name

Measuring Angles

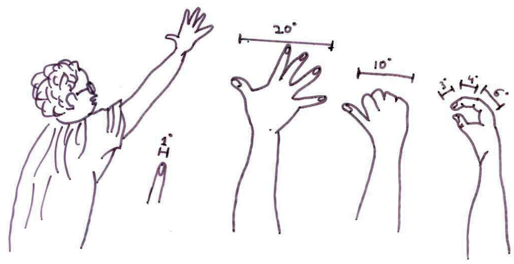
Fig 1: Islamic Astronomers of the Middle Ages in an Observatory in Istanbul.

Fig 2: Tycho Brahe in Denmark. His observations were later used by Kepler.

Have you ever thought how we determine the positions of stars, or the sizes of anything? If you want to know the size of Jupiter (or even just the moon), you can hardly fly to it with your ruler in your hand and measure it. However, the moon has a definite size in the sky. And what's the size of the entire sky? This seems a ridiculous question, however if we think in terms of angles it gets easier. One whole circle has 360 degrees. A huge cloud that occupies about one 10th of the sky then has a diameter of $180^o/10$, i.e., 18^o. Similarly, you can measure the diameter of the moon, which turns out to be about 0.5^o. So in Astronomy we always think in angles - *i.e.*, in "angular sizes." Thousands of years ago we observed and measured angles in the sky, and today we still do the same - and ironically we still use pretty much the same methods. In this Lab you will learn the simplest and most basic method of how to measure angles.

PART I

There are several methods of measuring angles and rather sophisticated instruments have been designed. Yet it is surprising how few people actually know how to determine angles with their own body parts… Maybe it is not quite as accurate, but at least it provides rather good estimates. This is how you do it – stretch out your arm. Your fist will cover an angle of about 10^o, your index finder 1^o, and you whole hand about 20^o.

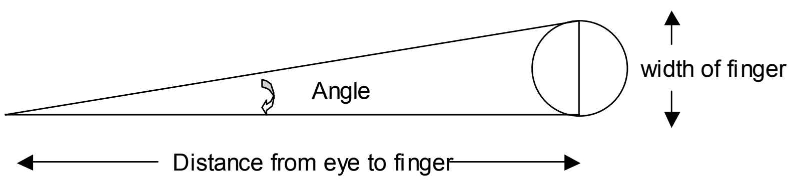


Let's check if this hypothesis. What is the angular size of your finger?

a) Extend your arm in front of you. Measure the distance between your eye and the tip of your index finger. ________________ cm

b) Measure the ***width*** of your index finger (across your finger nail). ________________ cm

c) Calculate the angular size of your finger in degrees. Consult the TOOLKIT to figure out which trigonometric function to use. Write the trigonometric function into the box. **SHOW** your calculation; **ZERO** points otherwise!



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d) Rewrite your answer using the rules of significant figures ________________ degrees

e) How could you determine the uncertainty in the angular size? Make a suggestion.

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Your estimated uncertainty (guess this) in the width of your finger is ________________ degrees

f) Rewrite your answer using significant figures and error estimates (Your answer should have the form of 13.4 ± 0.5 or so.) ________ ± ________ degrees

f) Does the One-Degree-per-Finger Rule apply to you? (In Astronomy we often use estimates. If your value falls within 30% of the expected value, your estimate is considered reasonable.) ________________

PART II

DETERMINING THE HEIGHT OF GIBBS LAB USING YOUR FINGERS

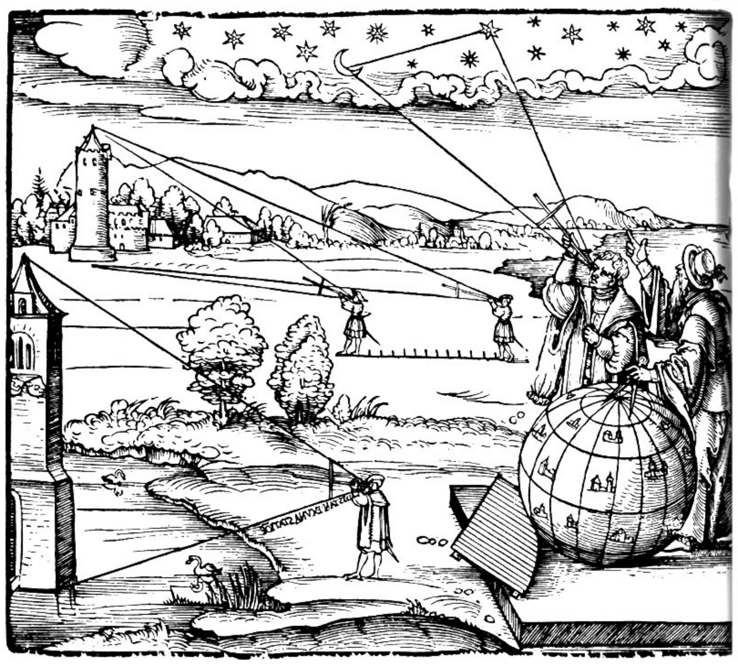

Fig 3: Woodcut from 1533: surveyors are using a cross-staff to measure angles.

Whether you use your fingers, or a cross-staff like in the above picture, the basic method is the same. While the measurements with the cross-staff are more accurate, your finger is a hell of a lot 'handier.'

a) From Prospect Street, ***how many*** finger widths is Gibbs Lab? Estimate the accuracy of your measurement. (Your answer should have the form of 13.4 ± 0.5 or so.) ________ ± ________ fingers

Go roughly halfway to the campus center. How many finger widths is the campus center at half that distance? ________ ± ________ fingers

Go roughly quarter the way to the campus center. ________ ± ________ fingers

b) What is the ***angular size*** of the campus center from building 4N? ________ ± ________ degrees

What is the ***angular size*** at half the distance to the campus center? ________ ± ________ degrees

What is the ***angular size*** at quarter the distance to the campus center? ________ ± ________ degrees

c) Explain in words how angular size and distance are related

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d) Abbreviate what you said (e.g., angular size increases/decreases as distance increases/decreases)

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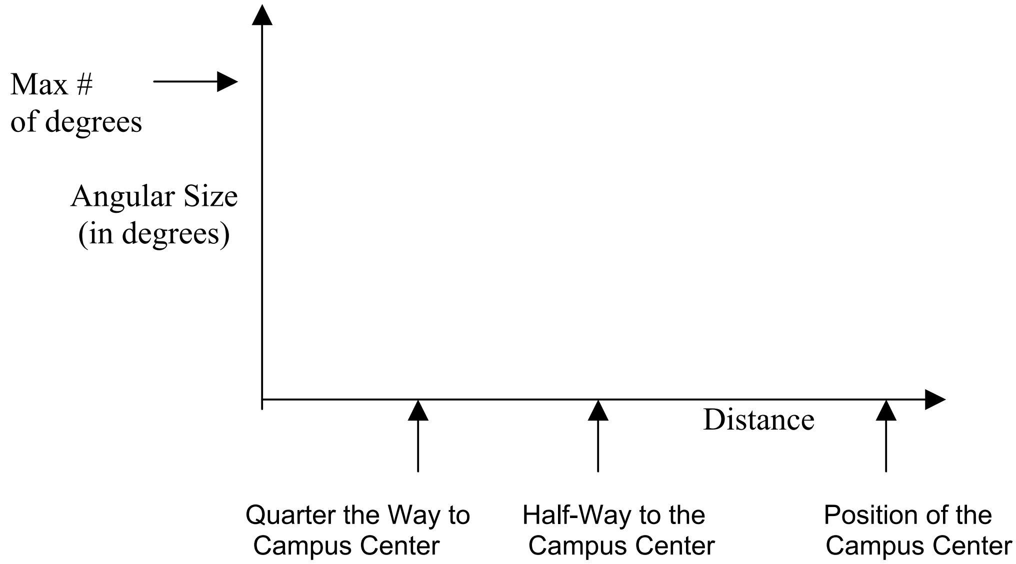
e) Insert three points into the plot below.



Is this plot consistent with your statement in (d)? ____________________

f) Now figure out the ***exact*** relationship between the angular size, the linear size and the distance.

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g) Given the distance to Gibbs Lab (from Prospect Street) is 110 meters calculate ***physical height*** in meters? Show your calculation.

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e) ***Estimate*** the uncertainty in that measurement. ____________ meters

f) The height of the campus center is ________ ± ________ meters

g) Let's check if this is a good method. Make an educated guess (in meters) of the height of each floor of Gibbs Lab. ________ ± ________ meters

h) Multiply by the number of floors to calculate the *physical* height ________ ± ________ meters

i) Are these two values consistent? (i.e., within 30% of each other?) ____________________

j) Do you think this is a good method to determine the height of Gibbs Lab? Would you use this method in Astronomy? **EXPLAIN.**

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PART III

DO AT Sunset

There is a rule of thumb (*no pun intended*) that the sun moves "one finger every ten minutes." Your assignment is to check this statement.

Observations

a) Find a spot where you can watch the Sun. Bring a watch and write down the time from the watch. ______________

b) Using your fingers determine the height of the Sun above the horizon. ______________ fingers

c) Estimate the uncertainty (fractions of fingers are okay) ______________ fingers

d) This corresponds to ... ±... degrees: ______ ± ______ degrees

e) Predict the time the sun will set according to the 10 min per finger rule. ______________

f) Come back at Sunset; record the time ______________

g) Was it close to your prediction?
(A measurement is generally regarded as "reasonable" if it falls within one third of the predicted value. For example if the predicted value is 100, any measurements within 60 and 130 are considered reasonable.) ______________

Theory

h) Calculate the theoretical value, *i.e.*, determine how many minutes it takes the sun to move 1^o. (HINT: The Sun takes 24 hours to move around the sky. This corresponds to 360^o. So you need to figure out how many minutes it takes the Sun to move 1^o.) **SHOW** calculation!

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i) Is the scheme of "10 minutes per finger" reasonable? (A measurement is reasonable if it falls within one third of the predicted value.) ______________

k) If it is not reasonable suggest a different wording

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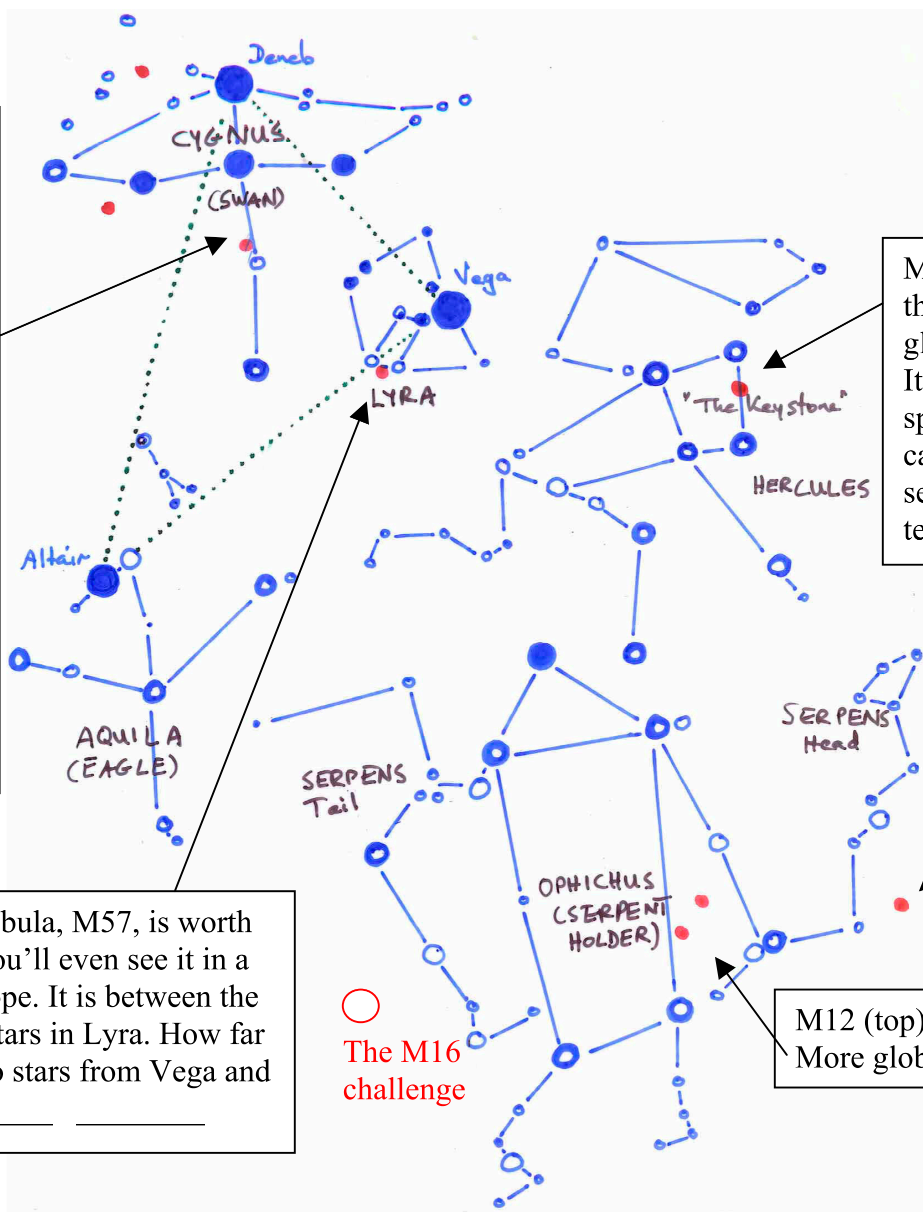
PART IV

DO AT Night

Go outside and look at the night sky and try to find the constellations below (look towards the Southwest, all the way up to the Zenith). You'll see Deneb and Vega above you (Vega in you Zenith), and Altair a little further South. These are the three brightest stars in the summer sky and are often referred to as the Summer Triangle. Use your fist and fingers to determine the size of the Summer Triangle. How far is Vega from Deneb, Deneb from Altair, and Altair from Vega? Use your fist and fingers to determine the distances. ____________ ____________ ____________

Deneb is in the constellation Cygnus (or Swan), which is sometimes called the Northern Cross. The star at the other end of the cross is Alberio, a rather spectacular double star. A little further to the south you'll see Altair in Aquila, west of that you'll see Hercules, and further in the Southwest will be Ophichus, the Serpent Holder. Scorpio (below Serpens) will be on the Southwest Horizon, but you might only see Scorpio's brightest Antares, which will be a little above the Horizon.



Cygnus X-1 is an elliptical galaxy with a dust-ring. It has a mass black hold in its center. It is in Cygnus, between Deneb and Altair. How many finger widths is it from Deneb and Alberio?

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M13 is one of the larger globular clusters. It is rather spectacular and can be easily seen with a small telescope.

The Ring Nebula, M57, is worth checking. You'll even see it in a small telescope. It is between the two fainter stars in Lyra. How far are these two stars from Vega and Altair? ________ _________

M5 – Globular Cluster

M12 (top) & M10 More globular clusters