Kinetic features in the Kelvin-Helmholtz instability

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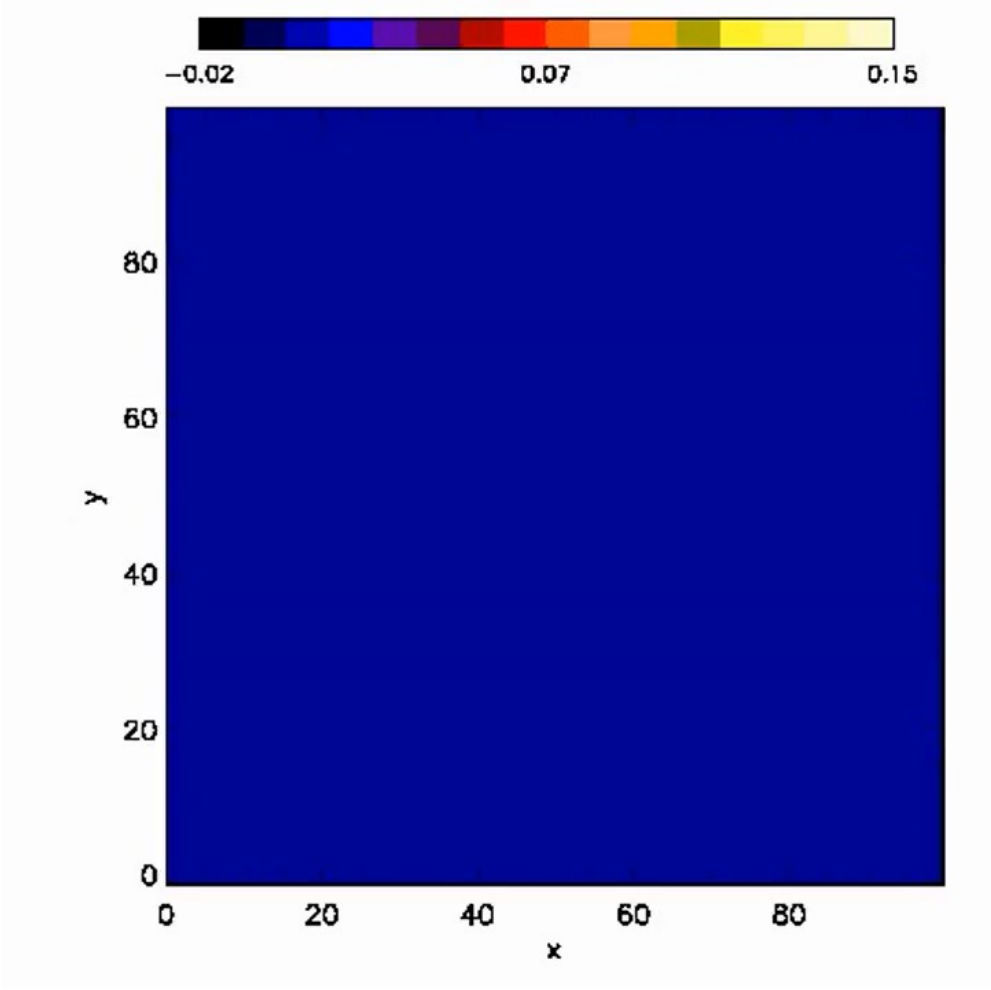
Hybrid simulation of KH instability

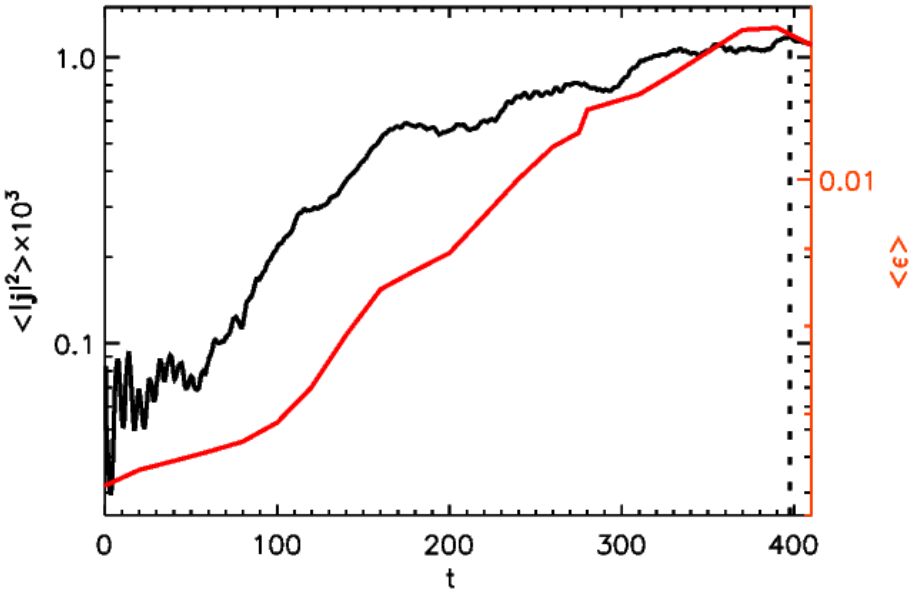
Iso-contours of proton current density along the entire simulations time



2D-3V simulation
with the HVM code (*Valentini et al. 2007*);

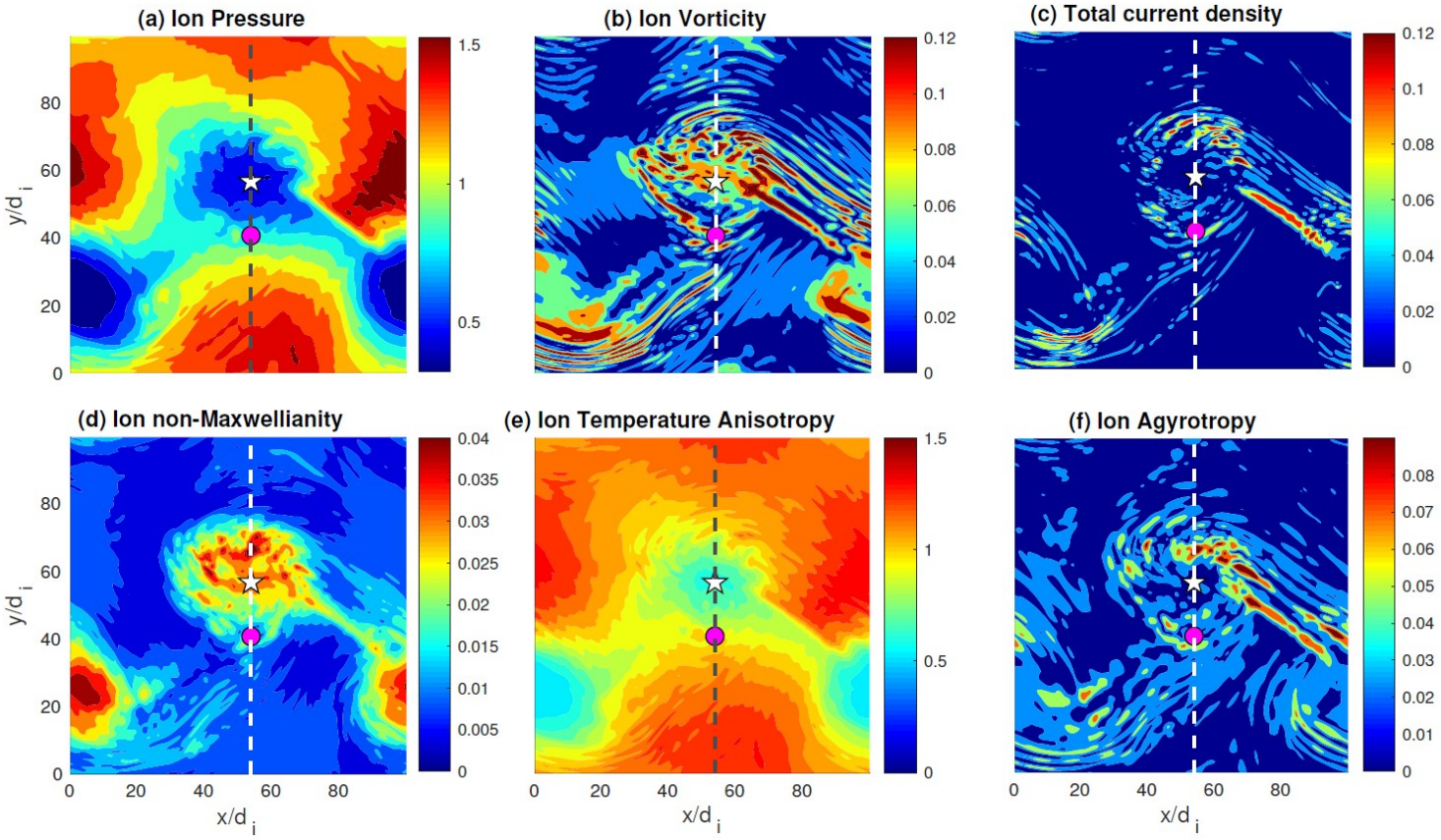
We start from an exact equilibrium configuration (*Malara et al.* PRE, 2018)

Generation of large scale structures that collapse in two vortices and form thin current sheets.

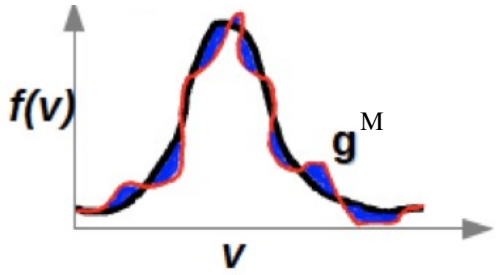


[Settino et al., **ApJ**, 2020]

Kinetic features



Ion non-Maxwellianity



$$\epsilon_M = \frac{1}{n_i}\sqrt{\int [f_i - g_M]^2 \, d^3v}$$

Greco et al. 2012

Ion Agyrotropy

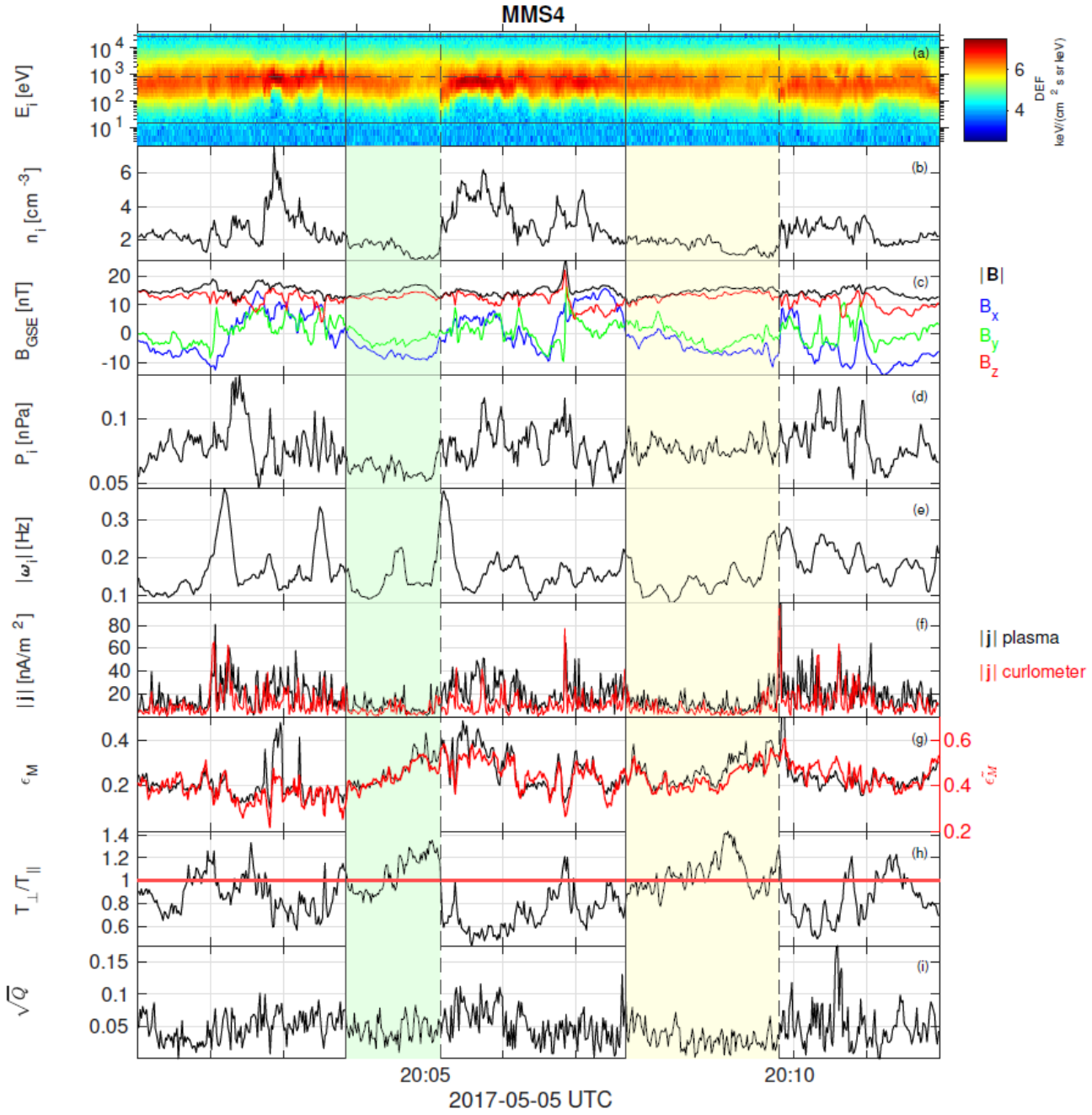
$$Q = \frac{P_{xy}^2 + P_{xz}^2 + P_{yz}^2}{P_\perp^2 + 2P_\perp P_\parallel};$$

Swisdak, 2016

1. |**j**| peaks at the edges of the vortex;
2. ϵ_M peaks inside the vortex.

[Settino et al., **ApJ**, 2021 (accepted)]

KH event observed by MMS



Ion non-Maxwellianity

$$\epsilon_M = \frac{1}{n_i}\sqrt{\int [f_i - g_M]^2 \, d^3v}$$

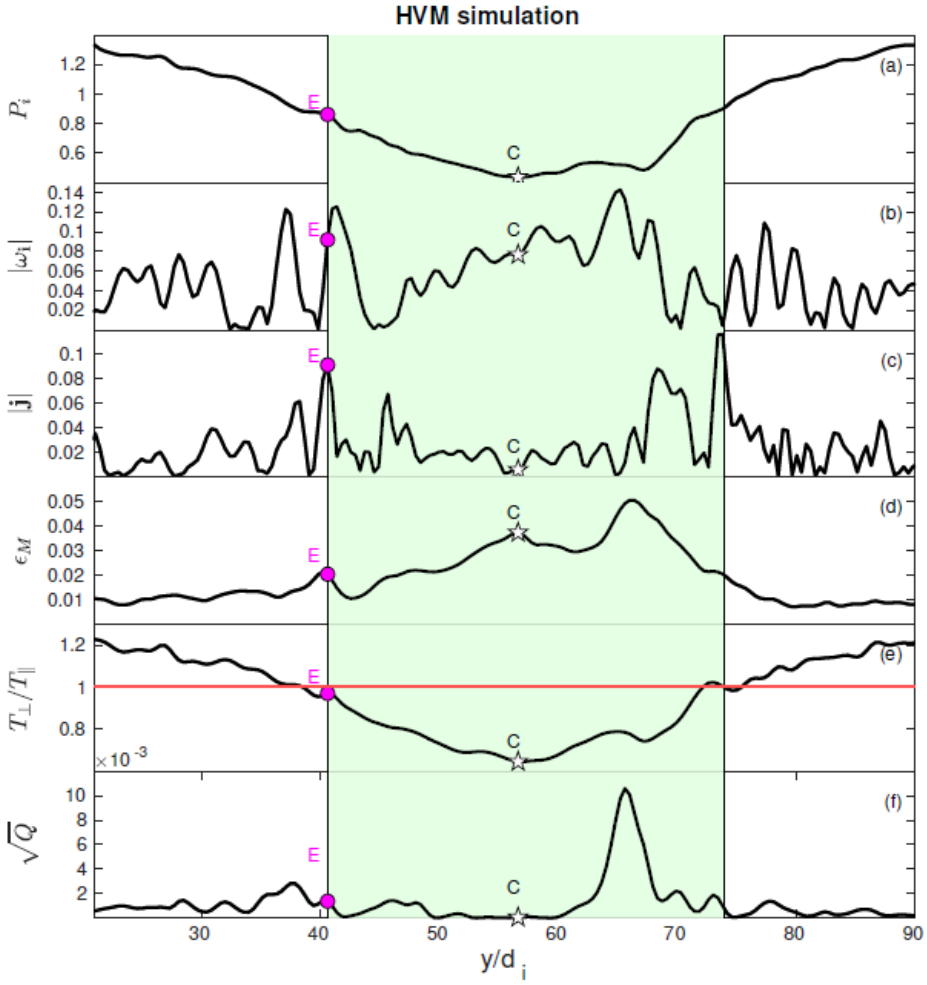
Greco et al. 2012

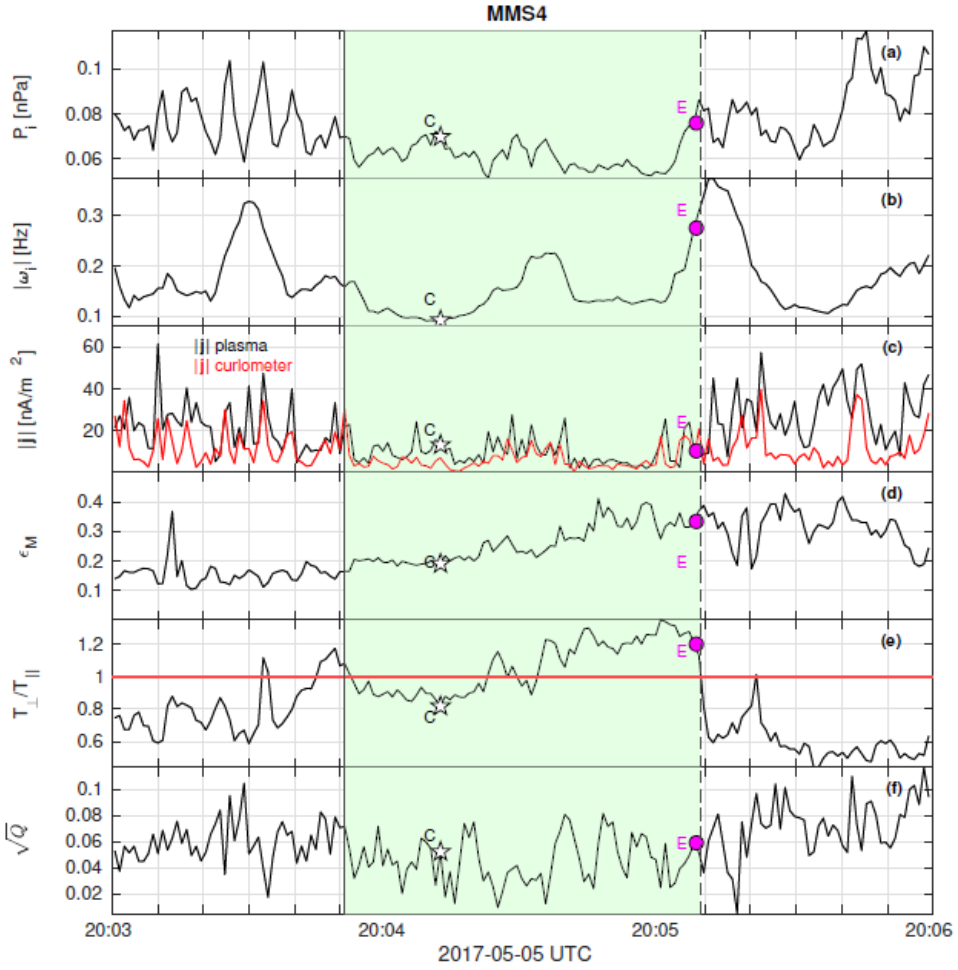
$$\tilde{\epsilon_M} = \frac{1}{2n_i}\int |f_i - g_M| \, d^3v$$

Graham et al. 2021, (arxiv)

[Settino et al., **ApJ**, 2021 (accepted)]

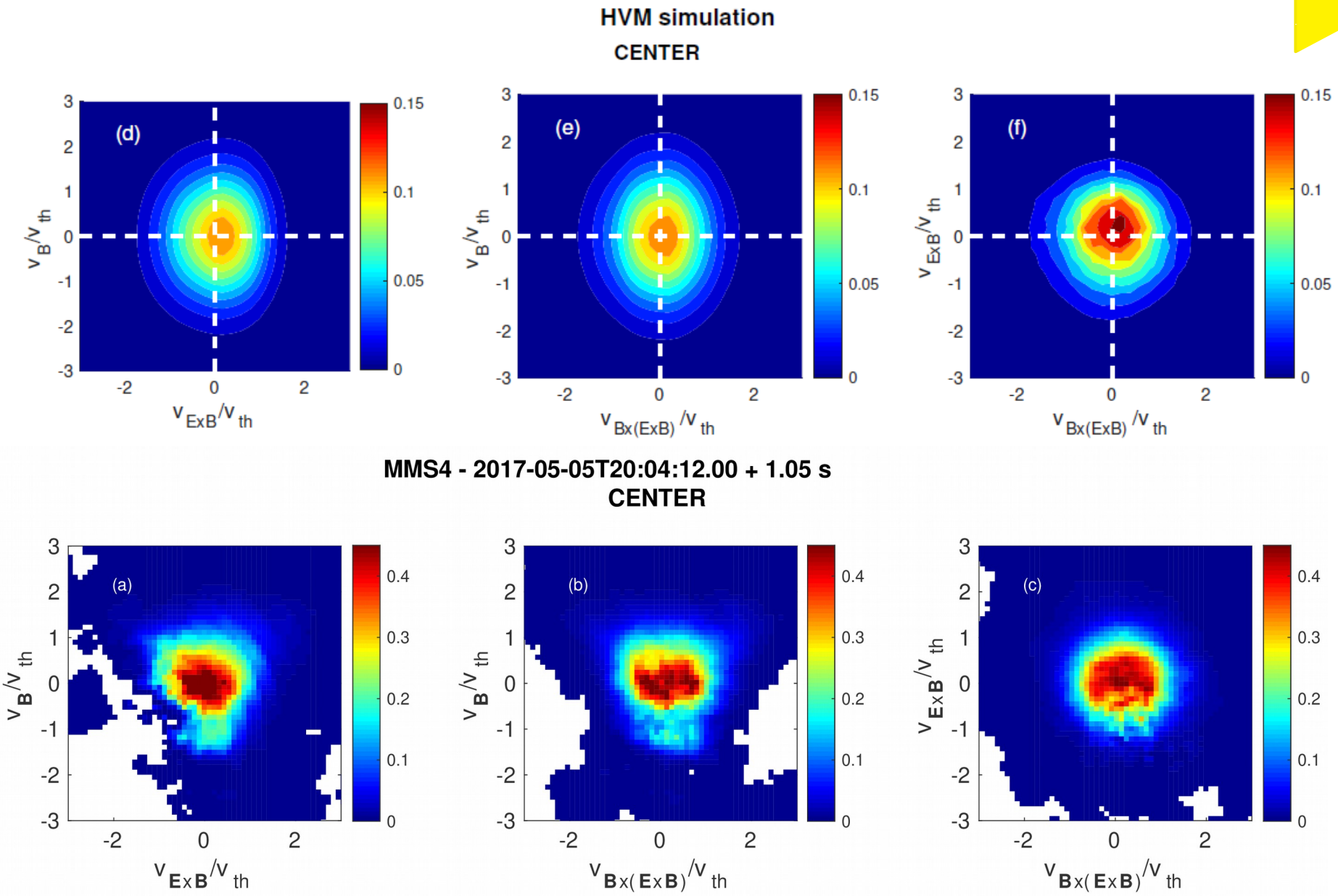
Comparison between simulation and observational data





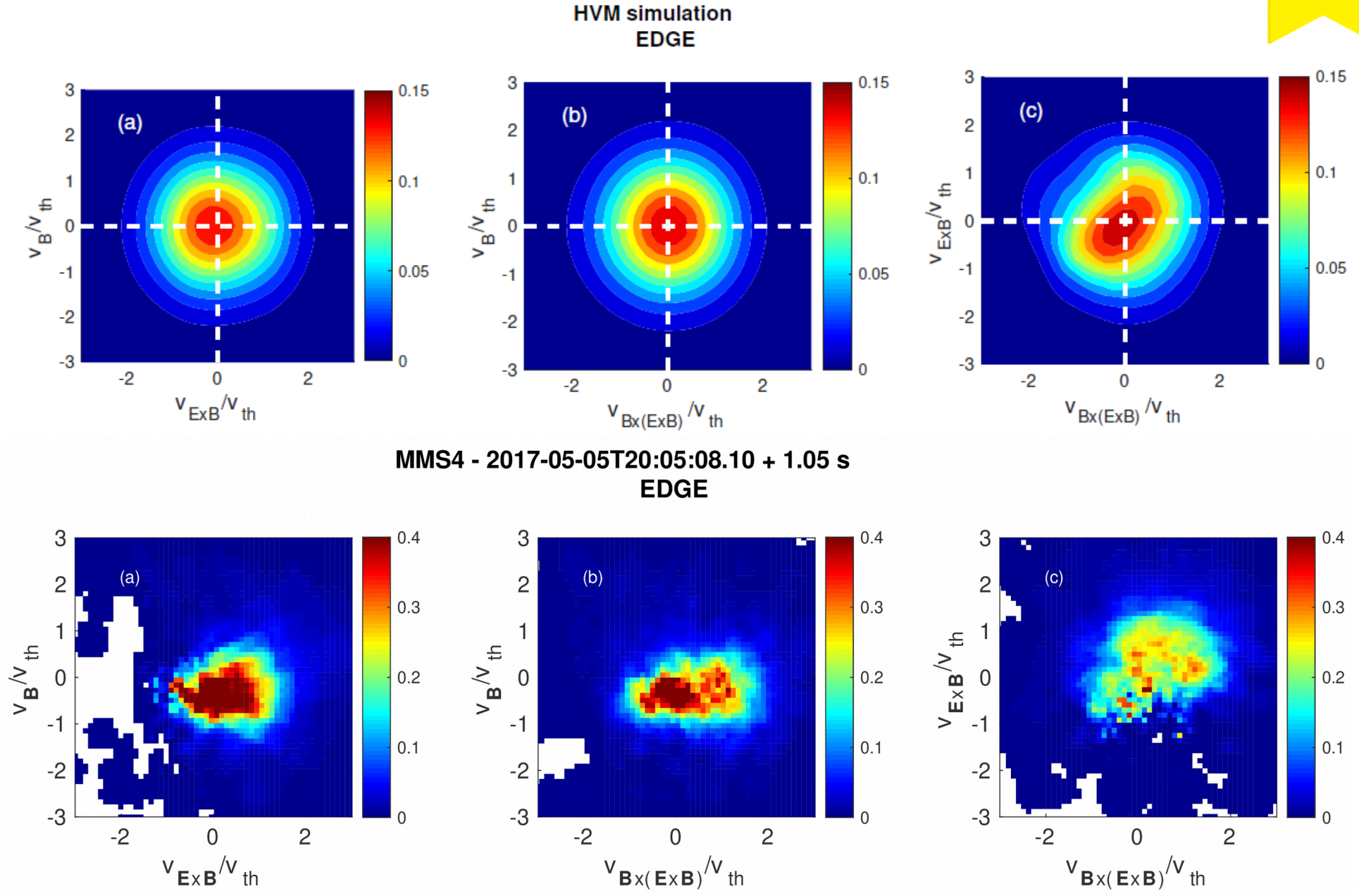
[Settino et al., **ApJ**, 2021 (accepted)]

VDF at the center of the vortex



[Settino et al., **ApJ**, 2021 (accepted)]

VDF at the edge of the vortex



[Settino et al., **ApJ**, 2021 (accepted)]

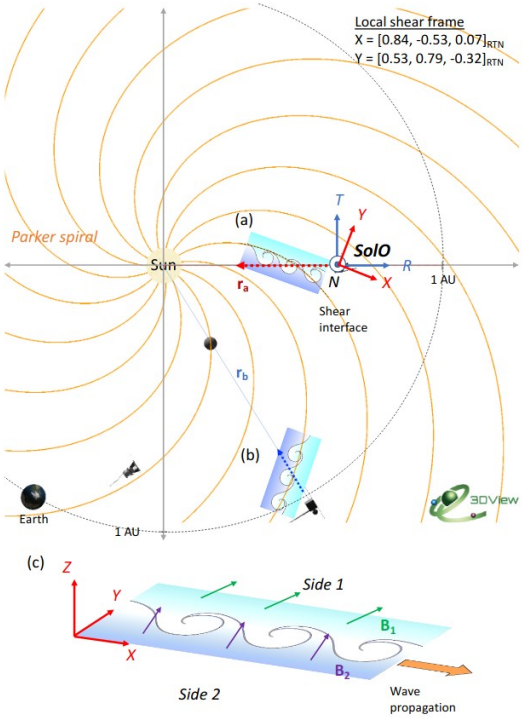
Conclusions

- Comparison between KH simulation and observations has suggested new quantities that can be used for the identification of vortices:

  1. Magnitude of the total current density peaks at the edges of the vortices and has a minimum inside the vortex;
  2. The ion non-Maxwellianity is low at the edges of the vortex and increases inside the vortex;
  3. Ion agyrotropy has the same behavior of the total current density;
  4. Change in the direction of the ion temperature anisotropy;

- Single spacecraft measurements which need a good resolution for the particles instrument;

- These quantities can be used in the Solar Orbiter mission to identify KH vortices.



[Kieokaew et al. 2021, **arxiv**]

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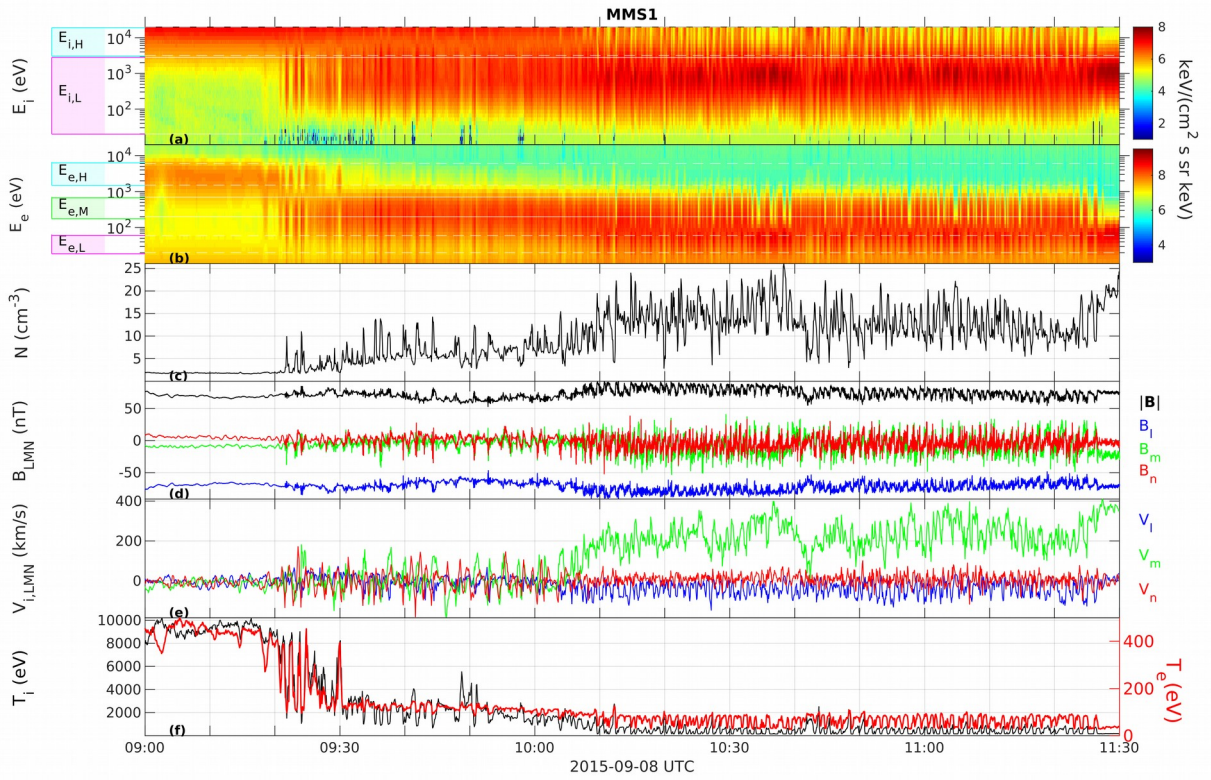
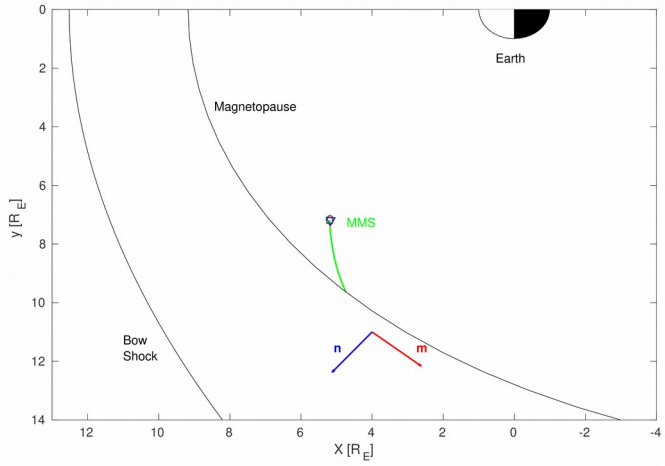
Mixing parameter

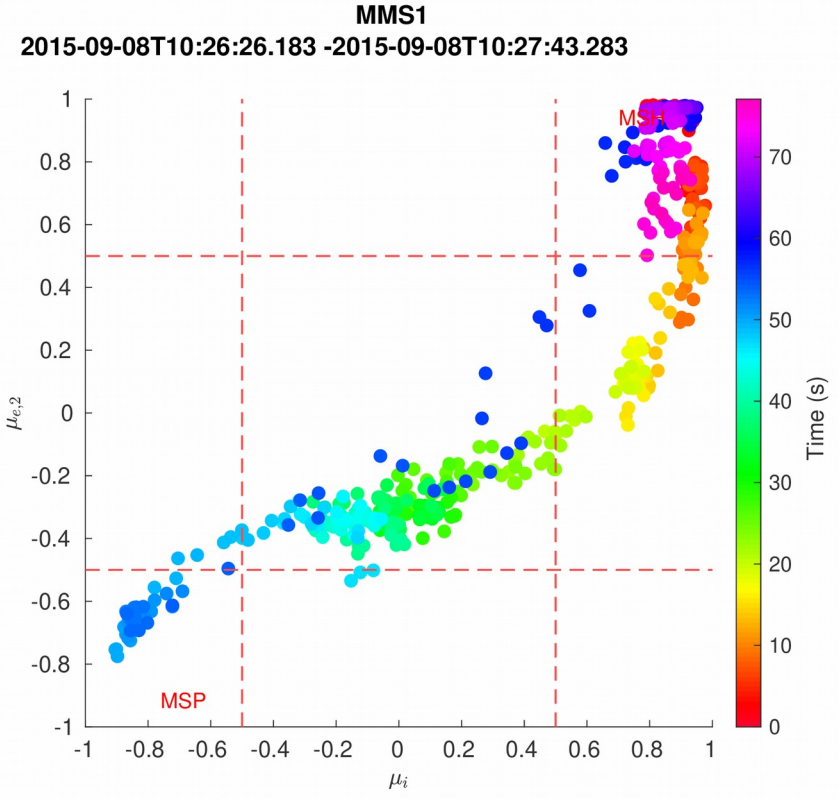




Ion mixing

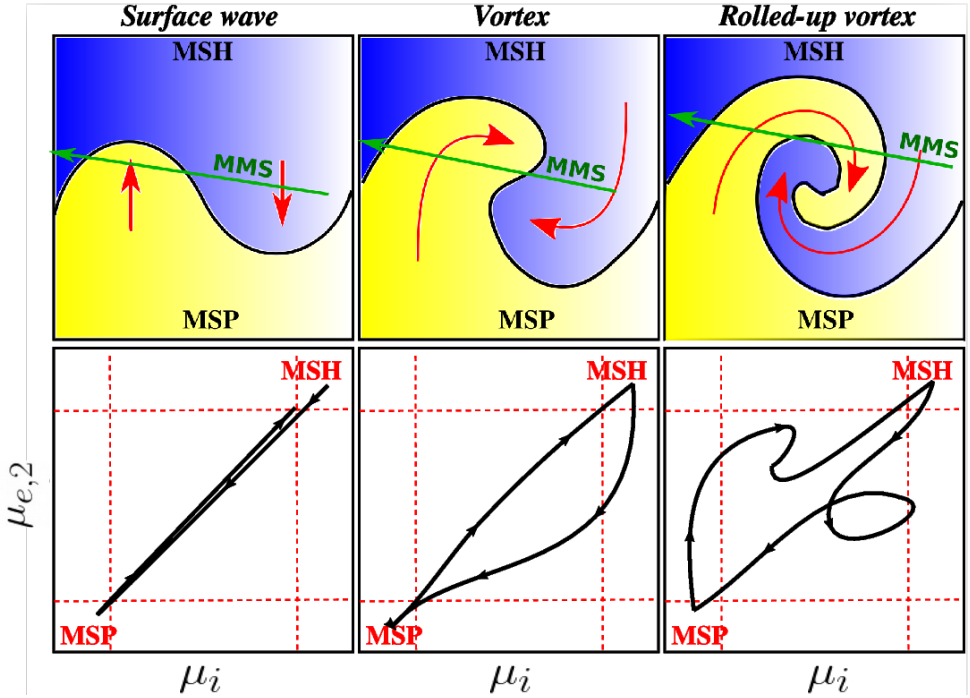
electron mixing

$$\mu_i = \frac{E_{i,L} - E_{i,H}}{E_{i,L} + E_{i,H}} \qquad \mu_{e,2} = \frac{E_{e,L} - E_{i,M}}{E_{i,L} + E_{i,M}}$$



[Settino et al., in prep.]

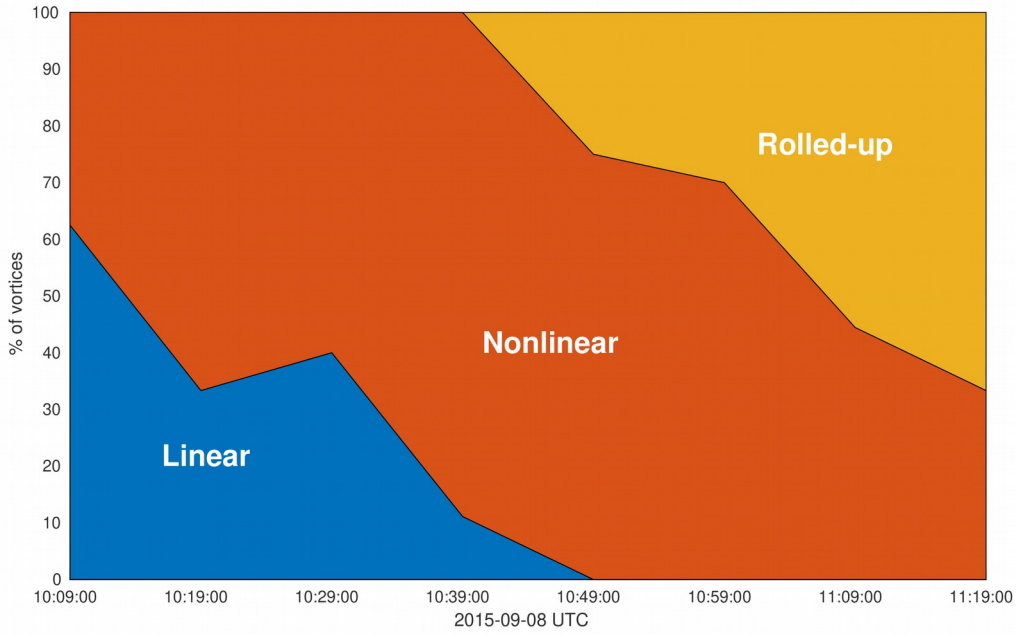
Statistical analysis



Three main shapes have been recognized in the space of the mixing parameter:

(a) same path trajectory;
(b) different path trajectory;
(c) complex trajectory with loops and twists.

- 69 crossings have been identified;
- Each crossing has been categorized according to its shape in the space of the mixing parameter;
- For each time interval the percentage of vortices has been evaluated.



[Settino et al., in prep.]