Aim: Investigate the light emitted from the sun

Apparatus: Computer Lab with the following software programmes and pictures

- **Tool:** Download at http://www.cabrillo.edu/~dbrown/tracker/
- **Other Software:** Update to lates Java
- **Pictures:** "solar spectrum.png", "H.jpg", "He.png", "Na.png"

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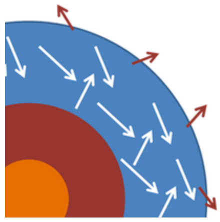
Background:



A star often is modeled as a blackbody, and electromagnetic radiations emitted from these bodies are known as blackbody radiation. The figure shows a highly schematic cross-section to illustrate the idea. The photosphere of the star where the emitted light is generated is idealized as a layer within which the photons of light interact with the material in the photosphere.

The sun generates its energy primarily through nuclear fusion of hydrogen (isotopes) to helium.

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

For details, refer to the lecture on *Nuclear Physics*.

Activity 1 The solar emission spectrum

Step 1. Launch Tracker software.

Fig. 1: Tracker's analysis tools

Step 2. Click  (or File|Open menu item) and select the picture "solar spectrum.png".

Step 3. To calibrate the points on the picture, click the **calibration tool**  and select **Calibration Points**.

Step 4. Change the axes to "X only".

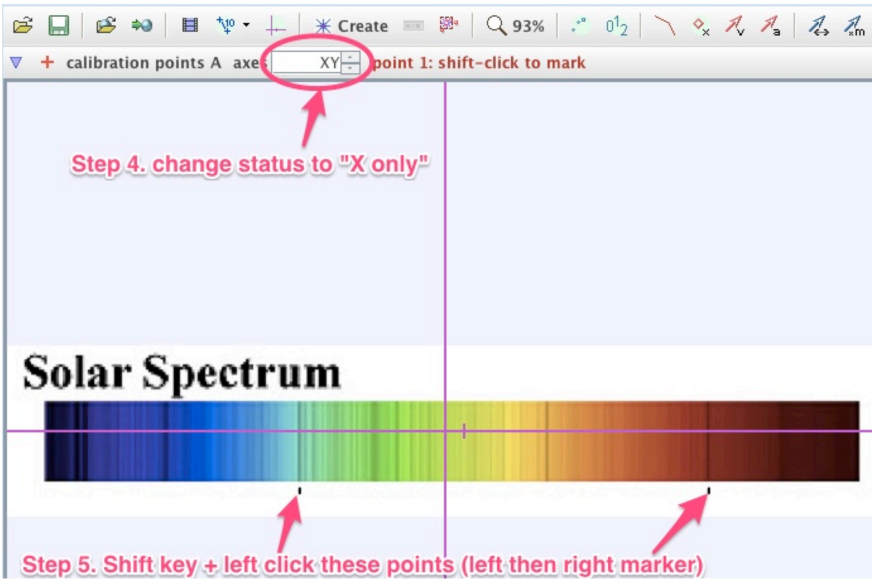


Fig. 2: calibrating the picture

Step 5. Hold the **shift key & left click** on the two black markers (left and right) below the spectrum (these are the reference wavelengths). Enter 486 nm and 656 nm for point 1 and for point 2 respectively.

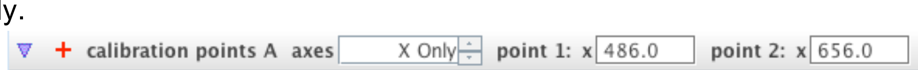


Fig. 3: Setting the reference wavelength

Step 6. Click **Create** Create and choose **Line Profile.**

- By holding down the **shift key, left click & drag** with the mouse across the spectrum (start from within the spectrum from the left to the right) to create a line profile.
- Change the **spread** to about 5 to take an average reading of the intensity of the spectrum.
- The plot on the right hand side shows the brightness/intensity (luma) against the wavelenght in nanometres.

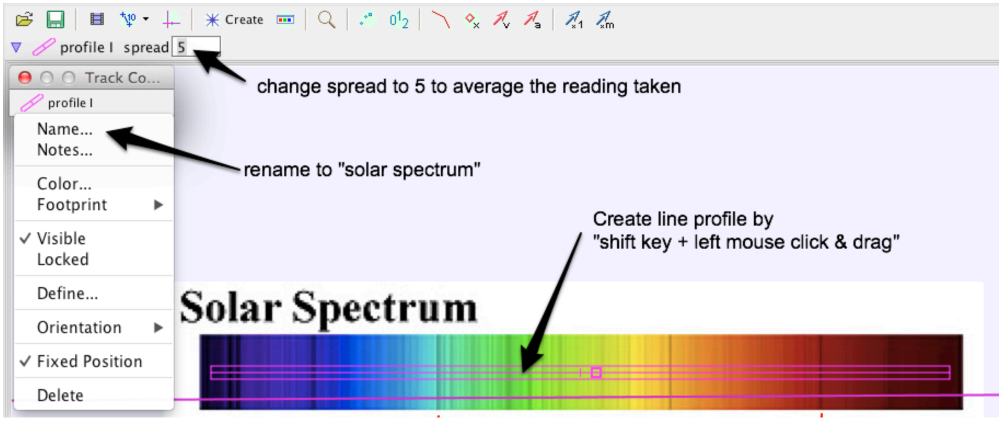


Fig. 4: Creating a line profile

Step 7. Right-click on the plot and choose **analyse…** in the popup menu.

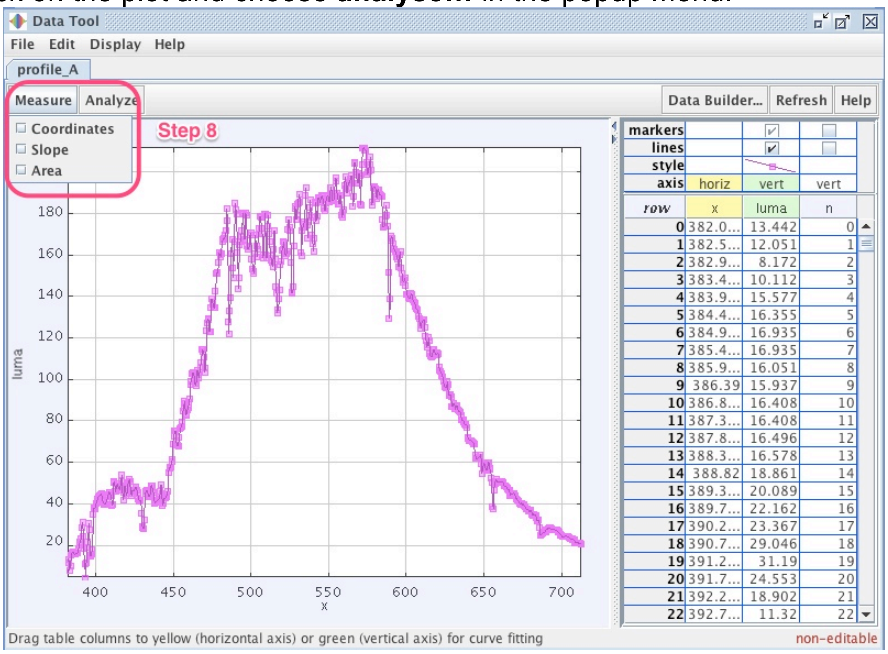


Fig. 5: Data analysis window

Step 8. Select **Measure** and then **Coordinates** checkbox. Move the crosshair within the graph area to read the wavelength (x-axis) and the corresponding intensity (y-axis).

Record the wavelengths of the spectrum where intensity dips by a large amount

λ_1 / nm	λ_2 / nm	λ_3 / nm	λ_4 / nm	λ_5 / nm	λ_6 / nm	λ_7 / nm	λ_8 / nm	

Explain why such dips occur.

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Activity 2 **Exploring the formation of the absorption lines in the solar spectrum**

Without closing the tracker software programme, analyse the emission spectrum of Sodium, Helium and Hydrogen ("Na.png", "He.png" and "H.jpg") following activity 1's step 2 to 8.

2.1 Sodium (Na.png)

Record the wavelength spike where the intensity is the highest.

$\lambda_{Na,1}$ / nm

Explain the origin of these spikes in the spectrum.

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2.2 Helium (He.png)

a. For step 5, hold the **shift key & left click** on the white markers (left and right) below the spectrum (these are the reference wavelengths). Enter 486 nm and 656 nm for point 1 and for point 2 respectively.

b. Record the two wavelengths spikes where the intensity is the highest

$\lambda_{He,1}$ / nm	$\lambda_{He,2}$ / nm

2.3 Hydrogen (H.jpg)

a. For step 5, hold the **shift key & left click** at the centre of the largest green blob (produced by a LED bulb) follow by the red spectral line as reference wavelengths. Enter 515 nm and 656 nm for point 1 and for point 2 respectively.

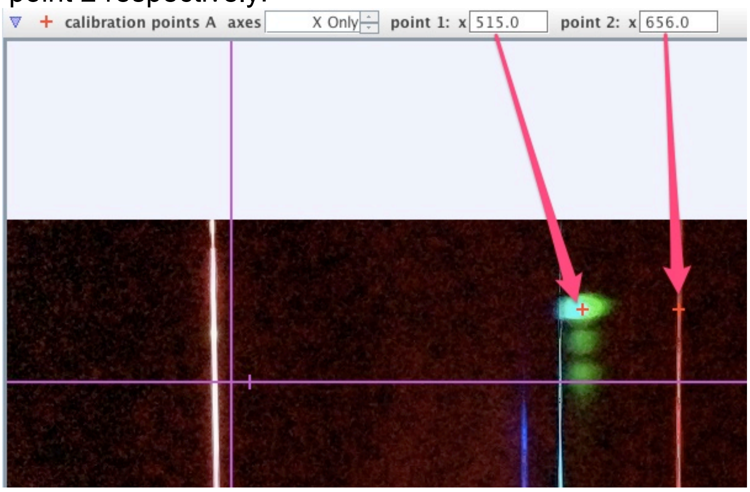

Fig. 6: Hydrogen spectrum with light from LED as reference

b. For the line profile, select the region away from the green blobs because the green blobs does not originate from the hydrogen gas.

c. Record the wavelengths of the Red, Cyan and Purple lines.

λ_{red} / nm	λ_{cyan} / nm	λ_{purple} / nm

d. From Balmer's experimental data, which you have also just successfully obtained, Rydberg derived a formula for the observed spectral lines

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \qquad \text{for } n = 3, 4, 5, \ldots$$

where R_H is known as the Rydberg constant.

Determine the Rydberg constant R_H from your data.

R_H = …………………………….. m^{-1}

e. After decades of research, we now know that the visible light emitted from hydrogen is due to the transition of the atom from higher energy state ($n > 2$) to the 2nd lowest energy state ($n = 2$) of the atom. The energy of $n = 2$ state is -3.4 eV.

Discuss how this energy value of the $n = 2$ state can also be obtained from Rydberg's formula.

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Hence deduce the energy of the $n = 1$ state.

E_1 = ……….. eV

f. Determine the value of each energy level of the atom from $n = 3$ to 5.

E_3 = ……….. eV E_4 = ……….. eV E_5 = ……………. eV

2.4 Composition of the sun

Using the data from activity 2.1 to 2.3, suggest explain what elements could be present in the sun.

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