EXPLORING THE INFLATED RADIUS OF THE SUPER MASSIVE SUPER-PUFF TOI-3757b WITH ATMOSPHERIC MODELS

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HOW ARE SUPER-PUFFS FORMED?

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Out of the ~10 known super-puffs (densities < 0.3 g/cc), TOI-3757b is the only known low-density massive super-puff discovered orbiting an M0-Dwarf. This planet is a prime candidate for atmospheric studies using instruments like HST and JWST. It has a high transmission spectroscopy measurement (TSM) of 190, making it one of the most characterizable gas giants with an equilibrium temperature below 1000 K. Hence, exploring TOI-3757b's atmosphere and its formation will answer our primary question, **Why does TOI-3757b have an inflated radius despite orbiting close to its host star, while maintaining a very low density?**

MODELING TOI-3757b's ATMOSPHERE USING PICASO

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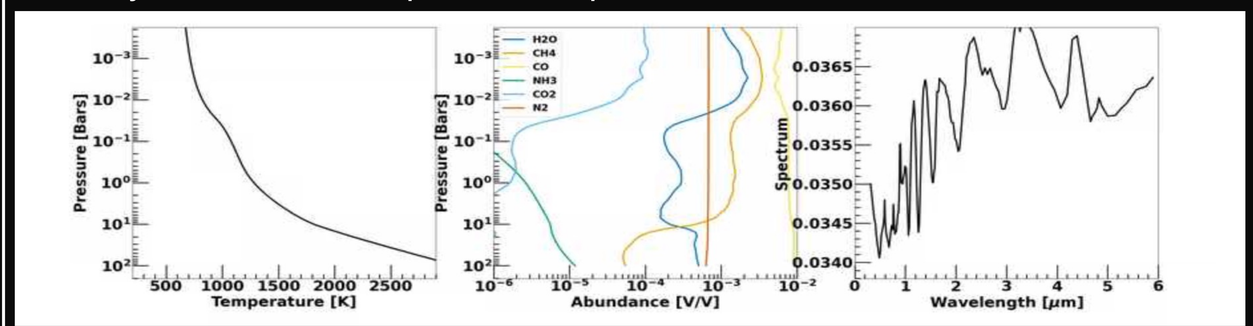
PICASO (Mukherjee et al. (2022)) is a software model that enables the computation of exoplanet compositions. With PICASO, I create different models by:

- Varying the Fe/H and C/O ratios for the planet
- Change the eddy diffusion coefficient (Kzz) at different pressure levels
- Modify the intrinsic temperature of planet



1. Pressure-Temperature Profile | 2. Abundances of different molecules in TOI-3757b's Atmosphere | 3. TOI-3757b's Spectrum

PROBING THE INTERIOR TEMPERATURE OF TOI-3757b

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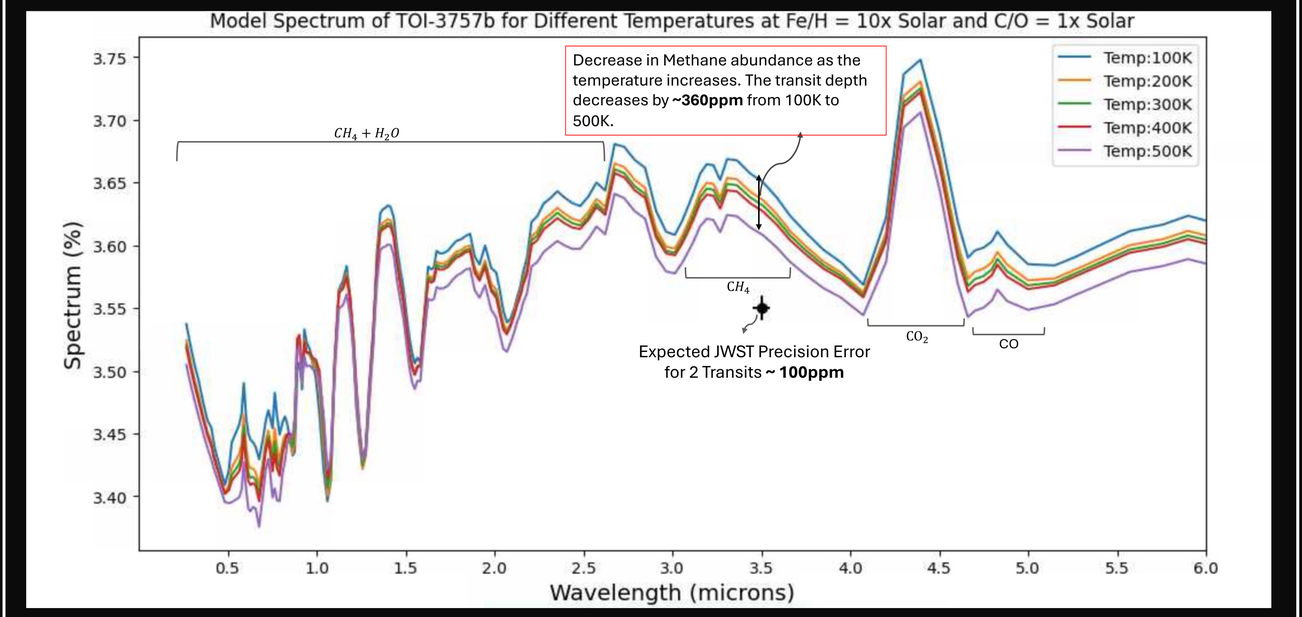

· ***Hot Interior Outcomes:*** The interior heats up, which can make Methane (CH_4) less abundant and Carbon Monoxide (CO) more abundant than expected with chemical equilibrium – an effect of Quenching. The atmosphere may expand due to the heat, contributing to the planet's inflated appearance. Vertical mixing is enhanced, affecting the distribution of gasses, and potentially impacting aerosols.

· ***Cold Interior Outcomes:*** Planet atmosphere is closer to chemical equilibrium with less vertical mixing leading to more Methane (CH_4) and little to no Carbon Monoxide (CO).

ABOUT TOI-3757b

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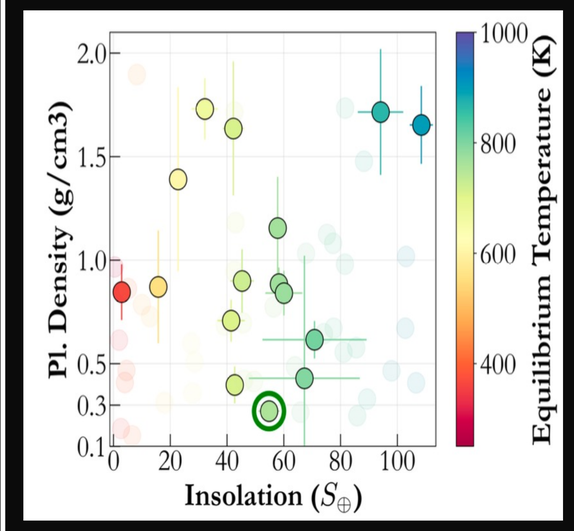
This planet is 1.08 times the size of Jupiter but less than 0.3 times the mass of Jupiter giving it a density of 0.27 g/cc; an anomaly according to core accretion theory. Plausible hypotheses were suggested in Kanodia et al. (2022) but we focus on High Internal Temperature or Low Metallicity Atmosphere to explain the low density of this planet.

RADIUS ($R_\oplus$)	$12^{+0.4}_{-0.3}$
MASS ($M_\oplus$)	$85.3^{+8.8}_{-8.7}\ M_\oplus$
DENSITY ($g\ cm^{-3}$)	$0.27^{+0.05}_{-0.04}\ g\ cm^{-3}$
ORBITAL PERIOD (days)	3.438753±0.000004
Equilibrium Temperature (albedo=0)	759±13 K
ECCENTRICITY	0.14±0.06

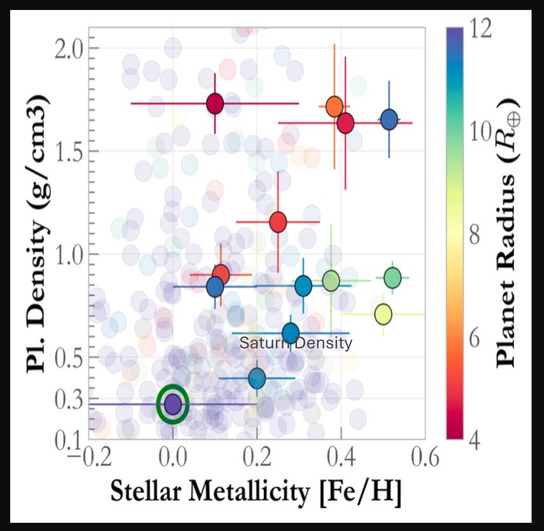
THE TWO PLAUSIBLE CAUSES FOR THE INFLATION:

1. HIGH INTERNAL TEMPERATURE



Kanodia et al. (2022)

2. LOW METALLICITY



Kanodia et al. (2022)

$$T_{eff} = T_{eq} + T_{int}$$

T_{eq}=759±13 T_{int}= To Determine

The equilibrium temperature is too low for TOI-3757b to have an inflated radius, hence the T_{int} is most likely contributing to the inflation.

Lower metallicity Disk ⇓ Lower Fraction of Metals in the Planet's Atmosphere

Effective temperature is directly proportional to H

$$H \propto \frac{T_{int} + T_{eq}}{\mu}$$

Mean Molecular mass (μ) of the atmosphere inversely proportional to H.

Factors contributing to the Scale Height (H): Height of the Inflated Atmosphere

WHAT'S NEXT?

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- Using Atmosphere Modelling to further explore clouds and hazes of TOI-3757b.
- Comparing my models to recently obtained James Webb Space Telescope observations and highlighting the implications of these results to explain TOI-3757b's inflated radius and other Super-Puffs.
- Exploring the abundance of different molecules in Atmospheres to explore other interesting categories of planets.

Interested in my work? Contact me at : nvd5373@psu.edu

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