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SOME RESULTS OF MEASUREMENTS CARRIED OUT BY MEANS OF CHARGED PARTICLE TRAP ON THE ELECTRON-2 SATELLITE

K.I.Gringauz, V.V.Bezrukikh,
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To be Presented to the VI-th International Space Sciences Symposium in Buenos Aires in May 1965

MOSCOW

SOME RESULTS OF MEASUREMENTS CARRIED OUT BY MEANS OF CHARGED PARTICLE TRAP ON THE ELECTRON-2 SATELLITE

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Among other instrumentation, Electron-2 carried a three-electrode charged particle trap similar to the traps mounted on other Soviet space probes beginning from the Luniks [1]-[5].

On January 30, 1964. Electron-2 was put out into orbit with an apogee of ~ 11.6. R_E (from the Earth's centre) with an inclination to the equatorial plane 61°. The perigee height was 400 km. In the early period of the satellite's flight the line connecting the apogee and the perigee of its orbit made with the Earth-Sun direction an angle of~80°, the angle between the Earth-Sun line and the plane of the satellite orbit was ~ 20° (Fig.1).

The potential of the trap outer grid was equal to the satellite body potential. Therefore, the trap could record positive ions of all energies exceeding the satellite potential with respect to the surrounding medium, which produced positive current in the trap collector circuit and fluxes of electrons with energies above 100 ev (higher than the inner grid potential) producing negative currents in the same circuit. Besides, the trap recorded photoelectrons from the inner grid also in the form of negative currents in the collector circuit. Thus, if the total current in the collector circuit is positive, this uniquely corresponds to the registration of positive ions. The collector current amplifier permitted one to record positive and negative currents beginning with 10^{-10}a. The maximum positive current which could be recorded was $3\cdot10^{-8}$a the maximum negative current was $2\cdot10^{-9}$a.

Although at present the three-electrode trap with the constant potentials on its electrodes is a very rough instrument, as compared to the traps with the varying potentials on electrodes, the use of it made it possible to obtain some interesting, in our opinion, results. This is due to the fact that results of this experiment are comparable with the results obtained earlier ([1] - [4]) owing to the identical technique and also to the fact that, in contrast to the 1959 Luniks the peculiarities of Electron-2's orbit permitted one to conduct observations in the region of circumterrestrial space lying beyond the outer radiation not investigated before 1964.

The present brief report is a preliminary one since in it only some portion of the results obtained from the Electron-2 charged particle traps is used.

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I. The Outlying Part of the Ionosphere

(H ~ 2000-20000 km)

Fig. 2 shows measured values of collector currents of the trap on the orbit portions close to the Earth. The character of the changes of currents is typical of all the satellite revolutions: each time the satellite approached the Earth, a comparatively sharp increase of the current produced by positive ions (beginning at heights from ~ 20000 km to 15000 km) was observed, while each time the satellite moved away from the Earth a decrease of the ion current of similar type was observed. These changes of the collector current are similar to decreases of the currents in charged particle traps on Soviet Luniks observed in 1959 when they moved away from the Earth ([1] - [3]). Then a comparison of the results of simultaneous measurements by means of traps with different potentials on their outer grids permitted one to conclude that the currents in the traps with zero and negative potentials on outer grids were produced by the ions of the Earth's plasma envelope which is a direct continuation of the regions of the ionosphere known earlier and consists of particles with low (thermal) energies [1] - [3].

In an experiment carried out from IMP-I in 1963 J.P.Serbu approximately at the same heights detected a decrease of the charged particle trap collector current produced by electrons with energies less than 5 ev [6]. In this case the current obviously was produced by the electron component of the same Earth's plasma envelopewhich was observed in 1959 by means of Luniks.

The estimate made in [3] showed that at height $H \sim 20000$ km the ion concentration was about $10^2 cm^{-3}$. Approximately the same results are obtained from analysis of observations of whistlers by D.L.Carpenter [7].

It should be noted that the Electron-2 orbit is such that its portions corresponding to heights of 15000 - -20000 km (at which sharp changes of the trap collector current were observed) lied over the Earth's equatorial region.

From the measurements of the charged particle collector current from Electron-2 (they are for a few tens of revolutions of the satellite) one can clearly see that a sharp decrease of the thermal ion concentration in the Earth's plasma envelope (the ionosphere) observed during single measurements from Luniks at heights of 15000 - -20000 km, takes place permanently. These heights lie much lower than the magnetosphere's boundary minimal height. Let us note that since the currents exceeding $30 \cdot 10^{-9}$a were beyond the amplifier range, with the satellite approaching the perigee. high ion concentrations corresponding to the lower part of the ionosphere could not be determined in this experiment.

Ion concentrations near the Earth by the trap collector current values were estimated, as in [3], with the following assumptions:

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1) The measured values of the collector current were modulated by the satellite rotation. From the measured values near the given height the greater value was chosen (corresponding to the greatest approach of the normal to the plane collector of the trap to the satellite velocity vector direction). These values of the collector current were considered as corresponding to the coincidence of the said two directions.

2) The influence of the satellite electric potential with respect to the surrounding plasma on the ion collection in the trap was not taken into account.

The reasonableness of this assumption at heights up to 3 R_E is confirmed by the Serbu measurements according to which this potential at the said heights is close to zero [6]. It is important to note that in the period from January 31, 1964, to February 13, 1964, with the satellite moving away from the Earth, the orbit portion corresponding to heights from $\sim$ 3000 km to $\sim$ 10000 km was not lit by the Sun, i.e. at these heights there was no photoeffect from the satellite surface and the satellite electric potential with respect to the surrounding plasma could not be positive. Besides, as was mentioned in [3], the ion current in the trap which is normal to the satellite velocity vector is the least sensitive to the satellite potential value. Fig. 3 gives some n_i values obtained during seven passages of the satellite near the Earth the dates of which are indicated in the figure. These data lead to the following conclusions:

1) As it was indicated in [1] - [3], the thickness of the ionosphere region in which the charged particles concentration is more then $10^2 cm^{-3}$ is $\sim 15000 \div 20000$ km.

2) The height distribution of n_i inside this region strongly differs from that given in [3]. If at heights of > 10000 km the height distribution of n_i is very similar to the distribution given in [3], the values of n_i referring to heights from 2000 km to 10000 km several times exceed the values given for these heights in [3]. These new values of n_i much better conjugate with the results of different direct measurements of electron and ion height distributions carried on after 1960 at heights from 1000 to 2000 km (including measurements from the Cosmos-2 ion traps made in 1962, according to which at heights of ~ 1500 km n_i is a few units per $10^4 cm^3$ [8]).

It should be noted that in [3] it was pointed out that the n_i values given in the paper may be lower then the true ones (for instance, by 2 times). In connection with the results obtained from Electron-2 we have revised the primary results of measurements near the Earth by means of charged particle traps in 1959. It was established that in values determinations at heights below 10000 km the limitation effect in the current amplifiers on the collector current values had not been taken into account which could lead to the decrease of n_i estimates at these heights, as compared to the true values.

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2. On the Possible Existence of the Soft Electron Component of the Outer Radiation Belt and Its Variations

Negative collector currents could be produced by a) photoelectrons emitted by the trap inner grid when the trap was lit by the solar ultraviolet and b) fluxes of electrons with energies E > 100 ev getting into the trap from the space surrounding the satellite.

It is natural to expect that the trap collector current component produced by photoemission from the inner grid lit by the Sun should change little along the orbit and from one revolution to the other. At definite portion of the orbit (approximately corresponding to the satellite passage through the outer radiation belt) on many revolutions of the satellite all the recorded values of the collector current turned out to be negative (irrespective of the trap orientation with respect to the Sun). The values of the collector currents at these portions of the orbit during three revolutions of the satellite around the Earth are shown in Fig.4 - 6. As evident from these graphs, the sizes of the zone of the existence of considerable negative currents change noticeably from revolution to revolution. At the same time there were cases when such zones were not observed at all (Fig.7). In Fig.4 - 7 the heavy horizontal line in the lower part of the graphs indicates the height intervals at which the outer radiation belt electrons were simultaneously observed by means of hard radiation counters (E > 100 kev) installed on the same satellite by S.N.Vernov and others [9]. While the negative collector currents at these portions of the orbit changed greatly from revolution to revolution, the readings of the hard radiation counters were relatively stable, their counting rate varied within 10 %. Electron fluxes producing maximal negative collector currents at the considered portions of the Electron-2 orbit (Fig 4-6) may be estimated as $2 \cdot 10^{8}$el.cm^{-2}sec^{-1}. At this portion of the Electron-2 orbit in the period from January 30, 1964, to February 17, 1964, the greatest electron flux was observed on February 2, 1964, and amounted to $3 \cdot 10^{8}$cm^{-2}sec^{-1}. It should be borne in mind that these estimates of electron fluxes recorded by the trap give their lower boundary, as besides electrons, positive ions reducing the observed negative current could get into the trap.

Comparatively stable readings of the hard radiation counters in the outer radiation belt give ground to believe that collector currents recorded by the trap in the same zone which considerably varies from orbit to orbit are produced by electrons with the energy E < 1000 kev.

These results may be interpreted as the evidence of existence of the soft component of the electron fluxes in the outer radiation belt whose variability in time is much greater than the variability of high-energy particle fluxes.

It should be mentioned that the region of the existence of the soft electron fluxes recorded by the trap always

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The problem of the existence and properties of the soft electron component of the outer radiation belt requires further investigations.

3. Fluxes of Charged Particles Beyond Radiation Belts, but Inside the Magnetosphere

The characteristics of the Electron-2 orbit (especially its inclination to the equator) were such that its outer (and greater) part was beyond the trapped radiation zone (whose outer boundary is indicated in Fig. 4-7). At the same time the measurements of the magnetic field along the orbit indicated the regular character of the magnetic field up to the apogee from which it follows that the satellite flight was fully inside the magnetosphere (in any case at the initial stage of the flight which is considered in the present communication). In Fig. 2 the currents recorded at the outer part of the orbit ($H \simeq 30000$ km) are seen as points near the abscissa. However, if these points are given on the graphs with larger scale along the ordinate one can see that the character of the currents changes from orbit to orbit (upper parts of Fig. 8 and Fig. 9) and sometimes during the same orbit (the upper part of Fig. 10). The lower two graphs in these figures show the results of simultaneous measurements of the magnetic field on the satellite (ΔT is the excess of the measured magnetic field over its theoretical value) and the values of the Kp indexes. Geocentric distances in R_E units are given along the abscissa. Magnetic measurements from the satellite were performed by Sh.Sh.Dolginov, Je.G.Yeroshenko, L.N.Zhuzgov and U.V.Fastovsky.

From the analysis of the currents recorded at the portion of the Electron-2 orbit considered in this section of the paper it may be concluded that there are positive ion fluxes in the magnetosphere beyond the radiation belts. The magnitude of these fluxes varies in time. Some considerations referring of these fluxes are outlined in [10].

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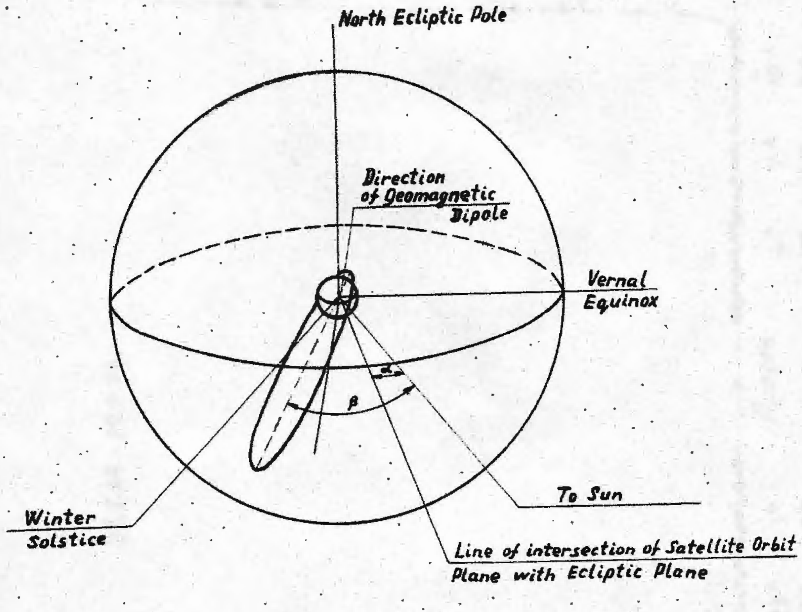
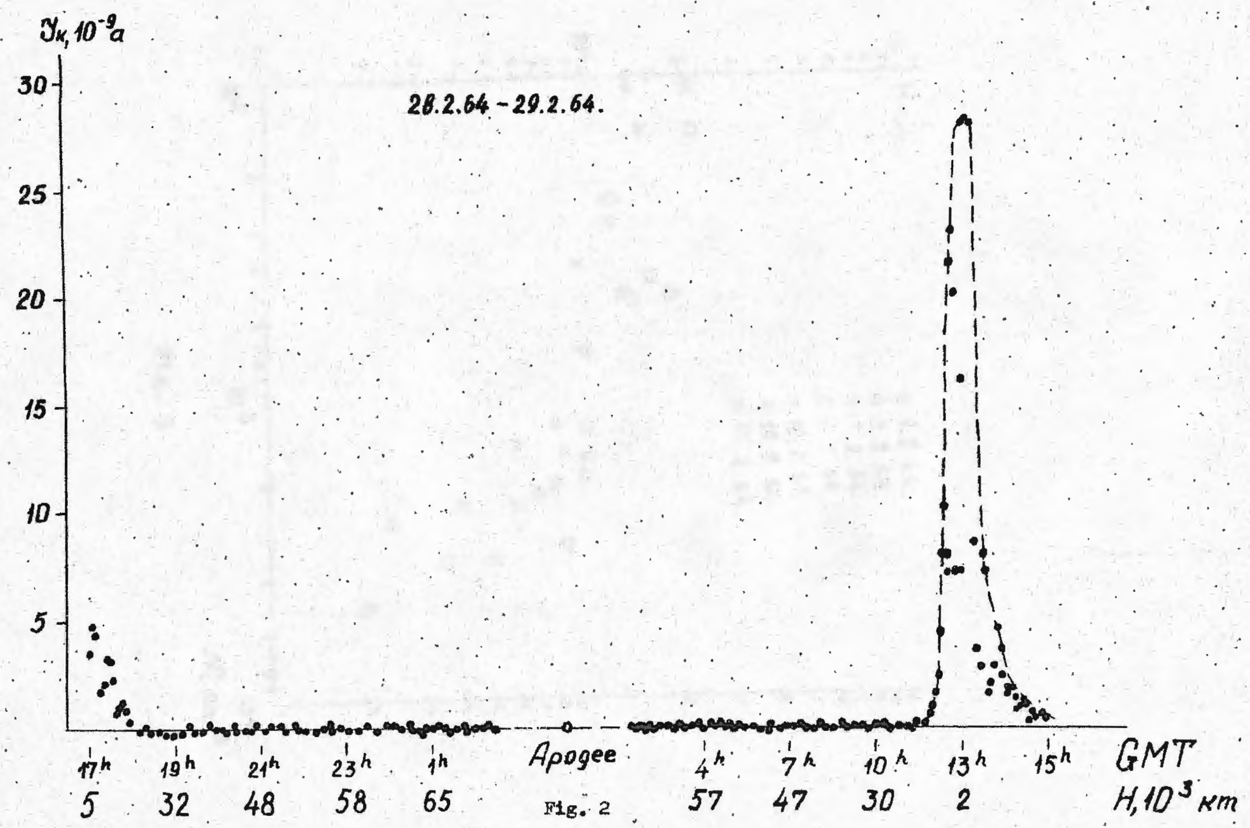

North Ecliptic Pole
Direction of Geomagnetic Dipole
Vernal Equinox
α
β
To Sun
Winter Solstice
Line of intersection of Satellite Orbit Plane with Ecliptic Plane

Fig. I


Jк, 10⁻⁹a
30
25
20
15
10
5
28.2.64 - 29.2.64.
17h
19h
21h
23h
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4h
7h
10h
13h
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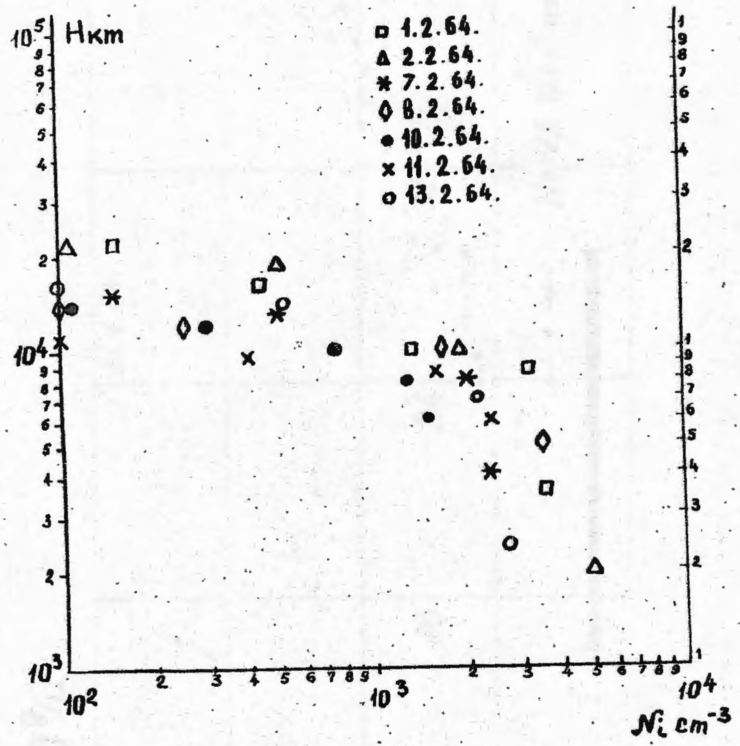
5
32
48
58
65
57
47
30
2
H, 10³ км

Fig. 2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10^5
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□ 1.2.64.
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Fig. 3

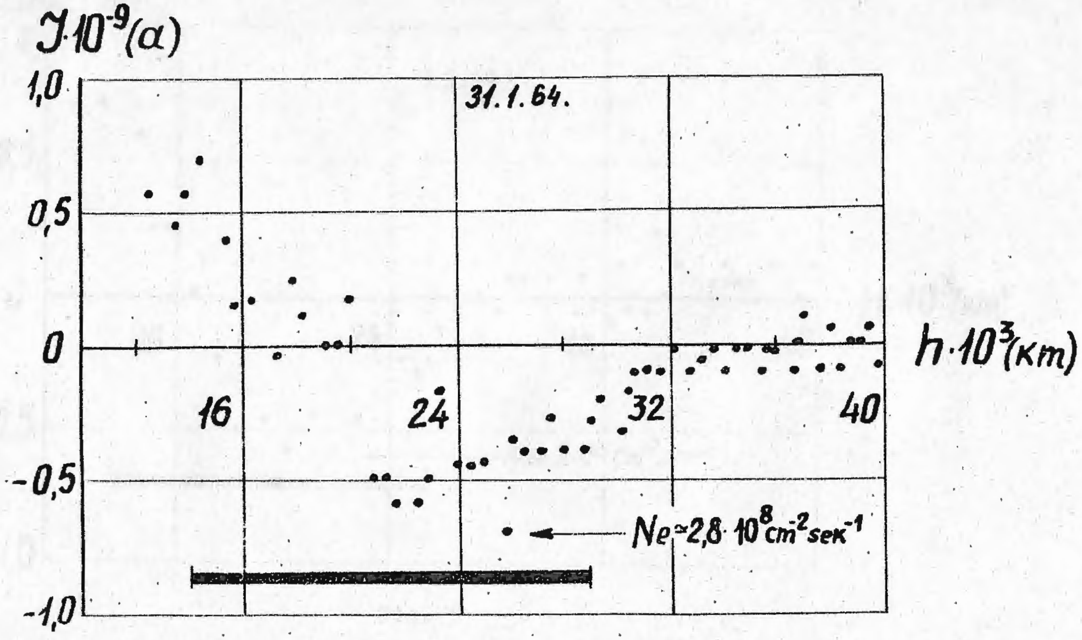
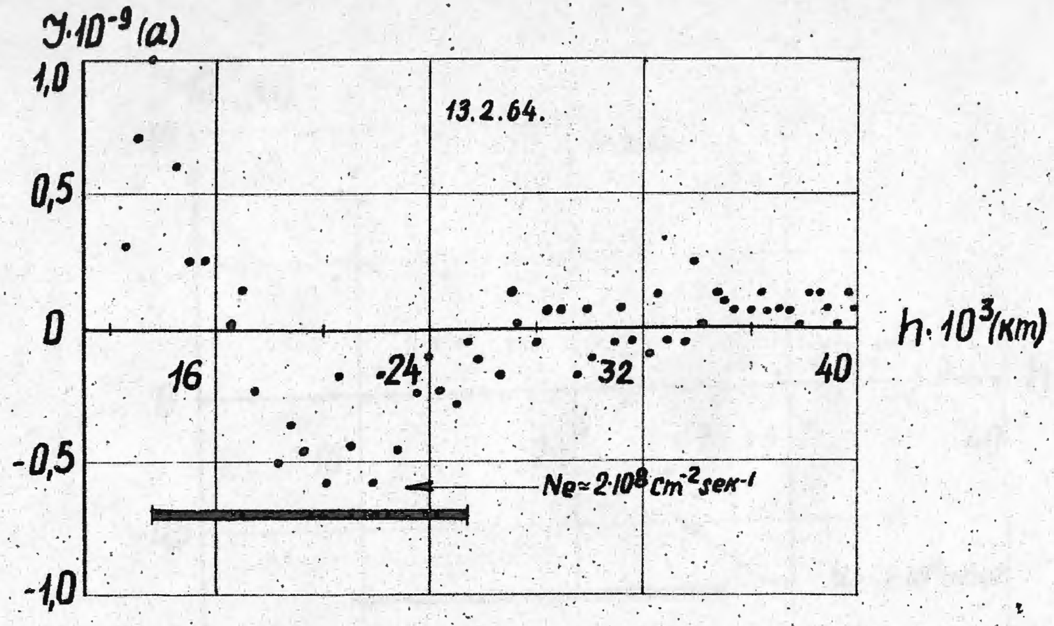


Fig. 4



$\mathcal{J}\cdot 10^{-9}$ (a)
1,0
0,5
0
-0,5
-1,0
13.2.64.
16
24
32
40
$h\cdot 10^3$ (km)
$N_e \approx 2\cdot 10^8$ cm^{-2} sek^{-1}

Fig. 5

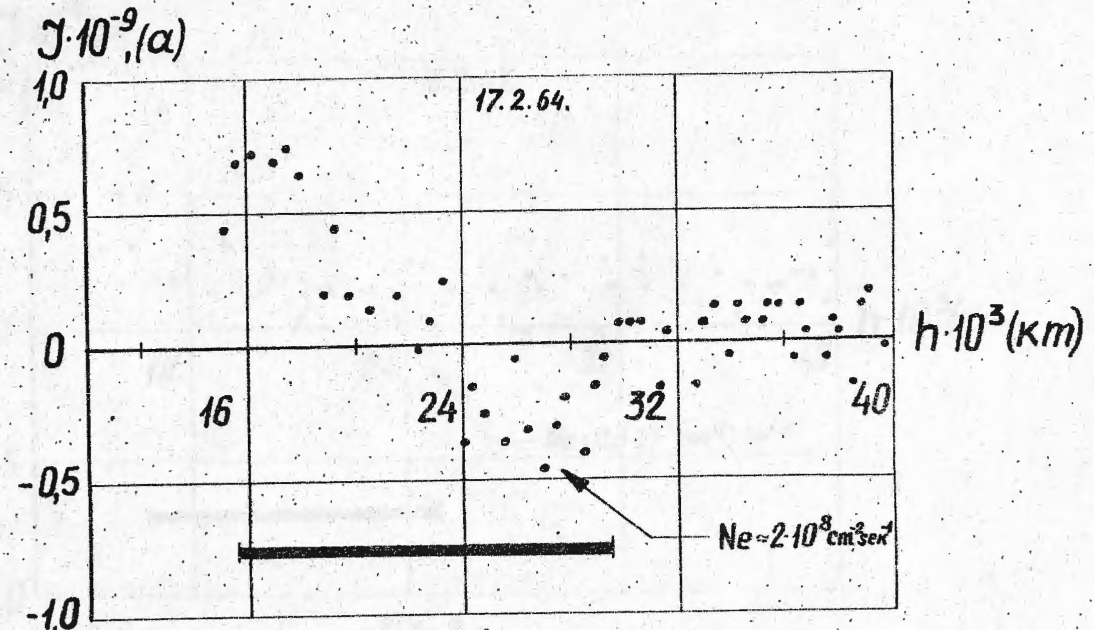
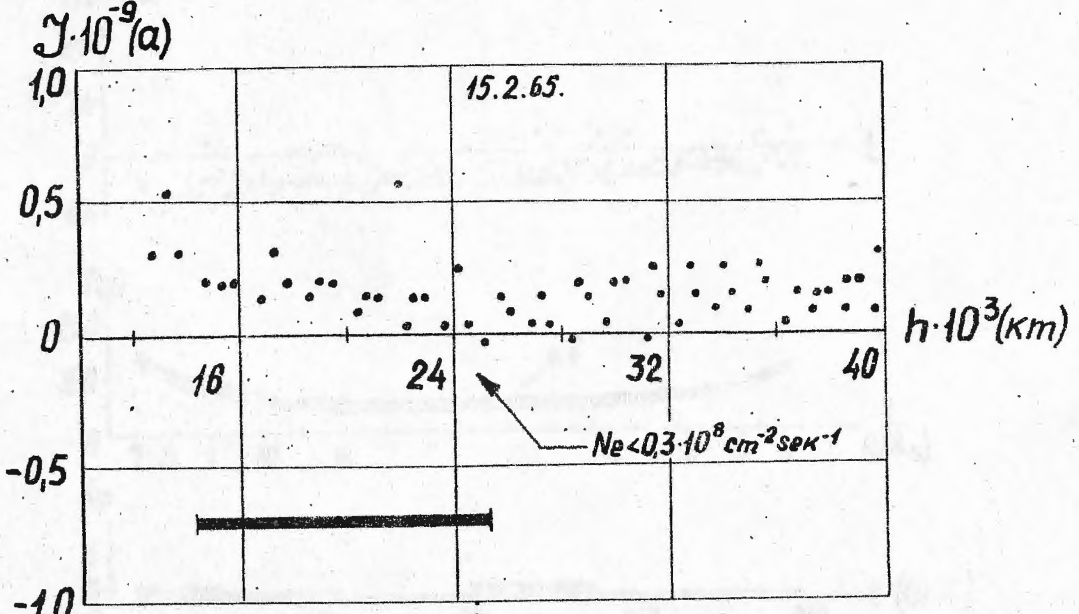


Fig. 6



$J \cdot 10^{-9} (a)$
1,0
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0
-0,5
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32
40
$h \cdot 10^3 (km)$
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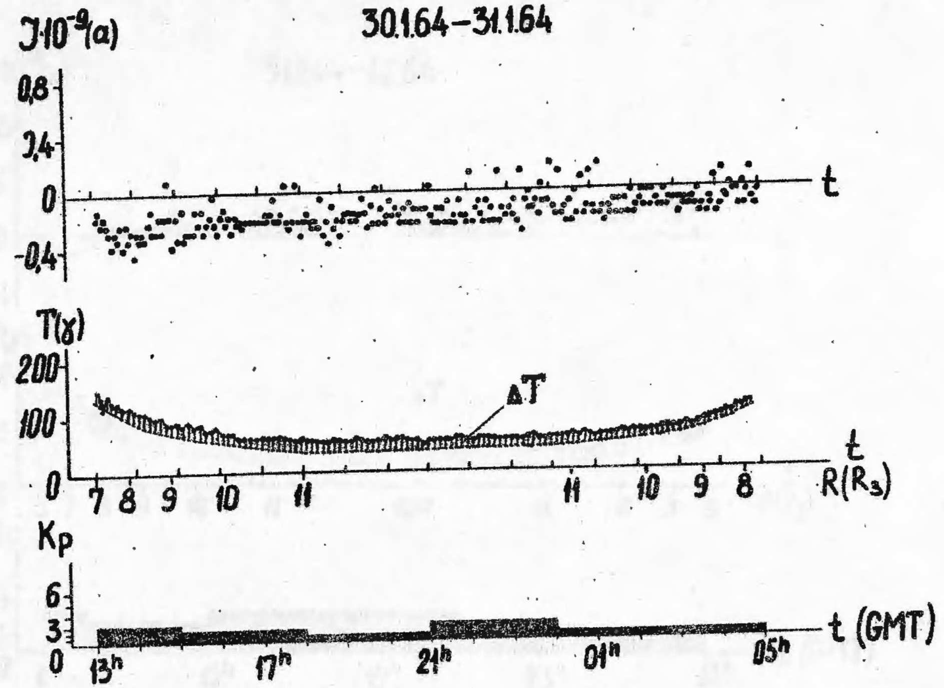
Fig. 7


30.1.64–31.1.64
J·10⁻⁹(a)
0,8
0,4
0
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t
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Fig. 8

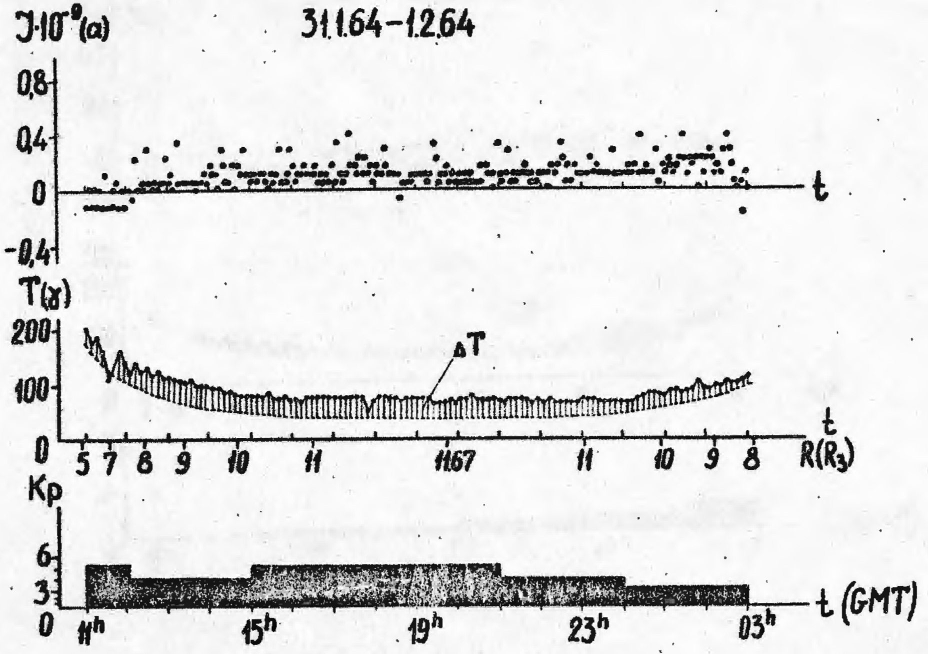
J·10^9(a)
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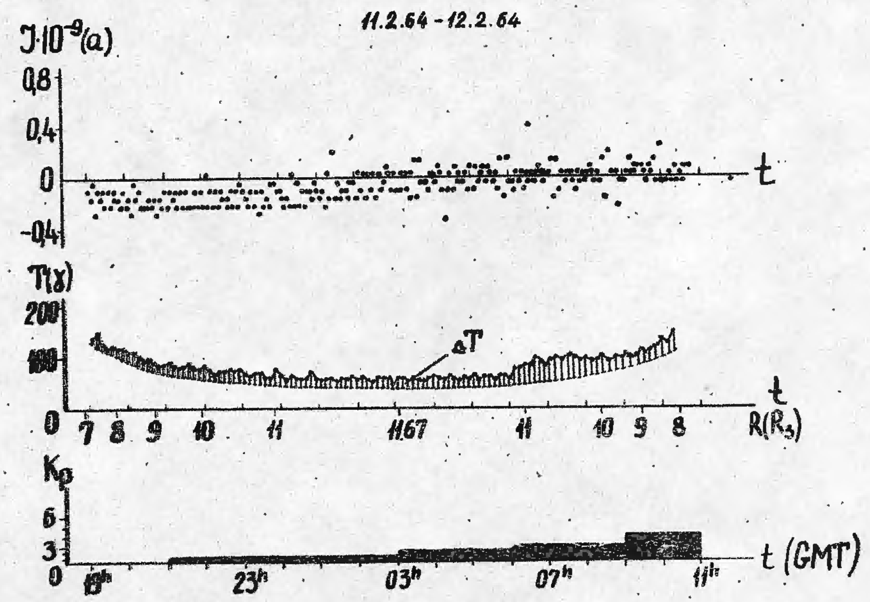
Fig. 9


11.2.64 - 12.2.64
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