Your Title

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 propose a program to observe phase curves of between 5 and 9 hot Jupiters with NIRSpec/PRISM (0.6-5.3μm). The 3D properties of hot Jupiters, their global circulation, hemispheric temperature structures, cloud coverage and chemical compositions are still unknown in detail. Their global chemical and temperature structure has implications for planet formation, observational analysis, and habitability.

Experience with the Solar System planets has shown that high-precision, multi-dimensional observations are needed to construct accurate models and theories; this program provides an opportunity to do this for an entire laboratory of a single class of planet. We identify the best observational targets for this program and organise them into two sets of five targets, varying either equilibrium temperature or orbital period while holding the other constant.

Anticipated Science Objectives:

Hot Jupiters are important because they have the most readily observable exoplanet atmospheres but major open questions remain about their formation [1] and atmospheric circulation. Their global circulation provides the most accessible example of the circulation of tidally locked planets [2], with key consequences for understanding the habitability of tidally locked rocky planets [3].

The complexity of Solar System atmospheres shows that global circulation cannot be understood in advance with numerical models; detailed observations are needed to constrain these models. The Juno mission provided unprecedented gravity and radar data for Jupiter, showing inhomogenenous ammonia abundances [4] and deep zonal flows [5], which were not predicted by numerical models.

Observing full phase curves containing at least one eclipse and at least one transit provides the required information about global energy balance, hot-spot shifts, night-side composition, and clouds [6, 7]; they also improve the fitting of instrumental systematics and break degeneracies when fitting models.

We therefore suggest observing a large sample of full phase curves of hot Jupiters with NIRSpec/PRISM, to cover the most important part of the SED and to probe the most relevant features. Figure 1 shows a target list for this program; the first panel shows targets ranked by emission spectroscopy metric [8]. The second panel shows two key subsets in equilibrium temperature and orbital period.

Observing the five planets with period ~ 1.4 days in Figure 1 will test varying equilibrium temperature. Observing the five planets with temperature ~ 1850K will test varying period. Observing all nine new planets (NGTS-10b has already been observed by program 2158) will require roughly 420 hours of observing time, which will approach 450 hours including overheads. This will provide an invaluable treasury for constraining models and deriving theoretical trends.

Urgency: Hot Jupiters are a central part of exoplanet science and most modelling and observing strategies derives from their study; the sooner they are fully understood, the better for the rest of the field.

Risk/Feasibility: The longest period phase curve would push the frontier of current observations, and re-acquisition may be necessary. With the demonstrated stability of the observatory, the impact on the science results should be minimal.

Timeliness: We currently rely on 3D models to interpret many observations of a variety of tidally locked planets but have no strong proof that they are accurate.

Cannot be accomplished in the normal GO cycle: These objectives require roughly 450 hours of JWST time, far beyond the capabilities of a GO program.

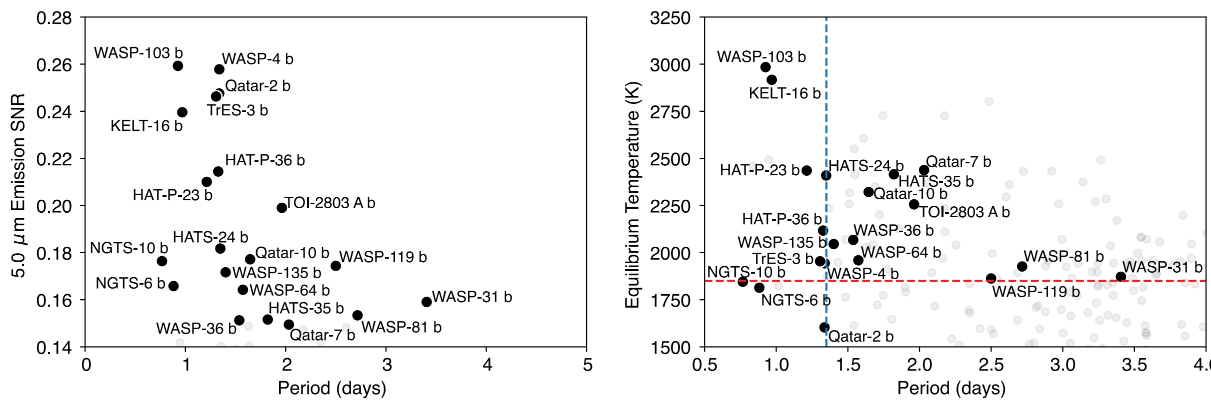

Figure 1: First panel: emission SNR versus orbital period for planets with K > 10.5, showing the best NIRSpec PRISM targets in terms of the expected signal and the time taken for a phase curve. Second panel: Equilibrium temperature versus orbital period for the best targets, showing how it will be possible to sample groups with fixed temperature and variable orbital period, or vice versa.

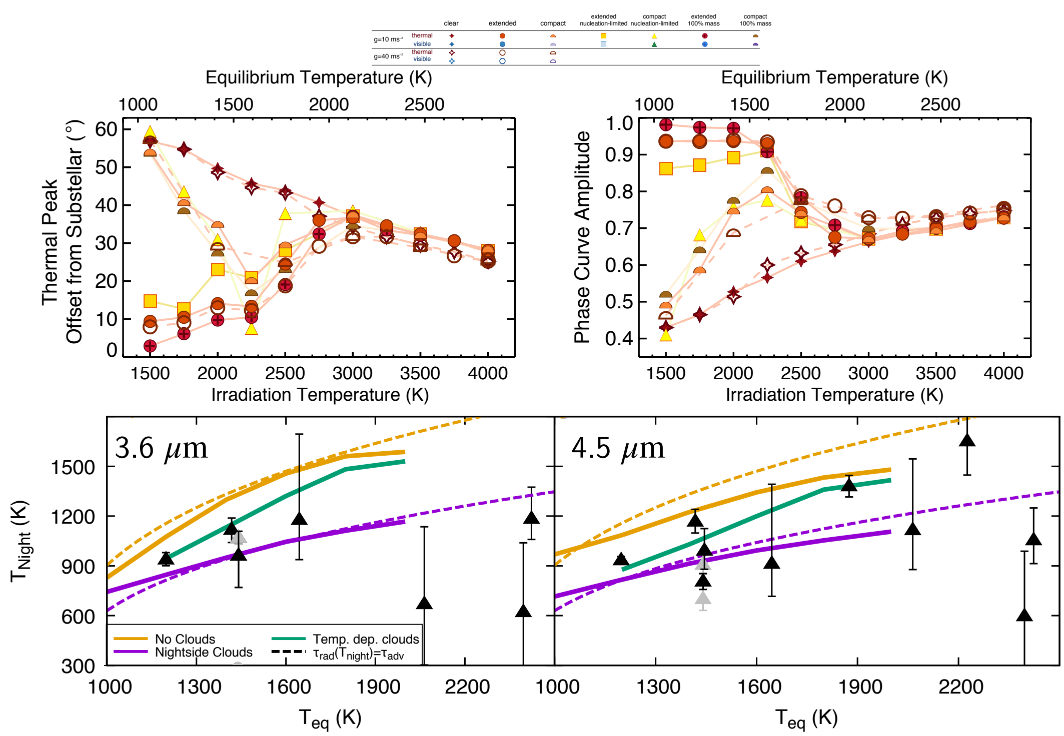

Figure 2: The coupled impact of atmospheric dynamics and clouds shape the expected phase curves of hot Jupiters. Top row: Predictions for thermal phase curve offset and amplitude from the cloudy GCMs of [9]. Bottom row: Predictions for the nightside brightness temperature (a key phase curve measurable) at $3.6\ \mu$m and $4.5\ \mu$m from GCMs with and without clouds. A broad set of phase curve measurements are required to determine the extent to which clouds, circulation, and other physical effects (gravity, rotation period, atmospheric drag) shape the observable properties of extrasolar gas giants. Figures adapted from [10] and [9].

References

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