

SCIENTIFIC CASE: What are the stars made of?¹

Team members

Writer:	_____
Computer technician:	_____
Reader:	_____
Spokesperson:	_____
Ambassador:	_____

Context

In 1671, Isaac Newton (1643-1727) described how, when a ray of sunlight goes through a crystal prism with a particular angle, it splits showing different colours..



Fig.1: Newton's *Experimentum Crucis* (Grusche 2015) -fragment | Fig.2: Prism splitting white light into spectral colours.

¹ Educational material manufactured by "[Asociación Planeta Ciencias](#)" under the initiative and coordination of the [European Space Agency](#) inside the [CESAR](#) program framework.

Source: Wikimedia.org .

Newton also explained that light coming from stars other than the Sun would also be separated by a prism in a similar fashion.

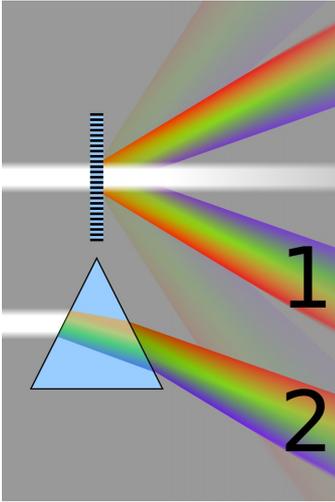


Fig 3. Comparison between a prism and a diffraction grating.

Source: Wikimedia.org

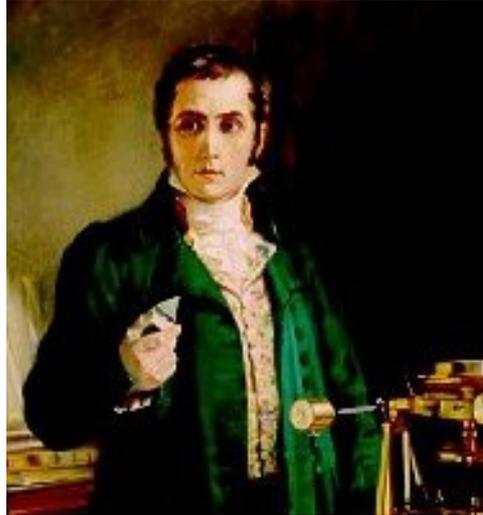


Fig 4. Joseph von Fraunhofer (1787 - 1826)

Source: Museo Alemán de Munich

More than a century later, in the first years of the 19th Century, Joseph von Fraunhofer (1787-1826) took a big step – he replaced the prism by a more effective optical component: **a diffraction grating**. This grating had the ability to separate or diffract light into several, more distinguishable rays.

That way, Fraunhofer could split sunlight with a better resolution and, when he did, he found out something extraordinary: **light wasn't continuous, but had black lines** along the spectrum.

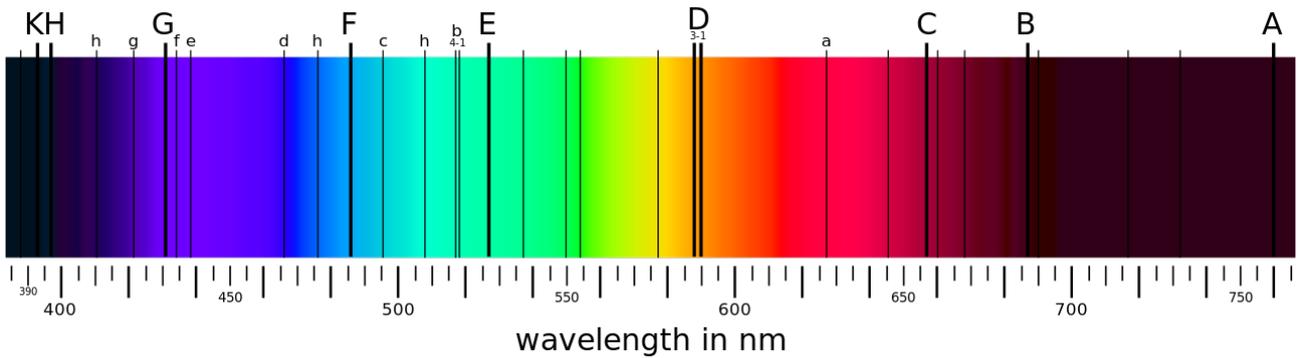


Fig 5. Fraunhofer's lines. Source: Wikimedia.org

So, what do these black lines mean?

The Sun emits light due to its high temperature but, on its way from the inside to space, elements in the star absorb part of that light. That is, each one of the Sun's chemical elements always absorbs the same colours. In other words: if we could know which lines are absorbed by which chemical elements, we could know what our star is made of!

Now imagine we could introduce a specific gas in a glass tube (for instance, hydrogen). If we apply an electrical current to it, its electrons will be excited and they will emit light.



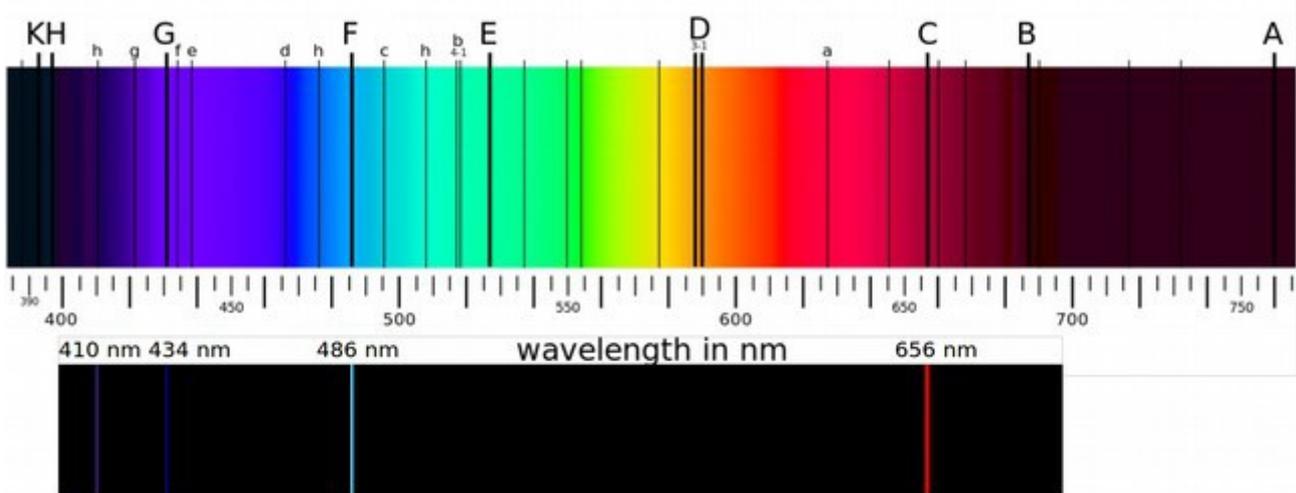
Fig 6. Hydrogen lamp. Source: Wikimedia.org

If, as Newton and Fraunhofer did, we then split up hydrogen light with a prism or a diffraction grating, this would be what we'd see:



Fig 7. Emission lines from Hydrogen's Balmer series. Source: Wikimedia.org

Now let's compare the Sun's spectrum with the lines emitted by hydrogen:



Figs 8. Comparison between absorption lines in the Sun and emission lines from hydrogen.

With this observation, Cecilia Payne (1900-1979) discovered that the lines that the hydrogen emits are a match for some of the Sun's absorption lines. Thus, **there is hydrogen in the Sun!** So, hydrogen in the Sun absorbs light in the same way hydrogen emits light when we excite its electrons.



Fig 9. Cecilia Payne (1900-1979)



With this finding, we just have to know the emission lines for other elements in order to know what the Sun is made of.

In the same way, we can also find other stars' composition by studying their spectrum, just as we did with the Sun².

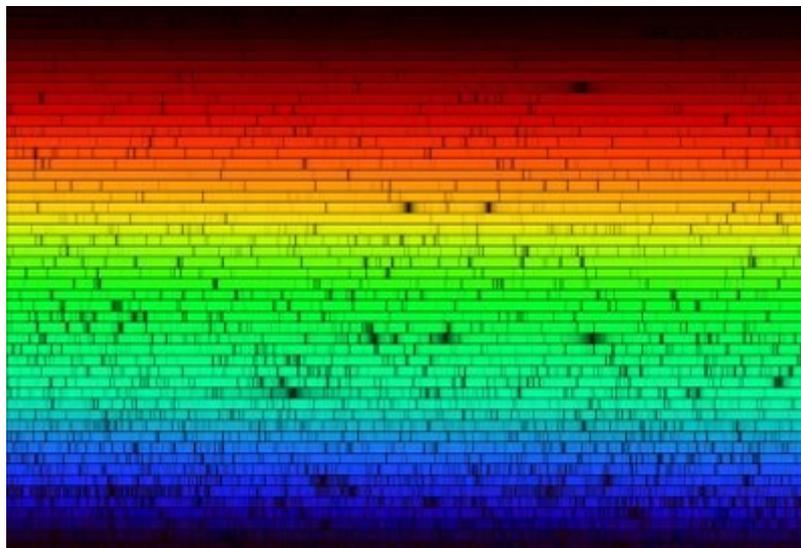


Fig 10. Complete visible range solar spectrum (N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF). Source: esa.int

More educational resources:

CESAR: <http://cesar.esa.int/index.php?ChangeLang=en>

ESA education: <http://www.esa.int/Education>

Stellar distances: <http://sci.esa.int/education/35616-stellar-distances/?fbodylongid=1667>

CESAR booklets: <http://cesar.esa.int/index.php?Section=Booklets&ChangeLang=en>

2 You can delve into these contents via these links: https://es.wikipedia.org/wiki/L%C3%ADnea_espectral ; https://es.wikipedia.org/wiki/Espectro_electromagn%C3%A9tico



Science case 1: Which elements make up the Sun and other stars?

The aim of this experience is **getting to know the main elements that make up the Sun and other stars.**

Research equipment

You have access to the following:

- Pencils, paper, rubber, ruler
- Diffraction glasses
- (Cell)phone
- Computer
- Spectra from several stars
- Emission lines from different gases

Procedure

PART 1 – Separating the components of light

Let's observe how to separate the light from different sources.

1. Put the diffraction glasses in front of the camera of your phone and take a picture of each source of light, as head-on and focused as possible.
2. Describe briefly what you see (use the photos to look more closely).
 - a. Sun light (look at the sky with the glasses on and take a picture).

WARNING: Never look directly at the Sun.



b. Artificial light in the classroom

c. Spectral lamp (next to to the educator): hydrogen tube

d. Spectral lamp (next to to the educator): helium tube

e. Spectral lamp (next to to the educator): mercury tube

PART 2 – Analysis of the spectrum

Stellar composition is related to its temperature, and we can classify them according to this criteria. We can differentiate 7 stellar classes (M, K, G, F, A, B y O). Specifically, Sun is a “type G” star. Your group will study one of these spectral types. If you want to study more about this concept, you can work on [this scientific case](#)³.

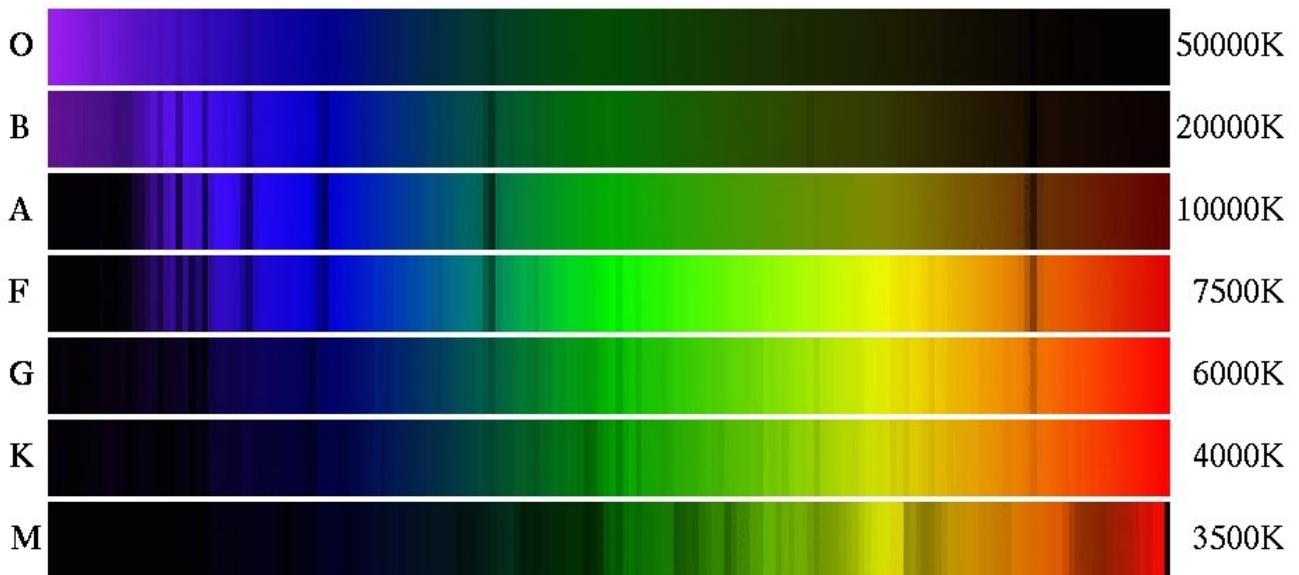


Fig 11. Spectral types. Source: Armagh Observatory

Write down what type of star you are going to analyze:

How to compare these spectra:

You can use two methods (A y B) to compare spectra.

³ More info in <http://cienciamasticada.blogspot.com/2017/12/clasificacion-espectral-clasica.html> and in <https://www.astromia.com/universo/clasestrellas.htm>



Method A:

Compare the absorption lines of your star with the emission lines from the gasses of different chemical elements that you can find as an attachment to this document (or opening the document⁴ [material_para_la_investigación.pdf](#)). Make the corresponding notes on the result sheets (see later).

In the *figure 8* you can see an example of how to compare and identify possible chemical elements.

Method B:

1. Open the explorer (Firefox or Chrome) and *login* at publiclab.org

User: esacsse

Pass: CursoEspectro (*including capital letters*)

2. Go to spectralworkbench.org and login again:

Log in

Use your PublicLab.org username to log in.
If you do not yet have one, [sign up there](#) first!

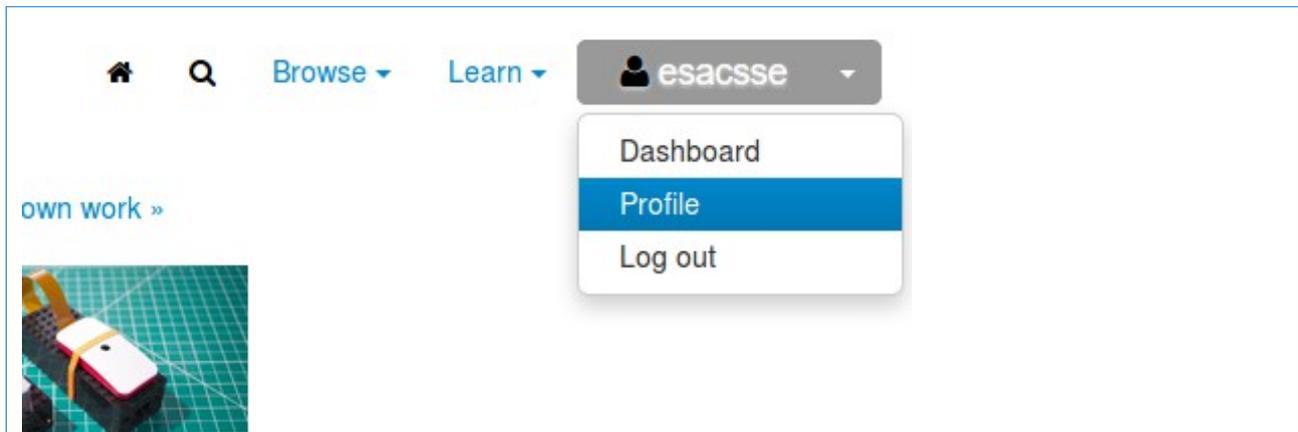
 Remember me

Site requesting	https://spectralworkbench.org
Account username	esacsse

 Yes No

3. At spectralworkbench.org , click on your profile:

4 You can do it by comparing just the clearest lines.



4. Choose the type of star you are going to analyze (for instance, “Star type G”). You will see the stellar spectrum and a graphic with peaks that correspond to the absorption ranges of that star.

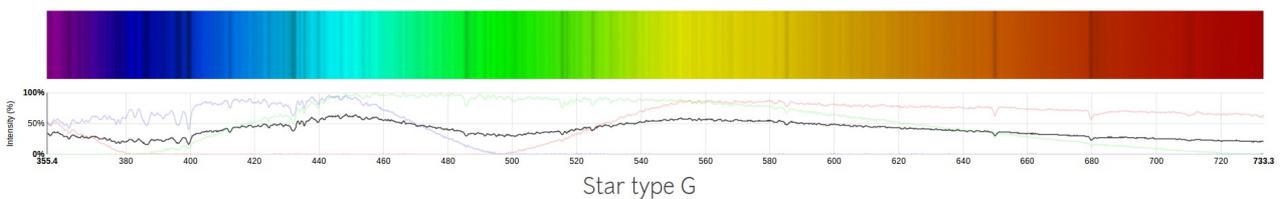


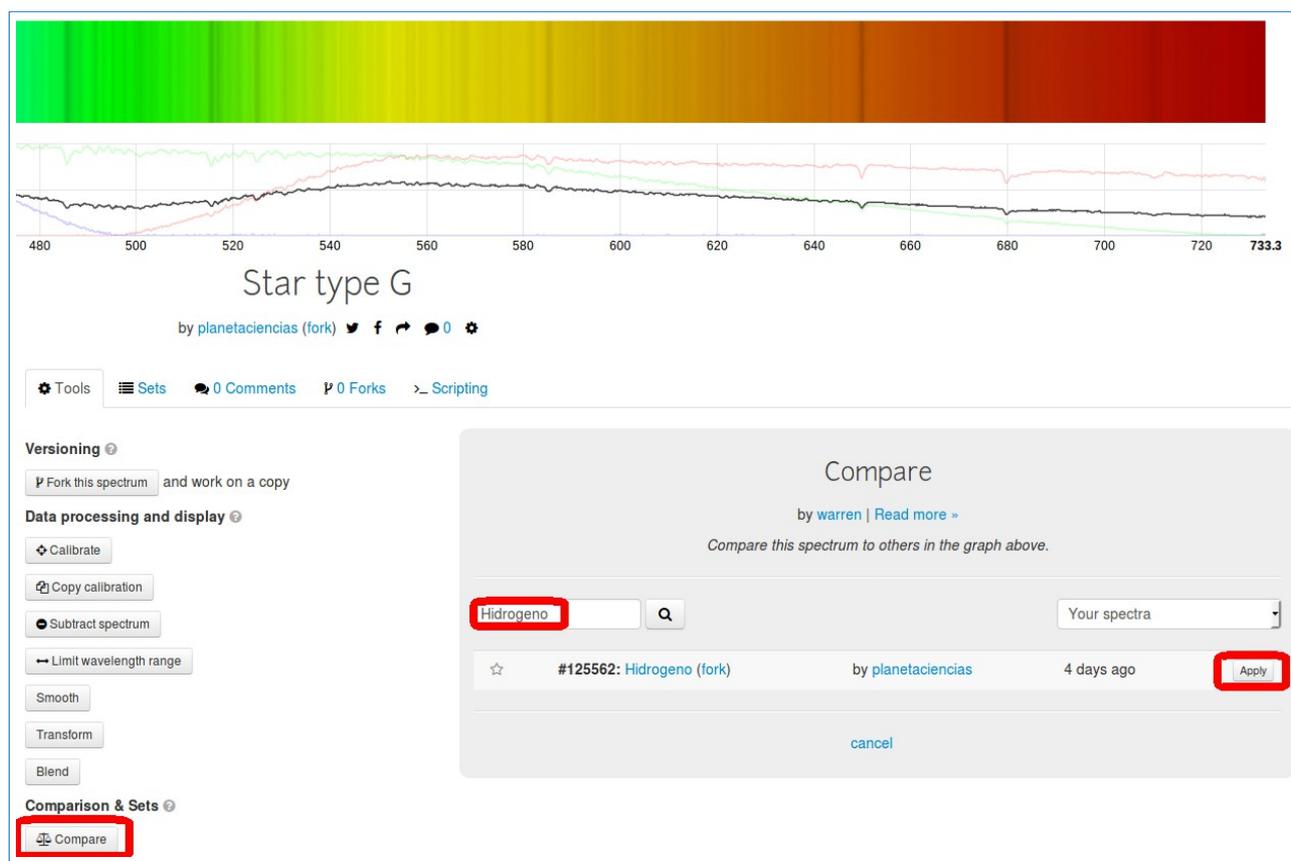
Fig 12. X axis corresponds to the wavelength of each color, expressed in nanometers (nm). Y axis refers to the intensity of light, as a percentage, between the points more and less luminous.

5. You have to compare the absorption lines of your star with the known emission lines of the gasses of the different chemical elements to know the stellar composition. Compare the graphics of your star with the different chemical elements using *Spectral Workbench*, by selecting the element you want to check.

Press on “compare” → write “name of the element (no accents)” → “apply” (see image below)⁵.

You can choose between: Carbon, Calcium, Helium, Hydrogen, Iron, Mercury, Neon, and Sodium.

⁵ Be patient, sometimes the graphic takes a few minutes to calibrate.



Finally, you can also use the spectral lamps in the classroom to check how the spectra correspond to those you are studying. If you want to see more spectra, you can go to <http://chemistry.bd.psu.edu/jircitano/periodic4.html> (clicking on each element of the periodic table).



Results

Type of star
Composition
Point out which elements are in the star, and which elements you think could be there, even if you are not certain. Reason your answers.

6. Lastly, share with the rest of the teams what you have found out and compare the compositions.



PART 3 – Questions and conclusions

What difficulties have you found? How could you improve this research?

Look closely at the periodic table of elements in the attachment

[material_para_la_investigación.pdf](#) (or in

<http://chemistry.bd.psu.edu/jircitano/periodic4.html>). Not every element appear in all the

stars. Why do you think that is?

It has been observed that stars' composition is similar to other stars with the same temperature. Why could that be?



Do you find any similarities between stars with close spectral types? Reason your answer.

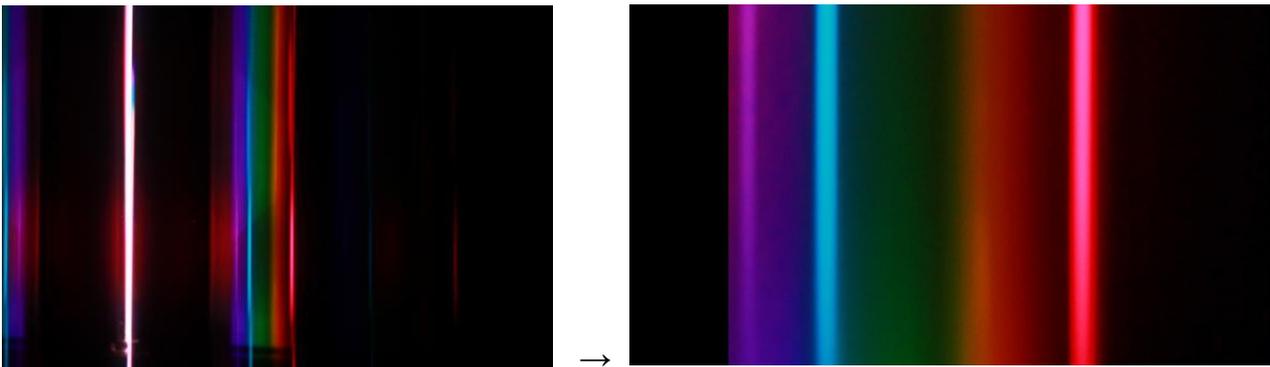


Science case 2: Perform your own calibration⁶

Our own spectra can be uploaded to Spectral Workbench, we can calibrate them and analyze them later.

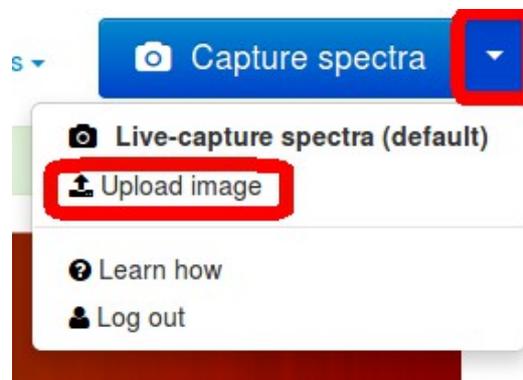
Procedure

1. Create your own account at spectralworkbench.org.
2. Download the pictures of your phone (made in Science Case 1, part 1) in the computer.
Note: You can send them to your email, and download them when opening your account in the computer.
3. Crop your picture with a program for image edition, so that just your spectrum is shown.



Figs 13 and 14. Homemade photography of an emission spectrum (left) and a zoom in photo (right)

4. Upload your picture to the app (top right on the image)



⁶ Definition of calibration: The **calibration** is the process of comparing the obtained values by a [device under test](#) with the corresponding measure from a reference (or standard) of known accuracy. (source: wikipedia)



... and download it in the program as shown below:

Upload a spectrum

The screenshot shows the CesaR upload interface. At the top left, there are buttons for 'Choose an image', 'Upload json (beta)', and 'Upload csv (beta)'. The main section is titled 'Choose an image to upload' and includes instructions to take a picture through a spectrometer. A red box highlights the 'Examinar...' button. Below it is a checkbox for 'Spectrum is vertical (see examples below)' and a 'Learn more »' link. There are two columns of spectrum images: 'Vertical, blue on top:' and 'Horizontal, blue left:'. A red box highlights the 'Upload & calibrate later' button. On the right side, there is a 'Describe your spectrum' section with a 'NOMBRE DEL ESPECTRO' field and a 'NOTAS' text area. Below that is a device selection dropdown and a calibration section with a 'New calibration' dropdown. At the bottom right, there is a 'Geotag' checkbox. At the bottom of the form, there is a license agreement: 'By uploading your data, you agree to release it under the Creative Commons Zero license'.

5. When you obtain your picture, you will have to adjust the X axis (wavelength) of the image⁷.

- Press the button "calibrate".
- Align B2 and G2 with their corresponding peaks in its calibration. Lines B2 and G2 should appear at ~ 435 y ~ 546 nanometers, respectively, if it is aligned with the standard spectrum.

Follow the instructions in the link below to find out more:

<https://publiclab.org/wiki/spectral-workbench-calibration>

If you want to do your own research, this link may be useful:

<https://publiclab.org/wiki/spectral-analysis>

⁷ This case is harder to complete, Check with the educator to perform these tasks.
