X-Ray Ejecta Kinematics of the Galactic Core-Collapse Supernova Remnant G292.0+1.8

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ABSTRACT

We report on the results of the analysis of our 120 ks Chandra HETGS observation of the Galactic core-collapse SNR G292.0+1.8. To probe the 3D structure of the remnant, and help locate its reverse shock, we measured Doppler shifts in emission lines from metal-rich ejecta knots projected at different radial distances from the expansion center. We obtain radial velocities in the range of -2200 ≤ v_r ≤ 1000 km s^{-1}. The distribution of ejecta knots in velocity-radial distance space suggests the kinematics of an expanding ejecta shell with a thickness of ~3 pc. We qualitatively estimate the locations for the reverse shock and contact discontinuity, based on the geometrical distribution of the ejecta knots. Our results suggest that the reverse shock has traveled inward to a radius of ~130 pc (-4 pc at d = 6 kpc), putting it in close proximity to the radio pulsar wind nebula.

INTRODUCTION

G292.0+1.8

- One of three known Galactic oxygen-rich core-collapse supernova remnants (CSCSncRns) [9]
- 3000 yr old [8.7, 18], angular size D = 9' [17], distance d = 6 kpc [5]
- Bright, ejecta-dominated in X-rays.
- Based on ACIS-S3 (40 ks), HRC (50 ks), and ACIS-I (530 ks) data:
  * Pulsar wind nebula (PWN) [10]
  * Radio pulsar (PSR J1124-5916) and PWN [1, 5]
- Evidence for an asymmetric explosion:
  * An X-ray ejecta temperature gradient in the N-S direction [18]
  * Higher optical knot velocities in the N-S direction, as compared to the E-W direction [18]
  * An X-ray ejecta temperature gradient in the NW-SE direction [17]
  * The FS is interacting with a red supergiant (RSG) wind profile (ρ ~ r^{-1})
  * Forward shock (FS) outlining a faint, diffuse boundary of shocked CSM
- We constructed a velocity-radial distance distribution plot (Fig. 4.5), including knots with statistically acceptable v_r values. The optical expansion center is marked with a black cross, and the pulsar PSR J1124-5916 by an arrow.

ANALYSIS AND RESULTS

Under the assumption of homologous expansion (i.e., v_r proportional to r, as occurs in free expansion and in self-similar hydrodynamics), Fig 1 is an illustration of how knowledge of a knot’s radial velocity (v_r) informs about its location along the line-of-sight. Knots projected close to the center, such as “knot A,” could actually be close to the outer boundary if v_r is large, or close to the center if v_r is small. On the other hand, knots projected close to the outer boundary, such as “knot B,” will have low v_r, since their motion is primarily perpendicular to the line-of-sight.

Based on our high resolution HETG spectroscopic data, we measured Doppler shifts in 32 knots and filaments. Using ACIS-I data [17], we identify 23 of them as metal-rich ejecta and 9 as CSM filaments based on their metal abundance measurements (Fig 2).

We fit atomic line emission profiles (Ne IX (13.447 Å), NeX (12.132 Å), Mg XI (9.1685 Å), Mg XII (8.419 Å), and Si XII (6.6477 Å)) with Gaussians to estimate Doppler shifts, using methods similar to those used for Cas A [13]. Fig 3 shows an example.

We constructed a velocity-radial distance distribution plot (Fig 4) for the knots with statistically acceptable v_r values (32 regions with χ^2 < 2.0). The distributions can be divided generally into three main groups:

1. Ejecta with high v_r (<1000 km s^{-1}), with projected locations close to the center
2. Ejecta with low v_r (<1000 km s^{-1}), with projected locations close to the outer boundary
3. CSM at low v_r, located mostly along the equatorial belt

Qualitatively, all ejecta knots appear to lie within an elliptical shell (r_e = 130°, r_c = 220°) in velocity position space. The inner and outer boundaries may correspond to the locations of RS (~130°), and the contact discontinuity (CD) at ~220° (Figs. 4 & 5). The forward shock location at 7.76 pc is also marked at ~265° [14], d is the distance to the SNR in units of 6 kpc.

DISCUSSION

Our preliminary analysis discloses an X-ray kinematic picture of G292.0+1.8 for the first time. Based on the distribution of ejecta knots on velocity-radius plots, we qualitatively estimate the positions of the RS and CD.

Ejecta knots projected within the RS boundary show high radial velocity (|v_r| > 1000-2000 km s^{-1}) (Fig 5). Knots projected at large radii between the RS and CD, however, have lower velocities of |v_r| < 1000 km s^{-1}, indicating their motion is largely perpendicular to the line-of-sight. These results indicate that the bulk of ejecta knots projected near the SNR center are located close to the CD along the line-of-sight.

CONCLUSIONS AND FUTURE WORK

The close proximity between the RS and the PWN suggests a likely interaction between the two. Asymmetries in the RS plane may affect the details of such an interaction. Recently, based on Suzaku data, faint Fe-rich ejecta has been reported to be detected in G292.0+1.8 [12], which may be consistent with our inferred location of the RS near the PWN.

An extensive study of ejecta and CSM features across the SNR using the deep ACIS data will be required to reveal the detailed geometry of this textbook-type CC SNR, particularly in conjunction with our kinematic study. Hydrodynamic numerical simulations would also be necessary to reveal details of the evolution of history and dynamics of these SNR, such as the origin of the inferred small R_{RS}/R_{CD}.

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