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Titan's ionospheric chemistry, fullerenes, oxygen, galactic cosmic rays and the formation of exobiological molecules on and within its surfaces and lakes

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Abstract

We present a model [1,2] about the formation of aerosols within Titan's thermosphere-ionosphere. Negative ion measurements by the Cassini Plasma Spectrometer (CAPS) Electron Spectrometer (ELS) [3] give evidence for formation of unsaturated anion carbon chains, while positive ion measurements of the Cassini Ion Neutral Mass Spectrometer (INMS) [4] indicate formation of more aromatic cation hydrocarbons. At this time there is no direct observational evidence for large neutral molecule growth in Titan's thermosphere-ionosphere. The hydrocarbon cations are expected to form Polycyclic Aromatic Hydrocarbons (PAH), and if nitrogen is present they are called PAHNs. We argue anion carbon chains can eventually become long enough to fold into fullerene $C_{60,70}$ carbon shells, of various charge states. Based on laboratory data the fullerenes can trap incoming O^+ magnetospheric ions that have relatively high energy collisions with the fullerenes and, once trapped, protect the oxygen atom from Titan's reducing thermosphere-ionosphere. The fullerenes then rapidly form into large aerosols and eventually settle onto Titan's surface. We have developed a Galactic Cosmic Ray (GCR) model that provides the energy source within Titan's surface, subsurface and lake bottoms to make precursor molecules (see [5]). Then due to large > 10 km meteor impacts and cryovolcanism liquid water can form near the surface so hydrolysis (see [5,6,7,8,9]) can occur and convert the precursor molecules to amino acids such as glycine with abundances ~ 2.5 ppb to 5 ppb.

1. Summary and Conclusions

As presented in our most recent paper [1] the reducing hydrocarbon-rich nitrogen atmosphere of Titan with contributing external energy inputs from solar UV, upstream plasma ions and electrons, energetic particles and GCRs can produce aerosols in form of PAHs, PAHNs and $C_{60,70}$ fullerenes within Titan's thermosphere-ionosphere. Then with the entrapment of magnetospheric oxygen ions in fullerenes could allow exobiological reactions and their products such as amino acids to accumulate on Titan's surface, lake floors and within its sub-surface. The addition of our GCR model to Titan's atmosphere, surface and sub-surface has allowed us to quantitatively close the loop on this important discussion with the formation of exobiological molecules on Titan's surface such as the amino acid glycine with abundances ~ 2.5–5 ppb over a 450 Myr time scale. But based on the work by [5] a two-step process is required (i.e., radiation plus hydrolysis). The GCR irradiation makes the precursor exobiological molecules while the hydrolysis process is provided by large meteor impacts upon Titan's surface over ~ Gyr time periods to convert the precursors to amino acids.

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References

[1] Sittler, E., Cooper, J., Sturner, S., and Ali, A., Icarus, in press, 2019.

[2] Sittler, E., Ali, A., Cooper, J., Johnson, R., Coates, A., Young, D., Planet. Space Sci., Vol. 57, 1547-1557, 2009.

[3] Coates, A.J., Crary, F.J., Lewis, G.R., Young, D.T., Waite Jr., J.H., Sittler Jr., E.C., Geophys. Res. Lett. 34, L22103, 2007. https://doi.org/10.1029/2007GL030978.

[4] Waite Jr., J.H., et al., The process of tholin formation in Titan's upper atmosphere, Science, 316, 870, 2007. https://doi.org/10.1126/science.1139727.

[5] Hudson, R.L., Moore, M.H., Dworkin, J.P., Martin, M.P., Pozun, Z.D.. Amino acids from ion-irradiated nitrile-containing ices. Astrobiology 8 (4), 2008. https://doi.org/10.1089/ast.2007.0131. 2008, Mary Ann Liebert, Inc.

[6] Lunine, J.I., Evolution of the atmosphere and surface of Titan. ESA SP-315, 159–165, 1990.

[7] Sagan, C., Thompson, W.R., Khare, B.N., Titan: a laboratory for prebiological organic, chemistry. Acc. Chem. Res. 1992 (25), 286–292, 1992.

[8] Thompson, W.R., Sagan, C., Organic chemistry on Titan. Surface interactions. In: Proc. of the Symposium on Titan. In: ESA SP. 338. ESA, Noordwijk, pp. 167–176, 1992.

[9] Artemieva, N., Lunine, J., Cratering on Titan: impact melt, ejecta, and the fate of surface organics. Icarus 164, 2003, 471–480. https://doi.org/10.1016/S0019-1035(03)00148-9.