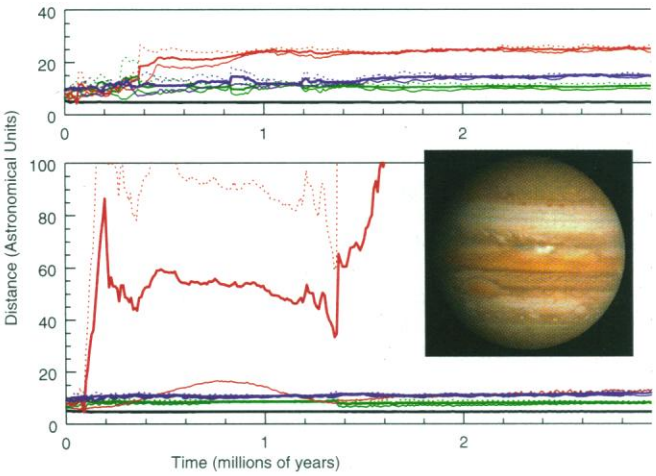
PLANETARY SCIENCE

Shaking Up a Nursery Of Giant Planets

What are Uranus and Neptune doing so far from the sun? The question has puzzled theorists for decades. Unlike the closest six planets, which orbit the sun inside of 10 astronomical units (AU)—that is, less than 10 times farther out than Earth—Uranus and Neptune orbit at 19 and 30 AU, respectively. Theorists don't believe they could have formed so far



Mere chance. In computer simulations, Jupiter (pictured) and Saturn sometimes rearrange Uranus and Neptune (purple and red) to resemble the solar system (top) and sometimes not (bottom).

out; there, gas and dust were too sparse to coalesce into planets. Now, a new computer model suggests that sibling rivalry might be to blame for their banishment. Runty Uranus and Neptune may have grown up in tight quarters much closer to the sun, only to have the big bruisers Jupiter and Saturn fling them into the outer reaches of the solar system.

"It's a fascinating result," says planetary dynamicist Brett Gladman of the Observatory of Nice in France. "I think it's marvelous it works." Forming Neptune and Uranus where it's practicable and then having them thrown outward "seems dynamically plausible," adds Stuart Weidenschilling of the Planetary Science Institute in Tucson, Arizona. "It certainly comes out ahead of any previous explanations."

The nine planets formed in a nebular disk of dust and gas, where chunks of primordial matter collided to form bigger and bigger chunks and eventually planets. For the next several million years, the resulting ice-rock cores of the outer planets grabbed gas from the nebula until the gas was all taken up or blown away by the sun. But out on the nebula's fringes, matter was spread too thinly for anything like planets to form. In the best simulations of the process, cores for Uranus and Neptune fail to form at their present positions in even 4.5 billion years, the lifetime of the solar system. "Things just grow too slowly" in the outermost solar system, says Weidenschilling. "We've tried to form Uranus and Neptune at their present locations and failed miserably."

Apparently, Uranus and Neptune formed somewhere else, presumably closer to the sun where the nebula was far denser. But how did they move outward billions of kilometers without disrupting their nicely circular orbits, which are in the same plane as the rest of the solar system? In this week's issue of *Nature*, planetary dynamicists Edward Thommes and Martin Duncan of Queen's University in Kingston, Ontario, and Harold Levison of the Boulder, Colorado, branch of the Southwest Research Institute demonstrate a two-step method that works, at least in their model. They assume that not just two but four or five ice-rock cores formed where Jupiter and Saturn now reside, between 5 and 10 AU—an assumption most theorists are comfortable with.

Conventional thinking also has it that once a core reached a critical mass—about 15 times that of Earth—it would grow faster and faster as its increasing mass gave it greater and greater gravitational pull on the gas. By chance, in Thommes and Duncan's scenarios, Jupiter hit runaway growth first, letting it grab 71% of the total mass of the outer planets; Saturn came in second with 21%, but late bloomers Uranus and Neptune got only about 3% and 4% of the mass, respectively, leaving them at the mercy of nearby Jupiter and Saturn. In the first 100,000 years of many of the simulations, Jupiter and Saturn gravitationally fling their nursery mates into steeply tilted, highly elongated orbits that can carry them 30 or 40 AU outward.

That's a dangerous situation for an undersized giant because the big guys could, and in some of the simulations do, eject a planet from the solar system entirely. But the debris remaining in the disk, which extends to 40 AU and beyond, can step in to defend the bullied planets. In a process called dynamical friction, innumerable gravitational interactions with bits of disk debris push Uranus and Neptune around as they pass through and over the disk. The dynamical friction eases the wildly orbiting planets once again into circular orbits in the plane of the other planets but beyond the disruptive influence of Jupiter and Saturn. Further planet-disk interactions can move the relocated planets even farther out. Of the 24 simulations Thommes and his colleagues have run, about half produced an outer solar system resembling ours. Most runs also leave a disk of debris beyond 40 AU that closely resembles the Kuiper Belt of icy objects discovered in 1992, beyond the mean orbital distance of Pluto.

"It's a very interesting idea," says Jack J. Lissauer of NASA's Ames Research Center in Mountain View, California. "They've shown it's not as unlikely as I would have thought." But he and others question the realism of the model and note that no one is sure what the earliest solar system was actually like. Lissauer wonders, for example, if the modelers haven't put a bit too much debris in the outer solar system. Renu Malhotra of the Lunar and Planetary Institute in Houston believes cores would have interacted with gas and ice-rock bodies in the giant planet nursery where they formed. Such interactions, which don't appear in the model, would "tend to damp this violent physics" of throwing Uranus and Neptune out. "Whether the modeling reflects what happens in nature is not demonstrated," she says.

More realism will require more complicated modeling and more computing power, says Duncan. In the meantime, astronomers are pushing their telescopes to the limits to catch a glimpse of more-distant Kuiper Belt objects. In many of Thommes's simulations, Neptune scatters these objects high and low before settling down itself. Like debris from a brawl, scattered Kuiper Belt objects would be a strong sign that the giant planets had an early falling out.

—RICHARD A. KERR

ANTHROPOLOGY

Proto-Polynesians Quickly Settled Pacific

The ancestors of the Polynesian people settled the islands of the East Pacific only a few thousand years ago, but anthropologists have long debated where they came from. Even after detailed scrutiny of bones, blood, DNA, pottery, and languages, researchers have remained divided. One camp, chiefly geneticists, argues that seafaring proto-Polynesians originated in Southeast Asia and quickly island-hopped eastward, sweeping through Melanesia in the West Pacific along the way. The other, chiefly archaeologists, argues that Polynesian ancestors originated in Melanesia itself, a hotbed of human diversity with a 45,000-year record of habitation. Now geneticists have combined DNA and linguistic data from Melanesia to make a new case that the archipelago was only a way station.

The study, in last month's *American Jour-*

CREDITS: (TOP TO BOTTOM) THOMMES ET AL.; JPL/NASA