ASTRO

by Tony Mash

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Question 1:
Astronomers are always turning to citizen scientists to help process the abundance of data that large telescope surveys generate. Imagine an example where astronomers have measured the blackbody radiation curves of every star in our Milky Way and now need the help of citizen scientists like you to interpret the data. Figure 1 illustrates the blackbody radiation curve of two different stars from the survey. Note that the star's maximum brightness has normalized the y-axis, so the curve peaks at 1. From this Figure, answer the following questions and help your fellow astronomers out:

a) Qualitatively discuss all of the relative differences between four properties of Star 1 and Star 2 that are known based on the information provided so far, assuming both stars are main-sequence stars. Explain your reasoning. [4 marks - approx. 200-400 words]

Star 2	Star1
High central density and temperature	Low central density and temperature
Big, high mass star	Small, low mass star
Higher luminosity	Lower luminosity
Shorter lifetime	Longer lifetime

Explanation

HYDROSTATIC EQUILIBRIUM

Main sequence stars essentially have a fixed size that is a function of their mass—the more massive the star, the greater the gravitational pull inwards. Therefore, the gas compresses more. Thus, exerting a gas pressure back resists the compression. In stars, this gas pressure alone is not sufficient to withstand the gravitational collapse. Once the core temperature has reached about 10 million K, hydrogen fusion occurs, releasing energy. This energy exerts an outwards radiation pressure due to the photons' action on the extremely dense matter in the core. The radiation pressure combined with the gas pressure balances the inward pull of gravity, preventing further collapse.

MASS

A star's ``lifetime'' on the main sequence is how long it takes to use up the hydrogen in its core. The luminosity (L) of a star is a measure of rapidly it is using up its hydrogen. The mass (M) of a star is a measure of how much fuel it has. The time it takes to use up the fuel is proportional to its amount of fuel (M) divided by the rate of fuel consumption (L). Expressed more mathematically,

$t = M/L$,

where t = lifetime (in units of the Sun's lifetime)

M = mass (in units of the Sun's mass)

L = luminosity (in units of the Sun's luminosity.

Note that since L = $M^{3.5}$,

t = M/L = M/$M^{3.5}$ = 1/$M^{2.5}$.

Consider a star of mass M = 0.2 M_{sun}. Its lifetime will be

t = 1 / $(0.2)^{2.5}$ t_{sun} = 56 t_{sun} = 560 billion years.

Similar calculations can be done for stars of other masses. Very hot and luminous stars have short lifetimes. However, cool and dim stars have a long lifetime.

b) UsingWein's Displacement Law, we can determine that the surface temperatures of the stars Are 4405 K and 23454 K. Describe what you would expect the spectrum of each star to look Like in terms of the strength of key absorption lines. Explain why the spectrum looks as you Describe in terms of each star's properties. [4 marks - approx 200-400 words]

Formally, Wien's displacement law states that the spectral radiance of blackbody radiation per unit wavelength peaks at the wavelength λ_{peak} given by:

> Where *T* is the absolute temperature. *b* is a constant of proportionality called *Wien's displacement constant*, equal to 2.897771955...$\times 10^{-3}$ m·K,[1] or $b \approx 2898$ µm·K. This is an inverse relationship between wavelength and temperature

λ_{peak}= b/T

2898/44059=0.66

2898/23454=0.124

Star 1 has a higher wavelength peak, while star 2 has got a lower wavelength peak. And thus, the absorption line of star 2 has to be slightly higher than that of star1 due to high spectrum density energy.

Main sequence stars vary in mass. You may imagine that a more massive star has more fuel available, so you can spend more time on the main sequence fusing hydrogen to helium. You would be wrong - the opposite is true. More massive stars have a stronger gravitational force acting inwards, so their core gets hotter. The higher temperatures mean that the nuclear reactions occur at a much greater rate in massive stars. They thus use up their fuel much quicker than lower mass stars. This is analogous to the situation with many chemical reactions; the higher the temperature, the faster the reaction rate. Lifespans for main sequence stars have a vast range.

Blackbody radiation as a function of wavelength for various temperatures. Each temperature curve peaks at a different wavelength, and hence the spectrum

Star 1 has a high spectrum as compared to star 2. This is due to:

- low luminosity
- low mass
- low central density and temperature

Question 2:
Due to your amazing performance in AST 201, a brand new telescope has been named after you. It is therefore only fitting that you get to make the very first set of observations. During your first night observing with the Vishala Maharaj Telescope, you observe two separate groups of stars
in the night sky. After measuring each star's properties, you plot their apparent brightness versus their colour (see Figure 2). Recall from the class that colour is determined by measuring a apparent star's brightness in two different wavelengths. It allows you to determine which stars are redder
or bluer relative to one another but not their actual temperature. From Figure 2, you conclude that
the groups are both previously undiscovered star clusters! Use Figure 2 to answer the following questions:
a) What features in Figure 2 help you conclude that the stars' groups are indeed star clusters? Explain your reasoning. [2 marks - approx 100-200 words].

If you look closely at the images above, you will notice a few things about this group of stars:

1. A handful of very bright stars dominates it, but there appear to be many fainter stars surrounding the brightest members.
2. The grouping of stars does not have a well-defined shape or boundary.
3. The brightest stars appear to be blue and to be surrounded by blue, wispy nebulae.
4. The stars are not very densely packed together.
5. Although there is a range of brightness among the individual stars, there are not a few very bright stars that dominate

   Hence the above is a cluster of stars.

From Figure 2 alone, which star cluster is younger? Explain your reasoning. [2 marks - approx 100-200 words]

star cluster 2 is younger, this is because of the following;

All of the massive stars have gone supernova, and the rest have evolved into red giants. The stars begin to evolve off of the Main Sequence.

The star cluster 2 has begun to evolve off of the Main Sequence. The red giant branch is populated with some of the originally more massive stars. Some of the first red giant stars that formed have already become white dwarfs.

Star cluster 1 is older. This is because the OBAFG stars are all missing from the Main Sequence, the red giant branch is very well populated, and there are also many white dwarfs. Only K & M stars remain on the Main Sequence.

c) From Figure 2 alone, which star cluster is closest? Explain your reasoning. [2 marks - approx 100-200 words]

Star cluster 2 is because it's an open star cluster.

Open clusters contain mostly young stars, with lots of hot, blue stars

we can make a fair comparison of the distance between the two clusters simply by matching up the stars on the main sequence with the same colours.

These are loose collections of a hundred to a few thousand relatively young stars. These are typically a few hundred million years old, a fraction of the few billion years that stars take to evolve. These clusters are found in our Galaxy's disc, the Milky Way and often contain clouds of gas and dust where new stars form. The typical diameter of an open star cluster is about 30 lightyears (10 parsecs).

Approximately six months after your observations of Cluster 1 were taken, each star's positions in Cluster 1 were measured again. With this additional data, what additional cluster properties can be determined? What can additional properties of individual stars in each cluster be determined? Explain your reasoning. [4 marks - approx 200-400 words

This is a globular cluster of star type;

Globular clusters are densely packed collections of ancient stars. Roughly spherical, they contain hundreds of thousands, and sometimes millions, of stars. Studying them helps astronomers estimate the universe's age or figure out where the centre of a galaxy lies.

There are about 150 known globular clusters in the Milky Way galaxy, according to the website. Most globular clusters are highly concentrated at their centres, having that corresponds to the Galaxy's tidal effects. The density near the centres of globular clusters is roughly two stars per cubic lightyear, compared with one-star per 300 cubic lightyears in the solar, stellar distributions that resemble isothermal gas spheres with a cutoff neighbourhood. A precise model of star distribution within a cluster can be derived from stellar dynamics, which considers the kinds of orbits that stars have in the cluster, encounters between these member stars, and the effects of exterior influences.

Question 3:
a) You are travelling in a spaceship at 0.8 c, heading to a distant galaxy that is 98 million Light Years away, as measured from Earth. What do you notice about the distance you measure to the Galaxy? Explain your reasoning. [1 mark - approx 100-200 words]
Space is usually bigger and hence the distance.

The closest star that is not the Sun is called Alpha Centauri.
The closest star to our solar system. It is 1.37 parsecs, or 41.53 trillion kilometres, from Earth.
. To get there, it would be like driving to the Sun almost 300,000 times! The closest Galaxy
Many stars, maybe even trillions that all clump together and are in orbit around each other.
Andromeda, one of the closest galaxies to our Galaxy, the Milky Way.
It is nearly 600,000 times farther than Alpha Centauri! The farthest galaxies I measure are over 100 times farther than Andromeda, and to get to the end of the visible universe, you have to go almost 150 times farther than
That. Anyway, if you wanted to drive to the end of the visible universe or pretty much anywhere out in space, it would take a long time.

b) You are sitting in a spaceship moving at speed 0.8 c. A friend is in a different spaceship moving toward you at speed 0.72 c. They are holding a mirror. You shine a white light toward the, and the light beam bounces back at you. What is the speed of the reflected beam , and why? [1 mark - approx 100-200 words]

1.6 c. this is because Light does not slow down during a reflection.

Light is a signal disturbance in electric and magnetic fields. These disturbances propagate through space at a fixed speed cc in a vacuum. The situation is completely analogous, in a mathematical sense, to a wave pulse that is sent along a string. When the pulse encounters a boundary, it flips direction and may or may not change phase depending on the type of boundary encountered.

If you emit a pulse of Light at a distance of 1 meter from a plane mirror and measure the amount of time it takes for the signal to return, you will find that it is 2 meters/cc, neglecting the refractive effects of the air. In this sense, we say that the Light has not slowed down, even though it has changed direction in the middle of its journey.

ASTRO

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FINAL GRADE

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GENERAL COMMENTS

Instructor

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