MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Influence of the charge moment change on sprite initiation altitude

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➢ Scope

- Develop a simplified and efficient numerical scheme to study the sprite problem;

- Study the effects of the charge moment change in the sprite initiation altitude.

Sprite model

The work here presented is a theoretical/computational study of the sprite inception mechanism based on the quasi-electrostatic approximation [*Pasko et al*., 1997] and the streamer-fluid model [*Luque and Ebert*, 2009].

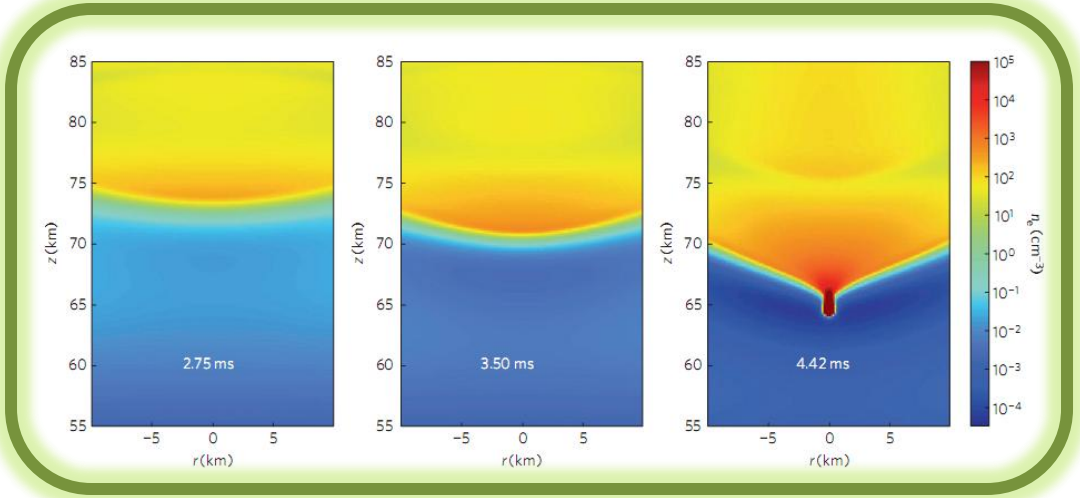
➢ Gas discharge model

$$\frac{\partial n_e}{\partial t} = \vec{\nabla} \cdot (\mu_e n_e \vec{\mathbf{E}} + D_e \vec{\nabla} n_e) + (\nu_i - \nu_a) n_e + S_{ph}$$

$$\frac{\partial n_p}{\partial t} = \nu_i n_e + S_{ph}$$

$$\frac{\partial n_n}{\partial t} = \nu_a n_e$$

$$\nabla^2 \phi = -\frac{e(-n_e + n_p - n_n)}{\varepsilon_0}$$



Luque and Ebert [2009]

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$$\Delta z = \Delta r = 100\text{m}$$

$$\Delta t = 0.1 \mu\text{s}$$

First order Eulerian integration

$$(n_e)_{i,j}^{k+1} = (n_e)_{i,j}^{k} + \Delta t \, S_{i,j}^{k}$$

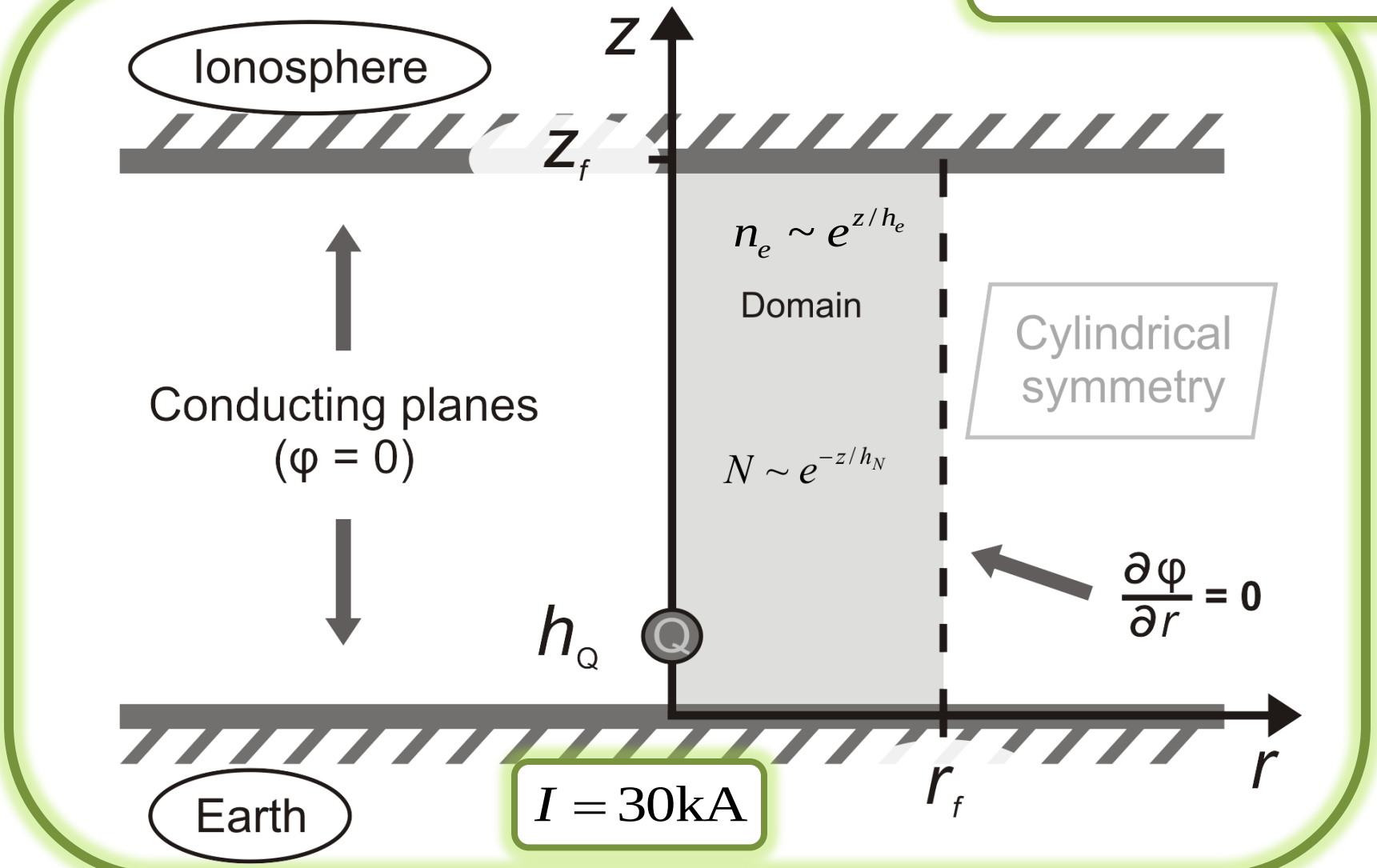
Overrelaxation method (SOR)

$$\phi_{i,j}^{l+1} = \omega \phi_{i,j}^{\text{SOR}} + (1 - \omega) \phi_{i,j}^{l}$$

➢ Simulation domain

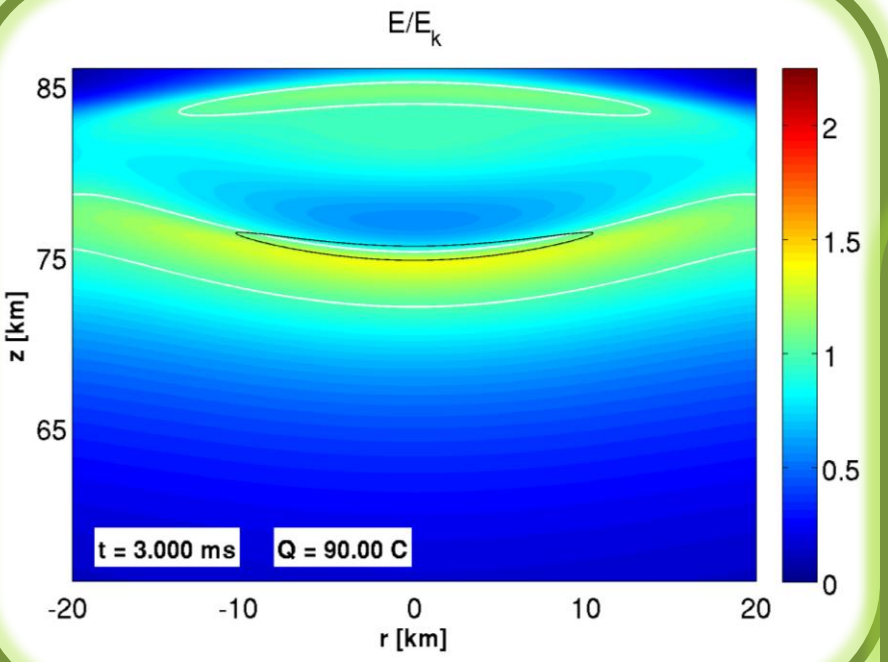
Initial conditions

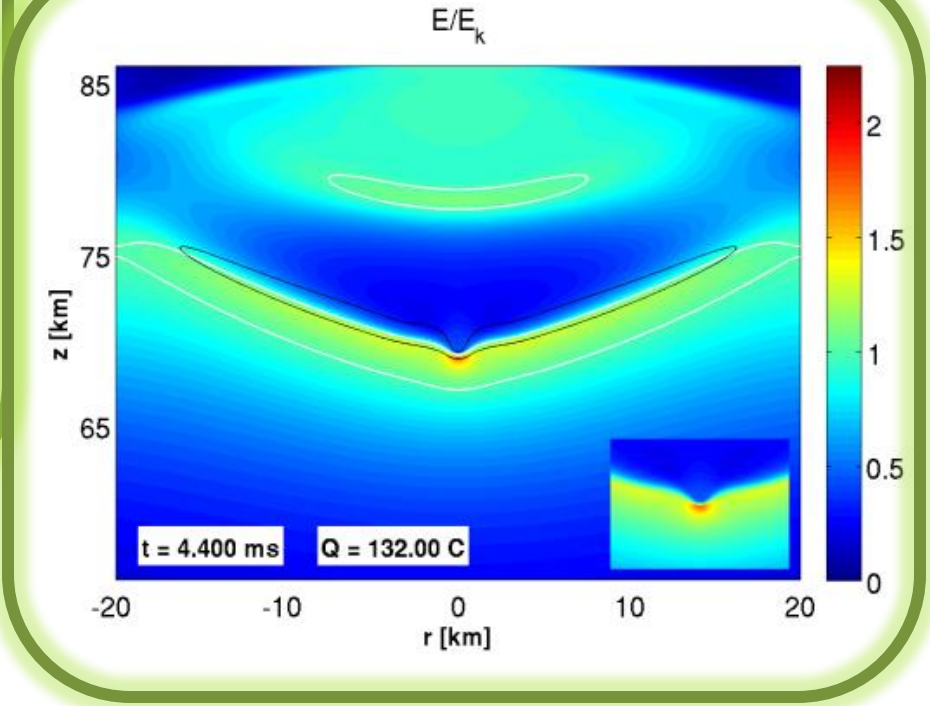
$n_e = n_p \quad n_n = 0 \quad \phi = 0$



Results

➢ Screening-ionization wave

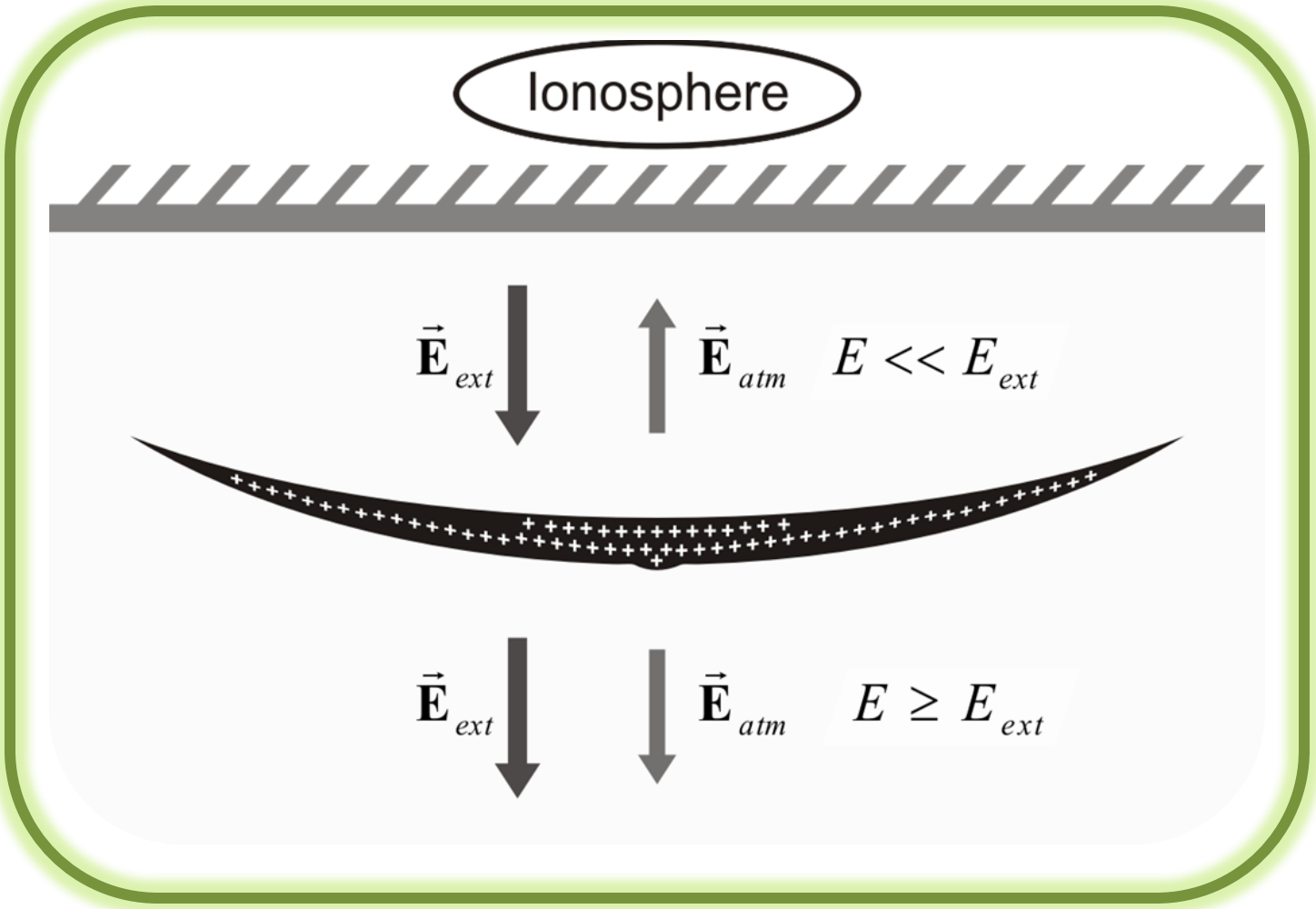




○ $E > E_k \equiv (3.23\times10^6\,\mathrm{V/m})\dfrac{N}{N_0}$

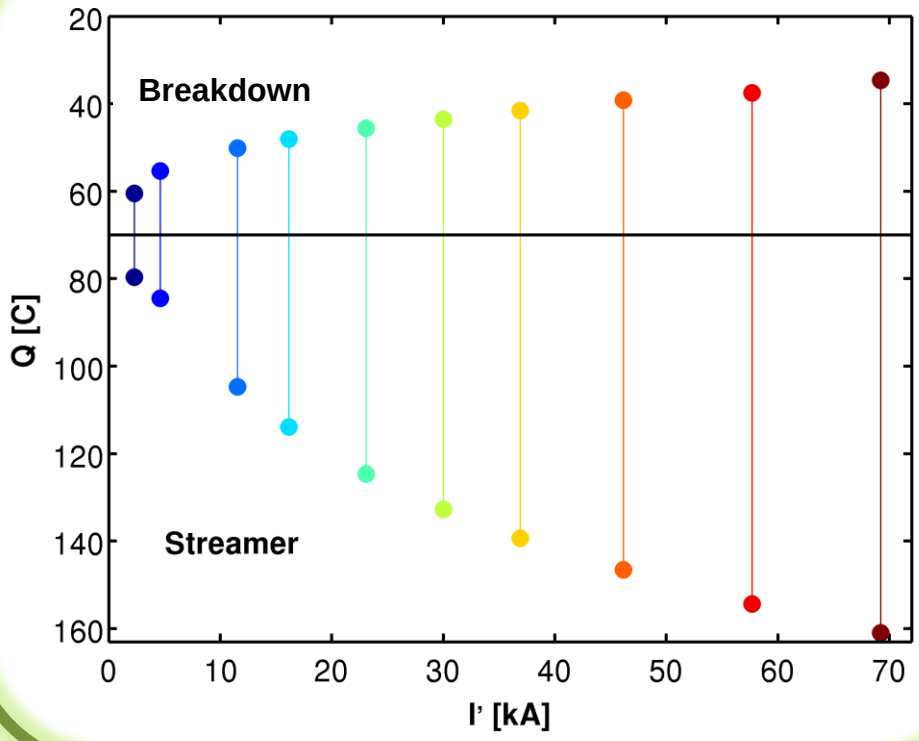
● $\rho \equiv q_e(-n_e + n_p - n_n) > 4\times10^{-12}\,\mathrm{C/m^3}$

➢ Physical mechanism



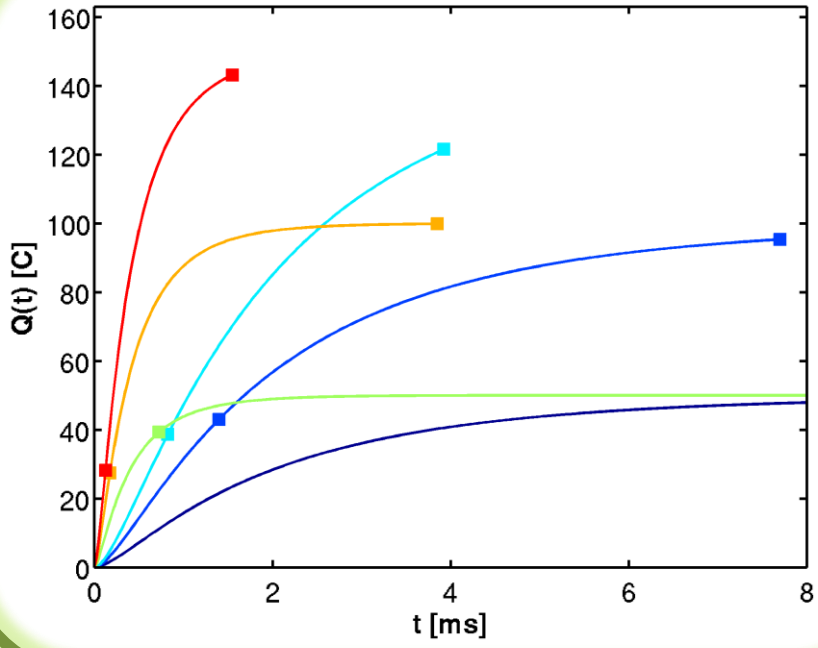
- Space charge strongly modifies the electric field.

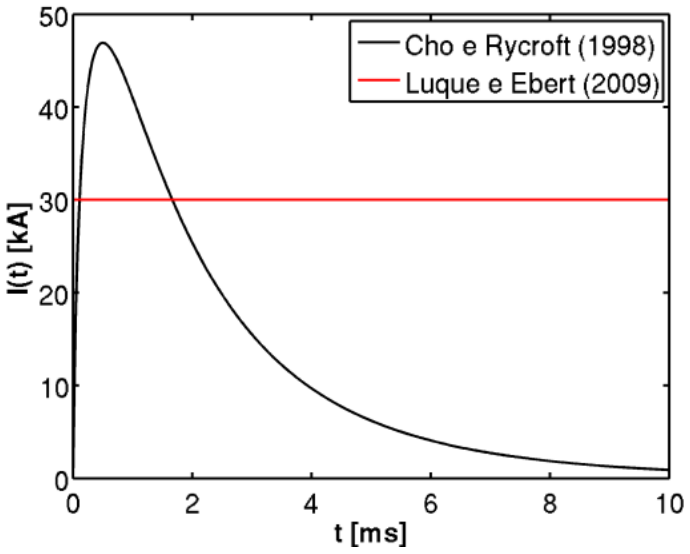
➢ Lightning current

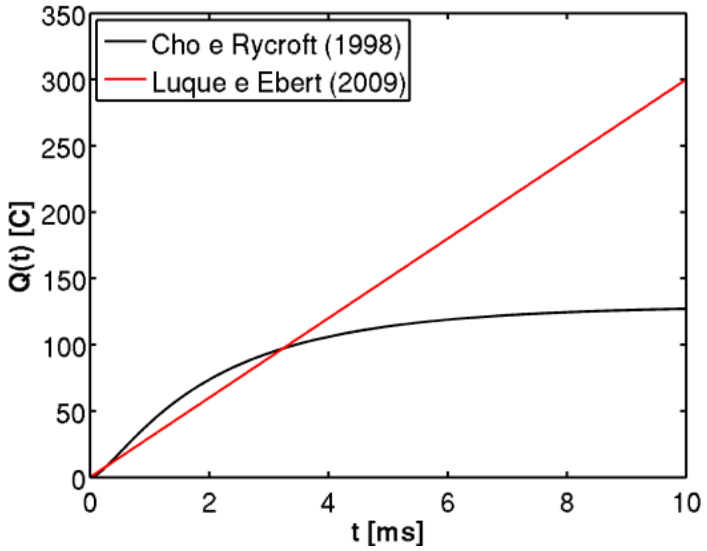


- The faster the current, the lower is the amount of charge to produce breakdown;
- Slower currents produce streamer with the removal of less charge, due to the field penetration mechanism.

➢ Realistic lightning current waveshape

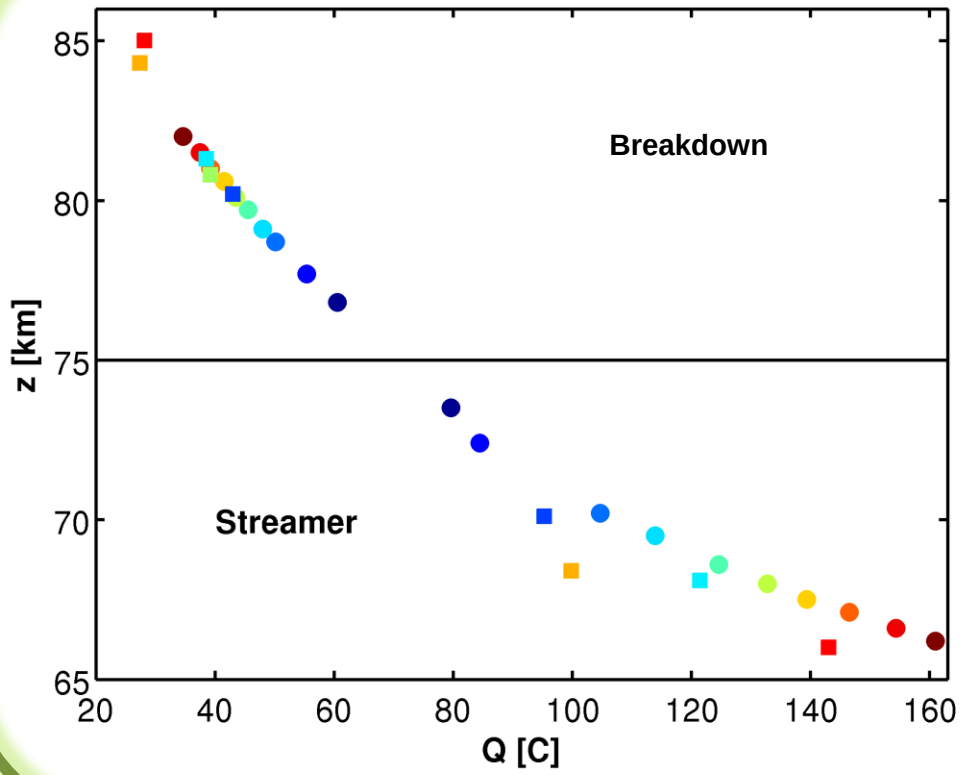






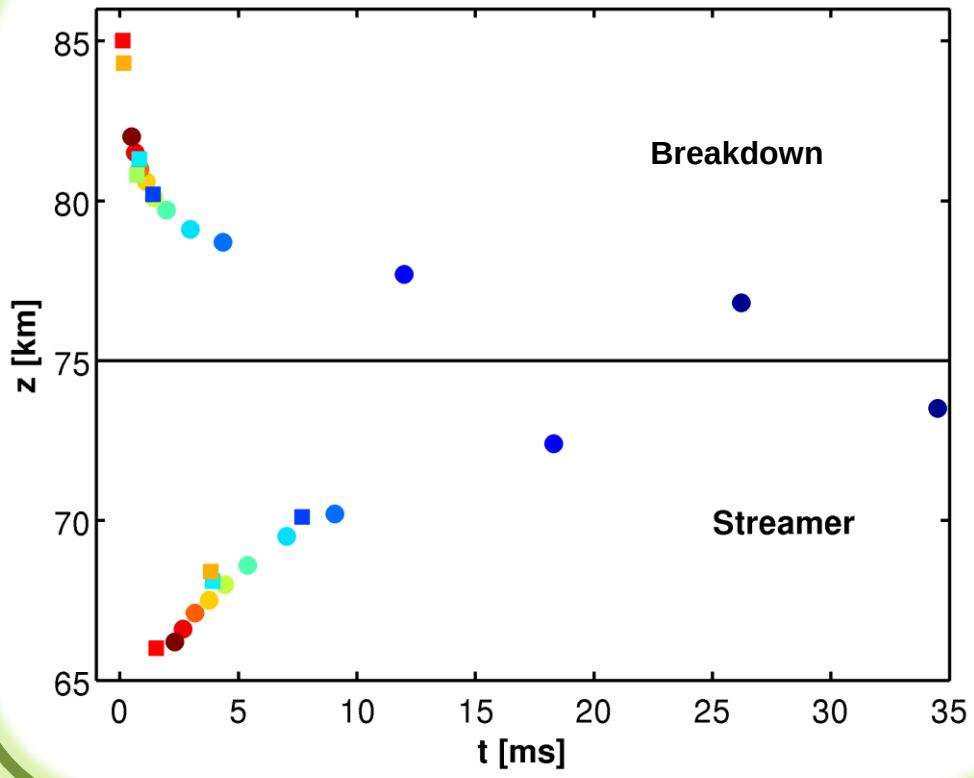
- Higher ionization in early stages and longer delay between streamer and breakdown.

➢ Relationship between altitude and charge moment change



- The downward development of the wave triggers a physical relationship between altitude and charge removed;
- More charge removal is required to produce breakdown and streamer in lower altitudes.

➢ Relationship between altitude and time delay



- More impulsive lightning produce breakdown in upper altitudes and streamers in lower;
- Long-delayed sprites are initiated in higher altitudes than short-delayed.

Conclusions

➢ Conclusions

- Slower currents produce streamer with the removal of less charge;
- The realistic lightning current waveshape produces higher ionization in early stages and longer delay between breakdown and streamer;
- More charge removal is required to produce breakdown and streamer in lower altitudes;
- More impulsive lightning produce breakdown in upper altitudes and streamers in lower;
- Long-delayed sprites are initiated in higher altitudes than short-delayed.

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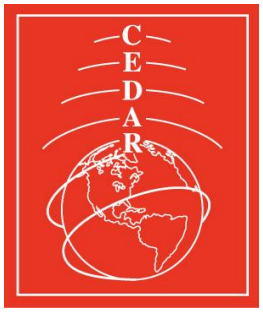

Thank you!

Look for me in the poster session to more detailed discussions!