Key

Do Not Remove!!

GS 104 Laboratory # 2
INVESTIGATING THE SOLAR SYSTEM

Introduction

We have sent unmanned spacecraft through the solar system, landed robot space probes on Mars, Venus, and the moon, have landed people on the moon, and have sophisticated telescopes to obtain data. We know that each planet and satellite (moon) has unique physical characteristics that set them apart from one another. We also know our solar system exhibits some regular patterns. During this laboratory you will try to discover some of these patterns. Much of the numerical data about our solar system, such as planetary size or distance from the sun, is so large that you will need to work with scale models. By studying planetary data we can compare and contrast conditions on other planets and their satellites (moons) to those of earth.

Goals and Objectives

- To describe similarities and differences among planets of our solar system
- To create scale models and make sketches that reasonably portray observations of components of the solar system
- To create graphs to communicate and interpret data from a variety of sources
- To use internet resources which contain current information on the solar system and cosmos

Pre-Lab Assignment

Laboratory Jump-Start Activity

INDIVIDUALLY

1. What do you already know about the Earth's place in the solar system?

2. List the planets in order of increasing distance away from the sun. Circle the planet that is smallest. Underline the largest planet.

SUN

3. Which planets can you see without the aid of instruments like telescopes/binoculars?

4. List as many physical characteristics (such as mass, surface temperature, etc.) that you think planets have.

5. Think of at least two ways to group or classify the planets according to physical characteristics.

IN YOUR GROUP

1. **Compare** your lists of planets made in order of increasing distance away from the **sun**. Make a list that your group agrees with.

SUN

2. **Which** planets have the members of your group seen without the help of instruments?

3. **Compare** the different ways you were able to classify planets. Which properties did your group members have in common? Which were different?

4. **Planets** are a bit different than stars. Many decades before we visited the planets with spacecraft, we knew their basic terrain, chemical composition, and atmosphere. Discuss how scientists deduced these things and what information was used to do it.

Part A – Scale Model of The Solar System

An *astronomical unit*, AU, is the average distance the Earth is from the Sun. That distance is 93,000,000 miles, 8.3 light-minutes, or 150,000,000 kilometers. It is convenient to work with AUs because the real distances are in numbers that can be cumbersome to deal with. Table 1, below, shows the AUs for planets in our solar system, using the Earth's average distance as the basic unit of 1 AU. Alternatively, you might find the orbital distances in terms of light-minutes more illuminating (pun intended). Choose which system of units (the column) you feel more comfortable with.

Your group will construct a scale model of the solar system based on average distance to the sun. Your model must fit in the hallway (54 meters long), the classroom, or outside (weather permitting). You must decide the scale you will use for your model. Additionally, place the satellites of each planet alongside their appropriate "host" planet.

Table 1: Solar System Data

Planet	Radius of Planet (Kilometers)	Mean Distance from the Sun (AU)	Radius of Planet (millionths of AU)	Mean Distance from the Sun (Light-Minutes)
Mercury	2439	0.39	16	3.25
Venus	6052	0.72	40	6.00
Earth	6378	1.00	42	8.33
Mars	3393	1.52	23	12.6
Jupiter	71,492	5.20	477	43.3
Saturn	60,268	9.54	402	79.5
Uranus	25,559	19.20	170	160
Neptune	24,766	30.10	165	250
Pluto *	1137	39.40	8	328
Sun	696,000	N/A	4,640	N/A

* **Note: In 1998, the Astronomical Society of America removed Pluto from the list of planets.**

Questions:

1. **What scale did you use for your distance?**

2. **What pattern did you notice about the spacing of the planets from the Sun?**

The terrestrial planets are grouped close together. The further out jovian planets are more widely spaced.

3. **What general pattern did you notice about the relative sizes of the planets?**

The smaller terrestrial planets are closer to the sun. The larger, Jovian planets are further aways.

4. **Which planets had the greatest number of satellites (moons)? Note that not all of the satellites in our solar system are shown. In fact new satellites are being discovered every few years.**

Saturn has 30 moons. In our model Jupiter had the most moons, at 4.

Part B – Classifying the Planets

Study the solar system parameters information in Table 2. The table provides information **scientists** believe to be true about the planets in the solar system based on the latest **technology** to help them. **By looking carefully at the data in this table you should be able to find some patterns, similarities, and differences among the planets in our solar system.** Some questions will assist you in thinking about what is considered a **pattern**, similarity, and difference. You will need to find more than just those. You **should** also look over Table 3 that contains other useful parameters. Also, you should **investigate** the samples of air, water or ice, typical rock, and lead (which approximates **metal** at high pressure). Because all the samples have the same volume, you can **investigate** the effect of density directly. Please pick each one up and compare their **masses** (and therefore, their densities).

Questions:

1. **Use** four physical properties of the planets in the solar system to group them into **general** categories or in general ways. (For example, try the atmospheric composition as one of the four physical properties.)

High ($> 10^{25}$ kg)	Rotational Period			Surface Temp		Surface Pressure		
	>>24 hrs	~24 hrs	<<24 hrs	>100 K	< 100 K	<<1 bar	~1 bar	>>1 bar
Jupiter Saturn Uranus Neptune	Mercury Venus Pluto	Earth Mars	Jupiter Saturn Uranus Neptune	Mercury Venus Earth Mars	Jupiter Saturn Neptune Uranus Pluto	Mercury Mars pluto	Earth	Jupiter Saturn Uranus Neptune Venus

2. **Write** any general statements you can draw from your study of the properties that could be cited as patterns in the solar system

Orbital periods increase away from the sun, while surface temperatures generally decrease. Planet masses are generally higher further from the sun, except for pluto. The planets can be put in two groups. The Jovian planets (Jupiter, Saturn, Uranus & Neptune) have similar characteristics, but are very different from those of the terrestrial planets (Mercury, Venus, Earth & Mars).

Table 2: The Planet Parameters table.

*	*Mercury	*Venus	*Earth	*Mars	*Jupiter	*Saturn	*Uranus	*Neptune	*Pluto
*Mass (10^{24} Kg)	0.3302	4.869	5.975	0.6419	1,898.6	568.46	86.83	102.43	0.0125
*Radius (Km)	2439	6052	6378	3393	71,492	60,268	25,559	24,766	1137
*Mean Density (Kg/m^3)	5,427	5,204	5,520	3,933	1,326	687	1,318	1,638	2,050
*Orbital Distance (10^6 Km)	57.9	108.2	149.6	227.9	778.3	1427.0	2869.6	4496.6	4913.5
*Orbital Period (days)	87.969	224.7	365.25	686.98	4330.6	10,747	30,588	59,800	90,591
*Rotational Period (hours)	1407.6	5832.5 (ret.)	23.934	24.62	9.92	10.5	17.24 (ret.)	16.11	153.3 (ret.)
*Ave. Surface Temp. (Kelvins)	440	737	288	210	129	97	58	58	50
*Surface Pressure	10^{-15} bars	92 bars	1.014 bars	0.008 bars	>>100 bars	>>100 bars	>>100 bars	>>100 bars	3 micro-bars
*Atmospheric Composition	98% He 2% H2	96.5% CO_2, 3.5% N_2	78% N_2, 21% O_2, 1% H_2O	95.32% CO_2, 2.7% N_2	89% H_2, 11% He	89% H_2, 11% He	89% H_2, 11% He	89% H_2, 11% He	methane & N2

Table 3: Other useful parameters.

Material	Density
Air	1.2 Kg/m^3
Water or Ice	1000 Kg/m^3
Typical Rocks	3000 Kg/m^3
Metal at High Pressure	10,000 Kg/m^3

3. **Which planet would float in water?** Saturn
(*Hint*: Less dense objects float in denser fluids.)

4. **How long is a day on Jupiter?** 9.92 hrs **, on Venus?** 5832.5 hrs, **on Mars?** 24.62 hrs.

5. **How many Earth years go by before one Mars year has passed?** 1.9 years

6. **Which 2 planets account for 90% of the total mass of all of the planets?**
Jupiter **and** Saturn

7. **Which planet seems unusually hot considering its distance from the sun?**
Venus

8. **By looking at the data, suggest a reason for this extreme hot temperature.**
Venus has a very dense atmosphere composed of 96% CO_2. This leads to a strong greenhouse effect that heats the the atmosphere to temperatures higher than it would be without the greenhouse effect.

9. **Estimate the density (from the mass) of the four samples by picking them up. (REM: Density = Mass/Volume and the samples chosen all have similar volumes).**
   a. **Air seems to be __________ times less dense than water.**
   b. **Rock seems to be __________ times more dense than water.**
   c. **Metal at high pressure seems to be __________ times more dense than water.**

~~10~~. **How many times larger or smaller do you think the densities are compared to water?**

~~11~~. **How do your guesses compare to Table 3?**

12. **Table** 3 provides information about the density of common materials found on Earth. **Compare** the densities of metal, rock, ice, and gas to the average planetary densities. **What** can you guess about the composition of each of the planets? Answer this by filling **out** Table 4. (Hint: You can answer in terms of *mostly* metal, rock, ice, or gas; or *combinations* of these.)

Table 4:

Planet	Deduced Composition
Mercury	rock & metal
Venus	rock & metal
Earth	rock & metal
Mars	mostly rock
Jupiter	mostly ice/water (liquid)
Saturn	mostly water (liquid)
Uranus	mostly water (liquid)
Neptune	mostly water (liquid)
Pluto	ice and rock

Part C – Graphing Planetary Data

Sometimes graphs can give you a different perspective about data that reading a table **cannot**. In this activity you will graph selected data. You will graph one set from the list **below**. Graph paper is provided at the end of this lab.

Activity:

Each person in your group should make a different graph of one of the sets of data listed **below**. (Your instructor may assign these or at least make certain there is a diversity of **graphs**.) Remember, don't *connect the dots* -- you should always try to estimate and draw **smooth** curves through your data points. When you are completed, present your graph **and** your conclusions about your graph to the rest of the members of your group.

- Mean Density vs. Orbital Distance from Sun
- Surface Temperature vs. Distance from Sun
- Orbital Period vs. Distance from Sun

Question:

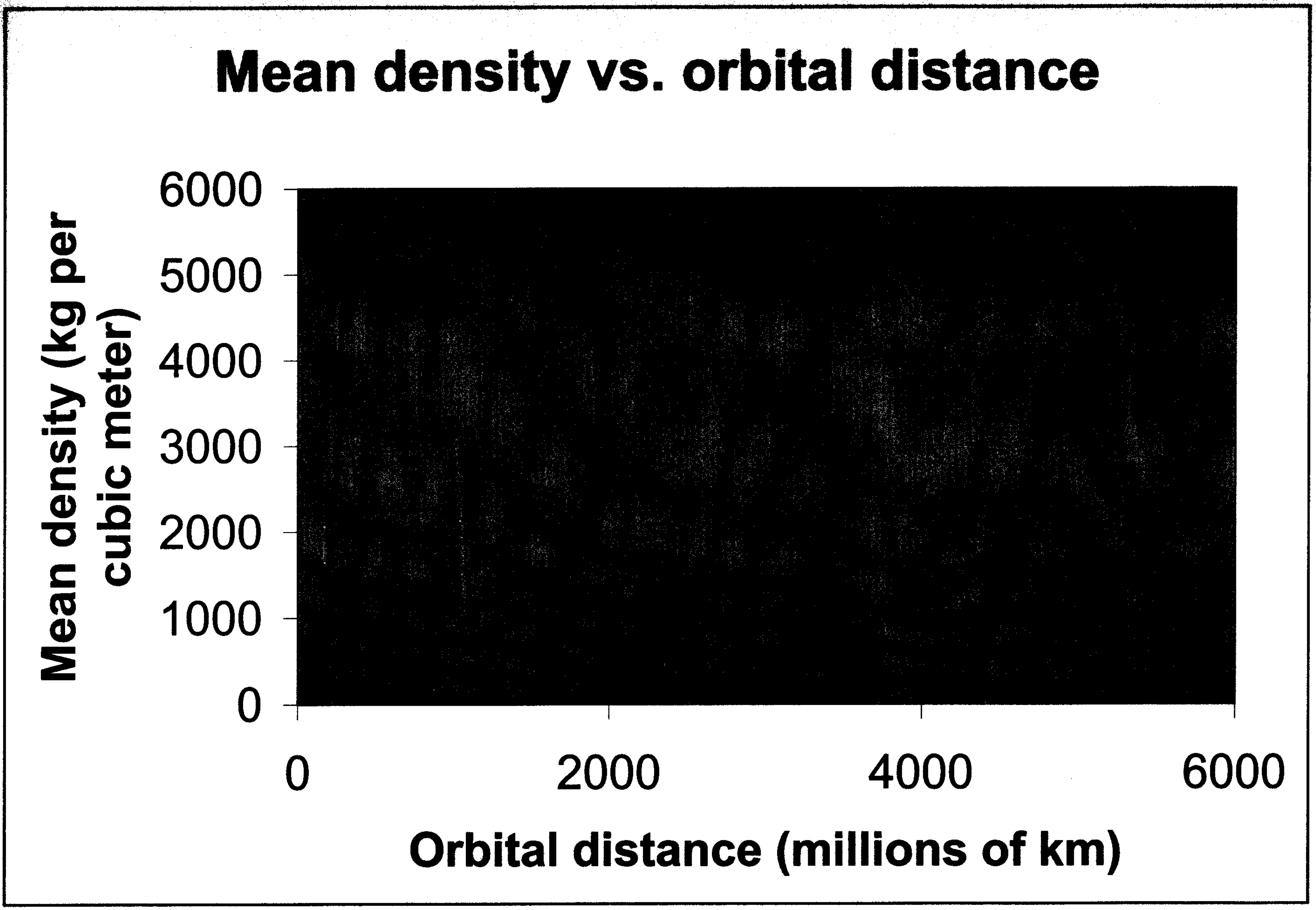
1. **Report the results of each graph. Consider the following questions: What does each graph tell you? What trends becomes more clear or obvious? What stands out as a result of graphing the data? (These questions will require a long answer so feel free to use the space provided below.) Also, be sure to include your graph with your report.**

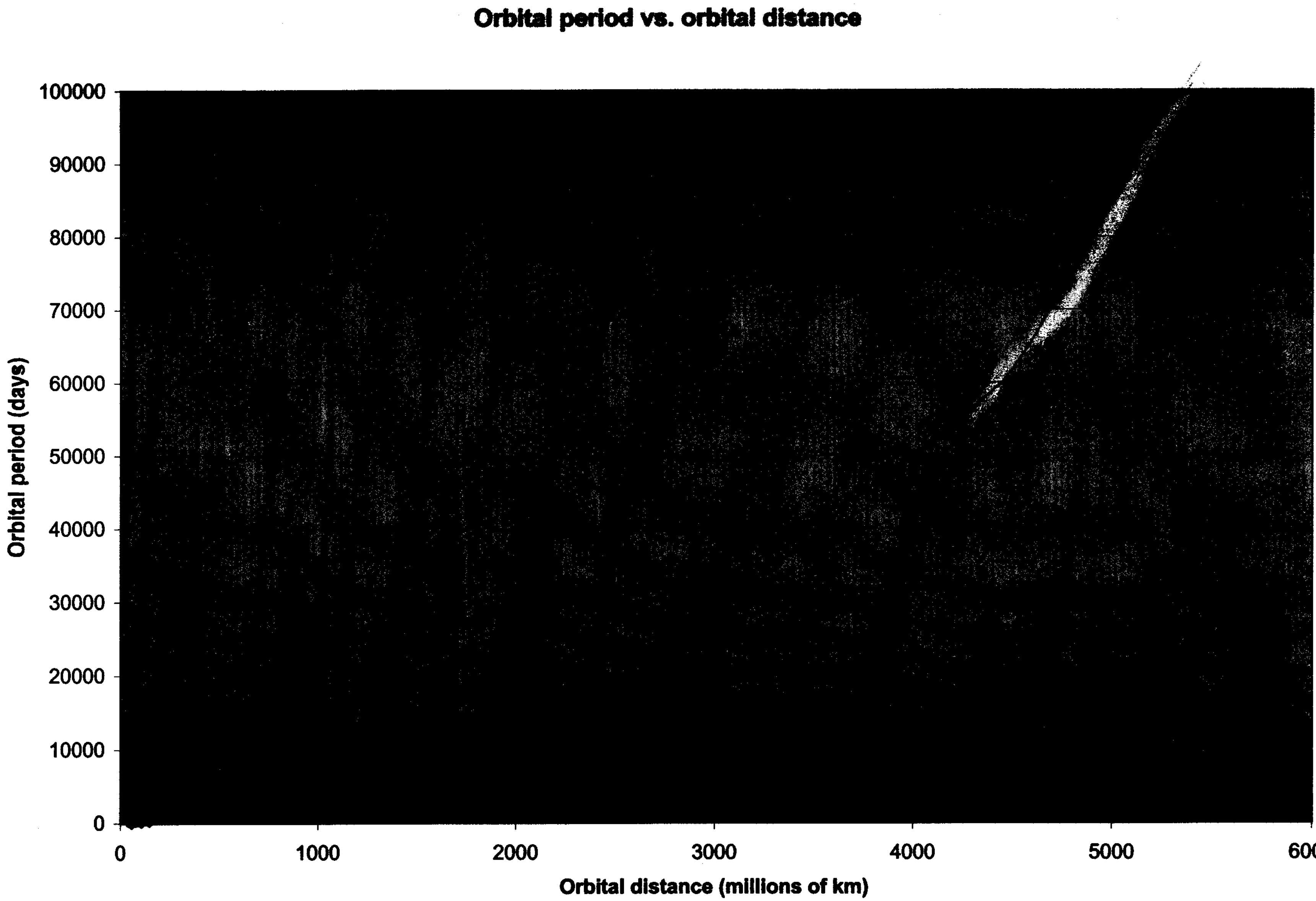
Mean density decreases with increasing orbital distance up through Saturn and then increases slightly moving from Saturn through Pluto. This relationship reflects the change in composition from rock & metal in the inner planets to liquids, gases, and ices in the outer planets.

Orbital period increases with increasing orbital distance. This makes sense as more distance planets have more distance to cover. The relationship is summarize by Kepler's 3rd law of orbital motion:

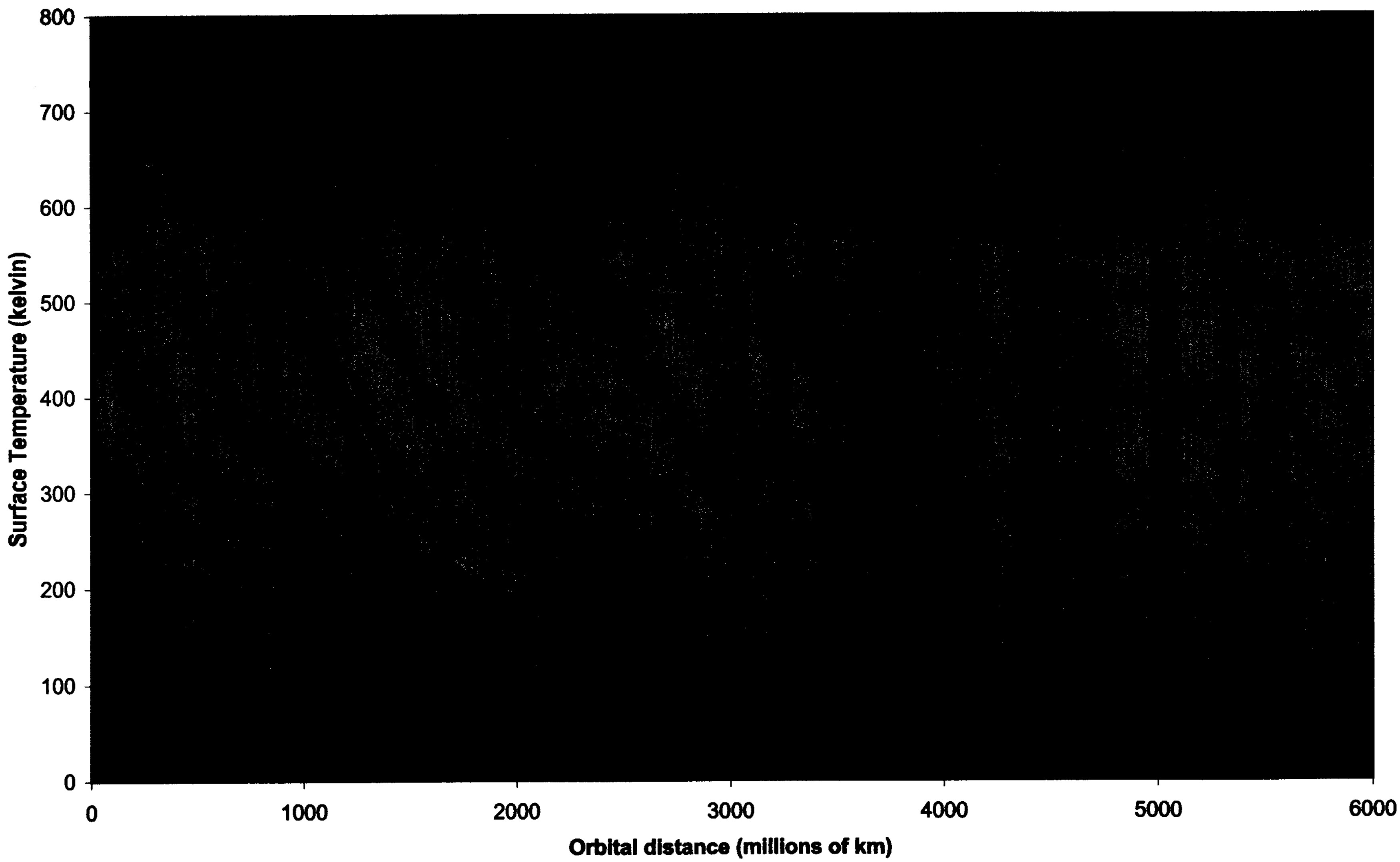
$$(\text{Orbital Period})^2 = (\text{constant})(\text{Orbital distance})^3$$

Surface temperature decreases with increasing orbital distance due to decreased solar radiation reaching the planets. Venus is an exception. Venus is anomalously hot due to a run away greenhouse effect caused by a thick, CO_2 rich atmosphere.


Mean density vs. orbital distance
Mean density (kg per cubic meter)
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
Orbital distance (millions of km)


Orbital period vs. orbital distance
Orbital period (days)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
6000
Orbital distance (millions of km)

Surface temperature vs. orbital distance



Out of Class Assignment: Solar System Investigation

Information about the cosmos as well as understanding of the cosmos is changing at a very rapid pace. To incorporate the latest knowledge (facts), ideas, and theories about the universe, it is necessary to access the latest information available. There are many excellent internet sites available with current information which is updated regularly. You will be assigned a cosmic body or phenomena to be investigated using one or more of these internet sites. To access your information use an internet search engine of your choice and key in specific terms such as: astronomy and (your assigned topic).

Next week (lab meeting) you are required to turn in a 1-2 page PRINTOUT OF THE INFORMATION OBTAINED and give a 1-2 minute oral presentation to the lab-class covering the information.

BE SURE TO FOCUS ON RECENT INFORMATION, but also include a summary of what is currently known about your assigned cosmic body.

Note; occasionally two students will be assigned the same cosmic body…so be sure to touch base with your colleague so as not to repeat information during the oral talk.

POSSIBLE COSMIC TOPICS

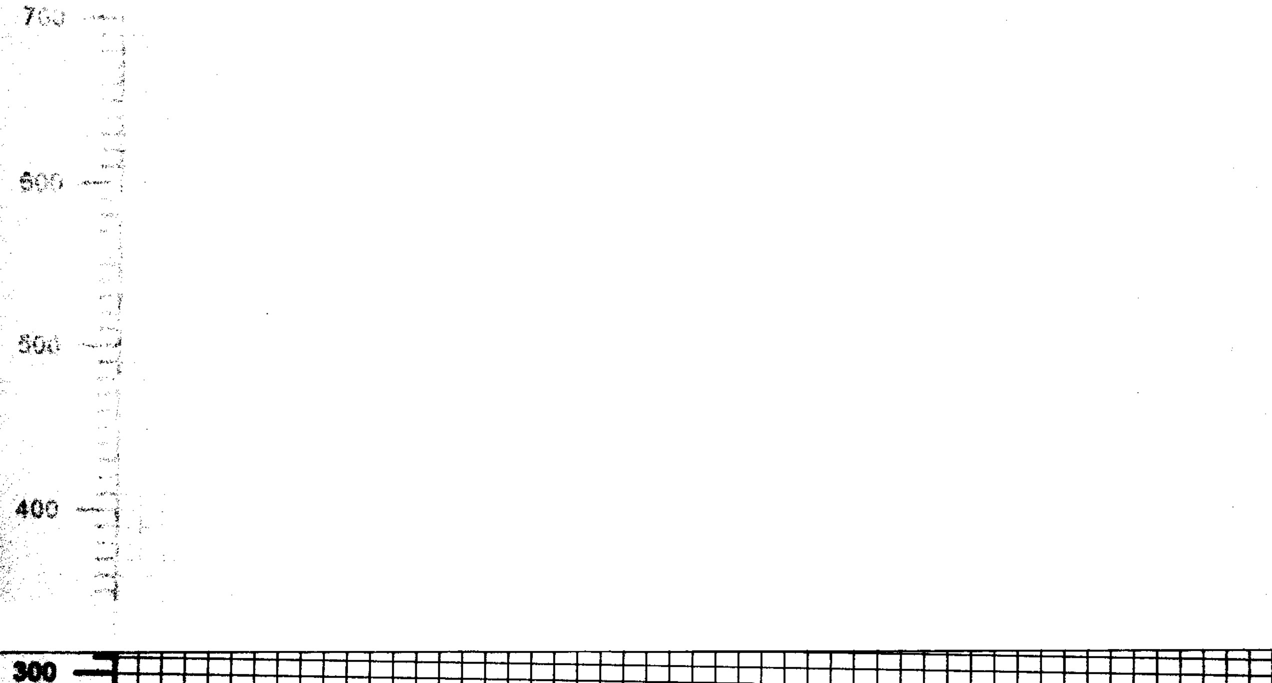
	Assigned to		**Assigned to**
Sun	____________	**Neptune**	____________
Mercury	____________	**Neptune Moons**	____________
Venus	____________	**Pluto**	____________
Earth	____________	**Kuiper Belt**	____________
Mars	____________	**Asteroids**	____________
Jupiter	____________	**Comets**	____________
Jupiter Moons	____________	**Meteorites**	____________
Saturn	____________	**Stars**	____________
Saturn Moons	____________	**Black Holes**	____________
Uranus	____________	**Galaxies**	____________
Uranus Moons	____________	**Hubble Telescope**	____________

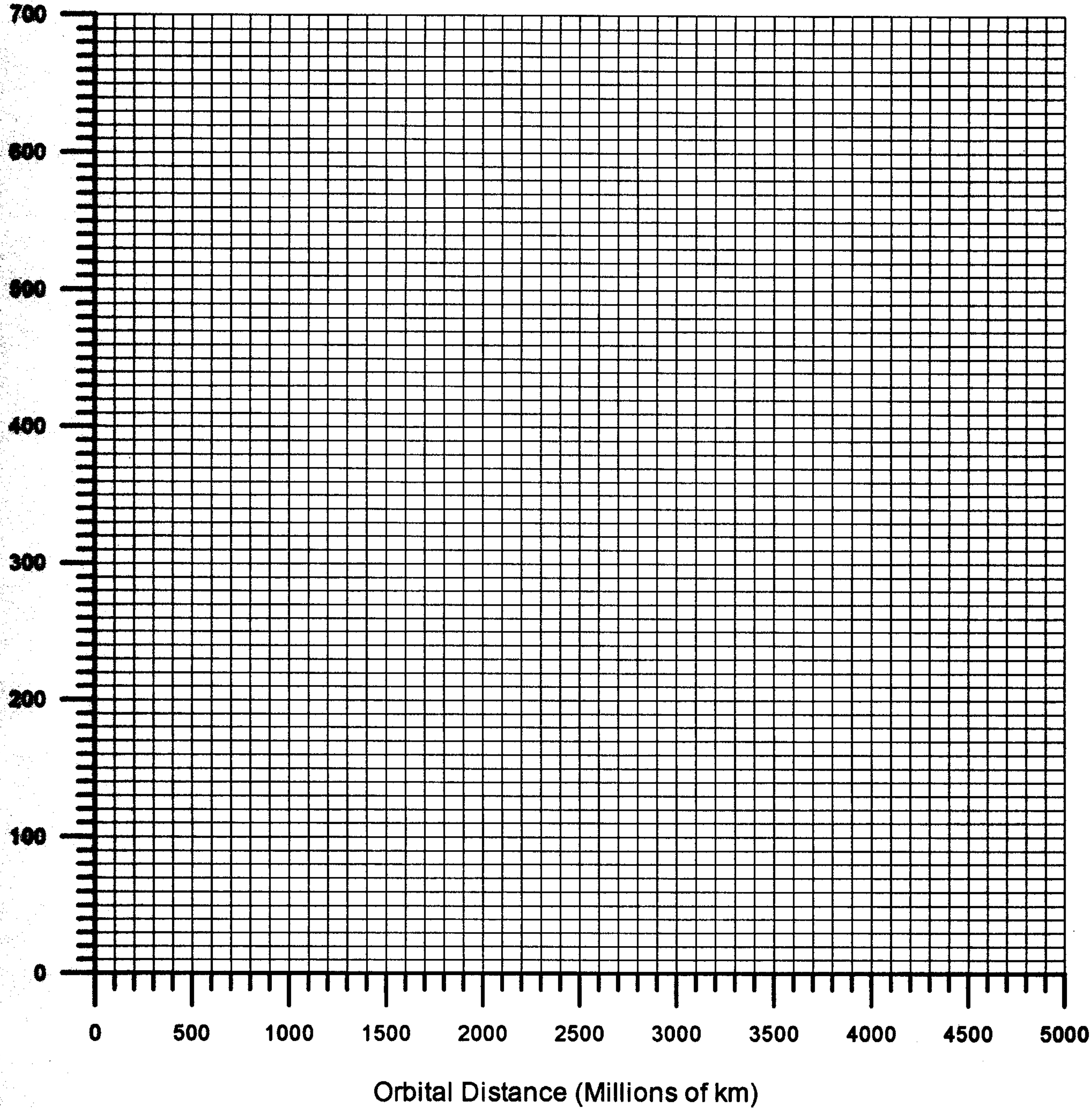
POST-LAB ASSESSMENT

1. Consider how unique Earth is. Make a table that identifies characteristics Earth shares with other planets and characteristics that are unique to Earth.

Earth Characteristic	Planets that share this Characteristic	Planets that are different in this Characteristic
Mass	Venus	All the rest
Density	Mercury, Venus, Mars	All the rest
Atmospheric Composition	None	all of the planets

2. In the past two labs, you have experienced information in a number of ways: physical models, pictorial models (sketches/diagrams), data tables and graphs. Which did you find most useful in your investigations, and why do you think it was useful for you?





[illegible] File c:wou:gs106:lab2a.grf