Tours stars membership in the Pleiades open cluster

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ABSTRACT

In this paper, we study the characteristics and physical properties of the young open cluster Pleiades (NGC 1432; M45; Melotte 22; Seven Sisters) using Near Infra Red, JHK pass bands. Our results have been compared with those found in optical, UBV, newly observations. The membership validity of some variable binary stars, which are Located in Tours constellation, and their relation with Pleiades cluster have been achieved.

1. INTRODUCTION

Pleiades and Hyades are the most famous star clusters in Northern Hemisphere which can be seen by the naked eye in the constellation Taurus the bull. The star cluster surrounding Aldebaran (the eye of the bull) is the Hyades. Pleiades is more famous than Hyades because it is more compact cluster and easy seen, higher in the sky ~ 10 degrees from Aldebaran, see Fig 1. Pleiades is located at J (2000) $\alpha = 03^h: 47^m: 24^s$; $\delta = +24^o: 07': 12''$; G. long. = 166.642^o and G. lat. = -23.457^o. The distance to the Pleiades is an important first step in the so-called cosmic distance ladder, a sequence of distance scales for the whole universe. The optical photometry catalogs of Webda and Dais refer to Pleiades as a rich young cluster locates at 135-150 pcs away from Earth. In optical observations, Pleiades covers a diameter of about 110 arcmin on the sky; its core and tidal radii are about 33 and 330 arcmins respectively. The cluster contains over 1000 statistically members, excluding unresolved binary stars. It is dominated by young, hot blue stars, which have formed within the last 135-150 million years. The dust that causes faint reflection nebulosity around the brightest stars is the remnants that left over from the very beginning formation of the cluster; $E_{B\text{-}V} = 0.03$ mag; see Fig 2. The total mass of the cluster is about 800 $\mathcal{M}_\odot$. On the other hand, it contains many brown dwarfs, about 25% of the star cluster, which are objects with less than about 8% of solar mass, i.e. not heavy enough for nuclear fusion reactions to start inside.

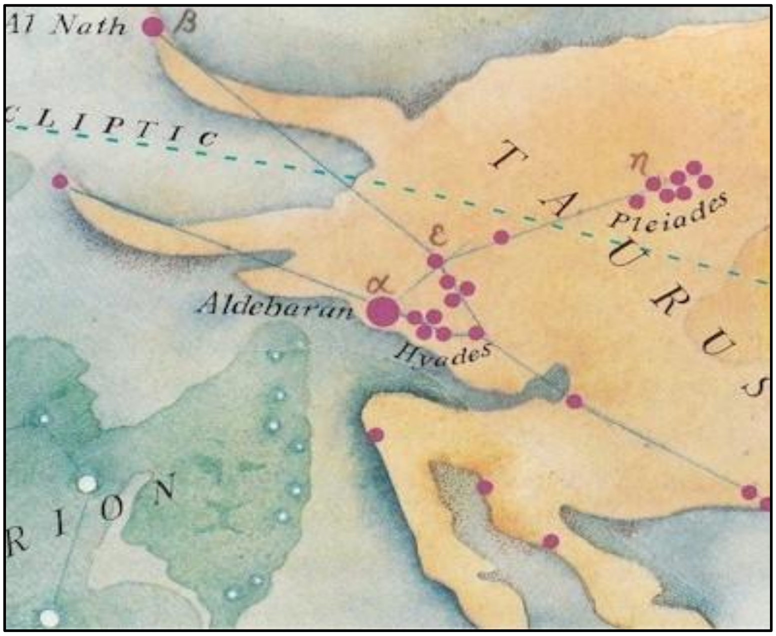

Fig 1: The constellation Taurus.

Fig. 2: The open star cluster Pleiades (NGC 1432; M45/ Melotte 22 / Seven Sisters).

North is up, and East on the left.

2. DATA EXTRACTION AND FIELD DECONTAMINATION

Data extraction has been performed using the known tool of VizieR[1]. The number of stars in the direction of Pleiades within a radius of 90 arcmin in the range of $5 \leq J \leq 13$ mag is found to be 2655 stars. Usually, field stars contaminate the CMDs of the cluster, particularly at faint magnitudes and red colors. In order to define the intrinsic CMDs of the cluster, we have to compare the CMDs of Pleiades with a nearby control field of the same area as the cluster. A control field is chosen at the same Galactic latitude, but with one degree away from the Galactic longitude of the cluster's center. Comparing the CMDs of the cluster and its control field at a given magnitude and color range; the number of stars in the control field should be subtracted from the cluster's ones. In this respect, for more accuracy, our data

[1] http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=2MASS

has been restricted with observational uncertainties of J, H, K<0.20 mag. Applying a cutoff of photometric completeness (J<13 mag) to both cluster and control field to avoid what is called over-sampling (Bonatto et al. 2004; Tadross 2008).

3. PLEIADES' DIAMETER ESTIMATION

To determine the cluster's minimum radius, core radius and tidal radius, the radial surface density of the stars should be constructed first. The tidal radius determination is made possible by the spatial coverage and uniformity of 2MASS photometry, which allows one to obtain reliable data on the projected distribution of stars over extended regions around clusters (Bonatto et al. 2005). We found that the background contribution level corresponds to the average number of stars included in the comparison field sample is 0.93 stars per $arcmin^2$. Applying the empirical profile of King (1962), the cluster's apparent radius turns out to be 70 arcmin, as shown in Fig 3.

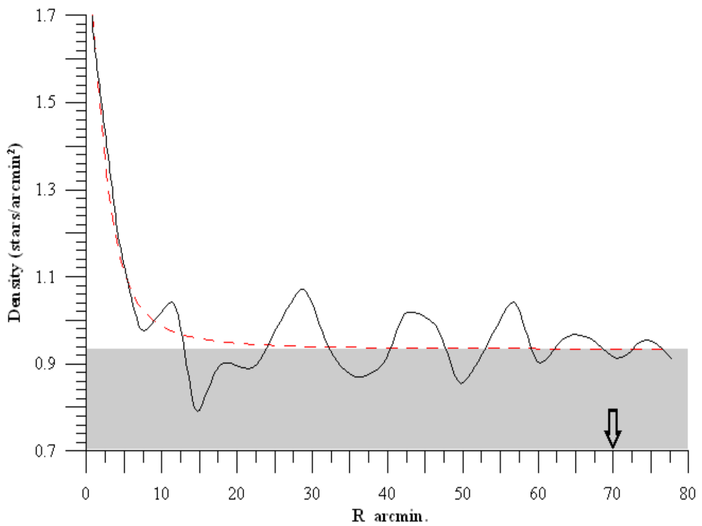

Fig 3: Radial distribution of the surface density of Pleiades (solid curve). The dashed line represents the fitting of King (1962). The arrow refers to the taken radius of the cluster (70 arcmin). The shaded region shows the mean level of the comparison field density, taken to be 0.93 stars per $arcmin^2$

4. COLOR-MAGNITUDE DIAGRAM ANALYSIS

Because the background field of Pleiades is very crowded and the cluster`s data is contaminated, the CMDs of Pleiades can be constructed with the stars inside radii of 1, 2, 3, etc., arcmin from the cluster center. Theoretical Padova isochrones of the solar metallicity (Z=0.019) with J, H, and K_S colors of Bonatto et al. (2004) have been used in fitting to derive the cluster parameters. Simultaneous fittings were attempted on the J ~ (J-H) and K_S ~ (J-K_S) diagrams for the inner stars, at which they should be less contaminated by the background field. If the number of stars were not enough for an accepted fitting, the next larger area would be included, and so on. In this respect, different isochrones of different ages have been applied on the CMDs of Pleiades, fitting the lower envelope of the points matching the main sequence stars, turn-off point, and red giant positions. The average age, reddening and distance modulus, within a ranging fitting error of about $\pm$ 0.10 mags, are determined. The data has been corrected for interstellar reddening using the coefficients ratios $\frac{AJ}{Av}$ = 0.276, $\frac{AH}{Av}$ = 0.176 and $\frac{AKs}{Av}$ =0.118 which were derived from absorption ratios in Schlegel et al. (1998), and Dutra et al. (2002) where R_v = 3.1.

Fig 4 shows the CMDs of the Pleiades, with magnitude completeness limit and the color filter for the stars within the apparent cluster radius of 70 arcmin. The membership criterion adopted here for inclusion of stars in CMDs that they must be close to the cluster main sequence, deviating by not more than about 0.12 mags. On this basis, the fundamental photometrical parameters of the cluster (reddening, apparent distance modulus, and age) can be determined simultaneously.

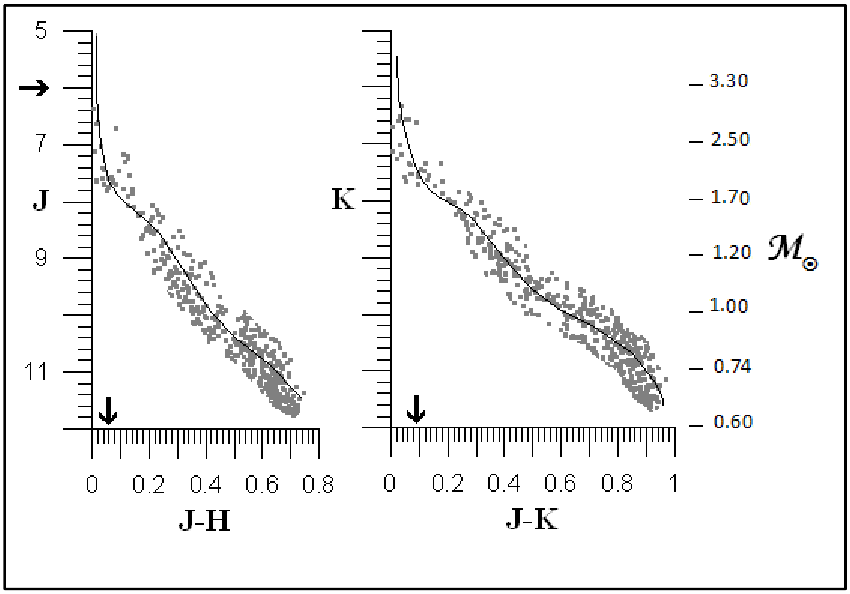

Fig 4: Padova solar isochrone (solid lines) with age of 150 Myr is fitted to the CMDs of Pleiades. Color and magnitude filters have been used in reducing the field star contamination of the cluster. The horizontal and vertical arrows refer to the values of distance modulus, and the color excess in each diagram, on the vertical and horizontal axes respectively. The scale of masses is presented on the right side of the figure, expressed in solar mass.

The overall shape of CMDs is found to be well reproduced with isochrones' age of 150 Myr old. The apparent distance modulus is taken at 6.00±0.10 mag, accordingly the intrinsic distance modulus of 5.83±0.10 mag, which corresponds to a distance of about 147±8 pc. On the other hand, the color excess E_{J-H} is found to be 0.06±0.03 mag, which corresponds to E_{B-V} of about 0.20 mags, which is agreement with Schlegel, et al. (1998).

The number of stars in the region of Pleiades is about 400 stars, with a mean mass of 1.9 $\mathcal{M}_{\odot}$. Then the total mass of Pleiades is 760 $\mathcal{M}_{\odot}$. It is noted that the mass estimation for unresolved binaries and low mass stars is always problem. Jaschek & Gomez (1970) claimed that approximately 50% of the main sequence stars might be hidden. According to this assumption, the total mass of Pleiades can be as large as 100ⁱ0 $\mathcal{M}_{\odot}$. Knowing the cluster`s distance in parsecs, the linear diameter can be easily estimated to be 6 pc. Applying the equation of Jeffries et al. (2001), the tidal radius of Pleiades is found to be 15 pc. The present photometric *JHK* work have been compared with previous *UBV* studies, e.g. WEBDA[2] and DIAS[3] catalogs, the results can be seen in Table 1.

5. THE VARIABLES IN TAURUS CONSTELLATION

The constellation “Taurus” contains many types of variable stars, the position of those that Located in the same area of Pleiades have been counted and drawn, on the face of the cluster, as shown in Fig 5. About 160 variables are found concentrated around the cluster’s center. The membership validity of those variables in the cluster area has been tested and expressed on the same CMDs of Pleiades, after applying the color and magnitude filters. 63 of them (~ 16% of the cluster’s stars) are found lie very closer to the cluster’s CMDs, and so their membership probability to Pleiades is photometric verified, as shown in Fig 6. Table 2 contains the details of the 63 variables members in Pleiades.

[2] *http://obswww.unige.ch/webda*

[3] *http://www.astro.iag.usp.br/_wilton/*

Table 1: Comparisons between the photometric parameters of the present *JHK* work and the previous *UBV* studies

Parameter	*Present work (JHK)*	*Previous studies (UBV)*
Distance modulus	6.00±0.10 mag.	5.97 mag.
Distance	147±8 pc.	150 Pc.
E_{J-H}	0.06±0.03 mag.	---
E_{B-V}	0.20 mag.	0.03 mag.
Age	150 Myr.	135-150 Myr.
Radius	70 arcmin (6 pc.)	60 arcmin
Tidal radius	15 pc.	---
Z	-60 pc.	-59.9 pc.
R_{gc}	9 kpc.	---
$X_{\odot}$	134 pc.	---
$Y_{\odot}$	32 pc.	---
Total mass	~ 1000 $\mathcal{M}_{\odot}$	~ 800 $\mathcal{M}_{\odot}$

Where Z, R_{gc}, $X_{\odot}$ and $Y_{\odot}$ are the distance from galactic plane, the distance from the galactic center, and the projected distances on the galactic plane from the Sun, respectively.

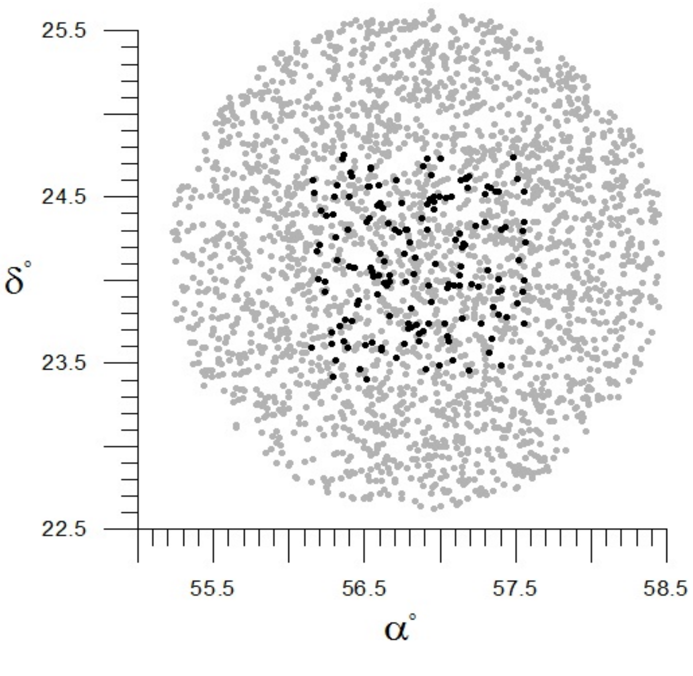

Fig 5: The variable stars that located on the face of Pleiades.

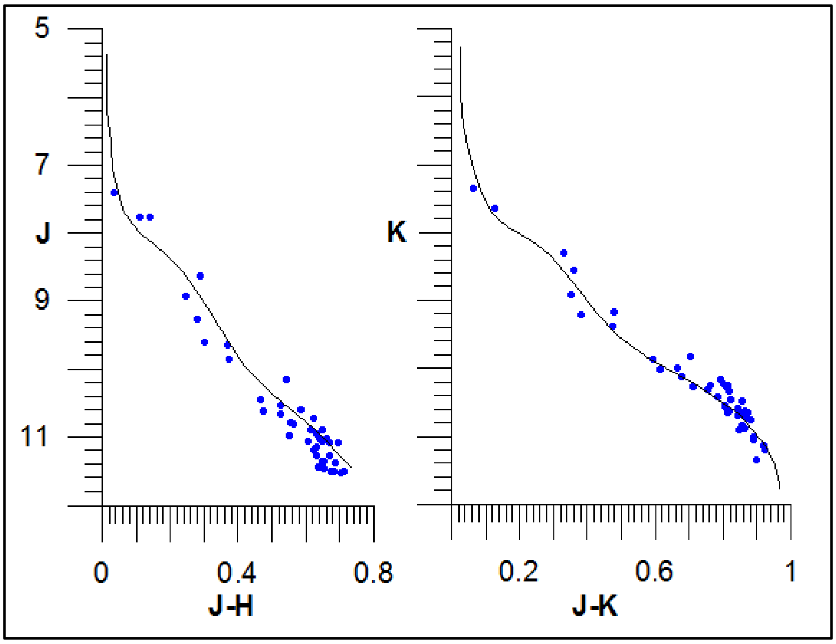

Fig 6: The membership validity of some variable stars in Pleiades' area; lying in the same CMDs of the cluster.

Table 2: The photometric data which obtained for the 63 variables of Taurus and located in Pleiades.

#	Name	r	RA J2000	DE J2000	J	H	K	J-H	J-K
1	BU	34.3851	57.2978	24.5194	14.093	13.626	13.552	0.467	0.541
2	NT	49.4368	56.1516	23.5965	15.894	15.241	14.795	0.653	1.099
3	NY	37.008	56.244	24.3912	14.711	14.318	14.126	0.393	0.585
4	NZ	30.9975	56.3047	24.2566	14.032	13.405	13.195	0.627	0.837
5	OT	33.7789	56.3732	23.7605	11.063	10.417	10.251	0.646	0.812
6	OW	26.881	56.4539	23.8529	11.476	10.822	10.661	0.654	0.815
7	PP	12.0526	56.6299	24.1174	11.284	10.614	10.461	0.67	0.823
8	QS	7.455	56.7959	24.231	14.269	13.72	13.398	0.549	0.871
9	QX	9.5706	56.9227	23.9719	11.066	10.461	10.312	0.605	0.754
10	V0338	37.7473	56.9989	24.7313	10.952	10.321	10.159	0.631	0.793
11	V0343	26.2268	57.072	24.5045	11.516	10.806	10.669	0.71	0.847
12	V0345	38.2476	57.0858	23.5171	14.431	13.816	13.533	0.615	0.898
13	V0352	17.0652	57.1478	24.2009	14.083	13.446	13.24	0.637	0.843
14	V0357	14.7287	57.0471	23.9501	16.251	15.903	15.818	0.348	0.433
15	V0360	42.2231	57.3258	23.564	13.665	13.146	13.108	0.519	0.557
16	V0369	39.8139	57.5465	23.9284	14.467	13.877	13.725	0.59	0.742
17	V0370	45.7666	57.5517	24.533	10.983	10.433	10.271	0.55	0.712
18	V0448	14.1959	56.6496	23.967	11.513	10.832	10.652	0.681	0.861
19	V0454	11.902	56.7759	24.3035	13.863	13.426	13.416	0.437	0.447
20	V0460	17.4625	57.124	23.9684	13.88	13.229	13.001	0.651	0.879
21	V0463	35.6185	57.189	24.624	14.078	13.465	13.172	0.613	0.906

Table 2: continued.

#	Name	r	RA J2000	DE J2000	J	H	K	J-H	J-K
22	V0527	24.4804	56.5857	24.4463	14.486	14.186	14.173	0.3	0.313
23	V0529	24.8685	56.6032	24.4651	13.651	13.266	13.145	0.385	0.506
24	V0530	12.6831	56.6665	23.9881	14.431	14.132	13.986	0.299	0.445
25	V0541	22.939	56.9216	23.7403	11.361	10.714	10.555	0.647	0.806
26	V0545	21.2057	57.2055	23.9773	10.658	10.133	9.992	0.525	0.666
27	V0554	44.8437	57.5563	23.7404	13.555	13.143	13.06	0.412	0.495
28	V0633	47.9025	56.153	24.601	14.932	14.466	14.414	0.466	0.518
29	V0646	5.0115	56.8256	24.0365	11.074	10.38	10.265	0.694	0.809
30	V0647	1.6994	56.8306	24.1391	7.767	7.627	7.639	0.14	0.128
31	V0650	26.3258	56.8618	23.6784	7.406	7.37	7.343	0.036	0.063
32	V0651	37.1801	56.91	24.7343	14.457	14.051	13.96	0.406	0.497
33	V0657	24.8378	57.0369	24.4943	15.331	15.144	14.782	0.187	0.549
34	V0669	46.6573	57.507	24.6135	14.479	13.905	13.578	0.574	0.901
35	V0703	34.1046	56.8903	24.6842	10.807	10.244	10.128	0.563	0.679
36	V0758	26.5463	57.1479	23.7682	13.659	13.364	13.369	0.295	0.29
37	V0787	22.9489	56.4337	24.0741	11.533	10.829	10.662	0.704	0.871
38	V0788	35.7599	56.5054	23.6111	15.442	14.683	14.539	0.759	0.903
39	V0789	31.9985	56.5287	24.5628	11.013	10.351	10.25	0.662	0.763
40	V0793	11.7098	56.9182	24.302	11.147	10.517	10.328	0.63	0.819
41	V0794	6.4847	56.9663	24.0965	13.8	13.207	13.023	0.593	0.777
42	V0813	32.2802	56.5271	24.5674	10.793	10.236	10.113	0.557	0.68

Table 2: continued.

#	Name	r	RA J2000	DE J2000	J	H	K	J-H	J-K
43	V0814	11.4522	56.6641	24.0297	10.454	9.986	9.859	0.468	0.595
44	V0815	24.2796	56.8064	23.7143	10.624	10.148	10.009	0.476	0.615
45	V0851	34.6691	56.2927	24.3922	14.363	13.64	13.386	0.723	0.977
46	V0854	39.4209	56.3646	23.6326	14.163	13.531	13.269	0.632	0.894
47	V0855	38.6823	56.4174	24.6272	8.624	8.337	8.294	0.287	0.33
48	V1006	51.8987	56.2914	23.4192	13.704	13.214	13.137	0.49	0.567
49	V1007	46.6558	56.3587	24.753	14.914	14.631	14.64	0.283	0.274
50	V1010	25.8624	56.4604	23.874	11.02	10.382	10.219	0.638	0.801
51	V1016	31.9607	57.1803	24.5565	15.001	14.594	14.521	0.407	0.48
52	V1044	16.9547	56.5579	24.0237	14.288	13.915	13.782	0.373	0.506
53	V1045	30.5685	56.5945	24.5702	9.274	8.994	8.923	0.28	0.351
54	V1065	46.4357	56.5172	23.4055	10.54	10.014	9.836	0.526	0.704
55	V1085	24.8671	56.3975	24.0832	8.921	8.673	8.562	0.248	0.359
56	V1088	37.5006	57.3371	24.5571	14.796	14.272	14.125	0.524	0.671
57	V1089	32.0883	57.3502	23.8393	9.854	9.482	9.378	0.372	0.476
58	V1090	35.249	57.388	23.7954	9.595	9.294	9.214	0.301	0.381
59	V1171	22.8488	56.6184	24.4339	9.638	9.27	9.159	0.368	0.479
60	V1172	39.0658	56.9083	23.4681	11.192	10.567	10.41	0.625	0.782
61	V1173	36.7509	57.5211	24.124	11.366	10.715	10.56	0.651	0.806
62	V1189	16.665	56.5536	24.0544	11.435	10.798	10.594	0.637	0.841
63	V1210	8.5927	56.7676	23.9952	7.77	7.658	7.642	0.112	0.128

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