ROLE OF DYNAMIC PHOTOLYSIS IN THE ORIGIN OF CHARON'S RED POLAR ALBEDO.

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The color images of Charon captured by the Multispectral Visible Imaging Camera (MVIC) during the 2015 New Horizons flyby showed its northern polar region marked with a distinct red hue. This red color has been attributed to tholin-like refractory material posited to result from interplanetary medium Lyman-α (IPM Ly-α) processing of methane, which accretes onto Charon's winter pole following escape from Pluto [1]. Photolysis by IPM Ly-α may not necessarily generate the red-colored species but may produce 'precursor' less-volatile hydrocarbons that remain on the summer surface to endure processing by other agents such as solar wind and photons to eventually produce the tholin-like red material.

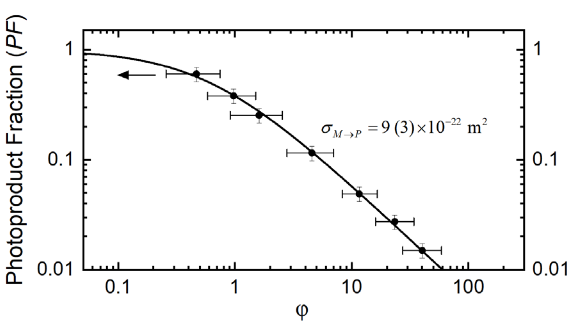

Figure 1: Photolyzed fraction (PF) in dynamically photolyzed methane films vs. φ. Mass loss during thermal desorption of photolyzed films recorded with a quartz crystal microbalance was used to quantify PF. The solid black curve is a fit of a simple photochemical model to the RF vs. φ data which gives the methane-to-refractory conversion cross section.

To constrain the contribution of IPM Ly-α to Charon's polar material, we performed laboratory experiments that simulate Charon's 'dynamic photolysis' conditions with high fidelity and report that the photolyzed fraction (*PF*) in the methane films processed by Ly-α photons during accretion depends strongly on φ, the ratio of CH_4 condensation rate to the Ly-α photon flux.

Figure 1 shows the decreasing dependence of photolyzed fraction with increasing φ. Accretion outcompetes photodestruction at high φ values, where methane molecules become quickly buried below the Ly-α optical penetration depth, ~ 35 nm, in solid methane [2]. Conversely, methane conversion to heavier hydrocarbons is more effective at low φ owing to the increased molecule-photon interactions during slow accretion.

An exosphere model [3-6] that tracks the ballistic motions of CH_4 molecules post-arrival from Pluto delivers the range of φ values on Charon's winter hemisphere, assuming a near-uniform flux of IPM Ly-α of 3.5×10^{11} m^{-2} s^{-1} [7]. A subset of these model-informed φ values is reproduced in the dynamic photolysis experiments.

A simple photochemical model that describes CH_4 photodestruction under continual methane loading [6] is fit to the measured φ-dependent photolyzed fraction (also shown in Figure 1) to derive a methane-to-photoproduct conversion cross section of $9\ (\pm 3) \times 10^{-22}$ m^2. This cross section is fed to the exosphere model to evaluate refractory synthesis from Ly-α photolysis of cold-trapped methane.

We find that the IPM Ly-α imprints a refractory distribution that steadily increases poleward, consistent with the latitudinal albedo gradient in the New Horizons images. While the refractory abundance is enhanced towards higher latitudes, the experiments also reveal a complexity gradient that increases away from the poles. Charon's low-to-mid-latitude regions host diverse, complex refractories emerging from low-φ photolysis, while ethane is the dominant polar hydrocarbon from high φ photolysis.

However, solid ethane is colorless [8] and may not sufficiently explain the observed red hue. Solar wind radiolysis of the ethane frost as it is warmed from the 10 K frigid winter temperature to the 60 K summer pole maximum may produce increasingly complex, redder refractories. Additional work constraining the contribution of solar wind to the Charon's color is warranted to fully understand the unique albedo of this enigmatic moon.

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