Astronomy 45. Introduction to Astrophysics

Problem set 1 Due Wednesday, February 15

1. Against all odds a *new* inner planet is discovered in the Solar System. It is given the name Metallica. It is observed on November 14, 1997, to be at *greatest eastern elongation* (see diagram in class notes) at an angle of 37° from the sun.

a) What is the radius of its orbit in AU? (Assume a circular orbit.)

b) Using the fact that it is orbiting the Sun (gravitational force equals centrifugal force), what is the period of its orbit in years?

c) What is its so-called *synodic period*, the time between successive inferior conjunctions (see diagram in class notes)? Hint: Convert periods to angular velocities, and go to the *rotating frame* in which the Earth and Sun are both stationary. What is the angular velocity of Metallica's orbit in this frame? From it get the synodic period.

d) What are the dates of Metallica's next inferior conjunction, superior conjunction, and greatest Western elongation after November, 1997?

You might like to know that the synodic periods of Mercury and Venus are 115.8 and 584.0 days, respectively, and that 1 year = 365.24 days. (You don't need to use these numbers except as possible sanity checks on your intermediate results.)

2. Using the understanding of synodic periods and/or rotating frames from the previous problem:

a) Calculate the time it takes Venus to transit (cross) the Sun, if it crosses at an apparent latitude on the Sun's disk of 42°N. You can take the angular diameter of the Sun, as seen from Earth, to be 32 arcminutes. The period of Venus' orbit is 0.615 years.

b) Two observers on Earth are separated by a North-South distance of 8000 km. How different are the apparent latitudes on the Sun's disk at which they see Venus cross? That is, if the N observer sees 42.0000°N, what dose the S observer see.

c) What is the difference in absolute time between when the N observer sees Venus first touch the Sun, and when the S observer sees this. That is, if it occurs for the N observer at 11:00:00.000, when does it occur for the S observer (in the same time zone?) (You can assume that Venus is a point for this estimate, if you want.)

3. Proper motion is the apparent motion of a star in the sky (relative to distant fixed stars) due to its actual velocity in space relative to the Sun.

Barnard's star is a well-known astronomical object, of interest because of its huge proper motion. Its position in galactic coordinates is $(l, b) = (+35°, +14°)$, it has a proper motion of 10.3 arcsec per year, a parallax of 0.55 arcsec, and a radial velocity (relative to the Sun) of -108 km s^{-1} (i.e., towards us). $m_V = 9.54$ is its visual apparent magnitude.

a) What is the distance of Barnard's star from us?

b) Calculate the absolute (visual) magnitude of Barnard's star, and compare its (visual) luminosity with that of the Sun.

c) Sketch a diagram of the Galaxy, showing the direction of the galactic center, the location of Barnard's star, and the direction in which the Sun moves in the Galaxy.

d) What is the velocity of Barnard's star? Compare this with the velocity of the Sun about the center of our Galaxy (220 km s^{-1}). What type of motion is Barnard's star participating in?

e) What will be the parallax of Barnard's star when it is at its closest distance to us? In approximately what year will that happen?

f) The present magnitude of Barnard's star is $m_V = 9.5$. Will the star ever become visible to the naked eye (at $m_V < 6$)? What will be its apparent magnitude in 10^5 years time? In 10^6 years time?

(Reading: Shu, pp. 261–264, 266).