A TRANSITING 'MEGA-EARTH' IN THE KEPLER-FIELD:KEPLER-10C . P. Futó[1] [1] University of West Hungary, Szombathely, Károlyi Gáspár tér, H-9700, Hungary (dvision@citromail.hu)

Introduction: The planetary system Kepler-10 with two identified planet (signed b and c) is located 565 light-years from Earth in the direction of constellation Draco. Kepler 10 b is a terrestrial super-Earth with a relatively great core mass fraction. The planet c orbits its very old G-type host star with a period of 45.3 days at a distance of 0.241 AU. The basic parameters of Kepler-10 c that had also been previously known and it was recently measured to have a precise mass of 17.2 $M_\oplus$ and a radius of 2.35 $R_\oplus$ [1].

The relatively high average density (7.1 g $cm^{3\ -1}$) indicates that a large mass fraction of gaseous envelope could not exist in the uppermost sphere thus the planet needs to have a mostly rocky composition as opposed to the Neptune in our Solar-system. Kepler-10 c is more compact having a relatively high bulk density which is consistent a terrestrial-like interior rather than a Neptune-like structure. Considering the formation and evolution of exoplanets,there are definitely massive terrestrial-type planets which have a mass exceeding to 10$M_\oplus$. The most important purpose of this study is to investigate a possible scenario for the internal structure of Kepler-10 c that is likely to constitute a transition in composition between Neptune-like and massive terrestrial planets. In this manner,a terrestrial-like composition is preferred to be modeled by metallic compounds/silicates/water ice combination.

Modeling for the internal structure of Kepler-10c: In terms of the demonstrated model,this planet has a metallic core and a silicate mantle which above a water ice belt constitutes the top solid layer. Considering the average density,Kepler-10 c has no dominant water ice content but it is composed mostly of silicates. Based on geophysical and cosmochemical considerations,its water-ice mass fraction consists of Ice VII,Ice X and in a small mass fraction liquid water,water vapor in the outermost layer.

In terms of the results of Umemoto and Wentzcovitch [1],the $MgSiO_3$ post-perovskite (ppv) dissociates into CsCl-type MgO and $P2_1$ /c-type $MgSi_2O_5$ at 0.9 TPa. $P2_1$ /c-type $MgSi_2O_5$ might dissociate further into CsCl-type MgO and Fe_2P-type SiO_2 on the transition pressure 2.1TPa. These polymorphs are likely to have been the characteristic mineral phases in the cores of gas giants and in the lowermost region of the silicate mantle of massive terrestrial super-Earths. The extreme internal pressure and temperature is expected in the deep interior of Kepler-10 c which parameters are significantly higher than those in the less massive terrestrial-planets,constraining the $MgSiO_3$ for further transitions. Therefore,I suggested the higher-pressure polymorph of magnesium-silicate post-perovskite in the deep mantle. The behavior of planet-building materials is investigated at high pressures up to a few thousand gigapascals.

In terms of the hypothesis for the formation of the coreless terrestrial planets (Elkins-Tanton & Seager,2008) [3],it might also be possible that the massive silicate interior of Kepler-10c consists of material which had been oxidized fully before the metal-rich material would sink to form a metallic core. The original iron-components,reacting with water,transform into iron-oxide which has been trapped in the mantle. However,in my model I focus on a composition with metallic core and silicate-mantle.

The utilized zero-pressure densities of planet building materials-Fe,Ni,FeO,ppv,Ice VII and Ice X-are 8.3,8.908,5.745,4.26,1.46 and 2.51 g $cm^{3\ -1}$,respectively. Vinet equation of states [4,5] have been used (<1000 GPa) for computing the interior structure. The modified TFD EOS [6] is used to derive planetary properties in the pressure range above ~1 TPa.

Results: Taking into account the compositional characteristics and the predictions of planet-forming theories,Kepler-10 c must have formed further away from the central star (beyond the snow-line of its system) than its present location.

The central pressure is calculated to be 3350 GPa. A relatively significant water content surrounding a silicate interior is likely for Kepler-10c. As shown in Figure 1,the thick mantle (6326 km) is surrounded by the water-ice mass fraction with two layer of ice-phases (Ice VII and Ice X). The Ice VII transforms into Ice X at ~ 2.168 $R_\oplus$. In the proximity of the host star,the planet could develop a thin water-vapour atmosphere which has a thickness of minimum 70 km. The mass of water vapour-sphere is likely to be less than 0.1 % by the total planetary mass. Underneath the steam layer,a liquid water layer consists the following spherical shell in a thickness of ~ 190 km.

Basic parameters for the metallic core has been calculated finding the core radius 0.983 $R_\oplus$ is for ~3$M_\oplus$ CMF. The modeled planet has a similar total radius to a same mass planet with a slightly smaller core mass fraction and a consequently greater mantle mass fraction. Moreover,if Kepler-10 c had no metallic core, a larger total radius would be computed for it in case of the same water-mass fraction than that of the modeled version.

In the lower region of the mantle,the pressure exceeds 0.9 TPa. Accordingly,a phase boundary is presumable located ~ 2625 km above the core-mantle boundary -depth 6084 km,at the radius of 1.395 $R_\oplus$,where $MgSiO_3$-perovskite undergoes to a higher pressure phase by structural transition. The lowermost mantle is made from CsCl-type MgO and $P2_1$ /c-type $MgSi_2O_5$ (post-post-perovskite,p-ppv). This phase might be more stable than ppv within the wide range of silicate-mantle (or complete interior) pressures for the case of most massive silicate-dominated planets. A density difference arises across the gradual dissociation which is estimated to be 3-4 percent above 0.9 TPa for the higher pressure phase of $MgSiO_3$. The p-ppv region is 26 % of the silicate-mantle volume fraction.

The viscosity values in the lower mantle of most massive terrestrial planets are might be extremely high>10^{31} Pas. The lower region of their mantle is assumed as being a non-convective zone. In terms of the geological time-scale, Kepler-10 c is very old,however,the internal heating is thought to be even sufficient to sustain convection in the upper-mantle. Moreover,the lower region of the mantle (above the core-mantle boundary,CMB) is a conductive zone with no convective system owing to the high viscosity which is a temperature/pressure dependent parameter.

In conclusion,Kepler-10 c has a silicate interior in a great fractional volume which is consisted mostly of ppv and in a less volume fraction the aforementioned ultrahigh-pressure phases of $MgSiO_3$.

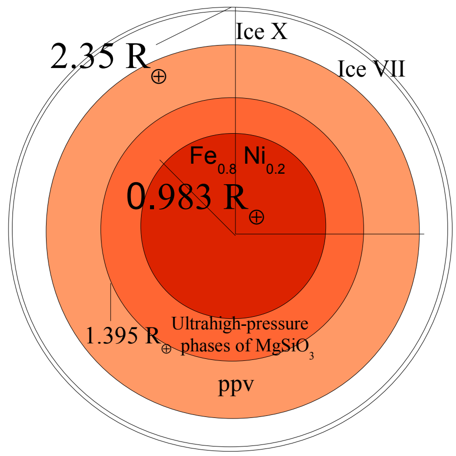

Figure 1. The modeled interior structure for Kepler-10 c:water ice mass fraction above a terrestrial composition.

Summary: Considering the modeled composition and the possible circumstances of Kepler-10c,it need to be interpreted as a new type of silicate planets which can be classified to a new planet-class,so-called 'mega-Earth'.

References:

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