Blob sizes and velocities in the Alcator C-Mod scrape-off layer

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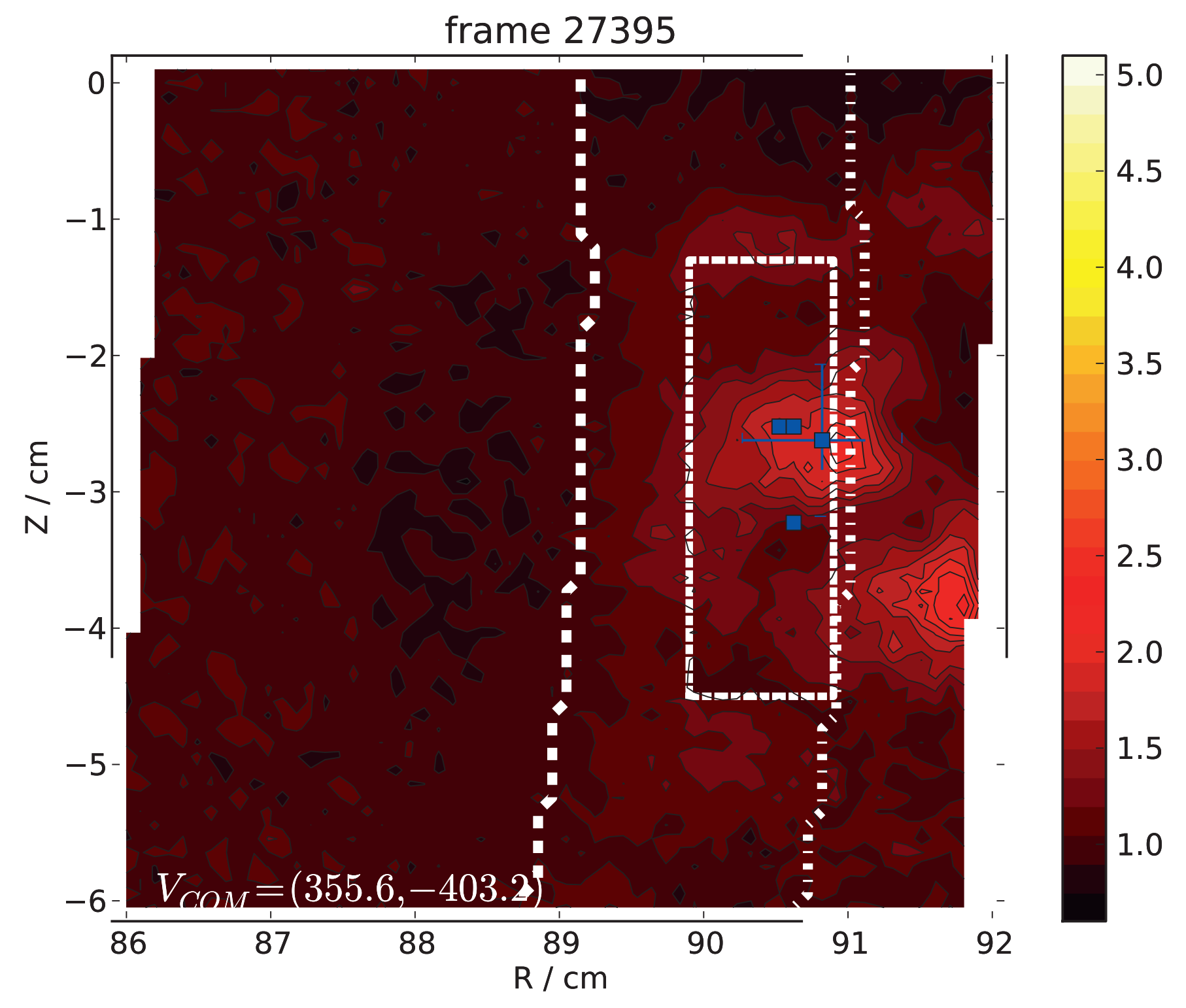
Introduction

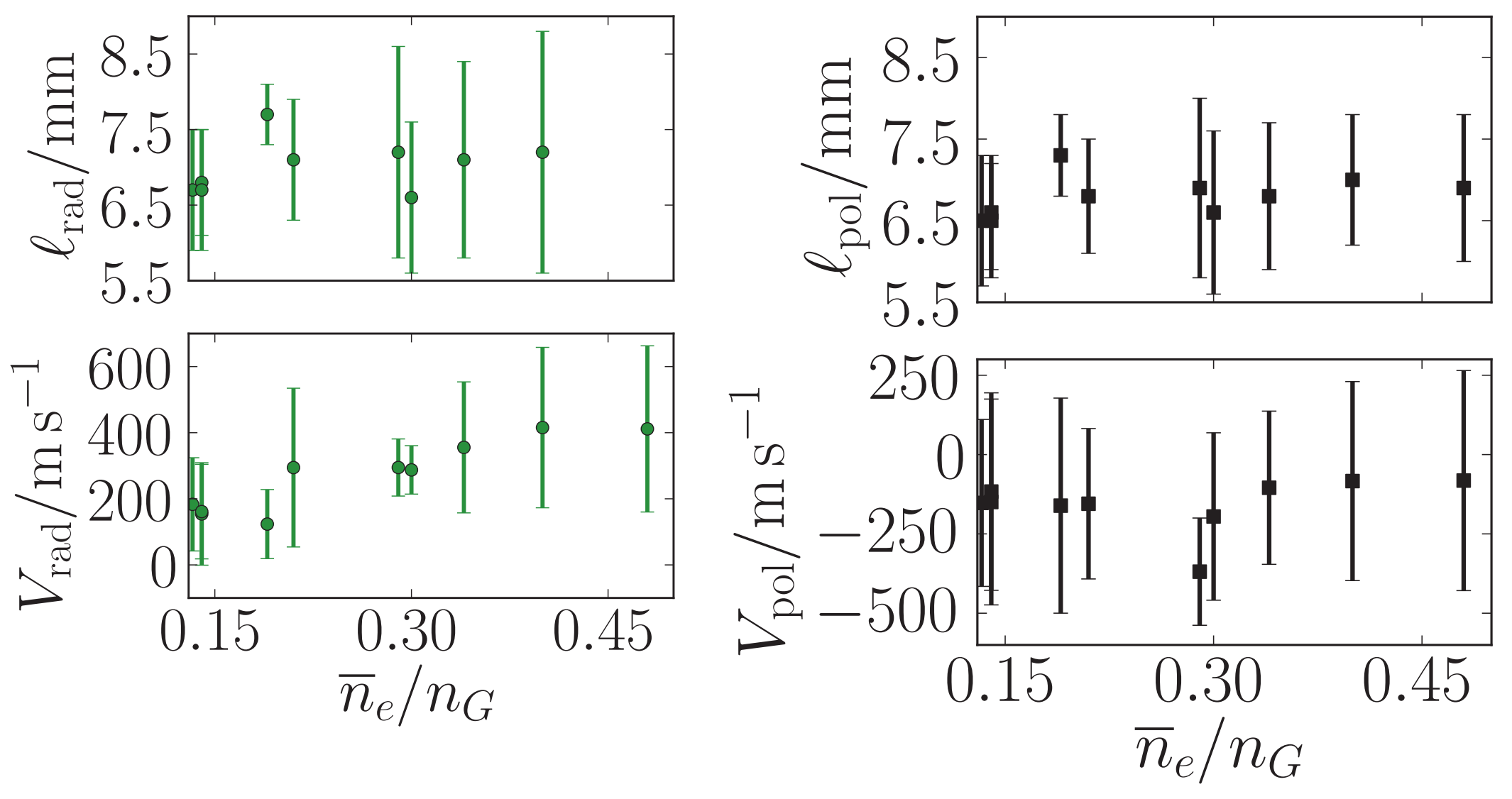
A new blob-tracking algorithm for the GPI diagnostic installed in the outboard-midplane of Alcator C-Mod is developed. It tracks large-amplitude fluctuations propagating through the scrape-off layer and calculates blob sizes and velocities. We compare the results of this method to a blob velocity scaling from a simple blob-model for sheath-connected blobs. We further present initial results from a fully three-dimensional blob model that features plasma resistivity as a free parameter.

Blob tracking

Blobs are identified as intensity maxima recorded by the GPI diagnostic. Radial and poloidal velocities are computed using center-of-mass coordinates. We use gaussian fits on the radial and poloidal intensity cross-section to identify blob sizes as the structure propagates through the SOL.



Results for 10 ohmically heated LSN discharges with varying n_e



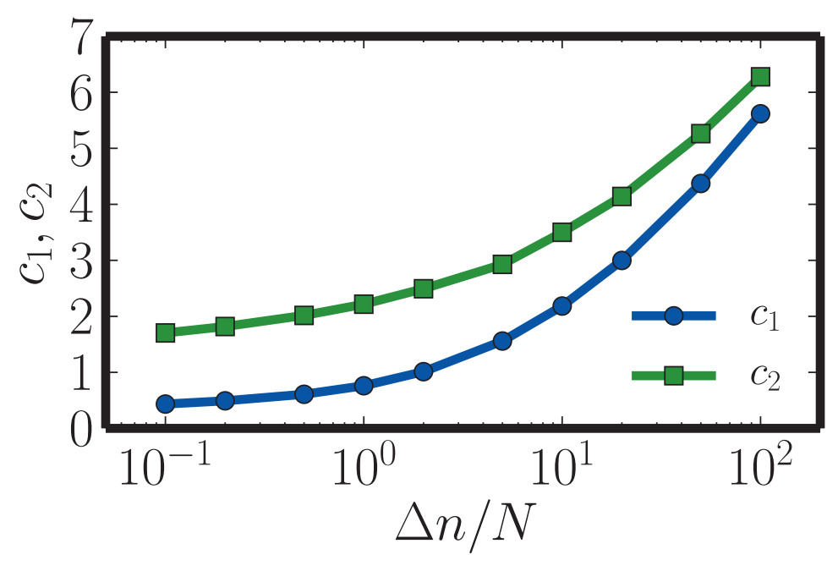
- Radial blob velocity increases with n_e
- Poloidal blob velocity in the ion-diamagnetic direction
- Blob sizes change little with n_e
- Results agree with correlation methods [3,4]

Comparison to theory

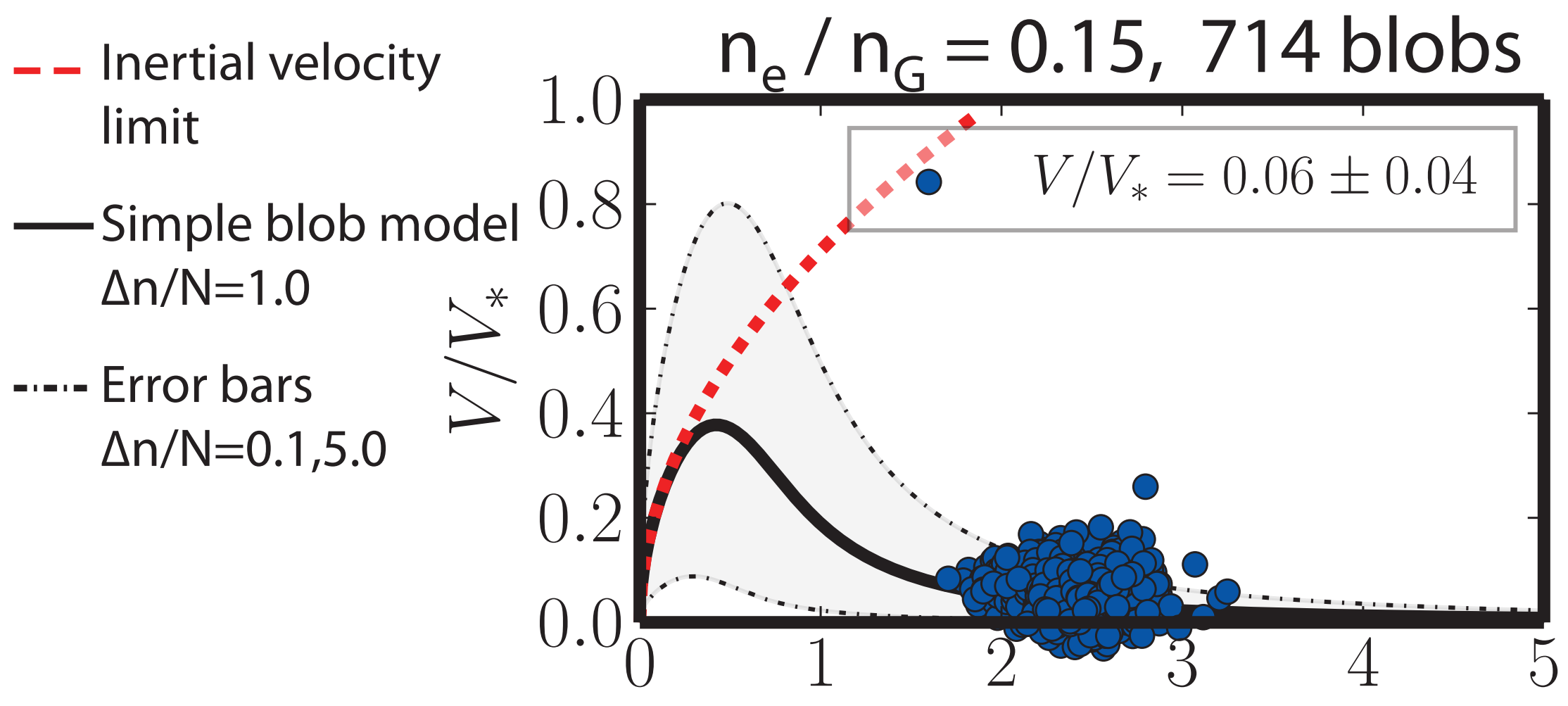
Simplified blob theory models blobs as homogeneous filaments elongated along B and terminating at sheaths formed where magnetic field lines intersect the divertor plates. In this case the radial blob velocity depends on its poloidal cross field size ℓ and its amplitude Δn/N.

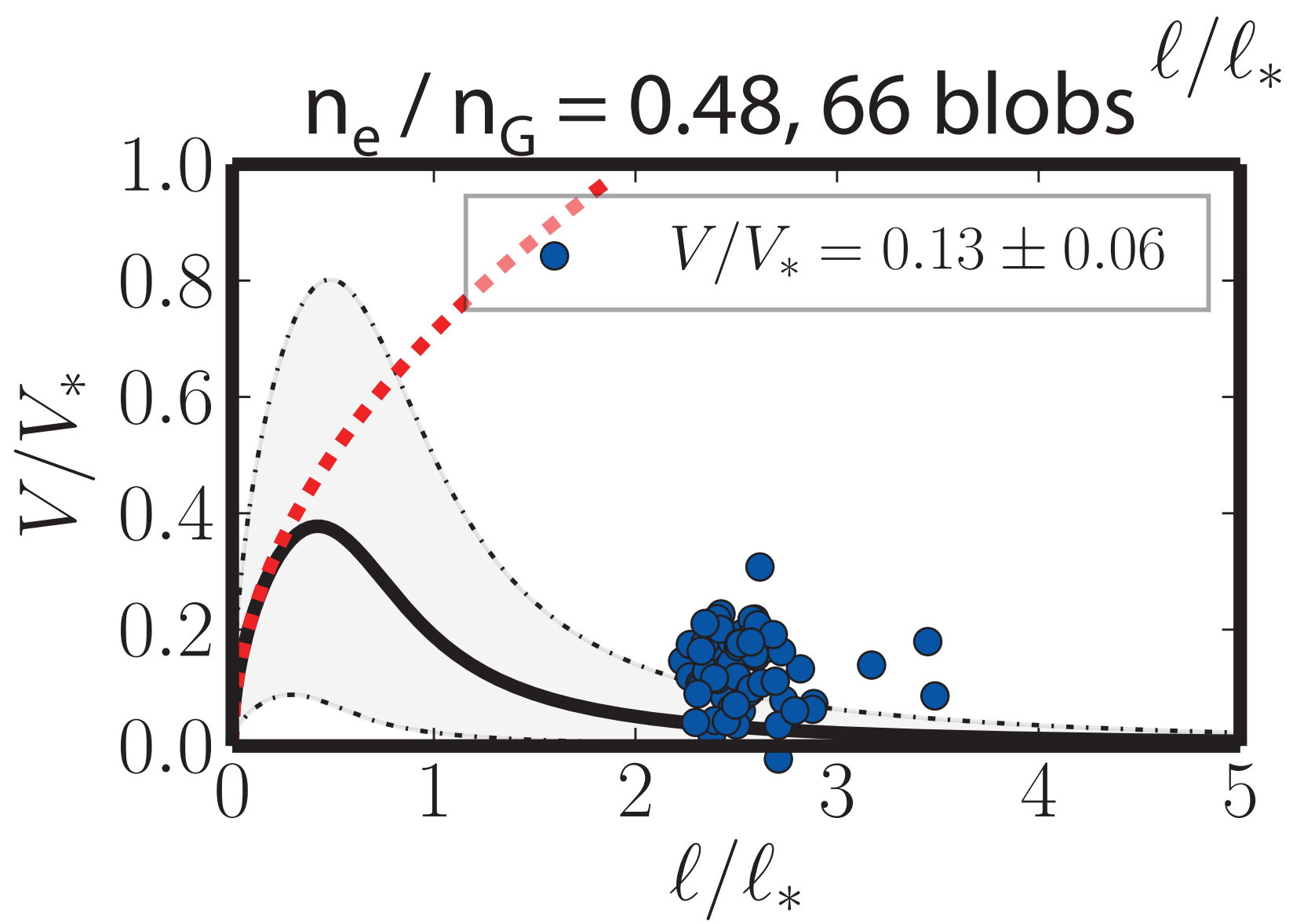
$$\frac{V}{V_*}=\frac{c_2}{2}\left(\frac{\ell}{\ell_*}\right)^3\left[-1+\left(1+\frac{c_1}{c_2^2}\frac{4\ell_*^5}{\ell^5}\frac{\Delta n/N}{1+\Delta n/N}\right)^{1/2}\right]$$

c1(Δn/N), c2(Δn/N) are determined from numerical simulations[1]



V_* and ℓ_* estimate the length scale on which a blob attains maximal velocity.
Here: V_* = 2.4 km/s and ℓ_*= 0.2 cm.





- Simplified model does not reproduce trend with increasing n_e
- We need a 3d model to include parallel dynamics, including plasma resistivity

3d blob model

Radial motion of isolated plasma filaments are described by an interchange model. We extended the model in [2] as to model the full particle density n and include finite variation along the magnetic field. We assume that cross-field drifts are dominated by the electric drift and neglect Hall terms in Ohm's law. Spatial scales are normalized to ℓ in the drift-plane, to $L_{||}$ along B, and temporal scales are normalized to an ideal interchange rate γ. In the z-direction along B we use sheath boundary conditions for J and choose between Dirichlet and Neumann boundary conditions for Ω and n. Plasma resistivity is parametrized in Σ.

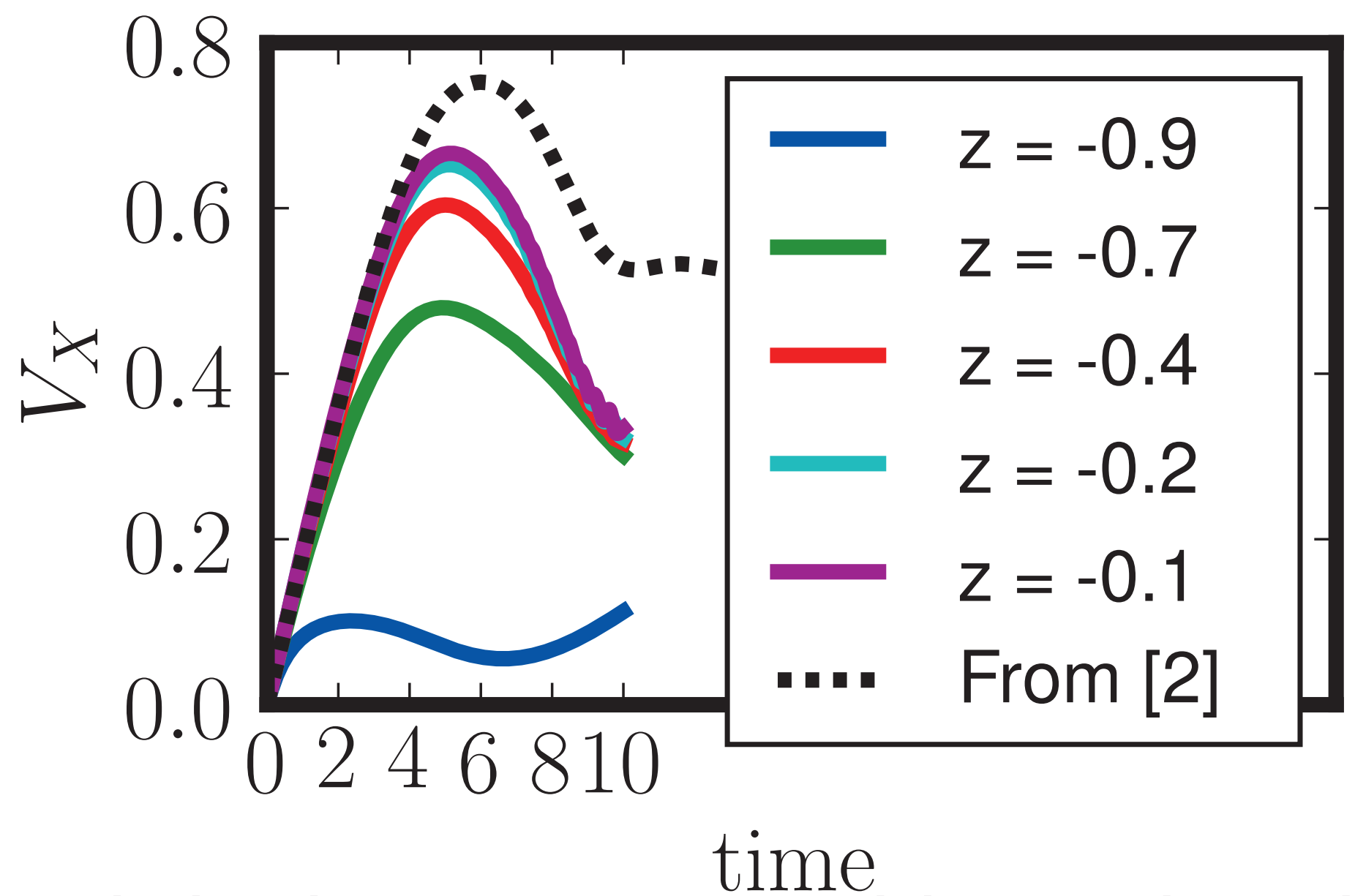
$$\frac{\partial \ln n}{\partial t}+\underline{z}\times\nabla\phi\cdot\ln n=\nabla\overleftrightarrow{\kappa}\nabla\ln n$$

$$\frac{\partial\Omega}{\partial t}+\underline{z}\times\nabla\phi\cdot\Omega+\frac{\partial\ln n}{\partial y}=\nabla\overleftrightarrow{\mu}\nabla\Omega+\Sigma\nabla_{||}J_{||}$$

$$\Omega=\nabla_\perp^2\phi\quad E_{||}=\eta J_{||}\quad \Sigma=\frac{B^2}{\gamma nm\eta}\frac{\ell^2}{L_{||}^2}$$

Initial results, simulation setup:
- Isolated blob, homogeneous along B
- Blob amplitude Δn/N=1.0, Σ=100

Compare radial blob velocity at various z positions to [2].



- Radial velocities comparable to 2d model [2]
- Finite resistivity gives inhomogeneous blob evolution along B
- Largest damping of radial velocity close the sheaths.

Conclusions and future work

Observed radial blob velocities and sizes agree with results from studies that use correlation methods [3,4]. We find that the radial blob velocity increases with line averaged plasma density. For n_e / n_G = 0.15 the average filament velocity is 150 m/s which increases to 450 m/s for n_e / n_G = 0.48. For the later case, observed radial blob velocities systematically exceed predicted values from simplified blob theory. Poloidal velocities are favorably in the direction of the ion diamagnetic drift and show larger variation than the radial velocities. The cross-field sizes of the blobs vary only little with n_e. This result implies that the radial blob velocity depends on local plasma parameters, as background density and resistivity, and motivates to extend existing blob theories as to include them. A fully three-dimensional blob model is proposed that includes plasma resistivity in a free model parameter. Initial results indicate that the rate by which electric currents parallel to the magnetic field damp the radial velocity of a blob as a function of z depends on the plasma resistivity.

References

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