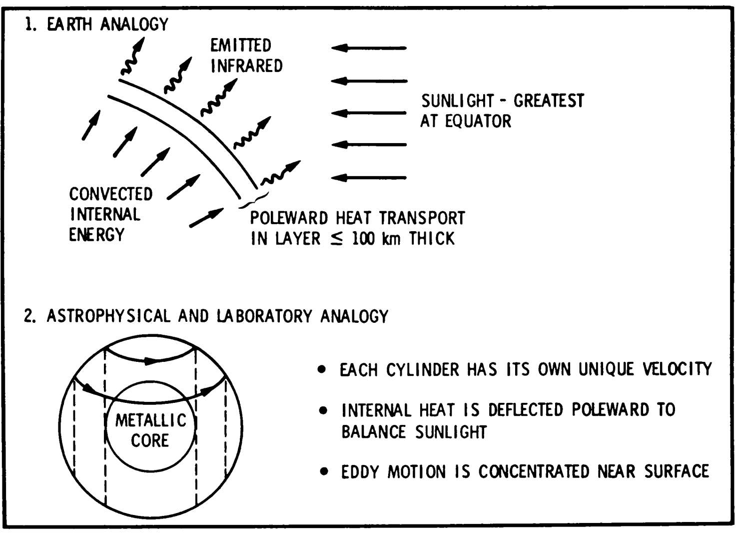
The book of Saturn: Judging by the cover

For more than a year prior to Voyager 1's recent flyby of Saturn, frustrated scientists peered in vain at the spacecraft's photos, hoping to find visible markings in the clouds other than the same old axisymmetric stripes. Pioneer 11, passing by 14 months before, had revealed virtually none, and it was not until the final weeks of Voyager 1's approach that some spots, swirls and other features began to be visible. Such details are keys to tracking the winds, vital clues to understanding the inner Saturn. But the new results are leaving many questions unanswered.



A. Ingersoll et al

An earth-type planet the size of Jupiter or Saturn would distribute its primarily solar heat via a thin atmosphere. The stripey "fluid" planets may circulate their largely internal heat through essentially a nest of rotating cylinders.

As the Voyager data show, Saturn's band of equatorial winds reaches speeds up to four times as great as Jupiter's and spreads nearly three times as wide, extending from 40°N to 40°S in comparison with the Jupiter belt's ±15° (see chart, SN: 11/22/80, p. 326). But, on a world that is both smaller and cooler, why? One explanation, suggests Garry Hunt of University College, London, may be that cooler Saturn has thicker cloud layers of water and ammonia than does Jupiter, and the extra heat released by their condensation rises to add more energy to the eddies that Hunt and others believe drive the zonal wind flows. The stronger flows, says Hunt, would naturally account for the wider latitudinal band along which the winds move before encountering radically different velocities that amount to shear zones. And indeed, although incoming solar energy and internal warmth combine to give Saturn barely a third of Jupiter's total heat (5 watts per square meter versus 14), says Andrew Ingersoll of Caltech, the smaller planet has about 16 times as much kinetic wind energy.

But this raises another question. Jupiter gives off about 1.8 times as much heat as it receives from the sun, just what one might expect from its compression and cooling, but Pioneer 11 scientists have calculated that Saturn's excess may be a factor of 3 or more. One thought has been that some of it could be energy released by the gravitational separation of Saturn's helium from its dominant hydrogen, a process proposed to be just beginning on Jupiter but underway for perhaps 2 billion years on the smaller world (which would supposedly cool more quickly to the point at which the helium could precipitate out). This ought to show as a reduced percentage of helium in the top of Saturn's atmosphere compared to Jupiter's, but Voyager 1 has confirmed Pioneer 11's indication that the two planets are the same. And with the seemingly obvious heat source ruled out, it's back to the drawing board.

One possibility is that the calculation from Pioneer 11 data of Saturn's excess heat is simply too high. Early looks at Voyager 1's data are believed to be pointing toward a lower number — but not enough lower to eliminate the discrepancy. Another factor, Ingersoll suggests, could be that Pioneer 11 saw only Saturn's southern hemisphere, and hence only one season, while Voyager 1 may have gotten a truer picture from its views of both north and south. A further uncertainty is the lack of knowledge about just how much heat a highly compressed ball of hydrogen and helium can actually hold.

Whatever the source of Saturn's "excess excess," Voyager 1's initial look at the winds is merely turning out to be confusing. "Theory actually predicts that the 'jets' should be broader," says Hunt, and the bands of wind indeed are. But the colored stripes visible in the photos are in fact *narrower,* forming an "enormous" number of belts and zones. And, as in the case of Jupiter, Voyager's infrared temperature maps of Saturn's upper atmosphere correlate more closely with the thin color stripes than with the winds.

Yet *some* mechanism drives the winds, and the numerous eddies revealed in closeup photos are still a candidate. Painstaking studies of Voyager 1's photos of Jupiter, Ingersoll says, show that the eddies are indeed giving energy to at least the visible stripes, rather than being


JPL

Cloud features near Saturn's south pole.

driven *by* them. The giant planet's famous Great Red Spot, for example, turns out to spin more rapidly than could be accounted for by the shear winds enclosing it. (Jupiter's eddies seem almost *too* energetic, in fact. Every 50 to 100 days, according to Jimmy Mitchell of Jet Propulsion Laboratory, they provide the equivalent of the total energy requirement of all the belts and zones, so why don't the winds just blow faster and faster? Apparently, he says, some of the eddies are actually "takers" rather than "givers," and bleed off some of the excess. A few even appear to have changed roles during their lifetimes.)

But what kind of internal heat-transport system do the eddies represent? The complex question is critical to Voyager's head-scratching interplanetary meteorologists. If, according to Ingersoll, Jupiter or Saturn were like the earth — predominantly hardrock worlds with thin atmospheric blankets and getting most of their heat from the sun — the incoming solar energy would be concentrated at the equator, from which it would be carried poleward by the blanket. Instead, most of their heat comes from within. One idea, says Ingersoll (though he calls it "extreme"), is that the inner motions of Jupiter and Saturn could take the form of concentric cylinders, spinning around each planet's rotation axis at different speeds. The visible (or wind-pattern) stripes would mark the intersections of the cylinders with the spherical "surface." Saturn's faster winds, he adds, could result because its smaller core (about 45 percent of its radius versus about 75 percent in Jupiter's case) leaves room for a greater number of cylinders, each turning faster than the one inside it. One problem with such a notion, however, notes Rita Beebe of New Mexico State University, is that the general hemispherical symmetry of Jupiter's winds sometimes breaks down, with windspeeds at a given northern latitude occasionally different from those at matching latitudes in the south, which would presumably be the opposite ends of the same cylinders. Saturn won't be easy. □