Astronomy 50

Lab Manual

Union College

Spring 2015

Professors Hallenbeck & LaBrake

Astronomy 50 Lab Policies **Spring 2015**
Professor LaBrake

For this course, you are required to complete five labs in three-hour sessions. Since you get Gen-Ed lab credit for AST-050, **the completion of the five labs is a requirement for the course**. For each lab you must show up, fully participate in the lab exercises, and turn in a written report. **Attendance will be taken**. In addition you will be required to attend one observatory open house. The schedule for labs and open houses is posted on the class schedule webpage, with as much notice as possible. If you have any conflicts, contact your lab instructor as soon as you know of the conflict (preferably, at least a week before the lab). If you miss a lab because of illness, contact your instructor as soon as you can and bring your instructor a note from the student health service (or whatever doctor or hospital you visited). **Please note that you cannot assume that you can just switch lab sections in a given week because the labs may not occur in parallel and because equipment is limited.**

The main goal of these labs is to teach you about the motions of the sky and several of the techniques by which the dimensions and motions of the Solar System have historically been determined. We'll find the size of and distance to the Moon, and the mass of Jupiter and an extrasolar planet (using Newton's law of gravitation). Weather permitting, there will be an outdoor observing laboratory, in which you will observe the Moon and any other bright planets visible in the evening hours. There will also be evening opportunities to observe using Union's 20-inch telescope on top of the Olin Center. Public open houses at the Observatory are scheduled regularly and will be posted on the class webpage. These events are weather-dependent: if it cloudy, they will be canceled. Check the Union College Observatory homepage for updates.
(http://www1.union.edu/wilkinf/observatory/observatory.htm or click on the link from the class homepage.)

E-mail: Evening labs may be canceled, due to weather for example, your lab instructor will send information regarding modifications to the schedule by e-mail, posts on Nexus, or on their website. If you want email sent to an account other than to your Union College account, please inform the instructor as soon as possible. Not receiving email or checking the posted lab schedule is not an excuse for missing lab, and will result in a failing lab grade.

Lab Reports: Each lab will require some written work to be handed in, and each student must hand in their own report. For some labs, only the completion of the appropriate pullout pages of the lab manual is necessary. Others may require a written report. Follow the instructions in the handouts for each lab.

Academic Honesty: Remember when you write the report, that it must be a reflection of your own knowledge and understanding. *Any report that has identical wording to another will be considered plagiarized*. In addition, if you take any material from of an *Internet source*, cite the source. Failure to do so will also be considered plagiarism.

Late Policy: Labs should be turned in by the deadline given at the time of the lab. There will be a 15% reduction in grade per day late and this includes weekends.

Note that Labs (and class activities) will count 20% towards your final course grade.

Astronomy 50, Spring 2015

Lab 1: Sky Motions and Planet Visibilities

In this lab, we will examine motions on the sky and the orbits of planets as seen from the Earth. We will use two-dimensional sky charts and the Voyager SkyGazer planetarium software that came with your textbook. Questions are listed on the Handout sheets – please fill in your answers there and hand in only those sheets.

I. Introduction

The Sky: Coordinate Systems. Since the goal of astronomers is to observe and understand things that we see in the sky, we need to establish a system for finding things on the sky. That is, we need to set up a "mapping" system for the sky so that whenever we choose to observe something, we need only to look up the position of that object, as defined in our mapping system, and point our telescope to that particular location on the sky. This is also called a "coordinate system:" we assign each object a set of coordinates that are defined by the mapping system. Here is a general overview of the most important aspects. First be warned that most of this is hard to follow just by reading unless you are exceptionally skilled at 3-D imaging of a verbal description and also keeping track of definitions at the same time. Refer to the Sky Motions Laboratory Readings (linked under Lab 1 on the Astronomy 50 Schedule webpage) and the SkyGazer planetarium program.

Mapping the sky is a bit complicated. The sky (as we view it from the Earth) is spherical, and not flat like a road map. This is not a new complexity, though; the Earth is also spherical. The logical solution is to set up a completely analogous system. So, imagine that the sky is a spherical shell surrounding the Earth, and that it has lines on it that look like the Earth's lines of longitude and latitude. We call this imaginary spherical shell the "**celestial sphere**." The terms that astronomers use for these lines on the celestial sphere are "**right ascension**" (often abbreviated either as RA or with the greek letter α) and "**declination**," (abbreviated either as dec or δ). The lines of Right Ascension are the extensions of the lines of longitude and the lines of declination are the extension of the lines of latitude. Since the apparent rotation of the sky is actually due to the rotation of the Earth, the "poles" of the celestial sphere are the points directly overhead the poles on the Earth. The celestial sphere, then, rotates like a sphere with a pole running through it from the north celestial pole to the south celestial pole.

A complication of mapping the sky is the rotation of the Earth, which causes the celestial sphere to rotate as we watch it, so that lines of right ascension and declination appear to move. The apparent motions of the sky depend on our location on Earth and what direction we view the sky. You will view the motions in the four cardinal directions (north, south, east, west) in the StarLab and sketch them on your worksheet.

It takes a "**sidereal day**" for a particular line of right ascension to return to the same location in the sky, i.e., it takes a sidereal day for a particular star to return to the same location in the sky. In contrast a "**solar day**", which is what we use for time, is the length of time for the Sun to return to the same location in the sky. A solar day is 24 hours long.

A sidereal day is 23hours 56 minutes long. It is shorter because the Earth travels in its orbit and so it must rotate a bit more before the Sun is back in the same apparent position. This means that a star will rise 4 minutes earlier each night. After a month, a star will rise 2 hours earlier. So our perspective of the Universe changes throughout the year. We must take these motions into account when timing observations.

We need also to define a system that describes the way a particular observer sees the sky at any particular moment in time. Several important terms are:

a) "**horizon**": defines the limit of what parts of the sky you can see at any particular moment. It is due to the ground and structures on the Earth blocking your view of the sky. If the Earth were transparent, you could also view the sky below your feet by looking through the Earth. But, since the Earth is not transparent, you can't see this part of the sky, we say, because it is "below your horizon."

b) "**altitude**" (or “**elevation**”): is the height of an object above your horizon at any given moment. It is measured as an angle (since you can't really define the linear distance of a star above the horizon). When a star is on your horizon (so that it is either just rising or just setting) its altitude is 0^{o} and when it is directly overhead, its altitude is 90^{o}.

c) "**zenith**": is the point in the sky directly overhead. The object at your zenith, then, has an altitude of 90^{o}. Since the sky rotates continuously, this point on the celestial sphere continually changes, unless you are standing on the either the North or South pole.

d) "**meridian**": is a line that runs through your zenith and through the north and south celestial poles. This is a useful because it defines the highest point of a star (the largest altitude) during its trek from East to West. Consider the following: As the Earth rotates; you will see the stars move across the sky from East to West. Some of the stars (the stars that are at the same declination as your latitude, meaning that they are on the same East-West line as you) will pass directly overhead on their trek westward. The moment that these stars are directly overhead (i.e. at the zenith) is, obviously, the moment when they are "highest" in the sky. But most stars will never pass directly overhead. However the meridian still marks their highest altitude in the sky. This is important because it is the best time to observe a particular object, and it also defines the mid-point of the time that a star is visible above the horizon (i.e. the moment in time exactly halfway between when it rises and when it sets). It is also the highest altitude for circumpolar (see below) stars.

e) "**transit**": (verb) means to pass through the meridian. So, if I ask when does Mars transit, I mean at what time of day is Mars highest in the sky. This is a typical question whose real meaning is "when is the best time to observe Mars?"

f) “**circumpolar**”: Stars which are near the north pole never rise or set, rather they are always above the horizon. At what location on the Earth are all stars circumpolar?

g) **ecliptic:** The planets and the Sun (and the Moon to some extent) follow approximately the same apparent path--this path is called the "**ecliptic**".

II. Voyager SkyGazer software

Follow these instructions and answer questions on the worksheet handout that you will hand in.

1. Open the SkyGazer software from the CDROM or use the program on the computer. Under the *Chart* Menu, click on *Set Location* to set the location to Schenectady (you can use the *List Cities* button). Next hit the *Now* button in the Time Panel to reset the time to the computer clock. You will need to do this whenever you open the program (you can save your settings on your own computer so you don't have to do this). SkyGazer now shows the view of the sky toward the West at the current time. Now change the time to sunset today – do this by clicking on the pull-down menu in the time panel and click on *Set Time to Sunset.*

   The SkyGazer software can operate in a planetarium mode, although it is projected in 2-D. Using SkyGazer, you can examine the motions of the stars and planets in time. To do this, set *Sky View* in the *Chart* Menu to Stereographic (Planetarium) mode. Under *Display*, click on *Sky and Horizon* and check on the *Cardinal Points* and change the Horizon to Opaque (at bottom). Hit OK to Exit. Zoom out (using the zoom buttons at lower left in your window – note that they may be located under the task bar) so your display shows the whole sky. Change the interval in the Time Panel to 1 min. To move the sky, press *Start* in the Time Panel; this causes the sky to continuously move using the interval indicated. Observe the motions of the stars. What can you say about the motion of the star? **Fill in your answers on the worksheet.**

   Are any planets visible in the early evening (just after sunset) today? If so, which ones and where would you look (e.g., give approximate angle above the horizon and direction such as West, Southwest, etc.)? You can scroll the sky using the scroll bars and/or change the zoom at lower left. **Fill in your answers on the worksheet.**

   Explore how the appearance of the sky changes as you change the latitude. Try locations further north, in the southern hemisphere, and at the equator.

2. SkyGazer can be used to visualize the Solar System and determine the visibility of planets. At left bottom, change "Local Horizon" to "Solar System." This will open a view of the Solar System with background stars. Click off the constellation grids. You can also click off the stars if helpful. Under Display, click on Planets and Moons and turn on the Planet Orbits. You can change the viewpoint of the Solar System using the *Latitude* arrow in the Location Panel. You can also zoom in or out of the Solar System using the *Distance* scroll bar. Change the settings until you have a feel for the shape of the Solar System. How would you describe the shape of the Solar System?

3. Now set the *Latitude* to 90 and the distance to about 5 AU. Click on *Now* in the Time Panel. Look at the position of Earth relative to the other planets. To see the direction in which the planets rotate, set the time interval to 1 day (click on the box giving the interval, and then choose a new interval from the box which pops up) and then press

the *Start* button in the Time Panel. Check the rotation directions of all the planets by zooming out using the *Distance* bar. How do the orbital speeds of the planets compare?

4. By examining the relative positions of the Earth and the other planets, you can tell which planets are visible at night now and when they are best observed during the night. Click on *Now* in the Time Panel. For each of the indicated planets, give the approximate times of visibility (e.g., "between 3am and dawn", or "dusk to 9pm"). Hint: Earth is turning in a counter-clockwise direction if you view the solar system from a latitude of 90. Determine first where you would have to be on Earth to see a dark sky. Then determine the location of sunset and sunrise. Now look at the locations of the planets and determine whether you can see them when the sky is dark. Start with Jupiter, then Saturn, and then look at the other listed planets.

5 . Now change the time interval to 1 month. Advance 1 month at a time by pressing the ▌► button instead of *Start*. Investigate how the visibility of each of the indicated planets varies over the next year and when each is best observed. Consider the following:
(a) The best observations of outer planets are made when the planet is in **opposition**, meaning it is located in a direction directly opposite the Sun. At what times of the night can a planet in opposition be viewed? At what time of the night is the planet best viewed when it is at opposition?
(b) Planets cannot be observed when they are close to **conjunction**, meaning that they are in the direction of the Sun. What planets will be in conjunction in the next year and when?
(c) The best observations of planets interior to Earth are made when the planets are at **greatest elongation**, i.e., the greatest apparent angular distance away from the Sun. What are the greatest elongation angles for Mercury and Venus? Do these planets reach greatest elongation in the next year? Why is it harder to see Mercury than Venus?

6. Each planet has its own orbital (sidereal) period around the Sun. Another important periodic motion as viewed from Earth is the **synodic period**, the time it takes for a planet to return to the same place in the sky with respect to the Sun, as viewed from Earth. Find the synodic period of Venus.

7. Explore how the motions of the planets looks from the perspective of Earth. Under the *Explore* menu, click on *Paths of Planets*. The demo opens showing the motion of the Sun along the Ecliptic. Press the ➤► button to see how the Sun moves along the ecliptic. Planets follow apparently **retrograde motions** on the sky. For example, select the "Looping Path of Mars". Observe the motion of Mars with respect to the Earth.

EXTRA CREDIT: Union College has its very own antique Orrery. It is displayed in Wold Building on the second floor near the stairwell. Stop by and view the Orrery. Union College is fortunate to have many fine pieces of antique equipment, and the Orrery is one of our best.

Astronomy 50, Spring 2015

Lab 1: Sky Motions and Planet Visibilities Worksheet

NAME:______________________________

<u>Lab 1, Part I: Sky Motions</u>

Check out links to readings to help you with this part at this webpage:
http://minerva.union.edu/koopmanr/links.htm

You may also find it useful to refer to your Voyager SkyGazer software to help answer some of these questions.

1. Make a sketch of the celestial sphere, as viewed from our latitude. Your drawing should look similar to the celestial sphere drawings that are under the “Readings helpful for Lab Material” link under Laboratory 1 on the schedule webpage or in Chapter S1 of your textbook. Identify the following in your drawing: horizon, zenith, north pole.

2. What is the significance of the North Star, in terms of the apparent motions of the stars as viewed from the northern hemisphere? Briefly explain why the apparent motions appear as they do.

3. Say that you observe the motions of the stars from the North Pole. How would the apparent motions of the stars differ from those observed in Schenectady? How would they differ if observed from a location on the Earth's equator? Make sketches of the motion of stars at the zenith.

4. Does the Sun rise and set in the same apparent locations throughout the year? Why or why not?

5. Why do all the planets and Sun, and to some extent the Moon, all generally appear along one line on the sky? What does that line represent?

Lab1, Part II: Voyager SkyGazer

1. What can you conclude about the motion of the stars? What planets are currently visible in the evening on the day of this lab? In which direction and at what approximate angle above the horizon would you look?

2. Describe the shape of the Solar System (e.g., round, football, frisbee).

3. Describe the motions of the planets around the Sun. In what directions do the planets move? Describe the relative orbital speeds of the planets.

4. Which of the planets are visible during dark hours tonight and what is the approximate time range over which they are visible? For each of the indicated planets, give the approximate times of visibility (e.g., "between 3am and dawn" or "dusk to 9pm"). If not visible, state this.

Mars:

Jupiter:

Saturn:

Venus:

Mercury:

5. (a) Which planets will be at **opposition** in the next year and when?

(b) Which planets will be at **conjunction** this year and when? (For Mercury and Venus, list the first conjunction, if there is one.)

(c) What are the maximum **elongation angle**s for Mercury and Venus? Do these planets reach maximum elongation in the next year? Why is it harder to see Mercury than Venus?

(d) Summarize how the visibility of each of the indicated planets varies *over the next year* and which months are the best to observe the planet in. Your answers should include a description of how the visibility of the planet varies over the entire year (e.g., "visible earlier and earlier in the evening until March, reappears in pre-dawn sky in August, visible earlier and earlier in the morning")

Mars:

Jupiter:

Saturn:

Venus:

6. What is the synodic period of Venus?

7. Why do planets as viewed from Earth follow retrograde paths? Explain in terms of the actual motions of the planets. Do both inner and outer planets follow retrograde paths and why or why not?

EXTRA CREDIT:
What year was the Orrery constructed?

How many planets are included in the Union College Orrery? List them:

Are all the planets geared (i.e., connected to the mechanism to simulate the correct orbit)? Why or why not?