A Content Secondary Science Newsletter from the
Southern Nevada Regional Professional Development Program

Science Dissected

Main Sequence Stars: How Lifespan Depends on Mass

Model-Evidence Link Diagram (MEL)

A star is a sphere of gas held together by its own gravity. The force of gravity is continually trying to cause the star to collapse, but this is counteracted by the pressure of hot gas and/or radiation in the star's interior. During most of the lifetime of a star, the interior heat and radiation is provided by nuclear reactions near the center, and this phase of the star's life is called the main sequence. A star's life cycle is determined by its mass.

This issue of Science Dissected addresses a common misconception that more massive stars life longer and provides an instructional resource for teachers to present students with the opportunity to examine several pieces of evidence about the connection between the mass of a star and its lifespan in the main sequence, and critically evaluate two competing models;

Model A:* *More massive main sequence stars live <u>longer</u> than less massive main sequence stars because they have more hydrogen as fuel.

Model B:* *More massive main sequence stars live <u>shorter</u> than less massive main sequence stars because they use their hydrogen fuel faster.

Evidence #1: The lifetime of a star depends on the amount of fuel to be burned divided by the rate at which the fuel is being burned.

Evidence #2: More massive stars also have higher core temperatures; higher temperatures lead to higher rates of nuclear fusion.

Evidence #3: The amount of fuel available to a star is roughly proportional to the mass of the star.

Evidence #4: When star clusters are studied, it becomes clear that more massive stars leave the main sequence before less massive stars.

The following is a suggestion for using this MEL with students:

1. Hand out the "Main Sequence Stars: How Lifespan Depends on Mass" Model Evidence Link Diagram (page 1). Instruct students to read the directions, descriptions of Model A and Model B, and the four evidence texts presented.

2. Handout the four evidence text pages (pages 3-7).

3. Instruct students to carefully review the Evidence #1 text page (page 3), then construct two lines from Evidence #1; one to Model A and one to Model B. Remind students that the shape of the arrow they draw indicates their plausibility judgment (potential truthfulness) connection to the model.

4. Repeat for Evidence #2-4 (pages 4-7).

5. Handout page 2 for the students to critically evaluate their links and construct un-

Once students have completed page 2, they can then engage in collaborative argumentation as they compare their links and explanations with that of their peers. Students should be given the opportunity to revise the link weighting during the collaborative argumentation exercise. If time permits, have students reflect on their understanding of the connection between the mass of a star and its lifespan and create questions that they might explore in the future.

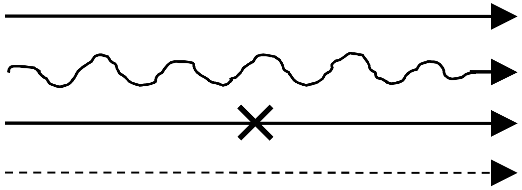
Archived Issues of Science Dissected, http://www.rpdp.net/link.news.php?type=sciencedis. Instructional Resource resulting from Plausibility, It's All About Connecting the Models Workshop co-sponsored by CPDD and SNRPDP Science March 6, 2012

Written by: Petya Crones

Name:__________________________________**Period:**________ **Title: Main Sequence Stars: How Lifespan Depends on Mass**

Directions: draw two arrows from each evidence box. One to each model. You will draw a total of 8 arrows.

Key:



The evidence **supports** the model

The evidence **STRONGLY supports** the model

The evidence **contradicts** the model (shows its wrong)

The evidence has **nothing to do with** the model

Standard: **E.12.B.1**

(Students know common characteristics of stars)

Evidence #1
The lifetime of a star depends on the amount of fuel to be burned divided by the rate at which the fuel is being burned.

Model A
More massive main sequence stars live **longer** than less massive main sequence stars because they have more hydrogen as fuel.

Evidence #3
The amount of fuel available to a star is roughly proportional to the mass of the star.

Model B
More massive main sequence stars live **shorter** than less massive main sequence stars because they use their hydrogen fuel faster.

Evidence #2
More massive stars also have higher core temperatures; higher temperatures lead to higher rates of nuclear fusion.

Evidence #4
When star clusters are studied, it becomes clear that more massive stars leave the main sequence before less massive stars.

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate descriptor (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write the letter of the model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

4. Circle the plausibility of each model. [Make two circles. One for each model.]

	Greatly implausible (or even impossible)									Highly Plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

5. Circle the model which you think is correct. [Only circle one choice below.]

Very certain that Model A is correct	Somewhat certain that Model A is correct	Uncertain if Model A or B is correct	Somewhat certain that Model B is correct	Very certain that Model B is correct

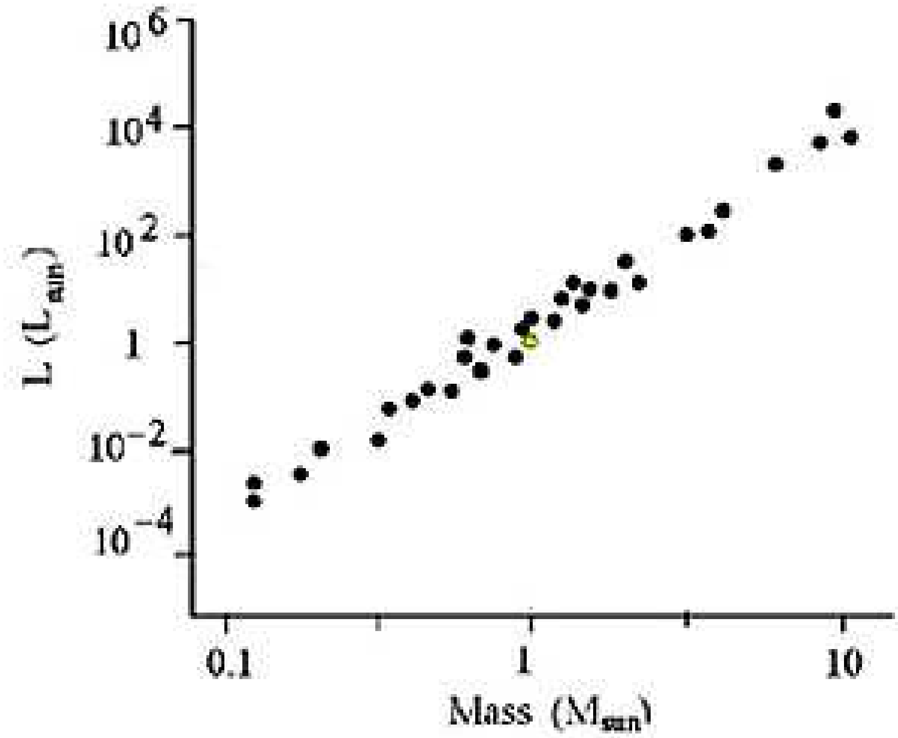
Evidence #1: The lifetime of a star depends on the amount of fuel to be burned divided by the rate at which the fuel is being burned.

Adapted from http://hyperphysics.phy-astr.gsu.edu/hbase/astro/startime.html, http://www.fas.org/irp/imint/docs/rst/Sect20/A5.html

The lifetime of a star depends on the amount of fuel to be burned (which depends on the mass of the star) divided by the rate at which the fuel is being burned (which determines the luminosity of the star).

The graph below shows how the luminosity (the total amount of energy emitted by the star every second) increases as the mass of the star increases. The luminosity of a star is a measure of its energy output, and therefore a measure of how rapidly it is using up its fuel supply. Please note that a 10 times increase in mass leads to a 100 times increase in luminosity.

Mass of the sun – 1; Luminosity of the sun – 1; all other stars are measured relative to the sun



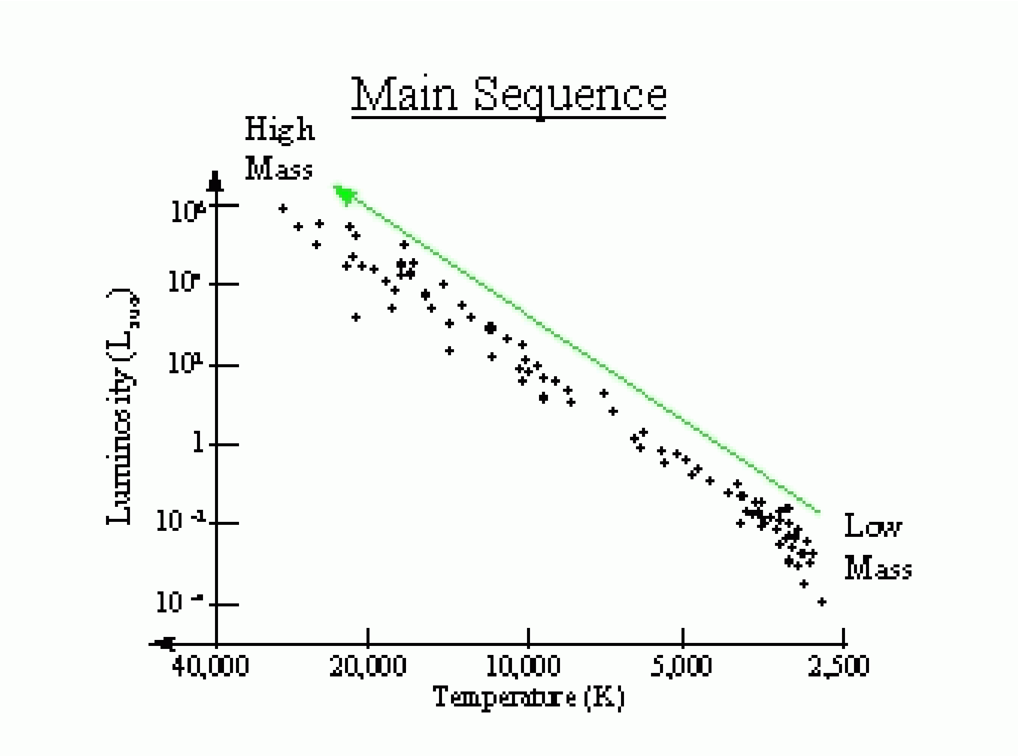
Mass - luminosity relation for main-sequence stars

Evidence #2: More massive stars also have higher core temperatures; higher temperatures lead to higher rates of nuclear fusion.

Adapted from:
http://www.astronomy.ohio-state.edu/~ryden/ast162_4/notes14.html
http://outreach.atnf.csiro.au/education/senior/astrophysics/images/stellarevolution/ppcnoenergy.gif

More massive stars also have higher core temperatures; higher temperatures lead to higher rates of nuclear fusion.

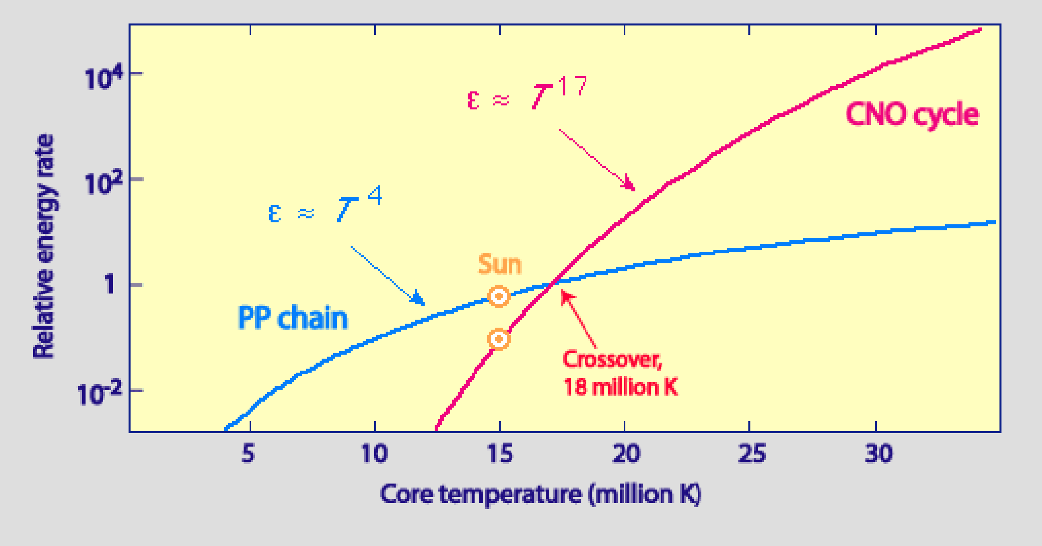
The graph below shows that more massive stars have higher temperatures than less massive stars. Please note that on the X-axis the Temperature increases to the LEFT.



Surface temperature – Luminosity relation for main sequence stars

The next graph shows that the speed of nuclear fusion reactions increases as the temperature of the core of the star increases – hotter stars use their fuel faster than lower temperature stars.

(PP chain and CNO cycle are the two possible types of nuclear fusion reactions, and for both of them the speed increases as the temperature increases.)



Core temperature – Relative energy rate (speed of the nuclear reaction) relation

Evidence #3: The amount of fuel available to a star is roughly proportional to the mass of the star.

Adapted from http://zebu.uoregon.edu/~soper/StarLife/starlife.html

The amount of fuel available to a star is roughly proportional to the mass of the star. (Roughly, because it is only the fuel at the star's core that counts here. The temperatures outside the center are not high enough for nuclear fusion to take place so the fuel located outside the center will not get used during nuclear fusion.). Bigger stars have more mass (thus more fuel).

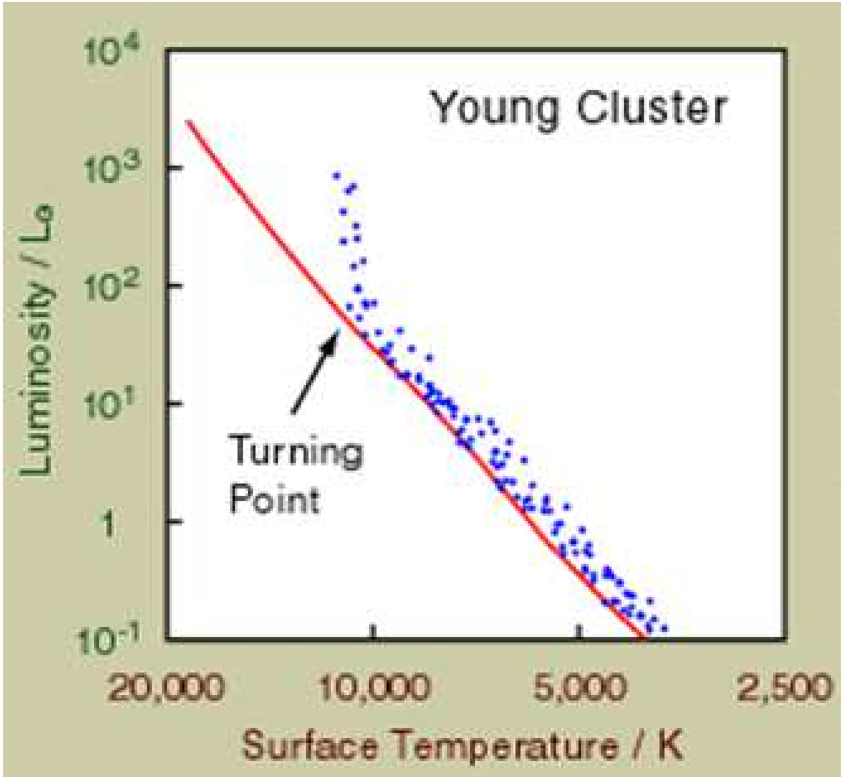
Evidence #4: When star clusters are studied, it becomes clear that more massive stars leave the main sequence before less massive stars.

Adapted from http://www.physics.hku.hk/~nature/CD/regular_e/lectures/chap15.html

When star clusters are studied, it becomes clear that more massive stars leave the main sequence before less massive stars.

Stars in a cluster formed at the about the same time, hence have roughly the same age, but their masses are different.

When we plot the stars of a cluster in the H-R diagram below, we see the more massive stars, which are stars in the upper left, have already evolved off the main sequence – started to die. And stars at the turnoff point are just about to die.



Surface Temperature – Luminosity relation for cluster stars