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Efficient mass modeling of strong lenses through deep learning

Strong gravitational lensing is a very powerful, widely used tool for understanding several open questions including properties of dark matter, dark energy, and the expansion of the universe (Hubble constant H0). For all of these applications one needs a mass model of the lens, which is currently often obtained with Markov-chain Monte-Carlo (MCMC) methods via likelihood sampling. This is a very time and resource consuming approach and will be not sufficient for the expected number of lens detections with upcoming surveys like the Rubin Observatory Legacy Survey of Space and Time (LSST) with around 100,000 lenses. Especially for planning follow-up observations of strongly lensed supernovae, which can be used to constrain the Hubble constant H0, a good mass model of the lens system is needed in a very short time. Therefore, we trained a Convolutional Neural Network (CNN) on images of lens galaxy and lensed source galaxy together to predict the five parameters of the Singular Isothermal Ellipsoid (SIE) model (lens center x and y, complex ellipticity which is equivalent to the axis ratio and position angle, and the Einstein radius) as shown in Schuldt et al. (2020). To train, validate, and test the network, we mock up images based on real observed galaxies from the Hyper Suprime-Cam (HSC) for the lens galaxy and from the Hubble Ultra Deep Field (HUDF) as source galaxy with corresponding redshifts. The velocity dispersion and redshift for the lens galaxies are taken from the Sloan Digital Sky Survey (SDSS). We tested different network architectures and also the effect of using only double or quads as images. We find in all tested cases that the neural network perform well for the tested SIE profile, with the Einstein radius recovered within 0.07" (1 σ). Based on the obtained model, we can predict the other appearing image positions and corresponding time delays with a fractional difference between the predicted and true time-delay of $\sigma = 0.04$. Based on these promising results, we investigate now a CNN that predicts the parameter values of the SIE profile plus external shear. Our final network is able to estimate the parameter values in fractions of a second on a single Central Processing Unit (CPU), such that we are able to process the huge amount of expected lens detections in the near future.

Presenter: STEFAN SCHULDT