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# Some problems in interpretation of the New Horizons observations of Pluto's atmosphere

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## Abstract

Here I briefly discuss (1) restrictions to LTE in the rotational lines of $H_2O$ and HCN and their effect on thermal balance of the atmosphere, (2) comparison of the model by Zhang et al. with Titan's data, (3) contradictions in the $H_2O$ influx from ablation of the interplanetary dust, (4) great differences between the haze observations and the model, and (5) some inconsistencies in the photochemical models.

## 1. Introduction

The radio and solar UV occultations and haze images at various phase angles observed during the New Horizons (NH) flyby of the Pluto system provide valuable information on the properties of Pluto's atmosphere, its thermal structure and chemical composition. Here we will briefly discuss some problems, difficulties, and inconsistencies that appear in existing published interpretation of the observational data.

## 2. Thermal balance

Pluto's upper atmosphere appears to be a cryosphere at $T \approx 70$ K [1] instead of the expected hydrodynamically escaping thermosphere. Strobel and Zhu [2] explained the observed cryosphere using the LTE cooling by $H_2O$ and HCN rotational lines up to 1200 km (Fig. 1). However, the LTE conditions for rotational lines become invalid for $A \geq kn$. Here $A$ is the transition probability, $k \approx 10^{-11} T^{½}$ cm$^3$ s$^{-1}$ is the collisional rate coefficient, and $n$ is the atmospheric number density. This means that the assumption of LTE becomes invalid for $H_2O$ and HCN above 700 and 820 km, respectively, and significantly affects the model results above 700 km (Fig. 1).

Zhang et al. [3] proved that the observed haze is more effective in heating and cooling of the atmosphere than the atmospheric gases. They extrapolated the haze attenuation measured by the

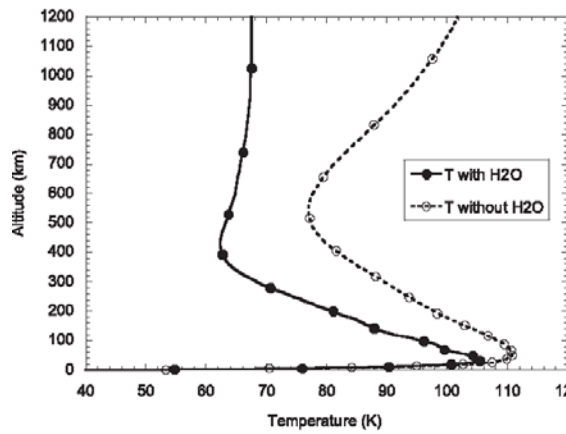


Fig. 1. Temperature profiles with and without $H_2O$ cooling. From Strobel and Zhu [2].

NH UV solar occultations from 350 to 700 km and adopted the particle radius of 10 nm for these altitudes. The haze heats the atmosphere by absorption of the solar light in the visible and cools by thermal radiation at 10-300 μm. The authors succeeded to fit the observed temperatures if the haze absorption coefficient is smaller by a factor of 4 in the visible and greater by a factor of 2.5 in the thermal infrared than that measured by Khare et al. [4] in their laboratory study. Both changes are opposite to those observed by the Cassini VIMS and CIRS on Titan [5]. However, absorption coefficient of the very small particles above 350 km on Pluto may significantly differ from that in Titan's haze.

## 3. Influx of water and dust

Strobel and Zhu [2] calculated the $H_2O$ mixing ratio of ≈10 ppm above 600 km assuming an exogeneous source of $H_2O$ near 500 km and its loss by condensation on the surface and the diffusion-limited thermal escape. The required source was 190 cm$^{-2}$ s$^{-1}$ scaled to the surface, that is, 88 g day$^{-1}$.

Wong et al. [6] included $H_2O$ and its detailed chemistry in their photochemical model and calculated the similar $H_2O$ abundances assuming the influx of $2.4\times10^6$ cm$^{-2}$ s$^{-1}$, that is, 1100 kg day$^{-1}$. Horanyi et al. [7] estimated ablation of 200 kg day$^{-1}$ of interplanetary dust on Pluto based on the NH and Pioneer 10 and 11 data. However, influxes of water on Saturn, Uranus, and Neptune are $\approx10^6$ cm$^{-2}$ s$^{-1}$ [8] and even greater on Titan ($3\times10^6$ cm$^{-2}$ s$^{-1}$ [9]) because of the $H_2O$ production from the Saturn rings.

## 4. Haze

The NH haze observations using LORRI and MVIC were analysed by Gladstone et al. [10]. They proved that the haze particles are fractal aggregates with effective radii of 0.2 μm that consist of monomers with radii of ≈0.01 μm. The haze vertical scattering optical depth is 0.013 in the red and the column surface area is 0.02.

The NH solar occultations [1] gave the line-of-sight optical depth of the haze at 180 nm of ≈2 near the surface and its vertical optical depth of 0.2 at 180 nm. The difference of a factor of 15 between the UV and red values looks reasonable for very small particles.

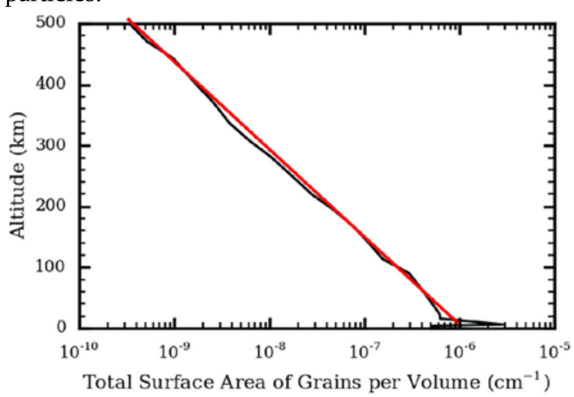


Fig. 2. Volume surface area of the haze in [11]. Red line is the exponential approximation.

However, the haze column surface area in Gao et al. [11] is equal to 8.8 (Fig. 2) and exceeds the value in the red by a factor of 440, though the model [11] is adjusted to fit the haze extinction at 180 nm. The difference may be partly caused by the large mean free path in Pluto's atmosphere, and the spheres of 0.2 μm are more appropriate as the condensation centres than the monomers of 0.01 μm. However, this reduces the difference by a factor of 20 but does not eliminate it.

## 5. Photochemical models

Two models by Wong et al. [6] and Luspay-Kuti et al. [12] have been developed. Inversions in densities of $C_2H_2$, $C_2H_4$, and $C_2H_6$ near 200 km observed in the NH UV solar occultations [1] are identified by Wong et al. as condensation of these species that is effective at 200-400 km. Sticking coefficients of the condensation process are used as parameters to fit the observations. The highly overestimated haze surface area from Fig. 2 is adopted; however, its effect may be simply corrected by proper scaling of the obtained sticking coefficients.

Luspay-Kuti et al. [12] indicate that the observed $C_2H_4$ and $C_2H_6$ cannot condense in Pluto's atmosphere except for a narrow layer near the surface. They substitute condensation by irreversible sticking with coefficients increasing from 0 at the surface to maxima at 400 km. However, the calculated total loss by aerosol trapping is extremely high, $\approx3\times10^{11}$ cm$^{-2}$ s$^{-1}$ for $C_2H_2$ in their figure 9, and exceeds the production by three orders of magnitude. This should be incompatible with the observed haze properties. The $C_2$ hydrocarbon densities near the surface are another set of fitting parameters in the model. The calculated peak total ion density of 30 cm$^{-3}$ is too low compared to ≈2500 cm$^{-3}$ on Titan. Scaling the heliocentric distances, the expected peak density is ≈800 cm$^{-3}$.

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## References


[1] Young L.A. et al. Icarus 300, 174, 2018.
[2] Strobel D.F., Zhu X., Icarus 291, 55, 2017.
[3] Zhang X. et al. Nature 551, 352, 2017.
[4] Khare B.N. et al. Icarus 60, 127, 1984.
[5] Vinatier S. et al. Icarus 219, 5, 2012.
[6] Wong M.L. et al. Icarus 287, 110, 2017.
[7] Horayi M. et al. EGU, Vienna, p. 3652, 2016.
[8] Feuchtgruber H. et al. Nature 389, 159, 1997.
[9] Krasnopolsky V.A. Icarus 236, 189, 2014.
[10] Gladstone G.R. et al. Science 351, aad8866, 2016
[11] Gao P. et al. Icarus 287, 116, 2017.
[12] Luspay-Kuti A. et al. MNRAS 472, 104, 2017.