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Cloudy nights on hot Jupiters

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Abstract

The atmospheres of hot Jupiters are inherently three dimensional and can be probed through the continuous observation of the planet brightness during it's orbit (aka phase curve). The phase curve amplitude and the offset of the maximum of the phase curve compared to the secondary eclipse is often used as a diagnostic of the day/night temperature contrast and the longitudinal shift of the hottes spot of the atmosphere. Current state-of-the-art global circulation models, however, systematically over predict the phase curve offset and underpredict the phase curve amplitude. Using a simplified cloud parametrisation we show that the presence of clouds on the nightside of the planet can affect both the phase curve offset and the phase curve amplitude, leading to a better agreement between data and theory.

1. Introduction

As shown in Figure 2, phase curves have been obtained for more than 10 hot Jupiters spanning a wide range of temperature. Phase curves taken at different wavelengths probe different layers of the atmosphere and a non-grey model are needed to interpret them jointly. Current state-of-the-art cloudless models (plain lines) systematically underpredict the phase curve amplitude and over predict the phase curve offset at all wavelengths.

2. Methods, results, conclusion

We use the SPARC/MITgcm [2], a global circulation model coupled with a state-of-the-art radiative transfer model [3] to study the atmosphere of hot Jupiters with equilibrium temperatures ranging from 1000K to 2000K. We study the effect of clouds on both the atmospheric circulation and the emission spectrum by running both cloudless models post-processed with cloud opacity and models with radiatively active clouds. When clouds are forced to be present on the nightside

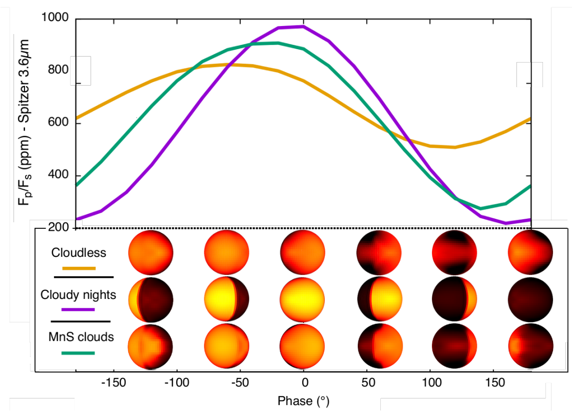

Figure 1: Phase curve and brightness maps of three hot Jupiter SPARC/MITgcm models with an equilibrium temperature of 1400K: a cloudless one, one with nightside clouds only and one with MnS clouds. The presence of nightside clouds affects both the phase curve offset and the phase curve amplitude.

of the planet, we find that they not only affect the phase curve amplitude, but that they also reduces the phase curve offset, whether or not the radiative feedback of the clouds are taken into account (see Figure 1). As shown in Figure 2, the presence of nightside clouds with a particle size of $\approx 1\mu m$ allows the models and the data to reach a much better agreement over a wide range of equilibrium temperatures. By investigating several different cloud parametrisation, we show that the cold-trap scenario discussed in Parmentier et al. 2016 [1] to explain the optical phase curves of hot Jupiters is generally consistent with the thermal phase curves, although more observations would be needed to confirm, refine or rule out the model.

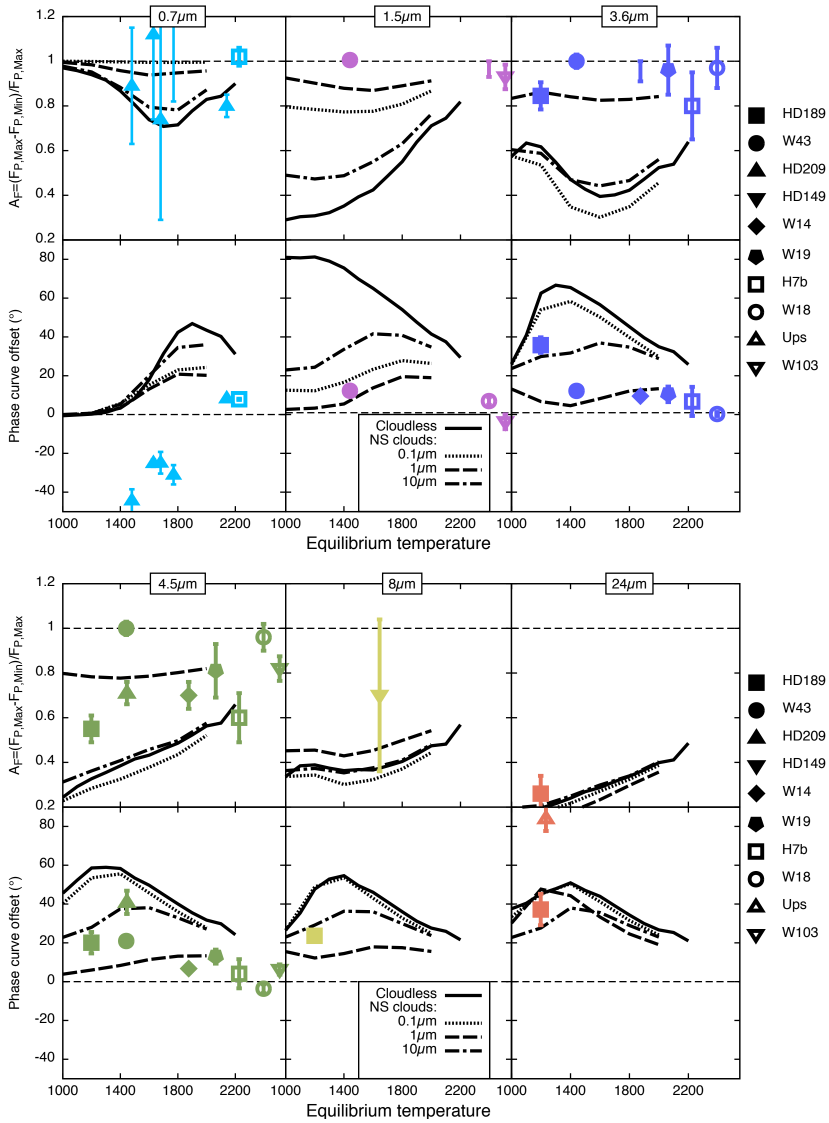

Figure 2: Phase curve offset and phase curve amplitude of hot Jupiter phase curves obtained at different wavelengths compared to a cloudless suite of global circulation models and a suite of models with imposed nightside clouds of different particle sizes. The presence of nightside clouds increases the phase curve amplitude and decreases the phase curve offset, leading to a better agreement with the observations.

Finally we explore the diversity of cloud signatures expected in the nightside of hot Jupiters and highlight the role of the cloud emissivity in shaping the nightside spectrum. We expect that a JWST/MIRI phase curve should be able to observe the signature of silicate clouds in the nightside of hot Jupiters and disentangle between different cloud scenario [4].

References

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