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

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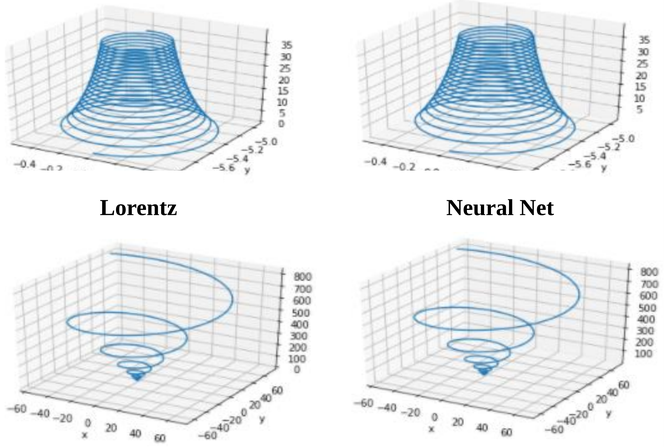
Overview

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) to simulate the motion of to a relativistic charged particles in varying electromagnetic fields and to deep learn a sparse dataset collected by Cassini across the Titan's atmosphere. The NN is able to reproduce a range of particle drifts and produce a non-linear model of Titan's atmosphere after exposure to a sparse and very high-dimensional dataset.

Charged Particle Motion

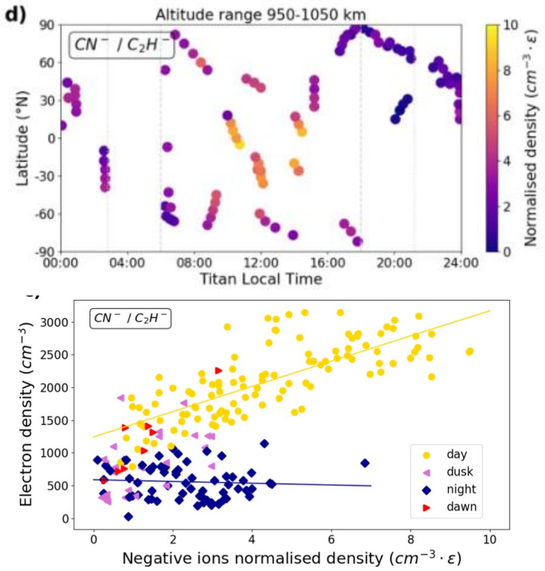
- Can a neural network obey physical laws and exploit sparse datasets? [Raissi et al., 2019]
- We used a LSTM (Long-Short Term Memory), Neural Network commonly used for time-series and NLP



Lorentz **Neural Net**

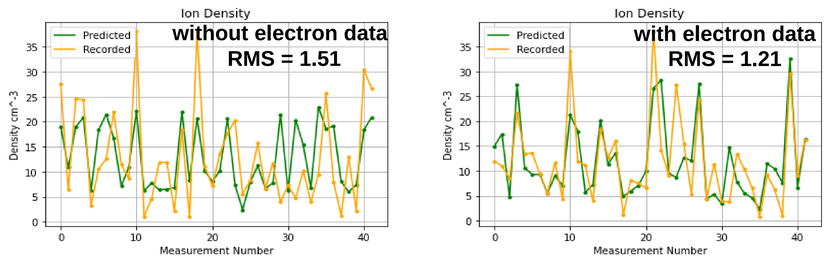
- Next we will couple to the Integrated Van Allen Radiation Belt (IVAR) [Desai et al., 2021]

Cassini CAPS Ion Maps (Mihailescu et al., 2020)



The discovery of large ions in Titan's ionosphere completely rewrote the text books for the moon

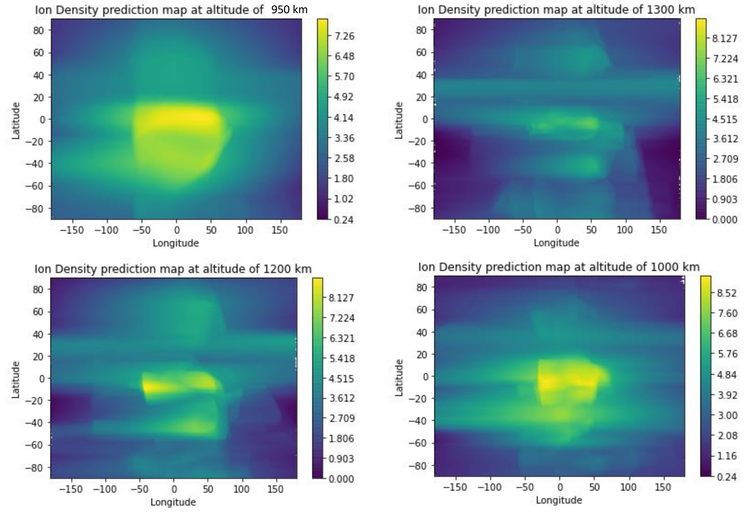
[Coates et al., 2007; Waite et al., 2007; Desai et al., 2017]



Objectives

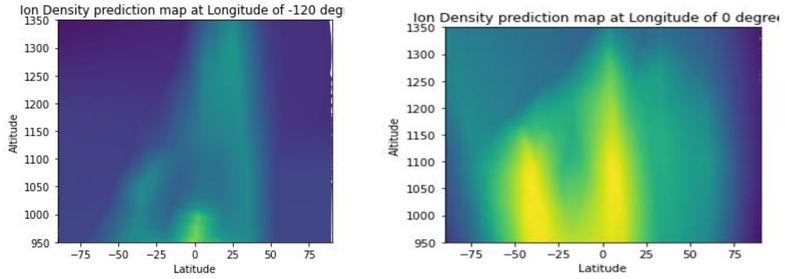
- Are Neural Networks (NN) a viable tool to probe Titan's complex chemistry?
- We derived a nonlinear map of Titan's ionosphere from a sparse and very high-dimensional dataset
- New atmospheric features appear, but model appears to be over-trained

Neural Network Ion Maps: First Results

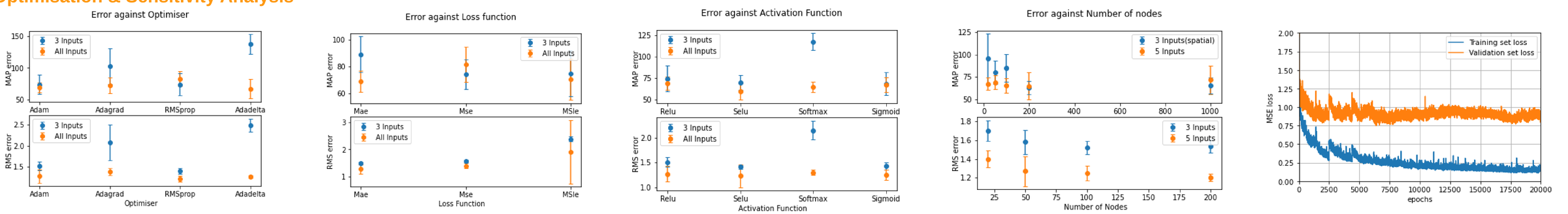


Next steps…

- Train with seasonal input data
- Incorporate physical laws (reaction rates) & further data (Cassini, ALMA)



Optimisation & Sensitivity Analysis



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