Exercise set three

1 On paper: Introduction to celestial coordinates

Materials

celestial sphere model

Instructions

Astronomers use several different coordinate systems to describe the locations of objects in the sky. We have been using the “altitude-azimuth” or “horizontal” system, because it is useful for describing the apparent diurnal motion of objects in the sky. There are two big disadvantage of the alt-az system: one is that almost everything in the sky is constantly and rapidly changing coordinates all the time, the other is that alt-az coordinates vary from place to place on the Earth, even at the same moment in time. Astronomers, therefore, tend to use coordinate systems in which at least some celestial objects are more or less stationary. The most common of these is the “equatorial” system.

Imagine projecting the Earth’s system of latitude and longitude lines out onto the infinitely-large celestial sphere. This becomes the celestial North pole. We’ll keep the lines of latitude and refer to this coordinate as the “declination”, δ, the angle between the celestial equator and a point in the sky (expressed in $\pm$ degrees, arcminutes, arcseconds; $+$ for N, $-$ for S). There’s still a problem with the lines of longitude, though.

Instead of fixing lines of longitude to a point on the Earth, astronomers fix this coordinate to a (more or less) fixed point relative to the stars called the Vernal Equinox (we’ll talk more about this later). The zero line of “right ascension” passes through this point and the celestial poles, much like the zero line of longitude on Earth (the “Greenwich meridian”) passes through Greenwich, England and the Earth’s poles. You may want to refer to a celestial globe at this point to help you visualize this coordinate system.

Right ascension (RA) is not measured in degrees, but in hours, minutes, and seconds, increasing to the East. There are 24 hours of right ascension around the sky, with 60 minutes per hour, and 60 seconds per minute. Note that a minutes or second of right ascension is *not* the same as an arcminute or arcsecond.

The coordinates of a celestial object might be written like this: $5^h52^m0^s$, $+07°24'57"$.

Note that the precession of the Earth’s axis very slowly changes where the North celestial pole points in the sky, and thus shifts the whole coordinate system. For this reason, very precise astronomical coordinates are always specified along with a year, and have to be converted to be accurate at later times.

Answer the following questions in your lab notebook. You may work with other students, but show all your work. It is very important to keep units straight in these problems.

1. What constellation contains the celestial North pole?
2. Why is right ascension is measured in units of time (i.e. why is this convenient)?
3. Why does right ascension increase to the East?
4. How many degrees are in $1^h$of RA (along the celestial equator)?
5. How long does it take for the Earth to rotate through $24^h$of RA? Think carefully about what we learned in the first lab before you answer. *I want your answer to this question and the next two be precise to the second.*
6. If a star at RA $0^h0^m0^s$ is on your meridian at midnight, what will be the RA of a star overhead at 1:30am?

7. What star (or at least what constellation) is at $5^h52^m0^s$, $+07°24'57"$?
8. At midnight, tonight, stars with a RA of $10^h11^m53^s$ will be crossing the meridian. When will the star from the previous question transit?

2 Indoor: Calibrate your hand to measure angles

Materials

you, ruler, string

Instructions

Sextants allow the precise measurement of angles, but not all of us carry one in our back pocket (plus, as you all found out, they take some practice). So you are going to calibrate various parts of your hand to allow you to measure angles.

Turn your head 90°and extend your arm straight out from the shoulder. Now extend your thumb like you're hitchhiking. This will be one of your basic measuring devices.

Label and record all your measurements and calculations:

Measure the width of your thumb across the nail. Use the string to measure the distance from your eye to your thumb at arm's length. Repeat each measurement a couple times to get it as accurate as possible. Calculate the angle subtended by your thumb in degrees.

Repeat this process for your index finger and the width across your knuckles when you make a fist.

You now have three "devices" you can use any time to measure angles.

3 Indoor: Measure angles with your hand

Materials

you, ruler, string, your calculations of the angles subtended by your thumb, finger, and fist, hallway with markers

Instructions

Do the calibration exercise before this one.

At the West end of the 14th floor hall I have put a line of tape on the floor. I have also put two vertical lines of orange stickers on the wall. **Use various parts of your hand to measure the angular separation between the two lines, and the angular height of each line. Make sure to record what body part you used, the measurement in "body-part" units, and the final measurement in degrees. Repeat each measurement at least twice (this means you should have at least 6 measurements, total).**

Get your partner's help in using the string to measure the distance from your eye to the wall. Measure the height of each line and the separation between them and calculate the angles you just measured. How well do your results agree? What are your sources of error?

4 Outdoor: Measure angles with your hand

Materials

you, star charts, your calculations of the angles subtended by your thumb, finger, and fist, the sky

Instructions

Do the calibration exercise before this one.

Measure the angular separation between the stars Betelgeuse and Rigel in Orion, between Sirius and Procyon, and between Castor and Pollux. Repeat each measurement at least twice.

5 Outdoor: Measuring the positions of planets

Materials

you, star charts, your calculations of the angles subtended by your thumb, finger, and fist, the sky

Instructions

Do the calibration exercise before this one.

Find Mars and Saturn. You can go in and use the planetarium software if you have trouble identifying them.

Identify nearby constellations and draw a chart (or charts) showing the position of each planet.

Measure the angles between each planet and at least three of the stars on your chart. You don't have to know each star by name, but at least draw its position in its constellation so that you can identify it later using planetarium software.

6 Outdoor: Measure angles between buildings with your hand

Materials

you, your calculations of the angles subtended by your thumb, finger, and fist, the sky

Instructions

Do the calibration exercise before this one.

Measure the angle between the Empire State Building and Time Warner Center. The TWC is about $4.8km$ away. If you assume the Empire State Building is at the same distance, how far apart are the two buildings? Is the real separation greater or smaller than this?