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WEEKLY 23 May 2026

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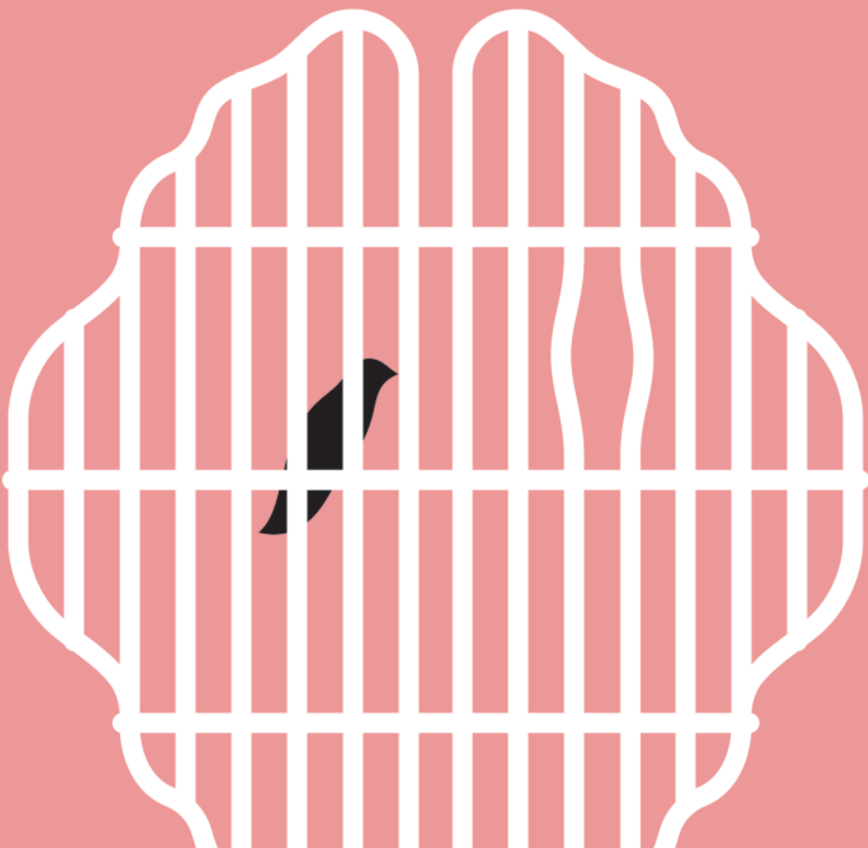

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Alien skies

A decade ago, we spotted the most promising place for alien life yet found. But does this faraway exoplanet have an all-important atmosphere, asks **Leah Crane**

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SEVEN Earth-sized planets line up neatly next to their tiny star. The first is far too hot, its surface probably a morass of lava. The seventh is much too cold and may even be frozen solid. But the middle planet? That one could be just right. Among the thousands of planets orbiting other stars we have so far discovered, this one may be the most promising place to hunt for life.

Even as the first members of this system of planets were discovered almost exactly a decade ago, it was obvious that this was a thrilling find. The star they orbit, known as TRAPPIST-1, is an M dwarf, the smallest, coolest type of star, which meant there was a decent chance of being able to study its planets in detail. It is also fairly nearby in cosmic terms, being only about 40 light years away, and has an orbit aligned perfectly for us to observe it. "There's been a lot of effort to find more systems like this, and we just haven't found any," says exoplanet researcher Ana Glidden at the Massachusetts Institute of Technology (MIT).

The fourth planet from the star, TRAPPIST-1e, is where most attention is focused, thanks to its Goldilocks position. But there has long been a nagging question hanging over it: does it have an atmosphere? If so, it would be a landmark discovery, the first temperate, rocky exoplanet with an atmosphere, and a huge boost to its credentials as a potentially habitable world.

If you could somehow transport yourself to the TRAPPIST-1 planets and hover above them, you would see a sight at once familiar and deeply strange. To be clear, we can't photograph these worlds, so we don't know precisely what they look like. But indirect observations tell us they are all rocky or icy planets of a similar size to Earth. On the other hand, they have tight orbits, all much closer to their star than Mercury is to the sun. That doesn't automatically mean they are scorched coals, however, because TRAPPIST-1 burns so much more gently than our star.

In fact, most of the radiation coming from the star is thought to be in the infrared part of the spectrum. This means the planets get heat, but not much light, so if you were standing on their surface, the sky would probably never get much lighter than Earth's does at sunset. To complicate things further, the strong gravitational pull these planets feel from their star may well mean that some or all are tidally locked. This would give them a day side that permanently faces their star and a night side looking out to the blackness of space. If this were the case, their two sides would have completely different temperatures and conditions.

When planets align

The discovery of the TRAPPIST-1 worlds came after more than two decades of searching for exoplanets, with the first ones detected in the early 1990s. Exoplanets are too far away for us to directly image, and the first few finds were made by watching for wobbles in starlight caused by the gravitational pull of an orbiting planet. Things started really ramping up with the use of the transit method. When a star and one of its planets are aligned just right, we can catch the planet passing between Earth and the distant host star, periodically dimming the star's light. The vast majority of exoplanets we know of were discovered using this method, largely with the Transiting Exoplanet Survey Satellite and the Kepler space telescope (see "Hunting for planets", page 38).

We have now discovered more than 10,000 exoplanet candidates, meaning signals that we think indicate an exoplanet, but haven't been conclusively validated. As for confirmed exoplanet discoveries, there are more than 6000 – but among these, TRAPPIST-1e remains uniquely exciting. One reason why is simply that terrestrial planets are rare finds (see "The four types of exoplanet", page 38). But even among that select group, this world stands out. "Typically, when someone says a planet might be habitable, they have a lot of caveats: only if it has a very CO_2-rich atmosphere, only if it has a very CO_2-poor atmosphere, only if it has a pretty bow on top," says astrobiologist Sukrit Ranjan at the University of Arizona. "But for TRAPPIST-1e, most of those caveats are gone." If this world has any atmosphere at all and a bit of water, it almost certainly has the right conditions for life.

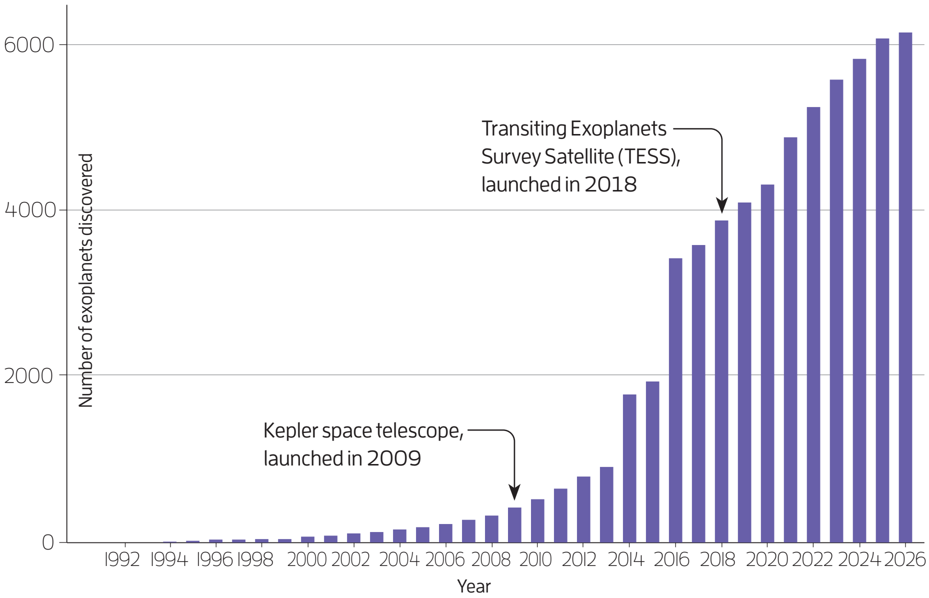
But in the decade since the planet's discovery, figuring out whether it has an atmosphere has proved tougher than anyone expected. As huge as our own sky seems from the ground, atmospheres are actually tiny. When a planet is found using the transit method, we look for an atmosphere by examining the dips in starlight in much more detail. If there is an atmosphere, there should be little bumps on either side of those dips, when the planet itself isn't blocking the starlight but its atmosphere is. Then, if we're lucky, we can characterise the atmosphere by looking at what wavelengths of light it blocks, in a painstaking process called transmission spectroscopy.

The larger the planet and the smaller the star, the easier all of this is, which is why planets around M dwarfs like TRAPPIST-1 have gained so much attention in recent years. While it would be a great boon to the search for habitable worlds to find an Earth-like planet orbiting a sunlike star, we simply don't have the telescope resolution to look for a planetary atmosphere there. "An atmosphere is like the skin of an onion, and that is too tiny against the backdrop of a sunlike star," says Sara Seager at MIT, a planetary scientist who focuses on small, rocky bodies. Essentially, a star the size of our sun would dim too slightly to discern as a planet passes in front of it, whereas with TRAPPIST-1, its planets blot out a greater portion of the light.

That doesn't mean the process is easy, ›

Hunting for planets

Thanks to the launch of two key telescopes, we have now spotted more than 6000 confirmed exoplanets



though. "You have to do a lot of work to try to rescue that little signal that is the atmosphere from this sea of noise that is the star," says Néstor Espinoza at the Space Telescope Science Institute in Maryland, who is leading one of the main efforts to do so. M dwarfs are also extremely active, and the flares, sunspots and various other phenomena that litter the surface of TRAPPIST-1 make it harder to root out the signal of any atmosphere, even with a telescope as powerful as JWST. "With TRAPPIST-1e and similar objects, James Webb is really struggling," says Ranjan. "It can, in theory, do it, but it's really pushing the limits of the telescope."

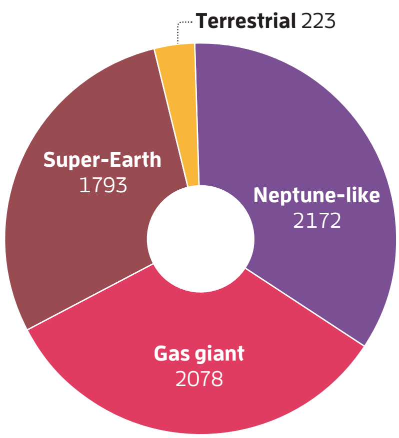
In the observations of TRAPPIST-1e that have already been analysed, that stellar activity has made it impossible to say for sure whether there is an atmosphere. "There was this persistent signal that was there in all of the observations, which is what an atmosphere would look like, but it could also be a persistent stellar feature that's in all of the observations," says Natalie Allen at Johns Hopkins University in Maryland, part of the team studying the TRAPPIST-1 system with JWST.

At first, the signal looked like it might be a sign of methane in the atmosphere, but further study revealed that methane would be incredibly unlikely to survive for long under the levels of radiation present on TRAPPIST-1e. "That sort of hints that these bumps and wiggles are stellar contamination and not a real atmospheric signal," says Glidden. Right now, Allen and several of her colleagues maintain that the observations we have leave us with a roughly 50/50 chance that TRAPPIST-1e has an atmosphere.

She and Espinoza have come up with a clever workaround for the problem of contamination from the star. Their trick is only possible because the TRAPPIST-1 planets are so similar. TRAPPIST-1b, the closest planet to the star, should look nearly identical to TRAPPIST-1e when it transits – except that 1b is so close to the star that there is no way it has an atmosphere. So, if we observe both planets within a few hours of one another, we should be able to simply subtract what we see in the 1b observations from the 1e observations, leaving behind only the signature of any atmosphere that 1e might have, without any of the contamination from the star that would be in both datasets.

The four types of exoplanet

Terrestrial, rocky worlds about the size of Earth are the ones we think are most likely to support life – and the rarest kind that we have found



In the spotlight

To do this, the team needed more than 100 hours of observation time on JWST to catch 15 transits of the planets in front of their star. It was a big ask, given the overall demand for time using the world's premier observatory, but it was approved and now there is only one observation left before the data is ready for analysis. "I think by the middle of the year, we should have some preliminary results, and by the end of the year, we should have a pretty solid answer," says Espinoza. In concert with that effort, other teams are trying to build a more-detailed model of TRAPPIST-1 and M-dwarf stars more generally to make it easier to subtract out the stellar activity from the possible atmospheric signal.

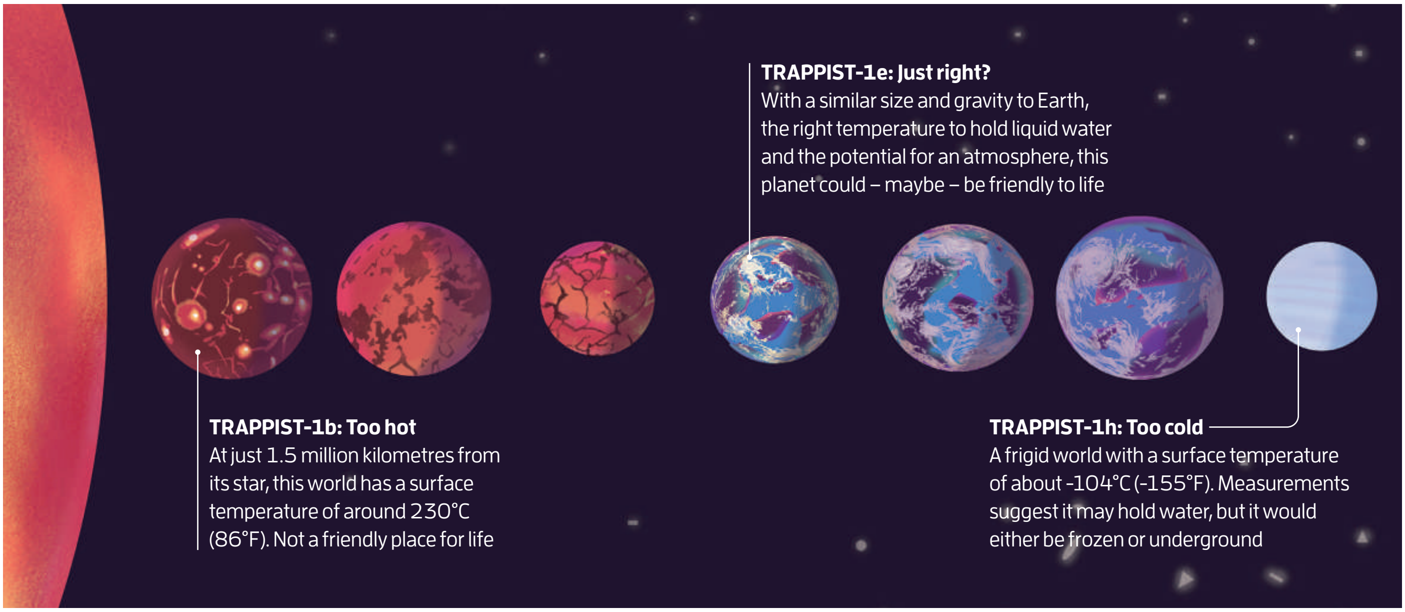
Even if it has a thick atmosphere like Earth does, TRAPPIST-1e is unlikely to be anything like our planet: its size and temperature are probably where the similarities end. "Whatever chemistry is happening on TRAPPIST-1e would be very different, because it's closer to its star," says Hannah Diamond-Lowe, also at the Space Telescope Science Institute. Radiation from the star streaming through the atmosphere would create different chemistry than occurs in Earth's atmosphere. This suggests that any life that may be found there would probably be very different to what we are used to.

In fact, that radiation is so strong that any atmosphere the planet may have had in its infancy would almost certainly have been stripped away. If there is an atmosphere there now, it must be what planetary scientists call a secondary atmosphere, restored by volcanism and outgassing from within the planet itself or by comet impacts.

That isn't necessarily a problem, though. "The short answer to 'Can secondary atmospheres support life?' is yes. We know that because we have a secondary atmosphere here on Earth," says Ranjan. Our own primary atmosphere was mostly stripped away by the impact that created the moon about 4.5 billion

Goldilocks worlds

The TRAPPIST-1 star system, discovered in 1999, hosts seven exoplanets – including our best candidate for one that could support life



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years ago, and the atmosphere we have now was formed when the world's molten surface spewed out gases, which were then altered significantly by the rise of living organisms.

If there is life on TRAPPIST-1e, too, we almost certainly won't be able to see signs of it with JWST or even the next generation of space telescopes. Even finding an atmosphere on a rocky world this small has been impossible so far, so the sort of close analysis that would reveal biosignatures – that is, signs of chemical compounds that could only be produced by life – remains out of reach. An atmosphere on such a world would be the best sign we have had so far that a planet is ripe for life and should be searched, though.

And that remains the case regardless of how familiar that atmosphere is. "Néstor the scientist will tell you the scenario that we would be most excited about would be to detect an Earth-like atmosphere – that might hint that there is something comparable to our solar system out there," says Espinoza. "However, I think Néstor the human will tell you that he's even more excited about the possibility that there will be an atmosphere that's completely different from anything in the solar system."

TRAPPIST-1e may be our best hope for a rocky planet with an atmosphere, but it isn't the only one. "There is a population of other M dwarfs with rocky planets that might be harder to get at, but for which the survival of an atmosphere might be more likely," says Diamond-Lowe. She and Espinoza lead a project called the Rocky Worlds survey that is looking into just that possibility. They have a list of nine small exoplanets orbiting M-dwarf stars that are promising candidates for atmospheres. All of them are harder to observe than TRAPPIST-1e – mostly because they are further from Earth and tend not to be aligned so perfectly for transit observations – but many orbit stars that are less active and therefore less likely to have destroyed any atmosphere that could be present. So far, only one of the nine has been observed – with JWST and the Hubble Space Telescope – and according to findings released in 2025, it seems to be a barren, airless rock.

Hopes remain high for the others, which will be observed over the course of the next few years, as well as a longer list of potential targets for future measurement, but there is no denying that the first results from the Rocky Worlds survey introduced a smidge of doubt. "It could be that there is just no getting around the harsh environments that these M-dwarf hosts are providing," says Diamond-Lowe. "We need to be prepared for that possibility." M dwarfs are the most common stars in the galaxy, though. So if we can't find a truly habitable world orbiting an M dwarf with JWST – and the TRAPPIST-1 system is by far our best chance to do that – it could be decades before we have another opportunity.

If, in a few months, it's announced that TRAPPIST-1e does have an atmosphere, the excitement will quickly give way to more questions. Give planetary scientists that evidence, and they will want to find out what it is made of, which requires even more sensitivity and even more filtering-out of stellar contamination. But characterising the atmosphere is the only way we currently have to look for signs of life in the form of combinations of gases that couldn't exist if they weren't being constantly replenished by some sort of living organism, and the only way to get a feeling for what things might be like on the surface. "You can't get both at the surface and the atmosphere directly, because there's probably clouds and other things that could make it hard to see the surface," says Glidden.

No matter what happens, TRAPPIST-1e is dragging the hunt for extant life on other worlds into the realms of science fact, and it's the only world we know of right now that's capable of doing so. "I just hope there are more TRAPPIST systems out there," says Seager. ∎

Leah Crane is a senior reporter at *New Scientist*, covering topics ranging from private space flight and cosmology to quantum mechanics