Name: ____________________

Homework #8

Due at 5pm on Monday, November 11

You may submit Parts 1, 3 and 4 either (a) electronically via Moodle or (b) on paper to my mailbox outside Merrill 213. Do NOT leave under my door or in the boxes outside my office.

Part 1 –

Complete a brief follow-up to the midterm survey at: https://goo.gl/forms/utEuj41PM26cW3p62

Exercise: Crater Counting : A quantitative exercise in determining crustal age

Objective: Making the assumption that the cratering rate on the Moon, as measured by the Apollo missions, is typical of the cratering rate for the entire inner Solar System, the student will extend the measurements of the lunar crater density (where we know the actual ages of the surfaces) to the surface of Mars. In doing so, we will estimate the ages of two specific regions on Mars.

Background Info: The Moon as a control surface

The Moon is the perfect control object for our study for three very important reasons*; 1) it is in close enough proximity for us to physically reach, 2) we have returned rock samples from various different places on its surface and radiometrically dated them in the lab, and 3) it has no atmosphere, water, erosion, plate tectonics, etc. to eradicate craters so its surface represents a pristine record of exposure to bombardments*.

By counting the number of craters in some defined area on a planet or satellite (i.e. determining its crater density) and comparing it to the number of craters on a different area of the same size on that planet, you can determine the relative ages of the two surfaces (e.g. one area is twice as old as another; recall our definition and techniques for relative age dating.

If, however, you want to determine the absolute age of the surface you are studying, you will need a rock sample of the material that composes that surface in order to run radiometric laboratory analyses. Fortunately for us, the Apollo mission astronauts brought back lots of rocks from six different locations on the Moon. By measuring the ages of the rocks from these six sites, and measuring the crater density at these sites, we can determine how the crater density is related to the absolute age at these sites. Now, at least for the Moon, if we can measure the crater density of any part of the Moon, we can compare it to the crater density at the Apollo sites to determine their relative ages. Since we now know the absolute ages of the rocks at the Apollo sites, we can determine the absolute age of any part of the Moon.

For this homework activity, we make the assumption that the cratering rate measured by Apollo on the Moon is typical of the cratering rate for the inner Solar System. We can now extend our measurements of the crater density on the Moon to estimate the ages of various regions on the surface of Mars.

The materials you will use for this exercise are two Mars images taken by the Viking 1 and 2 orbiters. The Viking project consisted of two separate spacecraft launched to Mars in the 70's. Each spacecraft consisted of an orbiter and a lander. After orbiting Mars and returning images used for landing site selection, the orbiters and landers detached. The landers entered the Martian atmosphere and soft-landed at the selected sites in the summer of 1976. The orbiters continued imaging and conducting other scientific operations from orbit, while the landers deployed instruments on the surface. The Viking 1 orbiter was turned off on 17 August 1980, after returning more than 30,000 images in 1485 orbits around Mars. The Viking 2 orbiter was turned off on 25 July 1978, after returning almost 16,000 images in 706 orbits around Mars.

Determining the Crater Density

On each of the two images at the end of this section are 5 white bars that represent 128, 64, 32, 16 and 8 km lengths. There is also a scale bar at the top of each picture, though you may need to zoom in on the image in order to read it.

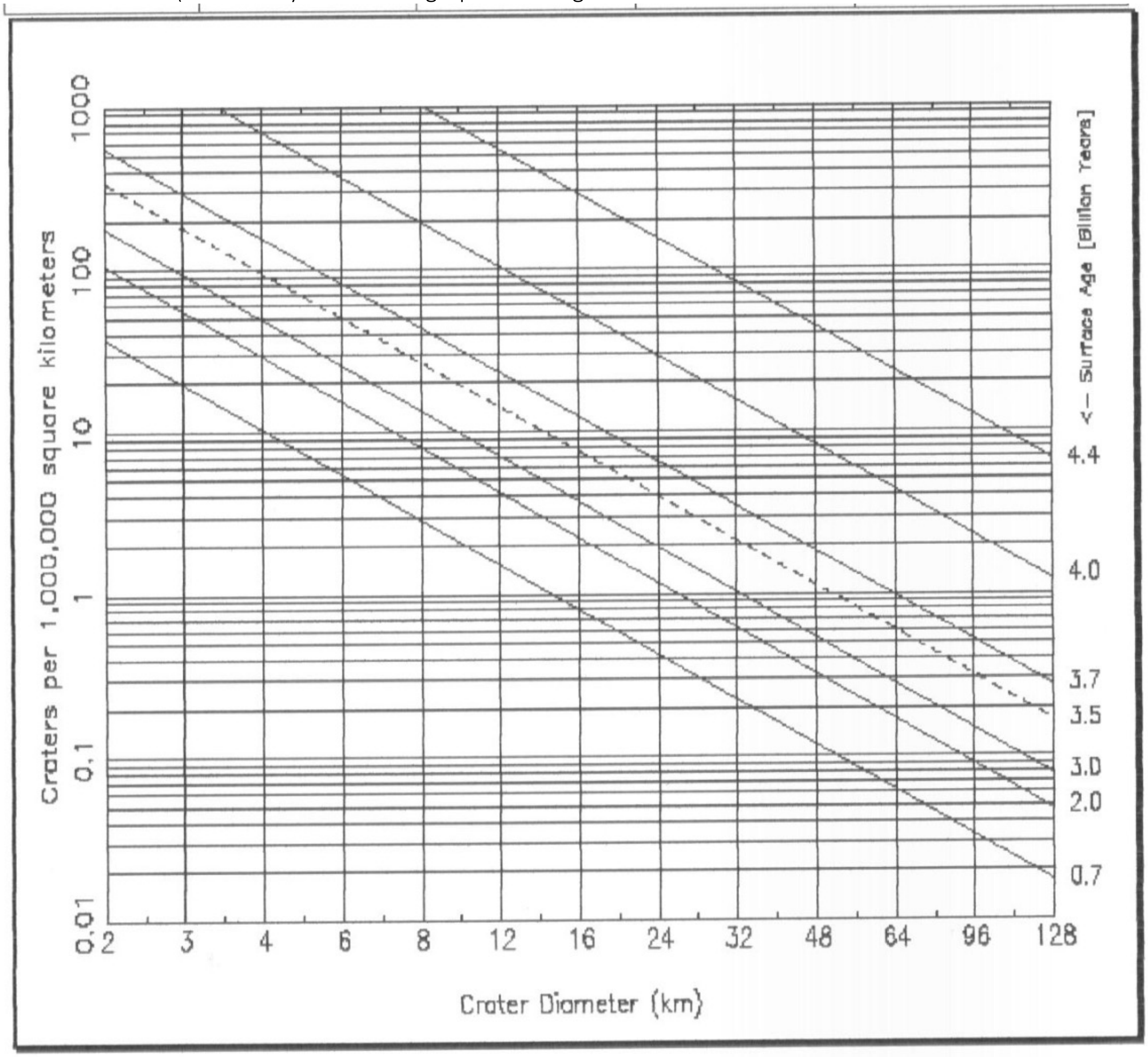
1. Use the white markings and/or scale bar to determine how many craters are in each size range in the image. You may not be able to use all the different size ranges. There may be no craters in some of the larger ranges or too many craters in the smallest ranges. There will also be a limit to the smallest craters you can positively identify, so use common sense in your counting of the smaller ones. Try to fill in as many of the size ranges as you can with as many craters as you can positively identify. Record the numbers in the Crater Density Table.

2. Martian Crater Density Data Table				
	Northern Hemisphere		Southern Hemisphere	
Crater Size Range (km)	Number of craters in image	Number of craters in 1,000,000km^2	Number of craters in image	Number of craters in 1,000,000km^2
<8				
8-16				
16-32				
32-64				
64-128				

3. The data for the crater density of the Apollo sites was determined over 1,000,000km^2. The total area of the images you are using is shown at the bottom of the image. Using the numbers from the table and the formula below, determine how many craters of each size range are found in 1,000,000 km^2. Record this number in the table.

Number of craters per 1,000,000 km^2 = Number of craters × (1,000,000 km^2 / (Image size) km^2)

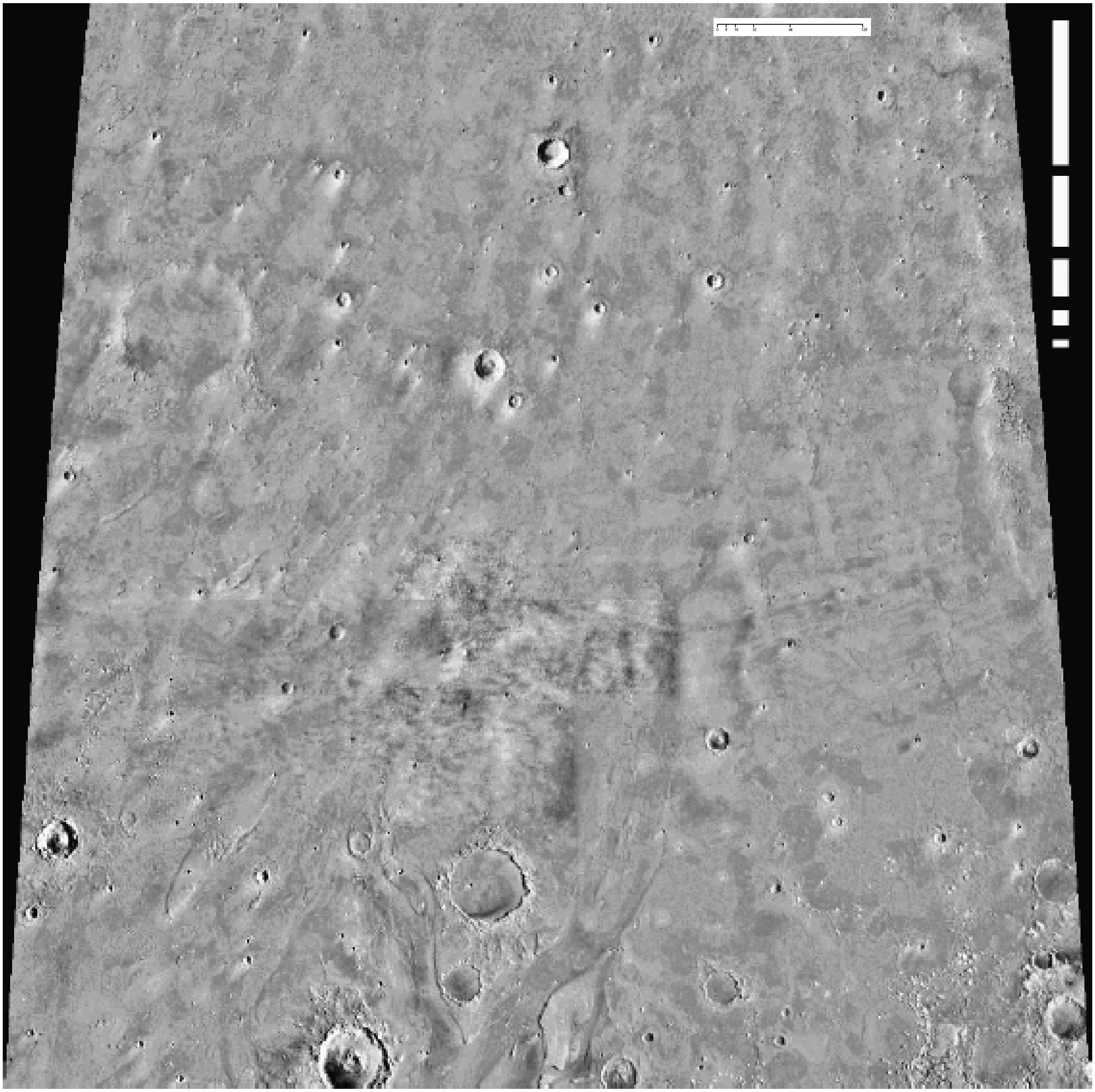
4. Plot your data points from the table on the Crater Density Graph. Put your points on the graph in the **middle** of your size range. For example, if you had 200 craters in the 0-8 km size range, you should put your point at the intersection of 200 on the y-axis, and 4 on the x-axis. (Note: the y-axis of this graph has a logarithmic scale.



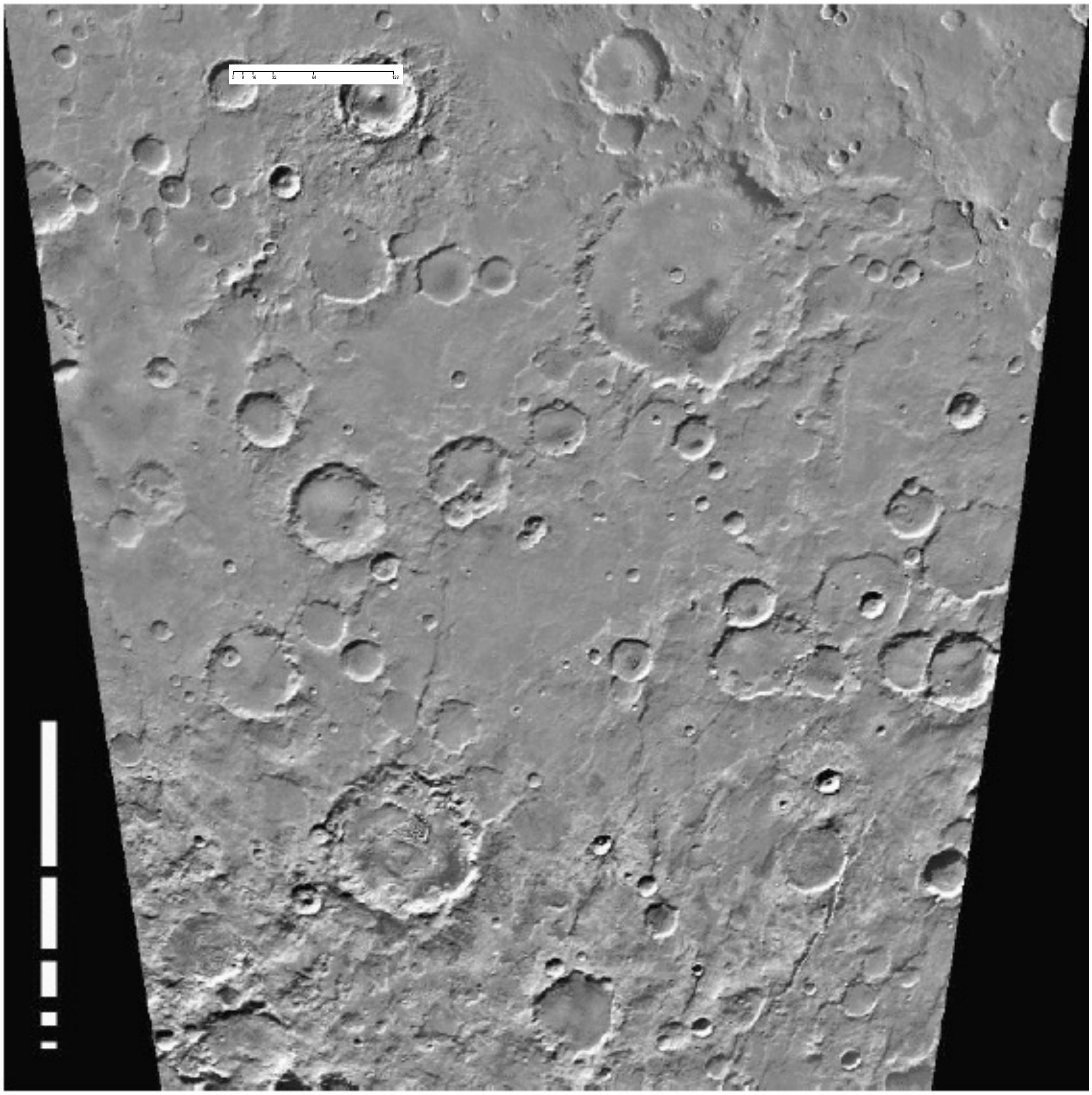
5. Determine the age of your surface. Once you have your points plotted, draw a bets-fit straight line through the points, as best you can. Your line should be parallel to the age lines on the graph. The line you have drawn represents the average age of the cratered surface you have been examining and defines that age where it meets the right-hand y-axis. Estimate the age by interpolating the age given by the line you have drawn with the age lines already on the graph.

Martian Northern Hemisphere Surface Age = __________ billion years old

Martian Southern Hemisphere Surface Age = __________ billion years old



Martian Northern Hemisphere - Image Size = 812,250 km^2



Martian Southern Hemisphere - Image Size = 774,250 km^2

Part 2 – Mastering Astronomy

Please complete this part through the course Moodle page. It's due at the same time as the rest of the assignment.

Part 3 – Checking in

Answer this portion on the same sheet of paper as Part 1.

a) What was the most interesting concept that you learned in class last week?

b) What was the most difficult concept that you learned in class last week? What is still confusing about it?

Part 4 – Observing

AS ALWAYS, THIS SECTION NEEDS TO BE HANDED IN ON A SEPARATE SHEET OF PAPER

This week's "observations" are a continuation of last weeks and require the same set of simulators at: http://astro.unl.edu/naap/atmosphere/atmosphere.html. Use the background information and simulators that you find there to answer the following questions.

Gas Retention Plot

This simulator presents an interactive plot summarizing the interplay between escape velocities of large bodies in our solar system and the Maxwell distribution for common gases. The plot has velocity on the y-axis and temperature on the x-axis. Two types of plotting are possible:

- A point on the graph represents a large body with that particular escape velocity and outer atmosphere temperature. An active (red) point can be dragged or controlled with sliders. Realize that the escape velocity of a body depends on both the density (or mass) and the radius of an object.
- A line on the graph represents 10 times the average velocity ($10 \times v_{avg}$) for a particular gas and its variation with temperature. This region is shaded with a unique color for each gas.
    - If a body has an escape velocity v_{esc} over $10 \times v_{avg}$ of a gas, it will certainly retain that gas over time intervals on the order of the age of our solar system.
    - If v_{esc} is roughly 5 to 9 times v_{avg}, the gas will be partially retained and the color fades into white over this parameter range.
    - If $v_{esc} < 5\ v_{avg}$, the gas will escape into space quickly.
- Note that speed may represent the escape speed of a planet (a point on the graph) or the average speed of a gas (a curve on the plot).

Exercises

Begin experimenting with all boxes unchecked in both the gasses and plot options.

Question 1: Plot the retention curves for the gases hydrogen, helium, ammonia, nitrogen, carbon dioxide, and xenon. Describe the appearance of these curves on the retention plot.

*Check "**show gas giants**" in the plot options panel.*

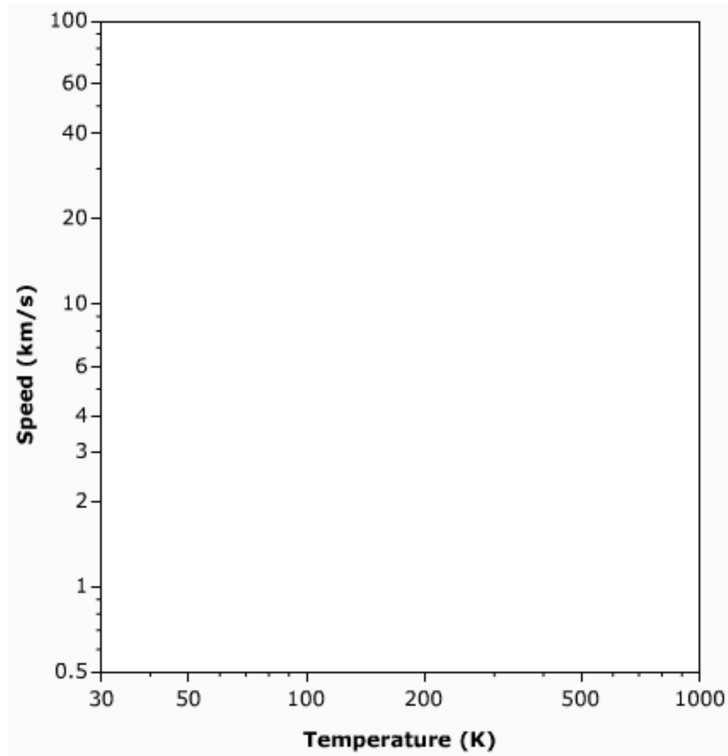
Question 2: Discuss the capability of our solar system's gas giants to retain each of the gases listed in Question 1 and describe how the plot supports your argument.

Question 3: Drag the active point to the location (comparable with the escape speed and temperature) of Mercury. The gases hydrogen, helium, methane, ammonia, nitrogen, and carbon dioxide were common in the early solar system. Which of these gases would Mercury be able to retain?

Question 4: Other observations by the Cassini probe have confirmed that Titan has a thick atmosphere of nitrogen and methane with a density of about 10 times that of the Earth's atmosphere. Is this finding completely consistent with Titan's position on the atmospheric retention plot? Explain. (Make sure that show icy bodies and moons is checked as well as the gasses methane and nitrogen.)

Question 5: Fill in each of the following on the plot at right.

a) The Earth has an escape velocity of 11.2 km/s and an average surface temperature of about 280 K. Indicate the location of the Earth on the plot.
b) Draw in a small region representing where terrestrial planets would be found.
c) Draw in a small region representing where jovian planets would be found.
d) Add the following satellites to the graph:
   - the moon has an escape velocity of 2.4 km/s and a temperature similar to the Earth's
   - Titan (satellite of Saturn) similar in mass and radius to the moon
e) Sketch in the 10 × v_{avg} curve for hydrogen and nitrogen.



Question 6: Based on your plot, which solar system bodies will clearly be able to retain hydrogen over long periods of time? Explain how you determined this from the plot.

Question 7: Based on your plot, Which solar system bodies will clearly NOT be able to retain nitrogen over long periods of time? Explain how you determined this from the plot.