Lab 4: Planets

Part I — Planetary Classification

The International Astronomical Union (IAU) has called you up and given you the task of creating a scientific definition for the word planet. Luckily, they have also provided you with a list of objects that might *potentially* be classified as a planet, as well as physical characteristics for each one. Unfortunately, the email they sent you cut off the names of the "candidate planets", so you're going to have to figure out the definition of a planet without knowing which object is which. In this exercise, you will compare the properties of these objects, and come up with a reasonable way to classify them.

1) The "composition" column indicates in which form most of the mass in the body is found. Find the average distance from the Sun (i.e. orbital radius) of "rock" objects, the average distance from the Sun of "gas" objects, and the average distance from the Sun of "rock and ice" objects. Are there any bodies whose distance values do not seem to fit in with the others in their composition class? Which ones? If so, recalculate the average distance for that class again without this/these member(s). Does the composition of an object strongly correlate with its distance from the Sun?

2) Orbital eccentricity ϵ tells us how the orbit is shaped. Very eccentric orbits are much longer in one direction than they are in the other, i.e. their orbits form a long oval. Orbits that are almost circular have low eccentricities (and perfectly circular orbits are not at all eccentric). Identify the bodies that have the most eccentric orbits – you can set your own "cutoff" value. Look at the other properties of the eccentric bodies. Is there anything they have in common?

3) Make a scatter plot of object mass versus distance from the Sun (orbital radius). The x-axis will be $\log_{10}(orbital\ radius)$ in units of AU, and the y-axis will be $\log_{10}(mass)$ in units of the Earth's mass (M_E). Do massive bodies tend to be farther from or closer to the Sun? What about low-mass bodies? Are there exceptions to this? If so, what are they?

- Why do you think I've asked you to plot these particular parameters using a $\log_{10}$ scale? (Hint: think about our very first lab... Alternatively, you can try making the plot on a linear scale and see what happens!...)
- Differentiate the data point markers on the plot by their composition (you can use different shapes or colors). Are you seeing any new patterns emerge?

4) Make a scatter plot of object density versus orbital radius. The x-axis will again be $\log_{10}(orbital\ radius)$ in units of AU, and the y-axis will be density in units of g/cm^3. Does there seem to be a relationship between density and distance from the Sun?

5) Make a scatter plot of the number of moons versus the mass of the objects. Let your x-axis be $\log_{10}(mass)$ in units of Earth masses (M_E) and your y-axis the number of moons orbiting around that object. How do these two quantities seem to relate to each other? What does this suggest to you?

6) The μ column tells us how much the body has "cleared out" its orbital zone – that is, "vacuumed up" stuff along its path around the Sun and accumulated it, leaving a gap along its orbit. More precisely, μ is the ratio of the mass of the body itself to the total mass of all other objects located within the orbital zone. Identify the objects with the lowest μ (define your own reasonable cutoff value). Look at the other properties of these low-μ objects. Is there anything that these objects share in common?

7) Based on what have you have done (or any of the numbers on your data sheet), come up with your own classification scheme for these bodies. Do you find obvious groupings in your plots, or is there no kind of correlation at all? You can have as many groupings as you want and as many objects in each group as you want, as long as they are justified by your reasoning. Are there bodies that don't seem to fit into any of your classification groups? Take your time. There is no wrong answer to this!! Write down which bodies are put into each grouping, and explain your classification system in a few sentences.

8) Now that you've come up with a classification system with different groups, which of these groups do you think should be deemed *planets*? Should they all be? Should none of them be? What are your criteria for what should be considered a planet? Write this down in a few sentences, and list the objects that you would include in this planet classification. (Again, there is no wrong answer to this – so long as you are reasonable and consistent.)

Table 1: List of celestial bodies in the Solar System

	Mass (M_E)	Density (g/cm^3)	Diameter (km)	Orbital Radius (AU)	ϵ	μ	# of Moons	Composition	Atmosphere
A	1.00	5.5	12,742	1	0.02	1.7×10^6	1	rock	78% N, 21% O, 1% other
B	17.00	1.6	49,500	30	0.01	2.4×10^4	14	gas	80% H, 20% He
C	0.055	5.4	4,900	0.4	0.20	9.1×10^4	0	rock	trace
D	95.00	0.7	121,000	10	0.05	1.9×10^5	83	gas	94% H, 5% He, 1% other
E	0.005	2.0	2,400	68	0.44	0.1	1	rock & ice	trace
F	0.10	3.9	6,800	1.5	0.09	5.1×10^3	2	rock	95% CO_2, 3% N, 2% other
G	0.002	2.0	2,376	39	0.25	0.077	5	rock & ice	trace
H	0.00004	3.4	525	2.36	0.09	0.10	0	rock	trace
I	0.00015	2.1	946	2.8	0.08	0.33	0	rock & ice	trace
J	15.0	1.3	51,000	19	0.05	2.9×10^4	27	gas	83% H, 15% He, 2% other
K	0.80	5.0	12,000	0.7	0.01	1.35×10^6	0	rock	96% CO_2, 4% N
L	320.0	1.3	143,000	5	0.05	6.25×10^5	92	gas	86% H, 14% He

1 AU = the distance from Earth to the Sun