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Effects of electron particle physics in global planetary models

Giovanni Lapenta

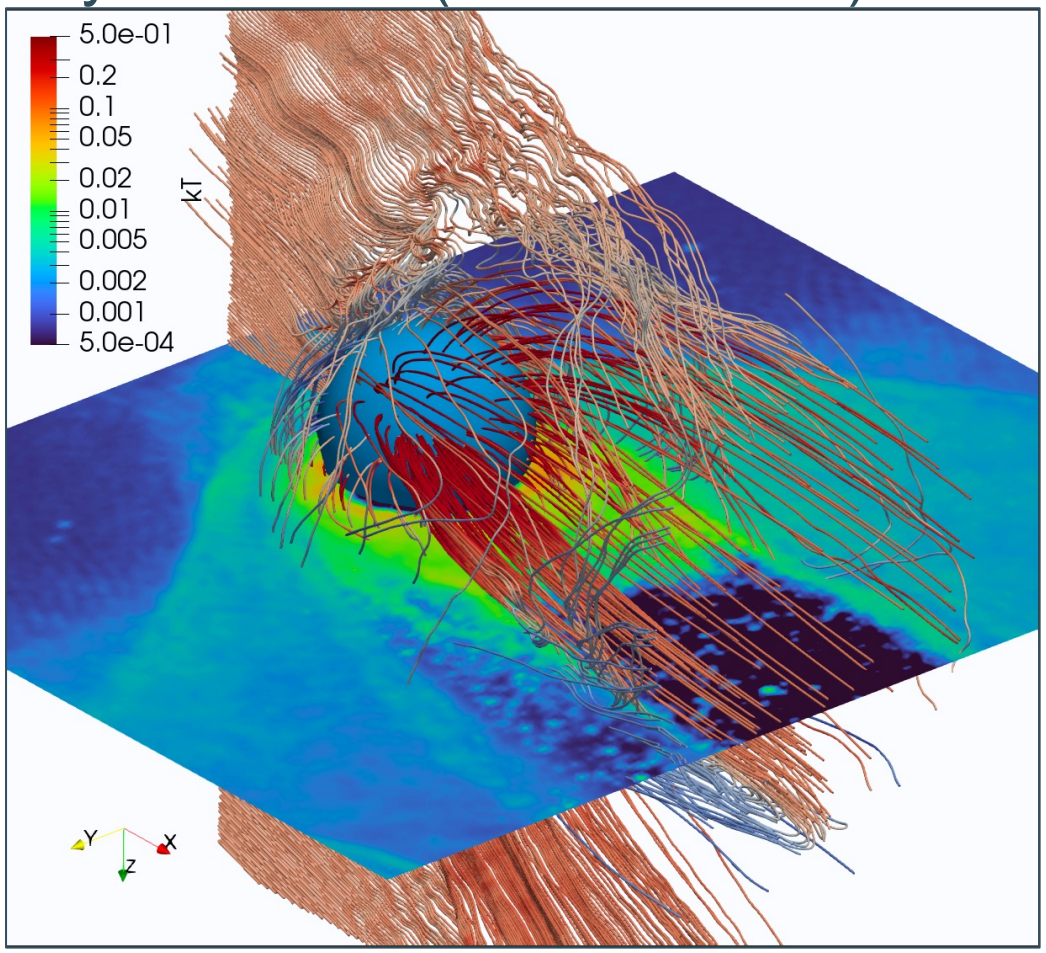
D. Schriver, H. Baeke, N. Echterling, R.J. Walker, M. El-Alaoui, P. Travnicek

EGU General Assembly, Vienna, April 25, 17:50 CEST

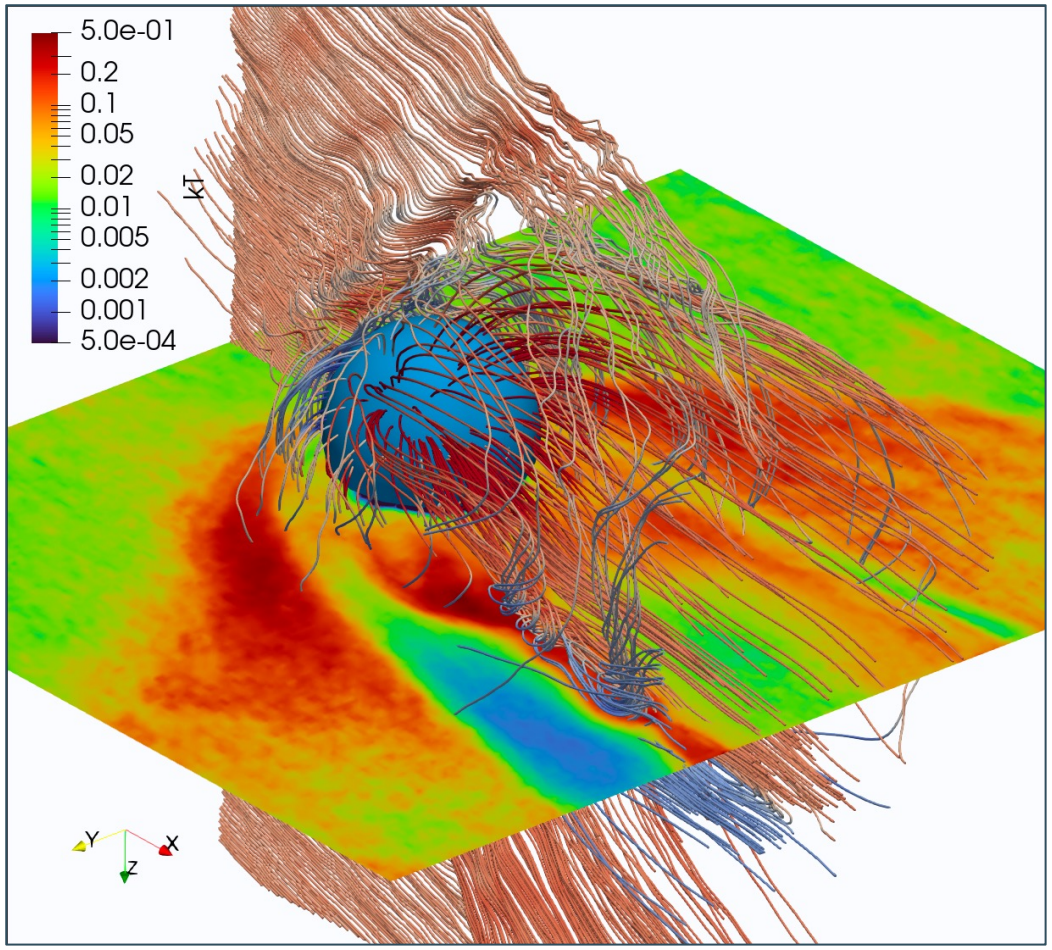
We modelled Mercury but can we model the Earth?

Electron Temperature in keV

Hybrid model (fluid electrons)



Full PIC (kinetic electrons)



Lapenta, et al., J*GR 127, e2021JA030241* (2022).

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The enabler is the implicit particle in cell method in iPic3D-Ecsim

SPACE

DEEP Projects

European Commission

Heterogeneous Computing
Space Weather

NASA

MMS Mission and
Heliospheric Grand Challenge

intel

Intel Exascience Lab

R&D 100

Bringing PIC to petascale

Adaptive methods and implicit PIC

Vector computers

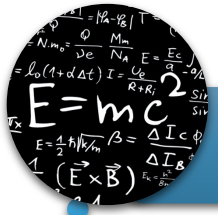
Los Alamos NATIONAL LABORATORY EST.1943

Heterogeneous computing

GPU-CPU

New direction

Energy conservation



2017: ECsim

Lapenta, JCP, 2017

Distributed computing

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2010: iPic3D

Markidis, Lapenta, MCS, 2010

Krylov methods

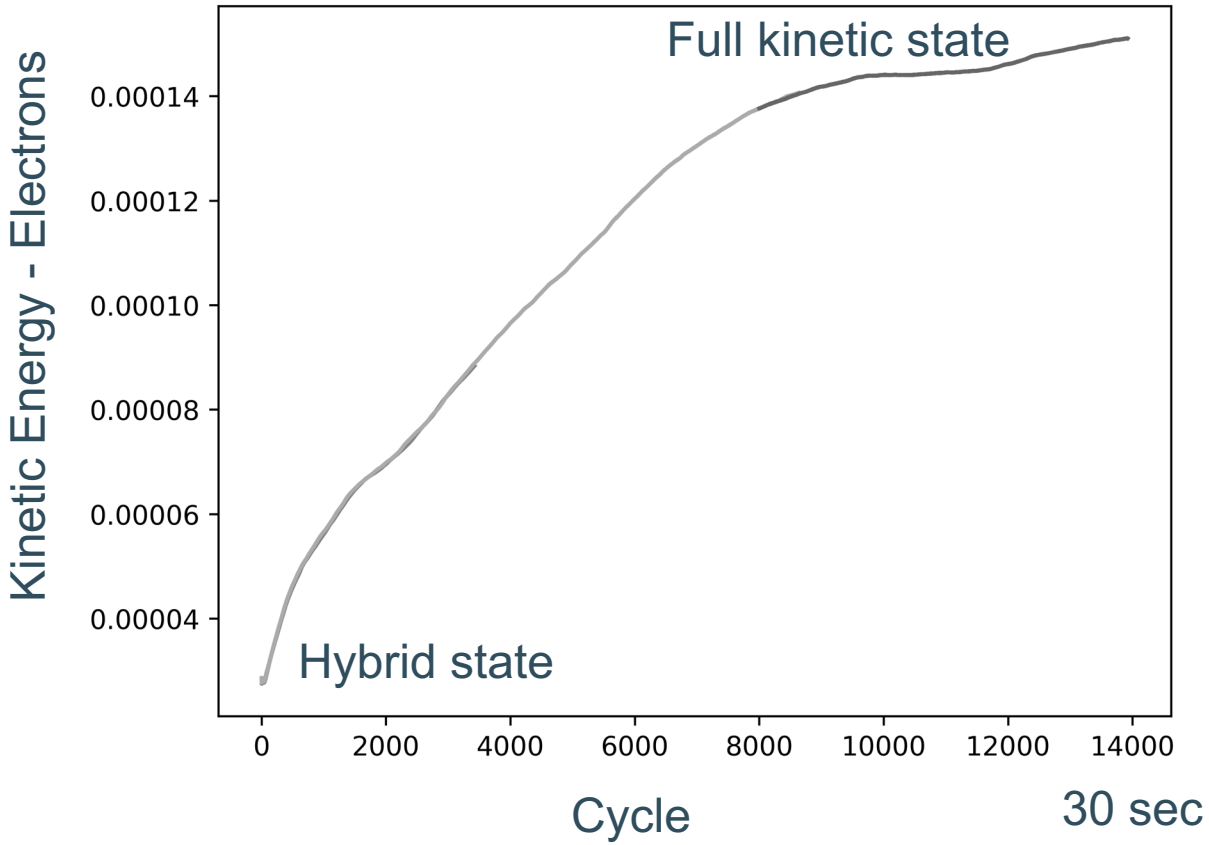
2005: Parsek

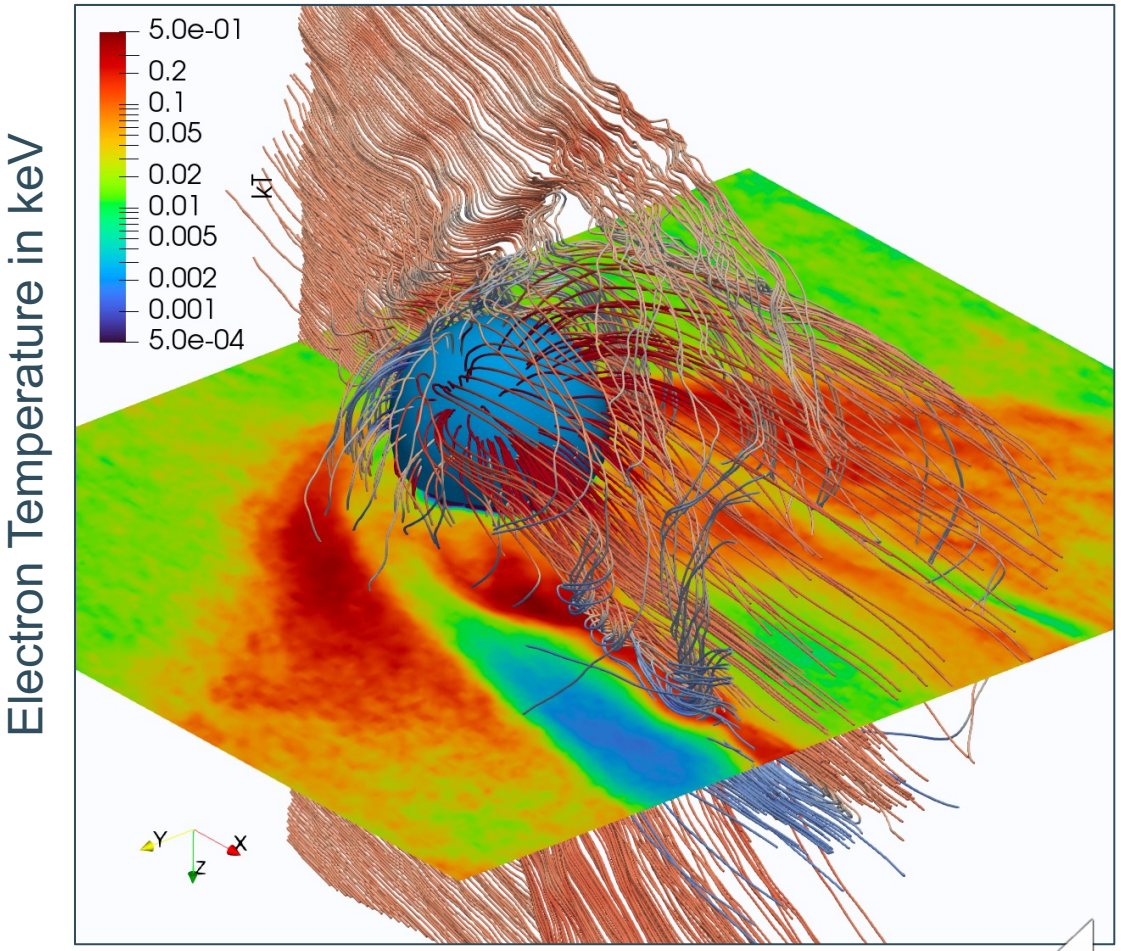
2005 RD100 Prize

1992: Celeste

Lapenta, et al., PoP, 2005

Electron total kinetic energy

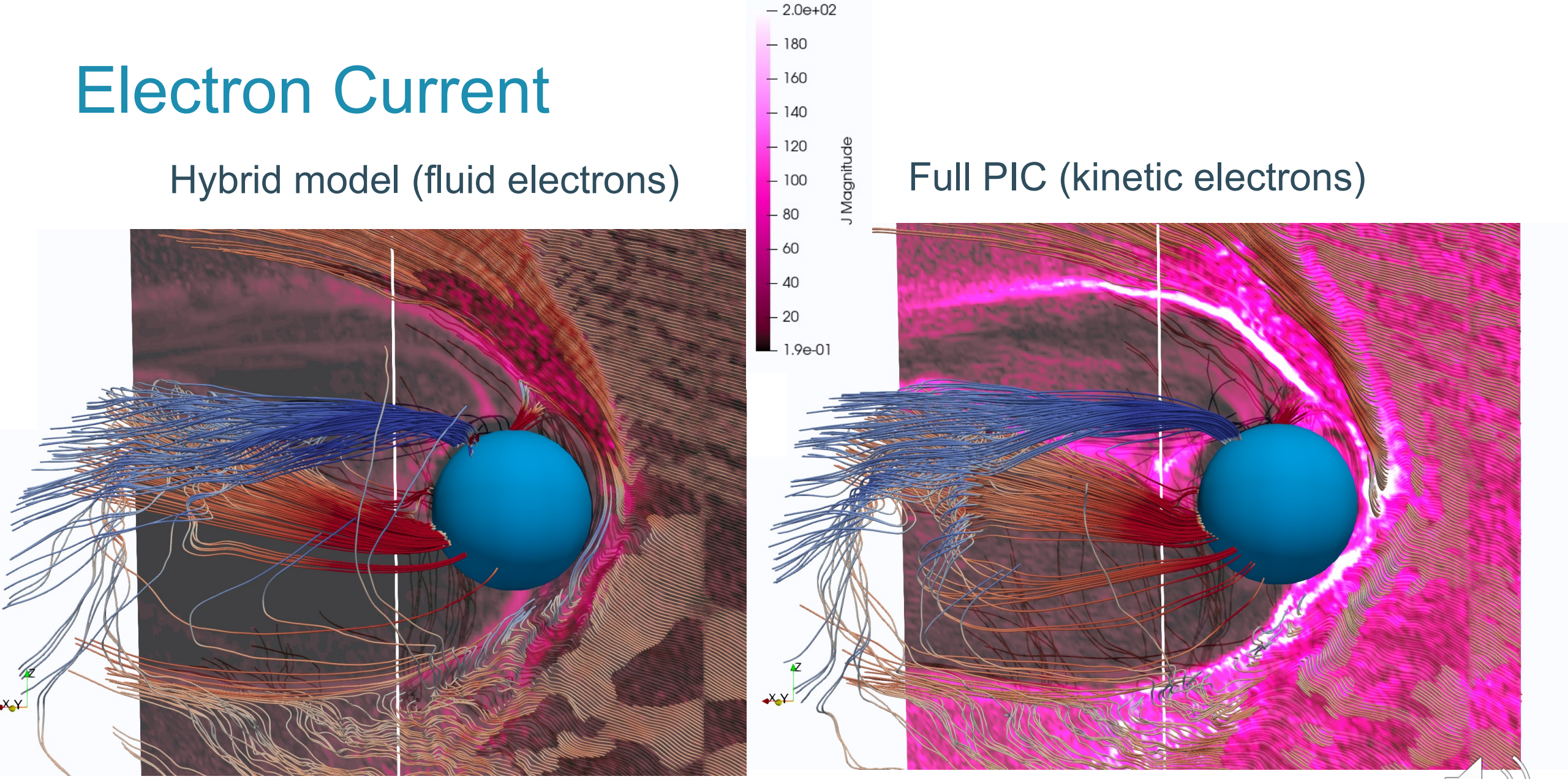




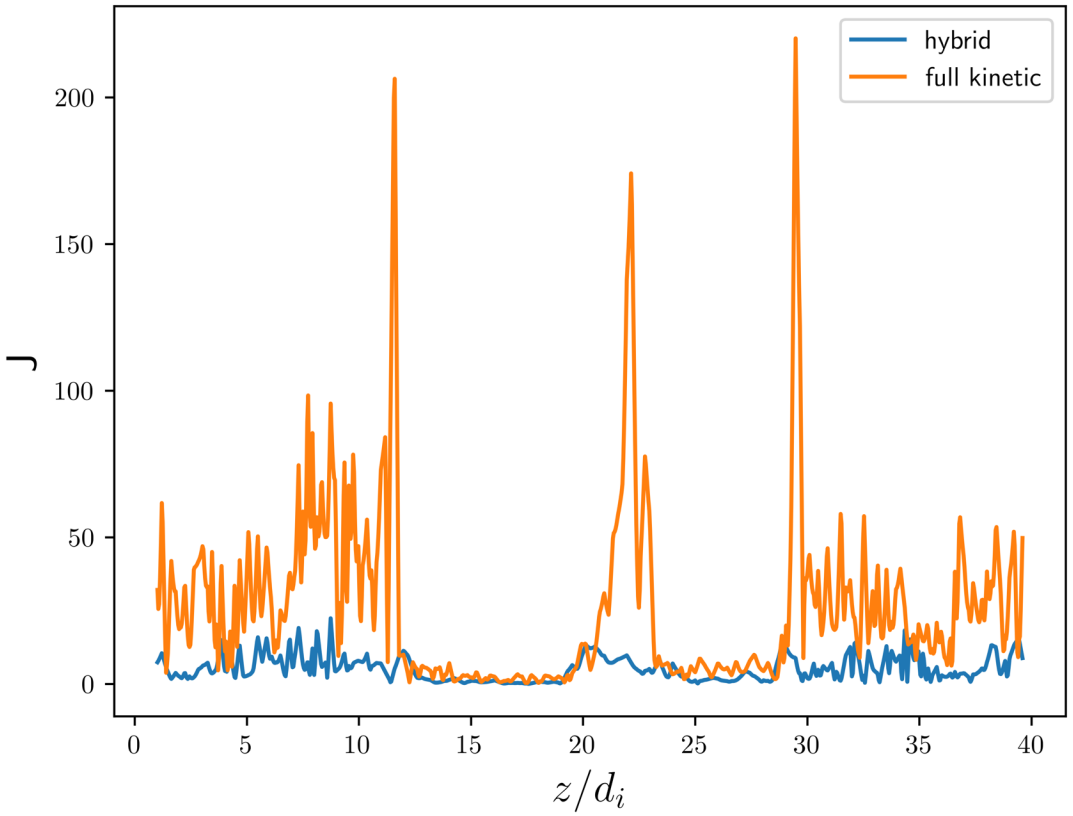
Electron Current

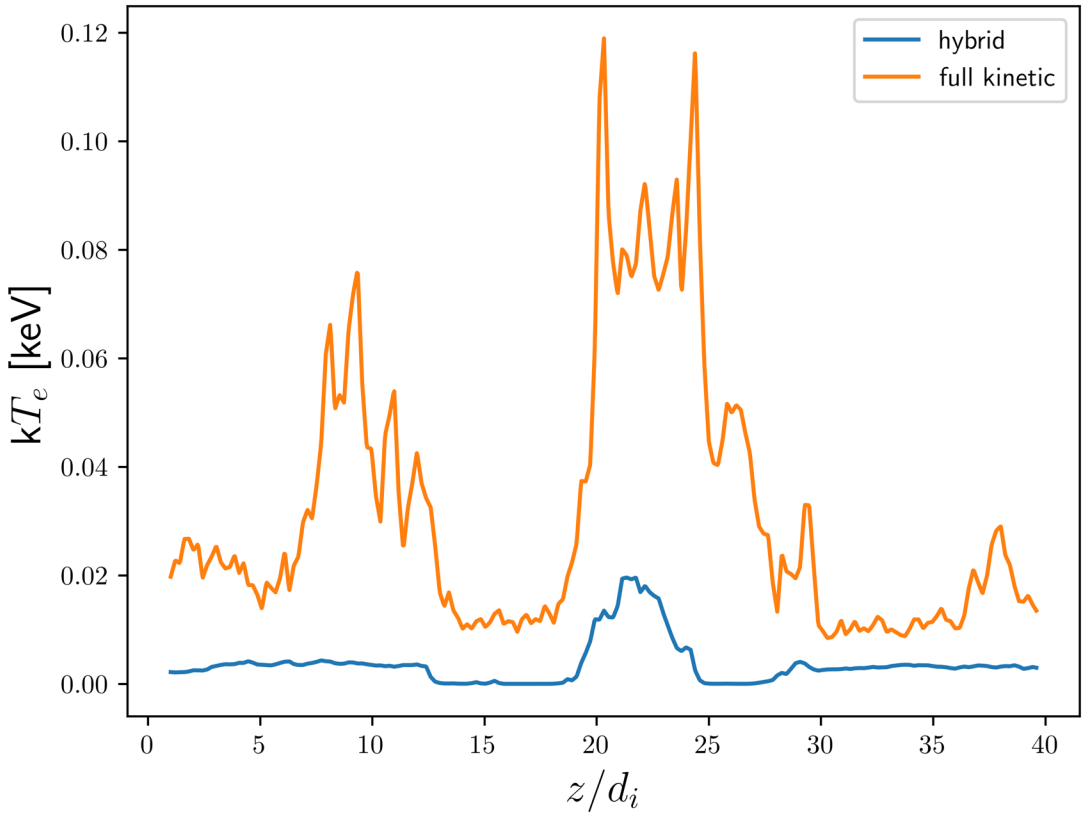
Hybrid model (fluid electrons)

Full PIC (kinetic electrons)



North-South fly through





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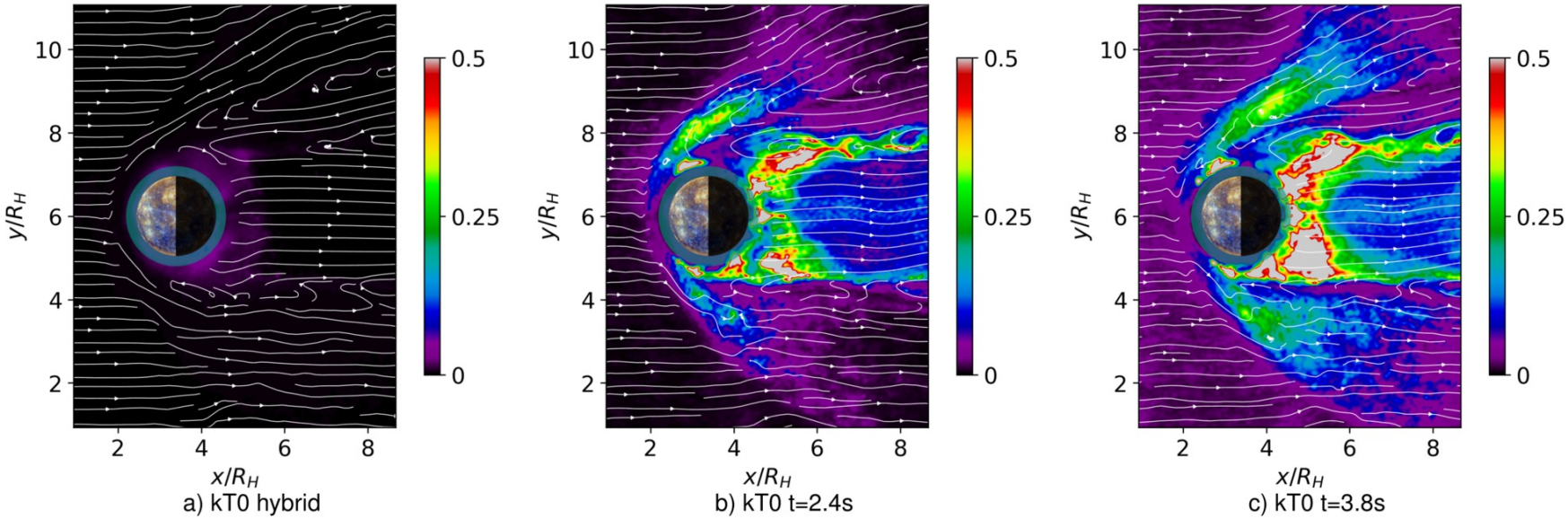
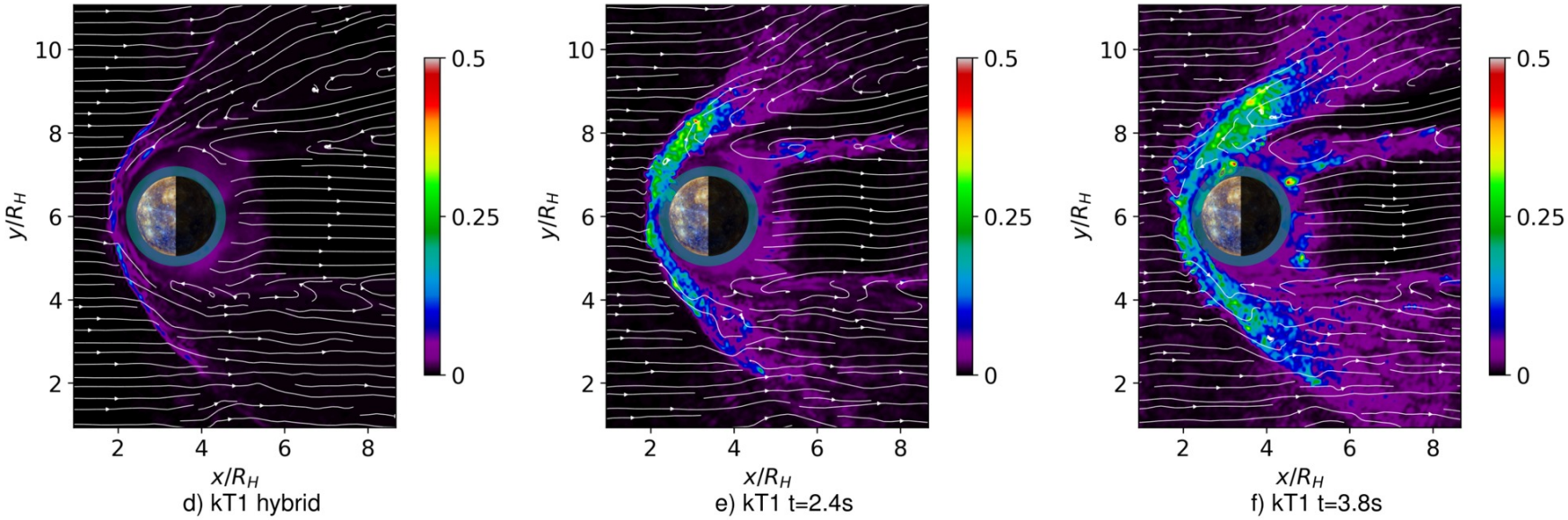
Energization

Electrons

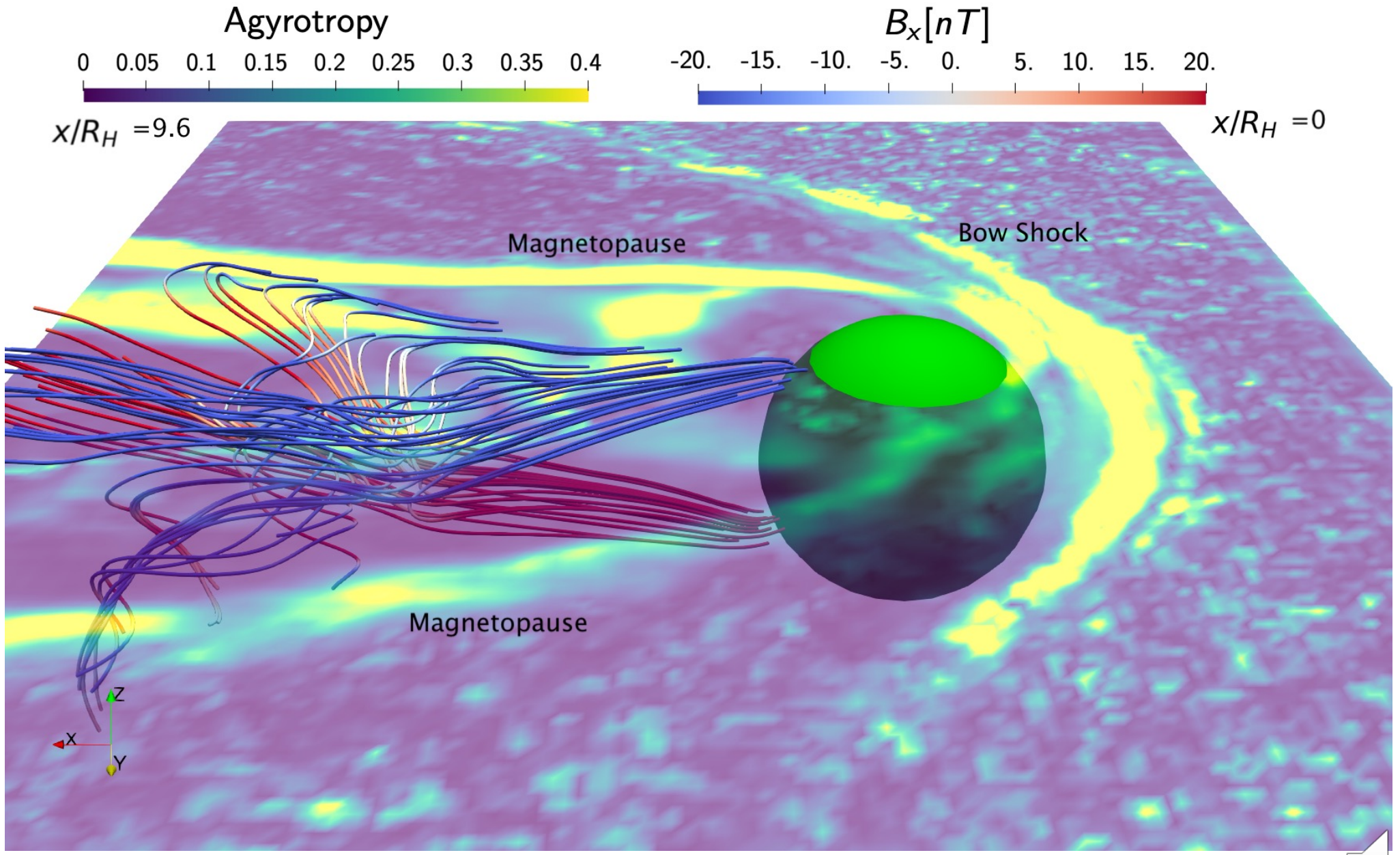


Ions



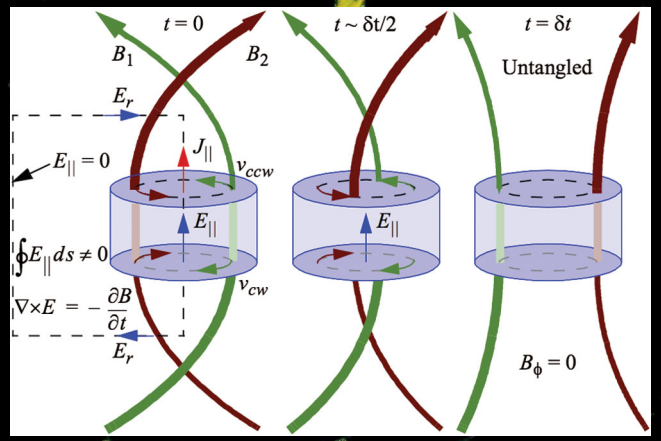
Lapenta, et al., JGR 127, e2021JA030241 (2022).

Reconnection regions



Lapenta, et al., JGR 127, e2021JA030241 (2022).

We use a precise reconnection identifier that is capable of including more complex 3D reconnection topologies, like tangling magnetic filed lines



Ergun, R. E., et al. PRL (2016): 235102.

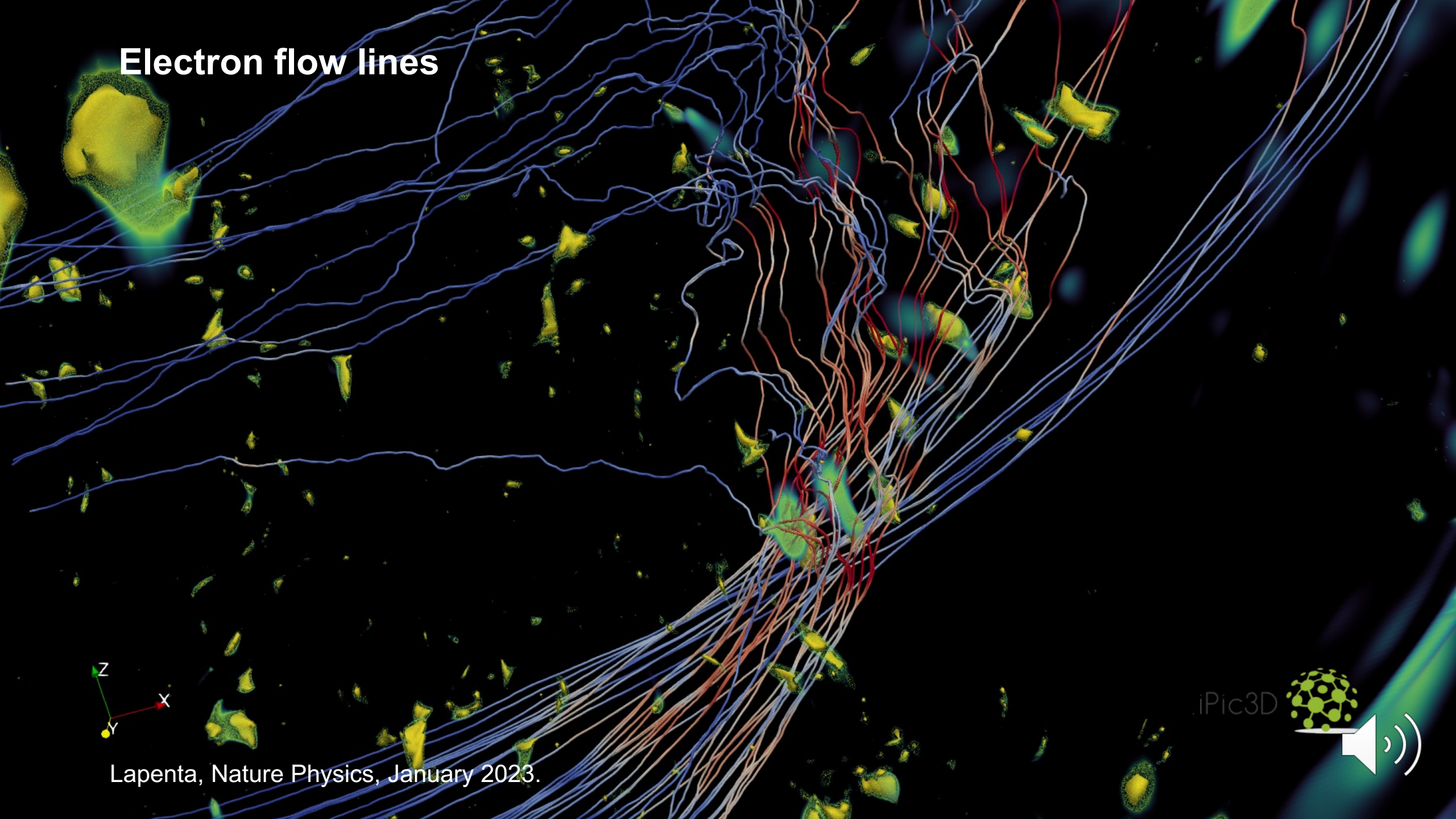
Lorentz Reconnection indicator
[Lapenta, ApJ 911.2 (2021): 147].

iPic3D

Vicinity of one 3D reconnection site

Lapenta, Nature Physics, January 2023.

Electron flow lines



Lapenta, Nature Physics, January 2023.

Conclusions

- Mercury-scale full PIC global models capturing both electron and ion scales are possible using **iPic3D-ECsim.**
- The electron scale particle physics induces:
  - ✓Stronger and more localized currents at interfaces
  - ✓Stronger energization of the electrons and the ions
  - ✓The processes of energization are linked with streaming instabilities and the formation of high energy populations
  - ✓Reconnection and turbulence interplay forming a myriad secondary reconnection sites
- Future work will need to use heterogeneous computers to model Earth (new **TerraVirtualE ERC Advanced Grant**)

Lapenta, et al., JGR 127, e2021JA030241 (2022).