TOWARDS THE OBSERVATION OF PREBIOTIC MOLECULES IN TITAN'S ATMOSPHERE

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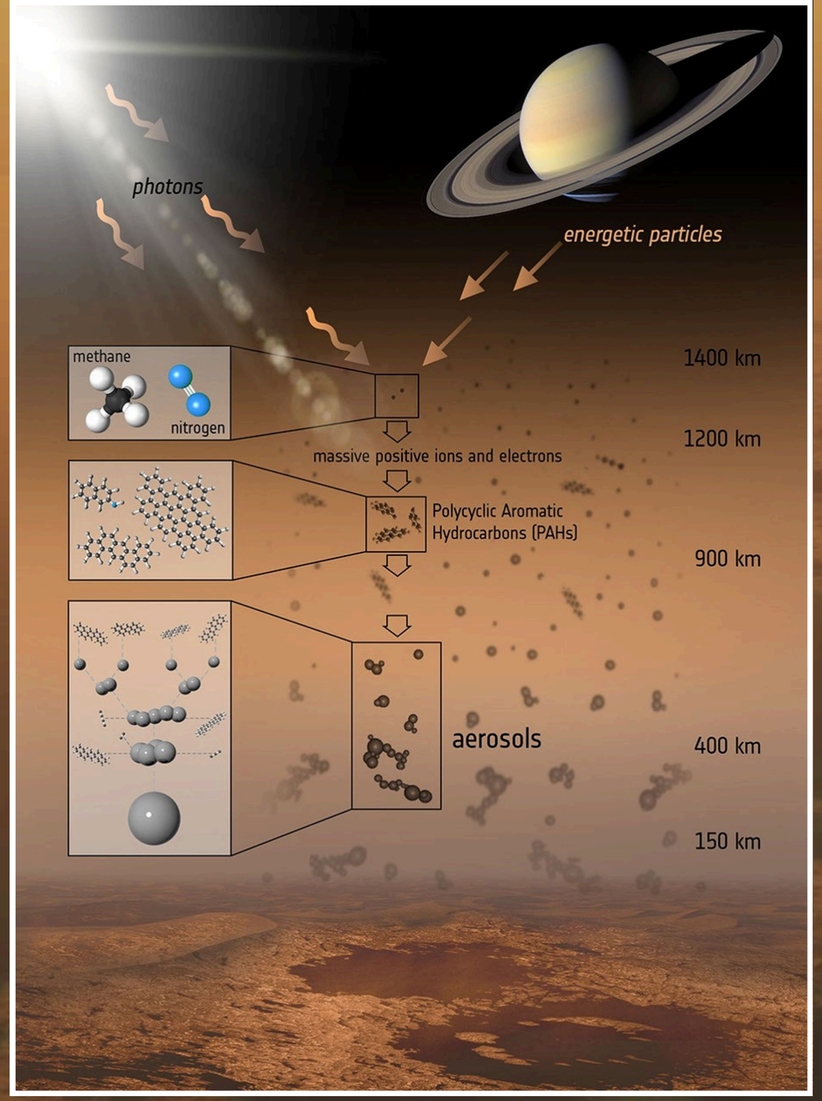
MEFT Student Workshop

Titan

- Saturn’s largest moon
- Only moon with a **dense atmosphere: N_2** (98%) and **CH_4** (2%) → largely anoxic (similar to the early Earth) → formation of organic haze
- **Stable surface liquids** → hydrocarbon lakes
- **Complex atmospheric chemistry**
  - Sunlight and energetic particles from Saturn’s magnetosphere trigger a **cascade of reactions** → wide range of **organic compounds** (Hörst, 2017; Nixon, 2024; Vuitton et al., 2025)



Motivation

Origin of life

At what point does organic chemistry become prebiotic chemistry?

Earth → transition happened when photochemically generated organics mixed into the primitive water ocean

Titan → **transient liquid water** from impact melts or cryovolcanic flows may play the same astrobiological role (Neish et al., 2010, 2018)

Motivation

Origin of life

At what point does organic chemistry become prebiotic chemistry?

Laboratory experiments → Titan **haze analogues** can produce **biological molecules**, including amino acids, when **mixed with liquid water** (Neish et al., 2008–2010; Ramírez et al., 2010; Poch et al., 2012; Cleaves et al., 2014)

Objectives

Problem

Despite decades of modelling and the wealth of data from Cassini-Huygens → **CH**, **C_2**, and **CN remain undetected** → short-lived radicals thought to play a **central role in building Titan's organic molecules**

Solution

Arrival of UHR spectrographs like **VLT-ESPRESSO** → we can now **search for these species** in the visible wavelength range

Methodology

Observations

Using ESPRESSO observations of Titan from December 2024 → determine **whether these radicals leave any detectable imprint** in the visible

Spectral features

The method successfully recovers **Titan's dominant absorbers**, particularly CH_4, and shows clustering of Titan-origin features in the expected wavelength regions

Results

However, **CH**, **C_2**, and **CN remain undetected**

Methodology

Observations

Using ESPRESSO observations of Titan from December 2024 → determine **whether these radicals leave any detectable imprint** in the visible

Spectral features

The method successfully recovers **Titan's dominant absorbers**, particularly CH_4, and shows clustering of Titan-origin features in the expected wavelength regions

Results

Low steady-state abundances → likely due to their short lifetimes

Challenges of searching for spectral signatures in the **visible**

Future Work

Infrared wavelengths

To truly probe Titan's photochemistry → infrared, where most atmospheric species of interest produce **deeper, more easily detected absorption features**

VLT–CRIRES+

Apply similar techniques to a **new infrared dataset from VLT-CRIRES+** → investigate the **pathways that lead from simple molecules to complex organic structures**

THANK YOU

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