EPSC Abstracts
Vol. 13, EPSC-DPS2019-931-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Origin of Charon's Red Poles: New Insights from Exospheric Modeling and Solid Methane Photolysis

Ujjwal Raut (1, 2), Ben Teolis (1, 2), Joshua A. Kammer (1), Carly A. Howett (3), Kurt D. Retherford (1,2) and G. Randall Gladstone (1, 2). (1) Southwest Research Institute, San Antonio, TX 78238 (2) Department of Physics and Astronomy, University of Texas at San Antonio, TX 78249 (3) Southwest Research Institute, Boulder, CO, 80302 (uraut@swri.edu).

1. Introduction

The stunning color images of Charon captured by the Multispectral Visible Imaging Camera (MVIC) revealed that the northern polar region is tainted with a distinct reddish hue. This color has been attributed to tholin-like refractory material resulting from interplanetary Lyman-α (IPM Ly-α) photolysis of solid methane, which accretes onto Charon's cold winter polar region following escape from Pluto [4]. This proposition, if confirmed, would constitute a seminal discovery of the New Horizons mission that advances our understanding of the synergism of planet-satellite gas transfer and photolytic processes active in the Pluto-Charon system and the role of these cooperative processes in the origin of the observed red polar cap.

Here we present preliminary results from our Charon exospheric model and laboratory experiments on Ly-α photolysis of solid methane. The goal is to estimate the contribution of the *IPM Ly-α photolysis of methane cold-trapped on Charon's poles* to the observed reddish color, and to better constrain the following processes:

1) Spatial/temporal variability of the methane accretion rate onto Charon's surface.
2) Photo-conversion rate of methane into refractories, especially in conditions of simultaneous CH_4 accretion and Ly-α irradiation that occur on Charon.
3) Optical constants of these refractories in the MVIC spectral range which is the color determinant.

Our work is intended to provide the required latitude dependent cold-trapping rates, photolytic refractory yield and optical constants needed for a comprehensive understanding of the origin of Charon's prominent polar albedo marking.

2. Charon Exosphere model

The discovery by the New Horizon's spacecraft of significant methane escape rates from Pluto's atmosphere [4] has shed new light on the physics of Charon's possibly seasonal exosphere. As Charon orbits through Pluto's outflowing methane cloud, CH_4 arriving at Charon's surface will thermally equilibrate and form a gravitationally bound Charon exosphere. This putative Charon exosphere – although insufficiently abundant for direct detection [7] – is likely to be highly seasonal owing to the Pluto-Charon system's high inclination. The distribution, flux and accretion rate of exospheric CH_4 to/from Charon's winter polar terrain, varies drastically with position and time, as the surface temperature responds to the seasonally rising and setting sun. Methane accretion rates will evolve differently in the north versus the south, as the Pluto/Charon system's distance to the sun differs substantially between northern and southern summer, depending Pluto's orbital eccentricity and precession over geologic time. Our Charon Monte Carlo exospheric model is intended to quantify the distribution and evolution of exospheric and condensed methane at Charon.

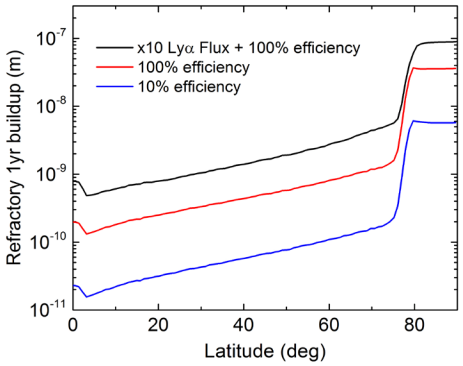

Figure 1: Predicted photolytic refractory thickness produced from condensed CH_4 on Charon surface over 1 Pluto orbit as estimated from our Charon exospheric model. The three cases shown are for different CH_4-to refractory conversion efficiencies.

The model considers the CH_4 flux onto Charon [6], Charon's rotation and the combined gravity field of Charon and Pluto, and seasonal methane adsorption/desorption to/from the poles. With the photolysis cross sections emerging from our laboratory experiments, we will integrate condensed methane photo-destruction and refractory synthesis by Ly-α photons into the model, including the dependence of these parameters on the methane accretion rate. We will use the exospheric model (together with lab experiments) to estimate the distribution of photolytic refractory material across Charon's polar latitudes (Figure 1), and compare to the distribution observed by MVIC.

3. Solid Methane Photolysis

While there have been several previous studies on UV irradiation of methane ice, the reported CH_4 destruction cross sections differ up to a factor of 15 [1], [3]. This disagreement most likely stemmed from the use of uncalibrated UV sources; Ly-α output can vary from 5-75%, depending on the operational configuration of the microwave discharge lamp. We have optimized our UV source to emit dominantly in the Ly-α (> 75%) as per the recipe provided in Ref. [2]. Additionally, the required measurements of the color evolution vs. dose and optical constants of photolyzed methane films are lacking.

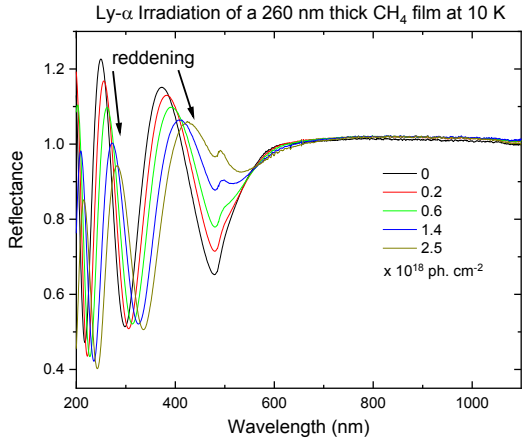

Figure 2 – Spectral reddening in Ly-α processed methane film irradiated to the indicated fluence. The reflectance is increasingly suppressed towards smaller wavelengths.

We show in Figure 2 the change in the UV-Vis-NIR reflectance (encompassing the MVIC spectral range) of a solid methane film condensed onto a gold-coated quartz crystal microbalance at 10 K (Charon's winter pole T) and irradiated with Ly-α photons to the indicated fluence. The oscillations are due to interference of light reflected by the CH_4 ice-vacuum and CH_4 ice-gold interfaces.

We observe spectral reddening as the CH_4 film is processed to higher dose; the reflectance is increasingly suppressed at shorter wavelengths as a result of photo-processing (indicated by the arrows in Figure 2). Future efforts will focus on deriving the imaginary refractive index *k* of the refractories that cause strong UV-Vis absorption to induce the reddening. Similar measurements will be performed under Charon like conditions where methane ice is irradiated during the winter accretion phase.

Acknowledgements

This work is funded by NASA NFDAP grant 80NSSC18K1391. We also acknowledge SwRI internal funding and support from the University of Virginia in establishing the lab facilities that enables this work.

References

[1] Bossa, J.-B., Paardekooper, D. M., Isokoski, K., & Linnartz, H., Methane ice photochemistry and kinetic study using laser desorption time-of-flight mass spectrometry at 20 K. Physical Chemistry Chemical Physics, 17, 17346-17354, 2015. **[2]** Chen, Y.-J., Chuang, K.-J., Muñoz Caro, G. M., Nuevo, M., Chu, C.-C., Yih, T.-S., Wu, C.-Y. R., Vacuum Ultraviolet Emission Spectrum Measurement of a Microwave-discharge Hydrogen-flow Lamp in Several Configurations: Application to Photodesorption of CO Ice. APJ, 781, 2014. **[3]** Gerakines, P. A., Schutte, W. A., & Ehrenfreund, P. Ultraviolet processing of interstellar ice analogs. I. Pure ices. A&A, 312(1), 289-305, 1996. **[4]** Gladstone, G. R., Stern, S. A., Ennico, K., Olkin, C. B., Weaver, H. A., Young, L. A., Zirnstein, E., The atmosphere of Pluto as observed by New Horizons. Science, 351, 2016 **[5]** Grundy, W. M., Cruikshank, D. P., Gladstone, G. R., Howett, C. J. A., Lauer, T. R., Spencer, J. R., Zangari, A. M. The formation of Charon's red poles from seasonally cold-trapped volatiles. Nature, 539, 65-68, 2016. **[6]** Hoey, W. A., Yeoh, S. K., Trafton, L. M., Goldstein, D. B., & Varghese, P. L. Rarefied gas dynamic simulation of transfer and escape in the Pluto-Charon system. Icarus, 287, 87-102, 2017. **[7]** Stern, S. A., Kammer, J. A., Gladstone, G. R., Steffl, A. J., Cheng, A. F., Young, L. A., Summers, M. New Horizons constraints on Charon's present day atmosphere. Icarus, 287, 124-130, 2017.