Modelling, interpretation, and preparation of JWST observations of the temperate super-Earth LHS 1140 b

Perrine Dupont, Martin Turbet, Alexandre Mechineau, Ehouarn Millour, Jeremy Leconte, Thomas Fauchez, Charles Cadieux, René Doyon

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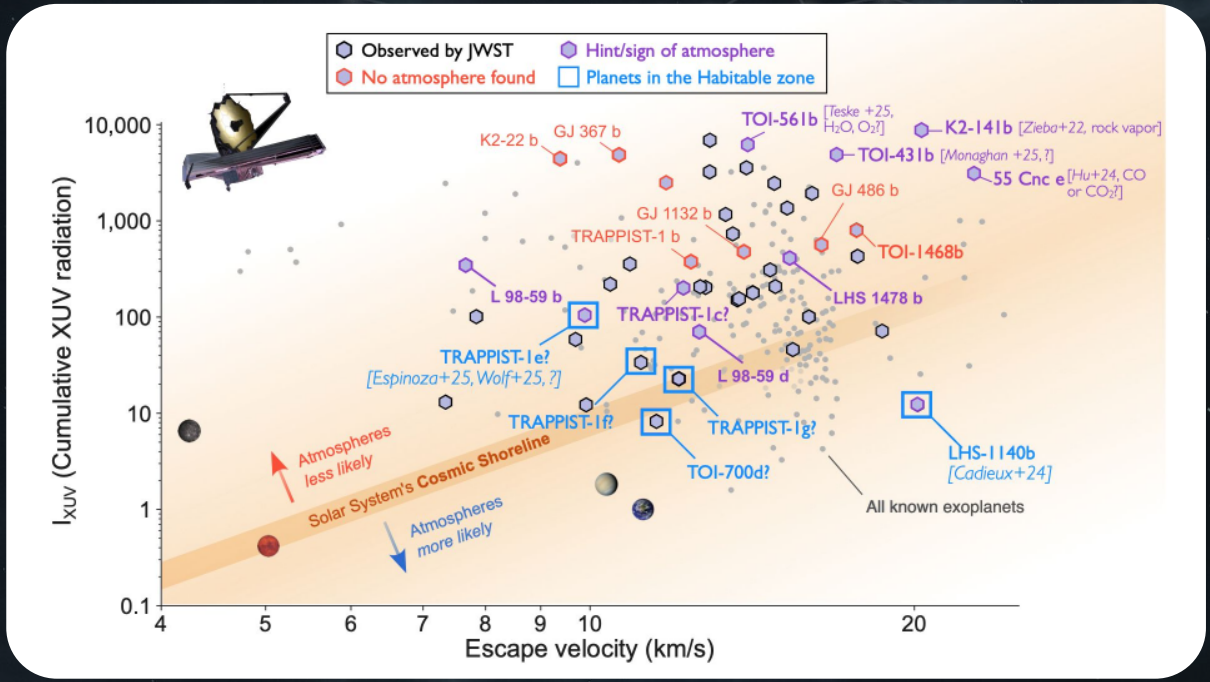
Tell me whyyyyyy ?

(me too Backstreet Boys, me too)

A bit of context...

Atmospheres around rocky planets

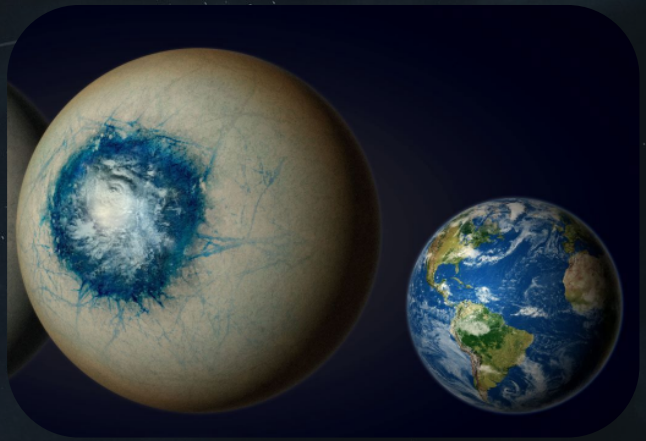


Credit: E. Ducrot

The best planet

LHS 1140 b

- **Distance to Earth** : 49 light-years
- **Size** : 1.730 $R_{\oplus}$
- **Mass** : 5.60 $M_{\oplus}$ → Low density
- **Period** : 24.737 days
- **Mean temperature** : 226 K
- In the **habitable zone**



Artist's impression © B. Gougeon, UdeM

2

JWST observations

(insert funny joke)

Timeline

In total : 184 hours of observations !

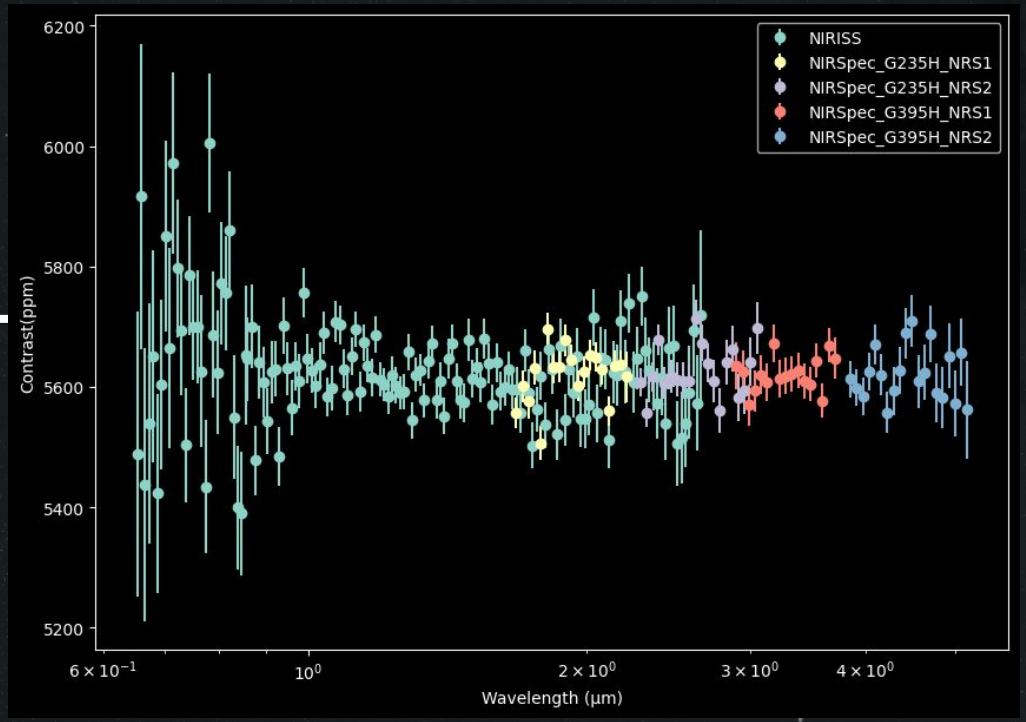
Timeline

2 **NIRISS transits**

December 2023

July 2023

2 **NIRSpec transits**



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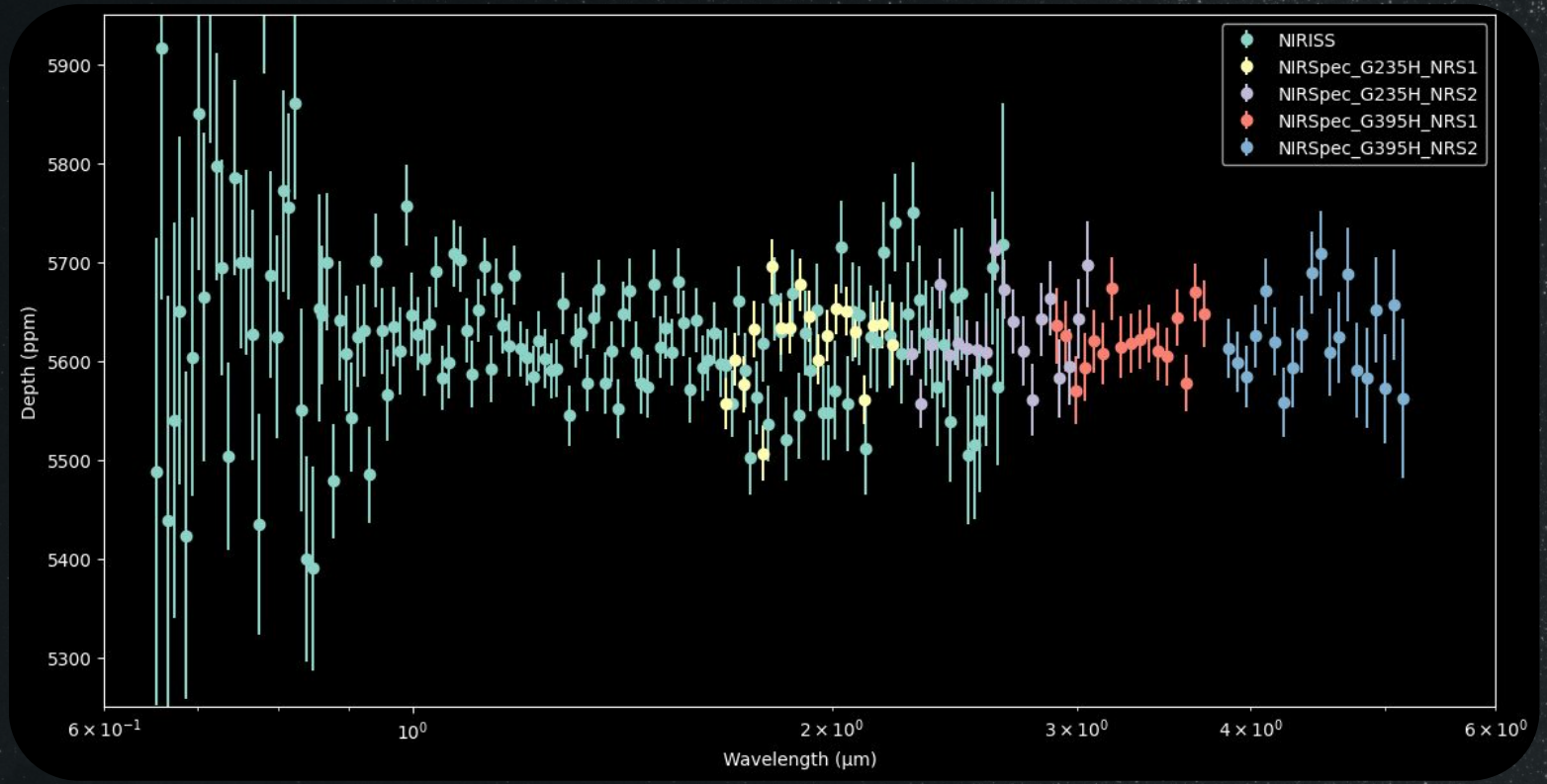
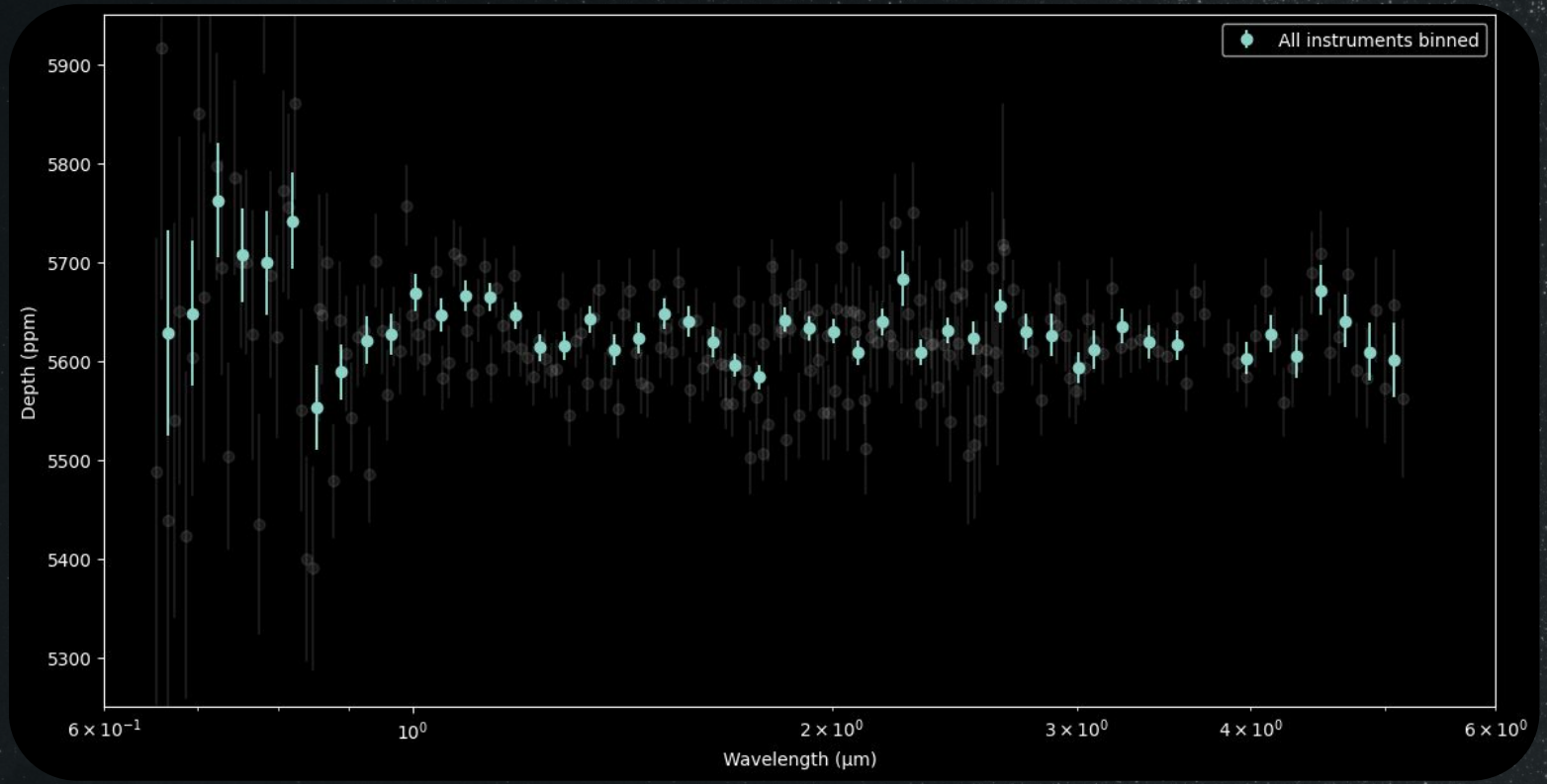
Methods

(me and my many problems)

Aggregating JWST data



Aggregating JWST data



3D modelling : Generic PCM

Why 3D modelling ?

- Presence of clouds in the atmosphere
- Possibility for emission spectra

Generic Planetary Climate Model

Credit: A. Gauvain

2 test simulations :

- 5 bar CO_2
- 1 bar N_2 400 ppm CO_2 (Earth-like)

3D modelling : Generic PCM

Why 3D modelling ?

- Presence of clouds in the atmosphere
- Possibility for emission spectra

(cool preliminary new logo)

Generic Planetary Climate Model

Credit: A. Gauvain

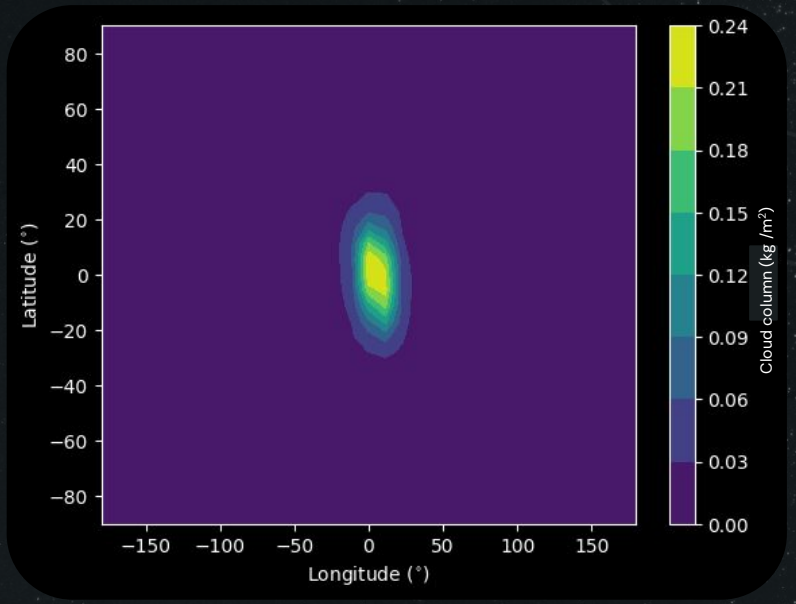
2 test simulations :

- 5 bar CO_2
- 1 bar N_2 400 ppm CO_2 (Earth-like)

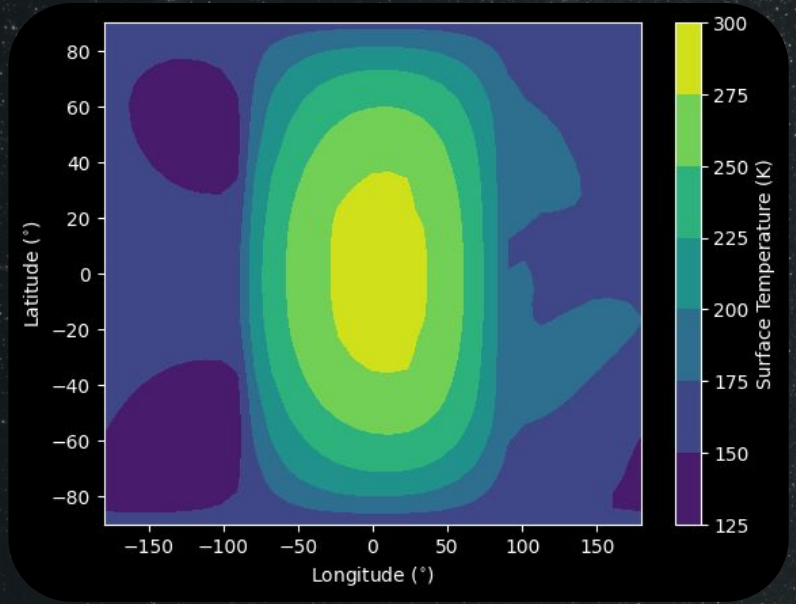
3D modelling : Generic PCM

Example of an Earth-like atmosphere

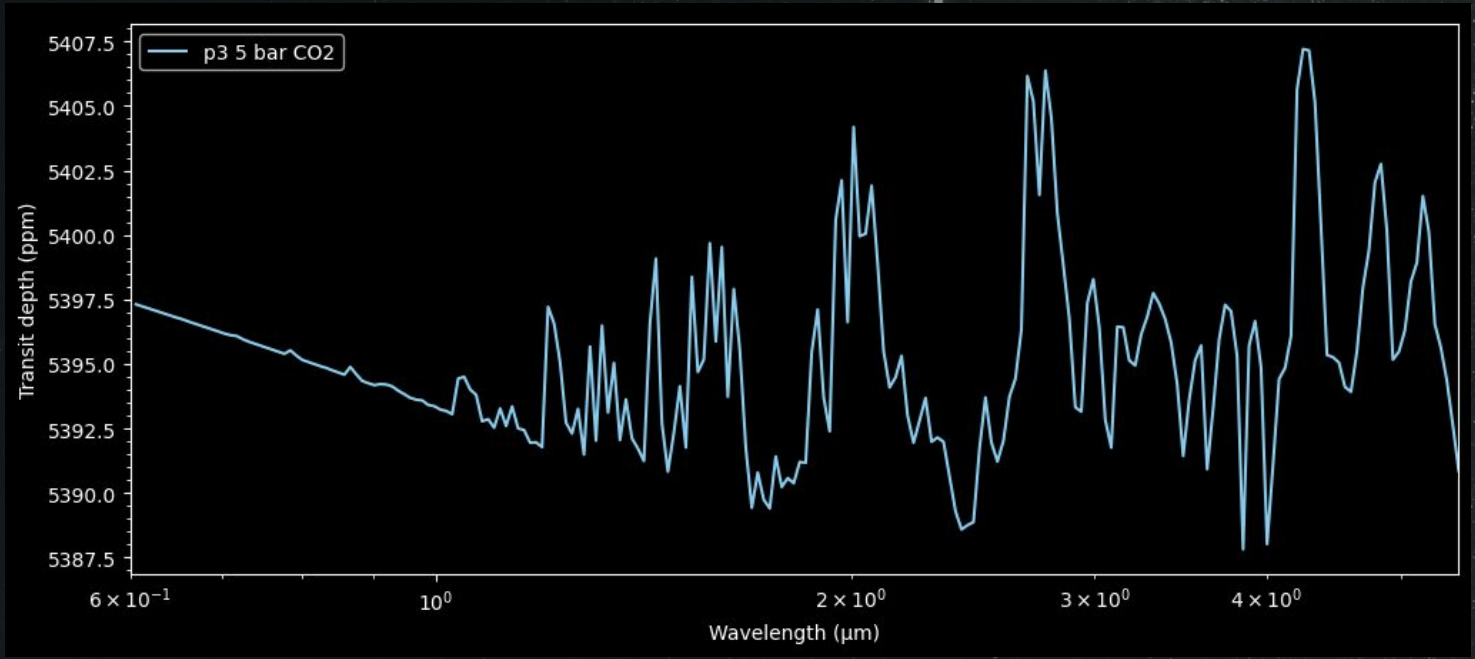
Clouds



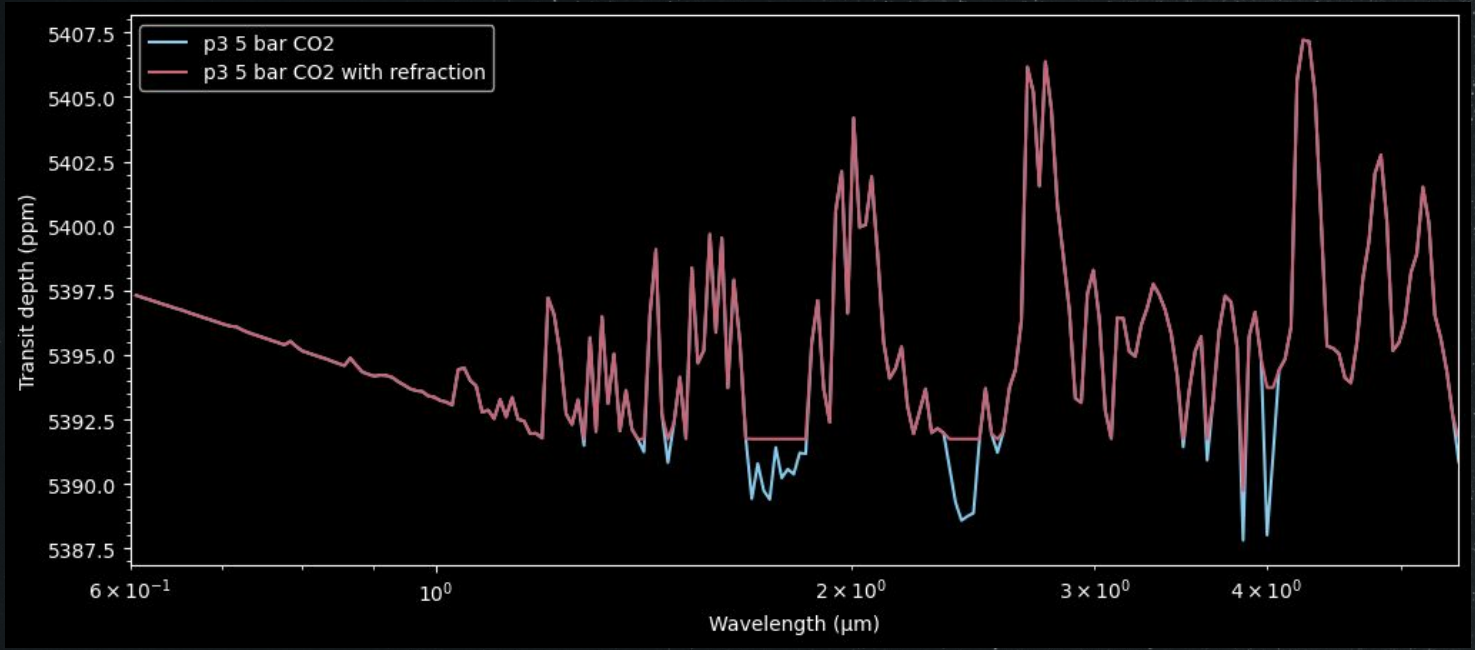
Heat map



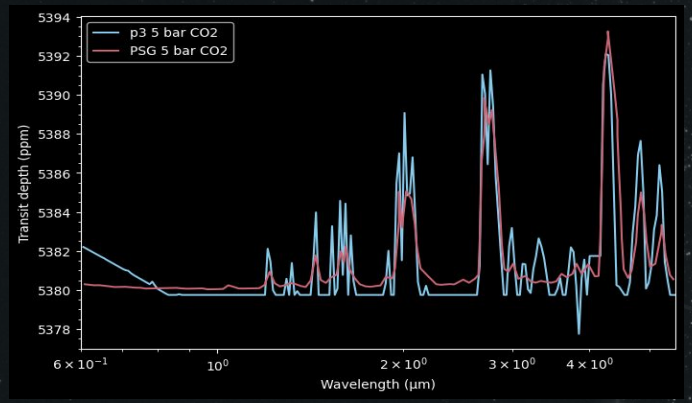
Pytmosph3R : refraction

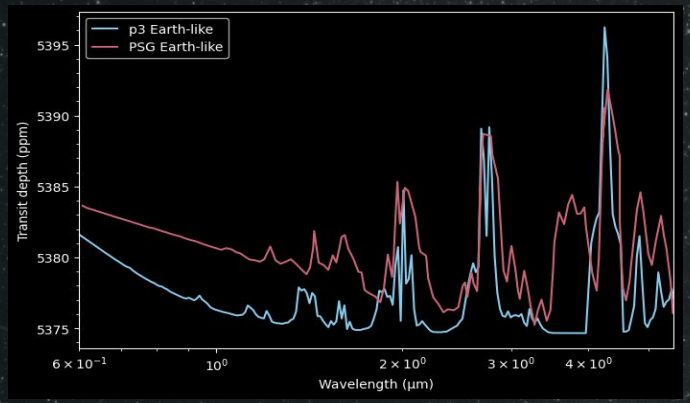


Pytmosph3R : refraction

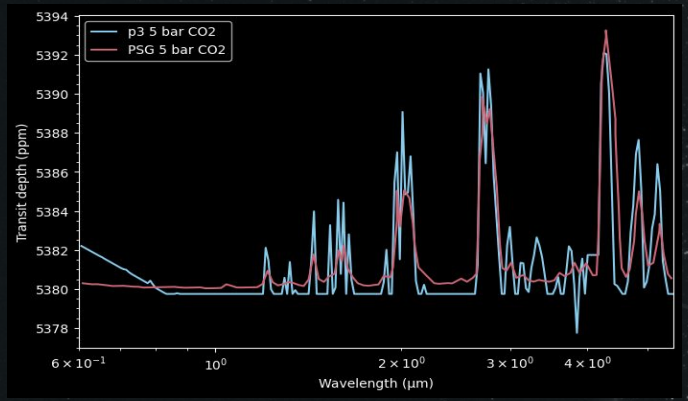


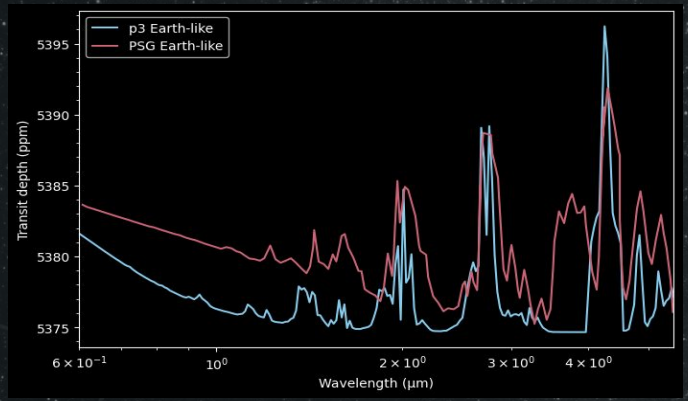
Benchmarking : Pytmosph3R vs PSG

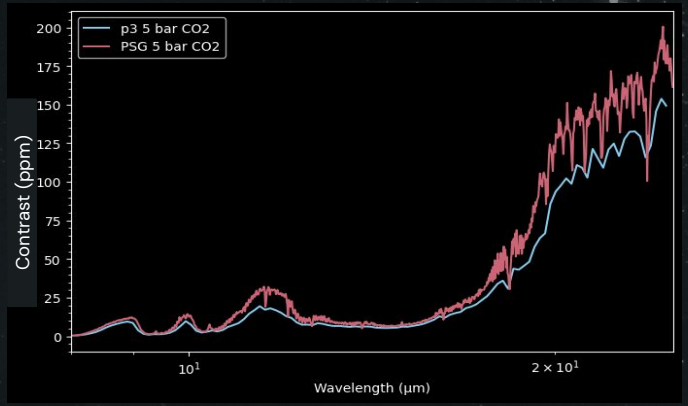


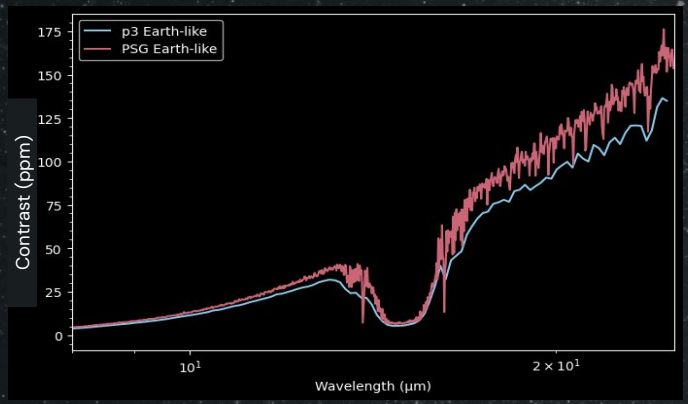


Benchmarking : Pytmosph3R vs PSG









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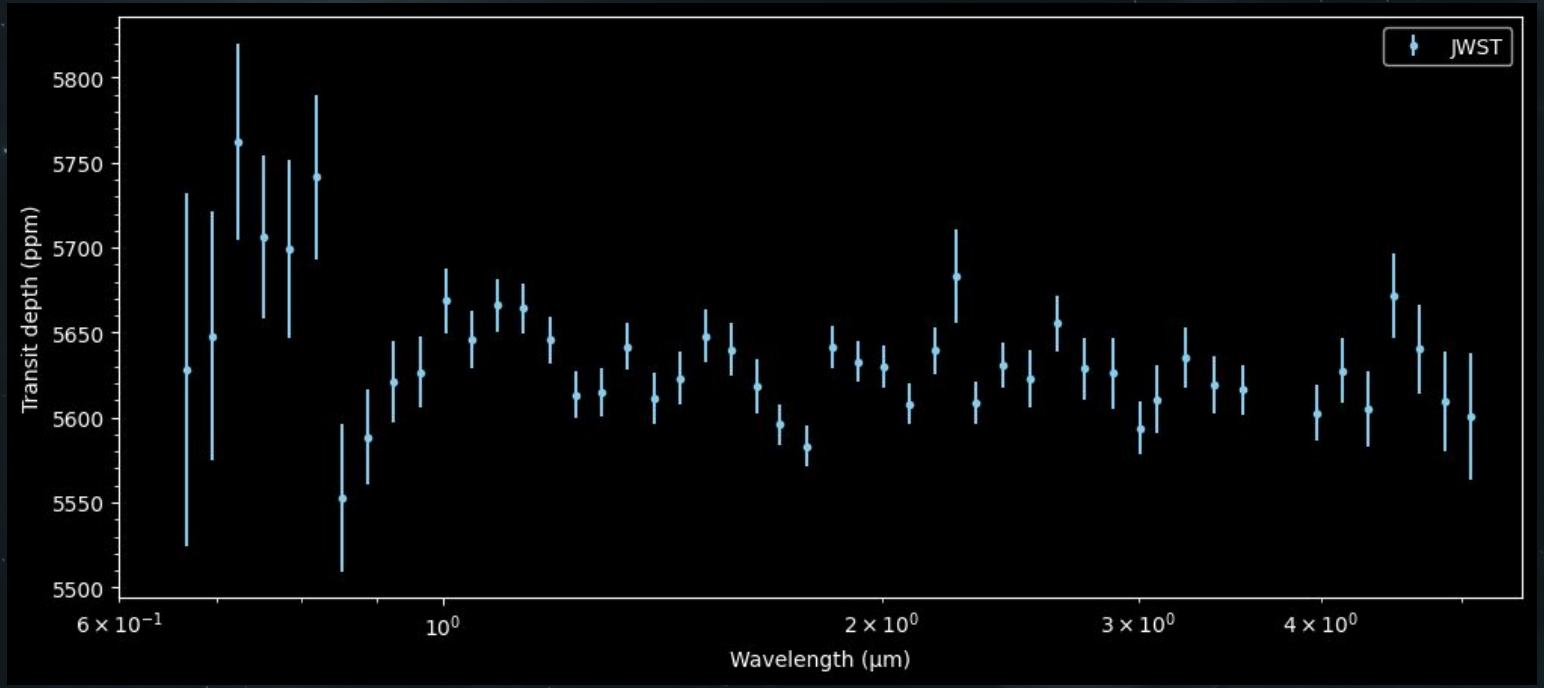
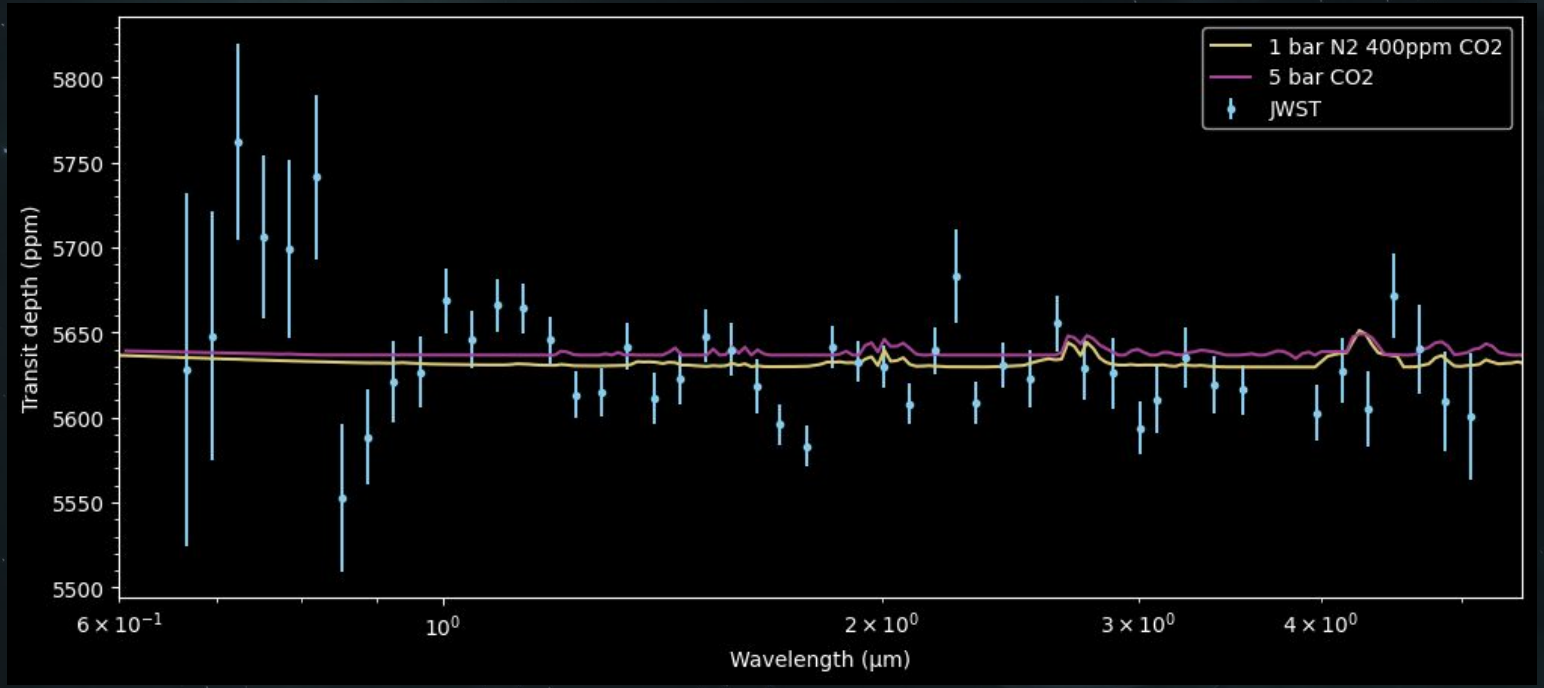
Preliminary results

(very preliminary)

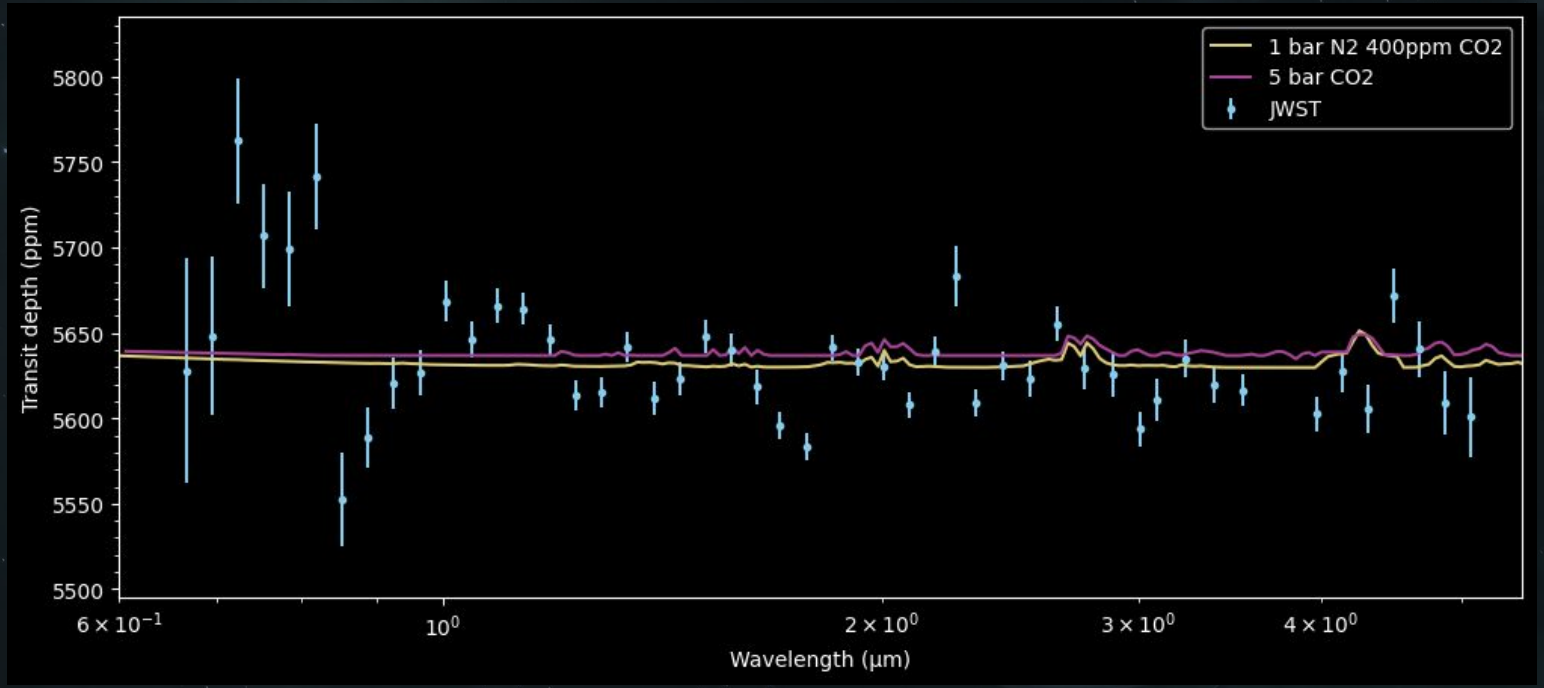
Transits


JWST
Transit depth (ppm)
5800
5750
5700
5650
5600
5550
5500
6×10^{-1}
10^{0}
2×10^{0}
3×10^{0}
4×10^{0}
Wavelength (μm)

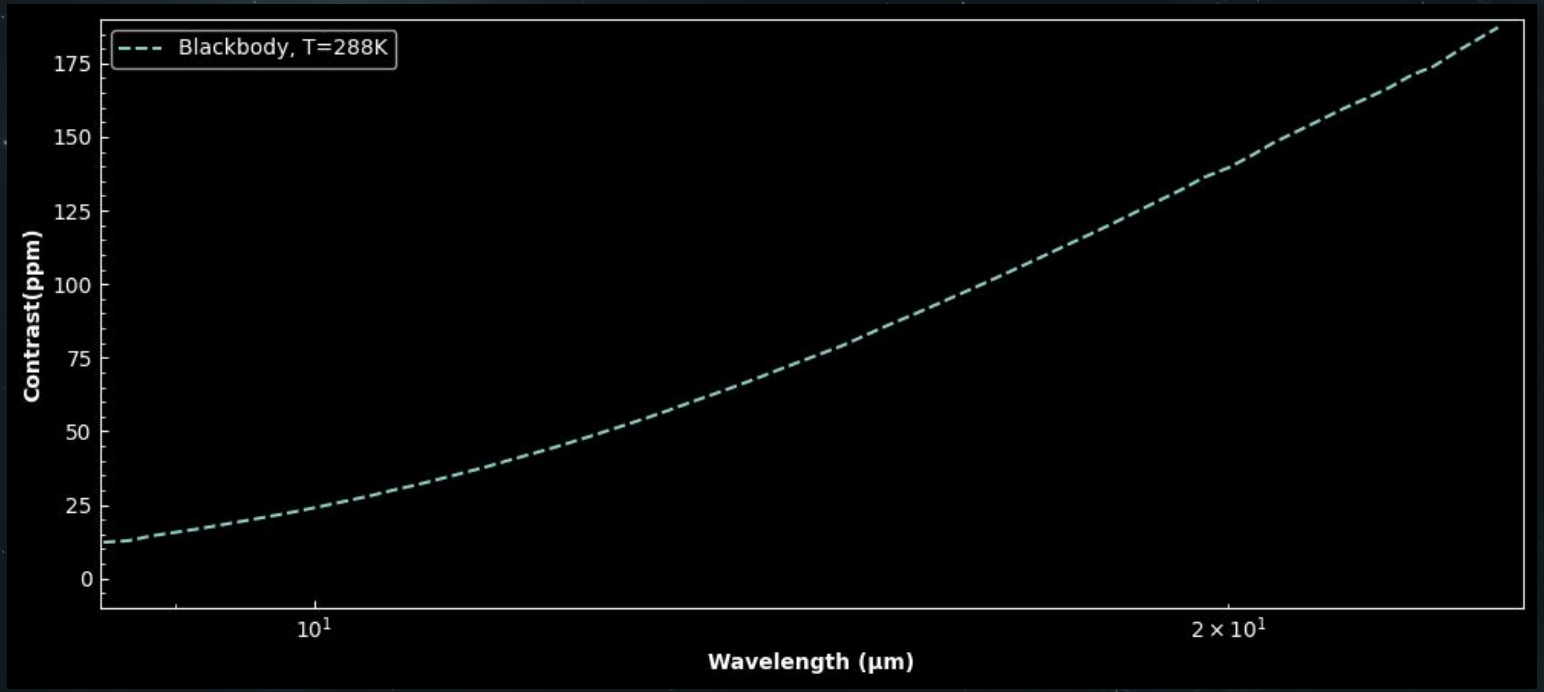
Transits


1 bar N2 400ppm CO2
5 bar CO2
JWST
Transit depth (ppm)
5800
5750
5700
5650
5600
5550
5500
6×10^{-1}
10^{0}
2×10^{0}
3×10^{0}
4×10^{0}
Wavelength (μm)

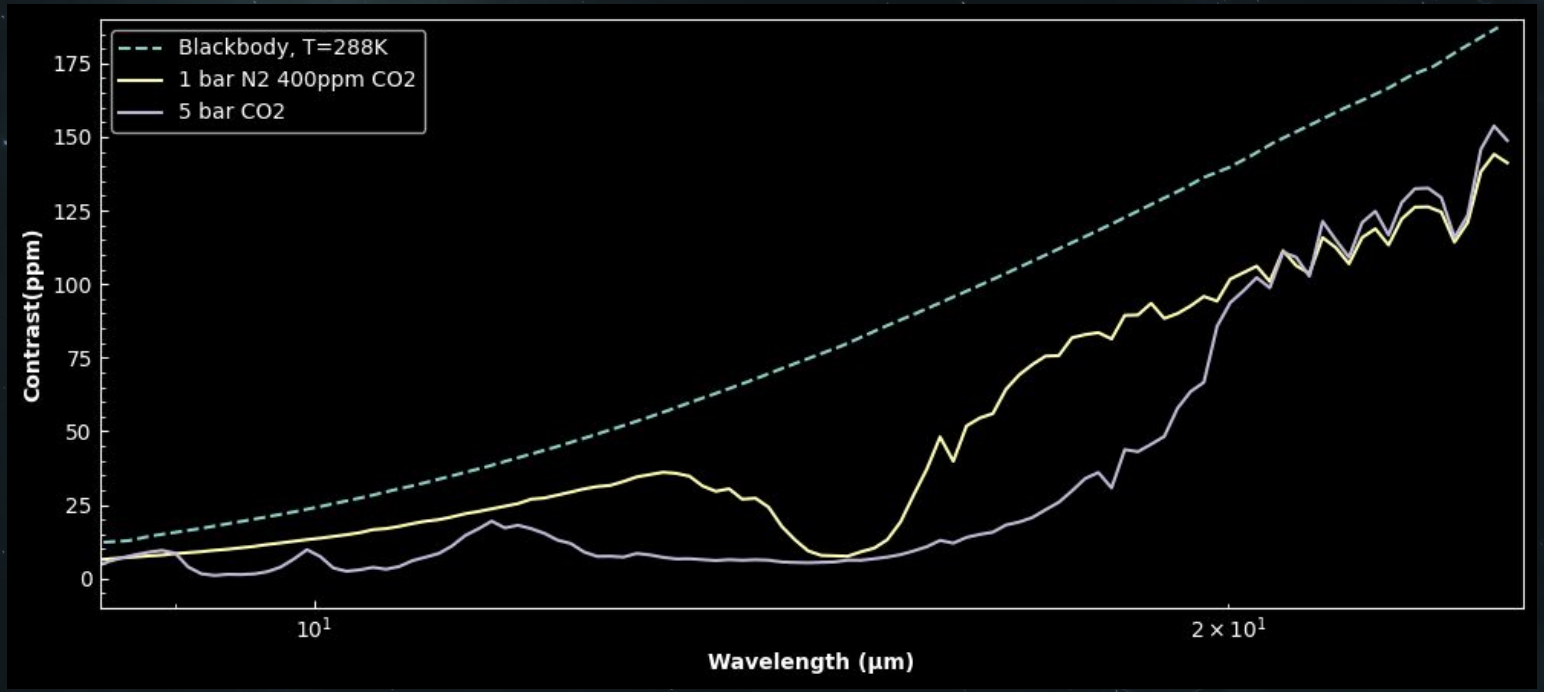
Transits


1 bar N2 400ppm CO2
5 bar CO2
JWST
Transit depth (ppm)
5800
5750
5700
5650
5600
5550
5500
6×10^{-1}
10^{0}
2×10^{0}
3×10^{0}
4×10^{0}
Wavelength (μm)

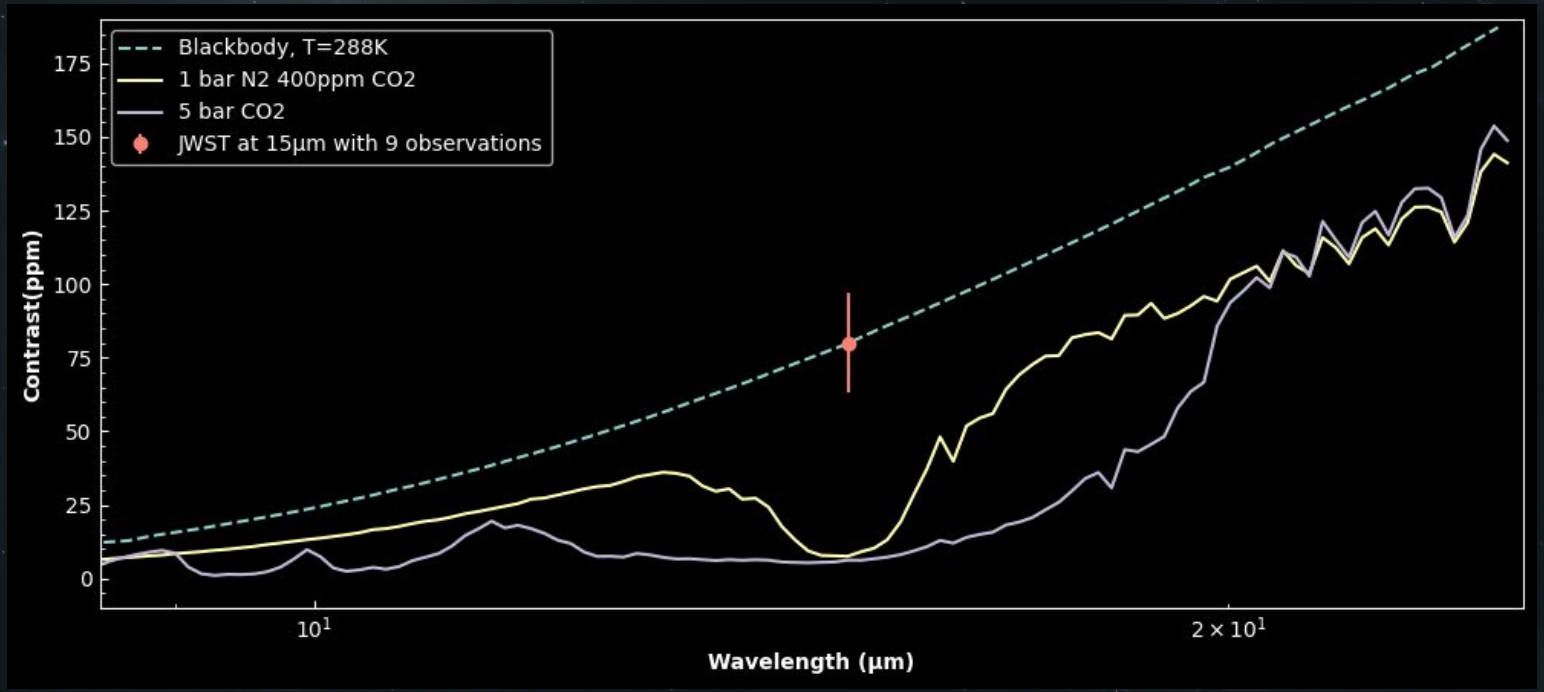
Eclipses


Blackbody, T=288K
175
150
125
100
75
50
25
0
Contrast(ppm)
10^1
2×10^1
Wavelength (μm)

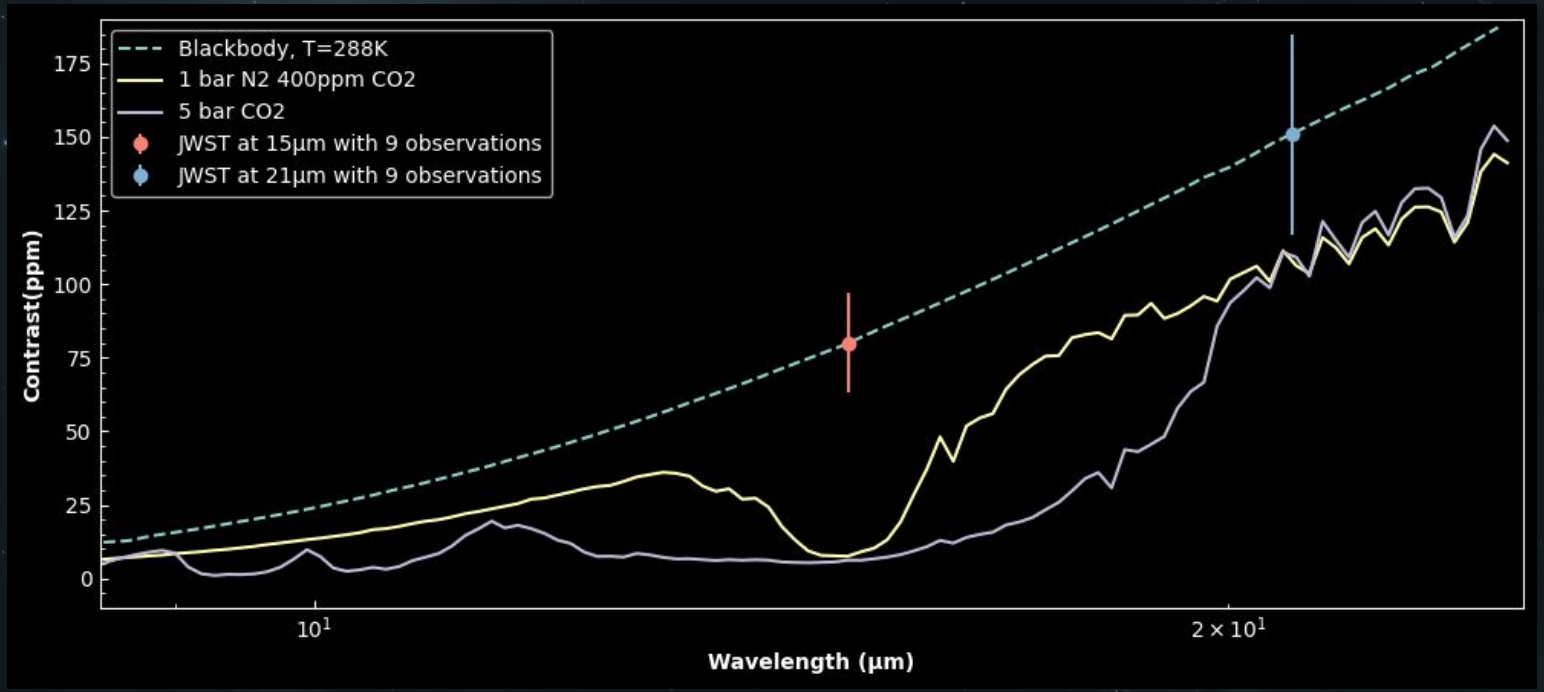
Eclipses


Blackbody, T=288K
1 bar N2 400ppm CO2
5 bar CO2
Contrast(ppm)
0
25
50
75
100
125
150
175
10^1
2×10^1
Wavelength (μm)

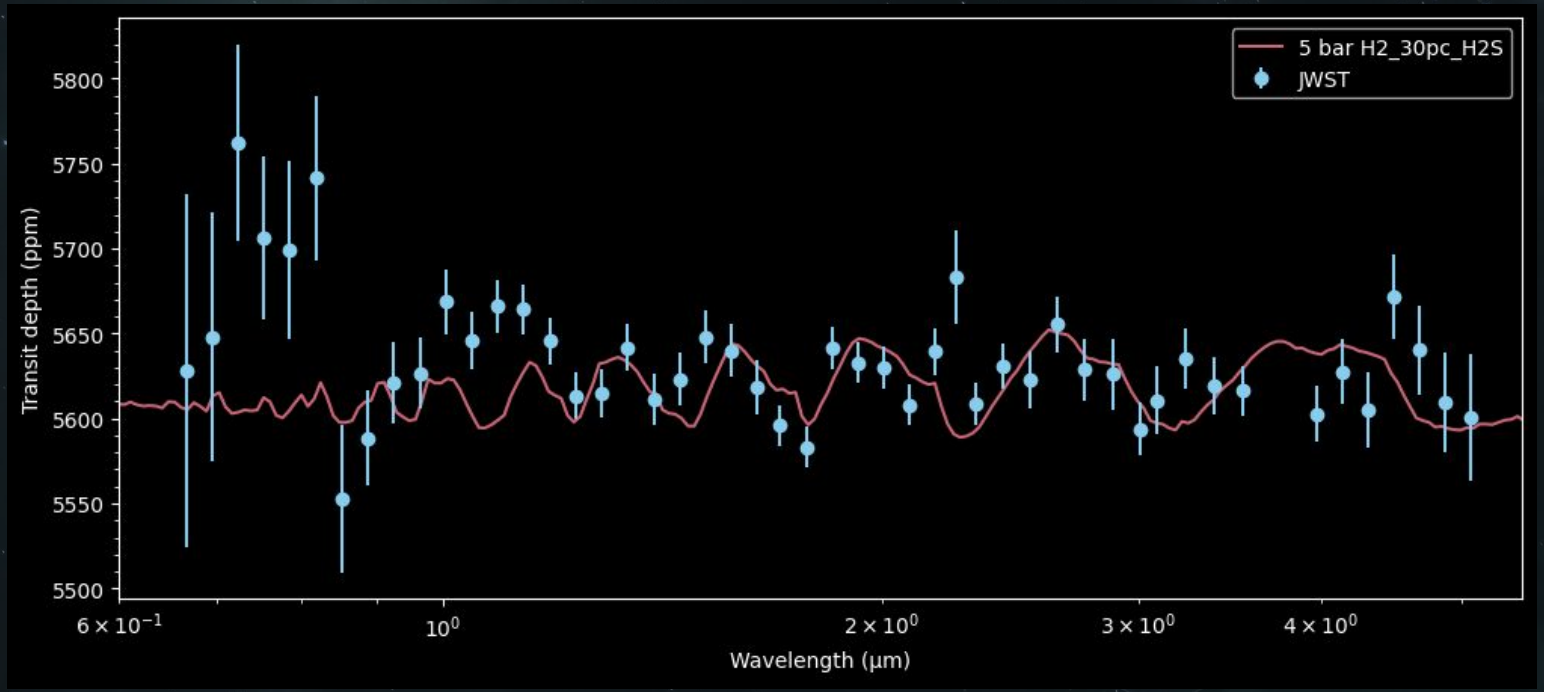
Eclipses


Blackbody, T=288K
1 bar N2 400ppm CO2
5 bar CO2
JWST at 15μm with 9 observations
Contrast(ppm)
175
150
125
100
75
50
25
0
10^1
2×10^1
Wavelength (μm)

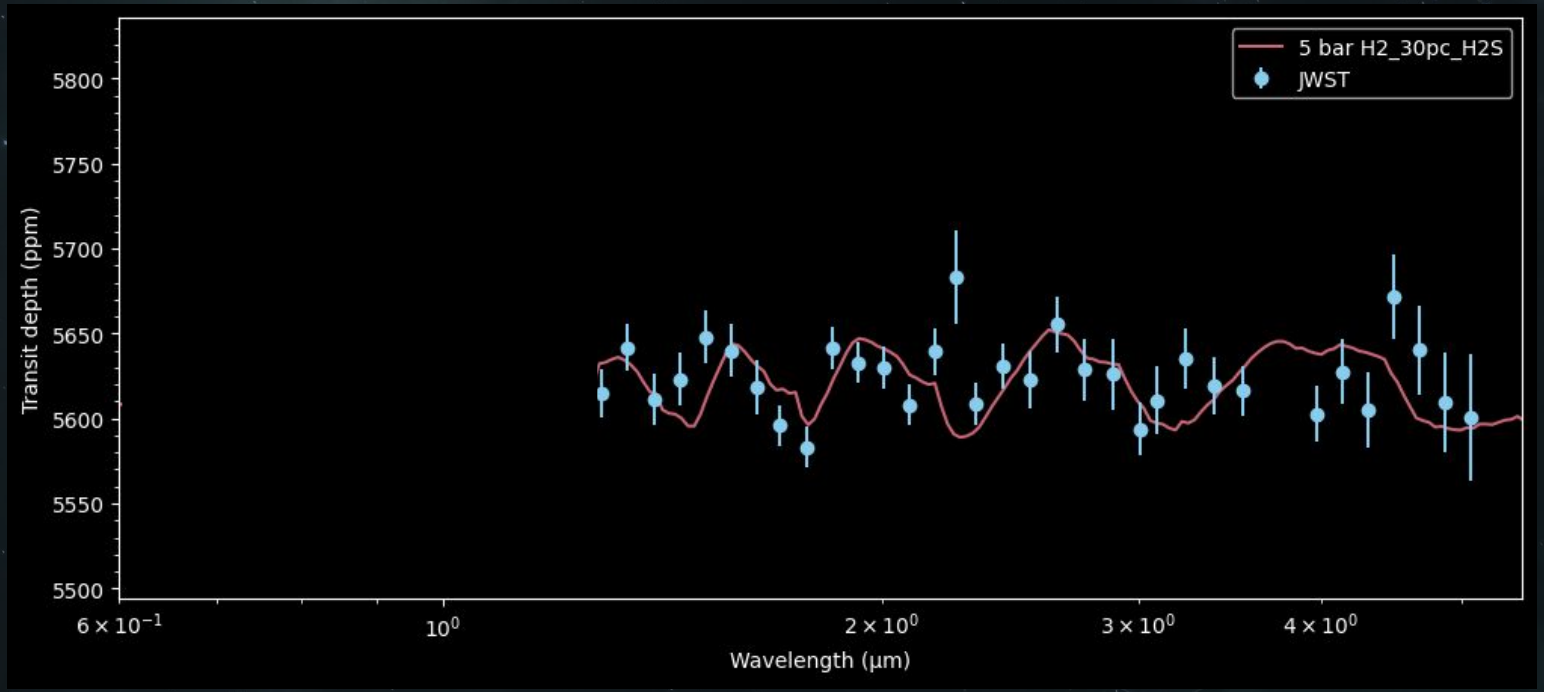
Eclipses


Blackbody, T=288K
1 bar N2 400ppm CO2
5 bar CO2
JWST at 15μm with 9 observations
JWST at 21μm with 9 observations
Contrast(ppm)
175
150
125
100
75
50
25
0
10^1
2×10^1
Wavelength (μm)

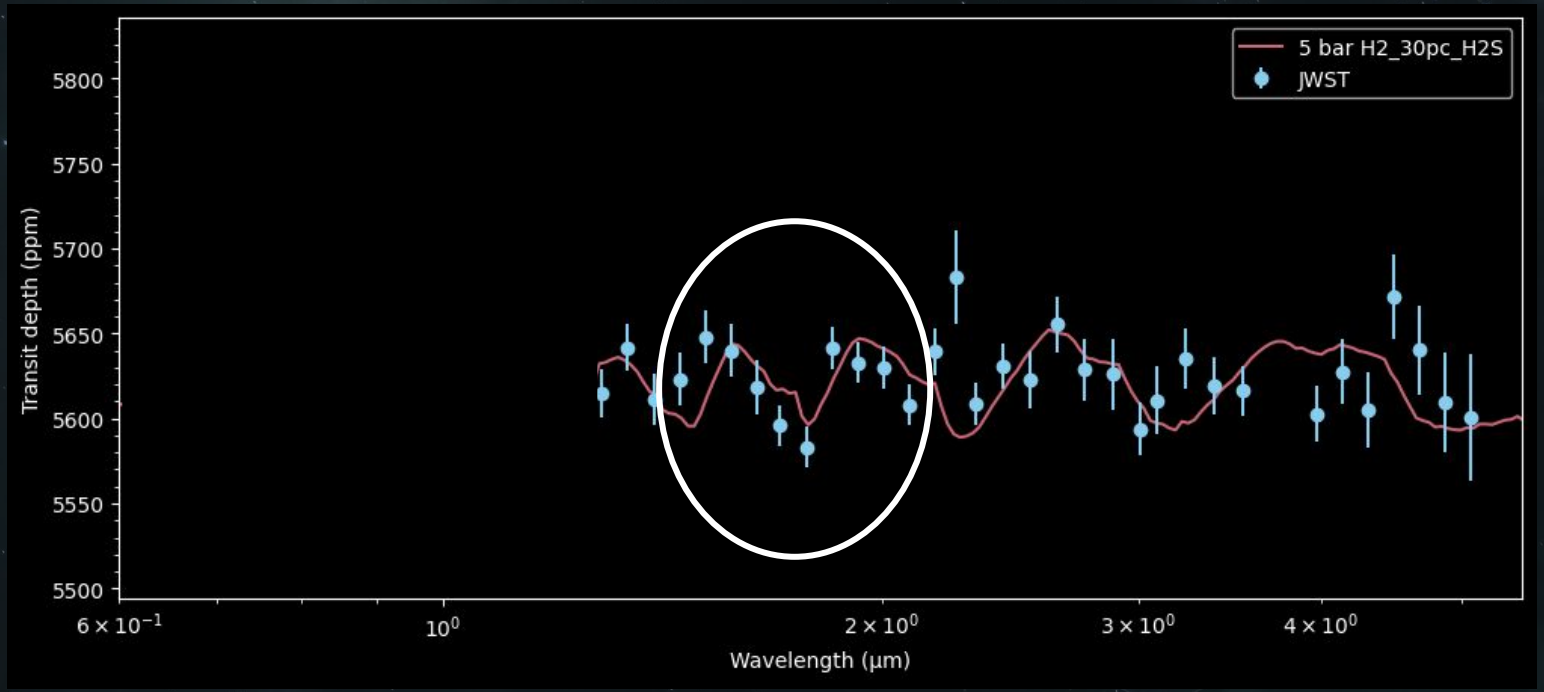
Spoilers : maybe H2S ?



Spoilers : maybe H2S ?



Spoilers : maybe H2S ?



Summary

- LHS 1140 b is currently the **most likely** rocky exoplanet around an M dwarf to have an atmosphere

  → If there is none, atmospheres on rocky planets might be extremely rare

- The next JWST observations should allow us to determine if there is an atmosphere, and in conjunction with GPCM models constrain its atmospheric composition

Thank you for listening !

Questions ? Remarks ? Concerns ?