

Prof.dr. Jos Roerdink

Institute for Mathematics and
Computing Science

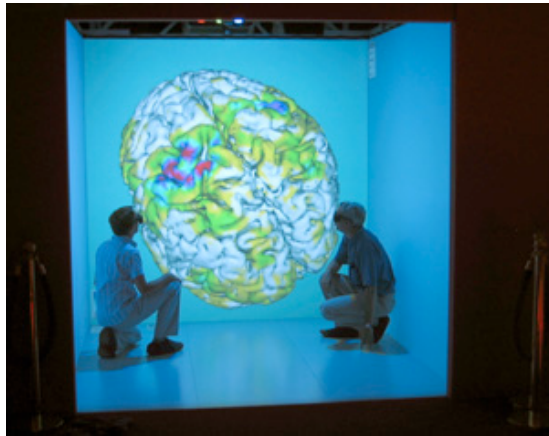
University of Groningen

URL: www.cs.rug.nl/svcg/

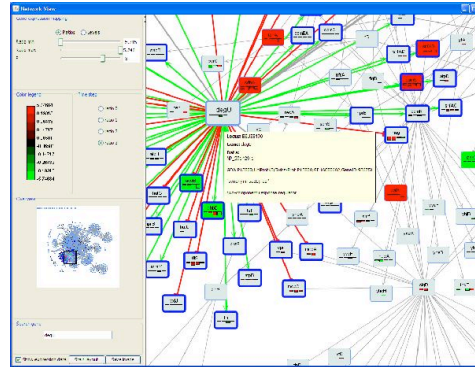


Scientific Visualization & Computer Graphics

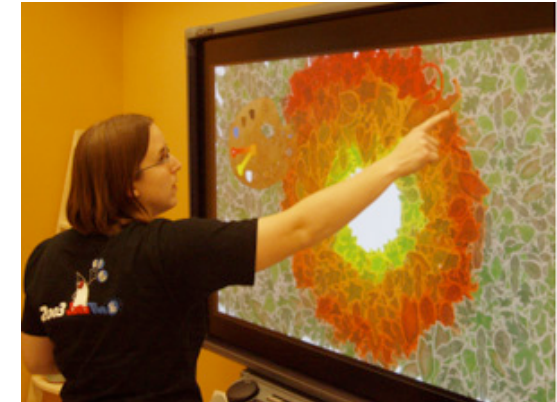
Functional neuroimaging



Genomics visualization



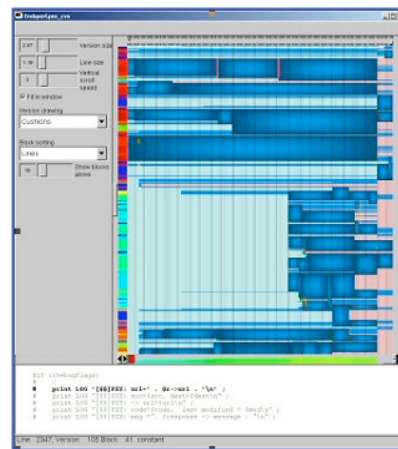
Innovative Interfaces



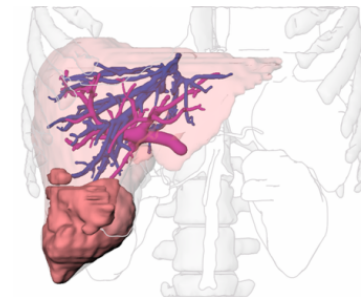
Multi-parameter Astronomical Data



Software visualization

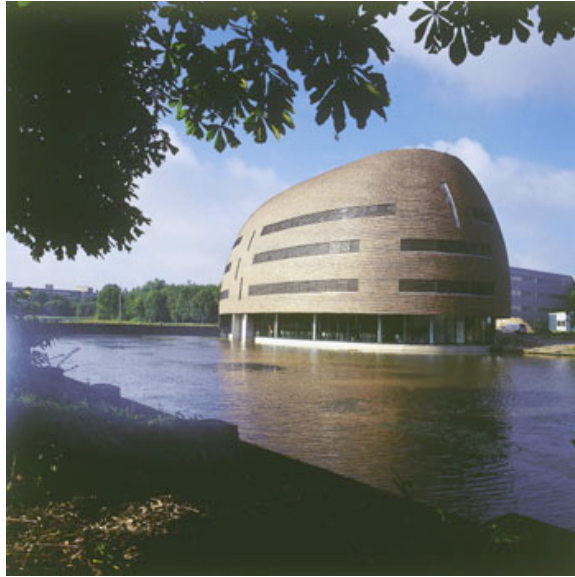


Non-photorealistic rendering





university of
 groningen



Zernikeborg



Cave



Theater

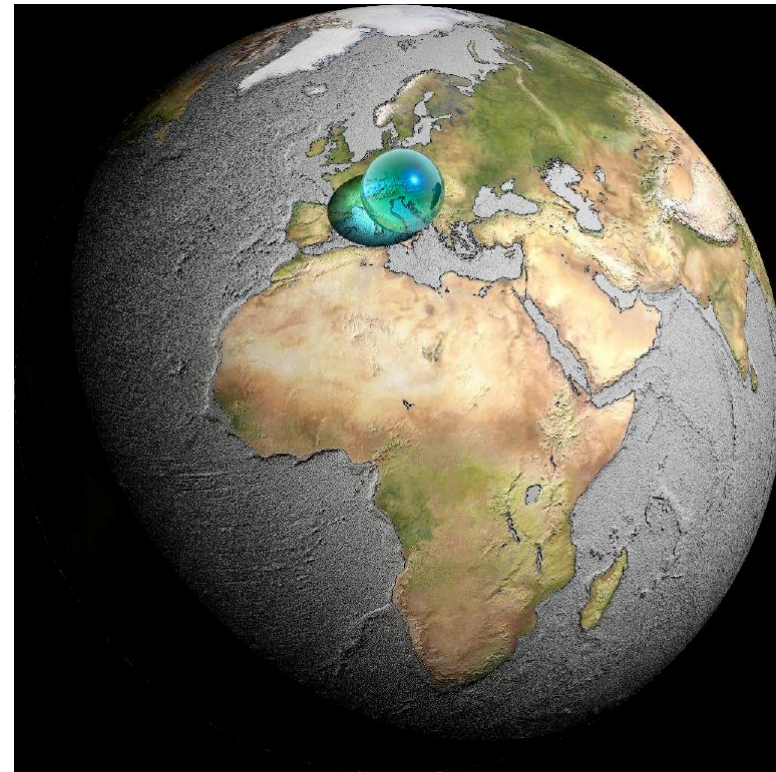
What is visualization ?

- **visualize**: ‘to form a mental image or vision of . . . ’
- **visualize**: ‘to imagine or remember as if actually seeing’

Visualization is a **cognitive** activity.

What is the purpose?

The purpose of visualization is
insight, not pictures *(after Richard Hamming)*



Images courtesy of Dr Adam Nieman

Why Visualization ?

- Exploits dominance of **human visual system** and human pattern recognition capability
- Essential for **interpretation** of data and **hypothesis building** in many scientific problems
- Prominent role for **interactive exploration**

What kinds of visualization?

- **Scientific visualization (Scivis):**
forming visual representations of physical data
(strong association to computational science)
Examples: fluid flow, volume visualization, spatial data (GIS, remote sensing)
- **Information visualization (InfoVis):**
forming visual representations of abstract data
Examples: network visualization, database visualization, program visualization, document visualization
- **Mathematical visualization:**
Using computer-generated visualizations to point the way to rigorous mathematical proofs

The visualisation cycle



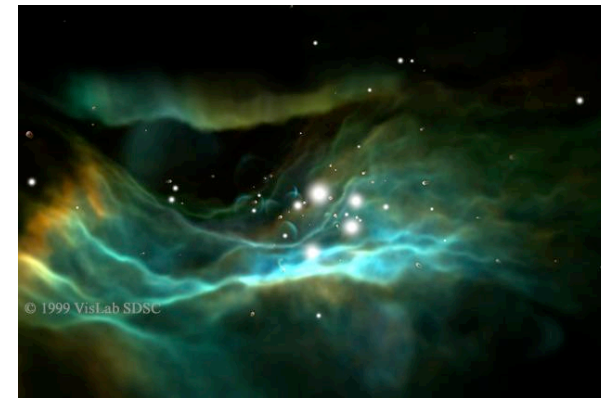
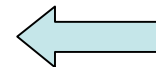
measure



process

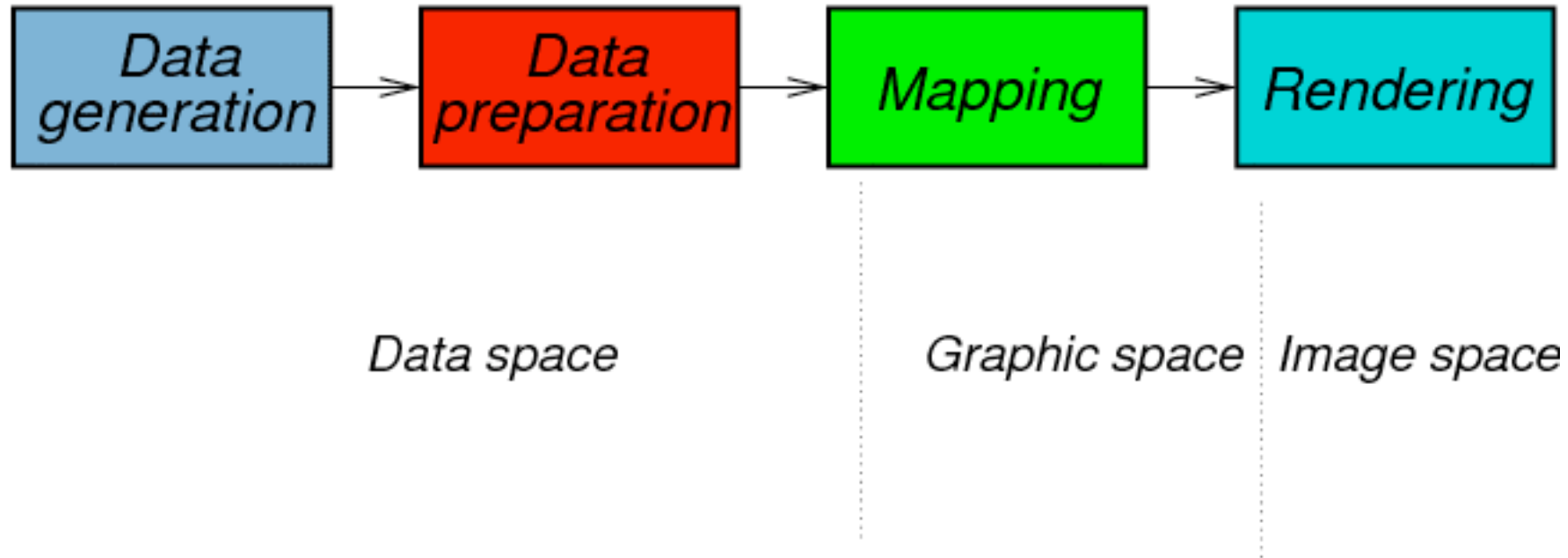


interpret

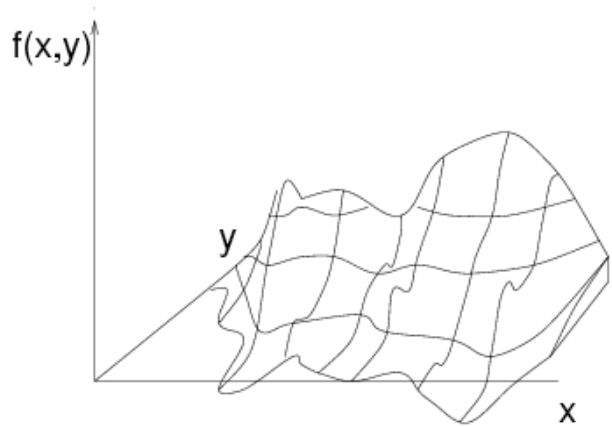


visualize

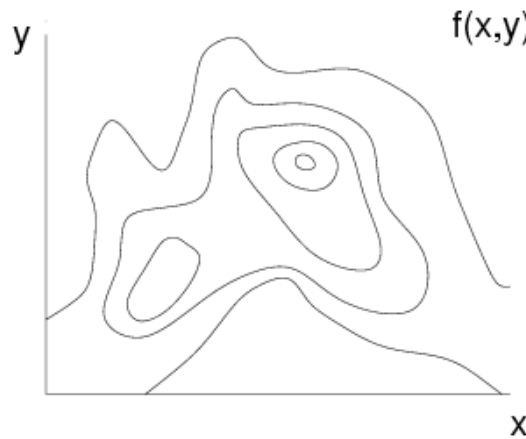
Visualization pipeline



Scalar data 2D



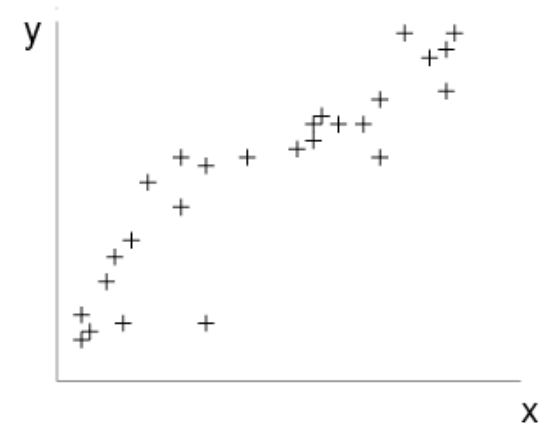
mountain plot/graph



contour lines

grey-scale contour map

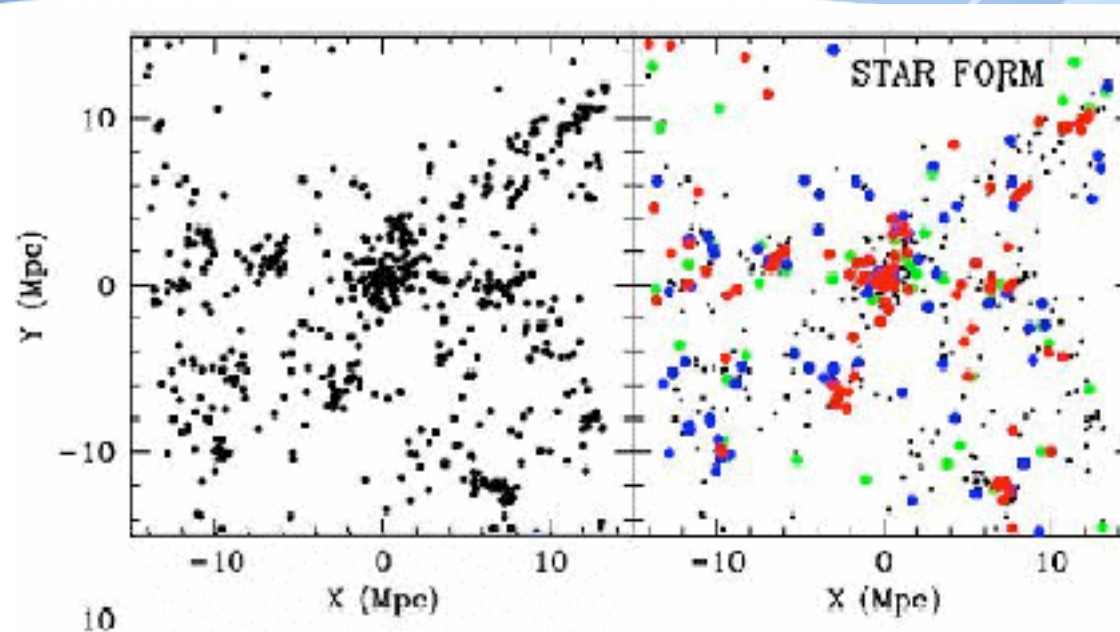
colour contour map



combinations (x,y)

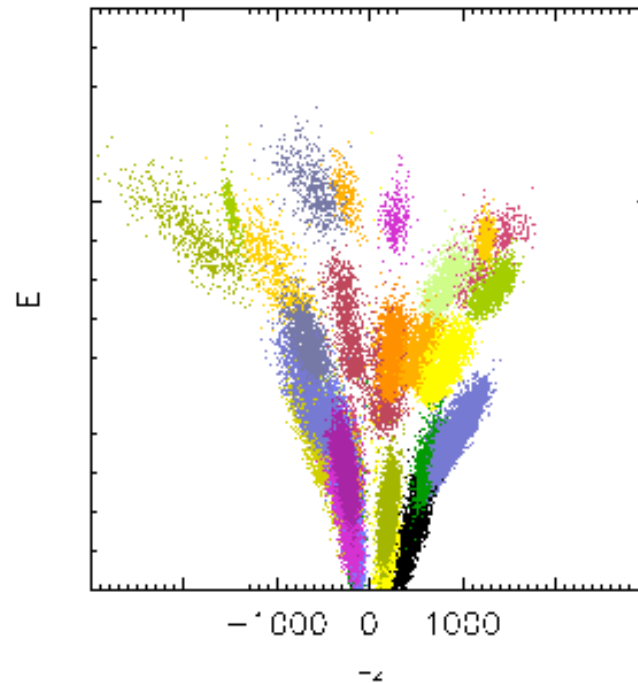
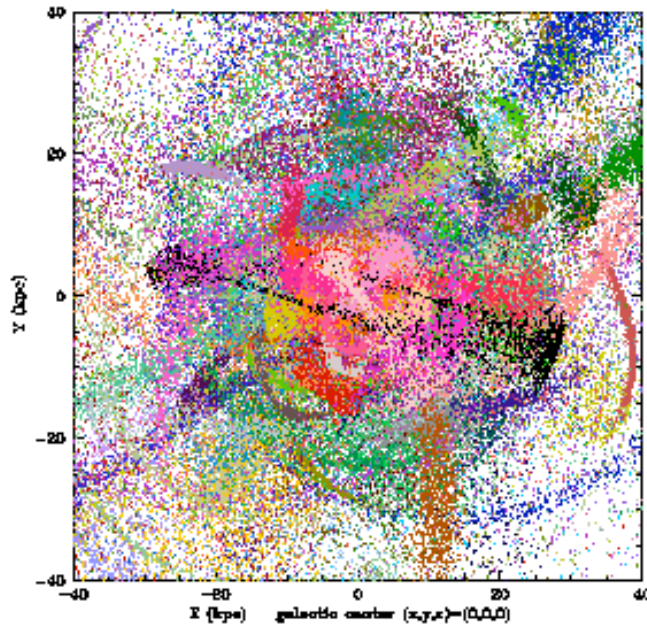
→ scatter plot

Galaxy density vs. star formation activity



Left: Distribution of galaxies in a 'slice' at redshift $z=0.05$.
Right: Galaxies with $10^{10}M < M < 3 \times 10^{10}M$ colour-coded according to star formation activity. **Red** = high; **green** = intermediate; **blue** = low activity. Galaxies with high star formation rates appear to populate the densest areas.

Optimal parameter spaces



Left: Galactic halo in phase-space, built up from 100 satellite galaxies. Only in the outskirts or for recent mergers are tidal tails easily picked out.

Right: representation in space of conserved quantities (angular momentum, energy). Each lump corresponds to one of 33 accreted galaxies. Colour coding is different for each panel (Helmi & De Zeeuw)

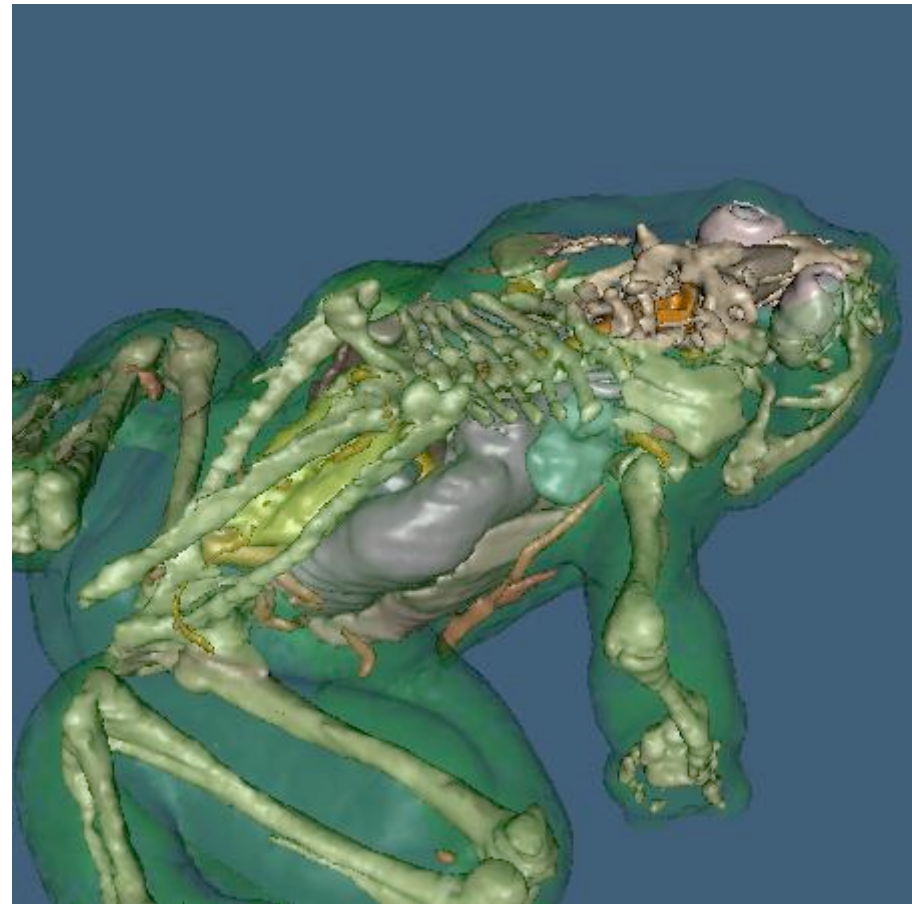
Iso-surface rendering

- Given a density function $f(x,y,z)$ representing the boundary between materials.

isosurface

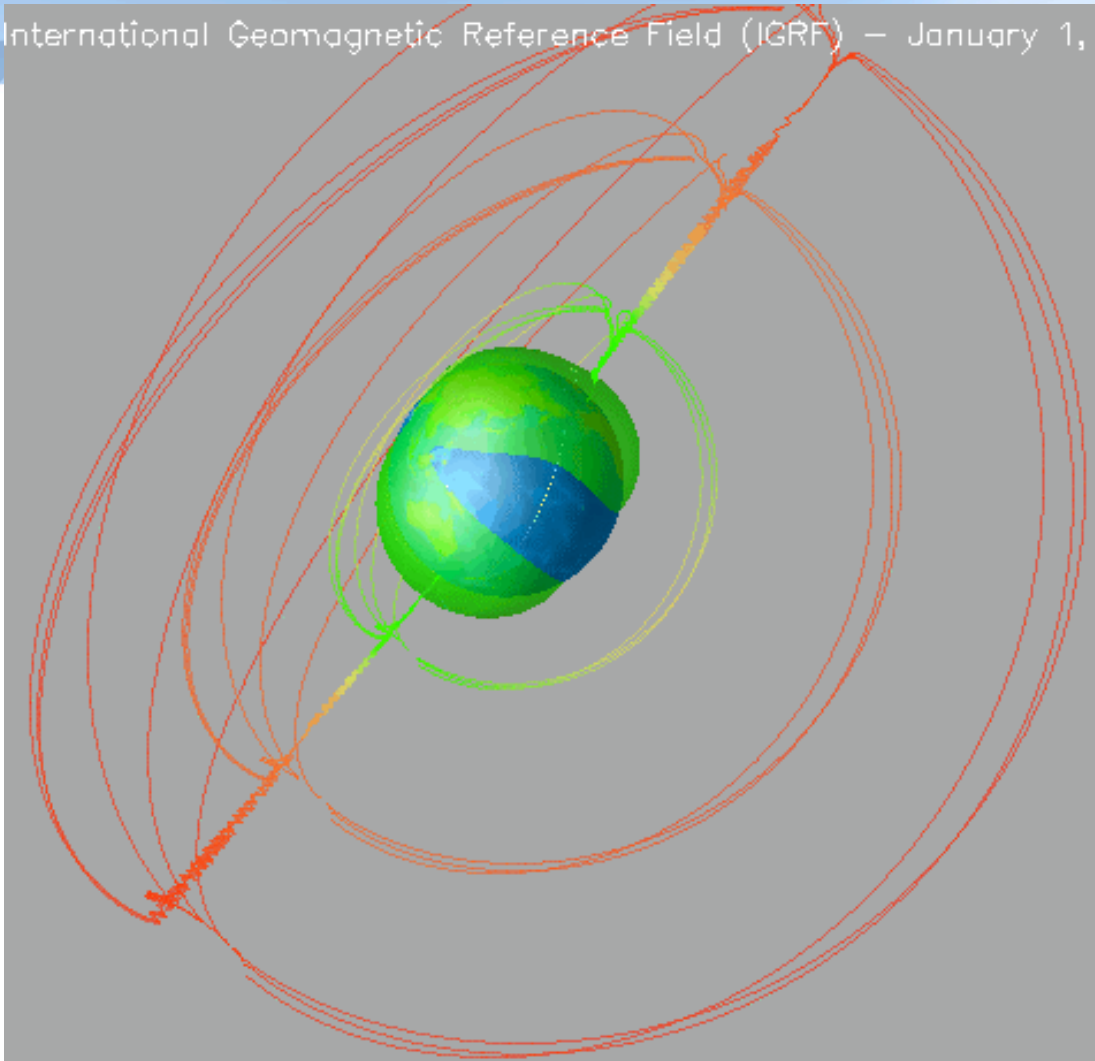
$$S(c) = \{r : f(r) = c\}$$

c =iso-value



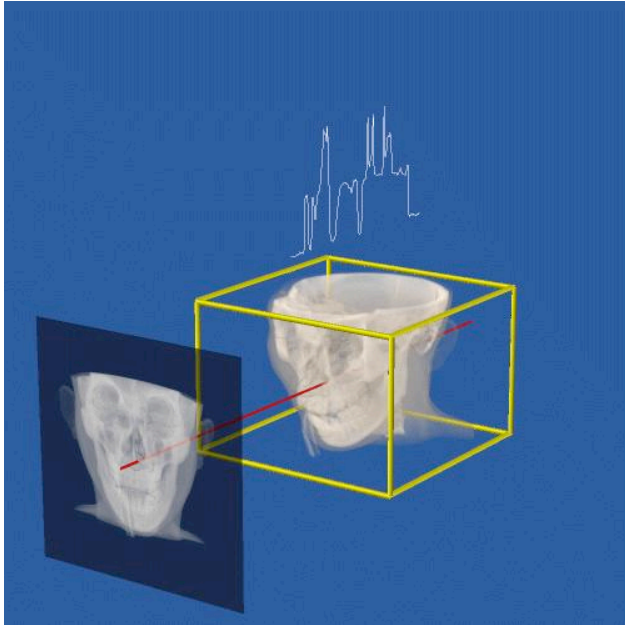
Earth Magnetic Field

International Geomagnetic Reference Field (IGRF) – January 1,



Earth's magnetic field from an empirical model. Streamlines pseudo-colored by field strength in an earth-centered, 3D coordinate system. A translucent isosurface of field strength is also shown, surrounding the north and south magnetic poles. *Data courtesy of NASA/GSFC, Greenbelt, MD. Visualization: IBM Data Explorer.*

Direct Volume Rendering



map volume data **directly** on screen (no graphical primitives) with semi-transparent effects

Volume rendering integral

$$I(\mathbf{x}, \mathbf{s}) = \int_{t_0}^{t_1} f(\mathbf{x} + t\mathbf{s}) e^{-\int_{t_0}^t \alpha(\mathbf{x} + u\mathbf{s}) du} dt$$

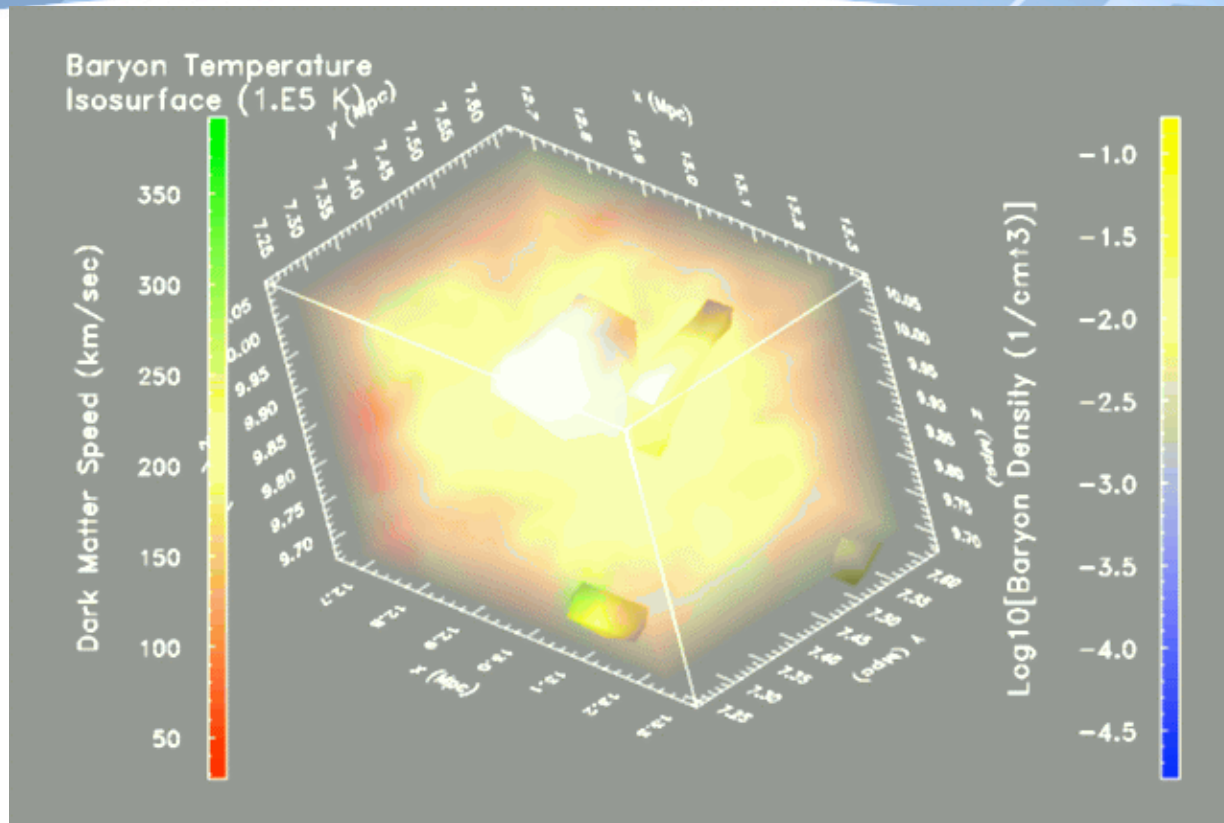
$I(\mathbf{x}, \mathbf{s})$: observed intensity

$f(\mathbf{r})$: measured density

\mathbf{x} : point on screen \mathbf{s} : view direction

α : opacity

Large-Scale Galactic Structure

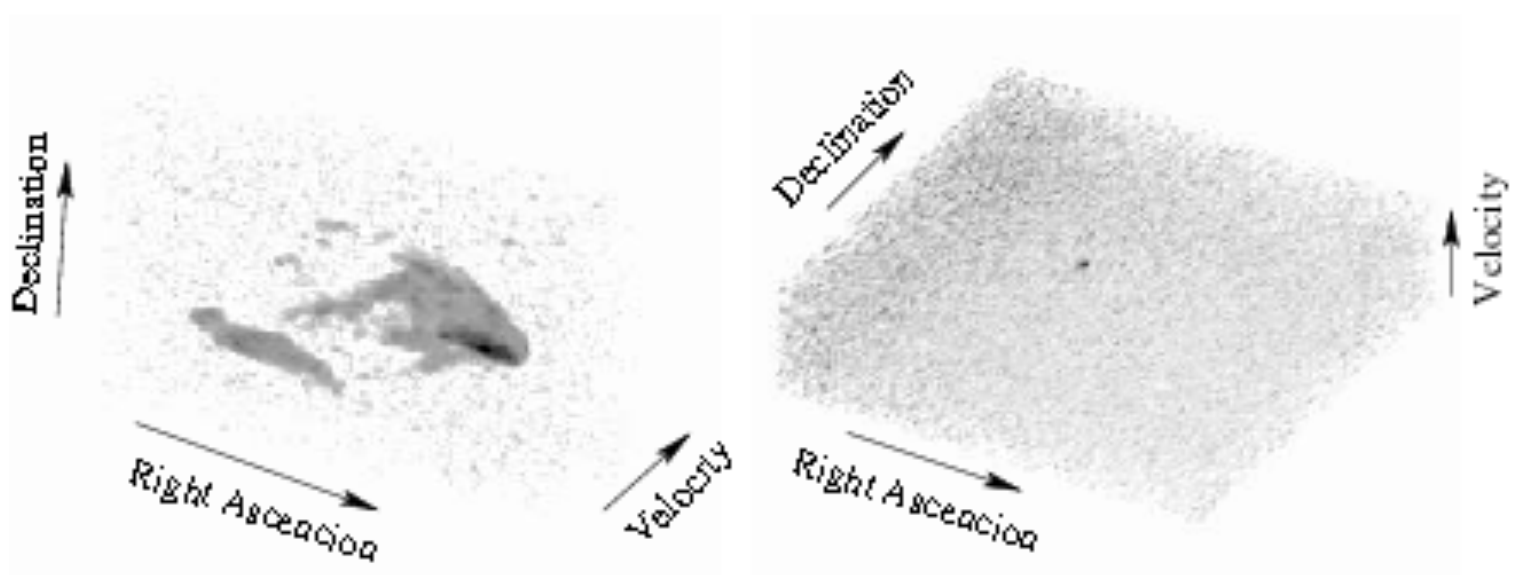


Distribution of baryons and dark matter in a simulation of galaxy formation. Volume rendering of dark matter speed and an isosurface of baryon temperature pseudo-colored by baryon density.

Data courtesy of Gus Evrard, University of Michigan, Ann Arbor, MI.

Visualization: IBM Data Explorer.

Radioastronomy



3-D volume rendered data cubes containing hydrogen (HI) emission from a bright pair of galaxies (left) and a faint single galaxy (right).

Direct volume rendering



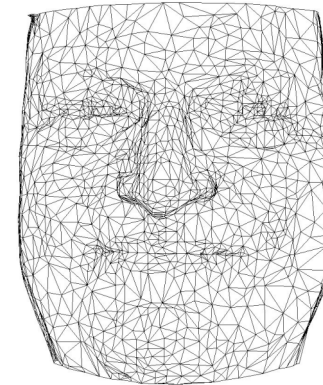
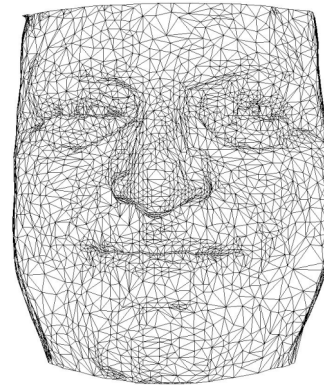
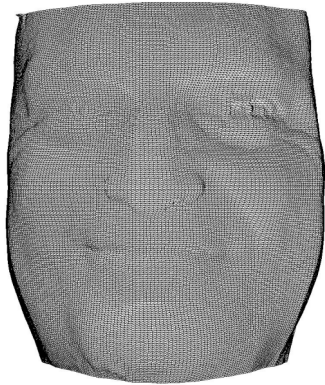
Volume Visualization of the Orion Nebula. San Diego Supercomputer Center (vis.sdsc.edu/)

Simplification Algorithms

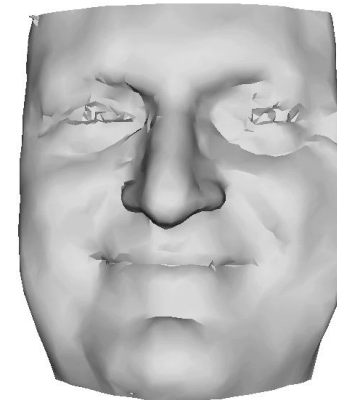
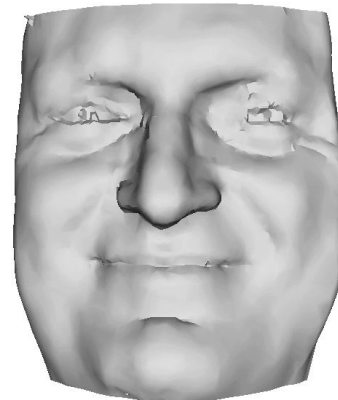
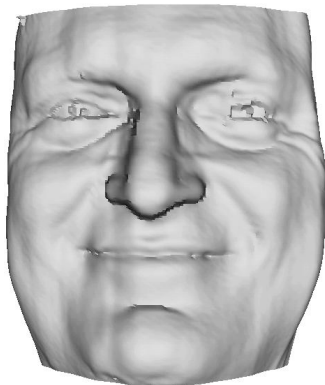
- Surface rendering: **mesh simplification**
(reduce amount of triangles)
- Direct volume rendering: **multiresolution methods** (use levels of varying resolution)
 - ❑ Method based on extraction information of different frequency (scale)
 - ❑ Tool: X-lets (X=wave, curve, edge, ...)
- Method based on extraction information of different **shape**
 - ❑ Tool: morphological image processing

Mesh simplification: example

wireframe



shaded

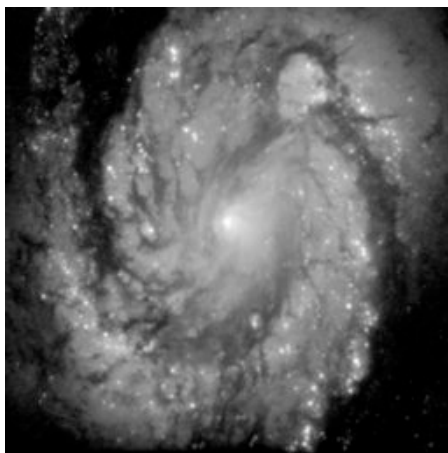
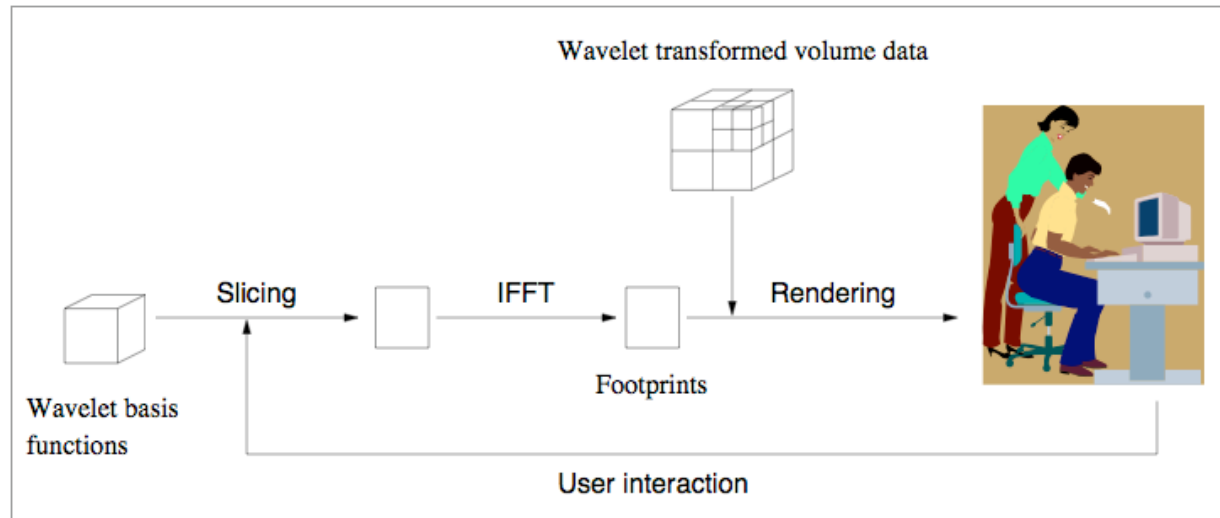


52260 triangles

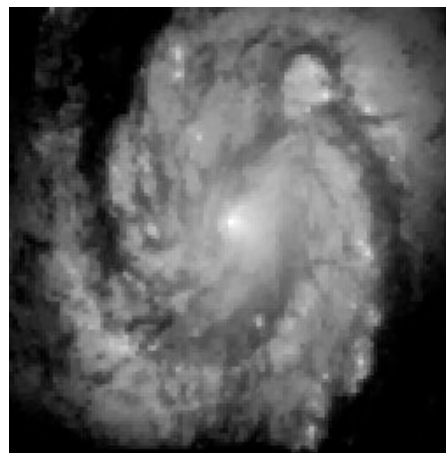
5225 triangles

2612 triangles

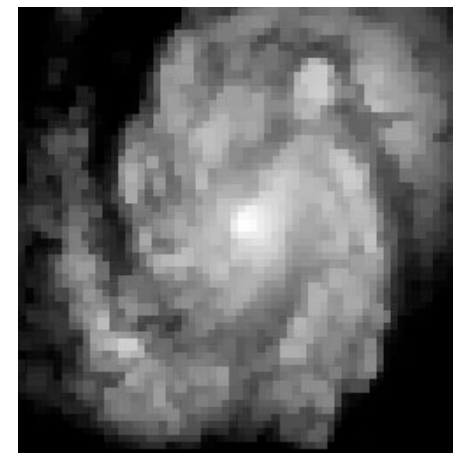
Wavelet Volume Rendering



SpiralGalaxyM100



25% of coeff. used

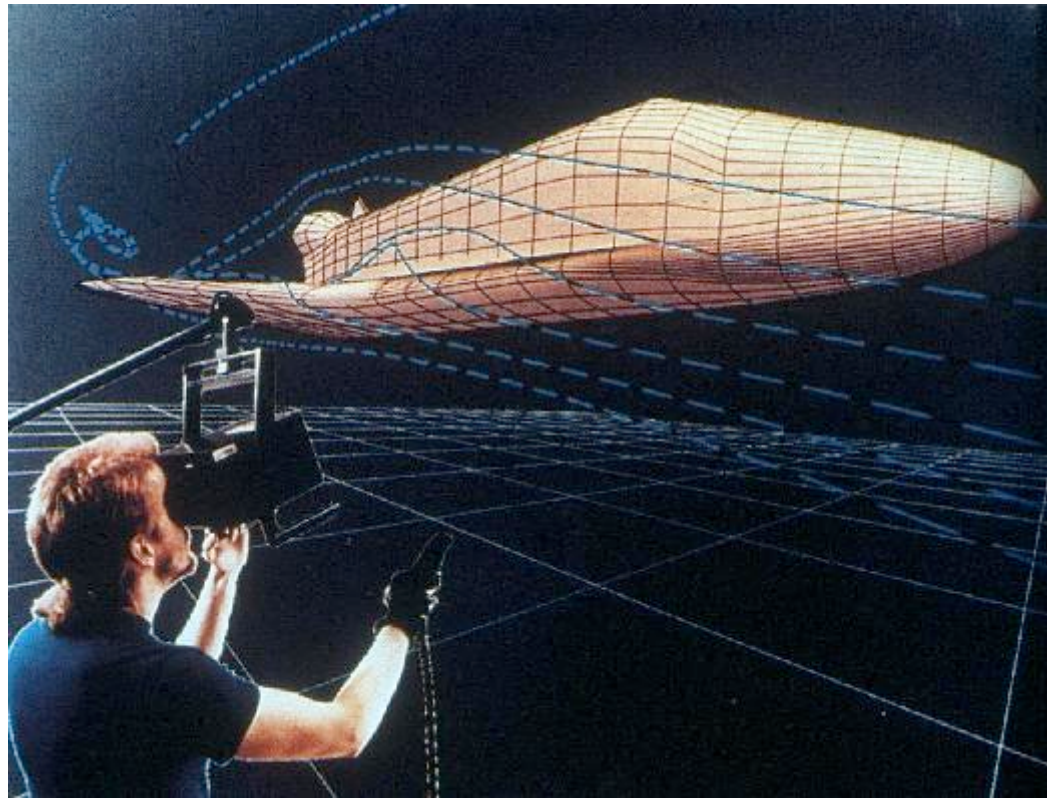


6,25% of coeff. used

Coupled processing and visualisation

- In **real-time analysis** (transient astronomical phenomena), full recomputation of algorithmic steps is unfeasible
- **Incremental** algorithms needed
- **Adaptive visualisation** using data stratification for transient data streams (Wong 2003)
- Use of graphics hardware (GPU)

Interactive environments



Virtual windtunnel

Hayden Planetarium

<http://haydenplanetarium.org>



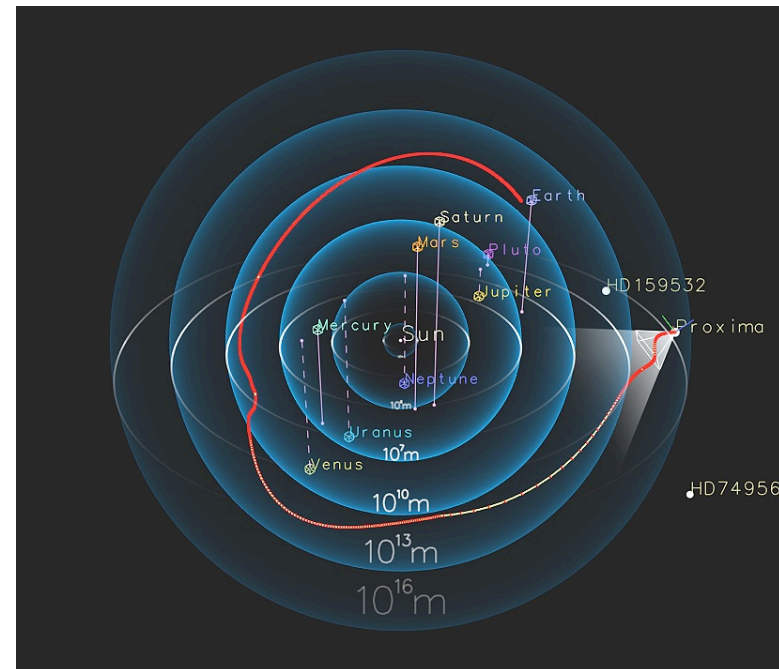
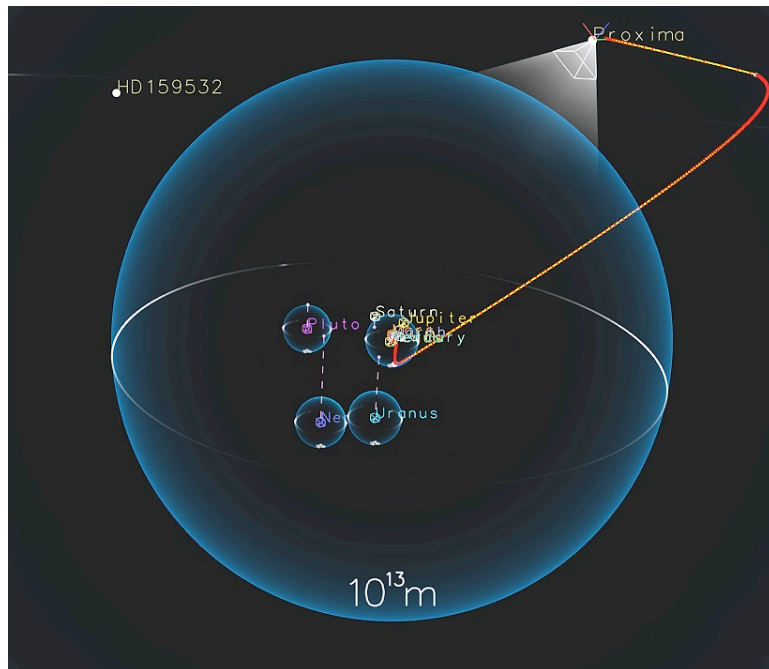
Hayden Digital Dome System

© D. Finnin/AMNH



Hayden Big Bang immersive imagery

Exploration in Large-scale Astrophysical Environments



Scalable world-in-miniature (WIM) map: a unifying interface to facilitate travel and wayfinding in a virtual environment spanning gigantic spatial scales

YingGang Li, Chi-Wing Fu, and Andrew J. Hanson, *IEEE Visualization 2006*
<http://www.cs.ust.hk/~cwfu/papers/scalewim/>

Challenges

- **Efficiency** of many existing algorithms with respect to speed and memory is too low for very large data sets (only order N algorithms feasible, where $N = \#$ data points)
- Visualization of **high-dimensional parameter spaces** requires development of good visual metaphores and efficient data exploration to find interesting projections and sections in d -space
- **Integration** of filtering and visualization in a Problem Solving Environment
- Tension between **automation** and **human interaction**