HCN Photochemistry in HD 209458 b and WASP-76 b

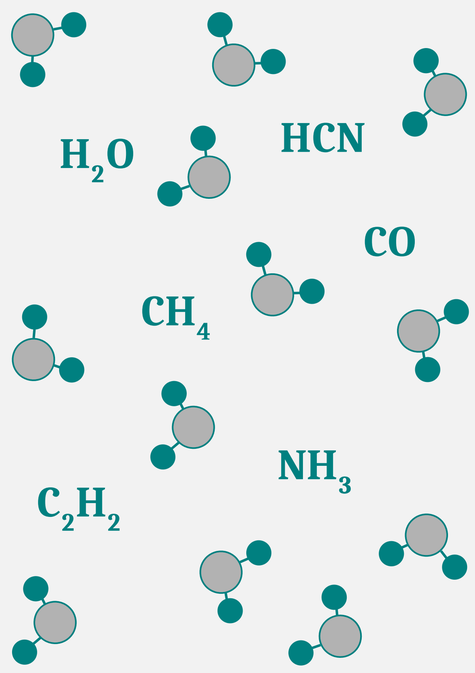
Investigating Recent HCN Detections with a 2D Photochemical–Advection Model

Robin Baeyens
with Jean-Michel Désert

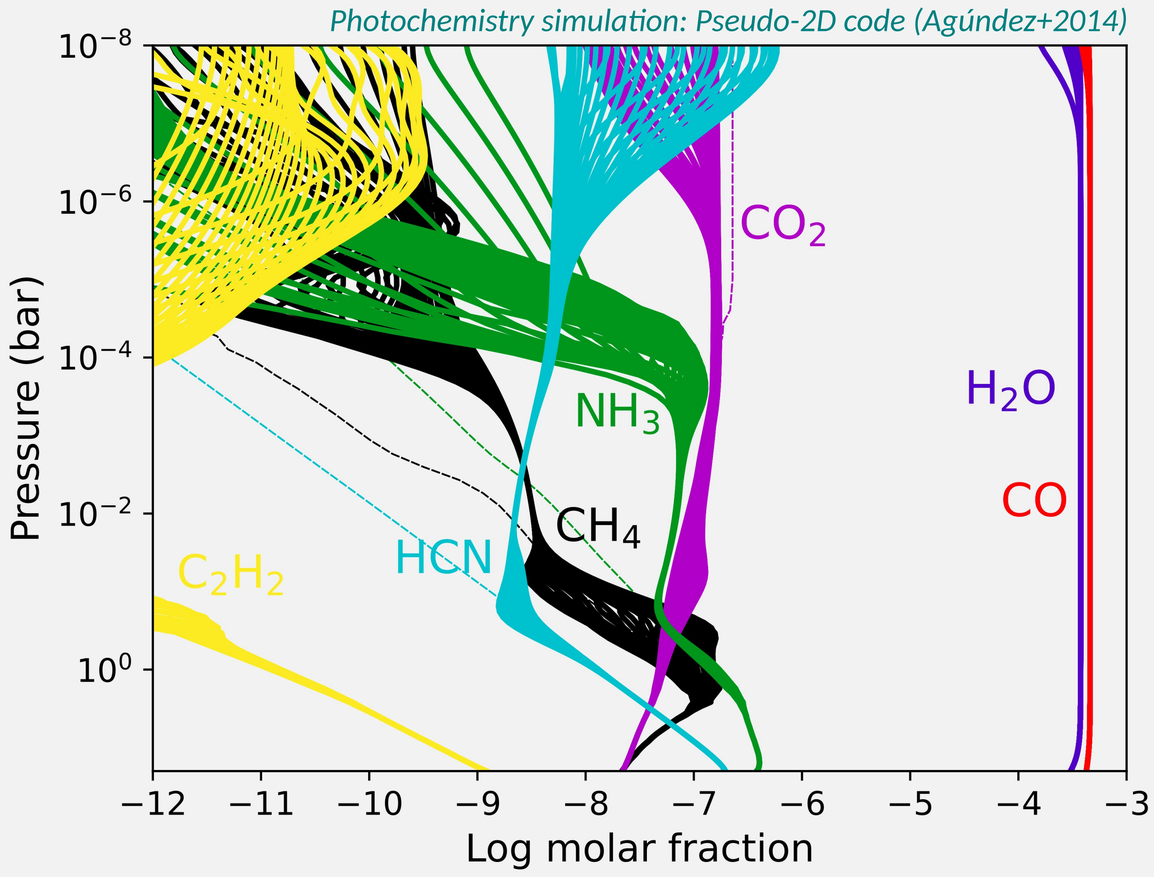
Irradiated gaseous exoplanets are intrinsically 3D objects. Predicting their atmospheric composition thus requires understanding the interplay between the physical and chemical processes taking place, including **photochemistry** and **horizontal transport**.

Observations of **HD 209458 b** with high resolution spectroscopy have shown an atmosphere with a rich molecular inventory (Giacobbe et al. 2021). The simultaneous presence of these species can indicate a high C/O ratio, and a **link to planet formation**.

On the other hand, **photochemistry may provide an explanation that does not necessitate C/O > 1**. We investigate the constraints to the C/O ratio using a sophisticated photo-chemical advection model and a solar elemental composition.



Photochemistry simulation: Pseudo-2D code (Agúndez+2014)



We find:
- enhanced HCN and C_2H_2 **(photochemistry)**
- enhanced CH_4 and NH_3 **(vertical mixing)**
- upper atmosphere limb asymmetries **(advection)**

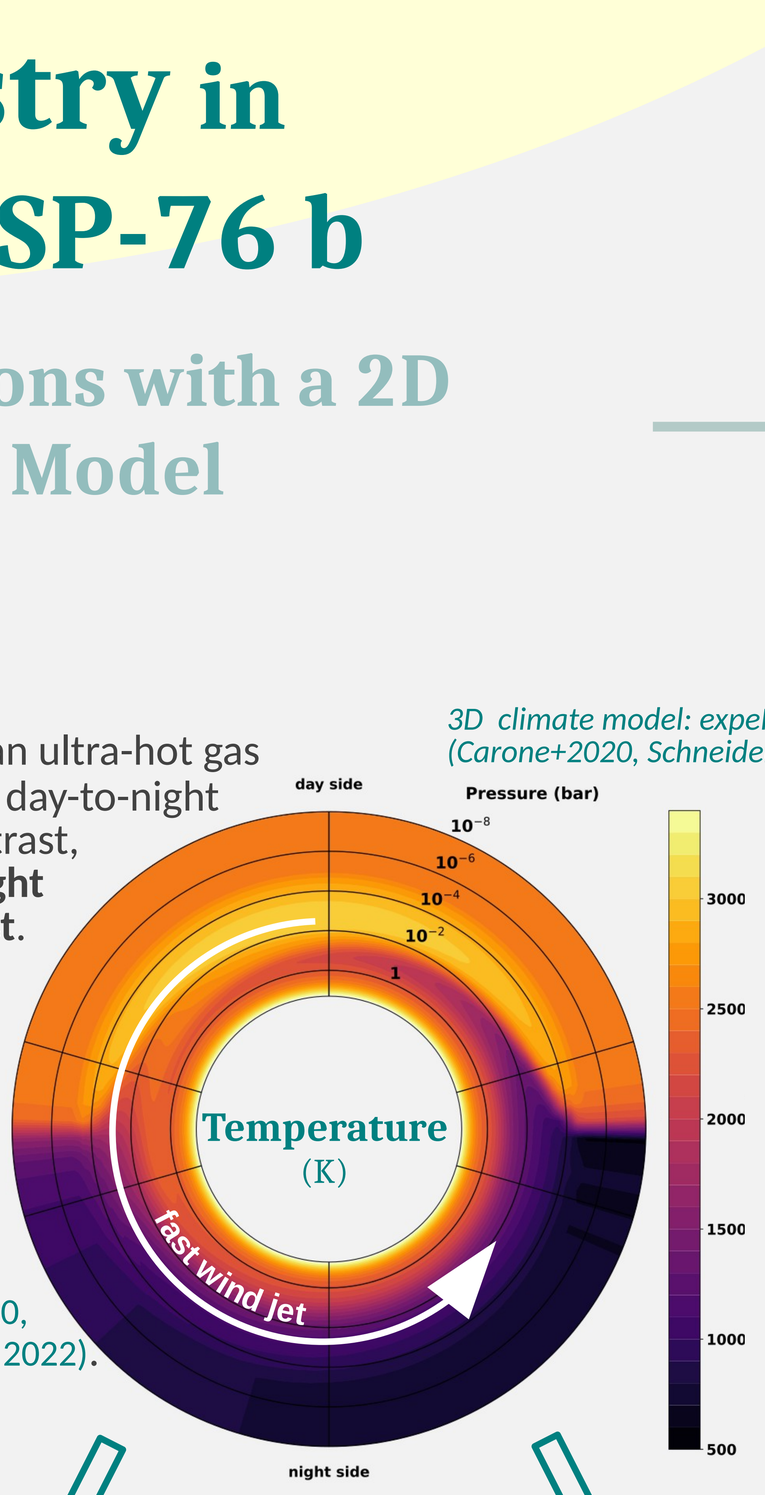
Next steps: **Increasing the vertical mixing rate K_{zz}** replenishes the upper atmosphere with parent molecules (CH_4 and NH_3) used for HCN and C_2H_2 photochemistry.

Day-side thermospheric heating can increase thermal dissociation, potentially leading to efficient HCN formation on the night side.

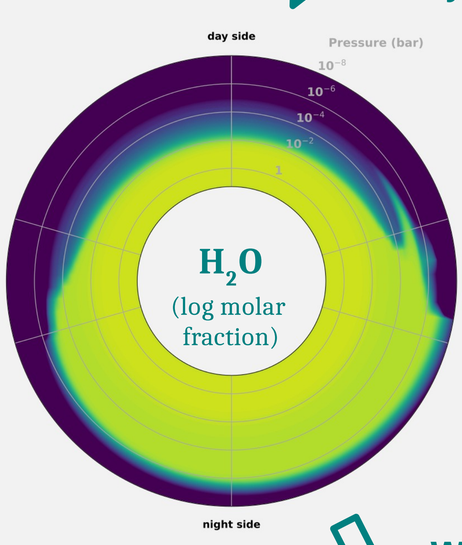
WASP-76 b is an ultra-hot gas giant with a large day-to-night temperature contrast, orbiting a **UV-bright F-type stellar host**.

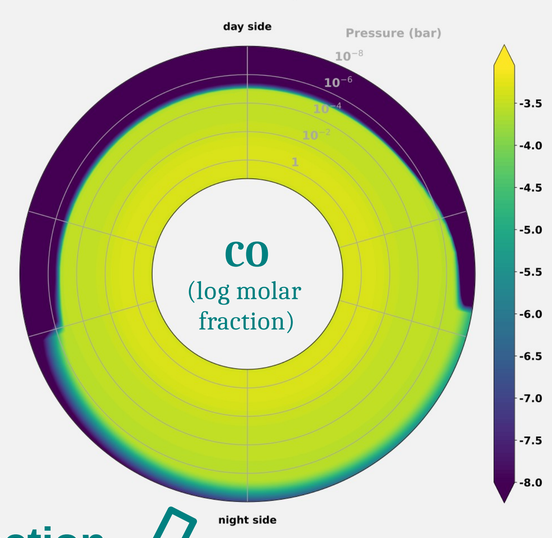
High-resolution observations of this planet have indicated **limb asymmetries** as well as **chemical gradients** (see e.g. Ehrenreich et al. 2020, Sanchez-Lopez et al. 2022).

3D climate model: expeRT/MITgcm (Carone+2020, Schneider+2022)



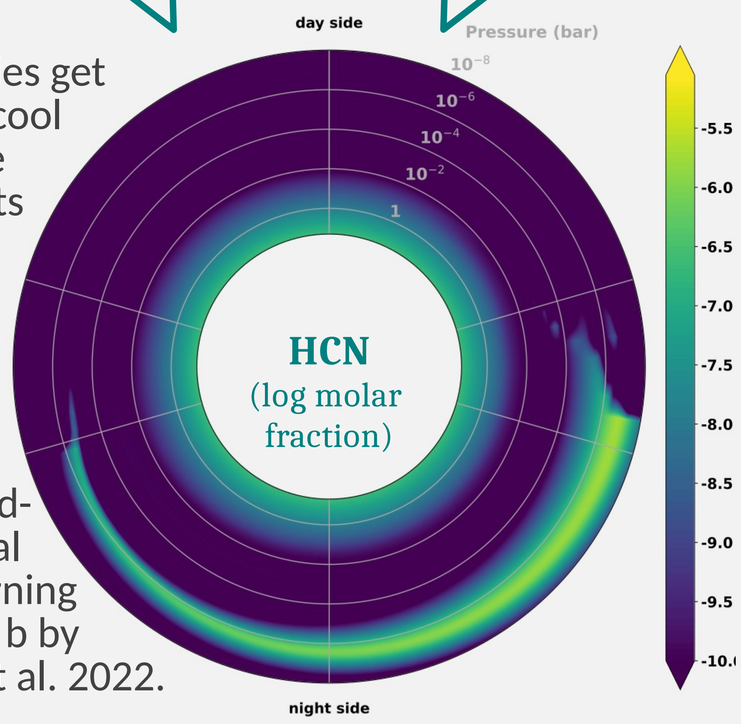
strong **thermal** and **photodissociation** of day-side H_2O and CO





wind advection of atomic species

Dissociated species get advected to the cool night side, where **HCN is formed**. Its abundance is highest at the morning limb.



This scenario can **explain the detection** of a red-shifted HCN signal found at the morning limb of WASP-76 b by Sanchez-Lopez et al. 2022.

Want to find out more?

A grid of pseudo-2D chemistry models for tidally locked exoplanets

I. The role of vertical and horizontal mixing **(Baeyens+2021)**
II. The role of photochemistry **(Baeyens+2022)**

Get in touch!
Robin Baeyens
r.l.l.baeyens@uva.nl

Anton Pannekoek Institute for Astronomy,
University of Amsterdam, The Netherlands

UNIVERSITY OF AMSTERDAM