

 Contenu archivé le 2024-06-18



Computing in the dark sector: a Cactus toolkit for modified-gravity cosmologies

Rapports

Informations projet

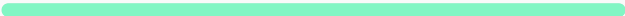
COSMOTOOLKIT

N° de convention de subvention: 249290

Projet clôturé

Date de début
1 Juin 2010


Date de fin
31 Mai 2013



Financé au titre de
Specific programme "People" implementing the
Seventh Framework Programme of the European
Community for research, technological
development and demonstration activities (2007 to
2013)

Coût total
€ 75 000,00

**Contribution de
l'UE**
€ 75 000,00


Coordonné par
MAX-PLANCK-GESELLSCHAFT
ZUR FORDERUNG DER
WISSENSCHAFTEN EV
 Germany

Ce projet apparaît dans...



Final Report Summary - COSMOTOOLKIT (Computing in the dark sector: a Cactus toolkit for modified-gravity cosmologies)

Project Context and Objectives:

Project COSMOTOOLKIT aims at designing, extending, and testing the community infrastructure of numerical relativity, contained in the Einstein Toolkit (<http://einsteintoolkit.org> ) and traditionally used to model systems of black holes and neutron stars, to tackle physical questions of cosmological interest and bring the full power of High Performance Computing to relativistic cosmology.

A question that has kept resurfacing in recent years is: does large-scale cosmology require a full, multi-scale relativistic treatment? The theory of general relativity is well studied in the isolated-object regime, which applies, for instance, to galaxies (which typically extend over a few kiloparsecs), and in the large-scale, statistically homogeneous regime, which is appropriate for regions of the universe larger than a few Gigaparsecs; general relativistic effects in these two regimes, however, are assumed not to “talk” to each other across the scales that separate them. In other words, one uses relativistic building blocks to construct a relativistic large-scale structure, but the way in which this structure is assembled is assumed to be almost exactly Newtonian.

The legitimacy of this approach is not so much rooted in an accurate study of the relativistic effects in the intermediate regime (a study of formidable computational complexity, which is only in its preliminary stages), as in the observational fact that the model deriving from this assumption reproduces the observations quite well. This result, however, comes at a price: the observational fits also indicate that over 95% of the energy density in the universe is provided by two components, dark energy and dark matter, of an as-of-yet unknown nature. As a consequence, exploring the nature of the dark sector has become a central theme in modern cosmology.

Filling this scale gap in our picture of the universe is thus not merely an academic exercise: over the past couple of decades, science agencies worldwide have invested the equivalent of several billions of Euros

for space missions aimed to measure some of the elusive properties of the dark sector, resulting in an unprecedented level of insight into the origin, evolution and fate of our cosmic habitat. Nonetheless, the new data has also opened up new questions, which can only be answered by refining the observations and developing detailed theoretical scenarios to frame them. The era of precision cosmology does not only involve precision data, but also a corresponding effort in precision modelling to correctly interpret these data.

Whilst the modelling of compact objects such as black holes and neutron stars has witnessed tremendous progress over the past two decades, both for the study of the strong-gravity regime (where potential deviations from general relativity would be largest) and for the detection of gravitational waves, the development of a full-3D relativistic cosmology is lagging behind. The description of crucial phenomena like the generation and the evolution of the seeds of cosmic structures are still limited to the perturbative regime, and the use of cosmological data to test the validity of general relativity is still in its infancy.

COSMOTOOLKIT aimed to change the status by adapting the infrastructure of numerical relativity to cosmological studies, producing the first fully-3D models of our universe, and thereby opening a field which could complement the theoretical efforts and verify them in concrete test cases. Full relativistic-hydrodynamics simulations of the large-scale universe are required to define the magnitude and properties of the relativistic, multi-scale effects in a cosmological spacetime, and thereby assess the regime of validity of the current “Newtonian” assumptions. Access to the relativistic non-linear regime would also amplify modified-gravity effects and guide the search for these effects in the wealth of cosmological data available today. Gravitational-wave signatures of deviations from general relativity are also within COSMOTOOLKIT’s scope and its planned infrastructure extensions.

COSMOTOOLKIT’s cycle started in June 2010 with an intense burst of code development, leading to the creation of the Cosmology suite, a collection of tools for the evolution of fluids such as cosmic dust and scalar fields, the generation of initial data and the analysis of the simulation data. These tools are based on state-of-the-art techniques such as automated code generation, a capability provided by the Einstein Toolkit. In particular, COSMOTOOLKIT’s legacy includes a parallel, multigrid solver for elliptic partial differential equations for the Cactus framework, an important infrastructural addition to the existing open-source Numerical-Relativity tools. The entire suite will be soon released as free software.

In addition to the new Cosmology suite, COSMOTOOLKIT has also contributed to the development of existing components of the Einstein Toolkit, such as the adaptive-mesh- refinement package Carpet, in order to generalize its mesh-refinement algorithm and extend its functionality to periodic spacetimes.

In several cases, fundamental issues with the problem formulation had to be resolved before a numerical effort could be devised. In parallel with the infrastructure development, and in collaboration with experts in mathematical relativity and cosmology, COSMOTOOLKIT’s focus has also come to include topics such as the existence and uniqueness of solutions on spacetimes that are spatially periodic, the choice of coordinate gauges in a non-asymptotically-flat spacetime, and the construction of periodic black-hole lattices. These may be regarded as the simplest relativistic solutions encompassing large-scale homogeneity and small-scale inhomogeneity; whilst these solutions were sought after for over fifty years, it was only within COSMOTOOLKIT that the first complete evolution was carried out and analyzed, unveiling

the lattice's surprising behavior and opening an abundance of questions for analytical and numerical researchers alike. These techniques were then refined and implemented in the expanding-lattice case, unveiling a rich phenomenology and laying the foundations for future studies on the propagation of light in generic cosmological spacetimes. COSMOTOOLKIT results placed themselves at the forefront of black-hole lattice research providing the first numerical time evolutions in both the contracting and the expanding phase.

Both the infrastructural and the physical developments have been disseminated in presentations and workshops in Germany and abroad, and the online portal blackholelattices.wikidot.com has been established to facilitate the exchange of data and ideas with remote collaborators. An outreach blog in Italian, chiaroeoscuri.wordpress.com has also been started to popularize cosmology to Italian-speaking readers. COSMOTOOLKIT's home page, aei.mpg.de/~bentiveg/cosmotoolkit.html will also serve as a repository for further developments and updates.

Dernière mise à jour: 27 Juin 2014

Permalink: <https://cordis.europa.eu/project/id/249290/reporting/fr>

European Union, 2025