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Hydrogen, nitrogen, and life on the early Earth

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In Earth's Hadean and Archean eras, the Sun was 20-40 % fainter than it is today, but there is no evidence for widespread long-term glaciation. An enhanced greenhouse effect via increased CO_2 levels is perhaps the simplest solution to the problem, but observational and theoretical studies both suggest only moderately elevated atmospheric CO_2 at this time. Other phenomena such as CO_2 / H_2O line broadening via increased atmospheric N_2 and a lower planetary albedo have been proposed, but are probably insufficient to explain the necessary warming alone.

Recently, we have suggested that increased hydrogen and nitrogen levels on the early Earth may have played a role in warming through H_2-N_2 collision-induced absorption (CIA). This process is well-known on Titan, where it dominates infra-red absorption across large regions of the spectrum. Broadening of the absorption bands at higher temperatures means that H_2-N_2 CIA can block the critical 800-1200 cm^{-1} water vapour 'window', allowing mean surface temperatures up to 280 K with only $\sim$20-80 $\times$ PAL CO_2 under a solar flux 75 % of that today.

Here we present our modeling results and discuss their potential relevance to climate in the Archean and Hadean. We consider the evidence for and against high H_2 levels on the early Earth and the main challenges in constraining outgassing and rates of hydrogen escape to space. We discuss the effects an H_2-rich atmosphere might have had on the early development of life, including its possible demise at the hands of the methanogens. Finally, we speculate on the possible importance of the H_2-N_2 warming mechanism for Earth-like rocky planets around other stars.