

= Kepler @-@ 10c =

Kepler @-@ 10c is an exoplanet orbiting the G @-@ type star Kepler @-@ 10 , located around 568 light @-@ years away in Draco . Its discovery was announced by Kepler in May 2011 , although it had been seen as a planetary candidate since January 2011 , when Kepler @-@ 10b was discovered . The team confirmed the observation using data from NASA 's Spitzer Space Telescope and a technique called Blender that ruled out most false positives . Kepler @-@ 10c was the third transiting planet to be confirmed statistically (based on probability rather than actual observation) , after Kepler @-@ 9d and Kepler @-@ 11g . The Kepler team considers the statistical method that led to the discovery of Kepler @-@ 10c as what will be necessary to confirm many planets in Kepler 's field of view .

Kepler @-@ 10c orbits its host star every forty @-@ five days at a quarter of the average distance between the Sun and Earth . It has a radius more than double that of Earth , but a higher density , suggesting a mainly rocky composition with around 5 ? 20 % ices by mass . For comparison , the Earth 's oceans represent only 0 @-@ 02 % of our planet 's mass , with an additional amount potentially a few times this stored in the mantle .

= = Discovery and confirmation = =

In January 2011 , the closely orbiting planet Kepler @-@ 10b was confirmed in the orbit of the star Kepler @-@ 10 after measurements of its transiting behavior (where it crosses in front of Kepler @-@ 10 , periodically dimming it) and a radial velocity effect detected in Kepler @-@ 10 's spectrum provided the information needed to prove that it was indeed a planet . An additional , longer @-@ period dimming was detected in Kepler @-@ 10 's spectrum , suggesting that a second planet existed in the system ; however , there remained the possibility that this signal could have some other cause , and that the transit event was a false positive . Attempts to measure the radial velocity effects of this object , now named KOI 072 @-@ 02 , were fruitless ; therefore , to rule out false positive scenarios , the Kepler team used a technique called Blender .

The application of Blender was supplemented by use of the IRAC instrument on the Spitzer Space Telescope , which was used on August 30 and November 15 , 2010 , to further define Kepler @-@ 10 's light curve at the point where KOI 072 @-@ 02 appeared to transit it . It was found that the transiting object did not produce a color , an aspect that is characteristic of stars . This suggested even further that KOI 072 @-@ 02 was a planet . In addition , the IRAC instrument found no difference in the transit signal when comparing the star 's light curve in the infrared and in visible light ; stars that are aligned with Kepler @-@ 10 might appear visibly similar , but would appear different in the infrared .

The WIYN Observatory 's 3.5m telescope was used for speckle imaging on June 18 , 2010 ; in addition , the PHARO camera on the Palomar Observatory 's 5m telescope was used for its adaptive optics capabilities . These observations , combined with observations of Kepler @-@ 10 's spectrum taken from the W.M. Keck Observatory , ruled out the possibility that a nearby star 's light was corrupting the observed spectrum of Kepler @-@ 10 and creating the results that had led astronomers to believe that a second planet existed in Kepler @-@ 10 's orbit . All of these possibilities , with the exception of if such a star existed exactly behind or in front of Kepler @-@ 10 , were effectively ruled out ; even with this , the Kepler team found that if a star was indeed aligned with Kepler @-@ 10 as seen from Earth , such a star would probably not be a giant star .

With a greater degree of certainty established , the Kepler team compared the models formed using Blender to the photometric observations collected by the Kepler satellite . The Blender technique allowed the Kepler team to rule out the majority of the alternatives including , notably , that of triple star systems . Blender then allowed the Kepler team to determine that although all models representing hierarchical triple stars (a binary system between a single star and a double star) can resemble the light curve of Kepler @-@ 10 , the aforementioned follow @-@ up observations would have detected them all . The only possible blends remaining after ruling out hierarchical triple stars was that of determining if the curve is caused by interference from a background star , or if it is

indeed caused by the orbit of a transiting planet .

Comparisons of KOI 072 @. @ 02 to the 1235 other Kepler Objects of Interest in Kepler 's field of vision allowed astronomers to use models that led to the confirmation of KOI 072 @. @ 02 as a planet with a high degree of certainty . KOI 072 @. @ 02 was then renamed Kepler @-@ 10c . The planet 's confirmation was announced at the Boston meeting of the American Astronomical Society on May 23 , 2011 .

Kepler @-@ 10c was the first Kepler target to be observed using Spitzer with the hope of detecting a shallow transit dip in a light curve . At the time of Kepler @-@ 10c 's discovery , Spitzer was the only facility capable of detecting shallow transits in the Kepler data to an extent at which the data could be meaningfully analyzed . The planet was also the third transiting planet that was validated through an analysis of statistical data (rather than actual observation) , after the planets Kepler @-@ 9d and Kepler @-@ 11g . In Kepler @-@ 10c 's confirmation paper , the Kepler team discussed how a large fraction of planets in Kepler 's field of view would be confirmed in this statistical manner .

= = Host star = =

Kepler @-@ 10 is a G @-@ type star located 173 parsecs (564 light years) from Earth . It is 0 @. @ 895 solar masses and 1 @. @ 056 solar radii , making it slightly less massive than the Sun , but approximately the same size .

With an effective temperature of 5627 K , Kepler @-@ 10 is cooler than the Sun . The star is also metal @-@ poor and far older : its metallicity is measured at $[Fe/H] = -0.15$ (29 % less iron than in the Earth 's Sun) . Kepler @-@ 10 has a measured age of approximately 10 @. @ 6 billion years .

Kepler @-@ 10 has an apparent magnitude of 11 @. @ 2 , which means that the star is invisible to the naked eye from the perspective of an observer on Earth .

= = Characteristics = =

Kepler @-@ 10c is the outermost of the two known planets of Kepler @-@ 10 , completing one orbit of the star every 45 @. @ 29485 days at a distance of 0 @. @ 2407 AU . The inner planet , Kepler @-@ 10b , is a rocky planet that orbits every ~ 0 @. @ 8 days at a distance of 0 @. @ 01684 AU . Kepler @-@ 10c 's equilibrium temperature is estimated at 584 K , almost four times hotter than Jupiter 's . The planet 's orbital inclination is 89.65° , or almost edge @-@ on with respect to Earth and to Kepler @-@ 10 . Transits have been observed at points where Kepler @-@ 10c has crossed in front of its host star .

Kepler @-@ 10c has a mass of 15 ± 19 Earth masses . With a radius only 2 ± 35 (2 ± 31 to 2 ± 44) times that of Earth (and so a volume 12 ± 15 times that of Earth) , and a density higher than Earth 's (6 ± 8 g cm $^{-3}$) , it is unlikely to contain significant amounts of hydrogen and helium gas . Outgassed or accreted hydrogen @-@ rich atmospheres would have been lost over the 10 @. @ 6 billion @-@ year lifetime of the Kepler @-@ 10 system . Instead , the composition is likely to be mainly rocky , with a water fraction of 5 ± 20 % by mass . The bulk of this water is likely to be in the form of high @-@ pressure " hot ice " phases .