Use data not models – Lensing of '69 as an example for data-driven inference

Jenny Wagner*[1]

[1]https://thegravitygrinch.blogspot.com – Germany

Abstract

Facing an under-constrained modelling problem, we often compensate the lack of necessary data by adding model assumptions. The latter are based on symmetry assumptions or other physically reasonable principles and heuristics. In this talk, I will show that the under-constrained problem to describe a gravitational lens has *multiple different* options to yield a self-consistent, well-constrained solution. Depending on the degree of desired details, the parameter space for the model of the lensing mass density becomes huge even for a single lens, in particular those on galaxy-cluster scale.
Beyond the problem of scanning this high-dimensional and vast parameter space, we can find several different models that describe the mass distribution causing the observed light deflections of background objects equally well. Which of these models comes closest to reality given the observations? This question can be answered by further evidence to support the assumptions that underlie each model, for instance the light-traces-mass assumption of some lens reconstruction algorithms. On the other hand, the forecast of observable data useful to gravitational lens reconstructions is very bright, predictions of 1000 multiple images per galaxy cluster are envisioned for the James Webb Space Telescope. Thus, the time has come to reduce the model assumptions in lens reconstructions and replace them by observations.

To achieve this goal without the need to set up a high-dimensional fitting problem with many constraints, I introduce "Lensing of '69", a highly efficient approach to infer local lens properties, like the reduced shear, directly from observed, extended multiple images without using any lens model. These local lens properties are *uniquely* determined from the data and they are the maximum information that all degenerate lens models agree upon.
Hence, they are the ideal starting point to extrapolate lens reconstructions to regions without multiple images. Hybrids of local lensing properties by "Lensing of '69" and extensions by machine learning techniques thus offer the possibility to reduce systematic biases in lens reconstructions, allow for a fully automated evaluation of many data sets in a homogenous way, and provide the results much faster than conventional lensing algorithms because the local lens properties pre-select regions in parameter space for the extrapolating model-based step.

In summary, combining the power of mathematically sound physical theories like the gravitational lensing formalism with up-to-date machine learning extrapolations, huge amount of upcoming survey data can be evaluated in a way that is immediately interpretable and understandable by humans.

*Speaker

Reference: https://ui.adsabs.harvard.edu/abs/2019Univ....5..177W/abstract

Slides: in PDF
Video: https://youtu.be/xRNKxsPAGpw

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