

# The first potentially habitable exoplanet, just 20 light years from Earth

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**The planetary system around the red dwarf Gliese 581, one of the closest stars to the Sun in the galaxy, has been the subject of several studies aiming to detect the first potentially habitable exoplanet. Two candidates have already been discarded, but a third planet, Gliese 581d, can be considered the first confirmed exoplanet that could support Earth-like life. This is the conclusion of a team of scientists from the Institut Pierre Simon Laplace (CNRS, UPMC, ENS Paris, Ecole Polytechnique) in Paris, France, whose study is published today in *The Astrophysical Journal Letters*.**

In the short time since planets were discovered around it, the red dwarf star Gliese 581 has had a controversial history. It was first in the news in 2007, when Stephan Udry and colleagues at the University of Geneva detected two planets orbiting not far from the inner and outer edge of its 'habitable zone' – the range of distances in which planets are neither too cold nor too hot for life to flourish. While the more distant planet, Gliese 581d, was initially judged to be too cold for life, the closer-in planet was thought to be potentially habitable by its discoverers. However, later analysis by atmospheric experts showed that if it had liquid oceans like Earth, they would rapidly evaporate in a 'runaway greenhouse' effect similar to that which gave Venus the hot, inhospitable climate it has today.

The Gliese 581 system made headline news once again in September last year, when a team of observers led by Steven Vogt at the University of California, Santa Cruz, announced that they had discovered a new planet, which they dubbed Gliese 581g, or 'Zarmina's World'. This planet, they claimed, had a mass similar to that of Earth and was close to the centre of the habitable zone. For several months, the discovery of the first potential Earth twin outside the Solar System seemed to have been achieved. Unfortunately, later analysis by independent teams has raised serious doubts on this extremely difficult detection. Many now believe that Gliese 581g may not exist at all. Instead, it may simply be a result of noise in the ultra-fine measurements of stellar 'wobble' needed to detect exoplanets in this system.

Following this controversy, Robin Wordsworth, François Forget and co-workers at the Institut Pierre Simon Laplace (Laboratoire de Météorologie Dynamique) in Paris decided to take a second look at Gliese 581g's big brother – the larger and more distant Gliese 581d. Although it is likely to be a rocky planet, it has a mass at least seven times that of Earth, and is estimated to be about twice its size. At first glance, Gliese 581d is a pretty poor candidate in the hunt for life: it receives less than a third of the stellar energy Earth does and may be tidally locked, with a permanent day and night side. After its discovery, it was generally believed that any atmosphere thick enough to keep the planet warm would become cold enough on the night side to freeze out entirely, ruining any prospects for a habitable climate.

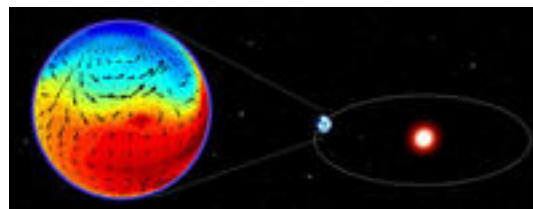
To test whether this intuition was correct, Wordsworth and colleagues developed a new kind of computer model capable of simulating possible exoplanet climates. The model simulates a planet's atmosphere and surface in three dimensions, rather like those used to study climate change on Earth. However, it is based on more fundamental physical principles, allowing to simulate a much wider range of conditions than would otherwise be possible, including any atmospheric cocktail of gases, clouds and aerosols.

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To their surprise, they found that with a dense carbon dioxide atmosphere - a likely scenario on such a large planet - the climate of Gliese 581d is not only stable against collapse, but warm enough to have oceans, clouds and rainfall. One of the key factors in their results was Rayleigh scattering, the phenomenon that makes the sky blue on Earth. In the Solar System, Rayleigh scattering limits the amount of sunlight a thick atmosphere can absorb, because a large portion of the scattered blue light is immediately reflected back to space. However, as the starlight from Gliese 581 is red, it is almost unaffected. This means that it can penetrate much deeper into the atmosphere, where it heats the planet effectively due to the greenhouse effect of the CO<sub>2</sub> atmosphere, combined with that of the carbon dioxide ice clouds predicted to form at high altitudes. Furthermore, the 3D circulation simulations showed that the daylight heating was efficiently redistributed across the planet by the atmosphere, preventing atmospheric collapse on the night side or at the poles.

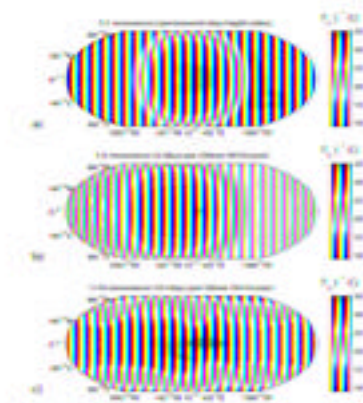
Scientists are particularly excited by the fact that at 20 light years from Earth, Gliese 581d is one of our closest galactic neighbours. For now, this is of limited use for budding interstellar colonists ? the furthest-travelled man-made spacecraft, Voyager 1, would still take over 300,000 years to arrive there. However, it does mean that in the future telescopes will be able to detect the planet's atmosphere directly. While Gliese 581d may be habitable there are other possibilities; it could have kept some atmospheric hydrogen, like Uranus and Neptune, or the fierce wind from its star during its infancy could even have torn its atmosphere away entirely. To distinguish between these different scenarios, Wordsworth and co-workers came up with several simple tests that observers will be able to perform in future with a sufficiently powerful telescope.

If Gliese 581d does turn out to be habitable, it would still be a pretty strange place to visit ? the denser air and thick clouds would keep the surface in a perpetual murky red twilight, and its large mass means that surface gravity would be around double that on Earth. But the diversity of planetary climates in the galaxy is likely to be far wider than the few examples we are used to from the Solar System. In the long run, the most important implication of these results may be the idea that life-supporting planets do not in fact need to be particularly like the Earth at all.



Schematic of the global climate model used to study Gliese 581d. Red / blue shading indicate hot / cold surface temperatures, while the arrows show wind velocities at 2 km height in the atmosphere.

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Surface temperature maps for simulations of Gliese 581d assuming an atmosphere of 20 bars of CO<sub>2</sub> and varying rotation rates. It is currently unknown whether the planet rotates slowly or has permanent day and night sides. In all cases, the temperatures allow for the presence of liquid water on the surface.

## Bibliography

"Gliese 581d is the first discovered terrestrial-mass exoplanet in the habitable zone?", R. D. Wordsworth, F. Forget, F. Selsis, E. Millour, B. Charnay, J-B. Madeleine. *The Astrophysical Journal Letters*, May 12, 2011.

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