Are SN 2008S-like Events Supernovae?

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Abstract

We present new, late-time Hubble and Spitzer Space Telescope observations of SN 2008S and NGC 300 2008OT-1, the prototypes of a class of stellar transients whose true nature is debated. Both objects have faded below the luminosity of their progenitors. Using dust radiative transfer models, we find that it is difficult, particularly for NGC 300 2008OT-1, to explain this flux decrease as being solely due to dust obscuration, supporting the interpretation that these transients are electron capture supernovae whose late time emission is due to a shock passing through the preexisting dense CSM.

SN 2008S-like Transients

These transients share many characteristics with SN "impostors" (e.g., SN IIn-like spectra but lower peak luminosities and ejecta velocities than typical supernovae), but their progenitors are lower-mass (~10 $M_\odot$), self-obscured extreme asymptotic branch stars (Prieto et al. 2008; Thompson et al. 2009), rather than the massive luminous blue variables usually thought to give rise to the SN impostor phenomenon (e.g., Smith et al. 2011; van Dyk & Matheson 2012).

The rate of SN 2008S-like events is ~20% of the SN rate, but the dusty progenitor stars are rare, implying that the dust-enshrouded phase is a short-lived phenomenon preceding the eruption (Thompson et al. 2009). They have been interpreted as non-terminal stellar outbursts (Berger et al. 2009; Bond et al. 2009) due to super-Eddington winds (Berger et al. 2009; Smith et al. 2009) or binary mergers (Kashi et al. 2010), and as electron-capture supernovae (Botticella et al. 2009).

Ultimately the nature of the outbursts must be decided by whether the sources return to their pre-outburst luminosity or fade to leave no surviving star.

SN 2008S & NGC 300 2008OT-1

SN 2008S was discovered by Arbour & Boles (2008) in NGC 6946. Just two months later NGC 300 2008OT-1, a near twin, was discovered by Monard (2008). Optical searches for the progenitors turned up empty despite deep limits (Prieto et al. 2008; Berger & Soderberg 2008). Obscured progenitors with luminosities of ~50,000 $L_\odot$ were found in archival SST data by Prieto (2008) and Prieto et al. (2008). The progenitors were likely obscured by dense (10^{-4} $M_\odot$/yr), dusty winds to have apparent photospheric temperatures of ~400 K.

During the transient, an unobserved shock breakout must have destroyed the obscuring dust to allow the observation of the optical transient. The sources again became dusty within two years of their discoveries, probably due to dust reforming in the previously emitted wind (Kochanek 2011).

We have been monitoring these two sources with HST, SST, and LBT. The sources are now undetected in all filters for which we have data with the exception of 4.5 μm, where the flux has fallen below that of the progenitor and is still decreasing. The 4.5 μm SST light curves are shown below in Fig. 1 and the latest images are compared to those of the progenitors in Fig.2.

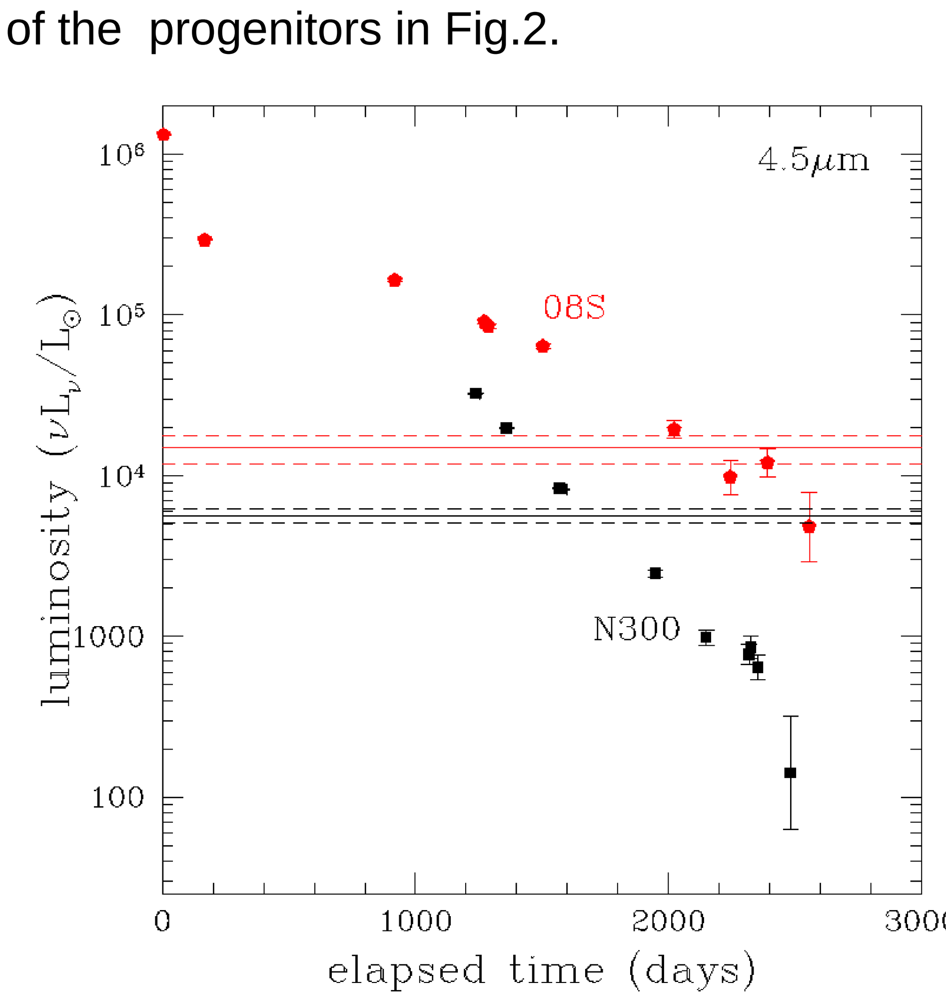

Fig. 1. *Spitzer* 4.5 μm light curves (from image subtraction) of SN 2008S and NGC 300 2008OT-1 with elapsed time since the discoveries of the transients. The fluxes for both sources have fallen below those of the progenitors (horizontal bands) and are still dropping.

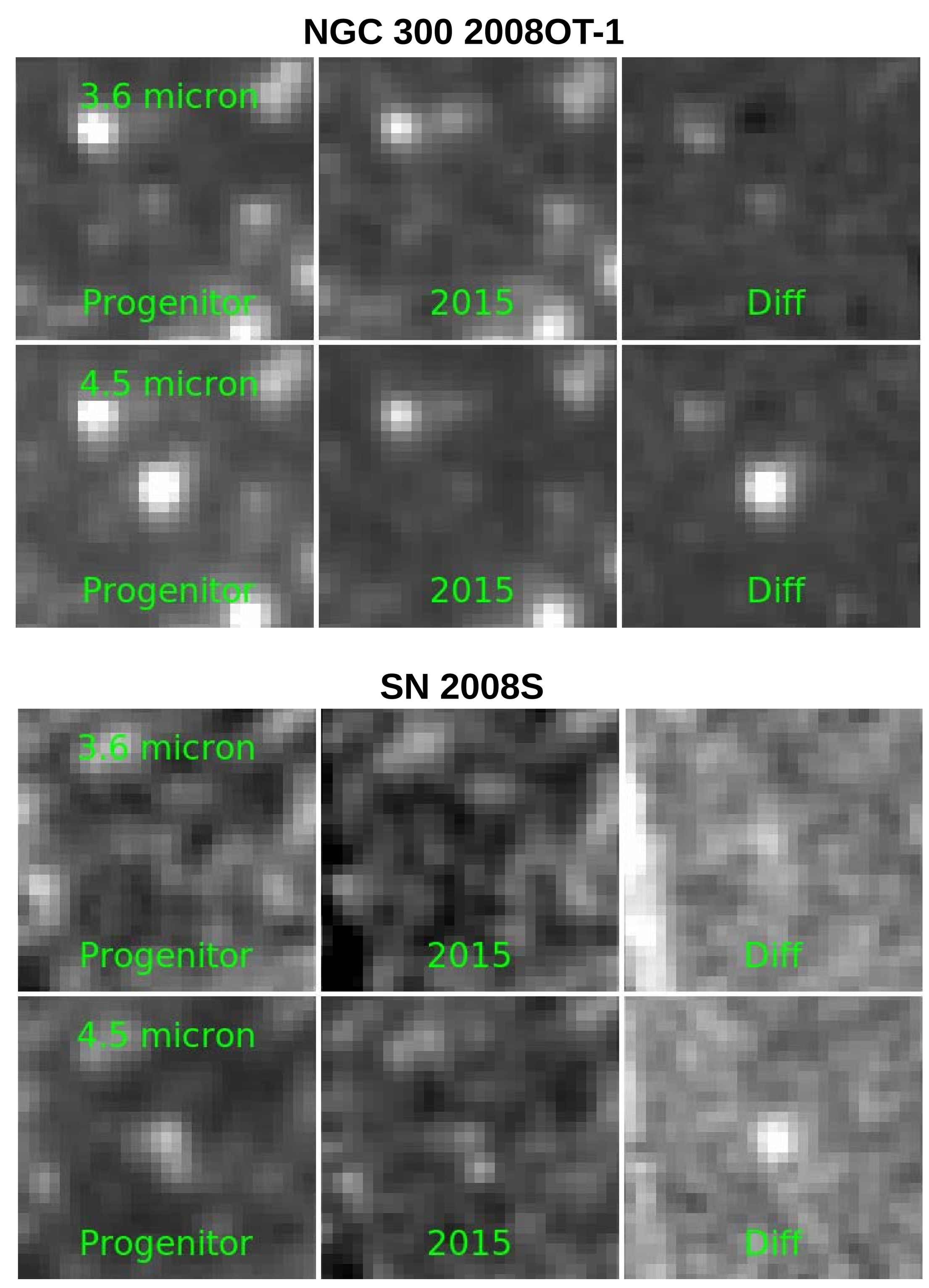

Fig. 2. SST images of the region surrounding NGC 300 2008OT-1 (top) and SN 2008S (bottom). The difference images (which show flux decreases as white) indicate that both sources are now fainter than their progenitors at both 3.6 and 4.5 μm.

SED Modeling

Figure 3 shows the current SEDs as compared to their progenitors. Both systems are now fainter than their progenitors, so we explored the presently allowed luminosities of any surviving star. We focus on two possible scenarios: the stars are obscured by either a dusty shell ejected during the transient or by a steady wind. For each case we model the SED of the source using DUSTY (Ivezic et al. 1999), a code for solving radiative transfer through a spherically symmetric dusty medium and find the maximum luminosity of a possible surviving star (see Fig. 4).

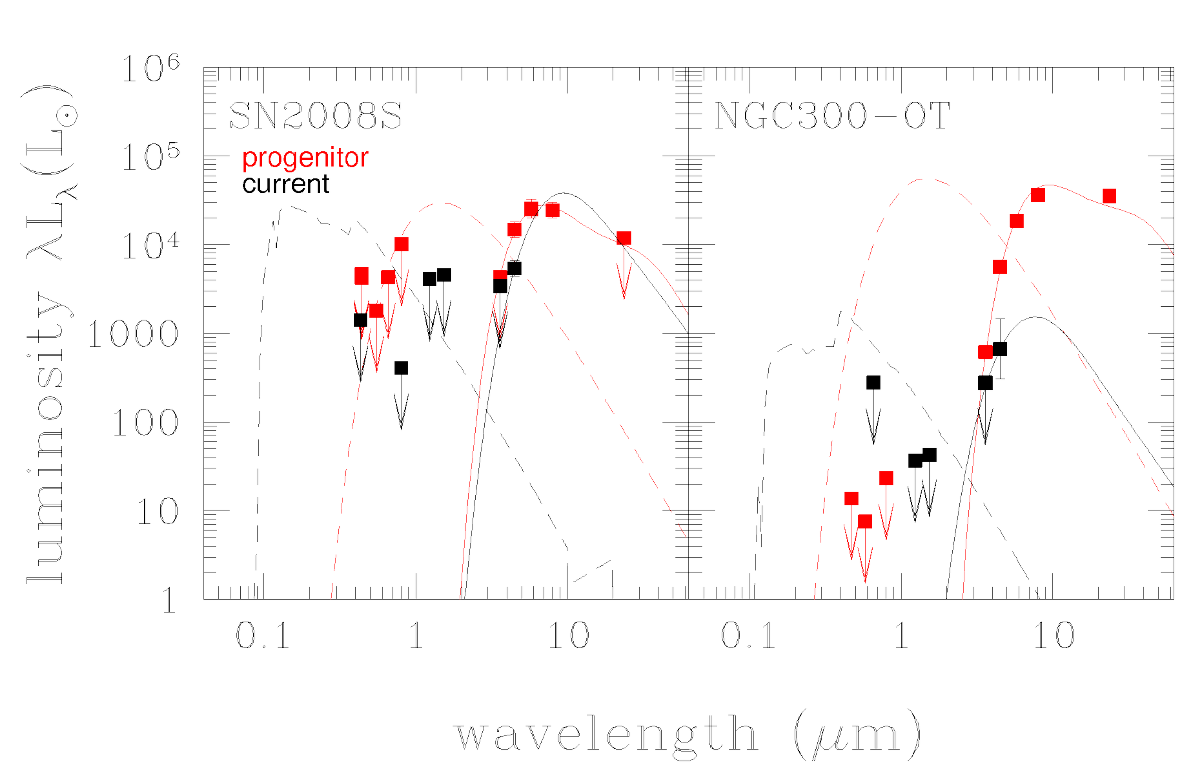

Fig. 3. Best-fit SEDs for possible surviving stars in the dusty wind scenario (black) compared to the SEDs for the progenitors (red). Since the only detections are at 4.5 μm) and there are no constraints at longer wavelengths there are some degeneracies in the solutions, with increasingly luminous survivors allowed with higher optical depths.

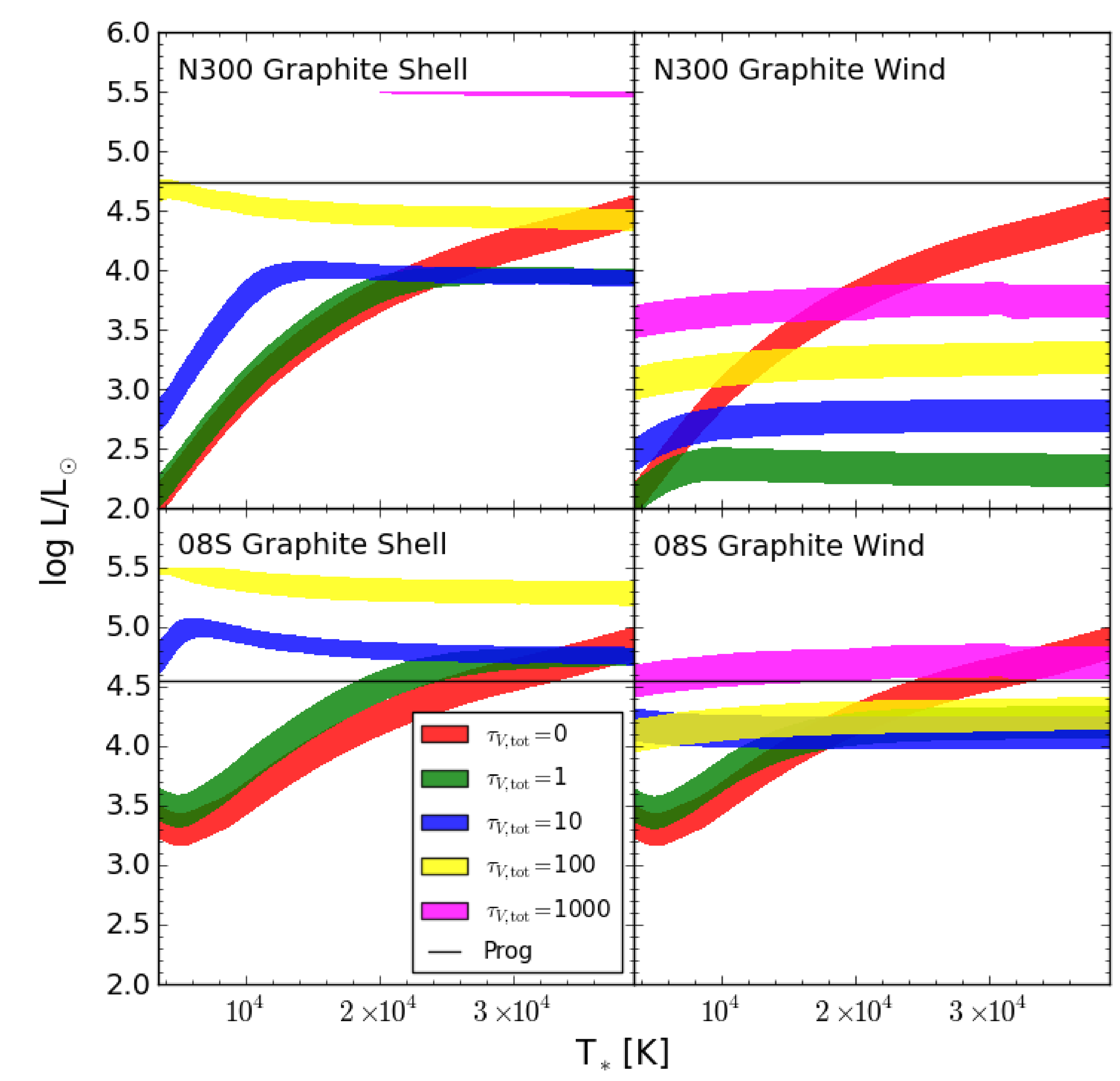

Fig. 4. SED modeling results for the luminosity and temperature of a surviving star when treating all filters as upper limits. The horizontal black line shows the progenitor luminosity. The colored bands show the luminosities within the 90-99.99% confidence intervals ($6.25 < \Delta\chi^2 < 21.1$ for three parameters – L_*, T_*, and τ) relative to no surviving star.

Discussion

We evaluate the ability of different scenarios to explain the observed decrease in luminosity (see Fig. 4).

Dusty wind – A luminous survivor to NGC 300 2008OT-1 cannot be hidden by a dusty wind, but this scenario is allowed for SN 2008S given a high enough optical depth.

Dusty shell – Both sources could be obscured by a dusty shell ejected during the transients, but in order to have the $\tau_V > 100$ needed to hide NGC 300 2008OT-1, the ejected mass must be > 1 $M_\odot$.

Bolometric Correction – The latest observations would allow unobscured survivors if $T_* > 40{,}000$ K for NGC 300 2008OT-1 and if $T_* > 20{,}000$ K for SN 2008S due to the lack of UV constraints. However, it is unlikely that the sources are currently unobscured since the evolution of the post-eruption SEDs clearly indicated dust formation.

Faint SN – The decreasing flux from NGC 300 2008OT-1 and SN 2008S can naturally be explained if these events were genuine SNe. Although the light curve decay of SN 2008S around 270 days was slower than ^{56}Co decay (Smith et al. 2009), this would be consistent with luminosity generated by a weak ccSN shock interacting with the very dense CSM.

Given the ~10 $M_\odot$ obscured progenitors, these events could be weakly exploding electron capture SNe, but ultimately longer wavelength IR (~10 μm) constraints from JWST may be needed to conclusively determine the fate of these objects.

Acknowledgements

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