Necessary Conditions for Earthly Life Floating in the Venusian Atmosphere

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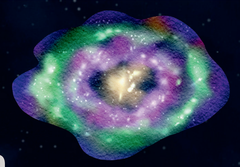
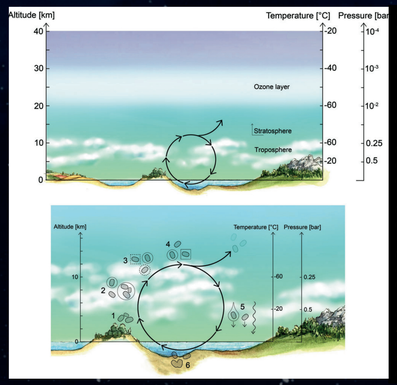
General Idea

Prompted by the recent observation of phosphine gas (a possible biomarker) in the Venusian atmosphere [arXiv:2009.06593], we investigate the possible existence of life in Venus. Our study rides on the life cycle for aerial microbes proposed in [arXiv:2009.06474]. We reexamine the feasibility that liquid droplets or aerosols containing microbes can remain floating in the Venus clouds enough time for replication to be effective. Key considerations include the size and characteristics of these droplets, their ability to persist against gravitational settling, and comparisons with microbial replication times on Earth. The research aims to evaluate the feasibility of microbial life in the Venus's atmosphere and contributes theoretical insights to astrobiological studies. For details, see [arXiv:2404.05356]



Earth



(1) Microorganisms (dashed blobs) are lifted from Earth's surface by updrafts.

(2) These microbes stay active within water cloud droplets (solid circles) while floating freely.

(3) They also serve as cloud condensation nuclei and promote ice nucleation, helping cloud formation.

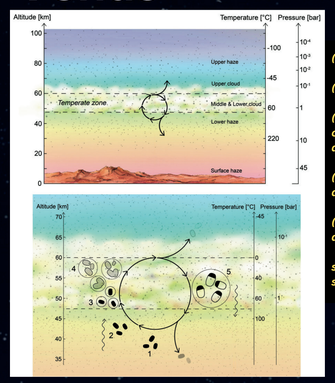
(4) The active microbes persist in the atmosphere, traveling long distances until they're brought back down by precipitation or downdrafts.

(5) Upon landing on a new surface, they start reproducing through active cell division.

(6) It's important to note that Earth's aerial microbial biosphere remains active throughout its life cycle, and survival doesn't depend solely on microorganisms capable of sporulation.

(7) Some free-floating cells can be carried up high into the stratosphere (up to about 38 km). If they don't return to lower altitudes within a couple of days, they'll perish due to severe dryness and exposure to high UV radiation (semi-transparent dashed blobs).

Venus



(1) Desiccated spores (black blobs) persist in the lower haze layer.

(2) Updrafts carry the spores up to the habitable layer.

(3) Spores serve as cloud condensation nuclei, and when surrounded by liquid containing necessary chemicals, they germinate and become metabolically active.

(4) Metabolically active microbes (dashed blobs) grow and divide within liquid droplets (solid circles), which grow larger through coagulation.

(5) The droplets eventually reach a size large enough to settle out of the atmosphere due to gravity. Higher temperatures and droplet evaporation trigger cell division and sporulation. The resulting spores, being small enough, withstand further downward sedimentation and remain suspended in the lower haze layer "depot."

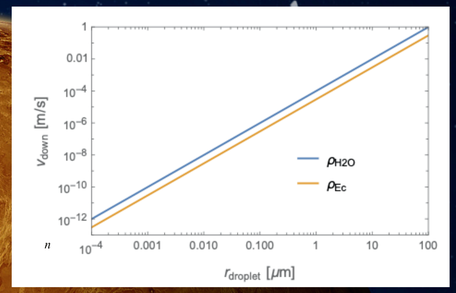
These figures are courtesy of Janusz Petkowski

Doubling time vs Fallout time

Doubling Time

NAME	REPRODUCTION TIME
Escherichia coli (or E. coli)	20 minutes
Pseudomonas natriegens	7 to 10 minutes
Bacillus subtilis	20 minutes
Pseudomonas aeruginosa	16 to 24 hours
Vibrio cholerae	20 minutes
Bacillus thuringiensis	20 minutes
Shigella flexneri	40 minutes
Streptococcus pyogenes	12 to 16 hours
Salmonella typhimurium	20 minutes
Clostridium perfringens	10 to 12 minutes
Pseudomonas fluorescens	1,5 hours

Terminal Speed



Replications Rates

If the observation begins with one bacterium, we can estimate how many bacteria will be present after six hours. The E. coli divides every 20 minutes, and so this bacterium divide (60/20 = 3) three times per hour. If the bacteria grow for twelve hours, each bacterium will divide: n= 3 times per hour times 12 hours = 36 times. Every time the bacteria reproduce, the number doubles. Then, the number of bacteria at the end of the growth period is

$$N_{final} = N_{initial}\ 2^{n} = 7 \times 10^{10}$$

Fallout Times

Stokes fallout time while droplets are spherical shaped can be determined by

$$v_{down} = \mu\, m_{droplet}\, g_{\varphi} \qquad v_{down} = \text{downward terminal speed} = 4 \times 10^{-3}\ m/s$$

$$\mu = \frac{1}{6\,\pi\eta_{\varphi}\, r_{droplet}} \qquad g_{\varphi} = \text{acceleration due to gravity} = 8.9\ m/s^{2}$$

$$t = 1\ month \qquad \eta_{\varphi} = \text{dynamic viscosity} = 2 \times 10^{-5}\ kg/m/s$$

For 10 km ⇨ this would correspond to $r_{droplet} = 10\ \mu m$

Take Home Message

- We've reconsidered the idea of life existing in the clouds of Venus, using Earth's biochemistry. We've found that aerosols take much longer to settle down in Venus's lower atmosphere compared to the time it takes for bacteria to replicate on Earth.
- Bearing this in mind, if there are upward air currents, it's possible that a stable population of microorganisms, could exist in the clouds of Venus.
- Life may have arisen in a good-nature surface habitat in the early history of Venus and the microbes lofted into the clouds before the planet suffered a runaway greenhouse.
- Such airborne microbial life might be waiting for exploration by missions like the Venus Life Finder (VLF) Mission [arXiv:2112.05153].

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See more details