Horizon Project: computer simulation extends our knowledge of the Universe

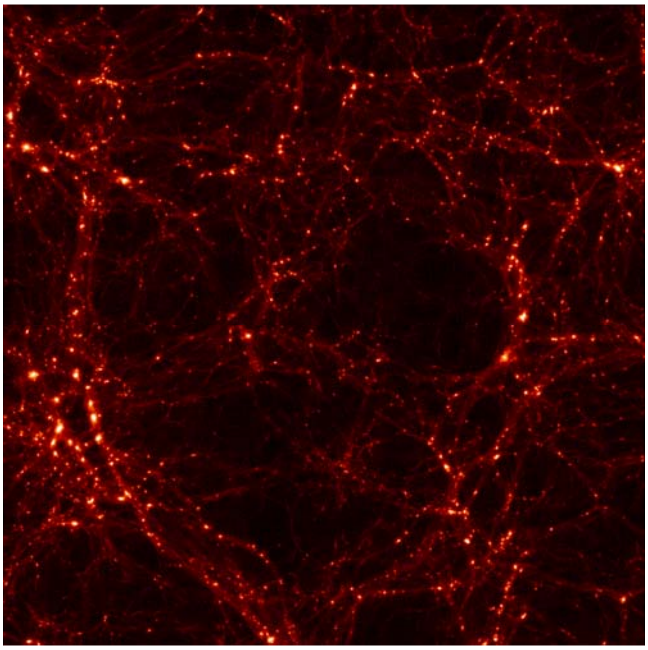
In Astrophysics, solving equations in the field of the mechanics of self-gravitating fluids, using more effective algorithms and increasingly more powerful supercomputers, helps us to model the structural formation of the universe and to compare models to astronomical observations with an unprecedented degree of realism.
This was the objective of a simulation carried out in 2007 on the computers of the CCRT.
The simulation was carried out as part of the Horizon project, a collaboration between the CEA, the CNRS and several universities bringing together around 20 scientists and academics.

In the first stage, the researchers defined the "initial conditions", likely to act as the departure point for the simulations, by observing the so-called cosmic background radiation at 3 degree K[1]; it is impossible to follow the individual trajectories of the large number of particles which are used to describe the cosmological fluid.

With nearly 70 billion particles and over 140 billion elements, the computation performed at the CCRT is the largest ever n-body system[2] modelled by computer.
For the first time in the history of scientific computing, it is possible to describe half the observable universe, as well as a galaxy like the Milky Way with over a hundred particles!

To simulate such volumes in such fine detail, the members of the Horizon Project team used the 6144 Intel Itanium2® processors that make up the BULL NovaScale 3045 computer at the CCRT for full-scale operation of the "RAMSES" program.

This program, developed at CEA in conjunction with the astrophysicists working on the Horizon Project, makes use of an adaptive mesh[3] that provides a spatial resolution never before achieved (equivalent to a cubic grid with sides of length 262,144 mesh elements!).



Thanks to the experts at BULL and the CCRT, the programme was able to draw on the computer resources for nearly two months, using over 18 Terabytes (i.e. 18,000 gigabytes) of RAM and generating approximately 50 Terabytes of data to disk.

The same project, performed on a single computer, would have taken over a thousand years to complete.

The Horizon Project simulation has made it possible to predict the distribution of matter in the universe with an unprecedented precision and realism. Researchers will soon be able to compare the model with observations of the entire sky. These observations will soon be available from the European Space Agency's Planck mission, which was launched in 2009.
They will also be able to prepare future experiments on the gravitational lens[4] such is the "Dark UNiverse Explorer" (DUNE) whose aim is to determine the nature of dark matter.

For further details, see: Website of the IRFU

[1] This kind of radiation is the fossil record of the Universe from the time that it finally became transparent to light - hence, it is 380,000 years old: This light reaches us 13 billion years later, and tells us about the conditions that reigned back then in the cosmological plasma.

[2] An "n-body system" is a set of matter points, or "particles" that are subject to mutual gravitational attraction. Powerful computers are needed to calculate the trajectories of each particle in an n-body system.

[3] To solve equations using computers in the field of fluid mechanics, it is necessary to discretise space into small volumes, or "elements". This set of elements, known as a "grid" or "mesh", represents the system one wishes to describe, in our case a large fraction of the Universe. To make the calculation more precise, smaller elements are used for dense regions such as galaxies: the mesh automatically adapts to local conditions, hence the term "adaptive mesh".

[4] The light from distant galaxies is deflected by the gravitational effect of the matter it encounters along its path. This gravitational lens effect, predicted in Einstein's general theory of relativity, is used to measure the quantity of matter between these galaxies and ourselves, thereby allowing us to test the overall theory of the formation of the structures of the Universe.