Predicting the physics of ion cyclotron emission from neutral beam-heated plasmas in the Wendelstein 7-X stellarator

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Recent observations of spontaneously generated radiation in the ion cyclotron range of frequencies from the KSTAR and DIII-D tokamaks, and from the LHD heliotron-stellarator, show that energetic neutral beam injected (NBI) ion populations can relax collectively in the edge plasma near their injection point, resulting in ion cyclotron emission (ICE). Its spectrum has strongly suprathermal peaks at harmonics of the local ion cyclotron frequency. Edge NBI ICE is due to the magnetoacoustic cyclotron instability (MCI), which has been simulated [for KSTAR, B Chapman *et al*., *Nucl. Fusion* **59**, 106021 (2019); for LHD, B C G Reman *et al*., *Nucl. Fusion* **59**, 096013 (2019)] from first principles, using particle-in-cell (PIC) kinetic codes which solve the Maxwell-Lorentz system of equations self-consistently for tens of millions of gyro-orbit-resolved particles. Comparison of ICE spectra from tokamaks and stellarators sheds light *inter alia* on the relative importance of overall magnetic field structure compared to spatially localised physics. Here we report PIC simulations that predict ICE spectra from imminent observations from NBI-heated plasmas in the Wendelstein 7-X stellarator. These simulations are computationally resource-intensive, partly due to the low ratio of the perpendicular velocity of the NBI ions to the local Alfvén velocity, requiring typically 200,000 CPU-hours apiece. Our simulations capture the entire frequency range from ion cyclotron through lower hybrid and well beyond, with high fidelity. It appears that both the MCI and the lower hybrid drift instability, found in related simulations (J W S Cook *et al*., *Phys. Rev. Lett.* **105**, 255003 (2010)), may operate simultaneously in the Wendelstein 7-X scenario. We explore how far they embody similar underlying physics, perhaps linked, at the level of first principles kinetics. The development of a predictive, as distinct from *ex post facto* interpretive, capability for linking ICE spectral structure to the velocity-space structure of the emitting ion population is important for the diagnostic exploitation of ICE in present and future fusion experiments.

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