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POLAR AND LOW-LATITUDE AURORA IN THE ULTRAVIOLET WAVELENGTH RANGE 115 - 135 NM FROM DATA OF KOSMOS-900 SATELLITE

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Abstract: Results of measurements of ultraviolet upper atmosphere emissions at polar and lower latitudes, obtained on board the Kosmos-900 satellite in April, 1977, are presented and discussed in comparison with simultaneous observations of charged particle fluxes.

Резюме Приводятся и обсуждаются результаты измерений ультрафиолетовых эмиссий верхней атмосферы полярных и низких широт с борта ИСЗ Космос-900 в апреле 1977г. Резултаты сопоставляются с одновременными наблюдениями интенсивности потоков заряженных частиц.

1. Introduction

Systematic measurements of ultraviolet emissions in the wavelength range 115 - 135 nm have been carried out on board of the satellite Kosmos-900, which was launched in March, 1977, into a near-circular orbit at about 500 km height with an inclination near 83° /1/ /2/. The satellite was three-axis-oriented, one axis being directed towards the Earth, another axis along the trajectory. In this paper we present the results of observations of emissions from the upper atmosphere and polar regions, obtained on the Kosmos-900 satellite in the first half of April, 1977.

For recording polar aurora and atmospheric emissions, an ionization photometer of the type described in /3/ was used, with a nitric oxide gas filling and a Mg F_2 window. The absolute sensitivity of this photometer for measuring photon fluxes was approximately an order of magnitude higher than indicated in /3/. The photometer was mounted along the longitudinal axis of the satellite in such a way that its entrance window always looked to the Earth.

The basic parameters of the photometer are given in Table 1. In order to protect the apparatus from scattered light, it was equipped with a special tubular collimator of 35 mm length with a grid system.

The range of spectral sensitivity of the photometer permitted to record not only Lyman-α, but also the atmospheric emissions of atomic nitrogen at 120 and 124.3 nm, and the oxygen triplet near 130.4 nm. In the Lyman-α line, the apparatus ensured reliable record of emissions with about 0.10 kR, whereas near the 130.4 nm triplet the sensitivity was about a factor 5 less than in the Lyman-α line. The recording frequency (i.e., the number of measurements per second) was on some revolutions 6 sec^{-1}, but in the majority of cases 0.2 sec^{-1}. The viewing area at the 100 km height level was a circle of about 80 km radius. With a measuring cycle of 6 sec^{-1}, the displacement of this area along the orbit projection between two consecutive measurements was about 1.3 km. In this case, the existence of significant differences between two consecutive measured values may be regarded as evidence for a discrete or an essentially inhomogeneous structure of the luminosity of the region under study.

It is well known that the nitrogen emission is basically generated by dissociative excitation of N_2, and that photodissociative excitation of N_2 is the main source of the daytime emission in the 120 nm line /4/. From the rather low probability of dissociative excitation of N_2, together with the lack of any differences between the photometer displays on illuminated and non-illuminated sections of the orbit (cf. below), it may be concluded that the contribution of nitrogen emissions is negligible.

Because of the large abundance of atomic oxygen in the upper atmosphere under certain conditions, particularly at daytime, the recorded emissions may be due both to Ly-α radiation and to the oxygen triplet.

2. Results of the observations

Inspection of the results of measurements over more than 20 revolutions of the satellite gives evidence of the variety of obtained information. First of all it has to be stated, that no 'parasitic' background of scattered radiation was observed. Some observational data, from those obtained in April 1977, are shown in figs. 1 - 6.

While on many revolutions of the satellite the signal of the orbit-aligned photometer did not exceed values about 0.1 to 0.15 kR, at latitudes of the polar oval bursts of intensities about 0.5 to 1.5 kR were often observed (see fig. 1a, b and e). (Here and in the following, intensities are given according to the calibration of the sensor in the Lyman-alpha line).

In several cases, an increase of luminosity up to 0.35 - 0.4 kR at daytime was observed over rather low latitudes (fig. 1, c, f, h), as well as signals of about 2 kR (fig. 2). Sometimes, intensity bursts over equatorial latitudes reached a magnitude of about 16 kR (see fig. 3). It is seen from fig. 2, that under quiet geomagnetic conditions there are cases where the observed atmospheric emissions are more intense at low and middle latitudes than at high latitudes. The positions of the polar oval, characterized by intensity outbursts at high latitudes, depend on geomagnetic activity and are concentrated in the range of in variant latitudes $\Lambda \approx 76 - 60^{\circ}$.

Sometimes, polar aurora was observed only at daytime (figs. 1 d, h). In the majority of cases, the zones of observable daytime polar aurorae corresponded to invariant latitudes about $72^{\circ} - 75^{\circ}$, in several cases they were shifted to $60^{\circ} - 62^{\circ}$ (cf., e.g., fig. 1h and g). With sharp increases of D_{st} or K_p geomagnetic activity indices, a rather remarkable enhancement of both the number and the mean magnitude of the recorded emission outbursts was observed (figs. 2 and 4).

Besides the signal amplitudes of about 0.1 kR, rather regular intensity signals of about 2 kR were recorded, as well as zones of even higher luminosity and zones of enhanced spatial density of the emissions. Such examples are shown in figs. 5 and 6, obviously corresponding to the daytime polar cusp. The satellite orbit was such, that in these regions the local magnetic meridian time was forenoon on the Northern but afternoon on the Southern hemisphere. The zones of daytime polar aurora were situated at extraordinarily low latitudes, in connection with strong magnetic disturbance (about $66^{\circ} - 64^{\circ}$ in the North, $64.3^{\circ} - 63^{\circ}$ in the South).

3. Discussion of the results

Analysis of the data given above in figs. 5 and 6 suggests that, independent of the intensity of the recorded emissions, their linear dimensions are of the order of 1 - 1.5 km along the projection of the satellite orbit, i.e. their structure was essentially discrete. On the satellite Kosmos-900 also two identical narrow-angle ($3^{\circ} \times 10^{\circ}$) electrostatic analyzers were mounted with antiparallel orientation under an angle of 22° to the local vertical direction /7/. The pitch-angles of the measured fluxes in the energy range 0.1 to 20 keV were determined by the orientation of the apparatus with respect to the magnetic field at the moment of measurement. The positions of the spectrometers were such that the total range of pitch-angle variations of the particles, recorded along the orbit, was $40^{\circ} - 140^{\circ}$. In particular, near the equator, fluxes with pitch-angles $80^{\circ} - 100^{\circ}$ could be recorded.

The cases of enhanced emission intensities in the equatorial region were associated, as a rule, with intense electron and ion fluxes. Since those fluxes are recorded mostly above 180 km altitude /5/, it cannot be excluded that these equatorial enhancements of upper atmosphere emissions are to be ascribed to a relative increase of the contribution of emissions in the oxygen triplet near 130.4 nm /6/, resulting from radiative recombination of additionally appearing ionospheric O^+ ions.

It must be kept in mind that the presence of intense proton fluxes may be associated with an enhancement of the Ly-α line emission, due to charge exchange processes caused by inelastic collisions between protons and neutral particles, leading to ionization and excitation.

The data presented in figs. 5 and 6, referring to daytime polar aurora of a disturbed period, have also been compared with the results of charged particle flux measurements. These results are shown in the lower parts of figs. 5 and 6.

The orientation of the analyzers with respect to the geomagnetic field in the given time periods permitted measurements of particle fluxes with virtually identical pitch-angles: 122^o - 121^o on the Northern, and 120^o - 111^o on the Southern hemisphere. From figs. 5 and 6 it is obvious that similar structures of the emissions correspond to similar characteristics of the observed charged-particle fluxes. In both cases, the ion fluxes were of the order of 10^7 $cm^{-2}s^{-1}ster^{-1}eV^{-1}$, and their energy was about 100 eV. The energy of the electrons varied from 500 eV to 10 keV on the Northern, and to 5 - 7 keV on the Southern hemisphere, respectively, and their fluxes did not exceed about 5×10^4 $cm^{-2}s^{-1}ster^{-1}eV^{-1}$. It is typical for both cases, that the zones of enhanced spatial emission density coincided with regions of simultaneous electron fluxes recorded on both analyzers, i.e., electrons moving in opposite directions. The fact, as seen in figs. 5 and 6, that single intensity bursts and their occurrence frequency were somewhat higher on the Northern than on the Southern hemisphere, well corresponds to the fact that the charged-particle fluxes are also by a factor of 1.5 to 2 higher on the Northern than on the Southern hemisphere, and that the maximum electron flux of about $(3 - 4) \times 10^6$ $cm^{-2}s^{-1}ster^{-1}eV^{-1}$ at an energy of about 1 keV is observed on the Northern hemisphere.

It can be assumed, that the observed daytime polar aurora in the ultraviolet wavelength range represents a predominantly discrete variant of the emissions, caused by the interaction between the hot magnetospheric plasma and the ionosphere. It is probable that the recorded intense and anisotropic fluxes of low-energy ions with pitch-angles of about 120^o - 110^o are the result of the acceleration of cold ionospheric ions in a direction perpendicular to the geomagnetic field /8/.

The pronounced variations of the electron fluxes, as well as their anisotropy and the existence of peaks in the energy distribution, suggest that in the case considered here the recorded charged-particle fluxes were inhomogeneous and turbulent. These properties must have been favourable for the formation of discrete structures of the emissions.

From the data obtained under quiet geomagnetic conditions, where $K_p \approx 1$, it can be supposed that a certain correlation exists between the flux and energy of the precipitating protons, and the emissions in the polar region. Obviously the emissions correspond to harder protons with energies mainly greater than 1 keV. If their flux intensity was less than 10^5 $cm^{-2}s^{-1}ster^{-1}eV^{-1}$, no emissions were observed. The observable charged-particle fluxes at the 500 km level did not in all cases cause a unique emission-generating effect on the atmosphere, because the particle precipitation and its effect upon the ionosphere underneath is determined not only by the flux intensity, energy and species of the invading charged particles, but also by the parameters of the cold ionospheric plasma and of the neutral atmosphere.

It follows from the foregoing, that the characteristics of the simultaneously recorded emissions and charged-particle fluxes suggest that there is not only one, but several mechanisms responsible for the generation of these emissions.

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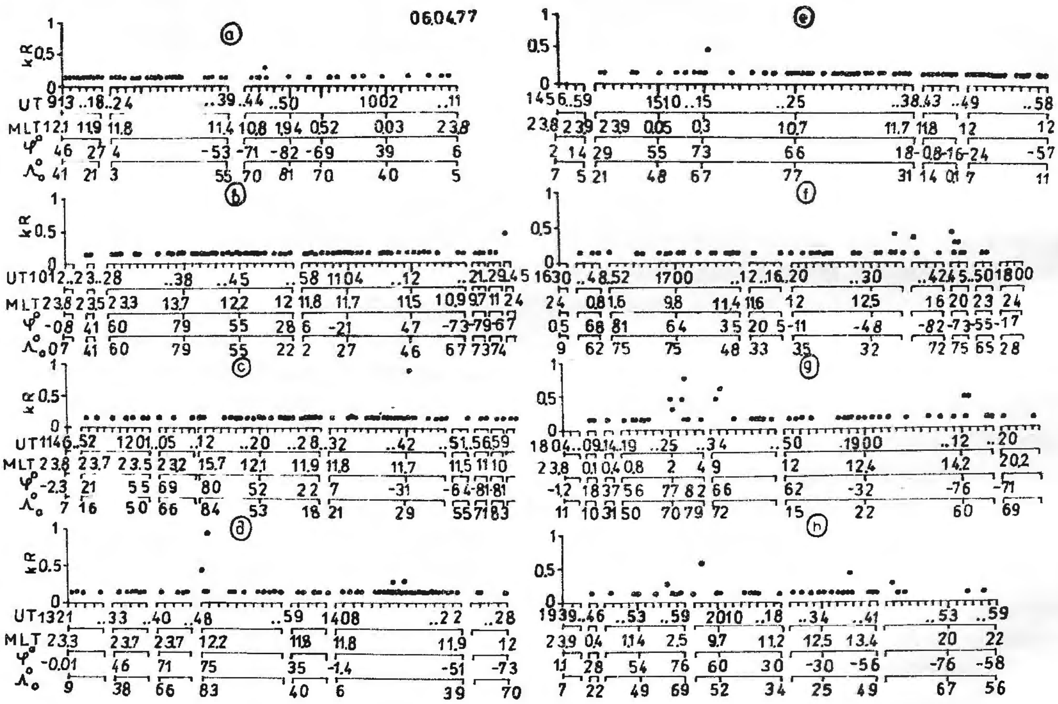

Fig. 1 Intensity of emissions during several revolutions of the satellite on April 6, 1977 (sampling frequency: 0.2 s^{-1}), on the abscissa, UT and local magnetic meridian time, geographic and invariant latitude are given.

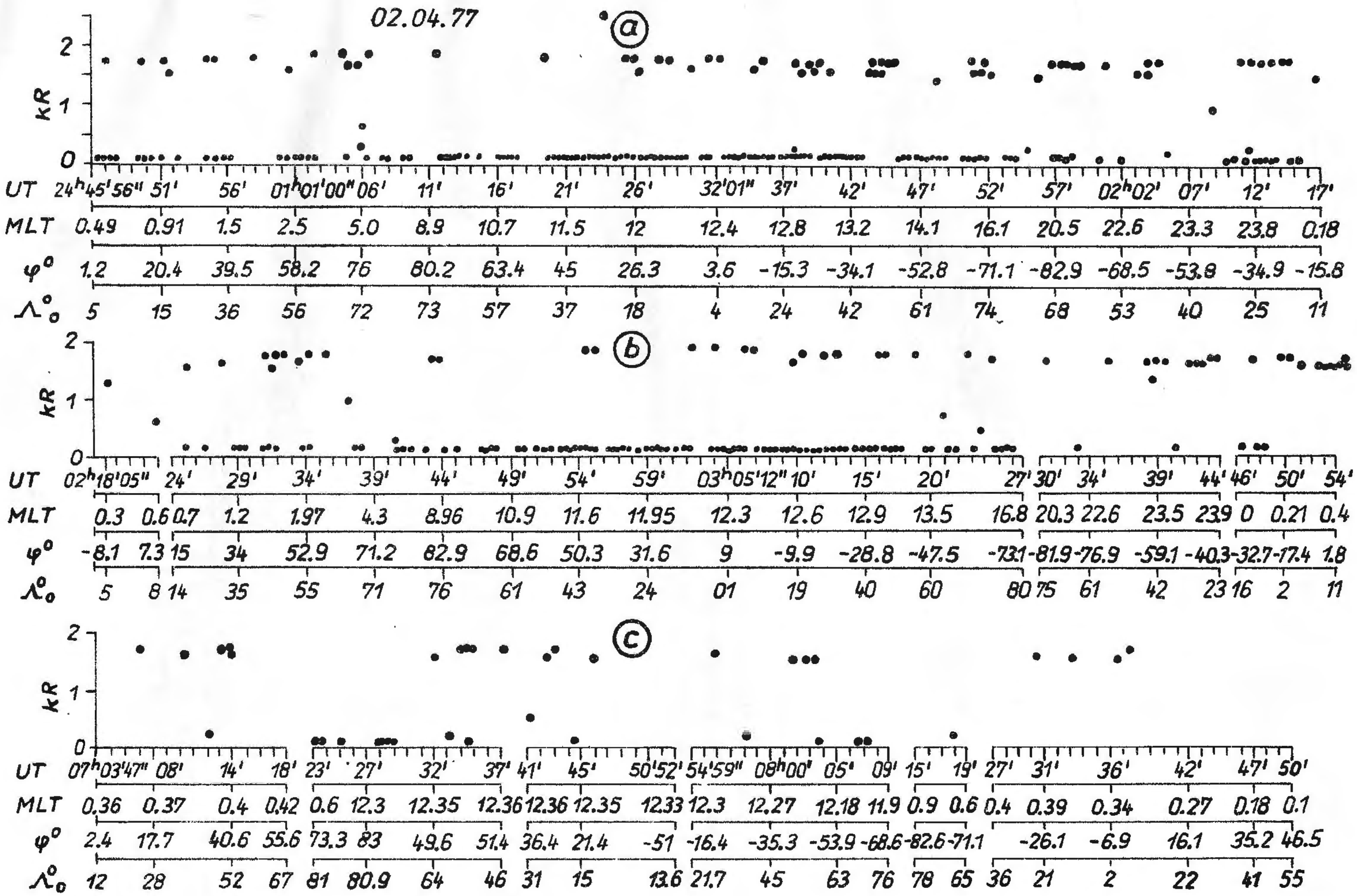

Fig. 2 Intensity of emissions during three revolutions of the satellite on April 2, 1977 (sampling frequency: 0.2 s^{-1}). Abscissa scales as before.

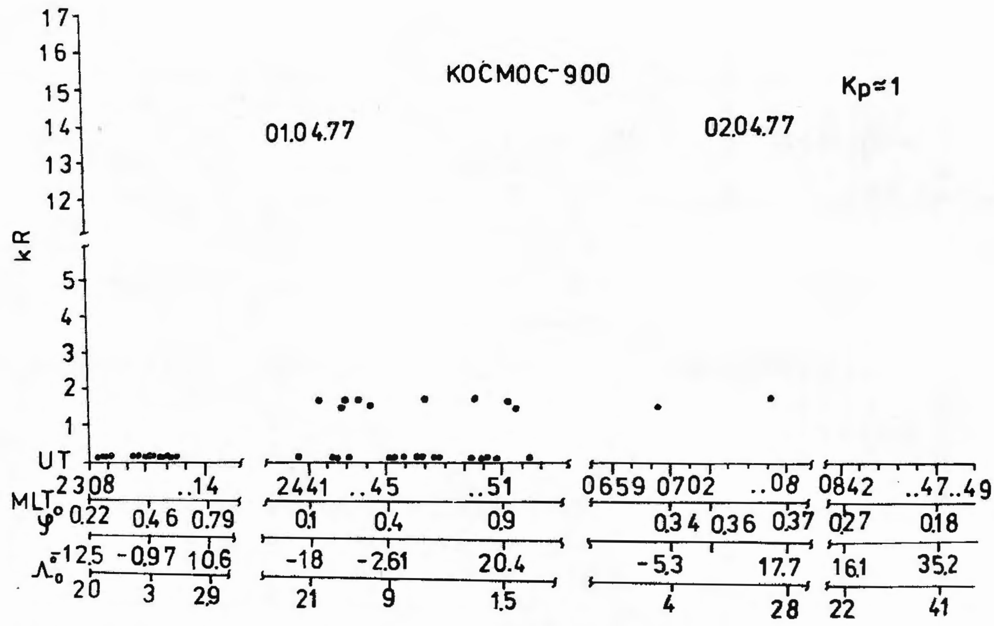

Fig. 3 Emissions at low and equatorial latitudes under quiet geomagnetic conditions (sampling frequency: 0.2 s^{-1}).

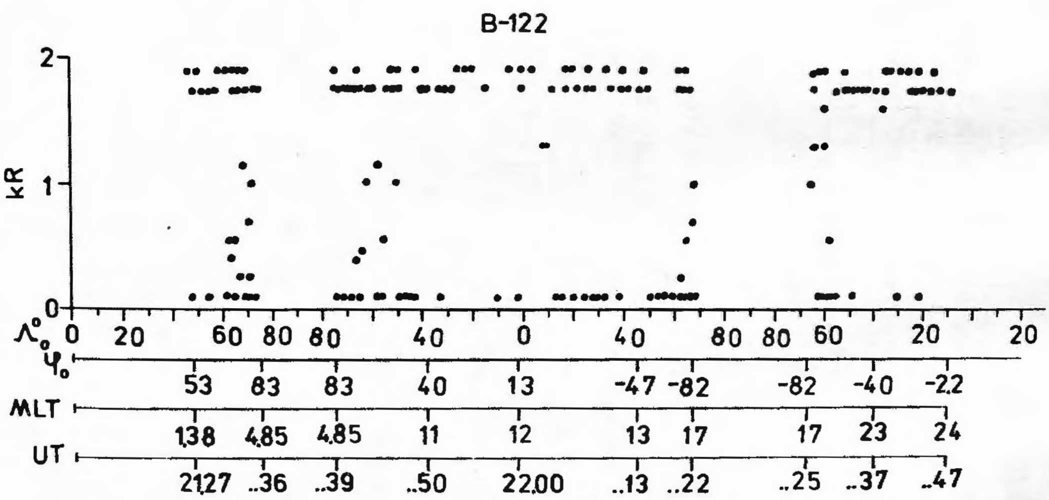

Fig. 4 Emissions at enhanced geomagnetic activity on April 6, 1977 (sampling frequency: 0.2 s^{-1}).

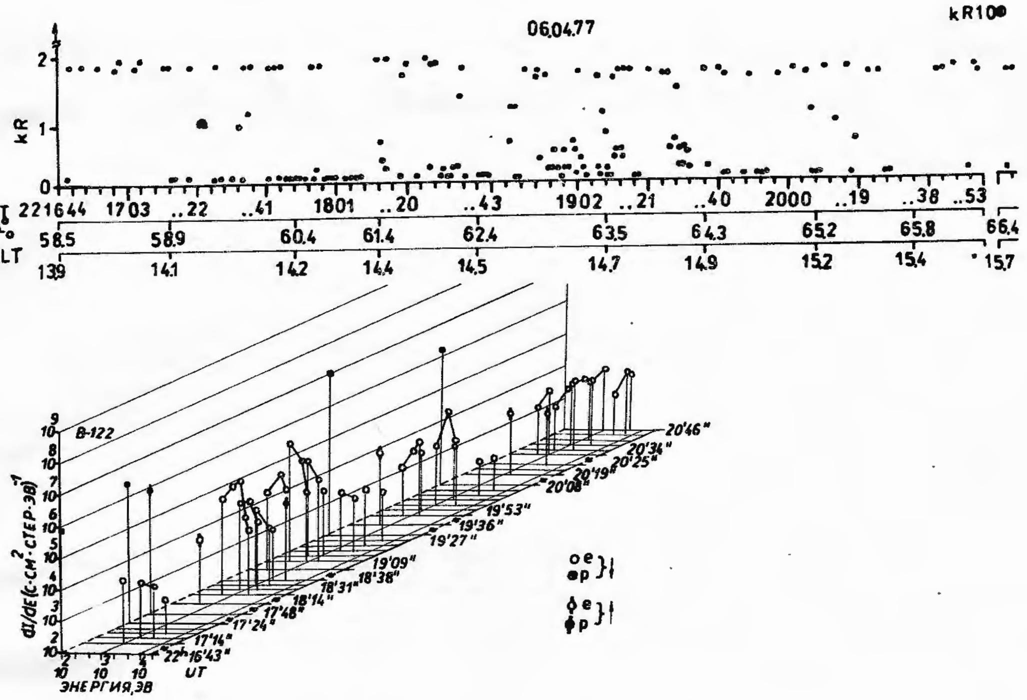

Fig. 5 a) Daytime polar aurora on the Northern hemisphere at $K_p = 7$ (April 6, 1977). Sampling frequency: 6 s^{-1}).

b) Simultaneous observations of charged-particle fluxes, in a 3-dimensional presentation of flux intensity, energy (for ions, assuming that protons or single-charged ions are recorded), and time.

o electrons	}	analyzer looking away from Earth
• ions		
ϕ electrons	}	analyzer looking towards the Earth
ϕ ions		

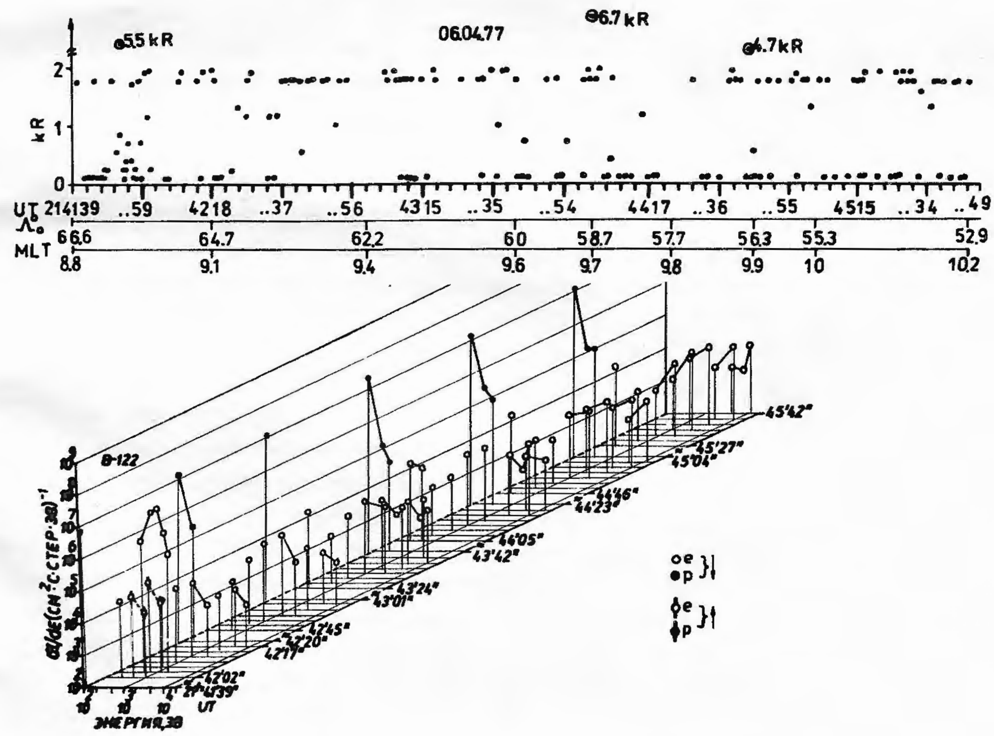

Fig. 6 Same as fig. 5, but for Southern hemisphere.

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THE IONOSPHERIC RESPONSE TO THE SOLAR ECLIPSE OF 26 FEBRUARY 1979 OBSERVED IN HAVANA/CUBA

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Abstract: The ionospheric response to the solar eclipse of 26 February 1979 has been observed in Havana (23.1°N, 82.5°W) by the Faraday rotation technique and vertical sounding. The Faraday rotation measurements show a significant decrease in the total electron content (TEC) induced by the solar occultation. The spectral analysis of the experimental data revealed wave like structures with periods of about 2 hours. The partial solar eclipse was accompanied by the occurence of a sporadic E-layer ionization over several hours. It is suggested that the observations are related to internal gravity waves induced by the solar eclipse.

Zusammenfassung: Der Einfluß der Sonnenfinsternis vom 26.2.1979 auf die Ionosphäre ist in Havana (23,1°N, 82,5°W) mit Hilfe von Faradayrotations- und Ionosonden-Messungen beobachtet worden. Die Faradayrotationsmessungen zeigen einen deutlichen Abfall der Gesamtelektronenzahl (TEC) infolge der Sonnenbedeckung. Die Spektralanalyse der experimentellen Daten lieferte wellenähnliche Strukturen mit einer Periodenlänge um ca. 2 Stunden. Während der partiellen Sonnenfinsternis bildete sich eine sporadische E-Schicht von mehreren Stunden Dauer heraus. Es wird angenommen, daß die Beobachtungen in Beziehung stehen zu internen Schwerewellen, die durch die Sonnenfinsternis angeregt worden sind.

1. Introduction

The ionospheric response to solar eclipses has been studied by many scientists in recent years. Since an eclipse provides well-defined conditions for turning off and on of the solar radiation it can be regarded as a large-scale active experiment in the ionosphere of the earth. Since CHIMONAS and HINES (1970) theoretically predicted the generation of internal gravity waves during solar eclipses, most related publications are dedicated to check this prediction. Due to the variety of physical processes taking place during solar eclipses some experimenters were able to observe wavelike variations in the ionosphere (e.g. DAVIS and DAROSA, 1970; LERFALD et al., 1970; DATTA, 1972; BERTIN, 1977; RAJ et al., 1982 HANUISE et al., 1982), but others had no success in finding internal gravity waves (e.g. SCHÖDEL et al., 1973; OLIVER and BOWHILL, 1974; DAS GUPTA, 1981).
According to CHIMONAS and HINES (1970), internal gravity waves are induced by the cooling spot of the lunar shadow sweeping across the earth at supersonic speed. The initiated pressure perturbation (maximum at about 50 km height) can be detected at ionospheric heights as traveling ionospheric disturbances (TID's).
This paper reports on observations of the total electron content of the ionosphere, N_F, by means of the Faraday rotation technique (BETTAC and WIENER, 1975) in correlation with ionosonde data during the solar eclipse of February 26, 1976. This partial eclipse occured during the morning hours (10.32 - 12.48 LST) accompanied by medium geomagnetic activity (Kp = 3...4).