Don't Stop Believin': The Importance of Continuing the Search for Atmospheres on Rocky Exoplanets with JWST

Thematic Areas (Check all that apply):

☒ (Theme A) Key science themes that should be prioritized for future JWST and HST observations
☐ (Theme B) Advice on optimal timing for substantive follow-up observations and mechanisms for enabling exoplanet science with HST and/or JWST
☐ (Theme C) The appropriate scale of resources likely required to support exoplanet science with HST and/or JWST
☐ (Theme D) A specific concept for a large-scale (∼500 hours) Director's Discretionary exoplanet program to start implementation by JWST Cycle 3.

Summary: The search for atmospheres on rocky exoplanets has begun. So far, many of the results have been relatively inconclusive, driving skepticism within the community about the fruitfulness of continuing to stare at rocky planets with JWST. This is understandable. However, we would also be remiss as a community turn our backs on this incredible opportunity to characterize rocky worlds and begin to understand the demographics of secondary atmospheres in our Galaxy. To find atmospheres on rocky planets, we should shift our focus to deeper searches around early M- and K-dwarfs, where the intensity of XUV radiation is less extreme than mid to late M-dwarfs. This could be in the form of a large DDT program or several GO programs. These proposals will require more transits and are by nature high risk, high reward. Still, the detection of a secondary atmosphere by JWST will be a huge push forward in our understanding of rocky planet demographics and habitability, which is one of the fundamental questions of our time.

Anticipated Science Objectives:

We have yet to find conclusive evidence of an atmosphere around any rocky exoplanet ([1, 2, 3, 4]; see Figure 1). This could be for two reasons: 1) there are no atmospheres in these systems, or 2) the atmospheres are there, but are buried underneath the noise. Moving forward, we need to change our observing strategy to optimize the likelihood of a significant detection. To do this, we need to reevaluate which stellar systems to prioritize and how many transits are truly needed.

Astronomers are often hesitant to submit a proposal looking at early M- or K-dwarfs, where more transits are required, though these planets receive less X-ray radiation and therefore are more likely to retain their atmospheres [5]. For the smaller stars observed in Cycles 1 and 2, typically only 2–3 transits/eclipses have been scheduled. However, we are finding these small number of transits to be insufficient due to optimistic estimates of scale height, as well as uncertainties of telescope systematics and the impact of stellar contamination in the spectra [2].

To make meaningful progress in our hunt for rocky planet atmospheres, an **increased emphasis should be made on searching for atmospheres on rocky planets around early M- to K-dwarfs with a greater number of transits scheduled per system.** While we should not neglect deeper surveys around mid and late M-dwarf systems to understand the landscape of these systems, as well as begin to probe exoplanetary surfaces, if we are in the business of finding rocky planet atmospheres, we should set our sights on deeper searches around larger stars.

Not only will more transits improve the S/N, but stellar variability could also be "averaged out", lessening the impact on the resulting spectrum. Additionally, broader wavelength coverage will allow us to tease out the impacts of stellar contamination and provide exquisite stellar spectra, an important contribution to the stellar astrophysics community.

Urgency: Many in our community are losing faith in our ability to gain meaningful scientific knowledge from rocky exoplanet observations. We need to change our observing strategy to mitigate these concerns and reach conclusive findings.

Risk/Feasibility: There is a possibility that none of the planets we observe have atmospheres. However, this would still be an incredibly important finding, as it would greatly restrict the types of systems we predict to be habitable.

Timeliness: The emphasis on deeper searches should be implemented prior to Cycle 3 observations.

Cannot be accomplished in the normal GO cycle: N/A.

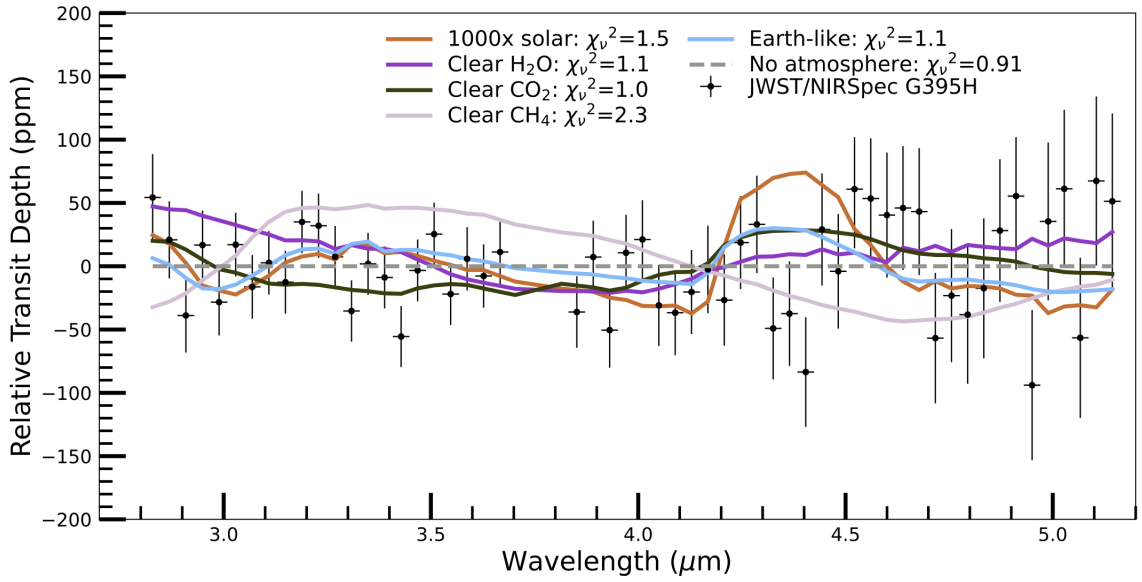

Figure 1: Transmission spectrum of the rocky planet LHS 475b, which orbits an M3.5V dwarf, from [1]. With two transits, the forward models reveal the spectrum is consistent with a bare-rock or a CO_2-dominated atmosphere. Retrievals demonstrate that no atmosphere, a high cloud deck, and a tenuous atmosphere are all equally likely. This demonstrates the greater precision needed (in the form of more transits, increased wavelength coverage, or a combination of transits and eclipses) in future JWST cycles to determine whether a given rocky planet likely has an atmosphere or not. Shifting toward earlier M- and K-dwarf systems will also maximize our likelihood of detecting a secondary atmosphere.

References

[1] J. Lustig-Yaeger et al. "A JWST transmission spectrum of a nearby Earth-sized exoplanet". In: *arXiv e-prints*, arXiv:2301.04191 (Jan. 2023), arXiv:2301.04191. DOI: 10.48550/arXiv.2301.04191. arXiv: 2301.04191 [astro-ph.EP].

[2] Sarah E. Moran et al. "High Tide or Riptide on the Cosmic Shoreline? A Water-rich Atmosphere or Stellar Contamination for the Warm Super-Earth GJ 486b from JWST Observations". In: 948.1, L11 (May 2023), p. L11. DOI: 10.3847/2041-8213/accb9c. arXiv: 2305.00868 [astro-ph.EP].

[3] Thomas P. Greene et al. "Thermal emission from the Earth-sized exoplanet TRAPPIST-1 b using JWST". In: 618.7963 (June 2023), pp. 39–42. DOI: 10.1038/s41586-023-05951-7. arXiv: 2303.14849 [astro-ph.EP].

[4] Sebastian Zieba et al. "No thick carbon dioxide atmosphere on the rocky exoplanet TRAPPIST-1 c". In: *arXiv e-prints*, arXiv:2306.10150 (June 2023), arXiv:2306.10150. DOI: 10.48550/arXiv.2306.10150. arXiv: 2306.10150 [astro-ph.EP].

[5] Tyler Richey-Yowell et al. "HAZMAT. IX. An Analysis of the UV and X-Ray Evolution of Low-mass Stars in the Era of Gaia". In: 951.1, 44 (July 2023), p. 44. DOI: 10.3847/1538-4357/acd2dc. arXiv: 2305.06561 [astro-ph.SR].