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Late Accretion and the Origin of Water on Terrestrial Planets in the Solar System

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Terrestrial planets in the Solar system generally lack surface liquid water. Earth is at odd with this observation and with the idea of the giant Moon-forming impact that should have vaporized any pre-existing water, leaving behind a dry Earth. Given the evidence available, this means that either water was brought back later or the giant impact could not vaporize all the water.

We have looked at Venus for answers. Indeed, it is an example of an active planet that may have followed a radically different evolutionary pathway despite the similar mechanisms at work and probably comparable initial conditions. However, due to the lack of present-day plate tectonics, volatile recycling, and any surface liquid oceans, the evolution of Venus has likely been more straightforward than that of the Earth, making it easier to understand and model over its long term evolution.

Here, we investigate the long-term evolution of Venus using self-consistent numerical models of global thermochemical mantle convection coupled with both an atmospheric evolution model and a late accretion N-body delivery model. We test implications of wet and dry late accretion compositions, using present-day Venus atmosphere measurements. Atmospheric losses are only able to remove a limited amount of water over the history of the planet. We show that late accretion of wet material exceeds this sink. CO_2 and N_2 contributions serve as additional constraints.

Water-rich asteroids colliding with Venus and releasing their water as vapor cannot explain the composition of Venus atmosphere as we measure it today. It means that the asteroidal material that came to Venus, and thus to Earth, after the giant impact must have been dry (enstatite chondrites), therefore preventing the replenishment of the Earth in water. Because water can obviously be found on our planet today, it means that the water we are now enjoying on Earth has been there since its formation, likely buried deep in the Earth so it could survive the giant impact. This in turn suggests that suggests that planets likely formed with their near-full budget in water, and slowly lost it with time.