Contribution ID: **61** Type: **Fractional talk**

CNNs reveal crucial degeneracies in strong lensing subhalo detection

Thursday, November 30, 2023 3:30 PM (7 minutes)

Strong gravitational lensing has become one of the most important tools for investigating the nature of dark matter (DM). This is because it can be used to detect dark matter subhaloes in the environments of galaxies. The existence of a large number of these subhaloes is a key prediction of the most popular DM model, cold dark matter (CDM). With a technique called *gravitational imaging*, the number and mass of these subhaloes can be measured in strong lenses, constraining the underlying DM model.

Gravitational imaging however is an expensive method. This is mostly due to the final stage of the analysis: so-called *sensitivity mapping*. Here, the observation is analysed to find the smallest detectable subhalo in each pixel. This information can be used to turn a set of subhalo detections and non-detections into an inference on the dark matter model. We have previously introduced a machine learning technique that uses a set of large convolutional neural networks (CNNs) to replace the expensive sensitivity mapping stage [1]. We exploited this new technique to test the sensitivity of *Euclid* strong lenses to dark matter subhaloes. Analysing 16,000 simulated *Euclid* strong lens observations we found that subhaloes with mass larger than $M > 10^{8.8\pm0.2} M_\odot$ could be detected at 3σ in that data, and that the entire survey should yield ~ 2500 new detections.

In the current work, we take our method much further to understand a crucial systematic uncertainty in subhalo detection: the angular structure of the lens mass model. We train an ensemble of CNNs to detect subhaloes in highly realistic HST images. The models use an increasing amount of angular complexity in the lensing galaxy mass model, parametrised as an elliptical power-law plus multipole perturbations up to order 4, and external shear. Multipole perturbations allow for boxy/discy structure in the lens galaxy. This is commonly found in the light profiles of elliptical galaxies but is almost always missing from the mass profile in strong lensing studies.

We find that multipole perturbations up to 1 per cent are large enough to cause false positive subhalo detections at a rate of 20 per cent, with order 3 perturbations having the strongest effect. We find that the area in an observation where a subhalo can be detected drops by a factor of 10 when multipoles up to an amplitude of 3 per cent are allowed in the mass model. However, the mass of the smallest subhalo that can be detected does not change, with a detection limit of $M > 10^{8.2} M_\odot$ found at 5σ regardless of model choice. Assuming CDM, we find that HST observations modelled without multipoles should yield a detectable subhalo in 4.8 per cent of cases. This drops to 0.47 per cent when the lenses are modelled with multipoles up to 3 per cent amplitude. The loss of expected detections is due to the effect of the previously detectable objects being consistent with multipoles of that strength. To remain reliable, **strong lensing analyses for dark matter subhaloes must therefore include angular complexity beyond the elliptical power-law**.

[1] O'Riordan C. M., Despali, G., Vegetti, S., Moliné, Á., Lovell, M., MNRAS **521**, 2342 (2023)

Primary author: Dr O'RIORDAN, Conor (Max Planck Institute for Astrophysics)

Co-author: Dr VEGETTI, Simona (Max Planck Institute for Astrophysics)

Presenter: Dr O'RIORDAN, Conor (Max Planck Institute for Astrophysics)

Session Classification: Contributed talks

Track Classification: Online