Intermittent distribution of micro-instabilities in space plasma

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Abstract

Weakly collisional space plasmas are rarely in equilibrium and often exhibit microinstabilities driven by ion temperature anisotropy.

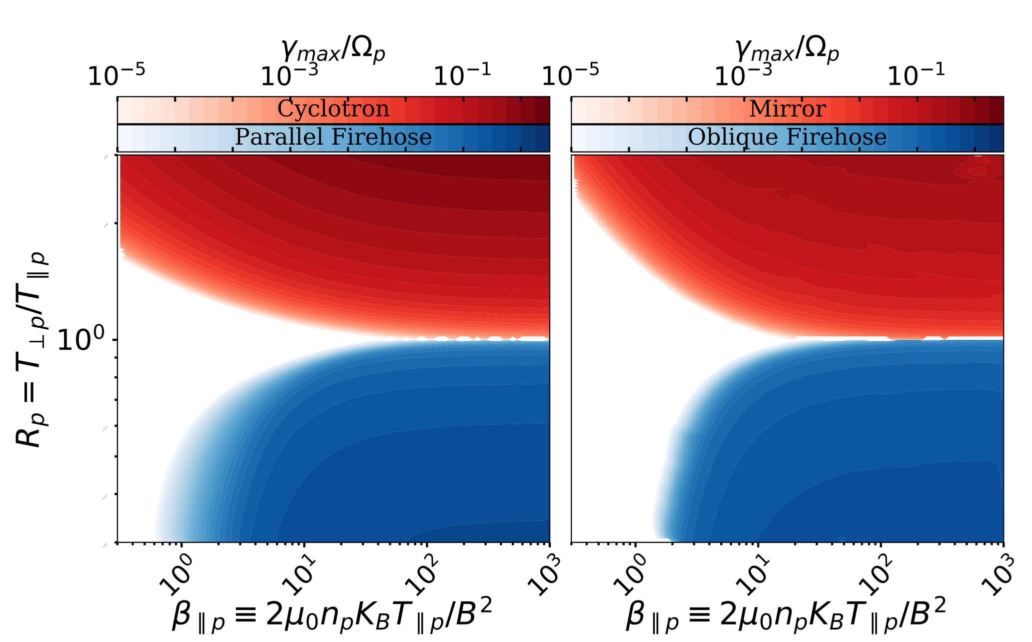
These instabilities play an active role in the evolution of space plasmas, as does ubiquitous turbulence induced by turbulent structures.

In this study, we apply linear Vlasov theory to both simulations and in-situ observations to explore how these two phenomena interact.

By using Particle-In-Cell (PIC) simulations and Magnetospheric MultiScale (MMS) Mission observations in the terrestrial magnetosheath, we calculate and compare the proton-temperature-anisotropy driven linear-instability growth rates for every available pointwise sample.

Introduction

Linear instability thresholds

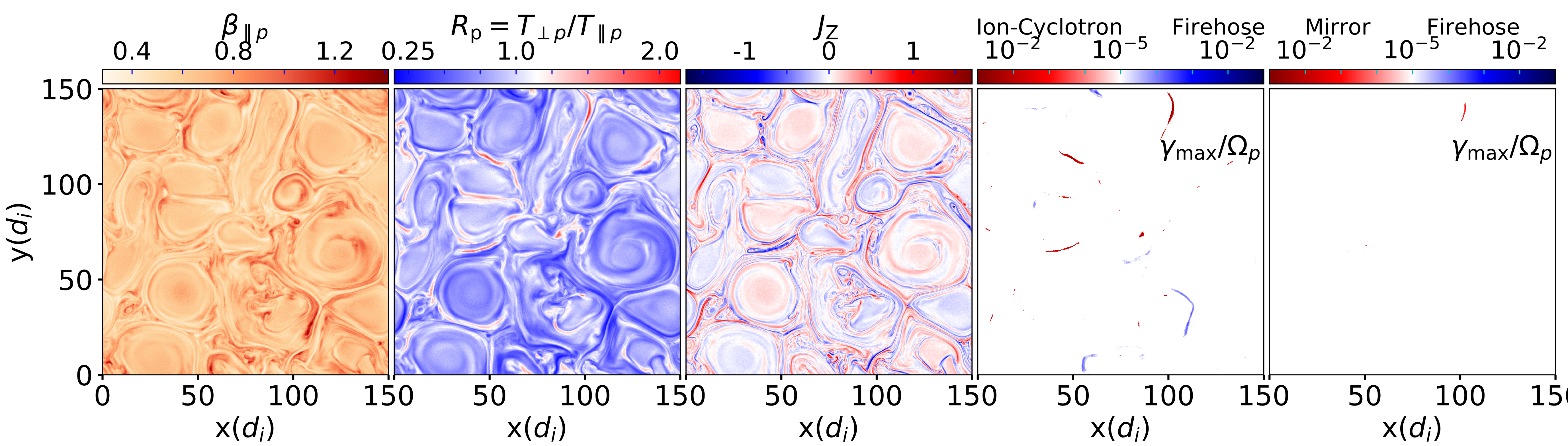


- The figure shows the proton tempooerature anisotropy driven instability threshold over the $\beta_{\parallel p}$, R_p-plane.
- Points with growth rates lower than 10^{-5} were considered stable.
- Thresholds were calculated using a linear Vlasov-solver.
- Thresholds are closely spaced for higher values of $\beta_{\parallel p}$ and R_p.
- Oblique instabilities have steeper slope for growth rates compared to parallel instabilities.

Results from 2.5D PIC simulations

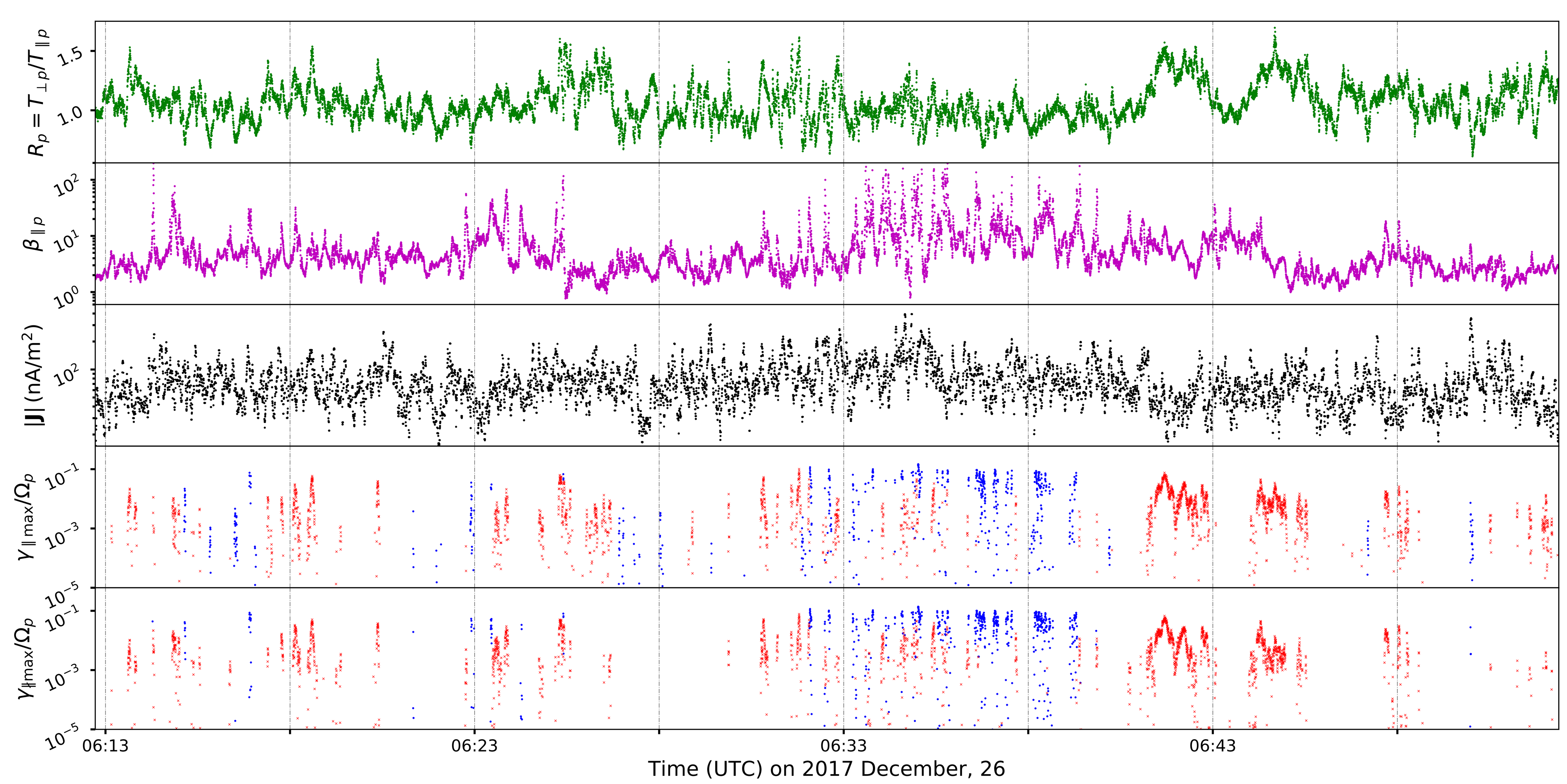
Initial conditions: $\beta_p = \beta_e = 0.6, T_p = T_e\ R_p = 1, \mathrm{N_x} = \mathrm{N_y} = 4096, \mathrm{n} = 3200/\mathrm{cell}, \delta b = 0.5 B_0, \delta v = 0.5 V_0$

Colorplot of various palasma parameters from a fully kinetic 2.5D PIC simulation. Fourth and fifth panels show the spatial distribution of $\gamma_{\max}$ for parallel and oblique propagation respectively corresponding to first two panels.



- $\beta_{\|p}$ and R_p values are intermittently distributed.
- Current sheets occur in the regions where anisotropy is high/low.
- Extreme values of growth rates occur in the regions close to current sheets, though not exactly on top of it.
- Significantly lesser number of growth rate for oblique instabilities.

Results from MMS



Data:

Magnetic field: FGM

Proton Measurements: FPI-I

Average Plasma Conditions :

n = 22 /cm-3

$\beta_{\|p}$ = 4.5

V = 238 km/s

- Similar number of parallel and oblique instability growth rates above threshold.
- Significatly higher number of growth rates above threshold compared to PIC simulation results.
- Overall distribution of growth rates is intermittent, similar to the results from PIC simulation.
- The points of instabilities are concentrated together, spreading over a time length of 4-8 seconds or about 50-70 d_i.

Conclusion and Discussion

- In both cases, simulation as well data from MMS, we find that the microinstabilities occur highly intermittently in the plasma.
- Simulation shows indications that the instabilities preferentially occur near current sheets.
- This suggests that, though microinstabilities affect the plasma globally, they act locally and develop in response to extreme temperature anisotropies generated by turbulent structure.
- The growth rates peak around the regions of intense current/current sheets, though they do not overlap precisely.

Future Work

- Study the correlation between and J_z, by using the propinquity method.
- Study the distribution of the width of growth rates from both simulation as well as MMS data.
- Extend the result to include solar wind observations.
- Compare non-linear and linear times scales.

References and Acknowledgements

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