The Physics of Pulsar Magnetospheres
June 6th 2016 - NASA GSFC

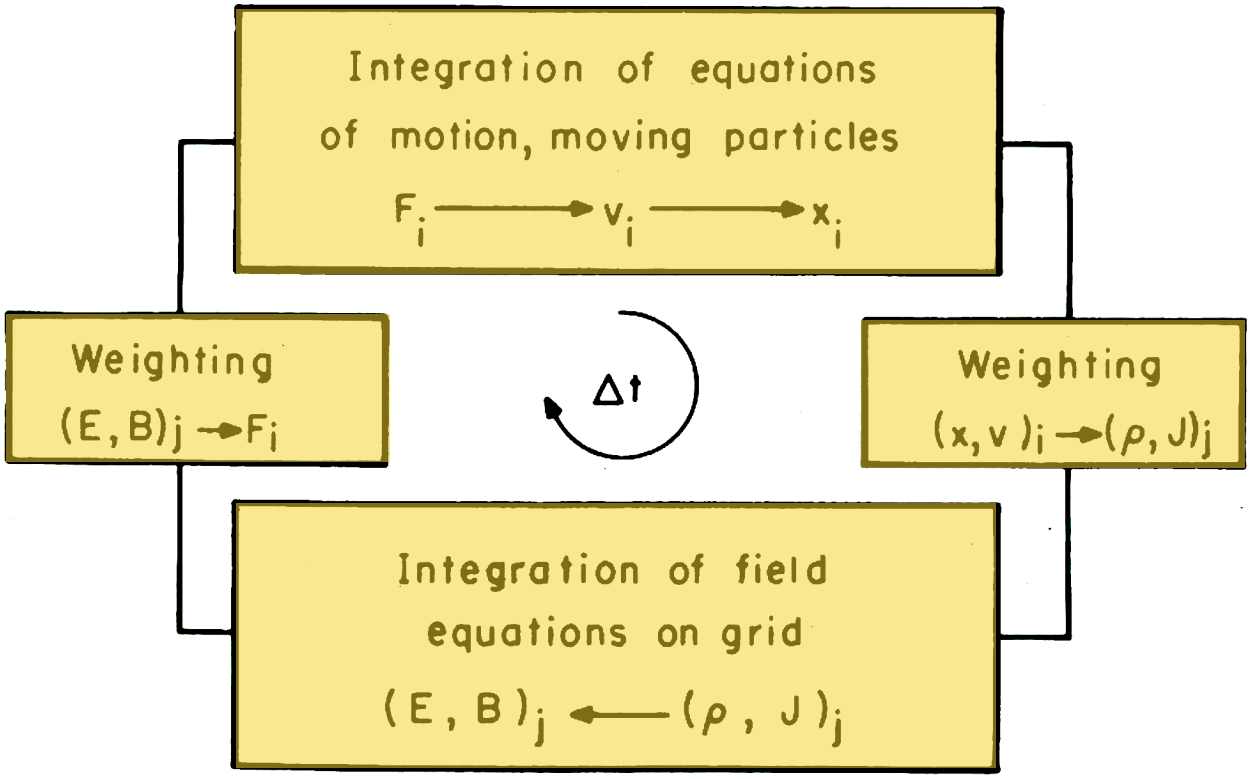
Developing of a specialized Particle-In-Cell code to study Pulsar Magnetospheres

Gabriele Brambilla
NASA GSFC, Università degli Studi di Milano

I'm a grad student and I work with:

Alice Harding
Andrey Timokhin
Constantinos Kalapotharakos
Demosthenes Kazanas

In PIC codes, particles moved by the fields form the currents that act on the fields themselves



Birdsall & Langdon 1985 *Plasma Physics via Computer Simulation* (New York: McGraw-Hill)

3D Cartesian

Electromagnetic
Relativistic pusher
Parallelized

PML

perfectly matched layer

Domain size

physical 3.0 R_{LC}
with PML 3.6 R_{LC}

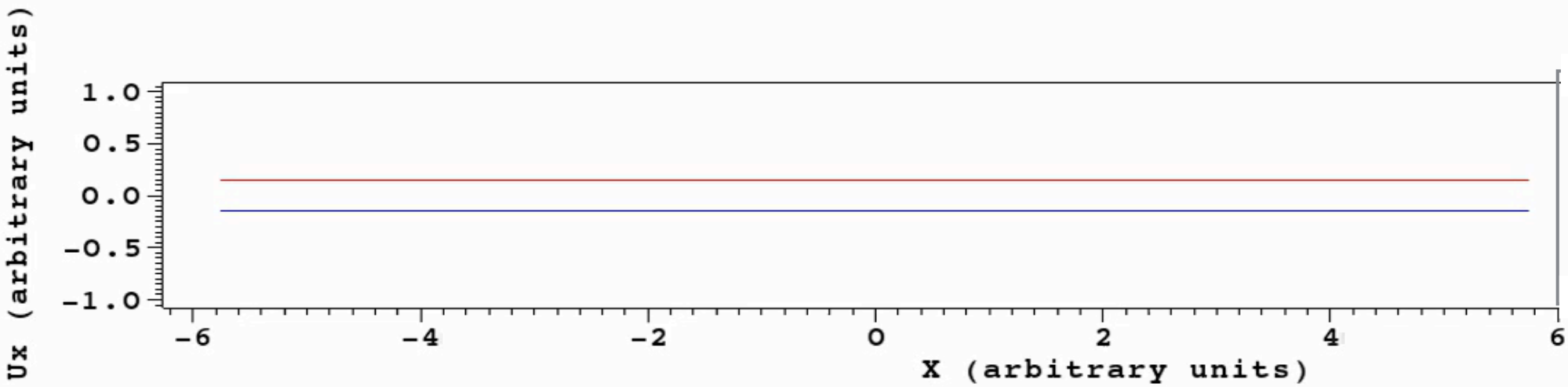
Resolution (max)

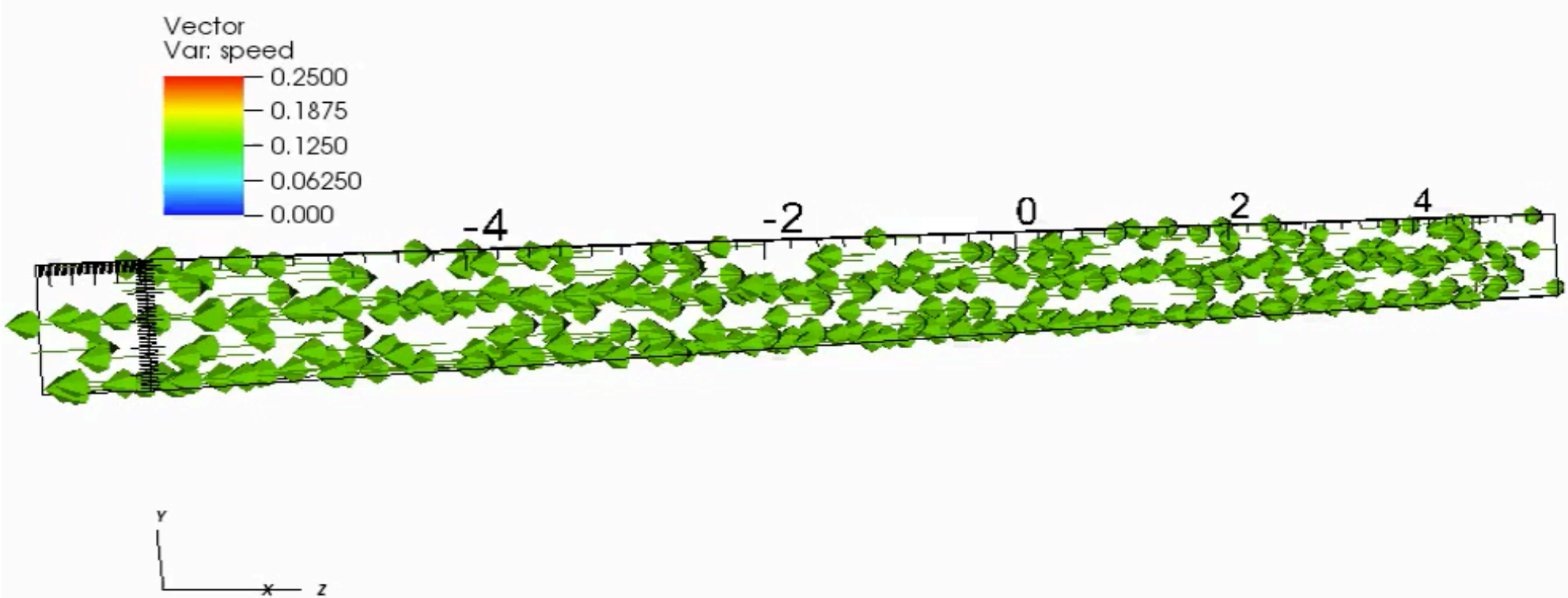
720^3 cells
1.5 10^9 particles

All the simulation run on Discover - NASA NCCS

Most of the plots and videos are done with VisIt (produced by LLNL)

We tested our code with typical plasma problems, like the two stream instability





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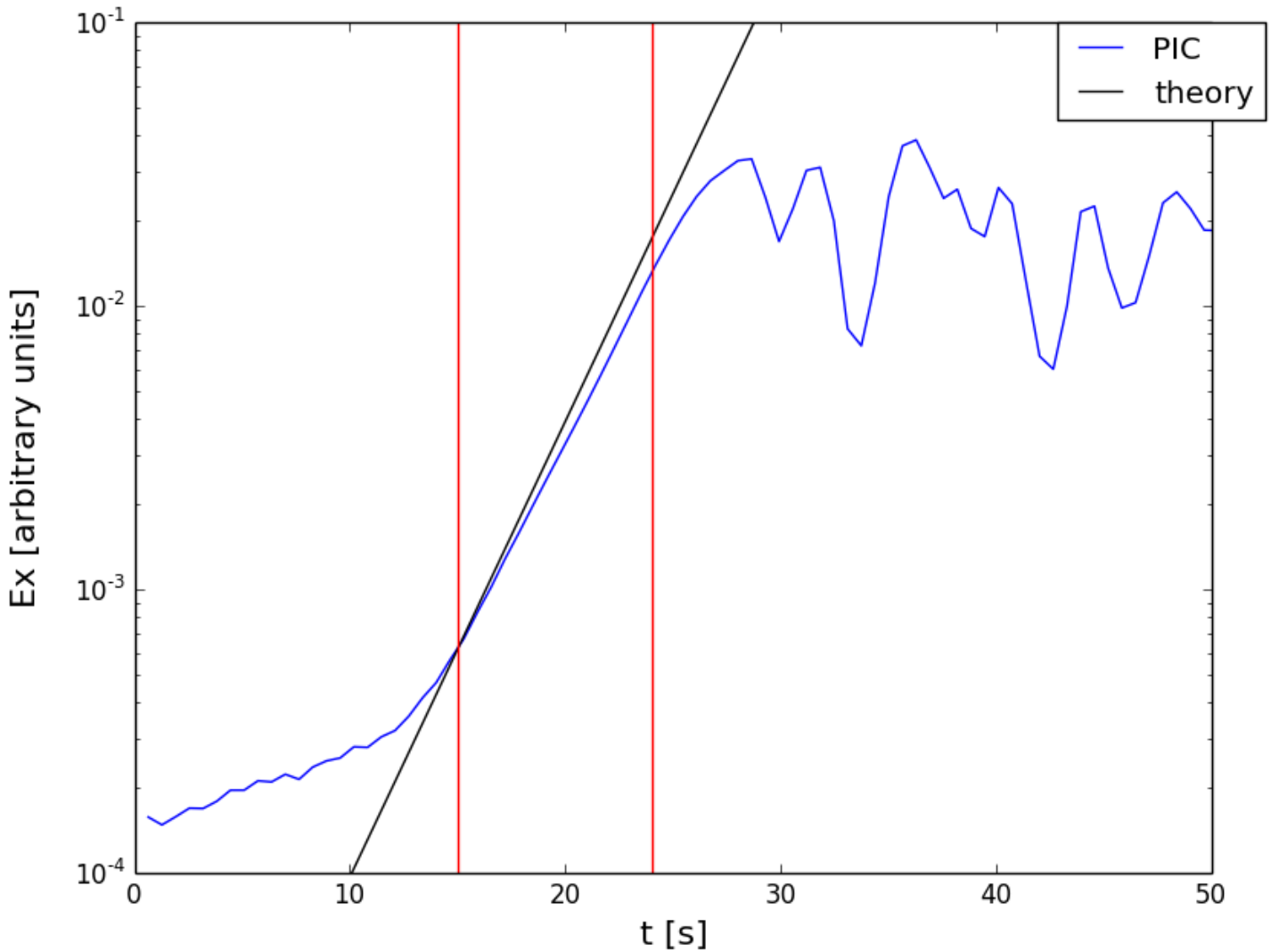
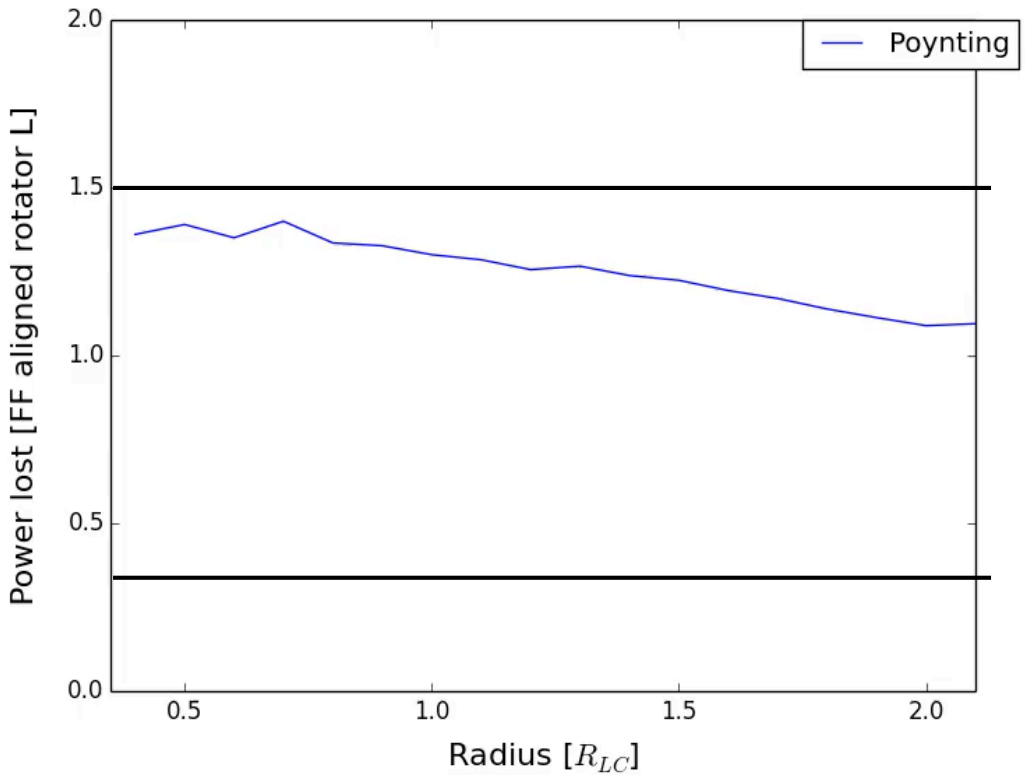
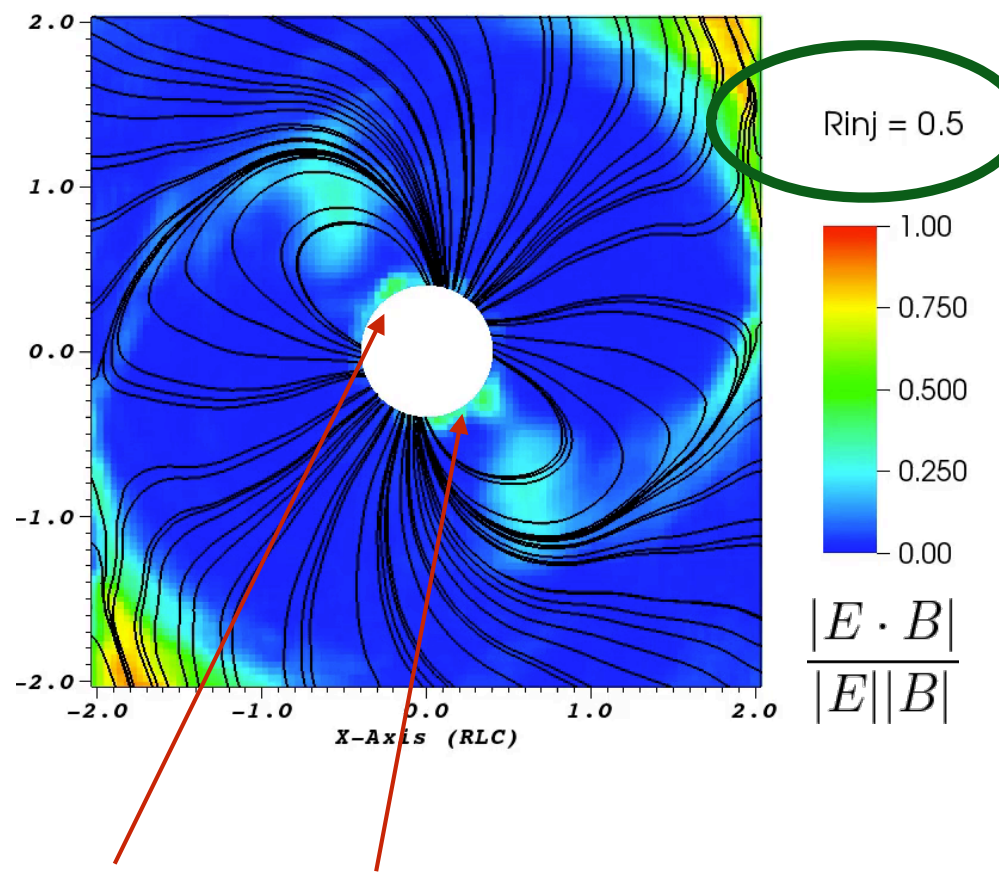


We inject neutral plasma everywhere until we reach a lower magnetization limit inside a fixed radius





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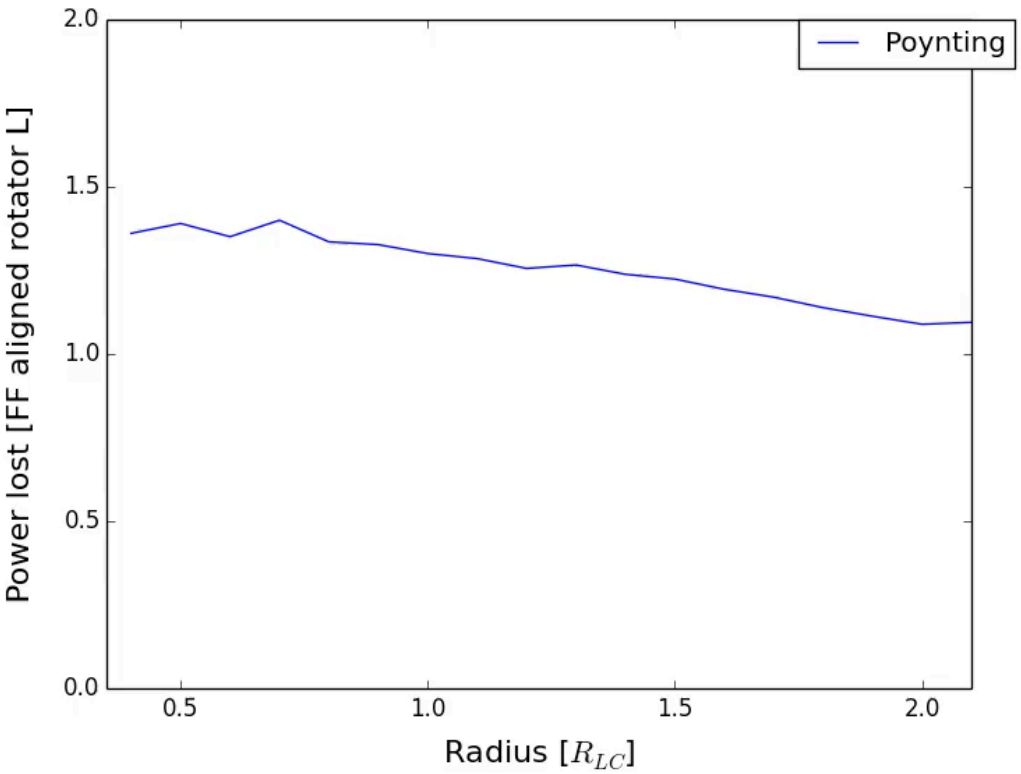

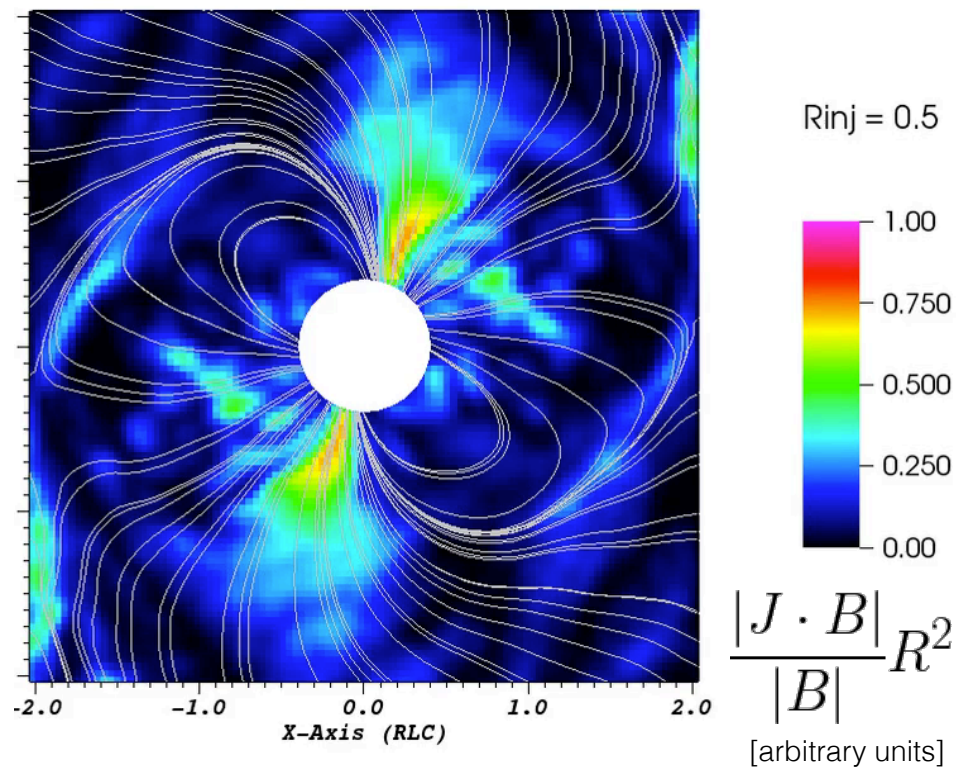

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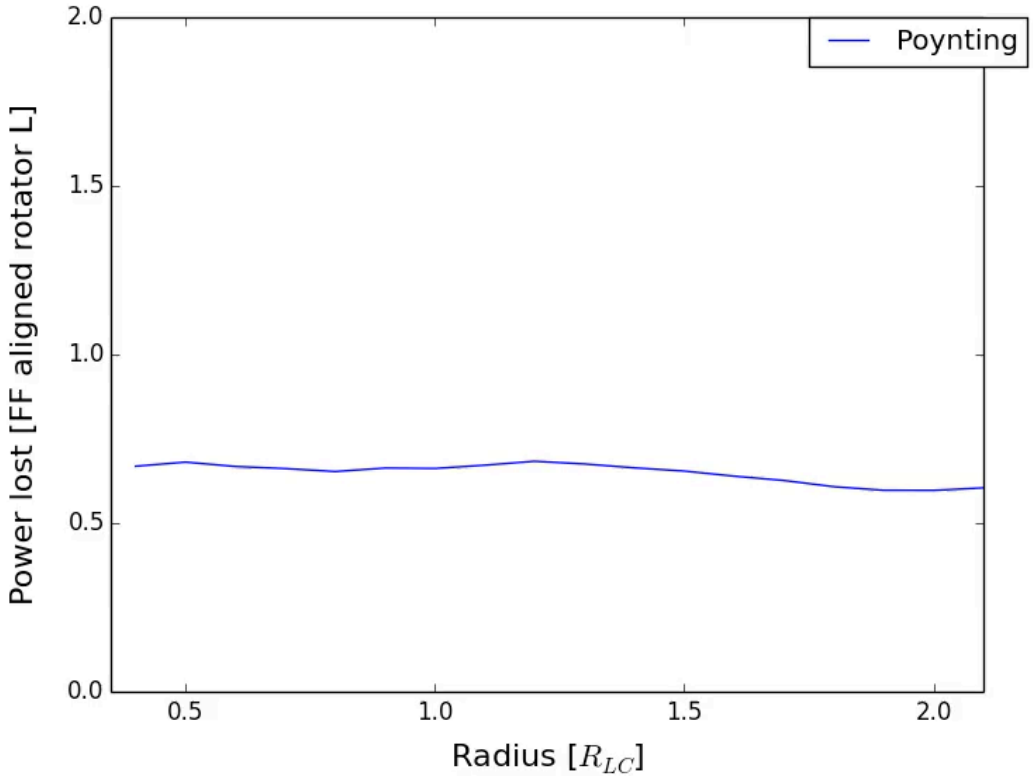

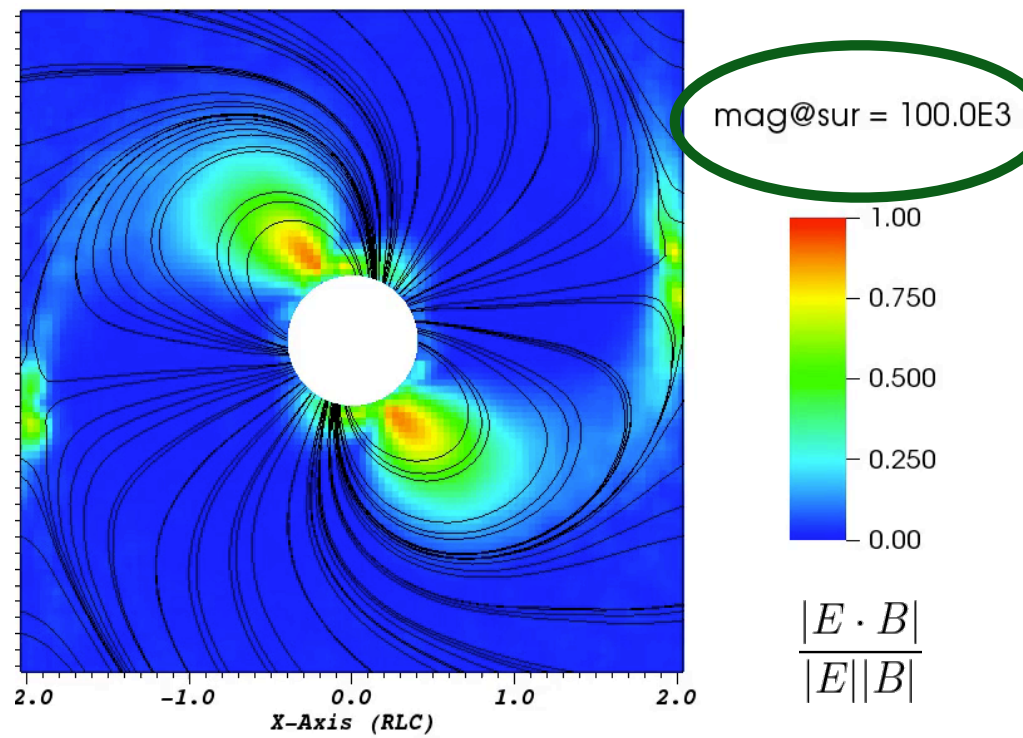

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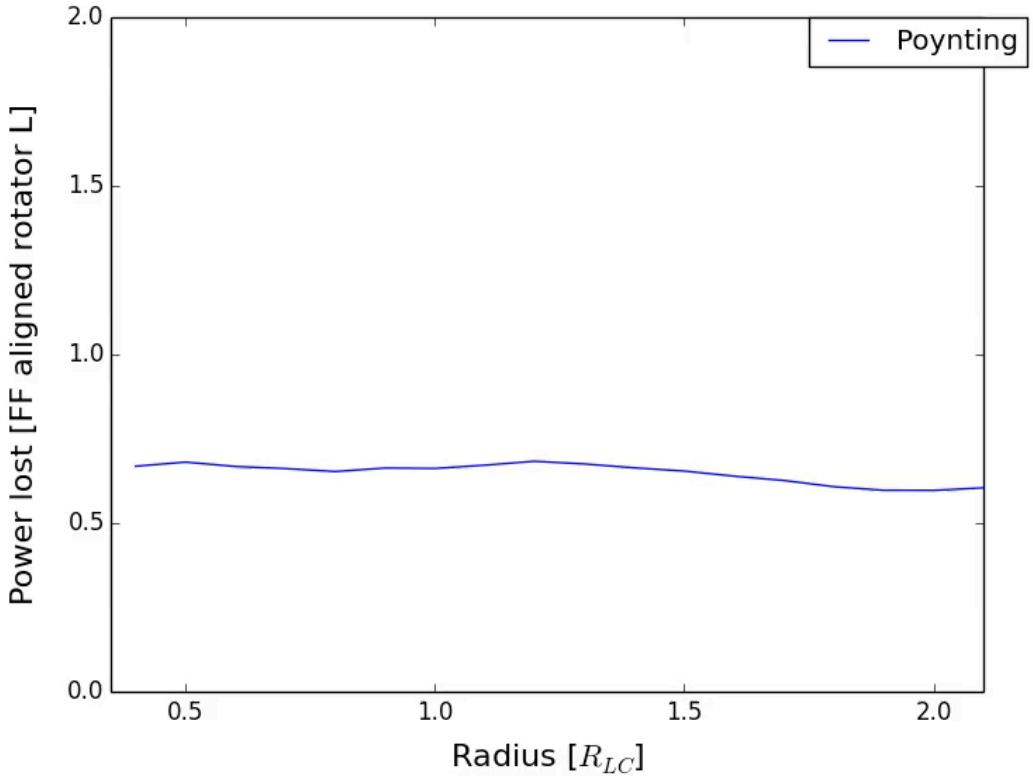
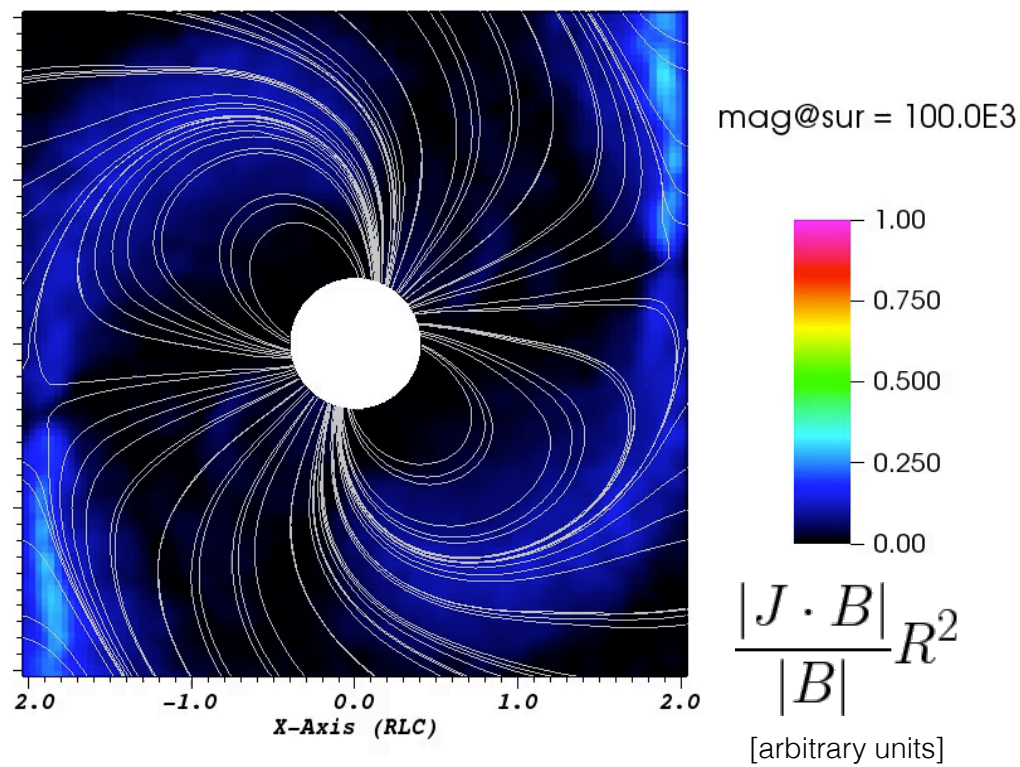
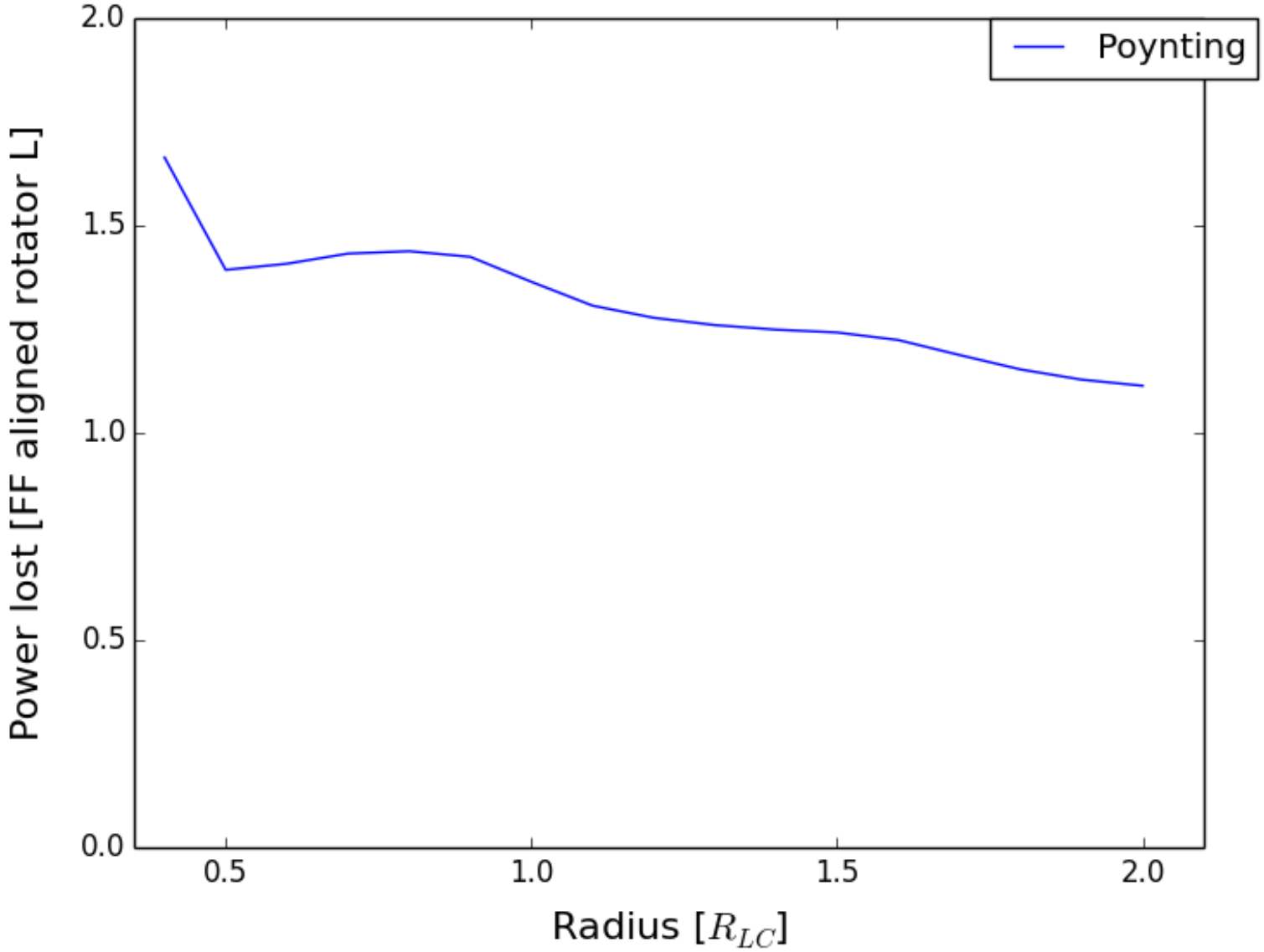
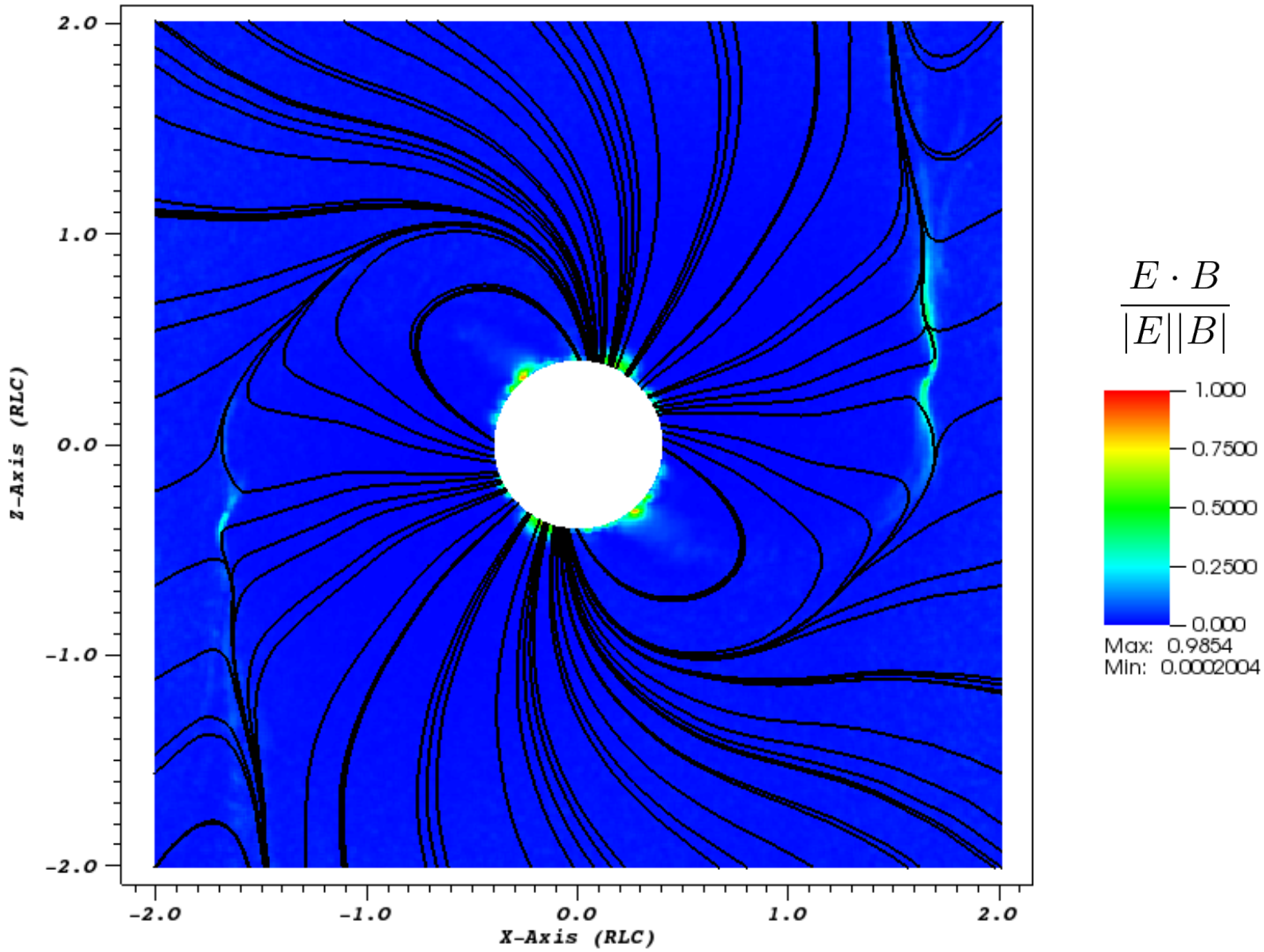




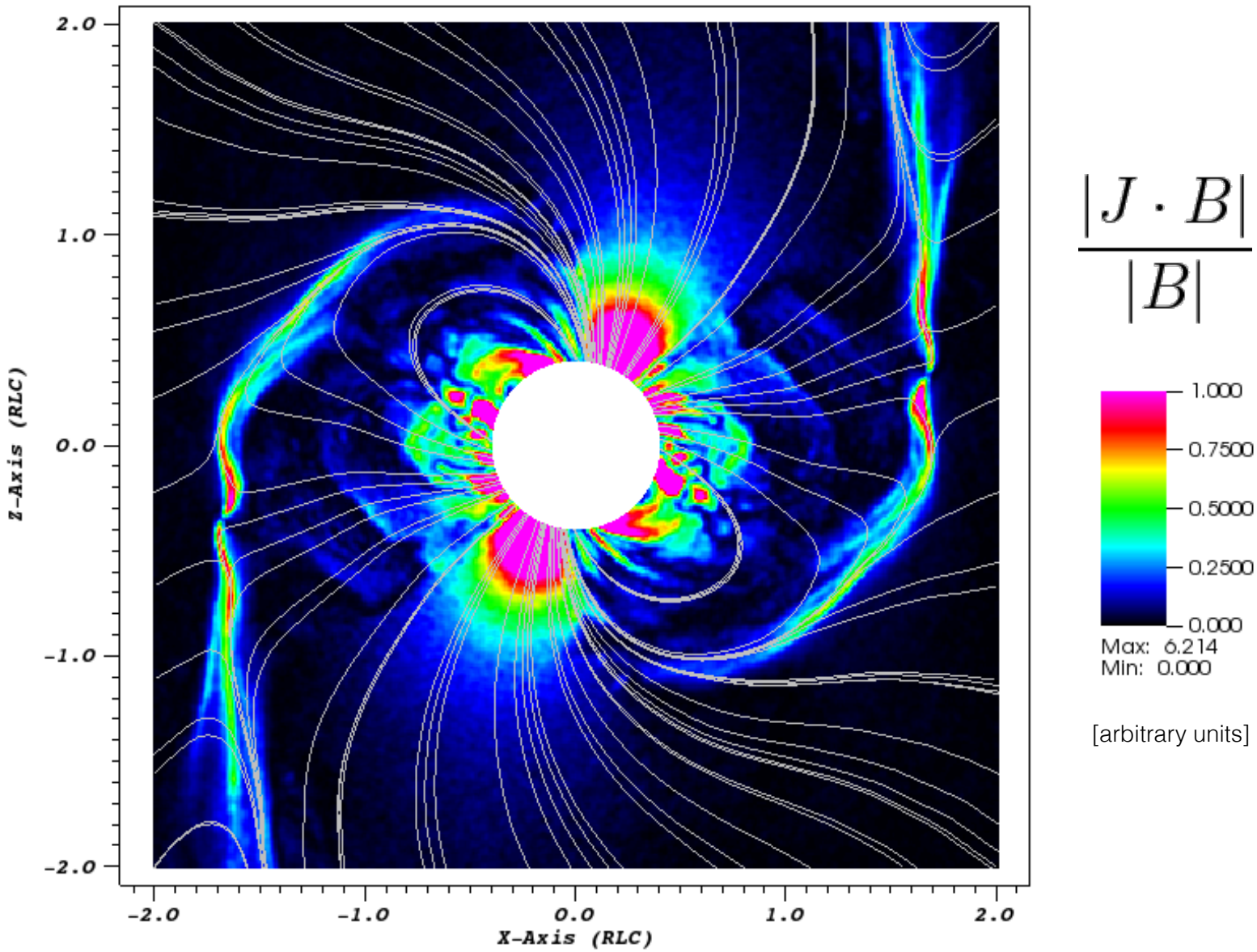
We reached a configuration similar to the force free gradually changing the injection parameters



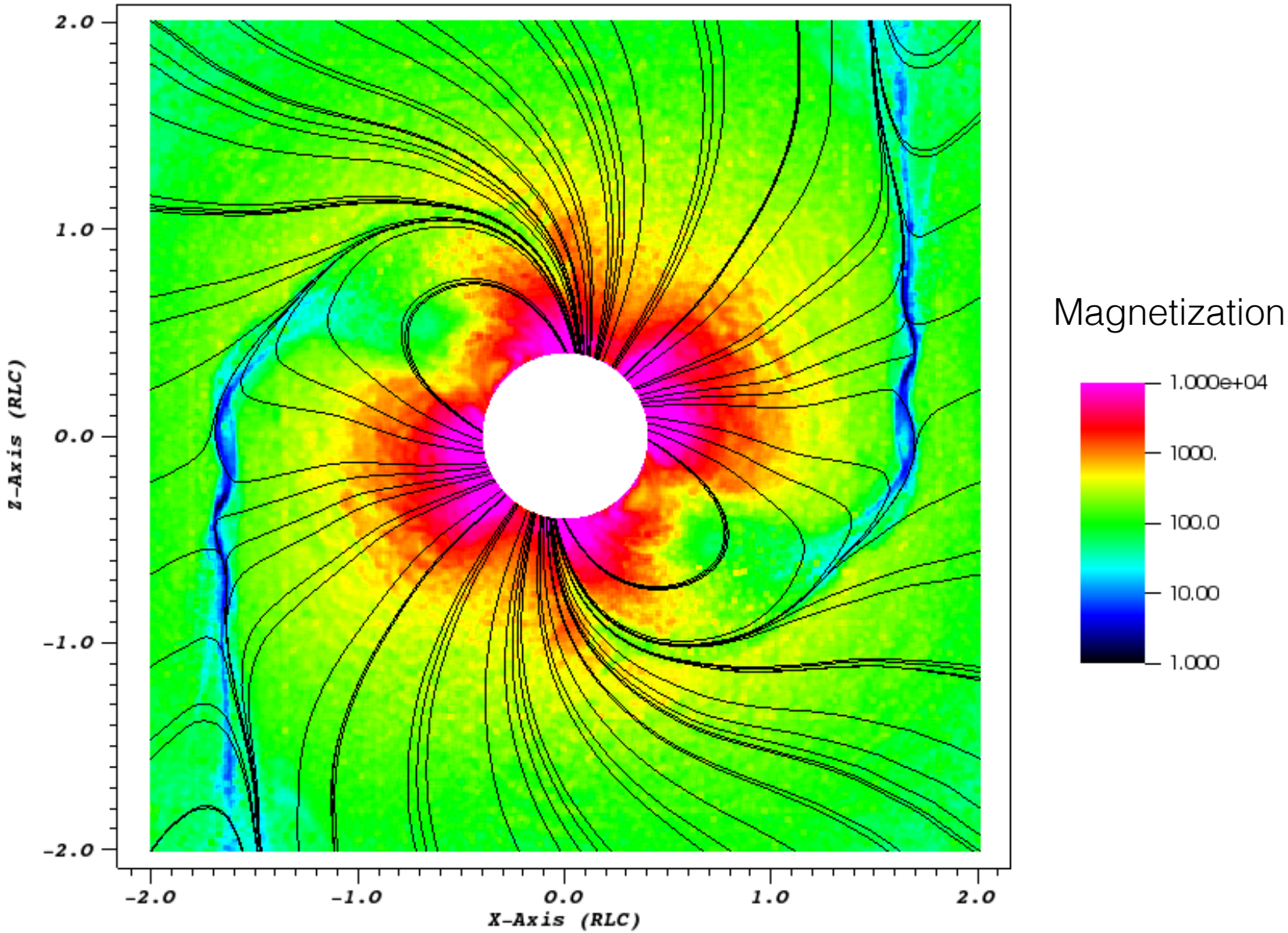
In the force free solution the parallel electric field is screened except for the current sheet



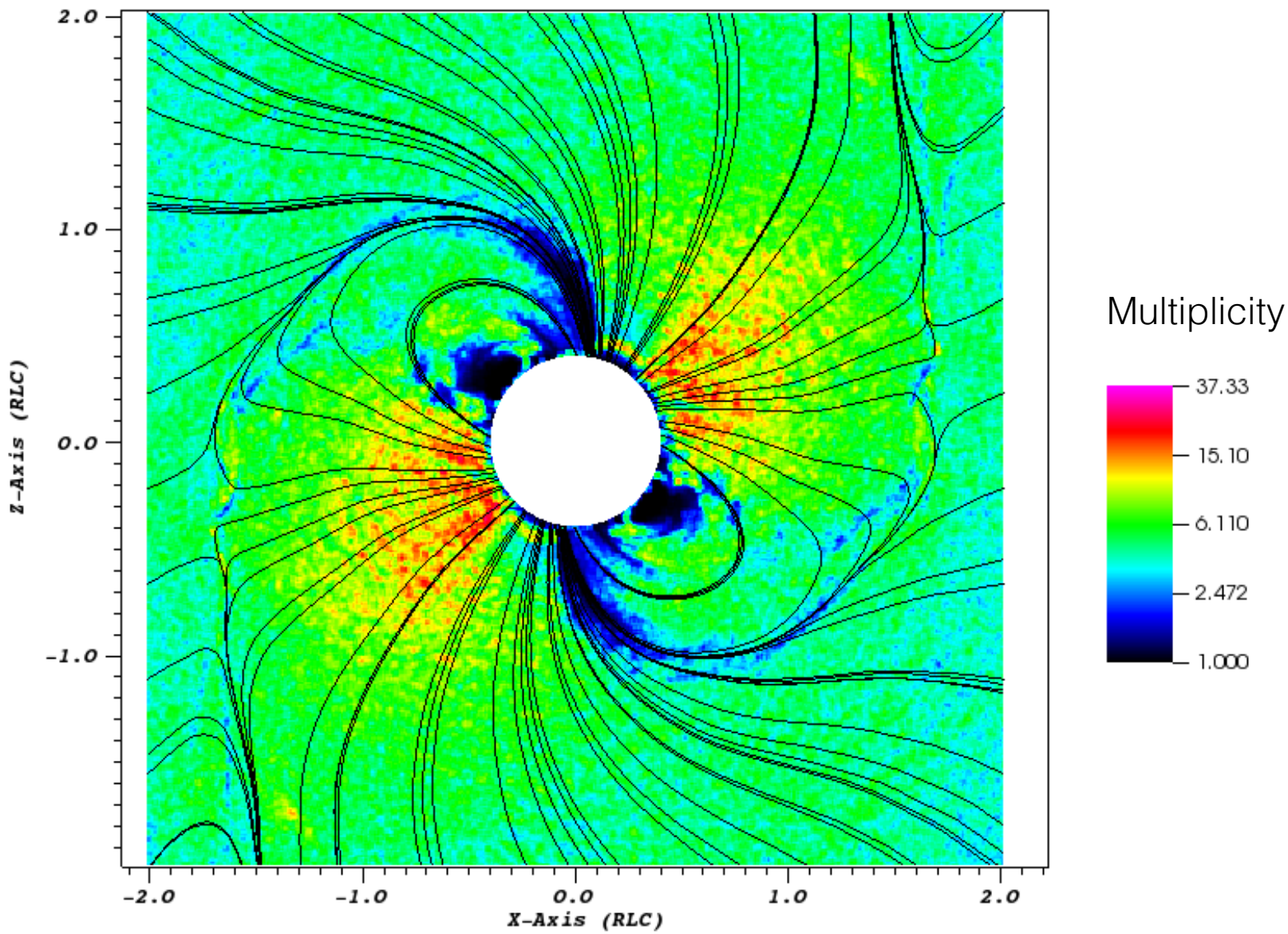
The currents flow on the current sheet and from the polar cap



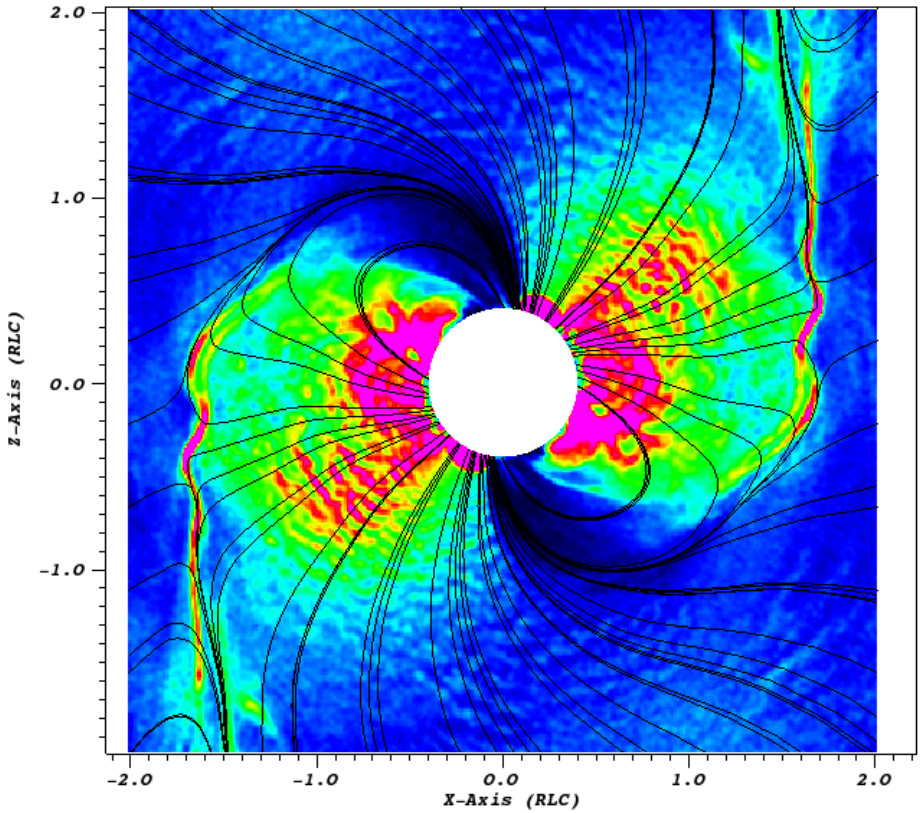
It is necessary to keep the magnetization high to resemble the real pulsar behavior



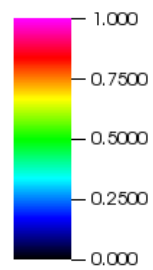
In PIC simulations the multiplicity is lower than in a real pulsar



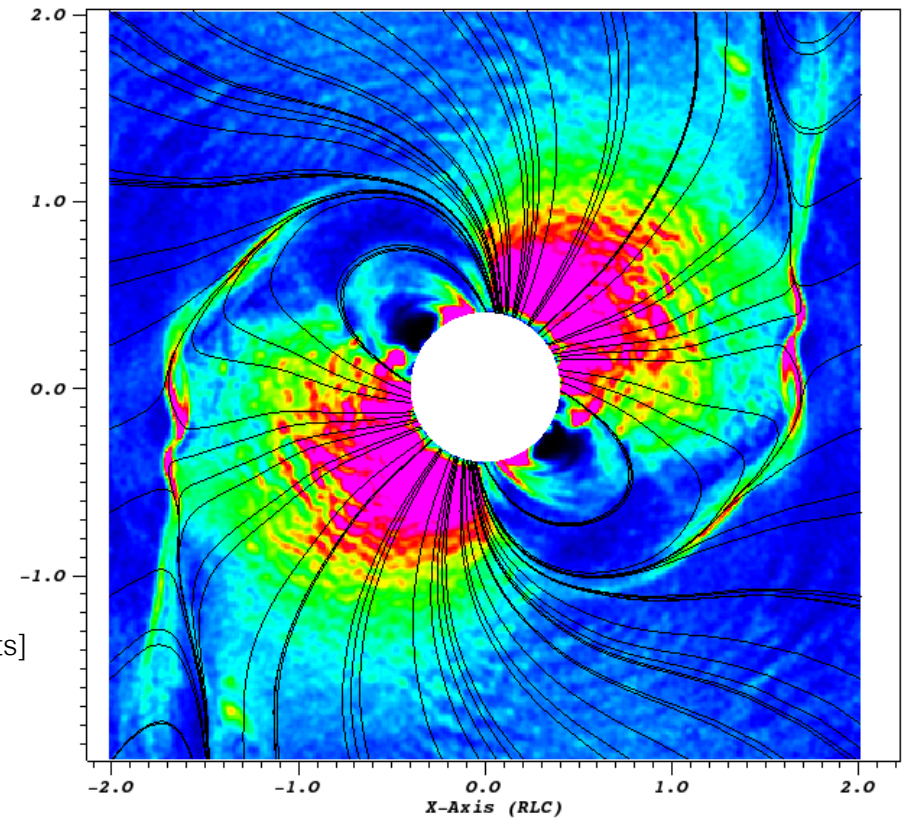
We can look at the different contribution of electrons and positrons to the current



$$\frac{|J \cdot B|}{|B|}$$



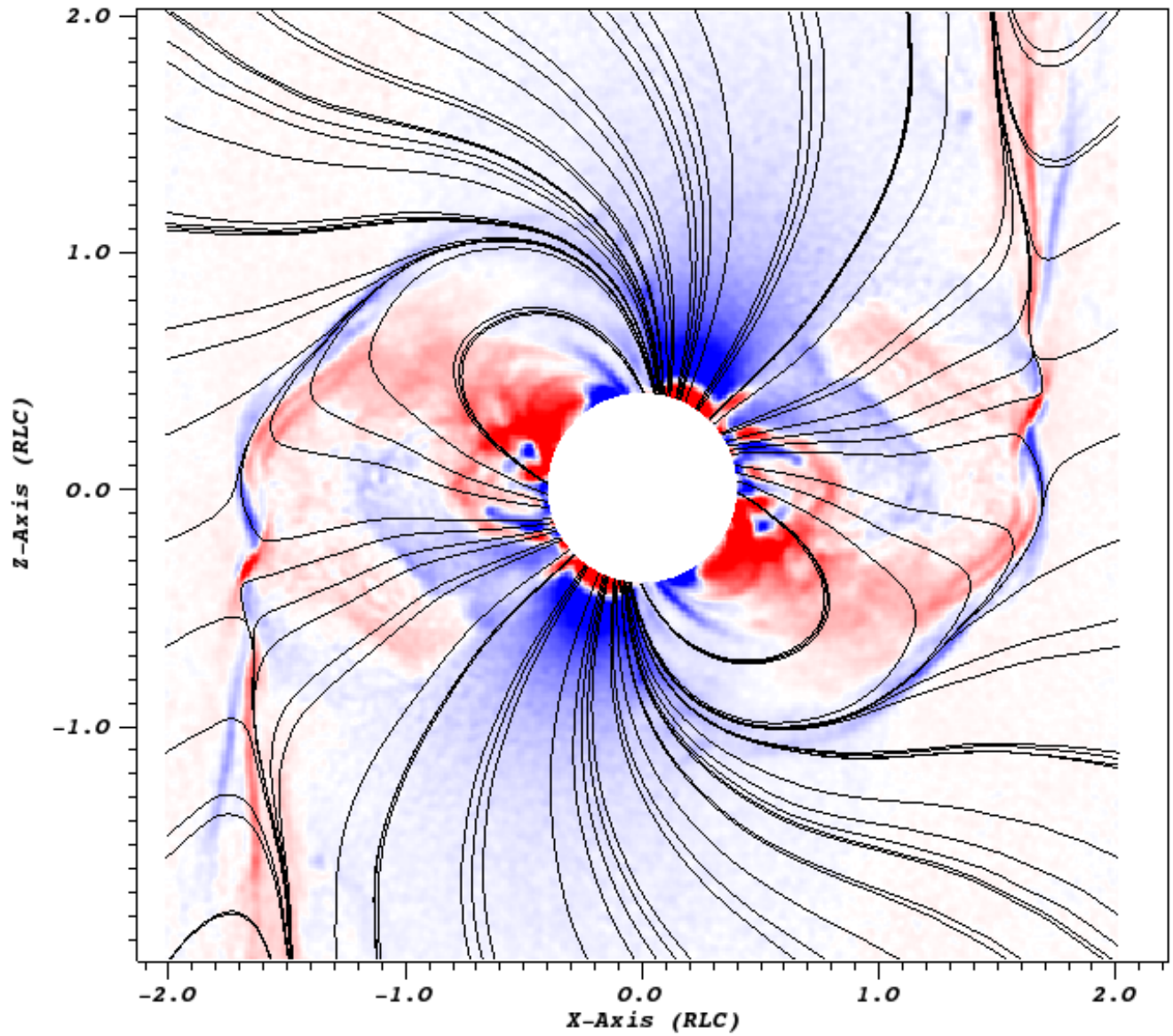
[arbitrary units]



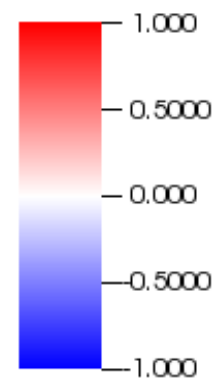
Positrons

Electrons

… And we can see where electrons mostly contribute to the current and where positrons do

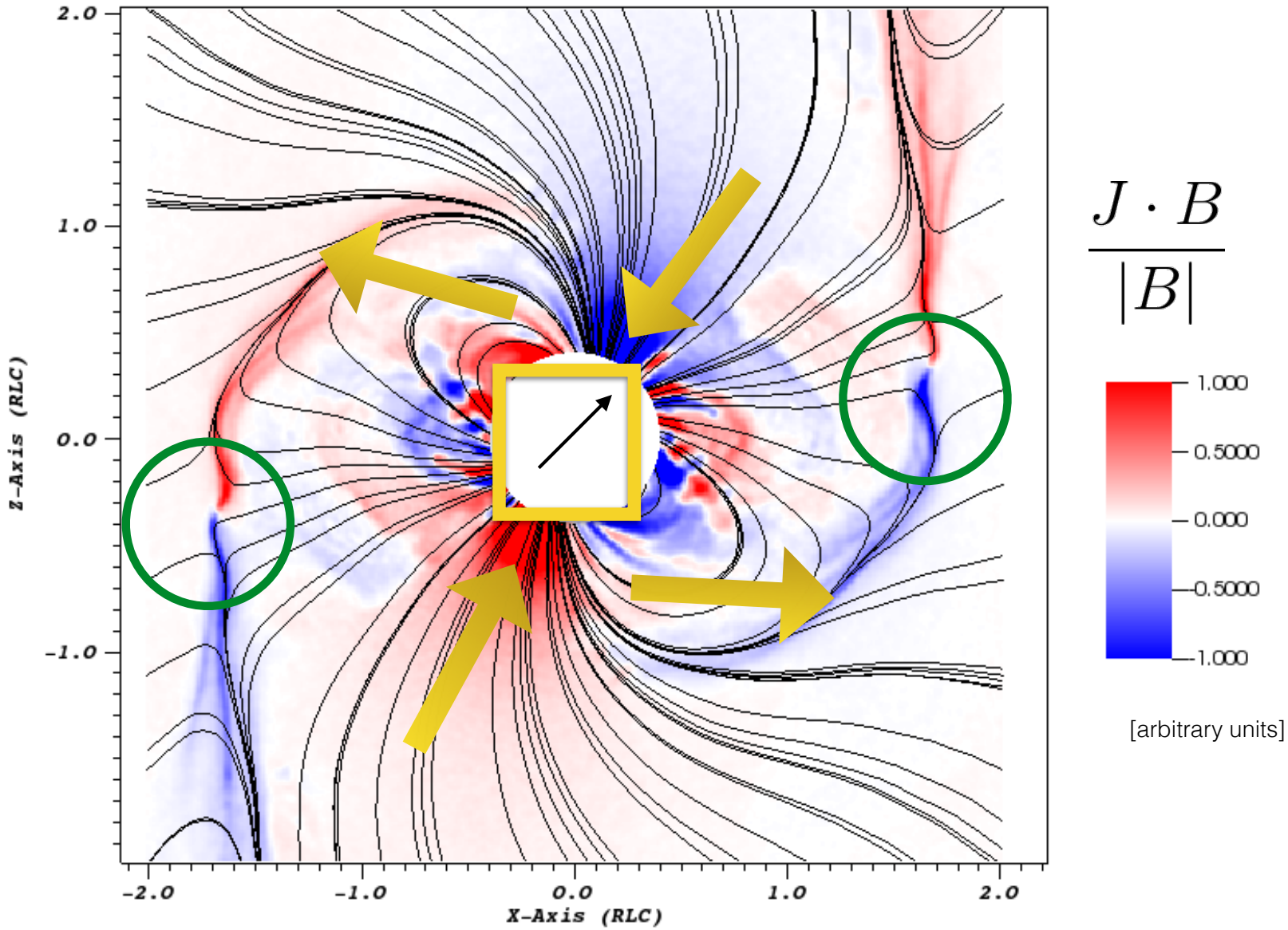


$$\left(\frac{|J \cdot B|}{|B|}\right)_{pos} - \left(\frac{|J \cdot B|}{|B|}\right)_{ele}$$

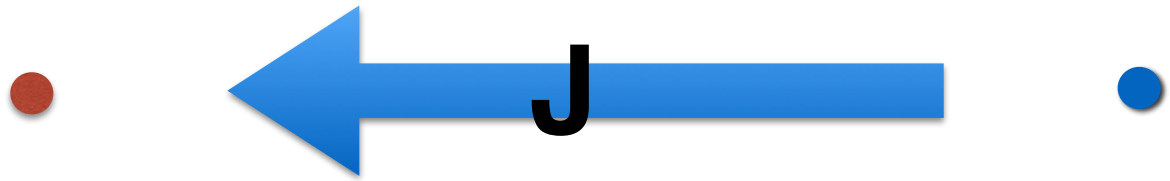


[arbitrary units]

We can also look at the direction of the flows



There are zones in which the flows counter stream and others in which they flow in the same direction



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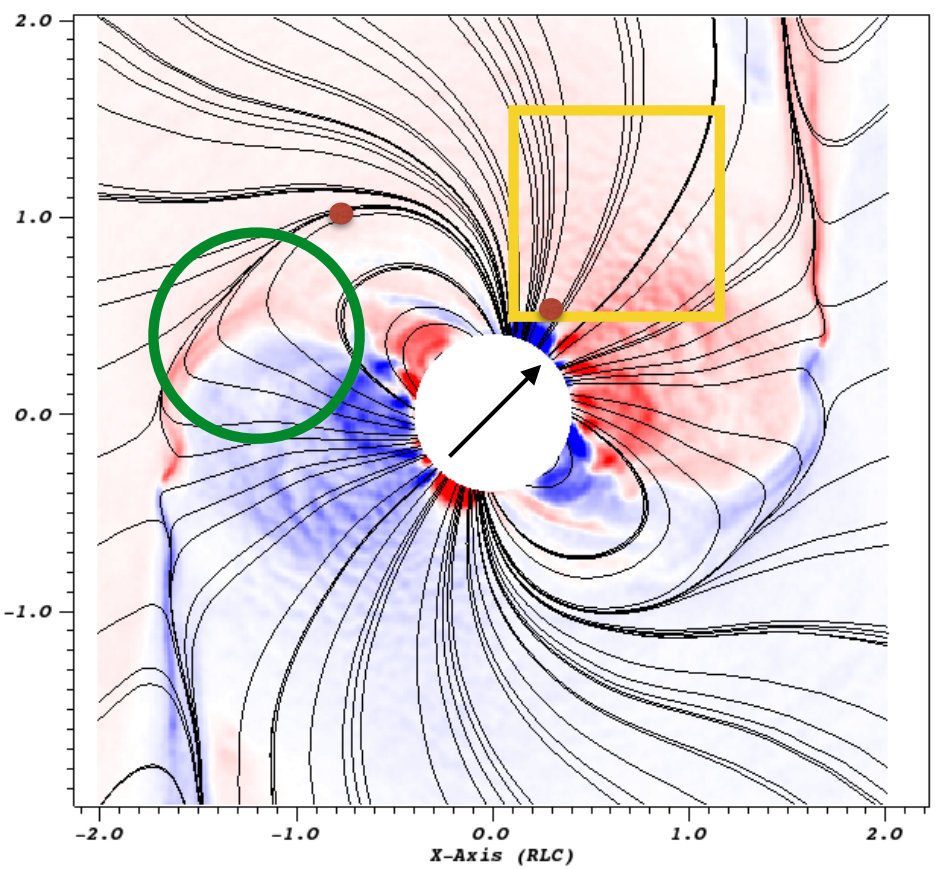
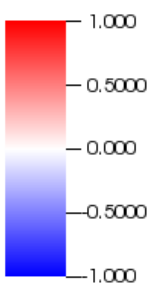


$$\frac{J \cdot B}{|B|}$$



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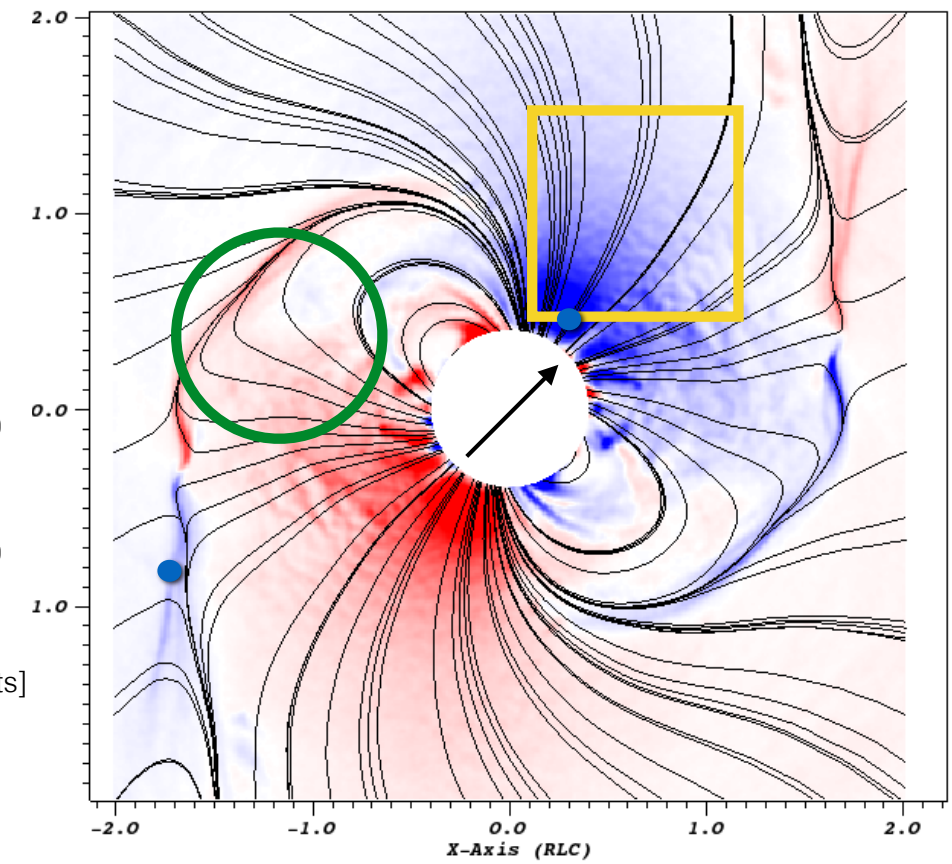
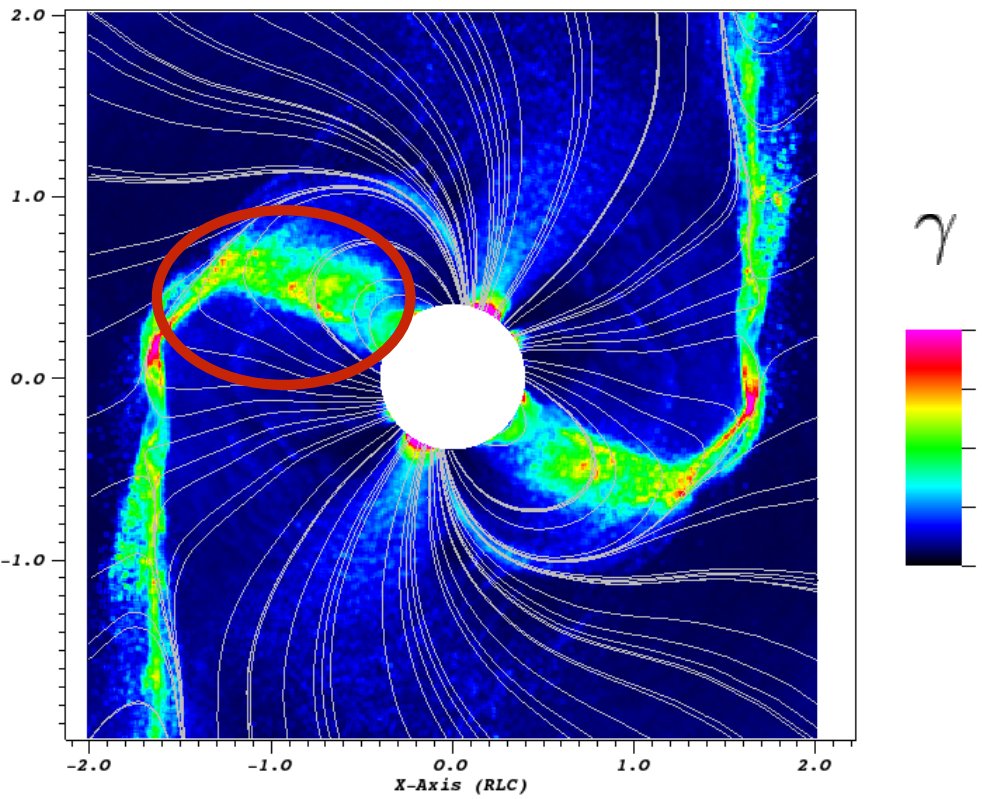
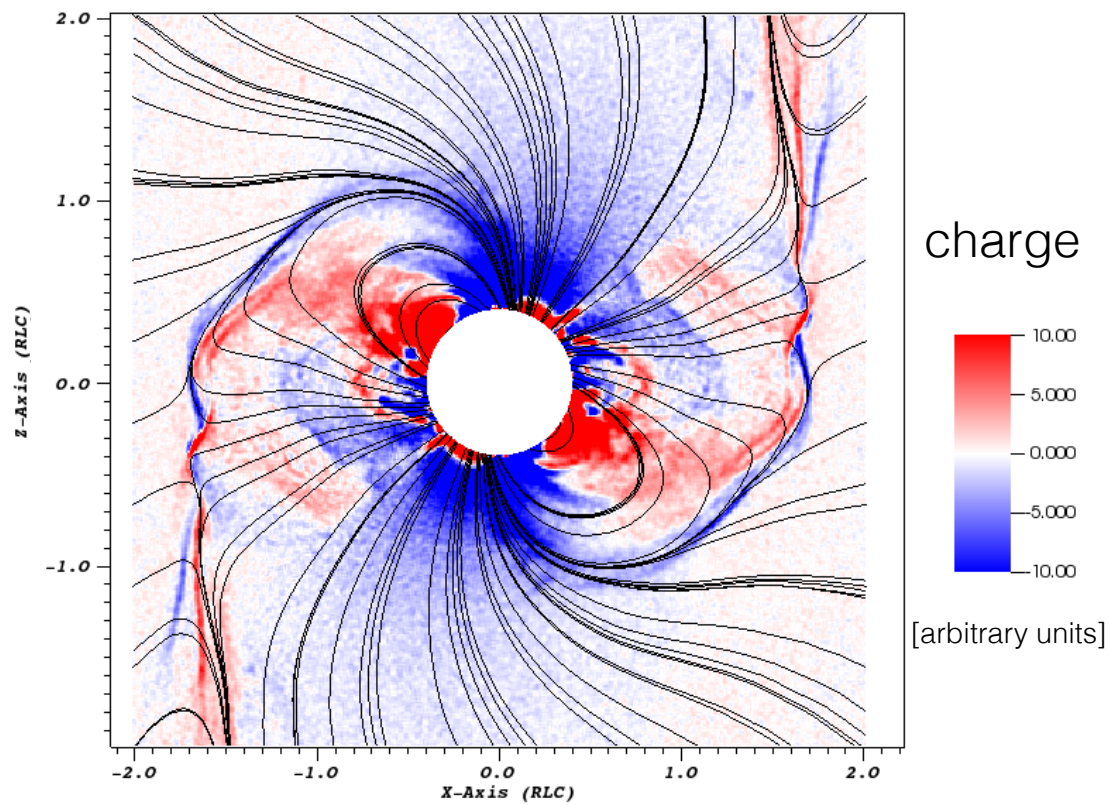


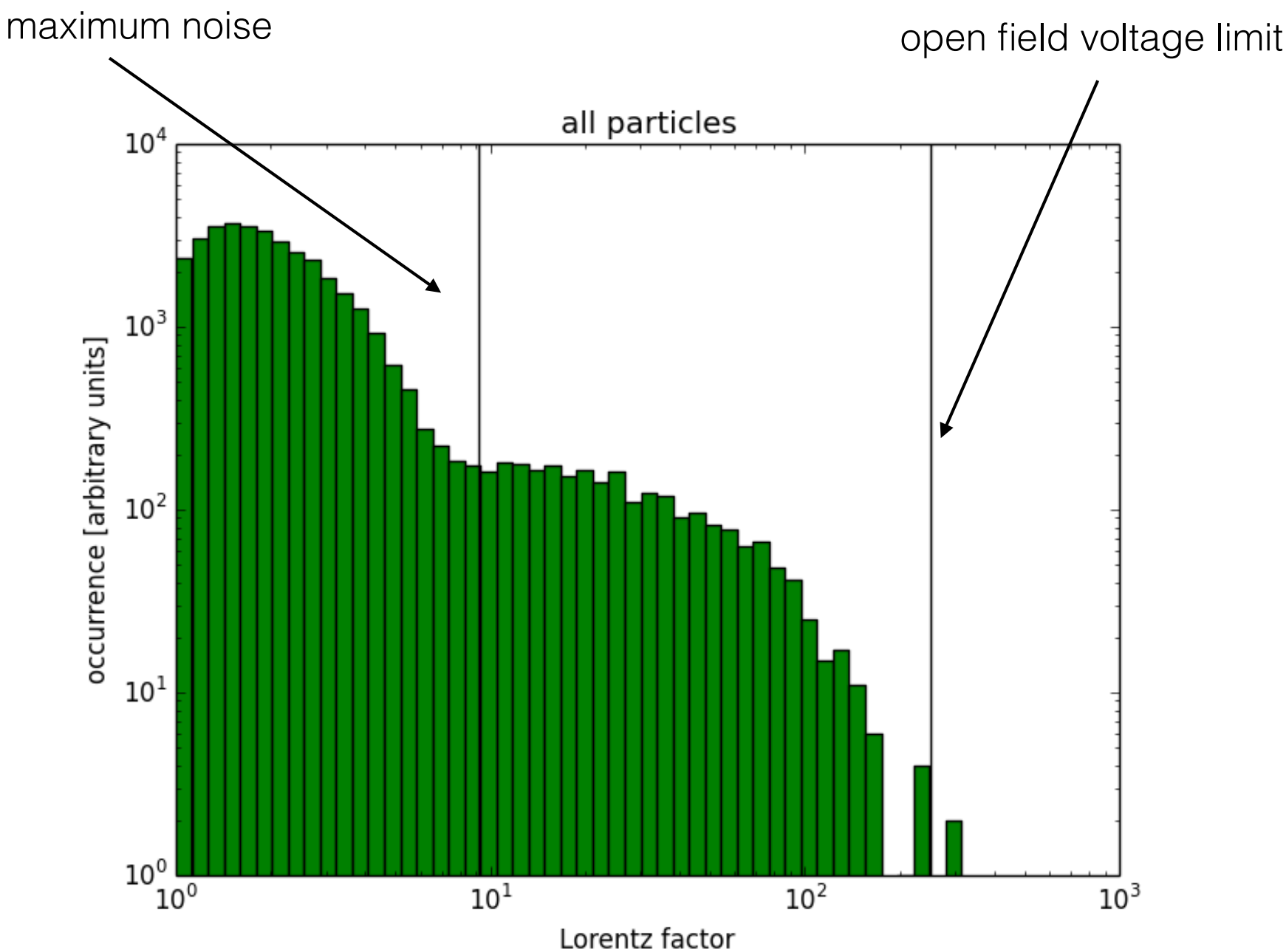
Looking at the energy of the particles we see the most energetic flow in the branches of the current sheet

$$\left(\frac{|J \cdot B|}{|B|}\right)_{pos} - \left(\frac{|J \cdot B|}{|B|}\right)_{ele}$$ [arbitrary units]



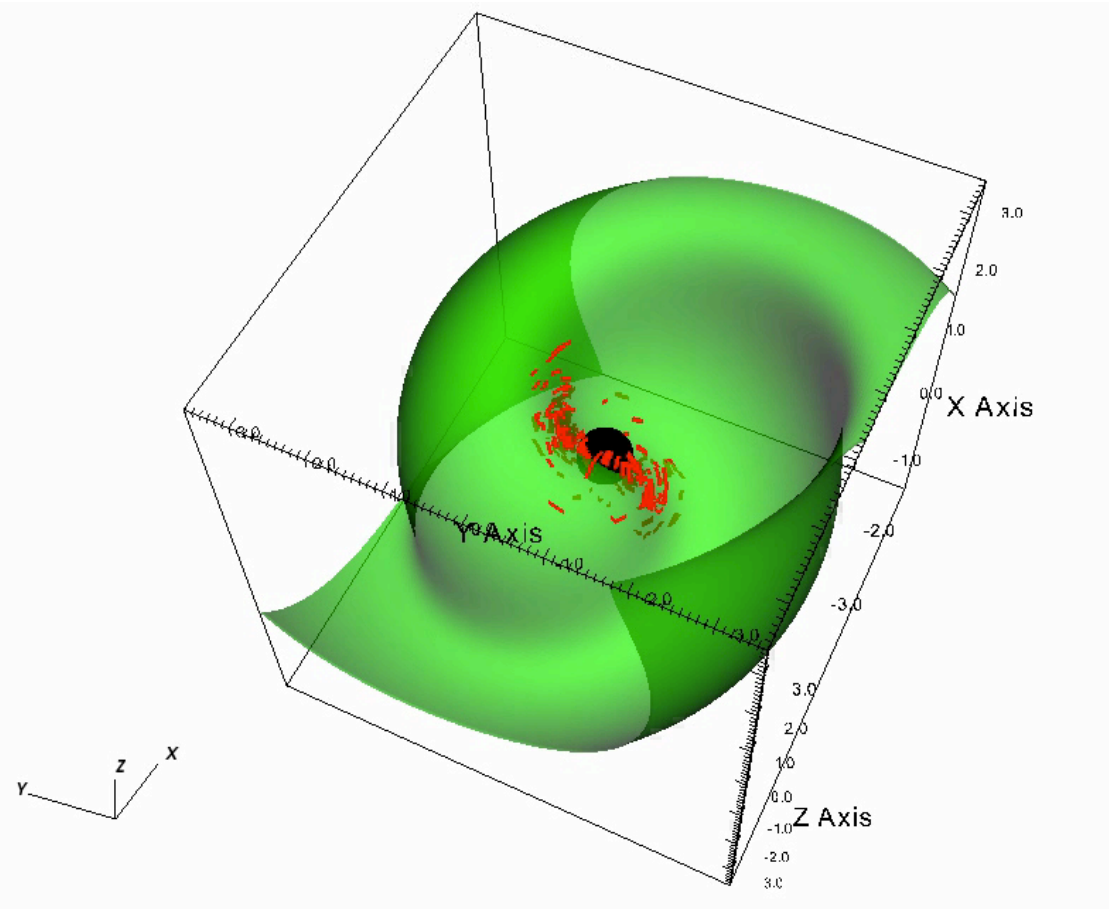


The knowledge of the particle energy distribution is limited by the noise and the magnetic field



In the whole 3D structure the most energetic particles flow out on the current sheet

corotating frame



inertial frame