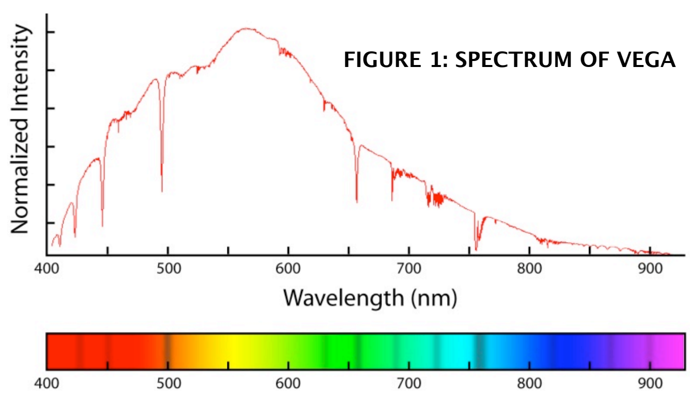
Name	
Partner(s)	
Date	

Grade		
Category	**Max Points**	**Points Received**
On Time	5	
Printed Copy	5	
Lab Work	90	
Total	100	

Spectral Classification of Stars

1. Introduction

Scientists across all fields use classification systems to help them sub-divide the vast universe of objects and phenomena into smaller groups, making them easier to study. In biology, life can be categorized by cellular properties. Animals are separated from plants, cats separated from dogs, oak trees separated from pine trees, etc. This framework allows biologists to better understand how processes are interconnected and quickly predict characteristics of newly discovered species. In Astronomy, the stellar classification system allows scientists to understand the properties of stars. Early astronomers began to realize that the extensive number of stars exhibited patterns related to the star's color and temperature. This classification was good, but had limitations (especially for studying distant stars).



By the early 1900's, a classification system based on the observed stellar spectra was developed and is still used today. A **STELLAR SPECTRUM** is a measurement of a star's brightness across of range of wavelengths (or frequencies). It is in a sense a "fingerprint" for the star, containing features that reveal the chemical composition, age, and temperature. This measurement is made by "breaking up" the light from the star into individual wavelengths, much like how a prism or a raindrop separates the sunlight into a rainbow. Figure 1 shows a spectral measurement of the star Vega, the brightest star in the constellation Lyra. The spectrum has many interesting features that allow astronomers to determine the physical properties of the star. By **WIEN'S LAW**, the temperature can be measured by recording the wavelength where the profile is the strongest. The chemical composition can be determined by the locations of the dips or dark patches (absorption lines) and properties such as density can be inferred by measuring the depth and width of the lines.

The main purpose of this exercise is to learn more about the stellar classification system. You will be asked to identify 14 "Unknown" stars based on their spectral properties. To do this, you will be given a list of "Reference" stars with various spectral types to be used as a basis for comparison. All the stars listed in this lab are members of a sub-classification called main sequence stars. Our sun is a member of this class. They are called main sequence because of a unique pattern they make when they are displayed on a plot of their Luminosity with respect to their spectral type. This plot is called a **HERTZSPRUNG-RUSSELL DIAGRAM** (or H-R diagram). To see this unique grouping, you will be asked to make an H-R diagram of your own using the stars (both the "Reference" and the "Unknown") in this lab. Lastly, you will use the given stellar masses to estimate the lifespan of a star in each spectral class. By the end of lab, you should have a good understanding of stellar types, how they are organized, and what properties each type represents.

2. Spectral Classification

Main Classification

The stellar classification system groups stars into the following categories:

TABLE 1 - STELLAR CLASSIFICATION SYSTEM

TYPE	COLOR	TEMPERATURE	ENERGY SOURCE
O	blue-white	35 000 Kelvin	Ionized helium
B	blue-white	21 000 Kelvin	helium
A	white	10 000 Kelvin	hydrogen
F	creamy	7 000 Kelvin	Ionized calcium

G	yellow	6 000 Kelvin	calcium
K	orange	4 500 Kelvin	titanium oxide
M	red	3 000 Kelvin	titanium oxide

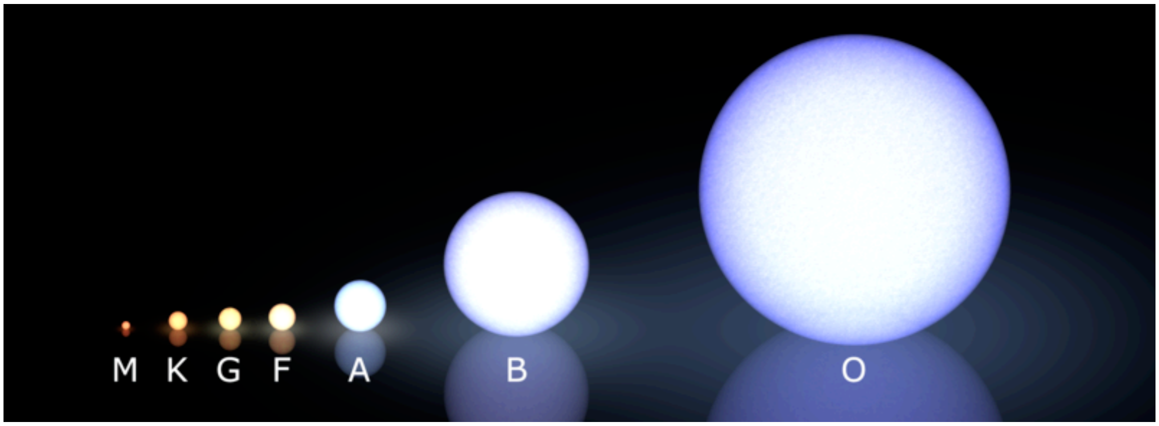


FIGURE 2 – ILLUSTRATION OF THE STELLAR CLASSIFICATION SYSTEM

Subclassification

Each spectral type is further sub-divided into narrower divisions to help classify the subtle differences in each type. This is done through the use of the numbers 0 - 9 and the Roman Numerals I - VII. The main star in each spectral type is represented by the number 0 and the number increases as the temperature decreases (moves toward cooler spectral type). The Roman Numerals indicate the stars luminosity and start with the brightest (I for **SUPERGIANTS**, II for **BRIGHT GIANTS**, III for **GIANTS** and IV for **SUBGIANTS**), and work down to fainter (V for **MAIN SEQUENCE**) and fainter (VI for **SUBDWARFS**, VII for **WHITE DWARFS**) stars.

- **Example:** Figure 1 shows the spectrum of Vega. Vega has a stellar classification of A0V, meaning that Vega is a Main Sequence star (V) and is the main spectral type for A-type stars (A0). From Vega's spectral type, we can quickly infer that Vega is a white star around 10,000 Kelvin that is fusing hydrogen and is of medium luminosity.

3. Determining Spectral Type

Attached with this lab is a transparency which displays a series of stellar spectra for a wide variety of main sequence stars. You are also given a series of "Unknown" spectral type stars you will be asked to identify. To do this, place the transparency of

"Reference" spectra over the target and move from type to type until you think you have found a match. Be careful! Not all the spectra are exactly the same and you may have to guess between two types. For example, if you were between a K0 and K5 star, you could estimate a K2 or K3. Or, if you were stuck between an A5 and a F0, you could choose an A7 or A8.

Make your estimates of the 14 "Unknown" sources and enter your results in Table 2. When you are done, move on to Part 2 - Mass, Luminosity and the H-R Diagram.

TABLE 2: STELLAR PROPERTIES

NAME	M/M_{SUN}	TYPE	LUMINOSITY
Zeta Puppis	40.0	O5	
Phi Orionis	18.0	B0	
Theta CrB	5.40	B6	
Alpha Gem	2.15	A1	
Beta Pictoris	2.10	A5	
Gamma Virginis	1.70	F0	
Eta Arietis	1.29	F5	
Beta Comae Ber	1.10	G0	
Alpha Mensae	0.93	G6	
70 Ophiuchi A	0.78	K0	
61 Cygni A	0.69	K5	
Gliese 185	0.47	M0	
EZ Aquarii A	0.21	M5	
BD63137	0.35		
Feige41	4.80		
HD6111	0.99		
HD17647	0.89		
HD23733	1.75		
HD24189	1.17		
HD27685	1.08		
SAO81292	0.18		
HD35619	20.1		

HD66171	**0.90**		
HD240344	**19.2**		
HD124320	**2.50**		
HZ948	**1.25**		
HD35215	**31.0**		

4. Mass, Luminosity and the H-R Diagram

The mass, Luminosity Relationship

At the core of these stars, matter is being converted into energy through fusion. This process is very sensitive and small changes in the stars mass can create dramatic changes in the **LUMINOSITY**. Expressed mathematically, the relationship has the following form:

$$L = M^{3.5}$$

Here, L is the luminosity of a main sequence star (in units of the Sun's luminosity) and M is the mass of a main sequence star (in units of the Sun's mass). For example: if

$$M = 2M_{Sun}$$

then,

$$L = 2^{3.5} = 11.3$$

Herzsprung-Russell Diagram

The H-R diagram is a common way for astronomers to display the stellar classification system. It is simply a plot of a star's luminosity versus its spectral type (or sometimes its color/temperature vs. absolute magnitude). Similar stellar types will tend to "cluster" on the H-R Diagram. The stars used in today's lab are all main sequence (sub-type V) stars and their grouping should be evident though plotting. Use the Mass, Luminosity Relationship from section 2.1 to complete the "Luminosity" column in Table 2 and plot the stars from this lab to reveal the pattern.

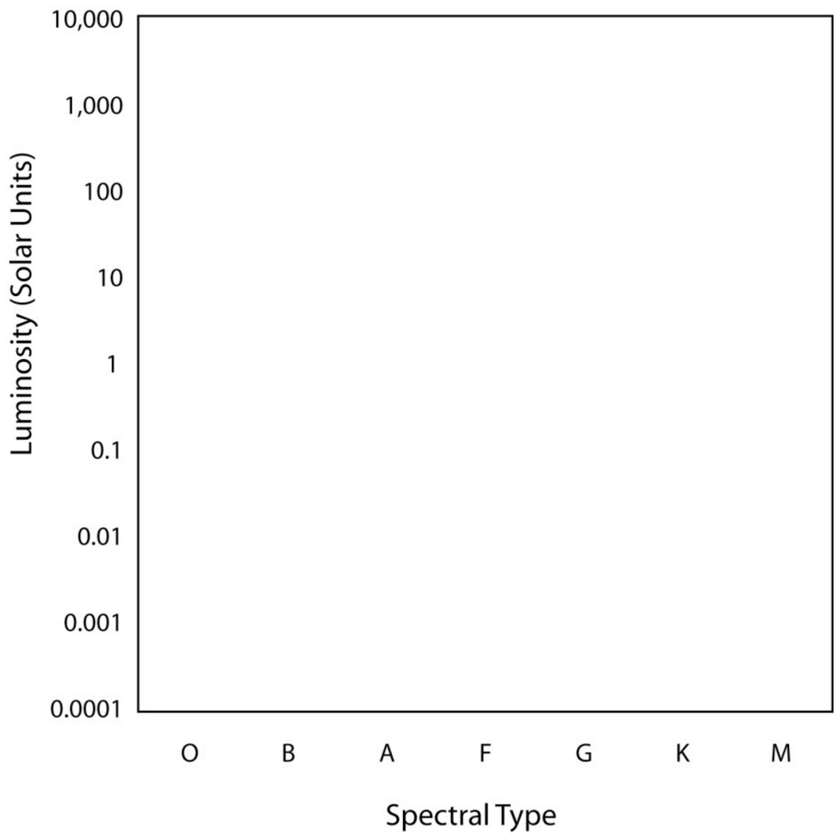


FIGURE 3 - H-R DIAGRAM

5. Main Sequence Lifetime

The length of time a star spends as a main sequence type depends on how long it takes to use up the hydrogen at its core. Stars with high luminosities require large amounts of energy and hence use up their hydrogen faster than stars with lower luminosities. The lifespan of a star is a measure of how much fuel it has divided by the rate at which it uses its fuel. In this case, the fuel is the mass, and the rate the star uses fuel is the star's luminosity. Using the **MASS, LUMINOSITY RELATIONSHIP** from section 2.1, it is straight-forward to see that the main sequence lifetime of a star is just:

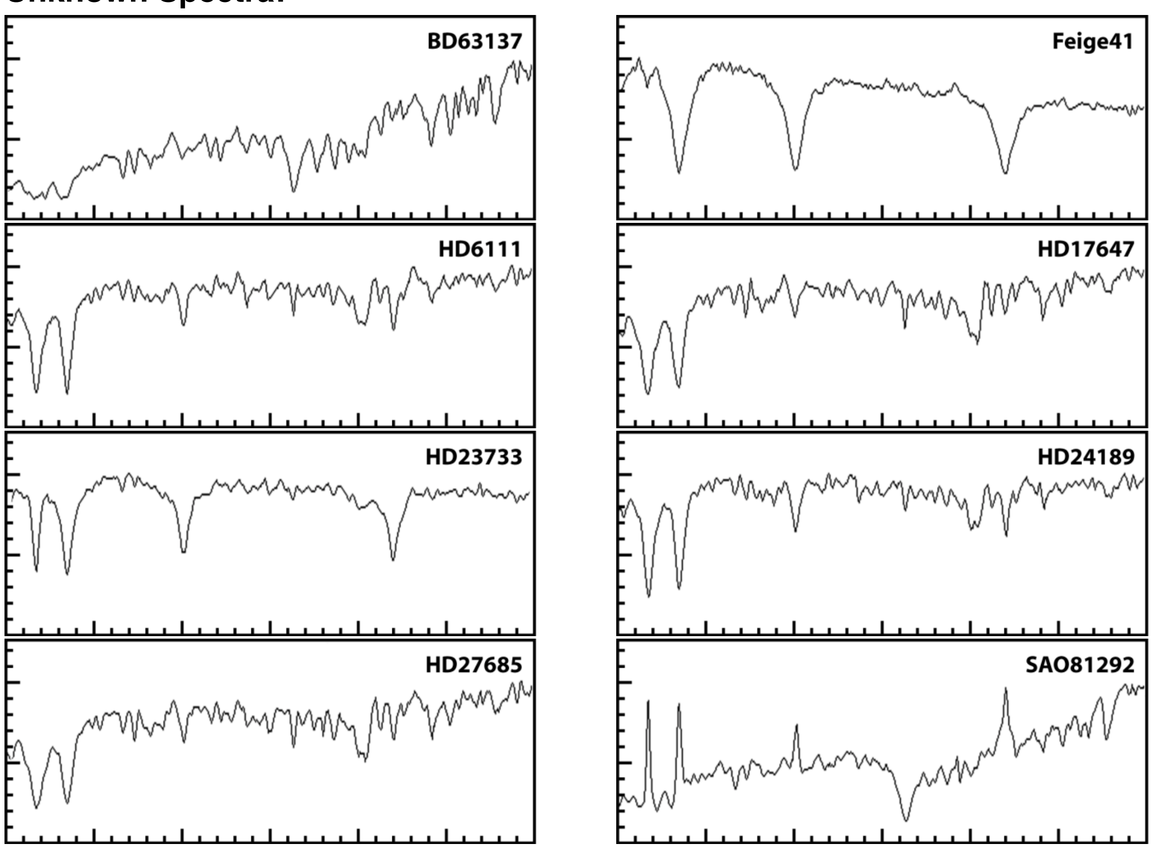
$$\tau = \frac{M}{L} \times 10^9 \text{ Years} = \frac{M}{M^{3.5}} \times 10^9 \text{ Years} = M^{-2.5} \times 10^9 \text{ Years}$$

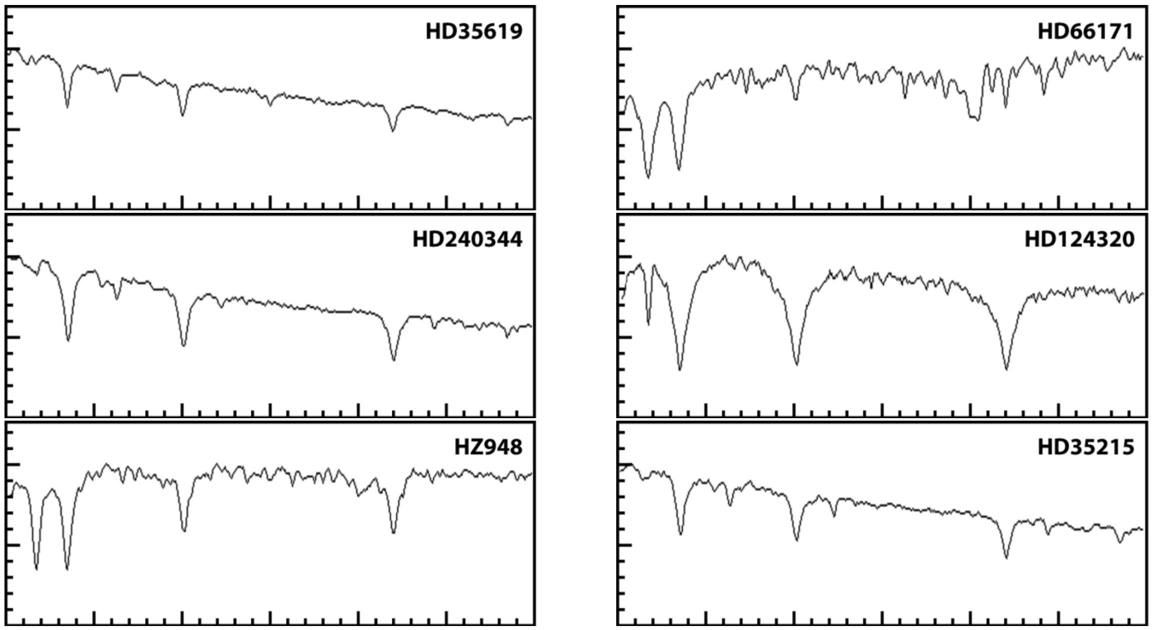
This means that for a star with a mass $M = \frac{1}{2} M_{\text{Sun}}$, then $\tau = 0.5^{-2.5} \times 10^9 \text{ Years} \sim 57 \times 10^9 \text{Years}$. Choose one star from each main spectral type and calculate the main sequence lifespan in the table below.

TABLE 3 – MAIN SEQUENCE LIFETIME

TYPE	MASS	LIFESPAN

Unknown Spectra:




HD35619
HD66171
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HZ948
HD35215