Student 1 Name: ___________________________ NetID: ________________
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# ASTR 150 - Astrometry of Asteroids Lab Exercise

**Due: March 4, 2011**

**This lab exercise will be graded out of 100 points (point values for each section and question are marked). You may work in groups of up to three students and turn in one report for your group. Be sure that all group members names are at the top of each sheet!**

## Part I (15 pts)

1. (3 pts) Sketch image 92JB05 in the box below.

**NORTH**

**EAST**

*Figure W1*
*Your Freehand Sketch of the Image*

2. (1 pt) Choose one of the brightest stars from the images, click on it, and note it for your own reference by writing the **number 1** next to it on your freehand drawn chart. Then, choose the second star form location reference and write a **number 2** next to it.
3. (4 pts) 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 W1, neatly label the asteroid's position on Image 92JB05 with a small **05** and its position on Image 92JB07 with an **07**.
4. (5 pts) After blinking through 92JB08, 92JB09, 92JB10, 92JB12, and 92JB14, mark the successive positions of asteroid 1992JB by dots labeled **08**, **09**, **10**, **12,** and **14** on Figure W1.

5. (1 pts) Draw an arrow in the space at right (Figure W2) to show the direction of motion. Don't forget the orientation of the image is different from what would be found on a traditional land map; see *Figure W1*.
6. (1 pt) What direction is this? (North, Northeast, Southeast, etc.)?

*Figure W2*
*Direction of Motion of the Asteroid*

## Part II (25 points)

1. (3 pts) After you match the GSC stars on the field, sketch all the reference stars from the reference star window on the left in the space below, then label the three stars you will use with 1, 2, and 3.

*Figure W3*
*Sketch of Reference Stars*

2. (22 pts) Following the instructions, fill in Tables W1 and W2.

**Table W1**
**Table of Reference Star Coordinates**

| Reference Star | ID # | RA | DEC |
|---|---|---|---|
| **# 1** | | | |
| **# 2** | | | |
| **# 3** | | | |

**Table W2**
**Measured Equatorial Coordinates**

| **COORDINATES OF ASTEROID 1992JB<br>MAY 23,1992** | | | |
|---|---|---|---|
| **File Name** | **Time (UT)** | **RA(h,m,s)** | **Dec (° ' " )** |
| 92JB05 | 04 53 00 | 15 30 38.7 | |
| 92JB07 | 05 03 00 | | |
| 92JB08 | 05 09 00 | | |
| 92JB09 | 06 37 30 | | |
| 92JB10 | 06 49 00 | | |
| 92JB12 | 06 57 00 | | |
| 92JB14 | 07 16 00 | | |

*Note: All the values for RA should be approximately the same.*

## Part III (30 points)

How fast is 1992JB moving? We can calculate its angular velocity in arcseconds per second of time using data taken in Part II of this exercise (See Table W2). The procedure we follow is to subtract the asteroid's starting position on image 92JB05 from its ending position on image 92JB14, and divide by the number of seconds between the starting image and the ending image. We express this mathematically as

$$\mu = \frac{\Delta\theta}{\Delta t}$$

where $\mu$ is the angular velocity of the asteroid, $\Delta\theta$ is the angular distance it moved, and $\Delta t$ is the time that elapsed.

***For your guidance in these calculations, approximate values appear in parenthesis beside some key answers. These are ballpark figures given to help reduce calculator errors. You should record your calculated values even if they are not near the given values.***

**Procedure for Part III**

# SHOW ALL YOUR WORK

***Measuring the elapsed time***

*a.* (2 pts) Record the time when image 92JB14 and 92JB05 were taken. *(These values are recorded in Table W2, Measured Equatorial Coordinates, in **Column 2 Time (UT)**.)*

Time of image 92JB14: ____hours ____minutes ______seconds

Time of image 92JB05: ____hours ____minutes ______seconds

b. (4 pts) Convert the hours to seconds to make subtraction easier. *(Note: Multiply minutes by 60 and hours by 3600 and add all the values together.)*

Time of image 92JB14: _____________seconds

Time of image 92JB05: _____________seconds

c. (2 pts) Subtract the time when image 92JB05 was taken from the time image when image 92JB14 was taken.

Time elapsed between 92JB14 and 92JB05 $\mathbf{\Delta t}$ = ______________seconds (8500)

***Measuring the angular distance traveled by 1992JB***

In order to calculate the angular distance traveled, we use the Pythagorean theorem, which states that:

$$c = \sqrt{a^2 + b^2}$$

As illustrated in Figure W4, because right ascension and declination are perpendicular coordinates, we can find the total angle moved using this mathematical relationship derived from the Pythagorean theorem.

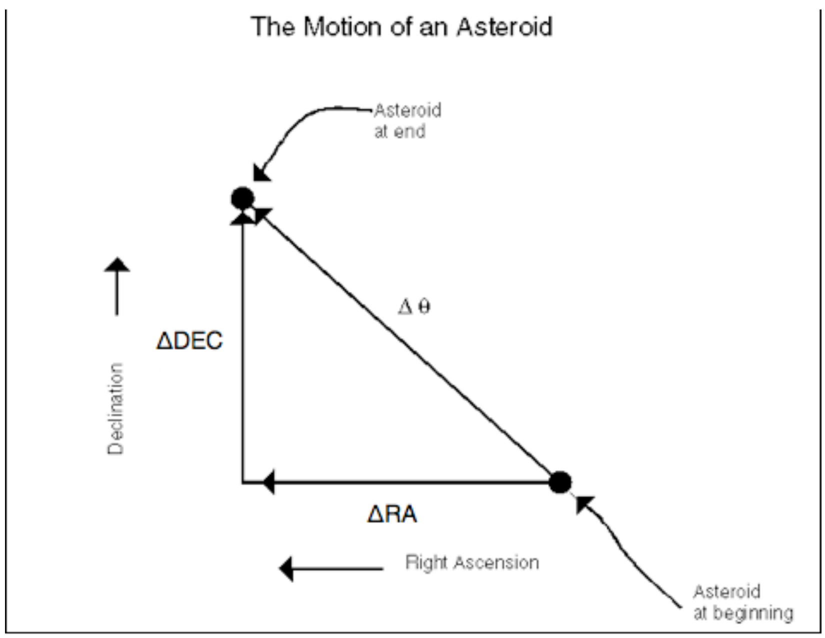


*Figure W4*
*The Mathematical Illustration of the Motion of an asteroid Asteroid*

Using Figure W4 as a guide, if we let **ΔRA** represent the change in the number of arcseconds in right ascension, and **ΔDec** represent the change in the number of seconds moved in declination, then using the relationship expressed by the Pythagorean theorem, we can construct the following equation to determine the total angle moved.

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

*d.* (2 pts) Record the values for the declination of the asteroid in images 92JB14 and 92JB05 below. (*These values are recorded in Table W2, Measured Equatorial Coordinates.)*

Declination of asteroid on 92JB14 _____ ° ________' _______"

Declination of asteroid on 92JB05 _____ ° ________' _______"

*e.* (4 pts) Convert the declination values to arcseconds to make subtraction easier. *(Note: Multiply ' by 60 and ° by 3600 and add all the values together.)*

Declination of asteroid on 92JB14 _______________"

Declination of asteroid on 92JB05 _______________"

f. (2 pts) Subtract to find the change in declination

**ΔDec**_______________" *(100)*

g. (2 pts) Record the values for the right ascension of the asteroid in images 92JB14 and 92JB05 below. (*These values are recorded in Table W2, Measured Equatorial Coordinates.)*

Right Ascension of asteroid on 92JB14 _____ h ________min _______sec

Right Ascension of asteroid on 92JB05 _____ h ________min _______sec

h. (4 pts) Convert the right ascension values to seconds to make subtraction easier *(Note: Multiply minutes by 60 and hours by 3600 and add all the values together.)*:

Right Ascension of asteroid on 92JB14 ____________seconds

Right Ascension of asteroid on 92JB05 ____________seconds

i. (2 pts) Subtract to find the change in right ascension:

**ΔRA**_______________ **seconds**

BUT WAIT! We're not done yet—1 second of RA is 15 arcseconds times the cosine of the declination. (Remember the RA lines come together at the poles, and so there are smaller angles between them at high declination. Multiplying by the cosine of the declination adjusts for this physical change). *Use **Declination** for the image center, any of the values on Table W2 will do, and you can round them to the nearest degree for simplicity! Note: Make sure your calculator is in Degrees Mode.*

j. (2 pts) **ΔRA(") = ΔRA(sec) x 15 x cosine(Declination( °)) =** ______________ **"**

k. (2 pts) Using the **Angular Distance Traveled Formula**, calculate **Δθ,** using **ΔRA** in arcseconds from step j and **ΔDec** in arcseconds from step f .

$$\Delta\theta = \sqrt{(\Delta \mathrm{RA}(''))^2 \ + \ (\Delta \mathrm{Dec}(''))^2} \ =$$ ____________" *(100)*

***Student Names:*** ______________________________

***Calculating the angular velocity of Asteroid 1992JB on May 23, 1992:***

$$\mu = \frac{\Delta\theta}{\Delta t}$$

l. (2 pts) Calculate $\mu$ by using $\Delta\theta$ from step k and $\Delta t$ from step c.

$\mu$ = ____________________ "/second. *(0.01)*

*Note: We've only calculated the angular (apparent) velocity of the asteroid. We need to know its distance to calculate how fast it's actually traveling in km/second. We will calculate the distance of 1992JB in the next section, using the method of parallax.*

## Part IV (20 points)

**1.** (4 pts) Using the images, address the following questions:

**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? _______**

**Using words and/or a diagram, try to explain why the position appears to shift, and explain the definition of parallax**.

***2. (4 pts) Measuring the coordinates of the asteroid in ASTEAST and ASTWEST***
Now using the methods you learned in part 2, measure the coordinates of the asteroid in ASTEAST and ASTWEST. You can use the **Images…Measure…Image** 1, and **Images…Measure…Image2** menu options on the main window. Tabulate your results below.

**<u>Measurement of Coordinates for ASTEAST and ASTWEST</u>**

| File | RA (h m s ) of 1992JB | Dec (° ' " ) of 1992JB |
|---|---|---|
| ASTEAST | ______________________ | ______________________ |
| ASTWEST | ______________________ | ______________________ |

***Student Names:***

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

a. (4 pts) Express the coordinates of 1992JB on both images in seconds/arcseconds to make subtraction easier:

| File | RA ( in sec ) of 1992JB | Dec ( in " ) of 1992JB |
|---|---|---|
| ASTEAST | ____________________ | ______________________ |
| ASTWEST | ____________________ | ______________________ |

b. (1 pt) Express the difference **ΔDec** in arcseconds: __________________ " *(5)*

c. (1 pt) Express the difference **ΔRA** in seconds: ________________seconds

d. (1 pt) Convert to arcseconds by using the equation below. The Declination is the total Dec not the difference. It is simply the standard declination of the asteroid. You can use the value from any measurement—e.g. table W2— as it need only be to the nearest degree.

**ΔRA(") = ΔRA(sec) x 15 x cosine(Declination°)** = __________________"

e. (2 pts) Calculate the total parallax in arcseconds:

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

using **ΔRA** in arcseconds from step d and **ΔDec** in arcseconds from step b.

**Parallax =** __________________" *(15)*

***4. 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

**Distance to the Asteroid = 206,265(Baseline/Parallax)**

where the baseline and the distance are both expressed in kilometers and the parallax in arcseconds.

f. (3 pts) Using this formula, calculate the distance of 1992JB on May 23, 1992 at 06 57 UT.

i. Distance of 1992JB = _______________km.

Convert this distance to Astronomical Units (1 AU is the average distance from the Earth to the Sun, 150 million km)

ii. Distance of 1992JB = _________________Astronomical Units. *(0.3)*

## Part V (10 points)

The tangential velocity, **V** $_t$, of an asteroid is the component of its velocity perpendicular to our line of sight. Again, a simple trigonometric formula lets you calculate its velocity in kilometers/second if you know its angular velocity (μ, in "/sec) and its distance (km). We determined the angular velocity in Part III step l and the distance in Part IV step f,i of this exercise. The tangential velocity is represented as:

$$V_t = (\mu \text{ x dist.})/206{,}265$$

1. (2pts) So using our results, calculate the tangential component of velocity of the asteroid.

**$V_t$ = ______________________ km/sec** *(3)*

**FINAL QUESTIONS:**

2. (3 pts) The average distance from the Earth to the Moon is 384,000 km. How many times further or closer is the asteroid than the moon? ________________________.

3. (5 pts) 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.

   Compare the distance to asteroid 1992JB with the distances (given below) to the orbit of Mars, the Asteroid Belt, and the orbit of Jupiter. Based on your results, what kind of an asteroid do you think 1992JB is? Why?

   FYI: Distance from Earth to…
   - …the orbit of Mars: 0.52 AU (78 million km)
   - …the Asteroid Belt: 1.8 AU (270 million km)
   - …the orbit of Jupiter: 4.2 AU (630 million km)

## EXTRA CREDIT! (10 pts)

Use the Astrometry program to analyze a set of image pairs listed in the table below. For each image pair, blink the images, and try to find an asteroid (*not all have asteroids!*). Note your findings in the table.

| Image Pair | Asteroid Identified (Y/N) |
|---|---|
| A1/A2 | |
| B1/B2 | |
| C1/C2 | |
| D1/D2 | |
| E1/E2 | |
| F1/F2 | |
| G1/G2 | |
| H1/H2 | |
| I1/I2 | |
| J1/J2 | |