

Photometric analysis of the open cluster NGC2420 and the globular cluster NGC6229

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ABSTRACT

We studied the photometry of the globular cluster NGC6229, and the open cluster NGC2420, by using g , r and i bands. By transforming g, r, i into BVR Johnson-Cousins photometric bands, we built a color-magnitude diagram (CMD) in this photometric system, and we determined the distance modulus (DM) of NGC2420, through the ZAMS (Zero Age Main Sequence) fitting, and of NGC6229, by comparing $M_V(\text{RR Lyrae})$ with $V(\text{RR Lyrae})$ in the Horizontal Branch (HB). Finally, we estimated the age of both NGC2420 and NGC6229 by fitting different sets of isochrones, for different metallicities Z , onto CMD. The age of NGC6229 has also been estimated by determining the difference $M_V(\text{TO}) - M_V(\text{HB})$.

I. INTRODUCTION

A star cluster is a group of stars born at the same epoch from the same molecular cloud with the same chemical composition, kept together by the gravitational force.

We can distinguish between globular and open clusters. The first ones are generally bigger and composed of a high number of old population II stars, and are distributed in the whole galactic halo. They have a visible spherical shape due to the strong gravity, which keeps a high stellar density in their centre. They do not have any gas or dust.

Open clusters have a lower number of stars, so their gravitational bound is weaker. They are generally very bright, because they contain young stars at a high temperature. By analyzing the light coming from an open cluster we can estimate its age. An abundance of blue stars implies that the cluster is young. The stellar density can be extremely variable, sometimes similar to that of the field stars, making the cluster hard to be recognized; anyway it is always lower than the density of the central areas of a globular cluster. Open clusters can be found only in the galactic disk of spiral galaxies and in irregular ones.

Generally, since all the stars in a cluster have about the same age, chemical composition and distance, every

difference in the stellar parameters is caused just by the initial mass of each star, that determines a different evolution.

When we create a color-magnitude diagram (CMD) or a H-R diagram of the stars in a cluster, its shape depends on the age of the cluster, showing an almost complete main sequence (MS) when younger than 500 Myr. Obviously, when the age of the cluster grows, all the typical features of the diagram become evident. The point in the diagram where the stars leave the MS is called turn-off (TO), and can be used to calculate the age of the cluster.

Since every star of the cluster is close to the others, the difference between apparent and absolute magnitudes, called distance modulus (DM), is constant. Therefore a CMD becomes a H-R diagram and it allows to estimate the distance if we have the DM.

II. OBSERVATIONAL DATA

We carried out the photometry of the globular cluster NGC 6229 (fig.1) and of the open cluster NGC 2420 (fig. 2).



Fig. 1: NGC6229.



Fig. 2: NGC2420

The globular cluster NGC6229, situated in the Hercules constellation, at RA = $16^{\text{h}} 46^{\text{m}} 58^{\text{s}}.9$ DEC = $+47^{\circ} 31' 40''$ (J2000), has an angular size of about $4.5'$ and it is of class 4, while the open cluster NGC2420, in the Gemini constellation, at RA = $07^{\text{h}} 38^{\text{m}} 23.9^{\text{s}}$ DEC = $+21^{\circ} 34' 27''$ (J2000), has angular size of about $10'$ and it is of class I 1 r.

We used the images extracted from the Sloan Digital Sky Survey (SDSS) Data Release 6, a survey conducted with the 120 Mpx CCD (*Charge Coupled Device*) of the 2.5-meters telescope in Apache Point (New Mexico, USA).

We did the photometry in the three photometric bands g , r and i , then we transformed them into the more common B, V and R bands of the photometric system by Johnson-Cousins.

The characteristic wavelengths of the photometric bands $ugriz$ are:

u	3551 Å
g	4686 Å
r	6165 Å
i	7481 Å
z	8931 Å

III. WORK DESCRIPTION

To carry out the photometric analysis of the images we used IRAF (*Image Reduction and Analysis Facility*) program, in particular DAOPHOT and IMAGES packages and their *daofind*, *phot*, *psf*, *allstar*, *tvmark* and *imexamine* tasks.

The techniques we can use for the photometric analysis are the aperture photometry and the Point Spread Function (PSF) fitting. The first one consists in adding up the pixel counts within circles centered on each object and subtracting off an average sky count, determined in a circle ring around the object, to obtain the effective flux of electromagnetic radiation. In this case this technique was not suitable because of the high stellar density, that made inaccurate, or even impossible for the globular cluster, the average sky count determination.

Therefore, we applied the PSF photometry. This is a mathematical model of stellar profile which describes the average distribution on the CCD surface of the photons coming from a single star. This distribution, because of the Earth atmosphere effect (*seeing*), has the trend of a Gaussian curve, whose typical width (FWHM) determines what we considered the edge of the star. To build the PSF model we chose stars that showed a regular distribution of light. These stars ought to be quite isolated, in order to avoid overlapping of the tail end of the light profiles. Besides, they had to be regularly distributed throughout the whole image. By using the *psf* command, we obtained an average profile model which, once applied to every star of the image, allows to define the exact position of the star and the flux.

From the flux values we subtracted the light intensity of the sky background and, dividing it by the exposure time, we obtained the star instrumental magnitude. We applied this procedure to the images in g , r and i band of both clusters.

Since the instrumental magnitude is only an indication of the photon flux collected by the detector, we had to obtain a standard magnitude, which can be determined with the following equation:

$$m = m_0 + (m_s - 25) - kx$$

where m_0 = constant depending on the considered filter, m_s = instrumental magnitude, k = atmospheric extinction coefficient, x = air mass and 25 = constant applied by the program to the instrumental magnitude values, to make them positive.

The parameters values, acquired by the SDSS catalogue for our *fields*, are:

NGC 2420	<i>g</i>	<i>r</i>	<i>i</i>
m_0	24.45	24.07	23.74
<i>k</i>	0.14	0.09	0.03
<i>x</i>	1.06	1.06	1.06

NGC 6229	<i>g</i>	<i>r</i>	<i>i</i>
m_0	24.58	24.12	23.75
<i>k</i>	0.20	0.11	0.06
<i>x</i>	1.18	1.18	1.18

Once we obtained the photometric values for all the stars, which were 915 in *g*, *r* and *i* band in case of the open cluster NGC2420 and 1970 in the same bands in case of the globular cluster NGC6229, we converted them in B, V and R magnitudes by using the transformation equations elaborated by Jordi et al. (2006) ^[1].

Then we used them to elaborate the CMD (B-V vs V), from which we determined the distance, the HR (color-absolute magnitude) diagram (B-V vs M_V), and the age of the two clusters. For NGC2420 we corrected the B-V color index with color excess $\langle E(B-V) \rangle = 0.05$ taken from literature for this cluster ^{[2][3][4]}, according to the usual relation:

$$(B-V) = (B-V)_0 + \langle E(B-V) \rangle$$

deducing $(B-V)_0$, and the V band data for the interstellar absorption according to the relation

$$V = V_0 + R\langle E(B-V) \rangle$$

where we put $R=3.1$.

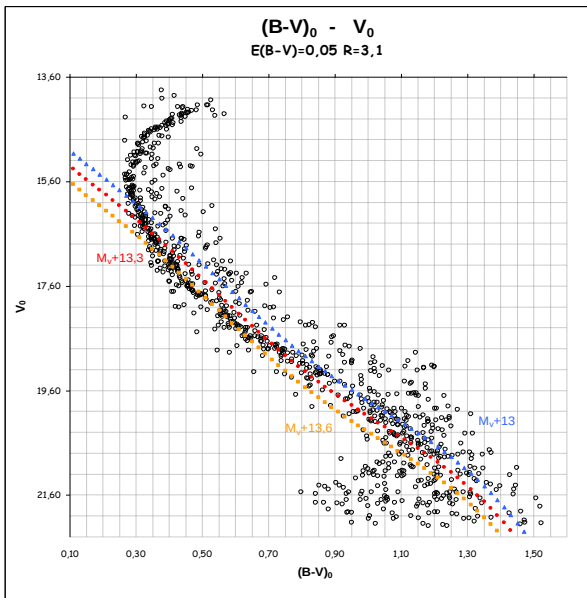


Fig. 3: ZAMS fitting.

To find the cluster distance we shifted the ZAMS, obtained with Johnson's data ^[5] until we fitted the

correct diagram, determining the distance modulus DM and obtaining (fig. 3):

$$DM(NGC2420) = 13.3 \pm 0.2$$

To determine the age of NGC2420 we fitted isochrones with different metallicities *Z* obtained from CMD 2.1 input form at http://stev.oapd.inaf.it/cgi-bin/cmd_2.1 getting the best result with ages between 1,26 Gyr and 1.59 Gyr and metallicity $Z=0.01$, as fig. 4 shows.

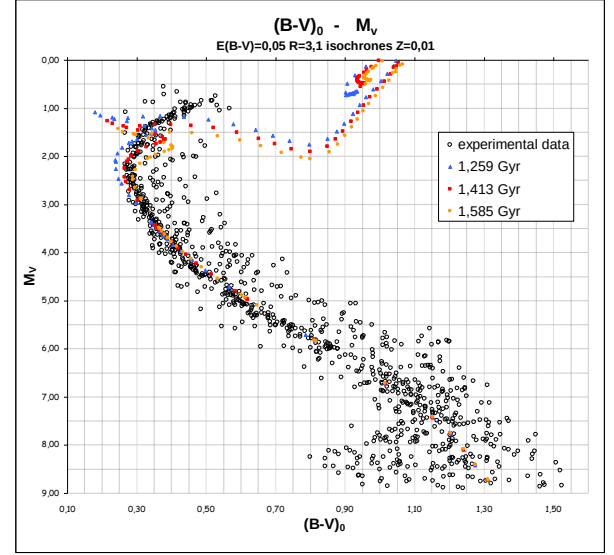


Fig. 4: CMD of NGC 2420 and Isochrones.

The correction of B-V and V values has not been done for the globular cluster NGC6229 since its $E(B-V)$ proves to be equal to 0 or at most 0.01 from literature. We built up the $(B-V)_0$ vs. V diagram (fig. 5),

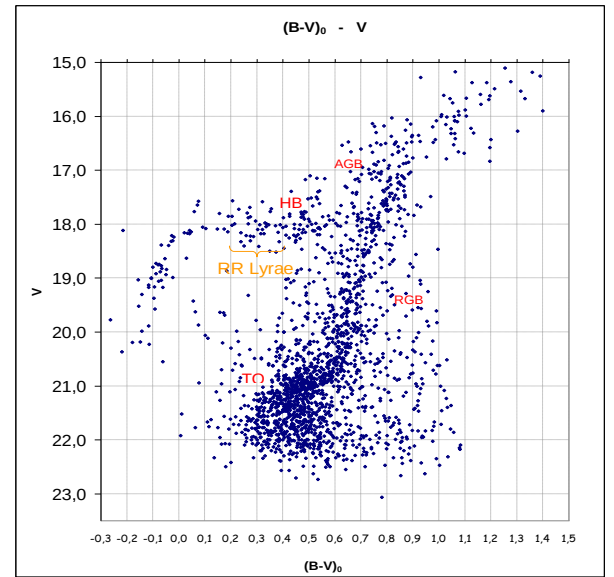


Fig.5: $(B-V)_0$ vs. V diagram.

and we deduced the DM by using the HB experimental visual magnitude and in particular the region where the pulsating variable stars RR Lyrae fall. These stars have a typical B-V color index between 0.2 and 0.4, and

their absolute magnitude is known, since it depends on $[\text{Fe}/\text{H}]$. It has been estimated in various ways for the globular clusters at $M_V = 0.60 \pm 0.12$ at $[\text{Fe}/\text{H}] = -1.5$ in particular after the studies carried out through HIPPARCOS satellite ^[6].

The HB, and therefore the RR Lyrae, have a visual magnitude of +18.1, therefore by comparing the observed visual magnitude with the absolute one we can obtain a $\text{DM} = M_V - V = 0.60 - 18.10 = -17.50$.

Afterwards we deduced also for this cluster the HR diagram ($B-V$ vs M_V) and we fitted different-metallicity isochrones to establish its age. We obtained the best fit with isochrones with metallicity of $Z=0.001$, and ages between 10.00Gyr e 14.13Gyr.

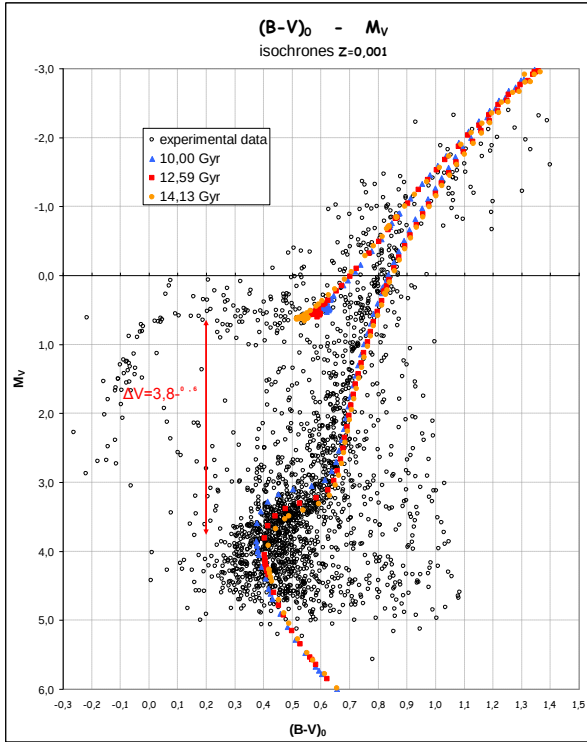


Fig. 6: CMD of NGC 6229, Isochrones and ΔV .

An other method we applied to calculate the age is based on the difference between the stars which are on the HB and those on the TO according to the following equation:

$$\text{Log } t_9 = 0.37 \Delta V - 0.03$$

where $\Delta V = M_V(\text{TO}) - M_V(\text{HB}) = 3.2$.

IV. RESULTS

The distance of the two clusters is calculated starting from the DM given by the equation:

$$M - m = 5 - 5 \text{ Log } d$$

which gives, for the open cluster, a distance of 4.6 kpc, a measure which remarkably differs from the officially accepted values. Likewise, the age determination of

1.4Gyr does not agree with the one reported in literature, although the sources report meaningfully different data, and this is due to the peculiar characteristics of the cluster. In this study, there is, probably, a systematic error in the acquisition of the photometric data, which causes the translation of $B-V$ values of about -0.2, so that ZAMS are fitted to a higher DM, consequently increasing the estimated distance and the isochrones fitting, therefore the valued distance.

For the globular cluster our results totally agree with those in literature; in fact, with the isochrones-fitting method, the distance is proven to be 31.6kpc and the age 12.6Gyr. This is substantially confirmed by the age determination of 14.2Gyr, obtained with the HB-TO distance method.

V. BIBLIOGRAPHY

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