White dwarfs could support life. So where are all their planets?

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This illustration shows a white dwarf surrounded by debris from shattered objects in a planetary system. Credit: NASA, ESA, Joseph Olmsted (STScI)

Astronomers have found plenty of white dwarf stars surrounded by debris disks. Those disks are the remains of planets destroyed by the star as it evolved. But they've found one intact Jupiter-mass planet orbiting a white dwarf.

Are there more white dwarf planets? Can terrestrial, Earth-like planets exist around white dwarfs?

A white dwarf (WD) is the stellar remnant of a once much-larger main sequence star like our sun. When a star in the same mass range as our sun leaves the main sequence, it swells up and becomes a red giant. As the red giant ages and runs out of nuclear fuel, it sheds its outer layers as a planetary nebula, a shimmering veil of expanding ionized gas that everybody's seen in Hubble images. After about 10,000 years, the planetary nebula dissipates, and all that's left is a white dwarf, alone in the center of all that disappearing glory.

White dwarfs are extremely dense and massive, but only about as large as Earth. They've left their life of fusion behind, and emit only residual heat. But still, heat is heat, and white dwarfs can have habitable zones, though they're very close.

Astronomers are pretty certain that most stars have planets. But those planets are in peril when they orbit a star that leaves the main sequence behind and becomes a red giant. That can wreak havoc on planets, consuming some of them and tearing others apart by tidal disruption. Some white dwarfs are surrounded by debris disks, and they can only be the remains of the star's planets, ripped to pieces by the star during its red dwarf stage.

But in 2020 researchers announced the discovery of an intact planet among the debris disk in the habitable zone around the white dwarf WD1054-226. If there's one, there are almost certainly others out there somewhere. Why haven't we found them? And does the fact that the first one we've found is a Jupiter-mass planet mean the WD exoplanet population is dominated by them?

A new paper posted on the *arXiv* preprint server examines the issue of exoplanets around white dwarfs and asks why rocky white dwarf planets seem to be rare. The paper is "The giant nature of WD 1856 b implies that transiting rocky planets are rare around white dwarfs," and it has been accepted for publication by the *Monthly Notices of the Royal Astronomical Society*. The author is David Kipping, Assistant Professor in the Department of Astronomy at Columbia University in New York.

White dwarfs are long-lived and stable. So even though their habitable zones are far smaller than the zone around a star like our sun, they still exist. In theory, planets in those habitable zones could support life.

The only intact planet around a white dwarf we know of for certain was detected by NASA's TESS spacecraft, and it's a whopper: 13.8 Jupiter masses.

"Given the relative paucity of giant planets compared to terrestrials indicated by both exoplanet demographics and theoretical simulations (a "bottom-heavy" radius distribution,) this is perhaps somewhat surprising," Kipping explains.

That statement may sound surprising to readers. A quick look at NASA's Exoplanet Catalogue shows 5,535 confirmed exoplanets; 1,898 of them are Neptune-like, and 1,756 of them are gas giants. Only 1,675 of them are Super-Earths, and a mere 199 are terrestrial. Kipping's statement that the exoplanet distribution is "bottom-heavy," meaning that small radius planets are more plentiful than large radius planets seems puzzling from this angle.

But our measured numbers don't reflect what's actually out there. Each detection method we use to find exoplanets has its own selection bias. In short: we only know what we've found. We don't know what's actually out there.

"… there is an emerging view that Jupiter-sized planets represent the minority of the planet population. Thus, the fact that the first transiting planet detected around a WD was found to be a giant planet is somewhat surprising," Kipping writes. WD 1856 b may be the only confirmed white dwarf planet, but there are other candidates, and most of them are Jupiter-mass or higher planets as well.

To Kipping, the implications of finding a massive gas giant around a white dwarf is concerning. "The implied hypothesis is that transiting WD rocky planets are rare," Kipping writes.

There's ample evidence for small terrestrial planets around white dwarfs. But the evidence is in the rocky debris disks from destroyed terrestrial planets. This indicates that these planets are out there, but the question then becomes, are there any intact ones in the habitable zones? Does WD 1856 b's detection tell us anything about the existence of terrestrial WD planets?

There are two ways to reconcile the evidence for small planets with the detection of WD 1856 b.

Firstly, there's no absolute reason why either small rocky planets or massive Jupiter+ mass planets need to dominate the WD exoplanet population. "Perhaps the distribution turns over at some radius, representing the most unlikely planetary radius, and then peaks back up," Kipping writes. There could be an infinite number of distributions; we just don't know yet.

The other way to reconcile it is simple. "A second possibility is that WD 1856 b is simply a fluke. Perhaps there truly is a bottom-heavy distribution and it was indeed highly improbable that a WD 1856 b-sized exoplanet would be the first to be revealed in transit." This is the challenge of working with only one data point.

Kipping calculated the odds of the first WD planet being a massive planet at 0.37%. That's extremely rare, but that doesn't necessarily lead to any reliable conclusions. "That's certainly interesting," Kipping writes, "but hardly overwhelming—in the history of astronomy, improbable events can and will occur given enough time."

So where does that leave us? We have a single WD planet detection and it's a massive gas giant, but we have multiple rocky debris disks around WDs that must have come from terrestrial planets. Where does that leave the hypothesis that small rocky planets around WDs are rare?

"For these reasons, we don't consider our hypothesis in any way established with conviction," Kipping writes.

Maybe it's just one of those things that, while interesting, can only lead to inaccurate conclusions. As is often the case, we need more data. "It would certainly be premature to abort on-going and future efforts to look for terrestrial planets around WDs."

White dwarf exoplanet science is only in its infancy. But it holds hope because WDs are so stable and long-lived. So are their habitable zones.

White dwarfs are unique among stars because their radius is the same as Earth's. They're smaller than other stars, and that could facilitate the detection of Earth-size planets. It could also facilitate atmospheric study, including the potential detection of biosignatures that can be more difficult around much larger stars.

Kipping's hypothesis that terrestrial planets are rare around WDs is easily testable. A focused search will no doubt start to reveal the true population of planets around white dwarfs.

If we find more Earth-similar worlds around white dwarfs, that opens up another pathway for habitability, and more potential for life to persist in the universe.

More information: David Kipping, The giant nature of WD 1856 b implies that transiting rocky planets are rare around white dwarfs, *arXiv* (2023). DOI: 10.48550/arxiv.2310.15219

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