Holy Solar Corona

Observations of holes in the sun's corona help explain fluctuations in solar magnetism

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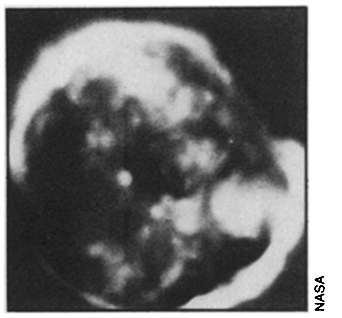

X-ray photo of sun shows coronal holes (dark features at center and on east limb).

The connection between things that happen on the sun and things that happen on the earth has been manifest for so long that the sun has often been worshipped as a god with power over terrestrial destinies. Since the dawning of the scientific age, the connections have been regarded as more physical than supernatural, but a number of them have been long-standing mysteries nevertheless.

One such mysterious connection is the relation between certain disturbances in earth's magnetic field that appeared to have a 27-day period like the rotation of the sun and solar conditions. It appears, according to A. J. Hundhausen of the High Altitude Observatory of the National Center for Atmospheric Research at Boulder, Colo., that these geomagnetic phenomena are connected to solar magnetism, and the linkage goes by way of the solar wind and a recently discovered phenomenon, holes in the solar corona. One of the possible results of this discovery, Hundhausen remarked in a summary presentation he gave at the recent meeting of the Plasma Physics Division of the American Physical Society at San Francisco, is that scientists may be able to study changes in solar magnetism by means of geomagnetic data.

These particular geomagnetic disturbances tend to occur near the end of each 11-year cycle of solar activity, and their appearance has been recorded for quite some time. At one point, Hundhausen uses the phrase "as in 1859" to describe them.

Attempted explanations came somewhat later than that. Plausible ones date from the early years of this century. The hypothesis was proposed that there were particular regions on the sun that were somehow responsible for the geomagnetic disturbances and that were carried around by the sun, hence the correlation with the sun's 27-day rotation period. As the nature of subatomic particles and their interactions with electric and magnetic fields became clear, it was suggested that these regions on the sun emitted bursts of protons that affected the earth's magnetic field. These solar regions were dubbed M regions, and, says Hundhausen, "People worked for 40 years" to elucidate the nature of the M regions "and got nowhere."

Then came the discovery of the solar wind and the decade of the 1960s. It was clear then that the sun emits protons, but it does it all the time, not in bursts. Still there are differences. There are fast and slow streams in the solar wind, the fast ones coming at rates around 600 kilometers per second. The differences in solar wind speed seemed related to the configuration of the interplanetary magnetic field, which is divided into sectors of alternating polarity. The slow streams tend to come along the boundaries of the sectors; the fast streams through the middles of them. If one attempts to compare the changes in the interplanetary magnetic field with those in the fields of the sun's photosphere, the two correlate well. A four-day delay between changes on the sun and those near the earth corresponds well to the observed speed of the solar-wind streams.

"Into this picture came the first observations of coronal holes," Hundhausen relates. Coronal holes are regions in the sun's corona, or outer atmosphere, in which the density of matter is extremely low compared with the rest of that part of the sun. They show up in X-ray and ultraviolet observations as sharply defined dark regions of very low emission. It appeared that the fast solar wind streams were coming down the coronal holes. But at first only a few coronal holes had been observed, and there were many doubts about whether they really had anything to do with the M region phenomenon.

"In Skylab all doubts get removed," Hundhausen says. Skylab permitted regular daily coronal studies, and with these the development and history of coronal holes could be followed. If the definition of coronal holes is allowed to be extended to mean the lowest brightness regions, then, says Hundhausen, it appears that "the coronal holes are the M regions."

With the Skylab observations, solar astronomers could watch the holes form and grow, and the solar wind rises and falls with them. Hundhausen calls it "amazing." The holes appear related to the polar regions of the sun, sharing their magnetic polarity as a kind of extension of polar influence toward the solar midlatitudes. Indeed, in 1973, a very fast burst of solar wind at the rarely observed speed of 750 kilometers per second was recorded. At the same time a very large coronal hole, an extension of the south pole to the equator was seen.

If you can accept the notion that the sun's basic magnetic field is a dipole, as simple as a planetary field, Hundhausen says, then the connection becomes clear. The hypothesis is that the holes (like the poles of a dipole field) are regions where the magnetic field lines are open-ended rather than curving back to the surface, and that most of the solar wind comes through the holes. The holes are definitely a coronal phenomenon; they do not appear in radiation characteristic of the photosphere or other layers.

If it is true, as alleged, that solar magnetic phenomena are convected from the interior to the surface, if the holes are indeed manifestations of solar magnetic patterns, and if the connection to the earth by way of the solar wind holds true, then it should be possible to study the behavior of solar magnetism over the years by reference to geomagnetic phenomena.

Watching the holes over time indicates that they grow and decay in a pattern of three: A new one will appear 120° west of an old one. This suggests that there is a modal pattern to the sun's magnetic field and the internal currents that generate it. Thus it seems there are three regions spaced around the sun's equator where holes can form if one of the poles of the tilted dipole points their way, and the hole will share the polarity of the pointing pole. This pattern rotates with the sun's equatorial rotation rate, which is different from the rate of the sun's atmosphere. So the sun has magnetic modes that rotate with a period different from that of the atmosphere. "That's weird," says Hundhausen, "but physically possible."

But then in 1974, things got even weirder, and produced the surprise with which the story has to end for now. "Suddenly it all stops," says Hundhausen. Instead of holes, there is a simple extension of the magnetic polar regions, which stay for a year or a year and a half. "It's the simplest sun we have seen for a whole activity cycle." And now the dipole doesn't rotate with the 27-day rotation period. This led to a suggestion by Robert Howard of the Mt. Wilson Observatory that the rotation rate of at least the outer layers of the sun changed by one day between 1973 and 1974.

"The whole surface has spun up," Hundhausen says. What that means and whether it will spin down again remain as questions for the future to answer. ☐