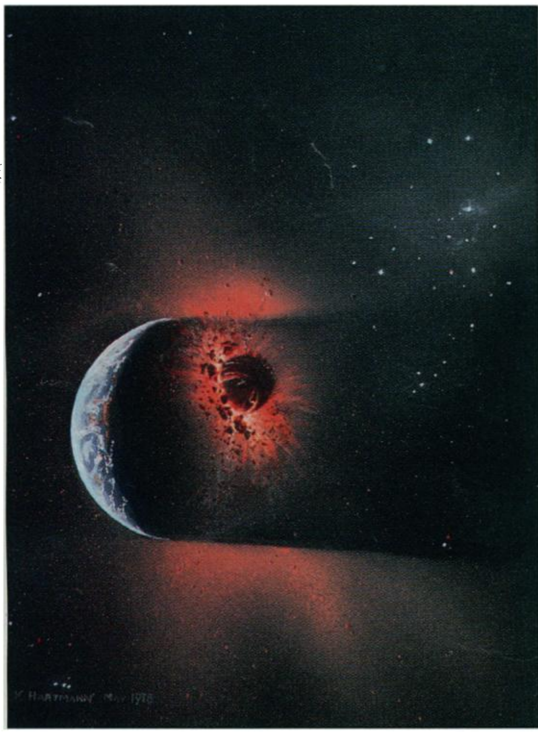
PLANETARY SCIENCE

Theoreticians Are Putting a New Spin on the Planets



A big bang. A lone giant impact on early Earth might have set it spinning 366 times a year.

In recent weeks the media have been filled with spin doctors, each advancing his own particular slant on how Ross, George, or Bill did in the presidential debates. But at the same time, a smaller and less publicized group of doctors was also debating the subject of spin. These doctors, though, were specialists in planetary dynamics, and the spin in question is literal: the rapid rotation of Earth and other planets. It seems that the origin of planetary spin has recently become a hot topic. The older theory, that myriad tiny collisions between the growing planets and smaller objects in the early solar system set the planets spinning, has been blown out of the water by two groups of critics—one from the State University of New York at Stony Brook and the other from the University of Toronto—who argue that the old view simply couldn't explain why Earth and Mars, for example, twirl hundreds of times a year.

Neither group claims to know exactly what actually set the planets spinning so furiously. But both groups—Stony Brook's Jack J. Lissauer and David Kary and Toronto's Luke Dones and Scott Tremaine—are ready with alternative scenarios. Lissauer and Kary favor a modified version of the small-collisions scenario, but Tremaine and Dones lean toward a more catastrophic mechanism, in which planets acquired their spins from a few giant impacts, or even one, late in their evolution.

The old idea, that planetary spins were a cumulative effect of many small impacts in the uniform disk of material that clumped together to form the planets, sprang from a simple observation. Six of the eight major planets, including Earth, rotate forward—in the same direction as the planets move around the sun. Something about the way growing planets swept up pebble-sized to asteroid-sized "planetesimals," it seemed, must have favored forward, or prograde, rotation. And over the past 25 years, calculations of how planetesimals would collide with a protoplanet showed a slight excess of the off-center hits that would impart prograde spin over hits that would twist the planet in the opposite direction. There's no simple physical explanation for the effect, says Lissauer; it was thought to stem from a subtle interplay between the slightly different speeds of planetesimals orbiting on either side of a growing planet and the elliptical shape of the planetesimals' orbits.

As it happened, says Lissauer, "almost all the previous calculations were wrong." He and Kary have done more accurate calculations and performed computer simulations of tens of millions of planetesimals encountering a protoplanet. "We came to the conclusion," says Lissauer, "that if you accrete planets from a uniform disk of planetesimals, [the observed] prograde rotation just can't be explained." The simulated bombardment leaves a growing planet spinning once a week at most, not once a day. As Dones and Tremaine reported last week at the Division of Planetary Sciences meeting in Munich, they have now confirmed that conclusion through calculations and another 100 million simulations. Considering both groups' work, "I think we have a robust result," says Lissauer. "Prograde rotation from a uniform disk is wrong."

But Lissauer thinks the original scenario may not have been completely off-base. He thinks it might work if, late in the growth process, a planet were pelted by a hail of planetesimals from farther afield in the solar disk. Such planetesimals could be more effective at imparting prograde rotation than ones following roughly the same orbit as the planet because their orbits could be more eccentric. In the first step in his new scenario, a growing planet would clear out a lane in the disk, much as moonlets have done in the rings of Saturn, before it reached its final size. Now far more massive and endowed with a longer gravitational reach, the planet could pull in more distant bodies. But by this point gravitational interactions among the planet and the planetesimals might have increased the eccentricity of colliding planetesimals. The net effect of such collisions, says Lissauer, might favor prograde spin strongly enough to account for the planets' observed rotation.

Tremaine, though, isn't sure this intricate celestial dance would be enough to get the planets spinning. "It's true that's a possible hypothesis," he says, "but there are no calculations that show that's what happens. We don't understand the formation of planets well enough to say that." Dones and he feel confident that, whatever effect the opening of gaps in the disk might have had, giant impacts would have made a much larger contribution to planetary spin. Current models that simulate the growth of planetesimals lead to a snowballing that produces some moon-sized to Mars-sized bodies, they note. The impact of one Mars-sized object on the nearly full-size Earth, according to a currently popular theory, splashed enough debris into orbit to form the moon.

If that theory is right, say Tremaine and Dones, the impact that formed the moon almost surely gave Earth its spin. They argue that the effect of a single impact would overwhelm any net spin accumulated from the innumerable and largely self-canceling impacts of smaller bodies. The same may hold for the other inner planets, in which case their generally prograde spin—the pattern that initially suggested that spin was a result of the accretion process—is no more than blind luck.

But Lissauer says that for the time being the choice of scenarios is "a matter of taste." And the theories offered by the opposing teams of spin doctors, he says, may not be as different as they sound. "The big impacts don't necessarily destroy the systematic component" of spin acquired from many smaller impacts, says Lissauer. Even the giant impactors could have tended to strike a growing planet with the slight prograde bias that he suggests for smaller planetesimals, "so even if Earth's [prograde] rotation were due to a giant impact, it doesn't mean it was purely random." Given these almost philosophical disagreements, perhaps Anthony Dobrovolskis of NASA's Ames Research Center at Moffett Field, California, has it right: "I'm inclined to think they both have hold of the truth from different ends."

–Richard A. Kerr