Antonio Ragagnin

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Research Interests

Numerical Cosmology

- Large cosmological hydrodynamic simulations of cosmic structures
- The formation and evolution of Dark Matter haloes
- Comparison between simulated and observed properties of haloes and galaxies

Code development

- Optimising and running large, high-resolution, cosmological simulations
- Gravity and hydrodynamic solvers on GPU/accelerators
- High Performance Computing (HPC) and code re-engineering of N-body code infrastructure.

Work experiences

2019 – current, Trieste (Italy): Postdoc – Giuliano Taffoni, INAF

My current position is focused on re-engineering Gadget, a code used to produce large cosmological hydrodynamical simulations. The re-engineering of the code I am working at is a necessary step for efficiently running the next generation of cosmological hydrodynamical simulations. In this context I worked in identifying problems that arise only at high resolution full-physics simulations, the goal of the upcoming cosmological and zoom-in simulation campaign. A correct solution of these problems is a complex task that cannot be done only with HPC knowledge: a deep understanding of the underlying simulated physics is a must.

I analyzed for the first time the impact of baryonic effects together with the cosmological dependence on the Mass-concentration and sparsity relation using a set of Dark-Matter only, adiabatic and full physics cosmological hydrodynamical simulations (Ragagnin et al. 2020 submitted).

I am currently studying the dependency of Halo Occupation Distribution (HOD) (from high mass satellites, M_star>1e11) and accretion histories from cosmological parameters in Magneticum simulations and from gravitational softening and resolution on Dianoga simulations.

Education and training

- 2015 – 2018: Ph.D. In Astrophysics (cum laude) – Ludwig Maximilian University (LMU), Munich, Germany
- 2014 Tonale Winter school in cosmology
- 2012 ICTP Summer school in cosmology
- 2012 – 2014: Master degree in Theoretical Physics (110/110 cum laude) – Università degli studi di Trieste
- 2008 – 2009: Bachelor degree in Physics (110/110) – Università degli studi di Trieste

Awards and collaborations

- PI of CSCS Piz Daint 30000 node hour GPU computing time
- Co-I of various CINECA proposals
- HPC-Europa3 2020 grants for 1 month visiting LRZ and 240k core-hours
- Core-team member of Magneticum and Dianoga simulations
- PI of Gadget group at CSC GPU Hackathon 2020 to bring zoom-in simulations to GPUs

Teaching

- A.A. 2020/2021: Attività Didattica Integrativa, Foundations of HPC (held by L. Tornatore)
- A.A. 2020/2021: Lab assistant, Laboratorio di programmazione avanzata per la fisica (held by G. Murante)
- A.A. 2019/2020: Lab assistant, Laboratorio di programmazione avanzata per la fisica (held by G. Murante)

First Author Publications

Cosmology dependency of halo masses and concentrations in hydrodynamic simulations (submitted, 2020)

https://drive.google.com/file/d/1SZmJZc_dyqkRn7mOD-8XkA9O_6BIewhP/

We employ a set of Magneticum cosmological hydrodynamic simulations that span over 15 different cosmologies, and extract masses and concentrations of all well-resolved haloes between $z=0-1$ for critical overdensities $\Delta_\texttt{vir}, \Delta_{200c}, \Delta_{500c}, \Delta_{2500c}$ and mean overdensity $ \Delta_{200m}.$ We provide the first mass-concentration (Mc) relation and sparsity relation of hydrodynamic simulations that is modelled by mass, redshift and cosmological parameters $\Omega_m, \Omega_b, \sigma_8, h_0$ and that includes the overall effect of baryon physics as a tool for observational studies. \juno{We also quantify the uncertainty propagation of sparsity relation obtained with the aid of our mass-concentration relation. In particular we quantify the scatter induced by the mass-concentration relation itself and by the assumption of NFW density profiles.} We find that converting masses with the aid of a Mc relation carries an additional fractional scatter ($\approx 4\%$) originating from non-NFWness of halo density profiles.

Gadget3 on GPUs with OpenACC (2020)

We present preliminary results of a GPU porting of all main Gadget3 modules (gravity computation, SPH density computation, SPH hydrodynamic force, and thermal conduction) using OpenACC directives. Here we assign one GPU to each MPI rank and exploit both the host and accelerator capabilities by overlapping computations on the CPUs and GPUs: while GPUs asynchronously compute interactions between particles within their MPI ranks, CPUs perform tree-walks and MPI communications of neighbouring particles. We profile various portions of the code to understand the origin of our speedup, where we find that a peak speedup is not achieved because of time-steps with few active particles. We run a hydrodynamic cosmological simulation from the Magneticum project, with $2\cdot10^{7}$ particles, where we find a final total speedup of $\approx 2.$ We also present the results of an encouraging scaling test of a preliminary gravity-only OpenACC porting, run in the context of the EuroHack17 event, where the prototype of the porting proved to keep a constant speedup up to 1024 GPUs.

Dependency of halo concentration on mass, redshift and fossilness in Magneticum hydrodynamic simulations (2019)

We study the dependency of the concentration on mass and redshift using three large N-body cosmological hydrodynamic simulations carried out by the Magneticum project. We constrain the slope of the mass-concentration relation with an unprecedented mass range for hydrodynamic simulations and find a negative trend on the mass-concentration plane and a slightly negative redshift dependency, in agreement with observations and other numerical works. We also show how the concentration correlates with the fossil parameter, defined as the stellar mass ratio between the central galaxy and the most massive satellite, in agreement with observations. We find that haloes with high fossil parameters have systematically higher concentration and investigate the cause in two different ways. First, we study the evolution of haloes that live unperturbed for a long period of time, where we find that the internal region keeps accreting satellites as the fossil parameter increases and the scale radius decreases (which increases the concentration). We also study the dependency of the concentration on the virial ratio and the energy term from the surface pressure Es. We conclude that fossil objects have higher concentration because they are dynamically relaxed, with no in-fall/out-fall material and have time to accrete their satellites.

A web portal for hydrodynamical, cosmological simulations (2017)

This article describes a data centre hosting a web portal for accessing and sharing the output of large, cosmological, hydro-dynamical simulations with a broad scientific community. It also allows users to receive related scientific data products by directly processing the raw simulation data on a remote computing cluster. The data centre has a multi-layer structure: a web portal, a job control layer, a computing cluster and a HPC storage system. The outer layer enables users to choose an object from the simulations. Objects can be selected by visually inspecting 2D maps of the simulation data, by performing highly compounded and elaborated queries or graphically by plotting arbitrary combinations of properties. The user can run analysis tools on a chosen object. These services allow users to run analysis tools on the raw simulation data. The job control layer is responsible for handling and performing the analysis jobs, which are executed on a computing cluster. The innermost layer is formed by a HPC storage system which hosts the large, raw simulation data.

The following services are available for the users: (I) CLUSTERINSPECT visualizes properties of member galaxies of a selected galaxy cluster; (II) SIMCUT returns the raw data of a sub-volume around a selected object from a simulation, containing all the original, hydro-dynamical quantities; (III) SMAC creates idealized 2D maps of various, physical quantities and observables of a selected object; (IV) PHOX generates virtual X-ray observations with specifications of various current and upcoming instruments.

Exploiting the Space Filling Curve Ordering of Particles in the Neighbour Search of Gadget3 (2015)

Gadget3 is nowadays one of the most frequently used high performing parallel codes for cosmological hydrodynamical simulations. Recent analyses have shown that the Neighbour Search process of Gadget3 is one of the most time-consuming parts. Thus, a considerable speedup can be expected from improvements of the underlying algorithms. In this work we propose a novel approach for speeding up the Neighbour Search which takes advantage of the space-filling-curve particle ordering. Instead of performing Neighbour Search for all particles individually, nearby active particles can be grouped and one single Neighbour Search can be performed to obtain a common superset of neighbours. Thus, with this approach we reduce the number of searches. On the other hand, tree walks are performed within a larger searching radius. There is an optimal size of grouping that maximizes the speedup, which we found by numerical experiments. We tested the algorithm within the boxes of the Magneticum project. As a result we obtained a speedup of 1.65 in the Density and of 1.30 in the Hydrodynamics computation, respectively, and a total speedup of 1.34.