R011-21
C 会場 ： 11/25　AM2（11:05-12:35）
11:35〜11:50:00

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A novel reconstruction method of auroral electron flux using neural network

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The energy distribution of precipitating electrons responsible for auroral emissions provides crucial information for identifying where in the magnetosphere the electrons originated and what mechanisms caused their precipitation. The energy distribution of the precipitating electrons can be obtained by in-situ satellite observations, however, it is difficult for a single satellite to capture its spatial distribution and temporal evolution. In contrast, three-dimensional (3D) auroral reconstruction from multiple images taken by ground-based multi-point observations enables us to continuously capture the spatiotemporal variation of the precipitating electrons' energy. So far, auroral computed tomography (ACT) method has been developed and used for 3D auroral reconstruction. Subsequently, we developed more generalized method, called generalized-auroral computed tomography (G-ACT), which can reconstruct the energy distribution of precipitating electron flux from multi-instrument data. However, these approaches discretize 3D space into a large number of voxels, so when increasing the spatial resolution, the number of unknown parameters increases in proportion to the cube of the number of divisions, resulting in significant computational costs.

Recent advances in machine learning and artificial intelligence (AI) technologies have led to the development of new 3D reconstruction techniques using multi-view images. For example, Neural Radiance Fields (NeRF) represent radiance and occupancy of a 3D scene as implicit continuous functions modeled by deep neural networks. This allows high-resolution 3D reconstruction and visualization by simply optimizing the neural network's weights without consuming large amounts of memory. Inspired by NeRF, we have developed a novel auroral reconstruction method using neural networks in collaboration with the National Institute of Informatics. Our neural flux field models the precipitating electron flux via a neural network that outputs the precipitating energy spectrum from an input position. Then, by incorporating an auroral emission model into the loss function, we train the network to directly reconstruct the energy distribution of precipitating electron flux that best match the instrument data. The 3D distribution of auroral emissions can be easily obtained from our model. The reconstruction can be done efficiently using the GPU to accelerate the training and inference of the neural network. We compared the reconstruction results returned by our method and G-ACT on numerical simulations, and found that the neural flux reconstruction is not only faster than G-ACT but also achieves higher accuracy. In this presentation, we will present the details of the neural flux reconstruction method and discuss its potential future applications, including the EISCAT_3D project.