DEISA Newsletter

DISTRIBUTED EUROPEAN INFRASTRUCTURE FOR SUPERCOMPUTING APPLICATIONS

Vol. 8, 2008

Galaxies Intergalactic Medium Interaction Calculation

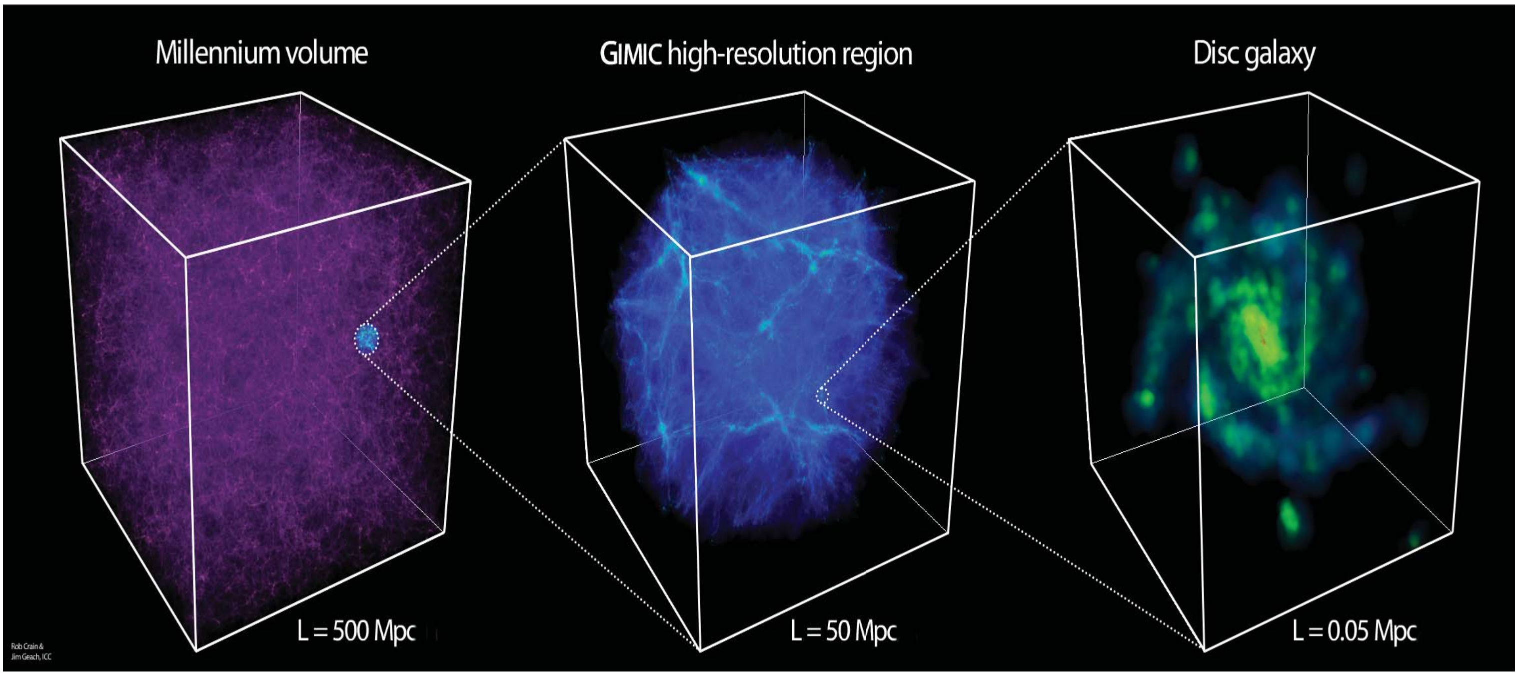

Fig. 1. The figure depicts structure formation in a computer simulated Universe covering a dynamic range of a factor of 10000 in linear scale. The left most image shows the Millennium simulation (Springel et al 2005) which models the distribution of dark matter on very large scales. The central image shows the results of a simulation of a particular region taken from of the Millennium simulation which has been resimulated at higher resolution than the Millennium simulation, and includes baryonic matter. This simulation was run as part of the GIMIC project, the aim of which is to model galaxy formation and its affects on the intergalactic medium. The GIMIC project used time on HPCx and was run under the auspices of the Deisa Extreme Computing Initiative. The right most image shows one example out of many of a disc galaxy forming within the GIMIC high resolution region. © Virgo Consortium

Millennium simulation is the largest ever calculation to follow the formation of the dark haloes that seed galaxies.

To understand the properties of the galaxies themselves, it is necessary to simulate how gas cools and forms stars in such haloes, says Professor Carlos Frenk, Director of the Institute for Computational Cosmology (ICC) and Principal Investigator of the Virgo consortium. Galaxies Intergalactic Medium Interaction Calculation (GIMIC) is a project of the Virgo consortium. Virgo is an international consortium of cosmologists that performs large numerical simulations of the formation of galaxies and the cosmic large-scale structure. GIMIC simulates the formation of galaxies in five regions selected from the Millennium simulation, but now it includes hydrodynamics. This allows Virgo members to obtain unprecedented insight into how galaxies form on truly cosmological scales

GIMIC makes full use of DECI's (DEISA Extreme Computing Initiative) common data repository and coordinated scheduling in a work farm approach to computation scheduling and post-processing, thereby facilitating joint international analysis. These simulations were performed within the DECI initiative of DEISA, and were run on HPCx with the assistance of EPCC.

GIMIC is a collaboration project between the Max Planck Institute of Astrophysics in Germany and the Institute for Computational Cosmology in Durham, in the UK. GIMIC includes also colleagues at Leiden in the Netherlands, at Sussex and at Nottingham in the UK. DEISA provides a focus for this large international collaboration, contributing important computing resources and a common data repository, which allows members in different countries to monitor the simulation and access the data.

Simulating the formation and evolution of galaxies and other structures in the universe from cosmological initial conditions, is one of the most difficult problems in computational physics. The non-local nature of the gravitational interaction makes it difficult to split the computational domain into more or less isolated areas that can be computed in parallel. In order to simulate the evolution of a patch of universe, one needs to account for the contribution of all matter in the rest of the universe. This requires subtle parallelization strategies.

The non-locality of the computational domains is the major bottleneck for the efficient use of cosmological computational codes on grid-based technology; one needs to have access to the largest parallel supercomputers with low latency interconnection, as available in DEISA.

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Provisional Results

"We are still actively analysing the data from the simulation. This is a non-trivial process because of the unprecedented size of the simulation, which requires the development of new analysis techniques. However, we have already been able identify where most of the matter in the universe is expected to reside. At present, astronomers have direct evidence for only about one percent of the mass in the universe", says Frenk. The Millennium simulation had clearly shown that the dark matter is arranged in filamentary structures made up of dark matter clumps – the cosmic web. GIMIC has now revealed that astrophysical processes separate the ordinary or baryonic matter from the dark matter even on large scales. As gas collapses to make a galaxy, the energy liberated by stars can blow powerful winds which heat the surrounding gas and pollute it with the products of nuclear fusion in the centres of stars – what astronomers call "heavy elements." "We now have an inventory of the distribution and thermodynamic state of the baryonic matter in the universe and its heavy element content. This will serve to guide astronomical searches for the currently missing bulk of the mass in the universe", explains Frenk.

In spite of the progress they have made in the GIMIC programme, the problem of galaxy formation remains largely unsolved. "Nobody in the world has yet succeeded in producing a realistic spiral galaxy like the Milky Way in a computer. We do not yet know if the reason for this is our poor understanding of the physics of galaxy formation or if our cosmological model is somehow incomplete. For example, the cosmological model that has been so successfully explored in the Millennium simulation assumes a particular kind of dark matter, the so-called cold dark matter. Since the particles that would make up this cold dark matter have not yet been discovered in the laboratory, we cannot be sure that our assumptions are correct. Petaflop machines will simultaneously allow us to model the physics of galaxy formation with increasing realism and to explore alternative assumptions for the cosmological model, including the nature of the dark matter. Ultimately, we would like to simulate a representative region of the Universe with full gas physics – in short to create a virtual universe", concludes Frenk.

Fig. 2. Professor Carlos Frenk explains their work on running a Galaxies Intergalactic Medium Interaction Calculation (GIMIC) computer simulation at EPCC under the auspices of DEISA.

Seismic wave propagation solutions for realistic 3D media

Dr. Martin Käser, Ludwig-Maximilians-Universität München, Germany
Dr. Michael Dumbser, Universität Stuttgart, Germany

The aim of this project is to provide realistic simulations of earthquake scenarios by running the highly accurate and powerful simulation code SEISSOL. The code is able to incorporate complex geological models and to account for a variety of geophysical processes that affect the seismic wave propagation, such as strong material heterogeneities, viscoelastic attenuation, and anisotropy. The synthetic seismograms for the models, describing real earthquake scenarios or volcano-triggered seismic events, are used in a variety of application fields.

Real earthquakes and seismic events

The objective of the SEISSOL project has been to perform highly accurate large-scale simulations of realistic wave propagation problems, such as real earthquakes or volcano-triggered seismic events. The models include a high degree of complexity involving heterogeneous material properties, real free-surface topography from digital elevation models and real source receiver locations. In this study, the sources consist of extended earthquake rupture models derived by inversion from real strong-ground motion data. On the one hand, the creation of highly accurate seismograms provides key datasets to investigate the physical properties of the earthquake rupture process. On the other hand, such synthetic datasets are used in volcano seismology to benchmark the moment tensor inversion routines and to determine their limits and applicability to real data in detail.

Performance improvements

As the underlying numerical method of SEISSOL is the Discontinuous Galerkin approach, it uses an explicit one-step time integration scheme to solve the governing partial differential equations. Therefore, a large amount of calculations are carried out on a rather small amount of data, i.e., the numerical algorithm is programmed in a cache-oriented manner. To achieve a performance improvement, the implementation of p-adaptation and local-time stepping on unstructured tetrahedral meshes has been investigated in detail. In particular, a more adequate mesh partitioning strategy, the use of optimized linear algebra library routines, and the use of optimized standard sparse matrix algorithms have been applied.

The simulations were performed on the HLRB 2 at the Leibniz-Rechenzentrum in Munich and typically used 256 to 512 processors. However, a few simulations were also carried out using 1024 processors, when the accuracy requirements for the results and therefore the number of elements or the approximation order was accordingly large.

Lancey Earthquake and volcano-triggered earthquakes

The project enabled us to create highly accurate data sets of synthetic seismograms for a variety of large-scale applications. Due to the incorporation of complex material properties, p-adaptation and local time stepping, an estimation of

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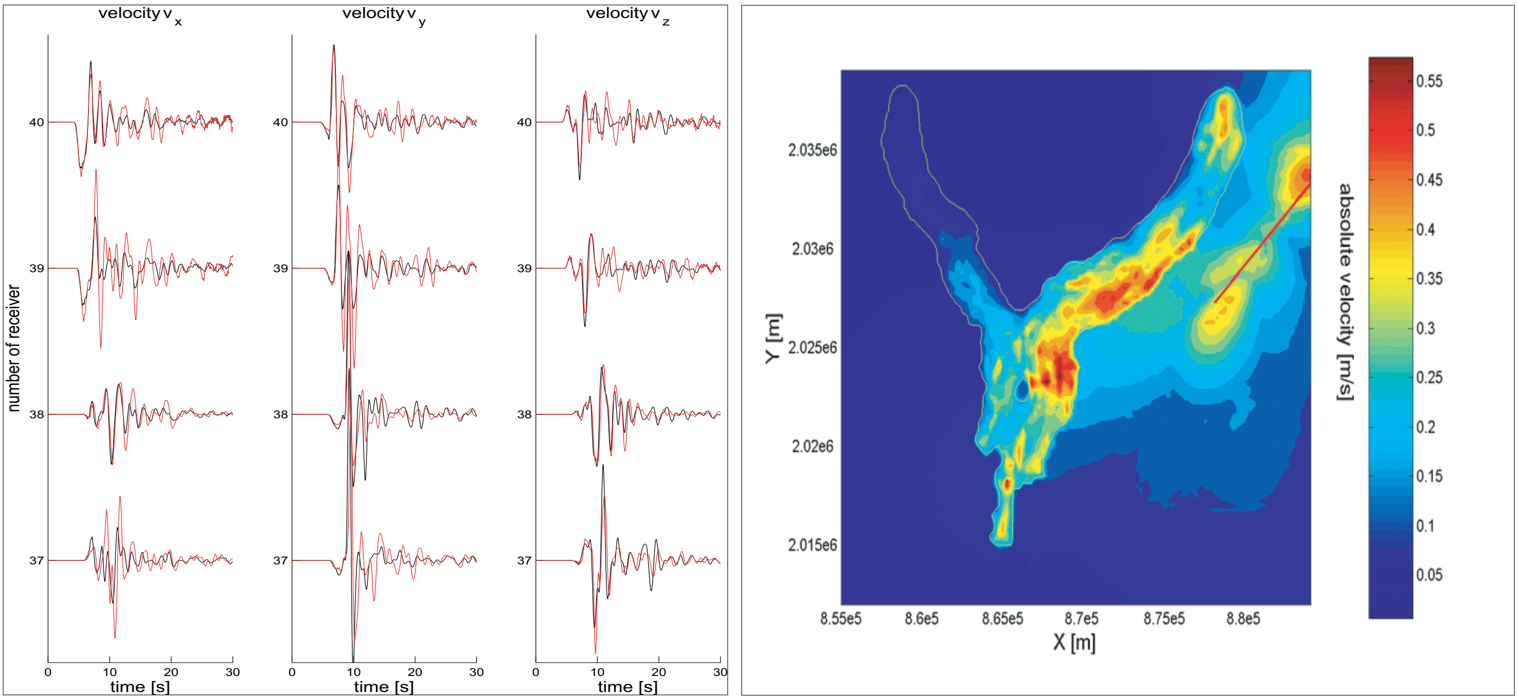

Fig. 3. Comparison of seismograms calculated for different receivers in the valley of Grenoble (left) Seismograms for a model without topography are shown in black, whereas seismograms with stronger amplitudes due to topography are shown in red. A map of the absolute velocity of the ground motion for the area of Grenoble shows the endangered regions (right). The thick red line shows the surface projection of the Belledonne fault, the thin yellow line represents the extension of the sedimentary basin below Grenoble.

the peak ground motion in the alpine valley of Grenoble could be performed. It was possible to analyse the influence of the topographic effect of the surrounding alpine terrain in detail, and a map of absolute velocity values of the ground motion along the Belledonne fault after the Lancey Earthquake of 8th September 1995 was produced (see Figure 1). Such data provides invaluable information for civil engineers when constructing earthquake resistant structures.

Furthermore, a comprehensive accuracy study was carried out. The influence of the geometrical source complexity on extended kinematic earthquake rupture models was also studied in great detail.

In addition, synthetic seismograms for the Merapi volcano in Indonesia have been calculated for a high-precision topographical model, allowing the effect on the seismic wave field to be determined. Different subsurface models of the volcano's interior structure have been assumed, which deviate from the homogeneous reference model. The distortion of the velocity structure in the modified models enabled the influence on the seismic signals recorded at the volcano's surface to be analysed. In this way, the performance of techniques to invert for the source location as well as for the seismic moment tensor that describes the volcano-triggered earthquake mechanism could be tested. This is an important issue, especially when searching for precursor signals for early warning systems that aim at the short-term forecast of future volcano eruptions.

DEISA Training: Portici, Naples, Italy, 17-18 September 2008

The training delivered in the DEISA (Distributed European Infrastructure for Supercomputing Applications) project in the past two years proved very successful. Therefore the training courses will be offered also under DEISA2 project. The first of these new training events took place at the CRESCO Supercomputer Centre in Portici, near Naples, in September.

The date and location of the event were chosen to coincide with a meeting of the EU-funded EUFORIA (EU Fusion fOR Iter Applications) project. EUFORIA aims to use High Performance Computing (HPC) to perform simulations of the plasmas inside fusion reactors, specifically focusing on the ITER (International Thermonuclear Experimental Reactor) project which is currently constructing the world's largest fusion reactor in the South of France. EUFORIA is one of the first European Virtual Communities to be supported by DEISA, hence this was an ideal opportunity to introduce them to the DEISA infrastructure. Most of the attendees came from the EUFORIA project, although the training was open to all DEISA users.

The first day covered the basics of the DEISA infrastructure and the fundamental middleware components for job submission and data management: UNICORE, DESHL and GridFTP. Attendees were given full DEISA accounts for the duration of the course, allowing them to submit real jobs to the live production infrastructure once they had installed and configured the DEISA software on their own laptops. The second day covered parallel IO, describing the IO functions available in the MPI standard and illustrating them with practical examples.

Two more training courses will be held by May 2009. For up-to-date details, keep an eye on the DEISA web pages at http://www.deisa.eu/news_press/training/.

DEISA Training:
http://www.deisa.eu/usersupport/training/
EUFORIA Project:
http://www.euforia-project.eu/
ITER Project:
http://www.iter.org/

Next DEISA events:

DEISA at Supercomputing 2008
Nov 15-21, 2008, Austin, Texas
Presentations at DEISA partners' booths and at ORNL booth.

DEISA Exhibition at ICT 2008
Nov 25-27, 2008, Lyon, France
Booth J18. More information:
http://ec.europa.eu/information_society/events/ict/2008/index_en.htm

DEISA Symposium and joint DEISA-PRACE scientific workshop
May 11-13, 2009
Amsterdam, The Netherlands