Origin of the 6.4 keV line of the Galactic Ridge X-ray Emission (GRXE)

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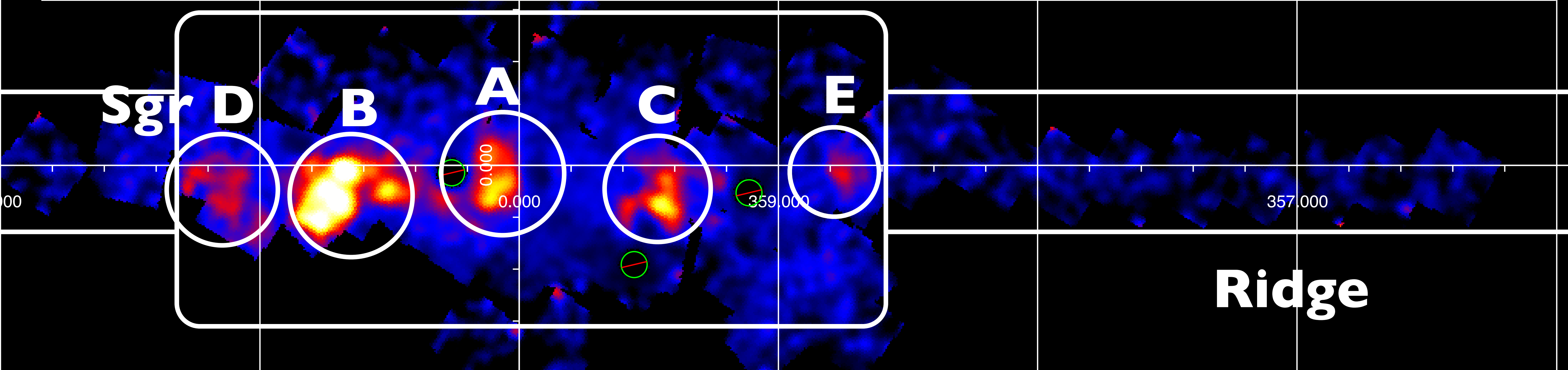
6.4 keV line emission from Ridge

EW map of the 6.4 keV line near GC

No region with such high EW has been discovered except the GC.



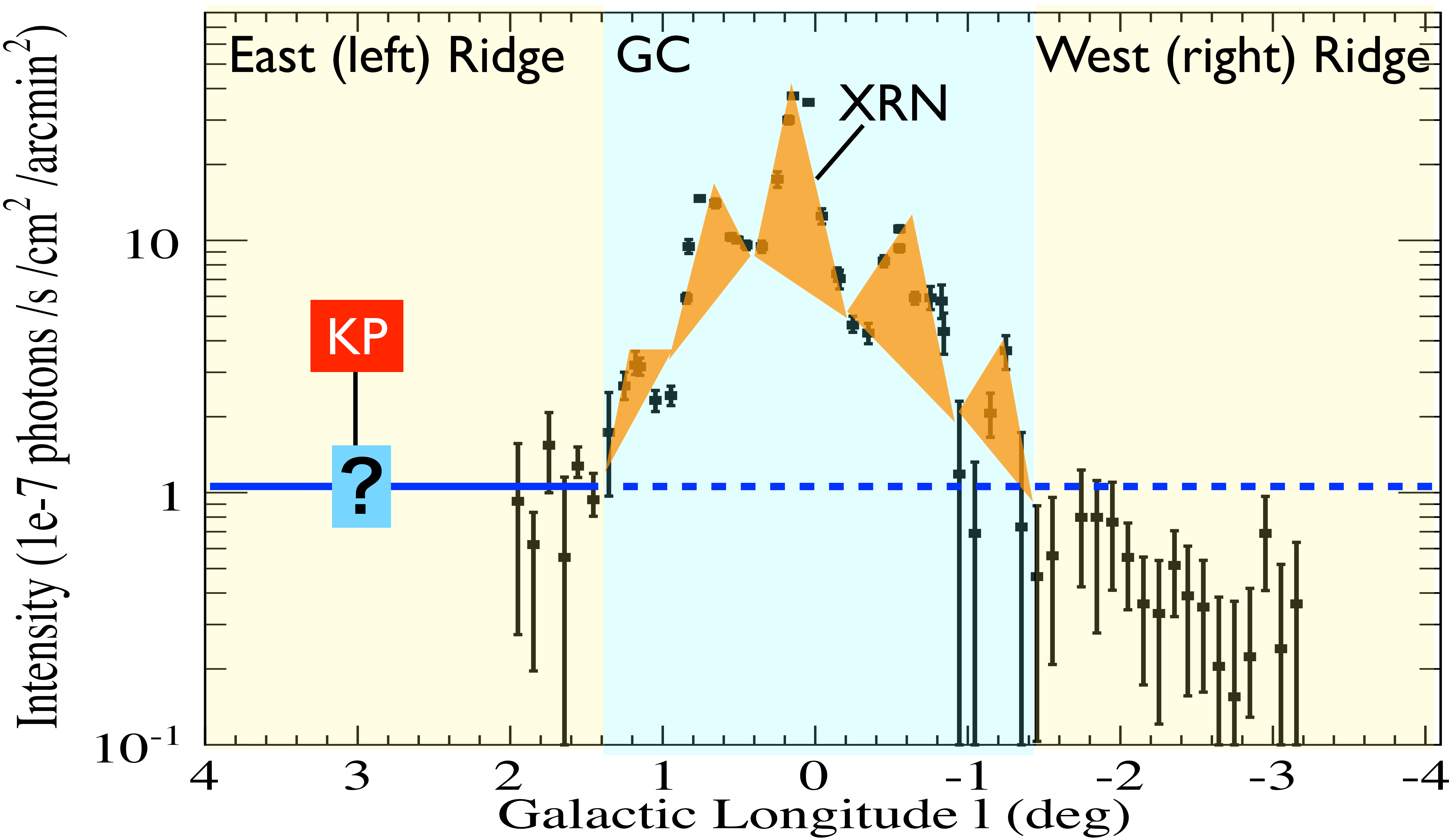
Suzaku found that 6.4 keV line emission with nearly equal EW uniformly exist.

extend toward the Galactic ridge.

Key Quesstion.
What is the origin of this 6.4 keV line emission in the Galactic ridge ?

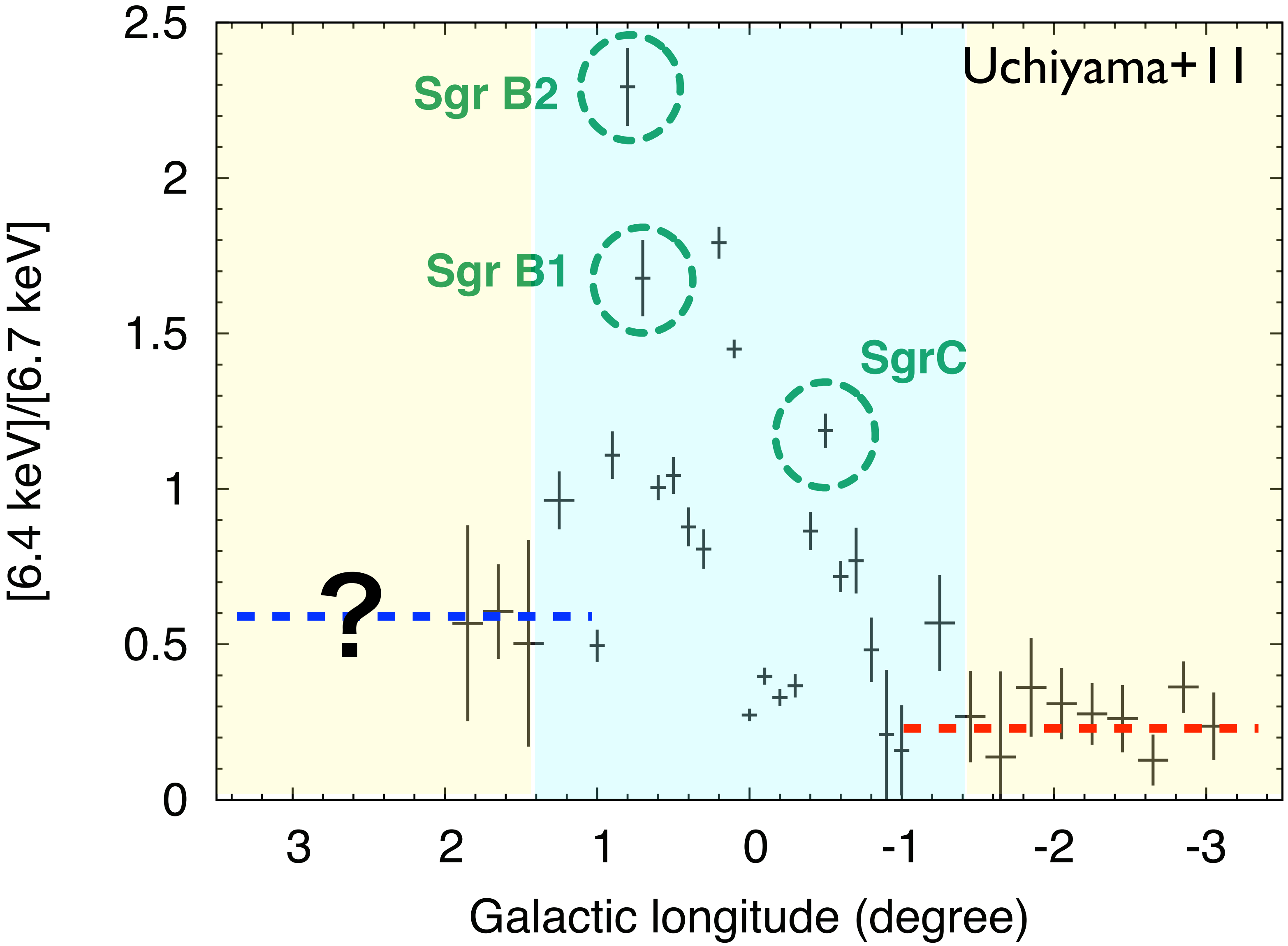
Asymmetric Distribution of 6.4keV line

6.4 keV line flux



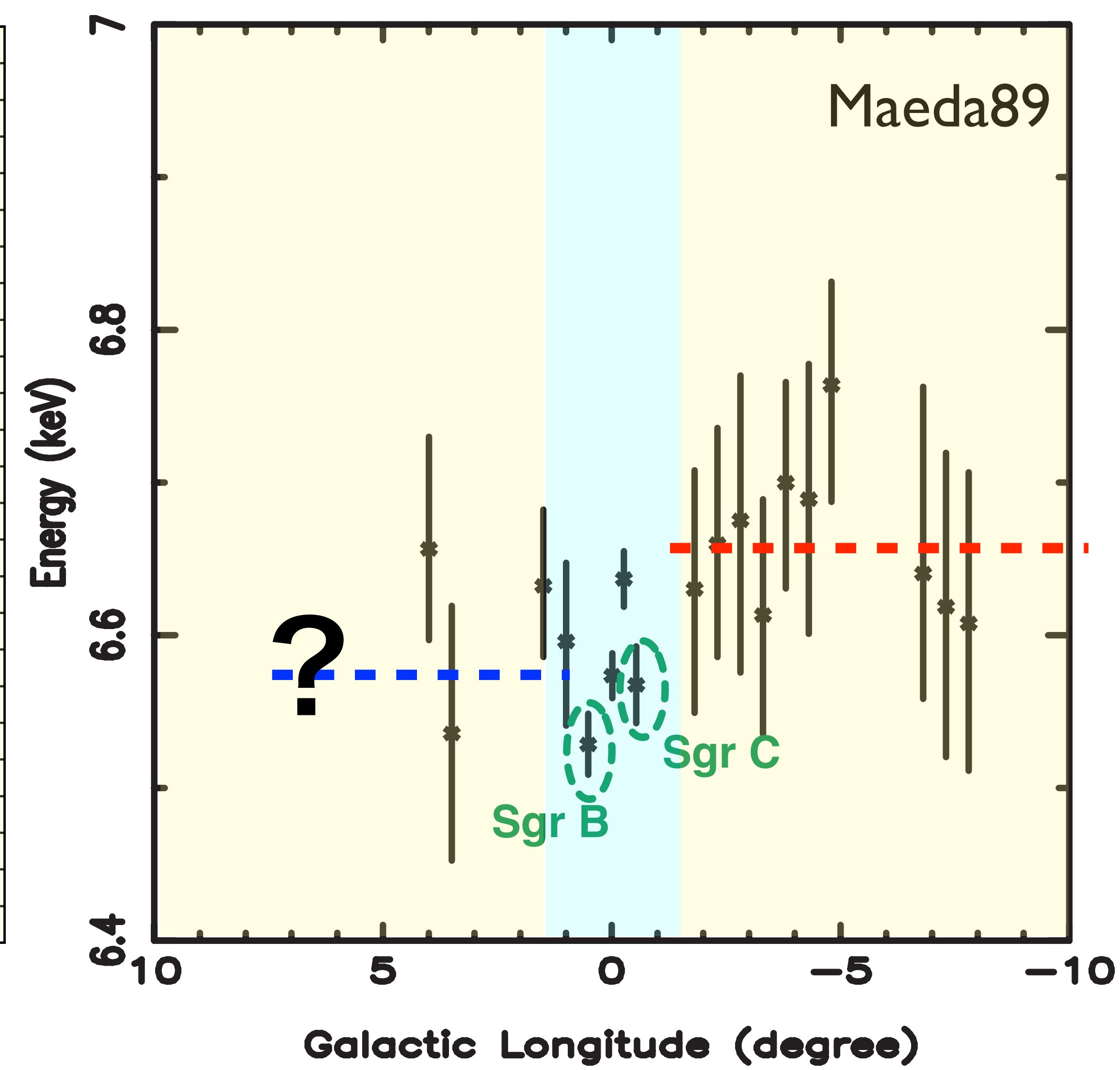
Asymmetric Distribution of 6.4keV line

Suzaku : 6.4 / 6.7keV flux ratio



Suzaku flux ratio between the two lines also shows asymmetric distribution.

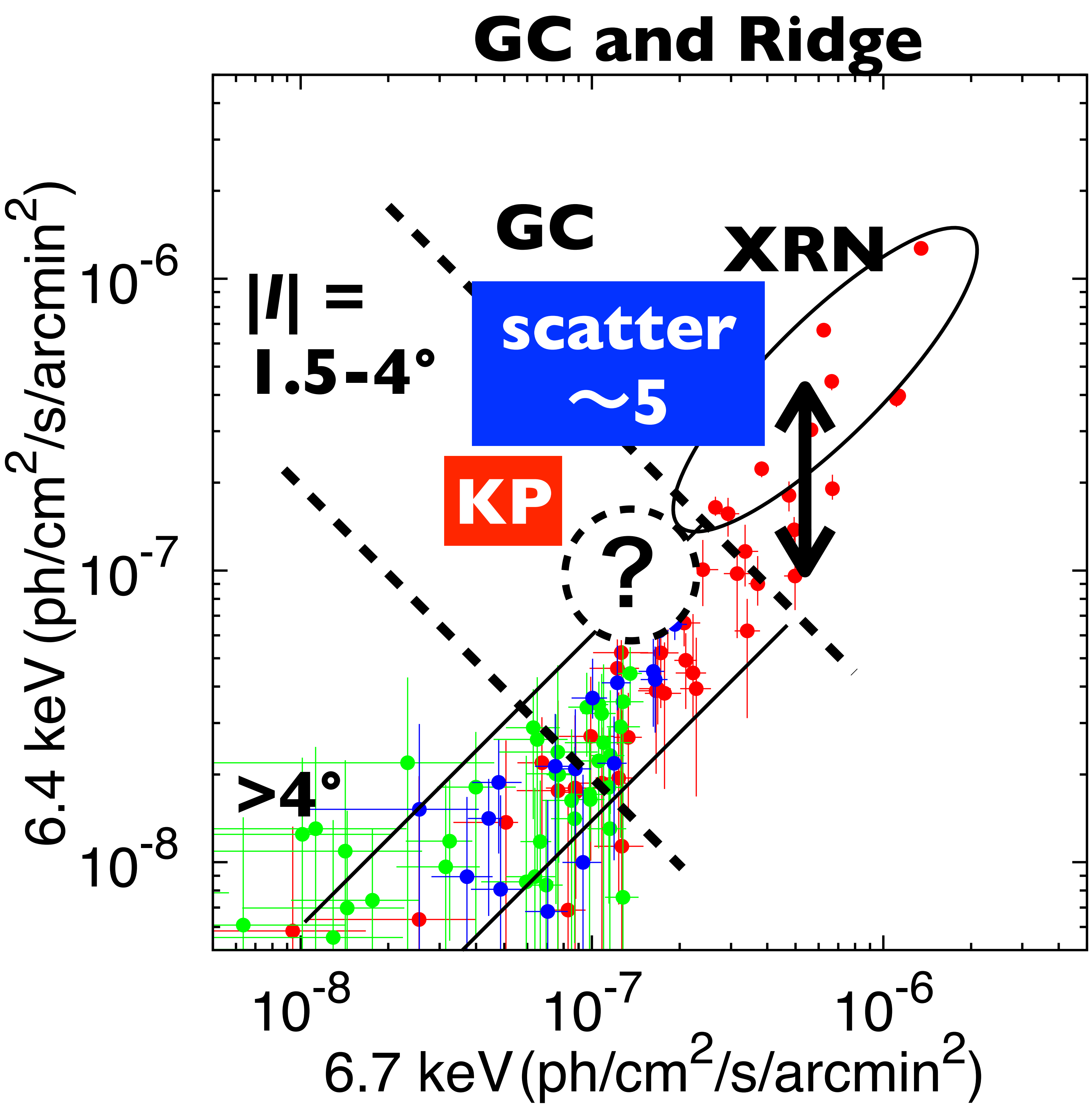
ASCA : Fe line center



Fe center energies distribute asymmetrically.

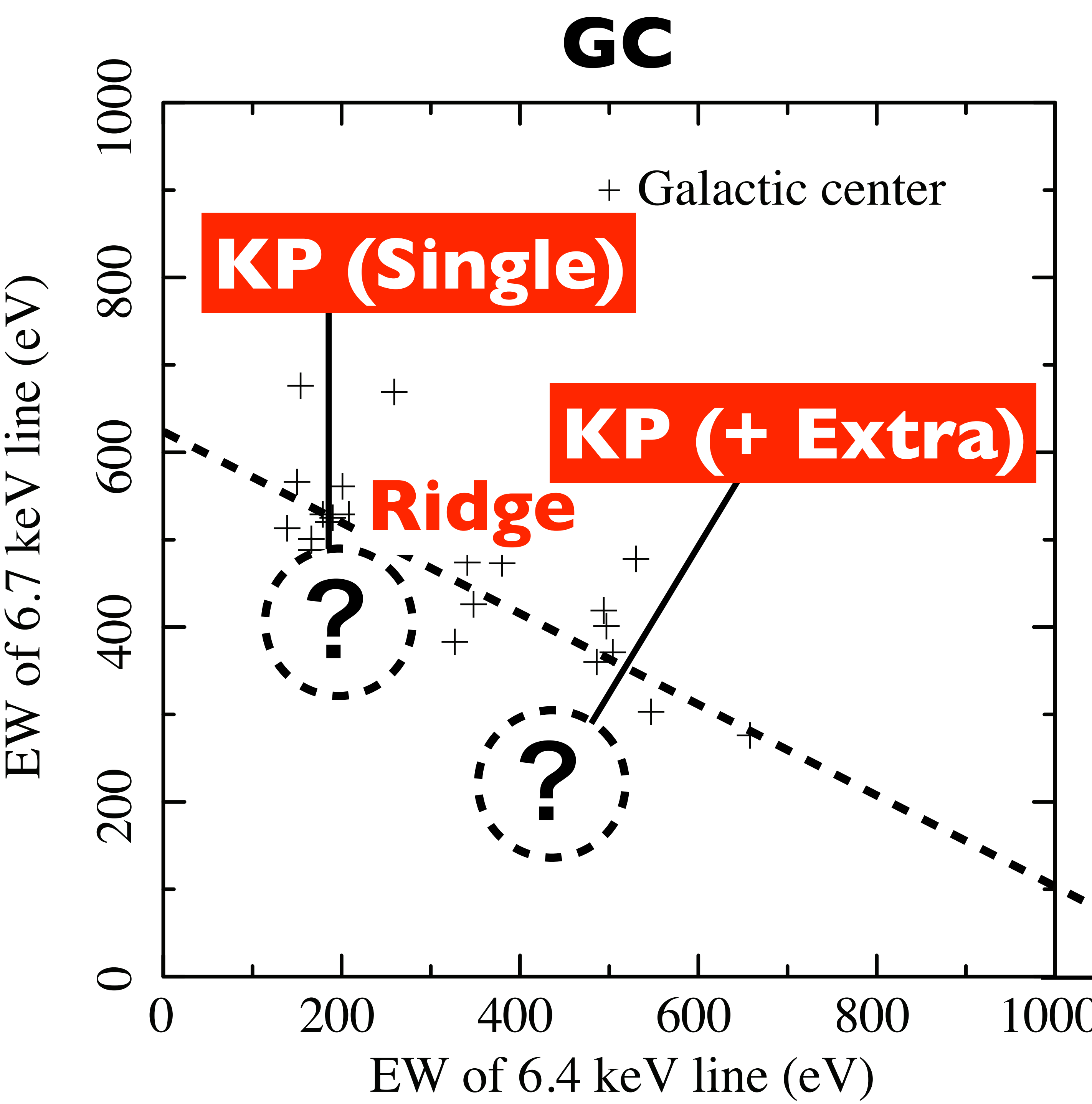
These results suggest the source of the 6.4 keV emission line distribute asymmetrically.

6.4 keV flux - 6.7 keV flux



- GC
  - 6.4 keV line emission has diffuse origin.
  - 6.4 and 6.7 keV lines have different origins
  - Their fluxes have a scattered correlation.
- Ridge
  - The correlation is on the natural extension from the GC.
  - The 6.4 keV line fluxes also scatter.
  - The expected KP data seem to be on the line of XRNe.

Single Origin ? or + Extra Source ?



- In the GC, the EWs are different from point to point.
- This is because Fe emission lines are mixture of multiple origins.

Objective 1

See if the plots of EW6.4 and EW6.7 concentrate in a single point or not.

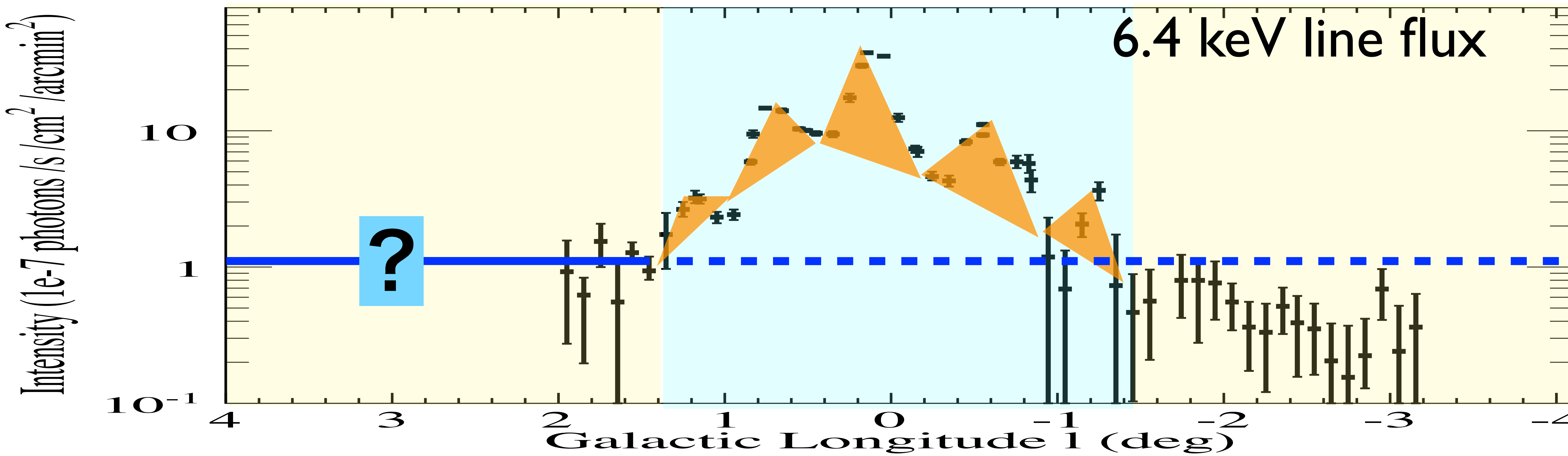
Examine if the spatial distribution of the 6.4 keV line emission is symmetric or asymmetric with respect to the GC.

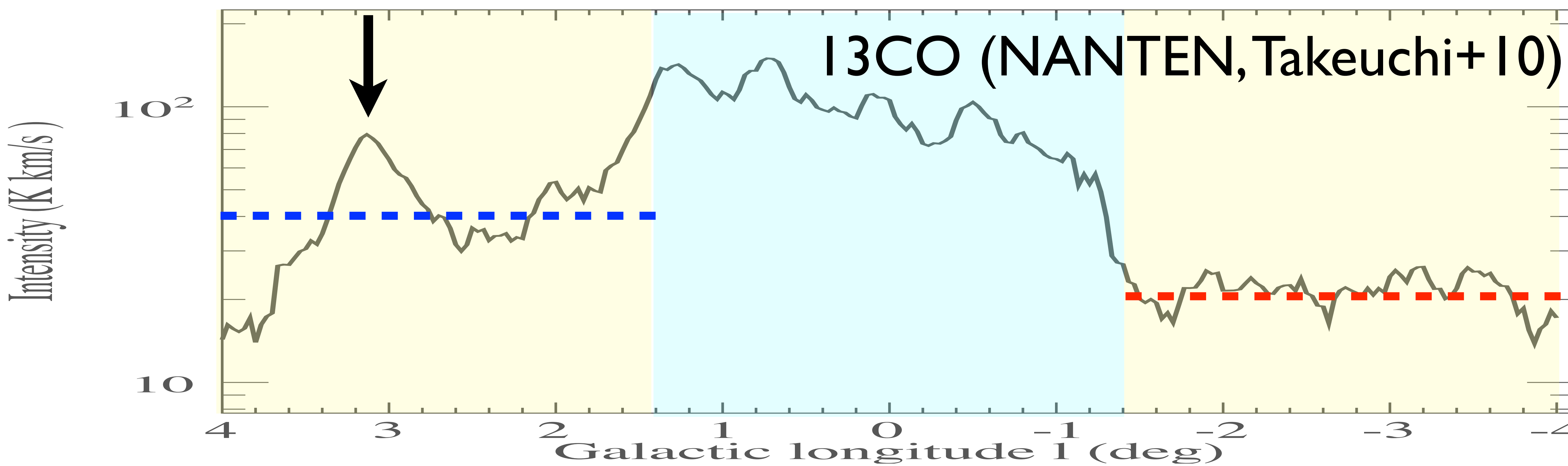
Case A : Single Origin (point source ?)

Case B : + Extra Source (diffuse ?)

Start with Case B...

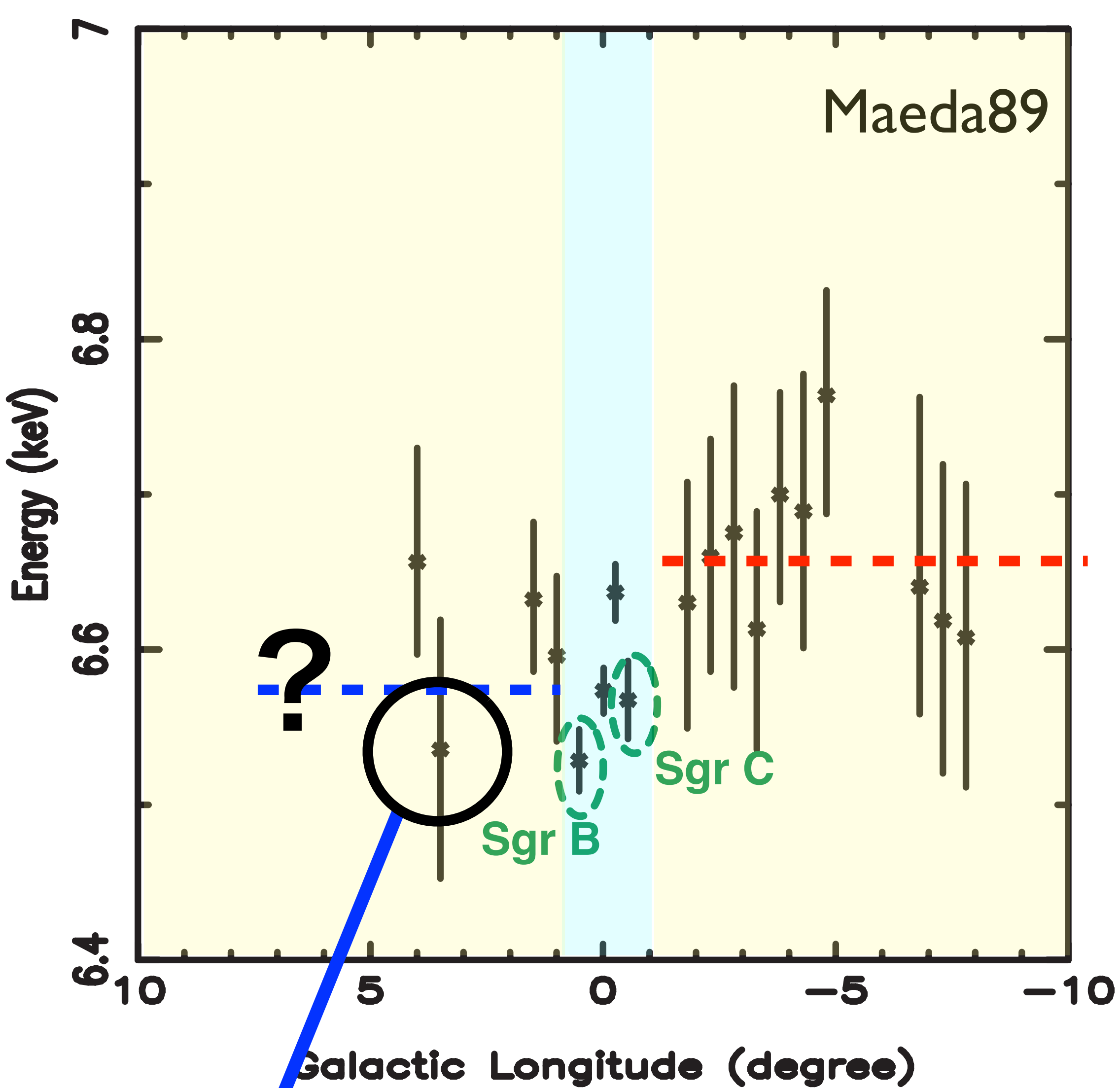
6.4 keV line emission correlates with MCs



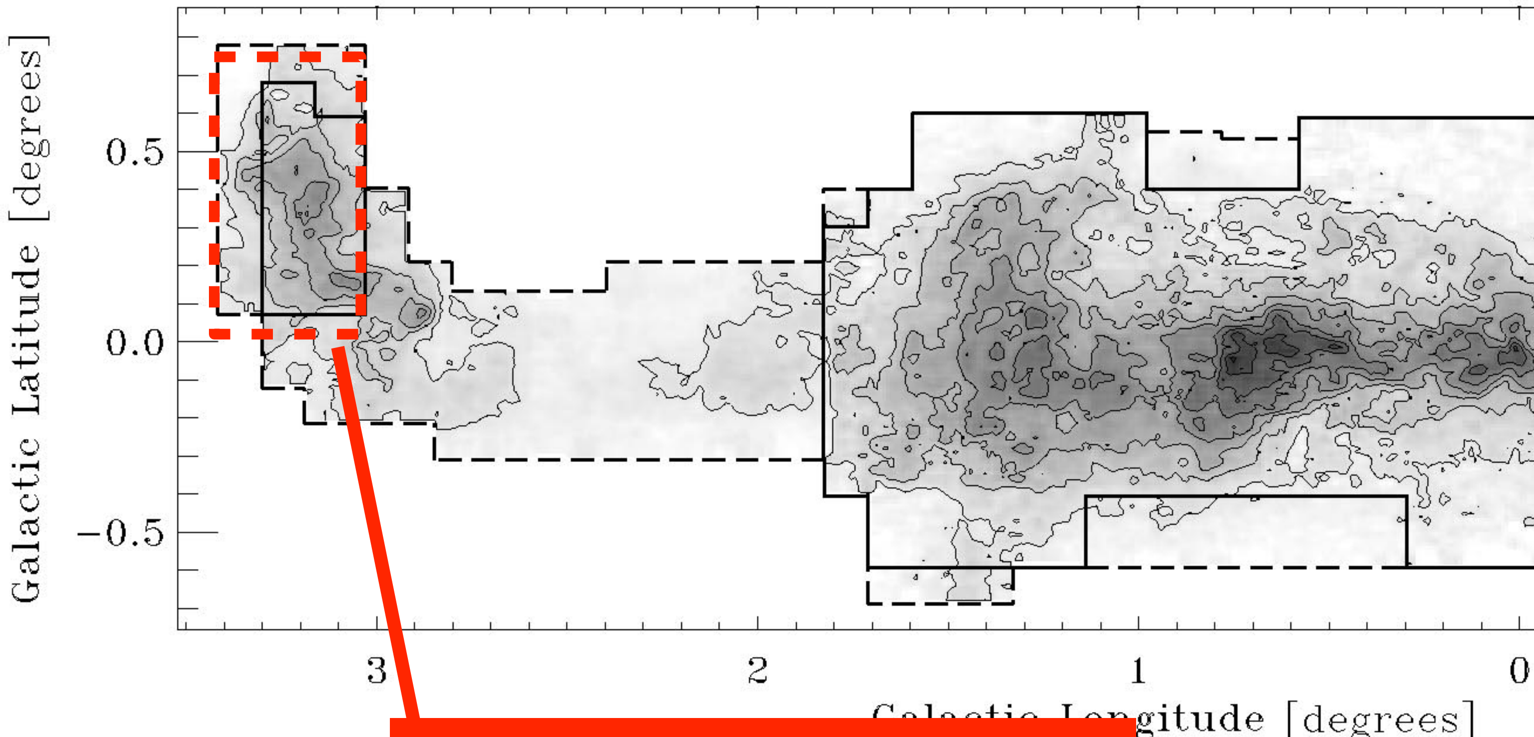


Strong 6.4 keV line emission from Clump 2

ASCA : Fe line center



12CO (Oka+98)



l = 3.2° "Clump 2"

l = 3.5° exhibits especially strong 6.4 keV line

Objective 2
Search of correlation with MCs.

Objective 3
Determination of the ionizing particle.

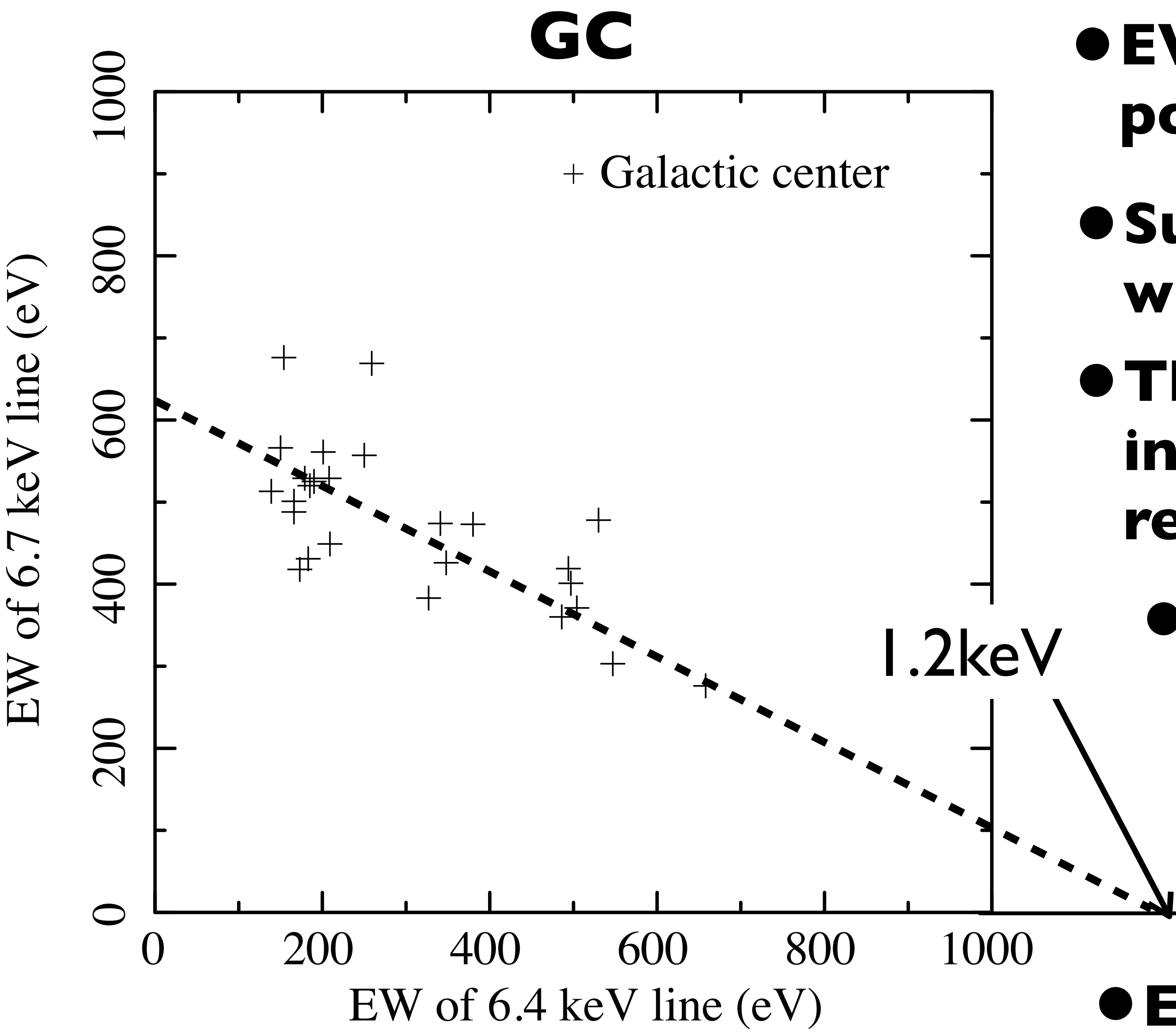
Candidates for the ionizing particles

- 6.4 keV flux ~1e-7 ph/cm2/sec/arcmin2 is expected in the KP observing region
- XRN (X-ray Reflection Nebula)
  - Already seen in the GC.
  - Sgr A* Lx(Sgr A*) ~10^41 ergs/s
- LECRp (Low Energy Cosmic Ray Proton)
  - NH ~ 1e+24cm-2 (observed at Clump 2)
  - Up > 75eV/cm3 ← equipartition with B > 50μG at R<400pc (Crocker+11)
    ⇒ ~0.5e-7 ph/cm2/sec/arcmin2
- LECRe (Low Energy Cosmic Ray Electron)
  - cf. Valinia+00
  - Ue~1 eV/cm3 x NH〜1e+23 cm-2

    ⇒ 〜1e-7 ph/cm2/sec/arcmin2

All the three processes are possible.

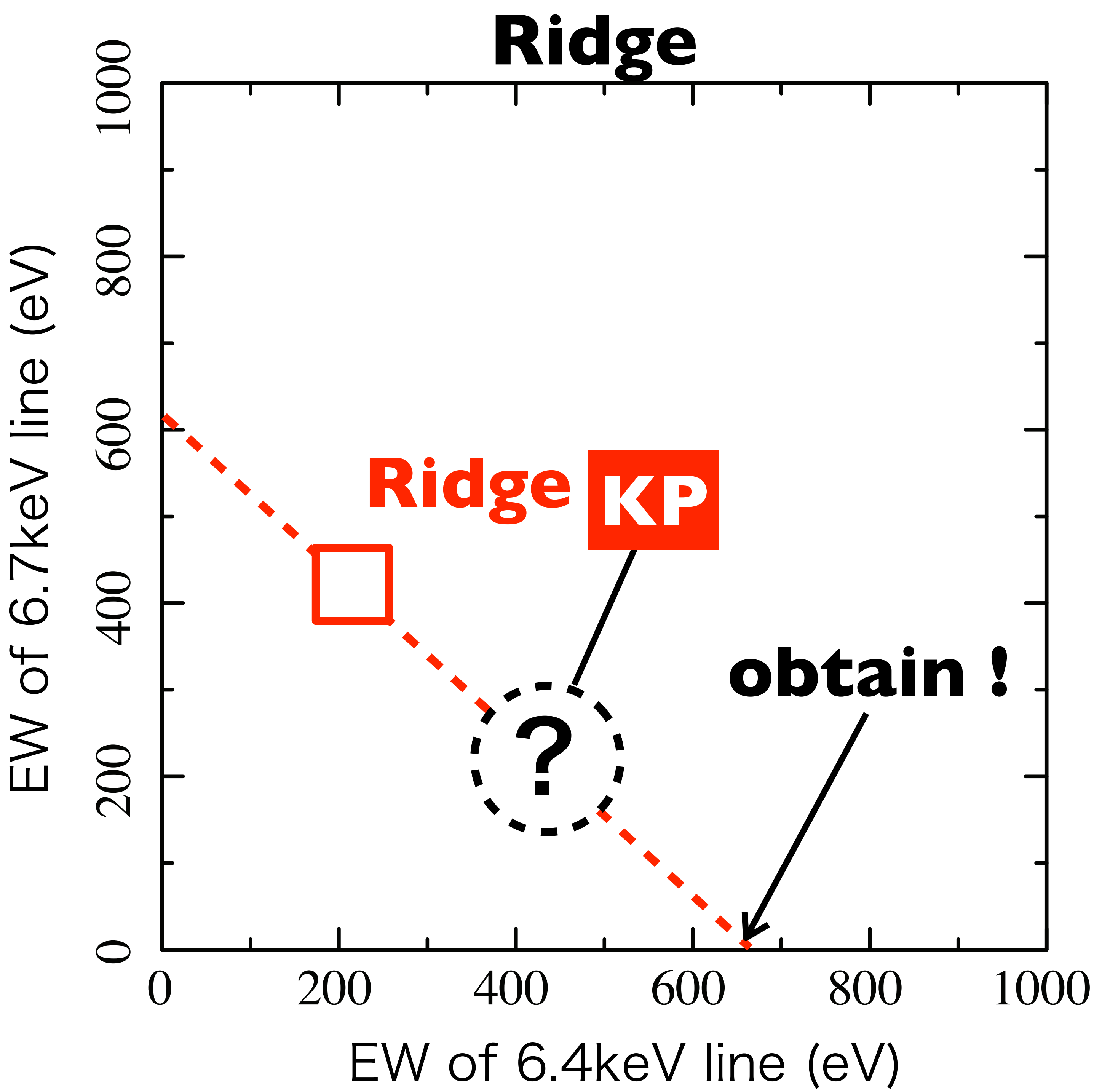
EW(6.4) of the 6.4 keV component 【GC】



- **EWs are different from point to point**
- **Successfully fit the data with a line.**
- **The emission is resolved into 6.4 keV- and 6.7 keV-related components.**
  - **The intercept is the EW of the 6.4 keV line emission against the continuum of the 6.4 keV-component.**
- **EW = 1.2keV → XRN**

Apply this method to the Ridge data.

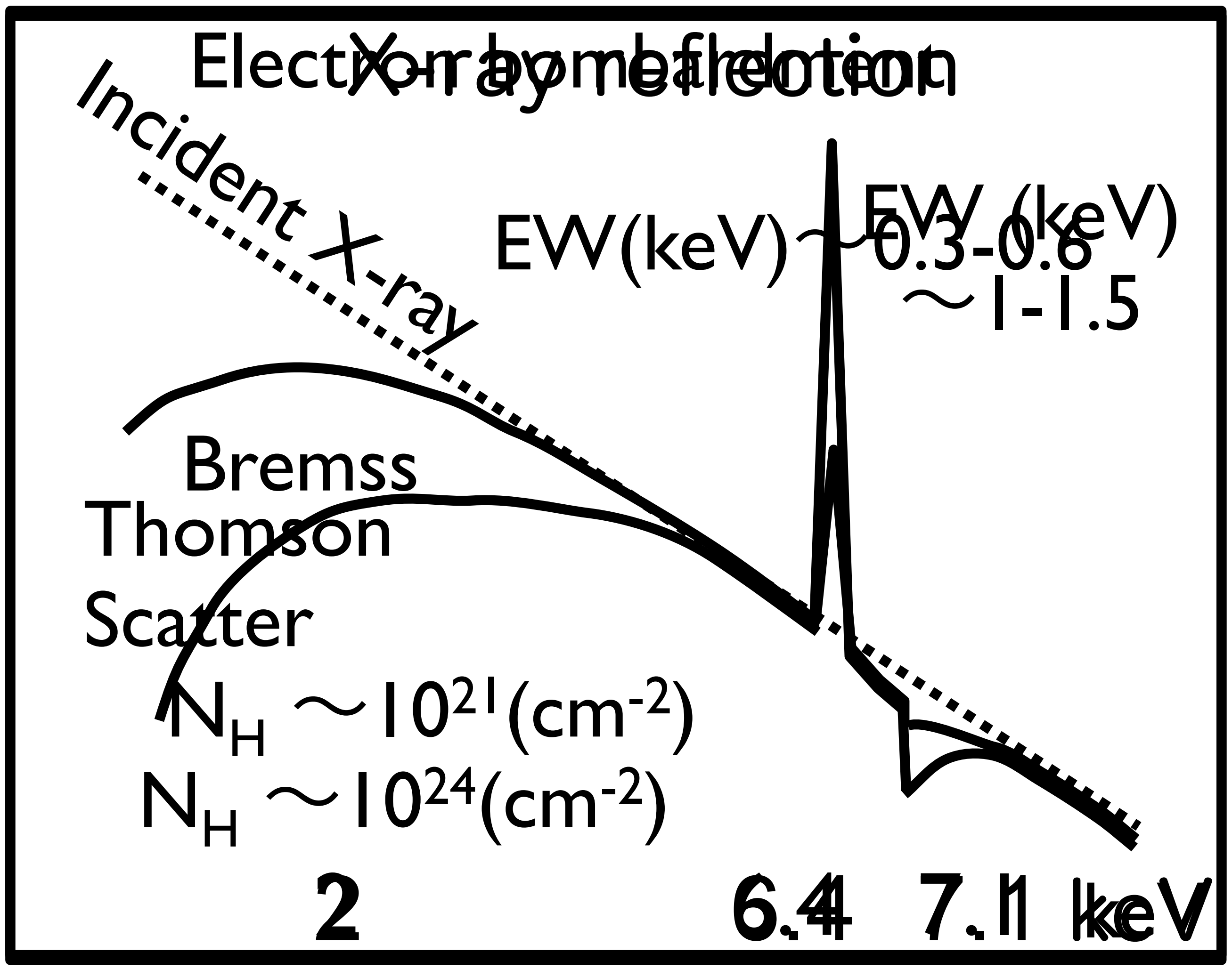
EW(6.4) of the 6.4 keV component 【*Ridge*】



- We are unable to fit the line only with existing data.
- Adding the KP data allows us to obtain the correlation line.
- Obtain EW(6.4) of the 6.4 keV- component.
- Referring to the value, we determine the ionizing particle.

Difference between XRN, LECRe and LECRp

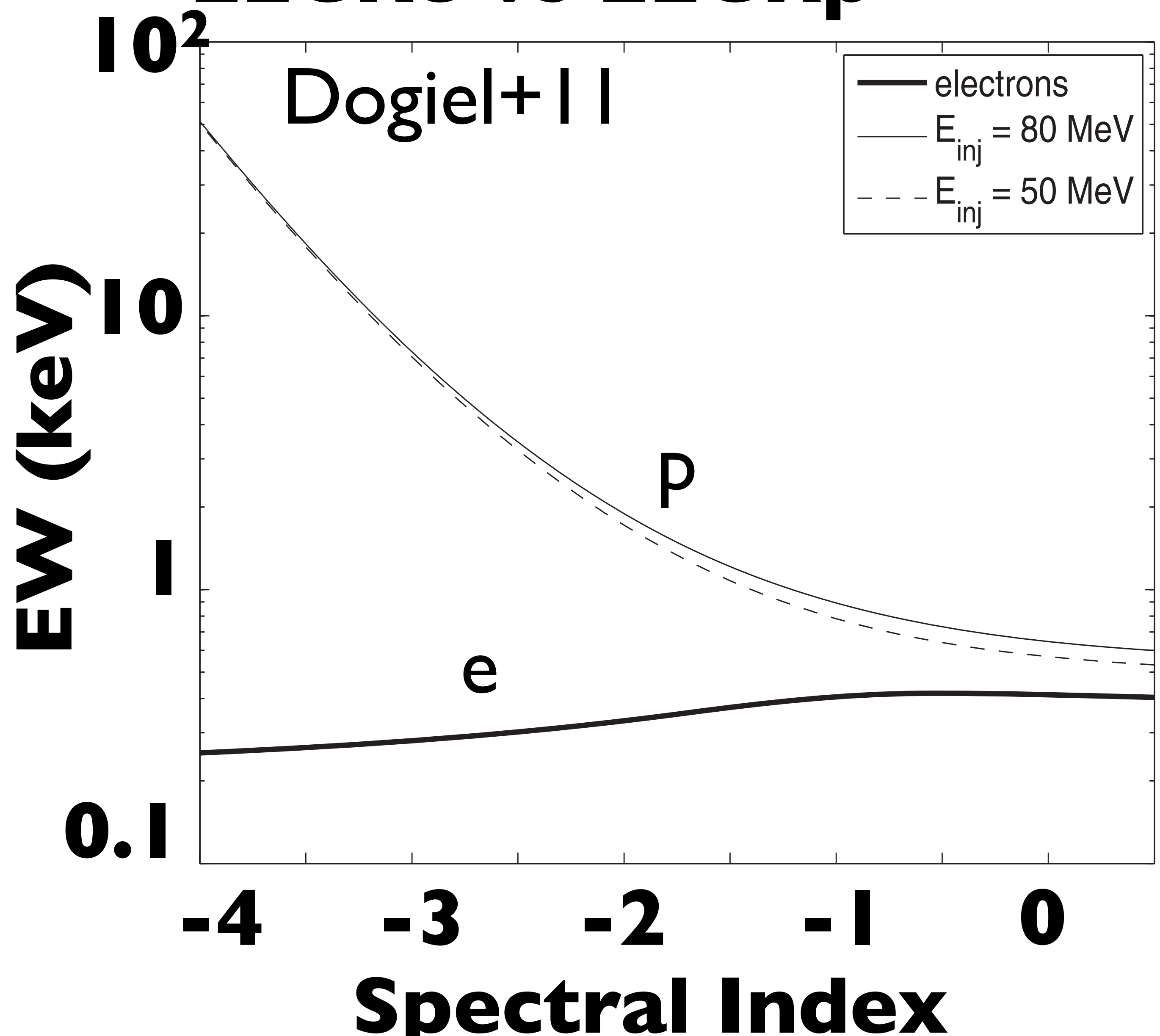
XRN vs LECR



XRN: large EW & deep absorption

LECR: shallow absorption

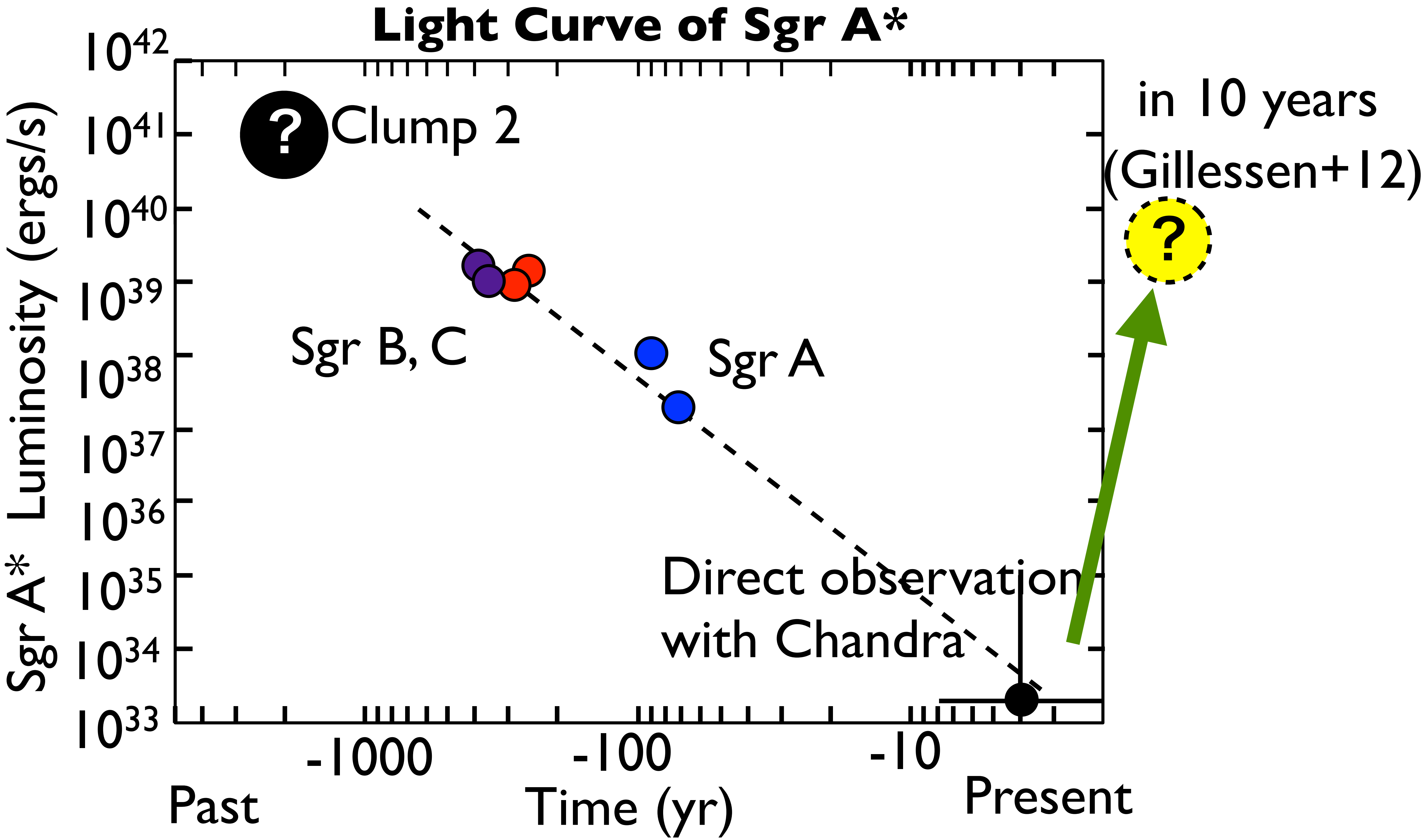
LECRe vs LECRp



LECRe ～ 300 - 600 eV

LECRp ～ 500 - 3000 eV

If XRN

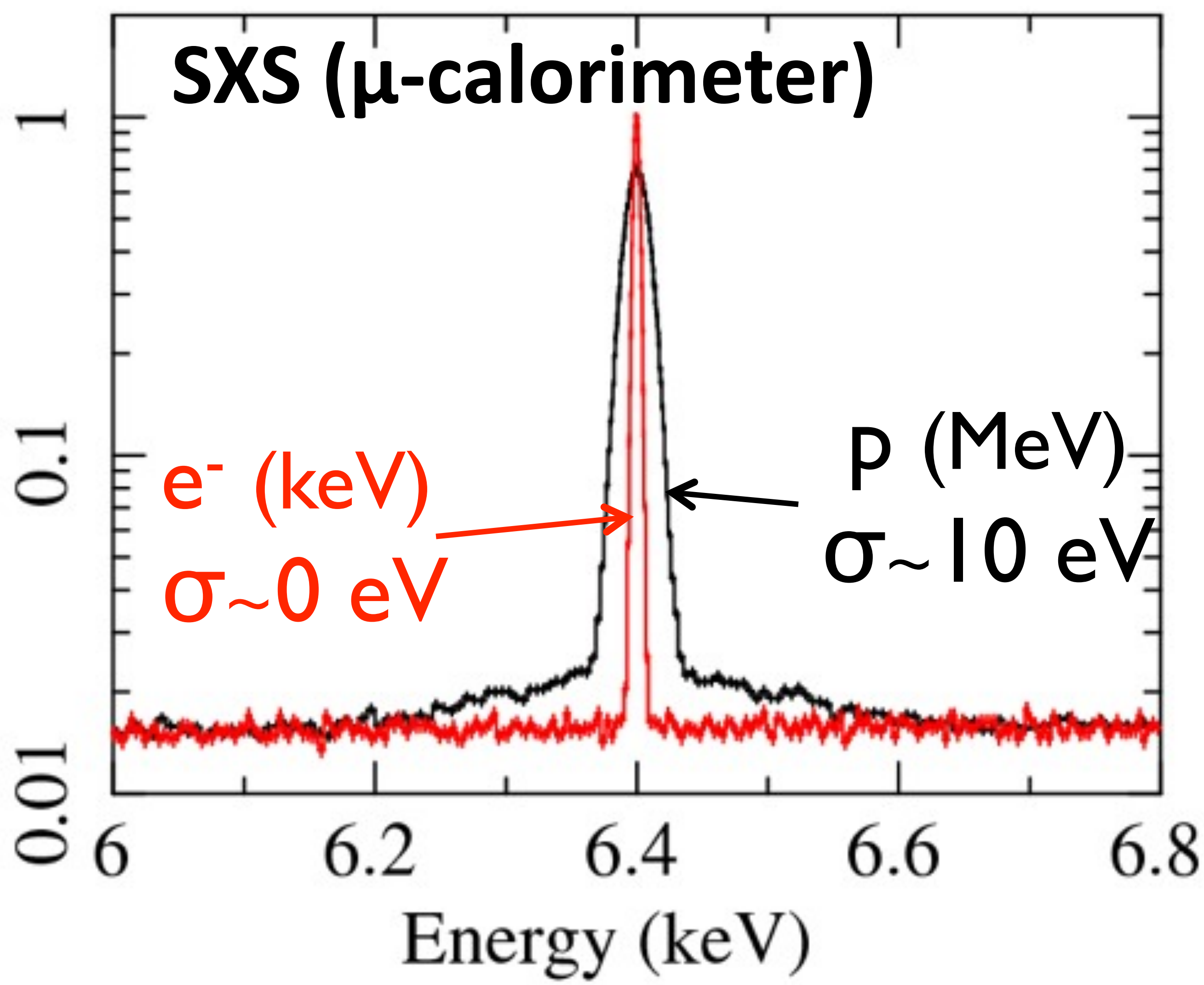


Reveal the Activity of Sgr A* (SMBH) in 2000 years.

LECRe vs LECRp

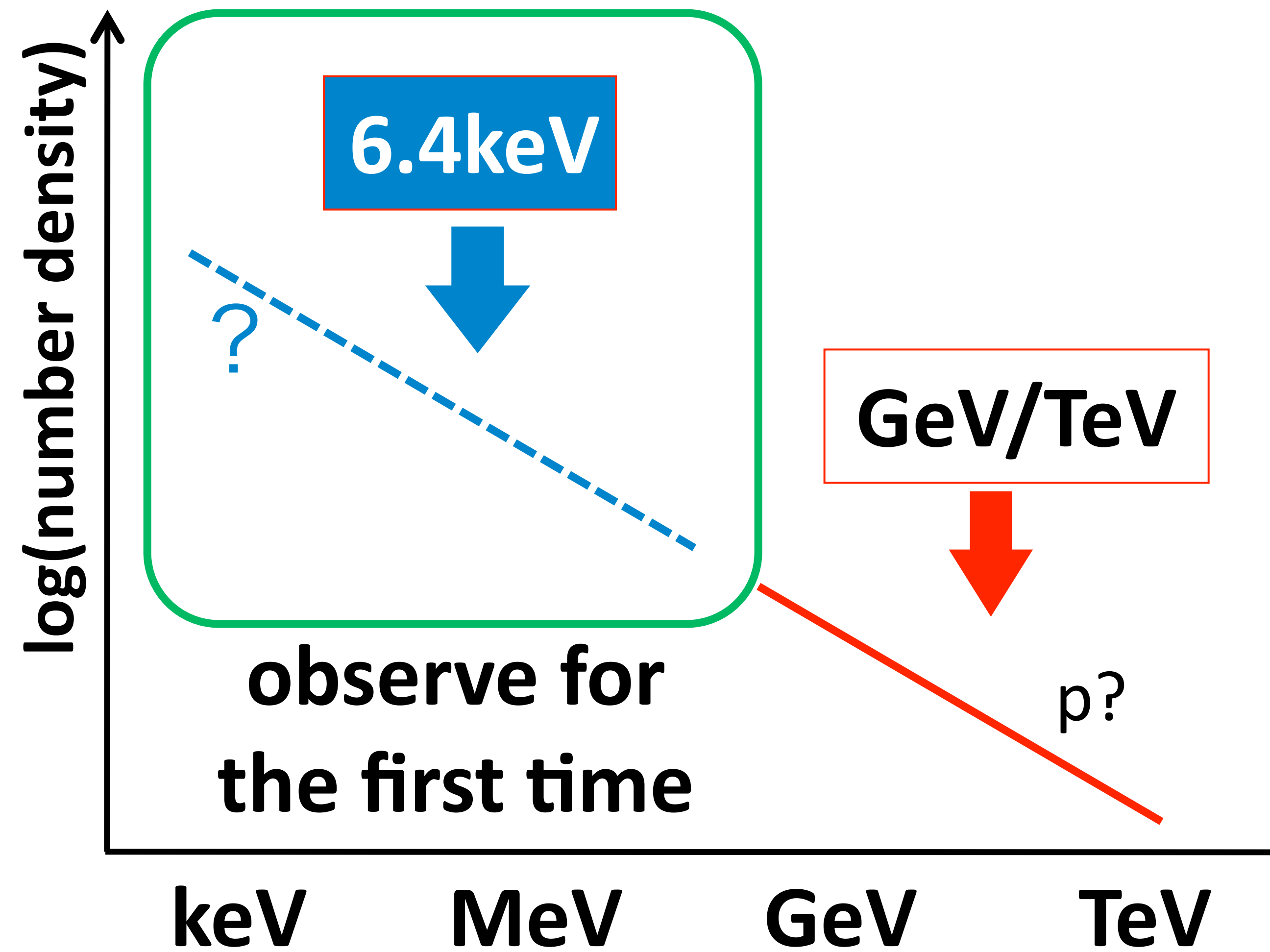
EW → **e or p**

ASTRO-H



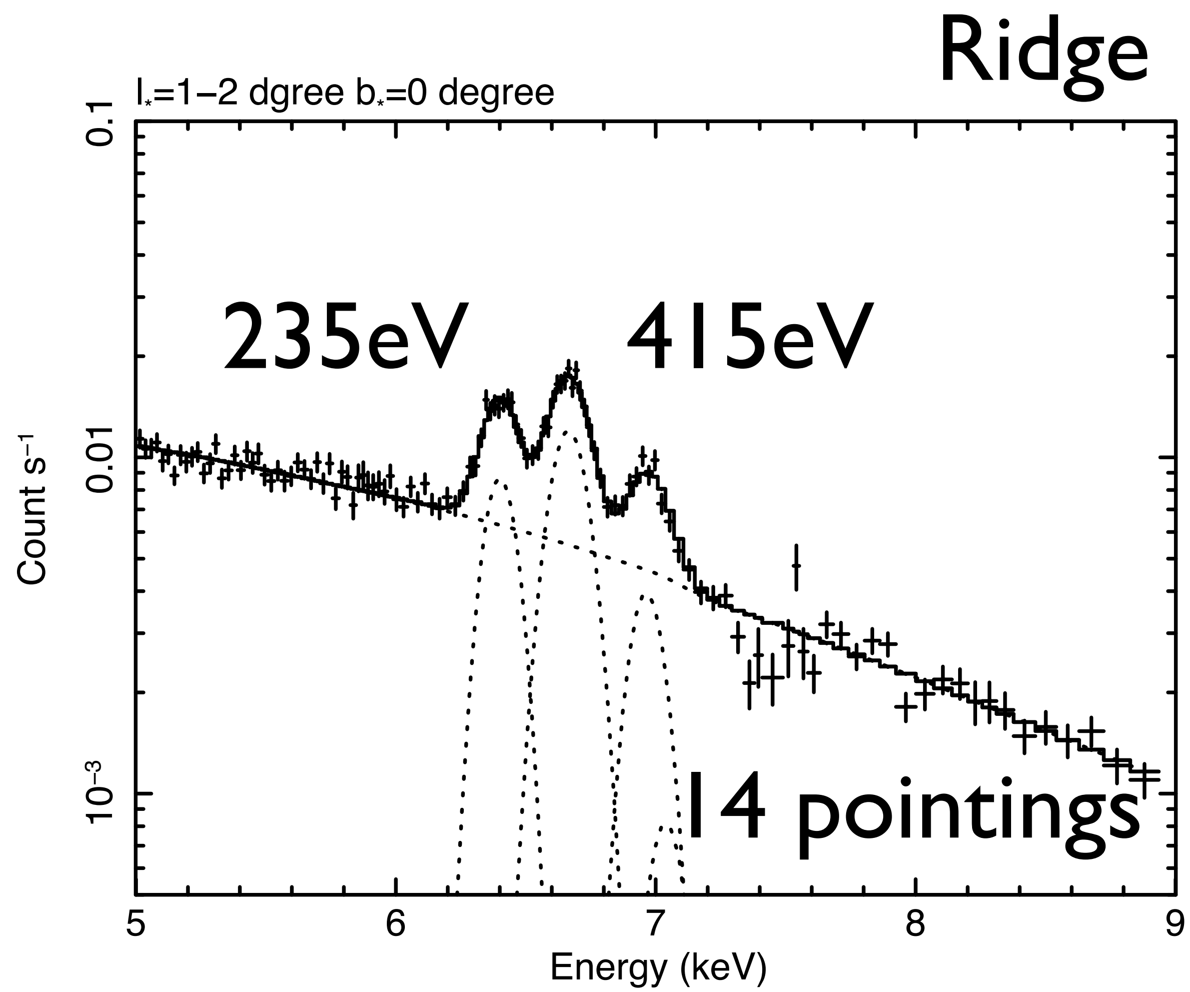
Line width → **conclusive evidence**

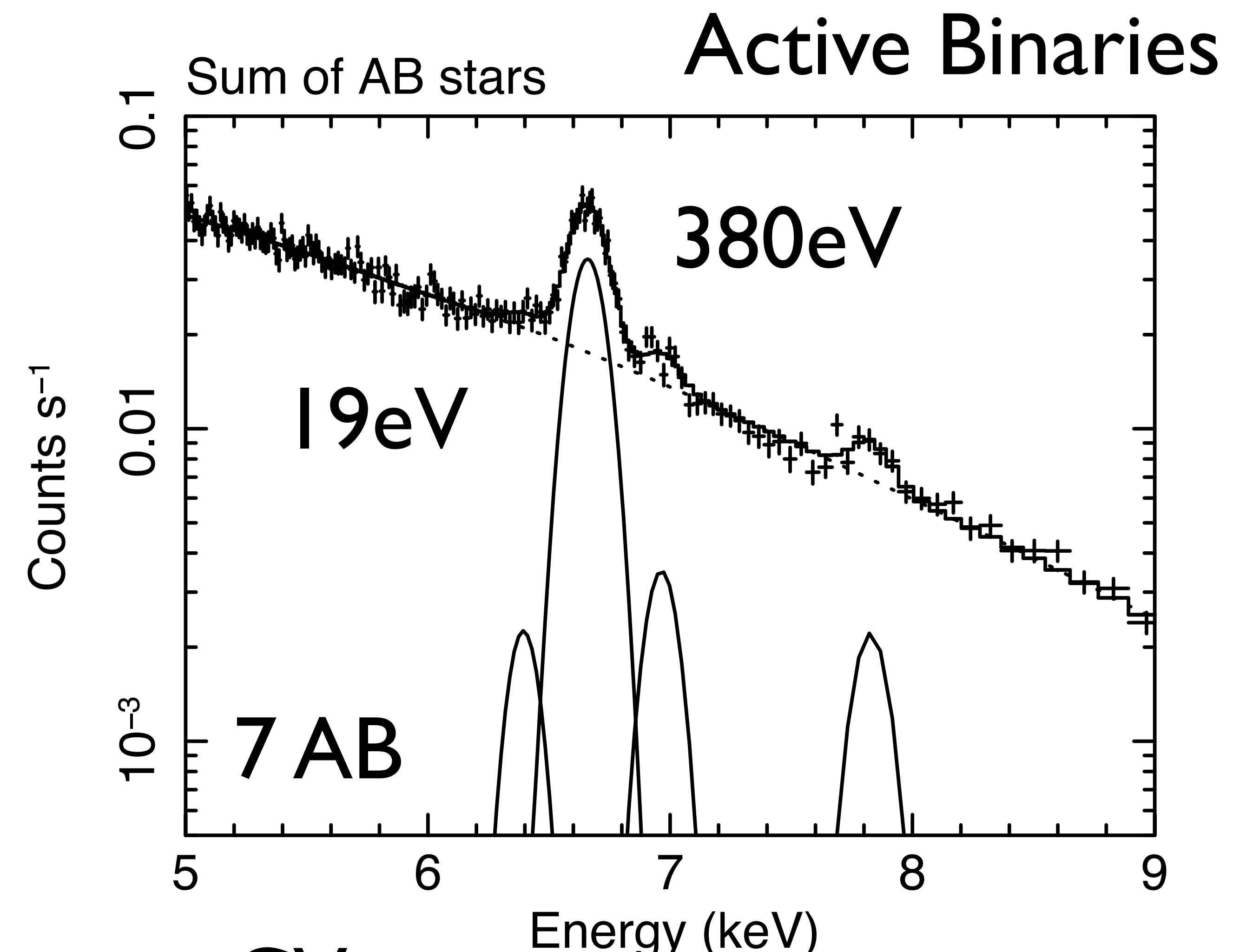
Cosmic Ray spectrum



Total amaount of energy of CR, Spectrum, Spacial distribution

Single Origin = Point Source Origin of 6.4 keV line (apart from 6.7 keV line)





6.7keV is from Active Binaries

6.4keV is from CVs

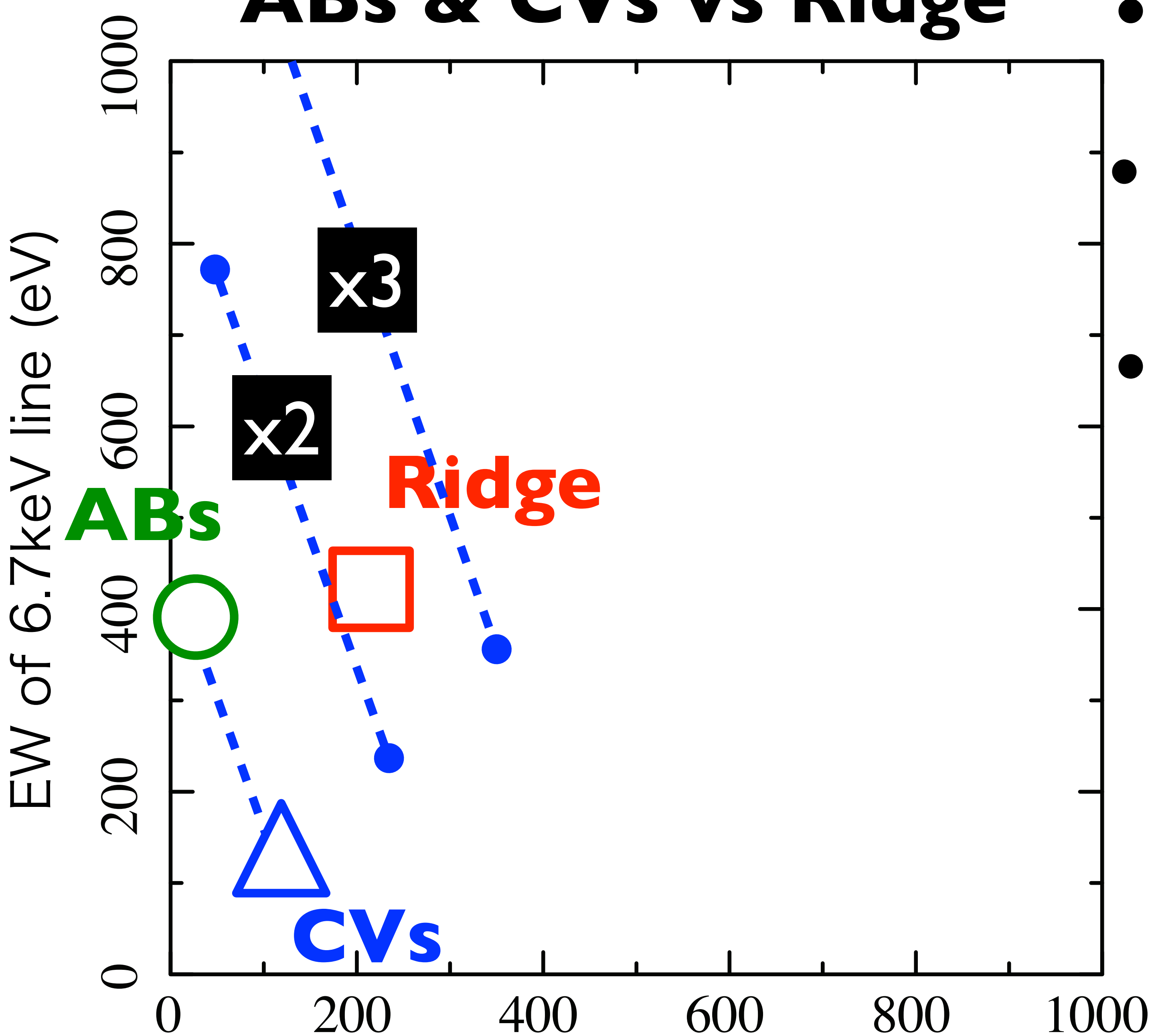
Continuum of ABs reduces EW of 6.4 keV line from CVs

CVs

16 CVs in Yuasa's D-Th
6.4keV ~110eV
6.7keV ~120eV
(given by Yuasa-san)

Point Source Origin of 6.4 keV line (apart from 6.7 keV line)

ABs & CVs vs Ridge



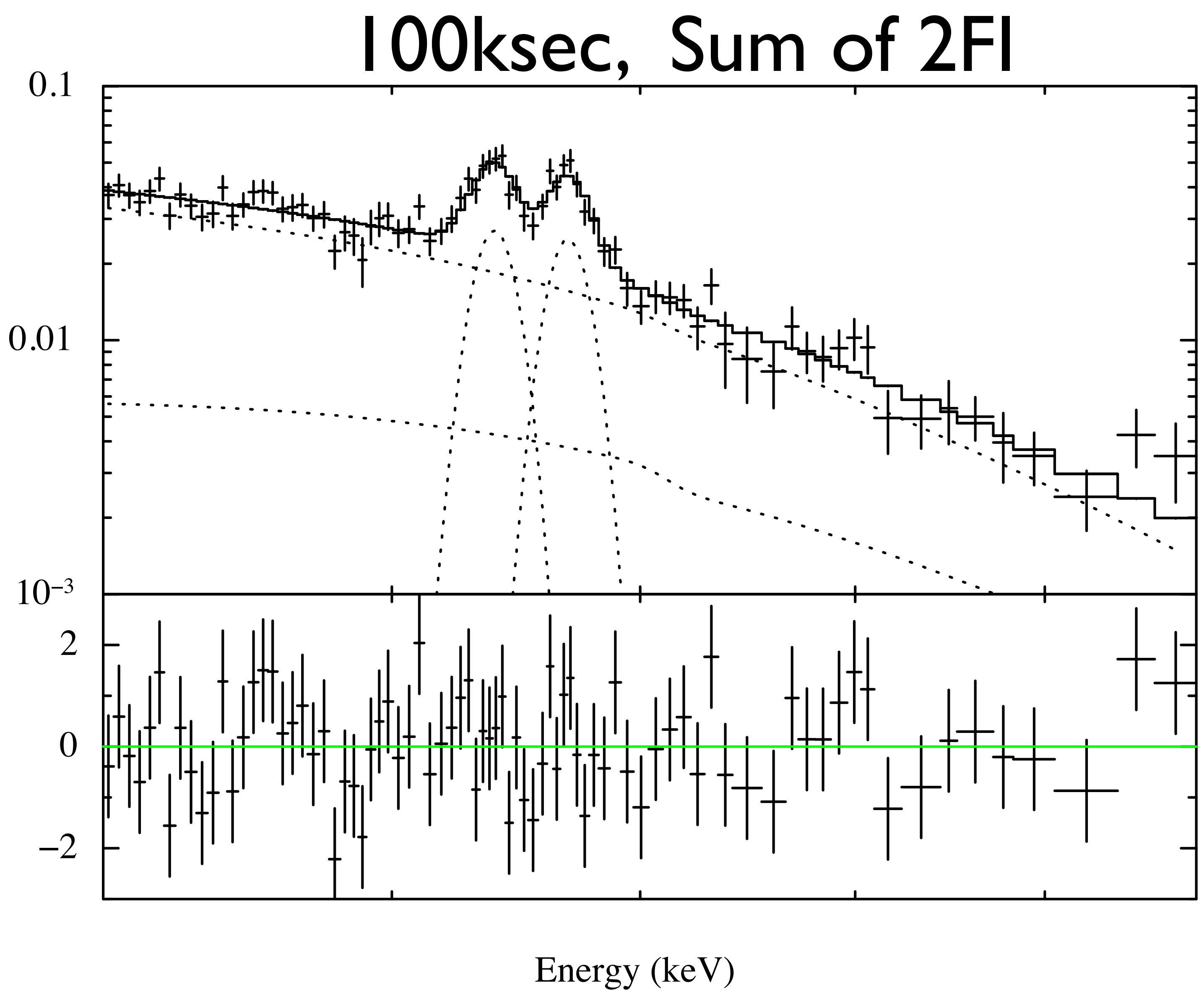
- Mixture of ABs and CVs can explain only the EWs on the line connecting the two.
- Simple mixture does not explain.
  ⇒ Fe(Local) x 2-3 is required.
- Abundance Measurements near GC
  - Giants (old >5x10^9yr) (bulge)
    ⇒ 0.6 solar
  - Super Giants (young ~10^8yr) (< 12')
    ⇒ 1.3 - 2.0 solar
  - X-ray Plasma (ISM present) (< 20')
    ⇒ Fe ~ 1.2 solar (Nobukawa+10)

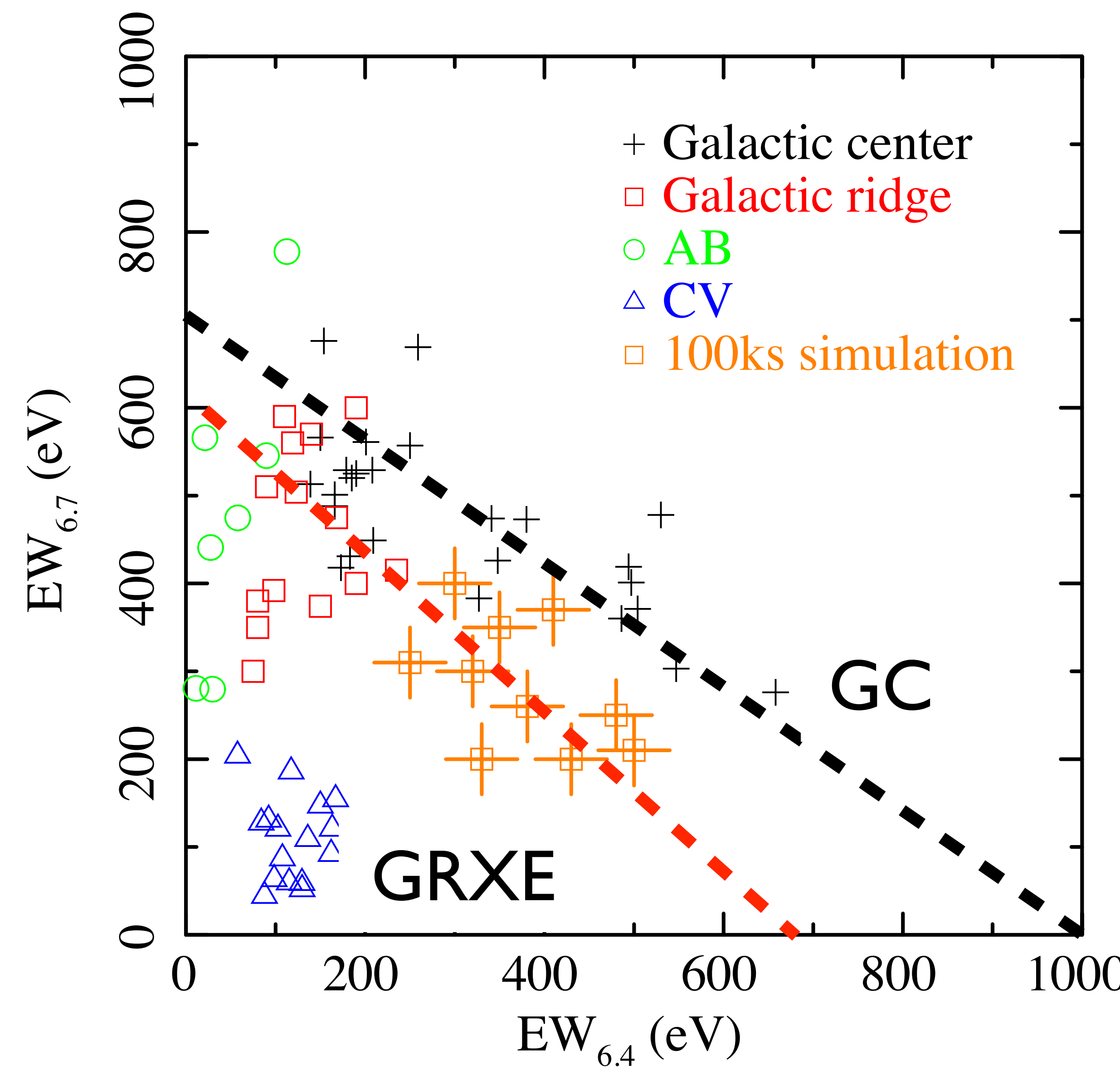
    (note: Si, S = 1.9-2.5 solar)

Objective 4

Measurement of the Fe abundance gradient toward the GC (along *l*) and Planes (along *b*).

Simulation : Spectrum and Correlation





- CXB and NXB are already taken into account in this simulation.
- ΔEW6.4 = ± 39 eV (90%)
  ΔEW6.7 = ± 44 eV
- A simulation of the correlation. (Scatter the data by hand)
- Can determine EW(6.4) with enough accuracy to distinguish the ionizing particles.

"True" Legacy : Serendipitous Discoveries

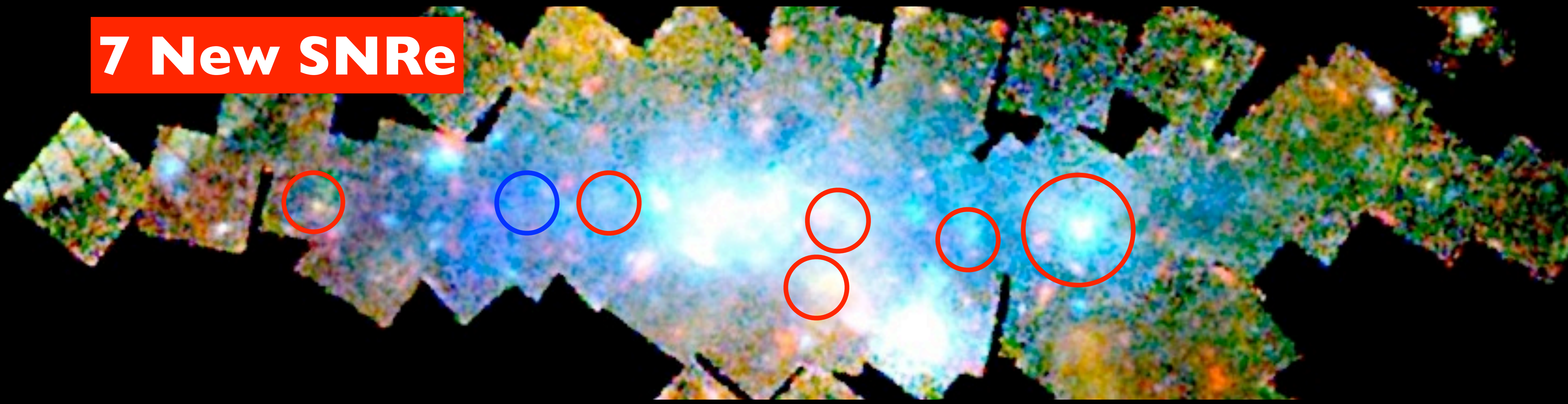
Published or Accepted 30

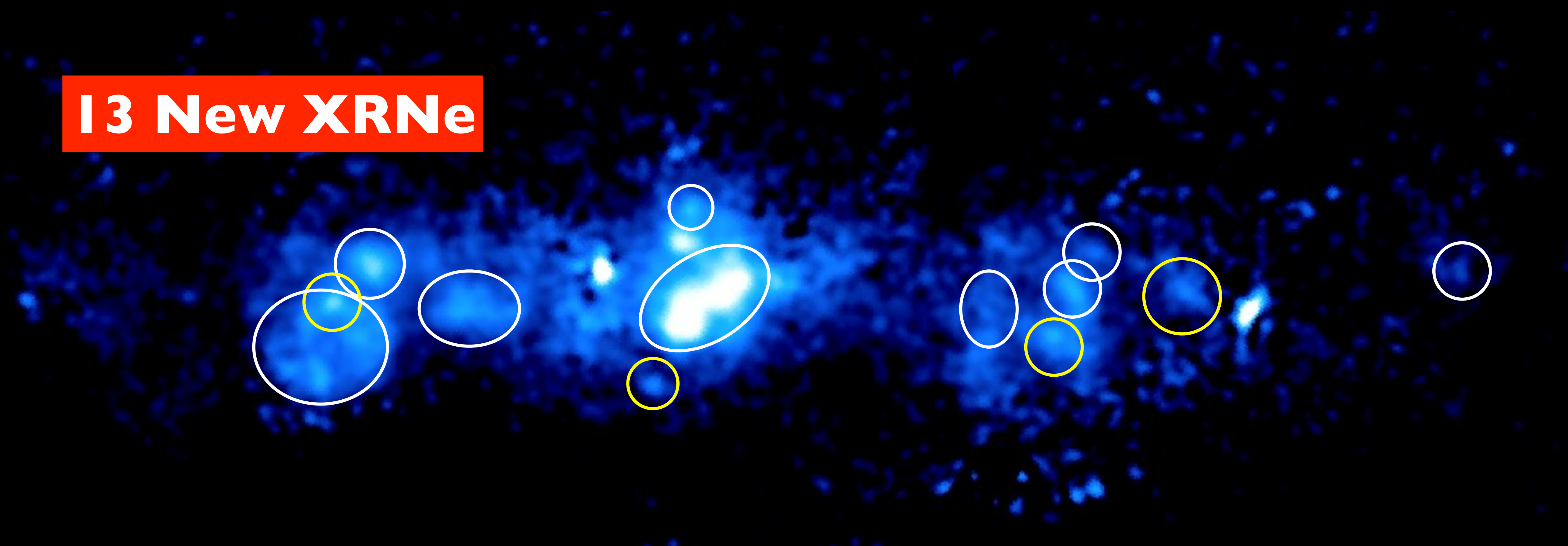
Line Diagnostics of GCDX	Koyama, Hyodo+
Spectrum of Sgr A East	Koyama, Uchiyama+
Hard X-Ray Emission the Arches Cluster	Tsujimoto+
Diffuse Iron line of the Sgr B Region	Koyama, Inui+
Peculiar Hot Star in the GC	Hyodo+
A Time Variable X-Ray Echo of Sgr B2	Koyama, Inui+
Diffuse Hard X-ray from the GC	Yuasa+
New XRN and SNR in the Sgr B1 Region	Nobukawa, Tsuru+
X-Ray Flare of A-type Star HD 161084	Miura+
SNR Candidate G359.79-0.26	Mori, Tsuru+
New X-ray views of the Galactic Center	Koyama
X-Ray Observations of the GC	Koyama
Variable Neutral Iron Line in Sgr B2	Inui+
Spatial Distribution of the GCDX	Koyama, Takikawa+
Suzaku Observations of Sgr D HII region	Sawada, Tsujimoto+
SAX J1748.2−2808	Nobukawa+
XRN in the Sgr C region	Nakajima, Tsuru+
Dips/Absorption Lines of AXJ1745.6-2901	Hyodo+
Thermal plasma near the Sgr C region	Tsuru, Nobukawa+
Iron lines from Galactic Ridge and GC	Yamauchi+
Superbubble	Mori, Tsuru+
Face-on view of Sgr B2	Ryu, Tsuru+
Foot-Point of the Radio Arc	Fukuoka+
Neutral Lines of Light Elements of Sgr A region	Nobukawa, Tsuru+
SNR and 6.4keV lines around the Great Annihilator	Nakashima+
RRC of G359.1-0.5	Ohnishi+
Structures of Diffuse Emission from GCDX and GRDX	Uchiyama+
K-Shell Emission of Neutral Iron Line from Sagittarius B2	Digiel+
Suzaku Discovery of Twin Thermal Plasma from the Tornado Nebula	Sawada, Tsuru+
Spatial and Temporal Variations of the Diffuse Iron 6.4 keV Line in the Galactic Center Region	Chernysov+

In prep. or Submitted 5

6.4 keV structure around Archies Cluster	Sawada+
A Time Variability of XRN in Sgr B2	Nobukawa+
3-D position of the Molecular Cloud of Sgr C in the GC	Ryu, Tsuru+
Spatial and Temporal Variations of the Diffuse Iron 6.4 keV Line in the Galactic Center Region	Chernyshov,
Broadband Spectral Decombosiion of the Galactic Ridge Emission	T. Yuasa

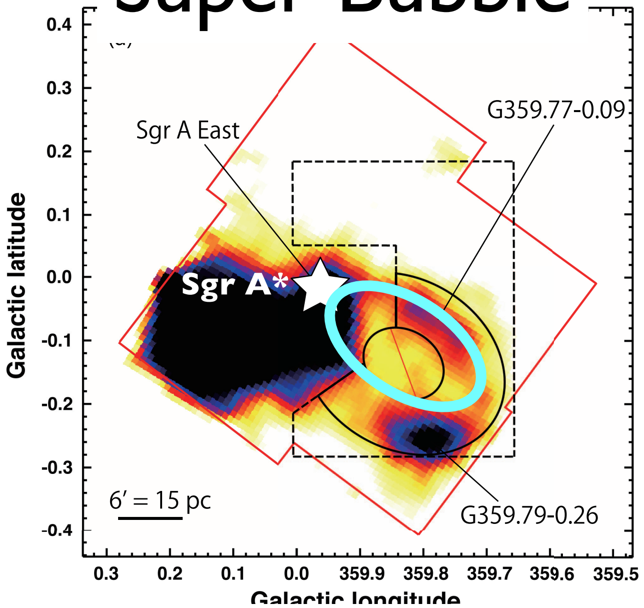
Doctor Thesis : 6 Nakajima, Inui, Hyodo, Uchiyama, Nobukawa, Yuasa


7 New SNRe

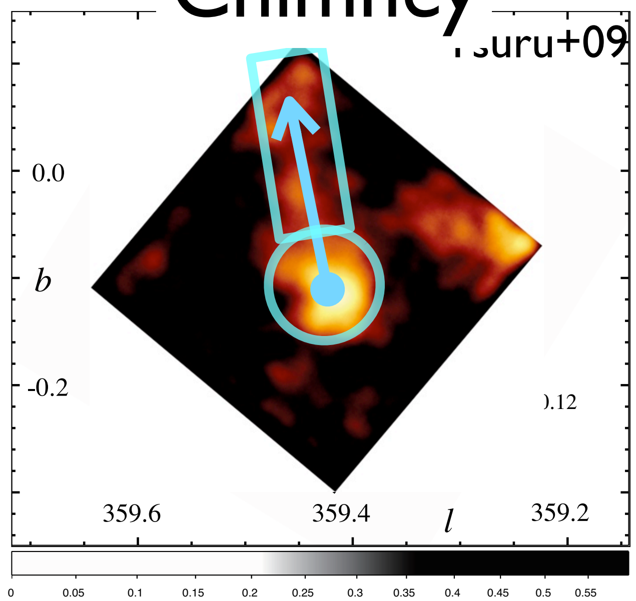

13 New XRNe

5 New Types of objects

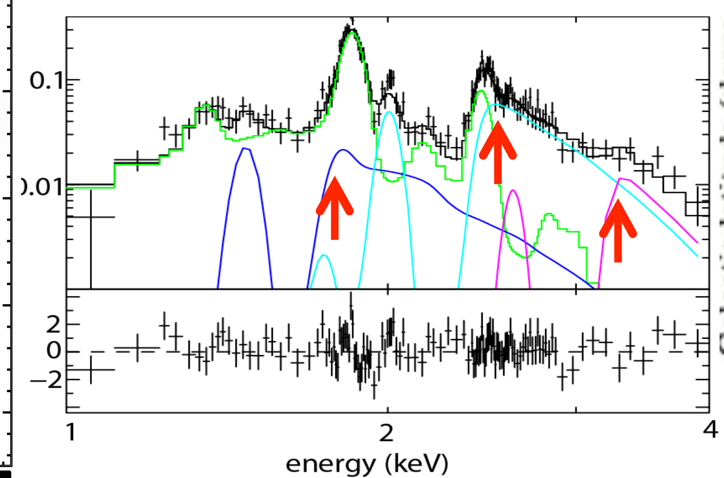
Super Bubble

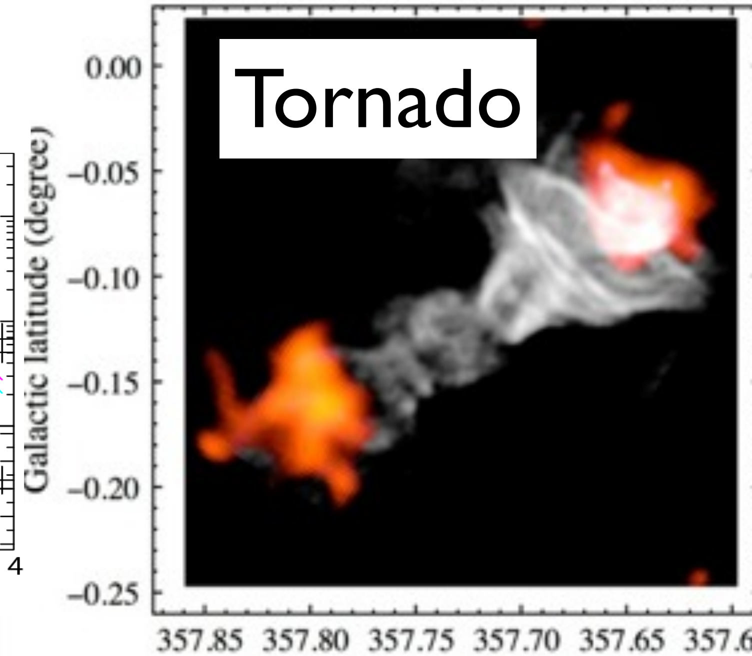


Chimney



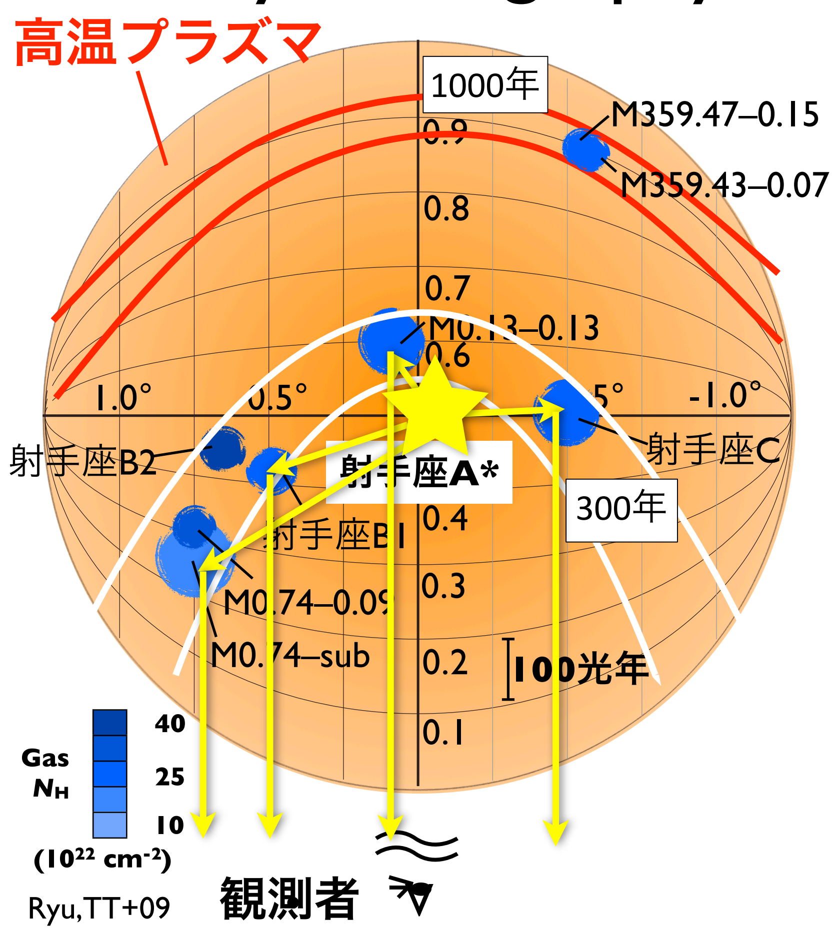
RRC-SNR



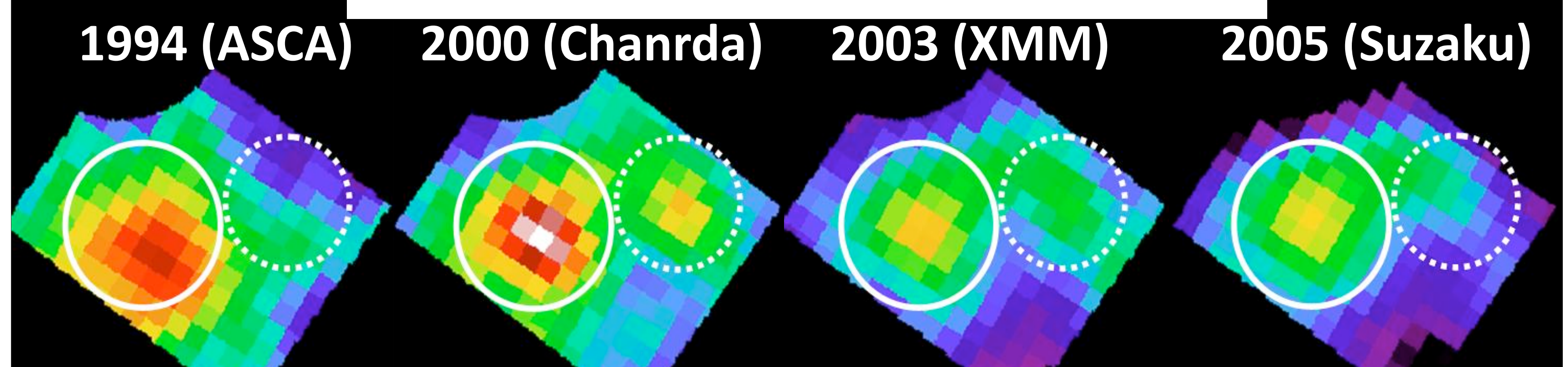


4 Unexpected Phenomena ・ New Perspectives

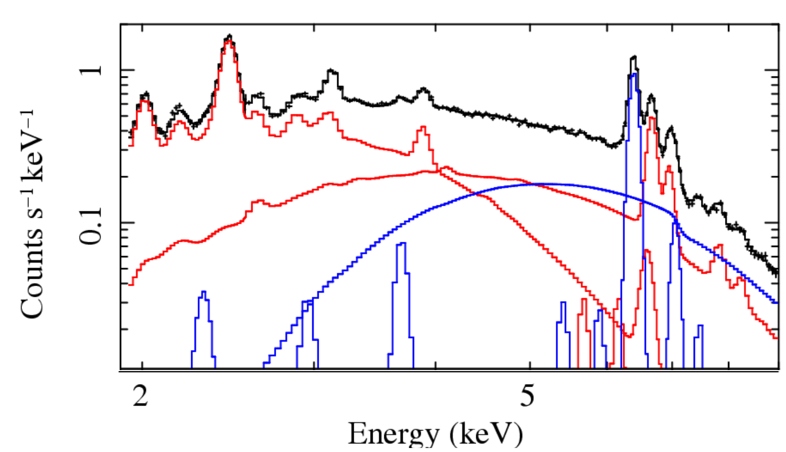
X-ray Tomography



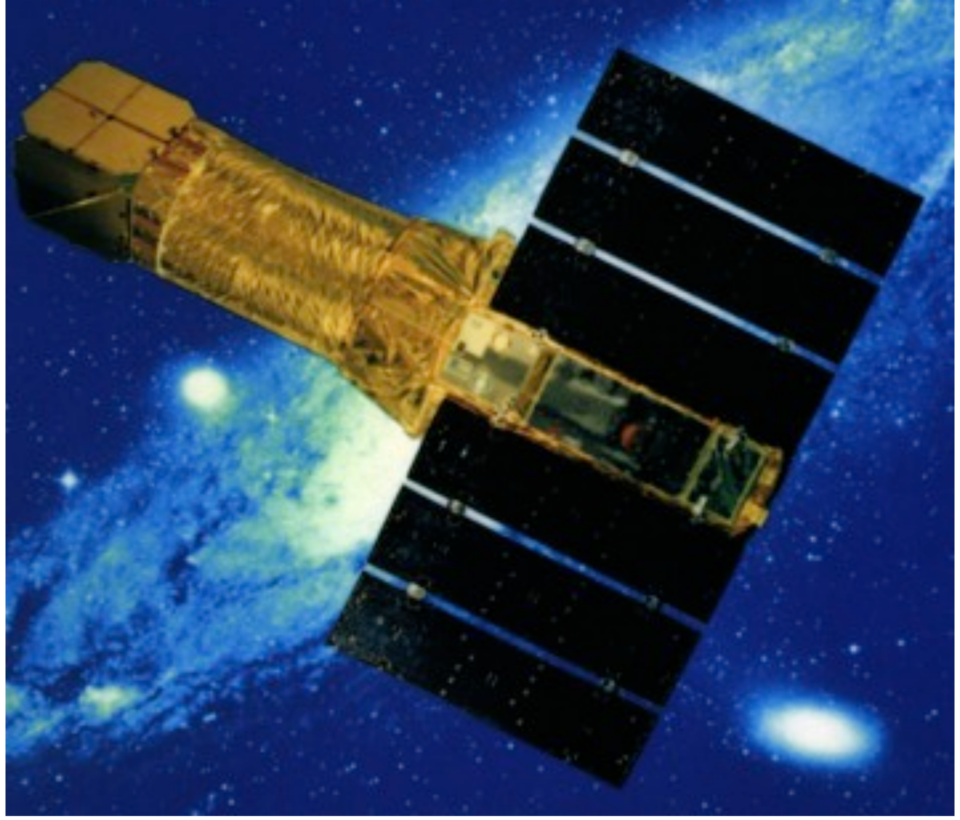
time variable 6.4 keV line



Neutral lines from light elements

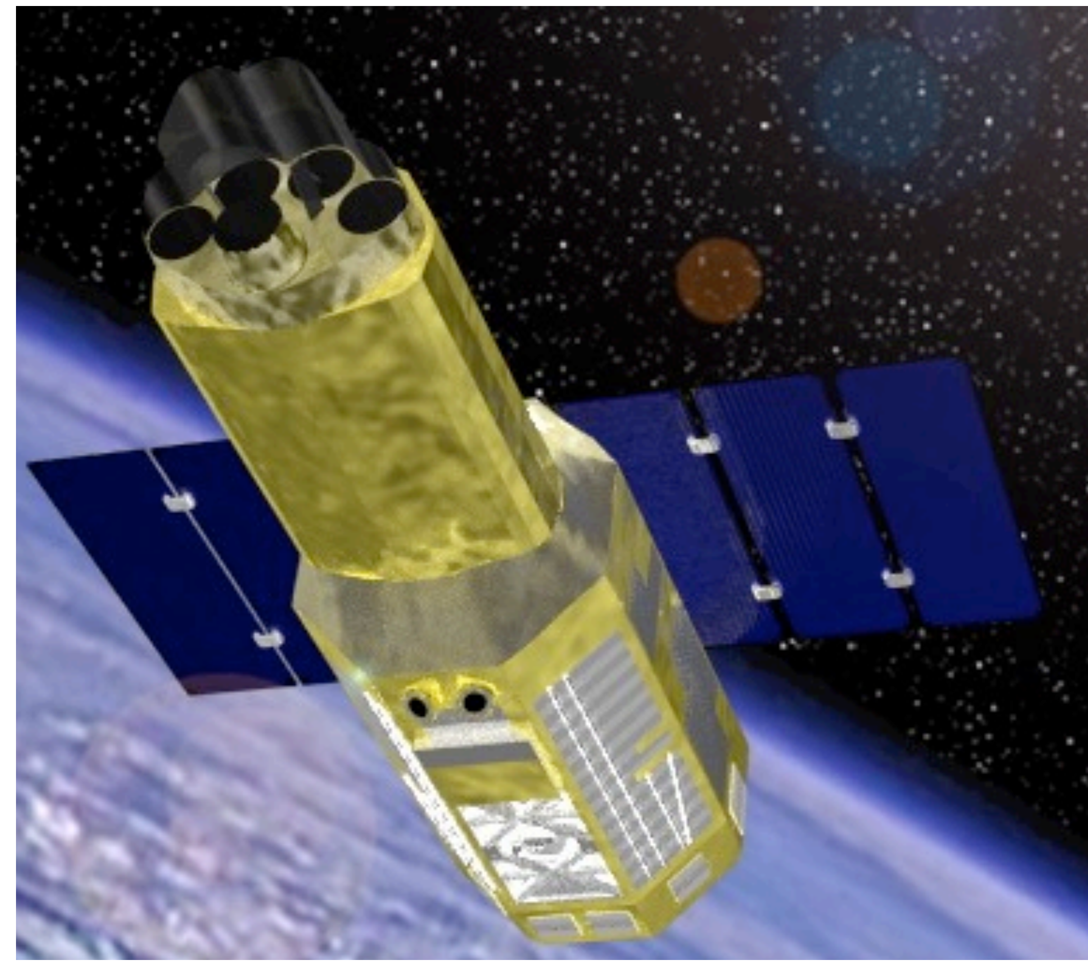


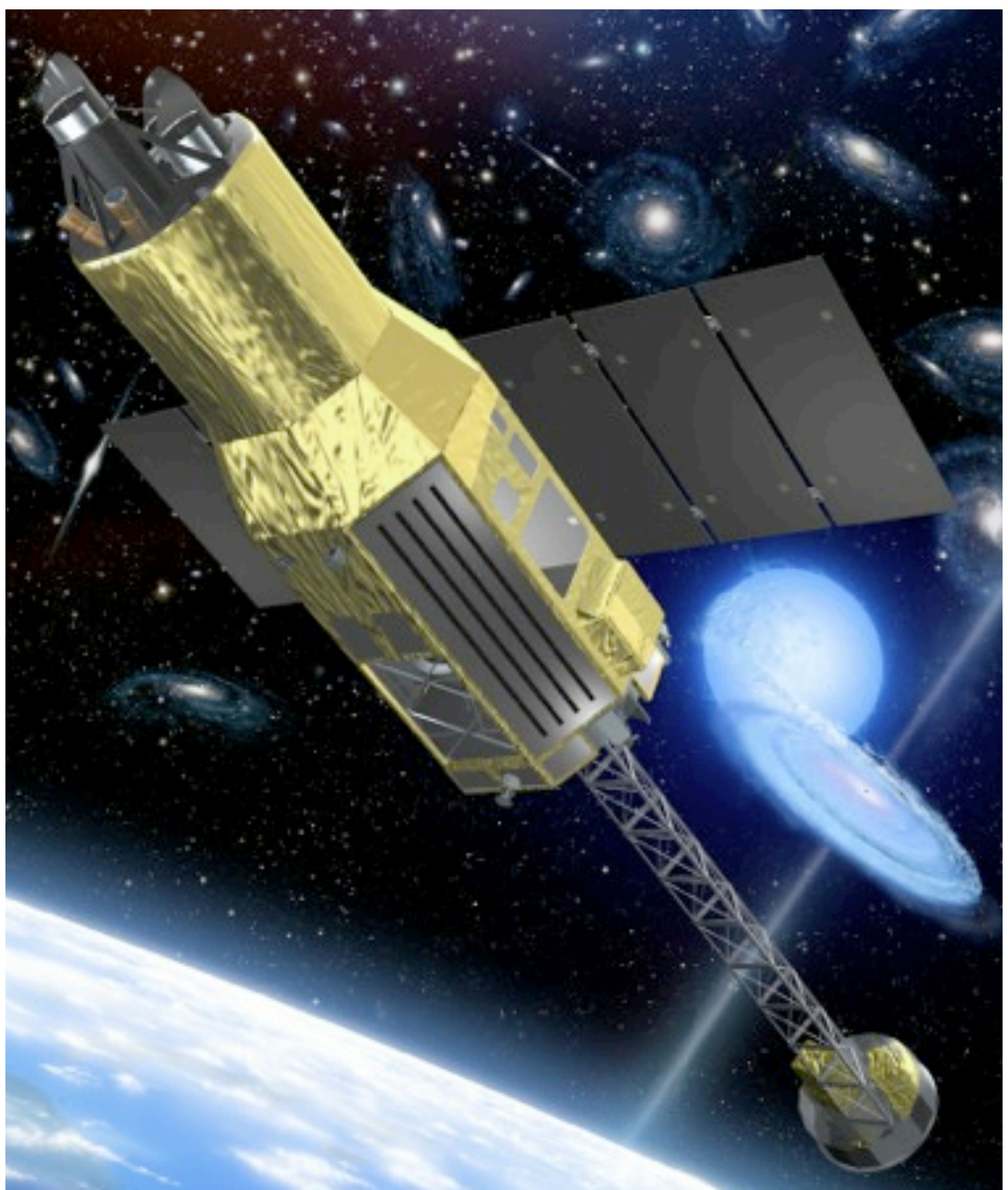
Thin Extended
6.4keV line
emission



Many AX J*** were discovered by the ASCA Plane Survey,

which eventually results in Suzaku's good achievements.





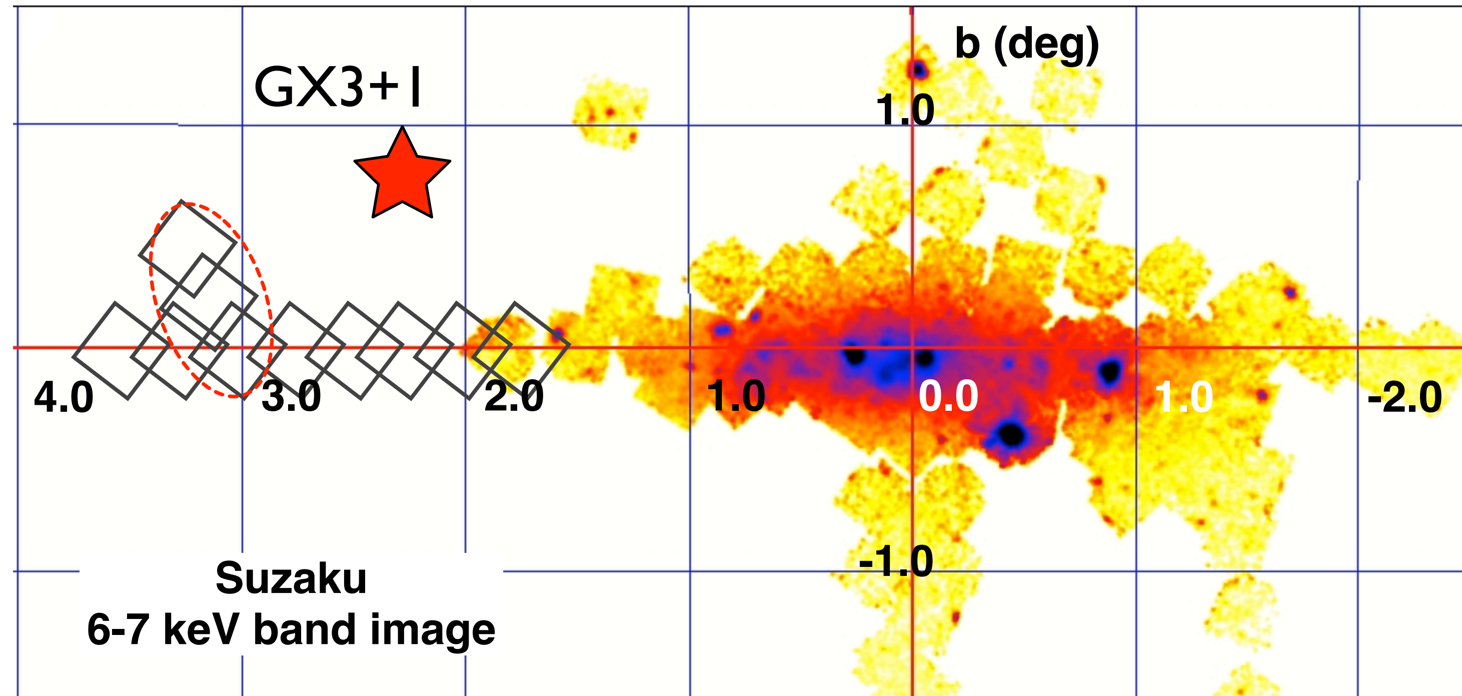
This KP will make many serendipitous discoveries,

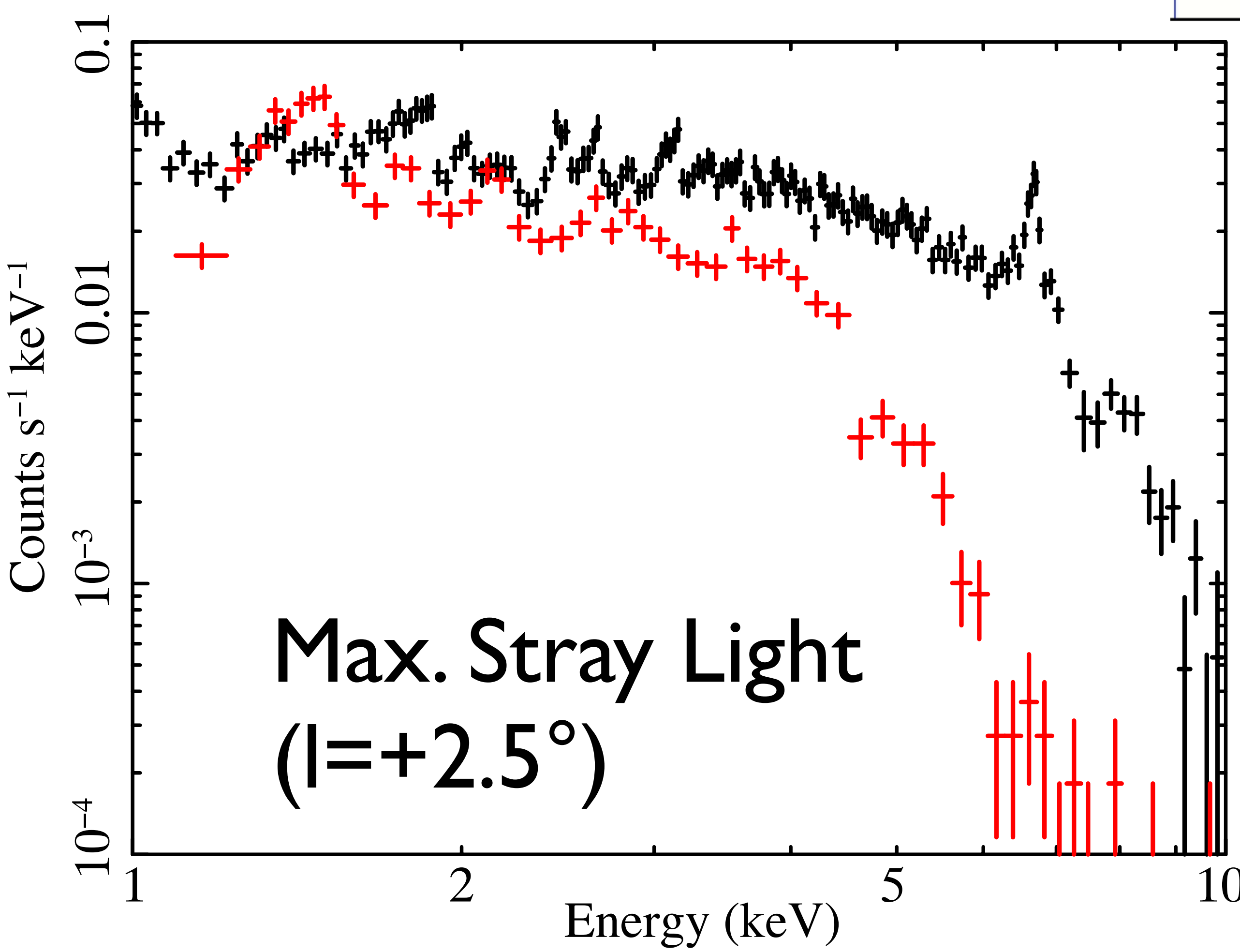
which leads to fruitful results with Astro-H

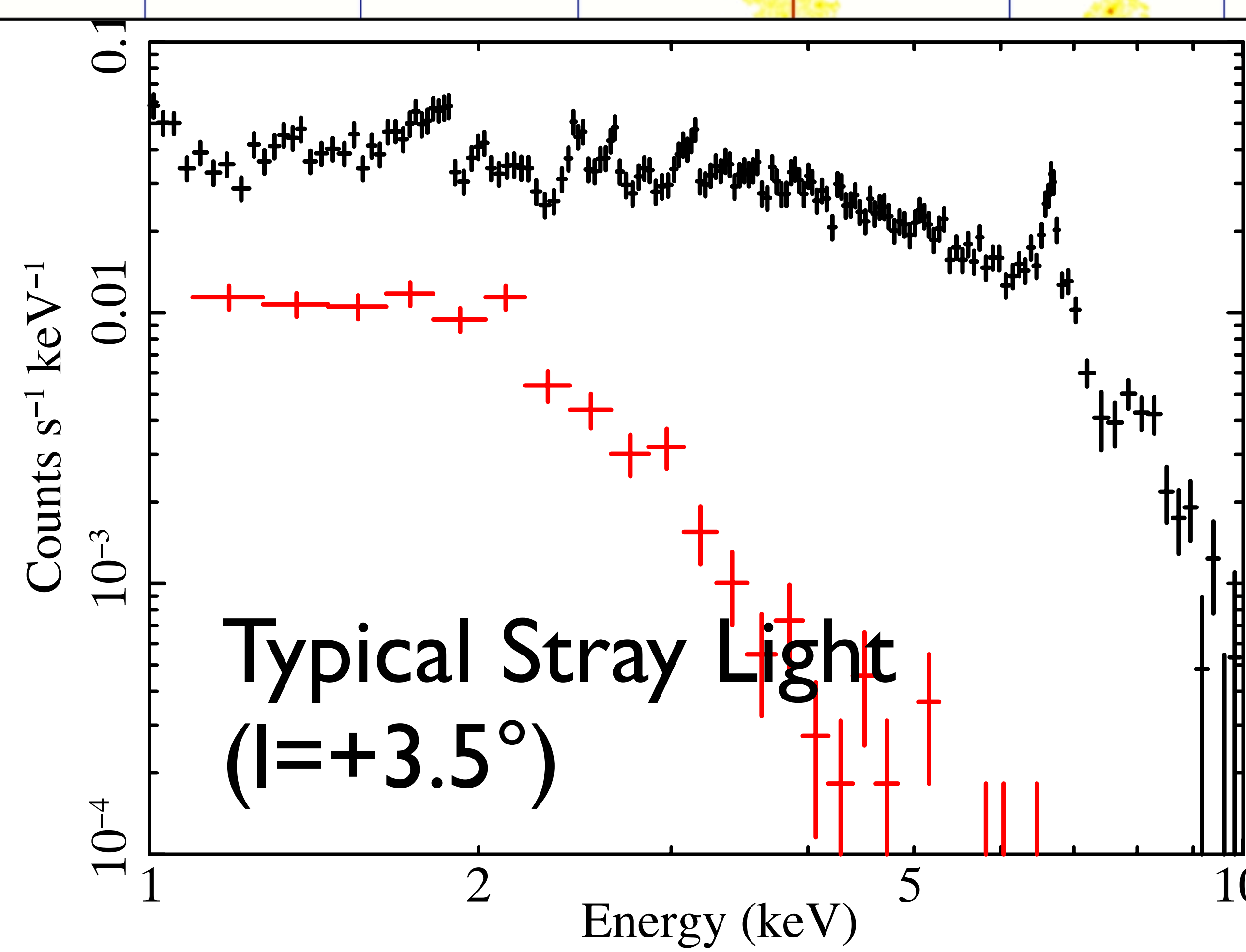
Thank you.

Pointing Positions, Exposure Time and Feasibility

- 10 x 100ksec
- Stray lights from GX3+1 does not affect the Fe-line studies.







Pointing Positions, Exposure Time and Feasibility