**Using a neural network to model ultra-relativistic charged particles and exploit sparse datasets**

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While often seen as an alternative to physics-based approaches, physics-informed machine learning has the potential to significantly enhance the manner in which physics is conducted. In this study we train a neural network (NN) for two distinct, yet related, applications. We first train the network to simulate the motion of a relativistic charged particle in electromagnetic fields. This has direct application to planetary radiation belts where the long-term self-consistent evolution is intensive to compute. The NN results agree well with theoretical predictions, accurately predicting a range of particle drifts. After demonstrating this underlying concept, we discuss how this approach might be efficiently applied to long-term modelling and extreme regimes where deep learning isn’t typically utilised. We then train our NN on a sparse dataset collected by Cassini across the Titan’s atmosphere, to derive underlying physical and seasonal trends. The NN is able to reproduce latitude, longitude and altitude trends after exposure to a small training dataset and, after exposure to the full dataset, provides a prediction at locations across the moon not sampled by Cassini. We thus discuss how deep learning informed by underlying physical laws can further probe the multi-faceted dynamics controlling Titan’s hazy atmosphere.