



A SPECTACULARLY SPOTTED STAR

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Stars like the Sun have dark spots on their surfaces. These dark spots are important for astronomers, because they allow us to track how quickly a star is spinning, which is related to the age of a star. Since Earth is close to the Sun, spots on the Sun are easy to see, but for distant stars, our telescopes are not powerful enough to see starspots. That is why astronomers have begun to use planets to study starspots. When a planet eclipses its star, the amount of light that goes missing depends on whether the planet is blocking out a bright part of the star or a dim part of the star, like a starspot. Using this technique, astronomers have determined that HAT-P-11, a star 20% less massive than the Sun, has spots just like the Sun, but its surface is 100 times more spotted than the Sun's.

SPOTTED, SPINNING STARS

All stars are spinning. When a Sun-like star is born, it spins dizzily fast, completing one rotation once every few hours. As stars age, they rotate more slowly. The Sun is a middle-aged star, and it completes

a rotation in about 26 days. Some older stars can rotate much more slowly than the Sun.

Imagine for a moment that you are spinning a white soccer ball, with only one black patch on it. You can tell that the ball is spinning because you can see the black patch moving from left to right across the ball, disappearing around the back side of the ball, and then returning on the left side again. Now, imagine that the ball is thousands of miles away, and you are looking at it through telescope. You might not be able to see the black patch moving from left to right across the ball anymore, but when the black patch is facing you, the ball appears darker than when the black patch rotates around to the back of the ball and you can only see only the white parts. So, by measuring the brightness of the ball carefully as it rotates, you would see that the ball is bright when the white side faces you, the ball is dimmer when the black patch faces you, and then the ball gets brighter again when the black patch rotates out of view once more and you can only see the white parts again.

The same is true for stars—since stars have dark spots on them, they appear to get brighter and dimmer as they rotate. If you measure the brightness of a star very carefully, you will find that its brightness varies from high to low to high again, as spots rotate into view and out of view. So, by measuring how long it takes for the star's brightness to vary from high to low to high, we can measure how quickly the star is spinning, even though we cannot see the details of its surface!

PLANETS REVEAL STELLAR SURFACE SECRETS

Most stars have planets orbiting them. Sometimes we are lucky, and the planet appears to **eclipse** (block the light from) its **host star** as it moves around the star in its orbit. If you measure the brightness of the star very carefully at this time, you will observe a "**transit**" event, which is described in detail in this *Frontiers for Young Minds* article. During a transit, the planet blocks out some starlight, and astronomers on Earth see a dip in the total amount of starlight, which lasts for a few hours [1].

The amount of light that goes missing during a transit event depends mostly on two things: how big the planet is, and how bright the star. If the planet is the size of Jupiter, it can block out 2% or more starlight. If the planet is small, like Earth, it might only block out only 0.008% of the starlight. The size of the planet changes the amount of starlight that goes missing.

Imagine that you are watching a bright television in a dark room. From across the room, your little brother comes walking slowly in front of the TV. Your brother has eclipsed the TV—the total amount of light that you would see from the TV would be lessened while he was in front of

ECLIPSE

When one astronomical object blocks out light from another object.

HOST STAR

The star that an exoplanet orbits.

TRANSIT

When an exoplanet blocks out light from its host star.

the TV. But what if the TV was turned off? Then as your brother passed in front, no light would go missing, since the TV is already dark. So, based on how much light goes missing when your brother passes in front of the TV, you can tell how bright the TV is (and probably how annoyed you should be at your little brother, too).

Now, let us imagine a Neptune-sized planet orbiting a star a little smaller than the Sun, like the planet HAT-P-11 b, which orbits a star called HAT-P-11. HAT-P-11 rotates once every 29 days. The planet blocks out 0.3% of its star's light once every 5 days, as it whips around its star in a fast, close-in orbit. If the star has a dark spot on it—like a TV screen that was partly turned off—the amount of light that goes missing when the planet passes in front the bright patch of the star is greater than the amount of light that goes missing when planet passes in front of a dark patch of the star. So, if we measure the brightness of a star very precisely during a planet transit, we can figure out how bright the star is beneath the planet, based on how much light the planet is blocking out as it appears to pass over the star.

HAT-P-11: A SUPER-SPOTTED STAR

NASA's Kepler space telescope took an image of HAT-P-11 once every minute for 4 years, to measure its brightness with extreme precision. The **exoplanet** HAT-P-11 b passed in front of its star more than 200 times during the mission, which allowed astronomers to measure the brightness variations on the surface of the star using the brother-and-TV technique we just described. When the planet passed over dark **starspots** on the stellar surface, less light went away than when the planet passed over bright parts of the star. The planet, therefore, allowed astronomers to study the individual dark starspots in detail, even though the telescope was not powerful enough to zoom in and see the spots directly [2]!

What astronomers found was that the spots on HAT-P-11 are quite like the spots on our Sun (see Figure 1) [3]. These spots emerge from similar locations on the star's surface, closer to the middle of the star than to the poles (ends) of the star. HAT-P-11's spots are also similarly dark when compared with **sunspots**—they are about 30% dimmer than the rest of the star's surface. The spots are also similar sizes to the Sun's sunspots, typically 10 times larger than Earth.

Perhaps the most remarkable discovery is the number of spots that astronomers found on HAT-P-11. It seems like the total area covered in spots is 100 times greater on HAT-P-11 than the area covered by spots on the Sun [3]. HAT-P-11 might have up to 14% of its surface covered by spots [4]. That is a lot of spots! This discovery is in agreement with our expectation that stars slightly smaller than the Sun, with similar rotation periods, should have more spots than the Sun.

EXOPLANET

A planet orbiting a star other than the Sun.

STARSPOTS

Dark spots on the surface of stars caused by strong magnetic fields.

SUNSPOTS

Dark spots on the surface of the Sun caused by strong magnetic fields.

Figure 1

This diagram shows an illustration of what the HAT-P-11 system might look like. The star is a red-orange color, with several dark spots on its surface. There is an exoplanet about the size of Neptune which orbits very close to the star.

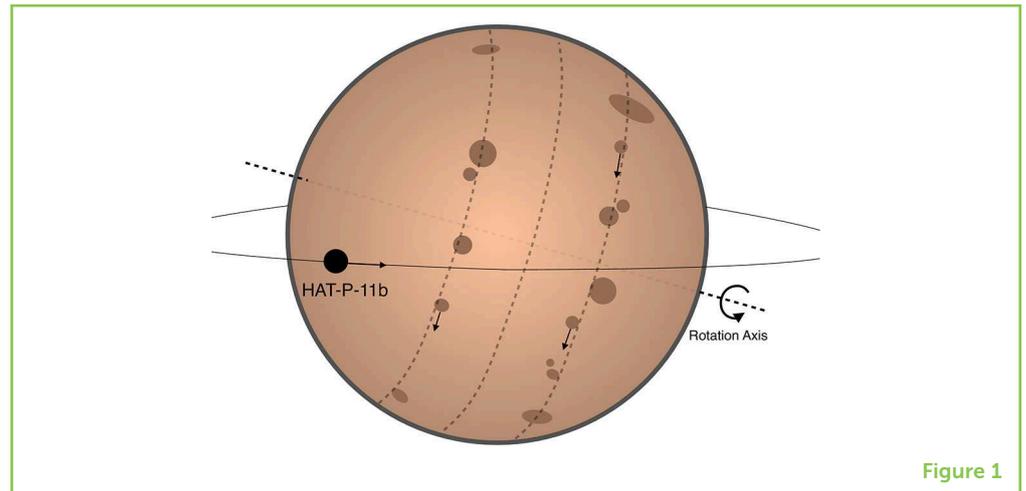


Figure 1

THE VIEW FROM HAT-P-11 b

If you were to visit the extremely hot planet HAT-P-11 b, you would have quite a view in the day-time sky, because the planet orbits very close its star. If you looked up at the star, it would appear to be 15 times larger than the Sun appears to us on Earth. The largest starspot astronomers have observed on HAT-P-11 would be twice the size of the Sun as observed from Earth. Of course, it would be very difficult to actually visit the planet HAT-P-11 b, because it is a gas giant planet without a surface, so there would be nowhere to stand, and since it is so close to its star, the atmosphere would be thousands of degrees. HAT-P-11 b would be quite an unpleasant place to visit.

WHAT IS NEXT?

From reading this article, now you know that rotating stars have dark spots on their surfaces, and stars a bit less massive than the Sun probably have spots that behave just like sunspots. You learned how astronomers can use planets orbiting distant stars to study their star's spots.

To see if HAT-P-11 really behaves like the Sun, there is one more thing astronomers would like to observe. The Sun goes through an 11-years cycle, from having few sunspots, to lots of spots, to only a few spots again. We would like to know if HAT-P-11 has a similar 11-years cycle, but we have only been observing it for about 11 years, so it is too early to know if the star has a cycle like the Sun's [5]. Astronomers will continue to use telescopes in the years ahead to observe HAT-P-11, to check if its cycle is like the Sun's.

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LAPWAI HIGH SCHOOL, AGES: 14–17

Lapwai High School is located near the Nez Perce Reservation in Lapwai, ID. This review was conducted by several American Indian Nez Perce students of Tami Church's mathematics class.

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