

**X-ray Study of
3-D View of the Galactic Center Region
and
1000-yr Activity History of Sagittarius A***

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on behalf of the Suzaku GC team.**

Observation of the GC region with Suzaku

2

1 deg



R: 0.5-2.0keV
G: 2.0-5.0keV
B: 5.0-8.0keV

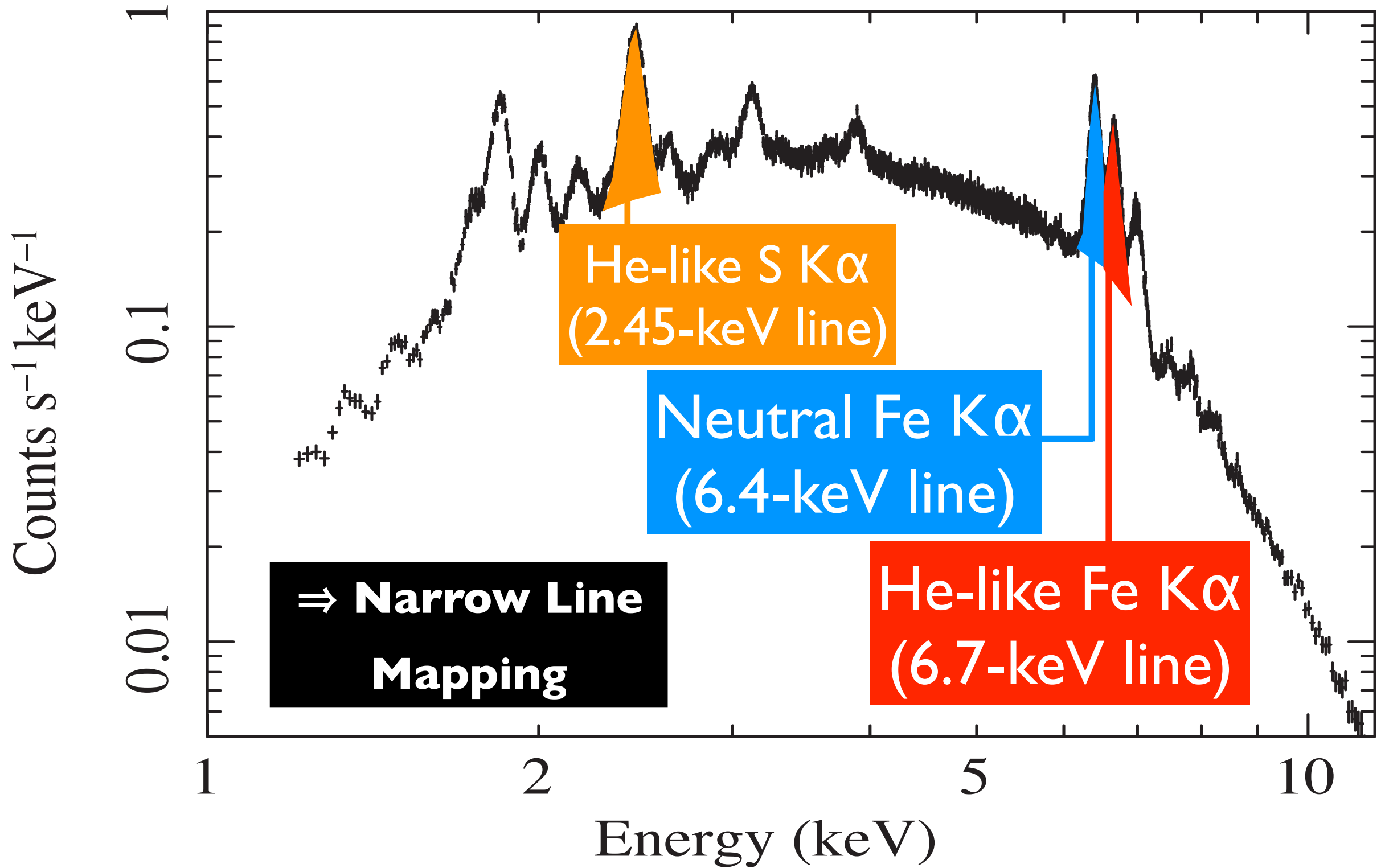
Suzaku is the best observatory to observe “diffuse” emission from the Galactic center region.

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

**204 pointings, 5.96 Msec
SWG, AO, LP, KP x2 ($|l| < 3.5^\circ$, $|b| < 5^\circ$)**

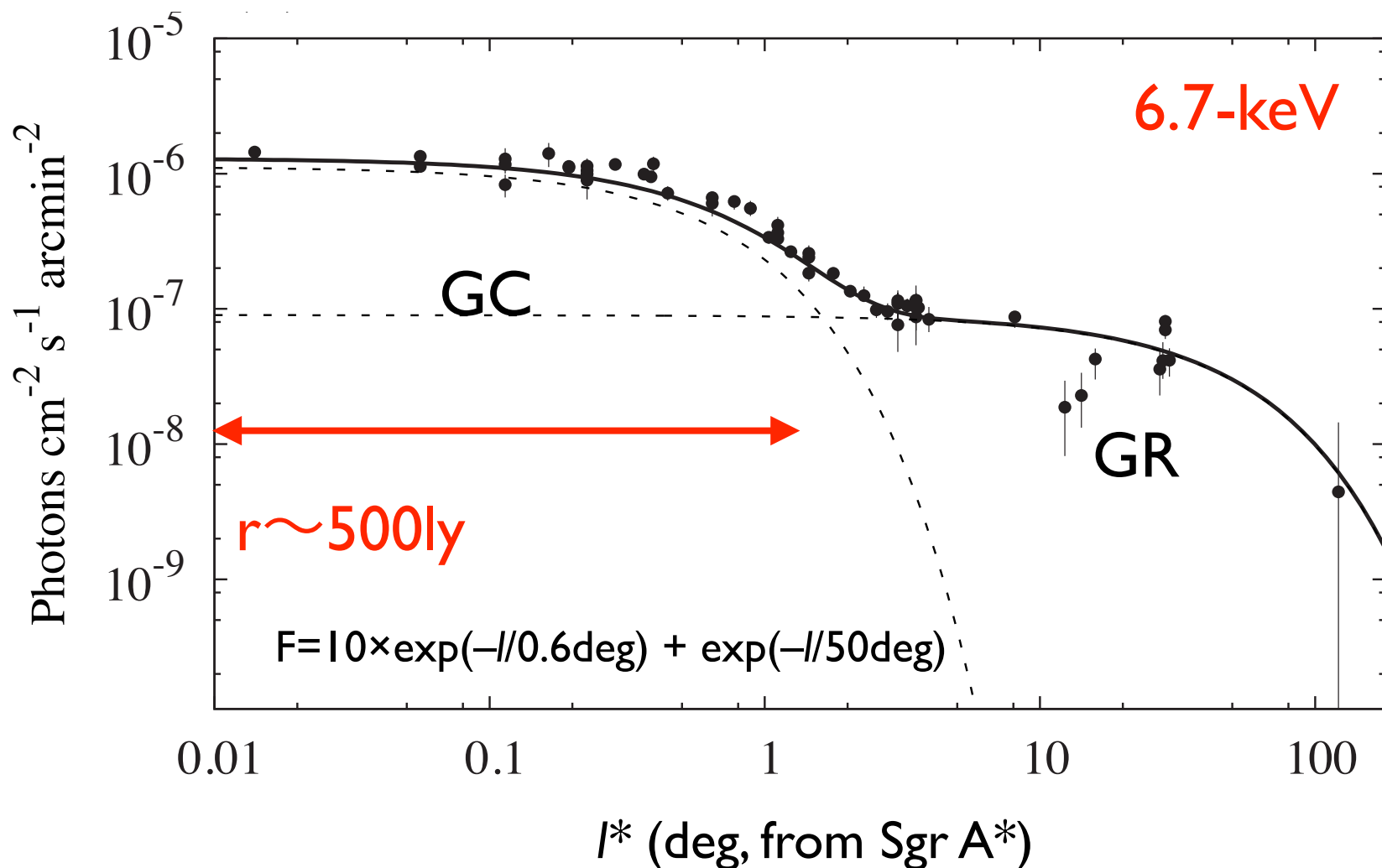
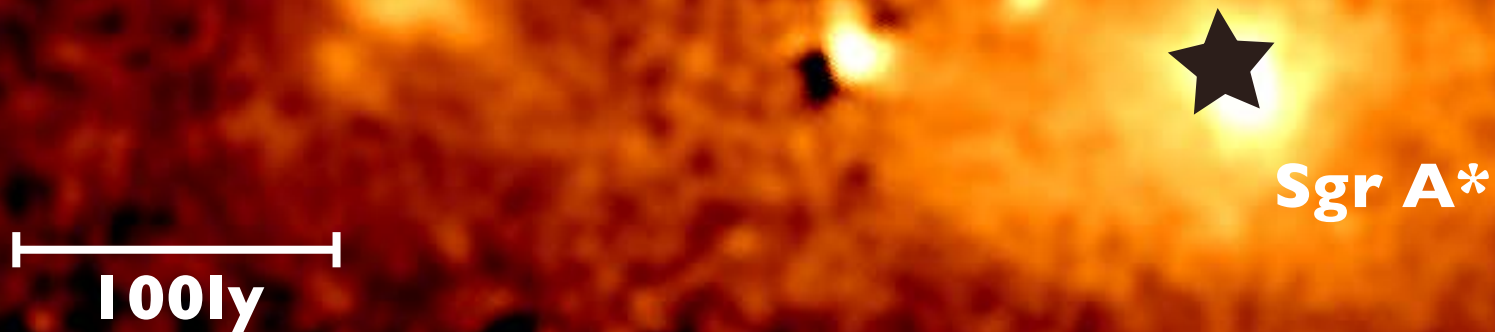
**36 refereed papers,
7 Doctor Theses.**

Suzaku Spectrum of the GC region



6.7-keV Line Image (He-like Fe $K\alpha$)

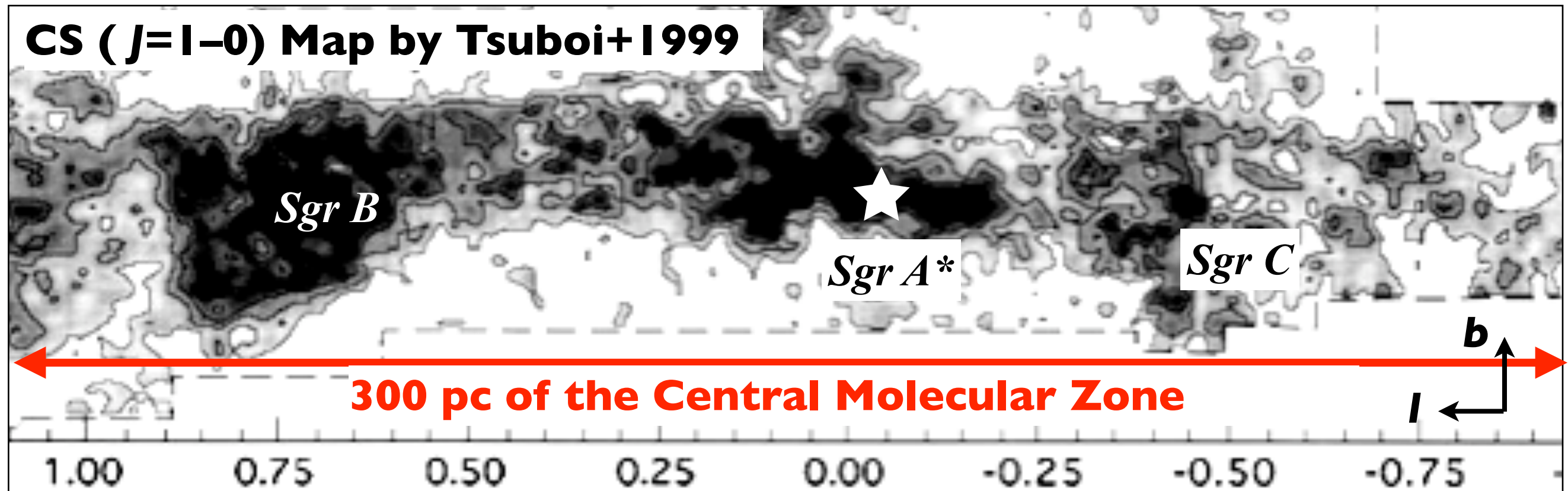
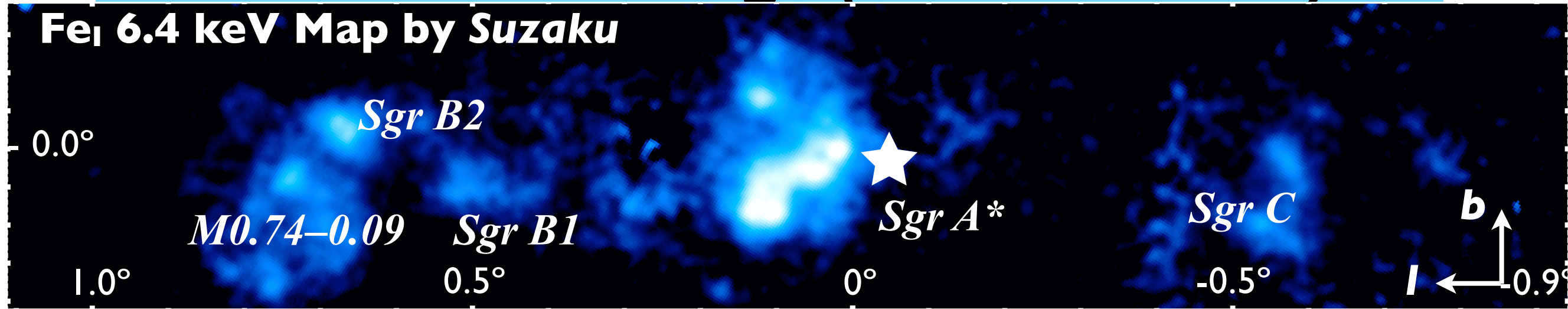
6.7keV (Continuum subtracted)



Uchiyama+11, +12

- Thermal Plasmas smoothly distribute in the GC region.
- The origin is still under debate.
 - Truly diffuse plasma filling in the GC region.
 - Or, collection of faint unresolved point sources.

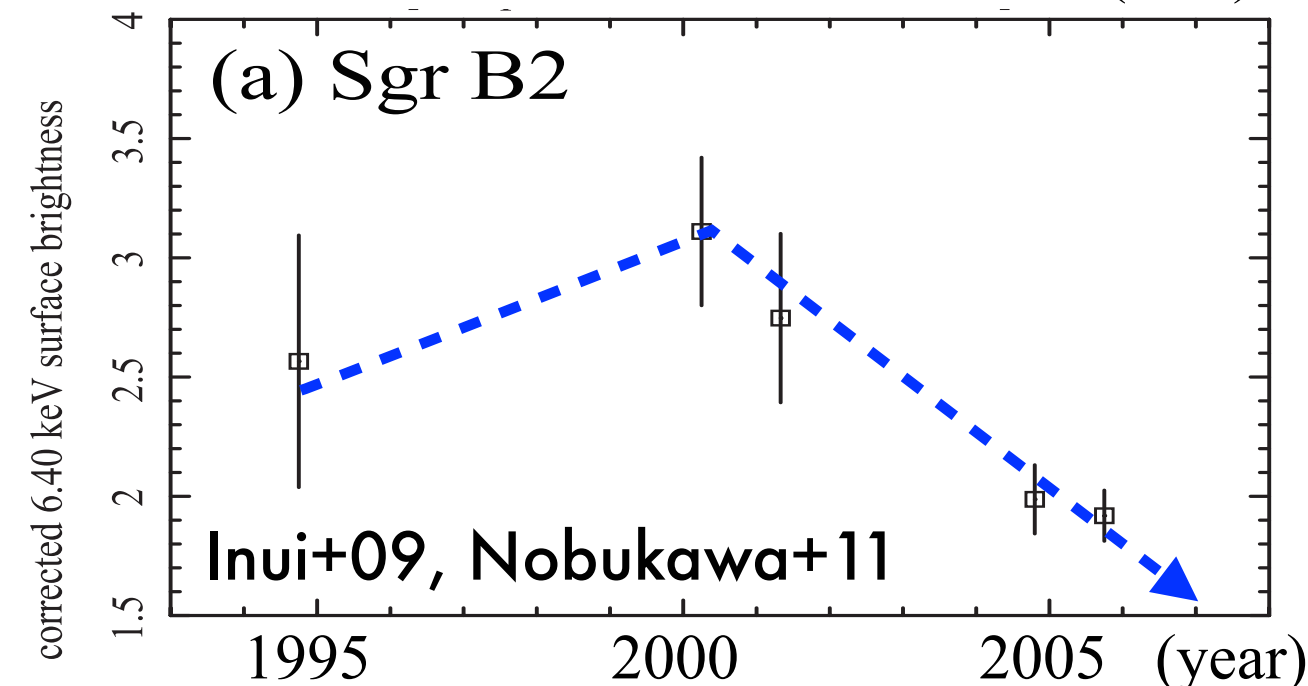
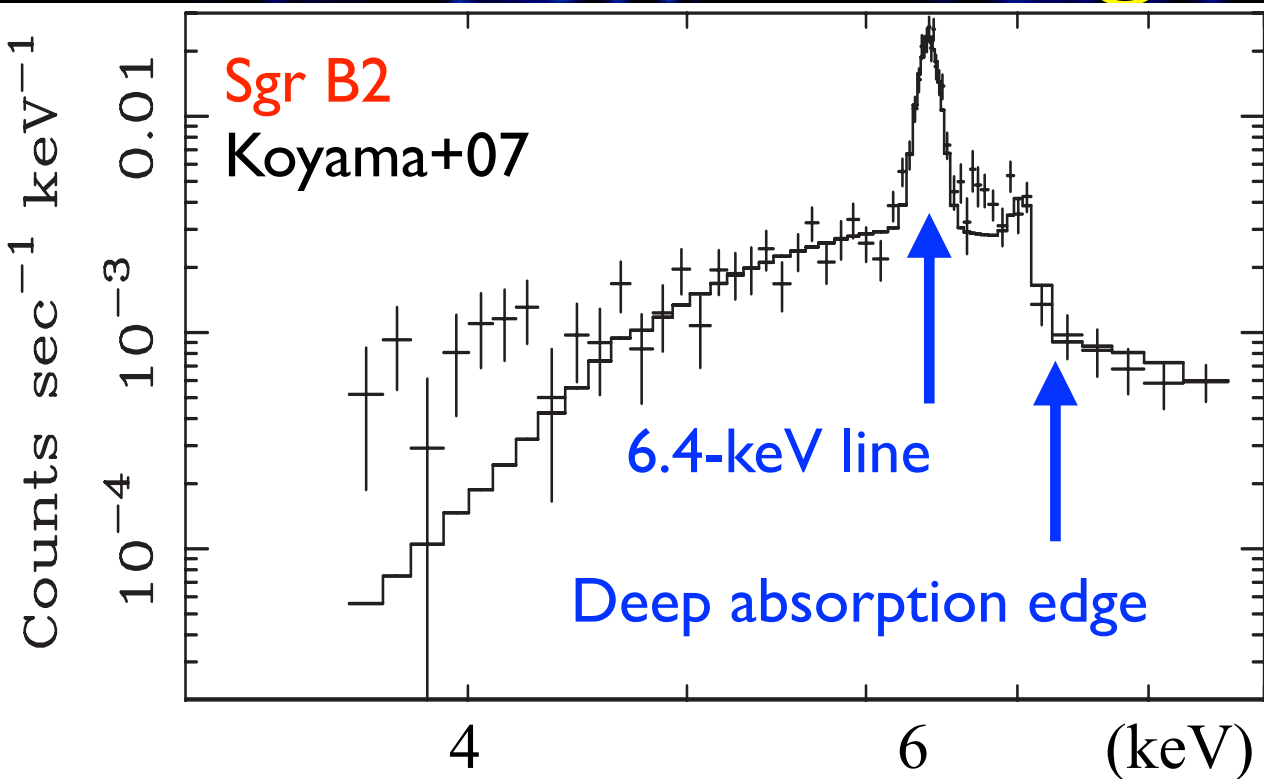
6.4-keV Line Image (Neutral Fe $K\alpha$)



- 6.4-keV line generally traces the distribution of the molecular clouds.
- 6.4-keV fluorescence line is emitted from MC.

What is the ionizing particles ? Electrons or X-rays ?

X-ray Reflection Nebula



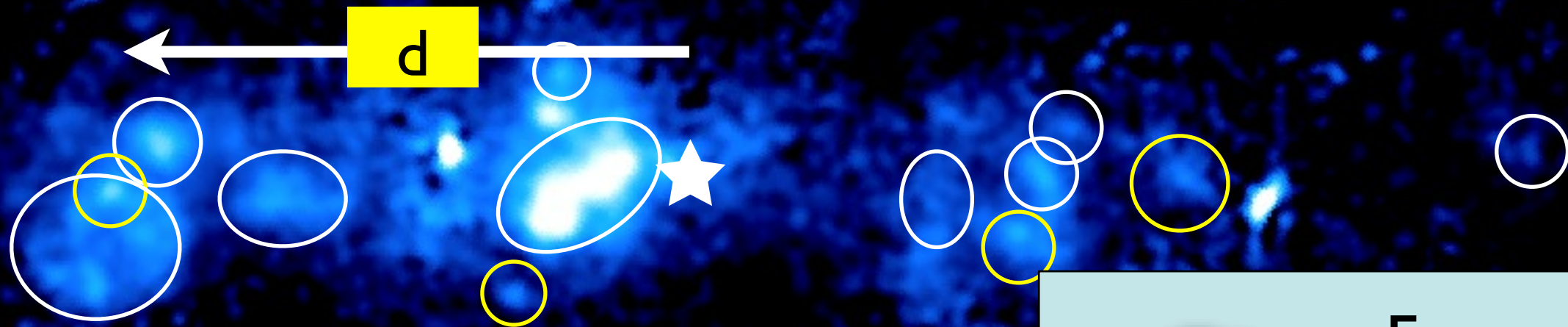
- Equivalent Width : 1–2keV
- K-edge : $N_{\text{H}} = 2\text{--}10 \times 10^{23} \text{ cm}^{-2}$
- Time Variable :
Size $\sim 10 \text{ lys}$, $\tau \sim 10 \text{ yrs}$

\Rightarrow Ionizing particle is X-ray
“X-ray Reflection Nebula (XRN)”

- Need a source
with $L_{\text{X}} \sim 10^{39} \text{ ergs/s}$
- No such bright source.
- Sgr A* is only one possible source.

Echo of the past activity of Sgr A*

Long Term Light Curve of Sgr A*



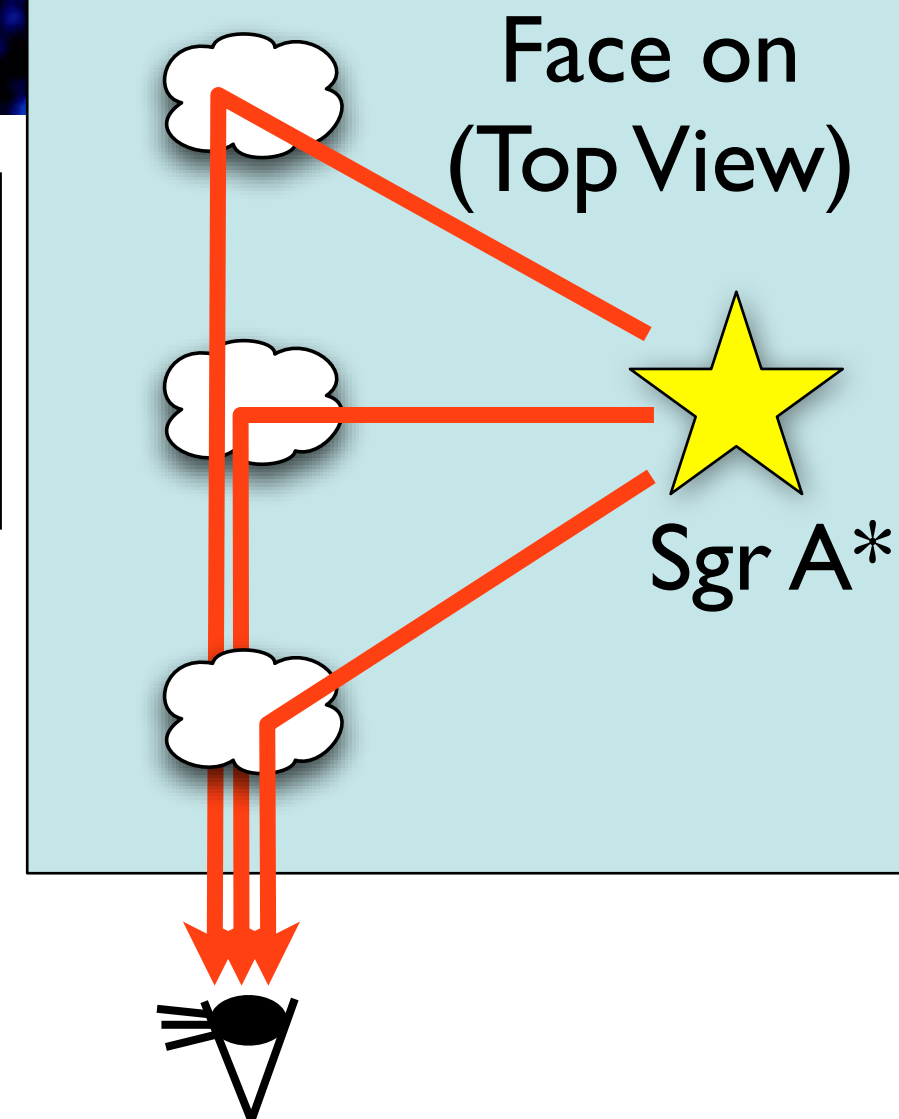
XRN
is
echo.

Collecting the data of XRNe allows us to obtain past activity of Sgr A* reaching ~1000yr.

Very Unique Study

Only Sgr A* allows us to access such a long-term activity of a SMBH.

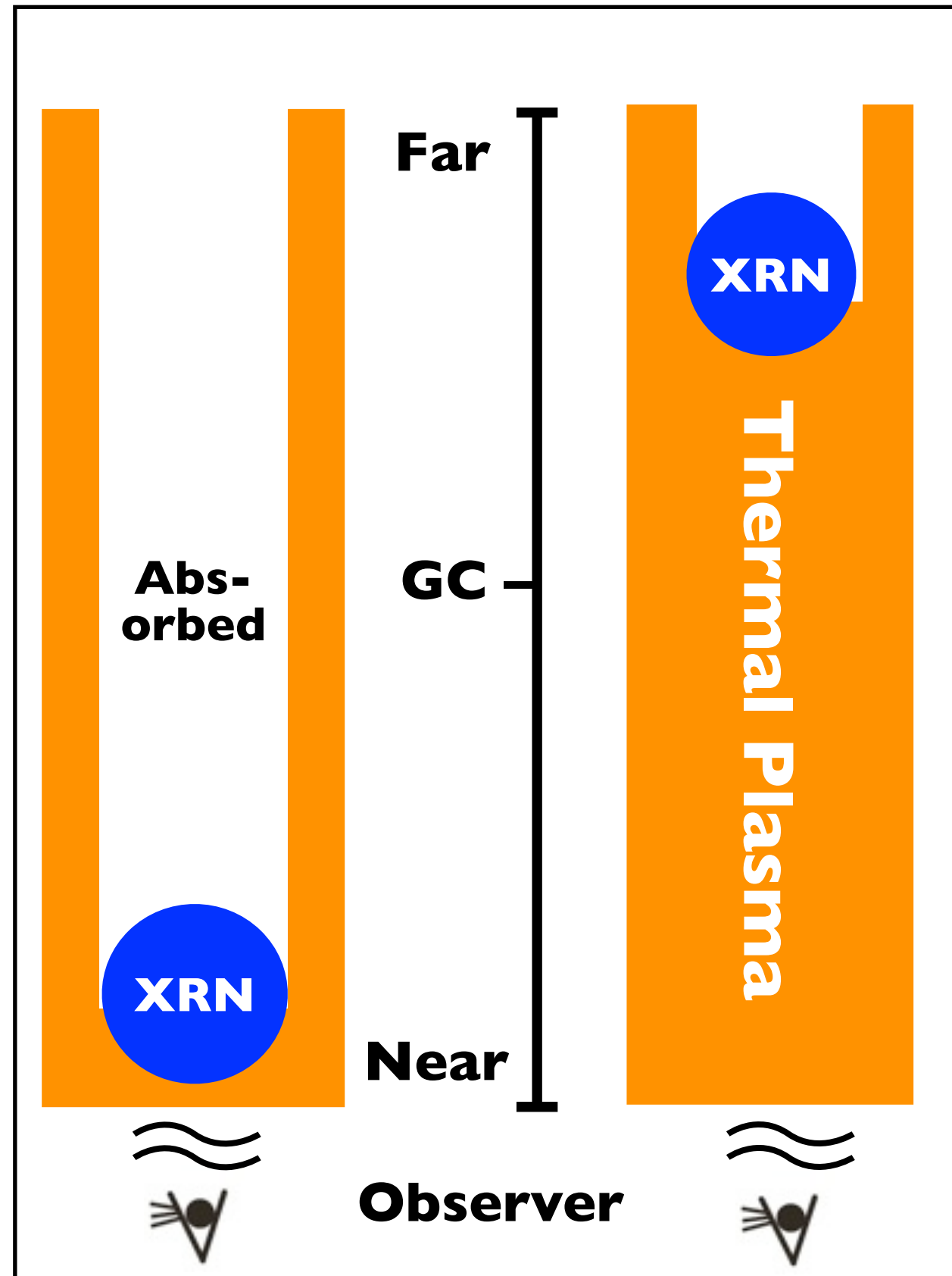
- $L_X(\text{Sgr A}^*) \propto L_X(\text{XRN}) \times \text{Mass}(\text{XRN}) \times d^2$
- Distance “d” between XRN and Sgr A*
→ Look back time.



The line of sight position of XRN is necessary.

“X-ray Tomography”

- The GC thermal plasma distributes smoothly.
- An XRN (e.g. Molecular Cloud: MC) is located in the GC thermal plasma.
- If an XRN (MC) is located in the near side of the thermal plasma, then soft X-rays from the plasma is absorbed by the XRN due to photo-absorption.
- In the case that the XRN (MC) is located in the far side of the thermal plasma, soft X-rays from the plasma is un-absorbed.



Cosmic X-ray Tomography

6.4-keV
(XRN)

XRN
Sgr B2

100 ly

6.7-keV
(Plasma)

100 ly

2.45-keV
(Plasma)

Strongly
Absorbed

100 ly

XRN
Sgr C

XRN

Thermal Plasma

Far

GC

Near

Observer

Absorbed

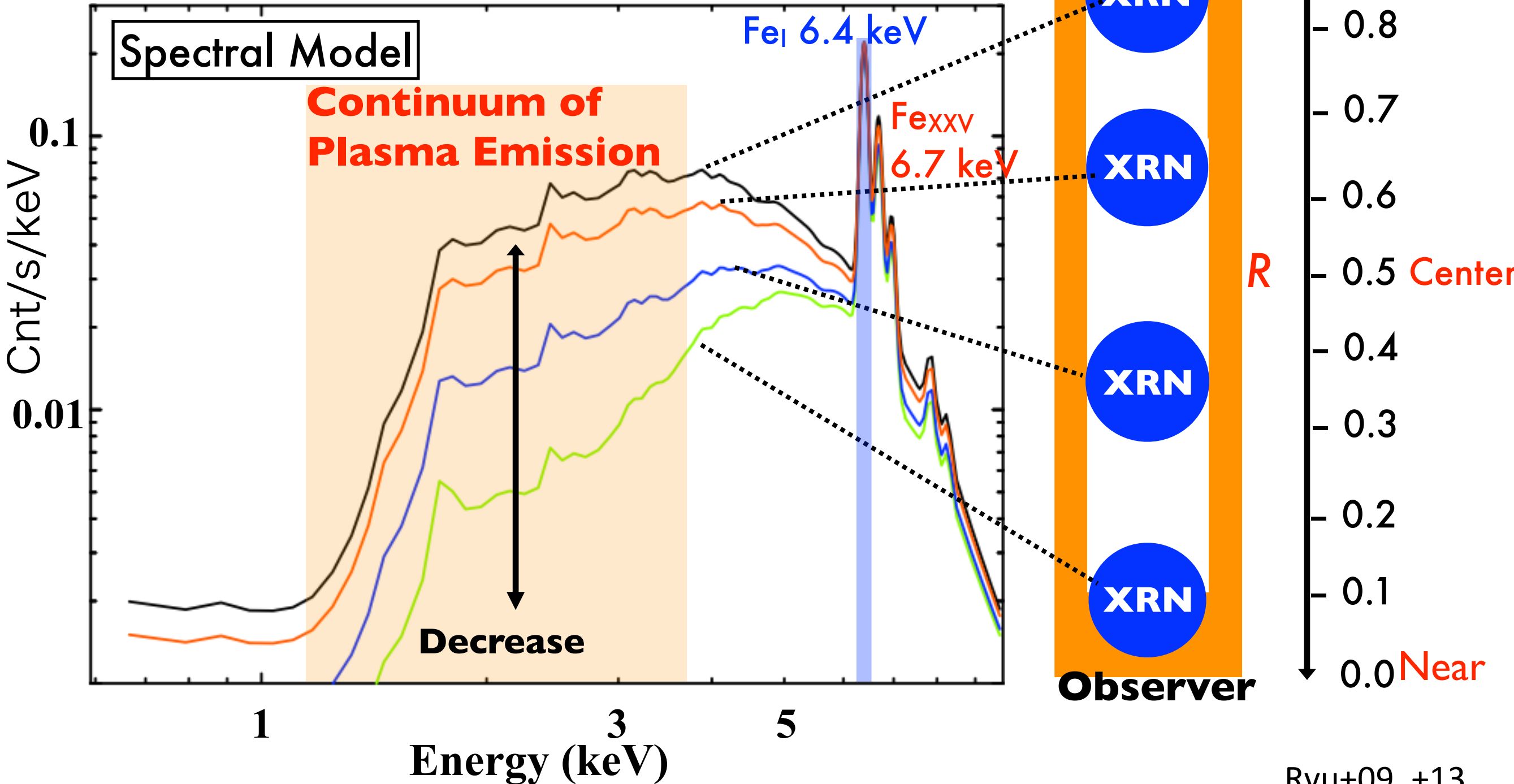
XRN

Less
Absorbed

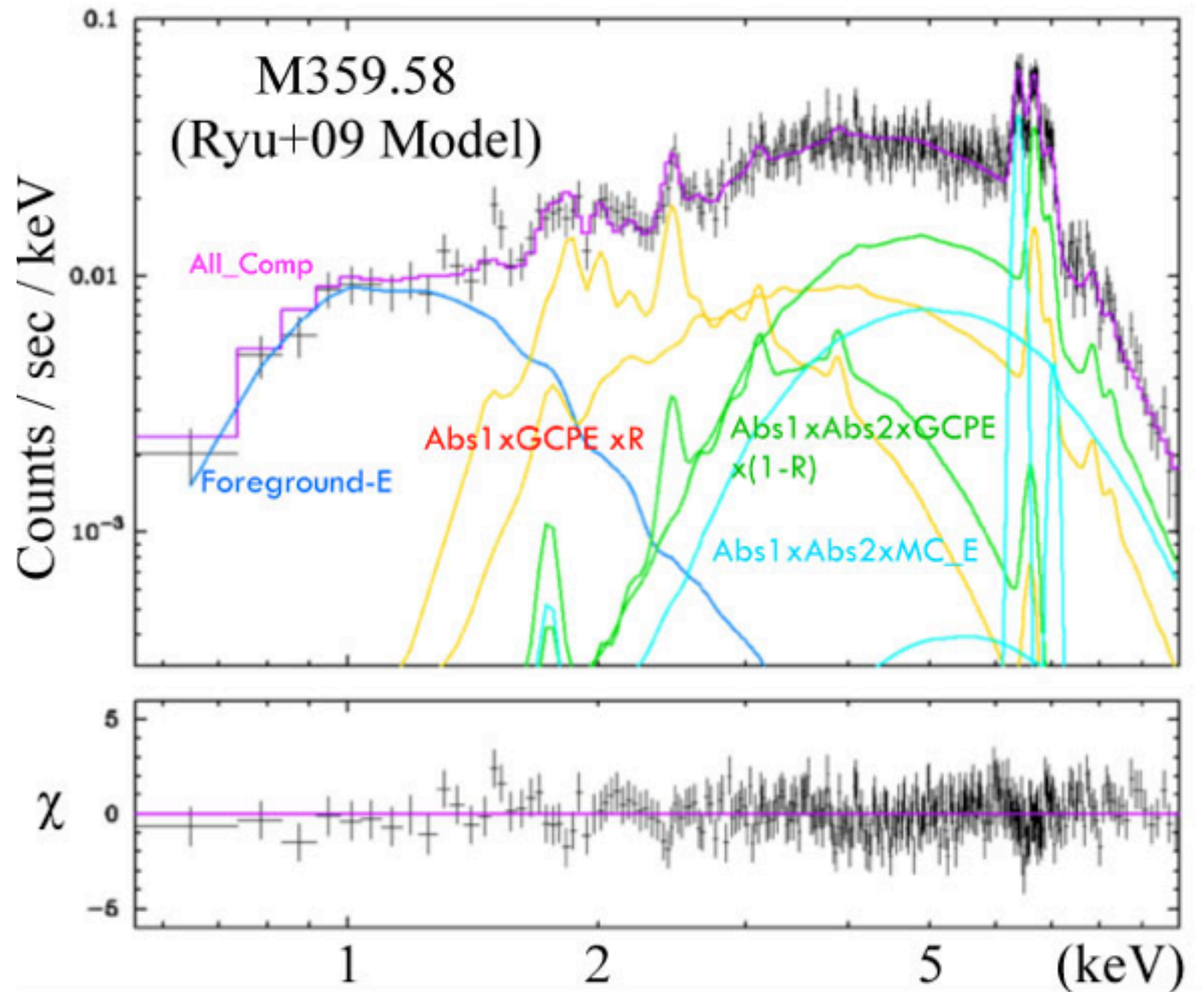
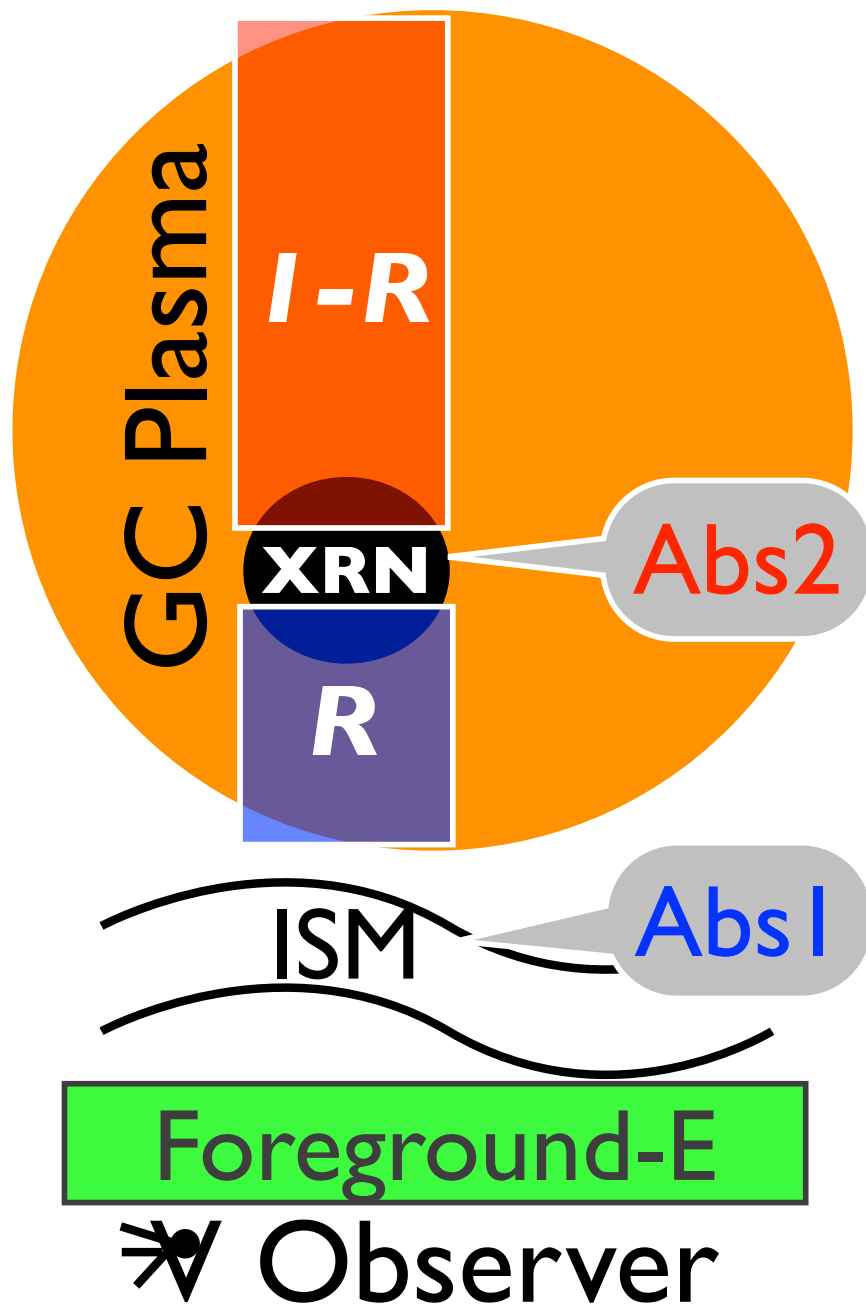
Quantitative studies allow us to obtain the line of sight positions of the XRNe.

Spectral Modeling

X-ray spectrum as a function of the line of sight position of XRN.



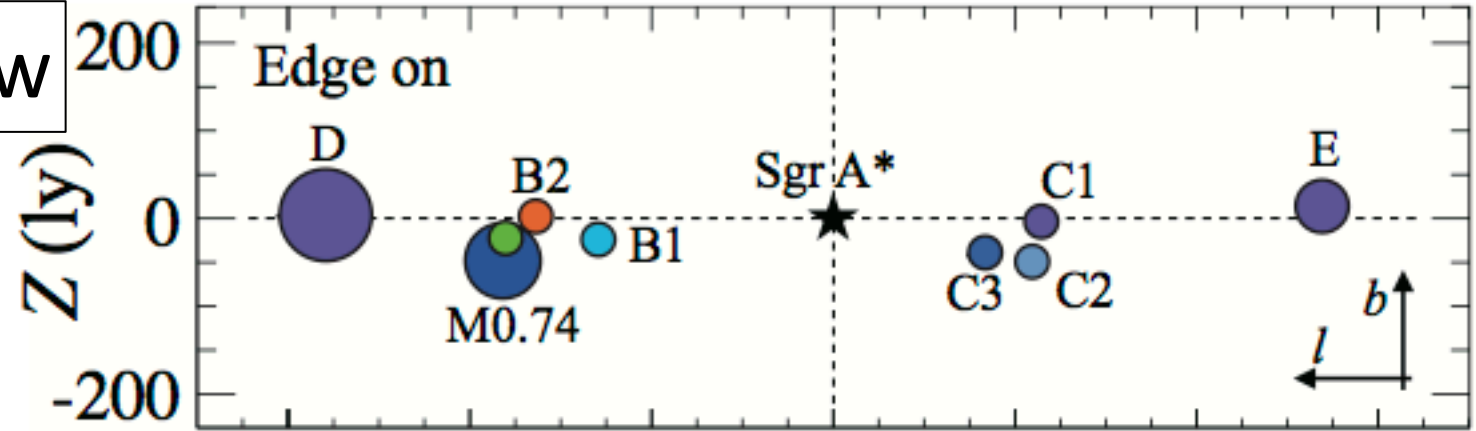
Spectral Fitting



$$\begin{aligned}
 \text{Flux (E)} = & \text{Abs1} \times (\text{GC-Plasma-E} \times \text{R}) \\
 & + \text{Abs1} \times \text{Abs2} \times (\text{GC-Plasma-E} \times (\text{I-R}) + \text{XRNE}) \\
 & + \text{Foreground-E} + \text{CXB}
 \end{aligned}$$

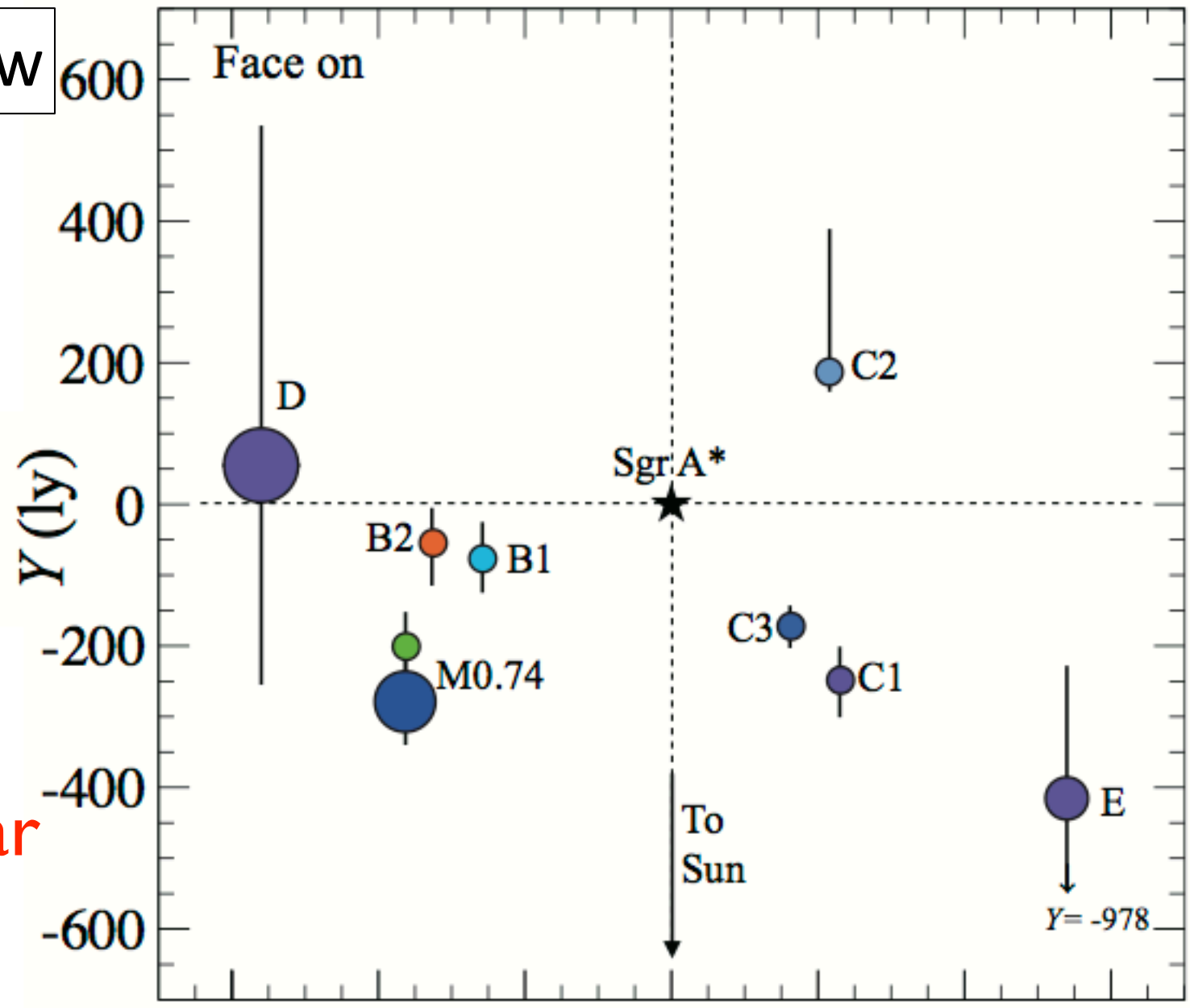
3-D distribution of XRNe

Edge-on view



Face-on view

far

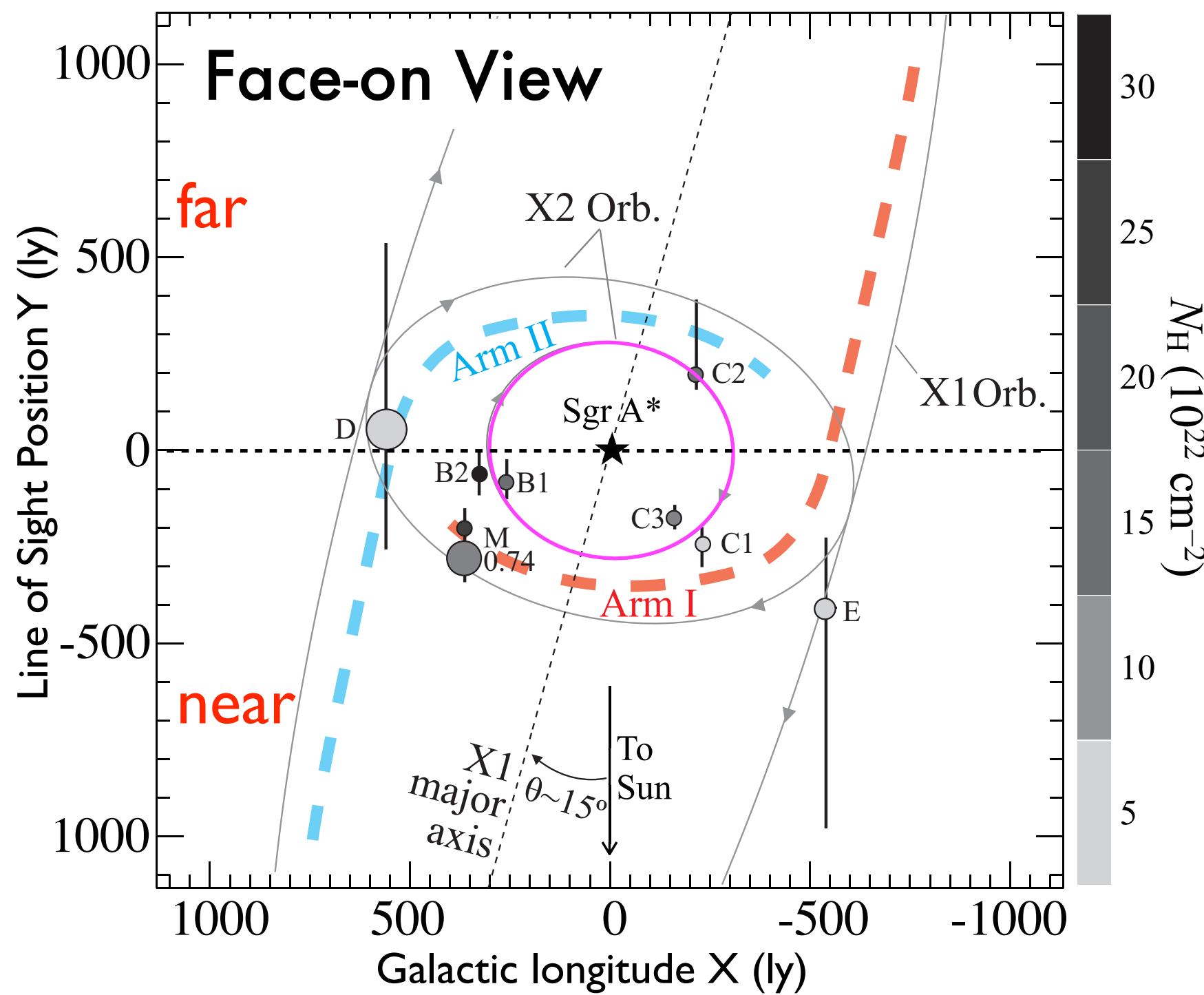


near

XRN with Tomography v.s. MC with Radio Kinematics

Radio

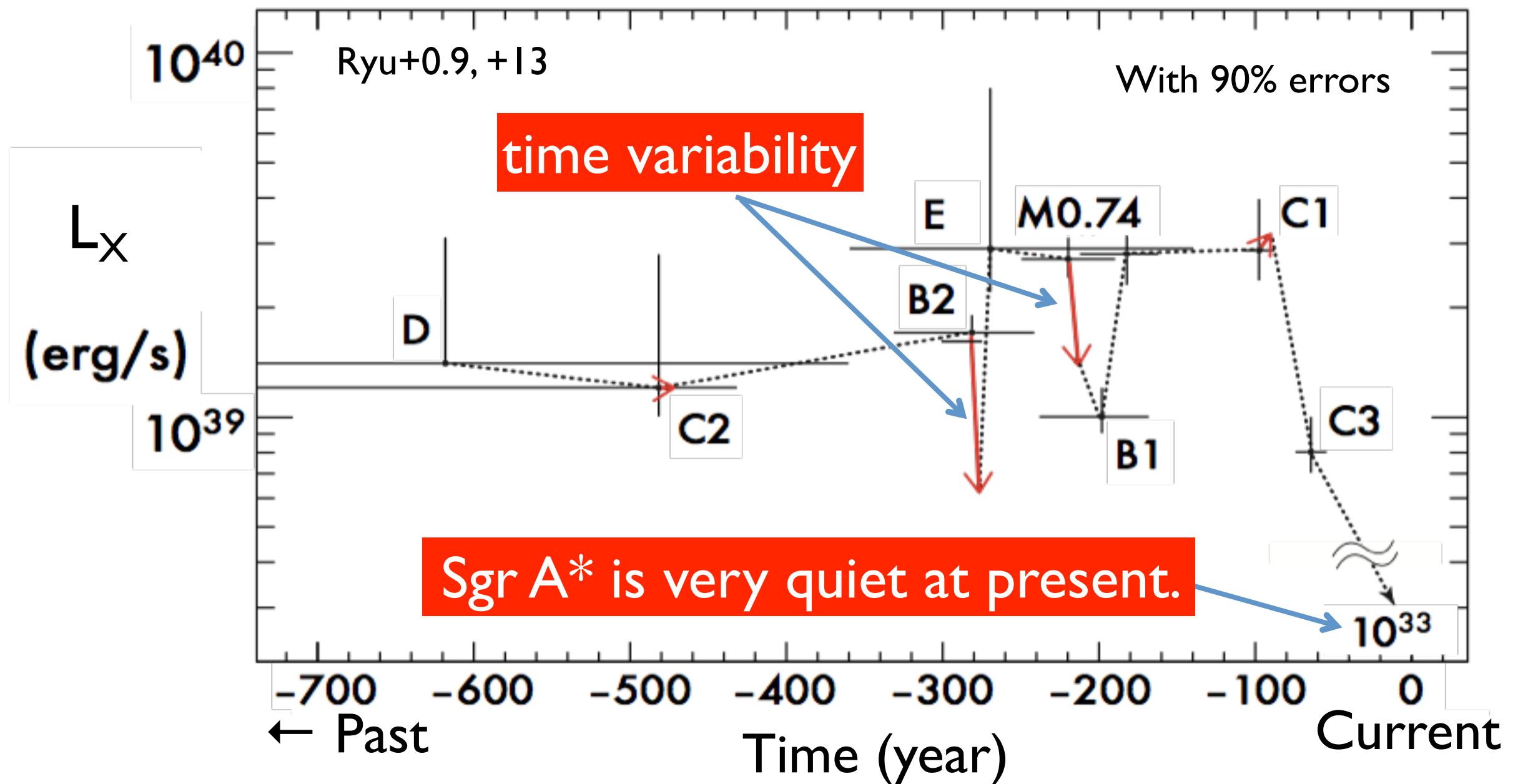
- Central Molecular Zone (Binney+91, Sofue+95)
- Assuming the kinematics model, with the observed line of sight of speed of MCs, the structures of
 - XI elliptical orbit
 - Arm I & II
 are obtained.



The X-ray and radio result are consistent with the each other.

Note that X-ray result is obtained without radio information.

Light curve of Sgr A* in the past

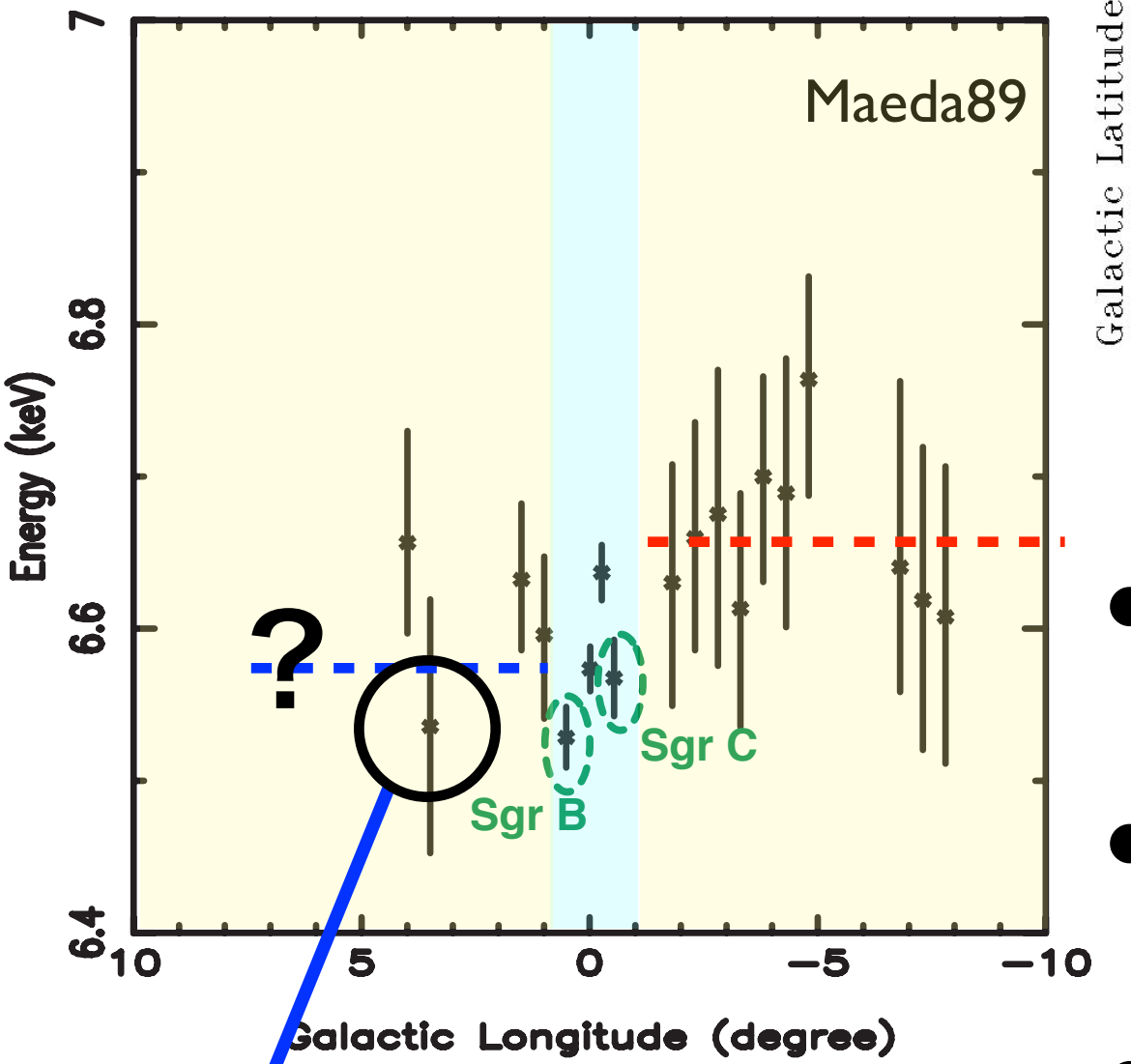


- Sgr A* had been in active phase from 50 to 600 years ago with $\sim 10^{39}$ ergs/s.
- Sgr A* made nearly one order of magnitude variation in a short time (< 10 years) at a couple of times.

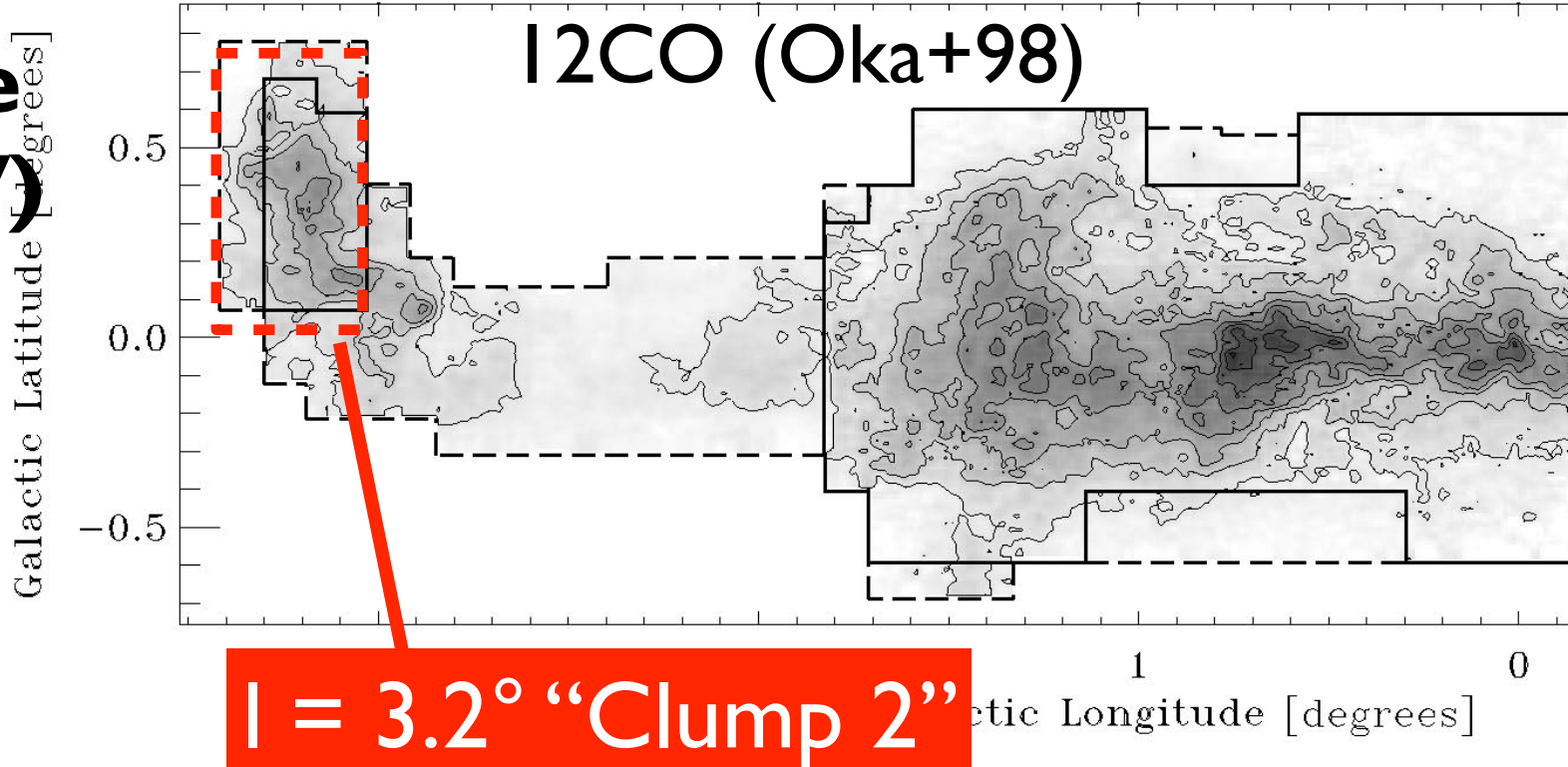
How about before 600 yrs ago ?

Access the activity of 1500 yrs ago

ASCA GIS : Center of Fe line complex (6.4-6.9keV)



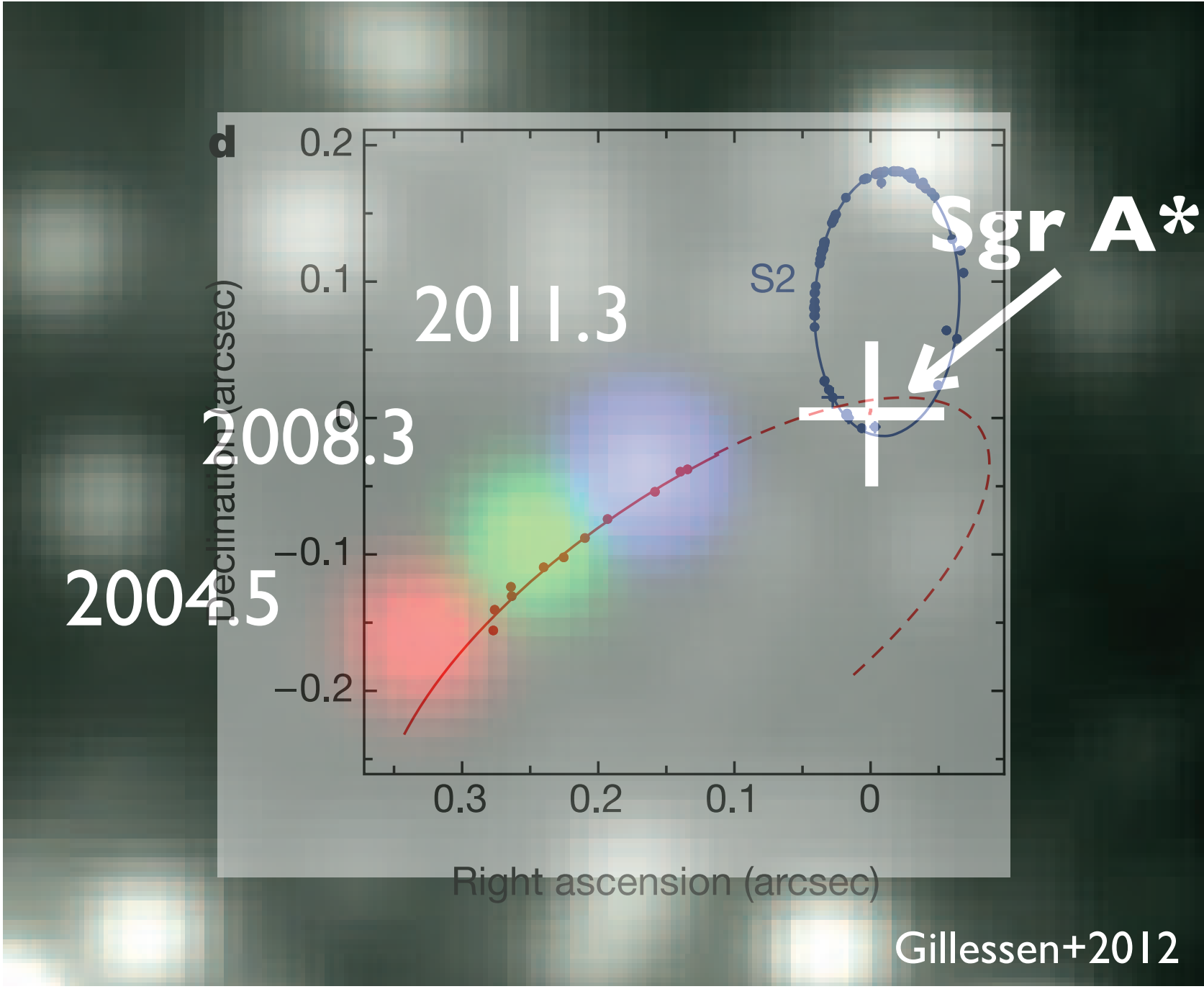
$l = 3.5^\circ$ exhibits especially strong 6.4 keV line



- MC called “Clump 2” is located at the Galactic longitude of 3.2 deg.
- The ASCA data suggest strong 6.4keV line, which would be due to Clump 2.
- We would be able to access the activity of 1500 yrs ago (if it would be an XRN).

⇒ making Suzaku observation now.

A “cloud” falling into Sgr A*



A cloud is passing at ~ 3100 times the event horizon of Sgr A*.

Summary

- Developed “X-ray Tomography”.
- Obtained 3-D position of each XRN with it.
- Obtained the X-ray light curve of Sgr A* in the past 600 yrs for the first time.
- Sgr A* has made a number of flares ($L_x \sim 10^{39}$ ergs/s) continuously in the past 600 yrs.
- Sgr A* became quiet ($L_x \sim 10^{33}$ ergs/s) in the last 100 yrs.



Thank you.