



# Distinct Types of Electron Velocity Distributions in Magnetotail Reconnection Exhausts

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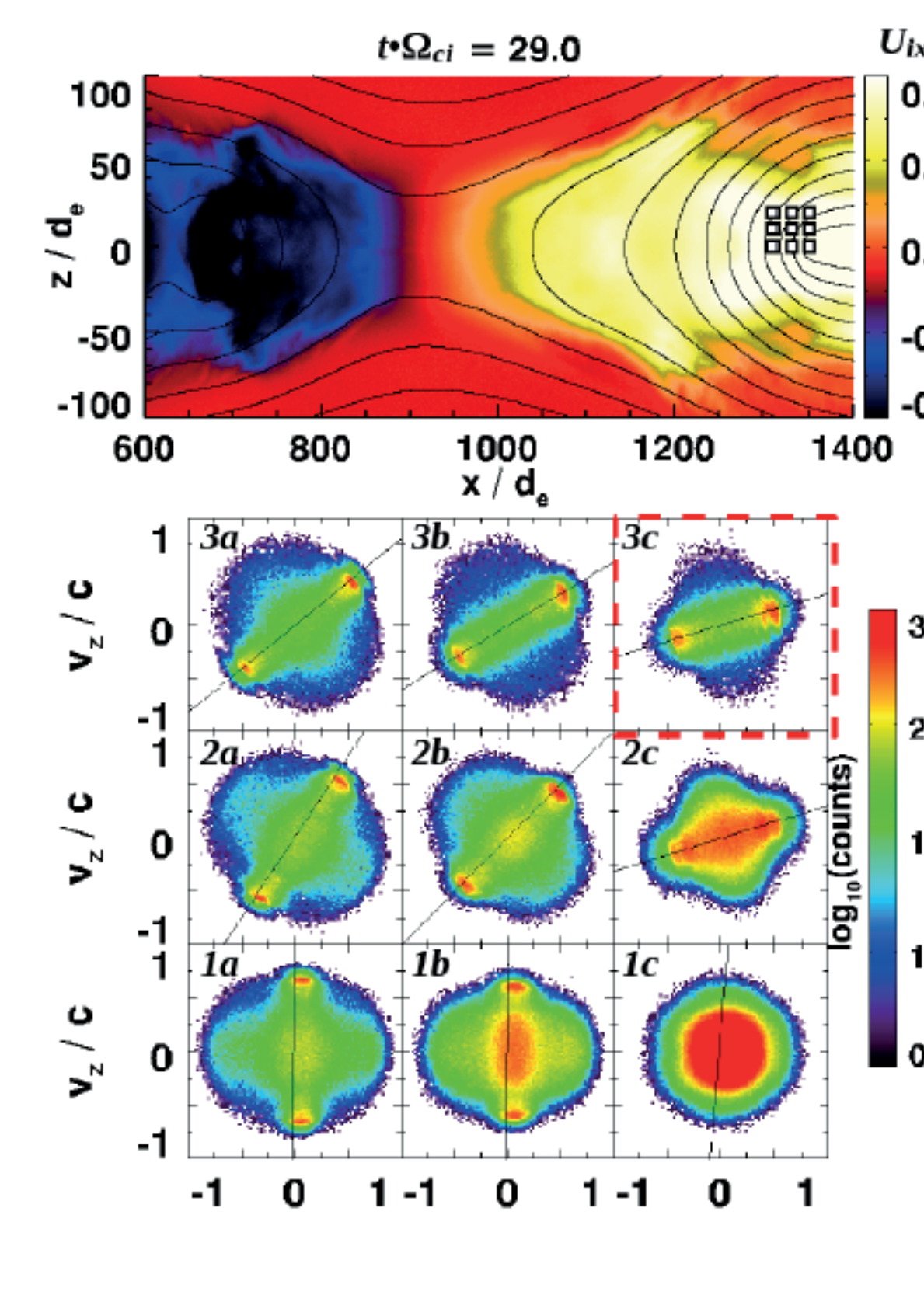
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## Introduction

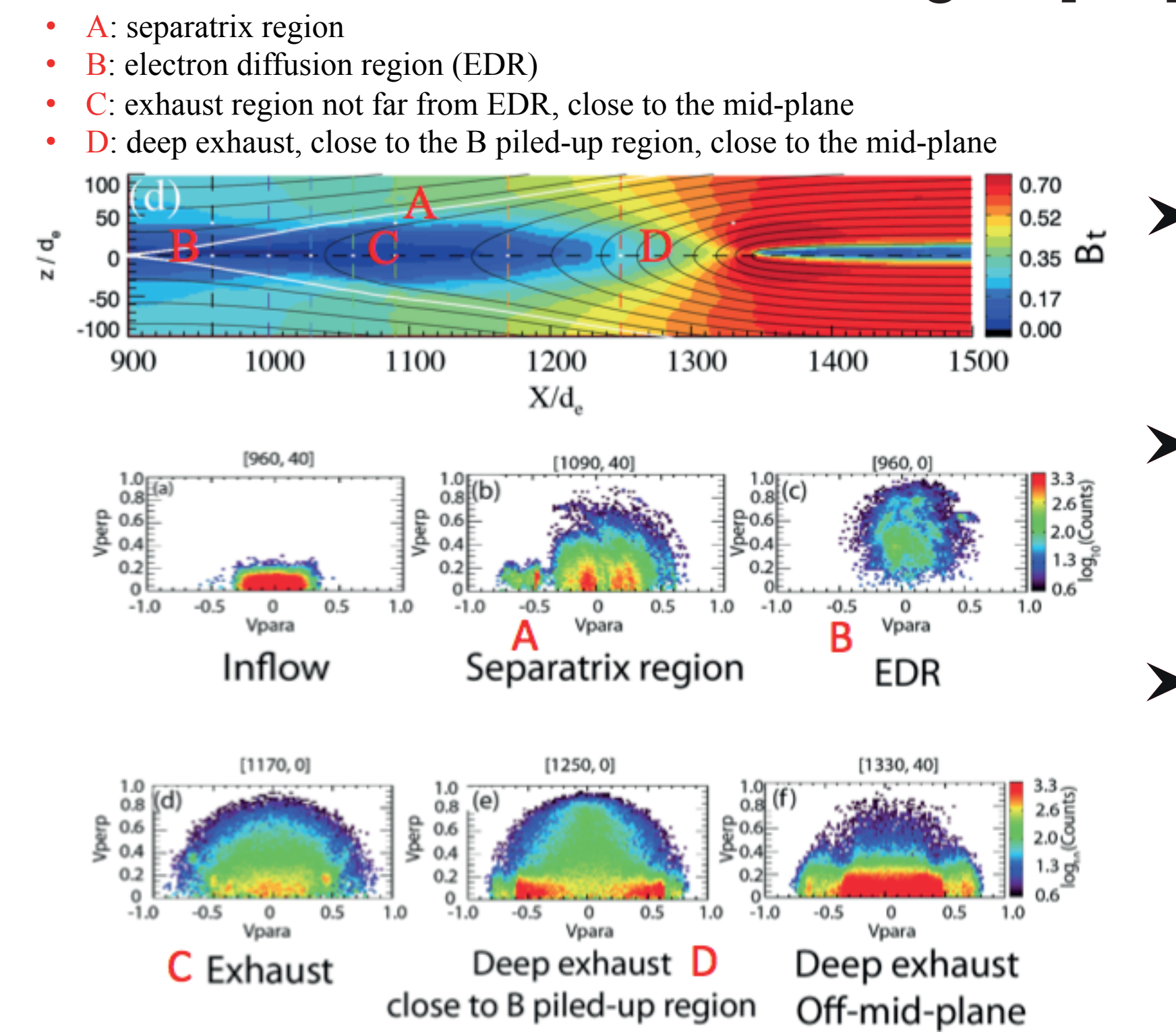
- ▶ Electron velocity distribution function is a very useful tool to identify reconnection region and analyze plasma dynamics in reconnection region [1-2].
- ▶ PIC simulation results show that the exhaust electron distribution develops various kinds of anisotropy with in several  $1/\Omega_{ci}$  after peak reconnection rate [3].
- ▶ In spacecraft observation, there has been no direct connection between electron distribution and temporal and spatial evolutions of reconnection.
- ▶ In this paper, we study exhaust electron distributions in 33 magnetotail reconnection events observed by Cluster spacecraft to establish such connection.



A sort of anisotropic electron distribution in exhaust region has been shown in PIC simulation and Cluster observation by Shuster et al. [3].

- Definition of each component**
- PEACE electron flux data has 12 pitch angle channels
  - The parallel component is the average of flux between 0 – 30 degree
  - The perpendicular component is the average of flux between 75 – 105 degree
  - The anti-parallel component is the average of flux between 150 – 180 degree
  - The 45 component is the average of flux between 30 – 75 degree
  - The 135 component is the average of flux between 105 – 150 degree

## The anisotropic signature of electron distribution in exhaust region [4-5]

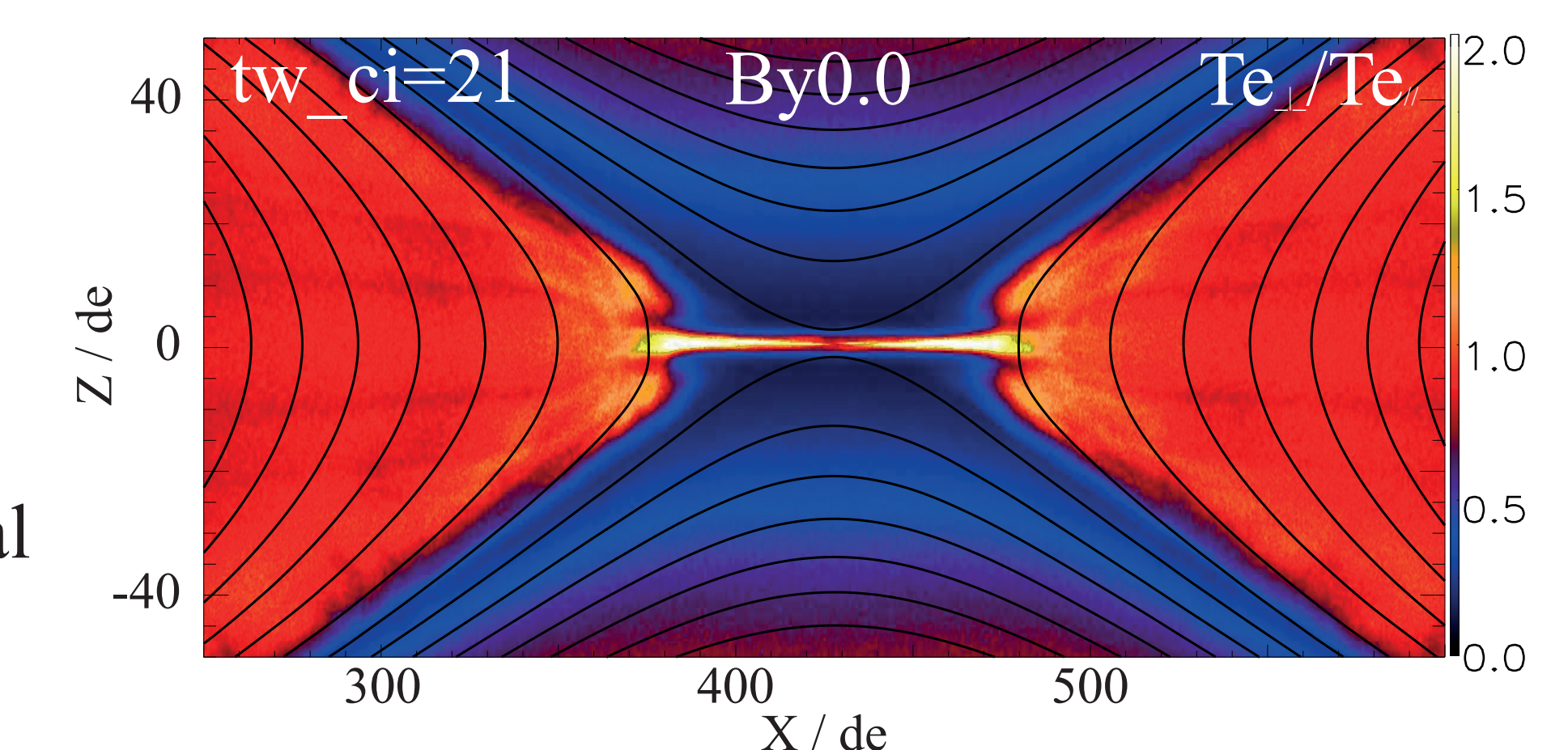


Reference

- [1] Chen L.-J., et al. (2008), *J. Geophys. Res.*, 113, A12213, doi:10.1029/2008JA013385
- [2] Chen L.-J., et al. (2009), *Phys. Plasmas*, 16, 056501, doi:10.1063/1.3112744
- [3] Shuster J. et al. (2014), *Geophys. Res. Lett.*, 41, doi:10.1002/2014GL060608
- [4] Electron Acceleration and Heating, AGU2014, SM13C-4169

Acknowledge  
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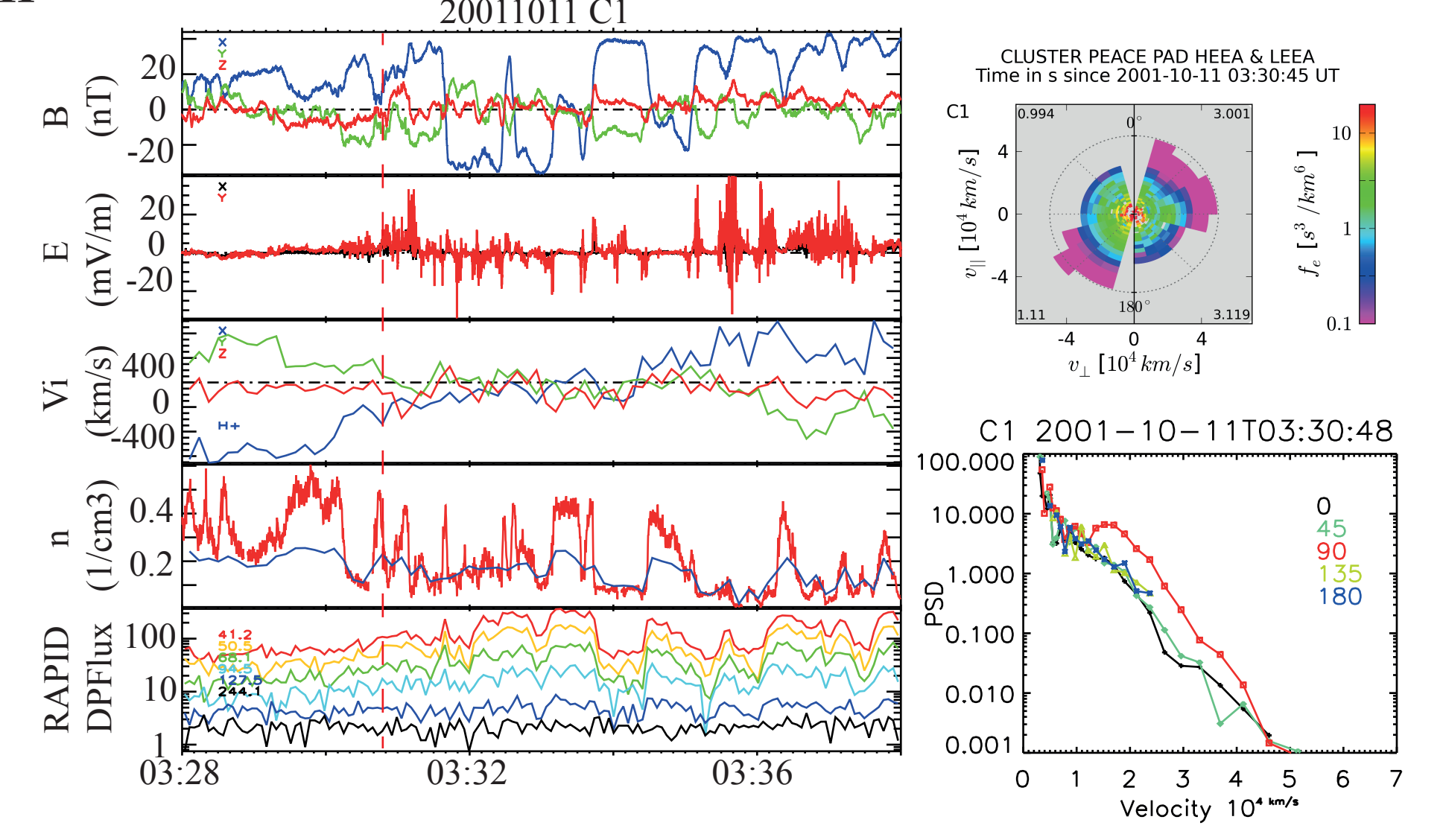
## Electron distributions with enhanced 90-degree fluxes in EDR



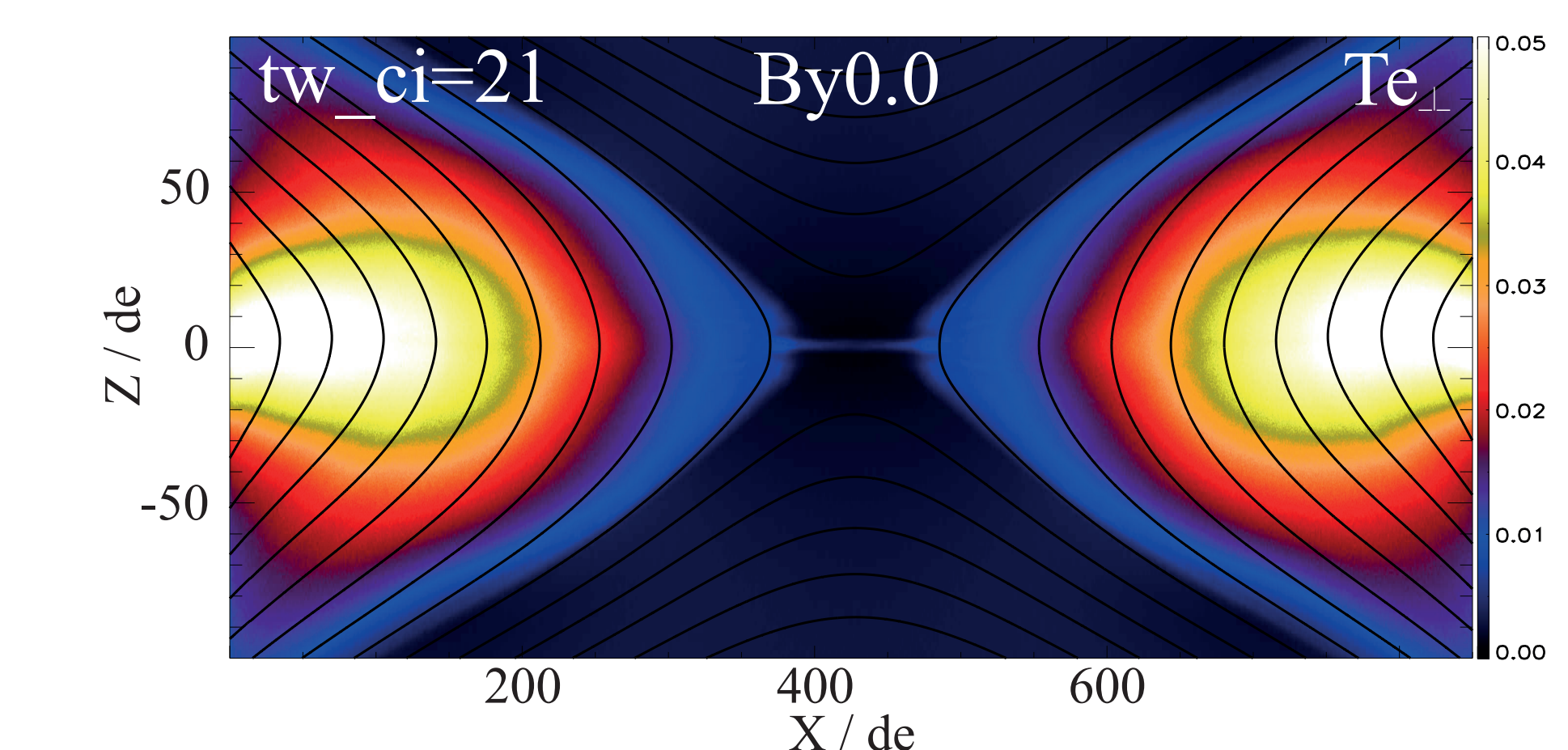
In spacecraft observation, we expect:

- ▶ Small B field;
- ▶ Small density;
- ▶ Close to ion flow reversal;

**Single spacecraft / snapshot observed;**



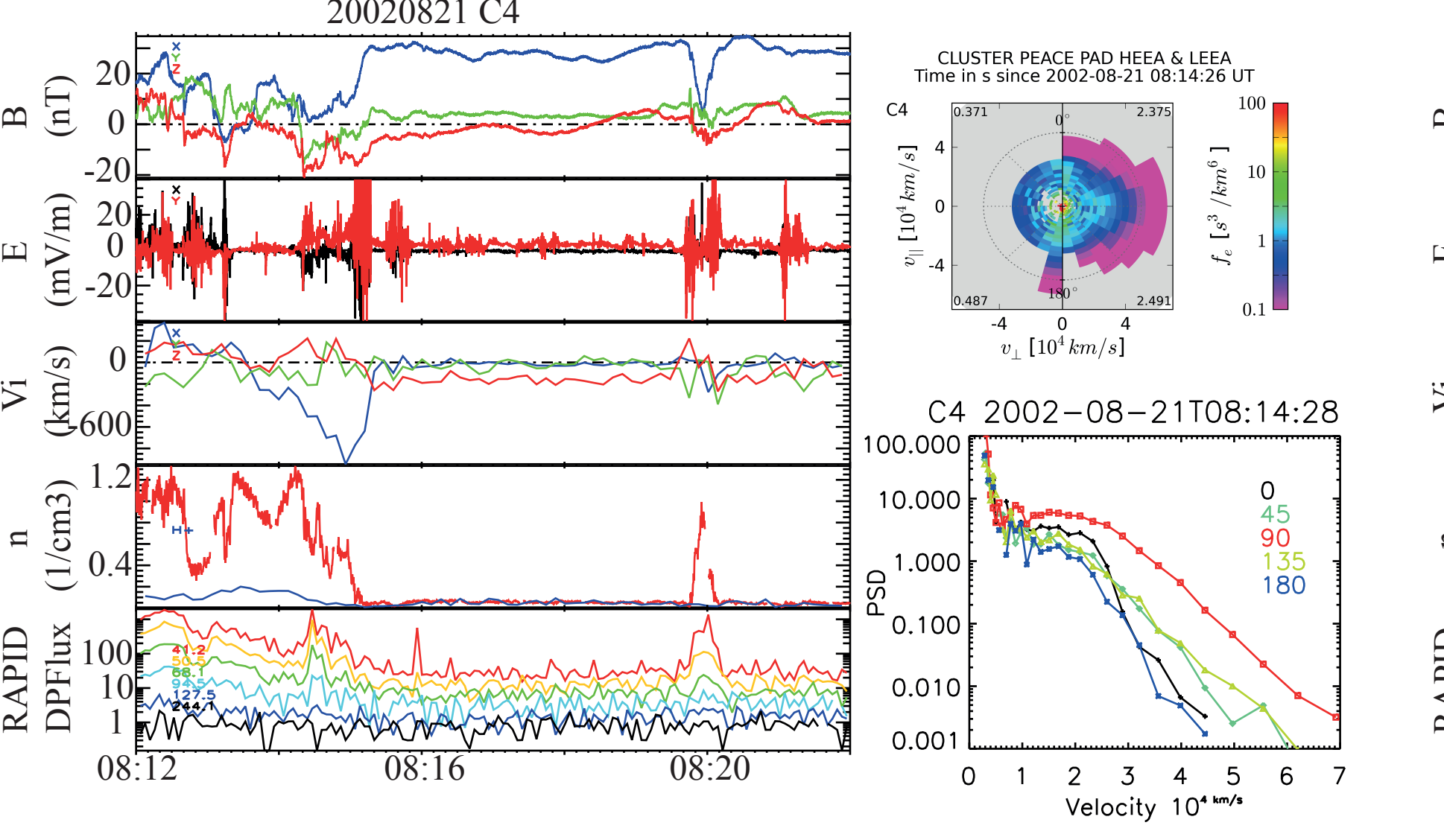
## Electron distributions with enhanced 90-degree fluxes in pile up region



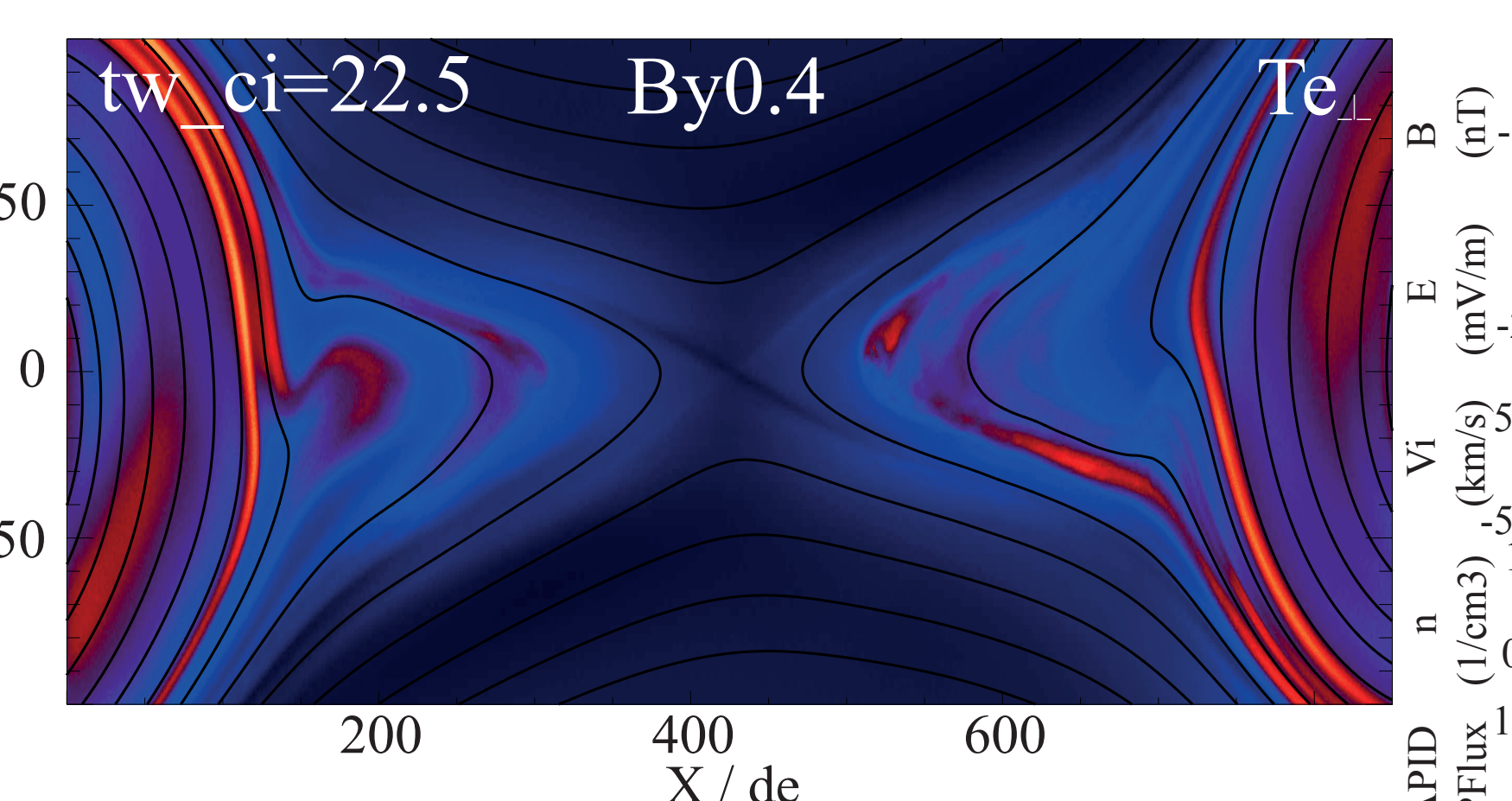
In spacecraft observation, we expect:

- ▶ Large Bz;
- ▶ Large density;
- ▶ After peak of ion bulk flow;

**Multiple spacecraft / snapshot observed;**



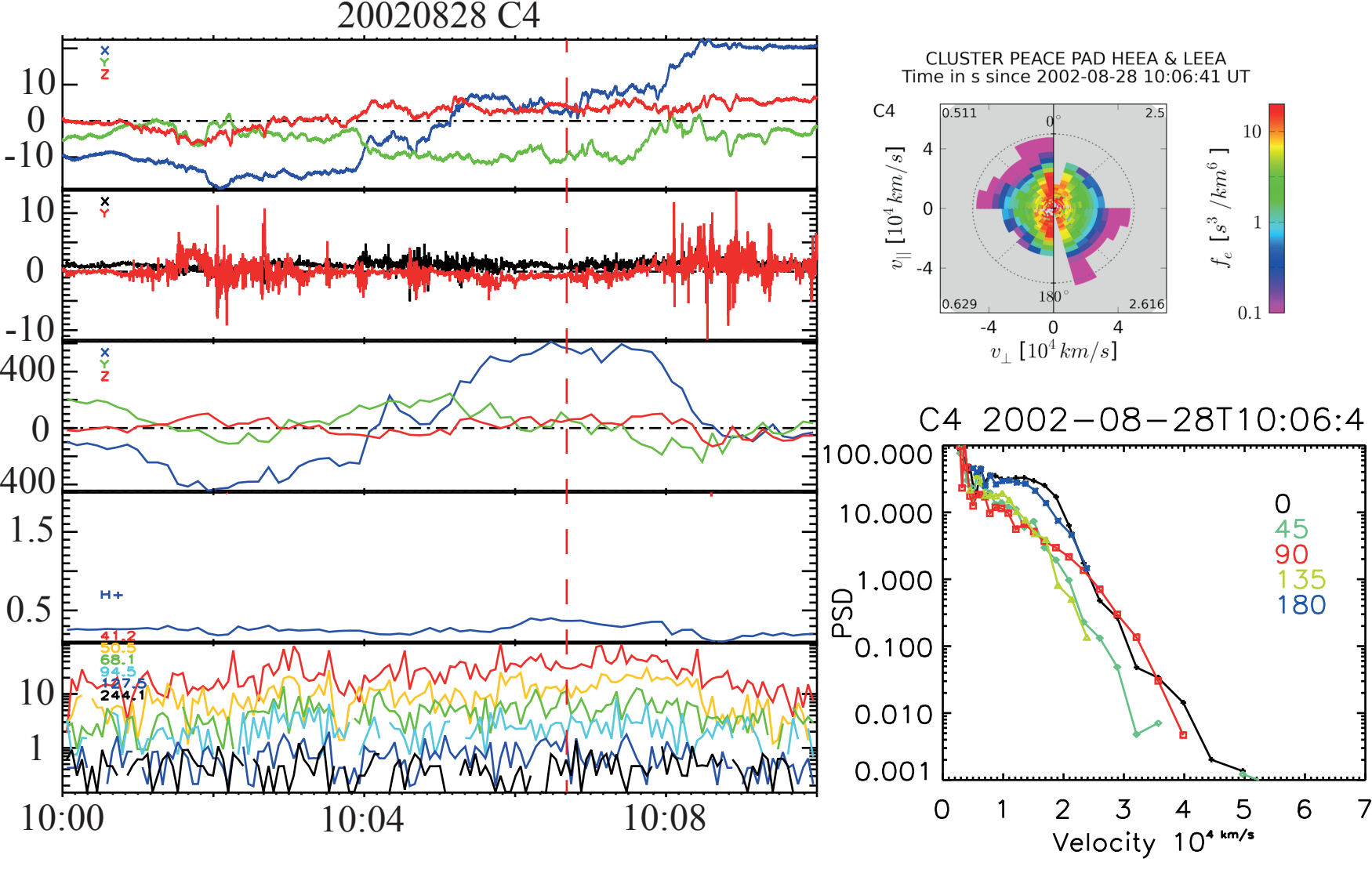
## The perpendicular enhancement in guide field reconnection



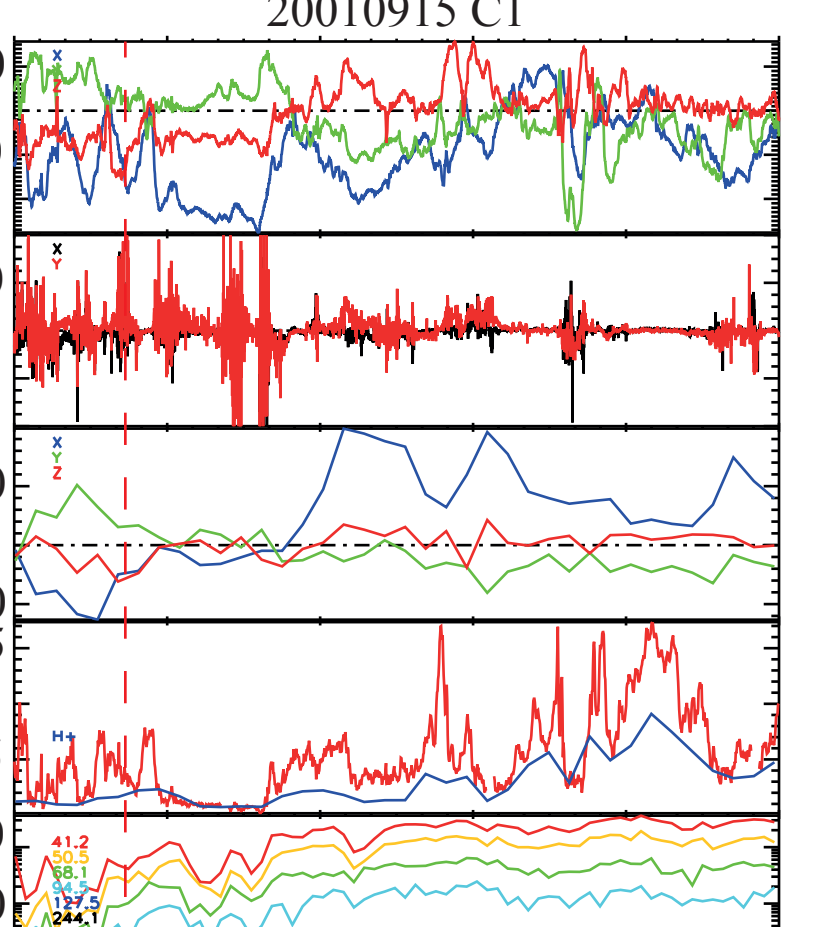
In spacecraft observation, we expect:

- ▶ Guide field;
- ▶ Parallel enhancement;
- ▶ During peak of ion bulk flow;

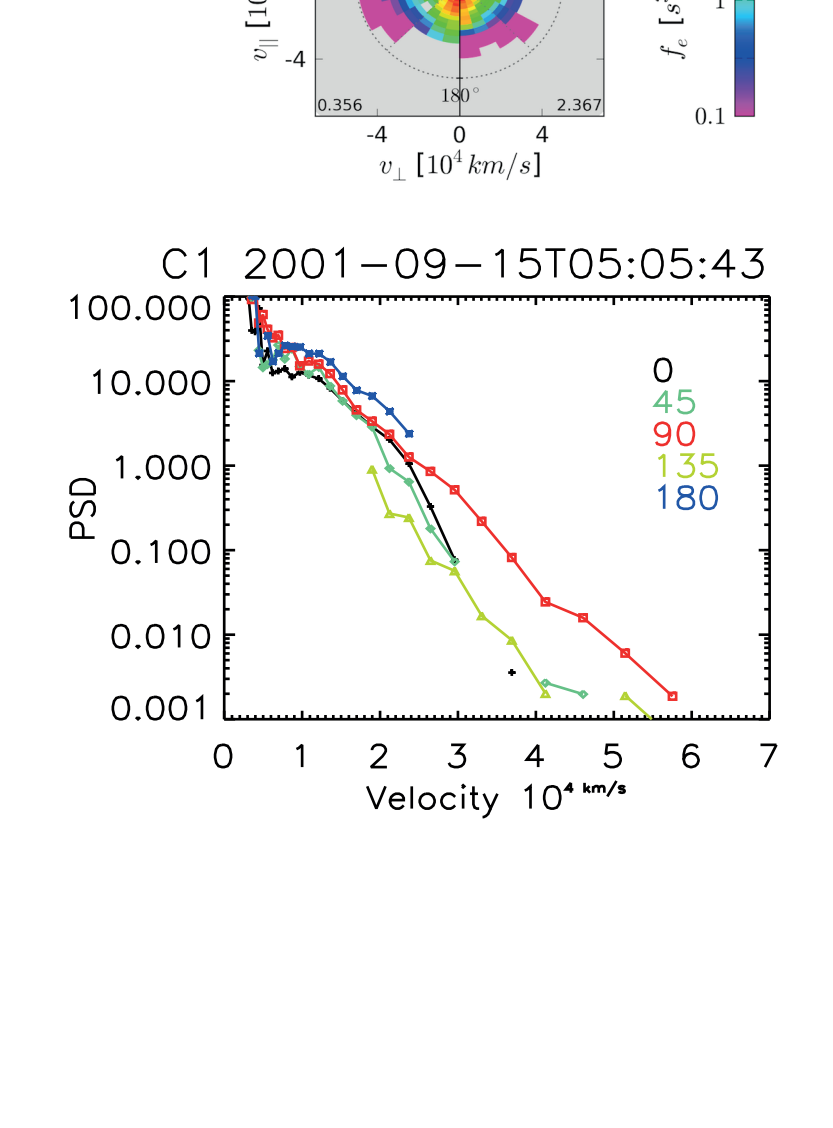
**Multiple spacecraft / snapshot observed;**



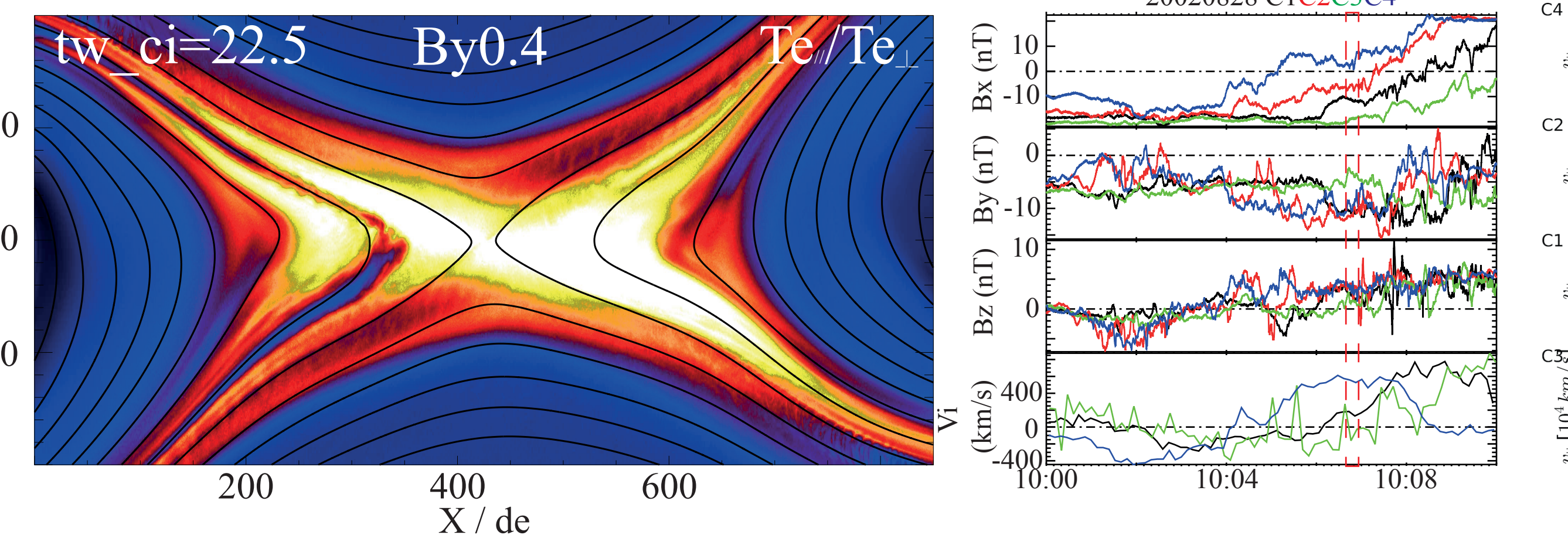
## The perpendicular enhancement near null points



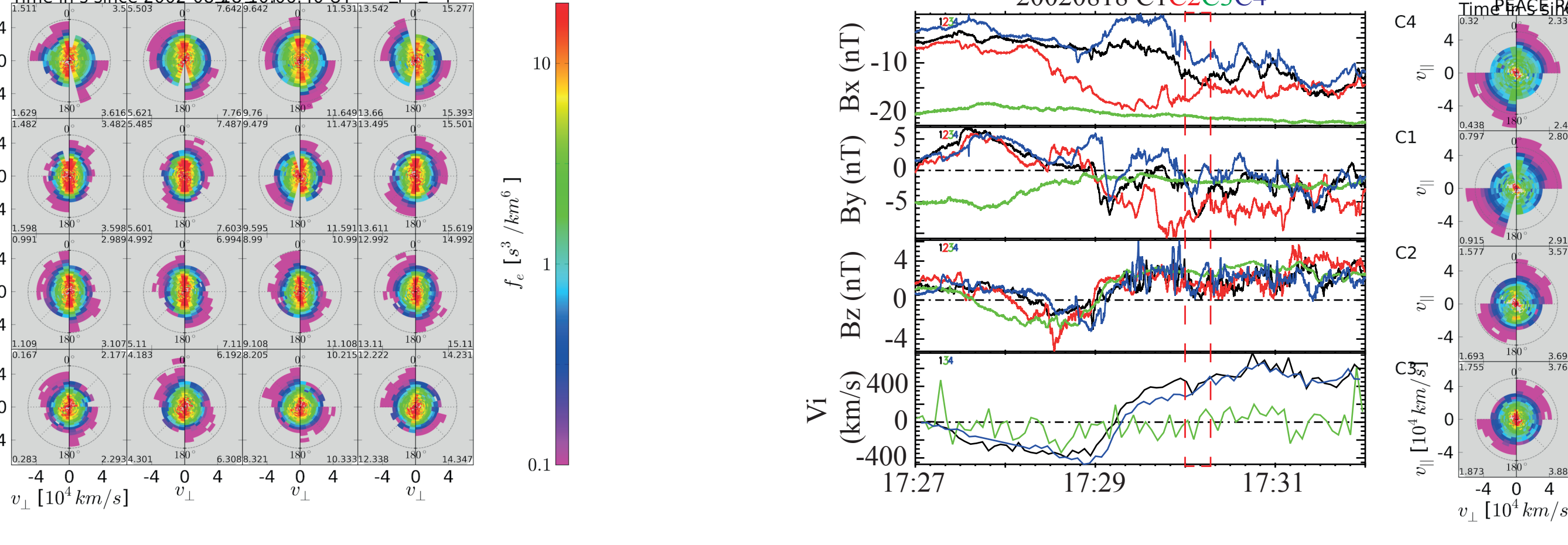
**Multiple spacecraft / snapshot observed;**



## The parallel anisotropy in guide field reconnection



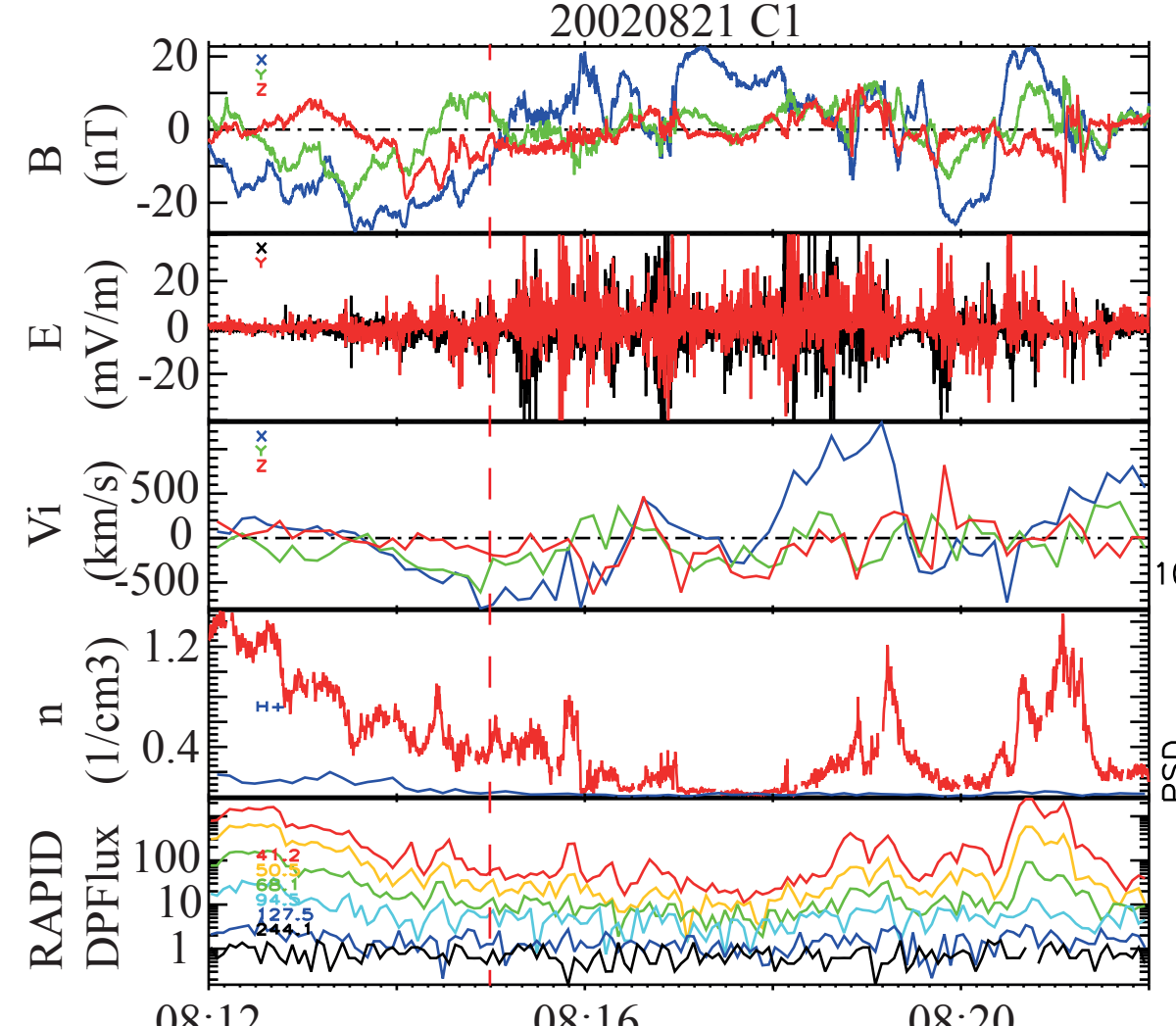
## The parallel anisotropy without guide field



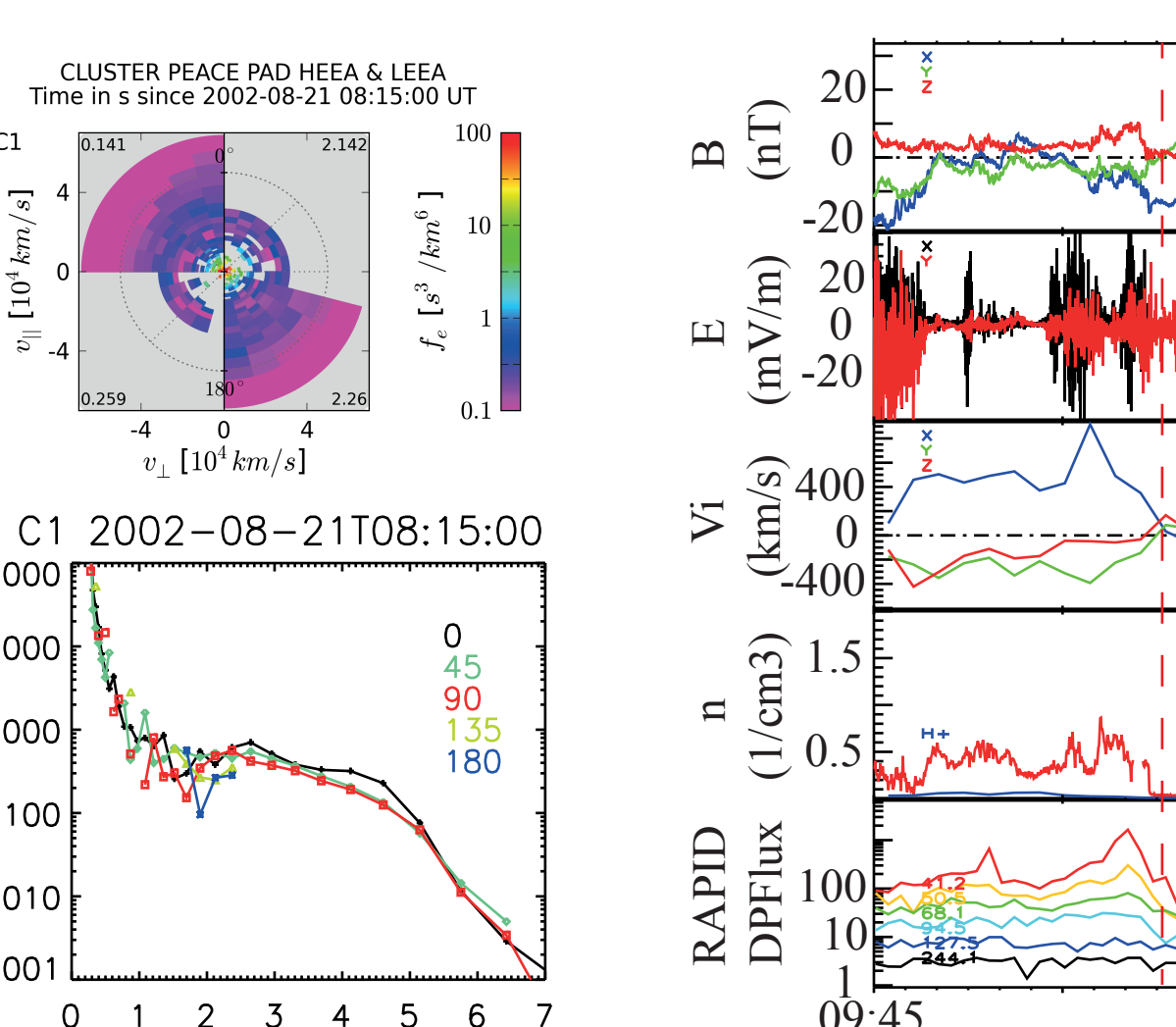
## Main Results:

- ▶ Electron distributions with enhanced 90-degree fluxes are observed at EDR and pile up region.
- ▶ Both hot and cold isotropic electron distribution are observed in exhaust region, and some of them are flattop.
- ▶ Parallel anisotropy and counter streaming beams are observed in zero guide field events, which is caused by the parallel acceleration during curvature drift.
- ▶ Guide field results in large region of parallel anisotropic distribution. The perpendicular enhanced region in guide field reconnection is filamentary.
- ▶ Cold electron distributions have large density and small ion outflow velocity, indicating early stage reconnection.

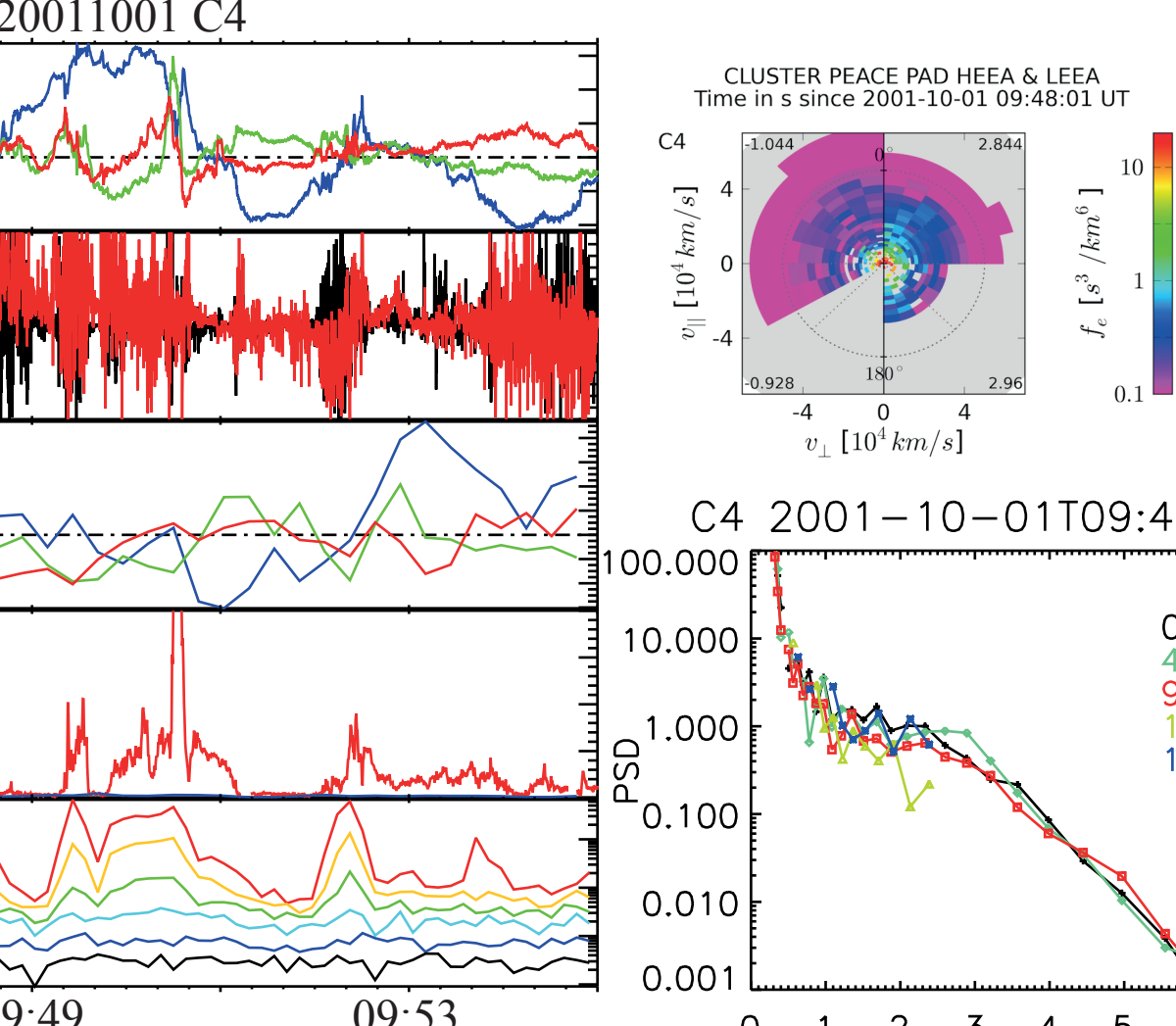
## Hot and flat top



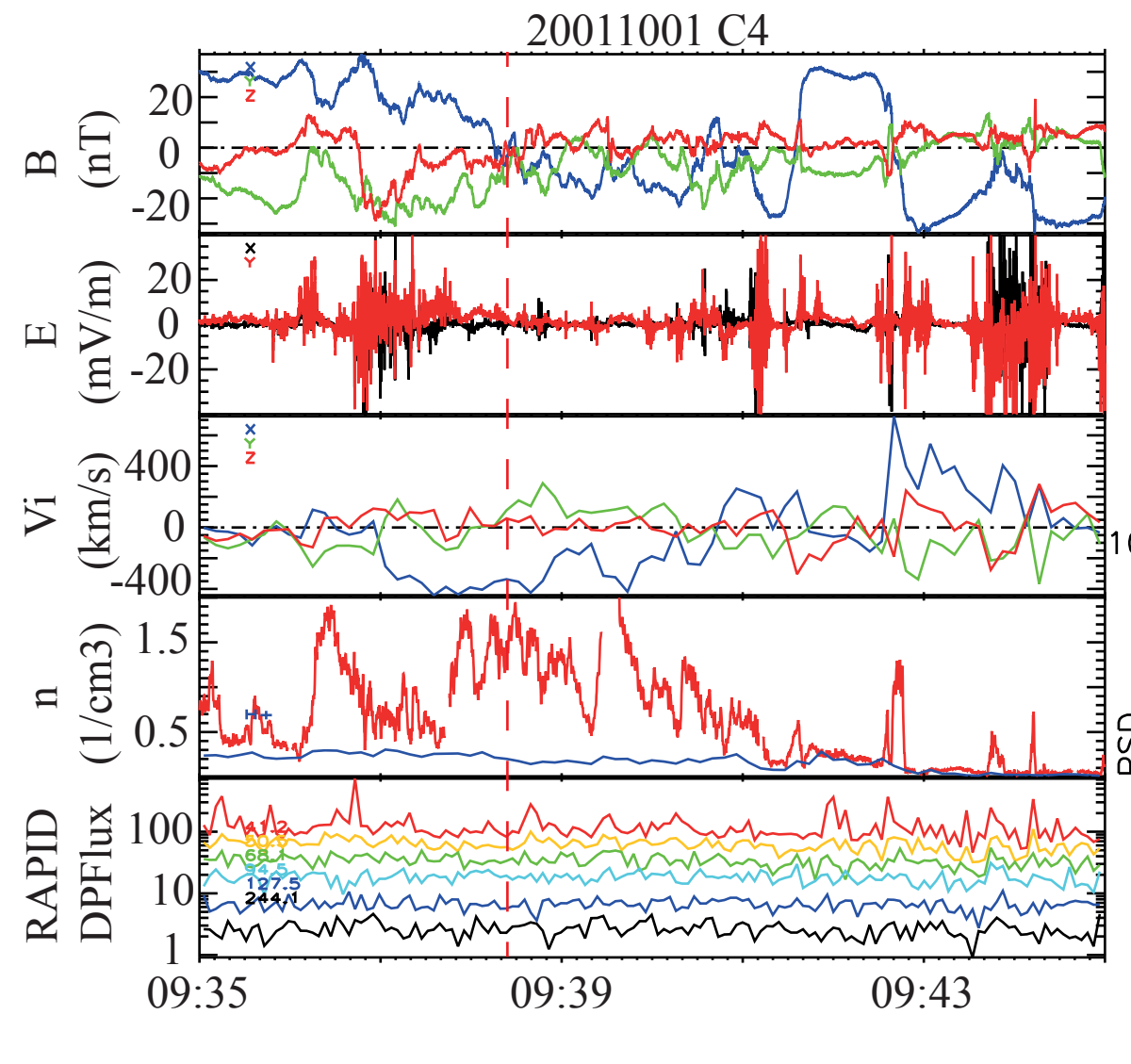
## Hot and not flat top



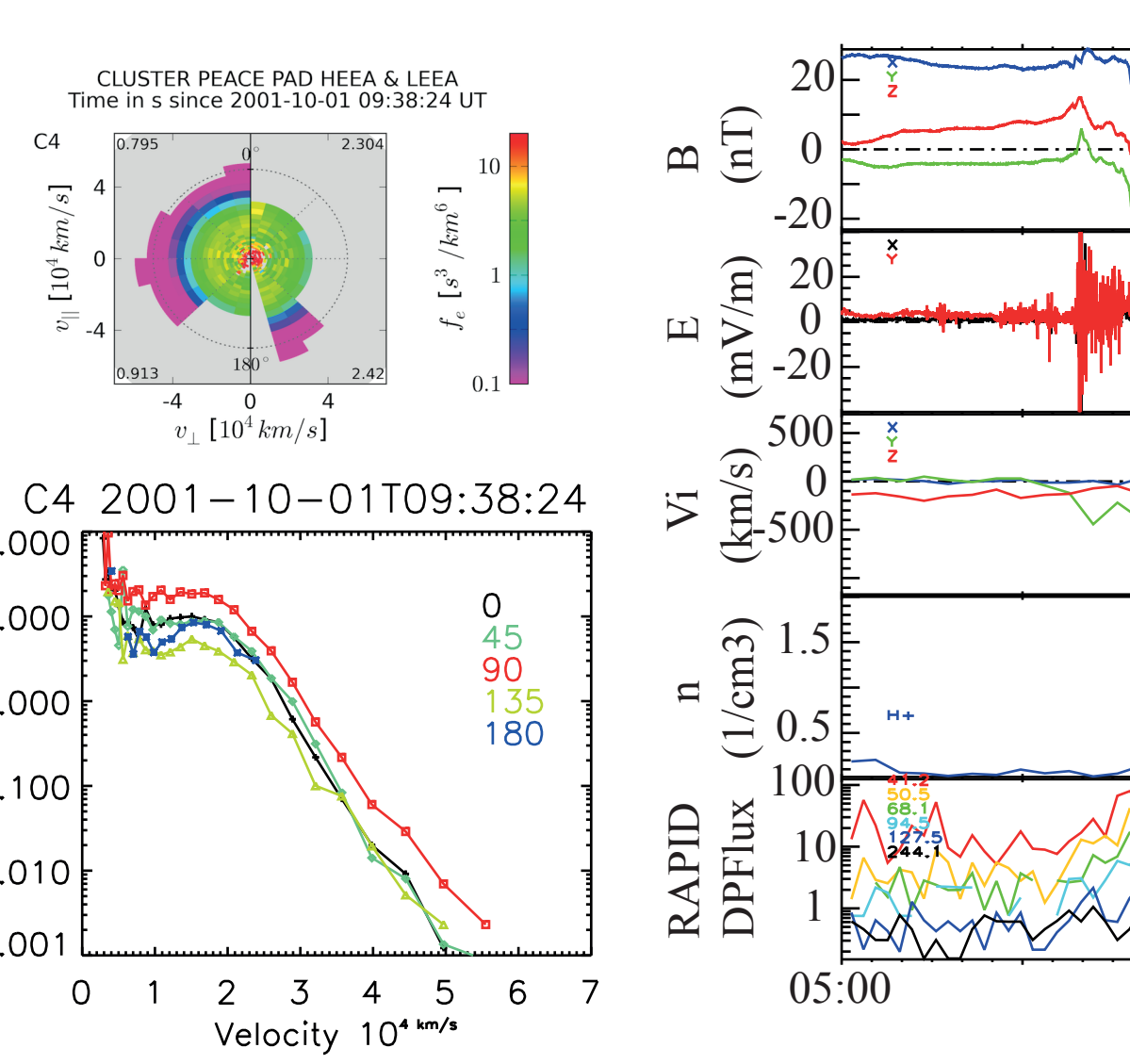
## Cold and not flat top



## Cold and flat top



## Hot and counter streaming



## Cold and counter streaming

