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Gaia: Surveying Heavens

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Abstract

In this paper we attempt to study an ongoing astrometry mission of the European Space Agency (ESA), named Gaia, whose aim is to make the largest and most precise three-dimensional map of our Galaxy. We present the scientific goals of Gaia and give a brief description of the space-craft. We also present a preliminary analysis of comparing distance estimates of Be stars from the first Gaia data release, Gaia DR1, and Hipparcos mission. From our analysis, we confirm that Gaia stands out as a promising mission in terms of the distance measurements when compared to Hipparcos, particularly for distances greater than 1 kpc.

Keywords: Gaia, parallax, Be star, Hipparcos, Distance

1. Introduction

On 19 December 2013, Gaia space observatory was launched by ESA (European Space Agency) from Kourou in French Guiana. The astrometric mission aimed to make largest and most precise three-dimensional (3D) map of our Galaxy, the Milky Way [4]. It was proposed in 2000 as an ESA-only mission whose phase implementation was from 2006 by Airbus Defense and Space. The analysis and processing of data were entrusted to Data Processing and Analysis Consortium (DPAC). Before Gaia, there have been attempts to make such maps of Milky Way Galaxy. Hipparcos was the predecessor mission by ESA for mapping the Galaxy [6]. The mission focused on nearby stars which

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measured the absolute parallax and proper motion with milli-arc second accuracy. A new set of reduction process for Hipparcos data was proposed in 2007 which increased the accuracy of distance to the stars with magnitudes brighter than 8 by a factor of 4 [24]. Using the star mapper of the ESA Hipparcos satellite, another astrometric catalogue (including position, proper motion, parallax, magnitudes in two bands), Tycho-2, of 2.5 million brightest (scanned the sky to a V = 11.5 magnitude) stars are generated and presented in [9]. On the other hand, Gaia intends to prepare a three dimensional catalogue that determines the proper motions and stellar parallaxes with very high accuracy.

2. Scientific Goals

Gaia is an ambitious mission to chart a 3D map of our Galaxy and in the process revealing the composition, formation and evolution of the Galaxy [4]. With respect to ground-based facilities, Gaia could provide more accuracy, sensitivity, dynamic range, and sky coverage. During the mapping, it will examine the kinematical, dynamical and chemical structure of stars and the evolution of our Milky Way Galaxy [16]. Many other discoveries such as planets around stars [7], moving bodies in Solar System [23], far-distant supernovae and quasars [18] and information about interstellar gas and dust, and dark matter can be obtained through this mission.

During the initial lifetime of five years, Gaia will examine the motions of about 1 billion stars and it will observe a single object approximately 70 times during its expected mission period [4]. At each epoch, photometric measurements are also made. Continuous space survey will provide data regarding the positional and kinematic distribution of stars in different regions extending from the Galactic center to the halo [18]. Combining the absolute luminosities of stars with the information of the physical properties and corresponding metallicities, it is possible to deduce the star formation histories of the stellar populations in the Galaxy [16].

The revolutionary accuracy of Gaia in parallaxes will help in deriving highly precise color-magnitude diagrams (CMDs) so that the CMDs can be calibrated with a very minimum error rate. With 1 billion parallaxes observed, Gaia will cover most phases of evolution across the stellar mass range. The photometric and spectroscopic data can reinforce our knowledge of multiple stars, Cepheid variables, quasars, supernovae in distant galaxies, brown dwarfs and other rare objects in space [17]. Also, astrometric data will be a strong tool in exoplanets research area such as the discovery of many Jupiter sized planets in multi-year orbits around their host stars in our Galaxy [7]. The full-sky coverage of Gaia will provide the detection of movement of faint objects in the Solar system such as asteroids and comets [23]. The spatial resolution of Gaia is sufficient to resolve and observe some Local Group galaxies.

Gaia data will be a strong tool for testing relativistic effects like light bending due to the gravitational field of Solar system on stellar objects and their motions [13]. So with an extensively accurate data on positions, parallaxes, photometric and spectroscopic measurements, the scientific goals of Gaia are so vast and immense which will probe deep into the star formation history, chemical evolution in the disk, bulge, halo and even in the outer parts of the Milky Way [4]. Exploration of inter-galactic interactions may reveal mass distributions of unresolved and invisible dark matter.

3. Spacecraft Overview

Gaia is placed in an orbit around the Sun, at the second Lagrange point L2 where it scans the entire celestial sphere during the course of one year [4]. Figure 1 represents the schematic diagram of the instruments loaded in the Gaia spacecraft. It is equipped with two identical telescopes that point 106.5° apart, around an optical bench. The single integrated focal plane assembly, besides wave-front-sensing and basic angle metrology, comprises three science functions: astrometry, photometry, and spectroscopy [4].

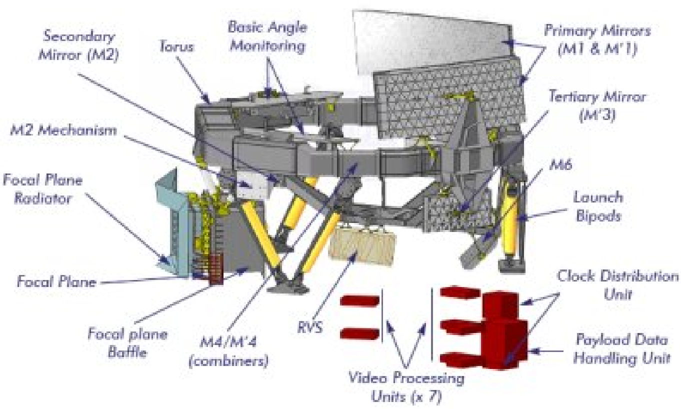

Figure 1. A pictorial representation of Gaia mission payload. The payload module is built around an optical bench which provides the structural support for the single integrated instrument that performs three functions: astrometry, photometry and spectrometry. Courtesy: www.sci.esa.int

Finding stars positions in 3D require further measurements which are performed by the payload module. It contains a single integrated instrument that performs the above three major functions. The astrometric instrument measures the position, parallax and proper motion of the star [5]. The spectral energy distribution is measured by the photometric instrument while the radial velocities of stars through Doppler shift measurements are taken from the spectroscopic instrument [4]. The mechanical and the electrical service module deals with the external elements supporting the instrument and the spacecraft electronics. It helps the Gaia payload and spacecraft for pointing. It supports electrical power control and distribution, data management and communications with earth [4].

4. Analysis

We carried out an analysis about the first Gaia data release, Gaia DR1 2016 (Gaia Collaboration 2016, hereafter Gaia DR1), consists of astrometric and photometric data for over 1 billion sources. The astrometric dataset contains the positions, parallaxes and mean proper motions for about 2 million of the brightest stars in common with the Hipparcos catalogue [6] and Tycho-2 catalogue [9] and the positions for an additional 1.1 billion sources. Compared to Hipparcos data, Gaia data provides much better catalogue in terms of the expected accuracies at current epochs with outstanding contributions.

We performed the analysis with a sample of classical Be stars using the first version of Gaia DR1 data release. A classical Be star is a non supergiant B-type star whose spectrum has, or had at some time, one or more Balmer lines in emission [10, 20]. They are main sequence stars presumed to be fast rotators spinning at 200 km/s or more [22]. It is having a decretion disk fed by mass ejected from the central star, which more precisely is an outwardly diffusing gaseous Keplerian disk [21]. The formation and structure of circumstellar disk [14, 25] and the evolutionary status of classical Be stars [19, 11, 12] are some of the unresolved problems.

4.1 *Data Analysis*

The selected Be catalogue [8], contains 1159 objects which has been cross-matched with Gaia DR1. Among this only 1007 Be stars has been matched with Gaia DR1 in which parallaxes of 736 are available. After rejecting the objects with negative parallaxes, 318 objects are obtained from Gaia DR1, and the parallaxes are also obtained from the Hipparcos catalogue. The data extracted from the two catalogues are listed in Table 1.

Table 1: The table presents the extracted Gaia DR1 and Hipparcos distances for 318 Be stars catalogued in Jaschek and Egret, (1982).

RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)	RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)
2.9041	58.2117	571 ± 160	463 ± 165	174.5209	-45.1387	1852 ± 1269	775 ± 673
8.011	67.1608	510 ± 70	362 ± 110	175.608	-62.4767	877 ± 215	538 ± 269
10.8262	61.91123	625 ± 90	299 ± 146	175.7816	-72.4451	437 ± 95	288 ± 54
16.4703	65.9708	407 ± 55	252 ± 48	177.0003	-62.2066	3846 ± 4438	505 ± 242
19.3589	57.6318	893 ± 415	559 ± 253	178.84	-63.7031	806 ± 182	962 ± 684
24.3419	74.3007	280 ± 27	293 ± 48	179.3062	-79.3589	107 ± 3	66 ± 15
28.1085	55.3312	7142 ± 13265	306 ± 93	180.0233	-78.1925	104 ± 3	116 ± 7
28.928	59.2732	559 ± 103	265 ± 59	183.507	-59.39	917 ± 261	694 ± 391
29.0294	56.5541	2500 ± 2688	870 ± 1149	186.718	-60.7534	935 ± 306	2000 ± 4960
30.6512	59.688	870 ± 174	340 ± 128	191.4747	-60.5	4000 ± 3840	1852 ± 6
31.2013	56.2619	2857 ± 2122	215 ± 64	193.7851	-59.018	1818 ± 826	455 ± 242
31.5348	63.3701	2500 ± 1500	926 ± 2323	194.5035	-59.084	690 ± 157	820 ± 1001
31.9718	57.1055	4000 ± 5280	1667 ± 2750	195.3954	60.6712	637 ± 114	336 ± 82
32.1887	65.0373	806 ± 150	1205 ± 1234	198.548	-63.3733	806 ± 169	382 ± 131
32.3566	56.9915	1667 ± 1000	2041 ± 4581	198.6695	-38.6516	658 ± 134	935 ± 856
33.7209	54.5315	800 ± 333	476 ± 190	201.8542	-62.6487	1266 ± 417	1493 ± 2874
33.7605	55.7928	833 ± 250	1075 ± 1179	202.0054	-61.0626	526 ± 94	379 ± 113
33.8038	64.0242	1064 ± 272	1000 ± 950	202.0304	-66.2795	1408 ± 536	481 ± 282
34.1496	49.8195	613 ± 143	410 ± 151	202.4774	-65.5015	1389 ± 463	3704 ± 10425
34.1627	56.7376	4000 ± 4160	971 ± 952	202.695	24.2328	327 ± 30	234 ± 55
37.431	60.6771	625 ± 98	513 ± 271	202.8173	-53.096	4545 ± 8058	2174 ± 5340
37.8308	56.8975	1316 ± 398	433 ± 245	204.0876	-63.1454	730 ± 139	758 ± 568
45.6574	57.6126	893 ± 183	1538 ± 2840	204.6491	-69.2935	1149 ± 383	752 ± 503
47.2251	62.3842	769 ± 183	617 ± 472	205.0892	57.2075	91 ± 3	88 ± 5
48.7301	48.6957	1250 ± 375	503 ± 222	208.0723	-66.404	654 ± 167	2632 ± 7964
49.2486	60.0668	575 ± 86	394 ± 146	210.965	-59.4627	2128 ± 1449	833 ± 965
50.0047	59.8635	633 ± 92	1099 ± 1534	211.3419	-62.5071	2222 ± 1235	1010 ± 1296
52.1632	62.4927	1136 ± 323	407 ± 164	211.8304	-59.5111	741 ± 165	901 ± 1063
52.359	46.938	164 ± 15	177 ± 23	211.9864	-61.5085	862 ± 223	714 ± 699
52.8875	47.8624	193 ± 17	220 ± 42	212.167	-64.19	1205 ± 421	485 ± 283
54.5038	55.1707	870 ± 204	360 ± 114	212.1874	-59.7168	699 ± 127	1020 ± 1197
55.282	37.5802	177 ± 29	248 ± 50	214.1135	-64.7802	680 ± 176	690 ± 66
57.0754	50.7362	265 ± 34	182 ± 28	216.0968	-82.848	269 ± 32	270 ± 39
57.6043	52.4813	571 ± 121	427 ± 179	217.3905	-70.2382	585 ± 106	826 ± 66
58.8462	31.0458	725 ± 252	826 ± 642	218.4032	-58.8205	877 ± 308	1370 ± 1651
59.0843	44.937	840 ± 177	2857 ± 8082	218.6217	-64.2019	25000 ± 168750	35 ± 357
62.4204	-7.8928	59 ± 1	56 ± 3	218.8218	-56.7706	781 ± 146	386 ± 212
63.5537	28.2033	138 ± 9	101 ± 28	220.0227	-59.9308	826 ± 191	806 ± 696
64.6296	28.4544	129 ± 5	137 ± 39	222.0017	-65.7398	806 ± 202	340 ± 106
64.8158	29.1075	127 ± 6	53 ± 13	225.283	-72.7187	532 ± 74	298 ± 71
65.4892	28.4433	177 ± 27	134 ± 39	227.2634	-61.8872	840 ± 254	1176 ± 1052
65.495	28.3017	125 ± 4	128 ± 21	228.0814	-53.6574	498 ± 72	1042 ± 1118
65.4975	19.535	139 ± 6	177 ± 49	228.8171	-58.1724	1064 ± 294	1042 ± 1237
66.4581	46.2335	680 ± 176	383 ± 167	231.6245	-64.2122	595 ± 113	345 ± 117
69.567	-24.6583	917 ± 429	1020 ± 1083	233.0967	-8.5336	229 ± 13	140 ± 26
69.6507	8.175	418 ± 86	602 ± 352	235.3471	-58.7743	775 ± 198	324 ± 246
70.1359	24.4422	405 ± 49	395 ± 284	236.3033	-34.2917	154 ± 7	159 ± 52
71.0215	-8.5031	820 ± 484	412 ± 139	237.1995	-54.3953	826 ± 212	578 ± 321
71.0539	40.7868	189 ± 18	166 ± 26	237.4907	-3.9209	111 ± 5	99 ± 8
73.94059	30.55161	153 ± 10	144 ± 20	239.1749	-42.3227	156 ± 6	198 ± 46
74.69218	29.84376	142 ± 7	131 ± 20	239.1762	-37.8208	169 ± 9	230 ± 189
75.5658	24.029	1961 ± 1461	2564 ± 8350	239.8683	-40.3642	151 ± 6	108 ± 33
76.12514	-3.7872	346 ± 34	1639 ± 6638	240.9349	-60.4978	901 ± 333	1266 ± 1186
76.9811	21.7045	251 ± 43	316 ± 81	241.0087	-47.4755	1042 ± 293	463 ± 306
77.4848	37.0043	1099 ± 326	7143 ± 53571	242.544	-40.1286	260 ± 26	676 ± 502
77.7001	41.0025	1099 ± 350	324 ± 128	244.7608	-49.4061	329 ± 44	191 ± 39
77.9289	42.165	847 ± 251	316 ± 143	247.2078	-44.8121	1064 ± 589	457 ± 209
78.0601	41.2147	813 ± 145	372 ± 173	248.0733	-50.5417	1087 ± 473	6667 ± 46667
78.3049	40.1932	1111 ± 383	3571 ± 11735	248.9521	-42.1226	1220 ± 416	366 ± 216
79.00195	-9.80971	325 ± 31	164 ± 44	250.0747	-23.8956	145 ± 6	150 ± 38
80.6464	37.6759	1031 ± 298	2564 ± 5851	250.1764	-41.1264	452 ± 82	312 ± 101
81.92824	-8.3273	385 ± 38	1136 ± 1201	252.3137	-14.3692	127 ± 14	95 ± 25
82.1867	-65.4486	14 ± 0	15 ± 0	253.6869	-36.8881	143 ± 5	145 ± 30
82.285	11.8703	469 ± 101	308 ± 136	254.0599	-46.8484	699 ± 161	380 ± 191
82.61458	25.3328	151 ± 9	204 ± 49	255.4472	-58.9578	901 ± 657	699 ± 391
82.8267	-5.7039	446 ± 52	422 ± 272	255.4747	-59.0474	2326 ± 3083	990 ± 902
83.9935	24.7485	160 ± 7	100 ± 20	259.5847	-32.5528	348 ± 40	386 ± 130
84.1058	-6.7162	610 ± 171	269 ± 396	259.8503	-38.0033	662 ± 123	12500 ± 154688
84.7271	26.3155	1887 ± 997	333 ± 191	263.2972	-58.5574	251 ± 28	219 ± 38
85.25952	-2.7168	420 ± 49	885 ± 838	264.3786	-35.3329	1754 ± 800	376 ± 191
85.5826	43.0594	752 ± 198	621 ± 374	265.004	-32.2007	472 ± 85	532 ± 257
85.7992	-4.9967	420 ± 60	422 ± 231	265.0997	-28.9224	478 ± 66	813 ± 681
87.2234	29.1357	2041 ± 1458	7692 ± 74556	265.8507	-46.5877	719 ± 171	402 ± 174

Continued on next page

Table 1 – *Continued from previous page*

RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)	RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)
88.3623	0.7793	455 ± 79	685 ± 619	266.0654	5.7141	373 ± 52	452 ± 20
88.3797	25.742	1149 ± 410	395 ± 184	267.1155	-26.9745	379 ± 53	348 ± 98
90.4999	16.5158	637 ± 154	606 ± 555	267.5046	24.4675	311 ± 40	300 ± 65
93.4257	8.7122	855 ± 226	775 ± 565	267.5784	-47.2299	495 ± 91	575 ± 314
93.9852	-44.6196	1111 ± 321	730 ± 362	269.0557	-46.7016	893 ± 399	1754 ± 3016
94.0315	-16.6174	327 ± 49	256 ± 47	269.9848	-33.4079	617 ± 118	1099 ± 1111
95.1504	-34.1439	465 ± 160	617 ± 202	272.3238	-23.9881	971 ± 330	541 ± 307
95.8525	15.1014	2941 ± 2595	398 ± 190	275.3654	25.0562	730 ± 245	513 ± 176
96.0852	-12.9617	332 ± 97	588 ± 260	275.3682	5.4357	472 ± 105	1031 ± 882
97.0728	-13.0529	610 ± 123	355 ± 138	277.3417	-25.256	568 ± 132	990 ± 951
97.5731	2.8477	1370 ± 507	741 ± 708	277.8505	-19.1582	617 ± 103	1563 ± 2515
97.6369	5.8663	752 ± 158	8333 ± 69444	278.3242	5.4449	602 ± 105	444 ± 170
98.1801	-7.5087	629 ± 123	1587 ± 2318	278.3456	30.8921	662 ± 294	455 ± 116
98.2716	10.3222	610 ± 115	290 ± 118	278.8347	-22.0902	1163 ± 717	476 ± 422
100.5537	-10.4979	1220 ± 506	426 ± 219	279.8754	-21.9652	1282 ± 444	1163 ± 1528
101.1181	-31.07	588 ± 318	800 ± 358	281.6789	52.9879	356 ± 66	667 ± 213
101.5133	-39.5399	287 ± 31	408 ± 93	281.9889	31.7564	413 ± 84	326 ± 59
101.9881	0.7754	943 ± 320	298 ± 105	282.0938	15.3939	546 ± 200	413 ± 145
102.3158	-12.6674	346 ± 45	610 ± 335	282.6964	8.7026	1031 ± 329	2128 ± 8239
102.4807	-5.5129	752 ± 215	769 ± 503	282.7902	-7.7986	6250 ± 12109	893 ± 917
102.5965	-31.706	179 ± 18	220 ± 27	283.0093	59.667	410 ± 40	274 ± 36
102.6098	-14.113	1724 ± 922	676 ± 438	285.4120	-36.8905	140 ± 7	136 ± 21
102.8891	-6.9667	340 ± 47	289 ± 67	286.1601	23.329	980 ± 356	279 ± 123
103.0431	-0.2949	1149 ± 542	725 ± 567	286.1996	-18.7071	532 ± 79	602 ± 399
103.4668	-13.1854	1190 ± 439	437 ± 206	287.7968	15.7880	293 ± 31	244 ± 54
104.079	-3.8065	1351 ± 621	787 ± 651	292.689	27.9649	136 ± 18	115 ± 9
104.9272	-11.1573	980 ± 327	2857 ± 13551	293.4038	3.7611	5263 ± 13019	610 ± 342
104.9429	-16.2007	2381 ± 1474	629 ± 459	293.9508	36.944	192 ± 23	226 ± 28
106.8437	-23.84	1449 ± 1239	909 ± 612	296.3024	24.0508	3846 ± 5769	389 ± 179
108.1894	-15.5014	3125 ± 3711	1299 ± 1619	297.3891	-1.1003	2857 ± 2612	322 ± 139
111.962	-16.0937	1053 ± 355	719 ± 564	297.5729	7.902	625 ± 281	476 ± 209
112.051	-27.3992	275 ± 47	1042 ± 1215	300.0289	32.7894	1351 ± 621	568 ± 213
112.3661	-21.8583	699 ± 186	690 ± 447	300.505	29.5855	877 ± 285	357 ± 162
114.4117	-14.4405	510 ± 102	348 ± 97	300.7604	5.73822	855 ± 351	5000 ± 28250
114.991	-37.5789	606 ± 312	415 ± 84	300.9229	36.4254	1370 ± 507	769 ± 426
116.897	-30.5479	794 ± 195	699 ± 411	301.0026	26.2712	2000 ± 1000	11111 ± 1493
117.4669	-40.9142	588 ± 121	546 ± 158	301.3568	46.6715	4762 ± 5896	1163 ± 960
118.0847	-26.4297	1149 ± 462	415 ± 262	303.3869	36.3281	926 ± 300	1786 ± 2041
118.0931	-59.4929	385 ± 36	366 ± 86	304.2006	32.3796	909 ± 289	1613 ± 1951
118.1252	-21.9992	1111 ± 432	524 ± 351	304.2905	15.8724	353 ± 57	362 ± 112
119.0659	-61.0993	224 ± 38	402 ± 81	304.3545	39.5937	400 ± 56	285 ± 46
119.2663	2.9503	725 ± 226	606 ± 397	305.11821	41.36426	1031 ± 244	108 ± 26
119.7102	-60.8242	379 ± 47	315 ± 47	306.0654	42.3003	935 ± 280	2439 ± 6841
119.7287	-32.557	820 ± 322	1923 ± 4105	306.386	54.6839	3448 ± 3804	769 ± 296
120.1837	-2.8814	613 ± 230	952 ± 862	307.3341	46.6666	2439 ± 1487	457 ± 254
122.1565	-37.6814	595 ± 230	543 ± 157	307.4489	36.9803	1250 ± 375	909 ± 545
126.96	-50.0997	952 ± 236	1515 ± 1423	309.8047	-2.4124	441 ± 111	377 ± 131
128.0969	-49.6013	943 ± 205	690 ± 247	310.5923	35.4558	578 ± 127	360 ± 80
129.2194	-63.6273	1333 ± 480	775 ± 361	312.1365	53.9058	971 ± 273	1250 ± 1031
131.2582	-41.5161	649 ± 126	5000 ± 21250	313.04	44.4342	1099 ± 712	752 ± 548
132.0863	-46.9103	5555 ± 19444	549 ± 257	313.4737	44.3864	112 ± 4	94 ± 6
133.78597	-43.4668	758 ± 172	412 ± 220	313.8458	40.2995	637 ± 219	645 ± 279
137.6747	-53.0458	870 ± 212	1818 ± 2083	315.4036	68.1634	336 ± 26	429 ± 114
138.3936	-47.3386	166 ± 16	170 ± 15	315.6079	27.8072	50 ± 1	50 ± 2
139.2317	-63.7749	417 ± 66	386 ± 80	317.4938	45.5022	444 ± 67	336 ± 69
140.4937	-51.1759	2941 ± 1990	382 ± 184	318.6892	59.7608	1087 ± 260	962 ± 647
141.1645	-58.6886	909 ± 248	1316 ± 1039	319.3282	58.6111	676 ± 164	775 ± 331
143.625	-66.1219	446 ± 56	690 ± 281	319.8422	64.8712	478 ± 176	331 ± 55
152.3253	-50.6394	1220 ± 416	667 ± 329	319.9366	53.9513	350 ± 35	546 ± 245
152.901	-59.8833	1923 ± 1442	787 ± 521	320.7127	40.6969	893 ± 327	309 ± 65
152.9436	-58.0603	649 ± 249	397 ± 79	321.1261	55.3664	3846 ± 3402	826 ± 430
153.2554	-59.9177	485 ± 99	606 ± 180	321.26	44.4514	787 ± 260	1042 ± 1031
155.7246	-59.6245	2941 ± 2076	1176 ± 830	322.3113	44.3379	794 ± 208	510 ± 169
156.5008	-57.8266	1923 ± 888	472 ± 227	323.9352	29.7451	1639 ± 806	549 ± 272
157.5285	-68.5517	344 ± 33	442 ± 127	325.6011	57.7358	962 ± 231	498 ± 144
157.5938	-57.0773	862 ± 238	990 ± 559	326.4673	50.2922	1370 ± 469	990 ± 912
157.6406	-61.336	1176 ± 332	1282 ± 1068	326.5113	50.6738	352 ± 45	346 ± 77
160.4661	-79.7832	329 ± 50	307 ± 45	328.45	62.6142	7692 ± 23077	719 ± 285
161.6176	-60.5633	3846 ± 3254	1724 ± 3151	334.7509	45.8018	4167 ± 5035	1087 ± 957
164.7788	-77.0278	188 ± 8	143 ± 38	335.0945	51.8606	1087 ± 343	909 ± 554
165.4662	-34.7047	60 ± 1	56 ± 7	336.2647	57.8413	2941 ± 1990	5882 ± 50519
166.8362	-77.6353	198 ± 9	210 ± 124	338.9677	39.6343	541 ± 175	196 ± 69
166.9196	-56.6604	1538 ± 615	1250 ± 1297	339.6326	55.8349	1818 ± 760	472 ± 216
167.0192	-77.6549	179 ± 8	175 ± 23	340.7385	44.7215	2326 ± 1947	256 ± 88
167.4607	-76.6132	184 ± 8	188 ± 36	342.1803	55.126	11111 ± 44444	1053 ± 898
167.5097	-60.0949	847 ± 172	741 ± 412	343.3147	62.1457	746 ± 184	840 ± 1208
167.8629	-63.2056	3448 ± 3210	787 ± 639	343.9458	43.5591	781 ± 153	249 ± 100

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Table 1 – *Continued from previous page*

RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)	RA (deg)	Dec (deg)	Gaia distance (pc)	Hipparcos distance (pc)
168.0242	-71.2172	226 ± 14	195 ± 27	344.0479	58.6672	398 ± 37	286 ± 176
168.1158	-76.7394	199 ± 9	318 ± 750	344.1774	62.6244	1205 ± 697	763 ± 559
168.2537	-57.0349	909 ± 231	990 ± 1020	345.2276	38.708	395 ± 75	273 ± 55
170.6325	-53.3701	649 ± 156	1042 ± 673	347.3196	49.6504	709 ± 347	649 ± 308
171.5055	-59.3524	676 ± 187	685 ± 366	349.8608	79.0036	19 ± 0	20 ± 0
171.9875	-62.805	971 ± 273	508 ± 211	350.0789	55.8075	2273 ± 1291	588 ± 315
172.779	-62.9467	680 ± 333	1538 ± 1775	350.5432	56.3479	526 ± 86	403 ± 135
172.9615	-68.0573	1250 ± 391	1538 ± 1846	357.471	62.2138	769 ± 195	1149 ± 898
173.3571	-70.1950	109 ± 4	103 ± 6	358.7671	28.6336	39 ± 0	42 ± 2

The right ascension (RA) and declination (Dec) of 318 objects with their distance estimations using Gaia and Hipparcous are listed in Table 1. We also carried out error estimations for both catalogue and are given along with the corresponding distance.

5. Discussion

We plotted the distance estimated from the Hipparcos data versus Gaia DR1 for a sample (Gaia distance ¡ 1 kpc) of 236 Be stars and is illustrated in Figure 2. Within the Gaia distance of 1 kpc, the objects with percentage error in distance more than 80% are eliminated from plotting in this figure and the rest are plotted with error bars. In the X-axis distances from Gaia DR1 data (distance limited to 1 kpc) and in Y-axis the corresponding distances calculated from Hipparcos data is taken. It is clear from the Figure 2 that, for nearby objects (in the range of 0 – 300 pc) the error is small, when distance increases for both Hipparcos and Gaia DR1, the error in distance gradually increases. But increase in error is more prominent for Hipparcos compared to Gaia. From the figure it can be concluded that for distance less than 250 pc both Gaia and Hipparcos missions produce reliable estimates of distance. Also, the distances obtained from Gaia DR1 data is more preferable, within the distance range 250 pc to 600 pc, than the Hipparcos data. For farther objects, distances calculated using both Gaia and Hipparcos contain significant error.

We also plotted histograms with distances of 318 Be stars from Gaia DR1 and Hipparcos data taken along X-axis and the number of objects along Y-axis. The clustered bars shows the objects with different percentage error corresponding to a particular distance range.

In Figure 3, the distance for 318 objects obtained from Gaia DR1 data are classified to 4 bins and are taken along the X-axis while the number of objects are taken along the Y-axis. The histogram shows clustered bars in different colours, representing the number of objects within the different ranges of percentage error (%) in distance. From the plot, it can be observed that, fordistances ranging from 0 to 0.5 kpc, 97 objects with percentage error less than 20% and 7 objects with percentage error in the range 20 to 50% are present. Within this range of distance there are no objects present with percentage error

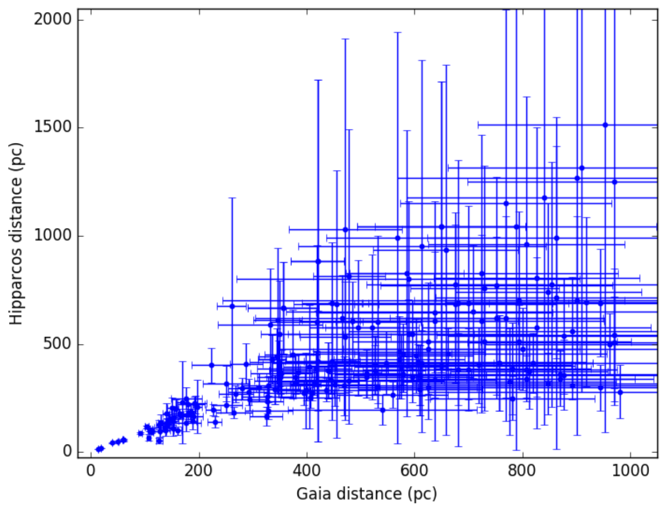

Figure 2. Figure represents Hipparcos distance versus Gaia DR1 distance for 318 Be stars from [8]. The X-axis shows Gaia distance within 1 kpc and Y-axis shows the corresponding Hipparcos distance. The objects are plotted with corresponding percentage error in both axes.

greater than 50%. For the distances ranging from 0.5 to 1 kpc, 28 objects fall in the range of ¡ 20%, 88 objects fall in the range of 20 to 50%, and just 4 objects fall in the range of 50 to 80%. Now, considering the distances ranging from 1 to 2 kpc, 47 objects are present within the range of 20 to 50% while there is no object present with a percentage error less than 20%. In this distance range, 10 objects have their percentage error in the range 50 to 80% and 1 object have percentage error > 80%. When moving to farther distances, greater than 2 kpc, Gaia DR1 data have a significant amount of error indicating 25 objects to be present in range of percentage error greater than 80%. Also 17 objects fall in the range of 50 to 80% and only no object have its percentage error less than 50%.

Similarly, in Figure 4, the distances obtained from Hipparcos data are arranged in 4 bins for 318 objects are taken along the X-axis and the number of objects are taken along the Y-axis. Here, in the distance range of 0 to 0.5 kpc, 41 objects are seen with percentage error < 20% which is much less than that observed in the case of Gaia. On the other hand, there are about 91 objects present within the range of 20 to 50% which is very much greater than in the case of Gaia. Also it can be seen that 20 objects have a percentage error greater than 50% and around 4 objects have a percentage error greater than 80%. Considering the distance range of 0.5 to 1 kpc, there is no object

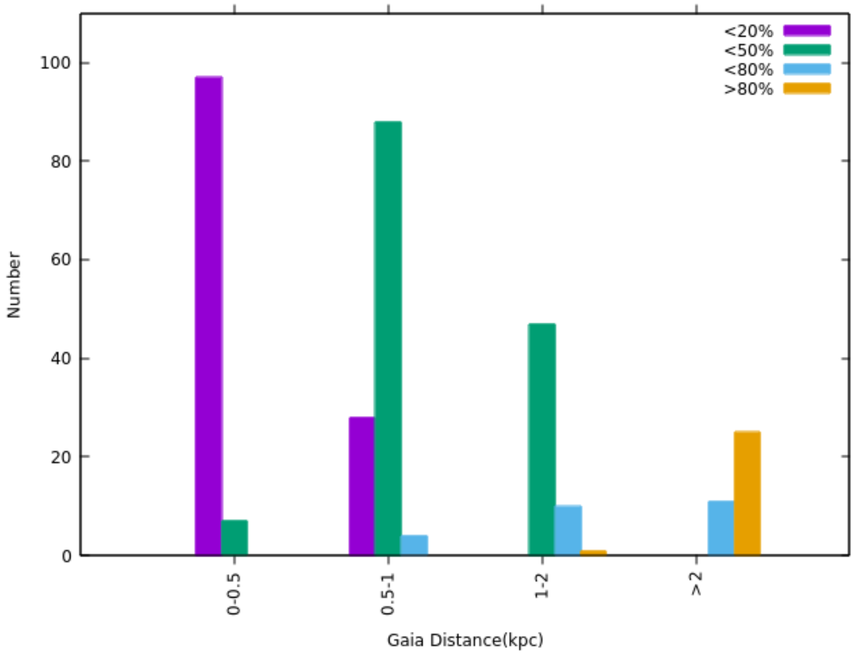

Figure 3. Histogram illustrates Gaia distances [4] of 318 Be stars. X-axis contains the distance bins (0 – 0.5, 0.5 – 1.0, 1 – 2, >2 kpc) for Gaia distances and the respective number of objects in Y-axis. The clustered bars shows the objects with different percentage error corresponding to a particular distance range.

present with percentage error less than 20%. But it is observed that, 29 objects are present with percentage error between 20% and 50%, 41 objects are present with percentage error between 50% and 80%, and 27 objects are having a much greater percentage error of more than 80%. The percentage error in distance calculated from Hipparcos data for our selected objects increases drastically with increase in distance. It is clearly visible that there are no objects with percentage error less than 50% in the distance ranging from 1 to 2 kpc. In the case of objects in our selected list with distance greater than 2 kpc, all the objects have their percentage error > 80%. From the Figure 3 & Figure 4, we can conclude that the Gaia DR1 data is more preferable than the Hipparcos data for our selected objects. For nearer distances (0 to 1 kpc), Gaia data consists more objects with percentage error less than 20% than Hipparcos data i.e., in this range, distances calculated using Hipparcos data contains percentage error greater than 50% and some objects have percentage error greater than 80%. At larger distances, both Gaia and Hipparcos consist significant error. But considering the objects in our list with distances greater than 2 kpc, Hipparcos data gives only objects with percentage error greater

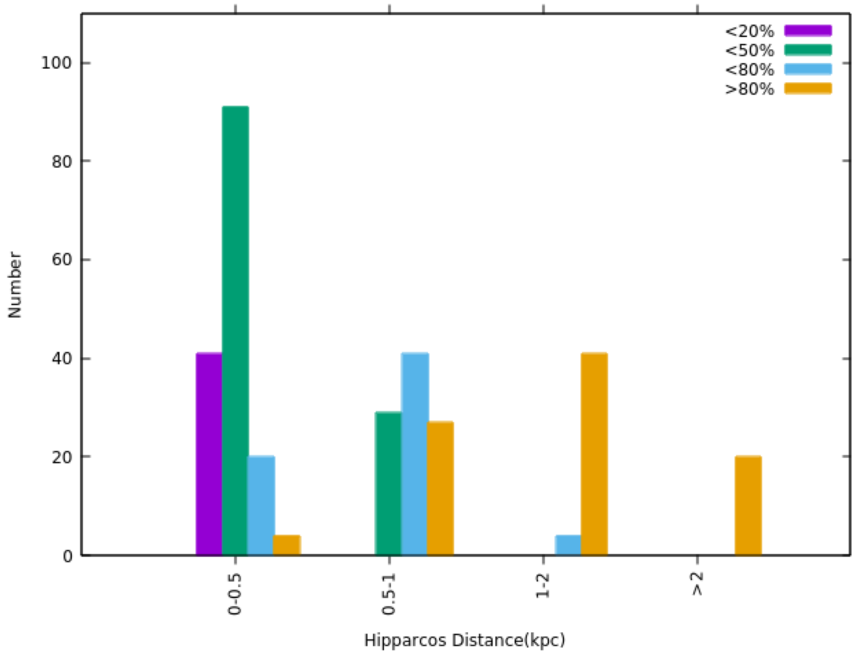

Figure 4. Histogram illustrates Hipparcos distances ESA [6] of 318 Be stars. X-axis contains the distance bins (0 – 0.5, 0.5 – 1.0, 1 – 2, >2 kpc) for Hipparcos distances and the respective number of objects in Y-axis. The clustered bars shows the objects with different percentage error corresponding to a particular distance range.

than 80% and there are no objects with less percentage error. Hence, we make an inference that, for our selected list of Be stars the Gaia data is more preferable than the corresponding Hipparcos data.

6. Conclusion

Gaia is the space-astrometry mission of the European Space Agency which is aimed to prepare a 3D spatial and velocity distribution of stars. The data of Gaia will have a strong impact on many other areas of astrophysical research. The Gaia satellite has been built under an ESA contract by Airbus Defense and Space and the raw data has been processed by the Gaia Data Processing and Analysis Consortium. The first intermediate release of Gaia DR1 comprises astrometry and photometry data. The advancement in technology makes Gaia DR1 more reliable than the Hipparcos data. We carried out a comparison of distances of Be stars from [8] with the available Gaia and Hipparcos data. Analysis of the data set through an illustration revealed that the obtained Gaia and Hipparcos distances show very low errors for nearby objects (< 250 pc). Two histogram representation of percentage error with distances of the selected objects from Gaia DR1 and Hipparcos data. The histogram implies that objects with higher errors (> 50%) are comparatively low in the data taken from Gaia (< 5 objects) than Hipparcos (> 65 objects) within a distance of 1 kpc. In summary, we infer that Gaia data is more preferable than the corresponding Hipparcos data. The second data release, in 2018, will publish the final Gaia catalogue which will be a census of our Galaxy of very high precision and more information about various astronomical objects.

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