



Star states

Lesson about star properties and their interrelationships

DynaLearn level 3 | Version 1.0

Summary	
<p>In this lesson we look more closely at the quantities and their characteristic values. When is a star a 'massive star' or a 'red dwarf' and how does that relate to, for example, the lifespan of stars or their peak colour (such as infrared or ultraviolet).</p> <p>This lesson builds on the Star properties lesson.</p>	
Given name	
Surname	
Class	
Date	
Comments by teacher	



Introduction

This lesson is the continuation of the *Star properties* lesson. This follow-up assignment therefore starts with the result of that first assignment.

In this assignment we look more closely at the quantities and their characteristic values. When is a star a 'massive star' or a 'red dwarf' and how does this relate to, for example, the lifespan of stars or their peak wavelength (infrared, ultraviolet, etc.).

1. Starting DynaLearn

There are several ways to log in. Use one of the options below. Then check whether the login was successful (see 'Check').

Via a code:

1. **Go** to DynaLearn (<https://create.dynalearn.nl/>).
2. **Click** on 'log in with code', at the bottom left.
3. **Enter** the project code and your (school) email address.
4. **Copy** the code from the confirmation email received from *dynalearn.nl* (see spam folder if needed) and **fill in** the other details.
5. **Log in** to DynaLearn.

By email invitation:

1. **Copy** the login details from the invitation email received from *dynalearn.nl*.
2. **Go** to DynaLearn (<https://create.dynalearn.nl/>).
3. **Log in** to DynaLearn.

Check!

After logging in, you will automatically enter in the white workspace of the assignment. You can recognize it by the grey question mark on the right side of the screen . Is the question mark missing? Then first do the following:

- In DynaLearn, click . Next **click** on 'Select template'.
- **Choose** 'Star states' and **press** 'Load'. You should see the model shown in Figure 1.

Save model file and start:

1. **Click** on  top left. Change the name to 'Star states' and **click** 'Save'.
2. How to proceed? **Just follow** the steps in this tutorial. Note! You can't skip steps. Ask for help if you do not understand a certain step. The **boxes** contain brief explanations about model ingredients. The video function  in DynaLearn shows how model ingredients can be created. Put a check mark ✓ next to the step you completed. This way you keep track of where you are in the assignment.



2. Mass of stars (1)

Let's start with the mass of stars.

In the previous lesson, star properties, you made a cause-and-effect model of important properties of stars. That model is the beginning of this lesson (see Figure 1). You may want to read **Boxes 1, 2 and 3** in the **Appendix** to refresh your memory (see end of this document).

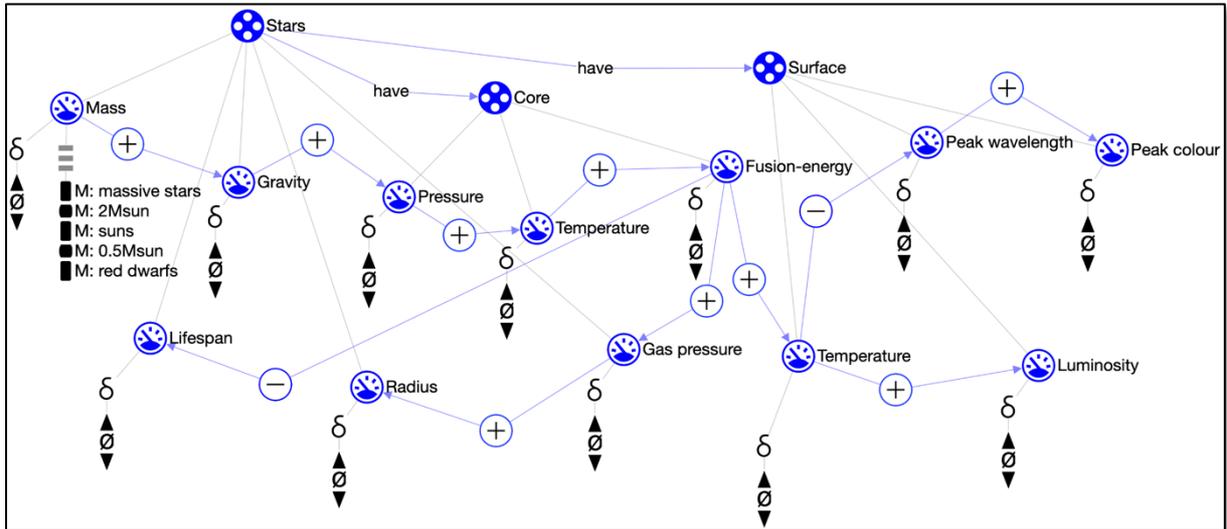


Figure 1. Outcome of the properties of stars lesson and the start of the star states lesson.

The model shows that *mass* is at the beginning of the cause-and-effect chain and therefore determines all other properties. In this lesson, we further develop the model from the first lesson. We start with the mass.

Stars are formed by the contraction of gas clouds (nebula). This process can take several hundred thousand years. Stars can have very different masses. The mass of a star determines many other properties. Our sun is not the largest star in the universe. Can you find the Sun in Figure 2?



Figure 2. Stars with different masses.



We often use our Sun as a starting point to compare to other stars. Stars that are at least twice as massive as our Sun are called 'massive stars'. A well-known massive star is Betelgeuse, a bright star in the constellation of Orion. Stars that are less than half the mass of our Sun are called 'red dwarfs' (in Figure 2 they are smaller than a pixel and therefore not visible). Table 1 provides an overview of the entities and associated quantities in the model.

In this lesson you will build on the model created in the Star properties lesson and add characteristic values to seven quantities. We use the notion of a **quantity space** for this, which consists of a series of intervals alternated with points. Details are explained below.

Table 1. Star properties.

Entity	Quantity	Unit
Star	Mass	M_{Sun} (mass of the Sun; so for the Sun, mass = $1M_{\text{Sun}}$)
	Gravity	Newton
	Gas pressure	Pascal
	Lifespan	Years
	Radius	R_{Sun} (radius of the Sun)
Core	Pressure	Pascal
	Temperature	Kelvin
	Fusion-energy	J/s
Surface	Luminosity	L_{Sun} (luminosity of the Sun)
	Peak wavelength	Metre
	Peak colour	'Words'
	Temperature	Kelvin

What is a quantity space?

1. Read Box 1.

Box 1. Quantity space

A newly created quantity  does not yet have a quantity space. By adding a quantity space, you can indicate which values a quantity can take on. A quantity space consists of alternating points (■) and intervals (▬).

- A *point value* is only one value. For example, a *boiling point*. A special point is the zero point, for which there is a separate symbol (\emptyset) in DynaLearn.
- An *interval* is a set of values. The liquid phase of a substance is an example of an interval. In the case of water, the interval 'liquid' contains all values between 0 °C and 100 °C. The values 0 °C and 100 °C are respectively the 'melting point' and the 'boiling point' between which the interval 'liquid' is located.

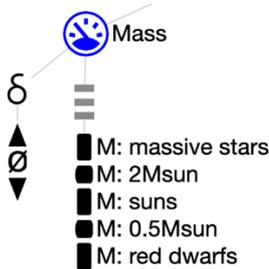
2. Watch the clip on how to create a quantity space. Use the video function in the DynaLearn software (see →).

In this lesson we use a quantity space consisting of 5 values to describe the Mass of stars, namely: massive stars, stars with a mass twice as large as the sun ($2M_{\text{sun}}$), stars with approximately the same mass as the sun (sun-likes), stars with a mass twice as small as the sun ($0,5M_{\text{sun}}$) and red



dwarfs. Here 0,5Msun and 2Msun are point values and red dwarfs, suns and massive stars are intervals.

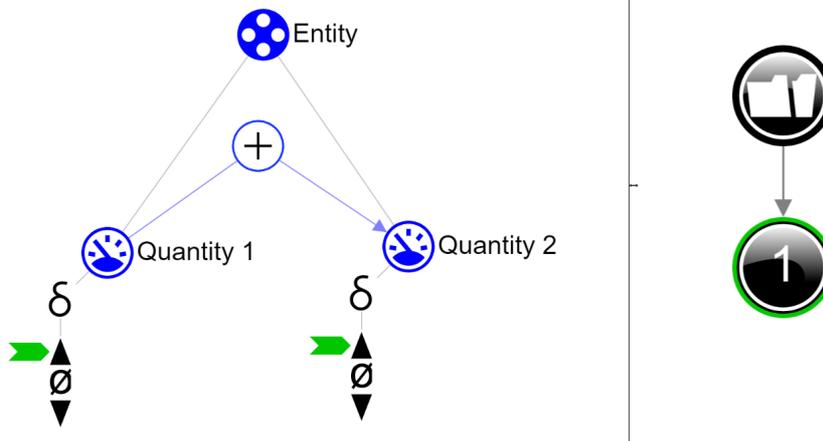
- The quantity space for the mass of the stars has already been added to the model. **Inspect** the quantity space for the quantity mass in the model. For sake of clarity, each value starts with the first letter of the quantity (here: M:). The quantity space looks as follows.



- To **simulate** your model, you must indicate (a) an initial value, and (b) an initial change (see →):
 - Set the **value** for *Mass* to *red dwarf*
 - Set the initial **change** in *Mass* to *increases*.
- Run** the simulation by clicking on and **check** the result by clicking on .
- Read** Box 2.

Box 2. Read the outcome of a simulation.

After starting a simulation (with) , a window appears on the right in which the possible states of the system are indicated. There is one possible state in this example .



You can click on the state to view the outcome. The state icon then gets a green circle. In the model, the change for this state is indicated by green arrows . The model shows that in state *Quantity 1* increases and that therefore *Quantity 2* also increases.



7. **Read** Box 3.

Box 3. Help function

If the explanation mark appears , something is wrong during the simulation. Click on the explanation mark  for a hint. Then click on a number, for example , to see where the error is in your simulation.

8. Does the quantity *Mass* get all possible values according to this simulation?

Note your observations here...

In the assignments below, we will discuss a solution to iterate through all values.



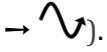
3. Mass of stars (2)

In Step 2, the simulation did not pass through all values for *Mass*. You set the mass to increase at the beginning of the simulation, but you have not told the software that the quantity *should continue to increase* during the entire simulation.

1. **Read** Box 4.

Box 4. What is an exogenous influence?

If you want a quantity to decrease, remain stable or increase throughout the simulation, you must add an external influence (an exogenous influence) to the quantity.

2. **Add** an external influence which ensures *Mass* increases during the entire simulation (see  → ).
3. **Simulate** the model again by clicking on  and check the result, and...? Does the simulation now pass through all values for the quantity *Mass*? Write your answer below.

Note your observations here...



4. Lifespan of stars (1)

Massive stars have a shorter lifespan. Massive stars have a higher fusion-energy and therefore burn faster. Short is relative because a massive star can still live to be a billion years old. Instead of a billion (a 1 with 9 zeros, so 1,000,000,000) we can also use the scientific notation: 10^9 . Red stars burn much slower and can therefore live much longer - an estimated 100 billion years, or 10^{11} years. The universe is 'only' 13.7 billion years old, so it will take some time before red dwarfs use up all of their fuel supply.

1. **Read** Box 5.

Box 5. Help function

If the question mark  or an ingredient in your model  is red, then something is wrong. Click the question mark  for a hint. Then click on a number, for example , to see where the error is in your model. Only use the question mark if you can't figure it out yourself!

2. **Create** the **quantity space** (see  → ) for the **quantity** *Lifespan (LS)* for the **entity** *Stars*. This quantity space has 5 values: 2 points (LS: 10^{11} year and LS: 10^9 year) and 3 intervals (LS: $>10^{11}$ year, LS: $\sim 10^{10}$ year and LS: $<10^9$ year). The symbol \sim means 'approximately'. Note the order of the values in the quantity spaces. Which value is at the top? Which value at the bottom? If needed, use the help function (see Box 5).
3. To be able to **simulate** your model, you need to set **initial values**. **Set** the **value** of *Lifespan* to *LS: $>10^{11}$ years* (the highest value).
4. Does the **initial change** for *Lifespan* still need to be set? **Write** your answer below.

Write your answer...

5. **Run** the simulation by clicking on  and watch carefully. What happens...? Are there 5 states (or many more)? If there are many more, can you explain what is wrong with this result? **Write** your answer below.

Write your answer...

In the next assignment, you will look for a solution for 'too many states'.



5. Lifespan of stars (2)

The mass and lifespan of stars are (inversely) linked. A higher mass is associated with a shorter lifespan. If the mass increases, then the lifespan decreases. For stars on the 'main sequence', red stars have a lifespan of 10^{11} years, and blue stars have a lifespan of 10^9 .

In the model we can indicate this by making **correspondences**.

1. **Read** Box 6.

Box 6. Correspondence

In a system, it can happen that only certain values of different quantities can occur together. You can then make a **correspondence** between the quantity spaces of these quantities.

2. **Make** a correspondence of type reversed inverse (see  → ) between the quantity space of *Mass* and the quantity space of *Lifespan* of the entity *Stars*.
3. **Simulate** your model. How many states are created now? (Write your answer below)

How many states are there?

4. If you see a blue exclamation mark (right top of the screen), **read** Box 3.
5. The inverse correlation between the star's mass and lifespan indicates that a star with higher mass has a shorter lifespan. **Explain** why this is so. **Make** use of the cause-and-effect relationships in the model ( and .

Write your explanation here...



6. Temperature

When astronomers talk about the temperature of stars, they often mean the temperature at the surface of those stars. Inside the star it quickly gets much hotter. The Sun has a (surface) temperature of about 5800 K (for stars we indicate the temperature in Kelvin). Massive stars have a higher temperature, more than 8000 K. Red dwarfs, on the other hand, have a lower temperature, less than 4000 K.

1. **Create** the **quantity space** for the **quantity** *Temperature (T)* for the **entity** *Surface*. This quantity space has 5 values: 2 points and 3 intervals. **Note** the order of the values. If needed, use the help function (see Box 5).
2. **Create** a **correspondence** between the quantity space of *Temperature* and one of the already created quantity spaces (see  → ). Which is the most logical one?
3. **Click**  to align everything neatly. **Click**  to make your model fit on your screen.
4. **Simulate** the model. 5 states should appear in which the quantities *Mass*, *Lifespan* and *Temperature* go through all values in their quantity spaces step-by-step.



7. Wavelength and colour

Figure 3 shows part of the electromagnetic spectrum emitted by stars. The hotter a star (on the surface), the bluer its colour. The cooler the star, the redder its colour.

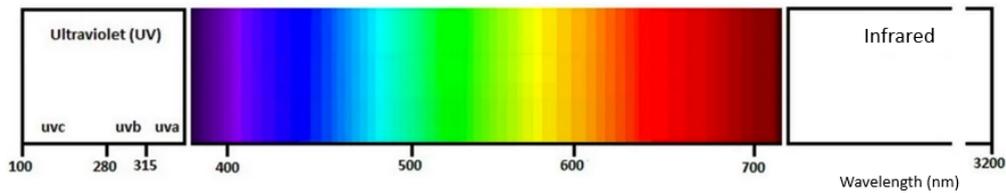


Figure 3. Electromagnetic spectrum.

Light consists of electromagnetic waves. The wavelength (see figure 4) determines the colour we perceive (see figure 3). Ultraviolet light has a shorter wavelength than infrared light. Green light has a wavelength of about 500 nm. The symbol \sim means 'approximately', nm stands for nanometre or 1/billionth of a meter.

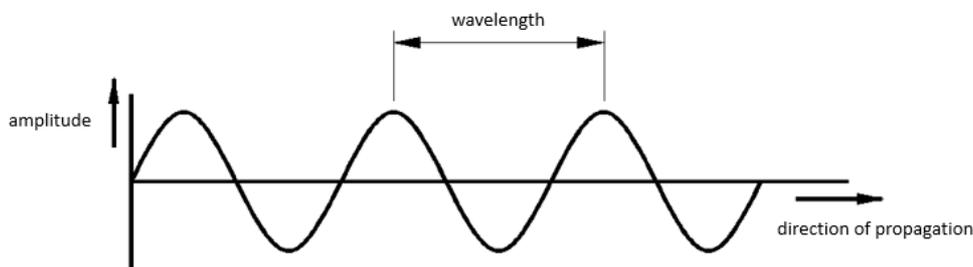


Figure 4. Waves – Amplitude and wavelength.

The colour green corresponds to a surface temperature of approximately 6,000 K. The temperature of the Sun is slightly lower, namely 5,800 K, and it is also green (yes, green! Why do we see the Sun as yellow?).

Figure 5 shows a red dwarf, a Sun-like star, and a massive star and their corresponding temperatures and the wavelength of the light they primarily emit. A red star has a low temperature and mainly emits light in the red and infrared part of the spectrum. A massive star has a high temperature and emits light mainly in the blue and ultraviolet part of the spectrum.

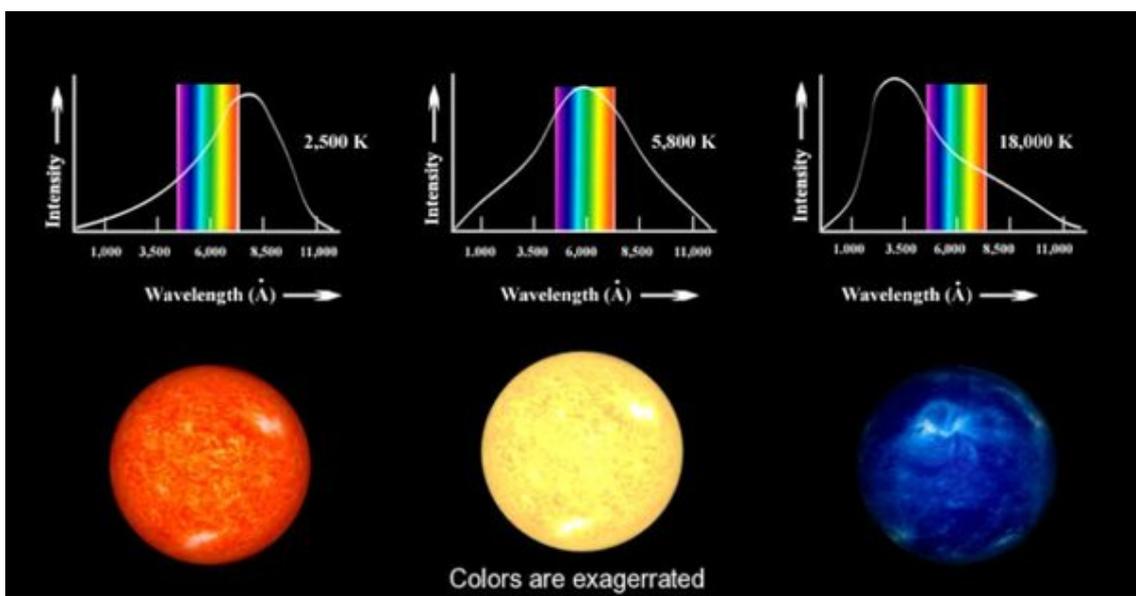


Figure 5. Stars – Temperature and wavelength.



1. **Create** the **quantity spaces** for the **quantity** *Peak wavelength (PW)* and the **quantity** *Peak colour (PC)* for the **entity** *Surface*. Both quantity spaces have 5 values: 2 points and 3 intervals. Note the order of the values and place the largest wavelength as the highest value in the quantity space.
2. **Create** a **correspondence** between the quantity space of *Peak wavelength* and the quantity spaces of *Peak colour*. Are *Peak wavelength* and *Peak colour* regularly or inversely corresponding? Check the direction of the correspondence carefully.
3. **Create** a **correspondence** between the quantity space for *Peak wavelength* and one of the already created quantity spaces. Which one is the most logical?
4. **Click** on  to neatly align the model. **Click** on  to fit your model to the screen.
5. **Simulate** the model. 5 states should appear in which all quantities with a specified quantity space go through all values in their quantity spaces step-by-step.



8. Star Luminosity

The brightness or luminosity of a star depends on its temperature. Figure 6 shows the stars on the main sequence in a graph in which temperature is plotted against luminosity. The luminosity is shown in relation to the luminosity of the sun. The luminosity of hot stars (i.e., blue, massive stars) is at least 10 times greater than that of Sun-like stars. The luminosity of red dwarfs is at least 10x smaller than that of Sun-like stars.

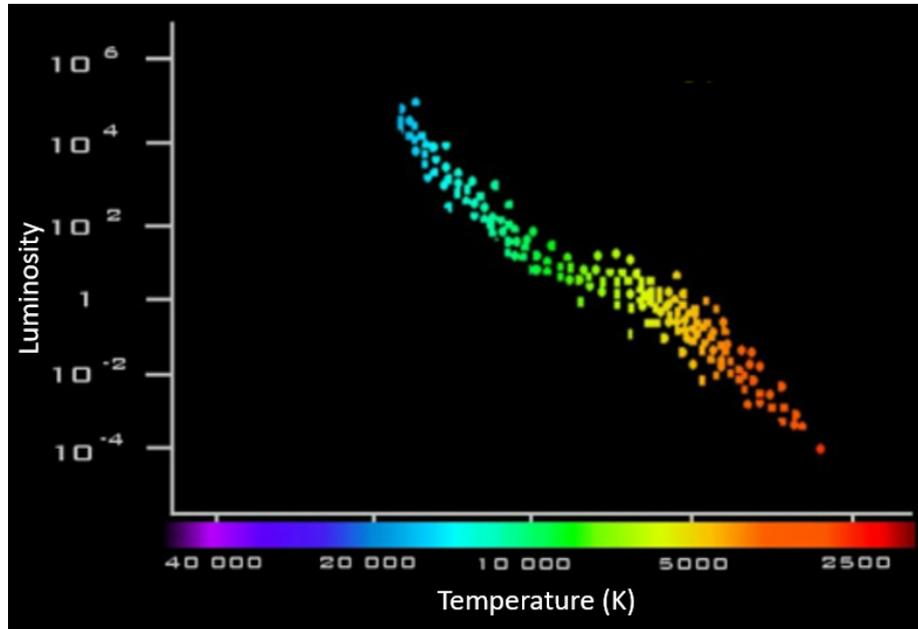


Figure 6. Stars – Luminosity, temperature and colour.

1. **Create** the **quantity space** for the **quantity** *Luminosity* (L) of the **entity** *Surface*. The quantity space has 5 values: 2 points and 3 intervals.
2. **Create** a **correspondence** between the quantity space for *Luminosity* and one of the already created quantity spaces. Which is the most logical? Tip: see *Figure 6*.
3. **Simulate** the model. 5 states should appear in which all quantities with a specified quantity space go through all values in their quantity spaces step-by-step.

9. Radius of a star

Figure 2 (at the start of this document) shows many massive stars. Massive stars have a lot of mass and therefore are large. The radius (r) of a massive star is at least 1.75 times the radius of our Sun. Red dwarfs are at least 0.6x smaller than our Sun.

1. **Create** the **quantity space** for the **quantity** *Radius* (R) of the **entity** *Star*. The quantity space has 5 values: 2 points and 3 intervals.
2. **Create** a **correspondence** between the quantity space of *Radius* and the quantity space of *Temperature*. Is the correspondence regular or inverse? Check the direction.
3. **Simulate** the model. 5 states should appear in which all quantities with a specified quantity space go through all values in their quantity spaces step-by-step.

You have now completed the assignment.



Appendix

1. **Read** Boxes 1, 2 and 3 to refresh your memory.

Box 1. Entity and quantity

An entity  is usually a physical thing in a system (e.g., car, human).

A quantity  is a measurable property of an entity (e.g., temperature, length).

Box 2. Cause-and-effect relationships

In DynaLearn, there are two types of cause-and-effect relationships:

- Positive relationship : the quantities change in the same direction (if quantity 1 increases, then quantity 2 increases also)
- Negative relationship : the quantities change in opposite direction (if quantity 1 increases, then quantity 2 decreases. Or vice versa: if quantity 1 decreases, then quantity 2 increases)

Box 3. Change of a quantity.

A quantity  can change. This is indicated by . The delta symbol (δ) is the mathematical sign for change (also called the derivative). The down arrow (\blacktriangledown) is a decrease, the zero (\emptyset) is constant and the up arrow (\blacktriangle) is an increase.