= HAT @-@ P @-@ 33b =

HAT @-@ P @-@ 33b is a planet in the orbit of HAT @-@ P @-@ 33 , which lies 1 @,@ 367 light years away from Earth . Its discovery was reported in June 2011 , although it was suspected to be a planet as early as 2004 . The planet is about three @-@ fourths the mass of Jupiter , but is almost eighty percent larger than Jupiter is ; this inflation has , as with the discovery of similar planets WASP @-@ 17b and HAT @-@ P @-@ 32b , raised the question of what (other than temperature) causes these planets to become so large .

HAT @-@ P @-@ 33b was difficult to confirm because its star experiences high jitter , which disrupted the ability to obtain accurate measurements . As such , a greater number of radial velocity observations were collected to make the confirmation , although it was later determined that HAT @-@ P @-@ 33b could not be determined using the radial velocity method . The planet 's confirmation came about after the planet 's light curve was collected , and the Blendanal process ruled out most false positive scenarios .

= = Discovery = =

HAT @-@ P @-@ 33b 's existence was first suggested after observations by the six @-@ telescope HATnet collaboration , a project that searches the sky for planets in transit of , or crossing in front of , their host stars . The presence of a planet in HAT @-@ P @-@ 33 's orbit had been suspected as early as 2004 , although high levels of jitter were detected . This jitter , or a random and shaky appearance that clouds the accuracy of measurements , made it difficult to easily verify the radial velocity of the planetary candidate 's host star , which usually leads summarily to the planet 's confirmation .

As a start , the spectrum of HAT @-@ P @-@ 33 was composed using the digital speedometer at the 1 @.@ 5 @-@ meter Fred Lawrence Whipple Observatory in Arizona . The collected data found that the star was a single dwarf star exhibiting a slight rotation . Several of its parameters , including its effective temperature and surface gravity , were found . Additionally , the SOPHIE échelle spectrograph at a 1 @.@ 93 @-@ meter telescope at France 's Haute @-@ Provence Observatory was used to observe the star . The resulting data invited the possibility that radial velocity measurements , which can exhibit anomalies that often indicate the presence of a planet , may have been because of background distortion (and not a planet) . This possibility significantly complicated the ability of scientists to verify this planet . After the observations , follow @-@ ups were postponed for several years .

Between September 2008 and December 2010 , twenty @-@ two spectra were collected using the High Resolution Echelle Spectrometer (HIRES) instrument at Hawaii 's W.M. Keck Observatory . This data was used to derive HAT @-@ P @-@ 33 's radial velocity . A far greater number of spectra were gathered for HAT @-@ P @-@ 33 than the number usually gathered for planetary candidates to compensate for the data 's jitter effect . It was concluded that the jitter in the data was caused by stellar activity and not the presence of other planets .

It became apparent to the investigating science team that radial velocity data alone could not prove the existence of HAT @-@ P @-@ 33b . As such , photometric observations of HAT @-@ P @-@ 33 were conducted using the Fred Lawrence Whipple Observatory 's 1 @.@ 2 @-@ meter telescope , which hosted the KeplerCam CCD instrument . This data was used to create the light curve of HAT @-@ P @-@ 33 . In doing so , a slight dimming was observed where HAT @-@ P @-@ 33b was believed to have transited its star .

Using a program called Blendanal , similar to the Blender technique used to verify the planets discovered by Kepler , the astronomers observing HAT @-@ P @-@ 33 hoped to rule out false positive alternatives that could explain the planet @-@ like signal seen in HAT @-@ P @-@ 33 's light curve and radial velocity . The use of Blendanal ruled out the possibilities that the signal was caused by that of a hierarchical triple star or a mixture between a bright star and a binary star in the background . The possibility that HAT @-@ P @-@ 33 is actually a binary star whose secondary companion is too dim to be distinguishable from the brighter star could not be ruled out . However ,

the data indicated that the planet HAT @-@ P @-@ 33b did indeed exist .

The discoveries of the high @-@ radii planets HAT @-@ P @-@ 33b and HAT @-@ P @-@ 32b , along with that of WASP @-@ 17b , contributed to the question of what factors , besides temperature , contribute to the large radii of these inflated planets . The discrepancy lies in planet WASP @-@ 18b , which is far hotter than the newly discovered HAT planets and WASP @-@ 17b , but has a far smaller radius .

The discoveries of HAT @-@ P @-@ 33b and HAT @-@ P @-@ 32b were reported together in the Astrophysical Journal . The paper was submitted on June 6 , 2011 . The authors of the discovery paper of the planets suggested the usage of the Spitzer Space Telescope to observe the occultation of HAT @-@ P @-@ 33b behind its star to better define its characteristics .

= = Host star = =

HAT @-@ P @-@ 33 , or GSC 2461 @-@ 00988 , is an F @-@ type star that lies 419 parsecs (1 @,@ 367 light years) away from Earth . The star has 1 @.@ 403 solar masses and 1 @.@ 777 solar radii ; the star is , in other words , 40 % more massive than and 77 % larger than the Sun . With an effective temperature of 6401 K , HAT @-@ P @-@ 33 is hotter than the Sun . It is also more metal @-@ rich , with a metallicity that is measured at [Fe / H] = 0 @.@ 05 . This means that HAT @-@ P @-@ 33 has 12 % more iron than the amount measured in the Sun . HAT @-@ P @-@ 33 is younger than the Sun , at an estimated age of 2 @.@ 4 billion years . The surface gravity of the star is determined to be 4 @.@ 09 . All the values above are determined with the assumption that planet HAT @-@ P @-@ 33b has an irregular , or eccentric , orbit .

HAT @-@ P @-@ 33 has an apparent magnitude of 11 @.@ 89 . It cannot be seen from Earth with the naked eye because it is so dim .

Because high levels of jitter have been detected in the spectrum of HAT @-@ P @-@ 33 , the ability to collect the most sensitive radial velocity measurements possible has been dulled . The loss of accuracy has prevented astronomers from disregarding the possibility that HAT @-@ P @-@ 33 is actually a binary star , where the secondary , dimmer companion is visually indistinguishable from the brighter primary companion . If this is the case , then the dimmer star in the HAT @-@ P @-@ 33 system would have to have a mass that is less than 0 @.@ 55 times that of the Sun . A search for a binary companion star using adaptive optics at the MMT Observatory was negative .

It is possible that other planets with shorter orbital periods than HAT @-@ P @-@ 33b exist in the system . However , at the time of HAT @-@ P @-@ 33b 's discovery , not enough radial velocity measurements had been collected to determine if this is so .

= = Characteristics = =

HAT @-@ P @-@ 33b is a planet that has 0 @.@ 764 Jupiter masses and 1 @.@ 827 Jupiter radii . In other words , it is about three @-@ fourths as massive as Jupiter , but is slightly less than twice Jupiter 's size . HAT @-@ P @-@ 33b orbits its star at an average distance of 0 @.@ 0503 AU , which is about 5 % of the average distance between the Sun and Earth . This orbit is completed every 3 @.@ 474474 days (83 @.@ 39 hours) . HAT @-@ P @-@ 33b has an equilibrium temperature of 1838 K , which is almost fifteen times hotter than the measured equilibrium temperature of Jupiter (124 K) .

The best fit for the shape of HAT @-@ P @-@ 33b 's orbit suggests that the orbit is slightly elliptical , as the planet 's orbital eccentricity is fit to 0 @.@ 148 . However , because the star HAT @-@ P @-@ 33 has such a high level of jitter , it is difficult to constrain the planet 's eccentricity with accuracy . Most of the planet 's defined characteristics are based on the assumption that HAT @-@ P @-@ 33b has an elliptical orbit , although the planet 's discoverers have also derived HAT @-@ P @-@ 33b 's characteristics on the assumption that the planet has a circular orbit . The elliptical model has been chosen because it is considered to be the most likely scenario .

HAT @-@ P @-@ 33b has an orbital inclination of 86.7º as seen from Earth . The planet is , thus , almost edge @-@ on when seen from Earth . The planet has been observed to transit its host star .