NAME:________________________

MAGNITUDES AND STELLAR BRIGHTNESS

What will you learn in this Lab?

We'll be looking at the stars tonight as something more than just pretty points of light. We're going to take special note of their location, their relative brightness, and even their colors. These types of observations were the fundamental work of both ancient and modern astronomers – giving us a unique record of the stellar brightness through the course of history.

What do I need to bring to the Class with me to do this Lab?

For this lab you will need:
- A copy of this lab script
- A pencil
- A scientific calculator
- Your field guide
- Your star charts
- Your star wheel

Introduction:

This exercise is designed to help the student become familiar with the *magnitudes* (*i.e.,* apparent brightness) and *colors* of stars.

Magnitudes: To describe the brightness of individual stars and to express the brightness differences between them, astronomers assign each star a *magnitude* number. The magnitude system was first used by the Greek astronomer Hipparchus, who divided the stars into six categories. He called the brightest stars in the sky `first magnitude' and the faintest `sixth magnitude'. Stars of intermediate brightness were assigned a number between 1 and 6. We still use a modified version of this system, with extensions to encompass a larger range of brightness by using numbers smaller than 1 and larger than 6.

The first thing you should notice about this system is that its ordering is backward: a small number (like 1, or even a negative number) denotes a brighter star than a large number (like 8 or 9). The brightest star in the night sky, Sirius, has a magnitude of -1.5 while the faintest star that can be seen with the unaided eye is about magnitude 6. For comparison, the magnitude of the Sun is -26.5. An easy way to remember that the magnitude system runs backward is to think of magnitudes in terms of rank. A `first-rank' star is brighter than a `second-rank' star, which in turn is brighter than a `third-rank' star, etc.

Another important feature of the magnitude system is that it is a logarithmic scale. When the system was first setup, it was thought that 1st magnitude stars were about twice as bright as 2nd magnitude stars, which were twice as bright as the 3rd magnitude stars, etc. Following this pattern, one would expect a 1st magnitude star to be about 32 (= 2 x 2 x 2 x 2 x 2) times brighter than a 6th magnitude star, but careful measurements have shown that this is not correct. Instead, the jump from 1st magnitude to 6th magnitude actually represents a change of 100 times in brightness. Each increase of one magnitude corresponds to a decrease by a factor of about 2.512 (= $\sqrt[5]{100}$) in brightness. For example, how does the brightness of a star with magnitude 1 compare to that of a star with magnitude 4? It is 3 magnitudes brighter, which means that is 15.85 (=2.512 x 2.512 x 2.512) times as bright.

Finally, the basic magnitude system used here is one based on the apparent brightness of stars. That is, how they appear in the sky to the observer. Hence, we call these *apparent magnitudes*. Without knowing the distance to an individual star, we cannot say anything about its intrinsic brightness. A truly bright star that is very far away can appear to be fainter than an intrinsically dim star that is very close by.

Colors: Astute observers will note that the brighter stars have discernable colors. While most stars look whitish to the eye, some have a distinctive blue, yellow, or reddish appearance. The perceived color depends primarily on the *energy distribution* of the star's emitted light, which is a function of the star's surface temperature.

Another factor that influences the perceived color is the *spectral response* of the human eye, which is most sensitive to light in the green/yellow portion of the spectrum, diminishing at both blue and red wavelengths. Hence, hot stars will appear bluish to the eye, and cool stars will look reddish, provided they are sufficiently bright. Dim stars simply do not register enough light to trigger a color response from the eye, so the faint stars all appear white.

Names of Stars: Most of the brighter stars can be designated by a lower-case Greek letter and the (often abbreviated) constellation name (e.g., γ Cas and β Ori). Usually the stars are named in **order of brightness**, with α being the brightest, β the next brightest, etc. Thus, the brightest star in Taurus (Aldebaran) is also called α Tau. Because this Greek letter/constellation name syntax is so common, you should become familiar with the lower-case Greek alphabet.

The Lower-case Greek Alphabet

α	alpha	ι	iota	ρ	rho
β	beta	κ	kappa	σ	sigma
γ	gamma	λ	lambda	τ	tau
δ	delta	μ	mu	υ	upsilon
ε	epsilon	ν	nu	ϕ	phi
ζ	zeta	ξ	xi	o	omicron
η	eta	o	omicron	ψ	psi
θ	theta	π	pi	ω	omega

Stellar Distance and Magnitude:
It stands to reason that if you know how bright a star appears to be and how bright the star really is, then you can figure out how far off that star should be. This raises the issue of the two main types of magnitudes that you will see referred to in astronomy textbooks: apparent and absolute magnitudes. The apparent magnitude is the observed magnitude we've been talking about – the brightness of the star according to the observer, where the faintest visible to the naked eye has m = 6.0. Absolute magnitude relies on the internal, or intrinsic, brightness of the star. But how do determine the brightness of star when it depends on your distance to it? The way this is done is to define a *standard* distance from which to measure or define the brightness of star. In other words, how would all stars appear compared to one another if they were all placed at a set distance from us. That distance is 10 parsecs. The magnitude of a star, if it was 10 parsecs away, is the absolute magnitude

An equation relates the apparent magnitude (m) and absolute magnitude of a star (M) to the distance to the star from the observer (d, measured in parsecs):

$$m - M = 5\log_{10} d - 5$$

such that if you know both m and M you can figure out the distance to the star.

PART I: OBSERVATIONS AND DRAWINGS

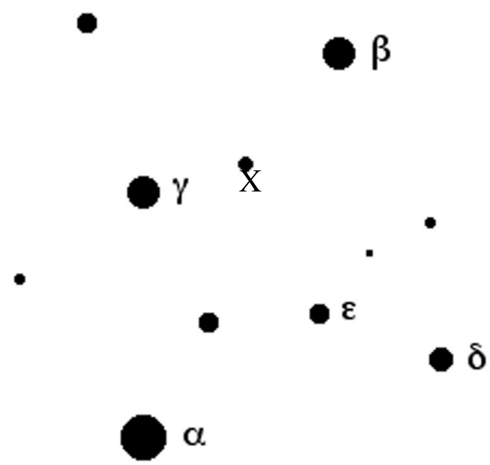
This exercise will give you the opportunity to replicate how stellar photometry (or the measurement of light) was done by ancient civilizations such as the Chinese and Arabs. The people in those days took measurements completely by eye, and even now, this approach is still practiced by many amateur observers to keep track of variable stars as they change their apparent brightness in our night sky.

Q1. Choose a constellation, or two adjacent constellations, located **high above the horizon**, **consisting of at least eight or more stars visible to your eye**.

Q2. Carefully draw this constellation on page 7, indicating the brightness of the stars in the same manner as they do on the star charts: with different sized dots, using larger dots for brighter stars and smaller ones for the fainter stars. Then label them with numbers so that 1 corresponds to the brightest star, 2 to the second brightest start and so on.

Q3. In the table on pg 8, next to the corresponding number, record the **GREEK NAME** of the stars you drew by using the **plates** in the Audubon (for example – α Canis Major). Note that you might not have gotten the stars in the right order, that's okay. For each star make an estimate of its magnitude, **using the table at the end of the lab and remembering that the faintest star you can see is probably ~3.5mag.** (DO NOT LOOK UP THE MAGNITUDES IN THE AUDUBON!)

EXAMPLE: In the set of stars below, some of brighter stars are labeled, together with some unknown stars. For this example let's look at star X. If we know that α has a magnitude of 2.3, γ is 3.8 and ε is 4.5, then we can make some estimate of how brightness of the unknown star. This star is very close in brightness to ε, but is slightly smaller and so, fainter. From looking at how much fainter γ is than ε, corresponding to a 0.7 mag difference, we can estimate how much fainter star X is than ε (probably 0.2 difference, so star X has a magnitude of 4.7).



Q4. Now make an estimate of each star's **color.** Colors of stars indicate their surface temperatures. The hottest stars (T = 10000 to 25000 K) appear quite blue, while the coolest stars (T = 3000 to 5000 K) look reddish. Using these facts, **circle the names of the hottest and coolest star** (so you should be circling two names only).

Q5. Pick an area **in the constellation you studied** to examine more carefully using a telescope. Use a 40 mm eyepiece so you have a nice wide angle view, and center the telescope on what you choose to be the best place – it should have a good collection of bright and faint stars. **Make a detailed and proportional (using the different sized dots) drawing of your field, as seen through the main telescope, on page 9.**

Q6. Using the same technique as step 3, **estimate the magnitudes of each star and simply write it next to the corresponding dot of your telescope drawing**. (NOTE: you will be able to see stars in the telescope that are fainter than 3.5mag).

Q7. Going back to your partially completed chart on page 8, and using the Audubon text, **record each star's actual name and magnitude.**

Q8. Using the equation for distance and magnitude, **solve for the distance** (d) in parsecs:

$$m - M = 5\log_{10} d - 5$$

Q9. Assume that all of the stars in your field have an *absolute* magnitude of M = +1.0. Calculate the corresponding distance to each star, in parsecs, based on your visual estimates of their apparent magnitudes (m). Record this in the chart on page 8.

PART II: QUESTIONS

Q10. Compare your estimated magnitudes in the Chart to the actual magnitudes. If they differed, why do you think this occurred?

Q11. Looking at the table at the end of the lab, is it always true that the star labeled α is always the brightest, and β the second brightest, etc.? If not, why do you think that this might be so?

Q12. Why do you think the measuring technique used tonight is better than just making a solitary measurement without comparing it to two or three stars at once?

Q13. The magnitude system may seem an archaic one, but now you have seen how it was originally formulated and applied to stars in the sky. Given that the system is essentially logarithmic, how many times brighter in appearance is a bright star in the sky (apparent magnitude of 0.0) compared to a star down at the limit of our naked eye vision (at a magnitude of 6.0)? (It is an astounding number and gives testament to how broad a range of light conditions our eyes can handle.)

<u>Summarize what you have learned in tonight's lab:</u>

Indoor Alternative

Using your star charts, pick a constellation and transcribe what you see drawn for the area of sky in question. Pay particular attention to naming the stars and getting their relative positions right. Do not just trace the positions, we'll be able to tell! If any of the stars you draw are listed in the table at the end of this script then mark their numerical magnitude next to the star's position and name. Extend your drawing to include the fainter stars that are unlabeled – assign some names to these stars (or numbers) so you can identify them. Using the technique discussed on page 4, make estimates of the magnitudes of all the stars in your drawing.

As in the fair weather exercise, assume that each star has an *absolute* magnitude of +1.0, and use this fact to calculate the distance to each of your stars in parsecs.

Constellation Sketch

a. Indicate the brightness of the stars with different sized dots, using larger dots for brighter stars and smaller ones for the fainter stars.
b. Identify N, S, E, and W on your diagram.
c. Then label them with numbers so that 1 corresponds to the brightest star.

Constellation Name(s): ________________________

Date: _________________ Time: ________ Instructor verification: __________

				(See Audubon Guide)		
Bright Stars	Your Assignment of Greek Letter	Your Estimate of Apparent Magnitude	Observed Color	Actual Name	Apparent Magnitude	Estimated Distance
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Telescope Sketch

Date: ____________________ Time: ________________________________

Table: Magnitudes of Brightest Stars in Some Spring Constellations

Auriga

α	0.09
β	1.90
γ	1.65
δ	3.72
ε	2.99
ζ	3.75 var
η	3.17
θ	2.69
ι	2.62
ν	3.97

Cassiopeia

α	2.24
β	2.27
γ	2.47
δ	2.68
ε	3.38
ζ	3.66
η	3.45
κ	4.15

Gemini

α	1.99,2.85
β	1.15
γ	1.93
δ	3.52
ε	2.98
ζ	3.79 var
η	3.20 var
θ	3.59
ι	3.80
κ	3.57
λ	3.58
μ	2.88
ν	4.15
ξ	3.37
ρ	4.16
υ	4.07

Leo

α	1.36
β	2.14
γ	2.61,3.80
δ	2.55
ε	2.96
ζ	3.43
η	3.52
θ	3.34
ι	3.93
λ	4.31
μ	3.88
ο	3.52
ρ	3.85

Orion

α	0.50 var
β	0.08
γ	1.64
δ	2.23,6.85
ε	1.70 var
ζ	1.77,4.21
η	3.35
ι	2.77
κ	2.04
λ	3.39
μ	4.12
π	3.19,4.36, 3.69,3.72, 4.47
σ	3.81
τ	3.60

Canis Major

α	-1.47
β	1.98
γ	4.10
δ	1.84
ε	1.50
ζ	3.02
η	2.40
ο	3.04,3.78

Perseus

α	1.79
β	2.12 var
γ	2.93
δ	2.99
ε	2.88
ζ	2.83
η	3.76
ι	4.05
κ	3.80
λ	4.29
μ	4.13
ν	3.77
ξ	4.03
ο	3.83
ρ	3.39 var
τ	3.95
υ	3.56
φ	4.06

Taurus

α	0.86
β	1.65
γ	3.63
δ	3.76
ε	3.54
ζ	2.99
η	2.86
θ	3.41,3.85
λ	3.47
ν	3.91
ξ	3.74
ο	3.60

Ursa Major

α	1.79
β	2.36
γ	2.44
δ	3.31
ε	1.76
ζ	2.05,3.96
η	1.86
θ	3.18
ι	3.14
κ	3.66
λ	3.45
μ	3.04
ν	3.48
ο	3.36
υ	3.77
χ	3.69
ψ	3.01