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Using Neural Ratio Estimation and Probabilistic Image Segmentation to detect Dark Matter Subhalos

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Analyzing the light from strongly-lensed galaxies makes it possible to probe low-mass dark matter (DM) subhalos. These detections can give us insight into how DM behaves at small scales. Traditional likelihood-based analysis techniques are extremely challenging and time-consuming. One has to marginalize over all lens and source model parameters, which makes it practically intractable. Near-future telescopes will provide a lot of observational data, therefore a fast automated approach is needed. We are using the likelihood-free simulation-based inference (SBI) method Neural Ratio Estimation (NRE). With NRE, neural networks learn the posterior-prior ratio.

I will describe how I am combining NRE with a U-Net to directly detect the mass and position of multiple subhalos at once. A U-Net is a CNN developed for image segmentation. It is used to classify each pixel of an image, where the network combines down- and upsampled information. Where 'traditional' image segmentation is only interested in binary predictions, 'probabilistic' image segmentation is able to calculate the pixel posteriors of the subhalos coordinates. To do this, one needs to correctly calibrate the results. With this approach, we can obtain predictions for every single pixel about the probability that there is a subhalo with a certain mass.

Auteur principal: M. DUBBELDAM, Elias (GRAPPA institute (University of Amsterdam))

Co-auteurs: ANAU MONTEL, Noemi (GRAPPA Institute (University of Amsterdam)); WENIGER, Christoph (University of Amsterdam); COOGAN, Adam (Université de Montréal and Mila); KARCHEV, Konstantin (SISSA / GRAPPA)

Orateur: M. DUBBELDAM, Elias (GRAPPA institute (University of Amsterdam))

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