Influence of plasma collective effects on the structure of the aurora borealis streamers

N. I. Dzyubenko, V. N. Ivchenko, G. P. Milinevskiĭ, and E. V. Mishin
T. G. Shevchenko Kiev State University, Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation

(Submitted April 1, 1980)
Pis'ma Zh. Eksp. Teor. Fiz. **31**, No. 11, 643–646 (5 June 1980)

A two-maximum altitude structure was observed in the glow produced by a beam of high energy electrons entering the ionosphere; this structure agrees with theory which takes into account the effect of collisions on the dynamics of strong Langmuir turbulence excited by the beam.

PACS numbers: 94.10.Sm, 94.20.Rr

1. Most of the aurora borealis is caused by the intrusion into the lower ($h < 200$ km) ionosphere of streams of high energy electrons whose energy is "de-excited" via the excitation and ionization of the neutral component of the weakly ionized ($n_e/N \lesssim 10^{-6}$) ionospheric plasma.[1] The volume intensity of the glow is proportional to the energy lost by the electrons in a given volume, so that the mechanisms for dissipation of energy of the intruding electrons can be determined from the glow dissipation. In fact, the ordinary (see Refs. 2 and 3) collisional interaction of a monoenergetic (at $h > 200$ km) beam gives a glow profile, with a maximum at the "destruction" altitude of the beam (h_d), which increases monotonically with decreasing altitude

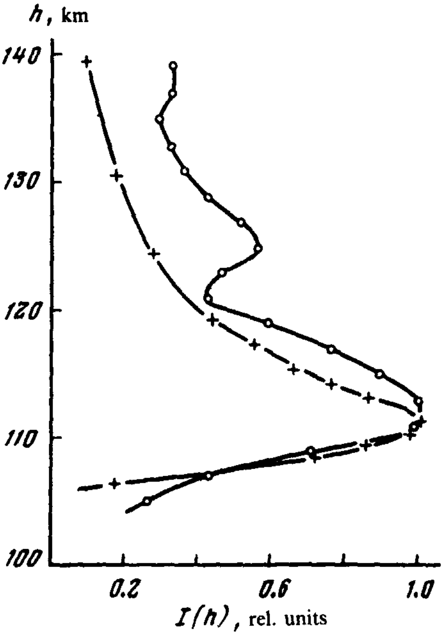

FIG. 1. Altitude profile of the glow of an AAB streamer (circles) and the calculated, collisional glow profile[2] (crosses).

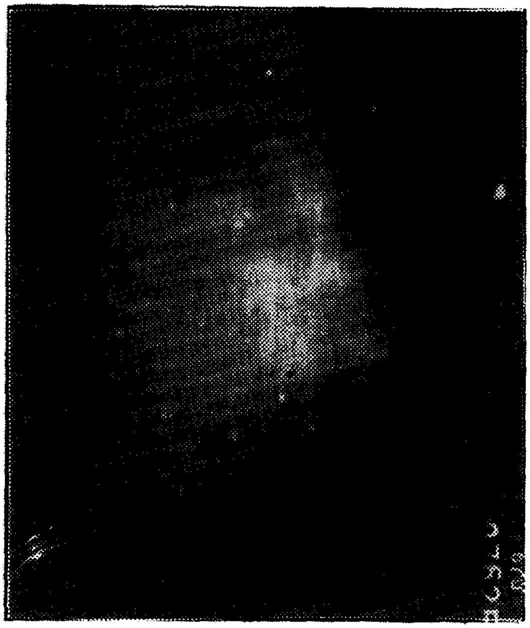

FIG. 2. Photograph of 11-point NAB streamer arc.

(increasing N). The width of the region of maximum dissipation (like h_d), which increases with decreasing initial energy of the beam, is 10–15 km for $\epsilon = 2$ keV ($h_d \approx 125$ km). On the other hand, it has recently been shown[4,5] that the collective interaction with the ionized component of the ionosphere, associated with the beam instability, leads to a considerable additional dissipation of the beam energy at altitudes $h > h_d$, and especially in the narrow layer $h_m - \Delta h \leqslant h \leqslant h_m$. The upper boundary of the layer is determined by the condition[1] $\nu_{en}(h_m) \approx [\omega_p \gamma_b (m/M)]^{1/2}$ (see Refs. 4 and 5), where ν_{ev} is the collision frequency of ionospheric electrons with the neutrals and γ_b is the beam instability increment. The layer thickness[5] is $\Delta h \approx 3$–5 km; the instability does not develop below the layer.

2. In this paper we give the results of measurements of the altitude profile $I(h)$ of the glow in artificial (AAB) and natural (NAB) aurora borealis streamers obtained by using high-sensitivity television cameras with a super-orthicon.[7] The rate of photographic recording of the image from the video monitor screen was 5 frames/sec; the exposure time of one frame was 0.17 sec. The AAB was produced by an electron beam with an energy $\epsilon = 7.2$ keV, which was injected into the ionosphere from a rocket (the "Zarnitsa-2" experiment[8]). During this experiment,[7] photographs of the AAB streamers, which showed a double-peak luminance distribution, were obtained. A microphotometric examination of the luminance distribution along the streamers, taking into account the foreshortening conditions during their observation, made it possible to obtain the $I(h)$ profiles (Fig. 1; the calculated "collisional" glow profile[2] is also shown).

Figures 2 and 3, respectively, show the photograph of the NAB obtained at Tiksi

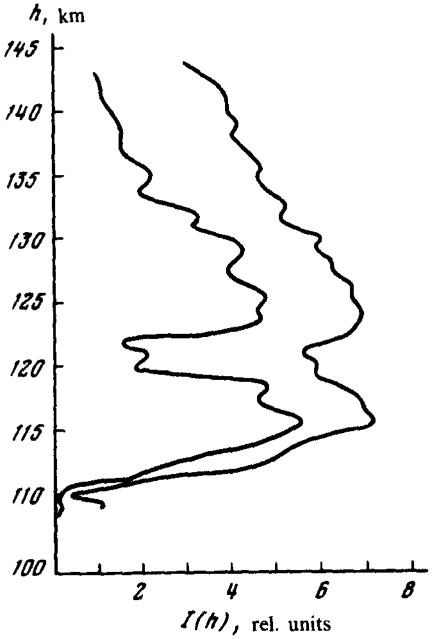

FIG. 3. Altitude profiles of the glow of NAB streamers (right and middle).

inlet, and its photometric $I(h)$ profiles, assuming that the bottom edge of the aurora is located at an altitude of 105 km.[2]

An analysis of the AAB and NAB photographs with a two-maximum, vertical luminance profile shows that in most cases the lower maximum is located at an altitude $h_d \approx 110$ km and the upper maximum, which is located at an altitude of $120 < h < 130$ km, has a width (with respect to the total half-width of the photometric profile) of about 4–6 km.

3. It is clear that the parameters of the upper maximum cannot be accounted for within the context of the collisional interaction. At the same time, the location and width of the lower maximum in Figs. 1 and 3 agree with the "collisional calculations"[2,3] (for $\epsilon = 10$ keV), respectively. We can therefore conclude that the upper glow maximum is due an additional dissipation mechanism, which is highly effective in a layer a few kilometers thick and which is ineffective at low ($h < 120$ km) altitudes (this is confirmed by the higher glow intensity, as compared with the calculations,[2,3] at high ($h > h_m$) altitudes). The collective interaction mechanism, in which the effect of collisions on the dynamics of strong Langmuir turbulence excited by the beam is taken into account,[4,5] has the indicated properties.

The authors thank V. N. Oraevskiĭ and V. D. Shapiro for a useful discussion.

[1)] This is the condition for the collision suppression of the "collisionless" collapse of plasma pockets produced as a result of the modulation instability of the beam-excited Langmuir oscillations.[6]

[2)]Similar NAB glow profiles, which are almost identical to those in Fig. 3, were observed earlier only twice,[9,10] although sudden luminance jumps along an NAB streamer have been mentioned repeatedly.[11] The data for the structure of an AAB streamer have been obtained for the first time.

---

[1]S. I. Isaev and M. I. Pudovkin, Polyarnye Siyaniya i protsessy v mangitosfere Zemli (Aurora Borealis and Processes in the Earth's Magnetosphere), Nauka Press, Leningrad, 1972.

[2]N. I. Izhovkina, Geomag. Aeronom. **19**, 176 (1979).

[3]M. J. Berger, S. M. Seltza, and K. Maeda, J. Atmos. Terr. Phys. **32**, 1015 (1970).

[4]N. I. Izhovkina and E. V. Mishin, Geomag. Aeronom. **19**, 585 (1979).

[5]A. S. Volokitin and E. V. Mishin, Geomag. Aeronom. **19**, 739 (1979); Fiz. Plazmy **5**, 1166 (1979) [Sov. J. Plasma Phys. **5**, 654 (1979)].

[6]A. A. Galeev, R. Z. Sagdeev, V. D. Shapiro, and V. I. Shevchenko, Zh. Eksp. Teor. Fiz. **72**, 508 (1977) [Sov. Phys. JETP **45**, 266 (1977)].

[7]A. T. Nesmeyanovich, V. N. Ivchenko, and G. P. Milinevsky, Space Sci. Instrum. **4**, 251 (1978).

[8]I. A. Zhulin and R. Z. Sagdeev, Vestn. Akad Nauk SSSR **12**, 874 (1975).

[9]T. M. Donahue, T. D. Parkinson, E. C. Zipf *et al.*, Planet. Space Sci. **16**, 737 (1968).

[10]T. Oguti, J. Atmos. Terr. Phys. **37**, 1501 (1975).

[11]N. I. Dzyubenko, Sb. Problemy kosmicheskoi fiziki (Coll.: Problems of Space Physics), No. 3, Naukova Dumka Press, Kiev, 1968.