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Radio pulsations associated with the solar flare of 1982 April 14

P. Pant and K. R. Bondal
Uttar Pradesh State Observatory, Manora Peak, Naini Tal 263 129

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Abstract. We report here the H-alpha observations of a large and complicated flare of optical class 2B which occurred on 1982 April 14. The flare showed significant activity for several minutes prior to its impulsive phase, as evidenced by the dynamic spectrum of the associated radio event taken simultaneously at Culgoora. The dynamic spectrograms showed strong chains of pulsating bursts superimposed upon the type IV continuum in close association with intermittent type III burst storms in metric and decametric bands. Traces of remote brightenings were also seen at a distance of $\sim 10^5$ km from the main flare site in its declining phase.

Key words : flare kernels—remote brightenings—radio pulsation—burst storms—type IV continuum

1. Introduction

In large solar flares, nodules appear in the earlier phases of their development which link up and generally form ribbon-like structures (Smith & Smith 1963). These ribbons tend to lie along the lines of demarcation between regions of opposite magnetic field polarities (Svestka 1976). High resolution and off-band H-alpha filtergrams show intense short-lived brightenings in limited parts of the flare area (Vorpahl & Zirin 1970; Zirin *et al.* 1971). These short-lived brightenings or flare kernels show brightness several times greater than that of the surrounding flare (Vorpahl 1972). These kernels are probably produced as streams of energetic electrons originating from the accelerating site at higher altitudes penetrate into the chromosphere (Svestka 1981).

2. Observations and analysis

(*a*) *Optical*

On 1982 April 14, while monitoring the sun through the 0.7 Å passband Halle H-alpha filter, we saw a complex structure containing a large sunspot. A flare of optical class 2B erupted around 0236 UT in the Hale-plage region 18310 and at heliographic location W03 S27 (Solar Geophysical Data 1982a). Filtergrams of this event were taken through a 15 cm, f/15 refractor using Yashica FR-1 camera. The exposure time used was 1/250s with the filter centred on H-alpha line. Exposures were taken at approximately 1 min interval. The flare coincided with a sharp peak in the soft x-ray flux recorded by the GOES-2 satellite (Solar Geophysical Data 1982b). For morphological description of the flare, marks have been put at certain distinct portions in the flare region (figure 1). These markings indicate the bright flare regions (cross-hatched line) and major sunspots (filled areas). A filtergram taken at 0251 UT shows that regions B, C and E are brighter than the others. The underlying sunspot is visible, the umbra of which is partially engulfed by flare kernel C. A faint tail loosely connected with E can be discerned as F. An overlying faint filamentary structure is visible joining B and C. Remote brightenings at a distance of about 10^5 km from the main flare site and at points north-west of the region A and south-east of the region E were seen (figure 1, 0254 UT). The fibril structure is seen here joining these points with the main flare region. Sometimes these brightenings outside the main flare region are caused by travelling flare waves over the chromosphere (Svestka 1976). Since our H-alpha filtergrams do not show evidence of any such waves, the remote brightening due to flare waves is ruled out. Tang & Moore (1982) have shown that the remote brightening is attributed to the interaction of electrons of type III-RS (reverse slope) bursts with the chromosphere. Close examination of dynamic spectra (figure 2a) shows no evidence of type III-RS bursts. Kundu *et al.* (1983) have observed faint H-alpha brightenings and 6 cm emission outside the primary flare site stretching $> 10^5$ km at the end of the foot-points of the loop which connects the main flare to these remote points. Hence these brightenings may be attributed to an interaction of the energetic electrons which spiral down the field lines to the remote patches in the lower chromosphere. The delay in the brightening of the main flare and the appearance of remote patches was about two minutes.

Later on, brightening at the end of the tail pertaining to E was seen (0258 UT). Regions B, C and D now have a continuous appearance, but A stands out distinctly. Around 0304 UT the fainter extension of E shows a twisted structure with bright points along the extension. At this point two distinct ribbons of the flare are visible corresponding to a continuous appearance of regions A, B, C and D for the shorter ribbon and E and F for the longer one. Harrison *et al.* (1983) have shown that the extension of brightness associated with the flare ribbon can be attributed to the rearrangement, during the declining phase of the flare of the magnetic field along the neutral line in which the two flare ribbons tend to lie (Svestka 1976). Region E has now thickened in the middle and shows a helical structure with a broken appearance (0314 UT). Filtergrams taken later do not show any appreciable change except that the end of region F shows a bifurcation, the ends of which orient in opposite directions (0330 UT). Around 0457 UT all flare regions except E have faded out.

(*b*) *Radio emission*

Time profiles at frequencies 1.0, 2.0, 3.75 and 9.4 GHz showed a complex flux density enhancement around 0232 UT reaching maxima at 0254 UT. The bursts are

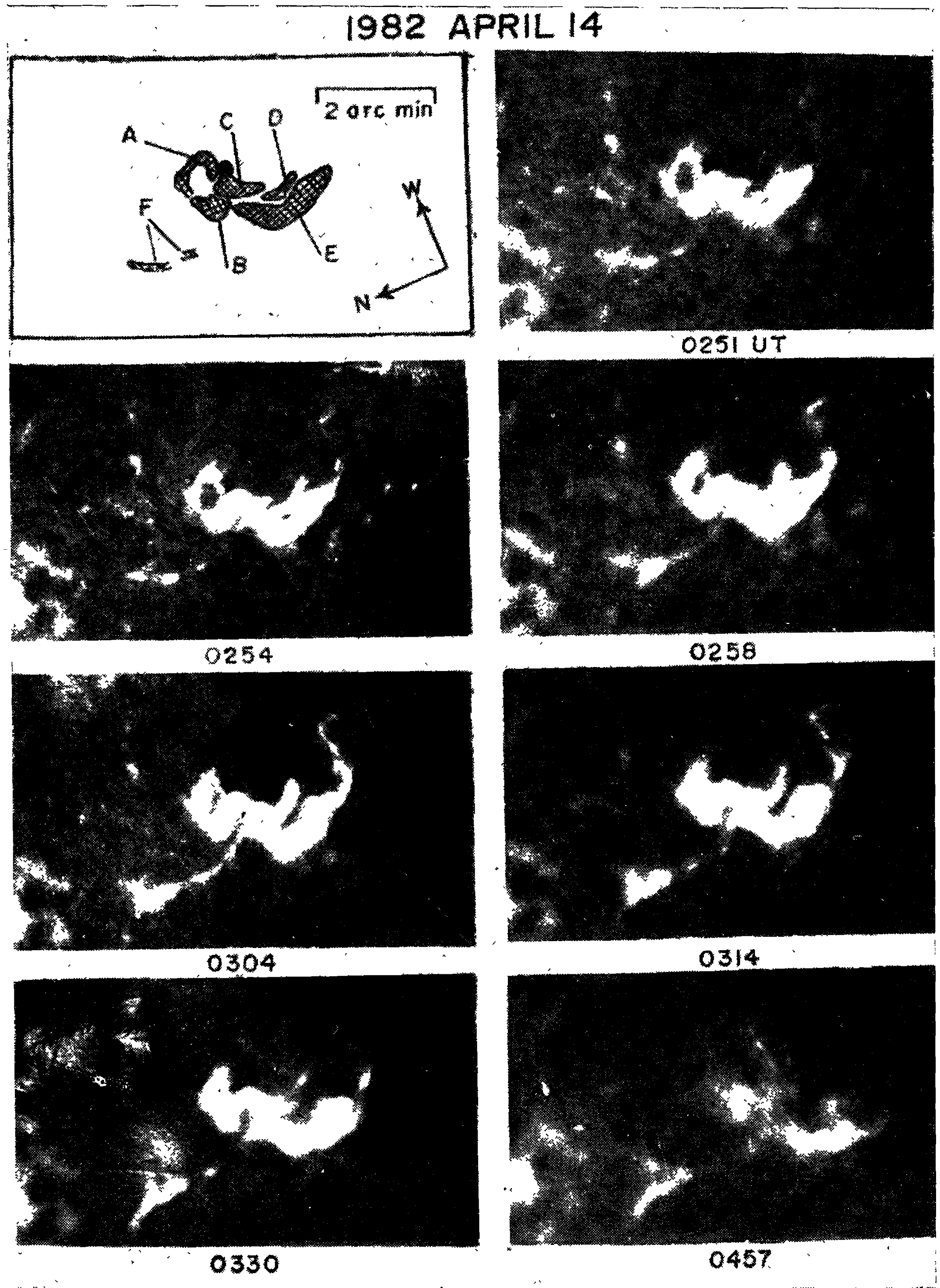

Figure 1. Selected H-alpha filtergrams showing the flare development.

of moderate intensities having peak flux value $\simeq 10^{-20}\mathrm{Wm^{-2}\ Hz^{-1}}$. The dynamic spectra of the event in the spectrograph bandwidth of 8–8000 MHz covered by six receivers were kindly provided by Prof. K. V. Sheridan of CSIRO, Division of Radiophysics, Culgoora. The main part of the radio spectrogram is illustrated in figure 2a. The time marks appear once every five minutes. Universal date and time are in the format : year, month, day, hour and minute.

From the H-alpha observations we see that the various parts of the flare brighten up at different moments and show quite different changes in the brightness. The onset of the flare is preceded by an ejection of mass from the active centre (Solar

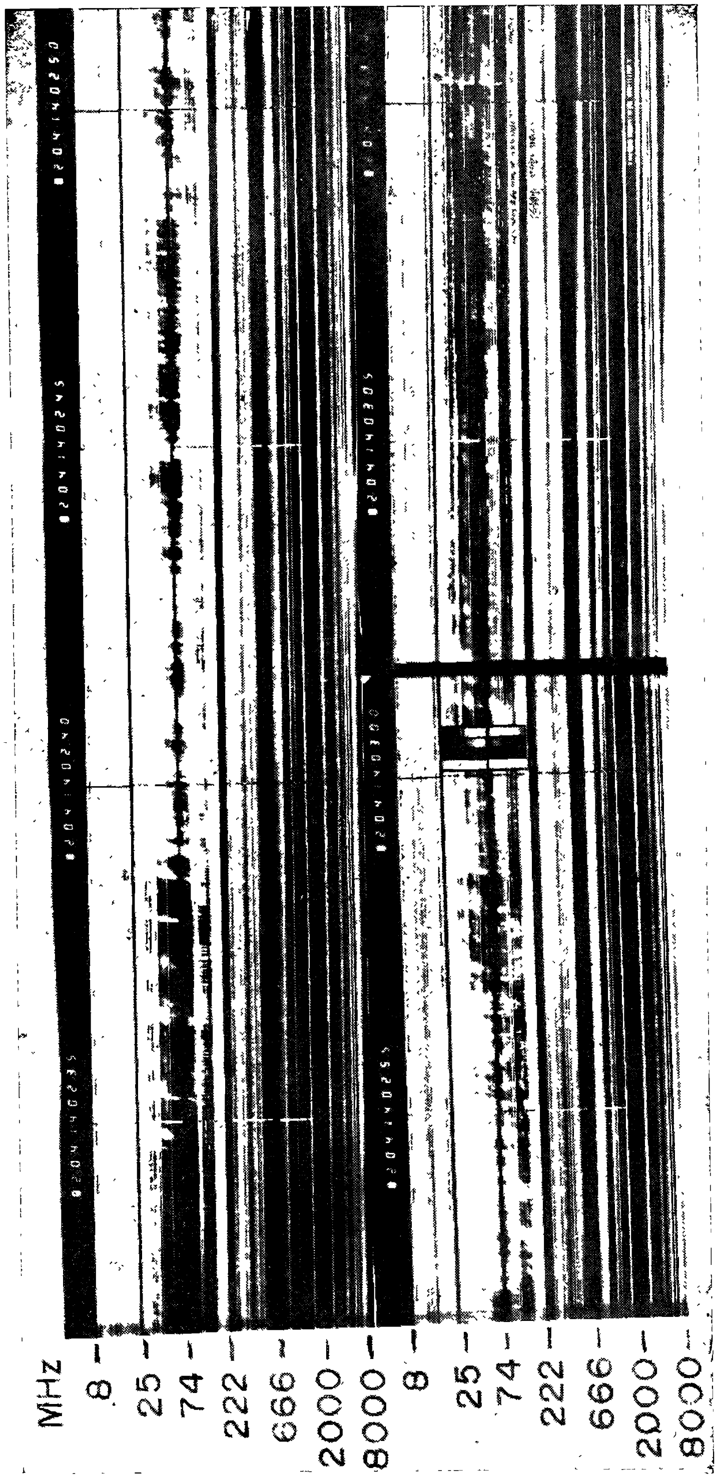

Figure 2(a). Dynamic spectrum observed with the CSIRO radio spectrograph, Culgoora.

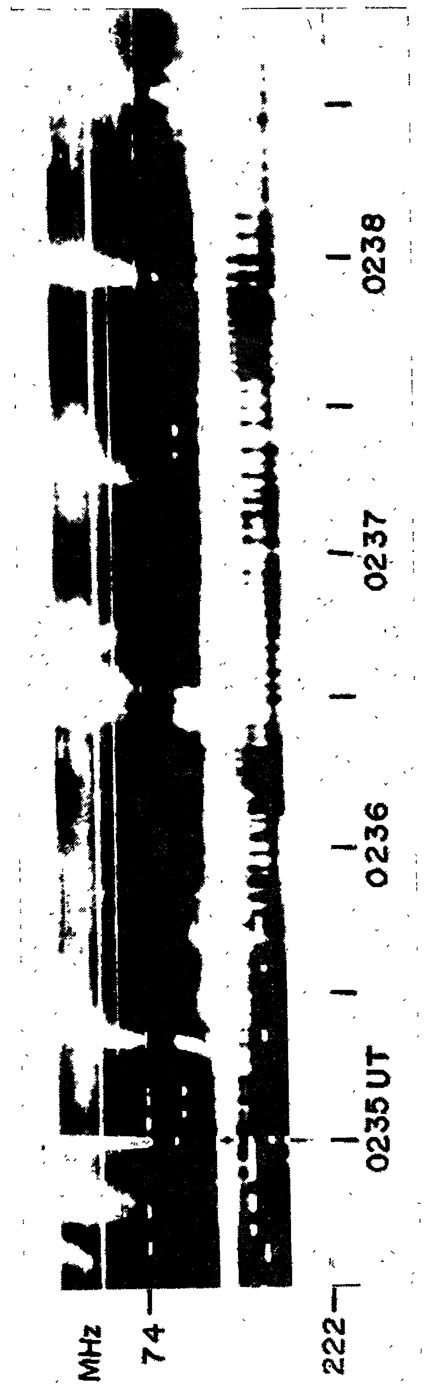

Figure 2(b). The enlargement of the pulsed event to show the pulses more clearly.

Geophysical Data 1982b). This ejected mass probably supplied the nonthermal electrons to a metre wavelength source over the active centre which is evident from the commencement of the type IV continuum and type III bursts in the metric and decametric bands (figure 2a), The emission in the radio region started a few minutes earlier than in H-alpha. The important feature to be noted here is the appearance of the radio pulsation in the metric band (figure 2b). The micro-density scans taken by us of the dynamic spectra in the time direction (figure 3) in the vicinity of 162 MHz showed recurrent enhanced pulses of fluctuating intensity followed by chains of periodic pulses with a mean period ranging from 0.5 to 0.7 s. The pulsation in the metric band seems to be peculiar phase of type IV emission appearing close to those reported by McLean *et al.* (1971), Abrami (1976) and Pick & Trottet (1978). A close examination of the dynamic spectrum shows trains of these pulsating structure preceded by a strong single type III burst or a group of type III bursts in metric band, the extension of which reaches up to the decametric band region (figure 2a).

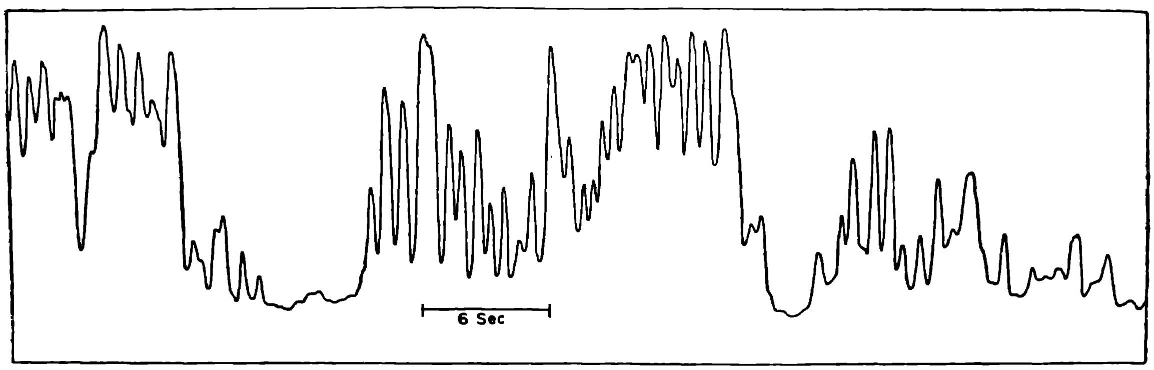

Figure 3. Microphotometric tracing of the pulsating structure (from $02^h36^m10^s$ to $02^h37^m04^s$; 1982 April 14) taken in the vicinity of 162 MHz.

3. Conclusions

We have described here the optical changes in the behaviour of a large and complicated flare and the associated radio events. Before the flare onset in H-alpha, radio pulsation, type IV continuum, type III burst storms and soft x-rays were observed. The development of an H-alpha flare as two ribbons is a secondary process, followed by the energy released during the impulsive phase. Different fragments of the flare (kernels) released streams of nonthermal electrons during the event. It is these electrons which probably generated type III burst storms which when traversing through the coronal plasma stimulated the electromagnetic emissions at local plasma frequency at each level. The inward flow of the electrons produced remote brightenings due to interaction with the lower chromospheric layers in the declining phase of the flare.

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