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Investigations for LSST with Machine Learning: Photometric redshift predictions, strong lens detection and mass modeling

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Photometric redshifts and strong lensing are both integral for stellar physics and cosmological studies with the Rubin Observatory Legacy Survey of Space and Time (LSST), which will provide billions of galaxy images in six filters, including on the order of 100,000 galaxy-scale lenses. To efficiently exploit this huge amount of data, machine learning is a promising technique that leads to an extreme reduction of the computational time per object.
Since accurate redshifts are a necessity for nearly any astrophysical study, precise and efficient techniques to predict photometric redshifts are crucial to allow for the full exploitation of the LSST data. To this end, I will highlight in the first part of my talk the novel ability of using convolutional neural networks (CNNs) to estimate the photometric redshifts of galaxies. Since the image quality from LSST is expected to be very similar to that of the Hyper Suprime-Cam (HSC), and training a network on realistic data is crucial to achieve a good performance on real data, the network is trained on real HSC cutouts in five different filters. The good performance will be highlighted with a detailed comparison to the Direct Empirical Photometric (DEmP) method, a hybrid technique with one of the best performances on HSC images.
To address further challenges in efficiently analyzing the huge amount of data provided by LSST, I will present in the second part of my talk some recent machine learning techniques developed within the HOLISMOKES collaboration, which focus on the exploitation of strongly lensed supernovae (SNe). These very rare events offer promising avenues to probe stellar physics and cosmology. For instance, the time-delays between the multiple images of a lensed SN allow for a direct measurement of the Hubble constant (H0) independently from other probes. This allows one to assess the current tension on the H0 value, and the possible need for new physics. Furthermore, these lensed SNe also help constrain the SN progenitor scenarios by facilitating follow-up observations in the first hours after the explosion. In particular, I will summarize our deep learning methods to search for lensed SNe in current and future wide-field time-domain surveys, and focus on our new achievements in the automation of strong-lens modeling with a residual neural network. To train, validate, and test these networks, we mock up images based on real observed galaxies from HSC and the Hubble Ultra Deep Field. These networks are further tested on known real systems to estimate the true performance on real data.
For all the networks, the main advantage is the opportunity to apply these easily and fully automated to millions of galaxies with a huge gain in speed. Both regression networks are able to estimate the parameter values in fractions of a second on a single CPU while the lens modeling with traditional techniques typically takes weeks. With these networks, we will be able to efficiently process the huge amount of expected detections in the near future by LSST.

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