I. Objectives

1. Practice using a star chart.
2. Utilize the equatorial coordinate system and right ascension and declination coordinates.
3. Calculate the number of degrees represented by your finger, fist and spread out hand on your outstretched arm.
4. Use your finger, fist and spread out hand as angular measuring devices.
5. Locate, become familiar with and calculate the angular distances between the stars in certain constellations.

II. Introduction

During the semester you will need to determine the angular distances between objects in the sky and to estimate how far the objects seem to have moved between observations. Your fingers, fist, and hand will prove to be useful measuring tools.

There are estimates that we can use to determine angular distances. Stretch your arm in front of you. Your fingers measure an angle of approximately 1^o wide, your fist is about 10^o, and the distance between your spread out fingers between your thumb and pinkie is about 20^o.

Since we don't all have the same size fingers, fists, hands or arms, however, these angular distances are only approximations. To calibrate these angular distances in order to make more accurate measurements, we will use a star chart and objects whose angular distances we can calculate using the equatorial coordinate system and right ascension and declination coordinates.

III. Theory and Calculations

We need to use a little spherical trigonometry, and a calculator to determine the angular distances between objects in the sky. You need not be concerned with the details of the math. Note that subscripts used in the formulas help distinguish one quantity from another, where a subscript of 1 indicates the first object and a subscript of 2 indicates the second object.

To calculate the angular distance between two objects:

1. Record the right ascension and declination, a_1 and d_1 for the first object and the right ascension and declination, a_2 and d_2 for the second object. These can be found in any star catalog.

2. Convert a_1 and a_2, given in h m s (hours, minutes, and seconds) to decimal degrees (see the example below).

3. Convert d_1 and d_2, given in ^{o} ' " (degrees, arcminutes, and arcseconds) to decimal degrees (see the example below).

4. Calculate the difference in right ascension, $(a_1 - a_2)$.

5. $\cos d = \sin d_1 \sin d_2 + \cos d_1 \cos d_2 \cos (a_1 - a_2)$ where d_1 and d_2 are the declinations of the objects in decimal degrees, $a_1 - a_2$ is the difference in right ascension of the objects converted from hours to decimal degrees, d is the angular distance in decimal degrees, and sin and cos are functions on your calculator.

6. $d = \arccos (\cos d)$ where arccos is another function on your calculator which may appear as $\cos^{-1}$ or acos.

IV. Example

Before we begin, lets do an example calculation. We will determine the angular distance between Rigel (B Orionis) with a_1 = 05h 13m 31.7s, $d_1 = -8^o$ 13' 30", and Sirius (a Canis Majoris) with a_2 = 06h 44m 13.4s and $d_2 = -16^o$ 41' 11"

1. Convert a_1 = 05h 13m 31.7s to decimal hours:

$$5h + 13m \times \frac{1h}{60m} + 31.7s \times \frac{1h}{3{,}600s} = 5.225h$$

2. Convert a_2 = 06h 44m 13.4s to decimal hours:

$$6h + 44m \times \frac{1h}{60m} + 13.4s \times \frac{1h}{3{,}600s} = 6.737h$$

3. Calculate the difference in right ascension, $(a_1 - a_2)$ in h:

$$5.225h - 6.737h = -1.512h$$

4. Convert the number of hours, h, in the previous step to degrees by multiplying by $\frac{15^o}{1h}$:

$$-1.512h \times \frac{15^o}{1h} = -22.680^o = (a_1 - a_2)$$

5. Convert d_1 to decimal degrees:

$$8^o + 13' \times \frac{1^o}{6'0} + 30'' \times \frac{1^o}{3{,}600''} = 8.225^o$$

Since this number is negative be sure to write a negative sign in front of it: -8.225^o

6. Convert d_2 to decimal degrees:

$16^o + 41' \times \frac{1^o}{6'0} + 11'' \times \frac{1^o}{3{,}600''} = 16.686^o$

Since this number is negative be sure to write a negative sign in front of it: -16.686^o

7. Calculate $\cos d = \sin d_1 \sin d_2 + \cos d_1 \cos d_2 \cos (a_1 - a_2)$:

$\cos d = \sin (-8.225^o) \sin (-16.686^o) + \cos (-8.225^o) \cos (-16.686^o) \cos (-22.680^o)$

$= 0.916$

8. $d = \cos^{-1} (0.916) = 23.652^o$

9. Convert d to ^{o} ' " (degrees, arcminutes, and arcseconds):

The integer part of 23.652^o is 23^o

$23.652^o - 23^o = 0.652^o$

$0.652^o \times \frac{6'0}{1^o} = 39.12'$

The integer part of 39.12' is 39'

39.12' - 39' = 0.12'

$0.12' \times 60\frac{''}{1'} = 7.2''$

so the result is $d = 23^o$ 39' 7.2"

10. We can conclude that the angular distance between these two stars is:

$23.652^o = 23^o$ 39' 7.2"

V. Prelab Definitions

1. calibrate

2. angular distance

3. right ascension

4. declination

VI. Prelab Questions

1. Knowing the meaning of right ascension and declination is important when observing. Why?

2. Fall semester: Where are the constellations Scorpio and Sagittarius located in the evening sky relative to your zenith and your horizon? During what night time period are they visible?

   Spring semester: Where is the constellation Orion located in the evening sky relative to your zenith and your horizon? During what night time period is it visible?

VII. Lab Procedure

1. Using your fingers, fist or spread out hand measure the angular distances between the pairs of objects listed on the *Fall Stars Calibration Data* table (if you are taking the course in the fall) or the *Spring Stars Calibration Data* table (if you are taking the course in the spring). In column C, record which calibration devices you used and how many were needed to measure those distances.

2. Convert the measurements that you made with your fingers, fists and spread out hand and write the results in column D, estimated angular distance in degrees. Remember that your fingers measure an angle of approximately 1^o wide, your fist is about 10^o, and the distance between your spread out fingers between your thumb and pinkie is about 20^o.

3. Calculate the numbers in column F, difference, which is the absolute value of Estimated angular distance in degrees minus true angular distance in degrees.
   F = | D - E |

Fall Stars Calibration Data

A	B	C	D	E	F
First star	Second star	How many fingers, hands, fists?	Estimated angular distance in degrees	True angular distance in degrees	Difference F = | D - E |
Ascella	Antares			33.80	
Antares	Kaus Australis			25.90	
Shaula	Nunki			20.39	
Antares	Shaula			17.28	
Shaula	Kaus Australis			10.61	
Ascella	Kaus Australis			9.30	
Graffias	Antares			8.62	
Nunki	Ascella			3.93	

Spring Stars Calibration Data

A	B	C	D	E	F
First star	Second star	How many fingers, hands, fists?	Estimated angular distance in degrees	True angular distance in degrees	Difference F = | D - E |
Betelgeuse	Rigel			18.61	
Bellatrix	Saiph			16.98	
Bellatrix	Rigel			14.79	
Rigel	Saiph			8.33	
Betelgeuse	Bellatrix			7.53	
Alnitak	Mintaka			2.74	
Alnilam	Mintaka			1.39	
Alnitak	Alnilam			1.36	

VIII. Lab Discussion

1. Of fingers, fist, or spread out hand, which do you think you will use most often? Which provided you with the most precise measuring device? Why?

2. How accurate were the measurements you made in the *Fall Stars Calibration Data* table or the *Spring Stars Calibration Data* table?

3. Which measurements were the most difficult? Why?

4. Other than mathematical errors, what are the possible sources of error?