# (1) Kinetic Effects of Intense E-Fields on Plasmas and (2) Large-scale Simulations of the Farley-Buneman Plasma Instability in the Auroral Electrojet


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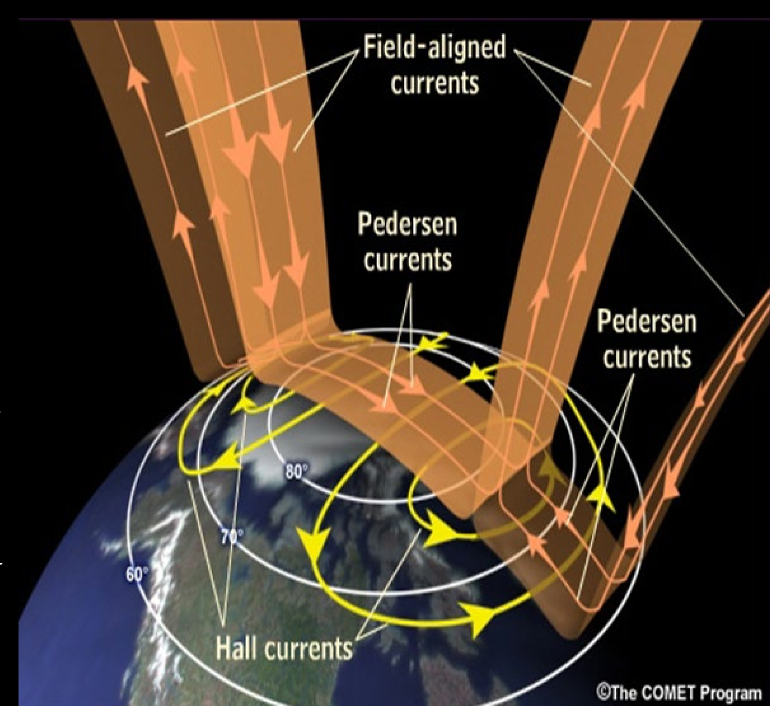
## Motivation

- Geomagnetic storms drive intense electric fields through the high-latitude E-region of the ionosphere.
- These fields drive the Farley-Buneman (FB) and the gradient drift (GD) plasma instabilities.
- These instabilities modify the conductivities and temperatures of the auroral electrojet.



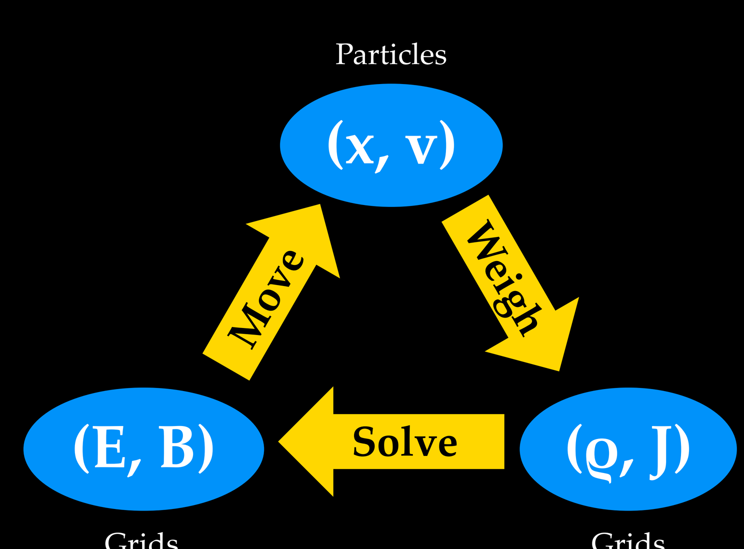

## Scientific Questions

(1) What are the kinetic effects of intense electric fields on the background ions in the E-region ionosphere?
(2) How does a spatially-varying ion-neutral collision rate affect the development of the Farley-Buneman (FB) instability?

## Method: EPPIC

- We performed 3D plasma simulations using EPPIC — the electrostatic parallel particle-in-cell simulator.

### How do PIC codes work?




## Kinetic BGK Collisional Model

- The Boltzmann equation with the BGK collision term is given by:

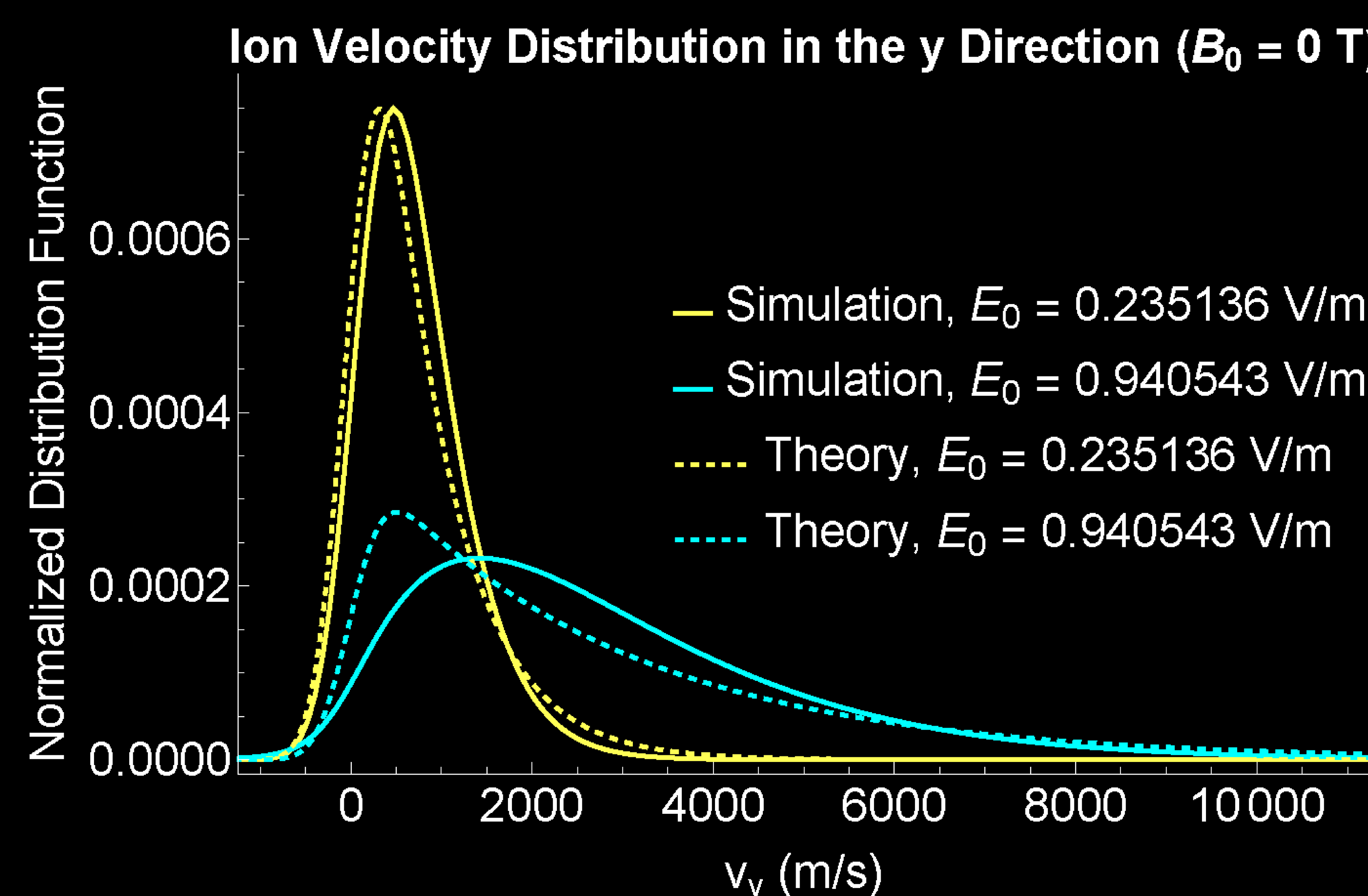
$$\frac{\partial f}{\partial t} + \frac{e}{m_i}\vec{E}\cdot\frac{\partial f}{\partial \vec{V}} + \vec{V}\cdot\frac{\partial f}{\partial \vec{r}} = -\nu_i\left(f - \frac{n_i(\vec{r},t)}{n_0} f_0^{Coll}\right),$$

where $f_0^{Coll}(\mathrm{V}) \equiv n_0\left(\frac{m_i}{2\pi T_n}\right)^{3/2}\exp\left(-\frac{m_i V^2}{2T_n}\right)$.

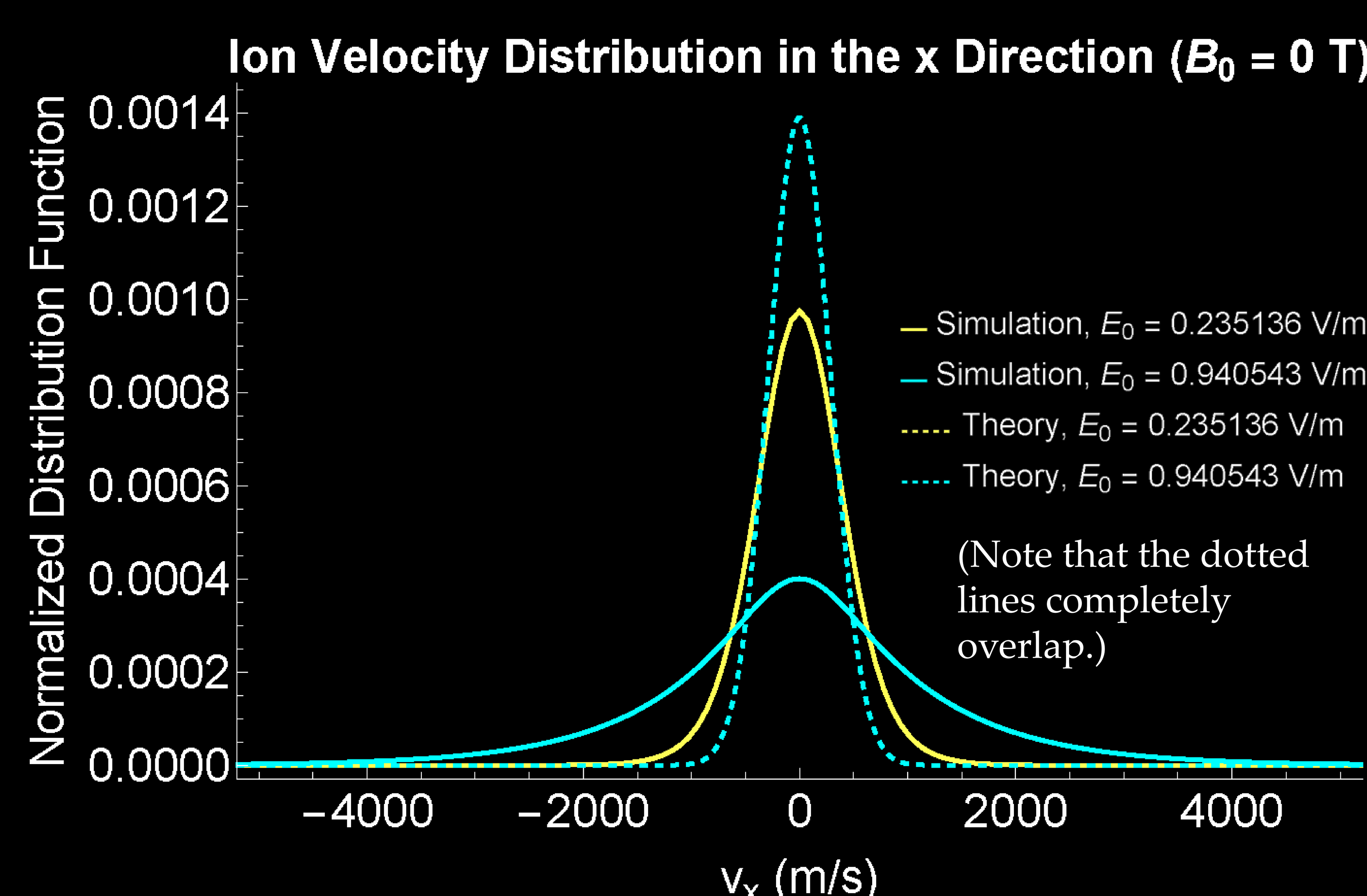
- We compare the solutions of the above equation (dotted lines) with the resulting ion velocity distribution functions from the simulations (solid lines).

## Effects of Intense E-Fields on Background Ions

### In the direction parallel to $E_0$:




### In the directions perpendicular to $E_0$:




The distribution in the z direction looks the same and is thus not shown.

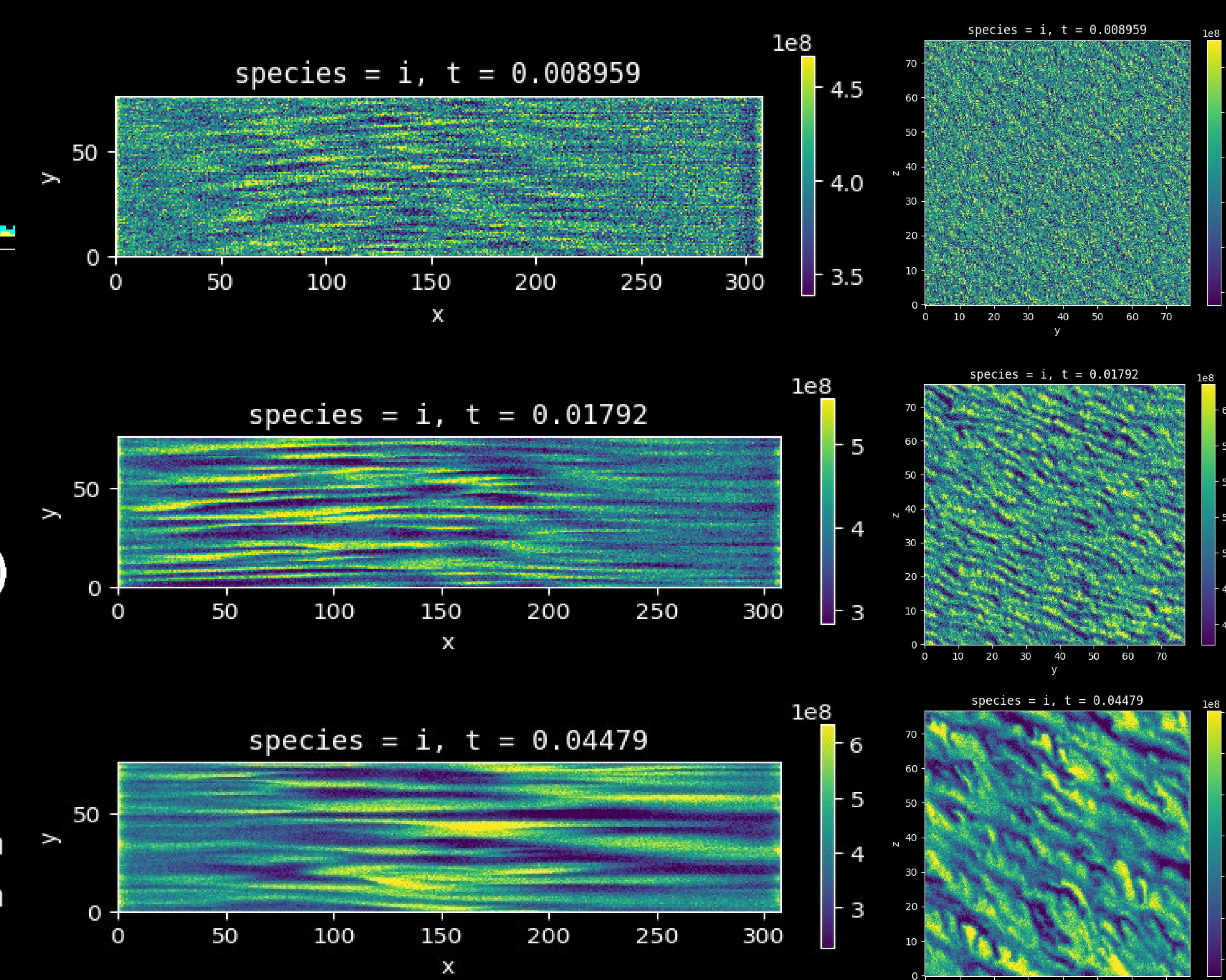
## Directional Heating Comparisons

HE: High E ($E_0$ = 0.235136 V/m), VHE: Very High E ($E_0$ = 0.940543 V/m)

| | $v_{th,x}$ (m/s) | $v_{th,y}$ (m/s) | $v_{th,z}$ (m/s) | $\sum v_{th}^2$ (J/kg) |
|---|---|---|---|---|
| HE Sim | 444 | 606 | 444 | 761508 |
| *HE Theory* | *287* | *753* | *287* | *731747* |
| VHE Sim | 1384 | 2157 | 1384 | 8483561 |
| *VHE Theory* | *287* | *2760* | *287* | *7782338* |

## Spatially-varying Collision Rate

- Collision rate decreases exponentially along x in these periodic simulations.




## Conclusions

(1) As predicted by the kinetic BGK collisional model, intense E-fields do distort the shapes of the ion distribution functions.
- The model overestimates the heating in the Pedersen direction (y) while underestimating the heating in the directions perpendicular to $E_0$ (x and z).
- The total thermal energies between the simulation and the model generally agree.

(2) A spatially-varying collision rate causes the FB instability to develop non-uniformly.