they had a chance to gravitationally interact with each other. If planetesimals grew more slowly, maybe they would accrete one another quickly enough to reduce the number of planets at the end.

So the researchers ran one more simulation, and instead of starting with a population of preformed pebbles, they allowed the pebbles to form slowly. "And then boom, that simulation worked," says Levison. But not for the reason they originally thought.

With more simulation runs and a close examination of the results, Levison, Kretke, and Duncan found that tuning pebble formation to a slower rate didn't lead to the planetesimals accreting each other. Rather, the larger planetesimals scattered the smaller ones to higher-inclination orbits. That meant the small objects spent most of their time in regions without pebbles. The large planetesimals were then able to efficiently accrete the pebbles in their vicinity and grow even larger.

The figure shows the results of two simulation runs illustrating the effect. The two runs have identical parameters except that one starts out with a population of preformed pebbles (top) and the other allows the pebbles to gradually grow (bottom). The difference in the end results is stark: Starting the simulation with preformed pebbles leads to many nearly Earth-sized objects that stop growing within 2000 years; on the other hand, allowing slow pebble growth produces a handful of Earth-sized planetary cores within a million years.

Levison, Kretke, and Duncan tested one other constraint on planet-building models. In some simulations, they placed Pluto-sized planetesimals out at orbits between 20 AU and 30 AU and confirmed that those objects stayed in low-inclination orbits but did not grow; that finding is consistent with what is observed in the Kuiper belt.

Still early days

John Chambers of the Carnegie Institution of Washington says that the new results overcome some long-standing

physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

The Southern Ocean's carbon sink gets stronger. Since 1750 Earth's oceans have absorbed nearly 30% of anthropogenic carbon dioxide emissions. Although the Southern Ocean—the circumpolar waters surrounding Antarctica—occupies just a quarter of the total ocean area, it's thought to be responsible for up to half of that uptake (see the article by Adele Morrison, Thomas Frölicher, and Jorge Sarmiento, PHYSICS TODAY, January 2015, page 27). Air–sea fluxes of CO_2 are proportional to the difference Δp in partial pressure of the gas in the atmosphere and in the ocean. In 2007 flux estimates indicated that the Southern Ocean's carbon sink had weakened in recent decades—a trend attributable to an intensification and southward shift of the westerly winds: The stronger the winds, the greater the upwelling of deep, carbon-rich waters. According to two new studies, the slowdown ended in 2002, and by 2012 the Southern Ocean had regained its expected strength, absorbing about 1.2 petagrams (1.2×10^{12} kg) of carbon per year. To reach that conclusion, an international collaboration led by ETH Zürich postdoc Peter Landschützer used new statistical methods to interpolate the relatively scarce Southern Ocean ΔpCO_2 measurements in space and time over a 30-year period. The other study, led by University of Colorado Boulder postdoc David Munro, found the same reinvigoration by analyzing a particularly dense time series of Δp measurements through just one region—the Drake Passage, which extends from the tip of South America to West Antarctica. What accounts for the trend reversal isn't entirely clear. The westerly winds have not weakened, though circulation-driven changes in sea-surface temperatures, which affect CO_2 solubility, is a likely factor. (P. Landschützer et al., *Science* **349**, 1221, 2015; D. R. Munro et al., *Geophys. Res. Lett.*, in press.) —RMW

Pebbles in comets. Comet Hartley 2's orbit extends from Earth's orbit to just beyond Jupiter's. In November 2010, when Hartley 2 neared perihelion, NASA's *EPOXI* spacecraft flew within 700 km of the 2-km-long comet, shown here. Among the mission's findings was a surprise: The gas and dust spewing from Hartley 2 contained gravitationally bound pebbles. Erosion could conceivably account for the pebbles, but Katherine Kretke and Harold Levison of the Southwest Research Institute in Boulder, Colorado, have proposed a different explanation. Although comets are thought to form through the stepwise agglomeration of ever-bigger pieces, a competing hypothesis has emerged: The collapse of a cloud of dust and larger particles through gravitational instability. Kretke and Levison asked themselves whether the pebbles that *EPOXI* detected could be the uncoalesced leftovers of a putative collapse. To answer that question, they created a family of models of the Sun's protoplanetary disk. They then identified the zones in the disks where orbiting particles are susceptible to the so-called streaming instability that triggers collapse. Because *EPOXI*'s camera couldn't resolve the pebbles, Kretke and Levison assumed a range of sizes dependent on the likely range of albedo. For reasonable albedo assumptions, it turned out that most of the observed pebbles matched predictions for the size of pebbles expected within the Sun's protoplanetary disk. The researchers' analysis also suggested that Hartley 2 formed close to the Sun, a finding consistent with the comet's chemical composition. (K. A. Kretke, H. F. Levison, *Icarus* **262**, 9, 2015. See the related story on page 16.) —CD

Democracy suffers a blow—in particle physics. Upon learning of the discovery of the muon, I. I. Rabi famously quipped, "Who ordered that?" After all, the muon appeared to be identical to the electron except for its mass. Indeed, in the standard model of particle physics, the charged leptons—electron, muon, and tau—interact in the same way with the model's gauge bosons, the particles that transmit force. As a consequence of that lepton democracy, the standard model prescribes the relative probabilities, or branching ratios, for a heavy particle to decay into one or another of the charged leptons plus other particles in common. Three years ago the BaBar collaboration at SLAC measured the branching ratios for B-meson decay to produce either a muon or a tau. For two slightly different decays, they found 2σ or greater deviations from the democratic standard-model expectation.