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# Characterizing Super-Mercuries by their infrared orbital photometry

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## Abstract

The photometric signal we receive from a star hosting a planet is modulated by the variation of the planet signal with its orbital phase. Already observed for giant exoplanets, those thermal phase curves should be measured with future telescopes (JWST and EChO) for hot rocky Super-Earths in transiting and nontransiting configurations. The nontransiting ones are the most numerous. We show here that we can infer from the thermal phase curve of a synchronous rocky airless exoplanet its radius, Bond albedo and the inclination of the orbit. When the orbit is eccentric, the planetary rotational period can be determined from the infrared photometric monitoring. Furthermore, the tidal dissipation within the planet can be constrained, that can allow us to improve tidal models.

## 1. Introduction

Results from Kepler [1] and Harps[2] reveal that more than 30 % of stars should host a short-period planet ($P < 50$ days) with a radius between 2 and 4 $R_\oplus$, and 90 % of them do not transit. Those planets being hot, it is reasonable to assume that large analogues of Mercury with no atmosphere exist within this population. We developed a model able to reproduce the thermal phase curve of a rocky airless planet in any observational and geometrical configuration, including or not the reflective flux. We have also the possibility to add noise to simulate observed phase curve and apply a procedure to retrieve planetary characteristics. We present here major results about synchronous and eccentric orbits.

## 2 Synchronous orbit

In the case of nontransiting planet on a synchronous orbit, the planetary radius, Bond albedo and the orbital inclination are unconstrained. For a given albedo, inclination and radius, we produce $n$ noisy phase curves for each spectral band 1 micron-wide from 5 to 15 $\mu$m. The only difference between these $n$ realizations is the random stellar photon noise, and the instrumental noise. For each noisy phase curve, we determine the values of $R$, $A$ and $i$ that minimize $\chi^2$ using the downhill simplex method.
We test our procedure to retrieve the radius, albedo and inclination for different star+planet systems and with different instruments. Figure 1 shows the results for the JWST telescope and for a planet at 0.02 AU of its star. The X-axis gives the *real* values of $R$, $A$ and $i$, which are used to produce the noisy phase curves and the Y-axis gives the median of the best-fit values. The error bar gives the 95 % confidence level (2 $\sigma$). A good retrieval should fall on the dotted-line. The knowledge of both the radius and the mass can then be used to assess the bulk composition of the planet.

## 3 Effects on tides and rotational period on eccentric orbits

Tidally-evolved exoplanets on eccentric orbits should rotate in either a spin-orbit resonance or in pseudo-synchronous equilibrium state that is crossed at some point in the evolution. In the latter case, the observation could discriminate between tidal models, for instance time-lag vs phase-lag [3] We model the surface temperature of rocky planets with no atmosphere including vertical diffusion of heat in the subsurface, because in the case of an eccentric orbit the substellar insolation varies with the planet-star distance: the pe-

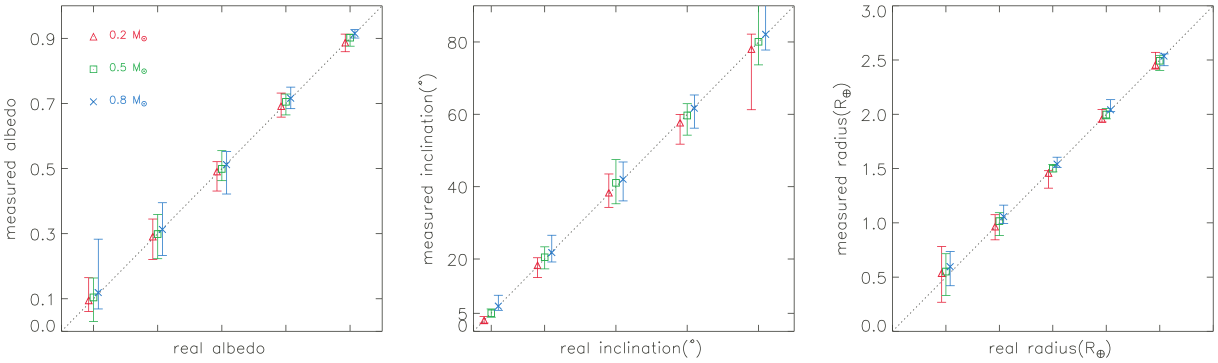

Figure 1: Ability to retrieve the albedo, inclination and radius of a synchronous rocky exoplanet with the JWST, for 3 different stellar masses. The orbital distance is a=0.02 AU. The triangles, squares and crosses correspond to 3 different stars ($M$=0.2, 0.5 and 0.8 $M_\odot$ respectively). For the albedo retrieval (left), the radius is fixed to 2 $R_\oplus$ and the inclination to 60°. For the inclination retrieval (middle), the radius is fixed to 2 $R_\oplus$ and the albedo to 0.1. For the radius retrieval (right), the albedo is fixed to 0.1 and the inclination to 60°.

riastron passage produces a hot spot on the surface that cools on a timescale determined by the thermal inertia.

We show in Fig. 2 that the rotational period can be measured by the modulation it produces in the apparent thermal emission of a 10 $M_\oplus$ planet around a M 3 dwarf. The relative photometric variations are larger than $10^{-5}$ (a precision achieved by Kepler in the visible and aimed by EChO in the infrared).

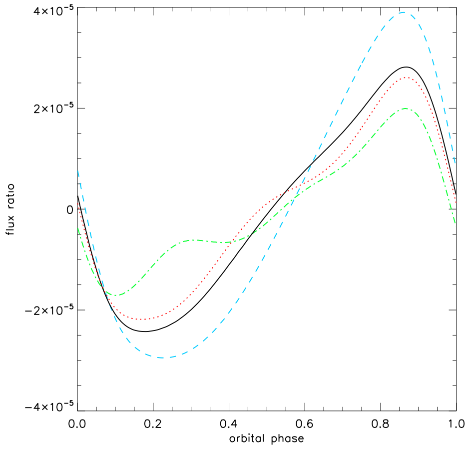

Figure 2: Variation of the thermal emission (8$\mu$m) for an eccentric planet without internal flux. The orbit is seen with an inclination of 60°. Black solid, the planet is in pseudo-synchronous rotation, blue dashed in synchronous rotation, green dash-dotted in 3:1 resonance, red dotted in 3:2 resonance. The planet mass is 10 $M_\oplus$, a=0.05 AU, e=0.2. The stellar mass is 0.2 $M_\odot$ and the thermal inertia is 3000 $\mathrm{J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}}$.

# 4. Summary and Conclusions

We use a thermophysical model to compute the surface temperature of a airless rocky exoplanet in any orbital configurations. In the synchronous cases, the radius, albedo and orbital inclination can be constrained. If the orbit is eccentric, the signal of the rotational period can be seen in the phase curve.

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