Cosmic ray-powered subsurface life?

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Photosynthesis is a highly efficient mechanism developed by terrestrial life to utilize the energy from photons of solar origin for biological use. Subsurface regions are isolated from the photosphere, and consequently are incapable of utilizing this energy. This opens up the opportunity for life to cultivate alternative mechanisms in order to take advantage of other available energy sources. Studies have shown that in subsurface environments, life can use energy generated from geochemical and geothermal processes to sustain a minimal metabolism. Another mechanism is radiolysis, in which particles emitted by radioactive substances are indirectly utilized for metabolism. One such example is the bacterium fueled by radiation, found 2 miles deep in a South African mine, which consumes hydrogen formed from particles emitted by radioactive U, Th and K present in rock. An additional source of radiation in the subsurface environments is secondary particles, such as muons generated by Galactic Cosmic Rays (GCRs). It is a steady source of a small amount of energy, and the possibility of a slow metabolizing life flourishing on it cannot be ruled out. Muon-induced radiolysis can produce H2 which is used by methanogens for abiotic hydrocarbon synthesis. We propose three mechanisms through which GCR-induced secondary particles, which are able to penetrate in deep subsurface environments, can be utilized for biological use. (1) GCRs injecting energy in the environment through muon-induced radiolysis, (2) organic synthesis from GCR secondaries interacting with the medium and (3) direct capture of radiation with the help of pigments such as melanin. We discuss the implications of these mechanisms on finding life in the Solar System and elsewhere in the Universe.

Ionizing radiation-powered life

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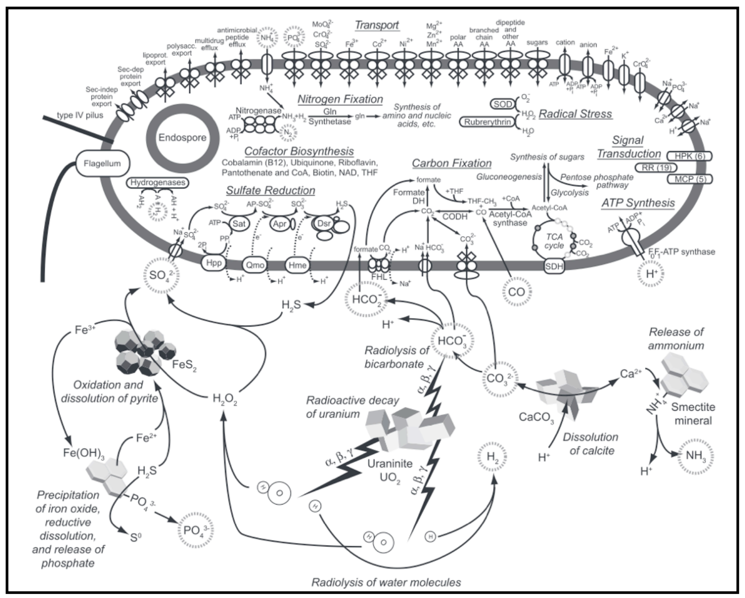


Lin, Li−Hung, et al. "Radiolytic H2 in continental crust: nuclear power for deep subsurface microbial communities." Geochemistry, Geophysics, Geosystems 6.7 (2005).

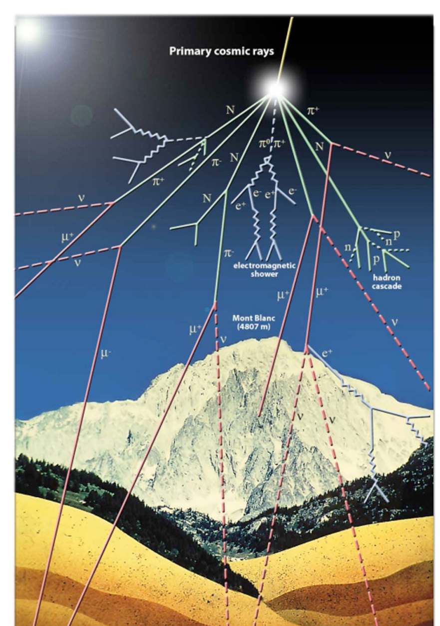
Chivian, Dylan, et al. "Environmental genomics reveals a single-species ecosystem deep within Earth." *Science* 322.5899 (2008): 275-278.

Energy source

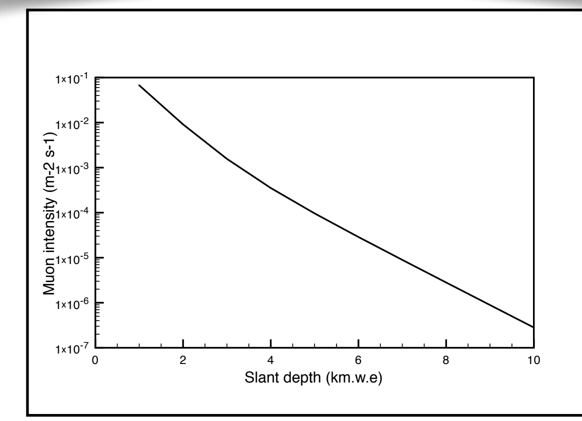
U, Th, K → α,β,Υ

Proposed energy source:

Cosmic ray muons → β, Υ



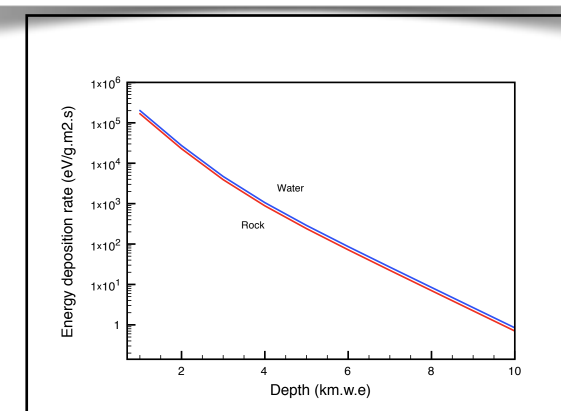
Measured muon intensity



Underground muon intensity as a function of slant depth. Based on the Depth-Intensity-Relation fit to the measured muon data obtained from 12 underground experiments around the world, compiled by Mei and Hime (2006).

Mei, D-M., and A. Hime. "Muon-induced background study for underground laboratories." Physical Review D 73.5 (2006): 053004.

Calculated Energy Deposition Rate



Energy deposition rate (eV/g.m2.s) of muons as a function of depth (km.w.e.) in rock and water.

Atri, Dimitra. "On the possibility of cosmic ray-induced ionizing radiation-powered life in subsurface environments in the Universe." arXiv: 1506.01274 (2015).