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Observations Of Toroidal Rotation Profiles Show Active Transport Of Momentum

Detailed measurements of rotation profile evolution in the Alcator C-Mod tokamak show that momentum can be spontaneously transported by the plasma or driven by microwaves

A new imaging x-ray spectrometer has allowed unprecedented measurement of spontaneous toroidal rotation, that is flows generated in the absence of external momentum input. Until recently, such detailed measurements were only possible during heating by injection of neutral beams of atoms. These beams imparted significant momentum to the plasmas and masked the underlying behavior. Plasma rotation is important because it has the potential to stabilize small and large-scale instabilities. However reactor-scale devices like ITER will have little or no external momentum drive, motivating the study of self-generated flows in confined plasmas.

In discharges exhibiting poor confinement properties, the rotation is found to be predominantly in the direction counter to the plasma current and varies in a complicated fashion with electron density, magnetic configuration and plasma current. In contrast, the rotation in enhanced confinement plasmas is mainly aligned with the current, and has a relatively simple parameter dependence, with the magnitude of the core velocity proportional to the stored energy normalized to the plasma current. The co-current rotation is observed to propagate in towards the center from the plasma edge following the transition to the high confinement mode of operation, on a time scale similar to the energy confinement time. The profile shapes range from relatively flat to centrally peaked, which in the latter case is indicative of the presence of an inward momentum convection or pinch. An example of a velocity profile exhibiting peaking due to an inward co-current pinch is shown in Fig.1. The velocity gradient region is typically in the outer 2/3 of the plasma.

Addition of microwave current drive power into high confinement mode discharges causes the rotation profile to become hollow in the core region, suggesting that the pinch has changed sign. In low confinement mode plasmas which have only microwave current drive, the rotation is strongly peaked in the counter-current direction in the central half of the plasma, with the strong gradient region in the inner third of the volume, demonstrating that the momentum pinch operates on rotation in either direction. An example of this is shown in Fig.2.

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Spontaneous toroidal rotation profiles and observations of momentum pinch in Alcator C-Mod plasmas
Abstract: BI2.00001
Room: Landmark B
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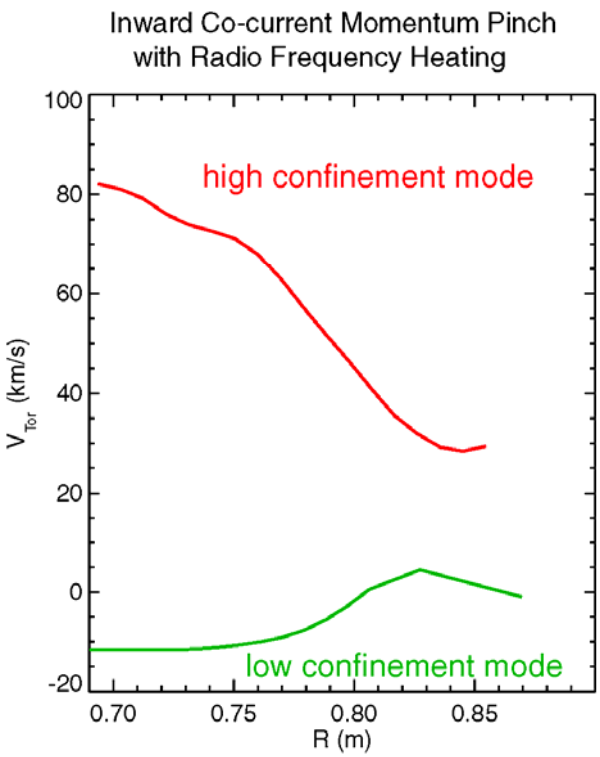
Inward Co-current Momentum Pinch
with Radio Frequency Heating
high confinement mode
low confinement mode
V_Tor (km/s)
R (m)
100
80
60
40
20
0
-20
0.70
0.75
0.80
0.85

Fig.1

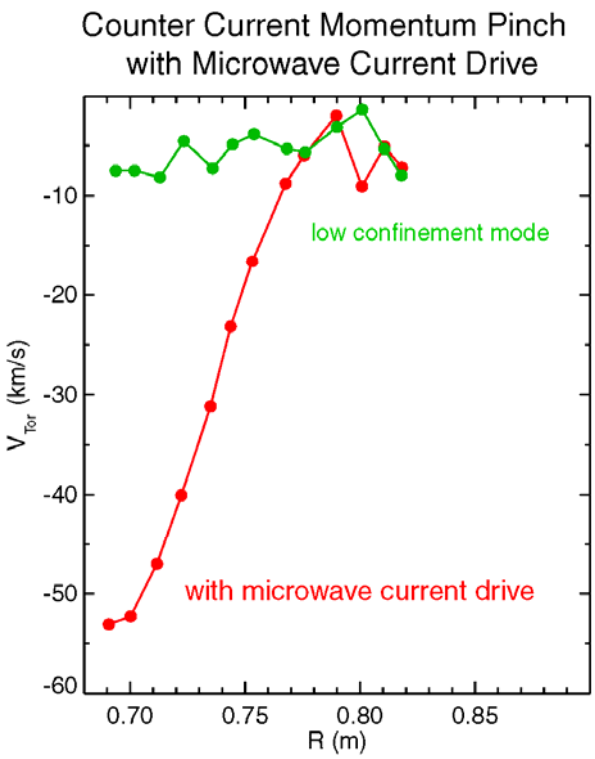
Counter Current Momentum Pinch
with Microwave Current Drive
low confinement mode
with microwave current drive
V_Tor (km/s)
R (m)
-10
-20
-30
-40
-50
-60
0.70
0.75
0.80
0.85

Fig.2