AN ENDOGENOUS SOURCE FOR PLUTO'S NITROGEN (N_2). Kelsi N. Singer and S. Alan Stern. Southwest Research Institute, 1050 Walnut Street, Boulder, CO 80302, United States (ksinger@boulder.swri.edu, astern@swri.edu).

Overview: N_2 is abundant in Pluto's atmosphere and on its surface [1-4]. What is the provenance of Pluto's N_2? We demonstrate that comets most likely could not have delivered enough N_2 mass to supply Pluto's atmospheric escape over time, and thus the N_2 is likely indigenous and acquired early in Pluto's history or created by chemistry inside/on Pluto.

Atmospheric Loss: In addition to Pluto's surface ice composition being dominated by molecular nitrogen, Pluto's atmosphere consists of a >90% mole fraction N_2 [3], with surface pressures estimated on the of order ~10 μbars [4]. Models predict the N_2 escape rate is 10^{27}–10^{28} molecules s^{-1}, varying by an order of magnitude over the course of Pluto's year [e.g., ref. 5]. For reference, the estimated global atmospheric mass of Pluto, based on pure N_2 of 10 μbars and 35 K is ~$5x10^{17}$ g [6].

Using the range of escape rates stated above, a simple linear extrapolation of the escape rate yields a total mass of N_2 lost over four billion years of $6x10^{21-22}$ g. This is equivalent to a condensed N_2 surface layer on Pluto of depth 0.4-4 km [6].

N_2 Delivery by Comets: Stern et al. [6] estimate an N_2 mass of $5x10^{10-11}$ g in a 1 km comet with a 50:50 ratio of H_2O to refractories and typical cometary nitrogen abundances [7-8]. Using observations of current Kuiper Belt Object (KBO) densities [9], typical KBO impact velocities onto Pluto of ~1-2 km s^{-1} [e.g., ref. 10], and Pluto's cross section, Stern et al. [6] estimate ~14,000 comets 1 km in diameter or larger would impact Pluto over 4 billion years. Based purely on 1 km-diameter comets, this number of impacts would deliver $7x10^{14-15}$ g of N_2 over 4 Ga, far, far less than the anticipated N_2 inventory lost over time to escape.

Even given uncertainties in the impactor flux, discussed below, it does not appear that comets could deliver enough N_2 to supply Pluto's atmosphere. Our 14,000 impactor estimate is comparable to, but on the higher end of other predictions in the literature [6,10-13]. Additionally, the impactor size distribution has a steep slope, meaning only a small percentage of the total number of impactors will be larger than 10 km in diameter. More specifically, Bierhaus and Dones ([10], rates from their Table 5) estimate 270-5600 d > 1 km impactors would bombard Pluto over the last 4 Gyr, and only ~10-50 of those are predicted to be greater than 10 km in diameter. Most of these estimates do not account for collisional and dynamical erosion of the Kuiper Belt leading to a smaller number of current KBOs compared with early in Solar System history [e.g., refs. 14-16]. Durda and Stern [2000] estimated a factor of 2 increase in KBO population size would increase the overall number of impacts in the Kuiper Belt by a factor of 2. Similarly, correction factors estimated by Greenstreet et al. [17], to account for a higher impact rate in the past, would increase the total number of impactors on Pluto over ~4 Gyr by only a factor of ~several to 10.

Discussion and Conclusions: Comets deliver six-to-eight orders of magnitude less N_2 than is necessary to support the current atmospheric escape rates over Pluto's history. It is unlikely that the uncertainties in the escape rate and impactor SFDs could make up for an ~10^7x difference. Except in the extremely unlikely scenario that a recent, relatively large impact is supplying the current atmosphere, these calculations imply endogenic sources must dominate replenishment of Pluto's N_2. As to a recent impact, a comet 100–200 km in diameter would be required to deliver enough N_2 to supply the current atmospheric mass of Pluto. Most estimates predict only one or a few impactors greater than ~50 km in diameter on Pluto over the past 4 Ga [10,11,17]. It is highly unlikely that such a large (basin-forming) impact occurred recently.

What will New Horizons Measure Related to the Provenance of Pluto's N_2? Images taken by the Long Range Reconnaissance Imager (LORRI) and Ralph imagers aboard New Horizons will provide better constraints on the impact history of both Pluto and Charon [10,18,19], and will provide the first real information on possible sources of endogenic activity in the present or past. The Ralph instrument contains visible and infrared mapping spectrometers for characterizing the composition of Pluto's surface units and will tell us about the spatial variability of various frosts, and possibly something about the depths of these frosts. Surface temperature measurements and atmospheric pressure/temperature profiles by the Radio Science Experiment (REX) along with Alice UV will further constrain atmosphere-surface interaction models [e.g., ref. 20]. All of these observations will yield information to further constrain the history of Pluto's N_2.

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