Observations

A New Theory of How the Moon Formed

Contrary to what we now think, it could be that it came from a violent impact that temporarily turned Earth into a "synestia"

By Simon Lock on June 9, 2017

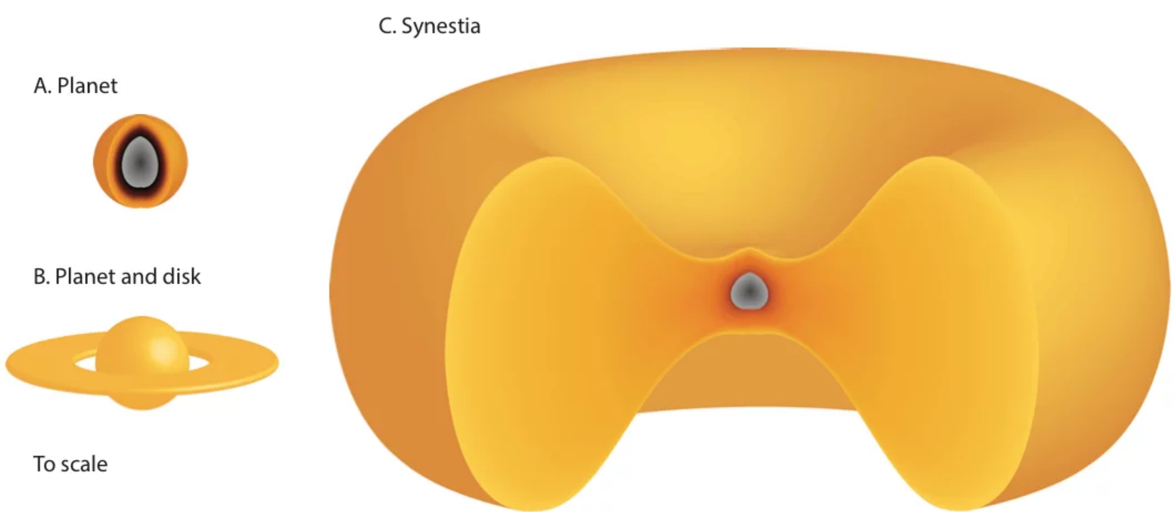
Credit: NASA, JPL-Caltech

The Moon has been a point of fascination in almost every culture since apes decided that walking was a pretty neat idea, honored with innumerable deities and the subject of many myths and legends. It hangs in the sky, dwarfing the stars and constantly changing through its monthly cycle. What's more, the Moon is the only place that humans have set foot outside of our own planet, the farthest we have strayed into the dark near-infinite cosmos. As a kid I shared this fascination. The Moon was just there. I couldn't see the man in the Moon that everyone talked about, but it was another world, close enough that I felt like I could touch it.

These days the Moon fascinates me for a very different reason. It holds, in its stately orbit and spotty surface, the clues to how the Earth formed and became the planet we know and love. Planet formation is an exercise in the survival of the biggest. The planets formed in a disk of gas and dust surrounding the sun where dust collided together to make pebbles, and then pebbles came together to make planetesimals hundreds of kilometers wide. The largest of these planetesimals grow faster than the ones around them and swallow their neighbors to grow into proto-planets. The last stage of planet formation is where these biggest bodies collide together. Impacts between two planet-sized bodies are colossal, vaporizing several percent of the impact bodies and melting most of the rest. It was out of one of these apocalyptic collisions that the Moon was born.

According to most textbooks, Theia, the planet that hit the Earth, was about the size of Mars, and the impact was slow and grazing, spiraling out material into orbit and forming a disk of molten rock around the Earth. Such models are based on the assumption that the Earth and Moon have the same amount of angular momentum (a measure of rotational inertia) now as they did right after they formed, when the Moon was much closer to the Earth. However, in 2012 this all changed. It was shown that the spin inertia of the Earth and Moon could have been much higher earlier in their history. This led to investigation of a range of other potential Moon-forming impacts, from two equal sized bodies colliding together to a small body breaking apart an already rapidly spinning Earth. This was the start of a new page in planetary science. Just over three years ago, Sarah Stewart, my graduate advisor, and I were in her office puzzling over the result of a simulation of one of these new, high spin impacts. We were writing a grant proposal to request money and resources from NASA to continue working on understanding the implications of these newly proposed models. Or at least we were meant to be. To be awarded a grant you need to convince a panel of other scientists that what you are proposing to study is worth looking at. To do this, you generally try and show them a teaser of what results they might expect from your study. But here we were, looking at this model of the Earth after an impact and nothing made sense. The planet and the disk that we had been told to expect were somehow squished together. This was something very different.

You often hear about Eureka moments in science, and this was ours. But it took us three years of hard work and innumerable other small breakthroughs to work out what we were looking at. It was a synestia, or at least that is what we have called it. The impact that Sarah had simulated made the Earth rotate so rapidly, and vaporized so much rock, that the central body expanded dramatically, with its outer edge of the body was rotating almost as fast as a satellite would in orbit. The body was continuous, seamless from the core of the Earth out to many tens of thousands of kilometers away. The name synestia—from *syn* meaning together and *Hestia* the Greek goddess of architecture and structures, loosely together-structure—was chosen to stress the fact that synestias are single bodies, not a separate planet and disk. Synestias come in a whole range of shapes and sizes; they're not just all megadonuts as some news outlets have termed them, they are a new astrophysical object that no one knew existed.



The conventional theory says a Mars-size planet hit Earth at low speed, vaporizing the outer layers into a ring that condensed to form the Moon. The new theory says a high-speed impact might have turned Earth into a "synestia." Credit: Simon Lock

The discovery of synestias is a game changer for our understanding of how the Earth formed. It is likely that several times during formation, the body that would become the Earth was transformed into an extended, substantially vaporized body. This dictates how the core of the Earth formed, how we acquired our ocean and atmosphere, and maybe how our planetary companion, the Moon, came into being. We have shown that the Moon could form from a synestia as it cools and condenses, solving a number of mysteries about the composition and orbit of the Moon. But synestias are not limited to our solar system, and not even to rocky planets like Earth. Almost any planet can become a synestia given the right persuasion; either an impact or the heat from its host star. In other solar systems around distant stars, synestias are lurking, waiting for us to discover them.

I now see something different when I look at the Moon. Like a phoenix, the Earth has been born out of the fire of impacts again and again, but the last time it was gifted a companion, a clue to how our planet formed. When I look at the Moon I see the history of our planet engraved on its pale grey surface. I have to see something, I still can't make out this “man” you tell me about.

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