Exercise set four

1 Outdoor: Telescopic observation in and out of the Galactic plane

Materials

lab notebook, writing implement, observing plan, full telescope set up

Instructions

Take a few minutes to look over your observing plan and make sure you know what you'll be doing when you go outside. **Write a couple sentences in your lab notebook about what you expect to see.**

Carry out your observing plan for a qualitative comparison of the densities of stars in and out of the plane of the Milky Way. **Record the date and time of your observations and any circumstance that might affect your observations (weather conditions, equipment failures, etc.). Write down a little bit about what you see around each of your targets and how they compare to each other. Draw a picture of each of your fields.**

After you have made your observations, write down some general impressions and answer these questions: Did your results confirm your expectations? Can you explain any discrepancies? How would you change your observing plan if you were to try this again?

2 Computer: Periods, velocities, and radii of circular orbits

Materials

lab notebook, writing implement, computer with orbit simulation software

Instructions

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?**

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?** Set this up in the orbit software and show it to me.

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? Set this up in the orbit software and show it to me.

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? Set this up in the orbit software and show it to me.

3 Introduction to celestial coordinates

Materials

lab notebook, writing implement, celestial globe

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. **Where does the projected North pole end up in the sky (this is 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 equation 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. **What is it?**

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 (the "Greenwich meridian") passes through Greenwich 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. **Why do you think RA is expression in units of time and Dec is not?** Note that a minutes or second of right ascension is *not* the same as an arcminute or arcsecond.

Answer the following questions in your lab notebook:

1. How many degrees are in an hour of RA (along the celestial equator)?
2. How many arcminutes are in a minute of RA?
3. How many arcseconds in a second?
4. If a star at RA $0^{\mathrm{h}}0^{\mathrm{m}}0^{\mathrm{s}}$ is on your meridian at midnight, what will the RA of a star overhead at 1:30am be?
5. How long (to the second) will it be until that star at RA $0^{\mathrm{h}}0^{\mathrm{m}}0^{\mathrm{s}}$ is directly overhead again?
6. If a star at RA $10^{\mathrm{h}}30^{\mathrm{m}}30^{\mathrm{s}}$ is directly overhead at midnight, how long (to the second) will it be before a star with RA $12^{\mathrm{h}}30^{\mathrm{m}}30^{\mathrm{s}}$ is overhead?

4 Computer: Motion of the Sun in the sky

Materials

lab notebook, writing implement, computer with orbit simulation software and planetarium software

Instructions

The path of the Sun against the stars is called the ecliptic. There are two points where the ecliptic crosses the celestial equator, called the Vernal Equinox and Autumnal Equinox. The Vernal Equinox, where the Sun crosses from the southern celestial hemisphere into the northern celestial hemisphere defines the $0^h0^m0^s$ line of right ascension.

Answer the following questions in your lab notebook before using the planetarium software:

1. Why is the ecliptic tilted with respect to the celestial equator?
2. The day and night are of equal lengths when the Sun is at either Equinox. Why?
3. What are the maximum and minimum declinations of the Sun, when do they occur, and what is the RA of the Sun at each point?

Now use planetarium software to watch the Sun's motion against the stars over the course of a year and check your answers to the last question. **Does the Sun move in the direction of increasing or decreasing RA? What constellations does the sun pass through over the course of the year, and when?**

5 Computer: Motion of planets in the sky

Materials

lab notebook, writing implement, computer with orbit simulation software and planetarium software

Instructions

Recreate the Solar System with just the Sun, Earth, and Mars. Approximate the *current* configuration of these bodies. **Draw it in your lab notebook.** You should use planetarium software to help you.

Using the planetarium software and orbit software, answer these questions:

1. Plot the RA of Mars against time (in, say, months) over the course of a year. Why does Mars sometimes move in the direction of increasing RA (Eastward) and sometimes in the opposite direction? Draw diagrams to explain. Hint: draw the relative positions of Earth and Mars at several different times and at each time draw a line connecting the two planets.
2. How long will it be before Mars is again in it's current configuration with the Earth and Sun?
3. Why do you think this configuration is called "opposition"?

6 Computer: Motion of the Moon in the sky

Materials

lab notebook, writing implement, computer with planetarium software

Instructions

Use planetarium software to watch the changing position of the Moon against the stars. **Roughly how fast does the Moon's RA change (in units of, say, minutes of RA per minute of time)? Why does the Moon's motion make a better clock than the motion of Mars?**

Before reliable clocks were available, navigators used to routinely take "lunar distances", meaning, essentially, that the RA of the Moon was determined by measuring the angular distance between the Moon and various stars of known RA. Tables of the RA of the Moon as a function of Greenwich time would then allow the determination of the time. Think back to some of our earlier labs: **Why is it important for a celestial navigator to know the time? What other sort of observation would the navigator need to make to determine longitude?**

Let's say you are using the "lunar distance" method to find Greenwich time. **If you were on the equator and wanted to be able to pinpoint your East-West location to within 10 nautical miles, how accurately would you have to measure the RA of the Moon?** Assume that the uncertainty in the RA measurement is the only appreciable source of error. Note: one nautical mile is defined (historically) as an arcminute along a great circle on the globe.