The Red Giant Stage of a Star

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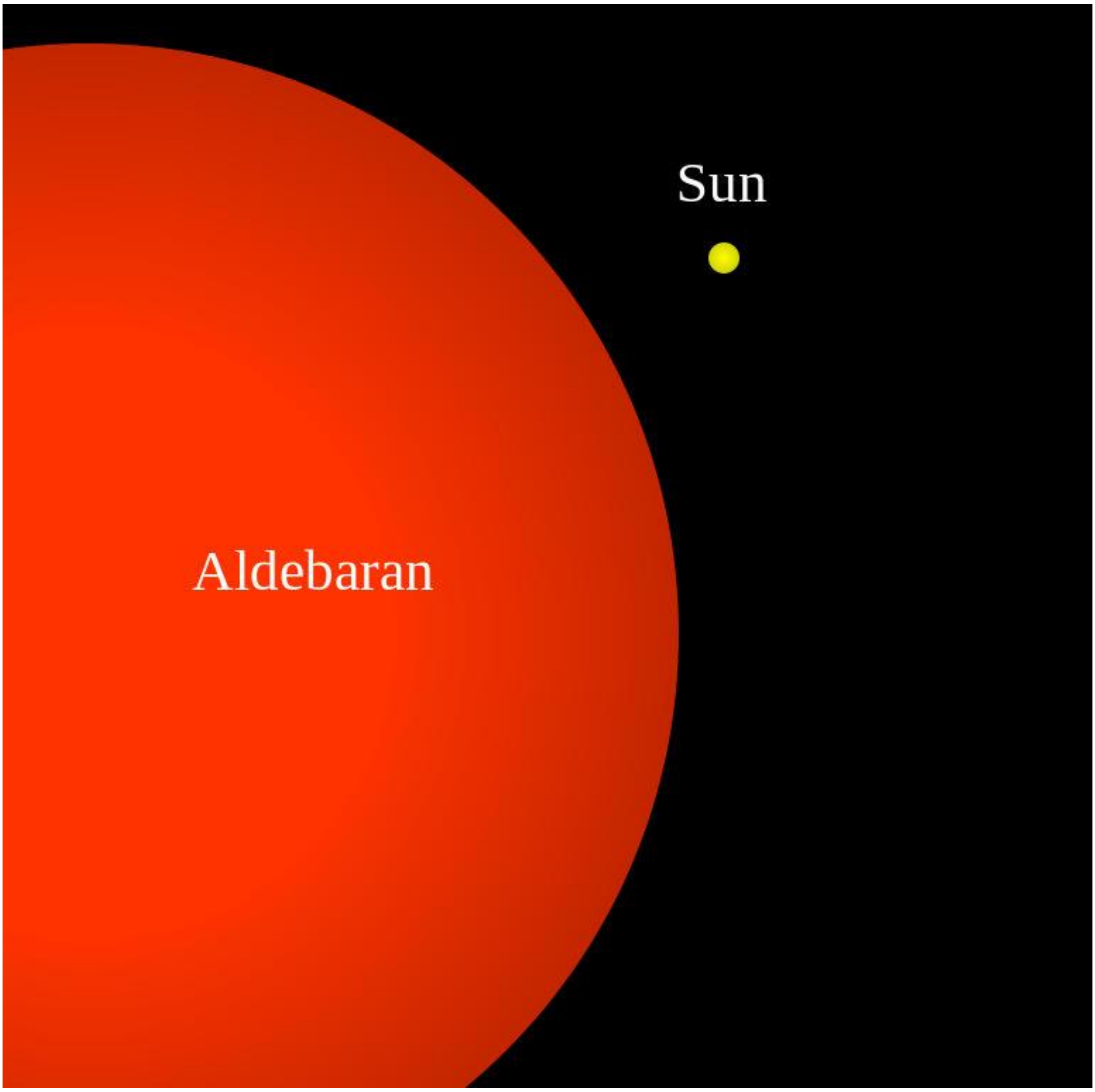
1 INTRODUCTION

A red giant is a luminous giant star of low or intermediate mass in a late phase of stellar evolution.



Betelgeuze:

2 THEORY

The hydrogen fusion is the source of energy which provides the power for keeping up the internal thermal pressure of the star which is then working countering the gravitational force. After a certain time the cores hydrogen is all used up. Without fusion, the protostar loses its balance, because there is no more thermal energy which is able to maintain the internal pressure. Because of that the star loses its ability to counter the force of gravitation, which leads to the degradation of the core, but also to the extension of the outer layer. While the radius is expanding, the star moves almost horizontally to the right in the Hertzsprung-Russell-Diagram and therefore develops into a sub giant star. During that outer expansion the luminosity is growing distinctly, which then makes the star move up in the H.-R.-Diagram. Over a span of one billion years, both, the size and luminosity grow until the star is classified a Red Giant.
When the core has used off all its hydrogen it is almost exclusively made up of pure helium. However, there is still a lot of it left surrounding the core, since the fusion has only taken place inside the core. The non fusing core of helium and its surrounding hydrogen starts to shrink again, caused by gravitation. That makes the shell become much hotter again and triggers the process of hydrogen burning (=hydrogen fusion in the stars shell). Because of the enormous heat, it is happening much faster in the shell then in the core. Now that output of thermal pressure leads to the stars surface to grow again until the luminosity is high enough to compensate for the rate of fusion. Most mass however stays focused in the center of the star as long as the helium there stays inactive. A higher fusion rate makes the temperature rise, a lower makes it fall. The newly created Helium again focuses itself in the center of the star and makes gravitation grow along with its mass. The hydrogen burning outer part and the core is shrinking all together which increases the suns density and also the overall temperature. Following that the rate of fusion keeps growing and throws more and more helium ashes towards the core. When a certain level of luminosity and temperature is exceeded, helium fusion in the core becomes possible. But the internal shrinkage also makes the overall radius extend.
It is generally expected, that all stars with lower masses (like our solar systems sun) will eventually become red giants.

The Process of Helium Burning

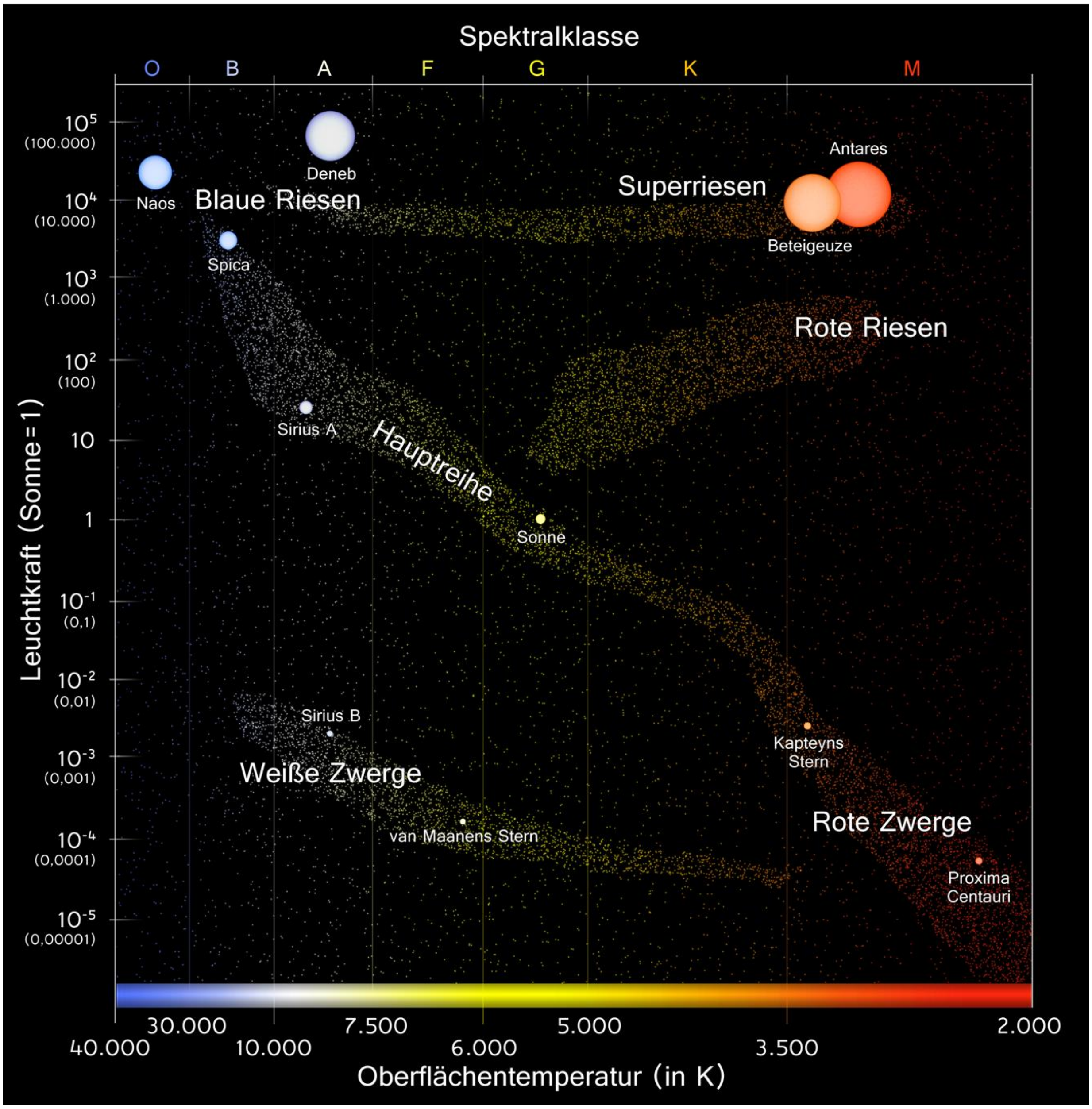
For a successful helium fusion, their cores are required to collide at an extensive velocity within a very high surrounding temperature. The process is called triple-alpha process. It transforms three helium cores to one carbon core.
The thermal pressure within the core at the start of the Helium burning process of low-mass stars is low to counteract with the gravitational force. Instead the degeneracy pressure is working against it. This pressure is not raising along with the temperature, so the beginning of fusion is raising the core temperature rapidly instead. The star is however not expending in that process. The suddenly raising temperature makes the rate of fusion raise as well, this is also called heliumflash. The heliumflash releases a gigantic amount of thermal energy from the core, which becomes big enough to make the degeneracy pressure irrelevant again. The thermal pressure is now high enough to

overcome gravity and to make the stars core expand again. That expansion makes the hydrogen burning shell move to the outer layer. This results in the rate of fusion and the temperature to decrease again. Although the fusion of helium and the hydrogen burning are taking place at the same time, the overall production of energy is decreasing compared to the overall maximum. This effect causes the luminous power to contract slightly and the surface temperature to rise.
After that, the red giant is transforming into a helium burning star. That means that its luminosity and size is decreasing. When the process of fusion is completed, the star ends up in the same kind of balance as it was before when it was still part of the main sequence. The only difference is that the fusion of helium in the core now keeps the temperature at a constant level.
That again causes the star to move downwards and left in the H.-R.-Diagram. After a matter of time all the cores helium has been fused into carbon. When that process breaks down, the stars balance is lost again. The force of gravity causes the core to shrink again. Similar to the previous development into a red giant the sun starts to expand again, the only difference now is that shells helium is being burned around the core which now consists of dead carbon. The sun is developing into a giant star. After all fusion has stopped with the creation of carbon, there is no longer a power source. The sun has reached the end of it development/life circle.
That end of life can either turn into a spectacular, colorful nebular which then ends up as a white dwarf star or it is developing into a supergiant which then again ends up as a supernova explosion or a neutron star / black hole.

Hertzsprung-Russell-Diagram

Between 1911 and 1913 Ejnar Hertzsprung and Henry N. Russell independently developed a diagram that shows the dependence of luminous power and the photosphere temperature of a star. These two have to be determined for a number of stars and then after sketched into the diagram. It results in the display of characteristic bursts. In different locations of the diagram there hardly are any stars shown. For historic reasons the diagrams temperature is shown increasing from right to left. It also represents the different spectral colors. The luminosity is axis is displayed logarithmically. The concentration of a certain combination of the two represents evidence for their physical properties.

Das Hertzsprung-Russel-Diagramm

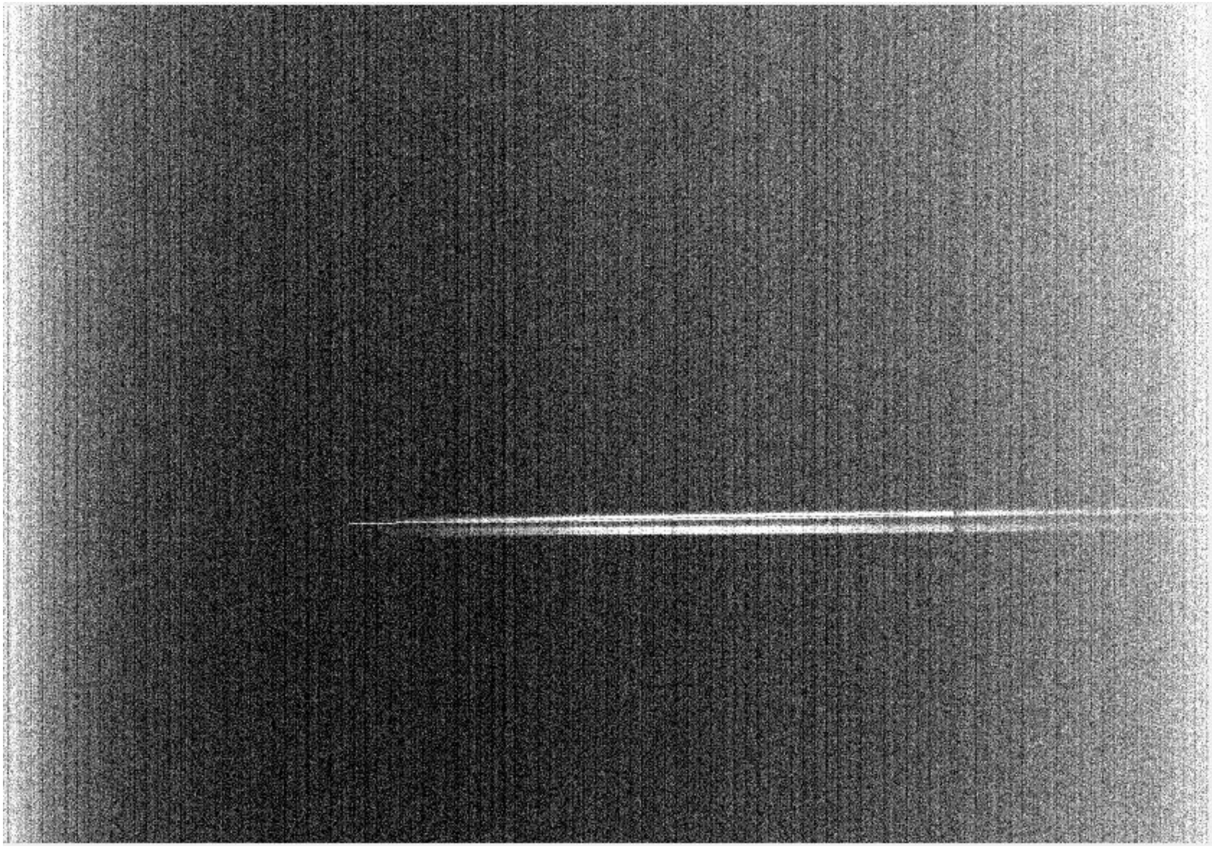


3 MOTIVATION

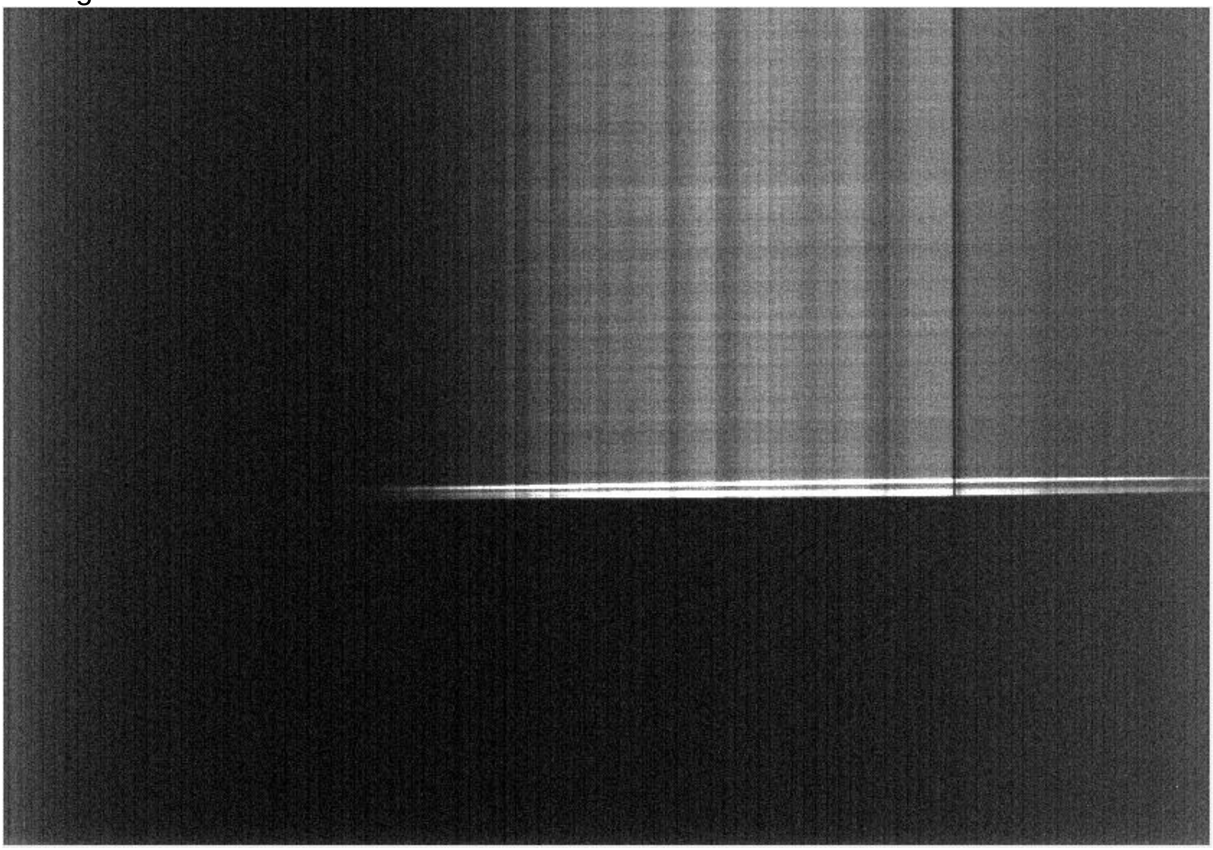
After a long wait to finally get good weather we started ,,our project. We meat to observe the nights sky of western Germany. Our special look out was for Red Giant stars, which we later wanted to spectroscope. Before we could get started on this, our teacher gave us an impressive but also very informative introduction to the stars that were visible that night. We already learned a lot before even getting started on our actual topic.
In preparation of our observation night we downloaded a variety of computer programs to help us such as RSpec or AstroArt6. We got started at about eight at night with setting up all the equipment needed. One telescope was set up with the LISA Spectrograph and a matching CCD-camera. We first did a trial run with the moon, which happened to be visible very good that night.
We used a different telescope to observe many stars along with some red giants. The longer we were watching, the more fascinated we all became with the enormous view that presented itself to us. Even lower and lower temperatures and the seemingly fast continuing time could change anything about that. When we finally picked the stars we wanted to observe for our project, at was as late as midnight. We chose to spectroscope Betelgeuze (from the shoulder of Orion) and Aldebaran (from the Taurus Constellation). At close to two and freezing temperatures we were all done observing. Caused by some technical difficulties we had to use spectral pictures from our teacher. He used the same set up a few years ago.

4 OUR SPECTRUM

Aldebaran:

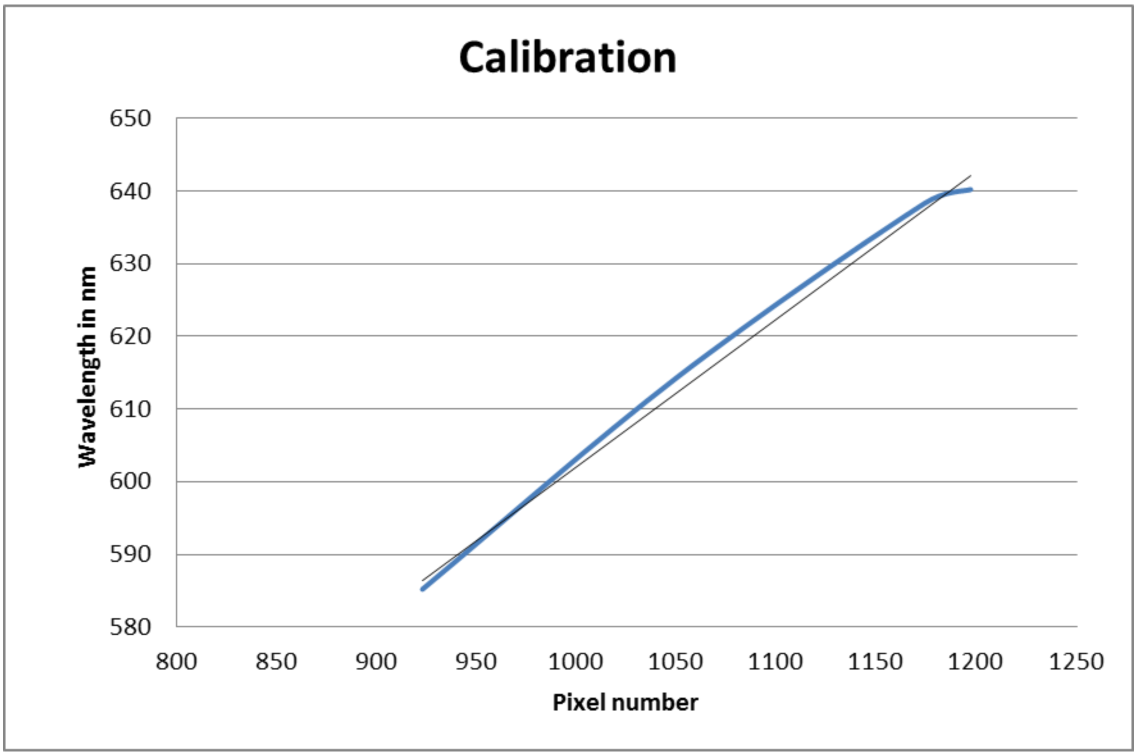


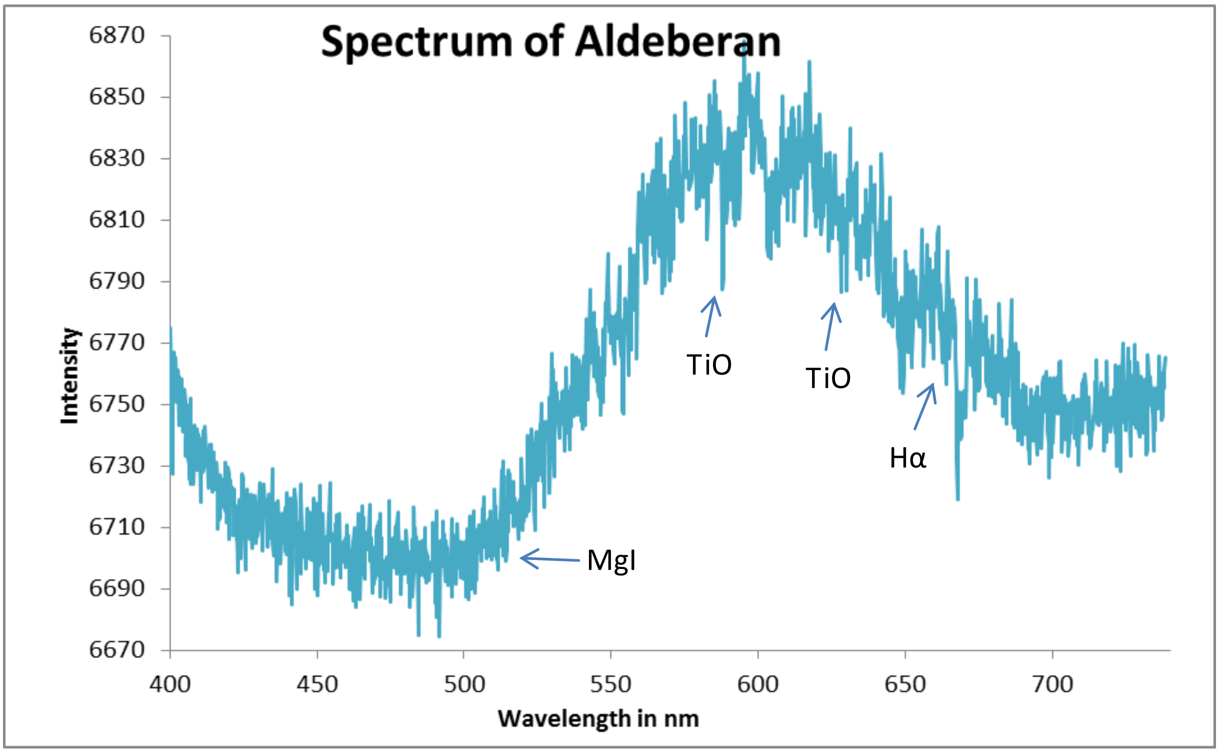
Betelgeuze:

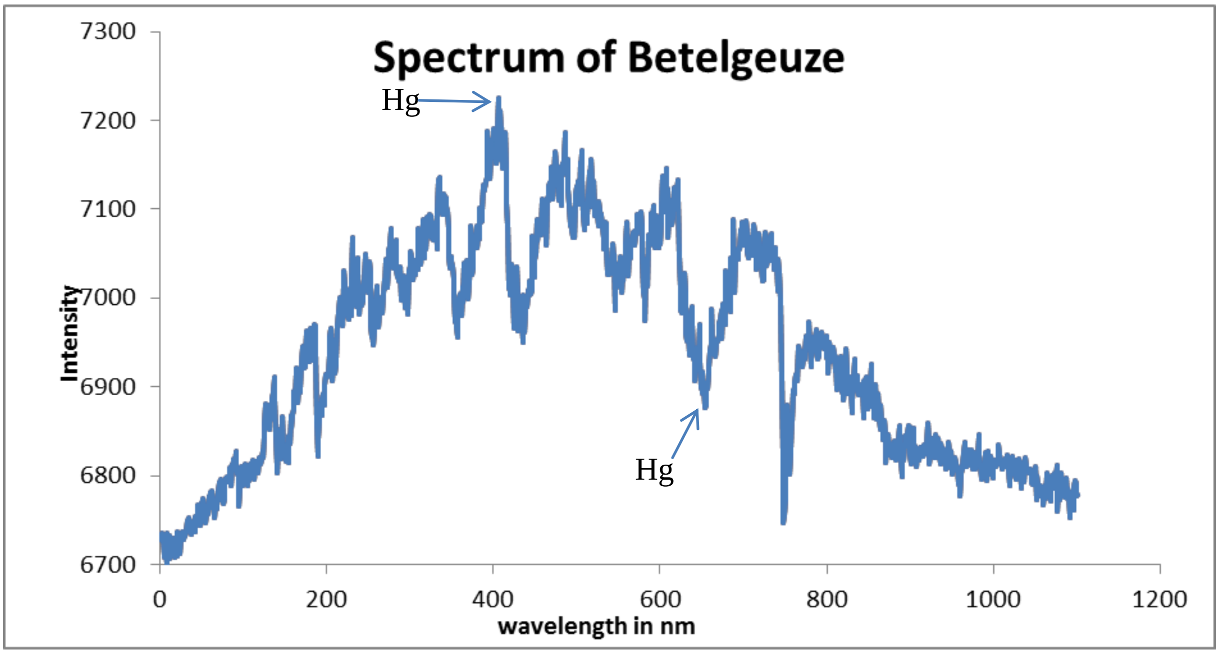


5 EVALUATION

Calibration with Neon:







Spectrum of Betelgeuze
Hg
Hg
Intensity
wavelength in nm
7300
7200
7100
7000
6900
6800
6700
0
200
400
600
800
1000
1200

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6 PROCESS OF EVALUATION

With the help of AstroArt6 creating a brightness profile we were able to determine the luminosity of the corresponding pixel. We used Neon to create the calibration function. The regression was used to make it truly linear.
We used that function to calibrate our two spectrums, so that we would be able to determine the wavelength. We then displayed our spectrums in diagram to visualize their wavelength and show the elements of our red giant. It showed that Betelgeuze has Hg and that Aldebaran has calcium, magnesium, Titanium oxide.

7 TEAM

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8 Sources

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