Considering the Single and Binary Origins of the Type IIP SN 2017eaw

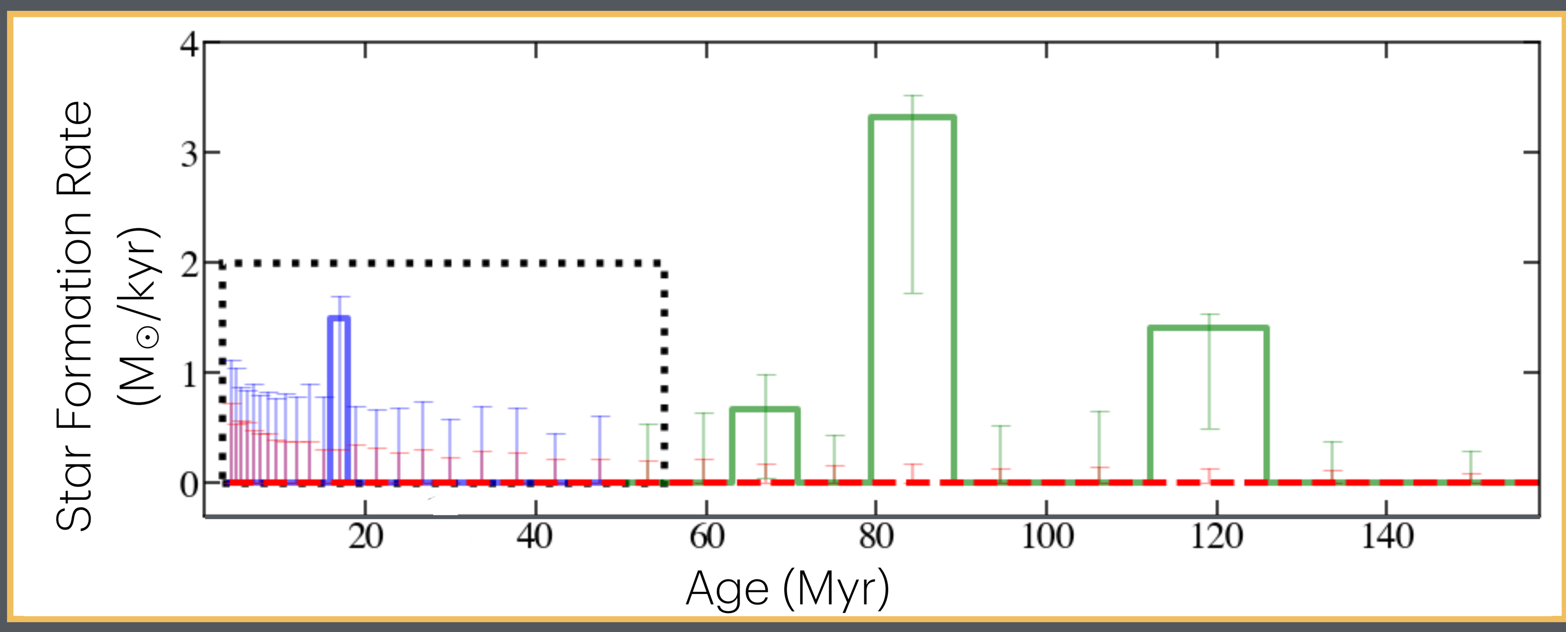
Azalee Bostroem, Emmanouil Zapartas, Brad Koplitz, Benjamin F. Williams, Debby Tran, Andrew Dolphin

Although the majority of massive stars are not single at birth, it is challenging to differentiate between single and binary progenitors of supernovae. One tool to look for binary progenitors is to combine constraints from multiple observables. Current population synthesis models show that binary evolution allows stars of lower mass (and therefore longer lifetimes) to explode. Thus, for hydrogen-rich supernovae, a progenitor that appears younger than its surrounding populations is a clear indication of prior binary evolution. SN 2017eaw is one of the closest Type IIP supernovae in the last decade. With a miryad of observations constraining the final helium core mass and stellar population constraints, SN 2017eaw is a strong candidate for the definitive identification of a binary progenitor.

Stellar Population Age

The surrounding stellar population ages from previous works implies a final helium core mass well below those measured by observations before and after the supernova explosion assuming single star evolution. With deeper observations and photometry and analyses customized for our field we rederived the population age, finding a value consistent with the near-explosion observations

Final He Core Mass	Initial Mass Reported	Initial Mass Derived from Final He Core Mass	Method	Reference
<3.4$M_\odot$	<10.8$M_\odot$	<10.9$M_\odot$	population age	Williams+ 2018 Koplitz+ 2021
4.7$M_\odot$	14$M_\odot$	14.3$M_\odot$	population age	This work



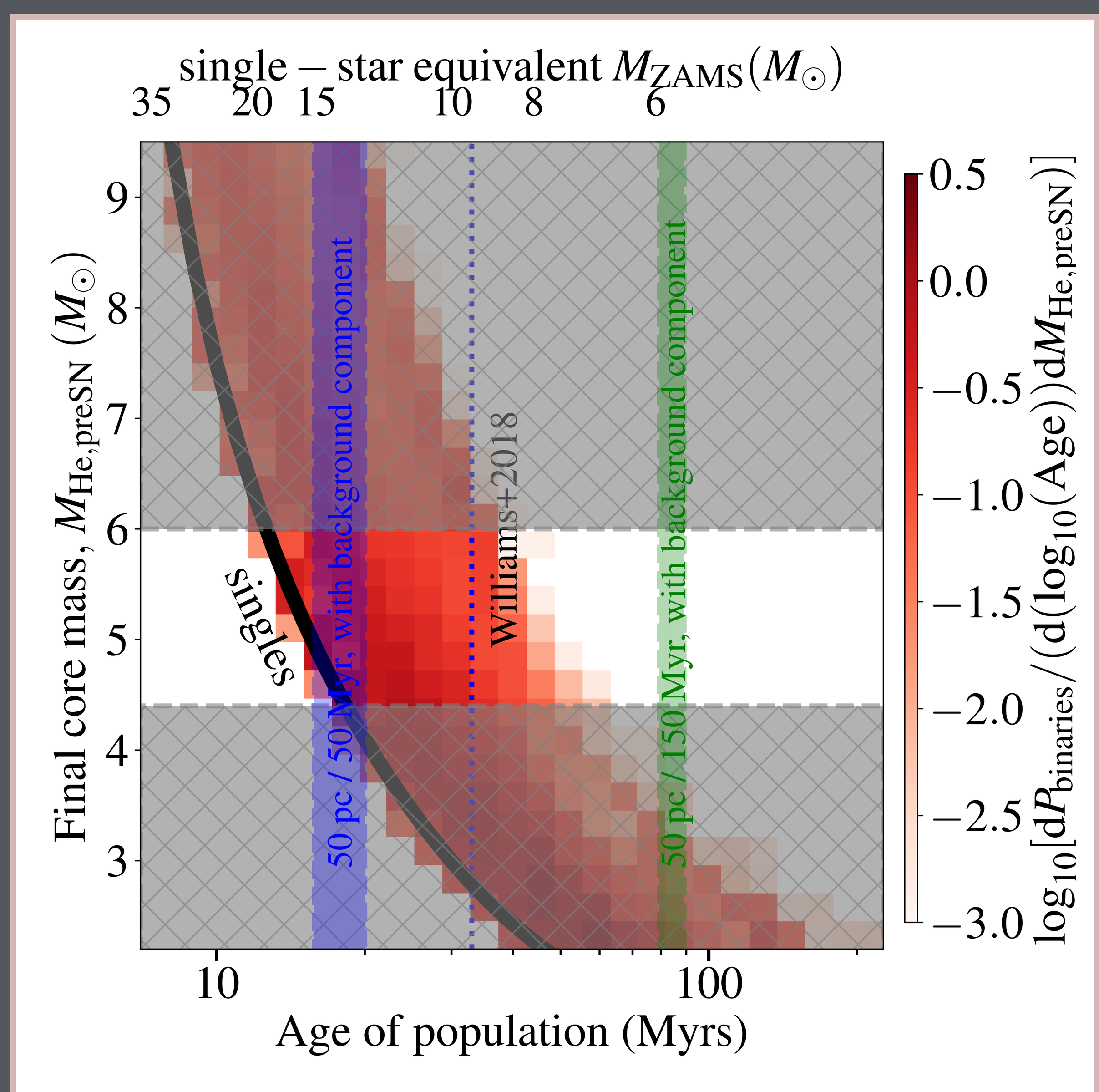
The star formation rate of a 50 pc region around SN 2017eaw when no background population is fit separately shows a peak of star formation at 16.8 yrs. We include the star formation history out to 150 Myr to encompass the ages expected from binary evolution scenarios although we find these later peaks inconsistent with the helium core mass derived from near-explosion observations.

Pre-Explosion He Core Masses

We measure the helium core mass near explosion of 4.4-6 $M_\odot$ using observations of the red supergiant (RSG) progenitor as well as the supernova light curve and late time spectra, all assuming single star evolution.

Final He -core Mass	Initial Mass Reported	Initial Mass Derived from Final He-core Mass	Method	Reference
4.4$M_\odot$	15$M_\odot$	13.4$M_\odot$	SN light curve	Morozova+ 2020
4.6$M_\odot$	14$M_\odot$	13.9$M_\odot$	SN light curve	Goldberg & Bildsten 2020
4.8$M_\odot$	13$M_\odot$	14.5$M_\odot$	RSG SED	Kilpatrick & Foley 2018
5.1$M_\odot$	13-15$M_\odot$	15.3$M_\odot$	RSG SED	Van Dyk+ 2019
6$M_\odot$	12$M_\odot$	17.6$M_\odot$	RSG SED	Rui+ 2019
4.4$M_\odot$	15$M_\odot$	13.4$M_\odot$	SN late-time spectra	Szalai+ 2019 Van Dyk+ 2019

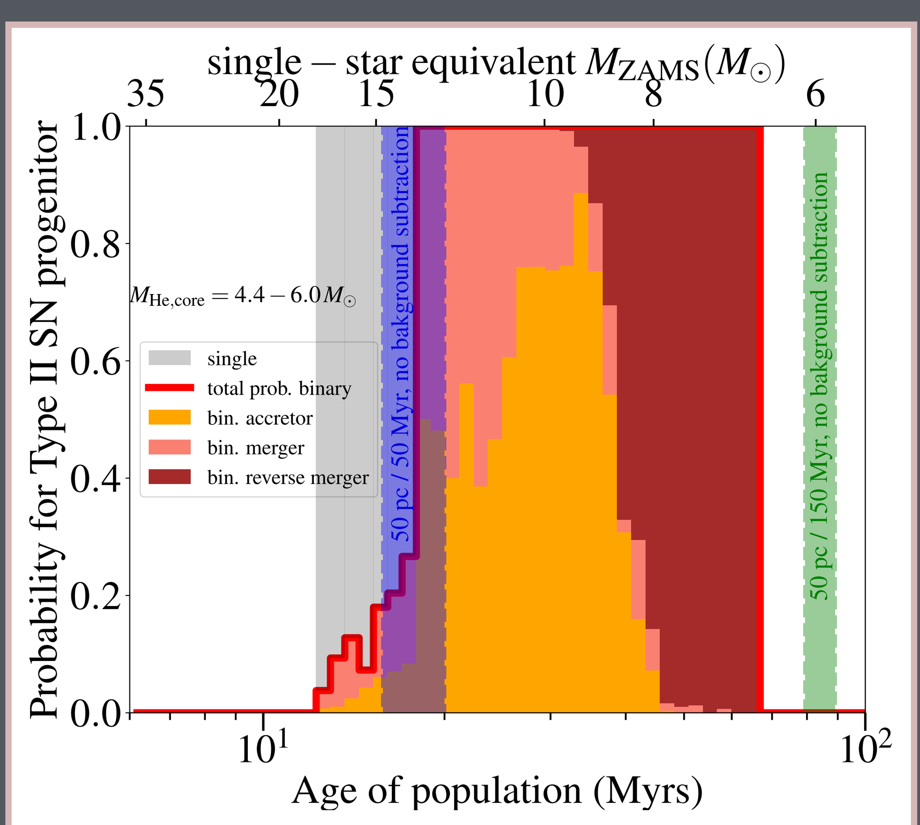
Binary Population Synthesis Modeling



The probability of a progenitor system having a given age and final helium core mass given rapid binary population synthesis models. Single stars (black) lie on a single line at the base of the binary distribution (red). The constraints from stellar population ages are show as vertical blue and green bars and the regions ruled out by the near-explosion observations are shaded in gray. **Combining the age and final helium core mass with population synthesis models we find:**

- **65% probability the progenitor was a single star**
- **35% probability the progenitor was a binary star**
- **The peak star formation rate when the full 150 Myr history is considered is inconsistent with the near explosion helium core mass**

Progenitor Scenarios by Age



The probability of different single and binary progenitor channels as a function of population age given the final helium core mass constraints. Binary scenarios dominate at older ages with **our age spanning populations dominated by single stars and binary mergers and accretors.** The oldest progenitors arise from reverse merger scenarios.