https://doi.org/10.18524/1810-4215.2023.36.290534

SPECTROSCOPIC INVESTIGATIONS OF POLARIS FIELD STARS

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ABSTRACT. We present the results of an analysis of 28 spectra of 18 Polaris field A–G V stars obtained in 2016–2023. Derived radial velocities and $T_{\rm eff}$ along with distances and reddenings from the Gaia DR3 catalog allowed us to calculate radii of the stars and compare them with calibration relationships "Specral type – Luminosity" for MS stars. As a result, radii and distances for 9 stars were found overestimated compred to those determined photometrically. Therefore, the DR3 distances are unreliable and should be revisited. Accordring to our data for these stars and their photometric distances, 15 objects belong to a possible old open cluster that is currently dissolved in the Polaris field at a distance ∼70–110 pc, while two objects belong to the thick disk, and one belongs to a possible another star group located at a distance of 130 pc.

Key words: Open clusters: Stars: Polaris field stars; radial velocities; main-sequence stars: effective temperatures, radii; GAIA DR3 effective temperatures, distances, reddenings, radii; spectroscopic binaries; pusating variables δ Sct type; thick disc; Individual: HD 5914, HD 10772, HD 11696, HD 14369, HD 14718, HD 16335, HD 66368, HD 90162, HD 163988, HD 203317, HD 209556, HD 224687, HD 224991, Polaris B, BD +86°44, BD +87°16, BD +87°26, BD +88°75. Cepheids: α UMi.

АНОТАЦІЯ. Даються результати аналізу 28 спектрів 18 зір Головної послідовності спектральних класів A-G з поля Полярної, відомої класичної цефеїди, отриманих у 2016-2023 рр. Проміряні променеві швидкості та $T_{\rm eff}$ разом із відстанями та почервоніннями, узятими з каталогу Gaia DR3, дозволили нам обчислити радіуси цих зір та порівняти їх з калібрувальними співвідношеннями "Спектральний клас – Світність"для зір ГП. Судячи зі спектрів, HD 90162 дійсно є спектроскопічно-подвійною системою, тоді як HD 14718 і HD 163988 є можливими подвійними. 61% досліджуваних об'єктів – незмінні зорі, а три об'єкти (HD 5914, HD 203317 і HD 224991) можуть бути низькоамплітудними пульсуючими змінними типу δSct. Наші оцінки ефективних температур, отримані за допомогою спектроскопії або фотометрії показали їх приблизну схожість з оцінками з каталогу DR3 для зір спектральних класів F-G, тоді як для більш гарячих зір A-типу різниця становить 300-500 K. Оцінки радіусів зір, розраховані за значеннями $T_{\rm eff}$, почервоніннями та відстанями з DR3 для половини зір виявилися завищеними і невідповідними їх спектральним типам. Перерахунки радіусів і відстаней для зір з використанням наших оцінок $T_{\rm eff}$ із калібрування "Спектральний тип – світність"для зір ГП також підтвердили, що для половини зір оцінки відстані з DR3 ненадійні. Найбільші розбіжності в оцінках відстані між даними DR3 і калібруваннями знаходяться на відстанях більше 130 пк і мають експоненціальний характер. Судячи з отриманих оцінок RV і фотометричних відстаней, 15 зір, ймовірно, належать до старого розсіяного скупчення, розчиненого серед зір поля Полярної і розташовані на відстанях ∼70–110 пк, але при цьому два об'єкти належать до товстого диска, а один належить до можливої іншої зоряної групи, розташованої на відстані 130 пс.

Ключові слова: Розсіяні скупчення: Зорі: Полярні зорі поля; радіальні швидкості; зорі головної послідовності: ефективні температури, радіуси; GAIA DR3 ефективні температури, відстані, почервоніння, радіуси; спектроскопічні подвійні; використання змінних δ типу Sct; товстий диск; Індивідуальні: HD 5914, HD 10772, HD 11696, HD 14369, HD 14718, HD 16335, HD 66368, HD 90162, HD 163988, HD 203317, HD 209556, HD 224687, HD 224991, Polaris B, BD +86°44, BD +87°16, BD +87°26, BD +88°75. Цефеїди: α UMi.

1. Introduction

This project is a continuation of our studies of Polaris field stars, which began earlier (Usenko et al. 2018) with the goal to discover whether these stars are members of a sparsely populated open cluster around the nearest Cepheid α UMi (α (2000) = 02 31 49.09; δ (2000) = +89 15 50.79). The main criteria for assessing whether these field stars belonged to the cluster were: 1) proper motions are close to those of Polaris ($\mu_\alpha = +44.48$ mas yr^{-1},$\mu_\delta = -11.85$ mas yr^{-1}); 2) radial velocities (RV) are close to that of Polaris (RV = -16.42 km s^{-1}); 3) distances are ∼90–110 pc (Turner 2005). However, estimates of radial velocities and the distances of these stars according to the Gaia DR2 catalog showed a significant scatter, which gave a reason to believe that this cluster may be dissolved among the field stars. Usenko et al. (2018) revealed an obvious discrepancy between the radii of some main sequence stars and their distances from Gaia DR2.

Over the past five years the Gaia database represented in the DR3 catalog has expanded significantly and included a number of important astrophysical parameters, such as $T_{\rm eff}$, log g and A_0, in addition to parallaxes and RVs. This makes it possible to determine accurate distances to the stars in the Polaris field, their spectral types, luminosities and radii as well as the probability of their membership in the cluster mentioned above. Additionally, using new spectra of Polaris field stars it became possible to compare the accuracy of the RVs and effective temperatures. These data will allow us to assess the reliability of the Gaia distance measurements.

As before we performed spectroscopic observations of the Polaris cluster main-sequence stars in order to determine their RV (to establish their membership in the cluster) and effective temperatures (to determine the radii and distances from known spectral types). These objects were taken from Turner et al. (2005).

2. Studied Objects

Table 1 summarizes basic data for the 18 targets that were taken from SIMBAD. According to these data, the stars are located quite close to Polaris, and the vast majority of them have noticeably large proper motions. Nine of these stars (HD 5914, HD 10772, HD 11696, HD 14369, HD 14718, HD 209556, BD +87°16, BD +87°26, BD +88°75) are designated in SIMBAD as stars with a high proper motion (HPMS). The components of their proper motion, as a rule, exceed two dozen milliseconds per year.

However, HD 16335, HD 203317, and Polaris B which meet these criteria are not designated as HPMS. HD 90162 is designated as a spectroscopic binary, and Polaris B is designated as a variable. All these objects are main sequence stars of spectral types from A0 to G0. As it is stated above, the values of μ_α and μ_δ for Polaris are also close to those of these HPMS stars that may serve as a fact of the general spatial dynamics of these stars. The next steps in studying the possible commonality of these stars will be measuring their RVs and determining their effective temperatures.

3. Observations and reduction of spectra

Twenty eight spectra of these eighteen objects were taken in 2016–2023 with the 0.81 m telescope of the Three College Observatory (TCO), located in central North Carolina, USA. They were obtained with an échelle spectrograph manufactured by Shelyak Instruments[1] in a spectral range from 4250 to 7800 Å with a spectral resolving power of $R \sim 12000$ and no gaps between the spectral orders. The data were reduced using the *échelle* package in IRAF.

The DECH30 package (Galazutdinov 2007) was used to measure line depths and RVs. Line depths of some metal lines in the atmospheres of cooler stars (F5–G0 V) were used to determine their effective temperatures. The syntetic spectra method was used for hotter stars. RVs were measured using metal (RV (met)) and hydrogen (H_α, H_β, H_γ,) absorption lines (see Table 2).

4. Radial velocities

Table 2 contains the dates of spectral observations, RV measurements from the TCO spectra, and RV data from other authors as well as from the Gaia DR2 and DR3 catalogs. As can be seen from the table, for more than six years of observations, more than two spectra

[1]http://www.shelyak.com

Table 1: Polaris field objects. Coordinates, proper motions, visual magnitudes and color indices.

Object	α (2000)	δ (2000)	μ_α (mas yr^{-1})	μ_δ (mas yr^{-1})	V (mag)	B-V (mag)	Spec Type
HD 5914⋆	01 33 50.71	+89 00 56.30	+64.873	-33.038	6.46	0.10	A3V
HD 10772⋆	02 03 34.87	+86 55 54.48	+49.208	-13.009	8.11	0.34	F5V
HD 11696⋆	02 34 32.66	+88 28 15.70	+52.918	-47.906	8.13	0.27	A3V
HD 14369⋆	03 40 54.04	+89 06 17.58	-51.778	-30.247	8.11	0.35	F0V
HD 14718⋆	03 17 32.24	+88 40 33.55	-158.016	+42.482	8.61	0.52	G0V
HD 16335	03 04 07.97	+87 01 33.89	-26.672	+18.044	7.84	0.36	F0V
HD 66368	09 21 48.47	+88 34 13.18	-6.429	+12.384	7.13	0.14	A0V
HD 90162 SB	10 49 13.59	+87 51 32.15	-23.671	-5.108	8.78	0.50	F8V
HD 163988	16 48 43.27	+88 09 22.44	-2.222	+12.015	8.11	0.47	F5V
HD 203317	20 47 59.82	+87 32 14.82	+30.650	+24.149	8.52	0.41	F2V
HD 209556⋆	21 36 02.50	+87 47 02.01	+24.927	+33.472	8.37	0.45	F5V
HD 224687	23 59 30.74	+86 42 23.05	+35.745	-1.381	6.74	0.06	A0V
HD 224991	00 02 27.83	+87 01 57.77	+18.454	+8.299	7.84	0.30	F0V
Polaris B VS	02 30 36.09	+89 15 39.20	+41.961	-13.562	8.20	0.57	F3V
BD +86°44	03 28 35.54	+87 23 40.90	-0.124	-3.805	9.14	0.50	F8V
BD +87°16⋆	02 48 59.14	+88 39 39.46	+47.850	-35.107	8.84	0.54	G0V
BD +87°26⋆	03 47 08.90	+87 53 48.25	+41.550	-44.376	8.81	0.48	G0V
BD +88°75⋆	12 37 42.37	+87 58 22.83	-56.249	+17.242	9.08	0.51	F5V

⋆ – High proper motion star (HPMS), SB – spectroscopic binary; VS – variable star (VS).

were obtained for seven stars, which makes it possible to verify the accuracy of the TCO results and compare them with the data from other authors. Noticeable differences between the data shown in Table 2 may indicate variability or binarity of the studied stars. The non-variable (within errors) RVs for HD 10772, HD 11696, HD 14369, HD 16335, HD 66368, HD 209556, HD 224687, BD+87°16, BD+87°26, BD+86°44 and BD+88°75 suggest that 61% of the studied objects are non-variable, single stars.

A significant scatter of the RV data for HD 90162 (over 40 $\mathrm{km\,s^{-1}}$), which is marked as a spectroscopic binary in SIMBAD, confirms this status. This fact is supported by the apperance of an additional component in the red wing of the H_α line (see Fig. 1). A similar noticeable scatter ($\sim$20 $\mathrm{km\,s^{-1}}$) in the RV data is characteristic of HD 163988, which may also indicate its binarity. HD 14718 has an RV data scatter within $10\,\mathrm{km\,s^{-1}}$. These two stars show an asymmetry on the red side of the H_α line core, which may be caused by the presence of a secondary component (Fig. 2).

Polaris B has noticeable differences between recent measurements and those obtained several decades ago. This is unlikely to be related to physical variability of the object, as indicated in SIMBAD, but most likely with its orbital motion. Judging from the minor differences in RVs and spectral types, HD 203317 and HD 224991 may be low-amplitude pulsating δ Sct type variables. Also, the difference between our and earlier RVs from that listed in the DR3 catalog for HD 5914 looks completely unexpected, $\sim$10 $\mathrm{km\,s^{-1}}$. If the latter is not erroneous, then HD 5914 can also be suspected of pulsational variability.

Also, average RVs of all the stars, with the exception of HD 14718 and HD 90162, range from +8 to -30 $\mathrm{km\,s^{-1}}$. This means that all but two of the 16 objects from our list may belong to the same general group. Attention should also be paid to the large RV differences determined from absorption lines of metals and hydrogen for HD 5914, HD 66368, HD 203317, HD 209556, and HD 224687.

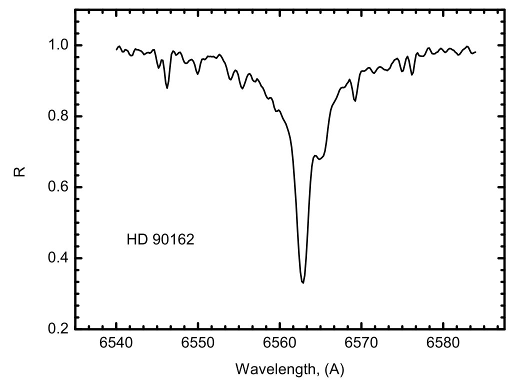

Figure 1: Fragment of the spectrum of HD 90162 in the H_α line region. Presence of the line core of the secondary component is noticeable in the red wing.

Table 2: Radial velocities of Polaris field stars

Object		<RV>						RV(Other authors)	
	HJD 2400000+	Metals	σ	NL	H_α	H_β	H_γ	<RV>	Source
HD 5914	58194.6932	-9.04	3.37	34	-4.17	-3.30	-0.42	-10.0	[b]
	58236.6245	-10.06	2.32	61	-4.09	-2.27	+0.25	-11.0	[c]
								-1.38	[l]
HD 10772	59080.7839	+8.27	2.38	81	+7.00	+6.56	-6.06	+7.83	[l]
	59185.6053	+6.07	2.47	105	+3.28	+3.57	+9.54		
HD 11696	59233.4995	+6.86	1.70	165	+7.69	+7.51	+7.39	+8.26	[j]
								+6.00	[l]
HD 14369	58214.5807	-8.48	2.14	157	-7.82	-6.38	-3.91	-6.56	[k]
	59186.6445	-6.16	1.77	160	-6.75	-6.25	-3.71	-6.76	[l]
	59267.5568	-6.66	2.18	275	-8.36	-5.70	-5.43		
HD 14718	60219.7693	-59.78	2.60	150	-63.40	-61.05	-59.61	-62.7	[f]
								-68.27	[k]
								-61.34	[l]
HD 16335	58182.6840	-27.07	3.02	363	-29.09	-28.79	-27.51	-24.27	[k]
	59225.4923	-27.79	2.78	205	-29.01	-27.14	-26.58	-24.68	[l]
	59267.5108	-27.72	3.02	221	-29.32	-26.31	-25.45		
HD 66368	58158.7237	-7.90	2.79	86	-4.40	-1.99	+8.95	-8.0	[a]
								-8.74	[i]
								-10.64	[l]
HD 90162	59621.7604	-69.18	4.11	150	-68.49	-67.08	-65.70	-23.0	[d]
								-24.97	[i]
								-41.90	[k]
HD 163988	57496.6113	+2.51	2.92	116	+6.21	+3.12	-1.59	-18.9	[b]
								-18.8	[f]
								-2.25	[k]
								-1.34	[l]
HD 203317	58972.7107	-7.64	2.06	30	-0.68	-8.73	-4.48	-7.81	[k]
								-12.35	[l]
HD 209556	58239.6102	-8.66	2.38	51	-13.53	-14.36	-3.40	-5.05	[k]
								-8.62	[l]
HD 224687	58125.5771	-16.34	2.10	30	-13.60	-8.39	-5.55	-17.3	[a]
	59193.5733	-17.42	1.38	47	-14.28	-15.84	-17.21	-18.3	[e]
	59198.5582	-16.98	1.65	54	-11.74	-14.84	-12.86	-17.3	[b]
HD 224991	58240.5511	-3.15	4.30	193	+0.58	+3.76	-1.22	+5.99	[k]
								+4.15	[l]
Polaris B	59248.5809	-19.22	3.39	79	-20.58	-21.96	-20.92	-8.0	[a]
	59255.5298	-19.21	2.60	138	-17.86	-20.96	-24.07	-13.0	[b]
								-18.90	[h]
								-22.25	[k]
BD+86 44	59529.6603	-18.09	2.56	171	-19.77	-19.32	-13.32	-18.60	[k]
	59531.6872	-19.04	2.74	178	-17.70	-20.00	-13.57	-19.11	[l]
BD+87 16	59527.6368	-8.27	1.31	187	-7.54	-8.26	-8.20	-8.38	[l]
BD+87 26	59523.7156	-4.48	2.18	217	-3.58	-6.49	-3.77	-4.10	[k]
								-4.45	[l]
BD+88 75	59622.7052	-9.48	1.74	214	-8.79	-9.88	-9.25	-9.40	[k]
								-10.40	[l]

a – Wilson (1953), b – Gontcharov (2006), c –Young (1939), d – Wilson & Joy (1950), e – Plaskett et al. (1921), f – Nordstroem et al.(2004), g – Pourbaix et al. (2004), h – Usenko & Klochkova (2007), i – 6 m SAO RAS: HJD 2455141.1960, j – 6 m SAO RAS: HJD 2455141.2975, k – Gaia DR2 Catalogue (2018), l – Gaia DR3 Catalogue (2022).

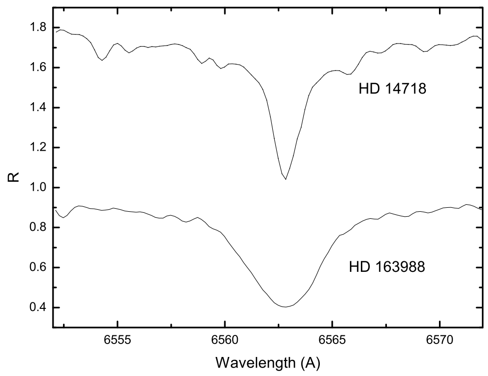

Figure 2: Parts of the spectra of HD 14718 and HD 163988 in the H_α line region.

5. Effective temperatures, reddenings, distances, and radii

All the objects we study are A - G main sequence stars, therefore, one can determine their luminosities from their effective temperatures. Because $T_{\rm eff}$ estimates are independent of the star's reddening, obtaining its spectroscopic estimate through the luminosity and radius allows determining the distance to the object. Conversely, from knowing the star's $T_{\rm eff}$ and distance one can determine its radius and compare it with that calculated from a calibration relationship. Since MS stars having these spectral types, the scatter in estimates of their radii is insignificant. Comparing the obtained estimates of the radius from a calibration, one can estimate the accuracy of the distance measurements. Nowadays we have a database of distances, as well as that of effective temperatures, gravities and reddenings from Gaia DR3, which gives us a convenient opportunity to compare our spectroscopic estimates of $T_{\rm eff}$ with the respective Gaia data and check out the accuracy of distances from this catalog.

Table 3 presents the results of the $T_{\rm eff}$ estimates obtained from our spectroscopy (as described above). Estimates of log g were determined either by balance of the Fe I and Fe II abundances or by using synthetic spectra. For two stars, $T_{\rm eff}$ were determined from Strömgren photometry. As can be seen from tables, the largest differences between the $T_{\rm eff}$ estimates (from 300 to 600 K) are more noticeable in hotter A–type stars. In latter spectral types, these differences decrease and do not not exceed 170 K. Estimates of log g are quite close and typical for MS stars. This means that all the objects we study are luminosity type V stars, for which there are calibration relationships that connect $T_{\rm eff}$ with spectral types, colors indices, absolute magnitudes and radii. In our previous study (Usenko et al. 2018) we used calibrations by Pecaut & Mamajek

Table 3: Effective temperatures and gravities of Polaris field stars.

Star	Our results		Gaia DR3	
	$T_{\rm eff}$, K	log g	$T_{\rm eff}$, K	log g
HD 5914	8800 (2)	4.00	8383	-
HD 10772	6900 (2)	4.00	6908	3.7925
HD 11696	7614 (3)	-	7514	3.9808
HD 14369	6721 (3)	-	6621	4.1525
HD 14718	5971 (3)	-	5930	3.8451
HD 16335	7220 (2)	4.00	6772	3.8301
HD 66368	9700 (2)	3.80	10310	3.9897
HD 90162	6175 (1)	3.90	6267	3.8558
HD 163988	6369 (1)	3.50	6509	3.3543
HD 203317	6650 (2)	4.00	6664	3.9941
HD 209556	6301 (1)	4.00	6334	4.1895
HD 224687	9700 (2)	3.80	10055	3.7103
HD 224991	7220 (2)	4.00	7173	3.9197
Polaris B	6900 (2)	4.30	6851	4.1529
BD +86°44	6179 (1)	3.50	6351	3.6227
BD +87°16	6095 (1)	4.20	6076	4.2384
BD +87°26	6169 (1)	3.80	6277	4.1664
BD +88°75	6169 (1)	4.00	6236	4.2091

1 – Lines depths of metal lines, [2] – synthetic spectra, [3] - Strömgren photometry

(2013), while in this paper we use improved ones from Mamajek (2022)[2] and Turner (2023)[3].

First, we decided to check how different are the stars' radii calculated from our $T_{\rm eff}$ estimates and those from Gaia DR3, if we assume that the distances and reddenings from DR3 are reliable. The results of our calculations are shown in Table 4. The results shoe that according to DR3 all the objects are located within the distance range from 80 to 290 pc and that their reddenings are insignificant, with the exception of HD 66368, HD 163988, and HD 224687. The differences in the radius estimates do not exceed 0.05 $R_\odot$ for the difference in $T_{\rm eff}$ of 100 K. However, they reach 0.2 - 0.5 $R_\odot$ for the $T_{\rm eff}$ differences from 300 to 500 K.

What is more noticeable is that for the stars located at distances greater than 140 pc, the radii may exceed the estimates typical for MS stars of a given spectral class by a factor of 2–3. From this fact we conclude that the DR3 distances for these stars are erroneous. A similar fact was noted in our previous study (Usenko et al. 2018). To check the accuracy of these distances, we decided to link the estimates of $T_{\rm eff}$ and A_0 from DR3 to their corresponding calibrations from Mamajeck (2023) and Turner (2023). The calculation results are shown in Table 5.

What one should pay attention to in this table:

1. According to the calibrations, for the majority of

[2]http://www.pas.rochester.edu/∼emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt

[3]http://ap.smu.ca/∼turner/A5500.html

Table 4: Absolute magnitudes and radii of Polaris field stars using our and Gaia DR3 $T_{\rm eff}$, distances, and reddenings.

Star	V (mag)	A_0 (mag)	d (pc)	$M_{\rm V}$ (mag)	Our data $T_{\rm eff}$, K	Our data R($R_\odot$)	DR3 $T_{\rm eff}$, K	DR3 R($R_\odot$)
HD 5914	6.46	0.0	101.7±0.3	1.42±0.01	8800	2.02±0.02	8383	2.22±0.03
HD 10772	8.11	0.0012	107.1±0.6	2.96±0.01	6900	1.63±0.01	6908	1.62±0.01
HD 11696	8.15	0.0003	163.1±1.1	2.09±0.02	7614	1.98±0.02	7514	2.03±0.02
HD 14369	8.10	0.0166	91.7±0.4	3.27±0.01	6721	1.48±0.01	6621	1.52±0.02
HD 14718	8.61	0.0303	102.8±1.6	3.52±0.03	5971	1.67±0.02	5930	1.69±0.02
HD 16335	7.84	0.0075	140.9±1.5	2.09±0.02	7220	1.98±0.02	6772	2.50±0.03
HD 66368	7.10	0.5474	142.3±1.7	0.79±0.03	9700	2.22±0.02	10310	1.96±0.02
HD 90162	8.78	0.0008	194.3±0.5	2.34±0.01	6175	2.68±0.03	6267	2.59±0.04
HD 163988	8.12	0.1522	275.8±2.5	0.77±0.02	6369	5.20±0.06	6509	4.98±0.05
HD 203317	8.52	0.0009	149.3±0.4	2.65±0.01	6650	2.01±0.02	6664	2.00±0.02
HD 209556	8.37	0.0014	87.2±0.2	3.67±0.01	6301	1.40±0.01	6334	1.38±0.02
HD 224687	6.75	0.2893	212.5±2.5	-0.18±0.02	9700	3.47±0.04	10055	3.23±0.04
HD 224991	7.84	0.0184	145.2±0.4	2.01±0.01	7220	2.27±0.03	7173	2.30±0.03
Polaris B	8.60	0.0005	137.2±0.6	2.91±0.01	6900	1.65±0.01	6851	1.67±0.02
BD +86°44	9.14	0.0463	283.5±0.9	1.83±0.01	6179	3.40±0.04	6351	3.22±0.04
BD +87°16	8.84	0.0027	92.4±0.1	4.01±0.01	6095	1.27±0.02	6076	1.28±0.02
BD +87°26	8.81	0.0010	108.4±0.2	3.63±0.01	6169	1.49±0.02	6277	1.49±0.03
BD +88°75	9.08	0.0006	116.2±0.2	3.75±0.01	6169	1.41±0.02	6236	1.38±0.01

the objects, the spectral types determined from the DR3 $T_{\rm eff}$ data are earlier than those given in SIMBAD (see Table 1), or coincide with them. Exceptions are HD 11696, HD 14369, HD 16335, and BD +88°75.

2. Distance estimates to stars derived from the spectral types based on the calibrations, nearly or virtually coincide with the DR3 estimates only for HD 10772, HD 14369, HD 209556, Polaris B, BD +87°16, and BD +87°26. The differences are within 20–30 pc for HD 5914, HD 11696, and HD 66368, while this difference ranges from 40 to 170 pc for the rest of the sample (HD 14718, HD 16335, HD 90162, HD 163988, HD 203317, HD 224687, HD 224991, and BD +86°44) that constitutes half of it.

3. Based on the radii calculated from the $T_{\rm eff}$ and A_0 taken from DR3 and distances from Table 5, one can conclude that the differences between the radii derived from Mamajek and Turner are in the range of 0.05–0.2 $R_\odot$ with the exception of HD 66368 and HD 224687, where this difference exceeds 1 $R_\odot$. If we compare the radii calculated using calibrations with those determined from the DR3 distances, it is clear that only 8 stars coincide within 0.3 $R_\odot$. The rest (HD 5914, HD 14718, HD 16335, HD 66368, HD 90162, HD 163988, HD 203317, HD 224687, HD 224991, and BD +86°44) show the differences from 0.5 to 2.9 $R_\odot$.

Thus, it turns out that for 10 stars out of 18, the radii determined from the distances, $T_{\rm eff}$ and reddenings taken from the DR3 catalog differ significantly from the average values ederived for the corresponding spectral types of the luminosity type V. This means that the DR3 distances for more than half (56%) of the sample are erroneous and need refinement.

Figure 3 shows the relationships of (O-C) in distances - Gaia DR3 distances for two different calibrations from Table 5. There calculated distances (C) were derived using data from Mamajek (2013) and Turner (2023), while the observed (O) values come from the Gaia DR3 catalog. As can be seen from Figure 3, both dependences are close to one another and have an exponential character that indicates that the errors in the distance determination to the target stars increase with increasing DR3 distances, which are larger than 130 pc. This fact means that the Gaia DR3 distances are unreliable.

Therefore, we decided to verify the distances to the stars using photometric data. To do that, we used color-indices (B-V), and thanks to the refined spectral types, intrinsic color indices, color-excesses, and reddenings, the absolute magnitudes for the ZAMS were determined. The latter allowed us to determine the distances. These data are presented in Table 6.

As can be seen from Table 6, the obtained reddening estimates for individual stars differ significantly from those shown in DR3. As for the distance estimates, they are closer to those obtained from the Turner (2023) calibrations. It can be seen that most stars are located in the distance range 70–110 pc and

Table 5: Comparison of absolute magnitudes, distances, spectral types, and radii of the Polaris field stars according to the Gaia DR3 data that is converted from the Mamajek (2022) and Turner (2023) relations.

Star			DR3	Mamajek		Turner			DR3	Mamajek			Turner
	V	M_V	d	M_V	d	M_V	d	$T_{\rm eff}$	R	SpT	R	Sp	R
	(mag)	(mag)	(pc)	(mag)	(pc)	(mag)	(pc)	K	($R_\odot$)		($R_\odot$)		($R_\odot$)
HD 5914	6.46	1.42	101.7	1.85	83.6	1.99	78.3	8383	2.22	A4V	1.819	A3V	1.71
HD 10772	8.11	2.96	107.1	2.88	111.1	2.98	106.1	6908	1.62	F1V	1.647	F0V	1.60
HD 11696	8.15	2.09	163.3	2.36	143.9	2.47	136.8	7514	2.03	A8V	1.747	A7V	1.71
HD 14369	8.10	3.28	91.2	3.27	91.8	3.40	86.4	6621	1.52	F4V	1.508	F3V	1.37
HD 14718	8.61	3.35	111.0	4.48	66.1	4.76	58.1	5930	1.83	G0V	1.100	F9V	0.95
HD 16335	7.84	2.09	140.9	3.05	90.5	3.15	86.4	6772	2.50	F2V	1.591	F1V	1.54
HD 66368	7.10	0.77	143.4	0.65	151.7	1.37	108.9	10310	1.99	B9V	2.417	B9.5V	1.42
HD 90162	8.78	2.35	193.5	3.83	97.7	4.11	85.9	6267	2.59	F7V	1.312	F7V	1.15
HD 163988	8.12	0.80	271.1	3.44	80.5	3.62	74.1	6509	4.91	F5V	1.449	F5V	1.34
HD 203317	8.52	2.65	149.3	3.21	115.3	3.32	109.6	6664	2.00	F4V	1.529	F2V	1.47
HD 209556	8.37	3.64	88.1	3.71	85.5	3.99	75.1	6334	1.42	F6V	1.353	F7V	1.19
HD 224687	6.75	-0.17	212.0	0.79	136.1	1.46	100.5	10055	3.23	B9V	2.325	B9.5V	1.48
HD 224991	7.84	2.01	145.2	2.61	110.2	2.70	105.8	7173	2.30	F0V	1.717	A8V	1.69
Polaris B	8.60	2.92	136.7	2.94	135.5	3.05	128.8	6851	1.71	F2V	1.630	F0V	1.58
BD +86°44	9.14	1.87	278.3	3.69	120.5	3.88	110.3	6351	3.15	F6V	1.359	F6V	1.25
BD +87°16	8.84	4.01	92.2	4.21	84.3	4.48	74.4	6076	1.28	F9V	1.178	F8V	1.04
BD +87°26	8.81	3.64	108.1	3.77	101.9	4.09	87.9	6277	1.43	F7V	1.333	F7V	1.14
BD +88°75	9.08	3.76	115.9	3.91	108.1	4.18	95.5	6236	1.36	F7V	1.279	F7V	1.13

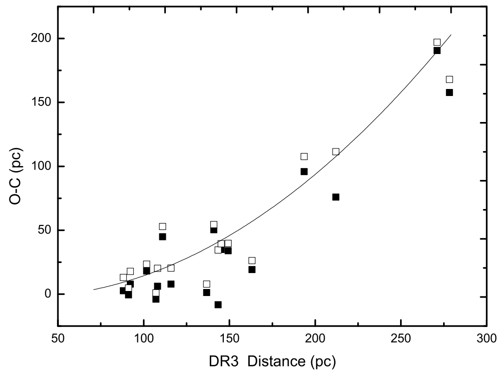

Figure 3: Gaia DR3 distances - (O-C) distances relationship for the Polaris field stars. Filled squares show calculations using Mamajek (2022) calibration, open squares show calculations using that of Turner (2023).

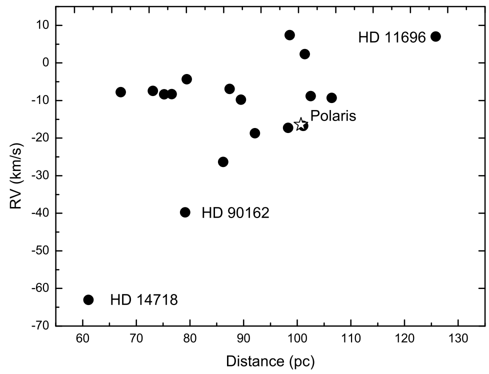

Figure 4: Photometric distance versus RV relationship for the Polaris field stars. Polaris is marked with an open five-point star.

only HD 14718 and HD 11696 fall out of this interval. If we look at the dependence of the average stars' RVs versus these distances, one can see that most stars form the group in a given distance interval with RVs from $+7.4$ to -26.3 km s^{-1} . This can be seen in Figure 4. One obvious (HD 90162) and one probable (HD 14718) drop out of the spectroscopic binaries group, and the star with the greatest reddening, HD 11696, is much further away.

It should be noted that with Polaris' $E_{B-V} = 0.^m02$, $A_V = 0.^m056$, the distance is 100.7 pc. Also, SIMBAD does not contain data on the distances from Gaia DR2 and DR3. This is probably due to difficulties in measuring parallaxes for bright stars.

6. Summary

1. According to the RV values, 15 target stars belong to the same moving group.
2. Two objects, HD 14718 and HD 90162, judging by their RVs, probably belong to the thick disk, while HD 11696 belongs to another group of the Polaris field stars.
3. Judging from the spectra, HD 90162 is indeed a spectroscopic binary, while HD 14718 and HD 163988 are possible binaries.
4. 61% of the studied objects are non-variable stars, and three objects (HD 5914, HD 203317 and HD 224991) can be low-amplitude pulsating variables of the δ Sct type. It is still unclear whether Polaris B is a pulsating variable, as indicated in SIMBAD.

Table 6: Color-excesses, reddenings, absolute magnitudes, and distances for the Polaris field stars.

Star	V (mag)	B-V (mag)	E_{B-V} (mag)	V_0 (mag)	A_V (mag)	M_V (mag)	V_0-M_V (mag)	d (pc)
HD 5914	6.46	0.107	0.017	6.412	0.048	1.99	4.422	76.6
HD 10772	8.11	0.342	0.000	8.110	0.000	3.14	4.970	98.6
HD 11696	8.15	0.270	0.540	6.628	1.522	1.99	5.498	125.8
HD 14369	8.10	0.413	0.058	7.938	0.162	3.23	4.708	87.4
HD 14718	8.61	0.516	0.000	8.610	0.000	4.68	3.930	61.1
HD 16335	7.84	0.379	0.069	7.657	0.183	2.98	4.677	86.2
HD 66368	7.10	0.174	0.174	6.613	0.487	1.56	5.053	102.5
HD 90162	8.78	0.504	0.000	8.780	0.000	4.29	4.490	79.1
HD 163988	8.12	0.475	0.020	8.064	0.056	3.93	4.134	67.1
HD 203317	8.52	0.405	0.045	8.394	0.126	3.26	5.134	106.4
HD 209556	8.37	0.468	0.000	8.370	0.000	4.05	4.320	73.1
HD 224687	6.75	0.081	0.081	6.523	0.227	1.56	4.963	98.3
HD 224991	7.84	0.282	0.000	7.840	0.000	2.82	5.030	101.4
Polaris B	8.60	0.390	0.020	8.544	0.056	3.52	5.024	101.1
BD +86°44	9.14	0.495	0.000	9.140	0.000	4.32	4.820	92.1
BD +87°16	8.84	0.540	0.003	8.832	0.008	4.45	4.382	75.2
BD +87°26	8.81	0.480	0.000	8.810	0.000	4.31	4.500	79.4
BD +88°75	9.08	0.505	0.000	9.080	0.000	4.32	4.760	89.5

5. Our estimates of the effective temperatures obtained using spectroscopy or photometry showed their approximate similarity with the estimates from the DR3 catalog for stars of the spectral classes F–G, while for hotter A–type stars the difference is 300–500 K.

6. Estimates of the stellar radii calculated using $T_{\rm eff}$ values, reddenings and distances from DR3 catalog for half of the stars turned out to be overestimated and inconsistent with their spectral types.

7. Recalculations of the radii and distances for the stars using our $T_{\rm eff}$ estimates and "Spectral type – Luminosity"' calibrations for MS stars also confirmed that for half of the stars the DR3 distance estimates are unreliable.

8. The largest discrepancies in the distance estimates between the DR3 data and the calibrations are found for distances lrger than 130 pc and have an exponential character.

9. Judging from the derived RV estimates and photometric distances, 15 target stars probably still belong to the old open cluster dissolved among the stars of the Polaris field and located at distances of ∼70–110 pc.

10. The distance estimates from the DR3 catalog are extremely unreliable and should be carefully revised.

Acknowledgements. This work has made use of the SIMBAD database, operated at CDS, Strasbourg, France, and data from the European Space Agency (ESA) mission *Gaia* (https://www.cosmos.esa.int/gaia), processed by the *Gaia* Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the *Gaia* Multilateral Agreement.

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