Interpretation of multibands emission in W49B
—Unveiling the spatial structure of the overionized plasma

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1 Abstract

The origin of Mixed-morphology supernova remnants is still controversial because of the variety of complex interaction effects between these remnants and the surrounding circumstellar and interstellar medium. Important pending issues are the presence of enhanced abundances and overionization (recently detected in W49B).

We investigate this intriguing issue through a multidimensional hydrodynamic model describing W49B that takes into account, for the first time, the mixing of ejecta with the circumstellar and interstellar medium, thermal conduction, and non-equilibrium ionization. The plasma of W49B is metal-rich and overionized and there are ring-like structures in IR and radio bands around its center, and shocked molecular material in its eastern and southwestern parts. We report on preliminary results about possible scenarios reconciling all the observational results in W49B.

2 Numerical model

1. Equations:

The model takes into account thermal conduction (including the effect of heat flux saturation), radiative losses, and the NEI effects.

Thermal conduction (both classical and saturated considered):

\[ q = \frac{1}{\kappa(T)} \left( T - T_e \right) \]

\[ \kappa(T) = 5.6 \times 10^{-7} T^{3/2} \text{ erg s}^{-1} \text{ K}^{-1} \text{ cm}^{-1} \]

Saturated conductivity:

\[ \kappa_{\text{sat}} = \frac{\epsilon}{\epsilon - \epsilon_0} \]

Continuity equations for each ion species:

\[ \frac{\partial n_i}{\partial t} + \nabla \cdot \mathbf{J}_i = R_i \]

where

\[ R_i = n_i \alpha_i^c S_i^c + n_i \alpha_i^e S_i^e \]

\[ \alpha_i^c \] represents the collisional and dielectronic recombination coefficients, and \[ S_i^c \] represents the collisional ionization coefficients.

2. Initial condition:

- The initial remnant contains 6 solar masses of ejecta and 10^51 ergs of explosion energy.
- The simulation domain is the r-z plane in cylindrical coordinate.
- According to the ring-like structures that are visible in IR and radio bands, a dense ring was introduced around the initial remnant.
- A dense wall was also introduced in the upper region, following the observed shocked molecular strip in eastern region.

3 Results

1. Density & temperature distribution:

The morphology is consistent with the observation:
- jet-like structure in the center;
- Hot and dense shell near the boundary of upper dense wall.

2. NEI effect:

The black contour on the left panel represents the distribution of ejecta material; the white contour on the right panel derived from DI map at zero.

3. Visibility of RRC:

- The radiative recombination continuum (RRC) is observed in the center and in the western region (lower region in simulation) (Ozawa et al. 2009, Miceli et al. 2010);
- The map of the ratio between the luminosity of RRC of FeXXV and thermal bremsstrahlung emission is an indicator of the visibility of RRC.
- The map of log10(\text{L}_{\text{RRC}}/\text{L}_{\text{bremstrahlung}}) of FeXXV indicates that the RRC is mostly visible in the center and in the lower region (western region).

4 Conclusions

- The thermal conduction is important in recovering the observed morphology of W49B.
- A non-negligible fraction of the ring material evaporates in the hot surrounding medium
- Large regions of overionized plasma form within the remnant.
- The physical origin of the overionized plasma is to be sought in the rapid cooling due to evaporation of ring material and in the rapid expansion of the plasma in the unbounded side of the remnant.
- The visibility of RRC predicted by the numerical model is consistent with the observations.