

letters

be able to acquire such a technology on their own if they wished, and I also believe that they would have an extra incentive to do so if the developed countries withheld the present technology from them.

► I believe that nuclear technology, on the balance, has been of immense benefit to mankind and therefore it would be very detrimental to halt its further evolution or to withhold its results and products from the developing countries.

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11/20/79

Einstein and Maxwell

I feel that another centenary should be mentioned, if not celebrated: James Clerk Maxwell died in 1879, the year Einstein was born. The opening sentence of Einstein's first paper on relativity: "It is known that Maxwell's electrodynamics—as usually understood at the present time—when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena." Considering the fact that Einstein's theory of relativity was born out of considerations based on Maxwell's theory of electrodynamics, the coincidence is striking!

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10/22/79

Our opening paragraphs to the "Einstein" issue (March, page 26) made brief mention of the coincidence. *The Editors*

Jovian issue

In August (page 15), Leonard Larks proposed that the "immiscible" character of the swirling vortices in the Jovian atmosphere might be caused by electromagnetic interactions.

There are two problems with this hypothesis. The first is that there is no detectable correlation between atmospheric and magnetic field features (see, for example, page 806 of *Jupiter*, T. Gehrels, ed., University of Arizona Press, 1976). Since the data have limited resolution, it might be contended that this is not a compelling argument.

A second, more convincing argument (at least from a theoretical point of view) can be made by considering the electrical properties at the relevant level of the atmosphere ($T \approx 130$ K, $P \approx 0.5$ bar). This is well below the ionosphere, yet well above the deep, conducting regions of the planet (see my review paper on page 395 of *The Origin of the Solar System*, S. Dermott, ed., Wiley, 1978). At this level, the only charge carriers would be non-equilibrium species produced by cosmic rays, thunderstorms, and so forth. Al-

though thunderstorm activity may be greater on Jupiter than on Earth (but not by much) it is difficult to justify an electrical resistivity much less than around 10^{15} ohm-cm, the value that characterizes the sea-level atmosphere on Earth (See the *CRC Handbook of Chemistry and Physics*). For this value, it is easy to show from the dynamo and magnetohydrodynamic Navier-Stokes equations that the ratio of Coriolis force to Lorentz force is around 10^{10} . Electromagnetic effects are not, therefore, directly important (for the same reason that they do not directly modify circulation in the Earth's atmosphere).

There is, of course, the possibility of an indirect effect. It is known, for example, that there is a correlation between solar activity and photometric brightness of Uranus and Neptune (G. W. Lockwood, *Icarus* 35, 79, 1978). It is conceivable, therefore, that the behavior of the ionosphere or magnetosphere may affect the behavior of the neutral atmosphere. However, this would hardly constitute an explanation for the "immiscible" character of the motions detected by the Voyager Spacecraft.

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8/23/79

THE AUTHOR COMMENTS: David Stevenson appears to represent the "conventional wisdom" as applied to the fascinating behavior of the Jovian atmosphere.

I agree completely that data of limited resolution do not form a compelling argument against my hypothesis, and while I have not had the opportunity to study the properties of the Jovian atmosphere in depth, I feel that there may be problems with Stevenson's analysis.

Stevenson states that he cannot justify a resistivity of the atmosphere (at the altitude imaged by Voyager's cameras) of less than the order of 10^{15} ohms, which would make the atmosphere a poor conductor or a reasonable insulator. If this estimate is correct, and if the current flux tube between Jupiter and Io, estimated in NASA publications to be on the order of 10^6 amperes (and a possible energy source according to some reports for the volcanic activity on Io), really exists, then the potential difference across the atmosphere where the flux tube penetrates it is on the order of 10^{21} volts. This is well above the atmospheric breakdown voltage given by the *CRC Handbook* for the Earth sea-level atmosphere as 10^9 volts. In the absence of large amounts of atmospheric discharge phenomena near the Jovian terminus of the flux tube one must conclude that

- the atmospheric resistivity is much lower or
- the current in the flux tube is lower than estimated or
- the electrical discharge characteristics

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