HU8206812

KFKI-1982-20

S. PINTÉR
V.P. GRIGORIEVA
K. KECSKEMÉTY
K. KUDELA

OBSERVATION OF SOLAR RADIO BURSTS OF TYPE II AND III AT KILOMETER WAVELENGTHS FROM PROGNOZ-8 DURING STIP INTERVAL XII

Hungarian Academy of Sciences
**CENTRAL
RESEARCH
INSTITUTE FOR
PHYSICS**

BUDAPEST

KFKI-1982-20

OBSERVATION OF SOLAR RADIO BURSTS OF TYPE II AND III AT KILOMETER WAVELENGTHS FROM PROGNOZ-8 DURING STIP INTERVAL XII

(10 APRIL - 21 JUNE 1981)

S. Pintér
Geophysical Institute of the Slovak Academy of Sciences,
947 01 Hurbanovo, Czechoslovakia

V.P. Grigorieva
Astronomical Institute of Moscow University,
Moscow, USSR

K. Kecskeméty
Central Research Institute for Physics
H-1525 Budapest 114, P.O.B. 49, Hungary

K. Kudela
Institute of Experimental Physics,
Slovak Academy of Sciences,
Košice, Czechoslovakia

HU ISSN 0368 5330
ISBN 963 371 903 8

ABSTRACT

Type II and type III radio events were observed at low frequencies (2.16 MHz to 114 kHz) by the Prognoz-8 satellite during the period of STIP Interval XII in April and May, 1981, respectively. This review covers briefly a chronology of the sub-megahertz radio events, and where possible their association with both groundbased radio observations and solar flare.

АННОТАЦИЯ

Радио события типа II и III при низких частотах (от 2,16 МГц до 114 кГц) были наблюдены на спутнике Прогноз-8 во время STIP Interval XII в апреле и мае 1981 г. соответственно. Показаны временные поведеиия радио событий ниже мегагерц и, где это возможно, показаны также совместные поведения с наземными радио иаблюдениями и солиечными вспышками.

KIVONAT

A Prognoz-8 űrszonda a XII STIP Interval során 1981 április-májusban II és III tipusu radiofrekvenciás eseményeket észlelt alacsony frekvencián (2,16 MHz-től 114 kHz-ig). Az összefoglaló röviden megadja a szub-megahertzes radio-események időbeli sorrendjét, és ahol lehetséges, a földi radiohullámu megfigyelésekkel, valamint a szoláris flerekkel való kapcsolatukat.

1. INTRODUCTION

In the STIP Interval XII approximately from 10 April to 21 June 1981 Prognoz-8 was suitable for the investigation of sub-megahertz frequency type II and type III radio bursts. During this period several significant solar flare events occurred. One can recognize that this interval offers a unique opportunity for a comprehensive study of interplanetary collisionless shock waves, energetic particle phenomena and various types of radio emission excited by these events. The purpose of this paper is to present a description and an analysis of the sub-megahertz type II bursts associated with coronal and interplanetary shock waves and type III bursts caused by electrons with energies of 10 keV to 200 keV which are travelling away from the Sun along open magnetic field lines (Malitson et al., 1973 a, b; Lin et al., 1973). These fast electrons excite plasma oscillations at progressively lower frequencies as they move outwards into regions of lower density. Measurements of type III solar radio bursts at hectometric and kilometric wavelengths provide information about physical processes along the path of the exciter electrons. A number of interesting events took place during and immediately before STIP Interval XII. The events thought to be of special interest are those occurred on April 10, April 24 and May 08, 1981.

2. EXPERIMENTAL DETAILS

The observation of radio emission to be discussed here were obtained with the Prognoz-8 satellite, which was launched on December 25, 1980. The orbit was a highly eccentric one with initial perigee and apogee of 980 km and 197 390 km, respectively, inclination of 65.83°, and period of 92.2 hours. The spacecraft is spin stabilized with a rotation period of ~120 sec. The Soviet-Czechoslovakian radio astronomical experiment on board the Prognoz-8 satellite consists of a multifrequency receiver, having 10 steps between discrete frequencies of 2 160 kHz and 114 kHz. The basic mode of operation samples the 10 steps successively in every 10 seconds, this is very good for the study of high and slow drifting radio emission. In the band of 1140 kHz the sensitivity limit is in the order of $\sim 3\times10^{-19} W/m^2 Hz$. The radiometer used in this analysis has a 80 dB dynamic range and 10 kHz bandwith. The observing frequencies were 2160, 1540, 1140, 780, 540, 273, 215, 139 and 114 kHz. All of the data presented in this paper were obtained while the satellite was in the solar wind.

3. THE OBSERVATIONS

The Sun was fairly active during the period of April to June 1981, with many flares observed in H-alpha. The study of the Prognoz-8 data shows that there are, at frequencies below 2.16 MHz, many fast drifting emissions which are type III bursts from the energetic particles propagating through the interplanetary medium guided by open field lines and a few slow drifting emissions which are type II travelling bursts from interplanetary collisionless shock waves. Table 1 gives a list of the most conspicuous events with their main characteristics: frequency, start and maximum times; Table 2 summarizes the solar activity, H_α flares, type II and IV radio bursts on metric wavelengths as reported in the Solar Geophysical Data (Boulder, USA) and together with associated Prognoz-8 radio bursts data e.g. starting and ending times and frequency range.

Conservatively estimating, many individual events or group of type III bursts, such as these shown in *Figure 1*, have been observed in the submegahertz frequency range during this STIP Interval XII. *Figure 1* shows the profiles at five selected frequencies. Within this type III classification, the variability of burst characteristics such as intensity, rise and decay time and drift rate reflect dynamic conditions occurring in the medium, and the injection and properties of the exciter particles.

At frequencies below 2,16 MHz type III bursts have several readily observed features. These type III bursts are characterized by a rapid decrease in frequency with increasing time. The modulation factor of the burst varies with frequency and time.

Boischot et al. (1980) using Voyager radio astronomical observations recognized in the hectometer range three different cases of slow drifting emissions associated with interplanetary shock waves. Our type II radio emissions are identical with the second class, i.e. only one or a few periods of emission lasting from a few minutes to half-an-hour at a fixed frequency.

4. EVENTS ASSOCIATED WITH APRIL 10 FLAKE

Two X-class events occurred on 10 April: (1) X1/1B from region 3035 (N13, L=234) at 1117 UT flare reached its maximum in H_α and was located at N11, E53. It was accompanied by metric type II at 1110 - 1135 UT and by metric type IV at 1114 - 1303 UT (both at Weissenau). Type I and type III bursts were observed by Oslo Observatory spectrograph in the frequency range of 500-530 MHz and 310-340 MHz.

(2) X2/3B from region 3025 (N08, L=317) was observed with maximum at 1655 UT located at N08°, W38°. This flare was accompanied by the following phenomena: (a) Optically, the flare was observed in H-alpha as two wide bands. There was 20% umbral coverage in the region. (b) Several intense metric type II and IV radio bursts were observed at 1625 UT; starting at ~75 MHz. (c) U-radio burst distribution. The major geomagnetic storm activity which began at 1439 UT on 12 April was almost certainly due to the 3B flare (58 hour delay time).

Both flare events were associated with hectometric and kilometric type III solar radio bursts observed by the Prognoz-8 radio astronomical experiment (AKR-2). The observations were made at frequencies 2.16, 1.54, 1.14 MHz and 780, 540 and 273 kHz. *Figure 1* illustrates a type III burst which was associated with a flare observed at 1100 UT. *Figure 1* clearly demonstrates the drift of the burst as well as the systematic the drift of the burst as well as the systematic increase in rise and decay times. *Figure 2* shows the intensity profiles for a sub-megahertz type III storm in April 10, 1981 starting at 16:45:21 UT on 2.16 MHz. One can see that this type III storm is composed typically of dozens of individual drifting bursts superimposed on a continuum background component. The burst distribution shows a hierarchy of intensities with a preponderance of smaller sizes. In many ways the characteristics resemble those of type I meter storms.

A kilometer wavelength type II radio emission was observed by Prognoz-8 radio experiment only at one 740 kHz frequency, beginning at 1750 UT. Assuming the density model for interplanetary medium deduced from RAE observations (Fainberg and Stone, 1974), the frequency emission at the plasma frequency is given by

$$f_{Hz} = 33.4 \times 10^{6} R^{-1.315}$$

where R is the distance from the Sun in solar radii. From this one obtains

$$r = \left(\frac{33.4 \times 10^{6}}{f_{Hz}}\right)^{0.7604}$$

We determined the velocity of the shock using a radial distance of $R = 12.18 \times 10^{6}$ km up to shock excited 740 kHz frequency and the time delay between coronal type II burst (1625 UT) and kilometric type II burst (1750 UT) which is 2350 km/sec. The kilometer-hectometer type II burst was observed by the radio experiment on board of ISEE-3 at a number of frequencies (Gergely, 1981). The speed determined from the time delay between the flare and geomagnetic SSC is only 940 km/sec, this means that the interplanetary shock wave strongly decelerated.

5. THE APRIL 24 EVENT

On April 24, 1981 a 2B flare at N18°, W50° was observed in H-alpha, starting at 13:23 UT and reaching its maximum intensity at 14:11 UT. It produced a metric type IV burst (starting at 13:56 UT, Weiss), a metric type III burst (beginning at 13:53.3 UT; Harvard), a metric type II burst (starting at 15:55 UT, Harvard), an interplanetary shock (at 26 Apr., 08:15 UT) wave and an energetic particle event were observed by Prognoz-8 satellite. Thus, the event displayed a wide range of phenomena that one associated with a powerful flare.

Single frequency Prognoz-8 radio observations at 2160, 1540, 1140, 780, 540 and 273 kHz during the April 24 burst are shown in *Figure 3*. As seen in Table 1 the type III burst at frequency 2160 kHz starts at 13:59:12 UT. The Electron observation from the Institute of Experimental Physics particles experiment (Košice, Czechoslovakia) are also displayed in *Figure 3*, showing that electrons in the >10 keV energy range were present (start at 13:53:54 UT), consistent with the idea that low frequency type III solar radio emission is caused by electrons with energies of 10-200 keV (Lin et al., 1973). From *Figure 3* it is clear that the radio burst was doublepeaked at the higher frequency, possible due to the beginning of type II burst; however there was only a single peak at lower frequencies. The intensity has a maximum at 14:01:04 UT and a second peak is observed at 14:04:29 UT for 2.16 MHz; and the merged peak is observed at 14:10:48 UT for 273 kHz. Much of this delay corresponds to the transit time for the energetic electrons from a heliocentric distance of 0.014 AU (2.16 MHz level) out to 0.2 AU (277 kHz level) indicating an outward speed greater than 0.2 c for the exciter. The flux density observed during this burst by Prognoz-8 reached maximum values exceeding 10^{-14}Wm^{-2}Hz at frequency 2.16 MHz.

The hectometer and kilometer type burst associated with this flare we obtained by our Prognoz-8 radio experiment at a number of discrete frequencies. It is possible that we observed a small part of a type II burst at frequency 2.16 MHz at 14:04:29 UT that orginated in a shock wave which was produced at 13:46, the time of the onset of the 3B flare. The time elapsed between the start of the flare and the observation of the radio burst was of the right order for a type II burst i.e. the velocity of the exciter is 2 180 km/sec. Futhermore, it was possible to detect a few relatively weak type II radiation. Starting times were approximately 15:48 UT at 540 kHz and 1754 UT at 273 kHz. It is well known that type II radio emission is often sporadic, occurring only when conditions in the interplanetary medium are favorable (Malitson et al., 1973 b). Again, if we use radial distances between the Sun and excitation of type II radiation at 540 kHz and 273 kHz i.e. $R_{540\ kHz} = 15.4\times10^6$km and $R_{273\ kHz} = 26.6\times10^6$km, respectively and delay times, we derive velocities of $\bar{V}_{s-540\ kHz} = 2030$ km/sec and $\bar{V}_{s-273\ kHz} = 1480$ km/sec, respectively. The average velocity of the shock between Sun and Earth is 900 km/sec, which suggests a significant deceleration from a relatively large shock velocity near the sun to $\bar{V} = 700$ km/sec at Earth. *Figure 4* shows approximate shock trajectory as inferred from the submegahertz slow drift of type II radio emission, SSC at the Earth. The trajectory is "approximate" in the sense that spherical symmetry is assumed. In this figure we clearly see the decelerating character of the shock wave.

6. THE MAY 8 EVENT

Region 3099 is a further active region during STIP Interval which produced an M7/2B flare at 2251 UT on 8 May, 1981. Strong discrete frequency and sweep frequency type II/IV bursts were observed at 2233 UT and 2235 UT, respectively. The geomagnetic field active conditions dominated the 10th of May with a very pronounced sudden commencement observed at Boulder at 2208 UT.

Figure 5 illustrates the hectometric and kilometric wavelength type III burst which is flare-associated. The starting frequency was 2.16 MHz at 22:42:35 UT, the drift rate was fast.

7. SHORT SUMMARY

We have presented a wealth of hectometric and kilometric type III and type II radio bursts data obtained by Prognoz-8 radio astronomical experiment, describing the evolution of these bursts during the period of August 8, to May 14, 1981. Some of the principal results of our analysis of these data are the following:

1. The spectral range (2160 kHz to 114 kHz) over which type III bursts are observed depends on the trajectory over which the energetic particles propagate and on the ability of the radio emission to reach the observer. Quite often, however, a burst observed at shorter wavelengths in seen over only a part of the long wavelength region, or not at all.

2. In all observed type III bursts there is a tendency for both the rise time and decay times of the bursts to increase as frequency decreases.

3. Measurements of the frequency drift rates of type III bursts provide information on the velocity of the exciter electrons. Exciter velocity ranging from 0.2 to 0.6 times the velocity of light with and average velocity of 0.4c. The result of calculation from measurements by the RAE-1 satellite for frequencies between 0.7 MHz and 2.8 MHz was 0.38 c. These drift rate measurements give electron velocities that are in agreement with the energy range of the solar electrons observed in the interplanetary space by the satellite experiments.

4. Peak intensities observed range from frequencies above 2.16 MHz down to 114 kHz.

5. Our records showed that sub-megahertz type II emission is always sporadic, and often occurs within a very limited range of frequencies at different times, occurring only when plasma conditions in the interplanetary medium are favorable indicating a strong dependence of excitation of type II emission on local shock and solar wind parameters.

REFERENCES

Boischot, A., Riddle, A.C., Pearce, J.B. and Warwick, J.W.: 1980, Solar Physics, 65, 397

Fainberg, J. and Stone, R.G.: 1974, Space Sci. Rev., 16, 466

Gergely, T.: 1981, STIP INTERVAL XII - Progress Report

Lin, R.P., Evans, L.G. and Fainberg, J.: 1973, Astrophys. J. Letters, 14, 191

Malitson, H.H., Fainberg, J. and Stone, R.G.: 1973a, Astrophys. J. Letters, 183, L35

Malitson, H.H., Fainberg, J. and Stone, R.G.: 1973b, Astrophys. J. Letters, 14, 111

Table 1

Date, U.T. 1981 / Frequency (kHz)	April 08		April 08		April 09		April 09		April 10		April 10	
	Start	Max.	Start	Max.	Start	Max.	Start	Max.	Start	Max.	Start	Max.
2160	10:22:24	10:23:65	16:25:31	16:26:26 16:28:26	17:12:04	17:13:04	18:31:35	18:32:36	11:07:15	11:07:46	16:45:21	
1540	10:22:45	10:24:17	16:25:42	16:26:53 16:28:05	17:13:25	17:13:25	18:31:45	18:33:17	11:07:36	11:08:17	Type III storm	
1140	10:23:05	10:24:37	16:26:12	16:27:45	17:13:25	17:13:50	18:31:35	18:33:27	11:08:06	11:10:09		
780	10:23:56	10:24:58 10:26:30	16:26:52	16:28:15	17:13:45	17:14:36			11:08:08	11:11:52 11:12:02		
540	10:24:27	10:28:33	16:26:23 16:27:24	16:10:18					11:10:20	11:13:44 11:15:47		
273			16:31:20	16:36:02								

Date, U.T. 1981 / Frequency (kHz)	April 10		April 10		April 24		May 08		May 14	
	Start	Max.	Start	Max.	Start	Max.	Start	Max.	Start	Max.
2160	19:53:36	19:53:56			13:59:12	14:01:04	22:42:35	22:47:00	08:34:50	08:38:30
1540	19:54:06	19:54:37	22:55:52	22:57:17	13:59:53	14:01:25	22:42:40	22:48:00	08:35:21	08:38:40
1140	19:54:27	19:55:08	22:55:52	22:57:17	14:00:03	14:03:07	22:41:30	22:48:20	08:35:42	08:39:27
780	19:55:08	19:57:01	22:56:54	22:59:07	14:00:13	14:07:03	22:42:00	22:48:50	08:36:23	08:40:39
540	19:56:30	19:57:11 19:58:53	22:58:46	22:59:37	14:01:55	14:09:06		22:56:40	08:42:31	08:41:30
273					14:04:31	14:10:48		22:50:40	08:38:26	08:45:25

Table 2

Date 1981	H_α flare			Metric type Radio burst			Radio burst from Prognoz-8		
	Start UT	Position	Imp	Start UT	Type	Int	Start UT	Frequency range kHz	Type
Apr. 08	10:28	S14 W27	3N	10:25	III	2	10:22	2160 - 540	III
Apr. 08	16:23	N11 W03	2B	16:21	III	3	16:25	2160 - 273	III
Apr. 09	17:12	N09 W23	3N	17:09	III	3	17:12	2160 - 780	III
Apr. 09	18:14	N07 W22	1N				18:31	2160 -1140	III
Apr. 10	11:17	N11 E53	1B	11:05	III	3	11:07	2160 - 540	III
Apr. 10	16:32	N07 W35	3B	16:42	III	3	16:45	2160 - 273	III
Apr. 10	16:32	N07 W35		16:49	II	3	17:50	740	II
Apr. 10	19:10	N18 E52	1B				19:53	2160 - 540	III
Apr. 10	22:58	N13 E45	SF	22:53	III		22:55	1540 - 540	III
Apr. 24	13:23	N18 W51	2B	16 53	III	3	13:59	2160 - 540	III
Apr. 24	13:23	N18 W51		13:56	II	3	14:04	2160 - 273	II
May 08	22:01	N08 E38	2B	22:27	III		22:42	2160 - 780	III
May 14	08:08	N20 E32	3B	08:39	III		08:34	2160 - 273	III

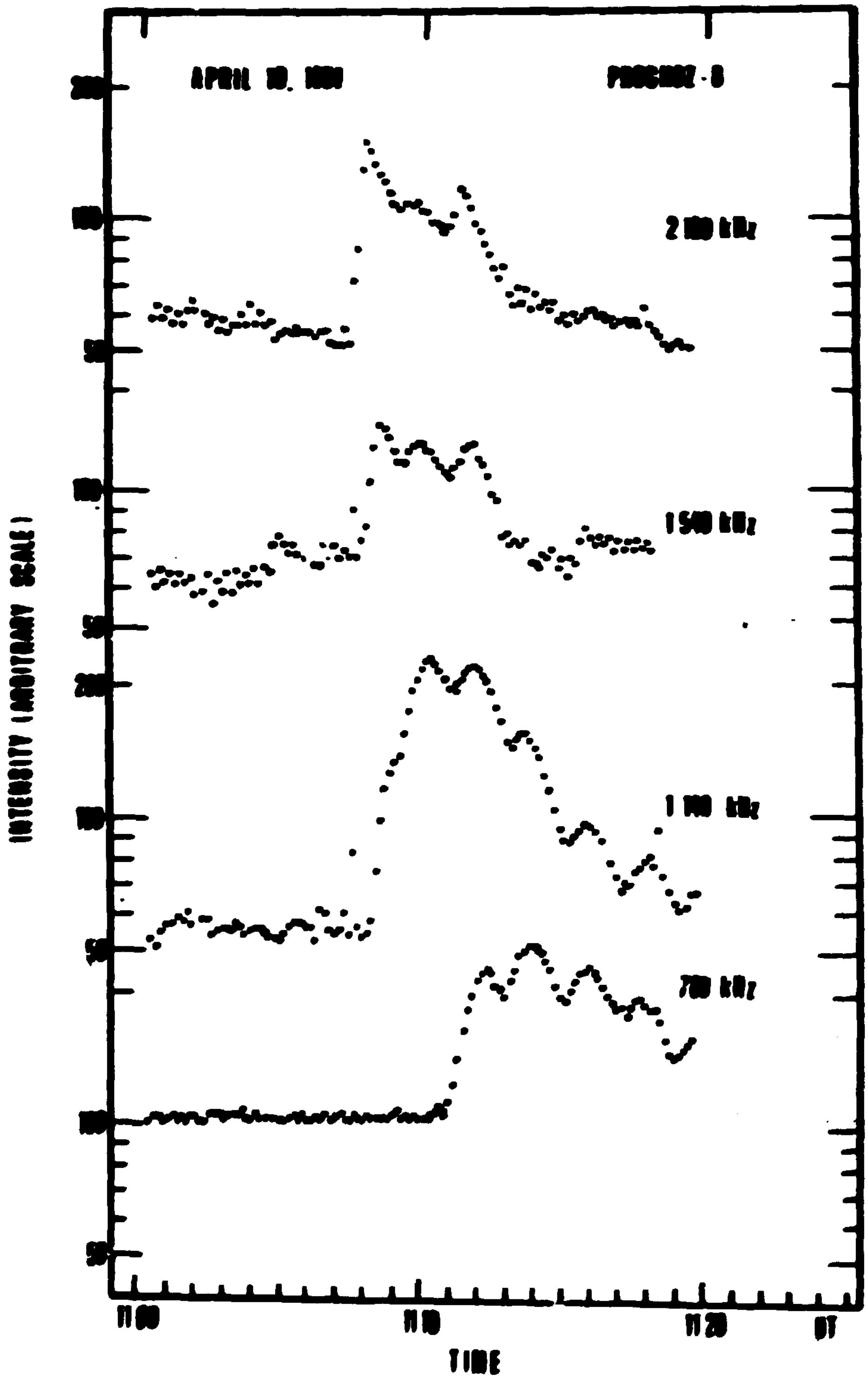
APRIL 10,
PROGNOZ-8
2100 kHz
1500 kHz
1100 kHz
700 kHz
200
100
50
INTENSITY (ARBITRARY SCALE)
1100
1110
1120
UT
TIME

Fig. 1

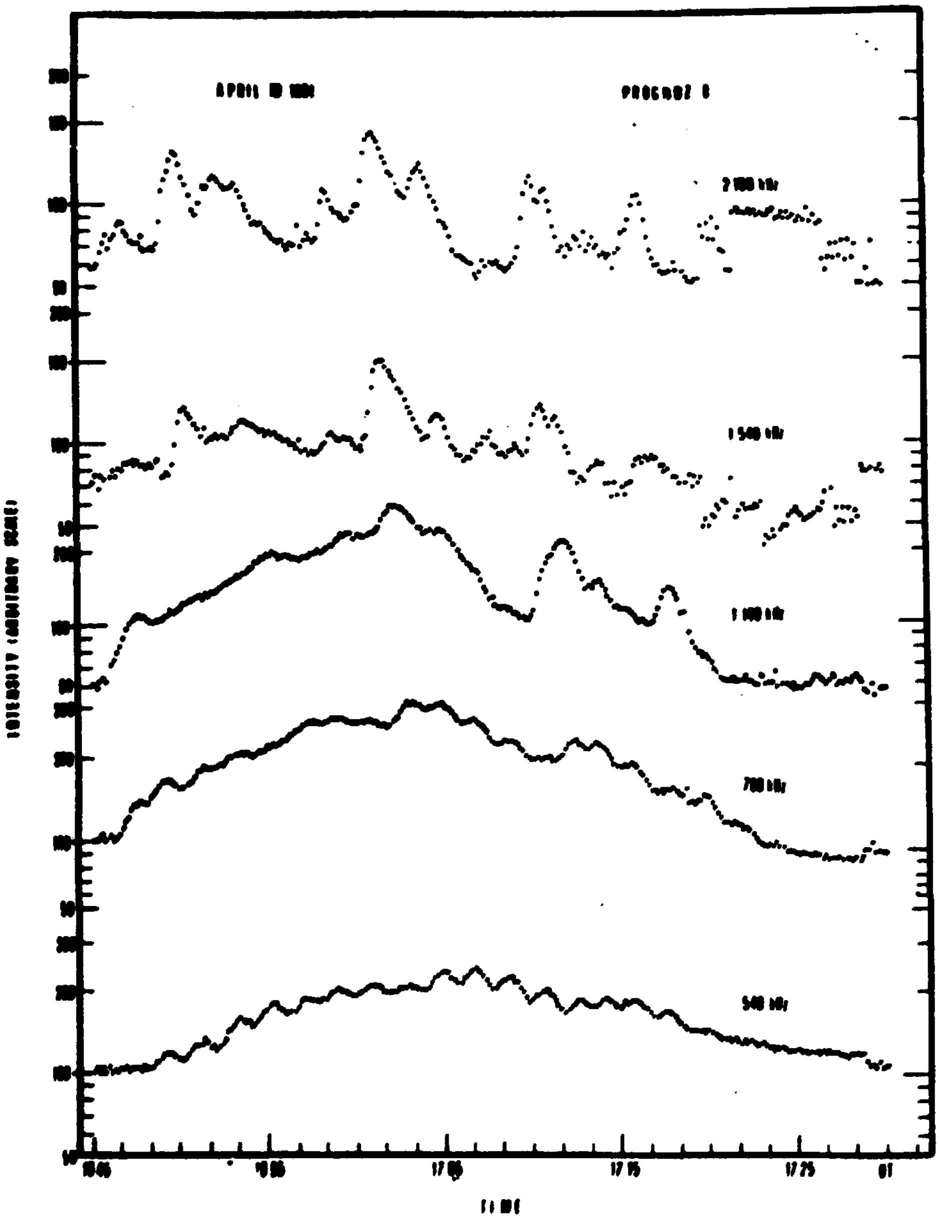
2100 kHz
1500 kHz
1100 kHz
700 kHz
500 kHz
INTENSITY (ARBITRARY SCALE)
200
100
50
17 05
17 15
17 25
TIME

Fig. 2

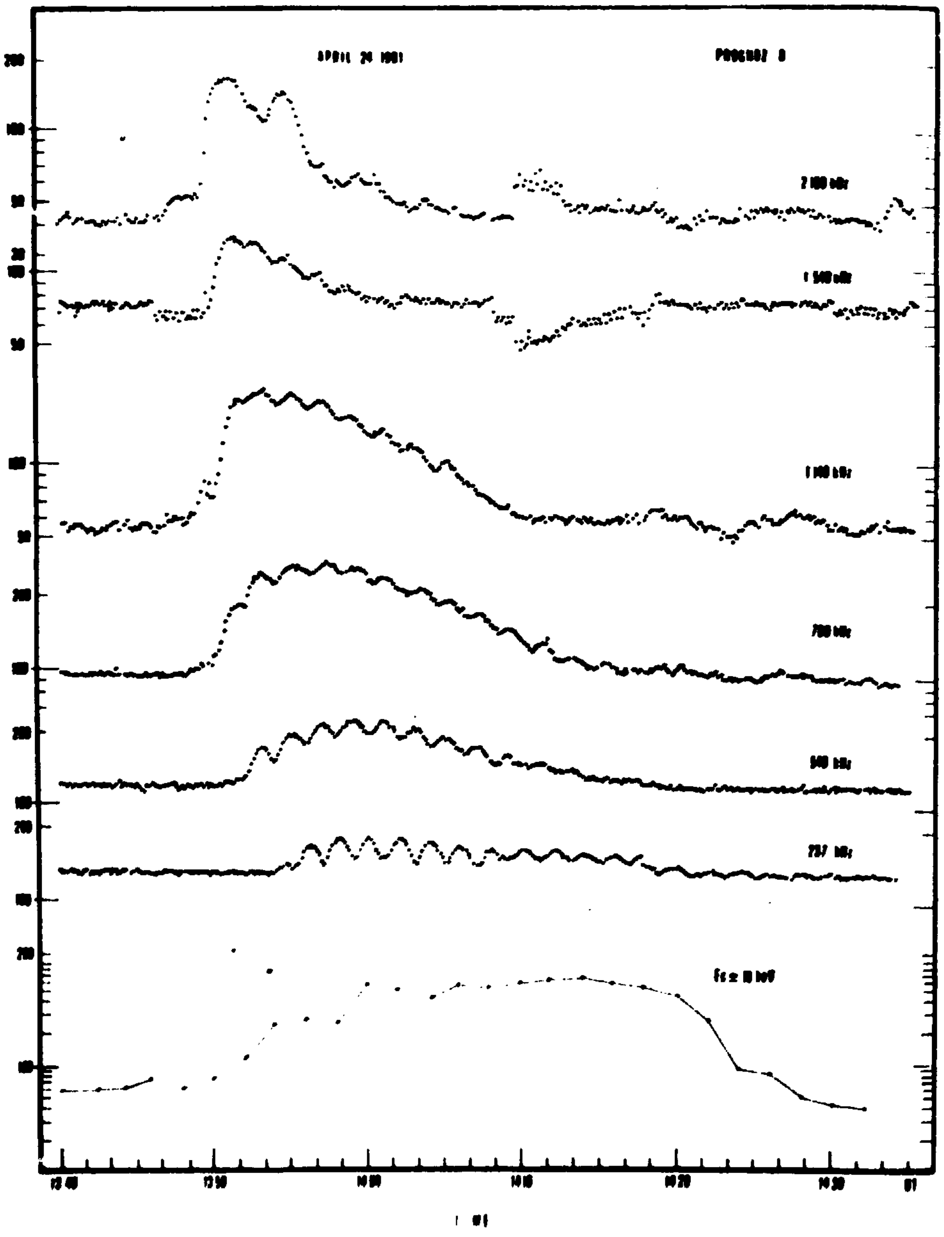

Fig. 3

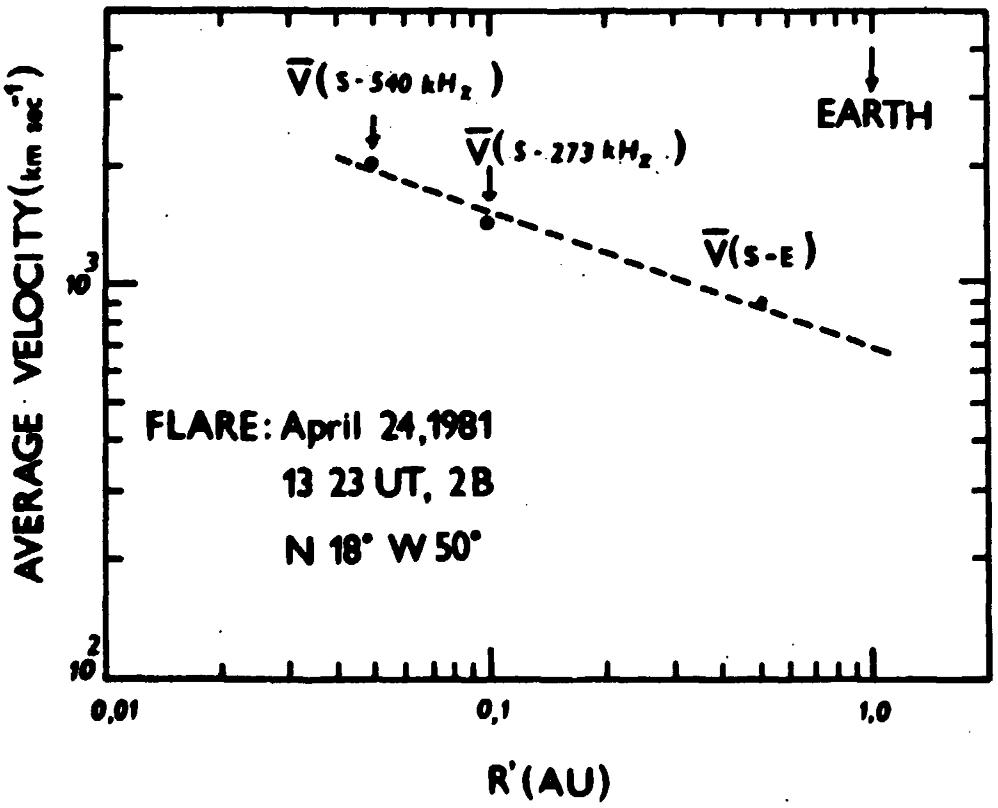
$\overline{V}$(S-540 kHz)
$\overline{V}$(S-273 kHz)
$\overline{V}$(S-E)
EARTH
FLARE: April 24,1981
13 23 UT, 2B
N 18° W 50°
AVERAGE · VELOCITY (km sec^{-1})
10^3
10^2
0,01
0,1
1,0
R'(AU)

Fig. 4

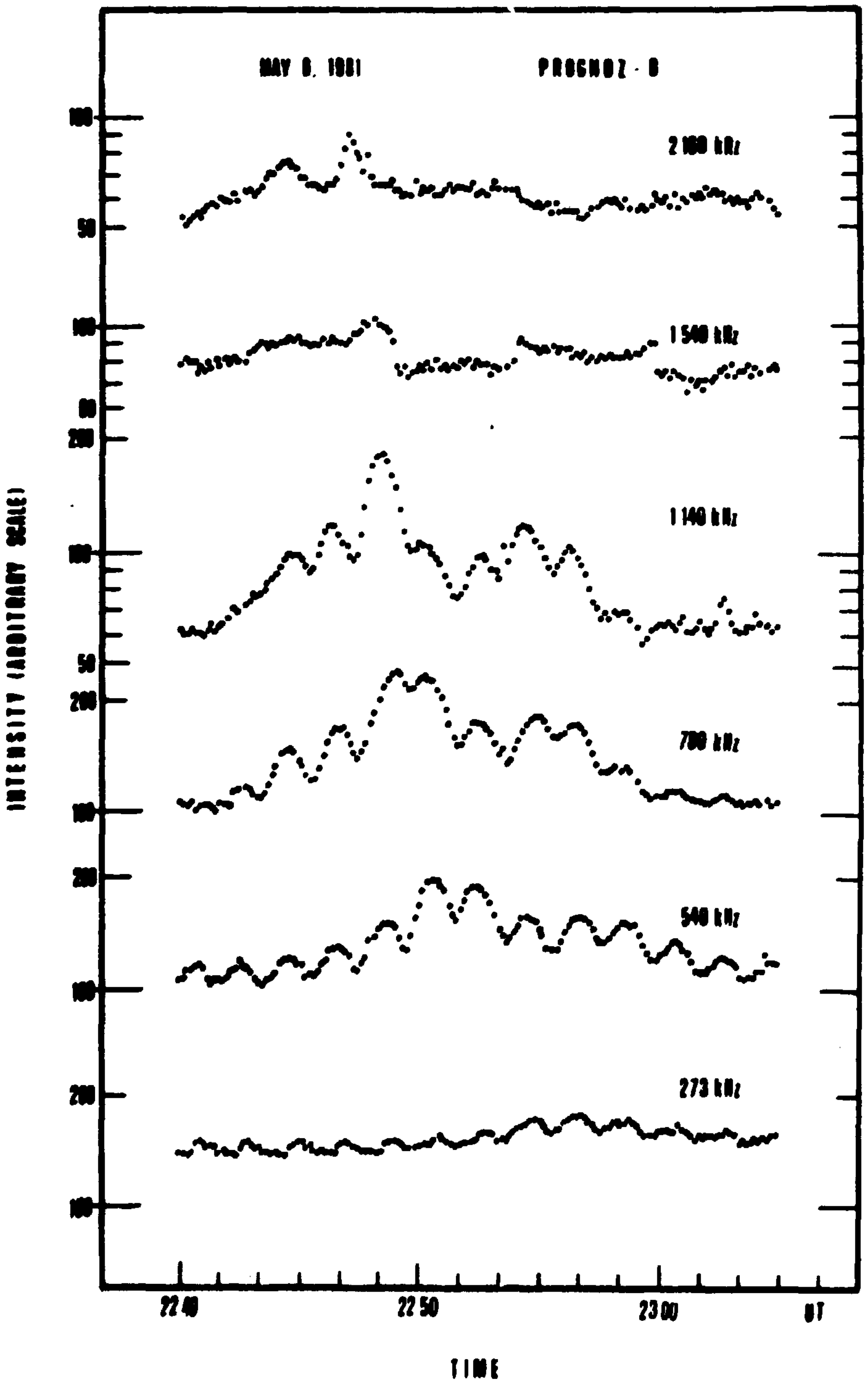
MAY 8, 1981
PROGNOZ - 8
100
2 100 kHz
50
100
1 500 kHz
80
200
1 140 kHz
100
50
200
700 kHz
100
200
540 kHz
100
200
273 kHz
100
INTENSITY (ARBITRARY SCALE)
22 40
22 50
23 00
UT
TIME

Fig. 5

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Szegő Károly
Szakmai lektor: Gombosi Tamás
Nyelvi lektor: Benkó György
Gépelte: Végvári Istvánné
Példányszám: 405 Törzsszám: 82-193
Készült a KFKI sokszorositó üzemében
Felelős vezető: Nagy Károly
Budapest, 1982. április hó