Terrestrial life for habitable oxygen worlds

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Abiotic oxygen builds up in substantial quantities on terrestrial planets whenever the stratosphere is wet and a massive photolysis of water allows hydrogen to escape to space. This will happen in particular during the initial runaway greenhouse state of M dwarf planets (Luger et al, 2015), such as ultracold TRAPPIST-1 system (Bolmont et al., 2017). The presence of early abiotic oxygen is however likely to preempt prebiotic evolution (Sies, 2013) and consequently also the development of life (Ruiz-Mirazo et al, 2014). Even potentially habitable oxygen planets may hence to be devoid of life.

Reversing the point one may ask if there is a realistic prospect for humanity to initiate evolutionary processes on potentially habitable exoplanets. The question would then be whether it is technically feasible and ethically acceptable to plan for Genesis-type interstellar missions carried out by autonomous and miniaturized interstellar spacecrafts (Gros, 2016). Slow cruising probes aiming to establish ecospheres of uni-cellular organisms on yet lifeless exoplanets could be propelled by arrays of laser and decelerated passively on arrival (Merali, 2016), where an on-board gene laboratory would synthesize in-situ bacteria and unicellular eukaryotes.

Oxygen worlds around M dwarfs resulting from an ocean-worth loss of initial water content could posses extreme oxygen partial pressures of the order of hundreds of bars and strongly varying final water contents (Luger et al, 2015). Terrestrial life on earth is adversely affected by elevated oxygen levels, primarily as a consequence of the subsequent build-up of hydrogen peroxide within the cells (Baez et al, 2014), with present-day bacteria tolerating, in contrast to eukaryotes, up to a few bars of oxygen. It is then conceivable that suitable cultivation techniques may prepare selected terrestrial bacterial strains for the conditions encountered on oxygen planets with high but not too extreme oxygen levels.

Going one step further one may consider to reprogram the genetic code of terrestrial life forms, including higher eukaryotes (Lajoie et al, 2016), e.g. by going from codons made of triplets of nucleotides to a quadruplet code (Chin, 2012). New functionalities are expected to result from the insertion of non-native amino acids, which could in turn allow terrestrial life to adapt to a wide range of exoplanetary conditions. In this contribution we point out that it may be worthwhile in this context to study the perspectives for the future evolution of life potentially present in our cosmic neighborhood.

References

Baez, A., Shiloach, J. (2014): Effect of elevated oxygen concentration on bacteria, yeasts, and cells propagated for production of biological compounds. *Microbial cell factories*, *13*, 1
Bolmont, E. et al. (2017): Water loss from terrestrial planets orbiting ultracool dwarfs: implications for the planets of TRAPPIST-1. *Mon. Not. R. Astron. Soc.* 464: 3728-3741
Chin, J. W. (2012): Reprogramming the genetic code. *Science*, *336*, 428-429
Gros, C. (2016): Developing ecospheres on transiently habitable planets: the genesis project. *Astrophysics and Space Science*, *361*, 324
Lajoie, M. J., Söll, D., Church, G. M. (2016): Overcoming challenges in engineering the genetic code. *Journal of molecular biology*, *428*, 1004-1021
Luger, R., Barnes, R. (2015): Extreme water loss and abiotic O2 buildup on planets throughout the habitable zones of M dwarfs. *Astrobiology*, *15*, 119-143
Merali, Z. (2016): Shooting for a star. *Science*, *352*, 1040-1041
Ruiz-Mirazo, K., Briones, C., de la Escosura, A. (2014): Prebiotic systems chemistry: new perspectives for the origins of life. *Chem. Rev*, *114*, 285-366
Sies, H. (Ed.). (2013): *Oxidative stress*. Elsevier