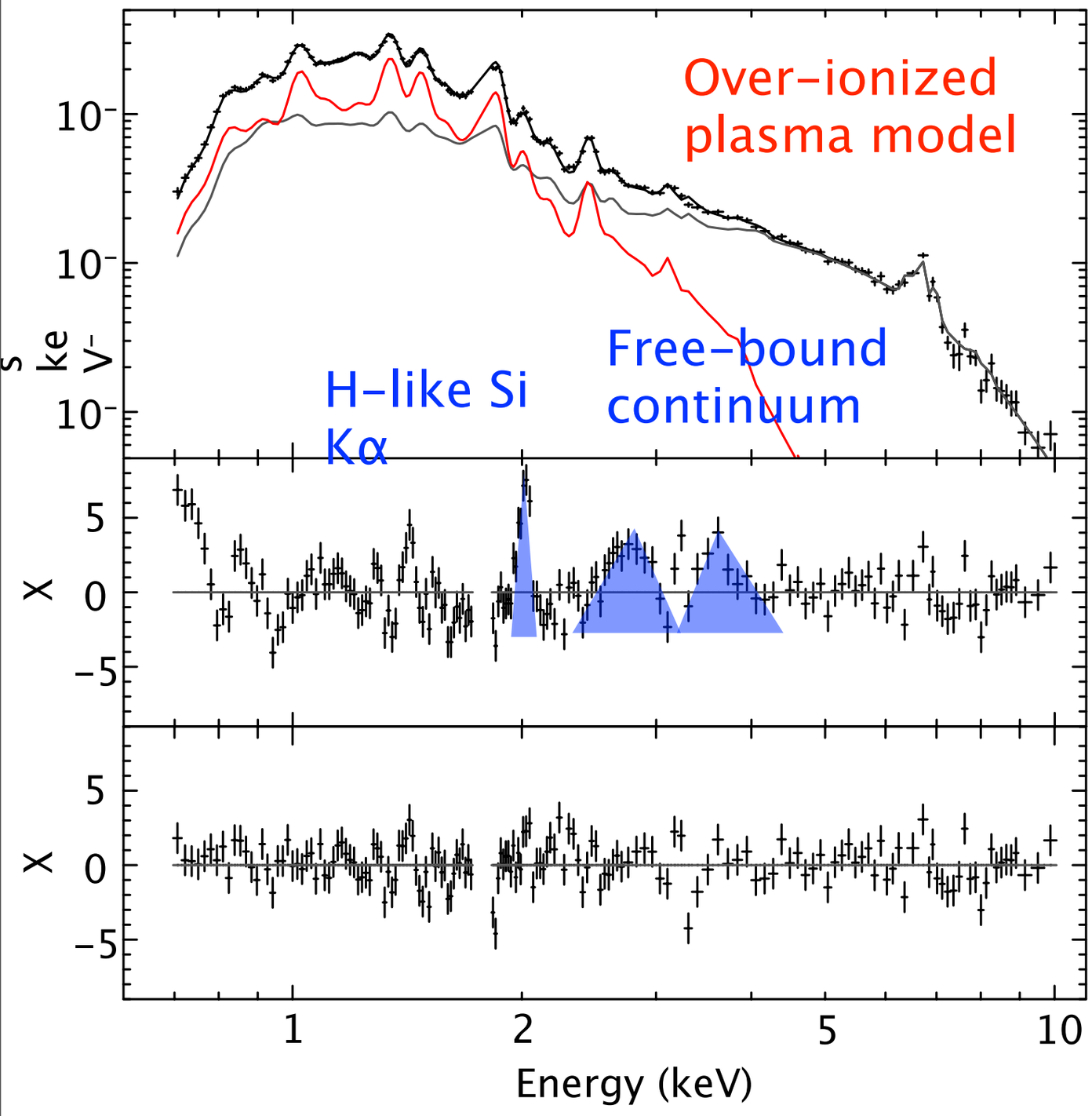

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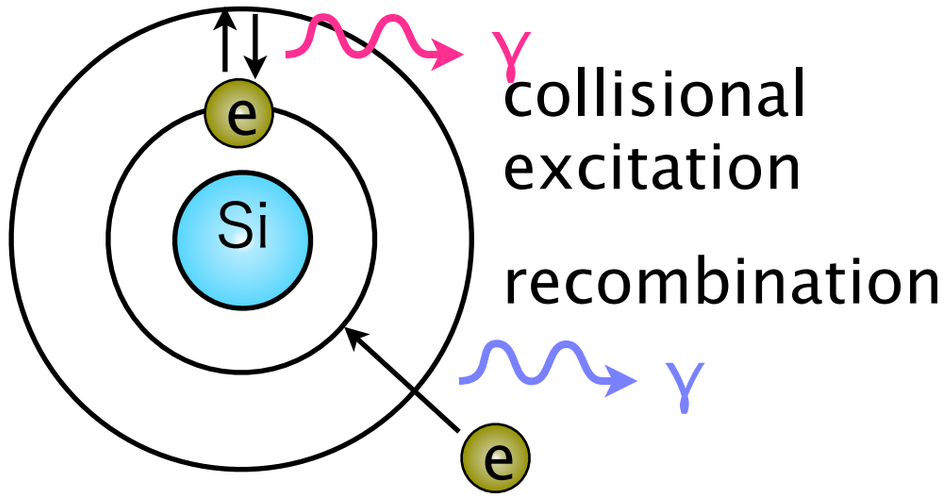

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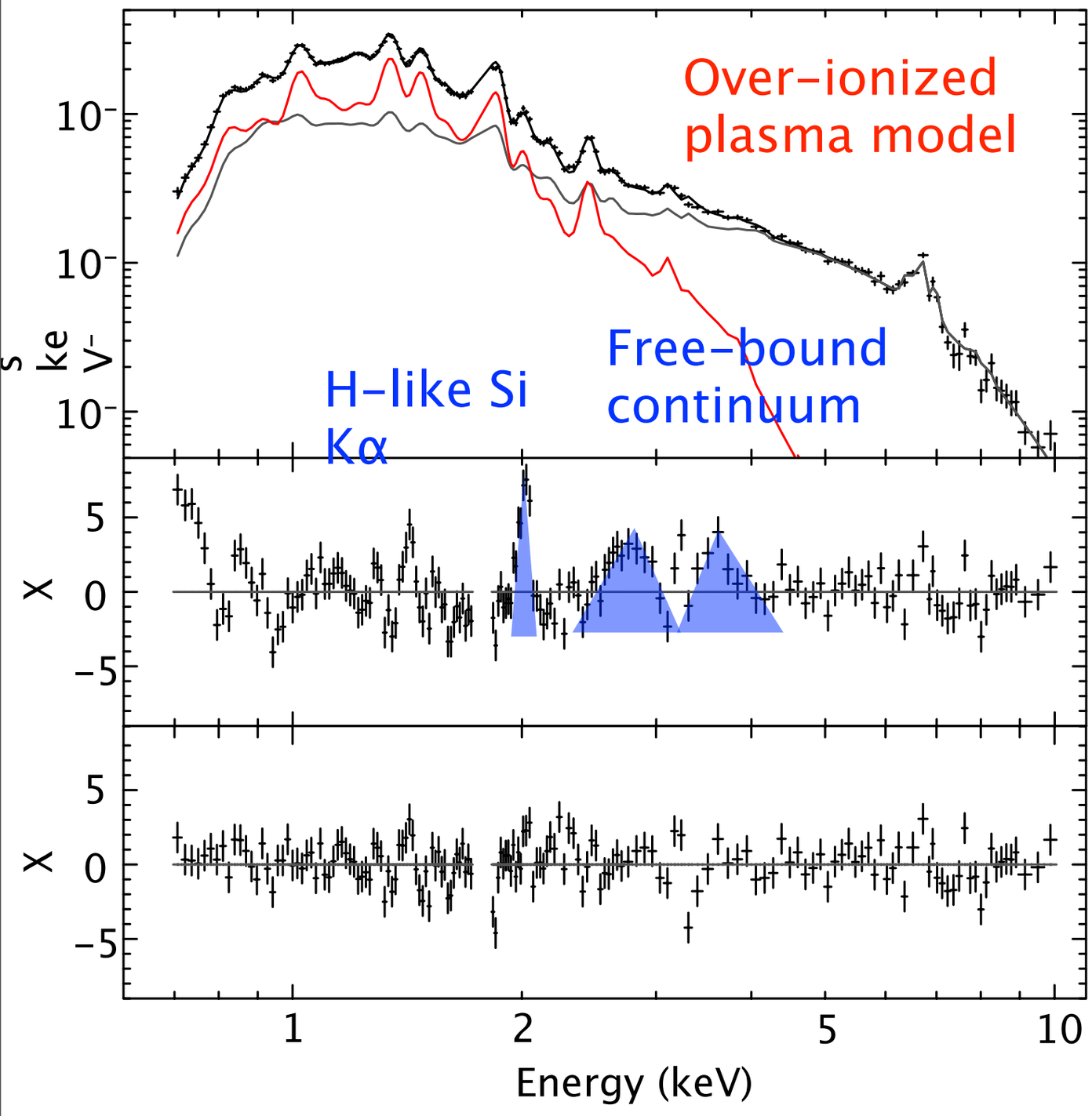

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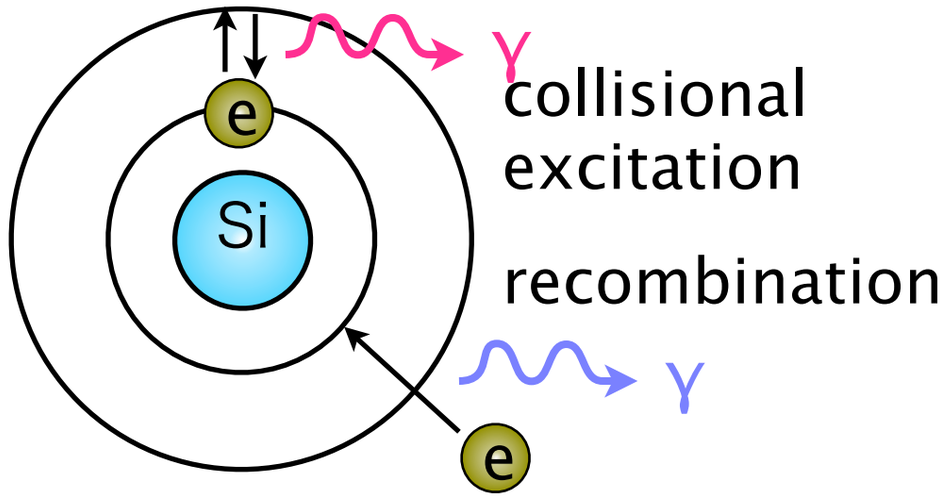
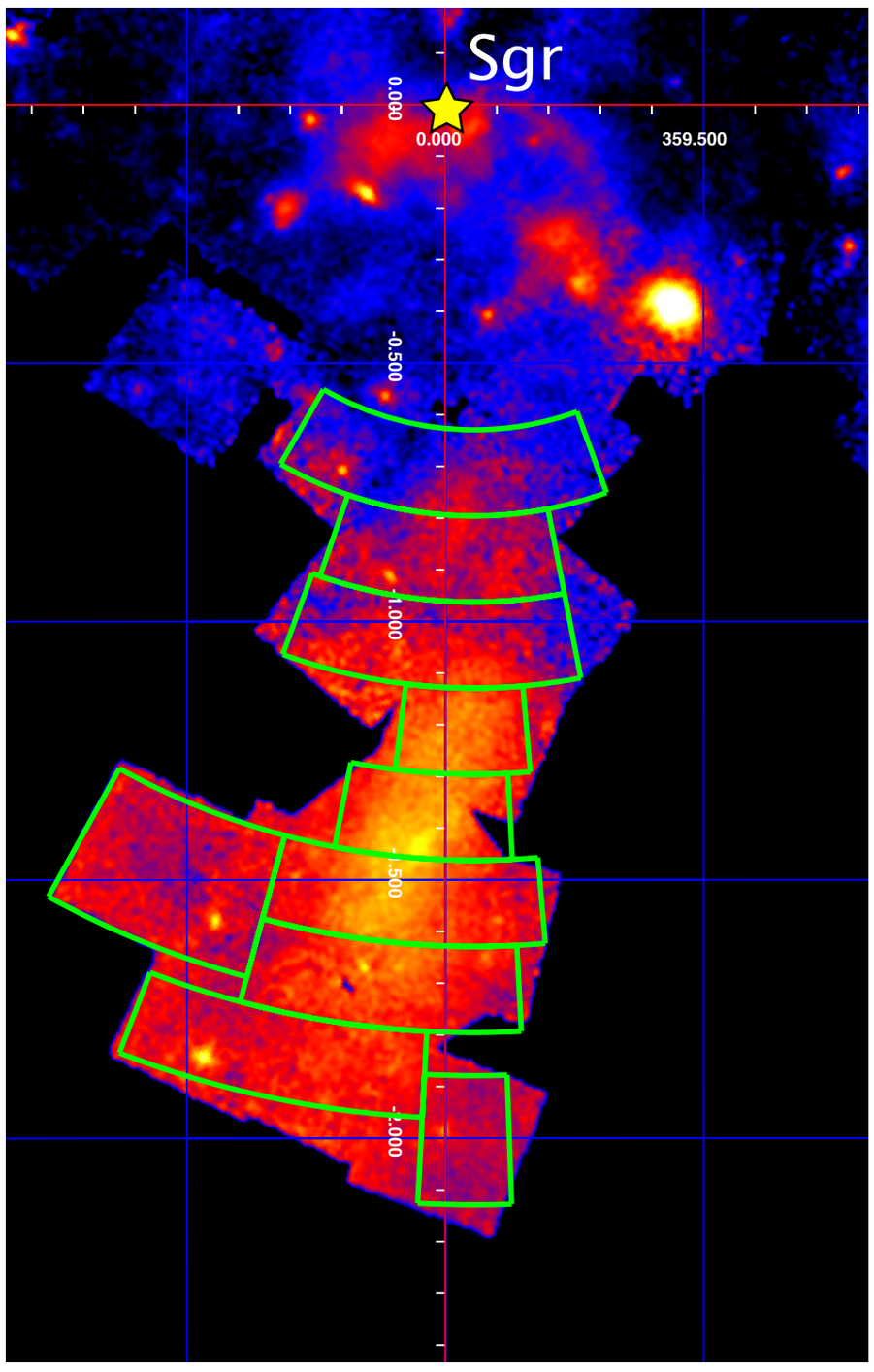
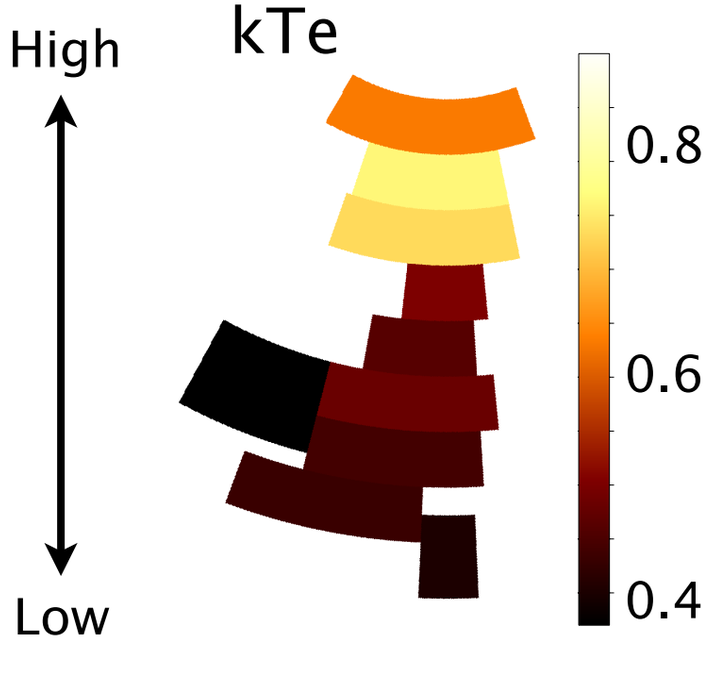


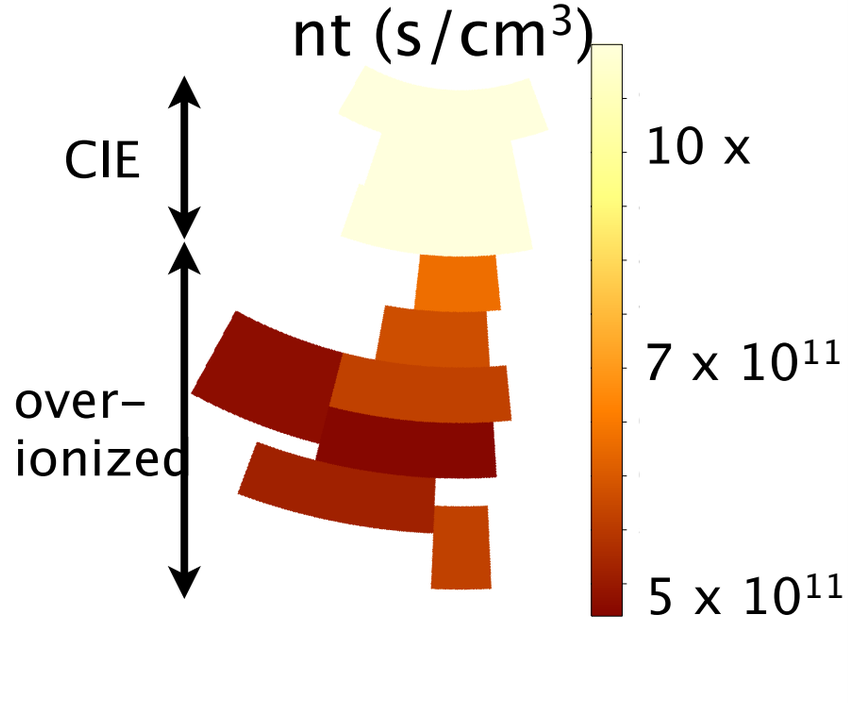
- Residuals indicate the plasma is over-ionized and dominated by recombination process.
- Plasma parameters
  - kTe = 0.5 keV
  - kT_{init} = 1.6 keV
  - nt = 5 x 10^{11} s cm^{-3}
  - N_H = 9 x 10^{21} cm^{-2} -> GC distance
  - n ~ 0.1 cm^{-3} -> age ~ 0.1 Myr

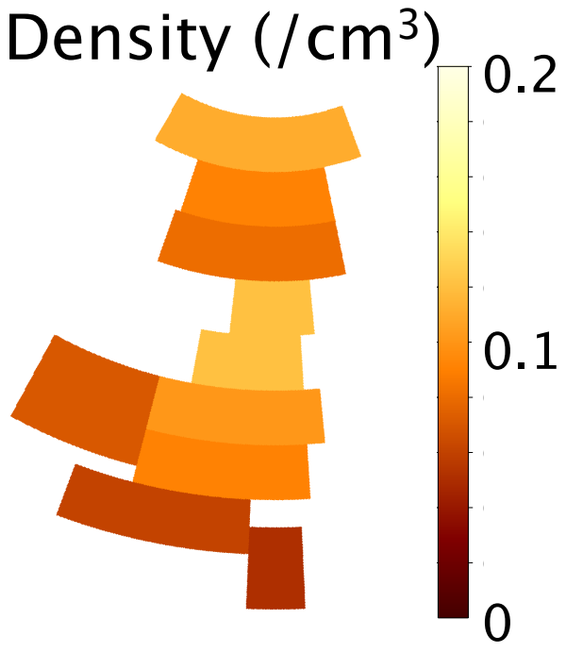
Spatial variation of plasma parameters

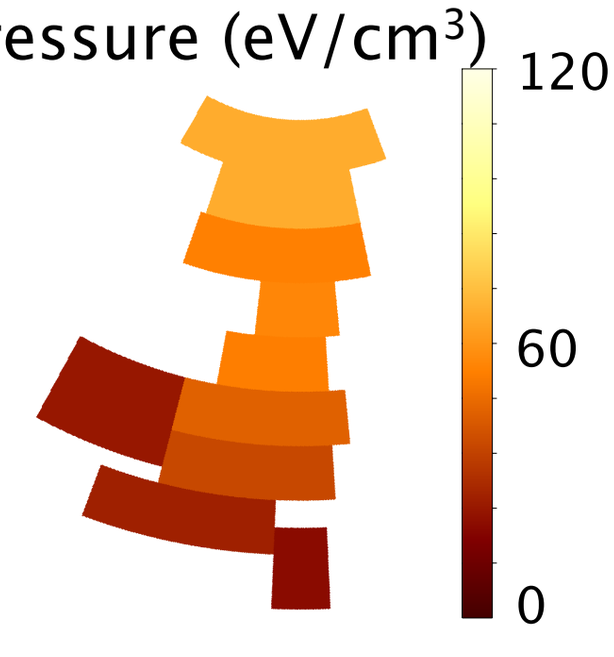
- Divide FOVs into annular regions and performed the same











Density & pressure are nearly uniform within a

Possible origin of the south plasma

- In order to form the over-ionized plasma, photo-ionization or rapid electron cooling is required.
- Large thermal energy of $>10^{51}$ ergs (100 times larger than a typical SNR). -> large energy injection is required.
  - Multiple supernovae is not favor because there is no star forming region.
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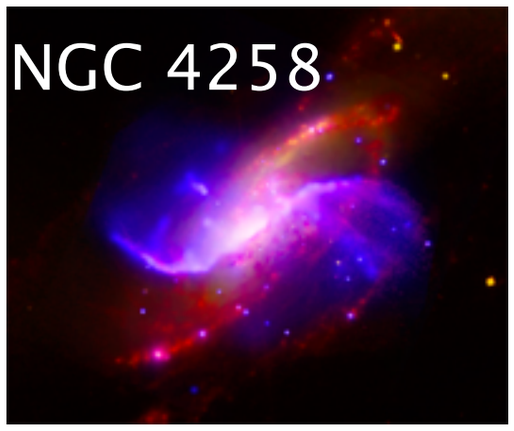

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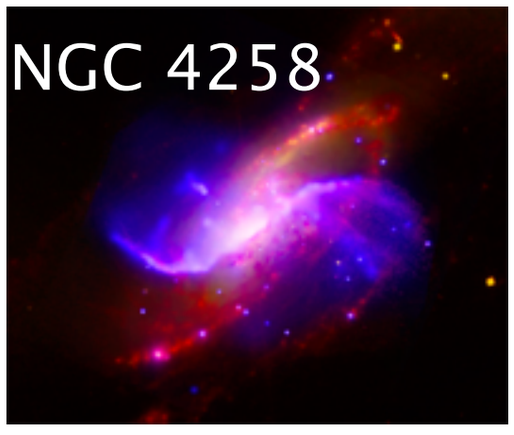
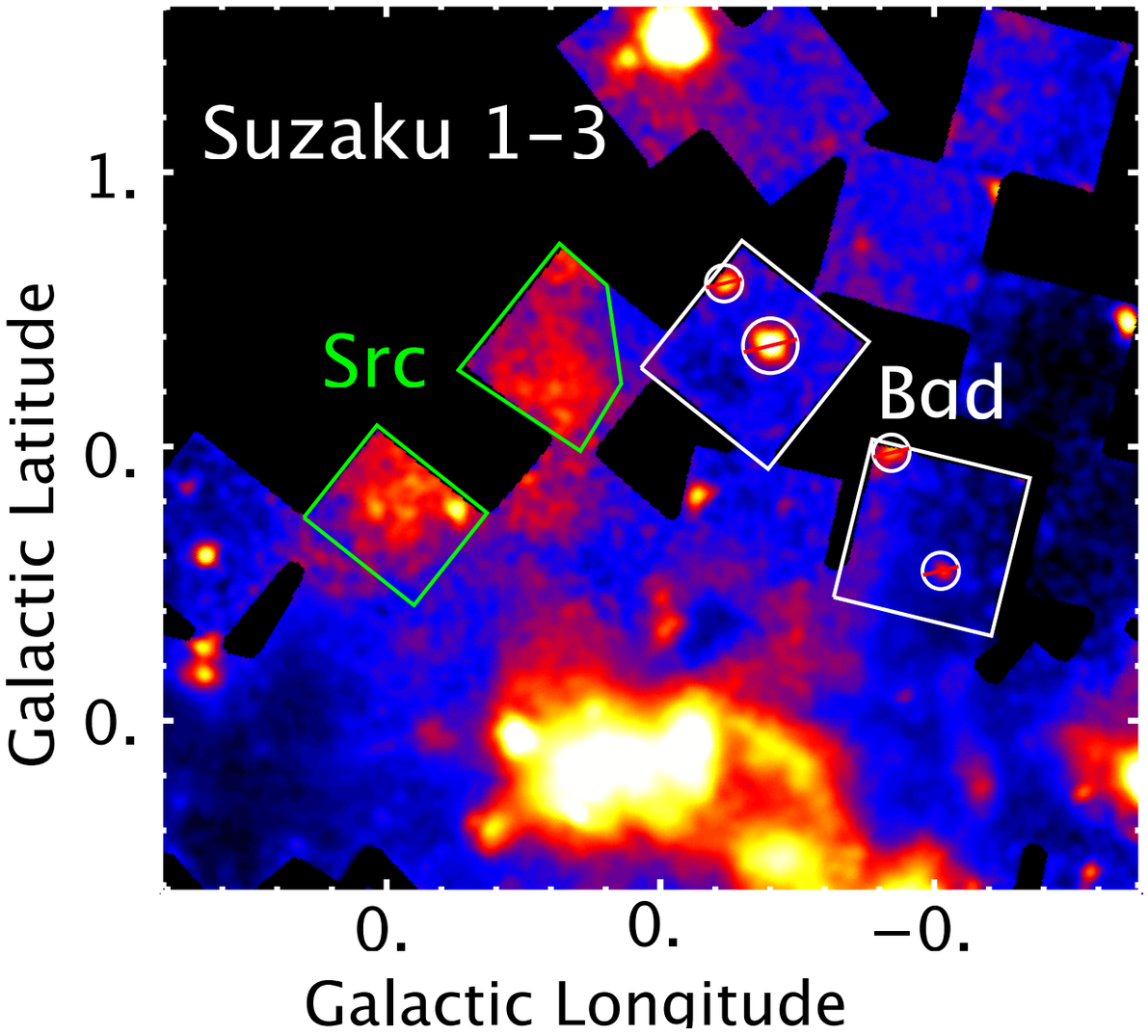
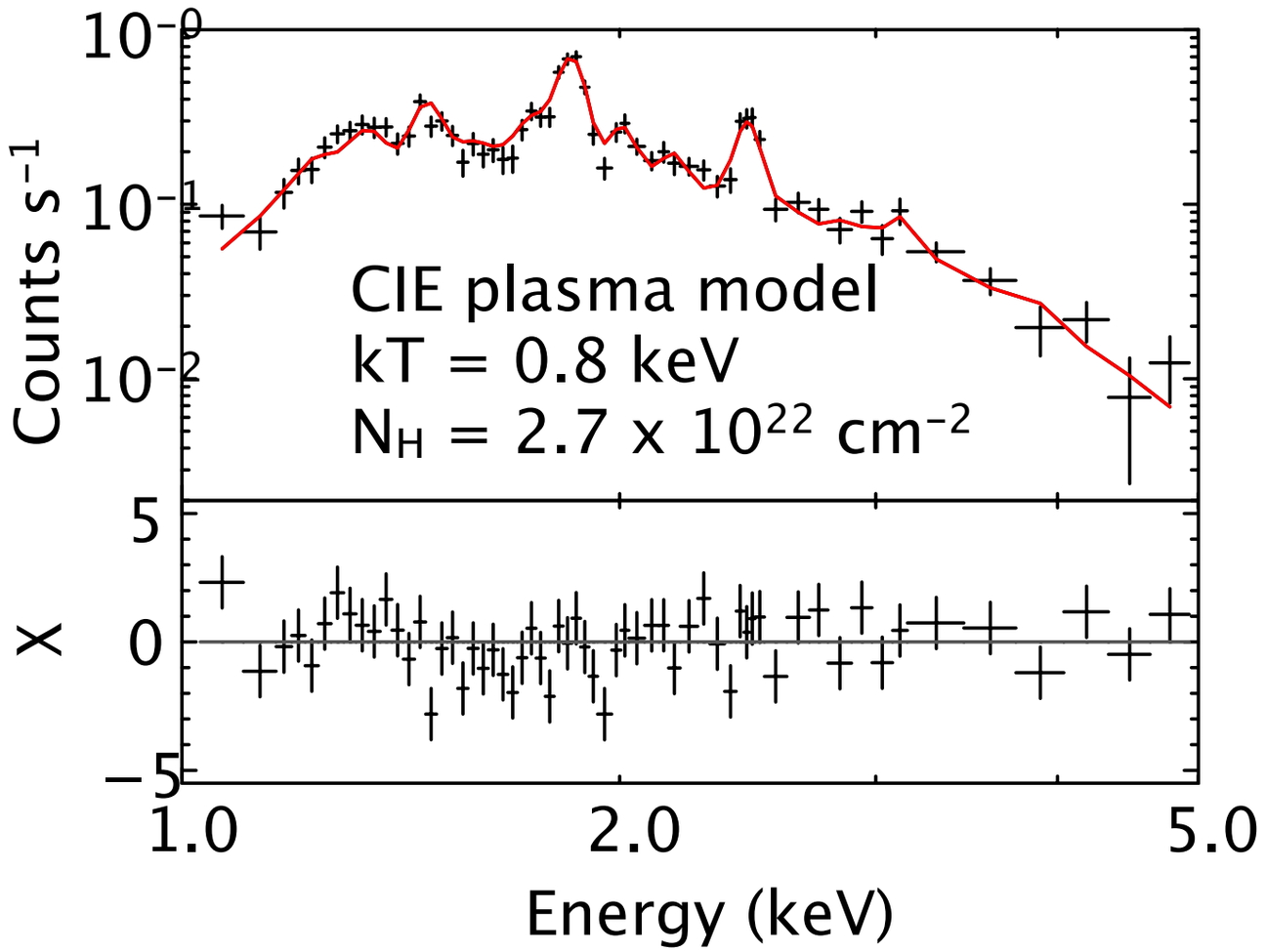


- Scenario 2 ... starburst origin (analogy of starburst galaxies)
  - Past mini starburst formed outflows of the plasma.
  - Adiabatic expansion caused rapid electron cooling.

Spectrum of the north emission

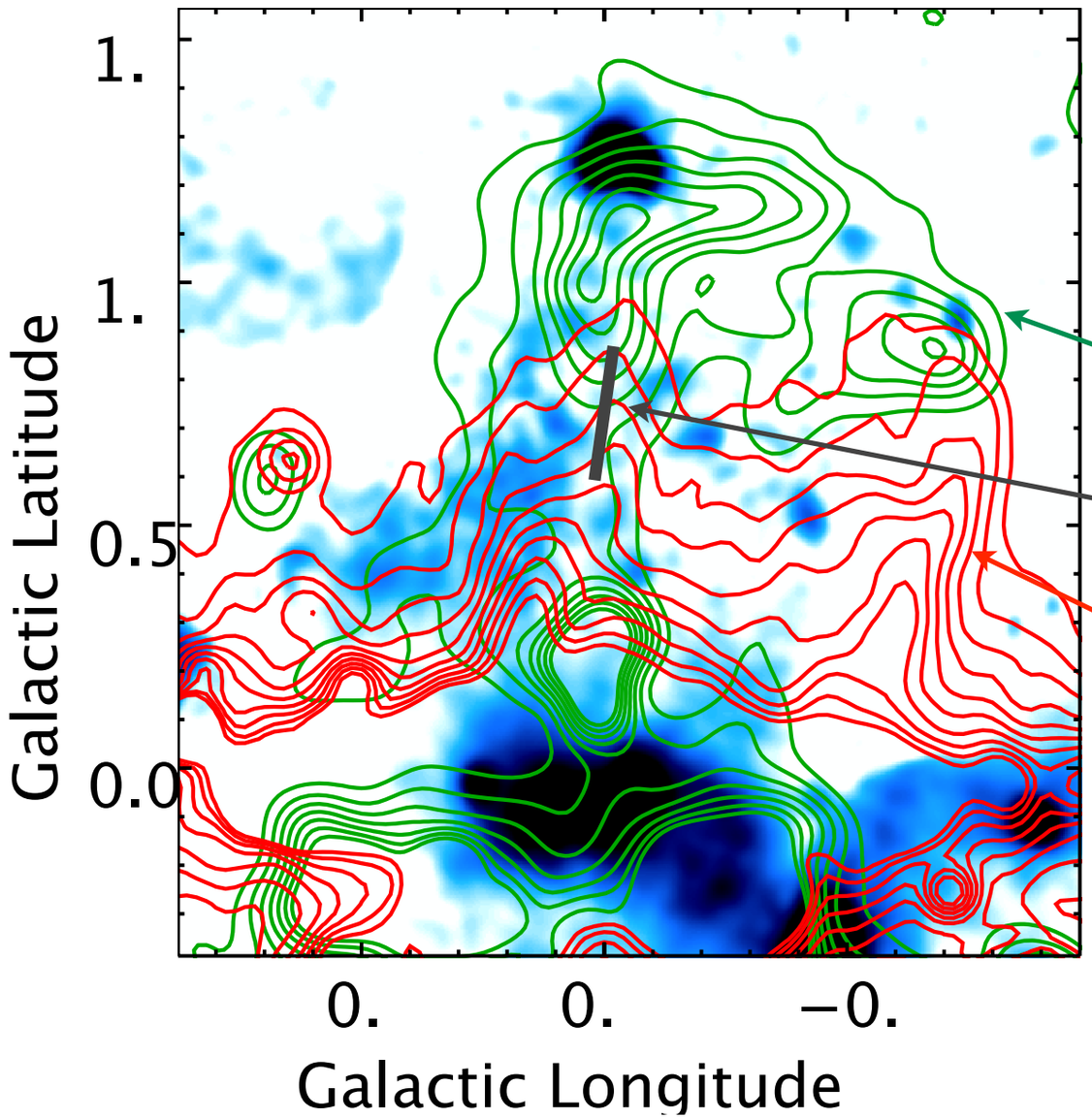




- Plasma is not in over-ionized state but in CIE, because 0.8 keV CIE plasma model represents the data -> consistent with low-latitude region of the south plasma.
- It is possible that plasma at higher-latitude region is in over-ionized state, considering the spatial variation of the south plasma.
- Hydrogen column density indicates the plasma is in the GC distance.

Correlation with other wavelength

- There is no clear counterpart for the south plasma.
- The north plasma spatially coincides with the features in other wavelength.



ASCA X-ray image

Hα emission (Law+10)

Double helix nebula (Morris+06)

GC radio lobe (Soufe+84)

=> These support the origin of past GC activity.

Summary

- From the ASCA and Suzaku observations, we discovered outflow-like X-ray emissions.
- Analysis of the south plasma shows that the plasma is in over-ionized state, and have large thermal energy. -> past Sgr A* jet or starburst is possible origin.
- Analysis of the north emission shows that the plasma is in CIE state, and have large thermal energy. -> correlation with south emission is not clear at this time, but the origin could be also past GC activity.
- The north plasma has a correlation with other wavelength.