Nature or nurture: constraining wide orbit substellar companions with JWST/NIRSpec retrievals

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Introduction

As part of the **JWST Cycle 1 GTO #1188** program (Hodapp et al. 2017), we employ JWST/NIRSPec IFU G395H/F290LP (**2.87 – 5.27 μm**) observations of **planetary-mass companions** ~13 M_{Jup} on **wide orbits** of hundreds of au to study their atmospheric composition.

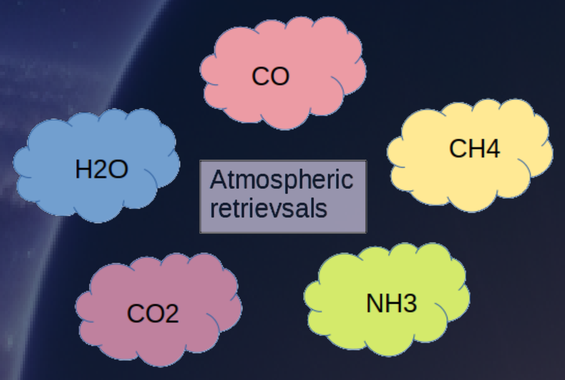
Gas giants or brown dwarfs?

Substellar companions of planetary-mass on wide orbits pose an interesting dilemma to how they formed.

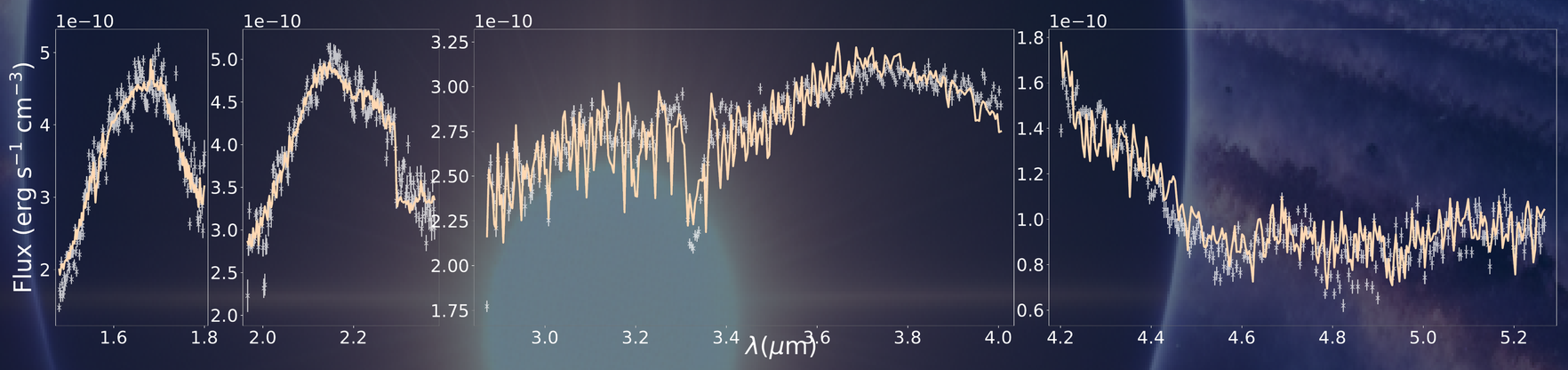
- The **low mass** suggest they formed through **core accretion**, similar to giant planets.
- Whereas the **large separations** indicate for more rapid processess, like **gravitational collapse**, more akin to stars.

Certain elemental abundance ratios such as the **C/O ratio** can be used as a **formation diagnostic** (Öberg et al. 2011).

Atmospheric retrieval

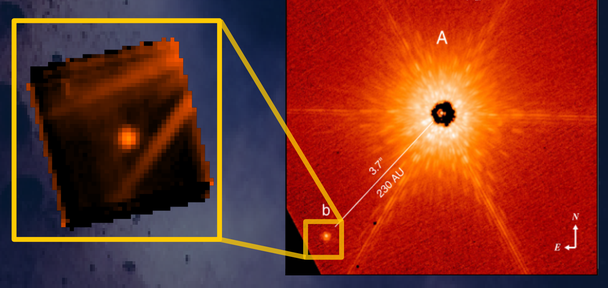


Our goal is to employ **atmospheric retreival techniques** to procure insights into the phsyical processes and **chemical invenotry** of the atmospheres of the companions, which may provide clues to whether they formed with similar **nature** to a binary star, or were **nurtured** as giant planets.



We employed the atmospheric retrieval code **APOLLO** (Howe et al. 2022) on **emission spectra** of the **directly imaged** planetary-mass companion **2M2236 b** to constrain its fundamental properties and molecular abundances such as CO, CO_2, H_2O, CH_4 and NH_3.

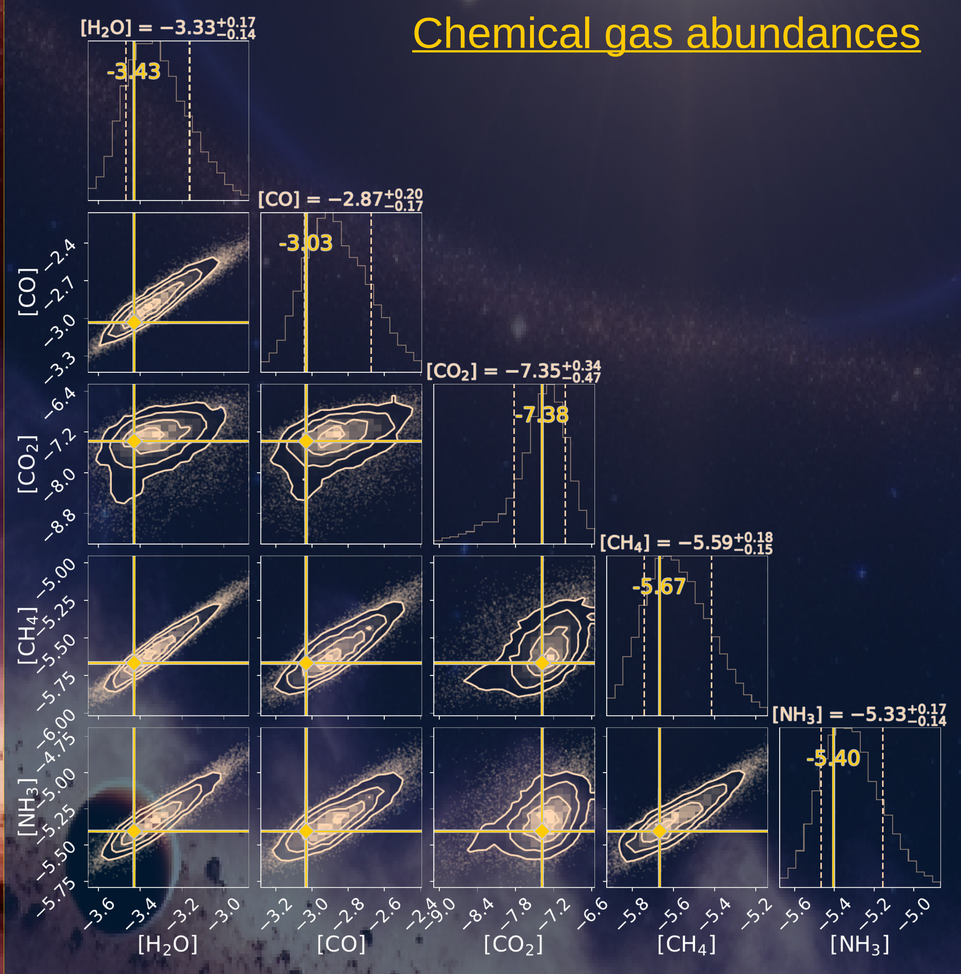
2M2236 b



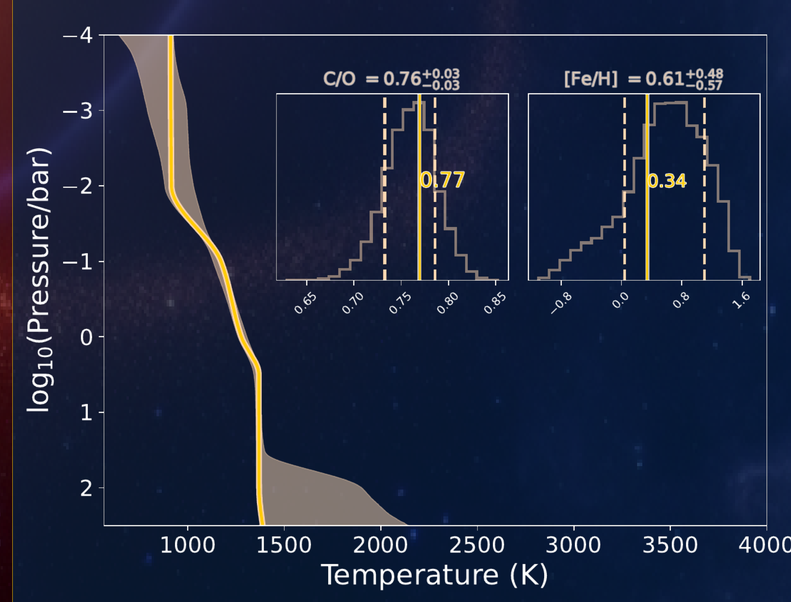
(Left:) Collapsed data cube from NIRSpec IFU observations. *(Right:)* Keck/NIRC2 image from Bowler et al. (2017).

One of our observed targets is 2MASS J22362452+4751425 b **(2M2236 b)**, a late **L-type**, **11-14 Jupiter mass** companion separated by **230±20 au** to a K7 host star in the **120-200 Myrs** old AB Dor moving group.

Chemical gas abundances



Tempearture-Pressure profile



- The Temperature-Pressure profile shows several **isothermal layers** in the structure of the atmosphere.
- The median retrieved **C/O = 0.74 ± 0.02** is enhanced compared to Solar of C/O_{Sun} **= 0.55.**

Takeaways

- JWST/NIRSpec data at **2.9-5.3 μm** contain valuable **chemical information.**
- We find no significant preference for **cloud opacity** for 2M2236 b.
- Our retrievals suggest that 2M2236 b joins a scarce group of known companions with **enhanced C/O ratio** and **metallicity**, following objects such as GJ 504 b (Skemer et al. 2016).

Future work

- Inclusion of **JWST/MIRI** data at longer infrared wavelengths.
- Other wide-orbit planetary-mass companions in our survey include HD106906 b, ROSS 458 c, GU Psc b.
- Comparison of C/O ratio to **host stars** and **free-floating objects** in the same young moving groups.

References

– Bowler, B. P., Liu, M. C., Mawet, D., et al. 2017, AJ, 153, 18. doi:10.3847/1538-3881/153/1/18
– Hodapp, K. W., Beichman, C. A., Lagage, P.-O., et al. 2017, JWST Proposal. Cycle 1, 1188
– Howe, A. R., McElwain, M. W., & Mandell, A. M. 2022, ApJ, 935, 107. doi:10.3847/1538-4357/ac559
– Skemer, A. J., Morley, C. V., Zimmerman, N. T., et al. 2016, ApJ, 817, 166. doi:10.3847/0004-637X/817/2/166
– Oberg, K. I., Murray-Clay, R., & Bergin, E. A. 2011, ApJL, 743, L16. doi:10.1088/2041-8205/743/1/L16

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