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Gaia DR3 data of very young open cluster NGC 6530: distance and evolutionary stage of selected stars

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Abstract:

Gaia EDR3 and Gaia DR3 data of selected stars in the very young (1.5-million-year-old) open cluster NGC 6530 are presented. All the selected stars have very accurate Gaia DR3 distances. Most of the selected stars are very young B stars and several of them are young stellar objects (YSO). From the analysis of selected stars, the distance to NGC 6530 is found to be 1318 pc. The two very red stars VAJ 304 and 338 have little bit less proper motion than other members of the NGC 6530 and their Mv values are found to be -3.57 and -3.68 respectively. They are much brighter than K5 III RGB stars and less luminous than massive K5 red supergiants. It is likely VAJ 304 and VAJ 338 are not members of NGC 6530 they may be field K5 type AGB or post-AGB stars. Further study of these two stars is needed.

Keywords: Stars – Young Open Star Clusters- stars- NGC 6530

1. Introduction

NGC 6530 is a very young open cluster. Sung, Chun and Bessell (2000) derived the age and distance to be 1.5 million years and 1.8 kpc respectively. NGC 6530 contains several pre-main-sequence stars and young stellar objects (YSO) (Sung et al. 2000 and references therein). They derived E(B-V) = 0.35 and confirmed the presence of a small amount of differential reddening across the cluster (see also van den Ancker et al. 1997). Van Altena and Jones (1972) (VAJ) performed a proper motion study of stars in NGC 6530 and assigned percentage of membership probability P (%). Stars included in this paper are given identifiers beginning “VAJ”. Photometric studies of NGC 6530 were made by Kilambi (1977), Sagar and Joshi (1978), Chini and Neckel (1981) and van den Ancker et al. (1997) using the proper motion data of van Altena and Jones (1972). My interest in this very young open cluster NGC 6530 dates to 1974 when I discovered two very red stars in NGC 6530 stars based on the very low dispersion objective prism spectra (Parthasarathy 1974) These two stars are VAJ 304 and VAJ 338. The membership probabilities P (%) based on the proper-motion data of VAJ 304 and VAJ 338 from the paper of van Altena and Jones (1972) are 73 and 69 respectively. The presence of such very red stars in the

extremely very young open cluster is very puzzling (Parthasarathy 1974). With this aspect in my mind, I decided to study the Gaia EDR 3 and DR3 data (Gaia Collaboration 2021, 2022) and in SIMBAD data base (Strasbourg, France) of selected high probability P (%) members of NGC 6530 (van Altena and Jones 1972). In this paper an analysis of 45 stars is presented.

2. Selected stars of NGC 6530

I have selected 45 NGC 6530 VAJ stars with membership probability percentage P (%) 60 and above. Their Gaia DR3 data is presented in Table 1. All the stars have accurate Gaia DR3 parallaxes, distances and proper motions. The V, B-V values and spectral types listed in Table 1 are from van den Ancker et al. (1997). Only four stars (Table 1) VAJ 114 (LkHA 108), VAJ 165, VAJ 173, and VAJ 203 have RUWE values more than 1.4. All the other stars in Table 1 have RUWE values less than 1.4. The forty-five stars listed in Table 1 can be considered as a subset of VAJ stars. The stars listed in Table 1 also form a subset of VAJ stars in the paper of van den Ancker et al. (1997). VAJ paper contains 363 stars and a good number of them have membership probability P (%) 60 and above. For most of these stars UBV photometry and spectral types are not available. I have selected 45 stars for which UBV photometry, and spectral types are available. I have not included binary stars. The aim of this research note is to work with a limited sample that is good enough to get distance and to understand the evolutionary stage of VAJ 304 and VAJ 338. Detailed analysis of Gaia DR3 data of all 363 VAJ stars is needed, which is beyond the scope of this research note.

Table 1. Selected stars

VAJ	P%	V	B-V	G mag	Spec	Mu (mas/yr)	d (pc)	Comments
30	64	12.43	0.20	12.38	B7	3.022	1296	
35	76	12.28	0.23	12.22	B8	3.074	1081	
93	83	11.70	0.32	11.53	B3	2.375	1336	
94	80	11.96	0.14	11.74	B6	2.298	1446	YSO
107	86	10.05	0.13	9.91	B2Ve	2.744	1158	YSO
113	78	12.24	0.26	12.22	B2	2.219	1279	YSO
114	77	11.71	0.42	11.56	B6e	2.270	1124	YSO
120	62	12.18	0.25	12.14	B3	2.264	1376	
138	77	11.95	0.21	11.89	B7V	2.478	1372	YSO
142	69	12.67	0.26	12.65	A0?	2.369	1297	
146	86	11.41	0.14	11.39	B7	2.183	1332	
147	62	11.62	0.26	11.54	B6e	2.345	1571	YSO
149	64	11.95	0.18	11.82	B7	2.531	1360	
152	84	10.37	0.12	10.35	B3V	2.486	1313	YSO
157	68	12.16	0.50	12.06	A0	1.941	1258	YSO
161	84	9.12	0.04	9.13	B1Ve	2.551	1379	
163	76	12.28	0.27	12.23	B9	2.157	1054	YSO
165	60	11.58	0.22	11.51	B8	2.659	1286	YSO
171	85	12.11	0.31	12.06	A0	2.094	1275	YSO

173	78	13.05	0.60	12.82	A1 III	3.021	1334	YSO
177	62	11.57	0.29	11.49	B9 III	2.354	1286	YSO
180	81	10.02	0.17	9.71	B1 Ve	2.526	1241	HB Ae/Be
181	61	12.51	0.42	12.38	A5	3.337	1017	
182	75	8.90	0.12	8.85	B1 V	2.693	1153	
184	81	9.74	0.15	9.60	B1 V	2.504	1318	
187	70	11.47	0.24	11.39	B3	3.184	1388	YSO
192	79	10.17	0.12	10.12	B2 V	2.470	1241	YSO
194	86	11.99	0.35	11.89	B8	2.035	1318	YSO
195	74	12.72	0.36	12.60	A5/A9	2.992	1298	YSO
197	83	10.54	0.13	10.42	B2 V	2.470	1233	YSO
202	86	10.70	0.12	10.62	B2 V	2.645	1226	YSO
203	83	12.01	0.47	11.88	A1	2.987	1305	YSO
204	85	9.68	0.09	9.48	B2 V	2.410	1349	YSO
210	75	10.45	0.16	10.42	B2 V	2.138	1224	YSO
216	79	11.92	0.26	11.83	B6	2.967	1431	YSO
223	84	8.51	0.04	8.53	B0 V	2.667	1438	YSO
229	77	11.41	0.14	11.32	B4	2.817	1469	YSO
240	70	11.22	0.24	11.16	B3 V	3.213	1226	YSO
245	79	11.95	0.43	11.72	B5Ve	2.814	1310	HB Ae/Be
247	81	11.50	0.25	11.43	B3	2.593	1525	YSO
250	86	11.71	0.27	11.62	B3/5	2.768	1397	YSO
256	71	10.81	0.30	10.73	B3 V	2.860	1225	YSO
266	80	11.71	0.29	11.63	B5	2.499	1313	
304	73	9.92	2.29	8.34	K7 III	1.906	1504	
338	69	10.26	2.36	8.80	K7 III	1.836	1514	

3. Analysis

A and F type stars may not be the members of NGC 6530. They may be foreground and background field stars. For several stars (Table 1) Gaia DR3 spectra are available and an analysis of them can yield their refined spectral types and astrophysical parameters.

Accurate radial velocities for most of the stars of NGC 6530 are not available. Gaia DR3 radial velocities of early type (OB) are available for some of the stars but they are not accurate. The Gaia DR3 radial velocities are derived using the wavelength interval from 846nm to 870nm. In this wavelength interval the hot stars spectra are dominated by Paschen lines with no other suitable spectral lines for radial velocity determination. The problems of Gaia EDR3 radial velocities of hot stars are discussed by Blomme et al. (2023). Randich et al., (2022) and Hourihane et al. (2023) derived high radial velocity values for some of the stars and they are not in agreement with the earlier radial velocities given in the literature. For example, for VAJ 35 and VAJ 113 Randich et al. (2022) give a radial velocity of 380 km/sec and 400 km/sec respectively. Similarly, Hourihane et al. (2023) for VAJ 177 and VAJ 180 give 47 km/sec and 45 km/sec respectively. These values are not in agreement with the radial velocities of other stars of NGC 6530. From Gaia DR3 data VAJ 107, VAJ 161, and VAJ 245 (LkHA 115) are found to be variable stars.

3.1 Distance to NGC 6530

Previous investigators estimated the distance to NGC 6530 ranging from 1 kpc to 2 kpc, With the advent of Gaia accurate distances and proper motions of stars in NGC 6530 became available. Based on the distances given in Table 1 I find the mean distance to NGC 6530 is 1318 pc. VAJ 304 and VAJ 338 are not included (see section 3.2). Sung et al. (2000) found 37 pre-main-sequence stars in NGC 6530. Based on the Gaia DR3 data of six stars brighter than V= 16.0 from their paper I find the distance to NGC 6530 to be 1258 pc. 1318 pc distance based on the data given in Table 1 seems to be the more correct distance to NGC 6530 when compared to previous distance estimates which are based on the photometry data and interstellar reddening corrections.

3.2 VAJ 304 and VAJ 338

The Gaia DR3 data, photometry, and spectral types of VAJ 304 and VAJ 338 are now available (Table 1) . Using the intrinsic (B-V)0 value of a K5 III star the E(B-V) values of VAJ 304 and VAJ 338 are found to be 0.79 and 0.92 respectively. Using the Gaia DR3 distances of these two stars given in Table 1 the absolute visual magnitudes (Mv) are found to be Mv = -3.57 (VAJ 304) and Mv = -3.68 (VAJ 338). The Mv values of normal K5 III and K5 I stars are -0.2 and -5.8 respectively (Cox 2000). Their absolute luminosities are more than that of K5 III Red Giant Branch (RGB) stars and significantly less than that of massive K5 I red supergiants. Their Gaia DR3 proper motion values (Table 1) are little bit smaller than proper motion values of other members of NGC 6530 (Table 1). VAJ 304 and VAJ 338 may be field stars. Their location in the HR diagram indicates they may be evolved field stars in the AGB or post-AGB stage of evolution. Their luminosities are not in agreement with the luminosities of K-type pre-main-sequence or main-sequence stars and K type RGB stars. Detailed chemical composition determination of these two stars is needed to resolve this puzzle.

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