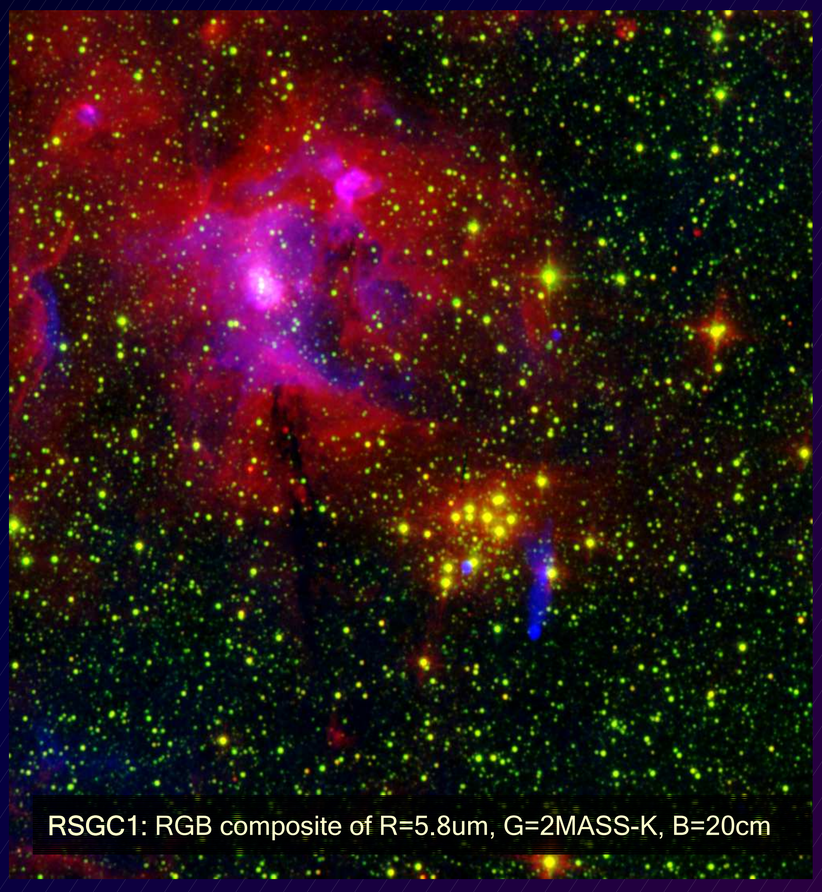
The Scutum Red Supergiant Clusters

Ben Davies[1], Don F. Figer[1], Rolf-Peter Kudritzki[2], John MacKenty[3], Casey J. Law[4], Francisco Najarro[5], Artemio Herrero[6]

[1]Rochester Institute of Technology, [2]University of Hawaii, [3]STScI, [4]Amsterdam, [5]CSIC Madrid, [6]Instituto Astrofisica Canarias

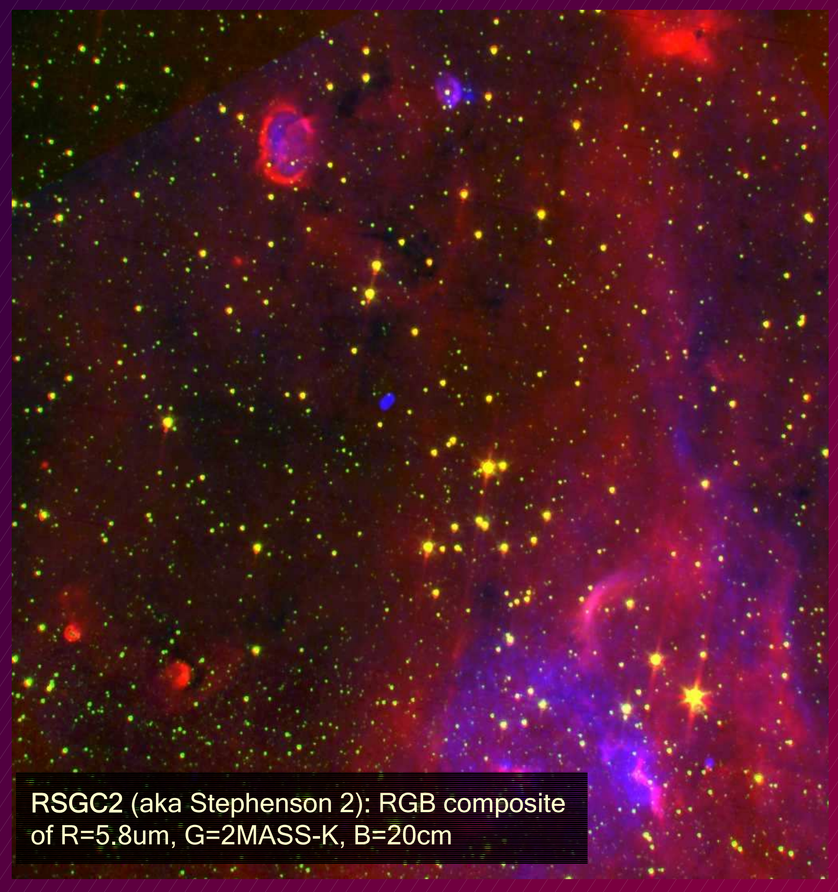
Abstract - We present the recent discoveries of two Galactic massive young clusters, which together contain 40 red supergiants (RSGs)–20% of all those known in the Galaxy–and as many in the entire Large Magellanic Cloud. From observations and evolutionary synthesis models, we argue that the cluster masses are comparable to the other Galactic "super star clusters" such as Westerlund 1 and the Arches Cluster. The distinctly different ages of the clusters, uniform metallicity, and large number of RSGs mean that these objects now offer an unprecedented opportunity to study the pre-supernova evolution of massive stars. Further, their location at the point where the Scutum-Crux spiral arm meets the central Galactic bar allows us to study the metallicity gradient at this location in the Galaxy, and the interaction between the bar and the disk.



RSGC1: RGB composite of R=5.8um, G=2MASS-K, B=20cm

Introduction -

Red Supergiants (RSGs) decend from stars with initial masses of 8-30$M_\odot$, and are observed to be the direct progenitors of Type-IIP supernovae (e.g. Smartt et al. 2003; van Dyk et al. 2004). However, their evolution towards SN remains poorly understood - it depends on the complex interplay between radiation pressure on dust grains in the outer atmosphere and dust formation rates, which in turn depend upon the stellar abundances. Moreover, as with all massive stars, RSGs are rare, and hence studies suffer from poor number statistics. In recent papers (Figer et al. 2006, Davies et al. 2007, Davies et al. 2008) we present two new clusters, RSGC1 and RSGC2, which harbour unprecedented numbers of RSGs. As the tricky variables of metallicity and initial mass are uniform throughout each cluster, these objects are the ideal testbeds with which to study several aspects of massive stellar evolution.



RSGC2 (aka Stephenson 2): RGB composite of R=5.8um, G=2MASS-K, B=20cm

Cluster properties -

We obtained high resolution spectroscopy of all K-bright objects in both fields. From these data, we made precise radial velocity measurements which allowed us to distinguish between the cluster members and foreground objects (Fig. 3). From the kinematic distance to each cluster and the strength of CO absorption in the stars' spectra, we were able to determine luminosities and temperatures for the stars, and hence place them on the H-R diagram.

From comparison with the model isochrones of Maeder & Meynet (2000), we determined ages for each cluster (see Fig. 4). Using these ages, and assuming a Salpeter Initial Mass Function, we then estimated the initial cluster masses required to produce the number of RSGs observed in each cluster. In each case, the derived mass was consistent with the dynamical mass calculated using the velocity dispersion of the cluster members.

The masses of the two clusters put them among the most massive in the Galaxy, comparable to e.g. Westerlund 1 and the Arches cluster. The cluster properties are summarized in Table 1.

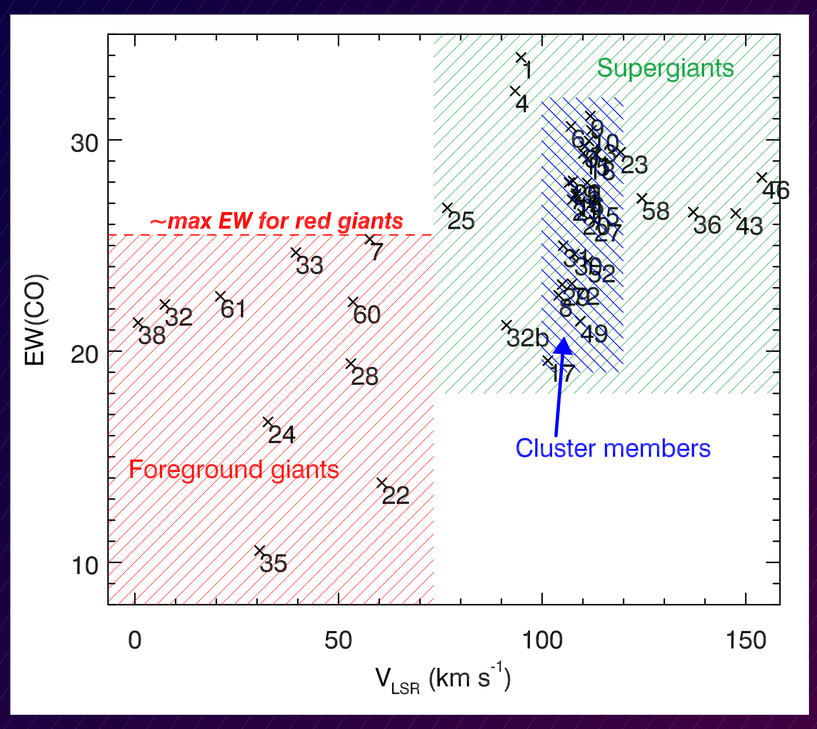


Fig. 3: Equivalent Width (EW) of CO 2.295μm absorption vs radial velocity for stars in the field of RSGC2. The maximum EW observed in Red Giants is indicated on the plot, thus any stars above this limit are likely to be supergiants. We identify the stars at the lower-left of the plot (red cross-hatched region) as foreground stars; while the tight grouping of stars around V_{LSR}~110kms^{-1} is identified as a physical association of supergiants.

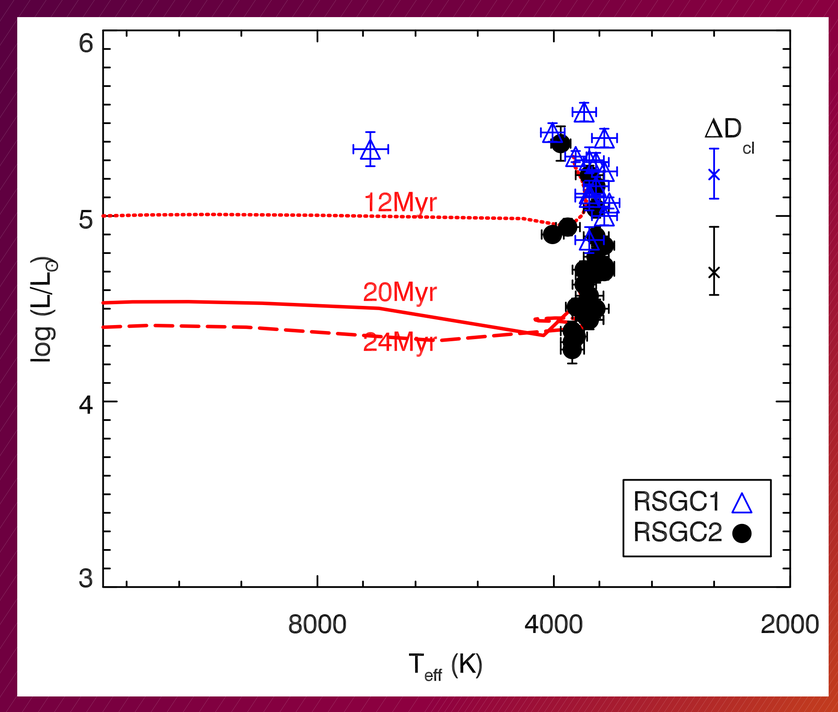


Fig. 4: H-R diagram for the two RSG clusters, overplotted with isochrones from the Geneva evolutionary models. RSGC1 is consistent with a cluster age of 12Myr, while the lower luminosities of the RSGC2 stars indicates a slightly older age. This implies that the stars of RSGC2 have lower initial masses than those of RSGC1.

Table 1: Physical properties of the two RSG clusters

	RSGC1	RSGC2
N_{RSG}	14	26
M_{cl} ($M_\odot$)	3×10^4	4×10^4
Age (Myr)	12±2	17±3
R_{cl} (pc)	1.5±0.3	$3.2^{+1.5}_{-0.7}$
$D_\odot$ (kpc)	6.6±0.9	$5.8^{+1.9}_{-0.8}$
D_{GC} (kpc)	3.2	3.5
$M_{\star,init\ (RSG)}$	18$M_\odot$	14$M_\odot$

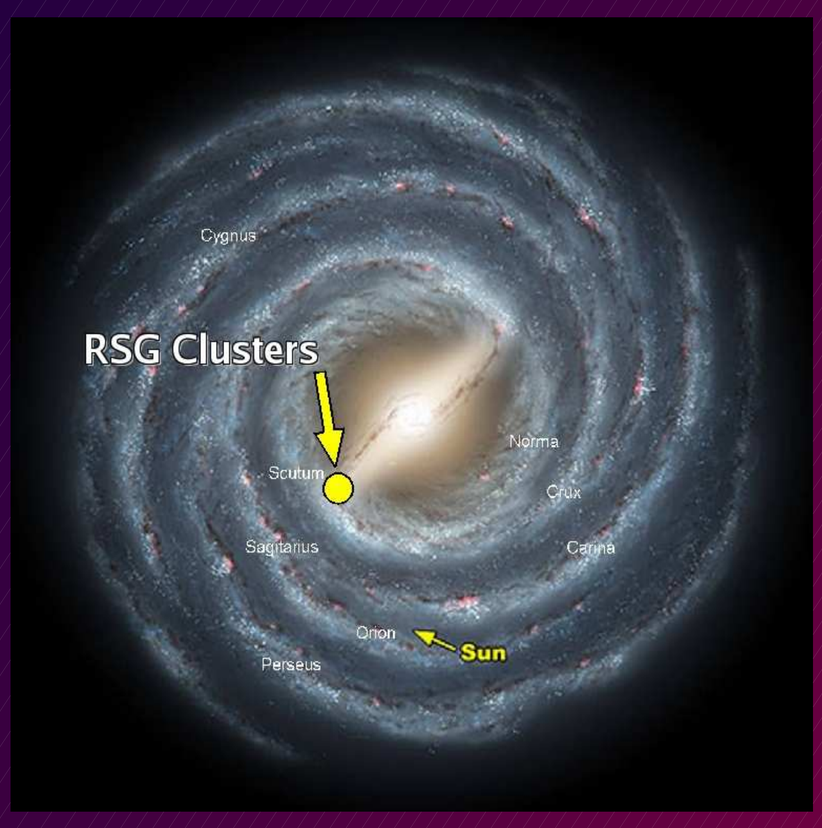


Fig. 5: Illustration of the RSG clusters' location in the Galaxy. The kinematic distance to the clusters puts them right at the tip of the Galactic Bar, around 3.5kpc from the Galactic centre.

Future Studies -

- Stellar Evolution: The two clusters contain statistically useful numbers of RSGs, at uniform metallicity and at two initial masses. Therefore, they are ideal natural laboratories to study various aspects of stellar evolution, such as surface abundances, pre-SN mass-loss behaviour, and maser activity.

- Galactic metallicity gradient: From their kinematic distances and Galactic longitude, we can place the RSG clusters at Galacto-centric distances of around 3.5kpc (see Fig. 5). They are therefore approximately coincident with the tip of the Galactic Bar, as proposed by Benjamin et al (2005). Abundance studies will indicate whether the clusters are disk-like (super-solar metallicity) or bulge-like (sub-solar), and hence provide insight into the star-formation history in the region of interaction between disk and bar.

References -

Benjamin et al. (2005) ApJ 630, L149

Davies et al. (2007) ApJ 681, 781

Davies et al. (2008) ApJ in press, astro-ph/0711.4757

Maeder & Meynet (2000) A&A 361, 159

Figer et al. (2006) ApJ 643, 1166

Smartt et al. (2004) Sci 303, 499

van Dyk et al. (2003) PASP 115, 1289