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A Thermal Evolution Model for Corot-7b

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Abstract

The discovery of extrasolar planets - planets that orbit stars other than our sun - has always been fascinating. Meanwhile more than 400 so–called exoplanets have been detected. These discoveries provide us with the opportunity to gain a better understanding of our own solar system. However, most the detected exoplanets so far are relatively large (beyond 10 M_{Earth}) and can be regarded as gaseous planets, which allows comparisons with the gas giants in our solar system. Scientists have always seeked after smaller and rocky planets, which could be compared to Earth or other earth–like bodies.

1 Introduction

Recently, the COROT mission discovered an object, Corot-7b, with a radius of only $1.68R_{Earth}$ corresponding to a mass of $4.8 \pm 0.8M_{Earth}$. This first low-mass exoplanet – a so-called *Super-Earth* – can be considered to be solid. Although still rather large it is much more similar to the solid planets in our solar system than the other discoveries before. Corot-7b orbits its primary at a very close distance and is therefore tidally locked in an 1:1 spin-orbit resonance. This implies a very inhomogeneous energy input from the star into the planet. Since the dayside is constantly exposed to the star, there is a strong temperature gradient towards the nightside. The surface temperature on the illuminated side is estimated with 2700 K, while the shadowed side is thought to be at 110 K. The high temperatures on the dayside will cause the evaporation of volatiles, which gives rise to the formation of an atmosphere.

2 Model

We introduce a three dimensional thermal convection model by solving the pertaining dimensionless hydrodynamical equations, derived from the conservation of mass, momentum and energy. With the code we compute the temperature field $T(r, \vartheta, \varphi)$, by employing a combination of a spectral and a finite difference method. We are especially looking at the formation of partially molten regions due to the inhomogeneous energy input onto the surface. The temperature of the surface and subsurface regions is enormously important for the composition of the atmosphere fed from volatiles, which escaped from the planet. The atmosphere is the only part of this exoplanet which can be observed with remote sensing methods. Henceforth, understanding the conditions for the formation of an atmosphere (i.e., surface temperature map) is an important step forward in understanding extrasolar planets.

3 Results

We found that the highest temperatures are reached below the sub-solar hotspot up to a depth of 2500 km. Fig. 1 shows a slice through the planet perpendicular to the terminator region, the star would be on the right hand side. It can clearly be seen that the temperatures are generally higher below the sub-solar spot. This is also illustrated by the temperature isosurface of 4270 K. The hot upwellings concentrate below the dayside.

Directly below the subsolar spot the material would be molten up to 200 km deep, while towards eastern or respectively western longitudes material freezes out in shallower depths. However, the solidus is at least slightly exceeded on the entire dayside hemisphere. There are interesting implications for this. As pointed out in [1] the column density of various elements and compounds rises with increasing temperature. Henceforth at least above the subsolar spot and nearby regions an 'atmosphere' should be present.

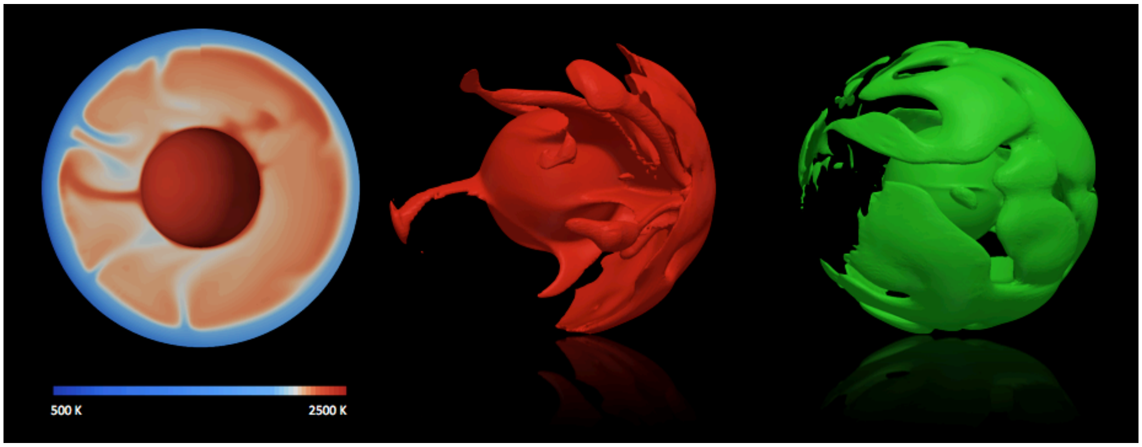

Figure 1: Left: temperature slice, Centre: temperature isosurface (red) of 4270K, Right: partial melt isosurface (green) of 50k above solidus temperature

4 Discussion and Conclusion

We kept the model simple in the first place, since a lot of parameters are unknown. The intention was to get a general idea of the 'behaviour' of Corot-7b's interior and draw first conclusions, which would then point to the next questions and subsequent models. As expected the high temperatures at the hemisphere facing the star strongly influences the thermal evolution and state of the planet. The planet develops a layer of partially molten material, which could be the source for volcanism, which itself favours outgassing. Since the exact gradient of the solidus is unknown, these results have to be regarded as highly uncertain. However, the solidus is empirically known up to 20 GPa, respectively. According to this the hemisphere facing the star should be largely molten and an atmosphere should be present. Which elemental composition this atmosphere could have is again not very well known.

References

[1] L. Schaefer, B. Jr. Fegley. Chemistry of Atmospheres Formed during Accretion of the Earth and Other Terrestrial Planets. *Icarus*, 2010, doi: 10.1016/j.icarus.2010.01.026