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Cosmic Cookie Cutter

Astronomers tackle an odd gap in exoplanet sizes

Just 30 years ago scientists weren't sure if any planets existed outside our solar system. Now they've detected more than 5,000 of them. But as astronomers have calculated these exoplanets' sizes, a strange gap has emerged. There are plenty of "super-Earths" out there—rocky orbs about 1.4 times wider than Earth. And there are lots of "mini-Neptunes" roughly 2.4 times Earth's width. But very few planets fall in between; it's almost like most worlds were sized using one of two cookie cutters. A new model published in *Astrophysical Journal Letters* offers a fresh answer to why this is so: it's all about collisions.

Previous hypotheses about the planetary "radius gap" suggested that high temperatures shrink certain planets, says Rice University astrophysicist André Izidoro, lead author of the new study. Planets tend to move closer to their host stars over time, he says. This makes relatively light planets slim down faster as rising heat strips away their outer gases, the thinking goes, whereas heavier planets have enough gravity to hold these gases and maintain their size.

Izidoro's work challenges this heat-based explanation, suggesting the gap results from planetary collisions instead. His team ran computer simulations based on theories of how planetary systems most likely develop: Planets that form close to stars are typically rocky, while farther-flung planets are generally extremely rich in water or ice—and most in both categories start out in the larger, mini-Neptune size range, Izidoro says.

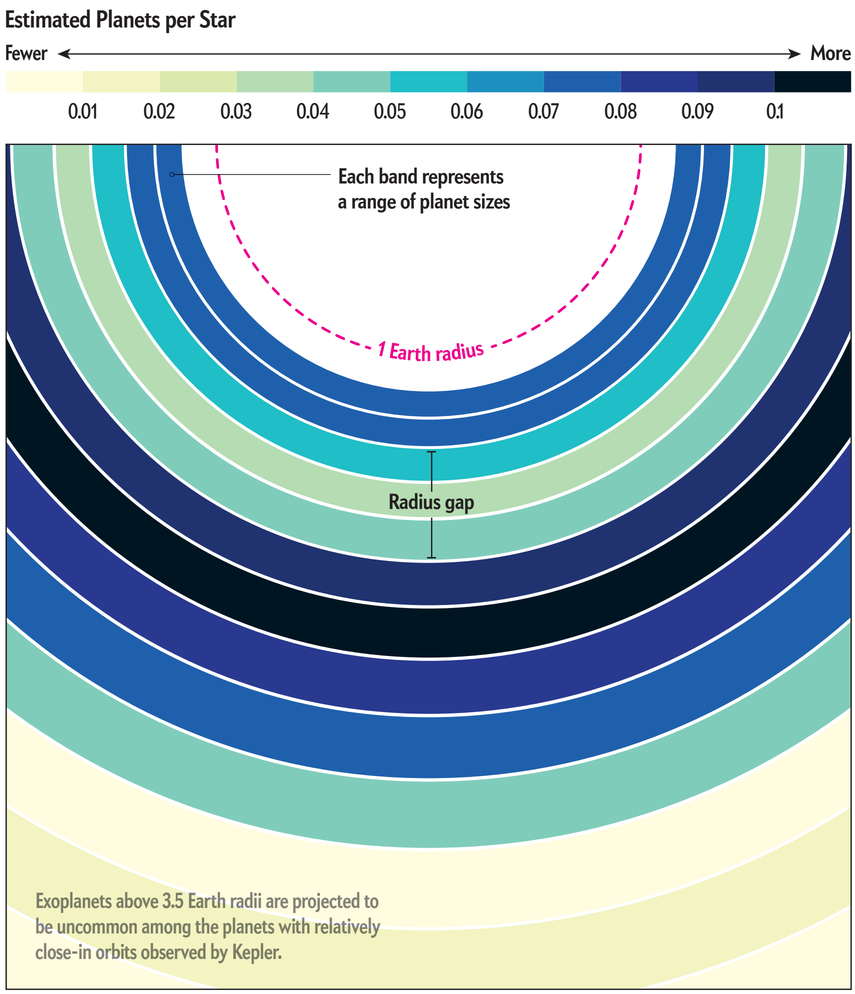
As planetary systems age and young planets drift toward their stars, the planets' orbits become unstable, and they often collide. When rocky planets smash together, they have a greater combined mass, Izidoro says. But they also lose gas layers, so their combined radius tends to decrease; the two form a single, denser planet. When two water-rich planets collide, Izidoro adds, "their size does not change that much because water is less dense, so they still stay above the radius valley" even after outer gases disappear. And a rocky planet colliding with a water-rich planet usually leads to a bigger water-rich planet—again above the radius gap.

For this collision model to hold true, planets must not lose as much mass to heat as had previously been thought, says James Owen, an astrophysicist at Imperial College London who was not involved in the new study. But on the other hand, Owen notes, "if you believe the mass-loss models, then you'd have to suggest that collisions between planetary bodies ... are much less frequent than we think."

To test both hypotheses, Owen says future high-resolution space telescopes could observe the makeup of mini-Neptunes. If exoplanets in this size range contain lots of hydrogen and helium, that would favor the mass-loss picture; a high proportion of water and ice would support the collision explanation.

Yet "there's no way to answer our questions entirely by observational means," says study co-author Hilke Schlichting, an astrophysicist at the University of California, Los Angeles. Planets' formation over millions of years cannot be observed in real time. "I think you need modeling research to understand what the data really tell us," Schlichting says—and such insights "may revolutionize our thinking about the formation of our own solar system."

—*Daniel Leonard*



After NASA's Kepler mission identified hundreds of new exoplanets, astronomer Benjamin J. Fulton refined the data and identified two clear peaks in exoplanet sizes, separated by a "radius gap" where planets are much scarcer. These data continue to inform new studies. (Values for planets below 1.2 Earth radii are omitted because of poor data quality.)

Source: "The California-Kepler Survey. VII. Precise Planet Radii Leveraging Gaia DR2 Reveal the Stellar Mass Dependence of the Planet Radius Gap," by Benjamin J. Fulton and Erik A. Petigura, in *Astronomical Journal*, Vol. 156, No. 6; November 2018 (*data*)

Graphic by Amanda Montañez