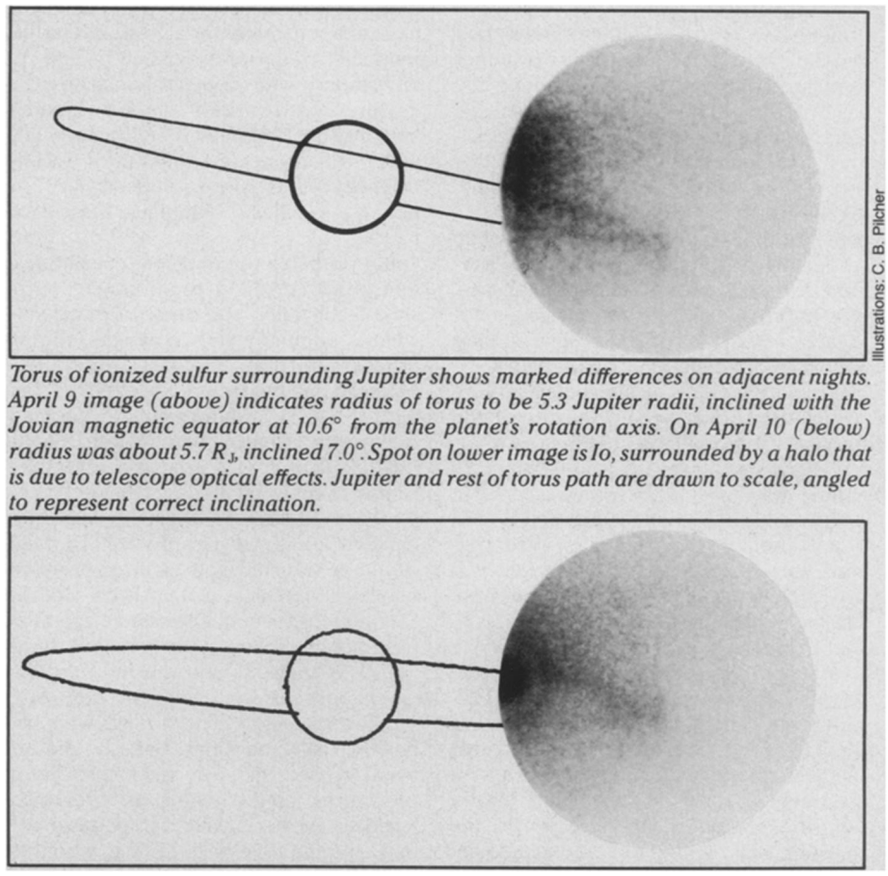
Jupiter's Sulfur Ring

Photographed at last, it's a shifty thing

BY JOHNATHAN EBERHART



Illustrations: C. B. Pilcher

Torus of ionized sulfur surrounding Jupiter shows marked differences on adjacent nights. April 9 image (above) indicates radius of torus to be 5.3 Jupiter radii, inclined with the Jovian magnetic equator at 10.6° from the planet's rotation axis. On April 10 (below) radius was about 5.7 R_J, inclined 7.0°. Spot on lower image is Io, surrounded by a halo that is due to telescope optical effects. Jupiter and rest of torus path are drawn to scale, angled to represent correct inclination.

Seen from its satellite Io, Jupiter would nearly fill the sky, a huge, looming presence that would boggle a mind accustomed to the much smaller disk visible on earthly nights. Yet in another sense, Io also fills the sky of Jupiter, by serving as the source of various atoms, ions and perhaps molecules that spread in vast, diffuse nebulae throughout much of the Jovian system. Though they are probably too rarified and faint to be visible to a human observer at the giant planet, they have been detected by instruments in both earth-based and spacecraft studies.

The most conspicuous from earth has been the sodium cloud, comprised of atoms sputtered up from Io's surface and visible by reflected sunlight as a faint, golden haze. First detected in spectral measurements some years ago, it was finally photographed late in 1976 (SN: 3/5/77, p. 155), and until recently was the only one of Io's various emissions to have actually had its picture taken.

Now there is a second. It is sulfur, again known for some time from earth-based data and lately measured directly by the Voyager 1 and 2 spacecraft. Some may be sputtered up from Io's surface by particles crashing in along Jupiter's magnetic field line, and some may be erupted from Io's newly discovered volcanoes. (The eruption velocities, though apparently often higher than those of terrestrial volcanoes, are still less than Io's escape velocity. But once tossed free, the sulfur atoms can be readily ionized by the Jupiter-trapped particles, and swept away by the fields.) But unlike the sodium, whose reflected brightness essentially disappears when it becomes ionized, the sulfur is rendered visible to some observations by ionization, although the resulting emissions are perhaps a thousand times fainter than the sodium cloud. The Voyager instruments yielded spectra, not images, but during the period between the two spacecraft encounters with Jupiter, the ionized sulfur was successfully photographed from earth.

The images show the sulfur in its singly ionized form, S^+ (the Voyagers also detected the more highly ionized species, S^{2+} and S^{3+}). They were made by Carl B. Pilcher of the University of Hawaii, using the 2.2-meter telescope at Mauna Kea Observatory and a narrow-band filter tuned to the 6731-angstrom "forbidden" emission line of S^+. Pilcher took the pictures on two successive evenings — April 9 and 10 of this year — and that fact is significant, for the results suggest that the S^+ is a highly variable phenomenon, changing markedly in a short period of time.

Because the S^+ is electrically charged, the ions are trapped and held by Jupiter's magnetic field lines, which conduct them into a ring-shape or torus surrounding the planet. The Voyager 1 and 2 measurements, taken about four months apart, showed appreciable changes both in the amount of sulfur and in the proportions of the different ionization levels. Pilcher's images, however, seem to indicate changes in the very size and shape of the torus — and over spans of 24 hours or less.

The images show only a partial arc of the torus, so Pilcher drew in the rest of the ring in each view (estimating from the visible portion) to indicate its shape and position. For three April 9 observations, he says, a ring with a radius of 5.3 times the radius of Jupiter ($5.3R_J$) seems to give "a good overall match" with the photos. In each view, the torus seems to be tilted about 10.6° from the planet's axis of rotation, which would mean, as expected, that the torus was aligned with the Jovian magnetic equator.

However, he says, "the ring had an entirely different appearance on the following night." It was larger — about $5.7R_J$, Pilcher estimates — and tilted only about 7.0°. A major part of the difference, he suggests, could be a matter of a difference in the kinetic temperature of the observed ions between the two nights. If the ions on April 9 were suitably energetic, calculations have indicated, they would have been distributed symmetrically around Jupiter's magnetic equator. If, on the other hand, they were cool and slow-moving enough on April 10, their motion might have been dominated by centrifugal forces due to the rotation of the magnetic field in which they were trapped. This would have moved them into a "centrifugal symmetry surface," which would show the observed 7° inclination. The first night's hotter S^+ would presumably have been more recently ionized, while that from the second night would have lost some of its energy from inter-particle collisions.

But there was another difference. On April 9, the torus was relatively thin in the north-south direction, no thicker than about 0.3 R_J, while on the second night its outer edge had flared out in a "fan" (not shown) as thick as 1.1 R_J. And that raises a problem in ascribing the appearance of the first night's torus to hotter, magnetically confined ions. If the ions came from neutral sulfur atoms originating on Io, and were being created throughout Jupiter's rotation, the April 9 ions should have been distributed over the 20° of magnetic lati-

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tion: Should adopted children know their genetic heritage so they know whether they have, or carry, a specific genetic disease? John R. Ball, physician, lawyer and senior policy analyst for the Office of Science and Technology Policy in Washington, replies: Although state laws are moving toward statutes that would allow adoptees to obtain genetic information while respecting the privacy of the natural parents, few state laws require genetic parents to provide genetic information about their families at the time they give up their offspring for adoption. It would be beneficial to adoptees if they knew their genetic history, Ball holds, because many genetic diseases have available methods of treatment, and because many genetic diseases can be diagnosed in the womb.

An even more difficult question arises: When should genetically defective persons receive medical treatment that will prolong their lives? A landmark court case dealt with this question, reports Charles H. Baron, professor of law at Boston College Law School. The case was brought before the Massachusetts Supreme Court in 1977 to decide whether Joseph Saikewicz, a mentally retarded patient, should receive medical treatment for his leukemia — a treatment that would extend his life by only a few months. In other words, the question was whether a short extension of life would be a curse or a blessing for a retarded person. The court ruled that it was better to withhold than to give treatment.

This case, however, has left the medical community with confusing legal guidelines over what they should do in future cases of this nature. Should they try to arrive at such decisions through the courts? Baron thinks so. Arnold S. Relman, professor of medicine at Harvard Medical School and editor of the NEW ENGLAND JOURNAL OF MEDICINE, strongly disagrees: "I fail to see how a judge, a total stranger, getting information from lawyers who are trained to fight each other, can really know what the patient would like under these circumstances." Relman believes that physicians should decide.

Robert A. Burt, professor at Yale University Law School, takes a compromise stance. He contends that courts and legislatures can provide general guidelines for a physician's conduct in terminating medical treatment for a retarded (or comatose) patient, but that these guidelines should be applied by courts only in after-the-fact review. In any individual case, Burt says, the physician and family members should be forced to accept the responsibility for making and acting on the treatment decision with the clear knowledge that a court might later rule that they had acted wrongfully. Why this posture? "I think the Saikewicz case showed that neither the judge nor the physicians took true responsibility for terminating Saikewicz's treatment," Burt replies. "Each pretended that the other was taking the basic responsibility for action, and in this mutual charade Saikewicz's individual circumstances were hopelessly obscured."

Still a fourth position on the question is held by Robert M. Veatch, senior associate with the Institute of Society, Ethics and Life Sciences in Hastings-on-Hudson, N.Y.: The patients' families should make these decisions.

But probably the toughest questions at this point surround reproduction by *in vitro* fertilization and embryo transfer — what is popularly known as test-tube reproduction. There are at least three potential uses for this technique, explains Barbara F. Katz, staff attorney with the Massachusetts Department of Public Health (SN: 6/2/79, p. 358). A woman with blocked Fallopian tubes could donate an egg to be fertilized in tissue culture by her husband's sperm, and then the fertilized egg would be transferred back into her womb for development. A woman with blocked Fallopian tubes could donate an egg to be fertilized by sperm from someone other than her husband, and the fertilized egg would be transferred back into her womb for development. Or a woman who had healthy Fallopian tubes, but who did not want to carry her own baby throughout pregnancy, could donate an egg to be fertilized by her husband's sperm in culture, and then the fertilized egg would be transferred into the womb of another woman (surrogate mother) to be carried to term. Each of these uses raises legal questions, says Katz, but especially the last.

Who would be the mother of the conceptus? The egg donor? The surrogate mother? If a surrogate mother were being paid for her services and a payment was missed, would the child she was carrying become hers? What if amniocentesis detected a defect in the fetus? Would the egg donor or the surrogate mother have the right to decide on an abortion? What if the egg donor died before birth of the fetus? Would the surrogate mother then become the legal mother?

Although legal requirements for government-funded *in vitro* fertilization and embryo transfer are starting to emerge, Katz reports, the legal aspects of human *in vitro* fertilization and embryo transfer conducted without government funds have yet to be tackled.

When will the above questions receive firmer ethical and legal responses? Not next year, or the next, and maybe not even for many years to come, says Elliot L. Sagall, president of the American Society of Law and Medicine. The U.S. legal system, he contends, is one generation behind medical science. Will the legal system catch up? Will the questions ever be satisfactorily answered? If there was one thing upon which participants at the law and genetics symposium did agree, it was that discussing such questions is a first step toward resolving them. □

. . . Jupiter

tude traversed by Io in a Jovian rotation, which would have produced a much thicker torus. Since they were indeed seen only in a thin, magnetic equatorial band, perhaps, Pilcher offers, they are created only at magnetic latitudes near 0°, when Io is actually in the equatorial plane. It is even possible that the narrow, magnetically confined ring existed on both nights, but was masked on the second night by the substantial amount of the lower temperature emission.

To make the picture still more complicated, it could be inferred from the images (though Pilcher is reluctant to commit himself) that changes take place in the torus on time scales considerably shorter than a day. One can get the impression that the 5.3-R_J circle Pilcher matched to the April 9 photos, for example, does not fit with the same degree of precision in each case. The 5.3-R_J size, in fact, as he acknowledges, was only an approximation, adopted to suit images that actually seem to range from about 5.0 to as much as 5.5 R_J. A smaller range — about 5.7 to 5.9 R_J — may be represented by the following night's views.

The mere presence of the veils, tori and other phenomena associated with Io is bizarre enough, and the possibility that those vast effects change rapidly on a scale large enough to see from earth is more striking still. But more work remains to be done — and nothing on Io is ordinary. □

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