Z105r Applications of Differential Programming in Observational Astronomy

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Advances in observational instruments have ushered astronomy into an era of extremely precise measurements. Interpreting such data requires detailed models that directly connect physical parameters to observables, driving remarkable demand for sophisticated data analysis. Differentiable programming — constructing programs using a framework of automatic differentiation — has drawn substantial interest since it enables efficient optimization and inference even with highly complicated models.

Thanks to frameworks like autodiff, JAX, and Enzyme, many astronomy applications now make the best use of differentiable programming. General data-analysis applications include, for example, generative astronomical image modeling (Celeste), optics modeling (∂ Lux), point-spread-function modeling (ShOpt), and X-ray spectral analysis (jaxspec). Science-driven applications span high-dispersion spectrum modeling of planetary and stellar atmospheres (exojax), gravitational lens modeling (JAXtronomy, Gravity), stellar population synthesis (DSPS), binary and exoplanet orbit estimation (Octofitter), microlensing studies (microlux, microjax), astrometric analysis (warpfield), and precision supernova light-curve modeling (JAX-bandflux).

Differentiable programming has contributed substantially to attempts that directly associate underlying physics and observations. This talk will introduce how differentiable programming works with actual applications, while focusing on use cases in my research field, image analysis and astrometry. We also discuss possible benefits of introducing differentiable programming into the data analysis of observational astronomy.