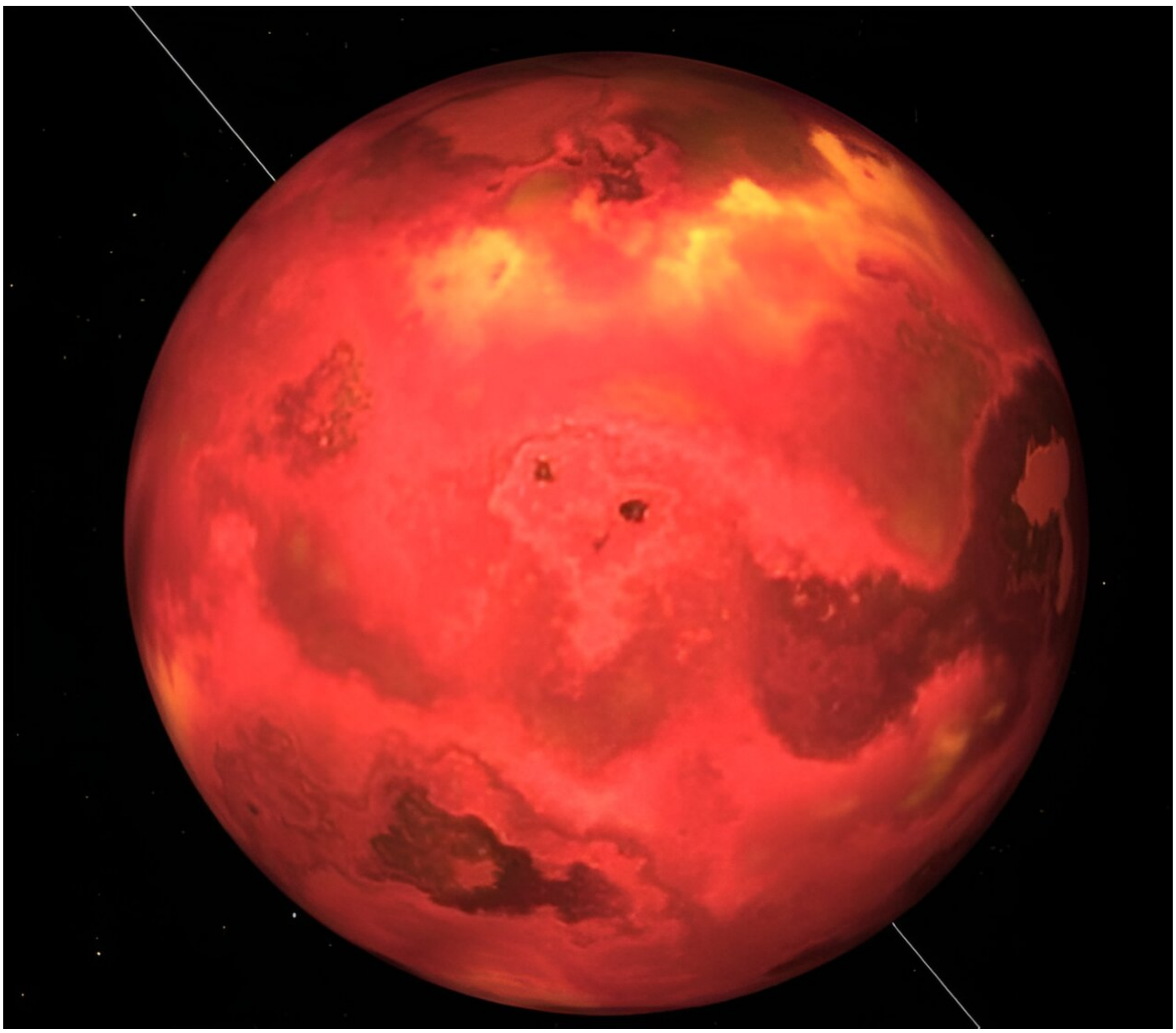
GJ 367b is another dead world orbiting a red dwarf, say astronomers

January 8 2024, by Evan Gough



An illustration of the exoplanet Gliese 367 b. It’s an oddball planet that may be composed entirely of iron. Its red dwarf star may have stripped away its outer silicate layers and its atmosphere. Credit: NASA

Red dwarf exoplanet habitability is a hot topic in space science. These small dim stars host lots of exoplanets, including small rocky ones the size of Earth. But the little stars emit extremely powerful flares that can damage and strip away atmospheres.

If we're ever going to understand red dwarf habitability, we need to understand the atmospheres of the exoplanets that orbit them.

In new research, astronomers studied the atmosphere of the often-mentioned exoplanet GJ 367b and found, well, nothing. The planet likely lost whatever volatiles it had long ago, and the red dwarf star it orbits is responsible.

Gliese 367 is a red dwarf star (M dwarf) about 30 light-years away with three known exoplanets orbiting it. Astronomers found GJ 367b and its siblings with NASA's TESS (Transiting Exoplanet Survey Satellite) in 2021. GJ 367b is an ultra-short period planet that takes only 7.7 hours to complete one orbit and is likely tidally locked to its star. It's so close to the red dwarf star that it receives hundreds of times more radiation than Earth does from the sun. All that radiation blasting its surface means its dayside temperature is about 1,500°C (1,770 K; 2,730°F).

GJ 367b is a sub-Earth with a radius of about 72% of Earth's. But it's extremely dense, almost twice as dense as Earth. Scientists think that it's mostly iron and that its outer silicate layers have been stripped away. It's sometimes called the Iron Planet.

It's easier to spot exoplanets around red dwarfs compared to other stars because they're so much dimmer and smaller. This helps find planets with both the transit method and the radial velocity method. So it makes sense to study them both because they're so numerous and because we can see so many of them.

In a new yet-to-be-published paper, researchers examined GJ 367b with the James Webb Space Telescope's Mid-Infrared Instrument (MIRI.) The paper is "GJ 367b is a dark, hot, airless sub-Earth." It's in pre-print now, posted to the *arXiv* server, and the author is Michael Zhang, a post-doctoral fellow in the Dept. of Astronomy and Astrophysics at the University of Chicago.

The paper's title gives the conclusions away, but the detail is interesting.

GJ 367b was never going to be habitable because it's way too close to its star. But astronomers are very interested in exoplanets that orbit red dwarfs (M dwarfs.) For one thing, red dwarfs are numerous; half of the stars in the Milky Way are probably red dwarfs, maybe far more than that. So, the bulk of the exoplanets in our galaxy are probably orbiting red dwarfs, and planet hunters have found an abundance of exoplanets around red dwarfs.

"The question of whether small rocky planets orbiting M dwarfs can host atmospheres is of prime importance for habitability," the authors write. Red dwarf planets are easier to study than sun-like stars because red dwarfs are dimmer and smaller. Larger, brighter stars like our sun can drown out exoplanet atmospheres. But when it comes to the potential habitability of red dwarf exoplanets, an elephant has crept into the room: flaring.

"However, it has long been suggested that the high-energy radiation, flares, and long pre-main-sequence of M dwarfs strip planetary atmospheres; the extent to which this happens is a subject of active research," the researchers explain.

The reason it's such an active area of research is that the fundamental mechanisms behind the creation of an atmosphere are poorly understood. There are two mechanisms: volatile delivery during a planet's formation and volatile release as a young magma ocean planet cools and solidifies. There are also two mechanisms that can strip an atmosphere, and they're also in need of more research: photoevaporation and stellar wind erosion.

There's a lot to learn, and that's what this research is chipping away at. "By observing M dwarf planets and determining which, if any, host atmospheres, we can build up a sample of empirical benchmarks that can be used to calibrate atmospheric mass loss models," the authors state clearly and distinctly.

The researchers examined GJ 367b dayside emission spectrum to ascertain what the surface is made of and what type of atmosphere, if any, is present, even if it's only a thin, tenuous atmosphere. They concluded that the planet has a zero albedo, no heat recirculation, and no atmosphere.

"GJ 367b is the first sub-Earth with thermal surface observations," Zhang and his co-authors write. "These observations reveal a planet with no detectable atmosphere, no heat redistribution, and a dark surface in the MIRI bandpass ($A_B \approx 0.1$) with a blackbody emission spectrum."

"The lack of heat redistribution rules out $\gtrsim$1 bar atmospheres for a wide range of compositions, while the emission spectrum rules out even thinner atmospheres for some compositions," the authors explain. For comparison, Earth's atmosphere is about 1 bar at sea level.

The lack of an atmosphere at GJ 367b is not a surprise. That's because it's above what's called the "cosmic shoreline." The cosmic shoreline is a metaphor for a statistical trend that links all planets together. It's a dividing line that appears when we compare the light a planet receives from its star and how easily the planet's atmosphere can escape into space.

"Given that the planet is far above the 'cosmic shoreline,' the lack of an atmosphere is not surprising, although it is not the best possible news for the prospect of measuring the atmospheres of M dwarf rocky planets," the authors explain.

GJ 367b was never going to be habitable. It's much too close to its star. But it's still important data that will help lead scientists to a better understanding of exoplanet atmospheres in general. And we need more data like it if we're going to understand red dwarf habitability.

"We encourage JWST observations of planets closer to or below the cosmic shoreline to understand which, if any, rocky planets orbiting M dwarfs have atmospheres," the authors conclude.

So what are the prospects for M dwarf habitability? There's growing evidence that red dwarfs do not make good bedfellows when it comes to exoplanet habitability. Since they're so dim, their habitable zone is much closer. That means that exoplanets in a red dwarf's habitable zone are subjected to intense flaring that can destroy atmospheres and bathe their surfaces in intense radiation.

More information: Michael Zhang et al, GJ 367b is a dark, hot, airless sub-Earth, *arXiv* (2024). DOI: 10.48550/arxiv.2401.01400

Provided by Universe Today