Odd discovery may help refine theories about how planets form

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An international team of researchers has found a planet around another star whose orbit is steeply tilted from the plane of the star's equator, a finding that contradicts some theories about how solar systems form.

In our own solar system, all of the planets orbit the sun almost exactly in the same plane as the sun's rotation - and that alignment is required by currently accepted theories of how stars and planets form from a collapsing disk of dust and gas. Any misalignment, such as the one the team found, must have occurred as a result of a disturbance sometime after the planet's formation, theorists say.

Astronomers are interested in exploring the characteristics of such distant planets partly to help refine theories of planet formation, and partly just to understand the kinds of variations that may be possible in the universe around us - to "see how the dice get rolled in other solar systems," says MIT physicist Joshua Winn, who led the team that measured the planet's tilted orbit.

Detecting this oddball orbit required a combination of good luck, advanced technology and ingenious methodology. Winn, assistant professor of physics in MIT's Kavli Institute for Astrophysics and Space Research, and a team of astronomers used one of the world's two largest telescopes to make the painstaking observations that confirmed earlier hints of this planet's unique orbit.

The planet, called XO-3b, was discovered in 2007 through a method that depends on a chance alignment of the planet's orbit with the line-of-sight between its star and the Earth. Because of that alignment, the planet sometimes passes directly in front of the star as seen from here - an event called a transit - thus causing a slight dimming of the star's light. That dimming can be detected with a powerful telescope connected to a highly sensitive light meter, or photometer. Of the more than 350 exoplanets discovered so far, fewer than two dozen have been found through this transit method.

Detecting the planet itself was relatively easy, as it dimmed the star's light by about 1 percent. But to go one step further and measure the angle of its orbit, even with such powerful tools, means that "we have to be sneaky about it," Winn says. It turns out that if a planet crosses the star's disk at an angle to the star's own rotation, it causes a distinctive pattern of change in the overall color of the star, as measured by a highly sensitive spectrograph, because of the Doppler shifts caused by the star's rotation.

Hints of such a spectral signature were seen last year by another team, but that team acknowledged that they could not be confident of their result. The new observations, carried out by Winn and his team in February at the Keck I Observatory in Hawaii, provided a clear, solid measurement of the planet's distinctive tilt, determining the angle of the orbit to be about 37 degrees from the star's equator. The results are reported in a paper in the Astrophysical Journal, which was recently posted online and will be published in the journal's August issue.

A majority of the planets discovered so far orbiting other stars - known as exoplanets - are very large planets comparable to the gas giants in our solar system, but orbiting their stars much closer in (and thus faster). That's because the method used to detect these planets makes it much easier to detect such close-in giants than smaller or more distant ones. In the case of XO-3b, it is about 13 times as massive as Jupiter, yet orbits

its star with a period, or "year," of just 3.5 days (Jupiter, by contrast, takes almost 12 years for an orbit). That size and closeness to its star are "unusual, even by the standards of exoplanets," Winn says.

Such "hot Jupiters" - so named because they resemble the solar system's largest planet, but would be much hotter because of their proximity to their parent stars - could not have formed in the places they are seen now, according to accepted planet-formation theory. They must have formed much further out from the star, then migrated inward to their present positions. Astronomers have come up with different mechanisms to account for the migration: the gravitational attraction of other planets as they passed close by, or the attraction of the disk of dust and gas from which the star and its planets formed.

Close encounters with other planets could greatly amplify a slight initial tilt, but attraction from the disk of material could not. So that theory could not account for a planet ending up on such a tilted orbit, which rules out that theory at least in the case of this particular planet.

In coming years, as new telescopes such as the Kepler space observatory begin to discover increasing numbers of exoplanets, "it will be interesting to identify more that are tilted, to find enough of them to be able to tease out patterns," Winn says.

In addition to Winn, the team included John Asher Johnson of the University of Hawaii; Daniel Fabrycky, Gil Esquerdo and Matthew Holman of the Harvard-Smithsonian Center for Astrophysics; Andrew Howard and Geoffrey Marcy of the University of California, Berkeley; Norio Narita of the National Observatory of Japan; Ian Crossfield of UCLA; Yasushi Suto of the University of Tokyo; and Edwin Turner of Princeton University. The work was funded by the NASA Origins program, an NSF postdoctoral fellowship and World Premier International Research Center Initiative.

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