Application of Markov Chain Monte Carlo Inference for Impurity Transport Experiments in W7-X and HSX

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Detailed knowledge of the transport plasma impurities is crucial for future fusion reactors since line radiation emitted by impurities provides radiative losses that degrade plasma confinement and can lead to issues such as radiative collapse and fuel dilution. In the W7X and HSX Stellarator experiments, impurities can be injected using laser blow off (LBO) systems. To model LBO experiments, the STRAHL code has been routinely applied to analyze characteristic line radiation of the injected impurities. By fitting synthetic and measured signals using gradient descent-based optimization schemes, anomalous impurity diffusion coefficients have been inferred [1]. Pinch velocities, however have been difficult to determine in part due to computational limits on the number of free parameters and presence of many local minima. To address these challenges and more effectively characterize fitting uncertainty, a Markov chain Monte Carlo (MCMC) scheme has been developed for modeling of Fe LBO experiments. This approach samples both diffusive and convective profiles in order to match forward modeled signals from pySTRAHL [2], a novel version of STRAHL which has been optimized for the application in stellarators. The new MCMC scheme based on pySTRAHL is applied for impurity transport studies in both, the W7X (standard configuration) and HSX (QHS configuration) stellarators. The presented analysis resolves the posterior space of possible diffusion and convection values and provides quantifiable determination of error in the inferred profiles. Disagreement remains for some of the lowest charge states, which will be addressed in future work that more accurately describes the impurity sourcing. Additionally, installation of a fast CXRS diagnostic for OP2 will be capable of providing spatially resolved impurity density measurements.

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