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Pulsar Planets Are Rare

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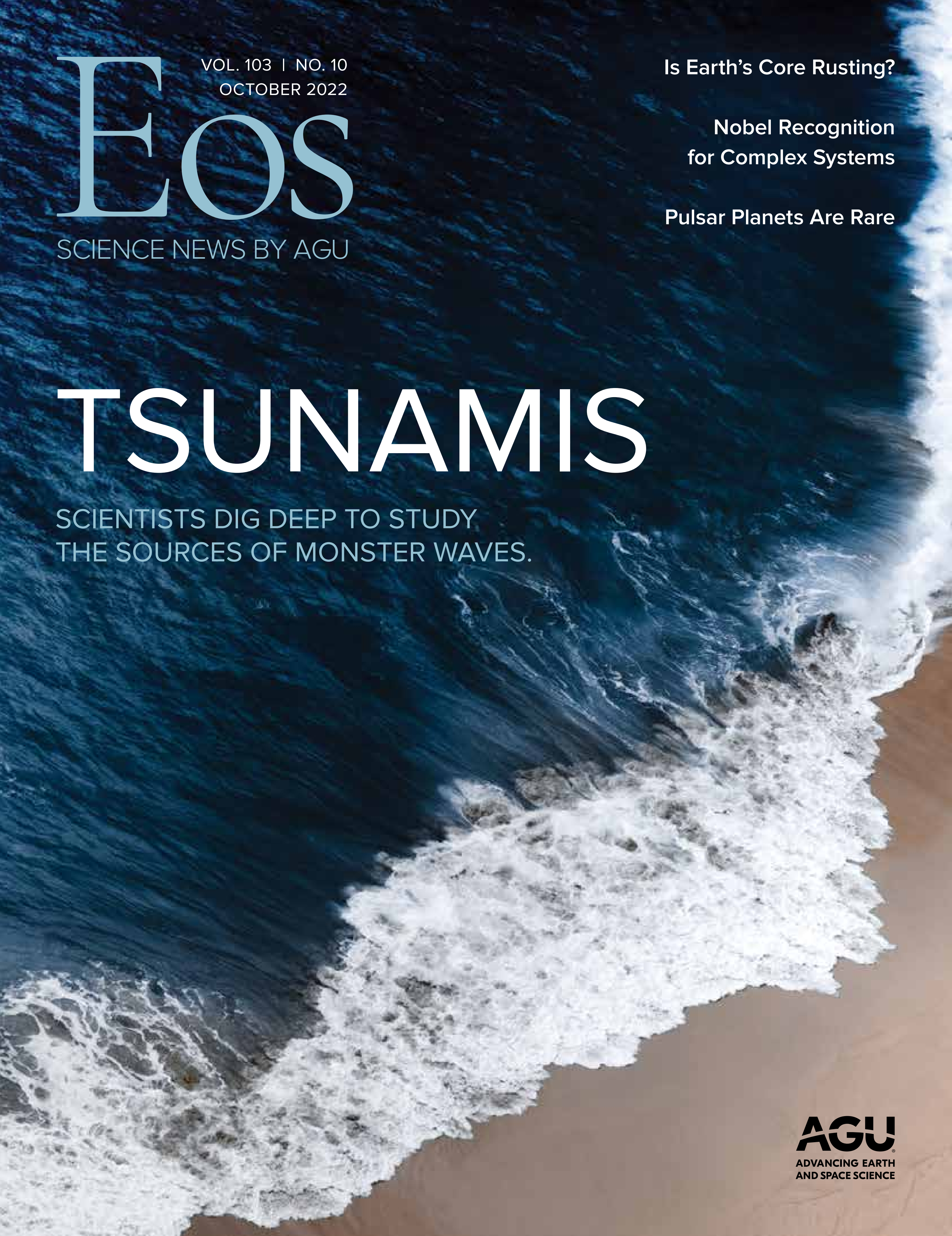

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products, Hazen said. In a second study also published in *American Mineralogist,* Hazen, Morrison, and their colleagues came up with a process to regroup the thousands of recognized IMA minerals on the basis of their formation processes and other characteristics that the current classification system misses (bit.ly/lumping-and-splitting).

Lumping and Splitting

In some cases, the team grouped several different IMA-recognized species together—for example, when species had the same structure, were compositionally similar, and were formed by the same process. In other cases, minerals that IMA combines could be split into new natural kinds, such as some types of calcite, because of the different ways they form.

"Water is the principal driver of mineral diversity."

The researchers also used a statistical approach to reveal combinations of physical or chemical properties that set minerals apart. For instance, they separated stellar moissanite, a silicon carbide formed around old stars and found in meteorites, into multiple types by considering differing isotopic signatures related to star type, Hazen said.

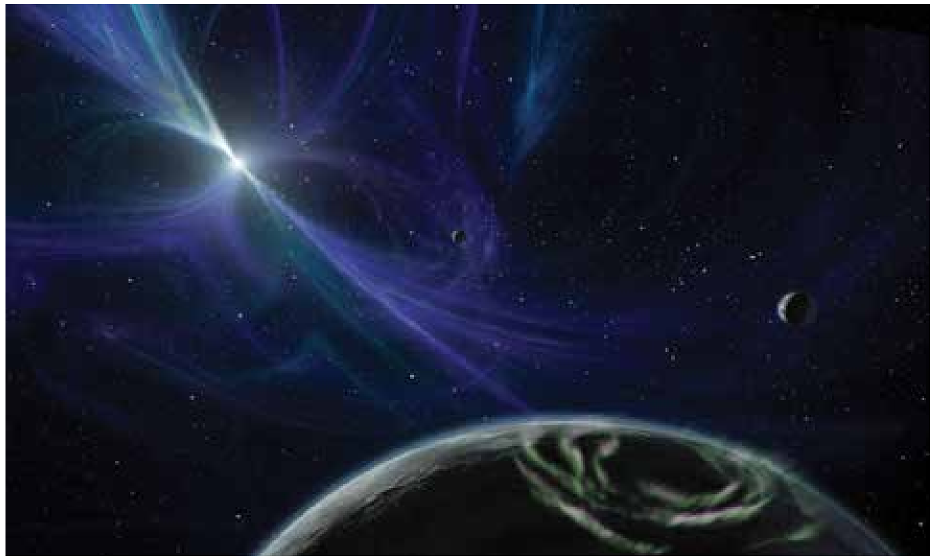
This lumping and splitting process yielded 7,816 natural mineral kinds. "It's really a big paradigm shift in the way we think about mineral classification," Yee said.

With new databases and tools, researchers could start making "incredible predictions" about where to find minerals and what minerals occur, and when, through geologic time, Yee said. Those insights could be useful in mining, studying microbial interactions with rock, and understanding the evolution of other rocky planets, like Mars. They may even allow researchers to establish a signature for whether a planet held life, Hazen said.

"If you reimagine minerals and how we describe them," Hazen said, "there's hardly an area of the Earth and planetary sciences that [classification] doesn't affect."

By **Carolyn Wilke** (@CarolynMWilke), Science Writer

Pulsar Planets Are Exceedingly Rare



The first three known exoplanets around a pulsar, illustrated here, were surprising finds given how rare these planets are. Credit: NASA/JPL-Caltech, Public Domain

Thirty years ago, astronomers discovered the first exoplanets, a trio of Earth-sized rocky planets orbiting a dead star acting as a cosmic lighthouse. A new survey of hundreds of these lighthouses, or pulsars, revealed that the existence of those planets is the exception rather than the rule. Fewer than 0.5% of pulsars are likely to host planets heavier than 4 Earths, which deepens the mystery of how any planets exist in those systems at all.

"One of the main things about pulsar planets is we don't actually know how to get a planet around a pulsar," said Iuliana Nițu, a doctoral student at the University of Manchester in the United Kingdom and lead researcher on the new survey. "It's circular: You need to study the population to learn more about and constrain your models, which then tell you more about populations."

Planets of the Dead

A pulsar is born when a massive star dies. The star reaches the end of its atom-fusing life, goes supernova, and leaves behind a small, dense ball of neutrons spinning a thousand times per second. The neutron star continues to shed energy through energetic beams, and if the star is oriented just right, one of those beams will sweep across our field of view on Earth and appear to "pulse" at regular intervals (see video at bit.ly/Eos-pulsar-planets).

If another object—a neutron star, a white dwarf, a black hole, or, in rare cases, a planet—orbits the pulsar, the object's gravitational pull can subtly change the timing of the pulsing. The three planets around PSR B1257+12 and the five other pulsar planets later discovered were all found through pulsar timing variations that they induced.

Astronomers want to know how those planets can survive the violent deaths of their stars to begin with, and then continue to orbit the stars' leftovers. "The discovery of the first pulsar planet, and the first exoplanet, around the millisecond pulsar B1257+12 sparked some really interesting research on solar system evolution and just how much planets can take and still hang around," said pulsar astronomer Matthew Kerr of the U.S. Naval Research Laboratory in Washington, D.C. Kerr was not involved with this research.

The planets might have been there presupernova and survived, they might have formed afterward out of debris, or they might have been captured as they wandered past. The only way to narrow down the options, Nițu explained, is to find more pulsar planets and see whether they have anything in common that could point to how they formed. "There's not really been any unbiased and big searches until now," she said.

"Once some of the new telescopes...start to build up long data sets, we'll be in a great place to find some planets, even if they are rare."

To initiate the search, the team used archival observations from the Jodrell Bank Observatory in the United Kingdom and analyzed the timing regularity of nearly 800 pulsars. After searching for timing variations from objects with a wide range of masses and at a wide range of orbits, their computer algorithm flagged just 15 pulsars with irregular timing, most of which were previously known to be irregular for non-planet-related reasons.

The researchers discovered one pulsar, PSR B0144+59, with timing variations that could be consistent with an exoplanet but would need follow-up observations to confirm. On the basis of their results, they calculated that fewer than 0.5% of pulsars are likely to host exoplanets of 4 Earth-masses or larger, but that Moon-mass planets might still be possible but undetectable. (In contrast, Sun-like stars are likely to have at least one planet, on average.) The team published its results in *Monthly Notices of the Royal Astronomical Society* (bit.ly/pulsar-planets) and presented them at the Royal Astronomical Society's National Astronomy Meeting 2022.

Out of the Ashes

For all their regularity, a pulsar's pulses can actually be quite noisy, suggesting timing variations that aren't really there. "That's a bit of a spanner in the works," Nițu said, "because how do you differentiate between the pulsars that are doing something weird and something orbiting around the pulsar?"

Despite these challenges, this is the largest survey of pulsar timing to date, and "I think the work and results are robust," Kerr said. "In particular, because [the researchers'] sample is large and the type of pulsar is varied, I think it's reasonable to treat their results as representative of the 'true' pulsar population, and thus safely conclude that terrestrial-mass planets around pulsars are quite rare, and Jupiter-mass planets are strongly excluded."

According to Kerr, some recent supernova research has suggested that disks of rocky and dusty debris could last long enough for a new set of planets to form from the ashes of dead stars. "Identifying planets from such debris disks is a cool way to constrain those models.... And I think once some of the new telescopes—CHIME, MeerKAT, FAST, all of which have superb sensitivity—start to build up long data sets, we'll be in a great place to find some planets, even if they are rare," said Kerr.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer