optimized the levels of dopants, impurities added to control the numbers of electrons and holes. But even as it stands, the new material has promise, because it outperforms the competition at temperatures below zero degrees Celsius. "People are desperate to find a material that will work much below room temperature," Kanatzidis says, "so it can take over where the other material leaves off."

–ADRIAN CHO

ASTRONOMY

Fine Details Point to Space Hydrocarbons

On Earth, it's hard to avoid polycyclic aromatic hydrocarbons, or PAHs. Made up of two or more fused benzene rings, they turn up in cigarette smoke, car exhausts, or just about anywhere that hydrocarbons burn at high temperature. But for nearly 2 decades, astronomers have argued about whether these molecules are as ubiquitous in space as they are here at home. They were puzzled by the fact that certain interstellar gas clouds in regions of space too cold to produce thermal emissions nonetheless produce characteristic emission bands in their infrared spectra. These bands look teasingly similar to the emissions bands produced by PAHs, but they are not exactly the same, and the failure of chemists to reproduce precisely the observed spectra in the laboratory has led some astronomers to argue that the emission bands are caused by small solid particles, such as soot or hydrogenated amorphous carbons. But astronomers picking over data obtained by Europe's Infrared Space Observatory (ISO), who met in Madrid last week,* believe they have evidence that clinches the case for PAHs in space.

Cold gaze. ISO spotted strong evidence for polycyclic aromatic hydrocarbons.

ISO, a 60-centimeter infrared telescope launched by the European Space Agency in November 1995, made over 26,000 observations before it ran out of the liquid helium needed to cool its telescope and detectors in April 1998. One of its tasks was to solve the riddle of PAHs. Some astronomers have suggested that PAHs could form in the atmospheres of carbon-rich stars and be ejected into interstellar space when the stars die. In the cold of space, such molecules would sometimes be struck by ultraviolet photons, causing the carbon atoms in the benzene rings to vibrate. Changes in vibrational energy are emitted as infrared light—a process called relaxation—just as sound is emitted from a gong when it is struck. Because of the numerous different shapes and sizes of PAHs, their spectra are dominated by bands of emissions, rather than discrete peaks.

Critics of this model argue that the emission bands just don't match those of PAHs in the lab. "The spectroscopy obtained [in lab experiments] with solid materials, such as anthracite, give a better spectral agreement," says Cécile Reynaud of France's Atomic Energy Commission in Saclay. PAH supporters counter that in cold interstellar space, there is simply not enough heat to produce thermal emissions from such solid particles. "With 15 degrees [kelvin], you won't have emission in the near infrared," says Alexander Tielens of the University of Groningen in the Netherlands. Very little ultraviolet radiation will cause relaxation in PAHs, however, so this could still occur even in the frigid environs of interstellar clouds.

Now, a team led by Christine Joblin of the CNRS Space Study Center for Radiation in Toulouse, France, believes it has convincing evidence. By studying the high-resolution spectra obtained with ISO's short-wave infrared spectrometer, they found that the emission bands are made up of a forest of sharp peaks. "This structure cannot be explained by solids—one expects wide and smooth bands—and we can explain this structure by assuming that we are dealing with a family of molecules," says Joblin.

To finally settle the matter, chemists will have to duplicate this detailed emission structure in the laboratory. Pascale Ehrenfreund of Leiden University in the Netherlands says finding laboratory spectra of PAHs that match astrophysical spectra is just a matter of getting the right mix of ingredients. But "if you have a family of 200 molecules, it is very difficult to pick the right ones on Earth. … You need a lot of laboratory studies in order to really make a perfect fit," she says.

Douglas Hudgins and his colleagues in the Astrochemistry Laboratory at NASA's Ames Research Center in Moffet Field, California, are attempting to do just that. And Hudgins believes that the ISO data will make his work much easier. "Up to this point, the quality of our laboratory spectra was much, much better than the quality of available astronomical data," but now the ISO spectra should make comparisons much sharper, says Hudgins. So will ISO data settle the matter? "Absolutely … I think there is overwhelming evidence supporting molecular PAHs and PAH ions in space."

–ALEXANDER HELLEMANS

Alexander Hellemans writes from Naples, Italy.

* ISO Beyond the Peaks. The 2nd ISO workshop on analytical spectroscopy, 2–4 February, Villafranca del Castillo, Madrid, Spain.

PLANETARY METEOROLOGY

Deep, Moist Heat Drives Jovian Weather

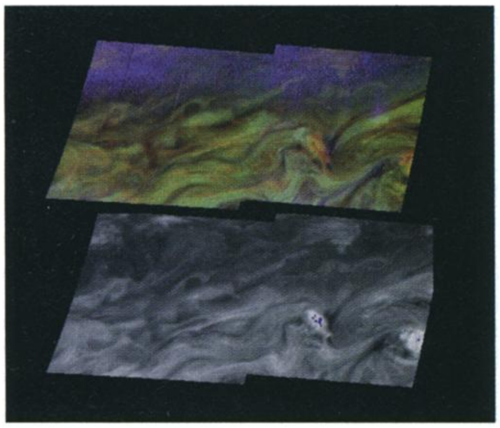
The weather on Jupiter is awesome but frustratingly mysterious. Great jets of 750-kilometer-per-hour wind girdle the planet, marking off distinctive, dark and light bands of clouds. And oval "storms" of various sizes and hues roll between the jets, ranging from small, short-lived eddies hundreds of kilometers wide to huge, long-lived swirls. The grandest of these ovals, the 20,000-kilometer Great Red Spot, has been at it at least since Galileo's day 300 years ago. But what, meteorologists have wondered, makes it all go? The sun bathes the jovian cloud deck in feeble light, while deep-seated heat energy that has lingered since the planet formed seeps out. Which of those two energy sources predominates in driving Jupiter's weather engine? And how does that energy get bundled into the small eddies on which the jets and spots feed?

In two papers in this week's issue of *Nature*, researchers provide an answer: Deep heat funneled upward by local storms is a major driver of jovian weather. They show that much if not all of the deep heat escaping the interior flows up through towering thunderstorms. These disturbances can go on to become small eddies that eventually give up their energy to storms such as the Great Red Spot. "Where these little guys come from has always been the question," says planetary meteorologist Timothy Dowling of the University of Louisville in Kentucky.

Lightning, captured by the imaging system aboard the Galileo spacecraft orbiting Jupiter, was the key to running down jovian weather's major energy source. On Earth and apparently on Jupiter, lightning and the water-fueled engine that drives thunderstorms are intimately connected. In a terrestrial thunderstorm, water vapor in rising warm air condenses. The condensation releases more heat that pushes the rising air upward even harder. This "moist convec-

CREDIT: ESA

tion" engine can also segregate electrical charges into different parts of a cloud; the reuniting of those charges is lightning. Although Jupiter has no ocean or wet ground, moist convection seems to work much as it does on Earth. "We're using lightning as a beacon to tell us where the convection is" on Jupiter, says planetary meteorologist Andrew Ingersoll of the California Institute of Technology in Pasadena, who co-authored the *Nature* papers with Peter Gierasch and Donald Banfield of Cornell University and their colleagues.



Night lights. Jovian storms (reddish in false color, top) sport powerful lightning strokes (blue, bottom).

By observing a thunderstorm hundreds of kilometers long just west of the Great Red Spot in daylight and in darkness, Gierasch and his colleagues could gauge how much heat thunderstorms are extracting from Jupiter's interior. In daylight, they watched the clouds carried by the air move up and away from the storm, which told them how much warm air the storm was raising. During the night, they measured the lightning associated with the storm. Then they surveyed about half the planet to determine the global abundance of lightning. They calculate that moist convection delivers a large part of the heat that is known to leak out of the interior. The Galileo data "is very good evidence the heat comes up localized in convective systems," says planetary meteorologist Conway Leovy of the University of Washington, Seattle, "just as it does in Earth's" lower atmosphere.

But that is where the terrestrial analogy stops, argue Ingersoll and his colleagues in the second paper. The Great Red Spot, they note, is not the hurricane-like storm that textbooks often describe. Neither it nor the whole hierarchy of smaller ovals on Jupiter draw their energy directly from their own moist convection, as hurricanes do. Instead, they argue, it's a two-step process. If jets don't tear apart the lightning-riddled jovian thunderstorms and take on their energy, the planet's rotation turns the thunderstorms into stable swirls of spinning air, or small eddies. They rotate in the same direction as the ovals without any more energy input from moist convection. This shared sense of rotation among small eddies and ovals seals the fate of the eddies, while feeding the large ovals.

CREDIT: GIERASCH *ET AL.*, *NATURE*

The eddies that form near the same latitude as the Great Red Spot, for example, scurry westward as much as 400,000 kilometers before encountering the slower moving Great Red Spot, says Ingersoll. Being only a couple of hundred kilometers deep, jovian spots behave as if they are two-dimensional, notes Louisville's Dowling. In a two-dimensional fluid flow, he says, "everything that touches, merges." The opposing winds at the point where eddy and spot contact tend to nullify each other; a common, quiet center forms between them; and they and their stores of kinetic energy merge.

Such resupplying of energy ultimately derived from the interior needn't happen all that often, notes Dowling. Even without its weekly recharging, he notes, the Great Red Spot would keep on spinning for centuries. "The reason it can get away with it is there's no surface friction; there's nowhere to stand" on Jupiter, only an atmosphere that becomes more and more dense with depth.

Although moist convection of deep heat now appears to be a prime driver of jovian weather, "there's still a puzzle," says Leovy. Some jets, such as the one the Galileo probe fell through, seem to increase in strength the deeper they go. That renewed a long-standing debate: Is all the weather seen at the jovian cloud tops relatively shallow—rooted only a few hundred kilometers down—or does part of it penetrate thousands of kilometers, to near the planet's heart (*Science*, 12 September 1980, p. 1219)? Galileo won't solve all the mysteries, it seems. —RICHARD A. KERR

NEUROBIOLOGY

A New Clue to How Alcohol Damages Brains

It's common knowledge that drinking alcohol can cause birth defects. Even so, 20% of women who drink continue to do so while they are pregnant, according to a 1996 report from the Institute of Medicine. As a result, roughly 1 infant in every 1000 born in the United States has fetal alcohol syndrome, characterized by facial abnormalities, stunted growth, and learning and memory problems. New work now provides some surprising new insights into how alcohol may cause some of that damage.

On page 1056, a team led by neuroscientist John Olney of Washington University School of Medicine in St. Louis and his former postdoc, pediatric neurologist Chrysanthy Ikonomidou (who is now at Humboldt University in Berlin), reports that alcohol works through the receptors for two of the brain's neurotransmitters, glutamate and GABA, to kill brain neurons in rat pups. The animals were exposed to one episode of high blood alcohol during the first 2 weeks after birth—a time when rat brains are going through developmental stages that occur in human brains during the third trimester of pregnancy. Although researchers have known for some time that alcohol exposure late in development causes brain damage in rodents, the new work provides the first possible explanation of how that damage occurs.

In doing so, says pharmacologist Boris Tabakoff of the University of Colorado Health Sciences Center in Denver, it provides "the first step to understanding how you might control that damage," possibly with drugs that block alcohol's effects on the receptors. But the work carries an even more important message for the public, says neurobiologist David Lovinger, who studies alcohol's effects on neurons at Vanderbilt University School of Medicine in Nashville, Tennessee. Late-pregnancy drinking "is really unsafe for the brain," he says.

Olney and Ikonomidou did not set out to investigate the effects of alcohol on the brain. They were following up on studies they performed last year on chemicals that block the so-called NMDA receptor for glutamate, an excitatory neurotransmitter in the brain. The team's earlier work showed that chemicals that block the NMDA receptor cause brain neurons to die by programmed cell death, or apoptosis, during the phase of development when the brain's neurons are forming connections with each other. The group went on to look for other drugs that trigger apoptosis and found that barbiturates and benzodiazepines, both of which suppress neural activity by activating the receptors for the inhibitory neurotransmitter GABA, caused similar neuronal die-offs.

Because ethanol blocks NMDA receptors and activates GABA receptors, "we thought it would be wise to test ethanol," Olney says. Indeed, the pattern of neuron death they saw with ethanol "seems to be a composite" of what they saw with GABA enhancers and NMDA blockers. That, Olney says, suggests that alcohol's effects on the brain are carried out through these two receptors.

Other groups had previously noted that alcohol exposure late in development causes widespread neuron death in rat brains, and there had been hints that NMDA receptors are involved. For example, pharmacologist Paula Hoffman of the University of Colorado Health Sciences Center and others have shown that blocking NMDA receptors kills