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Quantum Spacetime

New Hope for Pain Relief

Cleaning Up Greenhouse Gases

What Was It Like to Be a Dinosaur?

New insights into their senses, perceptions and behaviors

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Why do our findings differ from those of other studies? One important factor is what happens while people wait for more details. Watching events unfold over time, as in our animations, may be less uncomfortable than simply wanting a missing answer—imagine if Hsiung had just stared at the woodpecker while gaining no new information about it. Further, curiosity may feel different when people assume that answers are on the way. When opportunities to seek information abound, curiosity may favor its patient accumulation. But when it seems like waiting will yield limited information, people might prefer immediate resolution.

Our experiment also revealed that curiosity was highest at two key points: first, when uncertainty was the greatest, and second, when people were very close to identifying the drawings. To us, this signaled that curiosity seemed to evolve along with the question a person was asking, such as with a shift from an exploratory musing ("What could this drawing be?") to a more focused query ("Is this going to be an Easter egg?").

The desire for information also seemed to feel different across the journey to resolution. When uncertainty was greatest, curiosity was experienced with joy. But during the second peak, as people got closer to the big reveal, curiosity coincided with frustration, perhaps like the sensation when a word is right on the tip of your tongue. As curiosity evolves over different lines of questioning, the emotional tone may shift from playful happiness to urgent discomfort.

So as people watched the video, curiosity would grow, change in emotional timbre and then decline with resolution. Yet regardless of how curiosity changed, we found that greater curiosity encouraged engagement in the process and led to a greater desire to let a video play out rather than skipping to the answer.

Our work underlines the complexity of curiosity, opening new avenues for research to explore its varieties. Thinking about curiosity as going beyond the need for quick answers also highlights the power of what happens when we engage with uncertainty: having to ponder and anticipate answers can improve learning and memory, and curiosity can facilitate brain states that help us encode new information. Learning new things can be tough, but harnessing curiosity can help us savor the process of learning and delight in overcoming challenges as much as we like working out a whodunit—all in due time. ●

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Supernova Scars

Stellar explosions regularly shower Earth with radioactive debris

BY PHIL PLAIT

A SUPERNOVA would have to be fairly close to Earth to pose any real threat to our planet. For astronomers, though, "close" means something different than it does for other people. In this case, a supernova within about 160 light-years, or 1.5 quadrillion kilometers, would qualify.

On a human scale, that's a nearly unfathomable distance. On a galactic scale, it's in our immediate neighborhood. Still, it's a long walk, and supernovae are relatively rare, occurring roughly once a century in a large galaxy like the Milky Way. So the odds are good that any given exploding star will be far from Earth and will do nothing more for us than put on a pretty light show (if we can see it at all through the thick dust that shrouds parts of our galaxy).

But note my weasel words "any given exploding star." The thing about rare events is that, with enough time, they will happen. We again must think on cosmic scales: Generously speaking, one supernova per century is maybe once per human lifetime. But galaxies (and Earth) have been around for billions of years. That's more than long enough for the probability of a too-close-for-comfort supernova to become a certainty. I personally wouldn't bet against it. After all, we have convincing physical proof that it has happened in our planet's past.

In 2016 two teams of astronomers published a pair of papers with startling results in the journal *Nature:* they found elevated amounts of iron-60 in two different layers of ancient sediment from the deep seafloor. Each of those iron-60-enriched layers marks a time during the past nine million years when Earth was bombarded by a nearby supernova.

Iron-60 is a radioactive isotope of iron that decays into cobalt-60 with a half-life of 2.6 million years. This half-life means that if you start with a pure sample of iron-60, in 2.6 million years half of it will have decayed to cobalt-60. In another 2.6 million years, the remaining iron-60 in the original sample will have again decayed by half, leaving only one quarter of the starting amount of iron-60 and so on. Scientists can use this decay rate to get relatively accurate measurements of when the iron-60 formed. That is important because we know of only one natural place where this isotope can be forged: in the nuclear fires of a supernova.

In the first *Nature* paper, scientists examined interstellar dust on the ocean floor and found two peaks in the amount of iron-60 in sediments that were deposited around 7.5 million and 2.5 million years ago. (In a separate study, from 2016, another team of scientists found iron-60 in fossil bacteria on the ocean floor. That isotope was also consistent with a peak dating to circa 2.5 million years ago.) Curiously, the increases in iron-60 weren't the sharp spikes expected from a single supernova. Instead, in each case, the increases were spread out over more than a million years, implying that multiple supernovae contributed to each episode. The researchers' models indicated the material spent about 200,000 years coasting through interstellar space before it fell to Earth.

In the second *Nature* paper, scientists who were affiliated with the first team used these data to estimate where in space the supernovae were located. Iron-60 is created when massive stars explode. Such stars give new meaning to "cradle to grave," cosmically speaking, because they are born in giant gas clouds and die just a few million years later, still cocooned inside them.

This second *Nature* study flagged the most likely culprit for both supernovae as the Scorpius-Centaurus association, a loosely bound clump of young stars that are currently located about 390 to 470 light-years from Earth. Many of these stars are quite massive and exactly the kind that explode at the end of their life. Moreover, our sun sits near the middle of what's called the Local Bubble, a huge cavity carved out of the interstellar material that floats between stars in the galaxy. The bubble was inflated by supernovae in the Scorpius-Centaurus association some 14 million years ago and probably required the work of 14 to 20 such exploding stars. This timeline fits well with the iron-60 peaks observed in ocean sediments.

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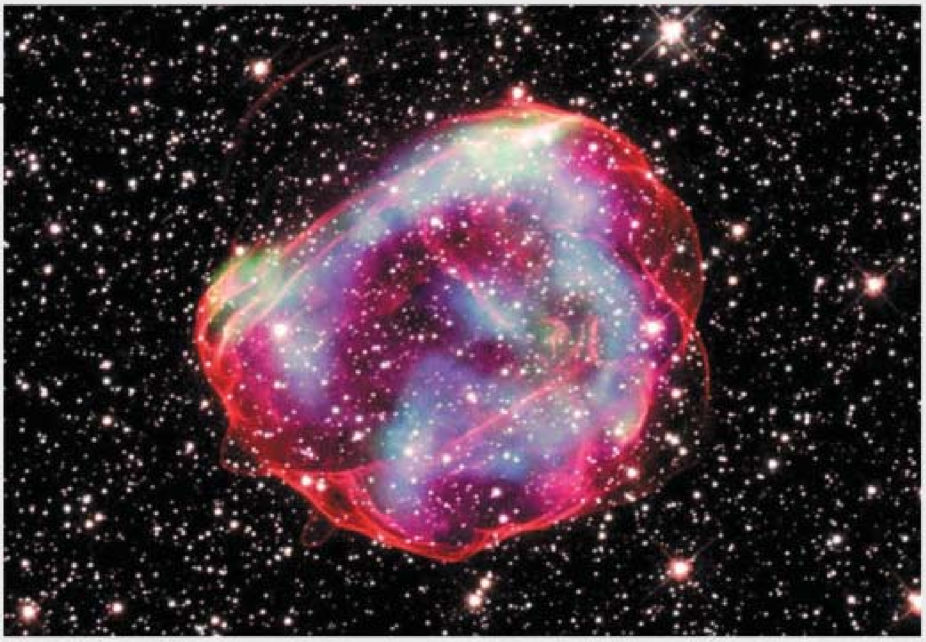
The scientists found that two supernovae might have contributed to the most recent peak, with one exploding 2.3 million years ago and the other doing so 1.5 million years ago. Both stars would have been about 300 light-years from Earth when they exploded. The amount of iron-60 in the sediments is actually quite small—very roughly 100,000 atoms per gram of material. (A gram of sediment has something like 10^{22} atoms in it, so the iron-60 makes up only an extremely tiny portion.) But the astonishing thing is that debris from exploding stars quadrillions of kilometers from us is here at all.

Bear in mind that iron-60 also makes up a small fraction of the material ejected during a supernova. The rest of the ejected matter—more than 10 octillion metric tons of it—is also accelerated outward at speeds of tens of millions of kilometers per hour. As matter expands away from the blast site, it thins out, so by the time the ejecta from a nearby supernova reaches Earth, perhaps a few hundred metric tons might rain on our planet over a length of time. That might sound like a lot, but about the same amount of meteoric material slams into our atmosphere every day. So supernovae aren't appreciably adding to Earth's weight, nor are they a big danger to us in this way.



A vast, expanding cloud of debris from a supernova is seen in x-ray and optical light by the Chandra X-ray Observatory and the Hubble Space Telescope, respectively.

NASA/CXC/GSFC/B. J. Williams et al. (x-ray); NASA/ESA/STScI (optical)

Still, the takeaway is stunning: Every few million years a supernova happens close enough to Earth to shower us with radioactive debris. That means that over the lifetime of our planet, we've been hit thousands of times with ashes from exploding stars, and some of that material has probably been close enough to cause some global damage.

In the specific case of the most recent nearby supernova, although humans weren't around back then, several of our near ancestors, such as *Australopithecus afarensis,* were. One particular member of that species, nicknamed Lucy, walked on Earth about three million years ago. She might have missed that particular event, but her descendants may have gazed up into the sky and wondered about the astonishingly bright light that appeared there, brighter by far than any other star, as bright as the full moon. It would've been luminous enough to be seen by day and cast shadows at night.

And here we are, millions of years later, still wondering about the same thing. The difference is that now we have the tools to both examine and understand the profound impact these cosmic explosions have on our planet. ●