1 Analysing the HR Diagrams of Star Clusters Using the HR Diagram App

In this exercise you will use the information in the worksheet and learn how to use the *HR Diagram App* to complete a table of data. You will (i) plot the colour–magnitude data for open clusters, (ii) fit a Zero-Age Main Sequence (ZAMS) to estimate the distance modulus and distance, and (iii) fit stellar isochrones to estimate cluster age. You will then use your results to answer the questions in the worksheet.

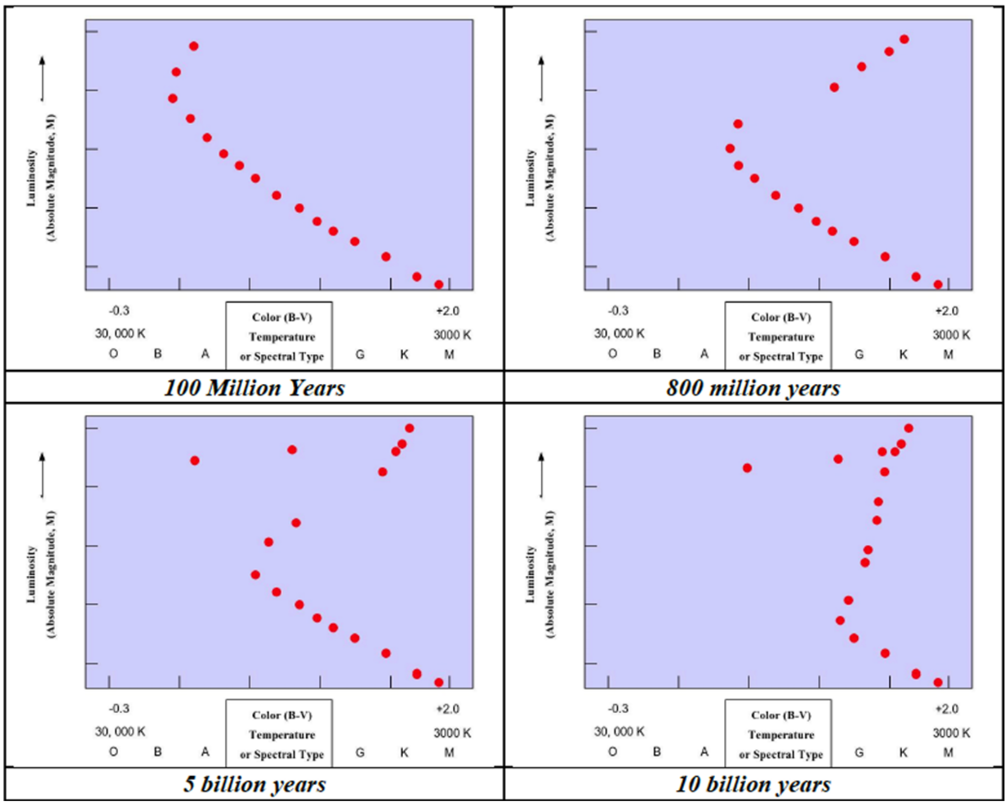


Figure 1: Four different HR diagrams are shown at four different times, for the same cluster of stars. As stars evolve with time, their temperatures and luminosities can drastically change. If we have a group of stars that were born at the same time, as in a cluster, at early times we see a full main sequence, shown here at 100 million years old. As the cluster ages, the most massive stars (from the top of the main sequence), become red giants, so their position moves to the top right of the HR diagram (as shown at 800 million years). As time progresses, less massive stars begin to move to the right as well, shortening the main sequence (5 billion years). When a cluster is very old, most of its stars have moved off the main sequence (10 billion years).

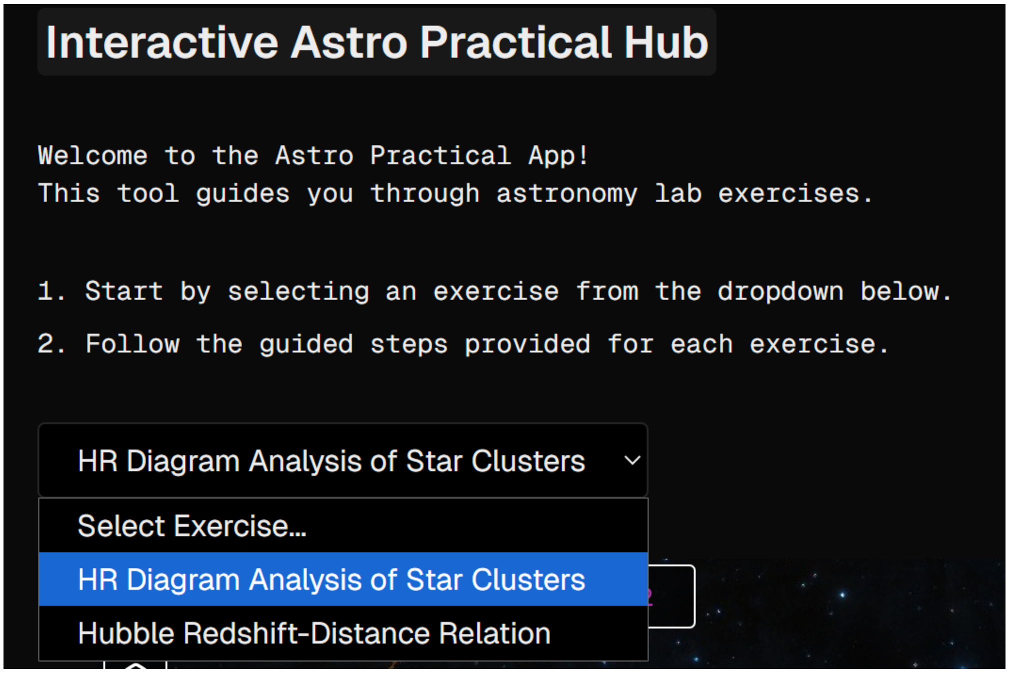
1.1 Using the HR Diagram App

After opening the app you will see the main *Interactive Astro Practical Hub*. Follow the steps below to access the HR diagram tools and complete your analysis.

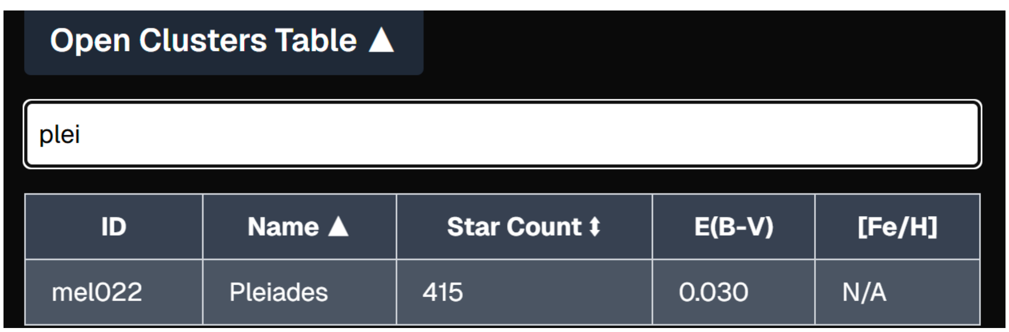
1. **Select the exercise.** From the exercise drop-down, choose `HR Diagram Analysis of Star Clusters`.

   (An *Instructions & Worksheet* link is available on this page for quick access to the activity sheet.)

2. **Load a cluster and display its HR diagram.**



Use the *Cluster Table* to select a dataset. The table lists the *Cluster ID*, *Name*, *Star Count*, *Extinction* $E(B-V)$, and *Metallicity* [Fe/H]. When you select a row (e.g. `mel022` *Pleiades*; Star Count 415; $E(B-V) = 0.030$; [Fe/H] N/A), the app loads the underlying photometry (V magnitudes and $(B-V)$ colours) and displays the colour–magnitude diagram with $(B-V)$ on the x-axis and V on the y-axis.[1] If an $E(B-V)$ value is provided in the table, it will appear as the default reddening for that cluster in the plotting controls (you may adjust it during fitting if needed).



Open Clusters Table ▲

plei

ID	Name ▲	Star Count ⬍	E(B-V)	[Fe/H]
mel022	Pleiades	415	0.030	N/A

Figure 2: Cluster Table with metadata (ID, Name, Star Count, $E(B-V)$, [Fe/H]). Selecting a row loads the photometry and renders the HR diagram.

3. **Fit a Zero-Age Main Sequence (ZAMS) and determine the distance.**

   In the HR plot panel, the *ZAMS overlay* is *on by default*; if it is not visible, enable it via the ZAMS toggle. The ZAMS is defined in absolute magnitude (M_V), whereas your cluster data are in apparent magnitude (V), so the two will be vertically offset by the distance modulus. Use the *Distance Modulus* $(V-M_V)$ control in the left sidebar to slide the ZAMS up or down until it best matches the observed main sequence. Aim for a fit that passes through, or as close as possible to, the bulk of the main-sequence points (the very top may be poorly fit in older clusters due to evolution off the sequence). Record the best-fit $(V - M_V)$ shown on screen and compute the distance using Equation (2) in the lab notes.

[1] $E(B-V)$ is the reddening due to interstellar dust; [Fe/H] is the logarithmic metallicity relative to the Sun. Remember that lower V means brighter apparent magnitude.

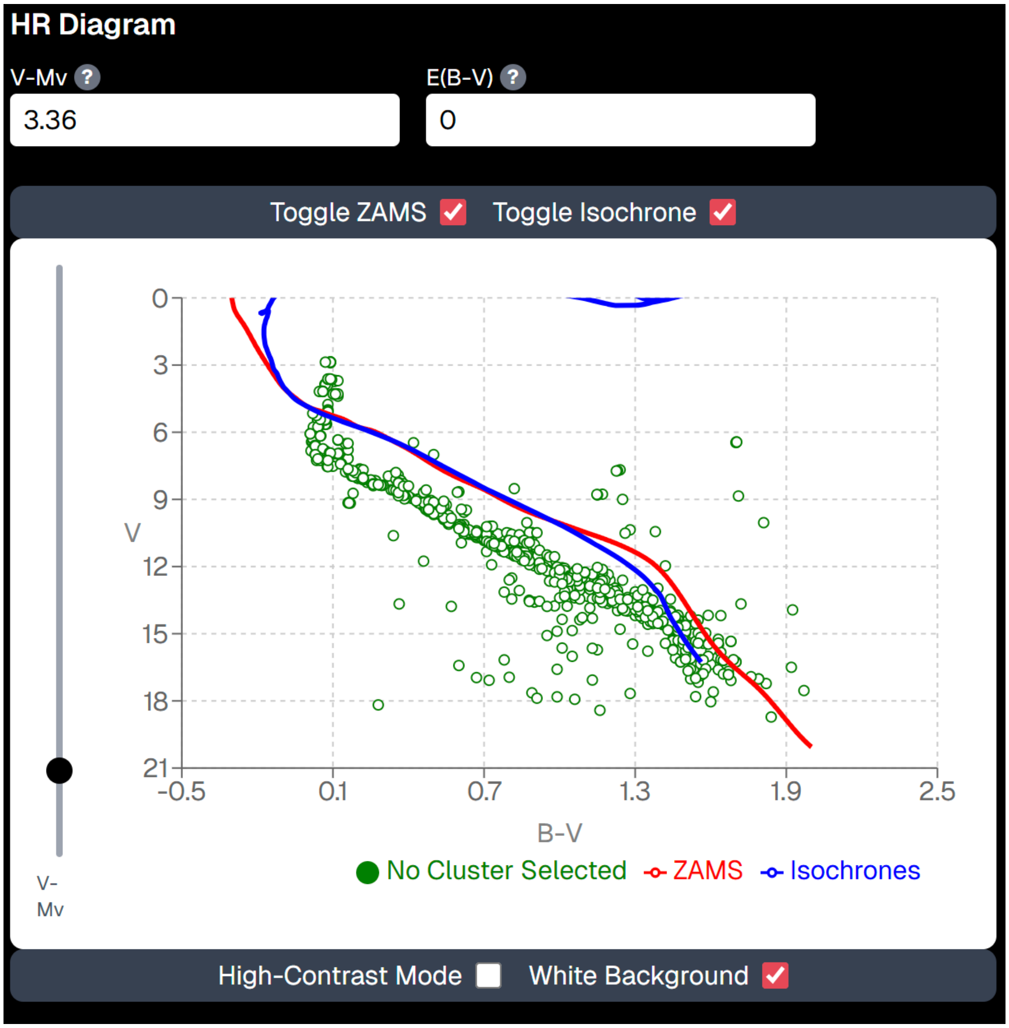


Figure 3: HR diagram with stellar photometry and the ZAMS and Isochrones overlay enabled. The distance-modulus slider has been used to align the ZAMS to the main sequence.

4. **Fit an isochrone to estimate the cluster age.**

   An *isochrone* is the theoretical locus of stars that all share the same age. In the HR plot, the *Isochrone* overlay is on by default; if it is not visible, enable it via the Isochrone toggle. Adjust the model until it matches the data, prioritising the *main-sequence turn-off* and sub-giant branch.

   The adjustable parameters are:

   (a) log(age/yr) — sets the population age,

   (b) $E(B-V)$ **(Reddening)** — accounts for interstellar dust shifting colours,

   (c) **[Fe/H] (Metallicity)** — sets the chemical composition relative to solar.

   A good fit passes through the densest locus of main-sequence points and the turn-off; do not worry if a few outliers are not matched. A practical sequence is to (i) set $E(B-V)$ so the lower main sequence aligns in colour, (ii) adjust log(age/yr) to match the turn-off, then (iii) fine-tune [Fe/H] only if needed. Once satisfied, record the age (Gyr), adopted $E(B-V)$, and [Fe/H] in your table.

⋆ When you have completed these steps for each cluster, proceed to Questions 1–5 in the worksheet.

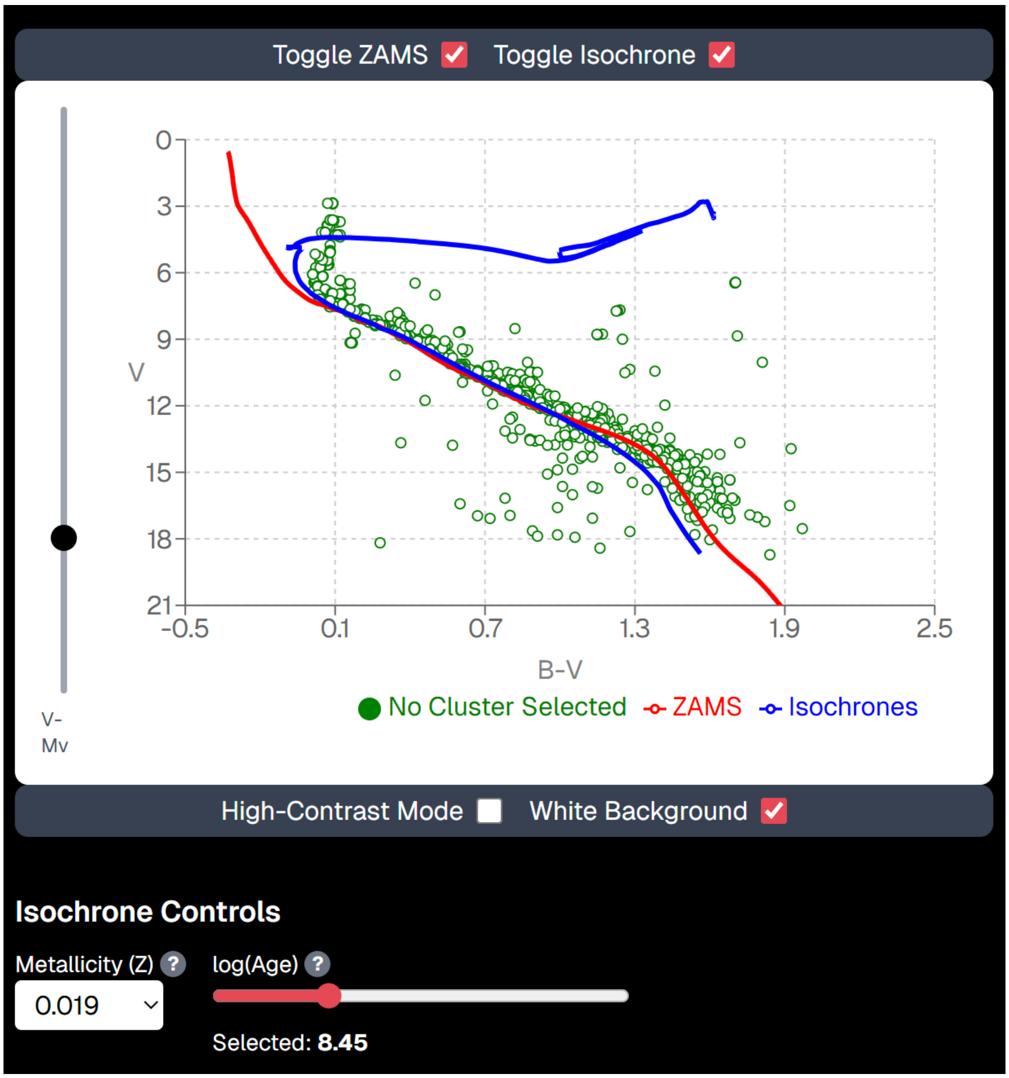


Figure 4: HR diagram with isochrone overlay. The age, reddening $E(B-V)$, and metallicity [Fe/H] controls are used to match the main-sequence turn-off.