5th International Symposium on Strong Electromagnetic Fields and Neutron Stars
10 –13 of May, 2017 -Varadero, Cuba

HABITABILITY OF THE MILKY WAY REVISITED

Rolando Cárdenas and Rosmery Nodarse-Zulueta

e-mail: rcardenas@uclv.edu.cu

Planetary Science Laboratory
Universidad Central "Marta Abreu" de Las Villas,
Santa Clara, Cuba

Abstract

- The discoveries of the last three decades on deep sea and deep crust of planet Earth show that life can thrive in many places where solar radiation does not reach, using chemosynthesis instead of photosynthesis for primary production.

- Underground life is relatively well protected from hazardous ionizing cosmic radiation, so above mentioned discoveries reopen the habitability budget of the Milky Way, turning potentially habitable even planetary bodies without atmosphere.

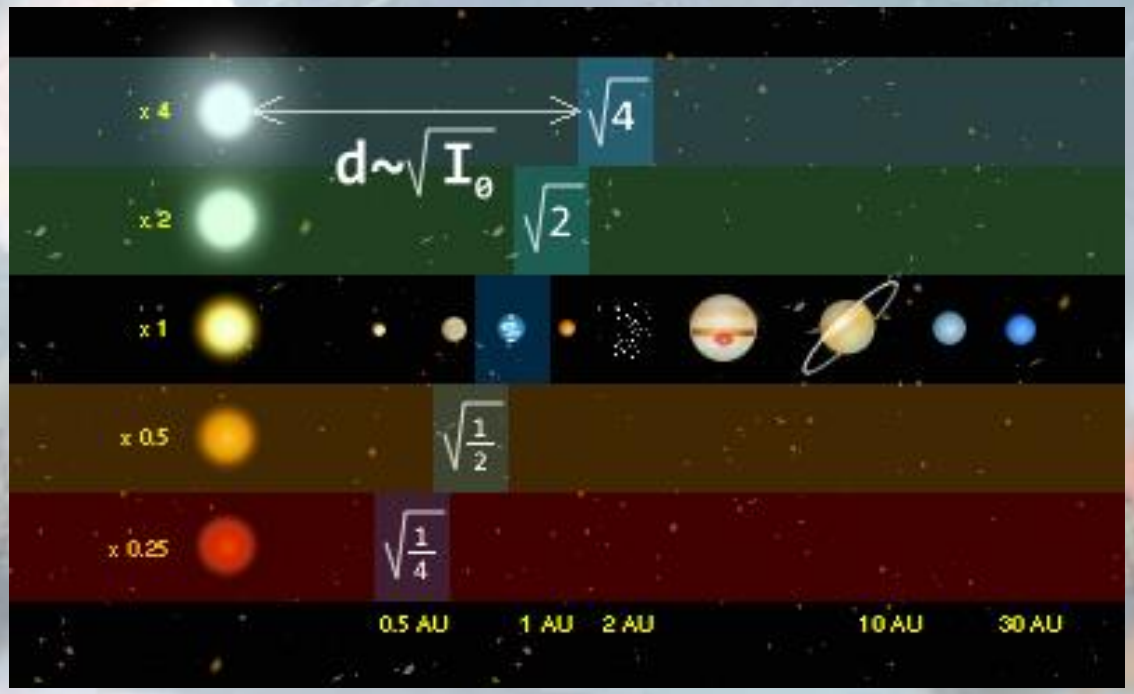
- Considering this, in this work the habitability potential of the Milky Way is reconsidered.

Energy Sources for Primary Habitability:

- Photosynthesis: Electromagnetic Waves, mostly in the range 400-700 nm. Dominant in planetary surface.

- Chemosynthesis: Energy released by redox chemical reactions. Dominant in deep sea and crust.

Circumstellar Habitable Zone



https://en.wikipedia.org/wiki/Circumstellar_habitable_zone. Accessed on 2017.04.28

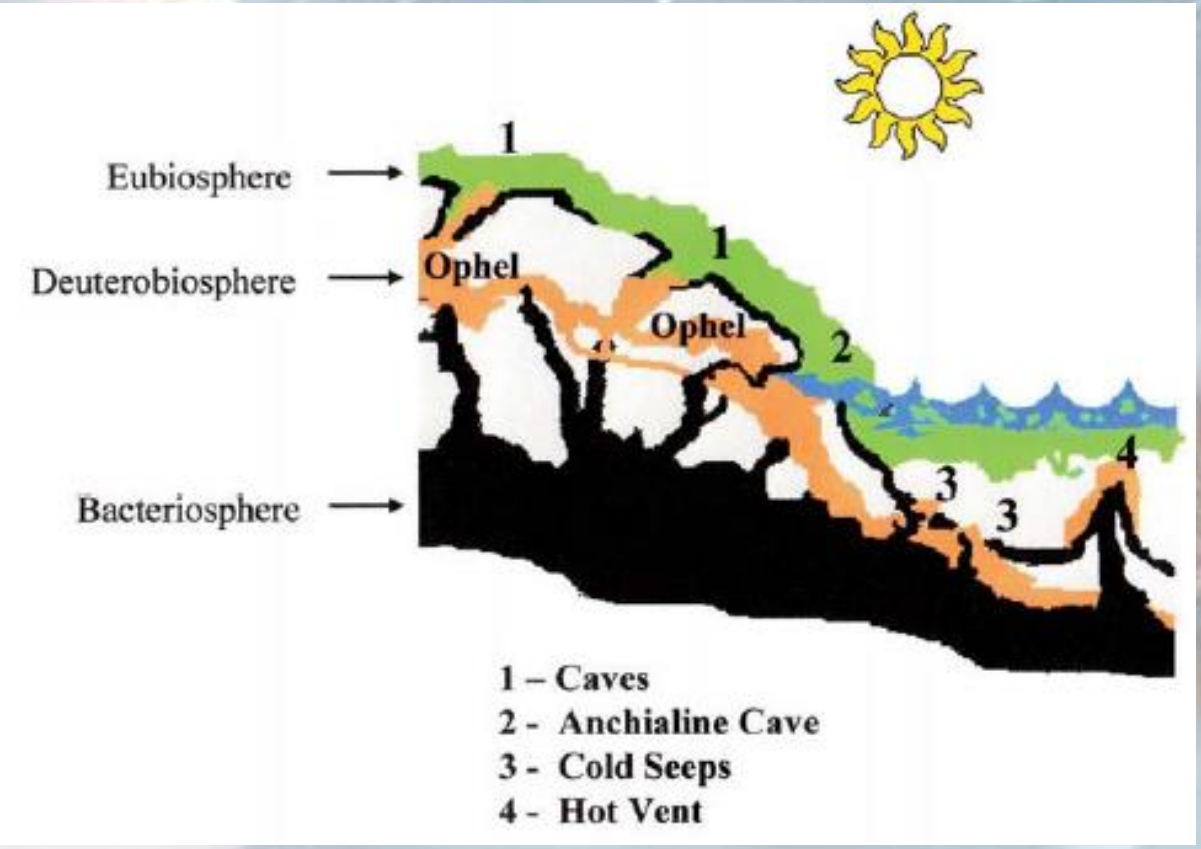
Liquid water at surface: biased towards surface (photosynthetic) life

Chemosynthesis: More common than previously thought…

- Any redox process giving at least 20 kJ/mol of free energy can support microbial metabolism. The following gives 794 kJ/mol:

Pohlman, J.: The biogeochemistry of anchialine caves: progress and possibilities. Hydrobiologia **677**, 33 (2011)

Three Biospheres!



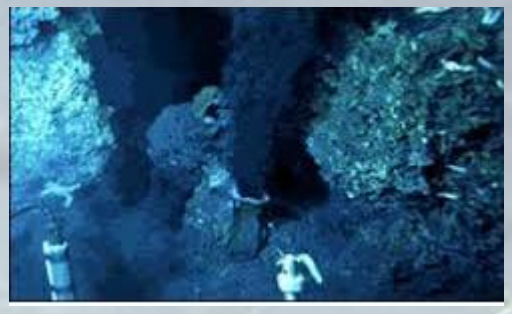
Por, F.: Deuterobiosphere the Chemosynthetic Second Biosphere of the Globe. A First Review. Integrative Zoology 3, 101 (2008)

Even the origin of life on Earth could have been at planetary depths:

“If the deep marine hydrothermal setting provides a suitable site for the origin of life, then abiogenesis could have happened as early as 4.0 to 4.2 Ga, whereas if it occurred at the surface of the Earth, abiogenesis could only have occurred between 3.7 and 4.0 Ga”

Maher, K., Stevenson, D.: Impact frustration of the origin of life. Nature, **331**, 612 (1988)

Chemosynthesis at deep hydrosphere



Black Smoker TY at 2,3 km depth, East Pacific Ridge (from Google Images)

- Primary energy source is mantle derived mostly from:

$$H_2S + 2O_2 \rightarrow SO_4^{2-} + 2H^+.$$

- Geothermal photons might still provide some potential for photosynthesis (Perez, N., Cardenas, R., Martin, O., Leiva-Mora, M.: The potential for photosynthesis in hydrothermal vents: a new avenue for life in the Universe? Astrophysics and Space Science **346**, 327 (2013)).

Chemosynthesis in sulfurous mineral caves

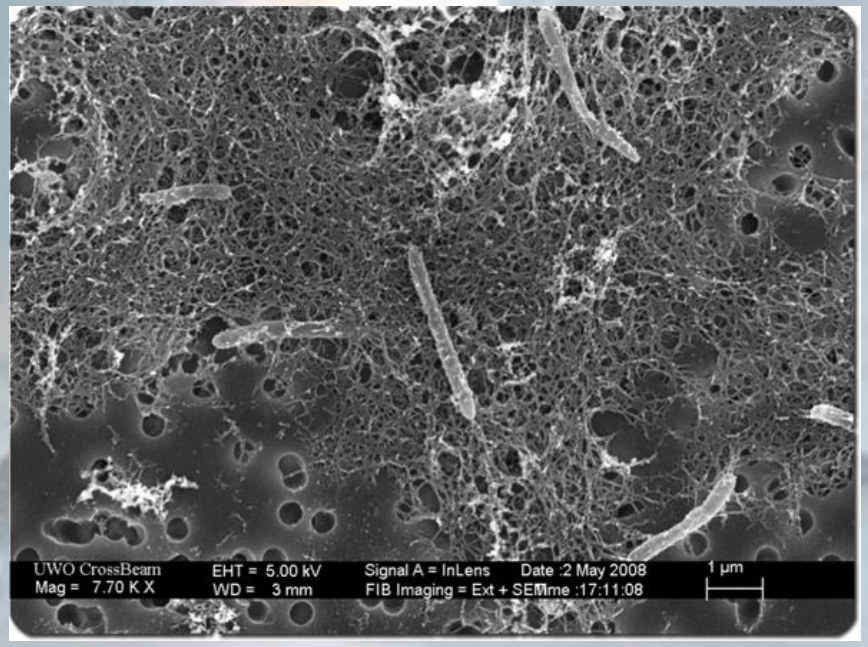
Movile Cave, Romania (from Google Images)

Energy also comes from:

$$H_2S + 2O_2 \rightarrow SO_4^{2-} + 2H^+.$$

This ecosystem totally depends on chemosynthesis as primary production mechanism.

Chemosynthesis induced by Radiolysis in Planetary Crust



A colony of *Candidatus Desulforudis audaxviator*, discovered at 2,8 km depth in a gold mine in South Africa

Radiolytic Agents:

- Radioactive decay of U, Th and K present in rocks.
- Cosmic Rays

Atri D. 2016 On the possibility of galactic cosmic ray-induced radiolysis-powered life in subsurface environments in the Universe. J. R. Soc. Interface 13: 20160459.

Energy Availability for Chemosynthesis

source	energy availability
GCR Mars subsurface	1.2×10^{7} eV g^{-1} s^{-1}
GCR Europa, Enceladus, Pluto, Moon subsurface	1.3×10^{7} eV g^{-1} s^{-1}
GCR Earth subsurface	1.5×10^{4} eV g^{-1} s^{-1}
radioactive rocks	1.0×10^{6} eV g^{-1} s^{-1}
hydrothermal vents	2.5×10^{6} eV/°C
geochemical	1.3 eV/e^{-} transfer

- Galactic Cosmic Rays in planetary bodies without atmosphere provide maximum values!

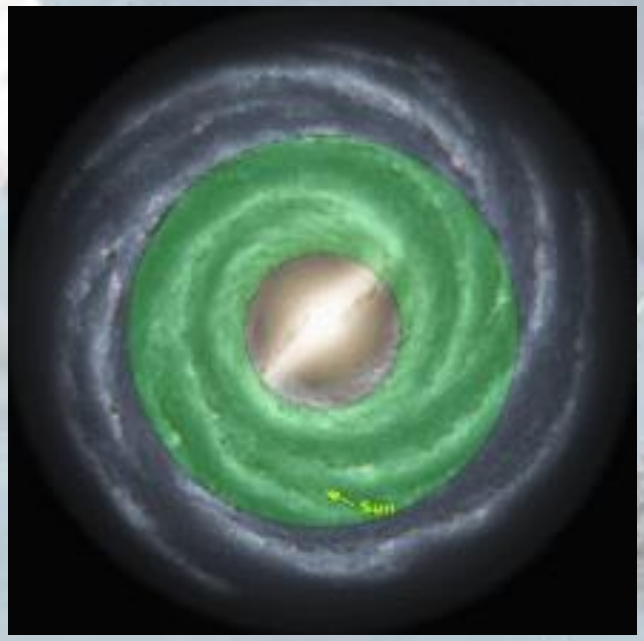
Atri D. 2016 On the possibility of galactic cosmic ray-induced radiolysis-powered life in subsurface environments in the Universe. J. R. Soc. Interface 13: 20160459.

Criteria for defining a Galactic Habitable Zone

- Chemical Evolution: Metallicity, radionuclides-geological activity-geomagnetism
- Catastrophic Events: Supernovae, GRB´s, excessive radiation, gravitational perturbations (inducing asteroid and cometary showers)
- Galactic Morphology: Spiral arms, galactic bar

https://en.wikipedia.org/wiki/Galactic_habitable_zone. Accessed on 2017.05.10

A Goldilocks Principle?



- The galactic habitable zone is often viewed as an annulus 4–10 kpc from the galactic center.

https://en.wikipedia.org/wiki/Galactic_habitable_zone. Accessed on 2017.05.10

A Conclusion:

- Chemosynthetic life at planetary depths is relatively well protected from (short-term) consequences of catastrophic events of astronomical origin, which suggests a reappraisal of the habitability of the Milky Way.

But:

- Long-term effects could still influence deep biospheres, for instance through biogeochemical cycles, thus a holistic planetary approach is required.

Perspectives:

- Developing habitability indexes for chemosynthesis-based biospheres (in progress) and compare with photosynthesis-based biospheres.

- To embed these ideas in models for the habitability of the Milky Way.