

CONSTRAINTS ON THE VENUSIAN LIFE HYPOTHESIS FROM PROPOSED ENERGY-METABOLISMS. S. Jordan¹, O. Shorttle^{1,2} and P. B. Rimmer^{2,3,4}, ¹Institute of Astronomy, University of Cambridge, Madingley Rd, Cambridge CB3 0HA, United Kingdom, ²Department of Earth Sciences, University of Cambridge, Downing St, Cambridge CB2 3EQ, United Kingdom, ³Cavendish Laboratory, University of Cambridge, JJ Thomson Ave, Cambridge CB3 0HE, United Kingdom, ⁴MRC Laboratory of Molecular Biology, Francis Crick Ave, Cambridge CB2 0QH, United Kingdom.

While the present day surface of Venus is uninhabitable, the lower cloud layer lies in a region of the atmosphere where pressure-temperature conditions are suitable for life (47-57 km altitude). It has been proposed that microbial life, harboured within the cloud droplets throughout this temperate region of the cloud layer, may persist at present in a strictly aerial biosphere [1-6]. If a biosphere exists on Venus today, it must be interacting chemically with the atmosphere, and will do so predominantly via the effect of its energy-metabolism. Three possible sulfur-based energy-metabolisms have been proposed which hypothetical Venusian life could use to obtain energy from its environment, based on the observed chemistry of the Venusian atmosphere [7,8].

If hypothetical life were sufficiently abundant, the effect of the energy-metabolism will be influencing the major atmospheric chemistry in ways that are not otherwise consistent with abiotic explanation. The enigmatic depletion of SO₂ in the cloud layer [9-11] is one such candidate feature in the major atmospheric chemistry that is difficult to explain abiotically and involves chemicals used in the proposed energy-metabolisms. These metabolisms thus raise the possibility of Venus's enigmatic cloud-layer SO₂-depletion being caused by the energy-metabolism of life. We test whether life could be present and abundant in the atmosphere of Venus by coupling each proposed energy-metabolism to a photochemical-kinetics code and self-consistently predicting the composition of Venus's atmosphere under the scenario that life produces the observed SO₂-depletion.

Using this coupled photo-bio-chemical kinetics code, we show that all three metabolisms can produce SO₂-depletions, but do so by violating other observational constraints on Venus's atmospheric chemistry.

Although the energy-metabolisms proposed for life in Venus's clouds cannot explain the planet's atmospheric chemistry, we can place limits on the abundance of life that could be present before violating the atmospheric chemistry. In doing this, we must assume that an abiotic chemical pathway can explain the SO₂-depletion [11]. For each proposed metabolism, an observational upper limit on the abundance of the limiting metabolic input species poses a strict upper

limit on the productivity of the hypothetical biosphere [12].

We explore the possibility of chemical recycling within a wider ecosystem involving multiple metabolisms occurring simultaneously. In this more complex scenario, the observational upper limit on H₂ abundance below the cloud layer poses a strict limit on the productivity of the hypothetical ecosystem [13].

Our results pertain to the specific atmospheric chemistry of Venus, however the prospect remains that other Venus-like exoplanets could host a habitable niche in the temperate region of their atmospheres. Aerial biospheres in general therefore have significant implications on the number and observability of potentially habitable planets beyond the Solar System. The methods employed here are equally applicable to aerial biospheres on Venus-like exoplanets, planets that are optimally poised for atmospheric characterisation in the near future [14].

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