The dynamics of Satellite Galaxies in Dark Matter Haloes

Near-Field Cosmology
Cosmology - the study of the formation and ultimate fate of structures and galaxies throughout the Universe - is without a doubt one of the most exciting fields in astrophysics today. Over the last twenty years a picture has emerged in which contemporary structures (e.g. galaxies, galaxy groups and clusters, and the filamentary network inbetween) have evolved by gravitational amplification of seed inhomogeneities that are likely of quantum origin and were produced shortly after the Big Bang. This picture ties together (observational) measurements of the cosmic background radiation, estimates of the primordial abundances of the light elements, measurements of the clustering of galaxies and, to a more limited extent, the characteristic properties of individual galaxies.

There is mounting evidence that the $\Lambda$-cold dark matter ($\Lambda$CDM) structure formation scenario provides the most accurate description of our Universe (cf. Komatsu et al. 2009). This model induces hierarchical structure formation whereby small objects form first and subsequently merge to shape progressively larger objects (e.g. Davis et al. 1985). Hence, to understand galaxy formation one also needs to understand the evolution of satellite galaxies, i.e. the “building blocks” within the CDM paradigm. As this approach combines our understanding of cosmological structure formation on large scales with observations in the local Universe it has been called “Near-Field Cosmology” (Freeman & Bland-Hawthorn 2002). Further, a new astrophysical discipline called “galactic archaeology” has emerged which tries to decipher the formation history of our very own Milky Way by utilizing the debris fields of tidally destroyed satellite galaxies (cf., for instance, Helmi & de Zeeuw 2000; Belokurov et al. 2006; Seabroke et al. 2008). Large observational projects (e.g. RAVE (Radial Velocity Experiment, Zwitter et al. 2008), SEGUE (Sloan Extension for Galactic Understanding and Exploration, Lee et al. 2007), and GAIA1) are being initiated to survey millions of stars for this purpose, i.e. they seek a detailed understanding of the sequence of events which led to galaxies, and in particular, the Milky Way.

In order to theoretically understand the formation of aforementioned structures the past twenty years have seen immense improvement in the modeling by means of numerical simulations of cosmic structure formation; these simulations have become a powerful theoretical tool to accompany, interpret, and sometimes to lead observations (e.g., Bertschinger 1998, Knebe 2006, Dolag et al. 2008). They bridge the gap that often exists between basic theory and observation and can be considered as the only “experiment” to verify a theory in astrophysics. The field associated with it has left us with highly sophisticated software tools for both simulations and the subsequent analysis. Despite the uncertain nature of dark matter and dark energy their effects are readily included in simulations of cosmic structure formation.

1 http://www.esa.int/esaSC/120377_index_0_m.html
**The Project**
The Local Group of Galaxies and its environment is the most well observed region of the universe. Only in this unique environment can we study structure formation on scales as small as that of very low mass dwarf galaxies. Within the CLUES\(^2\) project we have performed a series of constrained simulations of the local universe. These simulations reproduce the observed large scale structures around as well as the Local Group whereas small scale structures below scales of ~ 1\(h^{-1}\) Mpc are more or less random (yet still compliant with the respective cosmological model, of course). They therefore serve as the ideal tool for comparing the predictions of theoretical models to observational data.

The aim of the PhD project is to analyse the full set of simulations that comes in various flavours: we do have simulations based upon cold and warm dark matter as well as matching simulations that in- and exclude the (small scale) effects of baryonic physics (e.g. gas cooling, star formation, feedback, etc.) as well as different cosmologies. While \(\Lambda\)CDM superceds all other models on large scales there is still the debate whether or not warm dark matter particles (as opposed to cold dark matter) better explain the apparent lack of subhaloes in the Local Group: CDM simulations do predict a multitude of low-mass substructure orbiting inside galactic dark matter haloes which has yet to be found observationally while WDM models may alleviate that problem (e.g. Avila-Reese et al. 2001; Knebe et al. 2002; Polisensky & Ricotti 2010).

However, there are not only the CLUES simulations at our disposal but also various other (large-scale structure) simulations allowing to statistically verify the findings obtained for the simulated Local Group satellites. To this extent, the PhD will not solely focus on analysing the CLUES simulations but also the complementary MareNostrum Numerical Cosmological Project (MNCP)\(^3\). While the CLUES data is directly comparable to observations of the Milky Way and the Adromeda galaxy, the MNCP simulations will allow for a generalisation and distinguishing between uniqueness and universality of the results.

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\(^2\) Constrained Local UniversE Simulation, [http://clues-project.org](http://clues-project.org)

\(^3\) [http://astro.ft.uam.es/marenosrum](http://astro.ft.uam.es/marenosrum)