



Photometric analysis of the globular cluster NGC5466

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Abstract. We analysed the globular cluster NGC5466 in two different bands, g and r of the SLOAN photometric system, and then converted them in the UBVRI system by Johnson-Cousins to obtain an HR-diagram from which we determined the significant parameters: metallicity, distance and age. We successively compared the results about the age with those obtained using the method of RR-Lyrae.

1. Introduction

Star clusters are collections of stars kept together by their gravitational force. We can distinguish between open clusters and globular clusters. Open clusters do not have a regular shape and have from few tens to 10^3 stars, loosely bound to each others, which are spread in a very large space; therefore, their density is low. The population of open clusters is quite young and some bright blue stars are identified. Most of the open clusters lay in the Galactic disc and have a large quantity of interstellar medium. Globular clusters, instead, are characterized by a spherical shape, due to tight gravitational bounds. They present a high star density, which decreases as the distance from the centre raises, and count from 10^4 to 10^6 stars. They are generally very old, so that their stars are mainly weak and red. They also have low values of metallicity, which is a verification that they are very old objects (the universe, in its primaevial existence, was mostly made of hydrogen and helium; then, the percentage of metals rose as the time passed by, because of their formation in the nucleus of stars). Thanks to their lack of gas and dust, we can measure the stellar density and study theoretically the dynamical evolution in presence of tidal forces, due to the Milky Way, and calculate their relaxation time. Globular clusters can be found throughout the galactic halo of our galaxy; so they can be distinguished into two categories: bulge/disk clusters and halo clusters. The latter have even lower values of metallicity than the others. This is the case of NGC5466 (Fig. 1). It is a halo cluster and has one of the lowest known values of metallicity. We took a couple of images from the free software “WhereIsM13?” (<http://www.thinkastronomy.com/M13>) in order to show clearly the position of NGC5466 (Fig. 2). NGC5466 is also one of the least dense known glob-

ular clusters. It belongs to the XII class, according to the Shapley and Sawyer classification. All the stars of a cluster have the same origin. This implies that they have approximately the same age and similar chemical composition. Thus, they play an important role in astronomical studies because the evolution of each star only depends on its initial mass. Such as in all stellar clusters, all the members have the same distance, this gives the possibility to use apparent instead of absolute magnitude, in order to build the HR-diagram.

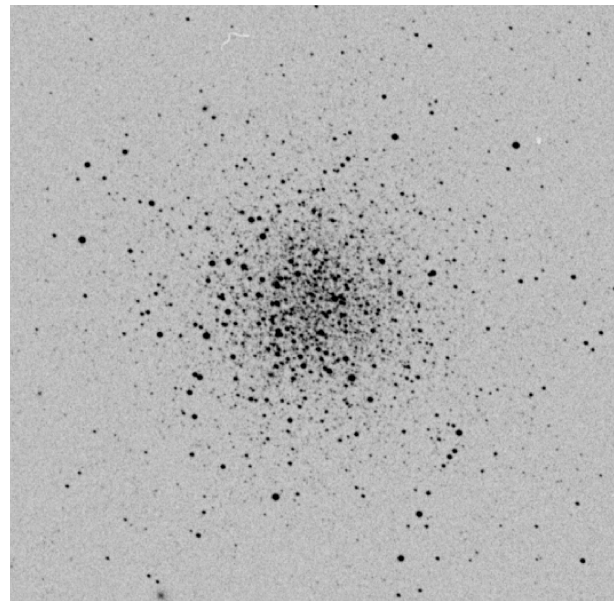


Fig. 1. Digitized Sky Survey image of NGC5466.

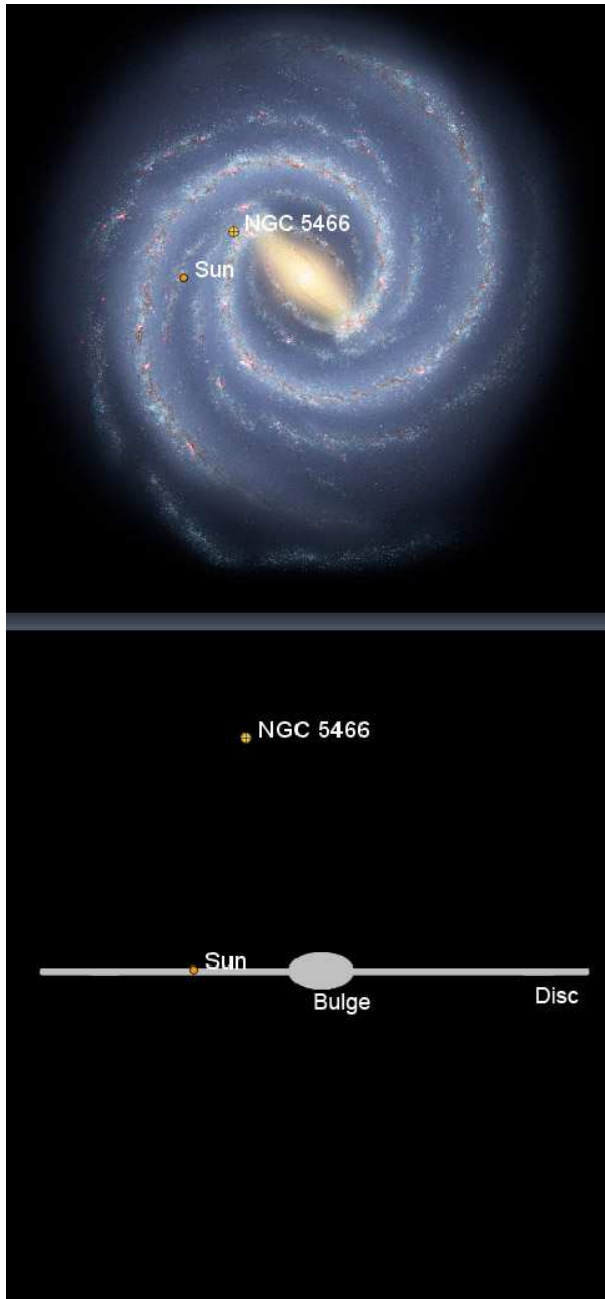


Fig. 2. Position of NGC5466 with respect to the Milky Way and the Sun.

2. Observational Data

The globular cluster NGC5466 is situated in the constellation of Bootes, at RA 14h 05m 27.36s and DEC +28° 32' 4.2". Its angular size is about 11'. We took the images from the Sloan Digital Sky Survey (SDSS) Data Release 7, a survey conducted with the 120Mpx CCD of the 2.5-meters telescope at Apache Point (New Mexico, USA), in the filters g and r of the ugriz photometric system. We had to convert magnitudes into the

more common UBVRI photometric system by Johnson-Cousins.

3. Work description

We used IRAF (Image Reduction and Analysis Facility) and DS9 to visualize images and Topcat to manipulate data tables. As first step, we examined 10-15 stars spread in the whole image, to acquire information about the average FWHM (Full Width at Half Maximum) of the image. This value was then used to allow IRAF to recognize stars and save their coordinates, by using the DAOFIND task. Then we calculated the instrumental magnitude of each star, using the PHOT task. This task applies a technique called aperture photometry (see Fig. 3). It calculates the flux of each star by summing the pixel values within a circle with a given aperture, centred on the star, and subtracting the average luminosity of the sky, calculated within a wider ring around the star. Then, the flux is converted in instrumental magnitude by applying the following equation:

$$m_{\text{instr}} = -2.5 \times \log \left(\frac{I_* - n_{\text{px}} \times I_{\text{sky}}}{t_{\text{exp}}} \right)$$

where I_* is the sum of the values contained in the circle centred on the star, n_{px} is the number of pixels contained in that circle, I_{sky} is the average intensity of the sky per pixel calculated within the ring, and t_{exp} is the exposition time of the image. As output, we obtained a text file with the coordinates of every star and its correspondent instrumental magnitude.

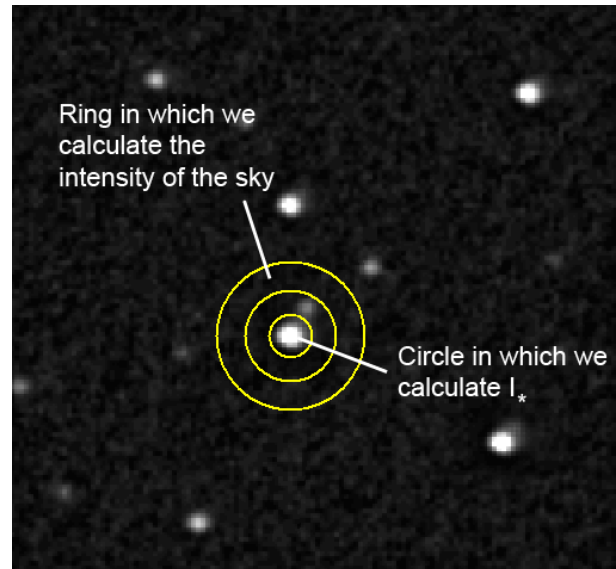


Fig. 3. An example of aperture photometry.

The same technique cannot be applied to the globular clusters, because the star density is too high. This

means that, in the image, there are no empty spaces around the stars to calculate the luminosity of the sky. We had to use another technique. The PSF (Point Spread Function) photometry (see Fig. 4), allowed us to discriminate one star from another in case they were too close or overlapped. This can be done using a PSF model based on the stars of our cluster. Using the PSF task, we selected about 20 isolated stars. This task use the selected stars to create a mathematical model of the PSF, using the function that best fitted the stellar profiles. The PSF model represents the light distribution of a point-like source modified by the seeing, due to the atmosphere. Then, using the ALLSTAR task, IRAF applied the PSF model to distinguish each star from the others and calculated their instrumental magnitudes. Again, we obtained a text file with the coordinates of each star and its corresponding instrumental magnitude.

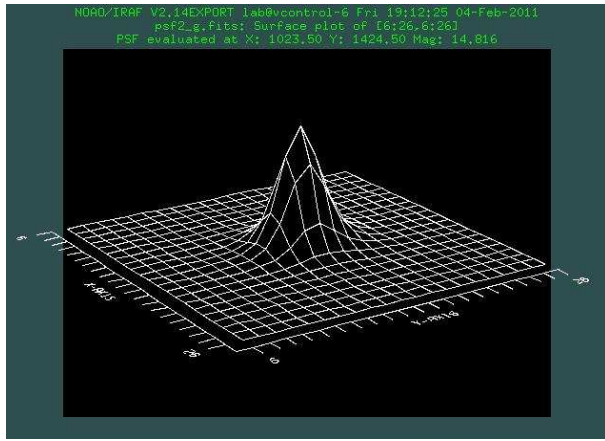


Fig. 4. PSF model.

We repeated the whole procedure twice for each filter, to obtain a larger sample of stars. At the end, we got data for more than 7000 stars. These data were elaborated with Topcat. At first, we transformed the instrumental magnitudes into the calibrated ones applying the following equations:

$$g_{\text{cal}} = 24.3897 + g_{\text{instr}} - 0.212 \times 1.185$$

$$r_{\text{cal}} = 23.96 + r_{\text{instr}} - 0.124 \times 1.172$$

Secondly, we calculated the magnitudes in the B and V bands using the equations:

$$B = g + 0.349 \times (g - r) + 0.245$$

$$V = g - 0.569 \times (g - r) + 0.021$$

We used these data to build an HR-diagram.

To calculate the age of our cluster, we downloaded isochrones with low metallicity, as we know that generally globular clusters have low values of metallicity.

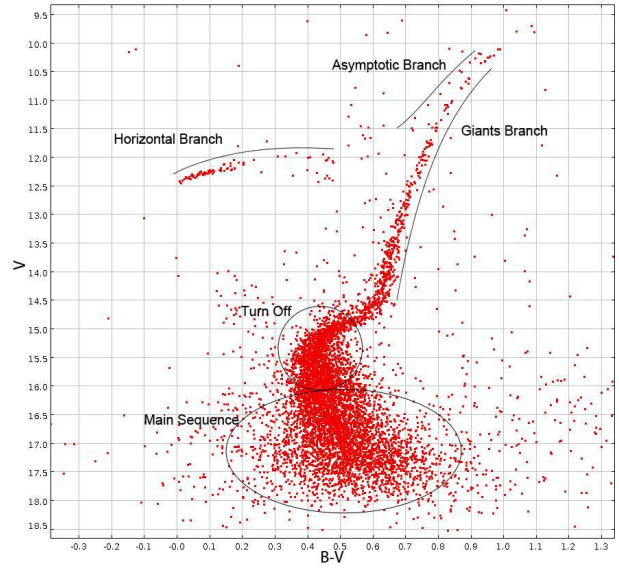


Fig. 5. The HR-diagram of NGC5466, with the $(B - V)$ colour index in the x axis, and V (apparent visual magnitude) in the y axis.

We found them on the Padova database of stellar evolutionary tracks and isochrones.

An isochrone is a mathematical model representing an HR diagram at fixed age and metallicity. We overlapped different isochrones on our observed diagram to find the one that best fitted in particular turn-off region, which represents the most important point for the age determination.

We also calculated the age of the cluster adopting the method of the RR Lyrae. This method is based on the difference, ΔV , between the magnitude at the turn-off and that at the horizontal branch for a given colour index (see fig. 5). We used the following equations:

$$\Delta V = m_V(\text{TO}) - m_V(\text{HB})$$

$$\log t = 0.37 \times \Delta V - 0.03$$

Finally, we calculated the distance of the cluster using the following equation:

$$d = 10^{\frac{(M_V - m_V) + 5 - A(V)}{5}}$$

where $M_V - m_V$ is the distance modulus, which corresponds to the shift, along the y axis, that we had to apply to the isochrone to match our HR-diagram. This is due to the gap between the apparent magnitude we obtained from the observation and the absolute magnitude of the given isochrone. $A(V)$, the visual absorption, is a function of the colour excess $E(B - V)$ (i.e. the shift along the x axis) according to the following relation:

$$A(V) = 3.1 \times E(B - V)$$

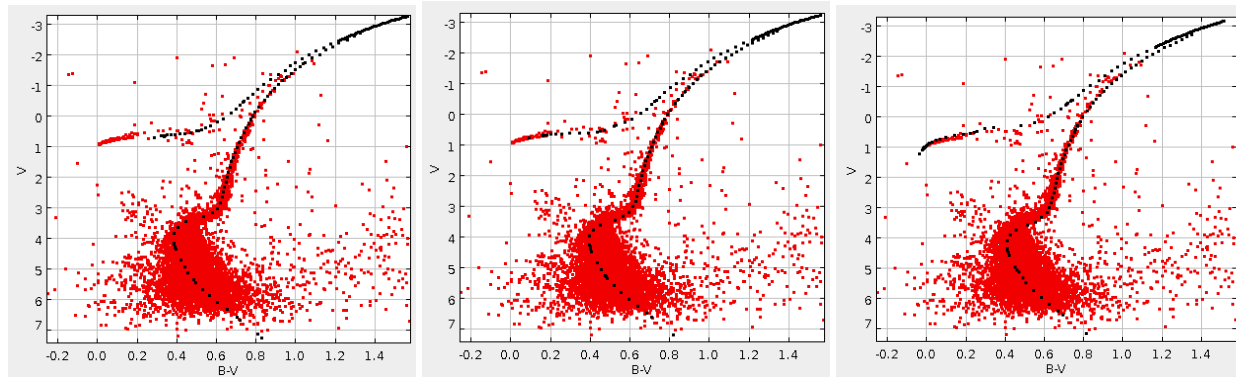


Fig. 6. Isochrone fits. From left to right: fit with 14.1 Gyr, 15.8 Gyr and 17.8 Gyr isochrones with $Z=0.0004$

4. Results

At first, we selected the data of the stars and built a $(B - V)$ vs V diagram combining the aperture and the PSF photometry techniques. Then, we analysed the diagram adopting two different procedures: the first consisted in comparing our diagram with the theoretical isochrones, the second was the RR-Lyrae method; both methods gave us an estimation of the age. Using the method of the isochrones, we obtained an age of approximately 15.8 Gyr, which is not very different from the age calculated with the RR Lyrae method, which results between 13.0 Gyr and 15.5 Gyr, having used ΔV between 3.1 and 3.3. The globular cluster NGC5466 results to be at a distance of 14.7 Kpc and to have metallicity $Z=0.0004$. The very low value of metallicity reflects some characteristics of the HR-diagram, such as the remarkable length of the horizontal branch and the marked slope of the giant branch (see fig. 5). Distance and metallicity values can be compared within the errors to the ones we can find in literature. Nevertheless, the results achieved for the age (at least the one obtained with the isochrone method) strongly disagree with the age of Universe, currently about 13.7 Gyr. We can find this incongruence in literature older studies. We have to say that there is a gap between the mathematical model provided by the isochrones and the empirical evidences, adding the errors that can affect our measurements. We can conclude that the origin of the globular cluster NGC5466 is to be placed in the primaeval Universe.

References

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