Carbon Flow Simulations of MAST Tokamak Shot in Conjunction with Coherence Imaging Spectroscopy

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Introduction

Impurities present in tokamak reactors can have significant effects on how a reactor performs as well as its longevity. For this reason a comprehensive understanding of how impurities move throughout the scrape-off layer (SOL) is imperative for the future development of fusion reactors. However, flow measurements are particularly challenging in tokamak plasmas and the majority of this data exists only at the divertor targets. This has led to a lack of validation of flow in edge plasma simulations. The development of the Coherence Imaging Spectroscopy (CIS) diagnostic, which has been installed on the MAST tokamak, allows for validation of SOL simulations to take place. The ability of SOLPS-ITER, an edge plasma fluid and neutral kinetic transport code, to accurately predict the flow of carbon ions in the divertor region of MAST will be investigated using CIS measurements.

Coherence Imaging Spectroscopy

The Coherence Imaging Spectroscopy diagnostic developed by Silburn [1, 2], and installed on the MAST tokamak, was capable of measuring flow velocities of He II, C II and C III ions in the divertor and midplane regions of MAST. This diagnostic uses the Doppler shift of delayed light emitted from the plasma to calculate the line integrated velocity of the emitting ions.

In the development of this diagnostic Silburn [1] also developed a method to invert the line integrated velocity measurement to a 2-dimensional poloidal slice of the measured region. This inversion technique allows for parallel velocities of specific species to be known accurately and therefore be used to compare with simulations. During this research Silburn's inversion techniques have been added to the PyCIS code developed by Dr. Joseph Allcock at CCFE.

SOLPS-ITER Simulations

SOLPS-ITER is a fluid-kinetic neutral code capable of simulating the complex interactions between impurities and the bulk plasma. It is for this reason and it's extensive use in the development of tokamak reactors such as ITER that made it the obvious choice for this study [3].

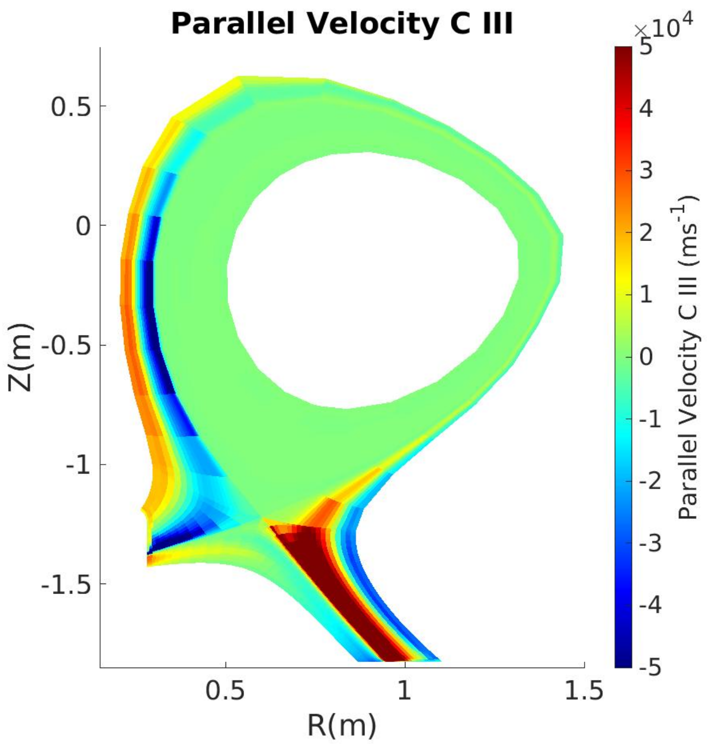

Figure 1: Parallel flow velocities for C III ions as predicted by SOLPS-ITER

It is the intention of this research to present a physically accurate simulation of a MAST shot from which parallel C III velocities could be extracted. The shot of interest would have to be stable with the CIS diagnostic operational and functioning properly. It was also important to this research that the data taken by the CIS instrument had a good signal-to-noise ratio. For this reason shot 29541 was chosen for examination. This shot was designated post-shot as "good shot for coherence imaging". The time which would be simulated was chosen to be 313ms as this offered optimal signal-to-noise and is just before the shot transitioned to H-mode.

Figure 1 shows the C III parallel flow velocities as predicted by SOLPS-ITER simulations. It can be seen that velocities outside the separatrix of the outer divertor leg are in excess of 50 km s^{-1}. Similar but reversed flows can be seen on the inner divertor leg. Neither flow profile is believed to be physical. To assess the source of these unrealistic flow velocities, comparison of electron density, n_e and temperature, T_e have been carried out and can be seen in figure 2. It can be seen that the simulations carried out do not agree with experiment, with very high densities and temperatures occurring around the separatrix. Electron temperature then decreases rapidly in the radial direction. This localisation of electron profiles around the separatrix has likely contributed to the abnormal velocities shown in the same radial location in figure 1.

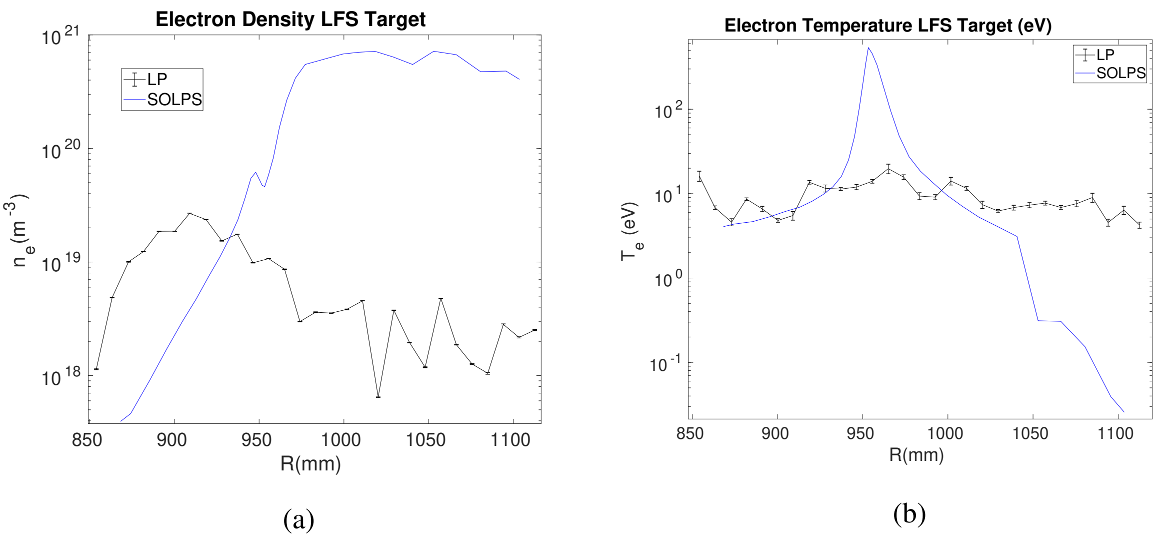

Figure 2: Comparison of Electron density, 2a and temperature, 2b as measured by Langmuir probes located on the outer target of the MAST tokamak at 313ms of shot 29541 and predicted by SOLPS-ITER simulations.

CIS Inversions

Using the aforementioned inversion technique developed by Silburn, data collected by the CIS camera was inverted on to a poloidal plane. Figure 3 shows the divertor region of MAST and the parallel flow velocity of C III ions in this area.

Partial agreement of flow direction is observed between figure 1 and 3, however quantitative comparisons do not display this same agreement. Artefacts can be seen in the PFR and inner divertor leg, these are believed to be derived from numerical instabilities during the demodulation of the raw CIS data. These artefacts are under investigation and further development is needed to enable detailed quantitative comparison, although the profile around the outer divertor is broadly as expected.

Further Work

It is the objective of this research to present full quantitative comparisons between CIS and SOLPS-ITER in order to validate the code's ability to predict the transport of impurities in the SOL. It has been determined that the inaccuracies seen in figure 1 are primarily due to a lack of radial transport during the simulation. This is being investigated concurrently with the artefacts present after CIS demodulation. It is also our intention to add drifts to upcoming SOLPS-ITER simulations, this is likely to aid radial transport and allow for more physical simulations to be presented.

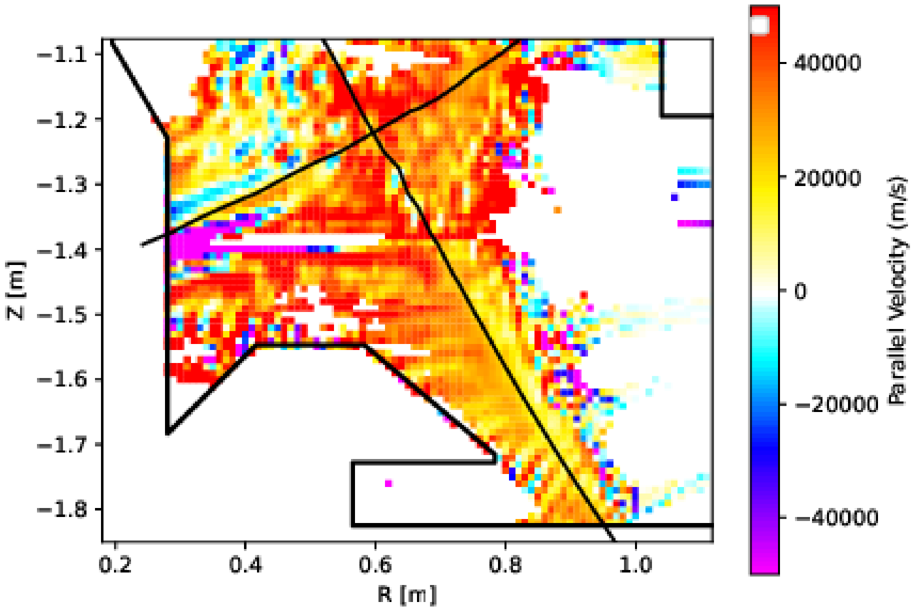

Figure 3: CIS data inverted on to a poloidal slice of the MAST tokamak

Acknowledgements

This work has been carried out within the framework of the EUROfusion Consortium and has received funding . It has also received funding from the Euratom research and training program 2014-2018 and 2019-2020 under grant agreement No 633053, as well as the RCUK Energy Programme (Grant No. EP/T012250/1). The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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