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Generating magnification maps for gravitational microlensing using Neural Networks

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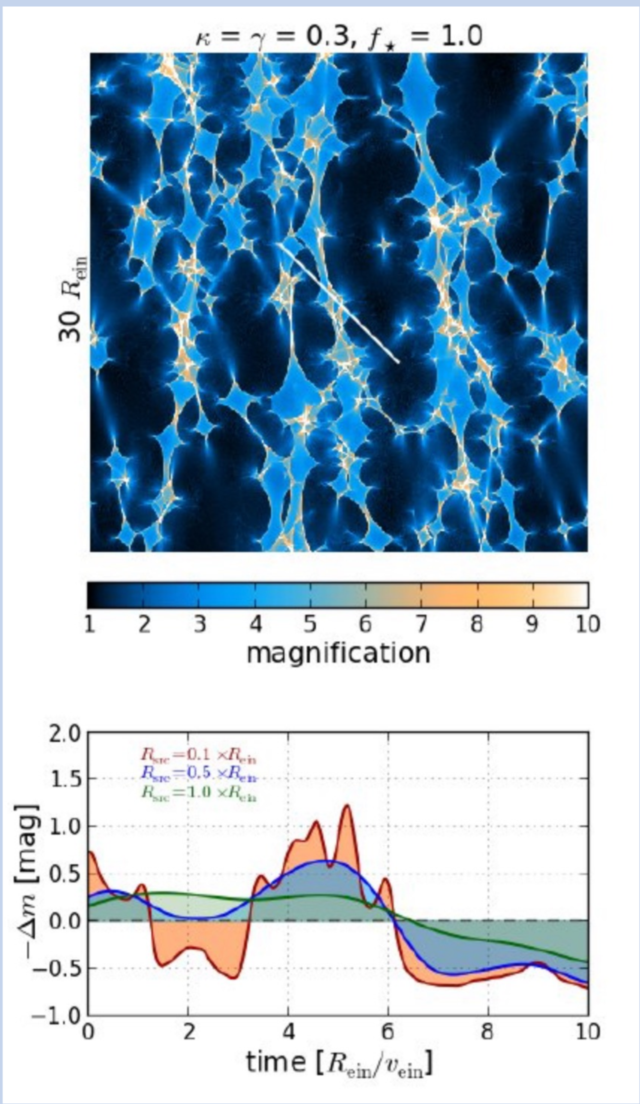
Gravitational Lensing

Looking at the night sky, what we see is a modified representation of what luminous objects really are. The gravity from massive galaxies between us and a distant astronomical object can create multiple resolved images of that object in a phenomenon called "strong lensing".

Gravitational Microlensing

- Additionally, the multiple images will be also affected by the individual stars and objects along their line of sight, which is called "microlensing".
- In order to model the microlensing variability, one needs to look at the distribution of stars within the lens galaxy and determine how each one affects the brightness of the source.
- For this purpose, a magnification map is calculated.

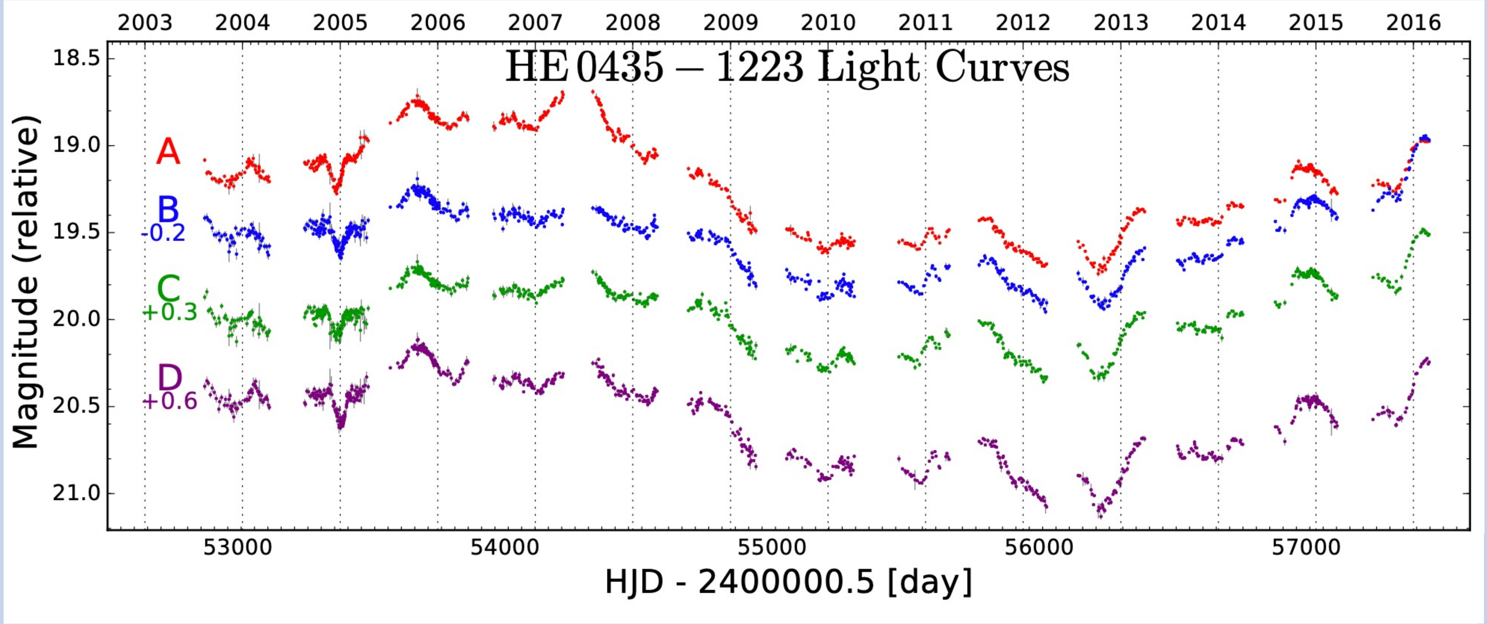


Dobler et. al. 2013

- This maps shows what the overall brightness of the source is at each point on the lens plane.

Why do we need extragalactic Microlensing?

- Study the structure of the objects that are strongly lensed
- Find the stellar to Dark Matter mass fraction as a function of galactic radius of the lensing galaxy for constraining models of galaxy formation
- Removing the microlensing variation which appears as a nuisance to strong lensing-based measurements of the Hubble Constant from multiply-imaged quasar and supernova light curves



Bonvin et. al. 2017

What is the Challenge?

- The most challenging aspect of quasar/supernova microlensing is interpreting the light curves.
- In order to model the microlensing-induced variability in light curves of multiply-imaged objects, one needs to know the distribution of the compact objects along the line-of-sight.
- The first step is to calculate an initial **magnification map** containing the overall effects of the gravitational fields of the compact objects which are the stars within the lens galaxy.
- **Calculating a single magnification map is very time-consuming and computationally expensive, and traditional modeling of each light curve needs generating many maps.**

Using an Autoencoder to generate maps

- We use variational autoencoders to compress magnification maps information to speed up their generation or to even bypass maps altogether and connect lightcurves with the lower dimensional manifold generated by the autoencoder instead.
- Our training set includes 7084 pre-computed magnification maps.
- We have trained a variational Autoencoder on these maps. An Autoencoder is a deep-learning based approach that reduces the dimensions of the input in a way that it will be able to reproduce the same input using the reduced dimension.
- The reduced dimensions form a small meaningful parameter space that contain the most important features in the input.
- This investigation results in a compressed version of the maps with a size of 12x12 pixels that contains the most important features.
- The reproduced maps show that the Autoencoder is well able to recreate the distribution of pixels, their contrasts and edges.