



**Context** Wide diversity of exoplanet atmospheres has been observed. To characterize their chemical compositions, photochemical models are needed (Line+ 2011; Moses+ 2011; Tsai+ 2017; Venot+ 2020; Veillet+ 2026). Their reliability is limited by the lack of absorption cross sections at high temperatures. Among the molecules of interest, hydrogen cyanide (HCN) plays a key role as one of the simplest N-bearing species, observed in solar system giant planets. In this work, we provide new VUV absorption cross section measurements of HCN at high temperatures, aiming to improve photochemical models and reduce uncertainties in predicted molecular abundances.

# Improving exoplanet photochemical models with new high temperature VUV absorption data for HCN

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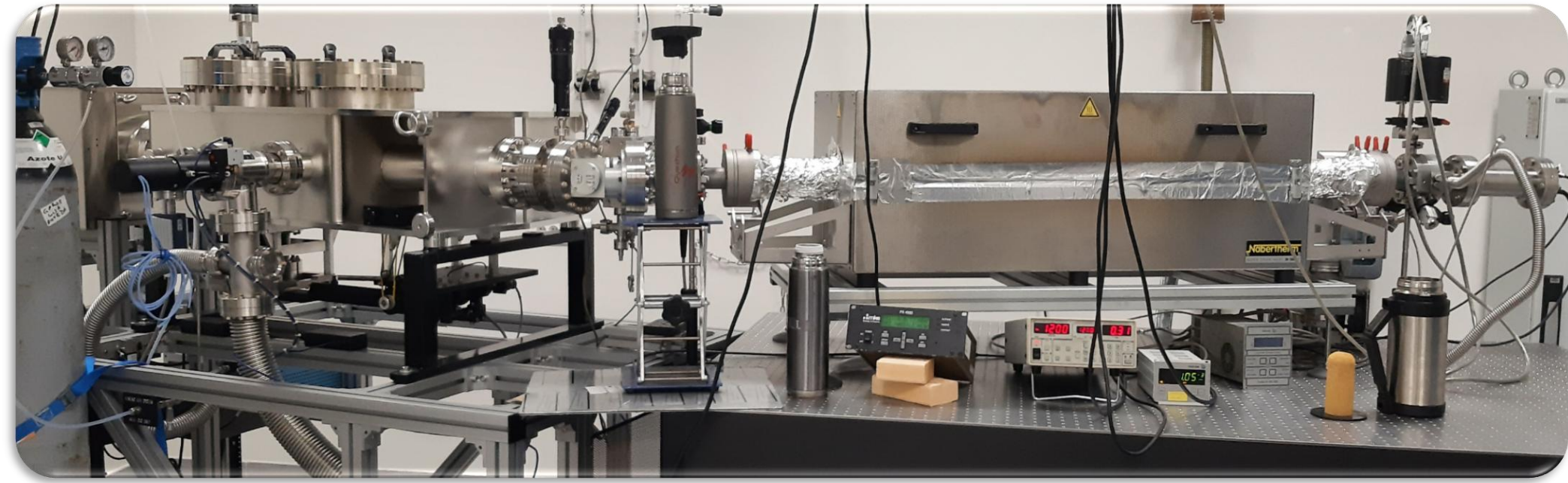
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## HCN measurements :

- $\lambda = [115 - 200]$  nm
- $T = [300 - 700]$  K
- 312 totals measurements

- Light source = D<sub>2</sub> lamp
- Gaz pressure =  $[5.10^{-3} - 400]$  mbar

## Experimental setup



## Thermo-photochemical model

### Modeling input:

We use the new dataset in the 1D thermo-photochemical model FRECKLL (Al-Refaie et al., 2024). Two identical simulations of a hot Neptune were performed, with a metallicity x100 solar and a C/O ratio of 1. All cross sections used (except HCN) are at the highest temperature available in the literature. The only difference between the simulations is the temperature of the HCN absorption cross sections: 298 K (solid line) and 700 K (dotted line).

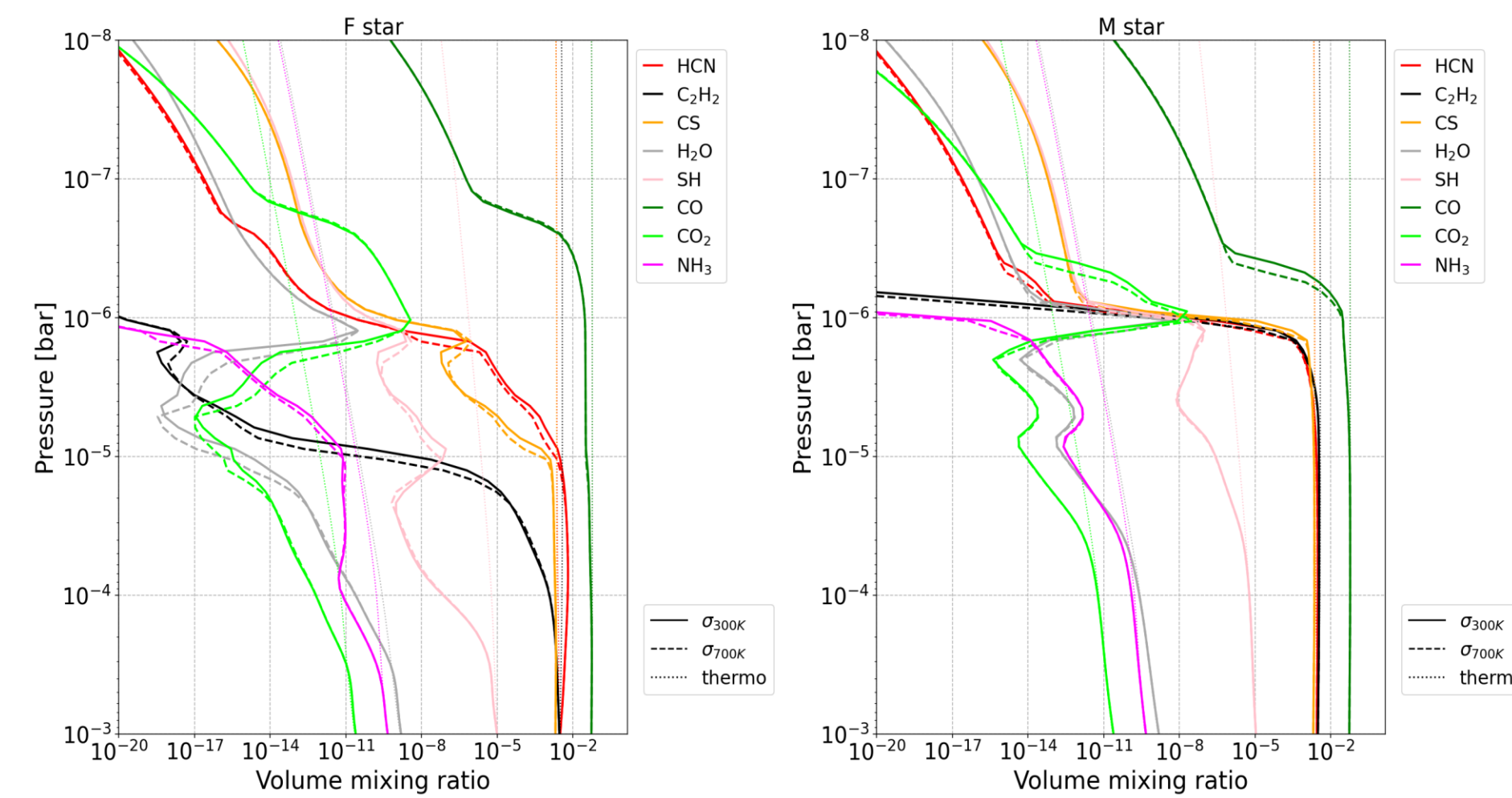


Fig. 3 – Vertical abundance of major species in an atmosphere around an F star (left panel) and M star (right panel). Solid line is the abundance using HCN  $\sigma_{300K}$  (blue) and dashed line when using  $\sigma_{700K}$  (red).

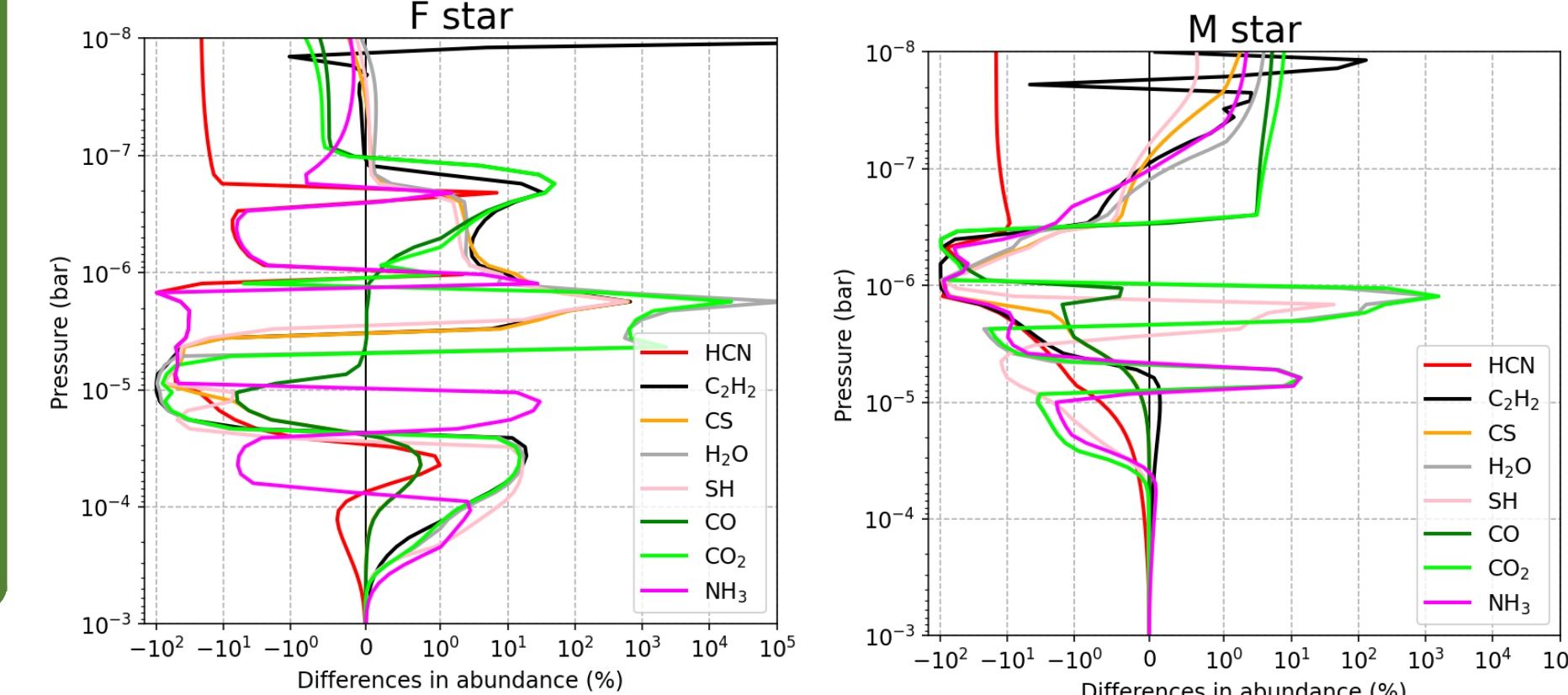


Fig. 4 – Relative abundance variation when using HCN  $\sigma_{300K}$  instead of HCN  $\sigma_{700K}$  in an atmosphere around an F star (left panel) and M star (right panel).

### Vertical abundances profiles F star :

Left panel Fig. 3 and 4 - Significant variations in the abundance of not only HCN, but also for other species is observed. HCN lower abundance, with some punctual increases, is caused by a higher photodissociation rate (see fig. 7). Other specie have variation exceeding that of HCN. H<sub>2</sub>O or CO<sub>2</sub> increase by a few thousand percent. HCN is not the molecule the more impacted by its absorption cross section thermal dependence.

### Vertical abundances profiles M star :

Right panel Fig. 3 and 4 - Similar to the F star result, other species are more impacted that HCN but with a less important increase. However, here HCN variation is strictly decreasing. Even around a cooler star (3 400 K), and so with less UV flux and photochemistry, HCN cross section thermal dependence still cause important variations in atmosphere composition.

### HCN photodissociation :

Fig. 7 - Using a higher cross section temperature induces faster photodissociation rate for HCN with both stars. At the top of the atmosphere, accounting for most of the photodissociation of HCN, increase by 30% around the F star and 20% around the M star.

### CO and H<sub>2</sub>O photodissociation – F star :

Fig. 8 - These molecules are interesting. They don't interact directly with HCN, like C<sub>2</sub>H<sub>2</sub> (with a 18 % decrease of its rate with  $\sigma_{HCN(700K)}$ , not shown). They still show variations (maximum variation of CO is -32 % and -64 % for H<sub>2</sub>O), indicating indirect paths leading to these variations. This enhance the importance of using high temperature cross section, since various means can impact physico-chemical process.

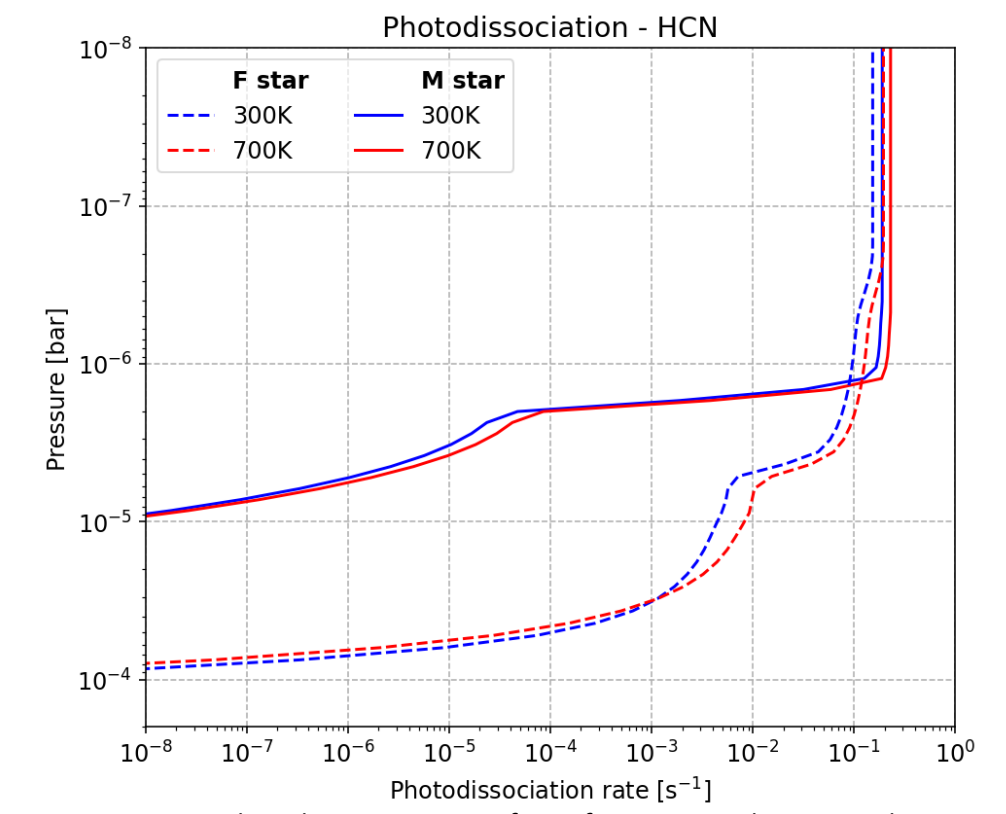


Fig. 7 - Photodissociation rate of HCN for an atmosphere around an F star and a M star

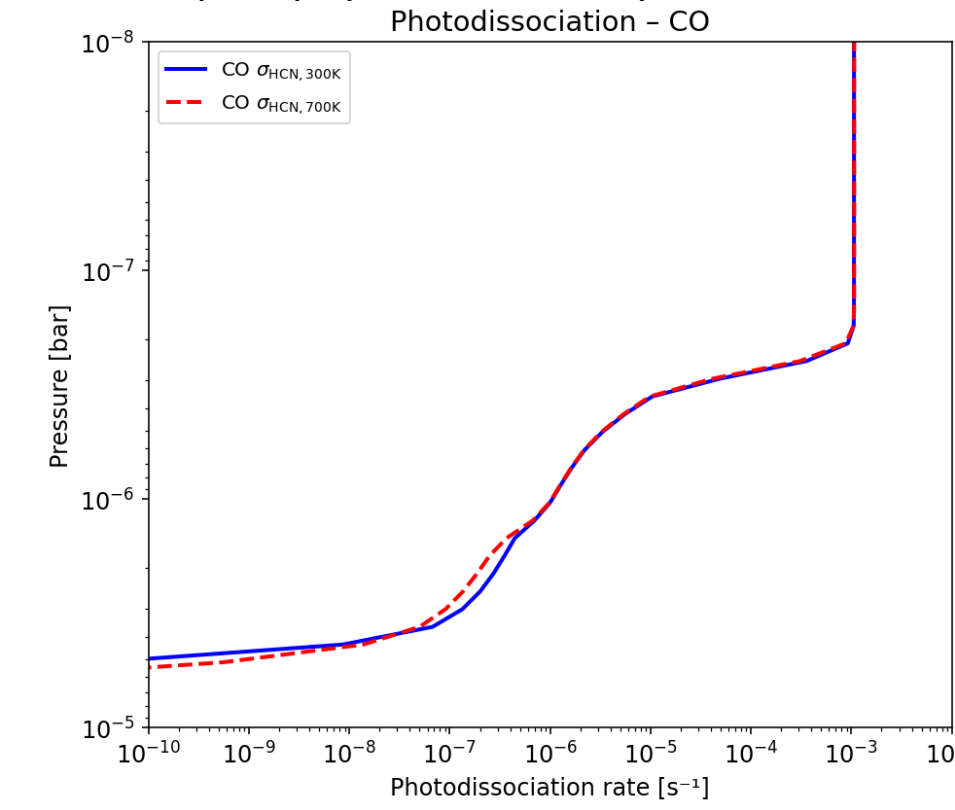


Fig. 8 - Photodissociation rate of CO and H<sub>2</sub>O for an atmosphere around an F star using HCN  $\sigma_{300K}$  (blue) and  $\sigma_{700K}$  (red).

### N<sub>2</sub> and CO photodissociation – M star :

Fig. 9 - In opposition with an F star, CO photodissociation rate increase with  $\sigma_{HCN(700K)}$  by an average of 150% and a maximum of 612%. N<sub>2</sub> increase even more, average of 296 % and a maximum of 1092 %. Thermal dependence has a greater impact on other molecules than an HCN itself.

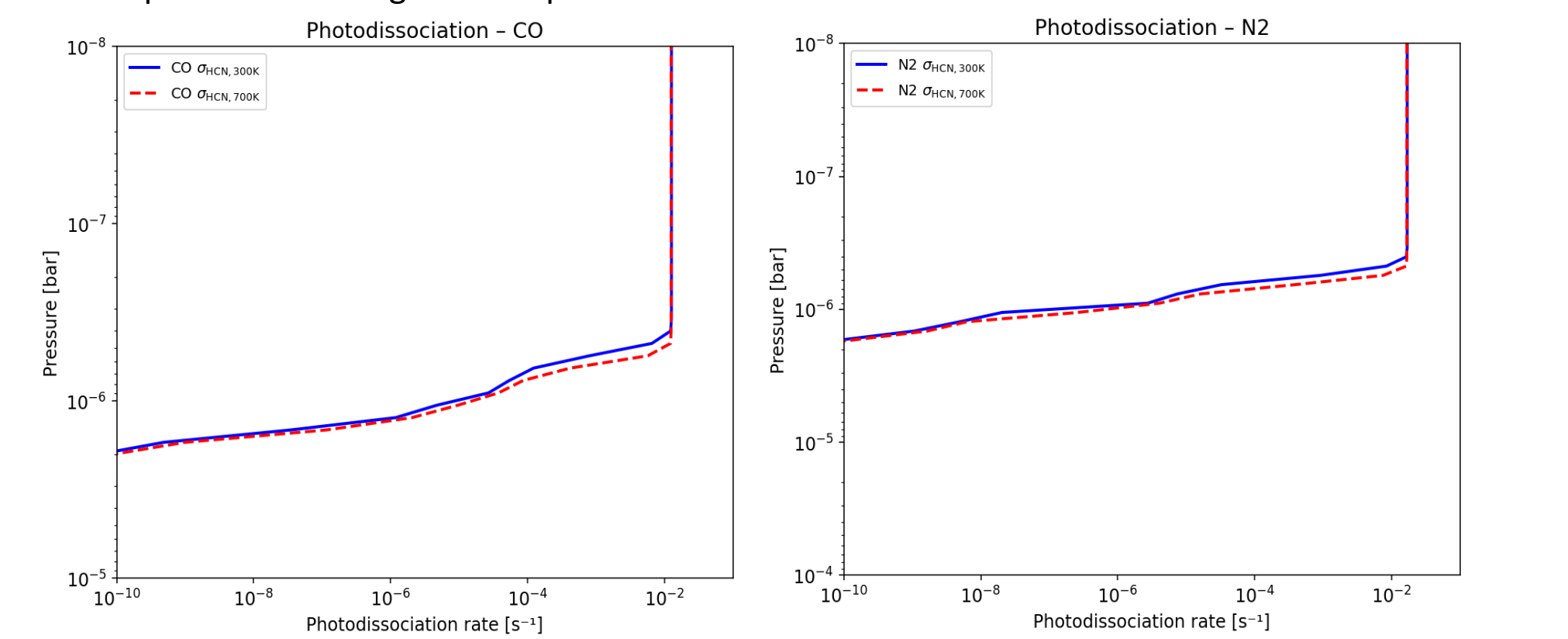


Fig. 9 - Photodissociation rate of CO and N<sub>2</sub> for an atmosphere around an M star using HCN  $\sigma_{300K}$  (blue) and  $\sigma_{700K}$  (red).

## Absorption cross section

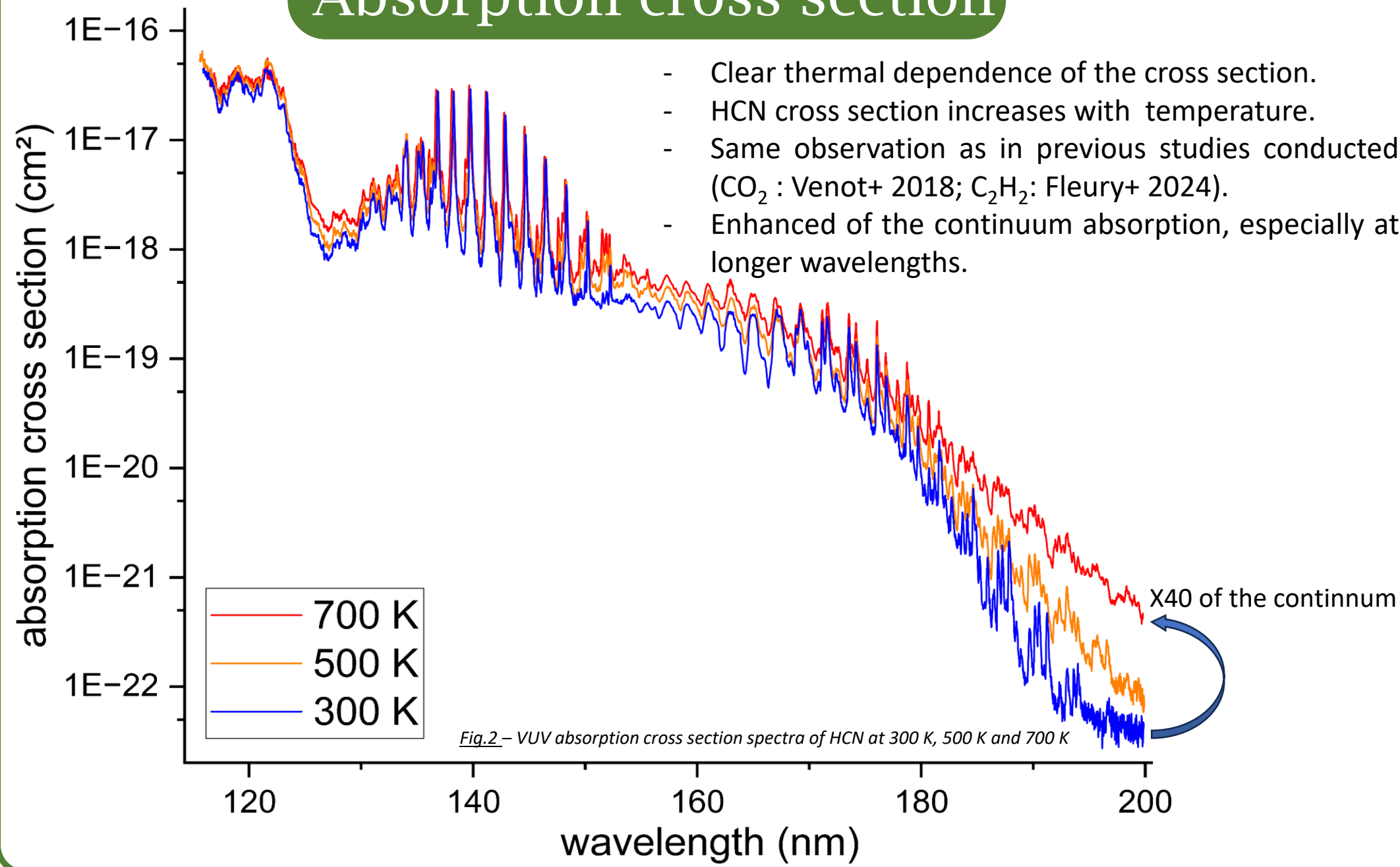


Fig. 2 – VUV absorption cross section spectra of HCN at 300 K, 500 K and 700 K

- Clear thermal dependence of the cross section.
- HCN cross section increases with temperature.
- Same observation as in previous studies conducted (CO<sub>2</sub> : Venot+ 2018; C<sub>2</sub>H<sub>2</sub>: Fleury+ 2024).
- Enhanced of the continuum absorption, especially at longer wavelengths.

### Opacity :

**F star :** HCN absorbs more of the stellar flux, the opacity at 180 nm of the atmosphere increases. HCN also creates a shielding effect on other molecules (CS and C<sub>2</sub>H<sub>2</sub>), causing variation in their absorption and photochemistry.

**M star :** HCN impact is localized to short wavelength with CO and N<sub>2</sub> been the more impacted. Contrary to the F star, the atmosphere is less opaque with  $\sigma_{HCN(700K)}$

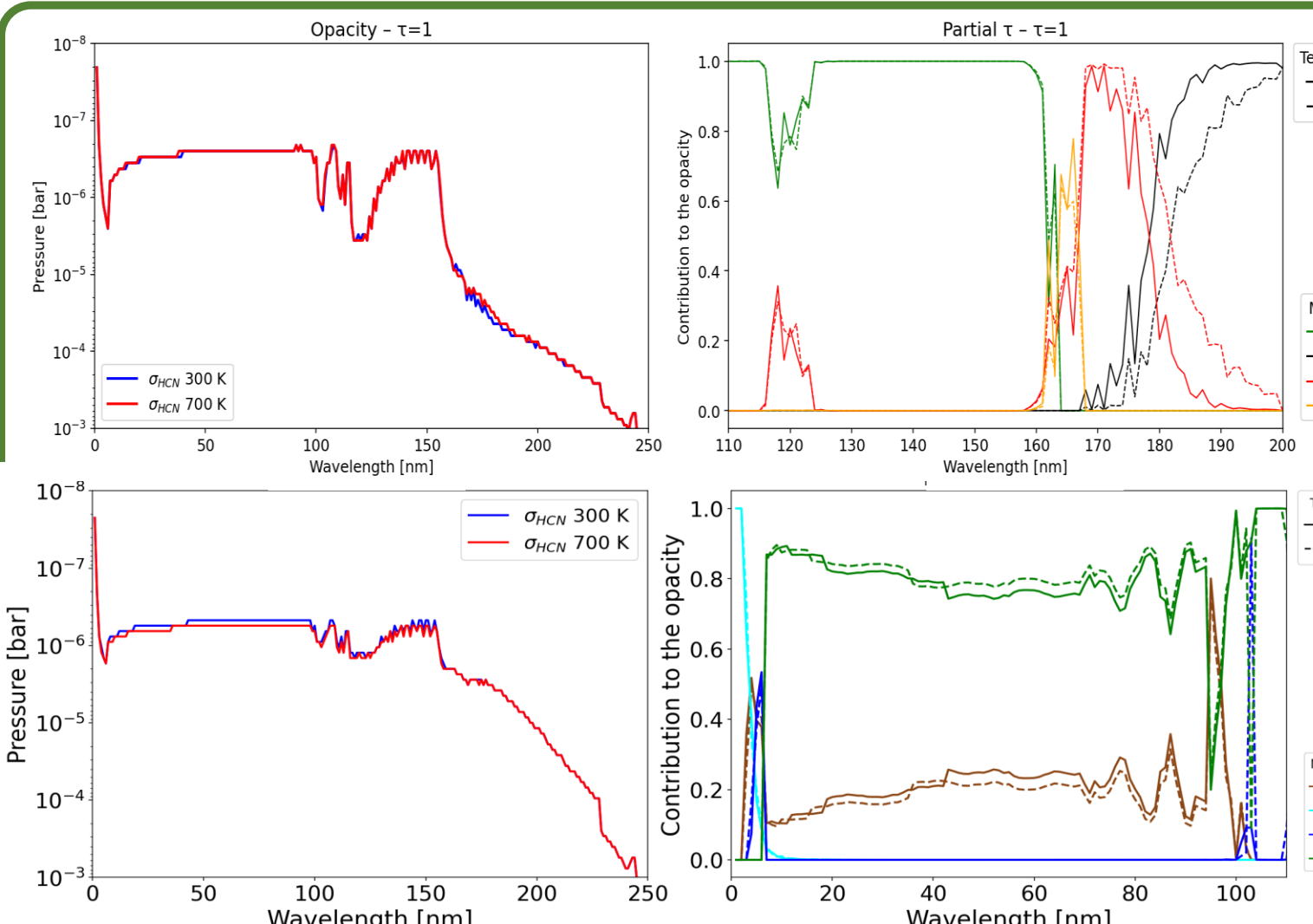


Fig. 5 – Left panels : Optical depth pressure where  $\tau=1$  with absorption cross section of HCN at 300K (blue) and 700nm (red). Right panels : contribution normalized of various species to the opacity of the atmosphere at  $\tau=1$

## References

Giacobbe et al., Nature, 592, 205–208 (2021)

MacDonald and Madhusudhan, ApJL, 850, L15 (2017)

Fleury et al., A&A, 693, A82 (2025)

Venot et al., A&A, 609, A34 (2018)

Al-Refaie et al., ApJ, 967 132 (2024)

Line et al., ApJ, 738, 32 (2011)

Tsai et al., ApJS, 228, 20 (2011)

Moses et al., ApJ, 737, 15 (2011)

## Conclusion and perspectives

- Cross section thermal dependence affects not only photochemistry processes but all physico-chemical processes.
- An atmosphere around a highly irradiating star doesn't mean a lesser impact
- Extending the database of experimental VUV absorption cross sections at high temperature, starting with sulfur compounds