Multiplicity properties of the pre-supernova population of NGC330

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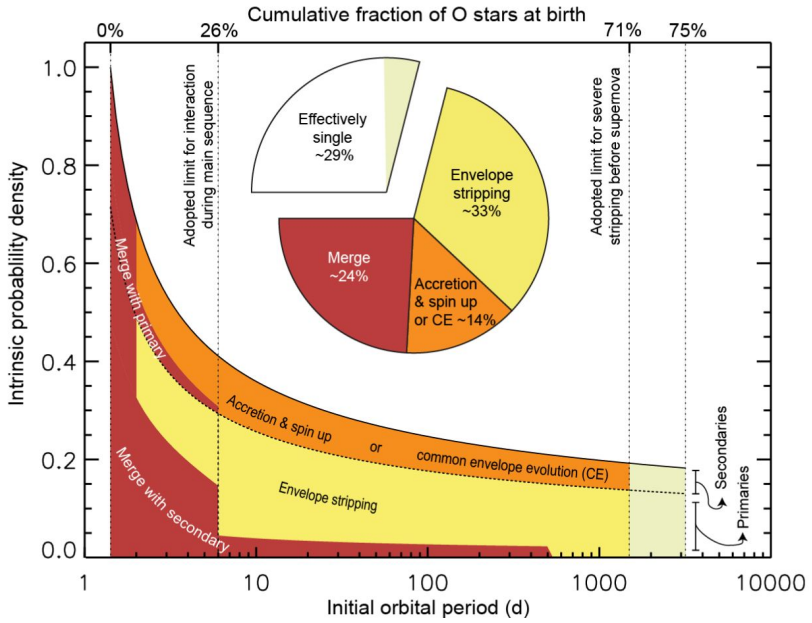
Abstract

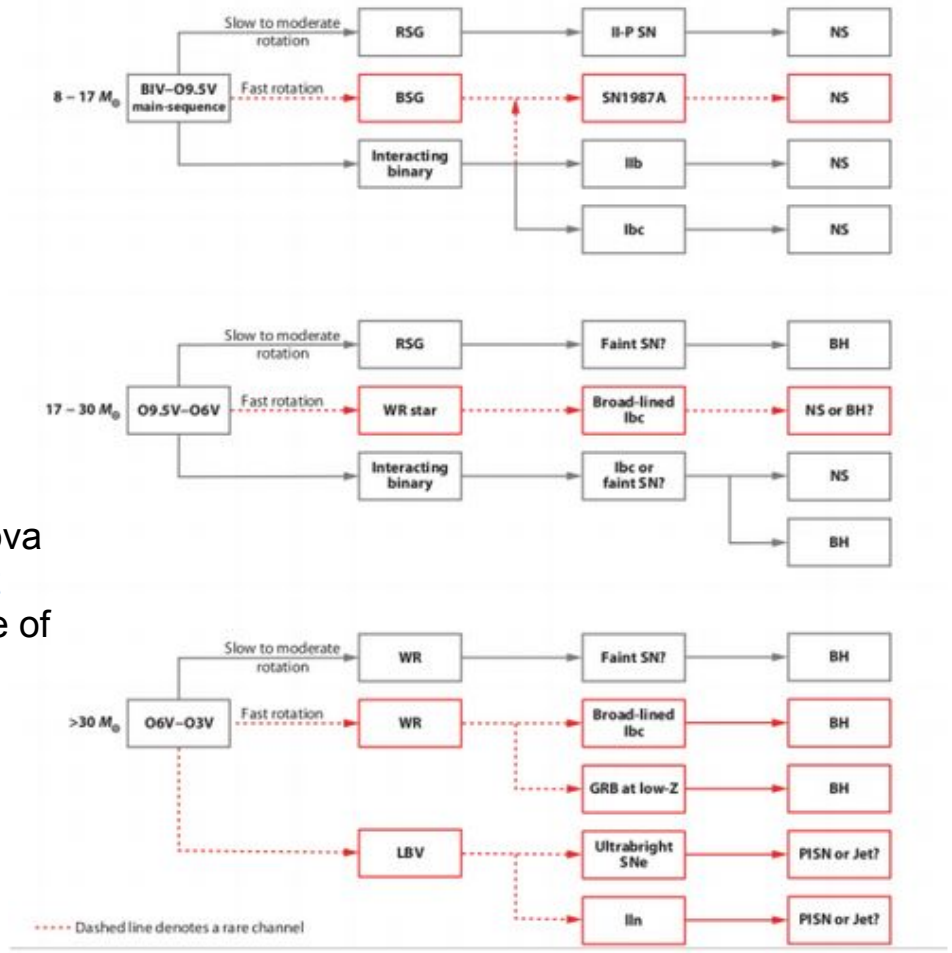
The multiplicity properties of massive stars are one of the important outstanding issues in stellar evolution. We investigate the multiplicity of an almost complete census of red supergiant stars (RSGs) in NGC 330, a young massive cluster in the Small Magellanic Cloud. Using a combination of multi-epoch HARPS and MUSE spectroscopy, we estimate radial velocities and assess the kinematic and multiplicity properties of 15 RSGs in NGC 330. We detect significant radial velocity variability in our multi-epoch observations and distinguish between variations caused by atmospheric activity and those caused by binarity. We account for observational biases and estimate the intrinsic binary fraction for RSGs in NGC 330 as $f_{RSG} = 0.3 \pm 0.1$ for orbital periods in the range $2.3 < \log P\ [\text{days}] < 4.3$, with $q > 0.1$. From the RSG population we estimate the age of NGC 330 to be 45 ± 5 Mya and estimate a red straggler fraction of 50%. The RSG binary fraction appears to be lower than that of main-sequence massive stars, which is understood as a result of binary interactions in previous evolutionary phases.

1. Context

- Most massive stars (>8 $M_{\odot}$) reside in binary or higher order multiple systems (Sana et al. 2012, Kobulnicky et al. 2014)
- The multiplicity of the final stages of massive star evolution is poorly characterised, particularly in the Red Supergiant (RSG) phase



The frequency of main-sequence massive stars in binary systems from Sana et al. 2012

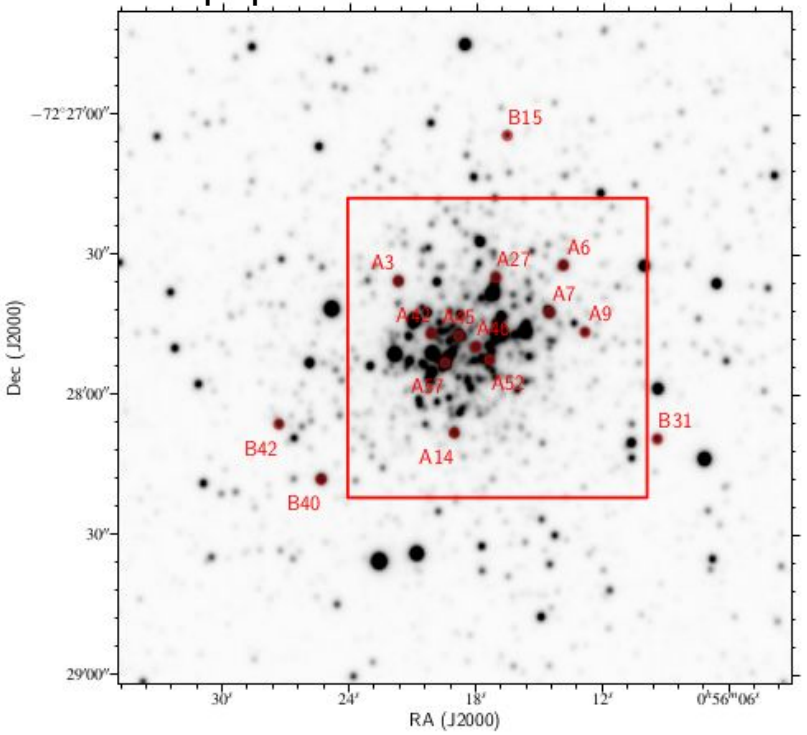


Canonical core-collapse supernova progenitor pathways from Smartt 2009, highlighting the importance of RSGs in this context

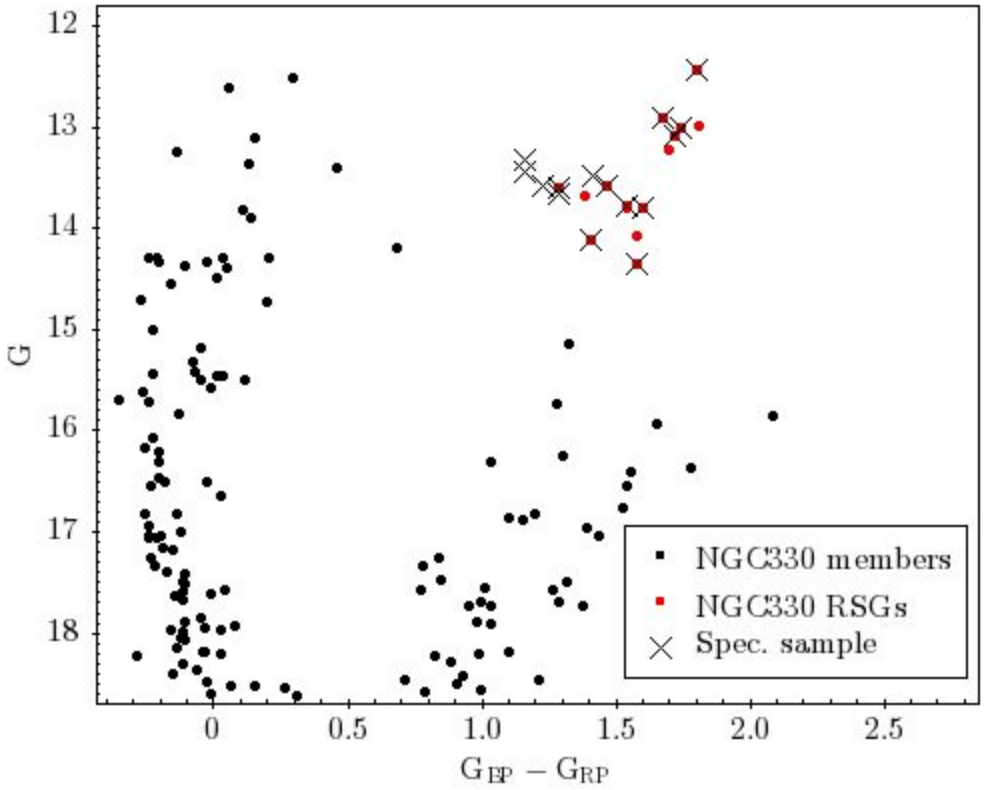
- RSGs are the evolved products of massive main-sequence (OB-type) stars with initial masses in the range 8 < $M/M_{\odot}$ < 40 (e.g. Ekström et al. 2012)
- RSGs are the final evolutionary stage of massive star evolution for most stars
- RSGs are the confirmed progenitors to the most common type of SN: SN II-P

2. Methodology

- To assess the multiplicity properties of RSGs we compile archival HARPS and new MUSE observations in the cluster NGC330
- NGC330 is a young massive cluster in the Small Magellanic Cloud whose appearance, because of its age and mass, is dominated by the RSG population it contains



B-band image of NGC 330.. Red circles indicate our targets, with identifications primarily from Robertson (1974). The approximate footprint of the observed MUSE field (Bodensteiner et al. 2020) is overlaid in red.



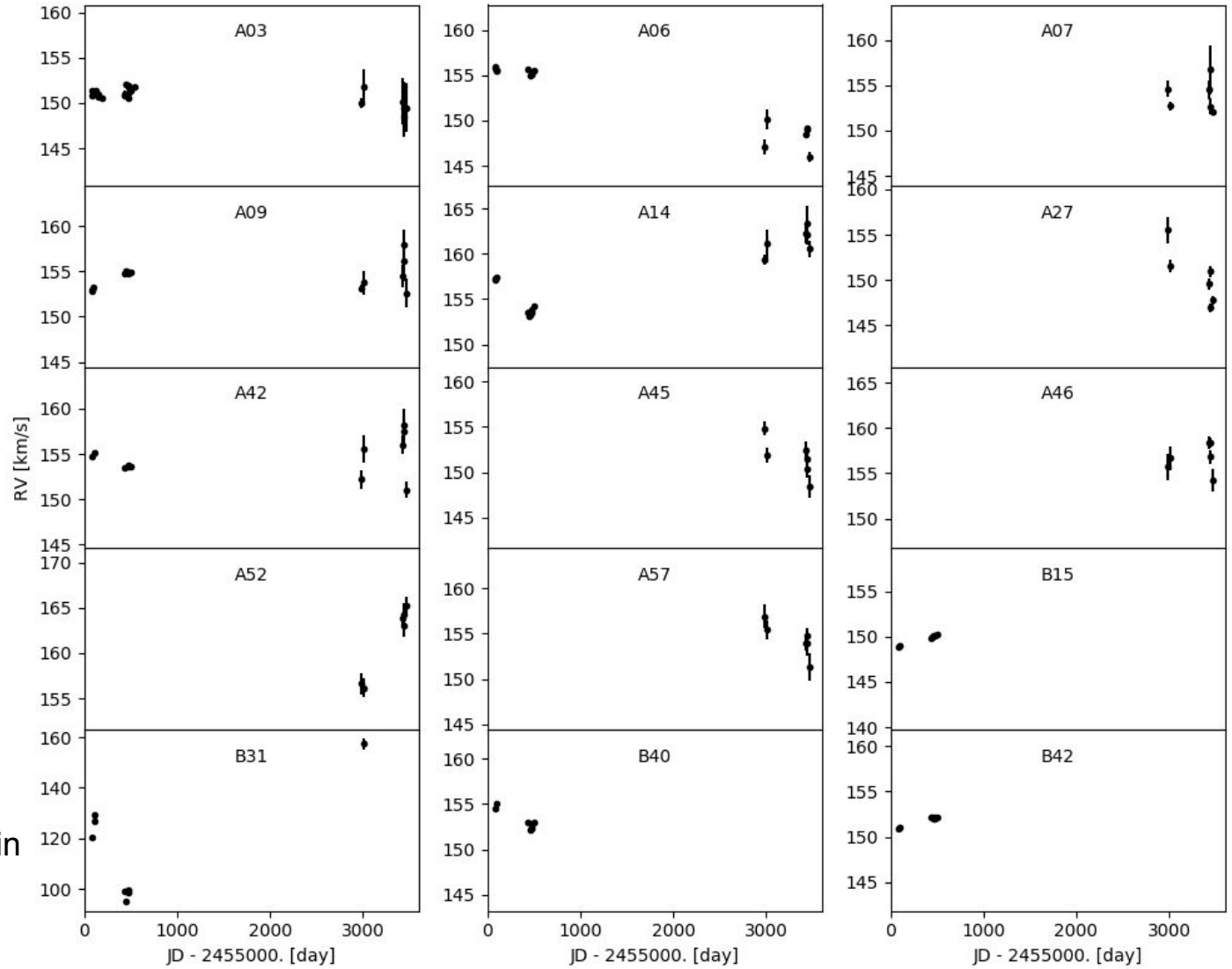
Gaia $G_{BP} - G_{RP}$ vs. G colour-magnitude diagram for NGC330 highlight the large RSG population. Our sample consists of 15 RSGs (Patrick et al. 2020).

- We estimate radial velocities for our targets using a tailored analysis technique defined in Patrick et al. (2019)
- We search for radial velocity variations that cannot be explained by intrinsic variability using a variability criteria defined by Patrick et al. (2020)

3. Results

- We measure radial velocities for 15 RSGs in NGC330 using the dedicated analysis technique adapted from Patrick et al. 2019

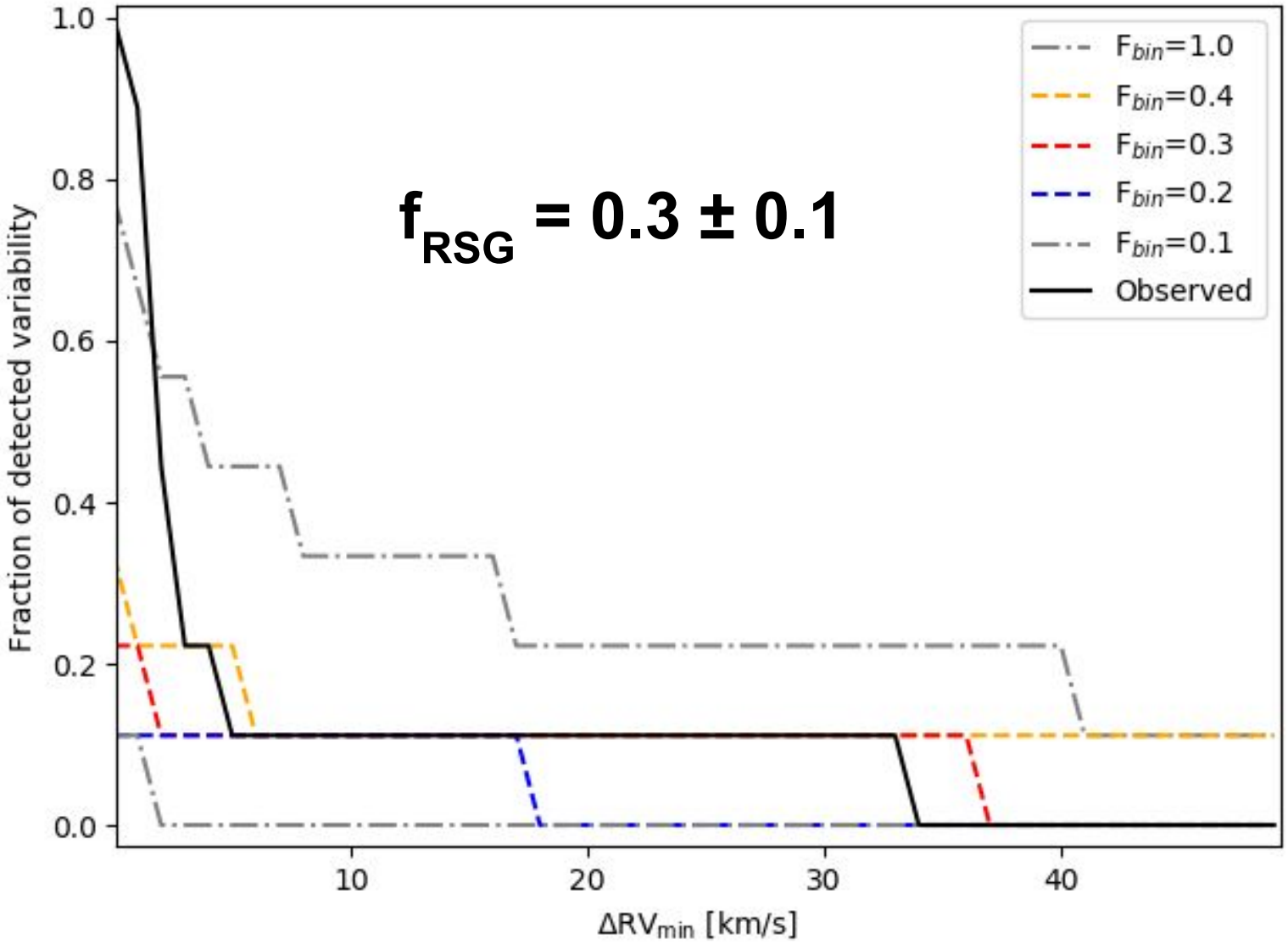
- In general, we find little intrinsic variability in the measured radial velocities. This points to an unexpected difference in the RV behaviour of RSGs between RSGs in the Galaxy and those in the NGC330, which requires further investigation



Multi-epoch radial velocity measurements for 15 RSGs in NGC330, measured using the technique developed by Patrick et al. (2019).

3. Results

- We detect significant radial velocity variability that cannot be explained through intrinsic variability of RSGs
- Observational biases are accounted for by simulating binary populations with different intrinsic binary fractions
- For the first time we calculate the intrinsic binary fration of RSGs. We find that 30 ±10% of RSGs are currently in binary systems
- The parameter space where we can detect binary motion is 2.3 < log P [days] < 4.3, with q > 0.1.



The fraction of RSGs which meet our variability criteria as a function of the maximum difference between radial velocity measurements (ΔRV_{min}). Dashed lines show simulations, accounting for observational biases, of our sample with different binary fractions. See Patrick et al. 2020 for more details

4. Impact and future prospects

- For the first time we have estimate of the intrinsic binary fraction of RSGs (30 ±10%)
- By studying the luminosity distribution of the RSG population we have identified binary post-interaction products in the RSG phase (see Patrick et al. 2020)
- This study paves the way for future studies of the Magellanic Clouds