type neutrinos strike electrons and scatter elastically. But in this case there are also contributions from charged currents because the electron neutrino can annihilate the electron, produce a charged intermediate vector meson, which then turns back into an electron neutrino and an electron.)

Since the Lee-Yang paper, various experiments have searched for neutral currents. Frederick Reines and his collaborators, using the Savannah River pile, have determined an upper limit on the cross section for an electron-type neutrino or antineutrino scattering off an electron. The results were consistent with no neutral currents within that limit. An experiment at Gargamelle has used muon-type antineutrinos scattering off electrons. Recently one event was found that could have been a neutral-current process, but it is difficult to distinguish it from background.

Weinberg feels that the new experiments from CERN and NAL provide an enormous shot in the arm for the whole idea of spontaneously broken gauge theories of the weak and electromagnetic interaction. He notes that it is hard to imagine such theories unless there were also neutral currents, although Sheldon Glashow and Howard Georgi actually did discuss such a theory about a year ago. A lot of physicists were beginning to feel, Weinberg told us, that if neutral currents were not found, perhaps something was wrong with the whole idea. Weinberg feels that if one takes the reported accuracy of the CERN and NAL experiments at face value, there is already significant quantitative agreement between theory and experiment.

Several experiments, which unlike the CERN and NAL experiments, are designed especially to look for neutral currents, will be running this fall and winter at Brookhaven. Both the CERN and NAL experiments are continuing.

Meanwhile, even if neutral currents are indeed found, no one is claiming that Weinberg–Salam theories must be right. Even Weinberg believes that the model he proposed in 1967 is probably not the final answer because it is not sufficiently pleasing from an aesthetic point of view. He feels that his model may be part of a larger theory in which there are intermediate vector mesons that are so heavy that they produce weak interactions weaker than the ordinary weak interactions—so weak that they have not yet been experimentally observed. —GBL

## Auroral effects seen in laboratory vortexes

An explanation of the aurora's undulating folds and rays may come from models of instabilities, some of which were developed to explain effects seen in the laboratory. The folds and rays appear to be vortexes of charge density that occur when the aurora charge sheet becomes unstable above a certain charge density. Work reported by Harold F. Webster (General Electric) and Thomas J. Hallinan (University of Alaska)[1] has centered on the analysis of charge distribution in current sheets and charge sheets in the presence of a magnetic field and its possible usefulness as an auroral model.

Laboratory experiments have shown that vortexes occur in electron beams when the charge density exceeds a certain threshold. Charge concentrations cause the sheet beam to ripple. In turn, there is electron flow toward these curves that serves to reinforce the charge concentration.

In addition to the more widely known charge-sheet instability, a current-sheet instability should exist that will produce geometrically similar instability patterns. In place of the drift velocity of charge caused by asymmetry in the charge sheet, is the transverse velocity of current caused by a perpendicular component of the magnetic field $B$ generated by the current. This form of instability has not, however, been directly confirmed by laboratory experiments.

The rate of instability growth for both the charge sheet and current sheet is dependent on several factors. The growth time of the charge-sheet instability $t_K$ is

$$t_K = (2B\epsilon_0/\rho)(\lambda/d)$$

where $\rho$ is the charge density, $\lambda$ is the wavelength of the disturbance and $d$ is the sheet thickness. The growth time $t_j$ for current-sheet instability is

$$t_j = 2\pi(2B/V\mu_0 j)$$

where $V$ is the charge velocity and $j$ is the current density. Both expressions show that a higher magnetic field suppresses the instability and a higher charge or current density promotes instability.

Photographic evidence appears to indicate that both types of instabilities contribute to auroral morphology. Auroral rays often appear as vortexes. Those that are about two kilometers across and spiral in a counterclockwise fashion when viewed antiparallel to $B$ are of the charge-sheet instability type, caused by an excess of electrons in a sheet of precipitating particles.

These particle sheets occur in groups and in some ways can act in unison and, therefore, be treated as a single thicker sheet. The thicker sheet forms clockwise spirals with a diameter of 30 to 1400 km. These spirals appear to be characteristic of current-sheet instability—electron flow in both hemispheres appears to be the cause of the particular rotational sense.

Another phenomenon is the occurrence of less complex auroral folds, folds whose development has been arrested in an early stage. These may be kink instabilities that, unlike a current-sheet instability, are dependent on a finite current-sheet width. Typically, current-sheet widths are too large for kink instabilities; hence it is expected that current instabilities dominate in aurora. —RAS

**A clockwise vortex structure** forms in a laboratory electron sheet beam (left). A model developed by Webster and Hallinan may serve to explain this pattern and one of similar appearance in aurorae (right). This example was recorded by a low-light TV camera.

### Reference

1. H. F. Webster, T. J. Hallinan, Radio Science 8, 475 (1973).