The Host Galaxies of Superluminous Supernovae from the Palomar Transient Factory

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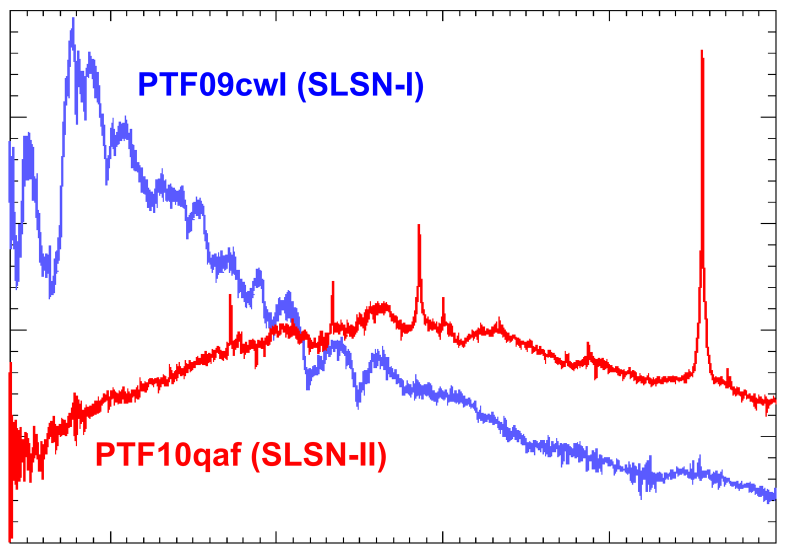
PALOMAR TRANSIENT FACTORY

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):

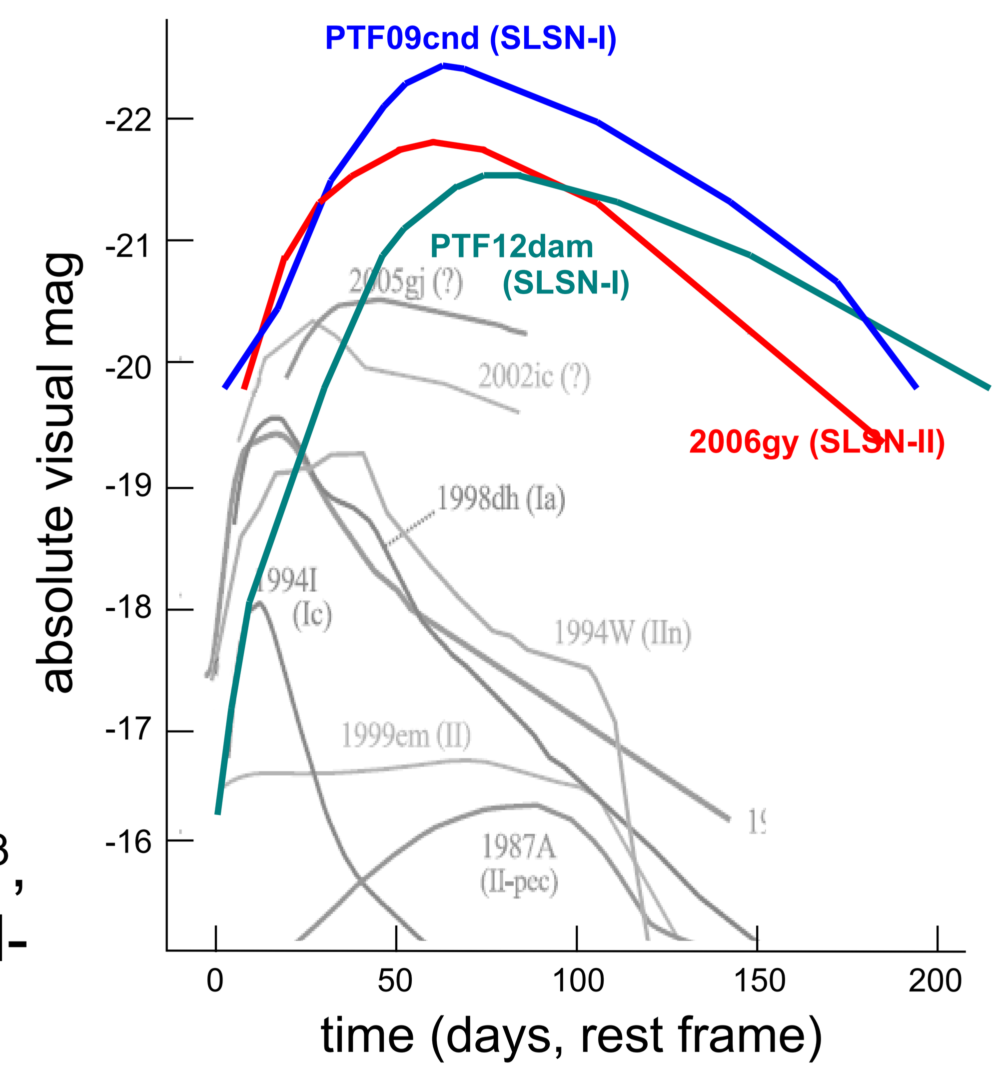


SLSN-I have no hydrogen or helium lines. Their spectra are typically very blue and dominated by broad UV absorption features.

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 (Figures 3-4) on their host galaxies to better constrain SLSN models and connections to other extreme transients.

SLSN hosts from this sample are quite diverse, spanning over 4 orders of magnitude in mass and star-formation rate and a factor of ~20 in metallicity. For every PTF SLSN we have recovered a host galaxy, although some are very low-luminosity (M ~ -15 mag).

Compared to typical star-forming galaxies SLSN hosts show many strong differences. Massive galaxies (>10^{10} $M_\odot$) produce about half of the Universe's star-formation yet host a small minority of both SLSN classes including only a single SLSN-I (Figure 5). Galaxies with high specific star-formation rates and low metallicities are strongly favored, even compared to galaxies of the same mass (Figure 6), although metal-rich and non-starburst hosts are also seen. SLSN-I hosts show these trends much more strongly than SLSN-II (and GRB) hosts.

Host metallicities are low but not extreme: values of 0.1-0.5 Solar are typical for SLSN-I hosts (or 0.4-1.0 for SLSN-II hosts), and the lowest-mass, lowest-metallicity galaxies produce them no more readily than somewhat more massive galaxies: the most common host class is a 10^9 $M_\odot$ compact starburst. It is not yet clear whether metallicity itself or a correlated factor (such as variations in the IMF or the starburst intensity) is most important for encouraging SLSN production, although there are some indications that both metallicity and metallicity-independent effects might be involved.

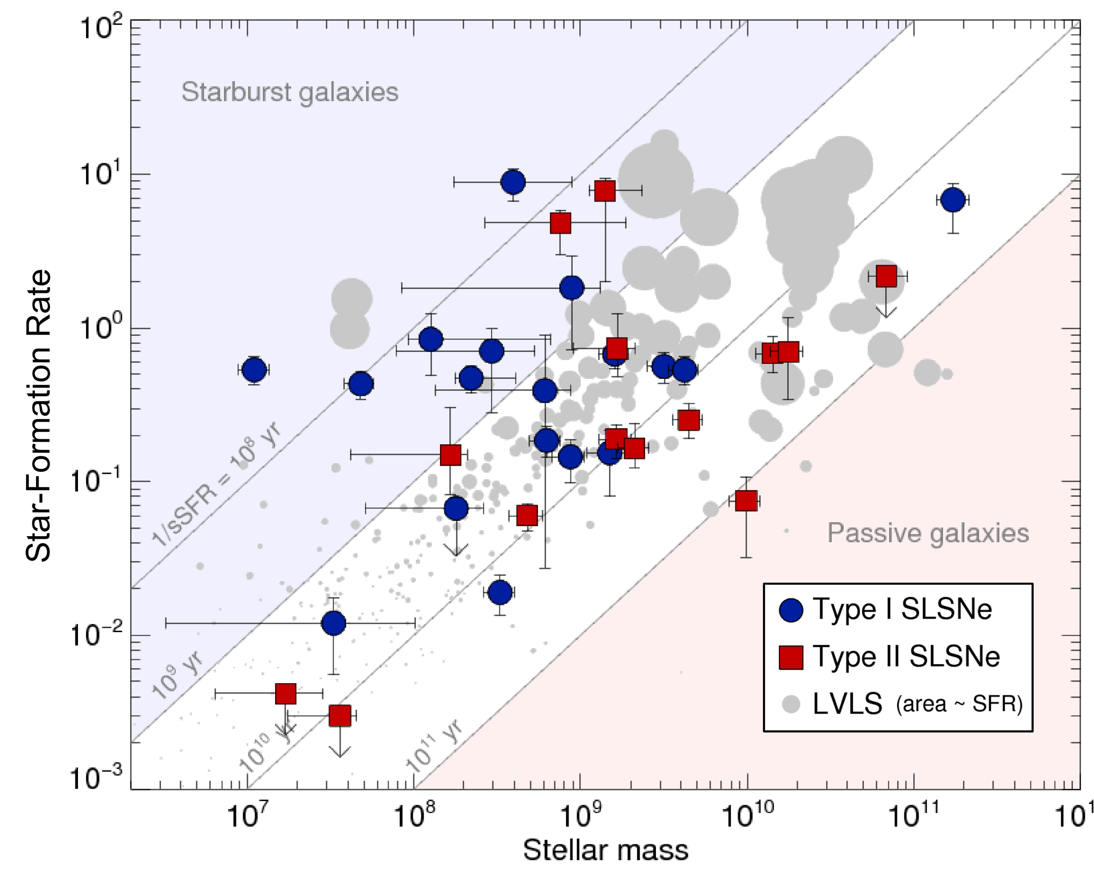


Figure 5 (above) – SED-inferred star-formation rate versus stellar mass for SLSNe versus nearby galaxies from the Local Volume Legacy Survey[7]. The symbol size for LVLS galaxies is scaled according to the star-formation rate to indicate their expected ccSN rate. Type I SLSNe show a strong aversion from massive galaxies and towards very young and active starbursting galaxies, but do not require either condition.

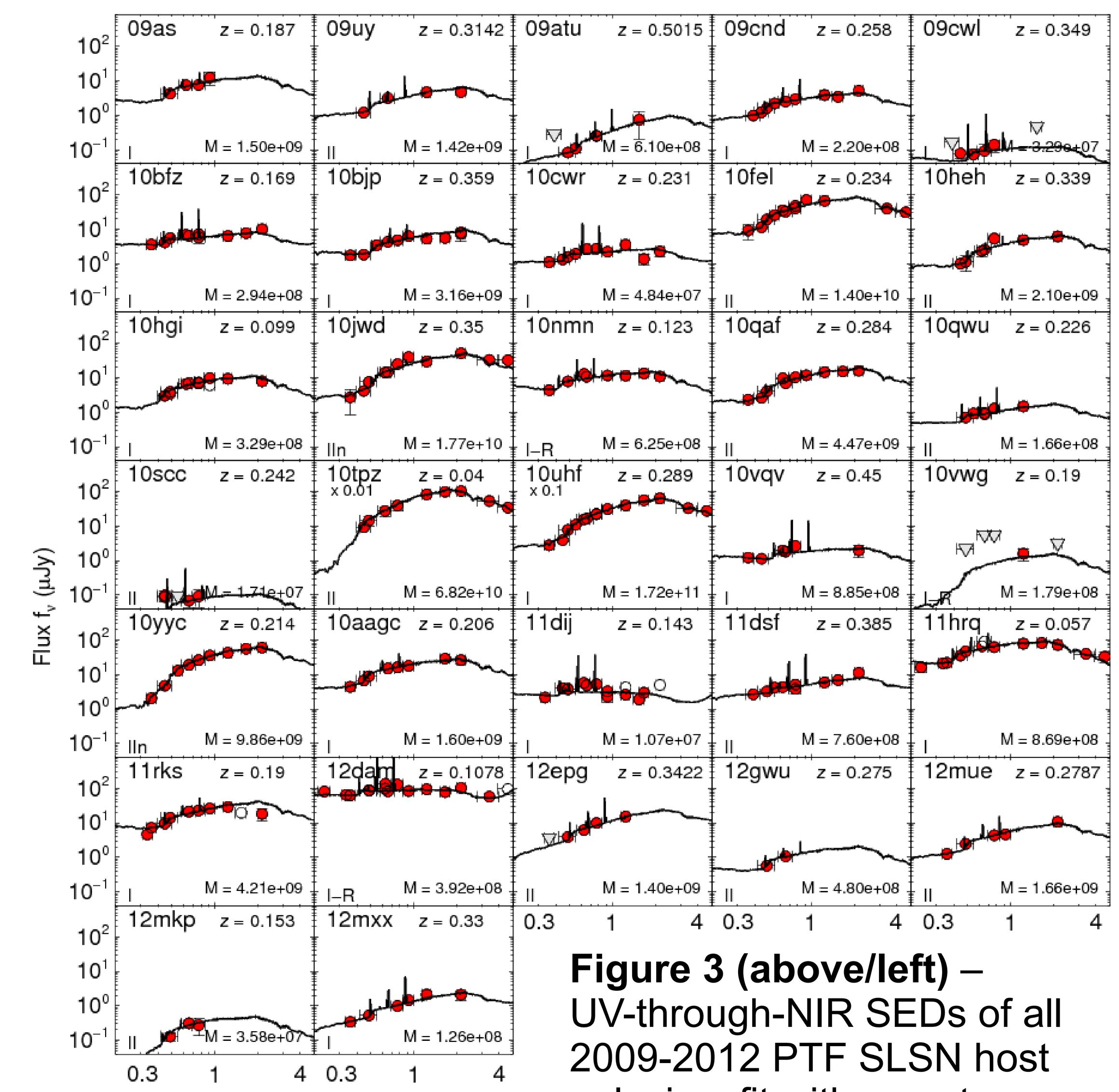


Figure 3 (above/left) – UV-through-NIR SEDs of all 2009-2012 PTF SLSN host galaxies, fit with a custom population synthesis model.

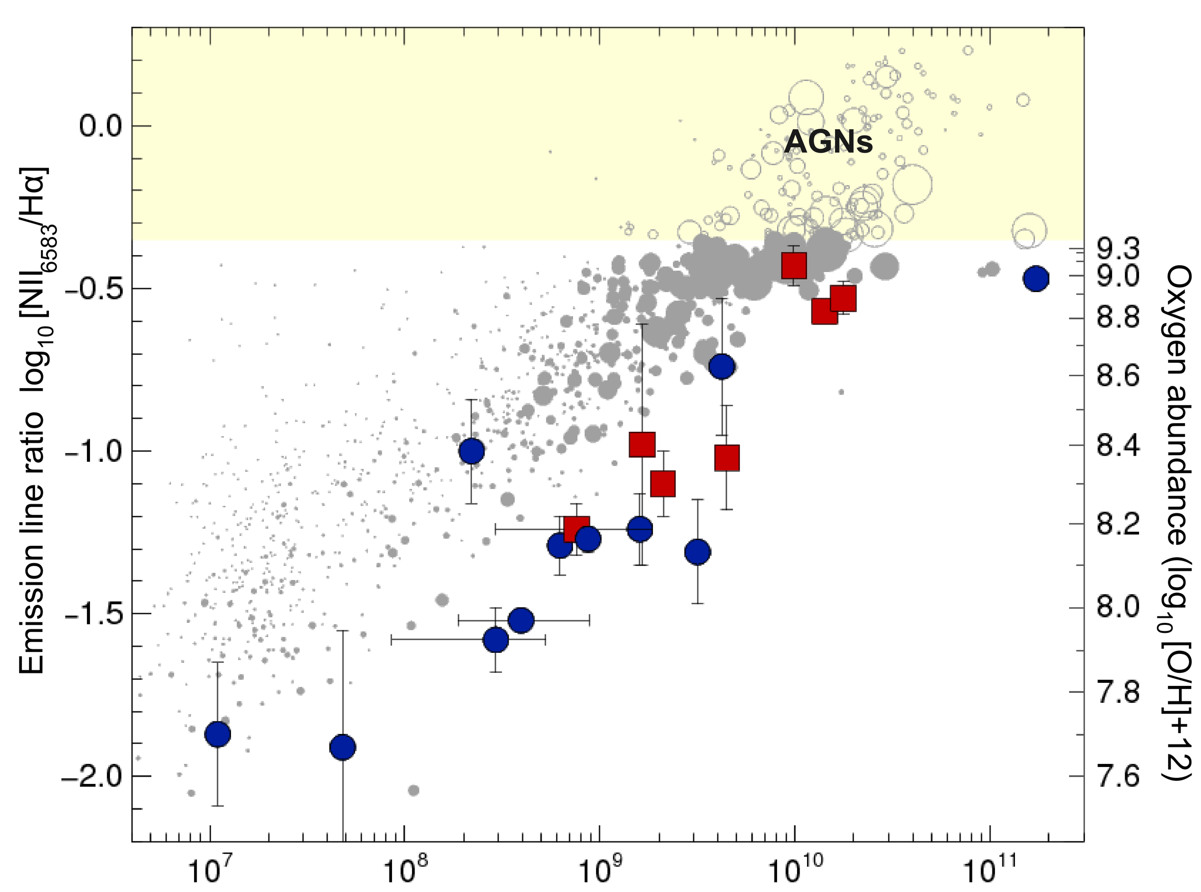


Figure 6 (above) – Metallicity versus stellar mass for PTF SLSN hosts and for z~0 galaxies from SDSS-NSAtlas[8]. Faint galaxies with no NII detection are excluded. At every mass range, SLSNe appear to occur in galaxies of low metallicity for their mass. Work is ongoing to rule out mass-metallicity evolution or differing mass derivations as causes of this effect.

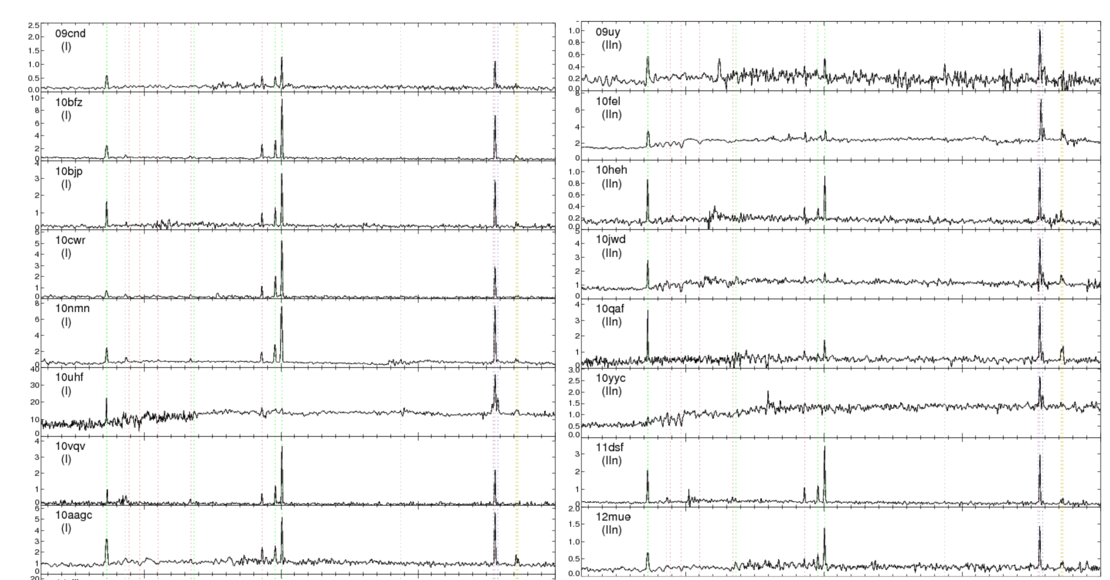
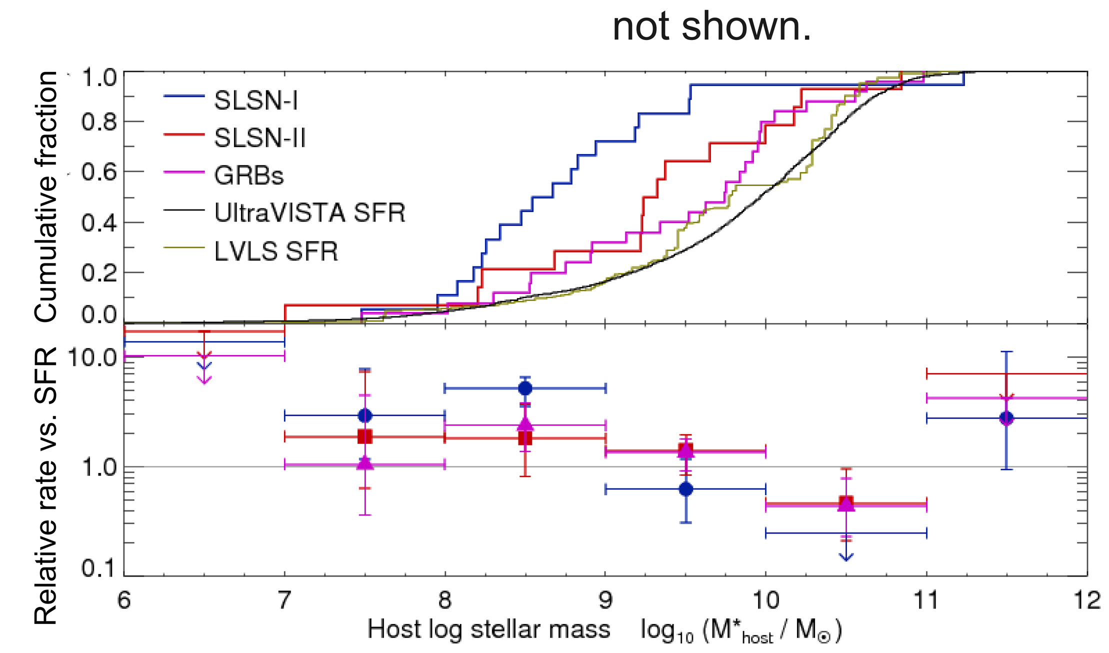


Figure 4 (above/left) – Keck/LRIS optical spectra of 20 SLSN hosts from PTF. Five SLSN hosts with spectra have faint or no line emission and are not shown.

Figure 7 (right) – Cumulative distributions of stellar masses of SLSN/GRB hosts and of cosmic star-formation (top panel). By comparing these curves we find that the rate of SLSN-I relative to SFR in low-mass galaxies is at least a factor of 10 higher than in moderately-massive galaxies (bottom panel).



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) Dale et al. 2009, ApJ 703:517 (8) Geha et al. 2012, ApJ 757:85