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P1_4 Liberating Venus' Atmosphere

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Abstract

Venus could quite possibly be habitable if the atmosphere was similar to that of the Earth. In this journal we investigated the implication of removing a portion of Venus' atmosphere, and how much energy it would require to do so. From some general assumptions and calculations, we found that the energy required to liberate enough atmosphere to make it similar to that of Earth's to be $2.5\ x10^{28}$J.

Introduction

Most people would consider Mars as the ideal location for colonization, however Mars has only 38% of the Earth's gravity [1] and the atmosphere is significantly lower. So with that in mind, we considered the possibility of colonizing Venus; it has 90% of the Earth's gravity [2] but its atmosphere is 96% CO_2 [3] and a lot denser than that of Earth. This led us to the question, how much energy would it require to terraform Venus' atmosphere?

Theory

First we consider the volume of atmosphere on Venus, 50km from the surface. We chose this height because at this altitude, the pressure is around 1 bar (1 Earth atmosphere) [5]. So in order to work out the volume of gas occupying the shell we simply use the volume of a sphere:

$$V = \frac{4}{3}\pi {r_1}^3 \quad (1)$$

where r_1 is the radius of the sphere. Modelling Venus and its atmosphere as spheres, using Eq. (1), to find the shell volume, we take the volume at 50km radius i.e. $6.051x10^6 + 50x10^3$ m and subtract the volume of Venus at radius $6.051x10^6$ m [8]. This gives a value of $V_a = 2.32x10^{19}\ m^3$.

The atmospheric mass of Earth is $M_{ae} = 5x10^{18}$kg [9] and $M_{av} = 4.8x10^{20}$kg [8] for Venus, so the difference in atmospheric mass $M_{ad} = 4.75x10^{20}$kg; this is the amount of mass we need to liberate away from Venus' atmosphere in order for it to become similar to that of Earth's.

The gases within Venus' atmosphere are gravitationally bound, therefore we must consider the energy required to liberate these molecules. We consider the gravitational potential energy equation[6]:

$$U = -\frac{GMm}{r} \quad (2)$$

where *G* is the gravitational constant, *M* is the mass of the gravitating object, *m* is the mass of the object being acted upon and *r* is the distance between the two objects.

Results

Using $G = 6.67x10^{-11} N\ m^2/kg^2$, $M = 4.87x10^{24}$ kg [7], $m = A_{md}$ and $r = 6.051x10^6 + 50x10^3$ m, we find that the minimum energy required to liberate the gas is $2.5x10^{28}$J. We have assumed that all the gas below the 50km altitude is simply just liberated by giving it energy, and that the gas is only gravitationally bound and atmospheric and fluid effects are negligible.

Analysis

The result is a very general estimate of the energy. We assume that the energy is evenly distributed, and that all the energy is converted into kinetic energy. A more complicated model could be produced if you considered fluid mechanics i.e. collisions between particles and intrinsic thermal energies. Realistically, there would also be a temperature difference between the day and night side of the planet which must be considered, that would affect the amount of energy required. Also we have not considered the implications of particles being recaptured by the planet so a further energy may be required to make sure the gas escapes the planet's potential completely.

Conclusion

The reduction of mass would allow for a much faster colonization of Venus and is a much more suitable planet for colonisation apart from the extreme atmosphere. Venus' similarity in size and mass to earth provides greater opportunities, than some of the other planets in the solar system such as Mars.

The energy needed to liberate the majority of Venusian atmosphere is large at 2.5 $x10^{28}$J which is currently far beyond our capability. This energy is similar to that of 10 billion thermonuclear explosions from the largest warheads developed by man [10]. So although not impossible it is impractical at best, due to the predominance of CO_2 in the atmosphere [4]. Removing such a significant portion of the atmosphere will cause a temperature difference between day and night, greater than that of the Earth due to the smaller orbital radius to the Sun. This is why most colonisation plans of Venus focus around floating cities at the 1bar height in the atmosphere as this is more practical [11].

References

[1] http://www.universetoday.com/14859/gravity-on-mars/ accessed on 15/10/2013.

[2] http://www.universetoday.com/14245/what-is-the-gravity-on-venus/ accessed on the 15/10/2013.

[3] http://csep10.phys.utk.edu/astr161/lect/venus/atmosphere.html accessed on the 15/10/2013

[4] http://www-spc.igpp.ucla.edu/personnel/russell/papers/Venus_Overview.pdf accessed on the 15/10/2013

[5] http://curry.eas.gatech.edu/Courses/6140/ency/Chapter12/Ency_Atmos/Planetary_Atmos_Venus.pdf accessed on the 15/10/2013

[6] P. Tipler, G. Mosca, *Physics with Modern Physics for Scientist and Engineers* (6th ed.), (2008), p. 374-375.

[7] http://www.esa.int/Our_Activities/Space_Science/Venus_Express/Venus_compared_to_Earth accessed on the 16/10/2013

[8] http://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html accessed on the 29/10/2013

[9] http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html accessed on the 29/10/2013

[10] http://books.google.co.uk/books?id=xAwAAAAAMBAJ&pg=PA63&dq=510.3&as_pt=MAGAZINES&ei=0VpnSuGLLoWQNuSdnaAB&redir_esc=y#v=onepage&q=510.3&f=false accessed on the 29/10/2013

[11] http://www.universetoday.com/15570/ accessed on the 29/10/2013