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PROPERTIES OF HIGH-LATITUDE IONOSPHERIC IRREGULARITIES BASED ON COSMOS 378 ION TRAP DATA

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The collector current of the spherical ion trap aboard Cosmos 378 often varies with a low-frequency quasi-sinusoidal form. Such signals are very often observed in ionospheric regions characterized by higher gradients of the geomagnetic field and the plasma density. Such oscillations of the flux density of ions recorded are interpreted as drift oscillations of the ionospheric plasma. Based on about 400 real time telemetry recordings the relative frequency of detection of these oscillations depending on some geophysical factors and geographic coordinates were investigated. Their probability increases towards the polar regions and where the gradient of the geomagnetic field in the Eastern Siberian geomagnetic anomaly region is a maximum.

1. Introduction

A three-electrode concentric spherical ion trap, with the outer grid having a floating potential for the measurement of the ionospheric positive ion density along the satellite orbit, was installed on board the Cosmos 378 satellite launched on 17 November 1970 (orbital inclination 74°, perigee 240 km, apogee 1740 km). The spherical parts of the electrodes of such a trap form a concentric system. The outer grid protects the investigated plasma from disturbances caused by internal fields of the trap. The internal grid prevents photoelectrons from the collector itself and, together with the outer grid, protects the collector from external interference fields. Free electric charges carried by the positive ions of the plasma are collected at the negatively charged collector and produce a current depending mainly on the ion flux and also on the outer grid potential, the temperature and mass of the ions and the grid transparency (0.53). The pass-band of the amplifier was 200 Hz.

From the study of ~ 400 real time telemetry recordings of 5—10 minute periods of collector current measurements made during the period from November 1970 to July 1971, numerous cases of collector current oscillations not associated with the satellite rotation were found.

2. The Main Properties of Observed Collector Current Oscillations

1. The amplitude of current oscillations sometimes reaches several tenths of the average level. The amplitude of the ion flux variations often has the value $(5-10) \times 10^9\ \mathrm{cm^{-2}\ s^{-1}}$.

2. The frequencies of these oscillations are from ~ 0.3 Hz to 20—30 Hz.

3. Oscillations with the same periodic structure are usually observed for only 2—4 sec. They are possibly associated with the limited dimension of the oscillating plasma region, this dimension therefore being 15—30 km along the satellite track.

4. The oscillation form, frequency and amplitude often change in a wide range during some periods.

5. The most typical feature of the majority of quasi-periodic oscillations is their anharmonic nature. In most cases oscillations look like a cycloid [1—3] (see Fig. 1a).

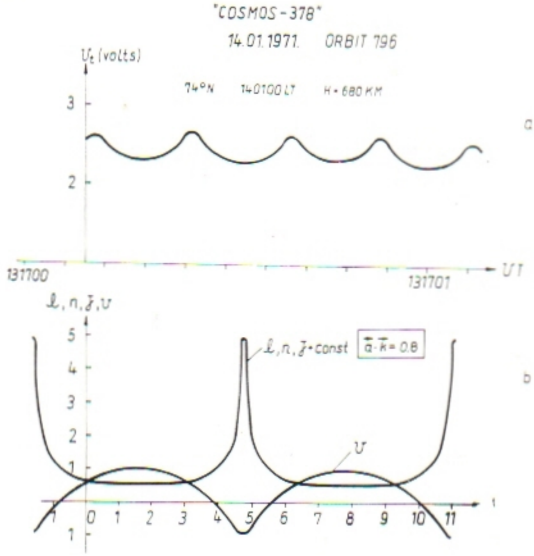

Fig. 1. a) Typical waveform of collector current oscillations of spherical ion trap installed on board Cosmos 378; U_t, telemetry voltage.

b) Calculated curves of the time dependences of the instantaneous frequency Ω, the concentration n, the oscillation velocity v and the total flux density j (relative to the trap) of particles oscillating in a simple harmonic compressional wave (in relative units). $\boldsymbol{a}$ is the amplitude displacement of an oscillating particle from its equilibrium position; $\boldsymbol{K}$ is the wave number vector.

6. The presence of these oscillations and their amplitude are not determined by the trap being in the free plasma flow or in the satellite wake.

7. The oscillation amplitude can also undergo oscillations with a lower frequency.

8. The average value of the oscillation amplitude is positively correlated with changes of the average ion flux.

These pecularities of the ionic current oscillations suggest that they are a typical plasma phenomenon; the properties of the measuring equipment do not vary so widely and, besides, in the absence of plasma flow, the oscillations are not observed. They are not connected with the characteristics of the plasma flow near the satellite. All these points indicate the detection of oscillations of the plasma flux existing in the ionosphere independently.

Detailed theoretical analysis [4] gives the result that the particle density, velocity and flux oscillating in a simple harmonic compressional wave and recorded by the measuring instrument experience non-sinusoidal oscillations due to the phase automodulation. Such oscillations look like cycloids resembling the oscillation recordings of ionic trap collector currents (see Fig. 1b).

3. Correlation with Geophysical Factors

To investigate the relation to geophysical factors and geographic coordinates of the oscillations considered several histograms of their relative frequency of detection were plotted. Their maximum probabilities are in the polar and low-latitude regions and where maximum gradients of plasma density and geomagnetic field exist (see Fig. 2a and b). The variation of their occurrence with season is evident.

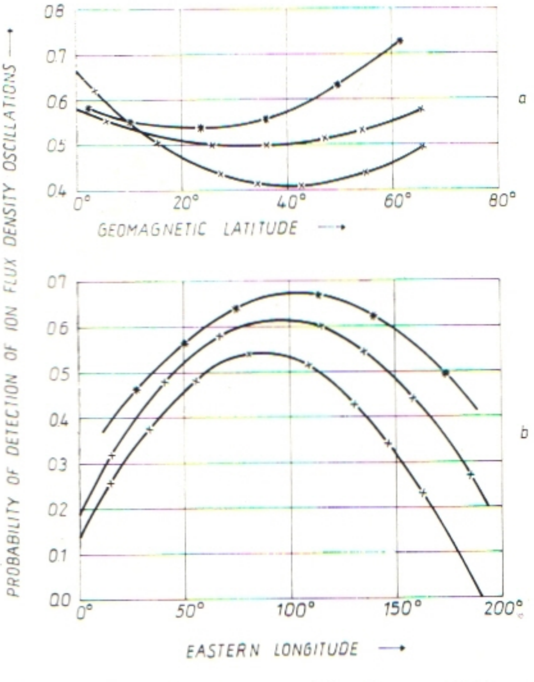

Fig. 2. Dependence of probability of occurrence of ion flux oscillations on: a. geomagnetic latitude; b. geographic longitude.

200 observations, orbits 2-796, 17 Nov. 1970—14 Jan. 1971; × (bottom curves in both a. and b.) 200 observations, orbits 807—3578, 15 Jan. 1971—31 Jul. 1971; + (middle curves in both a. and b.) 400 observations, orbits 2-3578, 17 Nov. 1970 to 31 Jul. 1971. Observations are based on all local times, the majority during day and evening hours.

In Fig. 3a the contours of occurrence probability in geographic coordinates, plotted on the basis of a two-factor regression on geographic latitude and longitude, are given. From this pattern highest probabilities are found in the polar region and in the low-latitude region characterized by the higher gradients of the geomagnetic field at the East Siberian geomagnetic anomaly region. In other aspects this pattern resembles the geomagnetic field [5, 6] (Fig. 3b).

As is well known, a heterogeneous magnetoactive plasma is unstable to the so-called drift oscillations associated with the presence of gradients of its different

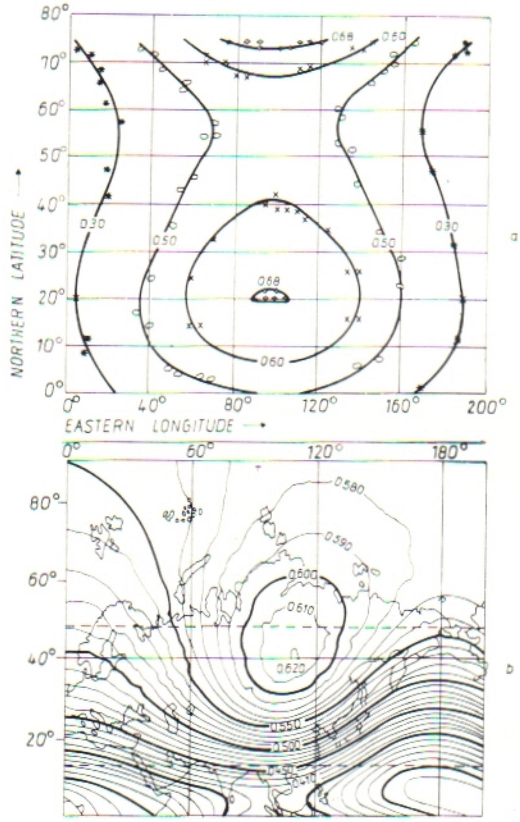

Fig. 3. a) Contour pattern for ion flux oscillation probability in geographic coordinates b) Part of chart of geomagnetic field intensity [5].

parameters: particle density, temperature, magnetic field, etc., causing the drift movement of charged particles. According to [7] these waves are unstable in the ionosphere at altitudes of more than 300—400 km and grow there. At lower altitudes the drift can result from the different collision frequency of ions and electrons with neutrals [8]. The wavelengths of such oscillations have dimensions across the magnetic field $\lambda_\perp \lesssim 100$ m and along the field $\lambda_\parallel \lesssim 10-100$ km, the
lation period is $T \lesssim 10^2-10^3$ sec. With such values of λ the above-mentioned
for the oscillation structure, corresponding to 20—30 km along the satel-
lite is in agreement if the angle of dip of the magnetic lines of force
is taken nt. It is simple to eliminate the apparent inconsistency between

such a large period of drift oscillations and the frequency of the oscillations measured if the Doppler effect is taken into account for the observer on board the satellite moving with the velocity $\boldsymbol{V}_\mathrm{t}$ relative to the medium in which there is a simple periodic wave:

$$f_\mathrm{obs} = \left| f - \frac{1}{2\pi} \boldsymbol{k}\boldsymbol{V}_\mathrm{t} \right| .$$

Here f_obs and f are the observed and true oscillation frequencies and $|\boldsymbol{k}| = 2\pi/\lambda$. With the different values of λ within the limits: $\lambda_\perp < \lambda < \lambda_{||}$, with all the possible values of the angle between $\boldsymbol{V}_\mathrm{t}$ and $\boldsymbol{k}$ and $|\boldsymbol{V}_\mathrm{t}| = 8 \times 10^5$ cm s^{-1}, $f_\mathrm{obs} \sim 0.001-100$ Hz. Such a frequency range is fully in agreement with that observed here.

Drifts essentially modify waves in the plasma. Even incompressible flow, e.g. an Alfvén wave which does not form density disturbances in a homogeneous plasma in the presence of density gradients disturbs the particle density [9]. These facts, and some others, apparently indicate the influence on the ion flux measured by the Cosmos 378 ion trap of drift waves possibly associated with the simultaneous presence of gradients of different plasma parameters: particle density, temperature, magnetic field, mean mass number, etc. [9, 10]. The effect of very low frequency acoustic oscillations with frequencies $f \ll (m_\mathrm{e}/m_\mathrm{i})^{1/2} \nu_\mathrm{i}$ might also be present, where ν_i is the frequency of collisions of ions with each other and m_e and m_i are the electron and ion masses. Their growth rate decreases markedly as their oscillation frequency falls [11].

In considering the dependence of the oscillation detection probability on indices of solar activity (SA) and geomagnetic activity (AE and Kp), positive correlations with indices AE (a measure of the auroral electrojet intensity) and SA were found. These can be explained by increasing gradient ion and electron drift velocities v_dr because of growing heat influx and increasing magnetic field gradients, e.g.:

$$\boldsymbol{v}_{\mathrm{dr},\nabla H,\mathrm{i}} = c \cdot \frac{m_\mathrm{i} v_\perp{}^2}{2eH^3} [\boldsymbol{H} \times \boldsymbol{\nabla} H]$$

where $\boldsymbol{v}_{\mathrm{dr},\nabla H,\mathrm{i}}$ is the velocity of the ion drift due to the magnetic field gradient $\boldsymbol{\nabla} H$, c is the velocity of light, e is charge of an ion, $v_\perp \sim (2kT_\mathrm{i}/m_\mathrm{i})^{1/2}$ is the component of the ion velocity perpendicular to the magnetic field, T_i is the ionic temperature, k is Boltzmann's constant and $\boldsymbol{H}$ is the magnetic field intensity. In the autumn-winter period of 1970 a positive correlation with Kp index was not found. This is possibly explained by the closer connection of these oscillations with substorm activity than with magnetic storm activity [12]. However, the data of 1971 show a positive correlation with the Kp index.

From the curve of the dependence on local time the tendency for the oscillation probability to increase towards afternoon is seen, with a maximum near about 16—20 LT. Its increase towards the polar regions is apparently associated with the ionospheric irregularities there [2] and the precipitation of auroral electrons [13].

Shorter periods of oscillation are more probable in the auroral region. This can be explained by the decreasing wavelengths of plasma oscillations, in accordance with the smaller scale of high-latitude irregularities [2] in comparison with low-latitude irregularities [3].

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