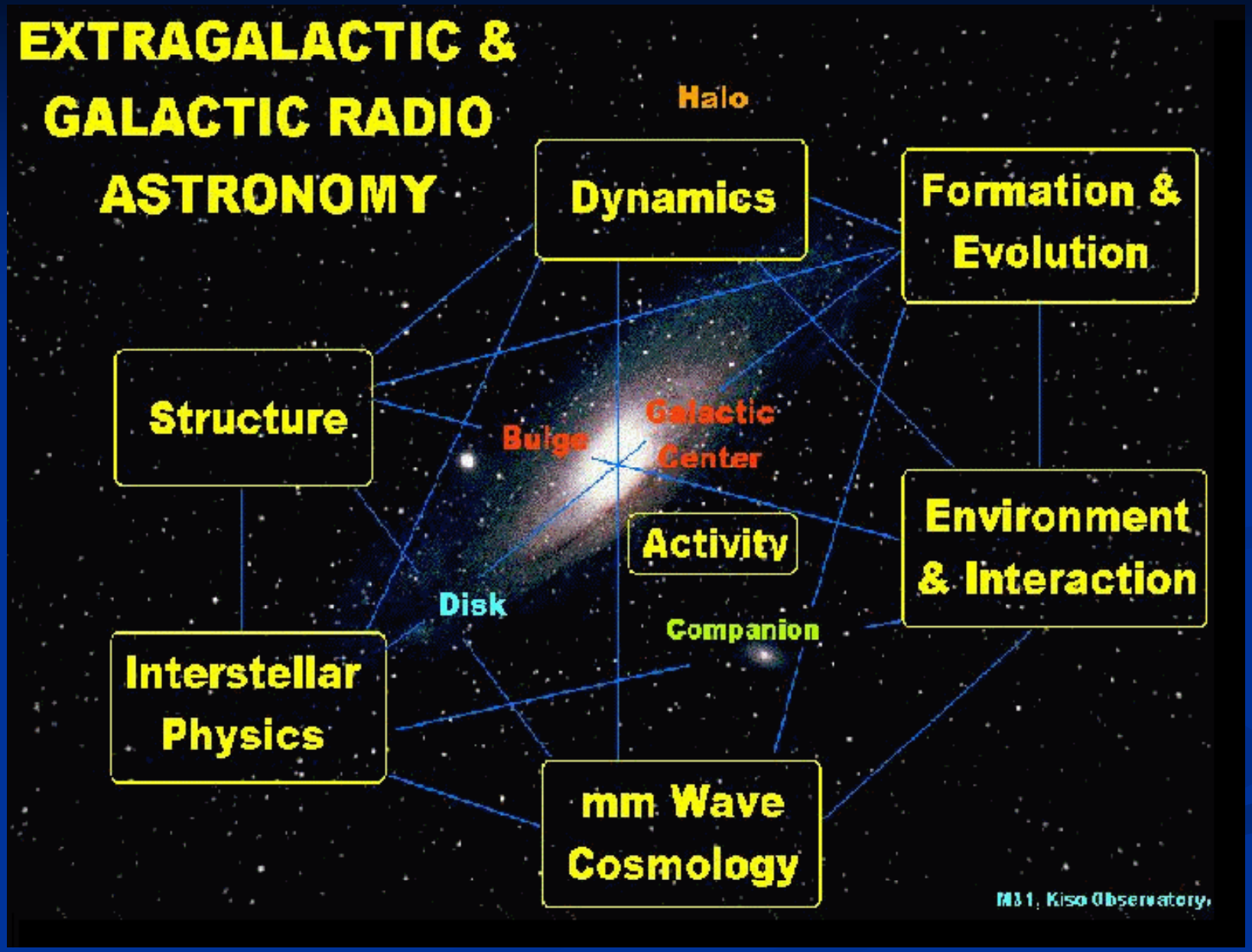
銀河系は爆発したか？

孤軍奮闘の30年論争

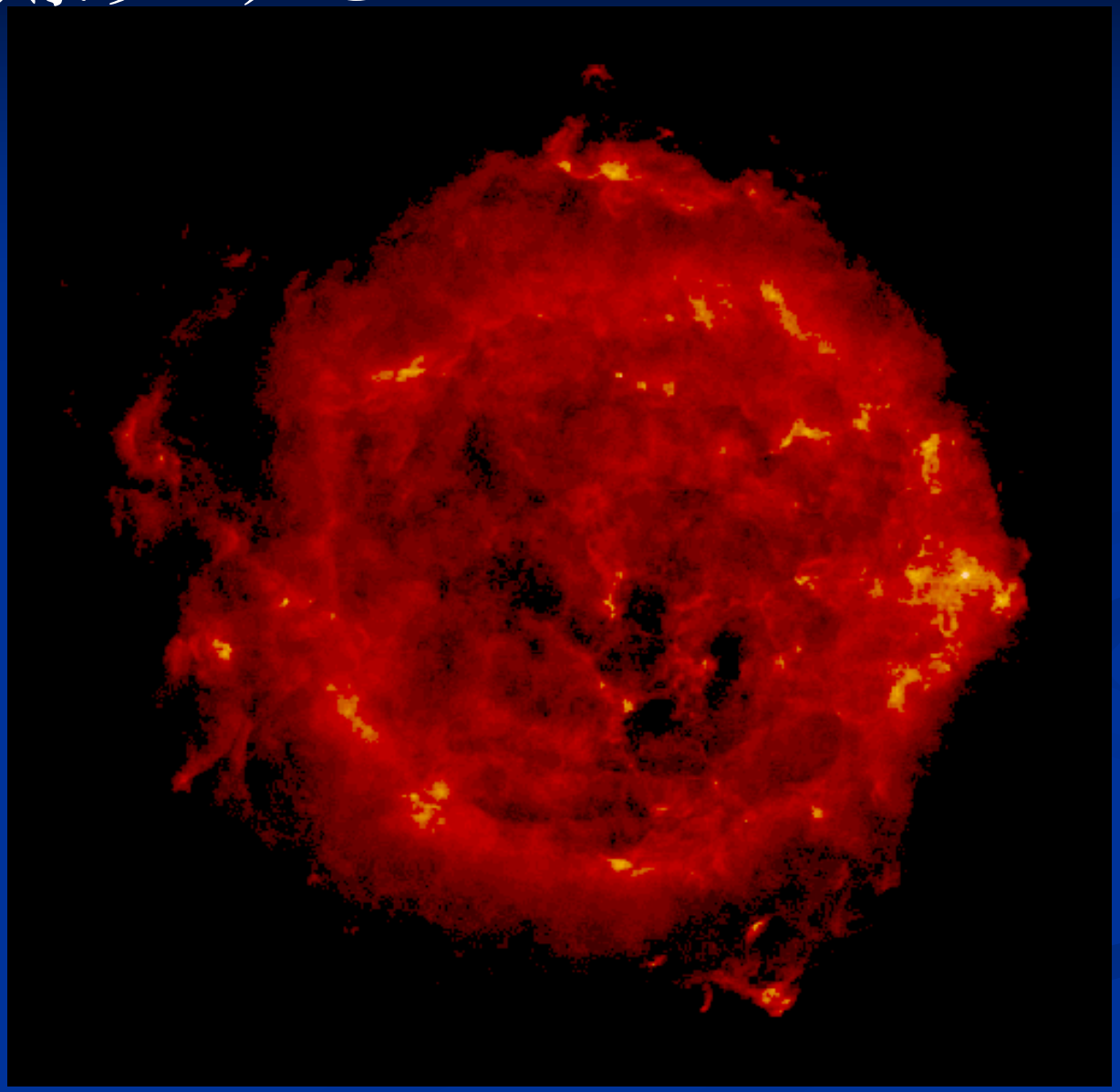
祖父江義明

2009.9.18 銀河ゼミ


EXTRAGALACTIC &
GALACTIC RADIO
ASTRONOMY
Halo
Dynamics
Formation &
Evolution
Structure
Bulge
Galactic
Center
Activity
Environment
& Interaction
Disk
Companion
Interstellar
Physics
mm Wave
Cosmology
M31, Kiso Observatory

太陽は爆発する

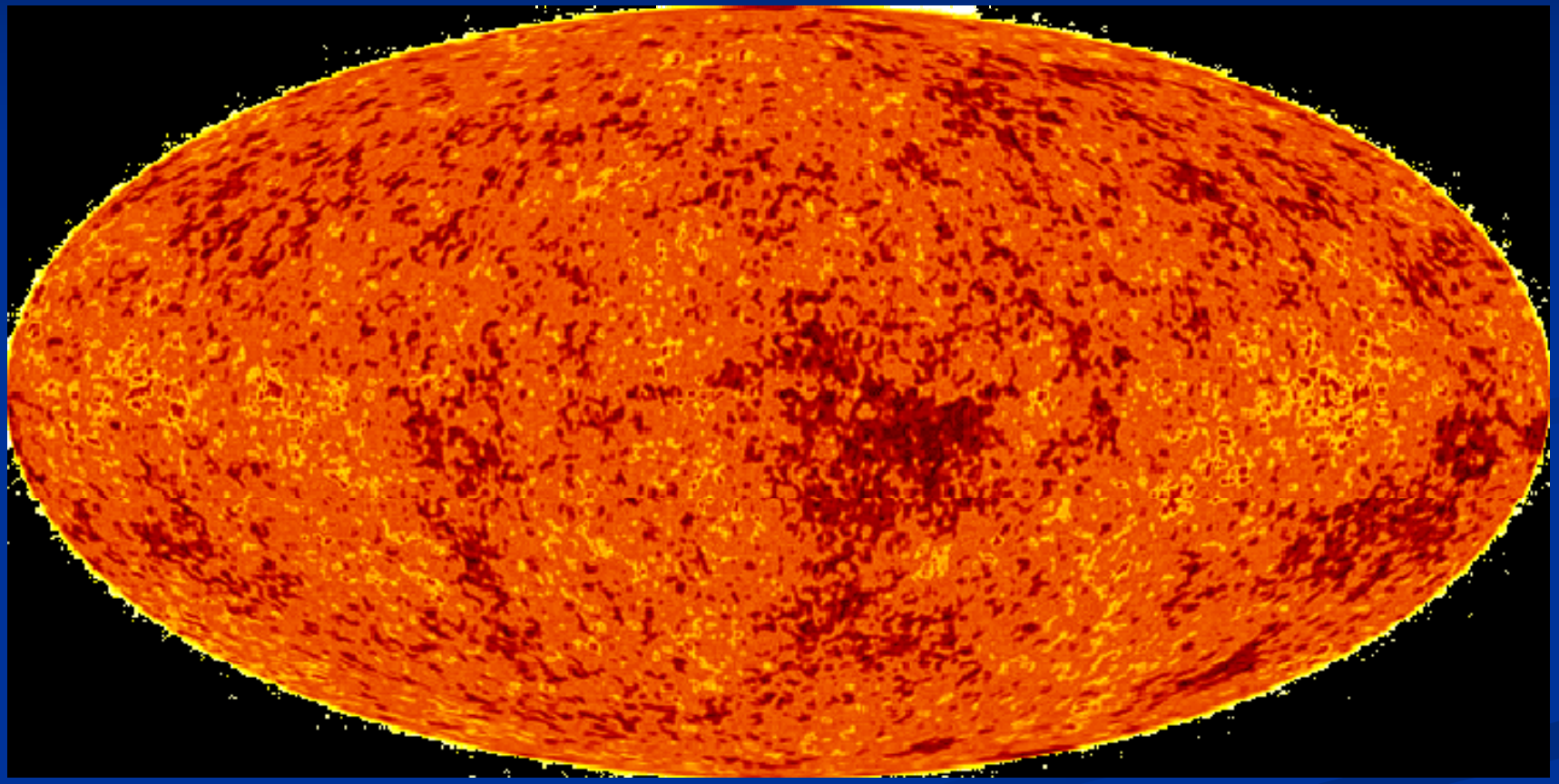
星も爆発する



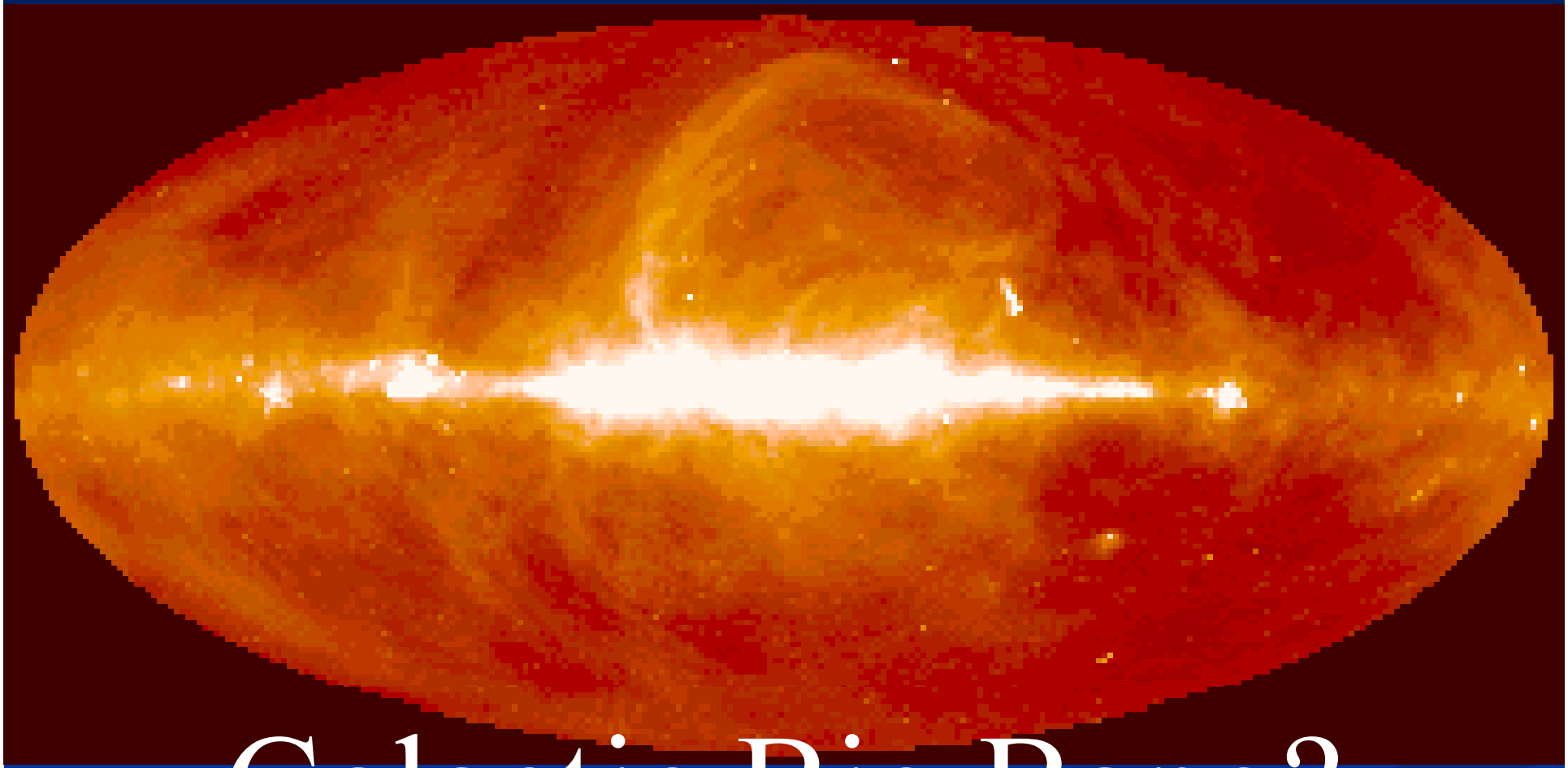
銀河は爆発する


M 82 (NGC 3034)
FOCAS (B, V, Hα)
Subaru Telescope, National Astronomical Observatory of Japan
March 24, 2000

宇宙は爆発した



では、銀河系は爆発したか



Galactic Big Bang?

本題に入る前に

SNR 説

Prof. Oort' suggestion,

Spoelstra,

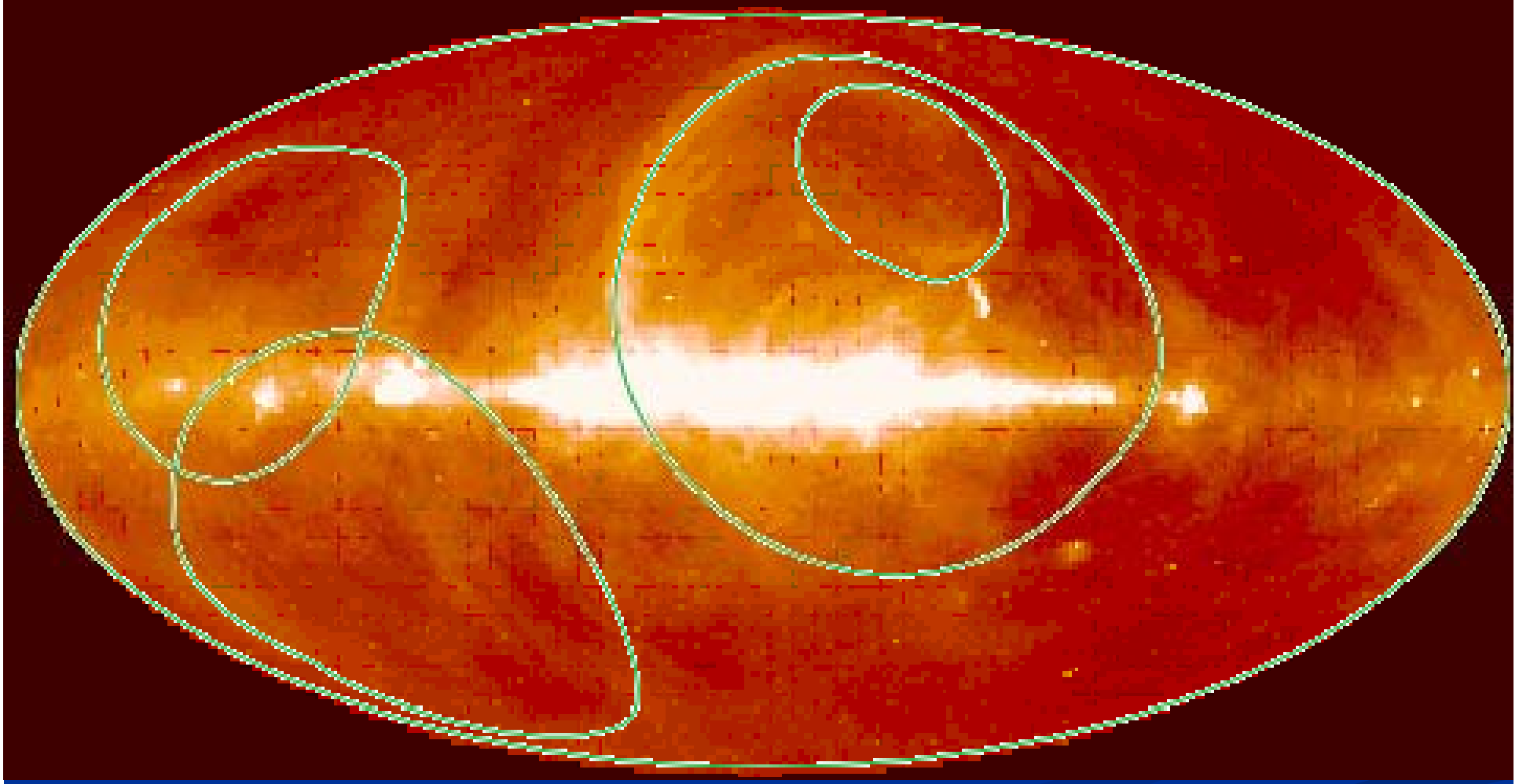
Berkhuijsen,

ROSAT PhD Thesis (SNR)….. et al.

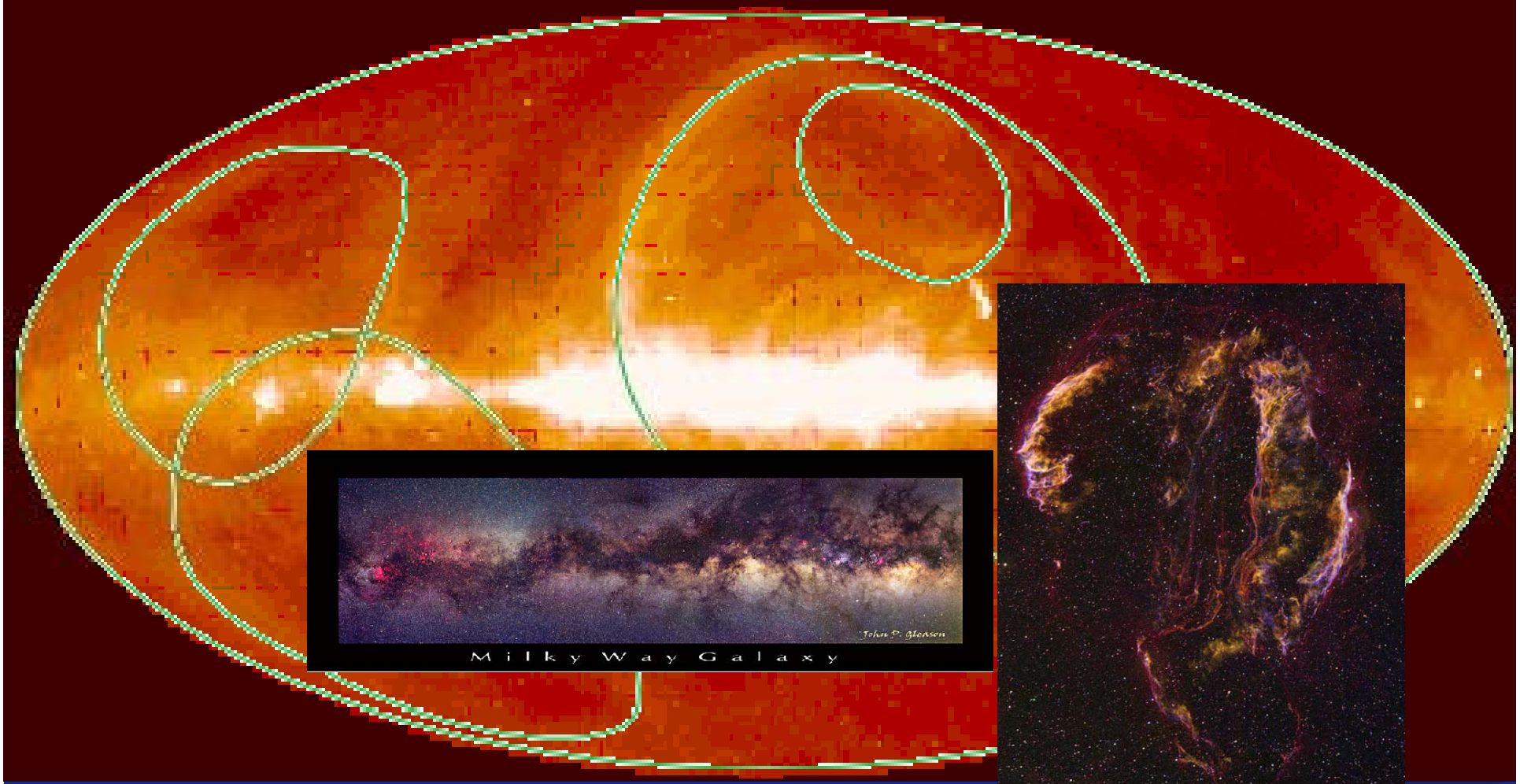
Even in Japan,

Oda, Hayakawa, ... et al

Galactic Radio Loops I, II, III, IV



Galactic Radio Loops I, II, III, IV



100pcという至近なのに光で見えない！

本当に超新星残骸か？

SNR 説

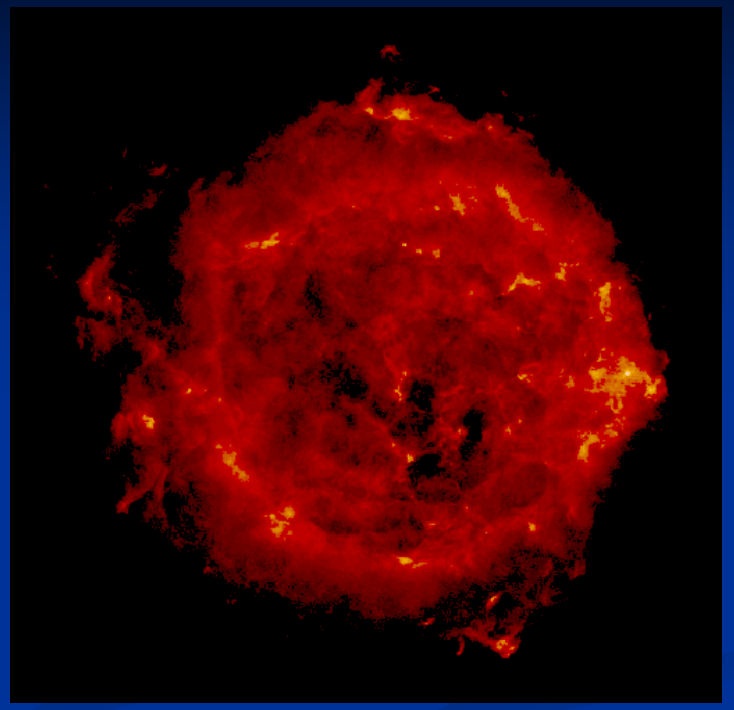
Σ—D relation

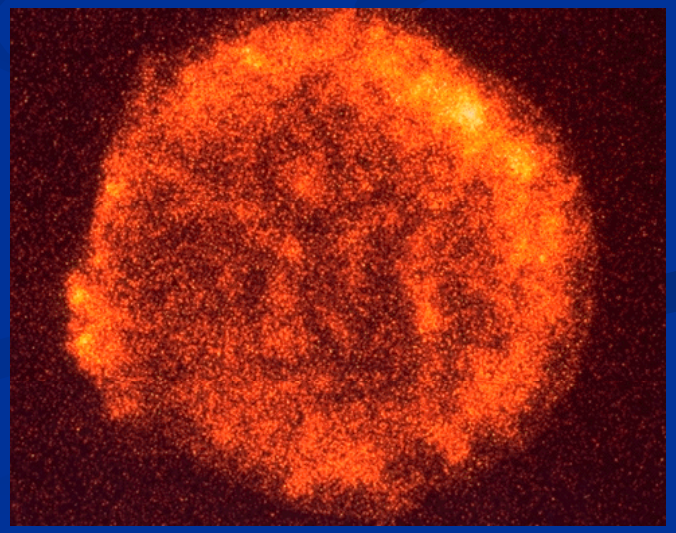
$\Sigma \sim D^{-4}$

D ~ 100 pc

Θ ~ 100 deg

Distance ~ 100 pc





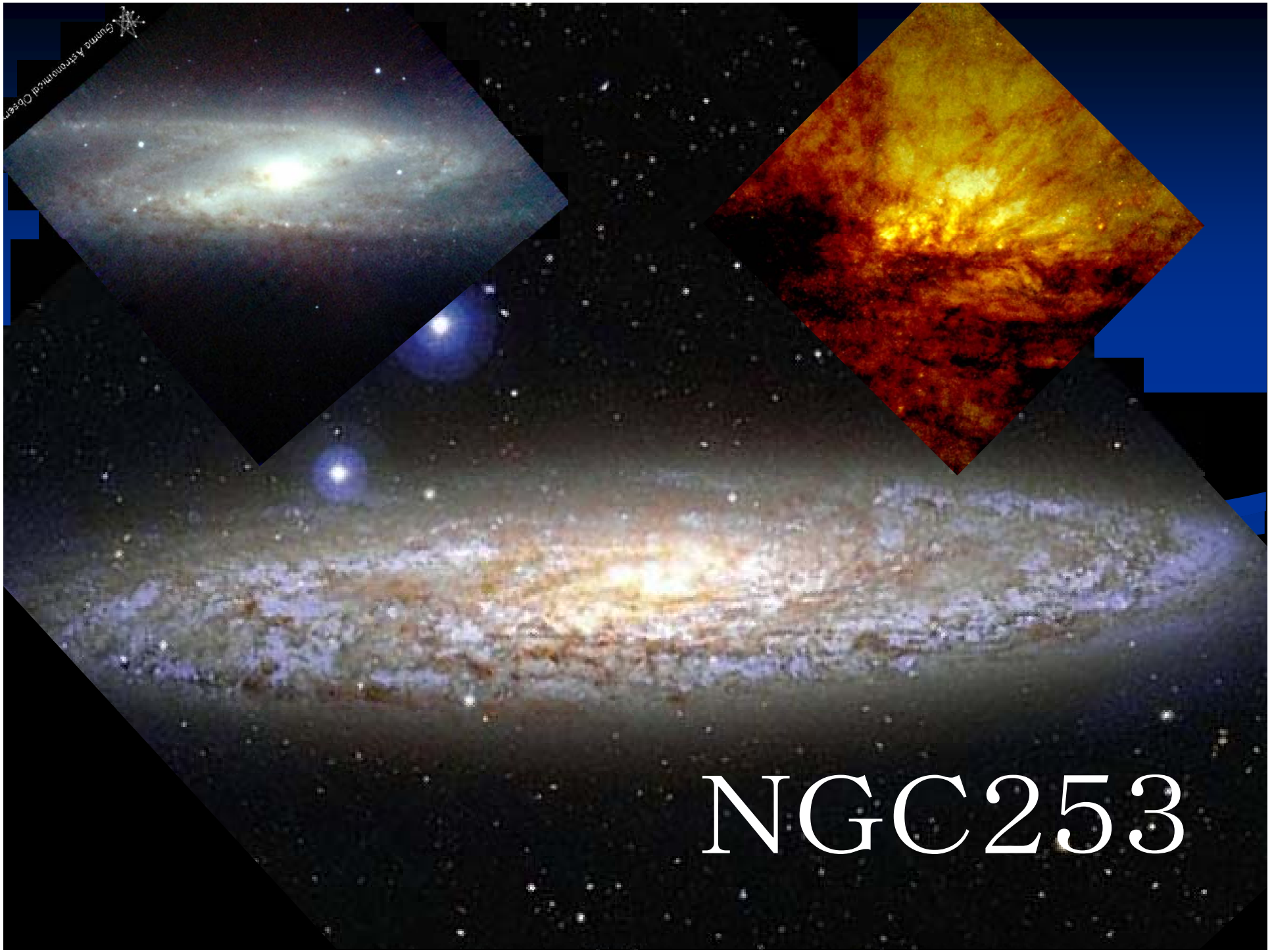
系外銀河

Starburst

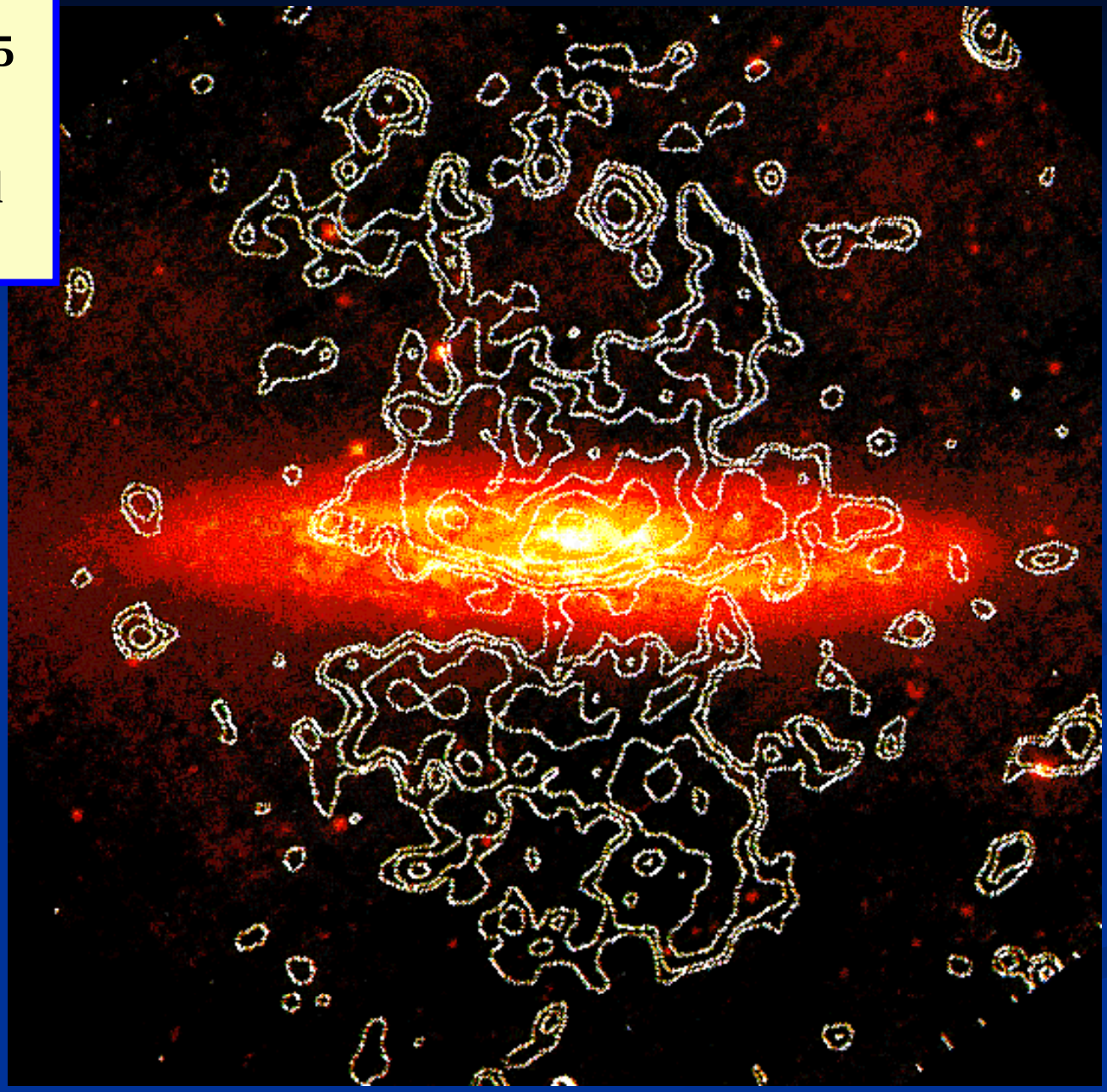
Shell / Outflow

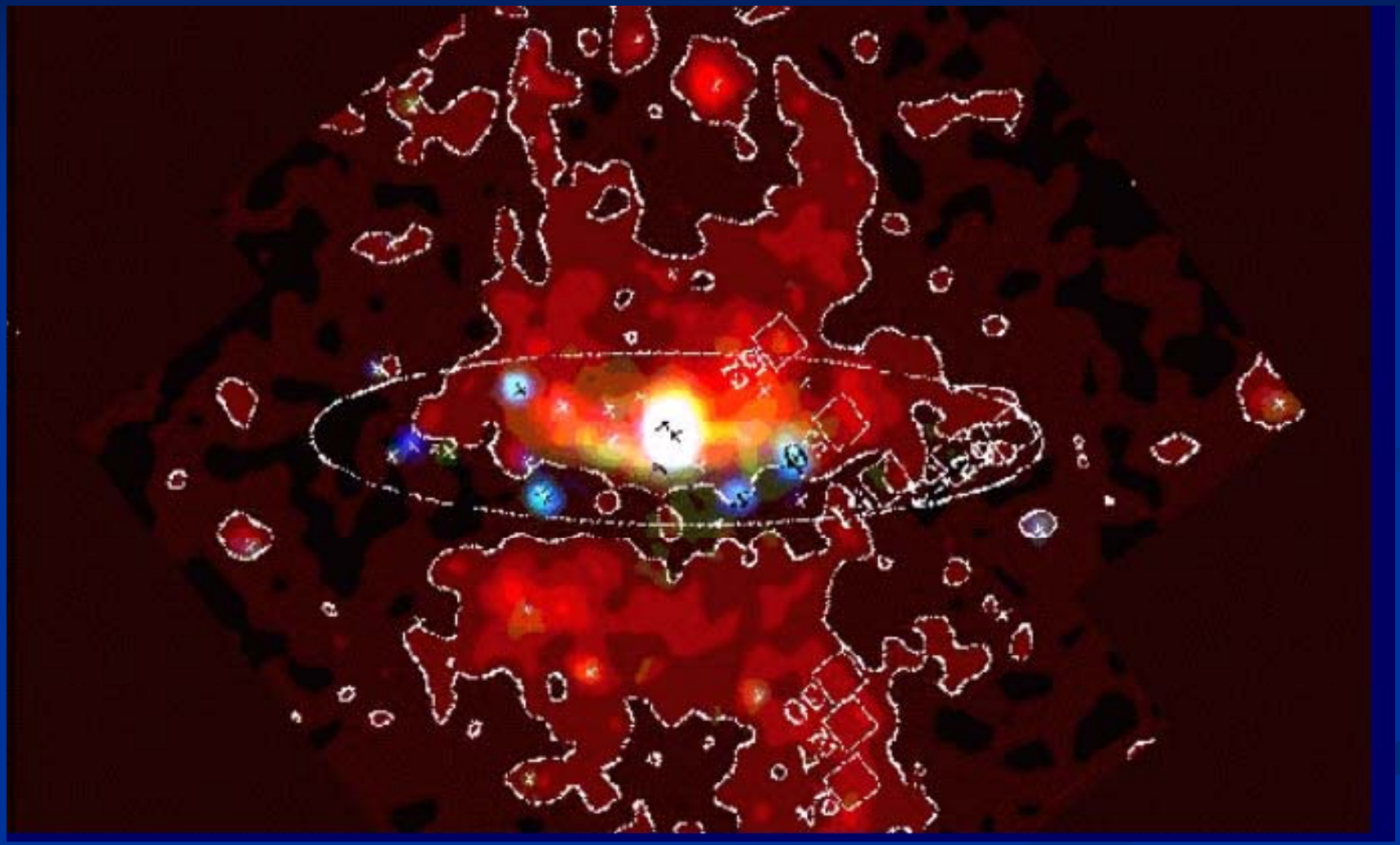
M82


M 82 (NGC 3034)
FOCAS (B, V, Hα)
Subaru Telescope, National Astronomical Observatory of Japan
March 24, 2000
Copyright© 2000 National Astronomical Observatory of Japan, all rights reserved

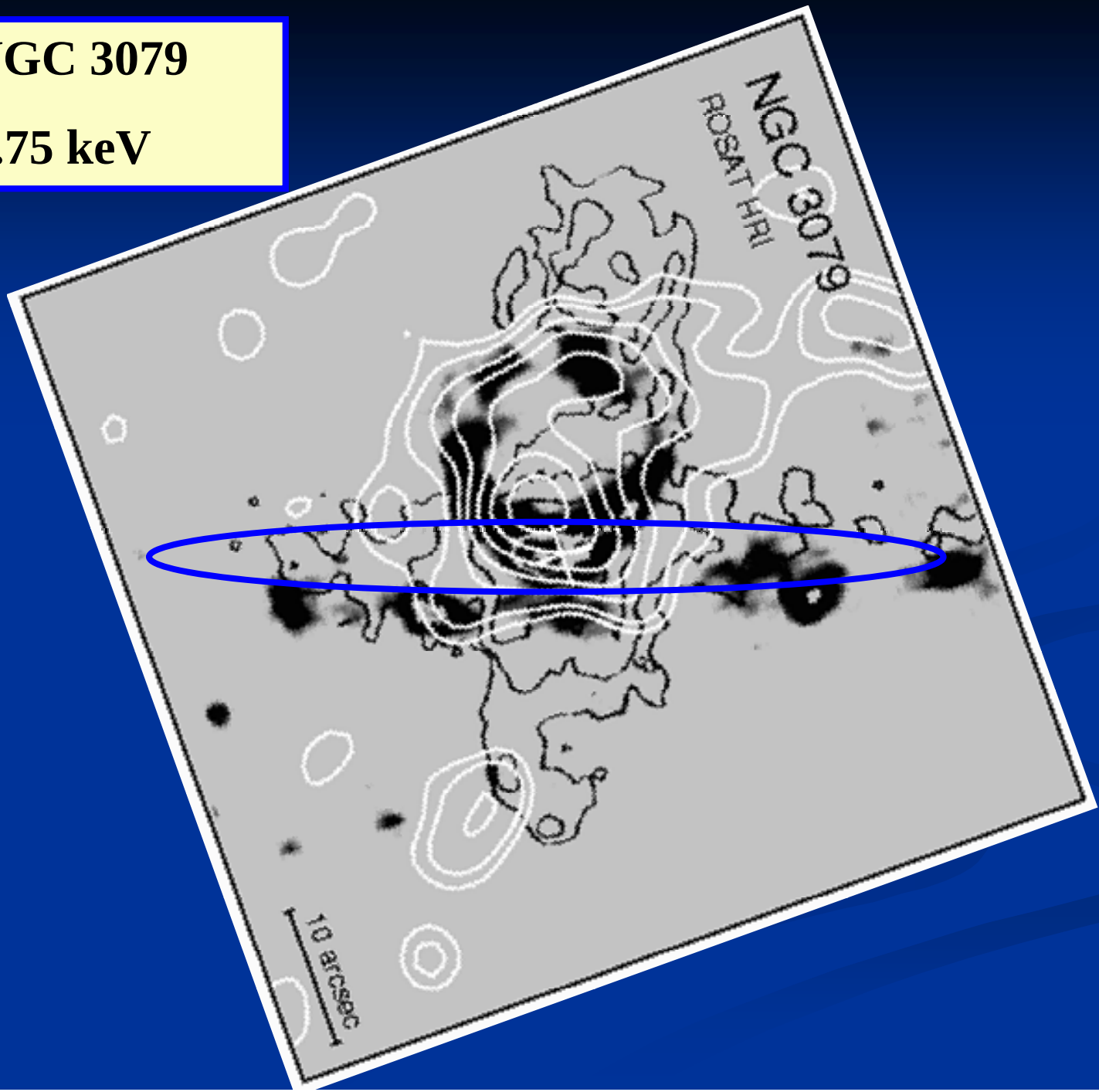

Gumma Astronomical Observ
NGC253

- **NGC 253**
- **ROSAT 0.75 keV**
- **Pietsch et al 1999**



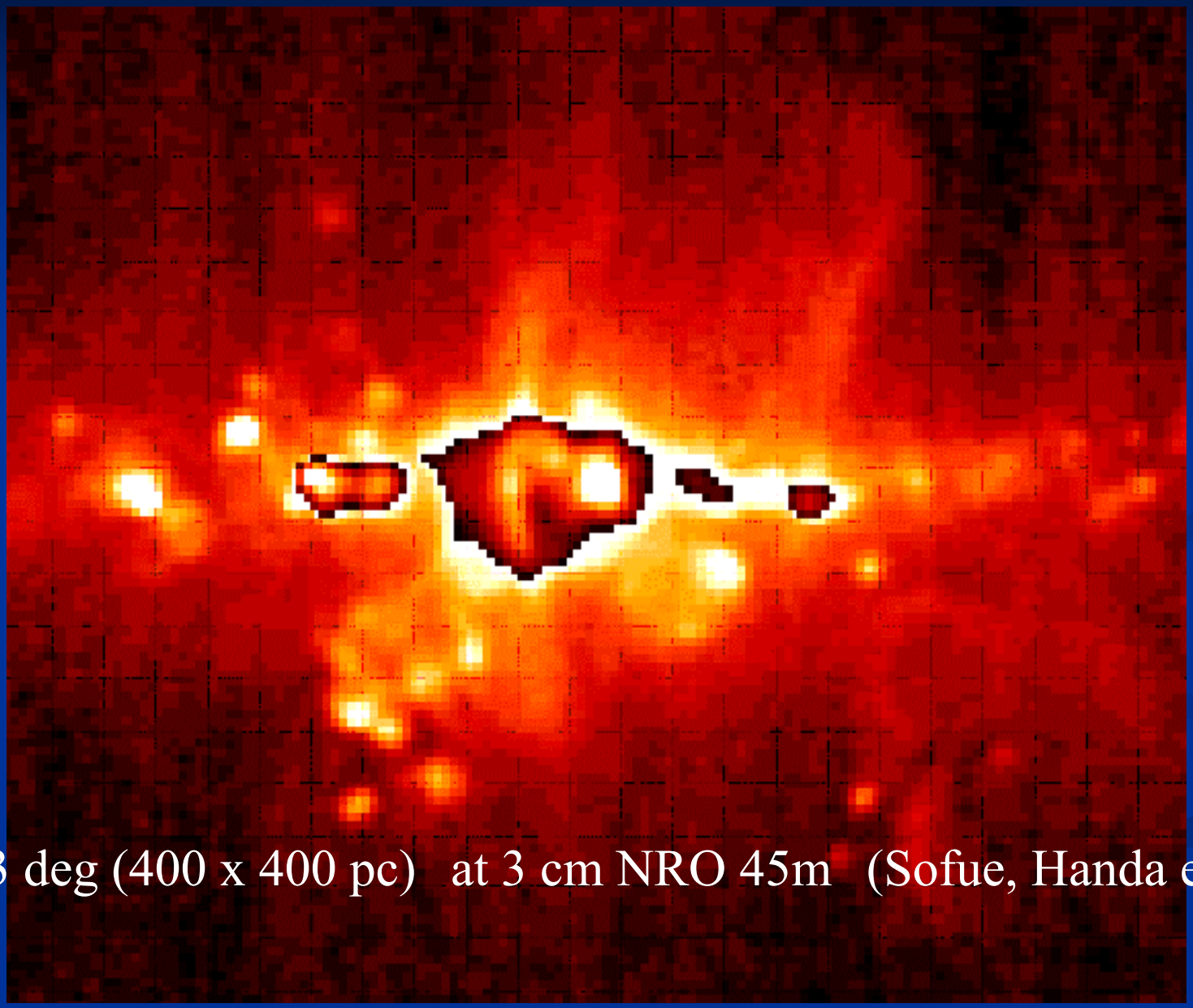


- NGC 3079
- 0.75 keV



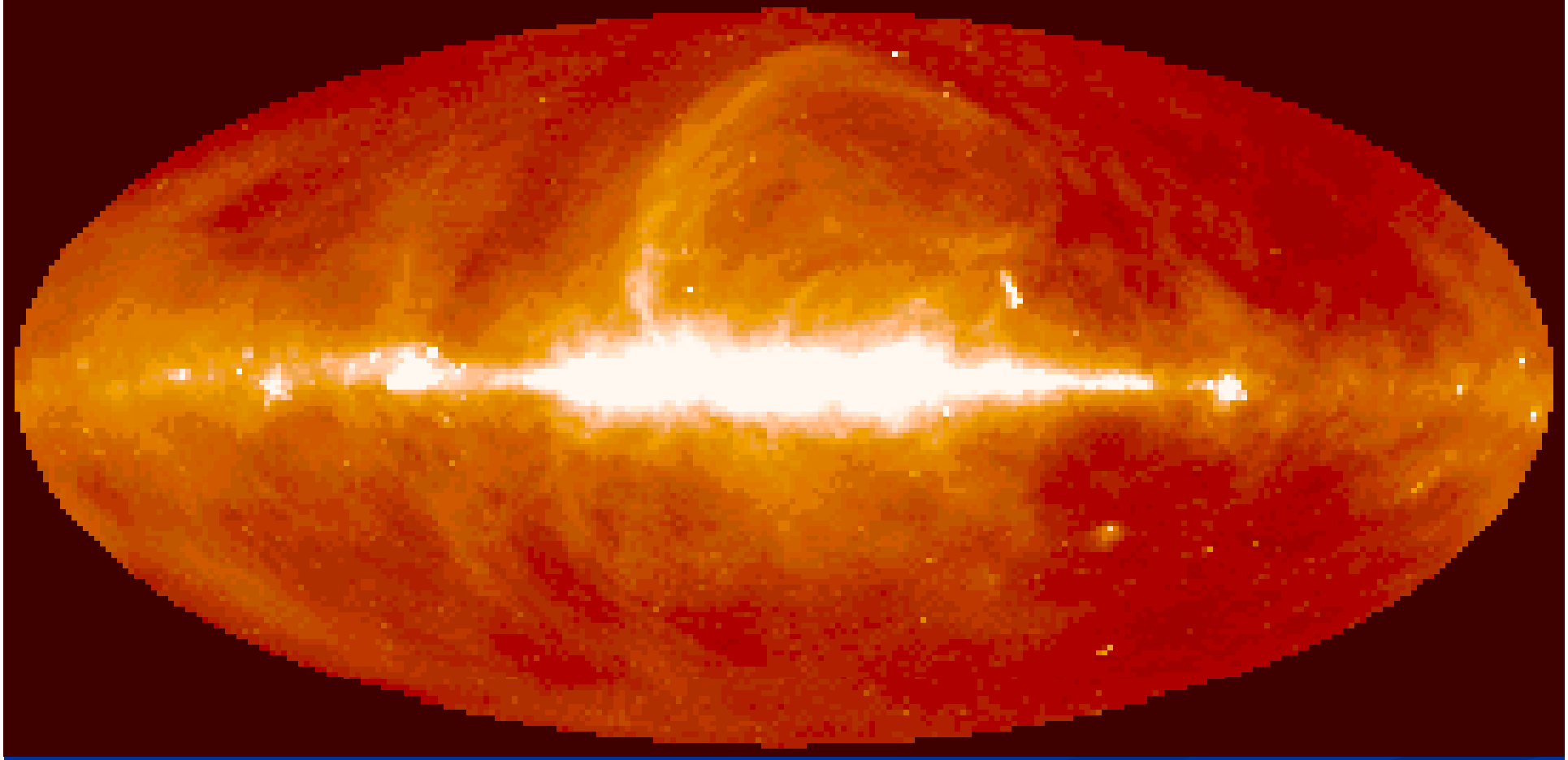
我が銀河系では？

GC ガス、磁場、宇宙線＝沸騰、噴出

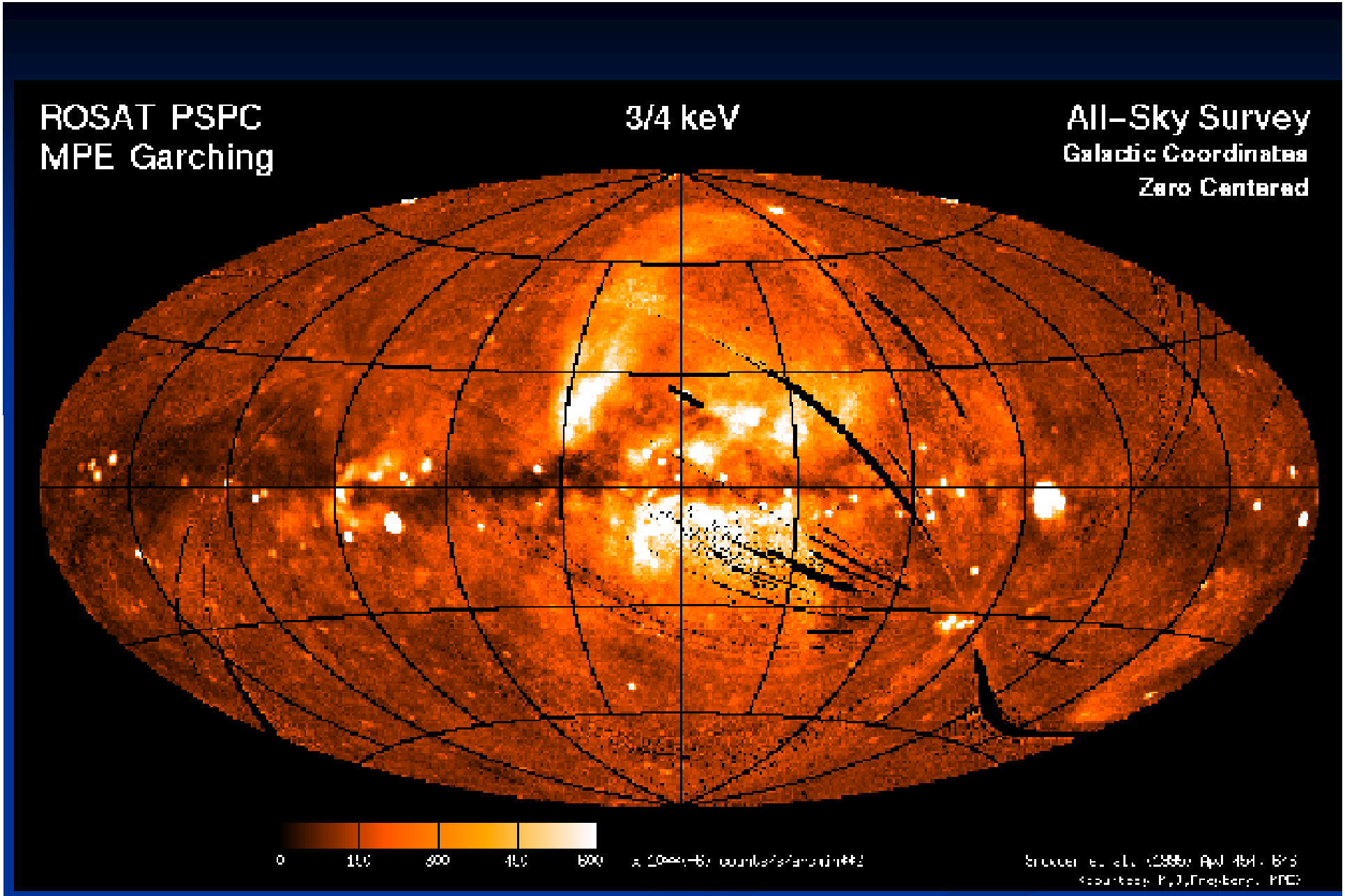


3x3 deg (400 x 400 pc)　at 3 cm NRO 45m　(Sofue, Handa et al.)

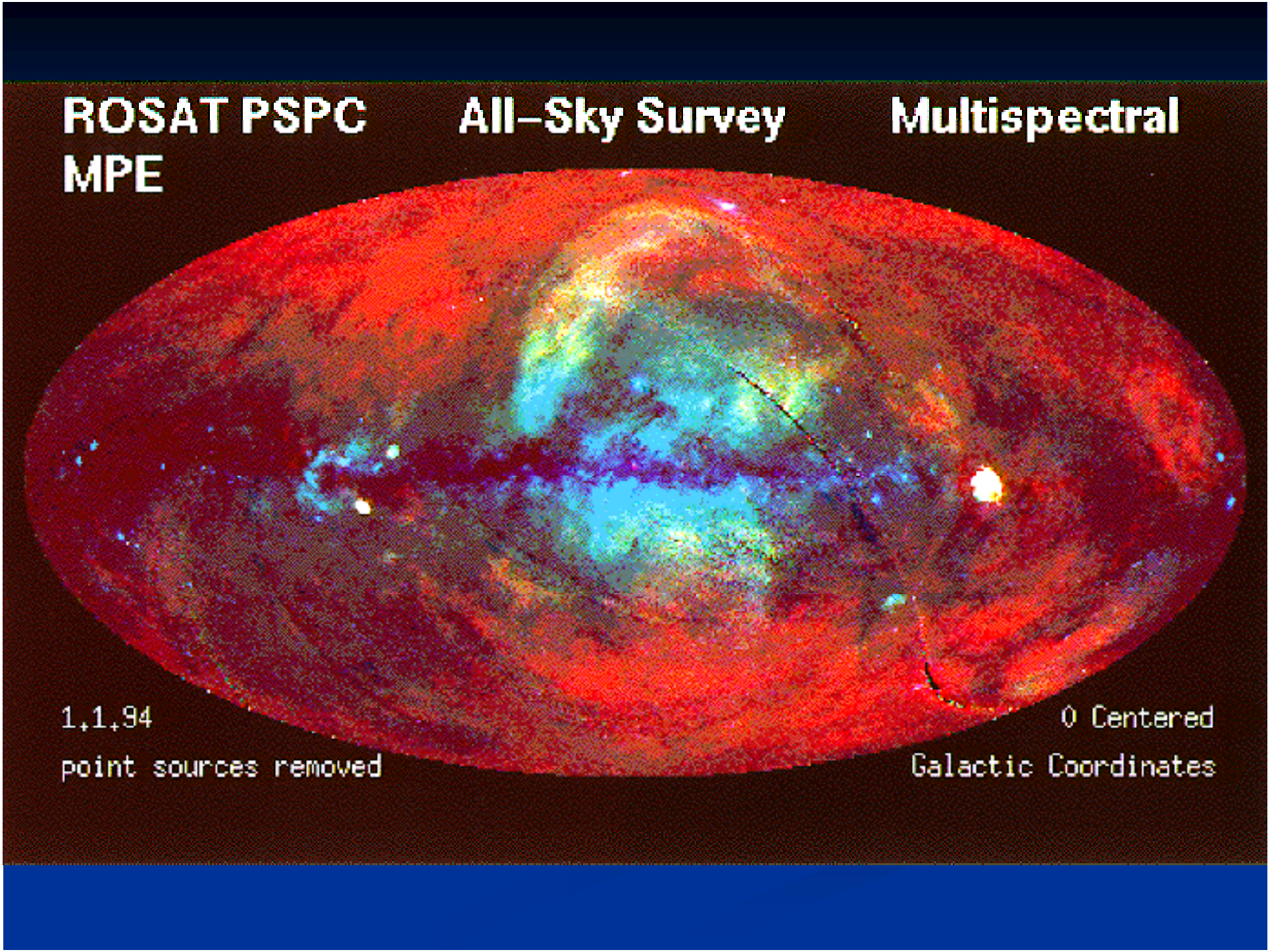
North Polar Spur 408 MHz



- 408MHz Radio
- Haslam et al 1982



- **Snowden et al 1998**


ROSAT PSPC All-Sky Survey Multispectral
MPE
1.1.94
point sources removed
0 Centered
Galactic Coordinates

Bipolar Hyper Shell Model

- Sofue 1977

• Fast MHD (compression) wave

$$\frac{dr}{dt} = V\, p_r/p,$$

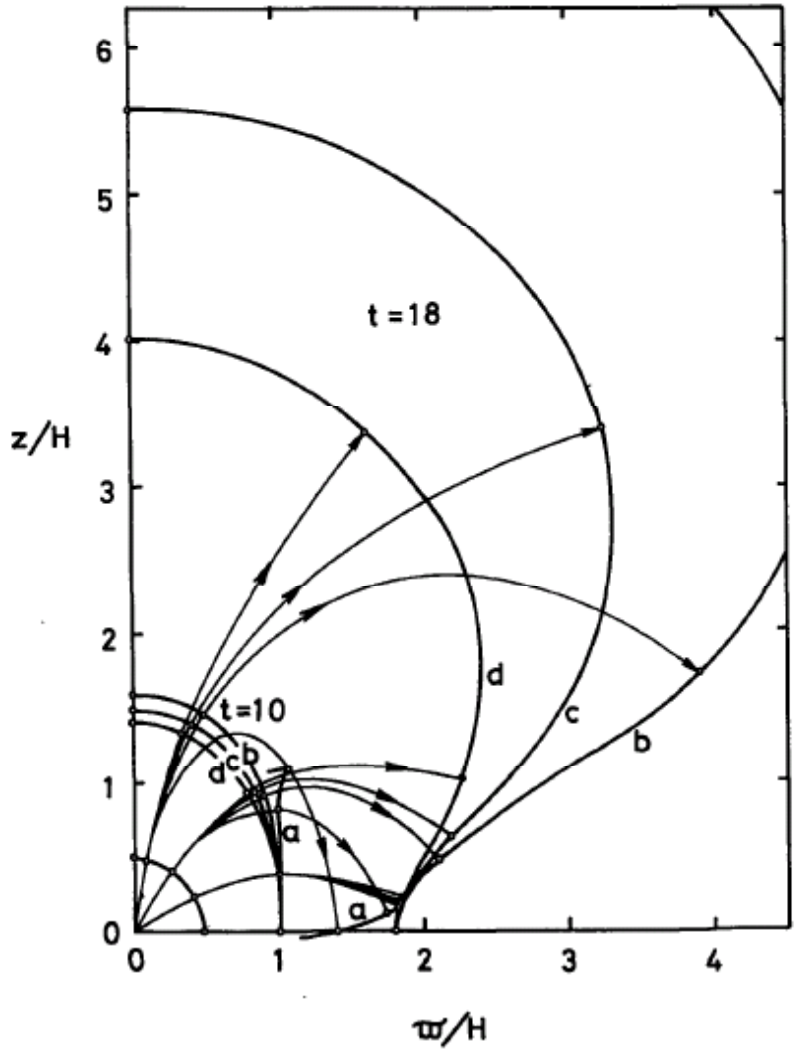
$$\frac{d\theta}{dt} = V\, p_\theta/rp,$$

$$\frac{d\phi}{dt} = V\, p_\phi/rp \sin\theta,$$

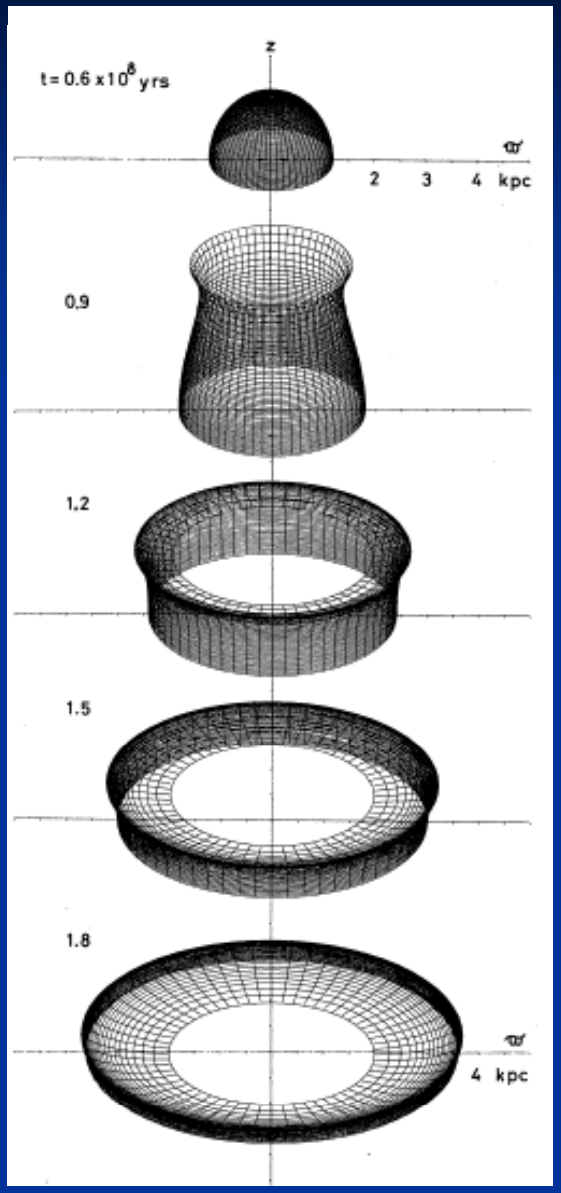
$$\frac{dp_r}{dt} = -p\frac{\partial V}{\partial r} + \frac{V}{rp}(p_\theta^2 + p_\phi{}^2),$$

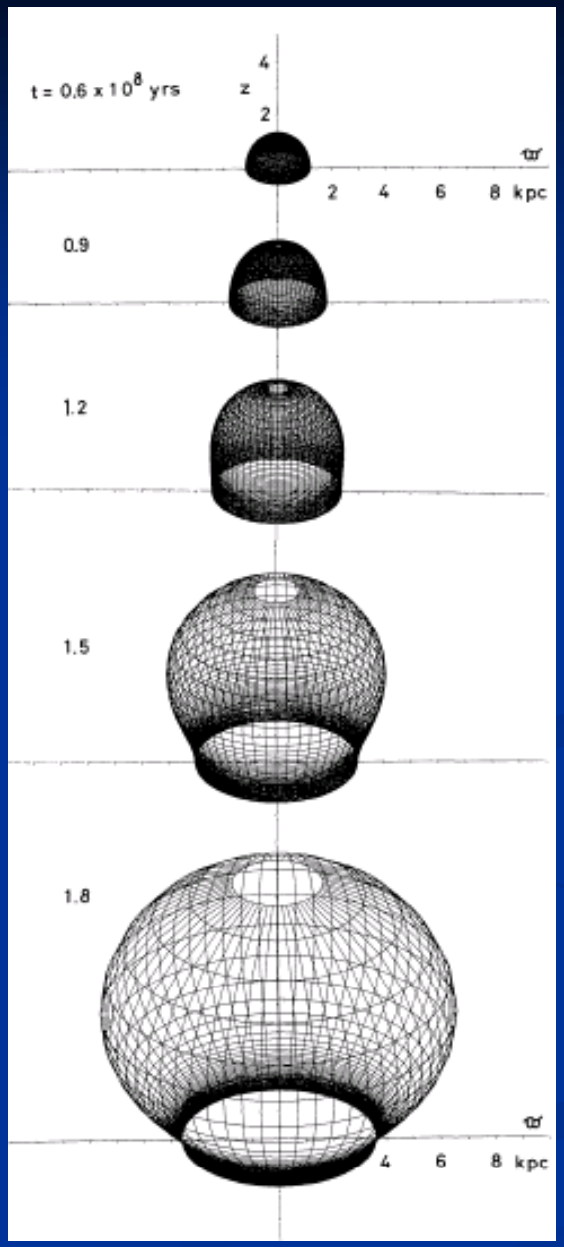
$$\frac{dp_\theta}{dt} = -\frac{p}{r}\frac{\partial V}{\partial \theta} - \frac{V}{rp}(p_\theta p_r - p_\phi{}^2 \cot\theta),$$

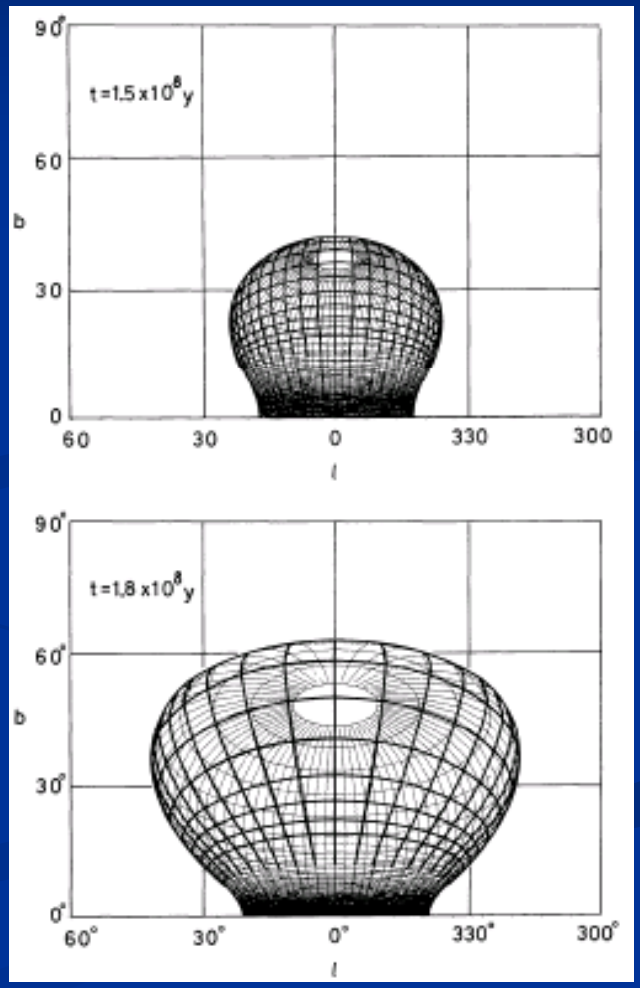
$$\frac{dp_\phi}{dt} = -\frac{p}{\sin\theta}\frac{\partial V}{\partial \phi} - \frac{V}{rp}(p_\phi p_r + p_\phi p_\theta \cot\theta),$$



- **Sofue 1977**


t = 0.6 x 10^8 yrs
z
ϖ
2 3 4 kpc
0.9
1.2
1.5
1.8
4 kpc


t = 0.6 x 10^8 yrs
z
4
2
ϖ
2 4 6 8 kpc
0.9
1.2
1.5
1.8
4 6 8 kpc


90°
t=1.5 x 10^8 y
60
30
0
b
60 30 0 330 300
l
90°
t=1.8 x 10^8 y
60°
30°
0°
b
60° 30° 0° 330° 300°
l

Radial-ray adiabatic Shock Sakashita, Moellenhoff method

$$E = \int_0^R \frac{P}{\gamma - 1} 4\pi r^2 dr + \int_0^R \frac{1}{2} \left(\frac{\partial r}{\partial t}\right)^2 \rho_0 4\pi r_0^2 dr_0 .$$

$$E = \frac{1}{3(\gamma+1)^2} \left(\frac{4(2\gamma-1)}{(\gamma-1)} JR\ddot{R} + \left\{ \left[2IR + \frac{8\gamma}{(\gamma+1)} + 3 \right] J + \frac{2M(\gamma+1)}{(\gamma-1)} \right\} \dot{R}^2 \right) .$$

Here,

$$I = \left(\frac{4\pi}{r_0} \frac{d\rho_0}{dr_0} \right)_R ,$$

$$J = \int_0^R \rho_0 4\pi r_0^2 dr_0 ,$$

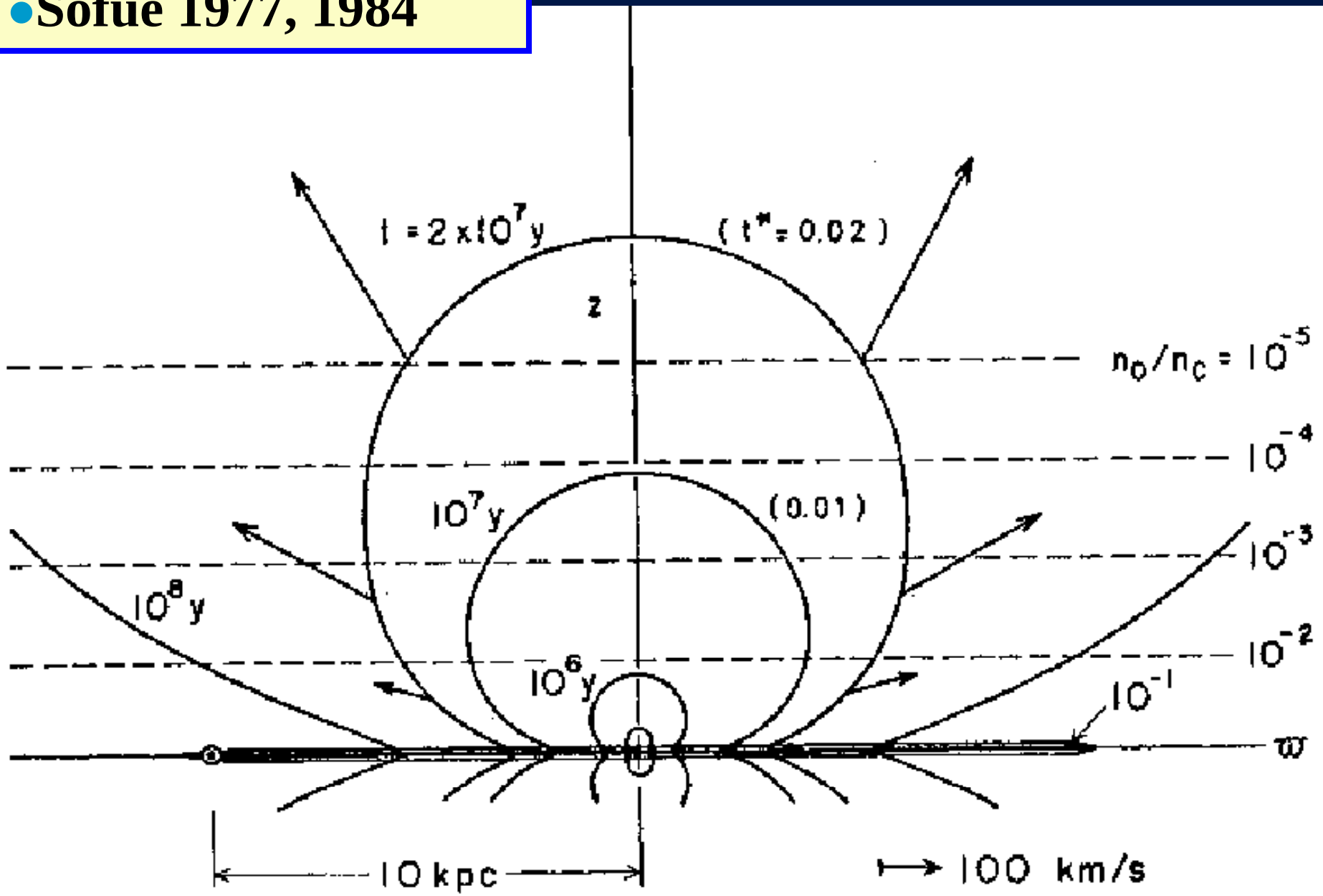
and

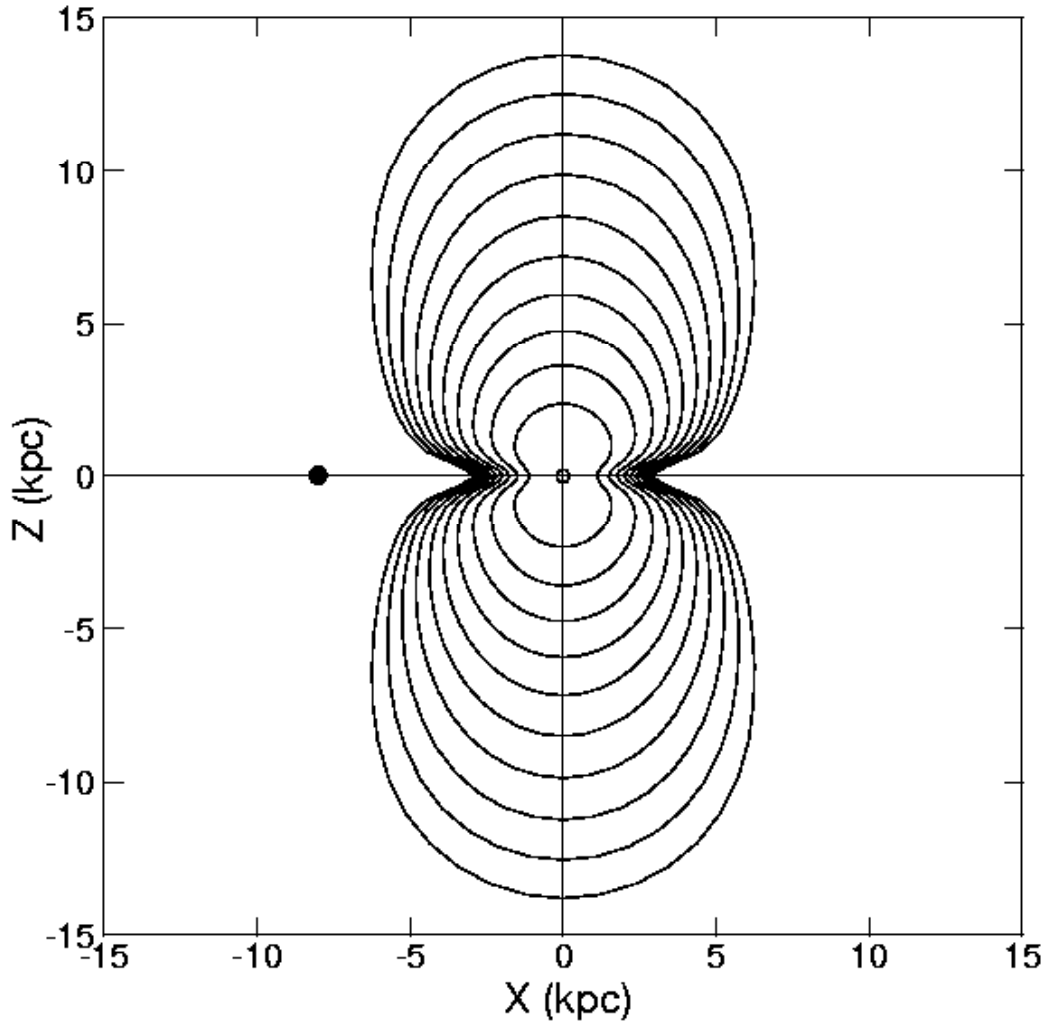
$$M = \rho_0 \frac{4\pi}{3} R^3 .$$

$$\rho_0 = \rho_1 \exp(-z/z_1) + \rho_2 \exp(-z/z_2) + \rho_3 .$$

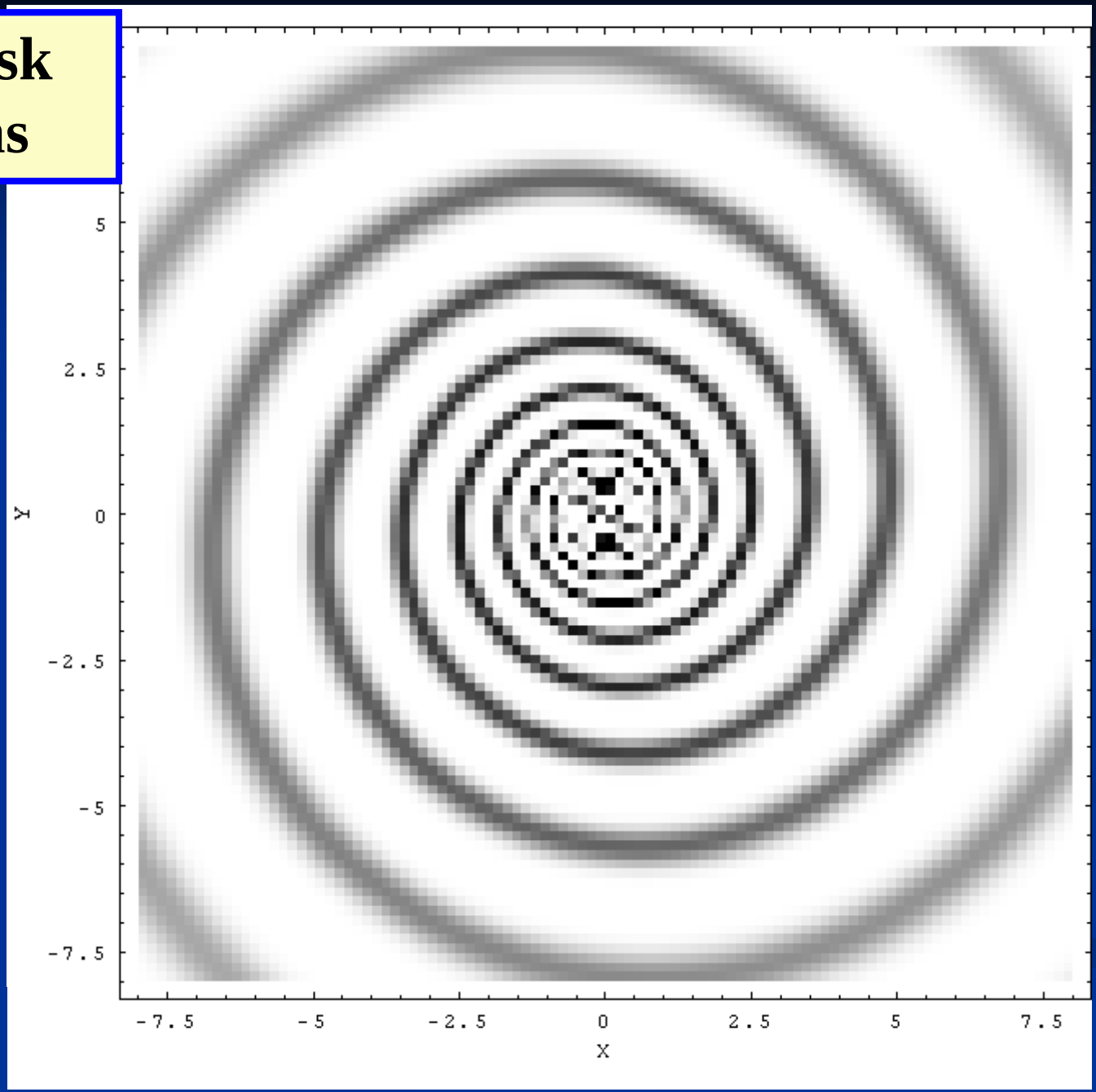
Bipolar Hyper Shell Model

- **Sofue 1977, 1984**




15
10
5
0
-5
-10
-15
Z (kpc)
-15
-10
-5
0
5
10
15
X (kpc)

- **HI Disk & Arms**



エネルギー

$E \sim 10^{55\text{-}56}$ ergs $\sim 10^{4\text{-}5}$ SN

$t \sim 10^{6\text{-}7}$ yr

衝撃波 $E \sim 1/2\, Mv^2 \sim 4\pi/3\, \rho r^3 v^2$

$\rho \sim 10^{-3}$ H/cc (Halo)

$r \sim 5$ kpc

$M \sim 10^7 M_\odot$

$v \sim$ 200-300 km/s

$T \sim 10^7$ K→ ソフトX線

Simulation 1

Radio synchrotron radiation

Compared with whole-sky 408 MHz map

Radio emissivity

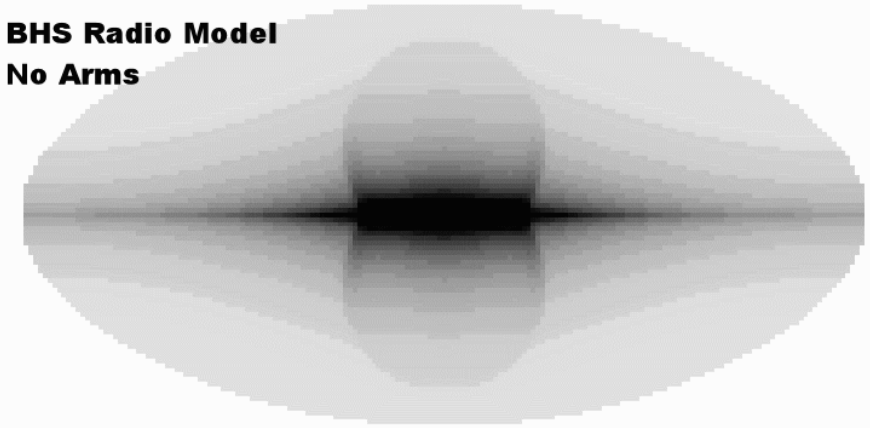
B-CR equipartition

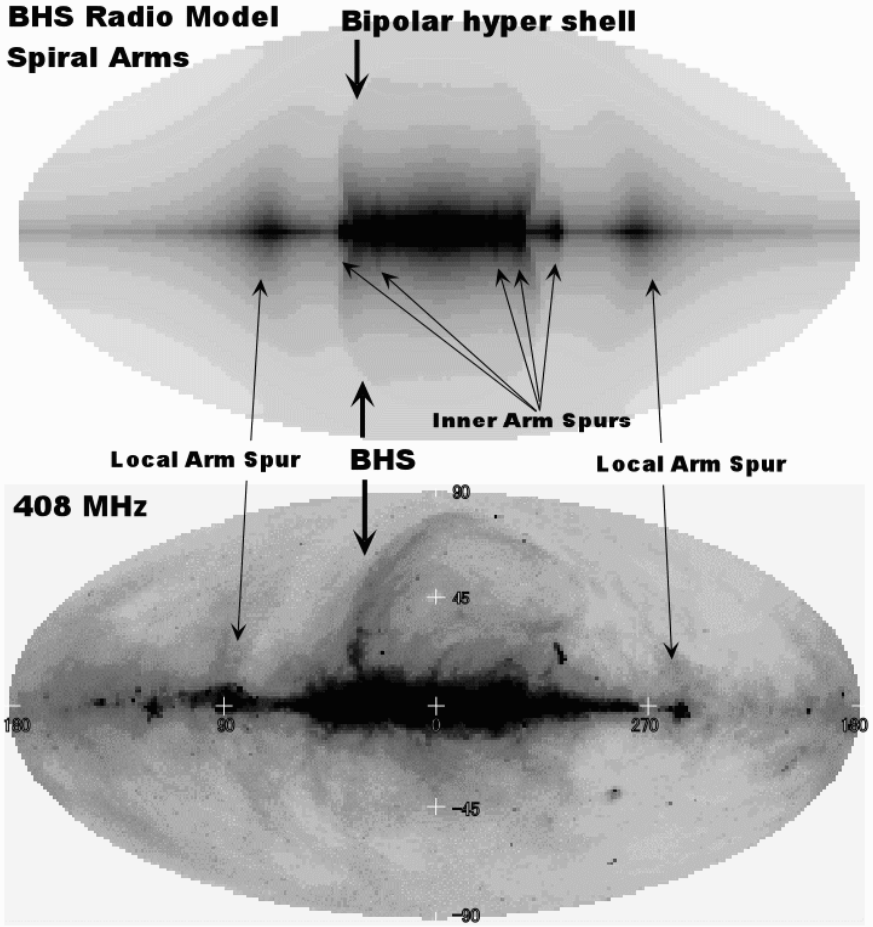
$$\varepsilon \propto B^{\gamma} \propto \rho^{\alpha}$$

- Radio
- No arm

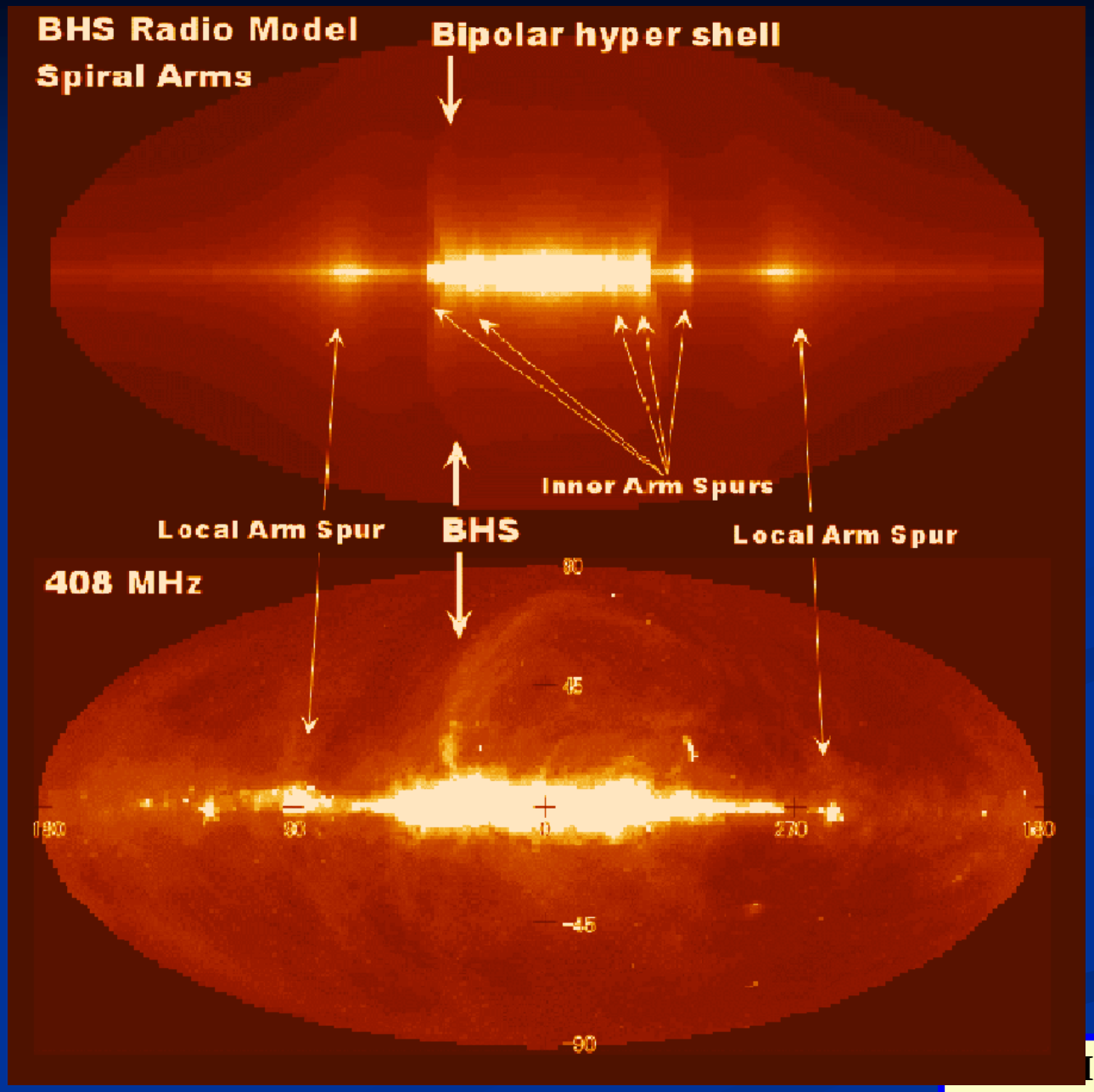
- Radio
- Arms

- Obs.
- 408 MHz Obs.





- Radio



Iz Radio

- Haslam et al 1982

Simulation 2

0.25, 0.75, 1.5 keV Soft X-rays

Emissivity $\varepsilon \propto \rho^2 T^{0.5}$

Transfer: Absorption by metals in HI Disk

$$dI/ds = \varepsilon - \kappa I$$

$$\kappa ds = d\tau = n_H ds / N_{H,0}$$

X-ray Absorption

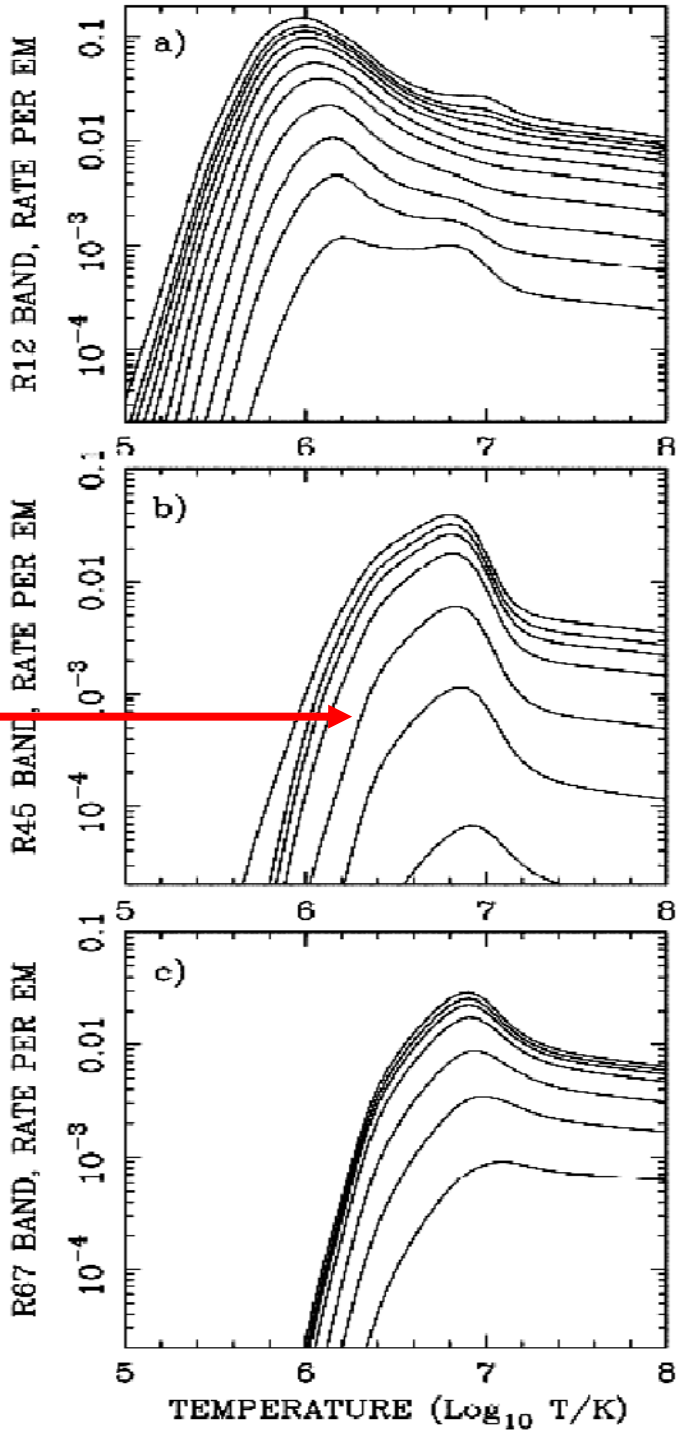
κat 0.25, 0.75, 1.5 keV

0.75 keV:

$\tau=1$ for

$N_{H,0}=3\times10^{21}$ H cm^{-2}

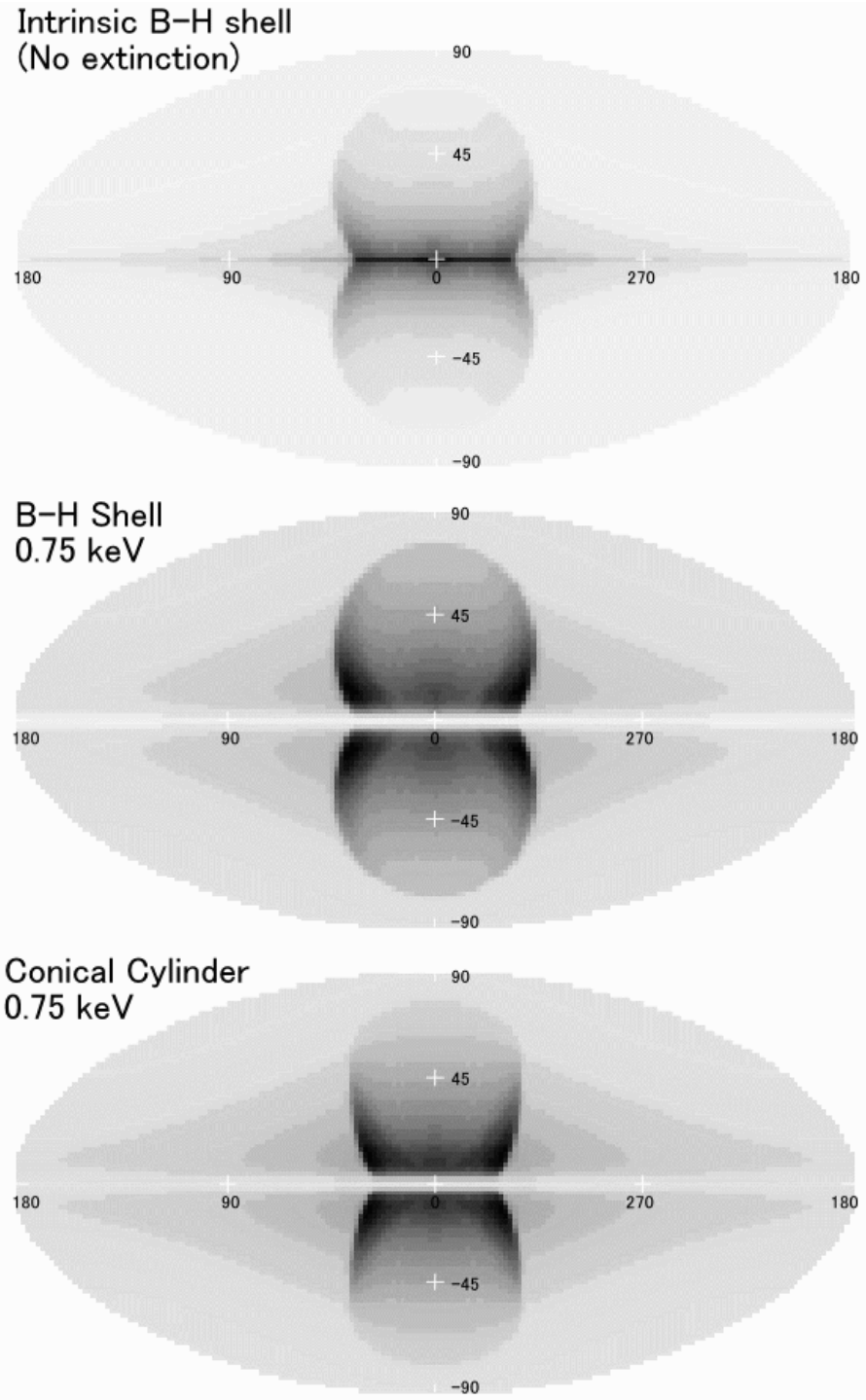
$=1$ kpc x 1 H cm^{-3}



- 1.5 keV
- No arm

- 0.75 keV
- No arm

- 0.75 keV
- No arm
- Cylinder/Cone

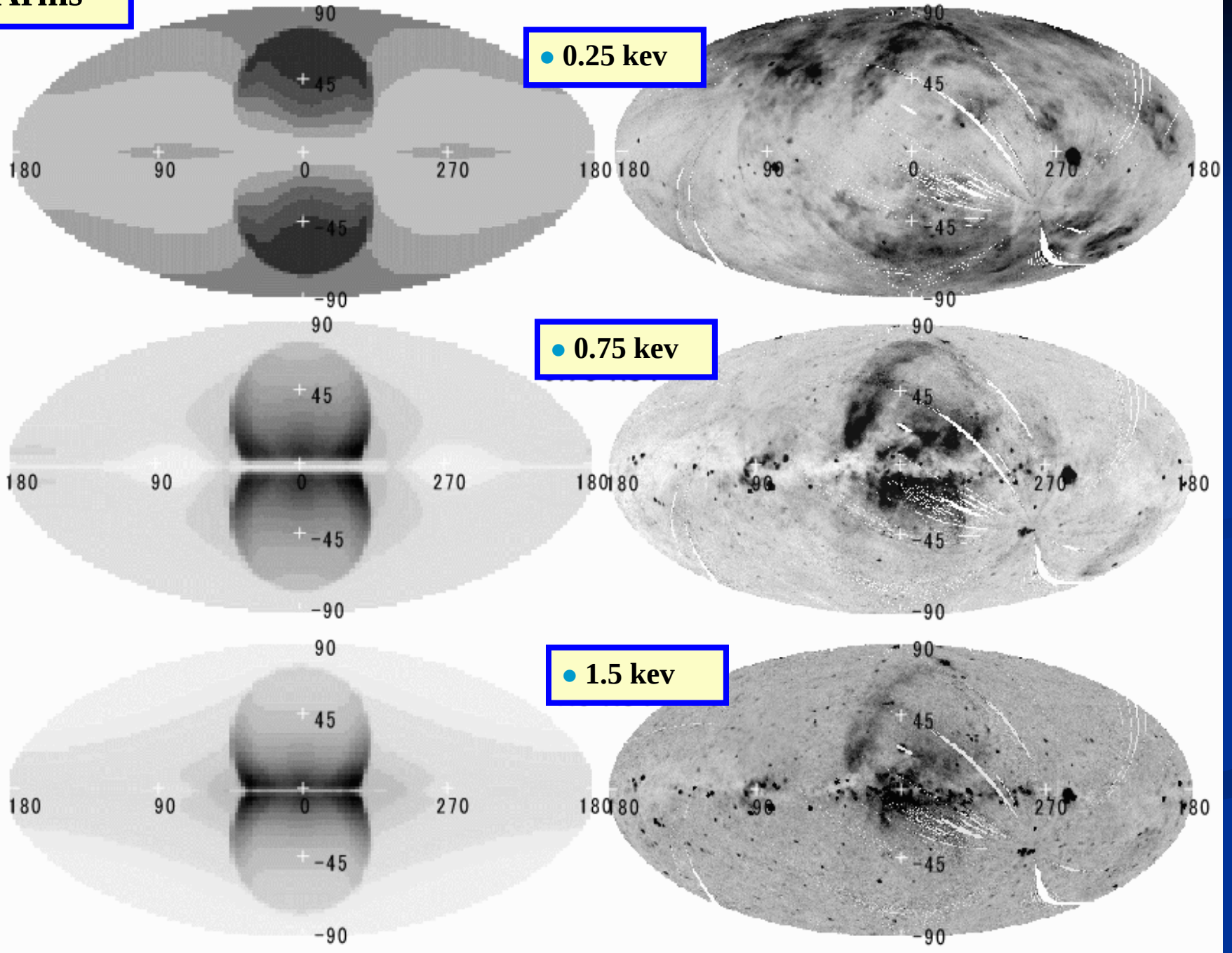


- **Arms**

Bipolar Hyper Shell Model

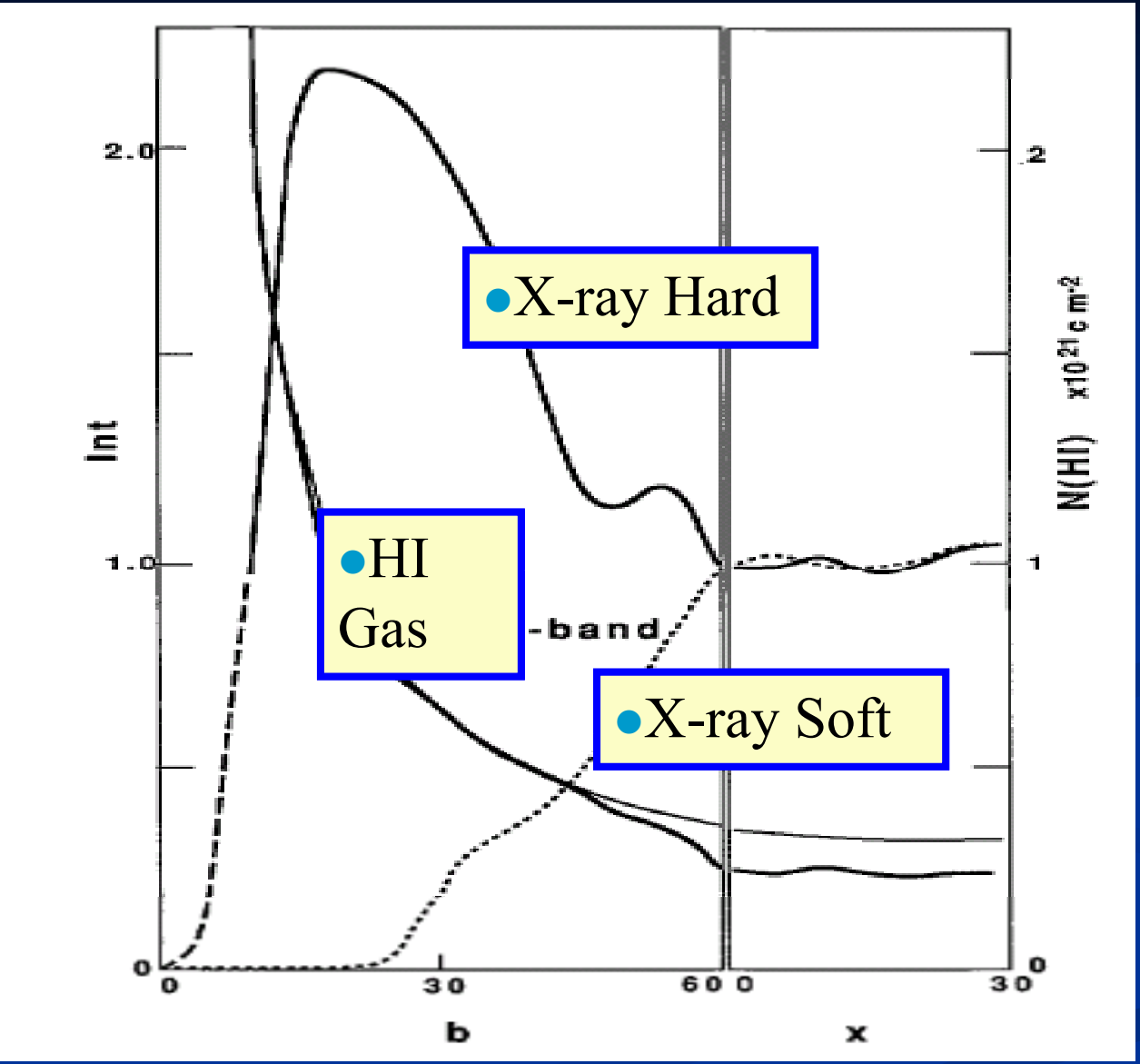
ROSAT

- **0.25 kev**

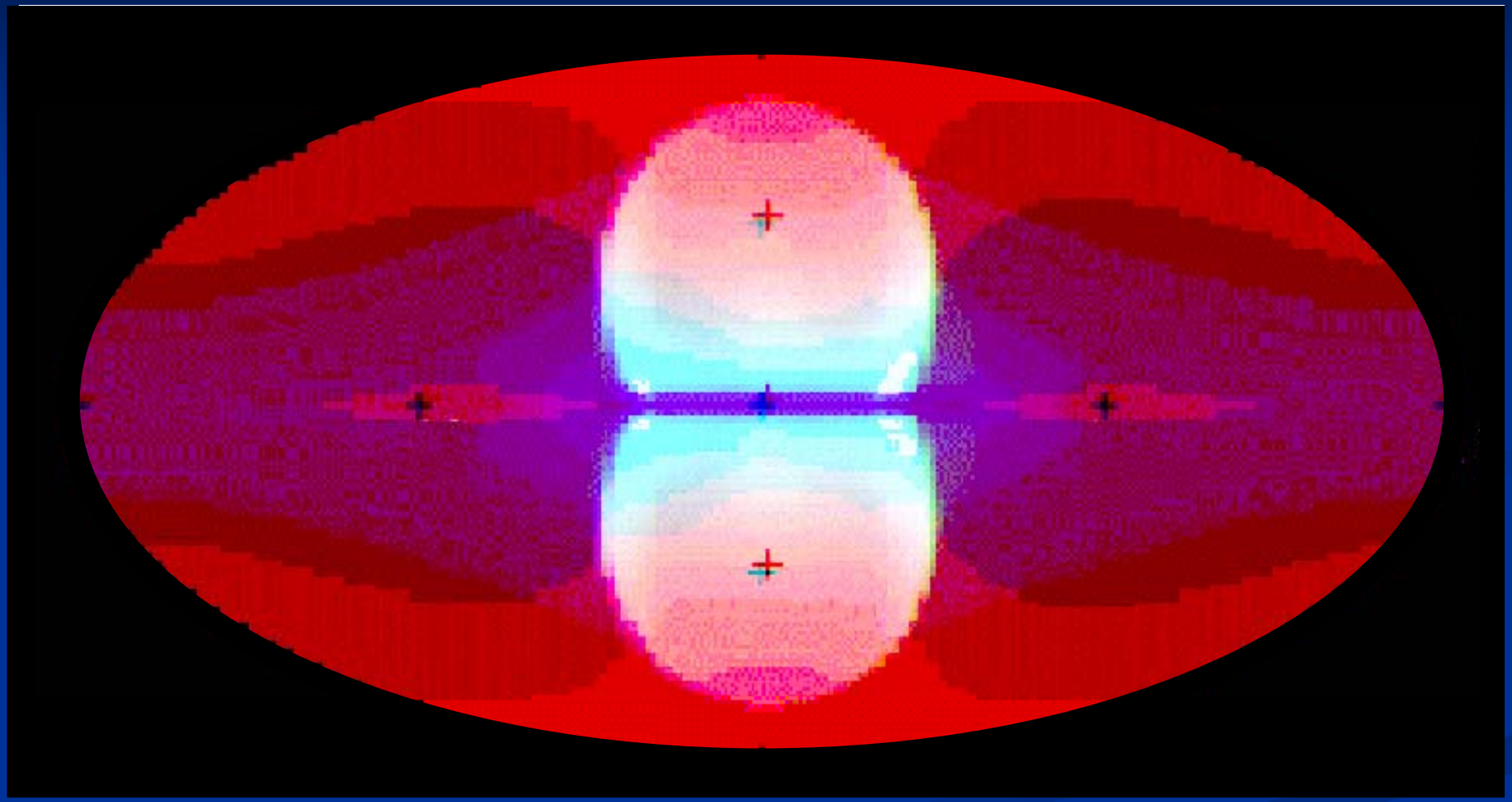


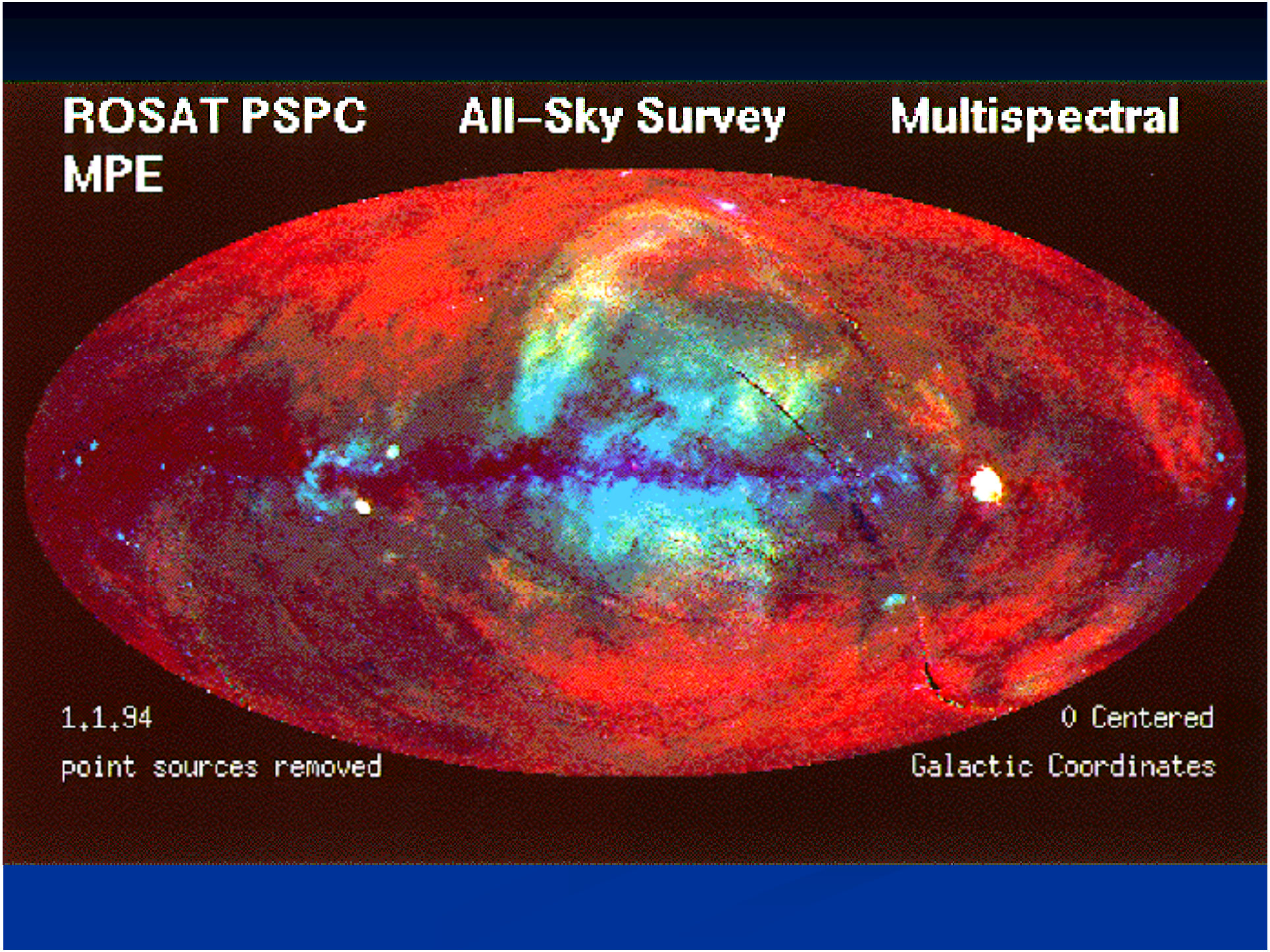
- **0.75 kev**

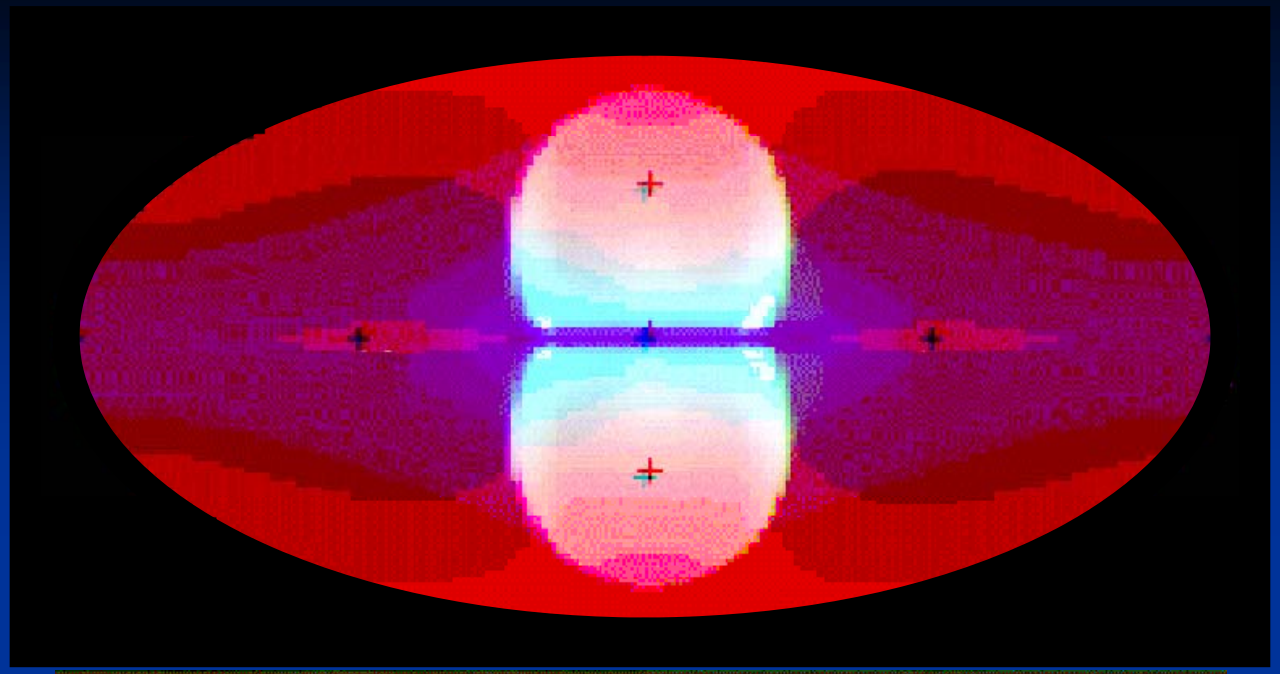
- **1.5 kev**

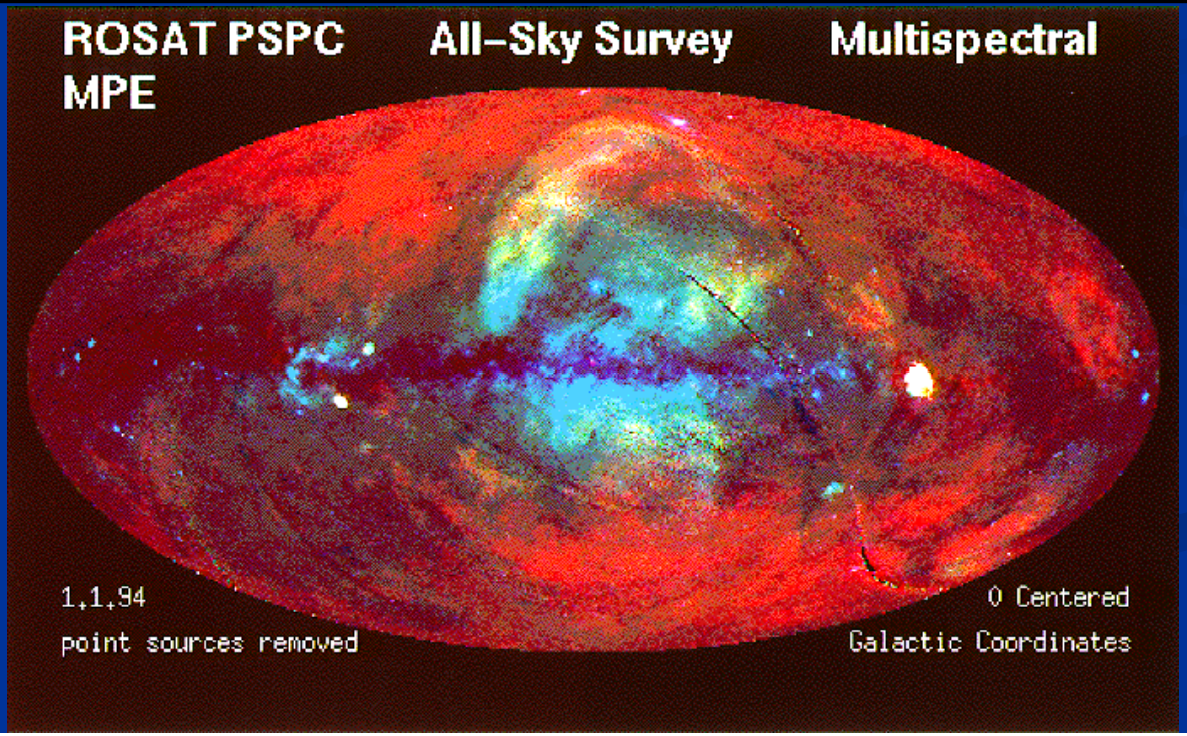


Sofue 1994 ApJL

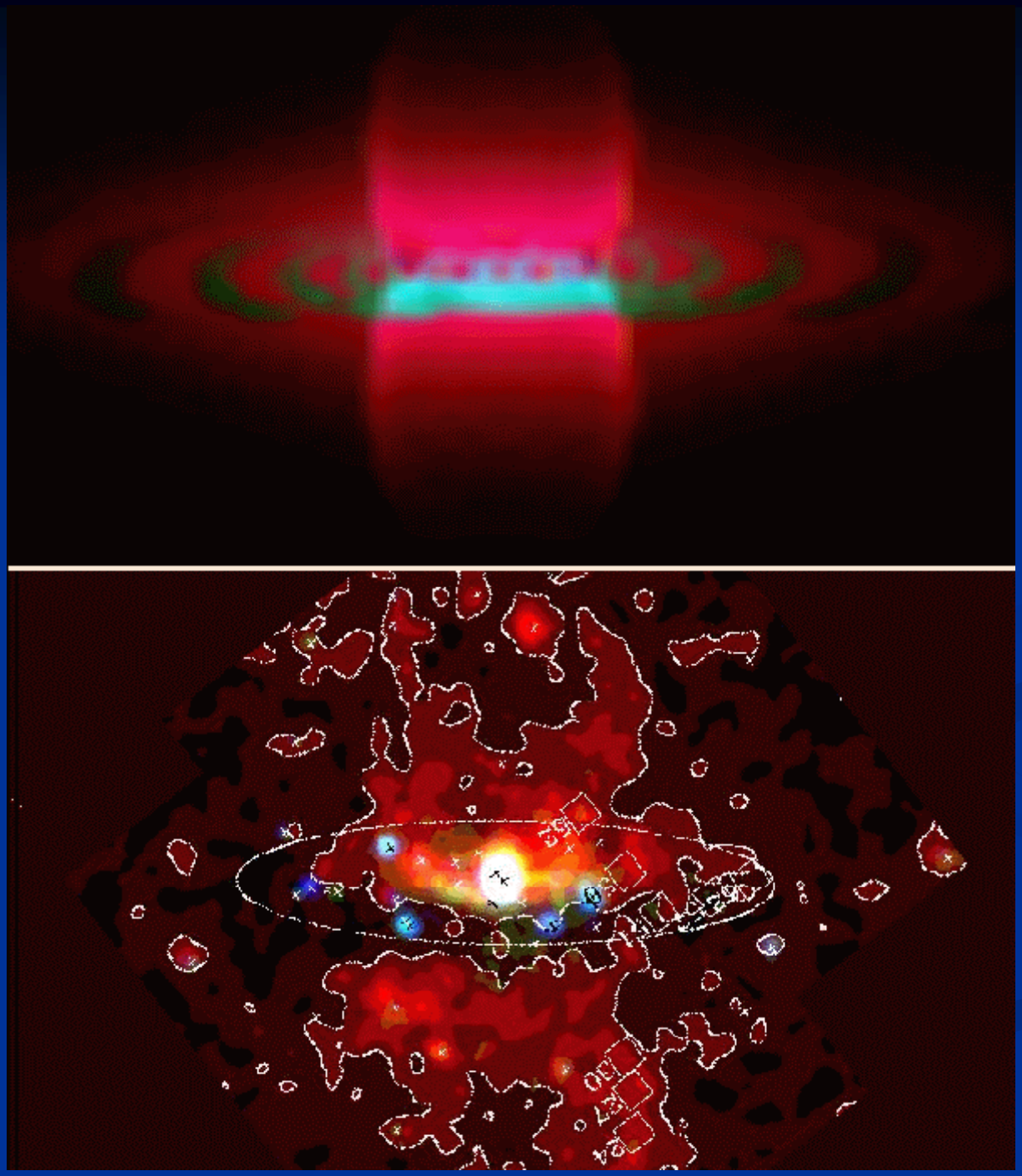


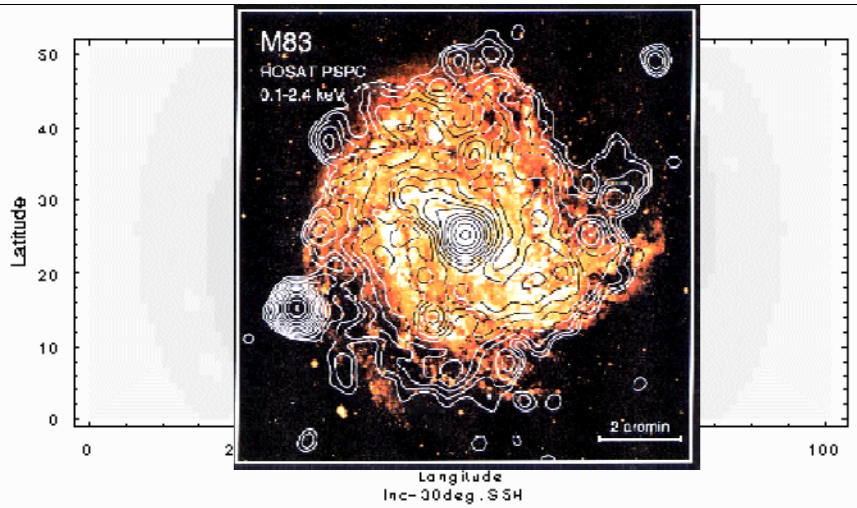

ROSAT PSPC All-Sky Survey Multispectral
MPE
1.1.94
point sources removed
0 Centered
Galactic Coordinates

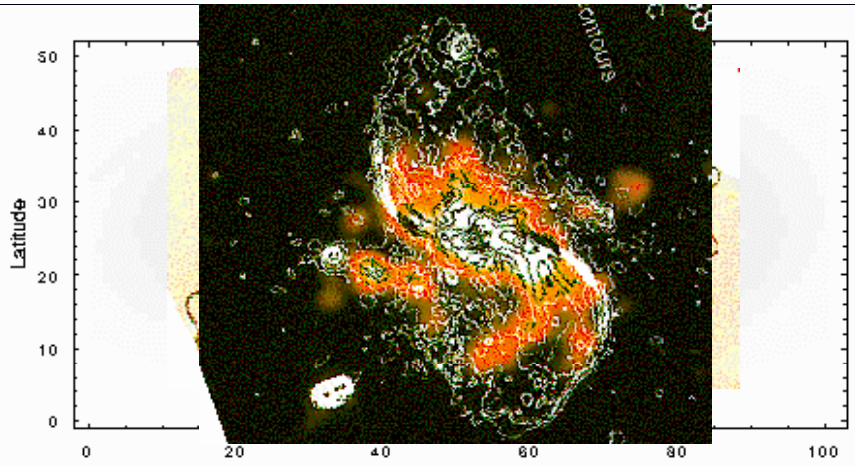


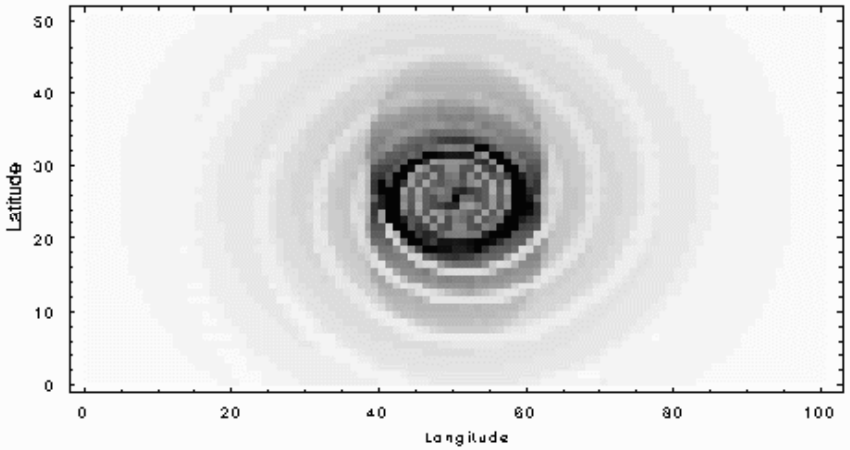

ROSAT PSPC All-Sky Survey Multispectral
MPE
1.1.94
point sources removed
0 Centered
Galactic Coordinates

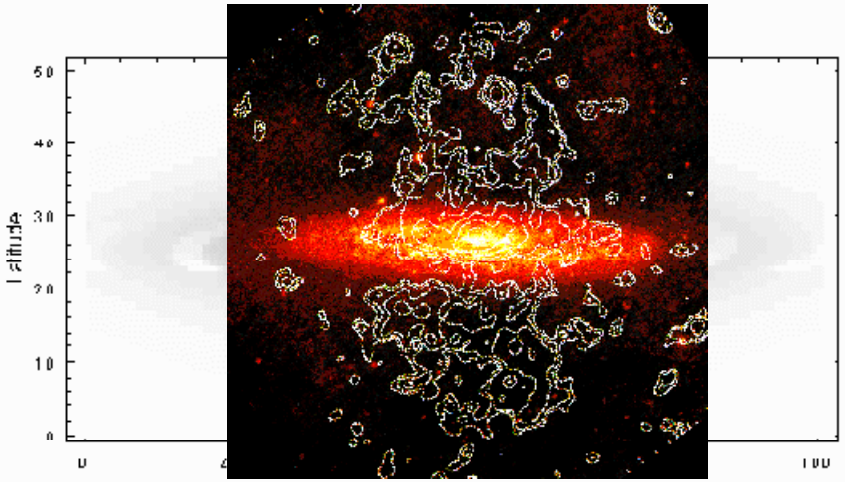
NGC 253
&
スターバースト銀河

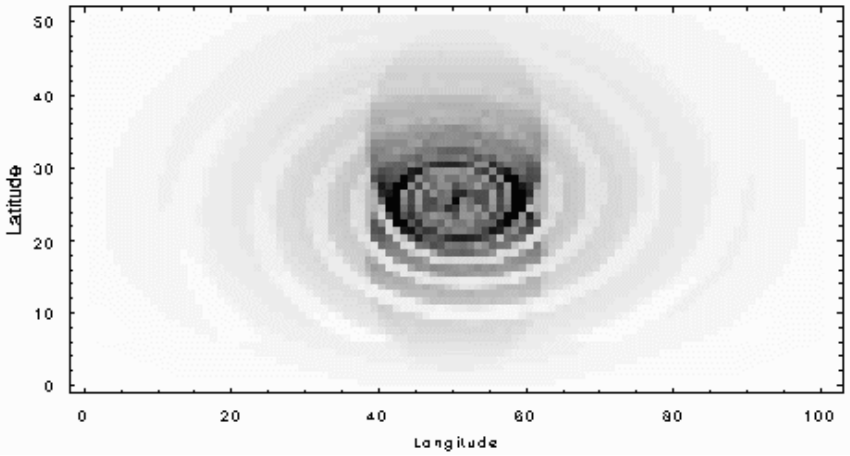


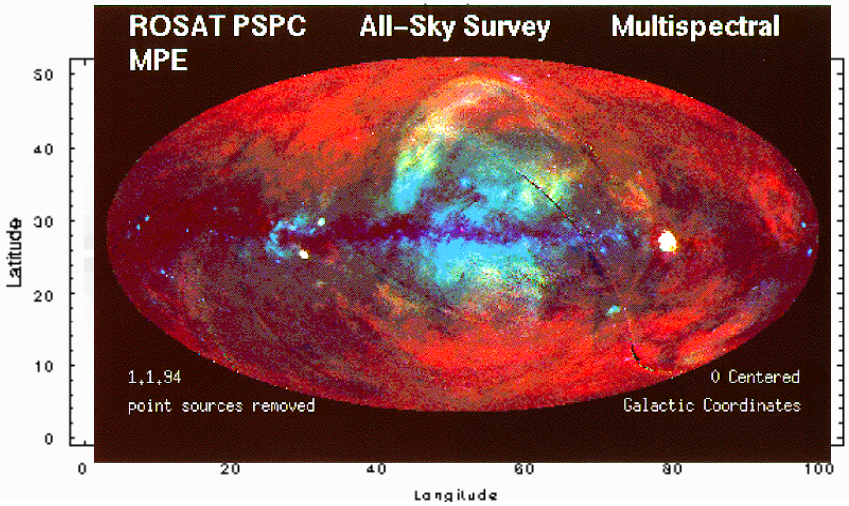

M83
ROSAT PSPC
0.1-2.4 keV
2 arcmin
Latitude
Longitude


Latitude
Longitude


Latitude
Longitude
Inc-30deg.SSH


Latitude


Latitude
Longitude
Inc-45deg.SSH


ROSAT PSPC All-Sky Survey Multispectral
MPE
1,1,94
point sources removed
0 Centered
Galactic Coordinates
Latitude
Longitude

Conclusion and Implications

The Galaxy experienced

Galactic big bang,

maybe Starburst

1.5×10^7 yr ago

$E \sim 10^{56}$ ergs $\sim 10^5$ SN

Similarly to NGC 253 Hyper Shell

1.4×10^7 yr ago

$E \sim 10^{55\text{-}56}$ ergs

Implications

Probing Starburst

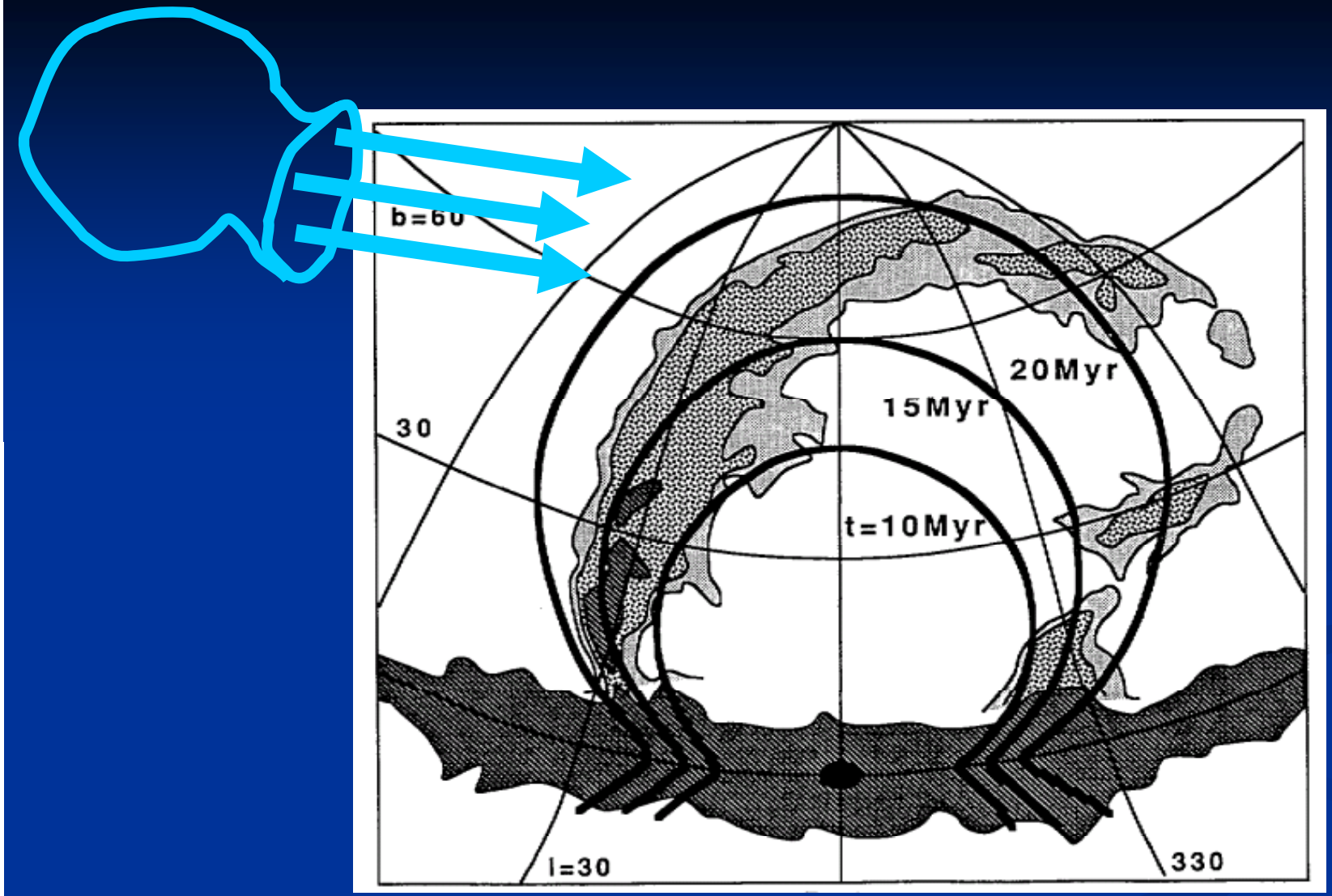
Probing HI disk

Probing Gas Halo

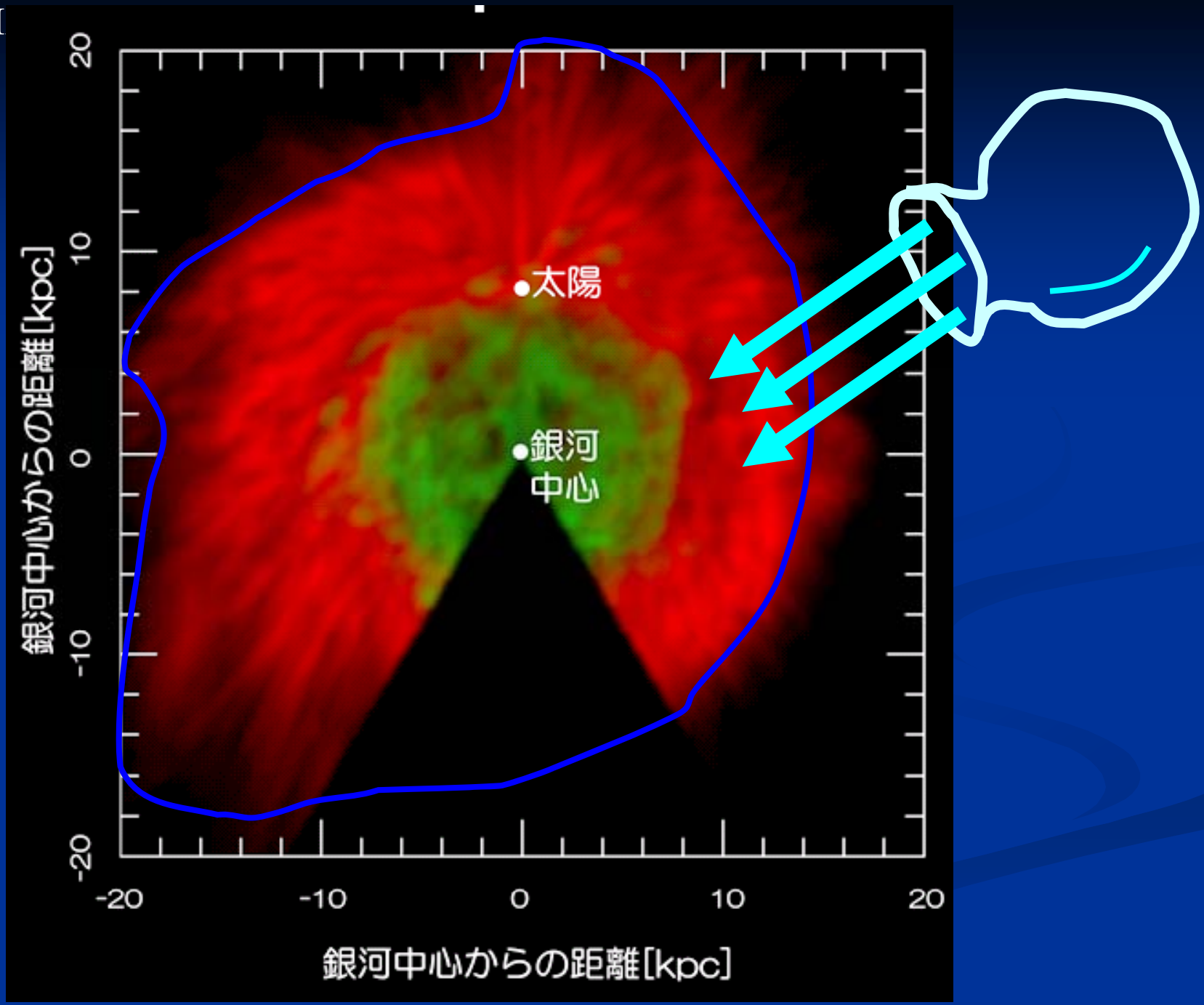
Probing Halo-IG Interface

Probing ICM, IGM

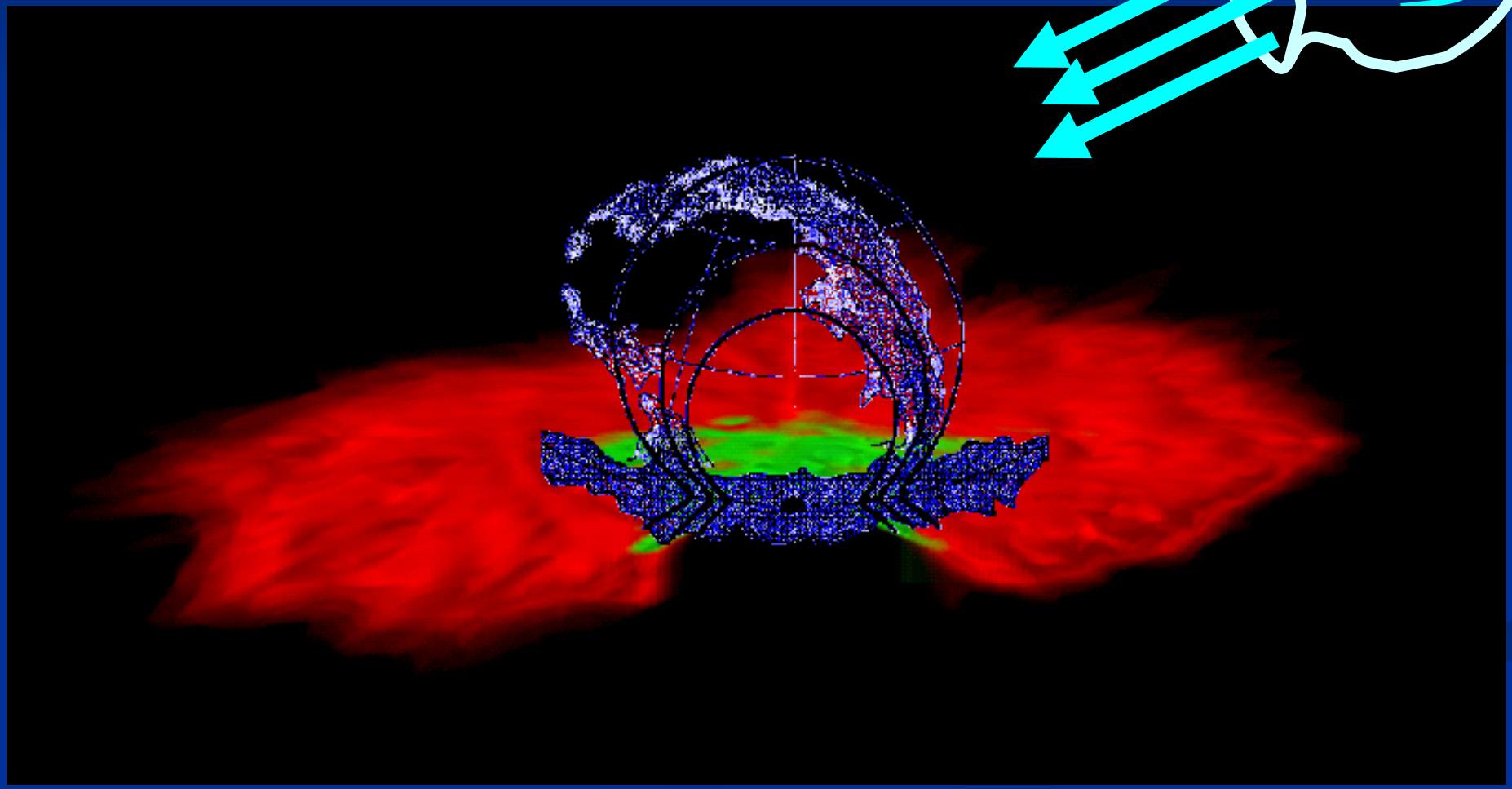
Probing Halo Window

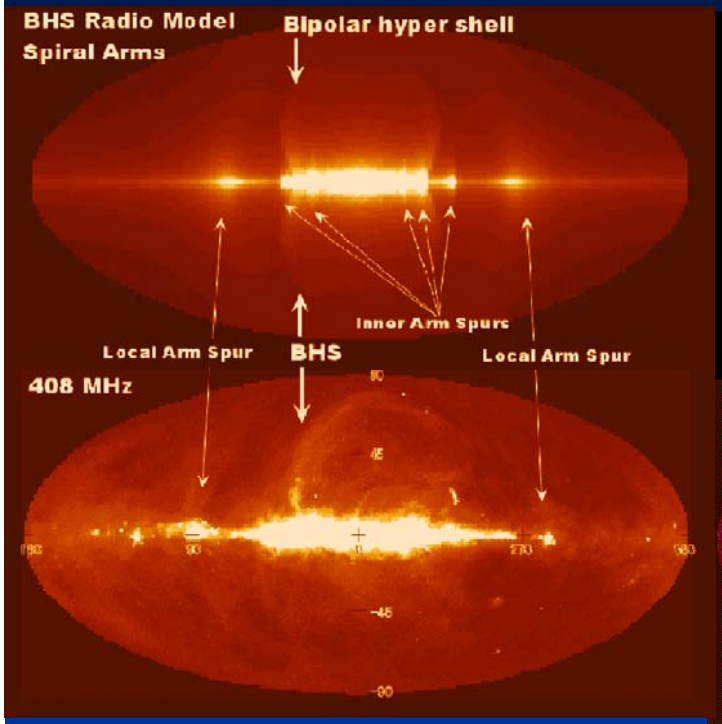

b=60
30
20Myr
15Myr
t=10Myr
l=30
330

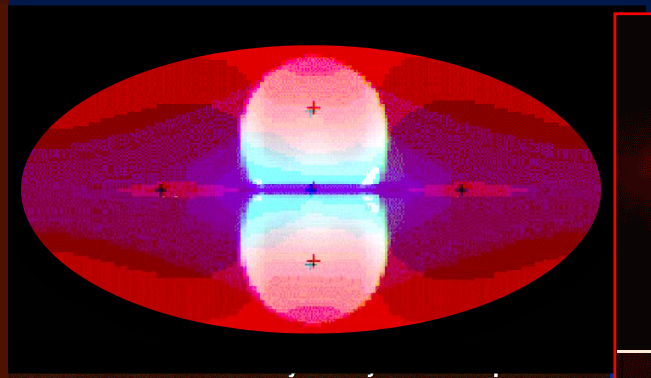
HI(red)+H
Nakanishi
2006

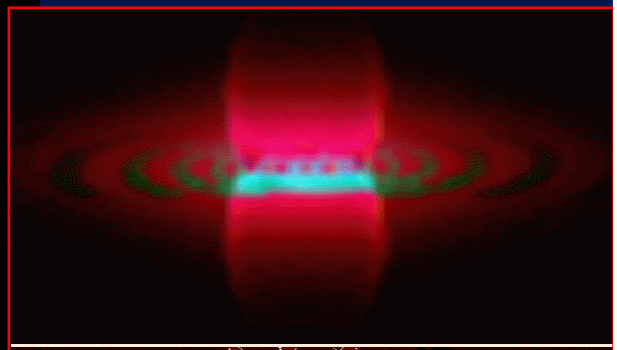


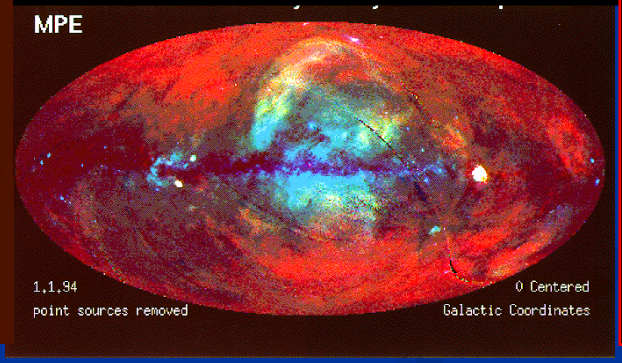
Galactic big bang in an intergalactic wind

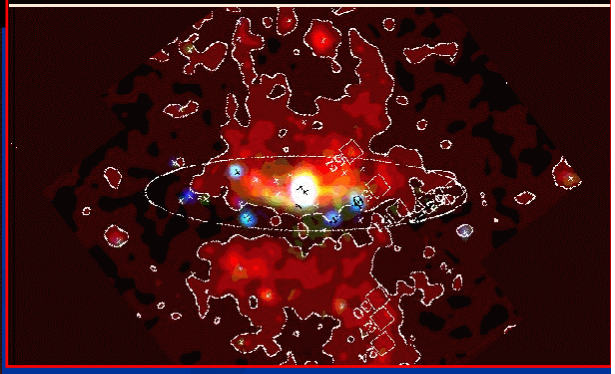



BHS Radio Model
Spiral Arms
Bipolar hyper shell
Inner Arm Spurs
Local Arm Spur
BHS
Local Arm Spur
408 MHz






MPE
1.1.94
point sources removed
0 Centered
Galactic Coordinates



Our Galaxy experienced

Galactic Big Bang

15 Myr ago,

10^{56} ergs.

Sofue, Y. 2000 ApJ 540, 224

Bipolar hyper shell, GC burst

Sofue, Y., Vogler, A. 2001 AA 370, 53

Bipolar hyper shell in NGC 253, etc..

しかし、未だ四面超新星説

西洋人はすぐに意見を変えないので、

もうしばらく

つづく