RevMexAA (Serie de Conferencias), **46**, 44–46 (2015)

STELLAR MULTIPLICITY OF THE OPEN CLUSTER ASCC 113

C. A. Guerrero[1] and V. G. Orlov[2]

RESUMEN

Presentamos un estudio de alta resolución angular de estrellas binarias y sistemas múltiples en el cúmulo abierto ASCC 113. Combinando nuestras observaciones de interferometría speckle con datos tomados de la literatura, estimamos una proporción de 27:7 (estrellas individuales a binarias) para los miembros más probables, por lo que la fracción de multiplicidad del cúmulo es 20.6% ± 3%. Para las estrellas de campo, estimamos una relación de multiplicidades de 125:27:4:1:0:0:0:1 (entre una y ocho compañeras), equivalente a una fracción de multiplicidad de 20.9% ± 1%. Concluimos que la fracción de multiplicidad del cúmulo y del campo son estadísticamente indistinguibles entre sí; también concluimos que la frecuencia de multiplicidad en este cúmulo abierto es menor a lo que se propone en la literatura, ∼ 20%, lo que está en acuerdo con estudios de alta resolución angular realizados en las Pléyades, las Híades, α Per y Praesepe.

ABSTRACT

We present a high angular resolution survey of binary stars and multiple systems in the galactic open cluster ASCC 113. Combining our speckle-interferometric observations with data taken from the literature, we estimated a ratio of 27:7 (single to binaries) for the the most probable members, so the multiplicity fraction for this cluster is 20.6% ± 3%. For field stars, we estimated a ratio of multiplicities to be 125:27:4:1:0:0:0:1 (between one and eight companions), which is equivalent to a multiplicity fraction of 20.9% ± 1%. We concluded that the multiplicity fraction in the cluster and in the field are statistically indistinguishable from each other; we also concluded that the multiplicity frequency in this open cluster is rather small, ∼ 20%, in agreement with high angular resolution surveys in the Pleiades, Hyades, α Per and Praesepe.

Key Words: binaries — open clusters and associations: individual (ASCC 113) — techniques: interferometric

1. INTRODUCTION

Galactic open clusters are gravitationally-bound systems formed at the same time from the same original cosmic cloud; they are ensembles of stars with low concentration and irregular shape. Open clusters represent examples of stars of comparable age and intrinsic chemical composition and are important in the study of star formation and stellar evolution.

Using classical photometry we can determine general characteristics of open clusters, but there is an observational problem due to the presence of unresolved binaries or multiple systems (Reid 1987): the luminosity of the system increases and the color index becomes redder. These combined effects affect the determination of physical parameters: the cluster's distance, reddening, metallicity and age (Jeffery 2009).

There are just a few observational studies in the literature regarding stellar multiplicity in open clusters; the most studied clusters with respect to multiplicity frequencies are: α Per, Pleiades, Praesepe and Hyades. Because of this and because binary stars have been commonly evoked to explain different cluster phenomena rather than actually being detected in clusters, we need to know the accurate stellar multiplicity fraction in open clusters. Using our own speckle-interferometric measurements and data obtained from the literature, we have initiated an investigation of the stellar multiplicity in open clusters, and we started with the open cluster ASCC 113. Another reason to study binary stars, is because estimating the orbital parameters of a binary system is the only direct method to calculate stellar masses.

2. OPEN CLUSTER ASCC 113

The open cluster ASCC 113 was first identified by Kharchenko et al. (2005) in the All-Sky Compiled Catalogue of 2.5 Million Stars (ASCC-2.5[3], Kharchenko 2001); its equatorial and galactic coordinates, taken from the WEBDA data base[4] (Mer-

[1]Observatório Nacional/MCTI - COAA Rua General José Cristino 77, CEP 20921-400, Rio de Janeiro, RJ Brasil (carlospena@on.br).

[2]Instituto de Astronomía, Universidad Nacional Autónoma de México, México, D. F. 04510, México (orlov@astro.unam.mx).

[3]http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=I/280B

[4]http://www.univie.ac.at/webda/navigation.html

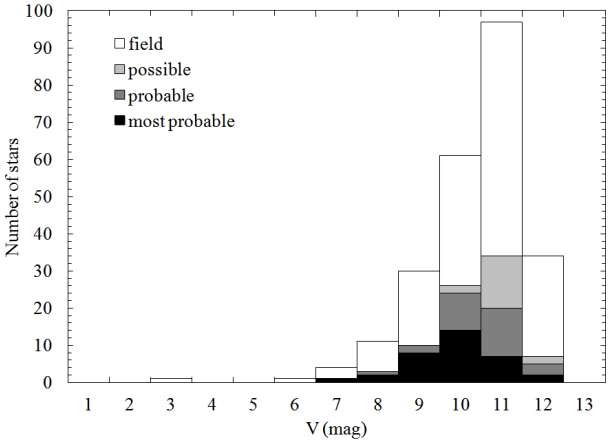

Fig. 1. Distribution of the apparent magnitudes of stars in the open cluster ASCC 113 and in the field around the cluster, separated in 1σ, 2σ, 3σ-members and non-members.

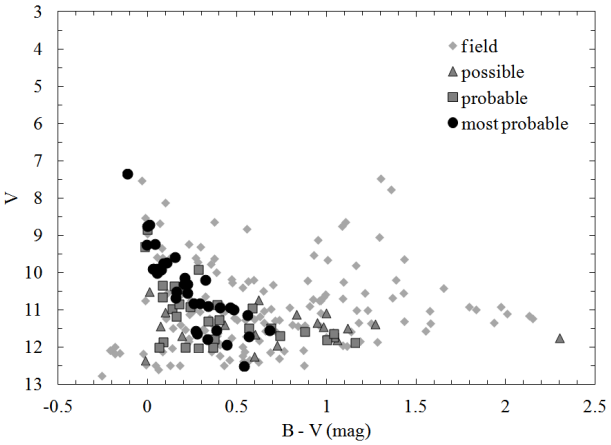

Fig. 2. V vs $(B-V)$ diagram for the 239 sample stars. Large solid circles represent the most probable members of the ASCC 113 open cluster, grey squares represent the probable members, grey triangles represent the possible members of the cluster and small diamonds the field stars.

milliod 1995), are: $\alpha_{2000} = 21^h\,12^m\,00^s$, $\delta_{2000} = +38^\circ\,35'\,59''$, and $b = 82.88^\circ$, $l = -6.65^\circ$, respectively, and it has a diameter of $56.4'$. Kharchenko et al. (2005) reported the following physical parameters: distance $d = 450$ pc (i.e., $1''$corresponds to 450 AU), reddening $E(B-V) = 0.00$ mag, distance modulus $V - M_V = 8.27$ mag, $\log(t,\,\text{years}) = 8.14$, core radius $r_{core} = 0.12^\circ$ and corona radius $r_{cl} = 0.47^\circ$.

In order to have a representative sample, we need to establish the member stars of the cluster, and for that, Kharchenko et al. (2004) defined a three criteria procedure: a kinematic constraint P_{kin} that takes into account the kinematic proper motion, a photometric selection P_{phot} to exclude background comoving stars and a position factor P_s which is equal to 1 within the cluster radius and zero elsewhere. Using such criteria, they defined the most probable members those stars for which $P_{kin}, P_{phot} \geq 61\%$ (1σ-members); probable member stars for which both P_{kin} and P_{phot} are between 61% and 14% (2σ-members), and possible members all stars within a 3σ-deviation, i. e., P_{kin} and P_{phot} between 14% and 1%. Stars with $P_{kin}, P_{phot} \leq 1\%$ were considered as non-members. Given those criteria, the open cluster ASCC 113 has 34 MP stars, 29 P stars, 18 p stars and we also analysed 158 field stars. In Figure 1, we show the apparent magnitude distribution for the 239 sample stars observed and the corresponding V vs. $(B-V)$ diagram in Figure 2.

3. OBSERVATIONS AND DATA REDUCTION

We obtained our data during two sets of observations at the 2.1 m telescope of the Observatorio Astronómico Nacional (OAN), México. The diffraction-limited resolution of the 2.1 m telescope is $0''.055$ for $\lambda = 550$ nm and $0''.088$ for $\lambda = 800$ nm (Orlov 2013). The observations were performed using an EMCCD iXon 885 DU from Andor Technology. During 7 nights, from September 27 to October 3, 2012, we used the $f/30$ secondary and, after calibration, we determined a scale of 28.6 mas per pixel, equivalent to a field of $25''$ for the total area of the detector; During 3 nights of the second set, from 27 to 30, October 2012, we used the $f/7.5$ secondary combined with a microscope, after calibration, covers a total field of $16''$ for the total area of the detector. For calibration we observed 30 wide pairs with very slow orbital motions and some of them with known orbital parameters. Typically 400 speckle frames of 900×900 pixel per object were taken with exposure times from 20 to 50 ms. We processed the data using the algorithm explained by Tokovinin, Mason & Hartkopf (2010). We estimated the seeing was better than $1''$ for both observational seasons, but aberrations introduced by the telescope had a larger effect. As a result, long exposure images have a resolution of about $1''.5$ and the mean error in the component separation is $0''.03$ and 1.5° in the position angle, modulo 180°.

4. RESULTS

We resolve systems as close as $0''.24$ and detected systems as wide as $23''.94$ in some directions; we detected speckle-interferometric companions for 35 of the stars in our sample. We astrometrically resolved 20 binary stars and two triple stars for the first time

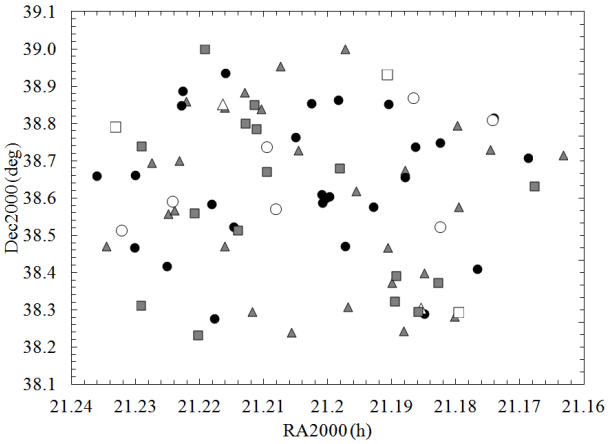

Fig. 3. Binary stars in the open cluster ASCC 113. Large solid circles represent the most probable members of the cluster, grey squares represent the probable members and grey triangles represent the possible members. Empty symbols represent binary and multiple systems.

and we also detected new companions in four objects, and confirmed ten previously known binaries. The objective of this study was to establish the multiplicity fraction of the cluster (see Equation 1) where *S, B, T*, etc., are the total number of single, binary, triple, etc., systems, respectively.

$$f_{bin} = \frac{B + T + \cdots}{S + B + T + \cdots}. \quad (1)$$

Together with our observations, we used the data published in the literature regarding stellar multiplicity of the stars in the direction of ASCC 113 and concluded that, for the most probable member stars of the cluster, the total single:binary ratio is 27:7, so the multiplicity fraction is $20.6\% \pm 3\%$. In Figure 3 we can see the random position of binary and multiple stars in the open cluster ASCC 113, i. e., there is not an apparent radial gradient in the superficial distribution of binary stars for this cluster.

We found that 28 of the 35 stars for which we detected interferometric companions are part of the sky area with ASCC 113; 16 of these stars are new binary detections and we discovered one new triple system. We use the components reported in the literature and our measurements to compute the ratio of multiplicities for stars in the field as 125:27:4:1:0:0:0:1 (between one and eight companions). Thus, the total multiplicity fraction for stars in the field is $20.9\% \pm 1\%$.

5. DISCUSSION

We have a magnitude-complete sample, which may be biased towards similar-mass or luminosities companions, but it can constrain models of star formation and evolution in the field and in clusters, in order to reproduce the fractions that we have found.

The motivation of this study was to investigate the so called "binary sequence" in the color-magnitude diagrams of open clusters. The member stars of an open cluster should form a one-dimensional sequence in the H-R diagram, due to the fact that they have the same age and intrinsic chemical composition. However, we can see a second sequence of stars ~ 0.75 magnitudes above the main sequence, which has been called a "binary sequence", since the most easy interpretation to this feature is that they are unresolved binary stars with both components having the same mass. With this study, we proved that the fraction of binary stars in the open cluster ASCC 113 is much lower than expected, and it is comparable to the fraction estimated for the four most studied open clusters, $\sim 20\%$.

6. CONCLUSIONS

We have initiated a survey of binary stars and multiple systems in Galactic open clusters and we started with the ASCC 113 open cluster. Combining our speckle-interferometric observations with data taken from the literature, we estimated a ratio of 27:7 (single to binaries) for the the most probable members, so the multiplicity fraction for this cluster is $20.6\% \pm 3\%$. For field stars, we estimated a ratio of multiplicities to be 125:27:4:1:0:0:0:1 (between one and eight companions), which is equivalent to a multiplicity fraction of $20.9\% \pm 1\%$. We concluded that the multiplicity fraction in the cluster and in the field are statistically indistinguishable from each other; we also concluded that the multiplicity frequency in this open cluster is rather small, $\sim 20\%$, in agreement with high angular resolution surveys in the Pleiades, Hyades, α Per and Praesepe.

REFERENCES

Jeffery, E. J. 2009, IAUS, 258, 141

Kharchenko, N. V. 2001, KFNT, 17, 409

Kharchenko, N. V., Piskunov, A. E., Röser, S., Schilbach, E., & Scholz, R.-D. 2004, AN, 325, 740

Kharchenko, N. V., Piskunov, A. E., Röser, S., Schilbach, E. & Scholz, R.-D. 2005, A&A, 440, 403

Mermilliod, J.-C. 1995, ASSL, 203, 127

Orlov, V. 2013, CEAB, 37, 1370

Reid, I. N. 1987, MNRAS, 225, 873

Tokovinin, A., Mason, B. D. & Hartkopf, W. I. 2010, AJ, 238, 709