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.

Lab 3: The Orbit of Mars

Needed Math: Geometry

Introduction
Kepler's determination of the orbit of Mars was at once a masterstroke of genius and a brilliant stroke of luck. His discovery that **retrograde motion** could be explained by placing the sun in the center of the solar system solved a problem that had been plaguing astronomers for over 1500 years. How did he do that?

In this lab, we will repeat Kepler's analysis, using real data that parallels those used by Kepler in the 1600's. We will also use the same assumptions applied by Kepler to solve the problem: that the sun is at the center of the solar system, and that the Earth revolves around the sun in a perfectly circular orbit.

Method
Neither we, nor Kepler know how long it might take Mars to orbit the sun. All we can do is assume that Mars will show up at the same point in space after each revolution. This assumption allows us to fix the position of Mars using paired data sets.

> For example, let us say that it takes Mars 100 days to complete one orbit around the sun. This means that Mars should be at more or less the same location in space every 100 days. On the other hand, Earth will not be in the same place, since it takes 365 days to orbit the sun. Therefore, if we note the direction of Mars from Earth on two separate occasions 100 days apart, and plot these directions on a piece of graph paper, Mars lies at the intersection of the two lines (see Figure 1)

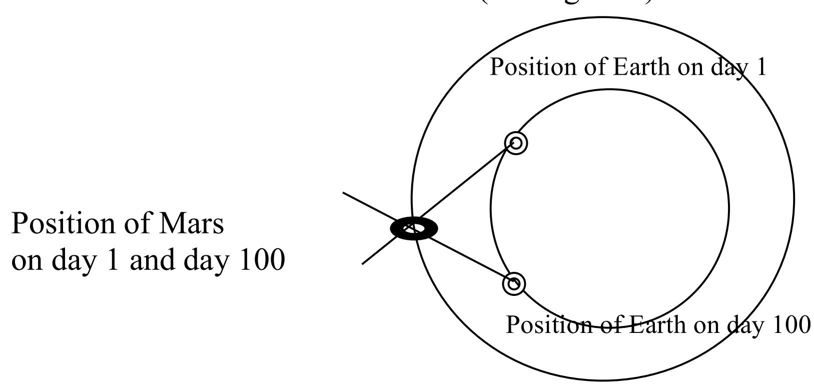

Figure 1

Since we do not know how many days it takes Mars to orbit the sun, like Kepler, we are forced to plot data points for several possible periods (e.g. 90 days apart, 100 days apart, etc) until the locations of Mars make sense. We will know we have found the orbit of Mars when all the points lay on a circular path around the sun.
On the attached chart are listed positions for Earth and Mars on several occasions. The data pairs are given for observations 677 days, 687 days, and 697 days apart. Our job is to plot these data and determine which set of pairs best describes the orbit of Mars.

To make a plot, place a piece of graph paper on the desk lengthwise. Mark a point ten dark lines from the top of the paper, and seven dark lines from the right side. This will be the position of the sun. Next use a compass to draw a circle with a radius of 7 cm centered on the sun, this will represent the Earth's orbit. Since we have chosen a position of the sun close to the edge of the paper, we won't be able to draw a complete circle. Don't worry – we won't need it. Finally, draw a vertical line along the 5th vertical extra-dark line from the right edge of the page. This will be the surface of the "celestial sphere" in our model.

Now, we need to figure out where the Earth lies in its orbit for each of the highlighted measurement dates (the 21st of each month, most of which occur in 1997). This data is given in the third column of the chart. To plot these positions, lay a protractor on top of the sun, so that its base lies horizontally (parallel to the x-axis). We will define March 21 as being at 0° – where the horizontal base of the protractor intersects the orbit of the Earth (to left). Negative angles will be measured clockwise from this point, and positive angles will be measured counterclockwise (the direction of Earth's revolution). December will be near the top of the circle, and June will be near the bottom. Plot each position given in the highlighted boxes.

Now we will draw the direction to Mars on each of these dates. These directions were measured from the Earth's Surface, so the data should be plotted by placing the center of the protractor on the Earth, and measuring the direction to Mars with respect to the positive x-axis (the direction to the Sun on March 21). In other words, place the protractor so that the Earth is in the center, and the edge is lined up along a horizontal line (as when you found March 21). Then measure the angle to Mars starting from the right-hand side of the protractor. Draw a line from Earth at this angle, extending it to the "celestial sphere" for each of the eight initial positions. Vary the color for each line.

Understand that the lines we have just drawn are lines of sight for Mars on certain days. That is to say that Mars will lie somewhere along these lines, though we have no idea how far away it actually may be. If we compare the movement of Mars to the stationary celestial sphere, we discover something pretty amazing – Mars displays retrograde (backwards) motion with respect to the stars.

> This completes the basic set-up for this lab. To finish the lab, ask your instructor what orbital period you should assume (677 days, 687 days, or 697 days) and plot the Earth position and Mars direction for each of the date pairs, just as you did above. Use the same colors for corresponding pair dates. The intersection of these pair lines gives the calculated position of Mars for that pair. When you have plotted all the pairs, connect the intersection points with a best-fit curve and look at your results. Do they make sense? What do they tell you about the orbital period of Mars? Answer the questions on your hand-in sheet, and staple your plot to the sheet before handing it in.

Date	Days from Start	Earth Position	Mars position wrt Earth
		(in degrees from March 21)	(in degrees ccw from +x-axis)
Dec 21, 1996	1	-90	176.5
Oct 28, 1998	677	-142	164.25
Nov 07, 1998	687	-133	169.75
Nov 17, 1998	697	-123	175
Jan 21, 1997	1	-60	185
Nov 28, 1998	677	-112	180.75
Dec 08, 1998	687	-102	187
Dec 18, 1998	697	-92	191
Feb 21, 1997	1	-30	185.25
Dec 29, 1998	677	-81	196.25
Jan 08, 1999	687	-71	200.75
Jan 18, 1999	697	-62	205
Mar 21, 1997	1	0	176.75
Jan 26, 1999	677	-54	208.25
Feb 05, 1999	687	-44	212
Feb 15, 1999	697	-34	215.25
Apr 21, 1997	1	30	168.75
Feb 26, 1999	677	-23	218
Mar 08, 1999	687	-13	219.75
Mar 18, 1999	697	-3	220.25
May 21, 1997	1	60	171
Mar 28, 1999	677	6	219.75
Apr 07, 1999	687	16	218
Apr 17, 1999	697	26	215
Jun 21, 1997	1	90	180.75
Apr 28, 1999	677	37	211
May 08, 1999	687	47	207.5
May 18, 1999	697	57	204.5
Jul 21, 1997	1	120	194.25
May 28, 1999	677	67	202.75
Jun 07, 1999	687	76	202.5
Jun 17, 1999	697	87	203.25

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Lab 3: The Orbit of Mars
NAME:

Examine your best-fit curve and comment on it. Is your curve a likely representation of the orbit of Mars? Explain.

Compare your best-fit curve with others. Be sure to examine the best-fit curves for each assumption of orbital period (677 days, 687 days, and 697 days). How do the three plots differ?

Which plot is most likely to be the true orbit of Mars? Explain.

What, then, is the orbital period of Mars? (circle one)

677 days
687 days
697 days