SOLAR FLARES, CONCURRENT COSMIC RAY BURSTS AND SUBSEQUENT GEOMAGNETIC STORMS

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Five large cosmic ray bursts in connection with solar flares have been observed till now. Two of them were followed by geomagnetic storms associated with cosmic ray disturbances when both the phenomena could be closely correlated. Two of the biggest geomagnetic storms recorded at Alibag have also been considered. Just as in geomagnetism, it was though that a study should be made not merely of individual flares but also of the evolution and progress of solar active regions for the above phenomena.

Big cosmic ray bursts along with solar flares occurred when the active regions on the sun had a long previous history of more than usual activity either when the active region was near the C. M. or near the western limb of the sun. In the former case a geomagnetic storm followed which could be closely correlated with a simultaneous cosmic ray disturbance. In the latter, no *such* type of geomagnetic disturbance followed. In the case of the two biggest geomagnetic storms, the active region was more ephemeral in age or history. The large flares occurred at the period of dissolution of the region soon after its C. M. passage.

The particles responsible for the very big solar flares have atomic numbers neither too low nor too large in the periodic table and are positively charged. The frequency of such events being small the elements involved must be from those in the sun whose abudence is relatively scarce. Detailed spectroscopic examination would decide what these elements are (Sr, Ba. etc.).

Geomagnetic disturbances and particularly the bigger ones among them called storms have been studied for a long time in relation to the progress and evolution of solar active regions during the sun's rotation. In most of the studies of large cosmic ray bursts or sharp increases at the time of or after solar flares, little attempt has been made to relate the events to the evolution of the related solar active regions, or the solar rotation. In fact, solar flares which have been listed as of nearly equal importance in the astronomical publications [1] have been arbitrarily classified under different categories based purely on cosmic ray observations [2]. The large events of solar flares and sharp increases in the cosmic ray ionization at the earth's surface that have been recorded are not very many. But still their study in relation to available geomagnetic and solar data has shown that some order could be obtained in their classification.

Among the non-periodic variations in the incoming cosmic rays at the surface of the earth, a perceptible disturbance — a decrease in general — has, sometimes but not always, been noted about the epoch of geomagnetic storms. On these occasions, the cosmic ray ionization curve with time followed closely the corresponding geomagnetic curve. Corresponding to the hump or crochets in the geomagnetic records at stations on the daylight side of the earth's

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hemisphere at the time of solar flares or chromospheric eruptions, the cosmic ray curves have occasionally shown abnormal increases at stations away from the geomagnetic equator. FORBUSH, STINCHCOMB and SCHEIN [3] gave four instances (Feb. 28th and Mar. 7th 1942 ; July 25th 1946 and Nov. 19th 1949). Recently a fifth instance has been added to the list and was commented upon even in the B. B. C. news broadcast. Even at low geomagnetic latitudes, the cosmic ray curves got affected very significantly.

The solar flares of Feb. 28th 1942 and July 25th 1946 were followed within 24 to 48 hours by geomagnetic storms with closely relatable cosmic ray changes. The solar flares of Mar. 7th 1942 and Nov. 19th 1949 were not followed by geomagnetic storms which could be correlated with contemporary cosmic ray changes. After the great solar flare of Feb. 23rd 1956, a geomagnetic storm was recorded on Feb. 25th. FENTON, McCRACKEN, PARSONS and TROST [4] report that there was no drop in cosmic ray ionization during the period of this geomagnetic storm. SARABHAI, DUGGAL, RAZDAN and SASTRY [5] who reported cosmic ray changes at Ahmedabad and at Kodaikanal and Trivandrum (very near the geomagnetic equator) did not notice any cosmic ray changes during the geomagnetic storm on Feb. 25th 1956.

By assigning characteristic indices as a measure of time fluctuations of cosmic rays in analogy with those used in geomagnetism, it has been shown [6] that while on disturbed days, there was a general trend for both geomagnetic and cosmic ray indices to increase together, two distinct groupings could be recognised as : (a) The cosmic ray index was relatively high while the geomagnetic index was not very large e. g. Feb.—Mar. 1942 and (b) The cosmic ray index was not very large but the geomagnetic index was high, e. g. Mar. 1941. Similarly while during the epoch of the geomagnetic storm of July 26th 1946, cosmic ray changes showed close correspondance, no such simultaneous changes have been reported in the case of the very much bigger geomagnetic storm of Mar. 28th 1946. The geomagnetic storms of Mar. 1st 1941 and Mar. 28th 1946 are the two biggest recorded at the Alibag Bombay Magnetic Observatory[7]. They happened while routine cosmic ray observations were available but yet no outstanding changes in the incoming cosmic rays have till now been reported at those epochs. As the two or three biggest cosmic ray changes without corresponding geomagnetic effects have to be considered, it would be justifiable to include the two biggest geomagnetic events without cosmic ray effect in this study.

[It may be especially pointed out that the Central Meridian (C. M.) distance on any day is to within a few degrees only approximate. For an identical very important flare even near the C. M. the active region No. 17 of the first quarter of 1956, at the same time, KANZELHOHE has assigned 2E while ONDREJOV assigned 10 W, a variation of 12° in the coordinates on the sun. This active region gave later the big solar flare of Feb. 23rd 1956.]

The relevant data have all been tabulated for comparision of each individual event : the five big cosmic ray bursts and the two biggest geomagnetic storms, seven in all. The Tables 1 to 6 have been summarized in Table 7.

Discussion

Re : active region No. 7. of 1941, the chief points to notice are that the region hardly lasted a week with C. M. distances 28E to 53W. Flares of importance 3 were reported towards the end of its life, i. e. when its age was about 6 days. The region was then situated midway between the C. M. and the western limb of the sun. The geomagnetic storm followed 43 hours after C. M. passage and it was perhaps the biggest one as far as geomag. storms are concerned recorded at Alibag/Bombay.

Re : active region No. 12 of 1942, it was observed when it first appeared at the eastern limb of the sun as of importance 3. It was a return of active region No. 5. which had C. M. passage on Feb. 1. 7. The region No. 12 continued active in its progress and even returned a third time as No. 17 with C. M. passage on Mar. 27. 4 with 17 observed distinct flares. The first cosmic ray increase occurred on Feb. 28th 12 U. T. when the active region No. 12 was near the C. M. of the sun. The geomagnetic storm that followed on Mar. 1st 1942 could be closely correlated with the cosmic ray time curves at the same epoch. The geomagnetic storm showed rapid fluctuations in the initial phase.

The second cosmic ray increase of active region No. 12 occurred on Mar. 7th when the active region was near the western limb of the sun. No geomagnetic storm with fluctuations which could be closely correlated with cosmic ray curves were recorded.

Re : active region No. 15 of 1946, though its age has been given at the time of C. M. passage as >6 in the I. A. U. Bull., only three independant flares have been recorded in its passage from 44E to 5E (in C. M. distance). The flares towards its end were of importance 3. *No cosmic ray phenomenon has been reported.* The geomagnetic storm that followed was the second biggest recorded at Alibag/Bombay and was associated with radio fade-outs and dislocation of submarine telecommunications.

Re : active region No. 51 of 1946, this could be observed when it was near the eastern limb of the sun (within a day) and the flares through its progress had importance 2 and 3. The cosmic ray increase occurred on July 25th 1600 U. T. when the active region was near the C. M. of the sun. It was followed next day by a geomagnetic storm whose fluctuations could be closely correlated with Cosmic Ray curves with time. When the active region was nearing the western limb, though it continued to be active, relatively to its previous history, it was less marked.

Table 1

Solar active region No. 7 of 1941. Central meridian passage Feb. 27. 3. No. of observed distinct flares: 7

Date	Station	Time (U. T.)	Coordinates ∅ C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1941							
Feb. 25.	Kodaikanal	0250—0330 (Max. 0300)	13N 28 E	1			
Feb. 26.	Meudon	1317—1328	15N 8E	2			
	Zürich	*1345*—1400	15N 9E	1—2			
Feb. 27.	Mt. Wilson	*0036*	16N 2E	1			
	Mt. Wilson	1953—2018 (Max. 2018)	16N 7W	2			
Mar. 1.	Zürich	*1328—1418*	16N 27W	1—2	Active. Imp. filament	Biggest. Geomag. storm Mar. 1st 0355 U. T. s. c.	No report of cosmic ray abnormality
	Meudon	1626	14N 30W	1	End of Imp. Flare (main large spot dissolving)	ΔH 45 γ; ΔZ —50 γ ΔD 1′ 4 to W.	
Mar. 3.	Greenwich	0840—*0910* (Max. before 0840)	13N 54W	3		Range: H > 1000 γ (1200 γ ?) Z 130 γ D 16′	
	Simeis	0925—1023	17N 53W	3	Several active centers		

[The active region lasted hardly a week. Its age at the time of C. M. passage was just two days. The big flares of Imp. 3 occurred when the age was 6 days, but when the region was neither near the C. M. nor near the limbs but when it was almost midway between the C. M. and the western limb.]

Table 2

Solar active region No. 12 of 1942. C. M. Passage Feb. 28. 8. 1942. No. of observed distinct flares : 17

Date		Station	Time (U. T.)	Coordinates ⌀ C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1942								
Feb.	21.	Meudon	1340—1509	7N 90E	3	Visible at edge 35 000 km above chromosphere. Invis. 1310 hr		
		Zürich	1342—*1352*	7N 90E	2		s. c. geomag. storm Alibag. Feb. 23rd 1329 U. T. to Feb. 24th 1600 U. T. Range: H 171 γ; Z 37 γ; D 3′. 9	
Feb.	25.	Taskhent	*0724—0736*	4N 47E	1			
	27.	Sherborne	1052—1114	6N 9E	1			
	28.	Kodaikanal	0235—0257	5N 10E	2			
		Arcetri	1100	5N 5E	3	Many brilliant spots		
		Sherborne	1242—1522	7N 4E	3	Exceptionally brilliant and spread out		Just before 12 U. T. of 28th cosmic ray burst except at Huancayo
		Greenwich	1415—1430	7N 6E	2	Very much spread out		
		Greenwich	1500—1505	7N 6E	2			
		Mt. Wilson	1714—*1732*	8N 2E	1		Severe s. c. geomag. storm. Mar. lst. 0726 U. T. Alibag. s. c. in H 75 γ., rapid fluctuations in H till 0905 U. T.	Cosmic ray decrease at all stations at time geomag. storm s. c. with corresponding changes later
Mar.	1.	Zürich	*1020—1055*	12N 4W	2			
		Zürich	*1520—1535*	7N 7W	1	Brilliant spot		
		Mt. Wilson	1745—*1816*	8N 12W	1			

[Mar. 2nd and Mar. 3rd prominent with flares of Imp. 2 and 3. Five observations.]

Table 2 (contd.)

Solar active region No. 12 of 1942

Date	Station	Time (U. T.)	Coordinates ∅ C. M. Dist.	Imp.	Remarks Solar	Remarks Geomagnetic	Cosmic Ray
1942							
Mar. 4.	Kodaikanal	0249	7N 42W	2			
	Taskhent	0700—0745	5N 55W	1			
6.	Taskhent	0456—0509	0 90W	1	Eruptive protuberance	Geomag. dist. g c. Mar. 5th 13 U. T. Range : H 142 γ Z 18 γ Radio fade-out day-light side of earth Mar. 7th 04 U. T.	Sharp cosmic ray increase about Mar. 7th 0415. U. T. except at Huancayo

[Note : Solar active region No. 12 of 1942 was a return of No. 5 with one observed flare and C. M. passage Feb. 1,7 ; third return of the region as No. 17 with 17 observed flares and C. M. passage Mar. 27. 4.]

The cosmic ray sharp increase occured on 28th 12 U. T. about the time active region was near C. M. that on Mar. 7th occurred when the region near the western limb of the sun. The first increase on Feb. 28th was subsequently followed by a geomagnetic storm which affected the cosmic ray ionization curve also. The second increase in cosmic ray intensity on Mar. 7th was not followed by a geomagnetic storm at all.

Table 3

Solar active region No. 15 of 1946. C. M. passage Mar. 26. 9. No. of observed distinct flares: 3

Date	Station	Time (U. T.)	Coordinates ∅ C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1946							
Mar. 23.	Worthing	*1235*—1245	23N 44E	1			
26.	Zürich	0656—0710	25N 22E	2			
27.	Kodaikanal	0410—0445	20N 5E	3			
	Taskhent	0430—*0732*	19N 5E	3	Two eruptive centers	Severest completely recorded geomagnetic storm at Alibag. Mar. 28th 0735 U. T. s. c.: ΔH 82γ; ΔZ —27γ; ΔD 1′·3 λ *W*. Range: H 1040 γ; Z 141 γ; D 22′. 8 Complete radio fade-out A. I. R. 1130 to 1530 U. T. of 28th Dislocation submarine cables Aurorae	No significant change reported

[Note: The active region did not show great activity though I. A. U. Bull. shows that its age at C. M. passage was more than 6 days. Geomagnetic storm after the C. M. passage of the active region. The solar flare on 27th though quite important from other consideration was not one from a continuously highly active region.]

Table 4

Solar active region No. 51 of 1946. C. M. passage July. 26. 8. No. of observed distinct flares: 37

Date	Station	Time (U. T.)	Coordinates ∅ C. M. Dist.	Imp.	Remarks Solar	Remarks Geomagnetic	Cosmic Ray
1946							
July 20.	Sherborne	1625—*1637*	21N 80E	1			
21.	Taskhent	0740—*0920* (Max. 0750)	22N 70E	2	End uncertain		
	Zürich	1525—*1630*	22N 70E	2			
22.	McMath	1546—1601	25N 46E	3			
23.	Taskhent	*0530—0645* (Max 0550.)	20N 48E	2	Two eruptive centers		
	Zürich	0700—0820 (Max. 0730)	20N 50E	2			
	Greenwich	0910—0950 (Max. 0918)	22N 45E	3			
	Arcetri	0940—0950	21N 52E	3			
	McMath	1413—1500	25N 40E	3			
	Greenwich	1505—1525	22N 42E	2			
	McMath	1715—1759	25N 40E	3			
	Sherborne	1716—*1813*	22N 36E	2			
24.	Greenwich	1345—1357	22N 34E	2			
	McMath	1520—1805	25N 30E	2			
25.	Greenwich	0946—1022 (Max. 1005)	22N 23E	2			
	Worthing	0956—1040 (Max. 1007)	21N 25E	2			

Table 4 (contd.)

Solar active Region No 51 of 1946

Date	Station	Time (U. T.)	Coordinates ⌀ C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1946							
July 25.	Meudon	*1504*—1830	20N 15E	3+	Great increase after 1616 hr	Radio fade-out 25th 1600 U. T. Sun-lit hemisphere	Sharp increase of cosmic rays at Godhavn, Cheltenham and Christchurch at 25th 1600 U. T. Huancayo and Teoloyucan showed no change
	Sherborne	*1513*—*1527* (Max. 1517)	22N 15E	2			
	Zürich	1610—*1800* (Max. 1640)	20N 18E	3+			
	Cambridge	1612—1740	20N 15E	3			
	Sherborne	*1615*—1810 (Max. 1627)	22N 15E	3+			
	Mt. Wilson	1621—*2030* (Max. 1641)	21N 18E	3+	Exceptionally large sun spot crossed C. M. (4000 millionth of sun's hemisphere in area)		
26.	McMath	1448—1503	20N 5E	2		Great geomag. storm at Alibag. Jul. 26th 1850 U. T.; ΔH 100γ; ΔZ —29γ; ΔD 3′. 1W followed by rapid fluctuations. Range : H 499γ; Z 103γ; D 12′. 5	Cosmic ray decrease and corresponding fluctuations with geomagnetic storm at Huancayo, Teoloyucan, Cheltenham, Godhavn and Christchurch
27.	McMath	1356—1436	20N 8W	3			
Aug. 1.	McMath	1555—1728	23N 77W	1—2			
	Meudon	1744—1815	21N 85W	2			
2.	Taskhent	0456—*0510*	22N 87W	1	Eruptive protuberance again active 0720 hr		
	Zürich	*0630*—*0645*	21N 82W	1			

[Note (a) Due to large number of flares from July 21st to Aug. 1st only those of Imp. 2 or more cited here. Active region No. 51 returned as region No. 62. C. M. passage Aug. 24.1 with three distinct flares. From July 22nd to 26th no other active region present.]

Cosmic Ray increase occurred when the active region was within a day of crossing the C. M. It was followed later by a geomagnetic storm which could be closely correlated with the corresponding cosmic ray changes. This active region was all along active from the time it was sighted in the eastern limb of the sun till after it crossed sun's C. M. It became less active as it reached the western limb, compared with its earlier history, though not absolutely.

Table 5

Solar active region No. 23 of fourth Quarter of 1949. C. M. passage Nov. 14. 1. 1949. No. of observed distinct flares: 17

Date	Station	Time (U. T.)	Coordinates φ C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1949							
Nov. 11.	Mitaka	*0522—0557*	3S 53E	1	Several eruptive centers		
17.	Schauinsland	*0925—1016* (Max. 0949)	2S 43W	2			
	Kodaikanal	1000	2S 46W	1			
	Wendelstein	*1119—1218* (Max. 1140)	2S 40W	2			
	Greenwich	1230—1237	3S 46W	2			
	Mitaka	*2345—2400*	3S 55W	2	With dark filaments of large radial speed		
18.	Mitaka	*0106—0125*	0 55W	2—		A g. c. geomag. storm at Alibag. Nov. 18th 0530 to 2000 U. T. Range: H 264γ; Z 71γ	
	Kanzelhohe	1130—*1139*	2S 59W	2			
	Wendelstein	1132—1142	2S 57W	2			
	Kanzelhohe	1340—*1356*	2S 60W	1+			
19.	Wendelstein	1029—1119 (Max. 1032)	5S 74W	3			Large sharp increase in cosmic rays Nov. 19th 1045 U. T. at high geomag. latitudes. Climax (Colorado) increased by 207 % and Cheltenham 43%. Not followed by a decrease of a geomag. associated storm
	Edinburgh	1630—*1209* (Max. 1632)	2S 70W	3+	Exceptionally important eruption with eruptive protuberance reaching 560 000 km height at 1059 U. T.		
	Greenwich	1037—*1130*	2S 70W	3			
	Ondrejov	1037—*1057*	2S 74W	2+			
20.	Zürich	1013—1022	5S 80W	1			

[Note : Solar flares of Imp. 1 have been omitted except at start and end of active region. No. 23 region was a reformation of No. 13 of the same quarter C. M. passage Oct. 18.8 1949 with 8 distinct observed flares. All the observations for Nov. 19 refer to identical flare.]

Though the age at C. M. passage of active region No. 23 is given as — 1 in I. A. U. Bull., it had been observed at least thrice before C. M. passage (during the three previous days). It was also a fresh formation on return of an older group and might therefore have reasonable continuity. The flares near the western limb were very prominent and the cosmic ray burst occurred then.

Table 6

Solar active region No. 17 of first quarter of 1956. C. M. passage Feb. 17. 8 No. of observed distinct flares : 32

Date	Station	Time (U. T.)	Coordinates ∅ C. M. Dist.	Imp.	Remarks Solar	Remarks Geomagnetic	Cosmic Ray
1956							
Feb. 10.	Capri (Fraunhofer)	1255—1301	22N 80E	1+			
	McMath	2110—2140	20N 90E	3			
11.	Abastumani	*0631—0710*	25N 77E	2			
13.	Abastumani	*0600—0719*	22N 52E	2			
	Capri F.	1007—1012	20N 40E	2			
	Sac. Peak	*1418—1558* (Max. 1450)	18N 47E	1+			
14.	Kodaikanal	*0538—0635* (Max. 0557)	23N 26E	2			
	Mitaka	*0539—0709*	20N 30E	3			
	Taskhent	0602—*0730*	21N 40E	3			
15.	Mitaka	0018—0058	20N 20E	2			
16.	Capri F.	*1118*—1153	24N 8E	2			
	Mt. Wilson	1821—*2039* (Max. 1837)	22N 6E	2			

Table 6 (contd.)

Date	Station	Time (U. T.)	Coordinates ⌀	C. M. Dist.	Imp.	Solar	Remarks Geomagnetic	Cosmic Ray
1956								
Feb. 17.	Abastumani	*0640—0834*	25N	4W	2			
	Abastumani	*1100—1225*	24N	4W	3			
	Zürich	*1104—1211*	19N	0	2			
	Nizamiah	*1110—1203* (Max. 1120)	21N	6W	3			
	Herstmonceaux	1113—1123	23N	2W	2			
	Kanzelhohe	1125—*1155*	18N	2E	3			[Sharp increase of cosmic ray ionization reported almost everywhere including low geomag. lat. stations like Kodaikanal Trivandrum etc. on Feb. 23rd 1956 0330 U. T Solar noise radio fade-out also reported
	Nera	1125—*1200*	19N	2W	2			
	Wendelstein	1125—1242	21N	9W	2+			
	Ondrejov	1152—1242 (Max. 1209)	16N	10W	2			
19.	Abastumani	*0755—0825*	19N	26W	2	Several eruptive centers		
	Abastumani	*0914—0943*	22N	24W	2			
	Sac. Peak	1430—*1657* (Max. 1445)	23N	27W	1+	[The flare was not reported on Feb. 24th showing that active region which was prominent for 13 days had passed out]		
	Ondrejov	1434—1435	27N	18W	2			No significant cosmic ray changes reported at time of geomag. storm of Feb. 25th 1956]
20.	Abastumani	*1134—1240*	19N	38W	2	Several eruptive centers		
	Wendelstein	1143—*1319*	20N	40W	1+			
	Herstmonceaux	1230—1240	20N	40W	2			Big cosmic and solar phenomena reported when active region was almost on western limb
23.	Mitaka	*0334—0414*	25N	85W	3			
	Kodaikanal	*0335—0510*	23N	80W	2—3			
	Taskhent	*0429*—0500	20N	76W	2			

Table 7 (Summary)

Year	No.	Coordinates ∅ L	C. M. Passage		No. of Disinct obsd. Flares	Date	Flare		Date of		Cosmic Ray affected Mag. Stm.	Interval between Magnetic Stm. and (in days)	
			Date on	Age at			C. M. Dist.	Age	Cosmic Ray Burst	Magnetic Storm		Flare	C. M. passage
1941	7	15N 354	Feb. 27. 3.	2	7	—	—	—	—	Mar. 1. 15.	No.	—	1,85
1942	12	7N 197	Feb. 28. 8.	+26?	17	Feb. 28. 5.	4E	+26?	Feb. 28. 5.	Mar. 1. 31.	Yes	0,81	0,51
1942			Feb. 28. 8.		17	Mar. 7. 18.	91W	+32?	Mar. 7. 18.	—	No.	—	—
1946	15	23N 10	Mar. 26. 9.	>6	3	Mar. 27. 2.	4W	>6	—	Mar. 28. 1.	No.	1,1	1,41
1946	51	21N 198	Jul. 26. 8.	>6	37	Jul. 25. 67.	16E	>5	Jul. 25. 67.	Jul. 26. 8.	Yes	1,13	0,0
1949/4	23	2S 116	Nov. 14. 1.	3	17	Nov. 19. 40.	75W	8	Nov. 19. 44.	—	No	—	—
1956/1	17	22N 176	Feb. 17. 8.	>6	32	Feb. 23. 13.	80W	11	Feb. 23. 13.	—	No	—	—

[Note. (a) C. M. distances and age refer to those of the solar active region numbered in each row.
(*b*) C. M. distances within a few degrees only approximate.
(c) For active region No. 23 of fourth quarter of 1949, the age at C. M. passage is given as —1 in Q. Bull of I. A. U. It was, however, observed on 11th Nov. at Mitaka, Nov. 13. at Kanzelhohe and again on Nov. 14 at Mitaka and the age has been changed here. However, in the Q. Bull., it is mentioned that the active region was a fresh formation on the return of No. 13 active region of the fourth quarter of 1949.]

Re: active region No. 23 of the fourt hquarter of 1949; its age at the stage of C. M. passage is given in I. A. U. Bull. as — 1 day. But it had been observed thrice within the three previous days of its crossing the C. M. (14. 1. Nov. 1949) i. e. from Nov. 11th. It has also been stated to be a fresh formation on its return of an earlier active region No. 13 with C. M. passage on Oct. 18. 8. No cosmic ray or significant geomagnetic phenomena were recorded at the time of the C. M. passage of the region. The region became more active towards the period of its approaching the western limb of the sun. The cosmic ray burst occurred when the active region was about a day's journey from the western limb of the sun. No geomagnetic storm nor marked correlatable cosmic ray decrease has been reported, subsequent to the flare. The sharp increase in cosmic rays at Climax was the largest till then recorded and drew wide attention.

Re: active region No. 17 of the first quarter of 1956, it was observed when it approached the eastern limb of the sun. It has been reported as of Imp. 3 by McMath. It continued very active in its passage to the C. M. and to the western limb of the sun. While the period could not be described as geomagnetically undisturbed, no geomag. storm which could be correlated with cosmic ray decreases were reported about Feb. 18 to 19 1956. The big cosmic ray increase occurred on Feb. 23rd 1956 when the region was almost at the western limb of the sun. The corresponding solar flare was also Imp. 2 to 3. The geomagnetic storm on Feb. 25th 1956 did not mark any cosmic ray decrease nor could if be correlated with cosmic ray curves at the same epoch.

The number of large events in cosmic rays with solar and geomagnetic events that have been observed has been small. But still a separate study of them might be fruitful. The summary given above of all related phenomena might, taking the number of events available into account be used to draw some conclusions.

The active regions No. 7. of 1941 and No. 15 of 1946 were either short lived or showed up only a limited number of chromospheric eruptions. Towards the end of their lives important flares were reported. Solar flares were also reported within a day (± 1 day) of the C. M. passage of the region. Subsequently within 24 to 48 hours very big geomagnetic storm took place.

The active regions No. 12 of 1942 and No. 51 of 1946 were active from the eastern limb to the western limb of the sun. Large solar flares occurred when these regions were within one day (± 1day) of the C. M., cosmic ray increases where recorded at many stations. Within 24 to 48 hours in each case a geomagnetic storm which could be correlated with cosmic ray changes at the same epoch was reported.

The active regions No. 12 of 1942, No. 23 of the fourth quarter of 1949 and No. 17 of the first quarter of 1956 were all active near the western limb of the sun, i. e within a day of it (± 1 day). Even No. 23 of the last quarter of

1949 had an active history extending beyond 5 to 6 days. The other two were very active for more than 11 days. At the stage of these regions nearing the western limb ($\pm$ 1 day) of the sun, sharp increases in cosmic rays were observed to coincide with the time of flares at many stations. In the case of the most active region, the increase has been recorded even near the geomagnetic equator.

If it is assumed that the facts brought out above have more than particular application, it may be concluded that large cosmic ray bursts have occurred in connection with solar flares associated with active regions with a long history of considerable activity at the stage of the active region being either near the C. M. or near the western limb of the sun. When it was near the C. M., a geomagnetic storm which could be correlated with a contemporaneous cosmic ray changes also followed. When the region was near the western limb, no such closely associated geomagnetic cosmic ray disturbance followed. The very big purely geomagnetic storms followed the C. M. passage of active regions whose history of activity was less marked, either it had begun only a few days earlier or its activity did not attract much notice. At the stage of dissolution soon after C. M. passage, the active regions showed chromospheric eruptions of Imp. 3 and the geomagnetic storms of very great intensity were recorded.

Another point that may be noticed is that the time interval between the C. M. passage of the active region and the geomagnetic storm was less in the instances when it followed a large cosmic ray increase and associated solar flare than in the case of a purely geomagnetic disturbance. Even if the time after the solar flare and succeeding geomagnetic storm is considered, the result is similar. The particles for the joint cosmic ray-geomagnetic disturbances have greater velocity than those for purely geomagnetic disturbances.

Conclusions. As the cosmic ray bursts are associated with solar active regions of long history and of abnormally large chromospheric activity, the particles responsible for cosmic ray changes can be assumed to have been accelerated over many days in those abnormally active regions. The particles emitted near the sun's C. M. would be normal to its surface while those at the limbs may be expected to be tangential to it. The purely cosmic ray bursts (i. e. not associated with geomagnetic storms related to cosmic rays) happened when the active region was near the western limb of the sun, even though at the eastern limb the same active region showed great activity, perhaps greater activity as shown by solar figures than when on the western limb, no cosmic ray burst has been reported. The particles must have definite polarity or charge and we may expect that the particles responsible for cosmic ray bursts when the active region is near the C. M. of the sun are also charged.

As the particles have to retain their identity at the stage of being accelerated for many days in the sun's active region before emission into space, the particles or atoms would neither be on the side of low or very high atomic numbers and would be positively charged. As the frequency of solar flare cum Cosmic Ray bursts have not been many, if group II elements be considered, one will have to look for Strontium or Barium atoms, constituting only 0.03 per cent of the amount in the sun compared with Calcium being emitted. It would therefore be necessary to look for these or other unusual elements in the spectrum of the solar flare on these special occasions.

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О СОВПАДЕНИИ УСИЛЕННЫХ КОСМИЧЕСКИХ ЛИВНЕЙ С СОЛНЕЧНЫМИ ВСПЫШКАМИ И О ПОСЛЕДУЮЩИХ ГЕОМАГНИТНЫХ БУРЯХ

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Резюме

До сих пор наблюдалось пять больших ливней космического излучения, связанных с солнечными вспышками. За двумя последовали геомагнитные бури сопутствующие помехам в космическом излучении, когда между обоими явлениями могла быть установлена тесная связь. Две из самых больших геомагнитных бурь, наблюдаемых в Алибаг, при этом тоже принимались в расчет. Как в геомагнетизме, так и здесь казалось уместным исследовать не только отдельные вспышки, но также и процесс развития активных солнечных областей этих явлений.

Большие космические ливни при наличии солнечных вспышек появились, если активные области на солнце имели длинную предысторию повышенной активности, или, когда активная область была близка к центру тяжести или к западному краю солнца. В предыдущем случае последовала геомагнитная буря, которую можно было коррелировать с одновременными помехами в космическом излучении. Во втором случае таких геомагнитных возмущений не было. В случае самых больших геомагнитных бурь время жизни и история активной области была более коротка. Большие вспышки наблюдались в периоде исчезновения области, скоро после ее перехода через центр тяжести.