M2 INTERNSHIP PROPOSAL

Laboratory name: LUTH (remark:will become LUX in 2025)
CNRS identification code: UMR8102
Internship director'surname: Yann RASERA
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Internship location: Observatoire de Paris, 5 Place Jules Janssen 92190 MEUDON
Thesis possibility after internship: YES
Internship Funding: YES Type of funding: by the lab (+ANR if a long internship is planed)

Probing dark energy and gravity at cosmological scales using relativistic effects

The origin of the recent acceleration in the expansion of the universe is a major mystery in current science. Beyond the cosmological constant hypothesis, two main scenarios are possible: a dark energy "fluid" (with negative pressure) or an alternative theory of gravity.

In this internship, we are looking for robust probes that will enable us to discriminate between these three scenarios. To do so, we will study the non-linear regime of the formation of the large-scale structure of the universe, which is sensitive to the nature of both dark energy and gravity.

We propose to carry out a series of cosmological simulations of the formation of large-scale structures, exploring different dark energy models. Within each simulation, we will propagate billions of rays between the sources (i.e. galaxies) and the observer according to the equations of general relativity, thus capturing relativistic effects (e.g. gravitational lensing effects) with a high level of precision. Based on these simulations, an emulator (i.e. an advanced interpolator) of relativistic effects will be built (which, to my knowledge, would be a novelty in the field).

A thesis topic following on from this internship will be proposed with a view to developing new models (modified gravity models), carrying out high-resolution cosmological simulations (numerical developments and high-performance computing), and more advanced analyses (higher-order statistics). Please do not hesitate to contact me for further information.

The galaxy surveys (in particular Euclid, launched in 2023) will measure the position and shape of billions of galaxies: only an in-depth theoretical and numerical study will enable us to extract the best cosmological information from them, in order to determine the nature of gravity and the dark sector of the universe.

Internship schedule
1/ Bibliography 2/ Getting to know existing codes (RAMSES and Magrathea)
3/ Creation of a suite of cosmological simulations and calculation of relativistic effects for different dark energy models, in order to pave the cosmological parameter space.
4/ Development of the relativistic effects emulator 5/ Report writing

Further information:
Example of simulations already carried out https://cosmo.obspm.fr/public-datasets/ - Example of a Python emulator for other quantities: https://arxiv.org/abs/2303.08899 - The internship will take place as part of the ANR ProGraceRay project https://anr.fr/Projet-ANR-23-CE31-0010

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:
Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: NO Theoretical Physics: YES