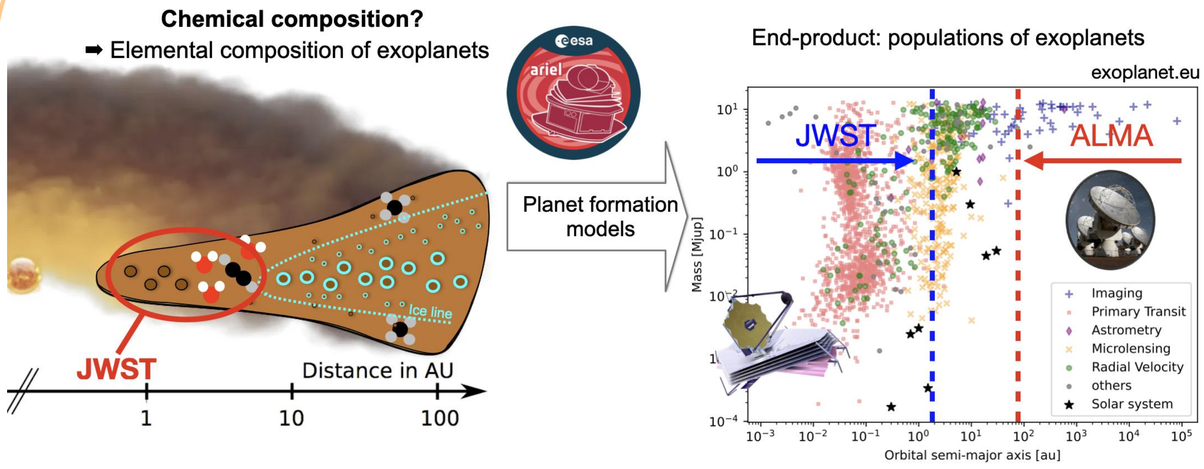
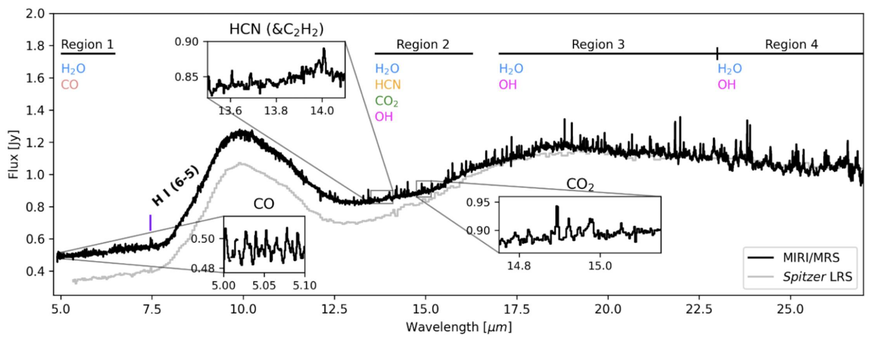
First constraints on elemental abundances in inner regions of T Tauri disks with thermochemical models

Pacôme Estève[1], Benoît Tabone[1], Emilie Habart[1]
Ewine F. van Dishoeck[2,3], Marissa Vlasblom[2], Inga Kamp[4],
Aditya Arabhavi[4], Simon Bruderer[3]

Context

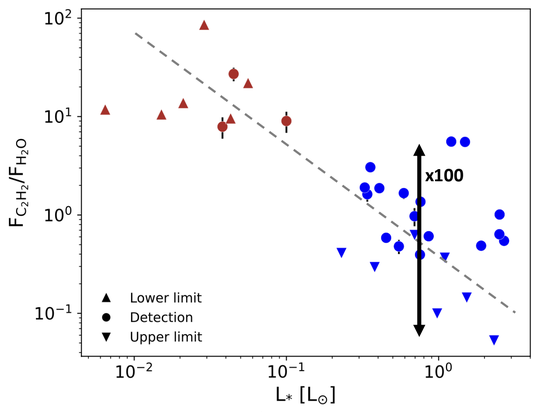


- JWST unveils the chemical content of inner regions of protoplanetary disks, where the majority of transiting exoplanets have been detected. Their atmospheric composition will be characterized by the future mission ARIEL.
- With its unparalleled sensitivity and spectral resolution in infrared, JWST is able to detect thousands of lines, emitted by gas-phase molecules in the hot inner regions of disks (<10 au).



JWST spectrum of Sz 98, a typical T Tauri disk. From Gasman et al. 2023

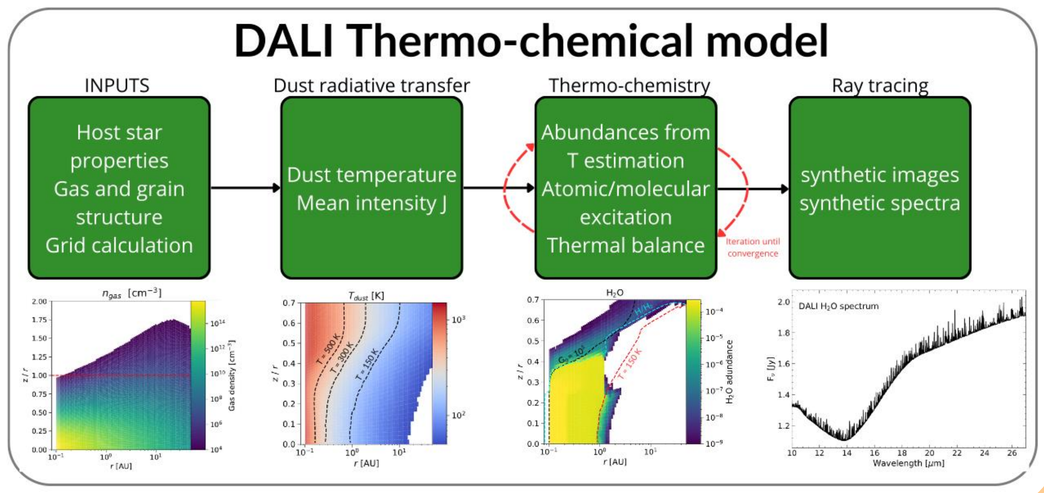
- Elemental abundances are crucial to contrain the formation history of exoplanets, in particular the C/O ratio.



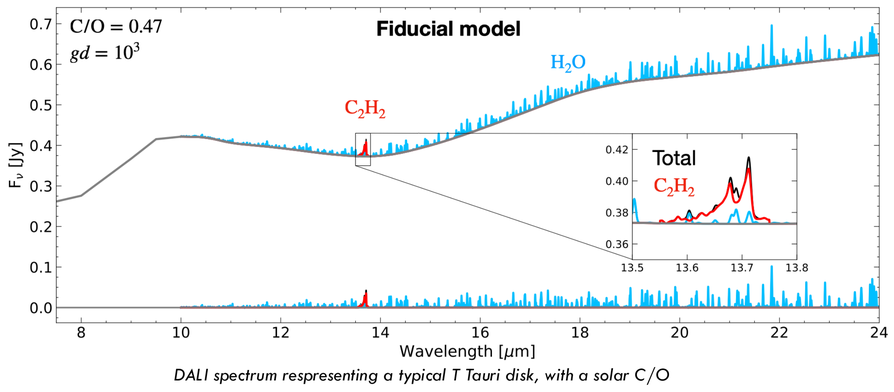
Correlation between acetylene/water flux ratio and luminosity. Adapted from Grant+2025

- JWST revealed that C_2H_2 and H_2O emissions vary tremendously from disk to disk.

Does the ratio C_2H_2/H_2O trace the C/O ratio of the inner disk ?

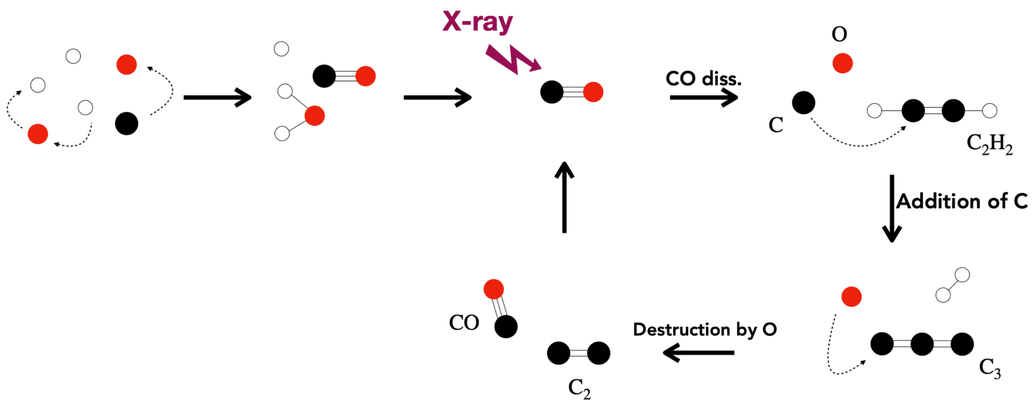


DALI results



DALI spectrum respresenting a typical T Tauri disk, with a solar C/O

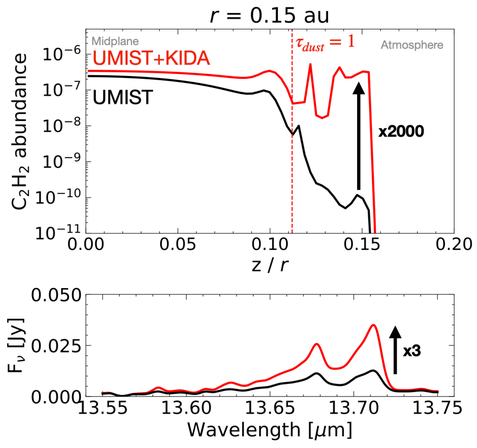
- With an extended carbon chemistry, we are able to reproduce a typical T Tauri disk observed with JWST.
- The oxygen abundance is prominent for carbon chains in inner disks



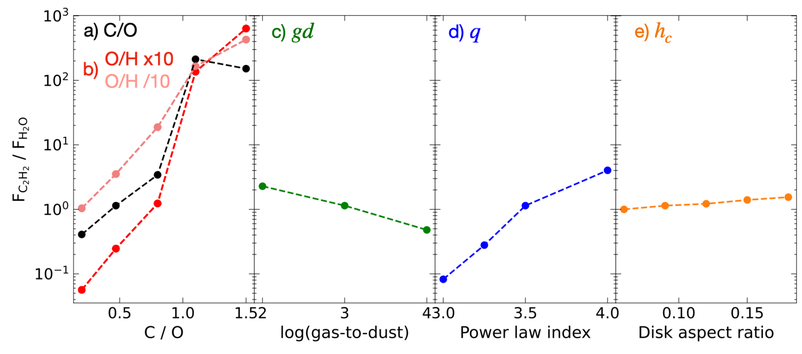
Sketch describing the carbon chemisrty in inner regions of protoplanetary disks

- Neutral-Neutral with high activation barriers are key in the carbon chemistry in inner regions of disks

$$C_xH_y + H_2 \rightarrow C_xH_{y+1} + H$$



- The line flux ratio F_{C2H2} / F_{H2O} is a promising tracer to estimate the C/O ratio.
- The estimation of the C/O ratio with this line flux ratio is limited by the knowledge of the dust size distribution.

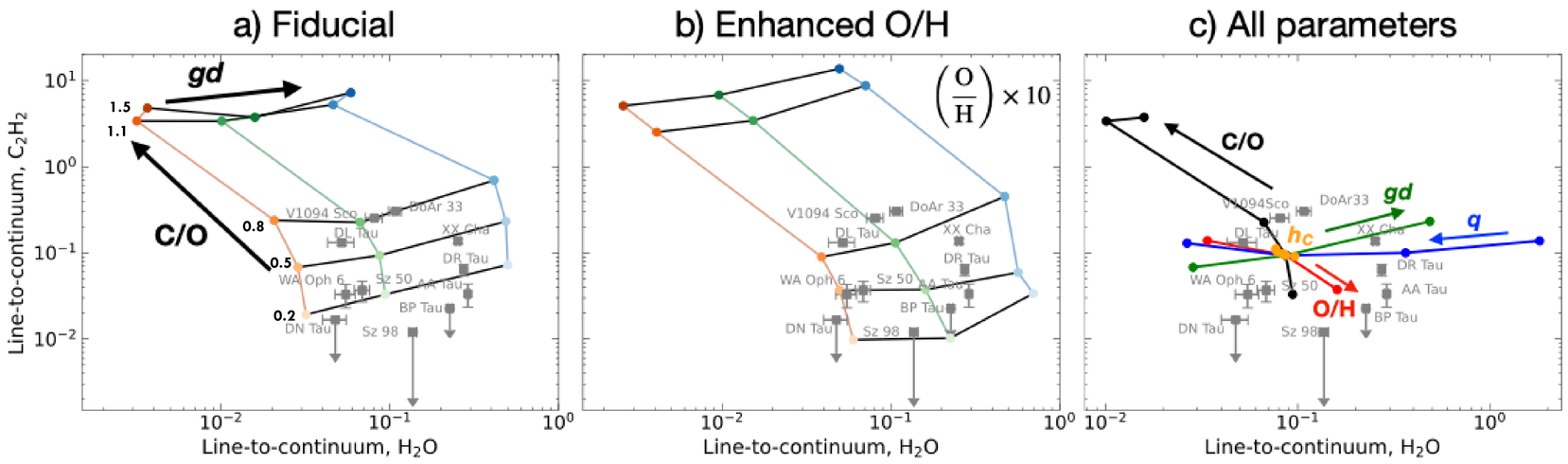


Sensitivity of F_{C2H2} / F_{H2O} to different parameters

Comparison with JWST observations

- Comparison with JWST observations suggests that C/O > 1 is excluded
- The grid with enhanced oxygen abundance covers also very well JWST observations of T Tauri disks.
- These results are consistent with the pebble drift scenario, in which icy pebbles from the outer disk enrich the inner disk in oxygen.

Mah+2023, Sellek+2025



Comparison of the model grids with JWST data (Colmenares et al. 2024, Grant et al. 2025)

The C_2H_2/H_2O flux ratio is an interesting tracer of the C/O ratio. The comparison with JWST observations suggests that C/O < 1 for inner disks of T Tauri stars with possible oxygen enrichment, providing important constraints for interpreting the results of the ARIEL mission.

[1]*Institut d'Astrophysique Spatiale, Orsay, France*
[2]*Leiden Observatory, Leiden University, Netherlands*
[3]*MPE, Garching, Germany*
[4]*Kapteyn Astronomical Institute, Groninguen, Netherlands*