BBC

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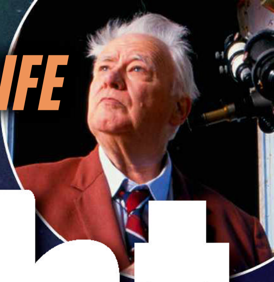

#214 MARCH 2023

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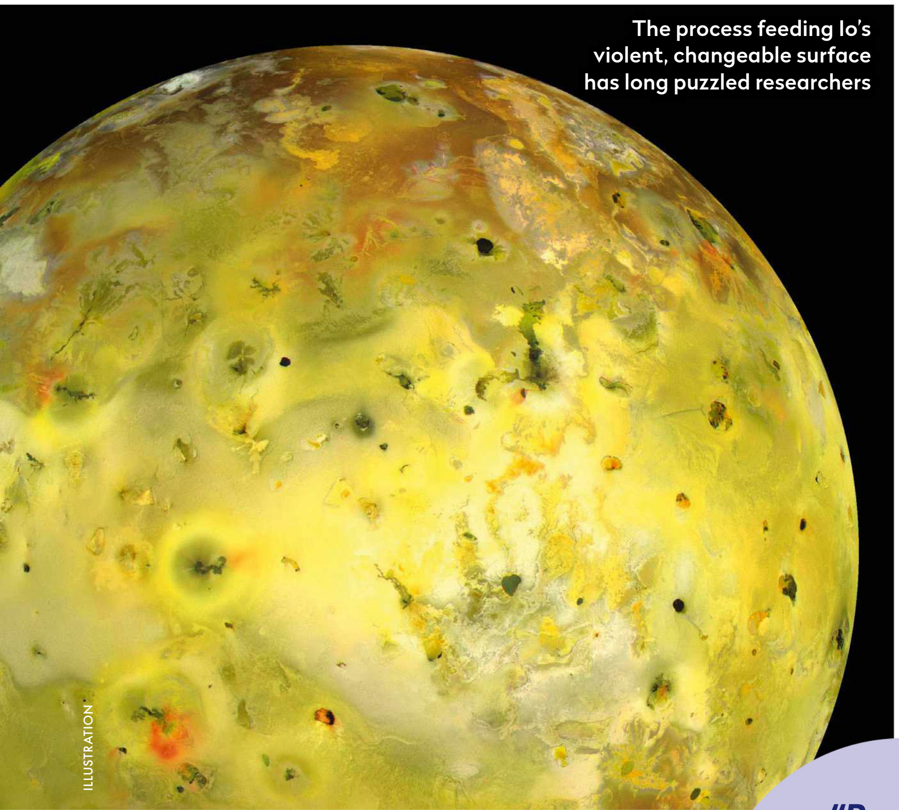


The process feeding Io's violent, changeable surface has long puzzled researchers

ILLUSTRATION

NASA/JPL/UNIVERSITY OF ARIZONA, ZWICKY TRANSIENT FACILITY

Io's molten heart

Jupiter's moon probably has a magma ocean, rather than a spongy centre

The moon Io, the innermost Galilean satellite of Jupiter, is a violent, tortured little world. Despite being almost the same size as our own Moon, the two couldn't be more different. Our Moon is a cold, dead world, while Io is the most volcanically active body in the Solar System – even more so than Earth – and is constantly spewing itself inside out with intense eruptions.

The driving force behind all this activity is tidal heating. The powerful gravitational pull of Jupiter tugging on Io constantly distorts its shape. This perpetual bending and flexing generates intense tidal heating in the interior of the moon, melting its silicate rock crust into hot magma. Normally, tidal effects would dissipate as the moon's orbit becomes more circular over time, and its rotation becomes locked to its orbital period. But in Io's case, the gravitational effects of the other Galilean moons keep nudging it into an elliptical orbit, maintaining this fierce tidal heating so that its volcanism has persisted for billions of years.

What's not well understood, however, is exactly how much magma melt there is below the surface, or what form it takes. This is important because it affects the dissipation of tidal heating, which is a key part in understanding Io's surface features. Recently, a reanalysis of 1990s data from the Galileo probe's magnetometer instrument has suggested that Io could have a global layer of largely molten rock at least 50km-thick underground. But does this exist as a complete magma ocean, or is it more like a 'magmatic sponge', with an interconnected network of solid rock soaked through with liquid magma?

Yoshinori Miyazaki and David Stevenson, both at Caltech in Pasadena, California, have built a computer model to study different possibilities for Io's subsurface magma, as well as different degrees of tidal heating. Their results indicate that the amount of tidal heating within Io is probably insufficient to maintain a spongey structure of interconnected solid rock bathed in molten magma. Such a composition would rapidly separate into two distinct layers: a magma ocean floating on top of a mostly solid shell. Since tidal dissipation acts much more effectively on the rigid characteristic of solids, this lower layer experiences most of the heating and keeps the ocean above it liquid (although Miyazaki and Stevenson note that the magma ocean need not be pure liquid – it's likely to contain some degree of solidified crystals). The magma ocean then transports that internal heat up to Io's surface, feeding its many volcanoes.

Miyazaki and Stevenson have shown that if the hypothesis of a melt-rich layer in Io's subsurface is correct, it should exist as a magma ocean rather than a magmatic sponge. And we may not have long to wait to find out for sure. The Juno mission is currently exploring the Jovian system, and through its fly-bys of Io will be able to measure the rigidity of the moon's crust. This will provide vital information on the details of a melt-rich layer in the subsurface.

"Does this 50km-thick molten rock layer exist as a complete magma ocean, or is it more like a magmatic sponge?"

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading… *A Subsurface Magma Ocean on Io: Exploring the Steady State of Partially Molten Planetary Bodies* by Yoshinori Miyazaki and David J Stevenson
Read it online at: arxiv.org/abs/2211.06945

Ancient explosion was a rare supernova

Astronomers have puzzled over the bright event for centuries

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Over 840 years ago, in August 1181, Chinese and Japanese astronomers saw a new star suddenly appear that remained visible for 180 days. We now know this was the violent death of a massive star, a supernova, and the 1181 event is one of only a handful to ever have been seen with the naked eye.

Now astronomers have started looking at the site of the supernova, in the modern constellation of Cassiopeia, in the hope of finding a remnant. Radio searches, which attempted to uncover a pulsar, failed to find anything suitable, but citizen scientist Dana Patchick, combing through data from numerous earthbound surveys, as well as the infrared WISE satellite, found an unusual circular nebula which surrounds a bright central star around 8,000 lightyears from Earth.

Studies of this new object have shown that the bright region is a shell of gas expanding at a rate of more than 1,000km per second. Projecting backwards, this gives an age for the object of nearly a thousand years, fitting perfectly with the recorded supernova. Another new paper, with deep images of the nebula, shows its structure, with filaments pointing away from the central star, which must therefore be the source of the gas.

But if this is a supernova remnant, then what is the central star? A supernova should produce a dense neutron star, or a black hole. But neither of those should shine brightly, whereas this observed star is more than four times as luminous as the Sun. It's detected not only in the infrared, but also in ultraviolet and in X-ray observations, which reveal a temperature of 200,000° Celsius. Spectra tell us that it is made of (mostly) carbon and oxygen, with none of the hydrogen and helium that accounts for most of the mass in the Sun and other main sequence stars.

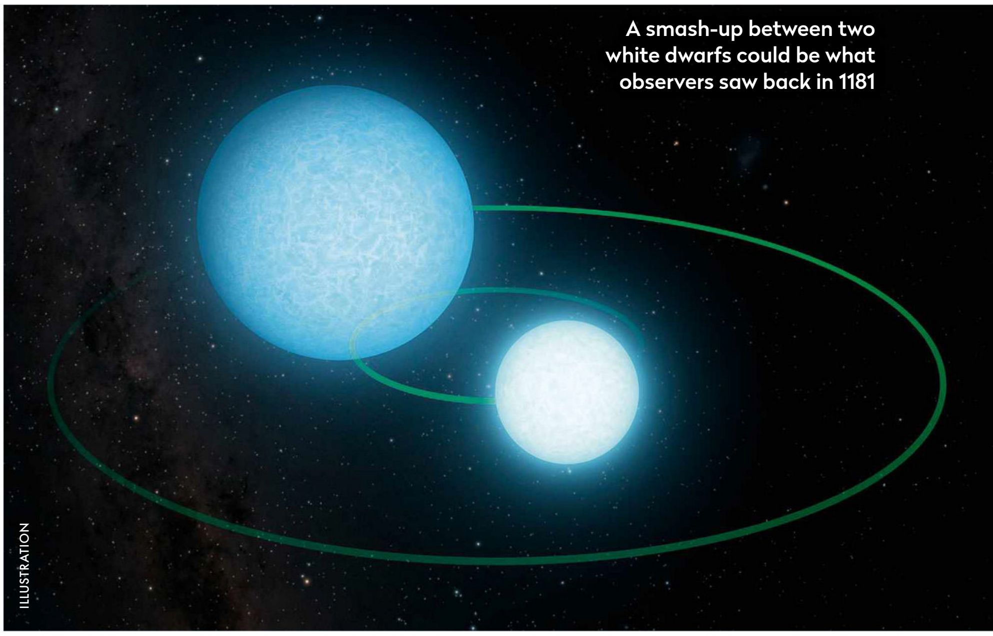
"In a Type Iax, both stars are white dwarfs, and the supernova is produced when the two collide and merge with each other"

It looks, in fact, like a hot white dwarf, but such objects are normally formed from the death of stars far less massive than those that go supernova. The paper by Bradley Schaefer resolves this conundrum by claiming the 1181 event was an example of a little-understood, rare class of supernova: a Type Iax.

Type Ia supernovae are typically caused by the interaction of a white dwarf with a binary companion. In a normal Type Ia, the white dwarf steals matter from an orbiting normal star until this piled-up material ignites, blowing the host dwarf apart. In a Type Iax, both stars involved are white dwarfs, and the supernova is produced when the two collide and merge with each other.

In this case, it seems we can explain everything that's been observed if we invoke a collision between two white dwarfs, one rich in carbon and oxygen, and the second in oxygen and neon. Crucially, such an event would have left only a single central star with no companion, exactly as observed.

If this is the end of the search for the ancient supernova's remnant, it will be the beginning of a new scientific quest. This is only the fifth time we have found the remnant of a supernova that was also seen in the sky, and it may help us understand these rare and spectacular events.



A smash-up between two white dwarfs could be what observers saw back in 1181

ILLUSTRATION

Chris Lintott was reading... *The Path from the Chinese and Japanese Observations of Supernova 1181 AD, to a Type Iax Supernova, to the Merger of CO and ONe White Dwarfs* by Bradley E Schaefer **Read it online at: arxiv.org/abs/2301.04807**