X-RAY EVIDENCE OF CORONAL PREFLARE EMISSION

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Flares are believed to derive their energy from localized nonpotential magnetic fields; this energy is somehow stored and initially released in the low corona. Therefore, knowledge of coronal conditions prior to flares is essential to our understanding of the flare process. The coronal plasma is constrained by the magnetic field and its characteristic emission is easily observed at soft X-ray wavelengths. Therefore, X-ray imagery is well suited for observing changes in emission influenced by nonpotential magnetic fields in the low corona. This study used soft X-ray images from the Skylab AS&E telescope to search for evidence of coronal preflare emission.

In previous studies Kahler and Buratti (1976) and Kahler (1979) found that there were no systematic preflare X-ray brightenings at the locations of subsequent small flares, and therefore no requirement for coronal preflare heating of the flare loops. However, there exist in the literature many specific examples of preflare activity in the form of discrete brightness changes and filament activation, which are interpreted as magnetic field changes. For example, Martin and Ramsey (1972) found that about half of the Hα flares they studied exhibited preflare filament activity. And during Skylab several examples were found of EUV and X-ray preflare brightenings in the active region (AR) where a flare occurred. The emerging flux model of flares (Heyvaerts, Priest and Rust, 1977) predicts preflare soft X-ray emission outside the flare site tens of minutes before flare onset. These observations and the existence of a specific model predicting preflare activity motivated this study.

This study addresses the following questions: Do systematic preflare X-ray brightenings exist either at the flare site or in adjacent parts of the AR; what are the characteristics of such brightenings; and what do they tell us about preflare coronal conditions? The study had two parts: (1) a statistical study of preflare X-ray events and (2) an analysis of the best observed events including comparison with high time resolution Hα data.

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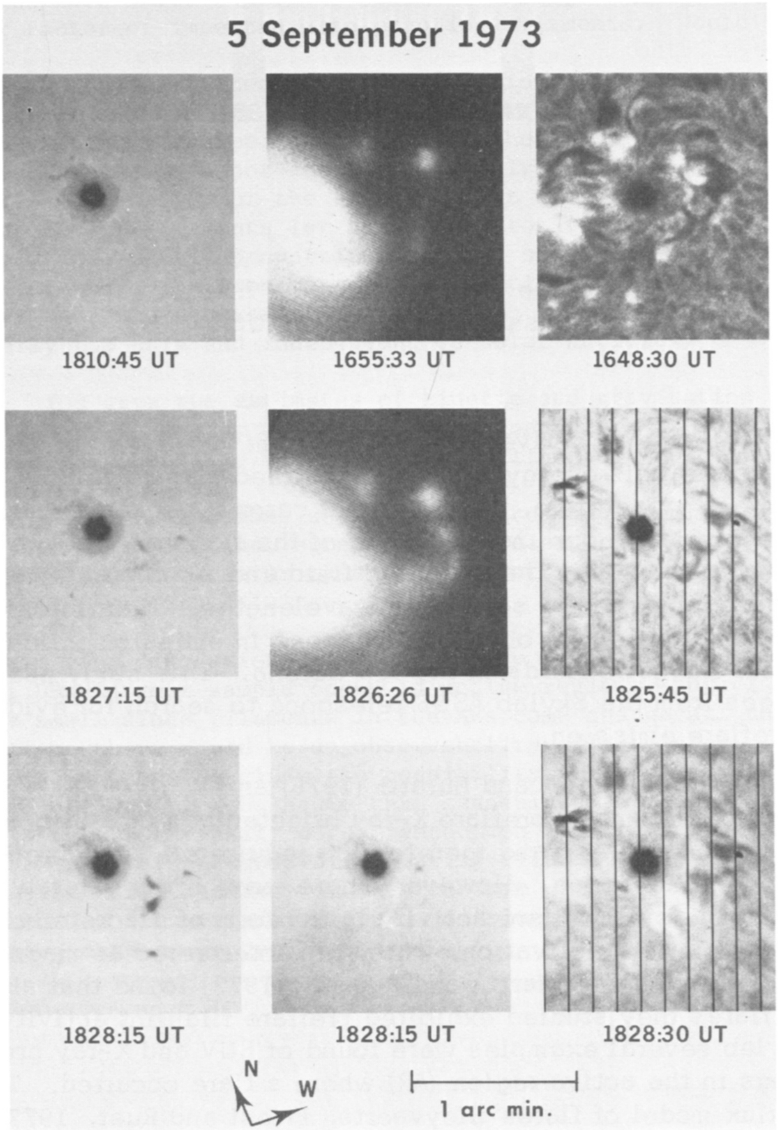

Figure 1. The central X-ray image at 1826 UT shows preflare emission associated with the activation of the filament to the lower right of the sunspot. Hα blue-wing filtergrams in the left column show the ascending filament mass before flare onset and displaced to the west of the flare site (bottom images). X-ray images are with the Skylab AS&E telescope with a passband of 2 - 17 Å. Hα images are courtesy of Sacramento Peak and Lockheed observatories.

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Our criteria for selection of events for this study were:

1. Observing period 28 May - 27 November 1973,
2. The X-ray flare profile and onset time (T_o) could be determined from Solrad and/or the Skylab XREA whole-sun detector,
3. At least two X-ray images available, one during flare rise phase and one during preflare period T_o -30 min, and
4. Flare not within 20^o of solar limb.

My study differed from the Kahler and Buratti, and Kahler studies primarily in that they used a preflare period of 20 min. I chose a 30 min period because the best observed evidence of preflare activity, filament motion, begins an average of 30 min before flare onset (Martin and Ramsey), and because this interval provided a reasonable number of events with several X-ray sequences.

The Table summarizes the results. A total of 25 events satisfied the criteria. Seventeen of the 25 events (2/3) had probable or possible preflare features (defined as observable transient brightenings) within the AR where the flare occurred. Eleven of the 17 events contained a single preflare structure (5 had 2 features and one had 3 features). Of the 17 events with preflare features, in 9 cases the feature was not at the flare site (in 5 cases it was at the flare site and in 3 it was mixed). Again, of the 17 events, in 11 at least one of the preflare features was not observed to reach flare intensity (in 7 cases at least one feature did flare and 1 was uncertain). In nearly all of the events, the preflare structure was either loop-like or a kernel. X-ray kernels have been defined as compact (5 - 7"), transient (5 - 10 min) knots of flare brightness occurring in ARs typically during the rise phase of flares (Kahler, Petrasso and Kane, 1976).

Evidence from my preliminary study comparing these events with Hα and from other studies suggests that the X-ray kernels are associated with bright Hα knots. Also at least some of the elongated preflare X-ray features are associated with the activation of filaments. Figure 1 shows an example of coronal preflare emission associated with the activation of a filament.

In conclusion I find that a majority, but not all flares studied, may have had X-ray preflare features. The preflare feature typically was not at the flare site, but was adjacent to the AR neutral line. A single feature was evident in most of the preflare events.

These observations suggest that preflare X-ray brightenings are associated with changing magnetic structures, and are evidence of magnetic energy release and coronal heating prior to the flare. One type of feature,

X-RAY PREFLARE EMISSION: STATISTICAL STUDY

Total Number of Events	25		
	Yes or Maybe	No	
Preflare Feature in Flare AR?	17	8	
Preflare Feature at Flare Site?	8	9	
Preflare Feature is a Flare?	8	11	
	1	2	3
Number of Features per Event	11	5	1
	Loop	Kernel	Sinuous
Morphology of Preflare Features	9	8	3

filament activation, is the signature of a major disruption of the magnetic field prior to the flare. Another preflare feature, an X-ray kernel, has been interpreted as a small emerging flux loop overlying an Hα kernel (Kahler, Petrasso and Kane). In a model of a simple loop flare an emerging flux loop might contact a pre-existing larger loop which bridges the neutral line. A neutral sheet might be formed which heats up due to a plasma instability. The initial (preflare) heating is first observed as the kernel because of its small volume. If the large loop is replaced by a filament lying along the neutral line, we have the situation of an activated filament preceding a two-ribbon flare. Therefore, the results of this study appear to be compatible with the emerging flux flare model for the majority of flares studied.

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REFERENCES

Heyvaerts, J., Priest, E.R., and Rust, D.M.: 1977, Astrophys. J. **216**, 123.
Kahler, S.W.: 1979, Solar Phys. **62**, 347.
Kahler, S.W. and Buratti, B.J.: 1976, Solar Phys. **47**, 157.
Kahler, S.W., Petrasso, R.D., and Kane, S.R.: 1976, Solar Phys. **50**, 179.
Martin, S.F. and Ramsey, H.E.: 1972, in P.S. McIntosh and M. Dryer (eds.) Solar Activity Observations and Predictions, MIT Press, Cambridge, MA.

DISCUSSION

Jackson: How do you know that the pre-flare brightenings are associated with the subsequent flare and not just random brightenings of adjacent features?

Webb: My study was limited by a lack of high time resolution data during Skylab. We do know that the X-ray brightenings are associated with filaments which show preflare motion and sometimes erupt at flare onset. Other brightenings, such as X-ray kernels, are associated wtih bright Hα bursts lying along the neutral line in the active region where the flare occurs. We need to perform a study to statistically check if such brightenings are random or not. We also will examine good quality Hα data to determine where the X-ray features are with respect to the flare site.

Levine: (Comment) In support of one of your interpretations, I would like to point out that I was able to find unambiguous pre-flare brightenings in EUV emission within pre-existing small loops prior to a small flare on November 28, 1973. Further, examination of solar magnetograms showed a direct association with emerging flux. (See Levine, *Solar Phys.*, *56*, 185, 1978).