1. She blinded me with science… [20 pts.]

A. Please name and explain the main properties of a scientific hypothesis according to the scientific method.
   1) Relevant
   2) Consistent
   3) Predictive
   4) Testable
   5) Simple (Occam’s Razor)

B. What do you think are the main differences between this approach to understand the physical world, and an alternative one like astrology (or magic)?

   Science is self-correcting, in the sense that false hypotheses that fail tests are discarded or modified. Testability is the key property of a hypothesis, and in fact ideas that cannot be tested are considered irrelevant to science (and left for philosophy, for example). Astrology or magic rely on the acceptance of hypothesis that either cannot be easily tested (e.g., people born under a fire sign have ‘choleric’ temperaments), or that clearly fail simple tests (e.g., specific predictions by groups of astrologers get the right result with the same frequency as random chance) yet erroneous results are attributed to “human error” or “divine intervention”. Science also puts a lot of emphasis on understanding and proving causality and its mechanisms (e.g., illnesses are caused by bacteria), while the mechanisms behind cause and effect in astrology and magic are by design mysterious.

2. Location, location, location [20 pts.]

A. Outline three good arguments for the Geocentric view. Why should the Earth be at rest at the center of the Universe?
   1) We have no perception of motion on the surface of the Earth
   2) Stars do not have a perceptible parallax motion
   3) We are the acme of creation. How could we not be at the center?

B. Who proposed the Heliocentric model first and when? What was the motivation?

   Aristarchus of Samos. His measurements show that the Sun was much larger than the Earth. How come the Sun is moving around us? The Sun should be at the center (of the Universe)

C. What was the crucial observation that finally proved geocentrism could not be correct? What was the prediction from the Geocentric model and what was actually observed?
Galileo’s observations of the phases of Venus were not compatible with the Geocentric view. It was clear that Venus was, when almost full, farther than the Sun, which would be impossible in the Geocentric system.

3. Erathostenes the astronaut [20 pts.]

A. On a given day the Apollo 11 flagpole on Mare Tranquillitatis casts no shadow (the Sun is directly overhead, that is, at 0 degrees from the zenith).
At precisely the same time, the flagpole on the Apollo 17 landing site, situated 640 km almost directly north of Mare Tranquillitatis in the Taurus-Littrow region, casts a pretty noticeable shadow because the Sun is about 21 degrees away from the zenith. What is the circumference of the Moon according to these numbers?

B. Research the sizes of Ganymede and Ceres. How far away from their equators (in km) will similar flagpoles have to be to cast shadows similar to the example above in these planets?

The radius of Ganymede is 2,631 km, corresponding to a circumference 
\[ P_{\text{Ganymede}} = 2\pi R = 16,532 \text{ km} \]. The radius of Ceres is 473 km, corresponding to a circumference 
\[ P_{\text{Ceres}} = 2,972 \text{ km} \]. Using the equation above with \( d \) instead of 640 km
\[
\frac{P}{d} = \frac{360^\circ}{21.0^\circ} = 17.1 \Rightarrow d = \frac{P}{17.1}
\]
So we can substitute the values of \( P_{\text{Ganymede}} \) and \( P_{\text{Ceres}} \) we found above and obtain
\[
d_{\text{Earth}} \approx 967 \text{ km} \text{ and } d_{\text{Mercury}} \approx 174 \text{ km}
\]

4. The distance to the stars [20 pts.] 

A. Parallax is the change in apparent position of an object against the background, as the observer moves. In annual parallax, the observer is carried ±150,000,000 km by the Earth in its orbit around the Sun. Think about a right triangle with the 90 degree vertex on the Sun, another vertex at the Earth, and a third at a very distant star. If the angle subtended by the Earth-Sun distance as seen from the star is 1 arcsecond (1” is 1/3,600 of a degree, or \( \pi/(180*3,600) \) radians), what would be the distance from the Sun to the star? That distance (D) is called a “parsec”, and it is a common distance unit in astronomy, useful because the parallax measured in arcseconds is the inverse of the distance in parsecs (P[arcsec]=1/D[parsec]). Hint: sketch a drawing and recall the definition of tangent of an angle.
\[
D = 150,000,000 \text{ km/tan (1/3,600 deg)} \approx 3 \times 10^{13} \text{ km}
\]

B. Barnard’s star is a red dwarf that happens to be one of the closest stars to the Sun. Its parallax is 545 milli-arcseconds. How far away is it in light-years? (Hint: one parsec is approximately 3.27 light-years. Recall the definition of parsec and why it is a useful distance unit for computing parallaxes)
\[
\text{Distance to Pollux [parsec]} = 1/P[”]
\]
P = 545 m" * [1 " / 1000 m"] = 0.545 "

\[ D [\text{parsec}] = \frac{1}{P [\text"]} = \frac{1}{0.545} \approx 1.835 \text{ parsecs} \]

\[ 1.835 [\text{parsecs}] \times 3.27 [\text{ly/parsec}] \approx 6 \text{ ly} \]

C. Did Tycho Brahe stand any chance of measuring Pollux’s parallax? What do you think this means about a crucial objection leveled against the Heliocentric model?
No, this is such a small angle that it is impossible to measure with the naked eye. Since this is one of the nearest stars, it is clear that it was impossible to measure any parallax motion before the invention of the telescope. The lack of parallax, which was a key objection against Heliocentrism that swayed many people (for example, Tycho Brahe), just implies that the Universe is VERY LARGE.

5. Kepler’s third law [20 pts.]

A. The minor planet 90377 Sedna orbits the Sun with a period of 11,400 years. Use Kepler’s third law to find out the semimajor axis of the orbit of Sedna, expressed in Astronomical Units (AU).

Kepler’s 3rd law states \( P^2 [\text{yr}] = R^3 [\text{AU}] \)
So Sedna's semimajor axis around the Sun is \( R = 11,400^{2/3} \approx 507 \text{ AU} \)

B. The first extrasolar planet (i.e., a planet orbiting another star) was found around the solar-type star 51 Pegasus in 1995. Its period is about 4.25 days (a very short year!). What would be its distance to 51 Pegasus? (Hint: solar-type means its mass is very similar to the mass of the Sun)

Because the mass of 51 Peg is very similar to the mass of the Sun, we can directly use Kepler’s third law without considering how the mass of the central object changes it. Its period around 51 Peg is \( P = \frac{4.25}{365.25} = 0.0116 \text{ yr} \). Thus this planet is at about 0.05 AU of the star (~7.5 million km)

C. Geostationary satellites complete a revolution around the Earth in 24 hours, so that for an observer on the Earth’s surface they appear fixed in the sky (they don’t partake of the daily motion). Use the full version of Kepler’s third law found by Newton to figure out the radius of their orbit in km. (The mass of the Earth is approximately \( 6 \times 10^{27} \text{ g} \), and the gravitational constant is \( G = 6.7 \times 10^{-8} \text{ cm}^3 \text{ g}^{-1} \text{s}^{-2} \). Note that it is important to make sure that the units are consistent throughout: convert the period to seconds, and the result will be the orbital radius in cm, which you can then easily convert to km.)

The full version of Kepler’s third law, due to Newton, is \( P^2 = \frac{4\pi^2}{G(M + m)} R^3 \),
where \( M \) is the mass of the central object (the Earth, in this case), \( m \) is the mass of the orbiting object (the satellite, which being much much smaller than the mass of the Earth we can set to zero), and \( G \) is the gravitational constant, which sets the units. Since I gave \( G \) in cgs units, we should use the mass of the Earth in grams. A little googling finds \( M_{\text{Earth}} = 5.9 \times 10^{27} \text{ g} \). Thus substituting values in the equation above we can write:

\( P^2 \approx 10^{-19} \text{ cm}^{-3} \text{s}^{-2} R^3 \Rightarrow R^3 \approx 10^{19} \text{ cm}^3 \text{s}^{-2} P^2 \)
Now the only thing we need to do is to express the period of the orbit, $P$, in seconds to obtain $R$ in cm, then convert to km. The period is $P=24$ hr=$86,400$ s. Thus the radius is $R \approx (10^{19} 86400^3)^{1/3} \, cm \approx 4.2 \times 10^9 \, cm = 42,000 \, km$
1. Read the course syllabus
Carefully read the course syllabus under my webpage at http://www.astro.umd.edu/~bolatto. Then sign below:

I have reviewed the course syllabus and understand the work involved and how my grade will be determined. I have also reviewed the University’s policies on academic honesty.

Signed: ___________________________ Date: ____________

2. Contact information (optional)
Although the instructor can find your official contact information, it’s common that this is not the best way to find you if you forget something in the class, etc. The best way to contact me (email address, phone number, etc) is ___________________________

3. Tell me how things are going so far
Are the lectures interesting? Have we covered something that you found particularly interesting? Did I miss (or did not properly develop) an interesting topic?