Saturn's Belt of Lightning: 40,000 Miles of Zap

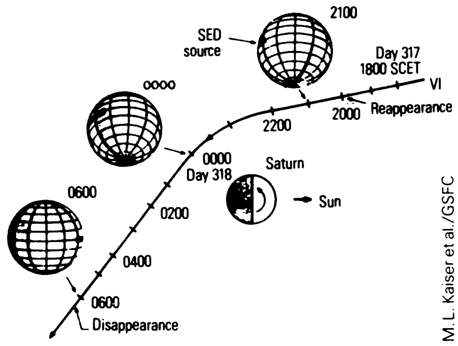
The list of the wonders of Saturn continues to grow, from its thousands of formerly unimagined ringlets to its 1,100-mile-per-hour equatorial winds. Now a reanalysis of data from the two Voyager spacecraft, which went there in 1980 and 1981, has suggested yet another dramatic phenomenon: a truly gargantuan lightning storm, 40,000 miles long, wrapping a sixth of the way around the planet (equivalent to nearly twice around the earth) and lasting at least the 10 months between the flybys.

What the Voyagers actually recorded was a peculiar kind of static, which indeed seemed to resemble the radio emissions triggered by lightning. It came in short bursts every few seconds, covering a wide range of frequencies, and the bursts occurred in episodes whose regular timing suggested that whatever their source might be, it was circling Saturn's axis about every 10 hours 10 minutes. Some Voyager scientists pointed out, however, that the emissions extended down to frequencies as low as 20 kHz, while the density of electrons in the planet's ionosphere (as measured by other instruments on the Voyagers and the earlier Pioneer 11) should have kept in any atmospheric signals lower in frequency than about 1 MHz, so that they would never reach the spacecraft. Thus, it was reported, the source of the bursts "clearly is not in the electrical discharges that might be expected to occur in the cumulonimbus clouds over Saturn."

Furthermore, it was noted, the 10^h10^m period of the burst episodes, though shorter than the planet's $10^h39.4^m$ day, corresponded to the orbital period of particles about 30,000 miles out in the rings. Perhaps, then, the source of the bursts (dubbed Saturn electrostatic discharges, or SEDs) was there, possibly a result of charges built up by collisions between the ring particles.

A year ago, however, at a meeting devoted solely to Saturn studies, Joseph A. Burns of Cornell University pointed out that the rings cast a large shadow on the planet's near-equatorial ionosphere, possibly reducing its electron density enough for the SEDs—low frequencies and all—to escape outward from the atmosphere. Now Michael L. Kaiser, J.E.P. Connerney and Michael D. Desch of the National Aeronautics and Space Administration's Goddard Space Flight Center suggest that the SEDs' "escape hatch" may in fact be far larger: the entire night side of Saturn.

In their analysis, reported in the May 5 NATURE, the researchers compared the duration of the burst episodes, the amount of Saturn's nightside visible to the spacecraft at any given time, and the frequency range of each burst. The clue that the atmosphere rather than the rings might truly be the source, says Kaiser, came "like a blinding flash" when he realized from a graph of the raw data that the bursts recorded in the few hours *before* each Voyager's closest approach to the planet actually contained no frequencies lower than about 5 MHz. Only those measured during and after the flybys showed the wideband emissions—and those were the ones taken when the spacecraft were largely facing Saturn's nightside. The pre-approach bursts were recorded over the dayside, where the density of the ionosphere is greatest.



M. L. Kaiser et al./GSFC

Voyager 1's views of Saturnian strip-storm.

The other part of the story lies in the fact that the periods of burst activity, though they are centered 10^h10^m apart, were also separated by about three hours of near-silence. Those, the Goddard team maintains, would have been the times when the SED source was hidden from each spacecraft's view. For a point-source 30,000 miles out in the rings, the researchers calculate, such "occultations" would have lasted only about two hours or less, since the ring-source would have been visible around a greater portion of Saturn's circumference. On the other hand, a single, localized lightning storm in the atmosphere would have promptly disappeared behind Saturn's limb, or edge, producing an occultation of about five hours. The only possible answer, the Goddard team reasons, would be if the source were a long, strip-like region in the atmosphere, extending, by the group's calculations, over 60° of Saturnian longitude—a span of nearly 40,000 miles. (A strip-source in the rings would shorten the occultations to *less* than two hours.) The proposed strip of atmosphere "readily" explains the low-frequency cutoff of the early measurements by the fact that it was then on the dayside of the planet.

The 10^h10^m period of the proposed strip suggests that it may not be right along the equator, but instead at about 4° north latitude, where Voyager's photos show cloud features to be moving with the same period. There may also be a corresponding southern-hemisphere region, but cloud features there could not be photographed because of the ring system's shadow, Kaiser says. The Voyagers did not detect similar lightning "signatures" at earth and Jupiter, he notes, simply because there are too many to isolate individual bursts — about 100 per second at earth and up to 80,000 at Jupiter, while Saturn shows only about one in five seconds. Question: Why? —*J. Eberhart*

Canine clues to narcolepsy

Human narcoleptics lead a dog's life: crippled by severe and incurable daytime sleepiness, they are often barred from the most normal human activities — driving an automobile, holding a job. Even very slight emotional arousal (a funny joke, for example) can trigger attacks of physical paralysis and irresistible napping; and many narcoleptics suffer in addition from terrifying hallucinations, a condition that has led to frequent misdiagnosis of schizophrenia.

Although physicians have known about narcolepsy for more than a century, scientists made little progress in understanding the disorder until a decade ago, when it was discovered that dogs also suffer from narcolepsy. With this natural animal model, scientists at Stanford University School of Medicine have been breeding narcoleptic dogs to study the genetics, electrophysiology and biochemistry associated with the disorder; and last week they reported the first evidence of a specific brain abnormality that appears to be consistently linked with canine narcolepsy.

Writing in the May 6 SCIENCE, Ivan N. Mefford (now at Boston College) and a team of Stanford neuroscientists (headed by Theodore L. Baker) report that they have found abnormally high concentrations of the neurotransmitter dopamine in several brain regions of narcoleptic dogs. The dopamine is concentrated within nerve endings rather than in the synapses, suggesting a problem with the normal release of the chemical messenger. Dopamine is suspected of playing a role in alertness, Baker told SCIENCE NEWS, and amphetamines, which are used to treat sleepiness, act in the brain by releasing dopamine.

In addition to the abnormal dopamine concentrations, Baker and his colleagues have also found a proliferation of brain stem receptors for another neurotransmitter, acetylcholine, suggesting that narcoleptics may have an overactive acetylcholine system. These neurochemical findings, Baker says, are consistent with a theory that views narcolepsy as a disease of two parts: excessive somnolence (presumably linked to the dopamine deficiency) and disordered REM (or rapid eye movement) sleep. Narcoleptics do not get less sleep than normal persons, Baker says, but the quality of their sleep is unique. Specifically, where it normally takes 90 minutes to enter the first period of REM sleep (or dream sleep), narcoleptics seem to possess what Baker calls "a hair trigger for REM"; they go immediately into REM sleep, dreaming even during the briefest naps. The overactive acetylcholine system, Baker suggests, may be related to this hair trigger.

REM sleep, even in normal sleepers, is accompanied by almost total paralysis, presumably to prevent people from physically acting out the content of their dreams. But in narcolepsy, Baker says, the elements of REM sleep seem to be dissociated; the paralysis (called cataplexy) is triggered before sleep onset (or it persists following waking), or in the case of hallucinations, the dreaming is triggered during wakefulness — with or without paralysis. Drugs that inhibit acetylcholine activity have been shown to reduce cataplexy and to suppress REM sleep, and drugs that enhance acetylcholine activity have been used to experimentally induce dreaming and to prolong paralysis—lending support to the theory that acetylcholine (probably in cooperation with other brain chemicals) is involved in the initiation of REM sleep.

Interestingly, narcoleptic attacks are usually triggered, in both dogs and humans, by pleasurable events; human narcoleptics typically nod out at parties, and canine narcoleptics experience attacks during sex or feeding. The neurotransmitters under study are very active in the older parts of the brain that are involved in dreaming and emotional processing, Baker notes.

Preliminary trials with a drug that increases dopamine activity while at the same time inhibiting acetylcholine turnover have shown promising results, Baker says. Earlier studies at Stanford have indicated that narcolepsy is clearly a hereditary disorder carried on a single recessive gene, suggesting, according to Baker, that only one of the neurotransmitter deficiencies is inherited; the other brain abnormality most likely develops secondary to the genetic defect. Although it is unclear which comes first, Baker says, narcoleptics usually begin experiencing extreme sleepiness during adolescence, while the cataplexy typically appears in adulthood. In addition, about 20 percent of narcoleptics never experience cataplexy, suggesting that it is probably the dopamine deficiency—and the resulting somnolence—that is passed from generation to generation. — *W. Herbert*

Puzzling search for the GUTs of physics

A little more than a hundred years ago James Clerk Maxwell devised a theory that united electricity and magnetism, showing the two classes of phenomena to be different aspects of an underlying unity. Since then many physicists have worked toward a totally unified field theory, one that would unite all the kinds of force in nature in a single description.

Almost exactly 100 years after Maxwell's achievement came the next successful step, the unification of electromagnetism and the forces of the weak interaction (which govern a number of radioactive processes) into what is called Glashow-Weinberg-Salam theory or "electroweak." Next on the agenda is the unification of electroweak with the strong interaction, the force that holds atomic nuclei together, in what is called a Grand Unified Theory (GUT). Several candidates have been put forward. The bad news is that several recent experimental negatives, mostly reported at the recent meeting in Baltimore of the American Physical Society, seem to rule out the simplest GUT candidate, known as minimal SU(5).

The negative reports are from experiments that look for effects predicted by minimal SU(5) and other GUT theories, but not expected by previous ununified theories.

Until GUTs came on the scene, physicists had believed that protons are absolutely stable. GUTs, however, predict proton decay. It should be extremely rare: the lifetimes calculated for protons in the various theories run around 10^{30} years.

The way to look for proton decay is to assemble a large volume of matter and wait for a proton in it to decay spontaneously. One puts the matter under a mountain or deep in a mine to shield it from the copious background of cosmic rays that would otherwise swamp the detectors. Eight thousand tons of water, 2,000 feet under Lake Erie in a Morton Salt Co. mine, form one such detector operated by what is called the Irvine-Michigan-Brookhaven collaboration. The water is in a cubical tank about 20 meters on a side. The sides of the tank are adorned with 2,000 photomultiplier tubes. If a proton in the water should decay into a positron and a pion, as minimal SU(5) says it should, the daughter particles, coming off in opposite directions, should emit cones of light, called Cerenkov light. When the cones of light reach the sides of the chamber, they should trigger two rings of phototubes. As previously reported (SN: 2/5/83, p. 85), no such events were seen in three months. G. William Foster of the University of Michigan in Ann Arbor, who reviewed the experiment at the Baltimore meeting, said that this nonappearance means that the proton has a much longer lifetime than minimal SU(5) predicts, and so it seems that theory is excluded.

IMB Collaboration

Diver adjusts phototube in IMB detector.

Other GUT theories predict proton decay into a muon and a K meson. An experiment located under Mont Blanc on the French-Swiss border has reported one of these. If that is correct, says Foster, the IMB experiment should have seen five or six. So far, he says, it has seen none it can be certain about. The statistics here are still too slim to hazard any conclusions.

Another prediction of some GUT theories—but not minimal SU(5)—is neutron oscillations. That means that a neutron may spontaneously turn itself into an antineutron or vice versa. If that happens in a nucleus, the antineutron will immediately annihilate itself with another neutron, producing a burst of pions with about two billion electron-volts energy. This will explode the nucleus, producing, in the words of Carl B. Dover of Brookhaven National Laboratory, "a spectacular experimental signature." According to Foster, the IMB experiment sees no neutron oscillations. Neither does an experiment set up in Homestake Mine in South Dakota by Michael L. Cherry of the University of Pennsylvania and four others reported in the May 2 PHYSICAL REVIEW LETTERS. The latter result enabled Dover and co-workers to calculate that the lifetime against oscillation for a neutron free in space must be more than 40 million to 60 million seconds (about 2 months).

Another prediction of GUTs is the existence of magnetic monopoles, single north or south poles existing in isolation. (Ordinary magnets are always at least dipoles). Here too there is one possible observation, by Blas Cabrera of Stanford University (SN: 5/15/82, p. 323). Cabrera has continued to experiment with better equipment but has not seen another instance. He and others continue to look.

David Cline of the University of Wisconsin in Madison intends to look for monopoles in iron ore from Minnesota. The company that owns the processing plant where the experiment will be done is not only happy to have the physicists, it foresees a commercial use of monopoles. This may not be so wild, Cline says. If monopoles and antimonopoles can be made to annihilate each other, they could be a source of energy. —*D. E. Thomsen*