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NCAR Hosts International Seminar

Boulder, Colorado . . . Scientists from around the United States, Canada, Japan, Italy, France, Australia, and Germany gathered in Boulder today to begin an intensive dialogue and discussion of modern astronomical knowledge about the shock waves produced by solar flares on the Sun that reach into interplanetary space.

The conference, sponsored by the High Altitude Observatory (HAO) of the National Center for Atmospheric Research (NCAR) here "should, hopefully, help us assemble a coherent, overall picture of the eruptive flare phenomena from the Sun through interplanetary space, to the orbit of the Earth at 1 au (astronomical unit) from the Sun," according to Arthur J. Hundhausen of NCAR/HAO. NCAR is sponsored by the National Science Foundation.

The energy and particles released from the Sun by solar flares can be damaging to men and machines unprotected in open space. In reaching the Earth, this radiation often announces its arrival with the spectacular light displays of aurora or "the northern lights." Thus, solar flares on the Sun's always stormy surface have terrestrial effects in that the invisible radiation and particles released into space by the flare that reach into our protective atmospheric blanket disturb the Earth's magnetic field. Such disturbances can cause outages of long-distance electric transmission lines and confusion in radio communications.

Solar flares were discovered 113 years ago and, in 1859, fluxes in the Earth's magnetic field were also noted. Despite this hint of a direct Sun-Earth link, much remained unknown about flares and the transit of their associated shock waves through space until the satellite era and the development of a whole new physics of collisionless motion.

The concept of shock waves in space is relatively new. Dr. Hundhausen explaines:

> "Scientists had previously noted abrupt changes in the Earth's magnetic field two to three days after a flare. In the 1950's, a new theory to explain this sudden effect was proposed.

> "The theory said that the arriving matter from the Sun could not be a diffuse cloud as had previously been thought. Only material rushing quickly through a slow moving material surrounding it could create such a shock---almost as though the Earth's magnetic field has been hit by a 'wall' rather than by something diffuse. The shock wave running in front of the flare ejecta is, in fact, analogous to the shock wave which runs in front of a supersonic aircraft."

More and more fragmentary evidence began to point toward the fact that interplanetary space was not a vacuum, and scientific theorists constructed a mathematical model of the solar corona---the Sun's outer atmosphere---showing how it could expand very diffusely to fill all space. At the orbit of the Earth, this so-called "solar wind" would always be flowing past at a very high speed.

In the early 1960's satellites began to confirm the existence of the then-theoretical medium in space. The USSR's lunar and Venus probes produced partial evidence of a flow of particles in space, as did Explorer X in 1961. Finally in 1962, Mariner II clinched the argument with completely unambiguous measurements made far from the Earth's magnetic field that detected the presence of a solar wind and measured its particle flow.

Now it remains for scientists to understand this newly discovered phenomena in physical terms. Hundhausen says:

> "If we view the flare as a change in the corona's solar wind, then presumably we could study the flare's effect as it moves outward through the Sun's layers into space. The energy created by the flow creates higher gaseous pressures in the flare area on the Sun and the flare ejecta should move as a single blob or unit as it bursts outward from the solar corona. Some of the energy is released by emission or brightening in various wavelengths of light; however, satellite measurements from 40-odd observations indicate that optical effects of the flare---hydrogen-alpha light, the traditional viewing spectrum for solar events, white light and other emissions, constitute, at best, only some 10% of the energy release of the flare. The rest of it---90 to 95%---is still there in the form of material and energy flowing past satellite observers in interplanetary space.
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> "Perhaps even more interesting is that the amount of matter released by a flare is a sizeable fraction of all that in the corona. In other words, in a matter of an hour, a solar flare can release as much material as the entire corona does in a quiet, flareless week."

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Observing radio emissions or sudden radio bursts is one classical way to observe the Sun's activity. Tracking the progress of matter through the solar atmosphere both optically and electronically would certainly help define the physical events that occur. To date this has been successfully accomplished on a few occasions. The Orbiting Solar Observatory (OSO)-7 and NCAR's solar observatory atop Mauna Loa in Hawaii both observed bright blobs in the solar corona, watched them during a flare as they moved out through the corona, while radio observatories simultaneously recorded characteristic radio bursts. The "cloud" observed moving through the corona as a bright blob was later correlated with measurements made by satellites and the total energy and mass flowing past the satellite were very close to other observations made at 1 astronomical unit. Hence, the conclusion that the flare ejecta continues to move through interplanetary space as a distinct blob. One possible geometric model to explain the hot blobs or ejecta staying together was devised by John T. Gosling, Hundhausen and Victor Pizzo of HAO. Their theory, to be explained at the present conference, says that magnetic bubbles or bottles can be formed by the merging of magnetic field lines behind material ejected from the chromosphere into the interplanetary medium at the time of some solar flares. Such a magnetic bubble would be thermally insulated from the solar corona; hence, the bubble would cool within itself as it expands into interplanetary space.

Among the 47 participants who were invited to give papers at the seminar are R. P. Lepping and J. Chao of NASA's Goddard Space Flight Center who will discuss the rare observational ploy accomplished by Explorer 33 and Pioneer 7 when both spacecraft observed the same flare-associated shock within 19 hours of each other on February 15 and 16, 1967. Lepping and Chao state:

"A consistent physical picture of the shock propagation will be given to explain the differences observed by the two spacecraft at their two widely separated positions in interplanetary space." The average shock speed from the Sun to each spacecraft and the local speed at Explorer 33 and their relations to the position of the initiating solar flare also will be discussed. They found the average speeds of propagation to Explorer 33 and Pioneer 7 to be 770 km/sec and 640 km/sec, respectively while the velocity of the solar wind is usually about 400 km/sec. Normal velocities require four days to move from the Sun to the Earth while the accelerated velocities of flare material require only some two to three days.

Four other invited scientists will give review talks attempting to summarize all known information about one facet of the production of shock waves by solar flares, the propagation of these waves through the Sun's corona and interplanetary space, and the physical effects of such shock waves on the solar and interplanetary plasmas. The four days of discussion will end with a summary and conclusions to be drawn together and presented by James Warwick, Department of Astro-Geophysics of the University of Colorado.

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