Mapping the atmosphere of WISE 1049AB

Natalia Oliveros-Gomez

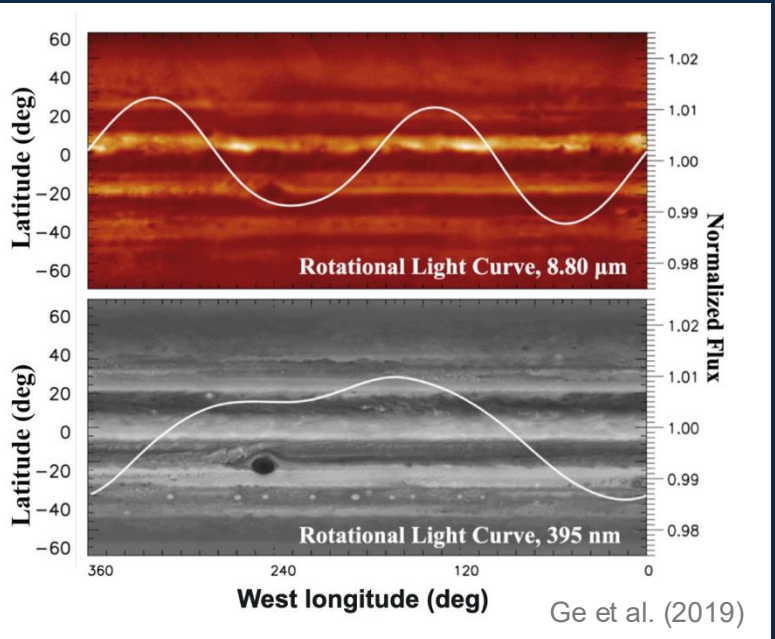
Johns Hopkins University – STScI Fellow
Third year graduate student

Advisor: Elena Manjavacas (STScI)

GO 2965- JWST Weather Report collaboration

Importance to study the variability

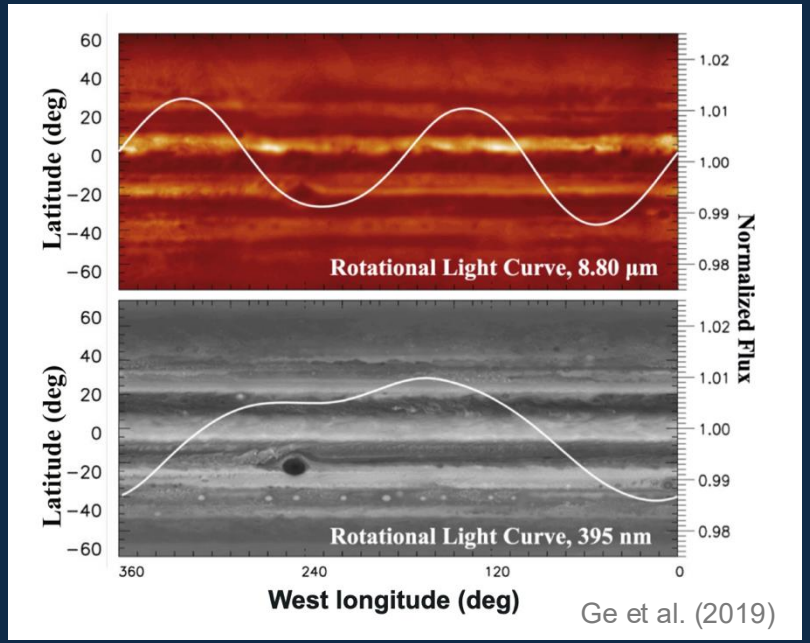
Light curves at
different wavelengths



Ge et al. (2019)

Importance to study the variability

Light curves at different wavelengths → Maps at different Depths of the Brown Dwarf Atmosphere



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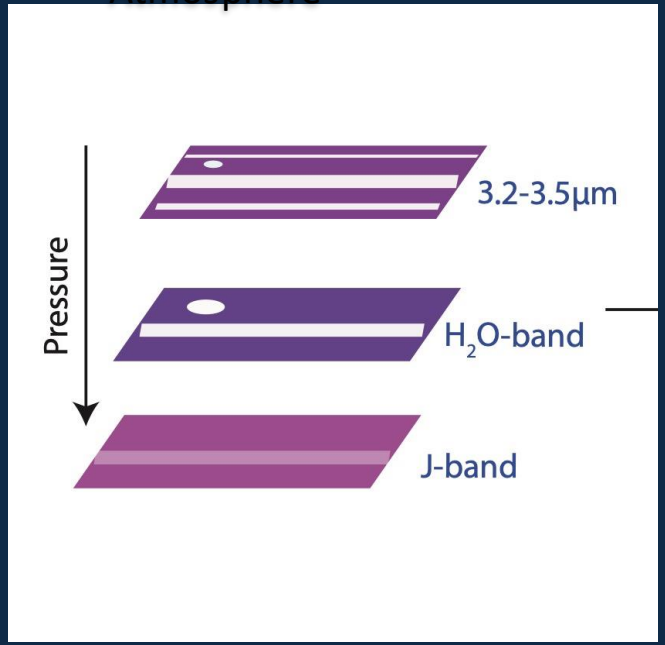
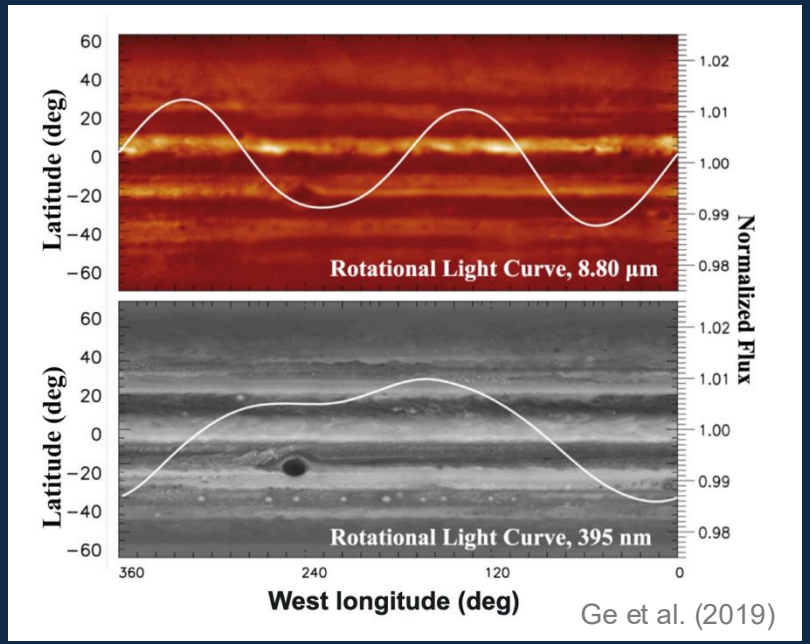


Importance to study the variability

Light curves at different wavelengths → Maps at different Depths of the Brown Dwarf Atmosphere → "Onion-like" 3D Atmospheric Map



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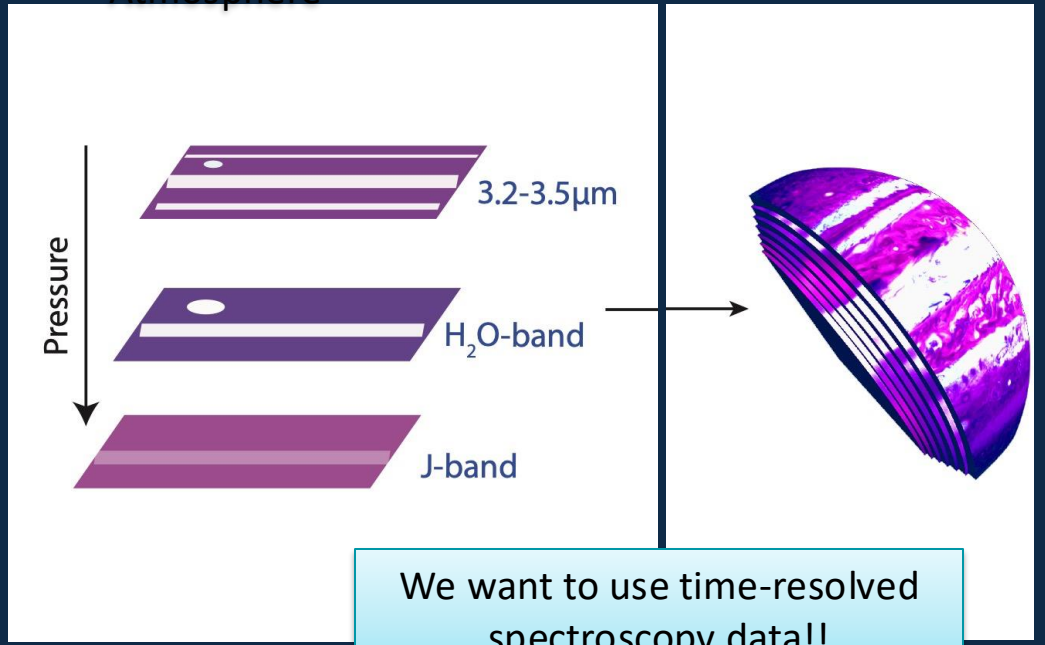
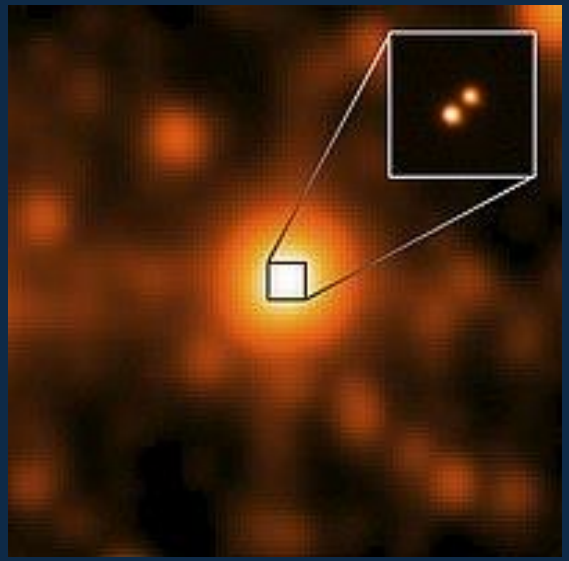


We want to use time-resolved spectroscopy data!!

WISE 1049 AB

Brighter and Closer system

L/T transition:
Primary is L7.5
Secondary is T0.5



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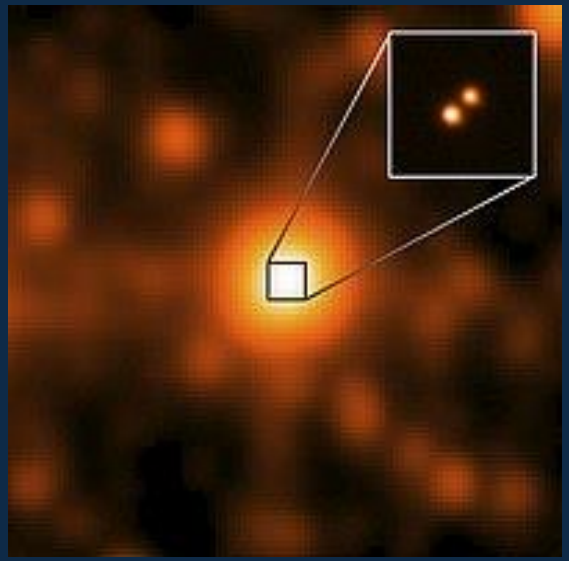
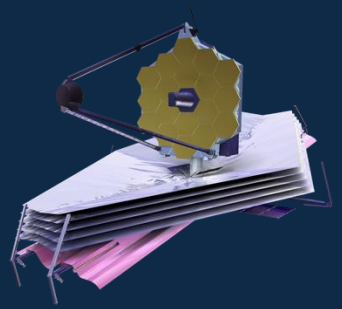


ID	Program Title	PI & Co-PIs	Exclusive Access Period (months)	Prime/ Parallel Time (hours)	Instrument/ Mode
2965	Clouds or Chemistry?: Pinpointing the drivers of variability across the L/T transition via the benchmark L/T binary WISE 1049AB	PI: Beth Biller	12	19.34/0	MIRI/LRS NIRSpec/BOTS



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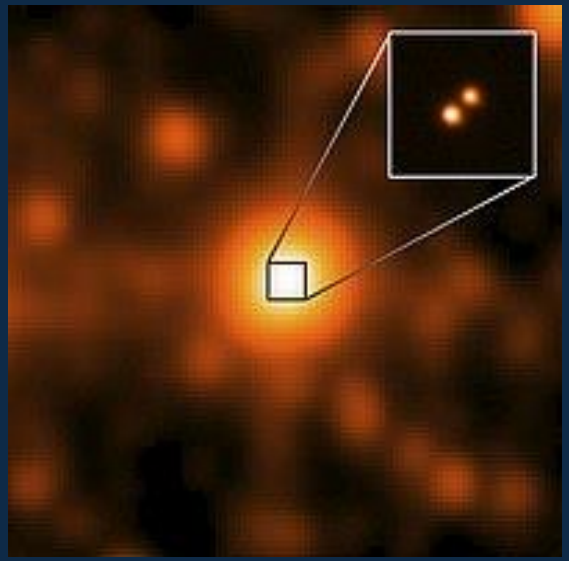

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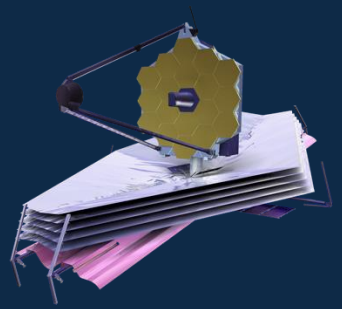

Time – resolved Spectroscopy
MIRI → 8h
NIRSpec → 8h
(57000 spectra)

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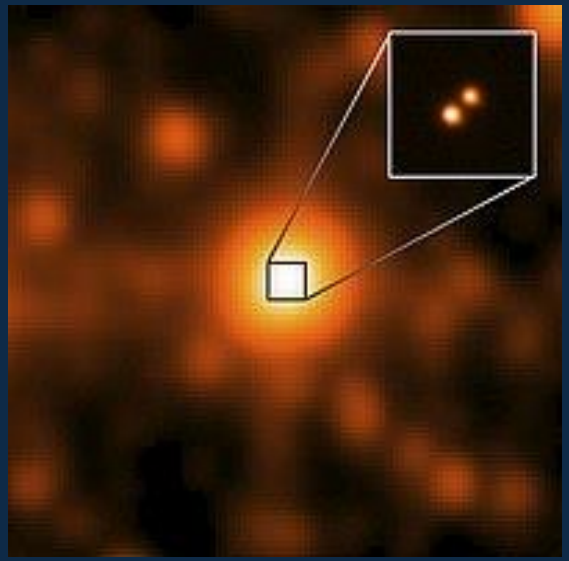

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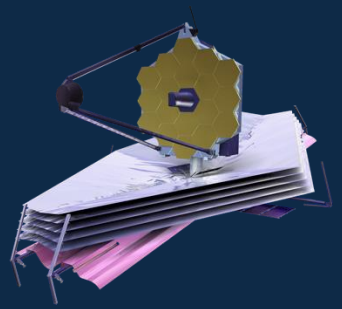

JWST reveals the Weather on the Nearest Brown Dwarfs I: multi-period NIRSpec + MIRI monitoring of the benchmark binary brown dwarf WISE 1049AB

Beth A. Biller[1,2]*, Johanna M. Vos[3], Yifan Zhou[4], Allison McCarthy[5], Xianyu Tan[6,7], Ian J.M. Crossfield[8], Niall Whiteford[9], Genaro Suarez[9], Jacqueline Faherty[9], Elena Manjavacas[10,11], Xueqing Chen[1,2], Pengyu Liu[1,2,12], Ben J. Sutlieff[1,2], Mary Anne Limbach[13], Paul Molliere[14], Trent Dupuy[1,2], Natalia Oliveros-Gomez[11], Philip Muirhead[5], Thomas Henning[14], Greg Mace[15], Nicholas Crouzet[12], Theodora Karalidi[16], Pascal Tremblin[17], Tiffany Kataria[18]

Time – resolved Spectroscopy
MIRI → 8h
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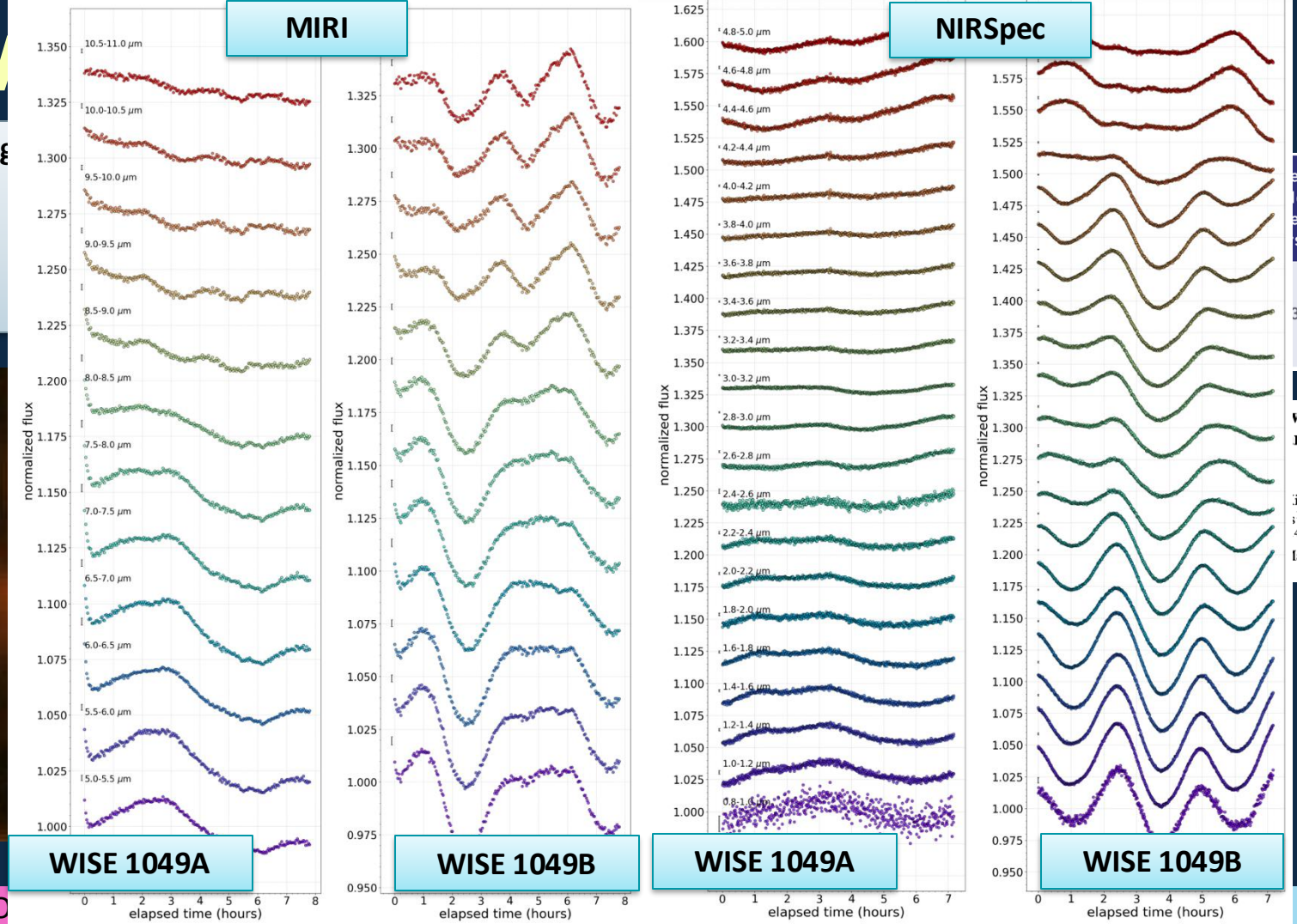
(57000 spectra)

Biller et al. (2024)
Chen et al. (2025)



Instrument/ Mode

MIRI/LRS
NIRSpec/BOTS

varfs I: multi-period
ry brown dwarf WISE

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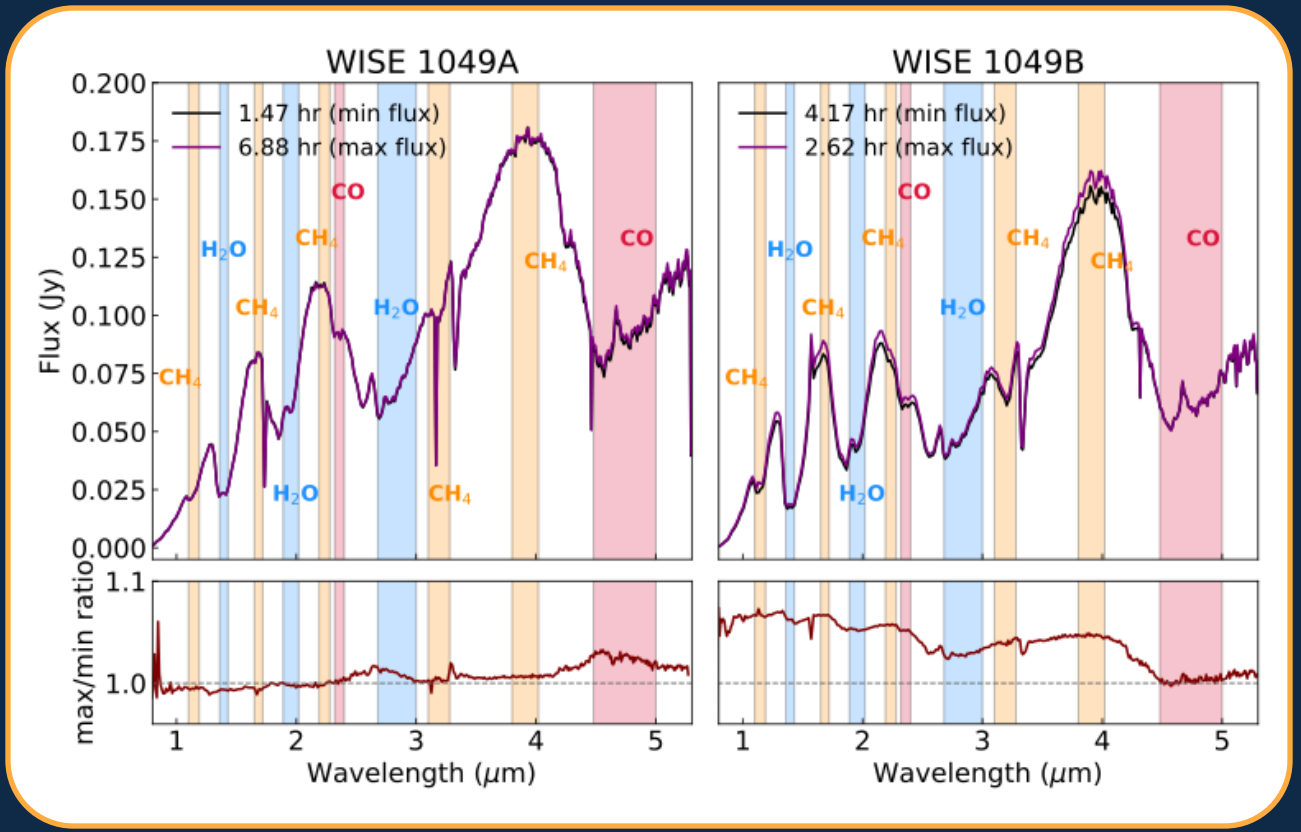
Time-resolved spectroscopy

Oliveros-Gomez + under review



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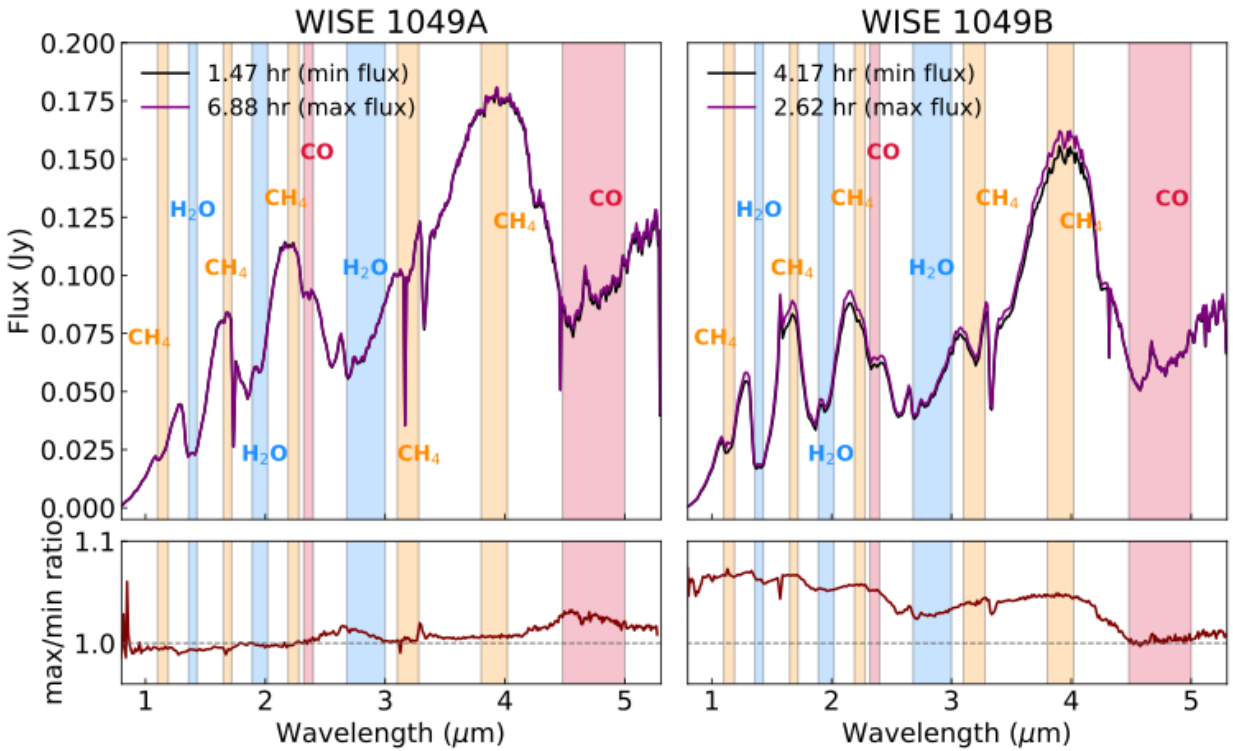

We follow the same scheme of color all the presentation

Time-resolved spectroscopy

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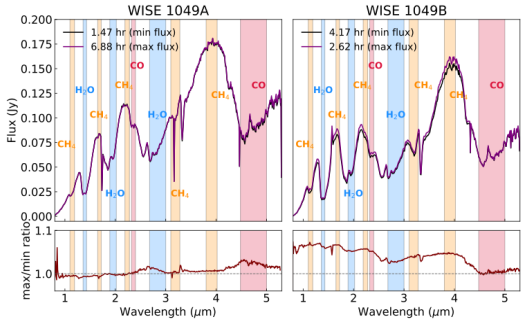

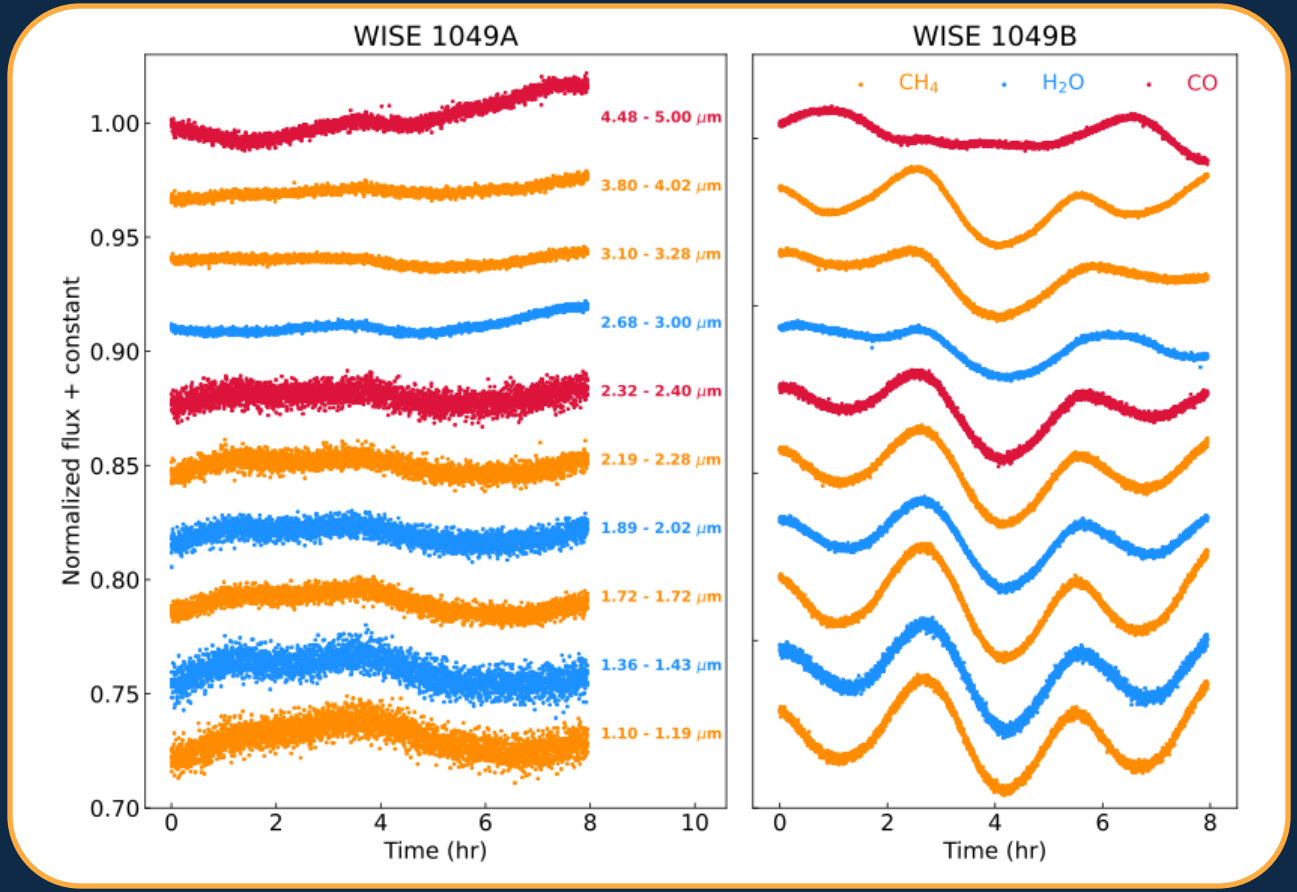

1

We use planetary-scale waves to explain possible bands or sports of clouds

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Fit sinusoidal functions

$$\sum_{i=1}^{6} A_i \sin\left(\frac{2\pi}{P_i} + \phi_i\right) + offset$$

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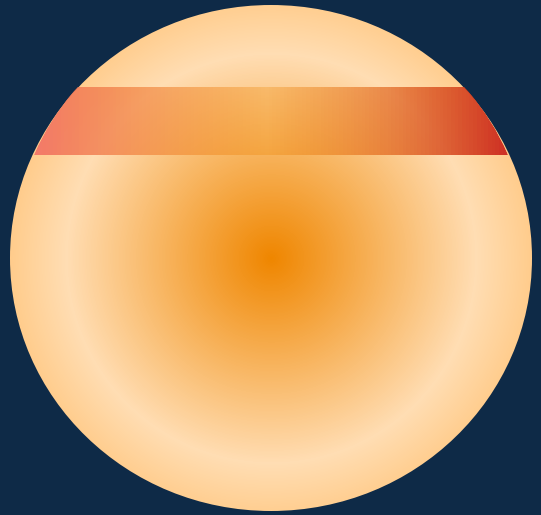
Best fit - 1 sin



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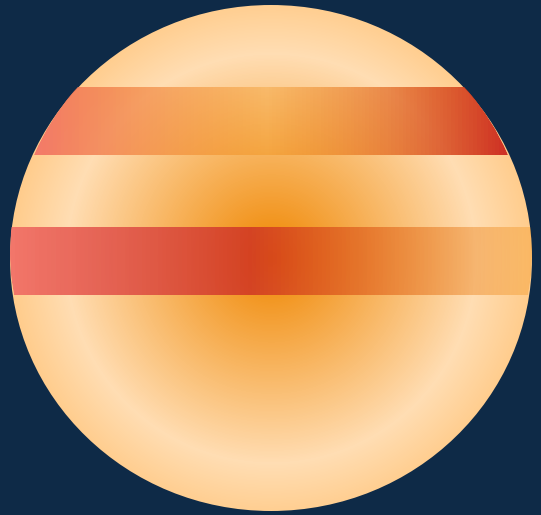
Best fit - 1 sin

Best fit - 2 sin



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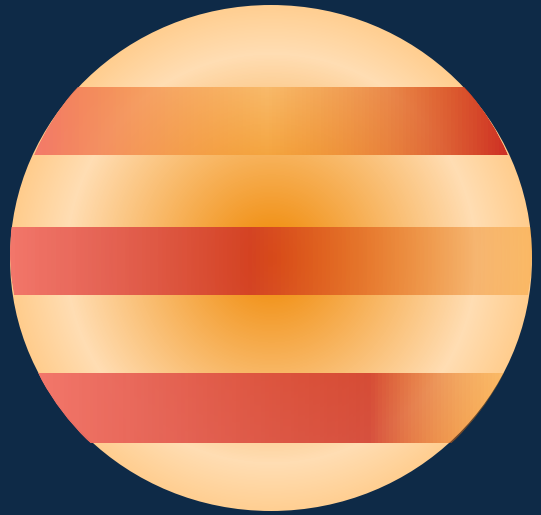
Best fit - 3 sin



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2

Dependence at different depths

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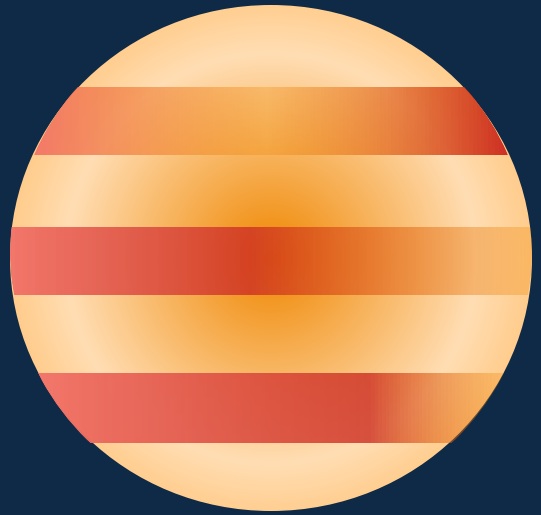

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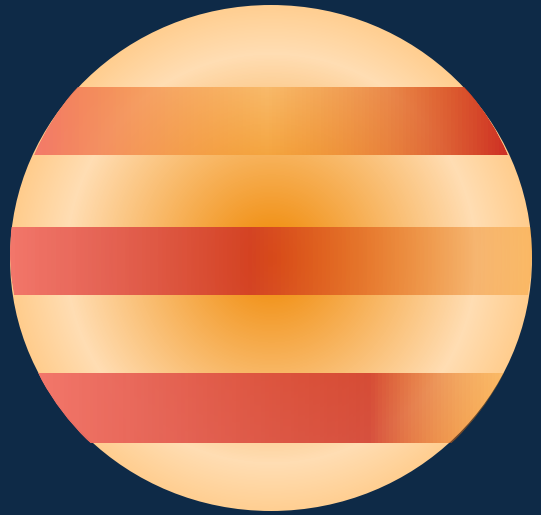


2

Dependence at different depths

We analyze how change the variability for the different molecular features at different regions of the atmosphere

CH_4

H_2O

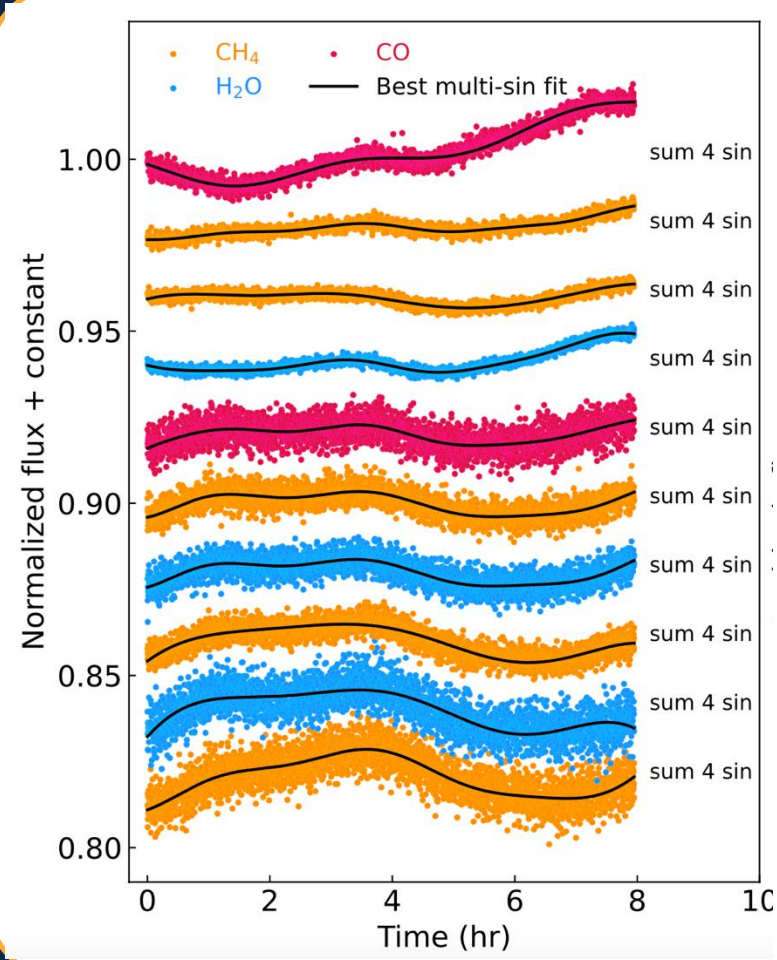
CO

1

A object (L 7.5)

All best fits:

4 sin



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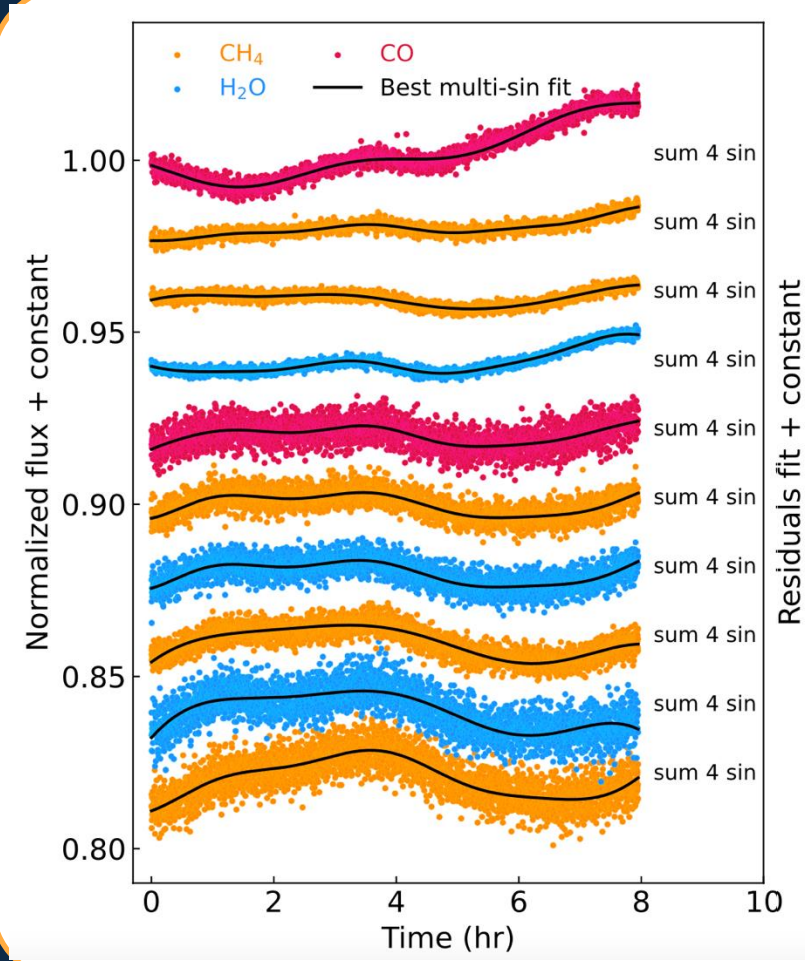
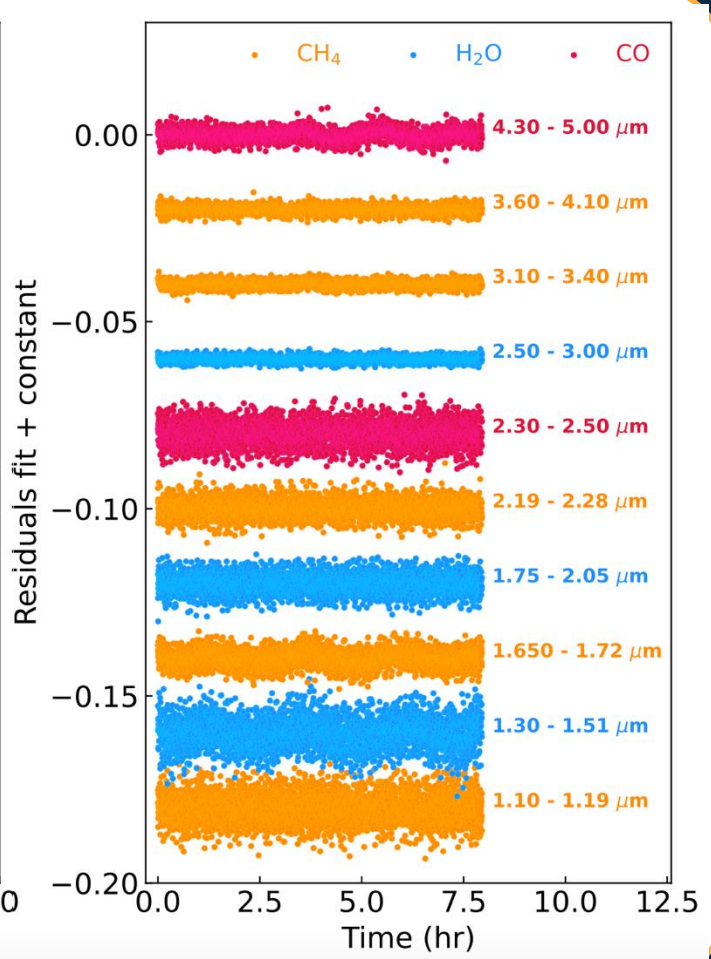
4 sin

Flat residuals



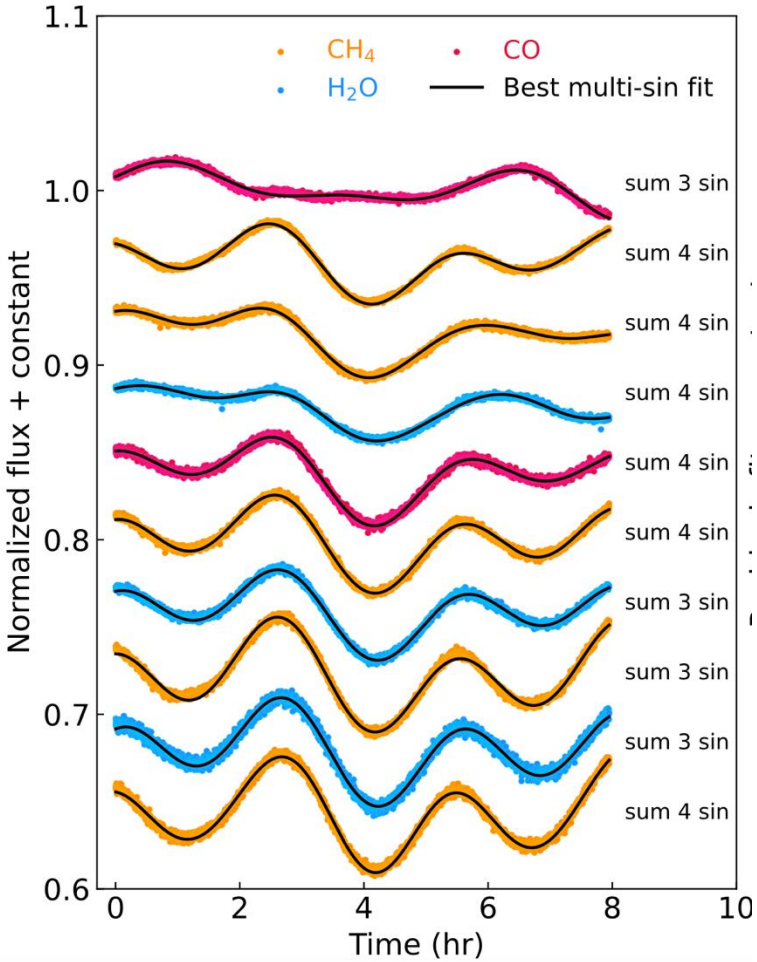


1

B object (T 0.5)

Best fits:

3 or 4 sin



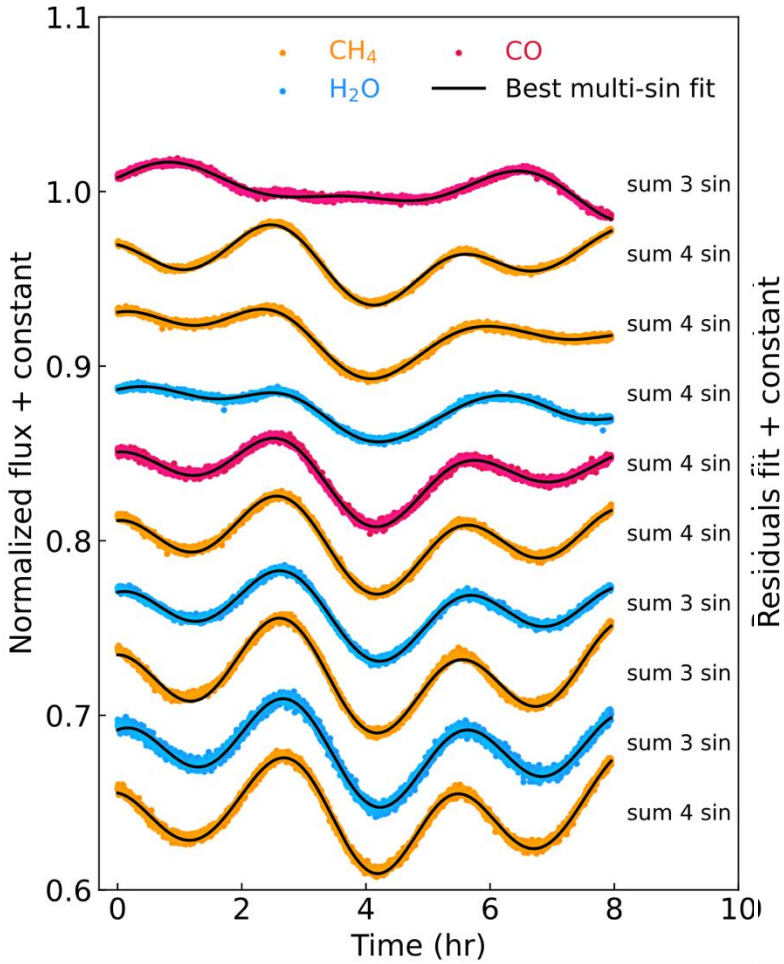
1

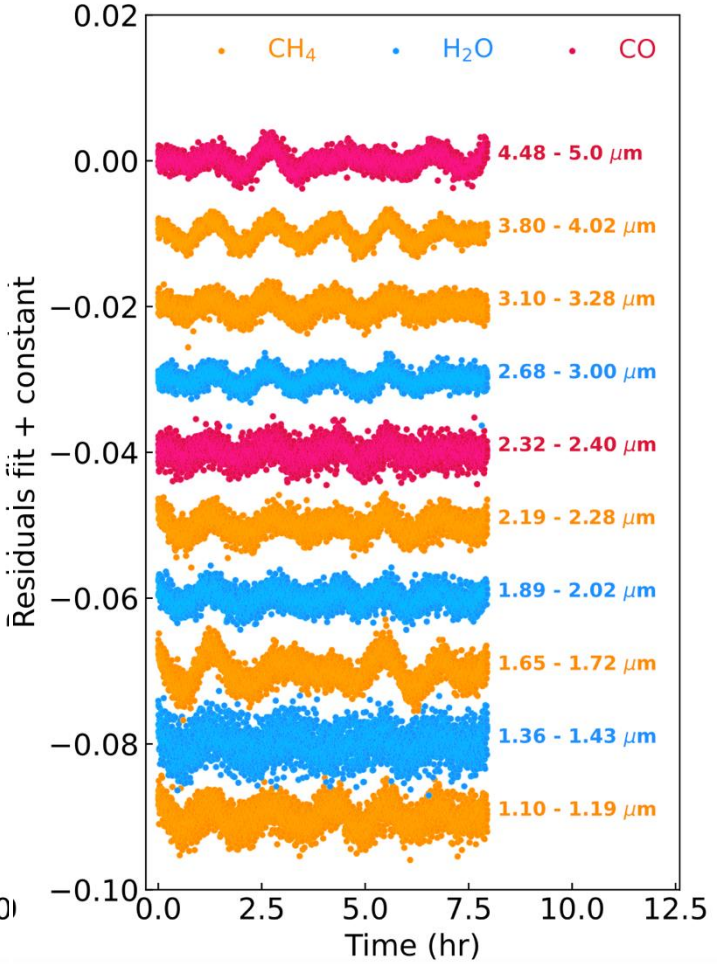
B object (T 0.5)

Best fits:

3 or 4 sin

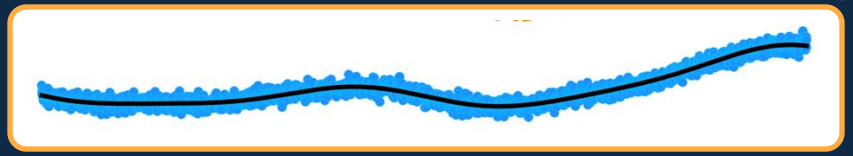
Not flat residuals





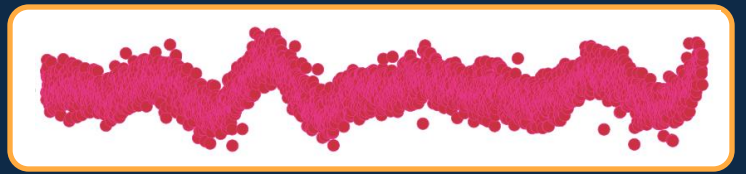
Summary

sinusoidal functions → # planetary-scale waves

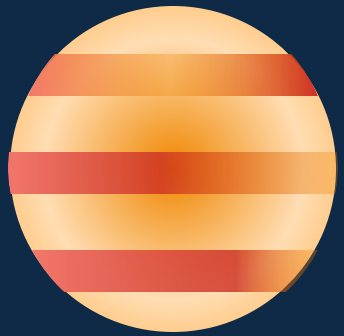


Fit

Residual



A object (L 7.5)



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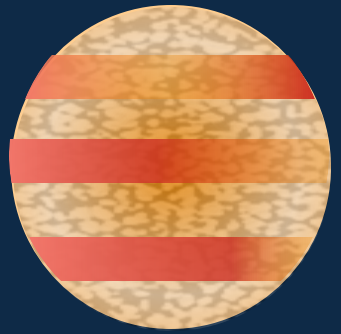

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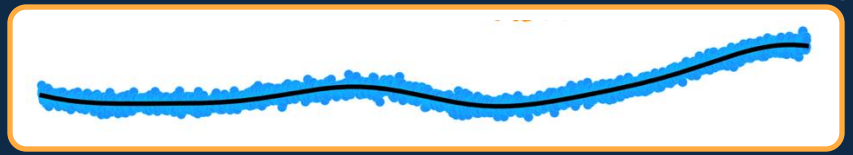

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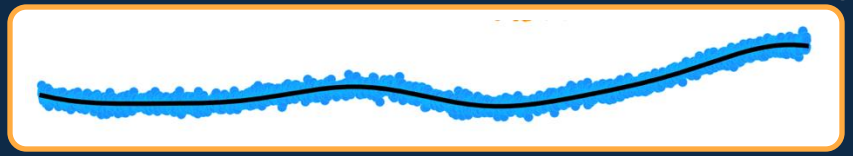

Fit

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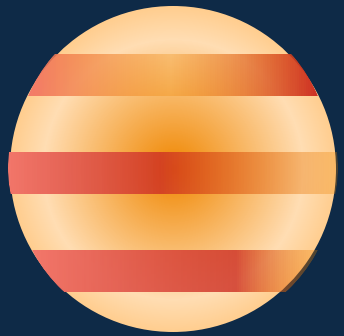

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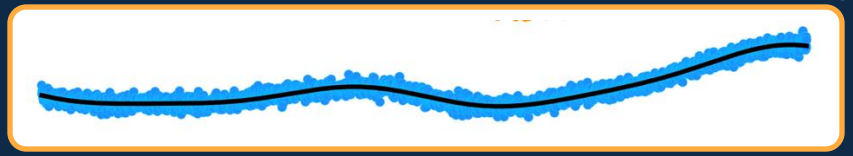

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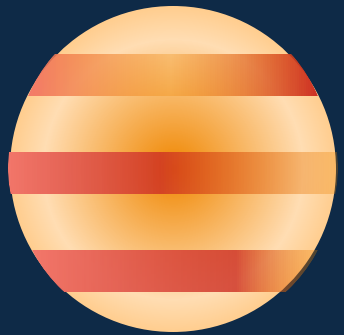

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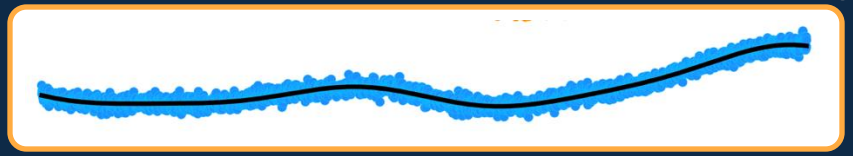

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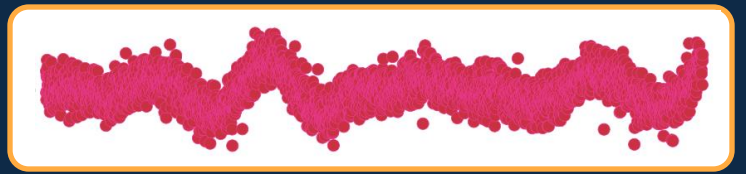

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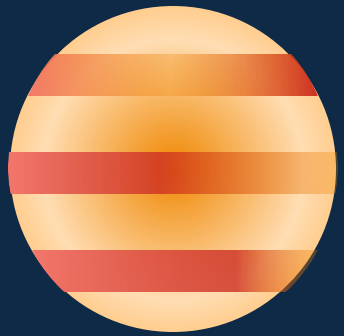

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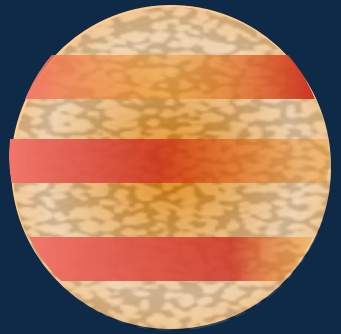
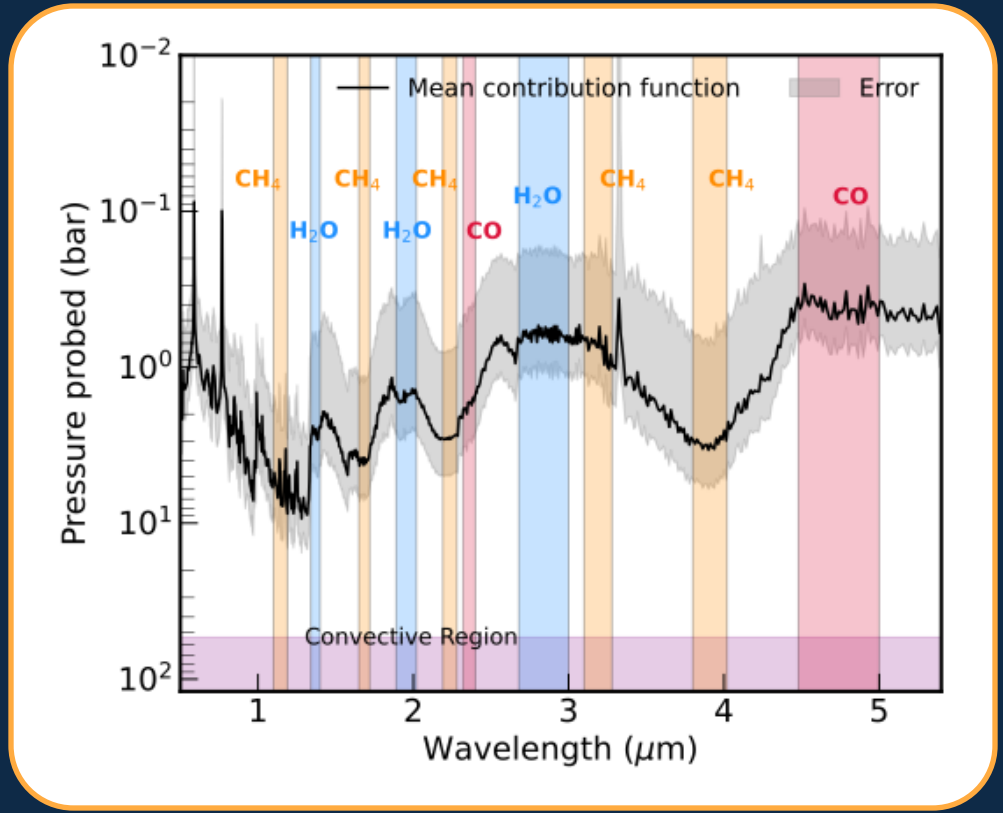


2

Contribution function

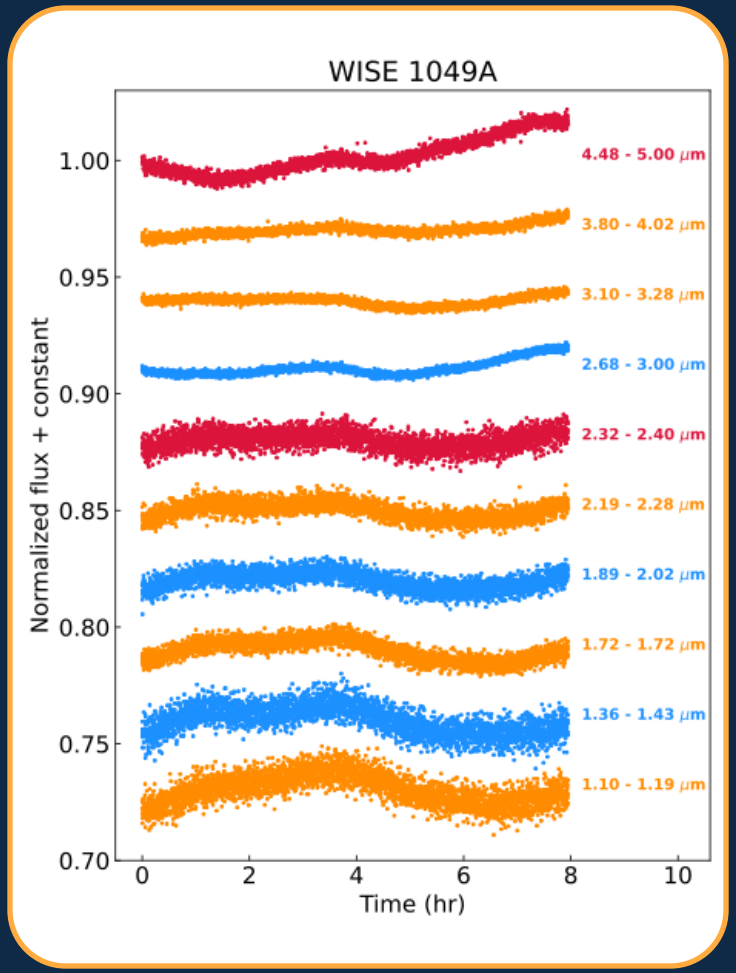


Modeled by picaso

Cloudy atmosphere

T_{eff}=1300K
logg=5dex
f_{sed}=2

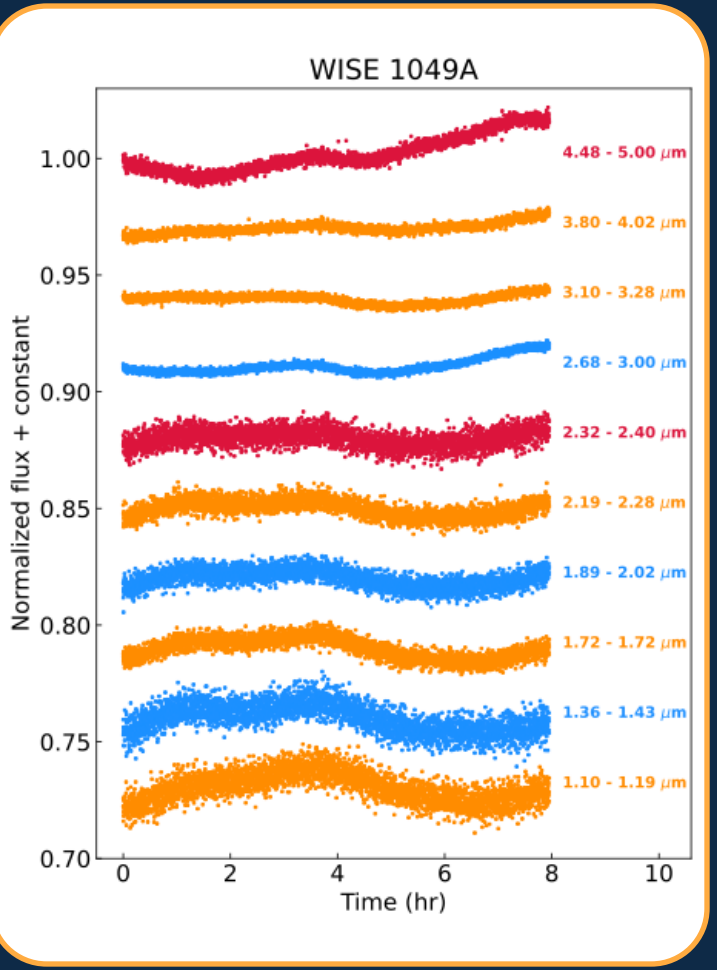
Oliveros-Gomez +



Contribution function

A object (L 7.5)

Oliveros-Gomez + under



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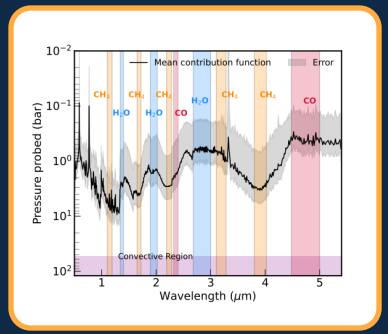

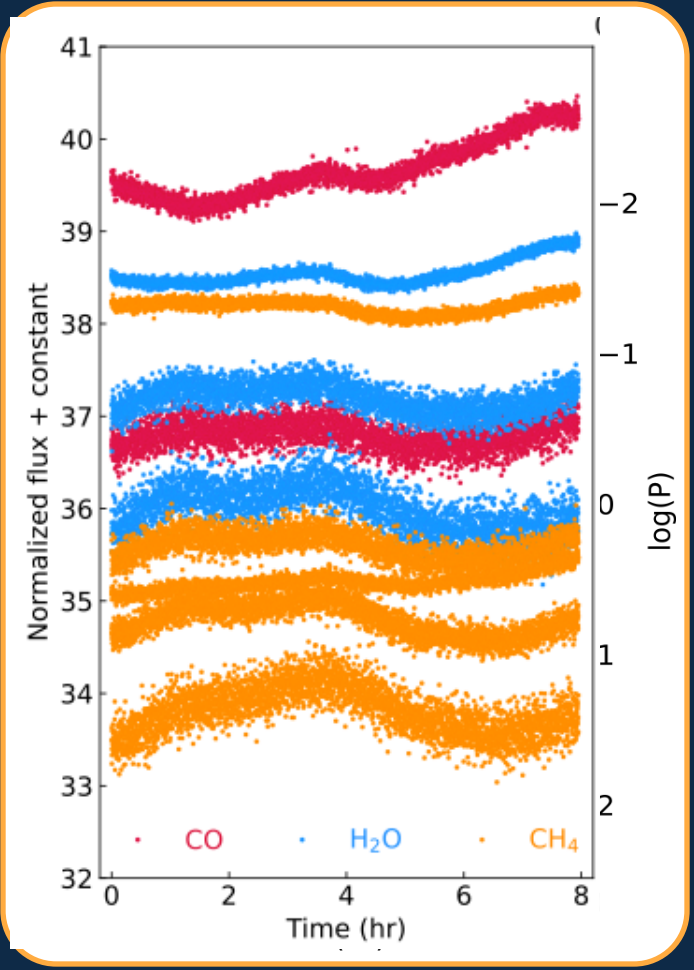

Oliveros-Gomez + under

Analysis

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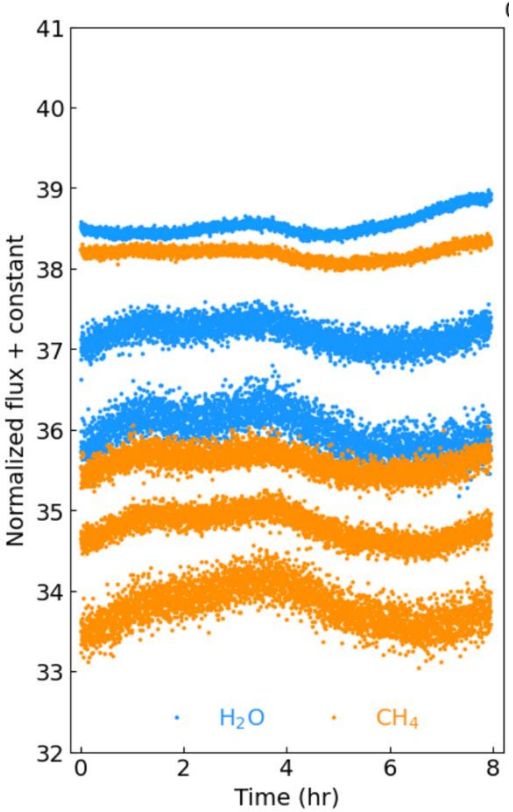
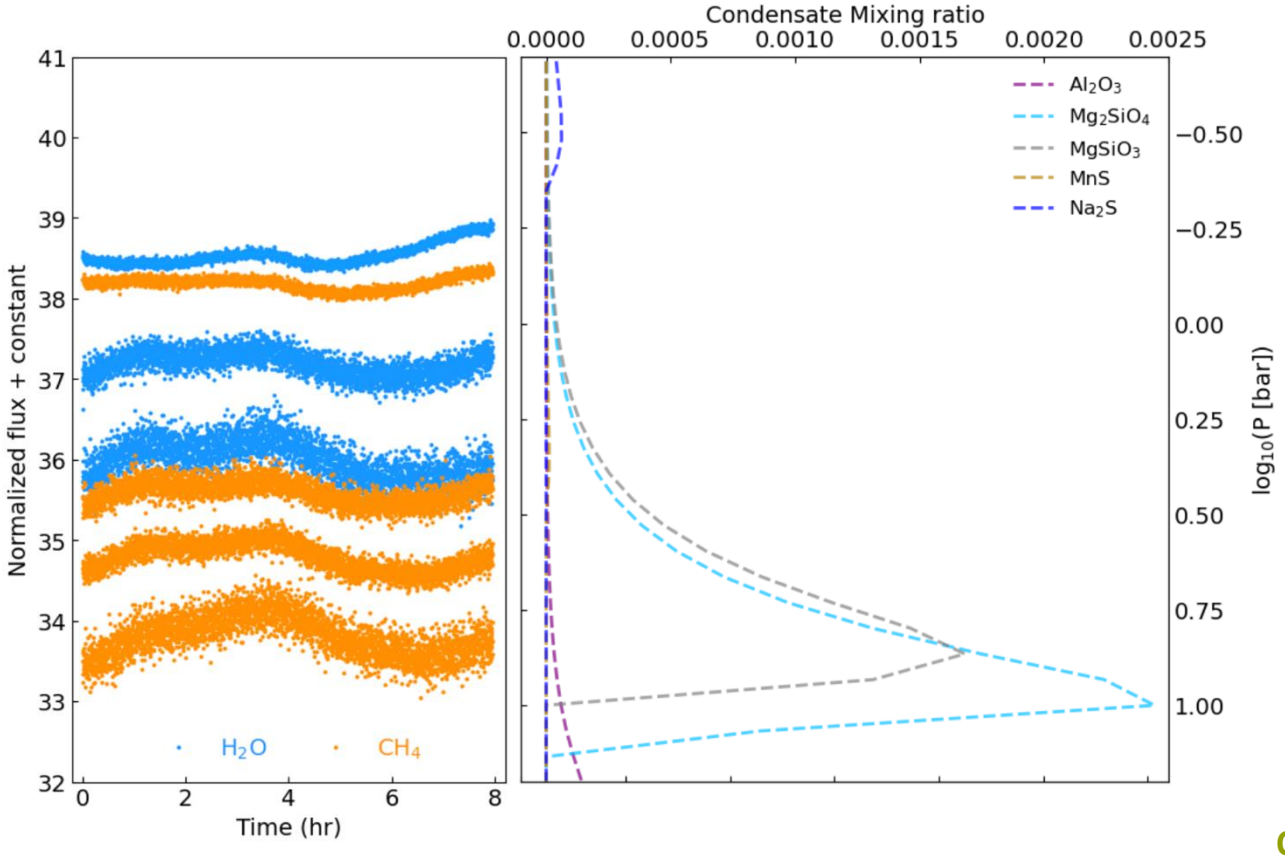


Oliveros-Gomez + submitted

Analysis

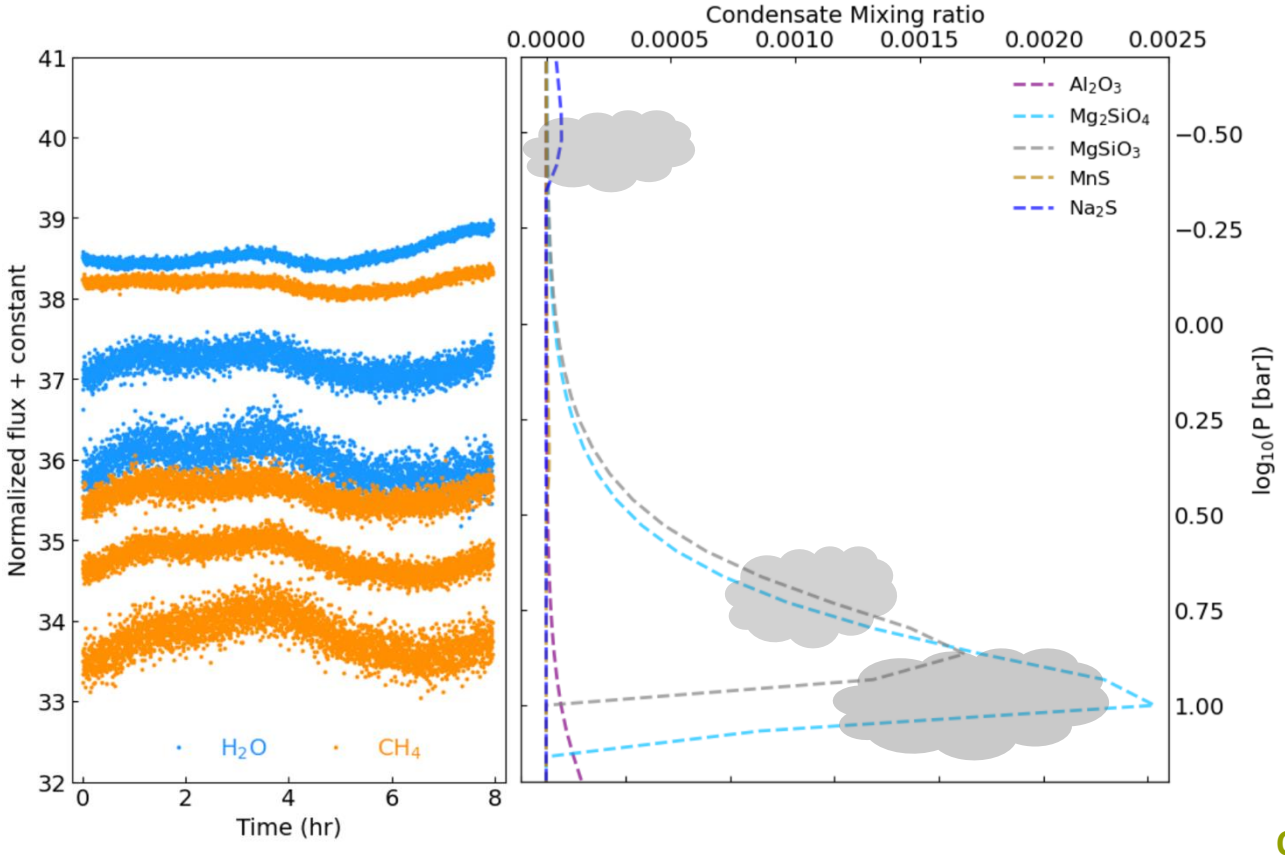
A object (L 7.5)



Oliveros-Gomez + submitted

Analysis

A object (L 7.5)

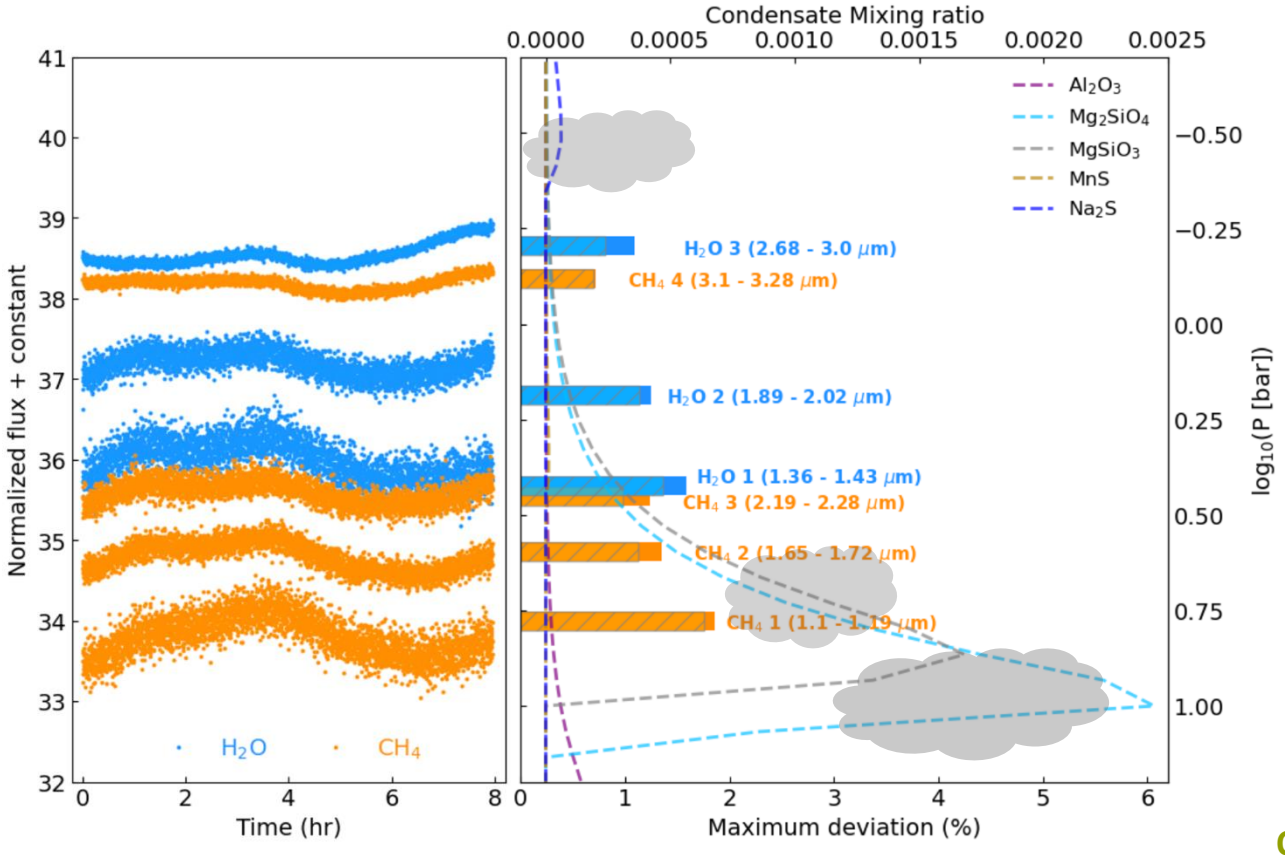


Oliveros-Gomez + submitted

Analysis

-- Clouds explain the variability

A object (L 7.5)

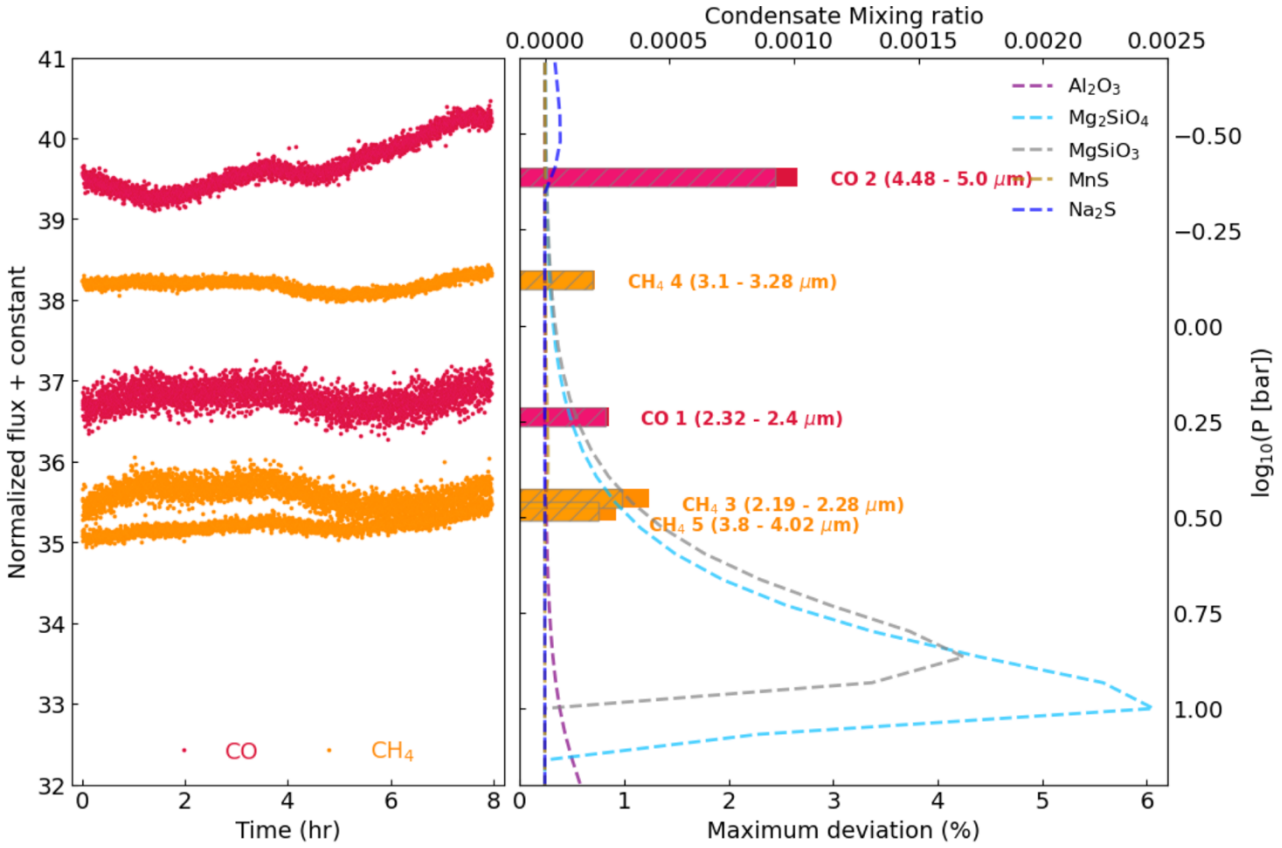


Variability increase with the depth

Oliveros-Gomez + submitted

Analysis

A object (L 7.5)

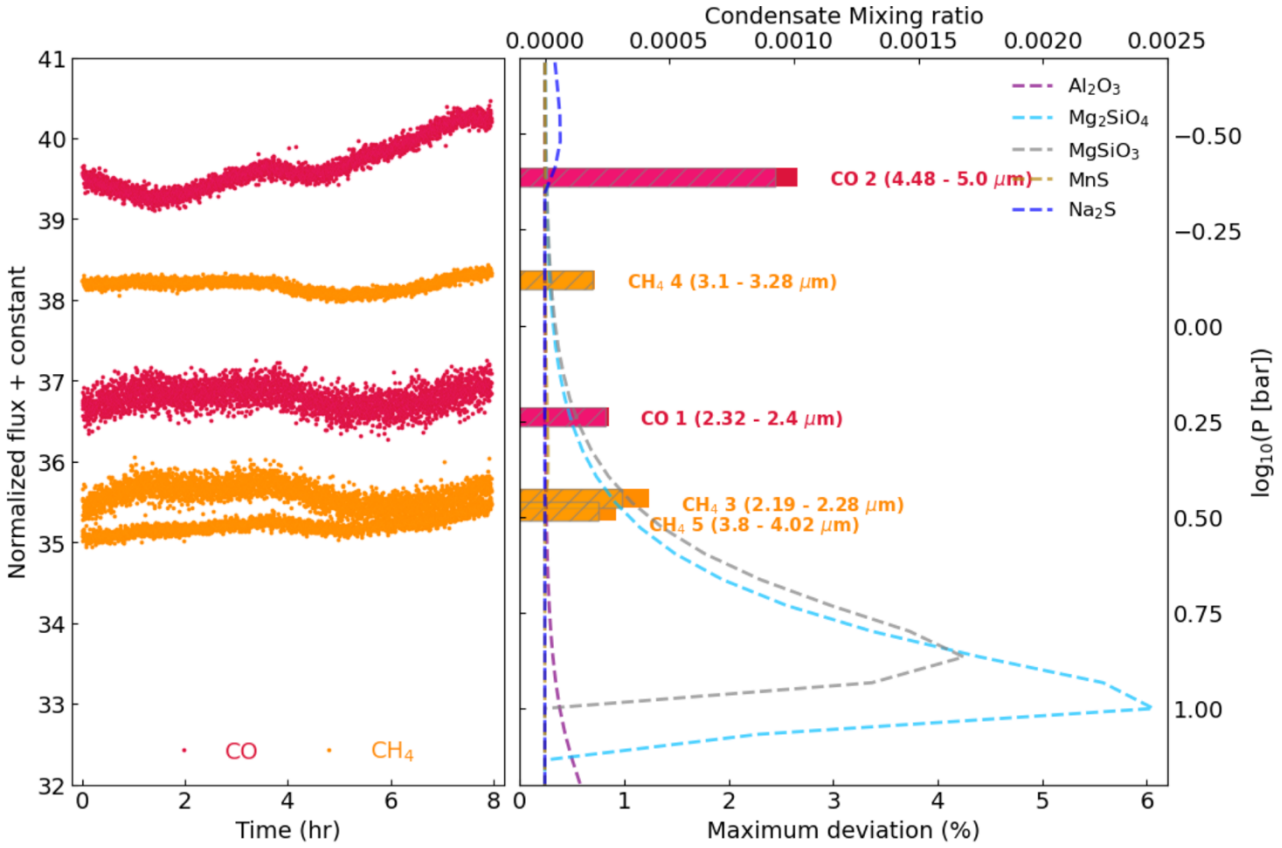


Oliveros-Gomez + submitted

Analysis

What happened here?

A object (L 7.5)

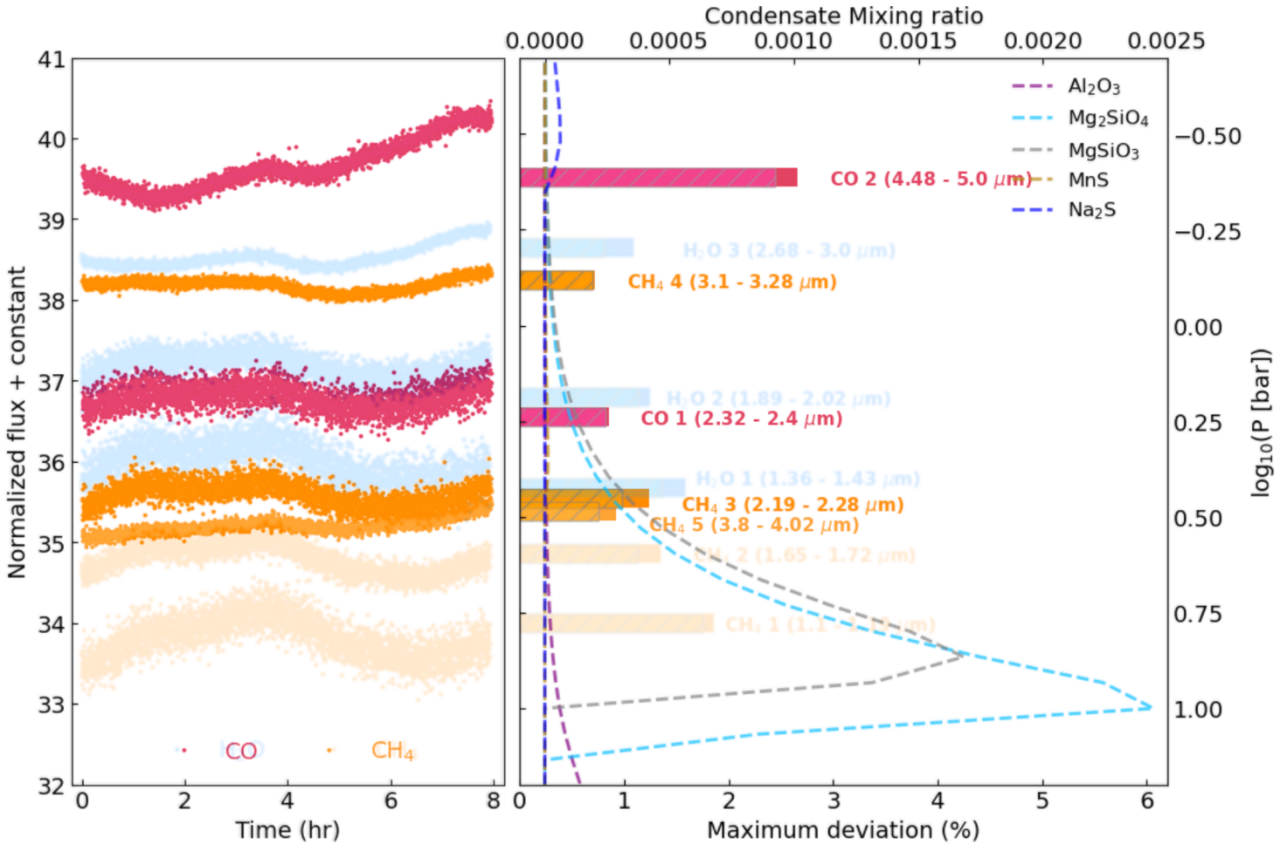


Oliveros-Gomez + submitted

Analysis

What happened here?

A object (L 7.5)



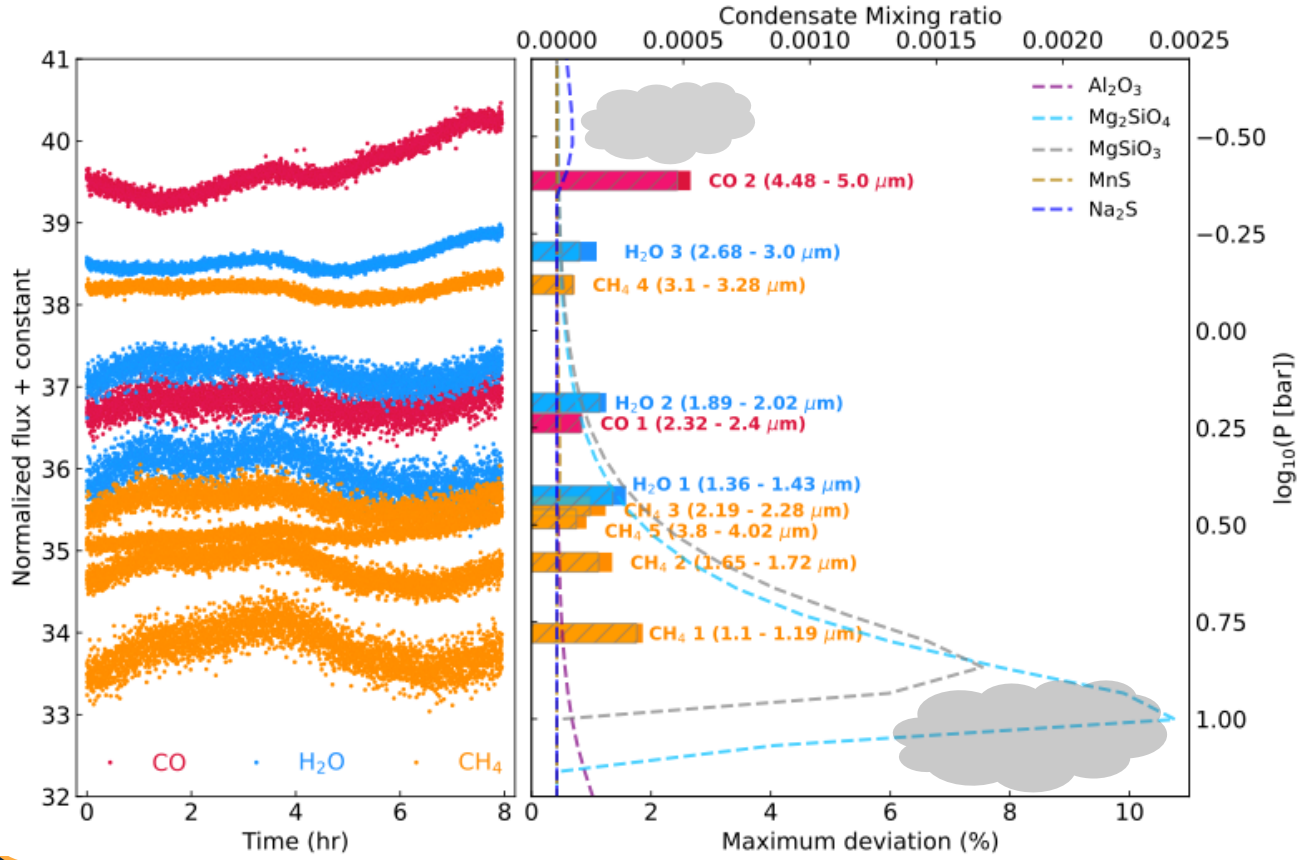
Thermochemical instabilities? Disequilibrium chemistry?

CO/CH4 Radiative convection?

Oliveros-Gomez + submitted

Analysis

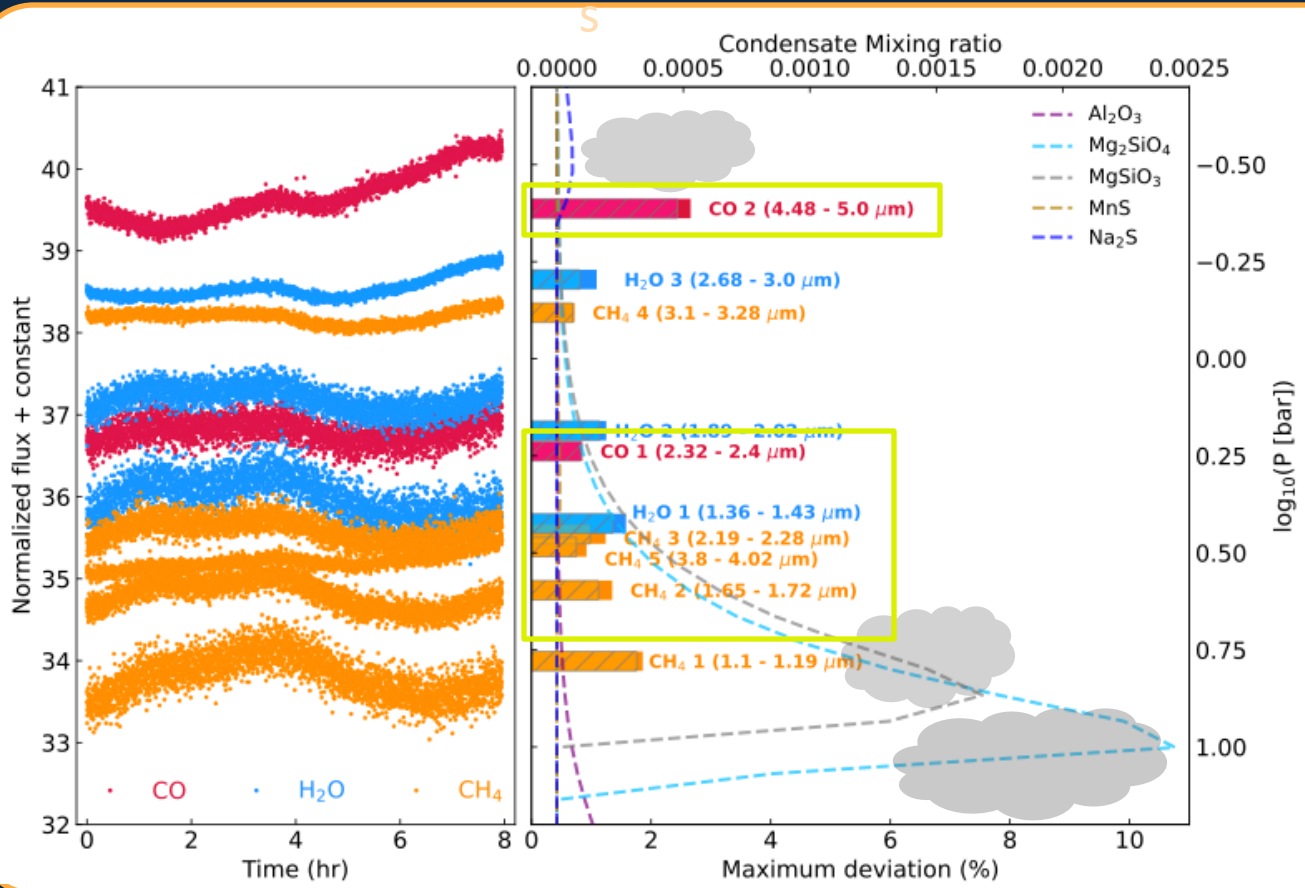
A object (L 7.5)



Oliveros-Gomez + submitted

Analysis

Cloud + Disequilibrium chemistry? **A object (L 7.5)**



The first observational evidence –using variability data- of thermochemical instabilities?

Oliveros-Gomez + submitted

Discussion

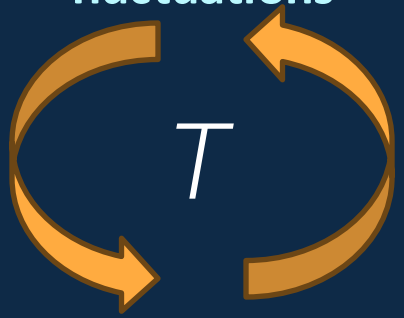
What say the models?

Clouds

Sonora models
Morley + 2024

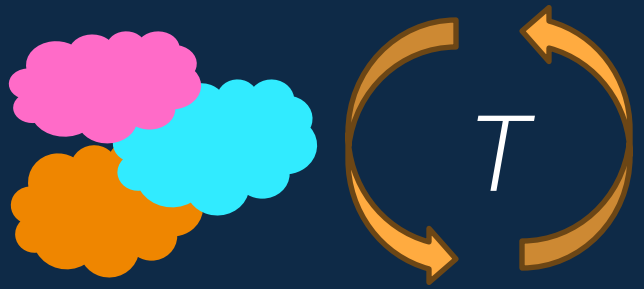
Desequillibrium chemistry

Thermochemical fluctuations



Tremblin + 2016

Clouds feedback



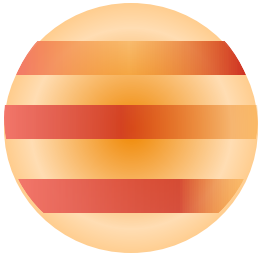
Lee + 2024

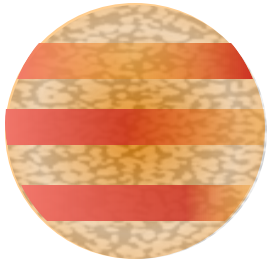
Our results are observationals and they are consistents with the models

Conclusions!!

Oliveros-Gomez +

We can infer cloudy structures using planetary-waves



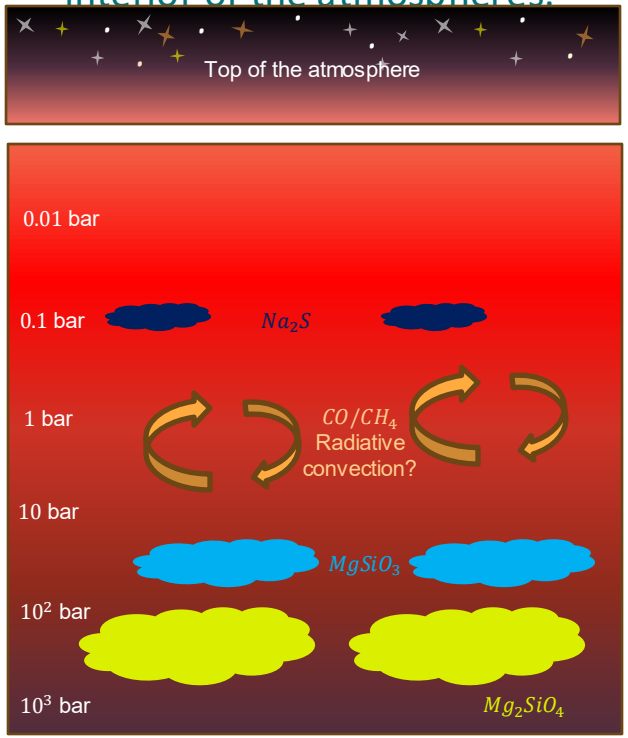


We need more than 1 rotation to extract more physical characteristics

Spectro-photometric variability

Clouds + Thermochemical instabilities?

We can approach to understand the physics about, what happened in the interior of the atmospheres.

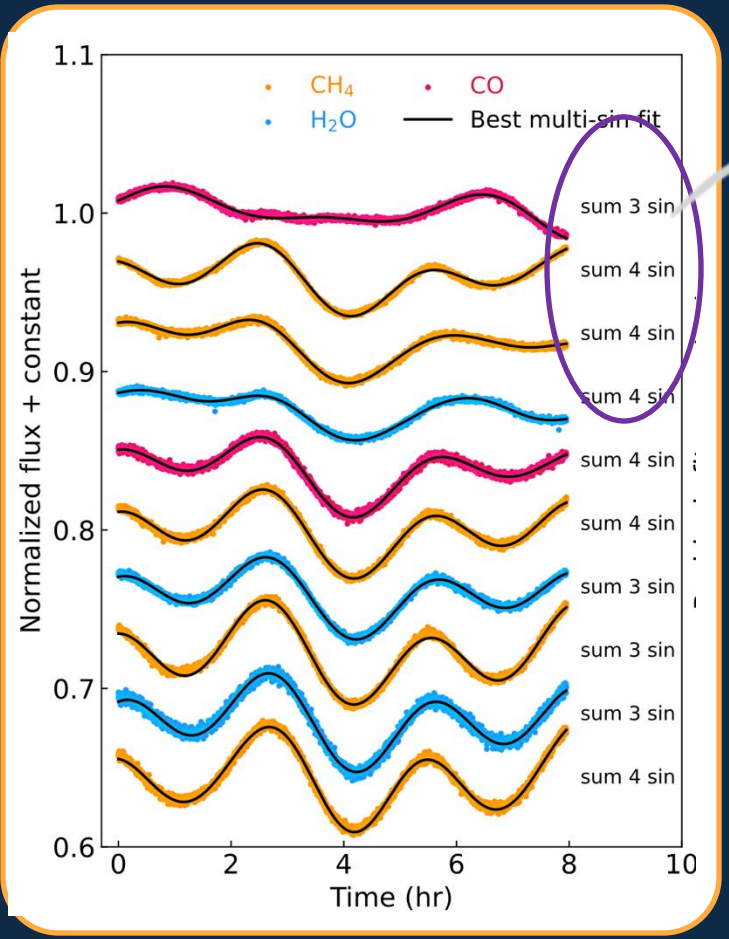


THANKS FOR YOUR ATTENTION

Questions?

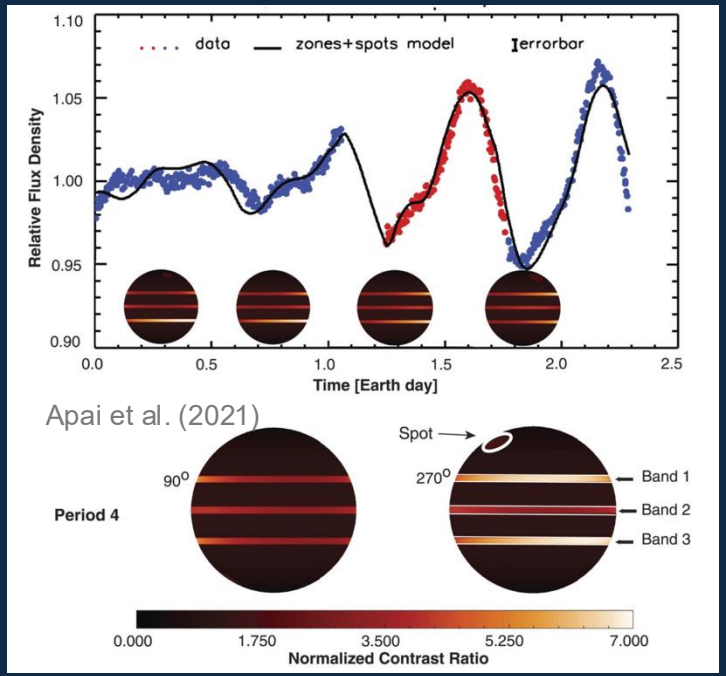
noliver8@jh.edu

Light curves



Number of sinusoidal functions

$$\sum_{i=1}^{6} A_i \sin\left(\frac{2\pi}{P_i} + \phi_i\right) + offset$$



Example of B object

Statistical test

-- F-test
-- AIC
-- BIC

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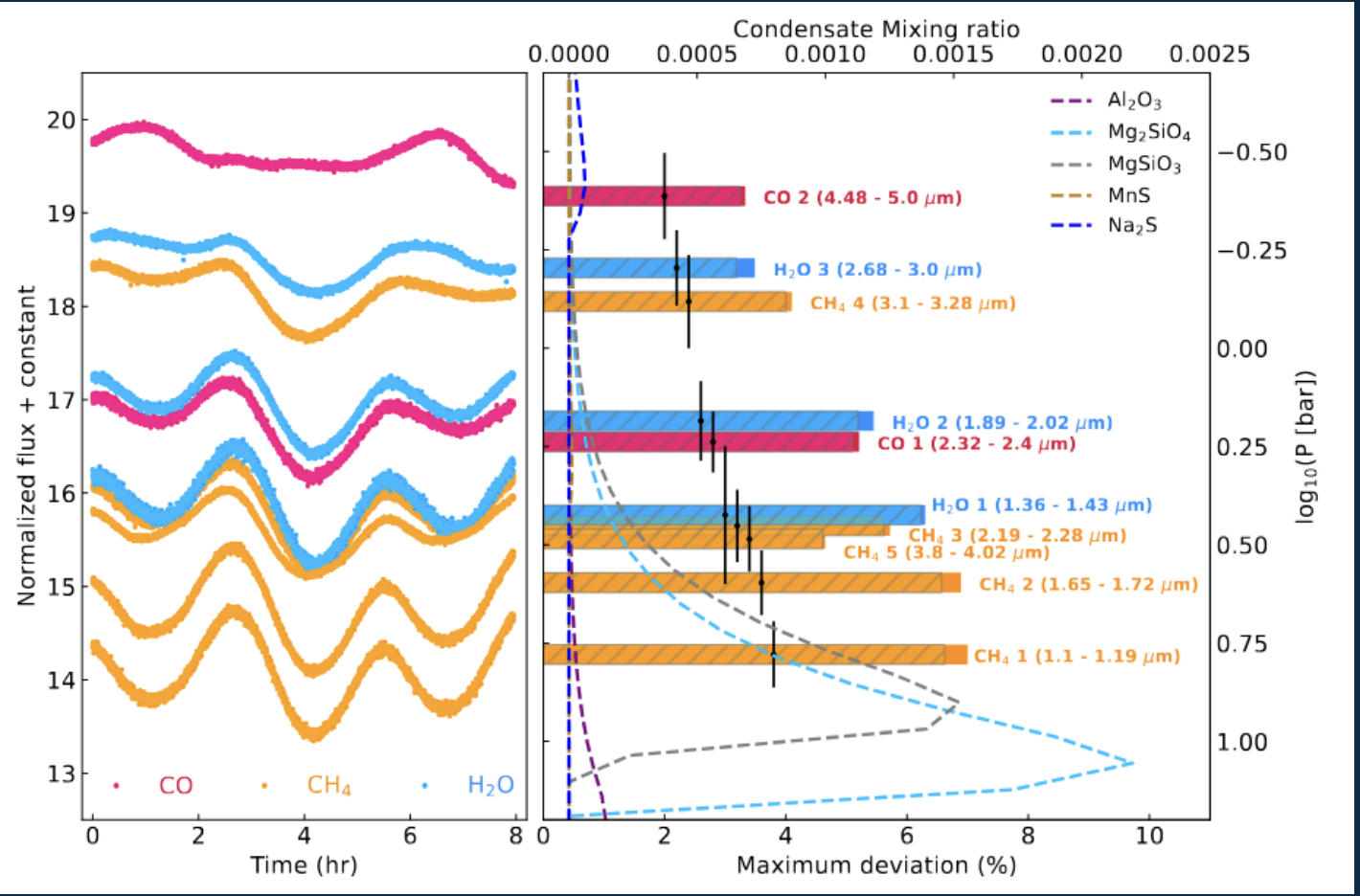
Example of B object



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$$CO + 3\,H_2 \longleftrightarrow CH_4 + H_2O.$$

CH4 and H2O
Correlated

CO vs CH4 and H2O
nocorrelated

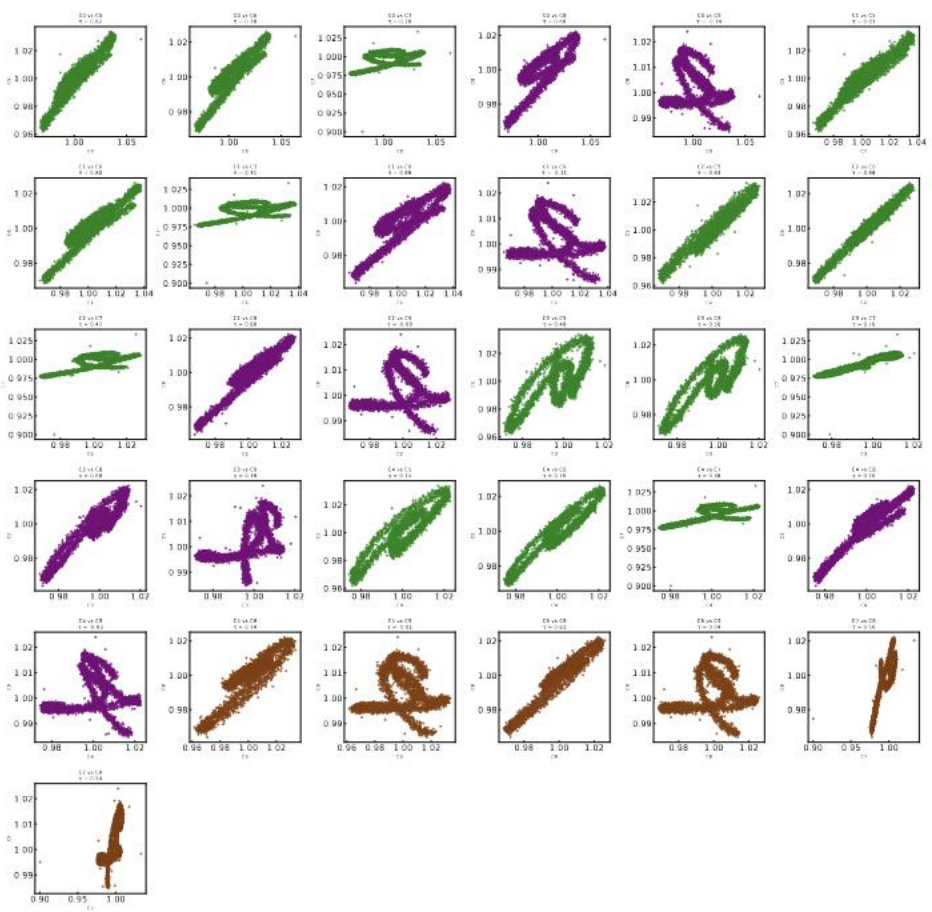

Figure 2: Correlation comparison of the light curve of WISE 1049B, of the molecular features of CH_4 vs H_2O (green), CH_4 vs CO (purple), and H_2O vs CO (maroon). The names C0 to C9 are the light curves C0-C4 are CH_4 -1,-2,-3,-4, and -5 respectively, C5-C7 are H_2O -1,-2, and -3 respectively and C8-C9 are CO-1, and CO-2.

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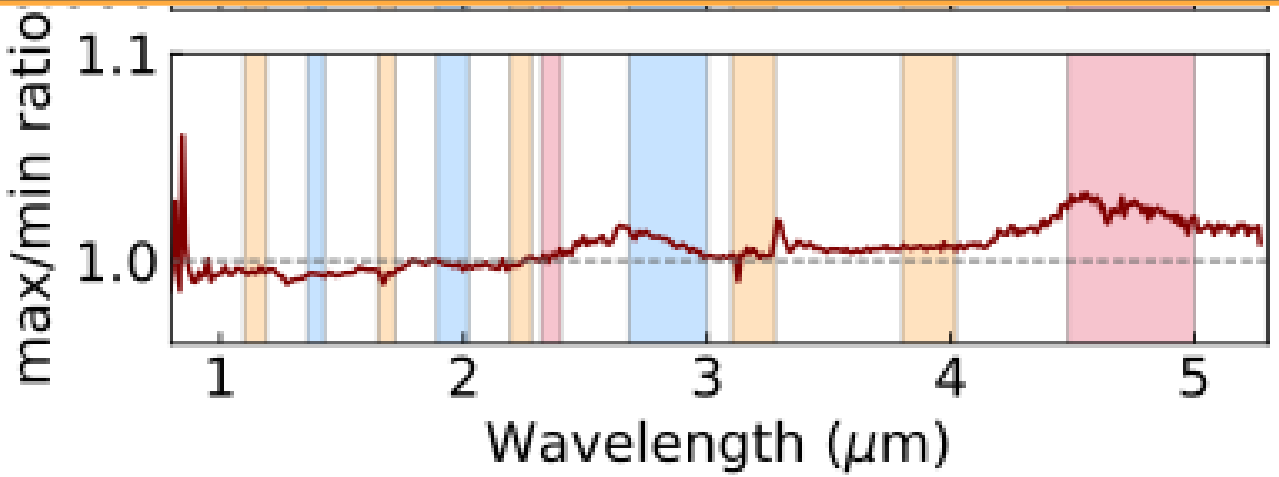
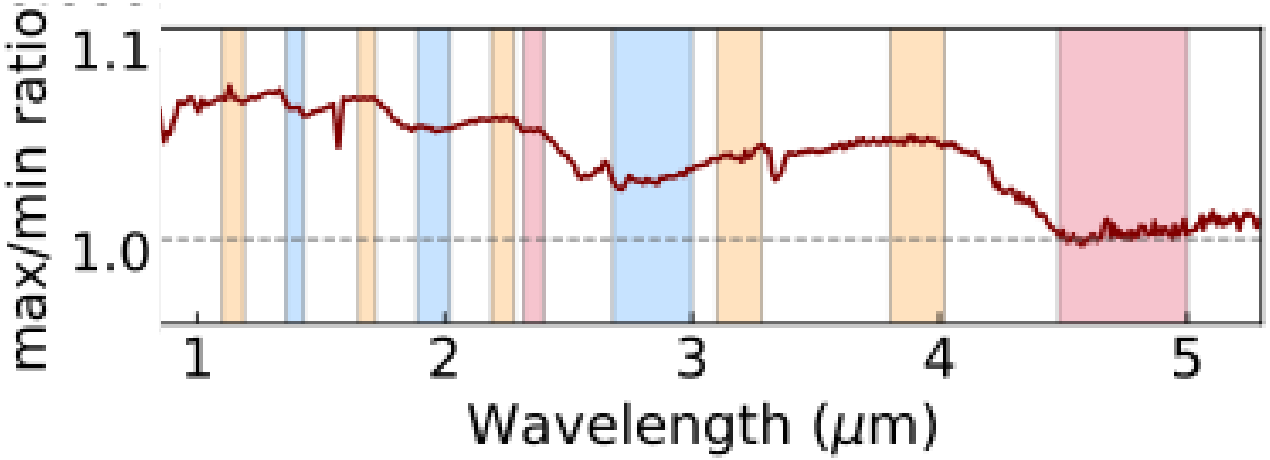
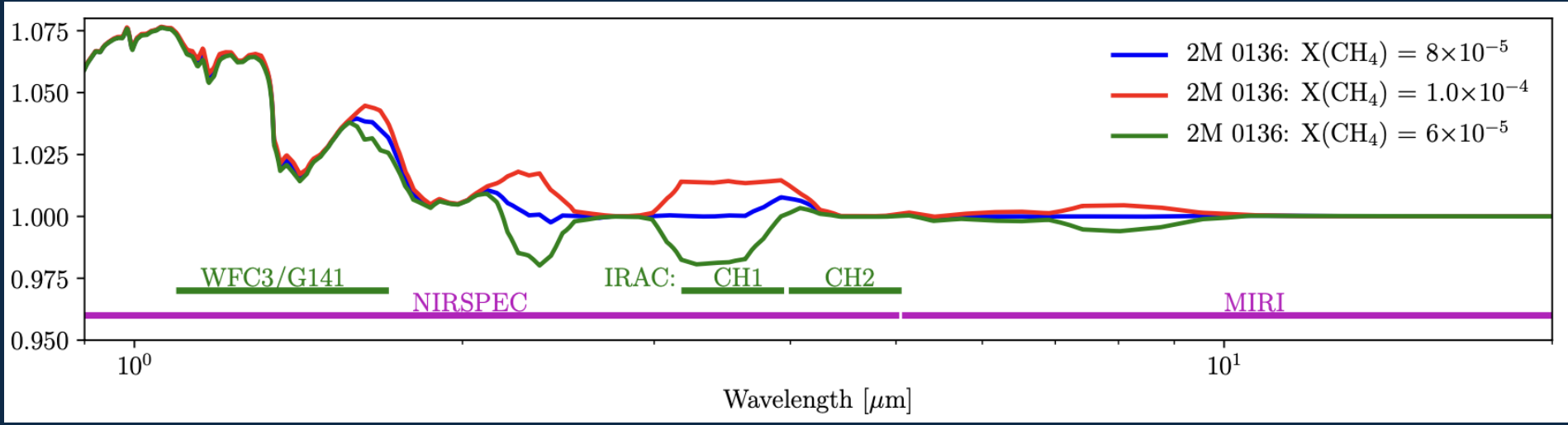
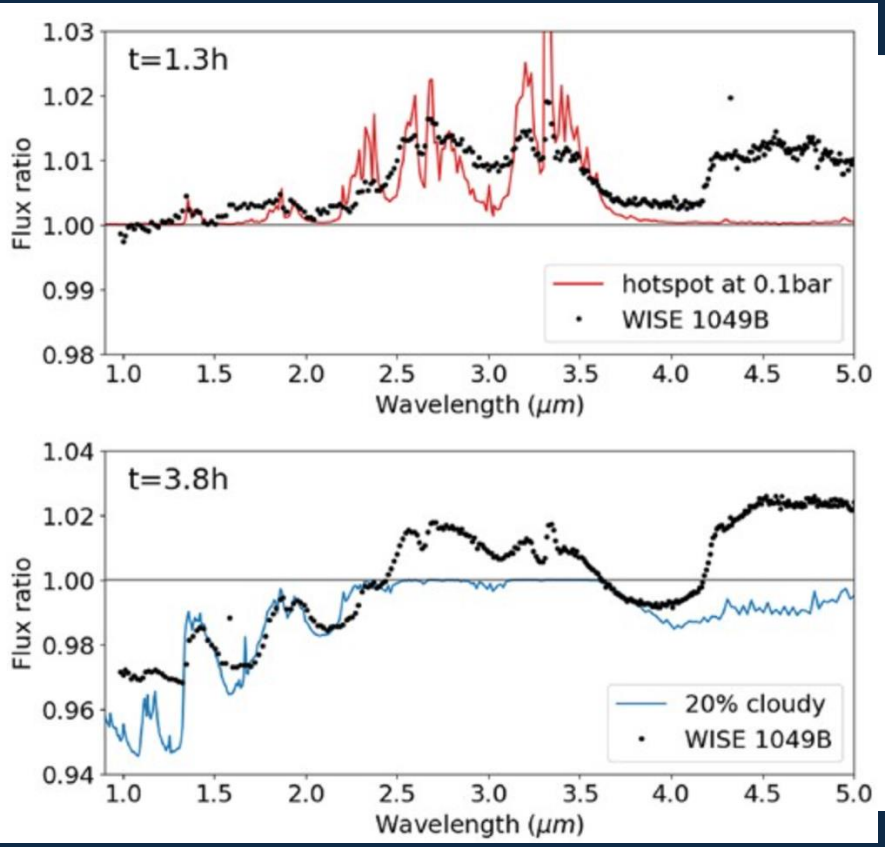
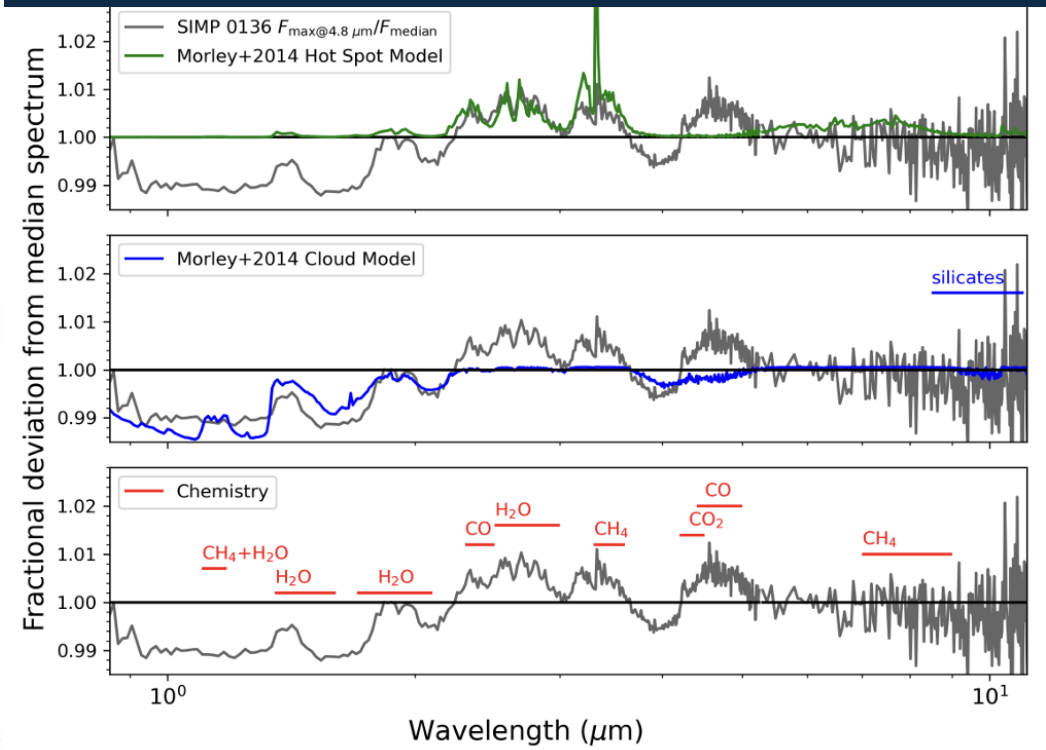

max/min ratio
1.1
1.0
1
2
3
4
5
Wavelength (μm)


max/min ratio
1.1
1.0
1
2
3
4
5
Wavelength (μm)



Pascal et al 2021





Chen et al 2025

McCarthy et al 2024