This hot Jupiter is doomed to crash into its star in just three million years

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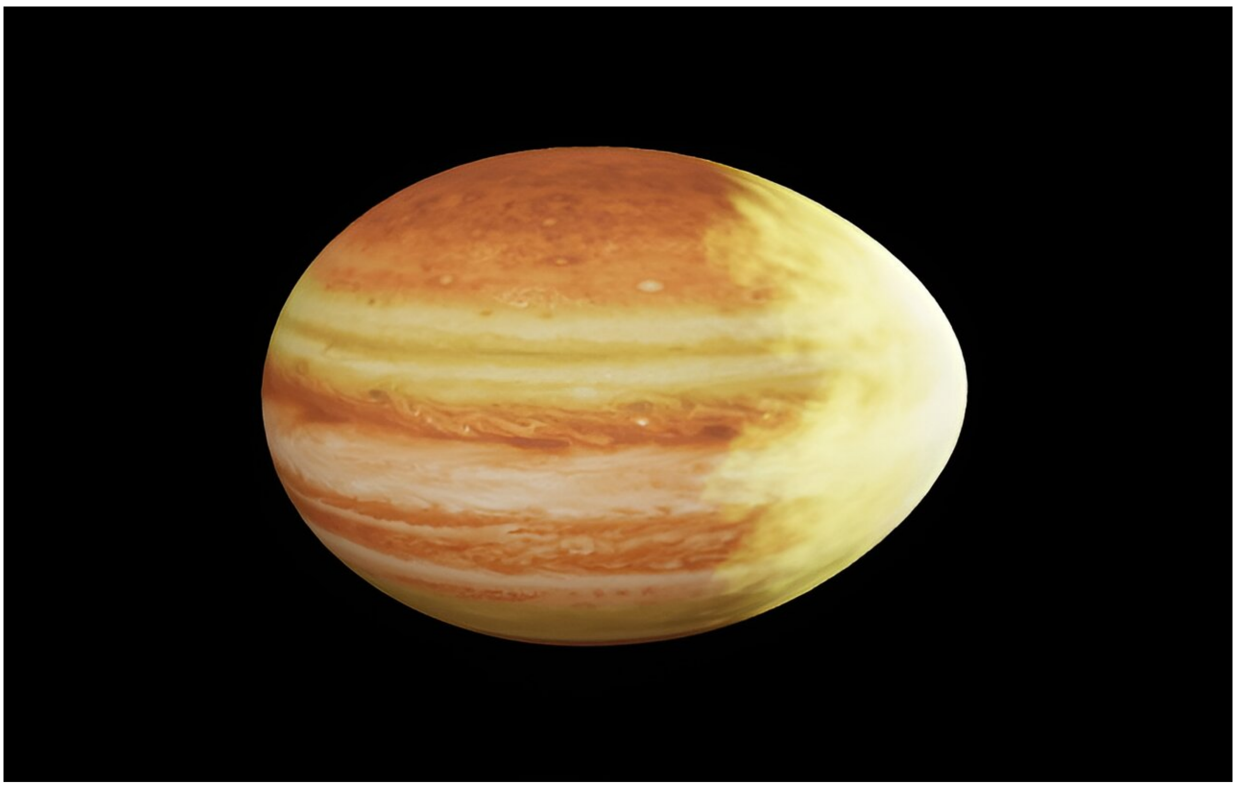

Artist's impression of WASP-12b, a Hot Jupiter deformed by its close orbit to its star. Credit: NASA

In 2008, astronomers with the SuperWASP survey spotted WASP-12b as it transited in front of its star. At the time, it was part of a new class of exoplanets ("hot Jupiters") discovered a little more than a decade before. However, subsequent observations revealed that WASP-12b was the first hot Jupiter observed that orbits so closely to its parent star that it has become deformed. While several plausible scenarios have been suggested to explain these observations, a widely accepted theory is that the planet is being pulled apart as it slowly falls into its star.

Based on the observed rate of "tidal decay," astronomers estimate that WASP-12b will fall into its parent star in about ten million years. In a recent study, astronomers with The Asiago Search for Transit Timing Variations of Exoplanets (TASTE) project presented an analysis that combines new spectral data from the La Silla Observatory with 12 years worth of unpublished transit light curves and archival data. Their results are consistent with previous observations that suggest WASP-12b is rapidly undergoing tidal dissipation and will be consumed by its star.

Their results were published in a paper titled "TASTE V. A new ground-based investigation of orbital decay in the ultra-hot Jupiter WASP-12b" accepted by the journal *Astronomy & Astrophysics*. It is available on the *arXiv* preprint server. The paper is the fifth in a series published by the TASTE project, a collaborative effort involving astronomers and astrophysicists from the National Institute of Astrophysics (INAF), the "Giuseppe Colombo" University Center for Space Studies and Activities (CISAS), and multiple Italian universities and observatories.

WASP-12b was one of many hot Jupiters discovered by the Wide Angle Search for Planets (WASP), an international consortium funded and operated by Warwick University and Keele University. In terms of exoplanet discoveries, WASP was second only to the Kepler mission and also relied on the Transit Method. This consists of monitoring stars for periodic dips in luminosity to infer the presence of planets and to constrain their size and orbital periods. Based on their observations of its F-type (yellow-white dwarf), the WASP survey determined it was a gas giant 1.465 times as massive as Jupiter with an orbital period of 1.1 days.

Pietro Leonardi, a Ph.D. Student in Space science and technology at the UniversitÃ di Trento was the lead author on the paper. As he told Universe Today via email, the discovery of hot Jupiters (HJ) represented a major breakthrough in exoplanet studies:

"The first discovery of an exoplanet around a Solar-type star by Mayor & Queloz (1995) completely revolutionized how we thought planets should and could be found orbiting a star. As human beings, we often have a tendency to envision new concepts close to those we already understand. This cognitive bias is equally applicable to scientists, who are, after all, ordinary individuals.

"Until 1995, it was widely assumed that exoplanetsâ€"planets orbiting stars beyond our solar systemâ€"would resemble those in our own solar system. We expected to find large, gaseous giants like Jupiter, Saturn, Uranus, and Neptune residing at significant distances from their host stars, while smaller, rocky planets like Mercury, Venus, Earth, and Mars would occupy the inner regions."

The discovery of a massive gas giant orbiting very closely to its star shattered these expectations and forced astronomers to reevaluate their theories on planet formation and evolution. For instance, scientists had long held that exoplanet systems likely resembled the solar system and that their planets formed close to where they orbited. In this scenario, rocky planets form closer to their suns while gas giants form in the outer reaches beyond the "Frost Line"â€"the boundary beyond which volatile elements (hydrogen, carbon, nitrogen, and oxygen) begin to freeze.

"It highlighted the fact that our solar system is not representative of the typical planetary system in the universe; rather, it appears to be an outlier," said Leonardi. However, WASP-12b stood apart from other HJs in that it was the only one that appeared to be experiencing variations in its orbit. Multiple scenarios were proposed for this, including the possibility that it was experiencing tidal decay (slowly falling into its star). As Leonardi explained:

"WASP-12b is a very extreme planet. It is indeed part of the sub-category called ultra-hot Jupiters. The planet is very close to its host star, orbiting it in just 1.09 days and having a surface temperature of 2600 K. Due to its extreme vicinity to its host star, the planet feels a strong gravitational pull that strips part of its atmosphere of heavy metals, which create a disk around the star. When it was first discovered that WASP-12b had a changing orbit, the other explanations that were explored were the RÃ¸mer effect and Apsidal precession."

In the former scenario, the timing variation was attributed to the star being closer to Earth in the direction of the line of sight. In the latter, it was due to a gradual rotation of the planet's orbit. For their study, Leonardi and his colleagues presented a new analysis based on 28 previously unpublished transit light curves gathered by the Asiago Observatory between 2010 and 2022. This was combined with all the available archival data and updated high-resolution spectra obtained by the High Accuracy Radial Velocity Planet Searcher-North (HARPS-N) instrument on the ESO 3.6-meter telescope at the La Silla Observatory.

These observations allowed the team to confirm that the planet's orbit is decaying and that its star will consume it sooner than expectedâ€"in 3 million years rather than 10. These results have effectively settled the debate about this planet's peculiar orbit and present opportunities for follow-up studies. Said Leonardi:

"This study helps us to get closer to understanding the rare scenario of orbital tidal decay and gives us a perfect laboratory to study the star-planet interactions. The system is still yet to be uncovered in various aspects, for example we still need to understand how this fast tidal dissipation is possible. According to our theories the tidal dissipation we observe should not be possible in a star still in the main sequence. However, our precise stellar parameters inferred from the HARPS@TNG spectra confirm that the star is still in the main sequence."

In the past 30 years, the field of exoplanet studies has experienced tremendous and accelerating growth. With more than 5,000 confirmed exoplanets available for study, the field is now transitioning from discovery to characterization. The more we learn about worlds beyond our solar system, the more we can infer about the nature of planets in our universe and how they form and evolve with time. Someday, this could lead to a new understanding of the nature of life itself and what conditions under which it can arise.

More information: P. Leonardi et al, TASTE V. A new ground-based investigation of orbital decay in the ultra-hot Jupiter WASP-12b, *arXiv* (2024). DOI: 10.48550/arxiv.2402.12120

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