

A COMPARATIVE STUDY OF IMPURITY AND PROTON POLOIDAL ROTATION IN THE TJ-II STELLARATOR

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INTRODUCTION. Previously, we studied the poloidal rotation of internal impurities (e.g. C^{4+}) as a function of density in the TJ-II stellarator and made comparisons between the deduced radial electric field and neoclassical theory [1]. However, a long-standing debate exists in the magnetic fusion community, beginning with the pioneering tokamak experiments [2,3] on whether the rotation of intrinsic impurities and that of main ions, being different, can be understood within the standard neoclassical framework. The present work contributes (at this stage only from a phenomenological point of view) to this ongoing discussion by presenting both main species and impurity rotation data in a stellarator magnetic configuration.

The problem of distinct rotation of main ions and impurities has been studied in the past in the DIII-D [2] and TEXT [3] tokamaks; these measurements were performed by changing the main species from hydrogen to helium. In contrast, the scope of the present work is to report proton, helium and other impurity rotation in either hydrogen or helium plasmas. The low density and small size of ECRH TJ-II plasmas (compared with DIII-D and TEXT), allows us to address this problem in relatively high T_e plasmas by means of passive spectroscopy. It is well known that many trends observed in plasma rotation remain unexplained; therefore, this area merits further investigation and analysis in both stellarators and tokamaks.

This paper is organized as follows. First, the details of the spectral system are reported; second, results of proton and impurity rotation in different plasma conditions of the TJ-II device, illustrating comparative behavior, are shown. Finally, some conclusions are drawn.

EXPERIMENTAL. The poloidal rotation measurements presented herein have been carried out with an upgraded version of the spectral system and data analysis method previously described in Ref. [4]. In order to cope with the lowering of spectral signal level produced by recently improved wall conditioning, the fiber bundle length was shortened from 10 to 3 m.

Also, 1 mm, instead of 200 μm , core diameter fibers were used. In addition, a larger back-illuminated charge-coupled device (CCD) detector was substituted for the previous front-illuminated one. A set of 9 parallel channels with an inclination angle of 5° and with a separation of 2.5 cm between them across the midplane, allow us to get spatial resolution in our measurements [see Fig. 1 of Ref. (4)].

The analysis of the proton rotation is carried out by decomposing the H_α line into three Gaussian components, as it has been explained in Ref. [5], and interpreting the intermediate one, dominated by charge-exchange, as associated with the thermal protons. The line shift of this intermediate component is used to obtain the line-averaged rotation of thermal protons. Impurity lines are analyzed by fitting the impurity line shape with a single Gaussian function. Although our data analysis procedure has the capability of simulating local rotation profiles, we will compare here only line-averaged data to show that the behavior of impurity and proton rotation can be significantly different, even considering the uncertainties and limitations due to spatial averaging effects.

RESULTS AND DISCUSSION. The TJ-II flexible heliac [6], where this experiment was performed, was operated during these measurements with a maximum ECR power of 600 kW, and in a few discharges with a co-injected NBI beam with an absorbed power of 300 kW. The main plasma parameters varied to perform this investigation were plasma density, magnetic configuration and working gas.

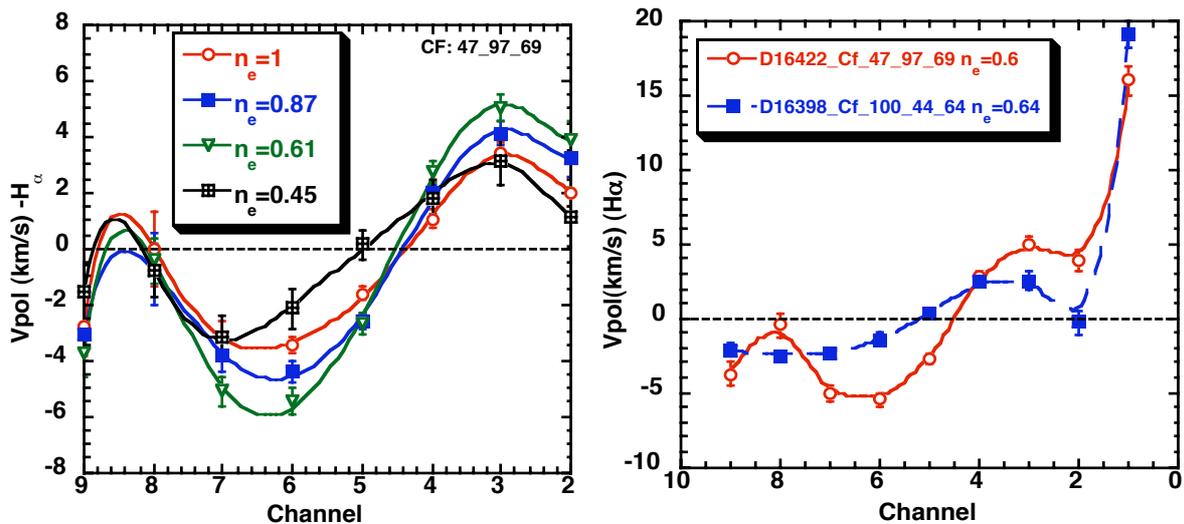


Fig. 1. On the left, the behavior of proton rotation for different plasma densities; on the right, proton rotation for different TJ-II magnetic configurations. Density is given in 10^{19} m^{-3} units.

We show, in Fig. 1, two plots of proton poloidal rotation: on the left side, the results of a density scan in ECRH plasmas, and on the right, the behavior of proton rotation for similar plasma density, but for two different magnetic configurations; the curves are guides for the eye only. These results have been selected to emphasize two points which contrast with previous studies of C^{4+} rotation: first, proton poloidal rotation evolves with plasma density but does not necessarily change its direction in the way exhibited by C^{4+} ; second, the proton rotation profile, as shown in the right plot, clearly responds to changes in the TJ-II magnetic configuration, in contrast to C^{4+} ions where the change was almost imperceptible. These results cannot be explained as resulting entirely from differences in the spatial profiles of the line emission.

We show, in Fig. 2, a comparison between the line-averaged rotation profiles of proton and C^{4+} poloidal rotation for two different line-averaged electron densities. On the left plot, corresponding to a low density case, both ions rotate consistently with a negative radial electric field, i.e. the upper plasma half, that corresponds to channels 6 to 9, has negative velocities according to the sign criterion chosen in reference [1]. On the right plot, a similar comparison at higher density is shown, where the C^{4+} ion has changed its rotation direction, which is not seen in the proton rotation (solid squares).

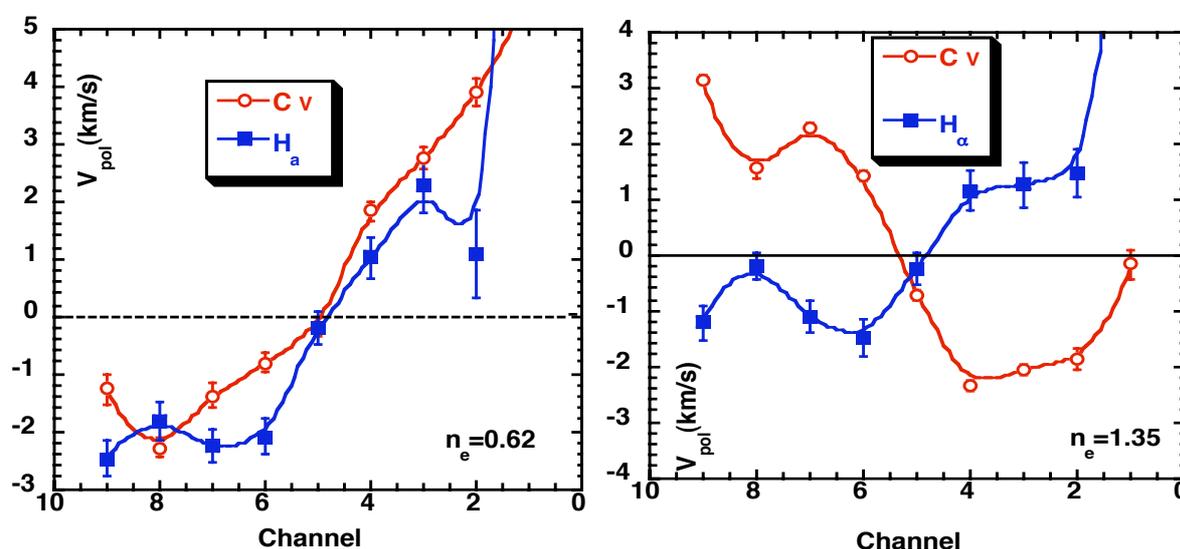


Fig. 2. Comparison between poloidal rotation of protons and C^{4+} for a low density case, on the left, where both ions exhibit a rotation with similar direction; and in a high density case where C^{4+} ions invert their rotation direction, which is not seen in the proton behavior.

Finally, we present results of poloidal rotation for protons, He^+ and C^{4+} ions in a discharge

where the working gas of the discharge was helium with residual hydrogen, see Fig. 3. On the left plot of this low density discharge, the carbon and helium ions rotate with similar velocities, but protons rotate in the opposite direction. The line-integrated brightness of the spectral lines used to measure the rotation is depicted in the right plot of this figure.

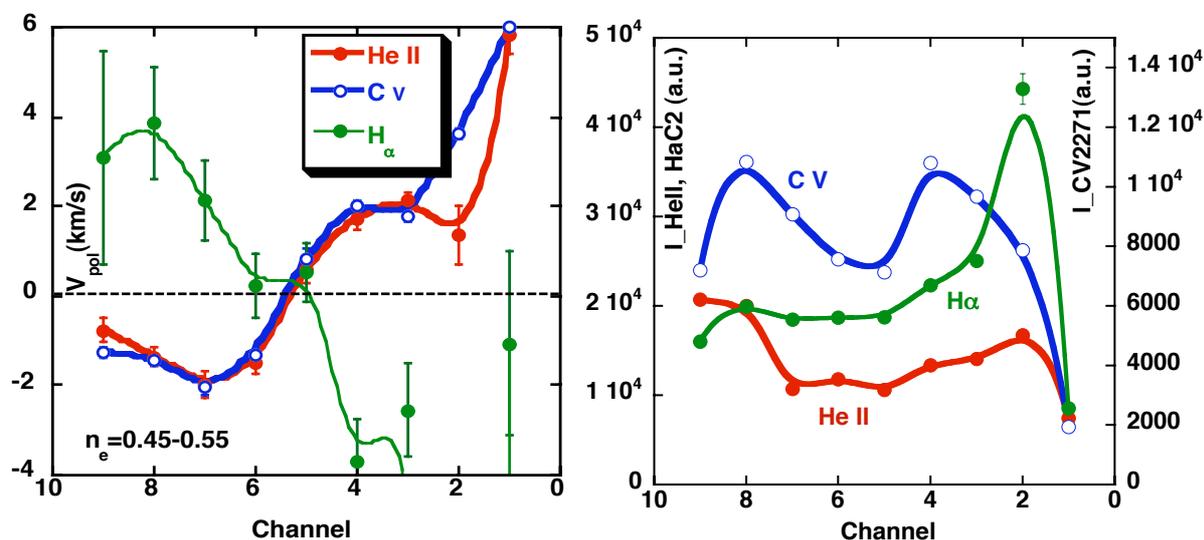


Fig. 3. On the left, we show the poloidal rotation of protons, C^{4+} , and He^+ in ECRH discharges, with He as the main species. On the right, the line-integrated emission of the different spectral lines is shown.

In conclusion, proton and impurity poloidal rotation experimental data have been compared for the first time in a stellarator device. They exhibit a distinctive behavior whose explanation is left for future work. We are investigating the roles played by different effects: 1) diagnostic assumptions; 2) the effect that neutrals could play on both type of ions; and 3) whether other mechanisms for driving rotation, aside from radial electric field, could explain the observed behavior.

References

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