Instabilities in counterstreaming bi-Maxwellian plasmas

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Solar wind temperature anisotropy at 1 AU

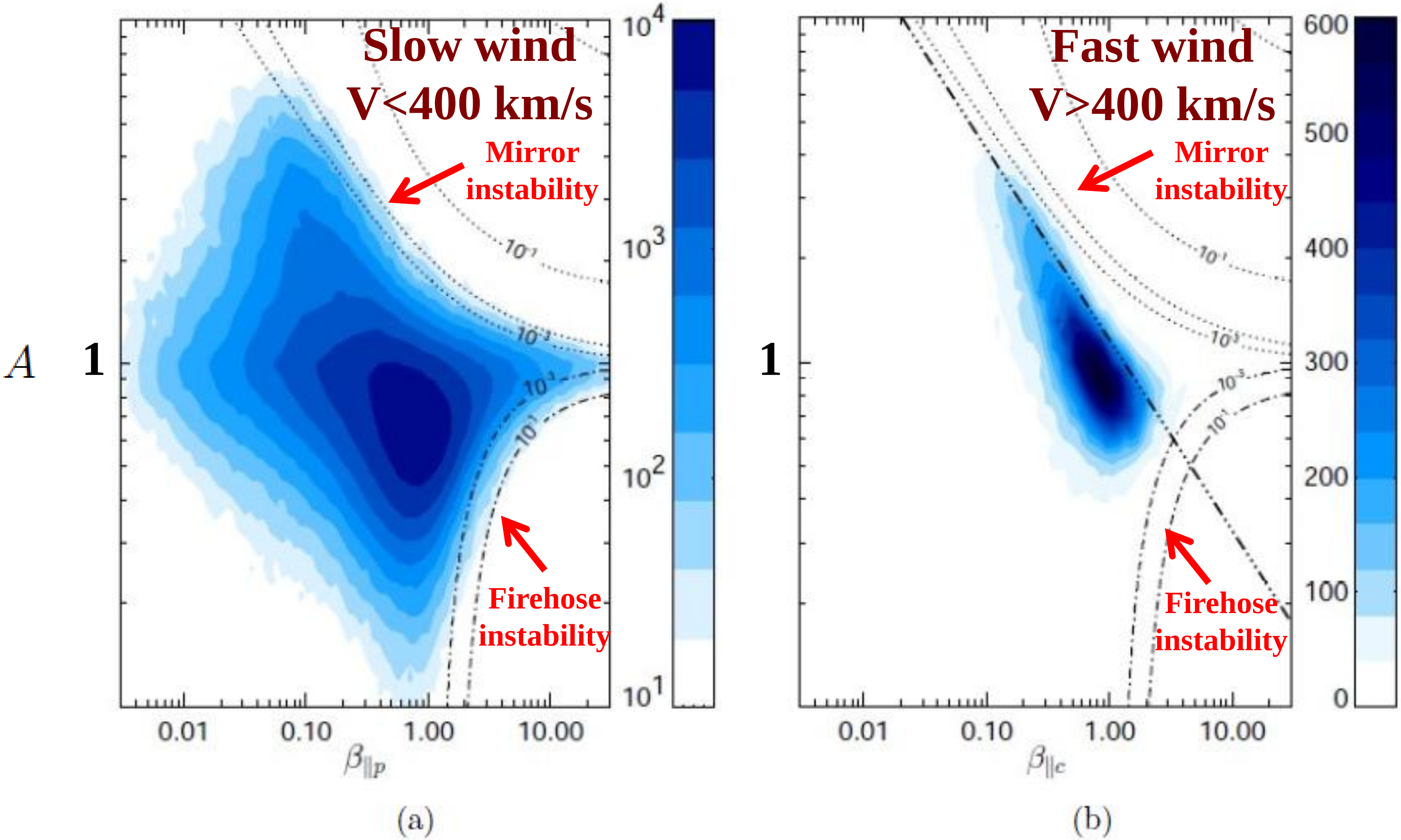
The temperature anisotropy of plasma component „a“:

$$A_a = \frac{T_{\perp,a}}{T_{\|,a}}$$

The parallel plasma beta of plasma component „a“:

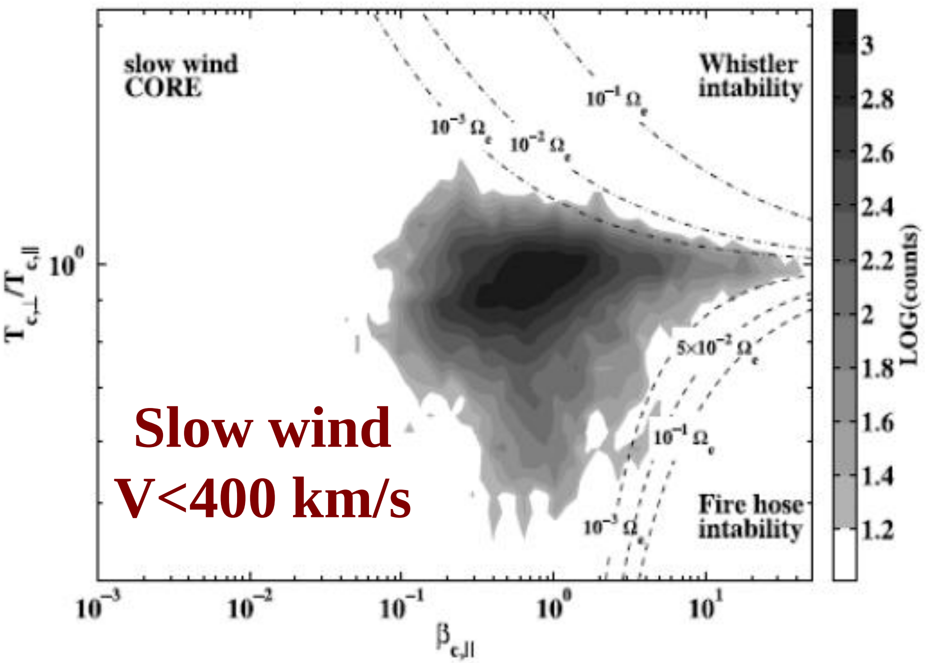
$$\beta_{\|,a} = \frac{p_a}{p_M} = \frac{n_a T_{\|,a}}{B^2/4\pi}$$

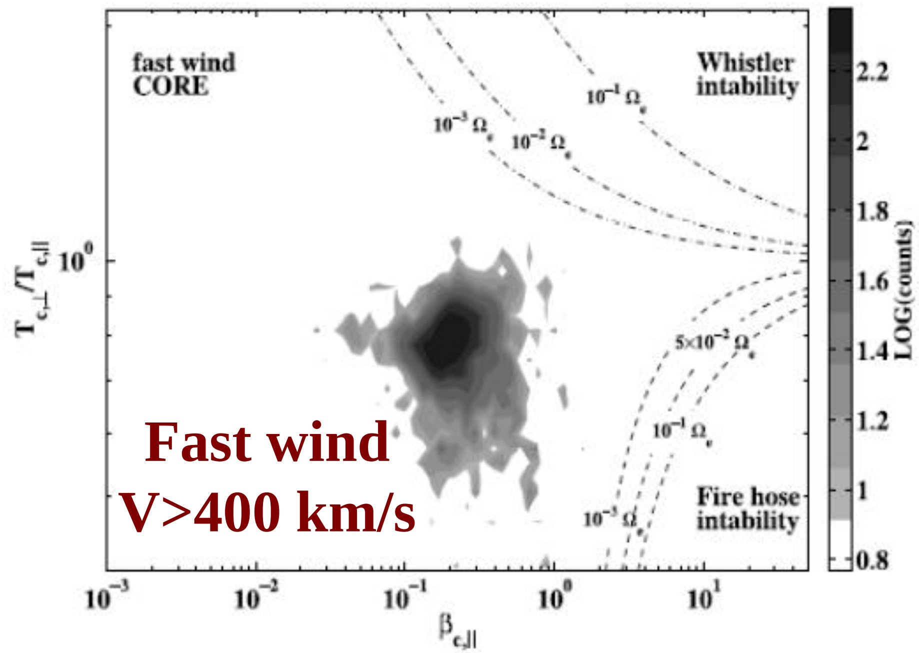
Proton temperature anisotropy at 1 AU



P. Hellinger, P. Travnicek, J. C. Kasper, and A. J. Lazarus. *J. Geophys. Res.*, 33:L09101, 2006.

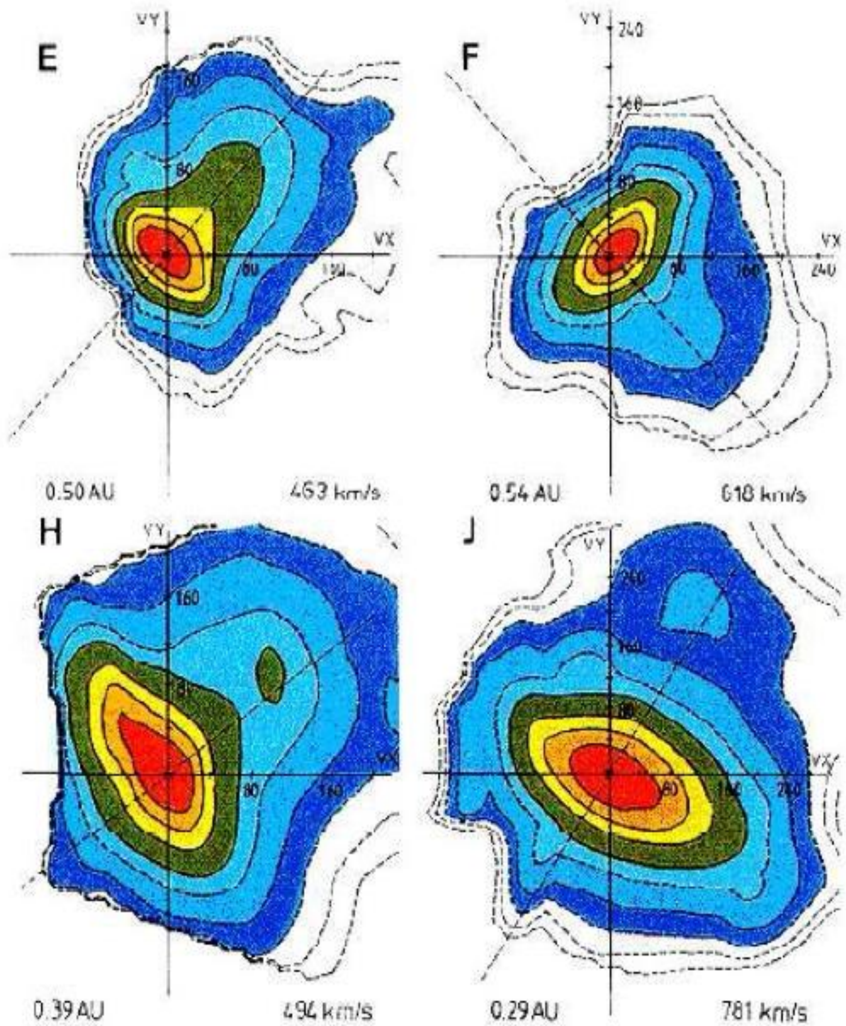
Electron temperature anisotropy at 1 AU





S. Stverak, P. Travnicek, and M. Maksimovic et. al. *J. Geophys. Res.*, 113:A03103, 2008.

Solar wind distribution function



E. Marsch. *Living Rev. Solar Phys.*, 3:1, 2006.

1. Plasma can stream along and against magnetic field direction
2. The distribution function might have a double-peak structure

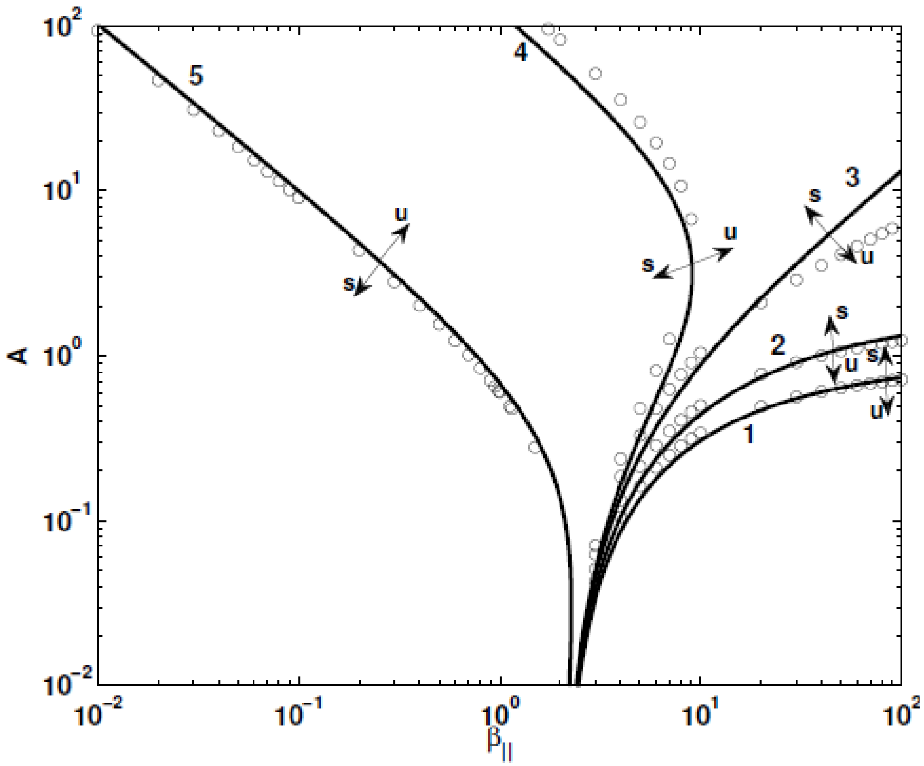
Counterstreaming bi-Maxwellian velocity distribution function

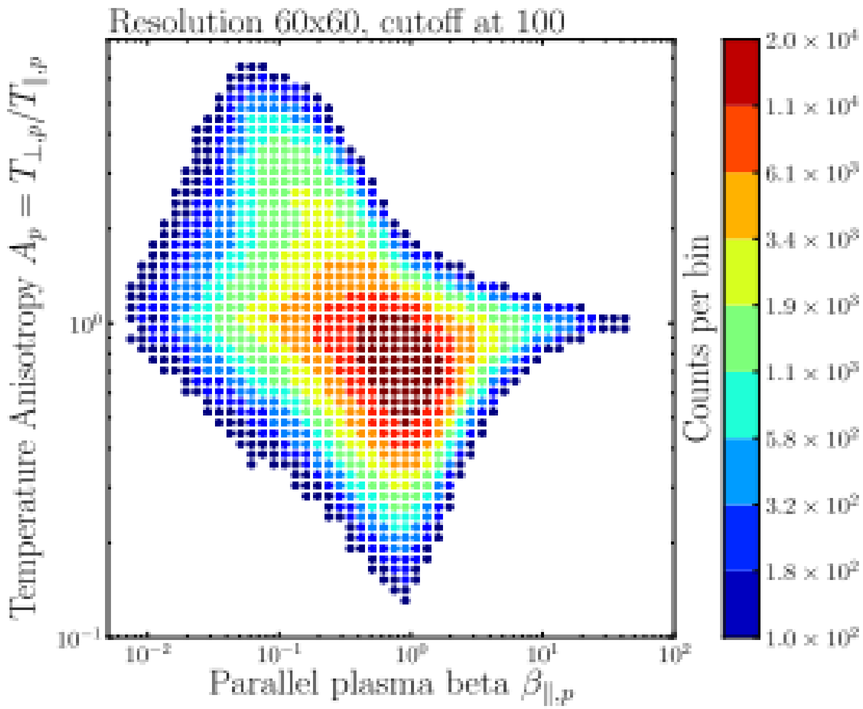
$$F_a\left(v_\perp, v_z\right) = F_{a,\perp}\left(v_\perp\right) \sum_s \epsilon_{a,s} F_{a,z}\left(v_z\right)$$

$$F_{a,\perp}(v_\perp) = \frac{1}{\pi u_{\perp,a,s}^2} \exp\left(-\frac{v_\perp^2}{u_{\perp,a,s}^2}\right)$$

$$F_{a,z}(v_z) = \frac{1}{\pi^{1/2} u_{\parallel,a,s}} \exp\left(-\frac{\left(v_z - V_{a,s}\right)^2}{u_{\parallel,a,s}^2}\right)$$

O-mode instability-1



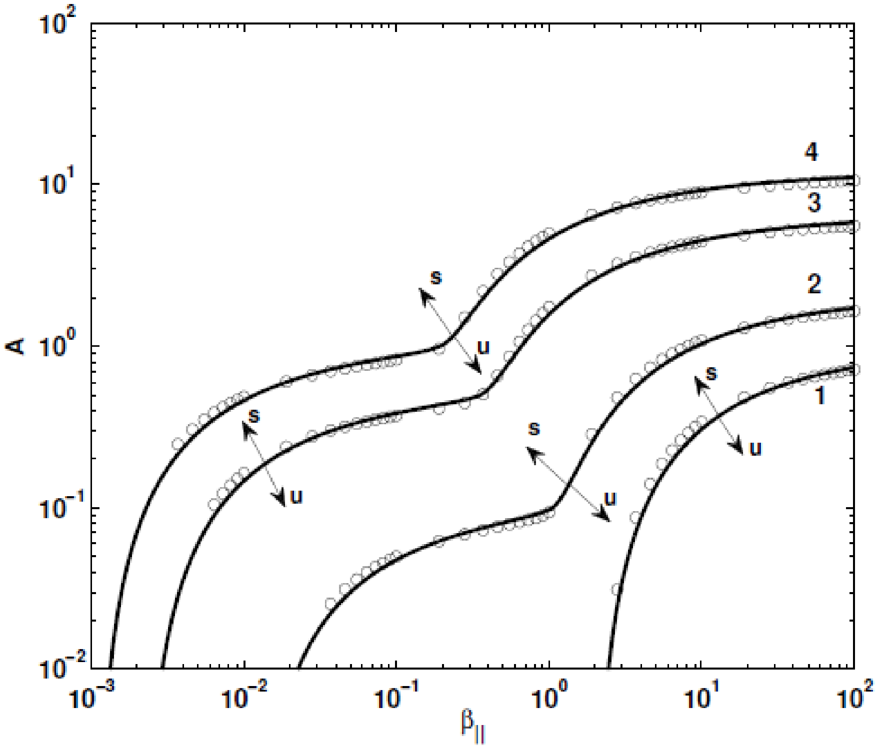


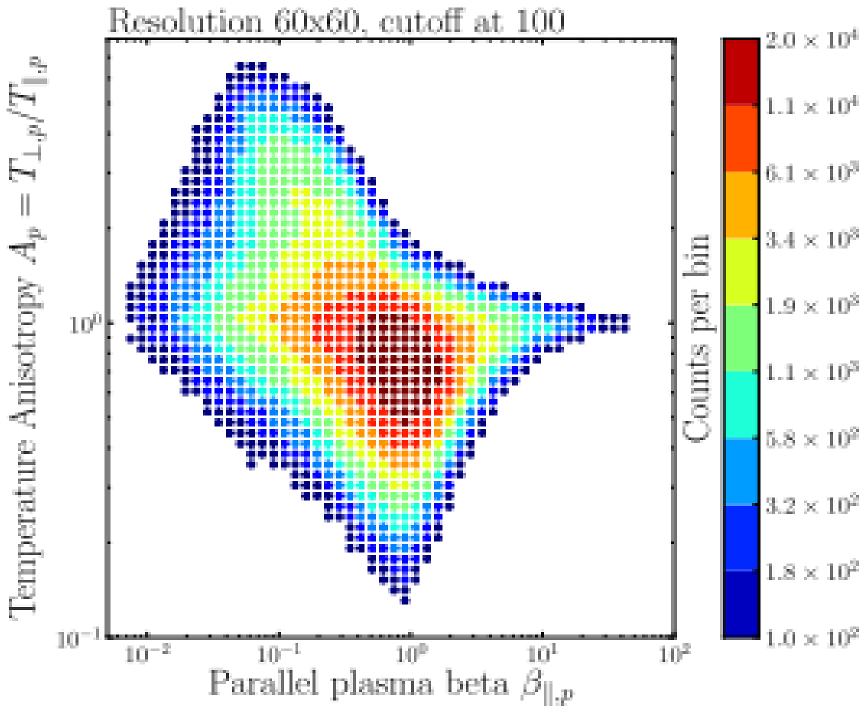
Existence condition of the O-mode instability in electron-proton plasmas for the case $R_\perp = const$ ($\nu = 10$). Curve 1: $U = 0$. Curve 2: $U = 0.5$. Curve 3: $U = 1$. Curve 4: $U = 1.25$. Curve 5: $U = 5$.

$$P(A, \beta_\|) = P_0 R_\perp A \beta_\| \qquad U = 2P_0 R_\perp \left(1 + \nu^{-1}\right) \qquad R_\perp = \frac{V_{n1}^2}{u_{\perp n}^2} = \text{const.}$$

S. Vafin, M. Lazar, and R. Schlickeiser. *Phys. Plasmas*, 22:022129, 2015.

O-mode instability-2

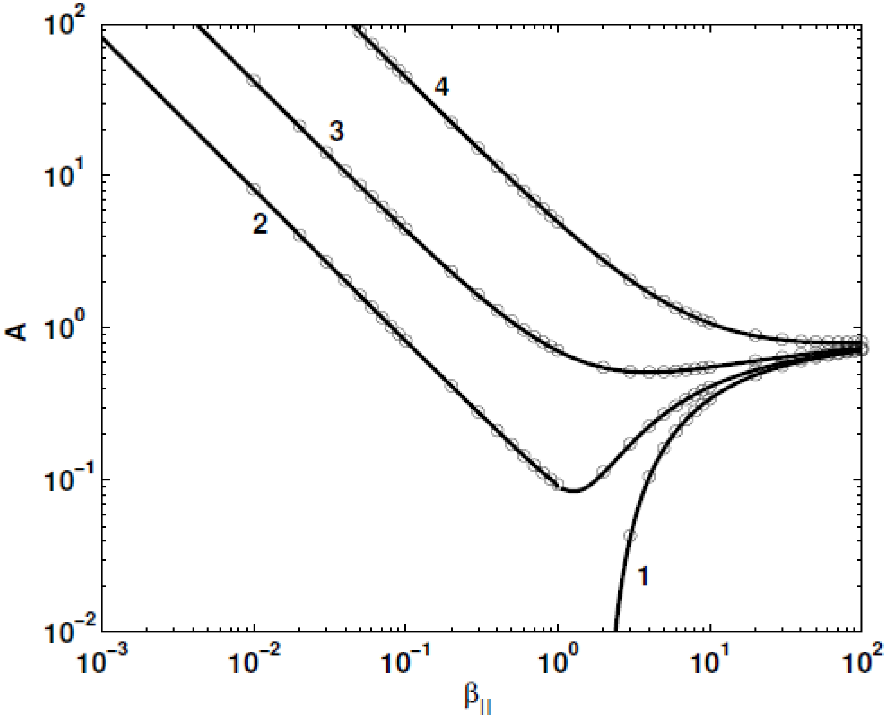


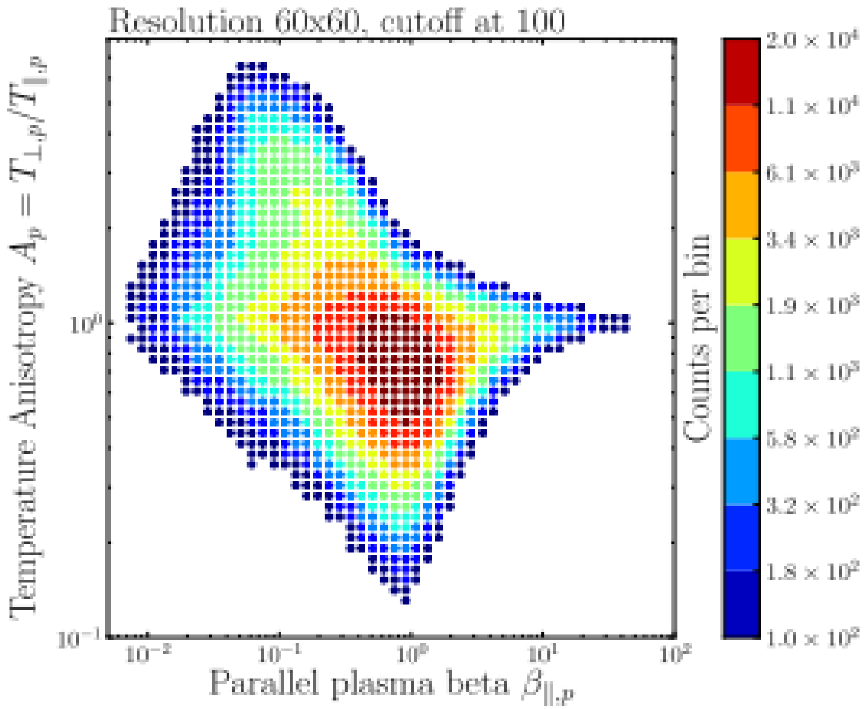


Existence condition of the O-mode instability in the electron-proton plasma for the case $R_{\parallel} = const$ ($\nu = 10$). Curve 1: $\eta = 0$. Curve 2: $\eta = 1$. Curve 3: $\eta = 5$. Curve 4: $\eta = 10$.

$$P(\beta_{\parallel}) = P_0 R_{\parallel} \beta_{\parallel} \qquad \eta = 2P_0 R_{\parallel} \qquad R_{\parallel} = \frac{V_{n1}^2}{u_{\parallel n}^2} = \text{const.}$$

O-mode instability-3

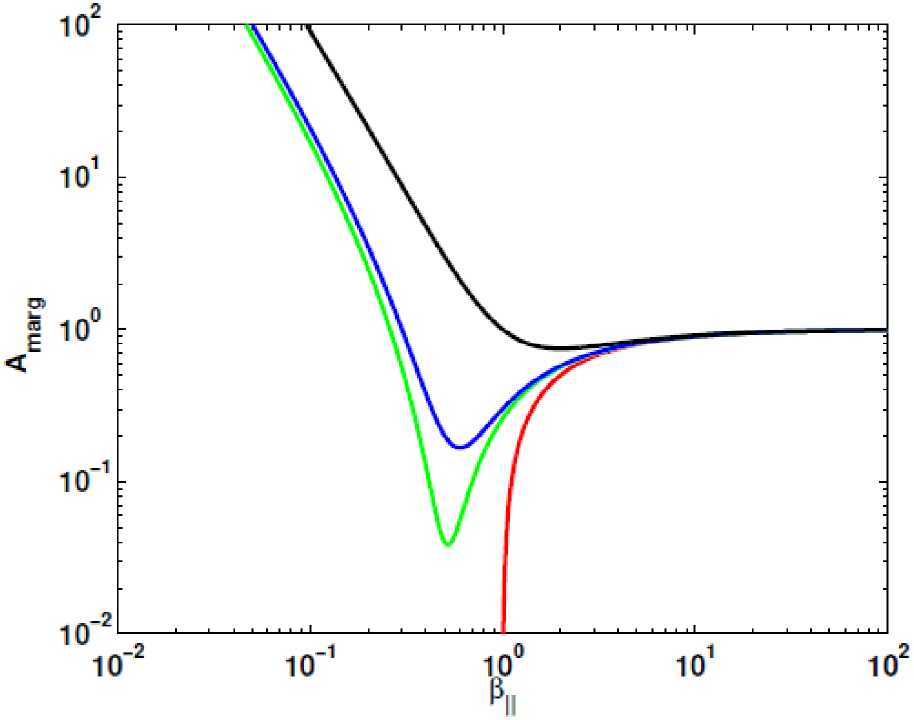


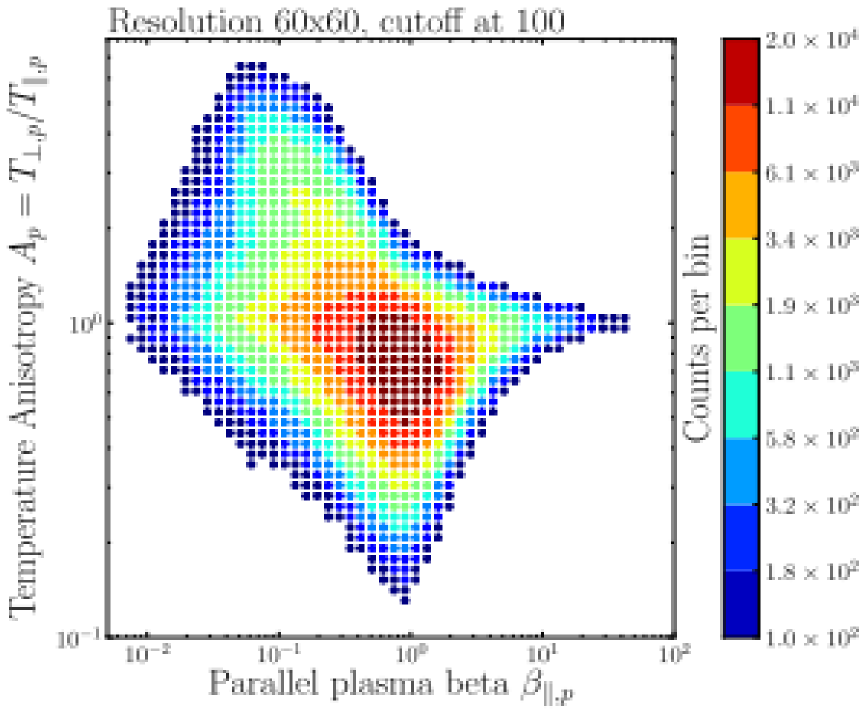


Curve 1: $P_n = 0$. Curve 2: $P_n = 0.5$. Curve 3: $P_n = 1.5$. Curve 4: $P_n = 5$.

$$P = const$$

Alfven instability-1



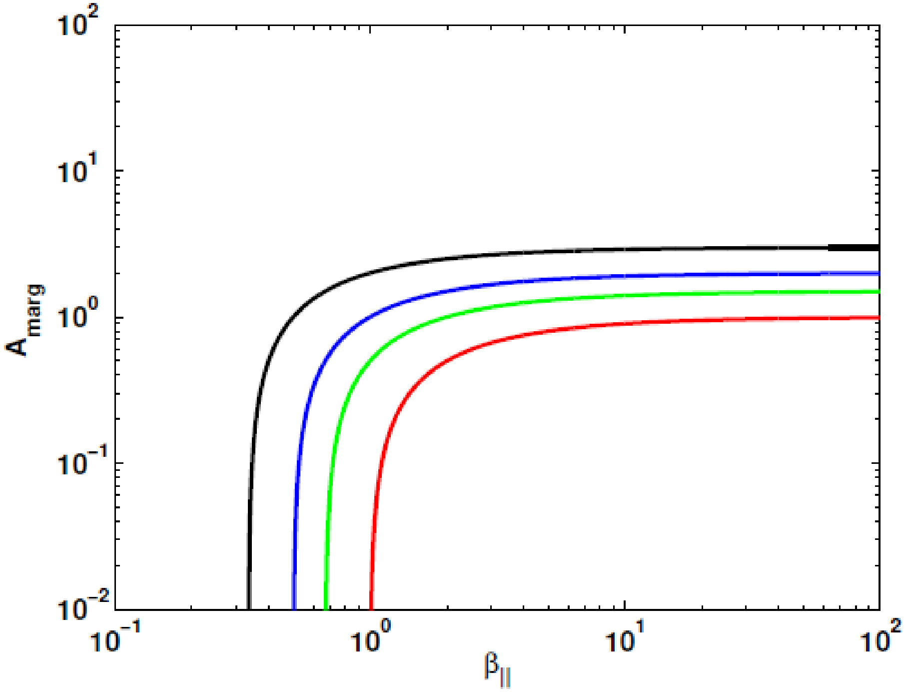


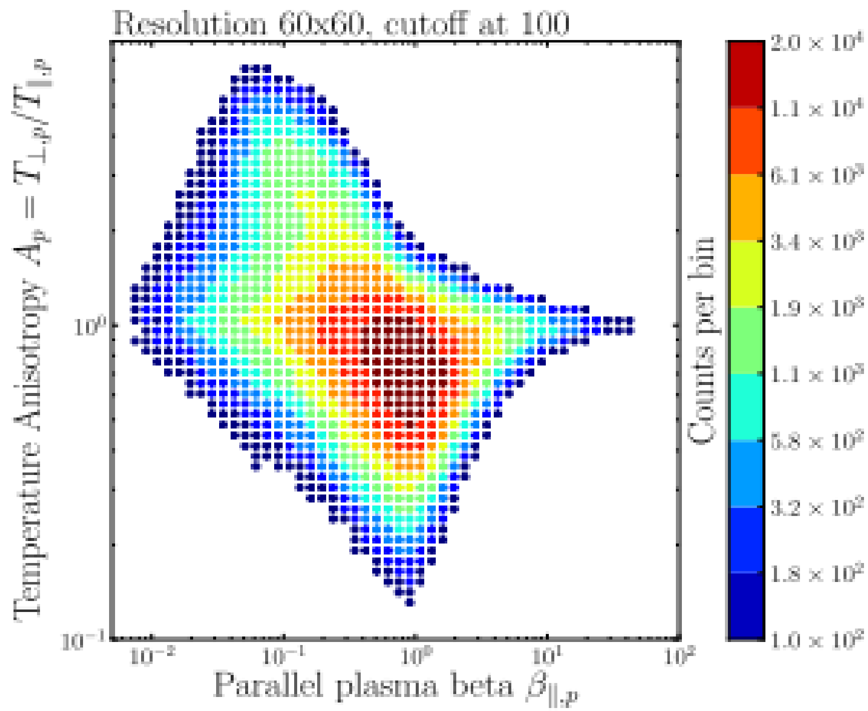
Red: $P_{0,1} = 0$. Green: $P_{0,1} = 0.26$. Blue: $P_{0,1} = 0.3$. Black: $P_{0,1} = 1$.

(1) $B = const$ and $T_{||} = const$ $\qquad$ $P = P_1 = \dfrac{P_{0,1}}{\beta_{||}}$

S. Vafin, R. Schlickeiser, and P. H. Yoon. *Phys. Plasmas*, 22:092131, 2015.

Alfven instability-2

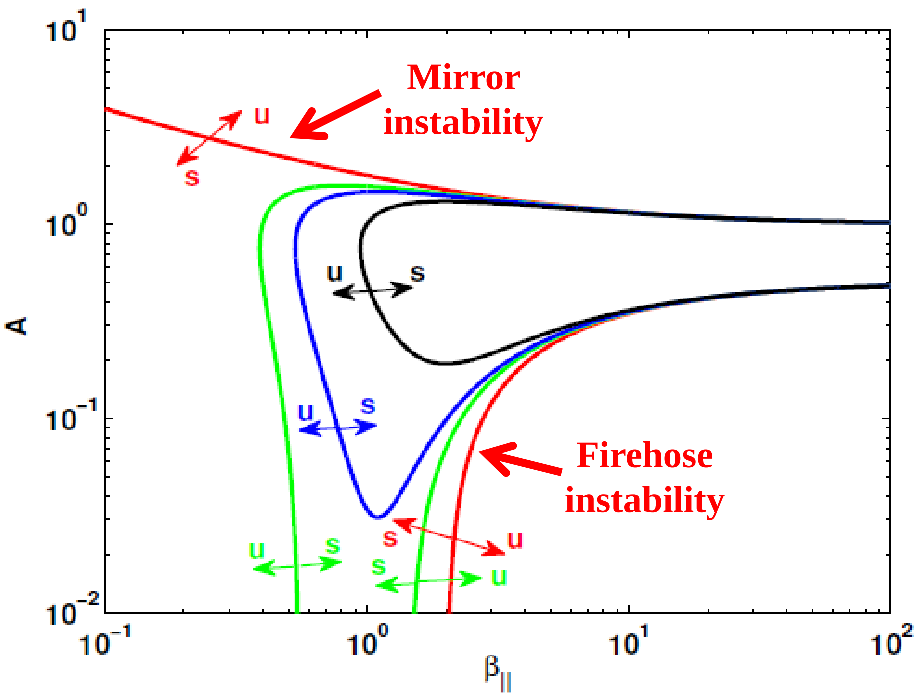


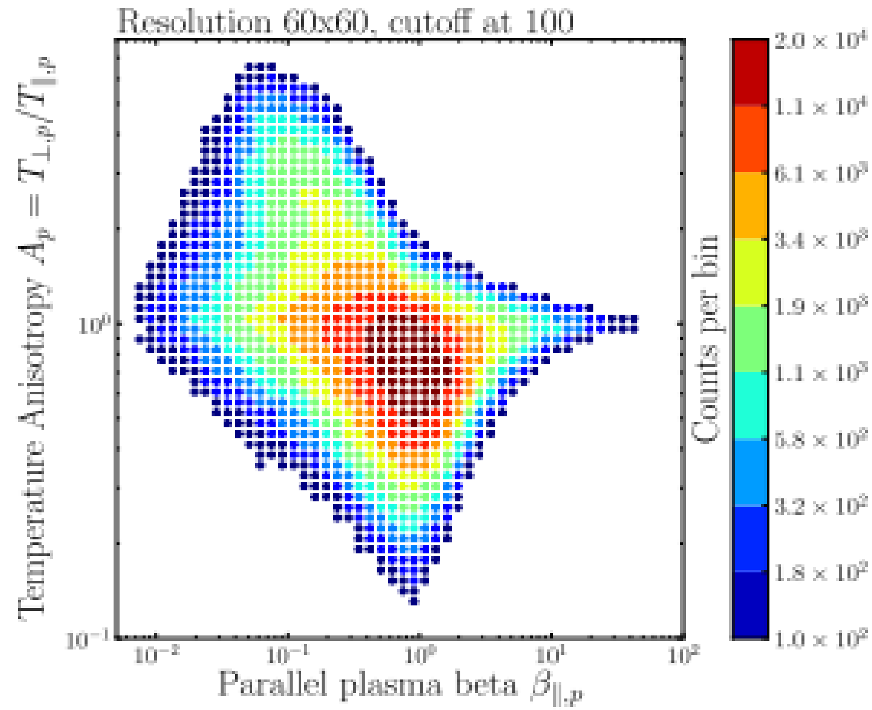


Red: $P_{0,2} = 0$. Green: $P_{0,2} = 0.5$. Blue: $P_{0,2} = 1$. Black: $P_{0,2} = 2$.

(2) $n = const$ and $T_{\|} = const$ $\qquad$ $P = P_2 = P_{0,2}\beta_{\|}$

Mirror and firehose instabilities-1



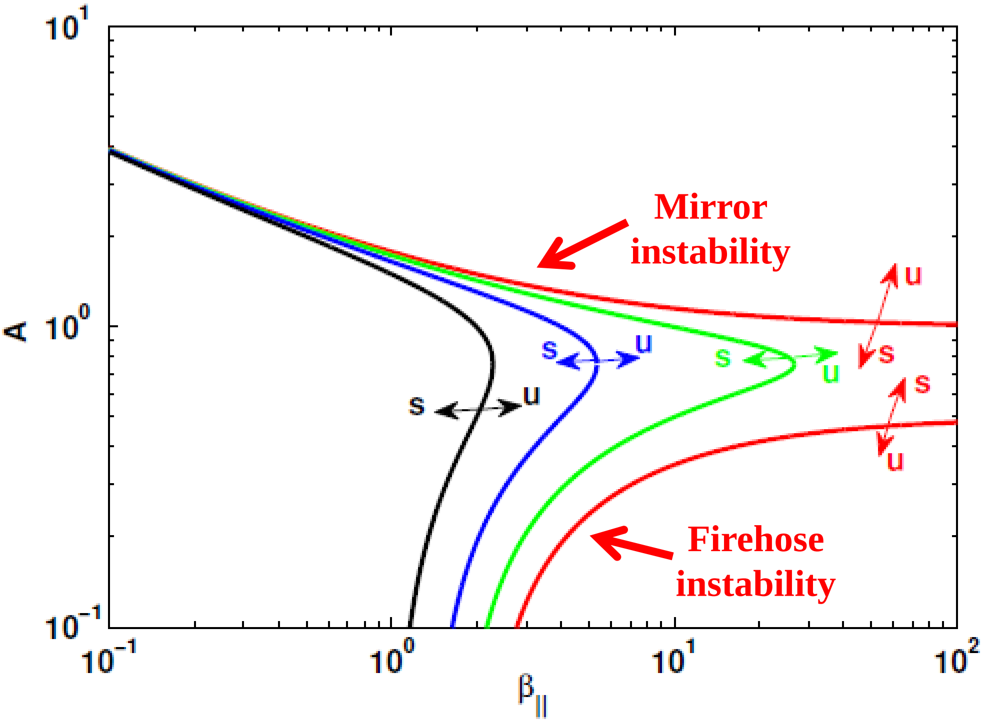


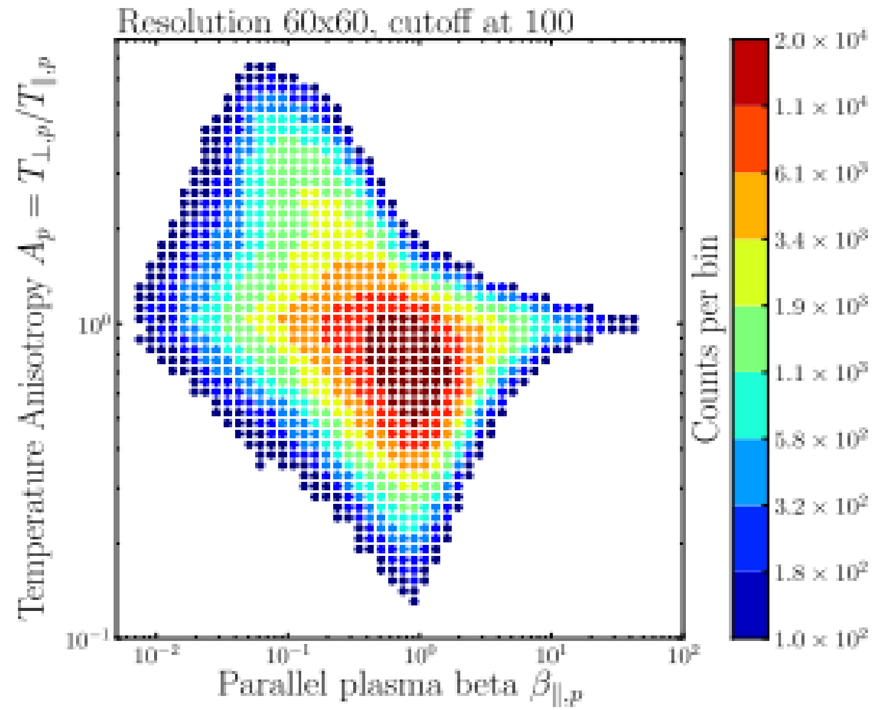
$$\zeta = \pi/4$$

Red: $P_{0,1} = 0$. Green: $P_{0,1} = 0.8$. Blue: $P_{0,1} = 1.1$. Black: $P_{0,1} = 2$.

(1) $B = const$ and $T_{\parallel} = const$ $\qquad P = P_1 = \dfrac{P_{0,1}}{\beta_{\parallel}}$

Mirror and firehose instabilities-2





$\zeta = \pi/4$

Red: $P_{0,2} = 0$. Green: $P_{0,2} = 0.2$. Blue: $P_{0,2} = 0.5$. Black: $P_{0,2} = 1$.

(2) $n = const$ and $T_{\|} = const$ $\qquad P = P_2 = P_{0,2}\beta_{\|}$

Summary

1. **The present project has analyzed stability of four fluctuation modes (O-mode, Alfven, mirror and firehose) in counterstreaming bi-Maxwellian plasmas.**

2. **The counterstreams have a considerable effect on the well-known instability conditions of these modes.**

3. **The results point out to a full potential explanation of the observed temperature anisotropy of the solar wind at 1 AU.**

Thank you for your attention!