C10, Week 5

You can't explain that.

1. Explain why there are *two* high tides (on either side of the Earth). Feel free to draw a picture, if it helps. There are many different ways to explain this – some more intuitive than others. **The high tide on the side nearer the moon is easy – the moon pulls on the near side *more than it pulls on the center* (because the force of gravity falls off with distance). As a result, the near side of the Earth accelerates towards the Moon (relative to the center). Thus, the near side is "stretched", which forms a bulge in the direction of the moon. This bulge is the high tide (water fills the bulge because its easier for the water to move than the Earth's rock). The far side is a little trickier. One way to think about this is that the Moon pulls on the *center* with more force than it pulls on the far side. As a result, the center of the Earth "falls out" from under the far side. The result is that you get another "bulge" because the far side and the center are moving apart from each other. Another way to think about this is using the concept of vectors – draw arrows representing the force of gravity at different points, then subtract out the force of gravity at the center of the Earth – this is in your course reader.**

2. What is the Roche limit, and its relation to tidal forces? **When we put two objects near each other, they experience tidal forces. These tidal forces *stretch* the objects in question (i.e., the high tides). The Roche limit tells us how far away we can place a small object (e.g., a moon) from a larger object (like a planet), without the stretching due to tidal forces completely breaking the small object apart.**

3. We often say that Earth-moon system is tidally locked *in one direction*. Explain what this statement means.

   The Moon is tidally locked – its period of rotation around the earth equals its period of revolution about its own axis. As a result, the *same* side of the Moon always faces the Earth. The reverse is not true for the Earth (hence the *one direction*.

4. The Roche limit can be expressed as $D_{\text{roche}} \approx R\left(\frac{\rho_M}{\rho_m}\right)^{1/3}$, where the numerator and denominator correspond to the densities of the massive object and the smaller object being disrupted and R is the radius of the more massive object (i.e., M). If I increase the mass of the Sun by a factor of 10, how does its Roche limit change (assume the smaller object is the same in both cases)? Calculate the Roche limit for the Sun, assuming $\rho_\odot = 1g/cm^3$ and $\rho_{\text{mercury}} = 5g/cm^3$. Do you think Mercury is in the process of being disrupted by the Sun? **The Roche limit, $D \propto \rho^(1/3)_\odot$. If we increase the mass by a factor of ten, but leave the *size* of the object the same (note that I didn't specify that the size of the object is fixed, but I should have), then the density increases by a factor of ten too. So:**

$$\frac{D_1}{D_2} = \frac{\rho_{new}^{1/3}}{\rho_{old}^{1/3}} = 10^{1/3} \tag{1}$$

   So, the Roche limit increases by a factor of $10^{1/3} \approx 2.15$.

Exoplanets: Doctor Who Edition[1]

5. The Daleks are planning an invasion of Planet Inferior. After having been foiled by the Doctor many times, they decided to do their homework and spent some time observing Inferior's star system for a while before their invasion. They find that that the brightness of Inferior's host star decreases by about 1% every 3 years.

   (a) What is the ratio of the radii of the planet and the star? How does the decrease in brightness change if you halve the radius of Inferior? **The "dip" in brightness in the light curve is**

[1] the exoplanets people bring in so much funding from rich folks that want to be the first to find ET; meanwhile, those of us studying galaxies are left high and dry

proportional to the ratio of the area of the planet to the area of the star. In this case, the decrease in brightness is 1%. So:

$$\frac{A_p}{A_*} = .01 = \frac{\pi R_p^2}{\pi R_*^2} \tag{2}$$

Square root both sides to find that $R_p/R_* = \sqrt{.01} = 0.1$. So the planet has one-tenth the radius of the star.

(b) Draw the light curve that the Daleks would see for both cases (extra points for getting it to scale!). **Easier to draw in section...we'll talk more next week.**

(c) **Bonus:** If the host star has $R = 10^8$km, what is the planet's radius, in Jupiter radii ($R_J = 7 \cdot 10^7$ m).

6. The Dalek invasion succeeded! They are so pleased with the results of their due-dilligence that they decide to survey lots of star systems using the "Doppler wobble" (note: this is different from the above "transit" method) method to look for invade-able planets before hand, to maximize their conquering efficiency. Unfortunately, they find a lot of "hot Jupiters" – Jupiter-ish mass planets very near their host star (with conditions unfavourable to the existence of exterminate-able life) Can you help explain why to the disappointed Daleks? **The Doppler wobble method relies on the fact that the planet "tugs" on the star, causing a slight change in velocity of the star (which we can then detect by looking at the spectrum of the star). The "tugging" is caused by the gravitational pull of the planet on the star. The force of gravity is $F_G = GM_1M_2/d^2$, so we would expect to find lots of hot jupiters – they have large masses, and are located at relatively small radii (i.e., d is small) – both of these effects will tend to *increase* F_G, so the Hot Jupiters will have strong tugs on their host star, leading to easily detectable Doppler wobbles.**

Are you ready for the midterm?

7. Briefly explain how a diffraction grating works.

8. What do we see through a diffraction grating when we look at a.) incandescent light bulb, b.) a cloud of cold gas, c.) a fluorescent neon lamp? *hint: think carefully about (b)*

9. Describe the properties of Jupiter's moons.

10. Star A has half the radius of Star B, but double the temperature. How do the luminosities compare?

11. Explain why Venus is so hot. How does this relate to climate change on Earth?

12. Explain why there is no dark side of the moon.

13. What are planetary rings made out of? How'd they get there?

14. Explain why, when ionizing an atom, you only need a *minimum* amount of energy.

15. I heat up a cloud of hydrogen gas, and then immediately afterward have you look at it through a diffraction grating. What do you see?

16. Kepler's law of equal areas in equal times is a consequence of the conservation of what fundamental quantity?

17. How does the length of a planet's year depend on the planet's mass?

18. If you double the radius of the Earth's orbit, by what factor would its period change?

19. What wavelengths does the visible spectrum correspond to?

20. Give a few reasons that we use reflecting telescopes over refractors (mostly) these days.

21. Telescope A is a UV telescope. Telescope B is an optical telescope, that operates at about twice the wavelength of A. It also has twice the diameter of A. Which one has a better angular resolution?

22. What do you expect seasons to be like on a planet with *no* tilt in rotational axis relative to the orbital plane if the planet has an a.) eccentric orbit or b.) a circular orbit?

23. Telescope A has an area A_A. Telescope B has three times the area. Assuming both telescopes are looking at identical objects, how much farther away can I place the object under inspection and still gather the same amount of light, using Telescope B?

24. If Star A has three times the temperature of Star B, how do the peak wavelengths compare? How about their luminosities? Assume $R_A = R_B$.

25. When does the full moon rise? What about the new moon? Give *two* reasons its so difficult to see the new moon.

26. If the tilt of the Earth were doubled from 23.5 to 47 degrees, how would the seasons change?

27. Explain how we can use a Doppler shift to measure the velocities of distance stars. *hint: how do we measure* $\Delta\lambda$*?*

28. Explain why Pluto was demoted from planet to dwarf planet.

29. The police are after me again for my armoured car heist. They've got a sniper in a car chasing after me at 50 m/s. The red laser dot from the sniper's laser is trained on me. What colour does the laser appear now? **Bonus:** How fast would the sniper have to be moving for his red laser to appear blue to me (approximately)?

30. What is the mass of the Sun, in solar masses?

31. What is the distance from the Earth to the Sun, in AU?