Exercise set four

1 Analysis: Plotting the positions of planets

Materials

data from Set 3 "Outdoor: Measuring the positions of planets", ruler, pencil, star chart of region with RA and Dec

Instructions

You should have the angular distances between two or three stars and each planet you observed. In this exercise you will use that information to plot the position of each planet on a star chart. **Each of you should make a separate chart.**

First, figure out the angular scale of the chart: measure the separation x between lines of declination in cm. If the lines of declination are spaced d degrees apart, then your scale is $s = d/x$ degrees per centimeter. **Record your scale. Why isn't the scale exactly the same for the whole chart? Why do you use the lines of declination and not right ascension (think about a globe)?**

Now, if you want to convert a measurement of d degrees into cm on the chart, you would use $x = d/s$. If you want to convert a measurement of x cm on the chart into degree you would use $d = xs$.

First check your measurements of angular separations of pairs of stars. **Make a little table:** for each pair of stars list: the stars, the separation you measured in the sky, the separation you measure from the chart.

Convert your measurements of star-planet angular separations into chart units (cm). Use some paper to make a makeshift compass and *in pencil* trace an arc of the appropriate radius around each star. ***In pen* draw a point to indicate the location of each planet. Label it with the date of the observation.**

2 Long-term outdoor: Tracking the positions of planets

Instructions

This exercise will be performed outside of lab. You will use the skills you have learned in lab so far to track the positions the visible planets over the course of a semester.

At least once a week (*this means you need at least eight observations by the end*) you should measure the angular separations between each visible planet and at least three nearby stars. Make sure the stars are ones you can identify on the chart you will use for plotting. It also helps if the stars you choose "surround" the planet and are not too close to each other. Be aware of the weather and take advantage of clear nights when they occur.

To summarize:

Once a week go outside, find Mars and Saturn, record date and time, record the angular separations between each planet and several nearby, identifiable stars. Later you should plot the positions of the planets on your chart to make sure you are getting useful data.

At the end of the semester you will use these observations to construct a final chart showing the movement of the planets and to measure the speed of their motion.

3 Indoor: Parallax through a window

Instructions

Imagine riding in a train or car and watching the scenery go by. Nearby objects whizz by the window, while objects farther away seem to move more slowly, and distant clouds or stars on the horizon seem to hang motionless in the sky. Astronomers take advantage of this effect to measure the distances to solar-system objects and to nearby stars. These measurements are the basis of everything we know about distances in Astronomy.

I have set up a baseline (two points marked on the floor) and a target (taped to the window) for you to use to make some parallax measurements. **First measure the length of your baseline. Let's call this b.** Now pick a distant object that can be seen through the window from both ends of the baseline. Call this your "background object". **Now measure the angles between the target and the background object at each end of the baseline. Call these θ_1 and θ_2.**

The total angle you will use is $\theta = \theta_1 + \theta_2$. **Calculate the distance r to your target using θ and b (see below).**

For small angles a useful approximation is $\theta = b/r$ where b and r are the baseline and distance (measured in the same units) and θ is the angle in radians. You can convert to degrees by remembering that degrees = 180radians/π. So for the above problem you would use the formula $r = (b/\theta)(180/\pi)$.

4 On paper: Periods, velocities, and radii of circular orbits

Instructions

The centripetal acceleration of an object moving in a circle of radius r and speed v is $a = \frac{v^2}{r}$. The force due to gravity between objects of mass m_1 and m_2 is $F_g = \frac{Gm_1m_2}{r^2}$. Write an equation for the speed v of an object in a circular orbit of radius R around a body of mass M (hint: $F = ma$). Now write an equation for the period P of that circular orbit (hint: $c = 2\pi r$; $t = d/v$).

Let's say the Sun were twice as massive as it is.

If you wanted to recreate the Solar System with circular orbits of the original radii what parameters would you have to change? By how much?

If you wanted to recreate the Solar System with circular orbits of the original *period* what parameters would you have to change? By how much?

If you wanted to recreate the Solar System with circular orbits of the original *orbital velocities* what parameters would you have to change? By how much?

5 Computer: Orbit Explorer

Materials

computer with "Orbit Explorer" or other orbit simulation software

Instructions

Do this exercise after the previous one.

Play around with the orbit simulation software. Make sure you understand what all of the settings mean. Recreate the Earth-Moon system and watch it in motion. Zoom in on the Earth. **Does it move? Why or**

why not? What happens if you make the Moon twice as massive? What happens if you make the Earth twice as massive, instead?

Recreate the Solar System. Zoom in on the sun. **Which planet is most responsible for the motion of the Sun? What is the next most influential planet?**

Now set up a Solar System with just the Earth and a Sun that is twice as massive as normal. **Verify your answers to the previous exercise.**