GAIA_EDA

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Background and Data [1-3 pages]

This project has made use of the GAIA data set produced by the European Space Agency, from mission GAIA (https://www.cosmos.esa.int/gaia). Mission GAIA is launched to record the movement and position of billion objects in the sky, with a purpose to gain deeper understanding of the history and evolution of the Galaxy.

The GAIA data records information on location, proper motions, parallax, colour, magnitude, etc., of billion celestial objects, from which a three-dimensional mapping of the Galaxy is formed (Gaia Collaboration et al. (2016b): The Gaia mission). The GAIA instruments and payload setup allow the European Space Agency (ESA) to detect even the faintest objects and observe them a few times a year at different positions on the sky. With such information, GAIA has the power to unveil the Galaxy's history and also predict its future.

The team is intrigued by the idea of unravelling the Galaxy's origin and evolution. We are also motivated to obtain more astronomy knowledge. As a result, we choose the GAIA data set to base our project. Out of billions of objects in the Galaxy, we are especially interested in knowing more about open clusters. We hope to use the GAIA data to provide insights into some of the most famous open clusters, Pleiades and M67.

• State the types of data in the dataset(s) and the structure of the dataset(s). Are the data numerical, categorical, or both? Time series? Coordinates? Diagnostic categories? This does NOT need to be an exhaustive list of every variable, just a few comments on the overall types.

There are a total of 153 columns within the GAIA dataset "gaiadr3.gaia_source".

The range of data types include:

- char
- short
- float
- boolean
- double

Which cover a range of information about the dataset including, but not limited to:

- Position
- Movement (direction, speed)
- Distance

- Photometry (colour, brightness)
- Correlation values
- Classification probabilities (Quasar vs Galaxy vs Star)
- Measuring metrics (measurement error)

• State how complete the dataset(s) are (i.e. how many missing, any structure to the missing data, whether there are errors in the data)

• If you used more than one dataset, state what steps you had to take to integrate the datasets

We ran two queries to gather two subsets of the dataset, each representing two open clusters (Pleiades and m67). This was gathered using the GAIA archive which filtered based on location, proper motion, present variables and error rates (Cánovas, 2022).

Ethics, Privacy and Security [1-2 pages]

One of the most important ethical considerations we emphasise is properly acknowledging the authorship of the GAIA data in our project. Authorship and accreditation are ultimately important, especially in scientific research, as they proclaim the contribution one has made to broaden our understanding of a specific matter. Thus, we want to ensure ethical sourcing of the GAIA data by giving credit to the people and institutes that have worked hard to make the GAIA data accessible to the public. Therefore, throughout the report, a frequent acknowledgement will be dedicated to the European Space Agency, and there will be citations of their work.

Secondly, we are wary of possible bias in understanding the data. With a certain level of interest in astronomy, we have obtained a level of understanding of our Milky Way before this project. However, to objectively gain a new perception of open clusters, we do not desire manipulation/handling of data that results in changes in the data and pivot the findings towards our biased preferences. Thus, we are approaching the data set with an open mind and staying aware of the possible bias that might affect the conclusion of this project.

Thirdly, we are concerned about retaining the outcomes of this report until it is substantiated or approved by an authority. We believe it is ethical to wait for the validation of our findings because unvalidated scientific discoveries might result in misleading education to the public. Especially when dealing with a vast topic such as space, we must be mindful of the negative impacts of wrong interpretations and knowledge. As a result, we want to keep the project findings confidential. Team members must be aware of discussing this project with anyone outside of the team, and extra care must be taken regarding the devices and communication platforms used.

Lastly, preventing a wrong understanding of the GAIA data is ethical. This raises the question of whether the data and methods used can produce reliable results. According to the ESA, there are a few prevailing issues with the data set, most commonly seen as insufficient data (many missing values). Having this in mind helps us determine a better approach to the data by focusing on relevant variables that have plenty of entries.

There are few privacy and confidentiality concerns, as the data is not about people and has also been published by the data owner (ESA) for public scientific usage of the data .

Exploratory Data Analysis [3-6 pages] For this section, do NOT try to summarize everything you can find in the dataset(s). Select a subset, highlighting features that you thought were interesting in the data. The plots do not have to be complicated; simple bar charts and scatter plots are fine.

• Several summary tables and/or plots, each describing one, two or three variables in the data that you thought were interesting • Explain the definitions of the variables in each table/plot • Comment on the main features of each plot • Include suitable labels and keys for each plot • Make sure all plots would be readable if printed in black & white, and adjust the point sizes and/or line thicknesses to improve readability • Lay out all tables so that they are clearly readable and clearly labelled, and do not use excessive significant figures

Open cluster subsets: m67 and Pleiades

The 9 features we are looking at are “ra”, “dec”, “pmra”, “pmdec”, “parallax”, “bp_rp”, “phot_g_mean_mag”, “distparsecs” and “abM”.

Ra and Dec stand for Right Ascension and Declination respectively. They are to the sky what longitude and latitude are to the surface of the Earth. Right Ascension corresponds to east/west direction (like longitude), while Declination measures north/south directions, like latitude.

PmRA and PmDec are proper motion in right ascension direction and declination direction respectively. This is the local tangent plane projection of the proper motion vector in the direction of increasing right ascension and increasing declination.

Parallax is the apparent displacement of an object because of a change in the observer’s point of view. Astronomers can use insights derived from the parallax measurements of the closer stars to estimate distances of those more distant.

Bp_rp is the colour of each star. More specifically, how blue it is. The more blue a star is, the higher its temperature.

Phot_g_mean_mag is the mean magnitude in the G band. This is computed from the G-band mean flux applying the magnitude zero-point in the Vega scale.

DistParsecs is the distance of a parsec which is 1 divided by the parallax divided by 1000. A parsec is a unit of distance used in astronomy.

Absolute magnitude is the intrinsic brightness of a star. This is calculated with the parallax and the observed colour from Earth.

We chose these paticular features because we wanted to isolate the most consistent, non-redundant, and relevant features to get the best insight into the GAIA dataset. We wanted a small number of features that are easy to explain because data that is too complex and unexplainable is not valuable. We especially wanted to look at position, distance, temperature and brightness of the stars in the dataset and those are the features we thought would give us the best understanding.

#summary of datsets

```
##        ra              dec             pmra           pmdec
##  Min.   :54.51   Min.   :22.16   Min.   :15.01   Min.   :-49.90
##  1st Qu.:56.02   1st Qu.:23.57   1st Qu.:19.14   1st Qu.:-46.33
##  Median :56.60   Median :24.12   Median :19.90   Median :-45.38
##  Mean   :56.61   Mean   :24.14   Mean   :19.91   Mean   :-45.36
##  3rd Qu.:57.20   3rd Qu.:24.67   3rd Qu.:20.67   3rd Qu.:-44.48
##  Max.   :58.79   Max.   :26.09   Max.   :24.94   Max.   :-40.05
##
##     parallax           bp_rp         phot_g_mean_mag   distparsecs
##  Min.   : 0.7815   Min.   :-0.4035   Min.   : 3.616   Min.   :  79.7
##  1st Qu.: 7.2311   1st Qu.: 1.7362   1st Qu.:13.568   1st Qu.: 133.6
##  Median : 7.3612   Median : 2.8521   Median :16.177   Median : 135.8
##  Mean   : 7.2837   Mean   : 2.4328   Mean   :15.164   Mean   : 143.7
##  3rd Qu.: 7.4878   3rd Qu.: 3.1662   3rd Qu.:17.309   3rd Qu.: 138.3
##  Max.   :12.5475   Max.   : 4.2187   Max.   :20.471   Max.   :1279.6
##                    NA's   :18
##       abM
##  Min.   :-1.837
##  1st Qu.: 7.793
##  Median :10.425
##  Mean   : 9.449
```

```
##  3rd Qu.:11.620
##  Max.   :15.631
##
```

```
## 'data.frame':    1079 obs. of  9 variables:
##  $ ra             : num  58.3 58.3 58.1 58.5 58.5 ...
##  $ dec            : num  23 23.1 22.9 23.3 23.3 ...
##  $ pmra           : num  18.7 19.7 15 18.1 20.2 ...
##  $ pmdec          : num  -45.2 -46.5 -49.6 -42.8 -44.3 ...
##  $ parallax       : num  7.421 7.339 0.842 6.977 7.416 ...
##  $ bp_rp          : num  3.06 2.59 1.21 3.61 1.84 ...
##  $ phot_g_mean_mag: num  16.6 15.4 16.5 18.2 13.5 ...
##  $ distparsecs    : num  135 136 1188 143 135 ...
##  $ abM            : num  10.92 9.72 6.15 12.38 7.9 ...
```

```
##                 vars    n   mean    sd median trimmed   mad    min     max
## ra                 1 1077 132.85  0.35 132.85  132.85  0.21 130.91  134.32
## dec                2 1077  11.84  0.34  11.82   11.83  0.20  10.07   13.57
## pmra               3 1077 -10.96  0.18 -10.97  -10.96  0.19 -11.47  -10.50
## pmdec              4 1077  -2.93  0.18  -2.93   -2.92  0.18  -3.50   -2.51
## parallax           5 1077   1.16  0.11   1.15    1.15  0.04   0.59    3.23
## bp_rp              6 1076   1.13  0.38   1.03    1.09  0.39   0.12    2.54
## phot_g_mean_mag    7 1077  14.87  1.74  15.00   14.93  2.03   7.95   18.21
## distparsecs        8 1077 869.40 69.91 867.31  867.29 33.96 309.19 1692.12
## abM                9 1077   5.18  1.76   5.26    5.22  2.01  -1.72    9.80
##                   range  skew kurtosis   se
## ra                 3.41 -0.30     4.67 0.01
## dec                3.50  0.21     4.13 0.01
## pmra               0.97 -0.11    -0.19 0.01
## pmdec              0.99 -0.22    -0.02 0.01
## parallax           2.64  7.67   140.98 0.00
## bp_rp              2.41  0.70    -0.28 0.01
## phot_g_mean_mag   10.27 -0.42     0.03 0.05
## distparsecs     1382.92  2.15    30.68 2.13
## abM               11.52 -0.33     0.06 0.05
```

```
##        ra              dec             pmra            pmdec
##  Min.   :130.9   Min.   :10.07   Min.   :-11.47   Min.   :-3.499
##  1st Qu.:132.7   1st Qu.:11.69   1st Qu.:-11.08   1st Qu.:-3.043
##  Median :132.8   Median :11.82   Median :-10.97   Median :-2.926
##  Mean   :132.9   Mean   :11.84   Mean   :-10.96   Mean   :-2.927
##  3rd Qu.:133.0   3rd Qu.:11.96   3rd Qu.:-10.83   3rd Qu.:-2.804
##  Max.   :134.3   Max.   :13.57   Max.   :-10.50   Max.   :-2.512
##
##     parallax         bp_rp        phot_g_mean_mag   distparsecs
##  Min.   :0.591   Min.   :0.1226   Min.   : 7.948   Min.   : 309.2
##  1st Qu.:1.124   1st Qu.:0.7884   1st Qu.:13.560   1st Qu.: 844.2
##  Median :1.153   Median :1.0328   Median :14.996   Median : 867.3
##  Mean   :1.158   Mean   :1.1297   Mean   :14.872   Mean   : 869.4
##  3rd Qu.:1.185   3rd Qu.:1.4079   3rd Qu.:16.287   3rd Qu.: 890.0
##  Max.   :3.234   Max.   :2.5372   Max.   :18.213   Max.   :1692.1
##                  NA's   :1
##       abM
```

```
##  Min.   :-1.724
##  1st Qu.: 3.872
##  Median : 5.258
##  Mean   : 5.183
##  3rd Qu.: 6.538
##  Max.   : 9.798
##
```

```
## 'data.frame':    1077 obs. of  9 variables:
##  $ ra             : num  133 133 132 132 133 ...
##  $ dec            : num  10.1 10.2 10.6 10.5 10.4 ...
##  $ pmra           : num  -10.7 -11 -10.5 -11.1 -11 ...
##  $ pmdec          : num  -2.62 -2.54 -2.53 -2.99 -2.83 ...
##  $ parallax       : num  1.17 1.07 1.13 1.31 1.14 ...
##  $ bp_rp          : num  1.071 1.715 0.822 1.906 1.163 ...
##  $ phot_g_mean_mag: num  15.4 17.3 14.4 17.5 15.7 ...
##  $ distparsecs    : num  854 934 889 763 877 ...
##  $ abM            : num  5.79 7.42 4.63 8.05 5.99 ...
```

```
##                 vars    n   mean    sd median trimmed   mad    min     max
## ra                 1 1077 132.85  0.35 132.85  132.85  0.21 130.91  134.32
## dec                2 1077  11.84  0.34  11.82   11.83  0.20  10.07   13.57
## pmra               3 1077 -10.96  0.18 -10.97  -10.96  0.19 -11.47  -10.50
## pmdec              4 1077  -2.93  0.18  -2.93   -2.92  0.18  -3.50   -2.51
## parallax           5 1077   1.16  0.11   1.15    1.15  0.04   0.59    3.23
## bp_rp              6 1076   1.13  0.38   1.03    1.09  0.39   0.12    2.54
## phot_g_mean_mag    7 1077  14.87  1.74  15.00   14.93  2.03   7.95   18.21
## distparsecs        8 1077 869.40 69.91 867.31  867.29 33.96 309.19 1692.12
## abM                9 1077   5.18  1.76   5.26    5.22  2.01  -1.72    9.80
##                   range  skew kurtosis   se
## ra                 3.41 -0.30     4.67 0.01
## dec                3.50  0.21     4.13 0.01
## pmra               0.97 -0.11    -0.19 0.01
## pmdec              0.99 -0.22    -0.02 0.01
## parallax           2.64  7.67   140.98 0.00
## bp_rp              2.41  0.70    -0.28 0.01
## phot_g_mean_mag   10.27 -0.42     0.03 0.05
## distparsecs     1382.92  2.15    30.68 2.13
## abM               11.52 -0.33     0.06 0.05
```

#check for missing values

```
##              ra             dec            pmra           pmdec        parallax
##               0               0               0               0               0
##           bp_rp phot_g_mean_mag     distparsecs             abM
##              18               0               0               0
```

There are 18 missing values in "bp_rp". All other features in the pleiades dataset have no missing values.

```
##              ra             dec            pmra           pmdec        parallax
##               0               0               0               0               0
##           bp_rp phot_g_mean_mag     distparsecs             abM
##               1               0               0               0
```

There are 1 missing values in "bp_rp". All other features in the m67 dataset have no missing values.

Comparison of Means between Clusters

	Means of Pleiades Dataset	Means of M67 Dataset
ra	56.604875	132.851449
dec	24.133723	11.835734
pmra	19.914683	-10.962243
pmdec	-45.360298	-2.926648
parallax	7.283866	1.157934
bp_rp	2.432774	1.129678
phot_g_mean_mag	15.157727	14.870049
distparsecs	143.780851	869.321879
abM	9.442023	5.181009

#correlation of pleiades

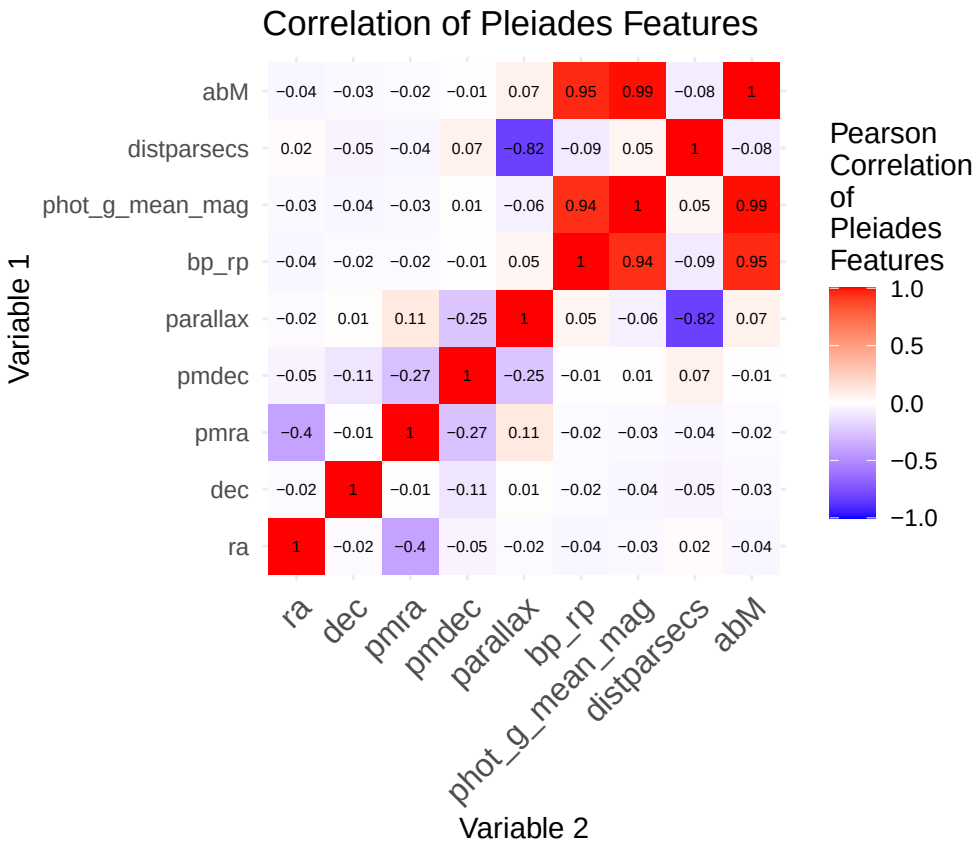
```
##
## ------------------------------------------------------------------------
##                    ra      dec    pmra    pmdec   parallax   bp_rp
## -------------------- ------- ------- ------- ------- ---------- -------
##        **ra**            1     -0.02   -0.4    -0.05    -0.02     -0.04
##
##        **dec**         -0.02     1     -0.01   -0.11     0.01     -0.02
##
##       **pmra**         -0.4    -0.01     1     -0.27     0.11     -0.02
##
##       **pmdec**        -0.05   -0.11   -0.27     1      -0.25     -0.01
##
##     **parallax**       -0.02   0.01    0.11    -0.25      1       0.05
##
##       **bp_rp**        -0.04   -0.02   -0.02   -0.01     0.05       1
##
##  **phot_g_mean_mag**   -0.03   -0.04   -0.03   0.01     -0.06     0.94
##
##    **distparsecs**     0.02    -0.05   -0.04   0.07     -0.82     -0.09
##
##        **abM**         -0.04   -0.03   -0.02   -0.01     0.07     0.95
## ------------------------------------------------------------------------
##
## Table: Table continues below
##
##
## ------------------------------------------------------------
##                   phot_g_mean_mag   distparsecs    abM
## -------------------- ----------------- ------------- -------
##        **ra**               -0.03            0.02       -0.04
##
##        **dec**              -0.04            -0.05      -0.03
##
##       **pmra**              -0.03            -0.04      -0.02
##
##       **pmdec**             0.01             0.07       -0.01
##
```

```
##     **parallax**            -0.06           -0.82      0.07
##
##       **bp_rp**             0.94            -0.09      0.95
##
##  **phot_g_mean_mag**          1             0.05       0.99
##
##    **distparsecs**          0.05              1        -0.08
##
##        **abM**              0.99            -0.08        1
## ------------------------------------------------------------
```

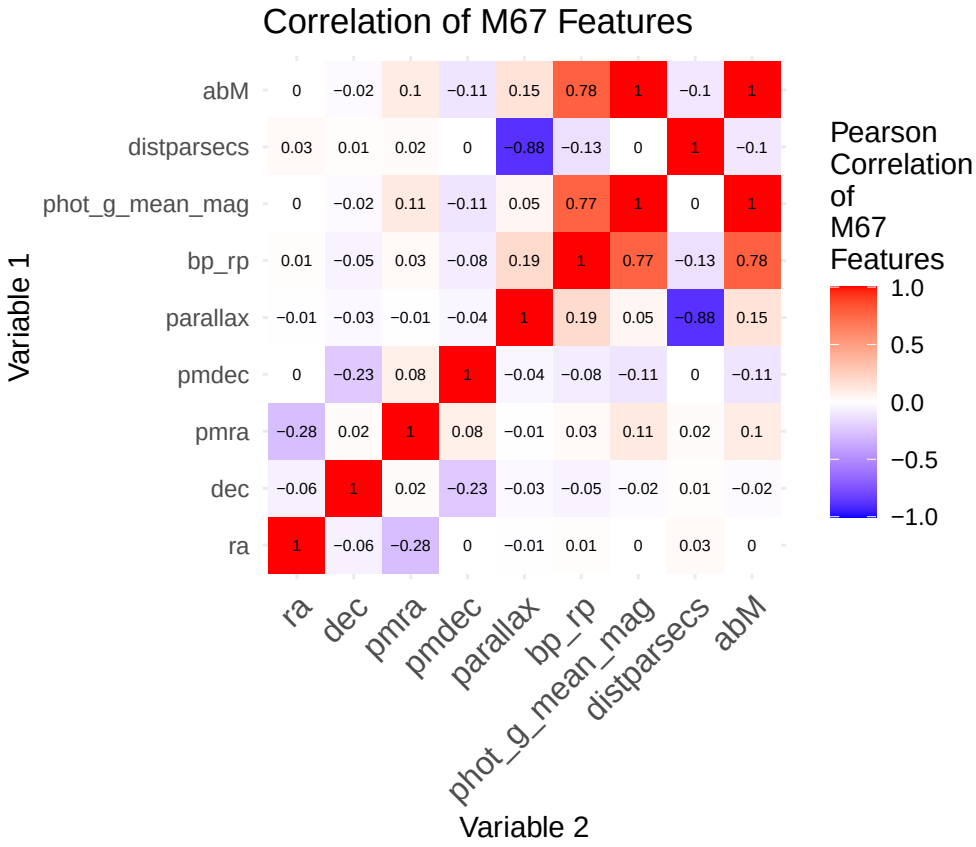
#correlation of m67

```
##
## ------------------------------------------------------------------------
##                     ra      dec     pmra    pmdec   parallax   bp_rp
## --------------------- ------- ------- ------- ------- ---------- -------
##        **ra**             1     -0.06   -0.28     0       -0.01     0.01
##
##        **dec**          -0.06     1     0.02    -0.23    -0.03     -0.05
##
##       **pmra**          -0.28   0.02      1     0.08     -0.01     0.03
##
##       **pmdec**           0     -0.23   0.08      1      -0.04     -0.08
##
##     **parallax**        -0.01   -0.03   -0.01   -0.04      1       0.19
##
##       **bp_rp**         0.01    -0.05   0.03    -0.08     0.19       1
##
##  **phot_g_mean_mag**      0     -0.02   0.11    -0.11     0.05     0.77
##
##    **distparsecs**      0.03    0.01    0.02      0       -0.88     -0.13
##
##        **abM**            0     -0.02    0.1    -0.11     0.15     0.78
## ------------------------------------------------------------------------
##
## Table: Table continues below
##
##
## ------------------------------------------------------------
##                   phot_g_mean_mag   distparsecs    abM
## --------------------- ----------------- ------------- -------
##        **ra**                 0              0.03         0
##
##        **dec**              -0.02            0.01       -0.02
##
##       **pmra**              0.11             0.02        0.1
##
##       **pmdec**             -0.11              0        -0.11
##
##     **parallax**            0.05             -0.88      0.15
##
##       **bp_rp**             0.77             -0.13      0.78
##
```

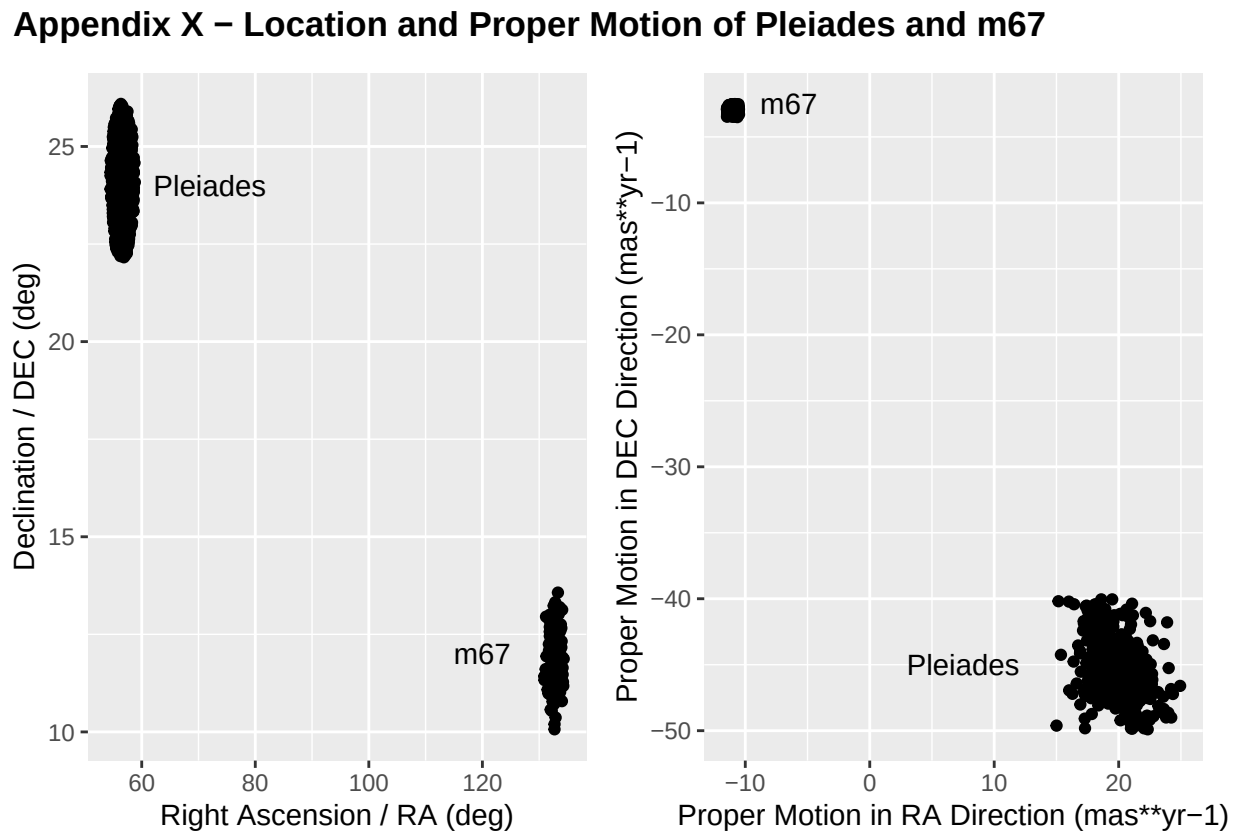
```
##  **phot_g_mean_mag**          1               0          1
##
##    **distparsecs**            0               1       -0.1
##
##        **abM**                1            -0.1          1
## ------------------------------------------------------------
```



#correlation matrices


Correlation of M67 Features
Variable 1
abM 0 −0.02 0.1 −0.11 0.15 0.78 1 −0.1 1
distparsecs 0.03 0.01 0.02 0 −0.88 −0.13 0 1 −0.1
phot_g_mean_mag 0 −0.02 0.11 −0.11 0.05 0.77 1 0 1
bp_rp 0.01 −0.05 0.03 −0.08 0.19 1 0.77 −0.13 0.78
parallax −0.01 −0.03 −0.01 −0.04 1 0.19 0.05 −0.88 0.15
pmdec 0 −0.23 0.08 1 −0.04 −0.08 −0.11 0 −0.11
pmra −0.28 0.02 1 0.08 −0.01 0.03 0.11 0.02 0.1
dec −0.06 1 0.02 −0.23 −0.03 −0.05 −0.02 0.01 −0.02
ra 1 −0.06 −0.28 0 −0.01 0.01 0 0.03 0
ra
dec
pmra
pmdec
parallax
bp_rp
phot_g_mean_mag
distparsecs
abM
Variable 2
Pearson Correlation of M67 Features
1.0
0.5
0.0
−0.5
−1.0

Display pmra/pmdec plot

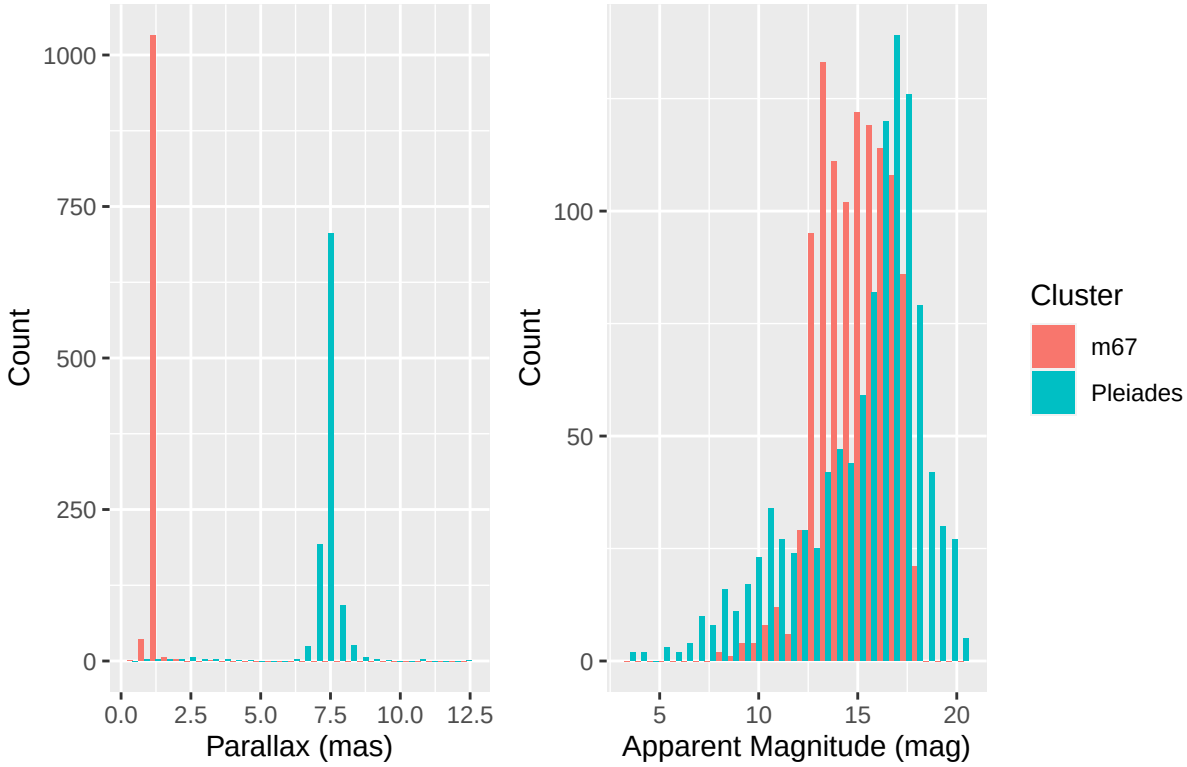


Right Ascension (RA) and Declination (DEC) are angular distances which are the astronomical equivalents of latitude and longitude. In other words, they are the position of stars within space.

Looking at the left-side graph, there is a clear difference between the two clusters on both RA and DEC, which shows that they are located in different positions in space.

The proper motions are astronomical equivalents of the movement of the stars in space. Looking at the right-side graph, there again is clear separation in the plots, representing the different directions the clusters are travelling in. The m67 cluster is travelling negatively in both RA and DEC, while the pleiades cluster is travelling positively in RA and more negatively in DEC (compared to the m67 cluster).

Appendix X − Parallax and Apparent Magnitude of Pleiades and m67



Parallax is a measurement which is used to estimate the distance of the star from earth, using the observed displacement of the star caused by the change of the point of view.

Looking at the left-side histogram, we see that the m67 cluster has a large collection of stars with a parallax roughly around 1, which matches the mean value of 1.16 (2 d.p) in the summary table. The Pleiades cluster has a large collection of stars around 7.5, which is close to the mean value of 7.28 (2 d.p) in the summary table. The distribution of parallax measurements for the Pleiades cluster is wider than the m67 cluster, which might mean that the Pleiades cluster is widely spread or the data needs more filtering.

Apparent magnitude is

HR diagram - use ages of cluster with diagram showing the comparison

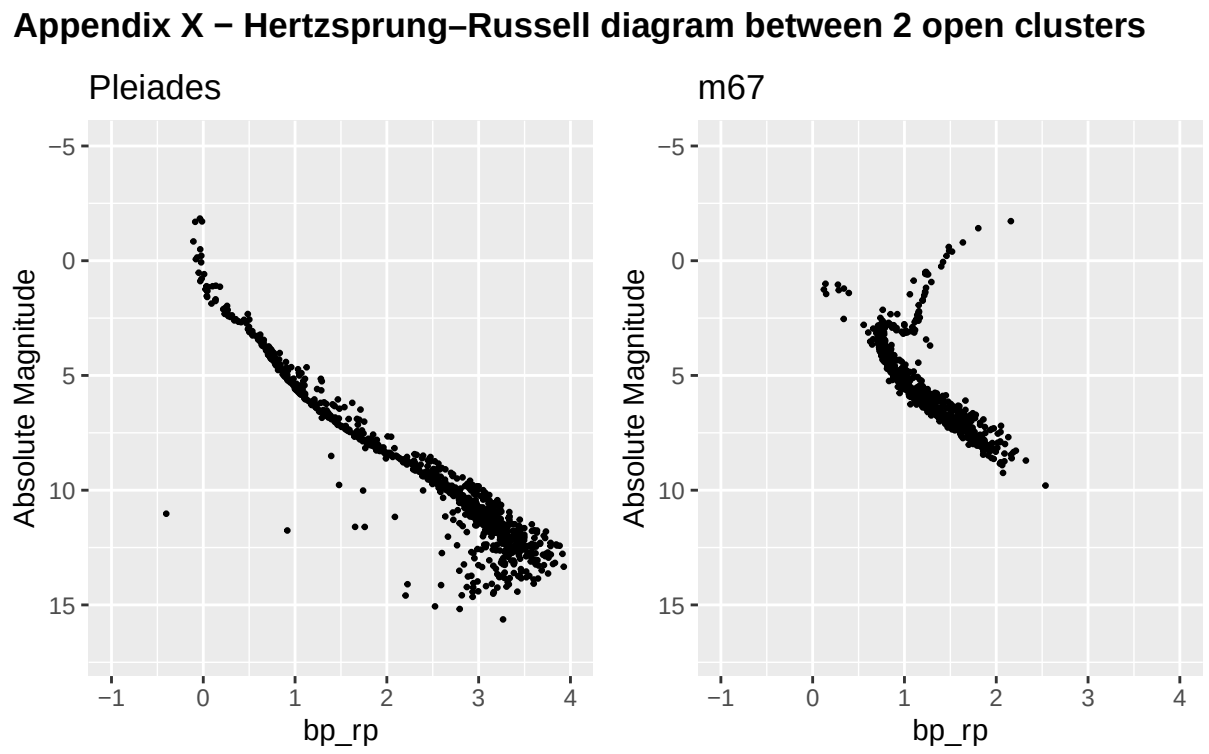


Figure X shows a colour-magnitude diagram of the two clusters. This shows the relationship between the Absolute Magnitude and BP-RP colours. Absolute magnitude is a term referring to the intrinsic brightness of a star, which was calculated using the distance of the star (parallax) with the observed colour from earth (phot_g_mean_mag or apparent magnitude). BP-RP colour represents the colors magnitude of the stars. A smaller BP-RP number indicates that the star appears bluer, and thus hotter; meanwhile a large BP-RP implies that the star has cooled off and is redder in appearance.

From this diagram we are able to estimate the age of the clusters (Palma, 2020). Pleiades has most of its stars on the 'main sequence', where they burn their hydrogen throughout their life time. On the other hand, many of the stars in M67 tails off of the main sequence, meaning they are dying stars that have already burnt out of hydrogen. As a consequence they move slower and fall behind. Therefore, we can conclude that the Pleiades is a much younger cluster that is still moving and burning; whereas M67 is older, and slowing down. Note that this is outside the scope of the EDA, but is useful to show to guide future analysis.

References

Dr Christopher Palma. (2020). Measuring the Age of a Star Cluster. PennState. https://www.e-education.psu.edu/astro801/content/l7_p6.html

Héctor Cánovas. (2022). Use Cases. European Space Agency. https://www.cosmos.esa.int/web/gaia-users/archive/use-cases

Individual Contributions [1 page]

• State what contribution each member of the group made to the data preparation, the analysis and the report

Overall Report These marks will be awarded for overall presentation, clarity and quality of the report. In particular, marks will be awarded for

• A clear logical layout

• Keeping to the page limits for each section, and using sensible font size

• Key facts being easily located

• Readability of tables and plots DATA 301 T2 2022 5

• Clarity of expression [Note: for non-native speakers of English: your English does not need to be perfect, it is the logic and correctness of your presentation that is most important. Nevertheless you are advised to get someone to proof-read your proposal.]

• Clear explanation of how your choice of exploratory plots and tables is relevant to your project, and how the ethical considerations apply to your project (i.e. not just a set of generalities)

• Make sure each time you use/refer to someone else's work you cite the source in the text, and include the reference in the list at the end. It does not need to be a long list; you may only need one or two references.

• Referencing should be correctly done: a complete list of references must be included. You can use any referencing style you wish; APA is fine if that's what you like.

Total: 35 marks

You will be expected to include a revised version of the Background, Ethics and EDA sections in the final project report; you do not have to rewrite those sections from scratch. You will be expected to consider any feedback you have received for this first report when revising it for the final report, and this will be taken into account when the final report is marked.