Ecole Ariel 2025

Microphysics of Hazes & Clouds

Panayotis Lavvas
GSMA/CNRS

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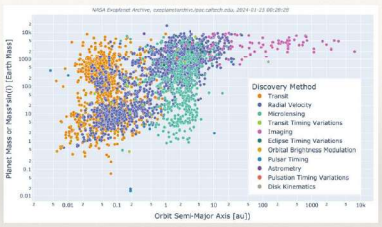
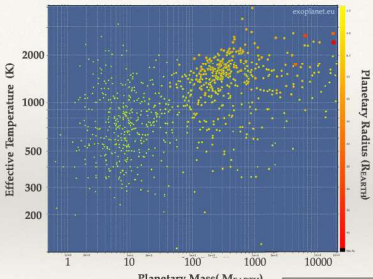
Exoplanets



- New type of planets
- Novel views of planetary system formation
- Vast range of planetary-stellar conditions
- Exotic atmospheric conditions/compositions
- Major implications for planetary evolution

Precise atmospheric characterisation

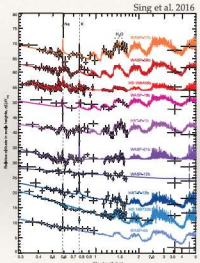
Approaching habitable zone conditions



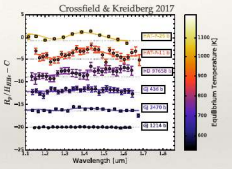
Precise atmospheric characterisation

Atmospheric characterisation through Transits

Hot-Jupiters



Sub-Neptunes



Hazes and clouds can strongly limit the atmospheric characterisation

An interesting obstacle

- Almost all atmospheres in the solar system present photochemical hazes /clouds. Most photochemical hazes are based on *organic composition*.
- Hazes/clouds have major implications for the *thermal structure* and *dynamics* of the atmosphere.
- Main *amino acids* are formed during experimental haze formation (e.g. Neish et al. 2018)
- On Earth they are a major concern for climate and public health, while in the past they may have affected the *emergence of life* (Trainer et al. 2005).

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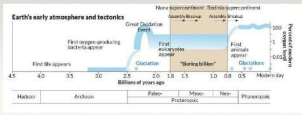
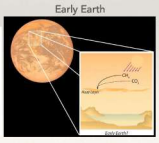
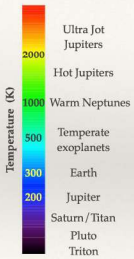
Earth's O_2 Level — Lyons et al. 2014



Early Earth



Atmospheric characterisation at different conditions



How hazes & clouds form?

How they affect their atmospheres?

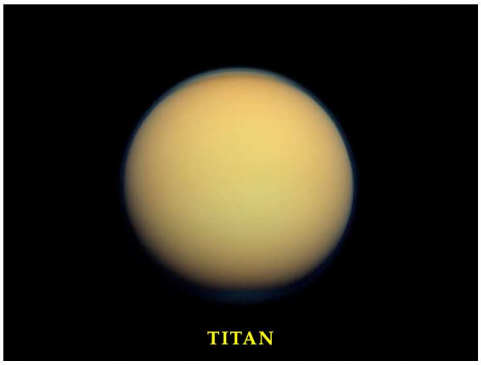
How solar system knowledge applies to exoplanets?

What information do they convey for exoplanets?

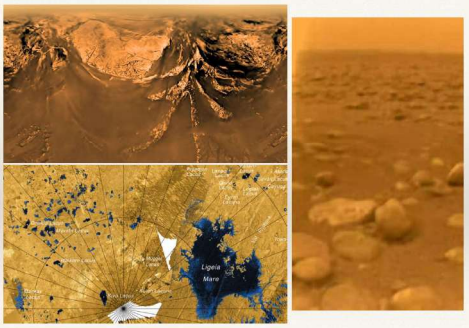
Solar System

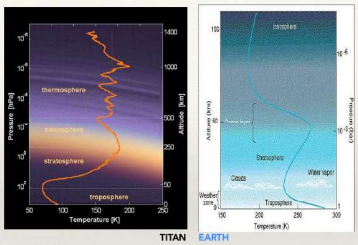
Photochemical hazes in the solar system

+ Ground based observations



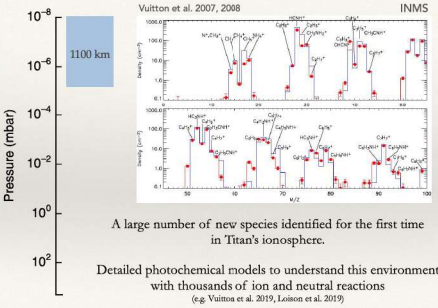
Cassini-Huygens Mission





	TITAN	EARTH
RADIUS:	2575 km	6371 km
COMPOSITION:	N_2 (95%), CH_4(5%)	N_2 (78%), O_2(21%), Ar(1%)
GRAVITY:	1.35 m/s²	9.81 m/s²
TEMPERATURE:	94 K	288 K
SURFACE PRESSURE:	1.5 atm	1 atm
ORBIT:	10 AU	1 AU

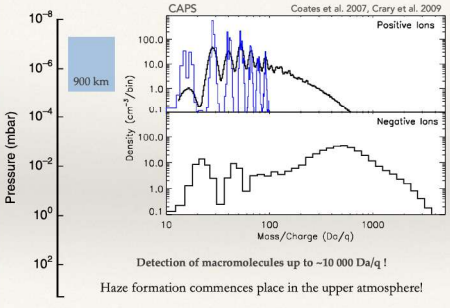
Haze lifetime on Titan: Ion chemistry



A large number of new species identified for the first time in Titan's ionosphere.

Detailed photochemical models to understand this environment with thousands of ion and neutral reactions
(e.g. Vuitton et al. 2019, Loison et al. 2019)

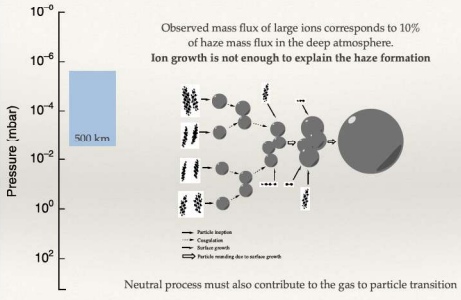
Haze lifetime on Titan: Macromolecule formation



Detection of macromolecules up to ~10 000 Da/q !

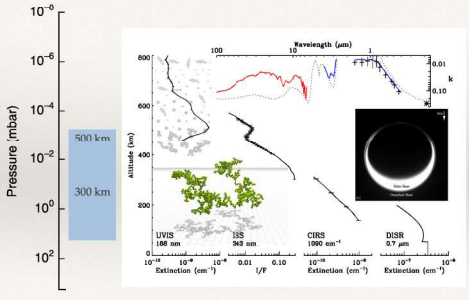
Haze formation commences place in the upper atmosphere!

Haze lifetime on Titan: Heterogeneous neutral chemistry

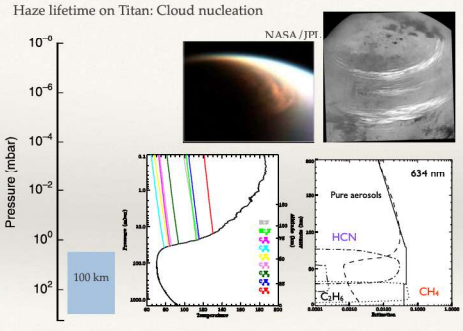


Neutral process must also contribute to the gas to particle transition

Haze lifetime on Titan: Coagulation



Haze lifetime on Titan: Cloud nucleation



Lavvas+ 2010, Rannou+ 2010, Koskinen+ 2011, Vinatier+ 2011, Seignovert+ 2018, Vuitton+ 2024