Photochemistry in Titan’s atmosphere: from the lab to the space mission

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Over the past 25 years, several photochemical models of Titan’s atmosphere have been developed independently to reproduce the observations to the best extent possible and to unveil the processes explaining their origin. Despite their quality, the Cassini’s mission has also highlighted their incompleteness, showing in the upper atmosphere numerous unexplained species and a fortiori unknown processes coupling nitrogen and hydrocarbon chemistry, and involving neutrals, and positive and negative ions. The complex mechanisms leading to the production of the organic aerosols surrounding Titan remain thus mostly unknown.

One way to study what is mostly unknown is to reproduce in the lab the whole chain of reactions occurring in Titan’s atmosphere simultaneously, with all the possible couplings between the reactive species (and not independent reactions) and to identify and analyze globally the processes occurring in a Titan-like global experiment. Several experimental set-ups have already been used in a few laboratories to simulate globally Titan’s atmospheric reactivity. Some of them use UV radiation as the energy source, others use various plasma discharges. We will present the advantage and limitations of the existing lab experiments with a specific focus given to the RF plasma setup, named PAMPRE (see figure 1).

Figure 1: Experimental scheme of the PAMPRE plasma reactor simulating Titan’s atmospheric chemistry.

The numerous data given by the Cassini-Huygens space mission provided the extraordinary opportunity to confront in situ-measurements with lab experiment results and to test the advantages and limits of lab experiments as tool for mimicking the physical and chemical processes prevalent in planetary atmospheres. An example can be given with the CIRS instrument onboard Cassini. The latter probes the stratospheric composition by infra-red limb or nadir measurements. A recent study of Gautier et al.
showed a quantitative agreement for nitriles between the CIRS in situ measurements and a PAMPRE plasma study.

Figure 2: Relative concentration of nitriles as a function of the number of carbons in the molecules. Red, green and blue dots represent experimental data obtained with the PAMPRE experiment. Empty black symbols are observational data and full black symbols are from computer modeling.