A Panchromatic Survey of Warm and Hot Jupiters

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: we advocate to exploit the greatest virtue of JWST for planetary sciences: to obtain the most thorough characterization of exoplanet atmospheres. We propose to observe the continuous ∼0.6–12 μm transmission spectrum and 2.8–12 μm emission spectrum for a sample of ∼6 planets. One full transmission and emission spectra for a planet will require 5 observations combining NIRISS/SOSS, NIRSpec/G395H, and MIRI/LRS. By collecting two full panchromatic spectra per planet, these observations will yield the most detailed and precise spatial- and time-resolved molecular inventory of exoplanetary atmospheres. Such a rich dataset will enable us to the test when and to which degree the different physical processes shape the composition of an atmosphere. This program requires a total of ∼500 hours of JWST time, yielding two panchromatic transmission and emission spectra for a sample of ∼8–9 exoplanets.

Anticipated Science Objectives: The panchromatic observations of WASP-39b (0.5–12 μm) have demonstrated the unrivaled characterizing power of JWST, revealing the presence of a multitude of species like H_2O, CO, CO_2, SO_2, and K [1, 2, 3, 4, 5]. Multiple molecular constraints are fundamental to assess which physical processes shape the composition of an atmosphere by disentangling the impact of different regimes (equilibrium or disequilibrium chemistry) and formation scenarios (different metallicities or C/O ratios). However, efforts to model the aggregated WASP-39b data have also found difficulties to reach a consensus on the planet physical properties (e.g., $10\times$ vs $100\times$ solar metallicities). Clearly, atmospheric inference is a challenging endeavor even for the most favorable targets. Lets also remind that theoretical models are still far from being fully understood (e.g, the ad-hoc $K_{\rm zz}$ parameterization for disequilibrium-chemistry processes). Since hot- and warm-Jupiters can yield much stronger atmospheric constraints than smaller planets [e.g., 6, 7], we pose that the best way to advance our knowledge of planetary sciences is through the in-depth study of Jupiter sized planets. Thus, ideal targets are those orbiting inactive host stars with magnitudes $\mathrm{K}_s \gtrsim 7$, where the entire 0.8–12 μm spectra can be obtained. A panchromatic approach will enable to probe the features from many C, N, and O-bearing species (abundance constraints or upper limits). Combining transits and eclipses will enable to spatially trace these abundances through the terminator and day-side hemisphere. Transit spectra can even trace abundance variations with altitude (Fig. 1). Lastly, re-observations will test the replicability of observations and reveal temporal variability. The sample can leverage already existing observations, a ∼500 h program would yield two panchromatic transits and two eclipses for ∼8–9 planets. Plausible high-S/N targets [8] are: HAT-P-32b, HAT-P-67b, KELT-7b, WASP-12b, WASP-39b, WASP-69b, WASP-76b, WASP-80b, WASP-107b, WASP-121b, and WASP-127b.

Urgency: The physics of planetary atmospheres is still a long way to be fully understood. Logic tells that first we should attempt to comprehend it before venturing to study it on lower S/N planets.

Risk/Feasibility: This program observes the highest S/Ns targets in existence therefore minimizing the science return risks. As for any exoplanet there is a risk of weak constraints due to clouds.

Timeliness: JWST is the only observatory in existence capable of achieving the spectral coverage and S/N.

Cannot be accomplished in the normal GO cycle: The investment of hundreds of JWST hours is beyond the scope of GO or Large Treasury programs.

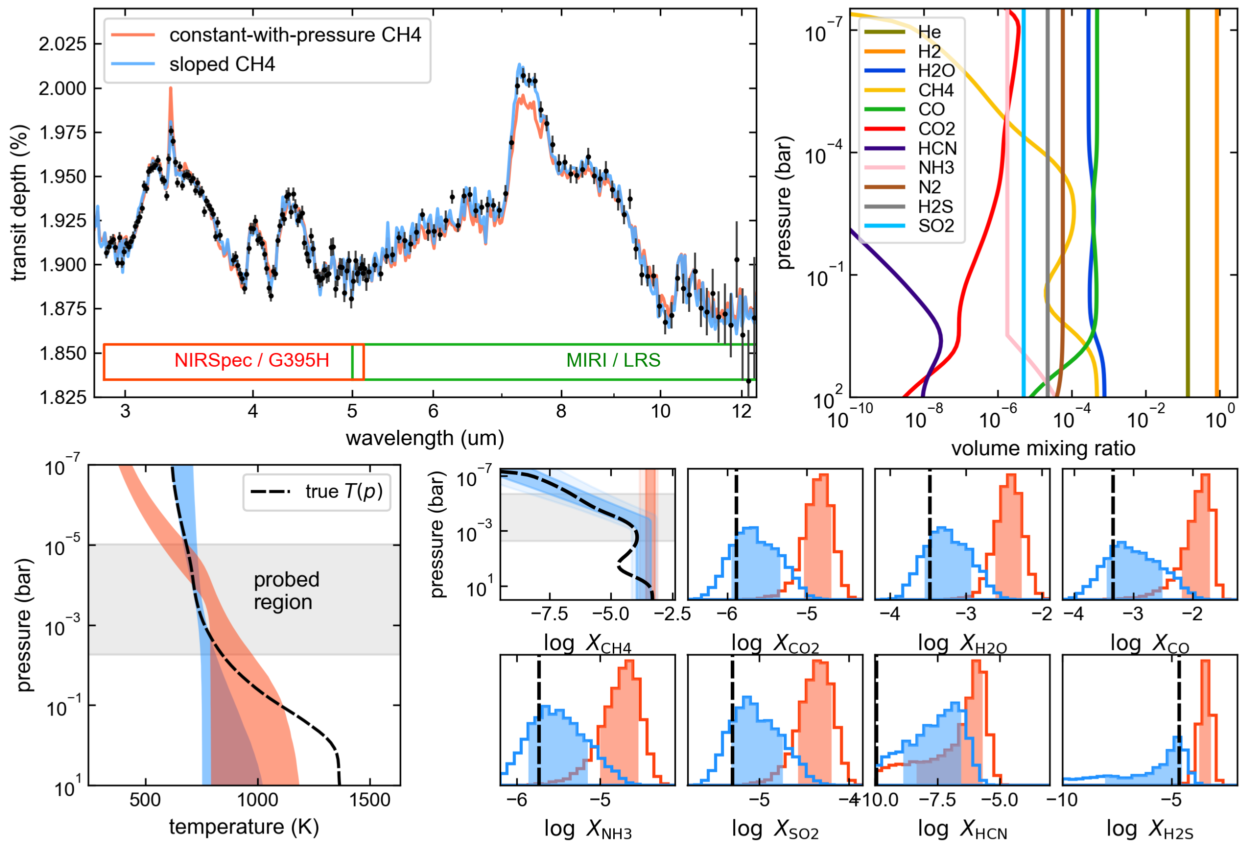

Figure 1: Example of a high-S/N atmospheric transmission simulation (NIRSpec/G395H and MIRI/LRS) for a cloud-free warm-Jupiter like WASP-69b [9]. We generated a transmission spectrum (black points with error bars) from a thermochemical- and radiative-equilibrium atmosphere with solar composition (top right panel). We then retrieved the spectrum assuming (1) the standard constant-with-altitude abundances approach (red posteriors, 1σ boundaries) and (2) a similar model but with a sloped CH_4 abundance that varies with pressure (blue posteriors). The retrieval results show that the constant CH_4 abundance not fails to fit the entire spectra, but also biases the retrieved abundances of all other species. On the other hand, the pressure variable model captures the CH_4 pressure structure of the input model and fits better the other abundances. This example shows that the S/Ns and spectral coverage of these kind of datasets can provide statistically significant detection of the abundance variability with pressure (in this case, $\Delta\log(\text{evidence}) = 95.9$) when main absorber probes a wide extension of the atmosphere (both in wavelength and pressures).

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