Explaining the Diversity of Cold Exoworlds with JWST

Genaro Suárez
Department of Astrophysics,
American Museum of Natural History

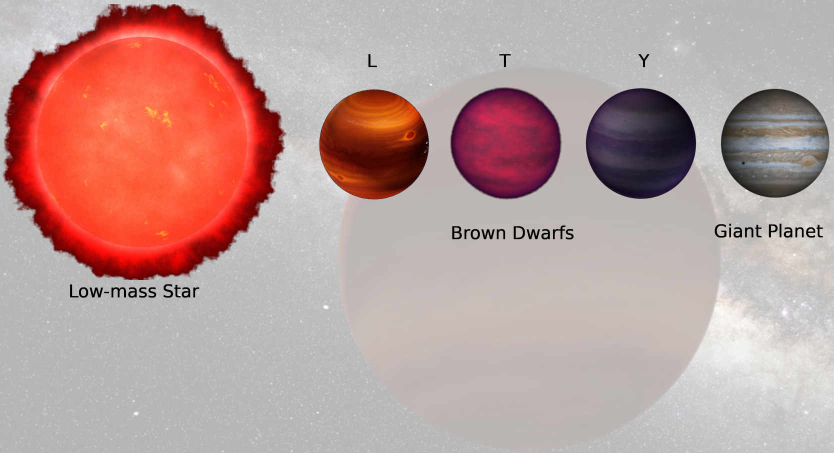
Collaborators:

J. K. Faherty (PI of GO 2124; AMNH), B. Burningham (U. of Hertfordshire), S. Alejandro Merchan (Hunter College, CUNY), D. Bardalez Gagliuffi (Amherst College), M. J. Rowland (UT at Austin), B. Lacy (UC Santa Cruz), R. Kiman (Caltech), J. Copeland (U. of Hertfordshire), J. Vos (Trinity College Dublin), N. Whiteford (AMNH), A. Rothermich (CUNY, AMNH), J. Gagné (Université de Montréal), E. Gonzales (SFSU), C. Morley (UT at Austin), D. Kirkpatrick (Caltech), A. Meisner (NOIRLab), A. Schneider (NOFS), D. Caselden (AMNH), F. Marocco (Caltech), C. A. Beichman (JPL), and the rest of the GO 2124 team

Cool Stars 22

San Diego, CA, USA. June 28, 2024

Brown Dwarfs: Link Between Giant Planets and Low-Mass Stars



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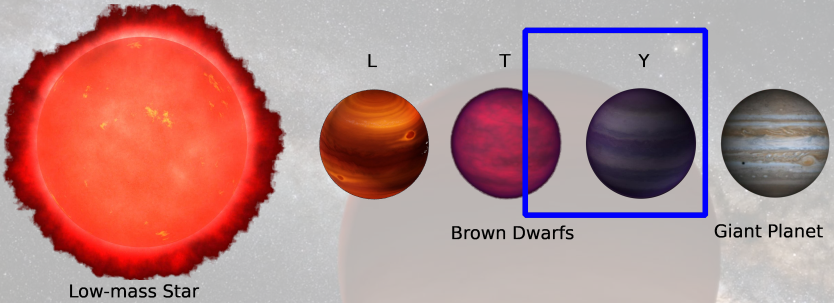
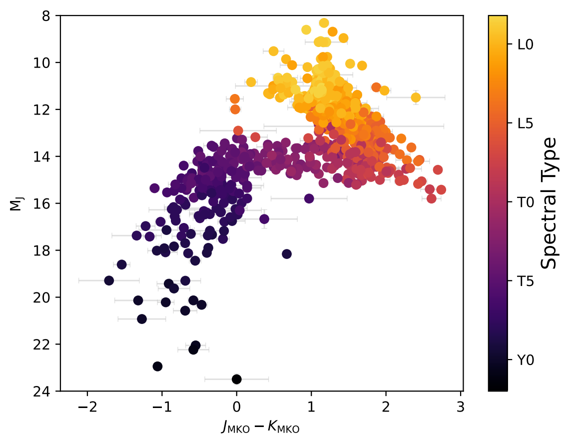


Challenges Predicting Properties of the Coldest Brown Dwarfs



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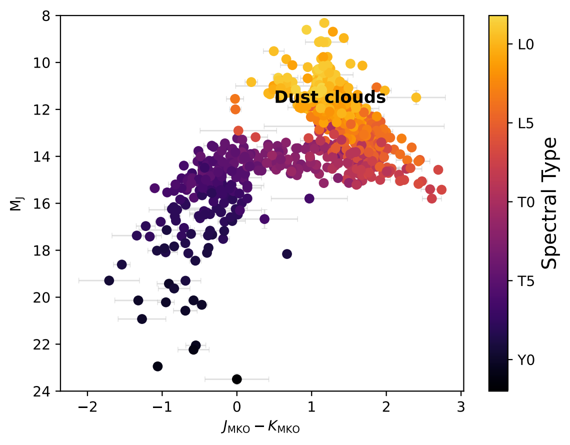

Appearance of the hottest ($\gtrsim$1000 K) brown dwarfs highly influenced by their viewing inclination and dust cloud distribution (Vos et al. 2017, Suárez et al. 2023).

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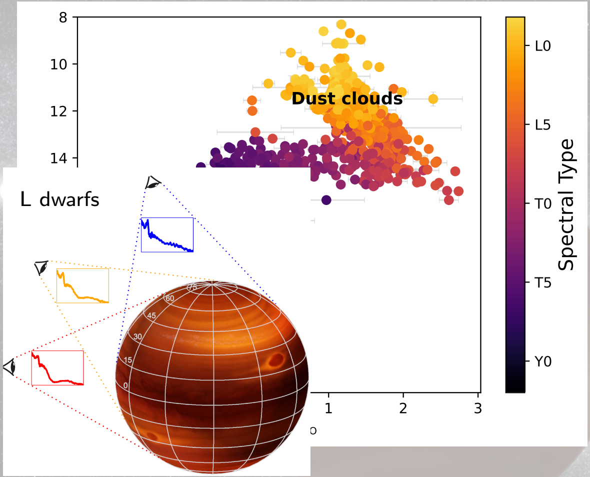

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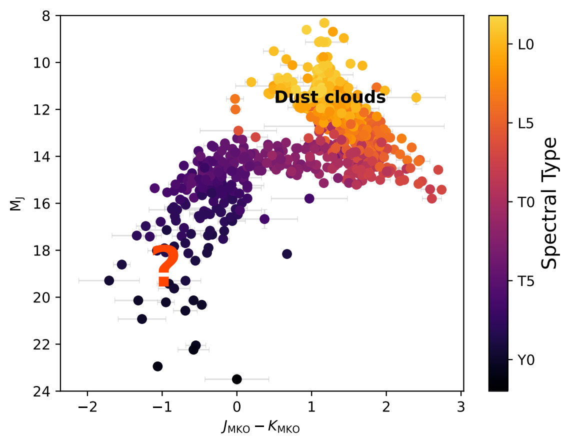

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What property domains the diversity of the coldest ($\lesssim$1000 K) brown dwarfs?

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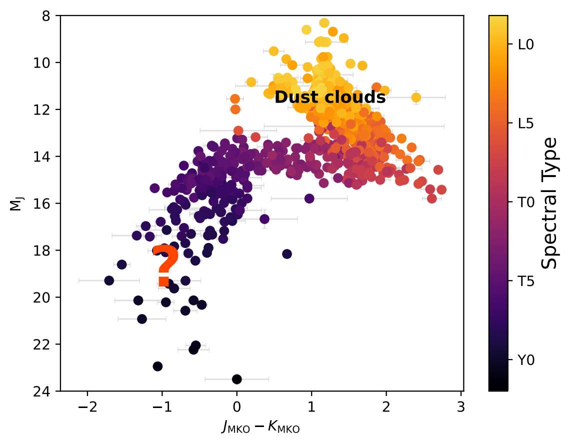
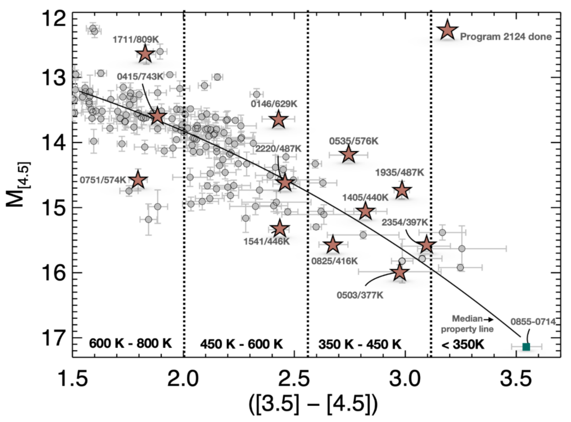


Appearance of the hottest ($\gtrsim$1000 K) brown dwarfs highly influenced by their viewing inclination and dust cloud distribution (Vos et al. 2017, Suárez et al. 2023).

What property domains the diversity of the coldest ($\lesssim$1000 K) brown dwarfs? Salt and/or water clouds, gravity, metallicity, non-equilibrium chemistry?

JWST Cycle 1 GO 2124 Program



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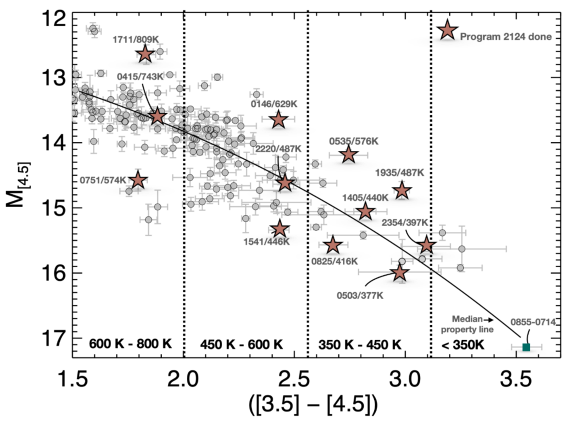

JWST observations of 12 late-T and Y dwarfs (PI: J. Faherty):

NIRSpec G235H ≈2700 2.9–5.1 μm spectra.

MIRI F1000W, F1280W, and F1800W mid-infrared photometry.

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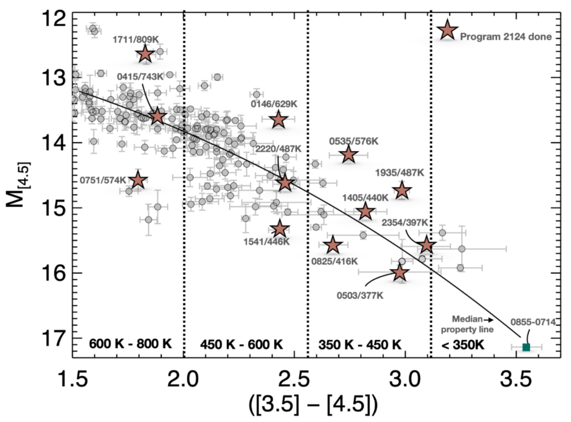

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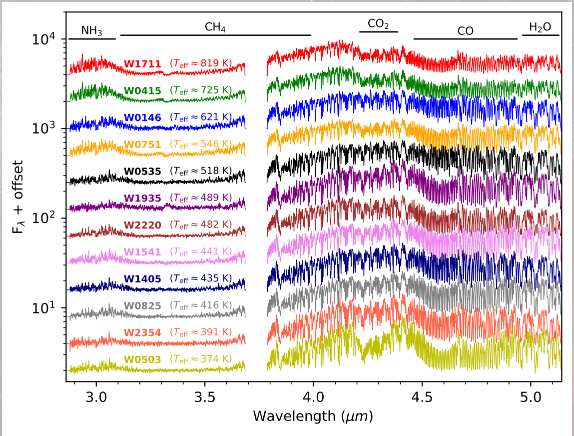
All spectra were reprocessed.

Spectra in JWST Cycle 1 GO 2124



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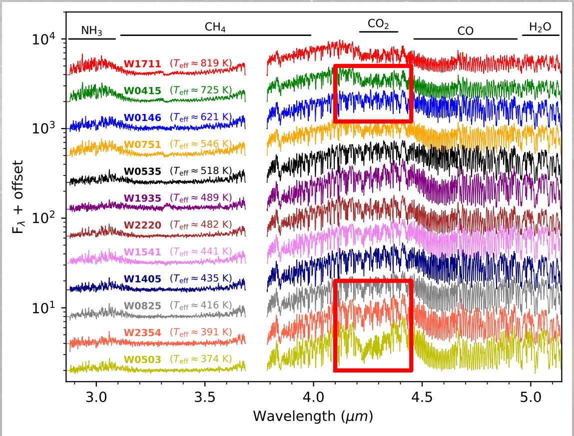

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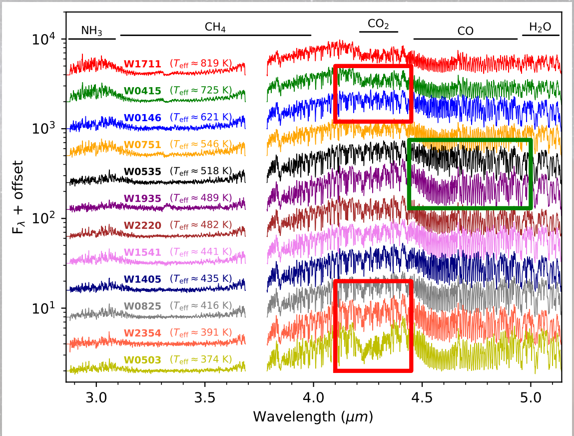

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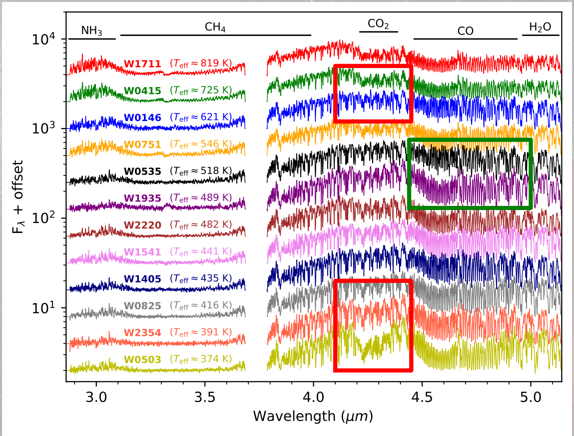

Diversity of spectral features for objects with similar temperature e.g. CO and CO_2.

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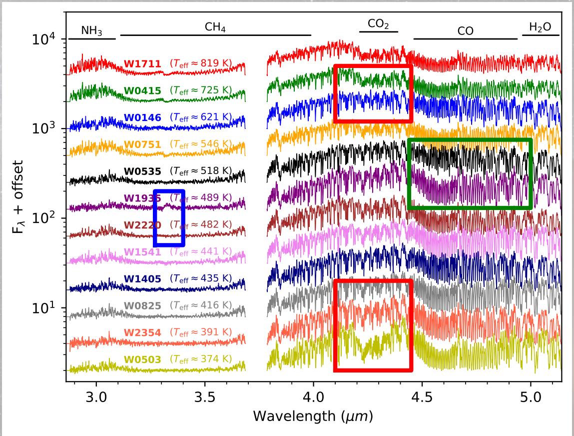

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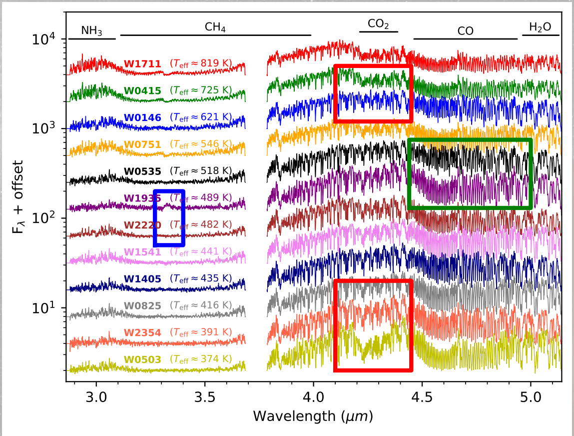

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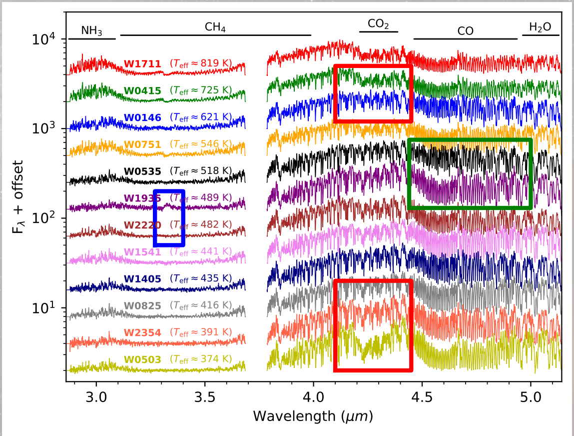

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Lacy+2024 (in prep.)
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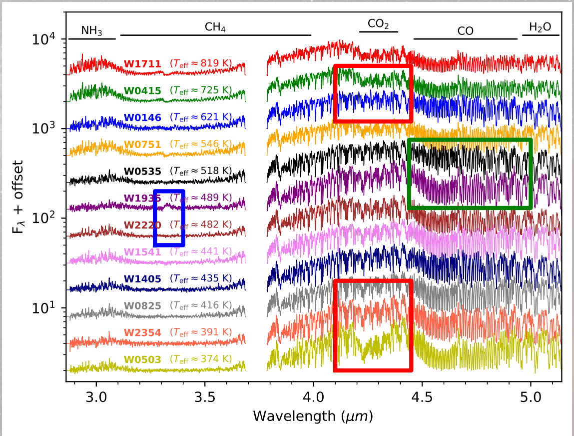

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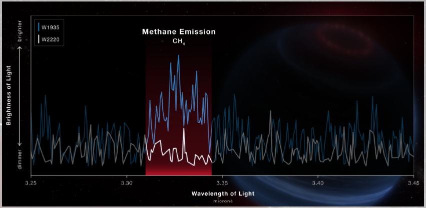
Complementary JWST Cycle 1 GO 2302 (PI: M. Cushing) that obtained NIR and MIR spectra for 24 cold brown dwarfs (Beiler et al. 2023, Kothari et al. 2024).

Methane in Emission

Faherty, Burningham, Gagné, Suárez et al. (2024, Nature)



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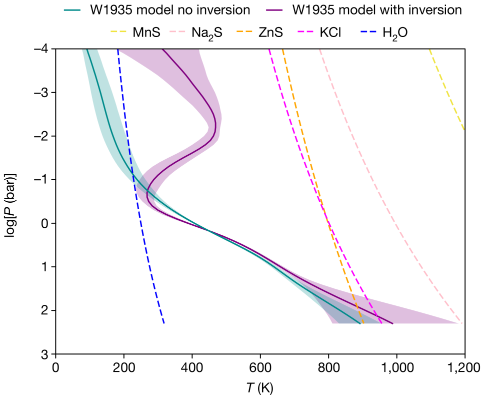

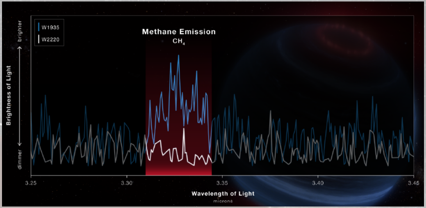

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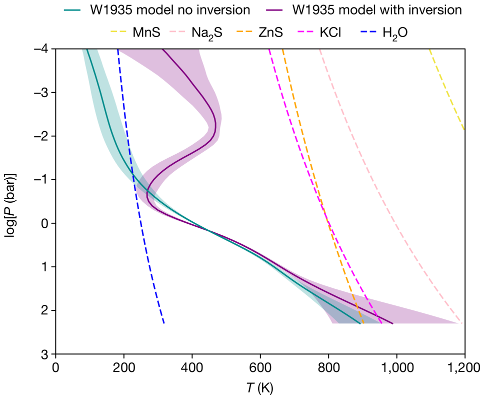
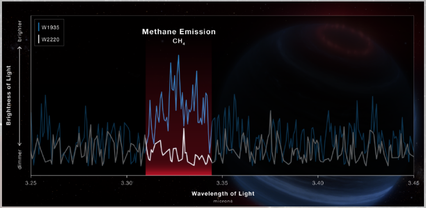
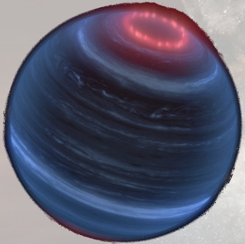




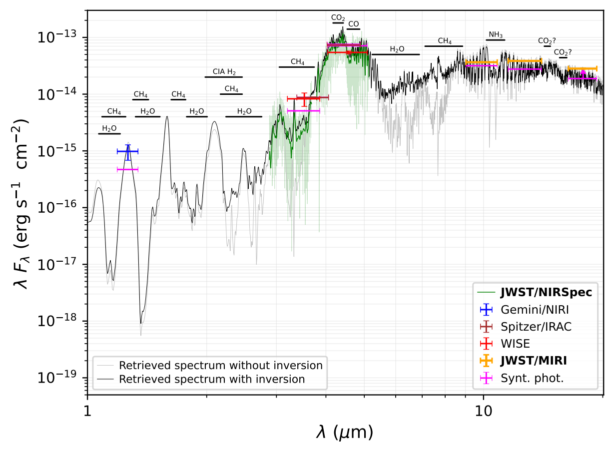


A temperature inversion of ≈200 K in the top (0.1–0.01 bar) atmosphere replicates the absorption feature.

Auroral activity could explain the temperature inversion.

Mid-infrared Prediction from Temperature Inversion

Suárez et al. (2024a, in prep.)



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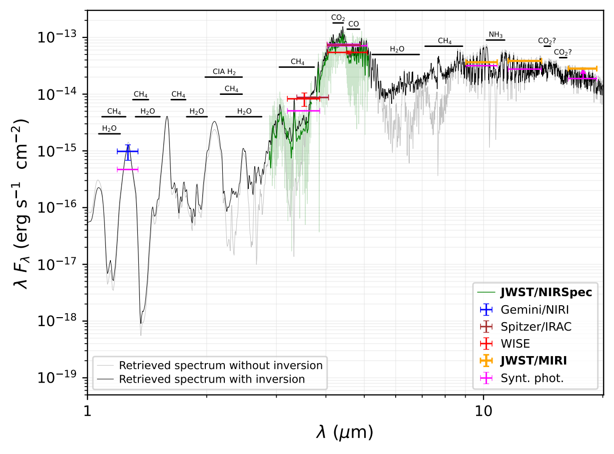

The retrieved spectrum with inversion predicts weaker mid-infrared water, methane, and ammonia features.

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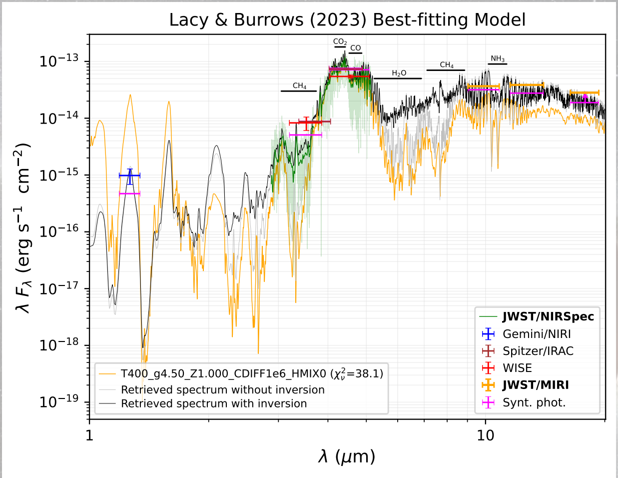

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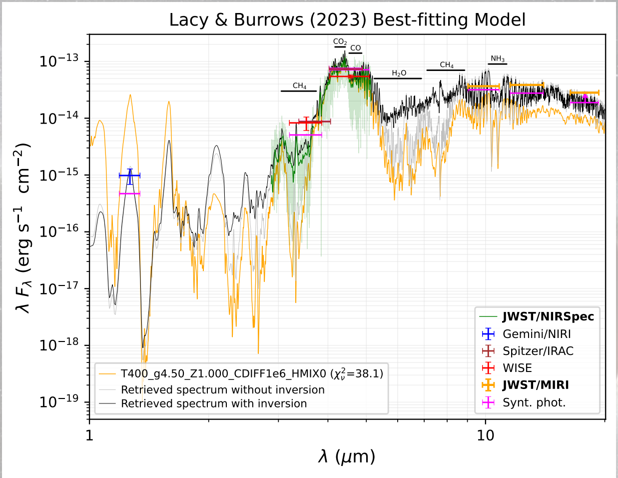

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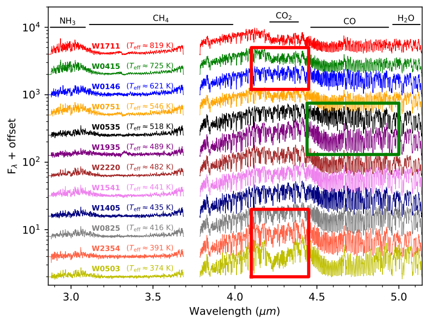
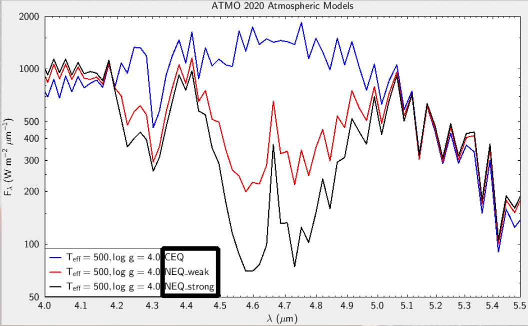
Modern atmospheric models face significat challenges to explain the SED.

Disequilibrium Chemistry or Youth?





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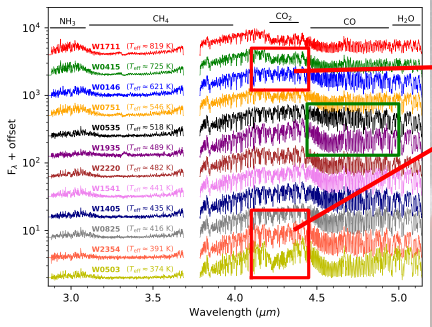

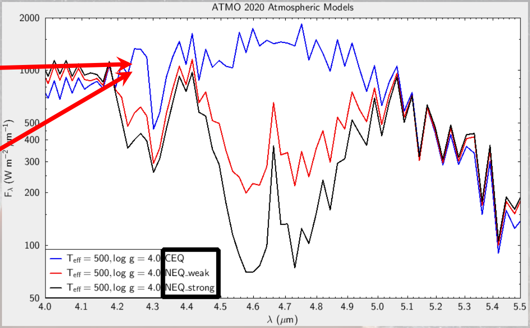

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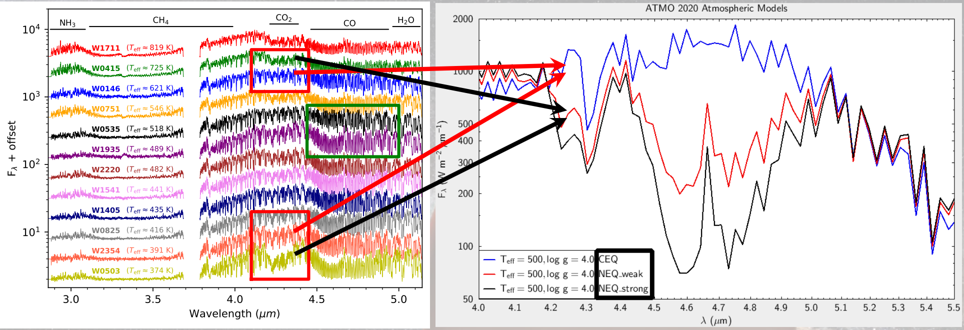

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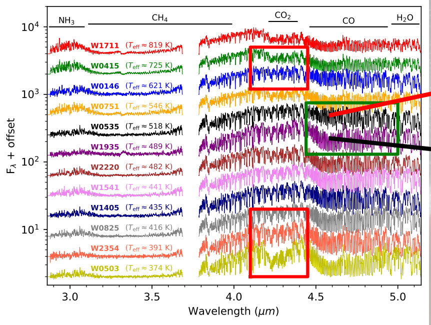

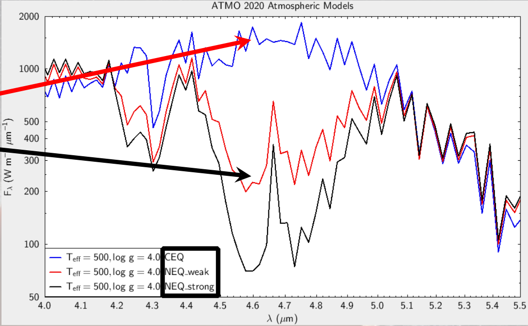

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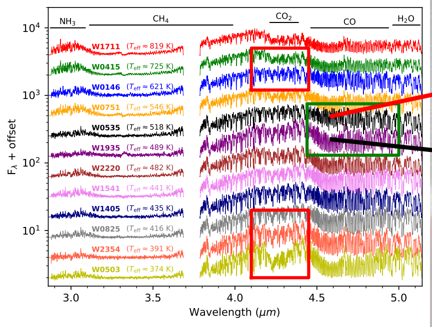

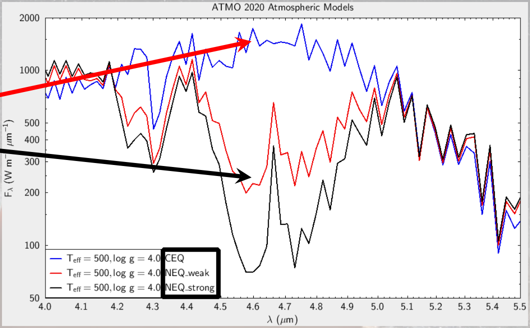

Disquilibrium chemistry significantly influences the ≈4.1–5.0 μm range.

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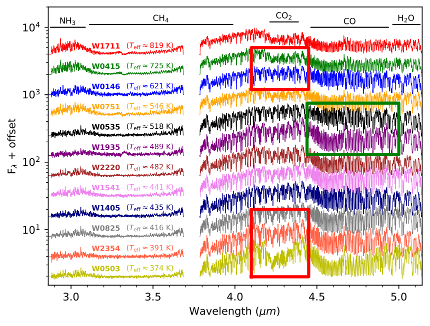

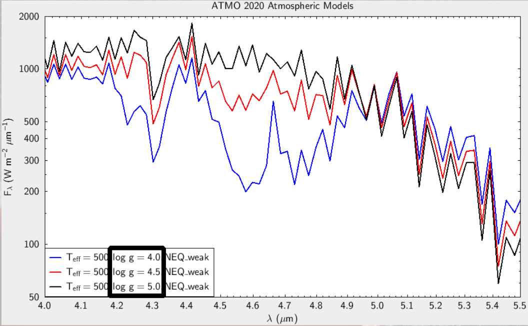

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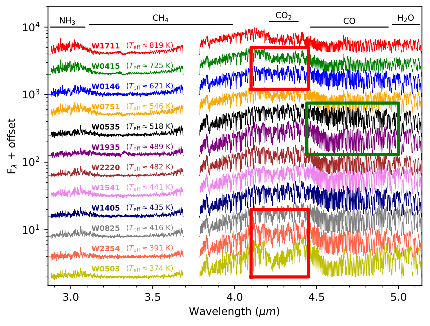
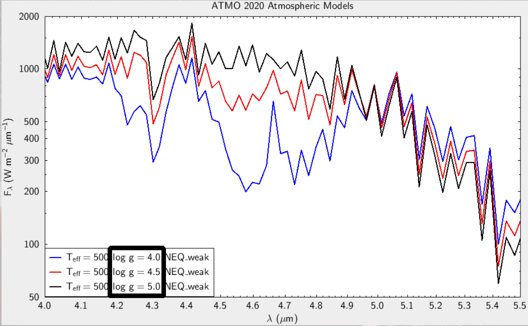


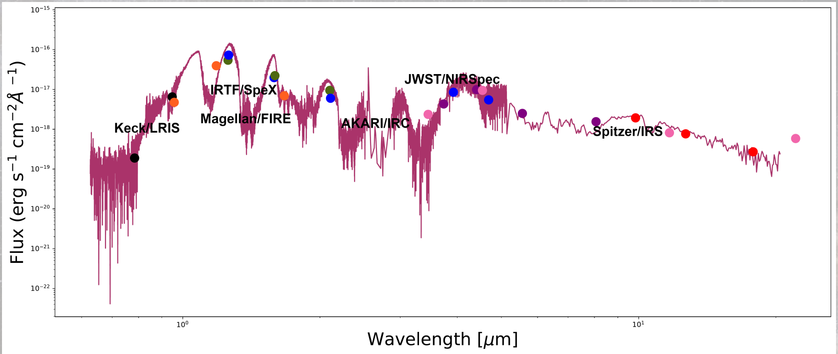


Disquilibrium chemistry significantly influences the ≈4.1–5.0 μm range.

Surface gravity may also affect the IRAC CH2 range but not as much as disequilibrium chemistry.

The Most Comprehensive SED of An Extrasolar Atmosphere

Alejandro Merchan, Faherty, Suárez et al. (2024, in prep.)



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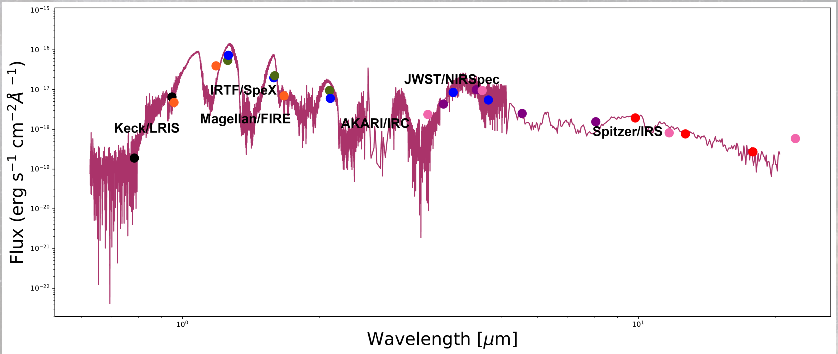

Other comprehensive SEDs of substellar atmospheres:

VHS 1256 b (Miles et al. 2023) and HN Peg B (Suárez et al. 2021).

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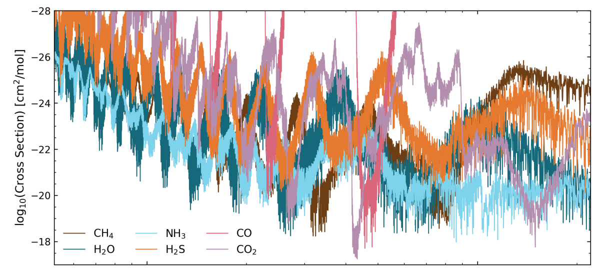
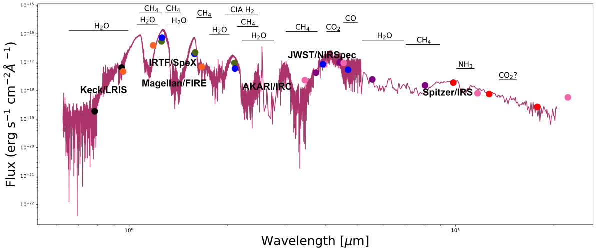
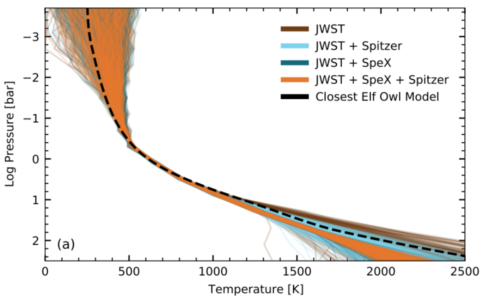




Retrieval Analysis of the Comprehensive SED

Hood et al. (2024, submitted)



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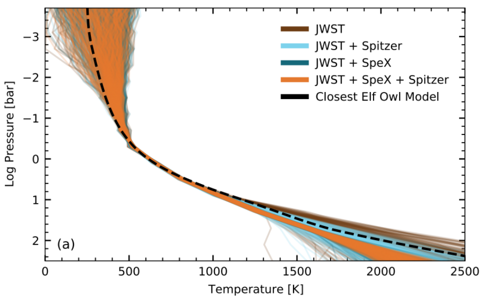

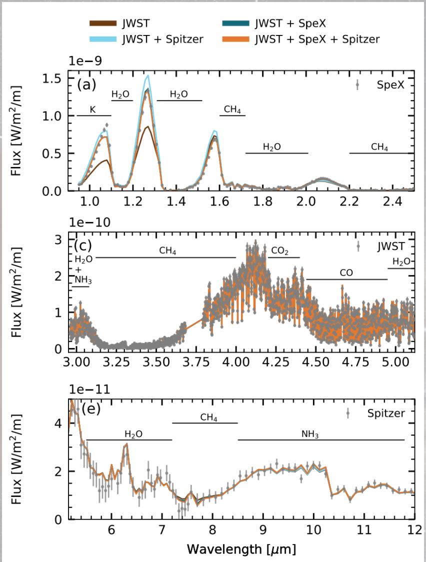

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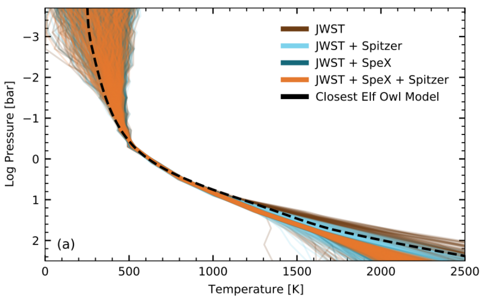
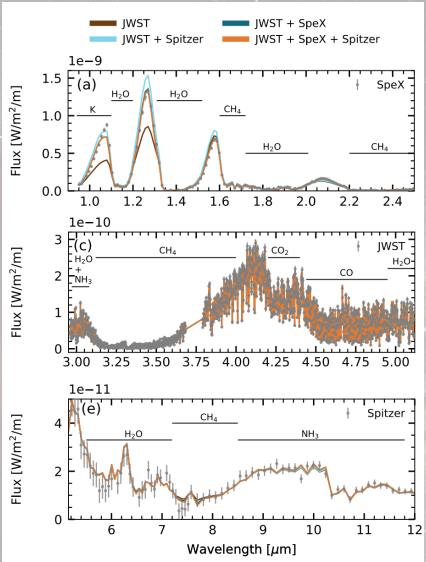
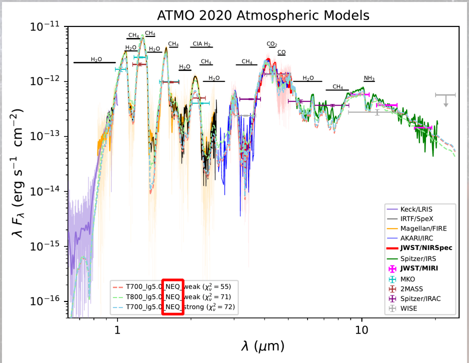




Precise constraints on major chemical abundances, isotopologues, and physical parameters.

Forward Modeling of the Comprehensive SED

Suárez et al. (2024b, in prep.)



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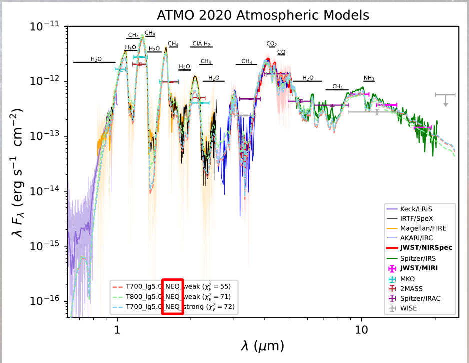

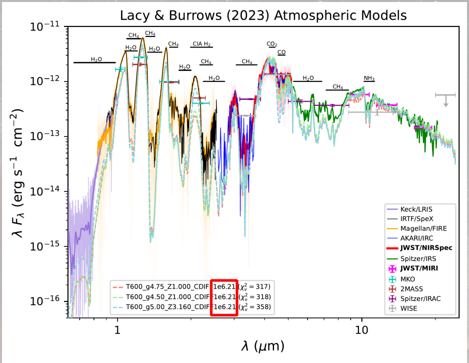

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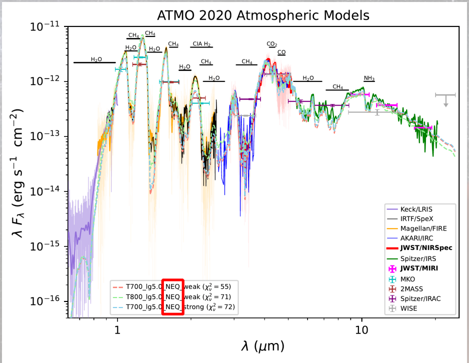

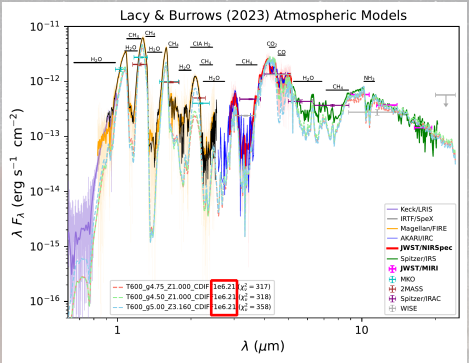

Non-equilibrium chemistry is favored.

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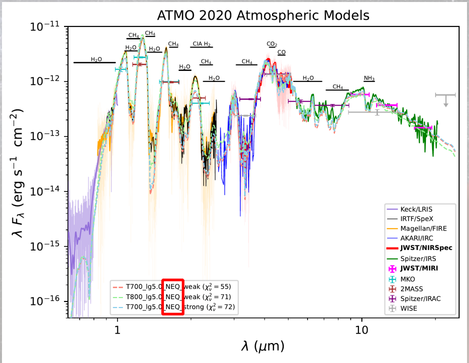

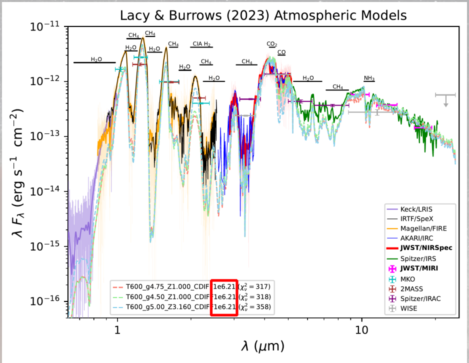

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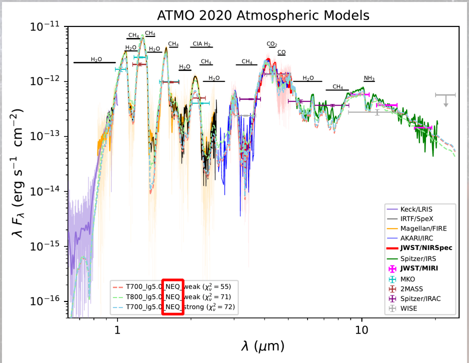
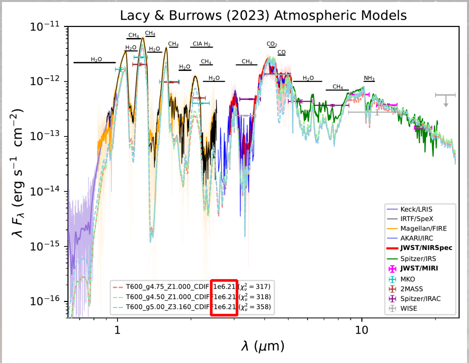
Forward Modeling of the Comprehensive SED

Suárez et al. (2024b, in prep.)





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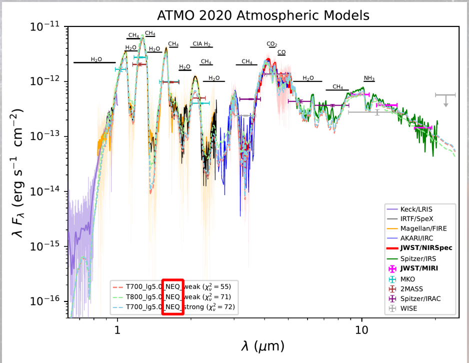

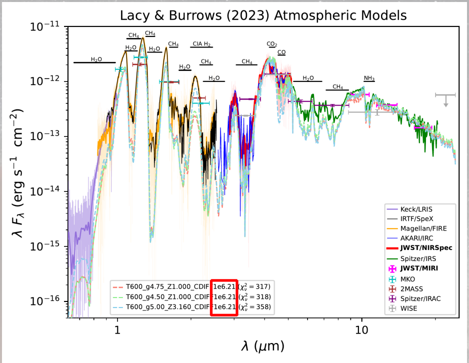

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Thanks for listening!