

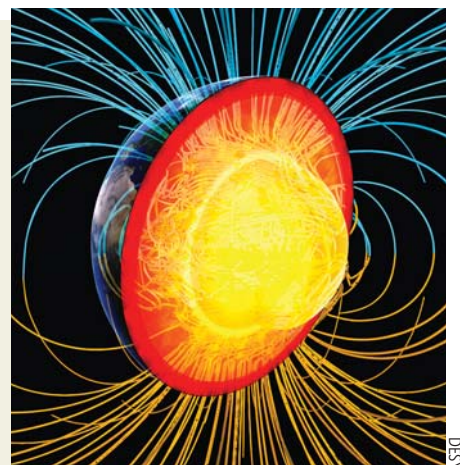
EXPERIMENTS RELATING TO EARTH'S INNER CORE RAISE QUESTIONS ABOUT ITS AGE

Earth's magnetic field (illustrated here) is sustained by liquid iron that is continuously churning in the planet's outer core. Iron that crystallizes onto the solid inner core releases latent heat, which powers convection that drives Earth's dynamo (see the article by Daniel Lathrop and Cary Forest, *PHYSICS TODAY*, July 2011, page 40). But lately scientists have questioned whether that set of mechanisms has always provided the energy for Earth's magnetic mojo. Simulations from a 2012 study suggested that iron has surprisingly high thermal conductivity under the extreme conditions that prevail in the core. The finding hinted that the core may export heat to the rocky mantle much faster than previously thought. If the core truly does lose heat so quickly, then it would have taken less than a billion years for the inner core to reach its current size. Some other process, then, would have had to power the dynamo for a significant interval of Earth's 4.5-billion-year history.

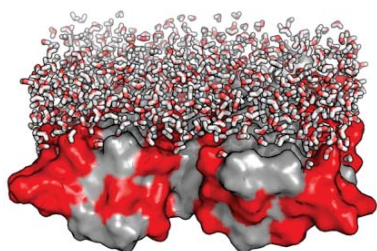
Now two research teams have heated

diamond-anvil cells with lasers to determine iron's thermal conductivity at core-like temperatures and pressures. Kenji Ohta and his colleagues crushed iron wires and determined their electrical resistance, which is inversely proportional to thermal conductivity. The team estimated a conductivity of 90 W/(m·K), a measurement that is roughly in line with the simulation predictions and sets an upper age limit for the inner core of about 700 million years. Zuzana Konôpková and her colleagues measured the propagation of laser-delivered heat through an iron sample. Her collaboration obtained a value of about 30 W/(m·K), which supports the more traditional view of a gradually cooling core with an early-forming solid center. David Dobson, who was not affiliated with either study, notes that the Konôpková result is more dependent on modeling than Ohta's, and any unnoticed melting of the iron could have skewed the measurement.

Follow-up experiments, perhaps ones



that capture electrical and heat-propagation measurements simultaneously on a single sample, could resolve the discrepancy between the two teams' results. Even in the absence of a solid core, theorists can devise exotic mechanisms, such as the wobble of Earth's axis, to explain how the planet could have maintained a magnetic field a few billion years ago. (K. Ohta et al., *Nature* **534**, 95, 2016; Z. Konôpková et al., *Nature* **534**, 99, 2016.) —AG



revealed an unanticipated subtlety. The surface of inaZ, shown in the figure with water molecules above it, alternates the hydrophilic regions (red) responsible for the enhanced SFG response with hydrophobic regions (gray). Close to the hydrophobic regions, the water resembles a liquid-vapor interface, but experimental and theoretical studies suggest that such an interface can boost nearby ice nucleation. The hydrophobic regions of inaZ may thus actually facilitate ice formation. Further SFG studies revealed another of inaZ's tricks—it arranges the water molecules so that vibrational energy transfer effectively whisks away the latent heat released when water crystallizes. (R. Pandey et al., *Sci. Adv.* **2**, e1501630, 2016.) —SKB

CHAOS LIMITS PREDICTABILITY OF HURRICANE INTENSITIES

Weather is the archetypical example of a chaotic system. Indeed, it was his calculations of weather models that led Edward Lorenz to his landmark 1963 paper that helped launch modern chaos theory. (See the article by Adilson Motter and David Campbell, *PHYSICS TODAY*, May 2013, page 27.) Lorenz famously gave a 1972 talk titled "Predictability: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" Chanh Kieu and Zachary Moon

at Indiana University Bloomington now report on a related question: How well can we forecast the intensity of a hurricane? For steady conditions, Kerry Emanuel has shown that thermodynamic arguments yield a wind speed—the standard measure of hurricane intensity—that's a reasonable upper bound for a majority of observed storms (see Emanuel's Quick Study, *PHYSICS TODAY*, August 2006, page 74). Using a minimal dynamic model, Kieu and Moon found that the limiting speed is stable: Simulated hurricanes approach that equilibrium value regardless of their initial conditions. Yet the errors in forecasts of hurricane intensity don't go away as one might expect; rather, speed errors level off at about 8 m/s (18 mph) after four to five days in real-time intensity forecasts.

Through full-physics simulations, the pair discovered that those errors arise from a so-called chaotic attractor at the maximum potential intensity limit. That finding implies that improvements in intensity forecasts are more likely to come from better modeling of the large-scale environment than from better knowledge of the storm's initial state. Even so, the researchers note, the maximum range of predictability is only about three days, and likely shorter for mature hurricanes. (C. Q. Kieu, Z. Moon, *Bull. Amer. Meteorol. Soc.*, in press, doi:10.1175/BAMS-D-15-00168.1. Hurricane Ike image courtesy of NOAA Environmental Visualization Laboratory.) —RJF PT

