INTERNSHIP PROPOSAL

Laboratory name: Institut d'Astrophysique de Paris (IAP)
CNRS identification code: UMR7095
Internship director surname: Yann Gouttenoire
International collaborations: Gabriele Franciolini (CERN, Geneva & Padua University, Italy) and Sten Delos (Carnegie Inst. Observ., Pasadena, California, USA)
e-mail: yann.gouttenoire@gmail.com
Web page: https://www.yanngouttenoire.com
Internship location: IAP, 98bis Bd Arago, 75014 Paris, France
Thesis possibility after internship: YES
Funding: YES **If YES, which type of funding:** Doctoral school

Gravitational Probes of the Early Universe

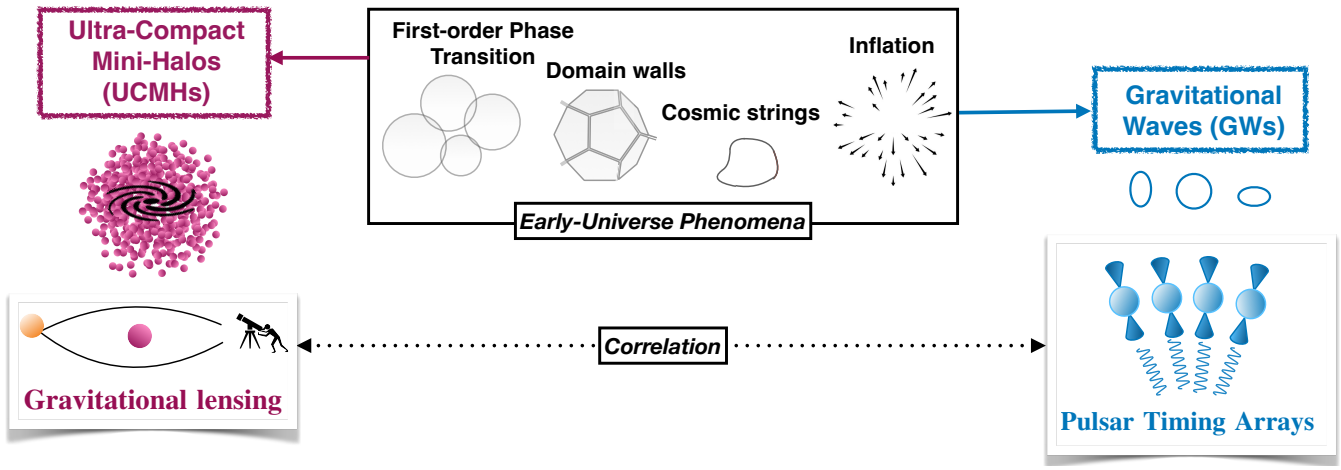
Understanding the origin of dark matter, neutrino masses, the matter–antimatter asymmetry, and other open questions in particle physics requires exploring new physics beyond the Standard Model [1]. Many such theories predict non-trivial field dynamics during the first second of the Universe—such as early matter-dominated eras, first-order phase transitions, or topological defects [1]. These processes could have left gravitational imprints in the form of gravitational waves (GWs), primordial black holes (PBHs), or ultra-compact dark-matter minihalos (UCMHs).

In 2023, Pulsar Timing Array (PTA) collaborations reported the first detection of a stochastic background of nanohertz GWs. If this signal is of primordial origin, its amplitude would require violent early-Universe phenomena likely accompanied by other signatures. One possible counterpart is the formation of solar-mass PBHs [2,3], already the subject of intense study following the ~300 merger events observed by LIGO–Virgo–KAGRA. Another, less explored — but promising — signature could be the presence of UCMHs [4].

This project aims to investigate how UCMHs could be detected through gravitational microlensing using surveys such as HSC, OGLE [5], and lensed-quasar monitoring [6]. Detecting or constraining such objects could provide a decisive test for the primordial origin of the PTA signal [7].

At the intersection of particle physics, cosmology, and astrophysics, the student will develop theoretical frameworks and analytical models to uncover new gravitational signatures of the early Universe, turning theoretical ideas into testable predictions with data from most advanced gravitational observatories.

[1] YG, Beyond the Standard Model Cocktail, Springer (2022)
[2] YG, Vitagliano, Domain wall interpretation of PTA signal confronting black hole overproduction (2023)
[3] YG, Phase Transition Interpretation of PTA Signal Is Consistent with Solar-Mass Black Holes (2023)
[4] YG, WIMPs and new physics interpretations of the PTA signal are incompatible (2025)
[5] Delos, Franciolini, Lensing constraints on ultradense dark matter halos (2023)
[6] Karami, Afshordi, Zavala, Forward modelling of quasar light curves and the matter power spectrum (2018)
[7] NANOGrav collaboration, The NANOGrav 15 yr Data Set: Search for Signals from New Physics (2023)



Condensed Matter Physics: NO
Soft Matter and Biological Physics: NO
Quantum Physics: NO
Theoretical Physics: YES