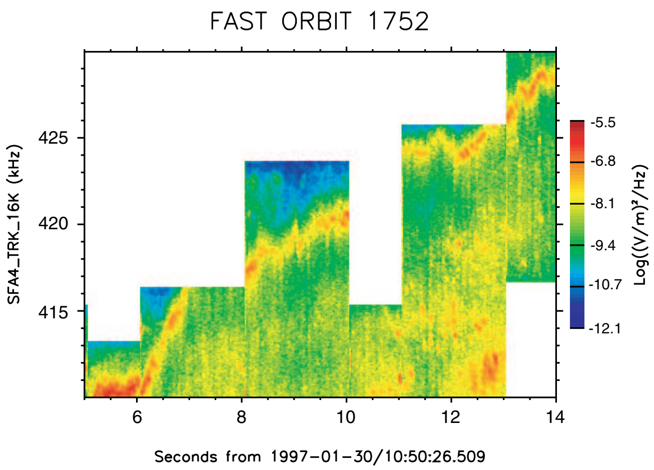
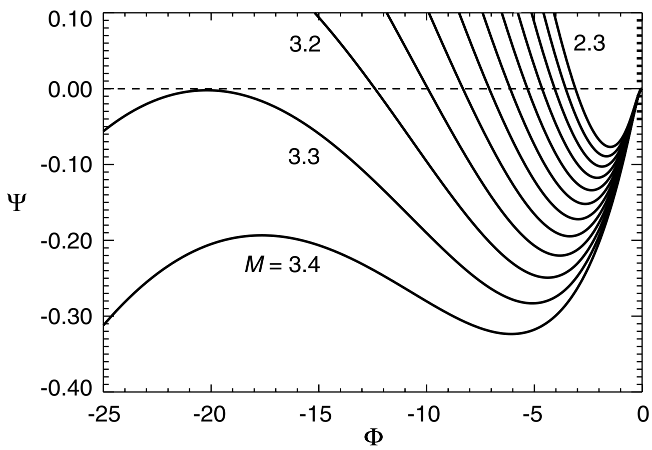
Double Layer Structure in Aurorae

We analyze high spatio-time resolutions of satellite (FAST),wave and particle measurements in the auroral magnetosphere (courtesy of the FAST team) at altitude around 2000 km. Main emphasis is on observation of the Auroral Kilometric Radiation (AKR). It has been demonstrated that it is to not a continuous broadband emission [6]. Instead, it consists of many discrete emission bands. The center frequency of the individual emissions often varies in a systematic manner, sweeping either upward or downward across the spectrum. The FAST observations allowed for a detailed study of the complex spectral structure of AKR [7-8] showing that each band consist of a large number of fast drifting 'Elementary Radiation Events' interpreted as travelling electron holes shown in the dynamic spectrum of the Figure. From theory [9-11,3-4] emission is beneath the local electron gyrofrequency ω_{ce} in regions containing field-aligned electric potential drops. The bandwidths of the emissions gives the radial extension of the parallel electric field layer being of order 10 km vertical extension along the magnetic field. The velocity matches that of ion-acoustic waves for the parameters of the lower magnetospheric source region of AKR suggesting these are electrostatic ion-acoustic shocks evolving in density depletions in presence of two electron populations of high temperature ratio [2], in the auroral plasma a cold ($\sim$ eV) and a hot ($\sim$ keV) component [1]. The right part of the Figure shows the existence regions of these structures. Solitons are found in the closed areas of the curves below the abscissa, while shocks evolve where the curves become tangent to the abscissa. They occur for Mach numbers close to $M_s = 3.3$. The selected threshold value for shocks corresponds to $k_B T_c = 5$ eV, $k_B T_h = 1$ keV, and an effective temperature of $k_B T_{\rm eff} = 30$ eV, which gives an ion-acoustic speed $c_{\rm eff} = 50\,{\rm km\,s^{-1}}$ and a density ratio $n = n_h/n_0 = 85\%$, typical at the base of the auroral magnetosphere.





Left: *Spectral dynamics of a narrow emission band in auroral kilometric radiation. Though the emission band remains stable over the entire period of 9 s, its drift across the spectrum experiences severe changes in time. In the average the band is moving towards lower altitudes (increasing frequency) suggesting that the source is riding on the auroral electron beam in the upward current AKR source region. The average drift speed re-calculated into real space corresponds to the ion-acoustic velocity.* Right: *The pseudo-potential $\Psi(\Phi)$ as function of the normalized electrostatic potential $\Phi(\phi)$. The calculation has been performed for $n = n_h/n_c = 5$, $t \equiv t_h/t_c = 200$, and $t_i = 0.1$. Solutions are allowed only for negative values $\Psi < 0$ of Ψ. Finite 'discrete' (or 'harmonic') solutions are obtained in the range of Mach numbers corresponding to the localized minima in Ψ. Those solutions are supersonic and correspond to solitary structures. Electrostatic shock solutions are possible close to the upper limit of the allowed Mach number which in this case is $M_s \approx 3.3$. Close to M_s the potential becomes asymmetric, and a real field-aligned potential drop builds up across the structure.*

Electrostatic shocks are thus microscopic double layers having potential drops of $\phi \approx 600$ V-1 keV. This requires several such narrow shocks to occur on a field line.An estimate of their field extension $w_s \approx \sqrt{|\Delta\Phi|/(2\langle|\Psi(\Phi)|\rangle)}$ yielding values of 50 Debye lengths the order of 1 km. The transverse extension is thus also not more than a few km, identifying the flux tubes where particles are accelerated as extraordinarily narrow. AKR is their remote signature that can be used to infer about their spatio-temporal and potential structures. It is interesting that such regions serve as particle accelerators of high efficiency

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