Reverse Astrobiology for Oxygen Worlds

Is it feasible?

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Summary

Abiotic oxygen buildup may occur on terrestrial habitable zone planets either due to a reduced efficiency of coldtrapping water vapor in the lower atmosphere [1], or due to massive photolysis of water and the subsequent escape of hydrogen to space. The substantial amount of early abiotic oxygen produced by this process, especially during the initial runaway greenhouse state of M dwarf planets [2, 3], may preempt prebiotic evolution and hence the development of life [4]. Otherwise habitable planets could hence turn out to be devoid of indigenous lifeforms.

It may on the other side be possible to launch within 50-100 years robotic interstellar probes which could seed selected exoplanets on arrival with a suitable mix of bacteria and unicellular eukaryotes [5]. We propose here that sterile oxygen planets offer promising conditions, in this context, for the establishment of ecospheres of autonomously developing unicellular biota.

Reverse astrobiology

Astrobiology research is dedicated to the investigation of the preconditions for non-terrestrial life, with the ultimate goal to discovery and study alien life forms. Reversely we may ask if distinct exoplanets could allow terrestrial life to embark new evolutionary pathways. Evolution could start over in the form of a precambrian ecosphere of unicellular auto- and heterotrophs, when seeding cells would be synthesized in situ, viz in orbit above the target planet, by the on-board gen laboratory of a Genesis craft [5]. Candidate planets range from transiently habitable planets, like brown-dwarf planets experiencing a continuously inward-moving habitable zone [6], to lifeless oxygen planets around M dwarfs.

Oxygen planets

Planets orbiting within the main-sequence habitable zone of M dwarf experience a runaway greenhouse state during the extended pre-main-sequence Kelvin-Helmholtz contraction phase, which lasts up to one Ga for late M dwarfs (but only 10 Ma for sun-like stars). The far- and extreme UV radiation produced by the young host star leads to a massive photolysis of the H_2O present in the wet stratosphere of the greenhouse state and with it to the escape of hydrogen to space. Several earth's oceans worth of water may be lost alltogether and one hence expects that most habitable zone M dwarf planets will leave the initial runaway greenhouse state with a massive oxygen atmosphere and rock dry. A substantial amount of water may however be retained for suitable orbital parameters, not too long greenhouse states and a substantial initial reservoir of volatiles.

The projected O_2 pressure of several of the seven planet of the TRAPPIST-1 system [6].

O_2 pressure (atm)			
T1-b	T1-c	T1-d	earth
420	350	30-490 (orbit)	0.2

Abiogenesis on oxygen planets

Life did originate on earth presumably within hdyrothermal vents akin to the 'lost city' [7]. Suboceanic thermal vents act as natural bioreactors in which redox reactions like $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ power rich prebiotic organic chemistries. The restricted geometries of the pores allow furthermore for concentration processes and hence, possibly, for the formation of protocells. We may envision several ways in which the very high concentrations of dissolved oxygen present in the ocean of oxygen planets will interfere with prebiotic reaction cycles.

- The influx of locally produced reduced compounds, such as H_2, will suffer.
- The lifetime of the locally produced prebiotic compounds may turn out to be too short for the subsequent concentrations process to reach the level necessary for the formation of protocells.
- Protocells need to adapt during the limited lifetime of a lost city complex (one Ma or less) to the high toxicity [8] of the oxygen dissolved in the surrounding seawater. The demise of their birthing thermal vent would otherwise spell out their own fate as well.

A massive initial abiotic oxygen atmosphere may hence preempt abiogenesis alltogether on otherwise habitable planets.

Genesis project timescales

Interstellar space exploration may be realized within this century through miniaturized probes [9]. These waferCrafts would be be accelerated photonically (by lasers) and decelerated with magnetic- and / or solar-sails [10, 11]. Mission timescales are naturally long, ranging from half a century for a α-Centauri flyby to one or a few thousand years for further out targets like the TRAPPIST-1 system [6] (at 40 light years from earth). Long-distance interstellar missions must hence be devised as launch-and-forget endeavors without any direct benefit for humanity. It is therefore unlikely that science missions to far away worlds will ever be initiated.

launch	laser	minutes
cruising	–	centuries
deceleration	magnetic sail	centuries
seeding	from orbit	centuries
evolution	on planet	Ma-Ga

The Genesis project is conversely all about extended timescales. The few millenia needed for launching, cruising, deceleration and seeding, pale in any case with respect to the geological timescales needed for post-seeding evolution. Further human involvement is not necessary.

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