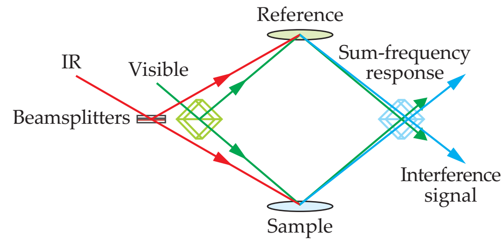
PHASE-SENSITIVE SURFACE SPECTROSCOPY, SIMPLIFIED



The interface between dissimilar materials—solid and liquid, solid and gas, liquid and gas, or even two different solids—is often the setting for interesting and important physical, chemical, and biological phenomena. Sum frequency generation (SFG) spectroscopy is a versatile tool for probing such interfaces: It reveals the vibrational spectra of molecules there and can be used to deduce the molecules' identities and orientations. It works by shining a visible laser beam of fixed frequency and an IR laser beam of adjustable frequency on the same spot on the surface. When the IR frequency matches an illuminated molecule's vibrational resonance, the molecule emits photons at the sum of the two beam frequencies. (See the article by Gabor Somorjai and Jeong Young Park, PHYSICS TODAY, October 2007, page 48.)

Most SFG spectroscopy setups, however, detect only the intensity of the surface response; phase and amplitude information—which contains details about dynamics, overlapping resonances, and more—gets lost. Phase measurements are difficult, in large part because they are vulnerable to subtle changes in geometry—due, for instance, to temperature drift. Jing Wang and colleagues in Mary Jane Shultz's lab at Tufts University have demonstrated a new approach that uses a nonlinear interferometer to stabilize and directly measure the phase response. The interferometer splits both input beams, directing one part of each split beam to the sample and the other to a reference surface (the experimenters used quartz). The SFG responses of the two surfaces get recombined, and the resulting interference pattern reveals the phase information with high sensitivity. Moreover, the interferometer can be used to actively compensate for drift. Without stabilization, the SFG interference can shift from constructive to destructive over minutes; with it, the interference is stable over weeks. (J. Wang et al., *J. Chem. Phys.* **147**, 064201, 2017.) —RJF

THROWING ICEBERGS AT WHITE DWARFS

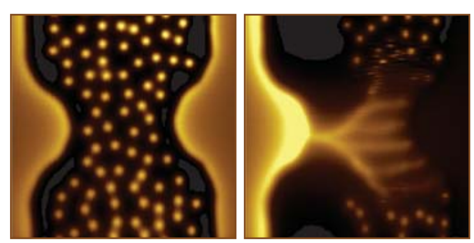
White dwarfs pack the mass of the Sun inside a radius that is 1% as small as the Sun's. Any elements heavier than helium that land on a white dwarf are dragged beneath the surface by the star's intense gravity. So when astronomers spotted evidence of silicon, iron, and other refractory elements in white dwarf spectra, they concluded that something must be replenishing those elements. Given that the sort of stars that become white dwarfs also host planetary systems, it's likely that some white dwarfs are consuming their former asteroid belts, which offer a nearby supply of those heavier-than-helium elements.

But a few white dwarf spectra have recently been discovered to exhibit nitrogen and other elements that come from volatile species found on icy planets, such as Neptune, and on icy dwarf planets, such as the ones in the Kuiper belt. Because the orbits of those planetary bodies typically lie far outside a star's asteroid belt, a question arises: How are the volatiles delivered to the white dwarf?

One plausible solution takes advantage of the fact that more than half of white dwarf progenitors are found in binary systems. Provided a white dwarf's stellar companion is suitably distant, it can trigger an orbital instability—the Kozai–Lidov mechanism—that can send one of the white dwarf's outer bodies along with its cargo of volatiles crashing into the white dwarf.

To evaluate the likelihood of that scenario, UCLA's Alexander Stephan, Smadar Naoz, and Benjamin Zuckerman simulated 4500 binary systems that contained a white dwarf and a normal stellar companion. One set of simulations included a Neptune-like planet around the white dwarf; the other set included a Kuiper belt object around the white dwarf. Each simulation drew its initial orbital parameters randomly from distributions typical of white dwarf binary systems. The simulations implied that 1% of white dwarfs should harbor volatiles delivered by a colliding Neptune and 7.5% by a colliding Kuiper belt object. Together, the results are consistent with the observation that about 10% of white dwarf spectra exhibit evidence of volatile species. They also suggest that white dwarf spectra could harbor insights into the outer planetary systems of some binary systems. (A. P. Stephan, S. Naoz, B. Zuckerman, *Astrophys. J. Lett.* **844**, L16, 2017.) —CD

SUPERFAST SUPERCONDUCTING VORTICES



Although all superconductors screen magnetic fields, many—including high-T_c cuprates and thin-film superconductors—allow a sufficiently strong field to penetrate as quantized vortices, supercurrent eddies that each surround a fixed amount of magnetic flux. As long as the vortices remain stationary, an applied current can flow across the material without resistance. Currents induce a force on a vortex, however, and above some critical current, the vortex will become liberated and dissipate energy as it moves quickly across the material. Just how quickly? Rough calculations suggest that vortices in a thin lead film could reach speeds of 40 km/s, two orders of magnitude faster than the perpendicular supercurrent driving them.

Little theory has been developed for such superfast vortices. But Eli Zeldov (Weizmann Institute of Science) and colleagues now report the first direct microscopic imaging of them. Crucial to the observations was a novel scanning probe: a nanoscale superconducting quantum interference device, or SQUID, residing on the apex of a sharp tip. That tool allowed the researchers to map, with single-vortex resolution, the vortex patterns in a Pb thin film designed with a 5.7-µm-wide constriction.

The figures show the vortices in a 2.7 mT field at zero current (left) and at the onset of vortex flow (right) above the critical current (flowing upward). The right image, capturing the time-averaged vortex motion from left to right, reveals the formation of vortex channels with cascading bifurcations. From their observations, the researchers extracted vortex speeds approaching 20 km/s. Minimal-model simulations corroborated the team's suspicions that weak local heating dynamically aligns the vortices and that repulsive vortex interactions cause the channels to buckle and split. Moreover, the simulations predicted that vortices could reach yet higher speeds, beyond the team's experimental capabilities, and metamorphose into new forms, with exciting implications for superconducting electronics. (L. Embon et al., *Nat. Commun.* **8**, 85, 2017.) —RJF PT