FIELD REPORT

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MARCH 2024

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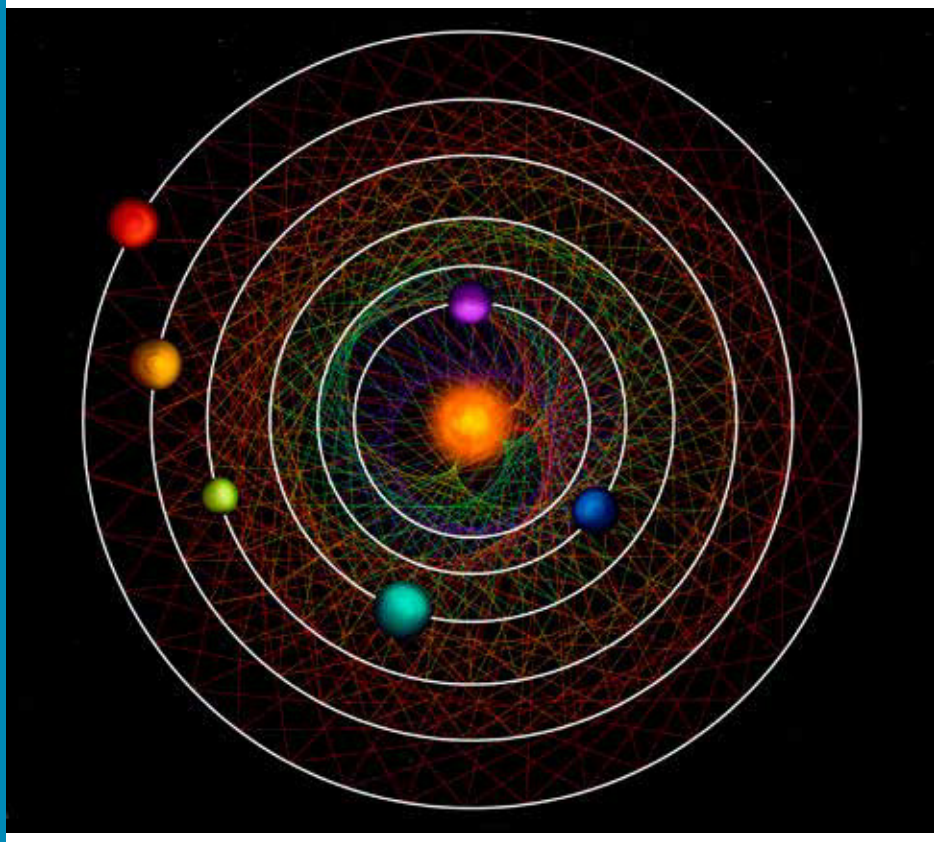
Vol. 52 • Issue 3

ASTRONOMERS FIND SIX PLANETS ORBITING IN RESONANCE

These half-dozen sub-Neptunes are an undisturbed treasure trove for understanding planet formation.



CHAINED HARMONY. The six planets of the HD 110067 system, shown in this artist's depiction, orbit in a resonant chain that links their periods mathematically.

A newly discovered system of six planets circling a nearby Sun-like star, HD 110067, may be the key to unlocking how planetary systems form. All between the size of Earth and Neptune, the worlds are orbiting in a so-called resonant chain — a rare configuration that offers a window into the system's uniquely gentle history. The discovery was published Nov. 29 in *Nature*.

The chain of discoveries began with an initial detection in 2020 by NASA's Transiting Exoplanet Survey Satellite (TESS), which searches for dips in brightness as planets cross in front of their parent star. At that time, based on the dips, researchers were able to confirm one planet and posit a second possible world.

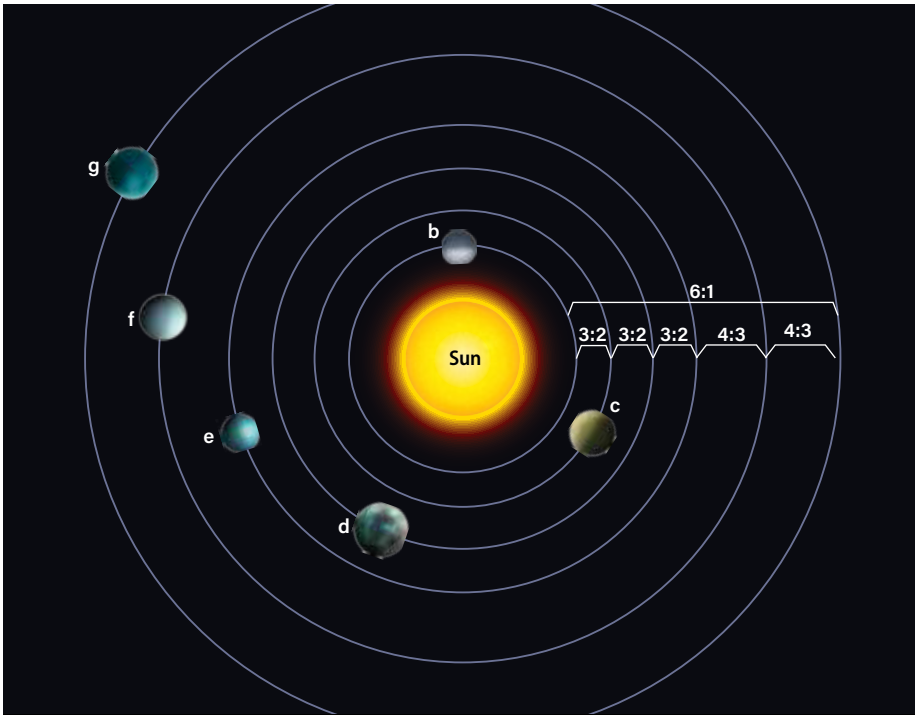
Then, using the European Space Agency's CHaracterising ExOPlanets Satellite (CHEOPS), they watched for additional transits from further planets. And after five or six observations, "we got a hit, like a battleship," said study co-author Hugh Osborn, an astrophysicist at MIT and the University of Bern in Switzerland, during a Nov. 28 press briefing.

They'd found a third planet. And the researchers noticed something intriguing: Each planet's orbital period was related to the next in line. The inner planet (called b) orbits every 9.114 days, the next planet out (c) every 13.673 days, and the last (d) every 20.519 days. Each of those periods is about 1.5 times the next, meaning the planets are in a configuration called a 3:2 mean motion resonance. For every three orbits of the innermost world, b, the next planet out (c) makes two. Then, for every three orbits of c, d makes two.

The team followed the pattern to look for more worlds in this "resonant chain." First, they modeled how often various additional planets in different resonances would transit, picking out the configurations that were most stable. Then, they went looking for the transits they expected from those models — and found three more planets: e, f, and g, with periods of 30.793, 41.059, and 54.770 days, respectively. The entire system could fit inside the orbit of Mercury.

In all, the innermost four planets are in 3:2 resonances. The outer planets f and g are in 4:3 resonances — each planet makes three full revolutions for every four orbits of the planet interior to it. Overall, for every six orbits the innermost planet b makes, the outermost planet g makes one full revolution.

Osborn was "shocked and delighted" when they began spotting planets transiting right when their models suggested. "My jaw was on the floor," he said. "Often we make the predictions and nature finds a way to do something else, to not quite match what we expect." But in this case, their predictions were spot-on.



DEEP RESONANCE. The orbital resonances of the planets of the HD 110067 system are shown in this diagram. For instance, in the time it takes planet b to complete three orbits, planet c completes two. *ASTRONOMY:* ROEN KELLY, AFTER ESA

Such resonant chains should be exceedingly common in nature — but they're not. That's because over time, chaotic events such as passing stars, meteorite impacts, and wandering giant planets muddy any resonances until they are gone.

But HD 110067's resonant chain has persisted for the billions of years since these planets formed, indicating "the evolution of this system has been very quiet, very gentle," said lead author Rafael Luque of the University of Chicago.

A KEY SYSTEM

HD 110067 isn't the first six-planet resonant system discovered, but it still stands out. The star is roughly 80 percent the size and mass of the Sun and glows brightly in the sky at magnitude 8.4, just 100 light-years away in the constellation Coma Berenices. And all six planets are some two to three times the diameter of Earth, falling into the category of planets called sub-Neptunes. In addition to cores of ice or rock, they also have thick atmospheres of hydrogen and helium.

This makes the planets prime targets for JWST to peer through their atmospheres as they transit, using the star as a backlight to look for the presence of light-absorbing molecules such as methane, carbon dioxide, water, and ammonia.

By contrast, the famous red dwarf TRAPPIST-1 is just 1/10,000 the brightness of HD 110067 at optical wavelengths. Further, TRAPPIST-1's seven planets are all rocky worlds with thin atmospheres — if any atmosphere at all.

In HD 110067 and its planets, Luque said, astronomers have a single, perfect testbed for studying how sub-Neptunes form and planetary systems evolve without outside influences. Each of the six planets formed from the same material and has experienced the same history as its peers. This lets astronomers compare these worlds to study how subtle differences in size, mass, temperature, and distance from their star might affect their evolution. The system is a "controlled experiment … that is going to set us up to learn so much in the coming years," said Luque. — ALISON KLESMAN

QUICK TAKES

SANDSTORMS

JWST observations of exoplanet WASP-107 b reveal that the gas giant has an analogue to Earth's water cycle based on silicates, the main component of sand. The silicates evaporate with trace amounts of water deep in its atmosphere, rise and form sand clouds, then rain drops of sand.

CROSSED WIRES

OSIRIS-REx's drogue parachute failed as the mission reentered Earth's atmosphere Sept. 24 with its precious sample of asteroid 101955 Bennu. NASA said Dec. 5 that loose usage of the word *main* in the craft's blueprints led engineers to mistakenly connect two "main" wires that caused the drogue's cord to be cut before it was deployed. Luckily, the main chute ensured a safe landing.

TIT FOR TAT

In an emerging inter-Korean space race, North Korea successfully launched a spy satellite Nov. 21, 2023, after two failed attempts earlier in the year. South Korea's first spy sat launched days later on Dec. 1 on a SpaceX Falcon 9.

GAMMA-RAYS BLAST EARTH

The gamma-ray burst GRB 221009A induced changes in current in Earth's upper ionosphere 300 miles (500 km) high, physicists reported Nov. 14. It's the first time such perturbations from a burst have been detected at those heights.

PARTICLE PHYSICS' DECADAL

The influential Particle Physics Project Prioritization Panel (P5) issued its once-a-decade slew of recommendations Dec. 7. Top priority went to the CMB-Stage 4 radio telescope array, which would study the cosmic microwave background. Neutrino experiments and dark matter detectors also made the list.

— MARK ZASTROW