Plasma flows due to blobs and drifts in Alcator C-Mod SOL

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49th Annual Meeting of the Plasma Physics Division, American Physical Society
Orlando, Florida 12-16 November 2007
Non-diffusive transport and large parallel plasma flows have been observed experimentally in the SOL of Alcator C-Mod and simulated with UEDGE code.

Reciprocating Mach probes showed:

1) Plasma flow velocity \( V_{||} \) (HFS) >> \( V_{||} \) (LFS)
2) \( M_{||} \sim 1 \) is in the far SOL at HFS
3) Plasma density and temperature decay lengths in the SOL are much higher at HFS than at LFS
4) Fluctuation RMS increases strongly toward the wall
5) \( \text{RMS}(\text{HFS}) \ll \text{RMS}(\text{LFS}) \)
6) Direction of plasma flow at HFS is always toward the X-point and practically independent on the direction of magnetic field

UEDGE code:

1) Incorporates non-diffusive “blobby” transport as anomalous outward convection of ion species.
2) Prescribes asymmetric “ballooning”-like profiles of transport coefficients and adjusts them to fit data.

UEDGE modeling confirmed:

1) Ballooning-like transport results in strong peaking of plasma pressure in the SOL around LFS mid-plane.
2) Total pressure gradient causes the parallel plasma flows.
3) Plasma flow attains \( M_{||} \sim 1 \) in the far SOL at HFS and it is stagnated at LFS.
4) Flow terminates at the HFS plate.
5) Impurities originated at LFS wall can be entertained by flow on HFS plate.
Large asymmetry in transport coefficients $\eta_{as}(\text{LFS/HFS}) \sim 0.1$ is required for agreement with measured data. Asymmetry affects the parallel flow, recycling and divertor plasma.

Asymmetry factors $\eta_{as}(V_{\text{conv}}, D_{\perp}, \chi_{\perp}) = 0.05 - 0.15$ have been deduced from matching measured profiles with UEDGE.

Asymmetry in all transport coefficients HFS/LFS $\sim 1/10$ results in $\sim 100$ asymmetry in plasma cross-field fluxes coupled to HFS and LFS.

Plasma flux on chamber wall is peaked at the outer midplane resulting in “main chamber recyling”.
UEDGE predicts two patterns of parallel plasma flow but only circular one is measured.

**Zonal flow**

**Circular flow**

Plasma in blue/green regions is moving toward the inner divertor plate and toward the outer divertor plate in red-yellow regions.
In zonal flow pattern the net flux through the inner leg is inside the inner divertor.

Large density is due to small plasma diffusivities. Plasma diffuses through the inner leg in opposite directions sustaining the zonal flows. Dense plasma regions can be a source of blobs propagating into the PF!
Blobby transport through the inner divertor leg with $V_{\text{conv}} \sim 10\text{m/s}$ is expected to drive the circular flow pattern.

Net hydrogen flows, Amps

$\eta_{\text{as(D)}} = 1/10$  $\eta_{\text{as(V)}} = 0$

From private
From SOL outboard
From core

Inner Leg Convective Velocity, m/s

Parallel ion velocity

Loading of inner divertor
In normal field, drifts strongly oppose the SOL flow into the inner divertor. Drift scale factor $\gamma_{\text{drift}} \sim 1/3$ is required to be consistent with experimental data.

Increase in $\gamma_{\text{drift}}$ above 0.4 changes the sign of parallel flow from the outboard SOL, which is not measured.

Drift driven flow from Private Flux region strongly increases with $\gamma_{\text{drift}}$.

For $\gamma_{\text{drift}} > 0.4$, the net plasma flow is dominated by drifts, whereas ballooning-transport driven flow is predominant for $\gamma_{\text{drift}} < 1/3$. 

Particle fluxes for the inner divertor
Full scale drifts affect strongly the inner SOL and divertor parameters.

In normal field, for $\gamma_{\text{drift}}>1/2$, the detached region is stretching over the whole INNER far SOL.

With full scale drifts in BOTH normal and reversed fields, the far SOL flows are dominated by drifts and the resulting plasma profiles are extreme, in which usually divertor and PF are deeply detached.

If cross-field transport in SOL and divertors is strongly intermittent and non-diffusive, the averaged ExB flow and the ExB flow calculated using average E can be very different. To our opinion, the usage of factor $\gamma_{\text{drift}}=1/3$ is rather realistic.
Conclusions

Edge-plasma in Alcator C-Mod was simulated with UEDGE code incorporating the non-diffusive cross-field transport, classical plasma drifts, and strongly asymmetric ballooning-like profiles of transport coefficients.

Various effects of asymmetric transport were simulated, including: $M\sim 1$ parallel plasma flows in SN, main chamber recycling at the LFS, asymmetries in decay lengths of plasma density and temperature, and divertor detachment.

We found that plasma flow patterns can be of kinds: with zonal and circular flows. Blobby transport on inner leg is important for circular flow realization.

We also analyzed the effect of drifts on SOL plasma flows in the normal and reversed field cases. The inner leg convection and drift scale factors $<1/3$ are found necessary for consistency with experimental data.

The UEDGE model incorporating the non-diffusive transport into fluid transport code requires further improvements, in particular, the description of stationary drifts under conditions of highly intermittent divertor and SOL.