



# Using MESA-Web to predict the future of the Sun

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## Purpose

The way a star evolves in time is extremely complicated. For this reason scientists in Astrophysics nowadays use stellar evolution codes to study and understand as much as possible the evolution in time of the various types of stars that have been observed with the telescopes until today.

Stellar evolution codes can be complicated to use, but the scientific community offers the MESA-Web, a web-based interface to the stellar evolution code, Modules for Experiments in Stellar Astrophysics ([MESA](#)).

MESA-Web can be used for education purposes to calculate stellar models over a range of physical parameters, extending capabilities of similar online tools such as Rich Townsend's [EZ-Web](#).

## Overview

In this lesson students will learn the basics of how to use the stellar evolution code MESA to study why and how a star evolves throughout its lifetime. They will examine one or more stars in detail (including our Sun) using images and other scientific representations (e.g., time-evolution videos) the MESA-Web interface provides the students with.

## Student Outcomes

After completing this lesson, students will be able to:

- ✓ Understand the basic characteristics of the HR-diagram.
- ✓ Use the MESA-Web interface to study the basics of the evolution of a star.
- ✓ Understand the basics of why and how a star like our Sun and a star bigger than our Sun evolve in time including the basics of the evolution differences between the two.
- ✓ Identify the basic form of an HR-diagram by pointing out the moment a star enters and leaves the Main sequence.
- ✓ Compare on an order-of-magnitude estimate the lifespan of our Sun in the Main sequence and the time it takes for the Sun to reach the tip of the red giant branch.

## Standards Addressed

Performance expectation: DCI code **HS-ESS1-3**- *Communicate scientific ideas about the way stars, over their life cycle, produce elements.*



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**Time**

2 class periods or approx. 2 hour

**Level**

9th - 12th grade - High School Astronomy

**Materials and Tools**

Students will need to:

- Have Laptops with Internet Connection and basic software
- Type in to the web browser the MESA-Web site: <http://mesa-web.asu.edu/>
- Have an email address

**Preparation**

Ensure that all students have an email address as well as ready access to the laptops and the website mentioned in the earlier section. Make sure the needed software is installed.

**Prerequisites**

None.

**Background**

- ❖ Fundamental of gravity physics: when nothing supports a massive object against gravity the massive object collapses. Light (energy) in stars is produced by the fact that hydrogen burning in the core acts against gravity leading to the existence of a star instead of a collapse.
- ❖ Fundamental of nuclear physics: hydrogen burning occurs in very high temperatures and leads to the production of helium.
- ❖ Basic knowledge of the **Hertzsprung–Russell diagram** as the graph showing the relationship between the stars luminosities versus their effective temperatures. Identify directly the main sequence on this diagram and understand its meaning (hydrogen-burning stars producing helium).
- ❖ The position of our Sun in the HR diagram as well as the basic positions and characteristics in the diagram of red giants and white dwarfs (connected to the relative masses and radii to our Sun).
- ❖ Basic knowledge of the path our Sun will follow when it leaves the main sequence including why this happens (hydrogen exhaustion leads to helium core and in most stars in helium burning).
- ❖ Basic knowledge of stellar evolution theory. Specifically, the fact that **Stellar evolution** is the process by which a star changes during its lifetime. Depending on the mass of the star, this lifetime ranges from a few million years for the most massive to trillions of years for the least massive, which is considerably longer than the age of the universe.

## Teaching Notes

Teachers should practice running some stellar models using the MESA-web interface before teaching it. They should make sure they received the relevant emails from the website in the appropriate time and that laptops have the needed software to unzip the folder sent from the web as well as the needed software to run the included video in the folder. They should also make sure to know the form of the name of the relevant video under study to point it out to students since the sent folder from the web includes other information data files as well and students could be easily confused on which to open and use.

## Assessment

The teacher should ask the students to answer two fundamental questions based on the stellar models they used. The right answer in these two questions clarifies which students accomplished the task of this course in a successful way.

The two questions include:

- ✚ How old is the Sun when it enters and leaves the Main sequence?
- ✚ How much time does it take the Sun to reach the tip of the red giant branch and how much is this time more compared to the result in the first question.