The Host Galaxies of Superluminous Supernovae from the Palomar Transient Factory

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PALOMAR TRANSIENT FACTORY

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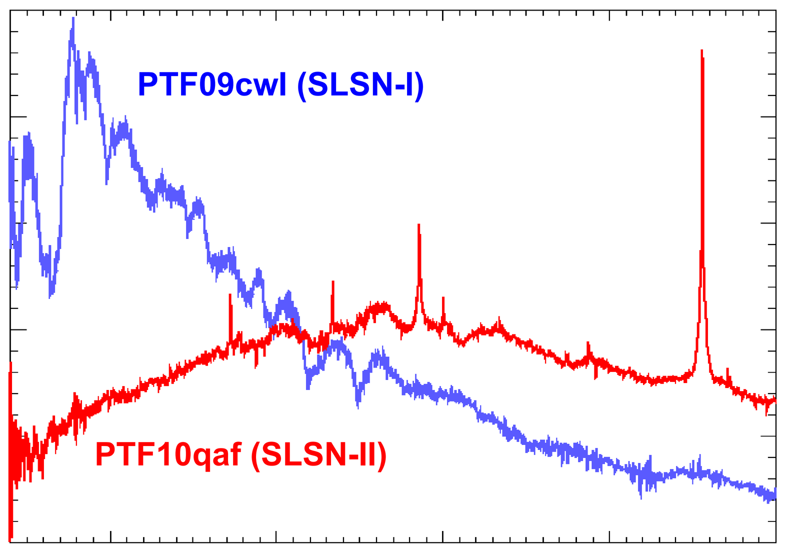
Superluminous Supernovae (SLSNe) are rare, luminous transients empirically defined as supernovae with a peak optical magnitude brighter than approximately -21, a factor of 10-100 times that of ordinary core-collapse supernovae[1] (Figure 1). They divide into two spectroscopic classes (Figure 2):

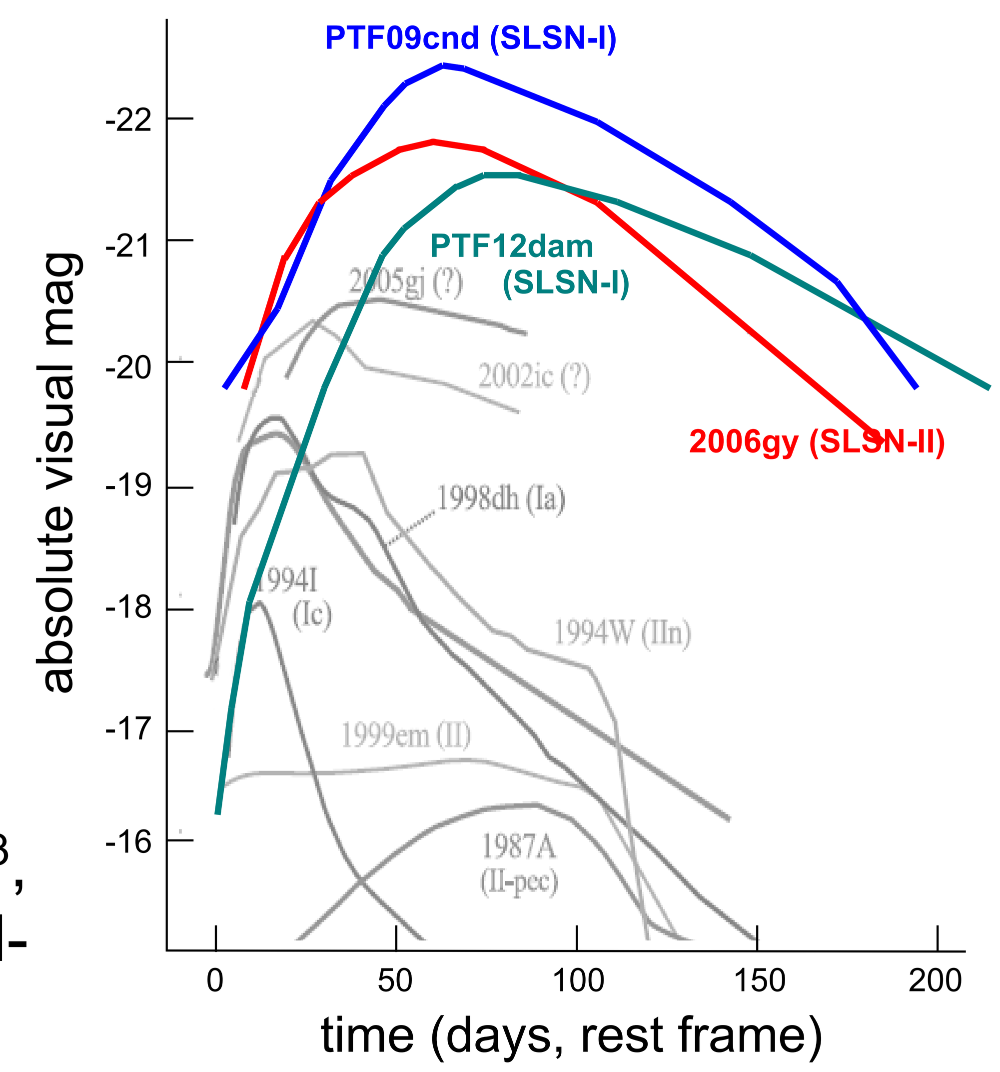


SLSN-I have no hydrogen or helium lines. Their spectra are typically very blue and dominated by broad UV absorption features.

SLSN-II have strong intermediate-width Balmer emission lines, and typically no other discernable features except at late times.

Figure 1 (right) – Light curves of some examples of SLSNe (colored) compared to examples of "ordinary" supernovae from [2] (grey).

Figure 2 (far left) – Example spectra of two PTF SLSNe, one from each spectroscopic class.



The origins of SLSNe are not well-understood. Pair-instability explosions of ultramassive stars[3], interaction of SN ejecta with very massive shells of circumstellar material[4], and and various central-engine-driven models[5] have been proposed.

The Palomar Transient Factory[6] discovered 32 SLSNe between 2009-2012, all of which are relatively nearby (31 at z<0.5 and 10 at z<0.2) We have been acquiring extensive photometric and spectroscopic data on their host galaxies to better constrain SLSN models and connections to other extreme transients.

SLSN hosts are diverse, and clear differences versus the star-forming galaxy population are seen among SLSNe-I: in particular, they are nearly absent from massive galaxies (Figure 4). Many SLSN-I hosts are in galaxies with an unusally high star-formation rate compared to other star-forming galaxies of the same mass (Figure 5). SLSN-II hosts are found in galaxies of all masses and star-formation rates.

Host metallicities for SLSN-I are low but not extreme: values of 0.1-0.5 Solar are typical for SLSN-I hosts, and the lowest-mass, lowest-metallicity galaxies produce SLSNe-I no more readily than somewhat more massive galaxies with metallicities up to 0.5 Solar.

The distribution of SLSN-I host properties is consistent with a metallicity upper limit of ~0.5 Solar and no dependence of the SLSN rate on metallicity, or any other parameter, below this value. This is lower than the equivalent limit for GRBs (~1 Solar)[7]. The high-metallicity host of PTF 10uhf stands out as an exception, and a (subdominant) preference for starbursts is not yet ruled out. **SLSN-II show no obvious preference for a particular type of host and exhibit no metallicity cutoff, though may weakly favor low-mass hosts also.** One probable SLSN-II in the sample is found very close to a galaxy nucleus and is an analog of SN 2006gy.

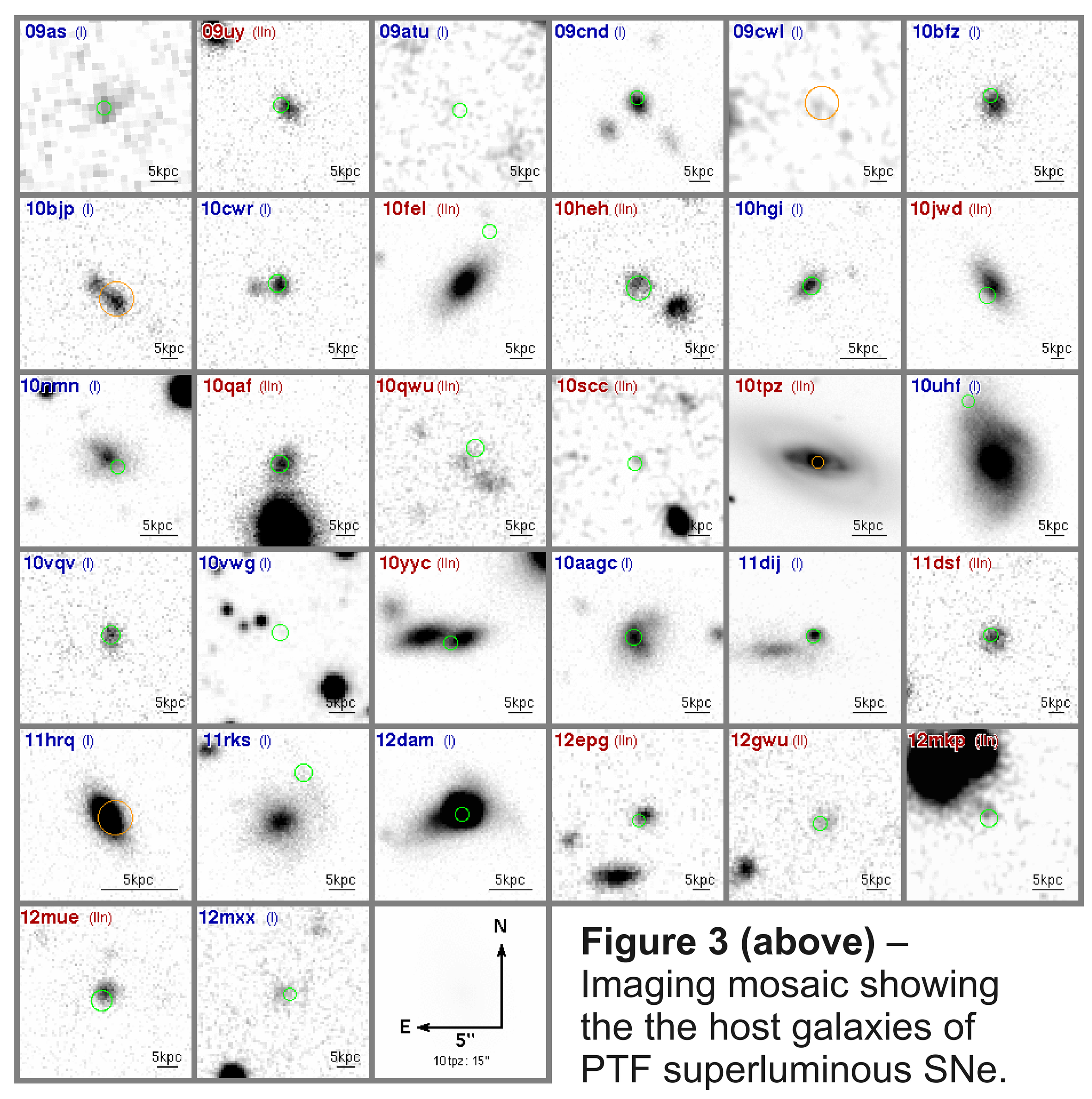


Figure 3 (above) – Imaging mosaic showing the the host galaxies of PTF superluminous SNe.

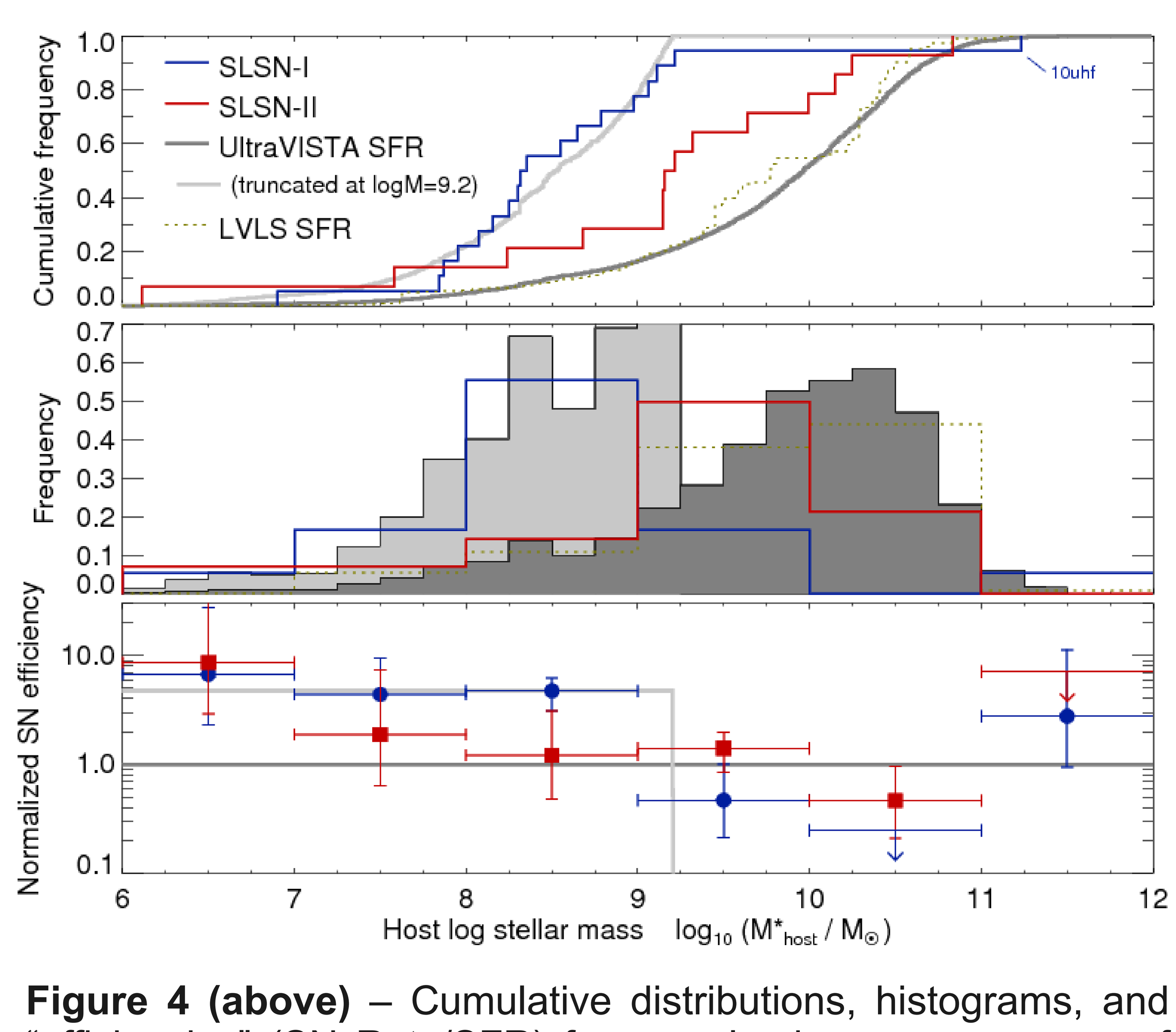


Figure 4 (above) – Cumulative distributions, histograms, and "efficiencies" (SN Rate/SFR) for superluminous supernovae of both types as a function of host-galaxy stellar mass. of stellar masses of SLSN/GRB hosts and of cosmic star-formation (top panel). SLSNe-I are almost exclusively found in galaxies below a stellar mass of 2x109 Mo but essentially trace star-formation below this threshold (compare to the "truncated" model shown in light grey). SLSNe-II exhibit a weak preference or no preference for low-mass galaxies.

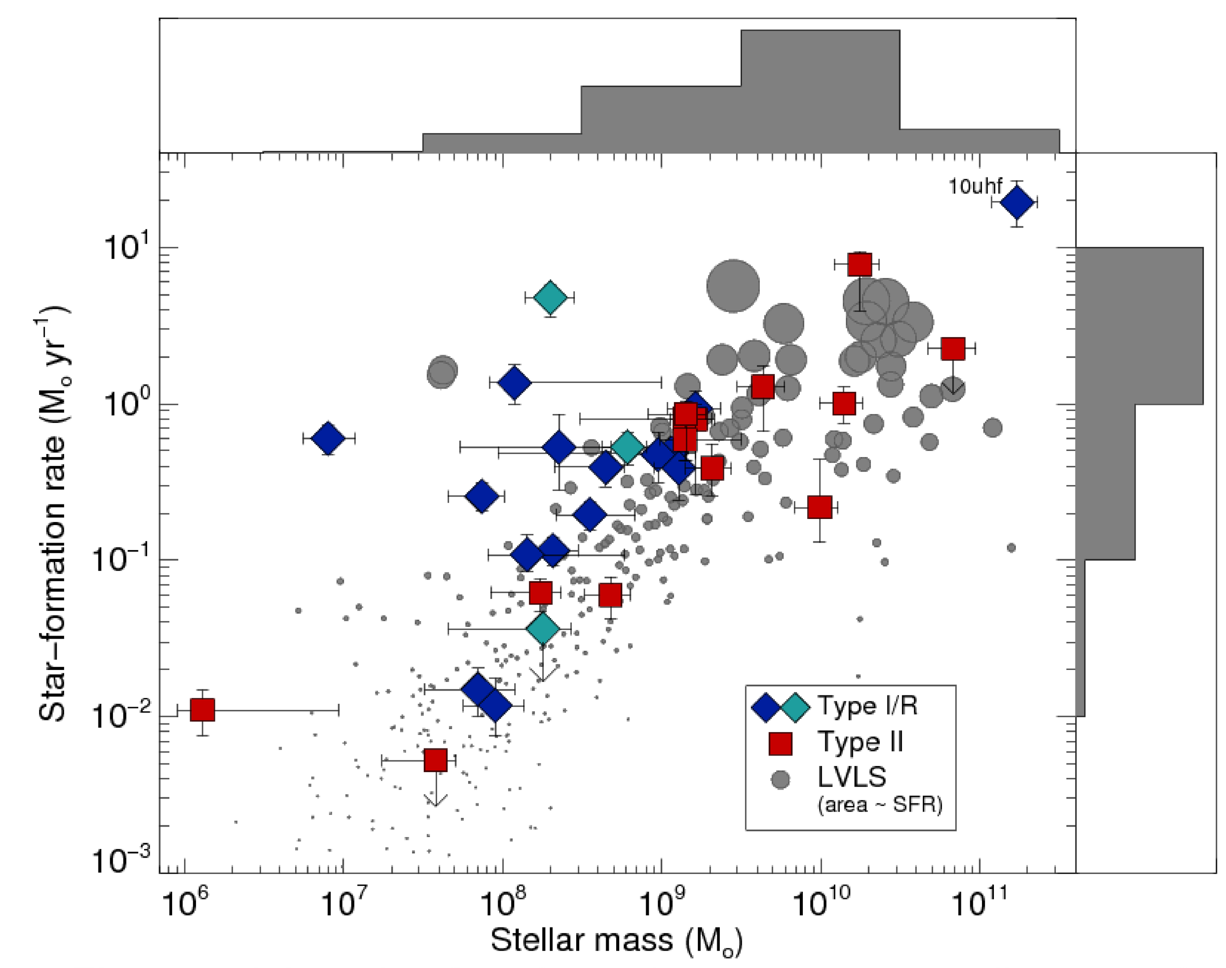


Figure 5 (above) – Star-formation rate versus stellar mass for SLSNe versus nearby galaxies from the Local Volume Legacy Survey[7]. The symbol size for LVLS galaxies is scaled according to the star-formation rate to indicate their expected ccSN rate, and the histograms show the summed SFR for all galaxies in a given mass or SFR range. Except for PTF 10uhf, Type I SLSNe are absent in massive galaxies. A significant fraction are also found in galaxies with particularly active star-formation for their mass.

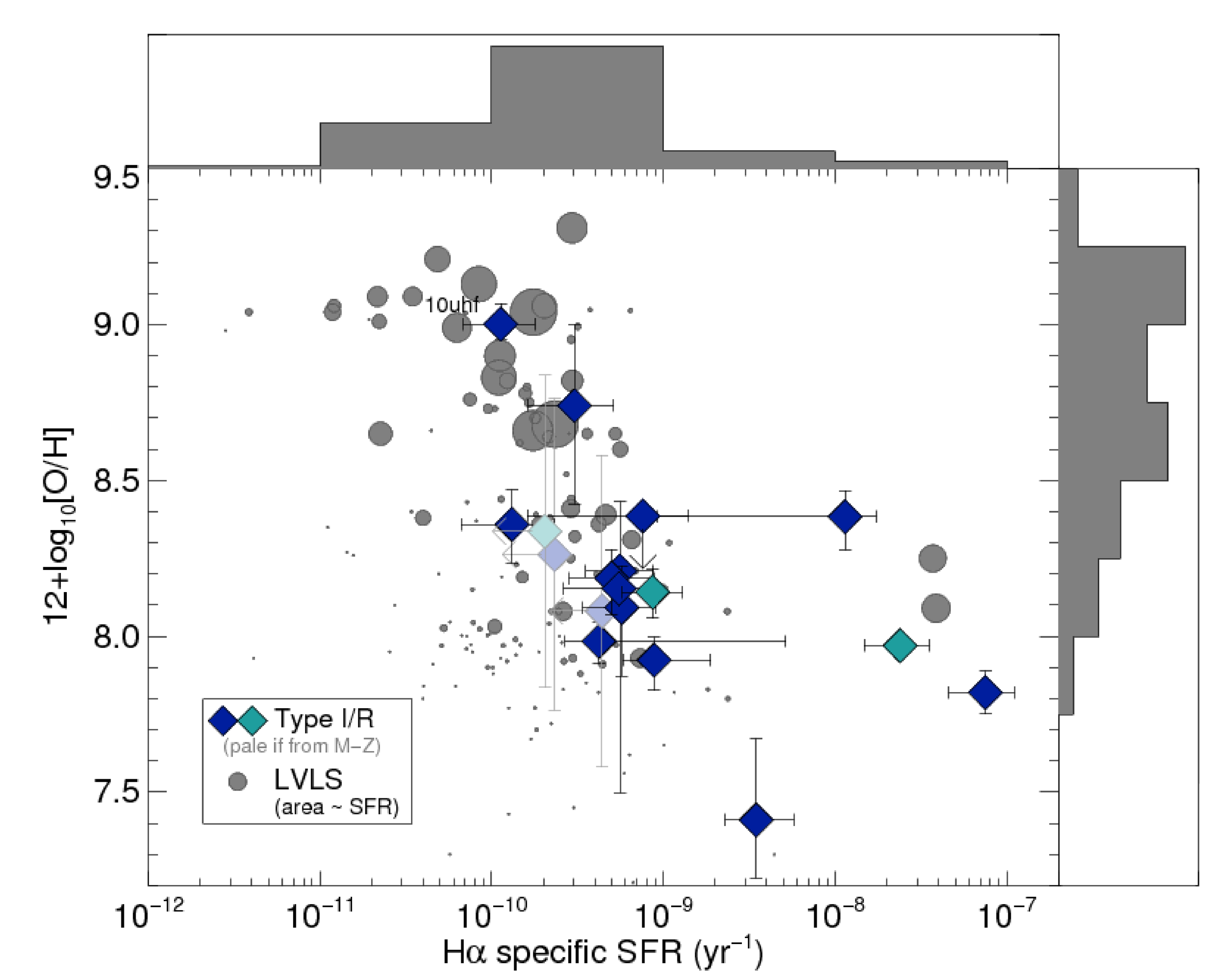


Figure 6 (above) – Gas-phase oxygen abundance versus specific star-formation rate for the hosts of Type-I SLSNe. All SLSNe-I (except one) are found in galaxies with oxygen abundances consistent with 8.4 (0.5 Zsolar) or below. The specific star-formation rates of most of these hosts do not differ dramatically from other galaxies of the same metallicity within the local volume.

References: (1) Gal-Yam et al. 2012, Science 337: 927 (2) Smith et al. 2007, ApJ 666:1116 (3) Gal-Yam et al. 2009, Nature, 462, 624 (4) Smith et al. 2010, ApJ, 709:856 (5) Inserra et al. 2013, ApJ 770:128 (6) Law et al. 2009, PASP 121:1395 (7) Perley et al. 2016b, ApJ 817:8