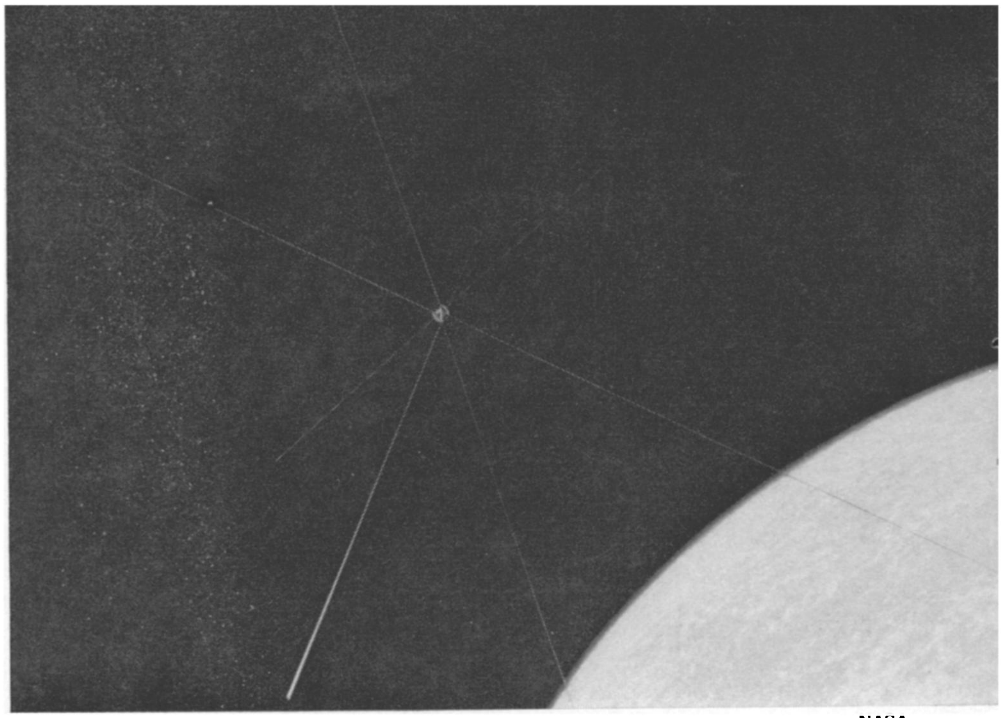
SOLAR PHYSICS

Monitoring the sun's violence



NASA

RAE-I: Above the ionosphere to map low-frequency radio waves.

Satellite detection of long-duration radio storms proves fruitful

by Dietrick E. Thomsen

To radio astronomers the sun is a very noisy object. It emits a bewildering variety of strong signals over a wide range of frequencies.

Many of these signals are sharp outbursts generated by physical processes going on in the outer layers of the sun. Study of these radio outbursts yields information about the mechanisms of solar activity, but the work has been difficult because the bursts are of very short duration—some only fractions of a second—and the locations of emission are hard to pinpoint.

Now there is evidence for a form of solar burst activity lasting over several days, at least four or five and in some cases an entire solar revolution period of 27 days, that promises to make the study somewhat easier. The prolonged activity consists of storms of so-called Type III radio bursts, locations that repeatedly emit such bursts.

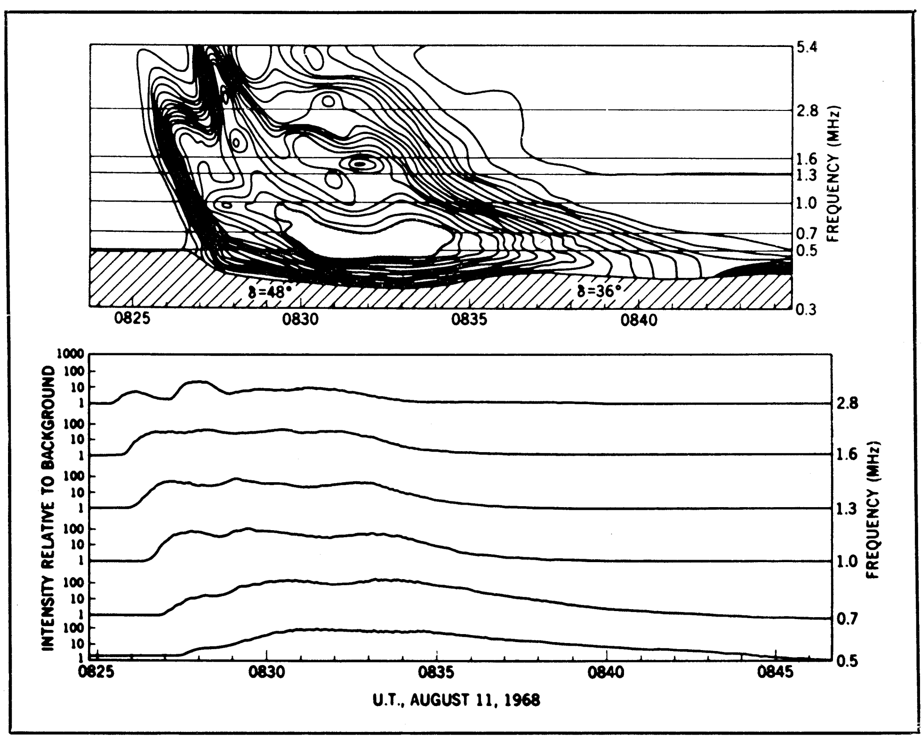
The discovery was made with the Radio Astronomy Explorer satellite RAE-I and is reported by Drs. Joseph Fainberg and Robert G. Stone of the National Aeronautics and Space Administration.

Type III bursts are defined by two characteristics: The first is a quick rise and fall of the signal intensity, lasting a fraction of a second at 100-megahertz frequency, 10 to 20 seconds at 1 megahertz. The second is that if one watches a Type III burst over a range of frequencies, the peak intensity comes first at high frequencies and later at lower frequencies.

Individual Type III bursts were noted and named at high frequencies. It was suspected that they might come in bunches or storms, but this could not be proven until it was possible to observe at very low frequencies. The Explorer satellite observed the bursts at frequencies ranging from 0.2 megahertz to 5.4 megahertz. Waves of this range are reflected by the earth's ionosphere so only a satellite can observe them.

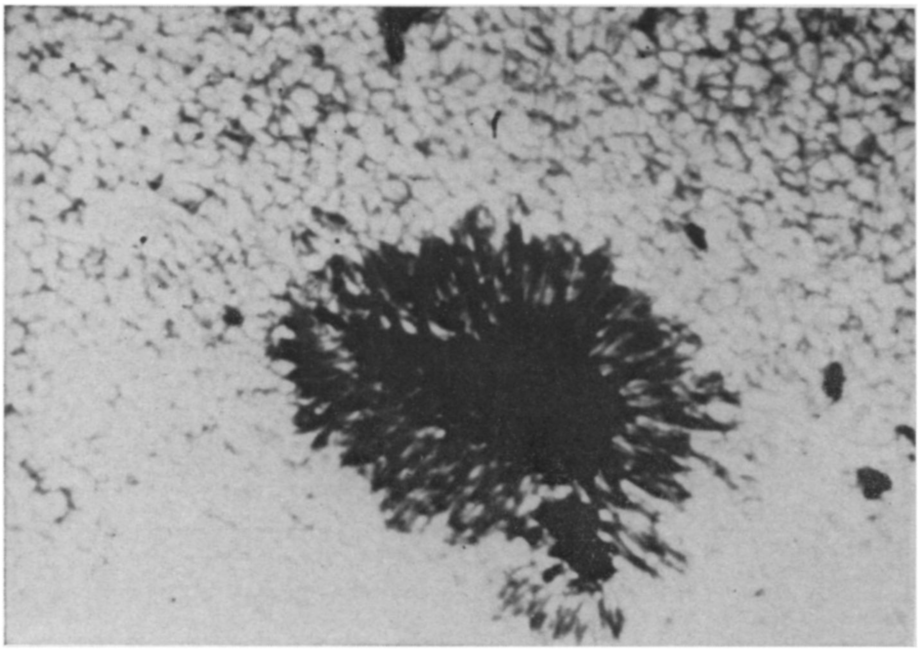
"Storms have been observed at decametric wavelengths (3 to 30 megahertz)," says Dr. Fainberg, "but it was difficult to know whether they were storms of Type III bursts or just (random) noise storms." At the higher frequencies the duration of Type III bursts is so short that they cannot be distinguished in the storms. Their greater duration at RAE frequencies allows individual bursts to be distinguished.

The ability to identify the storms and follow them for days on end opens new possibilities in the study of mechanisms that produce Type III bursts and the characteristics of the solar regions in which they are generated. "One important aspect," says Dr. Fainberg, "is that it enables us to make detailed studies of the region of the corona between 10 and 100 solar radii" from the center of the sun. (The solar radius is determined by the visible disk; the corona extends a great distance beyond.) Since the earth is 215 solar radii from the center



NASA

"Pile up" of Type III burst creates complex structures on RAE radiograph.



Dr. Martin Schwarzschild

Lines around a sunspot show magnetic fields in solar active areas.

of the sun, this region represents the inner half of the sun-earth distance.

Theorists have hypothesized that Type III bursts are generated by pulses of electrons that are driven off the surface of the sun by some disturbance and move out through the corona. The nature of that disturbance is not clear. In some way the energy of magnetic fields, which are fairly large in active regions of the sun, is converted to kinetic energy of the electrons. The process appears to be some analogue of the way particles are accelerated in laboratories on earth, but, says Dr. Fainberg, "The actual mechanism is a very, very hairy sort of problem."

The solar corona is a plasma of ions and electrons that gets less and less dense the farther from the solar surface it is. As the bunches of accelerated electrons move through the coronal plasma, they cause it to vibrate, and these vibrations generate radio waves. The frequency of the vibrations and of the resulting radio waves is determined by the density of the plasma at any given level. The denser the plasma, the higher the frequency. Thus the high frequencies are produced first, at the lower levels, and the low frequencies later. This explains why the peak of the burst drifts in time from high to low.

Study of the storms has allowed Drs. Fainberg and Stone to calculate the speed of the exciting bunches of electrons. For the distance between 11 and 30 solar radii they derive an average speed of 0.38 times the speed of light, or slightly more than 10 billion centimeters per second. This agrees well with the value derived from the theory.

Ultimately the electron bunches appear to reach the earth. Satellites orbiting near the earth have recorded occasional increases in electron density that correlate with the storms.

Further study of the storm emissions is expected to elicit information on the density and temperature of the solar corona at various levels, and the structure of the magnetic fields within it. One of the interesting questions, says Dr. Fainberg, is the number of electrons involved in producing "this tremendous amount of radio noise."

Since the storms last for days, the sun's rotation carries them past the line of sight. As they drift, the appearance of the signals changes. From this change and a knowledge of the geometry of the sun and earth, the locations of the emitting regions can be determined, even though RAE's antennas are not directional. It appears, says Dr. Fainberg, that the storms are associated with long coronal streamers, along which the exciting electrons travel, and which extend far out into interplanetary space.

As the sun rotates, it tends to wind up the streamers into a spiral shape. Data taken from a given storm over a number of days can be used to determine the amount of curvature of the streamers. That is the next part of the study and is now being worked on.

How far the streamers extend into space may be determined in future when still lower frequency observations, which will refer to greater distances from the sun, may be available. RAE-I is cut off at about 0.2 megahertz because there is still enough of the ionosphere above it to reflect frequencies lower than that. In 1972 NASA plans to launch RAE-II which will be put into orbit around the moon. Since the moon has no ionosphere, there should be no low-frequency cut-off. □