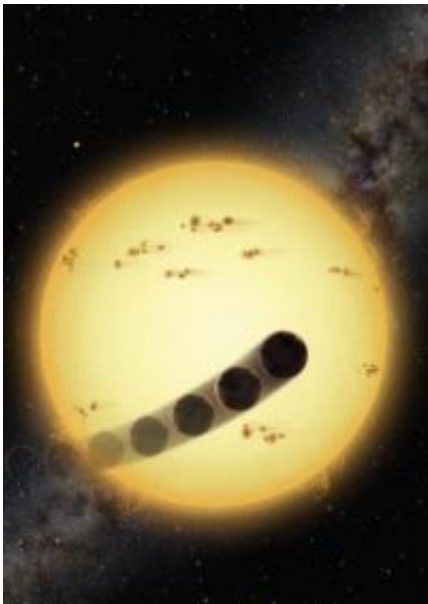


Flipping hot Jupiters: Why some planets orbit the wrong way

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The transiting giant planet orbits very close to the star and in a direction opposite to the stellar rotation. This peculiar configuration results from gravitational perturbations by another much more distant planet (upper left). Credit: Credit: Lynette Cook

(PhysOrg.com) -- In the last few years astronomers have observed that in some extrasolar systems the star is spinning one way and the planet, a "hot Jupiter," is orbiting the star in the opposite direction. A Northwestern University research team is the first to model how these huge planets got so close to their stars -- thanks to gravitational perturbations by a much more distant planet -- and how the planets'

orbits can flip in the process.

More than 500 extrasolar planets -- planets that orbit stars other than the sun -- have been discovered since 1995. But only in the last few years have astronomers observed that in some of these systems the star is spinning one way and the planet, a "hot Jupiter," is orbiting the star in the opposite direction.

"That's really weird, and it's even weirder because the planet is so close to the star," said Frederic A. Rasio, a theoretical astrophysicist at Northwestern University. "How can one be spinning one way and the other orbiting exactly the other way? It's crazy. It so obviously violates our most basic picture of planet and [star formation](#)."

Figuring out how these huge [planets](#) got so close to their [stars](#) led Rasio and his research team to also explain their flipped orbits. Using large-scale [computer simulations](#), they are the first to model how a hot Jupiter's orbit can flip and go in the direction opposite to the star's spin. Gravitational perturbations by a much more [distant planet](#) result in the hot Jupiter having both a "wrong way" and a very close orbit. (A hot Jupiter is a huge Jupiter-like planet in very close proximity to the central star.)

"Once you get more than one planet, the planets perturb each other gravitationally," Rasio said. "This becomes interesting because that means whatever orbit they were formed on isn't necessarily the orbit they will stay on forever. These mutual perturbations can change the orbits, as we see in these extrasolar systems."

Details of the study will be published May 12 by the journal *Nature*.

In explaining the peculiar configuration of an extrasolar system, the researchers also have added to our general understanding of planetary

system formation and evolution and reflected on what their findings mean for the solar system.

"We had thought our solar system was typical in the universe, but from day one everything has looked weird in the extrasolar planetary systems," Rasio said. "That makes us the odd ball really. Learning about these other systems provides a context for how special our system is. We certainly seem to live in a special place."

Rasio, a professor of physics and astronomy in Northwestern's Weinberg College of Arts and Sciences is the senior author of the paper. The first author is Smadar Naoz, a postdoctoral fellow at Northwestern and a Gruber Fellow.

The physics the research team used to solve the problem is basically orbital mechanics, Rasio said, the same kind of physics NASA uses to send satellites around the [solar system](#).

"It was a beautiful problem," said Naoz, "because the answer was there for us for so long. It's the same physics, but no one noticed it could explain hot Jupiters and flipped orbits."

"Doing the calculations was not obvious or easy," Rasio said, "Some of the approximations used by others in the past were really not quite right. We were doing it right for the first time in 50 years, thanks in large part to the persistence of Smadar."

"It takes a smart, young person who first can do the calculations on paper and develop a full mathematical model and then turn it into a computer program that solves the equations," Rasio added. "This is the only way we can produce real numbers to compare to the actual measurements taken by astronomers."

In their model, the researchers assume a star similar to the sun, and a system with two planets. The inner planet is a gas giant similar to Jupiter, and initially it is far from the star, where Jupiter-type planets are thought to form. The outer planet is also fairly large and is farther from the star than the first planet. It interacts with the inner planet, perturbing it and shaking up the system.

The effects on the inner planet are weak but build up over a very long period of time, resulting in two significant changes in the system: the inner gas giant orbits very close to the star and its orbit is in the opposite direction of the central star's spin. The changes occur, according to the model, because the two orbits are exchanging angular momentum, and the inner one loses energy via strong tides.

The gravitational coupling between the two planets causes the inner planet to go into an eccentric, needle-shaped orbit. It has to lose a lot of angular momentum, which it does by dumping it onto the outer planet. The inner planet's orbit gradually shrinks because energy is dissipated through tides, pulling in close to the star and producing a hot Jupiter. In the process, the [orbit](#) of the planet can flip.

Only about a quarter of astronomers' observations of these hot [Jupiter](#) systems show flipped orbits. The Northwestern model needs to be able to produce both flipped and non-flipped orbits, and it does, Rasio said.

More information: "Hot Jupiters From Secular Planet–Planet Interactions" Nature (2011)

Provided by Northwestern University

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