CORRELATED OBSERVATIONS OF IMPULSIVE UV AND HARD X-RAY BURSTS FROM THE SOLAR MAXIMUM MISSION

Chung-Chieh Cheng
E.O. Hulburt Center for Space Research
Naval Research Laboratory, Washington, D.C., U.S.A.

1. Introduction

In the past decade, impulsive hard X-ray bursts have been extensively observed (cf. Kane et al., 1980). These observations have increased our knowledge of the energy spectrum of the accelerated electrons and their temporal evolution. However, because of the lack of spatial resolution and direct plasma diagnostics, many important questions concerning the nature of the impulsive phase are still left unanswered. Since direct imaging of hard X-rays above 30 keV with high resolution of is still beyond our present technology, we have to use other indirect means to deduce the spatial structure of the hard X-ray source. With the recent launch of the Solar Maximum Mission (SMM) satellite, we are able to obtain correlated observations of the flare impulsive phase in hard X-ray and simultaneously in the UV lines of Si IV (1402 Å) and O IV (1401 Å). The Si IV/O IV intensity ratio is density sensitive and therefore provides plasma diagnostics in the emission region. Analysis of the spatially resolved UV observations with the correlated hard X-ray observations allows us to study the spatial structure and physical conditions in the UV and hard X-ray sources (Cheng et al., 1981; 1982; 1984). Descriptions of the various solar instruments on SMM can be found in Solar Physics (vol. 65, pp 5-116). In this paper, I briefly summarize the important observational results and discuss their theoretical interpretation.

2. Temporal and Spatial Evolutions of the Impulsive UV and Hard X-ray Bursts

Figure 1 shows an example of correlated observation of impulsive UV and hard X-ray bursts. The figure shows the Si IV raster images of the 14 Oct. 1980 flare and compares the light curves of the Si IV and the hard X-ray emissions. We see that the impulsive UV emissions occur in small kernels, whose size is as small as the individual pixel (4"x4"). The Si IV light curves are for these flare kernels, whose positions are indicated by solid pixels. Examination of the integrated Si IV emission summed over the entire field of view reveals somewhat dissimilar time profiles as that for hard X-ray bursts. But when the individual light curves are used for comparison, we find that individual Si IV peaks have corresponding hard X-ray peaks,

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particularly those with energies $\gtrsim$ 50 keV (Figure 1). The time
correspondence is indicated by letters identifying the peaks. For
example, the first Si IV burst (A), located at the westernmost pixel,
is correlated with the rather inconspicuous hard X-ray burst, also
labelled A. The subsequent Si IV/O IV brightenings at other kernels
correspond to other peaks as shown in the hard X-ray light curves.
Because of the close time correlation between the hard X-ray bursts
and their associated UV bursts, we infer that the hard X-ray emission
sources are located at the corresponding Si IV/O IV pixels. Figure 1
also shows that during the impulsive bursts, the density at the
flaring kernels, obtained from the Si IV/O IV ratio, increases from
their initial active region values of 10^{11} cm^{-3} to as high as 5×10^{12}
cm^{-3}. We note that, for the example there is no intensity correlation

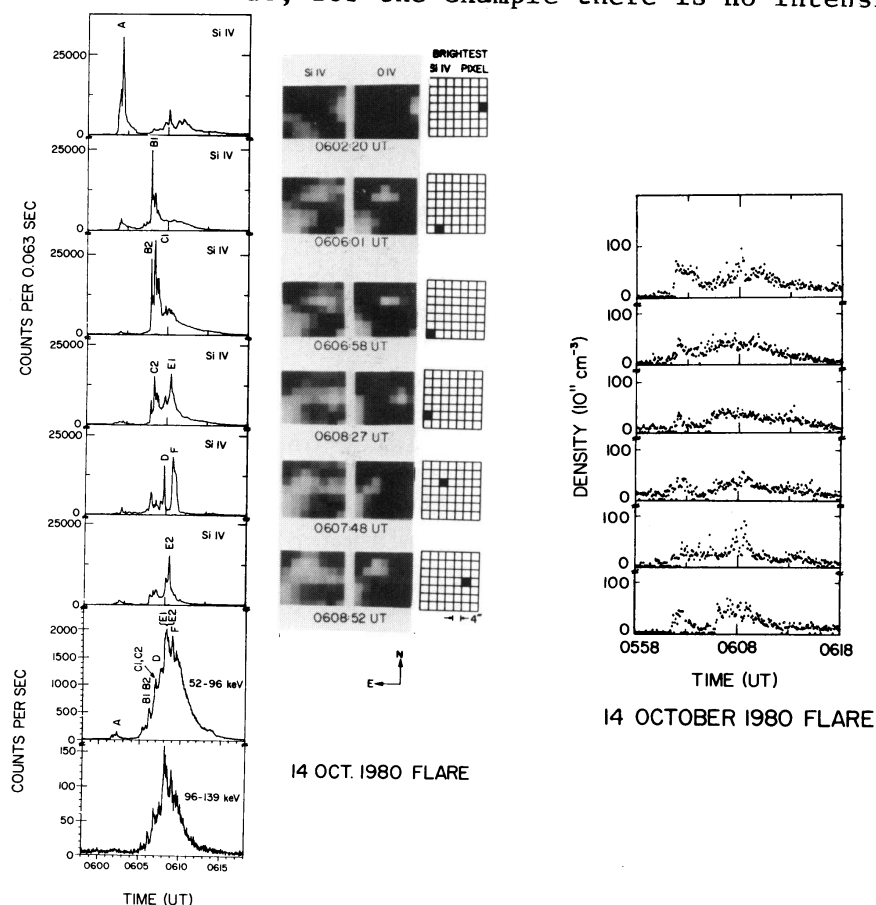14 OCT. 1980 FLARE

14 OCTOBER 1980 FLARE   Fig. 1

between the Si IV burst and its corresponding hard X-ray burst,
indicating inhomogeneous horizontal structure in the lower solar
atmosphere.

3. Diagnostics and Dynamic Evolution of the Transition Zone Plasma

The Si IV line is a resonance line and the O IV line is a
intersystem line. Their intensity ratio can be used for density
diagnostics in the flare transition zone plasmas (Cheng et al. 1982).
A number of flares were observed in the Si IV/O IV raster-through-the-

line (RL) mode, for which a crude line profile can be reconstructed for each pixel, thus providing information on mass motions during the impulsive phase. Here we show two examples. Figure 2 shows the raster images of the 8 April 1980 flare. As shown by Cheng et al. (1982), the impulsive UV and hard X-ray bursts occur in a low lying loop (lower part of set 11). Footpoint 1, located to the east, is the brightest kernel. Its intensity, density, and mass motion velocity evolutions are also shown in the Figure. The UV observation was interrupted at 0302 UT, during which time there was a strong hard X-ray burst, because the UV detectors were saturated. The impulsive bursts are accompanied by a large density increase and a downflow of ~ 30 km s^{-1} at the footpoint. Another example of the dynamic evolution
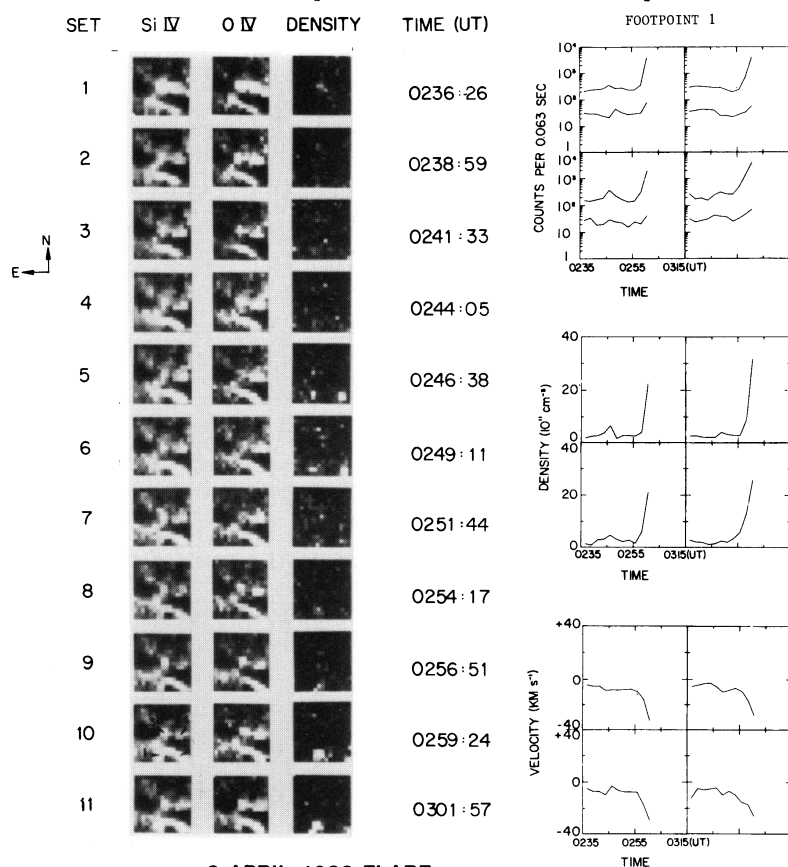

8 APRIL 1980 FLARE

Fig. 2

of the UV impulsive phase, for the 22 November 1980 flare, is shown in Figure 3. Again we see that the Si IV/O IV emission occurs at localized kernels. At the kernels, the density increases in synchronism with the intensity. The mass motion velocity maintains a downflow during the impulsive phase. However, as in other flares, the downflow tends to be the largest at the peak of the UV bursts (Cheng and Tandberg-Hanssen, 1985).

4. Discussion

The correlated observations show that the impulsive UV and hard X-ray bursts occur in small kernels, identifed as the footpoints of
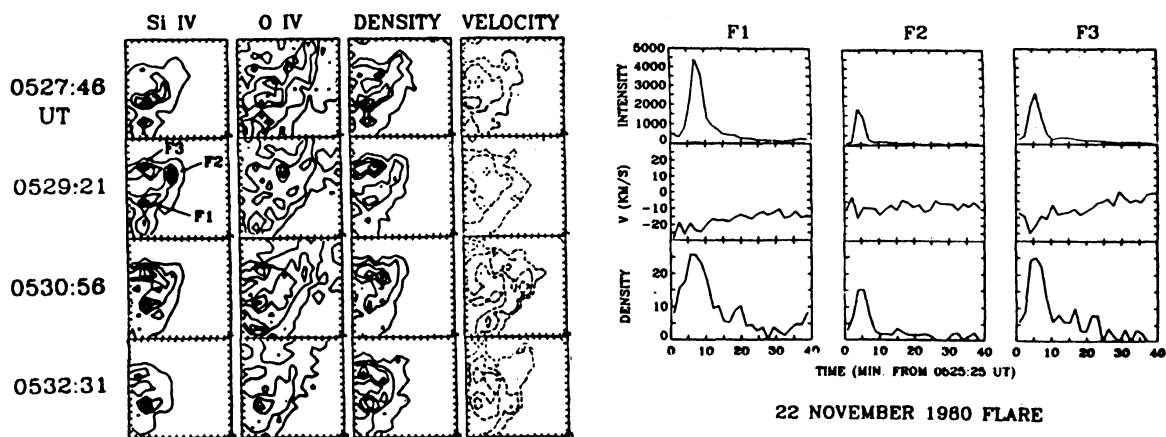
Fig. 3

loops. The density there increases by an order of magnitude and is
accompanied by large downflows. The physical picture presented by the
observations can be understood in terms of an electron beam model.
When the accelerated electrons stream down from the top of a flaring
loop, they impinge on the dense chromosphere, generating thick-target
hard X-rays. The heating of the lower atmosphere by the electron beam
pushes downward the preflare chromosphere and transition zone into
deeper and denser levels, resulting in the emission of UV bursts
there. This picture is in qualitative agreement with recent numerical
simulations of flare hydrodynamics (cf. Cheng et al., 1983; MacNeice
et al. 1984; Fisher et al., 1984). To make further progress in our
understanding of the physics of the impulsive phase, refined
observations and improvement in our numerical calculations are needed.

References

Cheng, C.C., Tandberg-Hanssen, E., Bruner, E., Orwig, L., Frost, K.J.,
    Kenny, K.J., Woodgate, and Shine, R.: 1981, Astrophys. J. (Letters),
    248, L39.
Cheng, C.C., Bruner, E., Tandberg-Hanssen, E., Woodgate, B., Shine,
    R., Kenny, P.J., Henze, W., and Poletto, G.: 1982, Astrophys. J.,
    253, 353.
Cheng, C.C., Tandberg-Hanssen, E., and Orwig, L.E.: 1984a, Astrophys.
    J., 278, 853.
Cheng, C.C., Karpen, J.T., and Doschek, G.A.: 1984b, Astrophys. J.,
    286, 787.
Cheng, C.C. and Tandberg-Hanssen, E.: 1985, preprint.
Fisher, G.H., Canfield, R.C., and McClymont, A.: 1985, Astrophys. J.,
    289, 434.
Kane, S.R. et al.: 1980, in Solar Flares, ed. P. Sturrock (U. Colorado
    Press).
MacNeice, P., McWhirter, P., Spicer, D.S., and Burgess, A.: 1984,
    Solar Phys., 90, 357.