Age dating star clusters

Modified from National Optical Astronomy Observatory’s Lesson *Jewels of the Night* in order to emphasize how graphs can help scientists to interpret and share their data.

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Overview: In this lesson students will explore and discuss how classification and graphing are used by astronomers to determine the age of star clusters. They will measure the color and brightness of stars, as proxies for temperature and luminosity, in the Jewelbox Cluster from a color image. These measurements will then be used to determine the age of the cluster by plotting their measurements on a color-brightness diagram.

Lesson concepts: As a result of this lesson, students will:
- Science is both a process and a body of knowledge
- Science aims to build increasingly broad and coherent explanations of the natural world.
- Graphs help scientists interpret and share their data.
- Graphs help scientists determine physical relationships between variables that may not be obvious in raw data sets.
- The process of science often involves obtaining results that inspire or lead to further exploration/testing.
- The age of stellar clusters can be determined by utilizing a plot of the stellar color versus brightness.

Grade span: 8–12

Materials: Images and instructions can be found in several formats at the *Jewels of the Night* lesson.
- Color transparency of the Jewelbox Cluster with Stargauge cut off

One copy of each of the below is needed per pair:
- Color printout of the Jewelbox Cluster and Stargauge
- Copy of the graph sheet with the 3 sample graphs at the bottom cut off
- Copy of the student instruction sheet (optional)
- Washable marker
- Ruler

Tip: To reduce color printing costs if you have multiple periods, try printing enough color copies for 1 period, then have students mark on a transparency sheet set over the color image using a washable marker or pen. This also facilitates sharing with the class—each pair of students can present their graph briefly using the overhead projector. They can wipe off the transparency at the end of the lesson and you’re all set for the next class.

Advance preparation: Gather materials and read teacher background material.

Time: ~1 hour (You could also have students do the measurements and graphing for homework and just do the pre and post lesson discourses in class. This would cut down needed class time to approximately 30 minutes)

Grouping: Pairs are optimal, but this can be done individually.

Teacher background: Stars are born in molecular clouds, often in large clusters. These clusters contain stars that were all formed at roughly the same time, but amongst the group there will be a wide range of masses. When astronomers study an image of a stellar cluster they know that all the stars in the cluster are the same age and also roughly the same distance away from the observer. This is important because it means that any differences in brightness do in fact represent differences in intrinsic brightness rather than differences in a star’s distance from the observer.

As they age, all stars become cooler, regardless of their initial mass, brightness, or temperature. However the rate at which they evolve to become cooler depends upon their mass. More massive stars are born hotter and brighter and evolve quickly, while less massive stars begin their lives relatively cooler and dimmer and evolve slowly.

With this knowledge of how stars of different masses evolve, astronomers can determine the age of a given cluster. This
is done by plotting the color versus brightness of the stars in the cluster, which are indicators of temperature and luminosity respectively. This type of plot is called a Hertzsprung-Russell diagram (HR diagram). For a young cluster, the HR diagram would show a more linear pattern called the main sequence, but as the more massive stars begin to cool, they move off of the main sequence line to become cooler and dimmer. As the cluster ages, one begins to see the less massive stars peeling off the main sequence as well. Thus, astronomers can determine the age of an entire cluster by looking at the point at which stars are exiting the main sequence line. For an excellent animation of this process, take a look at Professor Michael Richmond’s site.

By clicking on the graph you can watch the evolution of a cluster as it ages; note that the hotter, more luminous stars are the first to move away from the main sequence line. This gives an idea of what a plot of young cluster looks like compared to an older cluster.

**Student prerequisites:** Before beginning this activity, students should be aware of:

- a) Stellar distances
- b) Stellar color and how it relates to temperature
- c) The relationship between stellar brightness and distance

**Procedures:**

1) Using an overhead projector show the class the image of the Jewelbox Cluster (Make sure the Stargauge is not attached). Tell the students they are astronomers taking a first look at this image from a telescope. What do they see? What kinds of observations can they make? What data can be gleaned from the image? Record answers on the board. Students should mention characteristics such as color, radius, brightness, etc.

2) Ask students if there might be any relationships between the variables recorded on the board. Try to classify or connect those variables that appear to have some relationship and record on the board. For example, are blue stars generally brighter or dimmer? Is color related to brightness? Ask for predictions on which variables are related.

3) Ask students how they would determine if there was a meaningful relationship between variables, such as color and brightness. Would a graph help? Explain that scientists frequently use graphs to help them interpret data and observations such as those obtained from the image of the Jewelbox Cluster. Often graphs comparing two or more variables reveal a pattern that enables scientists to gain information not accessible by looking at raw data.

4) Suggest to the class that each person make a graph of the color versus brightness of the stars in the Jewelbox Cluster to see if there is any relationship. Before beginning, ask what they predict the graph may look like if there is no relationship (randomly scattered points) versus what it might look like if there is a relationship (some discernable pattern).

5) Ask students what sort of tools they will need to create such a graph (something to measure color and brightness). If the class wants to compare graphs, how will they ensure that everyone has the same idea of what color corresponds to “blue” versus “green,” etc.? Elicit the response that the class will need a standard for color and brightness. Scientists, as well, must agree upon standard measuring systems in order to compare results. Show them the Stargauge and explain that it is the standard that astronomers use for these variables. Note that although color is a continuous variable that is a proxy for temperature, for the purposes of this activity, the Stargauge uses discrete measurements of color. The same goes for brightness, which in this activity will be measured using the differently sized dots on the Stargauge. Size is used as a proxy for brightness because brighter stars appear larger due to atmospheric refraction.

6) Pass out a color image of the cluster, a marker, a ruler, and the graph sheet (make sure the bottom 3 sample graphs have been cut off so as not to give away the answer!). At this point you can also pass out the Student Instruction Sheet or you can simply read the instructions aloud.

7) When the graphs are completed, ask students to examine their graphs. Is there a pattern? If so, what does it look like? You can have student volunteers come up to the board to draw a rough example of what their graph looks like. Are there any differences among the groups? If so, what are they? What might explain those differences? Examples might include students who have more or fewer points along the main line. These probably represent what astronomers call “field stars”—stars that are not part of the cluster and therefore have a different age.

8) Once the class has agreed on a pattern and the fact that there may indeed be a relationship between color and
brightness, pass out the strips that you cut off the bottom of the graphing worksheet with the 3 sample graphs. Explain that astronomers have done this same graph for other clusters and have determined that the particular shape of the graph can help determine the age of the cluster. This explanation is also provided at the bottom of the Student Instruction Sheet. Depending on the level/ability of your particular class, you may want to include more discussion of the HR diagram and the main sequence at this point.

9) Finally, by comparing their graphs to the three sample graphs, ask students to determine the age of the jewel box cluster. Astronomers use a similar process, though using computer models, to find the age of star clusters.

10) To conclude the lesson, remind students that they were able to use very simple observable data from the image to find a more complex piece of information—the cluster's age. It is not something that can be seen from the image, but by using the technique of graphing we were able to find a relationship between variables. Students could then compare the pattern of their graph to the patterns found by other scientists when they graphed color (temperature) vs. size (brightness) of stars clusters of known ages. Thus, the students discovered a physical property that was not evident at first. This is an important and regularly used scientific process.

Extensions: To further illustrate how graphing can demonstrate whether or not there are meaningful relationships between observed variables, you could also assign students to graph color versus distance to the cluster center, for example. This plot will simply show randomly scattered points indicating that color and distance from the center are not related. This is something that the teacher could also do while students are working on their graphs of color versus brightness (Step 6) and present to the class during discussion or that could be assigned to students who finish the color vs. brightness graph quickly.