JWST-TST High Contrast: Medium-resolution spectroscopy reveals a carbon-rich circumplanetary disk around the young accreting exoplanet Delorme 1 AB b

Check out the paper !

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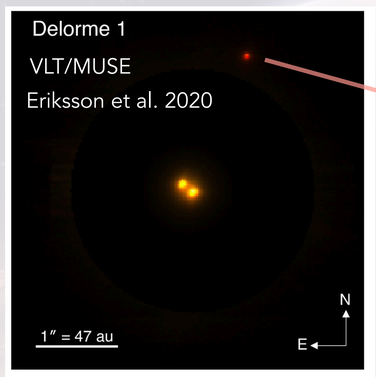
The Delorme 1 system

Delorme 1 AB b is the lowest-mass circumstellar companion with a high accretion rate. Its wide separation from the host stars is favorable for spectroscopy, making it the best target for observational studies of circumplanetary disk structure and accretion processes.

- Circumbinary companion at 84 au (1.78″) from its binary M star
- System at 47.2 pc and its age is estimated at **30 – 45 Myrs**
- Companion: Mass of 13±5 M_{Jup} & Spectral type L0 ± 0.5
- NIR emission lines ,high accretion rate : 0.2 to 5×10^{-8} M_{Jup}/yr → **hints for a CPD** : a reservoir of gas would be necessary to maintain such high accretion at this age.

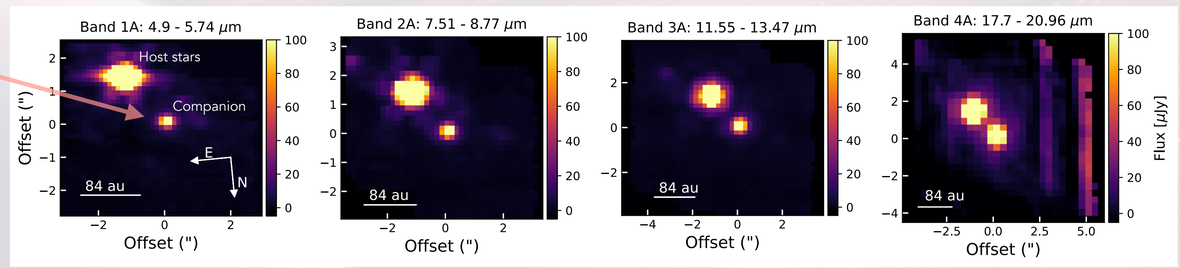
Delorme et al. (2013) and Betti et al. (2022)



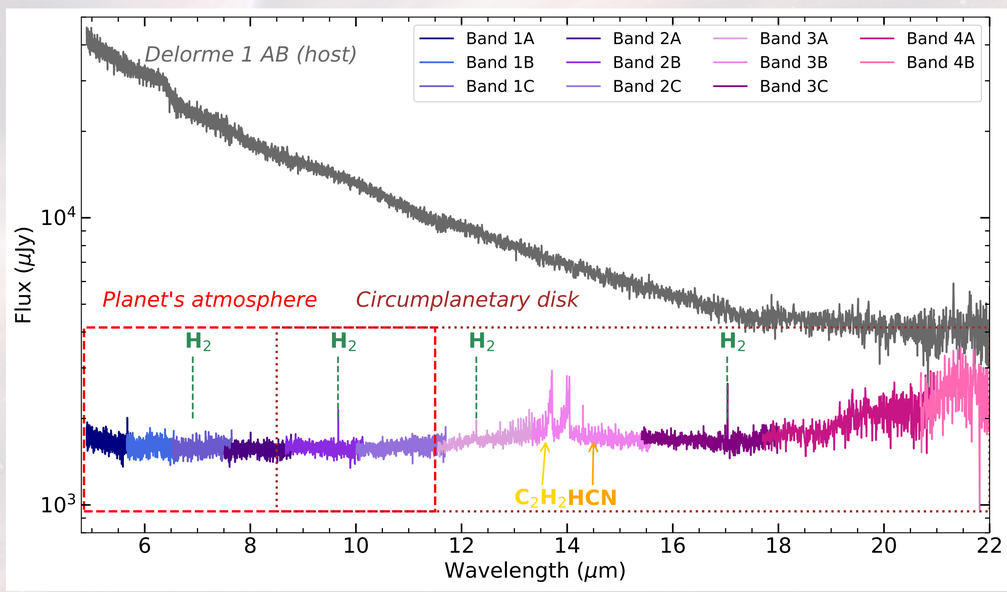
JWST MIRI Observations with the MRS

GTO 2778

Integral Field spectroscopy from 4.9 to 28 μm

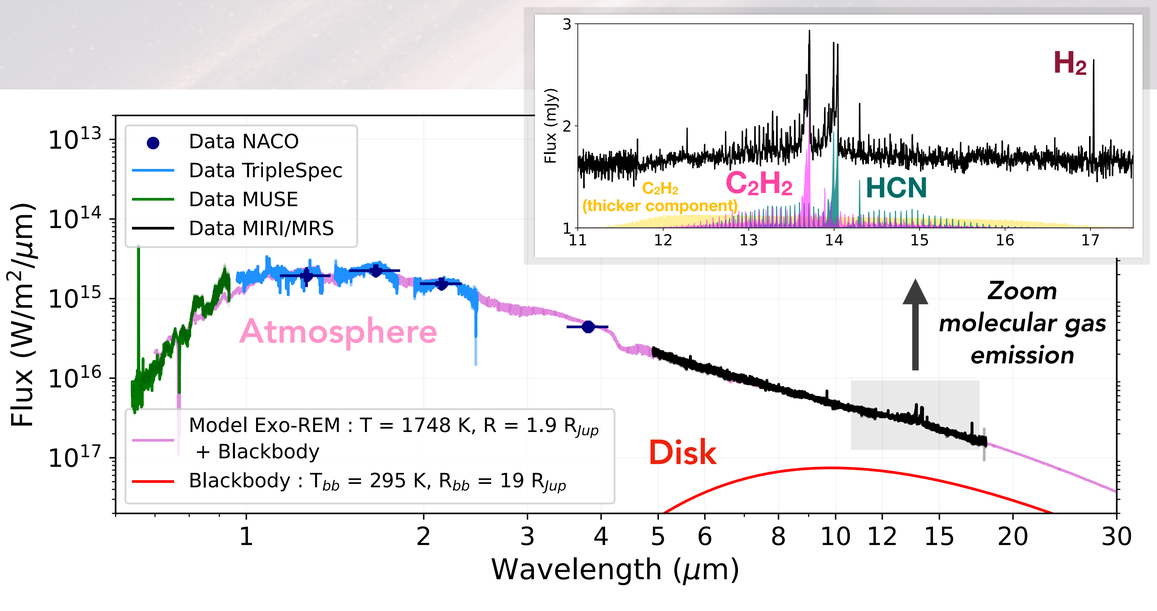


Host stars and companion mid-infrared spectra



Beyond 10 μm, the spectrum is dominated by emission from the circumplanetary disk gas rather than by the planet's atmospheric features.

Modeling the atmosphere and the circumplanetary disk



Results

Atmospheric characterisation

- Forward modeling of MIRI-MRS spectra combined with NIR datasets: NACO, TripleSpec, and MUSE (Delorme et al. 2013, Betti et al. 2022, and Eriksson et al. 2020).
- Atmospheric parameters derived from comparisons with various models: T = 1725±134 K and R = 1.9±0.1 R_{Jup}.
- The super-solar metallicity [Fe/H] = 1.5 and C/O = 0.6–0.8 can be explained by complementary scenarios: formation in a C-rich disk around an M-type star, formation between the H_2O and CO snowlines followed by outward migration, and late enrichment from the C-rich CPD.
- Detection of CO and H_2O molecular absorption in the atmosphere.

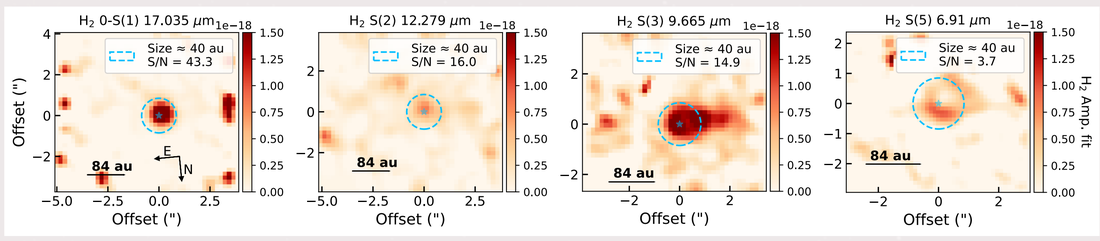
Circumplanetary disk characterisation

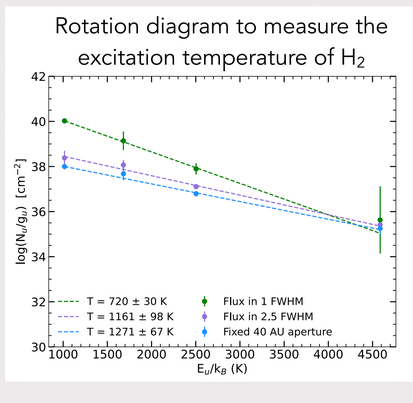
- No silicate dust detected: grains likely grown >5 μm and settled to the mid plane, suppressing mid-IR spectral features.
- The blackbody fit gives T = 295±27 K and R = 18.8±2.7 R_{Jup}, implying a dust cavity at R = 32.6±3.1 R_{Jup}.

Carbon-rich gas → high C/O

- Detection of hydrocarbons : HCN, C_2H_2, $^{13}C_2H_2$.
- Two C_2H_2 components : one optically thick and one more optically thin.
- No H_2O, CO, CO_2 or other hydrocarbons detected : less species detected in comparison to younger, more massive host objects.
- Presence of the gas is surprising for this system's age.

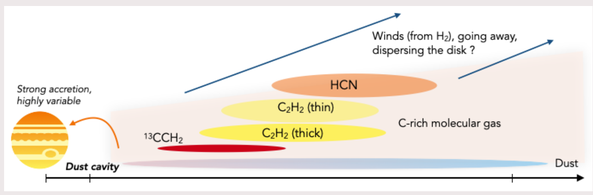
Evidence for outflows from extended H_2 emission





- The H_2 emission is extended ≥ 40 au (≈ 2 × R_{Hill} = 19.4 au), **beyond the gravitational sphere of influence of the planet** consistent with outflowing gas.
- Tracing **warm** gas, with indications that it may be at a higher temperature than the non-extended component.
- If this emission traces a **wind dispersing the disk:** Mass-loss rate of 2 × 10^{-10} M_{Jup}/yr
- Assuming all the observed H_2 originates from the wind: **Wind-to-accretion mass ratio** of $\dot{M}_{wind}/\dot{M}_{acc}$ ~ 0.004 - 0.1

Schematic of Delorme 1 AB b and its disk



Conclusion

- ☆ The MIRI–MRS spectrum reveals overlapping **atmospheric and circumplanetary disk** features for a 30–45 Myr old planet.
- ☆ This mid-IR medium-resolution spectrum of the CPD reveals a **carbon-rich** molecular gas composition, challenging standard gas-dispersal timescales in planet formation theories. The composition of its gas is the continuity of very-low-mass star disks (<0.2 $M_\odot$), implying that disks may follow a common evolutionary path regardless of the central mass. The dust continuum emission suggests an **inner dust cavity** in the CPD.
- ☆ This analysis reveals that this potentially **moon-forming disk** is carbon-rich, which could have important implications for satellite formation. A high carbon content may influence the composition and chemical diversity of any forming moons.
- ☆ Disk outflows can impact **disk evolution.** This raises the question of how the outflow is launched and how it affects the CPD.
- ☆ More CPDs observations with MIRI-MRS are scheduled (GO 6086, PI : K. Ward-Duong and GO 7538, PIs : G. Cugno and S. Grant)

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