HW 01: THE DISTANCE TO THE PLEIADES

BRYAN YAMASHIRO[1]

University of Hawaii at Manoa
2500 Campus Road
Honolulu, HI 96822

1. INTRODUCTION

The parallaxes of the Pleiades galaxy cluster utilizing the HIPPARCOS catalog (H-cat) were determined from an angular radius 2° angle of the RA/Dec coordinates, 03h47m00.0s +24d03m00.0s. H-cat was conceived from four years of data collected by the Hipparcos satellite in geostationary orbit (Perryman et al. (2014)). The objective of this study will be to derive a distance to the Pleiades cluster while invoking the various parameters measured by Hipparcos and an arsenal of astrophysical equations.

2. OBSERVATIONS

2.1. *Cluster Distance*

There was a total of 57 objects from H-cat, but 11 were rejected due to a large deviation off of the common parallax. The rejected individual objects included lengths that exceeded a 0.5σ statistical error above the most common parralax of 8 mas, shown in figure 1. The full list of objects and the subsequently removed outliers are provided in table 1.
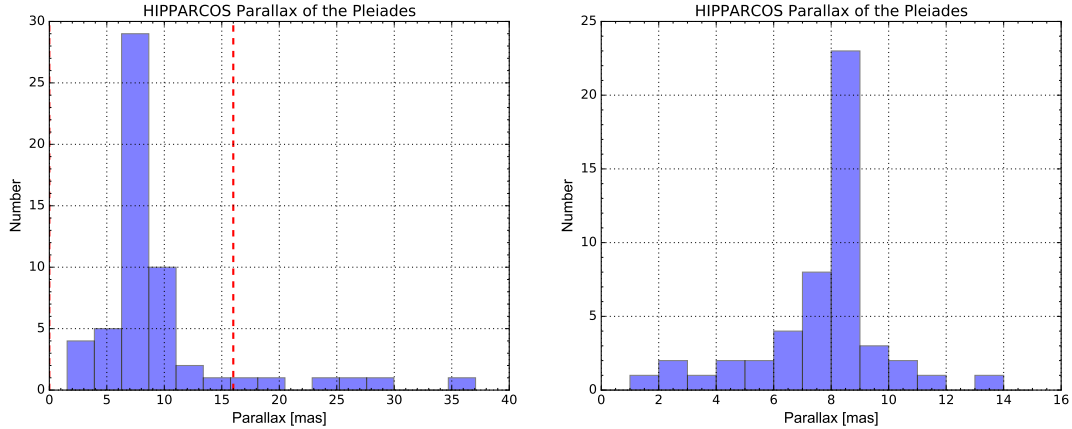

Figure 1. The photometric apertures containing both J-star (left) and J-standard (right). The contour levels are provided to observe the aperture localized intensities of both stars.

The cluster distance was derived using the relationship between an object and the correlating parallax angle, shown in equation 2 (Las Cumbres Observatory (2017)). An average of the object distances yielded a distance of (128.5 ± 15.1) pc, within the 2° limit as well as the parallax rejections. The error on the distance was found using error propagation on the parallax and amounted to an average, shown in equation 1.

$$\frac{1}{N}\sum_{i=1}^{N}\delta x_i \tag{1}$$

$$\text{Distance} = \frac{1}{\text{Parallax}} \tag{2}$$

Further testing of the cluster involved the use of the proper motion (μ), associated with the cluster. H-cat reports μ in terms of components in RA and Dec, therefore the magnitude is equated from equation 3.

$$\mu = \sqrt{\mu_{RA}^2 + \mu_{Dec}^2} \tag{3}$$

Since the proper motions and the distances of each object is defined, the transverse velocity (V_T) is obtainable. The transverse velocity will not allow for viewing redshift, but it yields an important relation relative to the other bodies. The transverse velocity is obtained via the bodies in motion and their distance, therefore it is implied that objects belonging to the same cluster will yield a linear property with respect to these variables. This linear trait is seen in figure 2 (right), and promulgates the fact that the rejected objects were indeed not part of the Pleiades. Another method of the object belonging to the cluster was to observe the magnitudes. The two magnitudes parsed included the Hipparcos magnitude (Median magnitude in the Hipparcos photometric system), and the (B-V) color index. Again this result showed the deviation that the non-members exhibited and are presented in figure 2 (left).
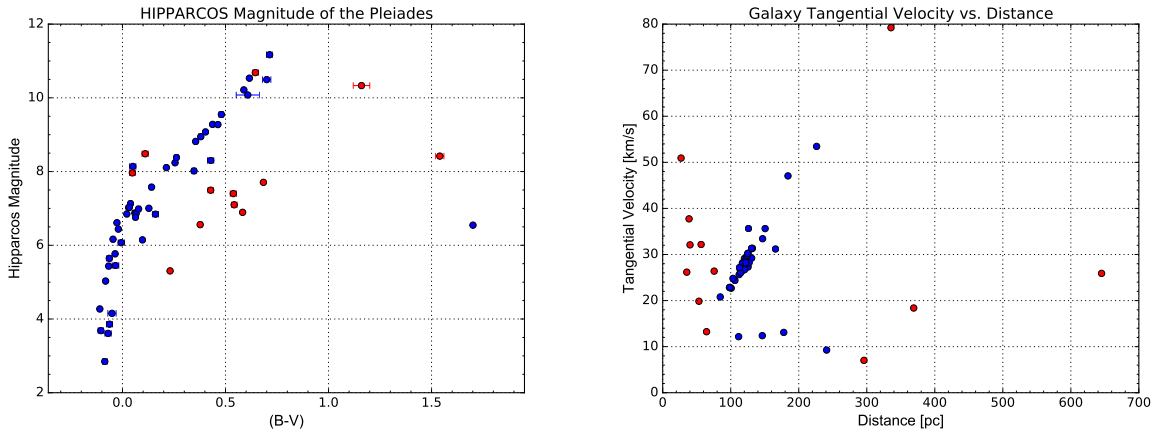
$$V_T = \mu D \tag{4}$$

Figure 2. **Left:** The color magnitude against the Hipparcos magnitude. The points in red represent the rejected objects, and the magnitudes are clearly not part of the spectrum. **Right:** The calculated distances against the derived tangential velocities. Red points represent rejected objects, and these show a clear deviation from the main cluster, which is somewhat linear as expected.

2.2. *Size of the Pleiades*

The general size of the Pleiades for a distance of (128.5±15.1) pc and a 2° angular radius was found with trigonometry in equation 5. The cluster size was found to be (201.8±23.7) pc across. This size is assuming that the cluster is symmetric and does not extrude variably in the direction toward and away from the viewer.

$$2 \times (128.5\text{pc} \pm 15.1\text{pc}) \times \arctan(1°) = \text{Cluster Size} \tag{5}$$

3. CONCLUSION

The distance to the Pleiades cluster, utilizing the Hipparcos database, was (128.5±15.1) pc for a 2° angular radius. Subsequently, the cluster size was (201.8±23.7) pc across the perpendicular plane of the sky. The Hipparcos team measured the Pleiades distance at 120.2 pc (Beatty (2014)), which is within the error of the calculated distance of this study. Against the Hipparcos study, the result obtained in this study yielded a sigma deviation of 0.55σ.

4. RESULTS

Table 1. Apparent Magnitude Data

Object Number	RA [deg]	Dec [deg]	Parallax [mas]	Distance to Galaxy [pc]	Proper Motion RA[mas/yr]	Proper Motion Dec [mas/yr]	Magnitude [mag]	B-V [mag]
16996	54.649	24.601	8.96 ±1.07	111.607±13.3	3.47 ±1.55	-22.69 ±1.46	8.300 ±0.0012	0.428 ±0.015
17020*	54.736	24.569	2.98 ±2.75	335.570	21.24 ±3.71	-44.93 ±3.32	10.68 ±0.0041	0.645 ±0.015
17034	54.777	24.702	8.32 ±0.79	120.192±11.4	23.91 ±0.97	-45.11 ±0.74	7.128 ±0.0008	0.039 ±0.008
17044	54.806	24.466	10.19 ±2.19	98.1354±7.6	23.24 ±2.62	-43.11 ±2.16	10.53 ±0.004	0.616 ±0.005
17091	54.921	23.290	11.82 ±1.94	84.6023±15.7	26.82 ±2.74	-44.23 ±2.11	10.07 ±0.005	0.608 ±0.056
17181	55.192	25.329	6.83 ±0.5	146.412±41.6	9.83 ±0.58	-14.86 ±0.5	6.146 ±0.0009	0.097 ±0.005
17225	55.345	23.487	8.1 ±1.06	123.456±7.6	21.78 ±1.42	-44.97 ±1.26	9.279 ±0.0019	0.437 ±0.006
17245	55.400	25.619	6.64 ±1.51	150.602±24	14.67 ±1.8	-47.59 ±1.67	10.21 ±0.0026	0.589 ±0.004
17289	55.519	22.858	7.65 ±1.5	130.718±25.8	20.04 ±1.89	-42.56 ±1.51	9.274 ±0.0024	0.463 ±0.003
17305*	55.566	22.786	18.77 ±0.84	53.2765	20.81 ±1.03	-75.66 ±0.88	7.494 ±0.0009	0.428 ±0.013
17317	55.600	22.421	8.27 ±2.07	120.918±21.9	18.87 ±2.22	-43.38 ±1.71	10.49 ±0.0051	0.7 ±0.02
17401	55.923	23.649	7.58 ±0.9	131.926±36	18.77 ±1.06	-46.36 ±0.95	8.016 ±0.0013	0.347 ±0.01
17403	55.929	25.080	7.93 ±0.6	126.103±14.3	22.38 ±0.97	-55.13 ±0.98	7.577 ±0.0015	0.141 ±0.008
17489	56.200	24.289	8.65 ±0.36	115.606±8	20.38 ±0.43	-44.81 ±0.37	5.450 ±0.0006	-0.034 ±0.016
17497	56.213	23.269	8.33 ±1.22	120.048±5.2	21.87 ±1.37	-43.18 ±1.08	9.074 ±0.0019	0.403 ±0.007
17499	56.218	24.113	8.06 ±0.25	124.069±18.8	20.84 ±0.28	-46.06 ±0.23	3.685 ±0.0006	-0.105 ±0.013
17527	56.290	24.839	7.97 ±0.37	125.470±3.9	20.36 ±0.45	-46.52 ±0.41	5.644 ±0.0006	-0.064 ±0.012
17531	56.302	24.467	7.97 ±0.33	125.470±5.8	21.24 ±0.38	-40.56 ±0.35	4.272 ±0.0006	-0.11 ±0.006
17572	56.453	23.147	8.24 ±0.75	121.359±4.9	20.5 ±0.85	-44.55 ±0.74	6.875 ±0.0011	0.06 ±0.011
17573	56.456	24.367	8.51 ±0.28	117.508±10.4	20.95 ±0.31	-45.98 ±0.28	3.859 ±0.0006	-0.063 ±0.015
17579	56.476	24.554	8.77 ±0.54	114.025±3.6	20.18 ±0.7	-44.87 ±0.62	5.767 ±0.0011	-0.036 ±0.008
17583	56.496	25.398	8 ±0.89	125 ±8.4	19 ±0.99	-47.23 ±0.94	8.108 ±0.0012	0.213 ±0.006
17588	56.512	24.528	8.58 ±0.56	116.550±12.1	19.88 ±0.73	-44.37 ±0.65	6.438 ±0.0012	-0.02 ±0.006
17608	56.581	23.948	8.58 ±0.37	116.550±7.6	21.13 ±0.35	-43.65 ±0.27	4.153 ±0.001	-0.051 ±0.02
17625	56.645	25.843	4.42 ±1.48	226.244±18.9	20.91 ±1.65	-45.13 ±1.38	8.816 ±0.002	0.355 ±0.007
17664	56.747	24.520	7.66 ±0.66	130.548±25.2	22.73 ±0.84	-45 ±0.85	6.848 ±0.0006	0.021 ±0.007
17684*	56.821	23.726	15.52 ±0.73	64.4329	-34.94 ±0.69	-25.54 ±0.55	7.098 ±0.0017	0.542 ±0.014
17692	56.837	23.803	8.9 ±0.77	112.359±8.3	18.56 ±0.75	-44.31 ±0.6	7.022 ±0.0011	0.03 ±0.001
17694	56.845	22.922	8.62 ±0.84	116.009±10.4	20.91 ±1.04	-44.88 ±0.87	8.238 ±0.0012	0.255 ±0.004
17702	56.871	24.105	8.09 ±0.42	123.609±12.8	19.34 ±0.39	-43.67 ±0.33	2.848 ±0.0006	-0.086 ±0.012
17704	56.872	24.288	9.42 ±0.75	106.157±4.7	18.33 ±0.87	-44.69 ±0.74	6.859 ±0.0013	0.066 ±0.006
17729	56.945	25.385	9.68 ±0.93	103.305±8	19.26 ±0.96	-46.75 ±0.91	8.381 ±0.001	0.262 ±0.008
17759	57.027	24.988	6.03 ±0.7	165.837±25.6	-28 ±0.78	-28 ±0.74	6.546 ±0.0044	1.701 ±0.001
17776	57.086	23.421	8.45 ±0.39	118.343±9.8	17.99 ±0.39	-46.57 ±0.32	5.435 ±0.0008	-0.067 ±0.008
17791	57.125	24.345	7.87 ±1.32	127.064±21.3	17.68 ±1.48	-43.28 ±1.37	7.003 ±0.0013	0.128 ±0.005
17812*	57.174	25.800	3.38 ±1.06	295.857	-2.22 ±1.53	-4.48 ±1.74	8.482 ±0.0023	0.11 ±0.015
17828	57.227	22.799	4.15 ±0.97	240.963±56.3	6.76 ±1.14	-4.45 ±0.93	8.139 ±0.0027	0.05 ±0.015
17832*	57.237	23.857	13.22 ±0.52	75.6429	46.63 ±0.53	-56.75 ±0.44	6.559 ±0.0008	0.377 ±0.009
17847	57.290	24.053	8.53 ±0.39	117.233±13.3	17.7 ±0.36	-44.18 ±0.32	3.608 ±0.001	-0.07 ±0.015
17851	57.296	24.136	8.54 ±0.31	117.096±5.3	18.07 ±0.3	-47.2 ±0.27	5.029 ±0.0017	-0.082 ±0.004

Table 1 *(continued)*

Object Number	RA [deg]	Dec [deg]	Parallax [mas]	Distance to Galaxy [pc]	Proper Motion RA[mas/yr]	Proper Motion Dec [mas/yr]	Magnitude [mag]	B-V [mag]
17862	57.340	24.381	8.18 ±0.59	122.249±4.6	17.42 ±0.65	-45.38 ±0.52	6.611 ±0.0012	-0.027 ±0.004
17892	57.409	22.533	8.3 ±0.66	120.481±8.6	18.52 ±0.8	-42.87 ±0.65	7.030 ±0.0011	0.033 ±0.008
17900	57.431	23.711	8.72 ±0.6	114.678±8.7	16.73 ±0.63	-44.82 ±0.53	6.164 ±0.0009	-0.046 ±0.007
17921	57.479	22.244	8.86 ±0.42	112.866±7.6	24.31 ±0.48	-44.46 ±0.39	6.072 ±0.0006	-0.006 ±0.015
17923	57.491	23.848	6.81 ±0.72	146.842±16	16.81 ±0.82	-44.88 ±0.68	6.760 ±0.0012	0.063 ±0.008
17928*	57.514	22.591	24.89 ±0.75	40.1767	156.86 ±0.88	-60.62 ±0.73	7.402 ±0.0012	0.538 ±0.015
17954*	57.578	25.579	17.71 ±0.55	56.4652	41 ±0.7	-112.74 ±0.73	5.304 ±0.0012	0.231 ±0.005
17999	57.718	23.961	9.93 ±0.75	100.704±4.3	18.86 ±0.83	-43.51 ±0.69	6.984 ±0.0006	0.078 ±0.009
18018*	57.762	23.903	28.27 ±2.57	35.3731	148 ±2.75	-48.5 ±2.44	10.33 ±0.0039	1.16 ±0.04
18046	57.855	25.162	5.62 ±0.5	177.935±22.8	-9.68 ±0.56	-12.09 ±0.44	6.843 ±0.0009	0.16 ±0.015
18050	57.863	24.518	7.65 ±1.34	130.718±8.5	21.84 ±1.4	-45.5 ±1.08	8.946 ±0.0021	0.38 ±0.009
18097*	58.022	22.672	37.07 ±0.73	26.9759	206.51 ±0.78	-339.56 ±0.62	7.706 ±0.0013	0.684 ±0.002
18106*	58.047	25.163	25.81 ±0.53	38.7446	-122.38 ±0.59	-164.51 ±0.48	6.893 ±0.0005	0.583 ±0.003
18154	58.222	24.715	10.13 ±1.66	98.7166±13.1	15.64 ±1.99	-46.22 ±1.66	9.548 ±0.0021	0.48 ±0.011
18181*	58.338	23.123	2.71 ±1.25	369.003	8.46 ±1.19	6.2 ±1.08	8.418 ±0.0015	1.54 ±0.02
18263	58.605	24.360	5.43 ±2.75	184.162±56.3	22.71 ±3.69	-48.76 ±3.27	11.16 ±0.0055	0.714 ±0.015
18296*	58.685	23.201	1.55 ±0.87	645.161	2.34 ±0.91	-8.12 ±0.81	7.964 ±0.0016	0.048 ±0.014

NOTE—All parameters of the Pleiades cluster within a 2° angular radius. The (*) denotes objects that were rejected due to a high deviation from the most common parallax of 8 pc. The error on rejected objects is not reported since statistics were not carried out on those targets.

REFERENCES

Perryman M.A.C., Lindegren L., Kovalevsky J., Hog E., Bastian U., Bernacca P.L., Creze M., Donati F., Grenon M., Grewing M., van Leeuwen F., van der Marel H., Mignard F., Murray C.A., Le Poole R.S., Schrijver H., Turon C., Arenou F., Froeschle M., Petersen C.S., "The Hipparcos Catalogue" (1997A&A...323L..49P)

https://lco.global/spacebook/parallax-and-distance-measurement/

Beatty, Kelly. "Resolving the Pleiades Distance Problem." Sky & Telescope. F+W Media, Inc., 29 Aug. 2014. Web. 30 Jan. 2017. ¡http://www.skyandtelescope.com/astronomy-news/resolving-pleiades-distance-problem-08282014/¿.