Dynamical transport of volatiles to the terrestrial planet region

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The origin of Earth's water is a longstanding mystery. There are three main candidate sources: the Solar Nebula, hydrated asteroids, and comets. The D/H ratio of Earth's water is one convenient tool to discriminate between these sources. The two measured Jupiter-family comets provide a match to Earth, as do some carbonaceous chondrites. Given that the terrestrial planets' local building blocks are thought to have been dry, volatile-rich bodies must have been delivered from colder regions. This dynamical transport occurred during planet formation. Some of the most compelling arguments in this story come from dynamical models of terrestrial planet formation. In classical simulations with Jupiter and Saturn on fixed low-eccentricity orbits the terrestrial planets are doused with volatiles because their feeding zones extend out to 3-4 AU. However, these simulations produce Mars analogs that are far too massive. Classical simulations with Jupiter and Saturn on more eccentric orbits reproduce Mars but volatile delivery is thwarted. The Grand Tack model proposes that the inner Solar System was sculpted by Jupiter's inward-then-outward migration, creating an edge in the distribution of planetary embryos that naturally produced the large Earth/Mars mass ratio. During Jupiter's outward migration, primitive material was scattered inward both into the asteroid belt and past it, into the inner Solar System. Volatile-rich bodies – essentially the parent population of C-type asteroids – polluted the terrestrial planet region. Earth accreted a water budget comparable to its current one, as did the other terrestrial planets. The Grand Tack model is able to reproduce the key constraints in the inner Solar System, and it brings into question whether C-types and Jupiter-family comets share a common origin.