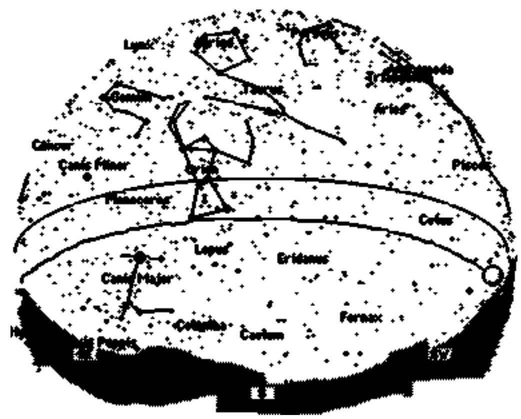
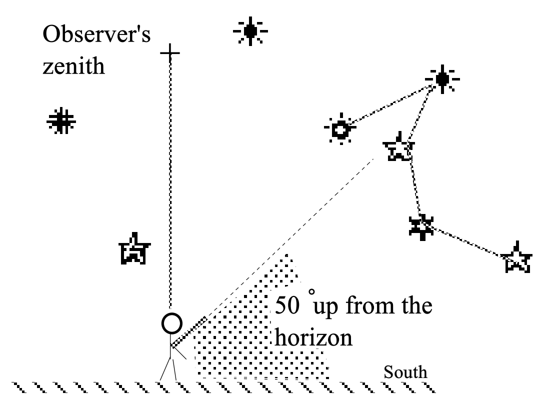
TAKE-HOME EXP. # 1
Naked-Eye Observations of Stars and Planets

Naked-eye observations of some of the brightest stars, constellations, and planets can help us locate our place in the universe. Such observations—plus our imaginations—allow us to actively participate in the movements of the universe. During the last few thousand years, what humans have said about the universe based on naked-eye observations of the night and day skies reveals the tentativeness of physical models based solely on sensory perception.



Create, in your mind's eye, the fixed celestial sphere. See yourself standing on the Earth at the center of this sphere. As you make the star-pattern drawings of this experiment, your perception may argue that the entire sphere of fixed star patterns is moving around the Earth and you. To break that illusion, you probably have to consciously shift your frame of reference—your mental viewpoint, in this case— to a point far above the Earth. From there you can watch the globe of Earth slowly rotate *you* , while the universe remains essentially stationary during your viewing
It is you that turns slowly underneath a fixed and unchanging pattern of lights.



Observer on local horizon plane

Naked eye observations and imagination has led to constellation names like "Big Bear" or "Big Dipper". These names don't change anything physically —except, and very importantly, they aid humans' memory and use of star patterns.

A. Overview

This experiment involves going outside to a location where you can observe a simple pattern of stars, including at least 2, but preferably 3 or 4 stars. If the Moon is nearby, you can include it in your pattern. After making sure that your position and orientation as an observer is known and reproducible, you can observe any changes that occur in the stars' locations with 3 separate observations and measurements over a 2-hour time period. The angle-measures you will use are relatively easy to learn, and it's fun to be able to locate things and have the language to communicate that information. Later in class, you can compare your readings to those of your investigative colleagues in the class.

If you are able to arrange it, it can be helpful to have one or two other colleagues to take the measurements with you. MAKE SURE YOU RECORD THEIR NAMES ON THE SHEET YOU HAND IN. As you will see when we discuss the detailed procedures, each person must make their own measurements, but the pattern you and your partners choose to observe can be the same.

B. Procedure for This Experiment

In choosing your observing time you should not start earlier than about an hour after sunset, so that evening twilight is over. (Or, if you would prefer, you can perform this entire exercise in relation to the predawn morning sky, finishing at least a half-hour before sunrise.)

In picking your observing location try to select a place where you have a relatively unobstructed (by buildings and trees) view of the sky. Find one that is as far away from streetlights as you can reasonably get. Ideally, the best location would be away from a metropolitan area.

It takes about 10 minutes for your eyes to "dark-adapt". Bright light changes the structure of chemicals your photosensitive retinal cells, particularly those that are most sensitive in dim light. These chemicals are constantly regenerated, but it takes about 10 minutes after exposure to bright light ends.

1. *Orient yourself to face directly SOUTH.*

> *Before making naked eye observations, you will have to determine which direction is south (as well as east, north, and west) by using a map or a compass*. Virtually all street maps are aligned with north at the top and south at the bottom. Sometimes our own assumed orientations are off. If you stand at a beach in Long Beach, California, looking out toward the ocean, you are usually looking more toward the south rather than west. Since you can

only communicate your observations accurately if you know which way you are looking, you need to take care in orienting yourself.

It will likely be helpful if you have a small penlight covered with red cellophane to use to look at diagrams and to record information. The reason for the red light is that it will not seriously reverse your eyes' dark adaptation.

When you are sure you are facing south, east will be on your left, west on your right. Your personal "meridian," meaning your line of longitude, comes directly up from the directly-south horizon you are facing, and passes through your zenith point directly over your head.

2. Come out again about one hour later.

(It is not too critical, since you will record the time.) *Orient yourself exactly in the same position as one hour earlier, and on the same diagram as above,* repeat the observations and recording of the same objects and kind of data in the first instance. Make a separate second table for the data.

3. Do the whole thing one more time, one hour later.

Again use the same diagram you started with, but construct a third separate table.

C. Easy-To-Use Angular Measures To Talk More Precisely about Your Observations.

Hand-At-Arm's-Length Estimates Of Angular Distance:

"Look at that star." you say to a friend, "Which one?" says your friend. "The one that's about two inches above that brightest star." "Two inches? How's that again?"[1]

Well, this clearly isn't an appropriate way to tell how far apart one star is from another in the night sky. Measures of length, whether in centimeters, inches, meters, or light-years, are unlikely to clearly communicate observations of positions of objects in the night sky. A better way is to use angular measures, numbers measured in degrees.

Angular measurement is the most effective and clearest way of speaking about star and planet positions from a fixed local position.

And its easy to do. Human beings are proportionally constructed so that the lengths of arms and the sizes of hands scale proportionately. Here's how to measure angles using your body.

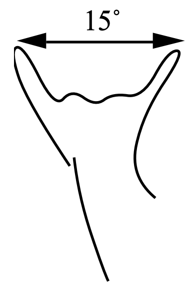
For all of these measurements:

IMPORTANT! Hold your arm out straight, *stretching to get your hand as far away from your eye as possible*. VERY IMPORTANT!

1) Keep your thumb tucked in, and stretch your little finger and your first finger as far apart as possible. The angle you see between the tips of your two fingers, from the tip of your little finger to the tip of your first finger, is about 15˚. To estimate 45˚ takes three of these distances.

A useful thing about this 15˚ measure is that it is the distance the Earth turns through in one hour.

So, if you are wondering "How long till sunset?", you can stretch out your arm and measure how many fingertip-to-tip spans there are to the position where the Sun sets. Two-and-one-half spans means 2 1/2 hours till sunset.

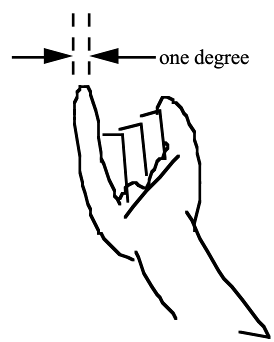


Don't forget to get this hand as far from the eye as you can by stretching out your arm, and there is no bend in your elbow.

2) With your palm toward you, make a fist with all but your little finger, which stays extended. Put it out at arm's length again, as far from your eye as you can get. The width of your little finger subtends an angle of one degree (1˚).

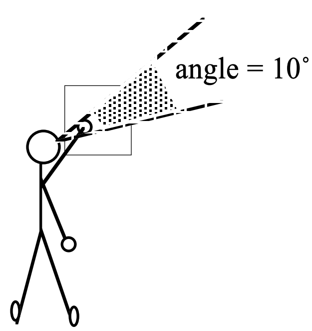
How wide do you think the Moon is? 3 degrees? 4 degrees? Try it. Most of you will have difficulty believing your eyes.

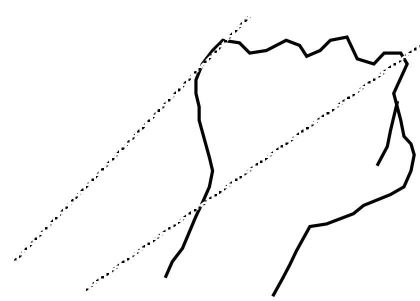
The Moon is only 1/2 degree wide seen from the Earth, about half the width of your little finger at arm's length!



Your arm must be stretched out, with no bend in the elbow.

3) Another measure you may find useful: looking at the back of your hand, make a fist with the thumb tucked underneath. Held at arm's length, the angular distance across the width of the knuckles is about 10˚ .





IMPORTANT! Hold your arm out straight, *stretching to get your hand as far away from your eye as possible*. VERY IMPORTANT!

D. Procedure for Drawing *(See example drawing on the next page.)*

1. *Draw a horizon line on a piece of paper.*
The horizon line is the line to which you point when you hold your arm and fingers straight out perpendicular to your standing body, and swing your arm horizontally left to right.

2. *Your diagram needs reference markers* drawn along the horizon line: a tree, a light pole, something that will allow you to come out an hour later, stand in the same place as before, and orient your view of the sky into exactly what it previously. Also, assuming you are facing South, mark East on the left side and West on the right.

3. *Indicate your meridian.* Your "meridian" is an imaginary line of longitude that passes through the N and S poles and your personal zenith, the point directly over your head. Thus a "meridian line" can be imagined as directly in front of you only when you are facing directly North or South.

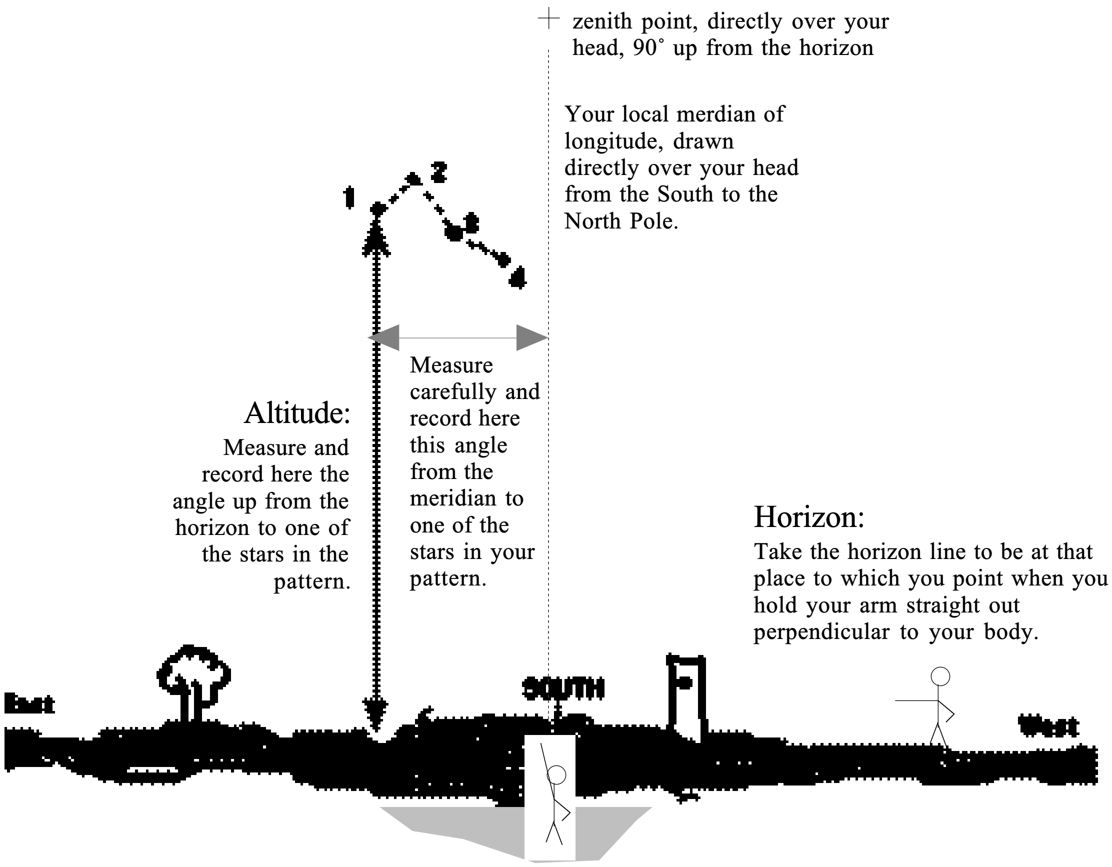
4. *Make a dot-diagram of the positions of a pattern of nearby stars.*
Any star-patterns that you observe are OK; there is no need to restrict yourself to just the formally named constellations. If not enough stars are available, the Moon can be included as part of the pattern. *Connect the star-dots so that you can more easily recognize the pattern later.*

5. *Use your outstretched arm and hand to make angular measures.*
IMPORTANT! Carefully measure the angle between the meridian and one of the prominent stars in your chosen pattern. Also measure its altitude, the number of degrees that a given star is directly above the horizon line. Take some pains to get the dots accurately located with respect to each other and to some horizon marker on your drawing.

The data that you will have to hand in are:

1) *one* diagram which records all three star-pattern sightings.
2) *three* data tables that record the information.
3) answers to the questions given later in this writeup.

An Example Of One Observation:



NOTE WELL:

The next two observations of your chosen star pattern are put on the <u>same single drawing</u>.

However, there are <u>three</u> <u>data tables</u>, like that below, one for each of the three observations. If there is room, the data tables can be put on the same page as your drawing, but it is not required.

Example Data Table:

Observation #1, 7 PM, 2/9/99

a) Facing directly south

b) Horizon markings and the meridian are shown on the drawing. Skies hazy, light pollution evident.

c) At 7 PM, star 1 is about 60˚ directly up from the horizon. Star 1 is about 15˚ directly east of the meridian. Stars 1 and 4 are a little over 10˚ apart.

d) The Moon was visible at the time. [If the Moon is in the range of your drawing, put in on your diagram, and measure its angular distance from the vertical meridian.]

See the back of the Data Sheet for a more general description of these data tables.

NAME (print) ___________________________________ ID# ___________________________________

PARTNERS NAMES (print)____

DATA SHEET

1. Did you face SOUTH as requested? **Yes** **No** If not SOUTH, what direction? ___________
How did you determine which way you looked? Did you use a map?

2. During the 3 observations, which way did the "celestial objects" you recorded move? west to east? east to west? north to south? *Look at your drawing for the answer, not in your head!*

3. Approximately, how many degrees per hour did your observed objects move during the course of your measurement? Here's how the answer to this question is constructed: Divide the angular distance that the star pattern moved by the time interval (in hours) required to make that change. An angular change occurs from sighting #1 to sighting #2, and from sighting #2 to sighting #3.

$$\text{angular speed of star pattern across sky} = \frac{\text{angular change in location of stars between sightings (in degrees)}}{\text{time interval between sightings}}$$

Show calculations here:

4. Finally, and this is important, estimate your uncertainty in the result by estimating how well you believe you were able to determine the various angles. Were you just a little finger's width uncertain (namely, an uncertainty of ±1°) , a fist-width's uncertain (namely, ±10° would be the uncertainty) , or somewhere in-between? State both the value determined in Ques. #3 above, and also state your estimate of uncertainty in the second space following the ± sign.

angular speed of pattern across the sky = ____________ ± __________ $\frac{\text{degrees}}{\text{hour}}$

5. State in explicit detail why the stars you observed seemed to move the way they did.

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(OVER)

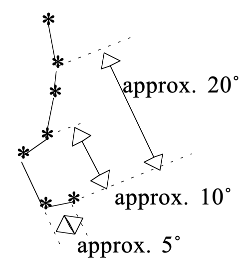
APPENDIX:

General description of a data table for these observations:

Observation #, time and date

a. The drawing shows your location and orientation with respect to local reference objects.
b. Sky conditions are given (i.e., clear, hazy, etc.).
c. IMPORTANT TO DO CAREFULLY. Make sure your arm is fully stretched out and your hand as far away from your eye as reasonably attainable. Measure the angular distance of one of the stars in your pattern with respect to your meridian; record it and label it. Also, measure the altitude angle of one of the stars. It is helpful to do the same measures for a second star in your pattern.
d. State if the Moon is visible, and record its shape, noting whether the curved lighted part of the surface of the Moon is toward the west or the east.

To the left is a possible reference constellation to check your angular measurements. This is the Big Dipper, also called The Big Bear or Ursa Major. It is visible in the northern sky for most viewers in the northern hemisphere. Its orientation may be anyway at all, since it appears to revolve once around the North Star every twenty-four hours.



Big Dipper

Your Report for this experiment consists of one star diagram with all sightings, 3 data tables, plus the answers to the questions.

Criteria To Use To Form Your Work
ORGANIZATION (clear and readable, with section headings)
DATA and DATA TABLES (clear and readable, with units and assigned uncertainties)
RESULTS (clearly indicated, correct calculation, units)
UNCERTAINTY ESTIMATES (data uncertainties are propagated to the results)
ANSWERS TO QUESTIONS (accuracy, completeness)

[1] The brief dialogue that begins Section C is from Guy Ottewell's book. For those of you interested in the general layout of the universe, shown in drawings with a 3-dimensional perspective, I recommend the purchase of *The Astronomical Companion* by Guy Ottewell, about $15, from Astronomical Calendar, c/o Dept. of Physics, Furman University, Greenville, S.C. 29613, (803) 294-2208.