HCN VUV Absorption cross section at high temperature for warm exoplanets

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Exosystemes V – IAP Paris

Context

<u>Consequences:</u>

Atmospheric conditions → 

+ 

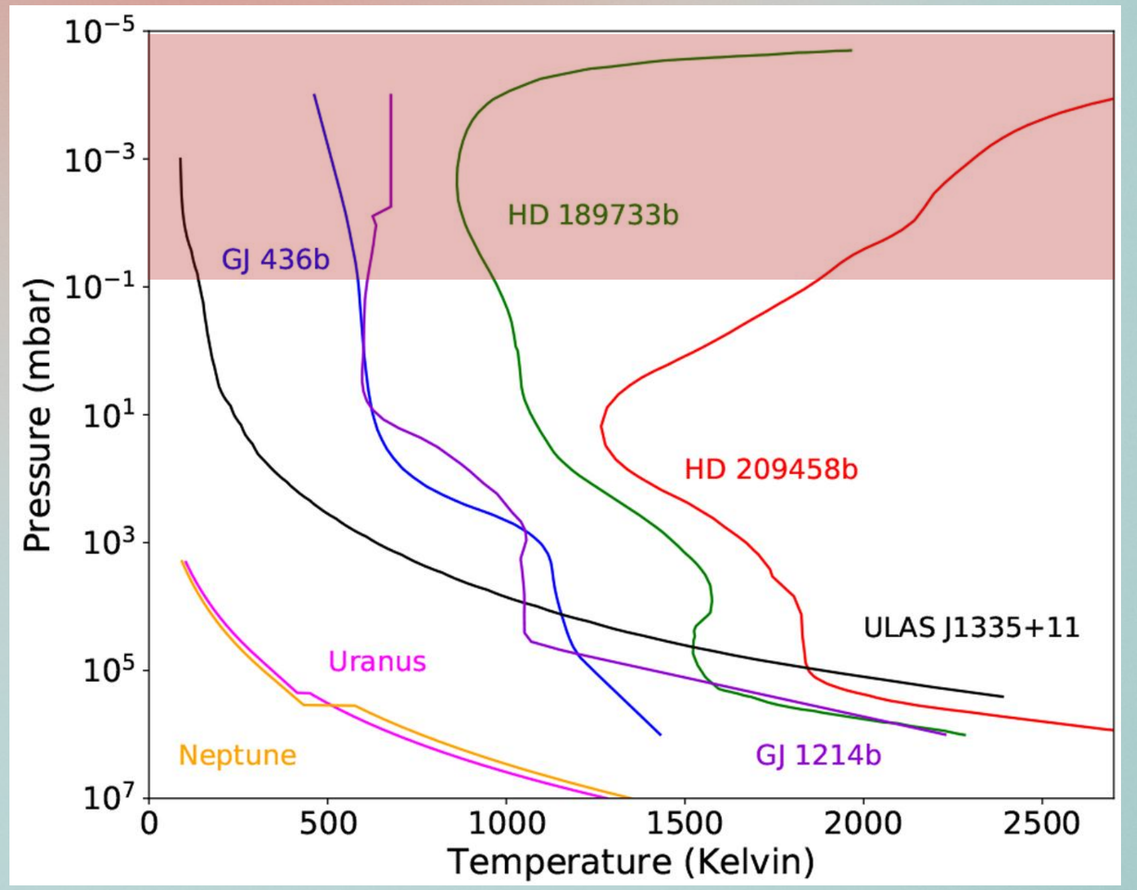
↳ Important photochemistry processes at high temperature

→ To interpret observations made by telescope we use atmospheric model to simulate the photochemistry

BUT…

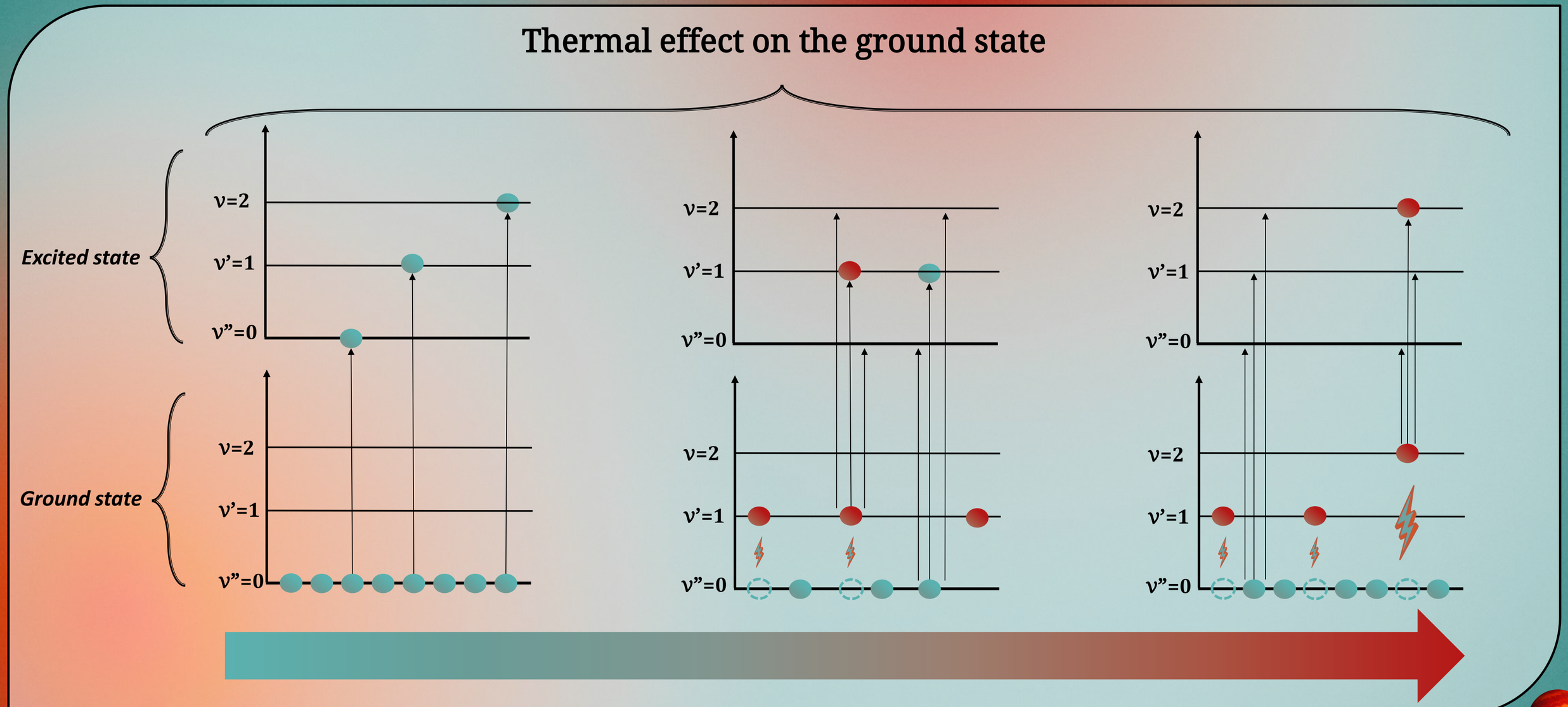
Absorption cross section ⟷ 

AND WE LACK DATA AT HIGH TEMPERATURE !



Venot et al 2019

Temperature and population love relation



Methodology

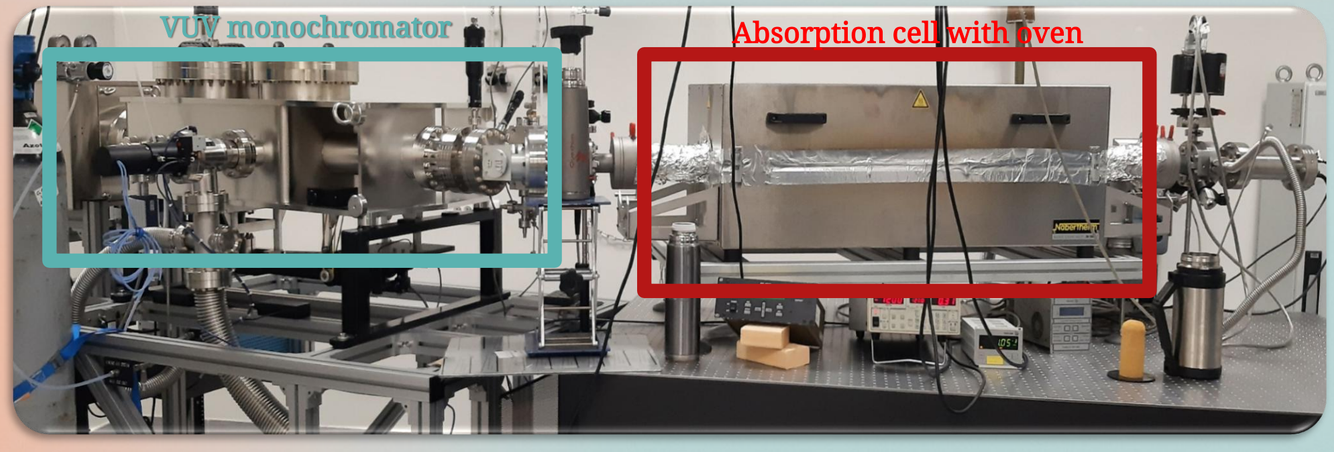
VUV spectroscopic platform

⟶ Measurement of around 10 to 15 nm
⟶ Each measure with 6 to 9 differents pressures
⟶ High temperature each pressure x3

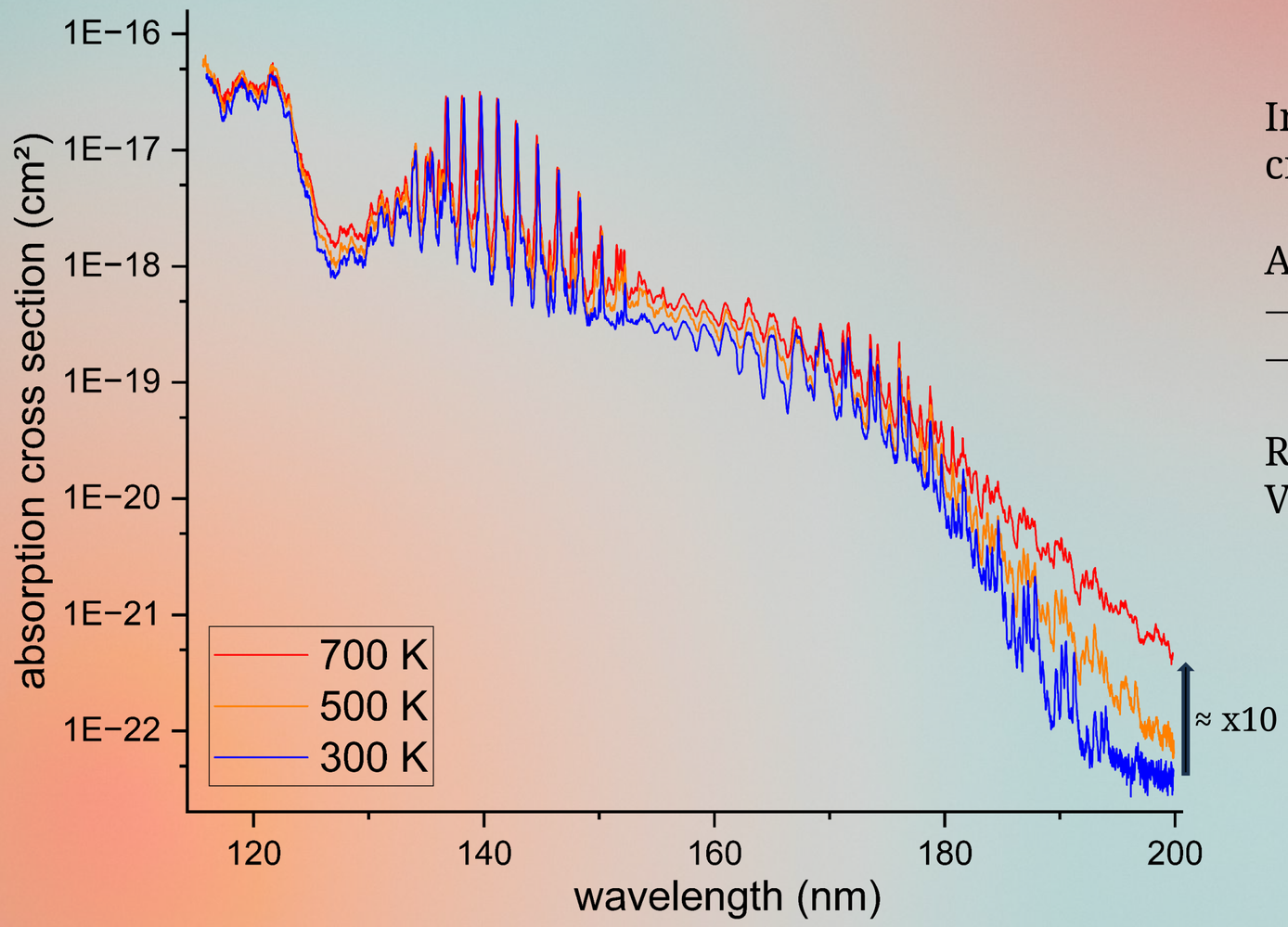
Wavelenght	115 - 200 nm
Temperature	[300 - 700] K
Light source	D_2 lamp
Gas pressure	[5.10^{-3} - 400] mbar

Beer-Lambert law: $\sigma(\lambda, T) = \left(\frac{1}{nL}\right) \times \ln\left(\frac{I_0}{I}\right)$

$\sigma(\lambda, T)$ is the absorption cross section (cm^2) at a given wavelength λ and temperature T, L is the optical pathlength (cm), n the volume density of the gas in the cell (cm^{-3}).



Results: HCN absorption cross section



Impact of the temperature on the absorption cross section of HCN

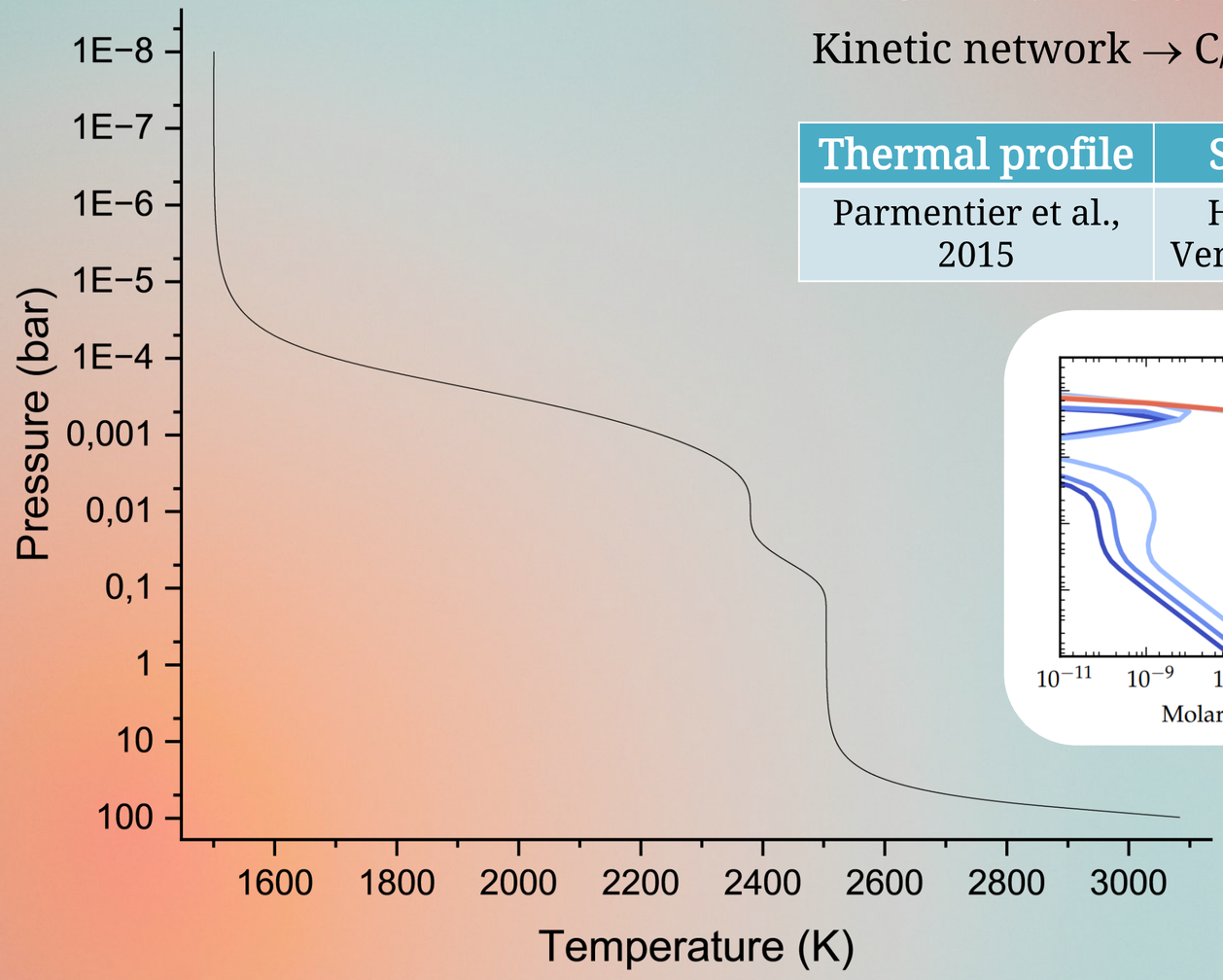
As temperature increases:
→ Absorption cross section increases
→ Factor of 10 between 300 K and 700 K

Result consistent with other molecules (CO_2, Venot et al. 2018; C_2H_2, Fleury et al. 2025)

Collado et al. In prep

Experiment is nice, but it there an impact on atmosphere chemistry?

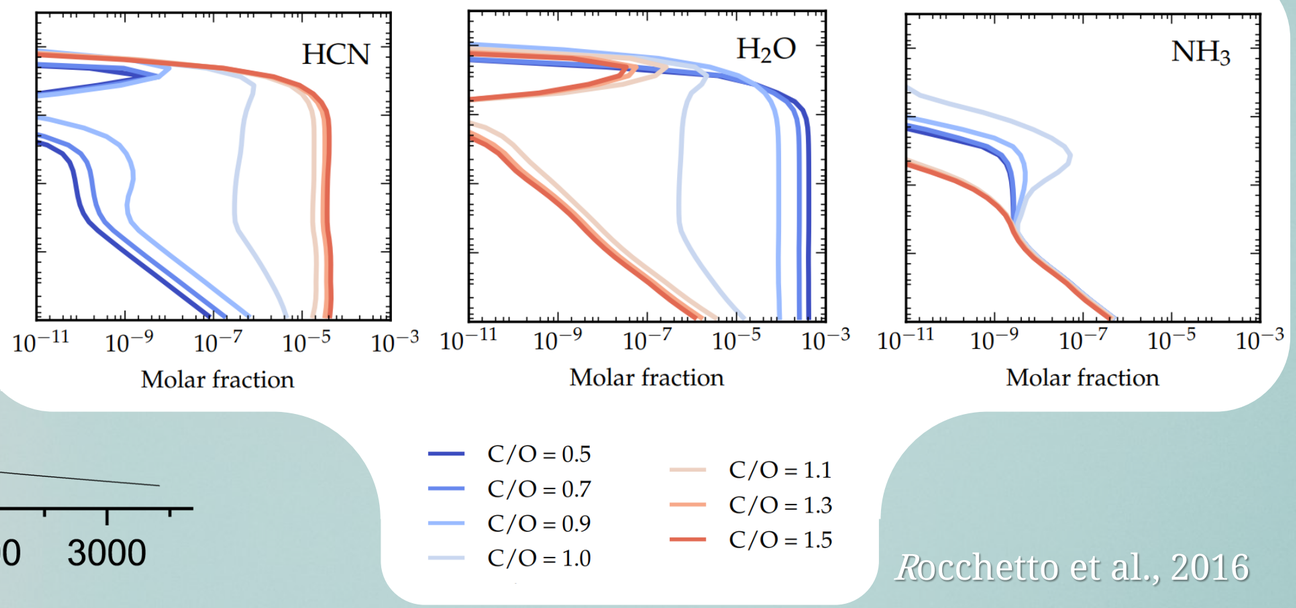
Modelling – Inputs parameters



FRECKLL → 1D thermo-photochemical model (Al-Refaie et al., 2024)

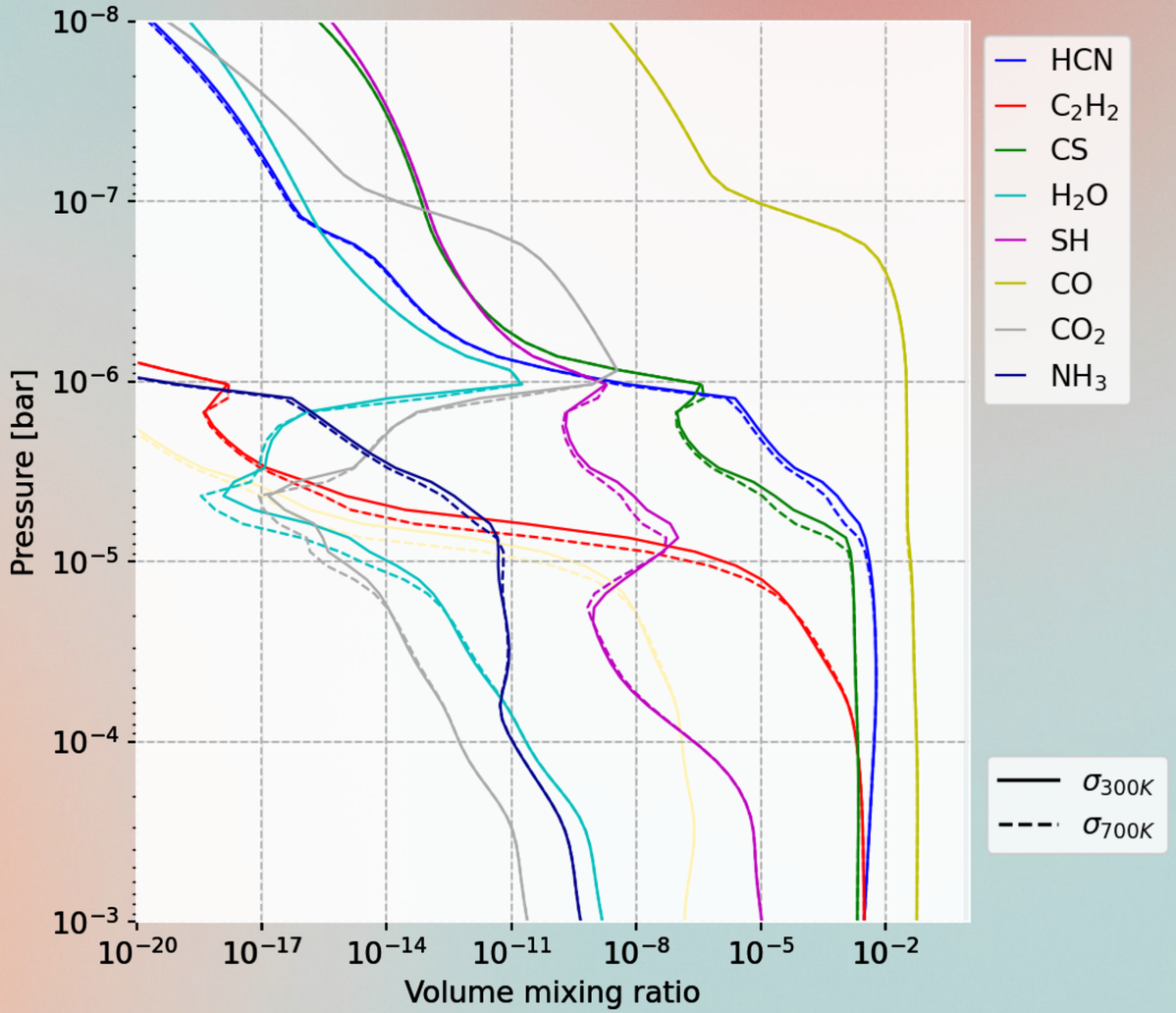
Kinetic network → C/H/O/N/S (Veillet et al., 2026)

Thermal profile	Stellar flux	$M_{\odot}$	K_{zz} ($cm^2.s^{-1}$)	C/O	Planet type
Parmentier et al., 2015	HD128167 (F) Venot et al. (2013)	100	10^9	1	Hot Neptune



*R*occhetto et al., 2016

Modelling – Vertical abundance



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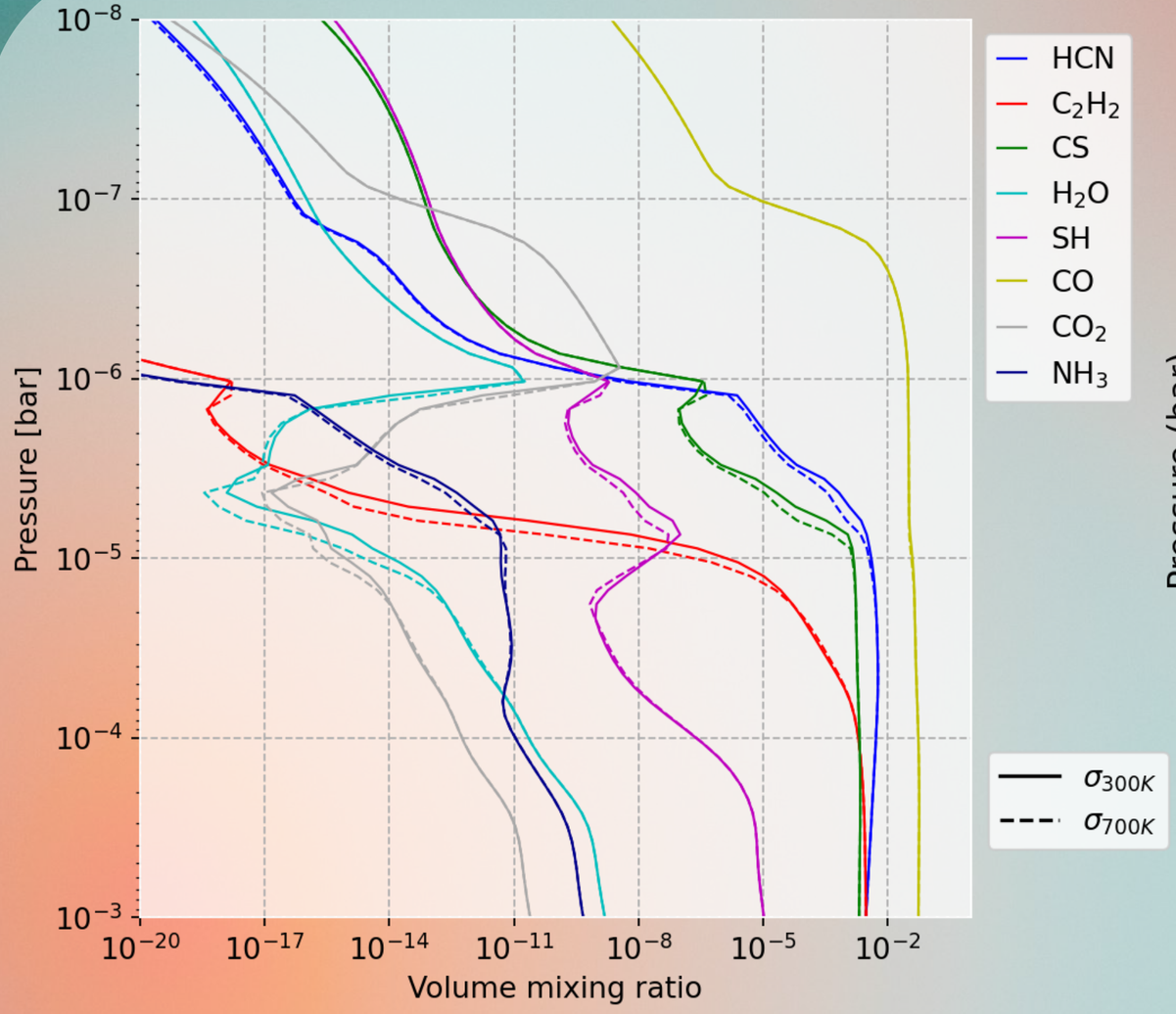
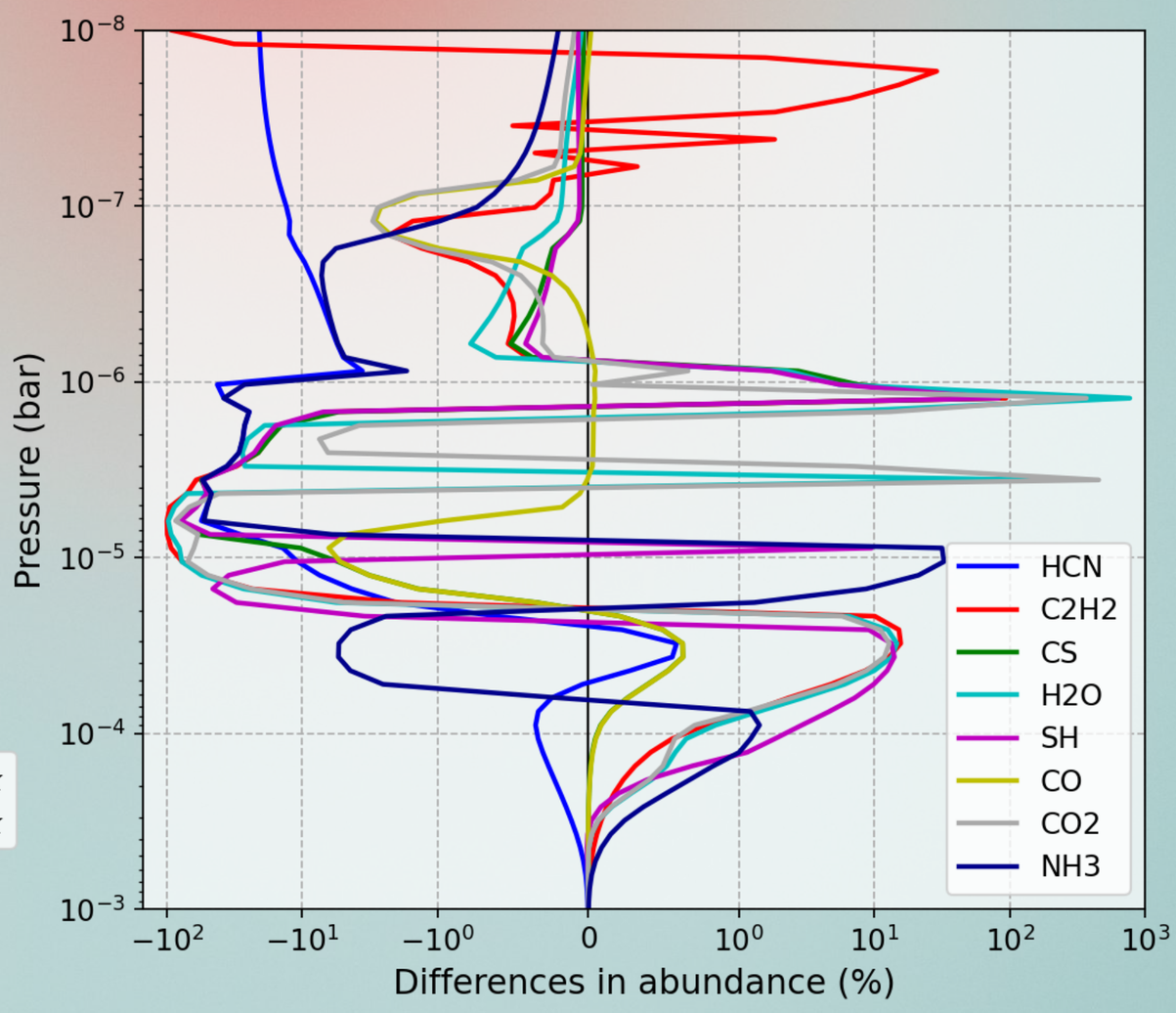
Modelling – Vertical abundance





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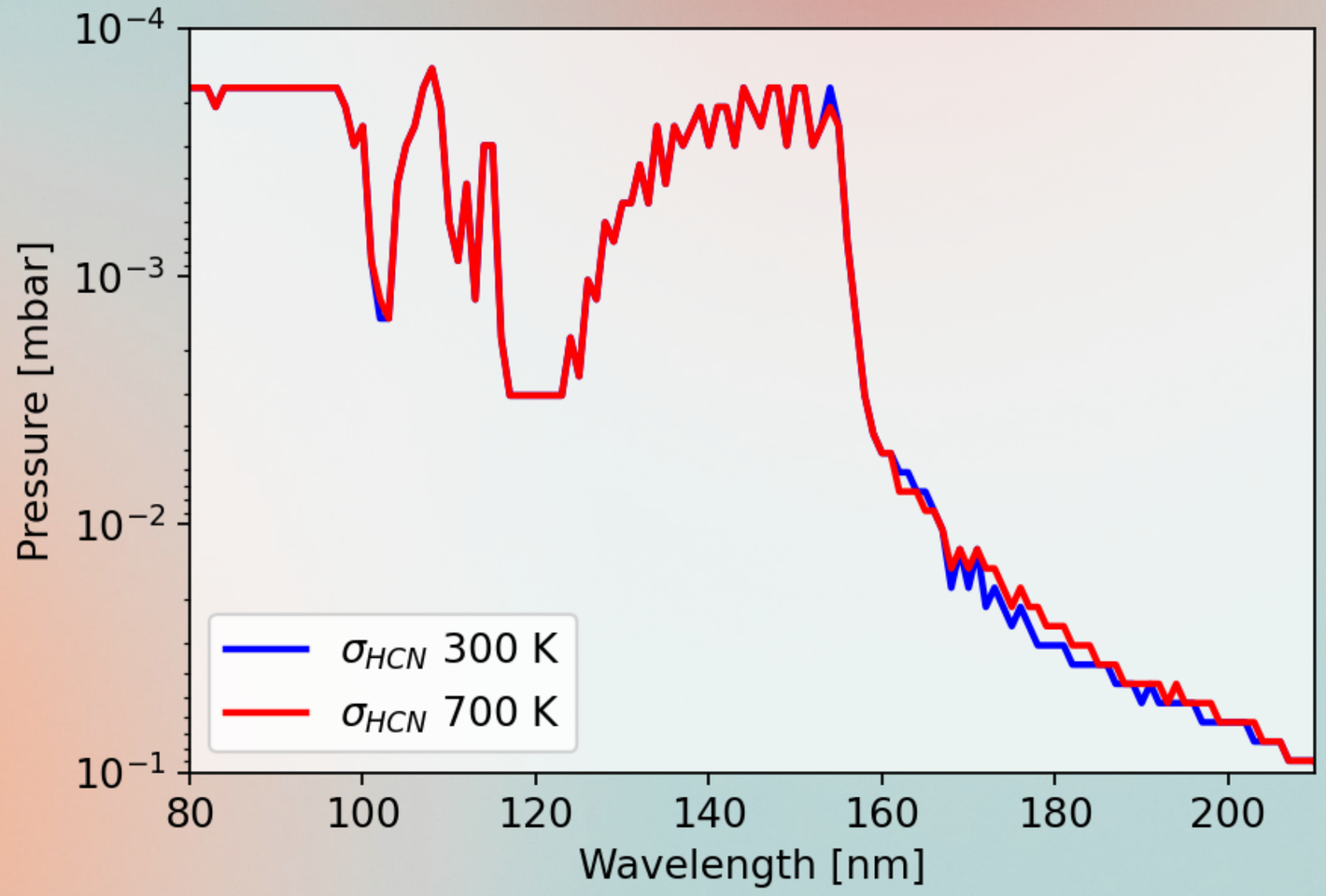
Modelling – Opacity

Contribution of molecules to the opacity of the atmosphere (level τ=1)



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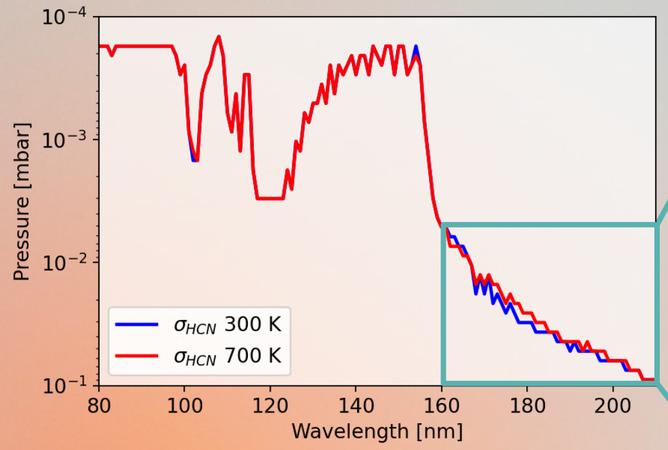

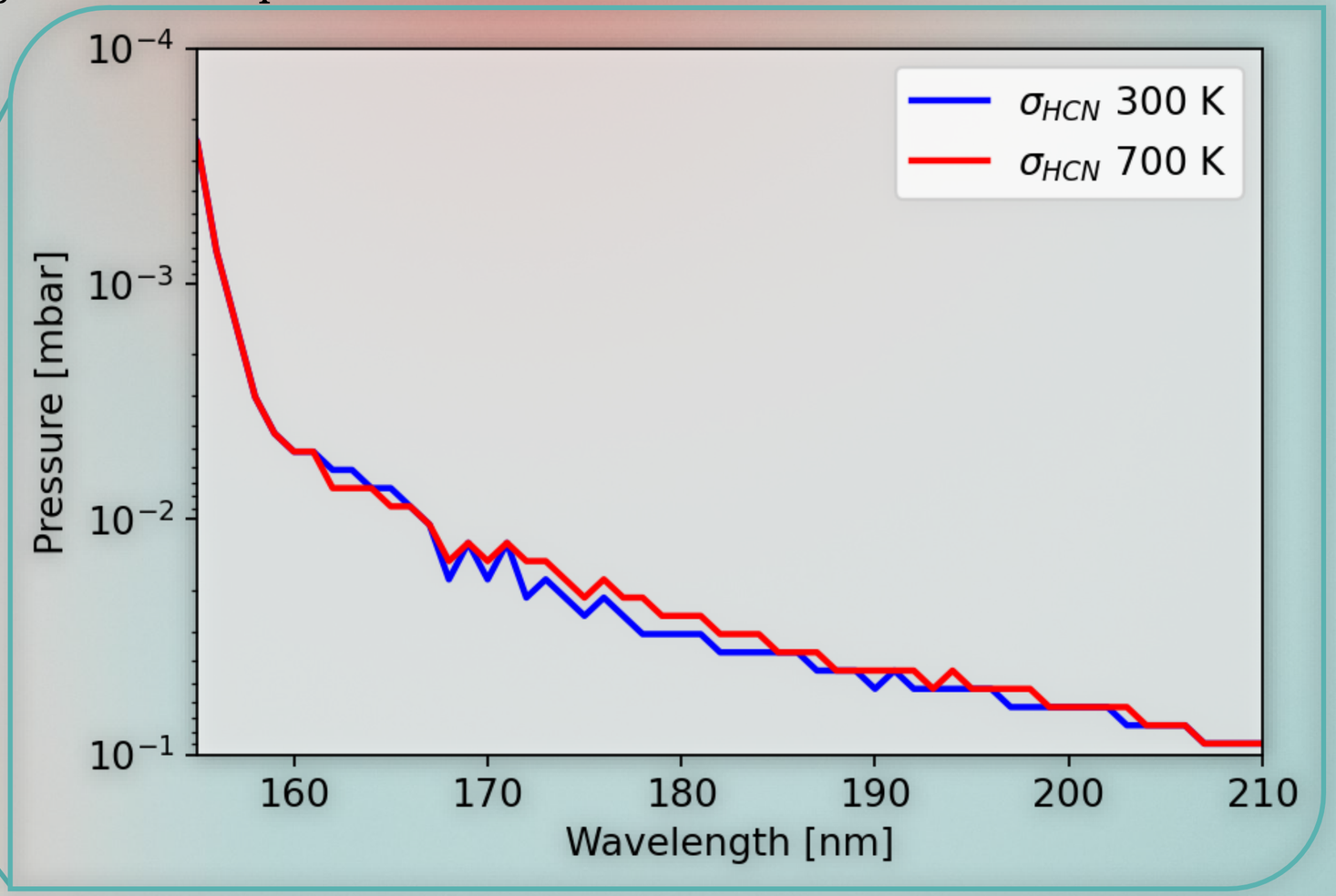

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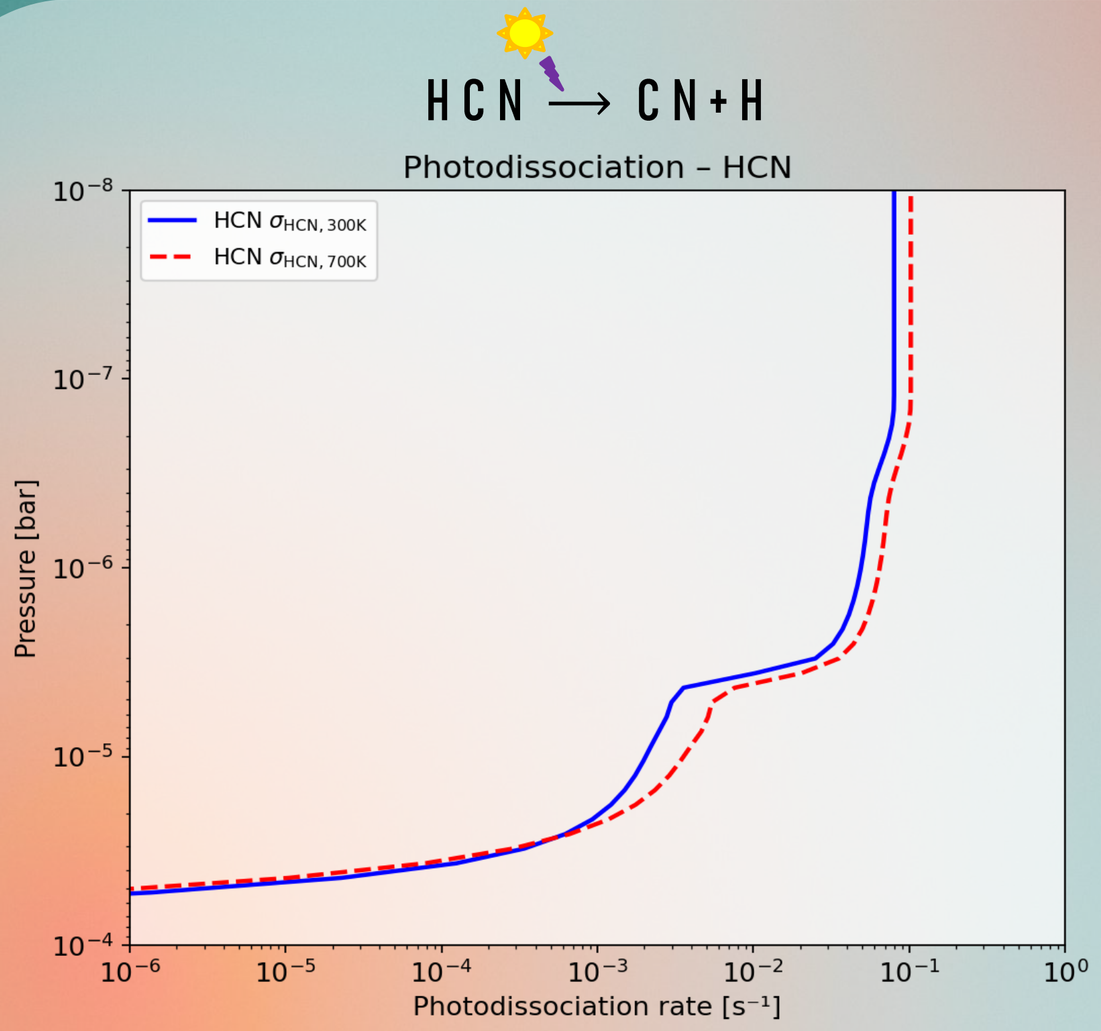

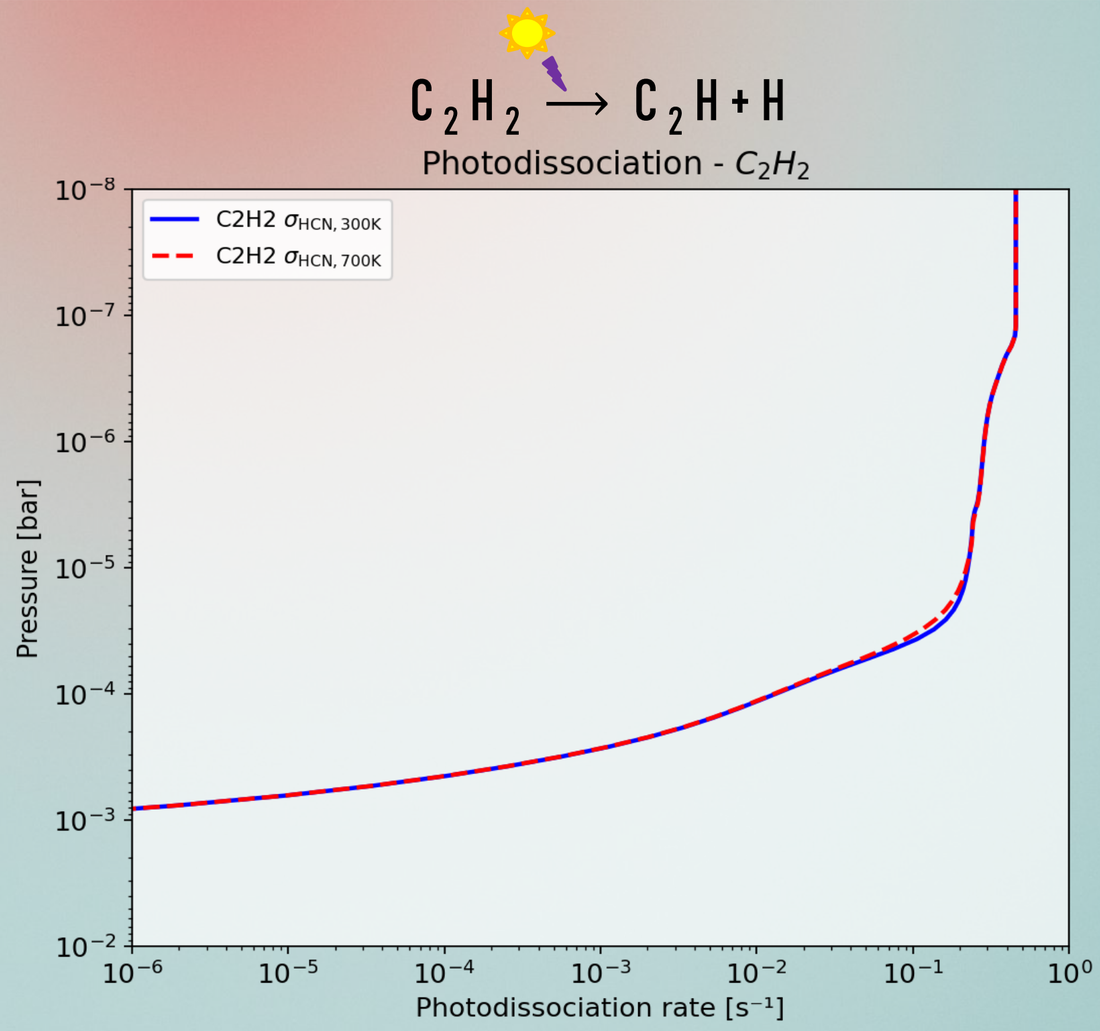

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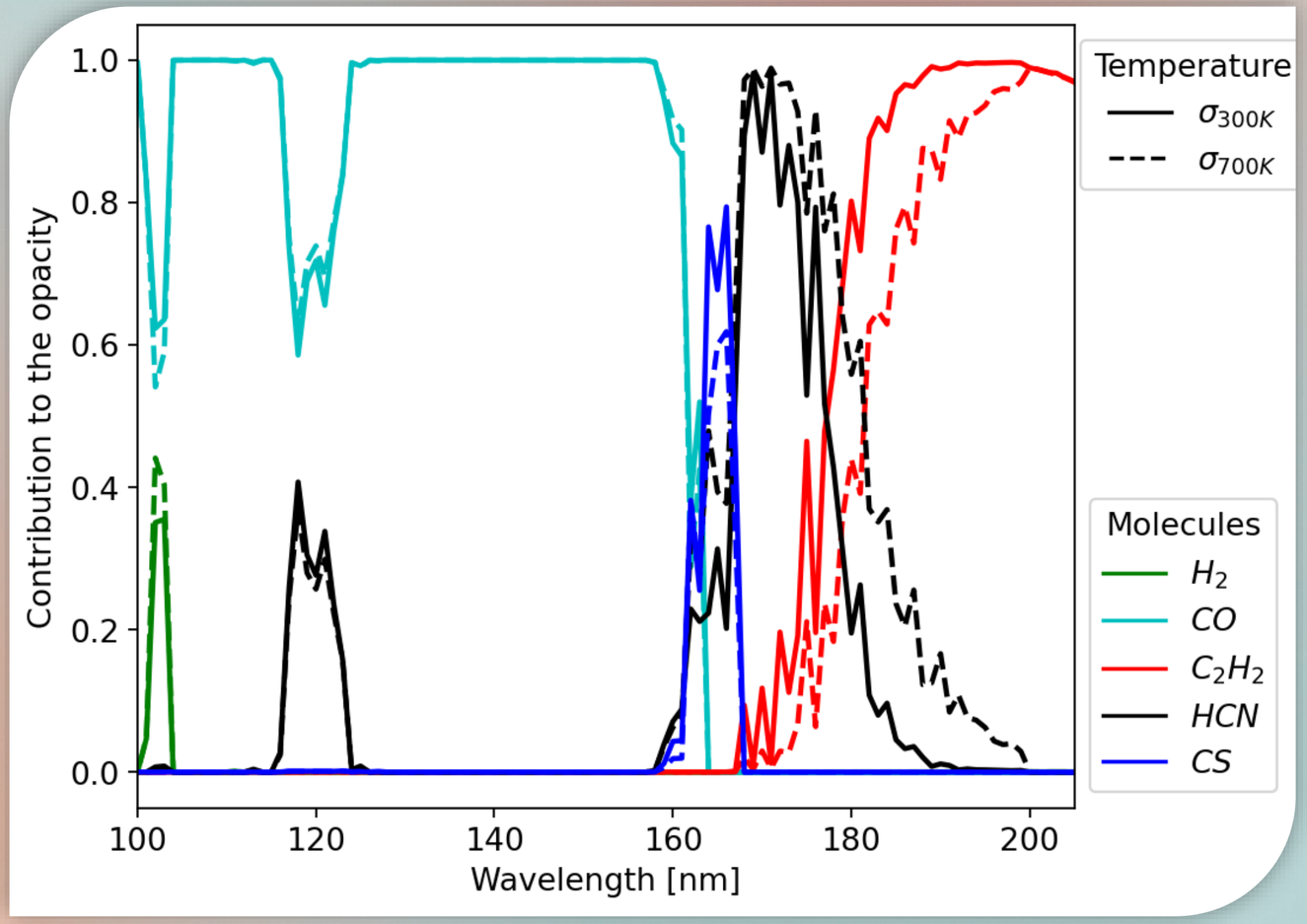

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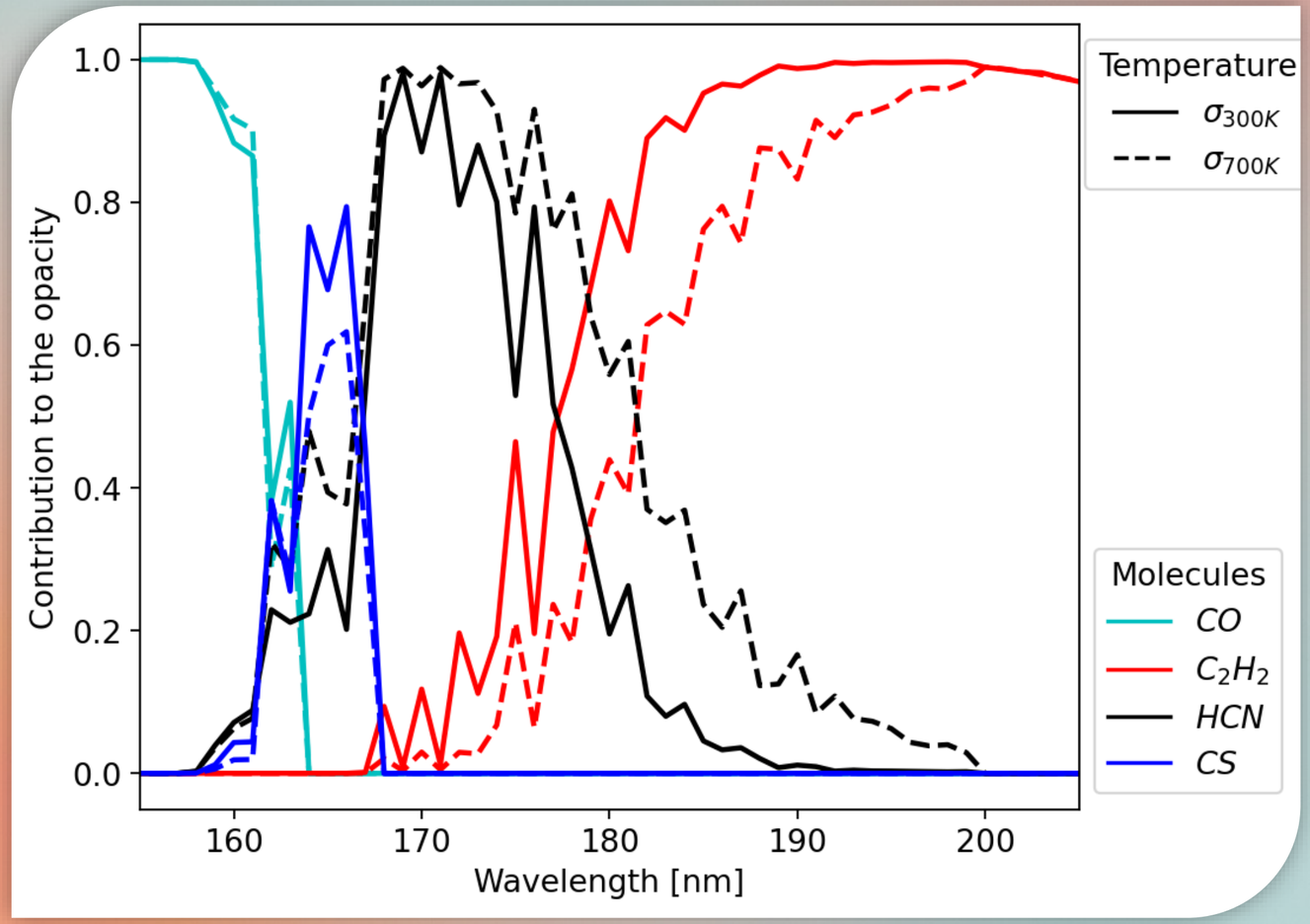

HCN shielding effect on C_2H_2 and CS

Energy budget from stellar flux change

Impact on radiative transfer and photochemistry

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Conclusion and takeaway

- Photochemistry important for exoplanet modelling
- Quantification of the cross section thermal dependence
- Absorption cross section increases by up a **x10 factor at 200 nm**
- Leading to significant variation in atmospheric chemistry composition and radiative transfer
- Hot exoplanet Atmospheric modelling is very sensitive to UV absorption cross section

So what is needed?

- Expand the measurements to other molecules, in particulary sulfur molecules (**SO_2, H_2S, CH_3SH**)
- Quantum yield dissociation
- Kinetic network : Study how the cross section change pathways reaction

Thanks for your attention!

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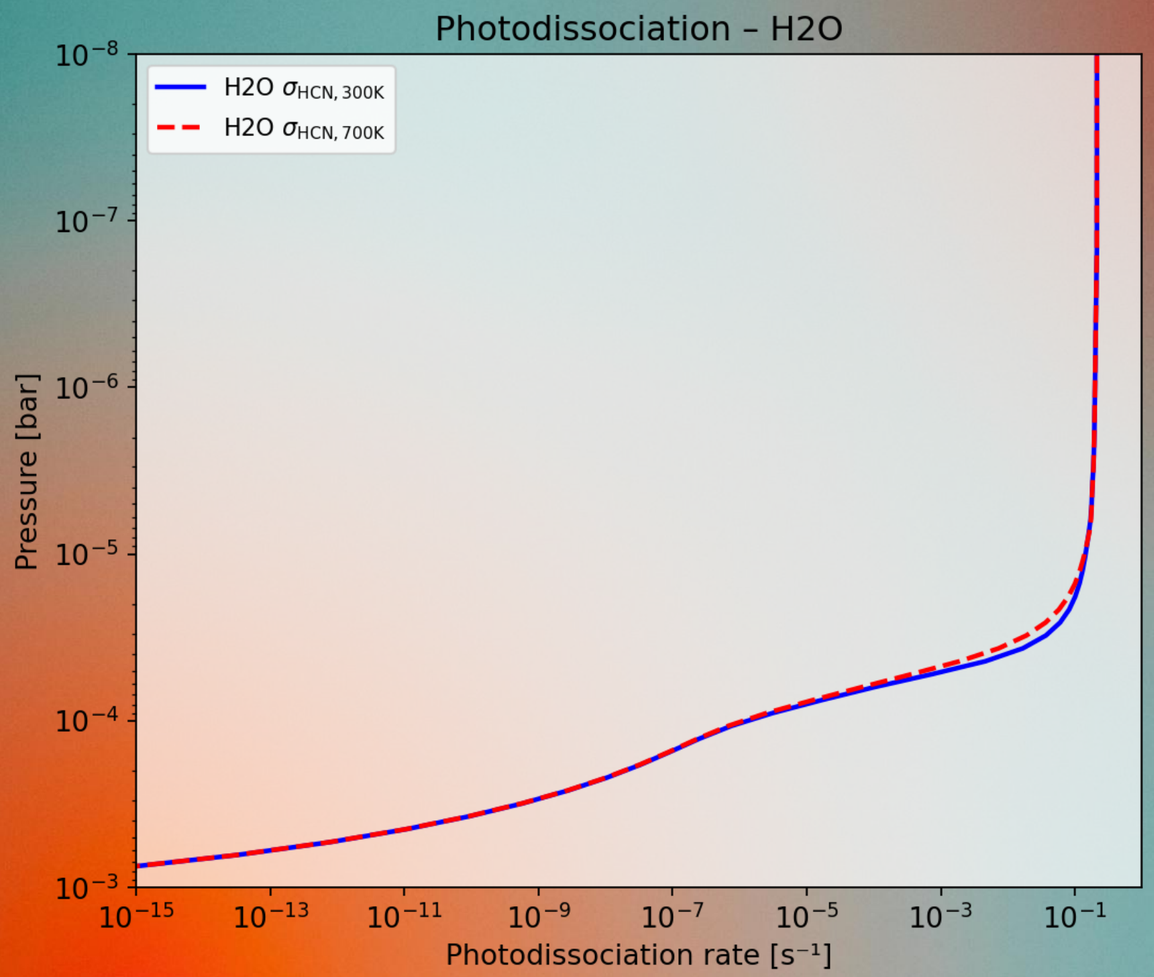
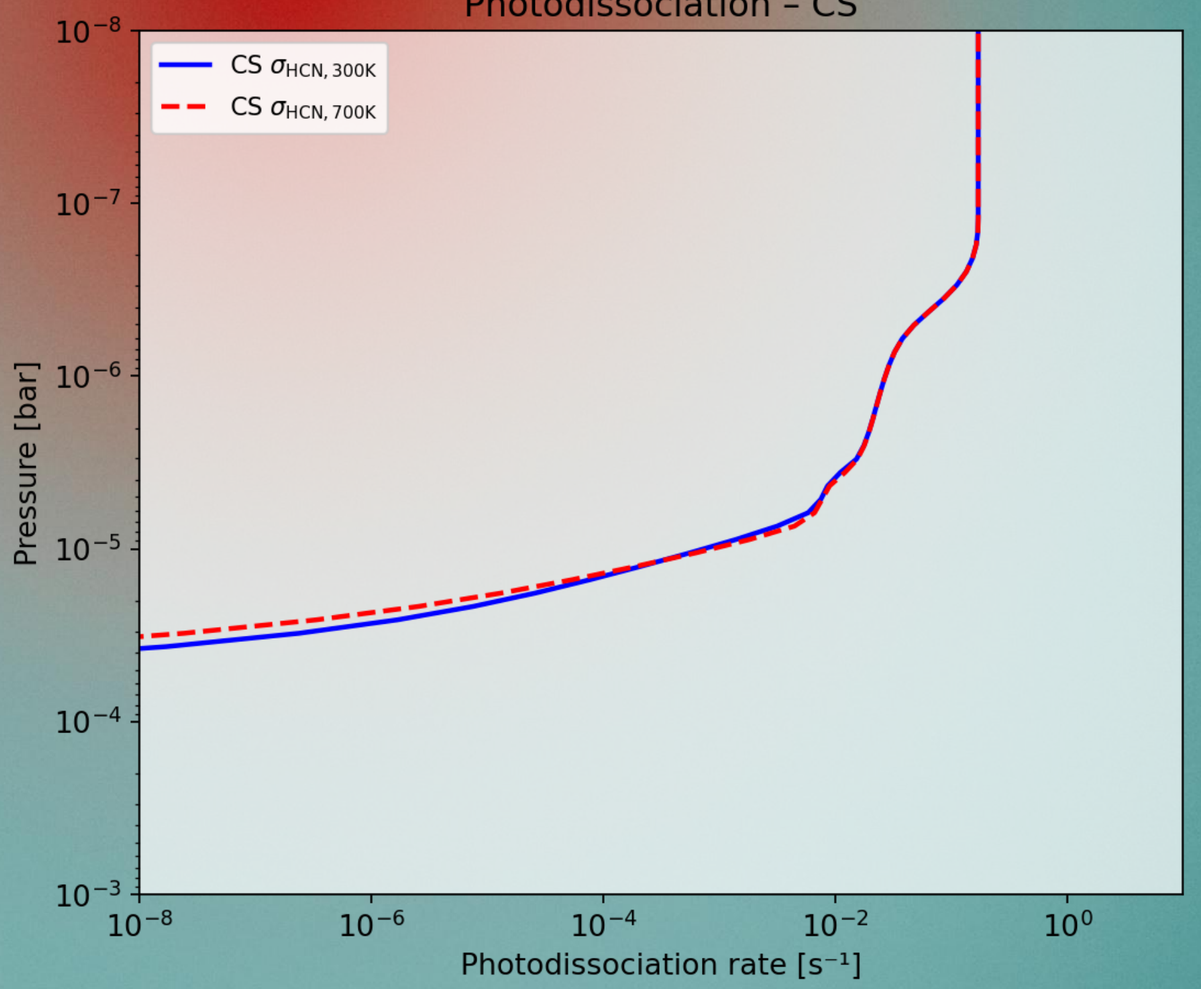
Appendix


Photodissociation – H2O
H2O $\sigma_{HCN,\,300K}$
H2O $\sigma_{HCN,\,700K}$
Pressure [bar]
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-15}
10^{-13}
10^{-11}
10^{-9}
10^{-7}
10^{-5}
10^{-3}
10^{-1}
Photodissociation rate [s^{-1}]


Photodissociation – CS
CS $\sigma_{HCN,\,300K}$
CS $\sigma_{HCN,\,700K}$
Pressure [bar]
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
Photodissociation rate [s^{-1}]