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Characterization of rocky exoplanets from their infrared phase curve

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Abstract. During the last few years, observations have yielded an abundant population of short-period planets under 15 Earth masses. Among those, hot terrestrial exoplanets represent a key population to study the survival of dense atmospheres close to their parent star. Thermal emission from exoplanets orbiting low-mass stars will be observable with the next generation of infrared telescopes, in particular the JWST. In order to constrain planetary and atmospheric properties, we have developed models to simulate the variation of the infrared emission along the path of the orbit (IR phase curve) for both airless planets and planets with dense atmospheres. Here, we focus on airless planets and present preliminary results on the influence of orbital elements, planet rotation, surface properties and observation geometry. Then, using simulated noisy phase curves, we test the retrieval of planets' properties and identify the degeneracies.

Keywords. methods: numerical, infrared: planetary systems

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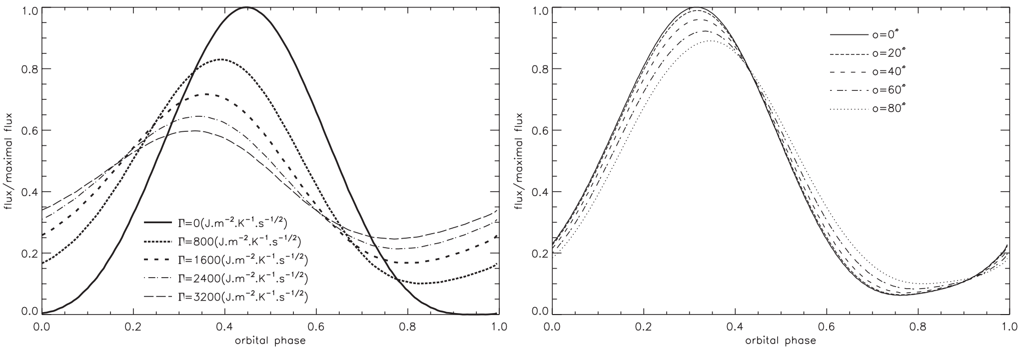
1. Infrared phase curve

The light received from a planet varies as the phase seen by the observer changes. At optical wavelengths, variations of the reflected light mainly depend on fraction of the starlit hemisphere in the field of view. At infrared wavelength, however, the phase curve is tightly connected to the temperature distribution on the planet. Infrared phase curves have been observed for short-period giant planets (in transit or not: e.g. Harrington *et al.* 2007; Swain *et al.* 2010), providing constraints on atmospheric circulation. The infrared phase curve of terrestrial planets will be observable provided that the planet is sufficiently hot and the host-star sufficiently cool. Short-period low-mass planets around M star (like for instance Gl581e) satisfy these conditions and are frequent enough to insure the existence of nearby targets.

Phase curves provide a powerful diagnostic for the presence/absence of a dense atmosphere. The temperature distribution, and therefore the thermal emission, of a planet with no atmosphere can be robustly modeled with a simple physical model depending on few parameters: albedo, thermal inertia (Fig. 1a.), rotation, obliquity (Fig. 1b.). In these examples, we assume here a circular orbit and a non synchronous rotation. In the first case, we have a zero-obliquity and we vary the thermal inertia Γ. For high thermal inertias, the heat is redistributed to the night side of the planet, because of the vertical heat diffusion in the subsurface (which reduces the amplitude of the variations) and the hottest region is shifted in longitude relative to the substellar point. A similar effect can be observed for fast rotators planets. The presence of an atmosphere will also make the transport of heat from tropic to pole more efficient. In the Fig 1b., it is the thermal inertia that is fixed, and we vary the obliquity, introducing a seasonal modulation, with a phase difference depending on the observer location relative to the rotation axis.



(a) (b)

Figure 1. Effect of thermal inertia and obliquity on phase curve. The inclination of the system is 90°(transit configuration). In a. the ratio of orbital by synodic period is 5, in b. it is 2.

2. Retrieval of planet properties

The model we developed computes the variations of surface and subsurface temperature by heat diffusion (Spencer *et al.* 1989), and the resulting infrared phase curve for any set of parameters: orbital elements, planet radius, rotation rate and obliquity, surface properties (thermal inertia, albedo) and observation geometry (inclination of the system). Using this model to produce phase curves, we can retrieve some of the planet properties using a genetic algorithm. When the planet is tidally-locked on a circular orbit, heat diffusion no longer matters and the only parameters to be retrieved are the radius and albedo of the planet and the inclination of the system. For an eccentric orbit, we add the synodic period and the thermal inertia. When the retrieved parameters are unrealistic or vary with the observed wavelengths, this points to the presence of a dense-atmosphere.

If you are interested by a collaboration in using our model, please contact A.S. Maurin.

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References

Harrington, J., Luszcz, S., Seager, S., *et al.* 2007, *Nature*, 447, 691
Spencer, J. R., Lebofsky, L. A., & Sykes, M. V. 1989, *Icarus*, 78, 337
Swain, M. R., Deroo, P., Griffith, C. A., *et al.* 2010, *Nature*, 463, 637

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