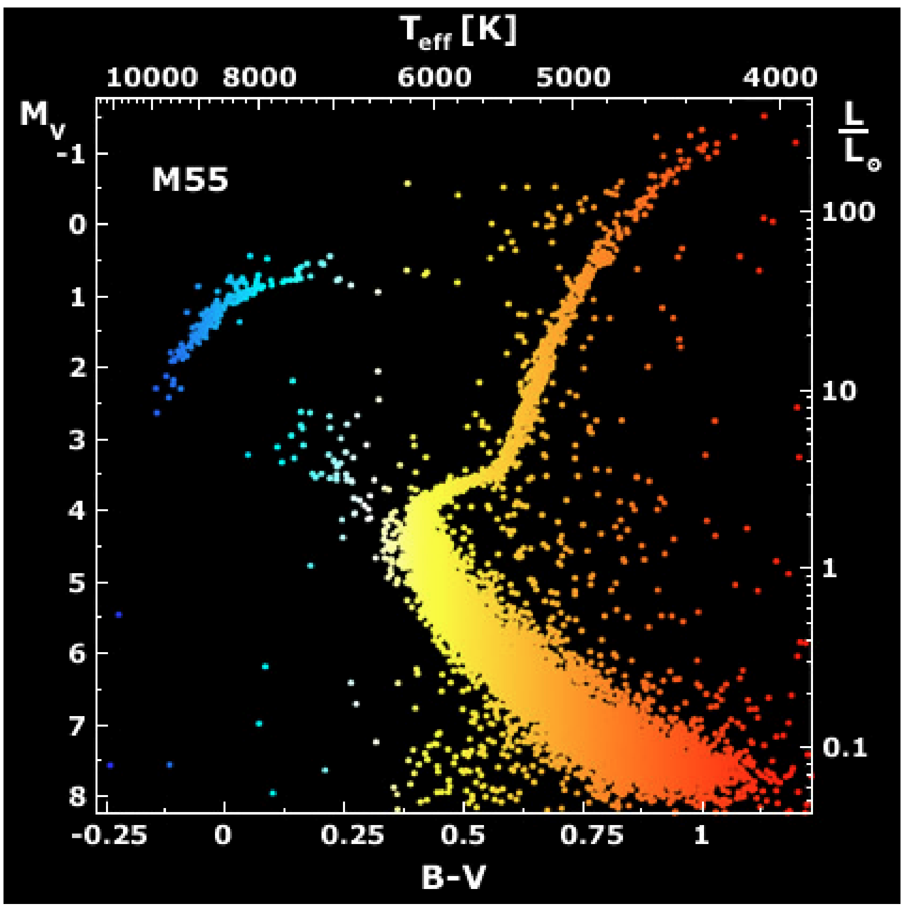
Published on *Astronomy 801: Planets, Stars, Galaxies, and the Universe* (https://www.e-education.psu.edu/astro801)

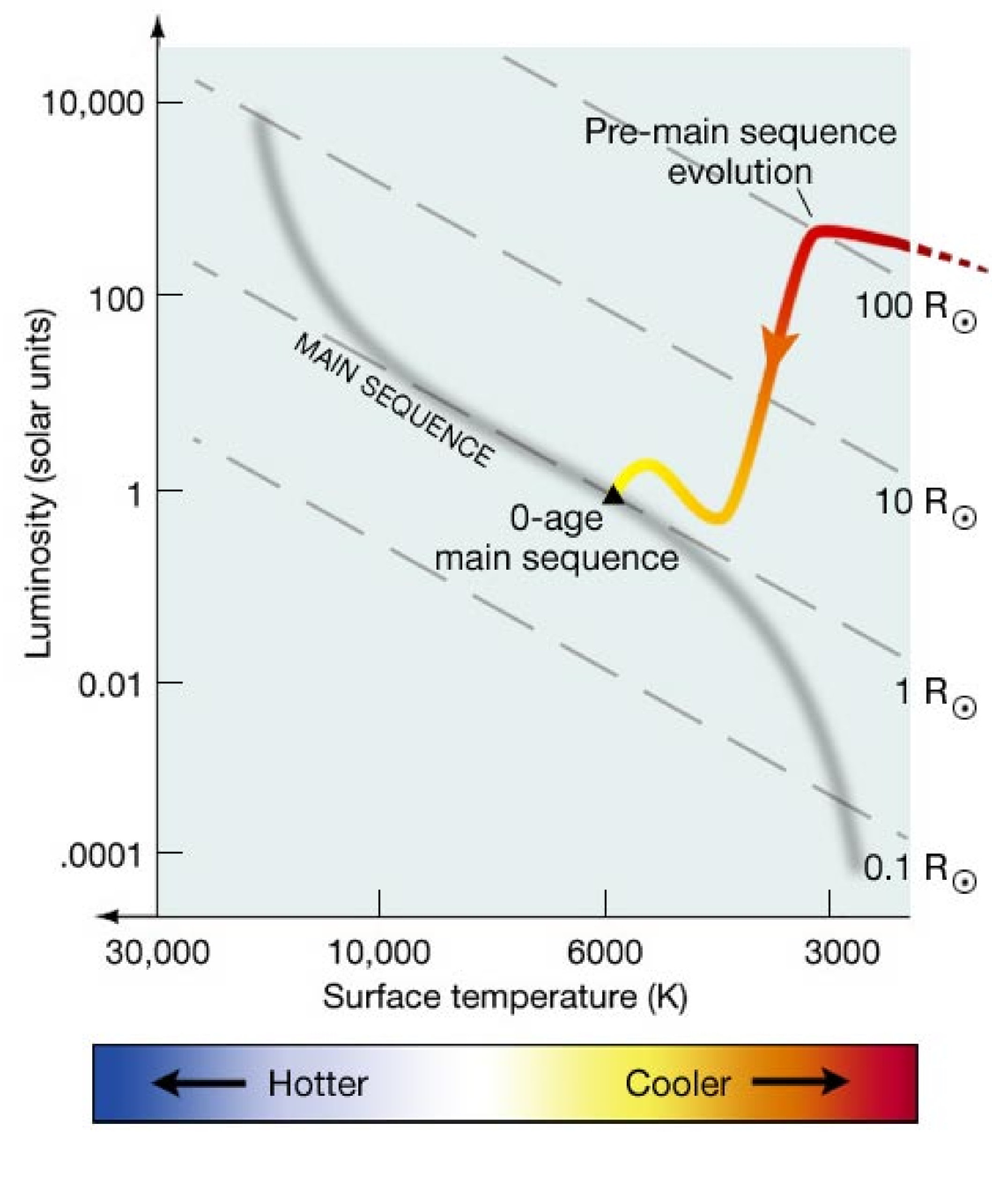
Stellar Evolutionary Tracks in the HR Diagram

We are now going to transition from the discussion of how stars form into studying how they evolve. The HR diagrams that we studied in Lesson 4 are very useful tools for studying stellar evolution. A typical HR Diagram (e.g., the one for the stars in the cluster M55, below) plots a single point per star to represent that star's color and luminosity (or brightness) as it is observed today. So you can consider an HR Diagram of that type to represent a snapshot of a moment in the lifetime of the stars plotted. At that instant, they have that color and that luminosity.



M55: Color Magnitude Diagram
Source: Astronomy Picture of the Day [1]

However, you can also plot a “track” on an HR diagram that represents how the temperature and luminosity of a star changes over time. For example, let's take a Sun-like (G type) star and follow it from formation until it reaches an age of about 5 billion years old (the current age of the Sun). During the early stages of the collapse of a clump inside a GMC, the object is enshrouded by gas and dust and is not visible outside of the cloud. When the object has collapsed to the point that it is considered a protostar and has an internal temperature of about 1 million Kelvin, it will be radiating approximately 1,000 times the Sun's current luminosity! However, the outer layers of this protostar are cooler than the Sun, so the point we plot on the HR diagram for this protostar is above and to the right of the Sun's current location in the diagram (temperature about 3,500 Kelvin). As the protostar continues to contract, its outer layers will heat up, but its luminosity will decrease. So, the point we plot for the protostar will move down and to the left (10 Solar luminosities, 4,000 Kelvin) as it evolves. During the T Tauri phase of pre-stellar evolution, the protostar will actually fluctuate in brightness, however, on average, T Tauri stars are cooler and fainter than their final location in the HR diagram (0.7 Solar luminosities, 4,500 Kelvin). Finally, when the star is fusing Hydrogen and has reached equilibrium, it will lie on the Main Sequence with a temperature of 6,000 Kelvin and a luminosity of 1 Solar luminosity. From the time the star reaches equilibrium until it exhausts its hydrogen, it stays on the Main Sequence. The red/orange/yellow line in the image below is the pre-Main Sequence track for a G star.



Watch out!

Studies have shown that this is a topic that can introduce and reinforce a misconception about stars. When studying the evolutionary tracks of stars, we often talk about how stars "move" in the HR diagram. Students can come away thinking that an HR diagram is like a map, and what the track plots is the star's motion through space, not its changing temperature and luminosity as it evolves.

We can now infer from our discussion so far the meaning of the Main Sequence in the HR diagram:

> The Main Sequence is the location in the HR diagram for stars in the first phase of their evolution, when they are fusing hydrogen in their cores.

If all Main Sequence stars are fusing hydrogen in their cores, what determines whether a protostar will become an O, B, A, F, G, K, or M Main Sequence star? The answer to this question is the star's mass. More massive stars have hotter cores because they contract further before they can generate enough radiation pressure to counteract the contraction. Thus, more massive stars produce energy at a much faster rate than low mass stars. This causes high mass stars to be much more luminous (remember, an O star is about 10,000 times more luminous than the Sun), but it also shortens their lifetime. Even though they begin with more Hydrogen, the most massive stars use up the hydrogen in their cores much faster than lower mass stars, so the lifetime of an O star on the Main Sequence is only about 10 million years, while the Main Sequence lifetime of a G star like the Sun is about 10 billion years. The Main Sequence lifetime of M stars may be 10 trillion years!

Instructor: Darren Williams; Author: Dr. Christopher Palma, Senior Lecturer in the Department of Astronomy and Astrophysics, The Pennsylvania State University.

Source URL: https://www.e-education.psu.edu/astro801/content/l5_p5.html

Links:
[1] http://apod.gsfc.nasa.gov/apod/ap010223.html