Planetary Astronomy

I. OBJECTIVES

Thousands of years ago, shepherds watched the night skies and measured time and seasons by the movements of stars and planets. This art, surviving through the centuries, is now the province of scientists. People no longer watch the heavens night after night. Street lights make city viewing difficult. Many adults do not even recognize the yearly motion of the stars or the wandering planetary paths through them. The purpose of this lab is to acquaint you with these motions and show you why they occur. By the end of this lab, you will be able to:

- read the SC001 star chart;
- use **Voyager II**, the computer planetarium;
- predict when you can view an astronomical object;
- recognize and understand the structure of the solar system;
- understand the motions of planets;
- predict what is going on in the sky throughout the semester;
- learn good observing habits.

II. PRE-CLASS PREPARATION

A. CONCEPTS. Read **Section III** of this lab concerning the ***celestial sphere***, ***right ascension and declination***, and ***altitude and azimuth***. Know what the ***ecliptic*** is, and where to find the ***zenith*** and ***meridian***. Understand what a constellation is and what is meant by saying that a ***constellation*** is part of the ***zodiac***.

B. APPARATUS. Make sure you understand the basics of using the Macintosh computer. Review the **Macintosh Computers** appendix of this manual. You should also examine the celestial sphere globes in the lab. Note the way it can be moved to simulate the position of Earth, the Sun, and the stars.

III. PLANETARY ASTRONOMY THROUGH THE AGES

A. SKY MOTIONS. Planetary astronomy is rooted in the very beginning of civilization. This can be seen in the ***constellations*** (from the Latin word meaning "group of stars"), which are imagined pictures among groupings of stars. Many constellations have names derived from ancient myths and legends; and while some constellations resemble the figures they are named for, most do not. You may be familiar with the pattern known as the Big Dipper, which is actually part of the constellation Ursa Major (the Great Bear), or with the constellation Orion (the Hunter). On modern star charts, 88 constellations cover the sky and are separated into 88 areas by constellation boundaries. Some of these areas are small (like Crux), and some are large (like Ursa Major).

Earth rotates from west to east once every 24 hours. This daily motion of the stars is called ***diurnal motion***. Diurnal motion causes the stars, the Sun, the Moon, and the planets to rise in the east and set in the west. If you see a constellation rising in the east right after sunset, you will see the entire pattern move across the sky as the night progresses. If you look again just before dawn, you will see the same constellation setting in the west.

The constellations that you see in the sky change according to where you are on Earth and where Earth is in its orbit. Wherever you are on Earth, half of the constellations in the sky will be below your horizon. In Tucson we see all of the northern constellations, but few of the southern ones (like Crux). We would have to go to the southern hemisphere to see them. We will also see different constellations as Earth moves in its orbit around the Sun. Because Earth takes a year to orbit the Sun, the darkened, nighttime side of Earth is gradually turned towards different parts of the sky. If you watch a particular star every evening, you will find that it rises approximately four minutes earlier each night.

Diurnal motions are not the only motions you see in the sky. Planets move across the sky relative to the stars. The word ***planet*** comes from the Greek word ***planetes*** meaning “wanderer.” These strange objects look a lot like stars to the naked eye, but there are a few differences. Most of the planets are brighter in the sky than stars (except the sun) and tend to “twinkle” less.

As seen from Earth, the planets wander across the sky, through the 12 constellations of the ***zodiac***, in a slow, eastwardly motion. This is called ***direct motion***. Occasionally the planets will seem to stop and then back up for several weeks or even months! This motion is called ***retrograde motion***. Both of these motions can be detected by mapping the position of the planet relative to the background stars from night to night over a long period of time.

For a long time, retrograde motion was not understood. Ancient Greek astronomers developed many theories to account for this backward motion. However, it wasn’t until Nicolaus Copernicus (1473-1543) worked out the details of a heliocentric system (in which the planets revolve around the Sun) that retrograde motion could be satisfactorily explained. The Greek astronomer Aristarchus then suggested the straightforward explanation that retrograde motion occurs when Earth overtakes and passes a planet (see Figure 1). Think of it this way: when you are driving down the freeway and pass a car that is moving slower than you, the slow car appears to move backwards while you pass it!

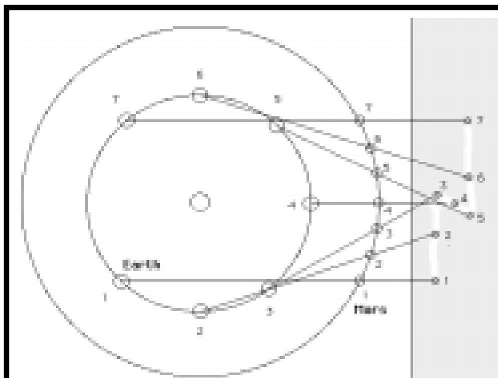

FIGURE 1: Retrograde Motion

B. THE CELESTIAL SPHERE. A useful way of visualizing the motion of the heavens is by using a ***celestial sphere***. The celestial sphere is an imaginary sphere that the stars are “attached to” and whose center is Earth. (See Figure 2) Although some stars are closer to us than others, to our eyes they all appear equally distant. By attaching them to an imaginary sphere the stars provide a reference for specifying the locations of objects in the sky. This works well because the stars in our sky are so remote that their relative motions are negligible over thousands of years.

The celestial sphere is a map of the sky not unlike a globe of Earth (see the globe in Figure 2). The ***celestial equator*** is Earth’s equator projected onto the celestial sphere, dividing it into northern and southern hemispheres. Projecting Earth’s north and south poles onto the sphere, we obtain the ***north and south celestial poles***. Next, we place a grid on the sphere (similar to longitude and latitude) called ***right ascension and declination***. ***Declination*** corresponds to latitude. It is the angular distance north (positive declination) or south (negative declination) of the celestial equator. ***Right ascension*** corresponds to longitude, but is measured in units of time rather than angular distance. The time units correspond to the time required for the celestial sphere to rotate through an angle (360˚ = 24 hours; one hour of R.A. = 15˚). In most catalogs of astronomical objects, positions are given by their right ascension (R.A.) and declination (Dec.).

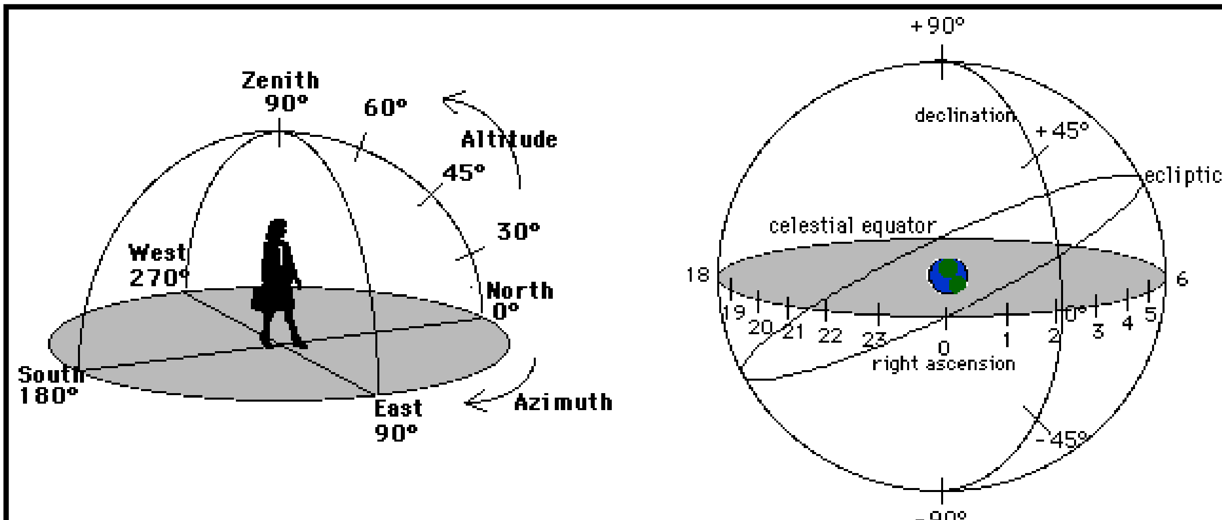

FIGURE 2: Coordinate Systems.

Although the celestial equator is a projection of Earth’s equator, it is not the same as the plane of the solar system. Earth’s axis is tilted 23.5˚ with respect to the plane of its orbit. It is this tilt that gives Earth its seasons.

The Sun and most of the planets can be found in the plane of the solar system. As Earth moves along its orbit, the Sun’s position with respect to the background stars changes. The Sun traces out a path along the celestial sphere that we call the ***ecliptic***. The constellations that the ecliptic travels through are known as the ***zodiac***. You can also find the planets near the ecliptic since most planets orbit in the plane of the solar system.

A few other useful coordinate references are the zenith, the nadir, and the meridian. The ***zenith*** is the point on the celestial sphere that is directly above the observation point on Earth (i.e., straight up!). The ***nadir*** is the point that is straight down on the other side of the sphere. The ***meridian*** is the line that connects the north and south celestial poles and runs through the zenith. When a celestial object crosses the meridian we say that it ***transits*** the meridian.

C. THE ALTAZIMUTH COORDINATE SYSTEM. Although the R.A. - Dec. coordinate system is the most commonly used coordinate system for celestial objects, it is not the only one. Another common choice is altitude and azimuth. ***Altitude*** is the angular distance of an object above the horizon. ***Azimuth*** is the angular distance of an object measured clockwise from north (in degrees) (see Figure 3). For example, a star to the north would have an azimuth of 0˚, to the east it would be 90˚, to the south it would be 180˚, and to the west it would be 270˚. The altazimuth system is useful for people who have *the same local horizon* (altazimuth is locally dependent) and wish to communicate where an object is in the sky. It is easy to estimate altazimuth coordinates by looking. If you hold your hand out at arm's length, the width of your index finger is approximately 1˚ and the width of your hand just below your fingers (not including your thumb) is about 10˚ (see Figure 2).

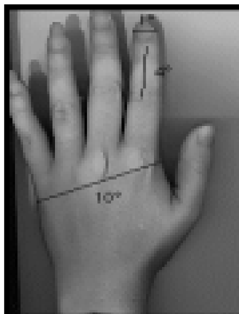

FIGURE 3: Angle approximations

D. ORBITAL GEOMETRIES. There are many interesting things that occur in our sky! Conjunctions are always popular...both with astronomers and the astrologers. ***Conjunctions*** occur when two celestial objects appear to come together in the sky. This does not mean that they are running into each other, just that they line up from our point of view. ***Eclipses*** are one type of conjunction. ***Solar eclipses*** occur when the Sun and the Moon conjunct, while ***lunar eclipses*** occur when the moon and Earth's shadow conjunct.

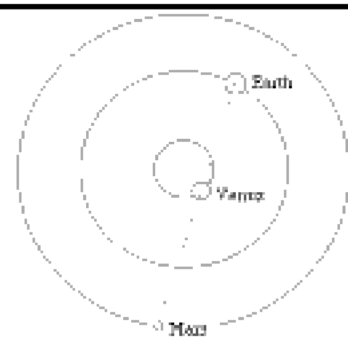

FIGURE 4: Conjunction

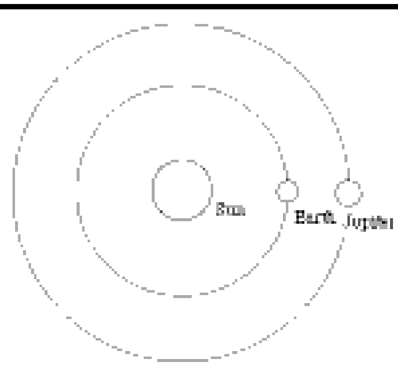

FIGURE 5: Opposition

We say that a planet is in ***opposition*** when it is directly lined up with Earth and the Sun, and Earth is in the middle. This is the best time to view a superior planet, because the Sun is in the opposite direction and won't interfere with your observation. (A ***superior planet*** is a planet that is farther from the Sun than Earth. An ***inferior*** planet is closer to the Sun.) Inferior planets can never be in opposition. A superior planet goes through opposition during its retrograde motion.

Elongation is the angular distance between the Sun and an inferior planet as seen from Earth. The greater the elongation, the farther a planet appears to be from the Sun. ***Maximum elongation*** is the greatest elongation achieved by a planet. Elongations can be either east or west. This means that the planet is to the east or to the west of the Sun. If it is west of the Sun, it will rise before the Sun does. This makes the best viewing time right before sunrise. If it is east of the Sun, it will set after the Sun sets. This makes the best viewing time right after sunset.

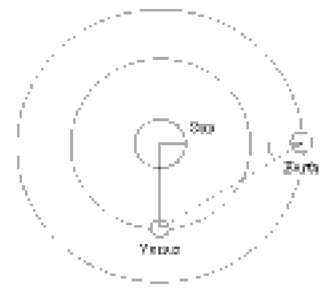

FIGURE 6: Maximum Elongation

IV. HOW DO WE MAKE OBSERVATIONS?

A. SETUP AND USE OF THE TELESCOPES. The Deep Space Explorer telescopes are easily moved. The tube rests in the base and is held there by two disks set in round recesses in the base. To move the telescope, one person should carefully lift the tube out of the base and carry it to the observation location. (Be careful not to bump it on doors, steps, or other obstacles!) The second person should carry the base. Although the base has a "handle," this is not a good way to carry it. You should fully support the base while carrying it to the observation location. Once in place, set the base down and place the tube in it. The tube should be set so that the eyepiece and finder are up when the telescope is pointed at the horizon. Note that you can swivel the base in a complete circle for easier viewing. This is an altazimuth mount. The swivel can be set to an azimuth, while the telescope can be pointed at an altitude.

You should be cautious around the telescopes during observations. The telescope does ***not*** have a lock, so it is easily moved by small bumps. This can make observations very difficult. Also, check to see how low an altitude you can obtain before the tube tips over.

Once your setup is complete, you can remove the caps protecting the mirror, lens, and finder. Keep these in a safe place. ***Do not lose them!*** You will put them back on at the end of the night. If you set them down, do not set them anywhere dirty. If the mirror cap gets covered in dirt, then the dirt can fall onto the mirror when the cap is replaced, ruining the telescope!

The finder is the small tube bolted to the telescope. To use the finder, look through it and line up the object you want to view in the center of the finder's field of view. This should place it in the telescope's field of view. Because the finder's field of view is larger than the telescope's, it is easier to find and line up objects this way.

The eyepiece is the protruding cylinder near the finder. There is a screw holding it tightly in place. When changing the eyepiece, loosen the screw and carefully remove the eyepiece by pulling it straight out. Place the new eyepiece in the correct position and tighten the screw until the eyepiece cannot move. Do not overtighten the screw. You have two eyepieces to choose from: a 26 mm and a 7.5 mm. They are discussed later.

Now you are set to look through the eyepiece at the sky! To focus, turn the cylinder holding the eyepiece. This moves the lens either closer to the telescope or farther away. Be careful not to bump the eyepiece, finder, or telescope while trying to make an observation. It will only result in having to realign the object in the finder.

B. DOCUMENTATION OF OBSERVATIONS. It is important to make clear and detailed reports of your observations! You should include a few basics in your report (your name, the date, the time, the weather conditions, etc.).

In addition to the basics, you should include the object's position in the sky. ***Altazimuth*** coordinates are generally the easiest to use, but remember that they are only good for your observation point. Therefore, if you use the altazimuth coordinate system, you must specify the location of your observation. You should also note the object's position with respect to the background stars. An easy way to do this is with a sketch of the sky showing the object in the proper place. Finally, you should include a description (and a sketch when appropriate) of the object. This is what you see with your eyes and through the telescope.

V. THE APPARATUS

A. THE STAR CHART. The SC001 star chart is a very useful tool. With it, you can predict which stars you will see on any day at any time. It is also much more portable than your computer! The SC001 shows the celestial equator labelled (across the center) with the hours of R.A. (0h to 24h) and declination labelled up to +60˚ and down to -60˚. The sine curve across the chart is the ecliptic. Along the ecliptic are date labels. These labels show where the Sun is at noon on that day. From this information you can find your zenith, meridian, and horizons. You can also take the star chart outside and hold it above your head to get a better idea of where to find things. You will note that when you face south and hold the chart above your head the direction labels (north, south, east, and west) are correct, but when you face north or look down on it they are not.

B. THE CELESTIAL SPHERE GLOBE. The celestial sphere globe is helpful for visualizing the movement of the heavens three dimensionally. You can set up the sphere to show the actual position of Earth, the Sun, and the stars.

C. VOYAGER II. Voyager II is a "Dynamic Sky Simulator." In other words, it is a computer program that lets you move around Earth and space to observe the motions of the objects in the sky. Within this program you will be able to choose your position and watch the stars, the planets, the Moon, asteroids, and other objects move across the sky through time. You can choose the date, time, objects, view angle, and time step (how fast time goes by) for your observing. **Voyager II** can also report on conjunctions, oppositions, elongations, positions (R.A. and dec.), lunar phases, and much, much more. This program is designed for the Macintosh and makes use of familiar Macintosh features, such as pull down menus, on-screen buttons, selecting and dragging with the mouse, and dialog boxes.

D. THE DEEP SPACE EXPLORER 8" TELESCOPE. The Deep Space Explorer 8" telescope is the telescope that you will use for your observations. There are 2 types of telescopes: ***reflecting*** and ***refracting***. This telescope is a reflecting telescope, or ***reflector***. Reflectors use mirrors and refractors use lenses to concentrate incoming light at a focus. To understand reflection, imagine light coming into the telescope tube perpendicular to the center of the primary mirror. The primary mirror is concave and focuses the incoming light to a point (known as the ***focus*** or ***focal point***) at some distance from the mirror (known as the ***focal length***). *The focal point is where you need to put your eye for viewing.* This works fine, except that the focus is inside your telescope tube, and your head just won't fit there! Isaac Newton had the same problem, so he devised the Newtonian reflector. He placed a secondary mirror in front of the focal point at a 45 degree angle to the primary mirror. The secondary mirror reflects the light rays through a hole in the tube where Newton placed an eyepiece lens to magnify the image. This is the same type of telescope you have!

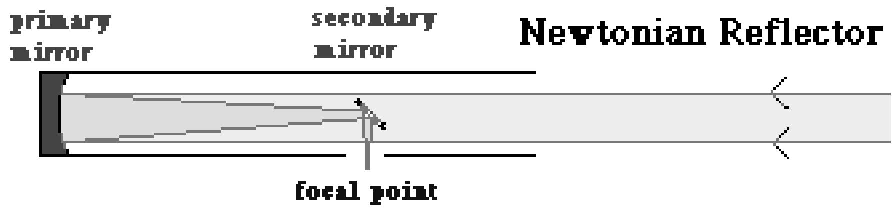

FIGURE 7: The Newtonian Reflector telescope.

The ***magnifying power*** of a Newtonian reflector is the focal length of the primary mirror divided by the focal length of the eyepiece. The focal length of your primary is 121.92 cm (48 inches). There are two different eyepieces available for use. One has a focal length of 26 mm, while the other has a focal length of 7.5 mm. **Compute the magnification for each lens.**

Which would be better for viewing the Moon? Venus?

If objects can be magnified using different eyepieces, why would astronomers want larger primary mirrors? Astronomers prefer large telescopes because large mirrors intercept and focus more light. Images are brighter and fainter objects are detectable. A large telescope also makes images sharper and crisper.

V. THE LAB SESSIONS

This lab will require two lab classes and usually two or more observing sessions to complete. You will help decide when observing sessions will take place and what objects and events are to be viewed. This decision will be based on the predictions you make in part **B** of this section. You will then complete the observations in part **C** of this section.

A. CONCEPTS

1. Using the Star Chart

STEP 1: Take out your SC001 star chart. You should already be familiar with R.A. and dec. labels. Your first step is to determine what you can see in the sky tonight!

Find today's date on the ecliptic. This is where the Sun is at noon today. From this point go straight up or down to the celestial equator. You are still at noon, so you will not be able to see the stars yet.....but you will at 8:00 pm tonight! So, let's go to 8 pm. Count 8 hours along the celestial equator going forward in time (in the direction of increasing numbers). If you draw a line from the north pole to the south pole through this point you will have your 8:00 meridian! To find your zenith, you need to know the latitude of your observing point. Tucson has a latitude of about 32˚N. Remember that north latitude corresponds to positive declination. Therefore, if you go to +32˚ declination on your meridian, you have your 8:00 zenith!

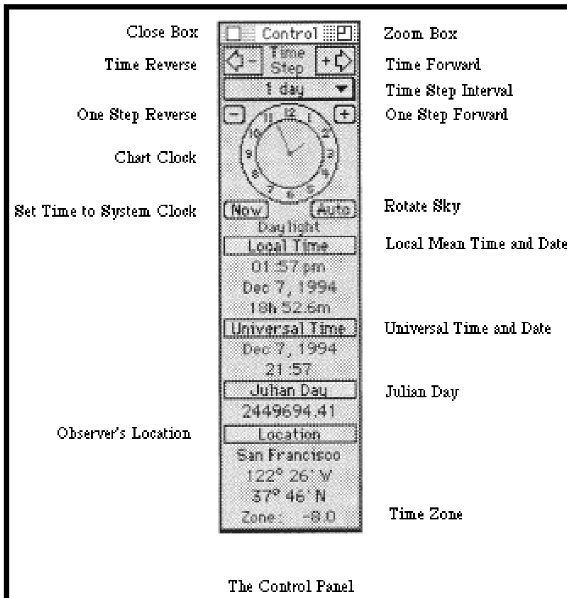

FIGURE 8: Voyager II CONTROL PANEL

Try following this procedure for today, a day in the middle of the semester, and a day at the end of the semester. You should also try this for times other than 8:00 pm.

STEP 2: Identify the portion of the star chart that will be visible tonight at 8:00 pm. You will be able to see approximately 90° to the north and south, and 6 hours to the east and west of your zenith. ***Mark these places on your star chart.***

STEP 3: Within the box found in **STEP 2,** identify constellations and bright stars that will be visible tonight at 8:00 pm. List them in Table 1.

Table 1: Constellations and Bright Stars

Bright Star	R.A.	Dec.	Constellation	R.A.	Dec.

2. Using the Celestial Sphere

STEP 4: Compare your screen to the celestial sphere globe.

• Start by placing Tucson (on the Earth sphere) directly under your zenith. (You can use the zenith you found on your star chart.)

• Next, set your horizon. The horizon is represented by the blue disk. Rotate the disk so that the directions on it point in the correct direction. The horizon (the edge of the disk) should always be 90° away from your zenith (Tucson).

• Now, lift the sphere above your head and look up through Tucson (Tucson should be on the ***far side*** of the globe). Make sure the northern point on your horizon (the blue disk) is pointing north (toward the front of the lab) and you are facing south (toward the back of the lab). The stars you see on the top portion of the globe are what you would see if you went out tonight at 8:00 pm!

When you look through the globe you should see the same thing you see on your star chart. Play with the globe until you understand how it works.

3. Using Voyager II

STEP 5: Open **Voyager II**. The sky chart should look like your star chart. Opening settings are for Tucson at today's date and time. You can change the time by clicking on the **Local Time** button or by clicking and dragging the hands of the clock to the time you want (see Figure 8). You may wish to change the time to 8:00 pm to compare the view to your star chart.

STEP 6: Next, you should go to the **DISPLAY** menu where you can add the meridian and horizon **Coordinate Lines** and the zenith **Reference Point**. Your meridian and zenith should be in the same places as on your star chart. Note the horizon lines. They should be 90˚ (or 6 hours of R.A.) away from your zenith. Examine other features in the **DISPLAY** menu (e.g., **Constellation Figures**).

STEP 7: In the **CONTROL** menu, open the **Chart Panel.** Change the field of view to 180˚ by clicking on the button and selecting 180°. You should see half of the celestial sphere.

Use the scrollbars to turn the globe. If you click on the scroll boxes you will get either a declination inclinometer or a right ascension compass in the lower right corner of the screen. This will help you move around the sky.

If you get lost moving around, you can reset the date and time by clicking on the **Now** button and using the **To Zenith** command in the **FIELD** menu. This will put the zenith back in the center of your screen.

STEP 8: On the **Control** panel (see Figure 8), find the button under the words "Time Step." If you click and hold this button you will get your choice of time steps. A time step is the amount of time that goes by for each “step” the computer makes. If you are looking at objects that go by quickly (like diurnal motion), then you should set the time step to a small value. If you are looking at the motion of stars over the course of centuries, you should set the time step to a larger value.

The buttons with the + or - let you move exactly one time step. The buttons with *arrows* and a + or - run the program until you stop it by clicking somewhere else.

STEP 9: We have been using the equatorial coordinate system (R.A. and Dec.) so far in **Voyager II**. However, **Voyager II** can handle four different coordinate systems!

Go to the **CHART** menu, and then the **Chart Coordinate** menu. You will find 4 different coordinate systems. You should be in **Star Atlas - Equatorial**. Go to **Local Horizon - Altazimuth**.

You should now be in the altazimuth coordinate system. When you click on the scroll boxes you will now get an altitude inclinometer or an azimuth compass.

You will also notice that you are now given a solid horizon. In the **CONTROL** menu you will find the command to **Define Horizon**. Here you can tell the computer whether you want the horizon to be transparent, translucent, opaque, flat, or custom. It should be set to ***translucent*** so you can see the stars under the horizon. Change it if you wish!

When the zenith is in the middle of the screen, 180° of the sky is showing, and the coordinate system is altazimuth, ***you see the sky as you would see it on the date and time specified on the control panel***. You may wish to rotate it until south is down to avoid confusion. Imagine that you are lying down with your feet pointing south. What you see now on the screen is what you’d see covering the sky.

STEP 10: Open the **PLANET PANEL** by clicking the button at the bottom of the screen that has the ringed planet on it. Here you can add planets, the Sun, the Moon, Earth’s shadow, asteroids, and satellites to the stars you have on your star chart.

The **Trail** button will leave a trail of dots on the screen for each object turned on. The interval between dots is the time step.

The **Path** button will connect the dots and leave a path.

To clear these off the screen, use the **Clear** button. They will come back again as you step through time unless you de-select the **Path** or **Trail** buttons.

Clicking on an object and number under **Date Label** will give you date labels for the object at a spacing of the number you selected multiplied by the time step.

STEP 11: You can get information, and sometimes pictures, of objects on your screen. Simply click on objects (stars, planets, *etc*.) on the star chart to get an information window. Clicking on the **target** in this window will show you where the object is on the sky chart. Clicking on the **picture frame** (if the object has one) will show you a picture of the object.

B. PREDICTIONS

1. Using Voyager II to Make Predictions

STEP 12: Predict when a planet of your choice is visible in Tucson. Pick a planet and put it on the screen. Add the Sun.

To determine when you can see the planet you need to find times that the planet is ***above*** the horizon and the sun is ***below*** the horizon. Be aware that you will not be able to see the planet if it is very close to the Sun.

One way to keep track of when the sun is up is to have the computer project true sky colors on your screen (*e.g.*, black for night, light blue for day, *etc*.) To have **Voyager II** do this, go to the **CHART** menu and find the **Chart Colors** menu. Under Chart Colors, choose **Natural Sky Color**. Now as you step through time it will be easy to distinguish night and day at a glance.

Pick 5 days spaced evenly across the semester and have **Voyager II** display the first day on the screen. Begin at 12:01 am and slowly step through the day. Record when the planet first becomes visible (above the horizon with the sun down). Continue to step through the day until the planet is no longer visible (either it sets or the sun rises). Record this time. You now have a range of time that your planet will be visible on that day. (Note that some planets will become visible in the evening and set early morning the following day. For example, you may have a time range that reads 7:10 pm - 3:25 am.) Follow this procedure to find time ranges for each of the 5 days.

Record your dates and time ranges in Table 2.

There are some days when you cannot see the planets. **Why?**

Planet:___________________

Table 2: Viewing a Planet

Date	Time Range

STEP 13: Use the information window to get the R.A. and Dec. for each of the planets listed below. ***Use 3 dates: today, a date midway through the semester, and a date at the end of the semester.*** You will use this to plot the planets on your star chart so that you can find them during the observation sessions.

Table 3: Planet R.A. and Dec.

Name	Date:		Date:		Date:	
	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.
Mercury						
Venus						
Mars						
Jupiter						
Saturn						

STEP 14: This step lets you explore some of the searches and reports **Voyager II** can do for you.

Under the **OPTIONS** menu you will find a number of useful commands.

- The **Conjunction Search** allows you to choose two or more objects and a time frame and will search for times in this range that these objects come into conjunction. If you double click on the conjunction report, it will be brought up on your screen. When using the conjunction search to find eclipses, change the angle of separation to 0.5°.

- The **Planet Report** gives you a list of features. These include oppositions, lunar phases, the motion of Jupiter’s moons, and lists of R.A. and Dec. positions of planets.

- The **Planet Gallery** lets you look at a planet, its moons, and its rotation at a variety of different magnifications.

- The **Solar Neighborhood** lets you move around in space, see the Sun as a star and see the stars that surround it.

Be aware that many of these functions list the ***Universal Time*** (UT) for an event. To convert this to Tucson time, subtract 7 hours.

Take some time to explore these functions, then use them to complete the following tables. You only need to include things that are occurring ***during this semester***, so some tables may be overfilled and some may be underfilled.

Table 4: Phases of the Moon

Date	Phase

Table 5: Conjunctions (excluding eclipses)

Objects in Conjunction	Date	Time (Tucson)	Can we see it from Tucson?

Table 6: Eclipses

Solar or Lunar?	Date	Angular Separation	Time (Tucson)	Visible in Tucson?

Table 7: Greatest Elongation

Planet	Date	Best Viewing Time (in Tucson)

Table 8: Oppositions

Planet	Date	Best Viewing Time (in Tucson)

STEP 15: Open the **RETROGRADE** settings file, which will be in an Astronomy Settings folder on the desktop. Time step forward to see the retrograde motion of Mars. Keep going forward in time until you find the next time that Mars goes into retrograde motion.

How often does Mars go into retrograde motion?

When is the next time Mars will go into retrograde motion?

Identify the planets that have opposition dates within this semester or within two months of the beginning or end of the semester. Use the planet panel to bring these planets up on your screen. Determine when these planets start and end their retrograde motion.

Table 9: Retrograde Motion

Planet	Date Retrograde Begins	Date Retrograde Ends

2. Using Voyager II For a New Point of View

STEP 16: Now, you are going to look at the solar system as a whole by stepping out of the ecliptic plane into space and looking back.

Open the settings file named **SOLAR SYSTEM** in the Astronomy Settings folder. This is a grid that represents the ecliptic plane and the nine planets. Time step forward or backward to see the paths of the orbits. Notice the scale. The four inner planets (terrestrial planets) are clustered around the Sun, while the outer (Jovian) planets are farther away and farther apart. Pluto is beyond the Jovian planets. Zoom in and out to see the planetary motions. The heliocentric **latitude** tells you how far above or below the ecliptic plane you are. If you set it to 0, you are looking at the plane edge on.

Are all the planets in the plane?

Are any of the planets exactly in the plane?

Are any of the planet orbits inclined (tilted) with respect to the plane? Which ones? How much?

Are the orbits of the planets circular? Explain.

3. Using The Star Chart to Make Predictions

STEP 17: Take the planet coordinates that you found in **STEP 13** and plot them on your star chart. You may wish to use a different color pen or pencil for each ***date*** to make it easier to read. Make sure you label each planet.

Use the same technique you used in **STEPS 1** and **2** to find the meridian and visible portion of the sky for each date at 8:00 pm and 5:00 am.

Predict what you will be able to see in the sky at 8:00 pm and 5:00 am on those days. In Table 10, record the name of the constellation closest to your zenith and the names of the planets that are visible.

Hint: If you mark each planet and meridian with the same color for one date, then you just need to look for planets of the correct color within the visible portion of the chart.

Table 10: Predictions

Date:			
5:00 am	constellation: Planets visible:	constellation: Planets visible:	constellation: Planets visible:
8:00 pm	constellation: Planets visible:	constellation: Planets visible:	constellation: Planets visible:

4. Deciding When to Observe

STEP 18: Knowing that you will need to view each of the planets, the Moon, and any interesting events occurring during the semester, what observation dates and times would you set? You will probably need at least two observation sessions. Can you find dates and times that will minimize the number of observing sessions required?

You may wish to find others within the lab who chose different planets to follow for **STEP 11**. If you share data, you may be able to complete this step more quickly. In fact, it might be wise to consult everyone in the class to see if anyone found an interesting event that you missed.

Table 11: When to Observe

Date	Start Time	End Time	Objects to Observe

C. OBSERVATIONS

- **Review Section IV on how to make and record observations before attending the observation session.**

- **Carefully read all steps in this section before attempting any of them!**

- **Bring your star chart, your list of objects to view, and your list of constellations and bright stars from STEP 3 with you to the observation sessions.**

STEP 19: You will need to answer the following questions at the end of this lab. Keep them in mind when you are observing.

1. Can you think of a basis for distinguishing Jupiter's or Saturn's moons from the background stars? What about on a longer time basis such as a few hours or days?

2. How does Earth's atmosphere affect your observations?

STEP 20: Set up the telescope.

You and your partner(s) will be provided with a flashlight, 2 eyepieces, and a clipboard.

Carefully move the telescopes (it will take two people) to the observing point. Set the telescope tube in the base so that when the telescope is pointed towards the horizon the finder is on top.

Carefully remove the protective covers and place them somewhere safe. Make sure you keep all optics clean! (This includes lenses and mirrors.) Make sure you have both eyepieces.

STEP 21: Observe the planets or events.

Use the data pages at the end of this lab to record your observations. Record the date, the location, and the general weather and sky conditions for your observations. Record the time and estimate the altitude and azimuth for each object you observe. Note which eyepiece you used for your observation.

STEP 22: Use your star chart to find the bright stars and constellations that you listed in **STEP 3**. Include any other constellations or stars that you identify in the sky. Record these observations in Tables 12 and 13.

STEP 23: Carefully replace the protective covers and put the eyepieces in their boxes. Take the telescope back to storage and return any other equipment to the instructor.

Table 12: Bright Stars

Name	Altitude	Azimuth

Table 13: Constellations

Name	Position

VI. DATA ANALYSIS

The objectives of this section are to organize your observations and then summarize your treatment of them. This section should include:

- data tables;
- observations;
- sketches;
- calculations (see **Section IV. D.**);
- procedures you improvised or are different from the write-up;
- comments on anything that may have adversely affected your measurements (accidents, clouds, mistakes, etc.).

VII. DISCUSSION

The primary objective of this section is to communicate the critical thinking that you applied to your data, predictions, and observations; that is, how you went beyond just mechanically performing the prescribed steps to get the intended answer. At a minimum, the discussion section should include:

- a synopsis of what will be occurring in the sky over the course of the semester;

  Be sure to include phases of the Moon, when and where you can see each of the planets, any conjunctions that will occur and the best time for viewing them, anytime there is an incidence of retrograde motion, when a planet reaches greatest elongation or opposition, and any eclipses you may find.

- a discussion of the structure of the solar system;

  What order are the planets in today? Does this change over time? Are they all in the ecliptic plane? Are they all roughly the same size?

- the significance of your data, predictions, and observations;

- a discussion of the problems with your observations and measurements and ways to reduce them;

- the answers to all questions asked in the lab write-up;

  You may wish to organize these into questions asked in the lab classes and those asked in the observation session.

- an understanding of how this experiment relates to planetary sciences.

Observation Data Page - First Session

Date ______________________________________

Observation Location ____

Weather/Sky Conditions ____

Object __________________________________ Time ____________________

Altitude __________________ Azimuth __________________ Lens ____________________

Description/Sketch of Object:

Object __________________________________ Time ____________________

Altitude __________________ Azimuth __________________ Lens ____________________

Description/Sketch of Object:

Object ______________________________ Time ________________

Altitude ______________ Azimuth ______________ Lens ________________

Description/Sketch of Object:

Object ______________________________ Time ________________

Altitude ______________ Azimuth ______________ Lens ________________

Description/Sketch of Object:

Object ______________________________ Time ________________

Altitude ______________ Azimuth ______________ Lens ________________

Description/Sketch of Object:

Observation Data Page - Second Session

Date ____

Observation Location ____

Weather/Sky Conditions ____

Object ____ Time ______________________

Altitude _________________________ Azimuth _________________________ Lens ____________________

Description/Sketch of Object:

Object ____ Time ______________________

Altitude _________________________ Azimuth _________________________ Lens ____________________

Description/Sketch of Object:

Object ______________________________ Time ______________

Altitude ______________ Azimuth ______________ Lens ______________

Description/Sketch of Object:

Object ______________________________ Time ______________

Altitude ______________ Azimuth ______________ Lens ______________

Description/Sketch of Object:

Object ______________________________ Time ______________

Altitude ______________ Azimuth ______________ Lens ______________

Description/Sketch of Object: