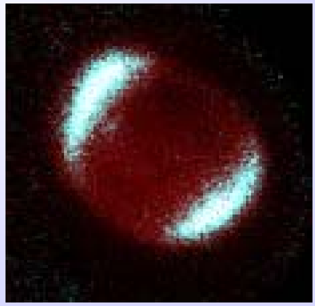
Fine Structure of the Thermal and Non-Thermal X-Rays in SN 1006



SN 1006 with ASCA

Aya Bamba

R. Yamazaki, M. Ueno, K. Koyama

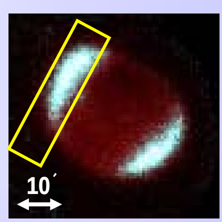
(Kyoto University, Japan)

1. Introduction

"How are cosmic rays accelerated up to TeV?"

Basic concept: Diffusive Shock Acceleration (DSA)
(Bell 1978; Blandford & Ostriker 1978…)

Koyama et al.(1995)
Discovery of synchrotron X-rays
from the shell of SN 1006



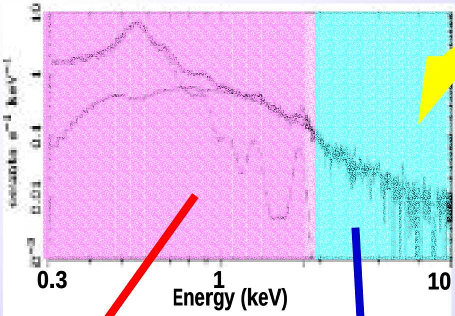
SN1006:
type Ia
d=1.8kpc

Next problem: More realistic model

"How do thermal and non-thermal electrons distribute on the shock?"

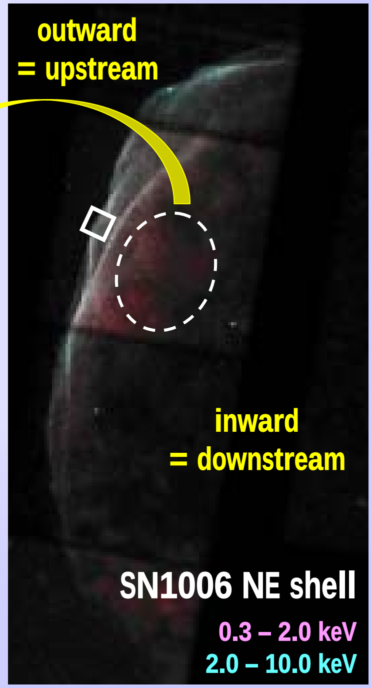
→ Spatial and spectral studies with Chandra

2.1. Image and spectrum



thermal
extended

non-thermal
sharp

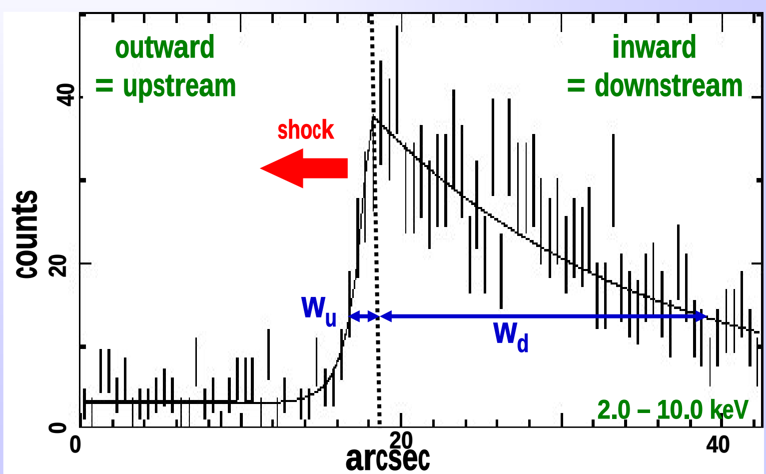


How large are the scale length of non-thermal component?

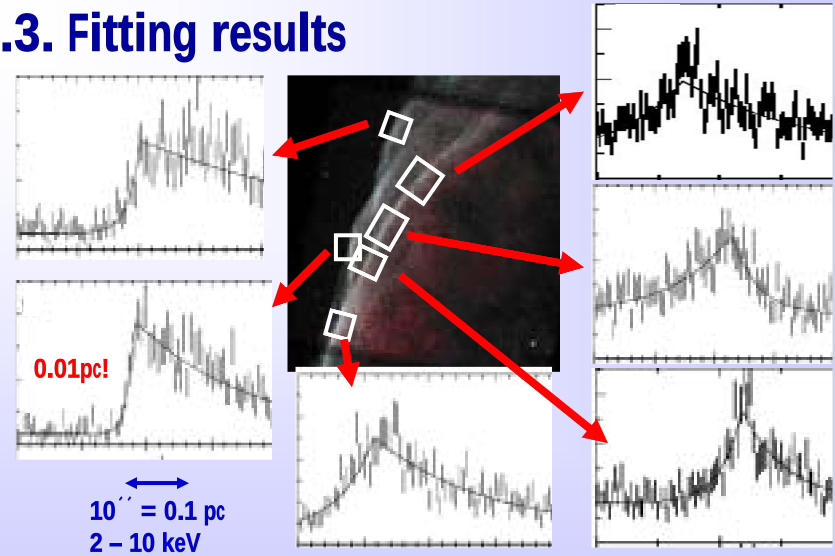
2.2. Analyses method

We want to know:

the scale length of non-thermal component in { upstream / downstream



2.3. Fitting results



	Upstream	Downstream
Mean value……………….	0.04 pc	0.2 pc
Minimum value……………	0.01 pc	0.05 pc

3.1. Discussion (1)
the observed and derived parameters

Observed parameters:

1. The wide band spectrum

$\nu_{break} = 8.4^{+2.4}_{-1.3} \times 10^{17}$ Hz → $E_{max} B_d^{0.5} = 0.30 \pm 0.03$ erg $G^{0.5}$

2. The diffusion coefficient K

$w_u = \frac{K_u}{u_u} \quad w_d = \frac{K_d}{u_d}$

$u_u = 4u_d = u_s = 2600$ km/s (Winkler & Long 1997)

→ $K = \frac{\xi E_{max} c}{3eB} \quad \xi \sim \frac{B}{\delta B} > 1$

$\frac{E_{max}}{B_d} > 6.4 \times 10^6$ erg/G

3. The acceleration and loss

$t_{acc} = \frac{4(K_u + K_d)}{u_s^2} = 10^{10}$s

$t_{sync} = 6.3 \times 10^2 E_{max}^{-1} B_d^{-2}$

→ $t_{acc} < t_{sync}$

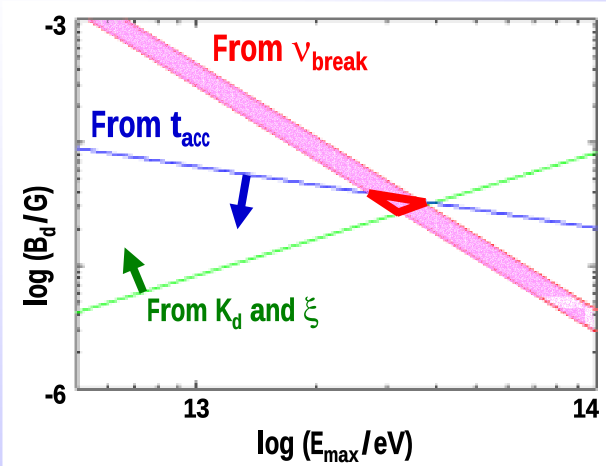
$E_{max} B_d^2 < 6.5 \times 10^{-8}$ erg G^2

Derived parameters from DSA:

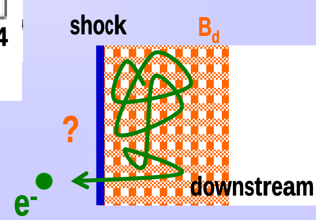
E_{max} , B_d

3.2. Discussion (2)

the E_{max} – B_d relation



E_{max} ~ 30 TeV
B_d ~ 30 μG
ξ_d < 1.3



Highly turbulent magnetic field!

3.3. Discussion (3)

in upstream

E_{max} ~ 30 TeV
B_d ~ 30 μG
$\frac{1}{4} B_d < B_u < B_d$

→ $7\ \mu G < B_u < 30\ \mu G$

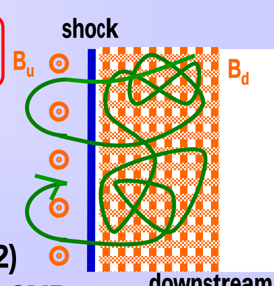
The gyro radius in upstream r_g:

$$0.001\ \mathrm{pc} < r_g = \frac{E_{max}}{eB_u} < 0.005\ \mathrm{pc} \quad \sim w_u^{min} = 0.01\ \mathrm{pc}\ !$$

Conventional DSA cannot explain the result.

the magnetic field in upstream
nearly parallel to shock plane
the new acceleration mechanism
e.g. Surfing acceleration (Hoshino & Shimada 2002)

Further analyses of SN 1006 and other SNRs



4. Summary

1. We resolved non-thermal emission from thermal plasma in spatially and spectroscopically.

2. The non-thermal filaments have very small scale length!

3. The conventional DSA should be revised to explain the small scale length.

   or the magnetic field parallel to shock plane only in upstream?
   new acceleration mechanism?