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Pluto bioenergetics

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Abstract
This study explores the potential for microbial life on Pluto's surface by comparing estimated energy requirements of Earth's *E. coli* with Pluto's surface irradiance. The analysis suggests that, given a source of complex organic compounds, Pluto's energy flux may be sufficient to generate and sustain microbial life, challenging assumptions about Pluto's habitability based solely on its relatively limited energy flux.

Keywords: *Biology; Physics; Microbial life; Energy flux; Habitability; Astrobiology; Pluto.*

Introduction
It is generally assumed that Pluto, by virtue of its distance from the sun, and limited size restricting available geologic activity, is entirely inhospitable to life. But this assumption is not necessarily justified, and empirical modelling could have important implications regarding how we should target searches for extraterrestrial life. To address this question requires two things an accounting of the energy needs of life, and an accounting of the energy fluxes on Pluto. This paper only addresses surface energy flux.

“What is the minimum energy necessary for life?” is a substantially complicated question, as there are a wide variety of assumptions that might reasonably be made depending on what we care about when we ask “Can this planet sustain life?”. Arguably the key questions of interest to astrobiologists are “Could life have arisen from the chemistry of this planet at some point in its history?”, and “If it did, could it still be there today?”. The first question is not realistically addressable, given how little is known about the conditions necessary to give rise to life. However, if there is sufficient energy today to sustain a modest microbial community on Pluto, that at least provides some evidence in favour of the notion that there was enough energy for *abiogenesis,* given that early on its history Pluto would have had substantially more potential for organic chemistry, than now, due to heat of formation. So to address these questions we will assume a simple model of minimum energy requirements derived from microbes on Earth, and then see whether energy fluxes on Pluto are sufficient for this requirement.

Model of energy requirements
While there exist extremophile communities on Earth, with minimal energy requirements, it is dubious whether these could arise without their first being microbes with more typical energy requirements, which have sufficient variety to enable that selection.

However, it is also the case that microbes on Earth will have selective pressures in favour of using more energy than is strictly necessary to sustain a modest, growing community, such that their energy consumption is not reflective of what would be necessary for a community that arose entirely from substantially energy limited conditions.

On this basis, we suggest that the stasis level energy consumption of a ubiquitous microbe, provides a reasonable estimate to use for the amount of energy flux necessary to sustain a dynamic, growing community of microbes that have always existed in harsh, energy constrained environments. *E.coli* is chosen due to how well it’s stasis energy consumption is characterized.

A recent paper [1] suggests that ATP consumption in *E.coli* is 0.4×10^6 ATP cell^{-1} s^{-1}. Next, we convert this to a more useful value of energy flux [2]:

$$ATP \rightarrow ADP + Phosphate + 30.5\ kJ\ mol^{-1},$$

$$1\ mol = 6 \times 10^{23}\ molecules,$$

$$\begin{aligned} \begin{matrix} Energy \\ consumption \end{matrix} &= \left(\frac{0.4 \times 10^{6}}{6 \times 10^{23}}\right) \times 30.5 \times 10^{3} \\ &= 2 \times 10^{-14}\ J\ cell^{-1} s^{-1}. \end{aligned}$$

Next, we make the assumption that for the energy to be available to our community it must be available through simple diffusion. This is not necessarily strictly accurate, but is a reasonable approximation. Assuming a typical surface area for *E.coli* of $3.7\ \mu m^2$ [3] we obtain a value for the energy flux we need to find on Pluto:

$$\begin{aligned} Energy\ flux &= \frac{2 \times 10^{-14}\ J}{4 \times 10^{-12}\ m^2 s^{-1}} \\ &= 3.2 \times 10^{-3} J\ m^{-2} s^{-1} \\ &= 3.2\ mW\ m^{-2} \end{aligned}$$

Specifically, this value represents the energy necessary such that any *E.coli* anywhere in any square metre is capable of meeting all of its energy needs, in stasis, via simple diffusion, i.e if we find this level of flux that implies a place capable of supporting 4×10^{12} of our hypothetical microbes. As a result, this value can also a reasonably sustain a *community* of life.

Energy fluxes

For this paper, we will only be considering energy available on Pluto's surface. A number of models suggest intriguing potential for organic chemistry at the interface of Pluto's rocky core and it's ice/liquid crust, but serious evaluation of those is beyond the scope of this journal, and we will mainly consider solar irradiance.

Pluto receives $0.872\ Wm^{-2}$ from the Sun [4]. However, a meaningful fraction of this will be absorbed, i.e. distributed through molecules in the atmosphere, and so this is not necessarily equivalent to $3.2\ mW\ m^{-2}$. Fortunately, the recent *New Horizons* flyby has given us robust estimates of overall light attenuation by Pluto's atmosphere. We assume an optical depth of 0.013 [5] and then calculate the incident surface radiation through rearrangement of the Beer Lambert law to get:

$$I = I_0 e^{-\tau}$$

Giving us:

$$I = 0.872 \times e^{-0.013} = 0.86\ Wm^{-2}$$

Conclusion

In this paper we evaluated the potential for sustainment of microbial life on Pluto, deriving a model of energy requirements based on the lag phase consumption of *E.coli* as a plausible model for the energy requirements of an active microbial community, and compared this to the available radiation on Pluto's surface. We find that, even taking into account optical absorption, solar irradiance at the surface of Pluto is 2 orders of magnitude greater than the energy consumption suggested by our model, and points to the idea that even nominally inhospitable places such as Pluto's surface may be capable of harbouring life.

References

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