# Do Stars Change as They Age?

## Course Outcomes Met

1. Communicate scientific issues effectively in oral and written form;
2. Effectively collect, analyze and present data and correctly construct and interpret charts, graphs and tables to draw scientific conclusions;
3. Apply the fundamental concepts and methodologies of physics and/or chemistry to investigate a scientific theme.

Tools used in this activity:

1. Star in a Box
2. Simulation of star pathways on and off the main sequence

Your text gave a detailed description of the stages of star formation, for the Sun as well as for larger and smaller stars. Stars from from a rotating cloud of gas and dust that is generally very much larger than any single star could possibly be (there is a upper limit of about 100 solar masses, at which point gas and radiation pressure blow it apart before it can become a star). For that reason, the cloud generally collapses into a large number of stars called an open cluster. All the stars in an open cluster form in a very short time, almost simultaneously.

## A. Young Stars

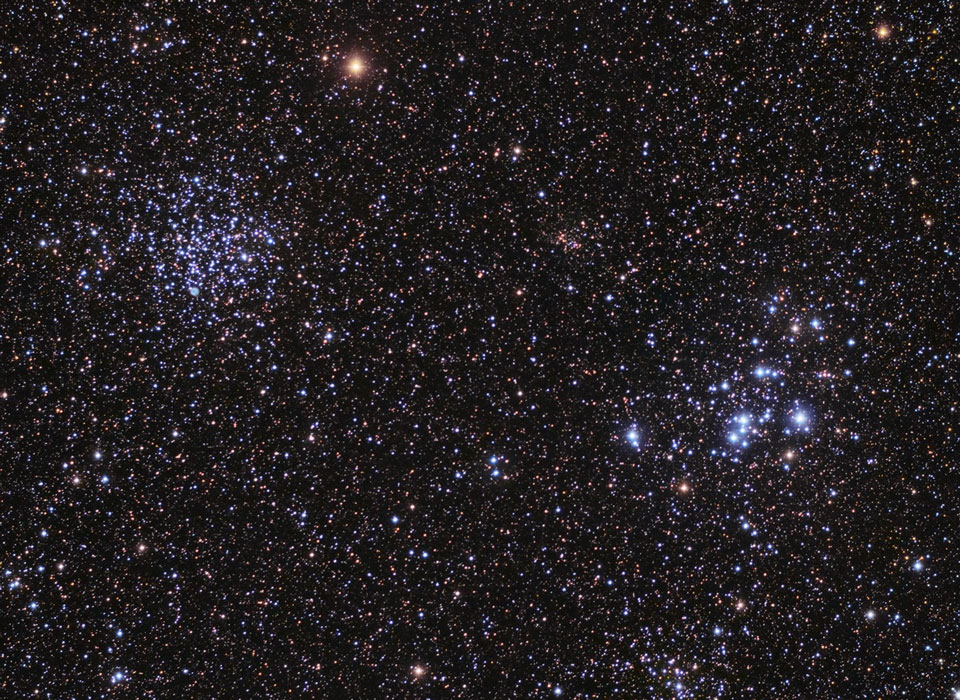
Recall what we have seen in previous activities to answer the following questions:

1. If you see a blue star, then it must be young, old, or can’t really tell? Explain your answer.

2. If you see a red star, then it must be young, old, or can’t really tell? Explain your answer.

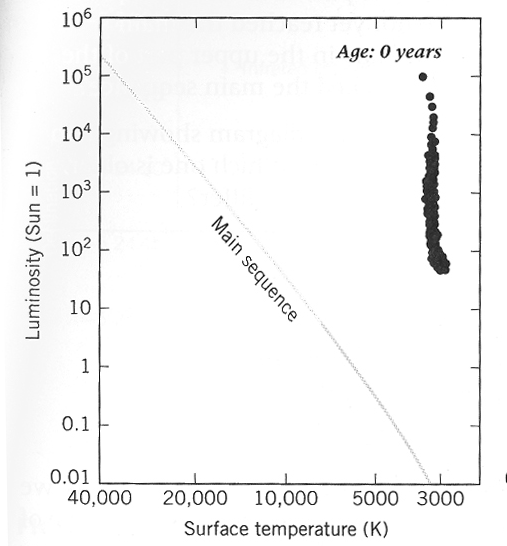
3. If you see an open cluster with both dim red stars and bright blue stars present, can you say anything about the age of the red stars? Explain your answer.

4. Here are images of three open clusters, the Perseus double cluster M46 and M47 in the first and M67 in the second. You have to be careful not to look at foreground and background stars and pay attention only to the clusters. Generally speaking, which cluster is the older of the three? Why?





5. Since all stars in an open cluster form at about the same time, they become protostars at about the same time. Protostars vary in luminosity, but that variation depends only on the mass, and therefore the surface area, of the protostar. They are all about the same temperature. In this HR diagram, each dot represents a star in an open cluster that have just reached the protostar stage. Reviewing the information in your textbook in chapter 21, especially figure 21.12, draw a sequence of HR diagrams that show what happens to this group of stars as the cluster ages.



**Discuss your results with your instructor at this point**

## B. Middle and Old Age

Go to the web site <https://starinabox.lco.global>. This is a simulator of what happens to stars from the time they reach the main sequence until the end of their lives. You have to be a little careful of it. The simulation does not run at a constant speed. That’s because if it did, some events you would be waiting all day to see while others would flash by without noticing them.

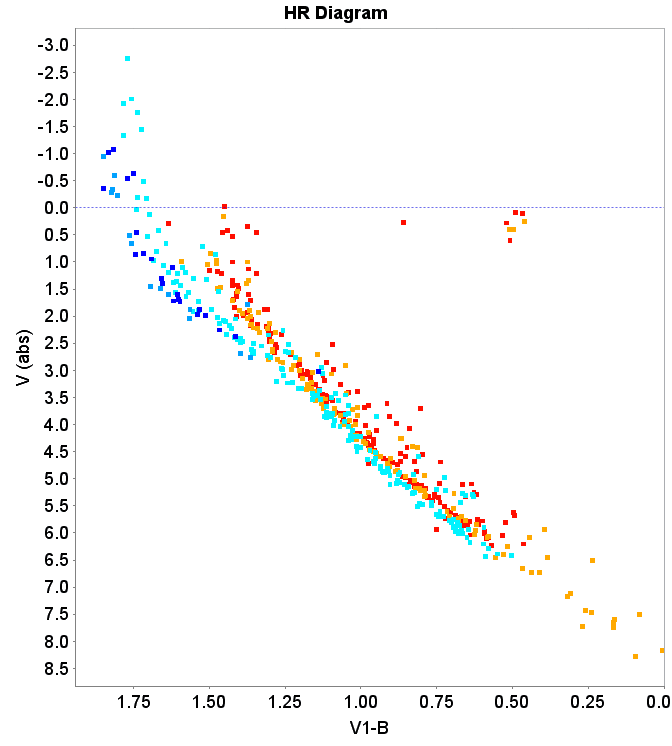
We can select a variety of masses to simulate, from very small to very large. On the right hand side, you can look at a variety of measures, which you can choose between using the icons above the play button. You can see what the star looks like, its temperature, its luminosity, the various stages it goes through and its mass.

1. Quickly run through the simulation for each mass. Note the final state of each star. Do they seem to group into similar fates? Is there a relationship with the mass?

2. Are there any common features in how they age? Do they all age at the same rate?

3. For each mass, there is a data table you can look at. The link to it is at the top right. That table gives you a variety of information about the changing properties of the star. Let’s pay attention to time spent on the main sequence. Is there a relationship between that time and the mass of the star? Is this consistent with what you learned from the mass-luminosity relation?

4. As mentioned previously, all stars in an open cluster form at almost the same time. Here is a color-magnitude HR diagram for several open clusters[[1]](#footnote-1). The orange dots are for the Hyades, and the light blue dots are for the Pleiades. What can you say about their relative age? What is your evidence?



5. There are several other clusters on this diagram as well. The red dots are for Praesepe, the medium blue dots are for IC 2391, and the dark blue dots are for IC 2602. How do you think the ages of each of these compare to the Hyades and Pleiades?

**Discuss your results with your instructor at this point**

## C. Some Real Clusters

Open the Word document HR Diagrams for Six Open Clusters. The name of each cluster is above its diagram. Note that these are plots of the *apparent (or visual)* magnitude, not the absolute magnitude. That’s why the main sequence does not appear to be in the same place.

1. Which cluster contains stars with the brightest apparent magnitudes?

2. The Sun is a G5V main sequence star. That means its color index is 0.656 and its absolute magnitude is 4.83. All other G5V stars should be about the same. Can you use this to put the clusters in order of distance from us? Explain your reasoning.

3. If we corrected for distance to change from visual to absolute magnitude, how would that affect the HR diagrams? Explain your reasoning. Consider both magnitude and color index.

4. Sketch the HR diagrams corrected for distance using your observation in question 3. Now you have absolute magnitude on the vertical axis instead of visual magnitude.

5. Putting this information together, which cluster contains the most red giants?

6. In which cluster(s) have white dwarf stars been detected?

7. For the cluster in question 6, what is the approximate difference in magnitude between white dwarfs and main sequence stars of the same temperature?

8. From what you observed in part B, can you put these clusters in order of age? Explain.

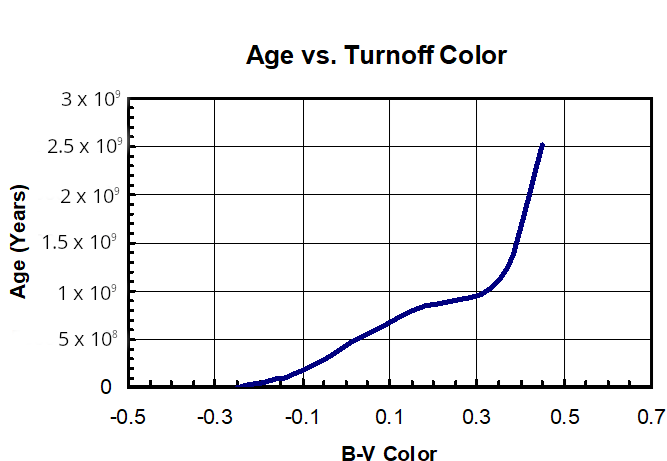
**Discuss your results with your instructor at this point**

9. On this site:

<http://rainman.astro.illinois.edu/ddr/stellar/beginner.html>

you can find simulations for a lot of different size stars. But down at the bottom, there is a simulation of an open cluster containing 10,000 stars. As the stars in the cluster age, what happens to the HR diagram? What single feature of the diagram could you look at to get an idea of age?

10. You should have seen by this point that there is a relationship between cluster age and the color at which the HR diagram turns off the main sequence. Models of stellar evolution backed up by observations of a large number of clusters of varying ages provide a quantitative relationship between these two.



What is the approximate age of each of these open clusters? Can you think of any source of uncertainty in this procedure?

11. We could certainly continue this graph up and up until it reaches a color turnoff of 2, which we have seen is the upper limit for the main sequence. However, no cluster has ever been discovered with a color turnoff greater than B-V = 0.9. Why do you think this might be the case?

**Discuss your results with your instructor at this point**

## D. What do we actually see?

From information in your text and Star in a Box, put together three timelines of images, one each for a low mass star, a medium mass star (like the Sun), and a high mass star. You can use the images in the Word document Star Images at Various Stages.

There are far more images than you need for each size star. Images may be used more than once. Some images are different versions of the same stage.

Along with each image you use, put the age time frame for that stage.

1. From comparing the timelines, what similarities and differences do you notice?
2. Thinking back on all the activities we have done this semester, do you see evidence for the things we have discussed in your timelines?

**Discuss your results with your instructor at this point**

1. Taken from Collaboration, Gaia & van Leeuwen, Floor & Vallenari, A. & Jordi, C. & Lindegren, Lennart & Bastian, U. & Prusti, T. & de Bruijne, J. & Brown, A. & Babusiaux, C. & Bailer-Jones, C. & Biermann, M. & Evans, Dafydd & Eyer, L. & Jansen, F. & Klioner, Sergei & Lammers, Uwe & Luri, X. & Mignard, F. & Zschocke, S.. (2017). Gaia Data Release 1: Open cluster astrometry: Performance, limitations, and future prospects. Astronomy & Astrophysics. 601. 10.1051/0004-6361/201730552. [↑](#footnote-ref-1)