Search for dark substructures in the Milky Way using maching learning techniques

Summary

We propose to develop machine learning methods that exploit both N-body simulations and the exquisite precision of the ESA Gaia satellite in the search for dark subhalos in the Milky Way galaxy.

Research field:	Earth sciences
Supervisors:	Maria Benito Joosep Pata
Availability:	This position is available.
Offered by:	National Institute Of Chemical Physics And Biophysics
Application deadline:	Applications are accepted between May 03, 2021 00:00 and May 31, 2021 23:59 (Europe/Zurich)

Description

Although Dark Matter (DM) represents roughly 85% of the matter content in the Universe, unveiling its nature has proven a difficult endeavor, and none of the proposed DM candidates have been detected yet. In the absence of any reliable signal, the only source of information to constrain DM properties is through its gravitational interaction. At the cluster and cosmic scales, DM has been extensively constrained to behave like Cold Dark Matter (CDM) (i.e. DM is composed of collisionless, classical, non-relativistic particles which have non-negligible thermal velocities at early times). Nonetheless, at the galactic scale, astronomical observations allow a variety of models in which DM behaves significantly different from CDM. The abundance of dark subhalos orbiting a host galaxy is a prediction of the cosmological framework and therefore, a promising way to investigate the microphysics or nature of DM. Subhalos, with masses below 10^8 solar masses, are unable to form stars, thus hindering their detection. As they cannot form stars, we must detect their presence and further infer their abundance from perturbations in the dynamics of visible stars.

Owing to the increasing data sizes (billions of stars) and the expected smallness of the perturbations from DM halos, we plan to investigate Machine Learning (ML) techniques to exploit the exquisite precision of the Gaia data and detect the dynamical effects of dark subhalos in their neighbouring stars. Both supervised and unsupervised learning techniques will be investigated, guided by the final sensitivity. High-precision numerical N-body simulations will be used to provide training data for the supervised search, and to estimate the strength of the expected signal. The methods developed in this project will help to boost the scientific value of the Gaia data, with possible applicability in neighboring fields with an increasing amount of observational data.

Applicants should fullfil the following requirements:

- Master’s degree in physics or astronomy
- Experience with large-scale numerical data analysis tools (e.g. Python, Numpy, Pandas) and relevant mathematical methods (e.g. Markov Chain Monte Carlo analysis, statistics)
- Experience with modern machine learning concepts (e.g. deep learning) and tools is beneficial but not required
- Experience with modern software development techniques (git, jupyter notebooks, continuous integration, data storage technologies) and parallel computing is beneficial

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