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GTC LONG-SLIT SPECTROSCOPY OF COMPACT STELLAR CLUSTERS IN M81

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RESUMEN

Presentamos espectroscopía de rendija larga obtenida con el Gran Telescopio Canarias (GTC), de cúmulos estelares compactos en la galaxia M81. La muestra espectroscópica incluye tanto cúmulos globulares antiguos como cúmulos jóvenes compactos de estrellas, que en algunos casos muestran la presencia de estrellas Wolf-Rayet. Los espectros se usan para determinar las masas y edades de los cúmulos. Asímismo obtenemos las condiciones físicas del gas ionizado que rodea a estos cúmulos jóvenes.

ABSTRACT

We present results obtained by analysing long-slit optical spectra, recently obtained using the 10-m Gran Telescopio Canarias (GTC), of compact stellar clusters in the nearby spiral galaxy M81. The spectroscopic sample includes both the old globular clusters, as well as relatively younger compact clusters, that in some cases show clear signature of the presence of WR stars. These spectra are used to determine the age and mass of the clusters. We also obtain the physical conditions of the ionized gas surrounding the young clusters.

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

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 an apparent lack of well-studied clusters of ages 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 ($\sim 10^8$ yr). Spectroscopic observations are vital to ascertain ages in these age ranges.

Compact clusters form in violent episodes of star formation, usually trigerred by interactions between galaxies. The most massive of these objects are capable of surviving over the lifetime of galaxies. This makes them useful as tracers of past major star formation events in galaxies. The nearby galaxy M81 was involved in a collision with M82 and NGC 3077 in the recent past (Yun et al. 1993). This interaction was responsible for a population of massive stellar clusters of <300 Myr age in M82 (Konstantopoulos et al. 2008; Mayya et al. 2008). It is still unclear whether this event also produced a population of clusters in M81. A search for compact clusters in M81 by Santiago-Cortés et al. (2010) has resulted in more than 200 CSCs and 172 GCs. The purpose of our observational project for GTC is to carry out spectroscopic observations of these CSCs, in order to identify the population of intermediate age clusters that may have formed following the last major interaction in the M81 group. The project was designed for the Multi-Object Spectrograph of the OSIRIS. Due to the unavailabilty of this instrument, we opted to use the alloted observing time (Observing ID: GTC11-10AMEX; PI: Rosa-González) to carry out long-slit spectroscopic observations of the brightest CSCs and the surrounding nebolosity. Preliminary results of the analysis of the ages of the clusters are reported in Mayya et al. (2011). In the present contribution, we summarize the results on the ages of the brightest CSCs and also discuss the physical condition of the gas surrounding the CSCs containing Wolf-Rayet stars.

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 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.

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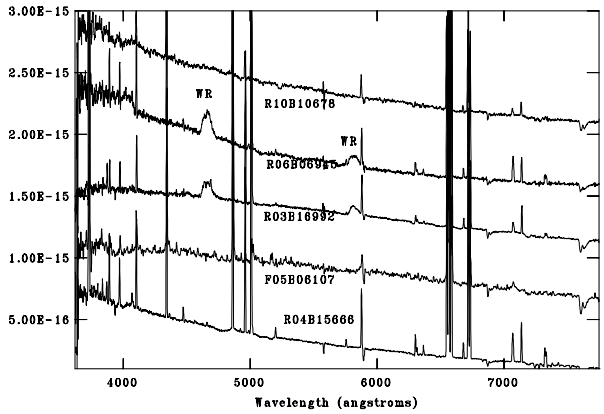

Fig. 1. Extracted spectra of 5 compact stellar clusters. The fluxes are in units of erg cm^{-2} s^{-1} Å^{-1}. The fluxes of the top 4 spectra are displaced upwards for the sake of clarity.

The data reduction was carried out in the standard manner using the tasks available in the IRAF 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 five of the clusters are shown in Figure 1.

3. SPECTROSCOPIC AGES OF OBSERVED CSCS

All the analyzed spectra show rising continuum in the blue, without any sign of absorption features typical of intermediate-age or old stellar populations. Two of the clusters (R06B06945 and R03B16992) show broad emission bumps, characteristic of Wolf-Rayet stars. The bluer of the two bumps is dominated by CIII λ4650 feature, while the CIV λ5806 feature dominates the redder bump. The presence of these bumps puts the ages between 4–6 Myr (Leitherer et al. 1999). Spectra also show emission lines from the nebula surrounding the clusters. An analysis of the Hβ emission equivalent widths, gives ages consistent with young ages of the clusters (Mayya et al. 2011). With these ages, we obtain photometric masses between 3000–18000 $M_\odot$ for the observed CSCs.

4. PHYSICAL CONDITION OF THE GAS SURROUNDING SSCS

We analyzed the nebular spectrum to determine the physical conditions of the ionized gas surrounding the observed CSCs. In 3 spectra we have detected the temperature sensitive lines of [OIII] or [NII] iones, which has allowed us to determine the metallic abundances of oxygen and nitrogen using the direct method (Osterbrock & Ferland 2006). The derived values for these regions are very similar with $12 + \log(\mathrm{O/H}) = 8.0 \pm 0.1$ and $\log(\mathrm{N/O}) = -0.75 \pm 0.03$. We derived the electronic densities using the [SII] doublet lines, resulting in values <90 cm^{-3}.

5. PROSPECTS WITH OSIRIS/MOS

All the clusters observed so far have $B < 21$ mag, which occupy the bright-end of the luminosity function. There are more than 200 CSCs brighter than $B = 22$ mag. Determination of ages of ∼100 clusters would allow us to establish firmly the presence or absence of intermediate-age clusters that might have formed as a result of interaction event in the M81 group. Needless to mention that this project requires the MOS capability of the OSIRIS.

6. CONCLUSIONS

We have carried out long-slit spectroscopic observations of 11 CSCs and 2 GCs using the 10.4-m GTC, and present here the results for 5 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 two of these CSCs, we detected WR features characteristic of WC stars. The determined young age of these bright objects, implies photometric masses $<2 \times 10^4$ $M_\odot$. Thus M81 lacks young massive CSCs, such as the type found in large numbers in its neighbor M82.

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