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LONG-PERIOD PULSATIONS OF DECIMETER SOLAR RADIO EMISSION AND EVOLUTION OF ACTIVE REGIONS

Y.A. Averyanikhina, M. Paupere and G. Ozoliņš

Radioastrophysical Observatory, Latvian Academy of Sciences, Turgeneva 19, Riga, LV 1527, Latvia

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Abstract. The results of an analysis of long-period pulsations of solar decimeter wave radio emission based on a large amount of statistically homogeneous data are given. Long-period pulsations always are observed on the growing phase and/or at the maximum size of a solar active region. The occurrence of the long-period pulsations is closely related with the rising of a new magnetic flux into the corona.

Key words: solar radio emission - dm wave pulsation - active regions - proton flares

1. Introduction

Both the observational data and the existing theories of the solar flares (Altyntsev et al., 1982) give evidence of pre-flare energy accumulation in active regions, located in the upper chromosphere and corona. The accumulation probably lasts hours or tens of hours and is accompanied by various types of instability, depending on the height and power of the energy source and parameters of the magnetic field inside the active region. As a result, changes of radio emission from these atmosphere levels can appear. Long period pulsations of the solar spectrum slope in the centimeter range (Kobrin et al., 1975), as well as of intensity of the decimeter range (Averyanikhina et al., 1982) have been detected 1 to 2 days before the proton flares. However, the dynamics of the processes inside the active regions leading to generation of the long-period pulsations is still not well understood. As a result, it is difficult to choose appropriate physical models of the processes, necessary to forecast the events.

2. Observations and discussion

To investigate the connection between the long period ($P >$ 20 min) pulsations (LPPs) of solar decimeter radio emission and evolution of the active regions (ARs), about a thousand of records of solar radio emission on 755 MHz frequency obtained with the RT-10 radiotelescope in 1984 to 1989 have been analysed. The initial levels of LPP amplitudes, i.e. LPP mean daily amplitudes of the quiet Sun, necessary for this study, have been obtained from our earlier data (Semenova et al., 1987), where methods of a short term forecasting of geoactive flares are proposed. The statistical analysis of solar decimeter range observations in 1979–1983 has shown that the increase of the LPP mean daily amplitudes $\bar{A}$ by two or more times with respect to the LPP amplitudes $\bar{A}$ of the quiet Sun (about 0.6%) is statistically significant, with 5% significance level. The mean daily amplitude of radio pulsations is determined as $\bar{A} = \sum A_i/N$, where N is the total number of pulsations observed each day.

In about 10% of records made in 1984 to 1989, we discover LPPs ($P >$ 20 min) with the levels exceeding 0.6%. Fig. 1 shows the mean amplitudes of pulsations on 755 MHz frequency for the whole period of observations; the proton flare moments are marked by triangles. It is evident that with the increase of solar activity, LPPs appear more frequently. However, we lack continuous observations for the years near solar activity minimum.

Since we had only the integral decimeter emission observations, their tying up with definite ARs was done by using the simultaneous observations with our centimeter-range specialized radiotelescope DRIFT, giving us information about the coordinates of the centre of gravity of solar radio emission. Twenty groups of records have been selected, having a possibility to be connected with the definite AR. Fourteen of these groups are related with the proton-active regions (Table 1).

As an example, Fig. 2 exhibits some characteristic events in which a change of the LPP mean daily amplitudes depends on the mean area of the proton and non-proton ARs. It is obvious that the long period pulsations are emerging at the maximum daily growth of the active region area.

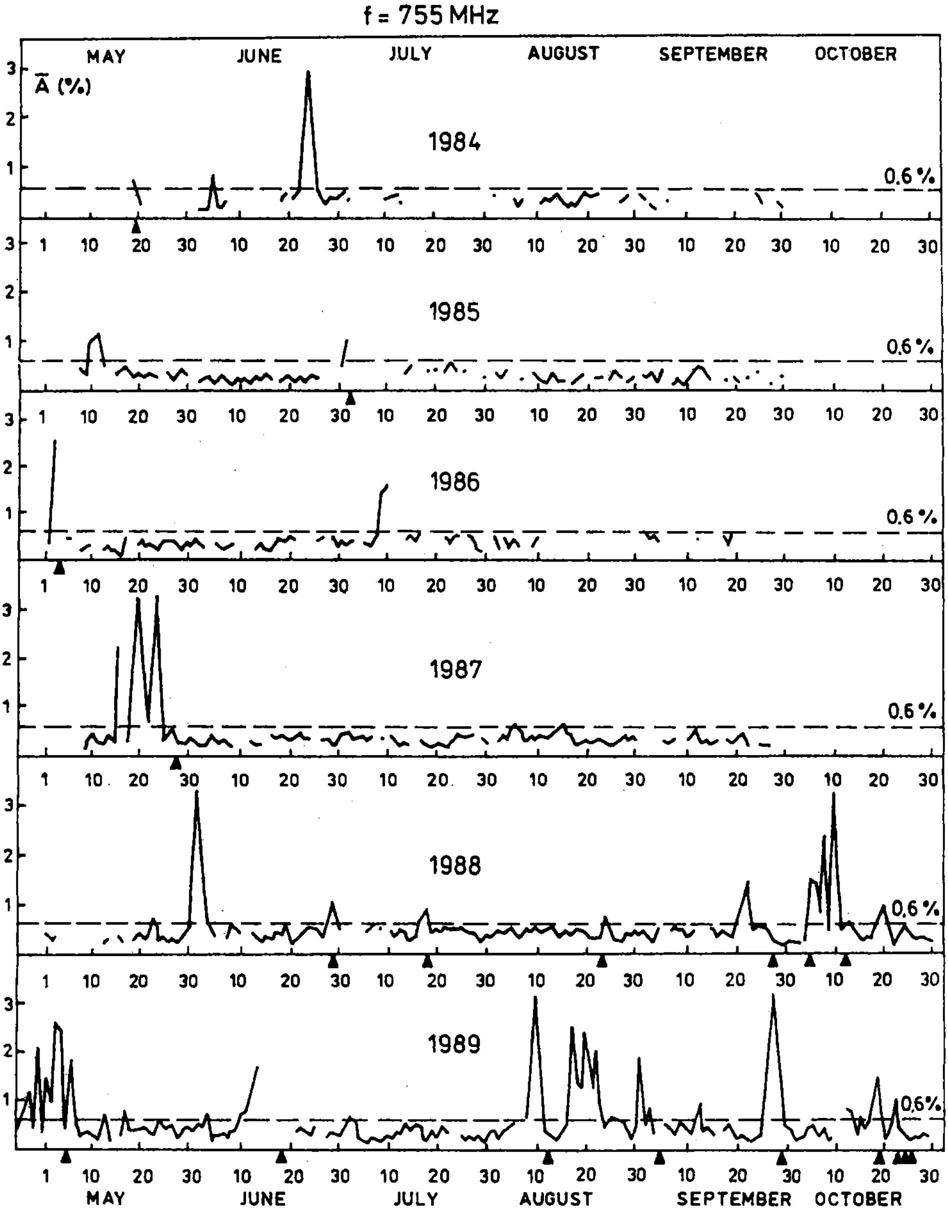

Fig. 1. The mean daily amplitudes of LPPs on $f = 755$ MHz. ▲ are the moments of the solar proton flares.

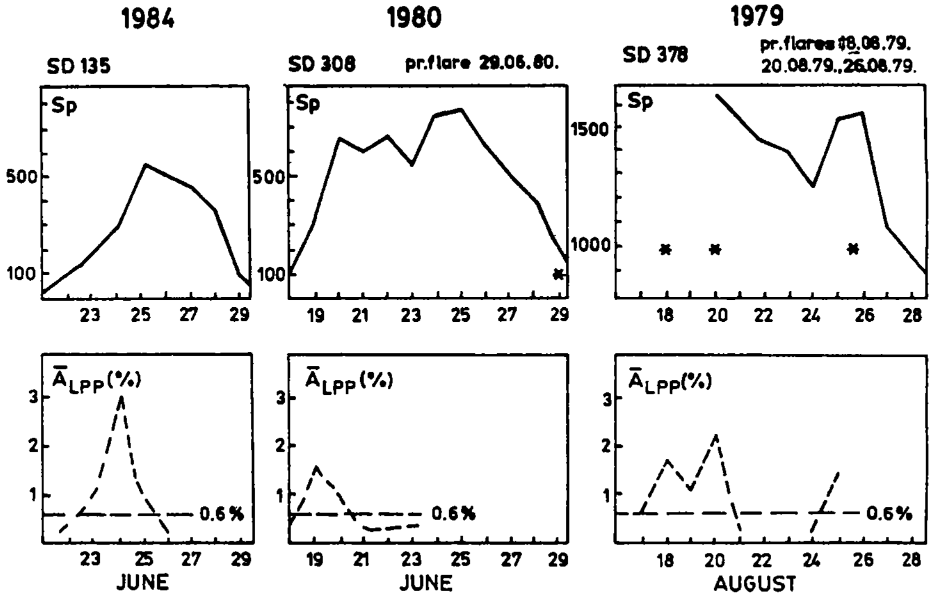

Fig. 2. Examples showing the changes of LPP mean amplitudes with the area of AR. Sp are the millionth parts of the solar hemisphere. Asterisks mean the proton flares.

Fig. 3 displays the longitude and latitude distribution of the AR centres with the observed LPPs. One can see that all ARs accompanied by LPPs have emerged in the regions of active longitudes, irrespective of were the proton flares observed or not. Table 2 gives the data of longitudinal distribution of ARs with LPPs for both solar hemispheres separately for each year.

The analysis of all LPP groups shows, that they are observed at the phase of increasing area and/or near the phase of maximum area of AR, while the proton flares are observed near the phase of maximum area or during the phase of decreasing area of AR. The histograms in Fig. 4 show distribution of the emerging moments and the lifetimes of LPPs and proton flares as a function of time of development of the AR area in days. Zero is the day with the observed $S_{\max}$. $N_{\rm LPP} = 1$ is the number of records with long period pulsations: $N_{\rm LPP} = 1$ for days with the observed LPPs. After that, using the superposition method of epochs, we obtain histograms for all the records.

When the area S of a certain AR has several significant maxima, emerging of LPPs and proton flares is considered with respect to the

Table 1. Observed groups of the long period pulsations connected with definite active regions

No.	LPP observing date (day, month, year)	Observing time (UT) (h, m)	Active region			Proton flare				Note
			No. SD	ϕ deg.	L deg.	Date (day, month)	T (UT) (h, m)	Imp.*	E MeV	
1.	19.05.84	0700–1520	113	–11.5	2.0	19 05	2151	1B/X4		
			114	–11.0	351.0	20 05	2218	2B/X10	5–40	
			115	–10.0	337.0	21 05	1932	2B/X3		
2.	03.06.84	0620–1540	125	5.0	154.0					
	04.06.84	0620–1530	125	5.0	154.0					
3.	23–25.06.84	0730–1430	135	–15.0	315.5					
4.	10.05.85	0800–1200	31	–14.0	0.0					
	12.05.85	0610–1230	31	–14.0	0.0					
5.	02.07.85	0510–1440	48	–19.0	358.0	02 07	2103	2B/M4	15	
6.	03.05.86	0700–1300	25	6.5	82.0	04 05	0939	/M1.2	5–90	a
7.	19–24.05.87	0700–1200	39	29.0	340.0	28 05			30	a
8.	31.05.88	0710–1330	107	25.5	359.0					
	01–03.06.88	0710–1350	108	25.5	359.0					
9.	22.06.88	0650–1410	118	–16.5	151.5					c
	24–25.06.88	0650–1355	118	–16.5	151.5					
10.	27–28.06.88	0650–1350	124	–22.0	5.0	29 06	0731	2B/M6.5	5–40	
11.	17.07.88	0630–1350	137	–21.0	153.0	18 07	1625	1F/C4.6		
	18.07.88	0630–1350	137	–21.0	153.0	19 07	0400	/C5.0	5–30	
						20 07	0650	/C1.5		
12.	05–08.10.88	0830–1220						2N/X2.5		
	10.10.88	0800–1220	222	–14.5	151.0	12 10	0511		5–90	b
	12.10.88	0810–1220								
13.	27.04.89	0740–1250	159	–19.5	317.0					h
			167	29.0	261.0					
	29.04.89	0800–1240	159	–19.5	317.0	05 05	0723	3B/X2.4	10	h
			167	29.0	261.0					
	01–06.05.89	0730–1250	159	–19.5	317.0					h
			167	29.0	261.0					
14.	10–11.06.89	0740–1250	225	–20.0	72.0					d
15.	08–10.08.89	0730–1300	308	–19.5	74.0	12 08	1358	2B/X2	10	
16.	17–23.08.89	0730–1230	316	16.0	328.0					
17.	31.08.89	0710–1230	338	–17.5	84.0	04 09	0856	2B/X1	10	
	01–02.09.89	0715–1240								e
18.	12.09.89	0730–1250	346	16.5	354.5	12 09	2355			
19.	27.09.89	0810–1320	363	–27.0	217.0	29 09		–/X9	600	a
20.	17.10.89	0810–1300								f
	18.10.89	0700–1250	401	–27.5	209.0	19 10	1232	4B/X13		
	21.10.89	0830–1300				22 10	1738	2B/X2.9	600	g
	22.10.89	0830–1300				23 10	1236	2B/X1.5		
						24 10	1736	3B/X5.7		

Notes
a flare beyond the limb,
b flare on the limb,
c durable flares of the X-ray pulses on June 23–24,
d protons with E > 10 MeV are observed from June 18,
e second appearance of group SD No. 308,
f series of proton flares,
g second appearance of group SD No. 363,
h the active regions SD No. 159 and No. 167 worked as one complex of activity on 27.04.89, 29.04.89 and 01–06.05.89, and the proton flare is observed from both groups simultaneously on 05.05.89.

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* Imp. means the importance of a solar flare in the optical and in the X-ray range.

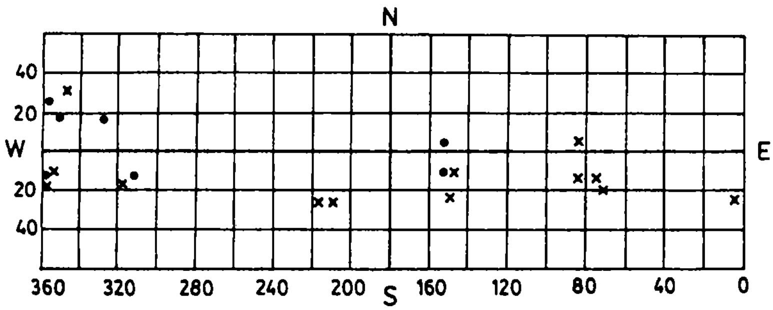

Fig. 3. Longitude and latitude distribution of ARs with LPPs for the years 1984 to 1989. The proton ARs are marked by crosses, the non-proton ones, by dots.

Table 2. Distribution of ARs in solar longitudes

Year	Northern hemisphere	Southern hemisphere
1984	150°–170°	340°–360°
1985		350°–360°
1986	70°–90°	150°–170°
1987	330°–350°	
1988	330°–5°	150°–160° 330°–360°
1989	340°–360°	70°–90° 210°–220° 310°–330°

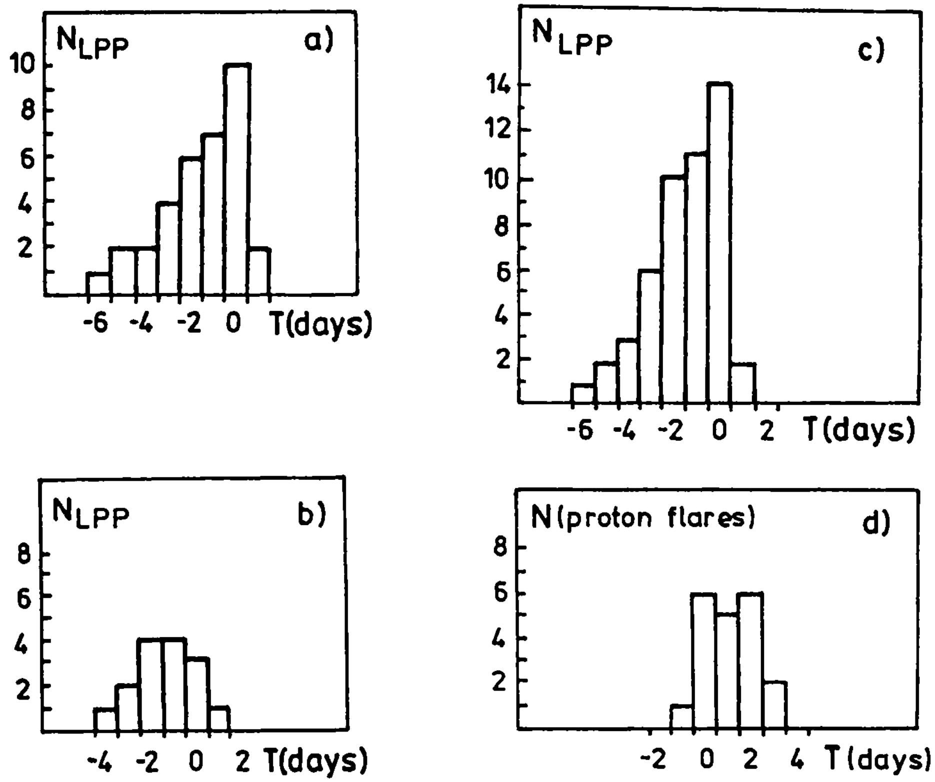

Fig. 4. Distribution of the emerging moments and lifetimes of LPPs and proton flares as a function of time of development of the AR area. Zero is the day with the observed S_{max}. Histogram (a) is for records of LPPs with the proton flares; (b) is for records of LPPs without the proton flares; (c) is for all records of LPPs taken together; (d) shows distribution of the number of proton flares depending on the time of development of the AR area.

local maximum. Similar results were obtained also for the earlier years 1979 to 1983. The data of AR were taken from the Solar Data (1984–1989) and the Cosmic Data (1984–1989) Bulletins.

The analysis of the cooperative observational programs carried out in the frame of KAPG* for the active regions SD No. 135, June, 1984 (Borovik et al., 1986) and SD Nos. 48&49, June, 1985 (Kolesov et al., 1987) shows, that the occurrence of decimeter range LPPs

* Commission for Cooperation of the East-European Academies of Sciences on the Project "Planetary Geophysical Investigations"

with a high degree of probability is defined by emerging of the new magnetic flux into the corona; this means that the magnetic field flux increases in pulses with characteristic time intervals of tens of minutes (Averyanikhina and Paupere, 1989). E.g., for SD No. 135 a powerful rising of the main magnetic flux occurs on June 23, 1984. On the same day, the most intensive growth of both the radio flux and magnetic field is observed. The maximum $\bar{A}$ of LPPs on 755 MHz frequency is observed a day later. For the region SD Nos. 48&49, emerging of a new magnetic flux is observed on July 1, 1985 but the maximum $\bar{A}$ of LPPs and a proton flare are observed also a day later.

The long-period pulsations appear after the magnetic field comes up to the photosphere. The delay of maximum amplitude moment of LPP with respect to the emerged main magnetic field depends on the rising velocity of the magnetic field (Krüger, 1984).

3. Conclusions

The analysis of the long period pulsations (LPPs) of solar decimeter range radio emission made on rather extensive statistically homogeneous data (1000 records) shows that:

- LPPs with levels exceeding zero level are found in 10% of all records;
- LPPs are observed on the phase of growth and/or maximum of AR area;
- All the AR having LPPs appear in the region of active longitudes;
- With great probability, the LPPs are related with rising of a new magnetic flux into the corona. LPPs reflect the nature of the changing magnetic field;
- No differences in LPP characteristics have been found for proton and non-proton active regions. This problem remains open for future research.

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