KEPLER-145B AND K2-66B: A KEPLER- AND A K2-MEGA-EARTH WITH DIFFERENT COMPOSITIONAL CHARACTERISTICS.

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Introduction

The most confirmed terrestrial exoplanets are being belonged to the mass category of super-Earths with masses lower than 10 Earth-masses ($M_\oplus$). A small population of the identified terrestrial planets are classified as mega-Earths having masses greater than 10 $M_\oplus$.

Kepler-145b is a supermassive terrestrial-like planet, having an orbital period of 22.951 days, has been detected in the original observing field (K1) of Kepler Space Telescope. Its mass and radius are (37.18 $M_\oplus$) and (2.648 $R_\oplus$) [1]. The mean density has been computed to be 11.04 g cm^{-3-1}, which from a typical terrestrial composition has been concluded.

K2-66 is a G1 subgiant star, which had been observed in the C3 field of Kepler K2 Mission. The star hosts an extremely hot sub-Neptune-sized (2.49 $R_\oplus$) planet (b) in the „photoevaporation desert" with an orbital period of 5.06963 days a mass of 21.3 $M_\oplus$ [2]. The mean density is calculated to be 7.609 g cm^{-3-1}, which indicates that K2-66-b needs to have a predominantly rocky composition.

Possible compositional and interior structure models have been made, which are limited to the measured mass and radius of Kepler-145 b and K2-66-b.

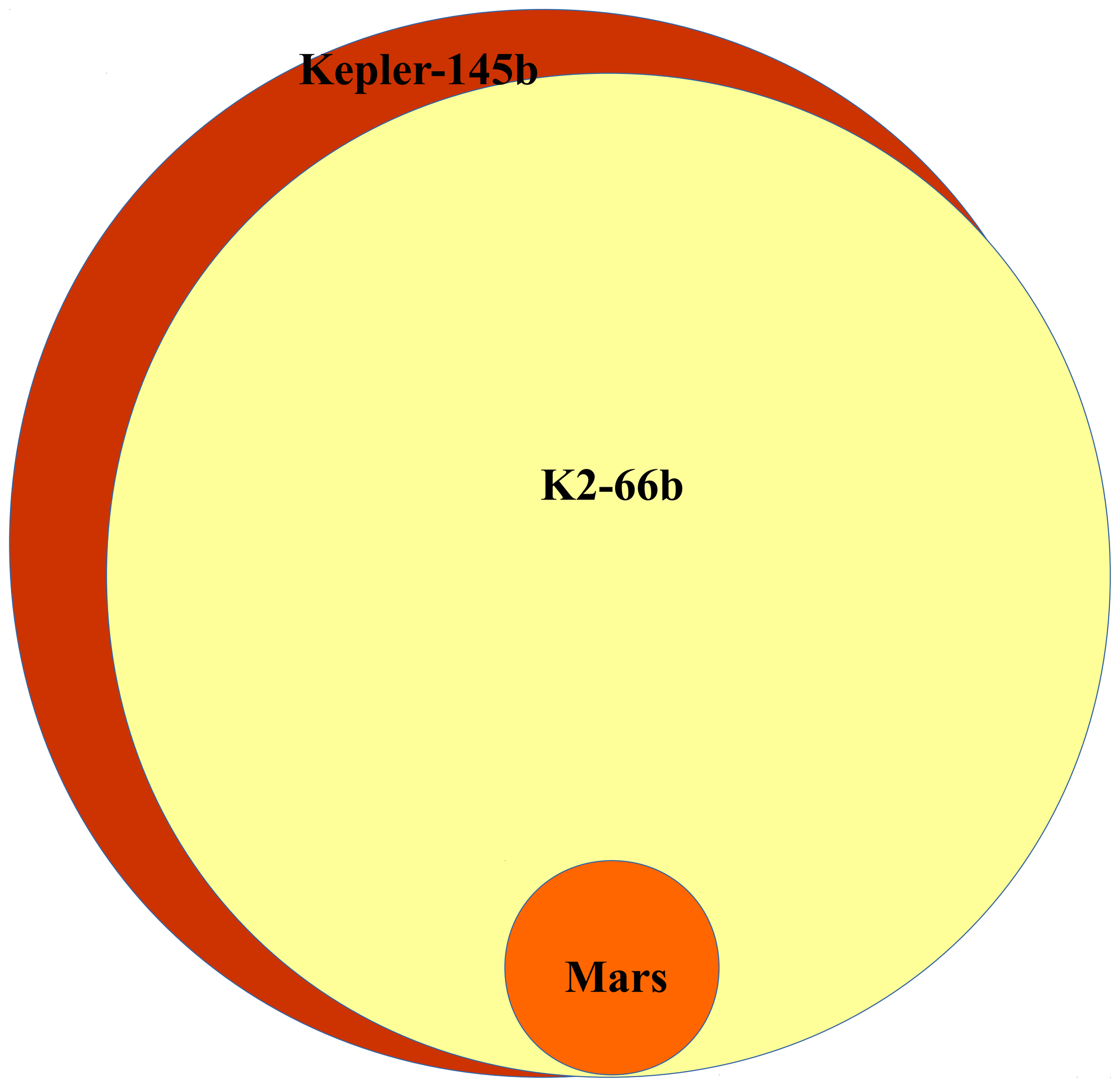


Figure 1. Schematic representation for the large rocky exoplanets Kepler-145 b and K2-66b. For size comparison, the Mars is also represented.

Model

A terrestrial analog silicate mineral composition has been assumed for the upper mantle and the uppermost region of the lower mantle in case of the both planet. The lowermost zone of the planetary mantles are thought to be consisted of ultra-high pressure (UHP) phases of $MgSiO_3$ perovskite.The planetary cores are taken to be composed of Fe and its relevant phases at given conditions.

In terms of the study of Umemoto [3,4], three-stage dissociation of $MgSiO_3$ occurs in the TPa to multi-TPa pressure range at given conditions. Post-pv is predicted to be dissociated into $I\bar{4}2d$-type Mg_2SiO_4 + $P2_1/c$-type $MgSi_2O_5$ at 0.75 Tpa (UHP1). The second transformation is being UHP1 transform into $I\bar{4}2d$-type Mg_2SiO_4 + Fe_2P-type SiO_2 at 1.31 Tpa (UHP2). The final-stage of the dissociation is UHP2 phase dissociated into CsCl-type MgO + Fe_2P-type SiO_2 at 3.09 Tpa (UHP3).

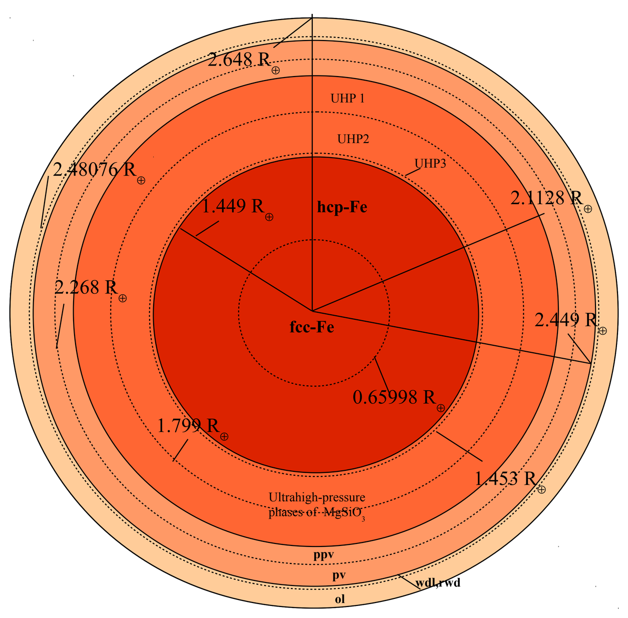
Vinet EOS [5, 6] has been used for calculating the material properties in the upper mantle and in the pv belt in the lower mantle. Murnaghan equation of state [7] is being suited at the calculation for pressure/density relation in the ppv and the UHP silicate mineral phases. The utilized zero-pressure densities of hcpFe[1] , fcc-Fe [2] , UHP silicate phases [3] [3] [4] [4] ,[8] [5] MgO [6] , ppv[7] , pv[8] , wdl/rwd[9] and olivine[10] are 8.255[1] [8], 8.06[2] [9], 3.67727[6] (calculated for MgO by the data of Strachan et al. 1999) [10], 4.27[7] [11], 4.152[8] [12] , 3.644[9] [12] and 3.347[10] [12] g cm^3 .

Plausible interior models for Kepler-145 b and K2-66b

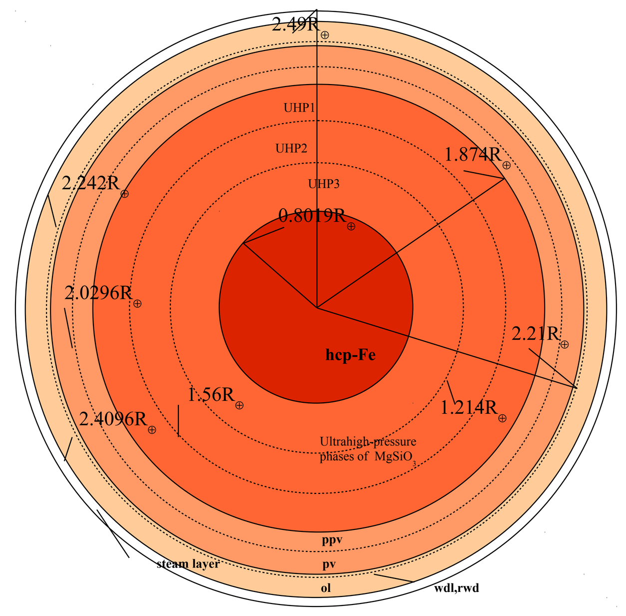
The values of globally averaged surface gravity are 52.06 m s^{-2}. (5.3 g Earth) (K-145b) and 33.746 m s^{-2} (3.44 g Earth) (K2.66b). The central pressures have been obtained to be 10.15318 TPa for K-145b and 4.266 TPa for K2-66b.

The UHP (1-3) phases of $MgSiO_3$ constitute the lowermost regions of the mantles for both planets. Kepler-145b has been found to have an Earth-like structure. The metallic core is being computed to be 1.449 $R_\oplus$,which is 54.72 percent of the total planetary radius. I has been built up from fcc-Fe and hcp-Fe at adequate conditions.

K2-66b is a silicate-dominated massive world. It has a relatively small-sized metallic core having been calculated with a radius of 0.8019 $R_\oplus$. The core thought to be composed of hcp-Fe.



a



b

Figure 2.

a: Schematic representation for K-145b. An Earth-like structure has been computed in the core/total planet radius ratio.

b: a simple two-component structure model for K2-66b. The rocky interior is being surrounded by steam atmosphere composed possibly of the combination of water steam, metal-oxides and hydroxide gases.

A thin dense water-steam bearing envelope is assumed in the top layer overlaid by the thick rocky interior.

Convectice zones may be expected for both planets overlying the highly viscous deeper region of the mantle.

Summary: Based on the modeling, Kepler-145 b has an Earth-like interior structure with a medium-size core mass fraction. According to a likely scenario, K2-66b is composed mostly of silicates, surrounded by a small mass fraction of a steam layer, having a small metallic core. In the future, the study of mega-Earths can help for better understanding the planet formation.

References: [1] NASA Exoplanet Archive [2] Sinukoff E. et al. (2017) *Astrophysical Journal.* 153. 271. [3] Umemoto K. et al. (2017): *Earth and Planetary Science Letters,* 478. 40-45 [4] Wu S. Q. et al. (2014): *Journal of Physics: Condensed Matter,* 26. 035402 [5] Vinet P. et al.1987. *Journal of Geophysical Research*,92, 9319. [6] Vinet P.et al.1989.*J.Phys.Cond.- Matter,*1, 1941 [7] Murnaghan F.D. 1944. *Proceedings of the National Academy of Science,*30, 244-247. [8] Wu S. Q. et al. (2011): *Physical Review B* 83, 184102 [8] Dewaele a. et al. (2006) *Physical Review Letters.* 97. 215504. [9] Dorogokupets P.I. et al. (2017) *Scientific Reports* 7. 41863. [10] Strachan A. et al. 1999.*Physical Review B*,60.15084. [11] Tsuchiya T. et al. 2004. *Earth and Planetary Science Letters,*224, 241 – 248. [12] Stixrude, L., Lithgow-Bertelloni C.2005.*Geophysical Journal International*,162, 610-632.