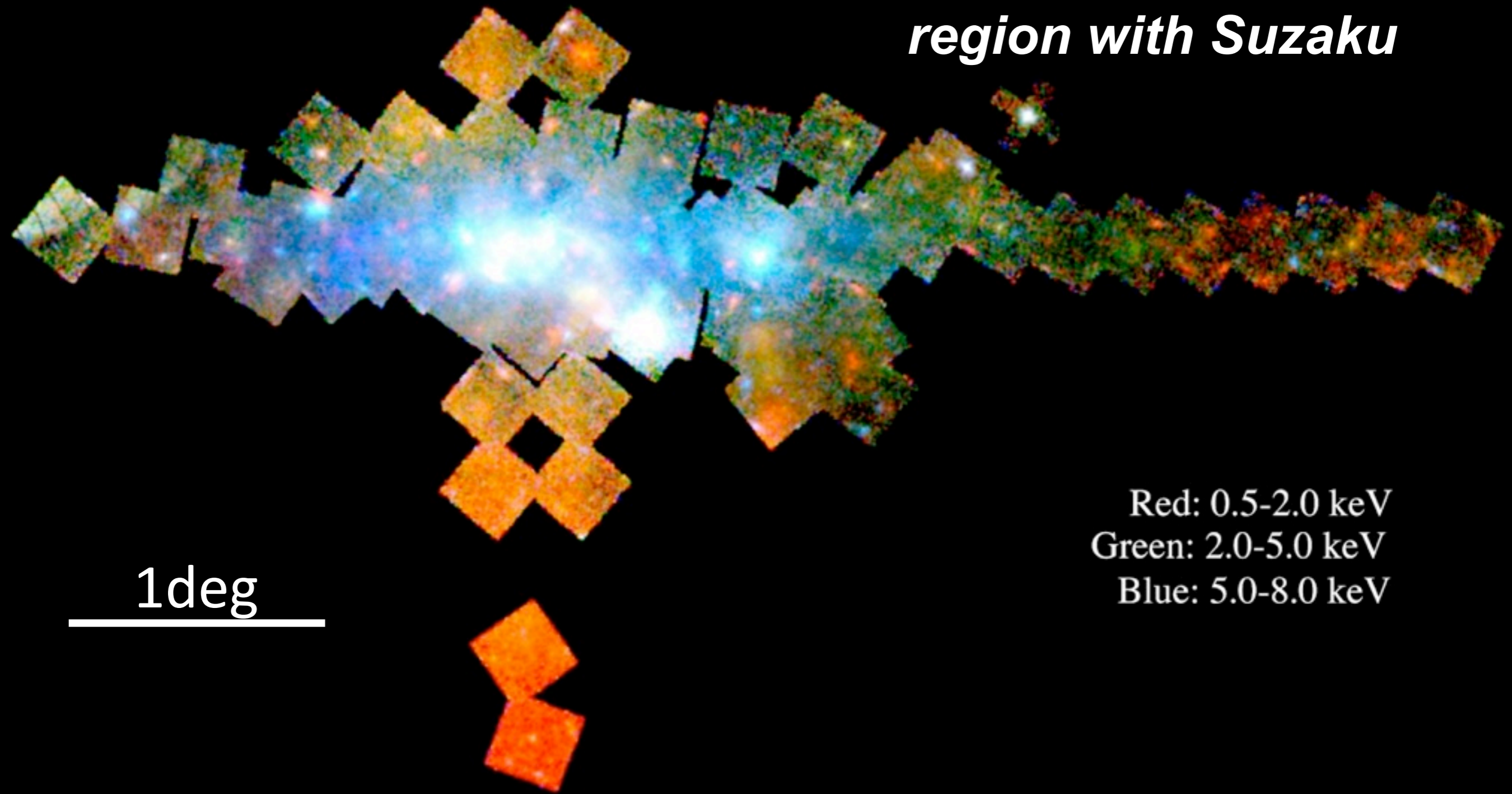


Suzaku Observation of the Galactic Center Region

Takeshi Go Tsuru (Kyoto University)

R.Fukuoka, Y.Hyodo, T.Inui, K.Koyama, S.Nakashima, M.Nobukawa, T.Ohnishi, S.G.Ryu, M.Sawada, Y.Takizawa (Kyoto), S. Yamauchi, (Nara WU), H.Uchiyama, T.Yuasa (Tokyo), H.Matsumoto, H.Mori (Nagoya), M.Tsujimoto (ISAS), J.Miura (Chuo), H.Nakajima (Osaka), D.Chernysov, V.Dogiel (P.N. Lebedev Institute) and more

***Observation of the GC
region with Suzaku***

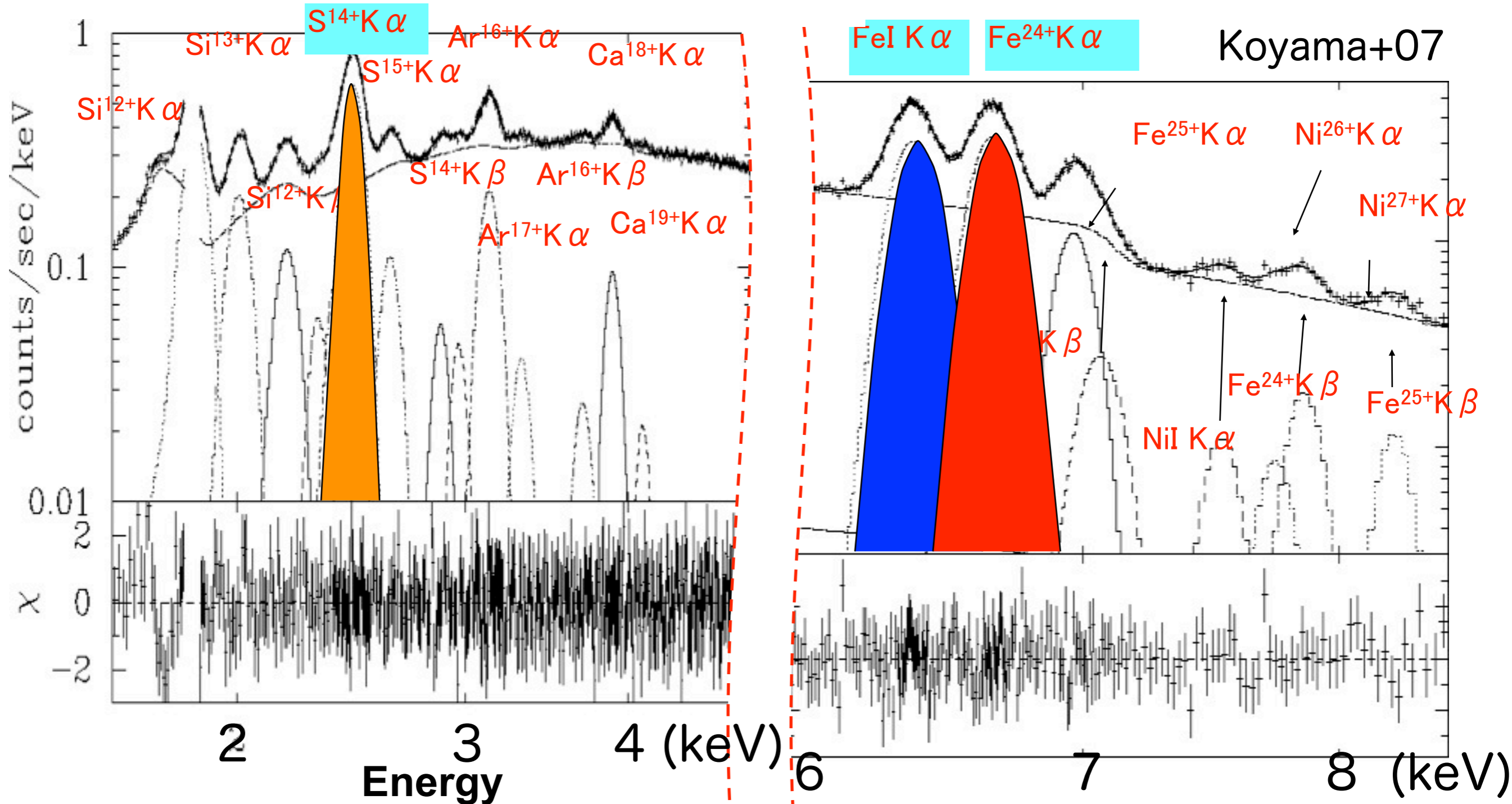


1deg

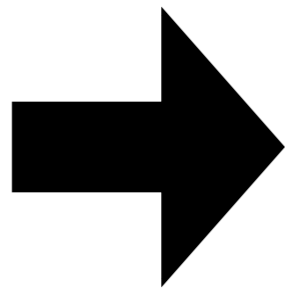
Red: 0.5-2.0 keV
Green: 2.0-5.0 keV
Blue: 5.0-8.0 keV

197pointings, 5.26Msec

SWG, AO, LP, KP ($|l| < 3^\circ$, $|b| < 5^\circ$)



**Narrow
Line
Mapping**



**High Spectral Resolution,
Large Collecting Area,
Low and Stable Non-X-ray Background**

The Galactic center region is the best target for Suzaku to take the most advantage of its Superiorities.

2.45keV (Continuum not subtracted)



Sgr A*

100ly

6.7keV (Continuum subtracted)



Sgr A*

100ly

6.4keV (Continuum subtracted)



Sgr A*

100ly



Papers and Thesis using the GC data



Published
or Accepted

30

Line Diagnostics of GCDX
 Spectrum of Sgr A East
 Hard X-Ray Emission the Arches Cluster
 Diffuse Iron line of the Sgr B Region
 Peculiar Hot Star in the GC
 A Time Variable X-Ray Echo of Sgr B2
 Diffuse Hard X-ray from the GC
 New XRN and SNR in the Sgr B1 Region
 X-Ray Flare of A-type Star HD 161084
 SNR Candidate G359.79-0.26
 New X-ray views of the Galactic Center
 X-Ray Observations of the GC
 Variable Neutral Iron Line in Sgr B2
 Spatial Distribution of the GCDX
 Suzaku Observations of Sgr D HII region
 SAX J1748.2-2808
 XRN in the Sgr C region
 Dips/Absorption Lines of AX J1745.6-2901
 Thermal plasma near the Sgr C region
 Iron lines from Galactic Ridge and GC
 Superbubble
 Face-on view of Sgr B2
 Foot-Point of the Radio Arc
 Neutral Lines of Light Elements of Sgr A region
 SNR and 6.4keV lines around the Great Annihilator
 RRC of G359.1-0.5
 Structures of Diffuse Emission from GCDX and GRDX
 K-Shell Emission of Neutral Iron Line from Sagittarius B2
 Suzaku Discovery of Twin Thermal Plasma from the Tornado Nebula
 Spatial and Temporal Variations of the Diffuse Iron 6.4 keV Line in the Galactic Center Region
 6.4 keV structure around Arches Cluster
 A Time Variability of XRN in Sgr B2
 3-D position of the Molecular Cloud of Sgr C in the GC
 Spatial and Temporal Variations of the Diffuse Iron 6.4 keV Line in the Galactic Center Region
 Broadband Spectral Decomposition of the Galactic Ridge Emission

Koyama, Hyodo+
 Koyama, Uchiyama+
 Tsuiimoto+
 Koyama, Inui+
 Hyodo+
 Koyama, Inui+
 Yuasa+
 Nobukawa, Tsuru+
 Miura+
 Mori, Tsuru+
 Koyama
 Koyama
 Inui+
 Koyama, Takikawa+
 Sawada, Tsuiimoto+
 Nobukawa+
 Nakaiima, Tsuru+
 Hyodo+
 Tsuru, Nobukawa+
 Yamauchi+
 Mori, Tsuru+
 Ryu, Tsuru+
 Fukuoka+
 Nobukawa, Tsuru+
 Nakashima+
 Ohnishi+
 Uchiyama+
 Digiel+
 Sawada, Tsuru+
 Chernysov+
 Sawada+
 Nobukawa+
 Ryu, Tsuru+
 Chernyshov, Nobukawa+
 T. Yuasa

In prep.
or Submitted
5

Doctor Thesis : 6

Nakajima, Inui, Hyodo, Uchiyama, Nobukawa, Yuasa



Our Talk Plans (Tsuru & Nobukawa)



- Discoveries of New SNR candidates
- New Aspects of Peculiar Diffuse Sources
- 6.7keV and 6.9keV line distribution
- Discoveries and Revisits of 6.4 keV clumps
- Discovery of diffuse 6.4keV emission from the intercloud region
- Discovery of neutral Ar, Ca, Cr and Mn lines
- Time variabilities of 6.4keV and Hard X-ray emission from XRNe.
- 3D-distribution of the XRNe

Nobukawa-san's Talk

I. L... of SN... idates



G1.2-0.0
(Sawada09+)

G0.42-0.04
(Nobukawa+08)

G359.77-0.09
(Mori+09)

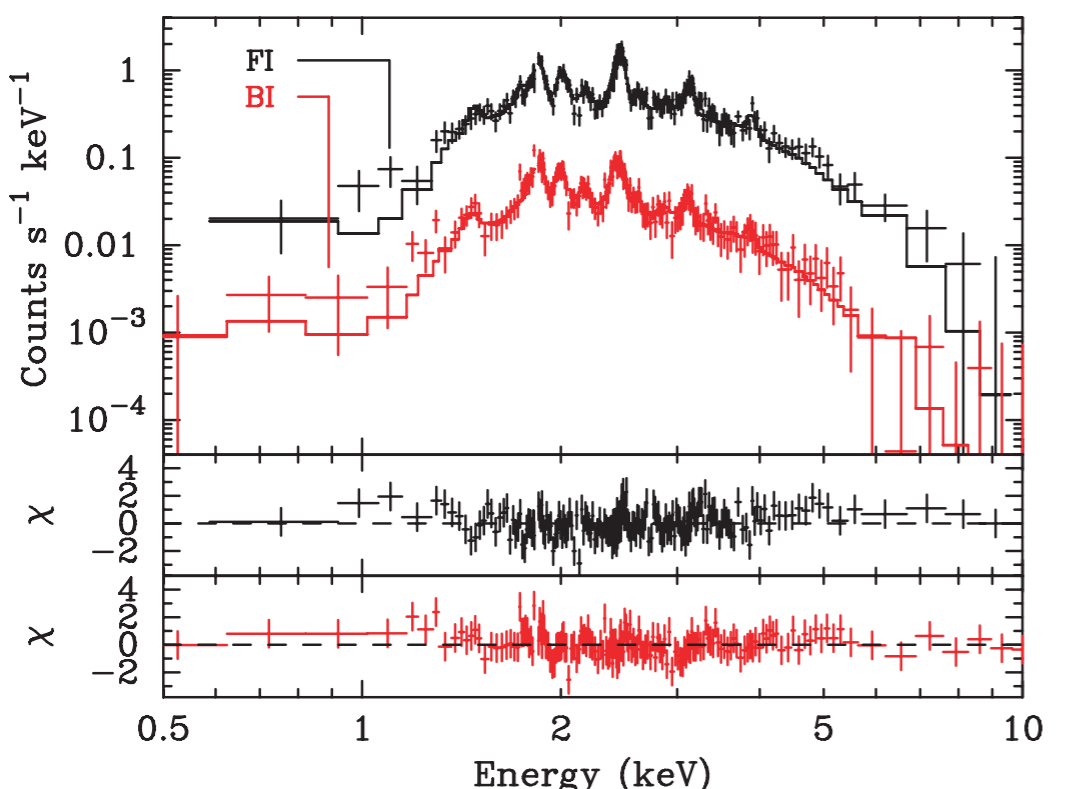
G359.12-0.05
(Nakashima+10)

G0.61+0.01
(Koyama+07)

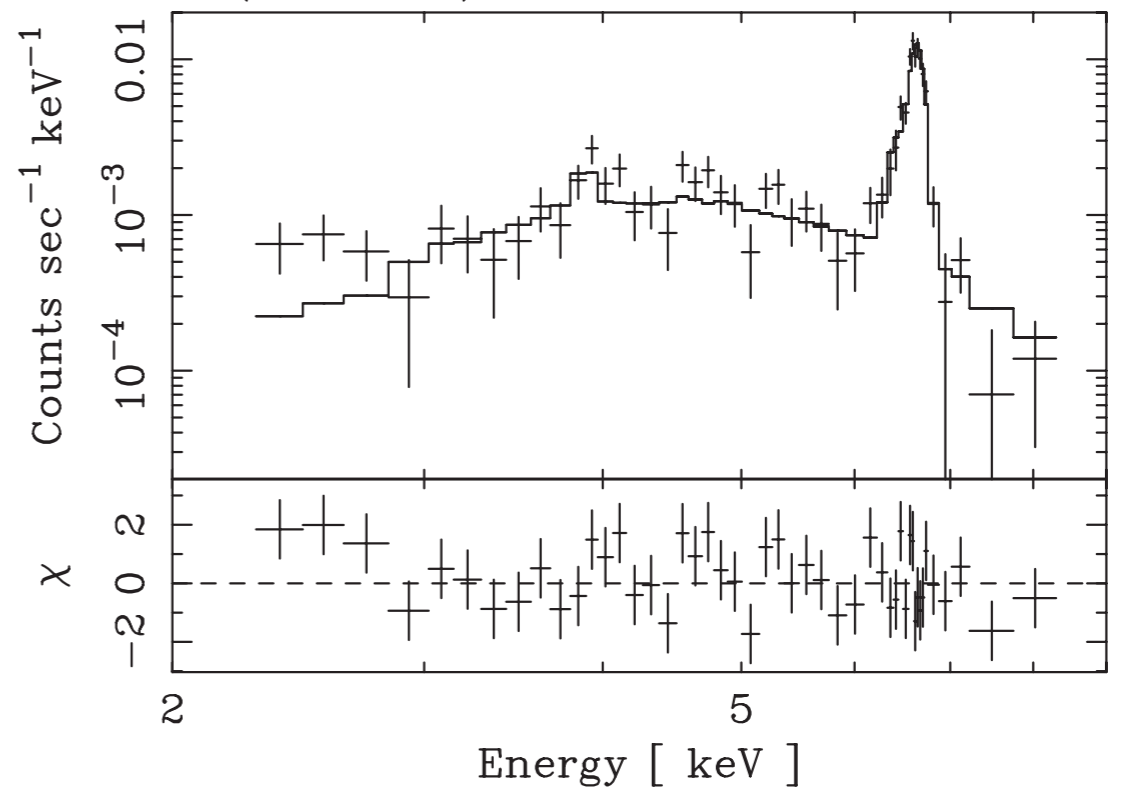
G359.79-0.26
(Mori+08)

G359.41-0.12
(Tsuru+09)

Middle-Aged (<10000 y) SNRs
kT~1 keV, Z~1



Young (<1000 y) SNR G0.61+0.01
kT= 3.2 keV, Z(Fe) = 5.1



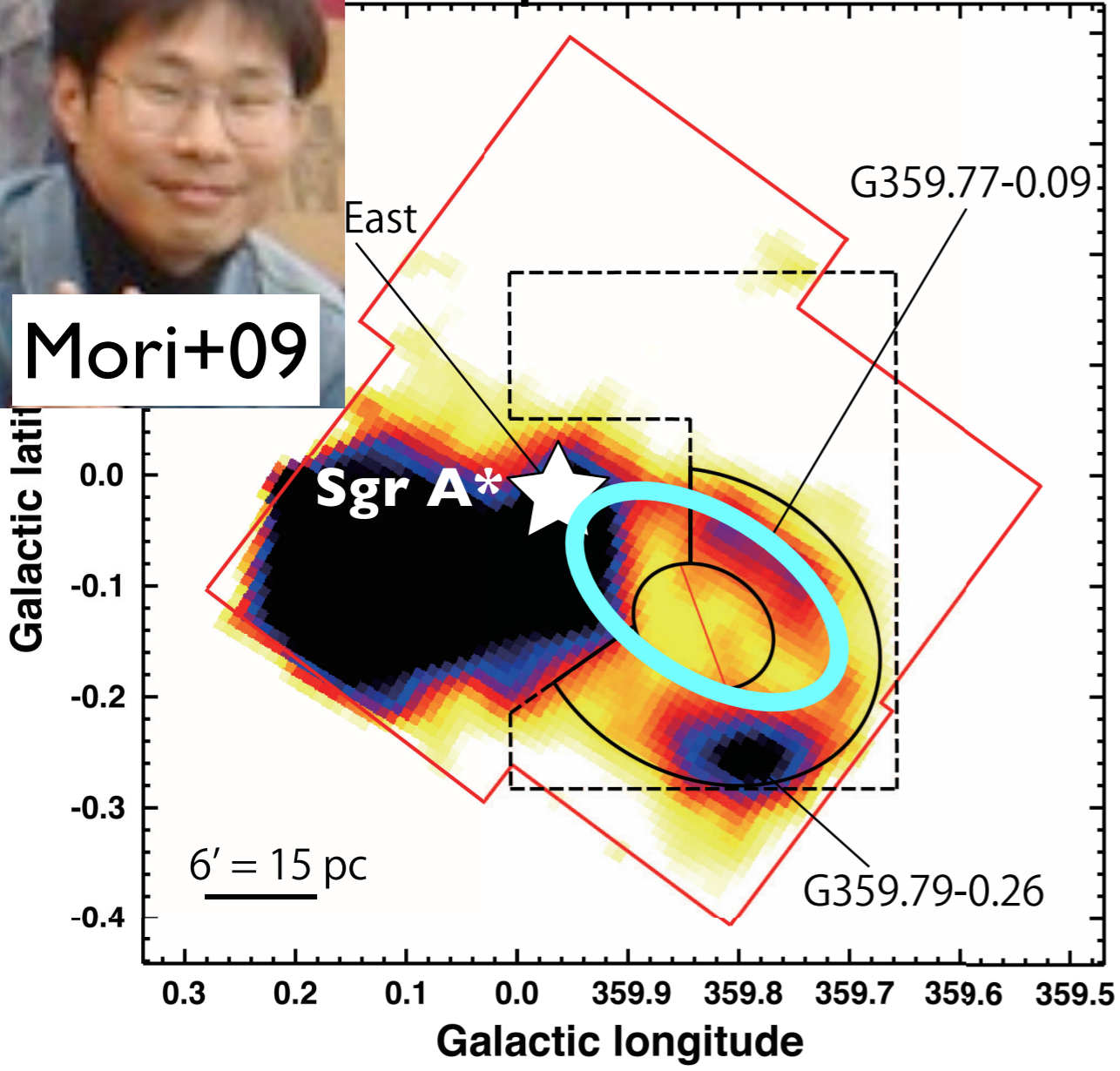


2. New Aspects of Peculiar Sources (I)



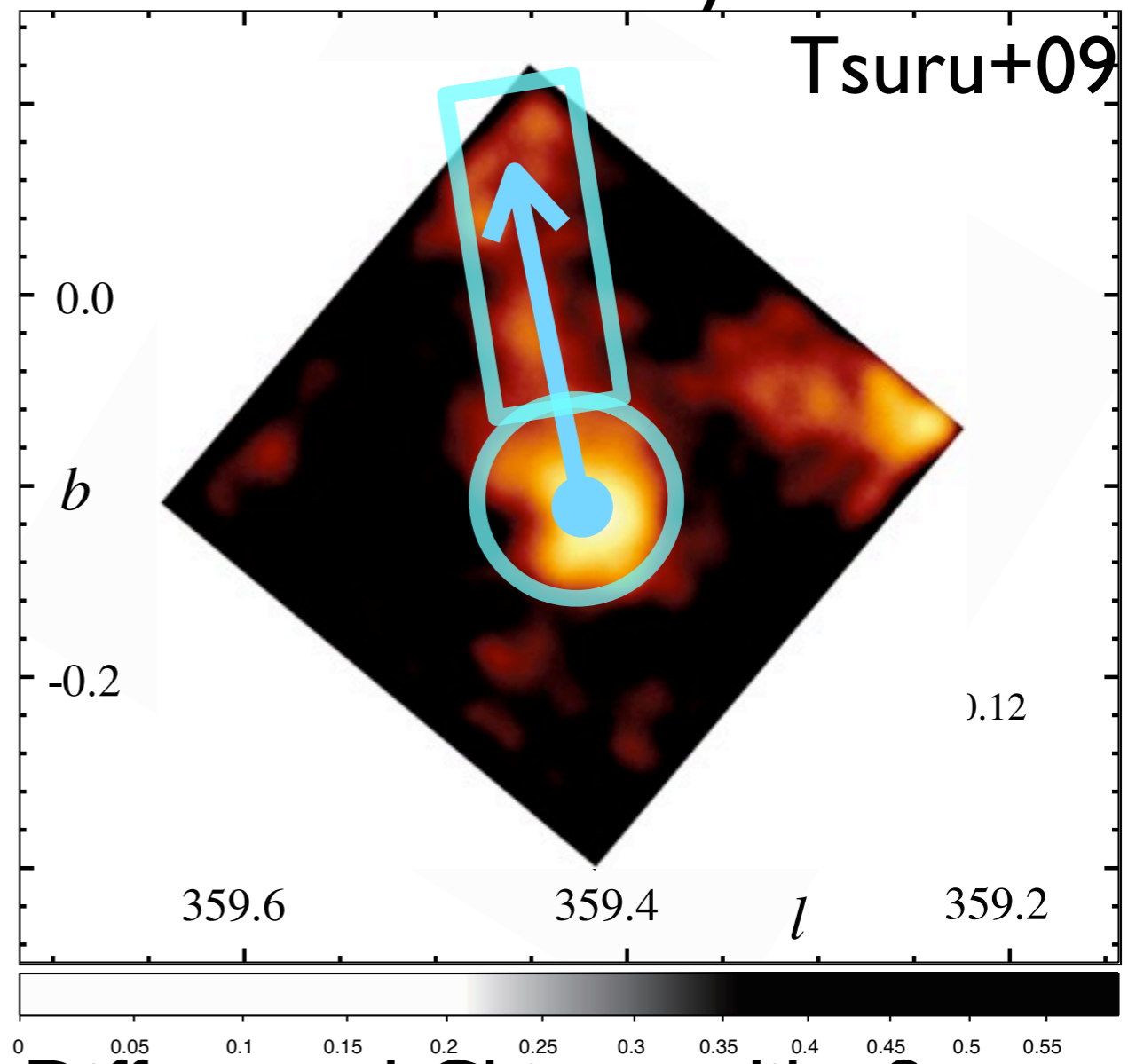
Mori+09

Super Bubble



Elliptical Ring Like Structure
 $E(\text{thermal}) = 1e51$ ergs
 Candidate for a Super Bubble

“Chimney”



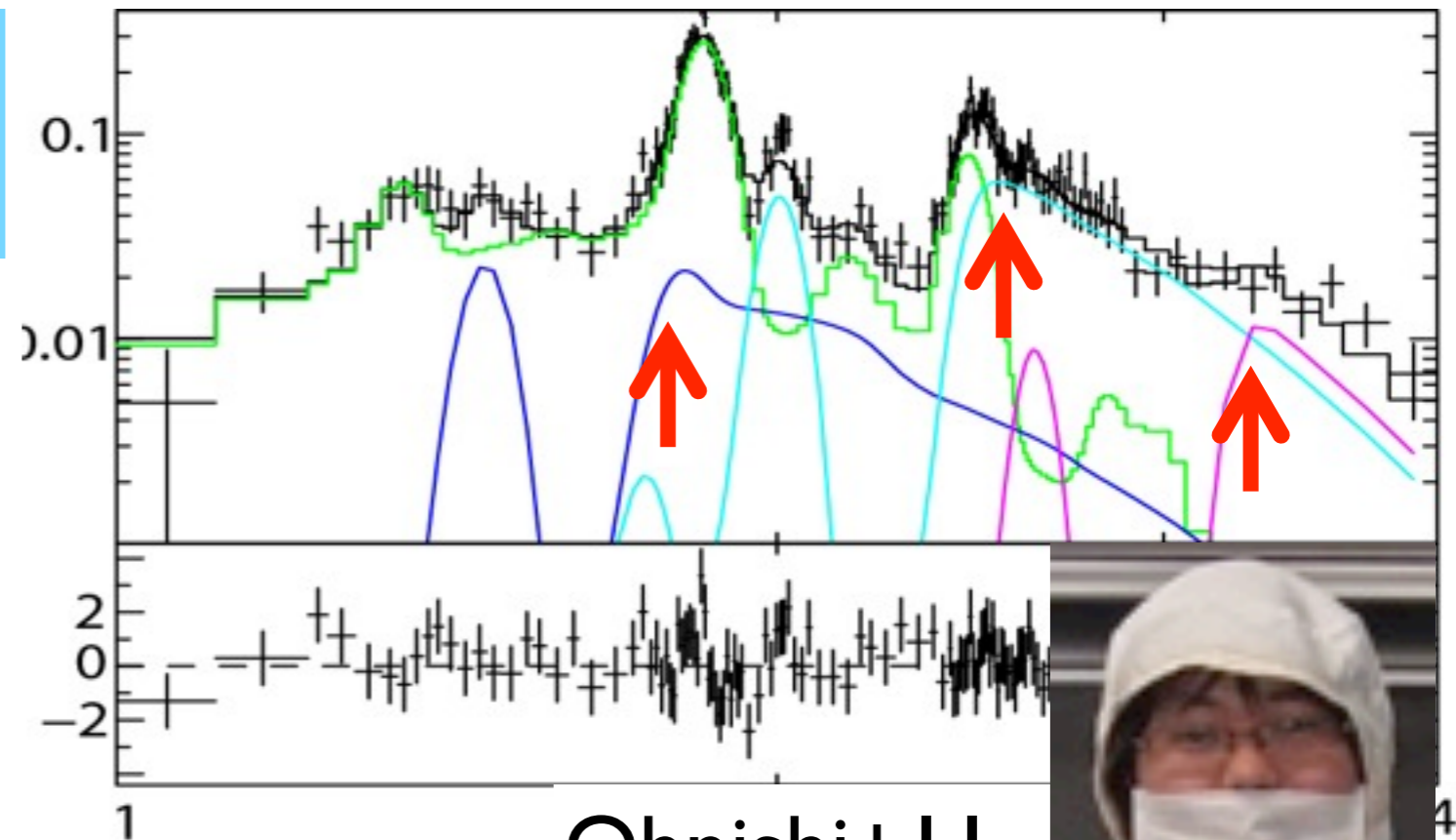
Diffuse and Chimney-like Structure
 Both have similar spectra.
 Physically Connecting.
 SNR and associated outflow

2. New Aspects of Peculiar Sources (2)

G395.1-0.5

near HESS J1745-303

Strong Mg, Si and S RRC
Extremely Over-
Ionized Plasma



Ohnishi+11

Ohnishi #27



Tornado

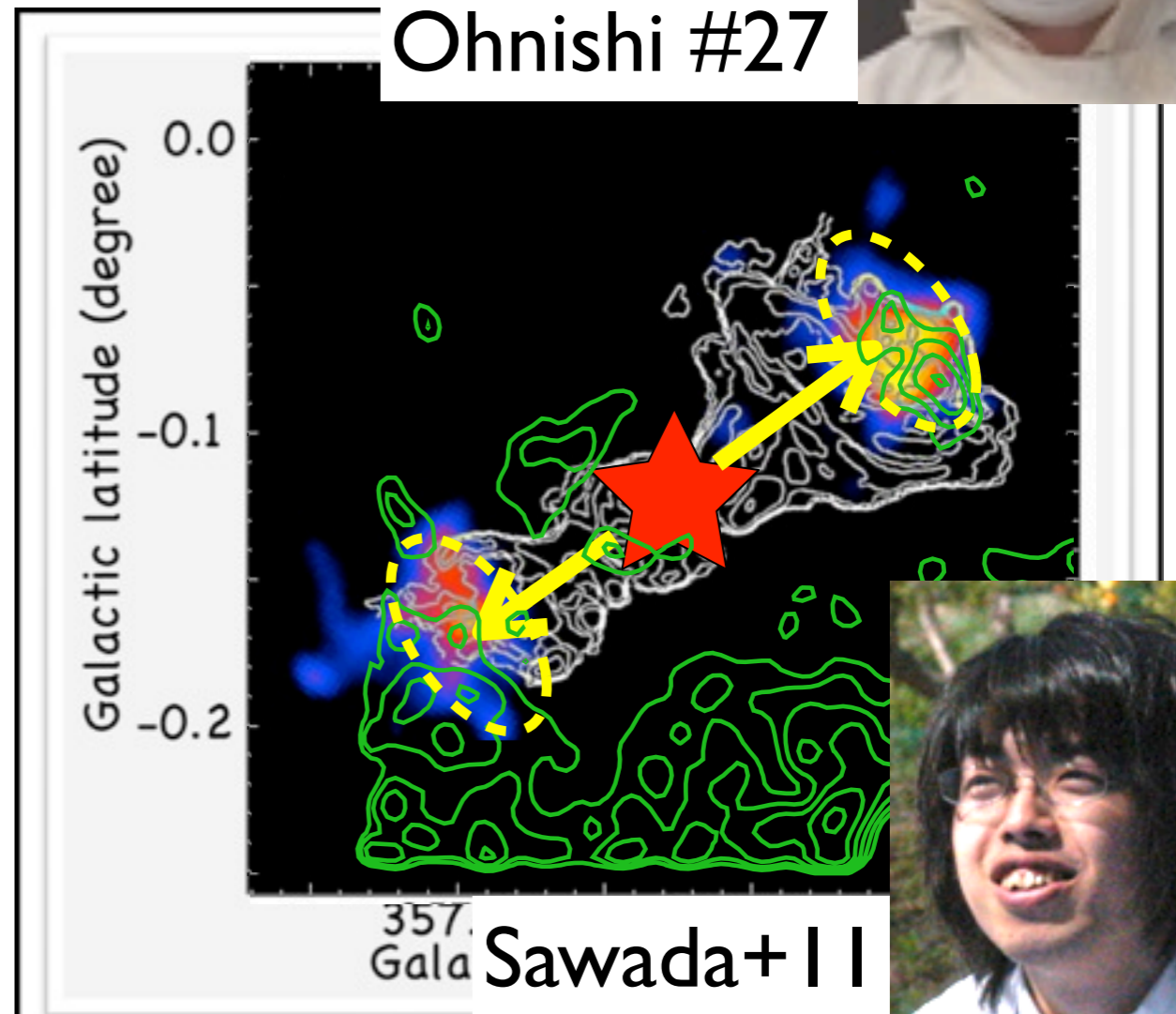
Peculiar radio source
with strong polarization

At the Head and Tail

Twin Plasma $kT = 0.6-0.7$

Molecular Clouds

Remnant of the bipolar flow
from a compact object.



Sawada+11



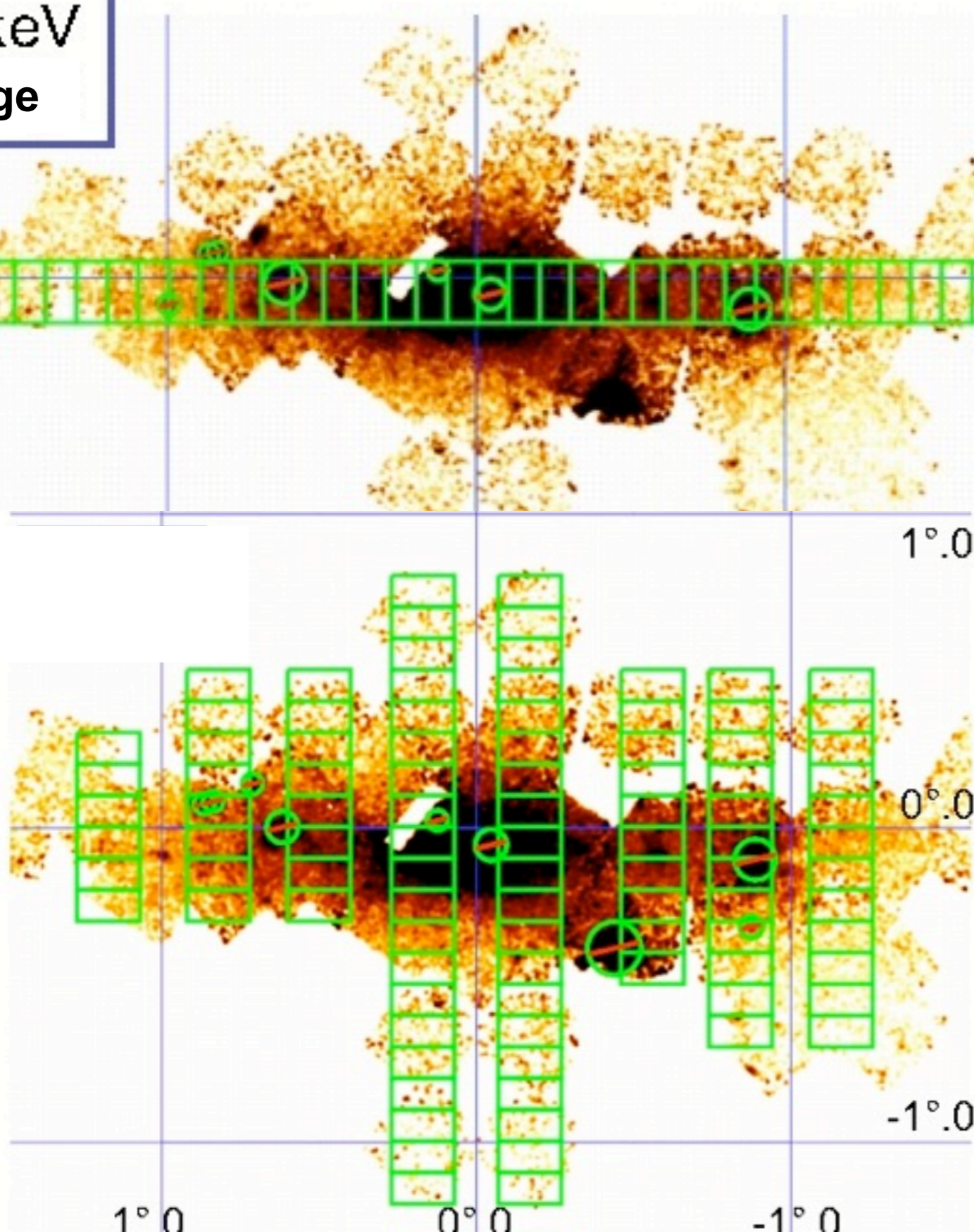
3. Fe-K Lines (6.7, 6.9 keV) Distributions

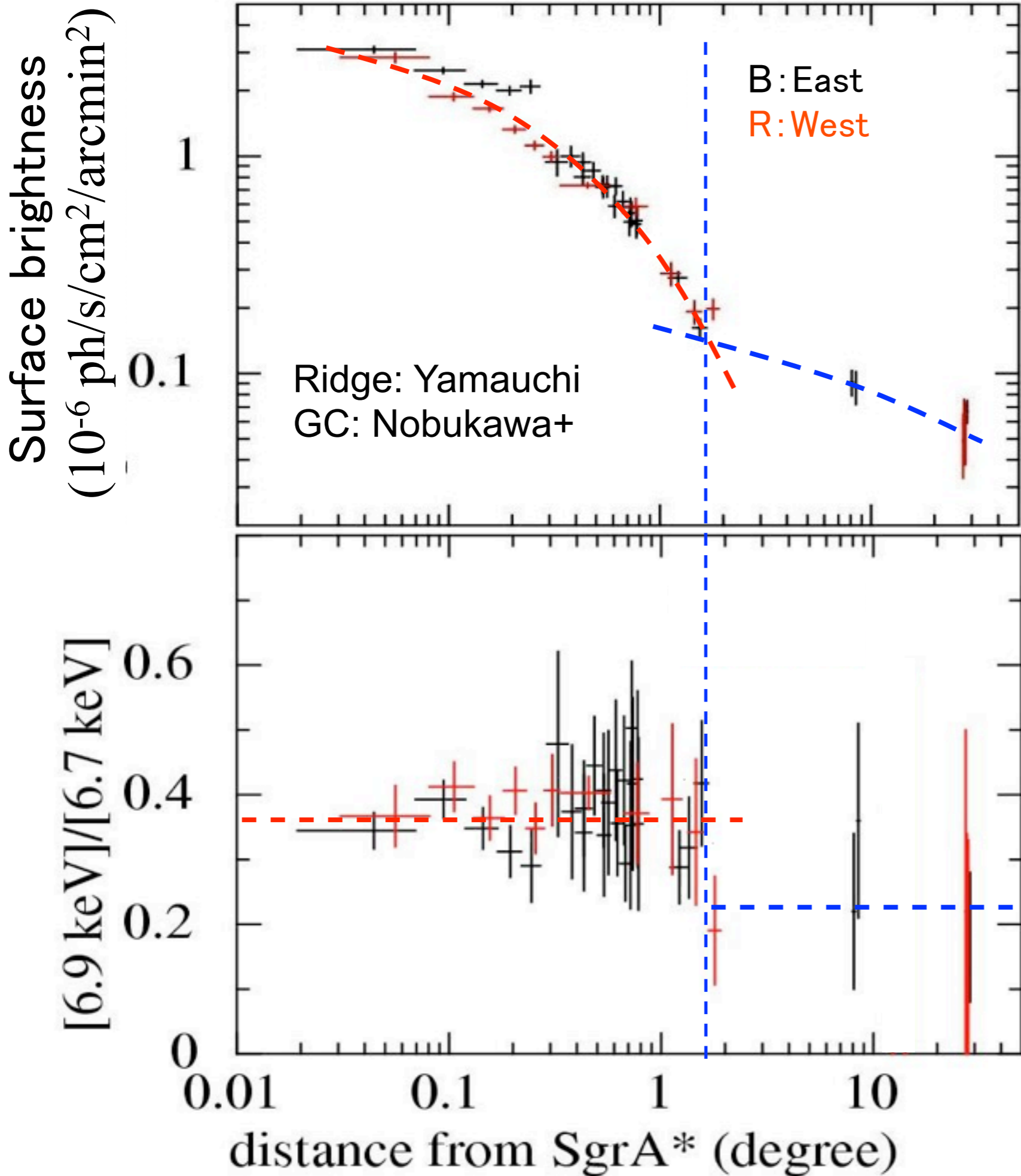
6.7 keV
Image

*Truly Diffuse or
Point Sources ?*

**Divided into small
areas and made
spectra, fit the
individual spectrum
with a power-law
+ Gaussians.**

Fluxes (F)
 $F_{6.7}$: 6.7 keV line
 $F_{6.9}$: 6.95 keV line





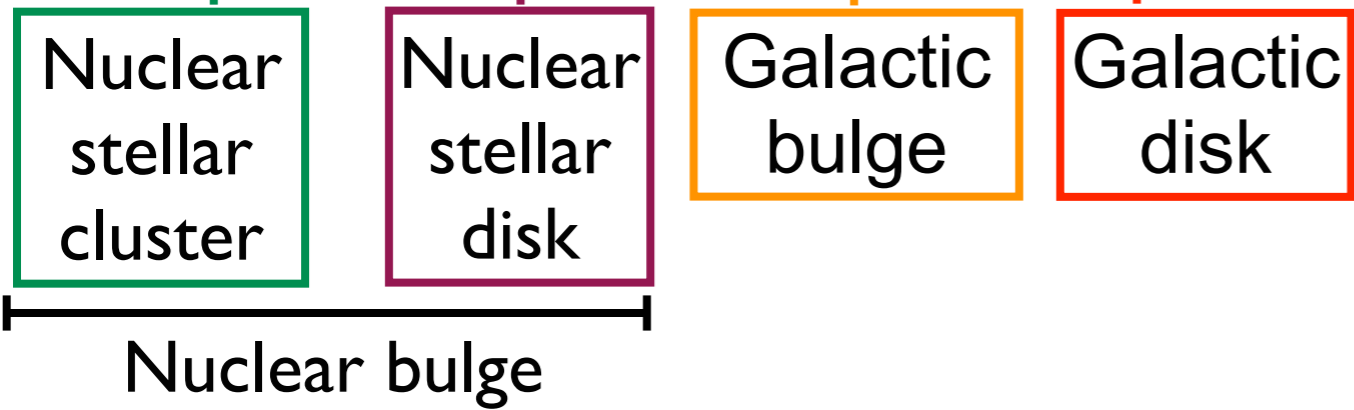
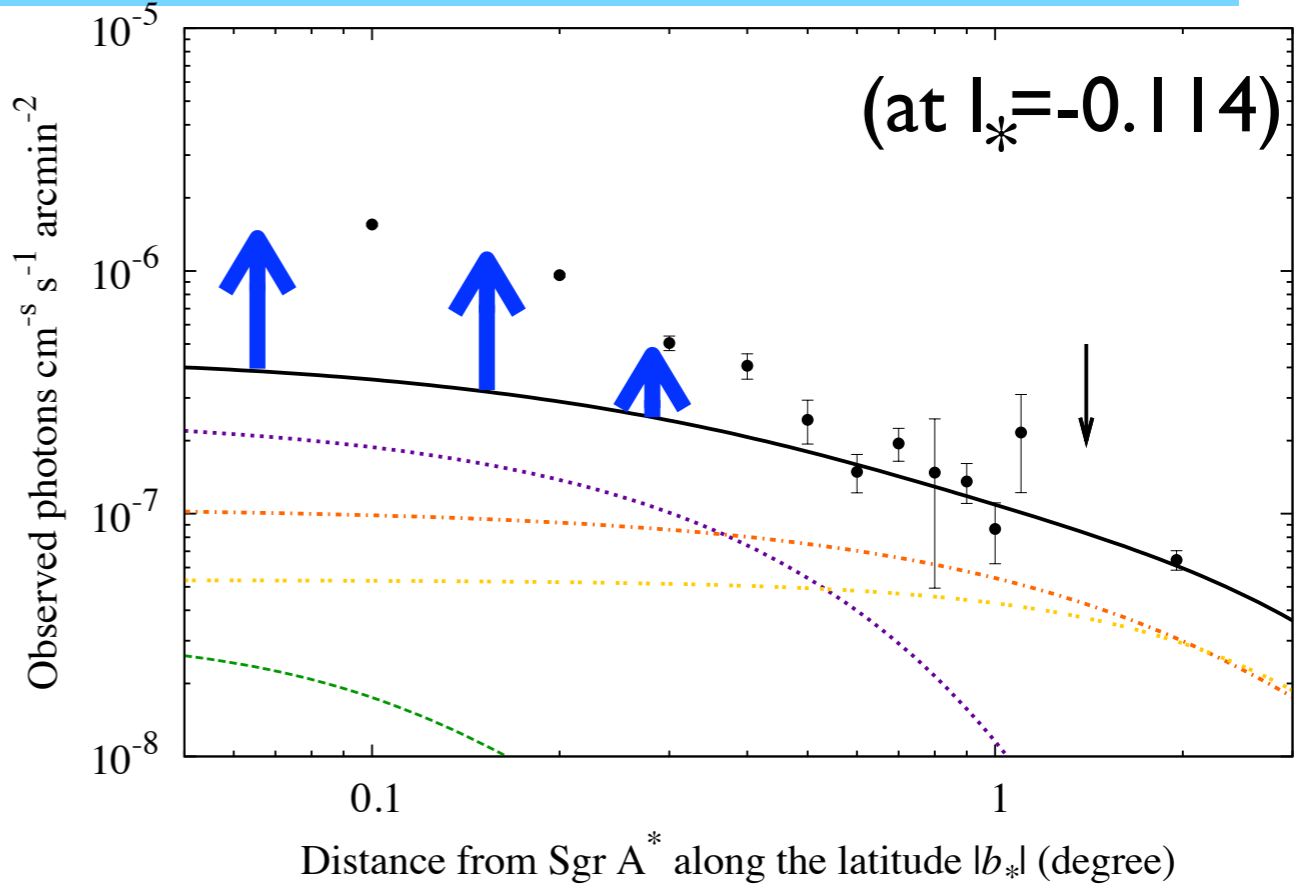
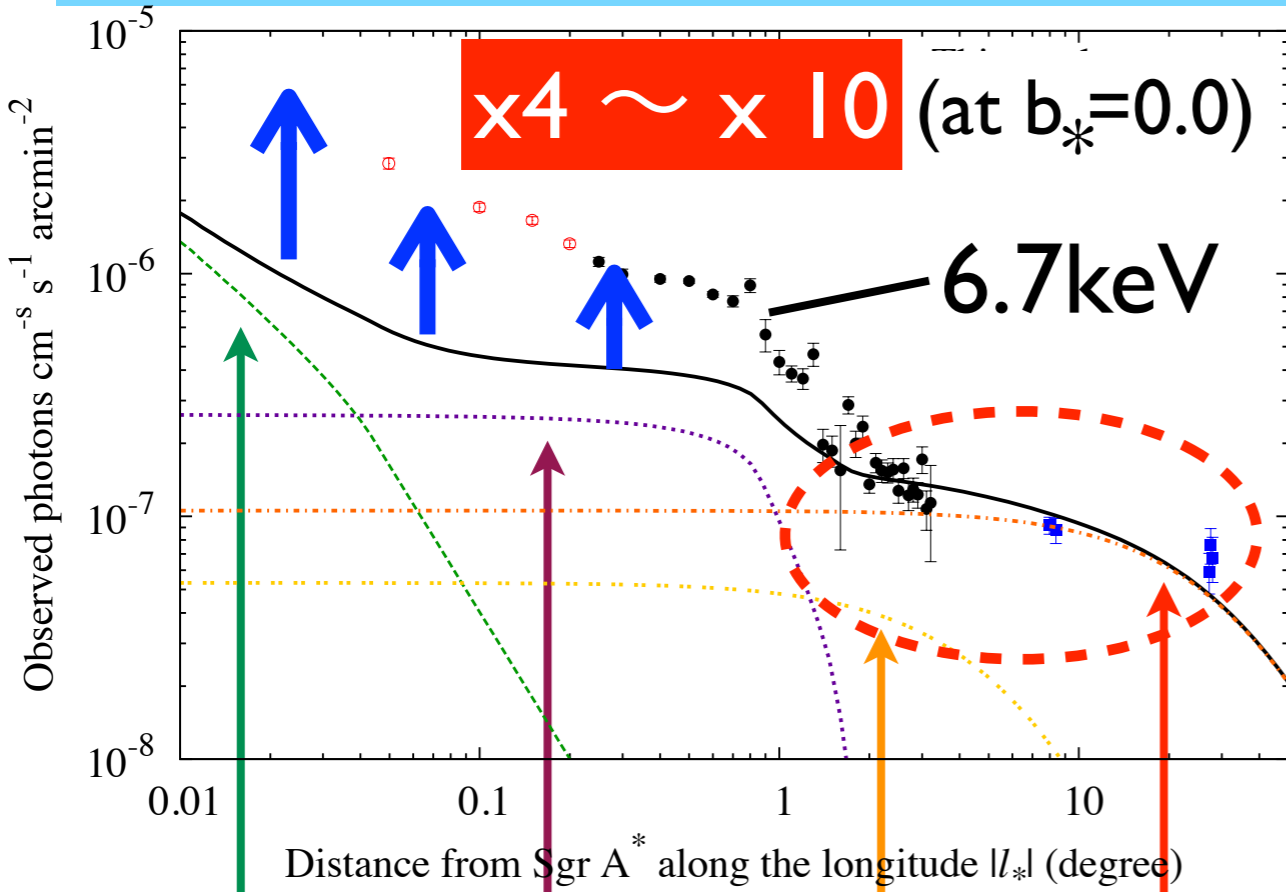
- The border between GC and GR is located at $l = 1 \sim 2 \text{ deg}$.

- The temperature of GC would be higher than GR.



Nobukawa, Hyodo+,
Yamauchi+09

6.7keV Line Profile vs Stellar Mass Distribution



A new population of point sources with a strong 6.7keV line.

or

Truly diffuse plasma

6.7keV Lines Excess at GC

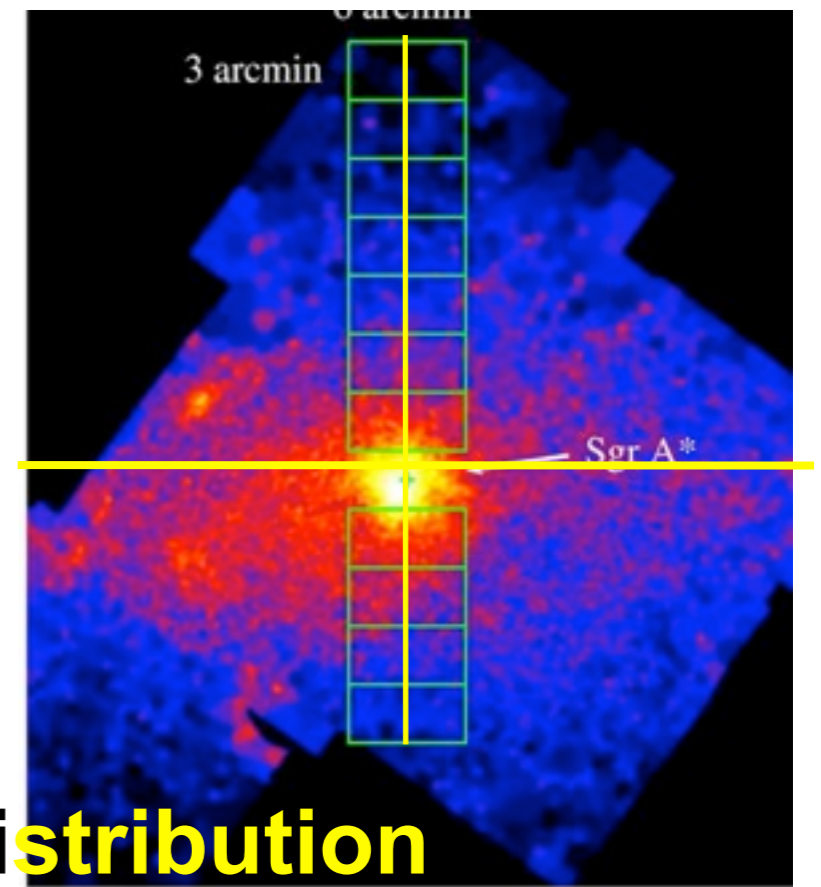
Origin of 6.7keV line in GC is different from GR

Uchiyama+11
Uchiyama #35



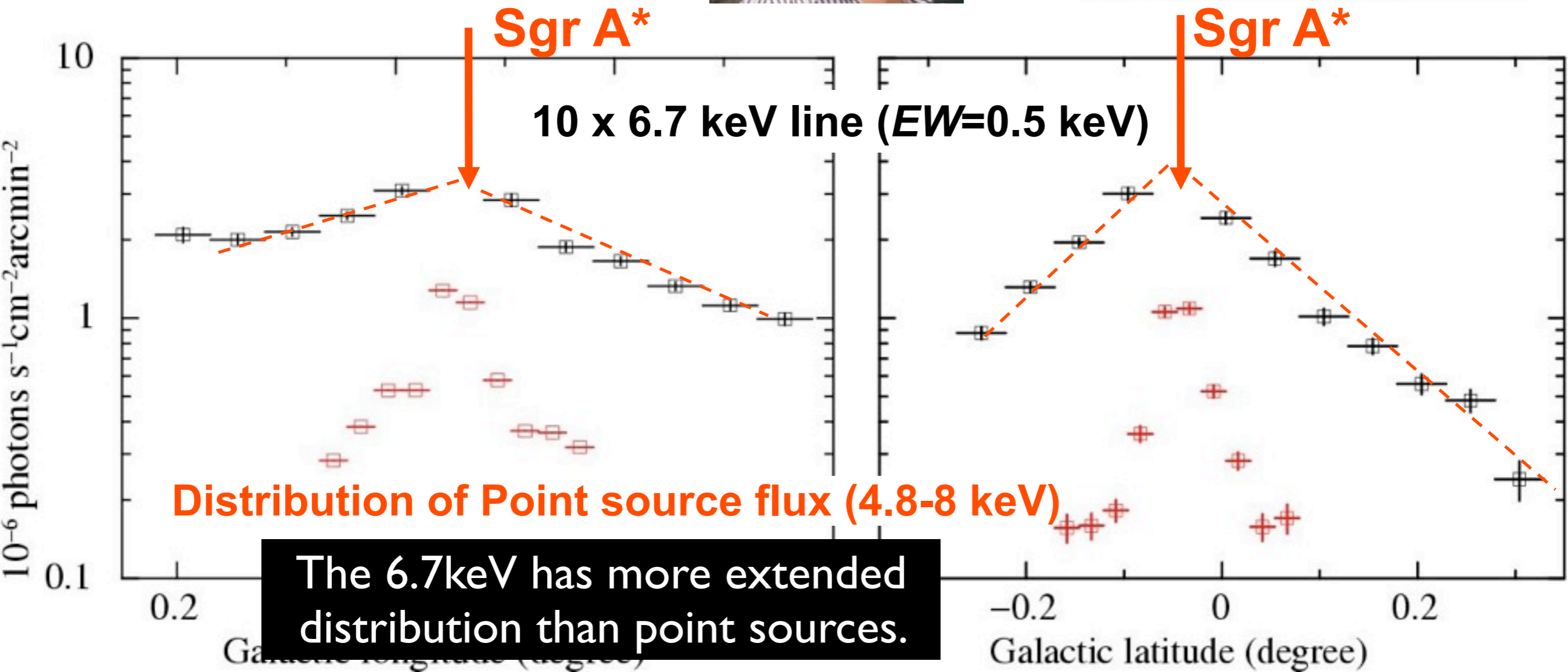
**The 6.7 keV line flux vs
Integrated point source flux
(Chandra deep exposure)
Near GC (< 0.3 deg)**

Nobukawa, Hyodo+



l-distribution

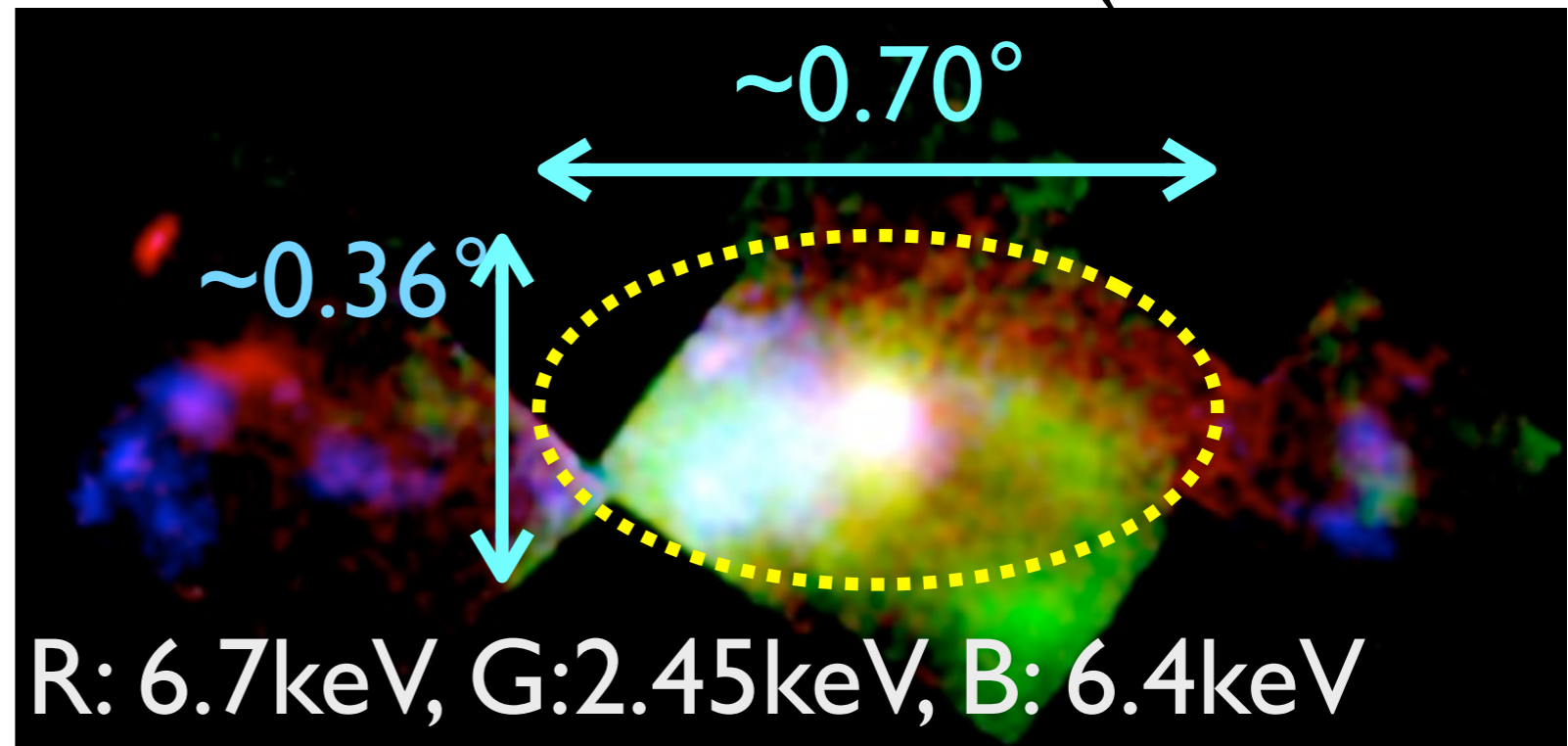
b-distribution



Plasma Parameters (assuming $Z_{\text{Fe}}=1.2$)

Tsuru+ (Suzaku2007)

- Size $\sim 50\text{pc} \times 30\text{pc}$
- $L_{2-10} \sim 2 \times 10^{36} \text{ergs/s}$
- $n_{\text{ave}} \sim 0.1 \text{cm}^{-3}$
- $n_{\text{peak}} \sim 0.4 \text{cm}^{-3}$
- $E_{\text{gas}} \sim 3 \times 10^{52} \text{ergs}$



- Escape Time scale (latitude) $\tau_{\text{esc}} = \text{Size}/C_s = 2 \times 10^4 \text{yr}$
- Heating Rate = $E_{\text{gas}}/\tau_{\text{esc}} \sim 5 \times 10^{40} \text{ergs/s} \sim 10^{-3} \text{SN yr}^{-1}$

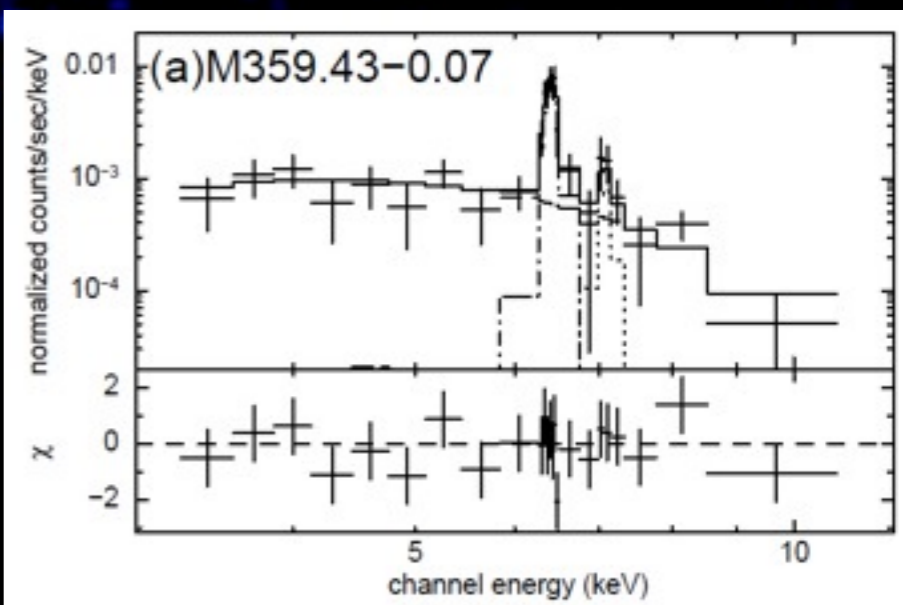
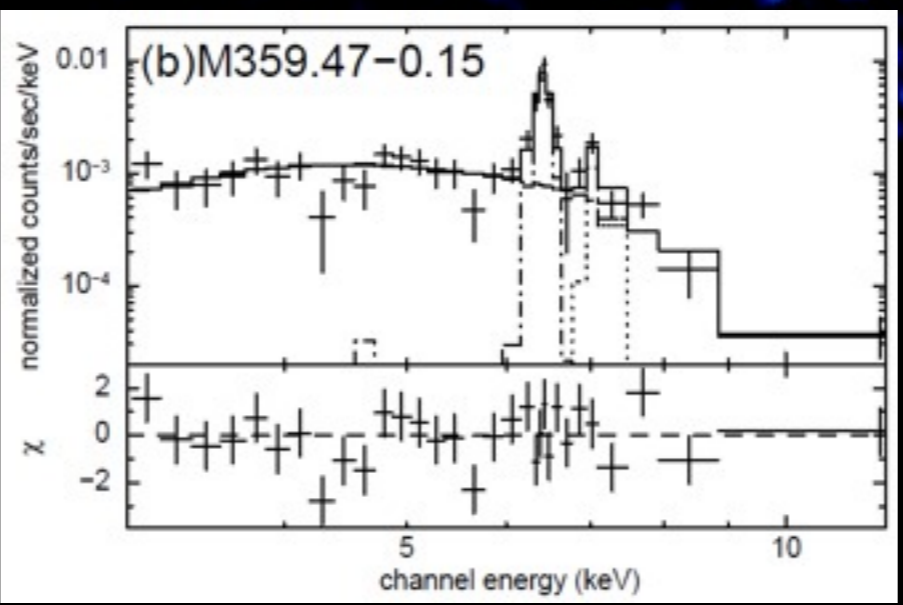
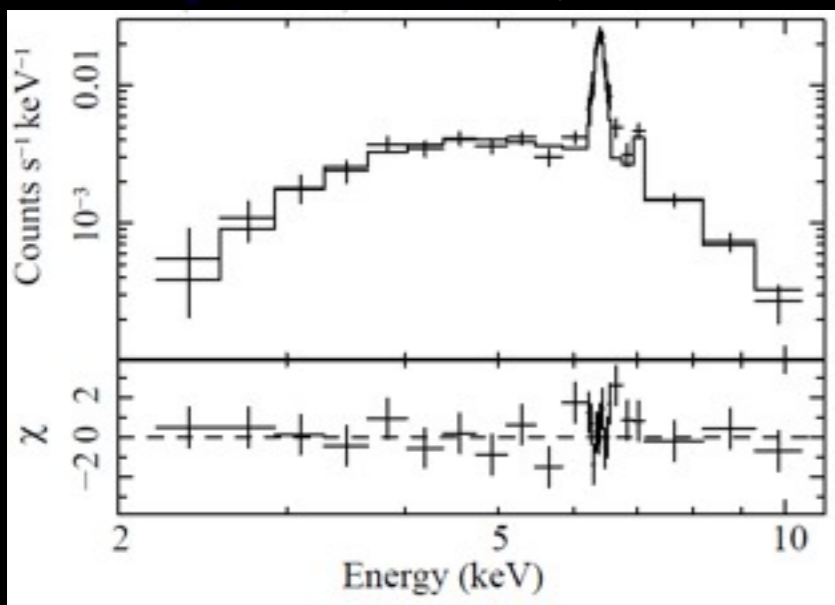
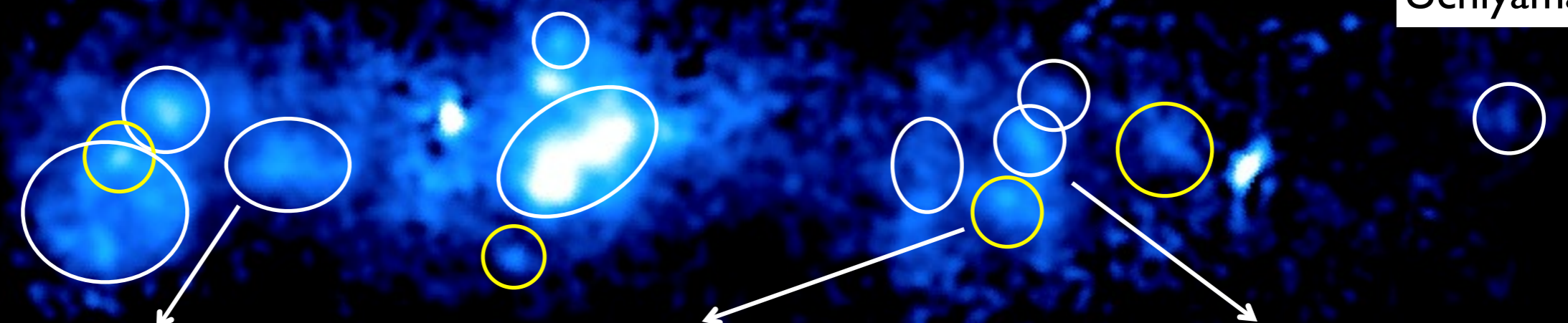
Much higher than the current activity of Sgr A* and $\sim 10^{-5} \text{SN yr}^{-1}$ expected from the stellar mass in this region.

- Plasma is in the ionization equilibrium or not ?

4. 6.4 keV clumps : New and Revisit



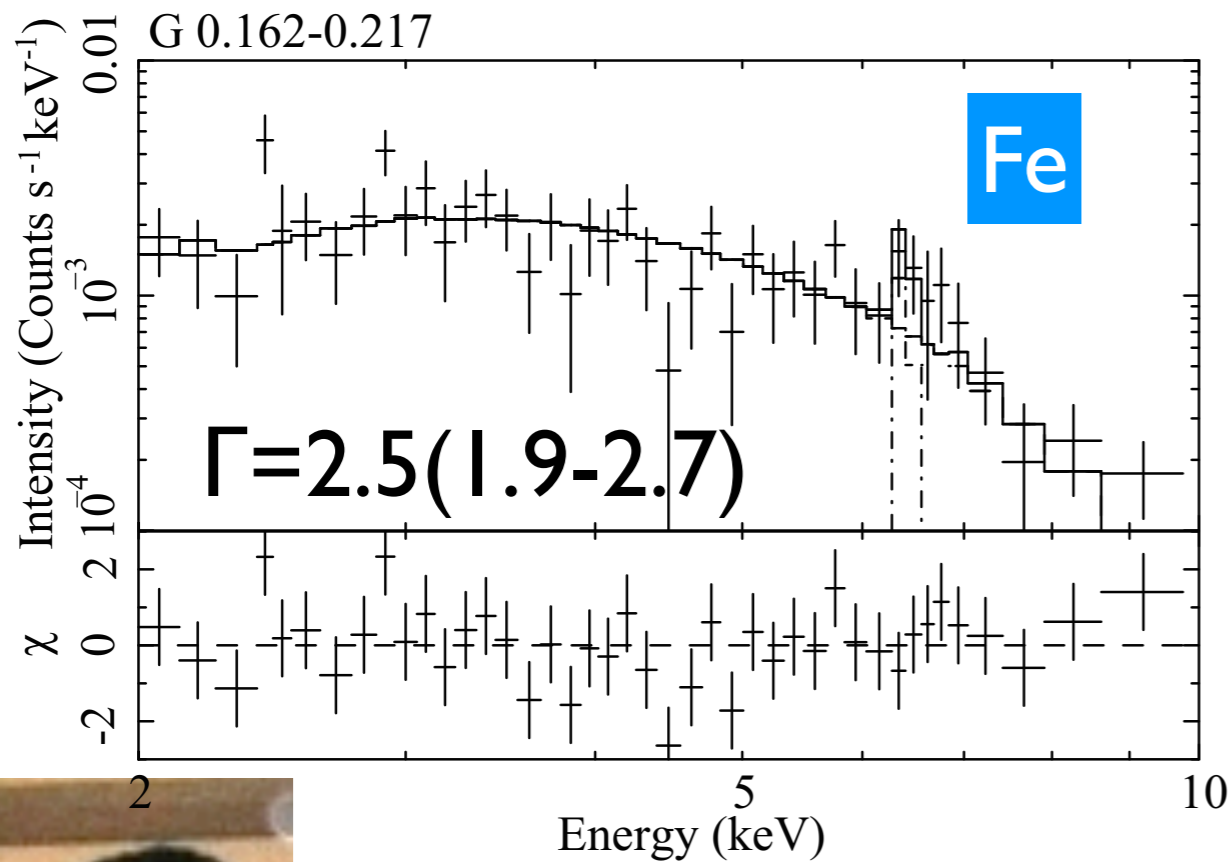
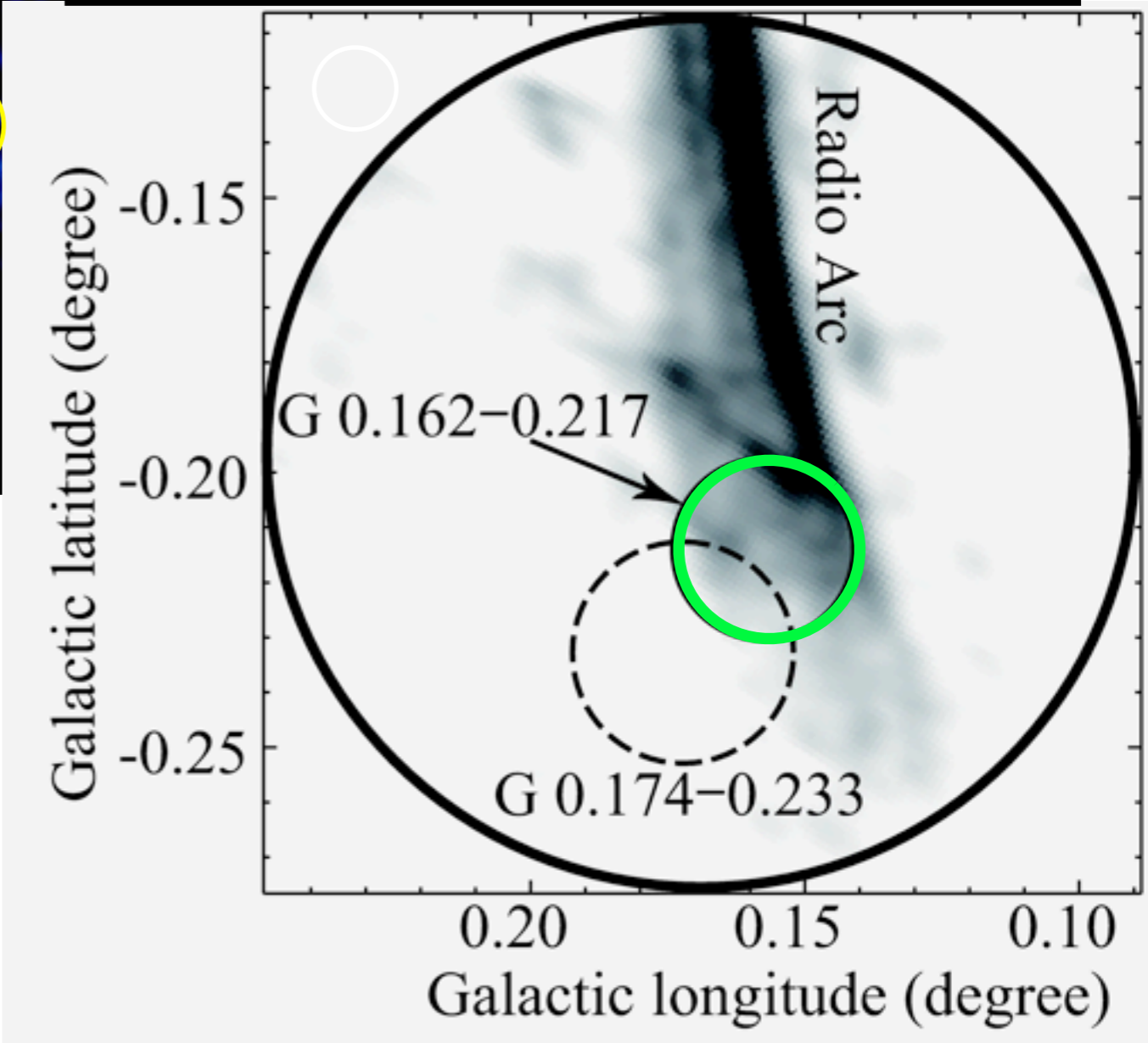
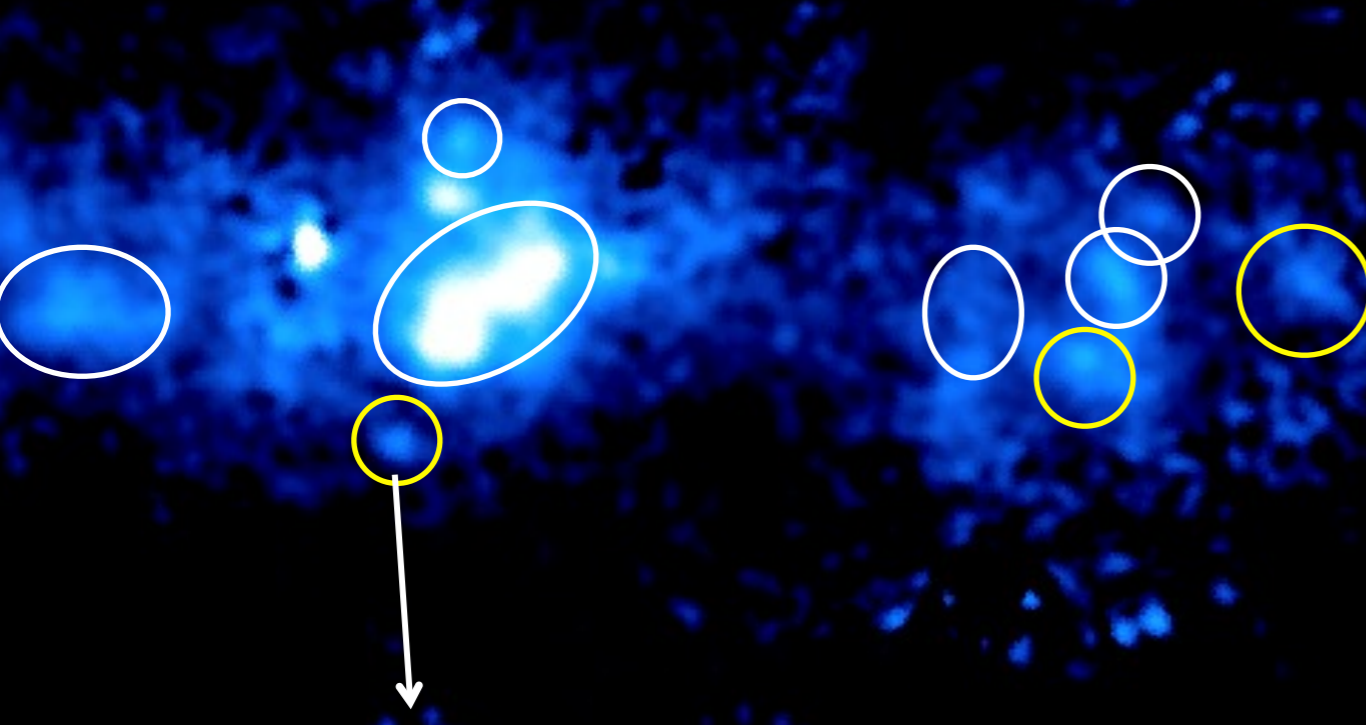
Inui+09 | Nobukawa+ | Hyodo+08 | Takigawa+ | Nakajima+09 | Jakashima+11 | Ryu prep | Uchiyama+11 | Uchiyama #35



E.W : 1–2keV
K-edge : 2–10 x 10²³ cm⁻²

X-ray reflection is more likely.

4.735GHz (radio) image



Since Radio Arc is a site of relativistic electrons, it may also include Low Energy Cosmic Ray electrons (LECRE).

$$EW(\text{Fe}) \sim 0.20 \text{ keV}$$

→ Electron bombardment is conceivable !

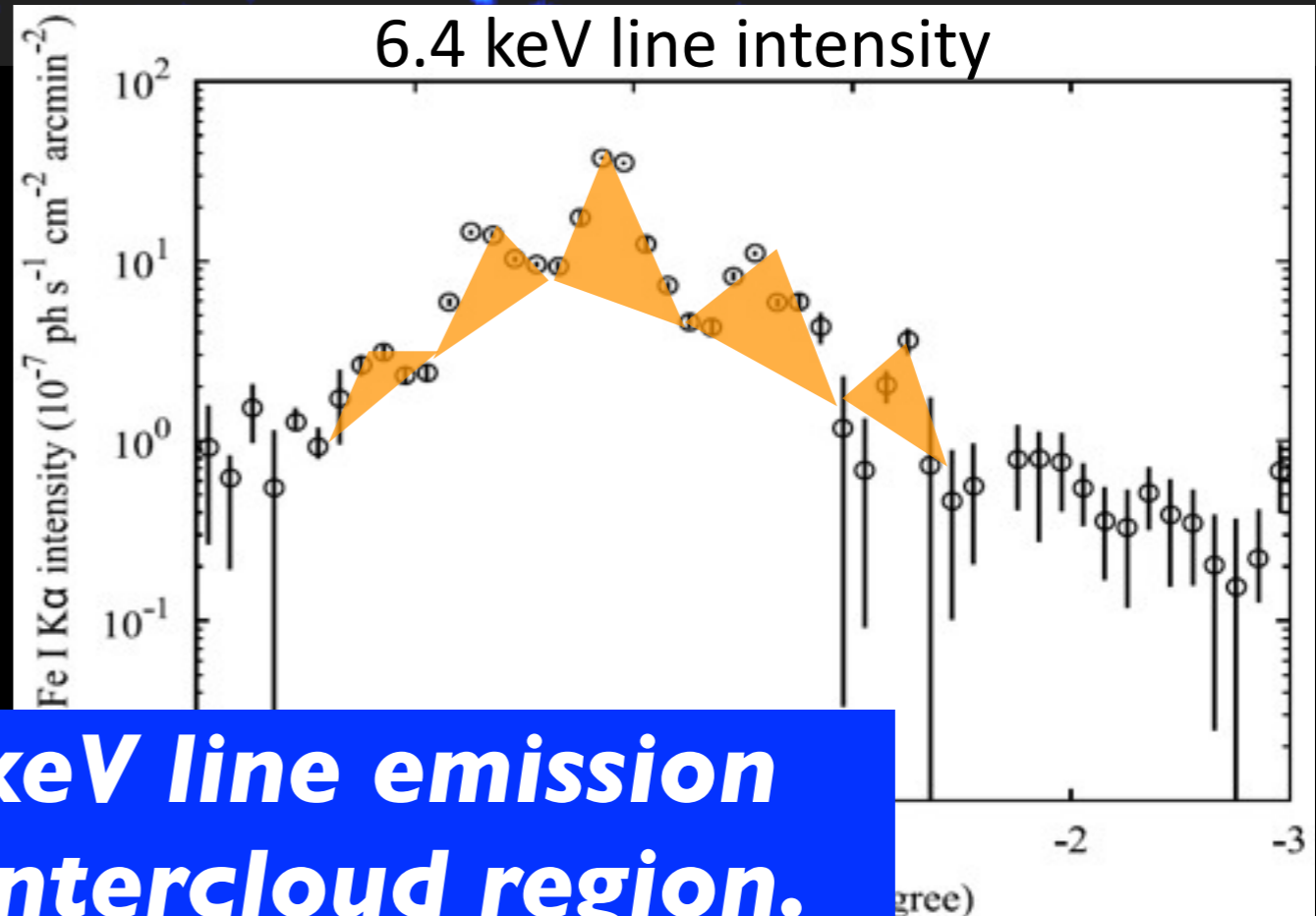
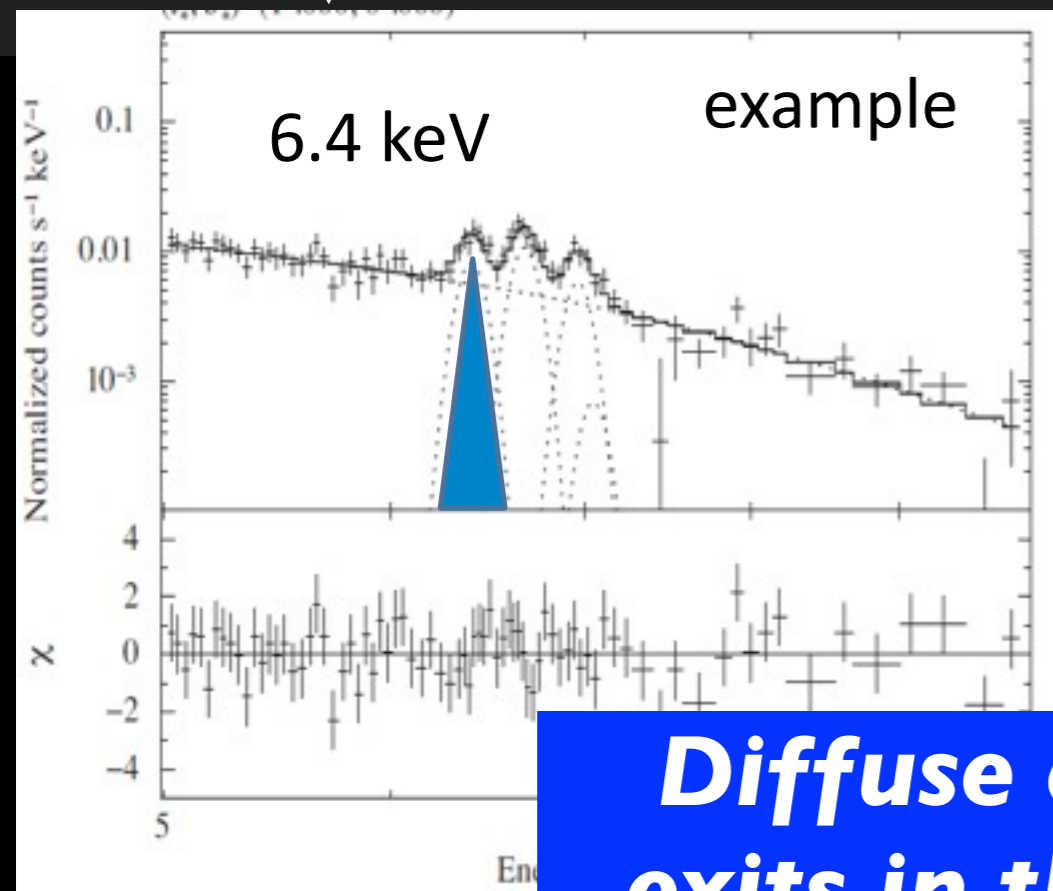
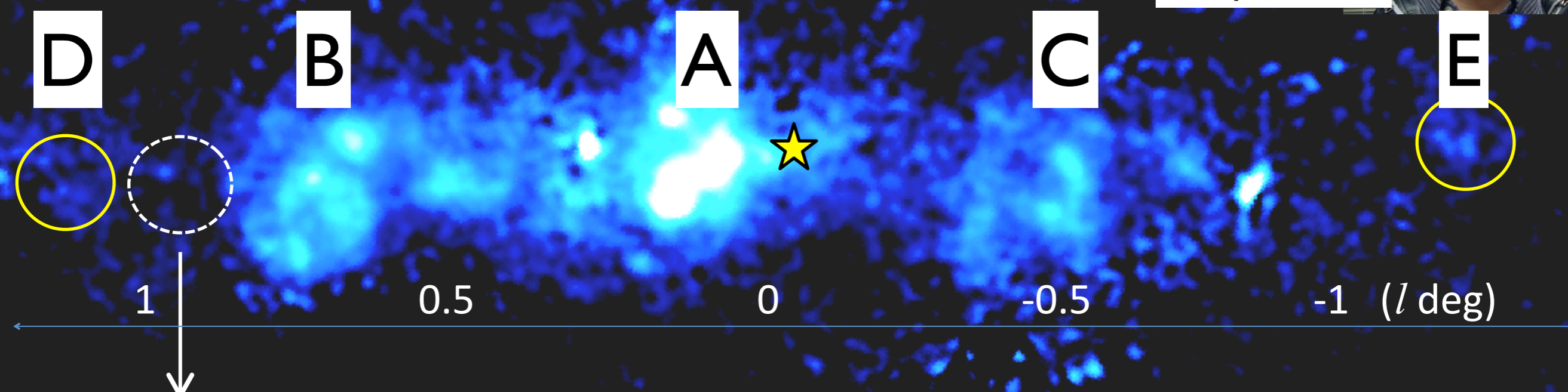


Fukuoka+09

5. Discovery of diffuse 6.4keV emission from the intercloud region.



Uchiyama+11
Uchiyama #35



Diffuse 6.4keV line emission exists in the intercloud region.



Summary of My Talk



- 6 Middle-Aged and 1 young SNR candidates
- Discovered a Super bubble, “Chimney”, Strong RRC of G359.1-0.5 and Diffuse Thermal Emission of Tornado
- Origin of He-Fe-K α in the GC is different from GR
- Discovered or Revisited 12 XRNe
- Discovery of a 6.4keV clump due to Electron bombardment.
- Discovery of diffuse 6.4keV emission from the intercloud region.

The data are open. A lot of (new) themes can be found. Please join us and explore new sciences in the GC region.



Thank you.

The data is open. A lot of (new) themes.
Please join us and discover new science !