Name:______________________________ **Date**:______________

SAOImage DS9 Laboratory: Stellar Spectra

Introduction

During the Hertzprung-Russell diagram discussion in class, you learned about the spectrum of a star, spectral classification and the color of stars with regard to temperature. In this laboratory exercise, you will make practical observations of stellar spectra. You will use SAOImage DS9 (ds9) to calibrate stellar spectra manually and measure absorption and emission lines and generate a line plot.

A spectrograph separates the components of light according to wavelength. Think of how a prism spreads light out into the colors of a rainbow. The spectrum of an object, such as a star, is a variation of intensity versus wavelength. Atomic structures, like Hydrogen, appear as either bright (*emission*) or dark (*absorption*) lines. The nature of the lines is described by Kirchhoff's Laws:

1. A hot solid, liquid or gas, under high pressure, gives off a continuous spectrum.
2. A hot gas under low pressure produces a bright-line or emission line spectrum.
3. A dark line or absorption line spectrum is seen when a source of a continuous spectrum is viewed behind a cool gas under pressure.

In order to accurately measure the position of line features in a spectrum, the spectrum must first be calibrated to a known source, such as Hydrogen. Other elements can be used for calibration depending on need. The spectra that you'll work with were collected with an SBIG DSS-7 low resolution spectrograph at the Observatory. The Hydrogen calibration spectrum was created by shining a Hydrogen lamp through the aperture of the telescope.

Calibrating Spectra

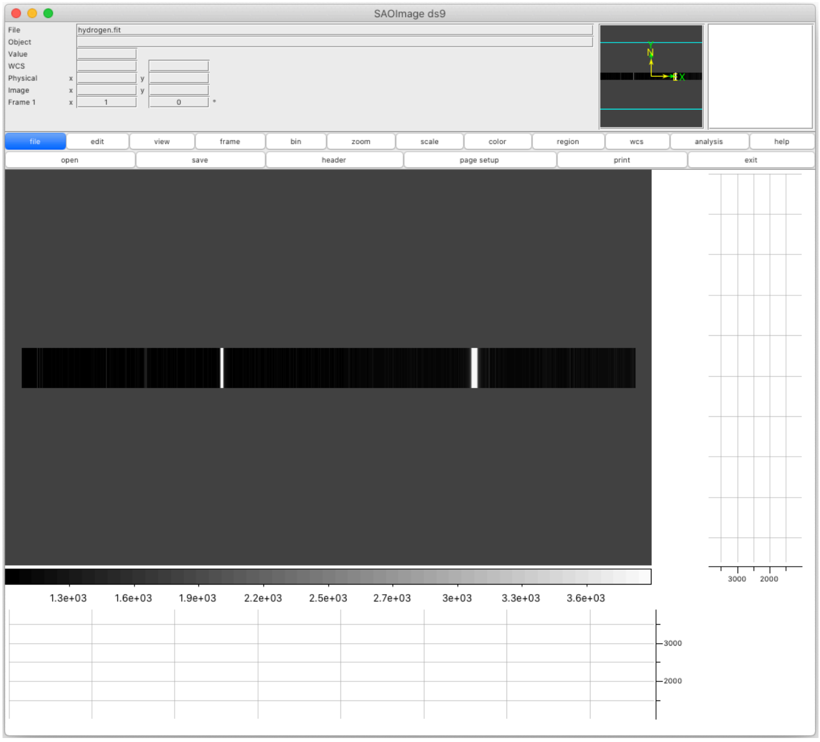
Angstrom (Å)
Wavelength (λ)

You'll begin by calibrating the Hydrogen spectrum to determine the *linear dispersion*, which is the measure of the spectrum's spread across the field. For this laboratory, the linear dispersion will be measured in angstrom-per-pixel (Å/pixel).

1. Launch ds9.

2. Choose **File > Open** and navigate to the resources folder you downloaded for this laboratory and open the "hydrogen.fit" calibration image.

3. From the **View** menu, select to view the **horizontal** and **vertical** graphs.



4. From the **Edit** menu, select the **crosshair** option. This will paint a green cross centered in the display frame. To move the crosshair, either click on a specific point in the image or click-and-drag. As the crosshair moves around the image, the information panel, magnifier, horizontal and vertical graphs are updated.

5. Center the crosshair on the H_β (H-beta) and then the H_α (H-alpha) lines and note the pixel *X* positions shown in the "Physical" section of the information panel. These will be the calibration lines. When the mouse pointer is in the display frame, you can use the arrow keys on your keyboard to move the crosshair one pixel at a time.

	Wavelength	**Pixel (X)**	
$\mathbf{H_\beta}$	4861.330 Å	______________	*(Primary Calibration Point)*
$\mathbf{H_\alpha}$	6562.852 Å	______________	*(Secondary Calibration Point)*

6. Calculate the linear dispersion of the spectrum.

$D_l = | \lambda_1 - \lambda_2 | \div | X_1 - X_2 |$ = ____________ Å/pixel

where...

D_l is the linear dispersion.
λ_1 is the wavelength of the primary calibration point.
λ_2 is the wavelength of the secondary calibration point.
X_1 is the physical position of the primary calibration point along the X axis.
X_2 is the physical position of the secondary calibration point along the X axis.
$| \lambda_1 - \lambda_2 |$ is the absolute value of $\lambda_1 - \lambda_2$.
$| X_1 - X_2 |$ is the absolute value of $X_1 - X_2$.

From the **Frame** menu, select **Clear Frame**. This will remove the current file from the ds9 and clear the image from the display frame.

Measuring the Positions & Wavelengths of Features

7. Open the "**vega.fit**" file from the resources folder. You'll notice the horizontal graph displays the full spectrum with several features that have much lower intensities than those around them. These correspond to the dark features in the spectrum and are absorption lines from atomic features (*Kirchhoff's Law #3*).

8. According to the National Institute of Standards and Technology (NIST), the resting wavelength of the Hydrogen gamma (Hγ) line is is 4340.47Å. Locate the Hγ line in the spectrum of Vega by determining the physical (pixel) position along the X axis.

   $X_{H\gamma} = ((\lambda - \lambda_1) \div D_l) + X_1$ = ____________

   where...

   $X_{H\gamma}$ is the physical position of the line along the X axis.
   λ is the wavelength of the line you want to locate.
   λ_1 is the wavelength of the primary calibration point.
   D_l is the linear dispersion.
   X_1 is the physical position of the primary calibration point along the X axis.

9. The physical width of a spectrum from the DSS-7 spectrograph is 765 pixels. Determine the shortest (L_1) and longest (L_{765}) wavelengths in the spectrum to calculate the spectral range.

   $\lambda = \lambda_1 + (D_l * (X - X_1))$ ...where X is the physical position along the X axis i.e.(1 or 765).

   L_1 = ____________ L_{765} = ____________

   Spectral Range = $L_{765} - L_1$ = ____________ Å

Spectrum of β Lyrae (Beta Lyrae)

10. Clear the current frame and open the "**blyra.fit**" file from the resources folder. The spectrum of β Lyrae was taken on the same night as the spectrum of Vega and the Hydrogen calibration spectrum. Therefore, use the same linear dispersion you calculated previously.

β Lyrae is a multiple star system dominated by an *eclipsing binary* pair. The two stars eclipse one another from our vantage point as they orbit. As a result, β Lyrae is a variable star with a period of ~12.9 days. The binary pair are so close together that it is extremely difficult to resolve them optically. The smaller of the pair is accreting material to its companion. This process creates an accretion disc that hides the system in such a way that we see a single point of light from the ground.

The spectrum of β Lyrae is complicated. It includes both emission and absorption features. The intensities and positions of the atomic features change depending on where one star is in relation to the other.

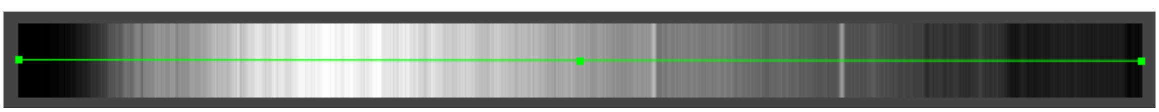
Creating a 2D Spectrum Plot

To reveal all of the features in the spectrum, create a 2D plot of the spectrum.

11. From the **Edit** menu, select the **region** option.

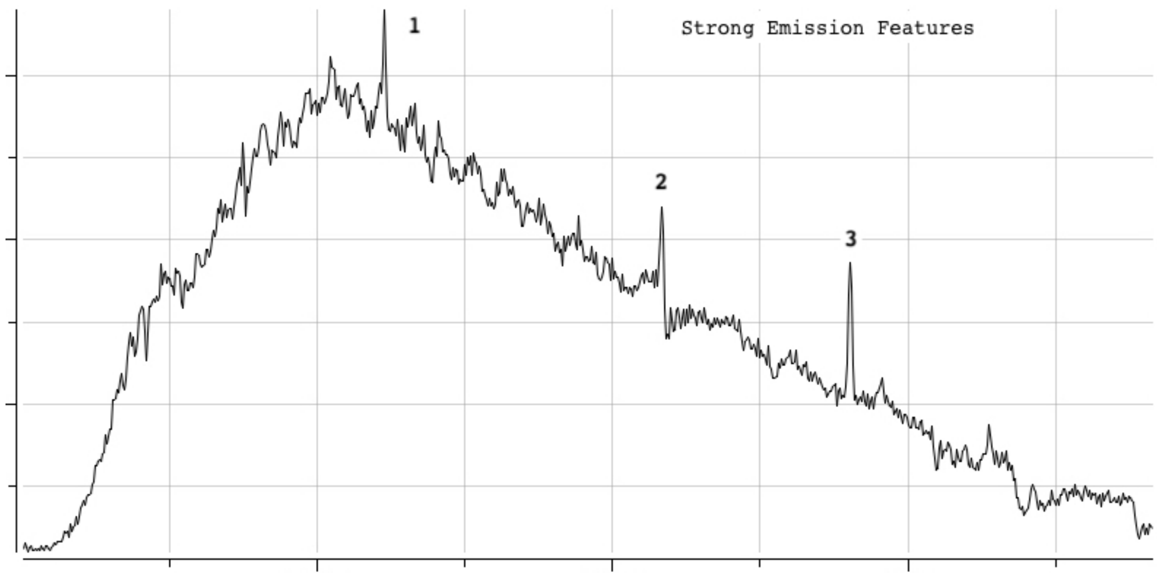
12. From the **Region** menu, select **Shape** > **Projection**.

13. Click-and-drag a projection region (line) from the physical beginning (x=1) to the end (x=765) of the spectrum in the display frame. When you release the mouse button, a 2D plot will appear that you can resize. Don't worry if you don't get the line exactly right. You can select the projection region and use the handles at each end to position it correctly.



Spectrum with Projection Region Drawn and Selected

14. If the plot does not show pixel positions along the x-axis, select the projection region in the display frame. From the **Region** menu, select **Get Information**. This opens the projection dialog box. With the projection dialog active, select the **Analysis** menu and uncheck **Plot 2D** and then check it again. The plot will reappear and should now have guides with pixel positions along the x-axis.



2D Spectrum Plot Showing Strong Emission Features

Feature #1 in the spectrum plot above doesn't show up in the horizontal graph at the bottom of the application window very well, if at all. It is revealed in the 2D plot you created and its pixel position along the x-axis can be estimated. To get a better idea of its x position within the spectrum, click-and-drag a box around the feature inside the projection (2D plot) dialog to zoom-in. To zoom-out, right-click anywhere in the projection dialog or press the ESC key on your keyboard..

15. Switch back to the crosshair (Edit > crosshair) to accurately measure the physical position of the three strong emission features noted in the plot above. What are their wavelengths?

Feature #1 (**H_β**) ____________ Å

Feature #2 (**He I**) ____________ Å

Feature #3 (**H_α**). ____________ Å

16. As previously mentioned, the spectrum of β Lyrae is constantly changing as the binary pair orbit one another. What is the change in the measured wavelengths of H_β and H_α in step 15 from their rest wavelengths?

	Rest λ	Measured λ	Δ λ
H_β	4861.330	___________	__________
H_α	6562.852	___________	__________

17. Are the measured wavelengths red-shifted (longer wavelengths) or blue-shifted (shorter wavelengths)?