Research Proposal for DAAD PhD scholarship
The Gaseous Cosmic Web

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1 General Information

Information of the Applicant

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More detailed information of the applicant can be found here `http://goo.gl/BPZGzK`

Information of the Project

Title	**The Gaseous Cosmic Web**
Field	Cosmology, Astrophysics, Physical Sciences
Advisor 1	Volker Springel, PhD. Heidelberg Institute for Theoretical Studies (HITS) & University of Heidelberg, Germany
Advisor 2	Jaime Forero-Romero, PhD. Universidad de los Andes, Colombia
University	University of Heidelberg, IMPRS PhD program
Time Frame	3 years

2 Abstract

3 Introduction

Since the filamentary nature of the large-scale matter distribution of the observable cosmos (the so-called cosmic web) was evidenced by the first compiled galaxy surveys (Chincarini & Rood, 1975; Gregory & Thompson, 1978; Einasto et al., 1980a,b; Kirshner et al., 1981, 1987), it has been identified as one of the most striking features of the Megaparsec Universe and an increasing interest in studying its dynamical properties and environmental influences on a plethora of different astrophysical phenomena has become evident. At present, a tremendous amount of observational data supports the cosmic web scenario at the point that it has become an essential part of the current standard paradigm in cosmology. Last generation galaxy redshift surveys, such as the *two-degree-Field Galaxy Redshift Survey* (2dFGRS) and the *Sloan Digital Sky Survey* (SDSS), do evince the intricate and complex structure of the cosmic web at a level of detail never seen before. In addition, other valuable observational resources like X-ray emissions of hot intracluster gas embedded into large clusters of galaxies, Ly-α forest absorption lines in the spectra of shock-heated neutral hydrogen gas residing in filaments and clusters, and weak gravitational lensing and imprints in the CMB field produced by foreground structures have also validated this picture undoubtedly.

On the theoretical side, early descriptions of the evolution of the large-scale Universe, based on gravitational instabilities in primordial stages and leaded by the seminal work of Zel'dovich (1970), are highly consistent with the cosmic web picture, where planar pancake-like regions of matter enclose enormous sub-dense voids and are bordered, in turn, by thin filaments and high-density clumpy knots (Bond et al., 1996). Since then, our understanding of the structure and dynamics of the cosmic web has been dramatically improved as new and more powerful theoretical and computational tools and more refined observational data become available. In particular, N-body simulations, fuelled by last generation computing systems and ever more efficient numerical algorithms, are acquiring an increasingly important role in fathoming the complexity of the large-scale Universe.

Due to the poorly interacting (and unknown) nature of the dark matter component of the cosmic inventory, observations have been devoted to establish the underlying structure of the cosmic web entirely based on detecting baryonic matter (with the exception of non-direct inferences based on gravitational lensing). On the other hand, the highly complex *gastrophysical* processes involved in baryonic dynamics, i.e. shock heating, photoionization, supernova feedback, stellar wind, radiative cooling, star formation and others, make extremely difficult to obtain a completely consistent and reliable scenario from numerical simulations as many of these processes are not fully understood yet. Accordingly, most of the related numerical research has been made based on dark matter-only N-body simulations, where the gas dynamics has been neglected. Although this duality between observations and simulations can be thought as a complementary situation, actually it also makes quite hard to splice both, observational data and numerical predictions.

In spite of most of the above-mentioned *gastrophysical* processes occurring in baryonic dynamics do represent a challenge for any endeavour for simulating the large-scale Universe, the merely hydrodynamic nature of the gas has been challenging enough even for the most simplified models. Traditionally, two different hydro-solvers has been used for astrophysical and cosmological applications, i.e. *Adaptive Mesh Refinement* (AMR) and *Smoothed Particle Hydrodynamics* (SPH).

4 Objectives

- ✓ Understanding, at the light of the last generation AREPO simulations, how is the dynamics of the baryonic matter component throughout the pipeline set up by the potential wells of the dark matter cosmic web.

✓ Quantifying gaseous environmental effects on galaxy formation and dynamics.

✓ Comparing our results with current (predicting new) observables and imprints of the gaseous cosmic web.

5 Methods

The proposed project is subject to a PhD study and will cover the following aspects

✓ *First, a set of simulations must be established for all succeeding steps. This may involve making new hydrodynamical simulations or adopting existing ones based on the AREPO code. This also includes a complete analysis of the simulations, i.e. characterization of physical fields (density, temperature, entropy), construction and analysis of catalogues of haloes, and others.*

As this project will be almost entirely based on numerical results, establishing a set of precise hydrodynamic simulations as a solid base for all our succeeding studies is, indeed, one of the key steps that must be fulfilled. The unprecedented accuracy and convergence achieved by the AREPO code regarding other traditionally used schemes will guarantee the needed precision. In Heidelberg, the required computer facilities and the access to the private code AREPO (of which Prof. Volker Springel is the main author) is granted.

✓ *Second, an exploration of the dark-matter cosmic web should be done. For this purpose, it is necessary an adaptation of some commonly used web-finding schemes (e.g. the V-web and the T-web) to the new Voronoi-based scheme established by the AREPO code. Once, a characterization of the gas residing in the found structures of the cosmic web will be done.*

6 Expected Results

7 Bibliography

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