Z101r Astronomical Applications of Differentiable Programming

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The rapid progress of machine-learning techniques is ushering in a new programming paradigm: differentiable programming (DP) based on automatic differentiation. While astronomy has long exploited derivative information – through numerical and symbolic differentiation – for data analysis and simulation, DP now lets us embed derivatives in code far more flexibly, efficiently, and accurately.

By formulating models of astrophysical phenomena and cosmology within a DP framework, we can not only perform gradient-based optimization but also carry out robust Bayesian inference with large parameter spaces via gradient-based samplers such as HMC-NUTS, langevin monte carlo, variational inference. At the simulation level, DP even allows simulators to be wired directly into inference pipelines. Inverse problems benefit as well: gradient-based sampling makes the inference of highly non-linear parameters much easier. Instrument design can likewise leverage DP to achieve more sophisticated optimization.

This “differentiable astronomy” session marks the first occasion (in Japan) on which these diverse applications of differentiable programming in astronomy are brought together. In my talk, I will outline the fundamentals of DP, using our exoplanet atmospheric retrieval code ExoJAX as a principal example.