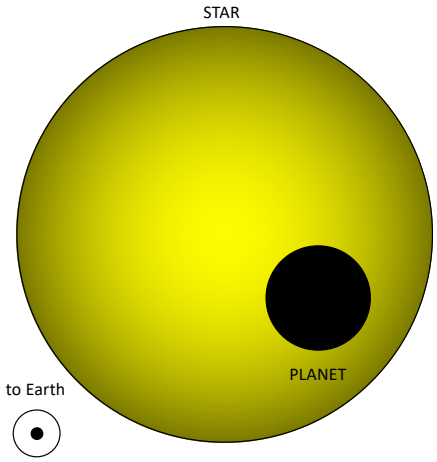
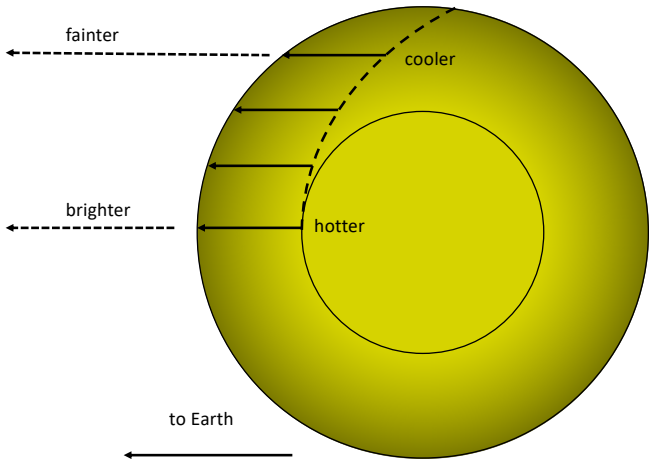
The effect of Stellar limb-darkening on transit light curves

why transits do not look like trapezoids?

There are two main bodies involved in modelling a transit phenomenon: the star and the planet. We are staring this educational journey by describing the stellar part of the transit model. Under certain circumstances related to the orbit of the planet, we will observe the planet passing in front of the star, as it is illustrated below:



Both the star and the planet have specific characteristics that play a role and influence the transit phenomenon and how this will be observed by us – the observers. In this issue, we will discuss how the star affects the transit: the **limb-darkening effect.** As you can notice in the figure above, the stellar disk does not look uniform, it gets darker as we move away from the centre of the disk. The light from the edge of the disk travels a longer distance within the star's atmosphere compared to the light coming from the centre of the disk. Because of this, the light from the edge will originate from a higher altitude in the stars' atmosphere. The temperature there is lower and so this light will be dimmer.



The strength of the limb-darkening depends on the physical parameters of the star (stellar temperature, stellar gravity, stellar metallicity) and the filter with which we are observing. This is the reason why we ask you to give us the observation filter for every transit that you upload. But how does the limb-darkening affect the transit? The weaker the limb-darkening is, the

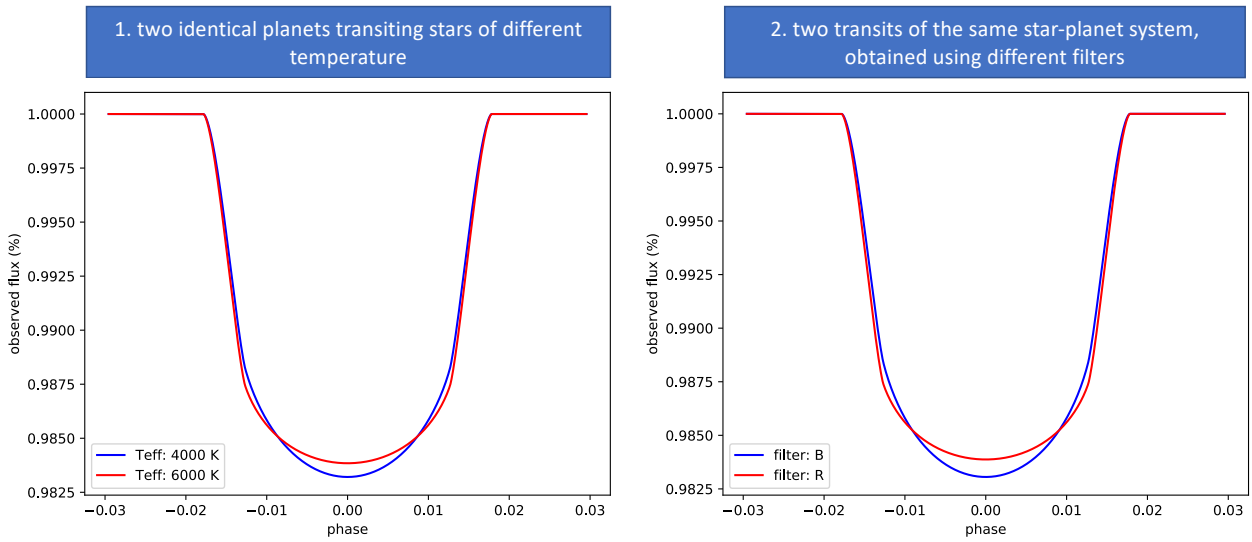
more uniform the stellar disk will be. This will produce a transit with sharper ingress and egress. Two factors affect the limb-darkening:

1. The nature of the star

Hotter stars have weaker limb-darkening. So, if we observe, with the same filter, two similar transiting planets around two different stars, the transit around the hotter star will look sharper.

2. The observing filter

Also, when the same star-planet system is observed at longer wavelengths, limb-darkening will be weaker, and the transit will look sharper. This is one reason why we prefer to observe transits with red filter, as the sharper transits give as better estimation of the transit timing.



Further reading:

One of the best ways we have to model this effect if the so-called 4-coefficients law:

$$I(\mu) = 1 - a_1(1 - \mu^{1/2}) - a_2(1 - \mu) - a_3(1 - \mu^{3/2}) - a_4(1 - \mu^2)$$

where **I** is the brightness of the stellar disk at a specific point, relatively to the brightness at the centre, **μ** is the cosine of the viewing angle (see figure below), and **a1,2,3,4** are the limb-darkening coefficients. More about this formula and other ones you can find in these papers:

- https://iopscience.iop.org/article/10.3847/1538-3881/aa8405/pdf
- http://articles.adsabs.harvard.edu/pdf/2000A%26A...363.1081C

Additional reading is available also within the references.