O.F.

Likhter, Afonin Vojta

1979

Reprinted from

(COSPAR) SPACE RESEARCH

Volume XIX

Edited by

M. J. RYCROFT

PERGAMON PRESS OXFORD and NEW YORK 1979

ИК-14

Likhter. Larkina

ELF-VLF EMISSIONS, ION DENSITY FLUCTUATIONS AND ELECTRON TEMPERATURE IN THE IONOSPHERIC TROUGH

Ja. I. Likhter*, V.I. Larkina*, Yu. M. Mikhailov*,
V.V. Afonin, G.L. Gdalevich**, K.B. Serafimov***,**
L.G. Bankov*, Ts. P. Dachev***, N.S. Trendafilov***,**
F. Jiricek+, J. Smilauer+, P. Triska+ and J. Vojta+

**Institute of Geomagnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Academy of Sciences USSR, Moscow, USSR*
***Space Research Institute (IKIAN), Academy of Sciences, USSR*
****Central Laboratory for Space Research, Bulgarian Academy of Sciences, Sofia, Bulgaria*
+ Geophysical Institute of the Czechoslovak Academy of Sciences, Prague, Czechoslovakia

INTRODUCTION

The experiments on board the Intercosmos 14 satellite (H_a = 1700 km, H_p = 340 km, i = 74°) have enabled several kinds of simultaneous measurements to be carried out:

- total ion concentration ($\sum n_i = N_i = N_e$)
- two values of the electron temperature corresponding to the motion of electrons in two directions perpendicular to one another ($T_{e\|}$ and $T_{e\perp}$)
- four components of ELF and VLF fields [1].

In this paper, variations of plasma concentration, electron temperature, as well as variations of the two field components of the ELF and VLF emissions (magnetic component $|b_x|$, electric component $|e_y|$) are discussed as measured when the satellite crossed the region of the main ionospheric trough and the adjacent high-latitude regions of the outer ionosphere in the month of December 1975, in a geomagnetically quiet period ($K_p \leq 3$).

EXPERIMENTAL RESULTS

Figure 1 shows an example of variations in T_e, the ion concentration N_i and in the amplitude of VLF radiation at 4.0 kHz ($|e_y|4$) and the ELF radiation at 0.72 kHz ($|b_x|0.7$ and $|e_y|0.7$). In revolution No 61 (K_p = 3+; Dst = -4γ), the satellite's orbit crossed the south-hemisphere oval (in the daytime) and, for about 25 minutes, it moved into the region of the inhomogeneities. The recordings start over the Northern Hemisphere when the satellite was leaving the trough region (see the N_i-curve). A sudden enhancement in temperature up to a value of about 6 x 10^3 K was observed together with an increase of concentration. It is well-known that the temperature maximum generally occurs simultaneously with the minimum plasma concentration, or it is somewhat shifted towards lower latitudes with respect to the plasma minimum [2]. The amplitudes of emissions at 4.0 and 0.72 kHz do not show any remarkable changes in this region. However, simultaneous wide-band records show an enhancement in intensity of the VLF emissions in the time interval 02.36:30 - 02.36:50 UT (see Fig. 2). This enhancement has been detected in the electrical component only; hence, this emission can be interpreted as LHR noise. The N_i-record shows an effect of concentration decrease in the equatorial region. An analogous decrease in concentration under these conditions has been observed with the Intercosmos 2 satellite [3]. The increase in temperature which started at about 02.56 UT is associated with the satellite's transition from the shadowed to the daylight ionosphere.

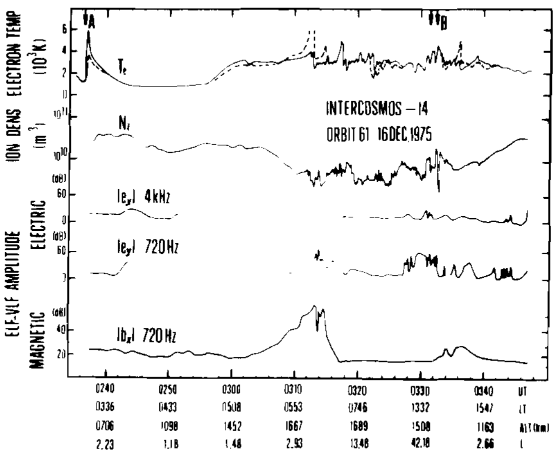

Fig. 1 Variations of (T_e), (N_i) and amplitude of VLF-ELF emissions. The dashed curve marks the second component of the temperature over path sections with a higher anisotropy

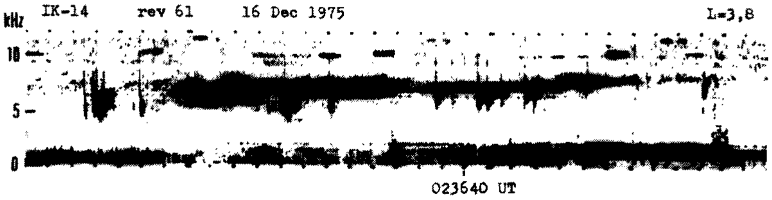

Fig. 2 Spectrogram of the VLF-emission near LHR recorded at point A shown in Fig. 1

At 03.05 UT, the Intercosmos 14 satellite reached the ionospheric trough of the Southern Hemisphere. The height and local time prompt the assumption that, in this case, a trough of light ions, connected with an increase in amplitude of emissions, very strongly emphasized especially at 0.72 kHz, appeared [4]. The enhancement in electron temperature was observed here in a narrow zone with a minimum N_i-value. At the same time, also a pronounced temperature anisotropy was observed.

At $L > 4.0$ an auroral increase in concentration was detected. Fluctuations in concentration together with fluctuations of electron temperature occurred here as well. The fluctuations are observable even in the amplitude of the ELF-emissions, particularly on the high-latitude side of the trough at $L = 5.2$, both in the electric and magnetic component ($|e_y|$0.7 and $|b_x|$ 0.7). The satellite then entered the polar cap region and continued its motion to higher L-values ($L > 13$) where a minimum in concentration, as well as a minimum amplitude of the magnetic and electric components of emissions have been observed.

On leaving the polar cap region (at about 03.31 - 03.33 UT), the satellite obviously crossed an area of a local minimum in concentration; an intensity increase in the electric field component at 0.72 and 4.0 kHz was observed at the same time. The absent magnetic component indicates the electrostatic nature of the waves. Such waves can be excited by streams of low-energy particles [5] that are generally observed in the cusp region [6]. Leaving the zone of inhomogeneities ($L \leq 4.2$), an increased amplitude of the electrical component of emissions ($|e_y|4$ and $|e_y|0.7$) was detected, the increase at 0.72 kHz also being accompanied by fluctuations. When the satellite entered the trough again, after leaving the zone of inhomogeneities (at about 03.36 UT), the amplitude of the magnetic component $|b_x|0.7$ also increased.

The described variations of T_e, N_i, $|e_y|$ and $|b_x|$ are characteristic of most Intercosmos 14 crossings of the ionospheric trough and adjacent regions of the outer ionosphere. These data show distinct differences between the nature of the variations over the Southern Hemisphere (daytime, high altitudes) and Northern Hemisphere (nighttime, low altitudes).

We will further discuss small-scale fluctuations of the plasma concentration and electron temperature together with amplitude fluctuations of the ELF-VLF emissions. Figure 3 shows the fine structure of ion concentration fluctuations, as well as of the electron temperature and amplitude of VLF emissions. The values originate from a one-minute interval taken from Fig. 1, corresponding to that instant when the satellite was leaving the polar cap area and entering the trough region.

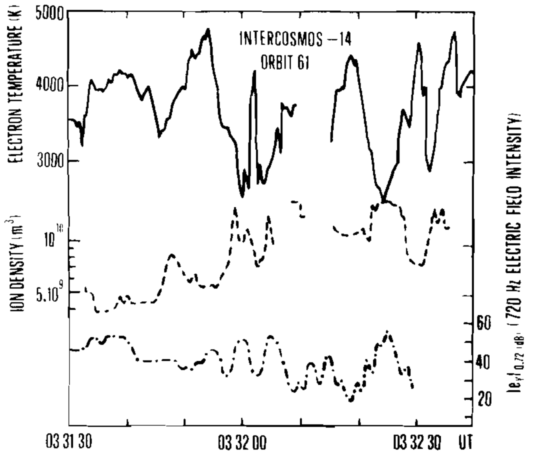

Fig. 3 The fine structure of fluctuations in N_i, T_e and $|e_y|$ 0.7 recorded at point B shown in Fig. 1.

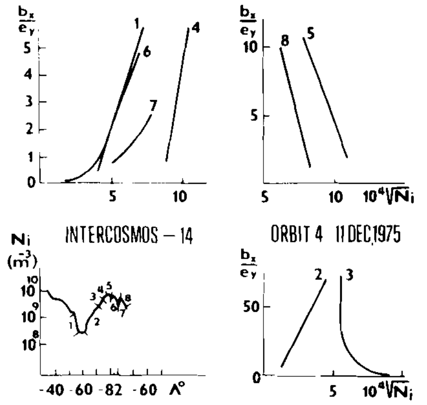

Fig. 4 Variations of $|b_x|/|e_y|$ ($f = 720$ Hz, arbitrary units) with N_i. The lower curve on l.h.s. gives the pattern of N_i vs. invariant latitude. The numbers 1-8 denote sections that have been analyzed.

It follows from Fig. 3 that the variations of the electron temperature and ion concentration are of opposite sense (in antiphase) to one another, this correlation being maintained for intervals of 1 - 2 seconds. Such simultaneous changes of concentration and temperature have not been observed for shorter time intervals. In the time period 03.32.00 - 03.33.30 UT, a well-marked correlation between the amplitude of emissions and the ion concentration can be seen. A direct explanation of this fact could not be found as yet, because the electron streams that would possibly be the cause of the enhanced intensity of emissions are not able to produce a sufficiently high, sdditional ionization at these altitudes. The phase dependence between variations in concentration and temperature has partly been investigated in [7,8], but a remark can be found in [7] that a simple 180°-dependence was not observed in intervals shorter than 5 - 10 minutes.

Some conclusions on the field structure of the VLF emissions can be based on the amplitude ratio of the magnetic and electric components of the field. From the Maxwell equation curl $\underline{e} = -\partial \underline{b}/\partial t$ it can be established that the ratio $|b_x|/|e_y|$ is proportional to the refractive index $\underline{n}$. This relation holds for arbitrary components of the vectors $\underline{b}$ and $\underline{e}$. The proportionality coefficient depends here on the wave characteristics $(\omega/\omega_{Be};\ \Theta)$, and on the orientation of the satellite's antennae. Since the refractive index in the ELF and VLF bands is proportional to ω_{oe}, one can conclude that the relation

$$Z = \frac{|b_x|}{|e_y|} \sim \omega_{oe} \sim N_e^{1/2}$$

should hold for the electromagnetic wave.

The satellite's orientation can change and this implies that the above mentioned dependence need not be linear; however, Z should increase with increasing N_e-values. Figure 4 gives examples of the dependence of changes in Z upon N_i for various sections of the satellite orbit when it crossed the ionospheric trough during rev. No 4 (11 December 1975). The expected increase has been confirmed in most cases, such a dependence being observed also over most of the satellite path.

Nevertheless, in individual sections of the orbit the Z-value decreases with increasing concentration. In these sections, no specific N_i-variations could be found that would be able to explain such a Z-pattern. In these cases, the absolute amplitude values of $|b_x|$ and $|e_y|$ were considerably higher than the threshold sensitivity of the receiver, so that (i) the phenomenon observed cannot be accounted for as a measuring error, (ii) the wave normal angle can be supposed to be reasonably smaller than the resonance cone angle.

The established decrease of the Z-value for increased N_i can be explained under the assumption that also electrostatic plasma oscillations exist in corresponding sections of the path. If this were so, the magnetic field induction could not be compared with the electrostatic field intensity, and all considerations about the dependence of Z upon concentration could not be applied in this case. These are probably the events in which streams of low-energy electrons, generally observed in the ionospheric trough region, are able to excite electrostatic plasma oscillations [5].

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