# Lab Report 3

Experiment (VI): Observation of the nearest open star cluster, the Hyades. Moving-cluster parallax

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# Contents

# 1 Determination of the Convergence Point

To determine the convergence point, we calculate the future coordinates of the given stars in the Hyades cluster. We take time steps of 100,000 years, 8 time intervals were found to be sufficient (0-700,000 years). The coordinates of the stars at each time step are calculated using the formula:

$$\alpha_{\text{new}} = \alpha_{\text{old}} + \frac{\mu_\alpha \cos(\delta)}{\cos(\delta)} * \Delta t * \frac{10^{-6}}{3.6} \tag{1}$$

$$\delta_{\text{new}} = \delta_{\text{old}} + \mu_\delta * \Delta t * \frac{10^{-6}}{3.6} \tag{2}$$

The factors that are added are used to convert from $10^{-3}$ arcseconds/year to degrees/year.

| *Hipparcos* catalogue number | α, J1991.25 (h m s) | δ, J1991.25 (° ′ ″) | $\mu_\alpha \cos\delta$ ($10^{-3}$ arcsec year$^{-1}$) | $\mu_\delta$ ($10^{-3}$ arcsec year$^{-1}$) | $v_r$ (km sec$^{-1}$) | $p$ ($10^{-3}$ arcsec) |
|---|---|---|---|---|---|---|
| 18170 | 03 53 09.96 | +17 19 37.8 | 143.97±1.06 | -29.93±0.84 | 35.0±2.5 | 24.14±0.90 |
| 19554 | 04 11 20.20 | +05 31 22.9 | 146.86±1.00 | 5.00±0.85 | 36.6±1.2 | 25.89±0.95 |
| 20261 | 04 20 36.24 | +15 05 43.8 | 108.79±0.95 | -20.67±0.82 | 36.2±1.2 | 21.20±0.99 |
| 20901 | 04 28 50.10 | +13 02 51.5 | 105.17±0.84 | -15.08±0.63 | 39.9±4.1 | 20.33±0.84 |
| 21589 | 04 38 09.40 | +12 30 39.1 | 101.73±0.96 | -14.90±0.76 | 44.7±5.0 | 21.79±0.79 |
| 22157 | 04 46 01.70 | +11 42 20.2 | 67.48±1.11 | -7.09±0.79 | 43.0±1.0 | 12.24±0.86 |
| 23497 | 05 03 05.70 | +21 35 24.2 | 68.94±0.75 | -40.85±0.52 | 38.0±1.7 | 20.01±0.91 |
| 24019 | 05 09 45.06 | +28 01 50.2 | 55.86±1.33 | -60.57±0.77 | 44.9±0.5 | 18.28±1.30 |

Figure 1: All external data on Hyades' Cluster stars used in the calculations.

The coordinates of all the stars at all the time steps are then plotted on the same 2D scatter plot with error bars to determine the convergence point. The error bars are not visible in the plot because the given percentage errors in the proper motions were very small. The convergence point is the point where all the lines are intersecting at. The coordinates of the convergence point are:

$$\alpha = 97.7 \pm 3.9^\circ \quad \delta = 9.1 \pm 1.4^\circ \tag{3}$$

The estimation of the convergence point is shown in the figure, and and error box is drawn around the point to show the uncertainty in the coordinates.
The coordinates of the convergence point obtained by Perryman et al. (1998) [1] are:

$$\alpha = 96.6^\circ \quad \delta = 5.8^\circ \tag{4}$$

The right ascension of the convergence point obtained by Perryman et al. is within the error box of our estimation. But, the declination is not. I do not know why this is the case. However, the calculations of the distance later were found to be more well aligned with the distances obtained from the trigonometric parallax measurements, than if the results by Perryman were used.

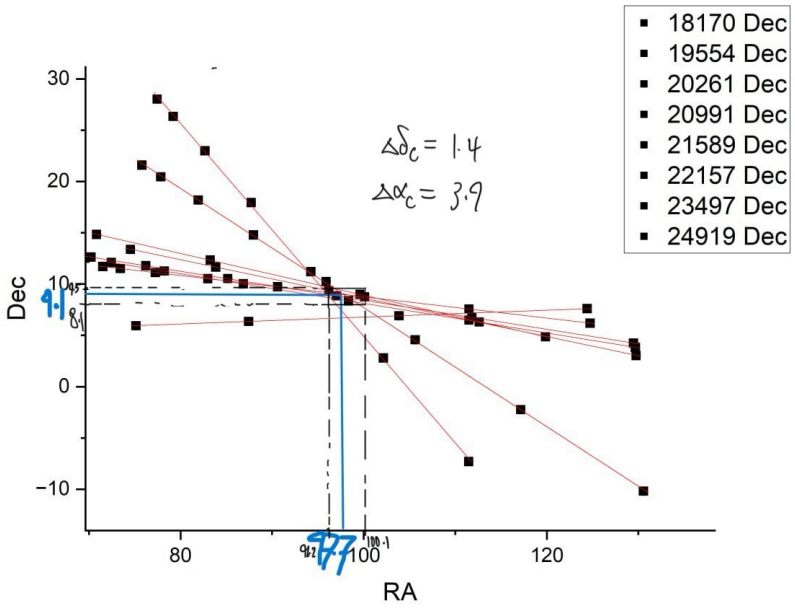


Figure 2: The convergence point of the stars in the Hyades cluster.

## 2 Determination of the velocity vectors and distances to the Hyades

The radial velocities of the stars given in the table are used along with the angle to the plane in which the stars are moving (which is obtained using the coordiantes of the convergence point) to calculate the tangential component of the velocities of the stars. We then use these with the proper motion of the stars to calculate the distance to them using the following formula:

$$d = \frac{v_t}{4.74047\mu} = \frac{v_r \tan\theta}{4.74047\mu} \tag{5}$$

where $d$ is the distance in parsecs, $v_t$ is the tangential velocity in km/s, $v_r$ is the radial velocity in km/s, $\theta$ is the angle to the plane in which the stars are moving, and $\mu$ is the proper motion in arcseconds/year. $\mu = \sqrt{(\mu_\alpha \cos\delta)^2 + \mu_\delta^2}$ is the total proper motion of the star.
The distances to the stars are calculated using the formula above, and the results are shown in the table below, along with the percentage errors in the distances.
The star 22157 is an outlier in the data (this and future results), so it was not included, to get a more accurate mean. The mean distance to the stars in the Hyades cluster using the moving-cluster parallax is:

$$d = 45.6 \pm 8.26\text{pc} \tag{6}$$

The average percentage error in the distances is 18.1%, which is quite high. The biggest contributor to this error is the error from the angle to the plane in which the stars are moving, which is directly related to the error in the coordinates of the convergence point.

| Hipparcos catalogue number | d (parsecs) | Δd (parsecs) | Percentage uncertainty in d |
|---|---|---|---|
| 18170 | 40.89008 | 6.71504 | 16.42216 |
| 19554 | 36.45224 | 5.75965 | 15.80054 |
| 20261 | 43.67987 | 7.14632 | 16.36068 |
| 20991 | 46.03914 | 9.01408 | 19.57916 |
| 21589 | 48.47023 | 10.07963 | 20.7955 |
| 22157 | -- | -- | -- |
| 23497 | 45.59984 | 8.98154 | 19.69643 |
| 24919 | 58.2619 | 10.49619 | 18.01552 |
| | | Average percent uncertainty= | 18.09571 |
| | Average d from cluster parallax = | 45.62762 | |
| | Absolute error= | 8.25664 | |

Figure 3: The distances to the stars in the Hyades cluster.

# 3 Comparison of moving-cluster-parallax and trigonometric-parallax distances

We now calculate the distances to the stars in the Hyades cluster using the trigonometric parallax method. The following formula is used:

$$d = \frac{1}{p} \tag{7}$$

We get the parallax of the stars from the table, and then calculate the distances using the formula above. The results are shown in the table below, along with the percentage errors in the distances. We see that the distances obtained using both methods are very similar, and the mean distance to

| Hipparcos catalogue number | p ($10^{-3}$ arcsec) | d from p (parsec) | Δd from p (parsecs) | Percentage uncertainty in d from p |
|---|---|---|---|---|
| 18170 | 24.14±0.90 | 41.42502 | 1.54443 | 3.72825 |
| 19554 | 25.89±0.95 | 38.62495 | 1.41729 | 3.66937 |
| 20261 | 21.20±0.99 | 47.16981 | 2.20274 | 4.66981 |
| 20991 | 20.33±0.84 | 49.18839 | 2.03238 | 4.13182 |
| 21589 | 21.79±0.79 | 45.89261 | 1.66384 | 3.62552 |
| 22157 | 12.24±0.86 | 81.69935 | -- | -- |
| 23497 | 20.01±0.91 | 49.97501 | 2.27273 | 4.54773 |
| 24919 | 18.28±1.30 | 54.7046 | 3.89037 | 7.1116 |
| | | | Average percent uncertainty= | 4.49773 |
| | Average d from trig parallax = | 46.71148 | parsec | |
| | Absolute error= | 2.10096 | parsec | |

Figure 4: The distances to the stars in the Hyades cluster using the trigonometric parallax method.

the stars in the Hyades cluster using the trigonometric parallax method is:

$$d = 46.7 \pm 2.1\text{pc} \tag{8}$$

So, both values are within their error boxes. However, the moving-cluster parallax method has a much larger error than the trigonometric parallax method. The trigonometric parallax method is much more precise.

We plot both results for each star against each other in the figure below. We also draw a straight

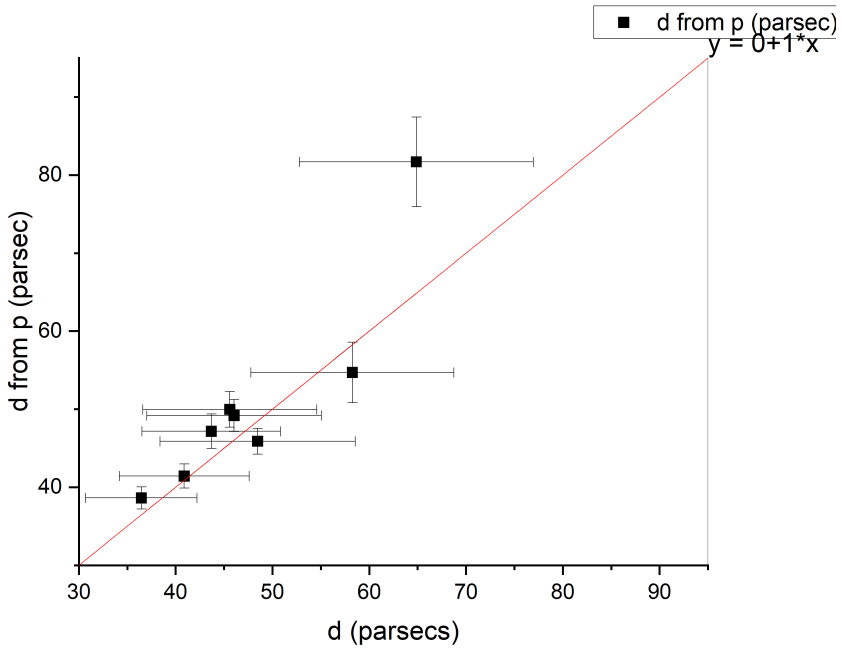


Figure 5: The distances to the stars in the Hyades cluster using both methods.

line with a slope of 1 to show the expected result if both methods give the same distance. We see that the line passes through all the error boxes, and the points are all very close to the line, except for the star 22157, which is an outlier. Hence, this is why we did not include it in the mean distance calculations.
We also obtain values for the mean velocity of the stars and mean absolute error in the Hyades cluster using the moving-cluster parallax method. The mean velocity is calculated using the formula:

$$v = \frac{v_r}{\cos\theta} \tag{9}$$

The following table shows the velocities and its errors of the stars in the Hyades cluster using the moving-cluster parallax method: The mean velocity of the stars in the Hyades cluster using the moving-cluster parallax method is:

$$v = 45.9 \pm 3.5\text{km/s} \tag{10}$$

The mean velocities and distances of the stars in the Hyades cluster according to Perryman et al. (1998) [1] are:

$$d = 46.34 \pm 0.27\text{pc} \quad v = 45.93 \pm 0.23\text{km/s} \tag{11}$$

So, the results we obtrain match up remarkably well to the results obtained by Perryman.

| Hipparcos catalogue number | vr (km sec$^{-1}$) | θ (rads) | v (km sec^-1) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| 18170 | 35.0±2.5 | 0.68345 | 45.13815 |
| 19554 | 36.6±1.2 | 0.60654 | 44.54576 |
| 20261 | 36.2±1.2 | 0.56462 | 42.85087 |
| 20991 | 39.9±4.1 | 0.52644 | 46.14851 |
| 21589 | 44.7±5.0 | 0.48619 | 50.55874 |
| 22157 | 43.0±1.0 | -- | -- |
| 23497 | 38.0±1.7 | 0.4277 | 41.7619 |
| 24919 | 44.9±0.5 | 0.4691 | 50.33768 |
| | | | |
| | | Average velocity= | 45.90594 |
| | | Absolute error= | 3.51725 |

Figure 6: The velocities of the stars in the Hyades cluster using the moving-cluster parallax method.

# 4 References


1. Perryman, M. A. C., Brown, A. G. A., Lebreton, Y., Gomez, A., Turon, C., Cayrel de Strobel, G., ... Crifo, F. (1998). The Hyades: distance, structure, dynamics, and age. Å, 331, 81-120. doi:10.48550/arXiv.astro-ph/9707253