

JD08 · Sydney, July 2003

Theoretical input to a Global Virtual Observatory

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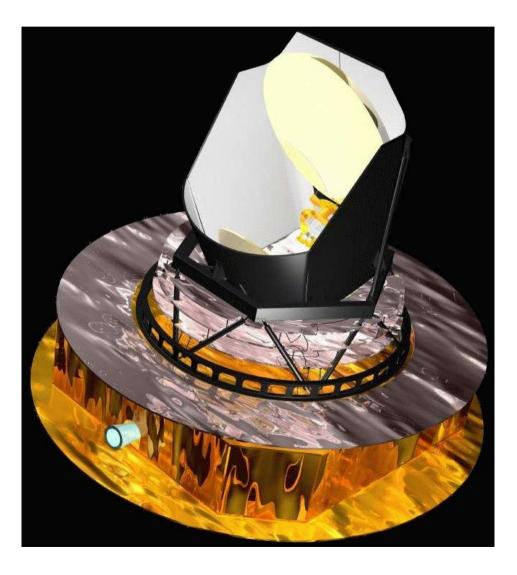
Functions of a Global Virtual Observatory

- Coordinated and transparent access
 - -- to data (MAST, CDS, Virgo)
 - -- to knowledge (astro-ph, ADS)
 - -- to tools (IRAF, Gissel, Cactus,...)
 - -- to computing resources (hardware, CPU cycles)
 - -- to expertise (web-tutorials)
- Communication
 - -- bandwidth
 - -- language (freedom from jargon, ease of use)
- Empowerment
 - -- capabilities independent of site and local resources
- Outreach
 - -- interfaces for non-professionals and non-academics

MPA Projects illustrating VO functionality

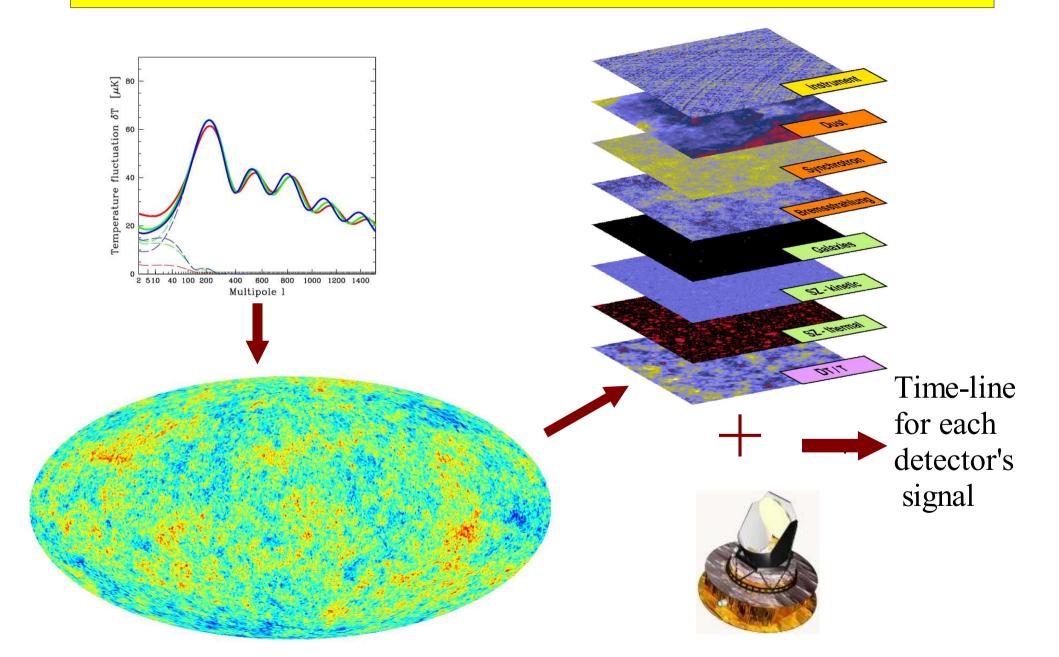
- Mission simulation pipeline for the Planck satellite
- Public archive for the Virgo Supercomputer Consortium
- Theoretical work within the German Astrophysical Virtual Observatory GAVO (see also poster 1433)
- GADGET distribution site
- Cosmic Cinema project

ESA's Planck Satellite



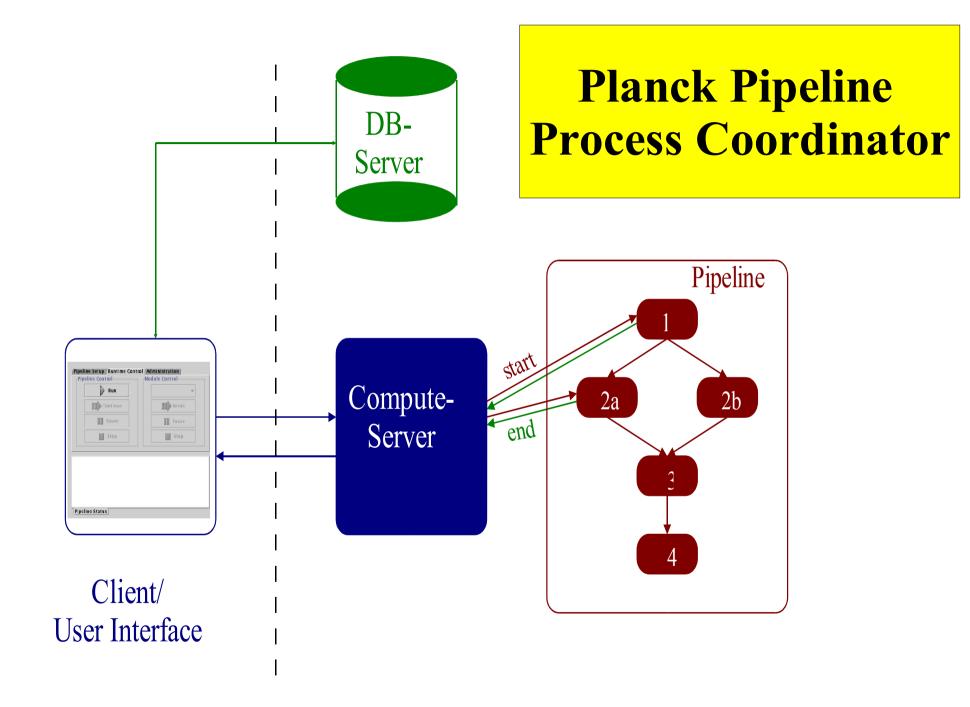
- Mission to map the Microwave background at 9 frequencies
- Launch in 2007
- Two broad instrument consortia and a telescope consortium
- Major contributions from ten European countries, USA and Canada
- Planned integrated analysis of all data in distributed Data Centres

Planck mission simulations



Features of simulation pipeline

- Programme modules user supplied in diverse languages
- Structure must be continually modified/updated
- Simulation process is distributed (non-simultaneous)
- Modular simulation products suitable for diverse groups
- Flexible but standard interfaces
- Object-oriented data model
- Distributed process coordinator



Simulating for a large distributed consortium

- Capability must match need
 - -- flexible, modular approach
 - -- users must be able to contribute elements
 - -- interfaces must work across a variety of platforms
 - -- CPU/memory/bandwidth resources must be sufficient
- Planning is needed to finish big tasks on time
- Documentation and communication are critical
 - -- well thought-out requirement/design documents
 - -- well defined development cycles
 - -- well defined interfaces

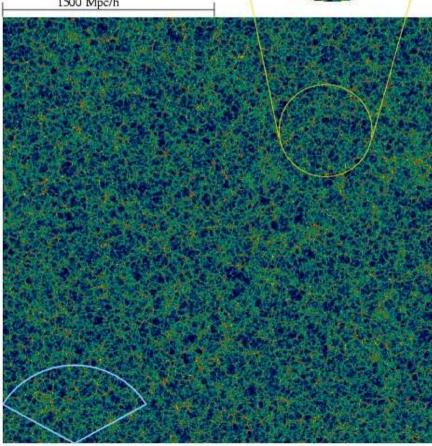
The Virgo Supercomputing Consortium

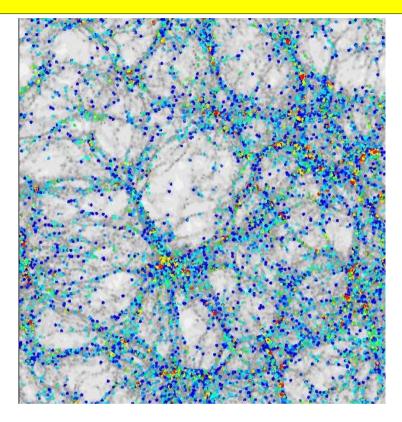
300 Mpc

The Hubble Volume Simulation

 $\Omega = 0.3$, $\Lambda = 0.7$, h = 0.7. $\sigma_8=0.9$ (ACDM) 3000 x 3000 x 30 h⁻³Mpc³ $P^{3}M: z = 35, s = 100 h^{-1} kpc$ 1000³ particles, 1024³ mesh T3E(Garching) - 512cpus Mparticle = 2.2 x $10^{12}h^1 M$ sol

1500 Mpc/h

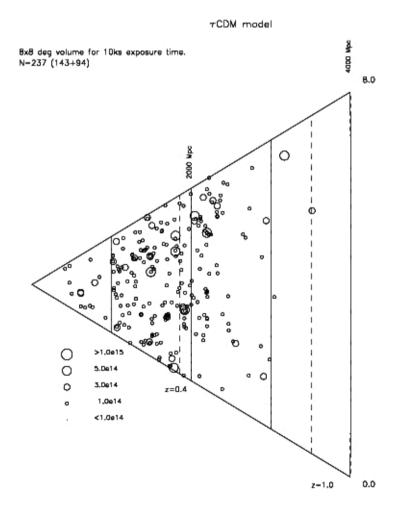


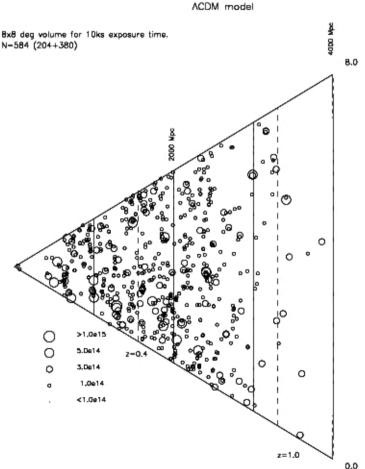


- Large consortium (UK, Germany, US, Canada)
- Aims to carry out largest feasible simulations of LSS/galaxy formation
- Goal to make simulation data public
- Archive/website at MPA

HV data use for a large XMM proposal

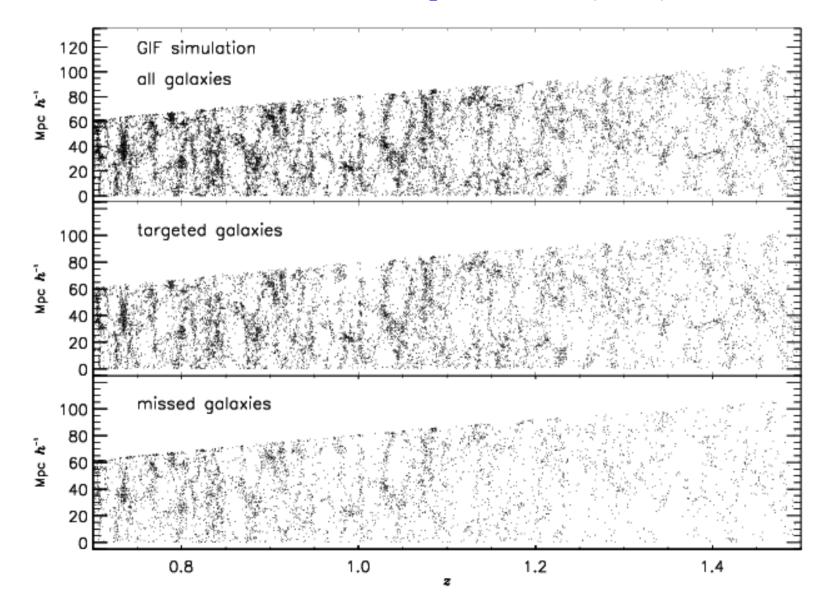
Pierre et al 2000





GIF data use for planning Keck/Deep surveys

Coil, Davis & Szapudi PASP (2001)



Evaluating infall models onto Perseus-Pisces

Hanski, Theureau, Ekholm & Teerikorpi A&A (2000)

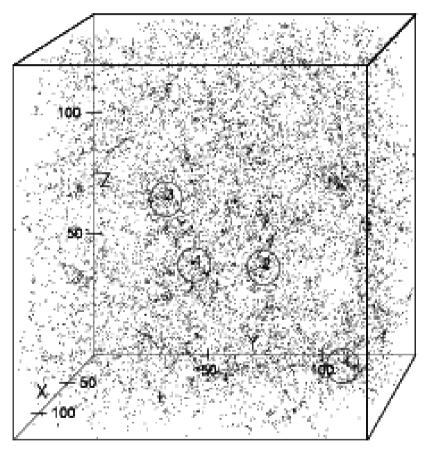


Fig. 5. The $(141 \ h^{-1} \ \text{Mpc})^3$ cabe of GIF N-body simulation galaxies. The simulation statted with 256³ dark halos, producing the 15000 galaxies seen in this figure. The four circles indicate the clusters for which we studied the applicability of the TB calculations.

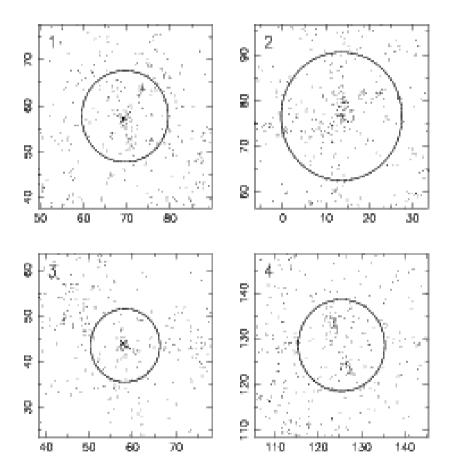


Fig. 6. The four GIF galaxy clusters extracted for further study. Figures show XY-planes from the previous figure, centered to the cluster centers. The width in Z direction of each plot is 30 Mpc. Circles with radii $R_{\rm s}$ are drawn. It is notable that these complexes are not spherically symmetric, resembling the situation with PP.

Theoretical modelling of galaxy-galaxy lensing

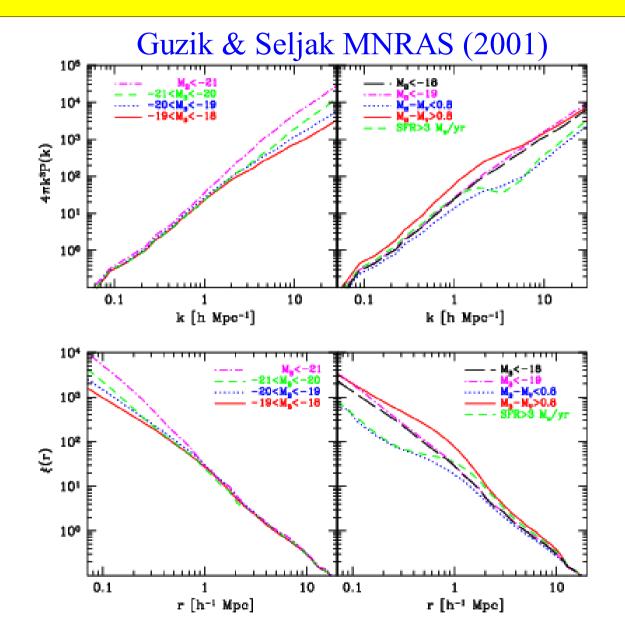


Figure 2. Galaxy-dark matter cross-power spectra and respective cross-correlation functions for luminosity bands (left panel) and colour and star formation rate (right panel). In the lower panels the cross-correlation functions are presented for the same samples as in the upper panel.

Galaxy halo masses from satellite motions

McKay + SDSS collaboration ApJ (2002)

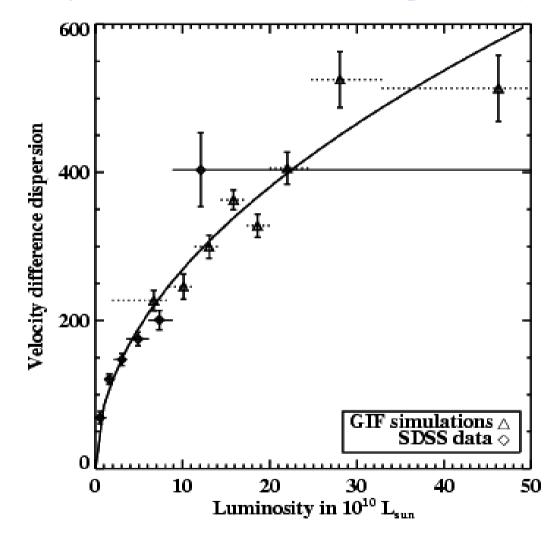


FIG. 2.— This figure compares measurements of satellite velocity dispersion vs. luminosity for real SDSS satellites (diamonds) and simulated GIF satellites (boxes). The two measures are well represented by a single relationship $\sigma_r \propto L^{0.5}$. Vertical error bars represent the uncertainties in determination of the satellite velocity dispersion. Horizontal error bars represent the range of host luminosities for each bin. The results from GIF simulations allow us to test the applicability of our mass estimator. The similarity of the simulations and observations at this observable level give some confidence in the comparison.

VIRGO

Public anouncement of the <u>Virgo data release</u>

Main U.K. site Top Page Members Links Gallery

MPA Numerical Cosmolo Back to NumCos



List of the available data

The following data except the cluster catalogues are very large in size and therefore it is practically impossible to download them via internet or ftp. By selecting data types and clicking "GO" you will get informations on the data such as number of pieces, size, magnetic tape format and also a detailed description of the data will be shown. Please read the description carefully and send the request as instructed.

Snapshot data

□ tCDM at z=0.0 (16 GB)

□ LCDM at z=0.0 (16 GB)

□ LCDM deep wedge (1.4 GB)

LCDM octant A (17.1 GB)

LCDM octant B (6.3 GB)

LCDM sphere A (9.2 GB)

LCDM sphere B (6.2 GB)

□ LCDM planar map (*)

Lightcone outputs : DESCRIPTION(<u>HTML/txt</u>) (* = not yet available)

- □ tCDM narrow wedge (0.5 GB)
- LCDM octant A (6.3 GB)
- LCDM octant B (6.3 GB)
- □ tCDM sphere A (6.3 GB)
- □ tCDM sphere B (6.0 GB)
- tCDM planar map (*)



- **Cluster** catalogues (downloadbable)
 - Snapshot : By FOF algorithm with linking parameter b=0.2 for tCDM and 0.164 for LCDM, ref 2.

<u>tCDM snapshot z=0.0</u> (36 MB) tCDM snapshot z=0.5 LCDM snapshot z=0.0 (42 MB) LCDM snapshot z=0.5

• Lightcone : SO algorithm with density threshold 200, ref 1, See also DESCRIPTION(HTML/txt)

tCDM narrow (160 KB) tCDM octant A (10 MB) tCDM octant B (10 MB) tCDM sphere A (29 MB) tCDM sphere B (28 MB) LCDM deep (430 KB) LCDM octant A (22 MB) LCDM octant B (11 MB) LCDM sphere A (40 MB) LCDM sphere B (40 MB)

Publically releasing simulation data

• Response is strong

-- e.g. ~35 papers (published or astro-ph) using GIF simulations since Kauffmann et al (1999)

• Response is diverse

- >60% of GIF papers by authors unrelated to simulators
- -- theoretical, observational and "proposal" uses
- -- wide geographical distribution (Germany, France, UK, Finland, US, Canada, Israel, China, Japan...)
- Web download is preferred
- Support is needed
- Usage is difficult to monitor/control

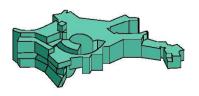


German Astrophysical Virtual Observatory (GAVO)



Collaboration of German institutes:

- Max-Planck-Institut für extraterrestische Physik, Garching
- · Astrophysikalisches Institut Potsdam
- · Max-Planck-Institut für Astrophysik, Garching
- · Hamburger Sternwarte
- Goals:
 - Publishing/federation of local catalogs (ROSAT, VIRGO, SDSS)
 - Develop advanced query and analysis algorithms (catalogue matcher, cluster extractor)
 - · GRID solutions for federated database queries
 - · GRID-enabled simulator
 - Develop the "Theoretical Virtual Observatory" (TVO)



Goals for Theory within the Virtual Observatory

- Public release of major simulation data
 - Products: raw data (position-velocity snapshots), halos, merger trees, mock galaxy catalogues, images, movies...
- Bridge theory/observation gap
 - · Use compatible standards and interfaces
 - · Develop common tools (e.g. Visualisation, joint queries)
- Develop standards for theoretical archives
 - Massive simulations need proper archiving with similar requirements to large observational datasets (history · metadata)
- Promote access to state of the art analysis algorithms
 - Online versions for friends-of-friends, N-point correlation functions, semi-analytical galaxy formation, telescope simulators
- Allow simulations on demand using GRID technology
- Allow a more detailed refereeing by clarifying the provenance of results.

Work Plan

- create a (*meta-*)*data model* describing simulation products. This model must be compatible with the IVOA data models for observations so that observational and simulation archives can be jointly queried
- define *protocols* for registering and maintaining metadata information about products available in simulation data centers.
- create services implementing these protocols for (simulation) data providers to register their products with GAVO and compatible VOs.
- create tools/adapters/plug-ins in standard computing languages for use by data centers/simulators, to ease publication/registration tasks.
- implement IVOA compatible browsing and query services on top of the simulation archives for astronomers to locate and retrieve desired products.
- expose advanced data analysis algorithms written by experts as standard, VO compatible (web) services, using the Globus GRID toolkit for optimal scheduling, security, accounting etc.
- use *GRID* techniques to allow users to bring their own query and analysis algorithms to where the data is stored.
- create the GRID-based GAVO Simulator allowing users to perform simulations on the fly, using observations as input for example to reproduce an observed galaxy merger.
- make all services available through a web browser interface (www.g-vo.org) as well as programmatically through XML/SOAP based web services.
- create a prototype using simulations available at MPA and AIP: large scale structure N-body, cluster hydrodynamics, supernovae, stellar evolution



GADGET galaxies with dark matter and gas interact

A code for cosmological simulations of structure formation

General

- Description
- Features
- Authors
- <u>Acknowledgments</u>
 News

Software

- License
- Requirements
- Download
- Mailing-List
- <u>ChangeLog</u>
 Examples
- Documentation
- Documentation
- Code-Paper
 Users Guide
- ReadMe

Publications

- Scientific Papers
- Pictures
- Movies

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Description

GADGET is a freely available code for cosmological N-body/SPH simulations on serial workstations, or on massively parallel computers with distributed memory. The parallel version of **GADGET** uses an explicit communication model that is implemented with the standardized MPI communication interface.

GADGET computes gravitational forces with a hierarchical tree algorithm and represents fluids by means of smoothed particle hydrodynamics. 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 (dark matter, stars), 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 radiative processes, **GADGET** can also be used to study the dynamics of the gaseous intergalactic medium, or to address issues of star formation and its regulation by feedback processes.

Features

- Hierarchical multipole expansion (tree method) for gravitational forces (geometrical oct-tree, Barnes&Hut-style)
- > Optional periodic boundary conditions (Ewald summation technique)
- \gg Smoothed particle hydrodynamics with fully adaptive smoothing lengths
- >> Shear-reduced artificial viscosity
- Individual timesteps of arbitrary size for all particles

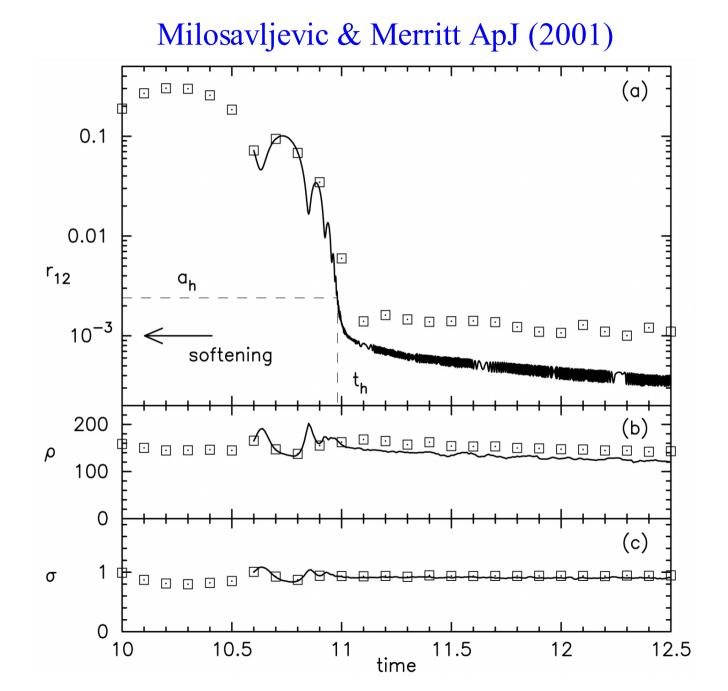
GADGET

- Public code for serial or massively parallel N-body/SPH simulation of galaxies and galaxy formation
- Single author
- Open source

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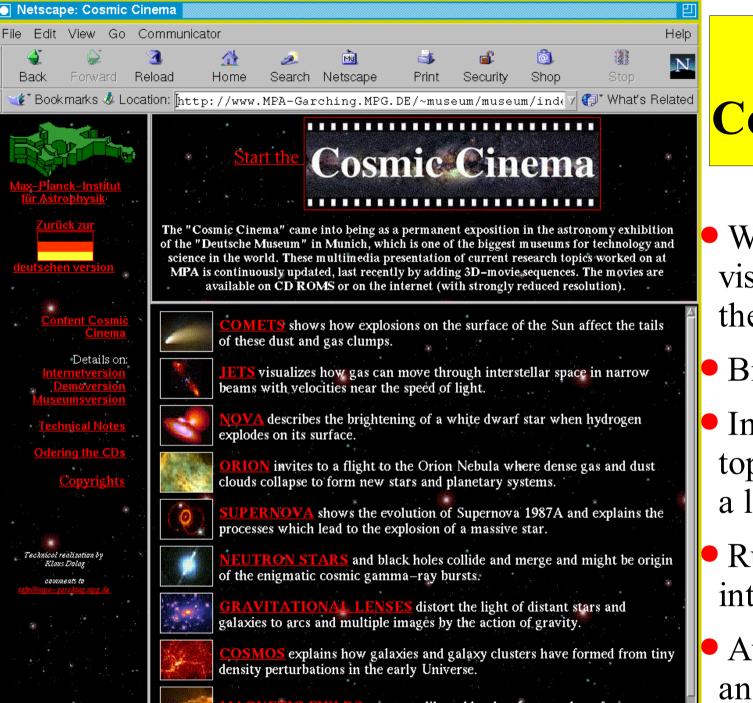
- Web-downloadable
- Documentation and example problems

Merging of galaxies with central black holes



Publically releasing simulation code

- Demand is high
- Continual support is needed
- Some comments lead to improvements, most not
- Impact of coding effort is substantially increased



MAGNETIC FIELDS penetrate like rubber bands a number of astrophysical objects, e.g. the Earth, the Sun and even distant galaxies.

SUN presents an outlook into the future of our own star, which will

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MPA's Cosmic Cinema

Web-based audiovisual presentation for the Deutsche Museum

Bilingual

Introduces research topics of the MPA to a lay audience

Runs permanently and interactively on a PC

Available also on cD and over the Net

Presenting theoretical work to a broad public

- Best combined with observational, instrumental and personal elements
- Visualisation through simulation movies or diagram animation combines well with non-technical narration and with music
- Presentations can be addressed to a broad range of audiences with relatively little modification
 - -- school and university students
 - -- senior or "club" gatherings
 - -- political levels of funding agencies
 - -- web browsers
 - -- museum visitors
- Helps establish the cultural importance of our science