KODAIKANAL OBSERVATORY

BULLETIN No. 179

The Cosmic Ray Flare of March 7, 1942

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Abstract

The variation of the dynamic characteristics of the cosmic ray limb flare of March 7, 1942 based on the K_{2s} spectroheliograms and H-alpha spectrohelioscope observations of Kodaikanal is presented. Although the flare had high flare ribbon velocities of the order of 17 km/sec. during the flash phase, with subsequent changes in its configuration, its effect on the nearby prominence was trivial. The loop prominence with typical condensations and knots formed at a height of 30,000 km. above the limb and connected to the chromosphere by thin curved threads was noticed, about 1½ hours after the flash phase.

Observations on limb flares are of great interest, as they give information about the vertical aspects of flares in the chromosphere. Observations of these flares are important, as the dynamic characteristics of the flares and of the loop prominences associated with these flares, during their evolution can be studied conveniently, free from the background of photospheric light.

The flare of March 7, 1942, is one of the 10 great solar flares observed so far which have generated cosmic rays recorded at ground level (Ellison *et al* 1961). Apparently the only sequence of spectroheliograms obtained of this solar event was those taken at the Kodaikanal Observatory. This flare occurred over the sunspot group (Greenwich 14015). Examination of the solar disc sketchings shows no other active region. The only other spot group present on March 7 and March 8 (Greenwich 14021) was not active. According to Greenwich, the spot group (Greenwich 14015) was first seen approaching the West limb by February 7, returned to the east limb on February 22 and passed the west limb on March 7, during its second rotation. It returned to traverse the disc during the next two rotations (Greenwich photoheliographic results 1942). The group during the second rotation, gave rise to three flares of importance 3*. The first one, on February 21, when on the east limb was recorded at Meudon, Newton (1947) the second flare on February 28, was described by Ellison *et al* (1961) and the third flare was on March 7, when the spot was on the west limb. From the sunspot drawing of Ellison 1961 it was seen that the group during its

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present passage across the solar disc was of complex magnetic type and the two main umbrae of the principal spot had field strengths of 5100 gauss (south) and 3900 gauss (north). The spot was of the potsdam δ—configuration, thus satisfying an almost

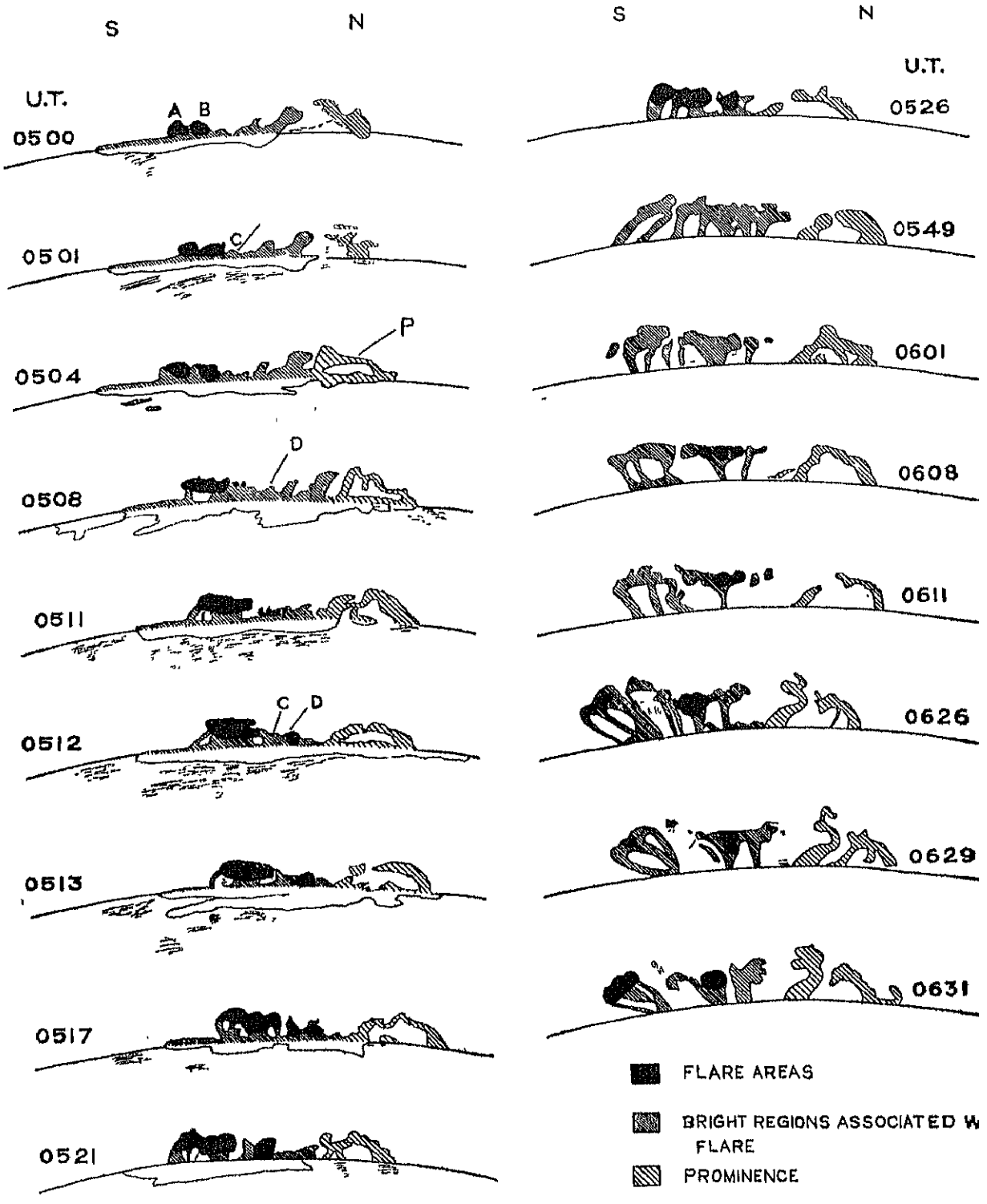

Figure 1: The Cosmic Ray Flare of March 7, 1942

necessary condition for generating a proton flare according to Warwick (1966). reached maximum area of 2048 millionths of the hemisphere on February 25. The ar

progressively decreased during the following days and on March 6 was only 907 millionths and on the day of the flare, 383 millionths. The spot group was at longitude 85° W and heliographic latitude 7°N at the time of the flare.

The Kodaikanal records on the March 7 flare, consist of a series of 50 spectroheliograms in K_{232}, H-alpha spectrohelioscope observations and original sketchings. The flash phase according to spectrohelioscope observations, is at 0445 U.T. and the time of maximum brightness at 0450 U.T. The times of the flash phase and the peak intensity based on ten best magnetic crochet records, Ellison *et al* (1961) are 0442± 1m U.T. and 0450 ±2m U.T. respectively.

In the spectroheliograms taken at 0424 U.T. and 0428 U.T. two thin loops of prominences originating from 1° South of the flare eruption region could be seen. They were not present in the morning spectroheliograms taken at 0258 U.T. These were also absent in the flare sequence spectroheliograms starting 0500 U.T. One of the loops, extended towards the SW direction, whereas the other, curved over the

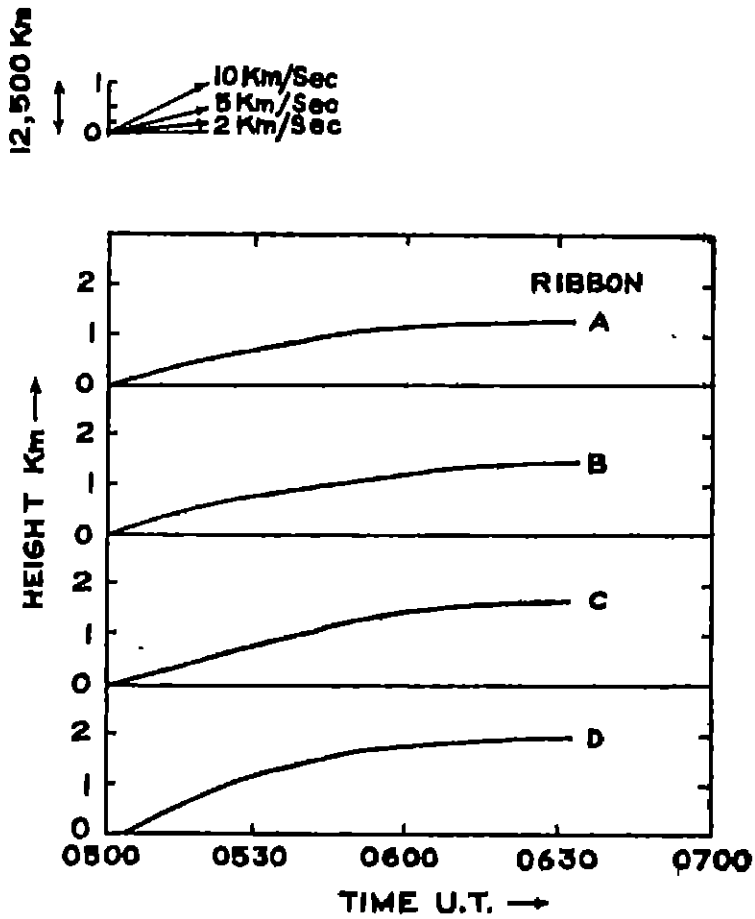

Figure 2: Time Height Graphs of Projected Height of Flare above the limb of four flare-elements. The drawing in the upper left hand corner gives the tangents for velocities of 10, 5 and 2 Km/Sec.

flare region towards an old prominence, formed on March 2-3 and situated to the north of the flare region. We now describe, the evolution of the main optical features in relation to the series of K_{232} spectroheliograms. In the first flare spectroheliogram taken at 0500 U.T. about 10 minutes after the flash phase, two very bright flare ribbons protruding beyond the solar limb were visible (A and B, Fig. 1). Their heights above

the limb at this instant were 11,000 km. and 9,300 km. respectively. The initial development of this flare, was almost opposite to the flare of May 4, 1960, where, the flare began as a brightening in an existing abnormally bright prominence at an elevation of 20,000 Km. above the limb (Ellison *et al* 1961). Assuming the start of upheaval of the flare ribbons to coincide with the flash phase of the flare, we find their mean projected velocity to be nearly 17 km/sec. This order of magnitude of the vertical velocity finds further support from the spectrohelioscope observations, where the line of sight velocities at two places were observed to be 145 km/sec. and 110 km/sec. at 0500 and 0505 U.T. respectively. Such high flare ribbon velocities are quite a rare phenomenon (Ellison 1949). The two rising flare ribbons at 0500 U.T. showed an initial conical shape. By 0501 U.T. they had become rectangular by expanding at their tips (at the rate of 62 km/sec.) but showed no change in height or the base line. At the same time, another bright ribbon C became conspicuous by moving away from the limb (V_h = 36km/sec.). The whole region then merged into one block and continued to expand southward at the rate of 55 km/sec. and gained in height (V_h = 19 km/sec.) till 0508 U.T. Some part of the matter, thus brought forth in view was of a lesser intensity than the original flare ribbons, particularly at the southern end. This gave a frayed appearance to the ribbons. By 0508 a small streak D, 1°N of the three ribbons which had the brightness of a prominence became very bright and moved, away from the limb (V_h = 10 km/sec.). The ribbon D and the ribbon C continued to move away from the limb, maintaining a rate of 10 km/sec. till 0513, without showing any decrease in their brightness. The rate of movement in the region of ribbons A and B and south of it was almost double (about 18 km/sec.) and hence, the portions near the limb and away from the limb, showed a decrease in intensity. In these regions the flare ribbons showed much filamentary structure. The rate of growth of the flare is shown by the time-height graphs for the elements A, B, C, & D. Fig. 2.

From 0513 to 0526 U. T. the whole region projected beyond the limb did not gain in dimensions, but continued to become fainter. At 0529 U. T. both the motion away from the limb and the south ward extension were seen to start again. Along with it, the whole region continued to become fainter, the bright intense regions being confined to few scattered patches which coincided with the original flare ribbons. This trend continued till 0633 U. T. when we have the last picture of the day. The average velocity away from the limb was about 4 km./sec. and the expansion rate was about 12 km./sec. These velocities showed an occasional rise by a factor of 3 to 4. Both the rate of rise and rate of expansion on the southern end were roughly twice, than at the northern end. In the spectroheliogram taken at 0626 U. T. the internal structures such as loops and arches became distinct in the flare; one end of the main loop apparently anchored on the biggest spot was also seen. Within the next 5 minutes, the typical condensations, knots and loops of a loop prominence were formed in the region, about 1½ hours after the flash phase. The knots at a mean height of 30,000 km. above the limb were connected with the chromosphere by thin, less bright curved threads.

Considerlfig the flare from its intense geomagnetic effects, its influences on prominence activity were surprisingly trivial. To the north of the flare, there was an old prominence P, formed around March 2. From the beginning of the flare till 0610 U.T. the prominence remained almost quiescent except for the formation of few condensations in it, and the dispersion by diffusion or occasional lateral motion of these condensations. From 0615 U. T., the prominence changed its shape and curved towards the flare regions with condensations at the top. In this respect, it differed distinctly from the flare of July, 20, 1961, which caused violent changes in the prominence nearby. (Gaizauskas and Covington 1962; Bruzek 1965). This leads us to believe that there were no great changes in the configuration of the magnetic field following the flare, as according to Severney, this change in the configuration is often sufficient

to affect the stability of a nearby prominence. A prominence ray appeared with the flare at 3° north of the flare ribbon zone. This attained its maximum height at 0508 U. T. and thereafter decreased in height, merging into the background by 0517 U.T.

Among the secondary effects of this flare studied by Ellison (1961) were the outstanding magnetic crochets recorded at many stations, which showed an extremely abrupt start and rise to maximum. This has been taken to indicate the rapid rise of the flare to peak intensity.

The increase of cosmic ray intensity was also recorded at 4 stations, the maximum at Cheltenham (Maryland) being 9% above the pre-flare level and which lasted for about 12 hours.

No magnetic storm and consequently no Forbush decrease in cosmic rays were observed following the flare. This is to be expected according to Newton (1943) for, owing to the large heliocentric angle of the flare, the ejected corpuscular stream would invariably miss the earth.

It is a pleasure to thank Dr. M. K. Vainu Bappu, Director, for suggesting this study and for continued help during the course of the investigation.

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ERRATA FOR MODAL ANALYSIS OF ... BULLETIN NO.180

Page	Line	For	Substitute
∴ 17	11	was	was λ 30 metres
∴ 24	24	$V(\cos\phi\cos\gamma_2 - \sin\phi\cos\gamma_1)$	$v(\cos\phi\cos\gamma_2 - \sin\phi\cos\gamma_1)$
∴ 25	6	Cos γ_3	cos γ_2
∴ 25	27	$\gamma I \lambda$	γ_λ
∴ 25	28	$\gamma_\lambda = \int_0^\infty G\psi\left(\frac{K\Delta\lambda}{K\lambda_0}\right)\frac{d\tau}{\mu}$	$\gamma_\lambda = \int_0^\infty G\psi\left(\frac{K_{\Delta\lambda}}{K_{\lambda_0}}\right)\frac{d\tau}{\mu}$
∴ 26	17	log t scale	log τ scale
	25	$\bar{x}$	Nia
∴ 27	2	(in eqn.13) K_λ	k_{λ_0}
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