First robust census of binary supermassive black holes : Deep Learning techniques applied to the Euclid space mission.

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The formation of dual and binary supermassive black holes (SMBH) is a solid prediction of the current hierarchical model of galaxy formation [1]. By studying these objects, several astrophysical questions can be addressed, related to the galaxy mass build-up, the feedback of active galaxy nuclei (AGN) on the star formation history of galaxies, or the expected amount of gravitational waves due to the final merging process of the SMBH pair [2]. Detecting such rare systems require simultaneously high angular resolution capabilities and a large surveyed sky area. The ongoing ESA space mission Euclid is groundbreaking in both regards, and offers therefore an unprecedented opportunity to detect and study numerous dual systems.
In this talk, I will present the first part of a methodology designed to automatically identify dual systems in the Euclid surveys, based on Machine Learning (ML) and Deep Learning (DL) techniques. The identification of the galaxies harbouring double or dual SMBH in the Euclid images will be done using a Convolutional Neural Network (CNN). As observations of genuine dual objects are scarce, we rely on the objects tagged as dual AGN in the Horizon-AGN cosmological simulation [3] to construct the CNN training database. However, since there are still very few identified systems, it is first necessary to increase the number of such images from the Horizon-AGN dataset.
To do this data augmentation process, I constructed a Variational Autoencoder (VAE) [4] that I combined to a normalizing flow [5], allowing one to generate synthetic images of dual AGN with similar properties (total flux, Gini shape parameter) and visual aspects as the initial images extracted from the simulation. I will present the technical properties of this model, including its structuration, the definition of losses, and the diagnostics used to inquire its capabilities. Using this flow-VAE model, producing a large set of images of dual AGN fulfilling a specified distribution of physical properties is feasible in a fragment of the time necessary to generate such images from the Horizon-AGN simulation.

References

[1] **Coevolution (or Not) of Supermassive Black Holes and Host Galaxies**, Kormendy J., Ho L. C., 2013

[2] **The Detectability of Kiloparsec - scale Dual Active Galactic Nuclei : The Impact of Galactic Structure and Black Hole Orbital Properties**, Li K., Ballantyne D. R., Bogdanović T., 2021, ApJ, 916, 110

[3] **Dual AGN in the Horizon-AGN simulation and their link to galaxy and massive black hole mergers, with an excursion of multiple AGN**, Volonteri M., Pfister H., Beckmann R., Dotti M., Dubois Y., Massonneau W., Musoke G., Tremmel M., 2022, MNRAS, 000

[4] **Auto-Encoding Variationak Bayes**, Kingma D. P., Welling M., 2014

[5] **Masked Autoregressive Flow for Density Estimation**, Papamakarios G., Pavlakou T., Murray I., 2016