EPSC Abstracts
Vol. 6, EPSC-DPS2011-908, 2011
EPSC-DPS Joint Meeting 2011

Measuring the albedo, inclination and radius of nontransiting terrestrial exoplanets

A.S. Maurin (1,2), F. Selsis (1,2), F. Hersant (1,2) and A. Belu (1,2)
(1) Université de Bordeaux, Observatoire Aquitain des Sciences de l'Univers, 2 rue de l'Observatoire, BP 89, F-33271 Floirac Cedex, France
(2) CNRS, UMR 5804, Laboratoire d'Astrophysique de Bordeaux, 2 rue de l'Observatoire, BP 89, F-33271 Floirac Cedex, France

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. Future telescopes (JWST and EChO) will have the capability to measure thermal phase curves of exoplanets including hot rocky planets in transiting and nontransiting configurations. We model the thermal emission of a synchronous rocky planet with no atmosphere and its apparent variation with the orbital phase for a given orbital inclination. We assume that the planet is detected by radial velocity. We simulate observed noisy phase curves and then apply a procedure to retrieve the radius and albedo of the planet and the inclination of the orbit.

1. Introduction

Results from Kepler [2] reveal that 20-25 % of M0 through K dwarfs host a short-period planet with a radius between 2 and 4 $R_\oplus$. For the same range of orbital periods, the same study shows that more than 18% of G-K dwarfs host a planet with a radius between 1 and 2 $R_\oplus$. Exoplanets with $P < 50$ days and $5 < M \sin i < 20\,M_\oplus$ have been found by the HARPS radial velocity survey around $30 \pm 10\,\%$ of the G and K stars [3]. The geometric transit probability being for most of the planets below 10 %, the characterization techniques requiring transit configuration miss more than 90 % of these planets.
We focus here on the specific case of a rocky planet that has no atmosphere and is tidally-locked in a 1:1 spin-orbit resonance on a circular orbit. It is reasonable to assume that large analogues of Mercury with no atmosphere exist within this population. The present work addresses the possibility to constrain the radius, the Bond albedo and the orbit inclination using the thermal phase curve observed in multiple spectral bands by the JWST or EChO, recently selected for the Assessment Phase for the Cosmic Vision program of ESA.

2. Methodology and Results

We consider a nontransiting exoplanet on a circular orbit. Some characteristics of the system are known to the observer but the planetary radius, albedo and the orbital inclination are unconstrained. With our model, we can produce these thermal phase curve variations and add to them unavoidable noise. For the spectral resolution, we consider ten 1 micron-wide bands from 5 to 15 μm. For a given albedo, inclination and radius, we produce n noisy phase curves for each spectral band. The only difference between these n realizations is the random stellar photon noise, and instrumental noise when included (for the JWST). For each noisy phase curve, we determine the values of R, A and i that minimize χ^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 EChO 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 σ). A good retrieval should fall on the dotted-line.
If we combine the projected mass $M \sin i$ measured from radial velocity observations with the constraint on the inclination from the phase curve, we obtain an estimate of the true mass. Retrieved mass and radius and their associated uncertainty can be compared with theoretical models to assess the composition of the planet. Figure 2 shows mass-radius relations of ice/rock and rock/iron planets from Fortney et al [1] and the range of mass and radii obtained from phase curves for 3 known exoplanets (HD40307 b, GJ581 b

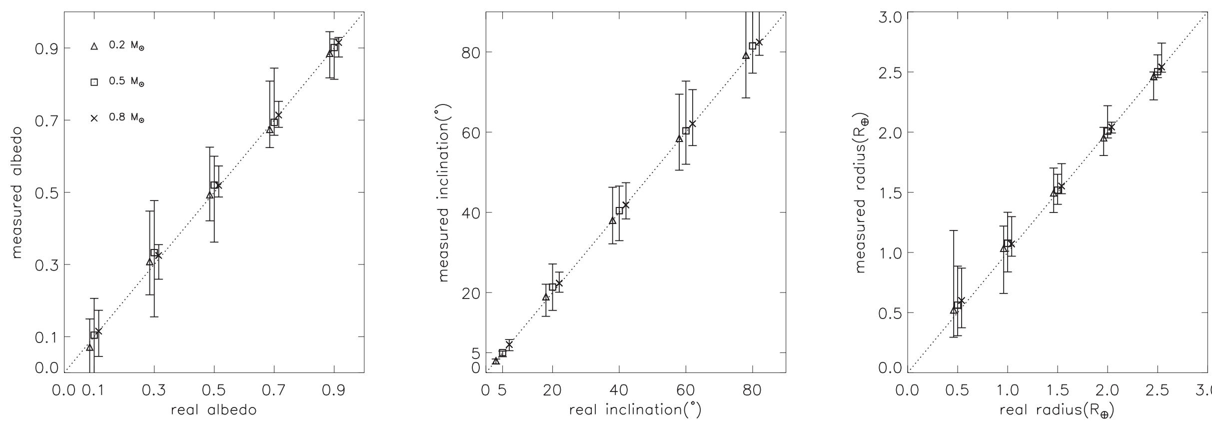

Figure 1: Ability to retrieve the albedo, inclination and radius of a synchronous rocky exoplanet with an ideal 1.5 m telescope (photon noise-limited observations), for 3 different stellar masses. The orbital distance is a=0.02 AU. The triangles, squares and crosses correspond to 3 different stars (M=0.2, 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°.

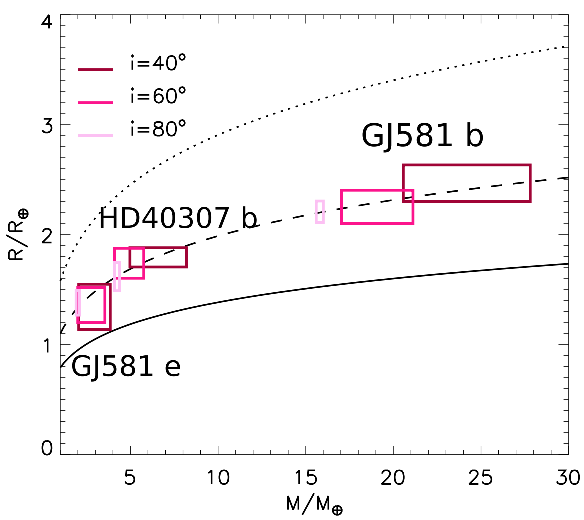

Figure 2: Precision on the mass and radius determination for three known exoplanets (GJ581 b, GJ581 e and HD40307 b). Wa assume a rocky composition for the planets (100 % silicates). The radius changes with the mass and thus with the inclination.

and GJ581 e) assuming that they are made of silicates.

3. Summary and Conclusions

In this study we have modeled the thermal emission of an exoplanet with no atmosphere, on a circular synchronous orbit. The modulation of this emission with the orbital phase at different wavelengths can be observed for exoplanets in nontransiting configurations, known from a previous radial velocity detection. We have shown that for an airless planet it is possible to constrain the radius and albedo of the planet as well as its orbital inclination. The constraint on the inclination yields a constraint on the mass using the value of $M \sin i$ measured by radial velocity. The knowledge of both the radius and the mass can then be used to assess the bulk composition of the planet.

Acknowledgements

FS acknowledges support from the European Research Council (Starting Grant 209622: E_3ARTHs).

References

[1] J. J. Fortney et al. Erratum: "Planetary Radii across Five Orders of Magnitude in Mass and Stellar Insolation: Application to Transits". *ApJ*, 668:1267+, 2007

[2] A. W. Howard et al. Planet Occurrence within 0.25 AU of Solar-type Stars from Kepler. *e-print ArXiv:*1103.2541, 2011

[3] M. Mayor et al. The HARPS search for southern extra-solar planets. XIII. A planetary system with 3 super-Earths (4.2, 6.9, and 9.2 $M_\oplus$). *A&A*, 493:639-644, 2009