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THE STELLAR POPULATION OF A NEARBY STARBURST: R136 IN 30 DOR

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RESUMEN

Se reportan observaciones con resolución de 0."15 en el cercano IR del cúmulo "starburst" R136. Obtuvimo imágenes de 12."8 × 12."8 usando el sistema de óptica adaptativa del MPE en el telescopio de 3.6-m del ESO La alta sensibilidad (mag 20 en K) y la alta resolución espacial alcanzada, sólo limitada por la difracción, no ha permitido comparar y combinar las imagenes en H y K con observaciones recientes de R136 hechas co la WFPC2 del *HST*. Haciendo ajustes de modelos teóricos a los datos obtenemos la población estelar, eda y dinámica de esta región de formación estelar. La variación radial de la función de masa y la dependenci del radio del núcleo con el rango de masa considerado, indican que existe una segregación de masas debid probablemente a la evolución dinámica del cúmulo.

ABSTRACT

We report 0."15 resolution near infrared imaging of the starburst cluster R136. Our 12."8 × 12."8 image were recorded with the MPE camera SHARP II at the 3.6-m ESO telescope, using the adaptive optics systen COME ON +. The diffraction-limited spatial resolution and high sensitivity (20th magnitude in K) of ou observations allow our H and K band images to be compared and combined with recent *HST* WFPC2 data o R136. Fitting theoretical models to the observed magnitudes we derive the stellar population, age and dynamic of this starburst region. The radial variation of the mass function and the dependence of the derived core radiu on the observed stellar mass range reveal strong mass segregation that is probably due to the cluster's dynamica evolution.

Key words: **GALAXIES: MAGELLANIC CLOUDS — STARS: EARLY TYPE — STARS: FORMATION**

1. INTRODUCTION

The 30 Doradus region in the LMC is the largest and most massive H II region in the Local Group. Withi a diameter of 15′ (200 pc) it contains several thousand OB stars and more than $8 \times 10^5 M_\odot$ of ionized ga (Kennicutt 1984). The bolometric luminosity of the inner 4.5 pc core of the cluster is $\sim 8 \times 10^7 L_\odot$ (Malumutl & Heap 1994) and hence much larger than in galactic H II regions. The center of the stellar association, R13 (HD 38268), is an unusually high concentration of massive and bright O, B, and Wolf-Rayet stars. R136 an its surroundings thus represent the closest example of an intense starburst region. We investigated this regio through high angular resolution NIR adaptive optics imaging observations (Brandl et al. 1996).

2. OBSERVATIONS

The ESO adaptive optics system COME ON + at the ESO 3.6-m telescope at La Silla, Chile, was use together with the MPE NIR camera SHARP II . This joint system has produced many interesting observation during its first years in operation (Léna 1994). COME ON + was the first adaptive optics system open to th astronomical community. The SHARP II near infrared camera is equipped with a 256 × 256 pixel Rockwel NICMOS III array detector and is optimized for high resolution imaging between 1.10 – 2.50 μm (J, H, an K).

We selected a field south-east of R136 with R136a near one array corner in order to cover a wide cluste radius and have Melnick 34, a relatively isolated, bright Wolf-Rayet (WR) star, in the field as a PSF reference It turned out that due to their high spatial concentration, the bright central stars forming R136a provide enoug light to close the wavefront correction loop on the object itself.

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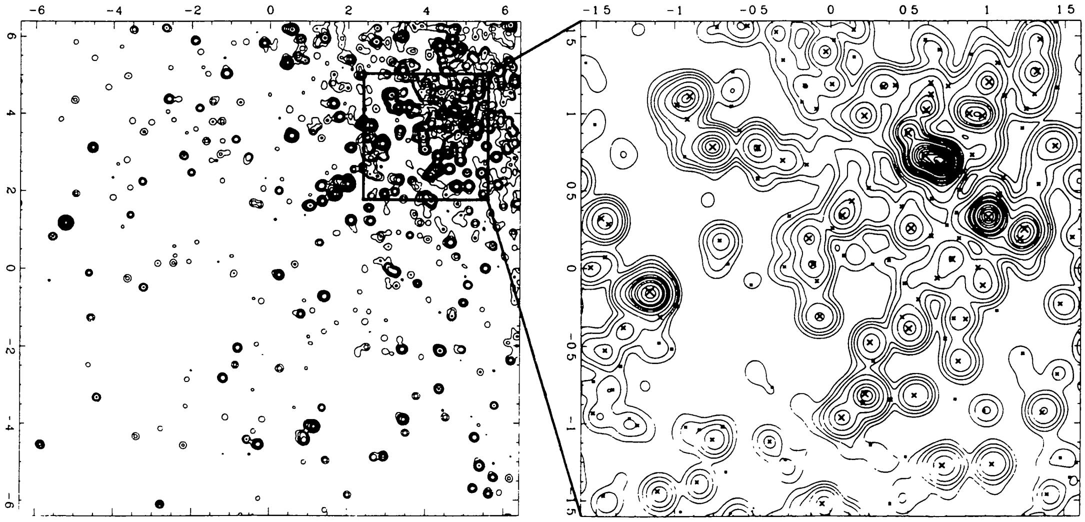

Fig. 1. Contour plot of our 12.″8 × 12.″8 field of view in H-band. The contour levels are at .1, .25, .5, 1, 2.5, 5, 10, 25, 50, 75, and 100% of the maximum intensity, which corresponds to 11.2^m in H-band. North is up and east is to the left. The spatial resolution is 0.″12. The inset enlarges the central 3.″2 × 3.″2. Crosses indicate the positions of the sources detected by the *HST*; their size is according to the measured V magnitudes.

The present analysis is based on total integration time of 190 minutes in K and 40 minutes in H, with an integration time per frame of 20 and 30 seconds, respectively. The faintest sources detected are 20th magnitude in K; the dynamical range in the image is 9 magnitudes. The data show no significant spatial variation of the PSF within the field of view. The long term optical seeing was below 1″.

We applied the Lucy-Richardson deconvolution algorithm (Lucy 1974) to "CLEAN" the image. Figure 1 shows a contour plot of the resulting H band image. For the first time at NIR wavelengths the crowded core of R136a is resolved into its individual components. The objects in our maps show excellent agreement with source positions in recent WFPC2 images (Brandl et al. 1995a,b).

3. COMBINING PHOTOMETRY AND STELLAR MODELS

We derived the stellar properties in R136 by fitting the measured stellar luminosities to theoretical models for each star. For this, model star luminosities were derived by combining recent stellar evolution calculations (Schaerer et al. 1993; Meynet et al. 1994) with the Kurucz (1992) Atlas 9.3 model atmosphere grid. In order to cover the widest possible wavelength range, we combined the flux information in our high spatial resolution H and K-band maps with recent WFPC2 observations in the U, V, and I (F336W, F555W, F814W) filter bands (Hunter et al. 1995). The photometric fluxes in H and K were determined with the program PLUCY (Hook et al. 1994). The combined *HST* and SHARP II data provide good photometric information on more than 1000 stars. A comparison of the observed band magnitudes with the models enables us to derive the initial mass, age, and foreground extinction for each individual star.

4. RESULTS

1. Extinction: Most stars in our field of view show extinction in excess of the $A_V = 0.71$ mag expected from our Galaxy and the LMC in the direction towards 30 Dor. Apparently the stars in the core of the cluster show almost no excess extinction, in contrast to stars that surround the core, which show correlated, enhanced extinction. The lack of excess extinction in the central core may be due to a clearing of gas by strong stellar winds or supernovae.

2. Stellar Population: We used SHARP II's circular variable filter to identify and sub-classify Wolf-Rayet WN-type stars spectroscopically from their He II (2.189 μm) and Brγ (2.166 μm) line emission.

We did not detect red supergiants in our field, but found about one hundred faint red sources that could only be matched to model spectra with very high excess extinction. Their magnitudes decrease steadily towards longer wavelengths, and they are too bright to be late-type main sequence stars. These red sources are most likely low or intermediate mass pre-main-sequence stars with significant infrared excess emission from their surrounding dust cocoons or protoplanetary disks.

The extinction-corrected stellar ages and ZAMS masses of about 500 well modeled main-sequence O, B and A stars permit a detailed analysis of the radial mass function of the cluster.

3. Cluster age: We can constrain the cluster age from the presence of WR stars, which indicates that star formation must have commenced at least 3 Myr ago. An upper age limit of less than 7 Myrs derives from the lack of red supergiants. A different constraint on the age of the burst is the observed number ratio of WR to O stars: $WR/O = 7/187 = 0.037 \pm 0.015$. Following calculations by Parker et al. (1995), this value agrees with a cluster age of 3.7 ± 0.5 Myr and a short burst duration.

4. Mass function Previous investigators have examined the IMF slope in R136 with apparently conflicting results, e.g., Malumuth & Heap (1994) calculated $\Gamma = -0.90 \pm 0.38$ inside the central $3.''3 \times 3.''3$, while $\Gamma = -1.82 \pm 0.41$ outside. Hunter et al. (1995) found no significant variation of $\Gamma = -1.2 \pm 0.1$ between 0.5 pc and 4.7 pc.

For our entire field of view, we find $\Gamma = -1.59 \pm 0.10$. However, for $r \leq 0.4$ pc we find $\Gamma = -1.33 \pm 0.16$ and for $0.4 < r \leq 0.8$ pc, $\Gamma = -1.63 \pm 0.18$. For $r > 0.8$ pc, we find that a single power law does not fit the distribution well, so we derived separate slopes for the higher ($m > 12\,M_\odot$) and intermediate ($m < 25\,M_\odot$) mass ranges. In the upper mass range, $\Gamma = -2.16 \pm 0.29$, indicating a strong deficiency of high mass stars, while at lower masses, $\Gamma = -1.52 \pm 0.09$, which is similar to the $\Gamma = -1.5$ measured by Parker (1992) for the entire 30 Doradus region.

5. Core radius: Fitting the projected cluster profile by a King (1962) distribution, Hunter et al. (1995) found an upper limit of the core radius $r_c \leq 0.''08$ (0.02 pc), whereas Malumuth & Heap (1994) calculated $r_c \approx 0.''96$ (0.24 pc). Several observers derived core radii within this interval. From the mass density distribution of all stars with $m > 4\,M_\odot$ we find $r_c = 0.''97 \pm 0.''07$ (0.24pc). At even higher cutoff values, we find r_c decreasing down to $0.''2$. Obviously, massive stars dominate at the center, their "core" is smaller than that of the light distribution.

6. Cluster dynamics: Following Lightman & Shapiro (1978), the half–mass relaxation time of our cluster is given by $t_{rh} = 5 \times 10^8\,\mathrm{yr}(N/5 \times 10^4)^{1/2}(\bar{m}/M_\odot)^{-1/2}(r_h/5\mathrm{pc})^{3/2} = 7.8 \times 10^7$ yr, where $N = m_{tot}/\bar{m} \approx 6 \times 10^4$ is the total number of stars in the cluster, $\bar{m} = m_{tot}/N = 0.5\,M_\odot$ is the mean stellar mass, and $r_h \approx 1.1$ pc is the half-mass radius. However, the relaxation times for the low-mass and the massive stars can differ substantially; following Spitzer (1987) we calculate that the WR and O star population will evolve about 80 times faster than the cluster as a whole, in about 10^6 yr, which is several times smaller than the estimated cluster age. Dynamical relaxation processes therefore certainly play an important role in producing the radial variations of the present day mass function. However, because the estimated half–mass relaxation time is close to the cluster age, we cannot rule out a position dependent initial mass function, but neither would there be a need to invoke one.

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