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# Surface-atmosphere interactions on Triton and Pluto

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## 1. Introduction

The surfaces of Pluto and Triton are covered by a variety of ices, the most volatile of which being $N_2$, CO and $CH_4$. Sublimation equilibrium of these ices at surface temperatures of ~40 K produces a predominantly $N_2$ atmosphere, in which CO and $CH_4$ must be present as well. However, the respective gas mixing ratios depend on the details of the surface-atmosphere interactions. For a long time, information of the gas abundances has been restricted to the single detection of $CH_4$ in Triton's atmosphere by Voyager [1] and in Pluto's from ground-based observations [2]. A further complication is that the atmospheres of Triton and Pluto, monitored by stellar occultation observations, are known to vary temporally.

## 2. Observations

We observed Pluto and Triton in 2008 and 2009 respectively, using the CRIRES spectrometer installed on ESO VLT UT1 telescope, using AO mode. We covered the 1.64-1.68 µm and 2.32-2.37 µm ranges at Pluto and Triton respectively, in both cases at a spectral resolution of 60,000. In Pluto's case, the spectral range shows many lines due to the $2\nu_3$ band of gaseous $CH_4$. Interpretation is complicated by the fact that Pluto's surface pressure and lower atmosphere temperature structure are uncertain. Nonetheless the data indicate a $CH_4$ / $N_2$ mixing ratio of 0.5 +/- 0.1 % [3].

At Triton, the 2.32-2.37 µm range contains both signatures due to the $\nu_3 + \nu_4$ band of $CH_4$ and to the CO(2-0) band. These observations represent the first observations of methane gas since Voyager and the first ever detection in CO in Triton's atmosphere [4]. The $CH_4$ partial pressure is found to be ~10 nbar, i.e. ~4 times higher than measured by Voyager. The CO partial pressure is determined to be ~24 nbar (to within a factor of 3). Stellar occultations indicate that Triton's surface pressure has increased by a factor of ~2 over the 1990s. This is a probable consequence of seasonal evolution, with passage through southern summer solstice in 2000. Assuming p = 40 µbar in 2009, this gives typical mixing ratios of $6x10^{-4}$ for CO and $2.4x10^{-4}$ for $CH_4$ at the surface.

## 3. Surface-atmosphere interactions

Three scenarios can be a priori envisaged for the nature of surface-atmosphere interactions (i) the "ideal mixture" (solid solution): in this case, the expected partial pressure of each species is the product of its solid mole fraction and its pure vapour pressure. Given the "bulk" abundances of CO and $CH_4$ ices on Pluto and Triton's surfaces, this scenario implies atmospheric abundances of CO and $CH_4$ much lower than observed (see Fig. 1 for Triton) and can be excluded (ii) the "pure ice" scenario. This case is relevant if segregated patches of the different volatiles are present on the surface. In this case the atmospheric mixing ratios are in simple proportion of the pure vapour pressures at the relevant ice temperatures, and, except for the main species controlling the pressure, of the fractional area covered by each ice (iii) the "detailed balancing model" [5]. In this case, seasonal evolution of a $N_2$-dominated solid solution, with preferential sublimation of $N_2$ creates a thin surface layer enriched in the less volatile species (CO and $CH_4$). This "detailed balancing layer" controls the surface-atmosphere exchanges, and in the simplest case where no diffusive separation occurs in the atmosphere, the atmospheric mixing ratios are identical to those in the volatile reservoir below the surface veneer.

We suggest that the detailed balancing model is adequate to explain CO at Triton, whose observed abundance in the atmosphere (~$6x10^{-4}$) and in the surface (~$5x10^{-4}$, [6]) are very similar. Moreover, the miscibility of CO and $N_2$ ices in all proportions, and the remarkably similar longitudinal distributions of

CO and $N_2$ ices at Triton [7] strongly argue against the presence of separate CO patches on Triton.

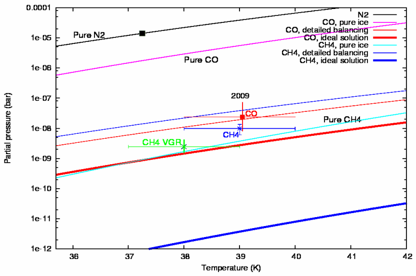

Figure 1: Abundance measurements and equilibrium curves for Triton's volatiles. The black, pink, and light blue curves show the vapour pressure of pure $N_2$, CO, and $CH_4$ ices. For CO and $CH_4$, the thick curves (red and blue, respectively) show the partial pressures for an ideal solid solution with $N_2$, with CO and $CH_4$ respective abundances of $5 \times 10^{-4}$ and $1 \times 10^{-3}$ in the ice. For CO and $CH_4$, the thin red and blue lines show the partial pressures expected in the framework of the detailed balancing model. The CO partial pressure we measure is consistent with expectations from the detailed balancing model, while $CH_4$ is lower. From [4].

On the other hand, applying the detailed balancing model to $CH_4$ would imply a $CH_4$ mixing ratio in the surface ice film as high as 50-80 %. This is well beyond the maximal solubility of $CH_4$ in $N_2$ (typically 10 %), so that the formation of pure $CH_4$ grains may be a more likely outcome of the seasonal evolution of a $N_2$-CO-$CH_4$ mixture. The presence of pure $CH_4$ patches is established for Pluto [8], and their ability to elevate the $CH_4$ atmospheric mixing ratio to ~0.5 % through their enhanced temperatures has been demonstrated [9]. Evidence for such pure $CH_4$ patches is not yet available on Triton, although the longitudinal distribution of $CH_4$ there is different from that of $N_2$ and CO. The increased $CH_4$ partial pressure in 2009 compared to 1989 is probably the consequence of seasonal evolution. Since the $CH_4$ vapour pressure is more temperature-dependent than that of $N_2$, we expect that the atmospheric $CH_4$ may increase at a higher pace than the pressure.

In summary, we believe that the CO atmospheric abundance reflects the detailed balancing model while that of $CH_4$ is the consequence of the presence of pure $CH_4$ patches on the surface. Additional observations expected in the summer of 2010 may shed further light on this problem. If successful, they will be presented at the meeting.

# References

[1] Herbert, F., and Sandel, B.R., 1991, JGR, 96, 19241

[2] Young, L.A., et al. 1997, Icarus, 127, 258

[3] Lellouch, E. et al., 2009, A & A, 495, L17

[4] Lellouch, E. et al., 2010, A & A, 512, L8

[5] Trafton, L.M, Matson, D.L. & Stansberry J.A. 1998, in Solar System Ices, eds. B. Schmitt, C. de Bergh, and M. Festou (Kluwer Academic Publishers), 773

[6] Quirico, E., et al. 1999, Icarus 139, 159

[7] Grundy W. M. et al. 2010, Icarus, 205, 594

[8] Douté, S. et al. 1999, Icarus, 142, 421

[9] Stansberry, J.A. et al. 1996, Planet. Space Sci. 44, 1051