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SCIENCE NEWS BY AGU

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How Stone Age Humans Chose Their Stones

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Perceiving Risk

How scientists and stakeholders separate hazards from hassles, and figure out how to plan accordingly.

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about the location and context of the red beds."

Armed with a sample of the red clay, the researchers measured its mineral composition back in the lab. They found that it mostly contained a type of clay mineral called kaolinite, which dominates tropical soils because it is resistant to extreme chemical weathering.

"These red clays are exactly the same, chemically and mineralogically, as the red earth, or *terra roxa,* we find all over Brazil," Jovane said. "We are confident that they represent the in situ, weathered upper surfaces of the lavas."

"This is a robust dataset," said Watts, who agreed with the team's interpretation that this area was once above sea level. He added that the research has important implications for understanding the magmatic and subsidence history of the rise.

Evidence collected in the 1980s, including drill cores containing shallow-water microfossils, had indicated that the western part of the rise was uplifted during the Eocene, Murton said. But "no one has found convincing evidence for subaerial volcanism and exposure of the western rise until now."

Coveted Minerals

The Rio Grande Rise is more than just scientifically fascinating. It also has potential economic value owing to its ferromanganese crusts. In December 2018, the Brazilian government applied to the United Nations to extend its maritime borders to include the Rio Grande Rise.

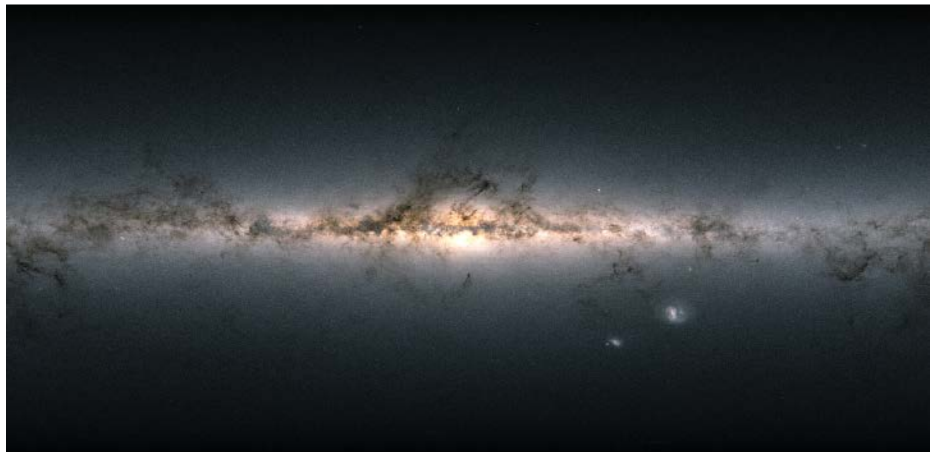
The rise is located in international waters and is well beyond Brazil's 370-kilometer-wide (200-nautical-mile wide) exclusive economic zone—the area over which coastal nations have sovereignty. To qualify for an extension, Brazil needs to prove that the rise has the same geological characteristics as the nation.

The rise's newfound status might help bolster that ongoing claim. "The Rio Grande Rise and the continent have the same soil and climate," explained Jovane. "In that sense, there is a direct relationship between the two."

Jovane said Brazil needs to prove not only that it has a correct claim to the Rio Grande Rise but also that it can mine the area sustainably. Currently, Brazil has regulations for mining only on land, and there is still no legislation for seabed mining in international waters.

By **Erin Martin-Jones,** Science Writer

Passing Stars Shorten Earth's Time Horizon



Year after year, the solar system's planets move around the Sun in a seemingly steady and unchanging orbital dance. But the Sun, planets, major moons, and dwarf planets constantly exchange gravitational energy and can subtly shift each other's orbits on thousand- or million-year timescales.

How well scientists understand these shifts determines how far back, or forward, in time they can reliably trace planetary orbits—a point known as the time horizon.

"There's a certain time frame beyond which you can't rewind the clock anymore," explained Sean Raymond, an astronomer at the Laboratoire d'Astrophysique de Bordeaux and Université de Bordeaux in France.

The most precise calculations of Earth's time horizon require the most precise measurements of solar system bodies. This includes everything from the Sun's slightly nonspherical shape to the sizes and positions of planets, moons, dwarf planets, and major asteroids.

Recently, astronomers demonstrated that a new factor should be considered when calculating Earth's time horizon: other stars whizzing past the solar system. Gravitational wakes induced by these stellar close encounters could shorten Earth's time horizon by up to 10%, or 7 million years, according to a study published in *Astrophysical Journal Letters* (bit.ly/passing-stars).

Precise knowledge of Earth's orbital past is key for understanding the solar system's history and the planet's paleoclimate, which was affected by subtle changes in its orbit.

From Order, Chaos

When trying to peer back in time, precision matters. Even the tiniest uncertainty in an object's mass or position today will grow exponentially as an orbit is traced back millions of years until, eventually, past orbits become too chaotic to track, explained the study's lead author, Nathan Kaib, a planetary scientist at the Planetary Science Institute in Tucson, Ariz., and the University of Oklahoma in Norman.

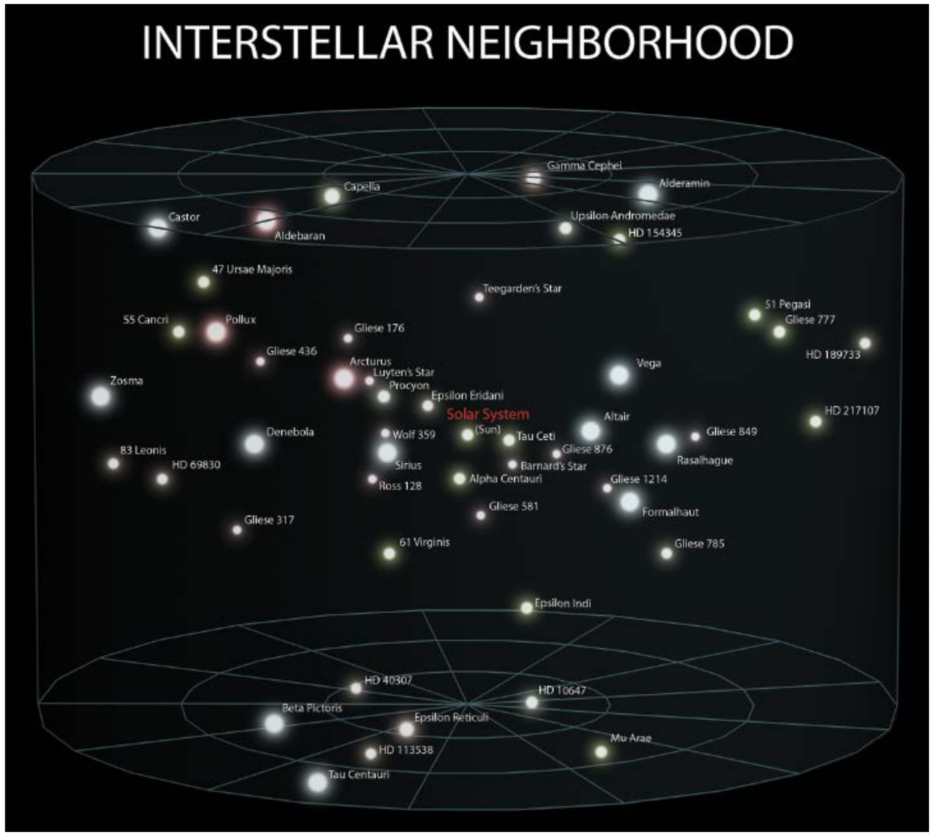
"There's a certain time frame beyond which you can't rewind the clock anymore."

The same principle applies to weather forecasts: Small uncertainties in weather prediction models mean that a forecast probably isn't reliable beyond more than a few days out. That's its time horizon.

Astronomers know the positions of solar system objects sometimes to within a meter, but "an error of a meter in Jupiter's position propagates, and so we can't rewind the clock as far back as we want," said Raymond, coauthor on the recent study.

Astronomers widely view Earth's time horizon as 60–70 million years (bit.ly/Earth-time-horizon). Beyond that, Earth's orbit is too uncertain for astronomers to trace or for paleoclimatologists to ascribe as the cause of major climate shifts. (This is not linked to the current rapid climate change caused by human-emitted greenhouse gases.)

However, the most precise time horizon calculations assume that the solar system exists in isolation, unaffected by the goings-on of the Milky Way, Kaib said. But astronomers know that the Sun has been visited by other stars in the past and estimate that an average of 20 stars come within about 3 light-years of the Sun every million years (bit.ly/stellar-encounters). How much gravitational influence they may have on the solar system and thus how they affect Earth's time horizon have been unclear.



Shown here are prominent bright stars within about 50 light-years of the Sun. This map does not include small red and brown dwarf stars, which are far more numerous. Credit: Andrew Z. Colvin, CC BY-SA 3.0 (bit.ly/ccbysa3-0)

Winding Back the Clock

Using computer simulations, the team traced Earth's orbit back 150 million years, accounting for gravitational influences of the planets, Pluto, and several major asteroids. They found that Earth's orbit became too uncertain to track after about 67 million years—in line with past time horizon calculations.

Then they placed their simulated solar system in the solar neighborhood and let stars travel past as they do in reality. The team found that if a passing star was large enough, moved slowly enough, or came within several light-years of the Sun, its gravity would jostle the orbits of the outer planets. Those orbital jitters affected Earth's orbit in turn and shortened its time horizon by 5–7 million years, or 7%–10%.

"The study is interesting and suggests that passing stars may need to be added to the list of small effects on the solar system's orbital evolution," said Richard Zeebe, a physicist at the University of Hawaiʻi at Mānoa in Honolulu. Orbital evolution models already include minor influences from asteroids, solar quadrupole moment, tidal dissipation, and solar mass loss, added Zeebe, who was not involved with this study.

Time to Adjust the Horizon? Not Yet

The authors demonstrated that a chance encounter between the Sun and another star can, theoretically, alter Earth's orbit. But has it actually happened?

The most recent data from the European Space Agency's Gaia mission, which is mapping the positions and motions of millions of stars in the galaxy, showed that the Sun-like star HD 7977 passed by the solar system around 2.8 million years ago.

It's uncertain just how close it came, but there is a small (5%) chance that it passed within 3,900 astronomical units (a distance less than one light year), or about 100 times the distance between the Sun and Pluto. The team's simulations showed that if HD 7977 passed that close, the star's gravity would have rippled through the solar system, stretching Earth's orbital eccentricity a bit and shortening its time horizon to only 50 million years.

That adjusted time horizon, broadly a limit on how far back scientists can estimate the influence of Earth's orbit on its climate, put it within range of a paleoclimate shift called the Paleocene-Eocene Thermal Maximum (PETM) (bit.ly/paleoclimate-shift). Geologic records from about 55 million years ago show an increase of more than 5°C in global average temperature that might have been caused by a change in Earth's orbital eccentricity (bit.ly/orbital-eccentricity).

Zeebe warned that the effects of a passing star on Earth's orbit would be subtle. "The notion that passing stars are an important driver of paleoclimate should be taken with caution." He added that "the chances that stellar encounters [like] HD 7977 are relevant to our computations or understanding of the PETM are very slim," agreeing with the study's conclusions.

The geologic data on the event describe what happened very clearly, Zeebe said. "Including stellar encounters in astronomical models could perhaps make a small difference in the computations…but not in the data," he said.

Though their simulations of Earth's orbit after an encounter with HD 7977 are consistent with the geologic record for the PETM, Kaib and Raymond said that HD 7977 did not trigger the warm period, nor do they claim that their calculated time horizon should be adopted as is. They emphasized that their model lacks many of the subtle, but important, details, such as tides and a nonspherical Sun or Moon, that go into the most sophisticated time horizon calculations.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer