Turbulence and Proton-microinstability Time Scales: Simulations and Observations

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MMS-SWT Meeting

- Several physical phenomenon affect the dynamics of space plasmas.
- Rate of influence determines which process dominates.
- We look at two processes:
  - Linear microinstablities
  - Turbulence

Temperature anisotropy driven instabilities:

$$R_j \equiv T_{\perp j} \,/\, T_{\parallel j}$$

Anisotropy $\Rightarrow$ Non-Maxwellian VDF $\Rightarrow$ Free Energy $\Rightarrow$
$\Rightarrow$ Unstable $\Rightarrow$ Micro-Instabilities $\Rightarrow$ Growth rate (γ_j)

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	Parallel ($\mathbf{k} \parallel \mathbf{B}$) & Propagating ($\omega_r > 0$)	Oblique ($\mathbf{k} \nparallel \mathbf{B}$) & Non-Propagating ($\omega_r = 0$)
$T_{\perp j} > T_{\parallel j}$ ($R_j > 1$)	Ion-cyclotron (Alfven mode)	Mirror (kinetic slow mode)
$T_{\perp j} < T_{\parallel j}$ ($R_j < 1$)	Parallel firehose (fast/whistler mode)	Oblique firehose (Alfven mode)

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$$\beta_{\parallel j} \equiv \frac{n_j \, k_B \, T_{\parallel j}}{B^2 \,/\, (2\,\mu_0)}$$

Non-linear time-scale:

$$\tau_{\rm nl} = \frac{2\,\pi}{(\omega_{\rm nl}/\Omega_{\rm cp})}$$

where $\omega_{\rm nl}$ is the non-linear frequency corresponding to a lag ℓ, given by:

$$\omega_{\rm nl} \sim \delta b_\ell / \ell$$

where δb_ℓ is the change in the longitudinal magnetic field:

$$\delta b_\ell = \left| \hat{\boldsymbol{\ell}} \cdot \left[\mathbf{b}(\mathbf{r} + \boldsymbol{\ell}) - \mathbf{b}(\mathbf{r}) \right] \right|$$

where $\mathbf{b}$ is the total magnetic field expressed in local Alfvén speed units ($\mathbf{b} = \mathbf{B}/\sqrt{\mu_\circ n_{\rm p} m_{\rm p}}$)

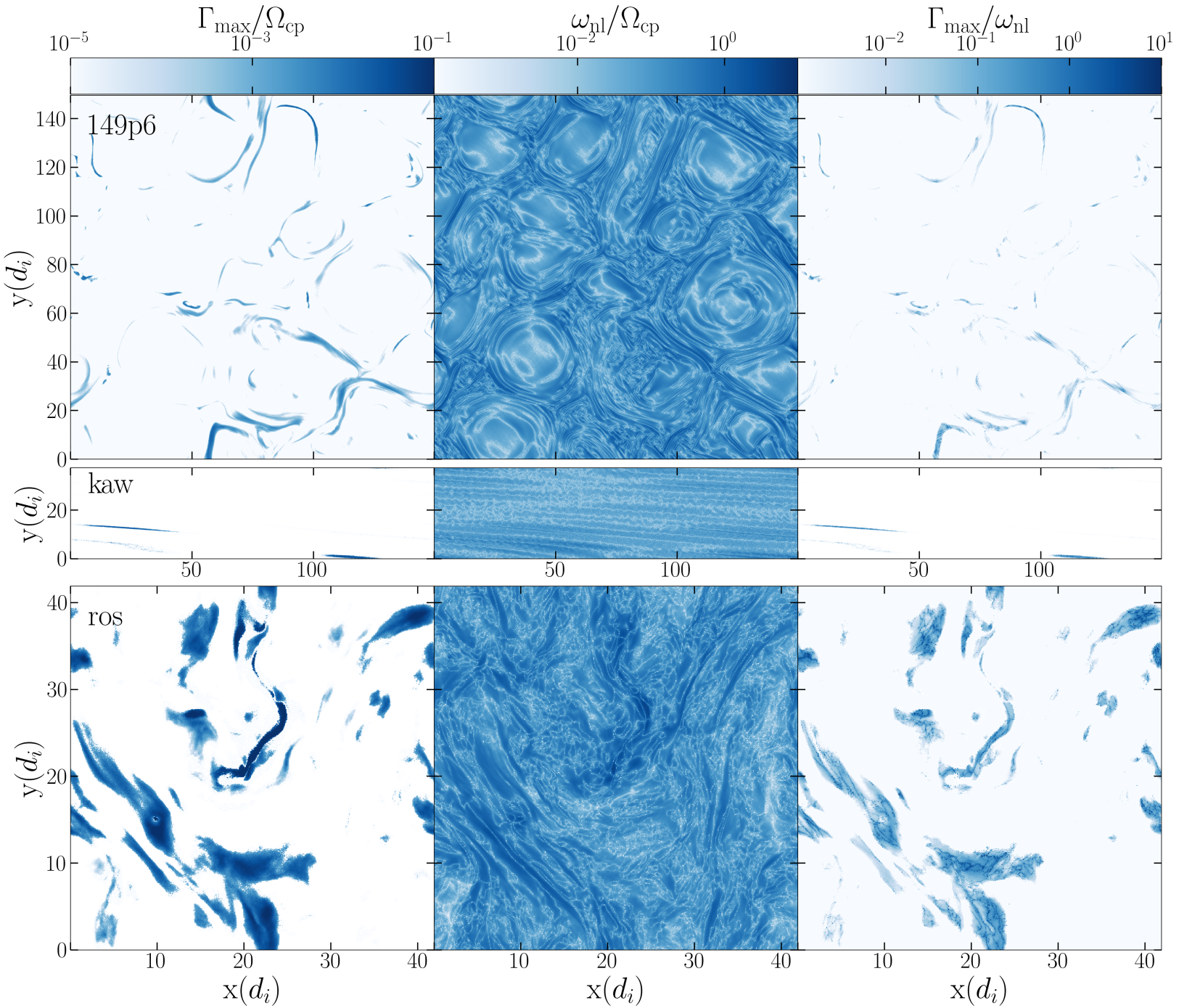
For our study,

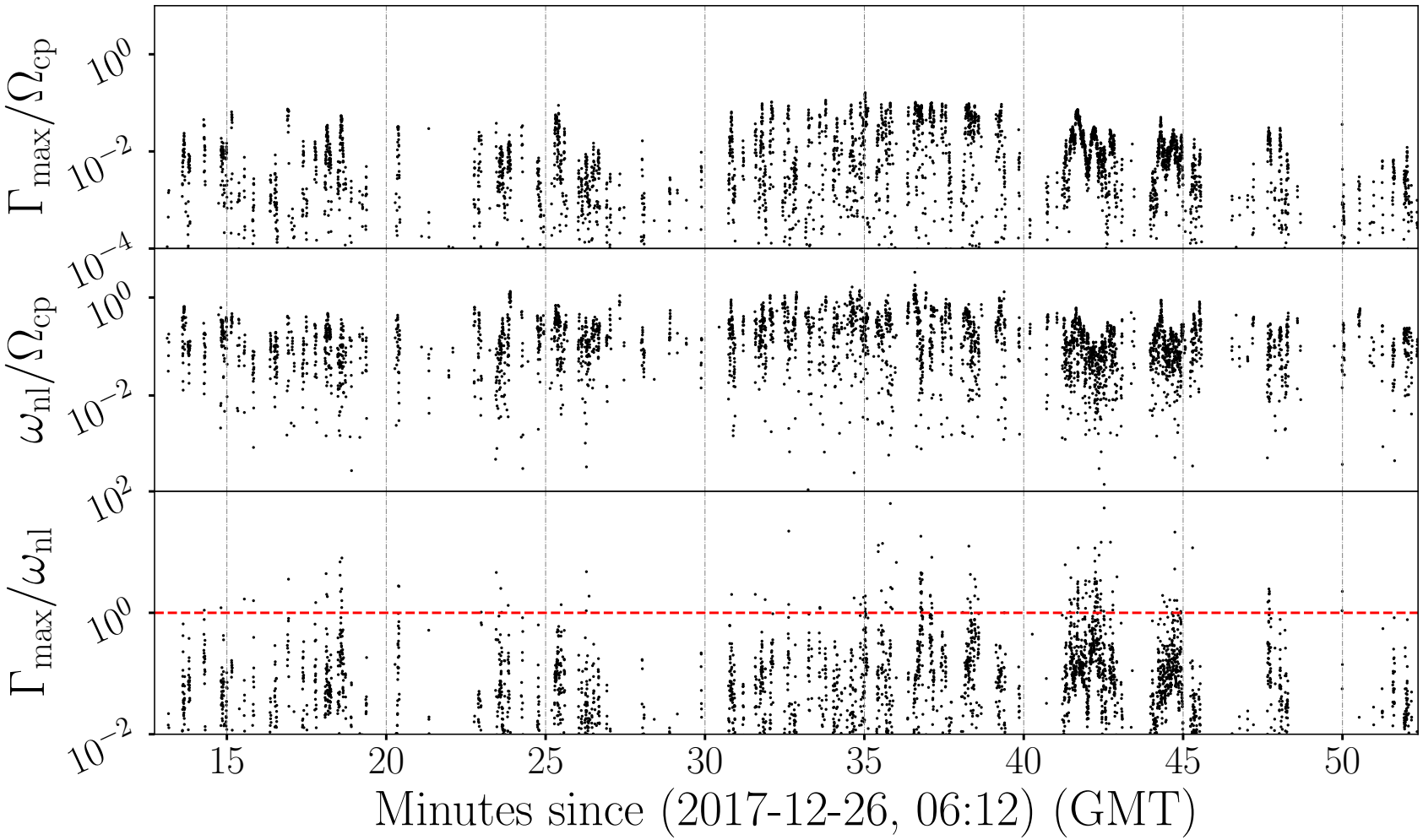
$$\ell = 1/k_{\mathrm{max}}$$

where k_{max} is the wavevector corresponding to the strongest microinstability present in the system.

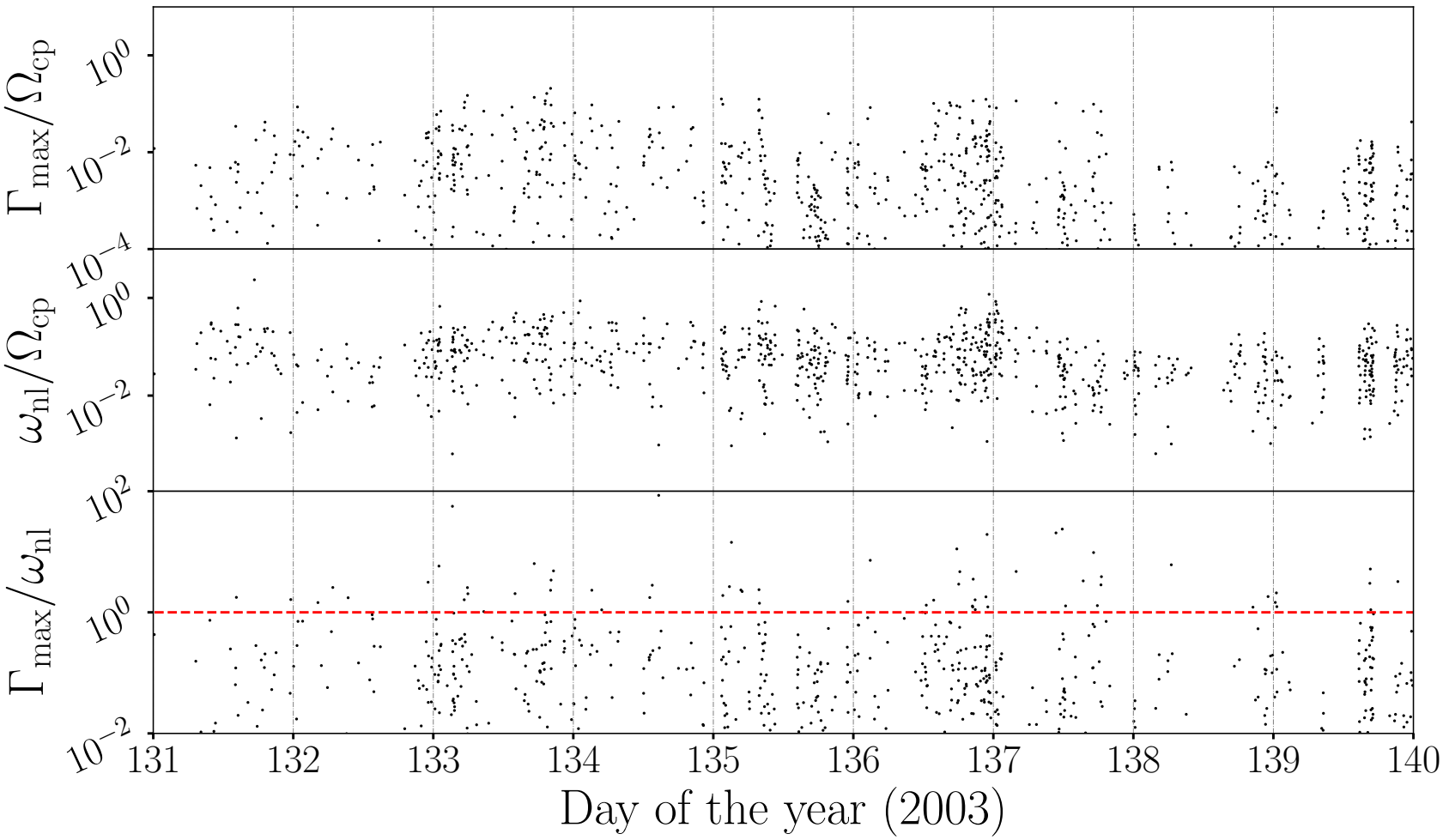
Strongest rate of microinstability growth rate is given by:

$$\Gamma_{\mathrm{max}} = \max\left(\gamma_{\mathrm{max,cyclotron}}, \gamma_{\mathrm{max,mirror}}, \gamma_{\mathrm{max,}\parallel\mathrm{firehose}}, \gamma_{\mathrm{max,}\nparallel\mathrm{firehose}}\right)$$


Γ_{max}/Ω_{cp}
ω_{nl}/Ω_{cp}
Γ_{max}/ω_{nl}
149p6
kaw
ros
y(d_i)
x(d_i)

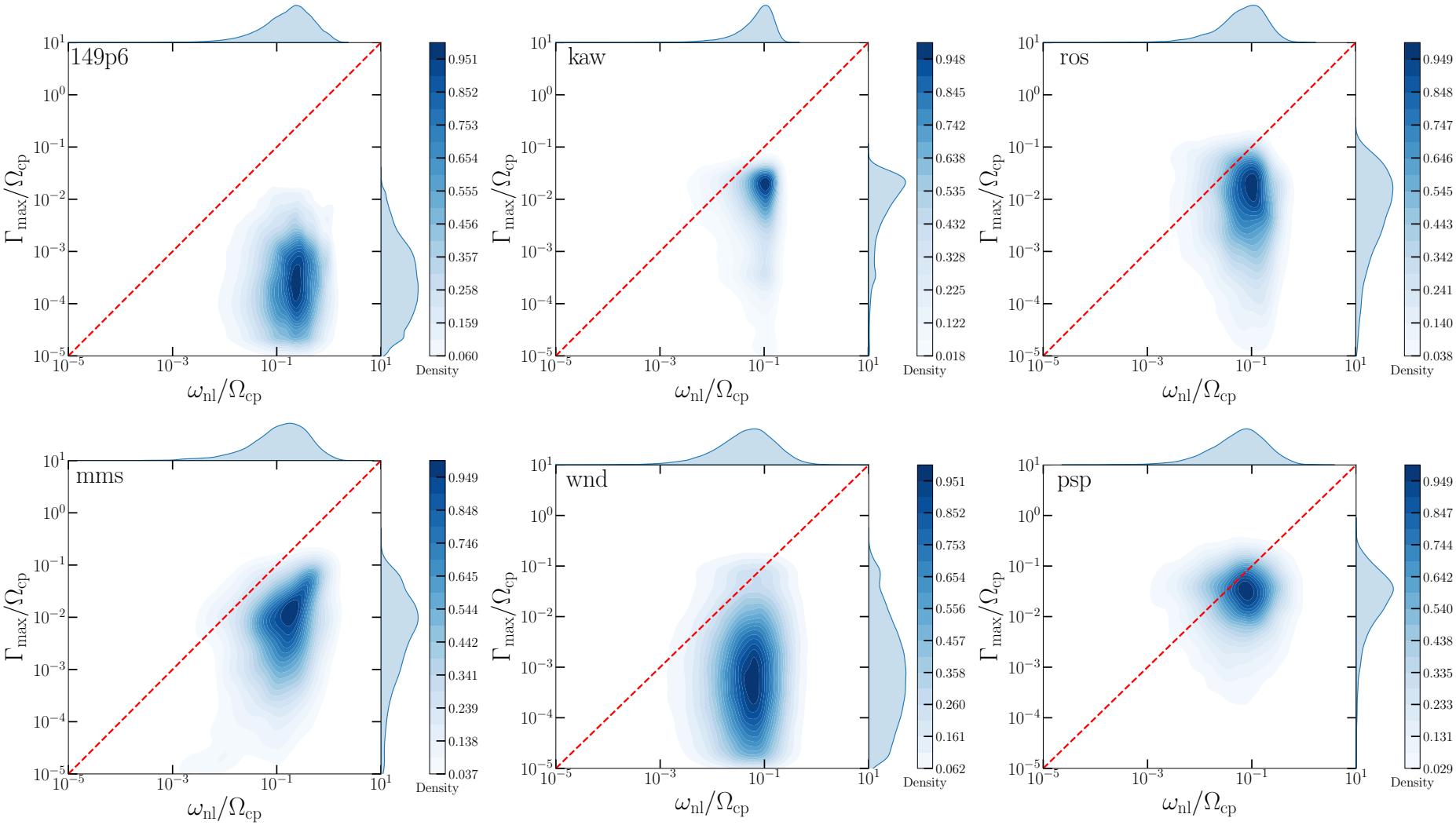


Magnetosheath observation from MMS (burst mode data)



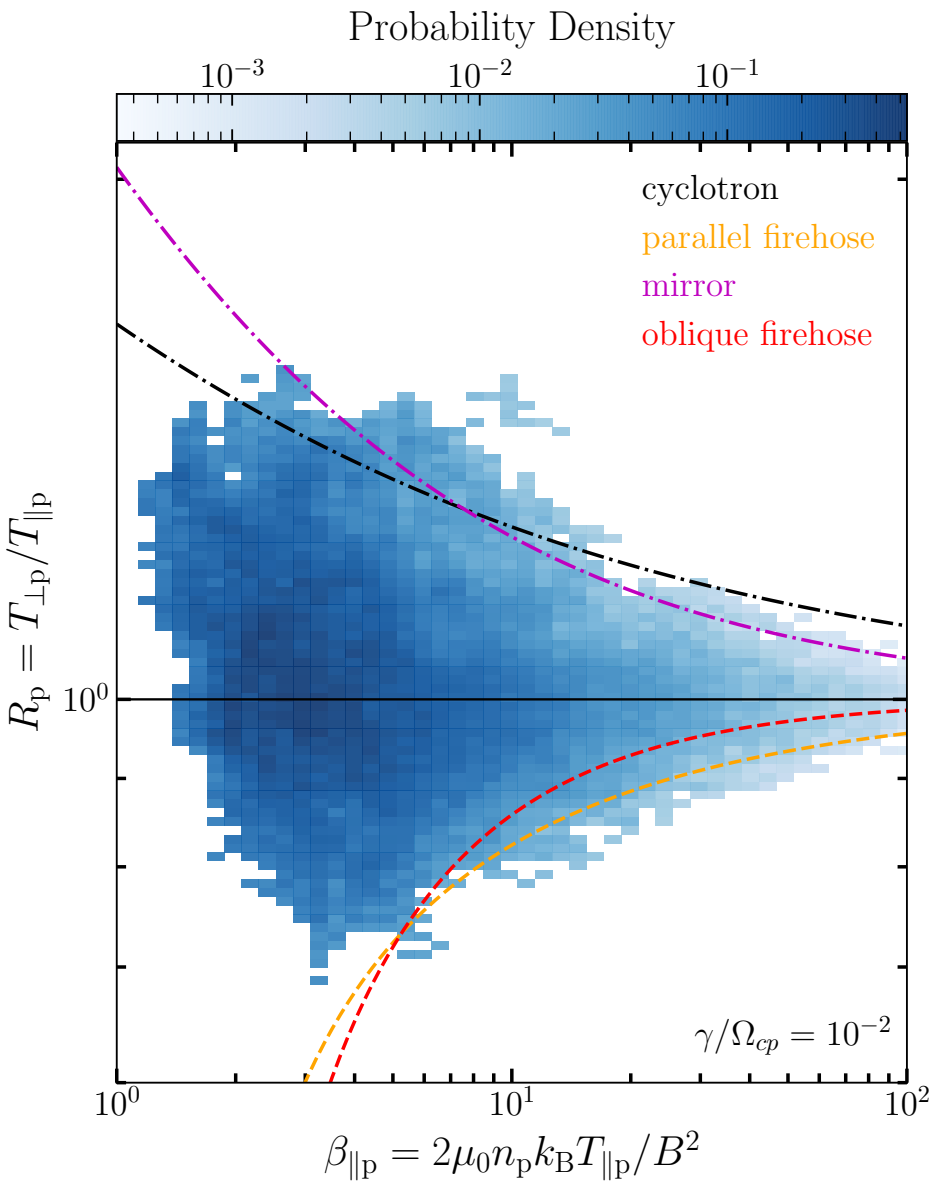
Solar Wind at 1 au observation from WIND

PIC Simulations

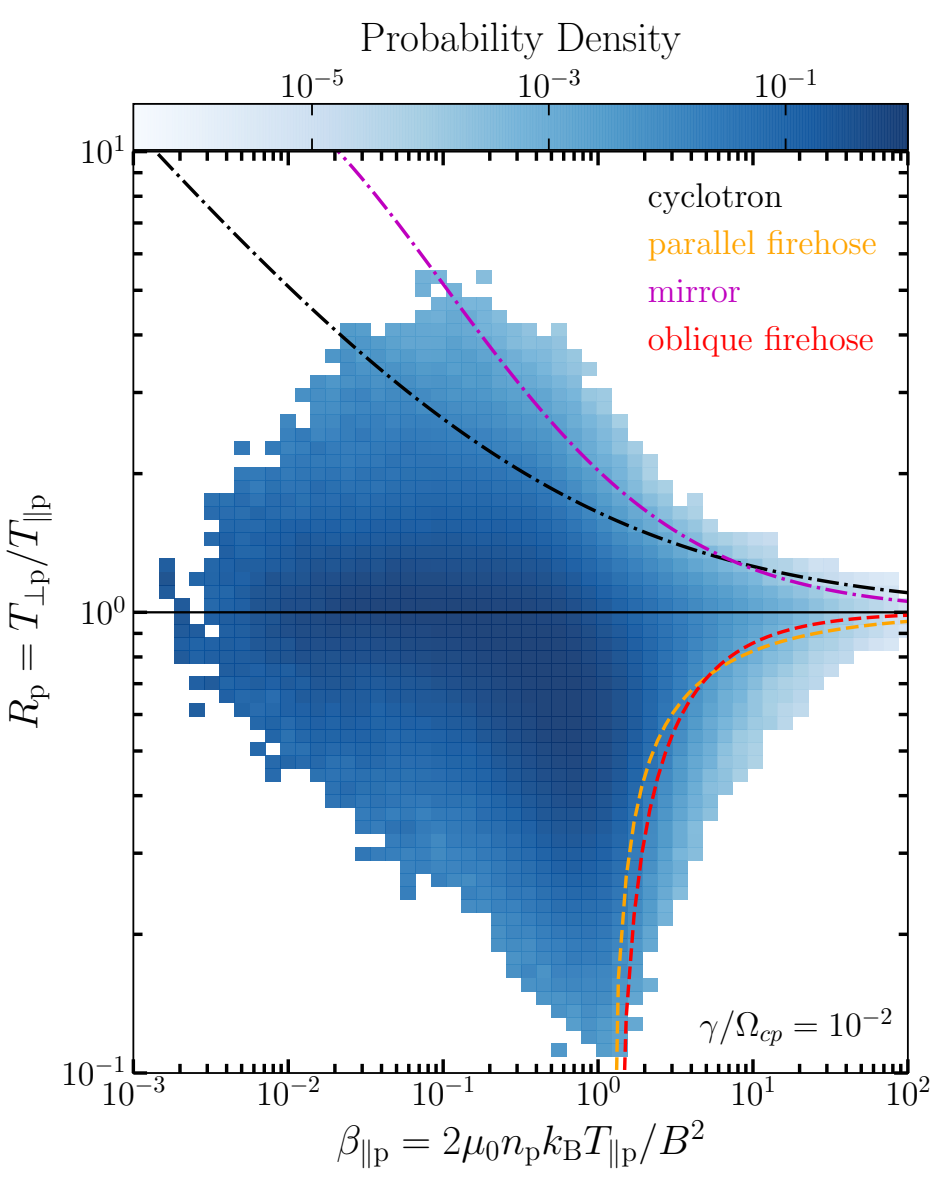


Spacecraft Observations

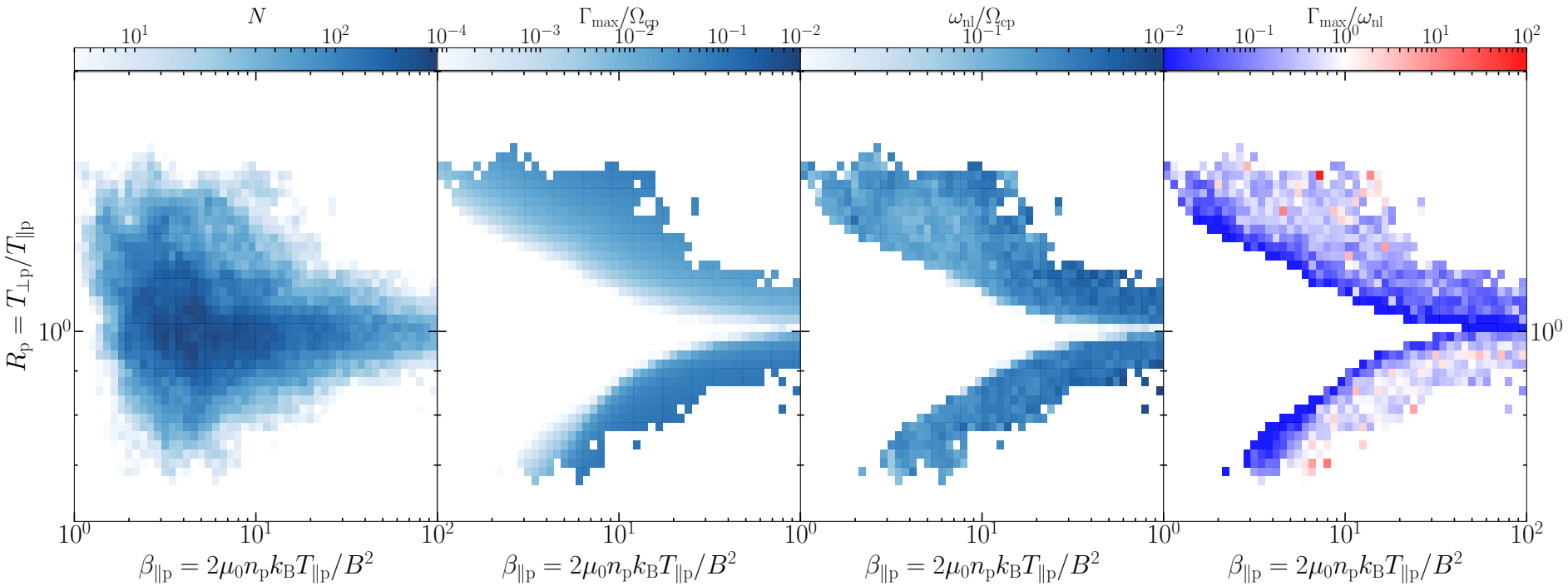
These analysis would lead us to conclude that the plasma dynamics will always be dictated by non-linear processes.



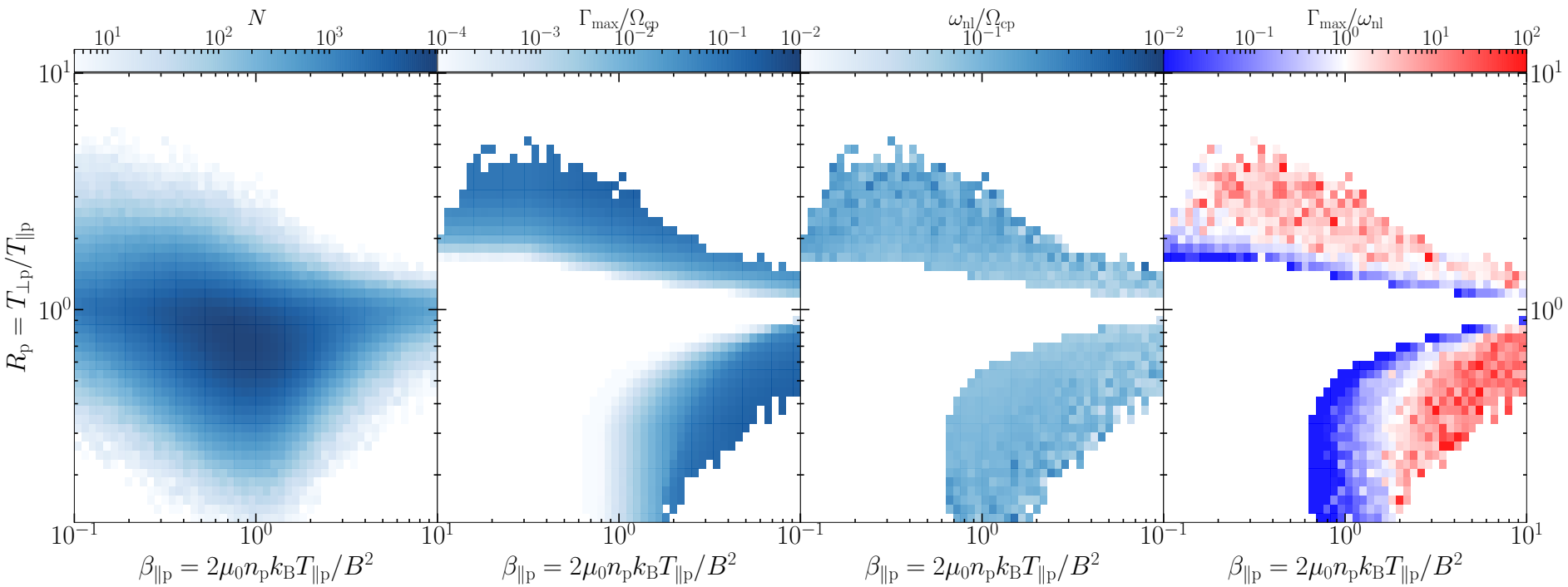
(a) MMS magnetosheath observation



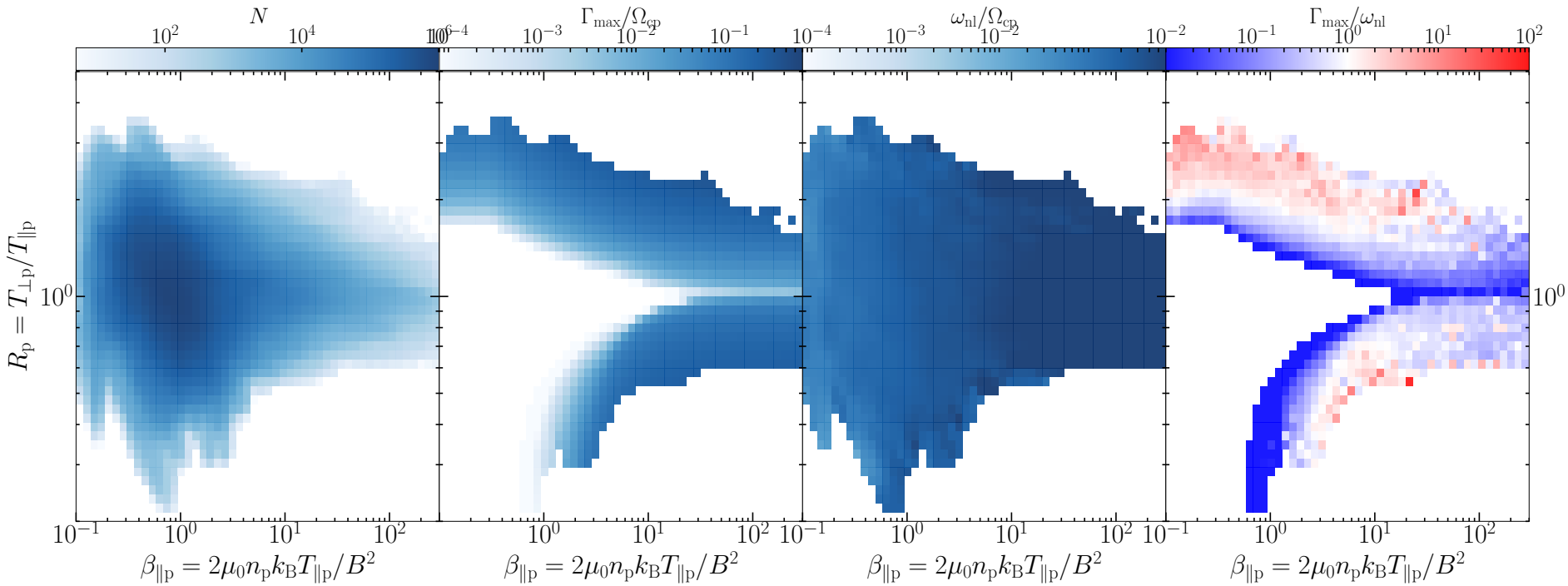
(b) WIND observation



MMS magnetosheath observation



WIND observation



(a) 3-D PIC Simulation

Conclusions:

- We investigated the linear and non-linear time scales of plasma in 6 different datasets.
- For all datasets, we found that, statisticlly, non-linear time scales are almost always smaller than linear time scales.
- This might lead one to conclude that the plasma dynamics will always be dictated by non-linear processes and linear processes will have little effect on the plasma dynamics.
- Observational evidence suggests otherwise.
- Distribution of two time scales on $(\beta_{\|\mathrm{p}}, R_{\mathrm{p}})$-plane sheds some light on why the linear processes might still affect the dynamics of the plasma.