Photometric analysis of the open cluster NGC 6791

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Abstract. We performed the photometric analysis of the open cluster NGC 6791 in the g and r bands of the ugriz photometric system. Through this process we estimated the parameters of the clusters, i.e., age, metallicity, distance, and reddening, by fitting Padova isochrones to the color-magnitude diagram.

1. Introduction

The aim of our analysis was to obtain information about the age, metallicity, reddening and distance of the open cluster by means of a fitting with the Padova university isochrones.

An open cluster is a group of stars which come from the same molecular cloud, are bound to each other by gravitation forces and they have an almost identical chemical composition and age. Also, it is to be found (most of the time) within the Galactic disk and is less populated compared to a globular cluster.

Studying open clusters is useful to describe, study and analyse a wide variety of aspects related to the structure, composition, dynamics, formation and evolution of the Milky Way.

Young open clusters are used to determine spiral arm structure, to map the rotation curve of the Galaxy, to investigate the mechanisms of star formation and to constrain the initial luminosity and mass functions in aggregations of stars.

Old open clusters are probes of early disk evolution. They can be seen to large distances because their brightest stars are strong-lined red giants that are excellent for measurement of radial velocity and composition. Also, they are tracers of the chemical and physical structure of the Galactic disk.

The main advantage of studying open clusters, rather than single stars, lies in the precision with which it is possible to get data about their reddening, distance, age and metallicity values.

Fig. 1. Cluster position within the Galaxy

Fig. 2. Cluster position in the Galactic disk
The open cluster in exam is classified with the ID NGC 6791 and is to be found in the Lyra constellation. It presents some peculiar characteristics since it is one of the oldest, richest of heavy elements and populated open clusters in the Milky Way.

![Fig. 3. Picture of the NGC 6791 open cluster](image)

2. Observational data

We used the following observational data, taken from the Sloan Digital Sky Survey (SDSS) data release 7 (dr7).

The Sloan Digital Sky Survey (SDSS, http://www.sdss.org/dr7/) consists of three surveys, named Legacy, SEGUE (Sloan Extension for Galactic Understanding and Exploration) and Supernova, carried out with a dedicated 2.5m telescope located at Apache Point Observatory in Southern New Mexico. Our data comes from Legacy survey which includes 230 million celestial objects. Celestial coordinates of the open cluster NGC 6791:

<table>
<thead>
<tr>
<th>RA</th>
<th>19°20'53.8&quot; *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec</td>
<td>37°46'18.8&quot; *</td>
</tr>
<tr>
<td>Cluster type</td>
<td>I 2 r</td>
</tr>
<tr>
<td>airmass</td>
<td>g 1.033</td>
</tr>
<tr>
<td></td>
<td>r 1.029</td>
</tr>
<tr>
<td>atmospheric scattering coefficient</td>
<td>g 0.233</td>
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<tr>
<td></td>
<td>r 0.151</td>
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<tr>
<td>exposition time</td>
<td>53.907456 s</td>
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<tr>
<td>photometric zeropoint (m0)</td>
<td>g 24.4365</td>
</tr>
<tr>
<td></td>
<td>r 24.0325</td>
</tr>
</tbody>
</table>

*(In year 2000)*

3. Work description

In order to carry out the photometric analysis of our open cluster we used the IRAF software (Image Reduction and Analysis Facility - tasks: daofind, phot, psf, seepsf, allstar).

The aim of our work was the creation of a color-magnitude diagram of the cluster which enables us to find out the age, metallicity and reddening values and the distance of it. We decided to consider the g and r bands of the ugriz photometric system.

By means of the analysis software we performed the photometry of the open cluster and, after having created the diagram, we inferred information regarding its physical and chemical characteristics. The first step of the process is the performance of an aperture photometry, which consists in the following steps: for first one defines one circular aperture (whose radius is typically 4-5 FWHM enclosing the source, and a ring outside the previous one that contains only sky (whose inner radius is typically 6-7 FWHM and thickness of about 1.5-2 FWHM). Then the software obtains the mean counts per pixel from the sky aperture, subtracts that mean from each pixel in the source aperture, and sums the remaining counts to find the total in the stellar image.

In this way we obtained the instrumental magnitude:

\[
m = -2.5\log \frac{I_{\text{star}}}{n_{\text{pix}}\times I_{\text{sky}}}\]

through the sampling, for each photometric band, of the flux of twelve stars and twelve fondo cielo regions. This first step had correctly identified many of the light sources actually identifiable in the image.

Afterwards, in order to optimise the identification process, we performed a second scan of the image by means of a PSF photometry.

The aperture photometry on crowded star fields, such as globular clusters or open clusters, will not yield reliable results because of many stars are faint and overlap due to the crowding in the image. We repeated the whole process on the residual image from the previous photometry using the same PSF model, so as to increase the number of identified stars.
This analysis has been performed in the $g$ and $r$ bands. The final result was the identification of about 5000 stars in both bands.

The data collected in the two bands have been compared by means of the TOPCAT software, which allowed us to detect the light sources which were common to both bands. We then performed the calibration of the magnitudes according to the formula:

$$m_{\text{cal}} = m_0 + m - k_m \times \text{airmass}$$

Using the calibrated magnitudes we created the color-magnitude diagram $g-r$ vs $g$ and, once we performed the conversion from ugriz to Johnson’s photometric system through these formulas

$$B = g + 0.349 \times (g-r) + 0.245$$
$$V = g - 0.569 \times (g-r) + 0.021$$

we created the $B-V$ vs $V$ diagram. This diagram proved to be concordant with the other analyses performed in the past and found in other Internet catalogs. Finally, in order to obtain information regarding the age, distance and metallicity and reddening values of the open cluster, we compared the diagram we created with a number of isochrones, which are theoretical curves which describe the evolution of identically aged stars in relationship with their initial mass.

4. Results

According to the visualization of the $B-V$ vs $V$ graph and the fitting with different isochrones, the open cluster NGC 6791 has a metallicity $z \approx 0.04$ (twice as much that of the Sun), an age of about 8-9 Gyr, a reddening value of $E(B-V) = 0.09$ and a distance modulus $V - M_V = 5 \times \log(d) - 5 + A(V)$ [$A(V) = 3.1 \times E(B-V)$] of 13.4. We have obtained a distance of about 4200pc.

Our results seem to agree with the suggestion that the metallicity of a cluster does not only depend on its age but also on its position in the Galactic disk. The metallicity, the position in respect to the Galactic centre (8 kpc) and the estimated age indicate that NGC 6791 does not well agree with the empirical law that describes age-metallicity relation (AMR) for the Galactic disk.

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**Fig. 4.** 3D gaussian curve of our PSF model

**Fig. 5.** 2D gaussian curve of our PSF model

**Fig. 6.** Our color-magnitude diagram in Johnson’s photometric system

**Fig. 7.** Graphical detection of the distance and the reddening. The vertical shift is connected to the distance whilst the horizontal shift is linked to the reddening value
Fig. 8. Comparison of the color-magnitude diagram with the best fitting isochrones

References


A. Bragaglia, Open clusters as tracers of the Galactic disk, Societe Francaise d’Astronomie et d’Astrophysique (SF2A), 2010