realized that splashing among molten asteroids would produce liquid blobs roughly 40 m in diameter—hardly droplets.

At the time, the pair were running simulations of droplet-forming, crater-making impacts,[3] such as the dinosaur-killing Chicxulub impact 65 million years ago (see PHYSICS TODAY, May 1982, page 19). In that incident, the asteroid hitting Earth was larger than 10 km and its fireball spewed countless spherules that, apart from their chemical compositions, are indistinguishable from chondrules. When Johnson calculated how quickly a big cloud of debris would cool after an even larger solid impact—between planetary embryos hundreds to thousands of kilometers in diameter—he found cooling rates of 10–1000 K/hr, consistent with what molten chondrules must have experienced.

The researchers were puzzled, however, at what mechanism might give rise to the melt needed to make the chondrules, given the constraint of slow collision speeds in the solar nebula. Melosh wondered if the porous nature of rocky asteroids might account for it, since the rock should heat up during compression just like air in an inflating bicycle tire. Johnson, meanwhile, hit on impact jetting.

High-speed jets

Johnson simulated the effect for a variety of embryos, large and small, at a range of collision speeds. When the edge of a spherical projectile collides with and penetrates either a flat plate, as shown in figure 2's simulation, or another embryo, he found that the resulting high pressures—exceeding 80 GPa in some cases—and nearly 2000-K temperatures can create a pocket of melt and vapor next to the near vacuum of outer space.[2,4] The enormous pressure gradient then accelerates a plume of molten rock and gas into the nebula at speeds well above the impact velocity.

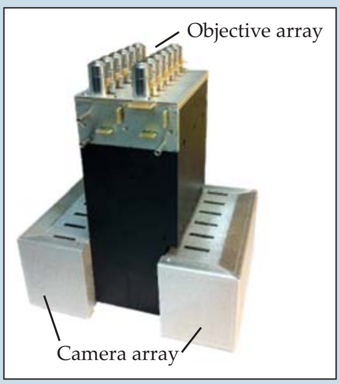
The ejecta's speed explains how the impacts—which spew much more, but slower, broken rock than melt—can end up making chondrule-rich meteorites. The only material that escapes the gravitational pull of the embryo, the researchers argue, is a jetted mixture of melt (nascent chondrules) and lightly shocked solids in which the chondrules eventually become embedded. And although the amount of melt squirted into space turns out to be small—just 1% of the impactor's mass—Johnson's simulations reveal that collision speeds as low as 2.5 km/s can create it.

To place the jetting model into a planetary context, Purdue University's David Minton simulated the orbital dynamics of bodies that would grow to become the planets and asteroids we see today. Starting with a reasonable mass of planetary embryos, whose initial size distribution ranged from 100 km to

physics update

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

Biomechanical measurements in the fast lane. The mechanical properties of cells and their environments strongly influence how biological systems function. They can determine the cells' shapes, dictate how the cells move, and even affect gene expression. When it comes to investigating those properties, though, traditional biophysical techniques, such as bulk rheological measurements, take a long time and can require large sample volumes. Now Richard Superfine, Leandra Vicci, and their colleagues at the University of North Carolina at Chapel Hill have built a microscope system to speed up the process. Shown here, their shoebox-sized instrument is an array of 12 independent fluorescence microscopes, whose objectives are spaced to work with a standard lab plate with 96 sample wells. Three stepper motors move the lab plate in an automated sequence over the objective array. The package is designed for a technique called passive microrheology, which measures the mechanical properties of a biofluid by tracking the thermal motion of small, fluorescent tracer beads embedded in it. In their demonstration, the researchers confirmed that the microscopes could correctly measure the viscosities of several well-known Newtonian fluids. Then they simultaneously measured 12 solutions of hyaluronic acid, a biopolymer found in extracellular tissue, at different concentrations. The measured viscosities compare well with other groups' reported measurements. And with the new microscope, the researchers say such measurements can be made nearly 100 times faster than with conventional techniques. (J. Cribb et al., *Rev. Sci. Instrum.*, in press.) —SC



How did dwarf galaxies form? Dwarf spheroidal galaxies are small, are old, and contain a greater proportion of dark matter than either larger galaxies or globular clusters, which are also small and old. Only the dwarf spheroidals that surround the Milky Way and the nearby Andromeda galaxy are bright enough to study. Despite their quirks, dwarf spheroidals (such as the one shown here) are nevertheless similar enough to their galactic hosts that they could conceivably have started to form at the same time. But that formation scenario faces a challenge. About 60% of Andromeda's dwarf spheroidals occupy a more-or-less spherical halo around their host. The rest, however, occupy a thin pancake-shaped region that encompasses Andromeda's galactic plane (see PHYSICS TODAY, March 2013, page 12). Such a confined distribution is difficult to produce if all the dwarfs began forming with the host galaxy when it first collapsed. An alternative scenario entails the on-plane dwarfs forming after the off-plane dwarfs from material spread about the system after Andromeda merged with another galaxy. To shed light on the mystery, Michelle Collins of Yale University and her collaborators used the DEIMOS instrument at the Keck II telescope to observe two of Andromeda's on-plane dwarf spheroidals. Having determined the dwarfs' chemical makeup and other properties, the researchers then compared them with existing observations of 12 on-plane and 17 off-plane dwarf spheroidals in Andromeda. They