Modeling the Effects of a Giant Planet Instability in the Early Solar System

Cosmochemists, planetary dynamicists, physicists, and astronomers have been working collaboratively to create numerical models of planetary orbits and the scattering of planetesimals during a time of instability in the formation of our Solar System from the **solar nebula**. The models strive to explain and match the modern observations of the planets, asteroids, and other bodies in our Solar System. The most widely known are the Grand Tack model of giant planet formation, which attempts to explain the low mass of Mars and the asteroid belt and the Nice model for the giant planets, which attempts to explain the great quantity of lunar basins that formed about four billion years ago (for more, see PSRD articles: ***Making and Differentiating Planets*** and ***Wandering Gas Giants and Lunar Bombardment***).

David Vokrouhlický (Charles University, Czech Republic), William Bottke, and David Nesvorný (both from Southwest Research Institute, Colorado) present results of their dynamical model (a variant of the Nice model), which begins with five giant planets in the outer Solar System (Jupiter, Saturn, Uranus, Neptune, and another Neptune-like body) surrounded by a primordial disk of about a billion smaller bodies and **planetesimals** of various sizes. Dynamical instability ensues long after the nebular gas disappears, with giant planets scattering planetesimals. Starting the numerical models with five giant planets has been tested before (see reference list for examples). According to the researchers, the dynamical instabilities that caused giant-planet orbits to migrate and planetesimals to scatter into the asteroid belt and beyond also ejected the fifth planet from the Solar System after a gravitational encounter with Jupiter. Vokrouhlický and coauthors set out to study how the hypothesized fifth giant planet, before eviction, may have gravitationally interacted with the untold number of disk planetesimals launching them into the main asteroid belt that we observe today.

A result of Vokrouhlický and team's five-giant-planet instability model is that the scattered disk planetesimals are ultimately captured in zones where P/D-type asteroids are observed, including the inner part of the main asteroid belt. They predict that most P/D-type near-Earth asteroids are relics from the same primordial population of disk planetesimals that evolved into the **Kuiper Belt** objects, the irregular-orbit satellites, and the Jupiter Trojans—asteroids that orbit the Sun on the same path as Jupiter.

Vokrouhlický and colleagues suggest that Tagish Lake, a unique type of carbonaceous chondrite meteorite [***Data link*** from the Meteoritical Bulletin] is a plausible sample of a D-type asteroid that was scattered into the inner part of the main asteroid belt as described by their model. Previous researchers also tagged Tagish Lake as a sample of a D-type asteroid. (See PSRD article: ***Tagish Lake—A Meteorite from the Far Reaches of the Asteroid Belt***.) If these ideas are true, the Tagish Lake meteorite—a rock we can hold in our hands—uniquely represents material from the early Solar System, formed far from the Sun, that eventually populated the Kuiper Belt, the region we know today that includes dwarf-planet Pluto (the brightest known Kuiper Belt Object) and its moon Charon as well as hundreds of thousands of icy bodies and an estimated trillion or more comets.

See Reference:

· Vokrouhlický, D., Bottke, W. F., and Nesvorný, D. (2016) Capture of Trans-Neptunian Planetesimals in the Main Asteroid Belt, *The Astronomical Journal,* v. 152:39, doi: 10.3847/0004-6256/152/2/39. [***abstract***].

See also:

· Hiroi, T., Zolensky, M. E., and Pieters, C. M. (2001) The Tagish Lake Meteorite: A Possible Sample from a D-Type Asteroid, *Science,* v. 293, p. 2234-2236, doi: 10.1126/science.1063734. [***abstract***]

· Nesvorný, D. (2011) Young Solar System's Fifth Giant Planet? *The Astrophysical Journal Letters,* v. 742:L22, doi: 10.1088/2041-8205/742/2/L22. [***abstract***]

· Nesvorný, D. and Morbidelli, A. (2012) Statistical Study of the Early Solar System's Instability with Four, Five, and Six Giant Planets, *the Astronomical Journal,* v. 144:117, doi: 10.1088/0004-6256/144/4/117. [***abstract***]

· Tsiganis, D., Gomes, R., Morbidelli, A., and Levison, H. F. (2005) Origin of the Orbital Architecture of the Giant Planets of the Solar System, *Nature,* v. 435, p. 459-461, doi: 10.1038/nature03539. [***abstract***]

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November 2016

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