Group B Astrophysics in the Classroom Working Group

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Sun: The star of the day

Background information for teachers

Overview of this lesson pack:

Name of the activity	Sun: The star of the day
Topics introduced	Star features, Sun's study, technologies to understand and study the stars including our sun, light and spectra, planet transit, photometry and the transit method,dimension scale in the universe, powers of ten.
Curriculum Connection	ITALY: solar system: components, movements and features, link to gravitational waves and our understanding of the universe around us (science), spectra and light (physics and chemistry), scientific method, data collection and analysis (math), realizing a graph (technology), reflecting and discussing on possible life on others planets, selecting data and article available online, checking their validity and source (Italian and English), Margerita Hack life and discoveries (to address the gender gap in science), use the energy from the sun (science and technology) PORTUGAL: Compare absorption and emission spectra of chemical elements, concluding that they are characteristic of each element. Identify, from selected information, some applications of atomic spectroscopy (for example, identification of chemical elements in stars. GREECE: study the "birth", evolution and "death" of stars, study the physical characteristics of the Sun - our solar system's star, study spectra and light, understand how experimental and theoretical physics cooperate, work on the experimental method. FRANCE :1st year of Highschool (classe de seconde) The topic covers the three parts of the curriculum Constitution and transformation of matter : constitution of the atom, and of its nucleus nuclear reactions inside the sun mouvements and forces : Description of a movement, relativity of the movement, gravitational forces Signals and Waves : analysis of spectra, continuous spectrum of a thermal source, link with temperature line spectra , composition of a star

Overview of this lesson pack:

Reference Demonstrator	Exploring the sun does the sun rotate , Rosa Doran (NUCLIO) http://www.frontiers-project.eu/demonstrators/exploringthesun/ Discovering alien worlds, Rosa Doran (NUCLIO) http://www.frontiers-project.eu/demonstrators/discoveringalien/ Planet hunters simulation (ZOONIVERSE) https://www.zooniverse.org/projects/nora-dot-eisner/planet-hunters-tess OTHERS EXERCISES-EUHOU: http://www.euhou.net/index.php/exercises-mainmenu-13/astronomy-with-salsaj-mainmenu-185/269-discover-an-exoplanet-v15-269 http://www.euhou.net/index.php/exercises-mainmenu-13/astronomy-with-salsaj-mainmenu-185/265-how-to-determine-astronomical-distances-using-cepheids Powers of ten https://www.youtube.com/watch?v=0fKBhvDjuy0 https://www.youtube.com/watch?v=i93Z7zljQ7I
Age of students	14 years- 15 years old (France)
Duration	6 hours

Overview of this lesson pack:

Type of activity	1. discussion, questioning, brain storming 2. guided discussion, focus on the sun and how we collect data about it 3. planning the investigation 4. performing the demonstrator 5. sum up on the main features of the sun, comparing it to others stars and the dimension scale in our solar system 6. final discussion , review and evaluation
Description of activity	Teacher activities: stimulating curiosity with question or pictures guiding the discussion (how do we know the stars? how do we know the sun?) introducing stars features, spectra analysis, photometry and the transit method focus on information from the light, methods and technologies used in astronomy compare and focus on the sun and the dimension scale in our solar system final discussion, review and evaluation Student activities: planning the investigation performing the demonstrator to discover the movement of the sun and identify the transiting body compare what observed in the star with our sun visualize our solar system and the other star in a dimension scale with video or photos final discussion and review
Equipment requirements	Computer. internet, projector
Prior knowledge for students	general astrophysics, chemical elements, spectra and nature/properties of light

Background and overview :

Background: general astrophysics

Overview: In this activities we can clarify how we collect data about the sun and others stars. We explain how light brings us a lot of informations and , using SalsaJ software, students will live an engaging experience collecting scientific data, analyze them (with graphs) and develop conclusions.Photos and video will be provided to the students to a deeper understanding of the sun features and to allow them to develop a right view on our universe and solar system on the dimension scale.

Review of the learning process: What are the main concepts that you have learned?Which competencies did you improve or acquire? How do you feel about the activity? What would you do differently?What would you like to know more about the Sun?

Presentation for students

Teacher guidelines can be found in the notes attached to each slide

Our Star … The Sun!

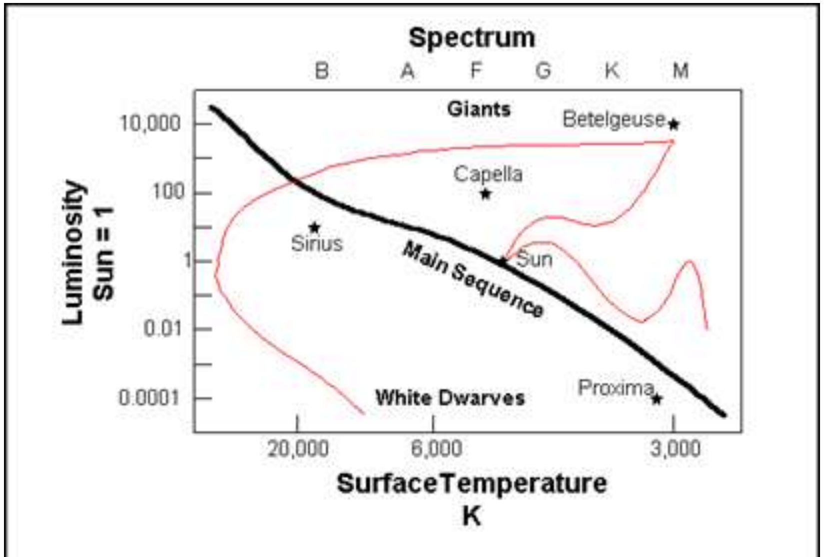
What we know about the sun?
How do we collect information about the sun?
How do we know what it is made of? What is its evolution?
Does it move?

Video: https://sdo.gsfc.nasa.gov/assets/gallery/movies/sdo-070210.mp4
Photos: https://sdo.gsfc.nasa.gov/gallery/animations/item/268

First, let’s get to know what a star is...

The stars can be considered to be hydrogen spheres which emit heat and radiation as a consequence of the nuclear fusion of hydrogen to helium. Their study is based on spectroscopy. The spectral types of the stars are symbolized with the letters W, O, B, A, F, G, K, M, R, N, S and each type of spectral type is another expression of the star’s surface temperature T.

In the beginning of the 20th century, *Ejnar Hertzprung* and *Henry Norris Russell contructed the so called* ***Hertzprung-Russel (H-R) diagrams*** shown belowQ:



Herzprung-Russell Diagram

During the period of their lives when stars burn hydrogen to helium, their lie on the ***Main Sequence*** Hertzprung-Russell diagram (bold black line).

The red line shows the sever phases that a typical star is passing through its lifetime.

The birth, evolution and death of a star differ depending on its mass.

The interstellar material usually consists of Hydrogen and Helium. When the density of interstellar mass exceeds the 1 particle per cubic centimeter then we have an interstellar

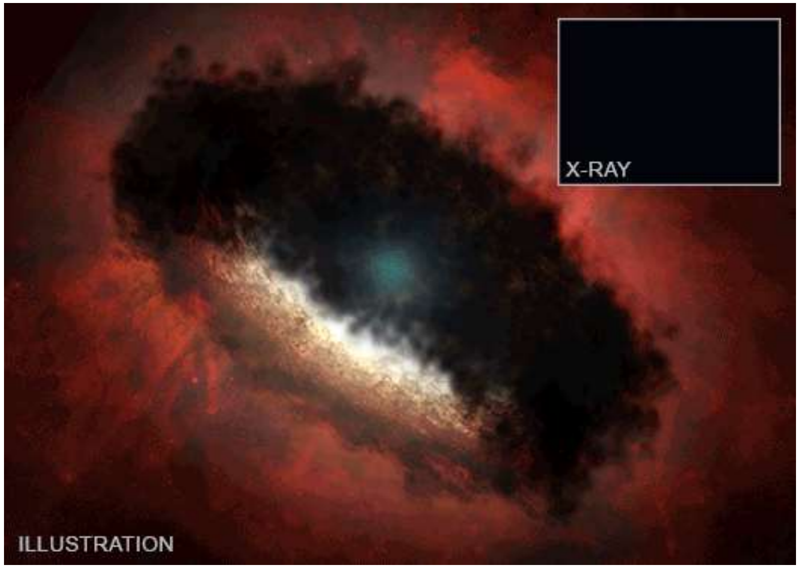
The particles of the cloud are pulled together due to gravitational interactions and its mass is compared or bigger than the Sun's mass, the acceleration of its particles causes the increase of its temperature (this could last from million to billion of years). The mass of the star has then turned into the so called plasma (hydrogen nucleus and a gas of electrons).

The phases of the star’s life:

Protostar (high temperature and radiation but nuclear fusion has not yet started)

New star when nuclear reactions begins

(Temperature ~15000000 K)



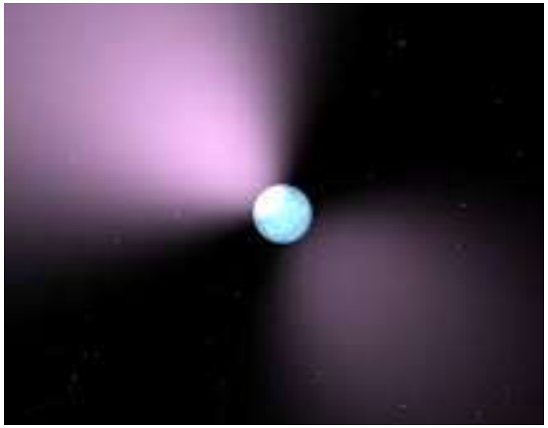
“Adult” star when Hydrogen converted to He due to nuclear reactions. Thermal and hydrostatic equilibrium state. Star in the main sequence of the HR diagram.

Red giant when the star star burns ~10% of its Hydrogen and increases its luminosity almost 50%. It is expanding whereas its outer layers are cooling and its light is red (due the cooling of the temperature)

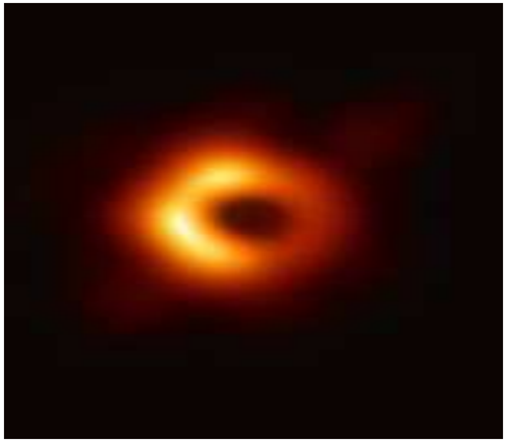
Finally, according to its original size, when nuclear reactions stops, the star collapses due to gravity and ends in a:

White Dwarf (original mass smaller than 4 Solar masses):

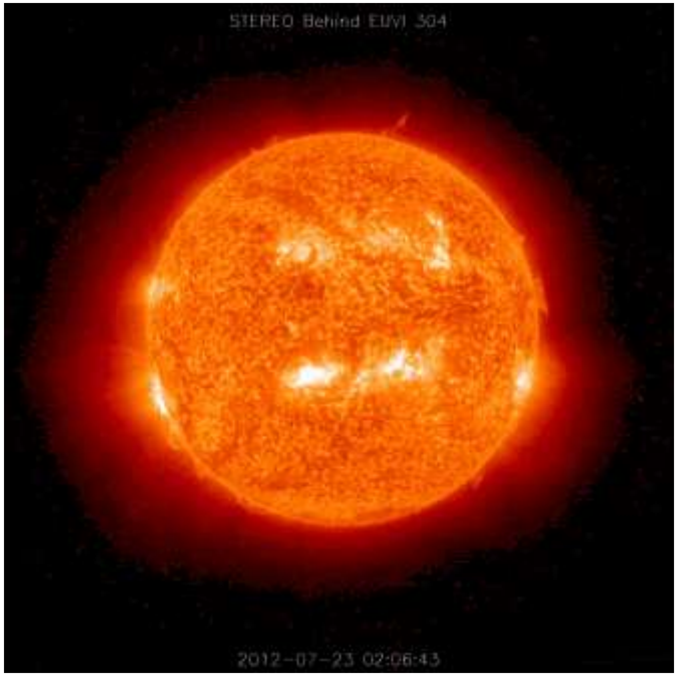
Neutron Star (original mass between 4 and 8 Solar masses):



Black Hole (original mass bigger than 8 solar masses):



Our Sun (the star of the day) is the most luminous object in the sky.



It is almost a perfect sphere with a diameter of 1.4 million km (109 times bigger than the Earth’s).

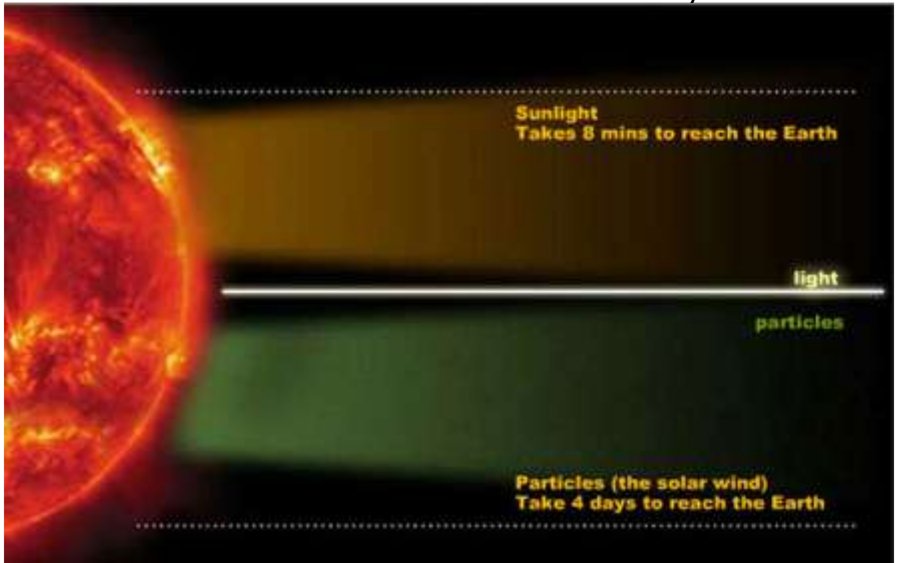
Its mass (2×10^{30} kg) consists the 99,86% of the mass of our solar system.

Sun is a typical small star in the Universe which now burns Hydrogen and belongs in the main sequence of the HR diagram.

When it “dies” it is going to become a white dwarf!!

We study the Sun analysing the light coming to us via spectroscopy.

Interesting information: a photon takes 8 min to come from Sun to the Earth which means that when we look at the Sun, we see its image 8 min ago!!



Lets now answer the question: How do we know what the Sun is made of?

How Do We KNOW What Stars Are Made Of? - YouTube

https://ed.ted.com/lessons/what-light-can-teach-us-about-the-universe-pete-edwards

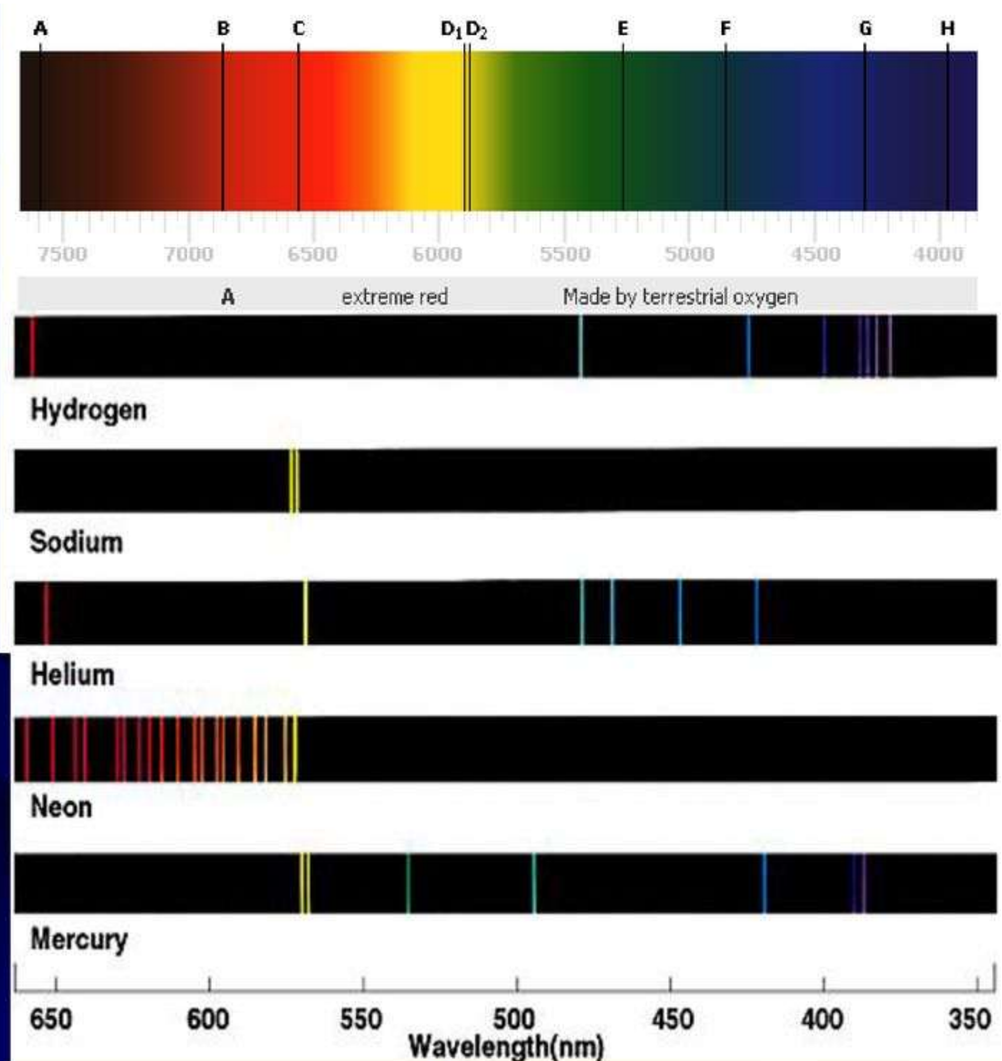
Here are some activities:

Test of flame https://youtu.be/kkBFG1mTSBk

Planification of a spectroscope:

http://www.euhou.net/index.php/exercises-mainmenu-13/classroom-experiments-and-activities-mainmenu-186/178-a-home-made-spectroscope

Sun →

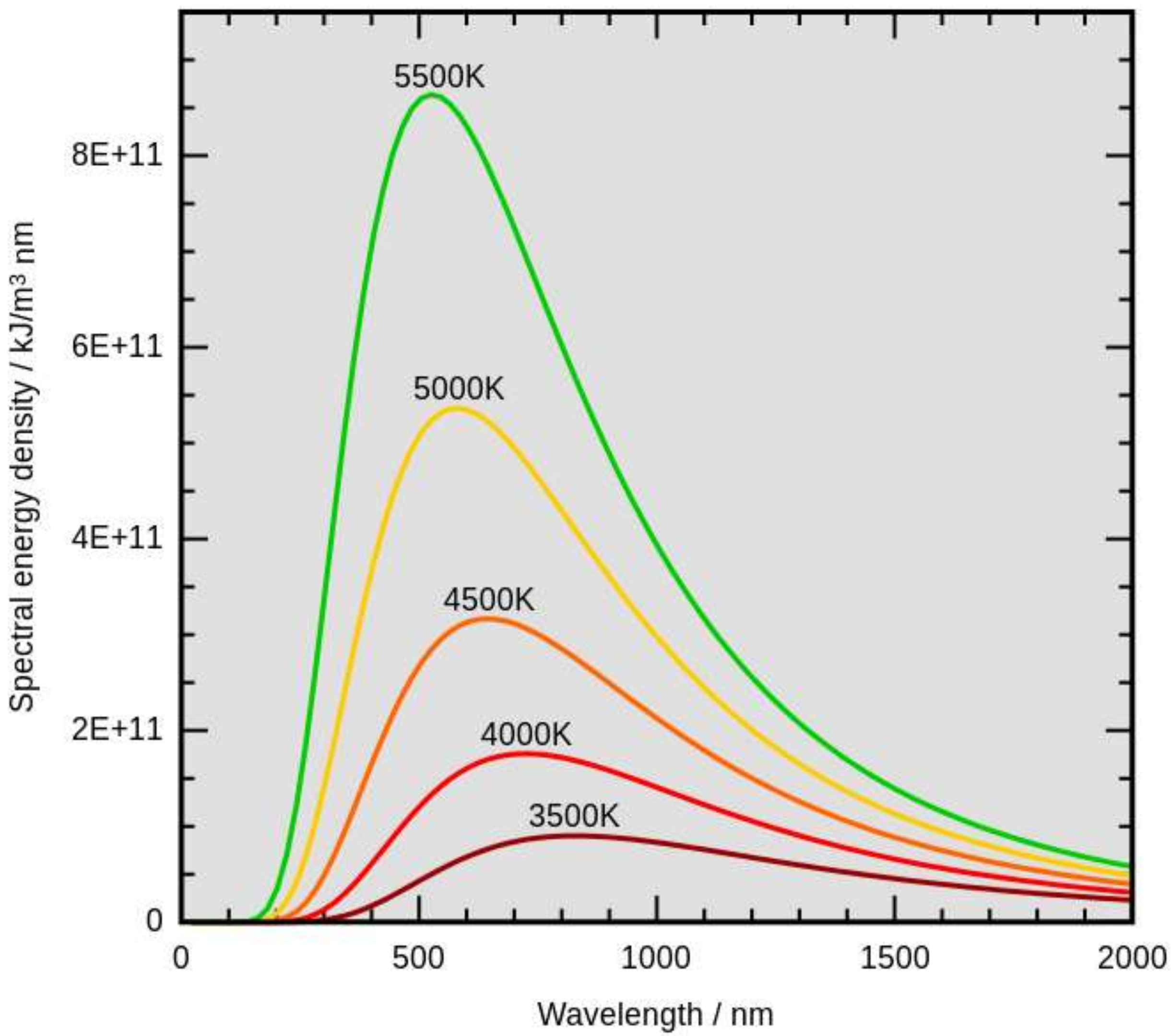


Compare Sun's spectrum (above) to the fingerprints of the "usual suspects" (right)

Hydrogen: B,F
Helium: C
Sodium: D

What do you see?
What can we conclude?

Temperature



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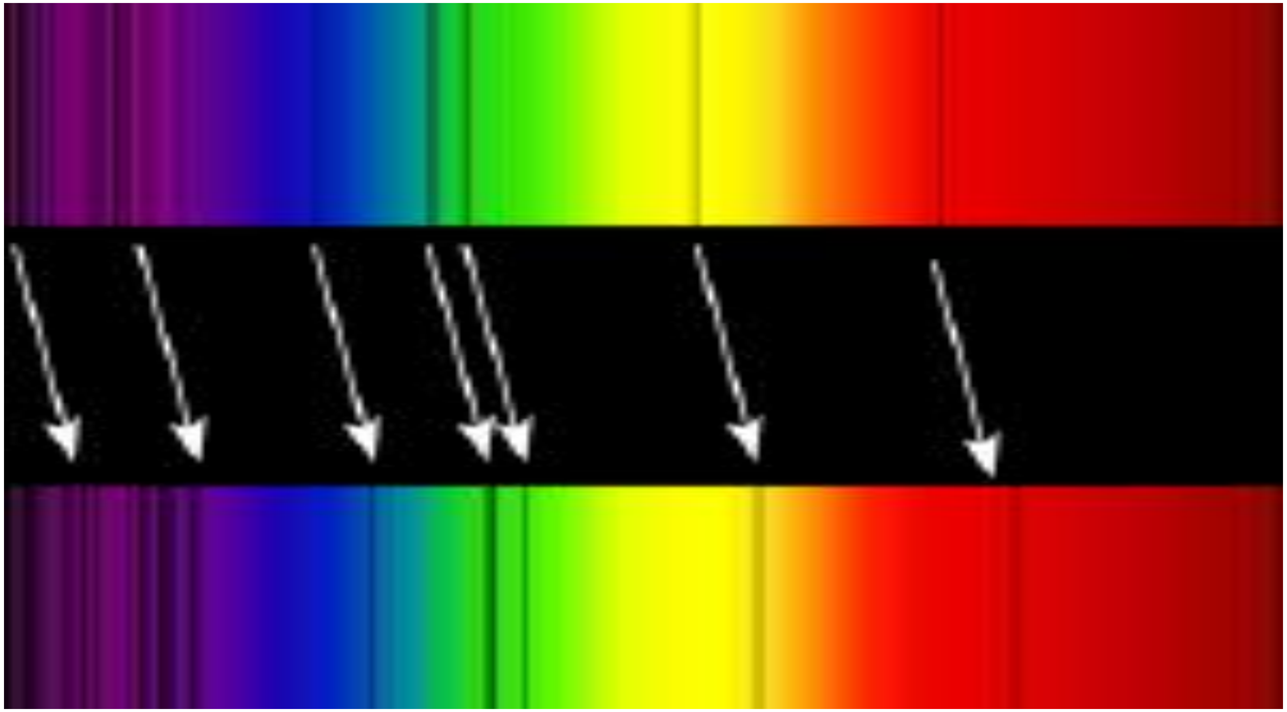


What do you see?

What is happening?

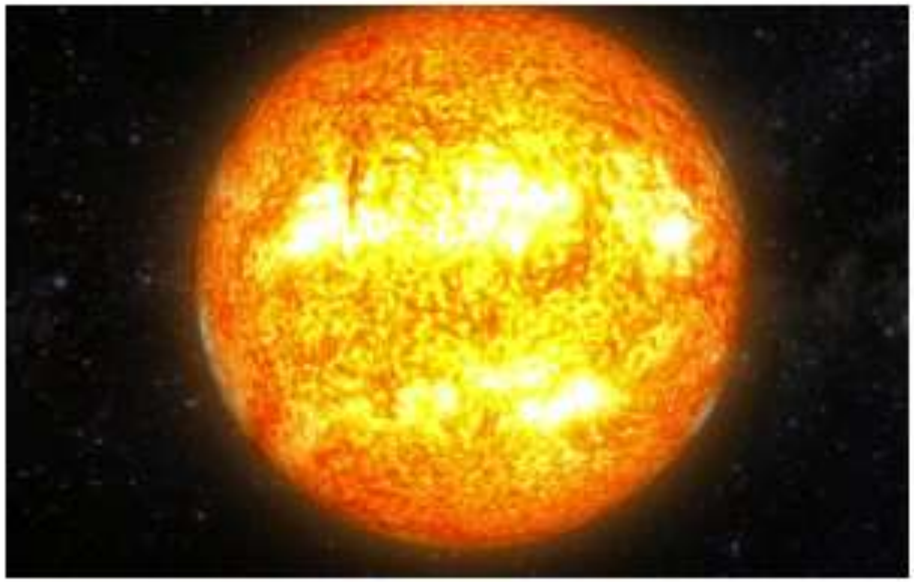
Light – Cosmic Messenger

Information Encoded in Light

- ★ type of object → spectrum type (absorption/emission) and images at multiple wavelengths
- ★ temperature → spectrum or dominant colour
- ★ composition → spectral lines
- ★ speed → Doppler effect on spectral lines
- ★ and more (rotation, presence of exoplanets around a star…)

How do you will work on this?

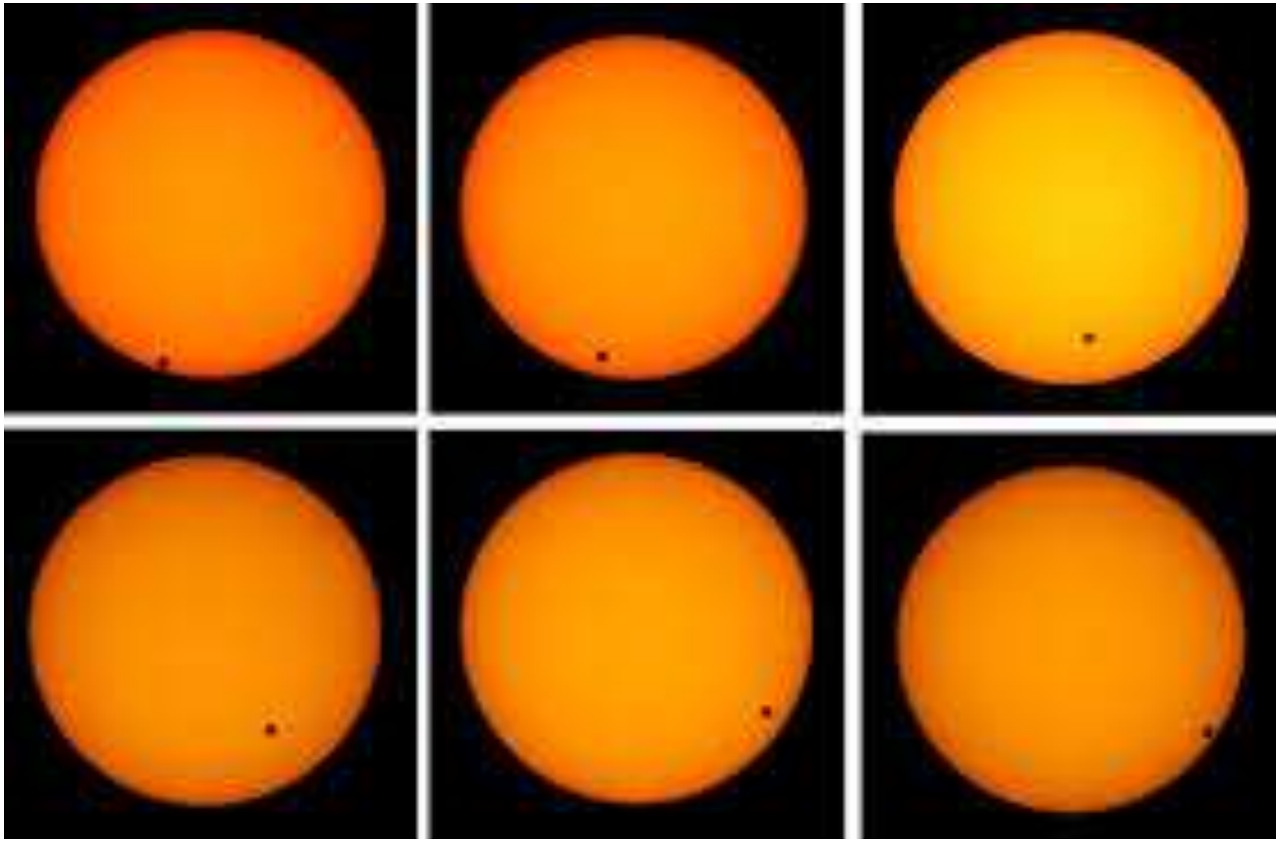
Does it move? How can you evaluate its movement?



Exploring the Sun Does the Sun Rotate?

PHOTOS COLLECTION ON THE DEMONSTRATOR: http://www.frontiers-project.eu/demonstrators/exploringthesun/

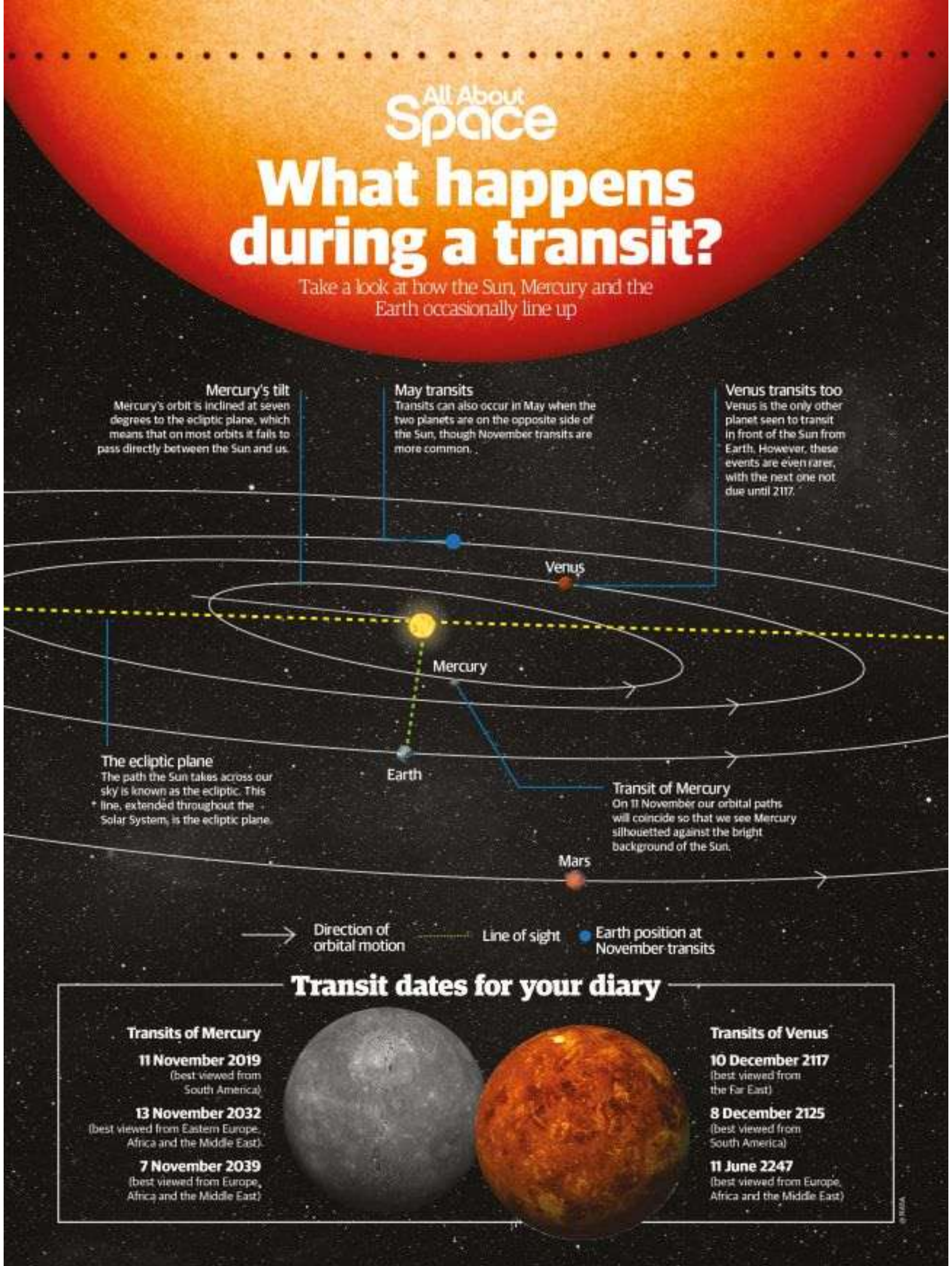
Does it have planets around? How can we prove it?



PHOTOS COLLECTIONS ON THE DEMONSTRATOR
http://www.frontiers-project.eu/demonstrators/exploringthesun/

Planet Hunters TESS Tutorial

https://www.zooniverse.org/projects/nora-dot-eisner/planet-hunters-tess

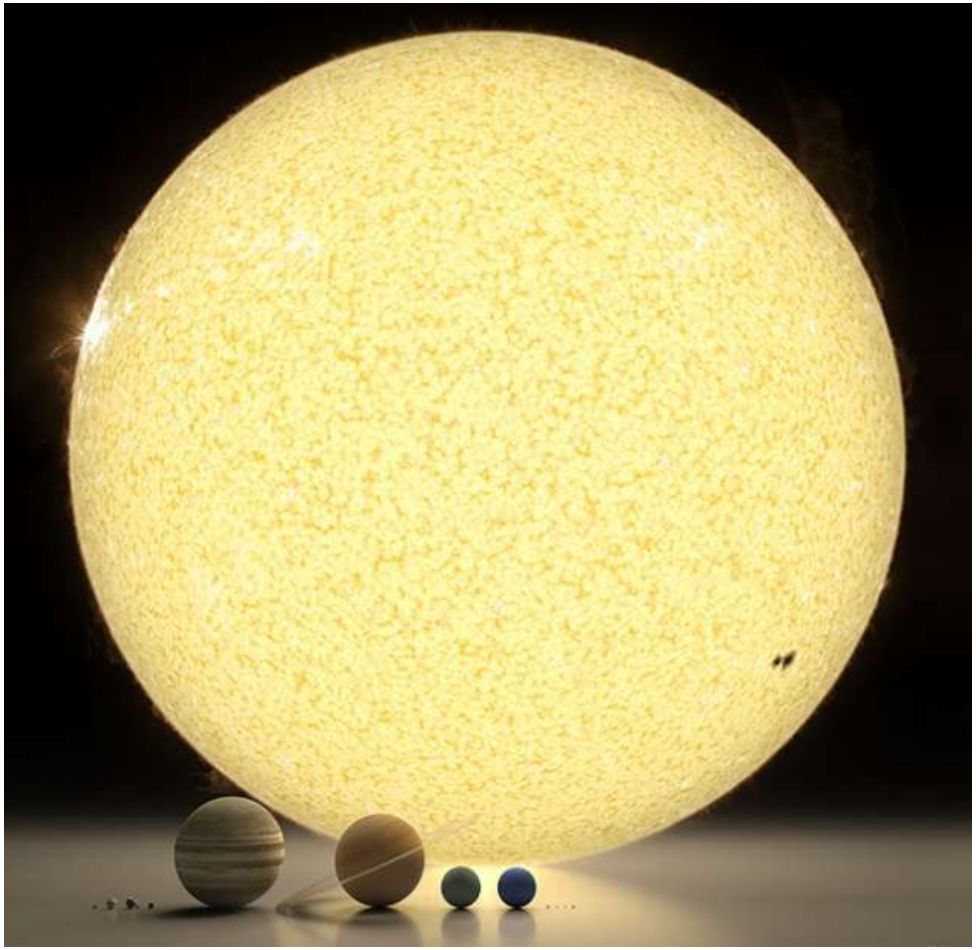


2019: transit of Mercury

https://www.youtube.com/watch?v=0yNzSwlnQ2Q

https://www.youtube.com/watch?v=dDd_cS6SHqA

Sum up and reflect about what you learned until now!



- ★ What are the main concepts that you have learned?
- ★ Which competencies did you improve or acquire?
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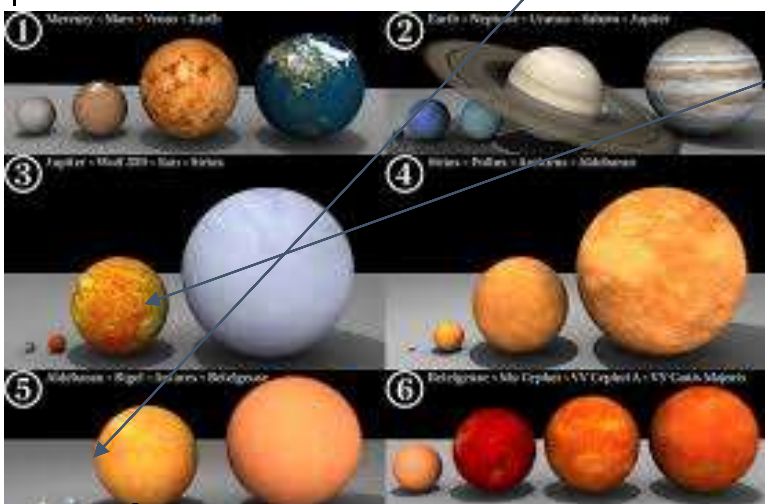
- ★ What would you do differently?
- ★ What would you like to know more about the Sun?

Comparison of stars

picture from stellarium



picture from
https://commons.wikimedia.org/wiki/File:Star-sizes.jpg

Rigel is the brightest star in the constellation of Orion.

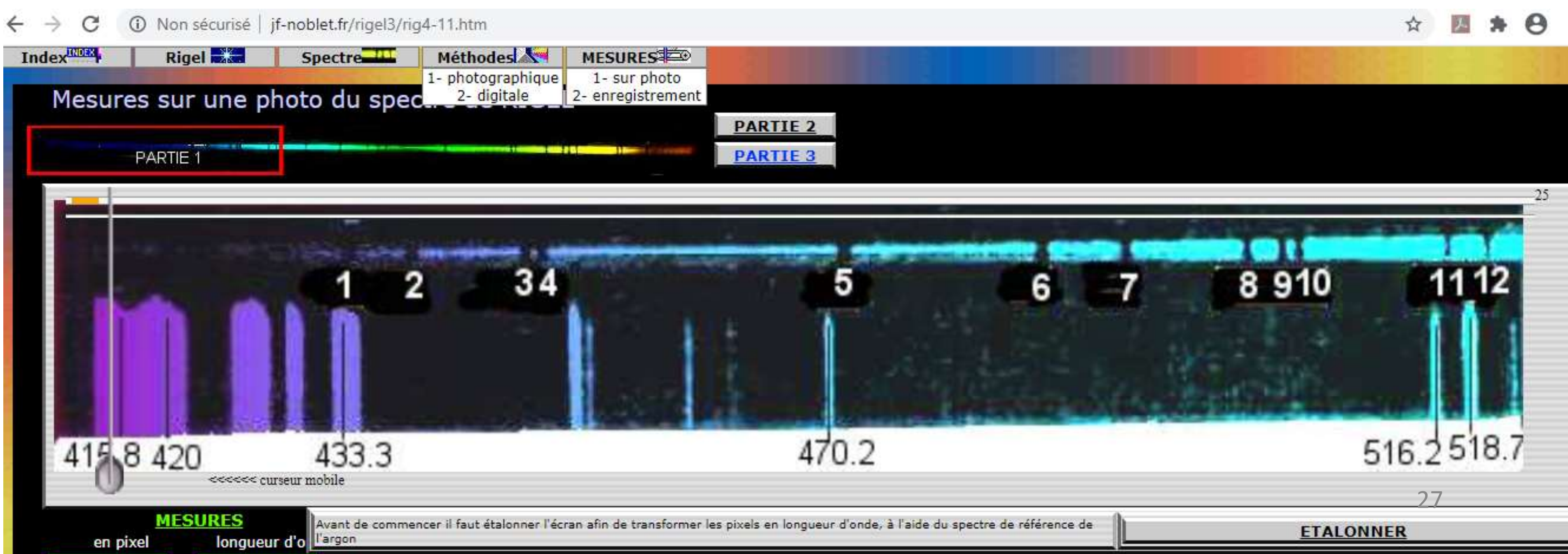
You can observe it easily in a winter night. It is 863 light years away from us, and appears as a blue star , it is much bigger than the sun.

The links below will enable you to measure the wavelength of lines in Orion spectrum and to find out which chemical elements are presents in its chromosphere (the part of the star responsible for its color)

http://www.jf-noblet.fr/rigel3/rig1.htm

How to use Rigel: le spectre d’absorption

To make measurements, in the menu choose mesure- 1 sur photo. Two spectra appear, the top line is the spectrum of the star, it is an absorption spectrum, the bottom line is the Argon emission spectrum, it will be used to calibrate the picture.



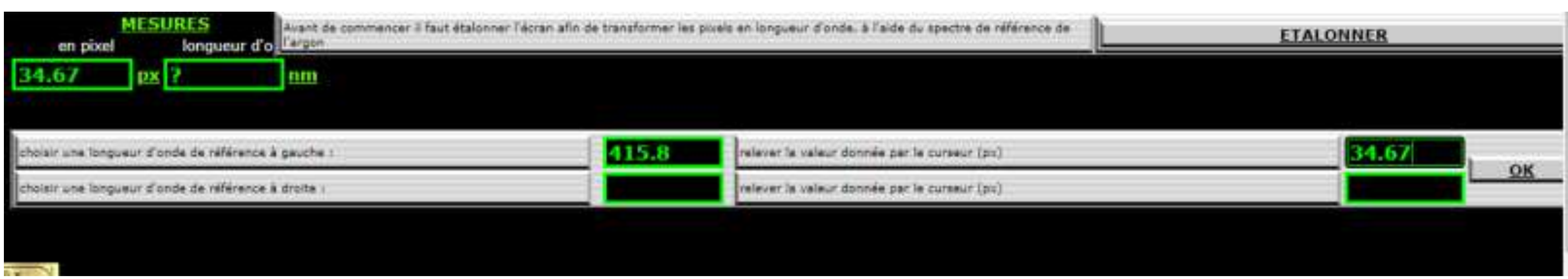
How to calibrate the picture

You select étalonner under the spectra, a new frame appears, you enter the values of the argon spectrum wavelength and of the pixels given by the cursor.

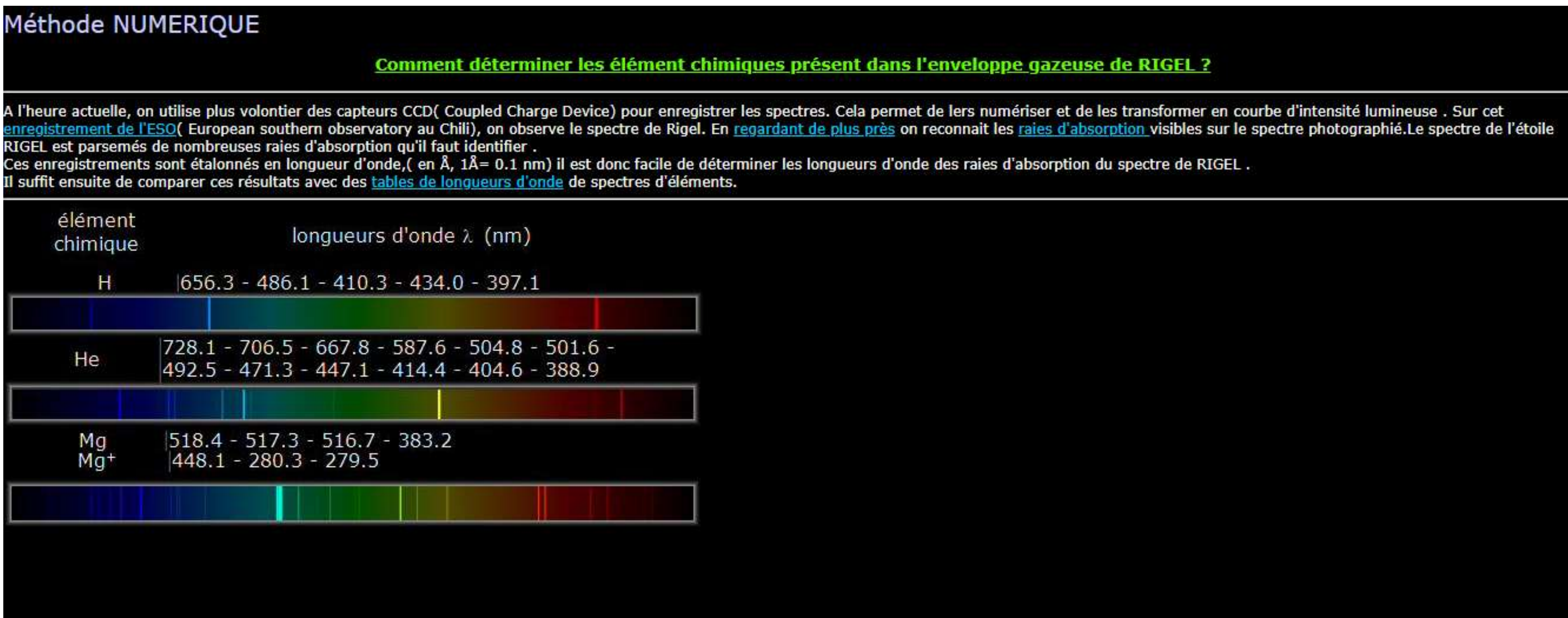
You need 2 lines, away from each other in order to calibrate the picture.

You then click on ok, and you collect all the wavelength of Rigel's spectrum, putting the cursor in the center of each dark line. The spectrum has been divided in 3 parts (parties 1, partie 2, partie 3) .

You will have to calibrate for each part



To find the elements in Rigel, you open the methode digitale in the menu and you select **table de longueur d'onde.** it gives you the wavelength values of known elements, and you can compare them with your values to check which chemical element is inside Rigel.


Méthode NUMERIQUE

Comment déterminer les élément chimiques présent dans l'enveloppe gazeuse de RIGEL ?

A l'heure actuelle, on utilise plus volontier des capteurs CCD(Coupled Charge Device) pour enregistrer les spectres. Cela permet de lers numériser et de les transformer en courbe d'intensité lumineuse . Sur cet enregistrement de l'ESO(European southern observatory au Chili), on observe le spectre de Rigel. En regardant de plus près on reconnait les raies d'absorption visibles sur le spectre photographié.Le spectre de l'étoile RIGEL est parsemés de nombreuses raies d'absorption qu'il faut identifier .
Ces enregistrements sont étalonnés en longueur d'onde,(en Å, 1Å= 0.1 nm) il est donc facile de déterminer les longueurs d'onde des raies d'absorption du spectre de RIGEL .
Il suffit ensuite de comparer ces résultats avec des tables de longueurs d'onde de spectres d'éléments.

élément chimique	longueurs d'onde λ (nm)
H	656.3 - 486.1 - 410.3 - 434.0 - 397.1
He	728.1 - 706.5 - 667.8 - 587.6 - 504.8 - 501.6 - 492.5 - 471.3 - 447.1 - 414.4 - 404.6 - 388.9
Mg	518.4 - 517.3 - 516.7 - 383.2
Mg^+	448.1 - 280.3 - 279.5