ACADEMY OF SCIENCES OF THE USSR

Preprint

# ABSORPTION OF ULTRAVIOLET SOLAR RADIATION IN THE UPPER ATMOSPHERE NEAR THE MAIN IONIZATION MAXIMUM ACCORDING TO MEASUREMENTS OF PHOTOEMISSION BY MEANS OF AN EARTH'S SATELLITE

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To be presented at the VII-th International Space Science Symposium in Vienna in May 1966

**MOSCOW**

# Absorption of Ultraviolet Solar Radiation in the Upper Atmosphere Near the Main Ionization Maximum According to Measurements of Photoemission by Means of an Earth's Satellite

by B.N.Gorozhankin, K.I.Gringauz, N.M.Shutte

The bulk of experiments aboard the Cosmos 2 satellite (1962) were devoted to investigations of the electron and ionic components of ionospheric plasma [1, 2, 3]. The present communication summarizes the results of determining integral absorption of solar short-wave radiation near the main ionization maximum from this satellite. Absorption of solar radiation was determined from measurements of photoelectron currents emitted by planar metallic photocathodes of three photoelectron analyzers. To study the distribution of photoelectrons by velocity components normal to the surfaces of the photocathodes a method of retarding potentials was used in a way similar to [4]. In the present paper the use was made only of data referring to the values of saturation photocurrents, that is, currents corresponding to the zero values of retarding potentials or to positive potentials.

The photoelectron analyzers were mounted on the satellite surface in such a way that normals to the photocathodes constituted three mutually perpendicular directions. Let us remind that the satellite was not oriented and had the orbit inclined to the equatorial plane at the angle of $\sim 49$ degrees, with apogee of $\sim 1550$ km and perigee of $\sim 212$ km.

Since the magnitude of photocurrent is proportional to the intensity of radiation by which it is caused, one can use the values of photocurrents for determining absorption of solar radiation. Measurements of photocurrents on the satellite were performed in the altitude range from $\sim 550$ km to $\sim 220$ km. Since photoemission of electrons from the surface of metals can be caused by electromagnetic waves with wavelengths $\lambda \leq \lambda_0 \cong 2000$ Å, the absorption coefficients given below characterize integral absorption of the extire portion of the solar radiation spectrum with $\lambda \leq \lambda_0$.

Apparently saturation photocurrents varied primarily due to changes of orientation of each analyzer with respect to the Sun. The minimal rotation period of the Cosmos 2 satellite [3] was approximately two minutes while the period of analyzing voltage variations was $\sim 1$ sec. Hence the change of satellite's orientation during one period of voltage variation did not influence the measured magnitude of saturation current. As far asthere were three analyzers situated as mentioned above, at some dependences of photoemission current on the incidence angle of solar radiation onto the photocathode one can determine without knowing these angles the magnitude of photocurrent corresponding to normal incidence of radiation onto the photocathode for those time instants when currents in all three analyzers differ from zero.

The determination of angular dependence of photocurrent under laboratory conditions is difficult due to complexity of obtaining wide parallel bunches of ultraviolet radiation similar to those which give rise to the photoemission of electrons under actual conditions. Therefore dependence of the analyzer's photocurrent on the radiation incidence angle $\varphi$ was obtained with accuracy up to a few degrees on the basis of studies of saturation currents variations at the portion of one of the satellite's orbits (see Fig.1). In this time interval the satellite's rotation was such that for a great period of time one of the analyzers was near the boundary of the satellite's optical shadow while illumination intervals of the two others were almost equal and corresponded to the analyzer's angular aperture. Thus it was possible to assume that the maximal values of photocurrents of the two analyzers took place at the moments of coincidence of the normals to their photocathodes with the direction of the Sun. The dependence of the analyzer's saturation photocurrent on the incidence angle of solar radiation found by help of Fig.1 is shown in Fig.2. For the sake of comparison, values of $\cos\varphi$ and $\cos^2\varphi$ are also given in Fig.2. It is seen from the graph that for $\varphi < 50^\circ$ the obtained dependence can be approximated by the $\cos\varphi$ function and for $\varphi > 50^\circ$ by the $\cos^2\varphi$ function. The approximation of this dependence to the $\cos^2\varphi$ function at $\varphi > 50^\circ$ is due to the fact that at $\varphi > 50^\circ$ the sunlit photoemitter's area begins to decrease owing to the design peculiarities of the analyzer.

Since for $\varphi < 77^{\circ}$ we have $\cos^2\varphi < f(\varphi) < \cos\varphi$ and for $\varphi > 77^{\circ}$ we have $f(\varphi) < \cos^2\varphi$, then taking into account these inequalities the dependence $\cos^2\varphi$ was chosen as an approximating function. Following from this, estimate was made of the values of saturation photocurrents $I_{sn}$ corresponding to normal incidence of solar radiation orto the photocathode. For comparison similar calculations were performed using the dependence $\cos\varphi$ as an approximating function. The spread of the $I_{sn}$ values obtained turned out to be greater than in the first case. Besides, in some cases, photocurrent of one of the sensors exceeded the calculated value $I_{sn}$ from the data of three sensors. Therefore processing was performed for the approximating $\cos^2\varphi$ function.

Thus for the instants when all three analyzers were illuminated (and this occurred often enough) there was an opportunity of restoring the values of saturation photocurrents corresponding to normal incidence of solar radiation onto the photocathode. It should be noted that materials of the photocathodes of the analyzers were different (two of them were made of platinum and the third one of nickel). However, since the quantum yield of these metals in the far ultraviolet region is approximately equal [5], comparison of photocurrents of three such analyzers is quite justifiable. The values of photocurrents given in Fig.1 correspond to two different photocathodes ( No.1 - Ni , No.2 and No.3 - Pt ). As is evident, photoemission of analyzers No.1 and No.2 was practically identical. Fig. 3 gives changes in $I_{sn}$ values at the portion of the satellite's orbit on April 8, 1962, at which the altitude varied from 220 km to 500 km. Similar dependences were obtained on other days too.

The decrease in photocurrent $I_{sn}$ with the satellite's plunging into the depth of the ionosphere, that is, with the decrease of height over the Earth, is apparently due to absorption of solar radiation causing photoemission of electrons. However, it should be taken into account that, simultaneously with the decrease of the satellite's height above the Earth, the Sun's elevation over the satellite's horizon also varied. Due to this, the observed change in photoemission to a considerable extent was caused by the increase of the distance $l$ passed by solar radiation in the atmosphere as the satellite plunged into the lower layers of the atmosphere. The $l$ value counted from the maximal height $h_{max}$ of the satellite over the Earth at the orbit portion being considered* (see Fig.4) was determined from the known orbital data as

$$l = -\sin\alpha_{\odot}\left(R_E + h_{max}\right) + \sqrt{\left(R_E + h_{max}\right)^2 + \left(R_E + h\right)^2 \cos^2\alpha_{\odot}} \; ,$$

where $\alpha_{\odot}$ - the Sun's elevation angle over the satellite's horizon,

$R_E$ - the Earth's radius,

$h$ - the current height of the satellite over the Earth.

Due to the fact that beginning from $h$ =290 km $\alpha_{\odot}$ acquires negative values (this means that at lower heights solar radiation passes some height range twice), analysis of the change in solar radiation absorption was limited to altitudes from 300 to 500 km. If one ignores the geographic and diurnal variations of the upper atmospheric density in the height range under consideration, that is, if one supposes that inside each of sufficiently thin spheric concentric layers into which the atmospheric region under consideration can be stratified, the ability of absorbing solar radiation during the passage of the corresponding height interval by the satellite remains invariable, and if one regards absorption above the height range under consideration as being absent, an opportunity appears to determine the height variation of the absorption coefficient of short-wave solar radiation out of available experimental data presented in Fig.3.

If one uses this supposition, then for each homogeneous spheric layer with thickness $\Delta h_i$ the relation

$$dI = -\varkappa_i I d\ell \qquad \text{or} \qquad \ln\frac{I}{I_0} = -\varkappa_i \ell_i$$

is valid, that is,

$$\varkappa_i = \frac{1}{\ell_i} \ln\frac{I_0}{I},$$

where $\varkappa_i$ - the absorption coefficient,

$I_0$ - photocurrent at the height $h_i + \Delta h_i$,

$I$ - photocurrent at the height $h_i$,

$\ell_i$ - the length of the ray passing in the layer $\Delta h_i$ thick.

To calculate the dependence $\varkappa(h)$ the $\Delta h_i$ value was taken equal to 10 km. The $\ell_i$ value was determined as

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$$l_i = \csc\alpha_{\odot i+1}\left[R_E + h_i + \Delta h_i - (R_E + h_i)\cos(\alpha_{\odot i+1} - \alpha_{\odot i})\right],$$

where $\alpha_{\odot i+1}$ – the Sun's elevation angle for a given ray at the height $h_i + \Delta h_i$ , $\alpha_{\odot i}$ is the same at the height $h_i$ ,

$$\cos\alpha_{\odot i} = \frac{R_E + h}{R_E + h_i}\cos\alpha_{\odot} .$$

The found dependence $\varkappa(h)$ is presented in Fig. 5 and corresponds to a change of the satellite's latitude from $\sim 38^{\circ}$ to $\sim 48^{\circ}$ Northern Latitude and of local time from $\sim 16$ hours to $\sim 18$ hours. Such small latitudinal variations cannot introduce essential changes into the height variations of the $\varkappa$ value. The changes of local time could give rise only to somewhat underestimated $\varkappa$ values at lower heights, because, as it has been shown in [8], the density of neutral particles at heights under consideration could decrease during the time interval from 16 hours to 18 hours by a ratio $\sim 1,5$. Using the known values of neutral particle concentration in the height range from 300 to 500 km (see [7] ) one can conclude that average cross-section of absorption of radiation with $\lambda < 2000$ Å at these altitudes varies little and amounts to $\sim (0,5 \div 2,0)\cdot 10^{-17}$ cm$^2$.

Thus, from the data about variations of photoemission of electrons from metallic surfaces along the portion of the satellite's orbit corresponding to heights from 300 to 500 km the height variation of the integral absorption coefficient of short-wave solar radiation have been computed. The experiment has demonstrated that although at these altitudes the absorption coefficient is not high, at oblique incidence of solar rays (for instance, near sunset or sunrise) solar radiation attenuation near the main ionization maximum is very considerable. The estimate of absorption average cross-section is close to the value of cross-section of solar radiation absorption by atomic oxygen for the wavelength range from 1000 to 200 Å [8]. Since the height range from 300 to 500 km can be considered as a region of dominating photochemical processes [9], one can suppose that solar radiation absorption observed is caused to a considerable extent by photoionization of atomic oxygen.

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## Figure Captions

Fig. 1 Variations of photocurrents at the portion of one of the satellite's orbits.

Fig. 2 Angular dependence of photocurrent $f(\varphi)$.

Fig. 3 Saturation photocurrents at the portion of the satellite's orbit on April 8, 1962.

Fig. 4 Scheme of motion of the Cosmos 2 satellite.

Position 1: $h = 500$ km,
- " - 2: $h = 300$ km,
- " - 3: $h < 300$ km.

Fig. 5 Height variation of the absorption coefficient $\varkappa(h)$ .

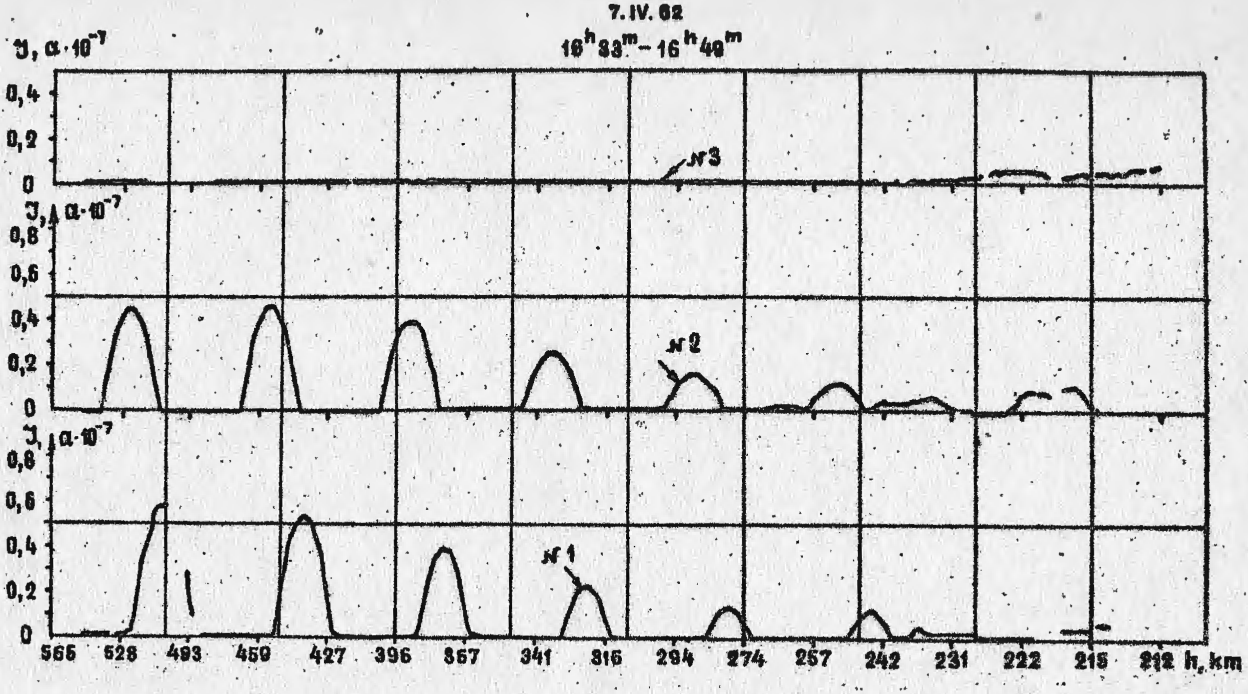
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Fig. 1

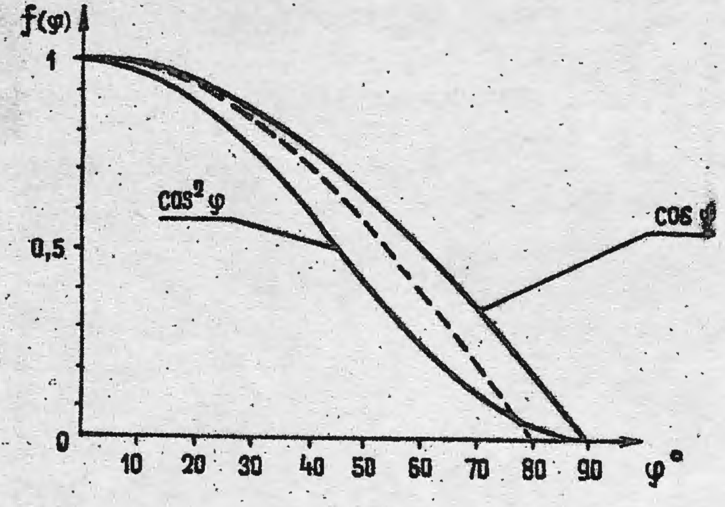

Fig. 2

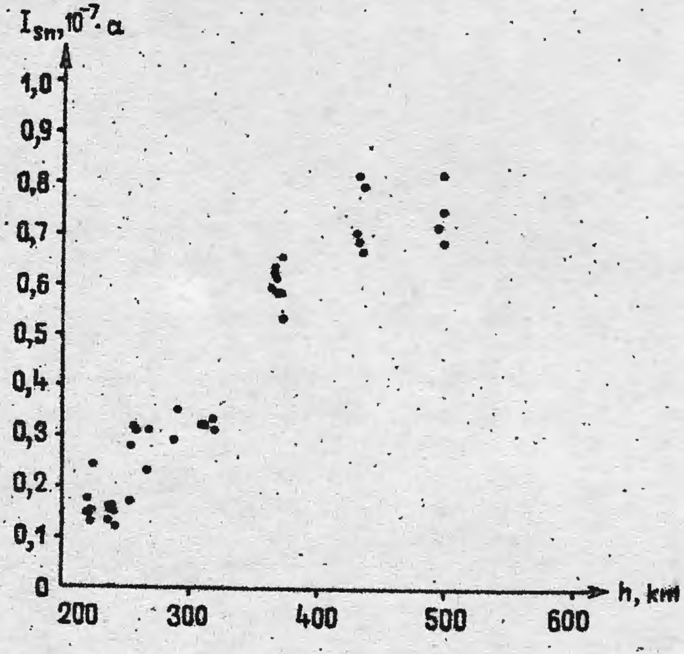

Fig. 3

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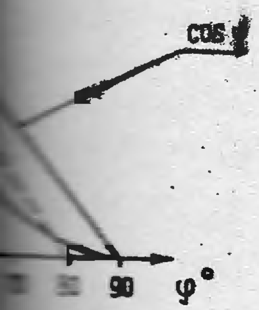

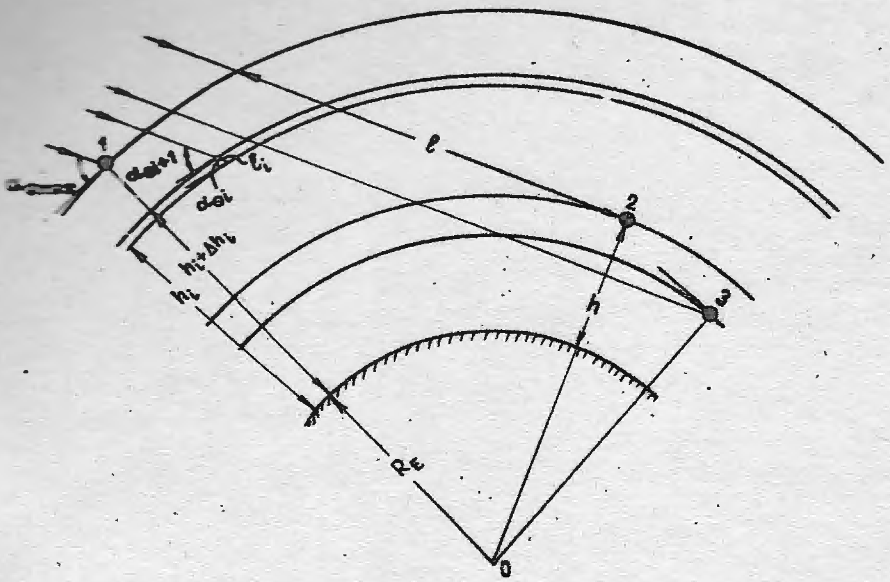

Fig.4

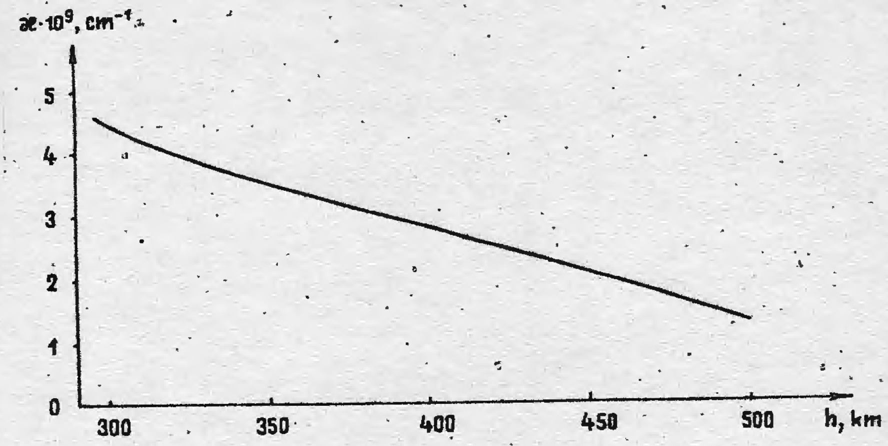

Fig.5

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