The Low-Mass Stellar Content of 30 Doradus

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Abstract. We have constructed very deep, broad-band V, I WFPC2 images of R136 from the HST archive, in order to sample the low limit of its luminosity function. In the new images, we detect stars down to a limiting magnitude of 24.7 ($\simeq$1 magnitude deeper than Hunter et al. 1995, 1996), and can identify two stellar populations with different spatial distributions. A comparison with evolutionary tracks by Bernasconi (1996) indicates that the reddest objects are pre-main-sequence stars in the mass range 2–0.8$M_\odot$. Such a population appears to be located $\sim$7$''$ from the centre of the cluster.

1. Introduction

The 30 Doradus nebula in the Large Magellanic Cloud is the closest Giant Extragalactic H II Region (GEHR) (Kennicutt 1991), and a unique laboratory for the study of star formation: one quarter of the total massive-star formation in the LMC is contained in a 15$'$ radius around this region (Kennicutt 1991). The central portion of the nebula is dominated by the cluster NGC 2070, which contains numerous dense clusters of massive OB and WR stars, the most luminous being R136. Because of its high concentration of massive stars compared to other star-forming regions in the LMC or in the Milky Way, R136 displays an extreme mode of star formation representative of what is seen on larger scales in more distant galaxies. Local starbursts, such as M82 (Rieke 1991) or NGC 3256 (Joseph 1991), have allowed detailed studies of their stellar population, and they are both deficient in stars having masses less than 3–5$M_\odot$. This has led to the suggestion that starbursts in general have a truncated IMF, with an abrupt cut-off at masses around 3–5$M_\odot$. Theoretical arguments also bolster the expectation that the lower mass limit could be unusually high in environments of intense star formation, with the further suggestion (Silk 1986) that the lower mass limit could be as high as 10$M_\odot$. R136, as an example of a locally intense star-formation event that is close enough to be resolved into individual stars, offers a unique opportunity to test these ideas. If the conclusion derived for

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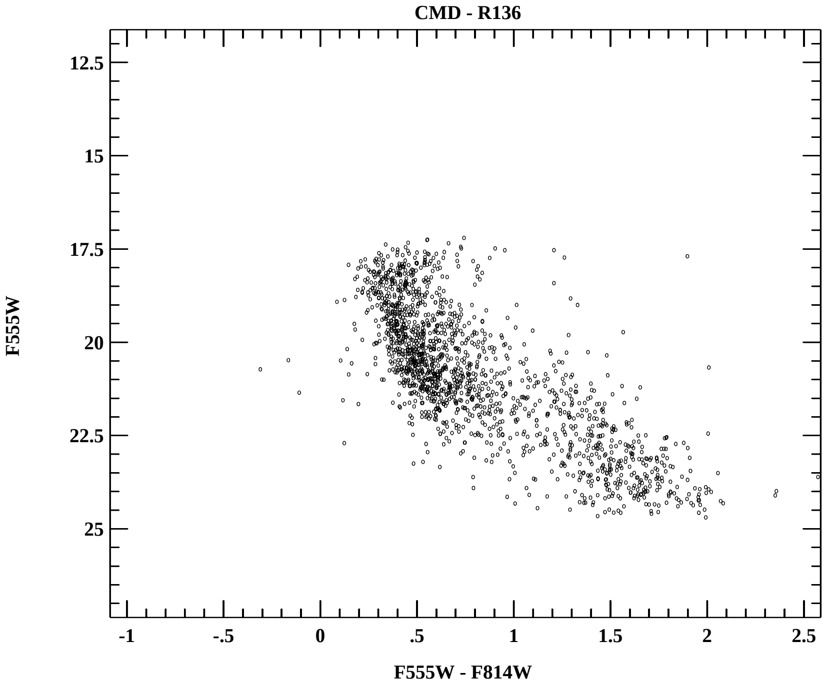

Figure 1. Colour–magnitude diagram of R136 for all stars measured in the combined images with photometric errors smaller than 0.2 magnitudes in both filters.

galaxies such as M82 is correct, we would expect R136 to have a lower mass limit of ~ 2–$10 M_\odot$. Previous studies of R136, both from the ground and with HST, have been limited to the luminosity function (Campbell et al. 1992; Malumuth & Heap 1994) or IMF (Parker & Garmany 1993) of the most massive stars. More recently, Hunter et al. (1995) used the refurbished HST to detect stars down to magnitude 23.5. Allowing for crowding and reddening, this corresponds to a minimum mass of $2.8 M_\odot$. Hunter et al. (1995) did not find any IMF cutoff. This prompted us to perform a study of the low-luminosity end of the IMF, and we present here some preliminary results.

2. Observations

Deep images of R136 were obtained with the WFPC2 in several bandpasses in 1994 January and September as part of proposals 5589 and 5114 (PIs Trauger, Westphal; Hunter et al. 1995, 1996). We extracted the deepest frames obtained with the F555W and F814W filters from the archive and reduced both datasets independently. The combined images have an overall exposure time of 1240 sec and 760 sec in the two filters, respectively. Because of the high density of bright stars in the core, the inner $2''$ of R136 have not been analyzed. Photometry has been performed on both images, using PSF fitting techniques in DAOPHOT. Magnitudes of the individual stars were determined relative to an aperture of radius $0''.5$, and transformations were made to bring the on-orbit magnitudes

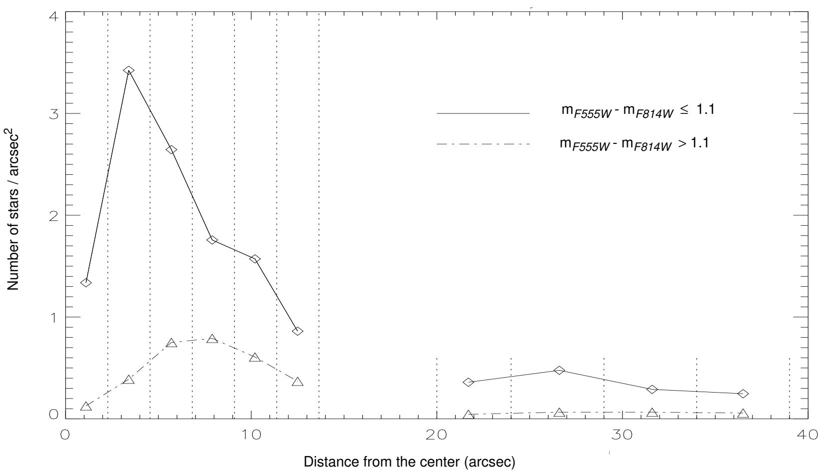

Figure 2. Radial star-density distribution for the two different populations. The solid line shows the stars with F555W − F814W < 1.1, while the dashed line show the distribution of stars with redder colours. Due to the high number of saturated stars in the core of R136, the first bin (0–2″) is severely affected by incompleteness.

to the WFPC2 photometric system using the calibration provided by Holtzman et al. (1995). Figure 1 shows the colour–magnitude diagram (CMD) of R136 for all the stars measured in the combined PC frame having photometric errors smaller then 0.2 magnitudes.

With this conservative threshold, we detect 1604 stars in both filters, down to a limiting magnitude of 24.7, which is ∼1 magnitude deeper than what was obtained from the individual frames by Hunter et al. (1995, 1996). Two different populations seem to be present in the CMD and appear segregated in colour at F555W − F814W = 1.1. We investigated the radial distribution of these two populations in concentric annuli starting from the centre of the cluster (Figure 2) out to 13″, and in an external region from 20″ to 38″. We find that while the bluest population decreases radially from the centre of the cluster outwards, the peak of the reddest population is clearly located at ∼7″ from the cluster centre.

3. Age and Mass

We have used isochrones constructed from theoretical stellar-evolution models provided by Bernasconi (1996) for pre-main-sequence (PMS) evolution at solar metallicity in order to assign masses to stars and to determine ages of the stellar population. We used Kurucz (1994) model atmospheres and the SYNPHOT software package to transform the stellar models from the '$\log(L/L_\odot)$vs. $\log(T_{\rm eff})$' system to the WFPC2 system. Figure 3 shows the dereddened CMD of R136 (extinction from Hunter et al. (1995): $A_{\rm F555W} = 1.37$ and $A_{\rm F814W} = 0.80$) and the PMS evolutionary tracks in the range 10^6–10^7 yr. The red population in the CMD is very well matched by the PMS isochrones and consists of low-mass stars

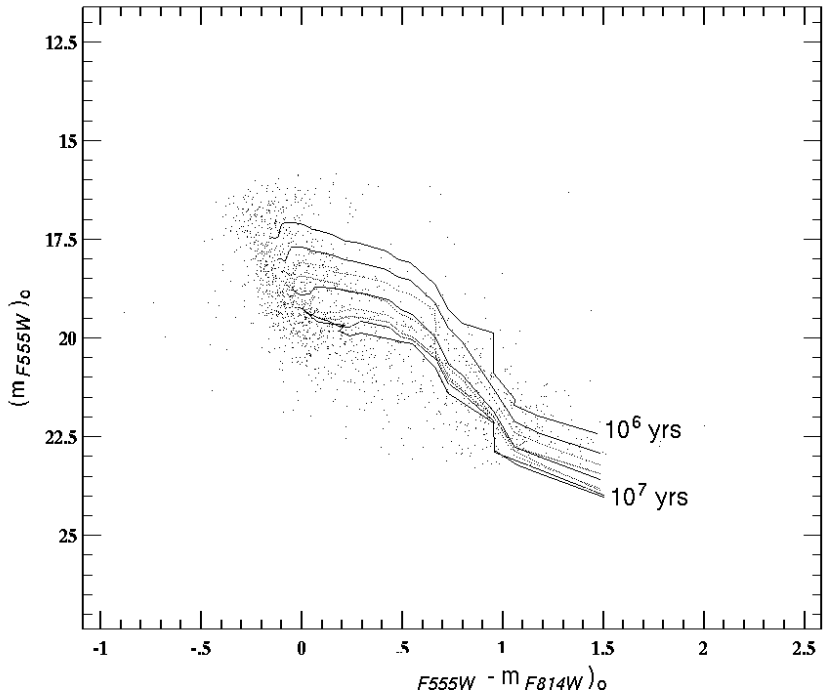

Figure 3. Pre-main-sequence isochrones for ages in the range 10^6–10^7 yr (Bernasconi 1996), superposed on the dereddened CMD.

(down to $0.8M_\odot$) still approaching the main sequence. Their age, 1–10 Myr, is in good agreement with previous R136 age determinations by Hunter et al. (1995) [4 Myr] and De Marchi et al. (1993) [3 Myr].

We then placed the stars into a HR diagram, by adopting a distance modulus of 18.6 to translate apparent into absolute luminosity. Figure 4 shows the theoretical HR diagram with the PMS evolutionary tracks for the mass range 0.8–$7M_\odot$.

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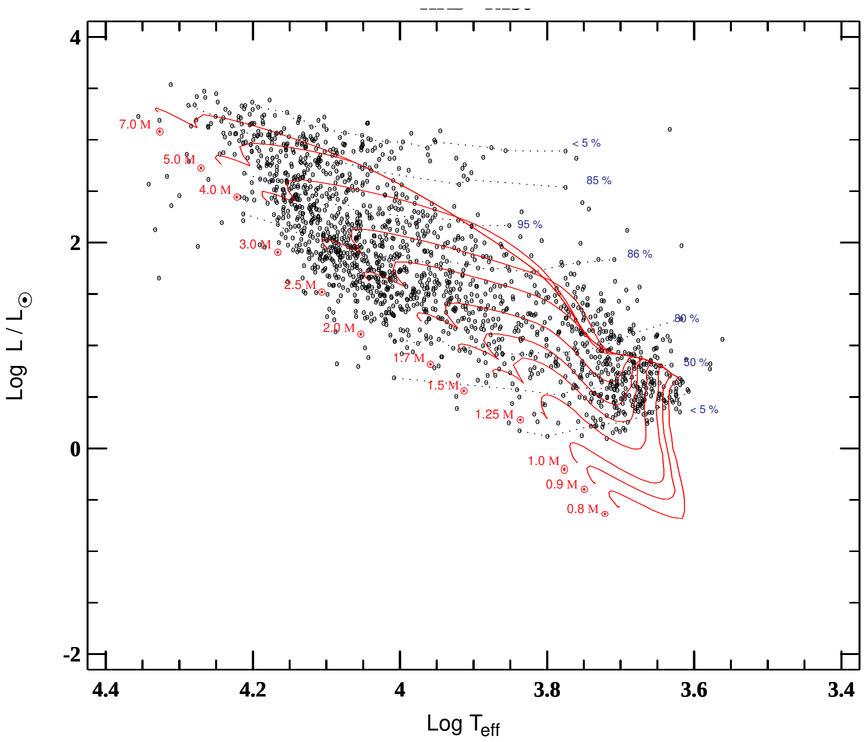

Figure 4. HR diagram, with theoretical pre-main-sequence evolutionary tracks from Bernasconi (1996) superposed for masses in the range 0.8–7$M_\odot$. Dashed lines mark different completeness regions.

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