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Solving inverse problems with physics informed neural networks: a radiation belt case study

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In an inverse problem one wants to infer the parameters of a model in such a way that the solution of that model matches observations the best it can. Since all physics models contain some degree of approximation and several assumptions, it is often important to understand whether the inaccuracies of a model are intrinsically due to those approximations, or if the model can be improved with a better choice of free parameters. However, solving inverse problems pose a significant challenge, since they are typically ill-posed and computationally much more costly than solving the associated forward model. Recently, a new framework based on physics-informed neural network has been introduced to solve forward and inverse problems.

In this talk, I will focus on the problem of solving the one-dimensional Fokker-Planck equation for radiation belt electrons, from a data-driven standpoint.We use aphysics-informed neural networkto discover the optimal diffusion coefficients that, once used in the Fokker-Planck equation, yield the solution with smaller discrepancy with respect to Van Allen Probes observations.Further, we train a machine learning algorithm that generalizes such coefficients for any radiation belt condition (boundary conditions and initial values). Interestingly, a feature selection analysis shows that the drift and diffusion coefficients are weakly dependent on the value of the geomagnetic index Kp, in contrast with all previous parameterizations presented in the literature.This approach, although well rooted in our physical understanding of the process in play, seeks to extract the largest amount of information from the data with minimal assumptions, and we believe it promises to shed light on the physics of resonant and non-resonant wave-particle interactions in the radiation belts.