Astrophys Space Sci (2008) 317: 133–137
DOI 10.1007/s10509-008-9851-2

LETTER

On the possibility of microbiota transfer from Venus to Earth

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Received: 22 March 2008 / Accepted: 20 June 2008 / Published online: 22 July 2008
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Abstract The possibility of the clouds of Venus providing habitats for extremophilic microorganisms has been discussed for several decades. We show here that the action of the solar wind leads to erosion of parts of the atmosphere laden with aerosols and putative microorganisms, forming a comet-like tail in the antisolar direction. During inferior conjunctions that coincide with transits of the planet Venus this comet-like tail intersects the Earth's magnetopause and injects aerosol particles. Data from ESA's Venus Express spacecraft and from SOHO are used to discuss the ingress of bacteria from Venus into the Earth's atmosphere, which we estimate as $\sim 10^{11}$–10^{13} cells for each transit event.

Keywords Panspermia · Interplanetary dust · Solar wind · Clouds of Venus · Life on Venus · Conjunctions of Venus

1 Introduction

The discovery of complex organic molecular structures in the Martian meteorite ALH84001 (McKay 1996) has led to a revival of interest in the possibility of microbial life being transferred between planets (Wallis and Wickramasinghe 1995, 2004; Napier 2004; Wickramasinghe 2007; Wickramasinghe and Napier 2008). Most discussions have focussed on the idea of impact-driven transfers of life-bearing rocks and dust that can take place sporadically over long dynamical timescales, $>10^7$ yr. Transfers over much shorter timescales between neighbouring planets would in principle be possible, but only if dynamical connection pathways can be identified. In this letter we propose one such pathway for transfers between Venus and Earth on a timescale of decades.

2 Clouds of Venus

Before discussing possible transfer pathways it is first necessary to discuss the feasibility of contemporary microbial life on Venus. Venus is $\sim$25% closer to the Sun than the Earth and has almost the same size, but the two planets differ in several crucial aspects. Of relevance to the present discussion is the fact that Venus has a thick convective atmosphere dominated by CO_2 producing a powerful greenhouse effect. The average variation of temperature with height is depicted in Fig. 1, showing a temperature difference between the surface and the cloud tops of $\sim$500 degrees. Current estimates of the atmospheric composition of Venus show CO_2 making up 96.5%, the rest including N_2, H_2O, CO, OH, HCl, H_2S, COS and SO_2 (Oyama et al. 1979; Svedhem et al. 2007; Piccioni et al. 2008; ESA Venus Express Data 2008). Venus's atmosphere has a high opacity to visible and ultraviolet light, reflecting $\sim$80% of the incident solar radiation. Despite the many spacecraft that have visited Venus since the 1970's it is remarkable that the cloud domain of the planet still harbours so many unsolved mysteries. In particular, a complete characterization of the cloud aerosols that impart an yellow tinge to the clouds still remains uncertain.

Whilst the conditions near the surface of Venus, $T > 460°C$, rule out microbial life, the temperature and pressure regime in the altitude range 70–45 km defines a habitable zone for some types of extremophilic bacteria that have actually been found on the Earth (see shaded area of Fig. 1). Here

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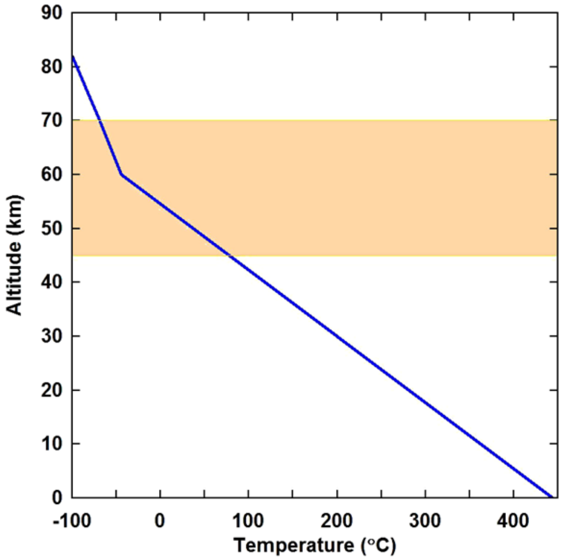

Fig. 1 The average temperature in the atmosphere of Venus as a function of height (The *shaded area* represents notional habitable zone for microorganisms; the pressure ranges from 0,1 to 10 bar)

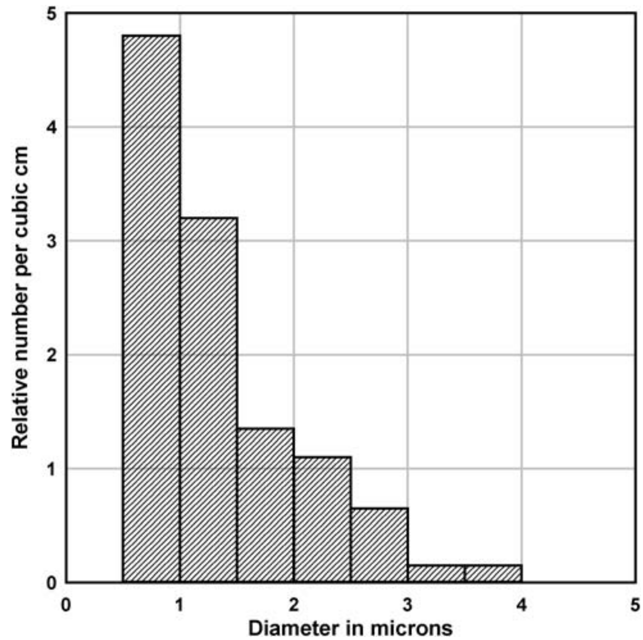

Fig. 2 The distribution of particle sizes in the upper clouds of Venus (approximately 55–65 km in altitude) from NASA Pioneer Venus data (Knollenberg and Hunten 1979)

the ambient temperature varies between −25°C and +75°C, and the pressure in the range ∼0.1 to 10 bar. Speculations relating to a Venus-adapted microbiota have been published over many years (Morowitz and Sagan 1967; Cockell 1999; Hoyle and Wickramasinghe 1981; Schulze-Makuch et al. 2004). Water, albeit in small quantities, has been identified in the atmosphere, adequate for microorganisms to concentrate and exploit. Furthermore, with a stable cloud system primarily circulating between 70 and 45 km, and with a steady supply of nutrients from sublimating meteorites, a Venusian aerobiology remains a distinct possibility (Hoyle and Wickramasinghe 1981, 1982).

Data from ESA's Venus Express probe (2008) has provided evidence of frequent electrical discharges (lightning) in the atmosphere. Such energetic events would be expected to generate large amounts of CO from CO_2. The absence of higher concentrations of CO than is observed, despite the lightning, might be taken as strongly suggestive of an exotic microbiology. There is a diverse group of terrestrial bacteria and archaea known as hydrogenogens that can grow anaerobically using CO as the sole carbon source and H_2O as an electron acceptor, producing CO_2 and H_2 as waste products (Wu et al. 2005). The presence of H_2S and SO_2 in the atmosphere could also point to the presence of extremophilic "sulphur" bacteria (Cockell 1999); and droplets of atmospheric sulphuric acid could provide a medium in which acidophiles can thrive.

As pointed out by Schulze-Makuch and Irwin (2002) the detection of COS (carbonyl sulfide) may also be taken as a indicator of biology (Bezard et al. 1993). Finally, the sizes and refractive indices of aerosol particles found in the upper clouds of Venus (55–65 km) (Fig. 2), are consistent with those appropriate for bacterial spores (Hansen and Arking 1971; Knollenberg and Hunten 1979; Hoyle and Wickramasinghe 1981, 2003). There is no a priori reason for droplets of sulphuric acid or other atmospheric aerosol to mimic either the mean refractive index or the distribution of sizes that is naturally attributable to bacterial spores.

We envisage a situation in Venus analogous to what happens in terrestrial clouds. Sattler et al. (2001) have demonstrated bacterial growth in supercooled cloud droplets, arguing that bacteria in tropospheric clouds are actually growing and reproducing. A stable aerobiology requires processes by which (a) bacteria nucleate droplets containing water and nutrients, (b) colonies grow within the droplets, (c) droplets fall into regions of higher temperature where they evaporate releasing spores to convect upwards to yield further nucleation. In the case of Venus this cyclical process would be expected to take place between the tops and bases of clouds.

3 Solar wind erosion of the Venusian atmosphere

The effects of the solar wind in producing erosion and evolution of planetary atmospheres over geological timescales have been extensively discussed. However, on much shorter timescales, sputtering losses due to solar wind interactions have in general tended to be ignored.

Atmospheric erosion due to the solar wind would be expected to be most efficient for planets such as Venus that have negligible magnetic field intensities thus providing little or no confinement of charged particles. For this reason

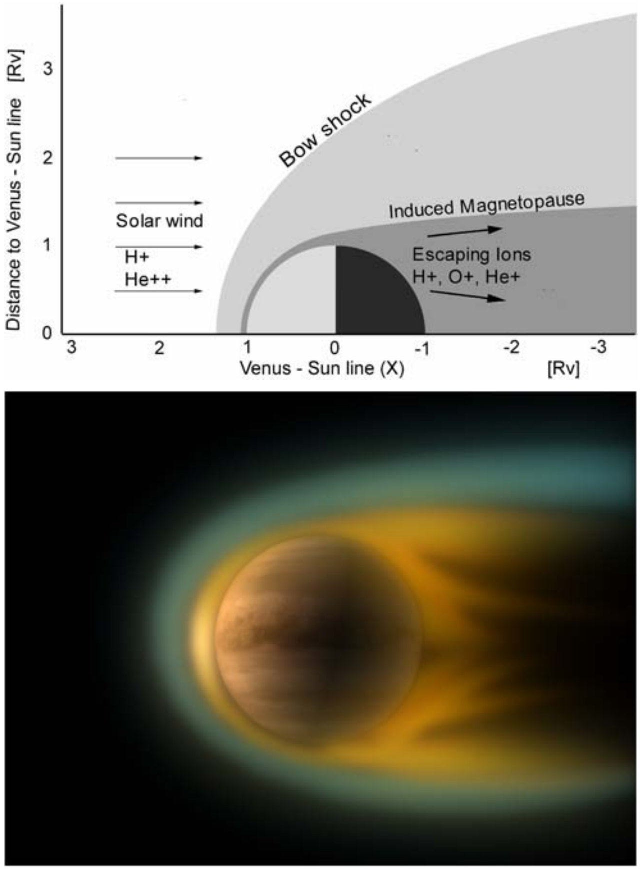

Fig. 3 Evidence of solar wind excavating the atmosphere of Venus (Courtesy ESA; http://www.esa.int/esaSC/SEMMAGK26DF_index_0.html; ESA Venus Express Data (2008); Svedhem et al. (2007))

there have been early suggestions that Venus and comets may have similar characteristics in developing wakes or tails though interaction with the solar wind (Russell et al. 1982; Wallis and Ip 1982; Russell and Vaisberg 1983). Whilst comet tails remain coherent over tens of millions of kilometers, the search for ions attributable a Venusian origin beyond ~10 Venus radii had produced negative results until very recently (Kar 1996).

The situation has recently changed dramatically, however. Firstly, Venus Express found evidence that the solar wind is causing a continual outflow of atmospheric gases including O^+ and H_2O^+ from the clouds of Venus in the form of a narrow wake or tail in the antisolar direction (Fig. 3) (Svedhem et al. 2007). In view of the largescale turbulence in the atmosphere, the wake would include material from the clouds where molecules and aerosols are present. Secondly, as part of the ion mass spectrometry program on the SOHO spacecraft, Grunwaldt et al. (1997) successfully detected a flux of O^+ and C^+ ions that originated in Venus and arrived near the Earth. The latter observation was made on June 10, 1996 when Venus was in inferior conjunction, and SOHO was 4.4×10^7 km downstream of Venus at the Earth's L1 Lagrangian point, 0.01AU sunward of the Earth. Grunwaldt

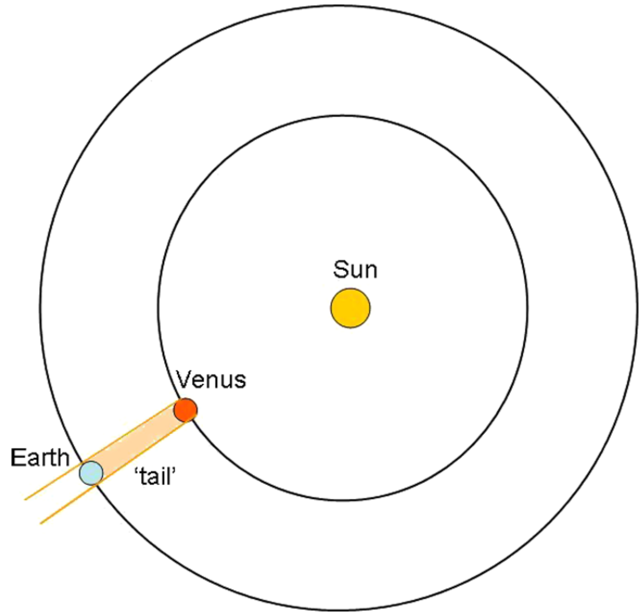

Fig. 4 Schematic mode of transfer of material from Venus to Earth during a planetary transit event. The tube of material reaching Earth is assumed to be 840 km wide, as indicated in the data of Grunwaldt et al. (1997)

et al. (1997) estimated the O^+ flux originating from Venus to be $\sim 3 \times 10^3$ ions $cm^{-2}\,s^{-1}$ near the Earth. With a Venus ray (tail) diameter of 820 km Grunwaldt et al. obtained a total flux of O^+

$$F_{O^+} = 1.6 \times 10^{19}\ s^{-1} \tag{1}$$

with F_{C^+} being $\sim 0.1 F_{O^+}$. The width of the Venusian tail as observed by Grunwaldt et al. at a heliocentric distance $r = 0.99$ AU will not be significantly different from that which could reach the Earth at $r = 1.0$ AU, if it is appropriately configured in relation to Venus.

Since the orbit of Venus is inclined at 3.4° to that of the Earth, material transfer would most effectively take place during inferior conjunctions that occur along the line of nodes (transits of the planet Venus). In such situations we can estimate the mass reaching the Earth, based on the measurements of Grunwaldt et al. (1997). The geometry of the Venus-Earth transfer process envisaged is schematically depicted in Fig. 4.

If ω_V and ω_E denote the angular velocities of Venus and Earth respectively in their orbits, the velocity relative to Earth of the footprint of the Venusian tail (assumed to be a 840 km wide cylinder) is

$$v = a_E(\omega_V - \omega_E) = 2\pi(a_V^{-3/2} - 1)\ \mathrm{AU/yr} \tag{2}$$

using Kepler's law. Setting $a_V = 0.75$ AU, we obtain a footprint speed of the Venusian tail to be

$$v \approx 20\ \mathrm{km/s} \tag{3}$$

The effective trapping cross-section for particles with the Earth will be larger than its geometrical cross-section because they are charged. It would be reasonable to assume that the trapping path length is the dimension of the magnetopause, say $\sim 20\, R_E \sim 1.3 \times 10^5$ km. Using (3) the inoculation time of Venusian particles into the Earth's environment would therefore be ∼6000 s.

From (1) the total number of O^+ ions introduced into the Earth's magnetosphere during each encounter is $\sim 10^{23}$, with the number of C^+ ions being a factor ∼10 less (Grunwaldt et al. (1997).

The solar wind at Venus could be assumed to have excavated not only CO_2 (which dissociates into C^+ and O^+) but also dust which forms a substantial fraction of the middle and upper atmosphere. Dust grains (putative bacteria) would be charged and coupled to the outflowing plasma tail. It would be entirely reasonable to speculate that the mass of grains carried along with the ions makes up ∼1% of the total outflow. Thus the mass of bacterial material carried into the Earth environment along with the O^+ and C^+ during a transit amounts to

$$M_{\mathrm{bact}} \approx 0.03 \text{ g} \tag{4}$$

The dry mass of a typical bacterium being $\sim 10^{-13}$ g, the total number of bacteria entering the Earth's magnetosphere is then $\sim 10^{11}$.

A possible transfer of $\sim 10^{11}$ microbial cells from Venus to the Earth's environment in a single injection event, although modest, cannot be ignored. It would require only a small fraction of this inoculant to find an appropriate terrestrial niche to effectively link the biosphere of Venus to that of the Earth. However, it should be noted that the estimate $\sim 10^{11}$ bacteria, based on a single set of measurements made by Grunwaldt et al., is on the conservative side, and possibly represents a lower limit. The time in 1997 when Grunwaldt et al. detected ions in the Venus tail near the Earth coincided with a deep minimum in the sunspot cycle. It is well-known that solar flare and solar wind activity increases near sunspot maximum, and varies erratically from one cycle to the next. Whenever a transit occurs during an active phase of the sun the bacterial mass from Venus that is added to the Earth could well exceed 10 g, giving rise to a total inoculant containing $\sim 10^{14}$ bacteria. Survival of microbes (particularly radiation-resistant microbes) in travelling between Venus and Earth would not pose a problem. The time of exposure to solar radiation in unshielded interplanetary space is $\sim 10^5$ sec, so high survival rates are to be expected even under the most pessimistic assumptions (Mileikowsky et al. 2000).

The fate of charged bacteria entering the magnetopause of the Earth is probably well represented by the known behaviour of 0.1–1 μm sized particles from Lunar ejecta that are known to enter the Earth (Mueller and Kessler 1985; Zook et al. 1984). Acted upon by the charge-dependent Lorentz force, convective drag forces, solar radiation pressure and gravity, bacterial dust grains diffuse through the magnetosphere to reach the atmosphere on timescales of ∼20–200 hr. However, the details of the entry process involve uncertainties and complications arising from charging and discharging of grains as well as instabilities in the field configurations of the magnetosphere. It is reasonable nevertheless to assume that a large fraction of the particles find their way ultimately into the troposphere where they could serve as condensation nuclei of raindrops (Hyde and Alexander 1989). If the terrestrial clouds can offer a niche that matches the essential characteristics of the Venusian clouds, an alien aerobiology would become established on Earth. Otherwise, the iterant Venusian microbes are discharged in the rain to either find a surface niche, or to perish.

Although an inferior conjunction of Venus occurs every 583.9 days a planetary transit event is much less frequent. The last inferior conjunction associated with a transit occurred in June 2004 and would happen again in June 2012. Calculations of celestial mechanics show that these events occur in pairs 8 years apart, and the pairs themselves recur with time separations of 121.5 and 105.5 years.

In conclusion it should be noted at the idea microbes from Venus reaching Earth was first proposed by Barber (1963) in an attempt to explain the periodic "fogging" of photographic plates at Sidmouth Observatory. At the time a mechanism for aerosol transfer between the planets was not identified, and moreover Barber would appear to have been far too optimistic in assuming transfers with every inferior conjunction. Realistically the two planets would be connected biologically over timescales of several decades.

Acknowledgements We thank Siegfried Franck for helpful comments that led to improvements to an earlier version of this paper, and to Hakan Svedhem and David Brain for information and references to Venus Express results.

References

Barber, D.: Perspective **5**, 201–208 (1963)
Bezard, B., et al.: Geophys. Res. Lett. **20**, 1587 (1993)
Cockell, C.S.: Planet. Space Sci. **47**, 1487 (1999)
ESA Venus Express Data (2008). http://www.esa.int/esaMI/Venus_Express/index.html
Grunwaldt, H., et al.: Geophys. Res. Lett. **24**, 1163 (1997)
Hansen, J.E., Arking, A.: Science **171**, 669 (1971)
Hoyle, F., Wickramasinghe, N.C.: Space Travellers. The Bringers of Life. University College Cardiff Press, Cardiff (1981)
Hoyle, F., Wickramasinghe, N.C.: Proofs that Life is Cosmic. Mem. Inst. Fundamental Studies, No.1, Sri Lanka (1982)
Hoyle, F., Wickramasinghe, N.C.: Astrophys. Space Sci. **285**, 538 (2003)
Hyde, T.W., Alexander, W.M.: Lunar Planet. Sci. **XX** (1989)
Kar, J.: Space Sci. Rev. **77**, 193 (1996)
Knollenberg, R.G., Hunten, D.M.: Science **203**, 792 (1979)

McKay, D.S.: Science **273**, 924 (1996)
Mileikowsky, C., et al.: Icarus **145**, 391 (2000)
Morowitz, H., Sagan, C.: Nature **215**, 1259 (1967)
Mueller, A., Kessler, D.: Adv. Space. Res. **5**, 77 (1985)
Napier, W.M.: Mon. Not. R. Astron. Soc. **348**, 46 (2004)
Oyama, V.I., Carle, G.C., Woeller, F., Pollack, J.B.: Science **203**, 802 (1979)
Piccioni, G., et al.: Astron. Astrophys. **483**, L29 (2008)
Russell, C.T., Vaisberg, O.: In: Hunten, D.M., et al. (eds.) Venus, pp. 873–940. University of Arizona Press, Arizona (1983)
Russell, C.T., et al.: In: Wilkening, L.L. (ed.) Comets, p. 561. University of Arizona Press, Arizona (1982)
Sattler, B., Puxbaum, H., Psenner, R.: Geophys. Res. Lett. **28**, 239 (2001)
Schulze-Makuch, D.H., Irwin, L.N.: Astrobiology **2**, 197 (2002)
Schulze-Makuch, D.H., et al.: Astrobiology **4**, 11 (2004)
Svedhem, H., Titov, D.V., Taylor, F.W., Witasse, O.: Nature **450**, 629 (2007)
Wallis, M.K., Ip, W.-H.: Nature **298**, 229 (1982)
Wallis, M.K., Wickramasinghe, N.C.: Earth Planet Sci. Lett. **130**, 69 (1995)
Wallis, M.K., Wickramasinghe, N.C.: Mon. Not. R. Astron. Soc. **348**, 52 (2004)
Wickramasinghe, J.T.: Ph.D. thesis, Cardiff University (2007)
Wickramasinghe, J.T., Napier, W.M.: Mon. Not. R. Astron. Soc. **378**, 153 (2008)
Wu, M., et al.: PLoSGenet **1**(5), e65 (2005)
Zook, H., et al.: Lunar Planet. Sci. **XV**, 965 (1984)