**THE ROLE OF AEROSOLS IN PLUTO'S $C_2$ HYDROCARBON PHOTOCHEMISTRY.** A. Luspay-Kuti[1*], K. E. Mandt[1,2], K. Jessup[1], V. Hue[1], J. A. Kammer[1], R. Filwett[2]. Southwest Research Institute, Department of Space Research, [2]University of Texas at San Antonio, Department of Physics and Astronomy ([*]aluspaykuti@swri.edu).

**Introduction:** On July 14, 2015 the *New Horizons* spacecraft successfully flew through the Pluto system, providing critical details about Pluto's atmosphere. Measurements made by the various instruments onboard *New Horizons* confirmed that the chemistry in Pluto's atmosphere is strikingly similar to Titan's, including the growth of aerosols [1, 2]. Chemistry is initiated by UV photons dissociating and ionizing $N_2$ and $CH_4$, whose products lead to the formation of complex molecules and organic haze in Pluto's atmosphere.

Vertical profiles of $N_2$ and $CH_4$, $C_2H_2$, $C_2H_4$, and $C_2H_6$ were derived from *New Horizons* Alice transmission data. These vertical profiles now allow the more accurate modeling of Pluto's atmosphere than in the pre-*New Horizons* era, and help better understand the physical and photochemical processes at play. The atmospheric $C_2$ hydrocarbon profiles in Pluto's atmosphere indicate that processes other than chemistry have a major impact on their altitude profiles [3]. The condensation and incorporation of hydrocarbons and nitriles onto Titan aerosols has recently been modeled providing good agreement with observations [4], suggesting that these processes may be important in the atmosphere of Pluto.

We present here our Pluto photochemical model, and evaluate the photochemistry of $C_2$ hydrocarbons in Pluto's atmosphere. We compare the dominant production and loss processes with a special emphasis on the role of aerosol interaction.

**The Pluto INP model:** We developed a coupled Ion Neutral Photochemistry model for Pluto's atmosphere (Pluto INP) based on our well-established Titan photochemical model [5-7]. Pluto INP is a 1D model which couples the ion and neutral chemistry by solving the continuity equation at each 10 km altitude grid from the surface up to 1800 km [8]. It includes a total of 46 neutral and 29 ion species. We use a constant thermal profile consistent with the line-of-sight *New Horizons* Alice transmission results [1]. The eddy diffusion profile ($K$) was determined by fitting the measured $CH_4$ densities with the model via [9]:

$$K = K_0\sqrt{\frac{n_0}{n}}$$

*Photon absorption.* Pluto INP employs temperature-dependent high-resolution (HR) $^{14}N_2$, $^{14}N^{15}N$ cross-sections from the coupled-channel Schrödinger equation for 70 K, binned into 0.03 Å bins between 845 Å and 1000 Å. HR CO cross sections were generated between 900-990.99 Å, and at shorter wavelengths used the available coarse resolution room temperature CO cross-section data sampled to 0.03 Å. In the higher wavelength range where HR cross-sections were not available, we used low resolution cross sections in 50 Å bins [5-7]. The HR solar flux for $F^{10.7cm}$ = 160 s.f.u. was calculated with a bin size of 0.1 Å, and interpolated into 0.03 Å bin sizes [6, 7]. In addition, we scaled the Ly α photon flux by 1.43 [3].

*Chemistry.* Because of the similarities between the atmospheres of Pluto and Titan, the chemical schemes and reaction rate coefficients were based primarily on our Titan model [5-7]. We also added the most important CO reactions to Pluto INP.

*Condensation.* The option of two methods [4, 10] for calculating the saturation vapor densities of atmospheric species have been incorporated into Pluto INP. Condensable species will have a higher atmospheric density than their saturation vapor density.

*Sticking to aerosols.* We use the effective aerosol surface area inferred from *New Horizons* observations [2], and estimate the sticking of $C_2$ hydrocarbons to aerosols particles. We determined the sticking efficiencies of $C_2$ hydrocarbons, and the stickiness of aerosol particles through empirical fits to the *New Horizons* data.

**Results:** Our best-fit eddy profile, and the Pluto INP fits to the *New Horizons* data are shown in Fig. 1. We found that an eddy profile of $K_0 = 10^6$ cm$^2$ s$^{-1}$ at $z$ = 0 km reaching $K_{max} = 3\times10^6$ cm$^2$ s$^{-1}$ at $z$ = 160 km satisfies the *New Horizons* data best.

Our results show that the *New Horizons* observations cannot be fit with photochemistry only, in agreement with recent results [3]. The inversion in the $C_2$ profiles indicates a significant nonchemical loss process between ~100 and 400 km. However, we find that condensation has minimal effect on the $C_2$ hydrocarbon altitude profiles, regardless of the method used. Instead, the dominant loss process that defines the altitude profiles below 500 km is loss by sticking to aerosols.

**Discussion and Conclusions:** With our coupled ion-neutral-photochemistry model developed for the atmosphere of Pluto, we were able to match the observed density profiles of $CH_4$, $N_2$, and the $C_2$ hydrocarbons. Our result implies a high eddy diffusion in Pluto's atmosphere, which is in agreement with [1] and [11], but is a factor of 500 higher than reported in [3].

We found that the sticking efficiency of $C_2$ hydrocarbons is inversely related to the aerosol surface area (Fig. 2), which has been inferred from observation to increase as altitude decreases [2]. This suggests that, similarly to Titan, the aerosols in Pluto's atmosphere harden and become less sticky as they age [12]. Such hardening with ageing is both necessary and sufficient to explain the vertical profiles of $C_2$ hydrocarbons in Pluto's atmosphere.

**References:** [1] Gladstone G. R. et al., (2016) *Science,* 351, aad8866. [2] Gao P. et al. (2016) *Icarus*, in press. [3] Wong M. L. et al. (2016) *Icarus*, in press. [4] Willacy K. et al. (2016) *ApJ*, 829, 79. [5] De La Haye V. (2008) *Icarus*, 197, 110-136. [6] Mandt K. E. et al. (2012) *JGR*, 117(E10). [7] Luspay-Kuti A. (2015) *ApJL*, 801, L14. [8] Luspay-Kuti A. (2016) submitted. [9] Bell J. M. (2010) *JGR*, 115(E12). [10] Fray N. & Schmitt B. (2009) *P&SS*, 57, 2053-2080. [11] Lellouch E. et al. (2016) *Icarus*, in press. [12] Dimitrov V. & Bar-Nun A. (2002) *Icarus*, 156, 530-538.

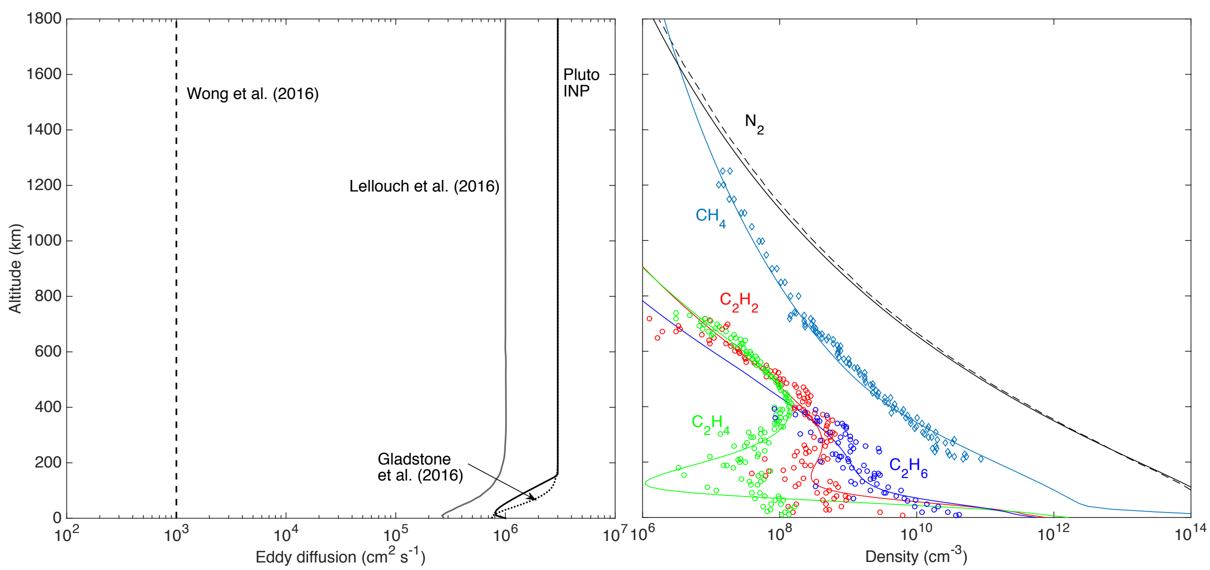


Fig. 1. Left: Comparison of eddy diffusion profiles in Pluto INP (black solid) with other recent results. Right: Comparison of altitude profiles from Pluto INP (solid curves) to the observed *New Horizons* data (circles and dashed curve).

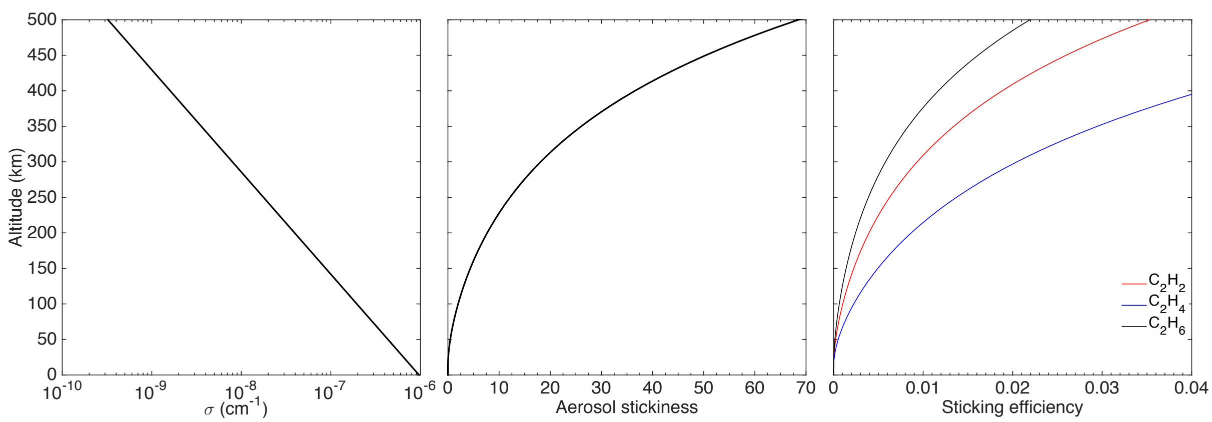


Fig. 2. Left: mean surface area of aerosol particles per volume (σ) from [2]. Aerosol stickiness (middle) and $C_2$ hydrocarbon sticking efficiency (right) determined through empirical fits to the *New Horizons* data.