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Bayesian inference of plasma and impurity parameters with visible spectroscopy at ITER

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Effective impurity control is essential for sustaining high-performance plasma operation in magnetic confinement fusion devices such as ITER. The visible spectroscopy reference system (VSRS) is designed to measure visible radiation, including bremsstrahlung, spectral lines, and synchrotron radiation, for the inference of key plasma parameters, such as the effective ion charge Z_{eff}, electron density n_{e}, impurity content, and the presence of runaway electrons. This study presents the development, implementation, and validation of a Bayesian model for the VSRS within the Minerva scientific modelling framework. A real-time application based on spectrally integrated polychromator signals has been developed for fast Z_{eff} inference to enable integration into plasma control systems. More advanced applications make use of full survey spectrometer data, incorporating spectral line contributions through asymmetric predictive distributions and anomaly detection techniques. Validation is conducted using synthetic data generated from IMAS-stored scenarios, including equilibrium and profile data, and cross-verified with the camera and spectroscopy emission ray tracer CASPER simulations. Furthermore, the model is extended to extract bremsstrahlung-subtracted spectra using Bayesian techniques, thereby enabling the automated identification of weak impurity lines. Feasibility studies on the detection of synchrotron radiation from runaway electrons have also been undertaken, demonstrating the potential of the VSRS to support rapid disruption mitigation strategies at ITER.

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