The thermal relaxation process in collisionless shock of SN1006

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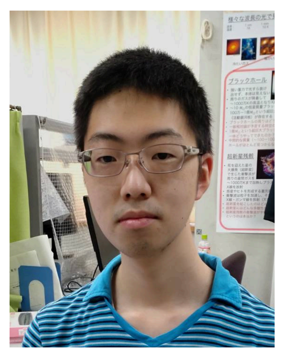
←PASJ accepted! (arXiv:2405.09040)



Introduction

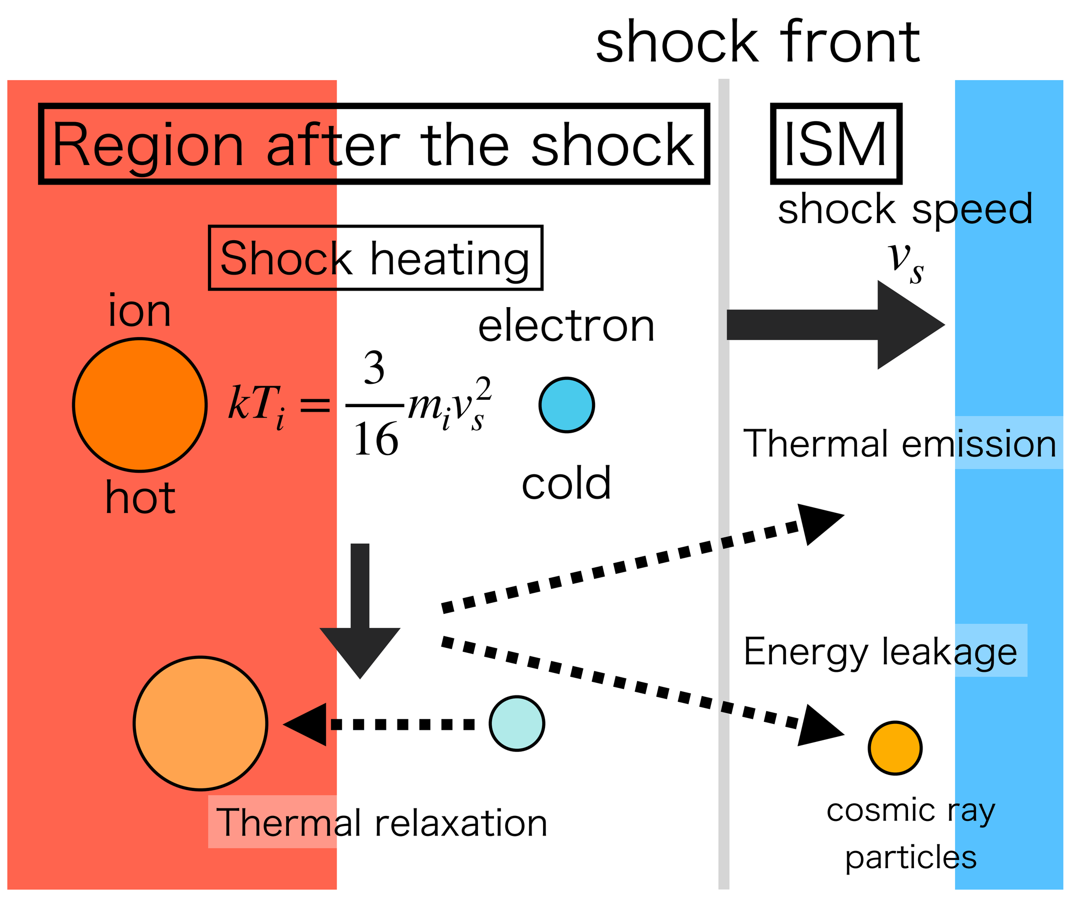


Fig.1
The image of energy balance near the shock

The environment of plasma near the shock : **non-equilibrium state**
Each particle has a different temperature
→**Thermal relaxation** between electrons and ions occurs
Ideal → Thermal relaxation due to the Coulomb relaxation[1]
Reality→ Energy leakage (thermal emission and cosmic ray acceleration)
→ **Different temperature distribution** from Coulomb relaxation

Thermal relaxation process cannot be observed in previous studies.
A sign of relaxation was observed in Puppis A[2]
→The relaxation dynamics was not discussed due to the lack of spatial resolution

Our purpose : 1.Observation of thermal relaxation
2.Estimation of energy leakage from near the shock

Observation

Object :
SN 1006
(the northwestern region)
Divide into 4×3 layers with a thickness of 15'' (0.16 pc) each
Model :
Non-equilibrium ionization collisional plasma model
Assuming that the emission is from **the shocked interstellar medium heated by the shockwave**
kT, nt and some abundance is assumed as free

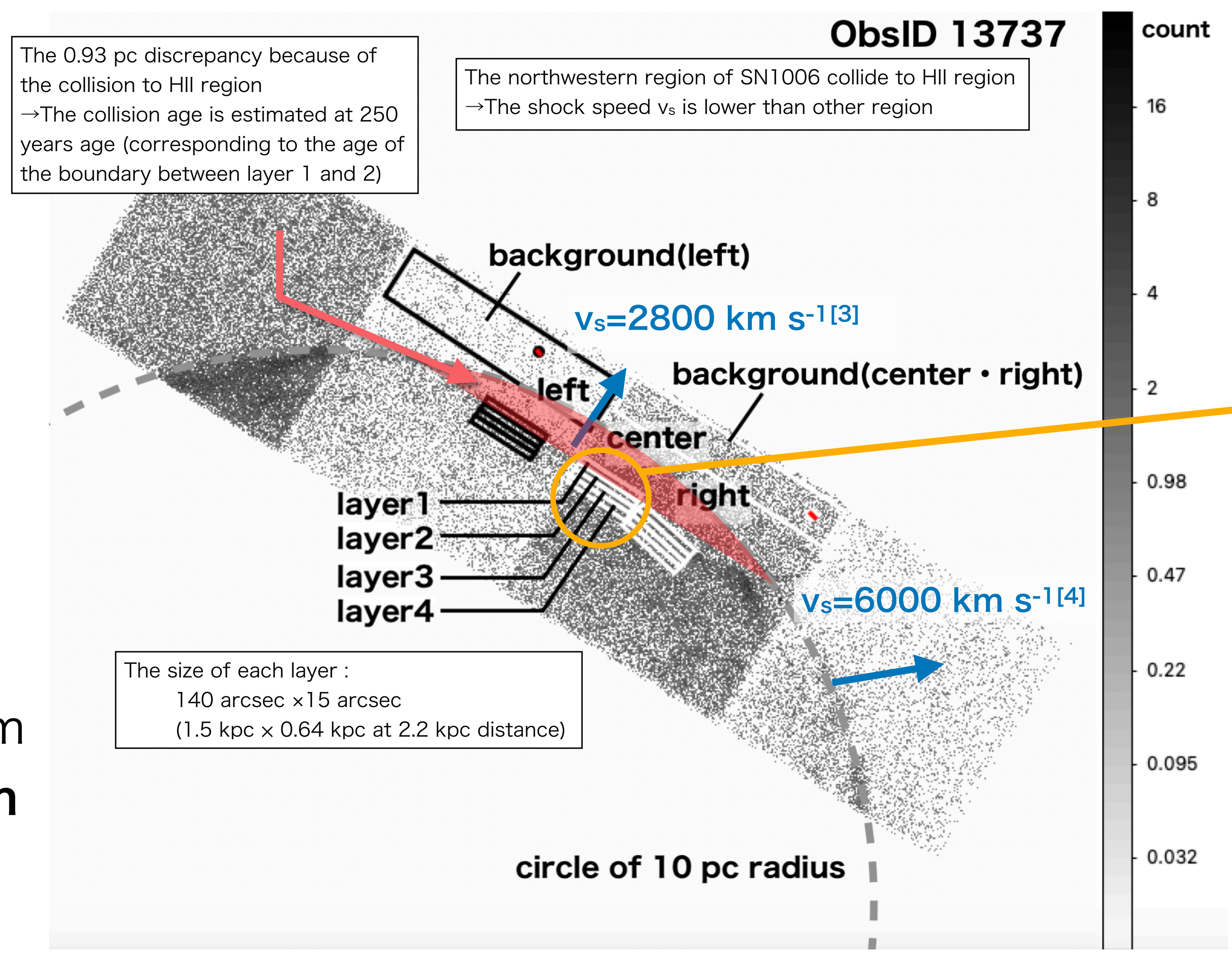


Fig.2
The images of the northwestern region of SN 1006

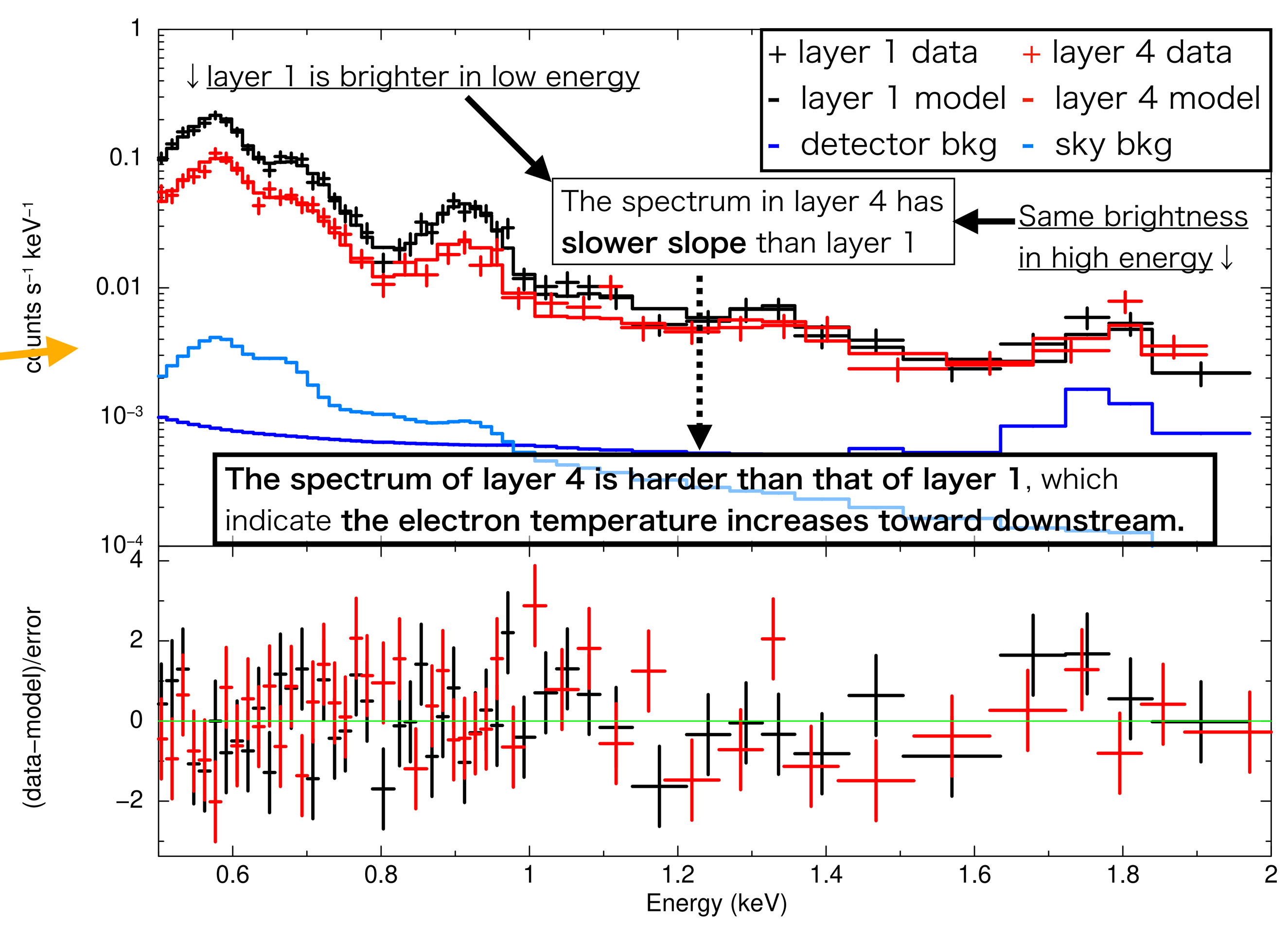


Fig.3
The spectra of layer 1 (black) and 4 (red) and the best-fit model

Result

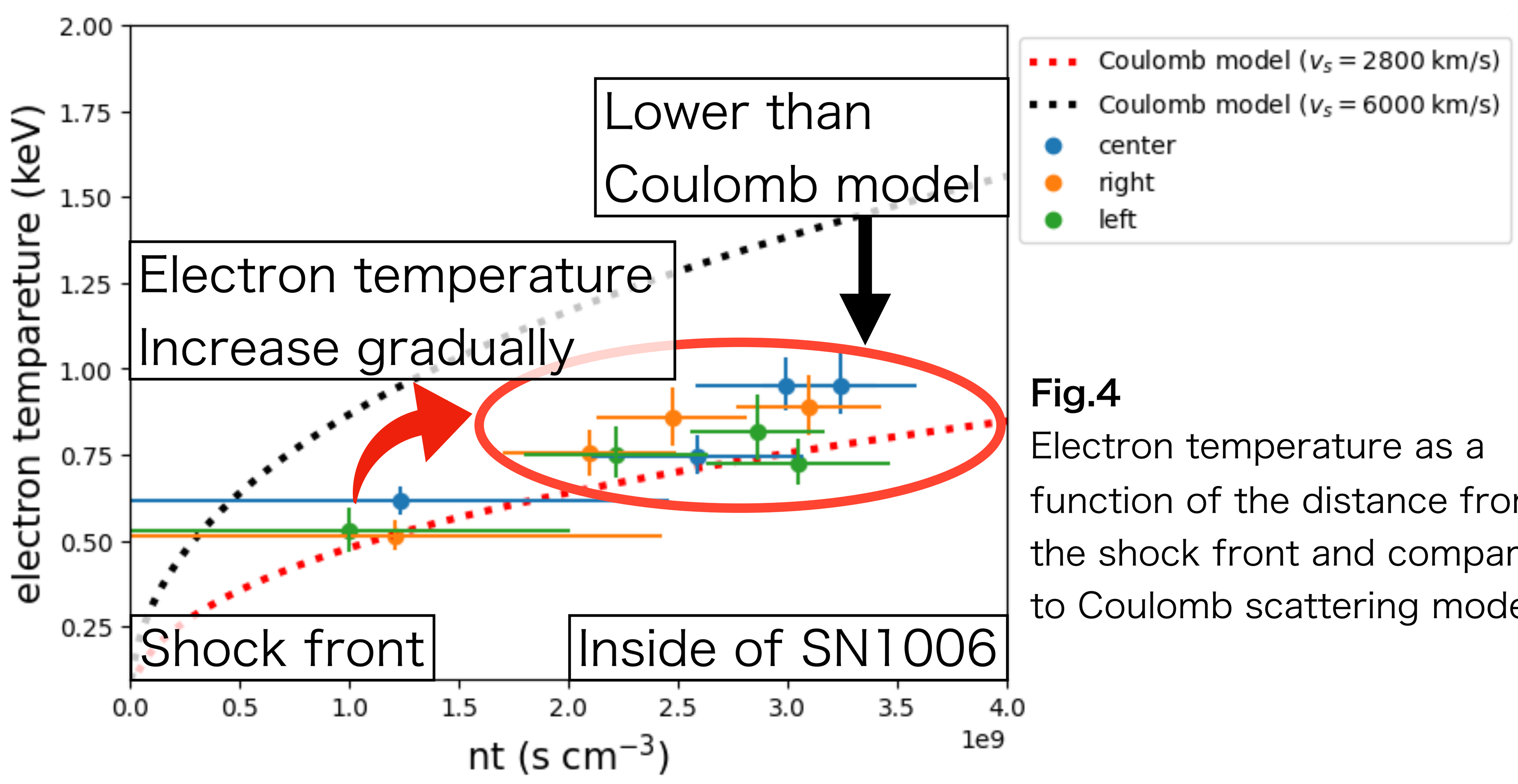


Fig.4
Electron temperature as a function of the distance from the shock front and comparison to Coulomb scattering model

Electron temperature
gradually **increase toward downstream (Fig.4)**

Comparison to the heating mechanism of electrons (Fig.4)
We compare to **the coulomb relaxation model** (the simplest heating mechanism)
layer 1 (v_s= 2800 km s^{-1}) : **consistent to the model**
layer 2-4 (v_s = 6000 km s^{-1}) : **observation is much lower**
※nt of each layer is estimated from electron density and plasma age
nt in best-fit parameter behave strangely, so we need further analysis

What cause this temperature discrepancy?
Projection effect, thermal emission, energy leakage to particle acceleration, etc...

To evaluate the energy leakage, **we also need to observe the ion temperatures**
Ion temperature → Estimated from **the Doppler broadening of characteristic X-ray lines**
However, The data set of Chandra has no energy resolution for the estimation of ion temperature...
→**Expect satellites with high energy resolution** such as XRISM (<5 eV [5]) and Athena (~2.5 eV[6])

Conclusion

- We analyze the northwestern region of SN1006 with Chandra for estimation of energy leakage from near the shock
- **Electron temperature increase toward downstream**, which is **lower than the Coulomb relaxation model**
- Ion temperatures cannot be measured due to the lack of energy resolution of Chandra.
- We will analyze the ion temperature near the shock by using satellites such as XRISM or Athena.

Reference

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