Massive Stars Near and Far
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How Much Hydrogen is in Type Ib and IIb SN Progenitors?

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Abstract. We compare pre-supernova observations with synthetic photometry from stellar evolution models to infer the progenitor properties of the seven known progenitors of Type Ib and IIb supernovae. Our results are roughly consistent with a hydrogen mass threshold of $\approx 0.033\,\mathrm{M}_\odot$ for a Type II appearance.

Keywords. stars: evolution, stars: massive, supernovae: general

1. Introduction

Type Ib and IIb supernovae (SNe) are sub-types of core-collapse SNe which differ by the absence of hydrogen lines in the former, in contrast to the early appearance of broad hydrogen lines in the latter. Radiative-transfer simulations yield disparate values of the amount of hydrogen which will give rise to a type II appearance (Dessart et al. 2011, Hachinger et al. 2012). Here we address the question of the hydrogen mass that can be 'hidden' in SNe with a different approach, by finding the best-fitting models for all known type Ib and IIb SN progenitors.

2. Inferring progenitor properties from pre-explosion photometry

Binary evolution is computed with the MESA code (version r10398; Paxton et al. 2018) in a similar manner to Gilkis et al. (2019). The endpoints (core carbon depletion) of 494 stellar evolution tracks are assigned synthetic photometry values by convolution of empirical or computed spectra with dust extinction (Cardelli et al. 1989) and with the relevant filters. Spectra are taken from Pickles (1998) for $T_{\mathrm{eff}} < 15000\,\mathrm{K}$, from Lanz & Hubeny (2007) for $15000\,\mathrm{K} \leq T_{\mathrm{eff}} \leq 30000\,\mathrm{K}$, from Lanz & Hubeny (2003) for $30000\,\mathrm{K} < T_{\mathrm{eff}} \leq 55000\,\mathrm{K}$ and from Todt et al. (2015) for $55000\,\mathrm{K} < T_{\mathrm{eff}}$. We take the pre-SN photometry from Aldering et al. (1994) for SN 1993J, Folatelli et al. (2015) for SN 2008ax, Maund et al. (2011) for SN 2011dh, Van Dyk et al. (2014) for SN 2013df, Eldridge et al. (2015) for iPTF13bvn, Kilpatrick et al. (2021a) for SN 2016gkg and Kilpatrick et al. (2021b) for SN 2019yvr. For each SN, we generate 100 realizations of the photometry assuming a normal distribution with the error as the standard deviation. For each realization the best-fitting model is found, providing a distribution of progenitor properties. This is done for four assumptions on dust extinction: (*i*) the dust extinction parameter R_V and reddening $E\,(B-V)$ are fixed; (*ii*) R_V fixed and $E\,(B-V)$ variable; (*iii*) R_V variable and $E\,(B-V)$ fixed; (*iv*) R_V and $E\,(B-V)$ variable. We present the results in Fig. 1 and show that within the uncertainties a hydrogen mass threshold of $\approx 0.033\,\mathrm{M}_\odot$ to distinguish between Ib and IIb SNe is plausible.

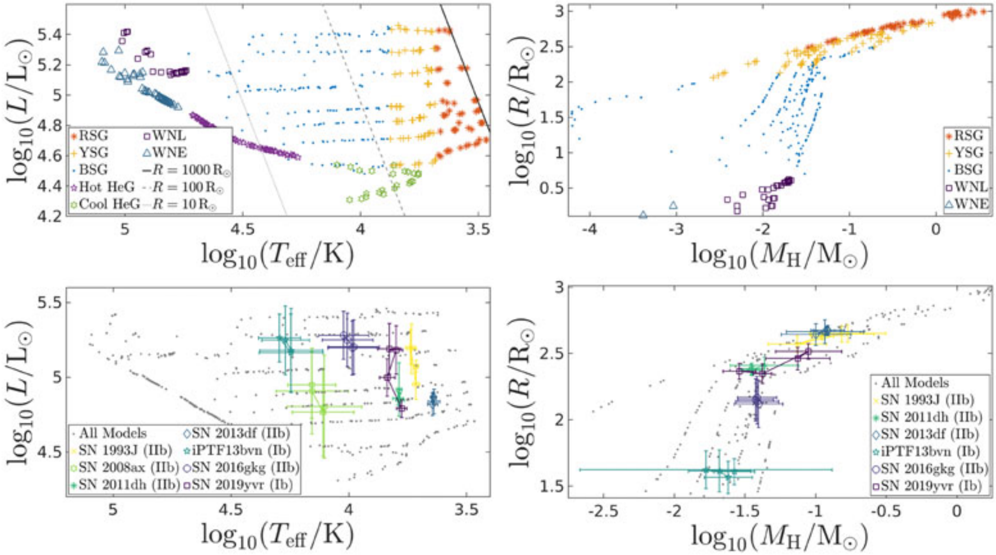

Figure 1. *Top-left:* Evolutionary endpoints marked by stellar types defined by the effective surface temperature T_{eff} and surface hydrogen mass fraction X_{s} as follows: red supergiant (RSG) - $T_{\mathrm{eff}} \leq 4.8\,\mathrm{kK}$, $0.01 \leq X_{\mathrm{s}}$; yellow supergiant (YSG) – $4.8\,\mathrm{kK} < T_{\mathrm{eff}} < 7.5\,\mathrm{kK}$, $0.01 \leq X_{\mathrm{s}}$; blue supergiant (BSG) – $7.5\,\mathrm{kK} \leq T_{\mathrm{eff}} \leq 55\,\mathrm{kK}$, $0.01 \leq X_{\mathrm{s}}$; hot helium giant (HeG) – $15\,\mathrm{kK} \leq T_{\mathrm{eff}} \leq 55\,\mathrm{kK}$, $X_{\mathrm{s}} < 0.01$; cool HeG – $T_{\mathrm{eff}} < 15\,\mathrm{kK}$, $X_{\mathrm{s}} < 0.01$; early nitrogen-sequence WR (WNE) – $55\,\mathrm{kK} < T_{\mathrm{eff}}$, $X_{\mathrm{s}} < 0.05$; late nitrogen-sequence WR (WNL) – $55\,\mathrm{kK} < T_{\mathrm{eff}}$, $0.05 \leq X_{\mathrm{s}}$. *Top-right:* Radii and total hydrogen masses for evolutionary endpoints marked by stellar types. *Bottom-left:* Inferred temperature and luminosity for Type Ib and IIb SN progenitors. *Bottom-right:* Inferred total hydrogen mass and radius for Type Ib and IIb SN progenitors.

References

Aldering, G., Humphreys, R. M., & Richmond, M. 1994, AJ, 107, 662

Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245

Dessart, L., Hillier, D. J., Livne, E., Yoon, S.-C., Woosley, S., Waldman, R., & Langer, N. 2011, MNRAS, 414, 2985

Eldridge, J. J., Fraser, M., Maund, J. R., & Smartt, S. J. 2015, MNRAS, 446, 2689

Folatelli, G., Bersten, M. C., Kuncarayakti, H., Benvenuto, O. G., Maeda, K., & Nomoto, K. 2015, ApJ, 811, 147

Gilkis, A., Vink, J. S., Eldridge, J. J., & Tout, C. A. 2019, MNRAS, 486, 4451

Hachinger, S., Mazzali, P. A., Taubenberger, S., Hillebrandt, W., Nomoto, K., & Sauer, D. N. 2012, MNRAS, 422, 70

Kilpatrick, C. D., Coulter, D. A., Foley, R. J., Piro, A. L., Rest, A., Rojas-Bravo, C., & Siebert, M. R. 2021a, arXiv e-prints, arXiv:2112.03308

Kilpatrick, C. D., et al. 2021b, MNRAS, 504, 2073

Lanz, T., & Hubeny, I. 2003, ApJS, 146, 417

—. 2007, ApJS, 169, 83

Maund, J. R., et al. 2011, ApJL, 739, L37

Paxton, B., et al. 2018, ApJS, 234, 34

Pickles, A. J. 1998, PASP, 110, 863

Todt, H., Sander, A., Hainich, R., Hamann, W. R., Quade, M., & Shenar, T. 2015, A&A, 579, A75

Van Dyk, S. D., et al. 2014, AJ, 147, 37

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