Boundary induced reduction of spoke-like activity

Eduardo Rodríguez[12], Valentin Skoutnev[12], Yevgeny Raitses[2]
Tasman Powis[12], Igor Kaganovich[2], Andrei Smolyakov[3]

[1]Department of Astrophysical Science, Princeton University
[2]Princeton Plasma Physics Laboratory
[3]Department of Physics and Engineering Physics, University of Saskatchewan *Work supported by AFOSR

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Introduction: experimental device

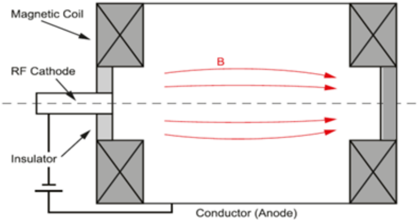

Figure 1: Diagram representing the main components of the Penning device, where a uniform field exists in the axial direction (along the beam), and a radial E

- Ion probe:

$$n = \frac{I_{\text{ion}}}{0.99 e A_p v_B}$$

where $v_B = \sqrt{T_e/M}$

- Emissive probe[1]:

$$V_p \approx V_f^{\text{hot}} + \alpha T_e \approx V_f^{\text{hot}}$$

for continuous recording of V_p

- 'Two-probe' method: cross field current estimation using local simultaneous V_p and n assuming a quasi-uniform azimuthally rotating spoke behaviour. Then,

$$j_{\text{ExB}}^{\perp} = ne \frac{E_\theta}{B_z}$$

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[1] B. Kraus and Y. Raitses, Physics of Plasmas, 25(3):030701, 2018

Experimental results: activity reduction

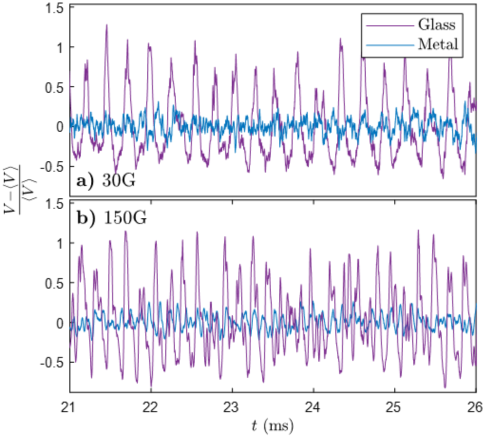

Figure 2: Change in oscillatory behaviour of the plasma in changing the boundary condition. (LEFT) Plots of $\hat{V} = \frac{V-\langle V\rangle}{\langle V\rangle}$, with V the measured ion probe signal, for 30G and 150G uniform field. (RIGHT) Spectrum of the ion probe signal

Experimental results: feature comparison - anomalous transport

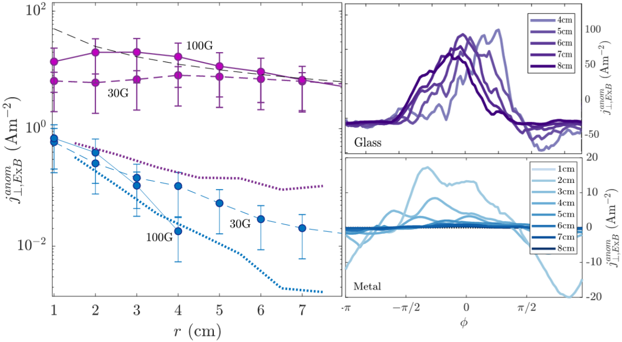

Figure 3: (LEFT) Comparison of time averaged cross field anomalous current density with radius. The dotted lines correspond to classical estimation of transport given measured gradients, $J_r = \frac{\sigma}{1+(\omega_{ce}/\nu_{eff})}\left(E_r + \frac{\partial T_e}{\partial r} + T_e \frac{\partial \ln n}{\partial r}\right)$ and $\sigma = \frac{ne^2}{m_e \nu_{eff}}$, using $\nu_{eff} = n_0 \langle \sigma_X v \rangle$. (RIGHT) Phase resolved transport, with $\phi = 0$ density maximum. These correspond to a 30 G field case.

Theoretical framing of results (i)

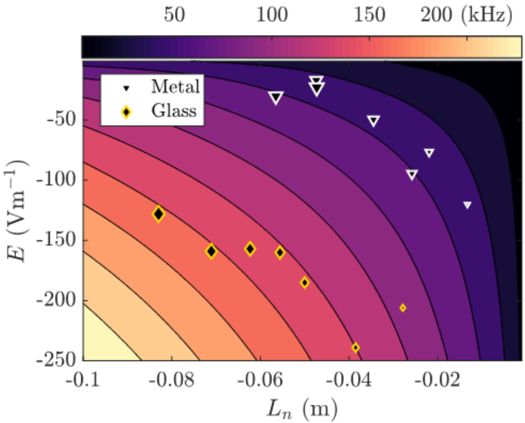

Figure 4: Estimation of growth rate, γ, using measured gradients for 150G uniform field (scatter). Calculations are based on Frias-Smolyakov gradient drift instability 3 field theory.[3]

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[2] Frias et al., Phys. Plasmas 20, 052108 (2013); doi: 10.1063/1.4804281

Introduction: theoretical basis

FRIAS-SMOLYAKOV 3-FIELD THEORY:[4]

Using relevant field gradients L_n and E, and noting that $L_B^{-1} \approx 0$ for this particular case, then the dispersion relation reduces to modified Simon-Hoh,

$$\frac{\omega_*}{\omega - \omega_0} = \frac{k_\theta^2 c_s^2}{\omega^2} \qquad (1)$$

so that instability growth rate is

$$\gamma = \frac{k_\theta c_s}{\omega_*} \sqrt{\omega_0 \omega_* - \frac{k_\theta^2 c_s^2}{4}} \qquad (2)$$

and $k_\theta \approx 1/R$

DRIFT FREQUENCIES:

$$\omega_* = -k_\theta \frac{k_B T_e}{eBL_n}$$
$$\omega_D = -2k_\theta \frac{k_B T_e}{eBL_B} \approx 0$$
$$\omega_{*T} = -k_\theta \frac{k_B T_e}{eBL_T}$$
$$\omega_0 = -k_\theta \frac{E_r}{B}$$

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[4] Frias et al., Phys. Plasmas 20, 052108 (2013); doi: 10.1063/1.4804281

Highlights

- The anomalous cross field transport is reduced by encasing the Penning discharge within all conducting boundary
- Density perturbations are reduced significantly (ie. up to an order of magnitude) but persist, with modified properties such as a more localised rotating perturbation
- The observations are framed within the three field gradient-drift instability theory, proposed as a likely seed of the 'spoke' instability.