Dark matter halos in the era of Euclid

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Context: The present proposal is made in the framework of Euclid. ESA's Euclid space mission for cosmology will complete a half-sky survey of the deep sky in optical and near infra-red bands, measuring the shapes of over a billion galaxies and obtaining accurate redshifts of tens of millions of galaxies. The data will be used for weak gravitational lensing and galaxy clustering studies, which are the primary cosmological probes to investigate the nature of dark energy, dark matter and gravity.
The Euclid space telescope is scheduled to launch on 2020. In the meantime the various science working groups of the Euclid Consortium are setting the standard for the state-of-the-art in Cosmology. The topic of the present proposal is one of the many tasks relevant for the scientific preparation of Euclid, namely the modelling of astrophysical correlations between the shapes of galaxies, which contaminate the weak gravitational lensing signal that Euclid will measure.
Portugal is a member state of the Euclid Consortium and CAAUL and CAUP are Euclid affiliated institutes. The supervisors of the present proposal are the two national coordinators of Euclid. The candidate will thus become a member of the consortium and benefit from an international working environment.

Abstract: The so-called intrinsic alignment is a correlation between the orientations of pairs of galaxies at highly separated redshift. It is due to a physical correlation between the foreground galaxy of the pair and the dark matter halo responsible for lensing the background galaxy. This effect is a major contaminant of the cosmological weak lensing signal that Euclid aims to detect.
This project will contribute to model this astrophysical systematic effect and propose ways to correct it. The student will investigate the process of angular momentum acquisition of galaxies by tidal torquing using dedicated N-body simulations of Large Scale Structure. The first step is to quantify the correlation between tidal shears of dark matter proto-halos at early times and study the dependence of tidal shearing on the environment. The simulations will be carried out with the public code Gadget 2 including only Dark Matter (DM) particles in a boxsize of 512 Mpc/h on the side and a total number of about 1 billion particles. The simulation is run from an initial condition at high redshift down to the present time storing the gravitational potential information. We then tag all particles in each halo, and trace back their properties at early times, which allows to compute the centre of mass, momentum of inertia, tidal shear tensor, and consequently the angular momentum for all proto-haloes at high z.
The next step is to place galaxies in the dark matter halos, according to a semi-analytic model, with orientations given as function of the halos angular momentum. The student will then produce a ray-tracing code, to be applied through the simulation in order to obtain 2D maps of projected ellipticities. The ellipticities will be correlated as a result of the angular momentum correlations acquired in the process of galaxy formation.

The final step will be to measure the correlation as function of redshift and use it as a template to correct a weak lensing signal. This can be done either by direct subtraction or in a parameterized way using nuisance parameters in an MCMC analysis.
Finally, the produced catalogue of dark matter halos can be used as a sub-product for other applications, such as constraining theoretical models for dark matter halo profiles with the method of galaxy-galaxy lensing.

Further reading:

"Intrinsic alignment-lensing interference as a contaminant of cosmic shear", Hirata C. M., Seljak U., Phys. Rev. D, 70, 063526 (2004), http://arxiv.org/abs/astro-ph/0406275

"Intrinsic galaxy shapes and alignments II: Modelling the intrinsic alignment contamination of weak lensing surveys", B. Joachimi, et al., submitted to MNRAS (2013) http://uk.arxiv.org/abs/1305.5791v1

"Review: galactic angular momenta and angular momentum correlations in the cosmological large-scale structure", Bjoern M. Schaefer, Int. J. Mod. Phys. D, 18, 173 (2009), http://arxiv.org/abs/0808.0203v1

"Euclid Mission: building of a Reference Survey", J. Amiaux (including I. Tereno and A. da Silva), SPIE Astronomical Telescopes and Instrumentation Proceedings, Volume 8442, id. 84420Z-84420Z-11 (2012), http://arxiv.org/abs/1209.2228

"Euclid Definition Study Report", R. Laureijs et al, ESA/SRE(2011)12, http://arxiv.org/abs/1110.3193