PIC simulation services at the CCMC in support of MMS mission

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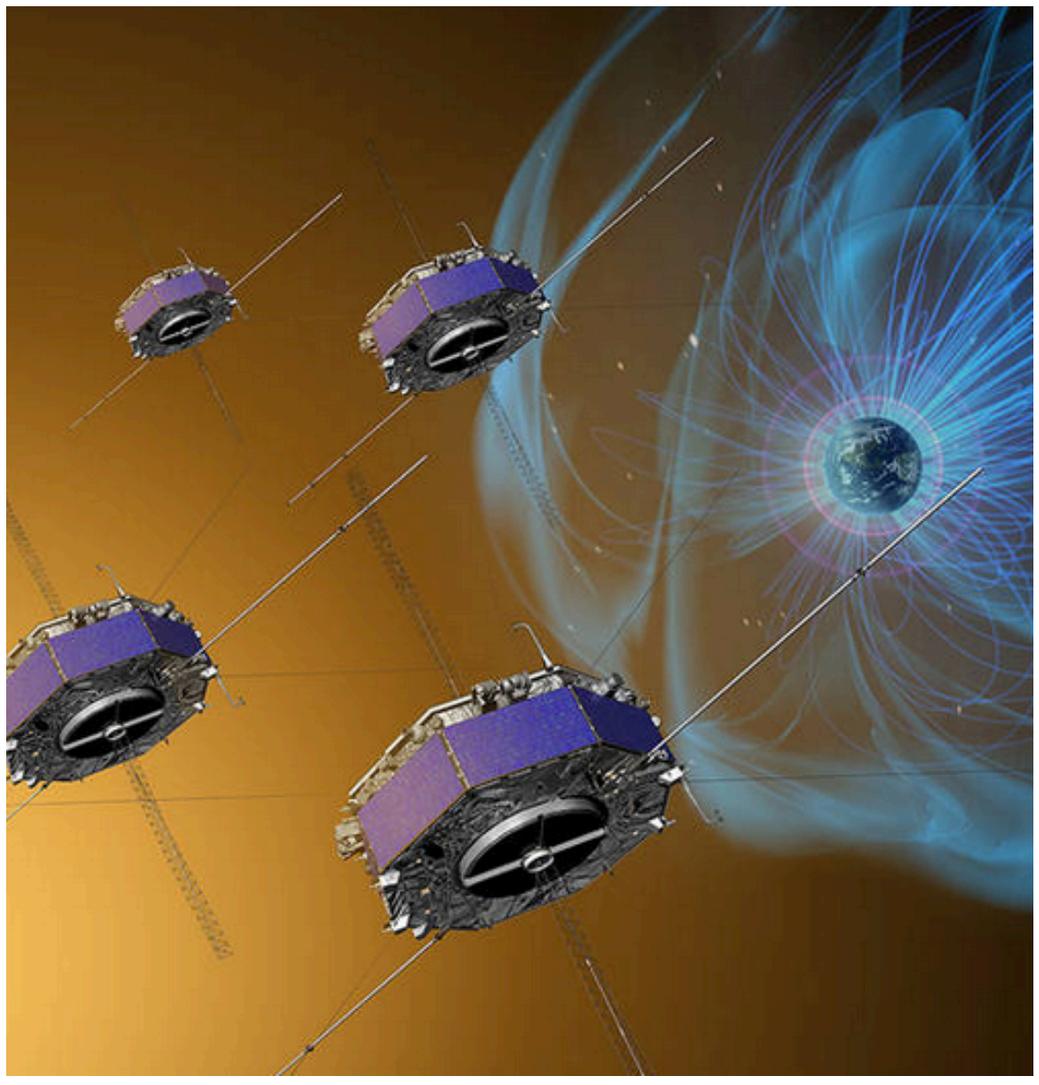
The era of MMS

Magnetospheric Multiscale Mission (MMS)



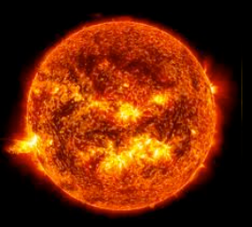
March 13, 2015

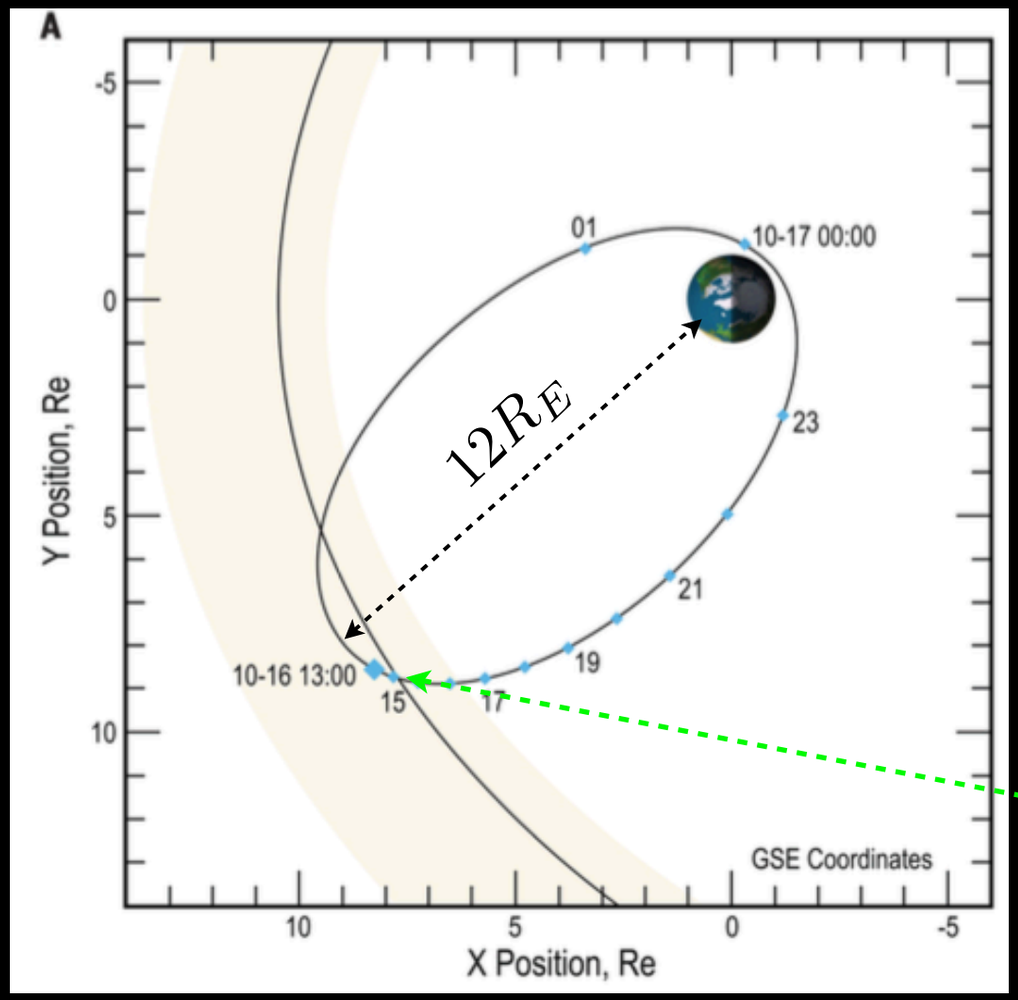
http://mms.gsfc.nasa.gov

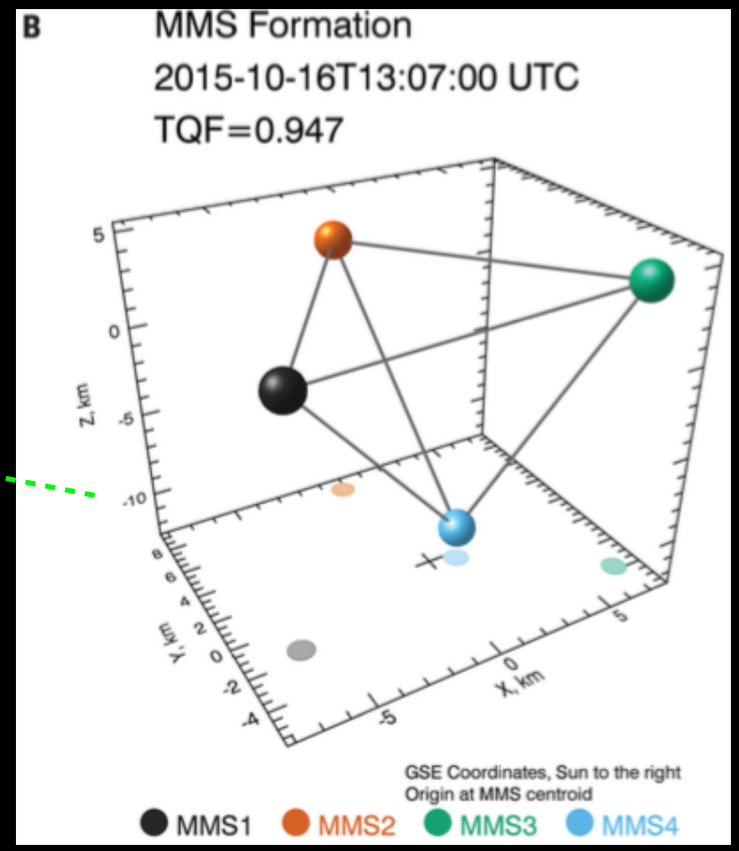
tight tetrahedron formation: separation down to 7 km!
100x faster for electrons (30 ms)
30x faster for ions (150 ms)

- MMS leads us into a stage where the electron-scale physics of magnetic reconnection, in nature, can be resolved in an unprecedented manner!!
- PIC simulations can self-consistently model these electron-scale physics.

Spacecraft orbit on October 16, 2015



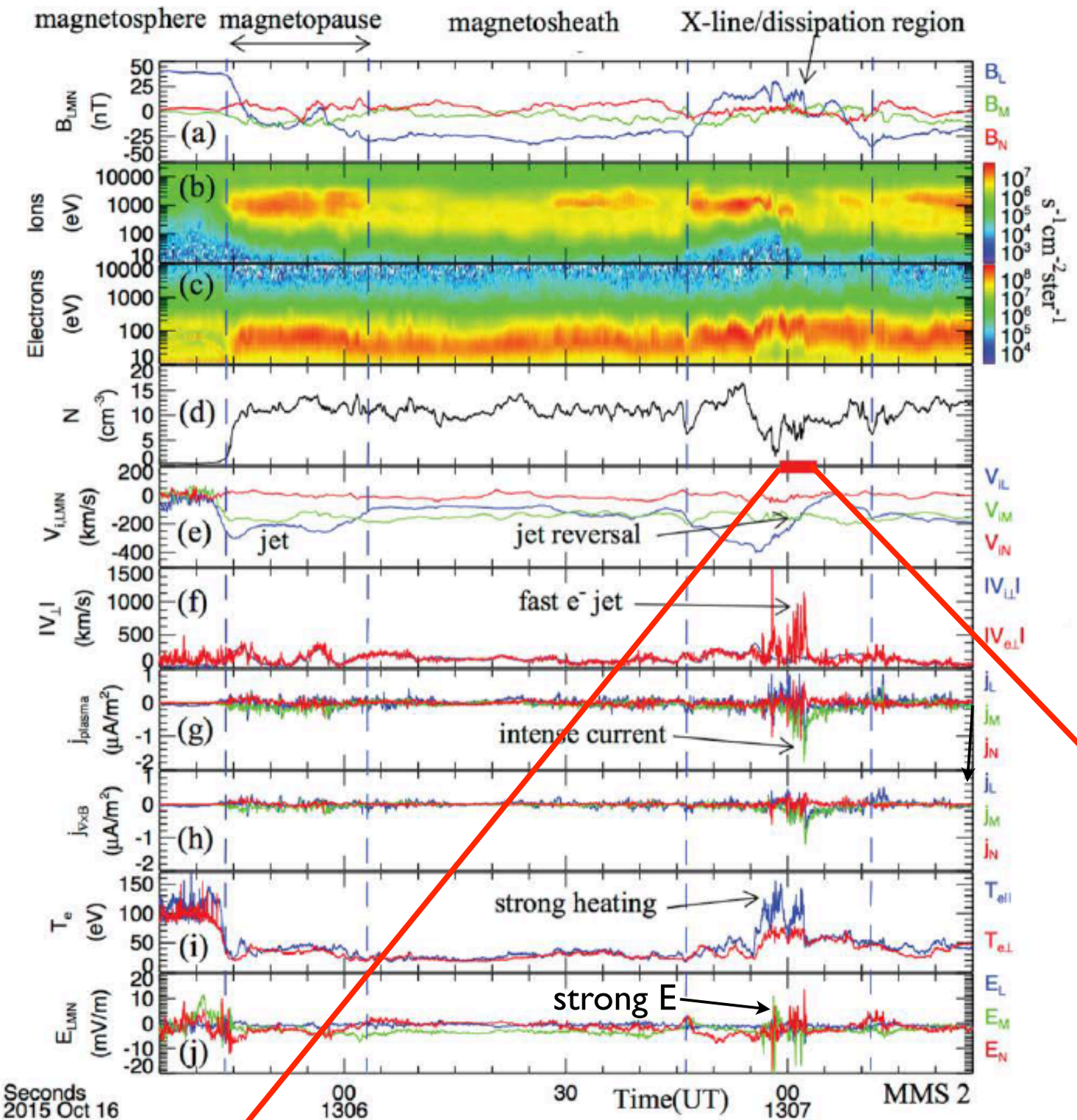


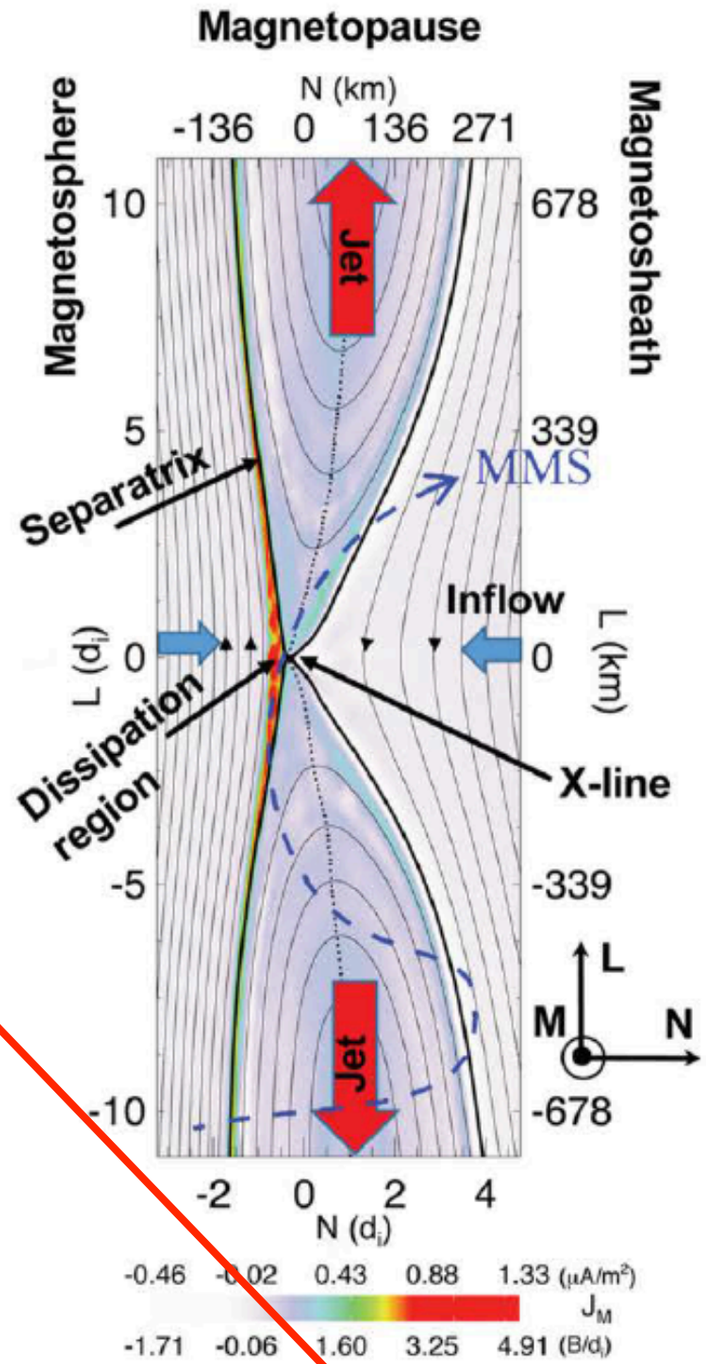


Encounter of the electron diffusion region!

MMS2

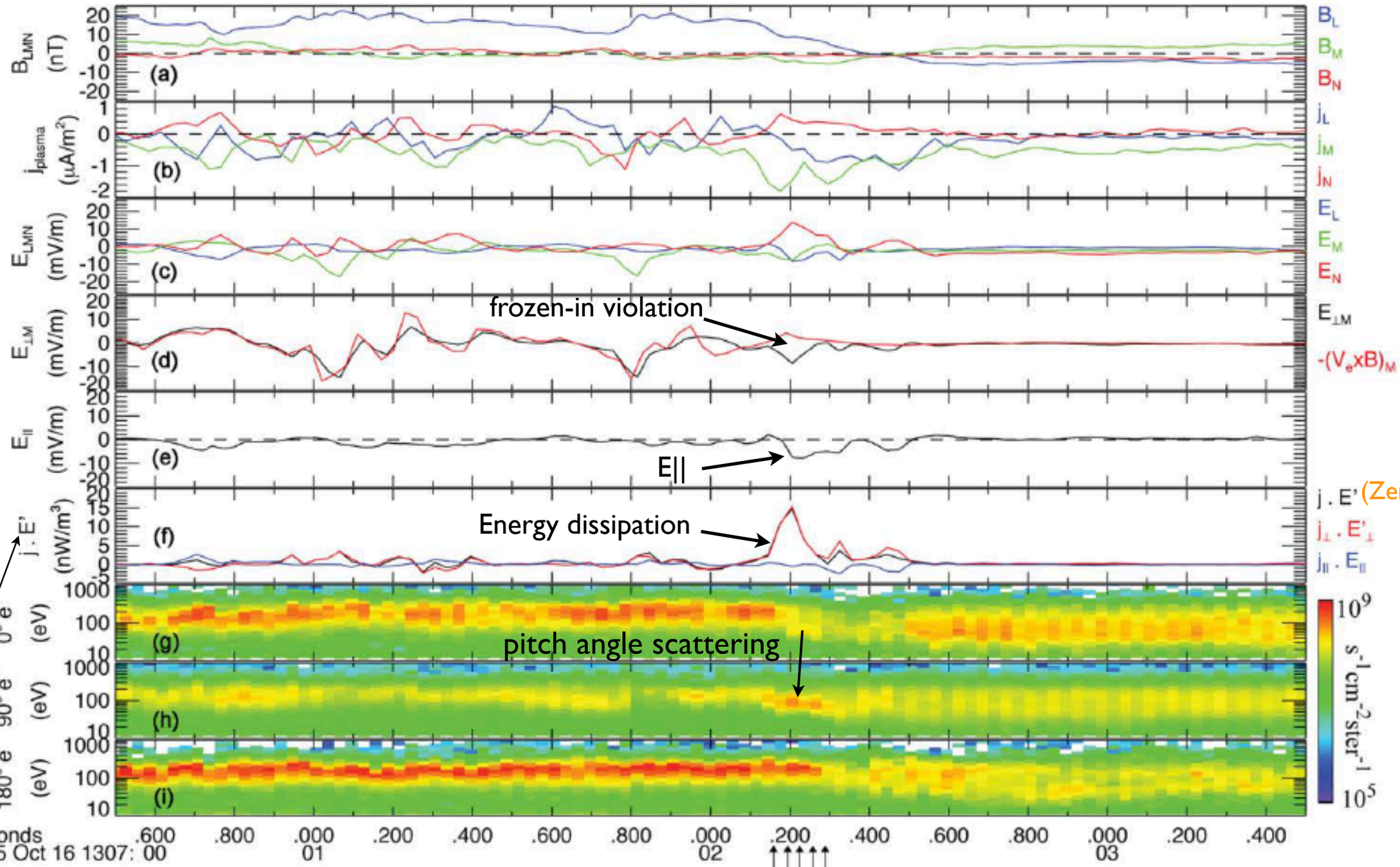
(Burch et al. SCIENCE 2016)





ER~ 1-5 mA/m
VA~ 400 km/s
vthe,sph~ 6,000 km/s; vthi,sph~ 300 km/s

More signatures of electron diffusion region...

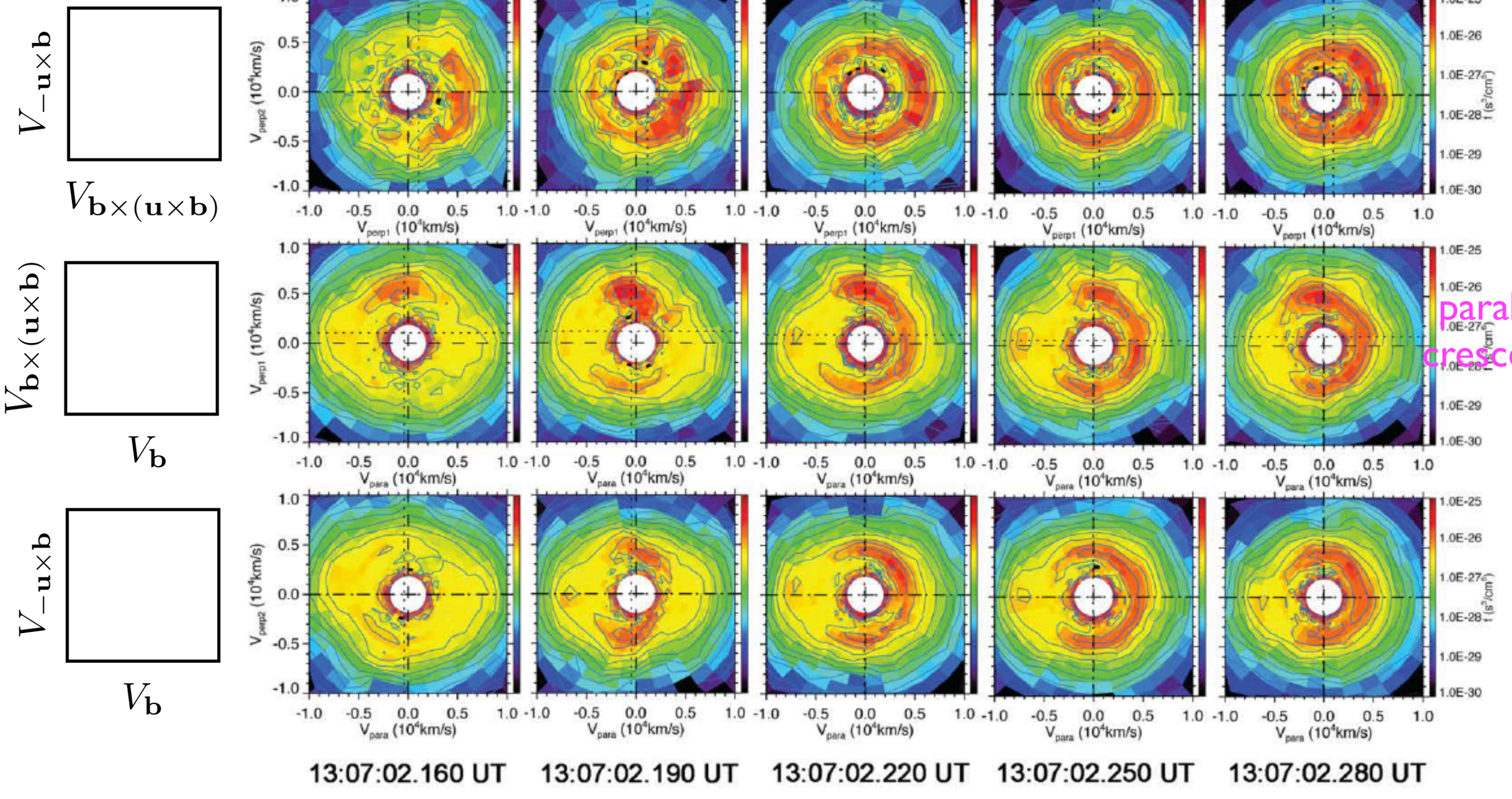


$$\mathbf{E}' = \mathbf{E} + \mathbf{V}_e \times \mathbf{B}$$

ER~ 1-5 mA/m
lambda_D~ 60 m
de~ 1.66 km; di~ 70 km
wce,sph~1000 Hz ; wci,sph~ 0.5 Hz
wpe.sph~10,000 Hz; wpi.sph~200 Hz
VA~ 400km/s
vthe,sph~ 6,000 km/s; vthi,sph~ 300 km/s

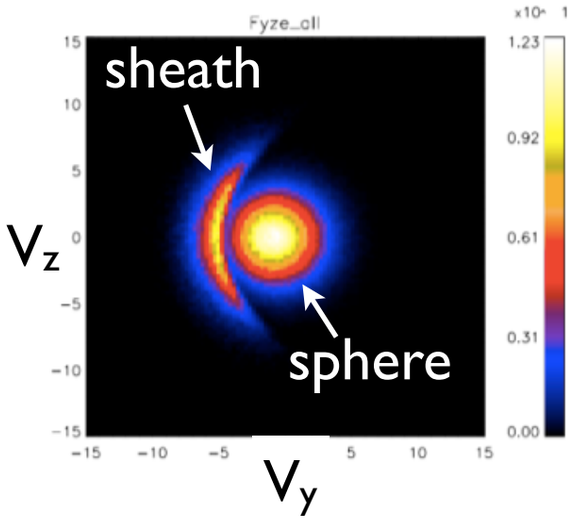
Electron distribution inside reconnection diffusion region

MMS2



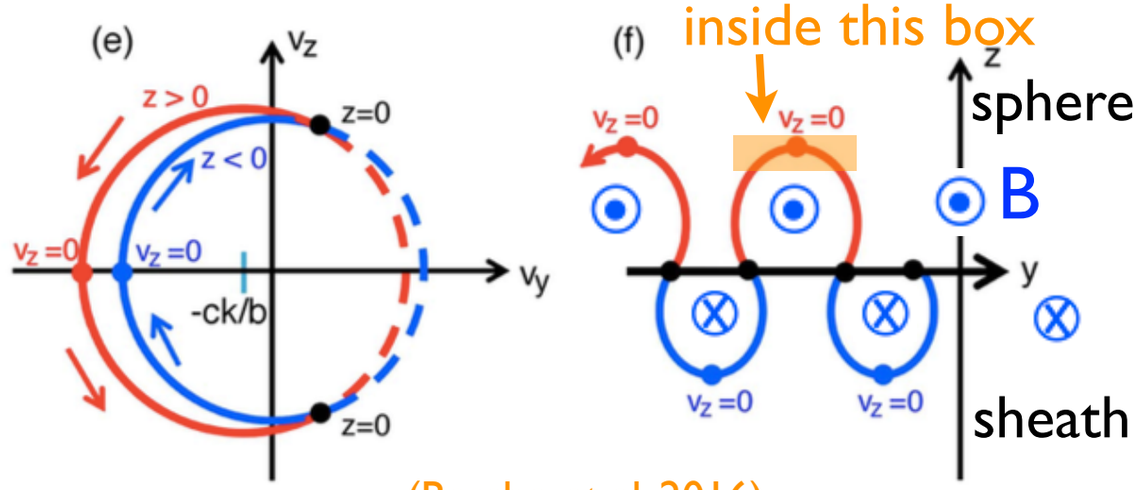
One of the popular distributions: Crescent

Reduced



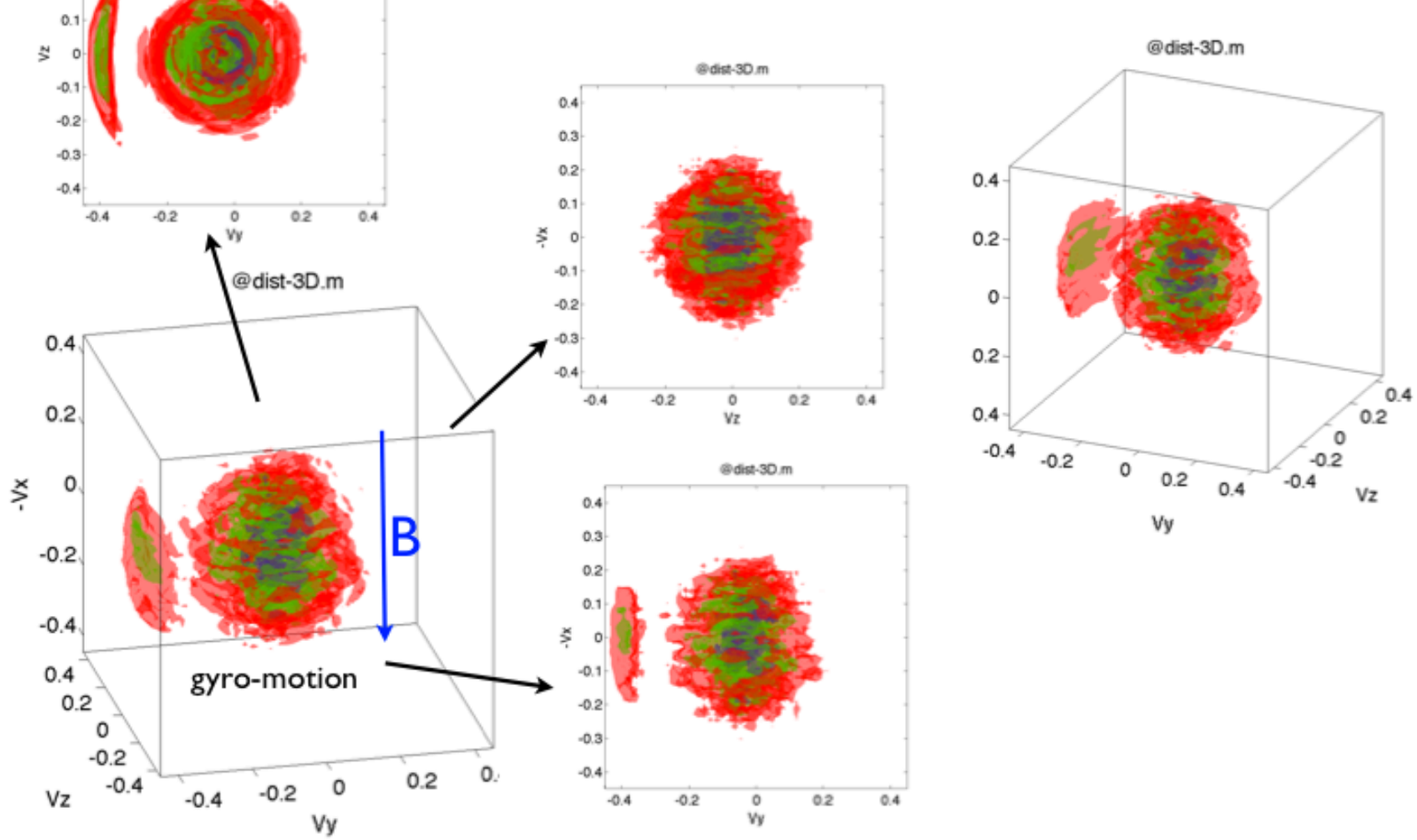
(Hesse et al. 2013;
Hesse et al. 2016;
Bessho et al. 2016;
Chen et al. 2016;
Shay et al. 2016;
Egedal et al. 2016)

collecting particles
inside this box



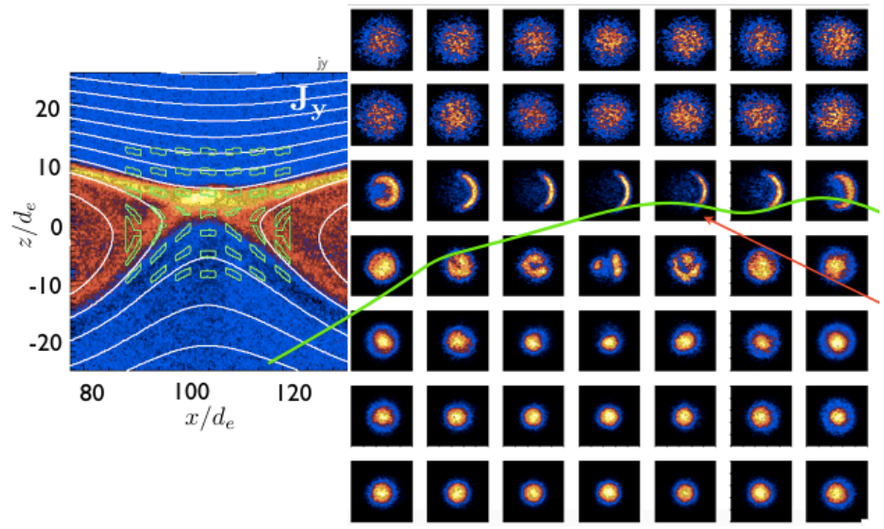
(Bessho et al. 2016)

Full 3D



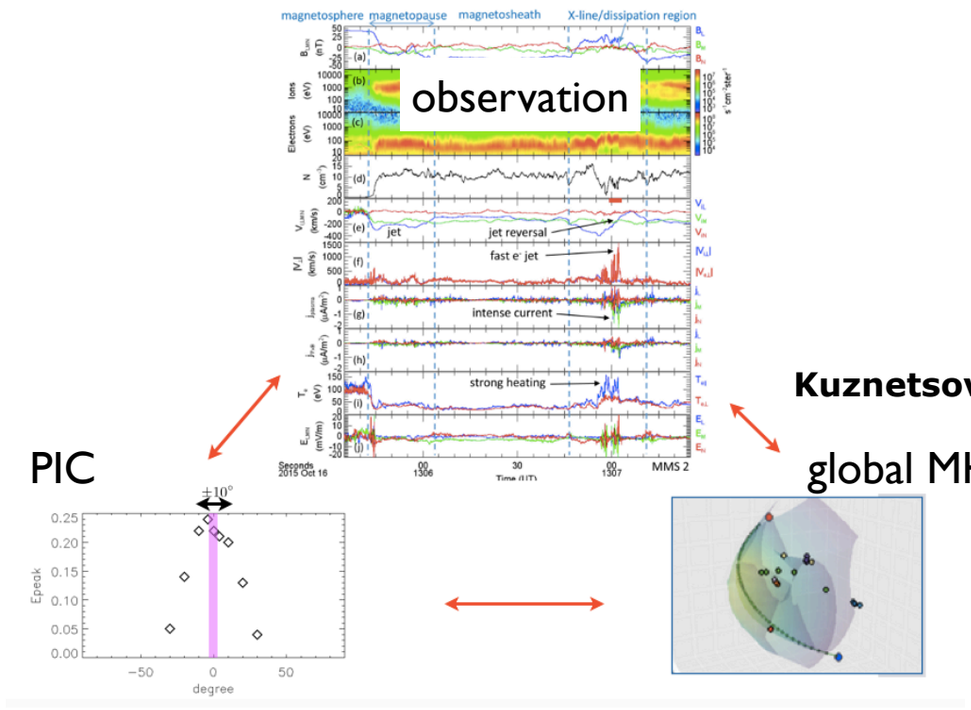
PIC services at the CCMC

1. Help interpret particle distributions at geometrically important locations.



2. Help determine the LMN coordinate.

- A potential science project that joints effort of
  MMS observation, local PIC & Global MHD simulations
  to evaluate the importance of local versus global physics in controlling the x-line orientation.



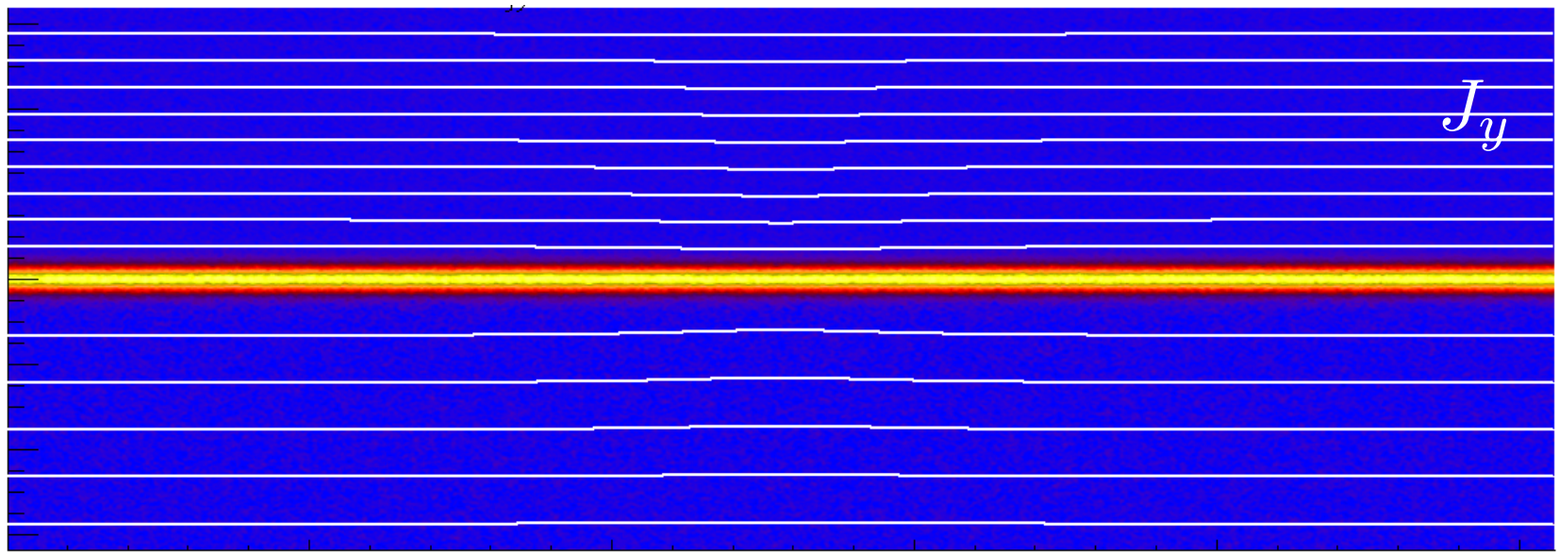
Kuznetsova et al., SM14B-08 (Monday 17:45)

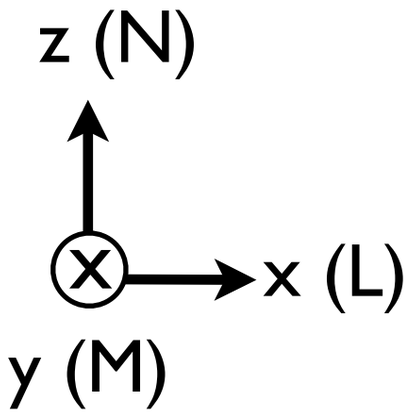
Service 1:

Help interpret particle distributions at geometrically important locations.

We have generalized the initial condition

B_{x2} B_{y2} n_2 T_2 V_{x2} V_{y2}



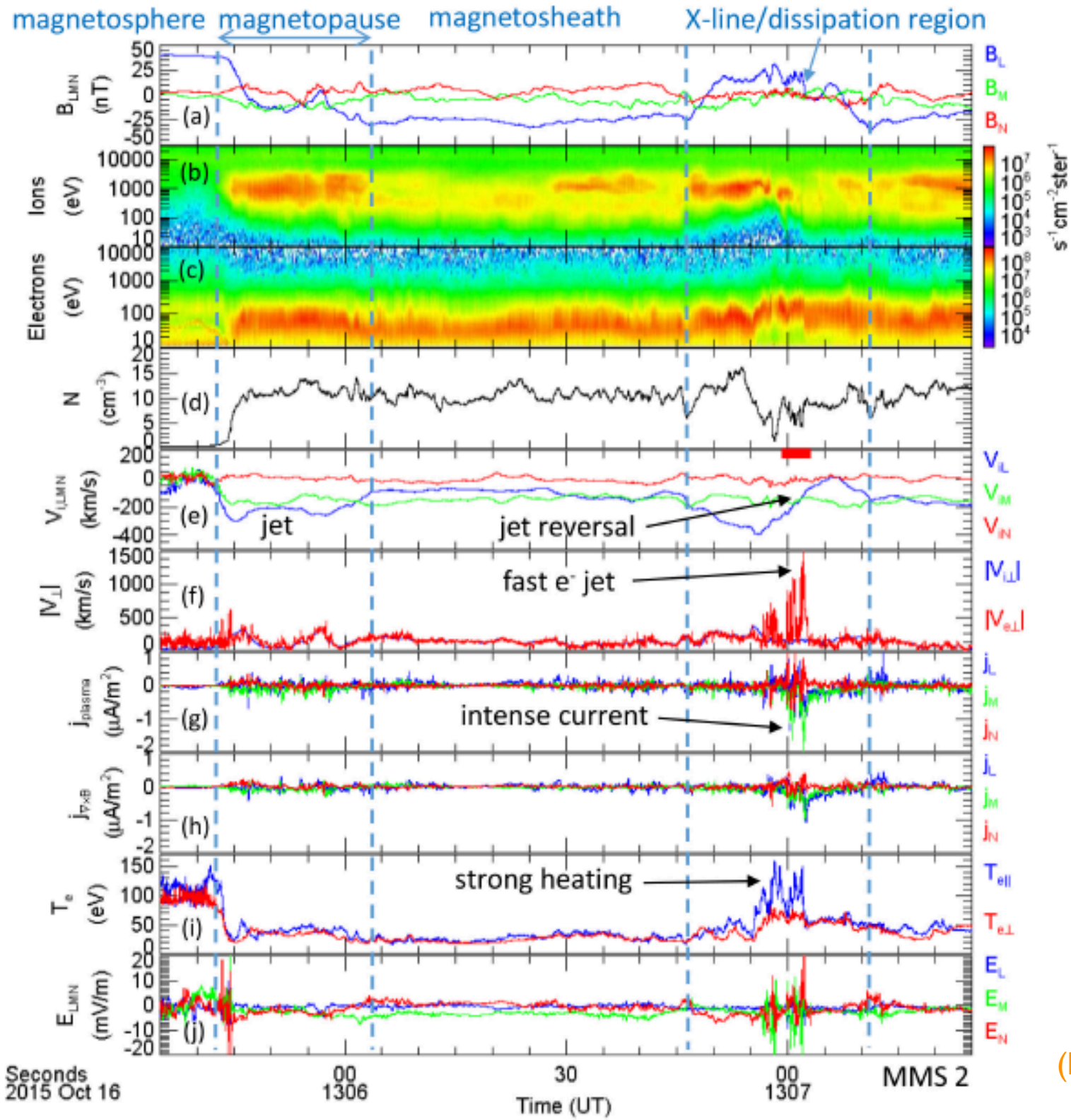


B_{x1} B_{y1} n_1 T_1 V_{x1} V_{y1}

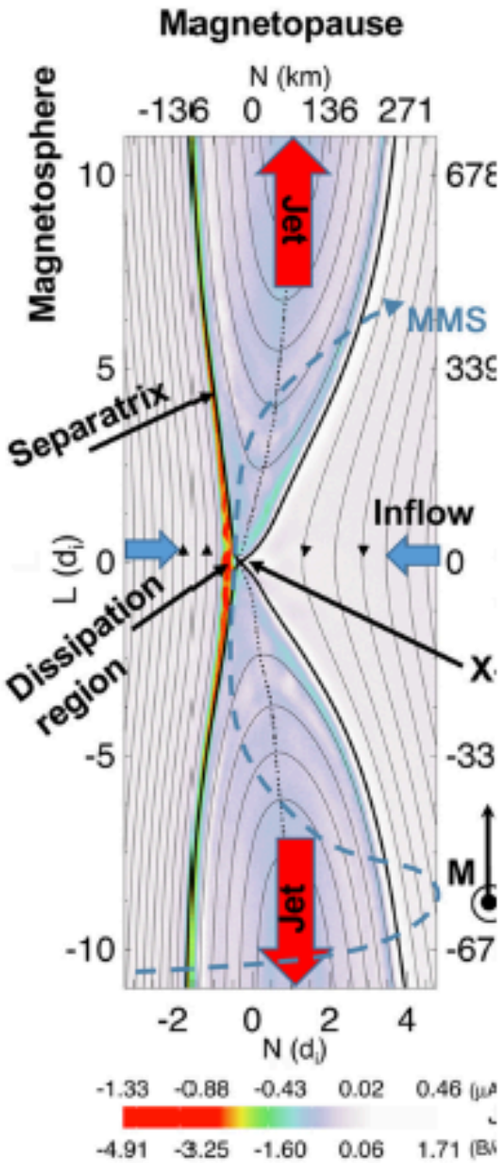
- The upstream conditions cover a wide range of variety.

Step1: Give us the upstream condition

2 1



PIC simulation



(Burch et al. SCIENCE 2016)

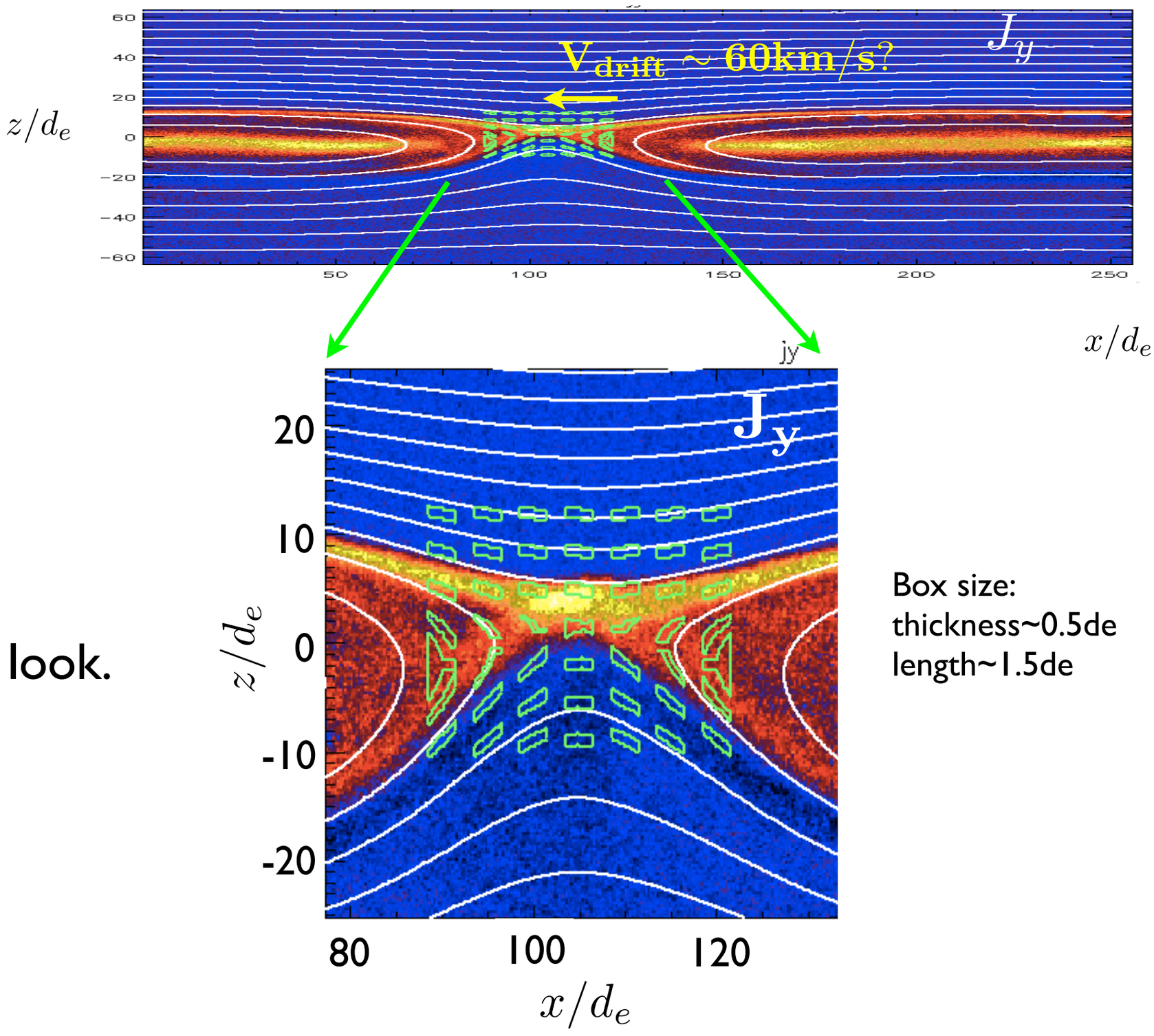
Step 2: We make a run, generate fields, moments & distributions

Quick-look:

- Field-aligned boxes.
- @ Geometrically important locations.
- ~ 7 x 7 boxes should be enough for a quick look.

User specification:

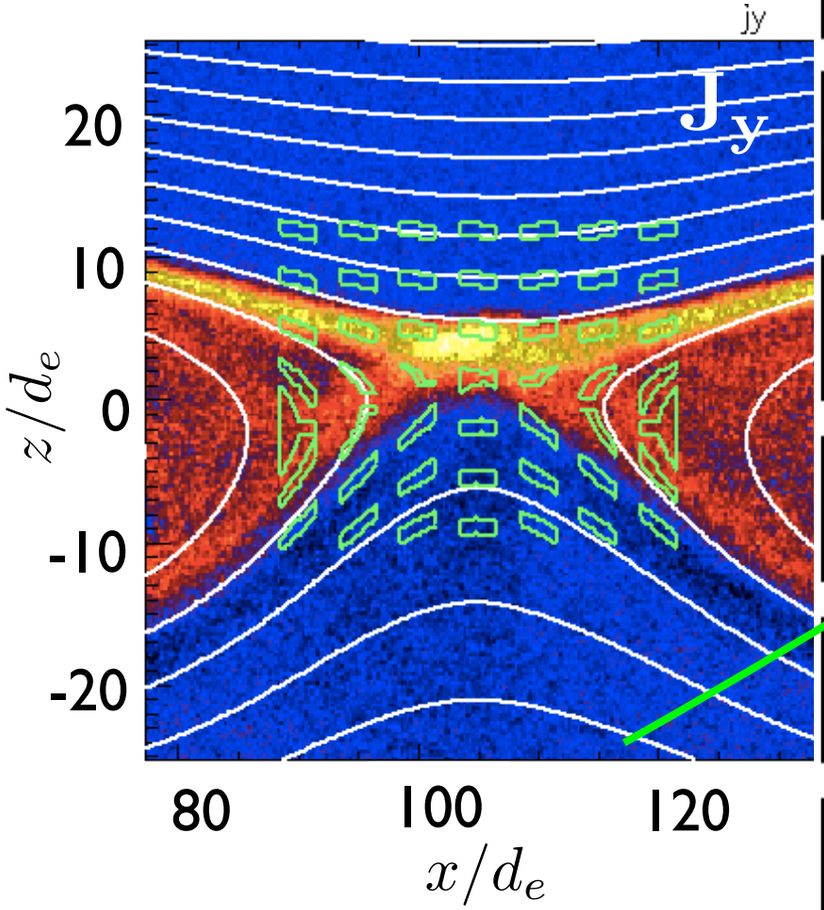
- You can request your own boxes.



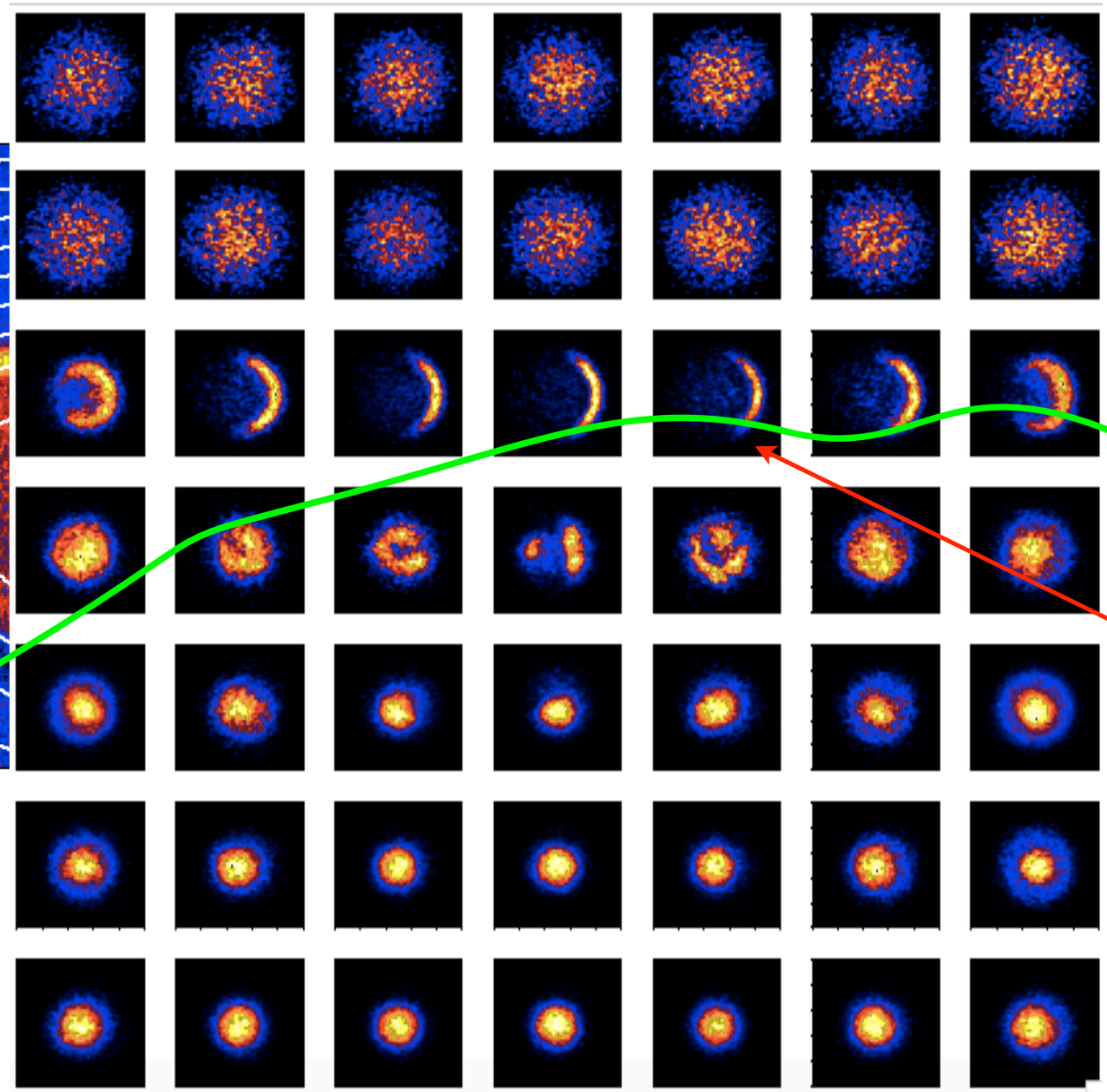
Box size:
thickness~0.5de
length~1.5de

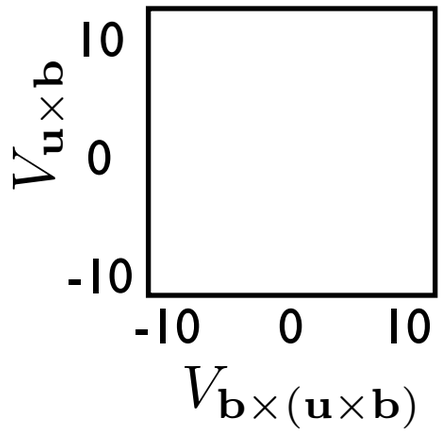
Step 2: We make a run, generate fields, moments & distributions

(e.g., Shuster et al. 2015)



Quick-look

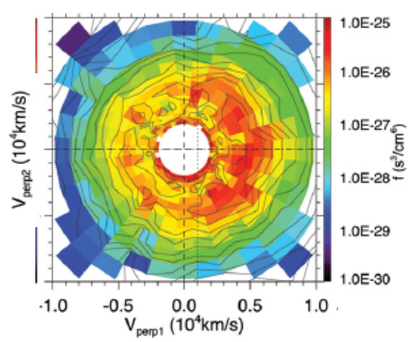




possible spacecraft trajectory

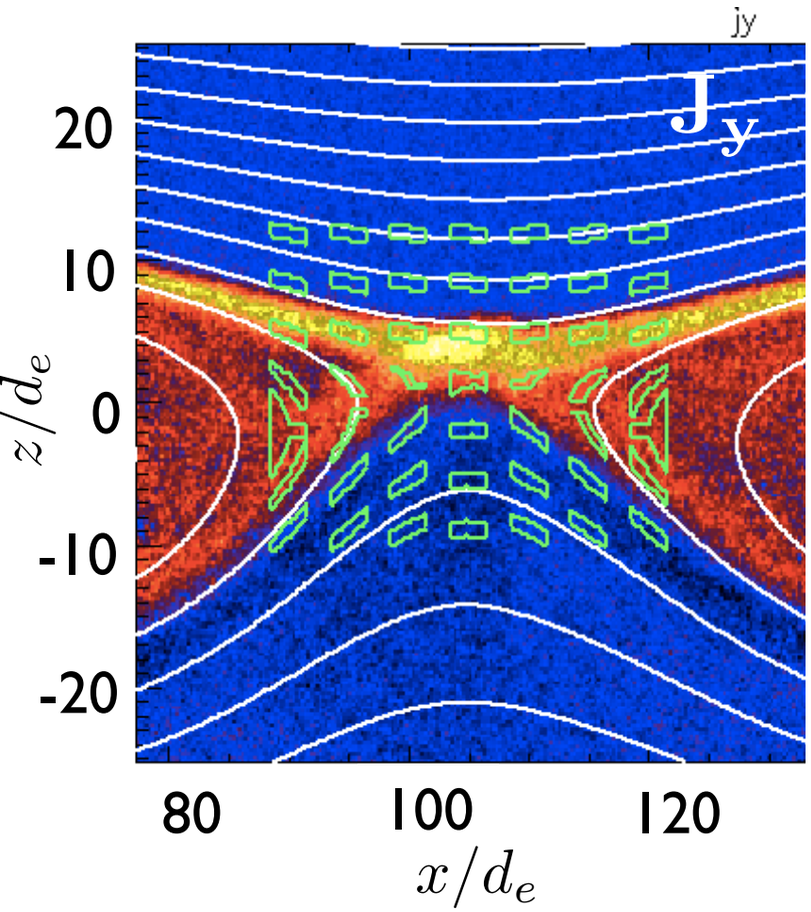
MMS data

Crescent!

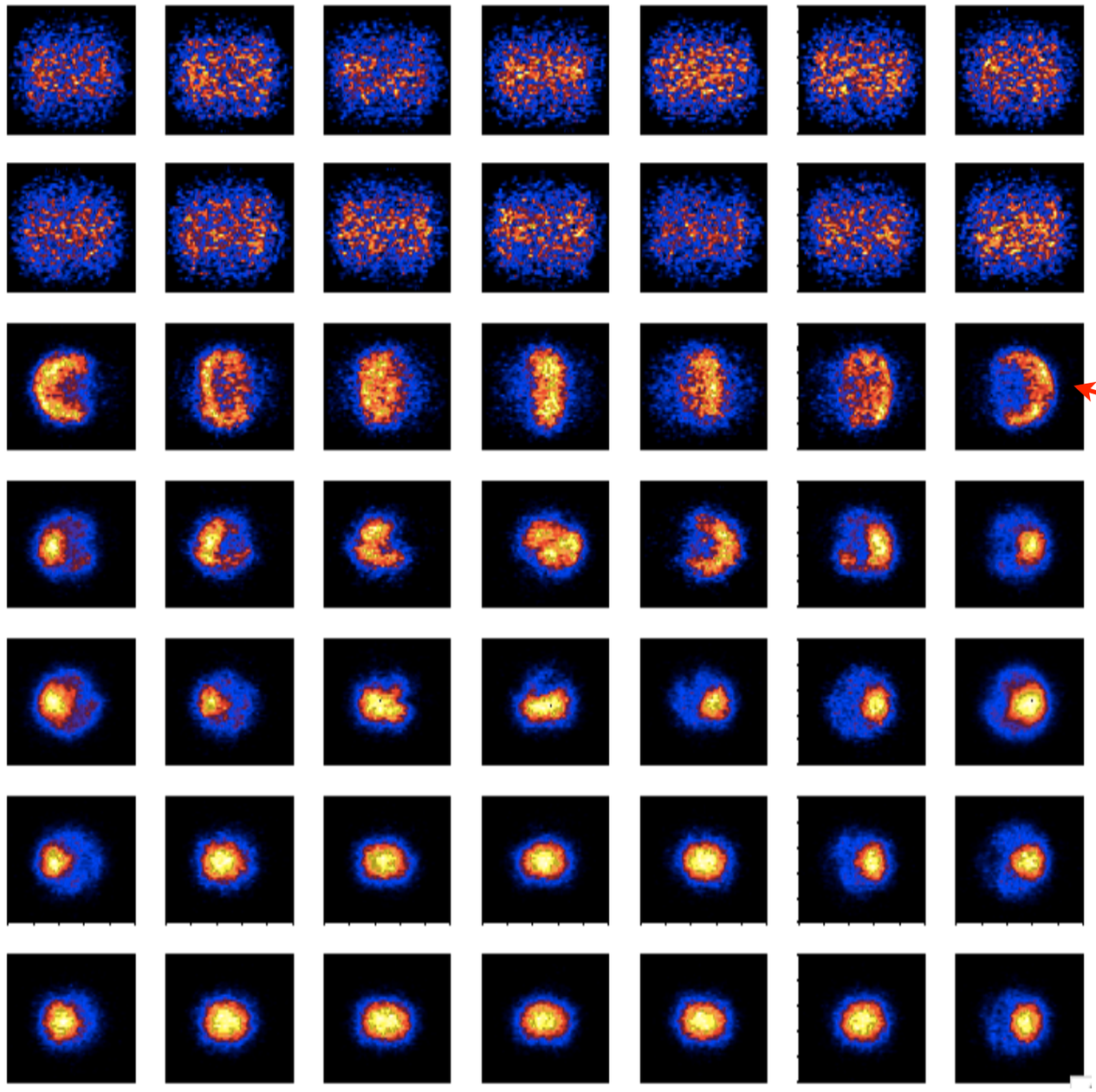


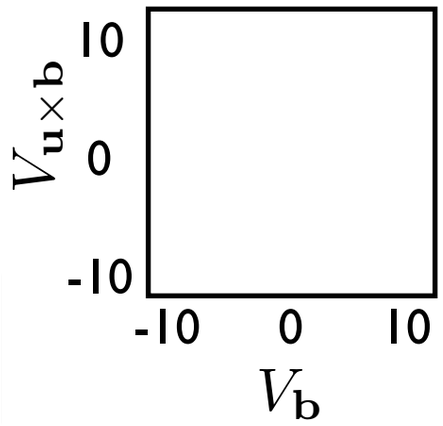
(Burch et al. SCIENCE 2016)

Step 2: We make a run, generate fields, moments & distributions



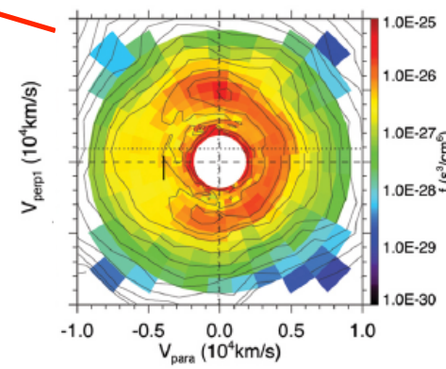
PIC simulation





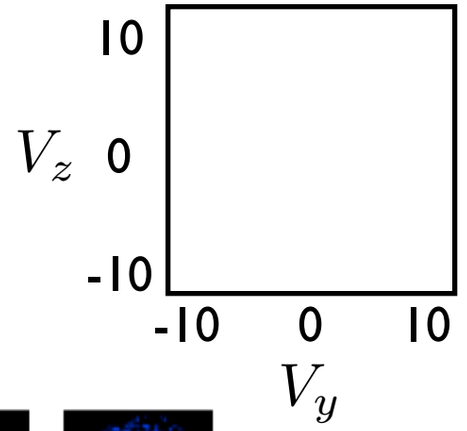
MMS data

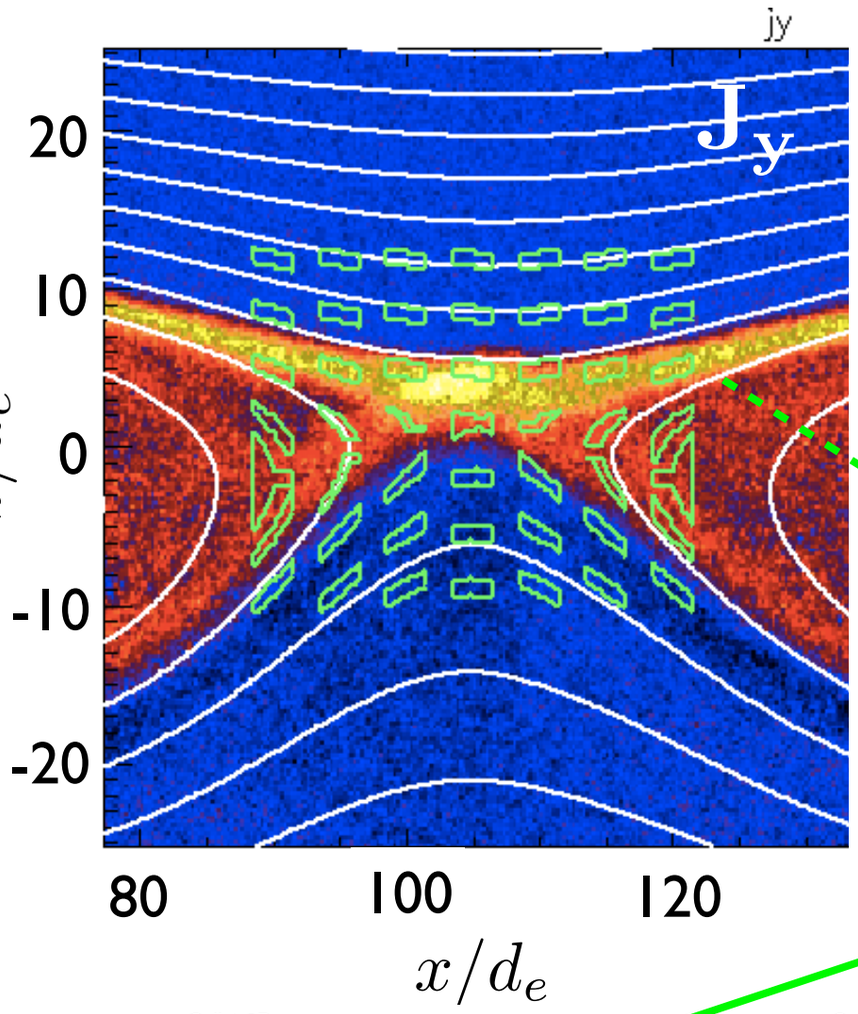
Parallel Crescent



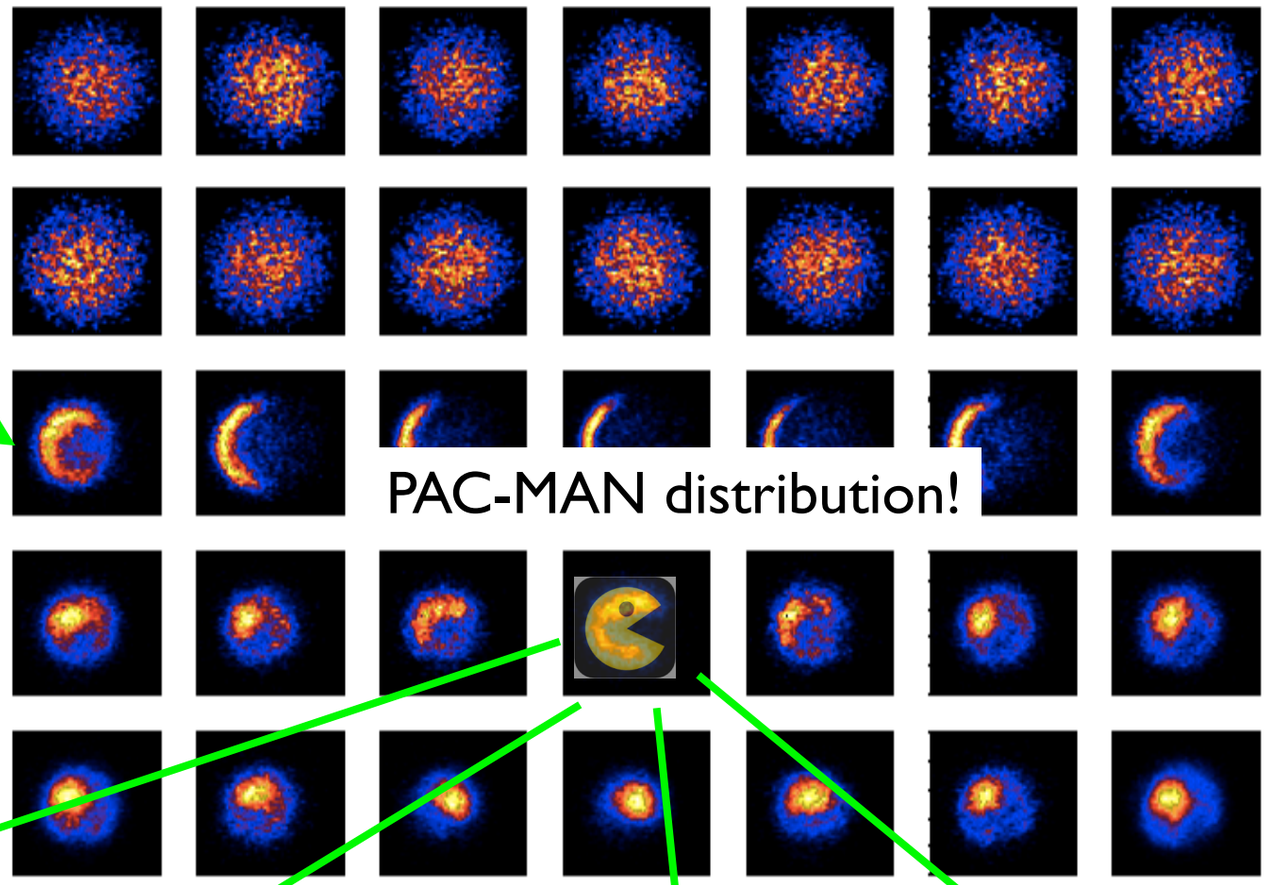
(Burch et al. SCIENCE 2016)

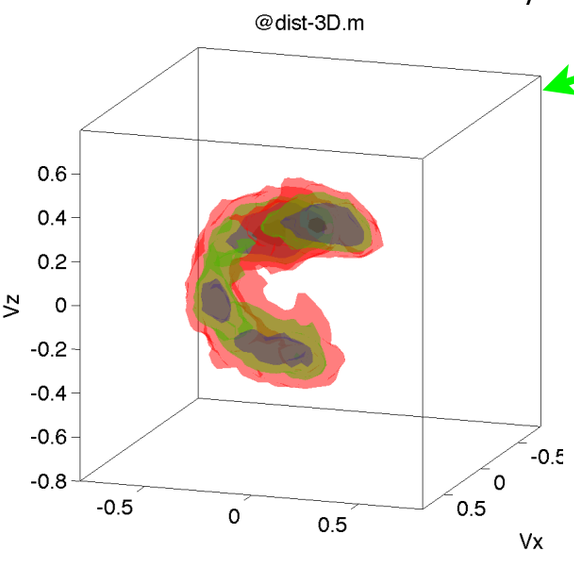
Full 3D distributions

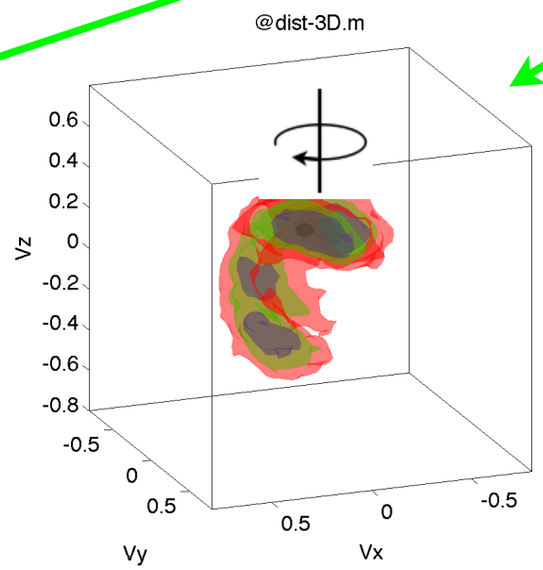


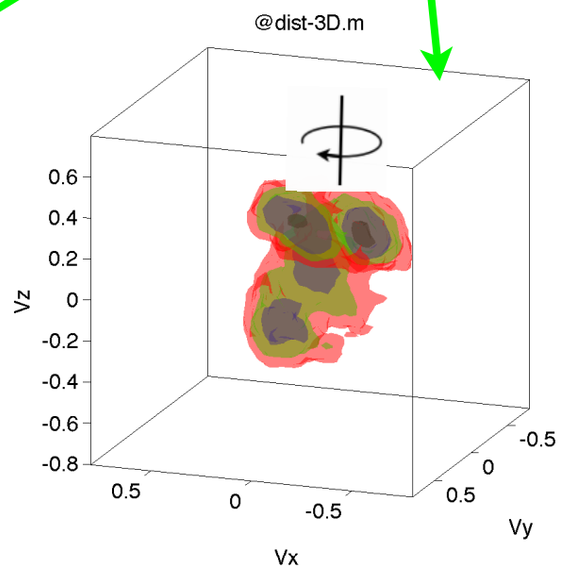


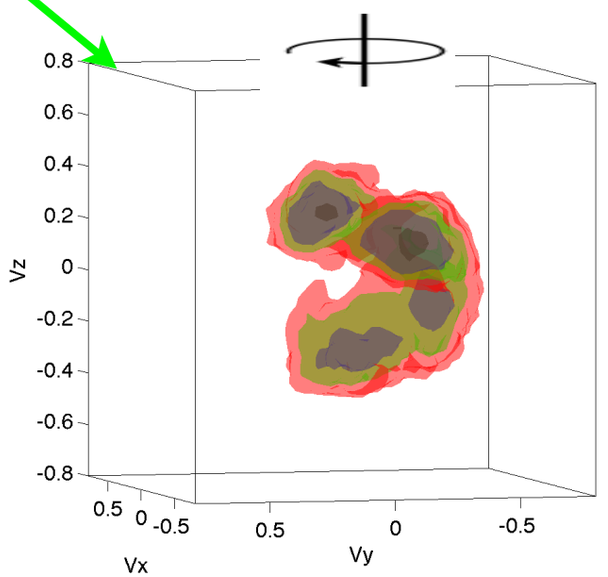
PIC simulation









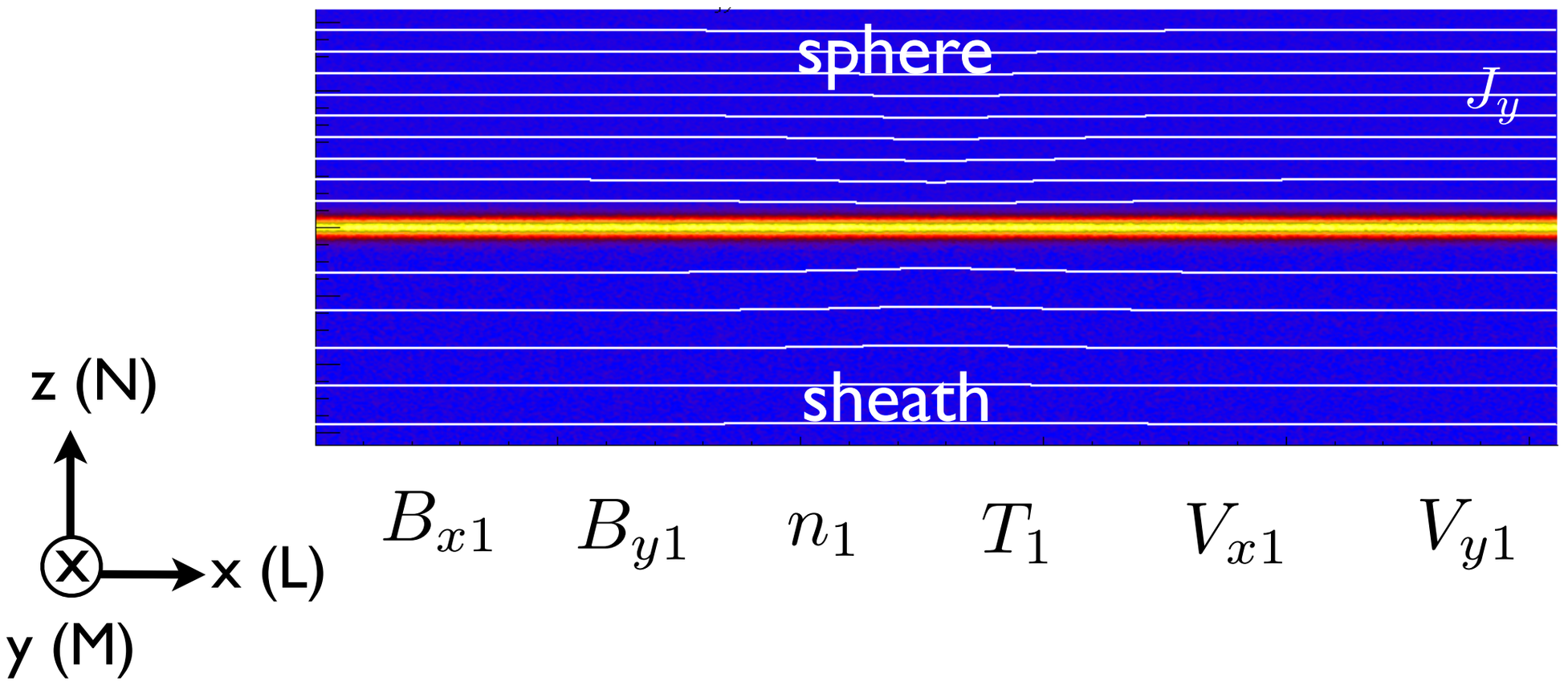


Run on Request (RoR) of PIC simulations at the CCMC

Run on Request

We have generalized the initial condition

B_{x2} B_{y2} n_2 T_2 V_{x2} V_{y2}



B_{x1} B_{y1} n_1 T_1 V_{x1} V_{y1}

- An user can request a run with customized upstream conditions.

-- CCMC generates particle distribution & field & moment.

-- All data is published on-line & can be analyzed interactively using tools on CCMC.

Profile employed

$$B_x = b_0[1/2 + \alpha_1 \tanh(z/L)]$$
$$B_y = b_0 b_g$$
$$n = \alpha_3[1 - \alpha_2 \tanh(z/L)]$$
$$T = [\alpha_4 - B_x^2/2]/n$$
$$V_x = \alpha_5 \tanh(z/L)$$
$$V_y = \alpha_6 \tanh(z/L)$$

& arbitrary rotation respected to z-axis is possible.

* Note, the pressure balance in the z-direction is always satisfied.

MMS science event (Burch et al., 2016)

Observer-inputs

% in nT
B_{1L}=-23;
B_{1M}=-2.278;
B_{2L}=39;
B_{2M}=-2.278;

% in km/sec
V_{1L}=-80;
V_{1M}=-150;
V_{2L}=0;
V_{2M}=0;

%in 1/cm^3
n_1=11.3;
n_2=0.7;

% in eV
T_{e1}=28;
T_{e2}=95;

T_i/T_e=10.0;

converting into code input

Modeler-inputs

m_i/m_e=25
T_i/T_e=10.0
w_{pe}/w_{ce}=4.0
B_{x2}/B_{x1}=-1.6957
n_2/n_1=0.061947
T_2/T_1=3.3929
B_{g1}=-0.14238
B_{g2}=-0.14238
V_{x_shear}/V_{A1}=-0.26817x2
V_{y_shear}/V_{A1}=-0.50282x2
V_{A1}/c=0.0719

determining

α_{1-6}

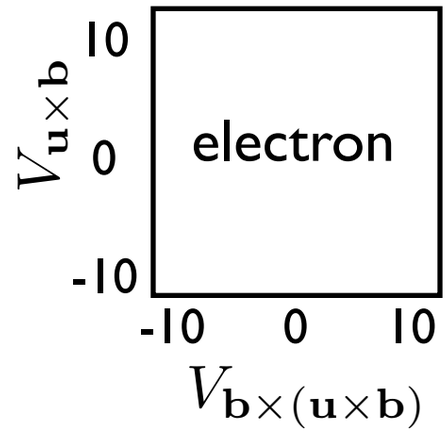
The prototype run size

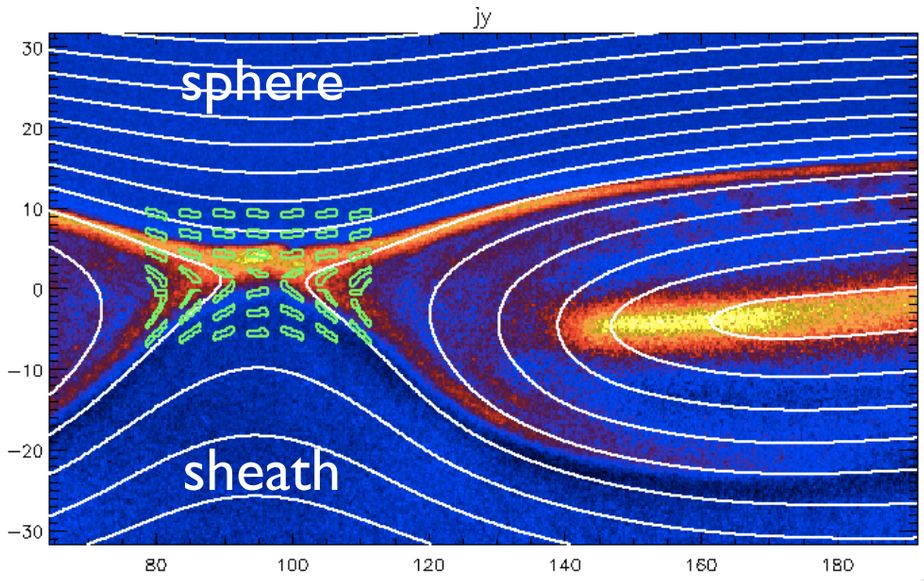
mi/me=25
particle/cell=200
Lx x Lz = 51.2di x 25.6di
nx x nz = 1024 x 512
wpe/wce=4.0

resource required:
256 CPUs x 1 hour ~ 256 CPU-hours
Particle data/frame ~ 3 GB
Total fields & moments data ~ 3 GB

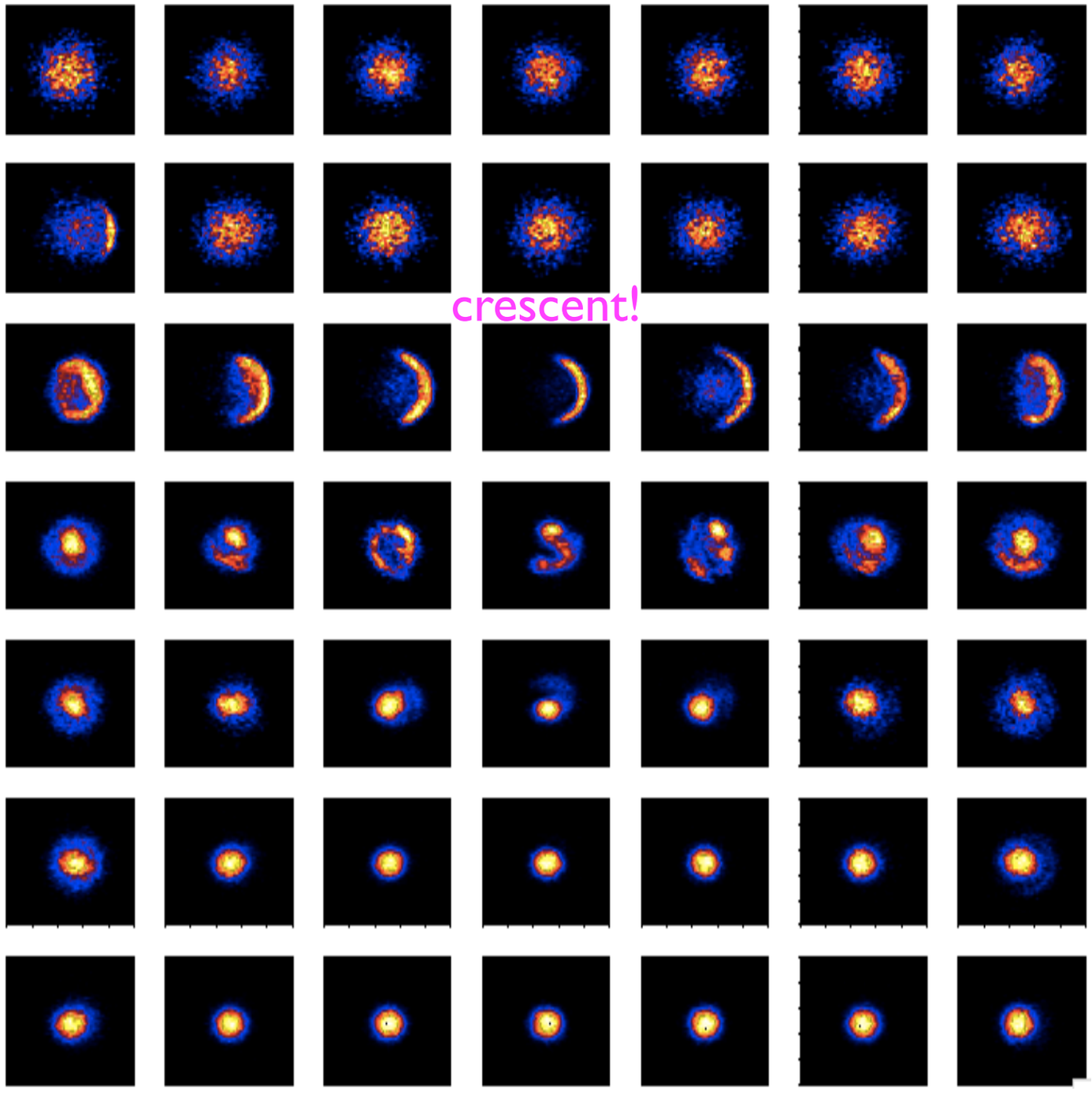
A customized run for the event in the SCIENCE paper

http://ccmc.gsfc.nasa.gov/RoR_WWW/PP/PIC_DIST/2016/Lutz_Rastaetter_20161121_PP_1/Lutz_Rastaetter_20161121_PP_1.php





Quick view



A customized run for the event in the SCIENCE paper

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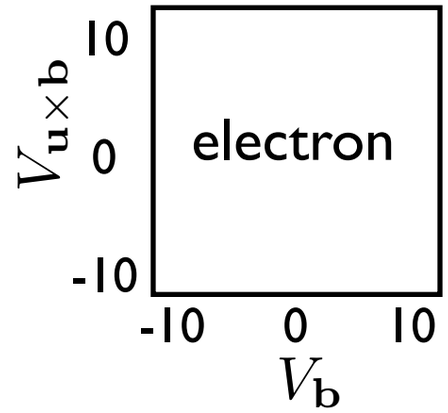

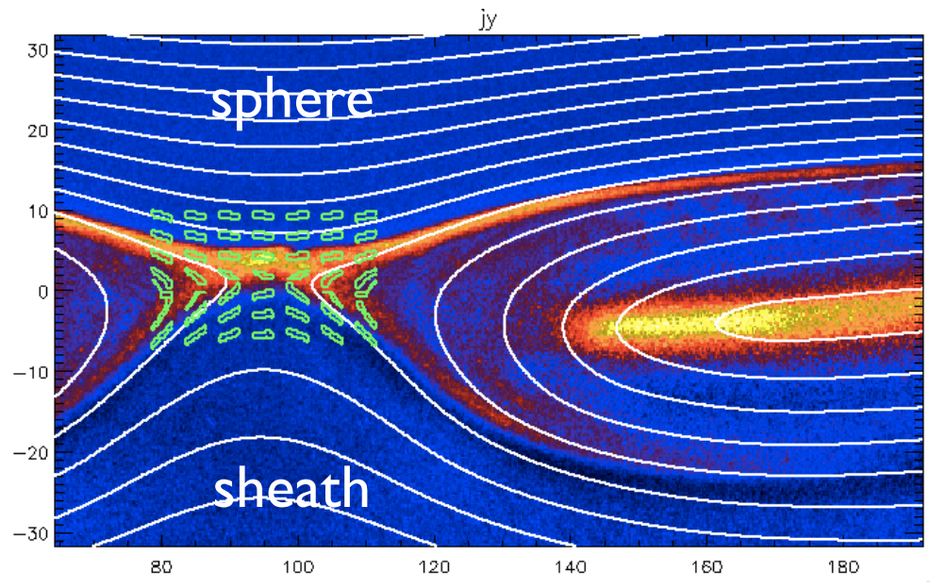

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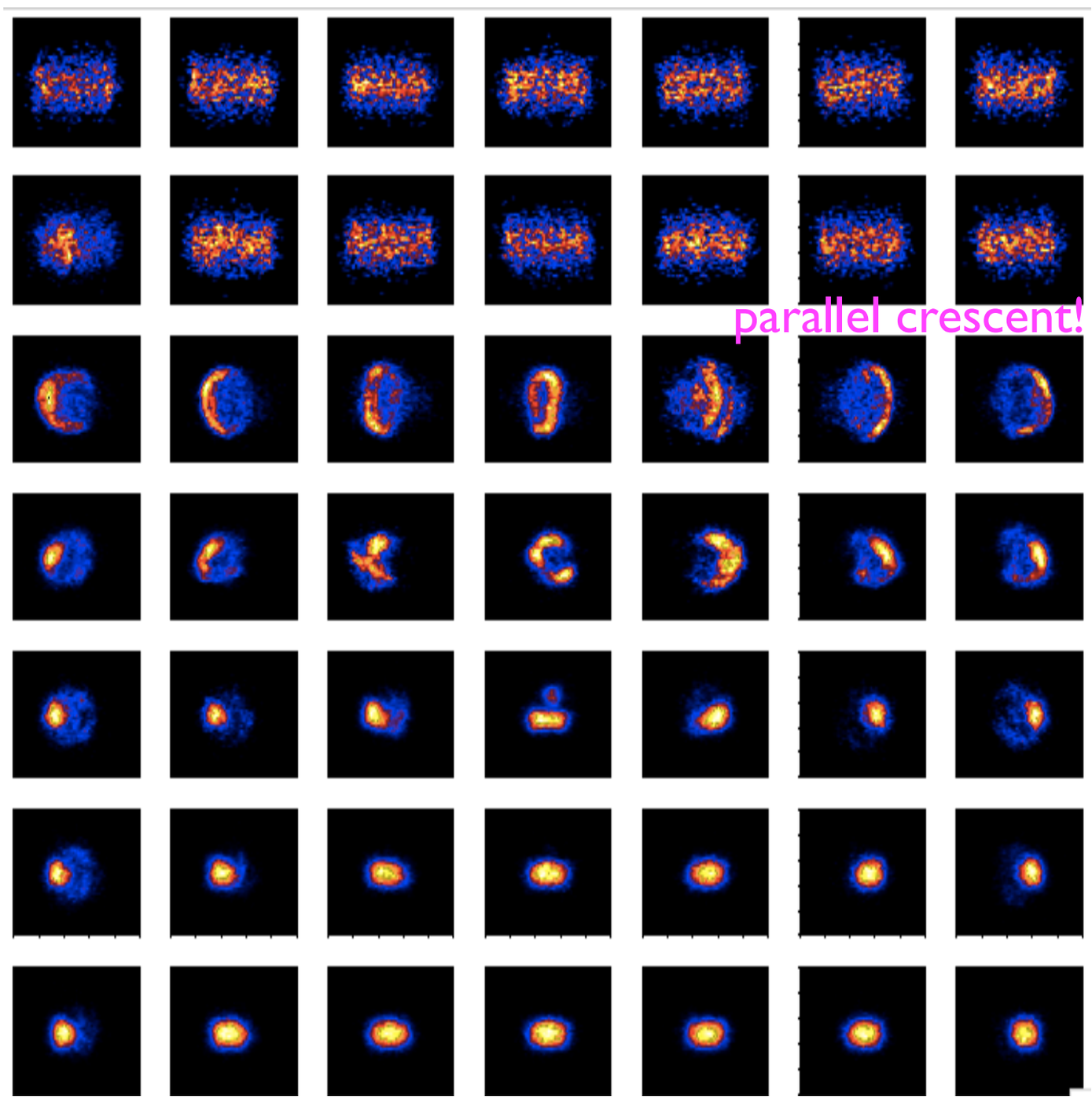

We are accepting order~

- For now, eMail to Lutz.Rastaetter@nasa.gov with the following information

% in nT	% in km/sec	%in 1/cm^3	% in eV
B_{1L}	V_{1L}	n_1	T_{e1}
B_{1M}	V_{1M}	n_2	T_{e2}
B_{2L}	V_{2L}		T_i/T_e
B_{2M}	V_{2M}		

we will design & conduct a run, publish it on-line, then notify you.

- Lutz is in the process of designing the on-line interface for the Run on Request (RoR)!

Demo by Lutz ....