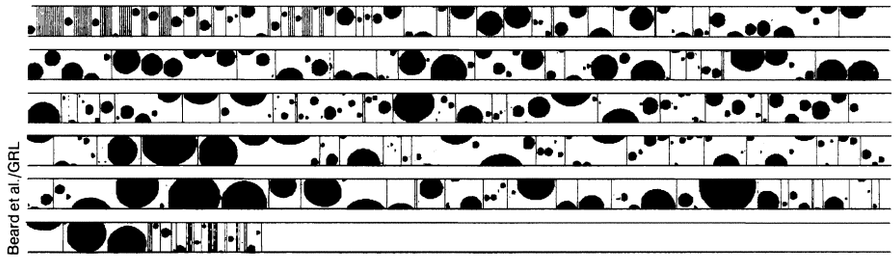
Getting the drop on 'giant' rain



Beard et al./GRL

Atmospheric scientists used an array of photodiodes aboard a research plane to record these shadows of falling raindrops in order to measure their sizes. This magnified record is a time sequence, with each vertical mark denoting the passage of 0.1 second.

You can get a world-class tan in Hawaii, but if you move a little off the island's eastern shore you can also get soaked by world-class rainfall. Each year, 300 inches of rain drop from a band of clouds near Hilo. Now these clouds have set a new kind of rain record. Atmospheric scientists report in the October GEOPHYSICAL RESEARCH LETTERS the discovery of the world's largest raindrops from warm clouds.

During the 1985 Joint Hawaiian Warm Rain Project, Kenneth V. Beard of the Illinois State Water Survey in Champaign and his colleagues found many drops measuring 4 and 5 millimeters in diameter, as well as one 8-mm drop. Drops up to 6 mm in size are known to form when cloud ice melts, but the conventional view of warm, tropical raindrops has held that they seldom get larger than 2.5 mm; earlier laboratory studies, modeling and field observations suggested that larger drops are routinely shattered when they collide with smaller drops.

Apart from showing that conventional thinking about the formation and survival of warm raindrops is all wet, the new finding is important to scientists who use radar to monitor rain clouds and estimate rainfall rates. To calculate these rates, meteorologists need an accurate account of the size distribution of drops in a cloud because the strength of radar signals reflected from a drop is strongly influenced by the drop's size. In addition, radar signals are affected by the shape of a drop, and the larger a drop, the more distorted it becomes (SN: 3/2/85, p.136).

Recent laboratory and modeling results have convinced Beard, David B. Johnson at the Bureau of Reclamation in Denver and Darrel Baumgardner at the National Center for Atmospheric Research (NCAR) in Boulder, Colo., that their finding of large drops in the Hawaiian clouds makes sense on a theoretical basis. Using a drop-size distribution commonly used in radar measurements, they calculate that 5-mm raindrops are destroyed once every 42 seconds. But using their actual observations, in which they found a much higher proportion of large drops than that standard model had predicted, the researchers obtain a destruction rate of only one 5-mm drop every 23 minutes.

"Because earlier observations suggested that these clouds don't have big drops, nobody was looking for them," says Beard. "And no one was doing any calculations to see if they were possible. Nature is often more interesting than what we theoreticians can invent."

Beard's group thinks the high water content of the cloud band near Hilo contributes to the unexpectedly high number of large drops. The clouds' large updrafts are also key because they suspend drops, enabling them to grow large before they fall. In addition, "relatively low numbers of small drops seem to be a necessary condition," says Beard, so that few collisions occur.

The researchers also suspect that the updraft may be tilted so that large drops fall out of the cloud, avoiding the cloud's rising small drops. Or, it may be that large drops are the first to fall from a cloud. "We certainly find large drops in the absence of significant numbers of small raindrops," says Beard. But, he adds, "we don't really understand how this part of it occurs."

In order to investigate the wind patterns that give rise to these clouds, Roy Rasmussen at the Bureau of Reclamation in Denver and Piotr Smolarkiewicz at NCAR simulated the formation of the cloud band with a three-dimensional computer model. They found that the trade winds approaching the island are deflected back and down the slopes of two 13,000-foot-tall volcanoes. The deflected winds then run head-on with low-level trade winds, the converging air rises and clouds form. In other rainy areas, such as the island of Maui, clouds form because the air is pushed up by mountains. Having the winds turn back on themselves is "is fairly unusual," says Rasmussen. "No one's reported on this phenomenon before." —*S. Weisburd*

Molecular divorce gives strange vibes

Common sense says that the more vigorously you vibrate something, the more likely it will break into parts. But laser-wielding chemists pushing around weakly bound, identical molecular twins are finding that the effects of vibration on the molecular scale may not be as straightforward.

Researchers at the National Bureau of Standards in Gaithersburg, Md., observed that the harder they 'shake' coupled twins, or dimers, of nitric oxide (NO) molecules, the longer it takes to break the weak bond that holds together the two individual NO molecules. Such bonds are governed by what are called van der Waals forces, which are, in part, responsible for the shapes of proteins and enzymes, as well as for some chemical and physical properties of all materials. The scientists' findings, which will appear in the Nov. 15 JOURNAL OF CHEMICAL PHYSICS, run counter to both intuition and existing theories about how and why molecules break into pieces.

In usual earthly situations, molecules rock, rattle and roll in an energetic dance at a dizzying pace. A molecule's constituent atoms rotate around bonds a trillion times every second. With each tick of the clock, these bonds twist and bend about 10 trillion times. The atoms vibrate toward and away from each other at an even faster rate. Meanwhile entire molecules are slam-dancing with their neighbors, making complex exchanges of energy. Twists become bends, which become vibrations that become rotations, or some other such choreography of transitions and motions. In those cases where all of this internal energy becomes too much — for instance, when solids melt into liquids or liquids change into vapors — molecules fragment until the smaller pieces are dancing at a pace that allows them to stick around.

When a molecule itself disintegrates or when it dissociates from another molecule to which it is bound, how are the complex internal energies redistributed throughout the fragments involved? Theories exist that fit well with observed patterns of molecular disintegration, but they are based on unexplained assumptions.

In the new research, a quartet of scientists, led by Michael Casassa, used ultrafast laser pulses to study how two identical and weakly bound NO molecules dissociate, a divorce that occurs in less than a billionth of a second. The researchers opted to study relatively simple NO dimers — two molecules, each composed of an oxygen atom and a nitrogen atom, which stick together due to van der Waals forces and form a trapezoidal molecule. Compared with more complex molecules, the four-atom NO dimer has a limited repertoire of dance moves. Yet even at room temperatures, motions

within NO dimers are extremely complex. To simplify these motions nearly to the point of removing them entirely, Casassa and his co-workers used a special molecular jet that cooled the molecules to near absolute zero, the point at which all internal motions come to a halt.

Then, by using trillionth-of-a-second laser pulses that were tuned to inject precise amounts of energy into the NO dimers, the scientists were able to choreograph from scratch a simple molecular dance. They directed the molecules to vibrate in one of two modes: symmetric vibrations, in which the back and forth oscillations of both nitrogen-oxygen pairs are synchronized; or asymmetric vibrations, in which the atoms of one NO molecule approach each other while the atoms of the other recede from one another.

After setting the dimers vibrating in one of the two vibrational modes, the scientists used another ultrafast laser to see how the dance was going. This laser could in effect take snapshots of the dances at different times after movement began. The researchers observed that the dissociation of the NO pairs took 890 picoseconds (1 picosecond = 1 trillionth of a second), or 40 times longer, to finalize when the scientists made them vibrate in the higher-energy asymmetric mode than when they made the dimers vibrate in the lower-energy, symmetric mode.

Intuition suggests that higher-energy vibrations should break apart weakly bound dimers more easily than can lower-energy vibrations. And a leading theory on how molecules break apart formalizes this intuition. But Casassa's experiments clash with both intuition and theory. Casassa suggests one possible explanation that he has not yet tested. He says that some of the energy from the asymmetric vibrations might be shunted into electronic motions in a way impossible for the lower-energy vibrations, which might vent their energies more readily by causing the dimer to dissociate. Hence, the longer dissociation times for the high-energy vibrations.

Whatever the explanation, the paradoxical molecular behavior that Casassa and his colleagues observed has turned a few heads in the scientific community. Physical chemist Richard Zare of Stanford University calls Casassa's work "very exciting" and praises the experiments as "elegant and beautiful." The next step, say Casassa and other laser chemists, is to critique more molecular choreographies to see if the behavior observed in NO dimers is a general phenomenon of molecules bound by weak van der Waals forces. *– I. Amato*

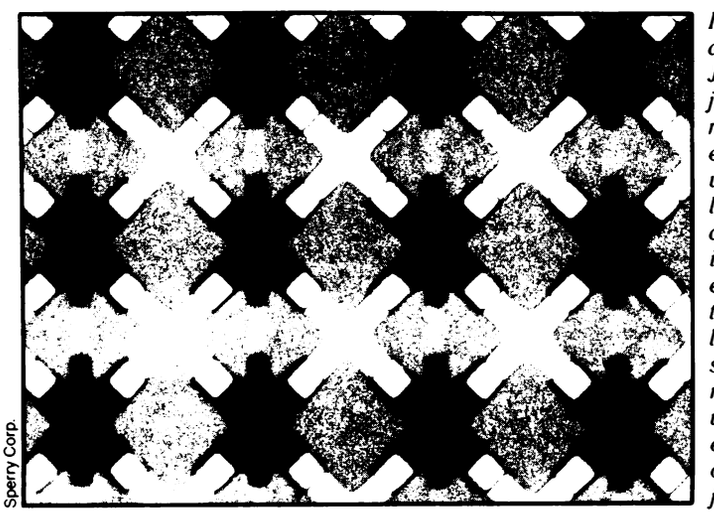
Checking out a theoretical superconducting transition

In the strange world of superfluids and superconductors, currents can flow forever. In order to study and understand this surprising behavior, physicists often turn to sophisticated technology. One approach is to construct a physical system – say a microelectronic device – that corresponds to a particular theoretical model. Researchers can then run experiments on the system to learn more about the theory.

Recently, scientists at the University of Minnesota in Minneapolis used a custom-made array consisting of a million Josephson junctions (SN: 10/27/84, p.265) to investigate something called the two-dimensional X-Y model. This theoretical model is useful for understanding currents in liquid-helium films and thin superconducting layers, such as those in Josephson junctions. It may also apply to processes like two-dimensional melting. Of particular interest is a special kind of temperature-dependent transition, known as the Kosterlitz-Thouless transition, found in the X-Y model's behavior.

Using the Josephson junction array, which was fabricated by Manjul Bhushan and her colleagues at the Sperry Corp. in St. Paul, Minn., the researchers found clear evidence for that transition. "I was amazed how sharp everything was," says Minnesota's Alan M. Goldman. Other researchers had seen the transition before but never this clearly.

The sharpness of the new results shows that this array is "an extraordinarily accurate realization" of the two-dimensional X-Y model, says Goldman. That makes the array a useful test bed for all sorts of ideas associated with the model.



Sperry Corp.

In this segment of a million-element, Josephson junction array, niobium electrodes show up as dark and light crosses. The different shades indicate that the electrodes are at two different levels. The little squares, only 8 microns wide, where the electrode arms overlap show the junction locations.

The Sperry device, a 1-inch square, consists of two layers of niobium separated by a thin, insulating silicon film. This set of layers is carefully etched to create a pattern of niobium electrodes.

In a typical experiment, the device is cooled to temperatures below 6° K. For a given temperature, a current is applied across the whole array and the voltage measured. This provides an estimate of the array's electrical resistance at various temperatures. The Kosterlitz-Thouless transition shows up as an abrupt resistance shift at a critical temperature.

Says Goldman, "This is a striking example of being able to make structures that are model systems of important statistical mechanical problems." Goldman and his group presented their results at last month's Applied Superconductivity Conference in Baltimore.

"It's a very competitive field," says Harvard's Michael Tinkham, who has done similar experiments using a somewhat different type of array. "There are lots of groups in it." One goal of this research is to find out what effect an externally applied magnetic field has on the Kosterlitz-Thouless transition. The question is controversial because different theoretical models make different predictions. Goldman and others are now using their devices to study this special, "frustrated" case of the X-Y model.

Researchers are also doing computer simulations to explore this model. However, computers are generally too slow or have too little memory to handle arrays that consist of as many as a million elements. A computer simulation with fewer elements, says Tinkham, isn't realistic enough.

Moreover, says Goldman, "it's always nice to have a real, physical system on which to make measurements. By doing this, you can often learn things about nature that get lost in a computer simulation." *– I. Peterson*