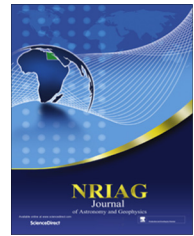




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FULL LENGTH ARTICLE

Infrared photometry of open star clusters Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78



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 Juchert-Saloran1;
 Patchick 78

Abstract In this work we present JHKs near-infrared photometric study for the poorly studied open star clusters Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78 based on 2MASS data. Astrometry and photometric parameters have been calculated using the Radial Density Profile (RDP) and Color Magnitude Diagrams (CMDs) fittings. Radius, distance, reddening, age, Luminosity Function (LF), Mass Function (MF), total mass and relaxation time have been calculated from the analysis of 2MASS data. The stellar memberships have been determined using a new method.

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1. Introduction

The conclusive tools for studying and tracing the formation and stellar evolution of galactic disk are Open Star Clusters (OSCs). Studying the OSCs traces back the first moments of the disk lifetime and putting essential constraints on its formation mechanism and evolution of the OSCs system, all this give us to examine the history of star and cluster formation over wide area of the galaxy. The strong interest in OSCs results comes from their unique and basic main characteristics, the

distance of the stars in stellar cluster is at the same from the Sun, and also they have the same age and chemical composition. Our galaxy has about 2000 known OSCs and most of these clusters are found in the galactic disk, while OSCs in the galactic disk to be of order of 10^6 at present. Piskunov et al. (2006) due to some estimation showed that, there are as many as 100,000 OSCs in our Galaxy, but less than 2000 of them have been confirmed and cataloged as OSCs. The fundamental physical parameters of OSCs, such as interstellar, distance, reddening, chemical composition, age and metallicity, are necessary for studying the clusters and the galactic disk. Kronberger et al. (2006) presented a list of some stellar groups, and their classifications as OSCs are needed to confirm. In this paper we would like to analyze the 2MASS data for some groups from this list, some of which are poorly studied. The groups which are selected for the present paper work are Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78. Fig. 1, represents the images of four OSCs as taken from Digitized Sky Surveys (DSSs).

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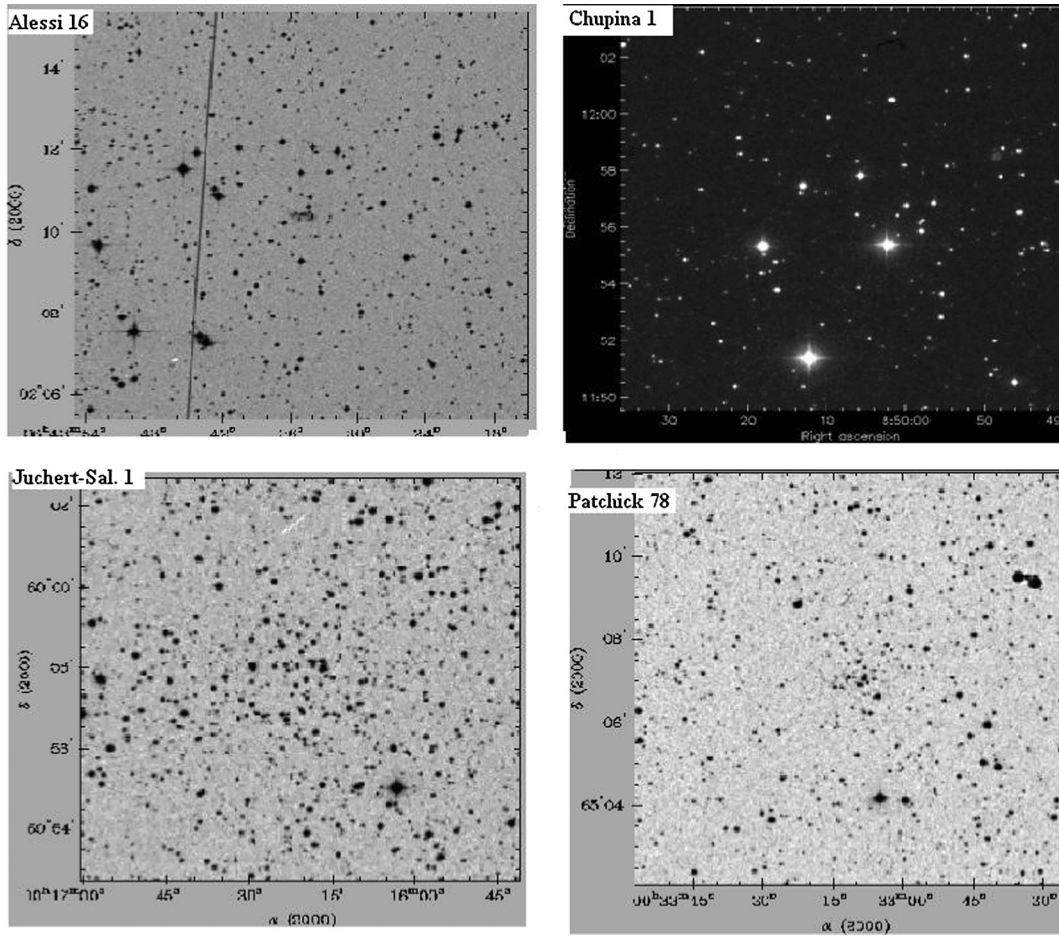


Figure 1 Images of the investigated OSCs Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78, as taken from DSS. North is up and east is the left.

Table 1 The coordinates of the clusters' sample.

Cluster vs. coordinate	<i>RAJ2000</i>	<i>DEJ2000</i>	<i>G.log (b)</i>	<i>G. lat. (l)</i>
	h:m:s	d:m:s	deg	deg
Alessi 16	06 43 35	+ 02 10 24	210.102	−0.755
Juchert-Saloran1	00 16 20.5	+ 59 57 43	118.547	−2.611
Patchick 78	00 33 10.2	+ 65 07 03	121.01	2.313
Chupina1	08 50 01	+ 11 56 07	215.399	31.694

This paper is organized as follows: In Section 2, the data analysis is presented; the astrometry and photometric analyses based on CMDs are presented in Sections 3 and 4 respectively. Luminosity Function and Mass Function & Dynamical State and Relaxation time are presented in Sections 5 and 6. Finally, the conclusion has been devoted to Section 7.

2. Data analysis

2.1. Data source and selection of cluster

2MASS data archive has been proved to be a powerful tool in the investigation of the structure and stellar content of open

star clusters Bonatto and Bica (2003), Soares and Bica (2002), Bica et al. (2003), and Selim et al. (2014). For the present investigation of four clusters (Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78), the only information known about these clusters is the equatorial coordinates (RA. and Dec.), which are taken from Dias et al. (2002) and Kronberger et al. (2006), and this information is listed in Table 1. From the equatorial coordinates of each cluster, the galactic longitude (l) and latitude (b) have been obtained directly using the following site: http://fuse.pha.jhu.edu/cgi-bin/eqtogal_tool.

The extractions of data have been performed using the known tool of VizieR for 2MASS database. The selected data of four selected clusters are extracted at a preliminary radius of

about 10 arcmin, centered on the optimized coordinates of the clusters. Also, for photometric quality, stars with errors in J, H and Ks more than 0.2 mag., have been excluded.

2.2. Angular sizes

The diameter of the cluster is one of basic physical parameters. RDPs have been used to determine the extent radius and study the structure of the clusters. The higher stellar density of stars in the cluster is considered as the cluster center. Firstly, in order to determine the clusters radii (real border) the radial surface density of the stars must be achieved. The cluster border is defined as “the surface which covers the entire cluster area and reaches enough stability in the background density”, i.e., the difference between the observed density profile and the background density profile, is almost nearly equal to zero (cf. [Tadross, 2009](#)). Several concentric rings around the cluster center have been synthetic and counting stars in each ring to determine RDP. So clusters area is divided into a number of concentric circles out to the preliminary radius of 10 arcmin. The stellar density (ρ) in each ring has been calculated as N/A , where A is the area of that ring and N is the stars number at this ring. Most stars have been found located in the central clusters region. Almost the stellar density decreases with radial distance from the center which finally nearly merges with the background field stars.

The observed stellar density (ρ) was calculated for each ring and plotted as a function of the angular radial distance from the cluster center (R). This density distribution was parameterized by King Model parameter ([King, 1966](#)):

$$\rho(r) = f_{bg} + \frac{f_0}{1 + \left(\frac{r}{r_{core}}\right)^2},$$

where f_{bg} , f_0 , and r_{core} are the background surface density, the central surface density and core radius, and their values for each cluster are listed in [Table 2](#). At the central surface density decrease to its half value the value of radius is called core radius of the cluster. The stellar density as a function of radial distance from the cluster center (R) has been plotted as shown in [Fig. 2](#). The point of the stellar density merges with the field (background surface density) star density considered the cluster extent. The estimated radii for each cluster are listed in [Table 2](#).

3. Photometric selection of candidate cluster members

K-means algorithm is one of the simplest clustering algorithms ([Chaturvedi and Green, 2001](#); [Kanungo et al., 2002](#)). In this section the new method presented by [Selim et al. \(2014\)](#) is used for open cluster membership determination based on K-means algorithm due to geometry and photometric properties. This

method consists of two stages; the first one is to clustering stars based on K-means (geometry) i.e. determining the centers of clusters by spatial density value is requiring reasonable initial values for the center and the radius.

The input of second stage of our method is clustering results from first stage, based on physical (photometric) properties criteria. We compute the difference in magnitude of color index $JH = Jmag - Hmag$ (color index), such that $-0.2 \leq \text{color index} \leq 0.2$. [Fig. 3](#) shows the CMDs of the stars member only located within its radius of each cluster, [Essam and Selim \(2015\)](#).

4. The color magnitude diagrams (CMDs)

The CMD of the cluster shows all the features of open star cluster. [Fig. 3](#) shows the J vs. $(J-H)$ of stars in the region of clusters Alessi 16, Juchert-Saloran1, Chupinal and Patchick 78 respectively.

The main parameters for each cluster (distance, age, and reddening) can be derived by fitting the solar theoretical Padova isochrones computed with the 2MASS J, H and Ks filters, ([Bonatto et al., 2004](#)) to the CMDs, and derive the cluster parameters. Several fittings have been applied to each cluster using different age's isochrones. Once the best fit has been obtained, we can get the age, distance and reddening $E_{(J-H)}$. As shown in [Fig. 3](#), the good matched isochrones give the interstellar reddening of $E_{(J-H)}$ and the true distance modulus $(m - M)_0$. The color excess $E_{(B-V)}$ can be also estimated, applying the relations, $E_{(J-H)} = 0.31E_{(B-V)}$, taken from [Joshi et al. \(2015\)](#), $E_{(J-H)}$ transforms into $E_{(B-V)}$. The clusters parameter has been listed in [Table 3](#).

4.1. Alessi 16

It is clear that the region of Alessi 16 contains much larger number of stars at the fainter magnitude range, where the main sequence branch star(s) can be seen. $E_{(J-H)} = 0.125$, with the true distance modulus $(m - M)_0 = 12.7 \pm 0.3$ mag. $E_{(J-H)}$ transforms into $E_{(B-V)} = 0.24$ mag using the relation $E_{(J-H)} = 0.23E_{(B-V)}$, taken from [Joshi et al. \(2015\)](#), and age in the range from 800 to 900 Myr.

4.2. Chupinal

Color Magnitude Diagrams (CMDs) of stars in region of Chupinal give the interstellar reddening of $E_{(J-H)} = 0.19$, the true distance modulus $(m - M)_0 = 12.3 \pm 0.2$, $Z = 0.019$, and age about 600 Myr. From the relation $E_{(J-H)} = 0.23E_{(B-V)}$, taken from [Joshi et al. \(2015\)](#) $E_{(J-H)}$ transforms into $E_{(B-V)} = 0.61$ mag.

Table 2 The clusters surface density and background values.

Clusters vs. parameters	Alessi 16	Juchert-Saloran1	Chupinal	Patchick 78
r_{core} arcmin	1.2 ± 0.02	1.6 ± 0.03	1.3 ± 0.025	0.78 ± 0.01
f_0	19 ± 0.3	29 ± 0.34	7 ± 0.1	155 ± 0.4
f_{bg}	3.2 ± 0.08	8 ± 0.07	1.9 ± 0.02	9 ± 0.05
Radius arcmin	3.5 ± 0.33	4.2 ± 0.2	2.4 ± 0.2	3.1 ± 0.12
Radius Pc	4.2	8.7	4	5.9

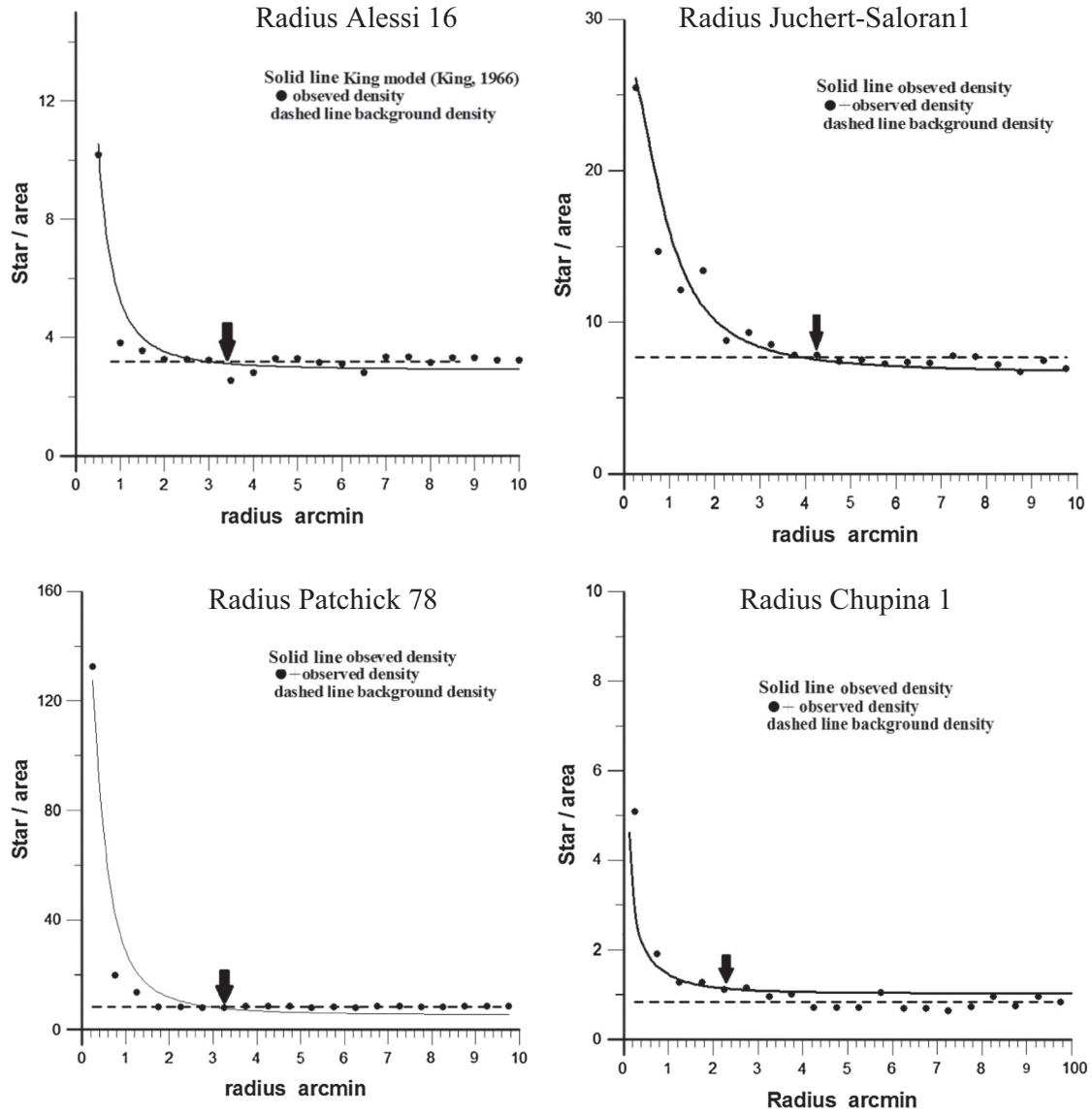


Figure 2 Radial density distribution for stars in the field of 4 open star clusters Alessi 16, Juchert-Saloran1, Chupina1 and Patchick 78. The arrow indicates the value of radius.

4.3. Juchert-Saloran1

J vs. $(J-H)$ color-magnitude diagram (CMD) of stars in the region of Juchert-Saloran1 the region of r_{lim} of about 4.2 arcmin contains much larger number of stars, and r_{core} of 1.6 ± 0.03 arcmin, while Bukowiecki et al. (2011) studied this cluster and gave its r_{lim} of 8.7 ± 0.6 arcmin and r_{core} of 1.09 ± 0.07 arcmin, and Ismail et al. (2015) studied this cluster and found r_{core} of 2.23 ± 0.49 and r_{lim} of 14.27 ± 0.25 . The interstellar reddening of $E_{(J-H)} = 0.24$, $(m-M)_0 = 11.7$, at $Z = 0.019$, and age about 900–1000 Myr. From the relation taken from Joshi et al. (2015), $E_{(J-H)}$ transforms into $E_{(B-V)} = 0.77$ mag.

4.4. Patchick 78

Color magnitude diagrams (CMDs) of stars in the region of Patchick 78 give the interstellar reddening of $E_{(J-H)} = 0.26$ mag.,

the true distance modulus $(m-M)_0 = 12.9$, $Z = 0.019$. From the relation $E_{(J-H)} = 0.31E_{(B-V)}$, taken from Joshi et al. (2015) $E_{(J-H)}$ transforms into $E_{(B-V)} = 0.83$ mag., and age = 600 Myr.

5. Luminosity function and mass function

Measurements of the stars number in a cluster with a given color and magnitude ranges are very important to understand the characteristics of the evolutionary stages of these objects. The stars count is essential tool for determining the luminosity functions of the investigated OSCs. LF gives the stars number per luminosity interval, or in other words, the number of stars in each absolute magnitude bin of the cluster. It is used to study the properties of large number of stars (groups or clusters) or classes of stellar objects. Before building the LFs, The apparent J band magnitudes of possible member stars have been converted into the absolute magnitude values using

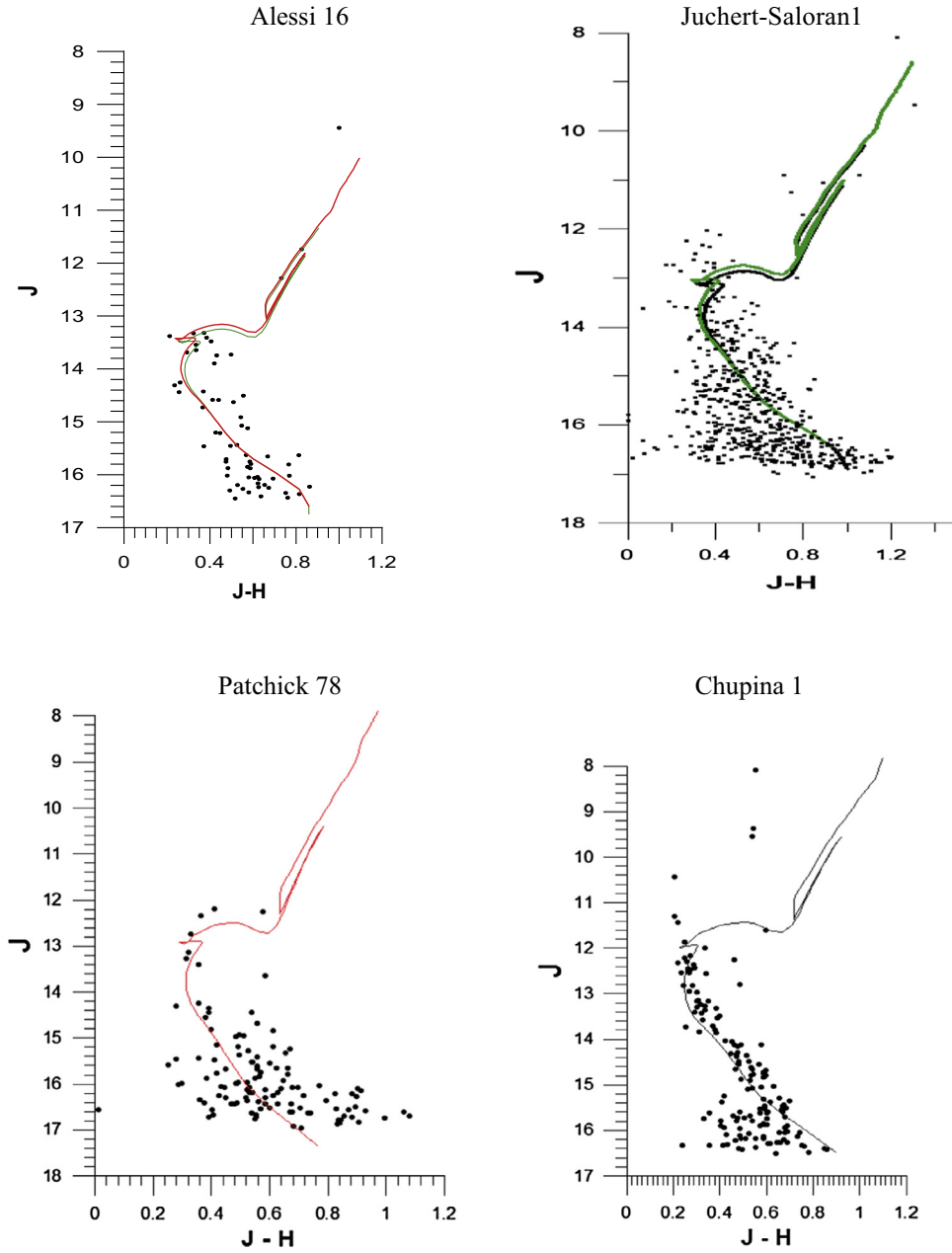


Figure 3 J vs. $(J-H)$ CMDs fittings with Padova isochrones, solar metallicity ($Z = 0.019$) for 4 open star clusters Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78, the J vs. $(J-H)$ color-magnitude diagrams. The solid lines represent the age of each cluster.

Table 3 The clusters properties.

Clusters vs. parameters	Alessi 16	Juchert-Saloran1	Chupina1	Patchick 78
Age (Myr)	900 ± 50	900–1000	600 ± 80	600 ± 50
$E_{(J-H)}$ (Mag)	0.125 ± 0.01	0.21 ± 0.01	0.23 ± 0.02	0.26 ± 0.03
$E_{(B-V)}$ (Mag)	0.40 ± 0.01	0.67 ± 0.021	0.76 ± 0.018	0.83 ± 0.02
$(m - M)_0$	11.6 ± 0.5	12.7 ± 0.3	12.3 ± 0.2	12.9 ± 0.7
Radius (R_lim)	3.5 ± 0.33	4.2 ± 0.2	2.4 ± 0.2	3.1 ± 0.12
Z	0.019	0.019	0.019	0.019

the distance moduli of the clusters. In order to estimate the LF we can count the observed stars in terms of absolute magnitude. We plot the cluster stars showing the number of stars at one mag intervals of M_J in the range of it. In our analysis,

the frequency distribution of the J absolute magnitude has been obtained, as shown in Fig. 4.

The luminosity function is transformed to the mass function based on the dependence of the mass on the luminosity

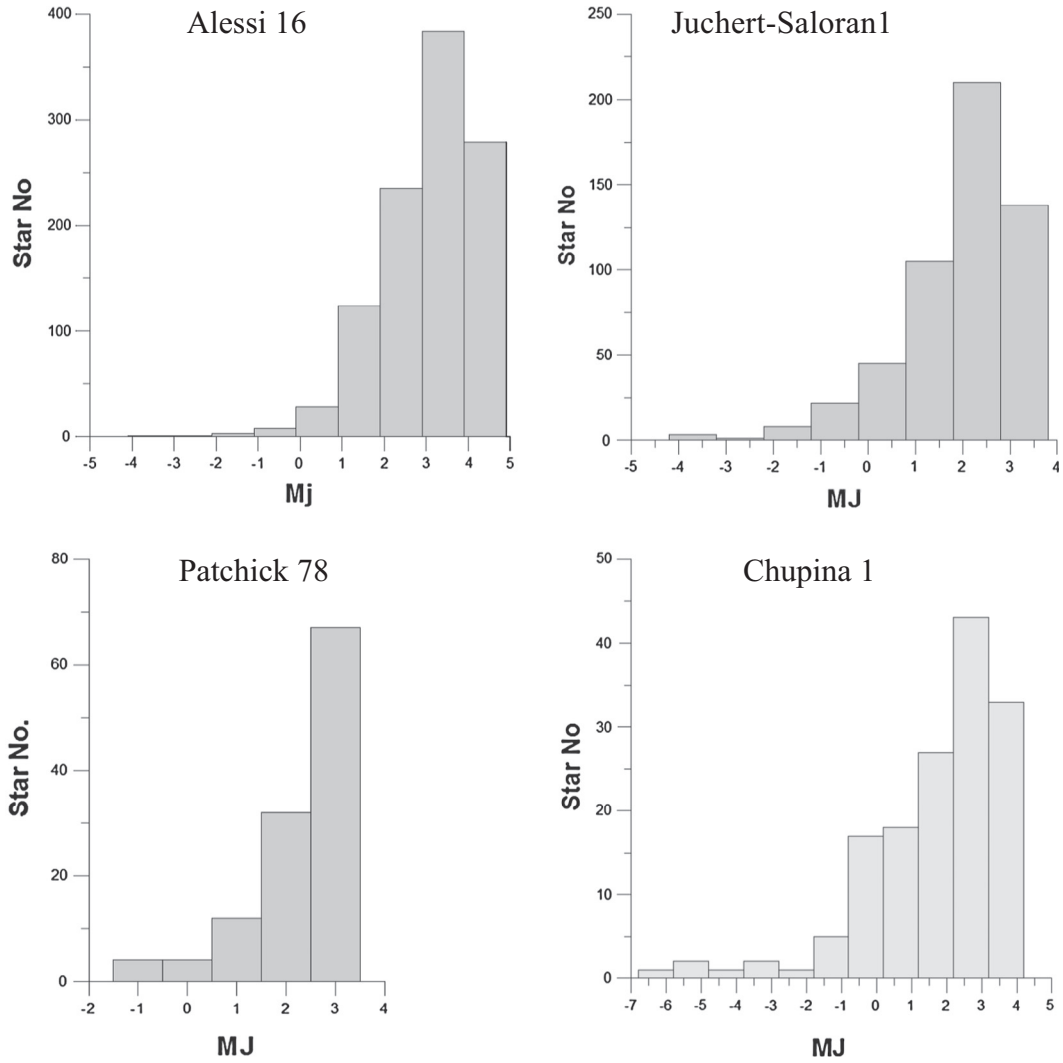


Figure 4 The luminosity functions of the clusters Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78.

Table 4 The dynamical parameters of the clusters.

Clusters vs. parameters	Alessi 16	Juchert-Saloran1	Chupina1	Patchick 78
Average star mass M_{\odot}	1.09	0.8	1.2	1.3
Total clusters mass M_{\odot}	135	419	182	158
Slope (IMF)	2.03	2.51	2.23	2.19
Relaxation time (Myr)	1.4	4.8	1.9	0.9

given in the selected theoretical Padova isochrones (Bonatto et al., 2004). The absolute magnitude and the masses for the selected isochrones with metallicity $Z = 0.019$ solar metallicity are used to construct the relation between M_{\odot} and absolute magnitude M_J . By counting the number of stars found in each mass bin, we derive the Mass Function (MF). We define the number of stars per mass bin, and the slope of the MF values is given in Table 4. The relation is a polynomial function of the second degree and has been used to determine masses of the cluster from the observed absolute magnitude M_J , then a histogram for the number of stars as a function of mass interval was performed and is presented in Fig. 5. We can estimate the total stellar masses for the total number of observed stars

within each cluster. The total mass has been calculated as the summation of the stellar masses in all bins. The number of stars in each bin has been multiplied by the mean mass of that bin; the result equals the total mass of that bin.

6. Dynamical stat and relaxation time

The dynamical relaxation time (T_E) is the time in which the individual stars exchange energies and their velocity distribution approaches a Maxwellian equilibrium T_E depending mainly on the number of members and the cluster radius and the mean total mass. It can be given in the next equation:

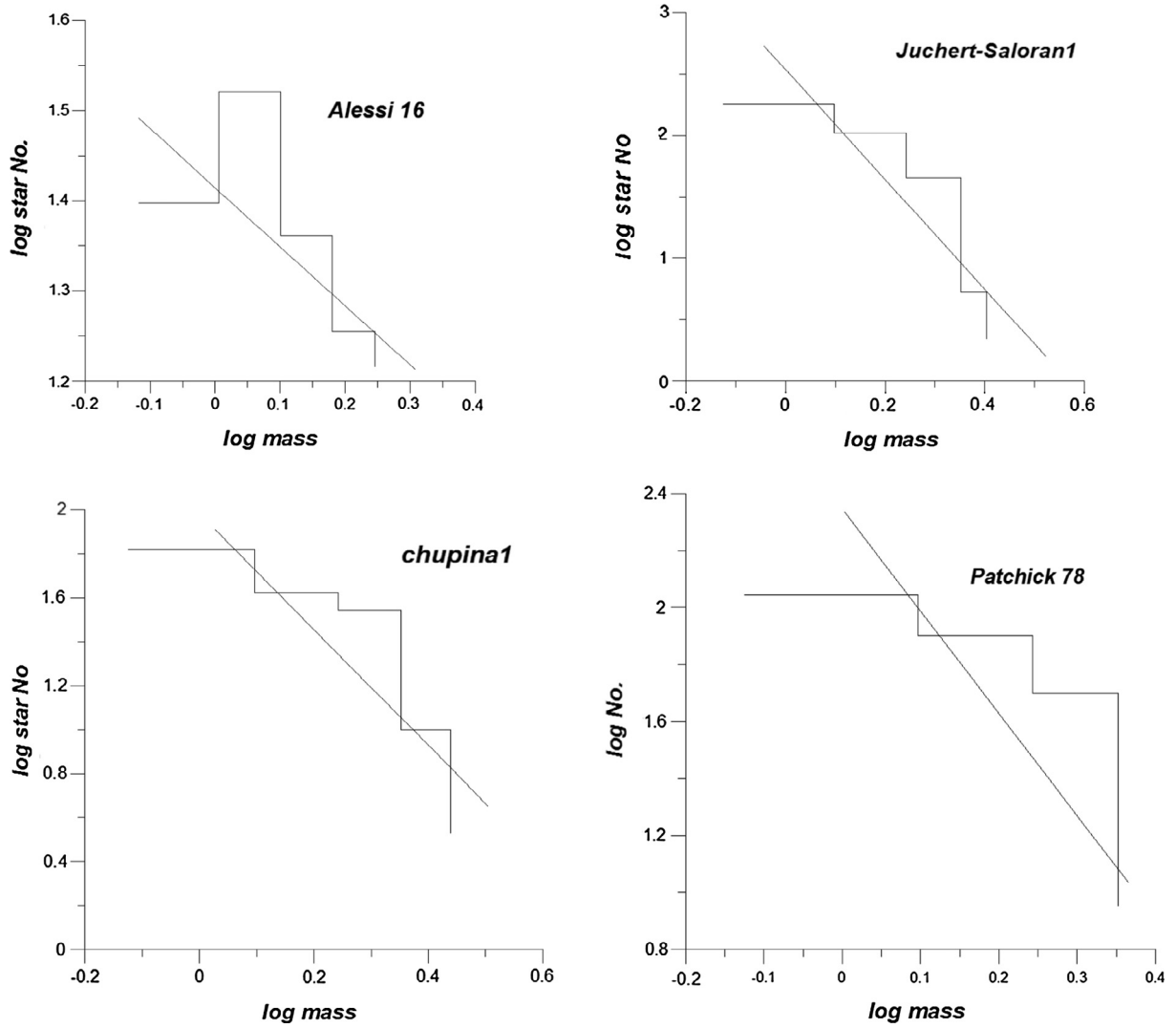


Figure 5 The mass functions of the clusters Alessi 16, Chupina1, Juchert-Saloran1 and Patchick 78.

$$T_E = \frac{8.9 \times 10^5 N^{1/2} R_h^{3/2}}{\langle m \rangle^{1/2} \log(0.4N)}$$

where R_h is the radius containing half the cluster mass, N is the number of cluster members, and $\langle m \rangle$ is the average mass in the cluster in solar unit (Spitzer and Hart, 1971). Using the above equation we can estimate the dynamical relaxation time of each cluster and compare it with its age (Age/T_E). The cluster dynamically relaxed due to, the cluster's age greater than its relaxation time, and vice versa. The calculated dynamical relaxation time (T_E in Myr) with R_h equals to half of the cluster radius in linear units, see Table 4. The T_E is smaller than the estimated cluster ages, and it may be inferred that the mass segregation effect and cluster dynamically relaxed due to dynamical evolution must be important.

7. Conclusions

In the present work, the JHKs 2MASS (infrared) data are used to determine the parameters of some new discovered stellar groups (poorly studied open star cluster). Our analysis has been applied for estimating the astrophysical parameters of

four really open star clusters, which have real stellar density profiles, the ages of these clusters have been determined and the CMDs of each cluster have been studied. Sharma et al. (2006) found several open clusters, and their sizes are usually larger in the near-IR bands, barring few exceptions, as compared to the optical bands. All parameters of the investigated clusters are listed in Tables 2–4.

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