Thesis abstract J. Chevalier

"Applying Stellar Population Synthesis to galaxies' photometric redshifts estimation for Rubin-LSST"

The standard model of cosmology has successfully described, since the 1930s, the Universe as homogeneous, isotropic, and expanding. At the very end of the 20th century, observations of Type Ia supernovae demonstrated that this expansion is accelerating, although the cause of this acceleration remains unidentified. Since then, astronomers and cosmologists have been probing the cosmos in search of this so-called Dark Energy. One method to achieve this involves mapping the large scale structure of the Universe in three dimensions using the redshift of objects – caused by the Universe's expansion – as a measure of distance. Accurate characterization of dark energy requires galaxy surveys that are both wide (covering a large area of the sky) and deep (detecting very faint objects). In this context, the Vera C. Rubin Observatory was built at Cerro Pachón (Chile) and commissioned in 2025 to begin the Legacy Survey of Space and Time (LSST). This photometric survey is capable of covering the entire sky of the southern hemisphere (18 000 deg2) in just three nights of observations, across six photometric bands ranging from near-ultraviolet to near-infrared, over a period of ten years. It is expected to provide cosmologists with an unprecedented sample of several billion galaxies down to a magnitude of 25.3 in the i-band (700nm to 800nm) for the "Gold" sample and up to 27.5 in r-band (550nm to 680nm) in total. To estimate the redshift of galaxies in LSST without relying on spectroscopy, which is incompatible with the scale of this survey, scientists use photometric methods. This thesis focuses on these methods and explores improvement prospects. To do so, we rely on spectroscopic data from three experiments: FORS2 at the VLT, GOGREEN (Gemini Observatory), and DESI (Kitt Peak National Observatory). These data were processed to associate photometry, from UV to IR, with the observed galaxies' spectra and to extract the intensity of emission lines present in the latter. We then used this information to fit a stellar population model and star formation history to each galaxy using the DSPS code. Next, we developed a photometric redshift estimation code, SHIRE, which uses the selected spectra as references to compare with LSST observations. This allows us to incorporate, into the redshift estimation, the evolution of reference galaxies according to the stellar population evolution model associated with each. This code is designed to operate within the LSST ecosystem and is particularly suited to large data volumes, thanks to its optimisation for GPU processing. We apply this code to three samples: a simulation of LSST data, COSMOS2020 observations, and the very first real data obtained at the Rubin Observatory during its commissioning phase. A reference code, BPZ, is used for comparison. Through several examples, we identify possible improvements in redshift estimation thanks to the use stellar population synthesis, although other factors, such as adding infrared photometry, are significantly more decisive. Finally, we discuss how to make the method better, particularly with a view to extending it to estimate other characteristic properties of the observed galaxies.