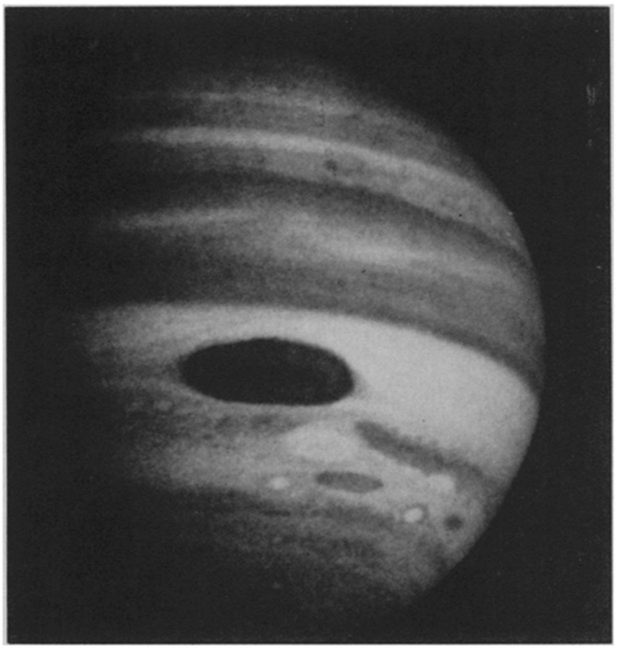
JUPITER



Being mostly atmosphere, Jupiter has lots of weather, which stretches itself into belts and zones. Explanations differ.

First of a two-part series

BY DIETRICK E. THOMSEN

Viking has reached Mars. The same week Soviet scientists in an ebullient and forthcoming mood presented the first interpretations of the data relayed by their Venus landers to a COSPAR meeting in Philadelphia. Earthlings' explorations of our near neighbors in space, the terrestrial planets, have become the staple activity of the world's two major space agencies.

The Pioneer 10 and 11 expeditions were unique in that they were the beginning of the extension of our comparative planetology beyond our own familiar homeground. They went to the definitely unterrestrial Jupiter, the mysterious giant of the solar system, the "planetless planet," the failed star that would look to an observer from Alpha Centauri like the sun's invisible dark companion. The Pioneers sent back an encyclopedic pile of Jupiter information, that might be called "Jupiter from core to magnetotail." A digest of it was presented during one of the weeks while Viking approached its rendezvous with Mars and the Soviet Venus experts approached the symposium in Philadelphia.

It seems appropriate to begin with Jupiter's atmosphere. The most salient characteristics of the terrestrial planets are their hard surfaces, against which our landers bang themselves softly—or so the engineers hope. Atmospheres, important though they may be, tend to be regarded as wrappers. In Jupiter's case, the bulk of the object is mostly atmosphere.

At exactly what level it ceases to be atmosphere and becomes some more exotic fluid, is a matter of argument, depending on the effects of pressure on the laws of gas behavior, but a solid surface, a silicate core like the bodies of the terrestrial planets, is so deep inside that its existence is a matter of some controversy. It is the top of Jupiter's atmosphere that we see through telescopes, and the features of that are those which astronomers have argued about for centuries.

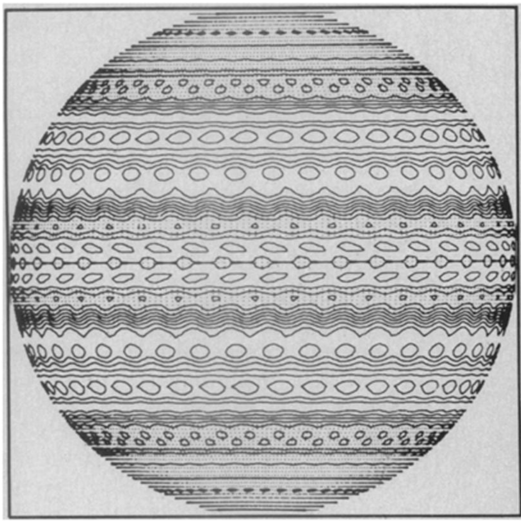
So if investigations of the terrestrial planets built up the science of cosmic comparative geology, the visit to Jupiter has made a salient contribution to that of comparative cosmic meteorology. Jupiter's weather has both important differences and significant parallels to that of the earth.

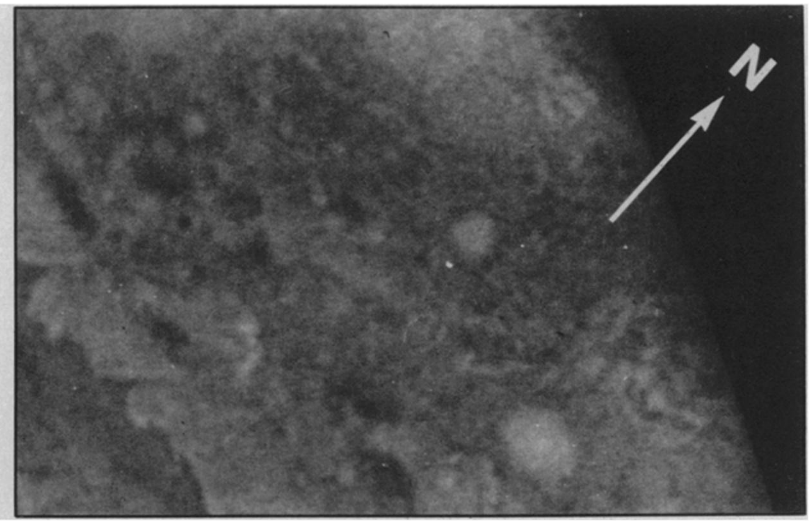
The most striking feature of the visible Jupiter is latitudinal striation. The top of its atmosphere shows zones separated by so-called belts. The belts and zones are nearly perfectly aligned along parallels of Jovian latitude.

Some things in this picture "we all agree on," says Andrew Ingersoll of the California Institute of Technology: "Everything in the picture is cloud. There's no solid surface within a conceivable range of what we see. The planet is entirely fluid. [Some would opt for a tiny rocky core.] The atmospheric motion is powered by internal heat," the famous and still somewhat mysterious internal heat source that generates about as much heat as Jupiter receives from the sun. Also the motions in the atmosphere are generally vertical.

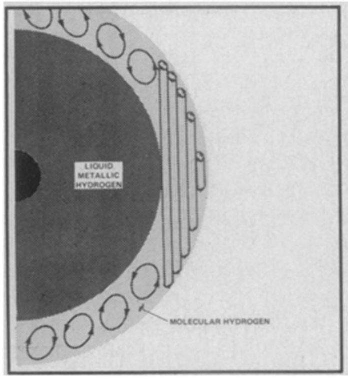
Among the number of possible theories of what causes the striations, on which there is much disagreement, Ingersoll proposes one that depends on the latent heat of condensation. Observation shows that the zones are cloudy and the belts clear, he points out. This can indicate that there is condensation present—of water vapor. Condensation releases a certain amount of heat, representing the energy lost by the gas molecules as they bind themselves into a liquid structure. The heat release would create cyclonic structures as it does on earth, but these structures would spread themselves latitudinally around the planet—great hurricanes stretched out all the way around Jupiter.

At first blush, this picture of a planet with weather circulating in strict horizontal bands seems to be radically different from earth, where the convection cells that are cyclones and anticyclones move east and west and north and south in complicated swooping patterns. But Ingersoll points out that this two-dimensional weather motion is characteristic of the earth's so-called temperate zones. In the tropics there happens to be a banded cir-

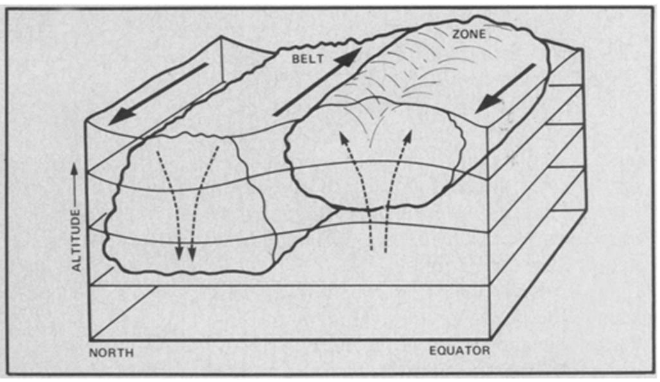




Computer simulation of turbulence in Jovian atmosphere by Gareth Williams of Princeton compared to Pioneer 11 photo.



In Ingersoll's view, warm, moist air rises in the belts; cool, dry air falls in the zones. Rotation deflects motion 90° to make horizontal circulation (r). Busse's picture has circulation in cylindrical shells parallel to planet's axis (l).



culation based on the Hadley cells.

Satellite pictures of the earth tend to show a cloud-band circling the equator with clear bands on either side of it. This looks much like a Jupiter zone-belt pattern. On the ground its effect can be traced in the band of rain forests that follow the equator around through South America, Africa and South Asia and in the semiarid to desert areas (e.g., the Sahara) that flank the jungles. It is also responsible for the tradewinds, which blow so steadily in one direction that part of the Lesser Antilles are called Leeward Islands and part Windward Islands, and in sailing ship days everybody knew which was which. Now, Ingersoll says that the wavelength, the characteristic breadth, of this cyclic pattern, happens to be about equal to the radius of the earth so that it has no opportunity to repeat itself in the midlatitudes. On Jupiter, a planet ten times as big as the earth, it can repeat itself.

Fritz Busse of the University of California at Los Angeles, presented a different theory, a model that, when depicted by one of NASA's painters led a participant to say "that's the sort of thing you might get in a pastry shop." Busse says the atmospheric circulation is in cylinders parallel to the axis of rotation. These cylinders are stacked around the axis in concentric circles. The spherical surface of the planet cuts off each layer of cylinders at a different length, and the cut-off tops and bottoms of the cylinders form the pattern of latitudinal striations. Busse points out that laboratory experiments intended to simulate conditions in the Jovian atmosphere yield this kind of cylindrical circulation pattern. When Jupiter is painted up according to these assumptions it looks like a structure of pastry rolls with chocolate frosting, a kind of planetological *croquembouche*.

One of the most famous features of Jupiter's atmosphere is the great Red Spot. Astronomers have engaged in endless speculation and argument about its nature. Observers have suggested that it was a column of the atmosphere hooked on the top of an extra-high mountain, or that it was a permanent hurricane. It seems now that these old explanations must be discarded in favor of one that sees the spot as a pure atmospheric feature, a kind of frozen wave pattern.

The spot lies between two zones in the south temperate region of the planet. The atmospheric flow in adjacent zones is in opposite directions so the spot would tend to rotate and roll along like "a giant gear wheel," as some of the scientists put it. Pioneer measurements show that the spot is the highest atmospheric feature; its top is some 8 kilometers above the surrounding cloud deck. (At this height phosphorous would condense out, giving the red appearance.)

Rather more elegant than the gear wheel is the description by Tony Maxworthy of the University of Southern California, which which refers to the Red Spot as a solitary wave solution. It is rather as if a wave approaching the beach and cresting did not break, but propagated itself through the water. Computer simulations of the flow in the Jovian atmosphere by Maxworthy and Larry Redekopp indicate that such solitary crests (called solitary because they stand alone and are not part of a pattern of crests as one sees on the ocean) will form, and that the Red Spot could be one. Such solitary crests would rotate as the Red Spot is seen to do. If the theory is correct, there should be other such solitary waves present, and indeed such spots are seen from time to time. They are not as spectacular as the Red Spot and they don't last as long, but the Red Spot's relative stability (it has been seen for more than 300 years) may be due to its great size. The theory predicts how two such solitary waves should interact when they collide with each other, and in fact, such a thing has happened on Jupiter. The theory says that the Red Spot and another spot should speed up as they approach each other, and after they cross each other with some mixing of their flows, they should emerge without change in shape. Photographs of Jupiter show such processes. □

Next: Jupiter's magnetosphere, the planet's evolution and the possibilities of life.