A white dwarf is surrounded by torn-up pieces of its inner planets and its Kuiper belt

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This illustration shows a white dwarf star siphoning off debris from shattered objects in a planetary system. Credit: NASA, ESA, Joseph Olmsted (STScI)

What will happen to our sun?

In several billion years, it'll cease fusion, shrivel into a white dwarf, and emanate only remnant heat. There it'll sit, dormant and comatose.

But the sun anchors the entire solar system. What will happen to Earth? To the rest of the planets? To the rest of the objects in the solar system?

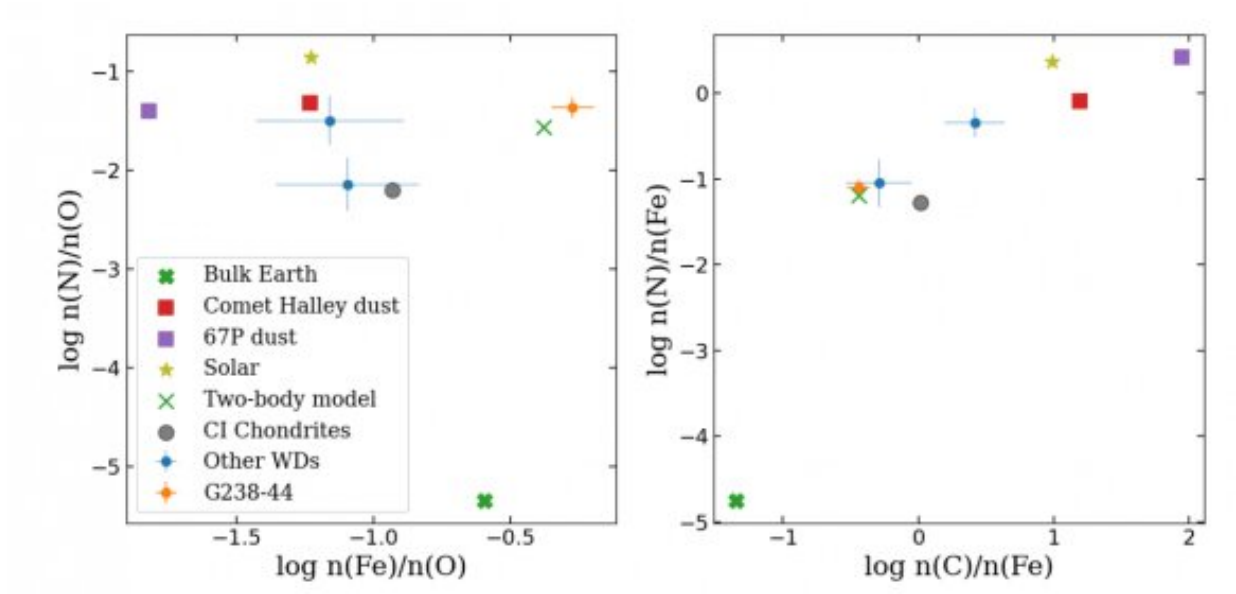
Our sun appears relatively placid during a human lifetime. It's solidly in the main sequence now and reliably goes about its business fusing hydrogen into helium. But this state won't last forever; stars do weird things as they age.

Eventually, the sun will age out of its life of fusion and become a red giant. Then it'll shed its outer layers into a beautiful nebula. The nebula will dissipate after 20,000 years or so, and only the dead core of our once glorious sun will remain. Without the outward pressure from fusion, gravity will take over and crush what's left of the star down to a ball of degenerate matter the size of Earth. It'll be a white dwarf, a simmering cinder of inert carbon and oxygen that radiates remnant heat for trillions of years—maybe longer.

White dwarfs are one of those weird end-states that some stars find themselves in after their life of fusion is over. But astronomers think that almost all stars host planets. What happens to the planets around a star as it transitions to a white dwarf?

Astronomers can't see the future, but they can observe existing white dwarfs and look for clues to the fate of their planets.

That's what a team of researchers in Germany and the U.S. did in their paper titled "Unusual Abundances from Planetary System Material Polluting the White Dwarf G238-44." They examined observational data on the white dwarf from the Hubble, the Keck Observatory, and FUSE, the Far Ultraviolet Spectroscopic Explorer. *The Astrophysical Journal* accepted their paper for publication, and it's available on the preprint site arXiv.org.



This figure from the paper shows the abundance of different element ratios for WD G238-44 and a variety of other objects, including other white dwarfs. The orange circle and the small green x represent the compositions of G238-44 and two parent bodies. They land nearly on top of one another in the chart, while no other single body comes close. Credit: Johnson et al. 2022

G238-44 is about 86 light-years away and has a hydrogen-dominated atmosphere polluted with other elements, including carbon, neon, oxygen, sulfur, and iron. Twenty-four years of data from Keck shows a stable and continuous accretion of these materials from a circumstellar reservoir onto the white dwarf. The researchers also say they discovered "an anomalous abundance pattern and evidence for the presence of metallic iron." Could the iron and the other elements come from a single parent body? Or are two bodies needed to explain the presence of all these materials?

The researchers say that if this metallic iron comes from a single parent

body, that parent body is unlike anything in our own solar system. "Within the uncertainties, we are able to determine that the parent material is rich in nitrogen and likely contains a significant amount of metallic iron," the authors write. "This mix is unlike any known solar system body."

If it came from two separate bodies, they write, then one is made of Mercury-like, iron-rich material, and the other could be an icy Kuiper Belt object. These objects have distinct compositions, and together they provide "chemical evidence for both rocky and icy bodies in an exoplanetary system," the paper states.

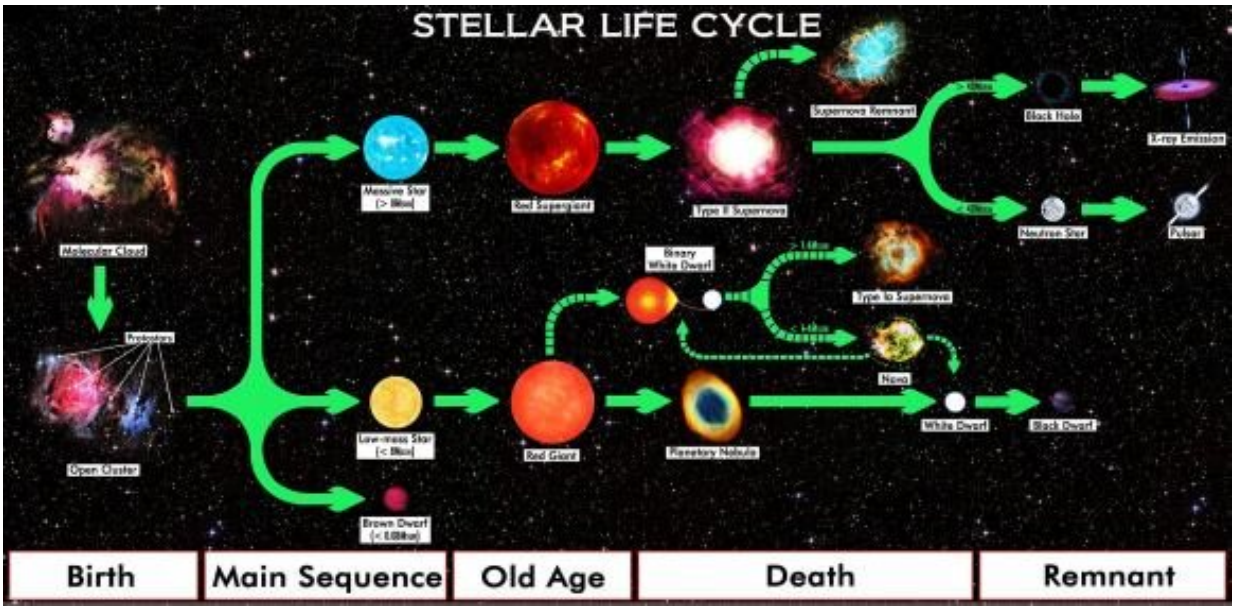
The mix of elements and how they appear in a solar system is key to this work. Oxygen is versatile and is found everywhere throughout a solar system, and is a component of all objects. But carbon, nitrogen, and iron are different. The authors describe them as "much more specialized." Objects that form close to the parent star have a greater abundance of Fe, while N only forms in significant amounts beyond the solar system's frost line. "We do not expect objects that are high in Fe to also be high in N. G238-44 breaks this trend and has both high Fe/O and N/O," the authors write. "The proposed two-body model is capable of reproducing this unusual characteristic."

"We suggest that G238-44 is simultaneously accreting a metal-rich exo-planetesimal and a volatile-rich exo-Kuiper Belt object. If our interpretation is correct, this would be the first evidence of the simultaneous accretion of two distinct parent bodies in a white dwarf," the authors write. They say the white dwarf is accreting material from a metal-rich body and a volatile-rich body in a ratio of 1.7:1.

The authors also say it's evidence for a planetary system that's so perturbed that it's capturing asteroid-like objects from the inner solar system and icy objects from the distant reaches of its system

simultaneously.

What does this mean for Earth and the rest of the solar system? It's difficult to think of Earth's distant future as the sun leaves the main sequence and eventually becomes a white dwarf. But as this study shows, it's unlikely that anything can survive the transition, especially something as close to the sun as Earth.



This diagram shows the life cycle of stars. Our Sun, as a solitary star, will follow the path on the bottom of the chart, from birth in a molecular cloud to a theoretical black dwarf. Credit: R.N. Bailey – Own work, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=59672008

Even in the most optimistic Muskian haze, it's impossible to imagine Earth and humanity surviving the catastrophic results of the sun leaving the main sequence. The sun will expand and destroy the inner planets, possibly engulfing Earth itself. This will all play out over billions of

years, and some thinkers suggest humanity will be able to "planet-hop" our way to the outer solar system, avoiding destruction and moving outward as the sun's habitable zone expands during the red giant phase.

But this study shows that even the distant Kuiper Belt might not escape the ravages of a dying sun. What does that mean for any impossibly distant human descendants?

Earth and humanity will be erased, and no other civilization will ever know about us and our crowning achievements—heavy metal, ice hockey, and the rest.

Instead, their astronomers will briefly notice an unremarkable white dwarf surrounded by heavier elements like iron, sulfur, and carbon. They'll conclude that rocky planets once surrounded the star and wonder how many. Maybe they'll write a paper about it.

Then they'll slew their telescope and move on.

But the sun won't be finished. It won't stay a white dwarf forever. In the most distant future anyone can possibly imagine, the sun will become a black dwarf, a theoretical object so ancient that none exists in our young universe yet.

But for now, the sun is reliable and calm, even if humanity isn't.

More information: Ted M Johnson et al, Unusual Abundances from Planetary System Material Polluting the White Dwarf G238-44, *arXiv* (2022). DOI: 10.48550/arxiv.2211.02673

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