Comparison Of Formation, Atmosphere and Habitability for Mercury and Venus

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Abstract. The solar system has very strong relationship with human. All the factors in it creates the distinctive circumstances for all life on Earth to survive. This study picks two planets in the solar system, i.e., Mercury and Venus, to discuss and compare on three features from the perspective of formation, atmosphere and habitability. According to the analysis, either planet is suitable for life's existence or human's residence based on the state-of-art techniques. To be specific, Mercury's formation is still a problem to be solved while Venus' is much clearer. Venus' thicker atmosphere contains CO_2, N_2 and sulfuric chemicals as well as PH_3, an indicator for the improbable life. Mercury's atmosphere is rather poor, but is important partly because it can offer information of the planet's formation. This article can help beginners obtain an understanding about two planets' features in three aspects and aid students on similar topics. Overall, these results shed light on guiding further exploration of solar system.

Keywords: Mercury; Venus; Formation; Atmosphere; Habitability.

1. Introduction

In general, there are eight planets in the solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, ranked by distance from the Sun. The first four are named terrestrial planets as they are similar to Earth in size (and Earth is itself). Jupiter and Saturn are gas giants because of their sizes and compositions, while the rest two are ice giants. Between the orbits of Mars and Jupiter is the asteroid belt, and the Kuiper belt lies behind Pluto, which was once the ninth planet in the solar system before the mistake in its size was corrected. The Oort cloud, home of comets, is the most distant region of the solar system.

The solar system is closely related to human civilization. Ancient people thousands of years ago observed and named them, and astrology was born since then. Day and night, summer and winter are brought about by motivations of Earth. In modern times, studies on the solar system are of great importance. They can predict possible dangers from the space, especially asteroids and comets, which can possibly destroy life on Earth. Moreover, exoplanet life may be found somewhere in the solar system, or human may be able to dwell on another suitable planet with the help of the researches in the future. Studies on the solar system is limited within its border, they can be applied to assimilate outer space bodies.

Plenty of previous studies have been carried out by various scholars. Miroslav et al. proposed that Mercury gained its large eccentricity during a close encounter with Venus. The results of simulations enhance the rapid pebble accretion theory [1]. Marcq et al. studied the compositions and evolution of Venus' atmosphere, modeling reactions to explain the chemicals' concentration [2]. Franco, et al. made simulations to repeat Mercury's formation event and draws the conclusion that Mercury is not likely to form in one impact from both the experiment and theoretical analyses, which reveals that very strict conditions were required to create a Mercury-like body in the impact. However, the authors point out that a series of smaller impacts is still possible [3]. Clement, et al. advocated that Earth and Venus were formed as a pair and collected material along the way migrating to outer orbits before Mercury arrived. Thus, it explains the features of the planets in a new way [4]. William et al. focused on the unexpected amount of phosphine and gives new models and assumptions to explain the discovery [5]. Hallsworth et al. investigated water activity on Venus and argues against the potential for life in its clouds [6].

In order to better illustrate the above information for the solar system, this paper presents a brief summary of some new findings on the formation, atmosphere and habitability of Mercury and Venus and to give future expectations; comparisons are made between the two planets to have a clearer view of their differences and similarities. Hopefully, the essay can help starters in astronomy acquire useful information and assist future researchers for further study. After an acknowledgement on basic information of the solar system, detailed features related to the three topics above of Mercury and Venus are listed, discussed, and compared. Then, limitations of current studies are pointed out and future outlooks are proposed. Finally, the whole essay is concluded and commented.

2. Description of solar system and its planets

As shown in Fig. 1, many planets (four terrestrial planets) and dwarf planets concentrate 'near' the Sun. With the help from precise telescopes, we can get accurate images of these bodies in the solar system. Human beings are obtaining deeper knowledge of each planet as technology develops. Probes have been sent to numerous planets and their moons so that the planets' local environments can be directly studied. One of them was the Galileo Probe to Jupiter launched in 1989. Jupiter is the largest planet in the system, consisting of various gases with S, P, H, He elements etc. It was found that the gas giant had a hot interior with heat left over from its early formation. The significant heat provides energy for the strong storms in the upper weather layer, most typically, the Great red spot. The amount of helium under different pressures was detected by the probe's helium interferometer (HAD) and its mole fraction ranged from 0.13 to 0.14 [7]. This is an interesting coincidence with the Sun, which has a very close fraction of He. This value's being smaller than the proto-solar value indicates a depletion process of helium under high pressure.

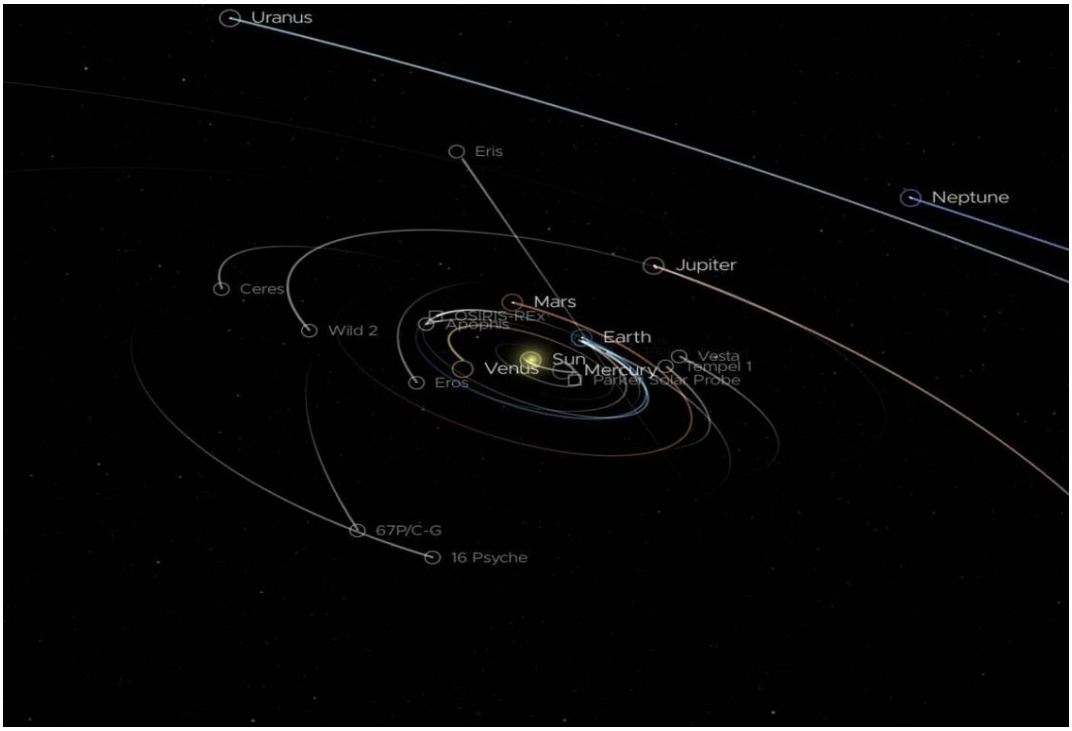

Fig. 1. The sketch of the inner part of the solar system.

As for Saturn, the other gas giant in the solar system, it pulls on Jupiter to stop it from migrating inwards. In other words, Saturn saves human because otherwise, Earth, together with other three terrestrial planets, would have been swept by Jupiter. Cassini was launched in 1997 towards Saturn. Studies on winds in this gaseous planet was advanced. From the Composite Infrared Spectrometer, the helium-hydrogen mole ratio ranging from 0.04 to 0.075 suggests a strong depletion of helium in Saturn's atmosphere [8]. However, compared to Jupiter, the process is enhanced because Saturn cooled down faster after formation and the lower temperature accelerated depletion of helium [7].

3. Description of Mercury

The general features of Mercury are summarized in Table. 1. Mercury turns out to have a very high core-mantle ratio (about 70%) as well as other 'strange' features like a small mass and close orbit to the Sun [3]. Hence, it is difficult to explain Mercury's formation with usual models while there are considerable evidence and theories that support these models. Some researchers assume it may originate from a collision of a proto-Mercury (about 2.5 times the current mass) and a projectile approximately 1/6 the target's mass. Whereas according to numerous simulations and mock impacts, such a process is of little possibility while there still exists a better chance that it may be formed in a series of smaller impacts. Applying this canonical model, the scientists saw few mercury-forming events trials and trials. There are two main theoretical arguments against this model. First, if Mercury was given birth to by a giant impact, it should have lost most of its volatile materials in crust, which contradicts with the abundance of these materials. Second, the impact would require a large amount of energy, which indicates the projectile's highly eccentric orbit, which could be hardly found in that day and age. Some other researchers assumed that Mercury formed even closer to the Sun than today but then migrated to its modern orbit [4]. In the hypothesis, terrestrial planets were formed closer to the Sun. Earth and Venus became a pair and cleared mantle materials in the disk ahead of Mercury, which explains Mercury's lack of mantle. The hypothesis also suggests that earth and Venus should have similar compositions. However, this theory depends much on the assumption of a thermal profile that supports the planets' outer migration and needs a larger range of simulations.

Table 1. General features about Mercury.

MEAN ORBIT VELOCITY	170,503km/h	EQUATORIAL CIRCUMFERENCE	15,329.1km
ORBIT ECCENTRICITY	0.20563593	VOLUME	60,827,208,742km^3
EQUATORIAL INCLINATION	0 degrees	DENSITY	5.427g/cm^3
EQUATORIAL RADIUS	2,439.7km	MASS	3.30104×10^{23}kg
SURFACE AREA	74,797,000km^2	SURFACE GRAVITY	3.7m/s^2
ESCAPE VELOCITY	15,300km/h	YEAR (around the Sun)	88 Earth days
SOLAR DAY (Full day-night cycle)	176 Earth days	DAY-NIGHT SURFACE TEMPERATURES	430 to-180 Celsius

Because of the high surface temperature and its small mass, Mercury only maintains a very thin atmosphere, as it can hardly keep the gas from escaping. According to some experts analyzing data from MESSANGER, the solar wind turns molecules in to ions near Mercury's surface and is an important source of its atmosphere, or Mercury would have no atmosphere at all [9]. Additionally, the study of gas losses of early Mercury provides evidence for hypotheses on its formation. Mercury may first form and then melted. Nevertheless, another analysis on metal elements violates the hypothesis. As a result, Mercury's formation is yet unclear.

Few people have considered migration to this planet. In fact, even machines can hardly bear the great changes in temperature on its surface between night and day. Moreover, because of the poor atmosphere and strong solar winds (as a result of the close distance to the Sun), it is much difficult to survive above the surface. Permanently shaded areas with ice can exist [10], but they are intensely cold. All the factors make migration to Mercury highly unlikely.

4. Description of Venus

Researchers have carried out quite a few models to explain the formations of four terrestrial planets. The conditions of Venus matched in-situ formation models well, (The rapid pebble accretion) [1, 11,

12], which basically states that there was a big disk around the Sun, full of materials that later accumulated and became planets. Being the Earth's twin, Venus is most likely to be formed in this way. The features of the Venus are listed in Table. 2.

Table 2. General features about Venus.

MEAN ORBIT VELOCITY	126,074km/h	ORBIT ECCENTRICITY	0.00677672
EQUATORIAL INCLINATION	177.3 degrees (retrograde rotation)	EQUATORIAL RADIUS	6,051.8km
EQUATORIAL CIRCUMFERENCE	38,024.6km	VOLUME	928,415,345,893km^3
DENSITY	5.243g/cm^3	MASS	4.86732×10^{24}kg
SURFACE AREA	460,234,317km^2	SURFACE GRAVITY	8.87m/s^2
ESCAPE VELOCITY	37,296km/h	YEAR (around the Sun)	225 Earth days
SOLAR DAY (full day-night cycle)	243Earth days	SURFACE TEMPERATURE	480 Celsius

Venus' atmosphere has numerous special features, mainly consisting of CO2 (66.5%) and N2 (36.5%), which take up almost 99.9% of the atmosphere [2]. This means Venus' atmosphere has a very high pressure (CO2: 44g/mol, N2: 28g/mol, O2: 32g/mol). Moreover, the sulfuric clouds and the hottest surface in the eight planets turn Venus into an 'Inferno'. The oxidation of SO2 followed by the reaction with H2O to produce, decomposition of H2SO4 and reduction of SO3 formed a balance. Other less common chemicals such as OCS and S3 also play an important role in the reaction cycles. Phosphine (PH3) detected on Venus (about 1ppb) indicates a series of unknown reactions, in which microbial life could participate, because the quantity cannot be explained by past models [5]. Though heat is extreme on surface, it is much cooler high above in the clouds, 30-70 degrees Celsius. Therefore, it is assumed that aerial life may be able to survive there. However, according to a recent study on water activity in the clouds, such lives hardly exist [6]. The relative availability of water in sulfuric acid droplets there is extremely low, no more than 0.004, while the least value for known extremophiles to survive is 0.585, over 100 times larger. The relatively high concentration of H2SO4 not only leads to little water availability, but results in the extreme acidity in the sulfuric clouds. Both factors create a harsh condition for possible life, as all known organisms require water and suitable pHs to guarantee life activities.

As discussed above, Venusian atmosphere is improbable to maintain life. Even people can find a way to live in the clouds free from the acids, strong winds as fast as 100m/s can occur, which can be very dangerous. Obviously, living on the surface is an even less practical idea. On account of the radical volcano activities till now, Venus is merely suitable for human now. The only possibility is when Venus cools down like what Earth once experienced, it may become ideal for migration. Nevertheless, the process may take too long for human to wait.

5. Comparison

According to the results given in Table. 1 and Table. 2, the two planets have similar density, but because of Venus' radius is about 2.5 times that of Mercury, Venus is much heavier, Mercury being the smallest planet in the solar system. In addition, resulting from its small distance from the Sun, Mercury has a relatively dominant eccentricity, 0.2 approximately, while Venus' is only about 0.0067. One of the interesting features of the two is that their 'days' are both longer than 'years', which means it will have already been the next year before one sees the next sunrise. This largely originates from their slow self-rotating angular velocity but relatively fast rotation around the Sun.

Compared to the widely accepted model of Venus' formation, those of Mercury are various while the truth remains a mystery. Venus is assumed to be born in the rapid pebble accretion, a more common way planets form. Mercury, with more complicated conditions, provokes a lasting debate on its origin. Though it is still unsure how Mercury formed, it must experience something unique.

Mercury has a very thin atmosphere. The strong solar winds that take away gas on most other planets are conversely vital to Mercury's atmosphere [9]. The high-energy particles vaporize molecules on surface and continuously add gas, including H2O, to the atmosphere. By contrast, Venus is big enough to keep the atmosphere itself. Plenty of sunlight and the dense greenhouse gases both contribute to Venus' hottest surface. The temperature is even higher than the day temperature of Mercury, the nearest planet to the Sun. Water do exist in the cooler clouds, but together with sulfuric acid. The chance for life is neither good for Mercury, where no known organism can adapt to because of intense radiation from the Sun and steep change in temperatures. The two planets are similarly unfriendly to human as well as other creatures to live on.

6. Limitations & Prospects

Based on the analysis, one can see that despite the larger and larger number of researches carried out, what scholars know about the planets is too little to ensure us the truth. Detections on more specific information and model's betterment will never come to an end. Current probes are designed to do their best; yet they are limited by various factors in the extreme environments. The more one knows, the more one will unknow. New findings may solve past mysteries, but will also bring even more to be solved.

Hopefully, many more probes will be sent to planets and other bodies successfully. Thus, with more solid evidence provided, one can perfect or create models and simulations to advance understandings of the solar system. In the future, probes may be able to bear harsher conditions and explore every corner of the system. Someday the rocketing technology may enable human to explore in extreme conditions on their own. On this basis, data can be acquired and analysed at once without the limitation of machines' ability. More and more mysteries will come to light. Interstellar migration may become feasible and plot in fictions may come real. Though one can never answer everything, the process of finding an answer will enrich our knowledge as well as contribute to the development of human civilization.

7. Conclusion

In summary, this paper discussed the differences between Mercury and Venus from the perspective of formation, atmosphere and habitability. According to the analysis, Mercury and Venus are neither habitable for different reasons. Mercury's being too close to the Sun causes strong radiation and extreme shifts in temperatures; while Venus' extreme surface heat and sulfuric clouds make it too difficult to stay for long. Mercury's formation process is more complex and mysterious than Venus'. The numerous models are in fight till now. Venus keeps a much thicker atmosphere with various chemicals and related reactions, storing a considerable amount of PH3 that raises people's interest in potential life. Mercury is unable to constrain much gas and its atmosphere relies on the supply from solar wind vaporization. Obviously, this article mentions only a few studies and is not profound enough. Because of the limited ability of the author, this essay may contain biases in discussion of different models. The limitations may be addressed if a review covering all recent researches is made fully and objectively. This study introduces recent discoveries of Mercury and Venus on formation, atmosphere and habitability and may add convenience and offer a guideline to future related studies.

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