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AN ACCURATE DISTANCE SCALE TO THE EXTREMELY MASSIVE CLUSTER STEPHENSON 2

C. González-Fernández,[1] I. Negueruela,[1] A. Marco,[1] and J. S. Clark[2]

RESUMEN

Sucesivos descubrimientos en los últimos años han establecido la existencia de una gran región de formación estelar en la base del brazo de Escudo-Cruz, en la que se han encontrado al menos cinco cúmulos de supergigantes rojas. Para entender la naturaleza de esta región necesitamos estimaciones precisas de la distancia a estos cúmulos. En este trabajo presentamos los primeros resultados de un estudio destinado a establecer los parámetros fundamentales (edad, distancia, etc.) del cúmulo masivo Stephenson 2 utilizando para ello las estrellas de su secuencia principal.

ABSTRACT

Discoveries during the last two years have revealed the existence of a vast region of star formation close to the base of the Scutum Arm, where at least five clusters of red supergiants have been found. In order to understand the nature of this region, we need to determine accurate distances to the clusters. We present here the first results of an ongoing program to derive fundamental parameters (such as age, distance, etc.) to the massive cluster Stephenson 2 studying for the first time its main sequence stars.

Key Words: Galaxy: open clusters and associations: individual — Galaxy: stellar content — supergiants

1. INTRODUCTION

Several clusters of red supergiants (RSGs) have been found at the base of the Scutum Arm. They are known as Red Supergiant Clusters (RSGCs), because only these stars have been seen through heavy obscuration. Their populations can be estimated using population synthesis models calibrated against the number of RSGs (Clark et al. 2009b), though these estimates are subject to large uncertainties. According to these models, the most massive of these clusters is Stephenson 2 (RSGC2). Davies et al. (2007) found 25 RSGs within 7′ of the cluster centre. For an estimated age in the 14–20 Myr range, population synthesis models suggest a mass $M_{\rm cl} \geq 4 \times 10^4\ M_\odot$ and perhaps up to $8 \times 10^4\ M_\odot$. Four other RSGC clusters have been found so far. All have similar ages, except RSGC1 (∼12 Myr), which may have $M_{\rm cl} \geq 3\times10^4\ M_\odot$ (Davies et al. 2008). RSGC3 is about half the size of Stephenson 2 (∼15 RSGs, ∼16–20 Myr; Clark et al. 2009a), but is surrounded by an extended association, which contains other RSGCs, Alicante 7 and Alicante 10, (Negueruela et al. 2011; González-Fernández & Negueruela 2012) and may have up to $10^5\ M_\odot$ in total. The final RSGC, Alicante 8, is smaller (∼16–20 Myr, $M_{\rm cl} \geq 10^4\ M_\odot$; Negueruela et al. 2010a).

We have identified several hundred objects within 50′ of Stephenson 2 whose infrared colours suggest they are luminous red stars. We have observed ∼100 candidates with WYFFOS and more than 20 are likely to be RSGs with radial velocities similar to the cluster. If this is confirmed by the higher-resolution spectroscopy we have recently acquired with AAT/AAΩ, this association will turn out to be the most massive by far star formation region in the Galaxy, and most likely in the Local Group. Why is there such a concentration of massive clusters in this region? Two main ideas have been considered: either the Scutum Complex is a localised starburst at the point where the tip of the Galactic Long Bar interacts with the Scutum Arm (López-Corredoira et al. 1999; Davies et al. 2008) or a projection along our line of sight of a huge star formation ring, located at the distance where the Long Bar ends (Negueruela et al. 2010a).

At present, we cannot decide between these two options because the distances to the clusters are rough estimates. RSGs show a very significant intrinsic spread of luminosities at a given spectral type (more than an order of magnitude, as progenitor masses may range from 10–40 $M_\odot$). Since there are no absolute luminosity diagnostics for RSGs in the near IR (where the clusters have been so far stud-

[1]Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal, Universidad de Alicante, Apdo. 99, E03080 Alicante, Spain (carlos.gonzalez@ua.es).

[2]Department of Physics and Astronomy, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK.

ied), and no unevolved members have been seen, spectroscopic distances to RSGC1-5 have not been derived. Consequently kinematic distances derived from a Galactic rotation curve have had to be utilized. The position of these clusters close to the tangent point of the galactic arm results in very significant uncertainties in their dynamical distances ($5.8^{+1.9}_{-0.8}$ kpc for Stephenson 2), which consequently feed through to other cluster parameters. And this before taking into account that the presence of the Bar potential may induce non-circularity in the orbits, substantially increasing the uncertainty.

2. SELECTING THE MAIN SEQUENCE OF STEPHENSON 2

As has been shown by Negueruela et al. (2011), the pseudo-colour $Q = (J - H) - 1.8 \times (H - K_{\mathrm{S}})$ can be used effectively to separate populations using only infrared photometry. Early type stars are expected to have roughly $-0.16 \leq Q \leq 0.08$. As the RSGs have $m_{\mathrm{K}} \sim 5$, the tip of the main sequence is expected to be around $m_{\mathrm{K}} \sim 11$. Combining photometry from 2MASS and UKIDSS we can select a set of stars fulfilling these criteria around the center of Stephenson 2. As the obscuration around this cluster is $A_K = 1.44$, in the i band these stars have $16 < m_{\mathrm{i}} < 17.5$. Therefore, I band spectra of high quality can be obtained using GTC and OSIRIS.

Low resolution spectra in this band can be used to perform accurate spectral classification (Negueruela et al. 2010b), and as the luminosity function of the main sequence is much better constrained than in the case of the RSGs, with a significant sample of main sequence stars a spectroscopic distance can be derived for Stephenson 2. Also, identifying the tip of the main sequence would help to constrain the age of the cluster, refining our estimation of other parameters such as the total mass.

3. OBSERVATIONS

Using OSIRIS with its R2500I grism and a slit of 0.6 arcsec a resolution of ∼2500 around 8500 Å is obtained. For a target with $m_{\mathrm{i}} = 17.0$ this requires an exposure of 2000 s to obtain S/N=100.

As the target density is high, slit angles are selected in such a way that every pointing includes two objects (plus an indeterminate number of serendipitous detections), allowing for the small offset that the ABBA scheme, needed to remove fringing effects, requires. In one night of observation, six observing blocks (OB) where obtained.

4. FIRST RESULTS FROM THE PROGRAM

From these OBs, 34 spectra where recovered: 11 targets and 23 background/foreground detections. Of the 11 targets, 8 turned out to be compatible with being members of the cluster blue sequence, with types from B1 to B5. Three other stars appear to be foreground blue population.

Of 23 serendipitous objects, 5 have spectra compatible with being early M supergiants, the population dominant in Stephenson 2 according to Davies et al. (2007). The fact that from a sample of 23 random stars, 1/4 turn out to be supergiants cements the existence of a diffuse population of RSGs around the cluster that could change significantly its estimated initial mass.

Although our sample of main sequence stars is not ample enough to derive precise parameters, a first estimation can be already performed:

- Although our very limited sample does not allow us to obtain a reliable figure of merit, it suggests that the cluster is slightly farther away than previously thought.

- The composition of the blue sequence of the cluster tips the age estimation towards older values, around 20 Myr.

- The extinction over the field seems to be rather uniform, with a mean $E(J - K_{\mathrm{S}}) = 1.68 \pm 0.13$.

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