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# Geophysics

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Figure 1

Figure 1: Figure 1

## Abstract

## Full Text

*Geophysics*

V. G. Istomin

# NITROGEN IONS IN THE EARTH' S UPPER ATMOSPHERE AND NIGHTTIME IONIZATION IN THE *E* REGION

*(Presented by Academician E. K. Fedorov, 26 XII 1960)*

The existence of molecular nitrogen ions in the atmosphere, as one of the principal constituents of the ionosphere, has been postulated, explicitly or implicitly, by many authors. The main argument was the presence of emissions of the first negative band system of  $N_2^+$  ( $\lambda$  3914, 3884, 4278, and 4737 Å), especially strong in the spectra of the twilight sky and of auroras illuminated by the Sun. When the first direct (mass-spectrometric) analyses of the composition of the ionosphere were carried out <sup>(1,2)</sup>, it turned out that nitrogen ions were not detected in sufficient quantity.

**Fig. 1.** Distribution of positive ions of molecular and atomic nitrogen in the atmosphere according to direct mass-spectrometric measurements:

*a*—during the rocket launch of 2 VIII 1958;

*b*—on the third artificial Earth satellite, May 1958;

*v*—during the rocket launch of 15 VI 1960;

*g*—according to indirect data <sup>(11)</sup> (horizontal segments indicate the averaging interval over altitude)

Ions with mass number  $M = 28^+$ , identified with  $N_2^+$ , were detected in the daytime at altitudes of 225–500 km as a small ( $\sim 3\%$ ) component in measurements on the third artificial Earth satellite <sup>(3)</sup>. In still smaller quantities ( $\sim 1\%$ ), molecular nitrogen ions were recorded in daytime rocket measurements at altitudes of 100–230 km <sup>(2,4)</sup>. Researchers in the USA made no definite conclusions about the distribution of  $N_2^+$  ions with altitude.\*

Being a small, but by no means negligible, component of the ionosphere,  $N_2^+$  ions play an important role, in particular, in the processes determining the overall balance of ionization in the atmosphere. It is generally accepted that molecular ions in particular must largely determine the effective recombination coefficient in the *E*, *F*<sub>1</sub>, and *F*<sub>2</sub> regions of the ionosphere. Knowledge of the concentrations

Fig. 2. Mass spectra showing the existence of thin layers of positive  $N_2^+$  and  $Fe^+$  ions in the atmosphere, in the rocket launch of 2 VIII 1958 (high-sensitivity channel): *a*—ascending branch, *b*—descending branch.

Figure 2: Fig. 2. Mass spectra showing the existence of thin layers of positive  $N_2^+$  and  $Fe^+$  ions in the atmosphere, in the rocket launch of 2 VIII 1958 (high-sensitivity channel): *a*—ascending branch, *b*—descending branch.

of  $N_2^+$  and  $N^+$  ions and of their distribution with altitude has made it possible to draw more definite conclusions about the causes of ionization of molecular nitrogen <sup>(6)</sup> than had previously been available <sup>(7)</sup>.

In the present article the results are summarized of mass-spectrometric measurements on rockets and on the third satellite, carried out in 1958 and 1960,

\* From the published materials <sup>(2)</sup> it is evident that ions with  $M = 28^+$  were recorded almost at the sensitivity limit of the instrument, while the data obtained on the ascending and descending branches of the trajectory differed substantially from one another. The same applies to an even greater extent to ions with mass number  $M = 14^+$ , identified with atomic nitrogen ions  $N^+$ . The exception is the night launch of the rocket on 8 VII 1955 up to an altitude of 115 km, in which ions with  $M = 28^+$  proved to be the only ones recorded both on the ascending and descending branches of the trajectory <sup>(5)</sup>.

in the detection and measurement of the altitude distribution of molecular and atomic nitrogen ions. In the 1958 measurements a 7-5-cycle radio-frequency mass spectrometer RMS-1 was used <sup>(8)</sup>; the 1960 results were obtained with the more sensitive radio-frequency mass spectrometer MX-6403.

A detailed description of the experimental procedure and of some of the results can be found in papers <sup>(1, 3, 4, 8)</sup>. The measurements were carried out in a container separated from the rocket and not oriented. As a result, the maximum possible purity of the experiment was achieved, although the lack of orientation was in some respects a hindering factor. In the altitude region 100-160 km, where the speed of the container exceeded or was comparable with the average thermal speeds of the ions, the sensitivity of the mass spectrometer depended substantially on the orientation of the instrument's inlet aperture relative to the velocity vector.

**Fig. 2.** Mass spectra showing the existence of thin layers of positive  $N_2^+$  and  $Fe^+$  ions in the atmosphere, in the rocket launch of 2 VIII 1958 (high-sensitivity channel): *a*—ascending branch, *b*—descending branch.

For this reason, at altitudes of 100-120 km, where there are thin layers of  $Mg^+$ ,  $Ca^+$  <sup>(9)</sup>, and  $Fe^+$  ions, uncharacteristic of a nitrogen-oxygen atmosphere, and where, as will be shown below,  $N_2^+$  ions were detected, measurements were not always possible, since the orientation of the container was not necessarily optimal. The detection of a thin layer of  $N_2^+$  ions was also made difficult by

the comparatively long mass-scan period\* and, in some cases, by the insufficient sensitivity of the instruments. For the reasons indicated, only a comparison of the results of two rocket experiments (2 VIII 1958 and 15 VI 1960) and data from the third satellite (May 1958) made it possible to draw definite conclusions about the distribution of  $N_2^+$  ions in the atmosphere.

\* For the RMS-1 the mass-scan period was 1.7 sec, which corresponded to a change in altitude  $\Delta H = 2$  km; for the MX-6403 the scan period was 3 sec,  $\Delta H = 4$  km.

In the processing, the following assumptions were made: 1) the sum of the concentrations of positive ions is equal to the electron concentration, i.e., negative ions are absent:  $\Sigma[M^+] = n_e$ ; 2) the sum of the amplitudes of the ionic peaks in the mass spectrum is proportional to the total concentration of positive ions:  $\Sigma i_{M^+} = k\Sigma[M^+]$ ; 3) the ratio of the amplitudes of the ionic peaks in the spectrum is equal to the ratio of the concentrations of the corresponding ions in the atmosphere:  $i_{M_1^+}/i_{M_2^+} = [M_1^+]/[M_2^+]$ . The absolute concentration of an ion with mass number  $M_1^+$  was thus found from the relation  $[M_1^+] = i_{M_1^+}n_e/\Sigma i_{M^+}$ .

The values of the electron concentration were taken from profiles obtained by the ultrashort-wave radio-interferometer method on 27 VIII 1958 (10), under similar conditions, and on 15 VI 1960—on the same rocket.

Fig. 1 shows the absolute concentrations of the ions  $N_2^+$  and  $N^+$  as functions of altitude. The measured values of the concentration of  $N_2^+$  agree satisfactorily with those determined from absolute photometry data for the emission  $\lambda 3914 \text{ \AA}$  in sunlit aurorae (11).

There is one interesting feature in the distribution of  $N_2^+$  ions that distinguishes them from the other ions characteristic of the nitrogen-oxygen atmosphere of the Earth ( $NO^+$ ,  $O_2^+$ ,  $O^+$ ,  $N^+$ ). In the  $E$  region, at altitudes of 100–120 km, there is a second, much thinner layer of  $N_2^+$  ions with the same concentration (of the order of  $10^4 \text{ cm}^{-3}$ ) as their principal maximum in the  $F$  region. The reality of the existence of such layers is demonstrated by Figs. 2 and 3.

**Fig. 3.** Same as Fig. 2 in the rocket launch of 15 VI 1960 (channels of medium and high sensitivity, only the ascending branch of the trajectory)

The question of the causes of ionization of molecular nitrogen in the terrestrial atmosphere has not yet been definitively resolved. In light of the considerations set forth in (7), and taking into account new data on the absorption of the He II line  $\lambda 304 \text{ \AA}$  (12), according to which this radiation, capable of ionizing the nitrogen molecule, is absorbed in the altitude range from 210 km (optical thickness  $\tau = 0.1$ ) to 150 km ( $\tau = 1$ ), the arguments of A. D. appear convincing.

Danilov, who explains the ionization of molecular nitrogen by a charge-transfer reaction with atomic nitrogen ions:  $N_2 + N^+ \rightarrow N_2^+ + N^*$  (6). This, of course, must be valid for the region of heights of 250 km and above. At the same time, it is obvious that the appearance of  $N_2^+$  ions in the  $E$  region at heights of 100–

120 km cannot be attributed either to direct photoionization of  $N_2$  (there are no quanta of the corresponding radiation) or to the charge-transfer reaction (there are no  $N^+$  ions).

Thus, the appearance of ions of a difficult-to-ionize atmospheric component—molecular nitrogen—in the  $E$  region indicates certain other ionization processes not connected with solar radiation. The key to understanding the nature of these processes and the nature of the ionizing agent is the ionic composition recorded at the given heights. As can be seen from Fig. 2, in the mass spectra of 2 VIII 1958, together with  $N_2^+$  ions, ions with  $M = 56^+$  are recorded, which should be identified with iron ions  $Fe^+$ . Their maximum concentration is of the same order as that for  $N_2^+$  and is  $1.2 \cdot 10^4 \text{ cm}^{-3}$  at heights of 103–105 km. In the launch of 15 VI 1960, at the same heights, magnesium ions  $Mg^+$  and calcium ions  $Ca^+$  were found, with a concentration ratio close to the ratio of the number of atoms of the named elements in meteorites (9), which was an argument in favor of the meteoric hypothesis of their origin. The maximum concentration of  $Mg^+$  ions was  $1.4 \cdot 10^4 \text{ cm}^{-3}$  at a height of 104 km. From Fig. 3 it is seen that in this same launch, at a height of 120 km,  $N_2^+$  ions also appear together with  $Mg^+$  ions. The heights at which the ions  $Mg^+$ ,  $N_2^+$ ,  $Ca^+$ , and  $Fe^+$ , “uncharacteristic” of this atmospheric region, appear are specific to meteoric phenomena. In the region 100–120 km, the smallest meteoric particles, according to current concepts, lose their cosmic velocities and evaporate completely or partially (and therefore make the maximum contribution both from the point of view of energy and from the point of view of the quantity of matter introduced into the atmosphere) (13).

It follows from what has been said that the observed ionization of  $N_2^*$  in the region 100–120 km, at least at middle latitudes\*\*, can be explained by meteoric activity—ionization of the atmosphere by rapidly flying evaporated atoms of meteoric matter. Along with this, ionization also occurs of the evaporated atoms  $Mg$ ,  $Ca$ , and  $Fe$  of the meteoric matter itself during their interaction with atmospheric molecules. It is obvious that the nighttime ionization in the  $E$  region as a whole can be explained by meteoric activity, since the electron concentration there at night is  $\sim 10^4 \text{ cm}^{-3}$  (14), which agrees in order of magnitude with the recorded ionic concentrations.

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## CITED LITERATURE

1. V. G. Istomin, *Collection: Artificial Earth Satellites*, issue 2, Publishing House of the Academy of Sciences of the USSR, 1958, p. 32.
2. C. Y. Johnson et al., *Ann. de Geophys.*, **14**, No. 4, 475 (1958).

3. V. G. Istomin, *DAN*, **129**, No. 1, 81 (1959).
4. V. G. Istomin, *Collection: Artificial Earth Satellites*, issue 7, Publishing House of the Academy of Sciences of the USSR, 1961.
5. C. Y. Johnson, J. P. Heppner, *J. Geophys. Res.*, **60**, 533 (1955).
6. A. D. Danilov, *DAN*, **137**, No. 5 (1961); *Collection: Artificial Earth Satellites*, issue 7, 1961.
7. J. W. Chamberlain, C. Sagan, *Planet. Space Sci.*, **2**, No. 2-3, 157 (1960).
8. V. G. Istomin, *Collection: Artificial Earth Satellites*, issue 3, 1959, p. 98.
9. V. G. Istomin, *DAN*, **136**, No. 5 (1961).
10. K. I. Gringauz, V. A. Rudakov, *DAN*, **132**, No. 6 (1960).
11. M. H. Rees, *J. Atm. Terr. Phys.*, **14**, 338 (1959).
12. H. E. Hinteregger et al., KOSPAR, Nice, 1960.
13. B. Yu. Levin, *Physical Theory of Meteors and Meteoric Matter in the Solar System*, Publishing House of the Academy of Sciences of the USSR, 1956; B. A. Mirtov, *Collection: Artificial Earth Satellites*, issue 4, 1960, p. 118.
14. S. K. Mitra, *The Upper Atmosphere*, IL, 1955.

\* The mass  $M = 28^+$  may, in addition, be identified with  $Fe^{2+}$  or  $Si^+$ , which does not contradict the proposed hypothesis.

\*\* In paper (5) there is an indication of the presence of a relatively large quantity of ions with  $M = 28^+$  at a height of 105 km, recorded by a mass spectrometer in a nighttime rocket launch in the Arctic during an aurora.

*Note: Figure translations are in progress. See original paper for figures.*

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