

Analysis of the Results of Mass-Spectrometric and Probe Measurements Carried Out on Intercosmos-12

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Introduction

Intercosmos-12 satellite was launched on October 31, 1974 with parameters: apogee — 718 km, perigee — 250 km, inclination — 74° . The main purpose of the experiment was to elaborate a measurement technique for charged particle density and ion mass composition of the ionospheric plasma. For that purpose, a mass-spectrometer and a set of probes for density and temperature measurements were mounted on board. That provided the possibility of comparing measurement results on ion composition between the mass-spectrometer and ion traps; on charged particle density between ion traps, Langmuir probe and radio-frequency capacity probe, and on the satellite potential-between all the instruments given above.

Unfortunately, because of technical reasons, both the ion traps and the Langmuir probe operated alternatively to the radio-frequency capacity probe.

This paper gives brief description on part of the above instruments and on some of the scientific problems which could be investigated by them.

The result processing is only in its initial phase, therefore here we would just compare results from mass-spectrometric measurements of ion composition to ion composition data obtained by simultaneous (or comparable) ion trap measurements. Such a comparison is important for the adjustment of the measurement results. Ion traps could give error in measurement of the main ion components (H^+ and O^+) because of small quantities of other ion components. On the other hand, the mass-spectrometer gives correct data only in a relatively small range of "attack angles", and the poor knowledge on the satellite orientation does not permit yet to obtain precise values both for absolute and for relative ion component densities.

Equipment

The radio-frequency mass-spectrometer was designed for measuring the ion composition as well as for elaboration of a measurement technique of neutral composition in upper terrestrial atmosphere. The radio-frequency mass-spectrometer (USSR and Czechoslovakia) and the calibrator (Romania) were mounted on independent waterproof container with inner temperature and pressure control.

The calibrator was designed for the flight calibration of the mass-spectrometer in the measurement regime of neutral composition [1]. The calibrator originates a calibration flux of molecular hydrogen at the input of the mass-spectrometer. The principle of hydrogen diffusion through a thin wall of stainless steel at constant temperature is used.

The analyser A-2 of the MH-6407 P 2 equipment was used as sensor of the mass-spectrometer. The electronic device is more refined than that of MH-6407P and has the following specifics: resonant ions penetrating the collector are modulated in the section of the radio-frequency grids, which are supplied with amplitude-modulated high-frequency voltage. An a. c. amplifier with synchronous detector at the input effects the automatic scale selection dependent on the input signal voltage.

In all there are four scales with amplifying coefficient ratios of 1:10:100:1000. In real time telemetry regime the mass-numbers are measured in three subranges — 1-4 a. m. u.; 4-20 a. m. u.; 16-60 a. m. u. The recovery of these sectors provides a possibility for more precise discrimination within the accelerating potential in each of the sectors by the mutual control of the measurements at both ends of the subrange. In memory regime there are considerably narrower sectors of the range: about 1 a. m. u., about 4 a. m. u. and 14-18 a. m. u. The most important parameters — the frequency of the supplied voltage, its amplitude with respect to the retarding potential, the emission current of the ion source and some others become stable.

The Bulgarian-Soviet experiment of measuring positive ion density and electron density and temperature was performed with the help of three-electrode spherical traps and Langmuir probe. Detailed equipment description has been given in [3].

In order to measure the electron density and the so-called "floating potential", a radio-frequency capacity probe was mounted on board, designed and made in the GDR [4]. This instrument measured the reactive impedance of a flat capacitor, immersed into the ionospheric plasma at a frequency of 10 MHz. The capacitor is a system of two disk grids 100 mm in diameter, fixed at 50 mm distance one from the other.

Results and Discussion

The volt-ampere characteristic of the spherical traps shows, as a rule, the availability of two ion components in ionospheric plasma at multiple orbital sectors (Fig. 1).

The analysis results for the case repetition frequency at a given difference of these components mass-numbers have shown that the maximal frequency of appearance of mass-numbers difference is about $M=14 \div 15$, which suggested that these components have to be considered as hydrogen ions (H^+ , $M=1$) and oxygen ions (O^+ , $M=16$). Based on that, the volt-ampere characteristic was effected under the consideration of the availability of these two ion species [5, 6].

On mass-spectrometric data, the information of reproduction seances Nos. 33, 77 and 78 (orbit 32, 76 and 77) was processed, as well as the direct emission of the 185th orbit for the following intervals: altitude — 500-710 km, geomagnetic latitude — $\pm 50^\circ$, local time — 20:30-22:30.

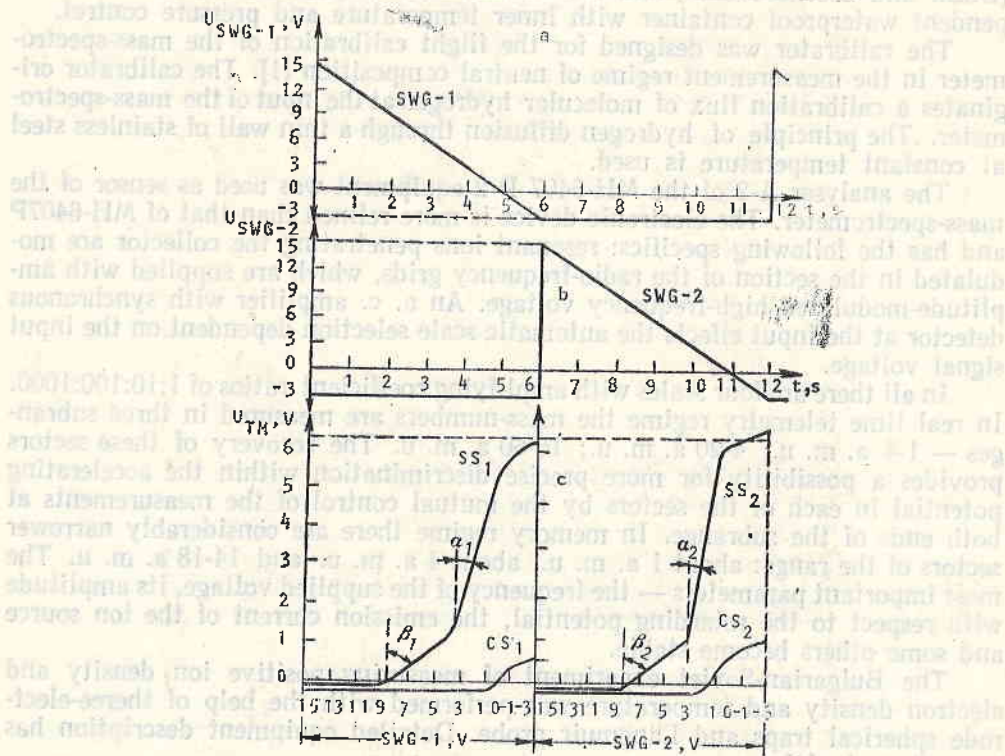


Fig. 1. Intercosmos-12: 34 orbit: $H=579$ km, $\Phi=+14.5^\circ$, $L=1.14$, $\Delta=19^\circ$, LT=21.37 h, $\lambda=134.5^\circ$

Table 1

Height, km	Geomagnetic latitude, deg.	Local time, hour min	Orbit	Mass spectrometer	Ion trap
711	-32	22 23	77	0.5-0.1	-
712	-29	22 27	76	0.5-0.1	0.2
711	-34		34		0.5
688	- 8	21 58	76	1-0.1	0.15
693	-21	22 41	32	1-0.1	
688	-13	21 57	77	1-0.2	
			34		0.4
638	11	21 34	76	2-0.4	0.72
553	34	20 58	76	2-0.4	0.72
560	20	21 30	34		2.0

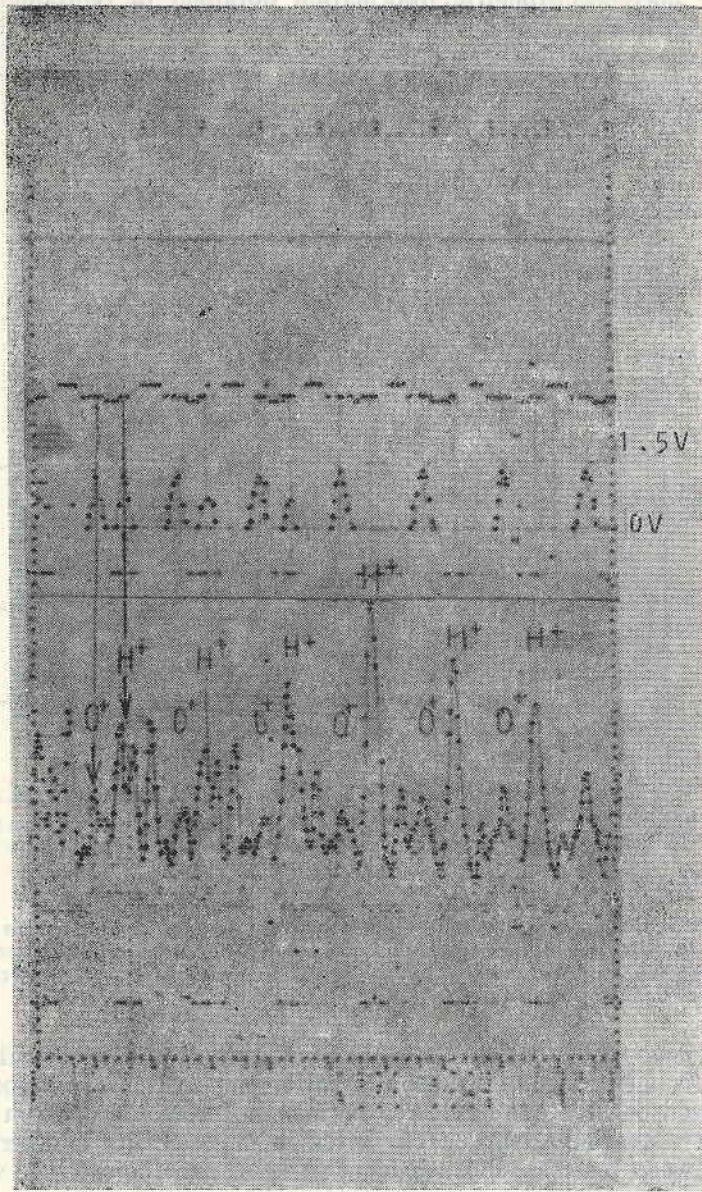


Fig. 2. Type of information obtained by mass spectrometer on board the Intercosmos-12 satellite. Data acquisition regime 77. SV — scanning voltage. The shape of the peaks determines the range of the mass (H^+ or O^+). IS — indication of sensitivity. The parameter is equal to: 0 volts at mass peaks below 6 V; 1.5 V — $<6 \times 10^3$ V; 3V — $<6 \times 10^3$ V, 4.5 V — $<6 \times 10^3$ V. The SI impulses are distorted (real shape is rectangle) due to the small transmission band of the telemetry storage device. MS — mass spectrum. The measured peaks corresponding to the H^+ and O^+ ions are designated. The rest — peaks of the ions subject to registration during the reverse course of scanning and limited by the amplifier at the automatic switching of its dial

The mass-spectrometric information obtained in reproduction seance No. 77 is given in Fig. 2. The selection of the processed material was determined by the volume of spherical trap data processed by now (orbits 34, 76 and 185). The results compared between mass-spectrometric and spherical trap data are given in Table 1 and Fig. 3.

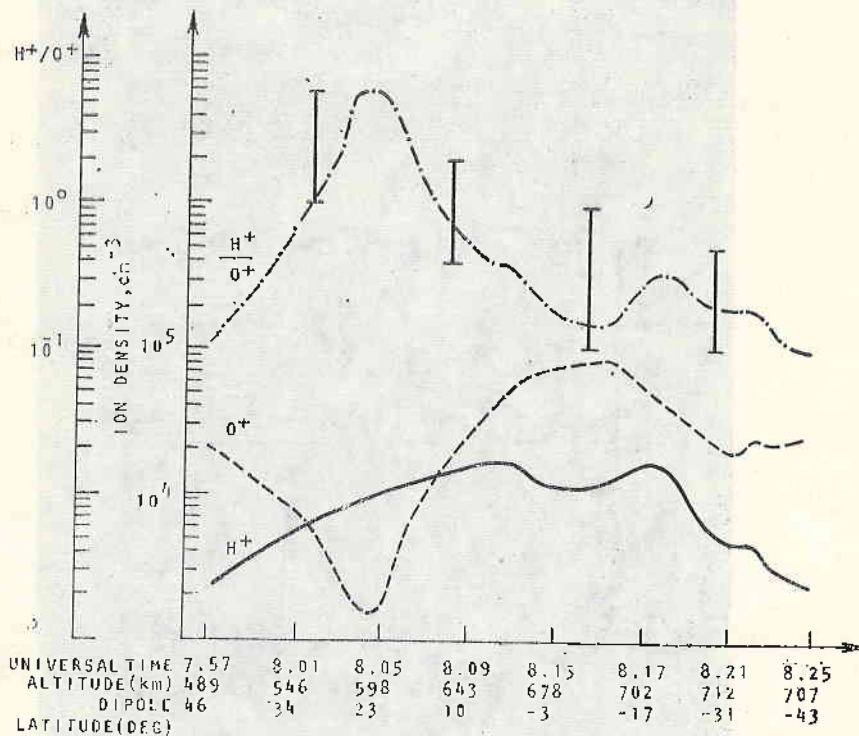


Fig. 3. Data about the ion composition obtained by traps and mass spectrometer in data acquisition regime 77 on the Intercosmos-12 artificial satellite. Traps, absolute ion concentration (solid and dashed lines). Traps, components ratio (dashed-dotted line)

The mass-spectrometric data have determined the ion density ratio $n [H^+]/n [O^+]$. As mentioned, the absolute calibration of mass-spectrometric data by the electron density was hampered because no processed data on satellite orientation were available, and that resulted in impossibility to determine the angle value between the mass-spectrometric analyzer and the satellite velocity vector. Because of that, the ratio $n [H^+]/n [O^+]$ is given with error bars for the minimum angle of attack (evidently exceeding 0°). In order to evaluate these error bars the "angle characteristics" of O^+ and H^+ obtained for the analogous experiment Oreol-2 [7] have been used. The minimum attack angles were obviously located within the limits of $30-60^\circ$.

Certain indeterminateness of the ratio of ion densities, determined in memory regime, is introduced by the electronics specificity (the dynamic range of the equipment was not fully realized). In real time telemetry regime the picture was more positive, providing the fact that the results along the 185th orbit were from this disadvantage. Data on ion composition, obtained at the 185th orbit, were used for the specification of the minimum attack angle as well as the den-

sity ratio $n[H^+]/n[O^+]$. These specifications were effected with the help of data on the absolute density values of O^+ and H^+ by trap data. As already mentioned, the processing of trap data was carried out under the assumption of only two ion species being available. Nevertheless, the recording of He^+ by the mass-spectrometer and the data obtained on the relative He^+ density with respect to O^+ have permitted the correction of the results for the absolute ion density measured by the traps. At the 185th orbit on mass-spectrometric data, at minimum attack angles (maximum current for O^+), $n[H^+]/n[O^+]=0.9$. And on trap data, considering He^+ , the same ratio is $5 \div 7$. (The interval is determined by the maximum scatter of the experimental points on trap data.) The discrepancy with the mass-spectrometric data from 6 to 8 times could obviously be explained with the discrimination of ions by the inlet angle, as the real attack angle is different from 0° . In order to explain such a discrepancy, we have to consider the value of the real attack angle being equal to $50-55^\circ$ (by the angle characteristics used in [7]). The O^+ current reduced to 0° is of the order of $(4.8-6.6) \times 10^{-11}$ a, which corresponds to $(1.4-1.6) \times 10^4$ cm^{-3} by trap data. Therefore, the sensitivity of the mass-spectrometer with respect to O^+ ranges between 3 and 4×10^{-15} A. cm^{-3} .

Thus the value of the "angle characteristics" of the mass-spectrometer, together with the absolute ion density values obtained by the trap data, made it possible to effect absolute mass-spectrometric calibration by O^+ ions at definite orbital sectors. That gave the possibility to obtain rectified values of the ion density ratio H^+/O^+ at some of the other orbital sectors, by mass-spectrometric data (with no knowledge on the instrument tube orientation with respect to the satellite velocity vector) using only O^+ absolute density values obtained by the trap measurements.

Conclusion

As seen in Fig. 3 and Table 1, the nature of the relative H^+ density changes with respect to O^+ obtained by mass-spectrometric data agrees sufficiently with the probe measurements. The values of this ratio, measured by the traps, is within the limits of the interval determined by the mass-spectrometer.

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Анализ результатов масс-спектрометрических и зондовых измерений, проведенных на спутнике „Интеркосмос-12“

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(Резюме)

Спутник „Интеркосмос“ был выведен на орбиту 31 октября 1974 г. Параметры орбиты спутника: высота апогея 718 км, высота перигея 250 км, наклонение орбиты 74° . Основной задачей эксперимента была обработка методики измерений концентраций заряженных частиц и массового состава ионов в ионосферной плазме. С этой целью на спутнике была установлена масс-спектрометрическая аппаратура и комплекс зондов для измерения концентраций и температуры заряженных частиц. Благодаря этому оказалось возможным провести сравнение результатов измерений состава ионов, полученных с помощью масс-спектрометра и ионных ловушек, а также зонда Лэнгмюра и радиочастотного емкостного зонда, и потенциала спутника — посредством всех перечисленных приборов.

Conclusion

As seen in Fig. 3 and Table 1, the nature of the relative H^+ density changes with respect to O^+ obtained by mass-spectrometric data agrees satisfactorily with the probe measurements. The value of this ratio, measured by the probe, is within the limits of the interval determined by the mass-spectrometric.

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