CO isotopologue ratio in exoplanet atmospheres

Yapeng Zhang [1], Ignas Snellen [1], Alexander Bohn [1], Paul Mollière [2], Christian Ginski [3], Jens Hoeijmakers [4], Matthew Kenworthy [1], Eric Mamajek [5], Tiffany Meshkat [6], Maddalena Reggiani [7], Frans Snik [1]

1: Leiden Observatory 2: Max Planck Institute for Astronomy, Heidelberg 3: Anton Pannekoek Institute for Astronomy, Amsterdam 4: Lund Observatory 5: JPL, California Institute of Technology 6: IPAC, California Institute of Technology 7: Institute of Astronomy, KU Leuven

arXiv: 2107.06297
2109.11569

yzhang@strw.leidenuniv.nl
https://home.strw.leidenuniv.nl/~yzhang/

Isotope ratios in the solar system and beyond

- Isotopologues ratios (such as D/H, $^{12}C/^{13}C$, $^{16}O/^{18}O$, etc.) play an important role in understanding planet formation and evolution in the solar system.
- Searching for isotopologues in atmospheres of extra-solar planets is getting mostly feasible for **^{13}CO** (Mollière & Snellen 2019).
- Carbon isotope ratios are found to be roughly constant ($^{12}C/^{13}C$ ~ 89) in the solar system, which differs from the ratio of ~ 68 in the current local interstellar medium (*Fig.1*).

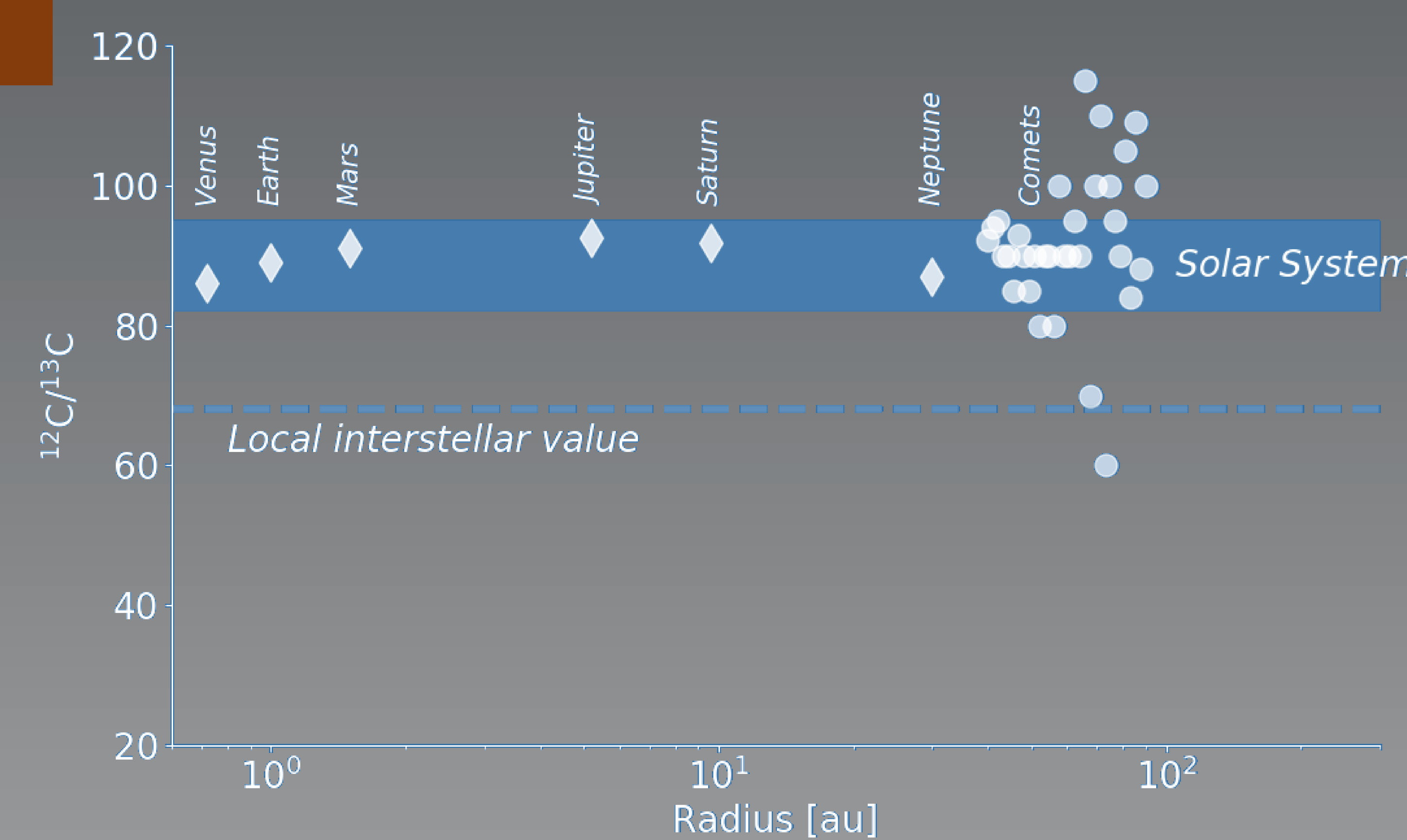

Figure 1 | $^{12}C/^{13}C$ ratios in solar-system objects.

^{13}CO in exoplanet and brown dwarf atmospheres

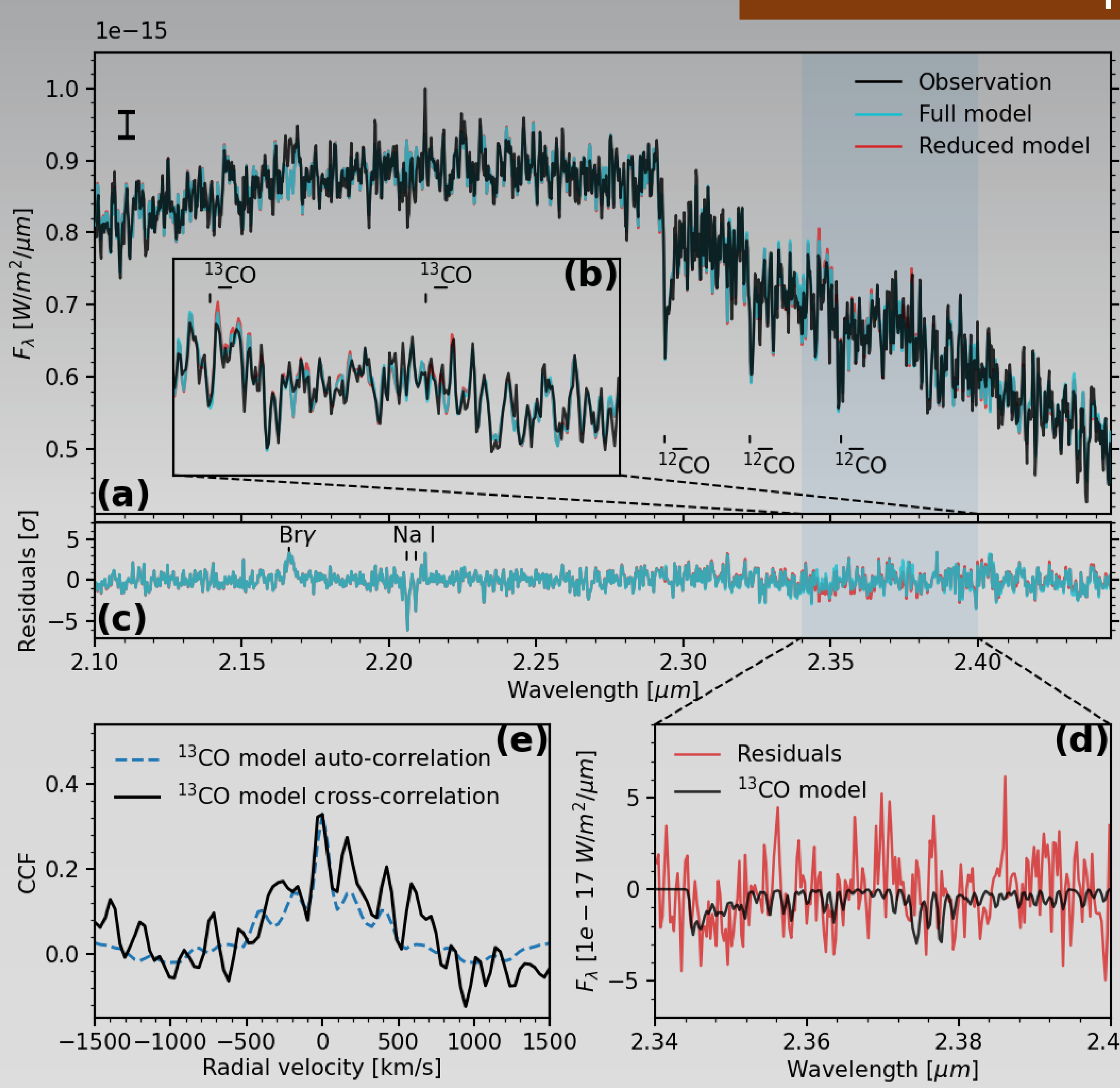

Figure 2 | Panel a) VLT/SINFONI spectrum (λ/Δλ~4500 at the K-band) of the exoplanet YSES-1b. The colored lines show the best-fit models with or without ^{13}CO opacity, obtained with Bayesian free retrieval analyses (Mollière et al. 2020). Panel e) Cross-correlation function between observational residuals and ^{13}CO template, with the central peak showing the detection of ^{13}CO.

We initiate the search for ^{13}CO in the super-Jovian exoplanet YSES-1b (Bohn et al. 2019), and compare its carbon isotope ratio with an analogous free-floating brown dwarf 2M0355 to shed light on their formation pathways.

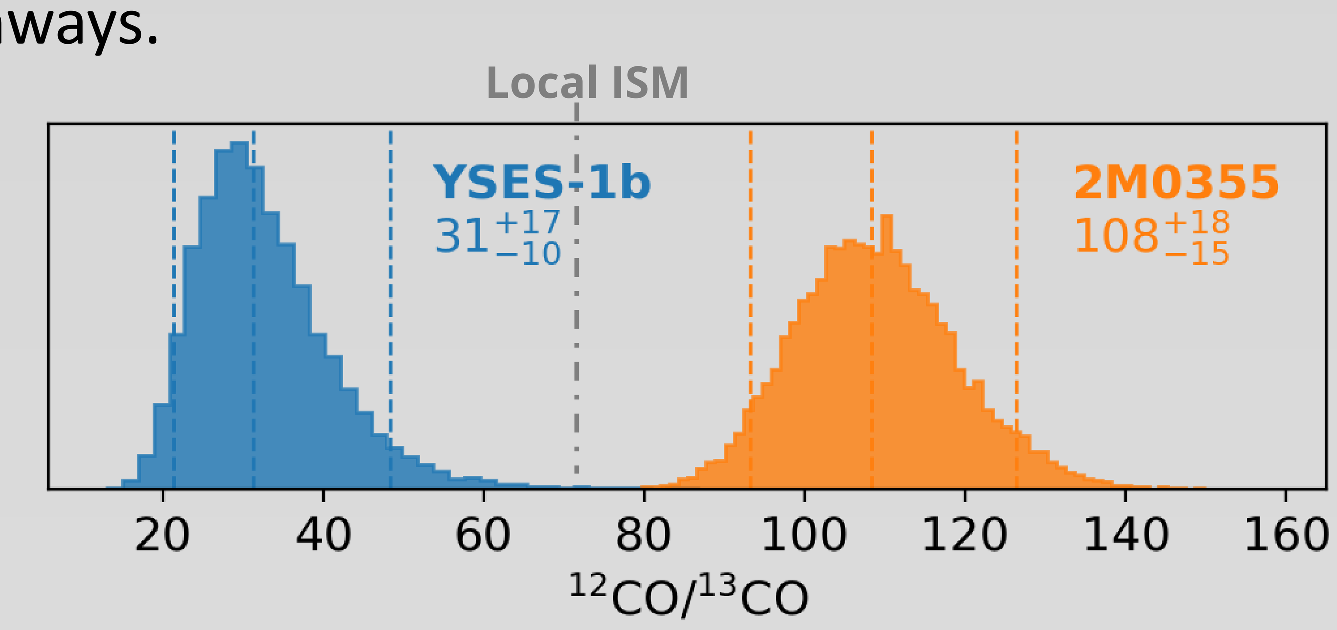

Figure 3 | Retrieved $^{12}CO/^{13}CO$ ratios of the exoplanet and brown dwarf.

Core-accretion VS Top-down collapse ?

Isotope ratios as probes of planet formation

- The distinct carbon isotope ratios may distinguish the bottom-up core-accretion formation of the super-Jupiter as opposed to the star-like formation pathway.
- The ^{13}CO-rich atmosphere indicates the exoplanet likely formed outside CO iceline, accreted the bulk of its carbon from the ice reservoir, which is enhanced in ^{13}C (*Fig. 4*).

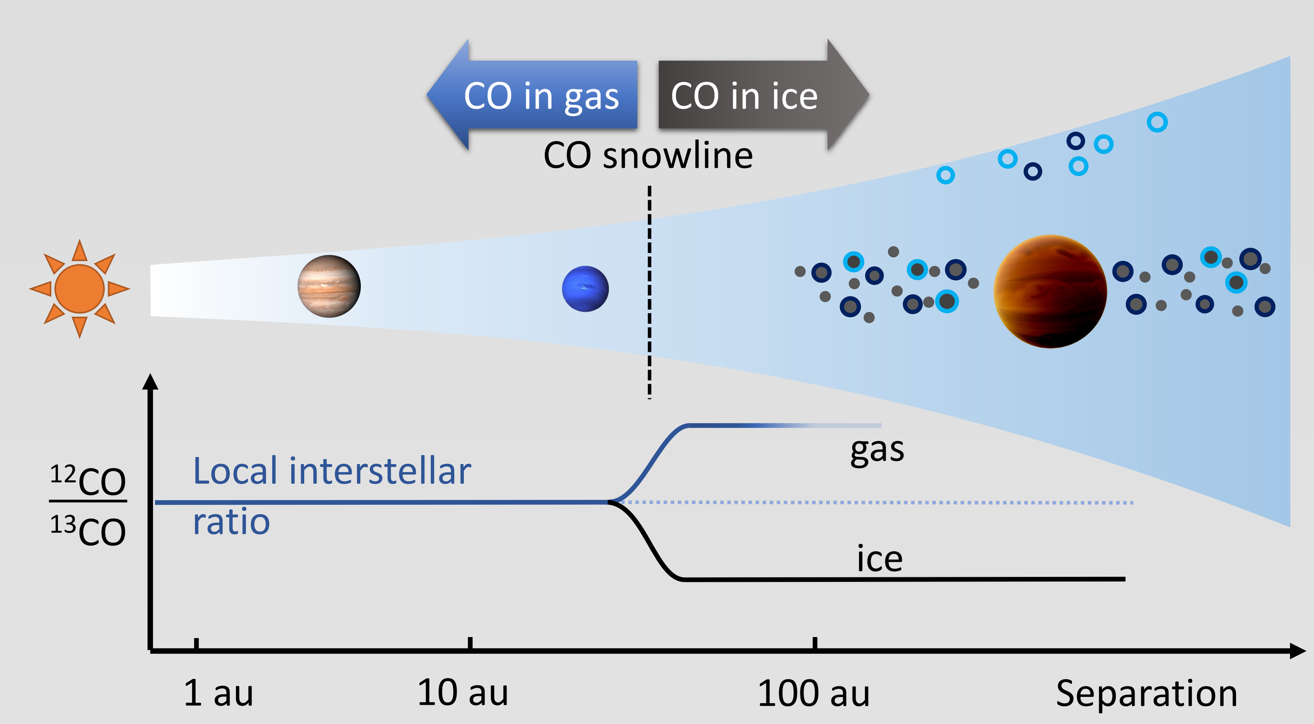

Figure 4 | Birth environment of planets in a proto-planetary disk, illustrating the discrepancy of $^{12}CO/^{13}CO$ ratios in ice and gas reservoirs. Beyond CO iceline, the ice may be enriched in ^{13}C through carbon fractionation, resulting in the observed ^{13}CO-rich atmosphere of the planet that formed out there.