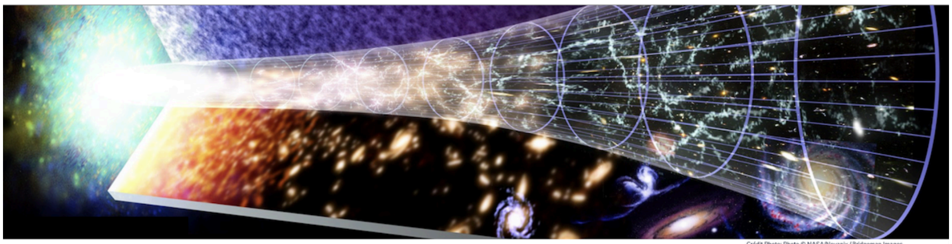
GDR CoPhy Episode 4



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ID de Contribution: **69** Type: **Non spécifié**

Gravitational lensing beyond approximations: relativistic lightcones for modern cosmological surveys

lundi 1 juin 2026 15:30 (30 minutes)

Are the standard approximations used in gravitational lensing still adequate in the era of precision cosmology? If not, how can we move beyond them?

As cosmological tensions sharpen, a new generation of surveys such as Euclid and LSST is set to deliver an unprecedented volume of data, with billions of galaxies analyzed through increasingly sophisticated pipelines, including machine-learning techniques. Despite the technical progress, the theoretical framework used to interpret weak lensing observations still relies largely on approximations that have remained essentially unchanged for several decades. In this talk, we revisit the relativistic foundations of gravitational lensing and explore a framework that moves beyond these standard assumptions and towards the precision needs of the next generation of cosmological surveys.

In particular, we introduce EXCALIBUR, a numerical approach being developed and designed to model light propagation in ΛCDM cosmological settings through the direct integration of null geodesics in first-order perturbed FLRW spacetimes. This method enables the extraction of fully relativistic lightcones for a given cosmological background and provides a unified description and extraction of weak and strong lensing signals within a single pipeline. It relies on evaluating relevant tensor quantities from which the full Jacobi mapping is reconstructed without relying on perturbative expansions. This framework gives direct access to lensing observables such as convergence and shear, while naturally extending to higher-order distortions beyond the standard weak-lensing formalism.

We will discuss how this approach compares to current weak lensing methods, validating our study on known analytical halo models before dwelling into different cases of mass shapes and profiles. In particular, we are interested in effects that arise when relaxing usual hypothesis, such as the Born and thin lens approximations. Generating mock observables this way allows us to naturally capture post-Born and relativistic effects (e.g. lens-lens couplings, light beam rotations, higher-order distortions, redshift and angular distances effects), and to assess potential systematics in shear measurements and cosmological parameter inferences.

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Classification de Session: Monday afternoon