Intermittent distribution of ion temperature-anisotropy microinstabilities in the terrestrial magnetosheath

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MMS-Telecon

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	Parallel ($\mathbf{k} \parallel \mathbf{B}$) & Propagating ($\omega_{\mathrm{r}} > 0$)	Oblique ($\mathbf{k} \nparallel \mathbf{B}$) & Non-Propagating ($\omega_{\mathrm{r}} = 0$)
$T_{\perp j} > T_{\parallel j}$ ($R_j > 1$)	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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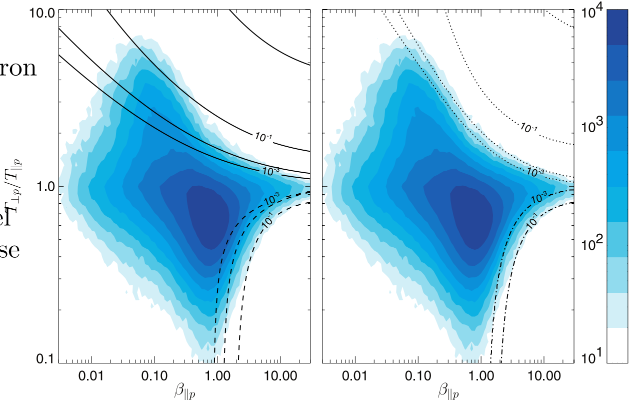
$$\beta_{\| j} \equiv \frac{n_j \, k_\mathrm{B} \, T_{\| j}}{B^2 \,/\, (2\,\mu_0)}$$

Ion Cyclotron

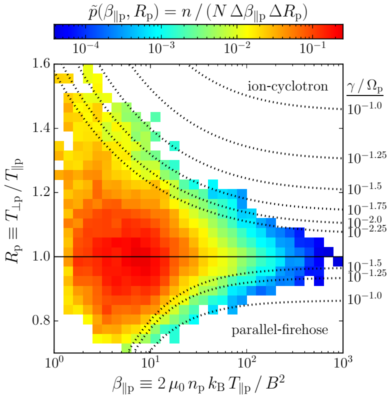
Mirror

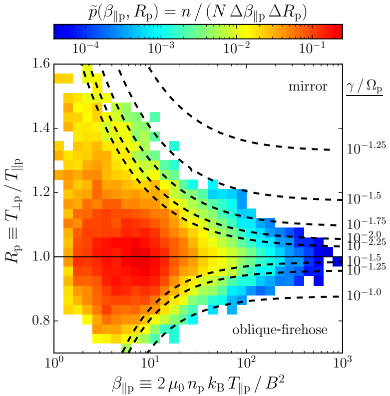


Parallel Firehose

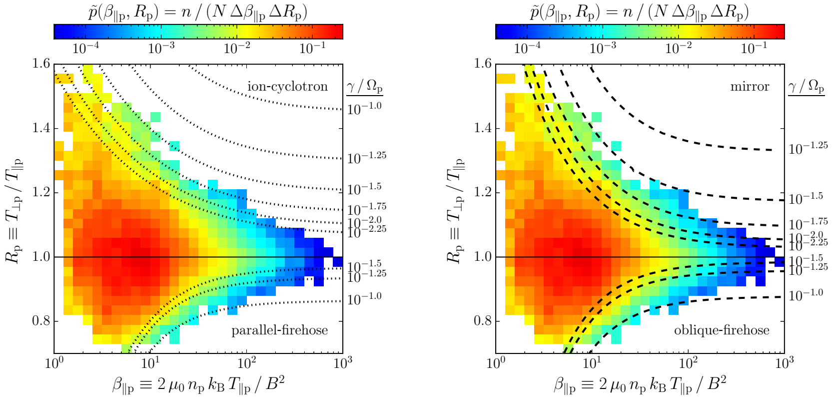
Oblique Firehose

Hellinger et al. (*GRL*, 2006)





Maruca et al. (*ApJ*, 2018)

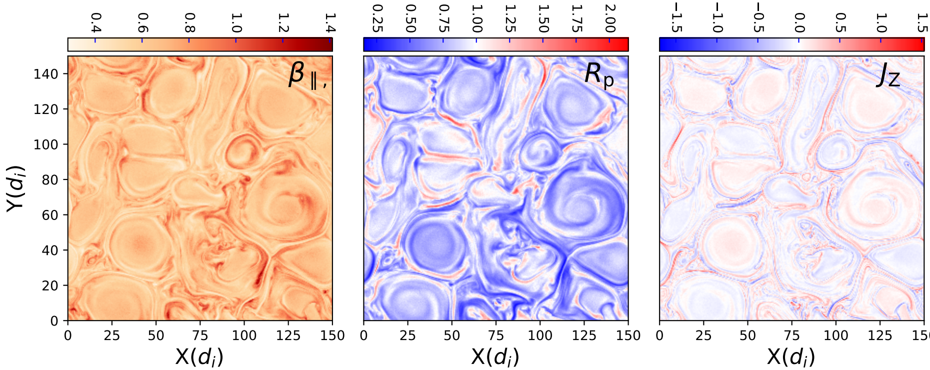


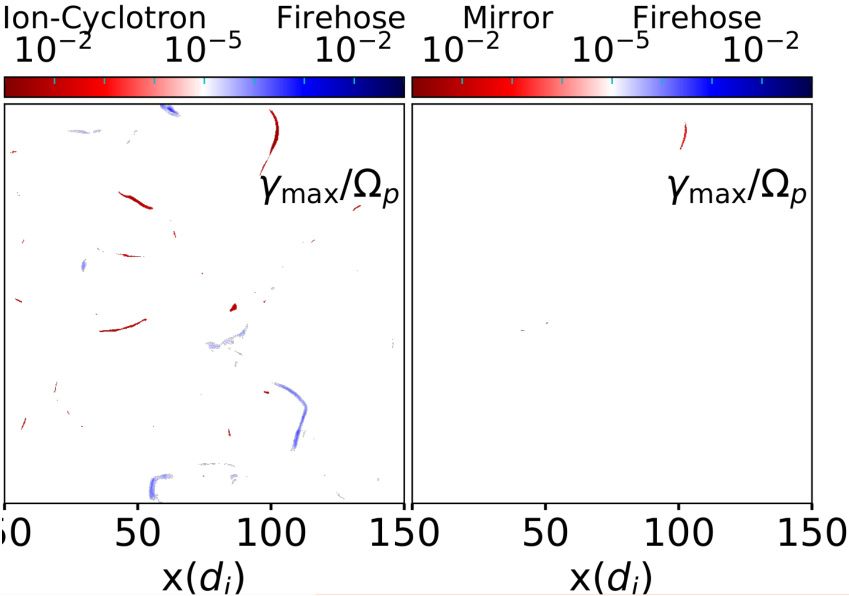
Marginally unstable plasma ($\gamma \gtrsim 0$) exhibits enhancements in:

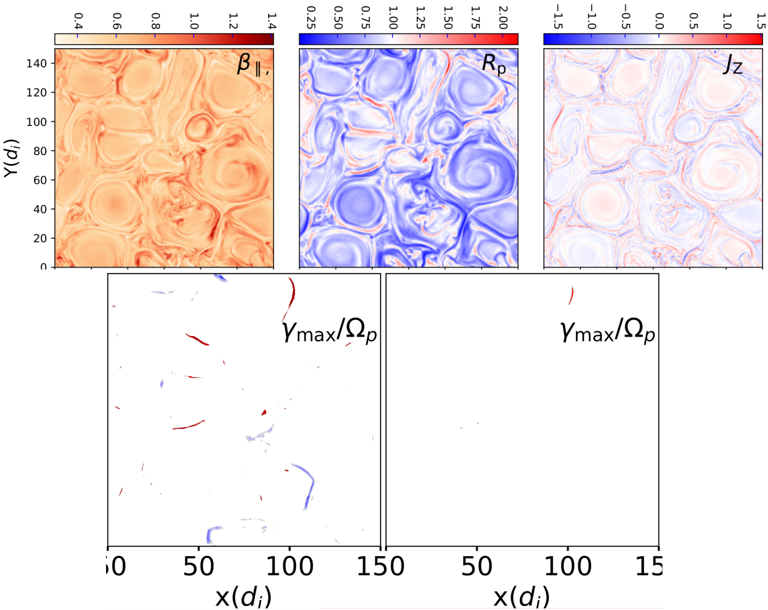
- Magnetic fluctuations (Bale et al., *PRL*, 2009)
- Temperature (Maruca et al., *PRL*, 2011)
- Turbulent structures (PVI) (Osman et al., *PRL*, 2012; 2013)

Used similar method of γ calculation on a fully kinetic PIC simulation:

$$\beta_p = \beta_e = 0.6, R_p = 1, T_p = T_e$$



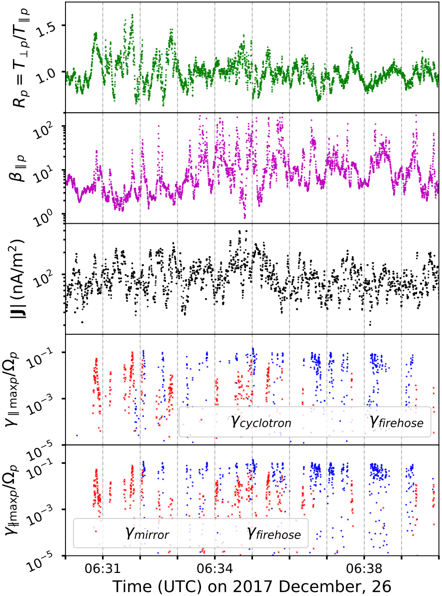

Ion-Cyclotron
Firehose
10^{-2}
10^{-5}
10^{-2}
γ_{max}/Ω_p
0
50
100
150
$x(d_i)$
Mirror
Firehose
10^{-2}
10^{-5}
10^{-2}
γ_{max}/Ω_p
50
100
150
$x(d_i)$

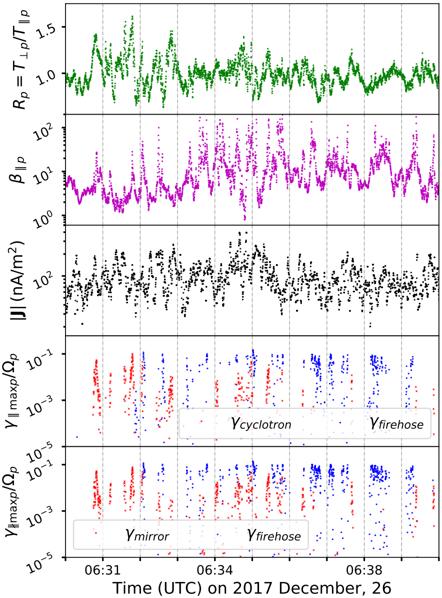


0.4
0.6
0.8
1.0
1.2
1.4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
$\beta_{\parallel,}$
R_p
J_Z
$Y(d_i)$
140
120
100
80
60
40
20
0
γ_{max}/Ω_p
γ_{max}/Ω_p
50
100
150
50
100
15
$x(d_i)$
$x(d_i)$

MMS observation in Magnetosheath

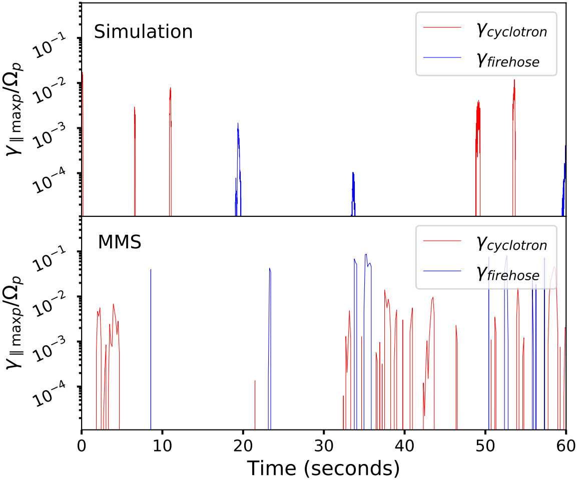
- Ion data from Fast Plasma Investigator (FPI) aboard MMS.
- In burst mode we get one proton distribution every 150 ms.
- Period analysed: Several burst modes from 2016 and 2018.
- Present results from 12/27/2016. Previously studied by Chasapis et al. (*ApJ*, 2017; *ApJL*, 2018).


$R_p = T_{\perp p}/T_{\parallel p}$
1.5
1.0
$\beta_{\parallel p}$
10^2
10^1
10^0
$|\mathbf{J}|$ (nA/m^2)
10^2
$\gamma_{\parallel \max p}/\Omega_p$
10^{-1}
10^{-3}
10^{-5}
$\gamma_{cyclotron}$
$\gamma_{firehose}$
$\gamma_{\nparallel \max p}/\Omega_p$
10^{-1}
10^{-3}
10^{-5}
γ_{mirror}
$\gamma_{firehose}$
06:31
06:34
06:38
Time (UTC) on 2017 December, 26



- $\beta_{\parallel p}$ is high
- A lot more unstable VDFs
- Distribution of instabilities are still intemittent

Comparison between PIC and Observation



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- Various studies (Osman et al. (*PRL*, 2011, 2012; Greco et al. (*PRE*, 2012) have shown intermittency to be associated with sharp gradients in magnetic field, thus implying presence of turbulence in those regions
- Since they lie in the same configuration space, it appears that temperature anisotropy is driven by turbulence
- Locally plasma was still homogeneous enough for γ_p to limit anisotropy