Applications of Bayesian Inference in Radiation Reaction Experiments

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Radiation reaction, the recoil of a charge upon emitting radiation, is the subject of ongoing theoretical and experimental research, particularly in highly intense electromagnetic fields in which quantum effects become significant. In such environments, a QED treatment of radiation reaction is required. Various suitable theories have been proposed but have yet to be validated experimentally. This work considers experiments in which electrons are accelerated to relativistic energies using a laser wakefield accelerator, before colliding with a tightly focussed, counter-propagating laser pulse. This allows electric fields strengths up to some fraction of the critical field (Schwinger limit) to be accessed in the rest frame of the electron beam. In these experiments, the collision conditions (e.g. the laser intensity at the collision) could not be measured on-shot. These conditions affect the radiative losses experienced by the electron beam but are extremely difficult to measure in practice. We have developed a Bayesian inference method which can retrieve the parameters that govern the collision between an electron bunch and laser pulse for different models of radiation reaction. The errors on the inferred parameters and on the predictions made by each model follow naturally from the Bayesian framework we have utilised. We find evidence of radiation reaction to 8σ, the highest degree of significance of any all-optical experiment to date. Using the Bayesian framework, we find that a quantum model of radiation reaction is more consistent with the spectrum of emitted radiation and the electron energy loss measured experimentally than a classical model.