

Will Titan lose its veil?

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Methane CH_4 is the only highly reactive and short-lived background component in Titan's atmosphere, so its overall reserve predetermines both features and duration of atmospheric chemical activity. Titan's global chemical activity is considered in terms of methane cycle. One cycle is defined as a period $T^0 = 7.0 \cdot 10^{14}$ s of complete photochemical destruction of methane's observable atmospheric content $\text{CH}_4^0 = 2.33 \cdot 10^{17}$ kg. Cycle duration T^0 , number of the past $N_P = 200 \pm 20$, future $N_F = 500 \pm 50$ and total $N_{max} = N_P + N_F = 700 \pm 70$ cycles are the main quantitative indices of the global chemical activity [2].

The fact that the period T^0 is much less than Titan's lifetime $T_T = 1.42 \cdot 10^{17}$ s implies that the current content CH_4^0 is continuously replenishing by methane global circulation. There are two sources of this replenishment, i.e. the outgassing of primordial methane reserve trapped in Titan's interior as the clathrate, and the (sub)ground liquid-phase reduction of non-saturated final products of the atmospheric photochemical process. Internal reserve provides the dominant portion (>95%) of general recycling, while reducing reconversion is the minor constituent of the global balance.

Yet, there is the problem of the *availability* of the off-the-shelf trapped methane. Overall admissible stock of the trapped methane depends on its internal allocation and falls in the range $(\text{CH}_4)_{max1,2} = (15.3 \div 33.3) \cdot 10^{20}$ kg, while continuous atmospheric activity during the whole Titan's life $T_{Sun} \sim 5.0 \cdot 10^{17}$ s needs only $(\text{CH}_4)_{crit} = (\text{CH}_4^0) \cdot N_{max} = \alpha \cdot (\text{CH}_4)_{max} \geq 1.65 \cdot 10^{20}$ kg. In turn, this bulk $(\text{CH}_4)_{crit}$ depends on the clathrate cage-filling efficiency (molecular packing index) α {kg CH_4 /kg clathrate} and can be provided if α equals respectively to [1]

$$\alpha \geq \alpha_{crit1} = (T_{Sun}/T^0) \cdot [(\text{CH}_4)^0 / [(\text{CH}_4)_{max1}]] = 5.45 \cdot 10^{-3}$$

$$\alpha \geq \alpha_{crit2} = (T_{Sun}/T^0) \cdot [(CH_4)^0 / [(CH_4)_{max2}]] = 2.51 \cdot 10^{-3}$$

Thus, the interrelation of overall trapped stock $(CH_4)_{max}$ and crucial α -values assigns the critical value $(CH_4)_{crit}$ that in turn predetermines the very fate of Titan's veil. If the real stock $(CH_4)_{real} \leq (CH_4)_{crit} = 1.65 \cdot 10^{20}$ kg, than Titan will lose its veil inevitably (scenario of the "*mosaic history*"), otherwise $(CH_4)_{real} \geq (CH_4)_{crit}$ the veil survives down to Titan's dying day ("*continuous history*").

References

- [1] H. B. Niemann and 17-co-authors, *Nature*, **438**, 779, (2005).
- [2] V. Dimitrov, *Prog. React. Kin. Mech.* **30**, N4, 227, (2006).