DEISA Newsletter

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Numeric computation reveals the mystery of turbulence

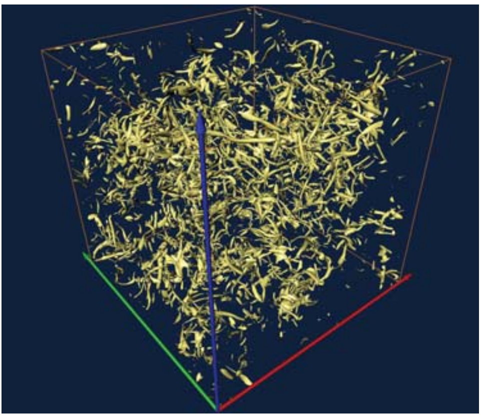

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Fig. 1: Most intense vortices in a turbulent flow. The figure shows an isovolume plot of the magnitude of vorticity. The maxima are organized in tube-like structures.

Resolving the nature of turbulence is one of the major challenges in physical research. The big question that remains unresolved in computational flow mechanics concerns the modeling of turbulence.

Joerg Schumacher at Ilmenau Technical University and his colleagues, have studied turbulent flows using a direct numerical simulation approach. Traditionally, turbulence has been modeled by means of averaged equations. Now, Schumacher has performed computations involving extremely fine whirls at a level where they are about to dissipate into non-existence.

"For the first time, we were able to really look into the inside of the phenomenon of turbulence. We have seen the powerful events that come into existence and die within turbulence", explains Schumacher, who took part in the 4th DEISA training session at CSC, Finland, in May 2007.

Simulation generated huge amount of data

The Direct Numerical Simulation (DNS) used by Schumacher is currently the most accurate method for numerical investigation of turbulent flow. The flow field is resolved directly from the Navier-Stokes equations without any averaging or turbulence modeling. The method requires immense computing capacity, and therefore, it has not been widely used. Schumacher's simulation took altogether 45 days and 800 000 CPU hours. This translates to 19 000 integration time steps of the mathematical model equations on 512 processors."Data processing was extremely challenging, because the simulation was so extensive. A particularly high resolution was applied in the computation. We used a spatial grid with over eight billion cells, so the simulation generated an enormous volume of data. We had to figure out in advance how to arrange the data in an optimal and efficient manner", says Schumacher.

The data volume was so large that it simply was not possible to store everything on a disk. "We were able to store only an approximate 15 percent of all the data", Schumacher says. This results still to 1.7 TBytes of flow data that were kept. Among these data are so-called quasi-Lagrangian fields that monitor not only the velocity at tracer positions during their roller coaster ride through the flow, but in their whole environment. Such analysis which has been done for the first time and which is not yet possible in experiments gives completely new insights into the dynamic formation of vortices in turbulence.

Simulation replaces windtunnels

"I believe that, in the future, the traditional flow calculation methods and our direct numerical simulation may converge. This, however, calls for a higher computing capacity", says Schumacher. By means of computational methods, we have, in recent years, been able to reduce the expensive wind tunnel experiments necessary in, for example, the automotive industry.

"Flow in the wind tunnel differs from the reality, if the parameters are not exactly accurate. The technology is expensive and laborious. So, if we can develop more sophisticated models for turbulence, there will be less need for expensive wind tunnel measurements for cars, trains and airplanes", Schumacher concludes.

Researchers of the Eta2006 project: Jörg Schumacher, Imenau Technical University; Bruno Eckhardt, University of Marburg; Katepalli R. Sreenivasan, ICTP Trieste.

ParCo2007 report

A DEISA Mini-Symposium was held as part of ParCo2007 in Jülich, Germany, on the 5th of September, 2007. It was a lively and colourful meeting, with nine talks presented to around 20 people in attendance. The talks were from three broad areas: an overview of DEISA and its constituent parts, the processes of supporting scientists within a distributed environment, and talks from scientists describing results which could not be obtained without DEISA.

The mini-symposium was opened by the head of DEISA, Victor Alessandrini, with a talk entitled DEISA: Enabling Cooperative Extreme Computing in Europe. Two talks followed on methods of accessing the DEISA infrastructure, namely Effective Methods for Accessing Resources in a Distributed HPC Production System, presented by Andreas Vanni, and Submission Scripts for Scientific Simulations on DEISA, given by Gavin Pringle.

Klaus Gottschalk presented GPFS: a Cluster Filesystem, where he gave an overview of GPFS now and in the future. Then Alice Koniges, from Lawrence Livermore National Lab, spoke about Development Strategies for Modern Predictive Simulation codes, which was of great interest to DEISA staff for developing and supporting software using distributed resources. Hermann Lederer then reported on a DECI success story, where a particular code had been scaled to thousands of processors, in a talk entitled Application Enabling in DEISA: Hypserscaling of Turbulence Codes Supporting ITER.

Finally, three scientific talks described groundbreaking work achieved on DEISA, namely First Principles Simulations of Plasma Turbulence within DEISA, presented by Frank Jenko, Heavy Particle transport in Turbulent Flows, given by Alessandra Lanotte, and mini-symposium was concluded with an excellent talk from Marc Baaden entitled Membranes Under Tension: Atomistic Modeling of the Membrane_Embedded Synaptic Fusion Complex.

Overall, the organisers were very pleased with the event and interested readers will be able to access the slides via the ParCo2007 website http://www.fz-juelich.de/conference/parco2007 and read the associated papers in the up-coming Conference Proceedings.

Planck satellite simulations

Fabio Pasian, Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Trieste, Italy, and
Hannu Kurki-Suonio, University of Helsinki, Finland
Samuel Leach, International School of Advanced Studies, Trieste, Italy

DEISA's supercomputing framework was used to simulate several times the whole mission of the Planck spacecraft's low frequency instrument, LFI.

The LFI is an array of 22 tuned radio receivers that will operate at –253°C on board the Planck spacecraft. The LFI will image the sky at three frequencies between 30 and 70 GHz.

ESA is preparing Planck to be launched in July 2008 with a mission to collect and characterize radiation from the Cosmic Microwave Background (CMB) using sensitive radio receivers operating at extremely low temperatures.

Data on how the universe began

CMB is relic radiation from the Big Bang, and ever since the detection of small fluctuations in the temperature of this radiation, announced in late 1992, astronomers have used the fluctuations to understand both the origin of the Universe and the formation of galaxies.

Planck will measure the temperature variations across this radiation background and provide a map of the Cosmic Microwave Background field at high angular resolution, covering at least 95% of the sky over a wide frequency range.

The LFI-sim proposal aimed at using the supercomputing framework provided by DEISA to simulate several times the whole mission of Planck's LFI instrument, on the basis of different scientific and instrumental hypotheses, and to reduce, calibrate and analyze the simulated data down to the production of the final products of the mission, in order to evaluate the impact of possible LFI instrumental effects on the quality of the scientific results, and consequently to refine appropriately the data processing algorithms.

The LFI-sim project within DECI concentrated on understanding the effect of optical systematic effects, i.e., the effects derived from the optical behavior of Planck receivers. In particular, one of the critical aspects previously impossible to evaluate was tackled, i.e., a complete study of the effect of observing the sky with realistic beams on the scientific results of the mission. This was successfully achieved.

Simulating the LFI data

The logical sequence for simulating and processing LFI data has been the following:

- from cosmological parameters, generate ideal CMB sky; optionally, add foregrounds to obtain an ideal reference sky at all LFI frequencies;
- "observe" the ideal sky with a numerical model of the LFI instrument (in this case with realistic beams and noise) and obtain time series of observed data; process, optionally removing systematic effect(s), the time series and obtain frequency maps;
- separate and remove foregrounds to obtain the CMB "observed" map;
- build the "observed" CMB power spectrum and compare with the predicted one.

Results

Several simulation runs were made, and part or all of the above steps have been performed for each run. The basic approach has been to work on ideal CMB maps and to evaluate the impact of realistic beams on the "observed" CMB maps, and on the resulting power spectrum: this has allowed to single out the effect of distorted beams on the scientific results of the mission, isolating possible interactions with other data processing steps. This approach was followed also when the first laboratory measurements of LFI beam shapes became available, with accurate values for the sidelobes, which mostly contribute to distortion. It was found that the measured effect of beam distortion on the scientific results (i.e., the power spectrum) is of the third order, but is not completely negligible and should be considered when the most refined results are to be produced.

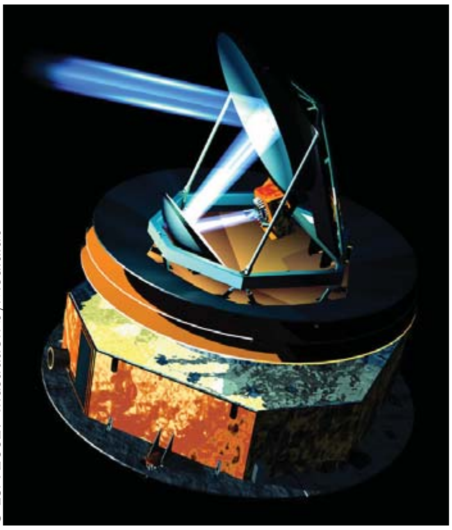
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Fig 2: Image shows the path of light aiming into the telescope and being reflected onboard Planck by mirrors into the focal plane assembly.

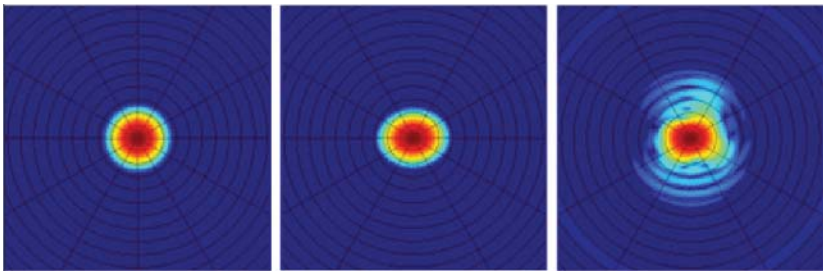
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Figure 1: Simulated response of the LFI-28 beam, observing the sky at the frequency of 30 GHz. From left to right: ideal beam response (circular); response non-ideal at the first order (elliptical); realistic respose (on the basis of laboratory measurements).

For this case, however, the beam deconvolution code available at the moment is not mature enough to consider realistic noise, and needs further refinement. Some simulation runs were performed to build and process full-fledged reference skies in various frequencies, with the purpose of understanding possible inter-dependencies of the various data processing steps. It was found that the processing steps are separable up to the numerical precision of the simulation.

Some interesting findings were achieved on the algorithmic aspects of the pipeline. First, the results of the optimal IGLS map-making algorithm are obtainable (within a level of error smaller that the intrinsic instrumental error) using hybrid codes, which combine concepts from both destriping and maximum-likelihood map-making, but are much more efficient to run. IGLS map-making could be run on the Data Processing Centre DPC hardware only to produce the "final" most accurate results.