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Maybe ultra-hot Jupiters aren't so doomed after all

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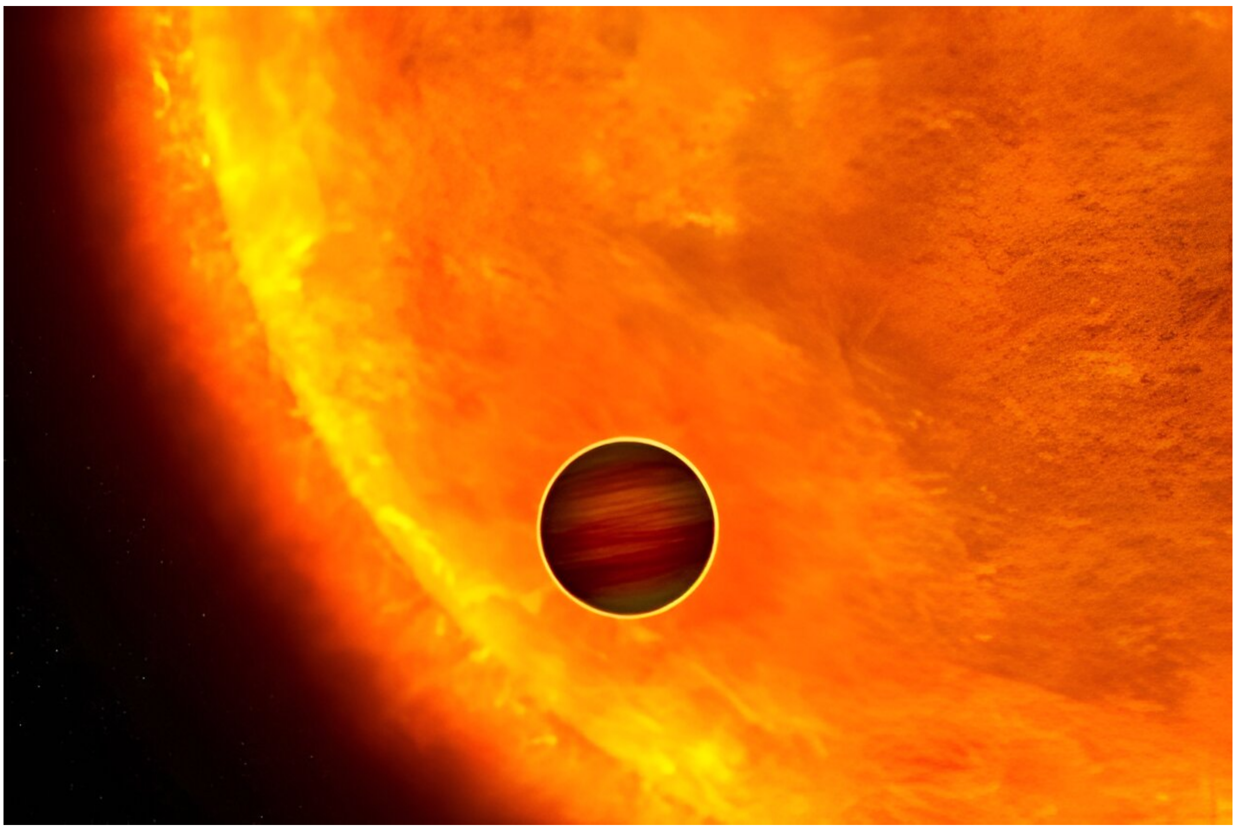

Artist's impression of an ultra-hot Jupiter. Credit: NASA, ESA and G. Bacon

Ultra-hot Jupiters (UHJs) are some of the most fascinating astronomical objects in the cosmos, classified as having orbital periods of less than approximately three days with dayside temperatures exceeding 1,930°C

(3,500°F), as most are tidally locked with their parent stars.

But will these extremely close orbits result in orbital decay for UHJs eventually doom them to being swallowed by their star, or can some orbit for the long term without worry? This is what a recent study posted to the *arXiv* preprint server and accepted to the *Planetary Science Journal* hopes to address.

The team of international researchers investigated potential orbital decays for several UHJs, which holds the potential to not only help astronomers better understand UHJs but also the formation and evolution of exoplanets, overall.

Here, we discuss this research with study lead author, Dr. Elisabeth Adams, who is a senior scientist at the Planetary Science Institute, regarding the motivation behind the study, significant results, follow-up studies, and the importance of studying orbital decay for UHJs and UHJs, overall.

So, what was the motivation behind this study regarding the orbital decay of UHJs?

"Ever since the first exoplanet, 51 Peg b aka Dimidium, was announced in a 4-day orbit, scientists have been deeply concerned about the long-term stability of these giant planets," Dr. Adams tells Universe Today.

"We've known for a while that objects the size of Jupiter can't exist with orbits shorter than about 19 hours (that's the Roche limit), but even giant planets with orbits of a few days are unstable over the long term because the tidal forces will inexorably cause their orbits to decay. The big unknown is what 'long-term' means: Will the planet decay while the star is still on the main sequence, or will the process take so long that the star dies first?"

For the study, the researchers used a combination of ground- and space-based telescopes to conduct stellar photometry and exoplanet light curve analyses of 43 UHJs with orbital periods ranging from 0.67 days (TOI-2109 b) to 3.03 days (TrES-1 b) with the goal of ascertaining their orbital period rate of change (i.e., increasing orbital period or decreasing orbital period [orbital decay]) measured in milliseconds per year (ms/yr).

This study consisted of both previously measured and new transit light curve data with the team performing some calculations to determine the orbital period rate of change for each of the 43 UHJs. Additionally, more than half of the 43 UHJs for this study have observational data of more than a decade with one exceeding 20 years of data (WASP-18 b at 32 years). So, what were the most significant results from this study?

Dr. Adams tells Universe Today, "The interesting thing is not only that this study didn't find any new cases of orbital decay, but also that we are starting to see several orders of magnitude difference in how long orbital decay takes.

"The two best cases for decaying planets (WASP-12 b and Kepler-1658 b) are decaying at rates that are >10–1,000 times faster than the planets that we don't find decay around (e.g., WASP-18 b, WASP-19b, and KELT-1b); if those latter planets were decaying as fast as WASP-12 b, we definitely would have detected it by now."

As noted, this comprehensive study helped identify new information regarding the orbital decay of UHJs, specifically pertaining to the lack of orbital decay for most of them, meaning some orbits could potentially be stable for the long-term despite orbiting extremely close to their respective parent stars.

Additionally, it helped challenge previous measurements pertaining to orbital decay of certain UHJs, which could help astronomers better understand the formation and evolution of UHJs throughout the universe. Therefore, given the comprehensiveness of the study, what follow-up studies are currently in the works or being planned?

Dr. Adams says, "We're just going to have to keep looking! This paper is the first one from our survey, and only covers about half the known UHJs, more of which keep being found; among our targets, half of them haven't been observed long enough, or with enough transits, to say if even very rapid orbital decay is happening. For the others, we may just need another few more years, or maybe a few decades, to observe it.

"Theorists are also hard at work to explain how the age and structure of the star contribute to different rates of decay, though the high uncertainty between theoretical models is why I like being able to empirically measure the decay rate."

Studying orbital decay is essential in better understanding both if and when two astronomical objects will collide with each other, including a planet and its satellite (most often a moon), a star and another planet or comet orbiting it (resulting in the latter's incineration), a star and another star (resulting in gravitational waves or gamma-ray bursts), and any astronomical objects orbiting each other (binary system).

For Earth, measuring orbital decay has been vital in learning when artificial satellites could burn up in our planet's atmosphere. But, regarding exoplanets, what is the importance of studying orbital decay for UHJs, and are they limited to only UHJs?

"Tidal decay is most important for large planets," Dr. Adams says. "Crazily enough, Earth-sized planets have been found in orbits as short as 4 hours and yet are predicted to be tidally stable for many billions of years. (I have previously published work on these smaller ultra-short period planets.) The bigger the planet and the closer it is to the star, the stronger the tidal effects and the faster the orbit will decay."

UHJs are unofficially designated as a sub-class of "hot" Jupiters. Like this study, past UHJs have also been examined using a combination of ground- and space-based telescopes. As noted by Dr. Adams, this study examined approximately half of the known UHJs, meaning there are approximately 100 known UHJs populating the cosmos.

As also noted, most UHJs are tidally locked with their parent star, meaning one side continuously faces the star throughout its orbit with the searing dayside temperatures causing molecules to break apart and recombine on the night side. These characteristics make UHJs some of the most intriguing and mysterious astronomical objects to be studied. But what is the importance of studying UHJs, overall?

"Ultra-hot Jupiters allow us to measure a fundamental property of stars (the tidal quality factor, which sets the decay rate)," Dr. Adams says. "Modeling their pasts and futures allows us to refine our theories of planet formation and migration. Some of them might also be losing their atmospheres, which we can look for.

"They are also some of the easiest planets to observe because they are big and hot and close to their star and make excellent targets for both high-precision observations (e.g., atmospheric studies with JWST) and outreach (they are excellent targets for interested amateurs with decent telescopes)."

This study comes as NASA and other space agencies around the world continue to discover exoplanets at an incredible rate, with NASA listing the number of confirmed exoplanets at 5,630 as of this writing. Of that number, 1,805 are classified as gas giants (Saturn- or Jupiter-sized), with countless numbers of these worlds orbiting their parent stars in just a few days or less.

As our understanding of exoplanets continues to expand, so will our understanding of UHJs, including their formation and evolution, along with the formation and evolution of their parent stars.

"My motto for studying exoplanets is to expect the unexpected," Dr. Adams says. "Even after three decades of observations, we keep finding planets in unexpected places doing strange things, and then we learn a lot about the universe by figuring out what they are doing and why. Definitely keeps you on your toes!"

More information: Elisabeth R. Adams et al, Doomed Worlds I: No new evidence for orbital decay in a long-term survey of 43 ultra-hot Jupiters, *arXiv* (2024). DOI: 10.48550/arxiv.2404.07339

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