ASTR 120 Problem Set 7: Due Tuesday, October 24, 2017

General reminders: You must show all your work to get full credit. Also, if any website was useful, you need to give the URL in your answer. Note that any website is fair game; you just have to cite it. If any book including our textbook was useful, you need to indicate where in the textbook you used a particular fact. This will be true in all homeworks.

1. [5 points] In daylight, Earth's surface absorbs about 400 W/m^2. Earth's internal radioactivity produces a total of 30 trillion W that leak out through our planet's entire surface. Calculate the amount of energy per time from radioactive decay that flows outward through each m^2 of Earth's surface. Compare with solar heating and comment on why internal heating is nonetheless the primary driver of geological activity.

2. [5 points] Micrometeorites will eventually erase the footprints left by the Apollo astronauts. Assume that the Moon is hit by about 25 million micrometeorite impacts each day (this number comes from observations of meteors in Earth's atmosphere) and that these impacts strike randomly around the Moon's surface. Also assume that it will take about 20 such impacts within a footprint to destroy that footprint. Your task is to calculate, to within a factor of 10, how long it would take for a footprint to be erased.

3. [5 points] It is possible to show that a "gravitational boost" of (say) a comet or asteroid by a planet (in which the comet passes by the planet and receives an increase to its speed relative to the Sun) can at most increase the speed of the comet or asteroid by the *smaller* of (a) the escape speed from the surface of the planet, or (b) twice the orbital speed of the planet.

Using this information, suppose that a comet or asteroid initially has an orbital speed relative to the Sun that is equal to the orbital speed of one of the planets in our Solar System (for the purposes of this problem, assume that each of our planets orbits in a circle with a radius equal to the semimajor axis of the planet's orbit). Calculate, for each of our eight major planets (using data from a website that you find and specify), whether it is possible for that planet to kick the comet or asteroid out of the Solar System. For example, if you are considering Mercury, you will assume that the asteroid initially had the orbital speed of Mercury; could a single gravitational boost from Mercury kick that asteroid out of the Solar System? As part of the problem, please comment on what relevance this has to the origin of distant comets in the Solar System.

4. [10 points] The Earth's major source of internal energy is radioactive decay, and as you should have learned in Problem 1, that energy is tiny compared with the energy we get from the Sun. The same is *not* true with Jupiter. In this problem we will explore some aspects of the differences.

a. The Sun's luminosity is $L_{\rm Sun} = 3.846 \times 10^{26}$ Watts. At a distance equal to the semimajor axis of Jupiter (look it up), what is the flux of energy from the Sun?

b. Say that Jupiter's radius is R_J; we'll treat Jupiter as a sphere. The effective area that Jupiter presents to the Sun is then πR_J^2 (because it looks like a circle from the distance of the Sun). However, only 27% of the Sun's radiation is absorbed by Jupiter (the rest is reflected back into space). Use this information to compute the energy per time absorbed from the Sun by Jupiter.

c. Jupiter's effective average temperature, over its whole surface, is $T_J = 134$ K. Assuming that Jupiter emits like a blackbody, compute the total energy per time emitted by Jupiter.

d. The difference between your answer to c. (energy per time emitted) and b. (energy per time absorbed from the Sun) is the extra energy per time generated by Jupiter. Unlike on Earth, where radioactive decay is dominant, for Jupiter it is a slow ongoing contraction that matters the most. For this part of the problem, you will estimate how long it would take to shrink Jupiter substantially. To do this, divide the approximate gravitational energy of Jupiter (with magnitude GM_J^2/R_J, where M_J is Jupiter's mass) by the excess energy per time that you found (i.e., your answer to c. minus your answer to b.). How does this compare with the age of the Solar System? Comment on how this relates to the general issue of volume to surface area ratio.

Bonus Question [2 points]

One of the early hints that an asteroid impact did in the non-avian dinosaurs some 66 million years ago was a layer of iridium from that time. Do a web search, and do your own thinking, to determine *why* this was a clue of an asteroid impact. **Hint:** what is the density of iridium?