

New Scientist

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Doomsday revisited



The first sightings of planets that seem to have miraculously survived the death of their stars is forcing a rethink of Earth's fate, says **Stuart Clark**

IT ALL seemed so simple when we knew the date of Earth's demise. In 5 billion years from now, so the story went, the solar system will have dramatically transformed. Instead of being the benign presence we are used to, the sun will have ballooned into a giant, hundreds of times bigger than it is today. In the process, it will wipe out the rocky, inner planets, including our own.

Or will it? We have recently caught sight of the dying stages of other stars for the first time. And, miraculously, some planets seem to be able to survive these apocalyptic periods. Such observations are challenging the story of how Earth will die and giving us hope that it might somehow outlast the sun. Even if it doesn't, all is not lost. The research is also giving us clues to where humanity could best take refuge.

The sun is powered by nuclear fusion, in which hydrogen atoms are melded together into helium, releasing vast amounts of energy in the process. But our star's fate is sealed by one fact: it has a finite supply of hydrogen.

As this begins to run out – in about another 5 billion years – the sun's internal structure will change and it will expand to around 200 times its present size. It will transform from the yellow dwarf it is today into a red giant.

After a further billion years or so, and another round of shrinking and ballooning, it will then die and shrink back down into a stellar corpse called a white dwarf.

As it grows to become a red giant, the sun will get hotter as the nuclear reactions inside its core creep outwards to find fresh sources of hydrogen fuel, closer to the sun's surface. In about a billion years from now, we think this will make the surface temperature on Earth hot enough to boil away the oceans, leaving the planet covered in salt flats and dunes. Without water, plate tectonics will stop and at a certain

point it will be hot enough to melt rock.

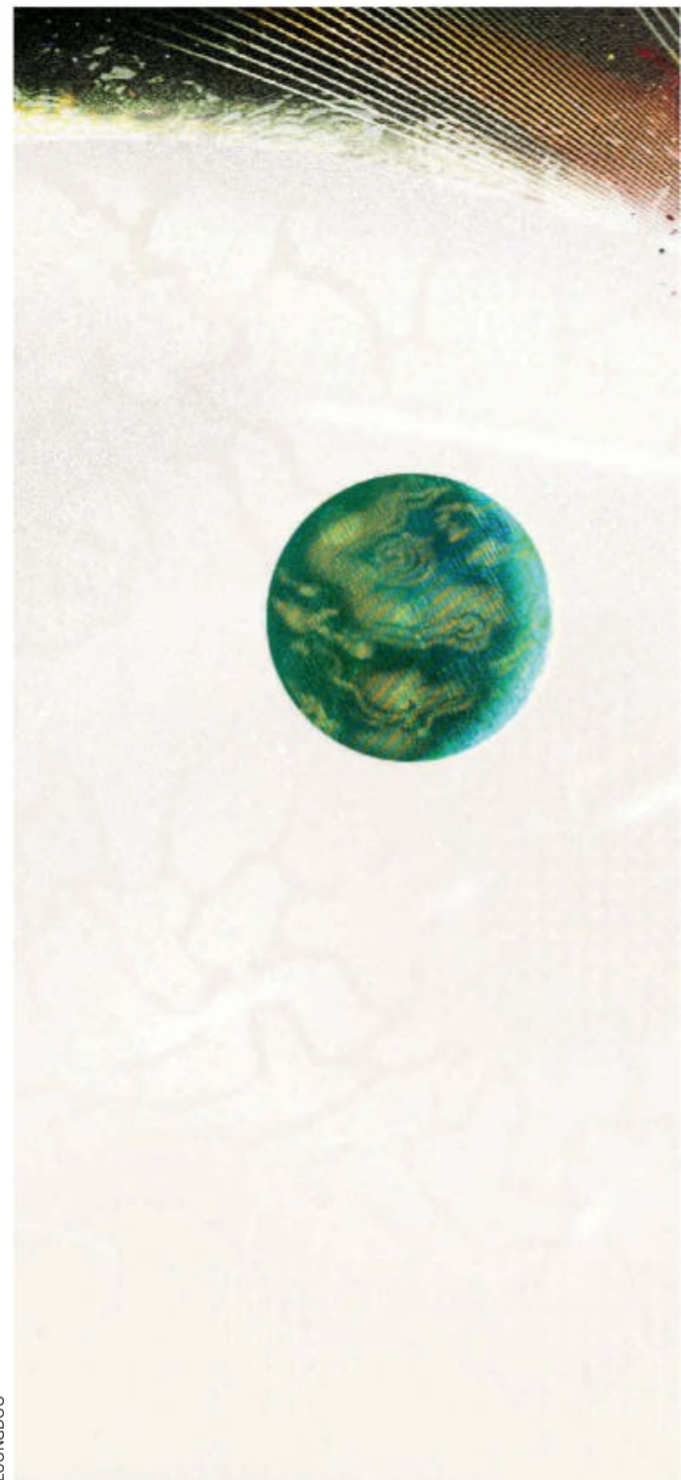
If humans are still around at this point, we may struggle to survive much longer, as there is, unfortunately, worse to come. As the sun grows, first Mercury, and then Venus, will be engulfed by it. Their outer layers will evaporate and the remaining cinders will spiral down into the fiery depths of the sun. Estimates suggest the red giant's surface will eventually be within touching distance of Earth's current orbit. So if it isn't subsumed into the sun, Earth will still be fried beyond recognition.

In March this year, Kishalay De at the Massachusetts Institute of Technology and his colleagues spotted this gruesome process in action for the first time. They found a star around 13,000 light years away that brightened by a factor of 100 over 10 days, indicating it had gobbled up a planet some 30 times larger than Earth.

Escape to Jupiter

Thankfully, astronomers have an escape plan for humanity. While the inner solar system will become utterly hellish, its currently frigid outer reaches will warm up. "When the sun becomes a red giant, the zone of habitability will extend further," says Rafael Luque, an astronomer at the University of Chicago. "We know there is a lot of water in the moons of Jupiter and Saturn, so there could be a second generation of habitability within our solar system."

We have solid evidence that gas giants akin to Jupiter can survive their parent star's death. In 2021, such a planet was observed in orbit around a white dwarf near the centre of our Milky Way galaxy. Astronomers could tell that the star and this planet had formed at around the same time, meaning this world survived

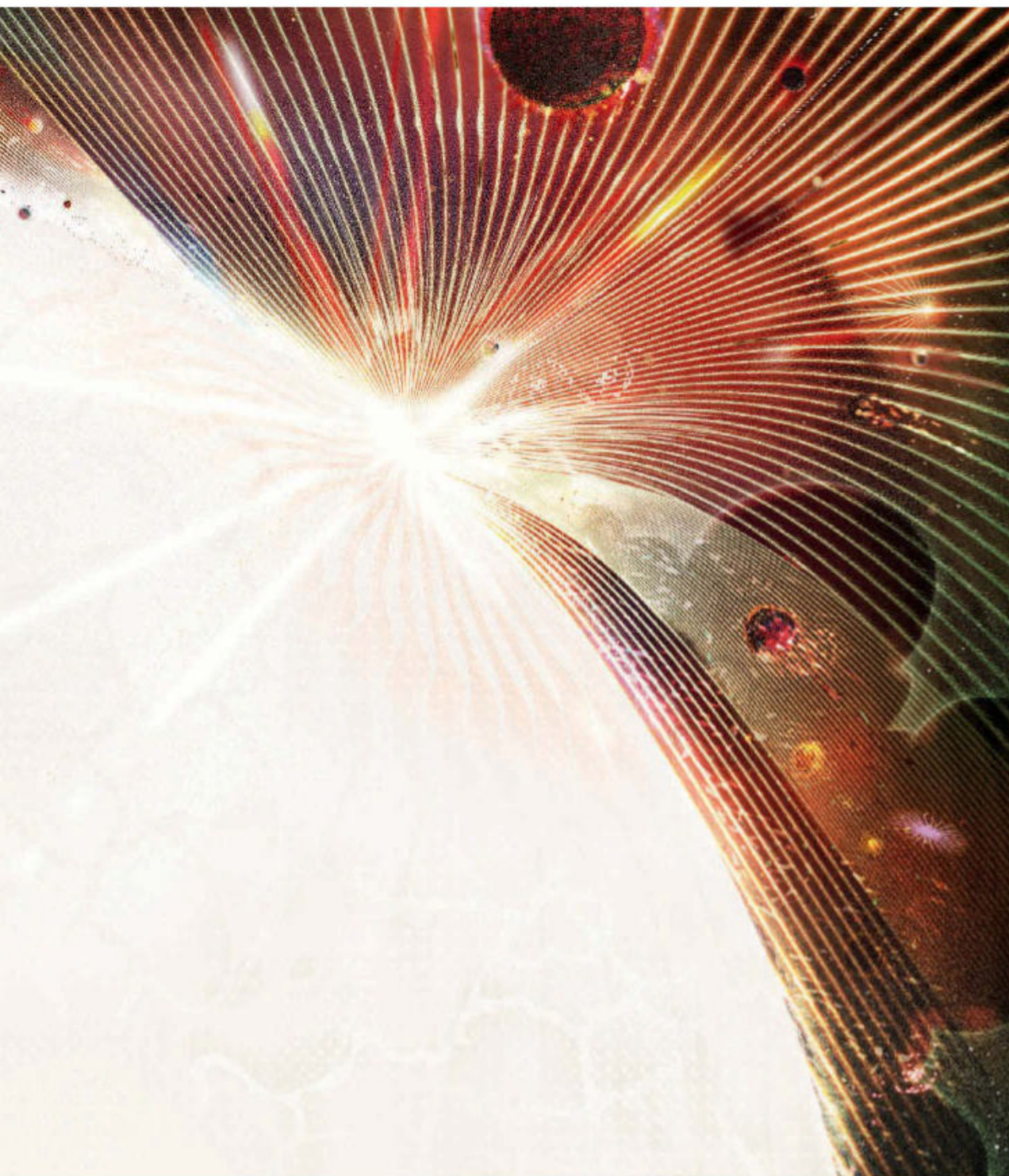


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not only the star's red giant phase, but also its dramatic death, when it completely shed the outer layers of its atmosphere and collapsed to become a white dwarf.

This survivor sits further from its star than Earth is from the sun, around 2.8 times the distance. Its existence suggests that we could indeed take refuge on the moons of a gas giant in our own cosmic backyard. Jupiter is 5.2 times Earth's distance from the sun. If that proves too hot, Saturn is nearly twice as far away.

However, there is a chance we won't need to take such drastic measures. Earth might just survive the sun becoming a red giant. Shreyas Vissapragada at the Harvard-Smithsonian Center for Astrophysics in Massachusetts suggests that it might be pushed outwards by the expanding sun's solar wind, which



would have been strengthened as it swelled into a red giant. Even if the solar wind doesn't come to our rescue, there is still hope – at least, that is what the discovery of a planet, known as 8 Ursae Minoris b, or Halla, suggests. This world was discovered in 2015. At first, it appeared to be a common-or-garden “hot Jupiter”, a gas giant orbiting close to its star, known as Baekdu. There was just one problem. “This planet should not exist today,” says Marc Hon at the University of Hawai'i at Mānoa.

Hon came to this remarkable conclusion in early 2023. By looking at the way the surface of Baekdu is oscillating, his team concluded that this star must be at an advanced stage of its evolution. Deep inside, it must be generating energy by fusing helium into carbon, instead of hydrogen into helium, as is happening

“If Earth isn't subsumed into the sun, it will still be fried beyond recognition”

inside our sun. This means that Baekdu has already gone through its red giant stage. By everything we thought we knew, Halla should have been engulfed long ago, burned to a crisp and otherwise evaporated away.

“This is the first system that we know of in which a planet survives so closely around a giant star that burns helium in its core,” says Hon. “From our understanding of how ordinary giant stars evolve, they begin burning helium only after they have swelled up to an immense size, and this swelling should have consumed this planet.” Exactly how Halla escaped destruction is unclear.

Even if Earth survives our sun's red giant phase and ends up orbiting a white dwarf, we may still not be safe. In November 2022, Abigail Elms at the University of Warwick, UK, and her colleagues discovered a white dwarf system 90 light years away littered with the remnants of dead planets. “By observing white dwarfs, we can conclude what the planet was made from,” says Elms. It looks like this graveyard is likely polluted by the debris of Earth-like planets, with traces of sodium, lithium, potassium and carbon.

If these planets survived the star's red giant phase, they may then have met a grisly fate. White dwarfs have roughly the mass of the sun packed into a volume smaller than that of Earth and this gives them extremely strong surface gravity. This creates such extreme tidal forces on any nearby surviving planets that they can be literally pulled apart. The orbiting material then spirals onto the white dwarf. If this fate befalls our home world, it would mean it has pluckily avoided death by fire, only to be pulled limb from limb.

However we look at it, if humankind sticks around for the next few billion years or so, it is highly likely that we will have to migrate from our planet. But the real kick in the teeth is that we probably won't be able to go directly to Jupiter's moons for refuge. They won't be warm enough until the sun is a complete red giant, but we will surely have to abandon spaceship Earth way before that.

So if we have to evacuate, and Jupiter isn't yet hot enough for its moons to become habitable, what do we do? At one and a half times further from the sun than the Earth, Mars could look very attractive indeed. It might buy us a few billion years or so, anyway. ■



Stuart Clark is making plans to escape to Mars