Earth's moon may not be critical to life

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Could Earth have become habitable without the Moon to watch over it? Credit: NASA/JPL/USGS.

The Moon has long been viewed as a crucial component in creating an environment suitable for the evolution of complex life on Earth, but a number of scientific results in recent years have shown that perhaps our planet doesn't need the Moon as much as we have thought.

In 1993, French astronomer Jacques Laskar ran a series of calculations indicating that the gravity of the Moon is vital to stabilizing the tilt of our planet. Earth's obliquity, as this tilt is technically known as, has huge repercussions for climate. Laskar argued that should Earth's obliquity wander over hundreds of thousands of years, it would cause environmental chaos by creating a climate too variable for complex life to develop in relative peace.

So his argument goes, we should feel remarkably lucky to have such a large moon on our doorstep, as no other terrestrial planet in our solar system has such a moon. Mars' two satellites, Phobos and Deimos, are tiny, captured asteroids that have little known effect on the Red Planet. Consequently, Mars' tilt wobbles chaotically over timescales of millions of years, with evidence for swings in its rotational axis at least as large as 45 degrees.

The stroke of good fortune that led to Earth possessing an unlikely Moon, specifically the collision 4.5 billion years ago between Earth and a Mars-sized proto-planet that produced the debris from which our Moon formed, has become one of the central tenets of the 'Rare Earth' hypothesis. Famously promoted by Peter Ward and Don Brownlee, it argues that planets where everything is just right for complex life are exceedingly rare.

New findings, however, are tearing up the old rule book. In 2011, a trio of scientists—Jack Lissauer of NASA Ames Research Center, Jason Barnes of the University of Idaho and John Chambers of the Carnegie Institution for Science—published results from new simulations describing what Earth's obliquity would be like without the Moon. What they found was surprising.

"We were looking into how obliquity might vary for all sorts of planetary systems," says Lissauer. "To test our code we began with integrations following the obliquity of Mars and found similar results to other people. But when we did the obliquity of Earth we found the variations were much smaller than expected—nowhere near as extreme as previous calculations suggested they would be."

Lissauer's team found that without the Moon, Earth's rotational axis would only wobble by 10 degrees more than its present day angle of 23.5 degrees. The reason for such vastly different results to those attained by Jacques Laskar is pure computing power. Today's computers are much faster and capable of more accurate modeling with far more data than computers of the 1990s.

Lissauer and his colleagues also found that if Earth were spinning fast, with one day lasting less than 10 hours, or rotating retrograde (i.e. backwards so that the Sun rose in the West and set in the East), then Earth stabilized itself thanks to the gravitational resonances with other planets, most notably giant Jupiter. There would be no need for a large moon.

An artist’s impression of the collision that formed the Moon. How was Earth spinning prior to the impact? Credit: NASA/JPL–Caltech.

Earth's rotation has not always been as leisurely as the current 24 hour spin-rate. Following the impact that formed the Moon, Earth was spinning once every four or five hours, but it has since gradually slowed by the Moon's presence. As for the length of Earth's day prior to the Moon-forming impact, nobody really knows, but some models of the impact developed by Robin Canup of the Southwest Research Institute, in Boulder, Colorado, suggest that Earth could have been rotating fast, or even retrograde, prior to the collision.

"Collisions in the epoch during which Earth was formed determined its initial rotation," says Lissauer. "For rocky planets, some of the models say most of them will be prograde, but others say comparable numbers of planets will be prograde and retrograde. Certainly, retrograde worlds are not expected to be rare."

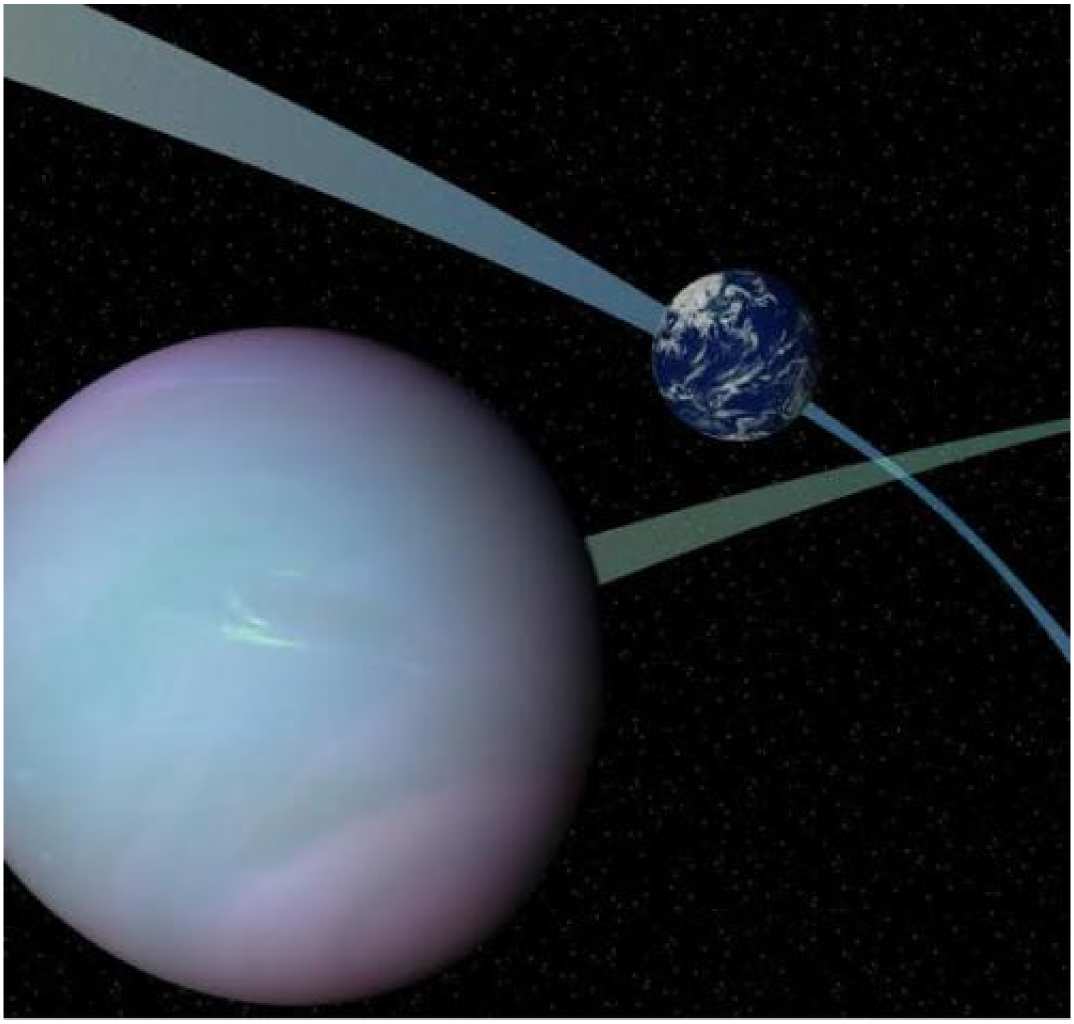
The upshot of Lissauer's findings is that the presence of a moon is not the be all and end all as once thought, and a terrestrial planet can exist without a large moon and still retain its habitability. Indeed, it is possible to imagine some circumstances where having a large moon would actually be pretty bad for life.

Rory Barnes, of the University of Washington, has also tackled the problem of obliquity, but from a different perspective. Planets on the edge of habitable zones exist in a precarious position, far enough away from their star that, without a thick, insulating atmosphere, they freeze over, just like Mars.

Barnes and his colleagues including John Armstrong of Weber State University, realized that torques from other nearby worlds could cause a planet's inclination to the ecliptic plane to vary. This in turn would result in a change of obliquity; the greater the inclination, the greater the obliquity to the Sun. Barnes and Armstrong saw that this could be a good thing for planets on the edges of habitable zones, allowing heat to be distributed evenly over geological timescales and preventing "Snowball Earth" scenarios. They called these worlds "tilt-a-worlds," but the presence of a large moon would counteract this beneficial obliquity change.

"I think one of the most important points from our tilt-a-world paper is that at the outer edge of the habitable zone, having a large moon is bad, there's no other way to look at it," says Barnes. "If you have a large moon that stabilizes the obliquity then you have a tendency to completely freeze over."

Barnes is impressed with the work of Lissauer's team.

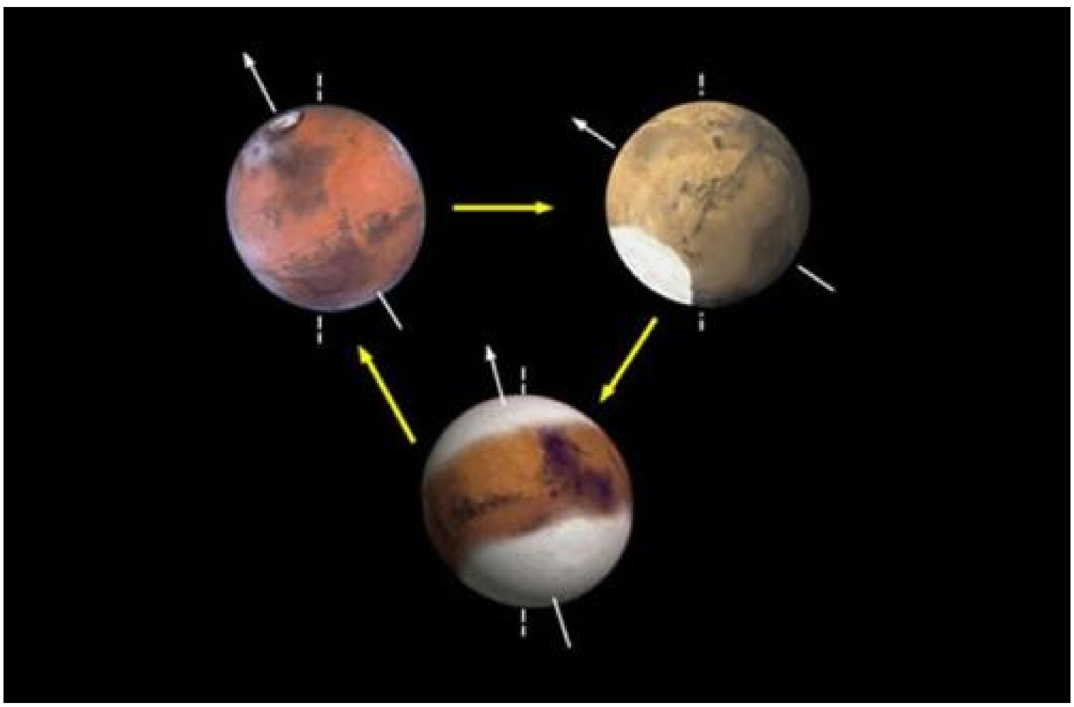


Planets with inclined orbits could find that their increased obliquity is beneficial to their long-term climate – as long as they do not have a large Moon. Credit: NASA/GSFC.

"I think it is a well done study," he says. "It suggests that Earth does not need the Moon to have a relatively stable climate. I don't think there would be any dire consequences to not having a Moon."

Of course, the Moon does have a hand in other factors important to life besides planetary obliquity. Tidal pools may have been the point of origin of life on Earth. Although the Moon produces the largest tides, the Sun also influences tides, so the lack of a large moon is not necessarily a stumbling block. Some animals have also evolved a life cycle based on the cycle of the Moon, but that's more happenstance than an essential component for life.

"Those are just minor things," says Lissauer.



The effects of changing obliquity on Mars' climate. Mars' current 25-degree tilt is seen at top left. At top right is a Mars that has a high obliquity, leading to ice gather at its equator while the poles point sunwards. At bottom is Mars with low obliquity, which sees its polar caps grow in size. Credit: NASA/JPL–Caltech.

Without the absolute need for a moon, astrobiologists seeking life and habitable worlds elsewhere face new opportunities. Maybe Earth, with its giant moon, is actually the oddball amongst habitable planets. Rory Barnes certainly doesn't think we need it.

"It will be a step forward to see the myth that a habitable planet needs a large moon dispelled," he says, to which Lissauer agrees.

Earth without its Moon might therefore remain habitable, but we should still cherish its friendly presence. After all, would Beethoven have written the Moonlight Sonata without it?

More information: J Lissauer, J Barnes, J Chambers; 'Obliquity Variations of a Moonless Earth', *Icarus*, 217 (2011) 77–87.

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