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The Inner Structure of the Planets Kepler-62 e and Kepler-62 f

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Abstract

Here we present a model for the possible inner structure of Kepler-62 e and Kepler-62 f combined with an estimate of their bulk densities. We computed a 5-layer-model for these planets based on the assumption that their internal structure is similar to the structure of terrestrial planets consisting of five main layers around G2V stars.

1. Introduction

In 2013, the detection of two nearly Earth-size planets Kepler-62 e and Kepler-62 f orbiting a K2V star about 368 pc away from the Solar System was announced [2]. These planets have radii of 1.61 and 1.41 Earth radii, respectively. Borucki et al. were not able to measure the masses of these planets because RV measurements were not accessible due to "the planets' low masses, the faintness and variability of the star, and the level of instrument noise"[2]. Those planets orbit their host star within the classical habitable zone [4] at semi-major axes of 0.427 $\pm$ 0.004 AU and 0.718 $\pm$ 0.007 AU. Kepler-62 b and c detected in this system have smaller radii than the planets mentioned above, but they orbit the K2V star in far too small distances to be of astrobiological interest. Kepler-62 has a metallicity of only $Z = -0.21$ [*Fe/He*] [5]. Nevertheless, this value is still above the lower threshold for the critical abundance for planet formation according to the model of [3].

There are several other models that describe the interior of terrestrial-like exoplanets, e.g. the uncompressed density model of [6], which has been applied for CoRoT-7 b. Due to the lack of information about extrasolar planets, any model can only give a rough estimate on the inner conditions and the habitability of these planets.

2. Bulk density

The maximum masses were determined by [2] as 36 and 35 Earth masses, respectively, which are values far too high for terrestrial-like planets. With the mass-radius-relation of [7], we estimated the masses to be about 5.69 $\pm$ 0.64 and 3.50 $\pm$ 0.63 Earth masses. This leads to bulk densities of 7512.5 $\pm$ 851.5 and 6892.2 $\pm$ 1248.8 kg/m^3, respectively. These values should be seen as an upper limit because the model by [7] is configured for solar composition. In addition, we developed a further mass-radius-relation based on the data of currently verified exoplanets with masses between 1 and 10 Earth masses (including the Earth itself), where the respective radii are known. An exponential fit of the radius as a function of mass yields us bulk densities of 5494.0 $\pm$ 697.9 and 5500.3 $\pm$ 1023.5 kg/m^3 for Kepler-62 e and f, respectively. This relation was determined by the use of planets orbiting G and K stars. As can be seen by the huge gap between the results of these two relations, the computation of the bulk density of an extrasolar planet is still a difficult task due to the lack of information about extrasolar planets.

3. Model of the Interior

We calculated a 5-layer-model for the mentioned planets, which is based on the five main layers of the Earth (inner core, outer core, inner mantle, outer mantle, crust). The estimated bulk densities refer to rocky planets dominated by a huge Fe/Ni-core. In our model, the core of Kepler-62 e is by a factor 2.25 larger than the Earth's core while we had to expand Kepler-62 f's core by a factor of 1.83. These multiplication factors for the inner and outer core were achieved by adjustment to the proper bulk densities which arose from the model of [7].

This leads to pressures at the center of the planets of around 1256 GPa and 862 GPa, respectively, which are far higher than the central pressure of the Earth of about 330 GPa [1]. The gravity at the surface of Kepler-62 e amounts to 21.6 m/s^2 and at the surface of Kepler-62 f to 17.3 m/s^2. The pressures at the inner mantle/outer mantle boundary are 18.8 GPa and 17.1 GPa, respectively, an amount which is similar to the values estimated for the transition zone (i.e., the 520-km-discontinuity) of the Earth.

4. Summary

Kepler-62 e and Kepler-62 f are Earth-like planets that are dominated by a huge Fe/Ni-core identifiable from their high bulk density. The core/mantle-boundary has a distance of about 7840 km and 6370 km from the center for Kepler-62 e and Kepler-62 f, respectively. In comparison, this boundary inside the Earth lies at a radius of about 3480 km.

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