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THE SOLAR MAXIMUM MISSION AND BEYOND

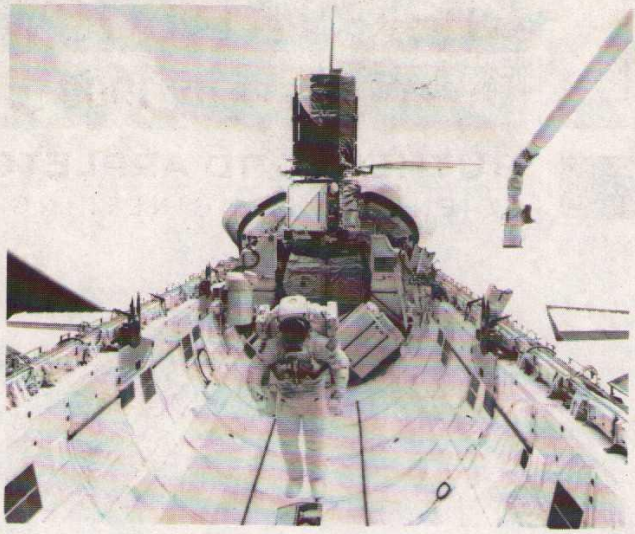
Although the sun's radiation output may seem to be constant day after day, certain explosive releases of energy called *flares* often occur, producing enormous increases of X-rays and other radiation outside the visible range. They are very occasionally seen with conventional white-light telescopes as brilliant white patches that last for a few seconds. The energy released is colossal – up to 10^{25} J (equivalent to 50 million times the energy of the largest fusion bomb exploded on earth!) – with large increases in ultraviolet and X-ray emission.

Spacecraft and rockets have been studying flares for over 30 years now, flying e.g. X-ray detectors above the absorbing layers of the earth's atmosphere. But it has only been in recent years that we have begun to understand basic flare mechanisms. A considerable advance was made in our knowledge with the NASA satellite *Solar Maximum Mission*. Solar Max was launched on February 14, 1980, had a major overhaul by Space Shuttle astronauts in 1984 and finally ended its days when it re-entered the earth's atmosphere on December 2, 1989. Its seven instruments returned vast amounts of data still being pored over. Solar Max had an almost complete coverage of the electromagnetic spectrum of a flare, ranging in wavelength from γ-rays (wavelengths less than 0.0001 nm) to white-light (wavelengths of around 660 nm). Imaging of active regions and flares was accomplished by three of the instruments, including one called the X-ray Polychromator (XRP), built and operated by a consortium of three institutes including the Rutherford Appleton Laboratory.

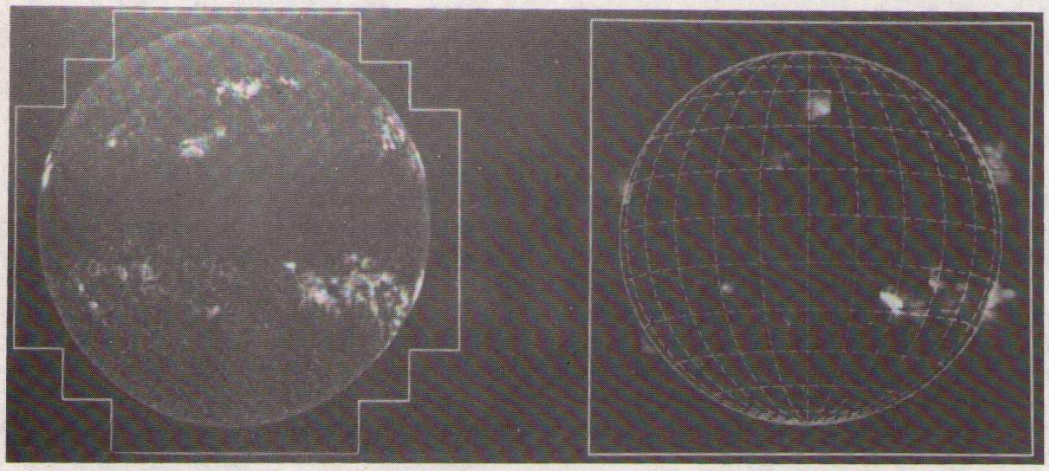
The sequence of events in a solar flare is very complex. There is usually one or more impulsive bursts of hard X-rays and radio emission at the onset, with a more gradual increase of soft X-rays (wavelengths greater than 0.1 nm) peaking several minutes later, with a decline often lasting tens of minutes. The flare in "Hα" (a visible wavelength absorption line in the red part of the spectrum) is gradual, like the soft X-rays. Solar physicists explain these phenomena by supposing that flares are initiated by a merging of magnetic field lines in the solar corona, which releases energy in the form of accelerated electrons and other particles. When these are guided towards the solar surface, they emit hard X-rays when they are suddenly "braked" – hence the hard X-ray impulses. Soft X-rays are emitted when chromospheric gas is heated and convected upwards into the corona.

Huge increases in total soft X-ray emission occurred for a limb flare on March 6, 1989, which the XRP instrument saw as a blob of high-temperature emission. Temperatures of up to 20 million K were recorded. This activity had a profound effect on the earth: the most notable was a huge auroral display visible down to tropical latitudes. There was a magnetic storm which, at the geomagnetic latitude of Lerwick, Scotland, could actually have been recorded with a compass needle, which showed a deflection at one point of several degrees!

Now that Solar Max has re-entered the earth's atmosphere, what are the prospects for future spacecraft



Solar Maximum Mission in place in the bay of the Space Shuttle Challenger *ready for repairs during the 1984 mission. S.M.M. was subsequently released and continued to return good data until its re-entry into the earth's atmosphere in 1989.*



Full-sun images obtained with the X-ray (XRP) and ultraviolet instruments on Solar Maximum Mission in Sept. 1988. The ultraviolet image shows the structure of the chromosphere, while the X-ray image shows active regions in the corona only.

studying the sun? Apart from X-ray monitoring satellites called *GOES*, there are no such spacecraft operating at present, but a Japanese satellite called *Solar A*, carrying four main instruments that will view hard and soft X-rays from flares will be launched in late 1991. An advanced series of *GOES* satellites will be launched by the U.S. in the next 2–3 years carrying telescopes that will image the sun in soft X-rays. A Soviet solar mission *Koronas F* is also due for launch in the mid-1990s. Non-flare missions are also planned for the mid-1990s and beyond, most notably the European Space Agency's *Solar Heliospheric Observatory* (SOHO), which will carry instruments viewing the quiet sun and global oscillations. RAL will have major involvement in the *Solar A* and SOHO missions. Thus, there is some hope that the problems and questions raised by Solar Max will be tackled in more detail and possibly solved in the coming decade.

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