CHIANTITOPICS
9th International Focus Workshop

ETH zürich

CENTRE FOR ORIGIN & PREVALENCE OF LIFE

Limitations on aerosol optical constants and gas phase kinetic constants data

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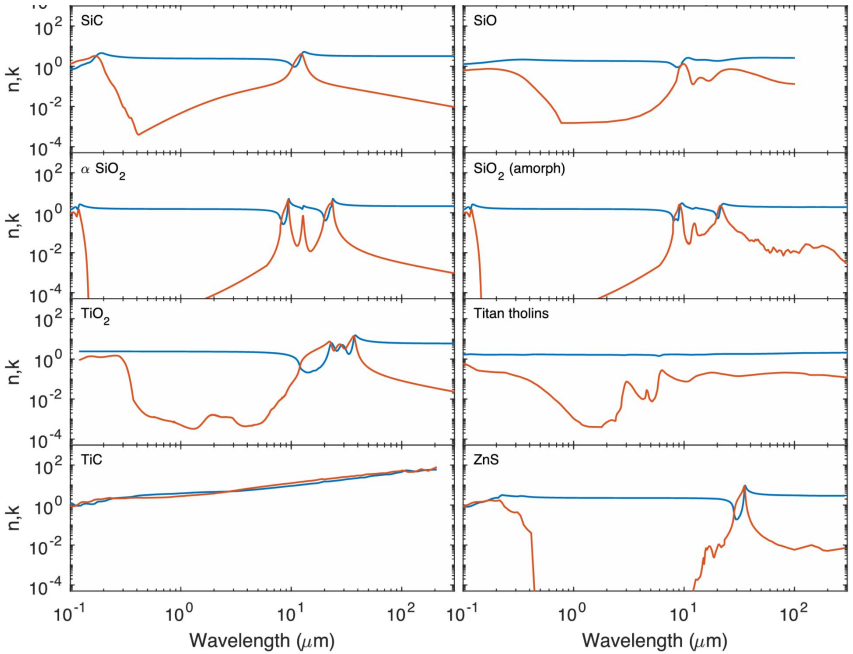
Aerosol optical constants for remote sensing observations



The intrinsic composition of aerosols is described using its complex refractive index quantifying dispersion and absorption of light :

N = n - i k

These data are used in Mie scattering codes to derive the extinction cross section, asymmetry parameter and single-scattering albedo for a given particle size distribution.

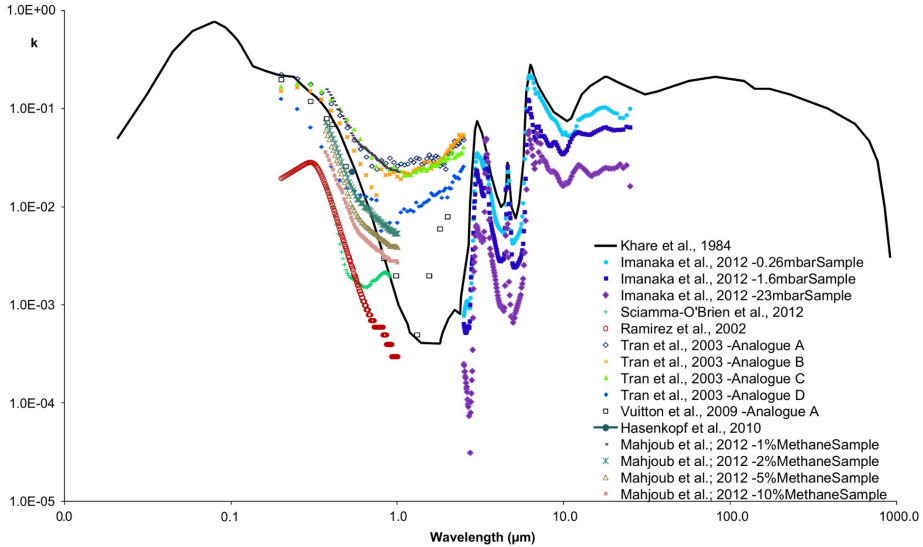
In planetary atmospheres, aerosols are mainly condensates, photochemical hazes or volcanic ashes.

Kitzmann & Heng 2018

Aerosol optical constants of photochemical hazes

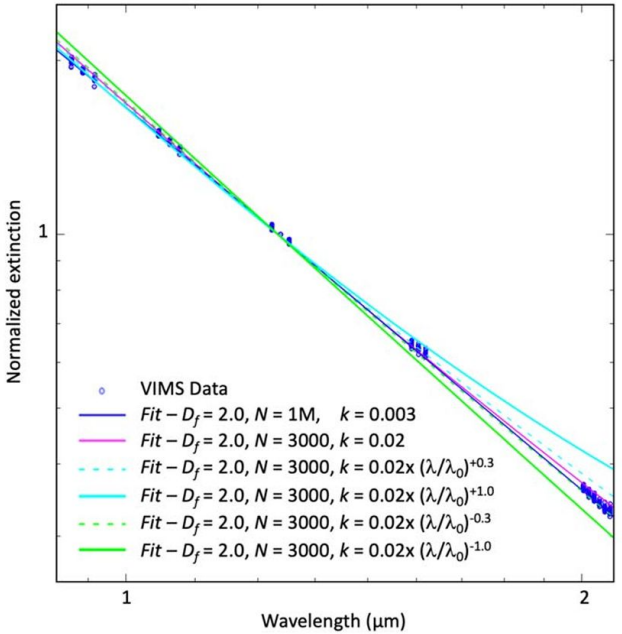
Comparison of optical constants for Titan haze analogs shows significant variations:

- UV-Visible absorption slope
- absorption in the Visible range
- variations of IR strengths



Brassé+2015

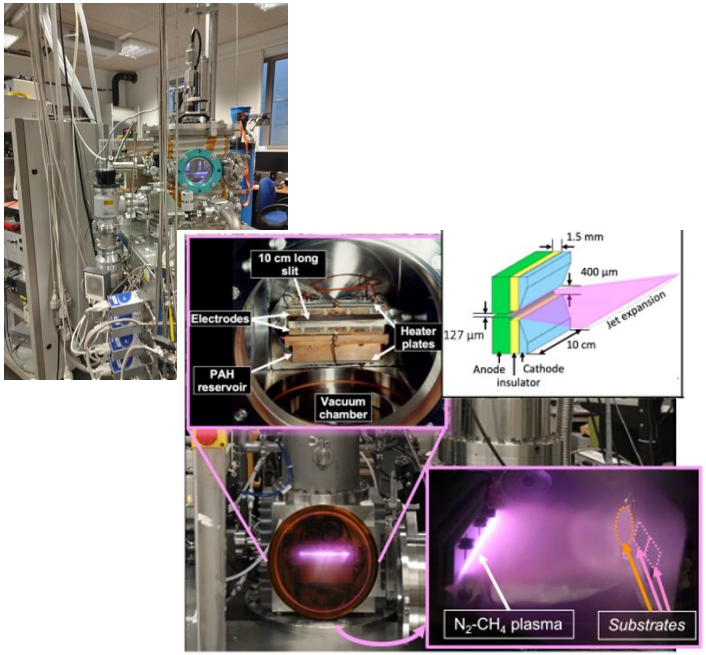
Remote-sensing observations of Titan are sensitive to the absorption properties of hazes

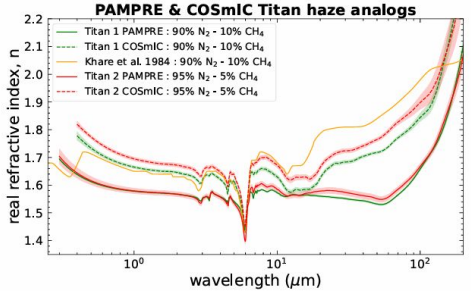


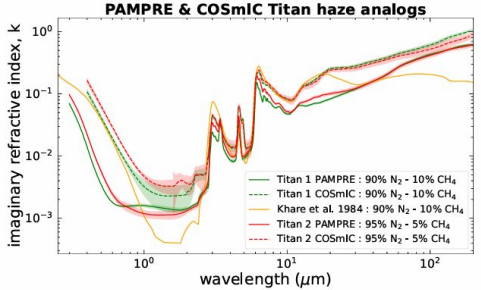
Sciamma-O'Brien+2023

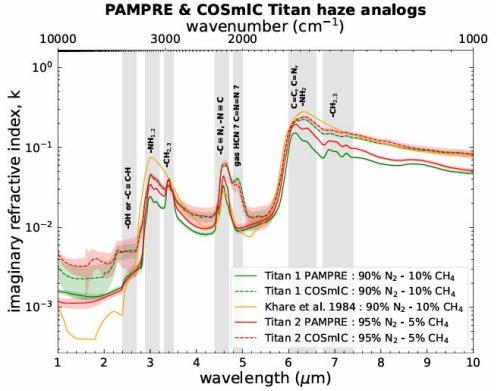
Drant+2026

Aerosol optical constants of photochemical hazes









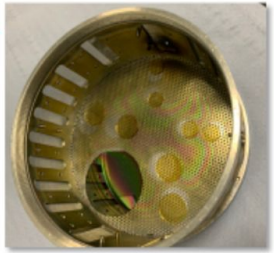
strong variations of optical constants depending on setup (gas temperature, residence time, irradiation) :

- more N in the COSmIC samples leading to stronger absorption in the entire spectral range
- additional IR features in the COSmIC samples

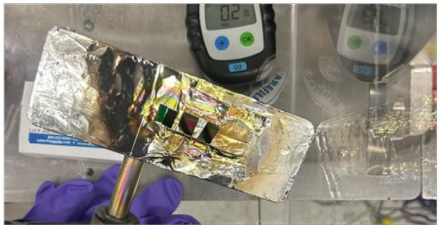
Drant+2026

Aerosol optical constants of photochemical hazes

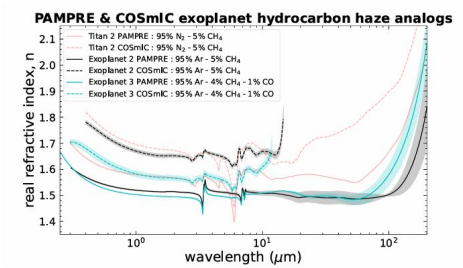
PAMPRE

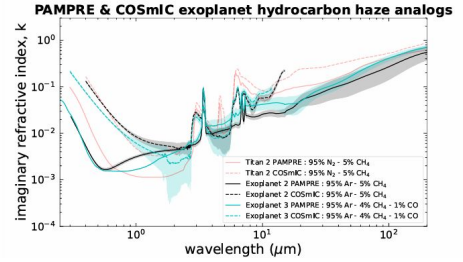


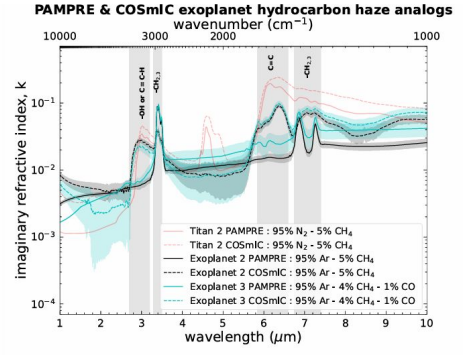
COSmIC

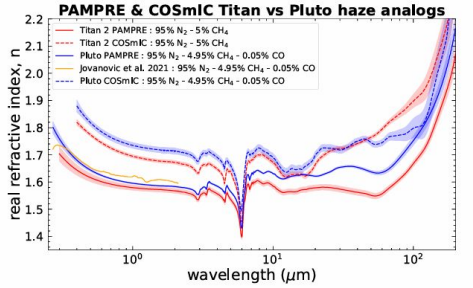


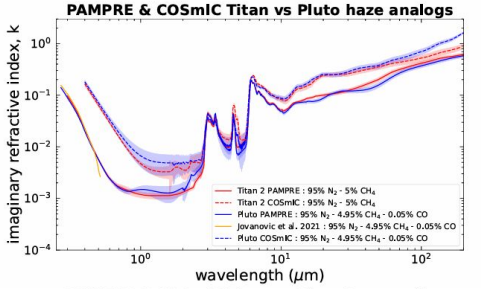
- Small influence of CO because of its low photo-dissociation efficiency
- Lower n and k values in the absence of nitrogen

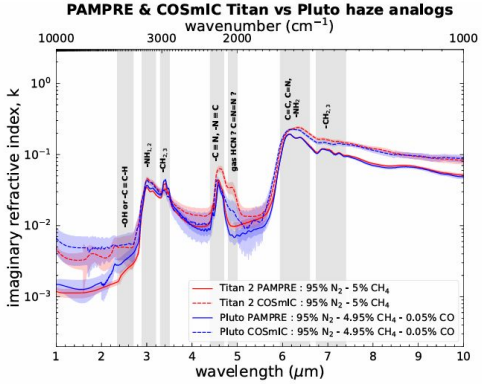






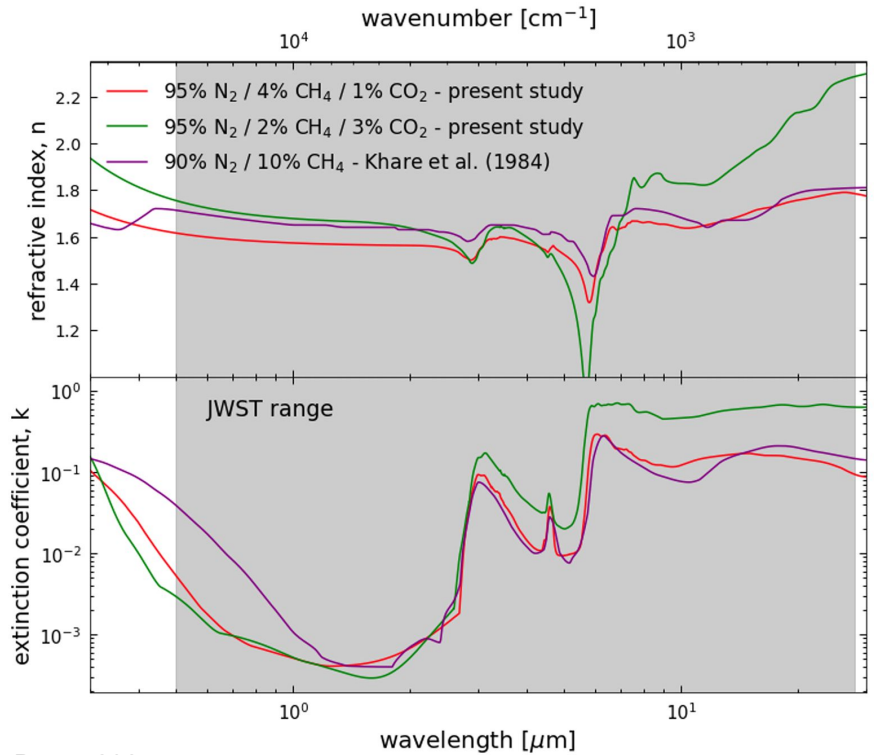




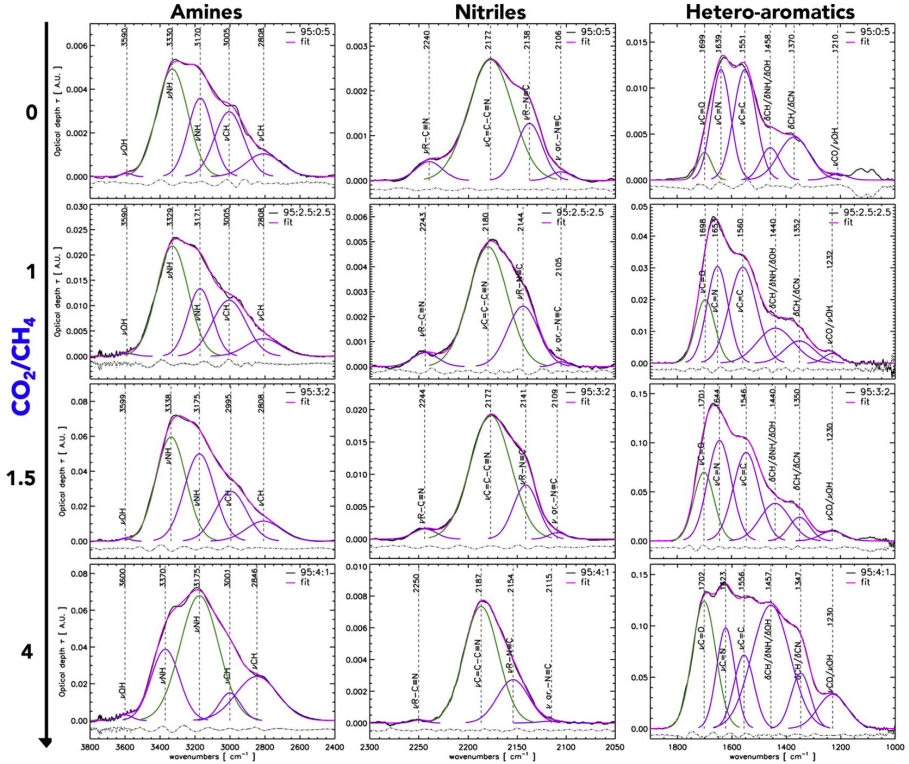


Aerosol optical constants of photochemical hazes

Variations of CO_2/CH_4 have a significant influence on the refractive indices



Drant+2024



Gavilan+2018

Aerosol optical constants of photochemical hazes

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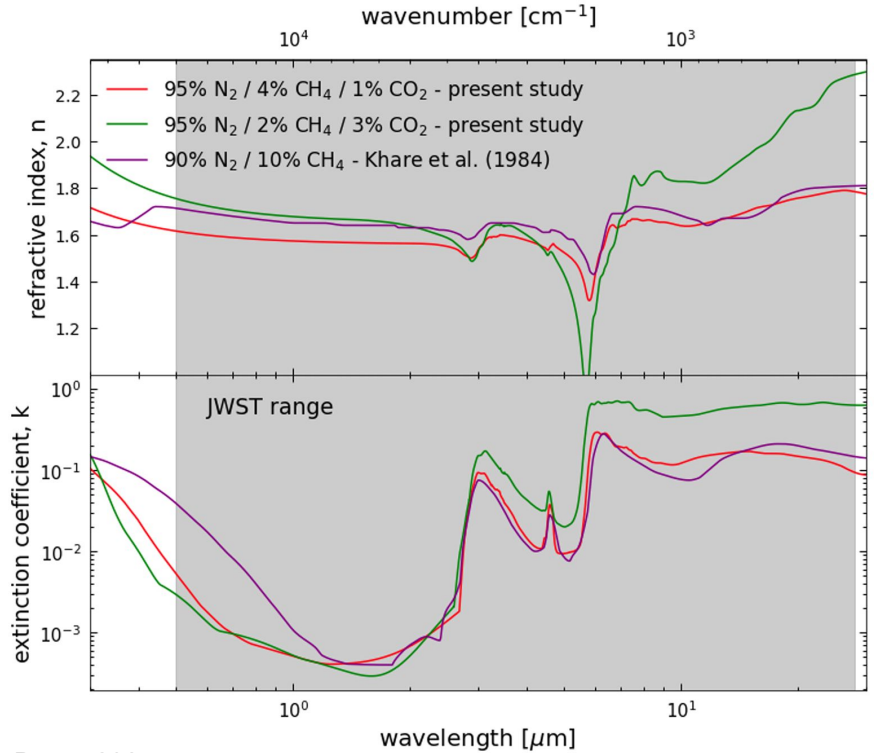
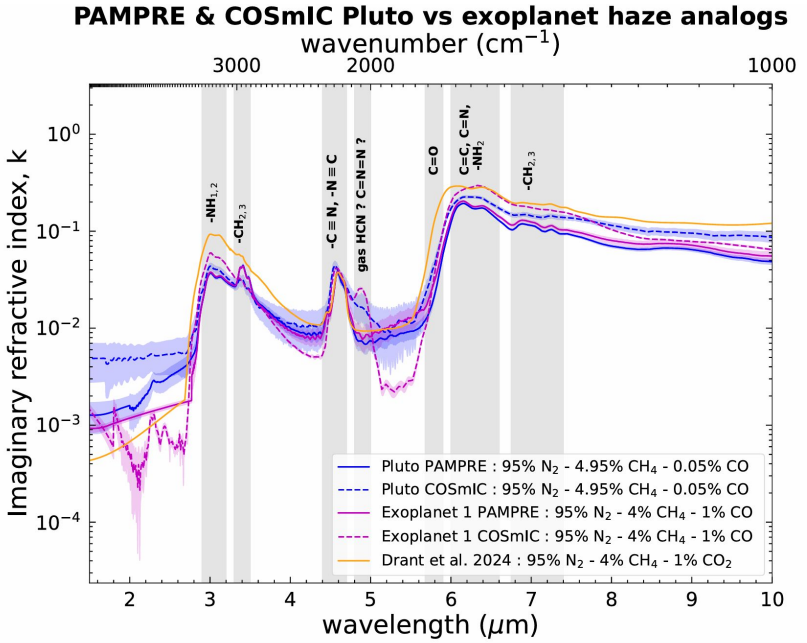
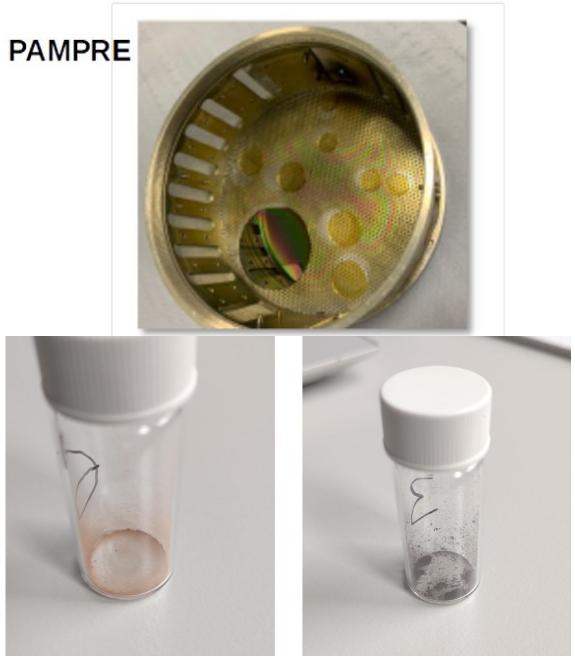


Drant+2024



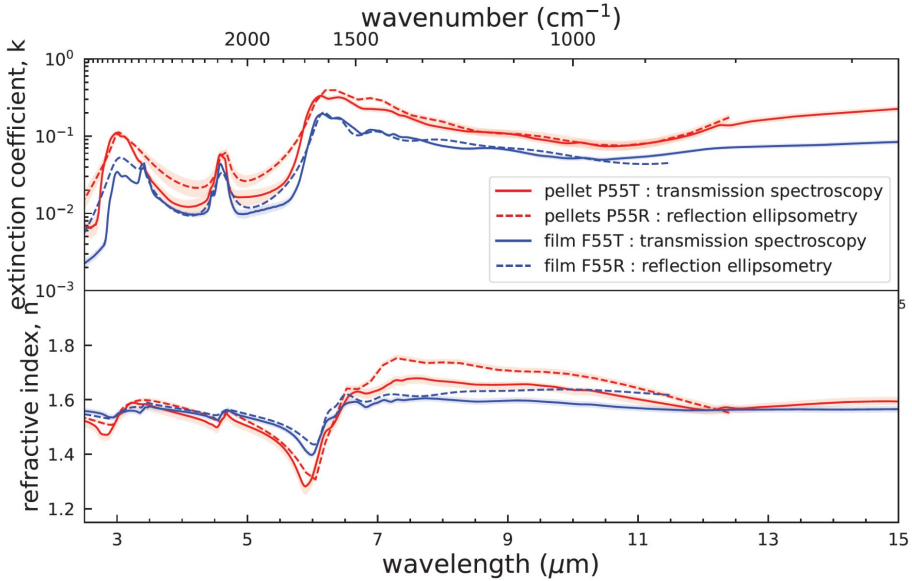
Drant+2026

Aerosol optical constants of photochemical hazes



Carrasco+2016

Samples	Thin films		Grains	
	N/C (XPS)	H/C (SIMS)	N/C	H/C
1%	0.4	~0.1	0.9	1.1
2%	0.3	~0.1	0.8	1.1
5%	0.2	~0.1	0.6	1.2
10%	0.1	~0.1	0.4	1.4



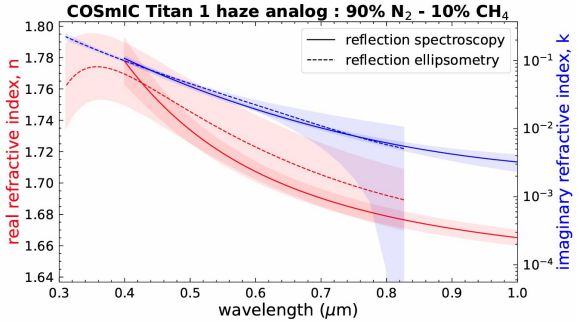
Perrin+2026

Important variations of N content and IR absorption properties based on the residence time

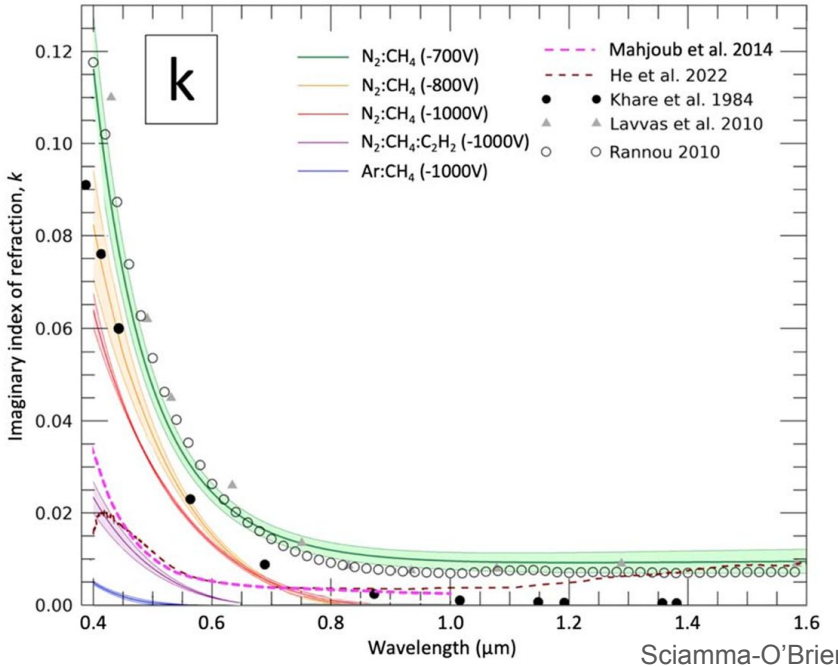
Aerosol optical constants of photochemical hazes

There are limitations in the determination of optical constants :

- difficult to retrieve k in the Visible-NIR
- different techniques can have different biases and errors



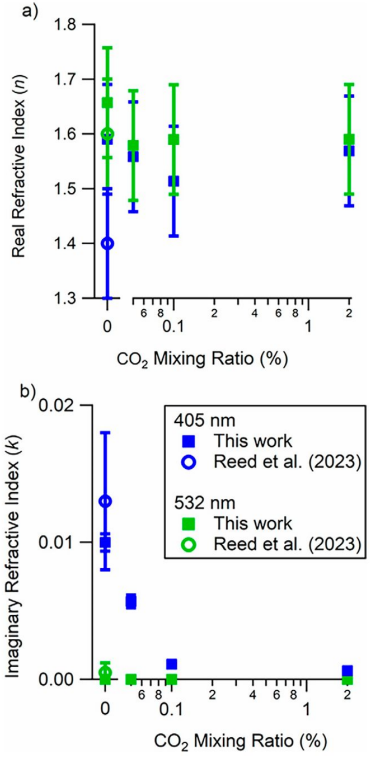
Drant+2026



Sciamma-O'Brien+2023

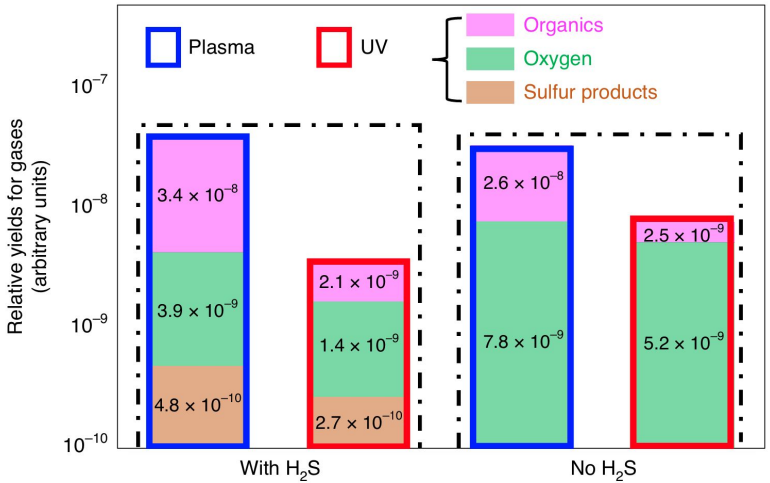
Aerosol optical constants of photochemical hazes

Sulfur-driven hazes are important for exoplanet atmospheres but their formation is very complex and no optical constants data exist

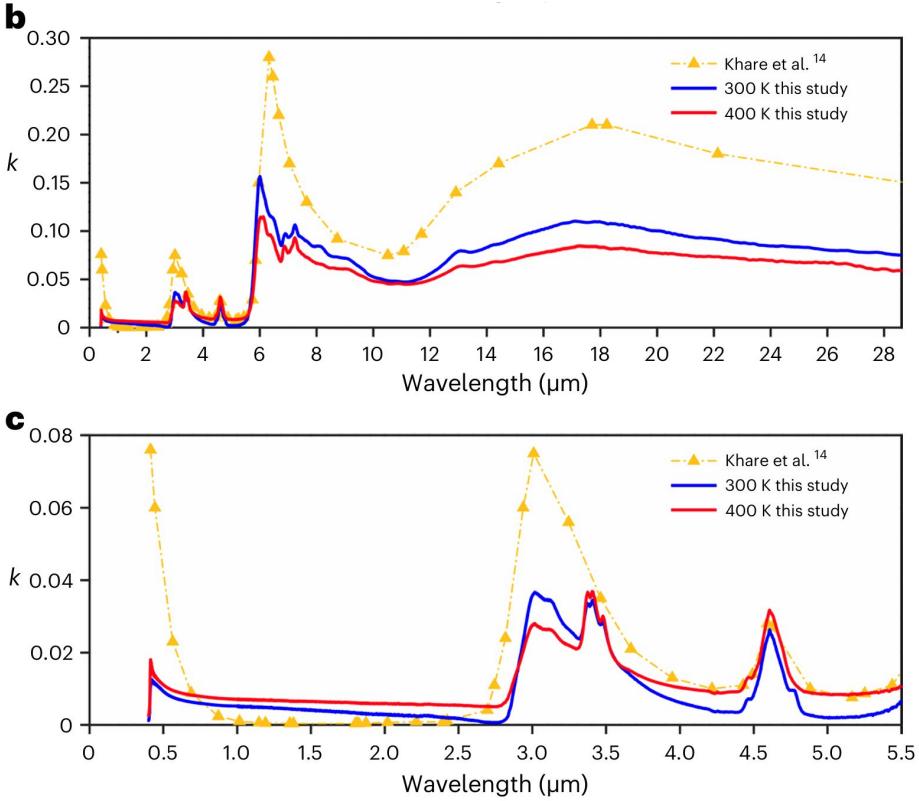


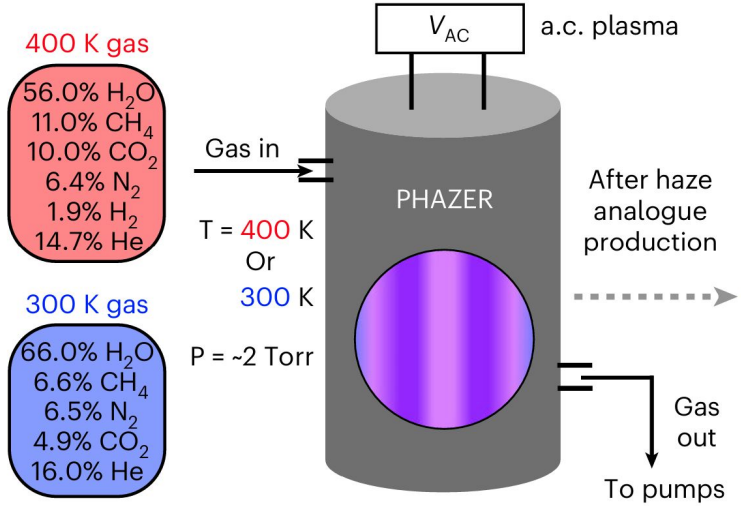
Jansen+2025

Hu+2020



Aerosol optical constants of photochemical hazes



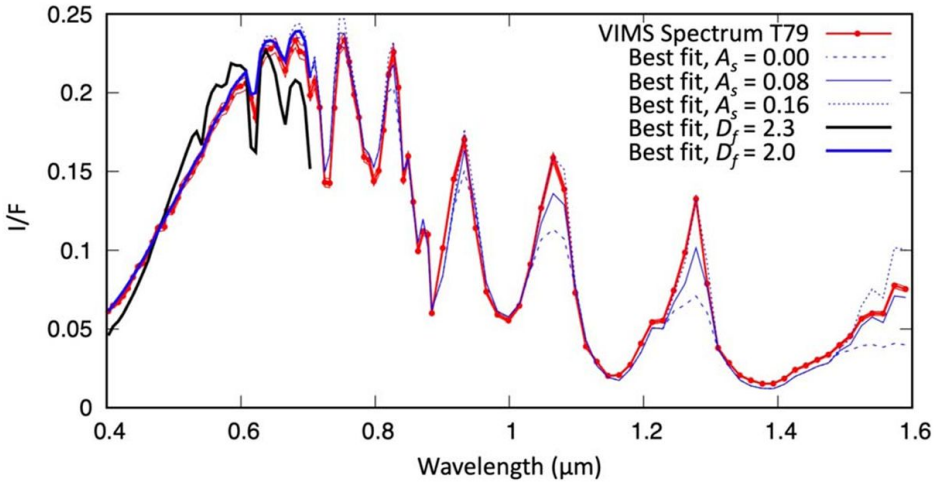


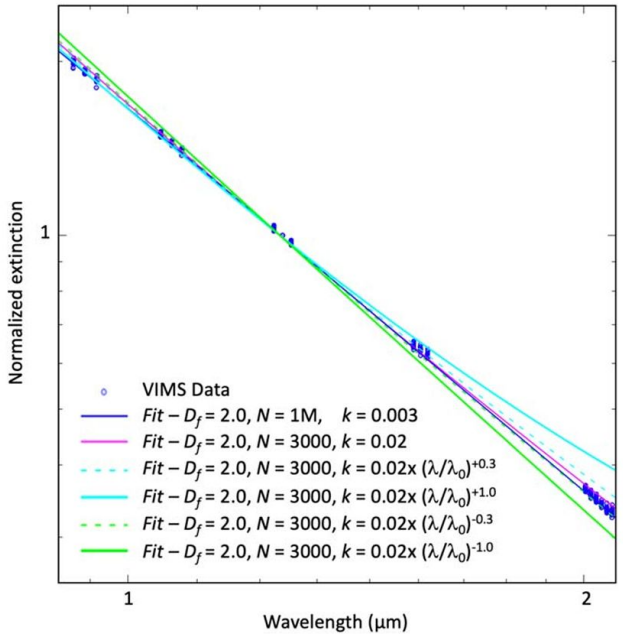
Other labs also see strong variations in IR absorption strength compared to the original data of Khare+1984

He+2024

Aerosol optical constants of photochemical hazes

Titan observations in reflection is very sensitive to aerosol optical constants to constrain the onset of absorption at shorter wavelengths

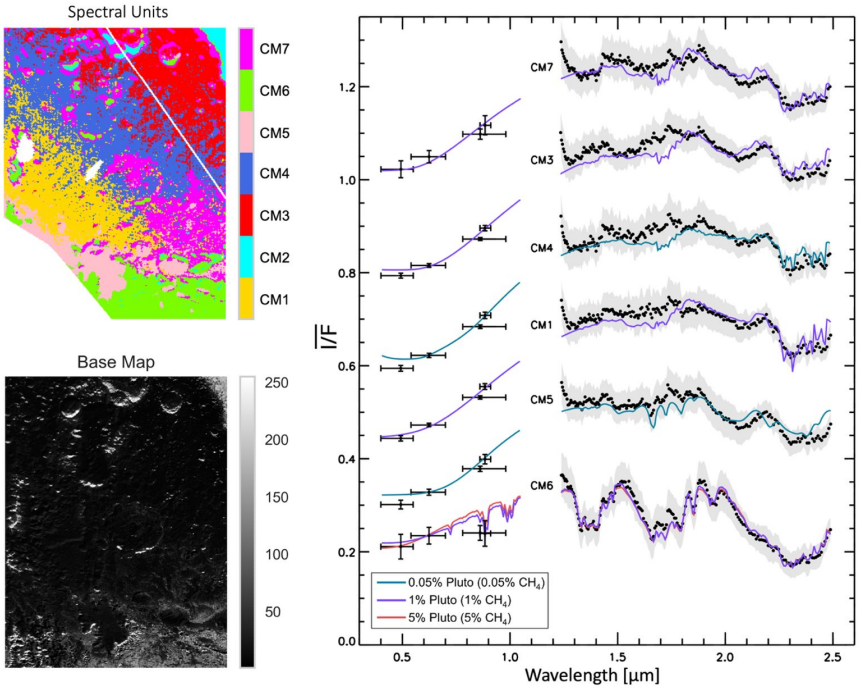


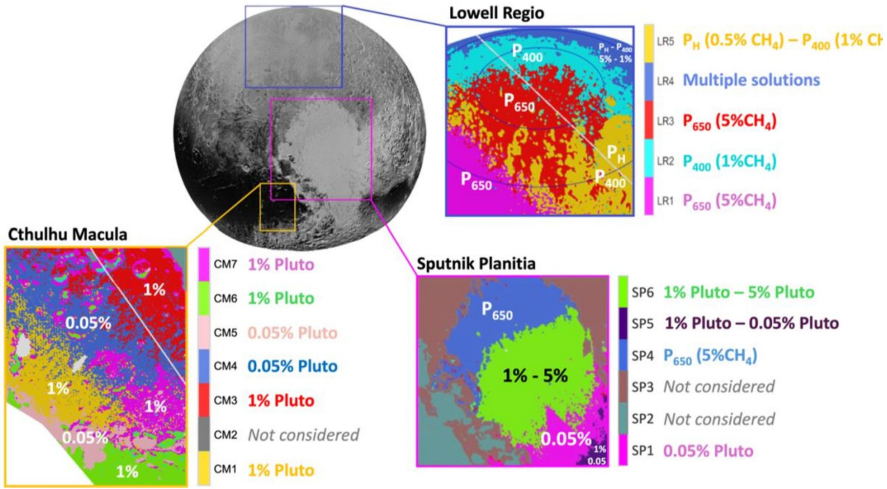


Sciamma-O'Brien+2023

Aerosol optical constants of photochemical hazes

Pluto surface observations by New Horizons revealed a heterogeneity in the colors of the terrains likely influenced by aerosols of different compositions



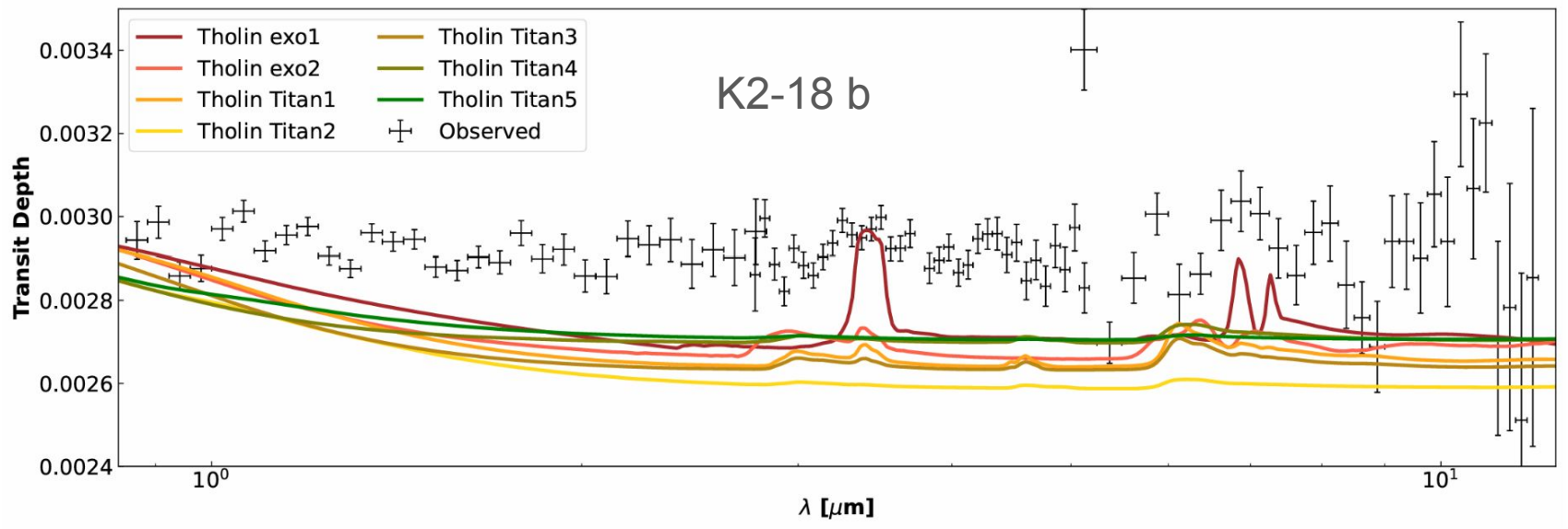


Sciamma-O'Brien+2026 (in review)

Aerosol optical constants of photochemical hazes

The presence of haze is expected in exoplanet atmosphere including sub-Neptunes currently characterized efficiently with JWST.

Haze optical constants have an important influence on the retrieved parameters including methane abundance, haze density and particle radius.

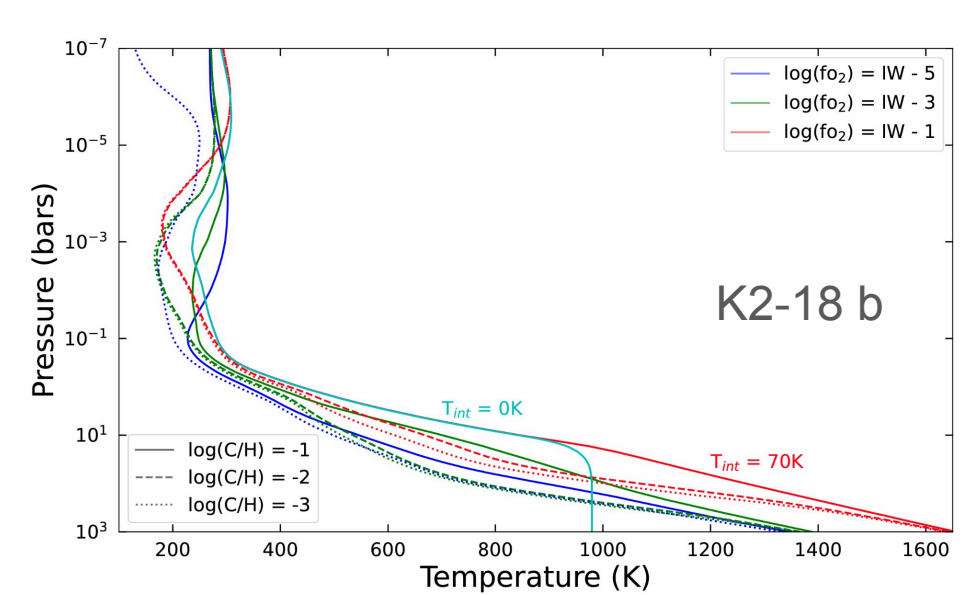


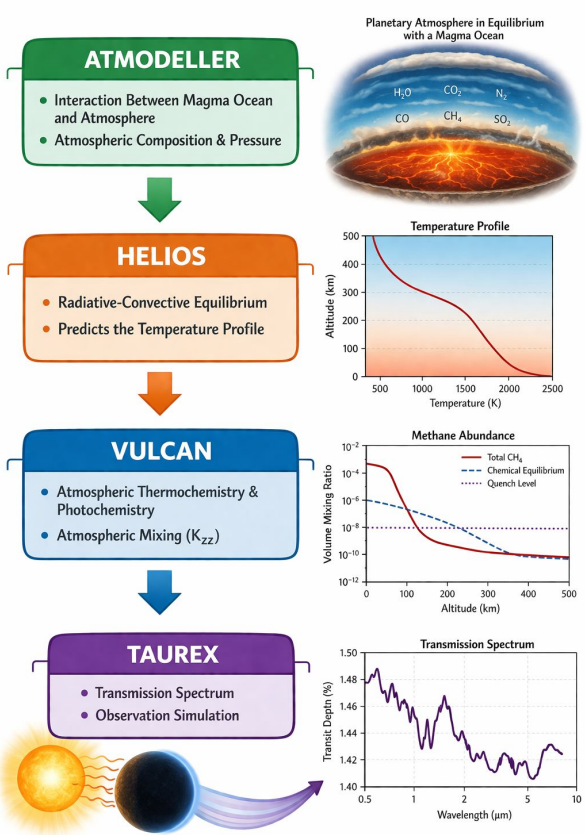
Jaziri & Drant 2025

Limitations in exoplanet observations and modeling

Limited data :

- H_2-CH_4 CIAs
- temperature-dependent photo-dissociation
- uncertain chemical kinetics constants

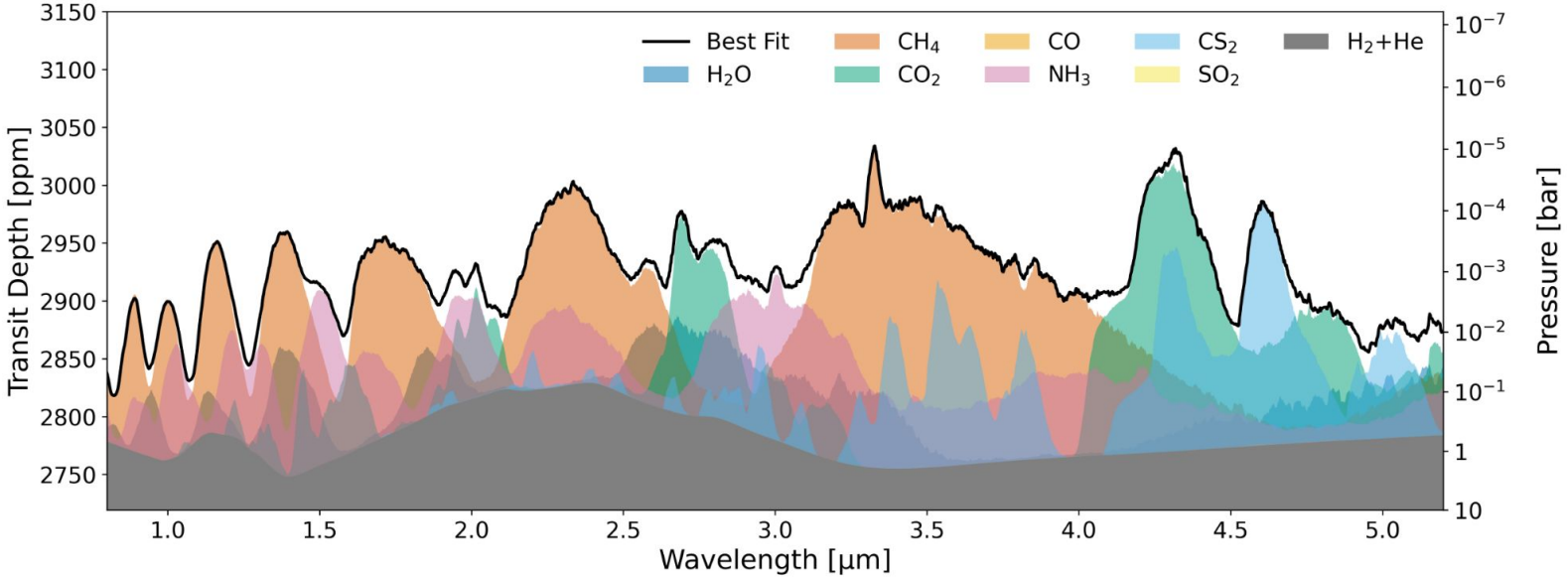




Drant+2026 (in prep)

Limitations in exoplanet observations and modeling

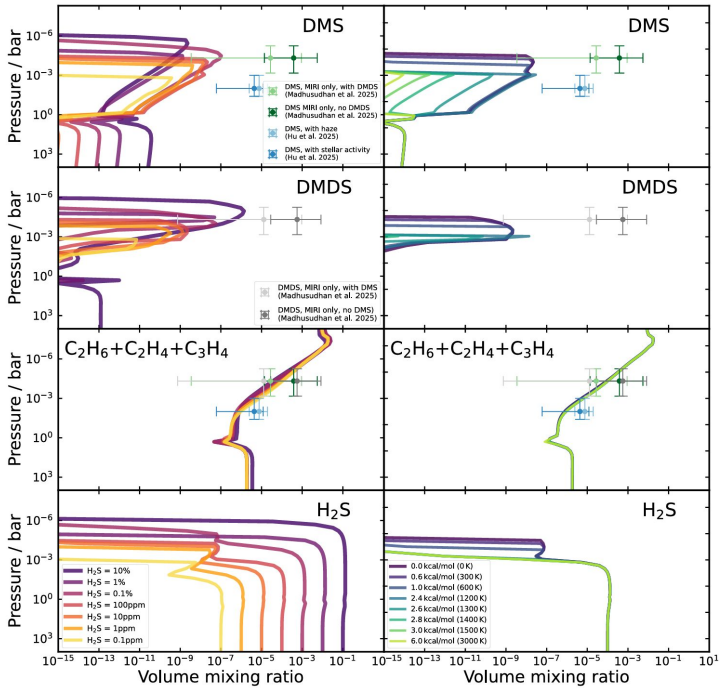
CS_2 detection for TOI-270 d : photochemical pathways coming from H_2S with kinetics controlled by one reaction

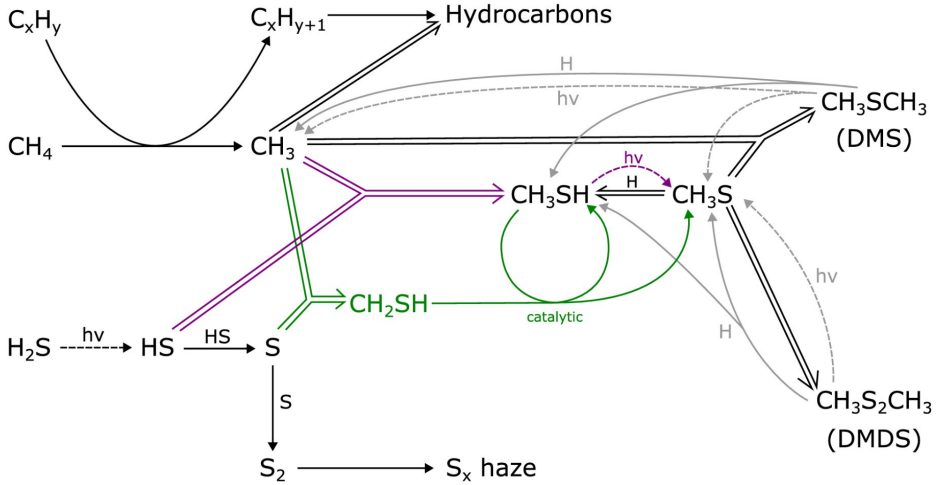


Felix+2025

Limitations in exoplanet observations and modeling

Organo-sulfur chemistry (K2-18 b) is limited by missing kinetics data





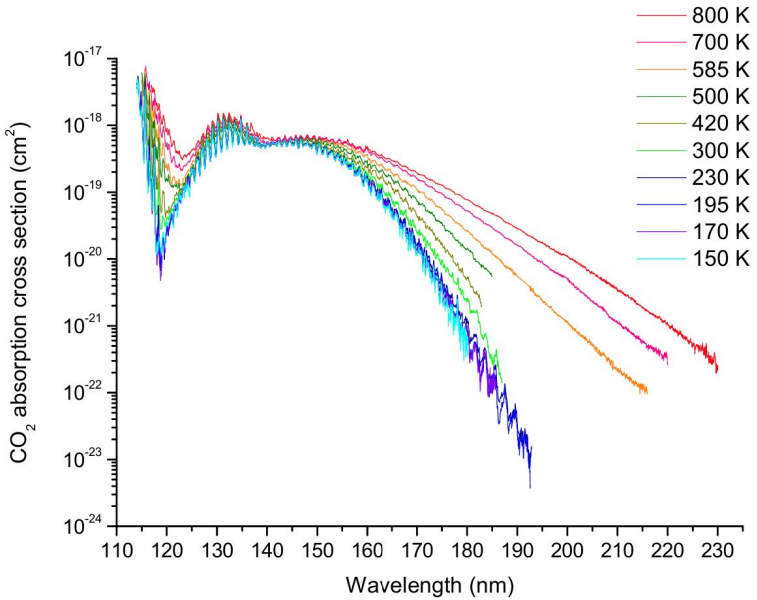
Termolecular

(R21) $CH_3S + CH_3 + M \rightleftharpoons CH_3SCH_3 + M$	3.05×10^{-26}	0.0	0.0	Est. here
	1.00×10^{-10}	0.0	0.0	Est. here
(R22) $CH_3S + CH_3S + M \rightleftharpoons CH_3S_2CH_3 + M$	3.05×10^{-26}	0.0	0.0	Est. here
	1.00×10^{-10}	0.0	0.0	Est. here
(R23) $CH_3S + H + M \rightleftharpoons CH_3SH + M$	1.36×10^{-10}	−3.79	3.86×10^{2}	Est. by R. Hu et al. (2025)[b]
	1.93×10^{-8}	−0.31	4.71×10^{2}	Est. by R. Hu et al. (2025)[b]
(R24) $CH_3 + S + M \rightarrow CH_2SH + M$	2.98×10^{-9}	−4.62	9.15×10^{2}	Est. by R. Hu et al. (2025)[b]
	1.02×10^{-9}	7.10×10^{-2}	6.49×10^{1}	Est. by R. Hu et al. (2025)[b]

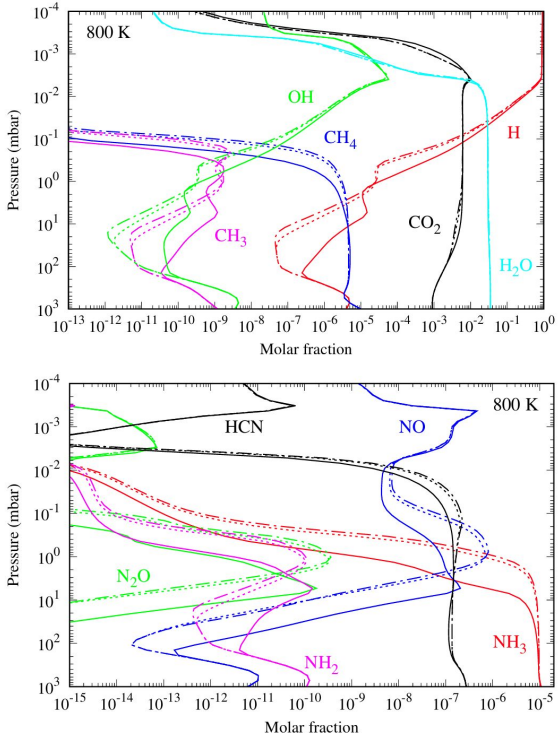
Jordan+2026

Limitations in exoplanet observations and modeling

For some species, such as CO_2, temperature can cause significant changes in photo-dissociation efficiency

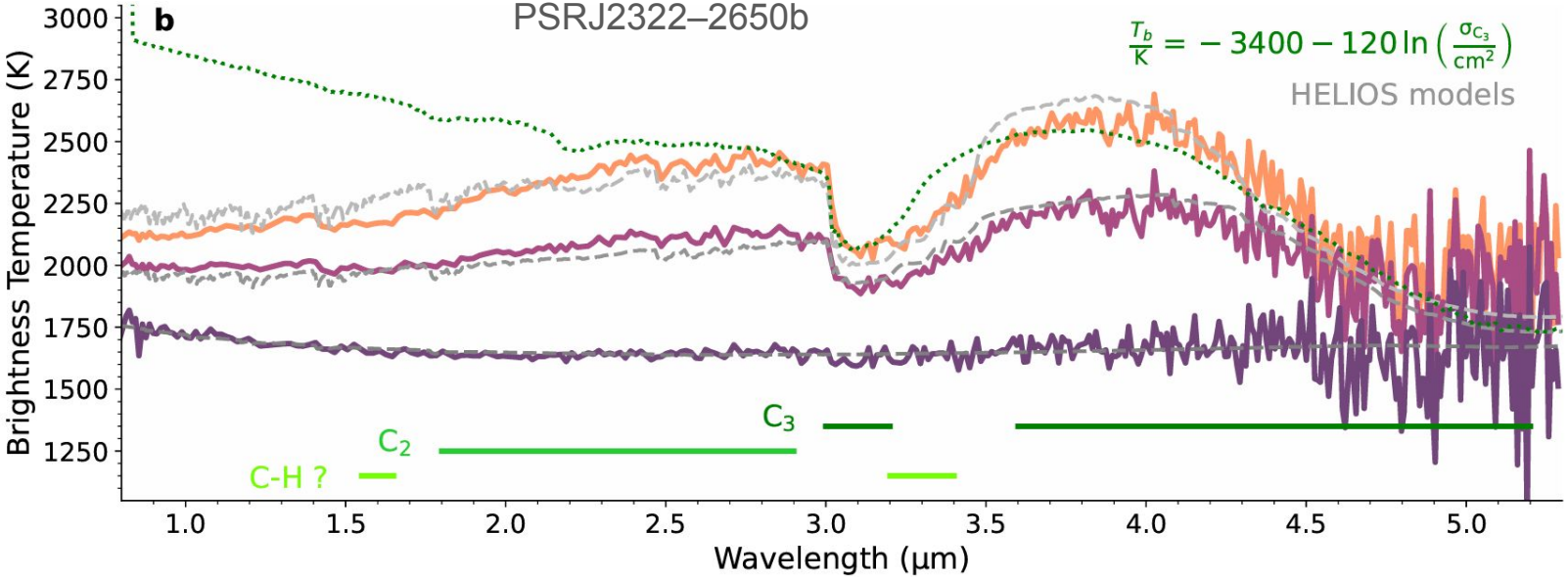


Venot+2018



Limitations in exoplanet observations and modeling

Really unexpected chemistry for this pulsar planet pushed the re-assessment of completeness of the opacity databases



Zhang+2025

Summary

- miscibility of Fe-Si-H-S in these high pressures
- solubility of volatiles in melts in H_2-rich systems

- H_2-CH_4 CIAs
- haze optical constants

- temperature-dependent photo-dissociation
- kinetics data of reactions (sulfur)

- opacities of unexpected species (C2, C3 etc)
- haze optical constants