Spatial distribution of soft X-ray and EUV emission associated with a chromospheric flare of importance 1B on August 2, 1972

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(Received 7 August; in revised form 13 November, 1973)

Abstract. Soft-X-ray and extreme ultraviolet spectroheliographs carried by the OSO-7 (Orbiting Solar Observatory) have been used to record the development of XUV emission associated with a flare of importance 1B on August 2, 1972. Spatial resolution was 20" and spectral resolution was adequate to select emission lines originating within well-defined ranges of electron temperature between 5 × 10⁴ and 30 × 10⁶K. The data show that heating only the pre-existing coronal material adjacent to the flare site cannot account for the soft X-ray emission measure observed during the event. The flare emission originating at Te ~< 2.3 × 10⁶K exhibits an impulsive component coincident with an impulsive microwave event. This radiation appears to coincide spatially with Hα radiation emitted at that time and is centered on the neutral line separating magnetic fields of opposite polarity. One soft X-ray-emitting feature, estimated to have an initial electron temperature of 2–10 × 10⁶K, forms during the impulsive phase immediately over the Hα flare. A second, arch-like feature observed at wavelengths near 1.9 Å and estimated to have Te ~ 30 × 10⁶K is located approximately 35000 km above the Hα event. Both regions have lengths of about 27000 km but transverse dimensions small compared to the spatial resolution of the spectroheliograph, i.e., less than 14000 km. The region with highest electron temperature exhibits the greatest stability in position. This region cools to approximately 10 × 10⁶K in 6 to 12 min which is compatible with cooling by conduction to the chromosphere. The best association with a dark surge is found in an emission line of Fe XIV.

1. Introduction

Observations from above the Earth's atmosphere by means of balloons, rockets and satellites provide the only means for observing directly the presence of the hot (Te > 5 × 10⁶K) quasi-thermal plasma frequently associated with solar flares. Early observations with broad-band detectors demonstrated not only the existence of short-lived X-ray enhancements in active regions (OSO-4 data reported by Vaiana and Giacconi, 1969) but also suggested that such enhancements may even occur in coronal regions not associated with active centers (Zhitnik et al., 1967). Unfortunately these early observations had inadequate spatial resolution (of the order of 1–2') to provide meaningful information on the shapes of the emitting sources and inadequate spectral resolution to define accurately the physical conditions within the regions. Somewhat later, observations of solar flares with improved spatial resolution but still with broadband spectral sensitivity (approximately 2–14 Å) demonstrated that the sources of X-ray emission appeared as long, filamentary structures about 1' long and 20" in diameter (Vaiana et al., 1969; Beigman et al., 1969). Vaiana and Giacconi pointed out that, although there were considerable similarities between the shape of the Hα flare and the X-ray distribution, there was in addition a bridge of X-ray emission between the two Hα emission centers on opposite sides of the magnetic neutral line. In 1969,
direct flare observations were made in EUV wavelengths (Tousey, 1971) and in hard X-ray wavelengths (Takakura et al., 1971), but no events had yet been observed simultaneously in two or more spectral regions. Furthermore, all of these observations were of short duration so that the evolution of the flare could not be studied.

With the Goddard Space Flight Center experiment on the OSO-7 satellite, we have had the benefit of prolonged observations so that we have been able to view a number of flares from beginning to end. In addition, we can observe events simultaneously in four wavelengths selected from within the wavelength region 1.8 to 400 Å, and by means of automatic switching can observe up to twelve wavelengths in any 6-min period. We thereby collect information on emitting regions in a single event with electron temperatures ranging from $5 \times 10^4$ K to $30 \times 10^6$ K. We will first present such observations made during an importance 1b flare on August 2, 1972 and then discuss the implications of these data on current flare models.

2. Instrumentation

The Goddard experiment on OSO-7 consists of two X-ray spectroheliographs, covering the wavelength ranges of 1.74 to 7.95 Å and 7.95 to 15.90 Å, and one EUV spectroheliograph covering the range 120 to 400 Å, all of which are co-aligned to within 5°. The wavelength selection of each instrument is independently controlled by ground command, as is the aperture selection of the EUV spectroheliograph. The spatial resolution of the X-ray instruments is produced by multi-grid collimators with fields of view of approximately $20" \times 20"$ FWHM, while that of the EUV spectroheliograph is provided by a Wolter Type II grazing-incidence telescope (Wolter, 1952; Mangus, 1970) which focuses the incident radiation onto the entrance aperture of a grazing-incidence, grating spectrometer with a spectral resolution of 0.8 Å FWHM. The X-ray spectral bands are defined by several balanced filter pairs (Ross, 1926).

The observations reported here were made while the spacecraft rastered the instrumental viewing directions over a $5' \times 5'$ area of the Sun. At the end of each raster, a pulse was generated which stepped the X-ray filter pairs to the next set (see Table I for the pass bands of the filter pairs), and which switched the EUV mask so that the alternate set of exit slits was uncovered. Unfortunately, because of telemetry limitations, only two of the three EUV detectors could be monitored. The spectrometer was set so that we recorded raster maps at 246.3 Å and 294.9 Å, alternating with maps made at 219.0 Å and 265.0 Å, all with an entrance aperture of $20" \times 20"$.

Since a $5' \times 5'$ raster takes 61.44 s to complete, each EUV line pair was observed every two minutes, approximately. However, there are six sets of filters in each of the two X-ray instruments, so their cycle time was approximately six minutes. (The cycle time is reduced to three minutes for the bands from 1.74 to 1.90 Å and from 14.50 to 15.90 Å since filter pairs 1 and 4 in each instrument are identical.)

In addition to having X-ray and EUV detectors, the Goddard experiment contains a small Ebert-Fastie spectrometer with a spectral resolution of about 0.8 Å FWHM for isolating the Hα line of neutral hydrogen. It is fed by the zero order reflection from