Title: Substructure lensing at milliarcsecond angular resolution

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Scientific case

A long-standing problem in observational cosmology is the strong discrepancy between the high number of low mass sub-halos predicted by simulations and the few dwarf galaxies observed around the Milky Way. This issue has become known as "missing satellite problem", and it is unsolved to date. Strong gravitational lensing is a powerful way to investigate directly this problem at any high redshift by means of "anomalies" in the gravitational potential (and its derivatives) caused by the presence of satellites. The angular scale for detecting the astrometric anomalies due to the critical satellite population ($M \sim 10^6 M_\odot$) is of a few milliarcseconds. Currently, such scales can be imaged only at the radio wavelengths with very long baseline interferometry (VLBI). Detecting and quantifying such anomalies in a statistical way provides an ultimate test to the nature of the dark matter particle (cold vs warm particle models).

Outline of the project

The PhD candidate will perform the data reduction and lensing analysis of new sensitive VLBI observations at milliarcsecond angular resolution of a sample of radio-loud strong lensing systems that clearly show anomalies in the second derivatives of the lens potential (i.e., flux anomalies). With these observations it becomes possible to study also the anomalies in the first derivative of the lens potential (i.e., astrometric anomalies), and combine all of them to study the content of substructure. Some of these systems show hints of faint extended gravitational arcs, which would add tight constraints to the mass density profile. Therefore, the main aim of this analysis is to measure the sub-halo mass function and put stringent limits on the nature of the dark matter particle.

Moreover, these data consist of "second epoch" observations, since the VLBI discovery data at the same observing frequencies have been obtained about 15-20 years ago. The candidate will also develop a novel study of relative proper motions in these lensing systems. The long time baselines enable the detection of proper motions as small as few µas / year in the most magnified systems (as demonstrated in a published proof-of-concept work). By using the lens modelling analysis, it is possible to discern if such motions are due to the background radio source (i.e., AGN jets) or the lensing object (i.e., a high redshift galaxy). Therefore, this project has the unique potential to extend the research on the dynamical evolution of galaxies from the Local Group to the early Universe.

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