REVERSE ASTROBIOLOGY FOR OXYGEN WORLDS: IS IT FEASIBLE? C. Gros, Institute for Theoretical Physics, Goethe-University Frankfurt, Max-von-Laue Str. 1, 60438 Frankfurt a.M., Germany.

Introduction: The habitability of a planet is generally considered to constitute a generic precondition for life to develop on other solar-system bodies and exoplanets. It has been pointed out, however, that abiotic oxygen build-up may occur on terrestrial habitable zone planets, either due to a reduced efficiency of cold-trapping water vapor in the lower atmosphere [1], or due to massive photolysis of water and the subsequent hydrogen escape to space, potentially occurring in the initial runaway greenhouse state of M dwarf planets [2,3]. Abiotic oxygen may hence constitute a false positive for life [4]. A substantial amount of early abiotic oxygen will preempt, furthermore, pre-biotic evolution and hence the development of life [5]. These studies hence indicate that a range of otherwise habitable planets [6] may actually be devoid of indigenous lifeforms.

Reverse Astrobiology: Astrobiology deals with the observation, the analysis and the simulation of life on extraterrestrial planetary systems. Reversing this stance one may ask what astrobiology has to say about the prospect of humanity getting actively involved in extraterrestrial life. Here we consider the case of habitable, but otherwise lifeless planets, asking the question: Is it technically feasible and ethically acceptable to plan for autonomous and miniaturized interstellar missions aiming to seed habitable, but lifeless extrasolar planets with unicellular terrestrial lifeforms? If so, which are the prospects of the target planets to enter a self-sustained evolutionary cycle leading eventually to complex life?

Genesis Project: It has been pointed out [7,8] that interstellar space exploration may be realized using miniaturized and laser-propelled probes. The probe may be decelerated passively on arrival, in addition, when cruising time is not critical [9], allowing for Genesis-type missions carrying a miniaturized gene laboratory for the in situ synthesis of a suitable mix of bacteria and unicellular eukaryotes [10]. The post-mission evolutionary time spans are expected to by exceedingly long for this type of mission, when targeting transiently habitable planets devoid of oxygen [9,11]. Complex life may only evolve once biologically produced oxygen has accumulated in the atmosphere of the target planet, a process which is slowed-down due to losses resulting from oxidizing the crust.

Oxygen Worlds: Oxygen worlds around M dwarfs result from an ocean-woth loss of initial water content. The resulting oxygen partial pressure may be extreme [2], of the order of hundreds to thousands bars, and the final water content small, whenever the planet is substantially smaller than earth [3]. Life on earth is adversely affected by elevated oxygen levels, with eukaryotes being especially susceptible, due to the subsequent build-up of hydrogen peroxide within the cells [12]. It is remarkable that already present-day bacteria can tolerate, in contrast to eukaryotes, up to a few bars of oxygen [12]. It is hence conceivable that it will be possible, using suitable cultivation techniques, to prepare selected terrestrial bacterial strains for the conditions encountered on oxygen planets with not too extreme oxygen levels.

Reprogramming the Genetic Code: A central motive for searching for non-terrestrial life forms regards the universality of the operating principles in general and of the genetic code in particular. Studies are being undertaken, reversely, in actively reprogramming the genetic code of terrestrial life forms, including higher eukaryotes [13], e.g. by going from codons made of triplets of nucleotides to a quadruplet code [14]. New functionalities are expected to result from the insertion of non-native amino acids, which could also allow to prepare terrestrial life to conditions found on exoplanets. The proposal [9], that interstellar microbes probes seeding exoplanets with unicellular lifeforms may be realizable, as a matter of principle, comes, on the other side, with severe ethical issues. The danger to interfere with the development of preexisting life to raising complexity is however absent for oxygen worlds around M dwarfs, which are unlikely to harbor indigenous life.

References: