Three-dimensional Visualization of Astrophysical Simulations and its role in Communicating Astronomy with the Public

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OUTLINE

• Introduction
  – Computational Astrophysics at CEA/Saclay : the COAST Project
  – The SDvision visualization software

• Communicating astronomy with the Public using 3D visualization of astrophysical simulations

• Impact on IYA2009

• Forthcoming projects and events
The COAST Project in CEA/Saclay

• The COAST COmputational ASTrophysics project is dedicated to the simulation of structures formation in the Universe using high performance computing
  ▪ PI Prof Romain Teyssier
  ▪ 28 staff scientists, post-docs and students
• It includes visualization tools, distributed databases, code optimization and parallel computing
• Main scientific topics :
  ▪ Cosmological structures formation
  ▪ Interstellar Medium
  ▪ Stellar Magnetohydrodynamics
  ▪ Protoplanetary systems
Astrophysical simulations and high-performance computing

- With the potential of the new generations of massively parallel mainframes, computational astrophysics is addressing problems of increasing complexity and size.
- High-resolution simulations are performed using several thousands of processors and several Terabytes of memory.
  - The most ambitious simulation so far has been conducted as part of the HORIZON “Galaxy Formation” project on the MareNostrum supercomputer in Barcelona using the RAMSES code:
    - 2048 processors for computing
    - 3 weeks of computations
    - 4 billion cells to describe the baryon gas
    - 1 billion particles to describe dark matter
    - 1 output = 100-200 GB (20 TB of data generated and stored)
Visualization with SDvision

- Interactive display of 3D data using IDL Object Graphics

- Described at the CGIV07 Computer Graphics, Imaging, and Visualization Conference

Visualization with SDvision: volume rendering of scalar fields

HORIZON « Galaxy Formation » simulation at MareNostrum

Formation of a galaxy cluster
Visualization with SDvision: isosurfaces

HORIZON « Galaxy Formation » simulation at MareNostrum

ASH simulation of the magnetic field in the Solar convection zone
Visualization of the Dark Matter particles (N-body module)

Rendering of dark matter as a cloud of ~ 2 million particles

Rendering of dark matter as Gouraud-shaded three-dimensional orbs (~5000 particles subset)
Communicating using visualization outputs

- The SDvision visualization software has several output capabilities available for communication purposes:
  - High-resolution images, up to 8192x8192 pixels in various formats: gif, jpeg, png, postscript
  - Standard (monoscopic) movies, by producing sequence of RGB images available for movie makers
  - Dual stereoscopic movies, available for the usual 3D stereoscopic display systems using left/right projectors and adequate glasses
  - 8-camera movies for the new generation of auto-stereoscopic (glass-free 3D effect) high-resolution screens
    » technology released by Alioscopy
    » each scene is viewed from 8 different point of views
    » the 3D effect is obtained without glasses using a network of spherical micro-lens located in front of the display panel
    » we use a 42-inch Full HD screen (1920x1080 pixels)
The role of the visualization of simulations in communicating with the public

- Astrophysical documents based on observations, such as the high-resolution images taken by the HST, are very appealing to the public.
  - the public has access to representations of the Universe in its present state, for example a snapshot of a cluster of galaxies in its current state of evolution
- Documents based on high-resolution simulations are a novelty and a source of public attention complementary to that provided by observations
- One major added value is the possibility to present animations showing the time evolution of astrophysical objects formations.
  - the past and the future of the Universe and the various astrophysical structures are accessible
  - such movies convey profound physical meaning that is accessible to the public, for example:
    - Gravitational clustering in cosmology
    - Galaxy formation by mergers
- The astrophysical objects can be visualized using complex exploration scenarii
Simulation of the Antennae Galaxies collision

The role of the visualization of simulations in communicating with the public

• The visualization of simulations is tightly coupled with the use of technologies that are very attractive to the public:
  - Stereoscopic displays of movies are very impressive and fun in particular for young audiences
  - Auto-stereoscopic screens are a brand new technology that catch the public attention

• Thanks to stereoscopic rendering, the three-dimensional structuration of astrophysical objects is better understood and easier to explain to the public
Impact on International Year of Astronomy 2009

• Our communication media :
  – « Cosmo3D », a 10 minutes-long 3D movie
    • intended for dual stereoscopic display systems with dual left/right projectors
    • built-up on 7 sequences arranged in the top-down hierarchical order : from cosmological structures to stellar MHD.
    • produced by CEA/Irfu and Palais de la Découverte (voice recording) using COAST simulations
  – « L’Univers en relief », a 10 minutes-long 3D movie
    • intended for auto-stereoscopic screens
    • include new simulations
    • High-resolution images
  – Our website : http://irfu.cea.fr/Projets/COAST
    • galleries of movies and images

• Our contributions :
  – A series of exhibitions and events organized throughout the year
“Voyage au Centre de la Galaxie”

• A 3-month long exhibition organized in the unique site of the Palais de la Découverte, starting February 1st, 2009
• Theme: a journey through our galaxy

“Voyage au Centre de la Galaxie”

- a combination of displays, movies and mini-workshops
- “Cosmo3D” stereoscopic movie show
- co-organized by the Palais de la Découverte, CNES and CEA

High impact on the Public:

- 181000 visitors
- 13000 have seen the Cosmo3D show
The Cosmo3D show at the “Voyage au Centre de la Galaxie” exhibition was covered by the “France 3” national TV news

- a two-minute report at 19h50 on Wednesday, February 4th
- introduced by Audrey Pulvar (most popular news presenter in France)
- the report was nicely commented by Patrick Hester, the science expert of the channel
- audience = 5 millions
- a big success in terms of public outreach
“Univers profond, Univers virtuel”

- A one-day event organized at Cité des Sciences et de l’Industrie in the “Jour de science” conference series, November 14th, 2009

- Theme: the new tools to understand the Universe, from giant telescopes to numerical simulations

http://www.cite-sciences.fr
“Univers profond, Univers virtuel”

- “Cosmo3D” stereoscopic movie show
- first commented by an astrophysicist
- then shown during 3 hours in the afternoon

- “round table” with the public
- total audience: 435
“Les Mystères de l’Univers”

- A 12 days-long exhibition in the Trocadéro Gardens organized by CNRS, CEA, CNES, ESA, and Mairie de Paris.

- Theme: an exploration of the Universe and the presentation of some aspects of research in Astrophysics in an immersive scenography, mixing mini-workshops, labs, conferences, movies, ...

High impact on the Public:
- 48000 visitors
- a permanent web page with plenty of contents

http://www.cnrs.fr/mysteres-univers
Scenography

Auto-stereoscopic screen

“Cosmo3D” Show

The Trocadéro Garden

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“Vous avez dit Univers ?”

- A 135 m-long mural in the Montparnasse underground station
- 58 images, 4.6 m-high, presented from October 28th to December 31st
- Theme: a mix of observations and simulations of galaxies, stars, planets
Forthcoming projects

• Building on the success of IYA2009, we are strongly committed to new projects for communicating with the Public:
  – a temporary exhibition in the « Tech’galerie » at Cité des Sciences:
    • a space dedicated to innovation
    • we will run a 3D show on a 47-inch autostereoscopic screen during three months starting April 1st
  – « Derrière l’Horizon », a permanent stereoscopic 3D show at the Musée des Confluences in Lyon
• a museum to explore the connections between Science and Society
• located in Lyon at the confluence of the Rhône and Saône rivers
The Museum will host a space dedicated to the questions of Origins and Destination from different cultures:

3D theater located in the exhibition hall
The Musée des Confluences is producing a 12 minutes-long show on Astrophysics to be run permanently:
- 1st half based on observations (monoscopic)
- 2nd half based on simulations (stereoscopic): from the primordial fluctuations to the formation of a Milky Way-like galaxy

The production is organized on a 18 months-long time scale with milestones and regular meetings between the Museum staff and the simulation & visualization crew

Museum opening in 2014

More information on [http://www.museedesconfluences.fr](http://www.museedesconfluences.fr)
CONCLUSIONS

- The visualization of astrophysical simulations is a source of interest for the public, complementary to astrophysical observations
- The combination with new technologies, such as auto-stereoscopic screens, is a huge incentive to attract the public
- The IYA2009 was a fantastic opportunity to develop and promote public outreach actions
- We are strongly involved in new actions, such as the Musée des Confluences, to continue the promotion of Astrophysics to the public by the means of simulations
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