

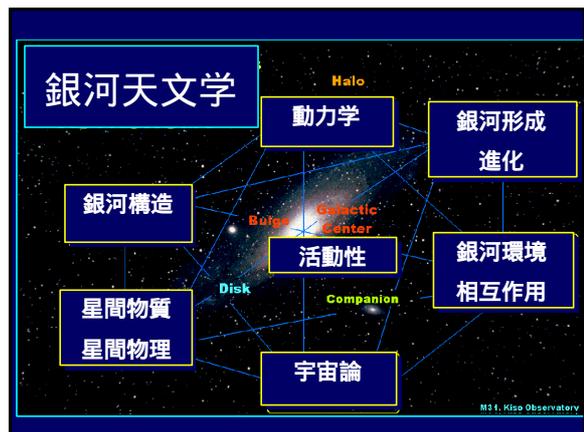
# 銀河系は爆発したか？

孤軍奮闘の30年論争

祖父江義明  
@鹿児島大学理学部  
2009.3.6.

# Galactic Big Bang

## 1. 銀河研究 3点セット

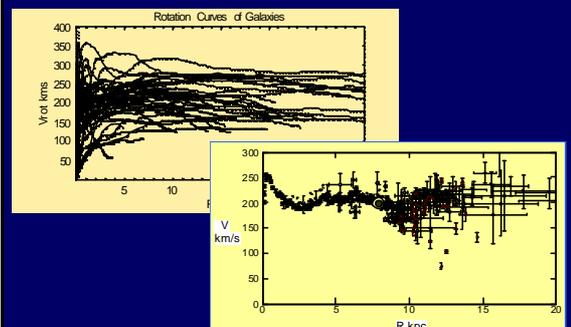


《王道を行くのが幸せ》

# 銀河回転

Sofue & Rubin 2001 ARAA

回転曲線=>動力学=>  
質量分布、骨格、ダークマター



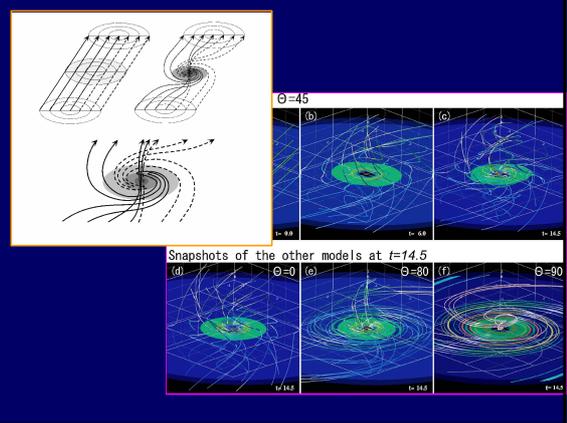
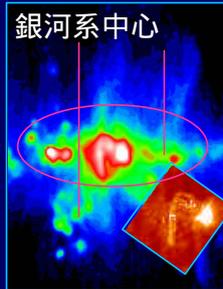
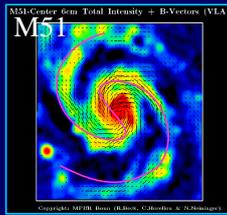
# 銀河系の骨格

ダークハロー  
ディスク  
バルジ  
ブラックホール

# 銀河磁場 星間物理

Sofue, Fujimoto, Wielebinski 1987 ARAA

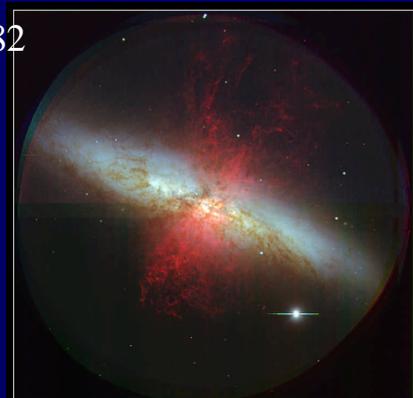
## 銀河磁場と星間物理学



# 銀河爆発

Sofue alone

M82



《王道を一息、ストレス解消テーマ》

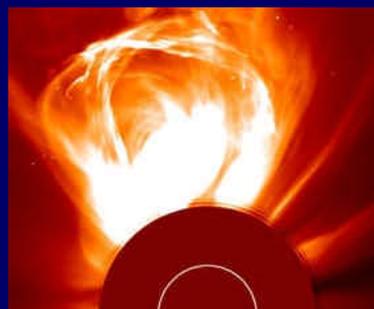
銀河中心、ブラック  
ホール、活動現象、  
爆発、形態

2.ところで、  
宇宙の爆発現象？

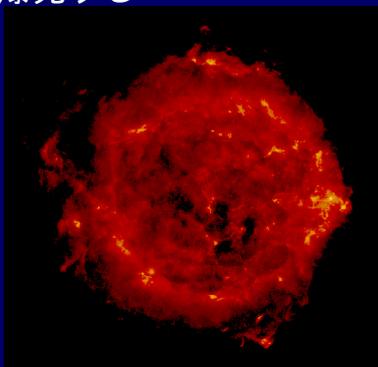
地球は爆発する。



太陽は爆発する



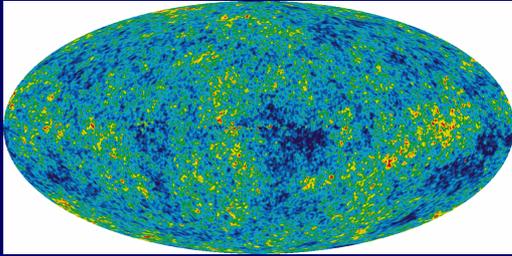
星は爆発する



銀河は爆発する

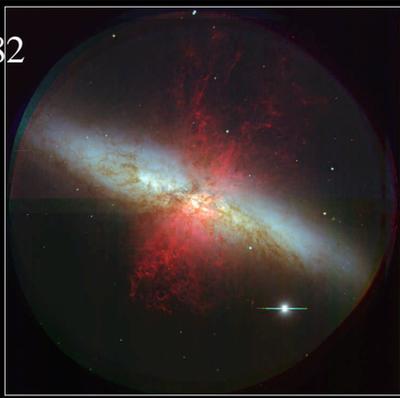


宇宙は爆発した、ビッグバン



### 3. 銀河の爆発 Starburst

M82



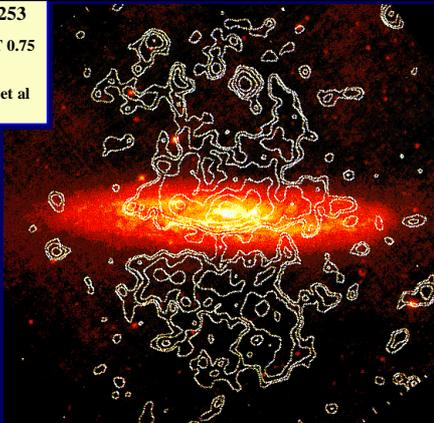
M 82 (NGC 3034)

FOCAS (B, V, H $\alpha$ )

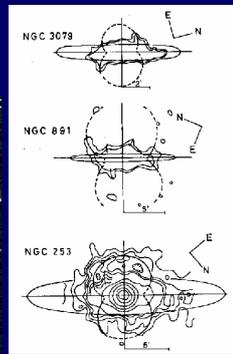
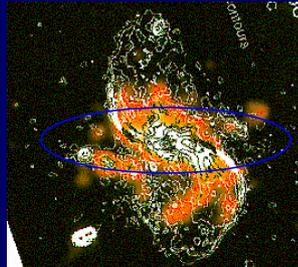


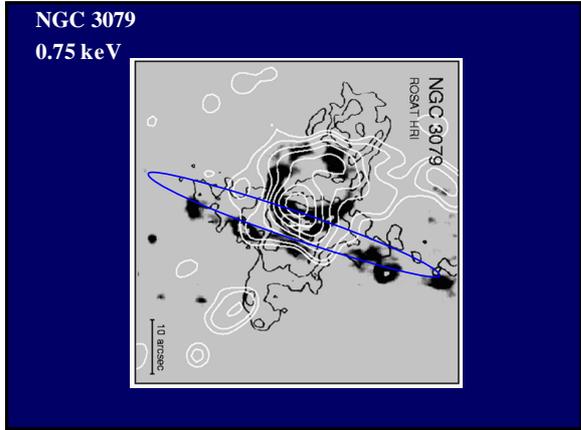
NGC 253

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

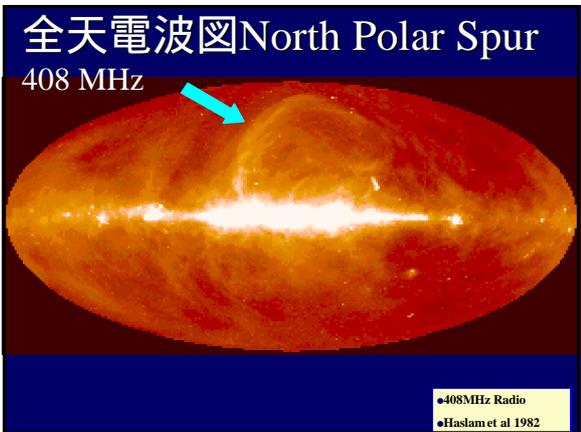
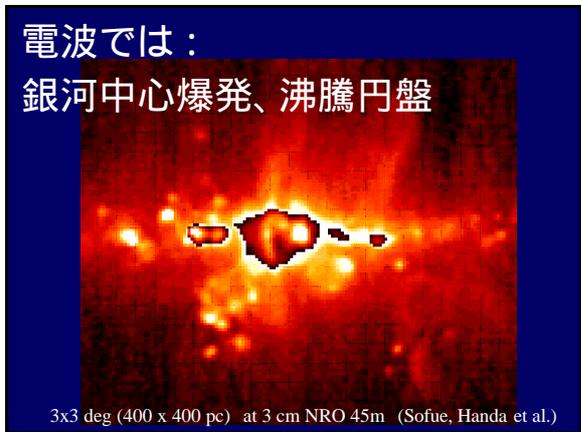
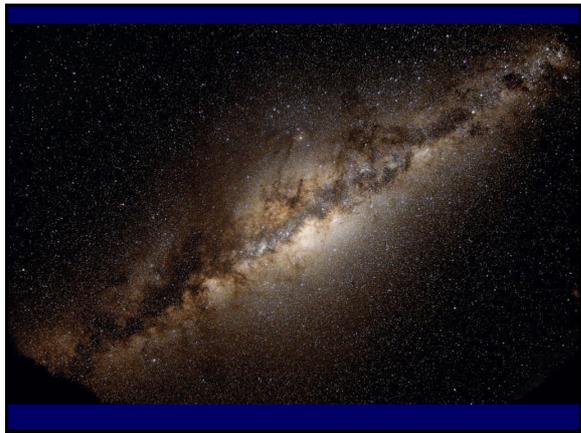


- NGC 253
- NGC 3079
- NGC 891
- NGC 4258

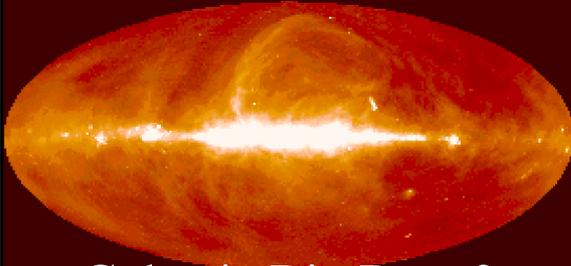




# 4. 天の川 銀河系では？

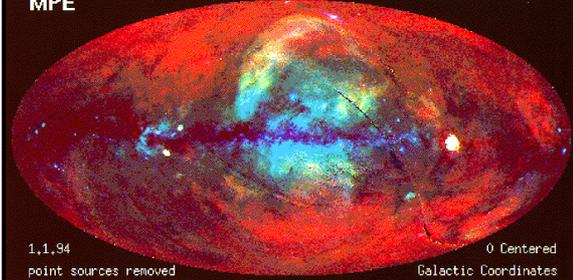


銀河系も爆発する! ?

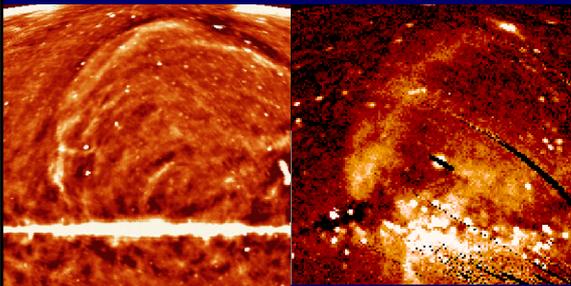


Galactic Big Bang?

ROSAT PSPC All-Sky Survey Multispectral MPE



North Polar Spur

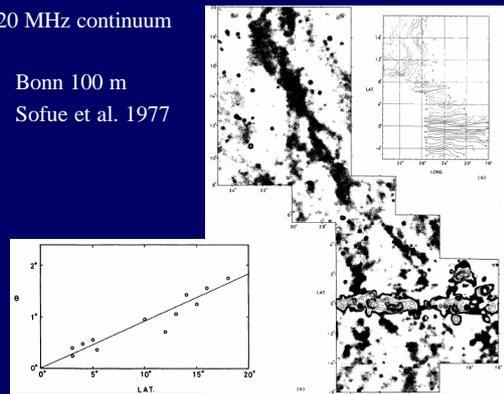


408 MHz

ROSAT 0.75 keV

1420 MHz continuum

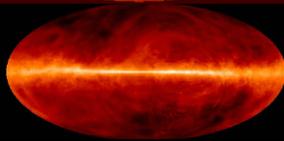
Bonn 100 m  
Sofue et al. 1977



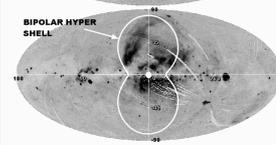
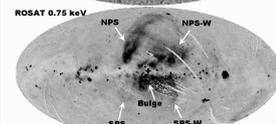
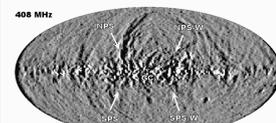
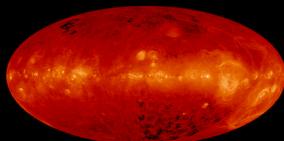
All-sky Radio

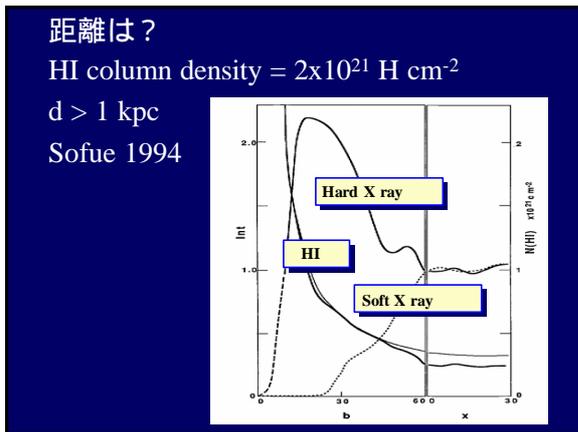
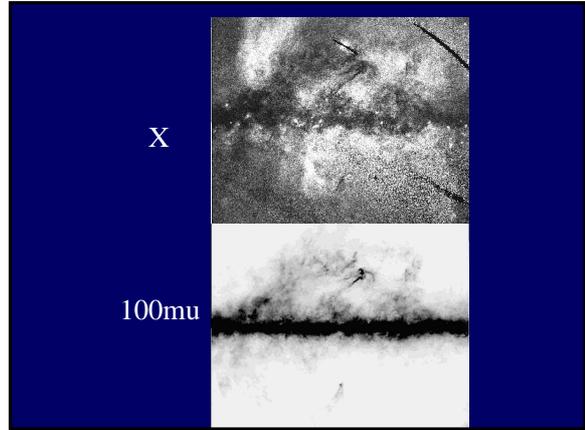
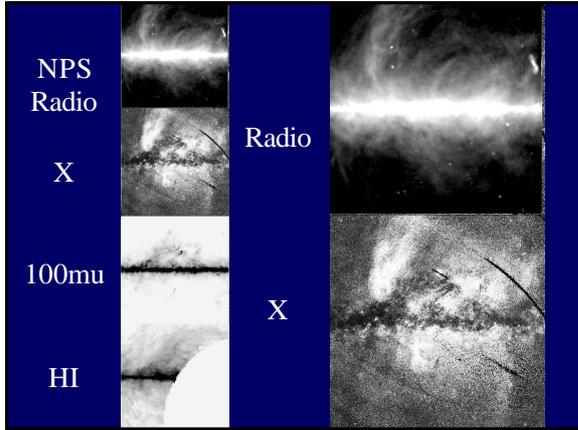


HI



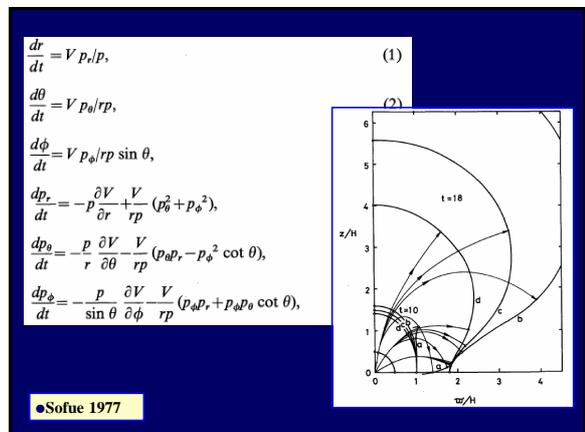
Halpha

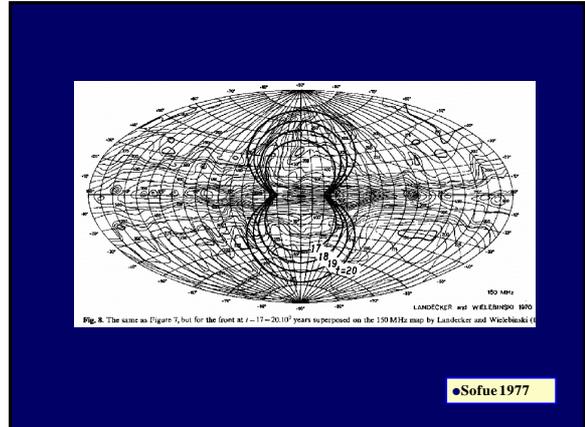
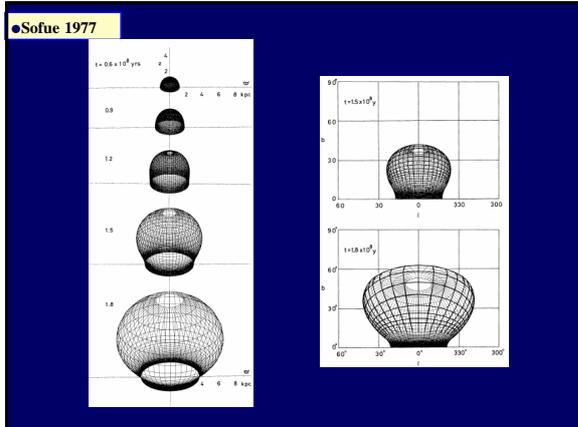




## 5. 銀河中心爆発 衝撃波シミュレーション

(1)  
 中心爆発  
 +  
 磁気流体波面近似  
 MHD fast wave approximation





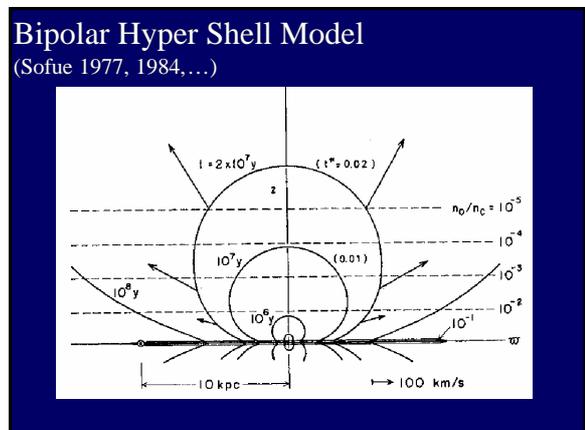
(2)  
 中心爆発 (スターバースト)  
 +  
 断熱衝撃波モデル

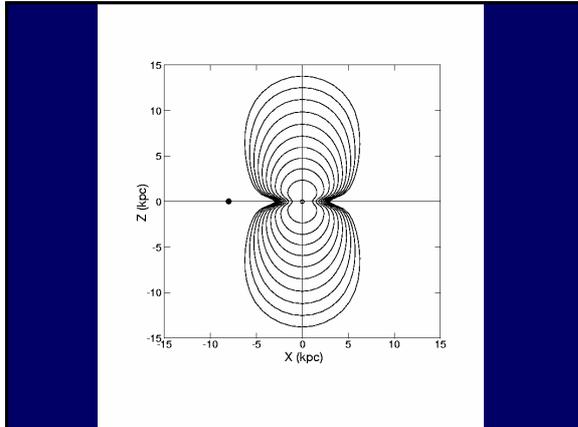
セミセドフ解

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

Radial Adiabatic Shock  
 Sakashita, Moellenhoff method

**Energetics**  
 $E \sim 1/2 Mv^2 \sim 10^{55-56}$  ergs  $\sim 10^{4-5}$  SN  
 $\sim 10^{-3}$  H/cc (Halo)  
 $r \sim 5$  kpc  
 $M \sim 4/3 r^3 v^2 \sim 10^7 M$   
 $v \sim 200-300$  km/s  
 $T \sim 10^7$  K X線  
 $t \sim 10^7$  yr

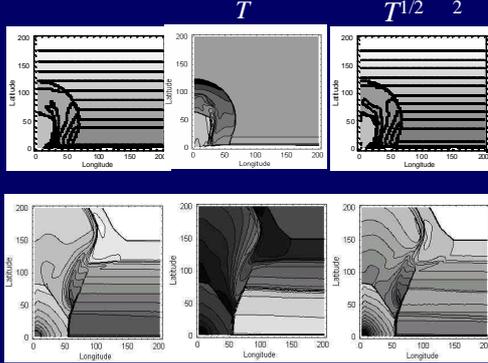




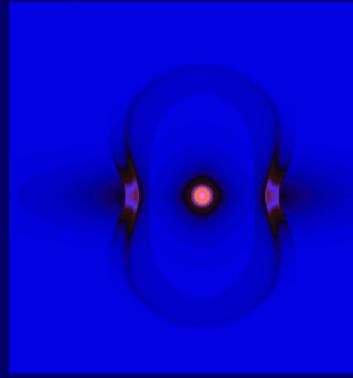
Hydrodynamical simulations  
(Tomisaka, Ikeuchi 1988; Suchkov et al. 1994)



Hydrodynamic Simulation (Sofue, Habe 2009)

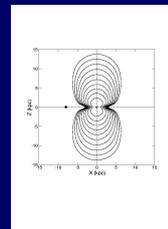


Hydrodynamic Simulation (with Habe)

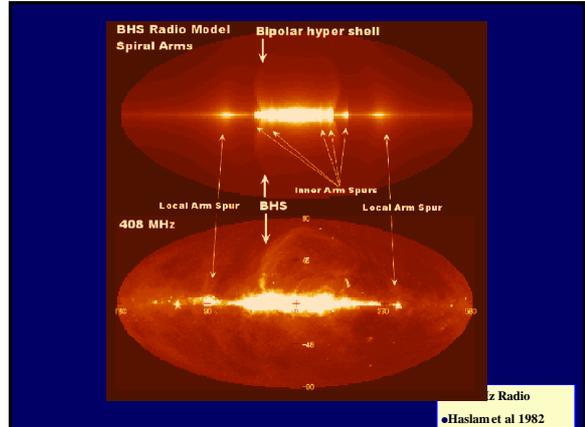


6. 電波、X線  
放射分布シミュレーション

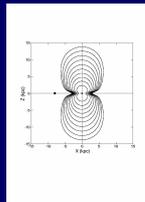
Radio synchrotron  
Emission  
 $B$



分布  
 = 衝撃波  
 + 円盤  
 + 渦状腕  
 + 八口一  
 + 銀河間ガス



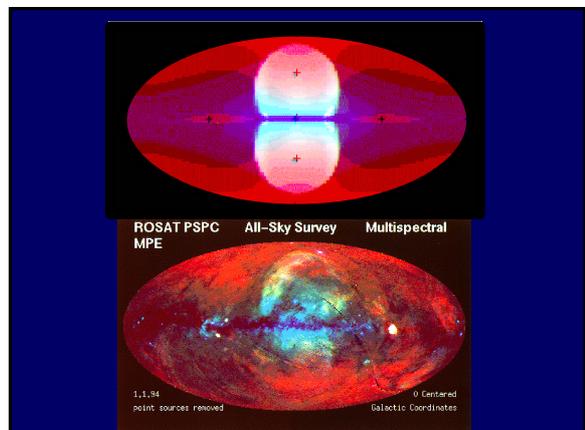
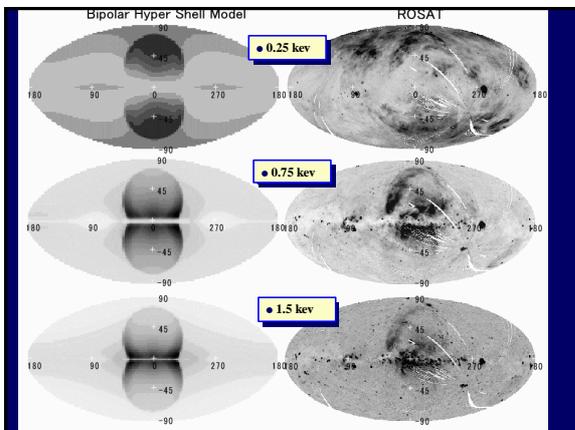
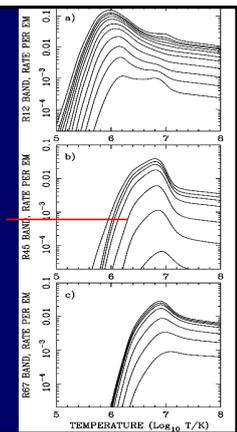
X-ray emission  
 = Thermal Bremsung  
 $2T^{0.5}$

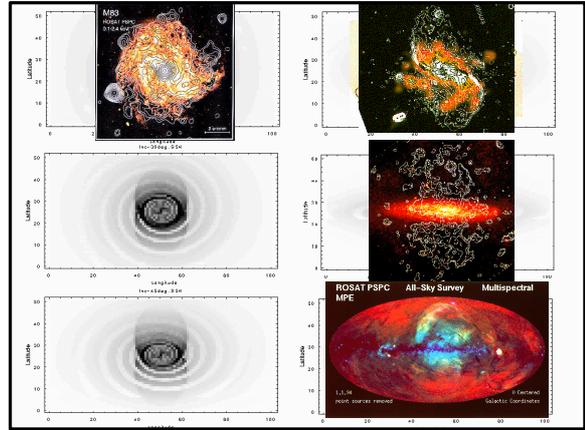
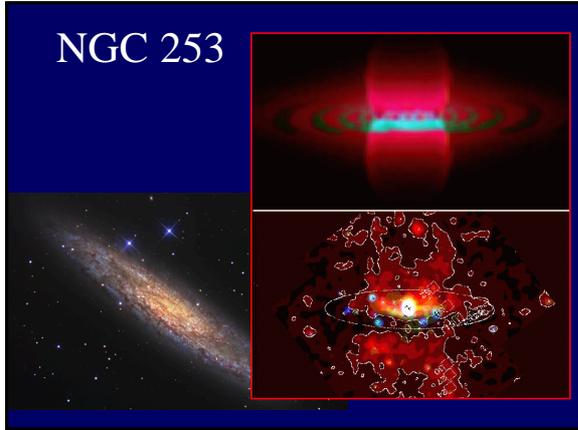


Transfer: Absorption by metals in HI Disk  
 $dI/ds = -I$   
 $d = n_H ds / N_{H,0}$

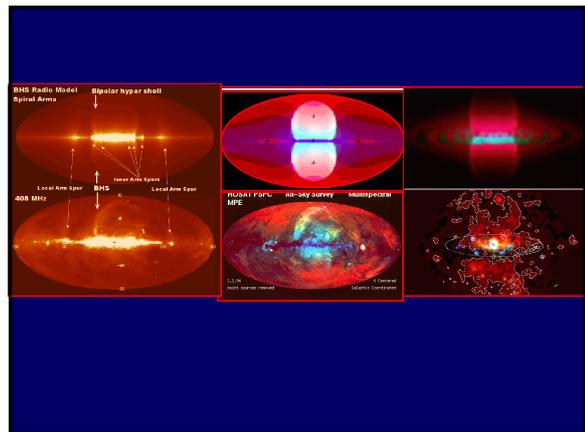
X-ray Absorption  
 at 0.25, 0.75, 1.5 keV

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





7. 結論、&  
これから



NPSは銀河系大爆発の  
名残り  
Galactic Big Bang  
t=1500万年前  
E=10<sup>55-56</sup> ergs.

Sofue, Y. 1970  
.....  
.....  
Sofue, Y. 1994 ApJ

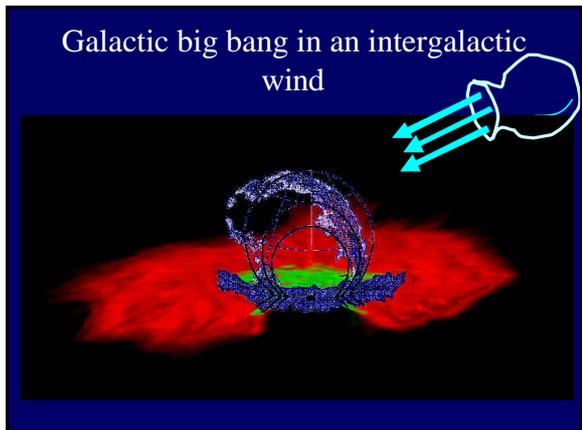
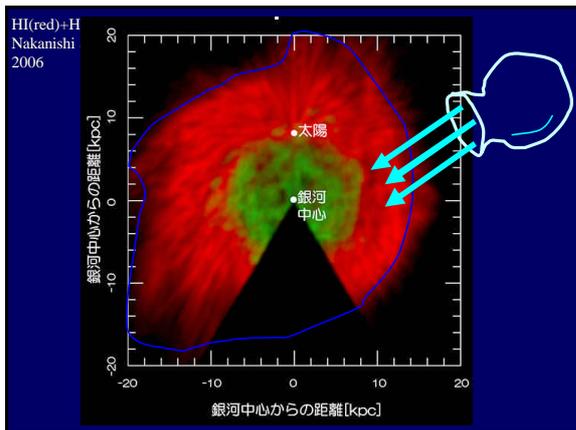
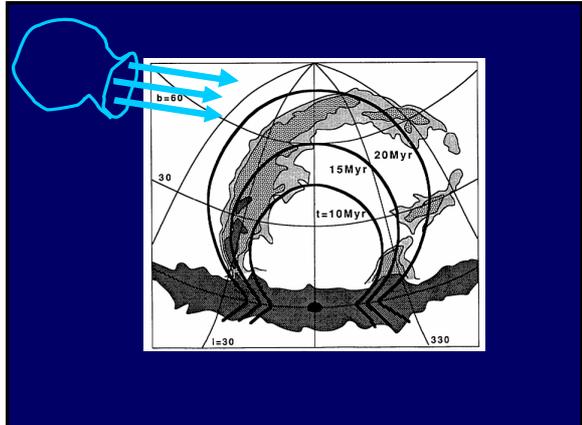
Sofue, Y. 2000 ApJ 540, 224  
Bipolar hyper shell, GC burst

Sofue, Y., Vogler, A. 2001 AA 370, 53  
Bipolar hyper shell in NGC 253, and many galaxies

Sofue, Y. et al. 2009+ in preparation  
Numerical shock simulation with Habe  
Halo/Intergalactic wind  
X-ray distance measurements  
Abundance : GC vs Local with Tsujimoto  
Radio polarization maps (WMAP 20 - 90 GHz)

# NPS研究の意味

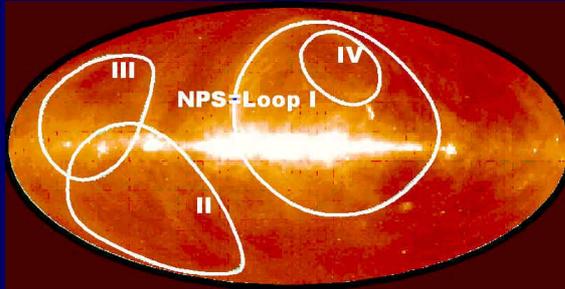
Probing the  
 Starburst  
 HI disk  
 Gas Halo  
 Halo-IG Interface  
 ICM, IGM  
 Halo/Intergal. Wind



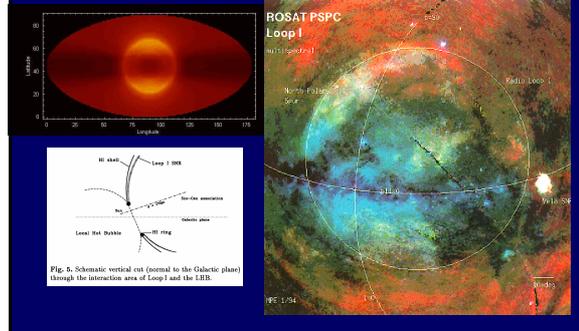
## 8. 孤軍奮闘の 30年論争 Since 1970'

ヨーロッパの 師曰わく」  
 Prof. Oort said, 'It may be an SNR.'  
 Spoelstra, Salter, Berkhuijsen,  
 ROSAT Egger's Thesis, ...  
 我が国の 師曰わく」  
 早川幸男先生(早川祖父江論争)、  
 小田稔先生、、、SUZAKU

## Galactic Radio Loops I, II, III, IV

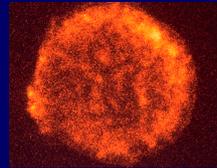
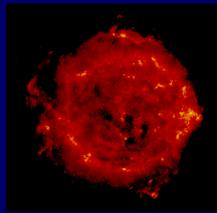
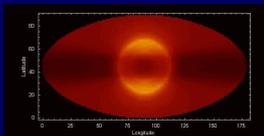


## Nearby SNR at 300 pc (Egger et al. 1995)

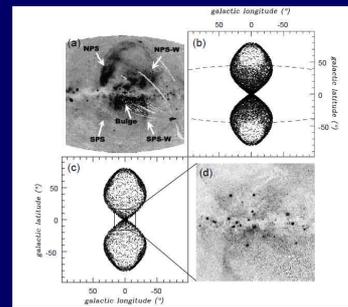


## SNR 説

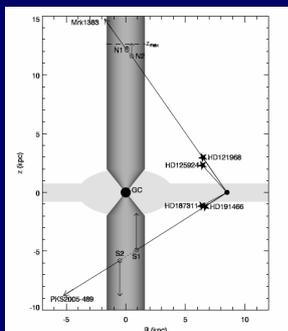
D relation  
 $\sim D^{-4}$   
 $D \sim 100 \text{ pc}$   
 $\sim 100 \text{ deg}$   
 Distance  $\sim 100 \text{ pc}$



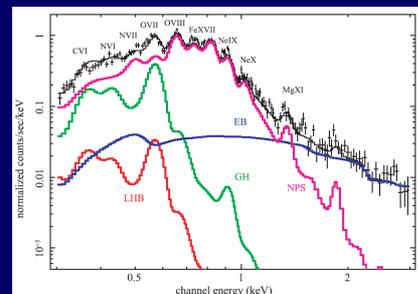
## 味方も現れた! Bland-Hawthorn and Cohen 2003 Galactic Wind model



## Keeney et al. 2006 Galactic Nuclear Wind model



## SUZAKUは味方か? X-ray Spectrum (Miller et al. 2009 PASJ) => Abundances



SUZAKU Metallicity (Miller et al. 2009)  
 Interpreted by T.Tsujimoto (2009 in prepa)

1. Fe/H : 太陽の半分と低い、ローカルだと低過ぎて難。中心衝撃波low-metalなハローガスで薄められた。
2. Mg/Fe : 太陽組成、local origin
3. O/H, C/H : 少ない。バルジの特徴。localでは期待できない。バルジのmetal-richな星ではmass lossが激しく起こりenvelopeが深く剥き取られ、onion-structureの外側でできるCやOができなくなる
4. N abundance 高い。起源に関する意味は不明。

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

銀河研究 - 三点セット  
 銀河回転  
 銀河磁場  
 銀河活動

