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P5_4 Tatooine Habitability

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Abstract

In the Star Wars franchise, protagonist Luke Skywalker grows up on planet Tatooine, which orbits two G-type stars [1], Tatoo I and II. We considered the orbit of the planet in three positions relative to the twin suns, calculating the habitable zone (HZ) for each, to conclude whether it is possible for this planet to exist in the HZ at all times. We found the range in which the planet can be in the HZ for its entire orbit: 1.42 - 1.90 AU from the centre of mass of the system.

Introduction

Tatooine is a desert planet in the Star Wars universe, moving in a circumbinary orbit around Tatoo I and Tatoo II, which are G1 and G2 type main sequence stars respectively [1]. In this paper, we will create a model of the system based on data given in the Star Wars franchise and some assumptions based on information about other binary systems. Using the model, we will calculate the habitable zone boundaries for three points in the planet's orbit, by comparing it to the solar system's habitable zone. From this, we can conclude whether Tatooine is able to stay in the habitable zone of the binary system for its entire orbit, and therefore, whether it could sustain life.

Theory

For this model, we assumed that all the orbits had an eccentricity of zero, and so are perfectly circular. The planet Tatooine is assumed to orbit in the plane of the binary orbit, so at two points in the planet's orbit it will only receive energy from one of the stars. We also assumed each star had equal mass and a radius of $1R_\odot$, as the exact radii are not known, and the sun is also a G-type star. The final major assumption we have made is that the semi-major axis of rotation of the binary stars is 0.176 AU, the same as the Kepler-35 system [2]. We made this assumption as the Kepler-35 system is another binary system of two twin G-type stars with a planet in a stable orbit around them, and data was not given on the Tatoo system in the Star Wars franchise, therefore a separation had to be assumed. Figure 1 below shows a diagram of the Tatoo system and will be referred to throughout this paper.

In order to compare the habitable zones of the Tatoo system with the solar system, we first calculated the irradiance of our Sun at the boundaries of the solar system's habitable zone, at 0.99 AU and 1.70 AU [3], using Equation 1 [4]:

$$I = \sigma T^4 (\frac{R}{D})^2 \tag{1}$$

where I is irradiance in Wm^{-2}, T is temperature in K, R is the radius of the star in m, and D is the distance between the star and planet in m. The irradiance corresponding to the limits of the habitable zone were found to be 1389 Wm^{-2} and

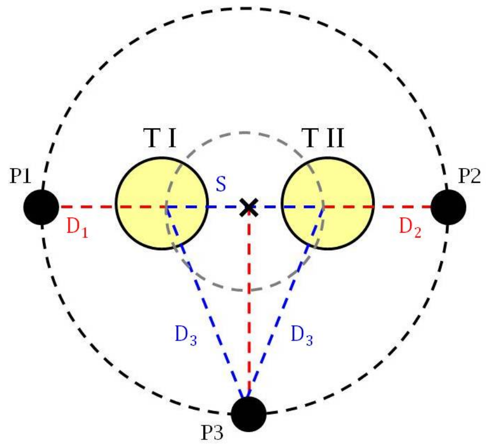

Figure 1: Diagram of the Tatoo system, showing the three positions of Tatooine that we will be calculating the habitable zone for: P1, P2 and P3. S is the separation between the stars, 0.358 AU. The D values are the distances between the planet in each position and the stars. The cross is the centre of mass (CoM) of the system.

471 Wm^{-2}. Equation 1 was then rearranged, so we could calculate the habitable zones at the three positions in Figure 1 for the Tatoo system. The rearranged equation is below and will be referred to as Equation 2.

$$D = \sqrt{\frac{R^2 \sigma T^4}{I}} \tag{2}$$

where all symbols have the same meaning as Equation 1.

Results

For Tatoo I, a G1 type star with temperature 5900 K (given by spectral type), with the planet at position P1, we found the D_1 values as 1.03 AU and 1.78 AU. This corresponds to radii from the centre of mass (CoM) of 1.20 AU and 1.96 AU respectively, as the CoM is not in the centre of either star, but in the centre of their orbit, so the semi major axis of rotation (0.176 AU) is added to the values of D_1 calculated.

Tatoo II is a G2 star, therefore having a lower temperature of 5800 K. Using the same approach as above for position P2, D_2 values were found to be 1.00 AU and 1.72 AU, corresponding to radii from the CoM of 1.18 AU and 1.90 AU. At P2, the planet would be receiving minimum power from the suns, as Tatoo I, the larger of the stars, is blocked out.

In position P3, the planet is receiving power from both of the stars, and the equation is changed to reflect this. Due to the assumption that the radii of both stars are equal, the equation is changed only so T^4 becomes $(T_1^4 + T_2^4)$. We found the values of D_3 were 1.44 AU and 2.47 AU. Using Pythagoras' Theorem, the radii from the CoM are 1.42 AU and 2.46 AU.

Therefore, in order for the planet Tatooine to be in the habitable zone continuously for its whole orbit around Tatoo I and II, it would need to lie between 1.42 AU and 1.90 AU.

Discussion

It is stated that Tatooine has an orbital period of 304 standard days [5], which, assuming a standard day is equal to a day on Earth, would give a radius of 1.11 AU. This puts Tatooine closer to its suns than our model, suggesting that the planet should be too hot to support life. Further investigation could be done on possible changes to our model that could make this radius realistic.

We have also not considered whether an orbit between 1.42 AU and 1.90 AU would be stable over long timescales, so more research would need to be done to conclude whether or not an orbit in this range would be viable.

Conclusion

We have concluded from our investigation that it is possible that Tatooine is able to exist in the habitable zone of its twin suns within the constraints of our model. The orbit would need to be in the range of 1.42 AU and 1.90 AU to stay in the habitable zone consistently throughout the whole orbit.

References

[1] Star Wars Episode IV: A New Hope (book), Alan Dean Foster, 1976

[2] `http://exoplanet.eu/catalog/kepler-35_(ab)_b/` [Accessed 17 October 2017]

[3] `https://goo.gl/QhSXGe` [Accessed 17 October 2017]

[4] `https://goo.gl/bd3u8x` [Accessed 17 October 2017]

[5] Star Wars: Absolutely Everything you need to know (book), 2015