Radial velocity variability of Red supergiant stars

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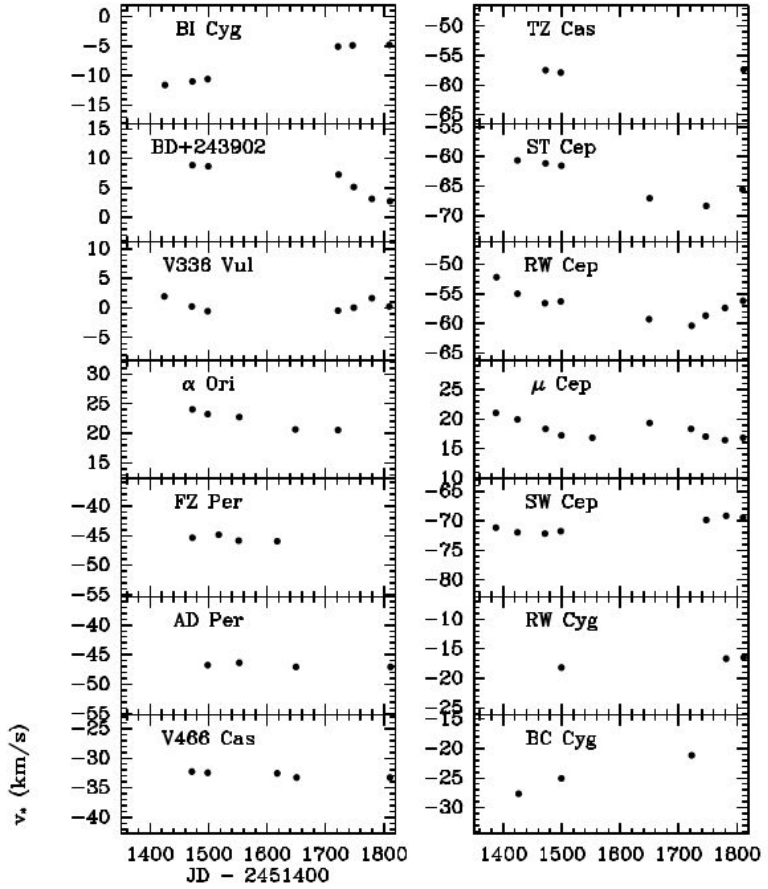
Abstract

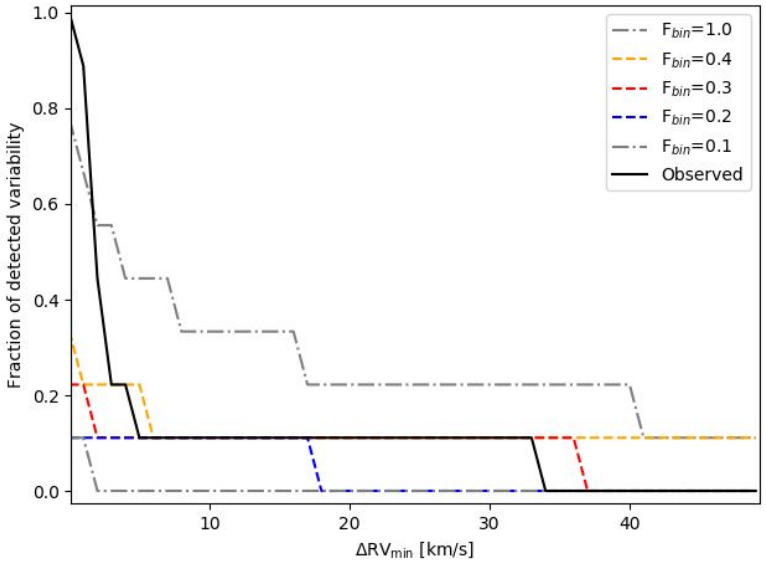
Massive stars are uniquely important for stellar feedback and the production of gravitational wave progenitors. The final evolutionary phase before supernova of most massive stars is the red supergiant (RSG) phase. RSGs have famously variable atmospheres that introduce uncertainties in their stellar parameters and in particular their multiplicity properties, the latter being a key unanswered question for RSGs. We present results for six Galactic RSGs to determine the amplitude and timescale of radial velocity (RV) variations. We will measure stellar parameters for all our targets and demonstrate in principle how RV variability depends on temperature and luminosity. These results act as a pilot study for a larger SONG study of Galactic RSGs. In this respect, these observations not only will advance the characterisation of atmospheric variability of RSGs, but are also vital to multiplicity studies of RSGs, which must take variability into account.

1. Context

Radial velocity variability of RSGs from Josselin & Plez 2007



- Red Supergiant (RSG) stars 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 have famously variable atmospheres (e.g. the recent dimming/brightening of Betelgeuse; Guinan et al. 2019) and as a result stars lose a significant amount of mass during the RSG phase (e.g. de Beck et al. 2010).

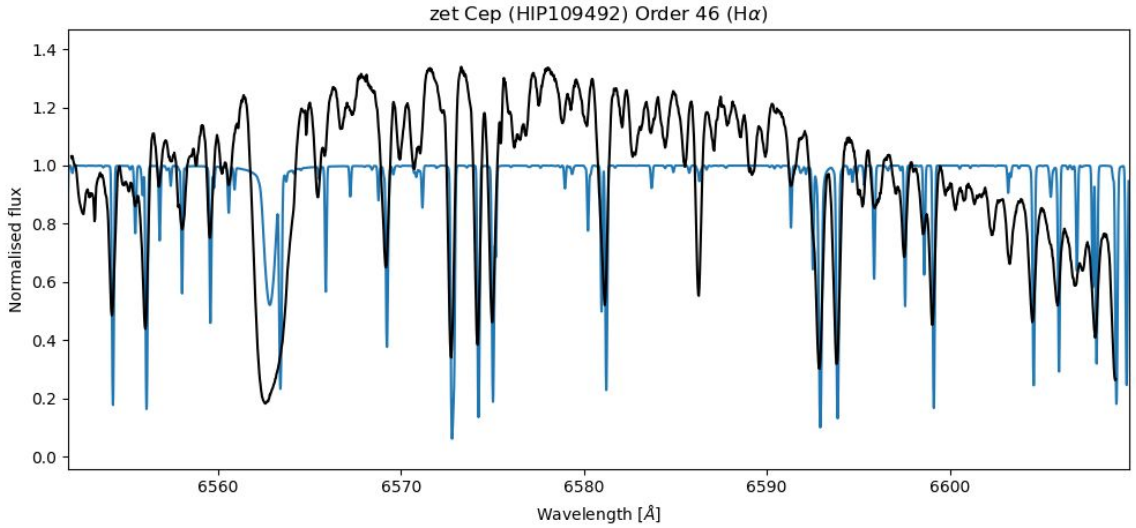


Intrinsic multiplicity fraction of RSGs as measured by Patrick et al. (2020) for a sample of 15 RSGs in the Small Magellanic Cloud.

- It is vital to take into account atmospheric variability in determining the fundamental properties of RSGs (e.g. effective temperatures, luminosities, masses and multiplicity statistics)
- However, what is known about the scale of radial velocity (RV) variability in RSGs comes from either a very small number of well-studied targets (e.g. α Ori, Smith et al. 1989; μ Cep, Kravchenko et al. 2019), or studies with much poorer time sampling (Josselin & Plez 2007)

2. Methodology

- As a pilot study we obtained multi-epoch spectroscopic observations of 6 RSGs from the Stellar Observatories Network Group (SONG) (PI: Patrick, L. R)
- SONG provides high resolution and high radial velocity stability, which is vital to achieve our science goals



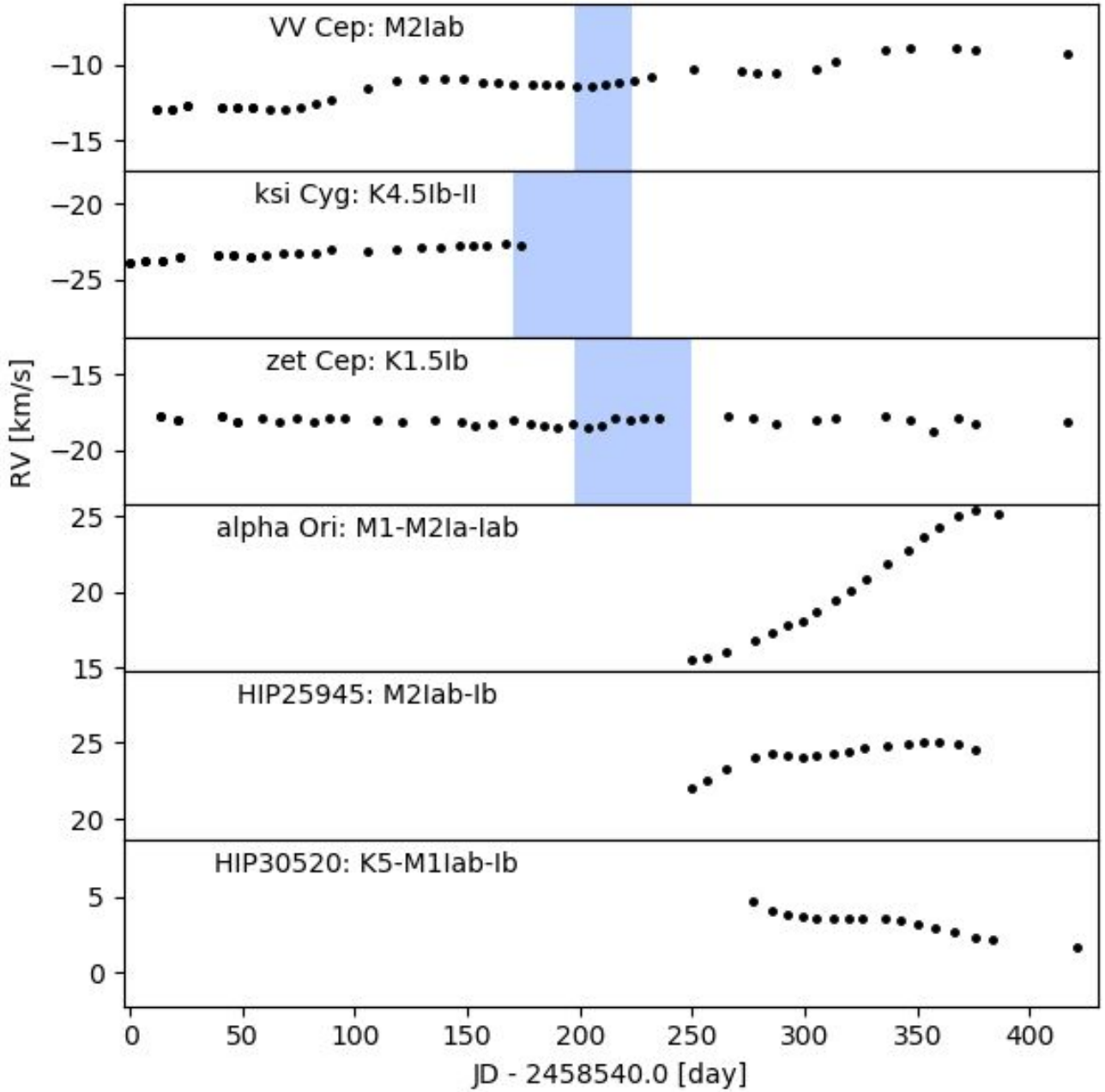
SONG spectrum of zet Cep (HIP109492; in black) shown against a synthetic RSG spectrum (in blue; from the MPIA-NLTE synthetic spectrum tools).

Hertzsprung SONG telescope at the Teide Observatory (IAC press release)

- To characterise Radial velocity variability, one spectrum every 7 days, over a baseline of at least 4 months, is observed for all our targets
- We study potential empirical correlations between the variability of the fundamental stellar parameters and RV variability using our c carefully selected sample of RSG to cover appropriate mass and temperature ranges

3. Results

- We measure multi-epoch radial velocities for 6 of the brightest RSGs in the northern sky
- Covering a baseline of over 400 days for our most well studied sample we detect radial velocity variations to varying degrees for all of our targets
- A separation is seen between low-radial velocity variable stars (below 5 km/s) and radial velocity variable RSGs (above 5 km/s)

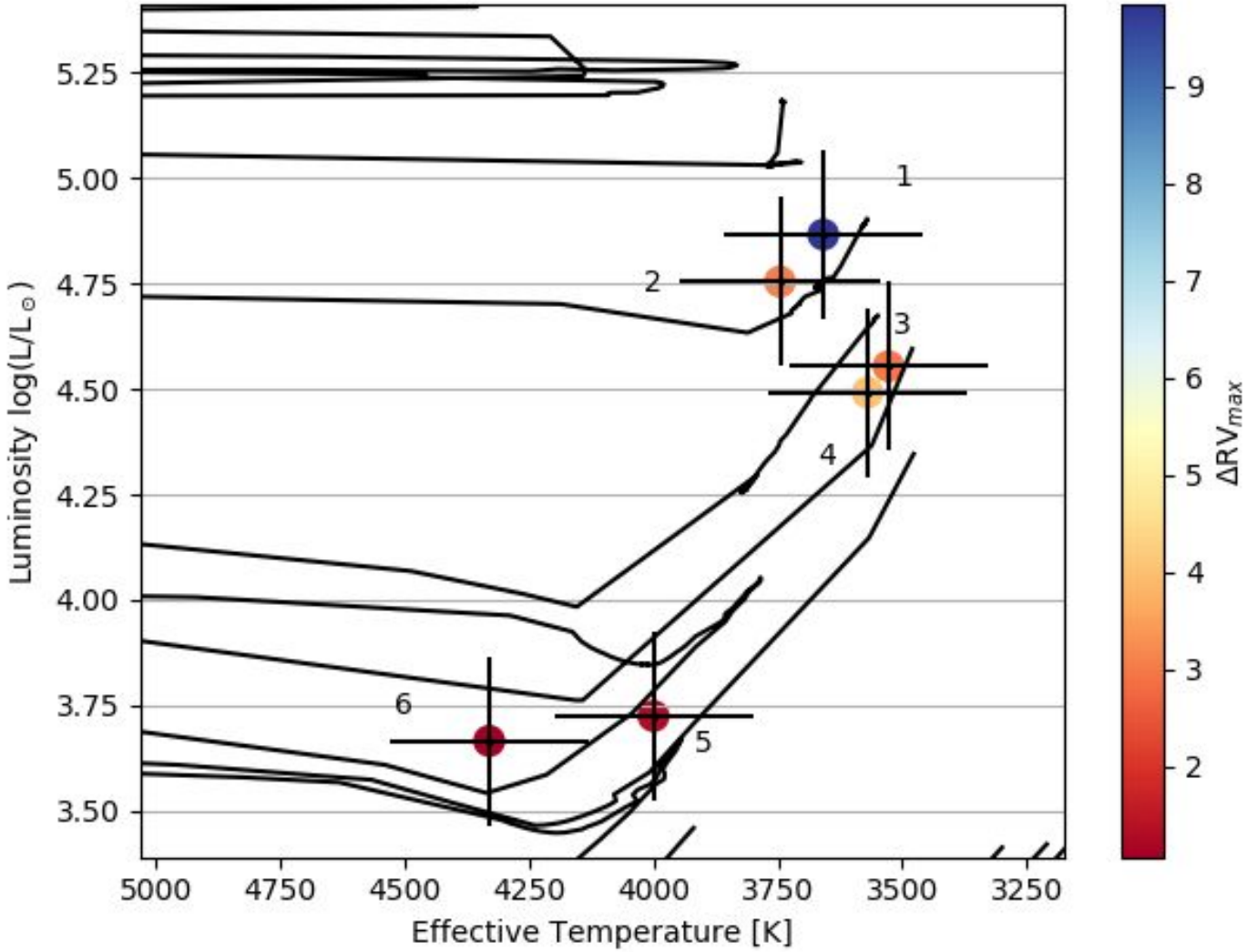


SONG Radial velocity measurements for our pilot study using 6 targets all shown on the same scale. All panels are shown on the same scale to highlight the difference. Blue shaded areas indicate complementary TESS observations. Note that the data for α Ori also covers the recent dimming period.

3. Results

- **We find some evidence for an empirical dependence on effective temperature and luminosity of radial velocity variability of RSGs**
- For the most luminous, coolest RSGs we observe larger radial velocity variability
- The least luminous RSGs in our sample show variability on the 1-2 km/s level

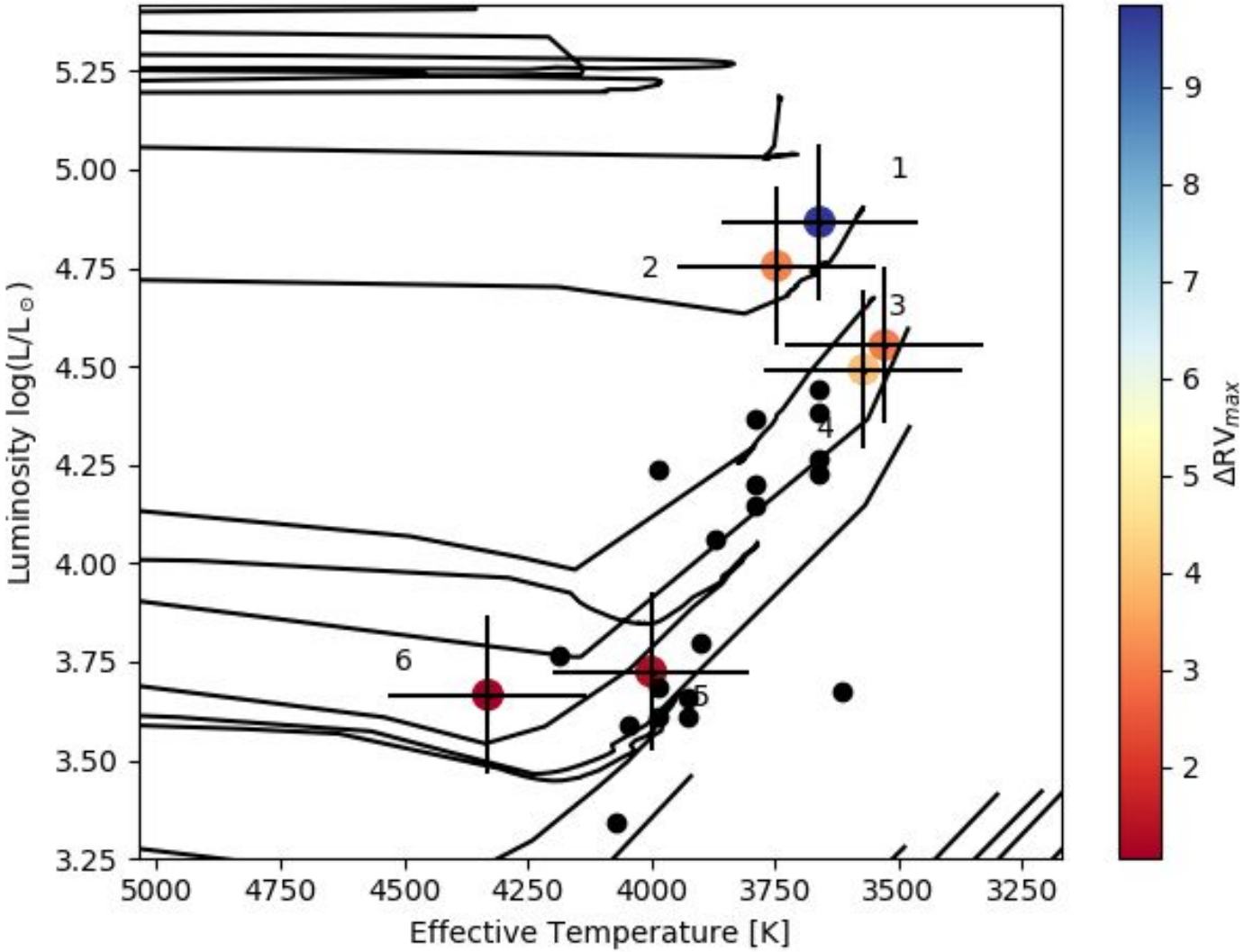
Demonstrates the large potential that RSGs have as kinematic indicators of stellar structure in galaxies (e.g. Patrick et al. 2020)



Hertzsprung-Russell Diagram for six of the brightest RSGs in the northern hemisphere. The colour of each target is scaled by the level of radial velocity variability observed

4. Impact and future prospects

- With a pilot study of six RSGs we demonstrate the dependence of radial velocity variability on fundamental stellar parameters
- These results have important consequences for determining fundamental stellar parameters of RSGs
- To fully characterise this dependence observations are currently underway with SONG to study 20 RSGs to better cover the RSG parameter space



Hertzsprung-Russell Diagram for six of the brightest RSGs in the northern hemisphere. The colour of each target is scaled by the level of radial velocity variability observed. Black points show proposed targets