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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 cluster, 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 NGC 6791 by fitting its color-magnitude diagram with the Padova isochrones.

An open cluster is a group of gravitationally bound stars which originate from the same molecular cloud, and have approximately the same chemical composition and age. Besides, the open clusters are usually located in the Galactic disk, and are less populated than the globular clusters. Studying open clusters is useful to describe, study, and analyze 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 the spiral-arms 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 aggregates of stars. Old open clusters are probes of the early disk evolution. They can be identified up to large distances because their brightest stars are strong-lined red giants that are excellent for the measurement of the radial velocity and composition. They are also 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. NGC 6791, in the Lyra constellation, is a peculiar cluster, since it is one of the oldest, richest of heavy elements, and most populated open clusters in the Milky Way.

2. Observational data

We used the data taken from the archive of the Sloan Digital Sky Survey (SDSS), data release 7 (dr7).
Celestial coordinates of the open cluster NGC 6791:
Photometric parameters:

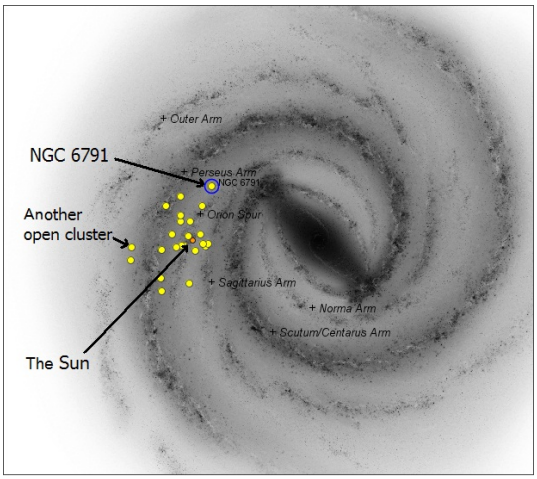

Fig. 1. Cluster position in the Galaxy.

RA	$19^h20^m53^s$*
Dec	37°46′18.8″*
Cluster type	I 2 r
	*(J2000)

– airmass

Band	Airmass
g	1.033
r	1.029

– atmospheric absorption coefficient

Band	k
g	0.233
r	0.151

– exposure time: 53.9 sec

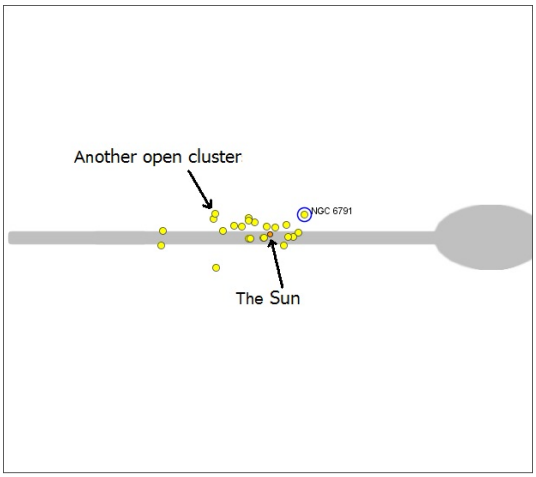

Fig. 2. Cluster position in the Galactic disk.

Fig. 3. Image of the NGC 6791 open cluster.

– photometric zeropoint (m_0)

Band	m_0
g	24.4305
r	24.0325

3. Work description

In order to carry out the photometric analysis of this 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 enabled us to find its age, metallicity, reddening, and distance. We decided to consider the g and r bands of the *ugriz* photometric system. By means of the software we analyzed 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 was the determination of the instrumental magnitude:

$$m = -2.5 \log \frac{I_{star} - (n_{pix} \times I_{sky})}{t_{exp}}$$

through the aperture photometry of twelve stars. This first step had correctly identified many of the light sources clearly visible in the image. Afterwards, we performed a second scan of the image by means of a PSF photometry. We repeated the whole process on the residual image resulted from the previous analysis using the same PSF model, so as to increase the number of identified stars. This analysis was performed in the

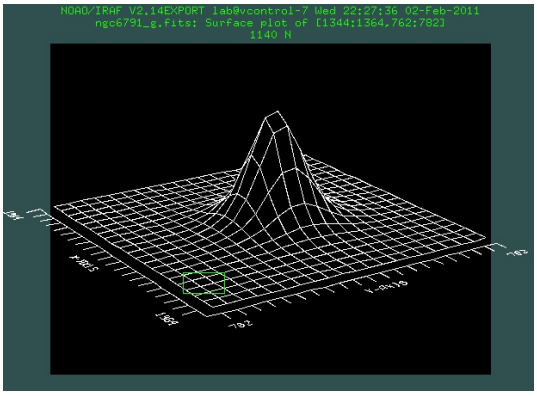

Fig. 4. Surface plot of our PSF model.

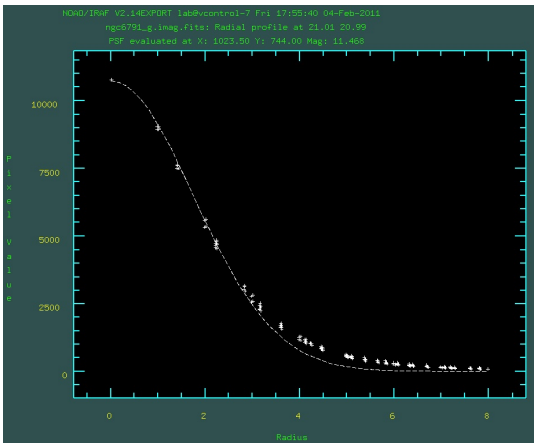

Fig. 5. Radial profile of our PSF model.

g- and r- bands. The final result was the identification of about 5000 stars in both the bands. The data collected in the two bands were compared by using the TOPCAT software, which allowed us to detect the common light

sources. We then performed the calibration of the magnitudes according to the formula:

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

Using the calibrated magnitudes we created the color-magnitude diagram $g - r$ versus g. We then performed the conversion from the *ugriz* to the Johnson photometric system through these formulas:

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

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

which enabled us to derive the $B - V$ versus V diagram. This resulted to be consistent with other ones found in literature through on-line catalogues. Finally, in order to obtain information regarding the age, distance, metallicity, and reddening of the open cluster, we compared the diagram we created with a sample of isochrones. They are theoretical curves describing the evolution of stars characterized by the same age and different initial mass.

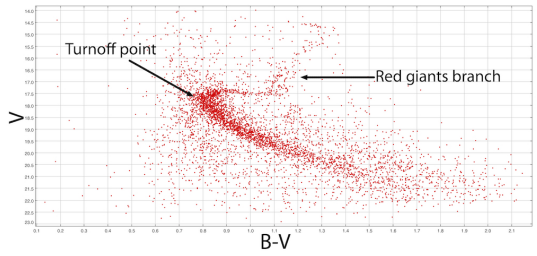

Fig. 6. Color-magnitude diagram in the Johnson photometric system.

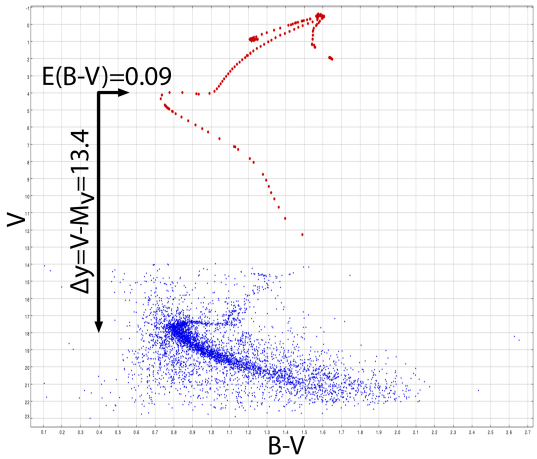

Fig. 7. Estimate of the distance and reddening of the open cluster, derived from the color-magnitude diagram.

4. Results

According to the $B - V$ versus V diagram 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 8-9 Gyr, a reddening value $E(B - V) = 0.09$, and a distance modulus $V - M_V = 5\log(d) - 5 + A(V) = 13.4$. We obtained a distance of about 4.2 kpc. 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 with respect to the Galactic centre (8 kpc), and the estimated age, indicate that NGC 6791 does not well agree with the empirical age-metallicity relation (AMR) of the Galactic disk.

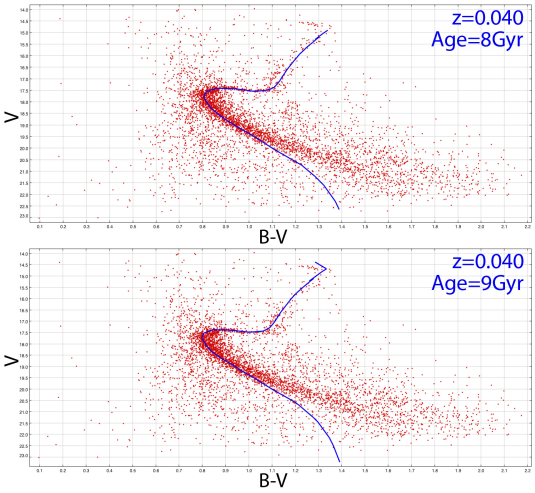

Fig. 8. Comparison between the color-magnitude diagram and the best-fit isochrones.

References

Friel, E. D. 1995, ARA&A, 33, 381
Friel et al. 2002, AJ, 124, 2693
Chen, L., Hou, J. L., & Wang, J. J AJ, 125, 1397
Bragaglia, A. 2010, SF2A, 335
Gratton, R., Bragaglia, A., Carretta, E., & Tosi, M. 2006, AJ, 642, 462