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ANALYSIS OF NIGHT SKY EMISSIONS ACCORDING TO OBSERVATIONS ON AES "KOSMOS-92"

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SUMMARY

Two components have been isolated during the night sky flare observed on AES "KOSMOS-92": one of them constitutes a proportional enhancement of all the standard components of atmosphere luminescence; the second apparently includes a γ-system of NO bands and the attending radiation. The question of the probable source of these emissions is discussed.

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The utilization of spacecrafts made possible the study of night airglow in the middle UV-region. The filter measurements on AES "KOSMOS-45" [1] have shown by means of the broad material obtained, that the night sky emission in the interval 1800 - 3500 A is extremely small and does not exceed 30 Rayleighs.

Local spectrophotometric measurements on rockets [2, 3] allowed us to identify the night sky emission in the 2500 - 3500 A interval with the Herzberg bands O_2 and also to show the very low level of emission in the shorter wave region. In another rocket experiment [4] the altitude profile was obtained of the very weak glow observed in the 1800 - 2500 A interval. It was found that it is distributed within the 125 - 175 km layer, with maximum at the altitude of 140 km. Mentioned as possible sources of glow were [4] the Vegard- Kaplan molecular nitrogen bands, alongside with those of Layman-Birdge- Hopfield, and the δ-, ε- and γ-bands of nitrogen oxide.

The study of night airglow was pursued on AES "KOSMOS-92" in the 1800 - 6000 A interval [5]. The method applied, alongside with the peculiarities of the instrumentation used, are described in detail in this last work [5], with the values of mean intensities (rayleighs/A) in seven spectral intervals for each of the 12 orbits during which measurements were conducted, compiled in Table 1 (columns 1 - 7). The pass band for the 3914 A filter is shown in it, while the data for the 5577 A filter are converted to the line $[OI]_{32}$ and brought out in rayleighs; the values of I_i mean the intensity in the interval $\underline{i}$. The negative intensities in the region 1800 - 2500 A could have arisen only on account of errors at subtraction of readings in different light filters, and characterize the level of these errors.

TABLE 1

ORBIT number	1800—2500 Å	2500—3150 Å	3150—3900 Å	3914 Å Δλ 100 Å	4000—5000 Å	5577 Å (релей)	5000—6000 Å	$I_2 - 0{,}95 I_3$	$I_5 - 0{,}485 I_7$
	1	2	3	4	5	6	7	2*	5*
1	0,73	1,3	0,9	1,05	1,9	260	2,4	0,45	0,74
2	0,52	1,55	1,15	1,3	1,9	425	2,25	0,45	0,58
3	0,26	1,38	1,04	1,15	1,55	385	2,54	0,38	0,37
4	0,12	0,87	0,82	0,85	1,2	290	2,0	0,1	0,23
5	0,12	0,69	0,74	0,81	1,15	230	2,1	—0,01	0,13
6	0,06	0,54	0,7	0,73	1,1	205	1,9	—0,12	0,16
7	0,04	0,57	0,58	0,65	0,85	170	1,8	0,03	—0,02
8	0,1	0,56	0,61	0,67	0,94	190	1,9	—0,02	0,02
9	0,04	0,63	0,63	0,68	0,92	180	1,95	0,03	—0,03
10	0,06	0,57	0,58	0,65	0,84	170	1,80	0,02	—0,04
11	0,02	0,6	0,6	0,66	0,82	170	1,75	0,03	—0,04
12	0,04	0,63	0,63	0,68	0,82	190	1,75	0,03	—0,03

TABLE 2

j \ i	1	2	3	4	5	6	7	2*	5*
1	1	0,73	0,49	0,64	0,94	0,21	0,69	0,86	0,985
2		1	0,93	0,98	0,92	0,8	0,94	0,96	0,8
3			1	0,98	0,77	0,96	0,94	0,8	0,56
4				1	0,87	0,87	0,98	0,89	0,69
5					1	0,54	0,89	0,95	0,95
6						1	0,8	0,6	0,3
7							1	0,86	0,7
2*								1	0,91
5*									1

As may be seen from Table 1, the mean intensities on orbits 5 - 12 change little from orbit to orbit and coincide with the results of ground obervstions in near and far ultraviolet regions [7 - 9], and with satellite and rocket data in the middle UV region of the spectrum. However, a significant intensity increase is observed on the orbits 1 to 4 in all wavelength ranges and particularly in the UV.

The detection of a significant emission level in the interval 1800 - 2500 A succeeded for the first time. This flare was registered by us at all observation points (±50° latitude) and thus had a global character, which is already interesting in itself. The region of observation included the eastern half of the Pacific Ocean and the adjacent regions of SE Asia and Australia. The flare was observed on 16 October 1965 from 0830 to 1500 hours UT. It was attended by an excessive rise in light filter 3914 A's readings and, therefore, could not constitute a low latitude aurora. Nor could it be referred to the so called clear nights [9], which is characterized mostly by the pull of continuum in the long wave part of the spectrum. Unfortunately, we failed to uncover a simple and direct link between this flare and the other geophysical phenomena. In order to be able to make any assumptions on the nature of emissions at flare time, we shall investigate the correlation of intensities in various portions of the spectrum. The correlation matrix, brought out in Table 2, is computed according to data of the first five orbits.

The interval 1 (1800 - 2500 A), whose emission correlates best with those of intervals 2 (2500 - 3150 A) and 5 (4000 - 5000 A), offers the greatest interest. However, in intervals 2 and 5 a significant fraction of emissions must correlate with the emissions in adjacent parts of the spectrum. In order to separate the remainder, which is linked with the emissions in interval 1, we shall introduce the quantities

$$I_{2*} = I_2 - \frac{I_{2cp}}{I_{3cp}} I_3 \quad \text{and} \quad I_{5*} = I_5 - \frac{I_{5cp}}{I_{7cp}} I_7; \quad \text{(subscript "cp" for "av")}$$

I_{2cp}, I_{3cp}, I_{7cp} represent the averaged intensities by all convolutions (orbits), beginning with the fifth, and characterize the hight sky airglow in the absence of flare. The quantities K_{2*} and K_{5*} are included in the matrix of Table 2.(*) Upon introduction of I_{2*} and I_{5*}, the former values of I_2 and I_5 offer no longer any interest, since they constitute a linear combination of other quantities (for example, $I_2 = I_{2*} + \alpha I_3$).

Since during flare a significant increase was observed in all spectral intervals, the level of the observed correlation is rather high. In order to separate the cases of good correlation from the worst ones, we compiled in Table 3 the departures of the correlation factors from average

$$\Delta K_{ij} = 2K_{ij} - K_i - K_j, \quad K_i = \frac{1}{6} \sum_{\substack{j=1\div 7 \\ j\neq i}} K_{ij},$$

where K_i are the mean correlation factors.

The positive values ΔK_{ij} are evidence of good correlation, and the negative of a relative poor one; the values close to zero represent an intermediate case.

TABLE 3

j \ i	2*	3	4	5*	6	7
1	0,26	−0,46	−0,2	0,65	−0,86	−0,09
2*		−0,01	0,12	0,31	−0,24	0,07
3			0,33	−0,36	0,51	0,26
4				−0,15	0,28	0,29
5*					−0,71	−0,12
6						0,15

It follows from Table 3 that during flare, the night sky emission may be broken down into two correlated groups: the emission in intervals 3,4,6,7, and also the main part of the emission in intervals 2 and 5 and the glow in intervals 1, 2* and 5*.

Thus, the night sky glow flare may be represented as a proportional increase of the usual night sky components in the considered spectral region (the Herzberg bands in intervals 2,3,4,5, the continuum in intervals 5, 7 and the line $[OI]_{32}$ 5577 A) and the appearance of new components (intervals 1, 2*, and 5*), which usually are either absent, or little developed. The mean intensity of the new components during flare constituted 250 rayleighs in the

(*) they are the coefficients of I_2* and I_5*, compiled in TABLE 1 interval 1800 - 2500 A, 150 rayleighs in the interval 2500 - 3150 A and 410 rayleighs in the interval 4000 - 5000 A.

In order to identify these emissions, data on wavelengths and probability of transitions for various aeronomically important systems of bands were borrowed from [10]. It was then ascertained that the observed intensity distribution cannot be induced by only one system of bands, even if we admit the excitation of separate oscillation levels. The assumption that in the intervals 3150-3900 A and 5000-6000 A there is also a fraction of unusual emission component, though smaller, which we failed to separate by our own means, does not alter the essence of the question. Therefore, the residual emission in the intervals 1800-2500, 2500-3150 and 4000-5000 A is induced at least by two sources closely interlinked. Then, of all systems of bands considered in [10], only the system of γ-bands of NO ($A^2\Sigma^+ \rightarrow X^2\Pi$) can satisfy the observed intensity distributions of 250 rayleighs in the 1800-2500 A interval, and 150 rayleighs in the 2500-3150 A interval. The realtive probabilities of transitions in the intervals 1800-2500, 2500-3150 A are computed after the data of [10] and compiled in Table 4.

TABLE 4

v'	0	1	2	3	4	5	6	7
1800—2500 Å	0,57	0,43	0,56	0,73	1	1	1	1
2500—3150 Å	0,43	0,57	0,44	0,27	0	0	0	0

As may be seen from Table 4, the various correlations in the populations of oscillation levels may satisfy the observed distribution of intensities (for example, the linear drop of populations to zero at v' = 6). The data, available to us, are so far insufficient for a fully reliable identification of emissio s during flare; however, the emission of γ-bands in NO is most realistically explaining the results of the experiment.

The nitrogen oxide is an important component of the atmosphere in the 70-200 km altitude range; its total content is $\sim 2 \cdot 10^{14}$ cm^{-2} [11]. However, in nighttime, a comparatively small number of processes may result in the excitation of γ-bands. The processes of NO formation as a result of triple or double collisions may excite only the lower oscillation levels of γ-bands (v' = 0,1,2).

The excitation of NO is possible under the action of L_α -emissions in 1216 A and OI 1300 A, which reach in nighttime 5 to 10 (k)rayleighs. However, the NO's absorption cross-section for these emissions constitutes $2.5 \cdot 10^{-18}$ cm^2, which, at NO content in $2 \cdot 10^{14}$ cm^{-2} leads to absorption of a very insignificant part of emissions L_α 1216 A and OI 1300 A.

The appearance is possible of excited states NO ($A^2\Sigma^+$) at radiational recombination

$$NO^+ + e \rightarrow NO(A^2\Sigma^+) + h\nu.$$

The recombination coefficient of NO constitutes about 10^{-7} cm^3/sec, although sometimes higher values are considered [14]; however, the main part of recombinations leads to dissociation of NO. At nighttime the concentrations of ions NO^+ and electrons of the E-region of the ionosphere are about equal; if we assume their values as being ~ 10^4 cm^{-3} [15], we may conclude that in the atmosphere ~ 10^8 cm^{-2} sec^{-1}recombinations will take place altogether. It should be noted that this quantity may strongly rise with the presence in the atmosphere of E_S-layers with substantially increased concentration of charged particles (by 1 - 2 orders [16]). Therefore, if a few percent of the recombinations are radiational, the observed intensity level of γ-bands of NO may be attained.

Note also that the continuous luminescence, marked in the process of radiational recombination, is concentrated mainly in the interval 4000 - 5000 A. Thus, the process of radiational recombination explains also the residual glow in 4000 - 5000 A and satisfies well the observed distribution of intensities (400 in the 1800 - 3150 A and 410 rayleighs in the 4000-5000 A range).

When choosing the glow excitation mechanism, one should take into account the fact that the estimates, based upon some average data, must not explain the high level of emission during flare.

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