Type Ia Supernova Rates: A Tale of Star Formation Histories, Binary Fractions, and Metallicity

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1 INTRODUCTION

• Supernova surveys have revealed that low mass galaxies are more efficient producers of type Ia supernovae (SNe Ia) than their higher mass counterparts (Mannucci et al. 2005). Invoking the correlation between a galaxy's stellar mass and its metallicity (e.g. Andrews & Martini 2013), Kistler et al. (2013) proposed that this could arise if lower metallicity stellar populations give rise to more SN events at fixed mass. Using the All Sky Automated Survey for Supernovae (ASAS-SN), Brown et al. (2019) used archival spectroscopic data to derive stellar masses for SN Ia host galaxies and found that the specific SN Ia rate - the rate per unit stellar mass - scales with approximately with the inverse square root of the stellar mass (i.e. $\dot{N}_{\rm Ia}/M_\star \sim M_\star^{-0.5}$).

• This mass dependence, however, depends on how abundant the underlying galaxy population is at a given mass. Gandhi et al. (2022) demonstrated that this scaling becomes shallower (approximately $\dot{N}_{\rm Ia}/M_\star \sim M_\star^{-0.3}$) with the steeper Baldry et al. (2012) stellar mass function than the Bell et al. (2003) form used by Brown et al. (2019). They demonstrate that this shallower dependence can be readily explained by a metallicity dependence that scales as $Z^{-0.5}$ or Z^{-1}, and that this does not significantly impact galaxy stellar masses and morphologies in the FIRE-2 cosmological zoom-in simulations (Hopkins et al. 2018).

• Kistler et al. (2013) postulated that this metallicity-dependence can arise because lower metallicity stars produce higher mass white dwarfs at fixed ZAMS mass (refs), but this isn't the only possible explanation. Based on stellar multiplicity measurements from APOGEE[1], the stellar close binary fraction is known to increase with decreasing metallicity (Badenes et al. 2018; Moe, Kratter & Badenes 2019). Since SNe Ia are believed to arise from binary systems, this should mean that there are more progenitors at low metallicity and consequently in low mass galaxies. Low mass field galaxies also have more extended star formation histories than high mass galaxies (refs), and we demonstrate in § X that this should be accompanied by a higher SN Ia rate at low redshift.

• In the present paper, we conduct order of magnitude calculations to investigate the sources of this scaling.

2 STAR FORMATION HISTORIES

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[1] Apache Point Observatory Galaxy Evolution Experiment (Majewski et al. 2017).

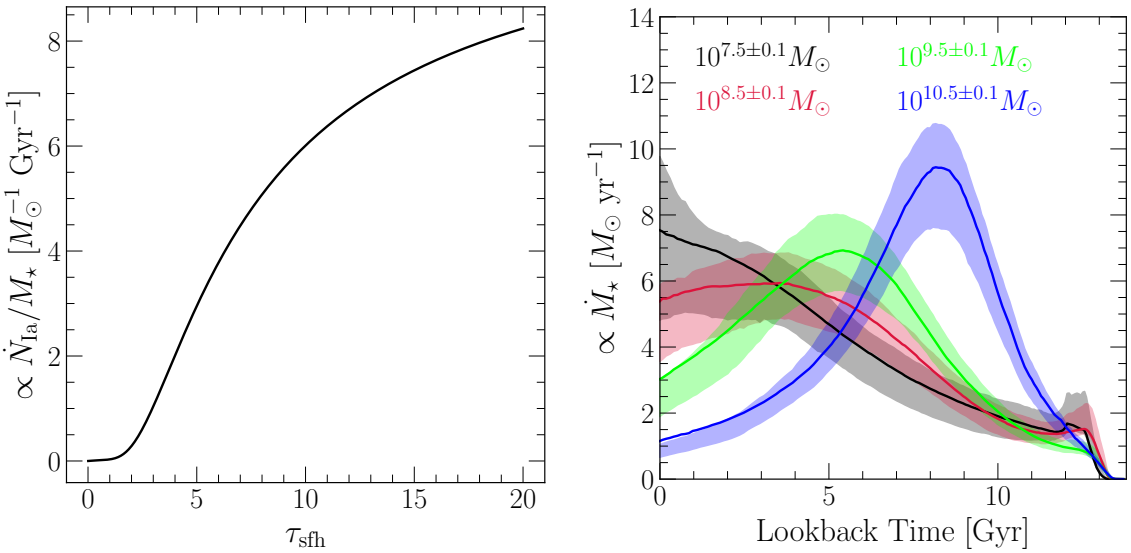

Figure 1. Star formation histories.

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