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GTC LONG-SLIT SPECTROSCOPY OF COMPACT STELLAR CLUSTERS IN M81

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RESUMEN

En este trabajo presentamos edades de 4 cúmulos estelares compactos de la galaxia cercana M81. Las edades fueron determinadas usando los espectros de rendija larga obtenidos con el Gran Telescopio Canarias (GTC). Obtuvimos edades entre 5–6 Myr para los 4 cúmulos, incluyendo para el cúmulo más brillante de M81. Uno de los cúmulos muestra características espectrales de las estrellas Wolf-Rayet. Las edades obtenidas sugieren masas entre 3000–18000 $M_{\odot}$. Los objetos observados fueron los más brillantes, y por lo tanto los más masivos, de toda la galaxia. Esto implica la ausencia de cúmulos compactos masivos (10^5 $M_{\odot}$) en M81.

ABSTRACT

We here present the ages of four compact stellar clusters (CSCs) in the nearby spiral galaxy M81, using long-slit optical spectra obtained with the 10.4 m Gran Telescopio Canarias (GTC). All the four CSCs, including the brightest in this galaxy, are found to have ages between 5–6 Myr, with one of them showing Wolf-Rayet spectral features. The photometric masses of these clusters, calculated using their spectroscopically-derived ages, lie between 3000–18000 $M_{\odot}$. The observed clusters are among the brightest objects, and hence the most massive, in the entire disk of M81. This implies the absence of massive (10^5 $M_{\odot}$) compact stellar clusters in M81.

Key Words: galaxies: individual (M81) — galaxies: star clusters

1. INTRODUCTION AND OBSERVATIONS

The similarity in the ranges of sizes and masses of the compact star clusters (CSC) and the globular clusters (GCs) has given rise to the notion of an evolutionary connection between them (de Grijs & Parmentier 2007). The vast difference in the ages of the two populations, and the absence of any prototypical cluster of age intermediate between these two extreme cases, has prevented progress in exploring further this idea. Crucial for understanding the evolutionary connection between these two populations is the identification of compact clusters of intermediate ages ($\sim10^8$ yr). Spectroscopic observations are vital to ascertain ages in these age ranges.

The nearby galaxy M81 offers a great opportunity to address the evolutionary connection, as this galaxy contains both the CSCs and GCs in large numbers (Chandar et al. 2001; Santiago-Cortes et al. 2010). Santiago-Cortes et al. (2010), using 29 HST/ACS fields cataloged 263 CSCs brighter than $B = 22$ mag, and 172 GCs. The photometric masses of the CSCs were found to be less than 2×10^4 $M_{\odot}$, assuming that the brightest clusters are younger than 10 Myr. According to a recent study by Bastian (2008), the highest cluster mass in a galaxy depends on its star formation rate (SFR). The expected highest mass of the cluster for the observed SFR of 1 $M_{\odot}$ yr^{-1} in M81 is around a factor of 5 greater than that inferred. On the other hand, if the brightest clusters are older than 100 Myr, observationally inferred maximum cluster mass would follow the relation suggested by Bastian (2008). We hence carried out spectroscopic observations of the brightest clusters with the goal of determining their ages, and therein, determine their masses.

2. OBSERVATIONS AND DATA REDUCTIONS

Spectroscopic observations were carried out using the long-slit of the spectrograph of the OSIRIS instrument at the 10.4 m GTC[2] in the service mode on 2010 April 4 and 5. Six slit positions were used to obtain spectra of 13 clusters brighter than $B = 21$ mag (11 CSCs, including the brightest CSC, and 2 GCs), and a few fainter CSCs. Spectra cover a range of 3630 to 7500 Å, at a spectral resolution of $\sim$7 Å. A slit-width of 1.0 arcsec was used. The estimated seeing during these observations is $\sim$1 arcsec.

The data reduction was carried out in the standard manner using the tasks available in the IRAF

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[2] Gran Telescopio Canarias is a Spanish initiative with the participation of Mexico and the US University of Florida, and is installed at the Roque de los Muchachos in the island of La Palma. This work is based on the proposal GTC11−10AMEX_0001.

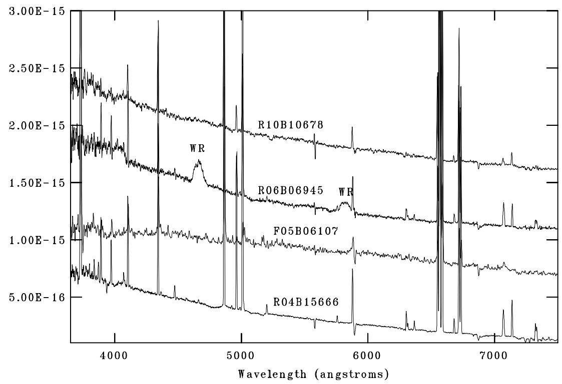

Fig. 1. Extracted spectra of 4 compact stellar clusters. The fluxes are in units of erg cm^{-2} s^{-1} Å^{-1}. The fluxes of the top 3 spectra are displaced upwards for the sake of clarity.

software package. The spectra were extracted so as to include all the observed Hα emission associated to the cluster in the spatial direction. Extracted spectra of four of the clusters are shown in Figure 1.

3. RESULTS

All the targeted CSCs are found to be associated with nebular emission. In this work, we show the results for the brightest CSC, R04B15666, and three other CSCs, all brighter than $B = 20$ mag. The Hβ emission equivalent widths (EW) measured on the extracted spectra are plotted against their $F435W - F814W$ ($B - I$ for short) color in Figure 2. It can be seen that all the clusters are consistent with ages between 5 and 6 Myr, with extinction $Av < 1.5$ mag.

Considering that the 1 arcsec slit-width (18 pc) encloses a region larger than the cluster size < 8 pc (see the contribution of Santiago-Cortés et al. 2011), the presence of emission lines at the position of the cluster does not necessarily imply that the cluster stars are responsible for the ionization. Massive stars in the field and associations around the cluster could as well be responsible for the ionization. The foolproof way of establishing that the clusters are young objects is by identifying age-sensitive spectral features originating in the atmospheres of cluster stars. All the four spectra show rising continuum in the blue, without any signs of absorption features typical of intermediate-age or old stellar populations, as can be seen in Figure 1. One of the studied clusters, R06B06945, clearly shows broad emission lines, which are denoted by the letters WR in the figure. We identify these as CIII λ4650 and CIV λ5806 features, characteristic of Wolf-Rayet stars of type WC. The age of this cluster as inferred from EW is consistent with the presence of WR features. Thus, our

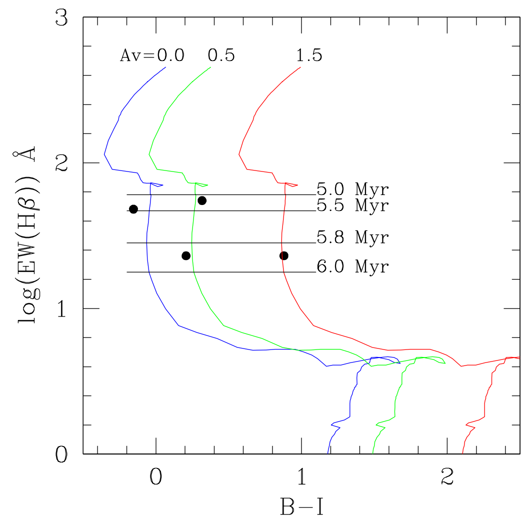

Fig. 2. Age and reddening of M81 clusters. Evolutionary track for an instantaneous burst model using STARBURST99 (Leitherer et al. 1999) is shown, rededdened by $Av = 0, 0.5$ and 1.5 magnitudes. The horizontal lines denote the EW at 4 epochs between 5 and 6 Myr.

spectra confirm the young age of the brightest CSCs. We obtain masses between 3000–18000 $M_\odot$ for the 4 CSCs, all below the upper mass limit of 2×10^4 $M_\odot$ derived by Santiago-Cortés et al. (2010).

4. CONCLUSIONS

We have carried out spectroscopic observations of 11 CSCs and 2 GCs using the 10.4 m GTC, and present here the results for 4 CSCs, including that for the brightest CSC. The Hβ emission equivalent width, optical colors from HST, and the absence of stellar absorption lines in the blue, together suggest ages less than 6 Myr for the clusters. In one of these CSCs, we detected WR features characteristic of WC stars. The determined young age of these bright objects, which lie in the upper part of the cluster color-magnitude diagram, ensures that there are no CSCs in M81 with masses exceeding 2×10^4 $M_\odot$. Thus, its seems that though compact clusters are formed in large numbers in star-forming galaxies such as M81, conditions in these giant galaxies don't favor the formation of massive clusters.

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