

A Review of Suzaku Studies of Stellar X-ray Emission

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1. Menu

2. Appetizer

3. Main Dish

4. Coffee

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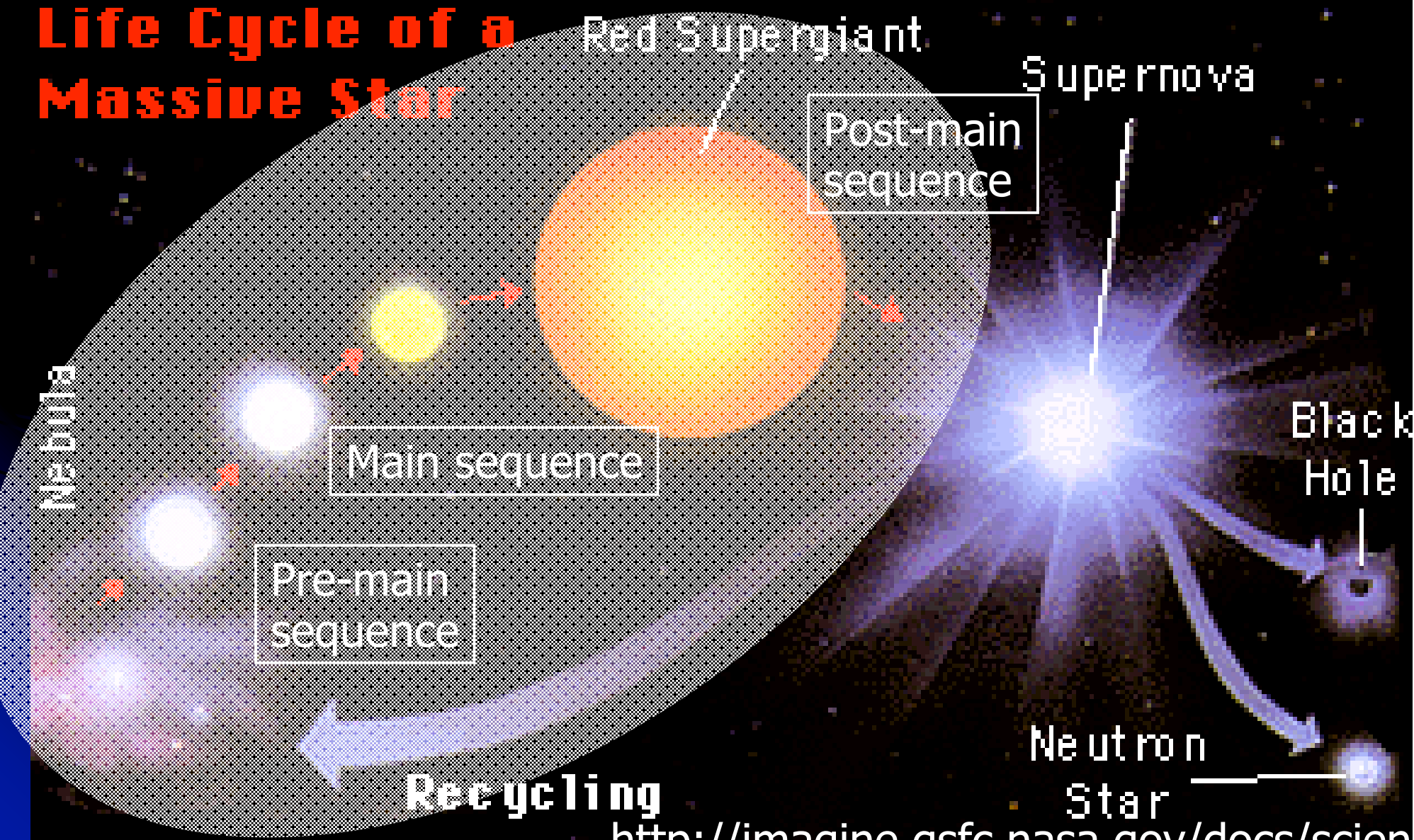
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1. Scope ... pre-explosion life of stars

Life Cycle of a Massive Star



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Appetizers

2. Publications ... 10% of sci. papers in special issues

A. Transient and variable stars.

1. "Discovery of a New Hard X-Ray Transient Source in the Scutum Region with Suzaku" ... Yamauchi, Ebisawa, et al.
2. "Suzaku Detection of an Intense X-Ray Flare from an A-type Star" ... Miura, Tsujimoto, Tsuboi, et al.
3. "Suzaku X-Ray Spectroscopy of a Peculiar Hot Star in the Galactic Center Region" ... Hyodo, Tsujimoto, Koyama, et al.

Main dish

B. Diffuse emission in HII regions.

4. "Suzaku Observation of Diffuse X-Ray Emission from the Carina Nebula" ... Hamaguchi, Petre, Matsumoto, et al.
5. "Suzaku Spectroscopy Study of Hard X-Ray Emission in the Arches Cluster" ... Tsujimoto, Hyodo, Koyama
6. "Suzaku Spectroscopy Study of the Extended X-Ray Emission in M17" ... Hyodo, Tsujimoto, Koyama, et al.

Appetizer



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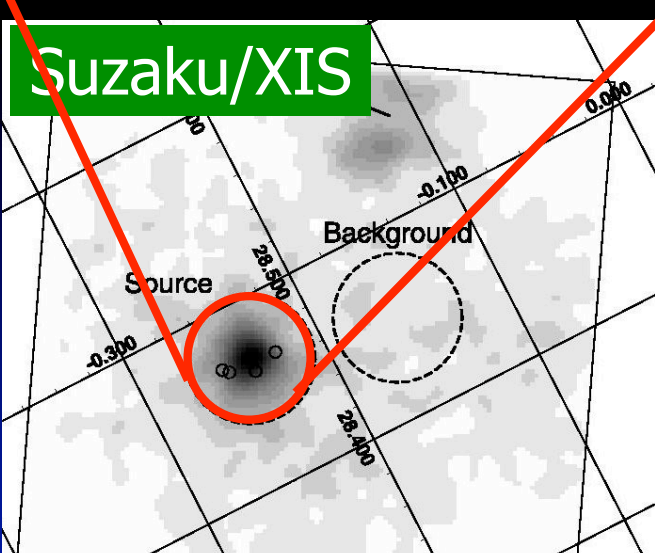
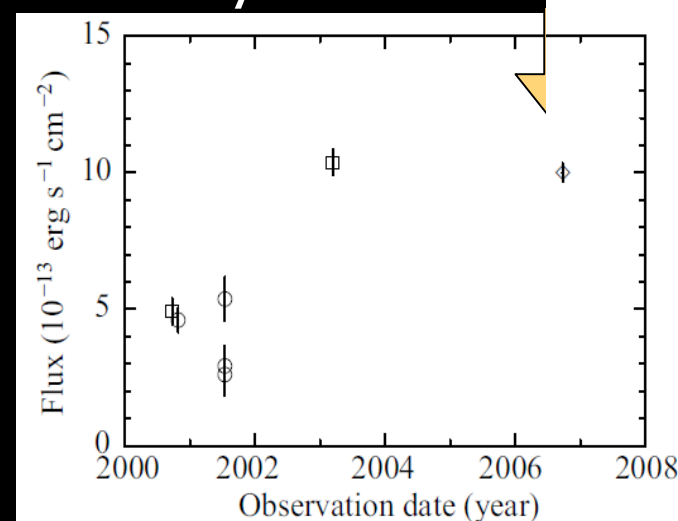
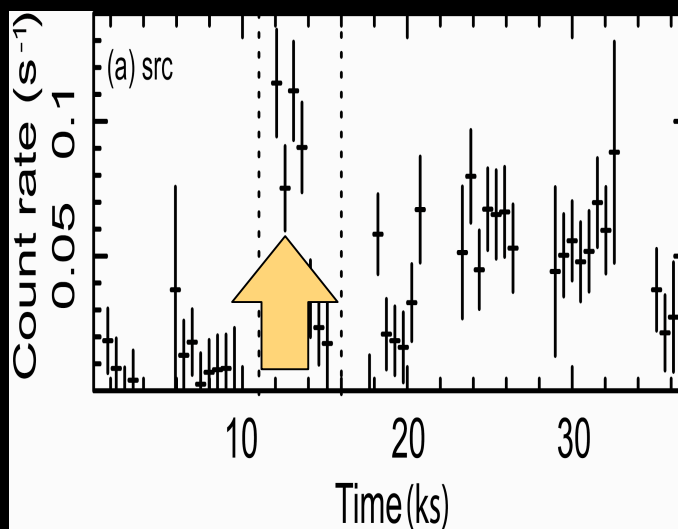
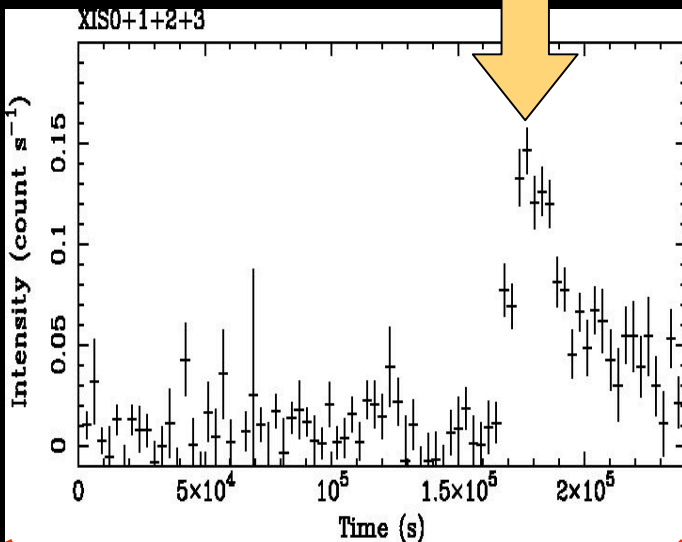
16

3. Transients and Variable Stars

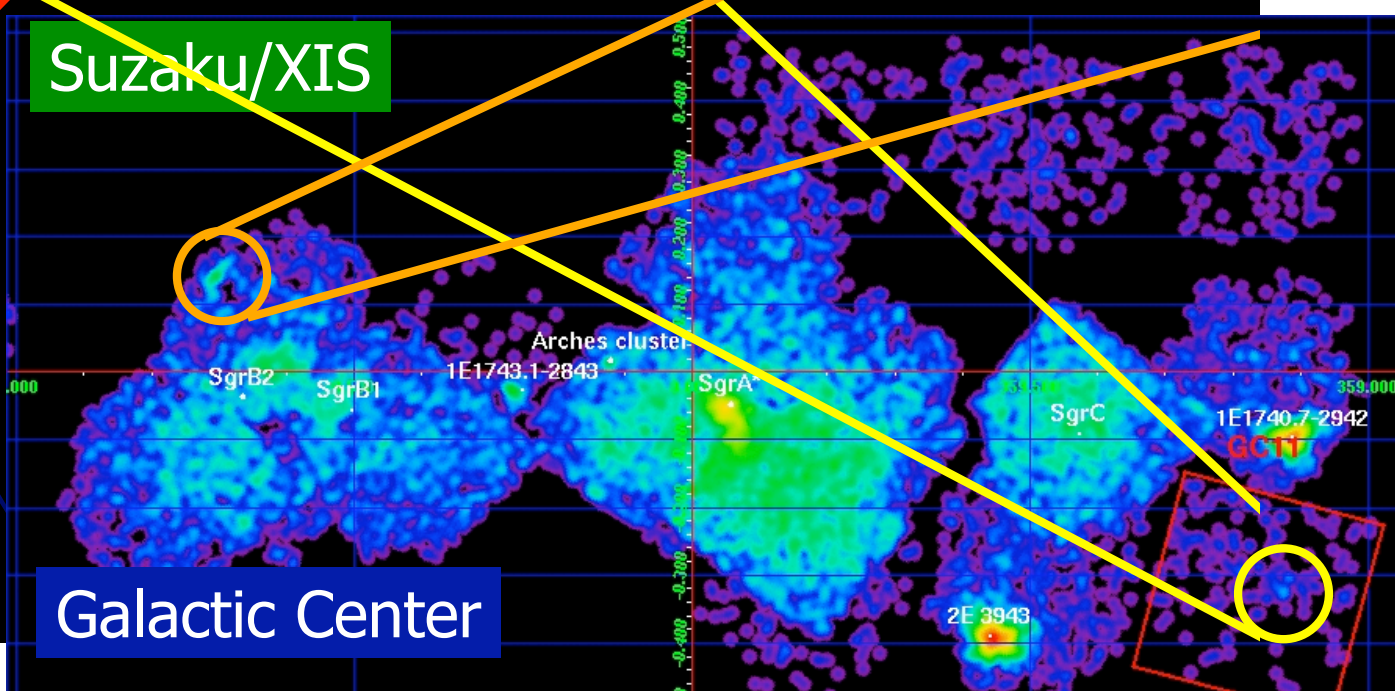
Yamauchi et al.

Miura et al.

Hyodo et al.

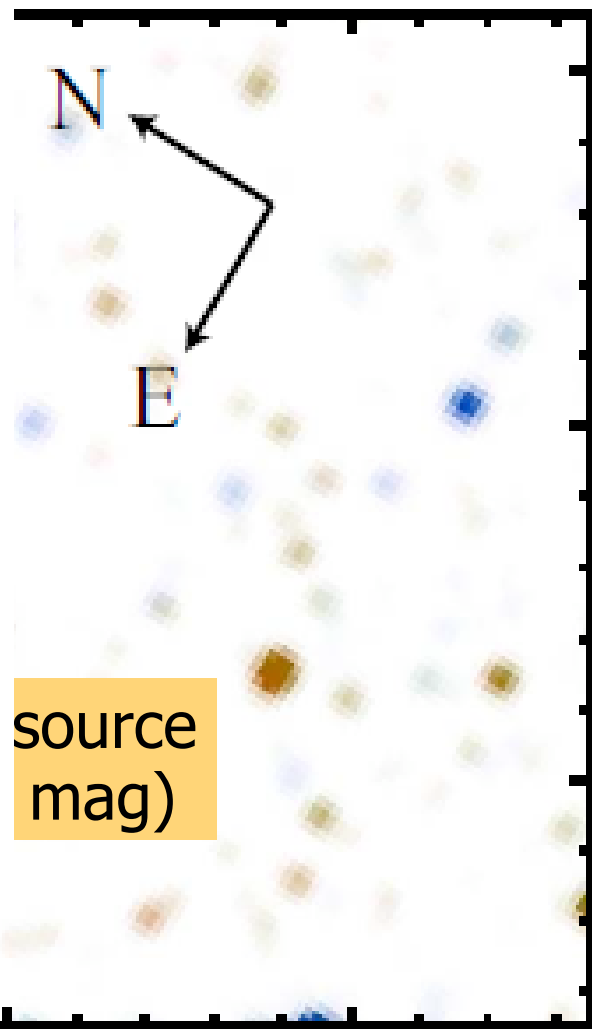
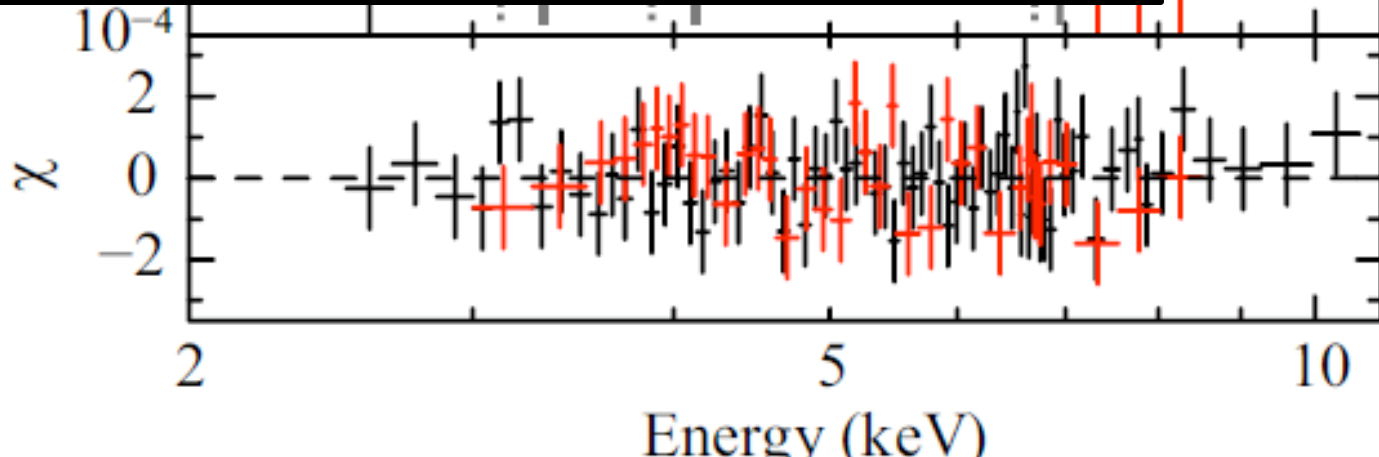


A Galactic Plane Reg.



Galactic Center

Chandra/ACIS



Ga

0.72 0.71 0.70 0.69

Galactic longitude (deg)

Fi

Main Dish



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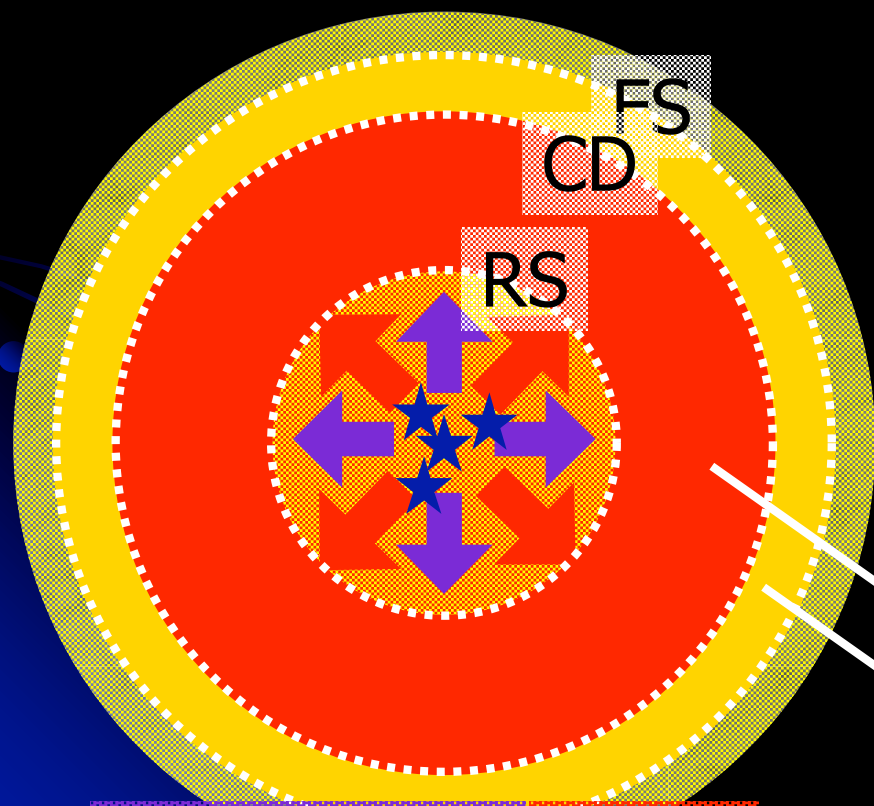
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5. Extended X-ray Emission in HII Regions

--- Theory ---

Pioneering work

- Dyson & de Vries (1972)
- Weaver et al. (1977)



| | SNR | Bubble |
|--------------|---------------|-----------------|
| model | Sedov | Weaver |
| energy input | instantaneous | continuous |
| radius | $t^{-5/2}$ | $t^{-5/3}$ |
| power source | SN | massive star(s) |

soft diffuse X-rays

optical (forbidden lines)

UV Radiation Winds

Einstein/IPC

Seward & Chlebowski (1982)

HD93205 [O3.5V]

Trumpler 14 [OB assoc.]

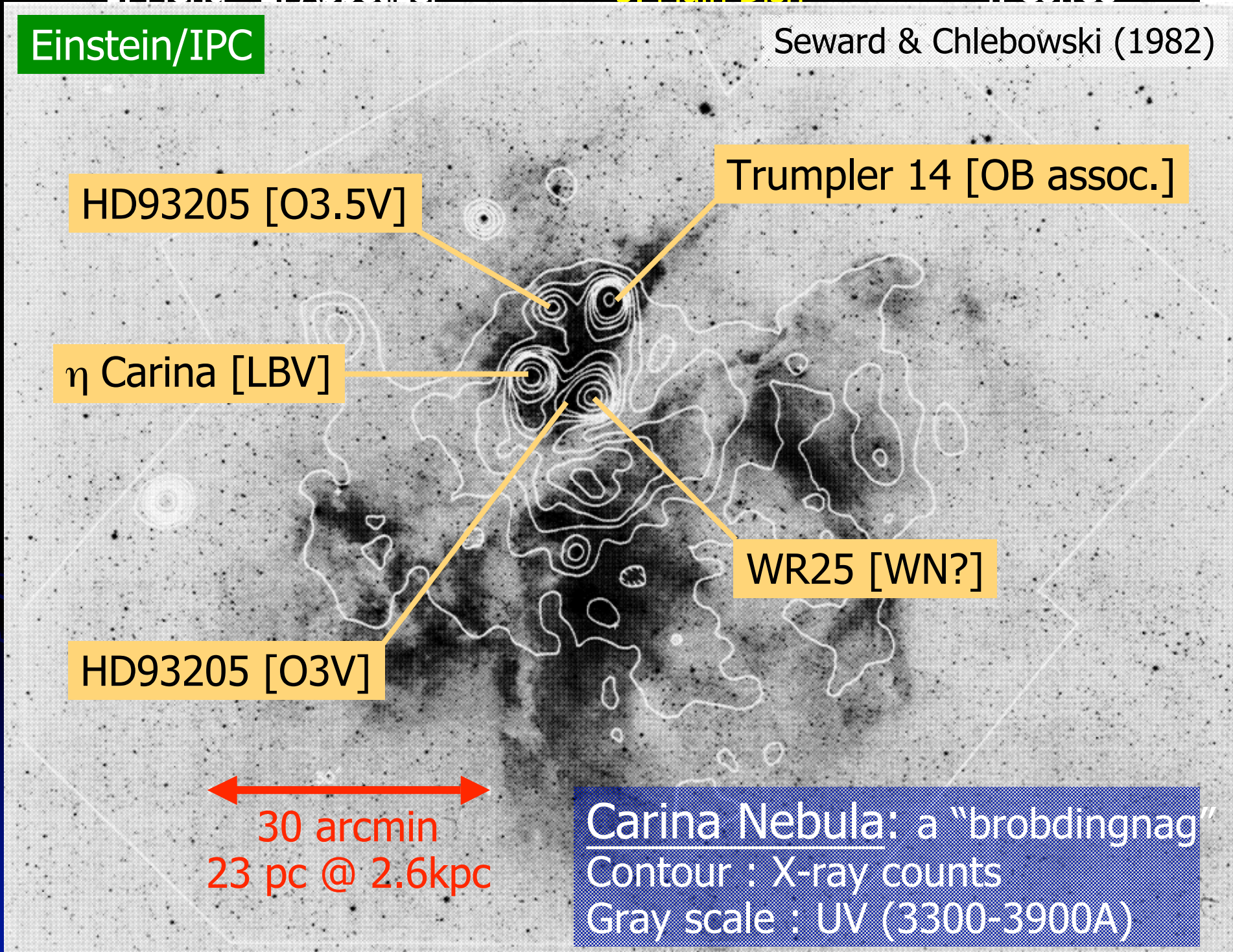
η Carina [LBV]

WR25 [WN?]

HD93205 [O3V]

30 arcmin
23 pc @ 2.6kpc

Carina Nebula: a "brobdingnag"
Contour : X-ray counts
Gray scale : UV (3300-3900A)



Chandra/ACIS-I

Feigelson et al. (2005)

Gaussian fit
 $L_{X(\text{peak})} \sim 10^{29.5} \text{ erg/s}$

Unobscurred Pop.

Obscured Pop.

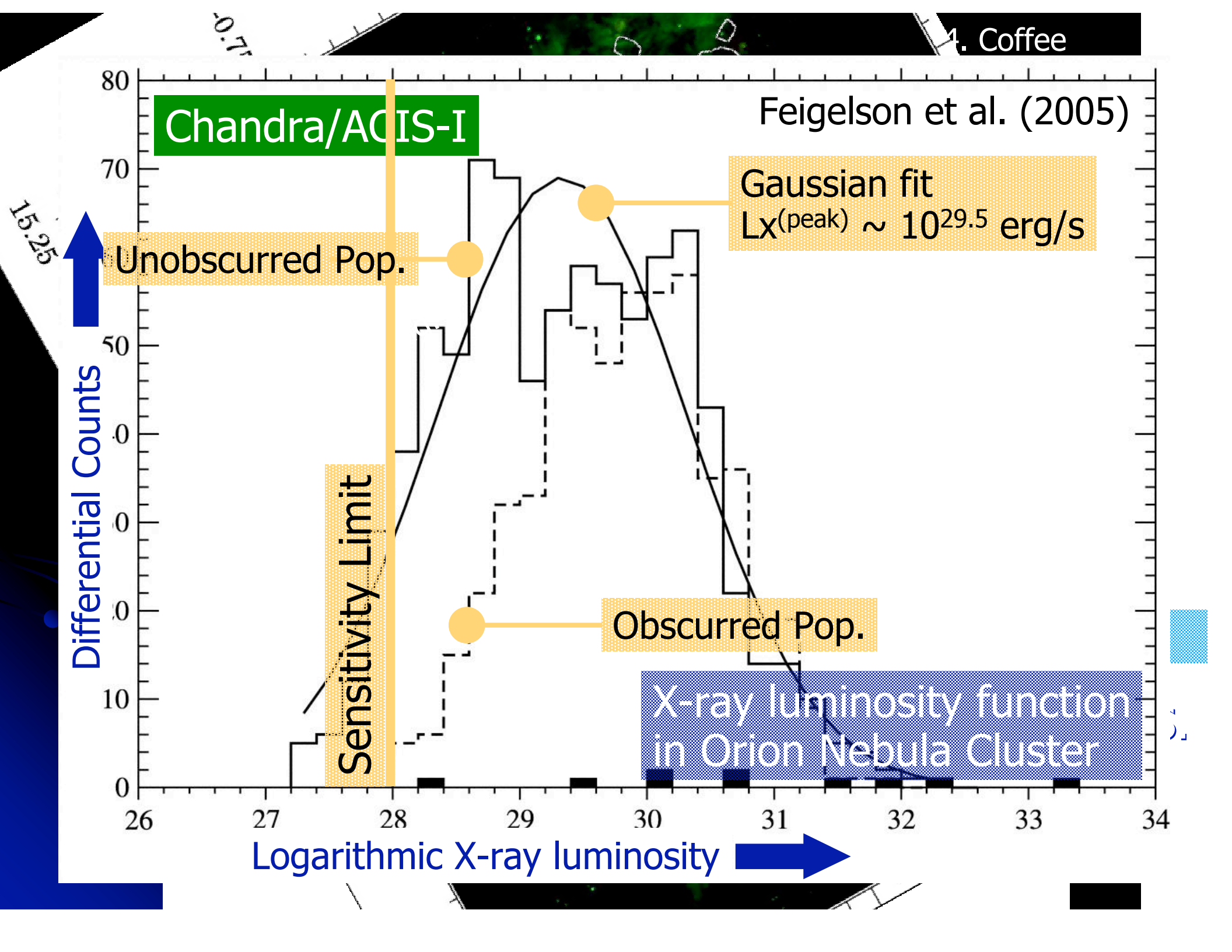
X-ray luminosity function
in Orion Nebula Cluster

Sensitivity Limit

Differential Counts

Logarithmic X-ray luminosity

15.25



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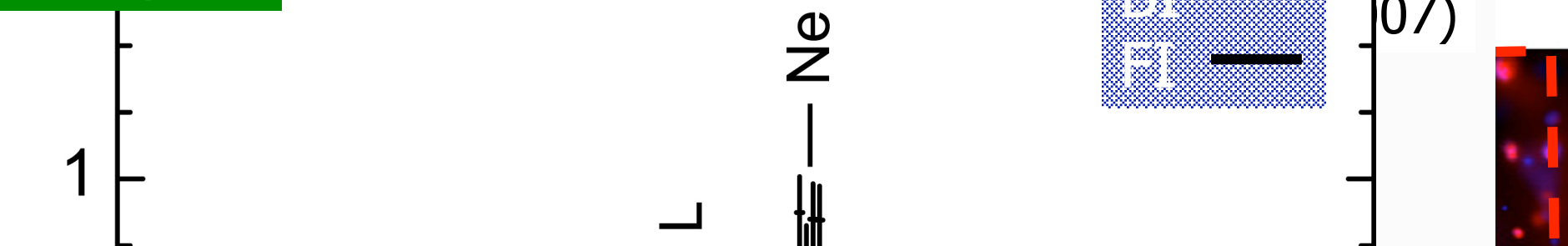
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Suzaku/XIS Spectroscopy (1) M17

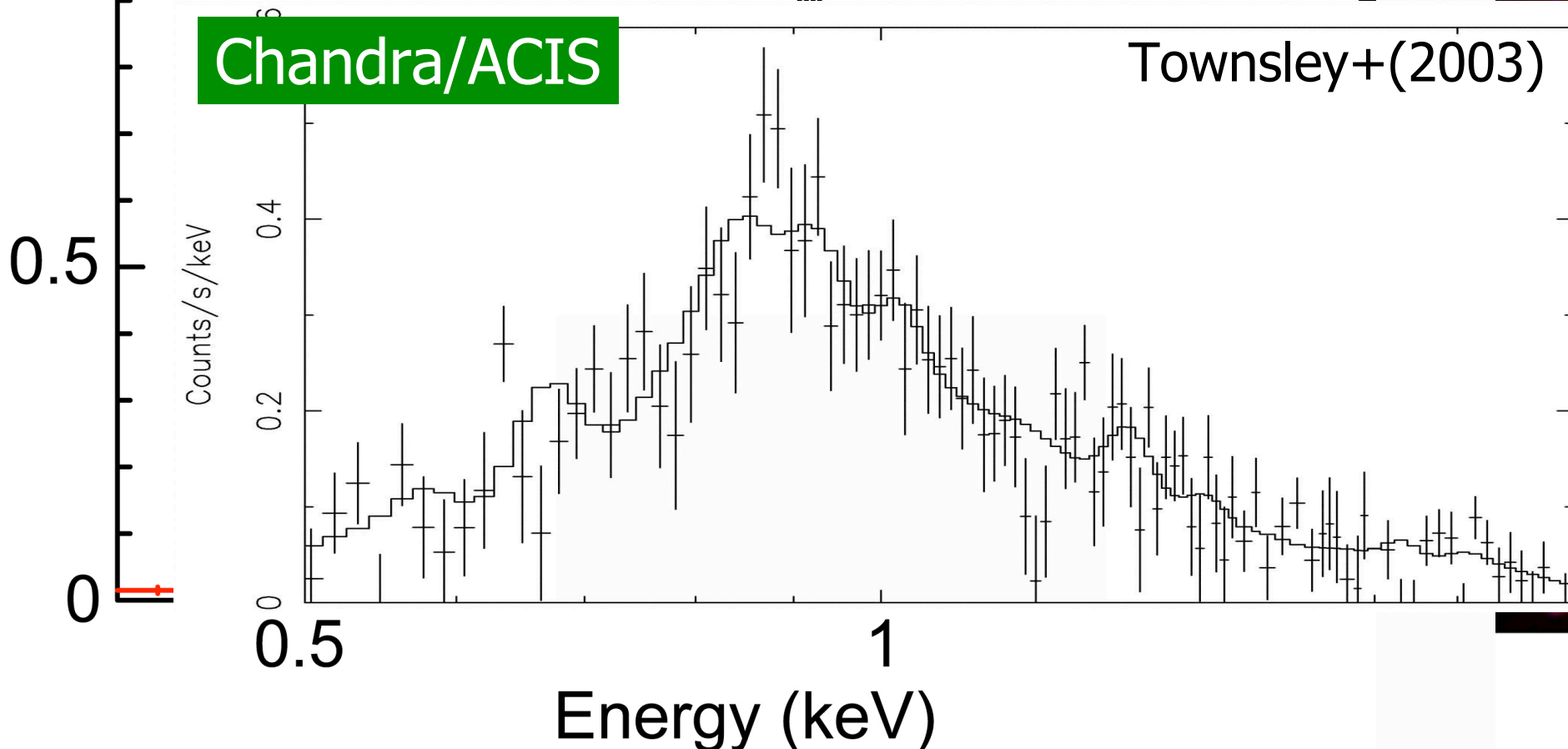
Suzaku/XIS

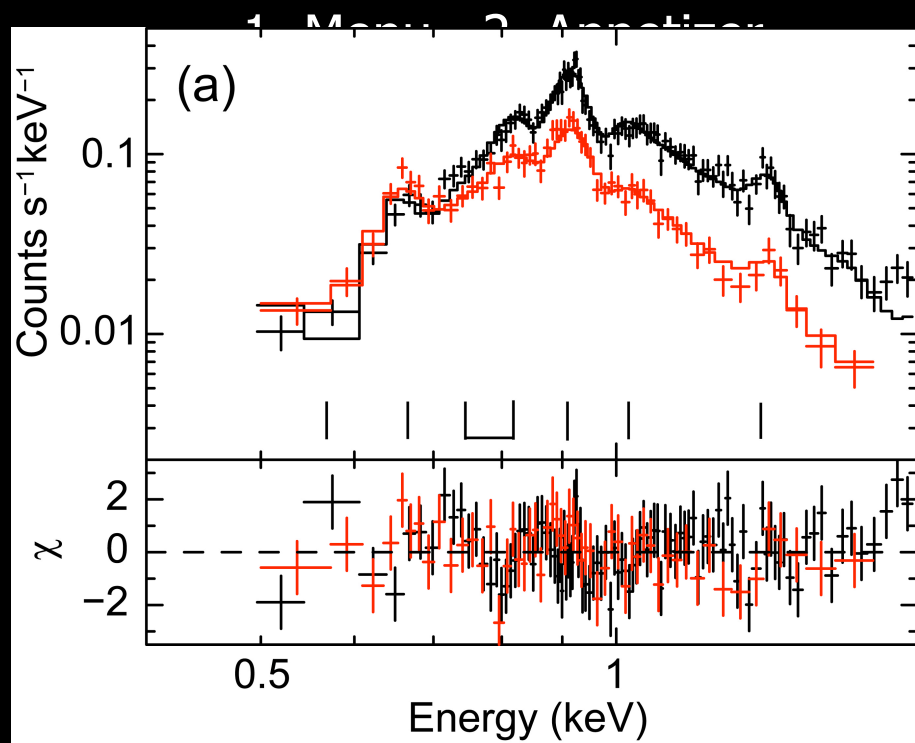
Counts s⁻¹ keV⁻¹



Chandra/ACIS

Townsley+(2003)





1. Main 2. Appetizer

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7 8 9 10 11 12 13 14 15 16

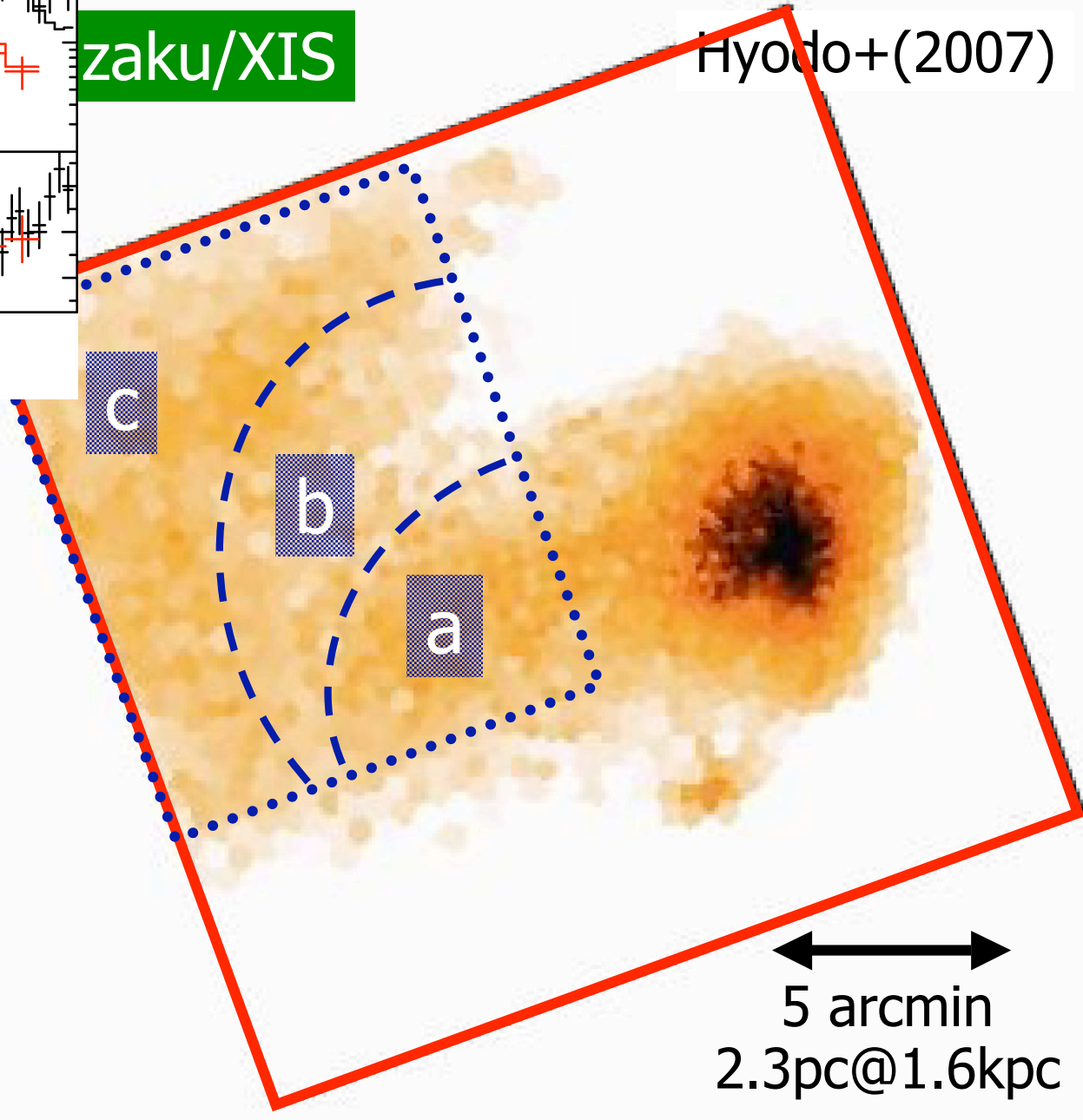
pectroscopy (1) M17

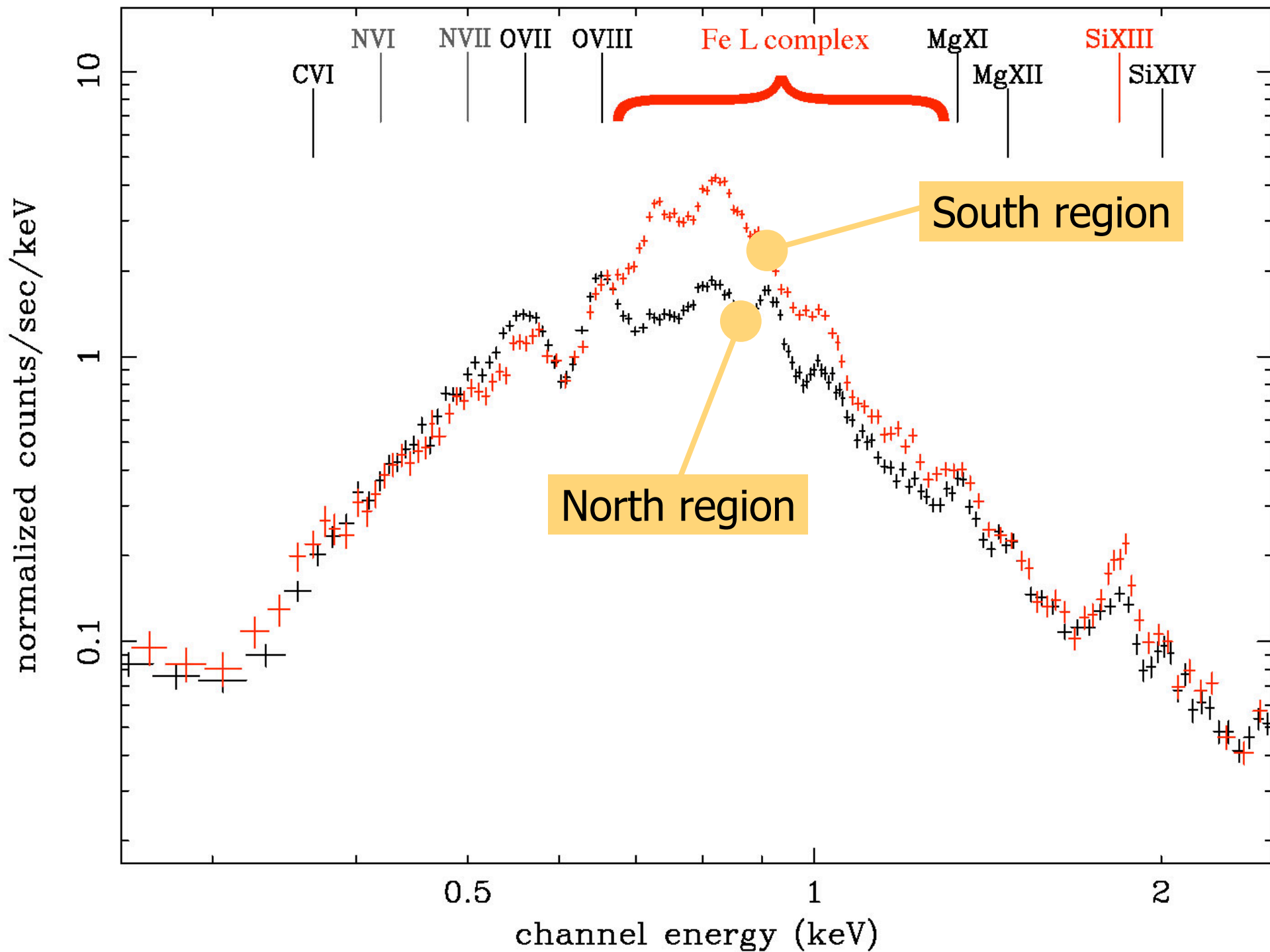
zaku/XIS

Hyodo+(2007)

Spatially-resolved spectroscopy

- Difference due to N_H
- Uniform T, Z_{metal}





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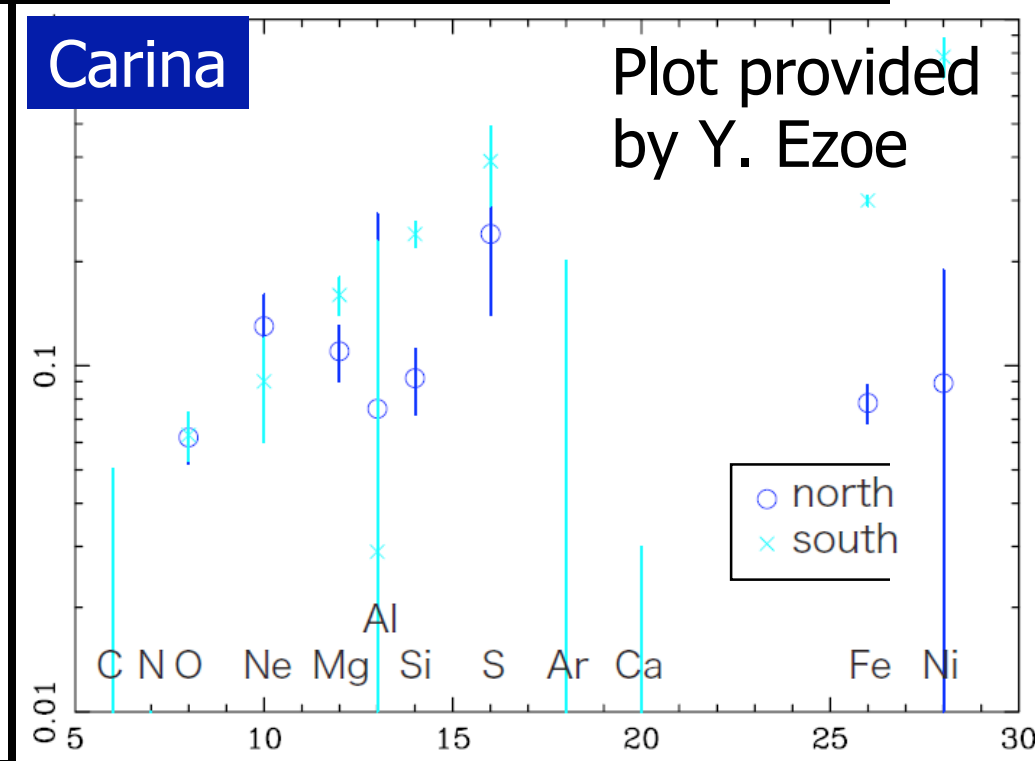
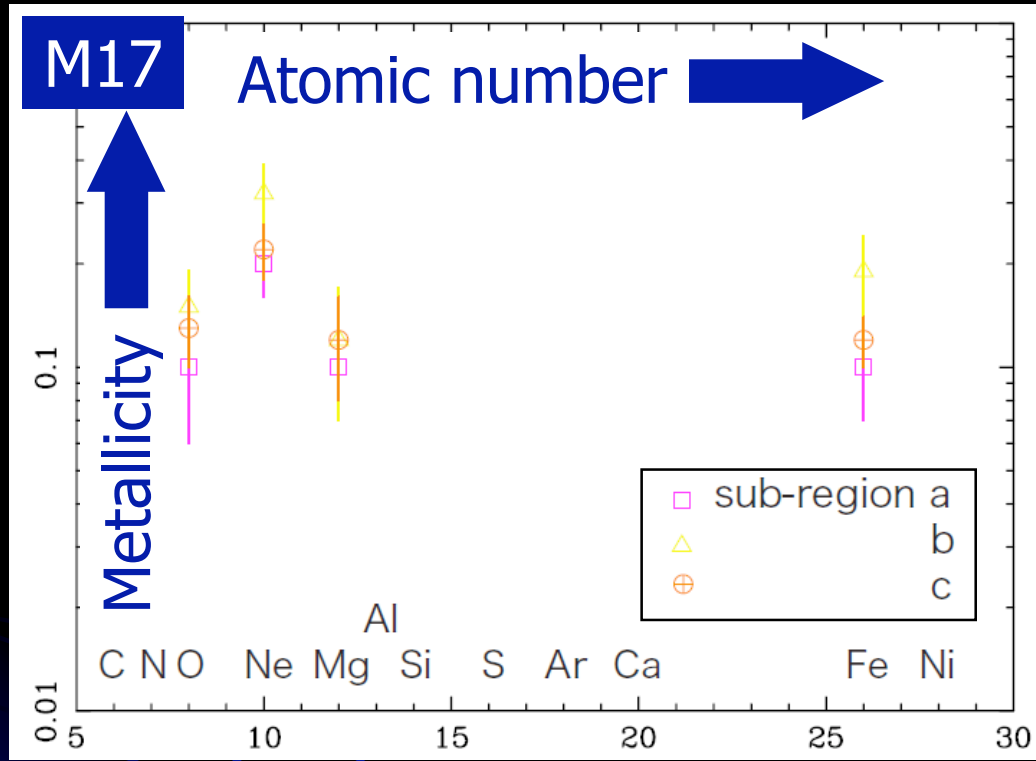
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11. Comparison M17 and Carina Nebula



Spatially uniform.

Abundance pattern similar to young stars, inconsistent with SN

\rightarrow origin: OB winds

Spatially non-uniform.

Abundance pattern inconsistent with η Carina & WR25 (Z_N/Z_O)

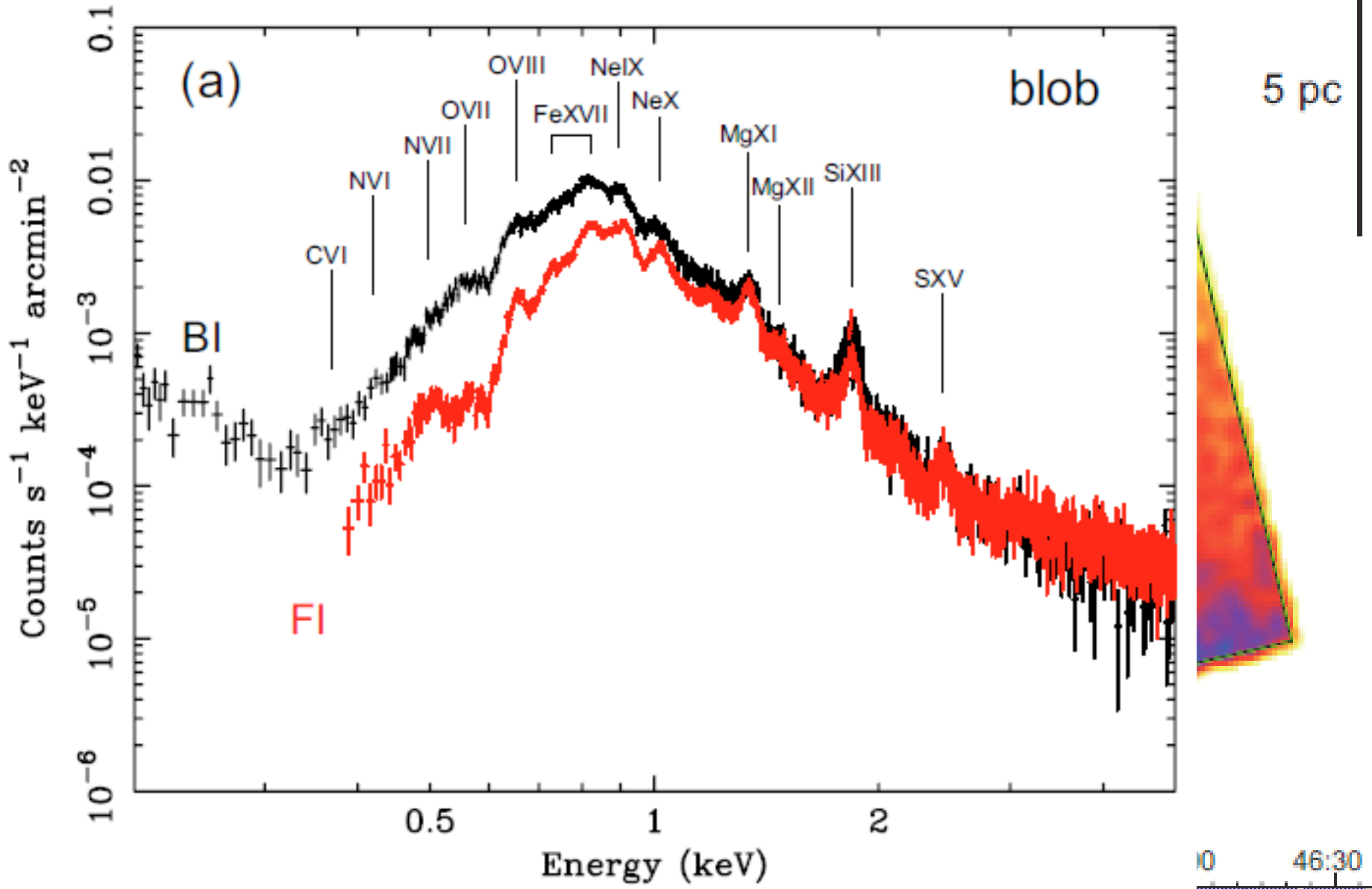
\rightarrow origin: SNRs involving

Einstein/IPC

Seward & Chlebowski (1987)

25:00 (a)

nw



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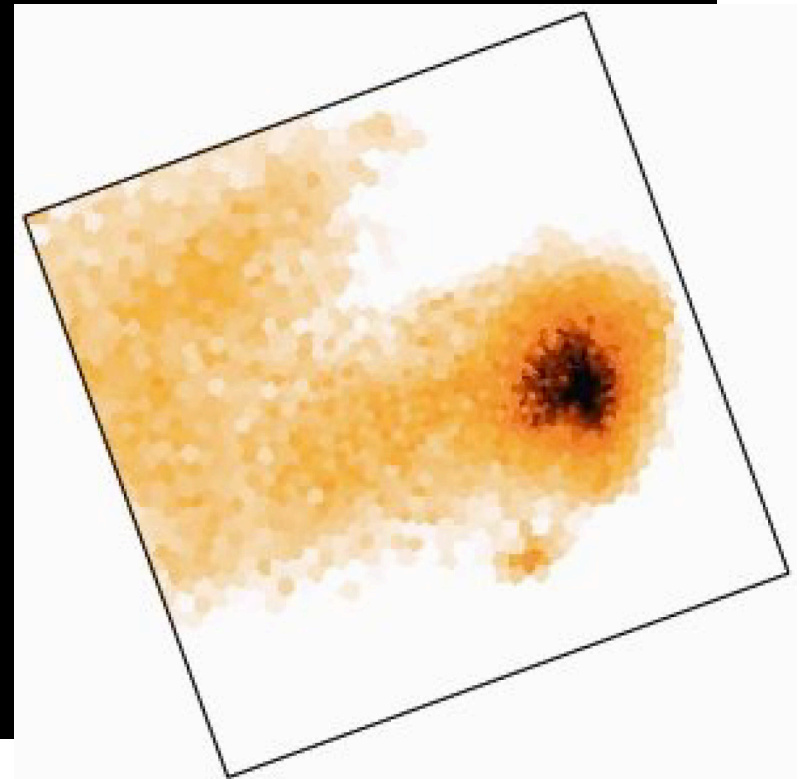
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13. Physics of Bubbles

1. Plasma volume & density : $V \sim 30 \text{ pc}^3$; $n_e \sim 1 \text{ cm}^3$
2. Plasma mass : $1 M_\odot \sim (10^{-6} M_\odot/\text{yr}) \times 10^6 \text{ yr}$
... Evaporated mass from ISM negligible.
3. Energy budget : $L_{\text{wind}} \sim 10^{35} \text{ erg/s}$; $L_x \sim 10^{33} \text{ erg/s}$
... X-ray radiation is tiny.
4. Thermal equilibrium
... Uniform T.
... $t_{\text{cross}} \ \& \ t_{\text{relax}} \ll t_{\text{system}}$
5. Magnetic field?



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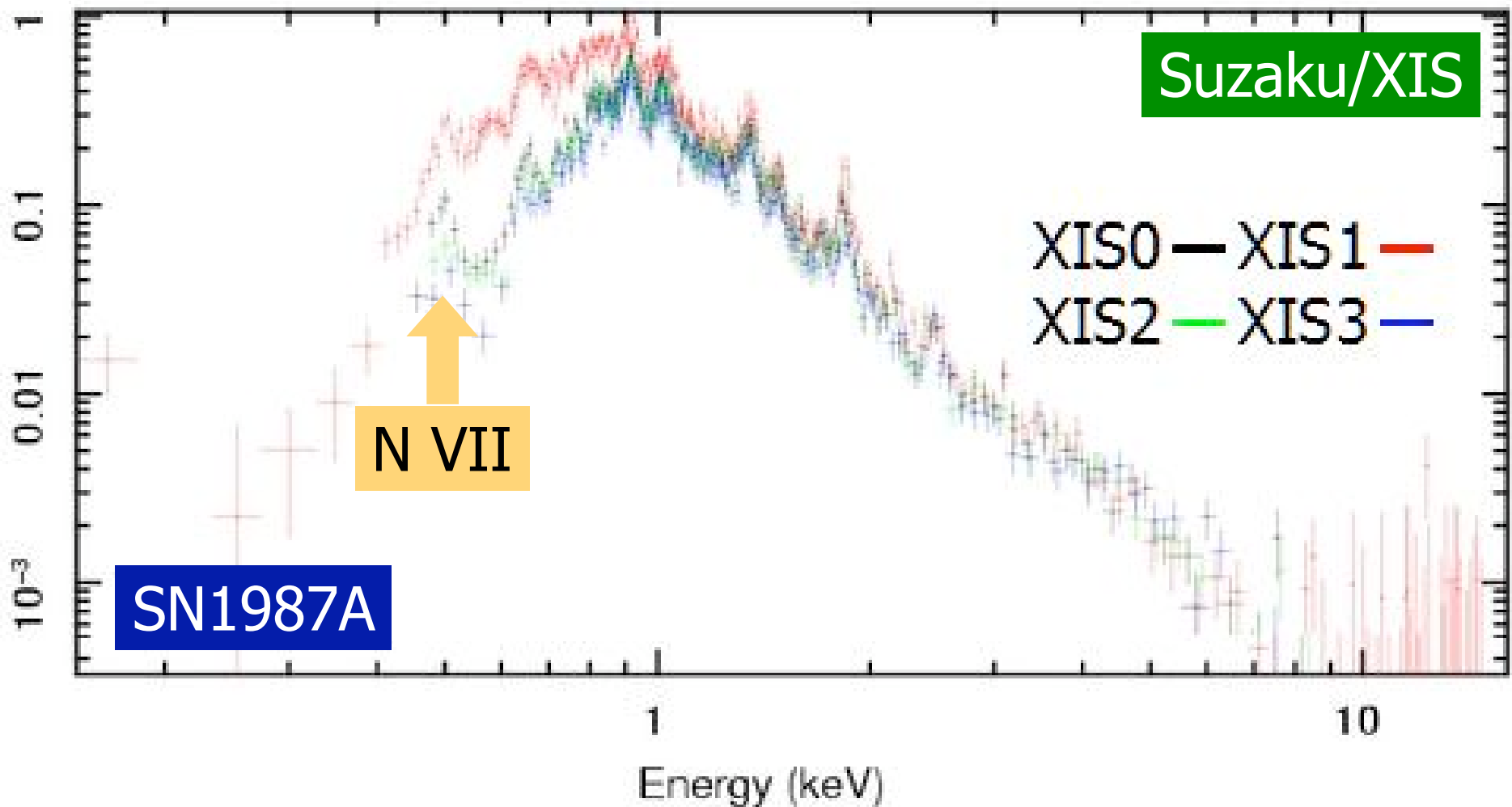
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14. Bubble – SN connection



XM

Suzaku/XIS

I [cnts]

I [cnts]

150

100

RCV

C

$\Delta I /$

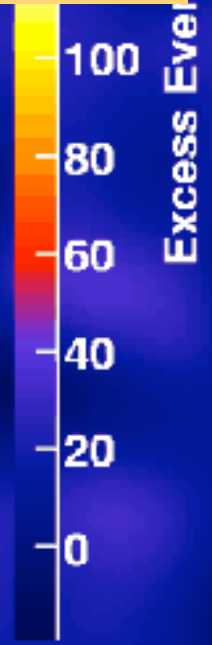
Chan

Declination (J2000)

-57° 0'
-57° 30'
-58° 0'
-58° 30'

H.E.S.S.

TeV emission
- Extended ($\sim 10'$)
- $L_\gamma = 3 \times 10^{34}$ erg/s



Excess Events

Simu

5pc@1.5kpc

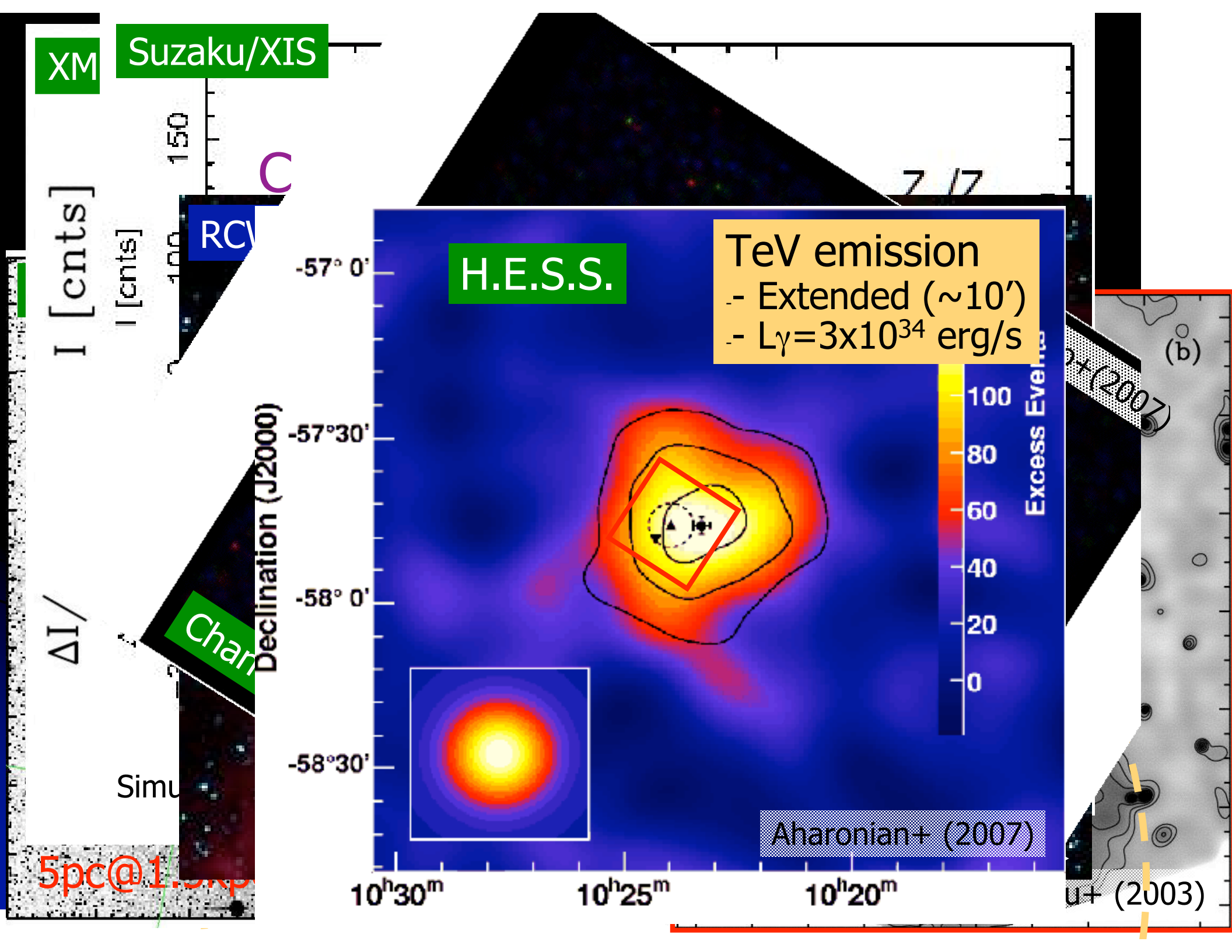
10^{h30^m}

10^{h25^m}

10^{h20^m}

Aharonian+ (2007)

u+ (2003)





Coffee

16. Summary

1. Transient & variable stars

... Some rare sources were serendipitously spotted
(Algol-type with long-term flux variation, isolated WC).

2. Diffuse Emission in HII Regions

- Pre-Suzaku: spectroscopic studies urged.
- Suzaku: spectroscopy done.
 1. Plasma parameters derived.
 2. Chemical abundance pattern determined.
 3. Some hints of the origin of the emission.

