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BULGARIAN GRID, BULGARIAN VIRTUAL OBSERVATORY AND SOME ASTRONOMICAL APPLICATIONS *

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Abstract: The development of the Bulgarian GRID, new possibilities for Bulgarian Virtual Observatory and some basic astronomical GRID applications from the published papers and internet are reviewed. Amongst the basic applications are N_body simulations, looking for dark matter, dark energy and neutrino, large scale structure of the Universe, stellar and galaxy evolution, active processes on the Sun, near earth object discovery, specialised software and firmware, network telescopes architecture etc.

1. INTRODUCTION

During the 2009 – 2011 years the Bulgarian High performance computing GRID for advanced scientific applications under the NSF DO 02-115/2009 grant is establishes. The first stage of the project is over – the grid system was configured and tested and it is under regular profit. The review presented here is based on the original published papers and internet information as well. The main goal is to point the possibilities of GRID for scientific investigations for the Bulgarian astronomical community.

ACM Computing Classification System (1998): A.0, I.4.0, J.2
Key words: GRID, Virtual observatory, astronomical grid applications, grid and VO software, GRID portals, simulations, dark energy, stellar and galaxies evolution.

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For the beginning one always could reviewed ***iSGTW*** web site:

- ***International Science Grid This Week*** (www.isgtw.org)

iSGTW is an international, weekly, on-line science-computing newsletter that shows the importance of distributed computing, grid computing, cloud computing and high-performance computing. It does so by reporting about the people and projects involved in these fields, and how these types of computing technologies are being applied to make scientific advances.

2. GRID PROJECTS

The picture could be fulfilled with portals and services. In the table below the ***basic Grid Projects,*** including some national and older ones, are summarised.

- European Grid Initiative	**National Grid projects**	**Previous projects**
EMI - European Middleware Initiative	Dutch Grid	EGEE
gLite - European middleware distribution	GridPP	European Data Grid
Open Science Grid - the U.S scientific Grid infrastructure	INFN Grid	Datatag
Virtual Data Toolkit - provides middleware distribution	LCG France	Grid2003
	NorduGrid	GriPhyN
	WestGrid EGI	iVDGL
	GÉANT - European academic and research network infrastructure	PPDG

- ***EGEE - Enabling Grids for E-sciencE*** (www.eu-egee.org)

The **E**nabling **G**rids for **E**-scienc**E** project is no longer active. The project ***officially ended on April 30, 2010.*** The distributed computing infrastructure is now supported by the ***European Grid Infrastructure.*** This long-term organisation coordinates National Grid Initiatives, which form the country-wide building blocks of the pan-European Grid. Here are some ***Regional Web Site pages.***

EGEE South East Europe Spain EGEE-III site Romanian Grid site	Bulgarian Grid portal Cyprus Grid site Hungarian Grid site	Russian website Portuguese website Slovak website

Welcome to Bulgarian Grid Portal (www.grid.bas.bg)

Grid computing is a form of distributed computing whereby a "super and virtual computer" is composed of a cluster of networked, loosely-coupled computers, acting in concert to perform very large tasks. This technology has been applied to computationally-intensive scientific, mathematical, and academic problems through volunteer computing, and it is used in commercial enterprises for such diverse applications as drug discovery, economic forecasting, seismic analysis, and back-office data processing in support of e-commerce and web services. What distinguishes grid computing from typical cluster computing systems is that grids tend to be more loosely coupled, heterogeneous, and geographically dispersed. Also, while a computing grid may be dedicated to a specialized application, it is often constructed with the aid of general purpose grid software libraries and middleware.

- ***AstroGRID*** (www2.astrogrid.org)

AstroGrid is the doorway to the Virtual Observatory (VO). It provides a suite of ***desktop applications*** to enable astronomers to explore and bookmark resources from around the world, find data, store and share files in VOSpace, query databases, plot and manipulate tables, cross-match catalogues, and build and run scripts to automate sequences of tasks. Tools from other Euro-VO projects inter-operate with AstroGrid software, so one can also view and analyse images and spectra located in the VO.

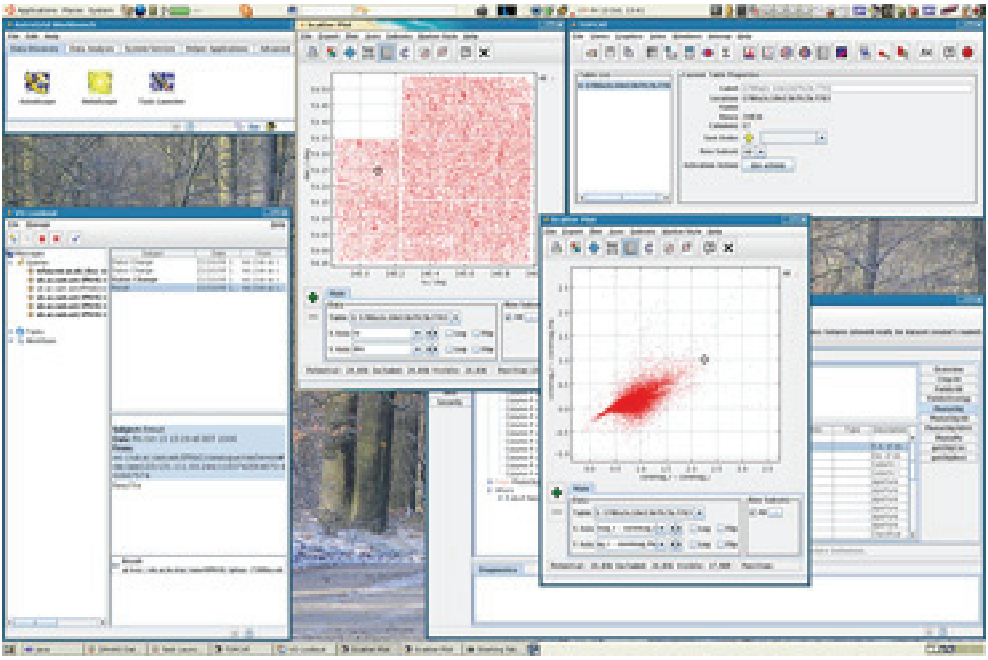


Figure 1: Screenshot from the AstroGrid WEB_page.

AstroGrid, a UK-government funded, open-source project, helps create universal access to observational astronomy data scattered around the globe. ***The AstroGrid consortium***, which ***consists of 11 UK university groups***, represents astronomy and computing groups with background in handling and publishing such data. The consortium worked with international partners to agree upon standards for published observational astronomy data, so that all astronomers could interact with all data sets.

The AstroGrid workbench is the main user interface for astronomers accessing the virtual observatory. The global set of standards agreed upon by the consortium and its partners allows any astronomer to query the virtual observatory to ask for information on a certain area of the sky.

Through AstroGrid, UK astronomers can also access workflows and applications for data analysis. AstroGrid has also created the "voSpace" program that allows astronomers to share their workflows. For a lot additional of possibilities see paper of Lawrence (2002).

- ***AstroGRID-D -*** enabling grid science in the German Astronomical community.

Figure 2: Screenshot from the AstroGrid-D WEB_page.

3. MIDDLEWARE and FRAMEWORKS

The structure of the instrumentation between software and hardware will be shortly reviewed in this part.

- FALKON, a Fast and Light-weight tasK executiON framework for Clusters, Grids, and Supercomputers. **Among**st the projects is ***AstroPortal.*** Large astronomy datasets are generally ***terabytes in size*** and contain ***hundreds of millions of objects*** separated into ***millions of files. The key question*** **is:** "How can the analysis of large astronomy datasets be made a reality for the astronomy community using Grid resources?" ***The answer*** **is: the *"AstroPortal",*** a science gateway to grid resources that is specifically designed for the astronomy community - http://www.cs.uchicago.edu/~iraicu/projects/Falkon/astro-portal.html .

- ***GRACIE: Grid Resource Virtualization and Customization Infrastructure*** (net.pku.edu.cn)**.** ***Gracie*** is a lightweight execution ***framework for efficiently executing massive independent tasks in parallel on distributed computational resources. Three optimization strategies*** have been devised to improve the performance of Grid system.

Pack up to thousands of tasks into one request.

Share the effort in resource discovery and allocation among requests by separating resource allocations from request submissions.

Pack variable numbers of tasks into different requests, where the task number is a function of the destination resource's computability.

Gracie is a computational grid software platform developed by Peking University (Li et al. 2008).

- ***NIMROD*** **(**messagelab.monash.edu.au/NimrodPortal**)** - A million questions or a few good answers? The ***tool set***, called ***Nimrod -*** http://messagelab.monash.edu.au/Nimrod , automates the process of finding good solutions to demanding computational experiments. Importantly, Nimrod is more than a job distribution system; it ***is a high level environment for conducting search across complex spaces***.

The number of jobs, and thus the parallelism, can be varied at run time, and the Nimrod scheduler places tasks on the available resources at run time. Users can ***ask complex questions such as*** "Which parameter values will minimize the output of my model?" This helps shield the user from the complexity of managing lots of independent jobs. In many cases it is possible to establish a new experiment in minutes.

- ***IMAGER: A Parallel Interface to Spectral Line Processing*** (Roberts & Crutcher 1997).

IMAGER is an interface to parallel implementation of imaging and deconvolution tasks of the Software Development Environment (SDE) of the NRAO. The interface is based on the MIRIAD interface of the BIMA (Berkeley-Illinois-Maryland Association) array and it allows for interactive and batch operations - with such instruments as the VLA and the BIMA telescopes one could have spectral line data sets in excess of a gigabyte... Astronomers need access to fast processing to allow the analysis of such large data sets and to use different methods of ***non-linear deconvolution***. ***Radio synthesis data reduction*** has been one of the most computer intensive operations in observational astronomy. In the common case of radio spectral line observations, large numbers of frequency channels lead to large amounts of data. The analysis of spectral line data, in which each channel is independent from every other channel, is an embarrassingly parallel problem.

- ***Parallel-Processing Astronomical Image Analysis Tools for HST and SIRTF***

NASA applied information system researches, develops and implements ***several parallel-processing astronomical image-analysis tools for stellar imaging data from the Hubble Space Telescope and the Space Infrared Telescope Facility –*** see, e.g. Mighell (2005). This project combines the enabling image-processing technology of the Principal Investigator's ***new digital PSF-fitting MATPHOT algorithm for accurate and precise CCD stellar photometry*** with enabling technology of Beowulf clusters which offer excellent cost/performance ratios for computational power. ***Data mining tools for quick-look stellar photometry and other scientific visualization tasks*** will also be written and used in order to investigate how such tools could be used at the data servers of NASA archival imaging data like the Space Telescope Science Institute.

4. SPECIALISED SOFTWARE

Here we present some selected specialised software for astronomical grid computing.

- ***AMEEPAR - Parallel processing for hyperspectral imaging***

The wealth of spatial and spectral information provided by ***hyperspectral sensors (with hundreds or even thousands of spectral channels)*** has quickly introduced new processing challenges. In particular, ***many hyperspectral imaging applications require a response in (near) real time*** in areas such as environmental modeling and assessment, target detection for military and homeland defense/security purposes, and risk prevention and response.

At the time being only a few parallel processing algorithms exist in the open literature – Plaza (2006a, 2006b).

To address the need for integrated software/hardware solutions in hyperspectral imaging, a highly innovative processing algorithms on several types of parallel platforms, including commodity (Beowulf-type) clusters of computers, large-scale distributed systems made up of heterogeneous computing resources, and specialized hardware architectures is developed.

Several parallel algorithms to analyze the AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) data were implemented. Amongst them is

- The automated morphological extraction (AMEEPAR). This is one of the few available parallel algorithms that integrate spatial and spectral information – Wozniak (2009). Using 256 processors, AMEEPAR provided a 90% accurate debris/dust map of the full AVIRIS data in 10s, while the P-ATGP algorithm was able to detect the spatial location of thermal hot spots in the WTC area in only 3s.

On the Figure 3 is ***hyperspectral image*** collected by the NASA Jet Propulsion Laboratory's AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) system ***over the World Trade Center*** (WTC) area in New York City on September 16, 2001. The data comprises ***614 samples, 3675 lines, and 224 spectral bands, for a total size of 964MB***.

Figure 3 shows a false-color composite of a portion of the scene, in which the spectral channels at 1682, 1107, and 655nm are displayed as red, green, and blue respectively. Here, vegetation appears green, burned areas appear dark gray, and smoke appears bright blue due to high spectral reflectance in the 655nm channel.

Figure 3: A hyperspectral image of the World Trade Center.

- ***GADGET-2 – a code for cosmological simulations of structure formation.***

Gadget **i**s a freely available ***code for cosmological N-body/SPH simulations*** on massively ***parallel computers*** with distributed memory. GADGET uses an explicit communication model that is implemented with the standardized MPI communication interface. ***The code can be run on almost all supercomputer systems*** presently in use, including ***clusters of workstations*** or ***individual PCs***. All details – in http://www.mpa-garching.mpg.de/gadget/ .

GADGET ***computes gravitational forces with a hierarchical tree algorithm*** (optionally in combination with a particle-mesh scheme for long-range gravitational forces) and represents fluids by means of smoothed particle hydrodynamics (SPH). The code can be used for studies of isolated systems, or for simulations that include the cosmological expansion of space, both with or without periodic boundary conditions. In all these types of simulations, **GADGET** follows the evolution of a self-gravitating collisionless N-body system, and allows gas dynamics to be optionally included. Both the force computation and the time stepping of **GADGET** are fully adaptive, with a dynamic range which is, in principle, unlimited.

GADGET can therefore be used to address ***a wide array of astrophysically interesting problems***, ranging from ***colliding and merging galaxies***, to the ***formation of large-scale structure in the Universe***. With the inclusion of additional physical processes such as radiative cooling and heating, **GADGET** can also be used to ***study the dynamics of the gaseous intergalactic medium***, or to address ***star formation*** and its regulation by ***feedback processes***.

GADGET comes with a ***number of small examples*** that can be run to develop a feel for working with the simulation code:

A pair of colliding disk galaxies (collisionless).
A spherical collapse of a self-gravitating sphere of gas.
Cosmological formation of a cluster of galaxies (collisionless, vacuum boundaries).
Cosmological structure formation in a periodic box with adiabatic gas physics.

- ***CRBLASTER : a fast parallel-processing program for cosmic ray rejection***

Many astronomical image-analysis programs are based on algorithms that can be described as being ***embarrassingly parallel***, where ***the analysis of one subimage*** generally ***does not affect the analysis of another subimage***. Yet few parallel-processing astrophysical image-analysis programs exist that can easily take full advantage of todays fast multi-core servers costing a few thousands of dollars. A major reason for the shortage of state-of-the-art parallel-processing astrophysical image-analysis codes is that the writing of parallel codes has been perceived to be difficult.

CRBLASTER - a new fast ***parallel-processing image-analysis program does cosmic ray rejection*** using van Dokknm's L.A.Cosmic algorithm. CRBLASTER (Mghell 2008) is written in C using the industry standard Message Passing Interface (MPI) library. For example processing a single 800×800 HST WFPC2 image takes 1.87 seconds using 4 processes on an Apple Xserve with two dual-core 3.0-GHz Intel Xeons; the efficiency of the program running with the 4 processors is 82%.

The code can be used as a software framework for easy development of parallel-processing image-anlaysis programs using embarrassing parallel algorithms: the biggest required modification is the replacement of the core image processing function with an alternative image-analysis function based on a single-processor algorithm.

- ***N_body-sh1p - a parallel direct N_body code*** (Gualandris et al. 2007)

This is an **Educational N-body integrator** with a shared but variable time step (the same for all particles but changing in time), using the Hermite integration scheme (Hut & Makino 2003) in *The art of Computer Science*. The source code has been ***adapted for a parallel ring algorithm*** using the MPI library.

Typical command line (generates : n24body.out)

% nbody_sh1p < n24body.in > n24body.out

Small ***timing test*** (perfomed by A. Gualandris) for 128, 256 and 512 particles ***with up to 32 processors*** on the ***Blue (Boewulf) linux cluster*** is presented at SARA.

- ***Parallel processing algorithms***

A papers and books present the parallel processing including algorithms, architectures etc. Among the basic books is one of Parhami (1999). Cosmological problems, solved with parallel processing are presented in Bode & Bertshinger (1995) and in Ferrell & Bertshinger (1995).

5. MODELLING AND SIMULATIONS

In this part selected astronomical simulations, modelling and experiments are presented.

- ***SkyMaker*** (www.astromatic.net/software/skymaker)

SkyMaker is a program that simulates astronomical images. It accepts object lists in ASCII generated by the Stuff program to produce realistic astronomical fields. SkyMaker is part of the EFIGI development project. The authors are Emanuel Bertin and Pascal Fouque (Bertin 2009).

Cosmic simulation - a lot of things in **http//www.igstw.org**

Cosmic structure formation theory has passed test after test, ***predicting how many galaxies will form***, ***where they will form***, and ***what type of galaxy they will be***. But for almost 20 years, its predictions about the central mass of dwarf galaxies have been wrong.

Worldwide, there are many teams working on their own versions; each attacks the problem from a different angle.

E.g. Governato et al. (2010) say: "Potentially, ***this is a very big problem for the model***. It might imply that ***the dark matter particle that we think is the correct one is not the correct one***, or ***maybe*** that ***gravity works differently*** than we think it does. So ***this is a very fundamental problem for physics.***"

A simulation running on computer resources at NASA Advanced Supercomputing Division, the Arctic Region Supercomputing Center, ***and TeraGrid*** may have resolved this conundrum. ***A more realistic model of how stars form and die, incorporated into the existing cosmic structure formation theory***. It turns out that ***when a star near the galactic center explodes, a lot of interstellar gas is blown away from the center of the galaxy***. As a result, ***less stars form at the center, because there is less gas***. When stars explode they can eject gas, but it is not clear enough how much it would impact galaxy formation...

To create the simulation about ***a million computer hours were used***, which means that it would have taken close to a hundred years to run the same simulation on the average desktop.

Klypin's team (Klypin et al. 1999, Klypin et al. 2007) is exploring ***the large-scale effects of energy released by young stars***.

Stars are forming, and ***young stars release large amounts of energy into the gas that surrounds them***. That energy finds its way to larger scales, ***affecting the motion of gas in the whole galaxy*** – even the way it is being accreted in the galaxy.

Over time, scientific understanding of processes such as star formation has evolved, yielding new equations. The equations can in turn be used to refine the computational model.

Bertshinger (1995) presented the COSMICS codes. Mayer et al. (2008) presented the formation of disk galaxies and on http://hydra.susx.ac.uk HYDRA consortium presented its N_body hydrodinamical simulations.

- ***Flip-flopping of black hole accretion disks***

The accretion disk of a black hole forms from gas attracted by the black hole's massive gravitational pull. For the last 20 years, astrophysicists have debated ***whether the whirlpool-like motion of the accretion disk will periodically reverse motion, a behavior called 'flip-flop'? According to*** a new ***simulation*** powered by ***TeraGrid***, the ***whirlpools of gas flip-flop as they are sucked into black holes*** (Blondin & Pope 2009)**.**

When ***flip-flopping first turned up in a 1988 numerical simulation***, some scientists argued that it explains recurrent x-ray flares observed by the European X-Ray Observatory in 1985. But in subsequent years, although ***some simulations showed flip-flop, others did not***, casting doubt on the existence of the phenomenon. The earlier work was criticized for a wide variety of reasons, but the chief among them was the lack of computer power and hence accuracy of the computation.

The most basic form of the equation used in the simulation was originally formulated by Fred Hoyle and Ray Lyttleton in 1939. The simulation shows that ***the accretion disk reversed direction repeatedly***, confirming that ***at least in this model of black hole accretion disks, flip-flop does occur***.

- ***Millennium Simulation Project***

The Millennium Simulation Project (www.mpa-garching.mpg.de/galform/virgo/millennium) is helping ***to clarify the physical processes underlying the buildup of real galaxies and black holes***. It has ***traced the evolution of the matter distribution***. The *Millennium Run* used more than ***10 billion particles*** to trace t***he evolution of the matter distribution in a cubic region of the Universe over 2 billion light-years*** on a side. It loaded the main principal supercomputer at the Max Planck Society's Supercomputing Centre in Garching, Germany for more than a month. By applying sophisticated modelling techniques to the 25 Tbytes of stored output, ***Virgo scientists*** have been able to ***recreate evolutionary histories both for the 20 million or so galaxies*** which populate this enormous volume ***and*** for the ***supermassive black hole***s which occasionally power quasars at their hearts. By comparing such simulated data to large observational surveys, one can clarify ***the physical processes underlying the buildup of real galaxies and black holes***. Amongst them are:

A journey through the simulated universe.

The dark matter distribution in the universe at the present time

The galaxy distribution in the simulation

on very large scales

for a rich cluster of galaxies

Slices of the dark matter distribution

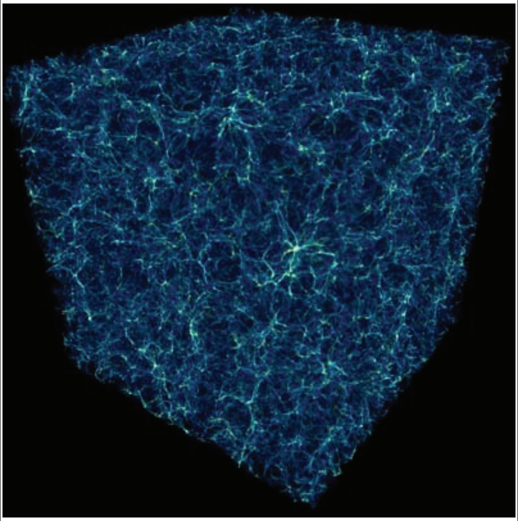
Halo and semi-analytic galaxy catalogues

How did the universe evolve into the structure we know?

The very early universe consisted of homogeneous gas with tiny perturbations. As the gas cooled over time, it collapsed under gravity into clumps and then galaxies. Bode et al. (2001) simulation is one example for large-scale simulations.

The researchers ran the largest detailed simulation of a cosmological structure to date. In the simulation, the region of study collapses from about 2 billion light years across to form a region of galaxy clusters only 25,000 light years across.

The distribution of galaxy clusters in the universe can actually help us to learn things about dark energy, how much matter there is in the universe, and how fast the universe is expanding...



The filaments indicate "***warm-hot intergalactic medium***", or WHIM. WHIM constitutes about half of the universe's non-dark matter, yet we cannot see it very well. It emits and absorbs largely in the UV and soft X-ray portion of the electromagnetic spectrum, much of which is blocked by the earth's atmosphere.

The knot-like structures at the intersections indicate large groups and clusters of galaxies—important objects to study for understanding the fundamental properties of our universe such as the amount of matter, dark energy, and the expansion rate. The largest knot, near the center, is a galaxy cluster.

Figure 4: Example of the largest detailed simulation of a cosmological structure (see the text).

- ***Dark Energy Survey*** (www.darkenergysurvey.org)

To understand better dark energy and its implications on our current knowledge of matter, energy, space, and time, scientists will conduct the ***large-scale*** Dark Energy Survey ***(DES), starting in 2012*** at the Cerro Tololo Inter-American Observatory in Chile. Researchers will use the ***4-meter Blanco telescope,*** equipped with the ***Dark Energy Camera***, to capture ***images of more than 300 million galaxies.*** They expect to measure quantities related to pressure and energy density five times more precisely than currently possible. The startling discovery that t***he universe's expansion is accelerating*** has led scientists to postulate ***the existence of an outward-pushing dark energy***.

Astrophysicists are trying to learn more about the physics of the big bang, and the origin of the large-scale structure. Computational tools and resources are indispensable to pursuing these fundamental questions. To test and debug the image processing programs, researchers use Open Science Grid to create complex simulations of telescope signals and Teragrid to process these simulations. The scientists feed the known position, brightness, and shape of about ***50 million galaxies and 5 million stars into software*** that renders simulated images of these objects.

- ***Visualizations in planetarium show*** (www.amnh.org/rose/spaceshow/journey)

"Journey to the Stars" is a planetarium show that uses grid-generated simulations to take audiences deep under the surface of the sun. Viewers embark on a journey through the lifespan of stars and the origin of life. ***Visualizations*** of the universe ***explain how stars first formed*** and then ***exploded*** to produce the chemical elements that make life possible. The 25-minute journey culminates in ***a flight to the center of the sun***. This was the most difficult sequence to accurately depict; the producers wanted to take viewers below the sun's surface, through its convective layer, and down to its core to reveal the underlying mechanisms that create its powerful magnetic field.

Using ***TeraGrid*** supercomputers complex computer ***models of the sun are build***. The ***sun's convection zone*** based on a sphere of hydrogen and helium plasma is modelled. Based on that model, the ***properties of hydrogen and helium***, and how they react to ***the sun' hea***t, the ***convective motions*** is produced. The resulting ***simulation allows*** planetarium visitors ***to take a peek at the sun's convective zone***.

Sunspots are actually concentrations of strong magnetic fields that occasionally erupt above the sun's surface. These provide ***clues to the sun's internal magnetic field***. Numerical ***simulations allow us to look several thousand kilometers into the sun*** and see how the surface structure we observe is related to convective motions that happen far below the visible surface. A ***three-dimensional virtual domain*** to replicate a region on the sun 31,000 miles in length and height and about 5,100 miles in depth. The domain was ***large enough to fit an entire sunspot***, which has a typical size of 12,000 to 19,000 miles, and provided enough resolution ***to view substructure on the scale of 20- to 30- miles***. The researchers then ***used TACC's Ranger supercomputer*** to solve complex solar equations ***for each of 268 million points spaced 20- to 30- miles*** apart within the virtual domain. This involved processing approximately ***a terabyte of data and took several days to run on 512 processors***.

Details could be found in
http://physics.ucsc.edu/~joel/SimulationVisualisation.pdf .

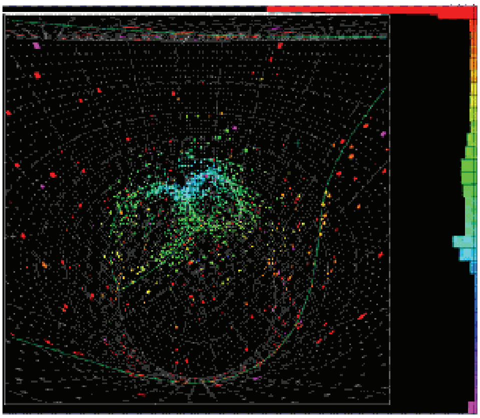
6. ASTROPHYSICAL APPLICATIONS AND PROJECTS

In this last part we shall make a short review of the basic astrophysical projects and applications.

- ***A neutrino's journey*** **-** the Tokai-to-Kamioka (T2K) experiment

Neutrinos are the introverts of the particle physics world. They travel through the universe largely unnoticed, except for the very rare interaction. Neutrinos are neutral – free of charge. That means that electricity and magnetism can't draw them out and force them to interact. We know that ***there are three types of neutrinos – the electron neutrino*** is the smallest, t***he tau neutrino the largest***, with ***the muon neutrino*** caught in the middle. We also know that ***when no one's looking, neutrinos go 'fuzzy' - an unobserved neutrino is all three types of neutrinos at the same time***. The likelihood that a scientist will see a particular type of neutrino changes periodically over time, ***oscillating***. Three different constant angles determine the rate at which those probabilities oscillate. Scientists have already seen muon and tau neutrino oscillation, and measured two of the three angles. The ***third angle, theta13***, is much tricker to measure, however, because it i***s very small***. That is the goal of ***the*** Tokai-to-Kamioka (T2K) ***experiment*** in Japan.

Super-Kamiokande in essence is a giant cylindrical tank filled with 50,000 tons of pure water located 1,000 meters underground. The inside walls of the tank are covered with photomultiplier tubes, which detect any sparks of light that occur inside the tank. ***When a neutrino strikes a neutron*** in a water molecule's nucleus, the two particles interact via something called the Weak Force. The neutrino and neutron go in, and ***out comes a proton and one of the three types of leptons*** (***electron, muon, or tau***, all of which are negatively charged).



The first T2K event seen in Super-Kamiokande. Each dot is a photo multiplier tube which has detected light. The two circles of hits indicate that a neutrino has probably produced a particle called a π 0, perfectly in time with the arrival of a pulse of neutrinos from J-PARC. Another faint circle surrounds the viewpoint of this image, showing a third particle was created by the neutrino.

Figure 5: Some events in Super-Kamiokande during T2K experi-ment.

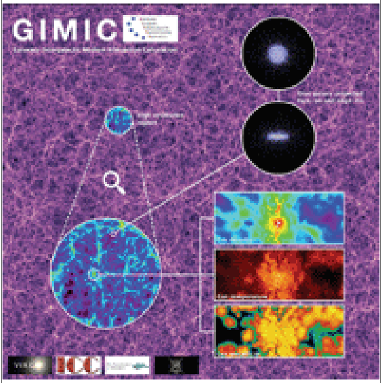
An electron neutrino will generate an electron, a muon neutrino a muon, and so on. The lepton is ejected, traveling at extremely high speeds. Although it does not travel as quickly as light does in a vacuum, it does travel faster than light does in water, ***c******reating*** Cerenkov radiation – the visual equivalent of a sonic boom. The ***photomultiplier*** tubes detect the scintillating light of the Cerenkov radiation, and in so doing, they ***indirectly detect the neutrino***

Maltoni et al. (2003) presented a results of three-neutrino oscillations [20].

- ***A virtual universe – GIMIC*** (Frenk 2008) - www.deisa.eu/science/deci/projects2005-2006/GIMIC ***and Millennium simulations***

With the aid of the grid, researchers are conducting ***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.***

Virgo is an international consortium of cosmologists that performs large numerical simulations of the formation of galaxies**.** Its ***Millennium Simulation*** is the largest ever calculation to follow the formation of the dark haloes that seed galaxies.

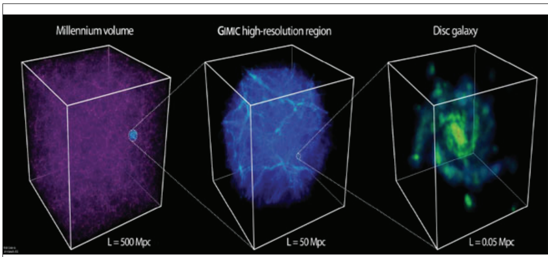


A key project of the Virgo Consortium ***is the Galaxies Intergalactic Medium Interaction Calculation (GIMIC)***, which simulates the formation of galaxies in five key regions of the universe, allowing Virgo members to obtain unprecedented insight into how galaxies form. ***GIMIC simulates the formation of galaxies in several regions selected from the Millennium Simulation, but now including hydrodynamics.*** This allows Virgo members to obtain unprecedented insight into how galaxies form on truly cosmological scales. ***GIMIC has now revealed that astrophysical processes separate the ordinary or "baryonic" matter from dark matter even on large scales*** – for details see http://www.deisa.eu – project GIMIC.

Figure 6: Titular page of the GIMIC project.

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 centers of stars – ***heavy elements***.

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.



Structure formation in a ***computer-simulated Universe*** covering a dynamic range of a factor of 10000 in linear scale. ***Left*** image shows the ***Millennium simulation*** which models the distribution of dark matter on very large scales. ***Center*** image shows the results of a ***simulation of a particular region*** taken from the Millennium simulation which has been resimulated ***at higher resolution and includes baryonic matter***.

The ***right*** most image shows ***one example out of many of a disc galaxy forming within the GIMIC high resolution region***.

Figure 7: Examples of the computer simulated Universe.

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. Detail for the Millennium Simulation project could be found in www.mpa-garching.mpg.de/galform/virgo/milleniuum/ and in Bode et al. (2001).

- ***Near Earth Objects*** (neo.jpl.nasa.gov)

While scanning through images from the Sloan Digital Sky Survey, Stephen Kent noticed something unusual — a few extended streaks scattered among the millions of stars and galaxies (Kent et al. 2009). During its eight years of operation, the ***SDSS obtained images*** of more than a quarter of the night sky ***and identified almost 400 million objects***. Although the survey was designed to detect stars and galaxies and determine their properties, it also helped identify ***more than 100 NEOs.*** To sift through the data for NEOs, Kent divided the SDSS data into fields, each containing about 1,000 candidate objects of all types. Using a special algorithm Kent bundled several hundred fields together and run the application on the grid.

The resulting 200 to 300 NEO candidates have been examined by eye to eliminate misclassifications and compile ***the final catalog of around 100 NEOs, ranging in size from about 20 to 200 meters in diameter.***

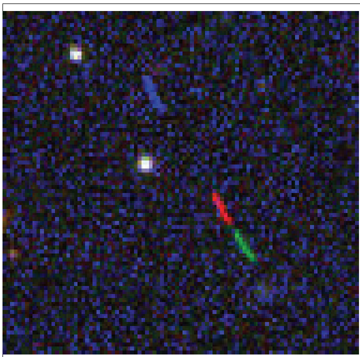
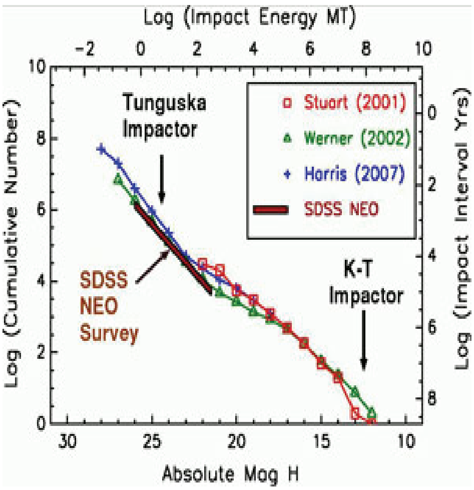


Image of a near-earth object detected by the Sloan Digital Sky Survey. The blue, red and green streaks show the object as it moves through three of the five SDSS filters over a period of five minutes. ***The two white objects are distant stars.*** Kent realized ***the streaks were produced by Near Earth Objects (NEOs), asteroids or extinct comets whose orbits bring them close to Earth*** — close enough that they could collide.

Figure 8: Detecting a Near Earth Objects.



This graph depicts the ***near-earth objects found by four sky surveys***, including Kent's grid-assisted search of the SDSS data. It shows that ***large NEOs*** such as the K-T Impactor that wiped out the dinosaurs 65 million years ago ***are quite rare***. The SDSS NEO Survey, indicated by the thick red line, searched for the more common smaller objects. Although these are not big enough to cause mass extinction, they are still quite powerful. The Tunguska impactor, for instance, burst about five to 10 kilometres in the air above Northern Siberia in 1908, knocking over an estimated 80 million trees in a section of forest over 2150 square kilometres in size.

Figure 9: Near-earth objects found by four sky surveys.

Kent estimates ***the total population of NEOs in the same size range to be around one million*** and the estimation of ***the Earth-NEO collision rate — about one every thousand years***.

- ***Scientific Applications of AstroGRID-D*** (www.gac-grid.org)

Figure 10: An extraction from the AstroGRID-D home_page.

The ***Dynamo*** scripts are designed to ***use a large number of compute nodes and are an easy way to run many independend jobs on them***. The package was originally an application for a magnetohydrodynamic simulation, but it has been developed further so it can be used fo general purposes.

Nbody6++ is a member of a family of high accuracy ***direct N-body integrators used for simulations of dense star clusters, galactic nuclei, and problems of star formation***. It is a special version of Nbody-6 ***optimised for massively parallel computers***. Some of the ***most important applications*** are ***simulations of rich open and globular clusters*** with a large number of binaries and ***galactic nuclei with single and binary black holes***.

GEO600 Data Analysis **-** The **GEO600 gravitational wave detector** is contributing to the **Laser Interferometer Gravitational Wave Observatory (LIGO)**, an international effort to ***directly measure the effects of gravitational waves***, as predicted in Einstein's theory of general relativity.

Clusterfinder
(www.gac-grid.org/project-products/Applications/ClusterFinder.html)

Clusterfinder is used within the AstroGrid-D project that ***tests the deployment and performance of a typical data-intense astrophysical application***. The algorithm for any point in the sky depends only on the data from nearby points, so the data access and calculation can easily be parallelized, making Clusterfinder well-suited for production on the grid. The ***scientific purpose*** of Clusterfinder ***is to*** reliably ***identify clusters of galaxies by correlating the signature in X-Ray images with that in catalogs of optical observations.***

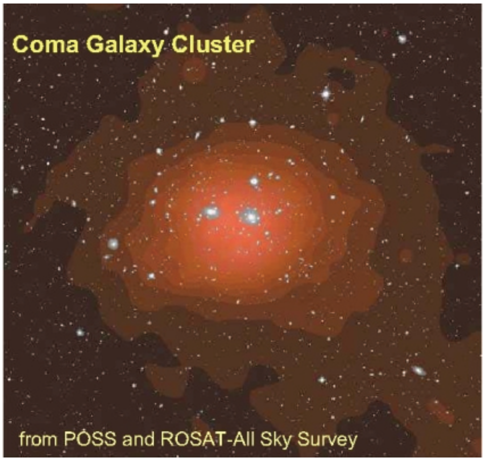


Figure 11: Coma cluster of galaxies.

Astronomy in recent years has observed a shift away from the study of individual or unusual objects to the statistics of large numbers of objects, observed at a variety of wavelengths across the electromagnetic spectrum, so that ***the techniques developed for Clusterfinder are applicable to many cutting edge astronomic studies*** – e.g. cosmology and galaxy clusters...

- ***Cactus.*** The **Cactus Computational Toolkit** is an open source problem solving environment designed for scientists and engineers. ***Cactus is used to numerically simulate extremely massive bodies, such as neutron stars and black holes***. An accurate model of such systems requires a solution of the full set of Einstein's equations for general relativity.

- ***Robotic Telescopes –*** **(www.gac-grid.org/project-products/Software/RoboticTelescopes)**

Global networks of robotic telescopes provide important advantages over single telescopes. Independent of daytime and weather, they can more efficiently perform multiwavelength observations and continuous long-term monitoring, as well as react rapidly to transient events such as GRBs and supernovas. With the number of currently existing robotic telescopes a very powerful network could already be built - this is the idea of ***OpenTel*** - an Open Network for Robotic Telescopes. OpenTel provides the means for interconnecting single robotic telescopes to a global network for sharing observation time, observation programs and data. OpenTel is an open network. Open means open standards, open source and open for telescopes to join.

Grid technology provides an ideal framework. It provides solutions for the management of Virtual Organizations, grid resources, computational jobs and observation, data and metadata. The architecture is built on two technologies: the grid middleware of the Globus Toolkit and the Remote Telescope Markup Language (RTML) for the exchange of observation requests.

Robotic Telescopes of the Astrophysical Institute Potsdam (AIP) (www.gac-grid.de/project-products/Software/RoboticTelescopes.html)

With five robotic telescopes the AIP provides the first hardware to OpenTel. The five telescopes are RoboTel, STELLA-I and II, Wolfgang and Amadeus.

RoboTel is located at the AIP. It is a 0.8 m telescope equipped with a CCD camera for imaging and photometry. Besides its science core-program, half of the observation time is reserved for schools and universities. The remaining observation time is dedicated to testing of new instruments, software and methods for the STELLA-I and II telescopes.

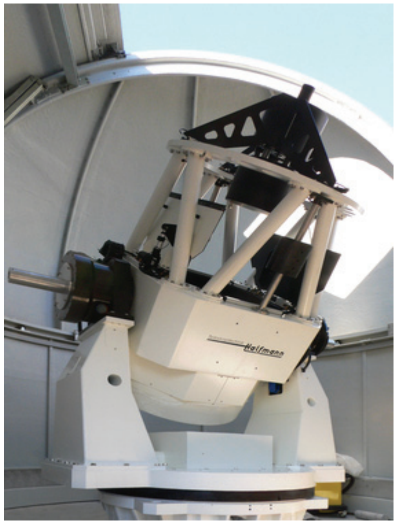


Figure 12: RoboTel - robotic telescope.

The ***STELLA robotic observatory*** is located at the Teide observatory in Tenerife, Spain. It consists of two 1.2 m telescopes, STELLA-I and STELLA-II. STELLA-I is equipped with a spectrograph and STELLA-II will be equipped with an imaging photometer. Scientific objectives are: Doppler imaging, the search for extrasolar planets, spectroscopic surveys and support observations for simultaneous observations with larger facilities.

Figure 13: The STELLA robotic observatory.

Wolfgang and Amadeus are located at the Fairborn Observatory in Arizona. They are two 0.75 m telescopes equipped with photomultipliers for photometry. The scientific objectives are the participation in multi-site observing campaigns and studies of variability timescales and life times of starspots, requiring monitoring of stars over periods of years.

Figure 14: Robotic telescopes Wolfgang and Amadeus.

ProC **–** The Planck Process Coordinator Workflow Engine. (www.gac-grid.de/project-products/Software/ProC_en.html)

	The vast amount of data produced by satellite missions is a challenge for any data reduction software in terms of complex job submission and data management. The demands on computational power and memory space qualify ***the satellite data reduction to be prototype of grid applications***. Therefore, the Planck Process Coordinator Workflow Engine ***ProC*** for the _Planck Survey or satellite has been chosen as a Grid Use Case within the AstroGrid-D project. The ***ProC is interfaced to the Grid Application Toolkit*** (GAT), which allows the execution of jobs on the submission host, on clusters via the PBS and SGE GAT adapters, and on the Grid, using the Globus Toolkit 2 and 4 GAT adapters for process-to-process communication.

Figure 15: Titular page of the PLANK project.

Below is the block-scheme of the ProC interfaces to the Grid Application Toolkit (GAT) which via its set of adapters offers job execution on the local host, on worker nodes of a local cluster, and on remote Grid hosts. Details in http://www.gac-grid.org/project-products/Software/ProC/proc.pdf .

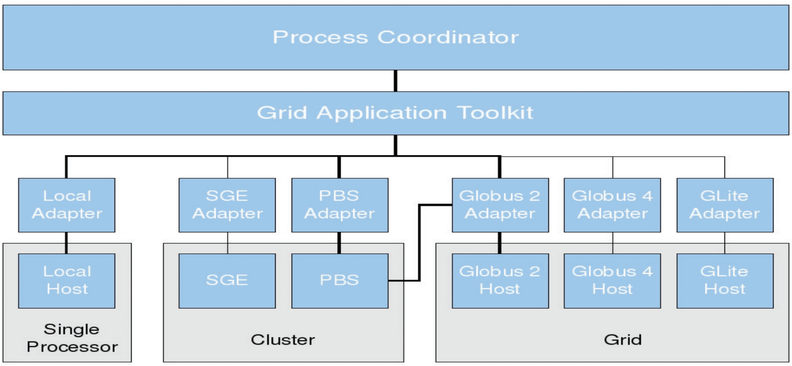


Figure 16: Block-scheme of the ProC interfaces.

- ***Black holes and their jets***

Jets of particles streaming ***from black holes in far-away galaxies operate differently than previously thought***, according to a study published recently in Nature.

High above the flat Milky Way galaxy, ***blazars dominate the gamma-ray sky***. ***As nearby matter falls into the black hole at the center of a blazar, "feeding" the black hole, it sprays some of this energy back out into the universe as a jet of particles***.

The recent study, which included data from more than 20 telescopes worldwide over a full year of observations, focused on one particular blazar jet, located in the constellation Virgo. Astronomers monitored it in many different wavelengths of light: gamma-ray, X-ray, optical, infrared and radio (blazars continuously flicker, and researchers expected continual changes in all types of light). As a result researchers observed a spectacular change in the jet's optical and gamma-ray emission: a 20-day-long flare in gamma rays was accompanied by a dramatic change in the jet's optical light.

Hayashida et al. (2010) turn suggests that the magnetic field lines must somehow help the energy travel far from the black hole before it is released in the form of gamma rays. The data suggest that ***gamma rays are produced not one or two light days from the black hole (as was expected) but closer to one light year***.

This simulation depicts ***a black hole with a dipole as a magnetic field.*** This system is sufficiently orderly to generate gamma ray bursts that travel at relativistic speeds of over 99.9% the speed of light.

The black hole pulls in nearby matter (yellow) and sprays energy back out into the universe in a jet (blue and red) that is held together by the magnetic field (green lines).

The simulation was performed on the Texas Advanced Computing Center resources via TeraGrid, consuming approximately ***400 000 service units***. (Picture from the Internet).

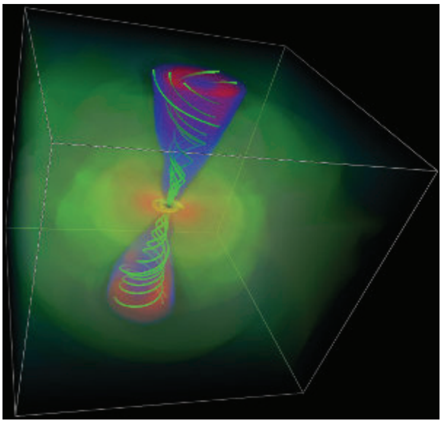


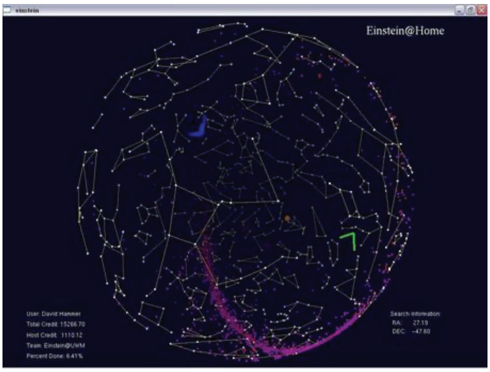
Figure 17: Simulation of the black hole and its jet in a magnetic field.

This new understanding of the inner workings and construction of a blazar jet requires a new working model of the jet's structure, one in which the jet curves dramatically and the most energetic light originates far from the black hole.

- ***BOINC-GridRepublic Astronomy projects*** (www.grid-republic.org)

  SETI@home

SETI (Search for Extraterrestrial Intelligence) is a scientific area whose goal is to ***detect intelligent life outside Earth***. One approach, known as radio SETI, uses radio telescopes to listen for narrow-bandwidth radio signals from space. Such signals are not known to occur naturally, so a detection would provide evidence of extraterrestrial technology. Radio telescope signals consist primarily of noise (from celestial sources and the receiver's electronics) and man-made signals such as TV stations, radar, and satellites. Modern radio SETI projects analyze the data digitally. More computing power enables searches to cover greater frequency ranges with more sensitivity. Radio SETI, therefore, has an insatiable appetite for computing power. See Rosetta@home and Einstein@home too.



Einstein@Home

To process the vast amount of data that is being generated by GEO600 and other detectors, the Einstein@Home ***software framework*** was developed. It uses BOINC as underlying middleware to split the data analysis into small computational tasks that can be distributed to available computers on the Internet and executed on any commodity hardware.

Figure 18: Screenshot from the Einstein@home.

Einstein@Home is managing the execution of these tasks on a large set of computational resources distributed world wide. What appears to be a screen saver to the layman is in fact a supercomputer providing 70TFlops/s to the search for gravitational waves. Additional information – in LHC@home and Milkyway@home .

- ***BalticGrid-II* astronomy *application*** (**www.balticgrid.org**)

  ElectroCap

This is a set of computer programs (Stellar Rates of Electron Capture) ***calculating electron capture rates with several nuclear structure models*** and modelling of core-collapse supernova requires nuclear input in terms of electron capture rates. Nuclear structure Information from the best available nuclear models is used to

calculate electron capture rates in the thermal environment of a collapsing star. Both the total and the partial electron capture rates ***as well as*** the ***emitted neutrino spectra*** are calculated for many nuclei and averaged for the stellar conditions. Both the total and the partial electron capture rates as well as the emitted neutrino spectra are loudspeaker for many nuclei and averaged for the stellar conditions. These rates and spectra are calculated for around 3000 nuclei and averaged according to the abundances at given stellar conditions.

SyntSpec - There are two demos (AVI files) in the WEB_page above. They have been presented for the first time in Catania, Italy, during the EGEE UF / OGF25, on 2-5.03.2009, at the BG-II demo stand "The Synthetic spectra modeling under GRIDCOM interface" (Mikolaitis & Tautvaišienė 2011).

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- ***GAJA mission*** (sci.esa.int/science-e)

Gaia is an ambitious ***mission to chart a three-dimensional map of our Galaxy***, the Milky Way, in the process revealing the composition, formation and evolution of the Galaxy. ***Gaia will provide*** unprecedented ***positional and radial velocity measurements*** with the accuracies needed to produce a stereoscopic and kinematic census ***of about one billion stars in our Galaxy and throughout the Local Group***. This amounts to ***about 1 per cent of the Galactic stellar population***. Combined with astrophysical information for each star, provided by ***on-board multi-colour photometry***, these data will have the precision necessary to quantify the early formation, and subsequent dynamical, chemical and star formation evolution of the Milky Way Galaxy.

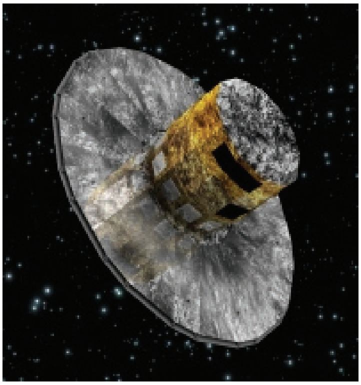	**LAUNCH DATE:** 2012 **MISSION END:**nominal mission end after 5 years (2017) **LAUNCH VEHICLE:**Soyuz-Fregat **LAUNCH MASS:**2030 kg **MISSION PHASE:**Implementation **ORBIT:** Lissajous-type orbit around L2 **OBJECTIVES:** To create the largest and most precise three dimensional chart of our Galaxy by providing unprecedented positional and radial velocity measurements for about one billion stars in our Galaxy and throughout the Local Group.

Figure 19: Gaja spacecraft.

Additional scientific products include ***detection and orbital classification of tens of thousands of extra-solar planetary systems***, a comprehensive survey of objects ranging from huge numbers of ***minor bodies in our Solar Syste***m, through ***galaxies in the nearby Universe***, to ***some 500 000 distant quasars***. It will also provide a number of stringent new tests of general relativity and cosmology. Hobbs et al. (2008) presented astrometric solution in the light of GAJA mission.

- ***Girls Engaged in Math and Science (GEMS) program*** (gems.ncsa.illinois.edu)

The GEMS program was created in 1994 through a partnership of the Champaign Community Unit School District and NCSA to encourage local girls to consider a wide range of mathematics and science-oriented careers. Recently, ***GEMS has turned its focus to astronomy***, making use of the largest-ever digital astronomy database, the Sloan Digital Sky Survey (SDSS).
Over the course of the GEMS after-school program and summer camp, ***the girls investigate the universe***. They make ***multi-wavelength images of galaxies***, measure the ***colors of stars and quasars***, ***detect asteroids and black hole***s, and even ***measure the expansion of the universe***—using the same data professional astronomers use.

The GEMS program is growing to include the use of emerging technologies and communication tools. The Girls on the Grid component of GEMS uses Access Grid technology to link girls in grades 6-12 to peers and leading women in science and mathematics world-wide.

Astronomy Programming: GEMS has recently partnered with the Department of Astronomy at the University of Illinois to offer a special Spring/Summer program, focused on introducing students to the rapidly expanding frontiers of digital astronomy. This program has been made possible through a grant from the National Aeronautics and Space Administration to Professor Robert Brunner.

- ***Distant Galaxy Search Applying Astrogrid-RU***

The first astronomical problem that has been experienced by IPI RAN together with the Special Astrophysical Observatory of RAS (SAO RAS) applying AstroGrid and Aladin is ***a distant radio galaxy search in the sky strip investigated in the "Cold" deep survey with the RATAN-600*** (large Russian radio telescope). Details are in the synthesis.ipi.ac.ru/synthesis/ .

It used RC catalogue as a list of initial radio sources. One had to select optical sources with certain properties taken from DR 3 SDSS and crossmatched them with the RC catalogue. The result of the crossmatch may contain candidates for distant galaxies that should be analyzed further applying their images and Aladin capabilities. Below an example of a result image opened in Aladin is shown.

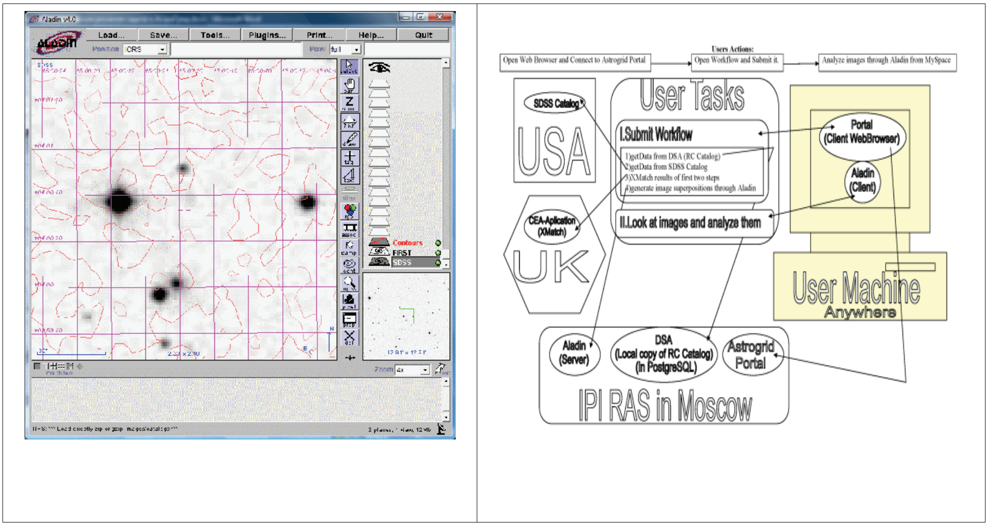

Figure 20: Screenshot from the WEB_page of Russian AstroGrid.

- ***Grid in a cloud***

There are recently experiments with ***running a grid inside a cloud in order to process massive datasets***, using test data drawn from something ***astronomically large - data from the Gaia project*** (see above). In order to execute the jobs and process the data, an in-house distributed computing framework was configured to run the ***Astrometric Global Iterative Solution*** (AGIS) (Hobbs et al. 2008), which runs a number of iterations over the data until it converges.

The system works as follows: Working nodes get a job description from the database, retrieve the data, process it and send the results to intermediate servers. These intermediate servers run dedicated algorithms and update the data for the following iteration. The process continues until the data converges. ***The nature of the AGIS process makes it a good candidate to take advantage of cloud computing because:***

- The amount of data increases over the 5-year mission.
- Iterative processing results in 6-month Data Reduction Cycles.
- At current estimates, AGIS will run for 2 weeks every 6 months.

To process 5 years of data for 2 million stars, 24 iterations of 100 minutes each were done, which translates into 40 hours of running a grid of 20 Amazon Elastic Compute Cloud (EC2) high-CPU instances. ***For the full billion-star project, 100 million primary stars will be analyzed, plus 6 years of data, which will require a total of 16,200 hours on a 20-node EC2 cluster.*** The estimated cost calculated for the cloud-based solution is less than half the cost of an in-house solution, even when the additional electricity and system administration costs of the in-house solution are not taken into account. A lot of possibilities of grid in a cloud are presented in Stanoevska-Slabova & Wozniak (2010).

- ***Databases in Grid*** (wwwas.oats.inaf.it/grid/)

"Databases in Grid" is a technological transfer project of INAF, co-funded by INAF - UIT (Ufficio di Innovazione Tecnologica) and NICE s.r.l., the industrial partner for this project.

The project aims at making the Grid technology able to access Databases. A software prototype will be developed, fully compatible with standards defined in EGEE (Enabling Grids for E-sciencE). The EGEE project is the UE established point of reference for what concerns the Grid technology. The so generated extended Grid, able to access Databases, is referred to with the term **G-DSE+QE**, where G-DSE (Grid-Data Source Engine) indicates the actual extension of the Grid middleware and **QE** (Query Element) is the new Grid element built on top of G-DSE and able to handle queries to be passed down to Databases in Grid.

- ***Grid-enabled Astrophysics*** – papers from workshop (Benacchio & Fabio 2006, Vuerli et al. 2008a, Vuerli et al. 2008b)

The volume collects the contributions to the "***Computational Grids for Italian Astrophysics: Status and Perspectives***" workshop, held at INAF headquarters, Rome, in ***November 2005***. The workshop aimed at taking a snapshot of the status within the Italian astrophysical community of the development and usage of computational and data Grid(s) with particular reference to the status of the **Grid.it** and **DRACO** projects. The results obtained by the scientists participating in the two projects were summarised, ***to evaluate the effectiveness of the porting of scientific applications on the Grid***, to recognise possible improvements, to foster cross-fertilisation with other sciences involved in Grid processing, ***to bring the requirements of astronomers to the attention of middleware developers*** and, maybe most important, ***to disseminate results so as to allow fellow astronomers to make use of the Grid***. An attempt to define the roadmap for the future was also made, to understand which resources are needed and how to procure them. The workshop ideally closed a complete loop initiated in ***July 2003***, when a first workshop called ***"Grids in Astrophysics and the Virtual Observatory"*** was organised. After two years of hard work and experience based on trial-and-error have shown that ***Grids are actually useful and have found application in many fields of astrophysical research, ranging from theoretical simulations to data processing, from distributed databases to planning of space missions***.

- ***GRID and the Virtual Observatory* – (**wwwas.oats.inaf.it/grid/)

SI-GRG: GRID Research Group at INAF SI in Trieste (**SI-GRG**) ***is doing research on Grid application and infrastructure development focused on Astronomical and Astrophysical problems.***

Virtual Observatories (VObs) aim at federating astronomical databases in a way that they are accessible in a uniform way irrespective of peculiarities characterizing each of them (format of data, requests syntax…). ***Virtual Observatories generally federate astronomical databases on a national basis***; they in turn join other national VObs to form wider alliances on an international basis - see Passian (2004). ***IVOA (International Virtual Observatory Alliance) is the worldwide alliance of all VObs***. The main goal of IVOA is to define a set of universally accepted standards in order to make possible a uniform vision of all federated Vobs – (Rixon 2109, Walton & Rixon 2008). ***IVOA also supplies tools and software layers to practically implement this uniformity***.

The concept of VObs therefore deals with data storage and retrieval. But astronomers need to process data once they have been retrieved and very often a considerable amount of computing power is requested to process such data. ***Because VObs offers astronomical data but not computing power a synergy between the VObs and the Grid appears as a natural choice*** (Schade 2001).

The interconnection of GRID and the VO is presented in Skoda (2009) and Taffoni et al. (2009).

DRACO Project (**D**atagrid for Italian **R**esearch in **A**strophysics and **C**oordination with the Virtual **O**bservatory) is a concept aiming at providing the scientific community with a distributed multi-functional environment allowing the use of specialized (observational, computing, storage) Grid nodes.

DRACO has been generated from a section of a project called ***"Enabling platforms for high-performance computational Grids oriented towards scalable virtual organizations"*** which has been approved and funded by the Italian Fund for Basic Research (FIRB). The ***astrophysical section of this project*** that terminated at the end of 2005 ***was composed of three demonstrators*** aiming at proving the feasibility of porting astrophysical applications within the framework of a national Grid infrastructure.

- ***HORIZON project*** (Wozniak 2009) - www.projet-horizon.fr

The HORIZON Project is built on several research teams in dierent institutes, namely the CEA/SAp in Saclay, the Observatories of Paris (LUTh and LERMA laboratories), Lyons and Marseilles. The scientific objective is specifically oriented towards studying galaxy formation in a cosmological framework. Its transverse and federative nature will however allow to develop in a few years high-level expertise in parallel and distributed (GRID) computing, in database management and virtual observations, in applied mathematics and computer science, and build in the same time a strong theoretical knowledge in astrophysics.

The consortium also studies the influence on the predictions of the resolution, the numerical codes, the self-consistent treatment of the baryons and of the physics included.

The main objectives are:
– the numerical study of galaxy formation in a cosmological framework using Grand Challenge applications;
– the development of advanced techniques in parallel computing and in applied mathematics to model galaxy formation and predict their observational signatures, as a function of physical parameters
– the gathering of renowned experts in computational astrophysics to share their software and expertise, and to optimize their access to national and international supercomputing facilities
– the delivery of a friendly access to state-of-the-art numerical simulations to the scientific community of both observers and theoreticians.

- ***Sifting for dark matter*** (ppd.fnal.gov/experiments/cdms/)

Think of grid computing as a sieve that physicists use to sift out those rare events that might just be signs of dark matter — the mysterious substance that appears to exert gravitational pull on visible matter, accelerating the rotation of galaxies.

FermiGrid, the campus grid of Fermilab and the interface to the Open Science Grid, ***recently helped researchers from the Cryogenic Dark Matter Search experiment to do just that: identify two possible hints of dark matter*** (Ahmed et al. 2010).

Dark matter has never been detected. And although the CDMS team cannot yet claim to have detected it, their findings have generated considerable excitement in the scientific community.

The experiment, managed by Fermilab and bringing together scientists from several universities, operates a set of detectors in the Soudan Mine in Minnesota, a half-mile underground.

Galaxies are mostly dark matter clouds: Over the evolution of the Universe, the dark matter particles formed structures, like water vapor forms clouds. These massive collections of dark matter particles became the galaxies. In fact, ***the gravitational force of dark matter helps hold galaxies together***. The stars and interstellar dust are just icing on the cake!

WIMPs, a name for dark matter: We know that dark matter particles generate gravity, but they interact very weakly otherwise. In our conception they are ***weakly-interacting, but massive particles*** - ***WIMPs*** for short (Bykov et al. 2004).

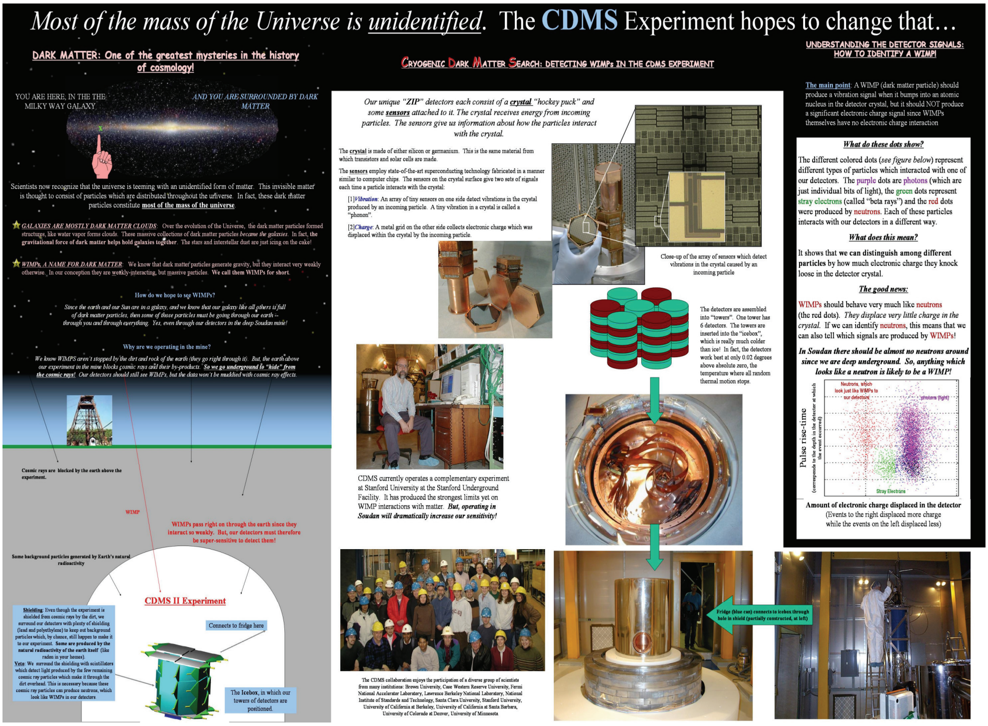

Figure 21: Cryogenic Dark Matter Search experiment poster.

- ***The Networked Telescope***

Plante et al. (2001) paper presented "...Progress Toward a Grid Architecture for Pipeline Processing". Pipeline processing systems for modern telescopes are widely considered critical for addressing the problem of ever increasing data rates; however, routine use of fully automated processing systems may discourage the typical user from exploring processing parameter space or trying new techniques. This issue might be particularly important with regard to radio interferometer data in which the post-calibration processing required to create an image for scientific analysis is not well defined. ***BIMA Image Pipeline*** attempts to address this issue. The pipeline by default is automated and uses NCSA supercomputers to carry out the processing. ***This same system can also be used by the astronomer to create new processing projects*** using data from the archive.

Here are some ways we want to allow users to interact with the pipeline:

(a) **prior to observations:** the astronomer can override default processing parameters to better suit the scientific goals of the project;

(b) **during observations:** the astronomer can monitor the telescope and data via the web;

(c) **after observations:** the astronomer can browse the archive's holdings using customizable displays;

(d) **prior to processing:** the astronomer can create his/her own scripts for reprocessing archival data;

(e) **during processing:** optional viewers can be opened up to monitor, and possibly steer, the deconvolving process.

The processing is carried out using AIPS++, which employs the Glish scripting language to glue processing objects together. Its event-driven programming model (combined with the toolkit nature of AIPS++) makes it ideal for building automated processing in a distributed environment. ***An important role for NCSA***, as a member of the AIPS++ development consortium, ***is to enable support for parallel processing on a range of mildly to massively parallel machines***, with a particular emphasis on Linux clusters. The Intel Itanium-based supercluster that will be brought on-line at NCSA this year will handle the bulk of the imaging and deconvolution chores for the pipeline, while smaller machines will handle the serial processing.

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