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INFRARED RADIATION OF THE UPPER ATMOSPHERE

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SUMMARY

This paper discusses extensively the work [1], proving that no such high emission as 10^3 ergs/cm$^2\cdot$sec may take place in the 300 - 500 km altitude range. To demonstrate his point the author analyzes the various forms of energy in the upper atmosphere taking into account the artificial changes and additional amounts of energy released during rocket launchings.

* *

It was indicated in the work [1] by Markov, Merson and Shamilev that in the 300 - 500 km altitude range the upper atmosphere emits up to 10^3 ergs/cm$^2\cdot$sec.

This work deals with the most intense maxima of infrared radiation, beginning from 280 km through 500 km (see Figs on pp. 113-115 and 116). Further, "for a measured flux ~ 10^{-2}watt/cm^2 the volumetric radiation density will constitute about $2\cdot10^{-10}$ watt/cm^3 (10^{-3} erg/sec cm^3), and the isotropic flux of a single layer about $2\cdot10^{-10}$ watt/cm$^3\cdot5\cdot10^5$ cm = 10^{-4} watt/cm^2. Therefore, this flux is about 0.07% of the value of solar constant, while the maximum value of the flux from all layers may be only several tens of a percent of that of the solar constant (and also of the magnitude of planet's radiation)" (see p.117). It is therefore referred to energy fluxes exceeding 10^3 ergs/cm$^2\cdot$sec. At the same time, the data of Fig.2, p.114, dated 6 June 1963, correspond to the time with K_p = 0 (see p.118). Thus far, the authors of [1] failed to publish anywhere that these data are erroneous.

N.B. The work [1], of 1965, is available in libraries in c.-to c.-translation.

The most abundant upper atmosphere components O, N_2, O_2 and N do not emit in the region of a few microns. Only oscillation-excited diatomic molecules, consisting of various atoms (for example, NO), and still more complex molecules, can be possible emitters. However, such components, even if they actually exist in the upper atmosphere, constitute insignificant amounts. The most effective oscillatory excitations may be expected at collisions between atoms and molecules of the atmosphere.

The energy U (in ergs), emitted by an atmosphere column with 1 cm^2 base in - second, can be represented as

$$U = Hn^{*}\nu u, \qquad (1)$$

where H is the height of uniform atmosphere for molecules capable of oscillatory excitation and emission in the region of a few microns; n^* is their number in 1 cm^3; ν is the number of effective collisions in a second, assuring the oscillatory excitation; $\underline{u}$ is the mean energy of the emitted quantum (~ 3 10^{-13} erg). Under no conditions of any kind will the desired excitation take place at each gas-kinetic collision. This is why ν may be represented as

$$\nu < \sqrt{32}n\sigma v, \qquad (2)$$

where $\underline{n}$ is the total number of particles in 1 cm^3, σ is the mean effective gas-kinetic cross-section of these particles (~ 10^{-15} cm^3) and $\underline{v}$ is their mean velocity. Substituting (2) into (1), we shall obtain

$$U < \sqrt{32}Hn^{*}n\sigma vu. \qquad (3)$$

The main characteristics of the upper atmosphere may be borrowed for our aim with sufficient precision from CIRA 1965 [2]. In order to obtain the optimum effect, we shall make use the model 10 atmosphere - the most extended in height. It corresponds to 1400 hours L.T. in the years of solar activity maximum. In the 300 - 500 km altitude region $\underline{H}$ can not be greater than $6 \cdot 10^6$ cm for diatomic molecules, while $\underline{v}$ does not exceed $1.8 \cdot 10^5$ cm/sec even for oxygen atoms. The concentration of molecules, capable of emitting in the region of a few microns, will always be substantially less than the total concentration of all molecules n^{**}. Then, taking into account all the above-said, we shall take instead of (3):

$$U \ll 2 \cdot 10^{-15} n^{**} \ [erg/cm^2 \cdot sec]. \qquad (4)$$

Knowingly and substantially overrated and unrealizable limits of U are compiled in Table 1. Mass-spectrometric investigations of the upper atmosphere still failed to detect above 300 km concentrations of NO that lend themselves to measurement. Because of their small number, we may not rely on other analogous NO molecules. Still less effective is the oscillatory excitation of molecules at collisions with electrons. Though their velocity is higher than that of neutral molecules, their concentration is, however, significantly lower and the effective excitation cross-section is too small.

TABLE 1

Altitude above ground km	n^{**} mol/cm^3	n all part/cm^3	U, ergs/cm^2· sec	H, cm	$n^{**}H$, molecules/ /cm^2	τ	U_0, ergs/cm·sec
300	$8 \cdot 10^8$	10^9	$\leqslant 1600$	$<6 \cdot 10^6$	$\leqslant 4,8 \cdot 10^{15}$	$\leqslant 4,8 \cdot 10^{-1}$	$\geqslant 2 \cdot 10^3$
400	$1,6 \cdot 10^8$	$4 \cdot 10^8$	$\leqslant 128$	$<6 \cdot 10^6$	$\leqslant 9,6 \cdot 10^{14}$	$\leqslant 9,6 \cdot 10^{-2}$	$\geqslant 10^4$
500	$4,8 \cdot 10^7$	$1,8 \cdot 10^8$	$\leqslant 17$	$<6 \cdot 10^6$	$\leqslant 2,9 \cdot 10^{14}$	$\leqslant 2,9 \cdot 10^{-2}$	$\geqslant 3 \cdot 10^4$

It becomes entirely evident that, because of the absence of a sufficient number of collisions, great energy liberations in the infrared region above all atmosphere levels indicated in the Table 1, are unrealizable.

Such molecules as NO may be excited in an oscillatory fashion at the expense of resonance absorption of unfrared radiation. For NO molecules the optical thickness is of the order of the unity, and, as such, it corresponds to not less than 10^{16} NO/cm^2 along the visual ray, while the equivalent width for all rotational lines of the oscillatory level in conditions of the upper atmosphere is no more than a few angstroms [3]. Compiled in Table 1 are also the optical thicknesses τ of the atmosphere above different levels for knowingly overrated concentrations of NO, equal to the total real concentration of all molecules, and the required energy fluxes of infrared radiation U_0 corresponding to the absorbed flux of 1000 ergs/cm^2·sec, when $\tau \approx 1$ is attained at 10^{16} molecules/cm^2. Let us recall that the energy corresponding to the solar constant, $1.4 \cdot 10^6$ ergs/cm^2·sec is spread in the region of several thousand angströms within the shorter wave region of the spectrum. It becomes then obvious that the resonance excitation is unacceptable from the standpoint of energy considerations.

The solar electromagnetic radial energy absorbed in the upper atmosphere does not exceed 10 ergs/cm^2·sec, but it too is absorbed mainly significantly below the 300 km level. The optimum energy liberation in the red oxygen emission line 6300 A of the upper atmosphere at a level above 300 km at the time of the most grandioze geomagnetic storm of 11 February 1958 did not exceed 300 ergs/cm^2·.sec. Only one such storm was recorded in the course of the last decades. But, usually the energy liberation at great altitudes is substantially lower. In the course of standard aurorae the energy is absorbed considerably below the 300 km level and, in the maximum case, it does exceed 600 ergs/cm^2·sec for the most intense aurorae IV IBC [4]. For the above indicated energy liberation of 300 ergs/cm^2 sec the crisis with collisions could be overcome (see expression (3)), as the energy of the emitted quantum [0 1] was by one order greater than $3 \cdot 10^{-13}$ erg in the case of NO or a similar molecule [5]. Even if during the time of this unique storm all molecules above the 300 km level were NO molecules, for the same number of collisions, the energy liberation in infrared oscillatory quanta of this molecule would not have exceeded 300 ergs/cm^2.sec, inasmuch as the emission in 6300 A is excited at collision of the very same NO and O.

The maximum possible reserves of thermal energy in the atmosphere above the 300 km level do not exceed a few thousand ergs. The reserves in dissociation energy are several times greater. However, the latter can not generally be realized at double collisions, the only ones practically possible at levels above the 300 km mark, but entirely ineffective for the recombination of atoms into molecules. The reserves of thermal energy could assure the infrared emission of 1000 ergs/cm^2·sec in the course of a few seconds, even if the required number of collisions, quite impossible above 300 km, were realized. Inconsistent is also the recourse to such sources of upper atmosphere heating as infrared oscillations, the gravitational and magnetohydrodynamic waves generated either in the very upper atmosphere, or in lower or higher regions, for the energy of these phenomena may be utilized for the oscillatory excitation of molecules in no other way but after its transformation into the thermal energy of the upper atmosphere characterized by the temperature. But in our estimates the optimum temperature which is included in CIRA 1965 was already utilized [2]. Therefore, on this path there is no possibility to find any substantiation for such an intense infrared radiation above the 300 km level as 1000 ergs/cm^2.sec. We should also bear in mind that any somewhat substantial concentrations of NO or of similar molcules are incompatible with the usual every day-heating of the upper atmosphere by solar shortwave radiation, inasmuch as they would have cooled the atmosphere and would allow the settling in it of the existing temperatures and densities.

M. N. Markov, Ya. I. Merson and M. R. Shamilov assume that the thickness of the radiating layer is approximately 5 km. At altitudes above 300 km there simply takes place the diffusive equilibrium. This is why the effective thickness of neutral molecule layer can not be less than the height of uniform atmosphere for these molecules. It would be inconceivable, how a layer of neutral molecules can exist with a thickness practically not differing from the length of molecules free path in this region ($\lambda = 1/\sqrt{32}n\sigma$, for $n \sim 10^9$ cm^{-3} $\lambda \approx 2\cdot10^5$ cm, and for $n \approx 2.10^8$ cm^{-3} $\lambda \approx 10^6$ cm). In the infrared region of the spectrum the radiation in a horizontal direction may in some cases be more intense than in the vertical direction. At temperatures above 500 - 1000°K, NO molecules may effectively transfer from the ground oscillatory level to a higher one and be located in it the greater part of the time, provided the term of their existence at that level $\underline{t}$ is greater than the time interval between collisions, i.e., when

$$t > \frac{1}{\nu} = \frac{1}{\sqrt{32}n\sigma v}, \qquad (5)$$

or when

$$n > \frac{1}{\sqrt{32}t\sigma v}. \qquad (6)$$

Since $t \approx 10^{-1}$ sec for a molecule NO with minimum oscillatory excitation [6], $\sigma \approx 10^{-15}$ cm^2 and $v \approx 10^5$ cm/sec, such conditions may be fulfilled for $n > 2\cdot10^{10}$ cm^{-3}. According to CIRA 1965 [2], such $\underline{n}$ are present below 150 km. In these regions, even with NO concentration considerably lower than the aggregate concentration of molecules ($\sim 10^{10}$ cm^{-3}) along the horizontal, there may be no less than 10^{16} NO/cm^2, required for a narrowly-directed forced radiation along this path with maximum content of oscillation-excited molecules NO. However, these conditions are not realizable over levels above 300 km.

For an intensity of infrared radiation above the 300 km level referred to by Markov, Merson and Shamilev, the upper atmosphere would be "<u>perpetuum mobile</u>", or would at least function as such. For that reason, the explanation of indicated intensities should be sought for not in any so far unknown processes, but only in the singularities of the method and of experiment technology.

But here we have to do not only with the peculiarities of the measurement apparatus utself. During rocket launchings there appear in the atmosphere enormous artificial changes and additional energy is released. Gravitational waves are generated. As a result of fuel burnout there remain a large number of molecules capable of emitting infrared oscillatory quanta. Most of the time, the apparatus moves with supersonic velocity. Thus a shock wave sets in, in which a substantial part of the air is transformed into oscillation-excited molecules NO, capable of deactivation by radiation. All these processes are intensified during geomagnetic disturbances, inasmuch as at that time the upper atmosphere is strongly heated, expanded, and its density increases at great altitudes. Lateral artificial processes of natural atmosphere distort and conceal the true processes of natural atmosphere, including the less intense natural infrared emission of NO, no longer doubtful, on which a reliable and trustworthy information is important for the physics of the upper atmosphere.

**** T H E E N D ****

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