Ballooning instability on the open magnetic field lines

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The necessary condition for the ballooning/interchange instability to grow is $(\kappa_p - \kappa_b - \kappa_c)\ \kappa_c > 0$, in which κ_c is the curvature, κ_b and κ_p are the magnetic field and pressure logarithm gradients toward the curvature center. Though this condition typically does not hold on the closed field lines in the central plasma sheet, in some cases it can be satisfied on the open field lines. In particular, the instability can evolve in the near-Earth part of the BPS (the boundary region between the plasma sheet and lobe) as well as in the NBZ field-aligned currents, the latter being unstable due to heating of the magnetospheric plasma by the field-aligned electric potential drop. We have derived the linear unstable mode dispersion relation under the suggestion that the curved part of the open field tube extents from the ionosphere up to ~10 R_E. As boundary conditions we adopted the electric current continuity in the ionosphere as well as the condition of radiation of the Alfvén wave going to infinity at the open part of the tube. The effect of propagating to infinity Alfvén wave is equivalent to that of the ionosphere with the height-integrated Pedersen conductivity equal to the wave conductivity at the distance of about 10 R_E, i.e. ~1 S, the quantity close to the conductivity of the moderately disturbed ionosphere. The calculated growth time of the unstable modes is about one minute. At the non-linear stage, the hot plasma tubes detached from the plasma sheet get through the lobes to the day- side till they reach the cusps and magnetopause. Their footpoints located in the polar cap move sunward with the velocity of 0.1-1 km/s. Due to the interchange, empty tubes from the magnetotail lobes successively fill up the plasma sheet, so that eventually it would be devastated in a few hours if there were no supply of plasma either from the ionosphere or solar wind. The footpoints of the empty tubes move antisunward. One can expect an inevitable reconnection between two approaching half-infinite empty tubes of opposite hemispheres, the newly formed closed tubes collapsing earthward. Thus, the ballooning/interchange instability of the boundary plasma sheet allows for magnetic flux transport through the plasma sheet. Besides, in the framework of the proposed mechanism it is easy to explain widely reported penetration of hot plasma segments deep into the lobes as well as polar cap arc formation.