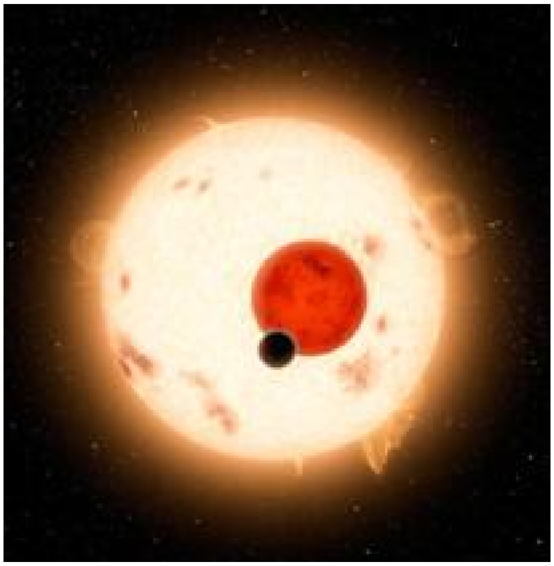
Predicting the Transits of the Stars Kepler-16 A and B



In 2011, the Kepler observatory detected a Saturn-sized planet orbiting the binary stars Kepler 16A and Kepler 16B. Nicknamed 'Tatooine', the view from this planet of its twin suns would be spectacular. The smaller star, Kepler-16B orbits once every 41 days at a distance of 30 million km from the larger star Kepler 16A, and the planet is in a circular orbit 108 million km from Kepler 16A which takes 229 days to complete. As seen from 'Tatooine', the small orange star Kepler-16B never gets more than 18 degrees from the much larger, yellow star Kepler 16A.

Predicting when Kepler 16B will pass across the face of Kepler 16A, called a transit, is made a bit more difficult because Tatooine is also moving along its orbit while Kepler 16B is in motion around the main star. To see a transit, Kepler 16B and Tatooine must be located in their orbits so that a line through their centers passes through the center of Kepler 16A at the center of the orbits. The circumferences of the two orbits are different, and they take different amounts of time to complete a full orbit. Given that you have just observed one transit, the time you must wait in order to see the next one depends on how long it takes for Kepler 16B and Tatooine to return to their 'straight line' configuration.

Problem 1 - What is the speed of the star Kepler 16B in its orbit in terms of degrees per day?

Problem 2 - What is the speed of Tatooine in its orbit in terms of degrees per day?

Problem 3 - What is the difference in angular speed between fast-moving Kepler 16B and slower-moving Tatooine?

Problem 4 - How many days will it take Kepler 16B to overtake Tatooine?

Problem 5 - Can you show that your answer to Problem 4 is just the time between transits?

Problem 1 - What is the speed of Kepler 16B in its orbit in terms of degrees per day?

Answer: SK = 360 degrees /41days = **8.78 degrees/day.**

Problem 2 - What is the speed of Tatooine in its orbit in terms of degrees per day?

Answer: ST = 360 degrees / 229 days = **1.57 degrees/day.**

Problem 3 - What is the difference in angular speed between fast-moving Kepler 16B and slower-moving Tatooine?

Answer: 8.78 - 1.57 = **7.21 degrees/day**

Problem 4 - How many days will it take Kepler 16B to overtake Tatooine?

Answer: T = 360 degrees / 7.21 = **50 days**.

Problem 6 - Can you show that your answer to Problem 4 is just the time between transits?

Answer: Students can sketch two concentric circles with Kepler 16B on the inner circle and Tatooine on the outer circle. Draw a line from Kepler 16A at the center of the circle to the location of Tatooine. Place Kepler 16B in its orbit on the line you drew to 'start' the clock. In 41 days, Kepler 16B will go once around its circle and return to this spot, while Tatooine will move 41 days further along its orbit. After 50 days, Kepler 16B and Tatooine will once again beon the same line to Kepler 16A.

Note: In astronomy, the synodic period, P, is related to the orbit periods of a fast-moving planet, t, and a slow-moving planet, T, by the formula

$$\frac{360}{t} - \frac{360}{T} = \frac{360}{P}$$

In our problem t = 41 days and T = 229 days so P = 50 days. The synodic period is a measure of the time taken for two planets to return to the same spatial configuration with respect to a central star. The synodic period of the moon is 29 days and this is the time between corresponding phases of the moon (full moon to full moon), when Earth, sun and moon are in the same orientation to produce the moons illumination.