Scientists reveal new clues into how Earth got its oxygen

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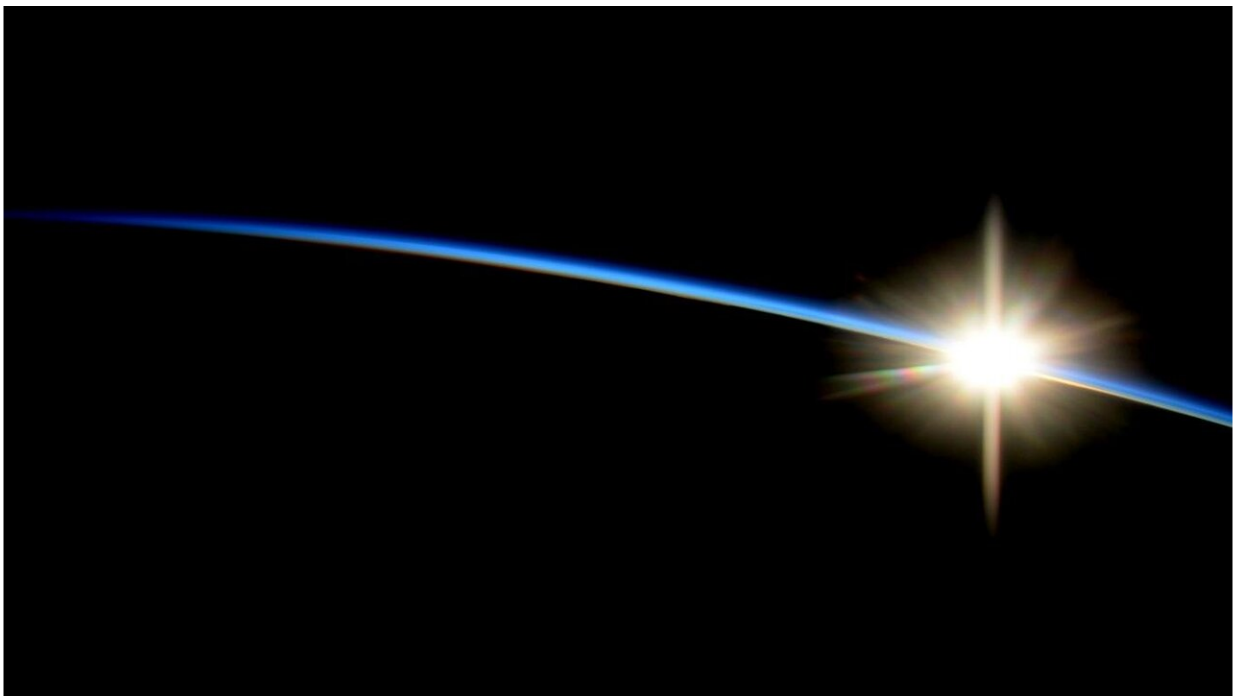

Earth's thin shell of oxygen atmosphere keeps us alive, though we still don't know exactly how it formed. A new study from the University of Chicago reveals clues in the role that iron had to play. Credit: NASA

For much of Earth's four and a half billion years, the planet was barren and inhospitable; it wasn't until the world acquired its blanket of oxygen that multicellular life could really get going. But scientists are still trying to understand exactly how—and why—our planet got this beautifully oxygenated atmosphere.

"If you think about it, this is the most important change that our planet experienced in its lifetime, and we are still not sure exactly how this happened," said Nicolas Dauphas, the Louis Block Professor of Geophysical Sciences at the University of Chicago. "Any progress you can make toward answering this question is really important."

In a new study published Oct. 23 in *Science*, UChicago graduate student Andy Heard, Dauphas and their colleagues used a pioneering technique to uncover new information about the role of oceanic iron in the rise of Earth's atmosphere. The findings reveal more about Earth's history, and can even shed light on the search for habitable planets in other star systems.

Scientists have painstakingly recreated a timeline of the ancient Earth by analyzing very ancient rocks; the chemical makeup of such rocks changes according to the conditions they formed under.

"The interesting thing about it is that prior to the permanent Great Oxygenation Event that happened 2.4 billion years ago, you see evidence in the timeline for these tantalizing little bursts of oxygen, where it looks like Earth was trying to set the stage for this atmosphere," said Heard, the first author on the paper. "But the existing methods weren't precise enough to tease out the information we needed."

It all comes down to a puzzle.

As bridge engineers and car owners know, if there's water around, oxygen and iron will form rust. "In the early days, the oceans were full of iron, which could have gobbled up any free oxygen that was hanging around," Heard said. Theoretically, the formation of rust should consume any excess oxygen, leaving none to form an atmosphere.

Heard and Dauphas wanted to test a way to explain how oxygen could have accumulated despite this apparent problem: they knew that some of the iron in the oceans was actually combining with sulfur coming out of volcanoes to form pyrite (better known as fool's gold). That process actually releases oxygen into the atmosphere. The question was which of these processes "wins."

To test this, Heard used state-of-the-art facilities in Dauphas' Origins Lab to develop a rigorous new technique to measure tiny variations in iron isotopes in order to find out which route the iron was taking. Collaborating with world experts at the University of Edinburgh, he also had to flesh out a fuller understanding of how the iron-to-pyrite pathway works. ("In order to make sulfide and run these experiments, you need understanding colleagues, because you make labs smell like rotten eggs," Heard said.) Then, the scientists used the technique to analyze 2.6 to 2.3 billion-year-old rocks from Australia and South Africa.

Their analysis showed that, even in oceans that should have tucked away a lot of oxygen into rust, certain conditions could have fostered the formation of enough pyrite to allow oxygen to escape the water and potentially form an atmosphere.

"It's a complicated problem with many moving parts, but we've been able to solve one part of it," said Dauphas.

"Progress on a problem this enormous is really valuable to the community," Heard said. "Especially as we're starting to look for exoplanets, we really need to understand every detail about how our own earth became habitable."

As telescopes scan the skies for other planets and find thousands, scientists will need to narrow down which to explore further for potential life. By learning more about the way that Earth became habitable, they can look for evidence of similar processes on other planets.

"The way I like to think about it is, Earth before the rise of oxygen is the best laboratory we have for understanding exoplanets," said Heard.

More information: Andy W. Heard et al. Triple iron isotope constraints on the role of ocean iron sinks in early atmospheric oxygenation, *Science* (2020). DOI: 10.1126/science.aaz8821

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