RevMexAA (Serie de Conferencias), **43**, 24–27 (2013)

SPECKLE INTERFEROMETRY OF BINARY AND MULTIPLE SYSTEMS IN OPEN CLUSTERS

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

RESUMEN

El estudio de la población de estrellas binarias y múltiples en cúmulos abiertos representa un importante campo de investigación en astrofísica estelar. Sin embargo, el diagrama H-R se ve afectado cuando estas estrellas no son tomadas en cuenta, ya que la dispersión del color entre las estrellas en el CMD a lo largo de la Secuencia Principal se debe, en parte, a una abundante población de estrellas binarias no resueltas. Pero este problema no puede resolverse mediante la fotometría clásica porque la fotometría no tiene suficiente resolución espacial. Una solución a este problema puede estar basada en la interferometría *Speckle*, una técnica que permite hacer mediciones astrométricas de alta precisión para estrellas binarias: separación angular y ángulo de posición.

ABSTRACT

The study of the binary and multiple star population in open clusters represents an important field of research in stellar astrophysics. However, the H-R diagram is afected if these stars are not taken into account, since the color dispersion among the stars in the CMD along the main sequence is due in part to a large population of unresolved binary stars. But this problem cannot be solved by classical photometry because this technique does not have enough spatial resolution. One solution to this problem can be based on speckle interferometry, a technique that allows high-precision astrometric measurements for binary stars: angular separation and position angle.

Key Words: binaries: general — open clusters and associations: general — techniques: interferometric

1. INTRODUCTION

The study of the binary and multiple star population in open clusters represents an important field of research. However, the H-R diagram is affected if these stars are not resolved. This problem cannot be solved by classical photometry because photometry does not have enough spatial resolution. One solution to this problem can be based on Speckle Inteferometry. Galactic open clusters are ensembles of stars with low concentration and irregular shape, gravitationally-bound systems formed at the same time from the same original cloud. Open clusters have an average diameter of about 10 parsecs and contain from some tens to several hundreds of stars. Typically, they are younger than a few hundred million years.

2. COLOR - MAGNITUD DIAGRAM

Classical photometry helps us determine the general physical characteristics of clusters. However, there is an observational problem due to the presence of stars in binary or multiple systems that are not resolved (Reid 1986). The color dispersion among the stars in the CMD along the MS is due in part to a large population of unresolved binary stars (Daniel et al. 1994). This observational bias affects the determination of the parameters of the stars in two ways (Stobie 1987): the first is that the star's luminosity is enhanced, and the second is that the color index of the system is redder. These combined effects affect the determination of the physical parameters. Figure 1 shows an example of Praesepe (NGC 2632), where the triangles represent posible binary stars (Bolte 1991).

3. SPECKLE INTERFEROMETRY

The limiting resolution of telescopes on the ground is not the diameter of the opening, but the atmosphere. A telescope of any aperture can rarely achieve a resolution in visible light less than 1″ arc. Labeyrie (1970) introduced the principle of interferometry speckles: traditional long exposure images consist of many spots which together form the seeing disk (Figure 2). Speckle interferometry uses high magnification and hundreds of images of very short exposures (Figure 3). When these images are combined and analyzed (in digital form), one can achieve the resolution limit of the telescope. Speckle interferometery provides information on the apparent positions of the binary stars and on the difference in mag-

[1]Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70-264, México, 04510 D.F., Mexico (cguerrero, orlov@astro.unam.mx).

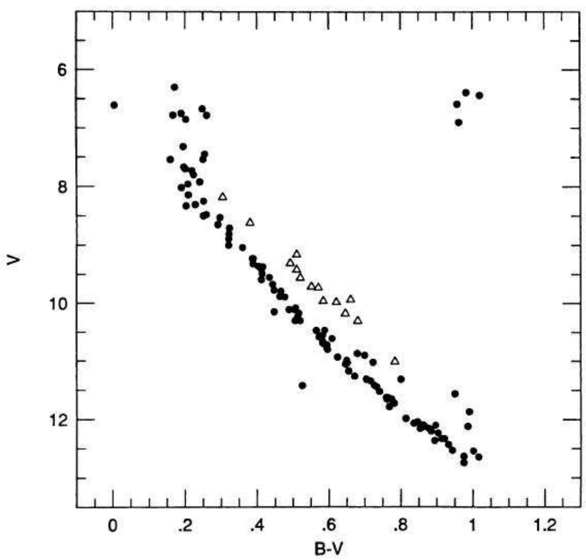

Fig. 1. CMD of Praesepe (NGC 2632). The triangles represents possible binary stars (Bolte 1991).

Fig. 2. Long-exposure image of +234 00 279 WDS obtained with the 1.5 m telescope of OAN/SPM.

nitudes of the components of the system. To obtain data on the magnitud diferences between the two componentes, it is preferable to analyse the power spectrum (Figure 4).

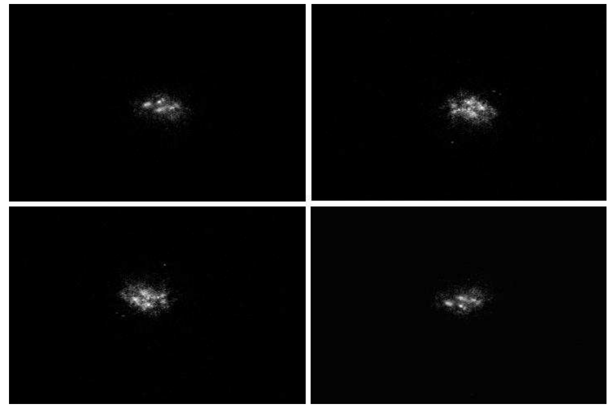

Fig. 3. Four consecutive speckle images of the binary star +234 00 279 WDS. 500 ms between each image.

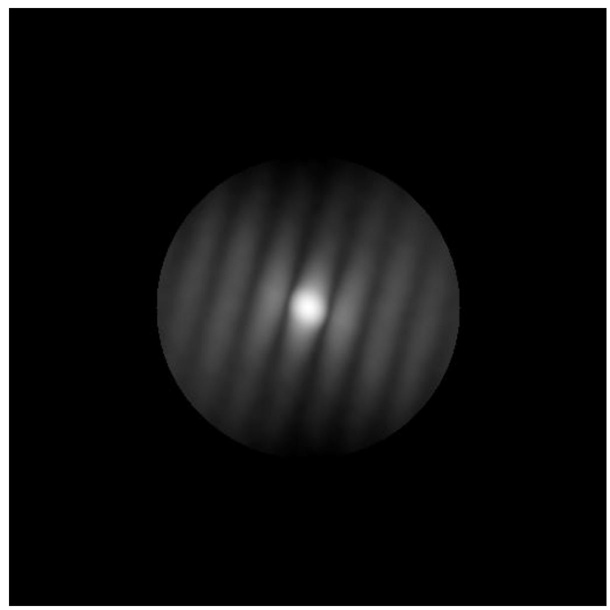

Fig. 4. Power Spectrum of the star +234 00 279 WDS.

The power spectrum can be described by:

$$P_{\mathrm{mod}}(\mathbf{f}) = P_0(\mathbf{f})[A + B\cos(2\pi\mathbf{f}\mathbf{r})], \quad (1)$$

where A and B define the magnitude diference, and $P_0(\mathbf{f})$ is the power spectrum of the reference star:

$$P_0(\mathbf{f}) \approx \exp[-3.44(f/f_0)^{(5/3)}(D/r_0)^{5/3}] \\ +0.435(D/r_0)^{-2}T_0(f), \quad (2)$$

and $T_0(f)$ is the diffraction-limited transfer function:

$$T_0(f) = 2/\pi[\arccos(f/f_0) - (f/f_c)\sqrt{1-(f/f_c)^2}]. \quad (3)$$

The contrast of the “fingers” in the power spectrum, $\beta = B/A$ is related to the difference in magni-

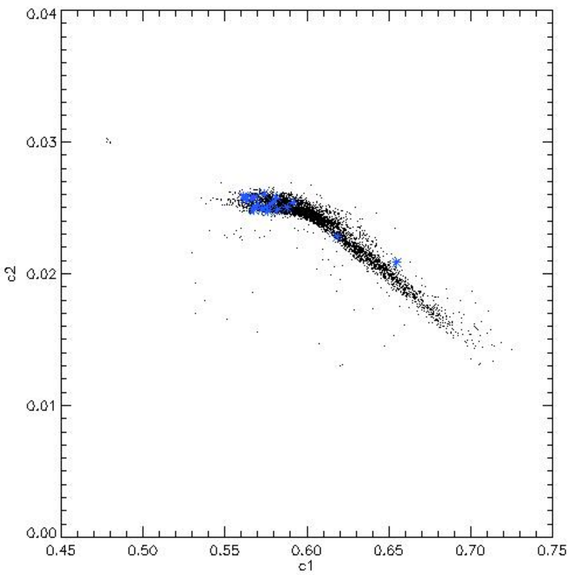

Fig. 5. Binary stars found in the WDS. The cross points represent the 31 binary stars found. One can see that almost all fall on the flat top of the graph.

tudes between the components of the binary system:

$$\Delta m = -2.5 \log_{10}[(1 - \sqrt{1 - \beta^2})/2]. \tag{4}$$

4. STELLAR MULTIPLICITY IN STAR CLUSTERS

The fraction of binary stars is dominated by several processes in star clusters. There is continuous formation and destruction of binary systems due to the interaction of binary stars, and individual stars. This scenario is complicated by the dynamic evolution of clusters, which produces radial gradients in the frequency of binary stars.

From the observational point of view, the fraction of binary stars has been estimated only in some globular clusters (Bolte 1991; Bellazzini et al. 2002; Clark, Sandquist, & Bolte 2004). Sollima (2008) conducted a detailed analysis using N body simulations, and concluded that to reproduce the observed morphology in the CMD diagrams, a fraction of binaries in the cluster core of about 11% is required, and throughout the cluster, of about 35% to 70% depending on the stellar density.

5. PHOTOMETRY OF OPEN CLUSTERS

The analysis of data from classical photometry is based on the use of different color indices. Due to the wide variety of stellar classes, effects of reddening, etc., these color indices may be equal to two entirely different types of stars; to distinguish between objects it is necessary to determine the absolute magnitude of each star, for which we need to know the distance. The color indices do not provide complete information on the spectral properties of the stars. Classical astronomy used color indices because they had available only two or three bands; modern astronomy now uses many other bands ($UBVBRIJHK$...), but still continues to use the color indices for the analysis. It would be nice to find a way to quantify the characteristics of objects using all available bands simultaneously.

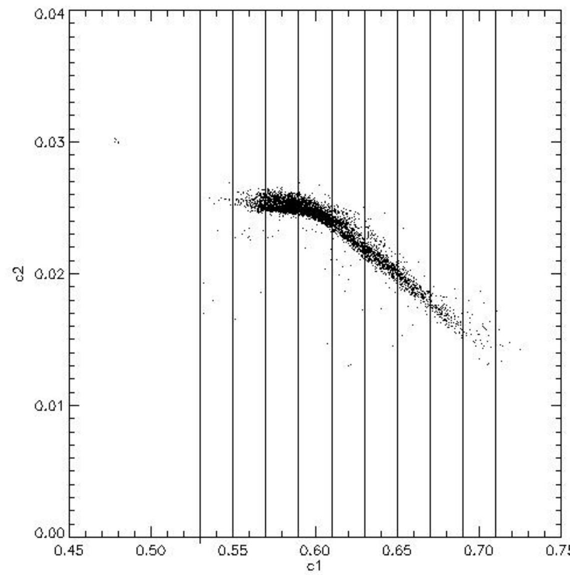

Fig. 6. Intervals for random selection of stars.

Using data from 5768 stars in open clusters to limiting magnitude $V = 14$, we constructed a diagram of photometric data in the bands of the Johnson-Cousinns photometric system. We did an extensive search of the literature to identify which of the stars observed were reported as binary stars or multiple, and found only 31 (Figure 5).

6. FUTURE WORK

We will classify groups of stars (Figure 6): divided by ten classes (intervals), we will randomly select 30 stars (or more) of each interval for testing and interferometric observations in five colors $UBVRI$. For each interval, we will determine the percentage of binaries discovered and establish a criterion of probability of occurrence of binary stars.

Using differential photometry, we can determine the spectral class of each component of the binary system; once determined, we can establish how the occurrence of binary stars affects the determination of spectral classes using classical photometry, which would affect its position in the H-R diagram, which in turn affects the determination of the physical parameters of open clusters.

7. CONCLUSIONS

With the data available in the literature, in combination with an observational technique that requires small telescopes, we can try to solve a problem that can not be solved using classical photometry, and that requires precision astrometry and high spatial resolution techniques.

We are developing a new method to identify potential binary or multiple stars. The goal is to make a statistical study of the abundance of binary stars and multiple systems in open clusters and obtain the astrometric and photometric properties of the system components in order to understand how the H-R diagram is affected.

REFERENCES

Bellazzini, M., Fusi Pecci, F., Messineo, M., Monaco, L., & Rood R. T. 2002, AJ, 123, 509
Bolte, M. 1991, ApJ 376, 514
Clark, L. L., Sandquist, E. L., & Bolte, M. 2004, AJ, 138, 3019
Daniel, S. A., et al. 1994, PASP, 106, 281
Labeyrie, A. 1970, A&A, 6, 85
Reid, N. 1986, MNRAS, 225, 873
Sollima, A. 2008, MNRAS, 388, 307
Stobie, R. S., Ishida, K., & Peacock, J. A. 1987, MNRAS, 238, 709