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Constraints for the Earth's Water from Isotopic Abundandances

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Despite our living embedded in the Earth environment, the origin of water on Earth is one of the most puzzling enigmas in the planetary sciences. Our planet that spawned our watery origins presently carries enough surface water in vapor or liquid form to cover the entire planet to a depth of about 3 km. Earth has substantially more water than scientists would expect to find at 1 A.U. Other compounds and elements also readily vaporize at Earth's distance. Typical protoplanetary disk models and meteorite data suggest that the 1 A.U. zone where the Earth formed was too hot for water to be directly incorporated in local planetesimals. The majority of the water must have been acquired by the Earth from material that formed farther from the Sun.

This puzzle was first addressed a couple decades ago by A. Delsemme, who proposed that Earth's water came from comets. Delsemme's theory was not completely satisfactory, but it provided a working hypothesis, until spectral measurements of comets Halley, Hyakutake, and Hale-Bopp, during their near-Earth passes in 1986, 1996 and 1997. The spectral analysis of the three comets showed that the abundance of the deuterium isotope of water is twice that found in Earth's water. Earth's water could not have come all from comets.

In this paper we summarize the current geochemical constraints that, together with published dynamical models, constrain the abundance of water delivered to the Earth from the region of the asteroid belt. We find that no single source satisfies all of the known constraints, and indeed it is necessary to invoke multiple sources at different times. This has important implications for the habitability of extrasolar planets, where the timing and abundance of sources of water may vary in an extreme way from that of the Earth.