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Problems of bright radiations in the upper layers of an atmosphere

A. Aramyan (1), G. Galechyan (1), G. Hrutyunyan (1), G. Manukyan (1),

N. Mangasaryan (1) and S. Bilén (2)

(1) Institute of Applied Problems of Physics NAS RA, Yerevan, Republic of Armenia, (2) The Pennsylvania State University, Pennsylvania, USA (ara@iapp.sci.am / Fax: +37 410-281861 / Phone: +37 410-241059)

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1 Introduction

Processes that are leading to radiation in optical range in mesosphere and lower ionosphere due to energetic electrons, which are accelerated by electrostatic field of storms, are bringing to conformity with such kind of excitations, in Aurora Borealis. However, Aurora can't occur lower then 90 km, but luminescence by way of sprites occurs in most of cases in lower heights. Theory of light excitation of atmosphere and sprite generation due to quasielectrostatic fields is discussed in [1, 2, and 3]. In these articles it was shown that molecular nitrogen is becoming excited, mainly *N21PG* stripe system. This mechanism, which is explaining sprite appearance, has his defects. For example, it is impossible to explain the appearance of blue flashes in heights of 20-44 km. In this work is presented new way of explanation of light excitation of atmosphere and sprite generation. The background of this mechanism is superluminescence of some electron transitions of atomic oxygen. Also in this work is presented the comparison between the flashes that were received in laboratory conditions [4,5] and the sprites in atmosphere [1].

1.1 Observations

Sprites are optical effects in upper air stratum, concerned with storms [1,2]. They are electrochemical processes in upper atmosphere and transportation of huge amounts of charge between different air stratums.

First clear sprite records appear in 1990 [6], which served as a big push in this field of researches. Many aspects of sprite formation and their influences on surrounding atmosphere yet are unclear. Observed flashes are dividing onto Red Sprites and Blue Jets. Red Sprites predominantly occur in heights of 50-90 km. Duration of Red Sprites is from hundreds of μs to tens of ms. In [7] analyzed in details the brightnesses of several separated single sprites and also get that total optical energy is up to 50 kJ per event. For comparison, we can get such kind of optical energy from tens of thousands of high power ruby crystal lasers. If we take the average sprite duration 3 ms, we can evaluate the momentary optical power of these single sprites, which will be in diapason of 0.3-15 MW.

In [3] was shown the spectral measurements of Red Sprites. From the mentioned spectral diagrams we can see the exact expressed spectral lines, in wavelength of $\sim$6700 Å.

Typical Blue Jet is appearing in way of flashes, which are propagating with the average speed of 100 km/s, from the top of troposphere storm upwards in narrow cone. The average angle of cone in [7] was determined by 19 events, it is $14.7 \pm 7.5^{\circ}$. By measurements from the airplanes were determined the maximal height of Blue Jets, it is 44 km. In most of cases duration of jet is about 200 ms.

Jets often are appearing in troposphere like a moving upwards continuations of thunderbolts. There were observed two jets, which were going one after another with interval of 10 ms. Also there are examples of jets, which were started from the same place and went by the same way with interval of 50-70 ms [7].

The average frequency of jet appearance is 2-3 per minute. Maximal brightness of jet can reach the brightness of the Red Sprite. Jet spectrum is not exactly measured yet, but preliminary analyze of three-colored TV signals showed that ratio between blue and green in the glowing part of the jet is about 5:1, when red component is absent.

1.2 Discussion

The sprites and jets have pulsed character, relatively monochromatic radiation and also high level of brightness density of flashes, so we can say that these flashes have forced, and not spontaneous character. Also we can see, that the responsible for these processes is the atomic oxygen, and not the molecular nitrogen. We can say that the phenomenon, concerned with dissociative recombination, which is presented in [4-5], is the laboratory model of sprites. The explanation of the phenomenon described in [5] is the following. The quenching of Ridberg levels, concerned with parameter of Messa, is leading to accumulation of excited atoms in lower bound of Ridberg levels. And when this accumulation is overcoming a certain threshold of overpopulation, occurs forced radiation in way of flashes (superluminescence). For this process is nessesary the presence of highexited atoms. Lets see how in atmosphere we get highexited atoms of oxygen. From [8,9] we can see that highexited state of oxygen atoms is forming in the result of single collision of electrons with molecules O_2

O_2 + $e \rightarrow O^* + O^+ + 2e$ (1)

Threshold of appearence of highexited atoms by schema (1), as it seen from [8] is about 30 eV. On heights of 80-90 km presence of electrons with such energy is possible, because the average free path of particles is $\sim$3$\div$20*10^{-3} m. But on heights of 20$\div$40 km, where are the Blue Jets, schema (1) has low-probability. As this is the height of the ozone stratum, it can be thought that highexited atoms of oxygen are racieved from dissociation of ozone molecule. This process can go on like

O_3 + $e \rightarrow O^* + O_2^-$(2)

So we can say that these processes, which are going on by schemas (1) and (2), lead to effective formations of highexcited oxygen atoms.

As highexcited state of atom is long-living ($\sim$3*10^{-6}s for n=5;6 in [9]) lets discuss destruction of these states of atoms in the result of collisions with atoms and molecules. In accordance with theory of atomic collision [10], probability of transition between two states strongly depends on parameter of Messa (probability is $\sim$*exp(-*ξ)). Parameter of Messa equals to

$\xi \quad \sim \quad \delta_e/nV_a$

where n - is principal quantum number, V_a- spead of nuclear movement, δ_e – quantum defect. As l >1, quantum defect is small and parameter of Messa is small as well, so corresponding transitions are taking place freely. There is another situation, when the transition is going on with highexcited states, when their orbital moment is l=0;1. In these cases parameter of Messa is $\xi \geq$1, when n is not very big. In these cases quenching of such states by collisions, has low-probability. So owing to quenching of highexcited states of atoms, by collision with atoms and molecules(with levels of n,l >>1) are quickly wasting and is taking place the accumulation on levels *6s, 5s, 5p* and $4s, 4p$.

As the quenching of levels *4p, 5p, 6s* has low-probability (as l=0;1 and n has not big values) [11], the next process is going on by transitions

$5p^3P \rightarrow 3s^3S$ -3692 Å

$4p^5P \rightarrow 3s^5S$ -3947 Å

$4p^3P \rightarrow 3s^3S$ -4368 Å

$6s^5S \rightarrow 3p^5P$ -5435 Å

In order to take place the quenching of highexcited levels of oxygen it must be fulfilled the following condition

$\nu_{cl} >> 1/\tau$ (3)

where ν_{cl}- frequency of collision of particles, τ- time of life of highexcited levels. For highexcited atom, with principal quantum number of 5 and 6, τ

10^{-6} s. Condition (3) fulfills only on heights of 20-50 km. Here ν_{cl} is more then 1/τ on three order. On higher heights ν_{cl} decreases and on heights of 70-90km is becoming comparable with 1/τ. So on heights of 70-90 km process of quenching of highexcited levels is not occuring. On these heights the destruction of Ridberg states of oxygen atoms is occuring by spontaneous photon emanation. Spontaneous process of destruction of oxygen Ridberg's atoms is taking place through *3p→3s* transition or, rather

$3p^3P \rightarrow 3s^5S$ -6726 Å

$3p^5P \rightarrow 3s^5S$ -7774 Å

$3p^3P \rightarrow 3s^3S$ -8446 Å

Conclusion

In conclusion we can say that by the mechanism of explanation of in [5] found effect, we can explain the optical effects in atmosphere (Red Sprites and Blue Jets).

The essence of this explanation is the following.

In atmosphere, by collision of electrons with oxygen and ozone molecules, is taking place the dissociation of these molecules and in result we get high excited oxygen atoms. Destruction of oxygen Ridberg's atoms occurs by two ways:

1. On heights of 20-40 km by quenching. Quenching process is leading to occupancy of levels with n >1 (up to 4;5;6), l=0;1. From these overpopulated levels

arises superluminescence, when is overcoming the threshold of overpopulation for superluminescence. Most probably, this kind of superluminescence is visible as Blue Jets.

2. On heights of 60-90 km, by spontaneous photon emanation. This process lead to occupancy of $3p$ levels. The superluminescence from $3p \rightarrow 3s$ transition most probably is visible as Red Sprites.

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