A Unified Calibration Framework for 21 cm Cosmology

Abstract:

Calibration precision is currently a limiting systematic in 21 cm cosmology experiments. While there are innumerable calibration approaches, most can be categorized as either “sky-based,” relying on an extremely accurate model of astronomical foreground emission, or “redundant,” requiring a precisely regular array with near-identical antenna response patterns. Both of these classes of calibration are inflexible to the realities of interferometric measurement. In practice, errors in the foreground model, antenna position offsets, and beam response inhomogeneities degrade calibration performance and contaminate the cosmological signal. Here we show that sky-based and redundant calibration can be unified into a highly general and physically motivated calibration framework based on a Bayesian statistical formalism. Our new framework includes sky-based and redundant calibration as special cases but can additionally support relaxing the rigid assumptions implicit in those approaches. We present simulation results demonstrating that, in a simple case, working in an intermediate regime between sky-based and redundant calibration improves calibration performance. Our framework is highly general and encompasses novel calibration approaches including techniques for calibrating compact non-redundant arrays, calibrating to incomplete sky models, and constraining calibration solutions across frequency.