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Exposing the remnant core of a giant planet

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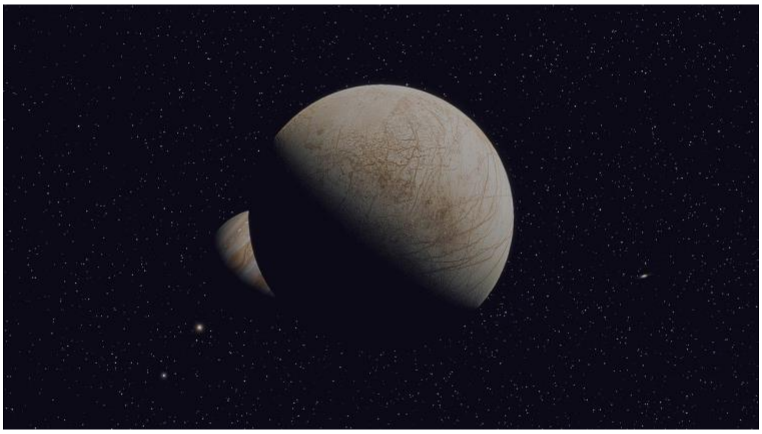
Beyond the Solar System, the universe includes numerous exoplanets: planets orbiting around other stars. The discovery of a giant exoplanet strangely lacking a gas layer on the surface reveals what the core of giant planets like Jupiter and Saturn, typically covered by a gas blanket, might look like.



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What's out there? — We always have lots to learn from "others". The hunt for extrasolar planets (exoplanets) sets us to explore the diversity of the universe around us. An exoplanet is a planet orbiting around a star outside the Solar System.

In the last few years, it has become clear that exoplanets are common; everywhere we look we can find them. There are weird and wonderful examples like Hot Jupiters, gas giants (giant planets—planets much larger than Earth—enveloped by gas) like Jupiter but far closer to their host star, and Super-Earths, terrestrial planets like the Earth but several times more massive. Studying these planets allows us to see our own home and Solar System in context with others like it, and can provide clues about how our local planets might have formed or evolved in the past. In particular, the cores of gas giants like Jupiter and Saturn remain hard to study, with dense atmospheres blocking even modern instruments from observing them directly.

TESS (Transiting Exoplanet Survey Satellite) is a NASA satellite observing nearly the entire sky in a search for new exoplanets. The satellite measures the stars' brightness over time, searching for characteristic dips in the light as planets pass between us and the star, blocking out some starlight. Such dips are called transits. In 2019, TESS discovered a series of transits from a candidate exoplanet with some unusual properties. This giant planet is named TOI-849b, and is nearly the size of Neptune (a small-size giant planet), orbiting very close to its star. The whole orbit is surprisingly fast and only takes 18 hours (compared to 88 days for Mercury, the closest planet to the Sun).

This was an exciting find immediately, as we typically don't see planets similar in size to Neptune this close to their star. We took more data to determine TOI-849b's mass, confirming that it was a true planet and finding that despite being slightly smaller than Neptune, the planet had a mass several times higher, and a density similar to the Earth.

Why is this so odd? When a planet forms, it slowly grows as small chunks of rock merge to build up to planetary size. For giant planets, there is a critical threshold — once the forming ball of rock is more than 10 times the mass of the Earth, it starts to rapidly gain light gases like hydrogen as well. This is how we think Jupiter formed with a core of rocky Earth-like material, then an outer layer of light gases forming a large envelope around it. The trouble is TOI-849b has a mass nearly 40 times that of the Earth. It is very hard to gain that much rocky material, and near impossible to avoid building up an atmosphere of hydrogen and helium. So where is the missing gas?

There are two ways to make a dense, yet massive planet like TOI-849b. Either the planet used to be a gas giant like Jupiter then lost its outer envelope, revealing the central core, or it got 'stuck' during formation, running out of material before it could grow larger. We can't prove which route TOI-849b took, but in either case, what we see is the remnant core of a giant planet, available for direct study in a way that Jupiter's core will never be due to the blanket of gas on top of it.

How might a Jupiter-like planet lose its gas blanket? Sometimes intense heat from the star can evaporate the atmosphere, but for a Jupiter-like planet this is not strong enough. More extreme events are required, such as the planet being ripped apart by tidal interactions with its star, or colliding with another planet during its formation. TOI-849b has several unique properties. The only hypothesis that can explain all of them together is the collision, where near the end of formation a violent impact between two planets blasts away the light gases and leaves a merged, rocky remnant behind.

What can we do with this unique discovery? We think the core is being evaporated by the star, and the small atmosphere this produces might be detectable with future telescopes like JWST. Detecting that atmosphere will let us study the composition of a gas giant core directly, opening up a new pathway to understanding the vast diversity of planets out there.