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SN 1006 in context: from Type Ia supernova to remnant

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Abstract. The evolutionary phases in going from a Type Ia supernova explosion to a 1000-yr-old remnant are reviewed. The explosion sets up the density and composition structure of the ejecta and can have radiative effects on the surroundings. The early shock interactions may be observable at radio and X-ray wavelengths if the circumstellar density is sufficiently high. The later interaction with the interstellar medium is affected by the collisionless shock physics and hydrodynamic instabilities.

Keywords. supernovae: general, supernova remnant

In the explosion of a white dwarf, as expected in a SN Ia (Type Ia supernova), the shock wave accelerates through the outer layers with rapidly declining density. The resulting density profile is a steep power law in radius that can extend out to relativistic velocities. The lack of detectable radio emission from SNe Ia suggests a low surrounding density and the shock interaction region is expected at a high velocity ($\geqslant 40\,000\,\mathrm{km\,s^{-1}}$) at an age of ~10 days. Based on experience with SNe Ib/c, which are observed as radio and X-ray sources, it is likely that synchrotron self-absorption is the dominant absorption mechanism for radio emission if their emission is close to current upper limits. X-ray emission is likely to be non-thermal, but is very uncertain. In this interpretation of the strongest radio limits, the circumstellar density is lower than a mass loss rate of $10^{-8}\,\mathrm{M_\odot yr^{-1}}$ for a wind velocity of $10\,\mathrm{km\,s^{-1}}$.

The recent apparent detection of SN 2005ke at X-ray wavelengths suggests a higher density for that case, but the detection cannot be regarded as completely secure. SN 2002ic appears to be running into very dense gas at some distance from the supernova and is the prototype of a number of similar objects; however, recent studies indicate it may not have been a SN Ia.

The expansion rate and deduced surroundings of SN 1006 are consistent with interstellar interaction. The same is true for other young SN Ia remnants, except for SN 1604 (Kepler). In this case, there is interaction with relatively dense surroundings, indicated by radiative shock waves, but there are some H I clouds at high Galactic altitude. The type of SN 1604 has been uncertain, but it is becoming regarded as a likely SN Ia. The general lack of evidence in SNe Ia for wind interaction is consistent with progenitor systems in which the companion star to the exploding white dwarf is a main sequence star or another white dwarf. This result is consistent with the possible stellar companion found in the central region of the SN 1572 (Tycho) remnant.

The SN 1006 remnant shows X-ray emission from ejecta close to the outer shock front, as does the SN 1572 remnant, where this property has been interpreted as indicating a narrow shocked region because of efficient cosmic ray acceleration. However, an inhomogeneous ejecta structure could give rise to a broad region of ejecta in the shocked region. The combination of non-radiative shock optical emission and synchrotron X-ray emission in SN 1006 make it an excellent laboratory for the study of fast shock physics.