Isotope Effects on Intrinsic Toroidal Rotation and Rotation Reversals

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JET is the largest tokamak in operation and the main link between smaller machines, where intrinsic rotation has been mostly studied, and ITER the next step in fusion research. While the main ion in present tokamak plasmas is a single hydrogen isotope, mainly Deuterium (D) in JET, future nuclear fusion machines, such as ITER, will operate with a mixture of D and Tritium (T). Recent experimental campaigns at JET performed a series of experiments with different hydrogen isotopes, designed to clarify the impact that isotope mass has on physics questions, and in particular transport and confinement questions, relevant for reliable predictions for ITER. This talk will report on experiments that studied for the first time the isotope effect on intrinsic rotation in a tokamak plasma, by comparing rotation measurements in Hydrogen (H), D and T in Ohmic plasmas. One of the objects of the JET intrinsic rotation experiments was to study rotation reversals, a puzzling phenomenon commonly observed in small and medium size tokamaks, where a transition from monotonic to non-monotonic rotation profiles is observed at a critical density, in some cases leading to plasmas with central and outer regions flowing in opposite directions. At JET, as the density increased, two consecutive core rotation reversals were observed. The first, shows a change from peaked co-current rotation to hollow profiles with the core in some cases counter-current rotating, similarly to observations in smaller tokamaks. Further increasing the density leads to restoration of monotonic profiles. The magnitude of the core rotation was found to depend on isotope type, stronger co-current rotation observed in H. Core counter-rotation was observed with D and T but not with H. Gyrokinetic calculations, show that the low-density rotation reversal, for all three isotopes, occurs close to the density of transition from dominant TEM to ITG instabilities. The type of instability cannot be associated to different directions of core rotation since for all three isotopes, co-rotation is observed with dominant TEM for the low-densities and ITG for high-densities. Non-linear modeling of rotation profiles with the low-flow model show changes of sign in rotation gradient, qualitatively consistent with the observation of peaked to hollow to peaked profiles as the density increased .These results have strong implications for ITER, as rotation extrapolations from present day experiments, mostly based on D plasmas, might not recover in full the physics mechanisms playing a role in momentum transport.