Internship/Thesis PROPOSAL

Title of the internship : Impact of photometric calibration on LSST performance

Level (L3, M1, M2)	M2
Period / length of the thesis (indicate the year)	October 1, 2021 to September 30, 2024
Supervisor	Sylvie Dagoret-Campagne/ Marc Moniez
Team/Service	GREEN (Dark Energy)
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Context of proposed work

The LSST telescope at the Vera C. Rubin Observatory is a large, wide-field imaging telescope, 8.4 m in diameter, currently being installed on Mount Cerro Pachon in Chile, which over the next decade will answer a number of scientific questions, both astrophysical and cosmological. In particular, LSST will produce the deepest and most complete catalog of galaxies to date, accurately mapping 20,000 square degrees of the southern hemisphere sky. This telescope will perform the photometric measurement of more than 37 billion objects

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(galaxy stars, quasars...) in 6 filters (u,g,r,i,z,y), up to the limit magnitude r=27.5, after coaddition of the images at the end of the 10 years of observation. This sensitivity should allow to reach redshifts of 3.

One of the major challenges for LSST is the possibility to exploit images taken under non-ideal conditions, which results in fluctuations in the transparency of the atmosphere induced by variations in aerosols, precipitable water vapor and also in the structure of thin clouds. The objective is to correct the observations for the effect of these variations, to achieve a final accuracy better than 5 mmag. Only an excellent knowledge of the atmospheric transmission will allow to correct with the required precision the photometric measurements of each source present in the LSST field.

To measure the transparency of the atmosphere as a function of the wavelength, an auxiliary telescope called AuxTel, 1.2 m in diameter and f/18 aperture is being installed on the same site as the LSST. It will be equipped with a slitless spectrometer with a transmission disperser, which will allow to measure the spectra of a number of standards to compare them with known spectra outside the atmosphere.

For a few years the group of cosmological physicists of FLUO (LSST group-Dark Energy) has developed a phase hologram as a disperser, especially adapted to the geometry of the Auxtel beam. Its advantages are on the one hand its excellent capacity of focusing at all wavelengths in the focal plane and on the other hand a high transmission coefficient which make it an option largely preferable to a simple periodic grating. The performances of this hologram were tested by the team during various observation campaigns at the CTIO (Chile) and at the Pic du Midi, but also on an optical bench, equipped with a simulator of the AuxTel beam and a CCD camera, which makes it possible to precisely measure the transmission efficiencies of the various orders of diffraction according to the wavelength. The Spectractor tool is currently being developed at LAL, in collaboration with Lyon and Paris (LPNHE) and allows the extraction of atmospheric parameters from the spectral image of the source observed by AuxTel.

Description of the thesis subject

The thesis will include two parts, a technical part focused on photometric calibration and a science part that can be specified later. The science subject will focus either on the research of dark matter or on dark energy, for example gravitational lensing with the indispensable measurement of photometric redshift.

The thesis will start during the commissioning period (commissioning) of Auxtel, which will

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take about 1 year, and during which many spectra of spectrometric standards will be accumulated with the whole range of atmospheric conditions expected at the site; it will continue during the operation phase of LSST which will see the very first production of scientific images of the device. The student will contribute within the team to define the best observation strategy to be programmed for Auxtel during these two periods. This strategy will consist in choosing at each moment the source to be observed - according to its magnitude and color - and the most appropriate observation mode, with or without filter, linked to the filter in place in LSST.
The process of choice of the spectrometric standards to be used during the LSST operations will be defined during the thesis. In particular, it will be necessary to study the relevance of the use of public data from the Gaia space mission, which will include at this time low-resolution (out-of-atmosphere) spectra of millions of stars. It will then be necessary to study the best way to compare them with the spectra measured by AuxTel to deduce the atmospheric absorption.

The student will contribute to the development of a simulation and analysis tool to estimate the effect of the different imperfections of the LSST calibration chain, and atmospheric effects in particular. Among others, he will have at his disposal the atmospheric transparency modeling tool libradTran which converts a set of atmospheric parameters into a wavelength-dependent attenuation function, as well as global databases of atmospheric parameters (MERRA2).

Finally, it will be necessary to study the impact of the imperfection of the calibration corrections, and of the atmospheric corrections on the accuracy of measurements in cosmology, such as the indispensable measurement of photometric redshift. This impact could be evaluated with the different algorithms developed then within the DESC (Dark Energy Survey Collaboration).

Description of the internship

The internship will focus on the preparation of the first observations with the AuxTel telescope, depending on the progress of its beginning. If the schedule allows it, participation in the observations and work in Chile is possible. The analysis of the data already in our possession, taken at the Pic du Midi and on the test bench of the holograms at the LPNHE will be able to be continued, according to the calendar of the first observations with AuxTel.

Description of the team/service

The Dark Energy team includes seven senior researchers and teacher-researchers. The activities of the team are structured around the LSST optical survey project and R&D for the mapping of 21 cm intensity. Sylvie Dagoret-Campagne, Olivier Perdereau and Marc Moniez

are more particularly involved in the LSST calibration activity with the auxiliary telescope, and will contribute to the supervision of the PhD student.

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