« Physics-informed deep neural network for characterising galaxy morphology »

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Mots clés : réseau de neurones ; galaxie

Compétences nécessaires : Master level degree in data science, AI, or closely related subject, or in astrophysics with strong experience in programming. Proficient with python and scientific python libraries An experience with deep learning and/or image processing is recommended Autonomy, teamwork, ability to work across disciplines, communication, flexibility and adaptability, analytical and critical thinking

Sujet scientifique de la thèse

<u>Context</u>

Observations and image analysis are essential for astrophysics research. Combined with numerical simulations, they are the only means to study the physics that governs astronomical objects. The visual characterisation of Galaxy Morphologies (GM) illustrates this paradigm, as they are correlated with galaxies' physical parameters and may provide insights into the physical processes that drove their evolutionary history. In particular, the diffuse tidal stellar features that surround galaxies result from past galaxy collisions and bring a testimony on the past mass assembly of galaxies. However, recent or near-future observation missions (e.g. DES, UNIONS, Euclid, LSST, Roman, ARRAKIHS) have collected or are about to collect a rapidly increasing amount of data that can no longer be analysed manually, even via crowd sourcing. This situation can only be resolved by developing automatic image analysis techniques.

<u>Aims & method</u>

The goal of this project is to produce automatic visual analysis tools for finely characterising GMs. In particular, we will focus on the faint tidal debris that have been largely overlooked by previous studies, but that are essential in understanding the collisional history of galaxies. Contrary to previous studies that simplified GM characterisation through discretising GM parameters, we will perform a regression of continuous parameters of interest. This will be achieved through a segmentation of the tidal structures. Previous studies used off-the-shelf deep neural networks (DNN) which were limited in the achievable accuracy for detecting the faint and diffuse tidal structures. To overcome the challenges associated with localising them, we will develop purpose-designed DNNs that integrate knowledge on the relationships between structures. This knowledge will constrain the learning and increase the localisation robustness. We will endeavour to making the methods applicable on a large scale to major observational missions such as CFIS, Euclid and LSST. Different missions operate at various (numbers of) imaging bands. This raises strong challenges to the practical applicability of automated visual analysis to all available imaging bands. We will explore transfer learning options to adapt the developed methods to the data from various instruments. This project will build on a DNN that was previously designed in our lab, and that is particularly sensitive to the texture and orientation of filamentary structures (Richards et al., 2022b). During the first year of the PhD, we will adapt this DNN to the detection and the segmentation of galactic structures, with a focus on low surface brightness tidal features. During the second year, we will further adapt the DNN's architecture in order to account for known relationships between galactic structures. The third year will be devoted to preparing the application of the developed methods to real observational data, with the aim to release a tool for the astrophysics community.

Informations complémentaires : two laboratories are involved in the supervision of this PhD: the LIS (Laboratoire d'Informatique et Systèmes) and the Strasbourg Astronomical Observatory. The PhD student will be based a t LIS an d will work in close collaboration with the Strasbourg Astronomical Observatory.