

Giant impacts, planet formation and the search for life elsewhere

December 9 2014, by Jonti Horner; Belinda Nicholson And Brad Carter



In the coming years, many planets that could host life will be discovered. But which will we target in the search for life elsewhere? Credit: IAU/L Calçada, CC BY

In the search for life beyond our solar system, we need to consider the system in which a planet moves, including the other planets and assorted debris that accompany it on its journey through the cosmos.

Over the past few decades our understanding of the formation of our planetary system has undergone a dramatic shift. From early theories that considered planet formation a gentle and relatively smooth process, a new theory has emerged.

Our current best model for our solar system's formation, and for planet formation in general, is that the latter stages are violent and dominated by catastrophic giant collisions.

Smashing planets – stability and life

In our solar system, evidence abounds for this violent planet formation. Mercury, closest to our sun, is a tiny, barren world – thought to be the shattered core of a planet that was once twice as large.

Towards the end of planet formation, that planet was the victim of a [hit-and-run collision](#) that stripped away its crust and mantle, leaving the shattered husk we see today.

The Earth-[moon](#) system is another example of a relic of a giant collision, thought to have involved the proto-Earth and a Mars-sized planet.

That collision was somewhat gentler than the one involving Mercury, but still stripped Earth's mantle and crust, leaving a cloud of debris that accreted to form the moon.

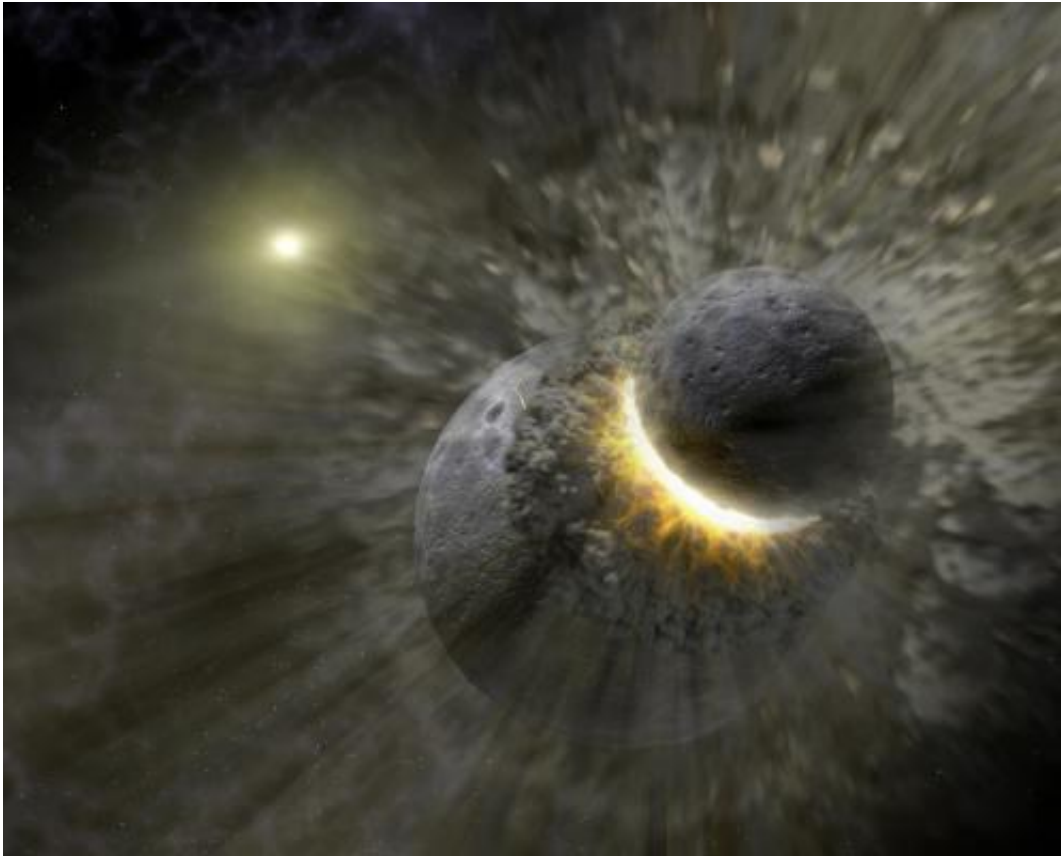
Recent studies of Mars suggest that its "hemispheric dichotomy" – one hemisphere of highlands and the other of lowlands – may be the result of an impact that [almost shattered the planet](#), leaving a crater spanning an entire hemisphere.

Uranus's peculiar spin, tipped by 90 degrees to the rest of the solar system, [may be another example](#) – as might the [slow spin of Venus](#).

Giant collisions are clearly an integral part of the planet formation process, but those in our solar system came to a halt in the very early days of the system. Other [planetary systems might not be so fortunate](#).

But there may be unexpected benefits to giant collisions involving Earth-like planets.

Giant collisions and giant satellites



The final stages of planet formation were a violent and chaotic time, leaving scars that are seen throughout the solar system. Credit: NASA/JPL-Caltech/T. Pyle (SSC)

Our moon is an oddity within the solar system – far larger, with respect to its host, than any of the satellites of the other planets – all as a result of its formation in a giant collision.

The only other satellites that we see rivalling the moon's scale, as a fraction of their host, orbit smaller bodies, out in the trans-Neptunian region.

The most famous example of such a system is around the [dwarf planet Pluto](#). Pluto's largest satellite, Charon, is about a sixth the size of its host. Just as is the case with the Earth-moon system, it is thought that the Pluto system, and others in the depths of our [solar system](#), are the result of [giant impacts](#).

The fact that a giant impact will sometimes birth a monster satellite around an otherwise normal object is of interest to our story, since the presence of our moon has been invoked as a factor that contributed to Earth's habitability.

From a claimed role stabilising the Earth's spin axis against chaotic excursions, to the potential origin of life in the vast inter-tidal zones driven on Earth by our youthful satellite, the moon regularly enters into discussions of Earth's habitability.

But recent research seems to suggest that the presence of our moon might not be as critical for life as we once thought. In fact, were our moon just slightly larger, it might actually render the Earth [far less habitable](#).

Taken together, this suggests that the existence of a large satellite might, at best, be considered a small plus for a given planet. Given the uncertainty about the moon's true influence, the absence of such a satellite around an exo-Earth would not be sufficient grounds for that target to be overlooked.

Impacts and the origin of water

It should be noted that not all impacts are bad. Our best models of [planet formation](#) suggest that the Earth should have formed [dry and arid](#) – we lie too close to the sun for water in the protoplanetary nebula to have frozen out and form ice.

Aside from a small amount of water acquired by the youthful Earth in the form of hydrated silicate rocks, the great bulk of Earth's water must have been delivered from beyond. The pummeling Earth received in its youth from asteroids and comets will have [delivered the water](#) that is so vital to life as we know it.



The moon may have played a key role in the development of life on Earth, but how important are such giant satellites in determining a planet's habitability?
Credit: NASA Earth Observatory

The problem is actually exacerbated by the collision that formed the

moon. That giant impact occurred after the proto-Earth had differentiated – with the heaviest elements (such as iron and nickel) settling to our planet's core. This means that the mantle and crust of the Earth, stripped off by the collision, would also have contained most of Earth's water at the time.

Without the asteroid and comet collisions that have occurred since the moon's formation, the Earth would most likely be dry and lifeless. But impacts are a stochastic, chance thing – some planetary systems will have architectures that are poorly set up from the point of view of the delivery of volatiles to any terrestrial worlds therein.

On the other hand, studies of the formation and evolution of the "hot Jupiters" – planets like Jupiter orbiting far closer to their hosts than Mercury orbits the sun – suggest that the inward migration of such planets could drag with them vast amounts of volatiles.

In those models, so much water is delivered to the inner reaches of those systems that any Earth-like planets that form are water worlds – drenched in oceans hundreds of kilometres deep.

While such worlds might well be teeming with life, it is unlikely that it would be easy to detect. Indeed, without continents, the oceans could be almost completely lifeless, with the only source of nutrients being volcanoes on the ocean floor.

If life on such water worlds did exist, it might be so deeply buried in the ocean that any sign of it would be extremely challenging to detect, particularly from a distance measured in tens or hundreds of light-years. As such, ocean worlds would most likely be poor targets for the initial stages of the search for life elsewhere.

But wait, there's more ...

The story of habitability is a complex one and it is certain that we have only scratched the surface of the influence of the system in which a given planet moves.

The future will doubtless reveal more factors that must be taken into account when assessing the suitability of a given planetary system as a host for [life](#) – just as is the case for our observations of the stars that host these planets.

In truth, that's part of the joy of science. Every new thing we learn opens up a dozen more questions that beg for answers.

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