Contribution ID: **1226** Type: **Regular Poster**

Intrinsic rotation reversals of JET and DIII-D plasmas in Deuterium and Hydrogen

Wednesday, May 12, 2021 12:10 PM (20 minutes)

Recent experiments at the JET tokamak with ITER-Like-Wall studied intrinsic rotation in a large tokamak, addressing questions related to the effects of collisionality and hydrogen isotope type on the amplitude of the measured toroidal rotation and rotation reversals of Ohmic plasmas. The isotope effect on the intrinsic rotation was investigated by comparing the rotation of the main ion in Hydrogen (H) and Deuterium (D) discharges. In order to assess the influence of machine size the JET studies were complemented by identity experiments performed at the DIII-D tokamak, providing a direct comparison of JET intrinsic rotation data with that of a medium size tokamak.

Increasing rotation shear in the plasma core is valuable for increasing thermal confinement, and yet what determines the shape of the rotation profile remains unclear. JET experiments studied the effect of density on the shape of the core rotation profiles of Ohmic divertor plasmas. Density scans in both H and D were performed at JET for the study of rotation reversals, in low triangularity configurations with $\mathrm{B_T} = 2.7\,\mathrm{T}$ in two different plasma currents ($\mathrm{I_p} = 1.7\,\mathrm{MA}$ and $2.3\,\mathrm{MA}$) and, in plasmas with a lower toroidal field, $\mathrm{B_T} = 1\,\mathrm{T}$, $\mathrm{I_p} = 0.9\,\mathrm{MA}$. The latter, were JET pulses for a JET-DIII-D identity experiment. The toroidal rotation of the main ion was measured from H_α or D_α charge exchange spectrum obtained during short bursts of Neutral Beam Injection (NBI).

At JET, as the density increased, two consecutive core rotation reversals (where the gradient of rotation changes sign in the middle of the plasma) were observed (Figures 1 (a) and (b)). At low densities co-current rotation decreased with a reversal on the core from peaked to hollow profiles. Further increasing the density leads to restoration of monotonic profiles, co-rotation now increasing as a function of density. Although rotation reversals in Ohmic plasmas have been a common observation in small and medium size tokamaks {1}, *the JET experiments described here, were the first clear observation of rotation reversals in a large tokamak.*

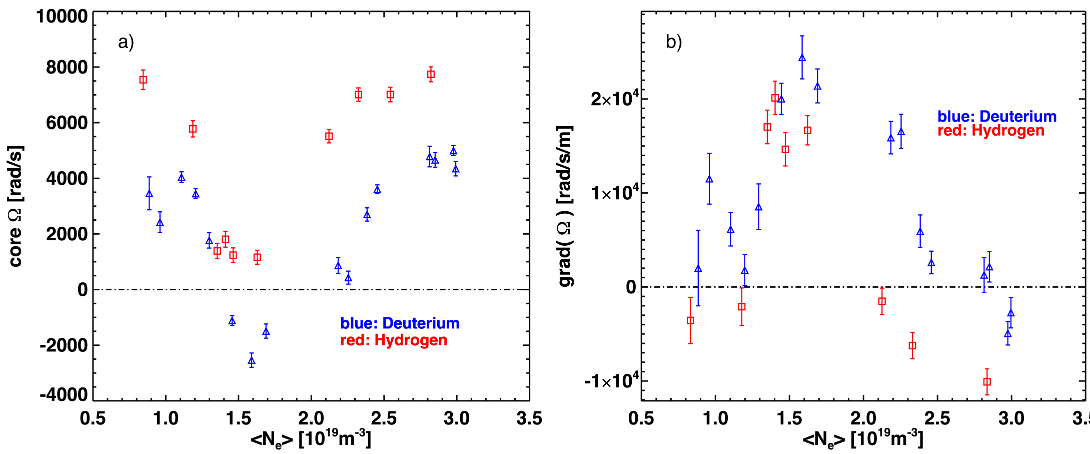

Figure 1: a) JET central main ion toroidal rotation (average over $r/a = 0.0 - 0.3$) versus average line density for $I_\mathrm{p} = 2.3\,\mathrm{MA}$, $B_\mathrm{T} = 2.7\,\mathrm{T}$, showing lower co-rotation for D. b) JET rotation gradient (averaged at $r/a = 0.3 - 0.5$) versus average line density for $I_\mathrm{p} = 2.3\,\mathrm{MA}$, $B_\mathrm{T} = 2.7\,\mathrm{T}$, showing two rotation reversals.

The phenomenology is similar in H and D, however *the magnitude of the core rotation was found to depend on isotope type*, stronger co-current rotation and larger co-current rotation gradients observed in H (Fig. 1 (b)). In all plasma configurations deeper counter-current rotation was observed in D. In addition, the critical densities for reversal, were found to depend on isotope type. Comparison of H and D rotation profiles at the same density, shows that the rotation difference is at the plasma core and not at the edge (Fig. 2).

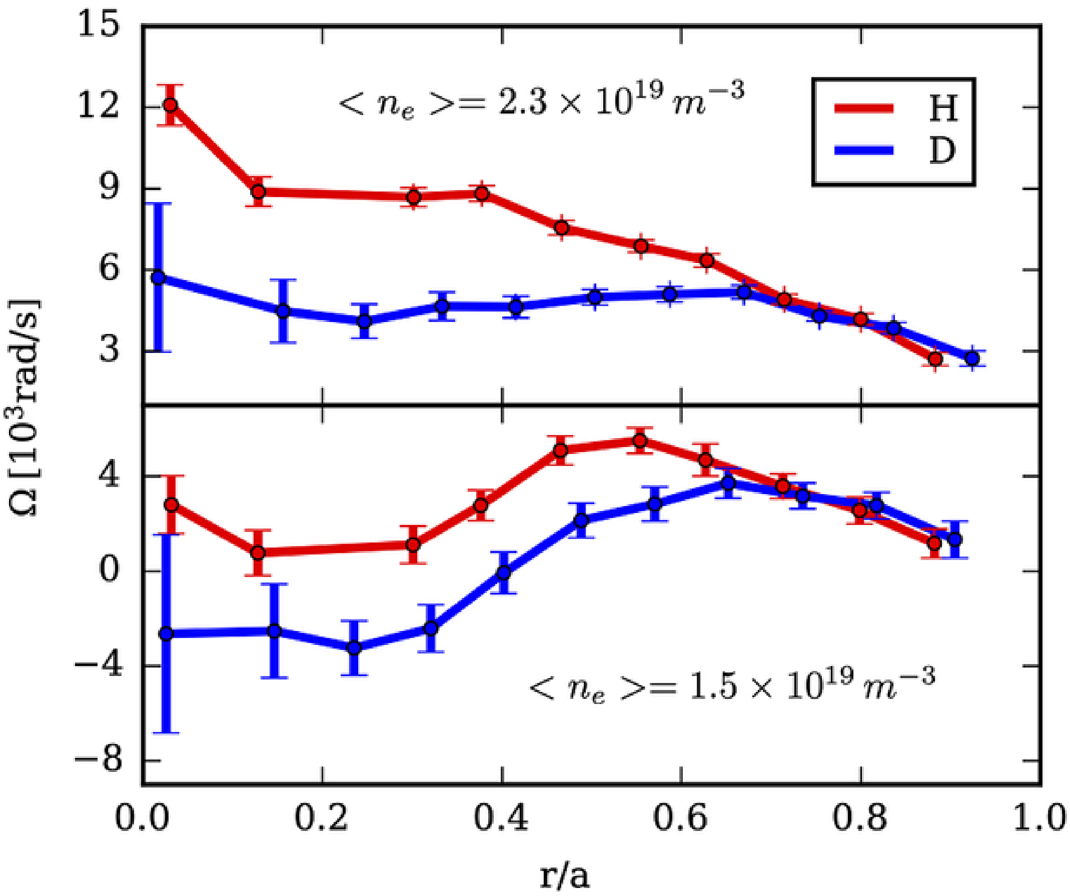

Figure 2: JET H and D toroidal rotation profiles for pulses with $I_\mathrm{p} = 1.7\,\mathrm{MA}$, $B_\mathrm{T} = 2.7\,\mathrm{T}$, showing isotope difference in the core rotation.

An important question, for reliable rotation prediction for ITER, is whether changes in the core rotation shear, thought to be a result of turbulent transport, depend on machine size and if it will scale into a significant effect in ITER. In order to investigate how machine size can affect the magnitudes of intrinsic rotation and rotation shear, a JET-DIII-D identity experiment was performed at JET and DIII-D. Rotation was measured in DIII-D plasmas {2} that matched the JET plasma shape, q_{95} and other dimensionless parameters thought to be key for intrinsic rotation and intrinsic rotation reversals, such as the normalized gyro-radius, collision frequency and plasma pressure. Rotation reversals as a function of density were also observed in DIII-D. *Both rotation reversals occur at lower densities in JET. Extrapolation to a larger machine such as ITER implies that intrinsic rotation profiles are likely to be in the peaked co-current rotating regime at the densities anticipated.*

In JET and DIII-D the low density rotation reversal was observed near the transition from the linear to the saturated Ohmic confinement regime (Fig. 3). Linear gyro-kinetic calculations, with codes TGLF and GS2, show that in both JET and DIII-D the low density rotation reversal occurs close to the density of transition from dominant TEM to ITG instabilities. However, from JET data where a clear high density branch with peaked rotation profiles was observed, *it is concluded that the instability type would not explain the rotation peaking at higher densities, since both hollow and peaked profiles are observed with dominant ITG.*

Comparisons between intrinsic rotation data and ongoing turbulent momentum transport calculations have been performed. Non-linear calculations with the low-flow model in GS2 {3} show changes of sign in rotation gradient, consistent with the observation of peaked to hollow to peaked profiles as the density increased, though the modelled rotation shear is lower than that measured.

Bibliography

{1} J. Rice et al. *Nucl. Fusion* **51**, 083005 (2011)
{2} B. Grierson et al. *Phys. Plasmas* **26**, 042304 (2019)
{3} F. I. Parra and M. Barnes. *Plasma Phys. Control Fusion* **54**, 045002 (2015)

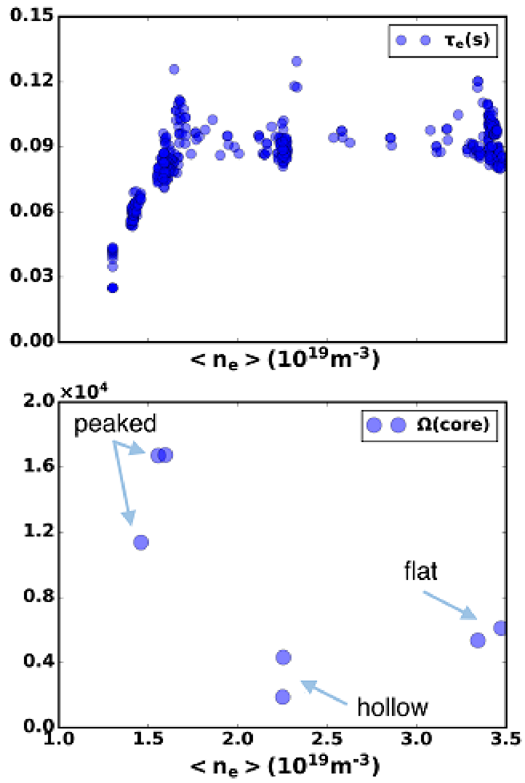

Figure 3: DIII-D (a) energy confinement time and (b) central toroidal rotation in $[rad/s]$ (averaged over $r/a = 0.0 - 0.3$) versus average line density; for a D pulse with $I_{\mathrm{p}} = 1.0\,\mathrm{MA}$, $B_{\mathrm{T}} = 2.0\,\mathrm{T}$ (plasma shape matched to JET). Near confinement transition from linear to saturate, the core rotation changes from peaked to hollow.

Acknowledgments

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. In addition, it has received financial support from Fundacao para a Ciencia e Tecnologia through contracts UID/FIS/50010/2013, IF/00483/2014/CP1214/CT0008 and grant PD/BD/105877/2014. The views and opinions expressed herein do not necessarily reflect those of the European Commission. The work was supported by US DOE under contracts DE-FC02-04ER54698 and DE-AC02-09CH11466. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Country or International Organization

Portugal

Affiliation

Instituto de Plasmas e Fusão Nuclear, Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento, Lisbon, Portugal

Primary author: Dr NAVE, Maria Filomena F. (Instituto de Plasmas e Fusão Nuclear, Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento)

Co-authors: Mr DELABIE, Ephrem (ORNL); Mr BARNES, Michael (Rudolf Peierls Centre for Theoretical Physics, University of Oxford, United Kingdom); Dr BERNARDO, Joao (Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Portugal); CASSON, Francis (UKAEA); CHRYSTAL, Colin

(General Atomics); Dr FERREIRA, Jorge (Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico); GARCIA, Jeronimo (CEA IRFM); GRIERSON, B.A. (Princeton Plasma Physics Laboratory); Dr LOMANOWSKI, Bartosz (Oak Ridge National Laboratory); Mr MAURIYA, Adwiteey (Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico); DEGRASSIE, John (General Atomics); Prof. PARRA, Felix (University of Oxford); Dr ROMANELLI, Michele (Culham Centre for Fusion Energy , CCFE); JET CONTRIBUTERS (See the author list of E. Joffrin et al 2019 Nucl. Fusion 59 112021); THE DIII-D TEAM (See the author list of C.C. Petty and the DIII-D Team 2019 Nucl. Fusion 59 112002)

Presenter: Dr NAVE, Maria Filomena F. (Instituto de Plasmas e Fusão Nuclear, Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento)

Session Classification: P3 Posters 3

Track Classification: Magnetic Fusion Experiments