



## Full length article

## Photometric and astrometric study of open cluster FSR 814 (Koposov 36) using SDSS/2MASS/PPMXL/Gaia DR2

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## ABSTRACT

We present multi photometric and astrometric study of open cluster FSR 814 (Koposov 36) selected from the FSR catalog in different bands of Sloan Digital Sky Survey (SDSS), 2MASS, PPMXL and Gaia DR2. This study contains new results with a very high accuracy for the first time and generates the multi decontaminated color-magnitude diagrams to estimate the main astrophysical properties (such as: diameter, age, distance, reddening, geometrical projected distances, luminosity and mass functions) of FSR 814. Our results have been compared with other literatures.

## 1. Introduction

Open star clusters were considered very important laboratories to understand the structure and stellar evolution of our Galaxy. Sloan Digital Sky Survey (SDSS) has an excellent data to study the open star clusters. The latest version of the SDSS survey was released in 2016, contains the most recent reductions and calibrations of all data, and covers more than one-third of the celestial objects (Abolfathi et al., 2017).

2MASS survey is a preferable catalog for astronomical studies inside the Galactic plane (Skrutskie et al., 2006). Roeser et al. (2010) constructed the PPMXL catalog of proper motion for all sky survey. The ESA mission Gaia has been used the astrometric, photometric, and spectroscopic measurements of the all sky survey (Gaia Collaboration et al., 2016). The latest version of the Gaia data (Gaia DR2) is started on 25 April 2018, it covers more than 1.3 billion sources and contains three photometric bands ( $G$ ,  $G_{BP}$ ,  $G_{RP}$ ), the proper motion and parallax (Gaia Collaboration et al., 2018).

Froebrich et al. (2007) calculated the core radius of open cluster FSR 814 (Koposov 36)  $R_{cor} = 1.2$  arcmin and number of stars  $N = 554$ . Bonatto and Bica (2008) found  $R_{cor} = 1.24 \pm 0.44$  arcmin, limiting radius  $R_{lim} = 5.3 \pm 0.4$  arcmin, the distance from the Sun  $d_{\odot} = 1.6 \pm 0.1$  kpc, absorption  $A_v = 3.0 \pm 0.2$ ,  $t = 30 \pm 20$  Myr and the distance from the galactic center  $R_{gc} = 8.9 \pm 0.1$  kpc. Koposov et al.

(2008) measured the color excess  $E(B - V) = 0.83 \pm 0.11$ , the true distance modulus  $(m - M)_0 = 11.16 \pm 0.16$ ,  $d_{\odot} = 1700 \pm 150$  pc, and  $\log t < 8.35$ . Kharchenko et al. (2013) found  $R_{cor} = 0.60 \pm 0.19$  pc,  $R = 8.4$  arcmin,  $E(B - V) = 0.831$ ,  $d_{\odot} = 1600$  pc, and  $\log t = 8.445 \pm 0.021$ .

In this study, we determined the astrophysical parameters of open cluster FSR 814 in four surveys SDSS (see Tadross and Hendy, 2016), PPMXL, Gaia DR2 and 2MASS. Fig. 1 shows the images of open cluster FSR 814 in optical (R-band) and 2MASS (J-band). This paper is organized as follows: Data extraction is presented in Section 2. Determination of cluster center and radii are described in Section 3. While the cluster membership probability is presented in Section 4. The color-magnitude diagrams analyses are clarified in Section 5. The luminosity and mass function are devoted in Section 6. Finally, the discussions and conclusion of our study are summarized in Section 7.

## 2. Data extraction

The coordinates of FSR 814 in J2000 are  $RA = 84.20417^\circ$ ,  $DEC = +31.21167^\circ$ ,  $l = 177.06160^\circ$  and  $b = -0.41170^\circ$ , taken from Dias et al. (2002).<sup>1</sup> We extracted the photometric bands *griz* from SDSS,<sup>2</sup> JHK from 2MASS<sup>3</sup> and  $G$ ,  $G_{br}$ ,  $G_{bp}$  from Gaia DR2<sup>4</sup> within a radius of 10 arcmin. We applied the transformation equations of Chonis and Gaskell (2008) of SDSS data, where the uncertainty is found less

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<sup>1</sup> <https://wilton.unifei.edu.br/ocdb/>.

<sup>2</sup> <https://sdss.org/dr14>.

<sup>3</sup> <http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=II/246>.

<sup>4</sup> <http://gea.esac.esa.int/archive/>, <http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=I/345/gaia2>.

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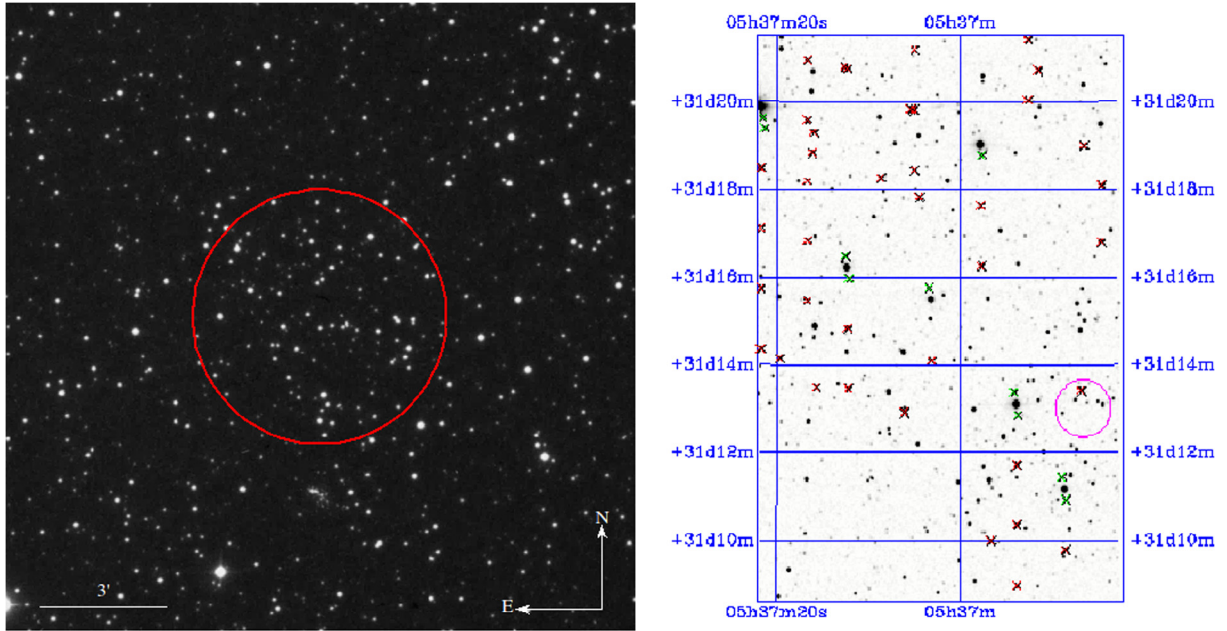


Fig. 1. The left panel (R-image) and right panel (J-image) of open cluster FSR 814 are extracted from the Digitized Sky Survey (DSS) and the (Two Micron All Sky Survey) 2MASS respectively.

than 0.009 and obtained the BVRI magnitudes. The limiting magnitudes of SDSS data g (4686 Å), r (6165 Å), i (7481 Å) and z (8931 Å) are 22.2, 22.2, 21.3 and 20.5 mag respectively. On the other hand, the limiting magnitude of 2MASS data J (1.25 μm), H (1.65 μm) and K (2.17 μm) are 15.8, 15.1 and 14.3 mag respectively; while of Gaia DR2 data G-band is 21 mag.

We extracted the proper motions of open cluster FSR 814 using the PPMXL catalog (Roeser et al., 2010). The mean error of the proper motion of bright stars ( $J \leq 10$  mag) and faint stars ( $J > 10$  mag) of this study are 5 mas/yr (Khalaj and Baumgardt, 2013). While in the Gaia DR2, we removed the negative distance (i.e. parallax  $\pi < 0$ ) by applying the relative error  $< 1$ , the mean error of the parallax and the proper motion for bright stars ( $G \leq 14$  mag) and faint stars ( $14 < G \leq 18$  mag) are 0.12 mas and 0.20 mas/yr respectively. We noticed that the accuracy of the proper motions using the Gaia DR2 is more accurate and better than the PPMXL, i.e. the errors in the proper motions using Gaia DR2 are better than the PPMXL by 25 times. The mean error in the photometric g-band and J-band of FSR 814 are 0.03 mag, 0.04 mag respectively, while the G-band magnitude of the Gaia DR2 is without error in that archive.

### 3. The cluster center and radii

We counted the stars in each right ascension (RA) and declination (Dec), the center of the open cluster is calculated at a value of the maximum stellar density of the cluster's area using the Gaussian fitting. The center of the open cluster FSR 814 is taken at RA = 84.19727° ± 0.00439 and DEC = 31.21595° ± 0.00430 as shown in Fig. 2, therefore, the Galactic coordinates are  $l = 177.05475^\circ$  and  $b = -0.41445^\circ$ . The differences of RA, DEC,  $l$ , and  $b$  between our results and what obtained from Dias catalog (Dias et al., 2002) are 0.414, 0.257, 0.411 and 0.165 arcmin respectively.

The open cluster area is divided to many concentric circles with a width of 0.2 arcmin. The star density  $\rho_i$  at the radius  $R_i$  in the  $i^{th}$  shell is estimated as  $\rho_i = N_i/A_i$ , where  $N_i$  is the stars number within the  $i^{th}$  circle and  $A_i$  is the circle area. To obtain the stars number within the suitable ring area, we subtracted the stars number within the  $(i + 1)^{th}$  circle from the number of stars in the  $i^{th}$  circle. The King's model (1966)

is applied to obtain the best fit of the radial density profile of FSR 814 as shown in Fig. 3.

$$\rho(R) = f_{bg} + \left[ \frac{f_0}{1 + (R/R_{cor})^2} \right]$$

where  $f_{bg}$ ,  $f_0$  and  $R_{cor}$  are the background density, central star density and the core radius of the cluster respectively. The bar errors are determined using the statistics Poisson error in each shell as  $P_{err} = 1/\sqrt{N_i}$ . By applying the King fit of RDP, we determined  $f_{bg} = 1.34 \pm 0.17 \text{ stars/arcmin}^2$ ,  $f_0 = 5.04 \pm 0.79 \text{ stars/arcmin}^2$  and  $R_{cor} = 1.17 \pm 0.27 \text{ arcmin}$ . The limiting radius of the open cluster FSR 814 was estimated at the radius that covers the entire cluster area, reaching enough stability of the background density for the cluster (Tadross, 2004), the stability value is taken at the limiting radius.

Bonatto and Bica (2009) estimated the density contrast parameter of star cluster as  $\delta_c = 1 + (f_0/f_{bg})$ , the ratio is within  $7 \leq \delta_c \leq 23$ . By according to this classification the density contrast parameter of open cluster FSR 814 is  $\delta_c = 4.76 \pm 0.11$  (i.e. FSR 814 is a compact open cluster, where our value is less than 7). The concentration parameter of FSR 814 is  $C = 0.68 \pm 0.05$ , by applying the equation  $C = \log(R_{lim}/R_{cor})$ , Peterson and King (1975). The core radius of open cluster FSR 814 ( $R_{cor} = 1.17 \pm 0.27 \text{ arcmin} = 0.59 \pm 0.14 \text{ pc}$ ) is in a very good agreement with Kharchenko et al. (2013), Bonatto and Bica (2008) and Froebrich et al. (2007), while our results of the limiting radius ( $R_{lim} = 5.6 \pm 0.4 \text{ arcmin} = 2.82 \pm 0.20 \text{ pc}$ ) are in a very good agreement with Bonatto and Bica (2008) more than Kharchenko et al. (2013).

### 4. Cluster membership probability

The membership of open cluster is difficult using only the radial density profile. To determine the membership probability, we used different methods, the first one of Haroon et al. (2014) for separating the open cluster FSR 814 from the field using SDSS. They calculated the statistical membership probability ( $P_i$ ) using the formula of Chen et al. (2004) for each star in the cluster as  $P_i = (1 - N_f/N_i)$ , where  $N_f$  is the mean number of the field stars inside the aperture radius and  $N_i$  is the total number of neighboring stars of  $i$ -star inside the same aperture. Chen et al. (2004) noticed that the distribution of field stars is not

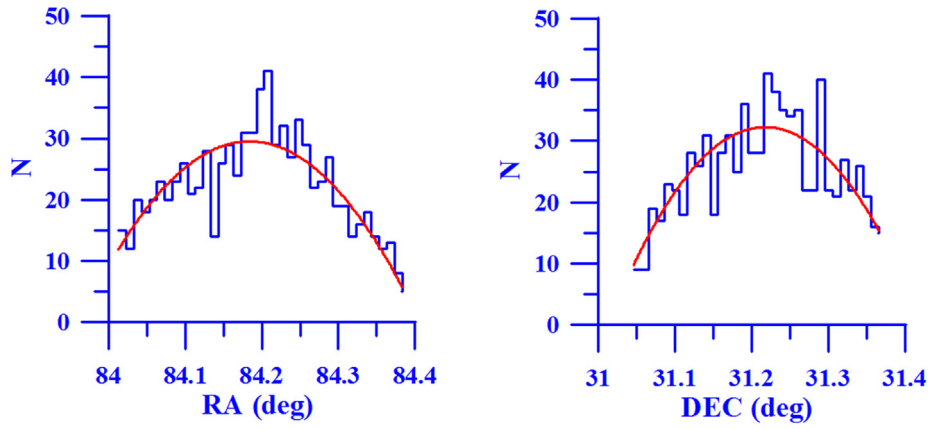


Fig. 2. The cluster's center in RA and DEC, which are presented in the left and the right panels respectively. The curved red line is the Gaussian fitting profile.

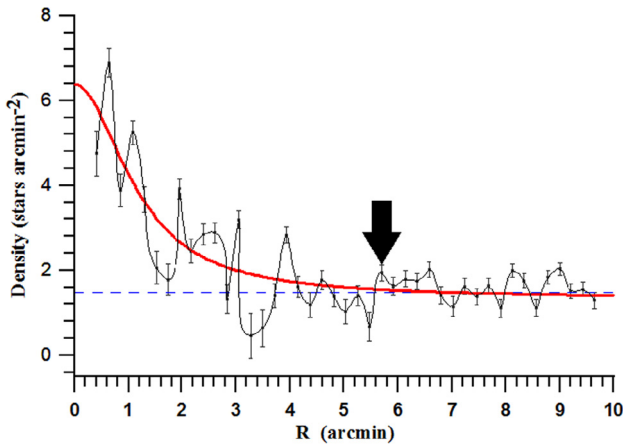


Fig. 3. The radial density profile of the open cluster FSR 814. The curved red line presents the King's model fitting (King, 1966). The value of the central star density is  $f_0 = 5.04 \pm 0.79 \text{ stars/arcmin}^2$ , while the estimated core radius and the limiting radius are  $R_{\text{cor}} = 1.17 \pm 0.27 \text{ arcmin}$  and  $R_{\text{lim}} = 5.6 \pm 0.4 \text{ arcmin}$  respectively.

homogeneous, because of the vertical gradient to the Galactic disk. We built a PYTHON code to count the stars inside different aperture radius (obtaining the best aperture radius). Starting from nearly 0.5 arcmin, containing more than 5–10 stars in the field region. Therefore, we obtained the membership probability  $P_i$  for more than 61% of each star in the studied cluster. The results of the star counting technique are used in building the CMDs  $[V_{\text{B}}(B-V), V_{\text{V}}(V-R), V_{\text{V}}(V-I) \text{ and } V_{\text{V}}(R-I)]$  of the SDSS as shown in Fig. 4.

The second method of the membership probability, using the proper motion of the PPMXL catalog (Roeser et al., 2010) to investigate the probable member stars. We applied the Gaussian fitting of the histogram in RA (Pmra) and DEC (Pmdec) of open cluster FSR 814, the mean proper motions are found to be  $2.10327 \pm 0.08443 \text{ mas/yr}$  and  $-9.62735 \pm 0.12309 \text{ mas/yr}$  in Pmra and Pmdec respectively. We determined the candidate stars within  $\pm 1\sigma$  from the peaks of Gaussian fitting ( $\sigma$  is the standard deviation). To calculate the membership probability using the PPMXL catalog, we used the same method of Kharchenko et al. (2004), also Bisht et al. (2018) used it:

$$P_k = e^{\left[ -0.25 \left( \frac{(\mu_x - \bar{\mu}_x)^2}{\sigma_x^2} + \frac{(\mu_y - \bar{\mu}_y)^2}{\sigma_y^2} \right) \right]}$$

where  $\sigma_x^2 = \sigma_{\mu_x}^2 + \sigma_{\bar{\mu}_x}^2$  and  $\sigma_y^2 = \sigma_{\mu_y}^2 + \sigma_{\bar{\mu}_y}^2$ , while the  $\mu_x$  and  $\mu_y$  are the proper motions of each star,  $\sigma_{\mu_x}$  and  $\sigma_{\mu_y}$  are the errors in the proper motion of each star. We obtained the membership probability for more than 61% of each star in open cluster FSR 814. Therefore, we defined

the member stars as the blue stars in the Vector Point Diagram (VPD), see the left upper panel of Fig. 5, while the red stars are the field stars, the results of this method are applied to the CMDs  $[J_{\text{V}}(J-H) \text{ and } J_{\text{V}}(J-K)]$  of the 2MASS as shown in Fig. 4.

In the Gaia DR2 data, we found that the mean parallax ( $\bar{\pi}$ ) of open cluster FSR 814 are  $0.48331 \pm 0.00897 \text{ mas}$ , see the right upper panel of Fig. 5. We selected the probable member stars within  $0 \leq \pi < 1$ , the mean proper motions are found to be  $0.53879 \pm 0.04211 \text{ mas/yr}$  and  $-3.34953 \pm 0.11036 \text{ mas/yr}$  respectively, see the lower panel of Fig. 5. The middle panels show the distance and true distance modulus distributions of stars in open cluster FSR 814 using Gaia DR2, the mean distance and true distance modulus of open cluster FSR 814 are found to be  $1.60401 \pm 0.03379 \text{ kpc}$  and  $11.23924 \pm 0.04926 \text{ mag}$  respectively. The results of this method are applied to the CMDs of the Gaia DR2 as shown in the lower panels of Fig. 4.

## 5. Color-magnitude diagrams analysis

The CMDs of the open cluster FSR 814 are built using the data from SDSS, 2MASS and Gaia DR2 are shown in Fig. 4. The CMDs of *griz* have been converted to BVRI photometry  $[V_{\text{B}}(B-V), V_{\text{V}}(V-R), V_{\text{V}}(V-I) \text{ and } V_{\text{V}}(R-I)]$ , while the CMDs of JHK 2MASS photometry and the  $G_{\text{BP}}G_{\text{RP}}$  Gaia DR2 photometry are  $[J_{\text{V}}(J-H) \text{ and } J_{\text{V}}(J-K)]$  and  $[G_{\text{V}}(G_{\text{BP}}-G_{\text{RP}}), G_{\text{V}}(G_{\text{BP}}-G) \text{ and } G_{\text{V}}(G-G_{\text{RP}})]$  respectively. The total number of the member stars in the CMDs for FSR 814 using the membership probability of Chen et al. (2004), Kharchenko et al. (2004) and the Gaia DR2 are  $\sim 495$ ,  $\sim 450$ , and  $\sim 380$  stars respectively.

To obtain the best fit for each CMD of the studied cluster FSR 814, we used the Padova isochrones of Marigo et al. (2017)<sup>5</sup> with the solar metallicity  $Z_{\odot} = 0.0152$  (Caffau et al., 2009, 2011), which covers the range of the ages  $6.6 \leq \log t \leq 10.13$ . The age of the open cluster FSR 814 is  $\log(\text{age/yr}) = 7.55 \pm 0.05$ , i.e.  $\sim 35.5 \pm 4 \text{ Myr}$ .

We used the absorption ratio of photometric systems in the different wavelengths (optical, infrared and ultraviolet) to the visual absorption ( $A_i/A_v$ ) (Cardelli et al., 1989; O'Donnell, 1994, and the Padova website (CMD)<sup>5</sup>). The absorption ratios of optical are:  $A_B/A_v = 1.297$ ,  $A_R/A_v = 0.815$  and  $A_I/A_v = 0.603$ , 2MASS:  $A_J/A_v = 0.296$ ,  $A_H/A_v = 0.182$  and  $A_K/A_v = 0.116$  and Gaia DR2:  $A_G/A_v = 0.859$ ,  $A_{\text{GBP}}/A_v = 1.068$  and  $A_{\text{GRP}}/A_v = 0.652$ .

These ratios have been used for correction of the magnitudes from the interstellar reddening and convert the color excess of optical, 2MASS and Gaia DR2 to  $E(B-V)$ :

$$R_V = A_V/E(B-V) = 3.1$$

$$E(B-V) = 1.690 E(V-R) = 0.801 E(V-I) = 1.523 E(R-I)$$

<sup>5</sup> CMD3: <http://stev.oapd.inaf.it/cgi-bin/cmd>.

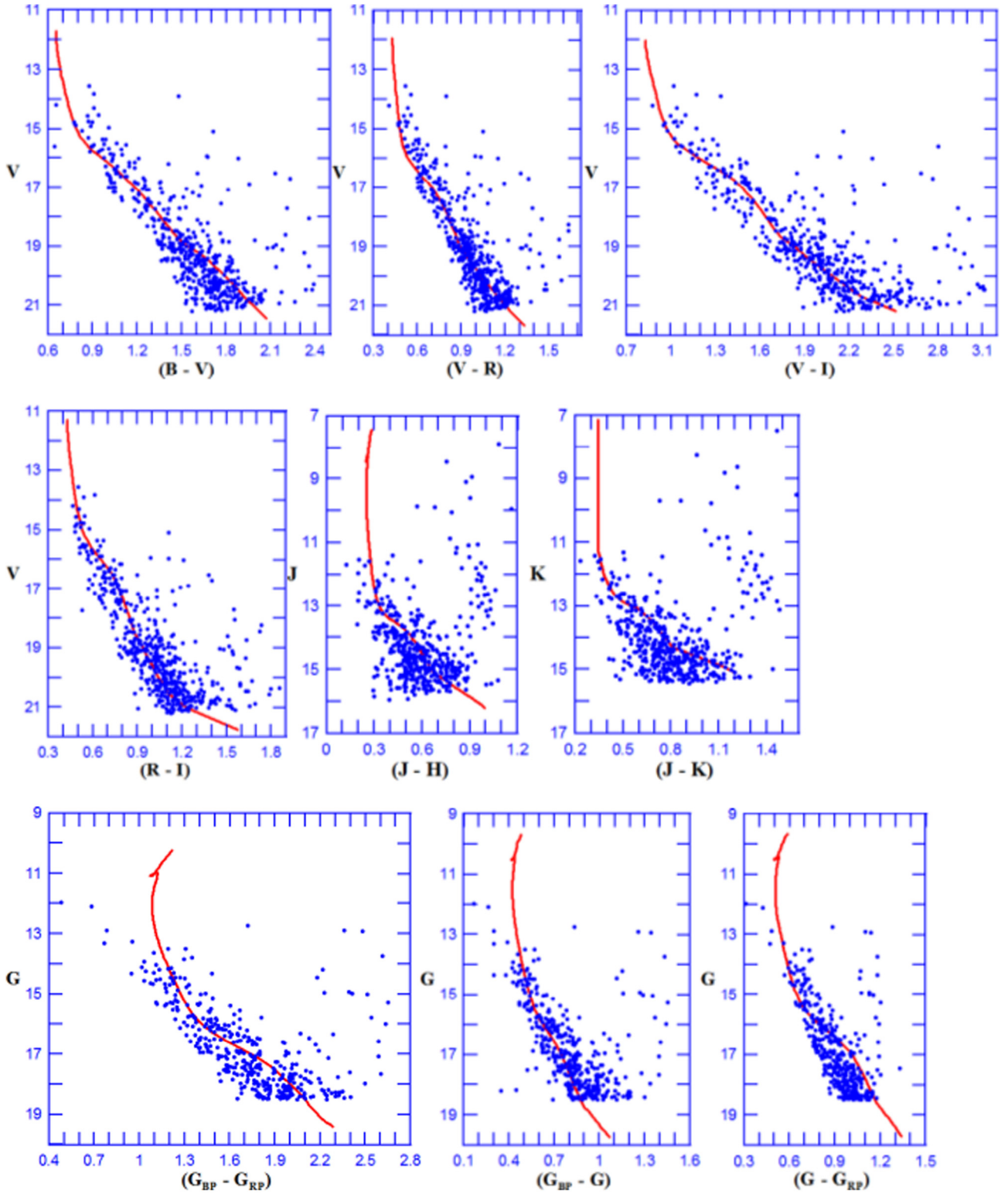


Fig. 4. Results of CMDs of open cluster FSR 814:  $V_{(B-V)}$ ,  $V_{(V-R)}$ ,  $V_{(V-I)}$  and  $V_{(R-I)}$  from SDSS,  $J_{(J-H)}$  and  $J_{(J-K)}$  from 2MASS,  $G_{(GBP-GRP)}$ ,  $G_{(GBP-G)}$  and  $G_{(G-GRP)}$  from Gaia DR2.

$$E(B-V) = 2.842 \ E(J-H) = 1.792 \ E(J-K)$$

$$E(B-V) = 1.289 \ E(G_{BP}-G_{RP}) = 0.647 \ E(G_{BP}-G) = 0.643 \ E(G-G_{RP})$$

The mean reddening, the true distance modulus, and visual absorption of the open cluster FSR 814 are  $E(B-V) = 0.94 \pm 0.02$ ,  $(m-M)_0 = 11.07 \pm 0.09$  and  $A_V = 2.93 \pm 0.06$  respectively. The distance of open cluster FSR 814 from the Sun is  $d_\odot = 1.64 \pm 0.06$  kpc.

The Galactic geometry calculations are determined using the sketch of Tadross (2011). The distance of open cluster FSR 814 from the Galactic center ( $R_{gc}$ ), the projected distances on the Galactic plane from the Sun ( $X_\odot$  and  $Y_\odot$ ) and the distance from the Galactic plane ( $Z_\odot$ ) are  $R_{gc} = 9.973 \pm 0.064$  kpc,  $X_\odot = 1.633 \pm 0.064$  kpc,  $Y_\odot = 0.084 \pm 0.003$  kpc and  $Z_\odot = -0.012 \pm 0.0005$  kpc respectively.

Our measurements (age,  $(m-M)_0$ ,  $E(B-V)$ ,  $A_V$ ,  $d_\odot$  and  $R_{gc}$ ) of the open



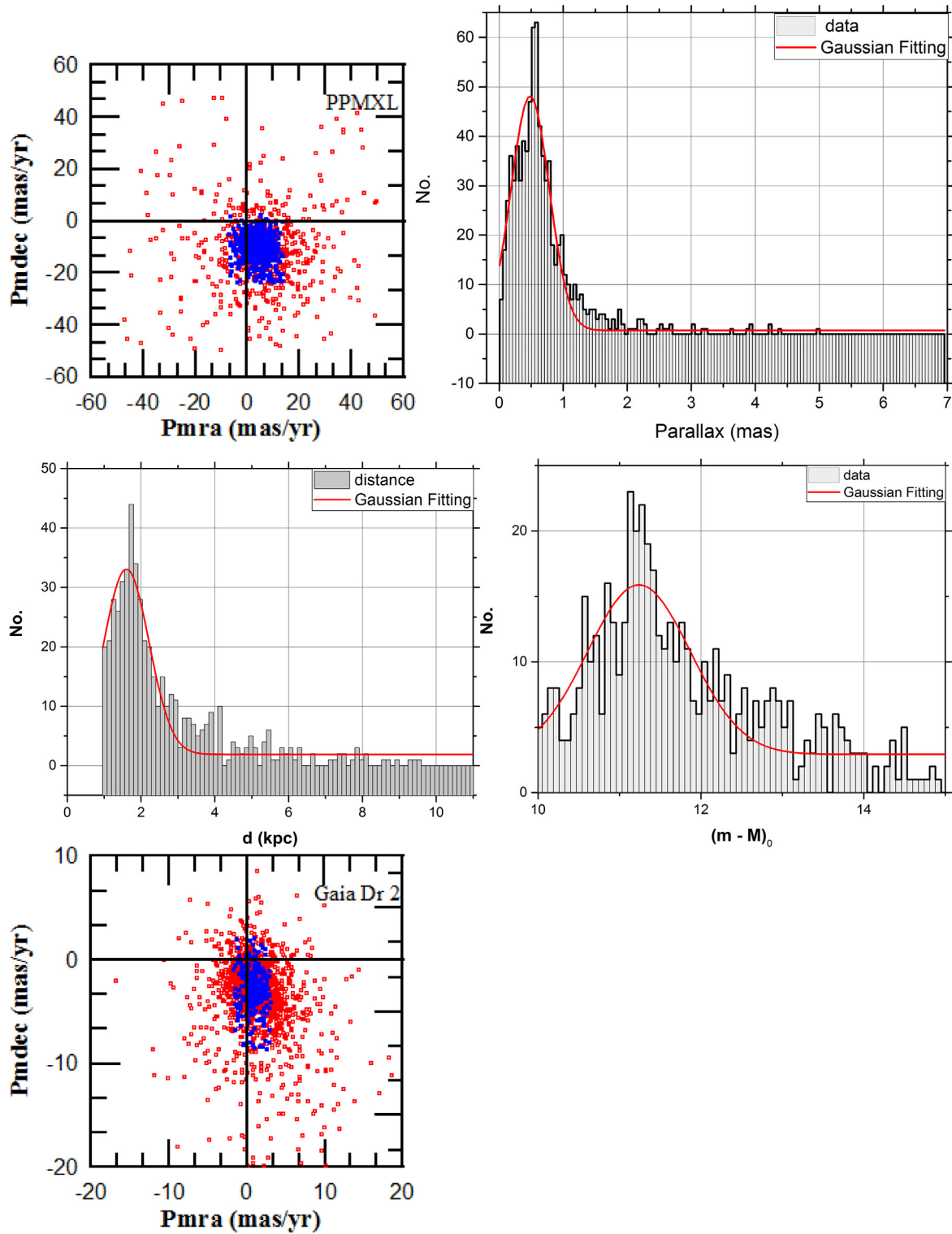


Fig. 5. The left upper panel presents the VPD diagram of open cluster FSR 814 using PPMXL, while the right upper panel presents the parallax distributions using the Gaia DR2. The middle panels show the distance and true distance modulus distributions of stars in open cluster FSR 814 from Gaia DR2 with  $0 \leq \pi < 1$  mas. The lower panel presents the VPD diagram of open cluster FSR 814 using Gaia DR2.

cluster FSR 814 are in good agreement with Bonatto and Bica (2008), Koposov et al. (2008) and Kharchenko et al. (2013). Using the astrometry measurements of Gaia DR2, we found that the mean distance of FSR 814 is  $d = 1.60 \pm 0.03$  kpc and the mean true distance modulus is  $(m-M)_0 = 11.24 \pm 0.05$  mag. These results are in good agreement with our results using the isochrones fitting.

## 6. Luminosity and mass function

We used the member stars in the CMDs of FSR 814 using the Gaia DR2 data ( $\sim 380$  stars) to determine the total luminosity ( $L_t$ ), total mass ( $M_t$ ), luminosity function (LF) and mass function (MF). The field star contamination, and membership uncertainty affected on results of the

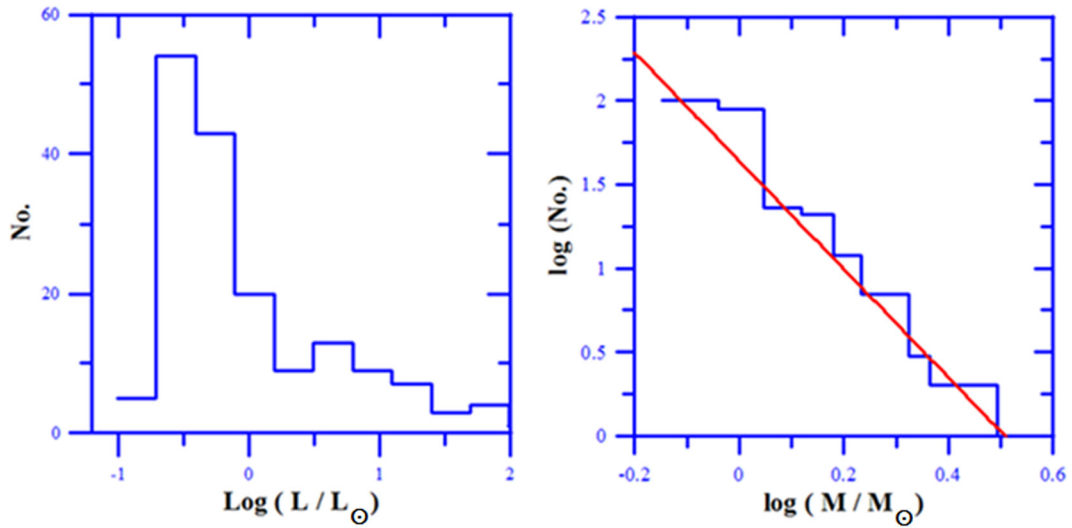


Fig. 6. The luminosity and the mass functions of open clusters FSR 814 are presented in the left and the right hand panels respectively.

Table 1

Comparison of our results with other literatures.

Parameter	This work	others
Coordinates center	RA = $84.19727^\circ \pm 0.00439$ DEC = $31.21595^\circ \pm 0.00430$ $\ell = 177.05475^\circ$ $b = -0.41445^\circ$	RA = $84.20417^\circ(1)$ DEC = $+31.21167^\circ(1)$ $\ell = 177.06160^\circ(1)$ $b = -0.41170^\circ(1)$
Membership (stars)	380	554 (2)
Mean parallax ( $\pi$ )	$0.48331 \pm 0.00897 \text{ mas}$	–
Mean proper motions	$\overline{Pmra} = 0.53879 \pm 0.04211 \text{ mas/yr}$ $\overline{Pmdec} = -3.34953 \pm 0.11036 \text{ mas/yr}$	–
Age	$35.5 \pm 4 \text{ Myr}$ $\log t = 7.55 \pm 0.05$	$30 \pm 20 \text{ Myr (3)}$ $\log t < 8.35 \text{ (4)}$ $\log t = 8.445 \pm 0.021 \text{ (5)}$
Metal abundance (Z)	0.0152	–
$E(B-V)$ (mag)	$0.94 \pm 0.02$	$0.83 \pm 0.11 \text{ (4)}$ $0.831 \text{ (5)}$
$(m-M)_0$ (mag)	$11.07 \pm 0.09$	$11.16 \pm 0.16 \text{ (4)}$
$A_V$ (mag)	$2.93 \pm 0.06$	$3.0 \pm 0.2 \text{ (3)}$
$d_{\text{sun}}$ (kpc)	$1.64 \pm 0.06$	$1.6 \pm 0.1 \text{ (3)}$ $1700 \pm 150 \text{ (4)}$ $1600 \text{ pc (5)}$
$d_{\text{linear}}$ (pc)	2.67	–
Radius (arcmin)	$5.6 \pm 0.4$	$5.3 \pm 0.4 \text{ (3)}$ $8.4 \text{ (5)}$
Core radius	$1.17' \pm 0.27 \text{ (} 0.59 \pm 0.14 \text{ pc)}$	$1.2' \text{ (2)}$ $1.24' \pm 0.44 \text{ (3)}$ $0.60 \pm 0.19 \text{ pc (5)}$
Concentration parameter (C)	$0.68 \pm 0.05$	–
Density contrast parameter ( $\delta_c$ )	$4.76 \pm 0.11$	–
$R_{gc}$ (kpc)	$9.973 \pm 0.064$	$8.9 \pm 0.1 \text{ (3)}$
$X_\odot$ (kpc)	$1.633 \pm 0.064$	–
$Y_\odot$ (kpc)	$0.084 \pm 0.003$	–
$Z_\odot$ (kpc)	$-0.012 \pm 0.0005$	–
LF	Estimated	–
MF	Estimated	–
IMF slope	2.29	–
Total mass ( $M_\odot$ )	250	–
Total luminosity (mag)	-3.93	–

References: (1) Dias et al. (2002). (2) Froebrich et al. (2007). (3) Bonatto and Bica (2008). (4) Koposov et al. (2008). (5) Kharchenko et al. (2013).

luminosity and mass function of open star clusters (Scalo, 1998). The new data of the Gaia DR2 is used to obtain good results for the member stars using measurements of the parallax and proper motions.

The luminosity function of the open cluster FSR 814 is determined by summing the V-band luminosities of all member stars. The true distance modulus of the open cluster FSR 814 has been used to obtain the absolute magnitude in V-band. We counted the absolute magnitude

with a suitable bin width to obtain the histogram of the luminosity function as shown in Fig. 6. The total luminosity has been calculated as the summation of the stellar absolute magnitude of that bin,  $L_t = -3.93 \text{ mag}$ .

The theoretical evolutionary tracks and their isochrones at  $\log(\text{age/yr}) = 7.55$  ( $35.5 \pm 4 \text{ Myr}$ ) of Padova isochrones of Marigo et al. (2017) have been used to obtain the mass ratio  $M/M_\odot$  of each member.

We applied the polynomial fitting on the relation between the absolute magnitudes ( $M_v$ ) and  $M/M_\odot$ . The total mass of FSR 814 is determined by deriving the masses of all member stars,  $M_t = 250 M_\odot$ .

The initial mass function (IMF) represents the experimental relation to obtain the mass distribution. It has been determined in terms of a power law as:  $dN/dM \propto M^{-\alpha}$ , where  $dN/dM$  is the number of stars within a mass interval ( $M: M + dM$ ), and  $\alpha$  is a dimensionless exponent. The IMF of larger than one solar mass (i.e. massive star) has studied by Salpeter (1955) with  $\alpha = 2.35$ . This means that stars number in each range of mass decreases rapidly with increasing the masses. The IMF slope of the open clusters FSR 814 is calculated to be  $-2.29$ , as shown in Fig. 6.

## 7. Discussions and conclusion

In this work, we presented the multi photometric systems of optical, infrared and astrometric data from the PPMXL and the Gaia DR2 (i.e. the highest accuracy of astrometry measurements nowadays) of open cluster FSR 814. We used the *griz* bands of the SDSS survey, applying the transformation equations of Chonis and Gaskell (2008) to obtain the optical bands BVRI.

We applied the Padova isochrones of Marigo et al. (2017) to obtain the best fitting to the CMDs. The absorption ratio of photometric systems in optical, infrared and ultraviolet (Cardelli et al., 1989; O'Donnell, 1994) have been used to correct the magnitude and convert the color excess from different wavelengths to E(B-V). Our measurements of the astrophysical parameters of FSR 814 are in good agreement with Froebrich et al. (2007), Bonatto and Bica (2008), Koposov et al. (2008) and Kharchenko et al. (2013). The comparison of our present work FSR 814 with previous studies is presented in Table 1.

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