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MEASUREMENT OF SCATTERED L_{α}-EMISSION OF THE SUN IN THE UPPER ATMOSPHERE OF THE EARTH FROM 1000 to 3500 KM

by

E.K. Sheffer

(USSR)

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SUMMARY

Presented in this paper are the results of measurements of the scattered L_α-emission of the Sun in the upper atmosphere of the Earth at altitudes from 1000 to 3500 km during the flight of the spacecraft "VERTICAL SPACE PROBE" in October 1967. An empiric model is constructed for the distribution of neutral hydrogen at these altitudes.

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The spacecraft named "VERTIKAL'NYY KOSMICHESKIY ZOND" or "VERTICAL SPACE PROBE" was launched on 12 October 1967. During its flight a great complex of measurements of the ionospheric parameters and of the upper layers of the atmosphere were conducted, as well as the measurement of the scattered ultraviolet emission of the Sun in the upper atmosphere of the Earth. The launching was accomplished during the evening hours with the Sun's height at about 8° above the horizon.

For the measurement of the ultraviolet emission, the apparatus described in [1] was used. Photon counters of the type SFM-1 filled with NO and provided with the LiF windows, were used as emission detectors. A CaF_2 crystal was placed in front of the window of one of these counters, which did not let the L_α-emission pass through. This counter could register the emission of the atomic hydrogen in λ1300 Å. The curves of spectral sensitivity of such counters are presented in the work [2]. The counters were screened with lead of 3 mm thickness. The characteristics of the counters and some parameters of the apparatus are shown in the table below

Counter Window	Effectiveness	Complementary Filters	Geometrical Factor $cm^2 \cdot$sterad
LiF	λ 1216 Å, 10%	Grid with 9% transmission	$1.2 \cdot 10^{-4}$
LiF+CaF_2	λ 1300 Å, 2%	Grid with 30% transmission	$1.2 \cdot 10^{-4}$

For the measurement of the pulse counting rate a logarithmic intensimeter with a range of 20-2000 pulses/sec was used.

After being placed in the assigned trajectory, the spacecraft was oriented in the outer space with great precision along three axes. The instrument was set on the spacecraft's shady side, and its optical axis was directed at zenith. It was switched on at the 1000 km altitude, and functioned normally up to the 3500 km altitude. As a result of well taken precautions, by the time the instrument was switched on, the spacecraft's gas escape became insignificant and did not practically affect the measurements.

Presented in Fig. 1, are the instrument's readings with the counters sensitive to the L_α-emission. The transition from the almost continuous level of intensity to the decrease of emission intensity with the flight altitude is well noticeable. Shown in Fig.2, are the readings of the counter with the CaF_2 filter. The signal of this counter was absent till reaching the altitude of about 1600 km, and then it began to increase. This rise is explained by the enhancement of the flux of the charged particles. The readings of the CTC-5 counter, which measured the cosmic ray background during the same experiment, and which were kindly presented to us by Yu. P. Kozyrev, are in agreement with the readings of our own counter with the CaF_2 filter. Hence we may conclude that at these altitudes the emission in the lines of the atomic hydrogen triplet (λλ1302, 1304 and 1306 Å) is practically absent.

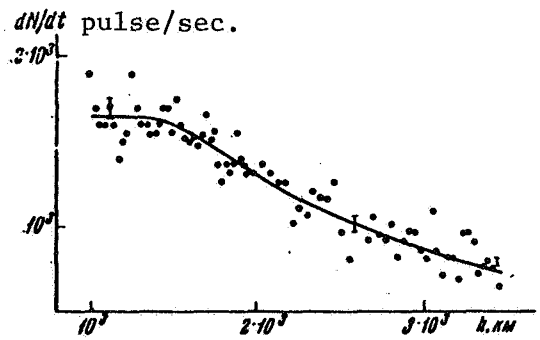

Fig.1

Readings of counter, sensitive to L_α-emission

Shown in Fig.3 is the averaged experimental curve of the L_α-emission intensity variation with altitude (in kilorayleighs). At the computation of the neutral hydrogen concentration n_H for these altitudes by the observed intensity, we assumed that the optical thickness in the line L_α is

$$\tau = \int_h^\sigma n_H \sigma_0 \, dh \ll 1,$$

where σ is the effective cross-section of resonance scattering at the center of line L_α. Then the emission intensity, registered by the instrument, will be

$$I = \int_h^\infty \frac{\pi F_S}{4\pi} n_H(h) \sigma_0 \left(\frac{2\Delta\lambda_D}{\Delta\lambda_S}\right) dh$$

$$[\text{ergs/cm}^2 \cdot \text{sec} \cdot \text{sterad}]$$

where πF_S is the direct current of solar L_α-emission, assumed to be equal to 4.5 ergs/cm^2·sec; $\sigma_0 = 1.5 \cdot 10^{-13}$ cm^{-2}; $(2\Delta\lambda_D/\Delta\lambda_S)$ is the ratio of the width of the scattering line to that of the L_α line of solar emission. This ratio was assumed to be equal to 1/25.

We did not take into consideration the albedo emission, which will somewhat increase the emission flux scattered downward. However, this will hardly increase the n_H value, determined in (1), by more than 1.5 times. Differentiating the experimental curve, we shall obtain, according to (1), the altitude distribution of neutral hydrogen (Fig.4, curve 2). Let us apply the indicated method at altitudes greater than 1800 km. Beginning with this altitude and below, the optical depth for the L_α-emission becomes of the order of 1. The emission intensity almost ceases to vary with the altitude.

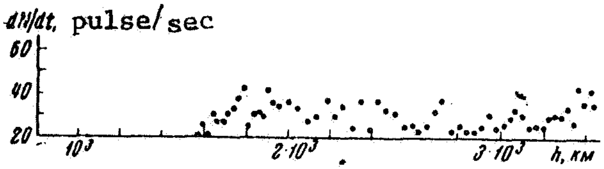

Fig.2
Readings of the counter with the CaF_2 filter.

It is interesting to compare the experimental data with the theoretical computations of the L_α-emission resonance scattering in the geocorona. The transfer equations in the theory of scattering [3] yield in the solution the value of I, which is the mean intensity of scattered emission as a function of the magnitude of τ/τ_0 where

$$\tau = \sigma_0 \int_h^\infty n_H(h)\,dh,$$

and τ_0 is the optical depth of the entire hydrogen layer to the level, where begins the pure absorption of L_α-quanta by hydrogen molecules (roughly to about 120 km). Therefore, for the computation, it is necessary to perform the transition from the optical depth to the altitude above the Earth's surface. For this purpose, we have used initially the Liwshitz model [4] for T = 1000°K (Fig. 4, curve 1). The τ_0 value in this model was found by us to be equal to 2. The thus computed values of scattered emission intensity agreed poorly with the results of measurements.

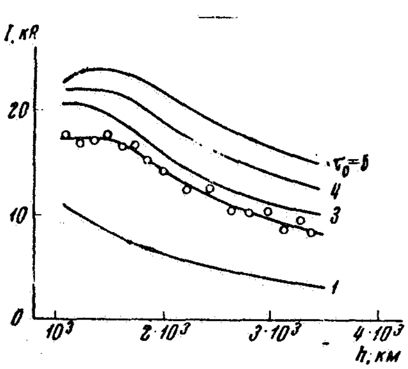

Fig.3

The curve of intensity distribution of scattered L_α-emission (in kilorayleighs)

The circles are the result of the averaging of five counter readings the interval between which is 30 km. The curves with the τ_0 = 1,3,4,5 are the result of the solution of transfer equations.

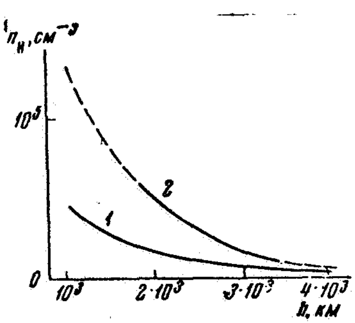

Fig.4

The distirubtion of neutral hydrogen according to the Liwshitz theoretical model (curve 1) and the empiric model of neutral hydrogen distribution (curve 2).

The broken line is the result of extrapolation of the empiric model in the exponential approximation.

Further we have taken the empiric model of neutral hydrogen distribution. In the assumption that the results of measurement respond to a certain exponential distribution of hydrogen atoms in height, a new τ_0 value was found. The latter was found to be equal to 4.3. The theoretical curves of intensity distribution of scattered emission in height for $\tau_0 = 1, 3, 4, 5$ and the Sun's 80° zenithal distance with the utilization of our own model for the transition from the optical depth to the altitude are shown in Fig.3. The theoretical curve with $\tau_0 = 4$ describes most satisfactorily the experimental course of intensity variations with the altitude. The difference in the absolute values possibly takes place on account of the uncertainty of photon counter calibration.

In conclusion I express my gratitude to V.G. Kurt, for his constant attention to the work, and to V.M. Tiyt for the great help during the calibration of the counters.

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*** THE END ***

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Volt Information Sciences, Inc.,
1145 19th Street, N.W.
Washington, D.C. 20036
Telephone: [202] 223-6700 X 36,37.

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