LIMITS TO CREATION OF OXYGEN-RICH ATMOSPHERES ON PLANETS IN THE OUTER REACHES OF THE CONVENTIONAL HABITABLE ZONE.

Abundant free oxygen appears to be a requirement for macroflora and macrofauna. To the best of our knowledge, a general discussion of which habitable planets are conducive to oxygen has not taken place. Theories for the rise of oxygen fall into 4 categories: (i) It is governed by an intrinsic rate of biological innovation, independent of environmental factors. (ii) It is caused by mantle evolution, probably consequent to secular cooling. (iii) It is caused by hydrogen escape, which irreversibly oxidizes the Earth. (iv) It is Gaia's response to the brightening Sun, its rise prevented until reduced greenhouse gases were no longer needed to maintain a clement climate. All but the first of these make implicit astronomical predictions that can be quantified and made explicit.

Here we address the third hypothesis. In this hypothesis hydrogen escape acts like an hourglass that continues until all relevant reduced mineral buffers have been oxidized (titrated, as it were) and the surface made safe for O2. The hypothesis predicts that abundant free O2 will be absent from habitable planets that have not experienced significant hydrogen escape. Where hydrogen escape is modest or insignificant, the atmosphere can be approximated as hydrostatic, which makes assessing radiative cooling by embedded molecules, atoms, and ions such as CO2 and H3+ straightforward. In particular, H2 is efficient at exciting non-LTE CO2 15 micron emission, which makes radiative cooling very effective when H2 is abundant. We can therefore map out the region of phase space in which habitable planets do not lose hydrogen, and therefore do not develop O2 atmospheres.

A related matter is the power of radiative cooling by embedded molecules to enforce the diffusion limit to hydrogen escape. This matter in particular is relevant to addressing the empirical observation that rocky planets with thin or negligible atmospheres are rarely or never bigger than ~1.6 Earth radii.