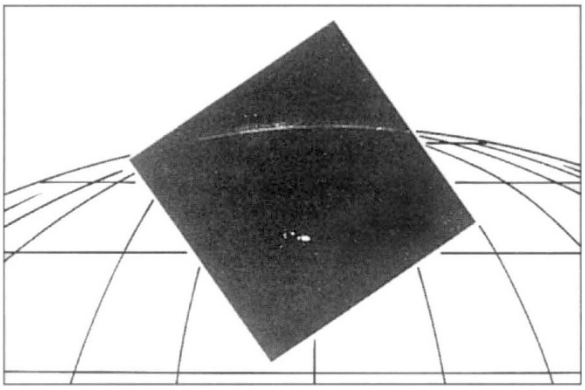
PLANETARY SCIENCE

Probing times for Jupiter

Andrew P. Ingersoll

On 7 December 1995, if all goes to plan, the Galileo spacecraft will swing into orbit around Jupiter, turning its back on the first-ever probe dropped into the planet's atmosphere. The probe, descending by parachute, should be able to take atmospheric data from above the tops of the clouds, where the pressure is several hundred millibar, down to a pressure of 25–30 bar, which is well below cloud base. Water is the key compound, both for the clues it contains about Solar System formation, and for its role in meteorology. On the Earth, moist convection is probably the single most important and least understood process in the climate system. Galileo will at last give us the chance to study moist convection on another planet.



Lightning flashes (below) and auroral arc (above) on the dark side of Jupiter as seen by the Voyager 1 spacecraft in March of 1979.

Lightning was detected by the earlier Voyager spacecraft in images of the dark side of Jupiter[1] and in electromagnetic waves emanating from the planet. So the Galileo probe carries a lightning detector amidst its complement of instruments that measure temperature, pressure, clouds, chemical composition, solar and infrared radiation, and winds. All bear on the abundance of water and the process of moist convection.

Until Galileo starts to supply the answers, modelling by extension of what we know to occur on the Earth is our best hope of understanding the climate of other planets. Two recent papers, one on page 592 of this issue, illustrate this: Yair *et al.*[2] and Gibbard *et al.*[3] apply knowledge of the Earth's atmosphere to calculate lightning in a jovian thundercloud. Heat from below drives rapid vertical motions, which carry cloud particles upwards. Charge transfer occurs when ice particles collide with partly frozen hail. Large-scale electrification follows as the small particles are swept upwards, leaving the large particles behind. A key point is that the modelled clouds produce lightning only when the water abundance exceeds a certain critical value which is close to 'solar' composition — what you would get by cooling a piece of the Sun down to jovian temperatures. Such an atmosphere would be 99 per cent hydrogen and helium. Water would be the most abundant compound, as oxygen is the next most abundant element on the Sun. Will the Galileo probe bear this out, and if so, what are the implications?

Water controls the stability of a climate system — how resistant the atmosphere is to convective overturning. If the atmosphere has abundant water and high stability, the weather might be confined to a layer less than 100 km thick within the jovian clouds. If the atmosphere has no water and low stability, the weather might extend 10,000 km or more into Jupiter's fluid interior. Such differences may help clarify an enduring jovian mystery — how storms like the Great Red Spot can last for hundreds of years whereas storms on the Earth last for days or weeks. Although the winds are stronger than on the Earth, the weather on Jupiter is more predictable. Galileo should help us understand why.

The amount of water on Jupiter has remained a mystery because its vapour pressure is low at the tops of the jovian clouds. Last year, waves from the impacts of fragments of comet Shoemaker–Levy 9 provided indirect evidence that the atmosphere is richer in water than solar composition[4], but the Galileo probe provides the definitive test. Apart from casting light on atmospheric motion, the water abundance will help in assessing the role of comets in distributing volatiles in the early Solar System. A high oxygen abundance relative to carbon and nitrogen suggests a large role for comets during the formation, not just of Jupiter, but of the Earth as well. Planetary scientists will be eagerly awaiting the first data from the probe. □

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2. Yair, Y., Levin, Z. & Tzivion, S. *Icarus* **115**, 421–434 (1995).
3. Gibbard, S., Levy, E. H. & Lunine, J. I. *Nature* **378**, 592–595 (1995).
4. Ingersoll, A. P. & Kanamori, H. *Nature* **374**, 706–708 (1995).

DAEDALUS

Reformed rubbish

Biology has no waste products. All exhaled or excreted matter, and every dead thing, is raw material for some other organism. It can be hydrolysed back to basic biomolecules and used again. Industrial society has no such general recycling reaction. Burning is a poor substitute: it breaks down and detoxifies most industrial and consumer rubbish, but yields only smoke and ash in return. Daedalus now proposes a true universal recycler — steam reforming.

Modern industrial steam reforming is conducted, often catalytically, on hydrocarbons. Hot, high-pressure steam converts them to hydrogen, methane and carbon oxides, useful feedstock gases. The process should work on almost any organic material. Daedalus now reckons that nature got there first. He recalls the mysterious geological process of petrifaction, which slowly replaces dead plants and animals by silica copies of wonderful fidelity. Much of our knowledge of ancient life forms comes from their petrified remains.

The process is badly understood. Normal groundwater contains far too little silica to replace the organic bulk of (say) a tree trunk. One theory is that petrifaction occurs with hot water, which can carry more silica; or even steam, which surprisingly can dissolve still more. (Silica dissolved in steam is a major headache for turbine engineers.)

So Daedalus reckons that petrifaction is simply geological steam reforming. Hot, silica-saturated steam from local geothermal action diffuses into the dead specimen and reforms it. The resulting gases do not dissolve silica, which is precipitated. The more organic material at any point of the specimen, the more steam is used up in the reaction, and the more silica is precipitated. The organic structure is thus perfectly replaced by silica. The process could be very fast — many vapour-phase cracking reactions use silica-based catalysts.

This elegant theory suggests a new form of rubbish disposal. Daedalus hopes to replace our unpopular incinerators with giant silicated-steam reformers for all kinds of organic and plastic junk. Old newspapers, discarded clothes and furniture, packaging and food waste, obsolete computers, all will be catalytically steam-reformed away to useful gases, leaving perfect silica copies in their place. These should really be crushed and fed back into the steam for recycling; but Daedalus likes the idea of burying them as landfill, to astonish future archaeologists. He also plans a steam reforming crematorium, which simultaneously produces a silica statue of the deceased.

David Jones