Coherent Radiation in Upper Atmosphere

Stanford University scientists experimenting with sending radio signals along the earth's magnetic field lines have made two important discoveries: Particles from the earth's radiation belts are being precipitated into the ionosphere by radio waves from electric power lines, and the coherent (laser-like) interaction between the waves and particles represents a fundamental new phenomenon in plasma physics. The group, headed by Robert A. Helliwell, will publish its findings in the JOURNAL OF GEOPHYSICAL RESEARCH.

Interest in particle motion along the magnetic field lines began several decades ago with the discovery of a peculiar, audio-frequency radio wave they produce, called a "whistler." Using very simple equipment (earphones connected to a fence line have worked), one can hear naturally occurring whistlers caused by lightning. It's a sound like that of a toy skyrocket descending. The Stanford group has been creating artificial whistlers using a 100,000-watt radio station with a 13-mile antenna at Siple Station, Antarctica.

The researchers were puzzled that their emitted signals were somehow amplified up to 1,000 times before they reached a receiving station at the other end of the magnetic field line, in Roberval, Quebec. In an interview with SCIENCE NEWS, Helliwell said the effect now appears to be a fundamental property of plasmas, not yet adequately explained by theory. Charged particles spiraling along the magnetic field line are apparently "organized" by the radio waves to radiate coherently (with one frequency, in phase) like a laser.

Amplification of the radio signal results from energy lost as radiation by the particles as they slow down. This process is just the opposite of one that takes place in high-energy laboratory accelerators, where radio waves are used to speed up atomic particles. Helliwell says similar phenomena may operate at the astronomical level and speculates that pulsars may involve some sort of coherent radiation from plasmas.

Meanwhile, some unintentionally produced artificial whistlers may be significantly affecting the ionosphere, the layer of the atmosphere used to bounce communication signals around the world. The sources of this disturbance are vast grids of electric power lines, which apparently radiate enough low frequency radio waves to cause "dumping" of charged particles from the radiation belts into the ionosphere. The current moving through these power lines has a 60-cycle frequency, but just as a violin string seems to produce one clear tone but in fact vibrates with a combination of many higher frequency

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Part of 13-mile antenna at Siple Station.

"harmonics," the power lines can radiate wave frequencies of several kilohertz.

These VLF (very low frequency) radio waves penetrate into the radiation belts, and as they are amplified, become so energetic that they tear loose some particles from the magnetic field line along which they are traveling. When these particles fall into the ionosphere they change its ability to propagate communications signals, much as do the particles from magnetic storms. Secondary radiation has been detected at altitudes as low as 30 kilometers, where it might produce some yet undiscovered weather changes. The dynamics of atmospheric electricity is one of the least understood components of weather formation and Helliwell calls a possible role of whistler-dumped particles "very tenuous."

Artificial whistlers hold the promise of being able to control the propagation properties of the ionosphere at will. By radiating VLF waves along specific magnetic field lines, engineers could control the particle content of the ionosphere below. Such control could be made virtually complete, Helliwell says, if additional particles were injected by giant electron guns mounted in spacecraft. (Whether such jiggering might also affect the aurora borealis remains to be seen.)

Whistlers themselves can also be used for communication—morse code signals have been sent along field lines from Siple Station to Roberval, using whistlers. But the most important use of the new technique may be as a scientific tool for exploring little known processes of the upper atmosphere. □

Quick X-ray source: Gravity wave power?

A number of astrophysicists have long contended that gravitational radiation would be an important factor in the evolution of certain kinds of astrophysical systems, especially closely spaced heavy binary-star systems. Gravitational radiation is the gravitational analogue to electromagnetic radiation. According to theory, it should be produced by heavy bodies undergoing accelerated motion. Binary star systems fit the prescription very well. Two theorists from the Institute of Astronomy at Cambridge University in England, J.E. Pringle and R.F. Webbink, believe that for the first time such a binary system dominated by gravitational radiation may now be under observation. It is the variable and transient X-ray source Ariel 1118-61 (Monthly Notices of the Royal Astronomical Society 172:493).

The reason for invoking gravitational radiation is the unusually quick pulse rate of this source, 6.75 minutes. This is much shorter than the pulse rates that theorists think are caused by orbital rotation of components in previously observed binary X-ray sources (typically days) and longer than periods believed to be the result of the spin of a single neutron star (a few seconds).

Pringle and Webbink propose that the periodicity is due to orbital motion. Because of the quick rate, the two components have to be very close to one another. Under the circumstances both components would have to be very compact, and the two theorists suggest that one is a white dwarf and the other a neutron star or black hole. Two such highly compact bodies would have very strong gravitational fields, and their rotation about each other at a close distance is a classic case, according to Einsteinian theory, for generation of gravitational radiation. Gradually they would transmute the energy associated with their rotation into gravitational waves and radiate it away.

The X-ray emanations would be produced by matter streaming from the white dwarf and falling on the companion. The rate of transfer would be governed by the rate of generation of gravitational radiation, and it is usually too much for the compact source to accept. So there will be a cloud of unassimilated matter surrounding the compact object that normally absorbs the X-rays and changes them to ultraviolet. Occasionally the mass transfer rate drops; the cloud dissipates, and X-rays get through. This explains why the Ariel satellite saw the object for only a few days. □