

# PHYS133 – Lab 3

## Triangulation and Parallax

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### Goals:

- Understand the principles of Triangulation.
- Discover moving objects in the sky using images taken at different times.
- Practice using the Celestial coordinate system (Right Ascension and Declination).
- Use the coordinate location of reference stars to interpolate the coordinates of an unknown object.
- Use parallax to determine the distance of an asteroid using the same technique astronomers use to measure the distance of stars.



### What You Turn In:

- The Data sheets at the end of the lab manual.
- Print outs from the program *Astrometry of Asteroids*.
- Answers to the questions in this manual.

### Background Reading:

Background reading for this lab can be found in the notes for the course and the background section of this manual.

### Equipment provided by the lab:

- Computer with Internet Connection
- Project CLEA program “*VIREO*”

### Equipment provided by the student:

- Pen
- Calculator

## Background:

This lab consists of two parts, a practical use of triangulation on land to measure the distance to objects and using real astronomical images to find actual distance to an asteroid using the program Astrometry of Asteroids.

### Triangulation on Land

To better understand the parallax technique used to measure the distance to nearby objects (planets, asteroids, nearby stars). To this end, we will first use triangulation to measure the distance to some nearby objects/buildings on the Northern Green. From this, we will see how accurate (or inaccurate) these measurements can be.

### Astrometrical Coordinate systems and the Technique of Astrometry

The PC portion of the lab involves the measurement of precise star positions, a technique called astrometry, which is one of the fundamental tools of astronomers. Astrometry, of course, enables us to make charts of objects in the sky, assigning two numbers or celestial coordinates to each object so that we can easily locate it. If you've ever used a roadmap or a map of the world, where two coordinates are used to mark the positions of cities and mountains, you know the usefulness of coordinate systems.

Astrometry also helps astronomers measure the changes in positions of objects in the heavens. One of these changes, called annual parallax, enables astronomers to measure the distances to some stars. Parallax is a semi-annual wobble in the position of a star caused by changing perspective as the earth circles the sun. Another change, called the proper motion of a star, is a continuous drift across the sky caused by the motion of the star itself with respect to us.

By using computers to measure the positions of stars on digital images of the sky, astronomers determine the coordinates of objects to high precision. Even the relatively simple program you will be using in this exercise can pinpoint objects to better than 0.1 arc-seconds, which is about the diameter of a dime viewed from a distance of 20 kilometers. This is not high enough precision to measure the parallax of most stars because most stars are too far away, and therefore have an extremely small annual parallax. So, we have chosen to demonstrate astrometric measurement using asteroids, those small rocky objects that orbit the sun—most of them between the orbit of Mars and Jupiter. You will be able to measure the parallax and the orbital motion of asteroids quite easily, and the techniques you learn here are applicable both to asteroid work and to the study of the positions and motions of the stars.

### The Notion of an Astronomical Coordinate System

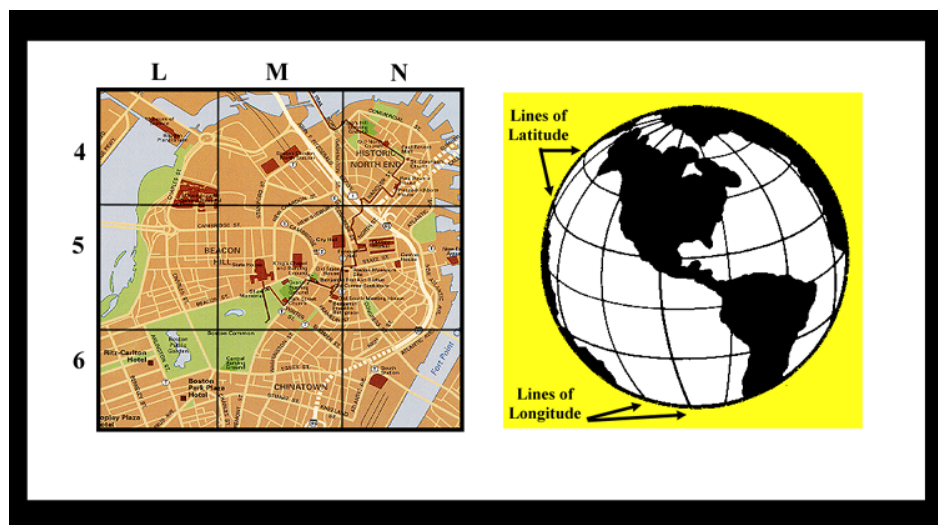


Figure 1  
Coordinate Systems

How do astronomers know where a star is in the sky? They use the same method we use here on earth to specify the position of a city on the globe or a street on a map of the city: they give two numbers, called the coordinates of the star, that enable us to pinpoint the object.

Imagine the sky covered with a grid of imaginary lines, labeled with numbers. To say that a star is at (X,Y) in the sky, is just like saying a city is at longitude 77 west, latitude 40 north, or that a street is at L, 5 on a map. To find the city, you just look to see where the longitude line labeled "77 west" intersects with the latitude line labeled "40 north," and there it is. To find the street, you just look to see where line L intersects line 5 on the map. Two coordinates are all that is needed since the surface of the earth, the city map, and the sky, all appear two dimensional to the observer.

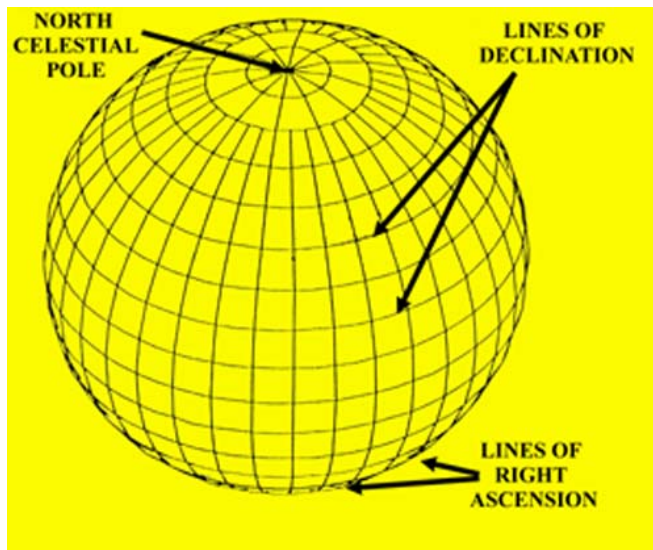


Figure 2 – Equatorial (Celestial) Coordinates

**The Equatorial Coordinate System: Declination and Right Ascension**

Earth's Surface		Equatorial (Celestial)	
<b>Latitude</b>	Based on Earth's Rotation. 0° is the equator, set to halfway between Earth's North and South Poles.	<b>Declination</b>	Project Earth's equator onto the sky for 0° Declination.  Line connecting Earth's North and South pole goes to the North and South Celestial Poles.
<b>Longitude</b>	Lines connect North pole to South Pole. 0° Longitude is Arbitrarily set to pass through Greenwich Observatory, U.K.	<b>Right Ascension</b>	Lines connect North and South Celestial Poles. Point where sun crosses the celestial equator (as seen from the Earth) is line of 0 hours R.A.  Often measured in <i>time units</i> as the Earth rotates once every 24 <i>sidereal</i> hours (23 hours, 56 minutes in solar time – more on this when we do solar rotation).

Positions are always measured with respect to something. For instance, latitude and longitude are measured with respect to the earth's equator and the Greenwich meridian. The two coordinates in the equatorial system are called Declination and Right Ascension and are projections of latitude and longitude onto the sky.

**Declination** are like lines of latitude on the earth, and are designated by their angular distance north or south of the celestial equator, measured in degrees (°), arc minutes ('), and arc seconds ("). There are 360 degrees in a circle, 60 minutes in a degree, and 60 seconds in a minute. A star with a declination of +45° 30' lies 45 degrees, 30 minutes north of the celestial equator; negative declinations are used for an object south of the equator.

**Right ascension** lines are like lines of longitude on the earth, running through the north and south celestial poles perpendicular to the lines of declination. They designate angular distance east of a line through the vernal equinox,

the position of the sun when it crosses the celestial equator on the first day of spring. Right ascension is measured in hours ( H ), minutes ( m ) and seconds ( s ). This may sound strange, but it's due to the Earth's rotation.

There are many catalogs of objects in the heavens which list their right ascensions and declinations. It's impossible to list all the stars in the sky, so a catalog usually contains stars that are selected by astronomers for a particular purpose. One of the most important catalogs is called the *FK5 Catalog*, because it is one of the fundamental catalogs used as a reference for measuring the positions to other stars in the sky (see the next section of this manual). The *FK5 Catalog* contains only 3522 stars, all of them rather bright. The right ascension and declination of the stars in the *FK5 Catalog* have been especially carefully measured and re-measured so that they can be relied upon as standard reference points for the measurement of the positions of other objects in the sky.

Another useful catalog which we shall use in this exercise is the *Hubble Space Telescope Guide Star Catalog*, (*GSC*). The *GSC* lists almost all the stars in the sky that are brighter than apparent magnitude 16, which is almost ten thousand times fainter than the faintest star you can see with your naked eye. There are coordinates of almost 20 million stars in the *GSC*. You can practically count on having several *GSC* stars with known coordinates anywhere you look in the sky. On the other hand, there are so few stars in the *FK5 Catalog*, that it's rare that a *FK5* star will be in the same direction as an object of interest.

In this exercise, you'll only be looking at a few specific spots in the sky. To save room on your computer, we've extracted only part of the *GSC* and stored it on your computer for use in this exercise.

### The Technique of Astrometry: Finding the Coordinates of Unknown Objects

The lines of right ascension and declination are imaginary lines of course. If there's an object in the sky whose right ascension and declination aren't known (because it isn't in a catalog, or because it's moving from night to night, as a planet or asteroid does), how do we find its coordinates? The answer is that we take a picture of the unknown object, U, and surrounding stars, and then interpolate its position from that of other nearby stars whose equatorial coordinates are known. The stars of known position are called reference stars or standard stars. (See Figure 3 below).

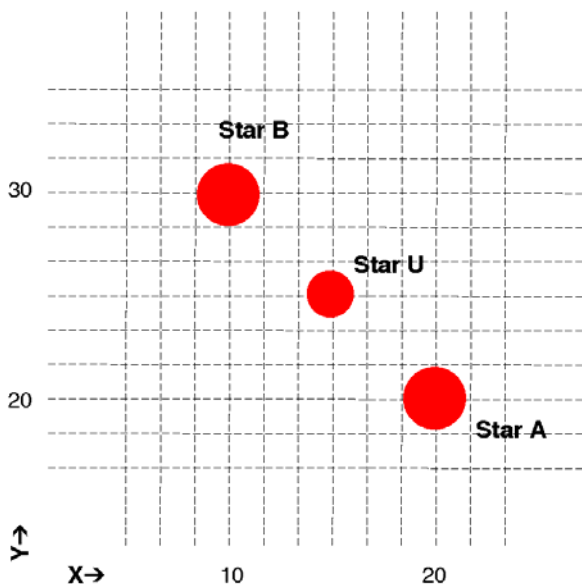


Figure 3 – Determining the Coordinates of an Unknown Object

In practice, it's a bit more involved than drawing lines using the Pythagorean theorem. Largely because the image of the sky appears flat and, in actuality, the real sky is curved. But it is not difficult to write software that will do the mathematics for you, and the program we supply does just that. To measure an unknown object's position from an image, the software will instruct you to choose at least three stars of known coordinates (for best results choose more). Then indicate the location of the unknown object by clicking on it. The computer performs what is called a coordinate transformation from the images on the screen to the equatorial coordinates, and prints out a solution showing you the coordinates of your unknown object.

The software we provide can, in principle, calculate coordinates with a precision of about 0.1 arc-second ( $60' = 1^\circ$ ,  $60'' = 1'$ ). That's approximately the angular diameter of a dime seen at distance of about 20 miles, a very small angle indeed.

For example,

Star	Right Ascension	Declination	X Position	Y Position
Star A	5h 0m 0s	10° 0' 0"	20	20
Star B	6h 0m 0s	25° 0' 0"	10	30
Unknown Star U	?	?	15	25

**The Problem of Finding Asteroids**

In this exercise, you will be using images of the sky to find asteroids and measure their positions. Asteroids are small rocky objects that orbit the sun just like planets. They are located predominately between the orbit of Mars and Jupiter, about 2.8 Astronomical Units from the sun. Asteroids do orbit closer to the sun, even crossing the earth’s orbit. Occasionally an earth-crossing orbit, may even collide with the earth. Hollywood movie producers have frequently used an asteroid collision as a plot for a disaster movie. The danger is real, but dangerous collisions are very infrequent.

Most asteroids are only a few kilometers in size, often less. Like the planets, they reflect sunlight, but because they are so small, they appear only as points of light on images of the sky. How then can we tell which point of light on an image is an asteroid, and which points are stars?

The key to recognizing asteroids is to note that asteroids move noticeably against the background of the stars because an asteroid is orbiting the sun. If you take two pictures of the sky a few minutes apart, the stars will *not* have moved with respect to one another, but an asteroid will have moved (see figure 4). It’s hard to see the forest for the trees, however. Often there are so many stars on a picture that you can’t easily remember the pattern when you look at another image, and therefore you can’t easily tell which dot of light has moved. You will use a technique that will make this process much easier.

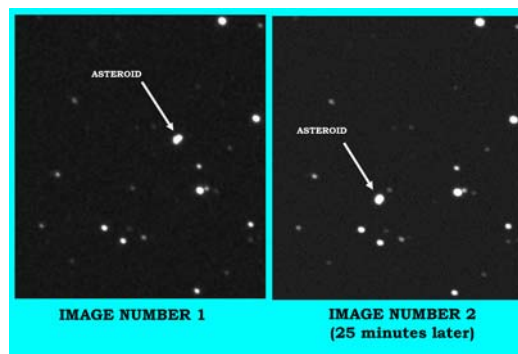


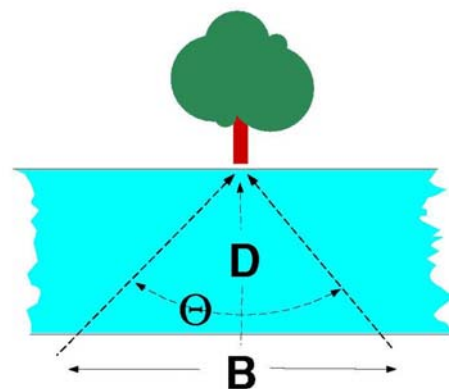
Figure 4 – Finding the Asteroid

Once you’ve identified an asteroid on a picture, you can then get the computer to calculate its coordinates by measuring its position with respect to reference stars (stars of known coordinates) on the screen. Comparing an asteroid’s position at particular time with its position at some other time enables you to calculate the velocity of the asteroid. While the computer can do this, you are not required to do this today.

**The Principles of Parallax**

Measurement of precise positions makes possible one of the most powerful methods astronomers have of measuring the distances to objects in the sky, a method known as parallax. Parallax is the most direct way astronomers have of measuring the distances to stars.

The parallax of an object is its apparent shift in position when you view the object from two different vantage points. It’s commonly used on the earth to measure the distance across a wide river (see Figure 5 to the right). You view a tree from two vantage points on the opposite shore then carefully measure the distance between the two vantage points, called the baseline, **B**. The angle between the two lines of sight to the tree, parallax angle designated as  $\Theta$ . Using trigonometry, you can find the perpendicular distance across the river. Since the



distance,  $D$ , is one side of a right triangle, the opposite angle of which is  $\Theta/2$ , and the adjacent side of which is  $B/2$ , the distance across the river can be represented as

$$D = \frac{B/2}{\tan(\Theta/2)}$$

In astronomy, a commonly used baseline is the diameter of the earth’s orbit and the parallax we measure is due to the shift in vantage point as the earth orbits the sun. If we view a nearby star from opposite sides of the earth’s orbit, and measure its position against a background of distant stars, we will see that it appears to move. For example, its equatorial coordinates measured in June, when the earth is at one side of the sun, will be different from its position in January when the earth is at the other side of the sun (see Figure 5). The farther the star, the smaller the parallax. Even the nearest stars have parallax shifts of less than a second of an arc, hard to see and hard to measure. However, astronomers have been able to measure the parallaxes of over a hundred thousand stars using sophisticated techniques and a special satellite called Hipparchos.

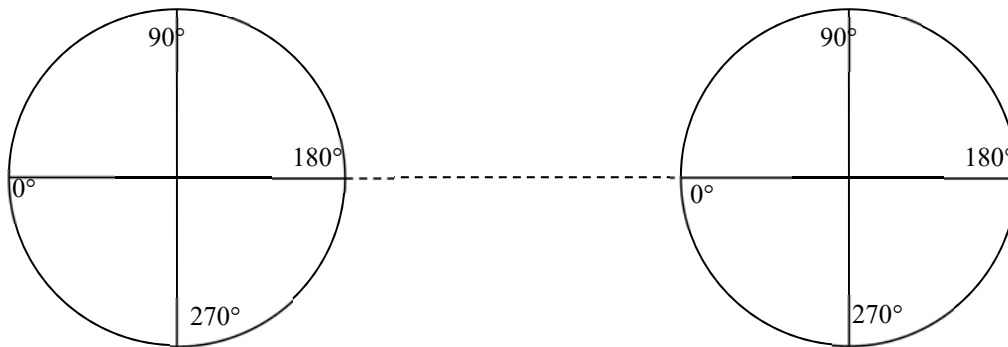
It is also possible to measure the distance to asteroids using parallax too. Because asteroids are closer, their parallax is larger, and we can even use a short baseline - like the diameter of the earth. Viewed from two points on the earth, asteroids show a very noticeable parallax, as you will see in Part IV of this exercise. Measuring the parallax of asteroids using astrometry is a useful exercise for showing us how the much smaller parallax of stars is measured in practice.

## Procedure

### Land Based Triangulation

1. Setup and align the sights.

Place them several meters apart and align them such that the  $0^\circ$  of one points to the  $180^\circ$  of the other:



2. Measure the Baseline distance by measuring the distance between the support poles as the base line.
3. Measure the angles to a distant object and compute the distance. Pick a distant object or building and measure the angles from each sight.
4. Vary the distance between the sights and measure the angles and baseline again to the same object.
5. Repeat procedure for another object.

## Part I – Finding Asteroids by Blinking Images

### Starting the program

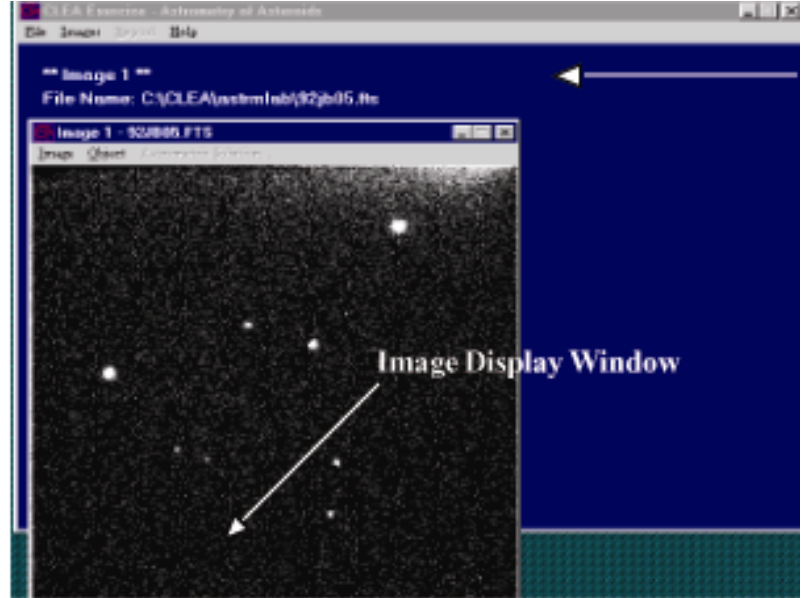
Under a typical installation, you will find *Astrometry of Asteroids* on the desktop or under **CLEA Exercises** in the **Programs** section of the Windows **Start** menu. If this is not the case, consult your instructor. When the program starts, the CLEA logo should appear in a window on your screen. Select **Login >** under the **File** menu. Fill in the

form that appears. When you have completed the form and clicked **OK**, the opening screen of the *Astrometry of Asteroids* lab will appear.

This software includes a series of images of a region of the sky, about 4 arc-minutes square, in which astronomers were searching for a faint earth-approaching asteroid designated 1992JB. The problem is to recognize the asteroid, which as the name suggests (aster-oid = “starlike”), looks just like a star.

Let’s look at one of the images. From the menu bar, choose **File... Load Image Files... Image 1**. A directory listing showing you a list of files appears. From this list, select 92jb05.fts, and click **Open** to load it.

1. The computer will show you the progress of the loading and creating a screen for display and then write the name of the file on the screen to let you know it has successfully loaded **Image 1**.
2. The image has been loaded, but is not yet displayed. To display it, select **Images** on the menu bar, then choose **View/Adjust... Image 1** from the pull-down menu. A window showing the image 92JB05 will appear on your screen.



3. The image is oriented with west to the right and north to the top. All the dots you see on the image are distant stars except one, which is the asteroid. We’ll make a chart of the image and mark the asteroid when we discover it. In the blank space located on your data sheet, make a freehand sketch of the image 92JB05. Try to pay attention to the details—draw it to scale and try to make it fit in the space.
  4. Now let’s find the asteroid. Load as before, but this time choose **File...Load Image Files ...Image 2** from the main program window (which appears blue not black as in the **Image 1** window). From the list of images, select **92jb07.fts**, and click **Open** to load it.
- **NOTE: The program can load up to four image files for blinking purposes, but for first-time users we recommend blinking only two at a time. Thus, you will be loading images only in the Image 1 and Image 2 slots. If at some point you wish to blink more than two images, try File > Load Image Files > Multiple Load. Then use the CTRL key to select multiple images.**

You can display this image in its own window by using the **Images. > View/Adjust... Image 2** selection on the menu bar. Since 92JB07 was taken 10 minutes after 92JB05, the asteroid will have moved. But it may not be immediately obvious which star-like object is out of place, even when you compare the images side by side.

So, we blink the images, first aligning them so they coincide, and then using the computer to flip from one image to the other. Here are the steps we use to blink the images.

1. We must first align the images. From the main menu bar located on the blue window, choose **Images...Blink**. You will see one window now, displaying just Image 1.

2. At the bottom right, a small instruction box asks you to click on an **alignment** star, which the computer can use to align the two images. If possible, you should try to choose two stars that are on opposite sides of the picture to achieve best results. (*The best combination is a pair of diagonally opposite stars.*) Choose one of the brightest ones, click on it, and note it for your own reference by writing the **number 1** next to it on your freehand drawn chart.
3. Click on **Continue** in the instruction box, and it will ask you for a second alignment star. (*Two stars are needed to account for possible rotation of the images.*) Click on this star, record it on the chart above as 2, and click again on **Continue**.
4. Now you will see Image 2, and you will be asked to identify star number 1 on Image 2. Check your chart, then click on the same star 1 that you chose in Image 1. If you are satisfied, click **Continue** in the instruction box. You are now asked to identify star 2 and again you click on the same star 2 that you chose in Image 1. Actually, based on your choice of stars in Image 1, the computer will make a good guess as to where the star should be on Image 2. It will draw a box around where it thinks it should be, and if, in fact, it comes close, you need merely click **Continue** to accept its choice. You'll find that the computer does this guesswork in many parts of the program, making it easier for you to make measurements quickly.
5. The computer now has all the information it needs to align the images and blink them. All you need to do is click on **Blink** from the menu bar at the top of the blinking window, and you will see the computer flip back and forth between Image 1 and Image 2 about once a second. The stars will not move, but you should easily be able to pick out the asteroid as the one object that does jump. Be careful when choosing! For example, occasionally a white spot will appear on one image, and not the other. It is not an asteroid, however, but a defect in the picture itself. This is usually caused by radiation—a cosmic ray most often—that exposes a single pixel in the camera during one exposure. You may also notice all the stars brighten and dim, since one image is a longer exposure and therefore brighter. Similarly, the background shade may be lighter in one image than in another. But the asteroid should appear clearly as a smudge of light that changes position from one image to the other.
6. To stop the blinking select **Stop** from the menu bar. To adjust the rate of blinking slower or faster at your convenience, select **Adjust...Blink Rate**. The Blink Rate Interval dialog box appears. The blink rate can be adjusted using the slide bar to increase or decrease the rate per msec that the images blink. The range is from 10 to 1000 msec with the default set at 500 msec.
7. To start over, select the **Adjust...Field Alignment** menu option to choose the alignment stars again.
8. When you have identified the asteroid on Image 1 (92JB05) and Image 2 (92JB07) mark the position of the asteroid with a dot on your chart. On the freehand drawing in Figure 2, neatly label the asteroid's position on Image 92JB05 with a small **05** and its position on Image 92JB07 with an **07**.
9. Now continue to find the asteroid on images 92JB08, 92JB09, 92JB10, 92JB12, and 92JB14 by blinking them. You will continue to use Image 92JB05 as Image 1.

To do this, simply select the **Load...Image2** menu item, and then **Image...Blink** to blink the images. You will be prompted to identify the alignment stars on the new image. Continue with images 09-14.

The procedure will then be the same as you followed with image 92JB07 as Image 2. Again, mark the successive positions of asteroid 1992JB by dots labeled **08, 09, 10, 12, and 14** on the chart you made in step 1.



**Part II – Measuring the Distance of Asteroid 1992JB by Parallax:**

In this section, we'll use our new-found skill in measuring coordinates to determine the parallax of asteroid 1992JB. For this purpose, we took two images of 1992JB *simultaneously* from observatories at opposite sides of the United States. One image, you have already seen: Image 92JB12, which we have also stored under the name ASTWEST. It was taken by Dr. Laurence Marschall using a 0.8m diameter telescope at the National Undergraduate Research Observatory in Flagstaff, Arizona. The other image ASTEAST was taken by Dr. Thomas Balonek using an 0.4 m telescope at the Foggy Bottom Observatory of Colgate University in Hamilton, New York.

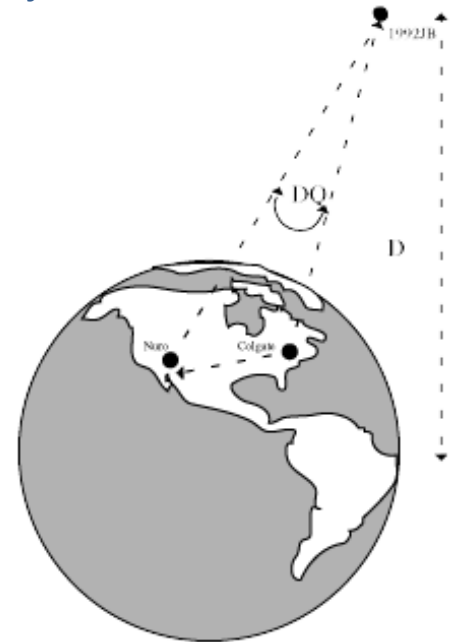


Figure 14 - Parallax Observations 1992JB

Time of Observation at Both Sites 06 57 00UT 23 May, 1992				
Site	Latitude	Longitude	Image File	Exposure
Foggy Bottom Observatory, Colgate University Hamilton, NY	42° 48' 59.1"	W 75° 31'59.2"	ASTEAST	120
National Undergraduate Research Observatory Flagstaff, AZ (Telescope Operated by Lowell Observatory)	35° 05' 48.6"	W111° 32' 09.3"	ASTWEST	120

Because the asteroid is much closer than the stars, it appears in a different position on the two images with respect to the background stars. This is called its *parallax*. By measuring the position with respect to reference stars on both pictures, we can determine the parallax, which is just the angular difference  $\Delta\theta$ , in arc seconds, between its position on the image taken from the eastern site and from the western site. Using simple trigonometry if  $B$ , the *baseline*, is the distance between the two telescope sites in kilometers, then:

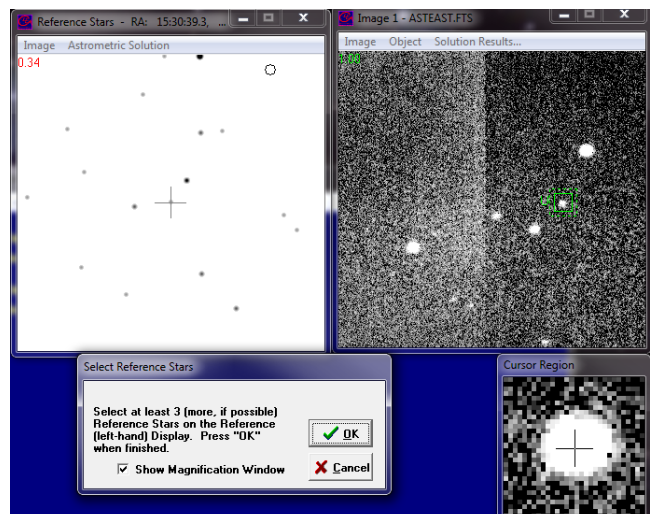
$$Dist\ to\ asteroid = 206,265 \cdot \frac{B}{\Delta\theta}$$

Using our program, then, the measurements can be done rather quickly.

**Procedure for Part II**

1. **Loading the Images**

Load **ASTEAST** as **Image 1**. Load **ASTWEST** as **Image 2**. Display the two images side by side for comparison. Note that the two cameras had different sensitivities (the east-coast telescope was smaller), and had CCD chips of different dimensions, so the images don't look quite the same. But the same reference stars are visible on both images. Find asteroid 1992JB again on each image (you can refer to your chart in part 1—remember ASTWEST is 92JB12)



**2. Measuring the coordinates of the asteroid in ASTEAST and ASTWEST**

Now, measure the coordinates of the asteroid in ASTEAST and ASTWEST.

- a. Select **Images...Measure...Image 1**. A dialog box will appear. **Click OK**.
- b. Four windows open:
  - i. The actual data image.
  - ii. A zoomed in location on the data image.
  - iii. A sky map of the same region as the image on which you will select the reference stars.
  - iv. A dialog box.
- c. On the Reference star map, choose three stars that you will use to find the coordinates of your unknown object. (Suggestion: use the three stars closest to the center.) After selecting each star choose OK in the dialog box and then click OK in the **"Select Reference Stars"** box.
- d. On the Image display, the target should already be identified. You need to identify the stars you selected on the star map.
  - i. Click and drag on the *image* until you have centered on the first star that you want to use as a reference. The cursor region window will allow you to center on it. Then click OK.
  - ii. If necessary, locate the target object and click OK.
- e. The solution box should appear. Record the target's **RA** and **Dec** coordinates.
- f. Repeat steps 2.b through 2.e for the other image (**Images...Measure...Image2**).

**3. Calculating the parallax of 1992JB**

The parallax of 1992JB is just the difference between the two positions. We can follow the methods of calculating the angular difference between two positions that we used Part 3. We separately calculate the difference in the declinations and the difference in the right ascensions in arc-seconds ( ") and then find the total angular difference as the square root of the sum of the squares of the declination and right ascension differences. Follow the steps on your data sheet to complete this process.

**References**

Laurence A. Marschall, "Coordinates and Reference Systems", in *The Astronomy and Astrophysics Encyclopedia*, Stephen P. Maran, ed., New York Van Nostrand Reinhold, 1992, pp. 131-133.

**This will conclude the data taking part of the lab.**

**Print out your data tables, diagrams and analysis and  
attach to your Write – up!**

Names: \_\_\_\_\_  
 \_\_\_\_\_

Section: \_\_\_\_\_

Date: \_\_\_\_\_

**Land Based Triangulation Data Sheet**

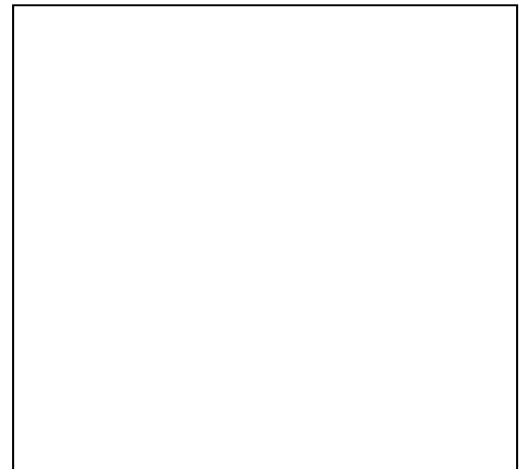
Location of base for measurement: \_\_\_\_\_

Object	Baseline Distance (B)	Angle (left)	Angle (right)	Angular Shift ( $\Theta$ )	Distance to Object

**Part I**

NORTH

EAST



*Your Freehand Sketch of the Star field containing 1992JB*

You should note the asteroid is moving in a straight line. Draw an arrow in the space above to show the direction of motion. What direction is this? (North, Northeast, Southeast, etc.)? Don't forget the orientation of the image is different from what would be found on a traditional land map.



← *Sketch of Reference Stars*

Part II

Measuring the Distance of Asteroid 1992JB by Parallax:

- Look at image ASTWEST. Compared to its position on ASTEAST, does 1992 JB look further to the east or further to the west with respect to the background stars? \_\_\_\_\_.
- Why is this what you'd expect? — explain using a diagram in the space below.

<u>Measurement of Coordinates for ASTEAST and ASTWEST</u>		
File	RA (h m s ) of 1992JB	Dec (° ' " ) of 1992JB
ASTEAST	_____	_____
ASTWEST	_____	_____

Express the coordinates of 1992JB on both images in decimal form to make subtraction easier. Convert to decimal degrees just as you converted to decimal hours above. (That is divide ' by 60 and " by 3600 to get the decimal values.):

File	RA (h.xxxxx) of 1992JB	Dec (°.xxxxx) of 1992JB
ASTEAST	_____	_____
ASTWEST	_____	_____

Express the difference  $\Delta Dec$  in decimal degrees: \_\_\_\_\_ °

Convert to arc seconds by multiplying by 3600.

$$\Delta Dec = \text{_____}''$$

Express the difference  $\Delta RA$  in decimal hours: \_\_\_\_\_ h

Convert to seconds by multiplying by 3600,  $\Delta RA$ : \_\_\_\_\_ sec

Convert to arc seconds by using the equation

$$\Delta RA \times 15 \times \cos(\text{Dec}) = \text{_____}''$$

Calculate the total parallax in arc seconds:

$$\text{Parallax} = \sqrt{(\Delta RA)^2 + (\Delta Dec)^2}$$

Parallax = \_\_\_\_\_ "

**Calculating the distance of Asteroid 1992JB:**

Knowing the parallax of Asteroid 1992JB when seen from the Flagstaff, AZ as compared to Hamilton, NY, and knowing *baseline*, i.e. the separation of the two telescopes (3172 kilometers). We can use a simple trigonometric formula to calculate the distance of the asteroid.

$$d = 206,265 \left( \frac{\text{baseline}}{\text{parallax}} \right)$$

Where the baseline and the distance are both expressed in kilometers and the parallax in arc seconds.

- Using this formula, calculate the distance of 1992JB on May 23, 1992 at 06 57 UT.

**Distance of 1992JB** = \_\_\_\_\_ km.

**Distance of 1992JB** = \_\_\_\_\_ Astronomical Units.

Compare this with the distance of the moon. How many times farther or closer is it than the moon?

\_\_\_\_\_.

Asteroids are classified by their average distance from the sun. Belt Asteroids orbit in the asteroid belt; Trojan Asteroids orbit at the same distance as Jupiter. Near-Earth or Earth Approaching asteroids have orbits that bring them near the earth. What kind of an asteroid do you think this is? Why?

**Questions**

1. Where is the location of this asteroid near earth, in the main asteroid belt?
  
2. What other information would you need to accurately locate the asteroid's location in the solar system?

**MAKE SURE YOU ATTACH ALL DATA SHEETS AND GRAPHS**