The Be Star Population in the SMC – Insights from the Clusters and the Field

Abhinna Sundar Samantaray [1*], **Eva Grebel** [1], **V. Ripepi** [2], **A. Pasquali** [1], **M. Gatto** [2]

[1]Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Germany
[2]INAF-Osservatorio Astronomico di Capodimonte, Italy

Multiple Populations in star clusters

Deviations from a perfect single-starburst isochrone for stars in young stellar clusters (YSCs) are caused by stellar rotation & internal mixing (in massive stars). This is now a widely accepted theory (Bastian and de Mink 2009; Kamann+2020) and the YSCs might not have multiple episodes of star formation (Milone+2009; Goudfrooij+2014). Thus, a search for these objects in YSCs becomes important. We look for these in the Small Magellanic Cloud (SMC), which has low-metallicity, extinction, and is close to the Galaxy.

We create a census for such objects, i.e. Be stars, which are hot, massive, rapidly rotating B-type stars (+ late-type O & early-type A) having a circumstellar decretion disk, which leads to a characteristic H-emission line (see Fig.1), especially in H_α ($\lambda \approx 6563$ Å), & can well mimic the age-spreads in the YCs.

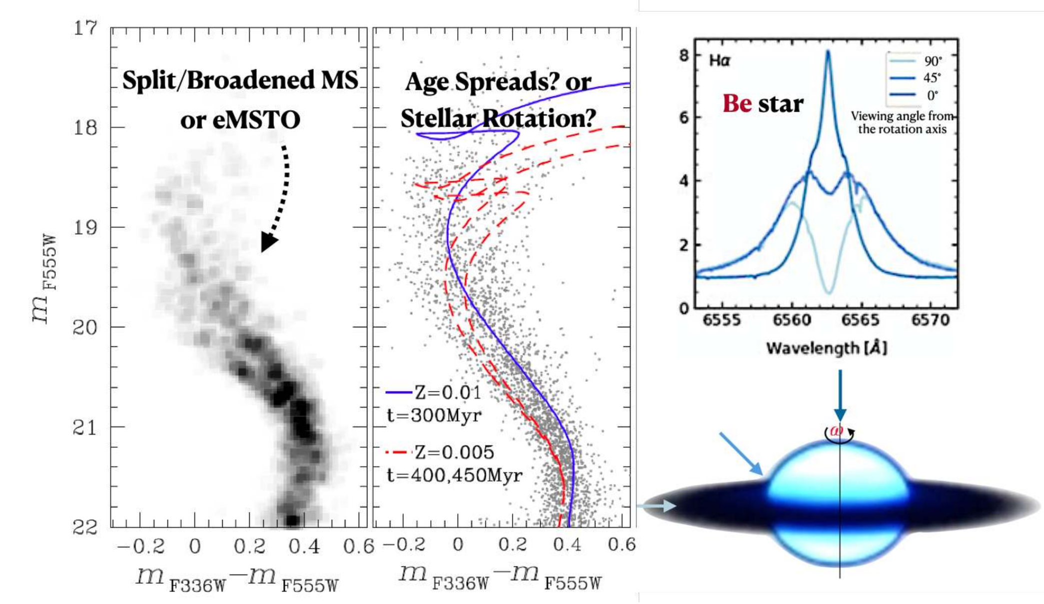

Fig 1: (left) A Young cluster NGC 1846 showing eMSTO; (middle) overplotted with isochrones of different ages; (right) a typical spectrum of a Be star. Credits: (Milone+2015; Bodensteiner+2021)

NGC 330: a Young Massive Cluster

Not many massive SCs known in the age range $\sim 10-40$ Myr exist (Galactic ones are highly reddened). Provided that Be stars usually survive better in the low stellar winds, NGC 330 in the SMC is a suitable target in a lower-metallicity environment & is also known to host a high fraction of Be star populations (Grebel+1992; Keller+1999; Bodensteiner+2020).

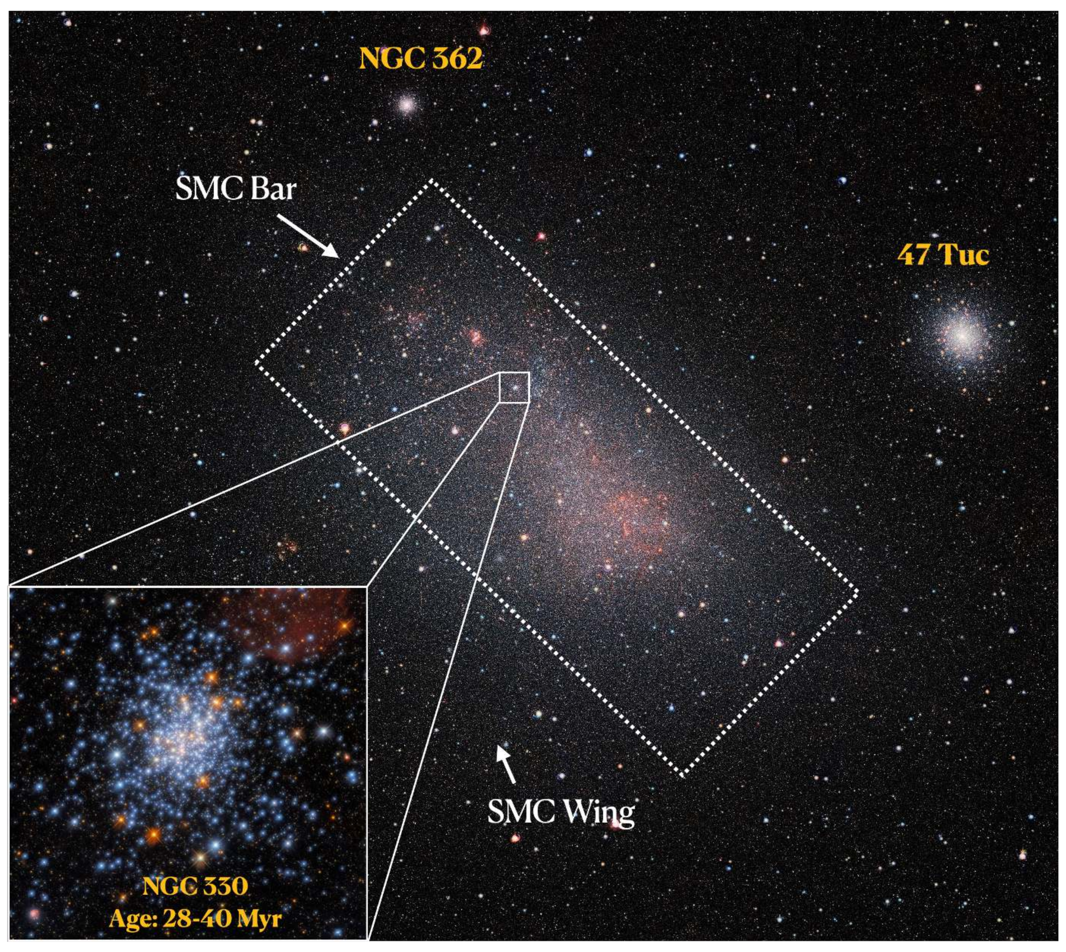

Fig 2: VISTA image of the SMC, and zoomed in is the HST image of the YMC NGC 330, credits: ESO, & ESA Hubble

Selection based on CMD & $H\alpha$ excess

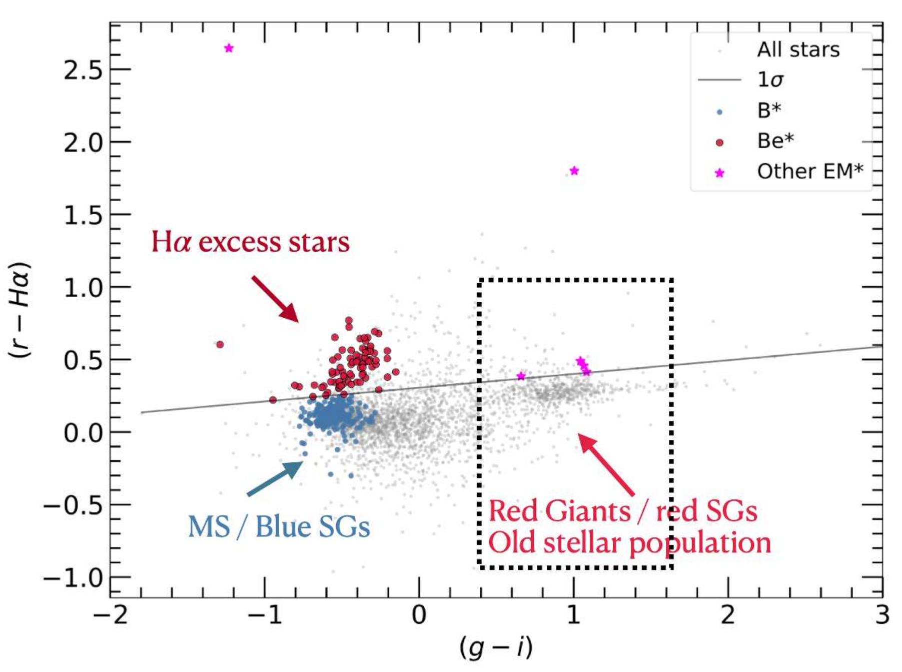

Fig 3: Color-color plot of NGC 330 stars using narrowband filter to separate $H\alpha$ emitting objects from other sources. The dotted fitted line shows the 1σ limit.

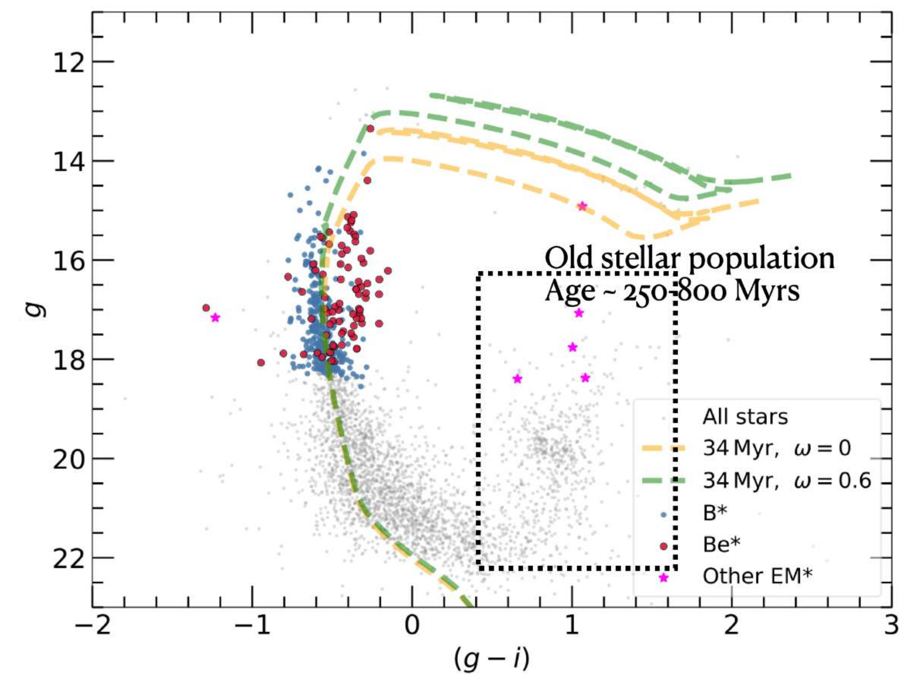

Fig 4: a CMD of g vs $(g-i)$ showcasing the red MS due to Be stars.

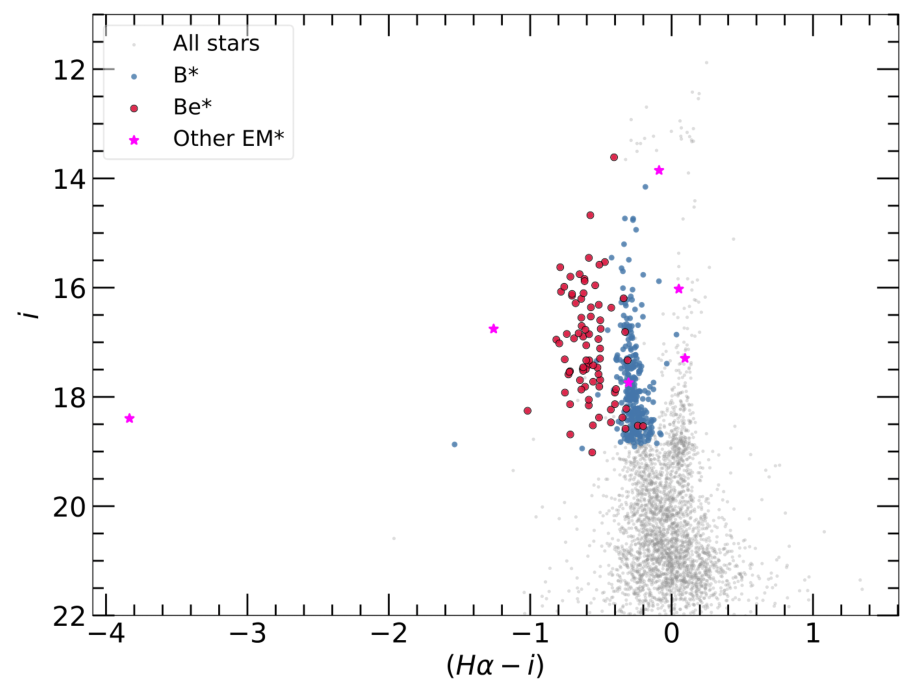

Fig 5: i vs $H_\alpha - i$ plot showing the segregation of Be stars from the MS.

We use the following limits: (a) V-band limit of 18.5 to identify B-type stars; (b) fit (and identify) the MS regions in the $(H\alpha - i)$ vs $(g-i)$ plot (Fig. 3) and g vs $(g-i)$ (Fig. 4); (c) Look for stars above 1σ above the fitted line in Fig. 3 to identify the Emission Line Sources (ELS) and which broaden the MS in Fig. 4. These Be star candidates segregate clearly in the i vs $(H\alpha - i)$ plot (Fig. 5).

Massive stars near cluster center?

Massive stars tend to reside near the core of the cluster, majorly due to the mass segregation as a natural mechanism of star formation itself, and the most massive stars are more concentrated than the low-mass stars (Bonell et. al. 2001a; Hillenbrand 1997).

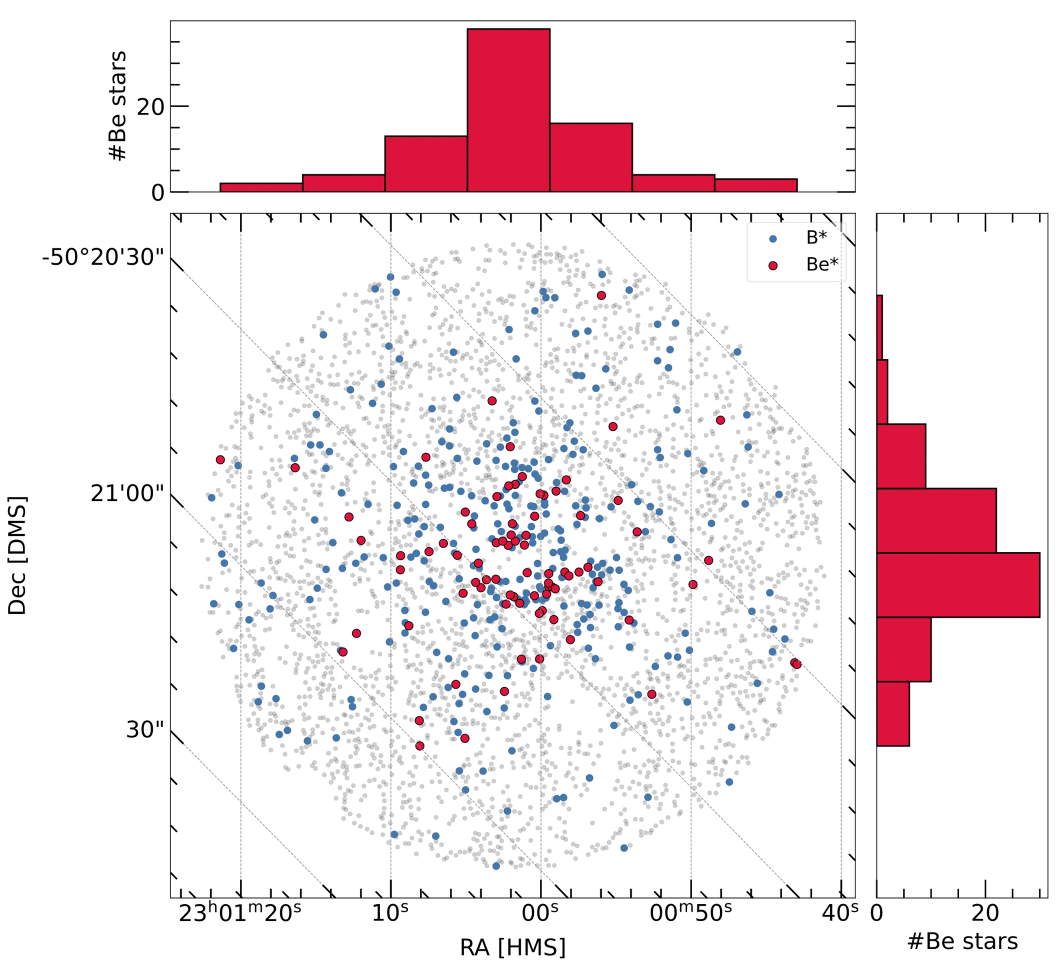

Fig 6: Skyplot of NGC 330 and the location of its B (302) & Be (80) stars.

Lack of late-type Be stars?

A lack of fainter Be stars may indicate a cutoff luminosity (or mass) below which B stars are no longer Be stars (Bastian et al. 2017).

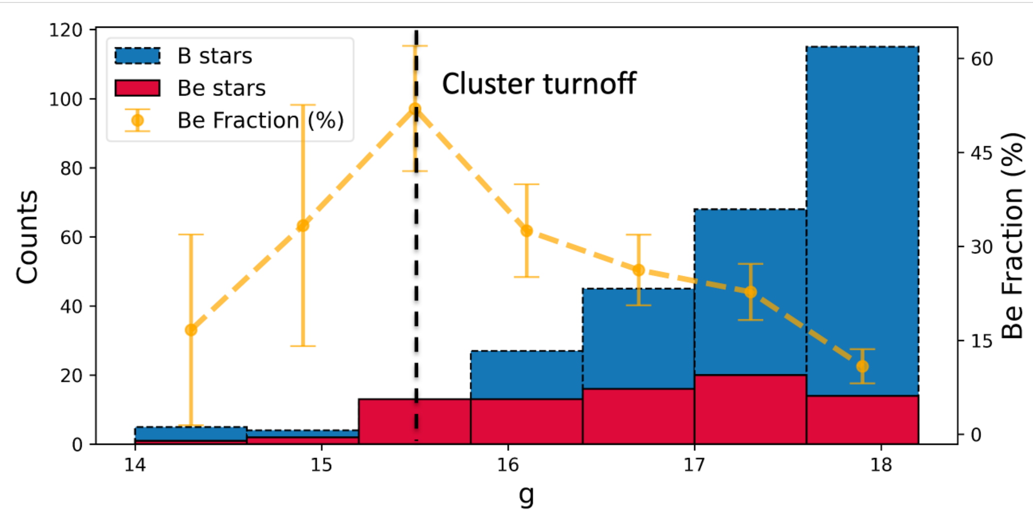

Fig 7: Distribution of B and Be stars for NGC 330 over g-band magnitude.

Distribution of Be* in SCs in the SMC

We find that the Be fraction – (a) decreases with the cluster's increasing age; (b) increases with decreasing metallicity (Ekstrom et. al. 2008) (see Fig. 8). We find that SCs with more than 20% Be fraction reside in the SMC bar, which may be due to active star formation.

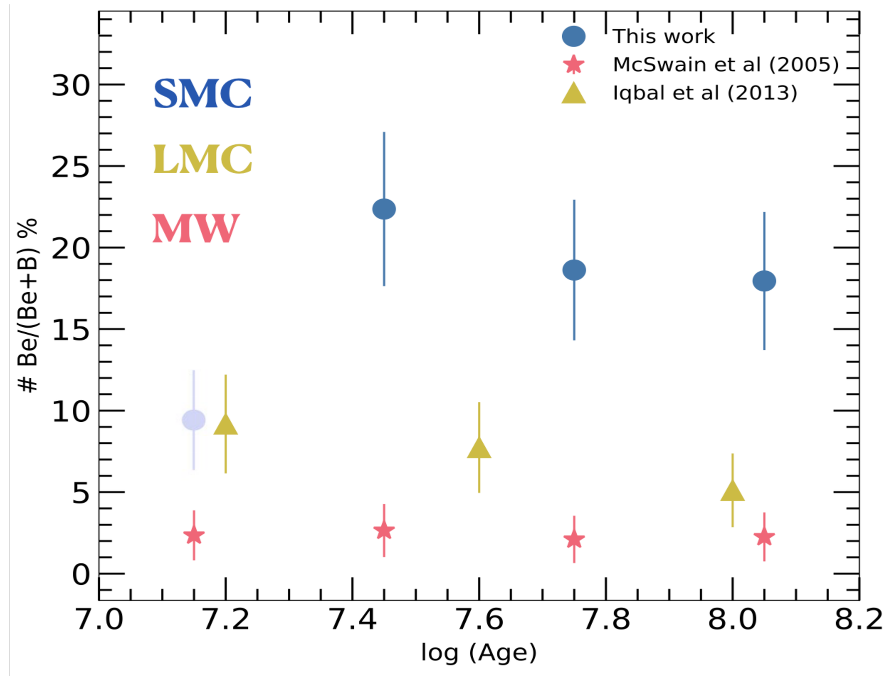

Fig 8: The average Be stars % in the clusters in SMC (blue filled circles), LMC (yellow triangles), and MW (red stars) binned in age.

SMC Field Star Population

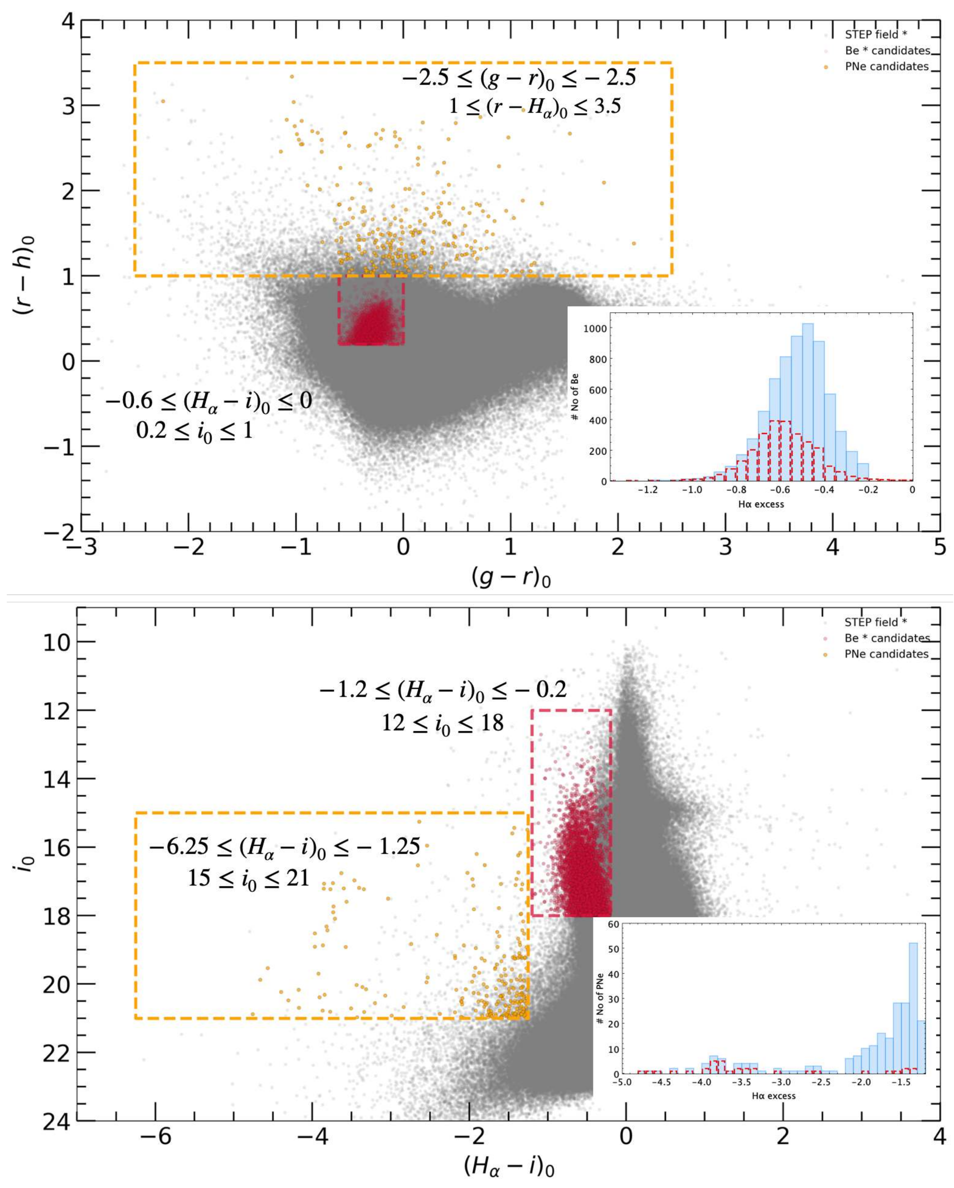

Fig 9: Color-Color plot (top) and CMD (bottom) of the SMC stars, red box showing the Be candidates and orange box showing the PNe candidates. Stars that satisfy both conditions are colored (red or orange). Inset histogram shows the population of new (blue) and known (red) Be and PNe respectively.

In the SMC field population, we expanded the existing census by increasing the number of bright-field Be stars ($12 < i_0 < 18$) from ~ 2700 to around ~ 6500. Serendipitously, we also identified some known and new Planetary Nebulae (PNe) candidates (+other ELS) with high $H\alpha$ excess using STEP filters (see Fig. 9) increasing their population from 34 to ~ 250.

Results and Conclusions

We did the first-ever systematic study of the massive fast rotators – Be star candidates in the SMC star clusters and in the field. We compared the Be fraction of the SCs with metal-rich LMC and MW and confirmed that the fraction decreases with increasing metallicity. We found many new Be star candidates in these young star clusters. Additionally, we increased the population of Be (and ELS) in the field as well. The confirmation of the Be candidates and other Emission Line Sources (ELS) will be done with the help of the spectroscopic observations rom SDSS-V LVM and 4MOST.

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*Correspondence to: abhinna.samantaray@uni-heidelberg.de | www.abhinnasundarastro.com | Cosmoparticle | abhinna_sundar