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CCD PHOTOMETRY OF M92

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RESUMEN

Se presenta fotometría en los filtros B y V de Johnson para el cúmulo globular galáctico M92. Se obtuvieron resultados fotométricos para un total de $\sim$ 30000 estrellas las cuales se grafican en un diagrama V vs $(B-V)$. Se ajustaron isócronas teóricas a este diagrama para obtener una estimación de la edad de M92. La edad que encontramos es $\sim 16 \times 10^9$ años con [Fe/H]=-2.03, $Y = 0.235$. El módulo de distancia al cúmulo resulta ser de $m - M = 14.6$ de acuerdo con el encontrado por Stetson & Harris (1988).

ABSTRACT

We present Johnson B and V photometry for the galactic globular cluster M92. Photometric results for a total of $\sim$ 30000 stars are obtained and are plotted on a V vs $(B-V)$ diagram. We fit theoretical isochrones to this diagram in order to get an estimate for the age of M92. The age which we find is $\sim 16 \times 10^9$ years with the following values for the metallicity and He-abundance: [Fe/H]=-2.03, $Y = 0.235$. The distance modulus to this cluster turns out to be $m - M = 14.6$, in accordance with that obtained by Stetson & Harris (1988).

Key Words: Galaxy: halo — globular clusters: general — globular clusters: individual (M92) — stars: evolution — techniques: photometric

1. INTRODUCTION

In this paper we present a detailed study of the globular cluster M92. This cluster is probably one of the oldest and most metal-poor globulars known so far, it, therefore, provides us with the opportunity of studying very old and very metal-poor stars. In Stetson & Harris (1988) it is shown that M92 is older and closer to us than M15 which is considered to be the most similar globular cluster to M92 in our Galaxy. Because of its galactic position at $l = 68.4$ and $b = +34.9$, its light suffers little reddening; this, combined with its low metallicity turns out into an almost perfect fit of the theoretical models for old metal-poor stars to the observations (see Bolte & Hogan 1995).

There have been several other photometric studies of M92. In particular, Johnson & Bolte (1998) give V and I photometry for this cluster. Grundahl et al. (2000) present Strömgren CCD photometry for M92 which they use in order to obtain a distance-independent determination of the age of M92 (≥ 16 Gyr). Andreuzzi et al. (2000) use HST (Hubble Space Telescope) observations down to $V \sim 27$ to obtain a luminosity function for this cluster. They find that the luminosity function becomes flatter going towards the centre of the cluster, as it would be expected if M92 is a dynamically relaxed system. In Stetson (2005) are identified 3115 M92 stars with values for B and V.

Lee et al. (2001) present HST IR (Infrared) observations of M92. They show that the metal-poor inner halo cluster NGC 6287 appears to have essentially the same age (± 2 Gyr) as M92, which is one of the oldest clusters in our Galaxy.

Lee et al. (2003) present wide-field CCD photometry of M92 in the V and I bands. They find a change in the slope of the mass function between the inner ($5' \leq r \leq 9'$) and outer ($9' \leq r \leq 15'$) regions of the cluster, clearly indicating a mass segregation in the cluster. There is some evidence for a tidal tail of M92 oriented perpendicularly to the direction to the Galactic centre.

2. THE OBSERVATIONS

We have obtained photometric CCD observations of the globular cluster M92 in the B and V Johnson filters at the National Astronomical Observatory (OAN) at San Pedro Mártir, Baja California.

For each position, we took one 10-s exposure, three 60-s exposures and one 300-s exposure for each filter, in order to attempt to see the centre of the cluster more clearly and also to get most of the stars towards the outer edge of the cluster.

The reductions were carried out by means of IRAF and DAOPHOT II in a standard manner.

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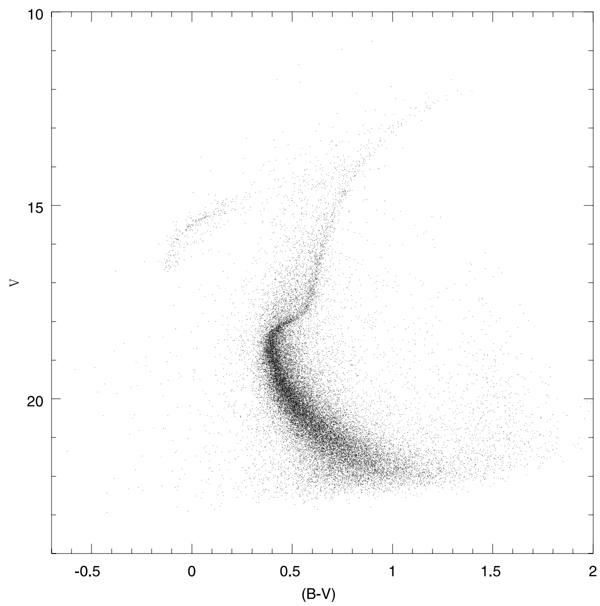

Fig. 1. Raw Colour-Magnitude diagram for M92.

3. THE HR DIAGRAM

From our reduced data we construct a colour-magnitude diagram for M92. This diagram has the advantage of allowing a relatively easy direct comparison between the observations and the theory. We know that the colour-magnitude diagram for a globular cluster reveals the evolution that all the stars in the cluster have undergone since their birth, and this may be fitted to different theoretical models (see Hanes & Madore 1980).

In Figure 1 we present the V vs $(B-V)$ diagram for more than 30000 stars. This is a raw diagram because it contains cluster stars as well as foreground and background objects. It is interesting to point out that, in spite of the presence of alien objects, this diagram presents clearly all the features expected for a globular cluster: i.e. main sequence (MS), horizontal branch (HB), giant branch (GB), etc.

4. CONCLUSIONS

We carried out successfully the reduction of a mosaic of 49 images in filters B and V which covered the globular cluster M92.

From the results of the reduction of these images, we formed a photometric catalogue containing more than 30000 stars, which we used to construct a colour-magnitude diagram for this cluster.

We calculated fiducial lines for the HR-diagram based on the evolutionary models of Proffitt & VandenBerg (1991) and Bergbusch & VandenBerg (1992). The fitting of the fiducial lines depends importantly on the values of the following parameters: (i) Reddening ($E(B-V)$): The value we used was 0.02 although it could be as large as 0.04 (calculated from reddening models Ruelas-Mayorga 1991). (ii) Distance modulus ($m-M$): We determined the distance modulus from fitting the cluster's MS to a sequence of low-metal abundance solar neighbourhood subdwarfs. We found $m-M = 14.71$; this figure is slightly higher than the most popular value given in the literature (14.6). (iii) The metal abundance of the cluster was calculated by means of the Sarajedini method (Sarajedini & Layden 1997) and the value found is [Fe/H]~ -2.3 which agrees, within the uncertainties, with values in the literature. It turns out that the metal abundance of M92 is one of the lowest for the group of galactic globular clusters. (iv) He-abundance (Y): We used the canonical value of $Y = 0.23$, although calculations with the R' method yield a He-abundance value of $Y(R') = 0.20 \pm 0.03$.

The colour-magnitude diagram turn-off point is best fitted with an isochrone of age equal to 16 ± 2 Gyr, this result is in agreement with that found by Stetson & Harris (1988).

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