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Good thing we found this Earth-sized planet now—it's about to be destroyed

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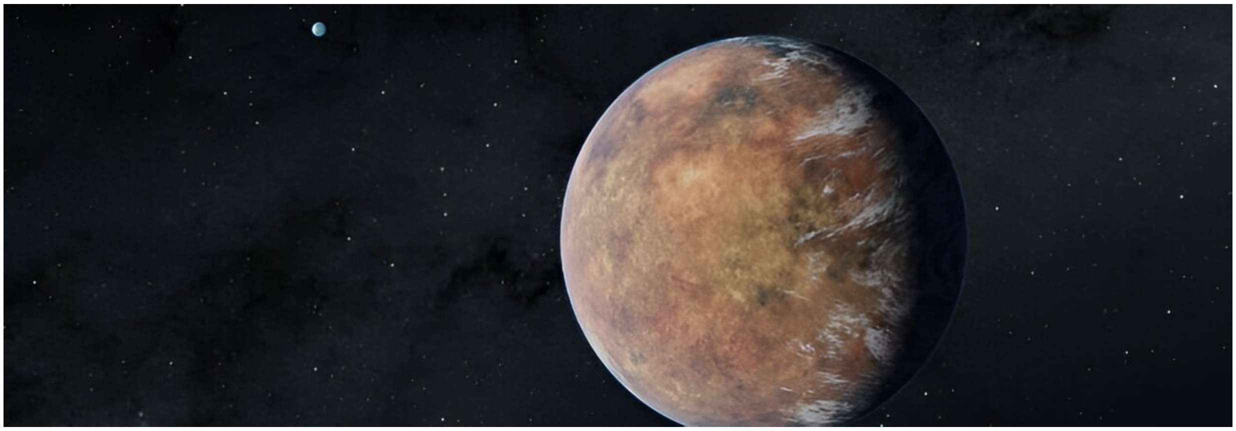

Illustration of an Earth-sized world. Credit: NASA/JPL-Caltech/Robert Hurt

Astronomers have confirmed the existence of exoplanets with extremely small orbits around their stars. But what about exoplanets that get close enough to be devoured by their star, and what if it's an Earth-sized exoplanet?

This is what a recent study posted to the *arXiv* preprint server and accepted to AAS Journals hopes to address. An international team of more than 50 researchers investigated an Earth-sized exoplanet with an orbital period of only 5.7 hours, known as "ultra-short-period" (USP) exoplanets, that could eventually experience what's known as tidal disruption, resulting in its devourment by its star.

This study holds the potential to help researchers better understand the processes responsible for this, along with continuing to challenge our understanding of exoplanetary architectures, as well.

Here, Universe Today discusses this amazing research with Dr. Fei Dai, who is an Assistant Astronomer in the Institute for Astronomy at the University of Hawai'i and lead author of the study, regarding the motivation behind the study, significant results, potential follow-up studies, the significance of this exoplanet being Earth-sized, and whether this could occur in our own solar system. Therefore, what was the motivation behind this study?

"Tidal disruption could be a potential fate of rocky planets," Dr. Dai tells Universe Today, as he notes a March 2024 study published in *Nature* that he was a co-author of and discusses tidal disruption, which was such a profound study that it was featured on the journal's cover.

"It seems like about 10% of sun-like stars might have engulfed their rocky planets. This system TOI-6255 is the best-known progenitor for those planet engulfment events. The tidal disruption of rocky planets allows us to probe their interior composition and compare with Earth."

For the study, the researchers analyzed TOI-6255 b, whose radius is ~1.08 and mass is ~1.44 of Earth's and located just over 20.4 parsecs (65.2 light-years) from Earth. However, while being Earth-sized holds promise for life, TOI-6255 b's 5.7-hour orbit not only makes this exoplanet far too hot for life as we know it to exist, but this also means its orbit takes it dangerously close to what's known as Roche limit.

This is the distance a smaller object can orbit a larger object until the larger object's gravity tears the smaller object to pieces, along with TOI-6255 b also experiencing the aforementioned tidal disruption, which is a common occurrence throughout the cosmos, including black holes. Therefore, what were the most significant results from the study?

Dr. Dai says, "This planet is doomed for tidal disruption in 400Myr which is short on the cosmic scale (~13Gyr). The planet is also tidally distorted to be football like in shape (10% deviation from sphere), in comparison, Earth's tidal distortion due to the moon is only $1e^{-7}$ [0.0000001] level."

Regarding potential follow-up studies, the researchers note they aspire to accomplish with NASA's James Webb Space Telescope, Dr. Dai says, "Orbital phase curve study of this planet could confirm that it is indeed tidally distorted. We know what the phase curve should look like for a spherical planet. A tidally distorted planet has a strong deviation from that. We can also see if the surface of the planet is covered by lava pool as would be expected on a planet this hot."

USPs are exoplanets whose orbits are less than one day and whose masses are less than 2x the Earth. While intriguing, only about 100 USPs have been discovered, with a 2014 study estimating approximately 0.5% exist around sun-like stars and a 2019 study discussing their bulk composition (i.e., mass of its iron core and mantle).

As noted, given their extremely short orbit, these worlds are likely too hot for life as we know it to exist, and along with USPs are the familiar "hot Jupiters" who orbit their stars in only a few days and astronomers estimate their population is in the hundreds. As their name literally implies, these worlds are Jupiter-sized or larger gas planets and are also potentially far too hot for life as we know it to exist. But what is the significance of TOI-6255 b being an Earth-sized planet as opposed to a Jupiter-sized planet, or larger?

Dr. Dai says, "Planets similar to Earth in size are most likely rocky, i.e., mostly made of iron core and silicate mantle. They show us what terrestrial planets in other planetary systems are made of. Jupiter-sized planets are most certainly covered by thick hydrogen and helium atmospheres. Jupiter-sized planets are unlikely to harbor life."

While TOI-6255 b isn't due for disassembly for another 400 million years, watching any exoplanet get ripped to shreds by its host star could provide important insights regarding the planet's exterior and interior compositions, thus helping us better understand the similarities between exoplanets and planets within our own solar system.

These unique worlds and their extremely tight orbits have challenged our understanding of solar system architecture throughout our Milky Way galaxy, as Mercury is the closest planet to our sun, and it still takes 88 days to complete one orbit.

For now, one similarity between our solar system and exoplanetary systems is the Roche limit. However, the study also focuses on tidal disruption that is physically distorting TOI-6255 b, with Dr. Dai mentioning above that "Tidal disruption could be a potential fate of rocky planets." Therefore, what are the chances of tidal disruption occurring for rocky planets in our solar system, and why?

Dr. Dai says, "Tidal disruption of planets is minimal in our solar system. However, the rings of Saturn are thought to originate from tidal disruption of satellites around Saturn. Tidal forces are strongly dependent on orbital separation, only objects with the shortest orbital period experience significant tides."

More information: Fei Dai et al, An Earth-sized Planet on the Verge of Tidal Disruption, *arXiv* (2024). DOI: 10.48550/arxiv.2407.21167

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