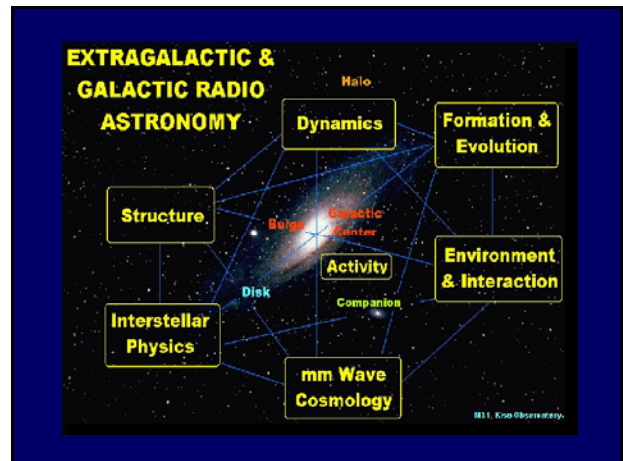


銀河系は爆発したか？

孤軍奮闘の30年論争

祖父江義明

2006. 3. 17 本郷



《王道を行くのが幸せ》

銀河の 回転

Sofue & Rubin 2001 ARAA

磁場

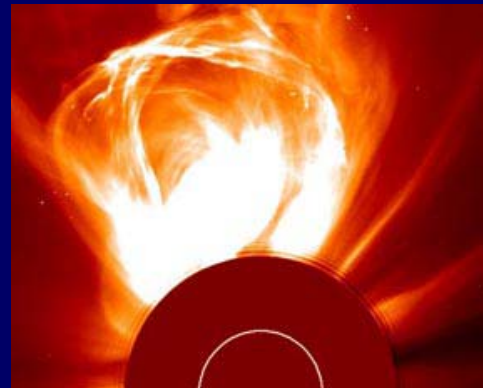
Sofue, Fujimoto, Wielebinski

1987 ARAA

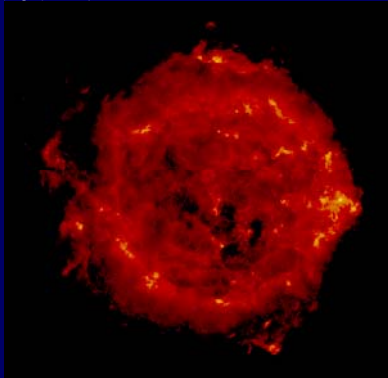
《王道を行くのが幸せ、でも》
《そう行かない時のストレス解消テーマ》

銀河中心 活動、爆発 モルフォロジー

太陽は爆発する



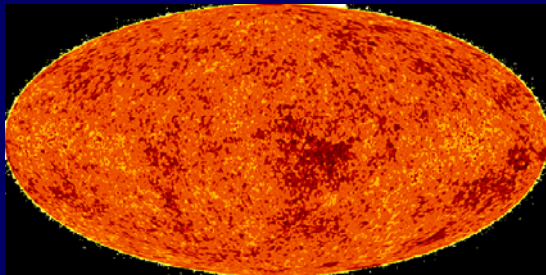
星も爆発する



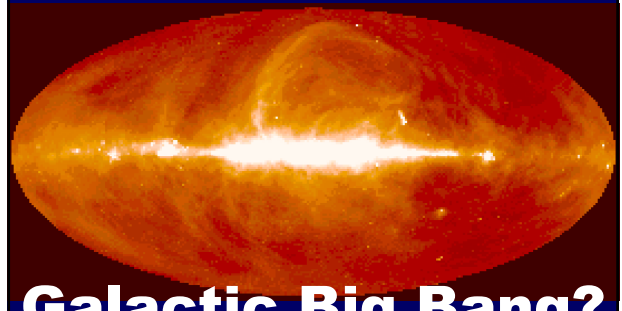
銀河は爆発する



宇宙は爆発した



では、銀河系は爆発したか



Galactic Big Bang?

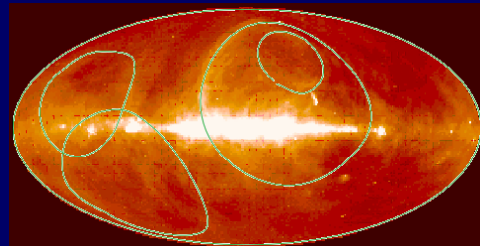
本題に入る前に

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

Hayakawa et al. 1977



SNR 説

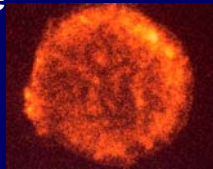
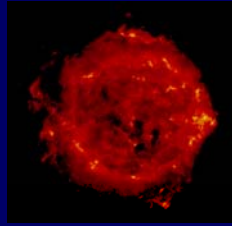
Σ -D relation

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

D ~ 100 pc

$\theta \sim 100$ deg

Distance ~ 100 pc

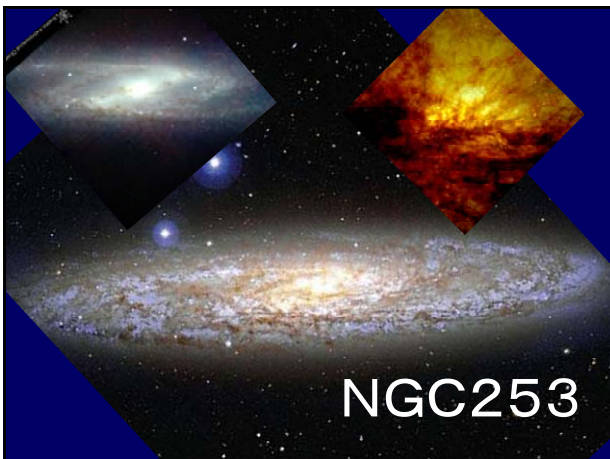
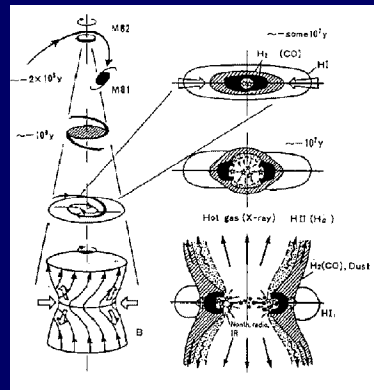


**系外銀河
Starburst
Shell / Outflow**

M82

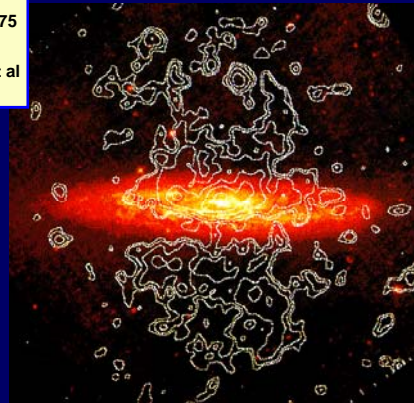


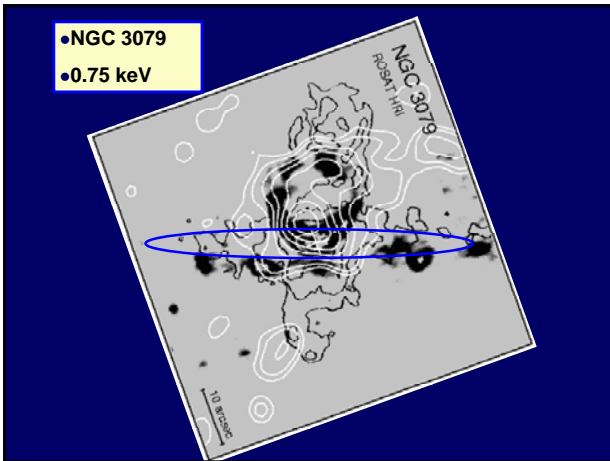
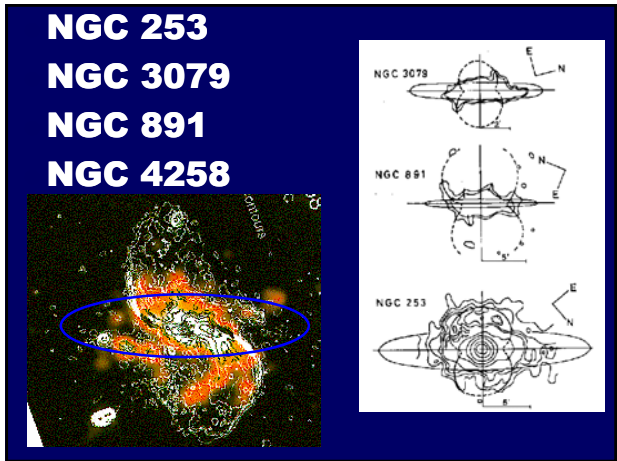
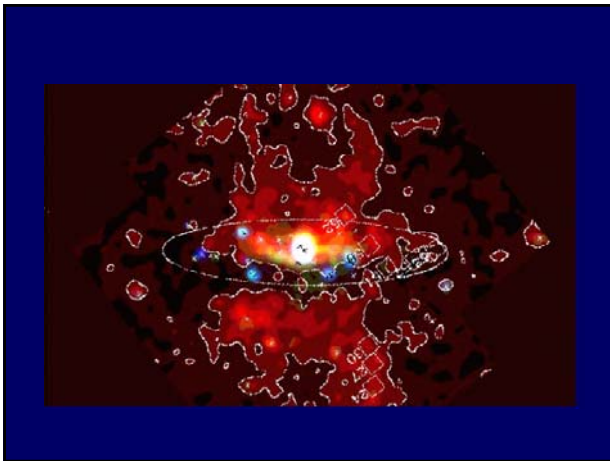
M 82 (NGC 3034) FOCAS (B, V, Hz)
Subaru Telescope, National Astronomical Observatory of Japan March 24, 2000
Copyright © 2000 National Astronomical Observatory of Japan. All rights reserved.



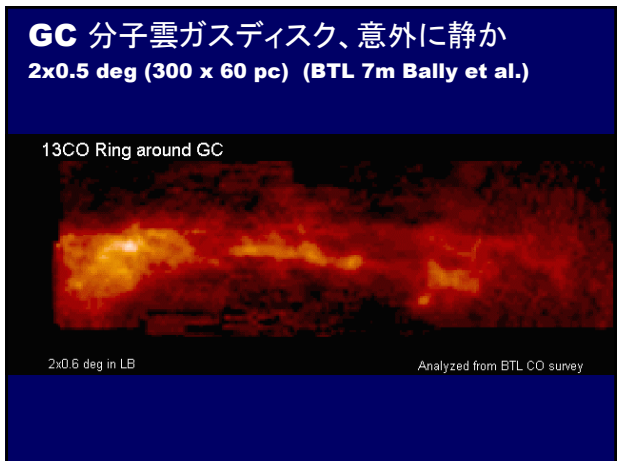
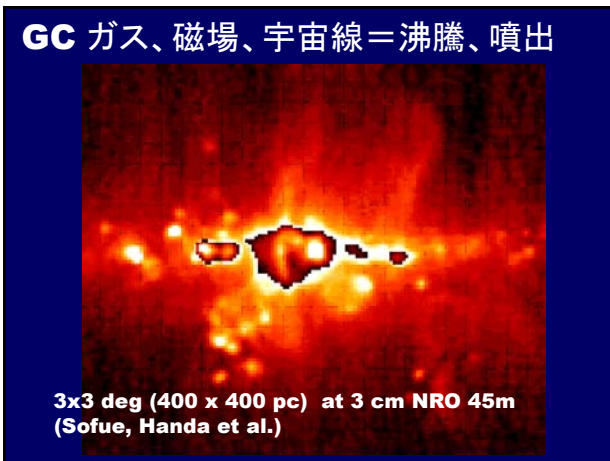
NGC253

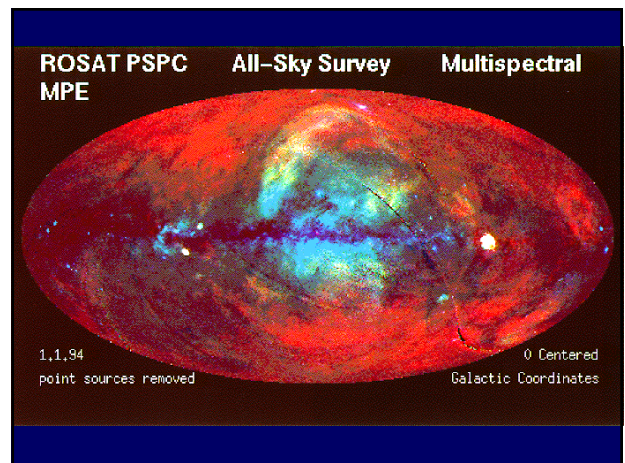
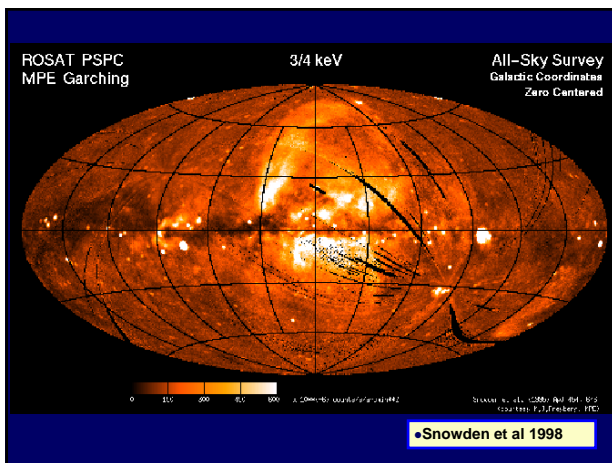
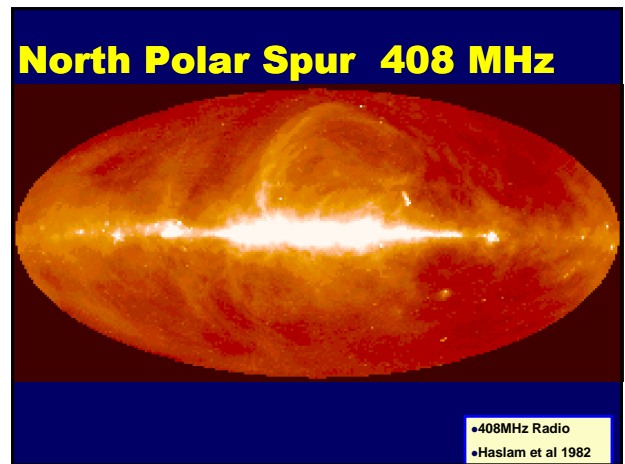
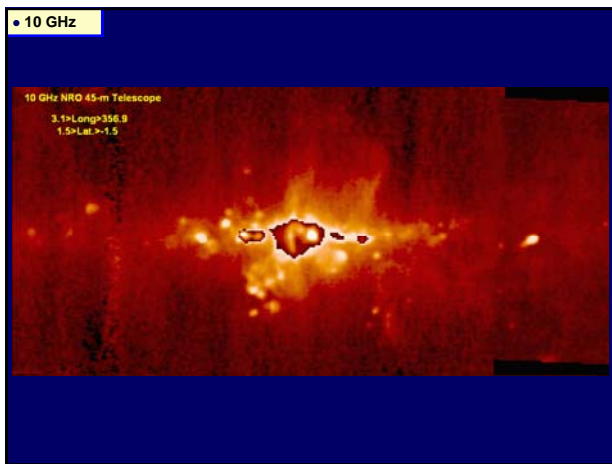
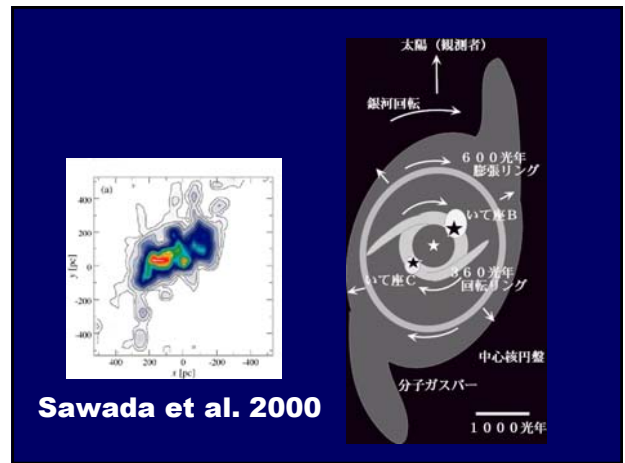
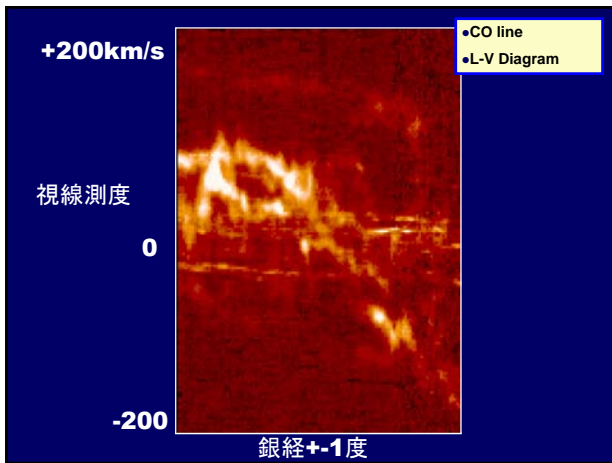
- NGC 253
- ROSAT 0.75 keV
- Pietsch et al 1999

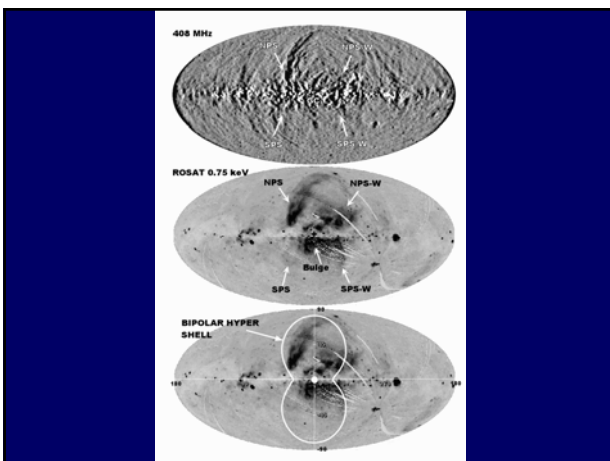
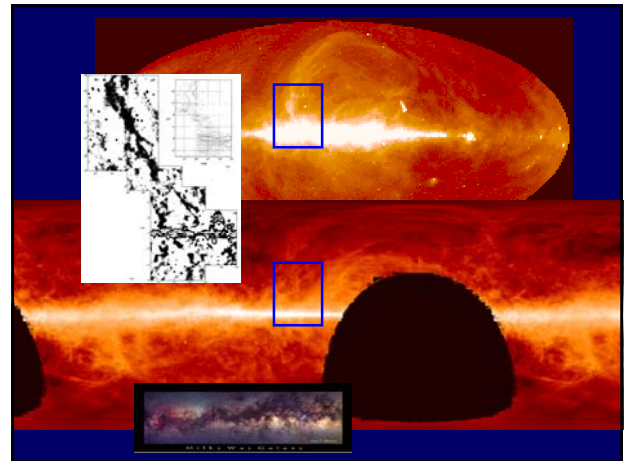
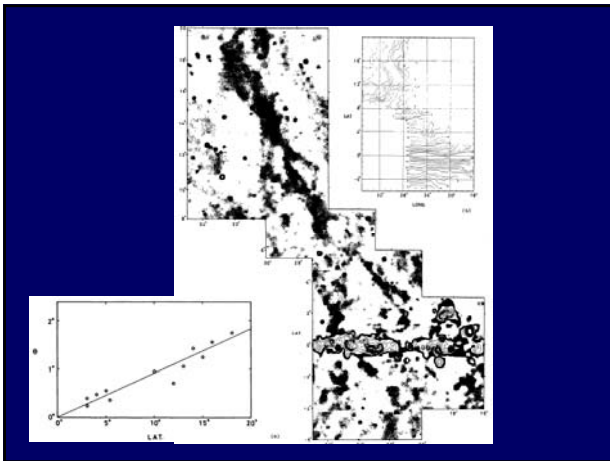
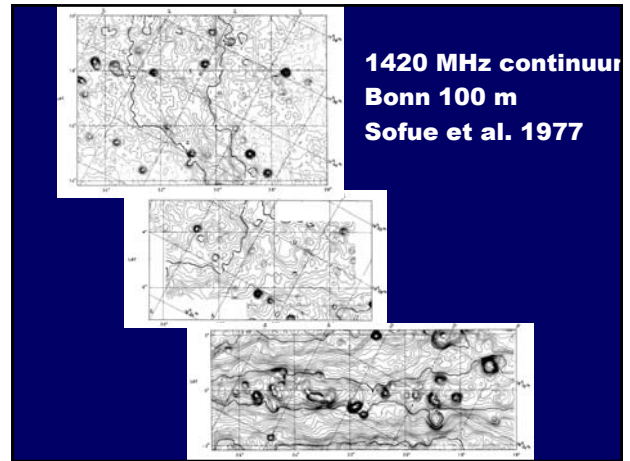
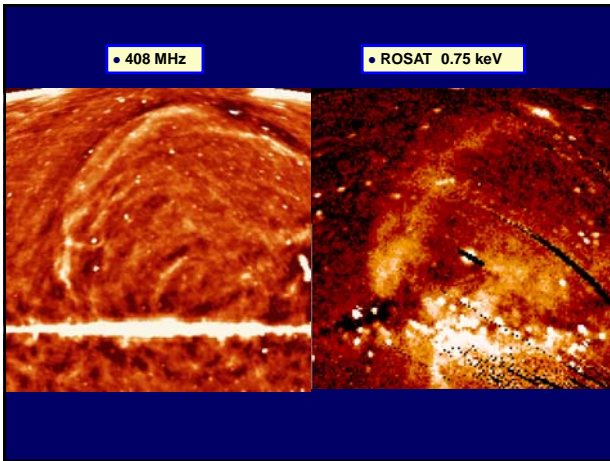




我が銀河系では？







Bipolar Hyper Shell Model

Point Explosion + MHD fast wave approximation

•Sofue 1977

• Fast MHD (compression) wave

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

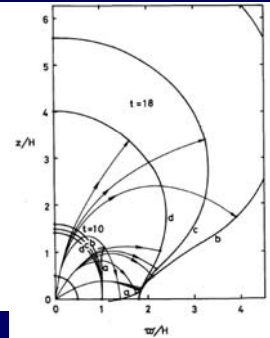
$$\frac{d\theta}{dt} = V p_\theta / r p,$$

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

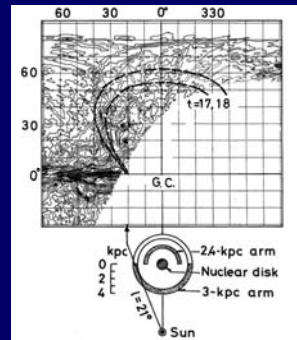
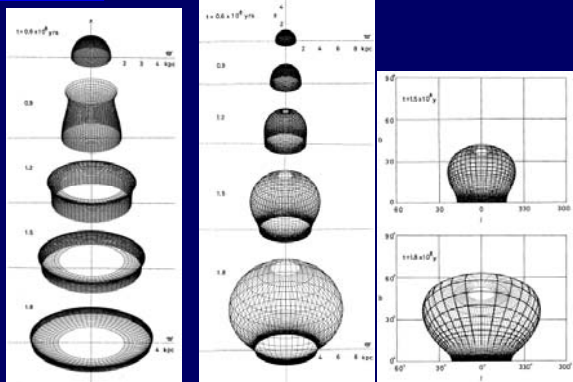
$$\frac{dp_r}{dt} = -p \frac{\partial V}{\partial r} + \frac{V}{r p} (p_\theta^2 + p_\phi^2),$$

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

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



•Sofue 1977



•Sofue 1977

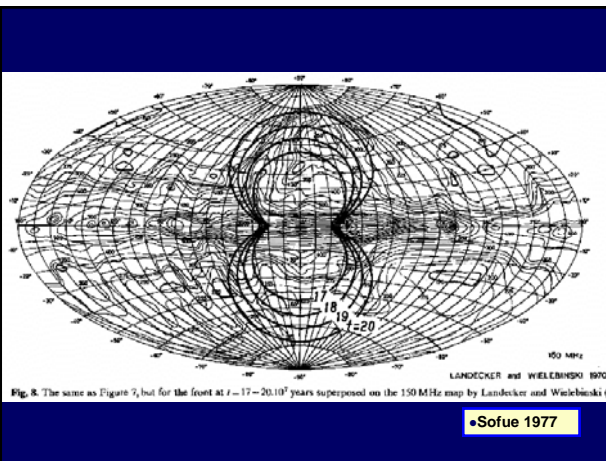


Fig. 8. The same as Figure 7, but for the front at $t = 17 - 20.10^9$ years superposed on the 150 MHz map by Landecker and Wielebinski (1970)

•Sofue 1977

Point explosion + Adiabatic shock model

エネルギー

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

$t \sim 10^{6-7}$ 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 \rightarrow ソフトX線

Radial-ray adiabatic Shock

Sakashita, Moellenhoff method

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

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

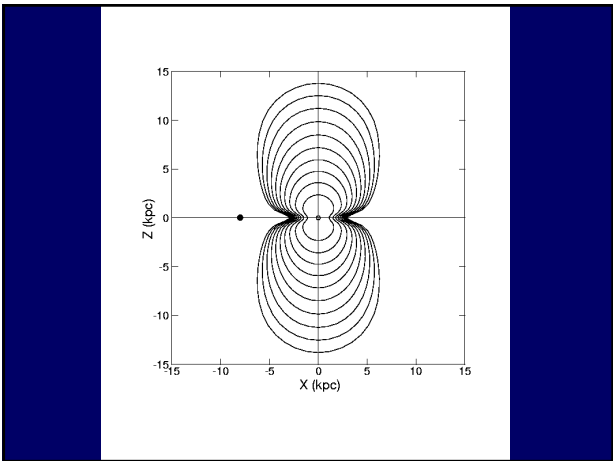
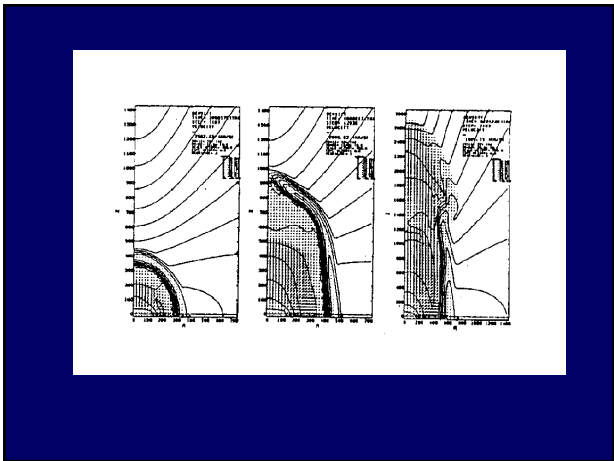
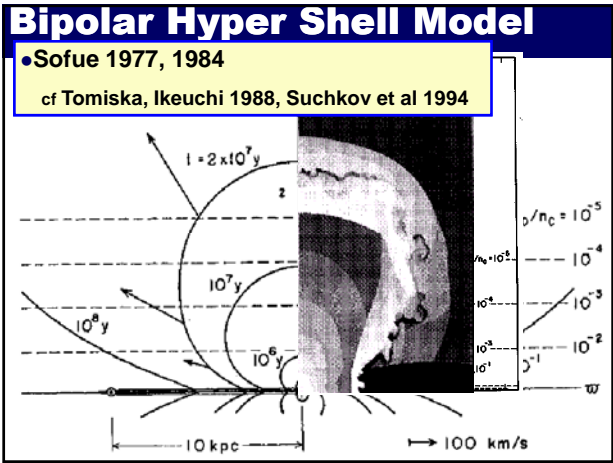
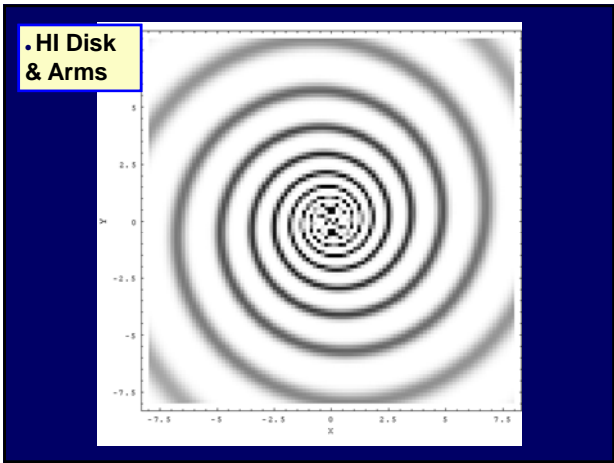
Here,

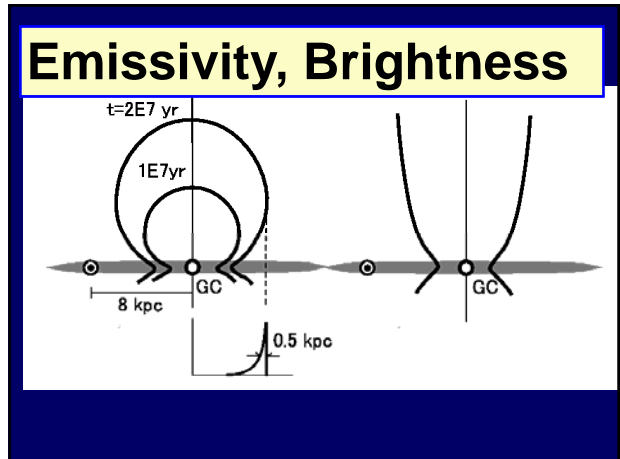
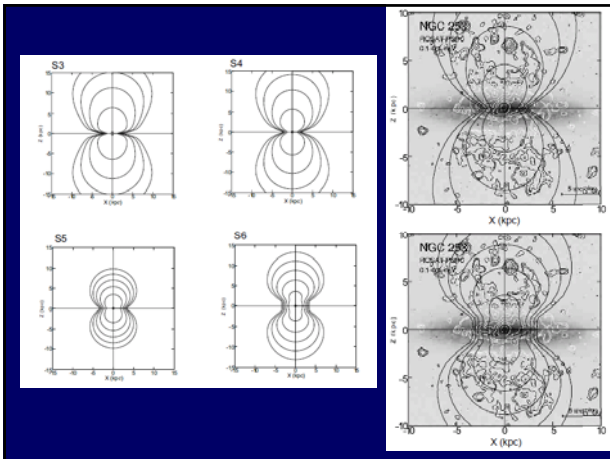
$$I = \left(\frac{4\pi}{r_0} \frac{d\rho_0}{dr_0} \right)_R$$

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

and

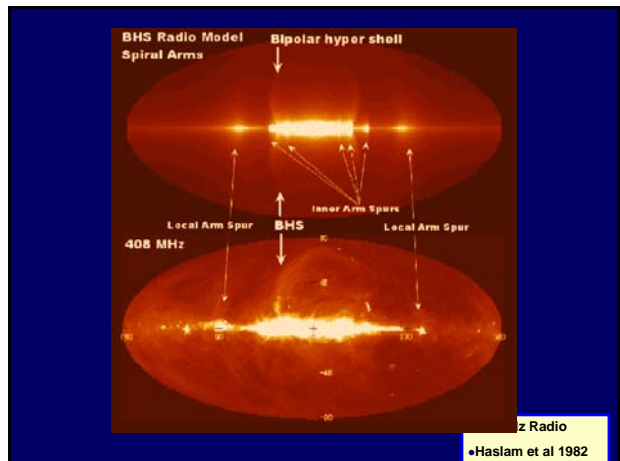
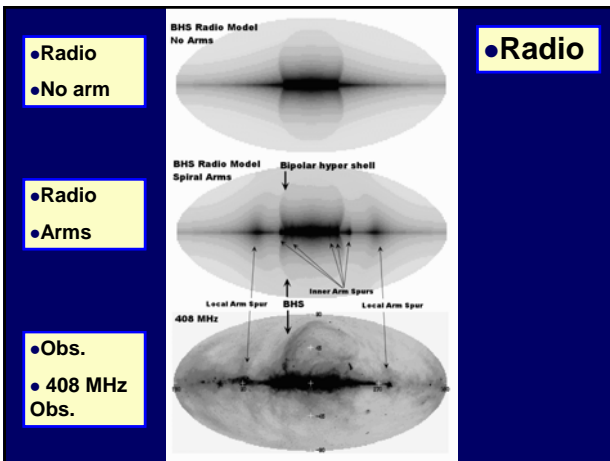
$$M = \rho_0 \frac{4\pi}{3} R^3$$

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




Simulation 1. Radio
Radio synchrotron radiation
 Compared with whole-sky
 408 MHz map

Radio emissivity
B-CR equipartition
 $\epsilon \propto B^{\gamma} \propto \rho^{\alpha}$



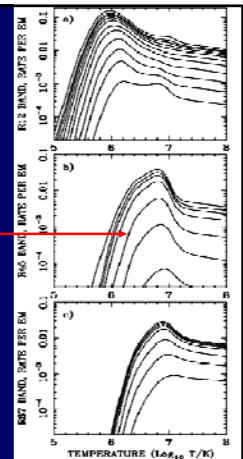
Simulation 2. X-rays
0.25, 0.75, 1.5 keV Soft X-rays
 Compare with ROSAT

X-ray emissivity
Bremsung
 $\epsilon \propto \rho^2 T^{0.5}$

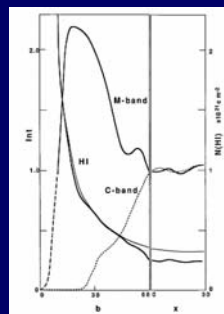
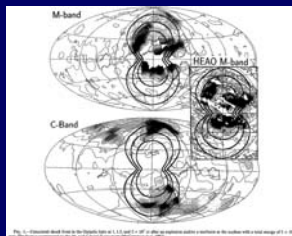
Transfer:
Absorption by metals in HI Disk
 $dl/ds = \epsilon - \kappa l$
 $\kappa ds = d\tau = n_H ds / N_{H,0}$

X-ray Absorption κ
 at 0.25, 0.75, 1.5 keV

0.75 keV:
 $\tau = 1$ for
 $N_{H,0} = 3 \times 10^{21} \text{ H cm}^{-2}$
 $= 1 \text{ kpc} \times 1 \text{ H cm}^{-3}$



Snowden et al. 1993

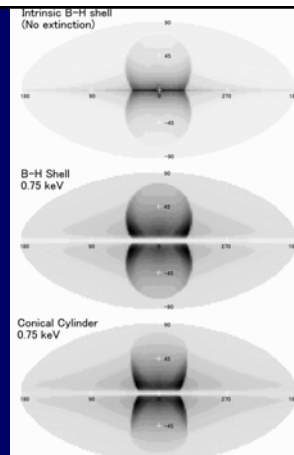


Sofue 1994 ApJL

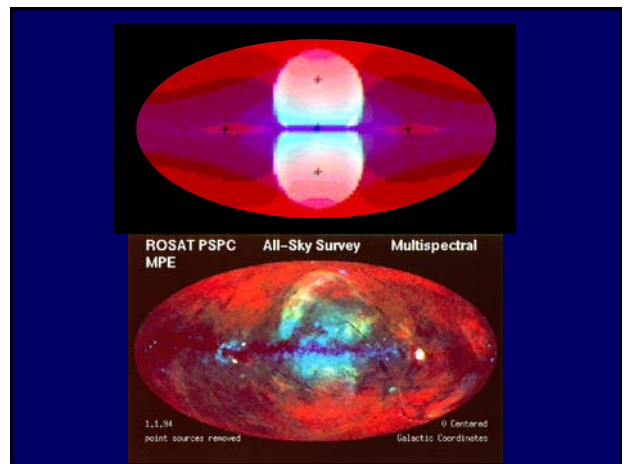
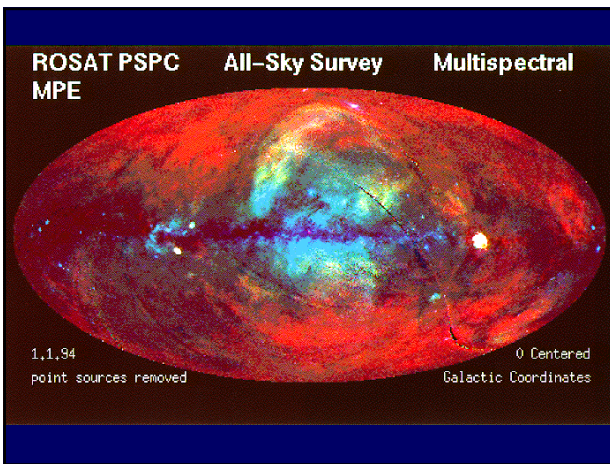
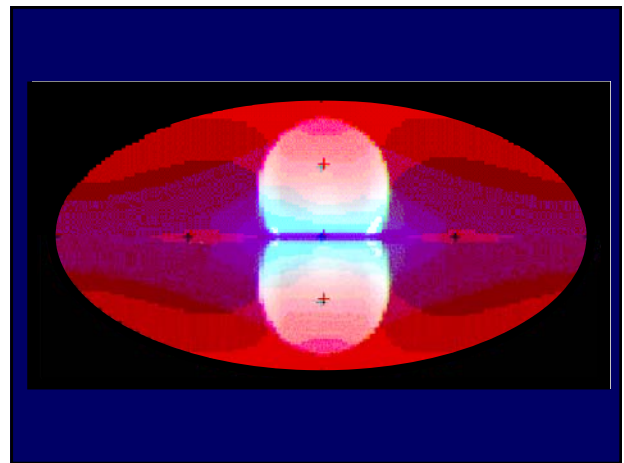
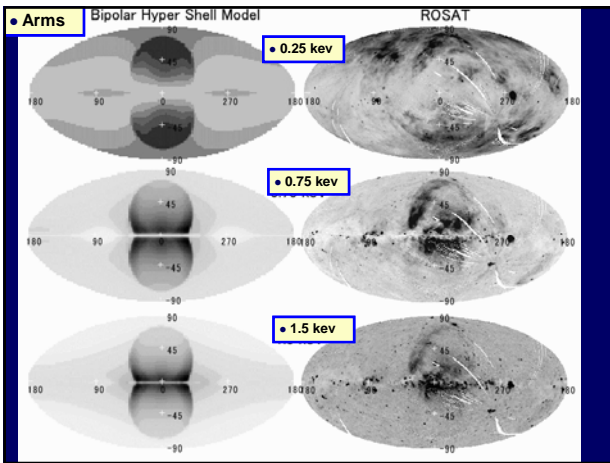
• 1.5 keV
 • No arm

• 0.75 keV
 • No arm

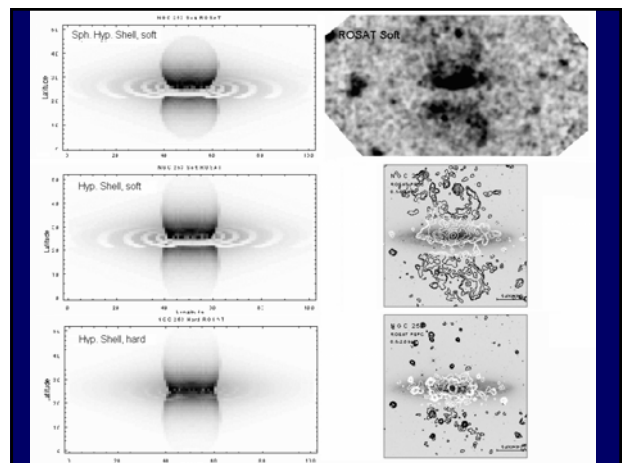
• 0.75 keV
 • No arm
 • Cylinder/
 Cone

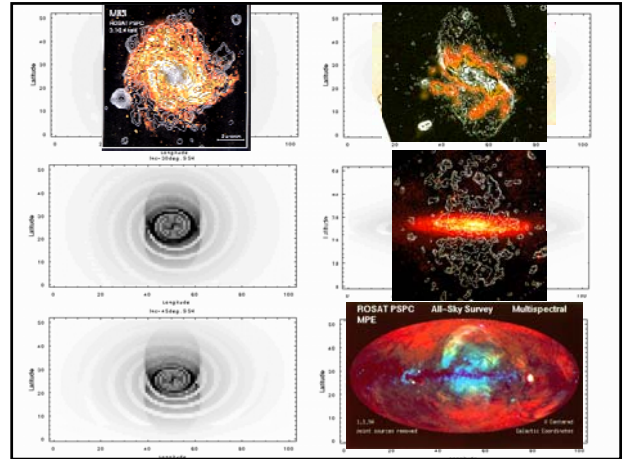
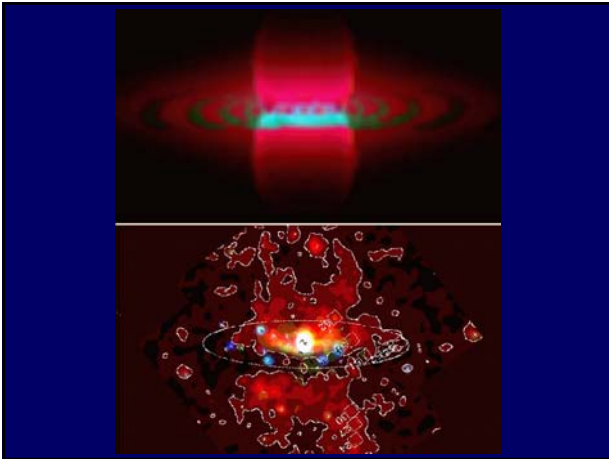


• Soft X



NGC 253



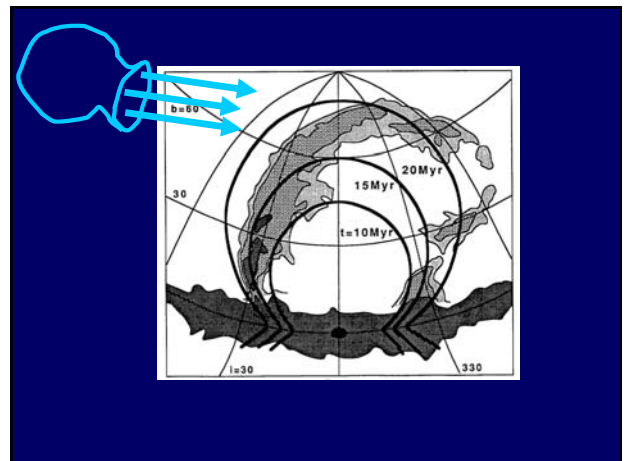


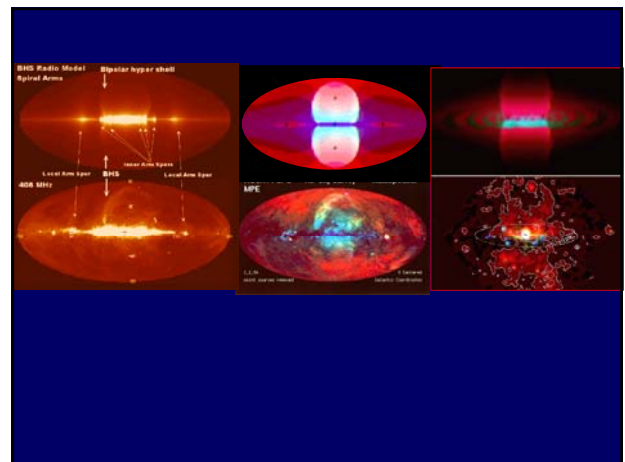
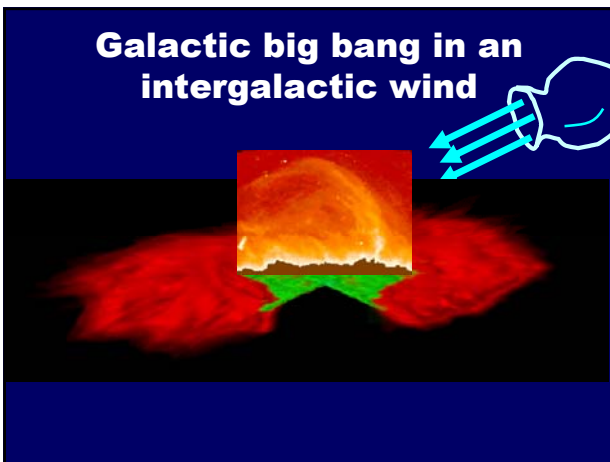
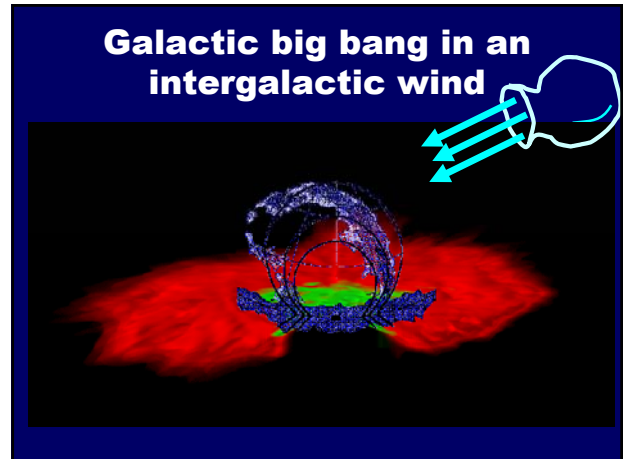
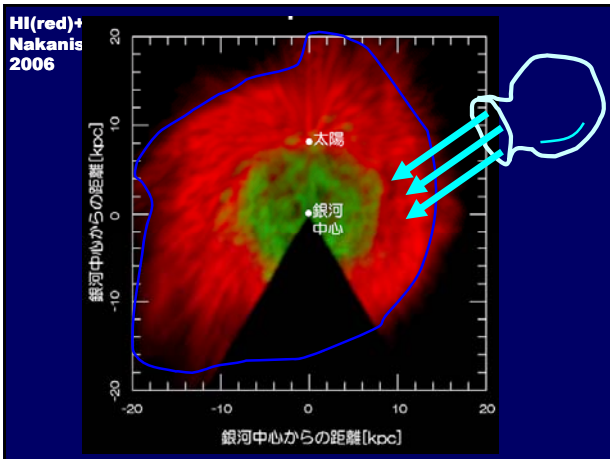
Conclusion and Implications

MW experienced Galactic big bang, maybe Starburst
 1.5×10^7 yr ago
 $E \sim 10^{56}$ ergs $\sim 10^5$ SN

Similar to NGC 253 Hyper Shell
 1.4×10^7 yr ago
 $E \sim 10^{55-56}$ ergs

- Implication**
- Probing Starburst
 - Probing HI disk
 - Probing Gas Halo
 - Probing Halo-IG Interface
 - Probing ICM, IGM
 - Probing Halo Window





**We experienced
Galactic Big Bang
15 Myr ago,
 10^{56} ergs.**

決着、、、と思ったけれど....

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、

もしばらく

つつく