A New Source of Power to Drive the Aurora

After fierce but brief magnetic storms peter out, mysterious waves from the sun keep the northern lights going for days

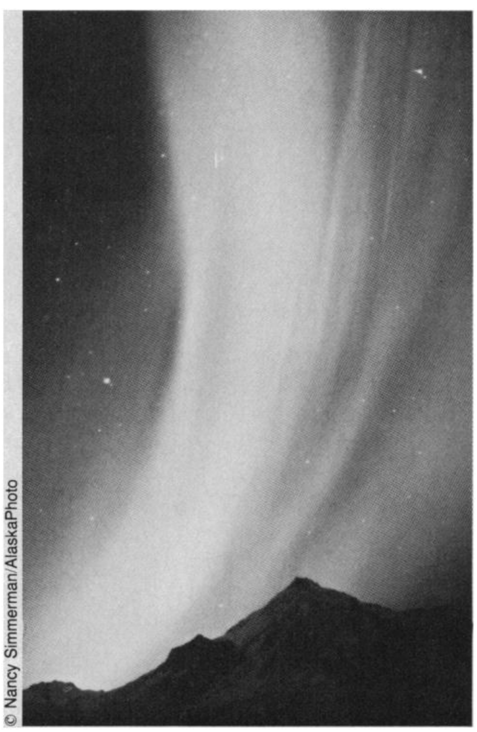
WHEN Bruce Tsurutani was launching balloons into the upper atmosphere of the far north back in the 1960s, the story was that the days-on-end episodes of northern lights there simply reflected the slow decay of solar energy that arrived earlier during a magnetic storm. There have been some refinements since those graduate student days of Tsurutani's, but the idea that all auroras are driven by the same solar energy source has lingered.

Recently Tsurutani and Walter Gonzalez of the Jet Propulsion Laboratory demonstrated for the first time that Alfvén waves, magnetic oscillations of uncertain origins on the sun, drive the aurora much of the time, even when there has been no recent magnetic storm. This realization clarifies why auroras occur but offers little encouragement to those attempting to improve the prediction of magnetospheric activity.

The ultimate goal of solar-terrestrial research is the prediction of the effects on the magnetosphere of Earth created by the energy and charged particles released by the sun. The magnetosphere is Earth's teardrop-shaped magnetic field that traps charged particles and channels part of the sun's energy into the aurora. Those solar effects include the lovely aurora as well as severe disruption of communications and interference with the operation of high-flying satellites. Unfortunately, most scientists in the solar-terrestrial community tend to stick with either the sun or the magnetosphere and ignore the link between the two. Researchers did reach general agreement almost a decade ago that a southward orientation of the weak interplanetary magnetic field thrown off by the sun acts like a key when it reaches Earth to unlock a door and allow the flow of solar energy into the magnetosphere. Still, even the sighting of a major flare on the sun does not allow reliable prediction of a magnetic storm, because no one can say for sure how the impinging magnetic field will be oriented.

Although implicit assumptions about energy sources had been made by others, Tsurutani and Gonzalez decided to pinpoint just what it is in interplanetary space that drives magnetospheric activity such as the aurora. So they compared two measures of magnetospheric activity determined on the ground with the ISEE-3 satellite's record of the interplanetary magnetic field and charged particles that were about to encounter the magnetosphere.

As others had noted in passing, magnetospheric activity could continue for days, sometimes almost a week, after an interplanetary disturbance—typically a shock wave followed by an accelerated solar wind, a burst of dense plasma, and an intensified magnetic field—had generated a 1- or 2-day-long magnetic storm. In two of eight cases during the August 1978 to December 1979 study period, protracted activity followed interplanetary disturbances that failed to produce a magnetic storm.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Making the sun-aurora connection. *The aurora or northern lights is the end of a 150-million-kilometer trip for solar energy that left the sun days earlier. The recognition that relatively slow Alfvén waves arriving up to a week after a magnetic storm can drive prolonged auroras extends the transit time from a few days to a couple of weeks. The colorful auroras occur at altitudes of 100 to 300 kilometers.*

The one element that the eight episodes of protracted activity had in common was the presence of Alfvén waves streaming out from the direction of the sun. These oscillations of magnetic field lines had been credited with helping to accelerate the solar wind to its speed of 400 kilometers per second but not with the transfer of solar energy to the magnetosphere. Tsurutani and Gonzalez make that connection because the presence of Alfvén waves coincided with the times of protracted activity, and the waves correlated in detail with magnetospheric activity. When the wave period is several hours, a strong correlation between the southward component of the Alfvén waves and magnetospheric activity is apparent to the eye. When the period is much shorter, the correlation is considerably lower, apparently because ISEE-3 was too far off the sun-Earth line to faithfully record such waves.

Surveying all the activity in the record, not just the eight strictly defined events of their quantitative study, Tsurutani and Gonzalez find that "a majority of all auroral activity is associated with Alfvénic fluctuations of this type." Thus, most auroras occur not during classic magnetic storms as a result of a sharp jolting of the magnetosphere, but later during a gentler, pulsating interaction that can also open the door between the solar wind and the magnetosphere.

The recognition of a second source of solar energy for the aurora does little to improve the outlook for long-range forecasting of the sun's disruptive effects. Researchers would like to monitor the sun in order to predict its effects at Earth 2 to 4 days later when the solar wind completes its trip. But no one is even sure how Alfvén waves are generated, and they cannot be detected near the sun.

The generation of the disturbances such as solar flares that produce the more intense magnetic storms can be watched from Earth, but by the time they arrive the orientation of their magnetic fields may have changed or another field picked up along the way may actually have unlocked the magnetosphere. The best solution to the prediction problem, says Tsurutani, may turn out to be a satellite upwind of Earth that can give at best an hour's warning. ISEE-3 is no longer there and its replacement, called Wind, is not scheduled for launch until 1993 or later. ■ RICHARD A. KERR

ADDITIONAL READING

B. T. Tsurutani and W. D. Gonzalez, "The cause of high-intensity long-duration continuous AE activity (HILDCAAs): Interplanetary Alfvén wave trains," *Planet. Space Sci.* **35**, 405 (1987).