SCIENCE NEWS of the week

Layers of Complexity in Ozone Hole

One more mystery has been added to the seasonal loss of ozone in the stratosphere over Antarctica. It now appears that the "hole" is an uneven one, with 2- to 3-kilometer-thick slices of ozone-poor air sandwiched within layers of only minimal depletion.

In 1985, British researchers reported the presence of a sharp ozone drop over Antarctica; previously collected data indicated that the hole made its first appearance in 1975 and has been returning each Antarctic spring. Climate researchers have been struggling mightily to explain why the hole appears (SN: 3/1/86, p.133; 10/11/86, p.239; 10/25/86, p.261; 11/29/86, p.344), but their theories have been modeled on a generalized ozone depletion.

Some scientists have put forth a chemical explanation – that the depletion is caused by chemical events spurred by the presence of chlorofluorocarbons created by industrial processes. This was bolstered this week with the announcement by the head of an ozone-research team that a chlorine-containing molecule related to chlorofluorocarbon use is abundant in the hole.

Others believe the hole is formed by dynamic air movement and mixing. A third group blames it on the sun, suggesting high solar-cycle activity produces ozone-destroying active forms of nitrogen above the stratosphere.

The new data on ozone stratification were collected by University of Wyoming researchers who went from Laramie, Wyo., to McMurdo Station in Antarctica last year. They sent up their first ozone-sensing balloon Aug. 25, before the seasonal hole began forming, and by Nov. 6 had sent up 32 more. The balloons sampled the atmosphere with sensors as they traveled to about 30 kilometers up, and beamed the results back to earth.

Ozone depletion is confined to a swath of air from 12 to 20 km up, the researchers report in the March 5 NATURE. But while the total ozone loss in that segment is 35 percent, the patch between 14 and 18 km lost more than 70 percent of its ozone from the initial high in August, and the researchers found depletions as great as 90 percent within 1- to 5-km-thick zones.

They also found great differences in adjacent layers – in some cases, a layer that had lost more than 75 percent of its ozone was adjacent to one with a loss of less than 25 percent. Another surprise, says Wyoming researcher David J. Hofmann, was the rapidity with which the depletion occurred – about half the ozone was gone after 25 days.

The findings leave both the chemical and dynamic theorists to explain the stratification and the speed at which the depletion occurs. The stratification doesn't necessarily hurt the chemical camp, Hofmann says – the layering could occur by air movements, after the ozone has been chemically depleted. But the chemists will have to explain how the depletion can be so quick.

Susan Solomon of the National Oceanic and Atmospheric Administration in Boulder, Colo., favors a chemical explanation. Solomon, who headed the U.S. National Ozone Expedition in Antarctica last year, says the Hofmann study "is a very important observation that's going to have to be explained."

The data, she says, "pose severe problems for all the models." The September depletion is earlier than predicted by either the chemical or physical model, both of which rely on the sun warming the air and predict an October depletion.

Data gathered recently by her group support the chemical theory, she says. At a congressional subcommittee hearing on ozone loss this week, Solomon said the ozone hole contains 20 to 50 times the expected level of OClO, a chlorine-containing molecule. Such chlorine molecules have been associated with chlorofluorocarbon use. But it is too early to say that chlorofluorocarbons cause the hole, she says.

The absence of the depletion above 20 km makes the solar-cycle theory unlikely, says Hofmann, since that theory predicts the greatest loss at higher altitudes. But one of the formulators of the solar-cycle theory, Linwood B. Callis of NASA Langley Research Center in Hampton, Va., says the data were collected during a period of low solar-cycle activity, when not much solar-related effect was expected; still, he prefers not to comment on what may have caused the hole in 1986, pending further analysis.

Data only alluded to in the NATURE paper are going to give the dynamicists some problems, Hofmann says. He and his colleagues found that other chemicals in the ozone-poor air were not depleted, making it less likely that the hole is caused by upwellings pulling in aerosol-depleted air. For upwellings to bring in air depleted only of ozone, and not of other trace chemicals, would take "immaculate transport," says Hofmann. "Our measurements show no upwelling."

Nonetheless, Mark Schoeberl of the NASA Goddard Space Flight Center in Greenbelt, Md., who is a proponent of dynamics, says the current research does not rule out a physical process. "Ozone is a long-lived tracer," he says. Only if all aerosols formed and decayed at the same rate and in the same place would air moved by upwellings have uniform concentrations of aerosols, he says.

Hofmann, while suggesting that the pink-and-green stratospheric clouds that form over Antarctica may somehow be a factor, is not taking sides. "I don't push any models," he says. "I take measurements."

– J. Silberner

Hot questions in superconductivity

Last month, researchers announced they had made a material that becomes completely superconducting at 94°K (-290°F). By losing all electrical resistance 17°K above the boiling point of the inexpensive coolant liquid nitrogen, it promises to make a host of technological dreams come true (SN: 2/21/87, p.116).

Now, in the March 2 PHYSICAL REVIEW LETTERS, the composition of the new material has been revealed by Paul C.W. Chu at the University of Houston, Maw-Kuen Wu at the University of Alabama in Huntsville and their colleagues. It contains yttrium (Y), barium (Ba), copper (Cu) and oxygen (O), with the composition $(Y_{0.6}Ba_{0.4})_2CuO_4$. Previous superconducting temperature records were set with lanthanum (La)-barium or strontium-copper oxides, with a typical composition of $(La_{0.9}Ba_{0.1})_2CuO_4$.

These new data, together with provocative but sketchy information on the crystal structure of the material revealed to SCIENCE NEWS this week by scientists at the Carnegie Institution of Washington (D.C.), raise a suite of scientific questions.

Chu and Wu were guided to the yttrium material by examining the behavior of the lanthanum compounds; they found that the relative sizes of atomic elements are important criteria in superconducting. But in spite of their success at navigating past the 77°K liquid nitrogen barrier, the hunt for high-temperature superconductors still involves a good measure of alchemy. And while scientists have a sound theory of superconductivity, they have yet to agree on what makes the yttrium and lanthanum compounds tick.

The basic theory of superconductivity, worked out 30 years ago, states that electrons in a crystal can communicate with one another by forming what are known as Cooper pairs. The conductivity of a crystal is enhanced because with Cooper pairs, the electrons scatter off the crystal lattice in a coherent, rather than random, way. The problem has been to explain the mechanism that couples normally repulsive electrons together.

The conventional mechanism holds that electrons interact through crystal vibrations called phonons. Marvin L. Cohen at the University of California at Berkeley thinks the electron-phonon interaction may still be a viable mechanism for the recent high-temperature superconductive materials. (Cohen and his colleagues announced March 2 that they had reached a superconductivity onset temperature of 100°K with a compound of the same composition as Chu's.)

But Chu and theorist Philip W. Anderson at Princeton (N.J.) University believe that the electron-phonon interaction cannot explain superconductivity at temperatures higher than about 40°K. Chu and Wu are intrigued by the fact that the yttrium material contains two different phases — two compounds of different composition and structure. A green phase is not itself superconducting, according to Chu. So the researchers believe that either the other (black) phase is responsible, or the superconductivity mechanism is taking place at the interface between the two phases, an idea first developed about 10 years ago.

However, Anderson says he would be surprised if the existence of two phases has anything to do with superconductivity in these kinds of materials. Instead he proposes in the March 6 SCIENCE another mechanism, in which the electrons in the yttrium and lanthanum oxides — and in other materials that are not quite able to become completely ordered magnetically — are coupled through magnetic and electronic interactions.

In interviews this week, Carnegie researchers who were asked to analyze the material said it contains two novel crystal structures. "The new structure will really set theoreticians to thinking," says Robert M. Hazen, "because [one aspect] lends itself to some very unusual electronic properties." They plan to reveal the exact nature of the structures in a paper submitted to PHYSICAL REVIEW LETTERS. *— S. Weisburd*

Scientists, 'boxed in,' scramble after supernova, find neutrinos

Supernova 1987A is "an event unique in our lifetimes," said Stanford Woosley of the University of California at Santa Cruz. He was speaking March 6 at a hastily convened workshop on the supernova, which brought about 100 people to the NASA Goddard Space Flight Center in Greenbelt, Md. It is unique in more ways than Woosley knew at that moment: On March 10 came reports from neutrino detectors in the United States and Europe of simultaneous detection of neutrinos from the supernova, the first neutrinos recorded from beyond the solar system.

One thing that seemed clear at the March 6 meeting is that theorists are having a hard time assimilating the information from this, the nearest supernova since 1604. According to David Helfand of Columbia University in New York City, it is also 100 times nearer than the next nearest one to explode since the space age began. "There are not many chances to learn from space observations," he said. "We have to seize this one."

Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., quoted the distance to 1987A as 50 kiloparsecs or 1.5×10^{23} centimeters and calls it the brightest since 1885 (an explosion in galaxy M31). Its nearness may be not a blessing but a curse, Kirshner said, particularly as astronomers try to answer the question, "What star is that?" and to classify the explosion according to one of the subtypes of either type I or II supernovas. Or, in Woosley's words, "IIb or not IIb?"

Data from the International Ultraviolet Explorer (IUE) satellite show that the ultraviolet intensity of the supernova fell off very rapidly, after which it became evident that the star astronomers first thought had exploded, Sanduleak -69° 202, had not. If the Sanduleak star had been the precursor of the supernova, astronomers would have had for the first time a supernova whose predecessor was known and had been studied somewhat. But as J. Craig Wheeler of the University of Texas at Austin put it at the meeting, "The fact that the sucker is still there is irritating."

A second star, a close companion to Sanduleak -69°202, is also still there. Speculation now centers on a bulge that several observers saw on the southeast side of the image of the Sanduleak star before the explosion. This could be an even closer companion that the telescopes can't separate — "star No. 3." However, star No. 3 would have to be very dim. It would also have to be a type II supernova, which has hydrogen (type I does not). IUE has found hydrogen, and this creates theoretical problems, because, as Woosley says, it's hard to make something dim into a type II.

All this is making the researchers feel somewhat claustrophobic. "We seem to be getting into a box," said Woosley at the workshop. "It's not my fault," responded Kirshner. "I'm beginning to feel the same box you are," added Wheeler.

According to a theory due largely to Woosley and Thomas Weaver of Lawrence Livermore (Calif.) National Laboratory, stars start out burning hydrogen to helium. Later in life they process the helium to heavier and heavier elements. The heavy elements gravitate to the center; hydrogen and helium remain layered on the outside. When a star "supernovas," the heavy core collapses, triggering a shock wave that moves outward, blowing off the outer layers. This could be a star that had very little hydrogen left when it blew, Wheeler told workshop participants. Then the hydrogen should thin out soon, enabling scientists to see into the helium layer, and the spectrum should look like type IIb.

Yet a few minutes later Wheeler jumped up to say that, based on the redshifts he had just calculated from radio data, they may already be seeing through thinning hydrogen into the helium layer.

But Roger Chevalier of the University of Virginia at Charlottesville, relating the first radio observations, caused more theoretical consternation. The radio work, done at three Australian telescopes, at Fleurs, Molonglo and Parkes, shows 1987A developing much faster than other supernovas, making changes in days that took others months or years. But 1987A is throwing out matter at a rate only a few hundredths or thousandths as fast as the others.

"I just felt the box get tighter," responded Wheeler.

Several people at the meeting mentioned a reported detection of neutrinos from the supernova by an experiment located under Mt. Blanc in Europe, and wondered why it had not been confirmed by detectors elsewhere. The Mt. Blanc finding has not been confirmed, but on March 10 Randy Black of the University of California at Irvine (UCI) informed SCIENCE NEWS that the IMB detector operated by UCI, the University of Michigan and Brookhaven National Laboratory in a salt mine at Fairfax, Ohio, recorded 8 bursts of neutrinos in a 10-second period on Feb. 23, the day the supernova began. At the same time, the detector at Kamioka, Japan, recorded similar signals. However, that time is five hours different from that of the Mt. Blanc report. For the moment that discrepancy is an unsolved puzzle.

"It's the coincidence that has everybody in the field excited," says Frederick W. Reines of UCI, one of the original discoverers of the neutrino itself. It means the finding is almost certainly reliable. Before now neutrinos have been recorded from terrestrial sources and from the sun, but not from outside the solar system. "It's the real beginning of neutrino astronomy," says Black. That neutrinos could survive the journey also has implications for the theory of the neutrino, whether it has mass and whether it is subject to radioactive decay. Those implications are just beginning to be explored. For the supernova, it means information from the very beginning of the event, from the collapse of the star's core. As Reines puts it, "It means seeing deep into the event, rather than just looking at the surface." *— D. E. Thomsen*