Abstract

This experiment was done to determine the effect of the temperature of a star on the strength of the hydrogen Balmer absorption lines in the star's spectrum. The spectra of stars from each spectral class were recorded using a DSLR camera equipped with a Rainbow Optics Spectroscope, mounted on a Meade 8-inch LX200 telescope. Spectra images were processed using IRIS and Vspec software to produce CCD response profiles. The equivalent widths of the absorption lines in each profile were calculated and analyzed. Greater equivalent widths indicate stronger absorption lines.

Type O stars, with temperatures around 20,000K and up did not have strong hydrogen Balmer lines. Spectral types K and M, with temperatures between 2,000 and 5,000 K also did not have strong hydrogen lines. The hydrogen Balmer lines were the strongest for type A1 stars, with temperatures around 10,000K. In order to create an absorption line, the hydrogen atom needs to be in the n=2 excited state so that the electron can absorb photons. The temperature of O type stars is so hot that most of the hydrogen atoms are ionized and unable to absorb photons. In cooler stars, such as types F, G, K, and M, more hydrogen atoms are in the ground n=1 state, and are unable to absorb photons. Type A stars have the optimum temperature to have the greatest number of hydrogen atoms with their electrons in the n=2 excited state, and so had the strongest hydrogen Balmer absorption lines.

Andrew Hitchner – Script for PowerPoint Presentation – A Study in Stellar Spectroscopy

Slide 1: Intro: Hello, my name is.......

Slide 2: Spectroscopy is the study of the dispersion of an object's light into its component colors, such as when white light passes through a prism to produce a rainbow. In the case of a star, the spectrum shown is an absorption line spectrum, with black bands showing the components of the star. The spectrum of a star can be used to reveal information about the star, including what type of star it is, the temperature and density of the star, the intensity of any stellar winds, and if the star is part of a binary system. The main purpose of stellar spectroscopy is to classify stars. Stars are classified by the Henry Draper Catalog, also known as the OBAFGKM sequence, which classifies stars by their temperature, with O stars being the hottest and M stars being the coolest. Stars are also classified by their luminosity, which shows their position on the Hertzsprung-Russell Diagram. In this project low resolution spectroscopy was used to observe and record the major absorption lines in the stellar spectrum of different stars.

Slide 3: The problem investigated was "What is the effect of the temperature of a star on the strength of the hydrogen Balmer absorption lines in the star's spectrum?" Absorption lines are caused by the photons of the spectrum created in the inner regions of the star being absorbed by the elements in the star's photosphere. The hydrogen atom will only absorb photons of certain wavelengths, specifically at 6563, 4861, and 4341 angstroms.

Slide 4: My hypothesis was: If the temperature of the star decreases, then the strength of the hydrogen lines in the star's spectrum will also decrease. In the OBAFGKM sequence, O stars are the hottest and M stars are the coolest. Spectral types O and B will have more prominent hydrogen lines than spectral types K and M.

Slides 5,6,7: First I had to set up the equipment (steps on slide)

Slide 8: Here is an example of the raw image. The image was then cropped and rotated to include just the spectrum. It was then converted to a .fit file so that it would be compatible with the Vspec software. I then used Vspec to generate an intensity profile. I then created a CCD response curve and a corrected intensity profile to compensate for the CCD camera's loss in sensitivity going from blue to green and green to red.

Slide 9: Here is a list of the stars used in this project. The Roman numeral represents the star's luminosity class. The number represents the star's temperature within the spectral class, with zero being the hottest and 9.5 being the coolest. The number in parenthesis gives the magnitude of the star. For types O,B, A, and G, luminosity class V was used because these are main sequence stars. For type F, luminosity class IV was used, and for types K and M class III was used. This is because main sequence stars become increasingly fainter as their temperature decreases. There were not any F, K, or M main sequence stars with a reasonable magnitude or location.

Slide 10: My constants were … (see slide)

Slide 11: This graph compares the intensity profile of a star from each spectral class. The X axis shows the wavelength in Angstroms while the Y axis shows the intensity of the line. On the bottom is a legend for each spectral class. Each dip in the profile is an absorption line. The hydrogen lines being compared are H Gamma and H Beta.

Slide 12: This graph compares the equivalent widths of the hydrogen lines for each of the stars. The greater the equivalent width, the stronger the hydrogen line. For Spectral type O stars, the equivalent widths were very low, ranging from 2.465 to 2.954 for the Hγ, and 1.474 to 2.074 for the Hβ. The equivalent width then increased until it reached maximum at spectral type A, ranging from 13.222 to 30.814 for the Hγ line and from 10.601 to 21.048 for the Hβ line. The maximum Hγ value was 30.814 and the maximum Hβ value was 21.048. The equivalent widths then decreased until they reached a minimum at spectral type M. The minimum value for the Hβ line was 1.372, while the Hγ line was no longer visible.

Slide 13: This graph compares the intensity profile of each type A star that was photographed. The X axis shows the wavelength in Angstroms while the Y axis shows the intensity of the line. On the bottom is a legend for each star. The box on the right shows the equivalent width for each star. The equivalent width increased from A0 until it reached maximum strength at A1V, then decreased from A5 to A8.

Slide 14: My hypothesis, as stated, was partially supported. The O type stars, with temperatures around 20,000K and up, did not have very strong hydrogen Balmer lines. However, spectral types K and M, with temperatures between 2,000 and 5,000 K also did not have strong hydrogen lines. The hydrogen Balmer lines were the strongest for type A1 stars, with temperatures around 10,000K.

Slide 15: In order to create an absorption line, the hydrogen atom needs to be in the n=2 excited state, so that the electron can absorb photons. If the temperature is too hot, the hydrogen atom receives too much energy, and loses its electron, becoming ionized. These ionized hydrogen atoms cannot absorb photons. If the temperature is too cool, more hydrogen atoms will be in the ground n=1 state and they will also be unable to absorb photons. The temperature of O type stars is so hot that most of the hydrogen atoms are ionized and unable to absorb photons. As the temperature decreases past that of type A stars, such as in type F, G, K, and M, more and more hydrogen atoms are found to be in the ground n=1 state, rendering them unable to absorb photons. A type stars have the "just right" temperature to have the greatest number of hydrogen atoms with their electron in the n=2 excited state.

Slide 16: This project could be improved by being able to collect more spectral data from more stars in each class. Weather conditions and the times various stars were visible made it difficult to collect data. A future spectroscopy project could include a custom built spectroscope. Other types of stars, such as variable stars, Type B Emission Stars, and Wolf-Rayet Stars could be

A Study in Stellar Spectroscopy

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Background

- Spectroscopy: the study of the dispersion of an object's light into its component colors
- Spectrum of Star can reveal information about that star
- Stars classified by Henry Draper Catalog, or OBAFGKM sequence
- Stars also classified by luminosity
- Low resolution spectroscopy can detect major absorption lines in stellar spectrum

Problem

- What is the effect of the temperature of a star on the strength of the hydrogen Balmer absorption lines in the star's spectrum?
  - Hydrogen atoms will absorb photons of wavelengths 6563, 4861, and 4341Å

Hypothesis

- If the temperature of the star decreases, then the strength of the hydrogen absorption lines in the star's spectrum will also decrease.

Procedure

Set Up The Equipment

- Set up the telescope
- Align the telescope's drivers
- Attach the spectroscope to the camera body
- Mount the camera onto the telescope

Procedure

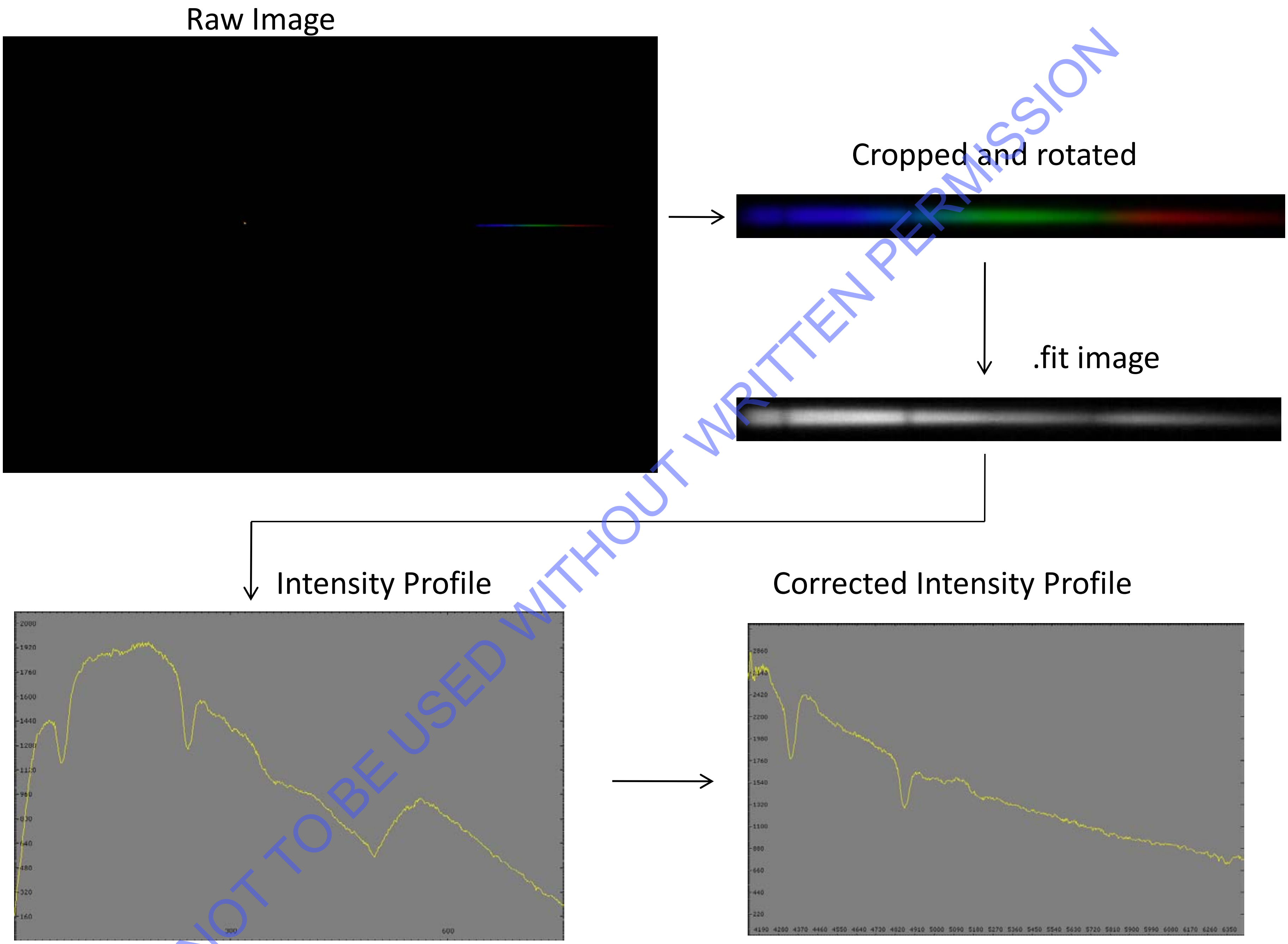
Take the Photograph

- Move the star and the first-order spectrum into the view
- Take test images to test focus
- Once focused, take exposures with appropriate time and ISO
- Record the number of the first and last image

Procedure

Process the images

- Download the pictures onto computer
- Open the desired picture in Photoshop and crop and rotate the image
- Open the edited photo in IRIS, and convert and save as *.fit* image
- Open the *.fit* image in Vspec
- Create an intensity profile of the image
- Generate a CCD response curve of the profile and a corrected intensity profile
- Repeat this procedure for all stars
- Open the desired profiles for comparison
- Select the desired absorption line and calculate the line's Equivalent Width


Raw Image
Cropped and rotated
.fit image
Intensity Profile
Corrected Intensity Profile

Star List

O	B	A	F	G	K	M
9.5V Zeta Oph (2.5)	0.5V Epsilon Per (2.87)	0V Alpha Lyr (0.0)	2IV Delta Gem (3.5)	3V Eta Cas (3.43)	0III Beta Gem (1.15)	0III Gamma Sge (3.50)
9.5V Sigma Ori (3.75)	2.5V Zeta Cma (3)	0V Zeta Aql (3)	5IV Alpha CMi (0.37)	8V Tau Cet (3.46)	0III Alpha Cas (2.21)	3III Mu Gem (2.84)
	3V 48 Per (4)	1V Alpha CMa (-1.5)			2III Alpha Ari (2.00)	
	8V Beta Per (2.6)	1V Alpha Gem (3)			4III Beta UMi (2.06)	
	9V Lambda Aql (3.4)	5V Beta Ari (2.6)			5III Alpha Taur (0.84)	
		7V Alpha Cep (2.43)				
		8V Alpha Aql (0.75)				
		8V Alpha Pis Aus (1.15)				

Constants

- Same telescope used (Meade 8in. LX200)
- Same camera used (Canon 400D)
- Same spectroscope used (Rainbow Optics 200 lpm grating)
- Same image processing programs used
- Same luminosity class used for each spectral class of the star

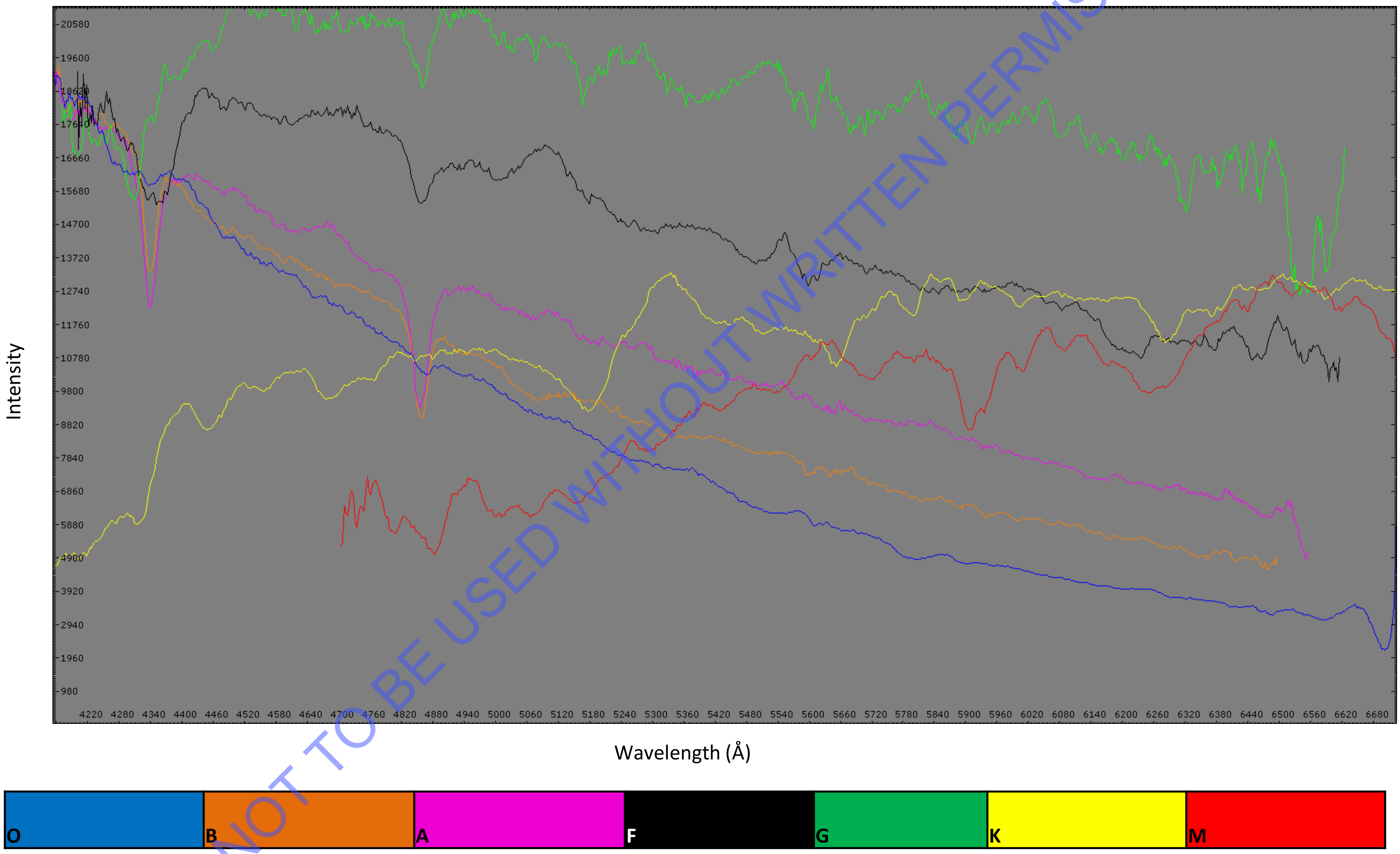
Independent Variable

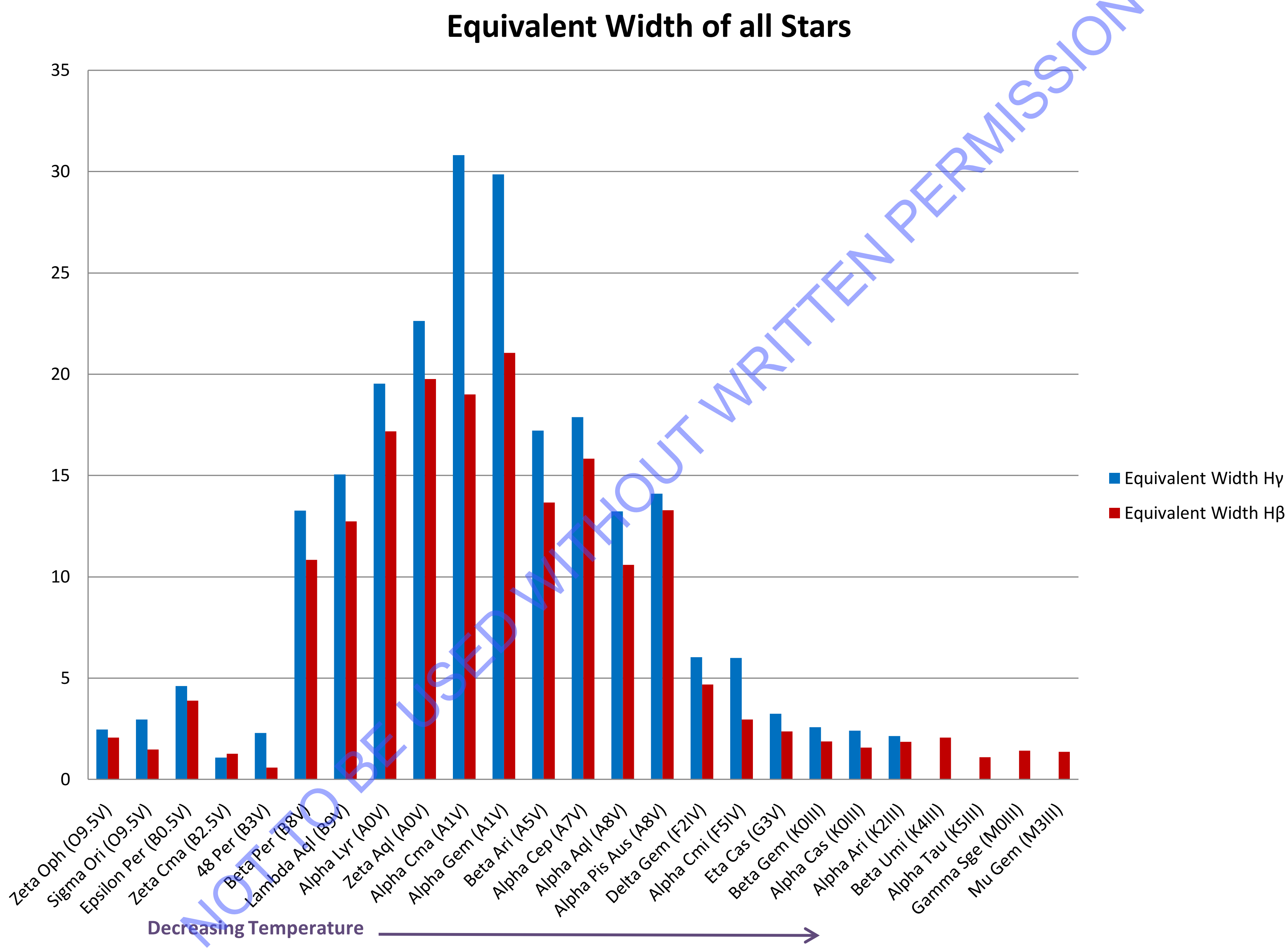
- The temperature of the star, indicated by the star's spectral class

Dependant Variable

- The strength of the hydrogen lines in the star's spectrum

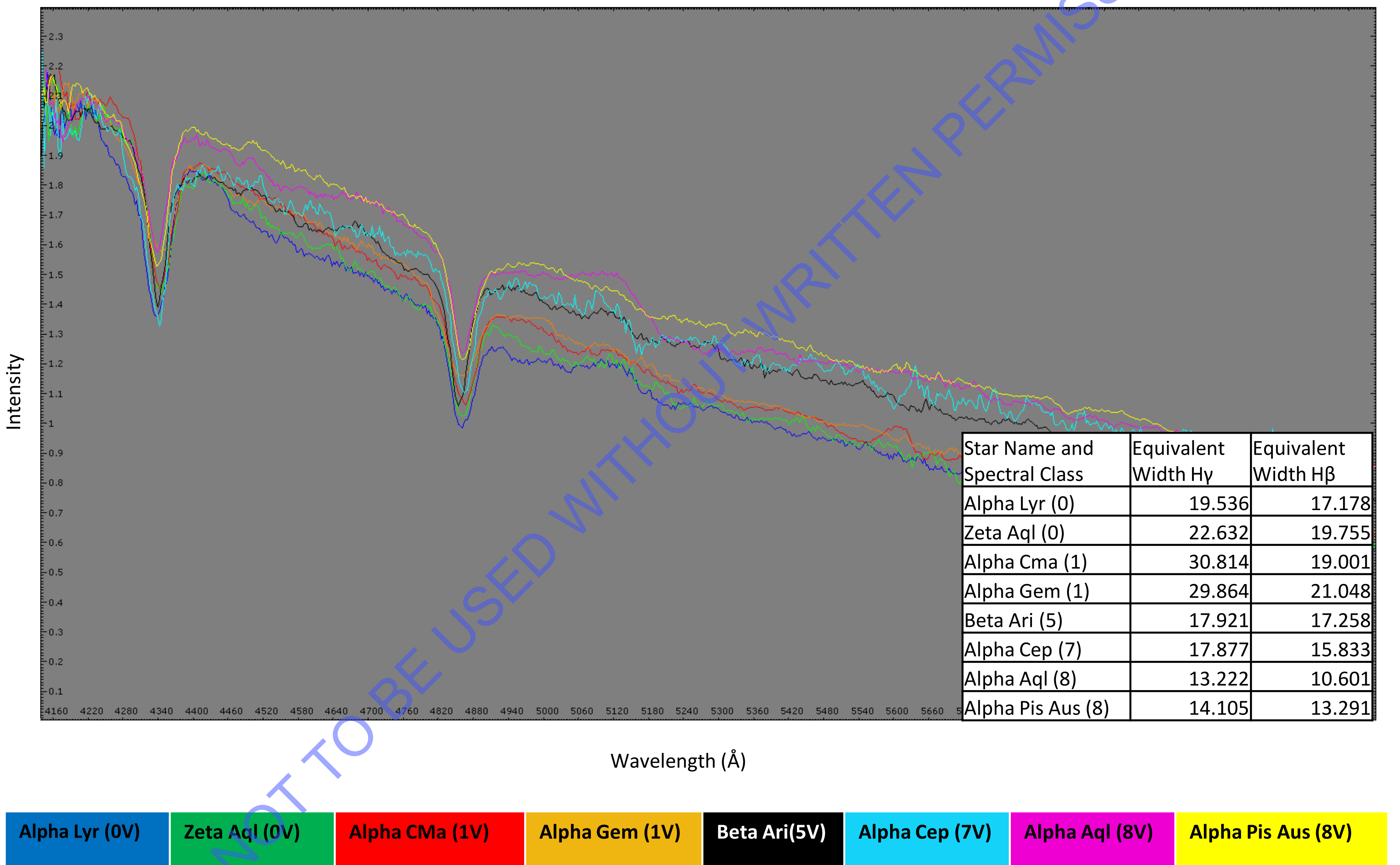
OBAFGKM Comparison





Equivalent Width of all Stars
35
30
25
20
15
10
5
0
Equivalent Width Hγ
Equivalent Width Hβ
Zeta Oph (O9.5V)
Sigma Ori (O9.5V)
Epsilon Per (B0.5V)
Zeta Cma (B2.5V)
48 Per (B3V)
Beta Per (B8V)
Lambda Aql (B9V)
Alpha Lyr (A0V)
Zeta Aql (A0V)
Alpha Cma (A1V)
Alpha Gem (A1V)
Beta Ari (A5V)
Alpha Cep (A7V)
Alpha Aql (A8V)
Alpha Pis Aus (A8V)
Delta Gem (F2IV)
Alpha Cmi (F5IV)
Eta Cas (G3V)
Beta Gem (K0III)
Alpha Cas (K0III)
Alpha Ari (K2III)
Beta Umi (K4III)
Alpha Tau (K5III)
Gamma Sge (M0III)
Mu Gem (M3III)
Decreasing Temperature

A-Star Comparison



Star Name and Spectral Class	Equivalent Width Hγ	Equivalent Width Hβ
Alpha Lyr (0)	19.536	17.178
Zeta Aql (0)	22.632	19.755
Alpha Cma (1)	30.814	19.001
Alpha Gem (1)	29.864	21.048
Beta Ari (5)	17.921	17.258
Alpha Cep (7)	17.877	15.833
Alpha Aql (8)	13.222	10.601
Alpha Pis Aus (8)	14.105	13.291

Conclusion

- Hypothesis was partially supported
- Type O stars did not have strong hydrogen lines (≥ 20,000K)
- Types K and M did not have strong hydrogen lines (2,000K – 5,000K)
- Hydrogen Balmer lines were the strongest for type A stars, with temperatures around 10,000K

Conclusion Continued

- Hydrogen atom needs to be in the n=2 excited state to absorb photons
- O Stars' temperatures are very high and most hydrogen atoms are ionized
- As a star's temperature decreases, hydrogen atoms have their electron in the ground state, n=1, and cannot absorb photons.
- Type A stars have the "just right" temperature to have the greatest number of hydrogen atoms with their electron in the n=2 excited state

Improvements/Future Investigations

- Collect more data for each spectral class
- Build a custom spectroscope
- Other Spectroscopy Topics
  - Variable, B emmission, and Wolf-Rayet Stars
  - Lunar, Solar, and Planetary Spectroscopy
  - High Resolution Spectroscopy