news and views

Io, the anomaly of the Solar System

from a Correspondent

JUPITER is surrounded by an extensive system of 13 satellites. They include four large planetary bodies Io, Europa, Ganymede and Callisto whose sizes are similar to that of our Moon. These satellites reside in the region of trapped radiation around Jupiter and their interaction with the Jovian environment is much greater than the Moon's with the Earth's magneto tail. But it is Io that is the anomaly, not only among the Galilean Satellites but also among all the bodies of the Solar System.

The density of Io, $3.5\ g\ cm^{-1}$, is the highest of the Galilean Satellites and comparable to that of the Moon and Mars. In general high-density bodies ($\rho>3$) are probably rocky silicate structures whereas low density objects ($\rho<2$) may have a large percentage of ice. During the Pioneer 10/11 flybys, it was found that Io efficiently absorbed electrons in the range 0.16–9 MeV (Fillius and McIlwain, *J. geophys. Res.*, **79**, 3589; 1974; and Simpson *et al. J. geophys. Res.*, **79**, 3522; 1974) but had little effect upon electrons of higher energies. Earth-based radio observations had shown that the position of the satellite on its orbit influences the decametric radio bursts from Jupiter.

Visual astronomers discovered a further puzzling feature. Some reported an increase in brightness of 0.1 mag lasting as long as 15 minutes upon re-emergence of the satellite from Jupiter's shadow though other observers have failed to detect any change in brightness. Does this suggest that the satellite may have an atmosphere? Certainly one would not expect a planetary body with such a low surface gravity to possess a substantial one, so that the discussions of an atmosphere on Io have always been controversial.

But Io does have an atmosphere and an ionosphere too—it is the smallest body in the Solar System with such features. The ionosphere was detected during the Pioneer 10 flyby (Kliore *et al.*, *Science*, **183**, 323; 1974) and was found to extend to some 700 km above the surface with a peak electron density of about 6×10^4 electrons cm^{-3} at an altitude of between 60 and 140 km on the dayside. A thinner and less dense region was observed on the nightside with a peak density of 9×10^3 electrons cm^{-3} at an altitude of 50 km. The diminished nightside ionosphere indicates that this region is produced by the action of solar radiation on the dayside and then decays during the 21 hour Io night.

The Io atmosphere is tenuous, with exotic constituents sodium, calcium, hydrogen, possibly also ammonia and nitrogen, and a surface pressure of between 10^{-8} and 10^{-10} bar. Sodium emission from the satellite's atmosphere provided Brown and Chaffee (*Astrophys. J.*, **187**, L125; 1974) with the first positive evidence for the atmosphere. Trafton, Parkinson and Macy (*Astrophys. J.*, **190**, L85; 1974) reported that the emission came from an extended space around Io. The total column abundance of sodium is estimated to be roughly $10^{11}\ cm^{-2}$ in this extended cloud and $10^{13}\ cm^{-2}$ in the atmosphere of Io.

As well as the sodium cloud, there is around Jupiter in the orbital plane of Io an extensive cloud of atomic hydrogen (Carlson and Judge, *J. geophys. Res.*, **79**, 3623; 1974). The mean diameter of the torus is about equal to the diameter of the orbit of Io. The torus is not complete, however, but seems to

Great Red Spot plastic wrapped by Jovian bolts

by John Gribbin

JOVIAN thunderbolts, occurring at a rate of one per square kilometre of Jupiter's surface every 10 min, may explain the presence of acetylene in the clouds of the giant planet.

Both ammonia and acetylene have been detected in Jupiter's atmosphere, and since both would be rapidly photodecomposed they must be being continuously produced by processes operating in the planet's atmosphere. According to Bar-Nun (*Icarus*, **24**, 86; 1975) ammonia could be produced in the hotter deep layers of the atmosphere and persist for long enough to be carried upwards by convection into the layers where it is detected. But the lifetime of acetylene under Jovian conditions is so short that it must be made closer to the top of the atmosphere.

Bar-Nun's model, which is backed up by laboratory experiments, suggests that the shock waves of thunderstorms are the chief mechanism by which acetylene is produced on Jupiter. The electric discharges of lightning will themselves contribute to some extent, but a much greater volume of gas is affected by the thunder, with the result that significant quantities of methane are converted to acetylene. Ammonia will also be produced in this way, together with hydrogen cyanide, cyanogen and other compounds.

Taking a typical terrestrial storm as a guide, Bar-Nun calculates that $5.3\times10^4\ km^{-2}\ yr^{-1}$ thunderbolts would be needed to produce the amount of acetylene detected. Since Jovian bolts are likely to be more impressive than their terrestrial counterparts, the number may in fact be rather smaller. The compounds produced in these shock waves are almost ideal for explaining the puzzle of Jupiter's colouration, with yellow-brown acetylene polymers and ruby red polymers containing hydrogen cyanide and cyanogen predominating; the correct colour intensity for the Great Red Spot could be produced if thunderstorm activity in the spot is larger than the Jovian average by an order of magnitude.