SCIENCE NEWS of the week

A Model Spot for Jupiter

Jupiter's Great Red Spot, a gigantic mass of circulating fluid in the planet's thick atmosphere, has survived for centuries despite the turbulence surrounding it. How such flow features can exist has been a longstanding scientific puzzle. Now researchers have managed to construct both a simple computer model and an analogous laboratory experiment that reproduce the Red Spot's main features.

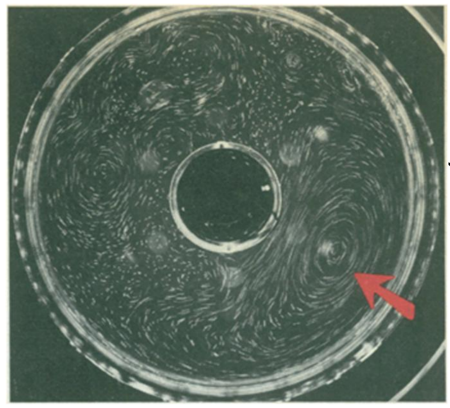
"We've reduced the problem to a very simple situation," says graduate student Steven D. Myers. "The actual Jovian atmosphere is more complicated, but we think we now understand the fundamental mechanism involved in the Red Spot — why it has such a long lifetime, why it exists at a particular latitude, and why it is the shape it is." Myers is a member of the team that did the experimental work at the University of Texas at Austin.

The experiments were inspired by the theoretical studies of Philip S. Marcus of the University of California at Berkeley. Several years ago, Marcus had suggested that organized features could appear in the midst of chaotic fluid flow (SN: 6/2/84, p.340). Subsequent numerical simulations showed that large, stable vortices arise naturally from solutions of the equations of motion governing Jupiter's atmosphere. Marcus's latest results, along with the experimental work done in Texas, are reported in the Feb. 25 NATURE.

The experiments were done in a rapidly rotating, circular tank, nearly 1 meter in diameter. A sloping bottom, highest near the center and lowest at the tank's rim, mimicked the effect of latitude on the forces responsible for skewing liquid flow. Water was pumped into the tank through an inner ring of six inlets, and it drained out through a corresponding outer ring.

At a sufficiently high pumping rate, with the tank spinning at 4 revolutions per second, the researchers found that a jet of water begins to flow in a direction opposite to that normally expected in a rotating system. As a result, some water moves in one direction while the rest moves in the opposite direction, establishing a shear zone. A large, stable vortex, bounded by the zone's edges, forms within this layer.

This result matches the observation that Jupiter's Red Spot also sits in a shear zone, rolling like a giant ball between a westward current to the north and an eastward current to the south. The laboratory model's pumping action, which is responsible for establishing the shear zone, may imitate planetary convection currents that carry fluid into and out of the layer containing the Red Spot.



Myers et al./Univ. of Texas at Austin

Plastic beads suspended in water show the formation of a large, stable vortex within a tank rotating at 4 revolutions per second.

Both the computer simulations and the experiments show that a large vortex may initially form by the amalgamation of many smaller vortices. Furthermore, despite forces that dissipate its energy, a large spot seems to maintain its size over a long time period by absorbing tiny vortices that happen to form in its vicinity.

— *I. Peterson*

Violating a not-so-exclusive exclusion principle

The Pauli exclusion principle stands at the basis of the structure and stability of matter. It prevents atoms, nuclei and larger structures, up to and including neutron stars, from collapsing on themselves. It does so by decreeing that no two particles of the class called fermions that have the same set of properties (the same quantum numbers) can be in the same place at the same time. The particles of physics are divided into fermions and bosons, and while any number of bosons can be in the same place, the exclusion principle maintains structures made of fermions (electrons, protons, neutrons) by restricting them.

Historically, physicists have believed the principle to be absolute. But now a few are asking, "Can it be violated?"

To explore that question, Oscar W. Greenberg and Rabindra N. Mohapatra of the University of Maryland at College Park have developed a theory that permits a slight violation of the exclusion principle. Experiments to test their theory are likely to follow.

According to Greenberg, the argument underpinning the absoluteness of the exclusion principle, using the statistical laws obeyed by fermions and bosons, makes a couple of false assumptions. As he said in a lecture last week at the National Bureau of Standards (NBS) in Gaithersburg, Md., those statistical principles are not general enough to support the argument. Greenberg and Mohapatra searched for a more generalized statistical law. When they found it, they discovered that it permits the existence of particles they call "parafermions" or "parons," which can violate the exclusion principle. The chance of violation is extremely small, about 1 in 100 million. However, this could produce unusual atomic states.

The experiment that may be closest to realization is one proposed by Daniel Kelleher of NBS, which would use helium atoms. Helium has two electrons, and according to the exclusion principle the spins of these two electrons must always be in opposite directions. However, a "paronic" helium atom, if one exists, could have its electron spins parallel. Each spinning electron is a little magnet producing a small magnetic field, or magnetic moment. With the spins antiparallel, the two magnetic moments cancel each other and the helium atom has no magnetic moment overall. Parallel spins mean parallel magnetic moments, which add together to give the atom a net magnetic moment. Kelleher's experiment would use magnetic fields to deflect and count paronic helium atoms. He told SCIENCE NEWS that he expected to hear in a few days whether NBS would fund the work.

In addition to producing unusual atomic states, the proposed violation of the exclusion principle relates to two important questions in modern particle physics, the many-dimensioned or Kaluza-Klein theories and the CPT theorem. Attempting to unify all of physics in one grand theory, theorists have postulated that space really has up to a dozen dimensions. We do not perceive the extra dimensions because they are tightly curved into microscopic balls around each point in ordinary space. The exclusion-principle violation can be related to the existence of these extra dimensions, and finding it could be evidence that they are really there.

The CPT theorem, one of the fundamental principles of physics, proposes that nature is symmetric with respect to matter and antimatter. If the exclusion principle is violated, so is CPT.

Greenberg doesn't know what the ultimate effects of a violation of the exclusion principle might be, but as he said at NBS, "Small-scale phenomena can have large-scale effects."

— *D.E. Thomsen*