CLOUD-GAZING AT IO

Growing numbers of earthly eyes are turning to the most conspicuous phenomenon of a moon that is noted for its strangeness

BY JONATHAN EBERHART

Jupiter's moon Io could easily have been invented to satisfy the needs of some over-contrived science-fiction melodrama: It has strange electrical properties, serving as one pole of a "flux tube" through which particles ride back and forth between moon and planet along the Jovian magnetic field lines. It has also been described as a "switch," seemingly controlling Jupiter's decametric radio emissions. Some believe that after being eclipsed from the sun by Jupiter's shadow, Io emerges more brightly reflective than when it went in.

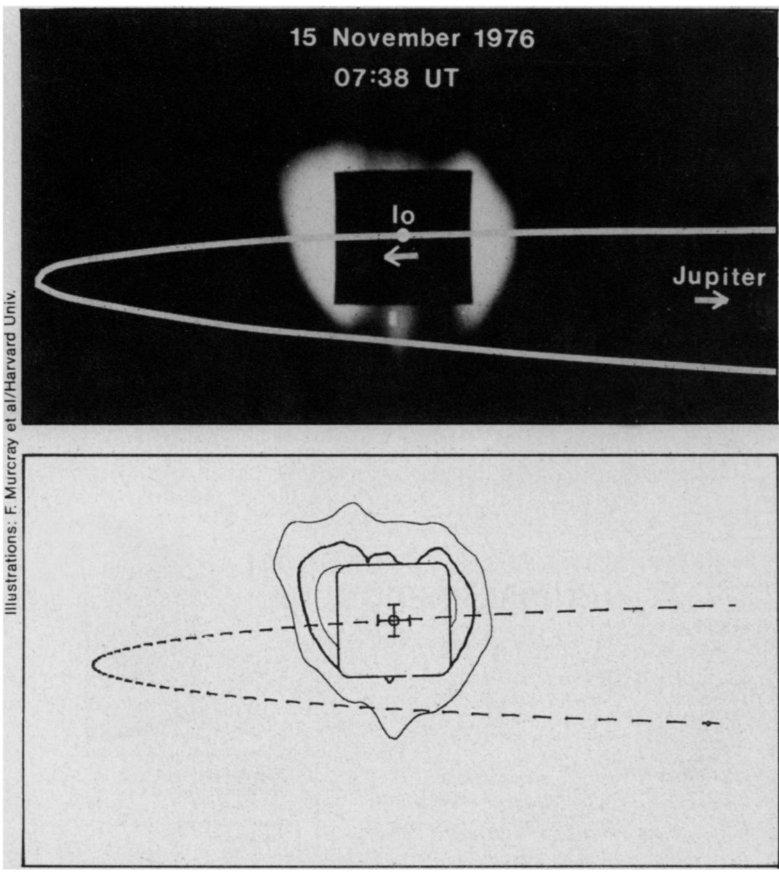
And it has clouds. Not the fluffy, white kind that earthlings know, nor the gossamer hazes that sometimes hide large portions of the Martian surface from view, nor even the surrealist swirls and stripes of host-planet Jupiter. Instead, they are almost invisibly pale and many, many times larger than the whole of Io. One is of hydrogen, the most common element in the universe as a whole and in Jupiter itself. Another may be of sulfur, believed to be a major constituent of Io's surface (SN: 5/28/77, p. 348) and known at least in association with Jupiter. The brightest of the lot, however (though it would still be relatively faint to a human visitor's unaided eye), is the sodium cloud, the only one that reflects sunlight strongly enough for earthbound observers actually to take its picture.

The first such true photograph (SN: 3/5/77, p. 155) was taken last Dec. 3 by a group of California researchers. To do it, they had to catch Io near its maximum angular distance from Jupiter as seen from the earth, so that the far brighter light reflected from the planet would not wash out the faint cloud. It is so faint, in fact, that Io itself could drown it out, so the observers blocked out the moon with a tiny dot of aluminum on a glass plate.

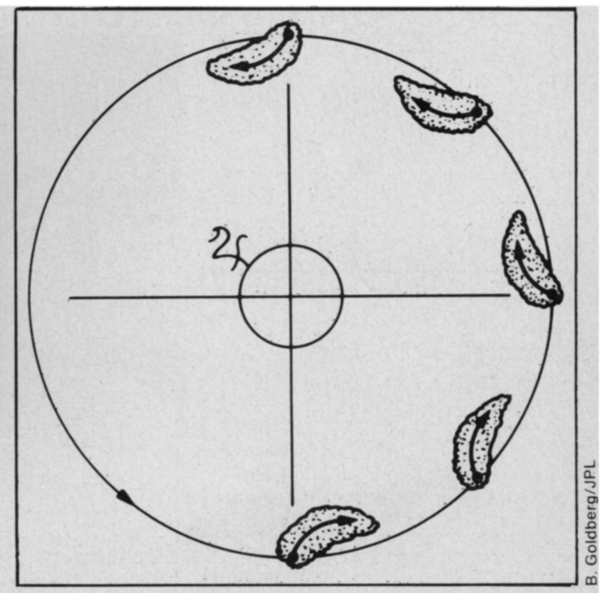
The resulting image was little more than a smudge of light—actually two smudges, representing the characteristic 5890- and 5896-angstrom spectral emission lines of sodium. The smudge-image extended for perhaps six times Io's diameter, and that is only the innermost portion of a cloud which some scientists believe extends throughout the entire vast Jovian system. The smudge was sufficient, however, to let Jay Bergstralh, Dennis Matson, Bruce Goldberg and colleagues from Jet Propulsion Laboratory, together with Robert Carlson of the University of Southern California, determine brightness contours for an intensity map of the cloud's central region.

Since then, improved techniques have provided a more "realistic" portrayal of the cloud. One such image was obtained on Feb. 19, using the same 24-inch telescope (at JPL's Table Mountain Observatory) that was used for the Dec. 3 photo. The result, combined with an earth-based photo of Jupiter in proper perspective (see color photo, top right), gives an idea of the cloud's place in the Jovian scheme of things.

Meanwhile, a team of researchers from Harvard University has succeeded in producing images of the cloud in a slightly different way. Using the 1.5-meter telescope at Harvard's Agassiz Station (with Io blocked out by a one-millimeter-square piece of black tape), they have constructed "pictures" of the cloud by measuring the brightness along each of about 50 close-together slit spectra and then extrapolating the miss-

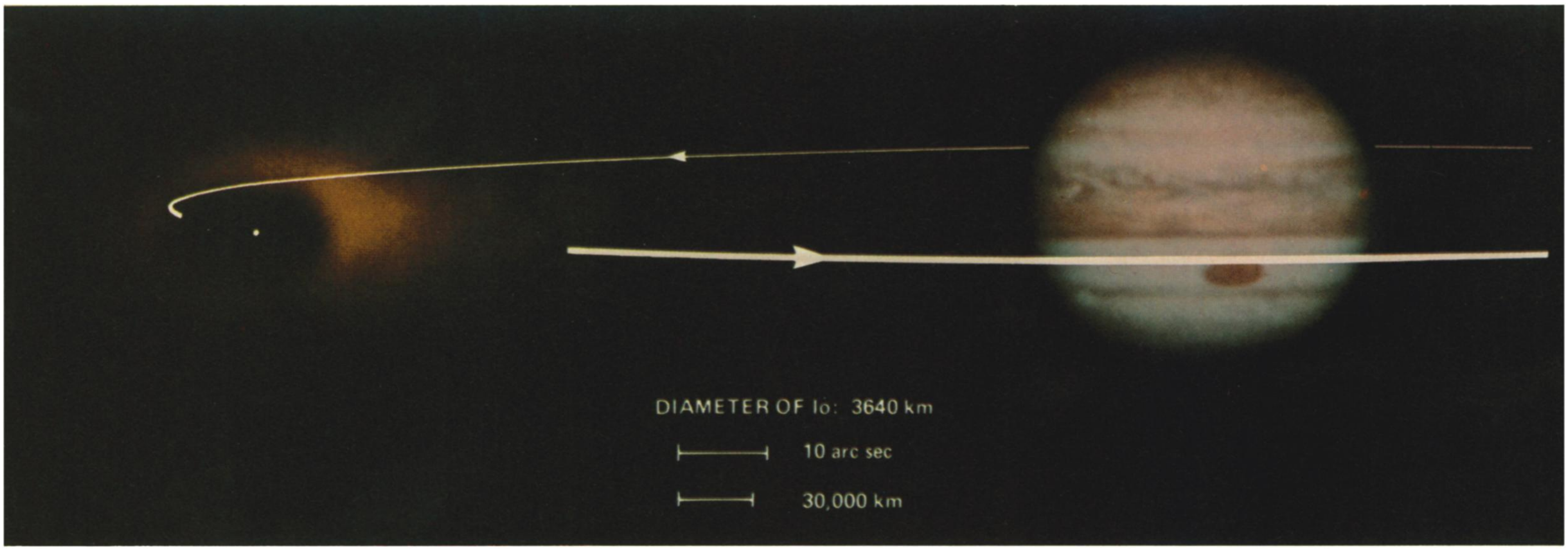


Illustrations: F. Murcray et al/Harvard Univ.

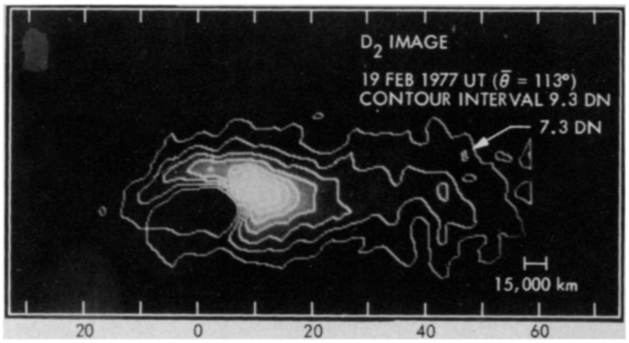


B. Goldberg/JPL

Sodium cloud appears round in multi-slit spectral image (above left) and contour map (lower left), although Io has not yet reached the "end" of its orbit. This indicates that the cloud is angled inward toward Jupiter and thus is here seen end-on. Diagram (above) shows cloud at successive positions in its orbit as viewed looking down from above the plane of the ecliptic.



D. Matson et al/JPL



Bright portion of Io's sodium cloud is shown in left of photo (above), together with proper relationship to Jupiter. Contour map (left), computer-drawn from photo, indicates 5890-angstrom structure.

ing regions in between the slits. About 60 images were made in this way from November of 1976 through February 1977, says Frank J. Murcray of Harvard's Center for Earth and Planetary Physics. Aided by the large telescope, the Harvard team was able to use exposure times of 5 to 20 minutes, thus producing less "velocity smear" in the images than with the 3-to3.5-hour exposures required by the JPL group. On the other hand, the more "direct" JPL imaging technique provides spatial resolution of about 2 arc-seconds, compared with about 4 arc-seconds in the Harvard images.

The bright, central portion of the cloud—the part recorded in both sets of images—is not a sphere with Io at its center. The dynamics of the atoms in the cloud produce more of a banana or hot-dog shape, curving in toward Jupiter from Io's leading hemisphere (in contrast to the hydrogen cloud, which trails behind) at an angle of about 30° to 45° from a tangent to the moon's orbit. This shows clearly in an image made by the Harvard group on November 15, 1976, when Io, as seen from earth, was still on the far side of its orbit, moving away from Jupiter. If the bright portion of the cloud were basically straight—a tangent to the orbit at Io—or even if it curved along the orbit, it would still appear somewhat elongated in such a picture. Instead, it is seen nearly end-on, giving it a spherical appearance. (The JPL image shown here gives a more elongated view.)

But again, there is much more to the sodium cloud than either set of images can show. Carl B. Pilcher and W. V. Schempp of the University of Hawaii, for example, took single-slit sodium spectra at increasing distances from Jupiter, ranging as far afield as 34 times the radius of Jupiter—about six times the distance of Io—and sodium showed in all of them. The emissions seem concentrated in the satellite's orbital plane, since a check at about 33 Jupiter-radii south of the plane showed a much dimmer emission.

As all these cloud-mapping efforts continue, the scientists are getting a better understanding of how the cloud is generated, sustained and modified. The basic mechanism seems to be that sodium atoms are "sputtered up" from Io's surface by charged particles that come diving in along Jupiter's powerful magnetic field lines. Many of Io's strange properties, in fact, are probably related to the fact that it is the solar system's only moon of such size that is so deeply immersed in such a strong field. According to Harvard's William H. Smyth, about 50 million to 100 million sodium atoms are sputtered from each square centimeter of Io's surface every second to sustain the observed brightness. The mean emission velocity, he says, is about 2.8 kilometers per second (spread over a range from next-to-nothing up to about 4 km per second), and the average sodium atom spends about 20 hours in the cloud before it is ionized by a particle trapped on a Jovian field line, which ends the atom's characteristic emissions and effectively causes it to disappear. (At least one researcher believes that this vanishing act can be seen as a slight reduction in the cloud's brightness along the Jovian magnetic equator.)

The cloud was not even discovered until 1973, and images of it have been available for scarcely a year, so plenty of work remains to be done. Norman Ness of the NASA Goddard Space Flight Center has recently suggested, for example, that the appearance of the cloud be checked for correlations with Io's Jovian longitude, to see if there is any link with Io's seeming effect on Jupiter's decametric emissions. Researchers are developing new chemical models for Io's surface, and the two Voyager spacecraft, now *en route* to Jupiter, carry sensors that should add yet more data. Also, there are signs that Io may possess yet another cloud—this one of potassium—adding yet another wonder to what is perhaps the solar system's weirdest moon. □

Vast extent of cloud shows in single in-plane spectra taken far outside Io's orbit.

C. Pilcher et al/Univ. of Hawaii