

# Introduction to Visualisation: iVEC intern program 2009

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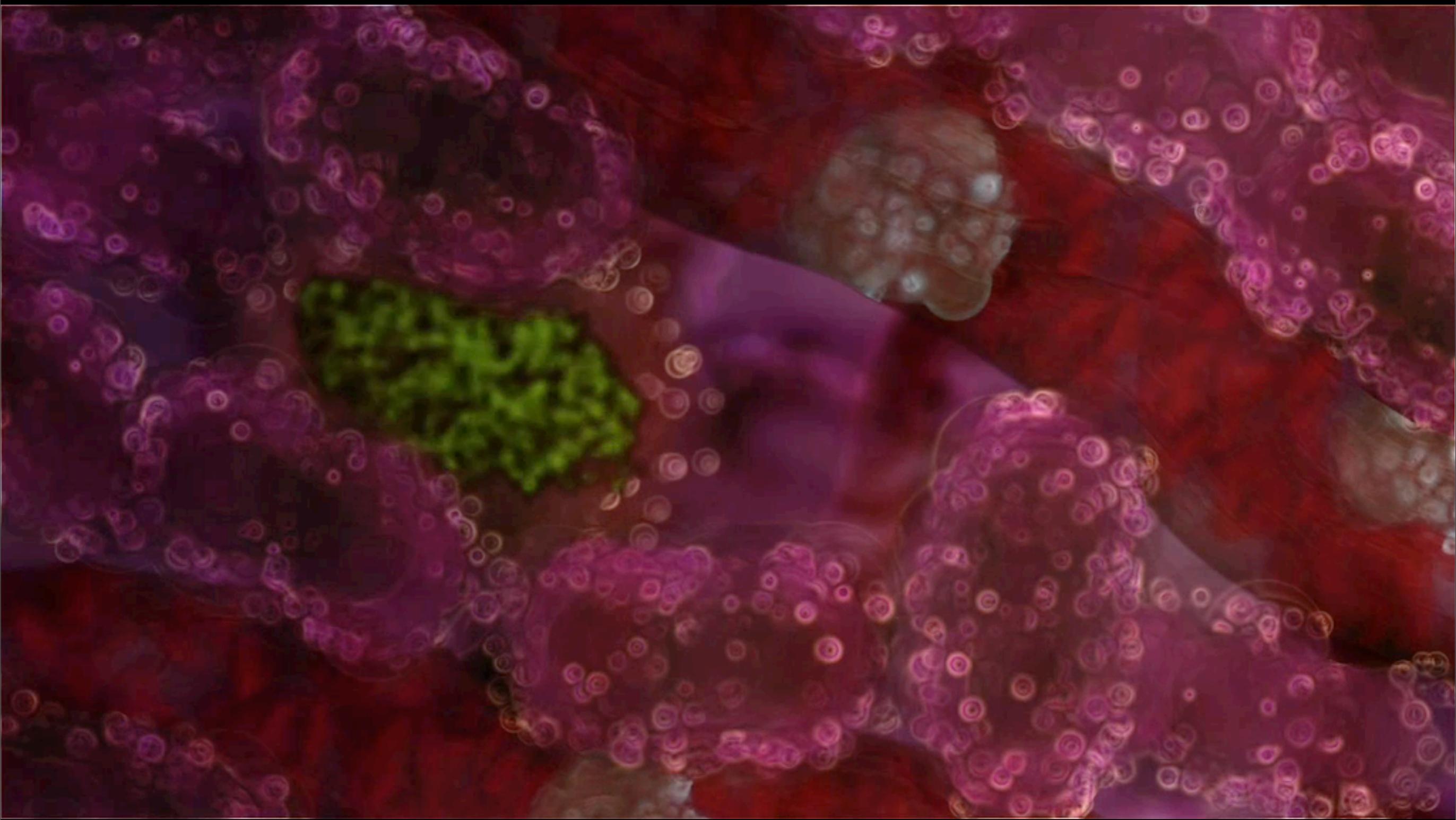
# Contents

- Visualisation
  - What is it and what's it good for?
  - General techniques, tools, technologies, standards, file formats ...
  - Challenges
- Examples and discussion
  - Selection of visualisation examples from 2007-2009 from Australian researchers
- Novel display technologies
  - Stereoscopy
  - Immersive displays
  - Rapid prototyping, crystal engraving
  - Holography
- Tour of visualisation laboratory
  - Tiled display
  - Single wall stereoscopic display
  - Immersive hemispherical dome (iDome)
- Hands on volume visualisation example (teaching laboratory)
  - Use Drishti to demonstrate volume rendering principles

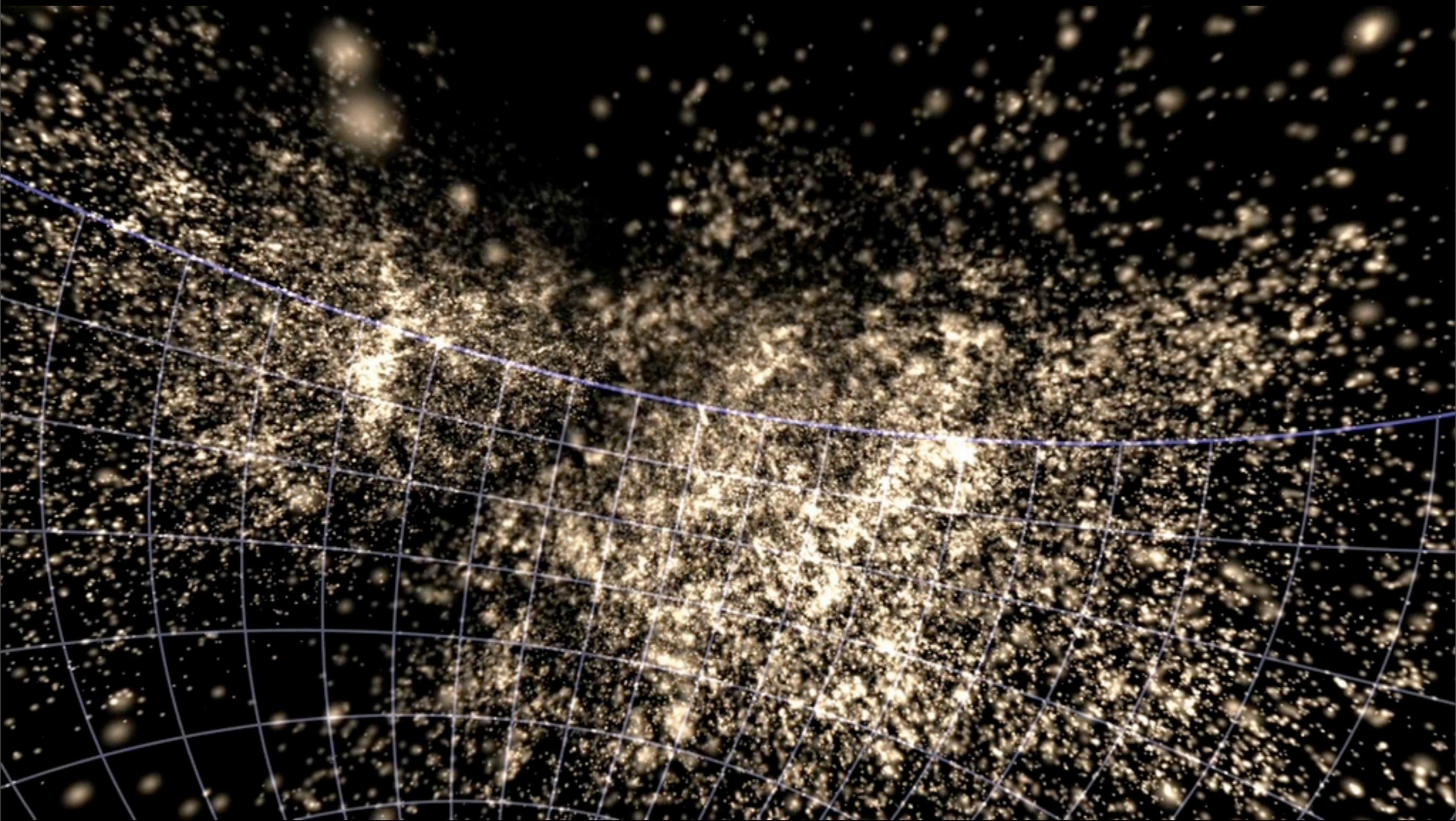
# What is it?

- Presenting data in an informative way using computer algorithms and computer graphics.
- Will make a distinction between data visualisation and illustrative visualisation.  
Illustrative visualisation: conveying an understanding of some principle without necessarily having any real data involved. Generally targeting a non-expert audience.
- Aims of scientific data visualisation
  - Allow researchers to find new relationships within their datasets.
  - Allow researchers to more quickly understand their datasets.
  - Visually identify errors in the datasets.
- Sources
  - Experimental data, for example 3D scanning, surveys, photogrammetry, etc.
  - Simulation data, for example from numerical methods.
- Science visualisation outcomes
  - Used by scientists as part of their research.
  - Used to convey research outcomes to their peers, eg: conferences, papers.
  - Used to educate a non expert audience, eg: public education/outreach.

# Example: Illustrative visualisation



# Example: Data visualisation



# Data types

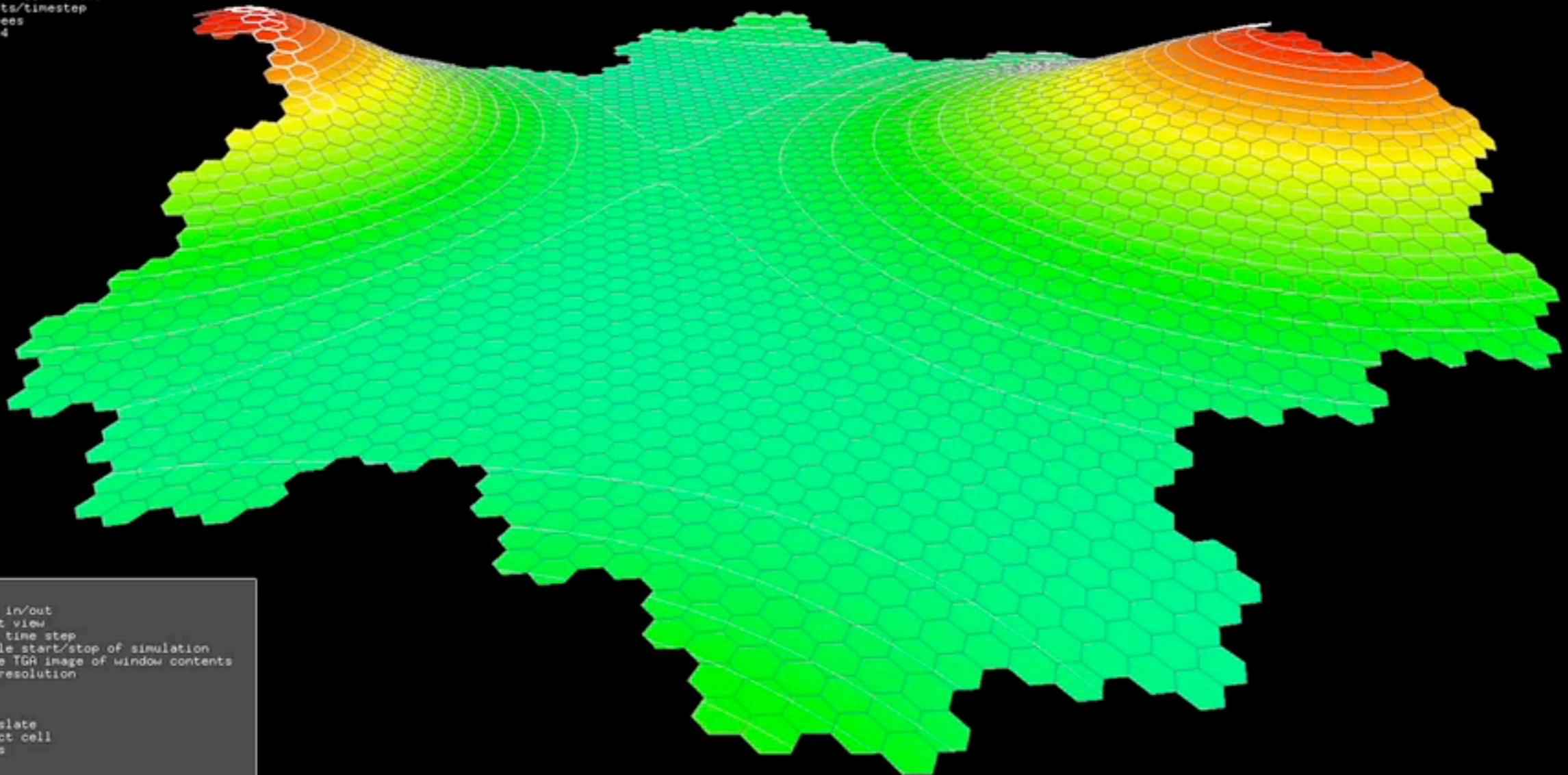
- Visualisation is most commonly a mapping between data variables and geometry.
- In some cases the mapping is very obvious, for example a mesh describing a landscape, or ball/cylinders representing molecular structure.
- Often there is no obvious relationship between the data and a geometric entity, one can then choose the most informative geometric or visual representation.
- Common to map variables to colour maps/ramps.
- Common to use “glyphs” to represent variables. In this context a glyph is usually a 3D object made up from units each of which is a mapping from a data variable.
- Common considerations
  - The dimensionality of the data, how many independent variables.
  - The variable dimension: binary, category, scalar, vector, etc.
  - Discrete or continuous variables.
  - Static or dynamic data: is one producing images or movies.
  - How the data is sampled: on a regular grid, randomly, volumetric.

# Example: Cortical wave model

Showing surface layer  
Time step: 358  
Resolution: 4 (2401 cells)  
Radius: 49.57 units  
Connection stddev: 5 units  
Aggregate gain: 1.000  
Connection Speed: 1 timesteps/cellradius  
Required history length: 17 timesteps  
Integration length: 12 timesteps  
Connections: 2033647

Stimulus scale: 7  
Surface layer range: -0.271402 -> 1.00867  
Hidden layer range: 0 -> 6.92725  
Colour ramp scale: -1 -> 1  
Height scale factor: 10

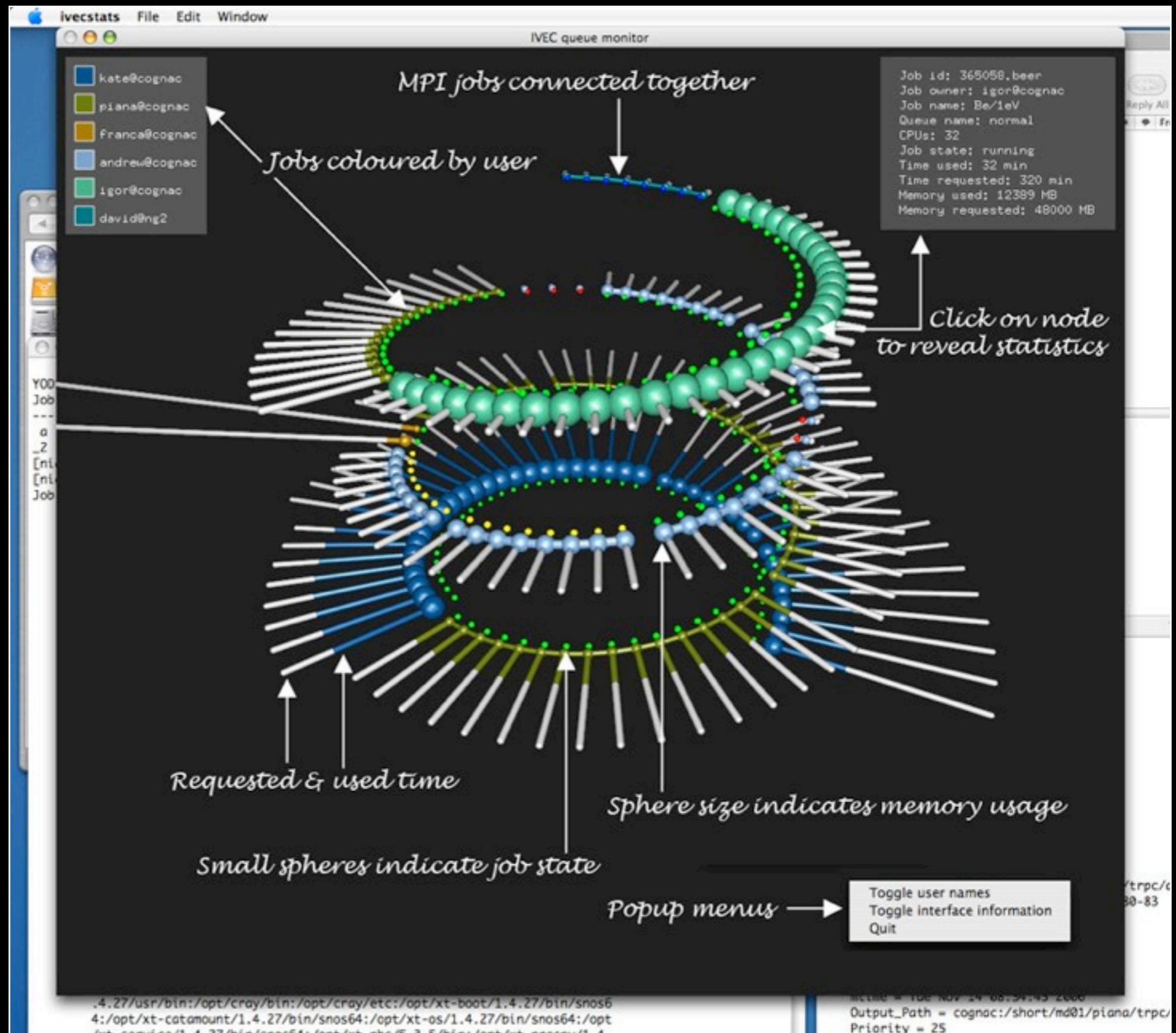
Bar dimensions: 21 x 1.74 units  
Bar speed: 0.2 units/timestep  
Bar angle: 45 degrees  
Cells under bar: 14



Key commands  
-,+ zoom in/out  
r reset view  
n next time step  
s toggle start/stop of simulation  
w write TGA image of window contents  
1..6 set resolution  
ESC quit

Mouse buttons  
left translate  
middle select cell  
right menus

# Example: Glyphs



- Colour maps
- Geometry mapping
- Category data
- Continuous data
- Data-geometry mappings

# File formats

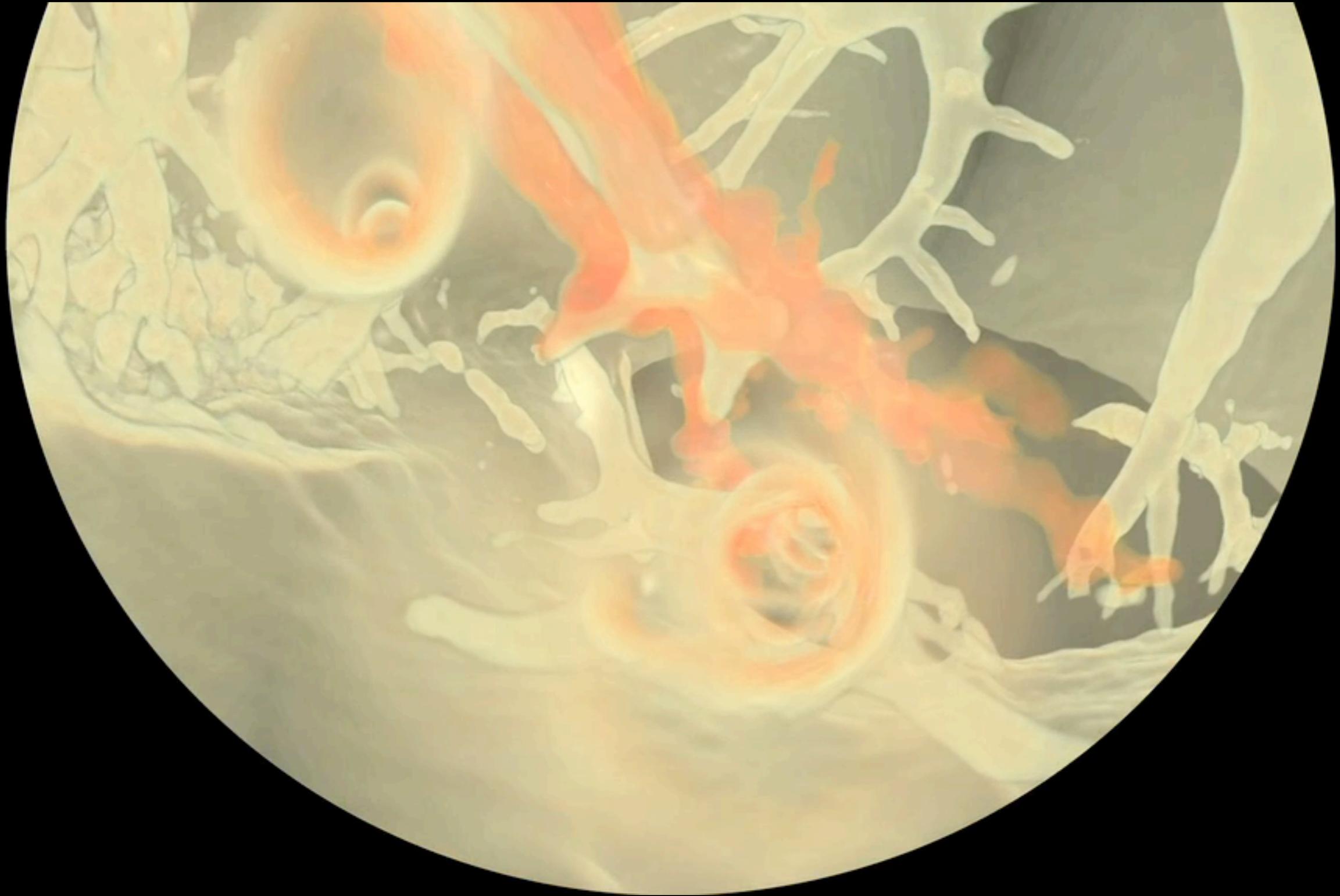
- Visualisation often requires considerable time converting data between file formats. Software X requires data in format Y, the data is provided in format Z.
- Often researchers save data in their own “made up” formats. At least these are usually simple and well known.
- There are industry standards, but there are lots of them and they are often discipline or problem specific.
- For example, the storage requirements in GIS (Geographic Information Systems) are very different to those required for storing molecular data.
- Examples of standard formats are HDF, NetCDF, FITS, DICOM, and so on .... many of these are very complex since they have been designed to support a wide range of data characteristics. Many have associated APIs to assist with reading, parsing, and saving.
- There are also visualisation packages that in general have their own proprietary format. Example of some of these are: OpenDX, VTK, AVS Express, IRIS Explorer, AMIRA, and so on.

Quote: “Standards are good ... lets have lots of them”.

# Volumetric data

- A very common type of data that arises in many fields is so called volumetric data.
- For example: MRI, CAT, CT, MicroCT, X-ray tomography, etc.
- Can be considered as a 3D image. An image has a fundamental element of a pixel (a rectangle), the 3D equivalent is called a voxel (a box).
- A volumetric dataset is a regular (usually) sampling within some rectangular region of space. The voxels (samples) contain some value, usually a scalar but may be multivalued or a vector.
- Visualising volumetric data has traditionally been challenging.
- Most realtime volume visualisation today occurs on the graphics card.
- Scalar volumes are often reduced to 1 byte per voxel in order to maximise the volume size supported by the available memory. More common to use a 2 byte integer, but most volumetric datasets are originally floating point values per voxel.
- Typical volume sizes for “small” volumes is  $100 \times 100 \times 100$  voxels.  
“Medium” size volumes are around  $500^3$  and can now be handled fairly easily in realtime.  
“Large volumes are those greater than  $1000^3$  and can be quite difficult both as prerendered and in realtime. For example, a  $1000^3$  volume of short ints (2 bytes) per voxel is 2GB.

# Example: Introduction to volume rendering

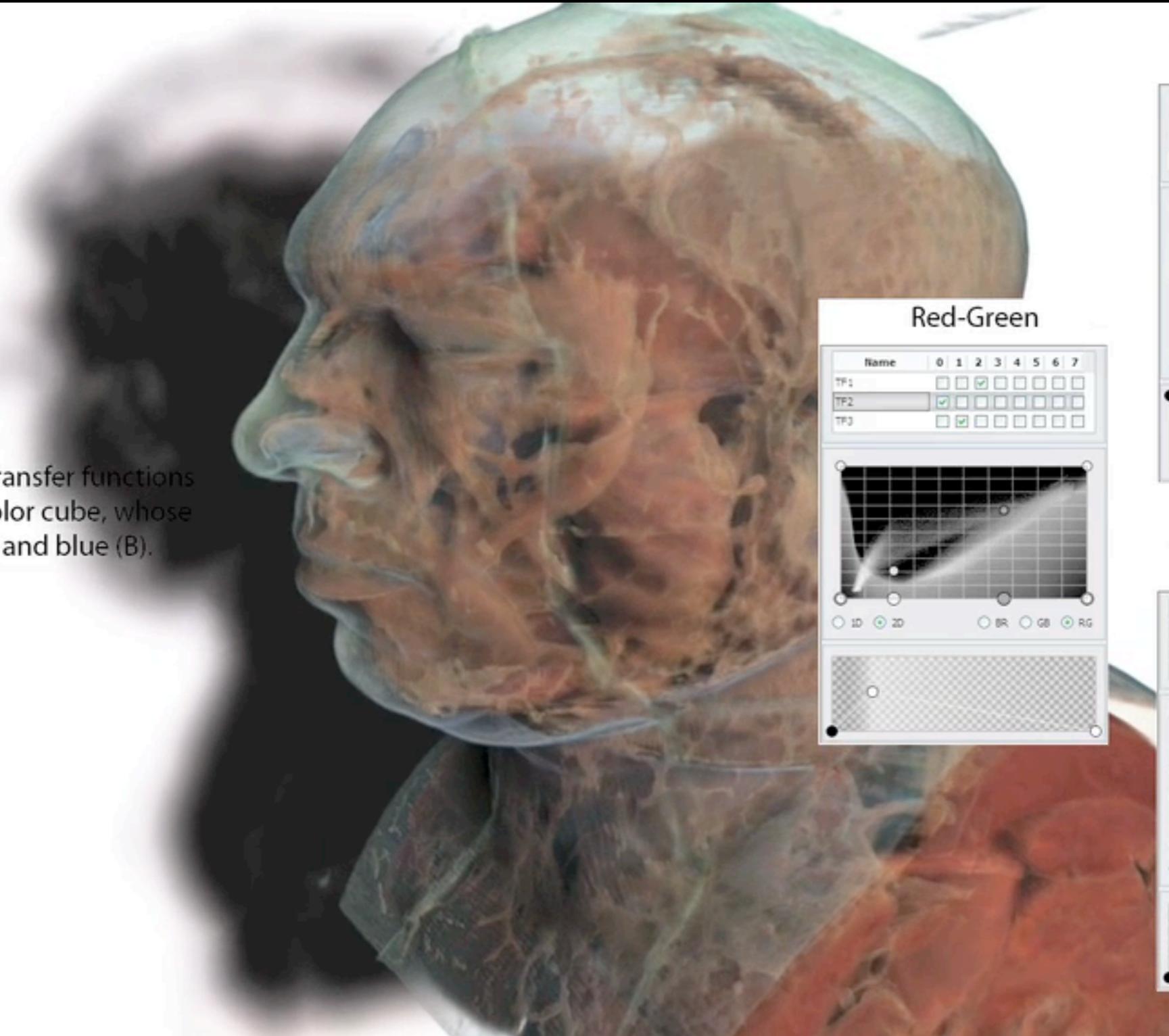


# Example: Volume rendering - CT



# Example: RGB volumes

Drishti employs 3 opacity transfer functions defined on 3 faces of the color cube, whose axes span red (R), green (G) and blue (B).



### Red-Green

Name	0	1	2	3	4	5	6	7
TF1	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
TF2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TF3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1D  2D  BR  GB  RG

### Green-Blue

Name	0	1	2	3	4	5	6	7
TF1	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
TF2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TF3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1D  2D  BR  GB  RG

### Blue-Red

Name	0	1	2	3	4	5	6	7
TF1	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
TF2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TF3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1D  2D  BR  GB  RG

# Challenges

- Datasets are growing in their spatial and temporal resolution.
  - data acquisition/scanning tools are always striving for and achieving higher resolution.
  - high performance computing is allowing for higher resolution simulations to be performed.
- Expectation of realtime visualisation as the data volume grows.
- Increasing resolution of display devices.
- Desire to work from personal workstations rather than a dedicated visualisation laboratory.
- Expectation of higher quality visuals, driven by improved fidelity and realism in games.

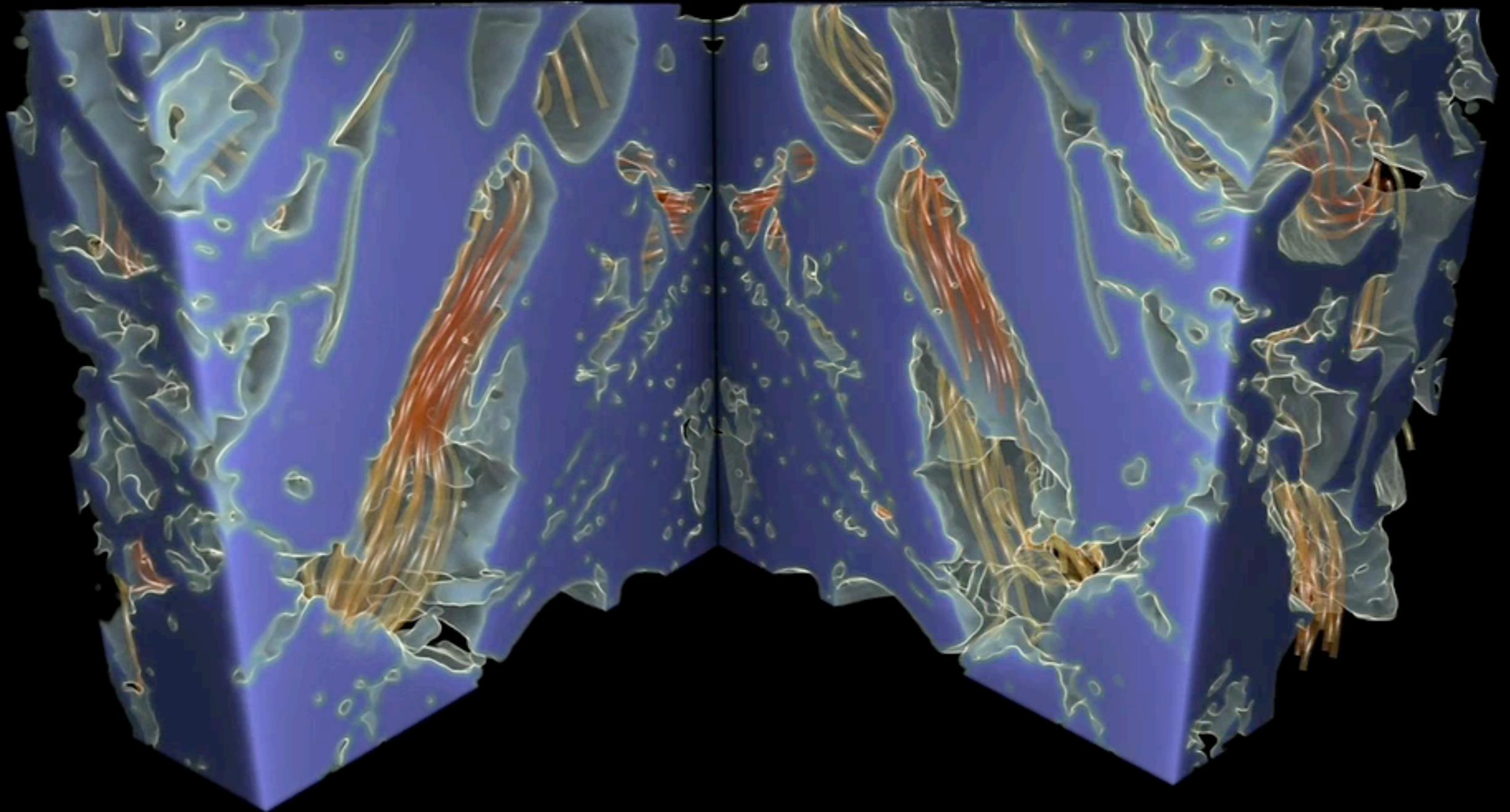
# Addressing challenges

- Growing capability of graphics cards.
- Use of efficient data structures so that larger datasets can remain in RAM.
- Efficient disk spooling of data to/from RAM.
- Development of techniques that allow one to trade off quality for interactivity.
- Adding dedicated visualisation support to HPC facilities.  
Problematic due to non-realtime / batch operation mode of most HPC.

# Example: Disaster simulation



# Example: Flow simulation visualisation



# Example: Virtual heritage

# Antarctica Virtua

[antarcticavirtua.net](http://antarcticavirtua.net)

# Novel display technologies

- Visualisation is largely concerned with the human visual system, that is, presenting information to our brain through our sense of sight.
- ARRC and WASP both have stereoscopic 3D viewing systems. Presents a sense of 3D that we expect in the real world given images from our two eyes.
- iDome is a hemispherical dome projection system. Ideally suited to placing the observer “inside” their data.
- Tiled display that allows one to present very high resolution data while reducing the need to zoom and pan.
- All of these exploit characteristics of our visual system not normally engaged when using a standard small monitor.
  - Stereopsis.
  - Peripheral vision.
  - Visual fidelity.
- Also have applications to public outreach and engaged learning.

# Stereoscopy

- Irrespective of the stereoscopic system used the goal is to present two correctly formed images independently to each eye.
- Technologies include shutter glasses, polaroid filters (WASP), Infitec (ARRC).
- Glasses free systems are being developed but generally still low resolution and have viewing constraints.

[Demo later]



# Peripheral vision: iDome

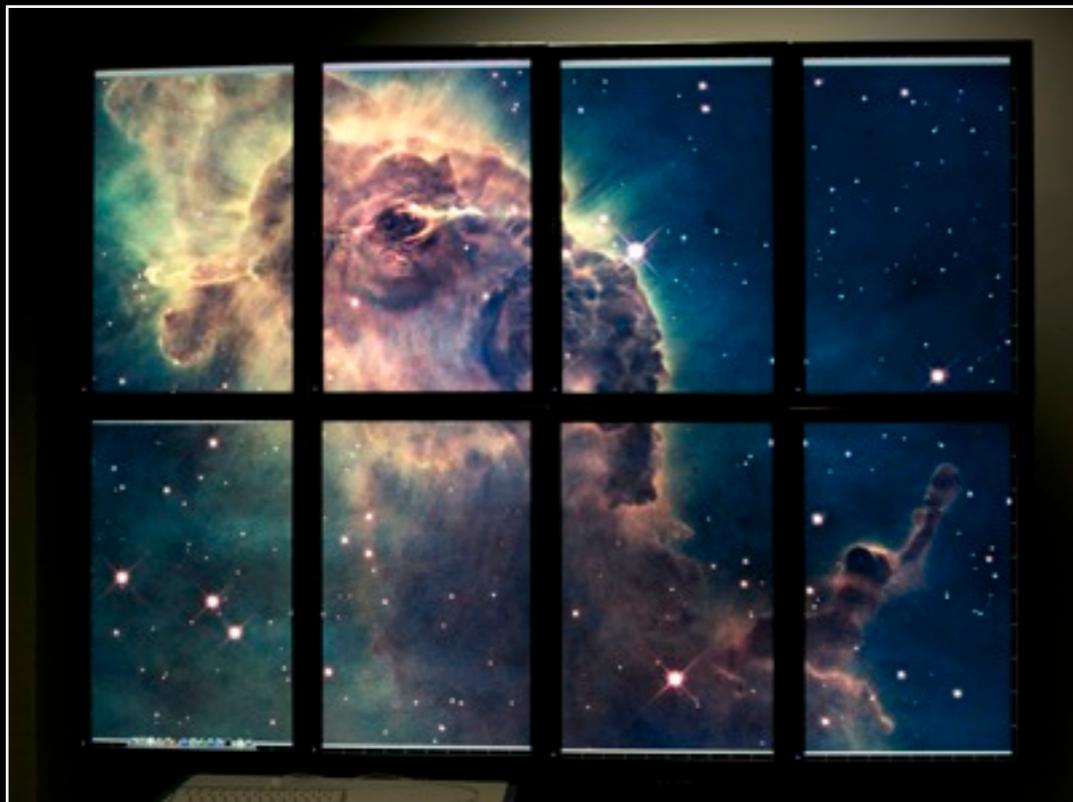
- Many geometries have been used, eg: cubic rooms (CAVE), cylindrical displays (AVIE).
- We are experimenting with a hemispherical surface, called the iDome.
- Similar in principle to a digital planetarium but orientated at a different angle.
- Projects so far have included molecular visualisation, virtual heritage, volume rendering, remote operations, gaming/entertainment.

[Demo later]



# Tiled display

- The highest resolution displays (readily) available are 2560x1600. Data projectors mostly peak at 1920x1200, 4K projectors have prohibitive price tags.
- In order to get higher resolution the choice is to tile projectors or displays.
- Projectors are generally edge blended so one get a seamless image at the cost of high maintenance.
- Tiling displays has the disadvantage of borders between the tiles but a simpler software model.
- The display here is 8 x 30" DELL monitors, each 1600x2560. So total resolution of 32MPixels.



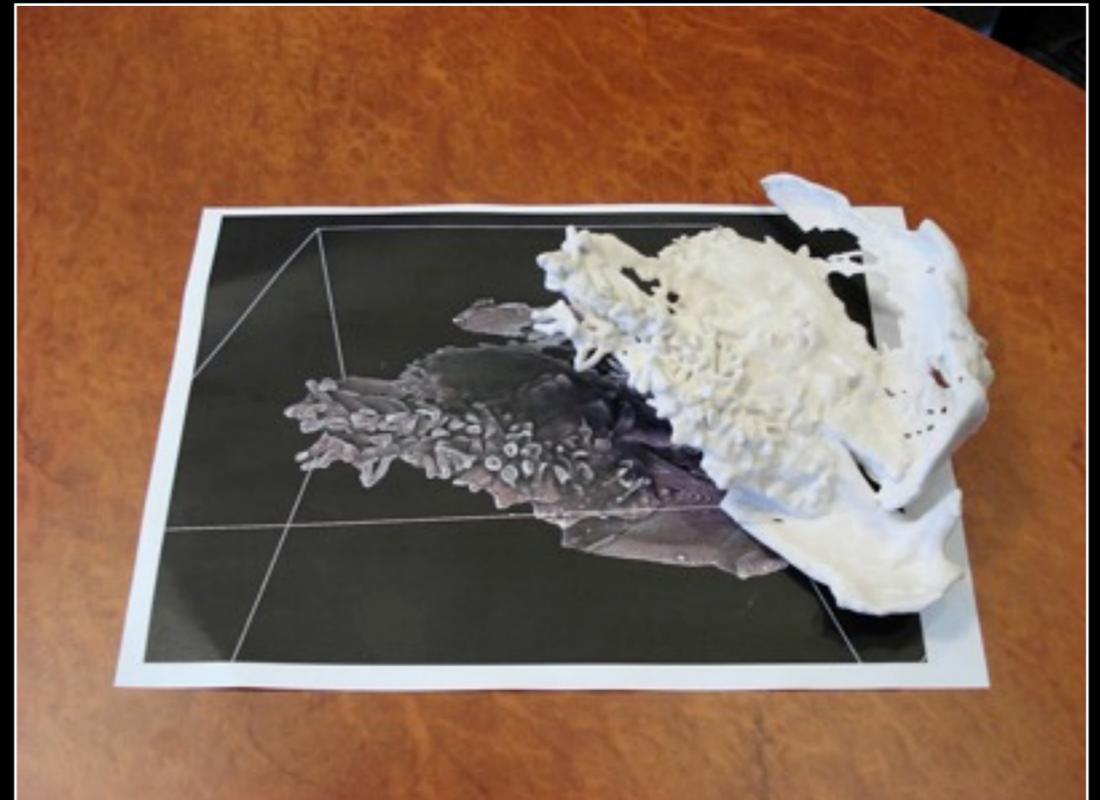
# Unusual presentation technologies

- These largely arise from the desire to
  - Allow researchers to present their data without the need for specialist hardware.
  - Allow educators to present research data in engaging ways, again without expensive resources.
- While visualisation is often concerned with the sense of sight, we have other senses, how might they be used to achieve the same aims of visualisation?
- Sonification is the term given to the conversion of data to sound. Only works in a small class of cases but is often employed to add another dimension to purely visual experiences.
- The sense of touch is used reasonably often. Technologies exist that allow one to “feel” data, for example haptic (force feedback) devices, piezoelectric sensors, etc.
- Considerable effort is being made to create glasses free stereoscopic displays.
- Will demonstrate 3 examples (from local efforts)
  - Rapid prototyping [tactile]
  - Crystal engraving [tactile]
  - Holography [glasses free]

# Tactile visualisation - Rapid Prototypes

- A number of technologies exist that will allow one to automatically build a physical object from a computer model. Essentially 3D printing.
- Designed mainly for the mechanical engineering fields and component/product design. Also used in the medical area for pre-surgery planning and implant design.
- Each technology has certain advantages and disadvantages, many of which are also related to cost.
- UWA possesses a Z-Print colour rapid prototype machine.

[Show examples]



# Tactile visualisation - Crystal engraving

- Rapid prototypes can only practically be used for a small number of connected parts.
- Crystal engraving (usually found in tourist shops or for engraving human faces) allows disjoint or even point datasets to be captured as a physical object.

[Show examples]



MRI Mummy dataset



Human heart

# Holography

- The ultimate form of 3D display would be a hologram.
- Note that there are lots of technologies being proposed that use the word “hologram” and very few are truly holograms.
- A true hologram encodes the interference pattern of light from an object with a reference beam. Upon illumination of the hologram the light field is reconstructed by a process called diffraction.
- A discrete approximation to a hologram has been developed and now called a “holographic panoramagrams”.



Placoderm jaw and “teeth”

# Demonstration in the WASP VisLab

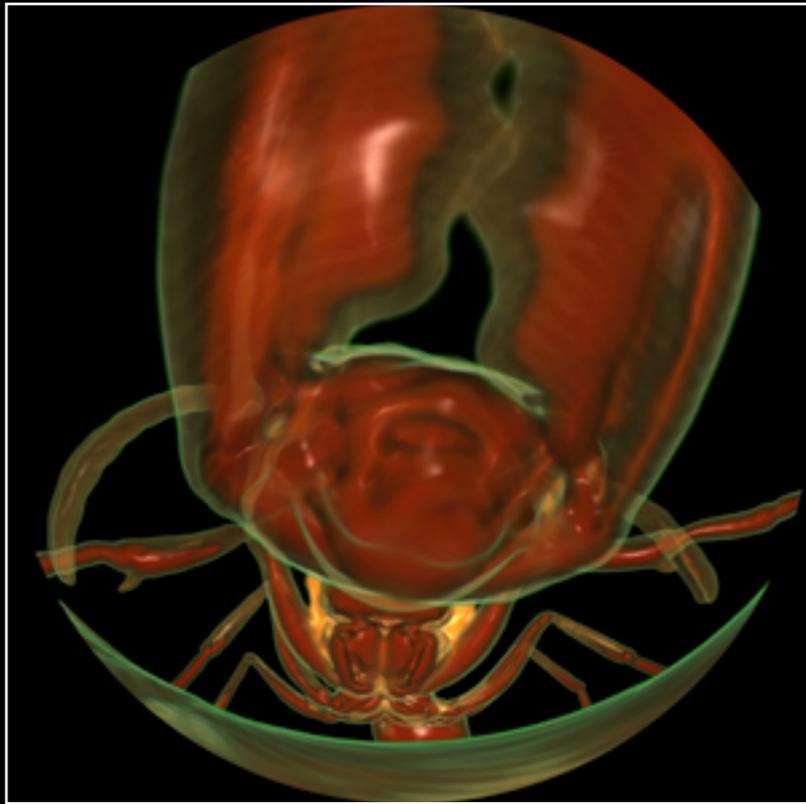
- Will demonstrate three tools that can be used to assist in some visualisation problems.
- Visualisation generally presents data to the human brain using the sense of vision.
- Each of these tools exploit a characteristic of the human visual system not normally engaged when using a standard small desktop display.
  1. High resolution.
  2. Stereopsis.
  3. Peripheral vision.
- High resolution displays allow one to see more detail and a greater sense of the whole. Allows one to perform fewer zoom in / pan / zoom out operations.
- Stereopsis exploits our depth perception arising from our 2 horizontally offset eyes. Allows us to appreciate depth relationships in geometrically complicated data.
- Peripheral vision enhances our sense of immersion or “being there”. It thus allows one to reside within a dataset and be able to appreciate the space without continual panning or rotations.

[Move to VisLab]

# Volume rendering exercise

- For most volumetric datasets one knows some scalar quantity at each position in a box, called a voxel (3D pixel). The quantity can however equally be a vector, RGB, or multivalued.
- In most cases the volume is regularly sampled but this isn't always the case.
- The process of volume visualisation is generally one of mapping voxel values to colour and transparency. Some volume visualisation packages also deal with local gradient, this can then support diffuse and specular shading models.
- Drishti achieves interactive performance by loading the volume into texture memory on the graphics cards and performing a ray casting using shaders.
- Drishti is one of many volume visualisation packages available.
- 6 volumetric datasets have been made available from the microCT scanner at the ANU.

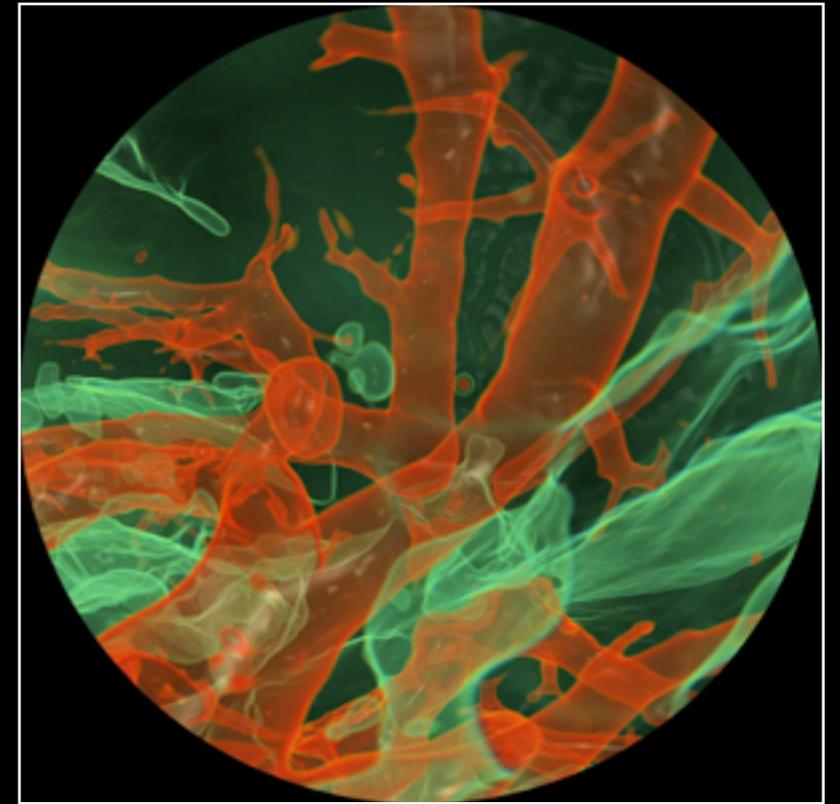
[Move to the teaching laboratory]



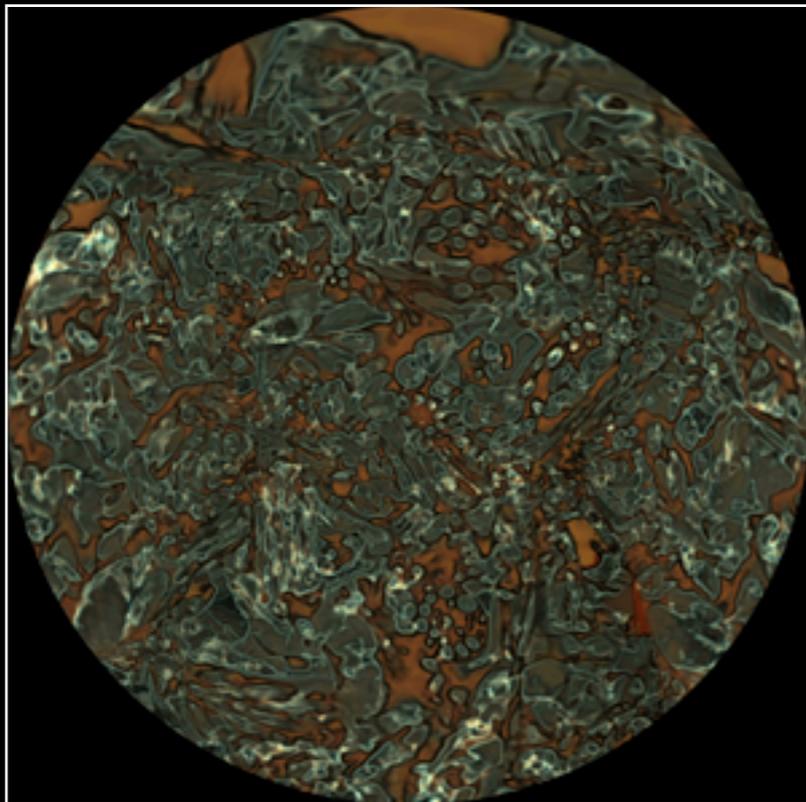
Terror Ant



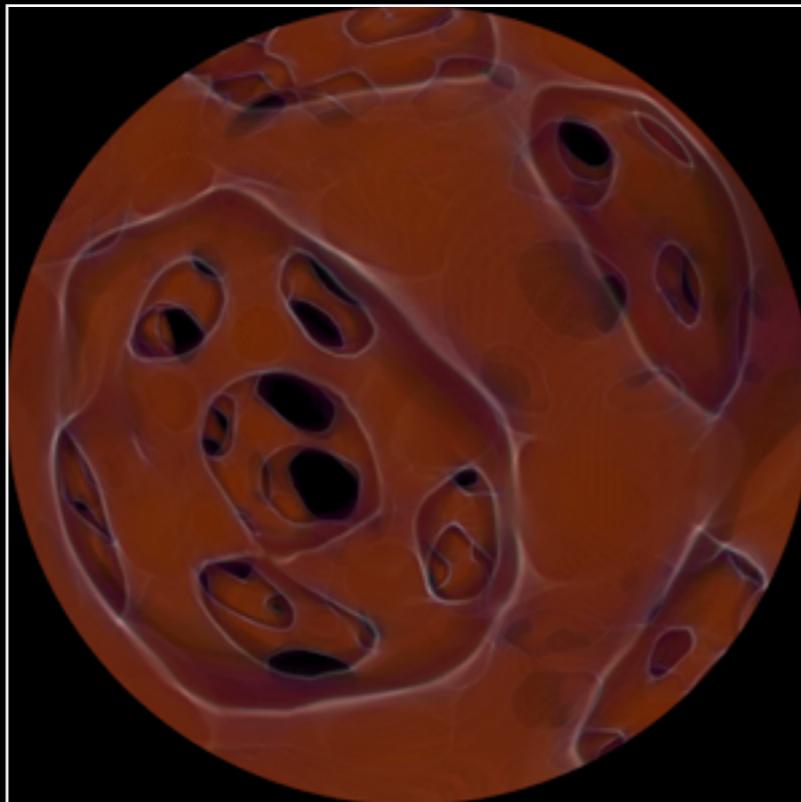
Ear bone of a fossil whale



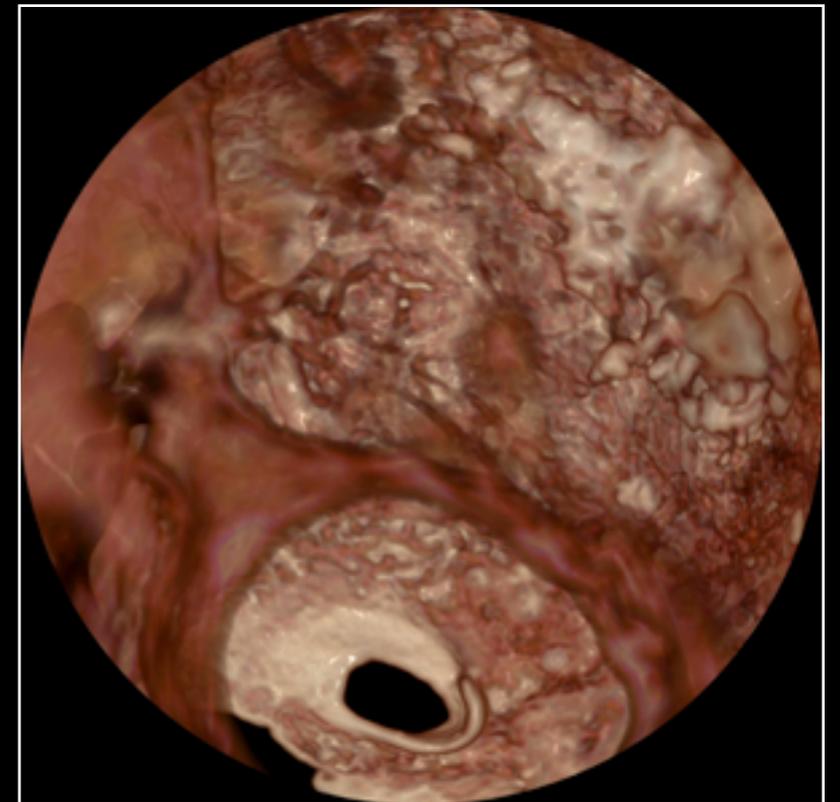
Rabbit Liver



Mt Gambier limestone



Reticulite (Rock)



Gogonasmus skull (fossil fish)



Recycle Bin



F-PROT Antivirus f...



FileZilla Client



Drishti-1.0



Volumetric examples

Drishti Launcher

Stereo    **Prithvi**    Import    Paint    Composite

Open 1 volume, start with reticulite

Drishiti - Volume Exploration and Presentation Tool

File View Image Size Toggle Help

Transfer Function Editor

New Refresh Remove

Replace existing transfer functions at keyframes

Morph transfer functions during keyframe animation

Name	0	1	2	3

1D 2D

Load volume files

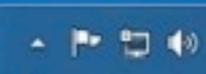
Volumetric examples

Search Volumetric examples

Name	Date modified	Type
cochlear_trim.pvl.nc	24/11/2009 11:33 ...	NC File
gogo.pvl.nc	24/11/2009 11:33 ...	NC File
liver.pvl.nc	24/11/2009 11:33 ...	NC File
MtGambier.pvl.nc	24/11/2009 11:33 ...	NC File
<b>reticulite.pvl.nc</b>	24/11/2009 11:33 ...	NC File
terrorant.pvl.nc	24/11/2009 11:34 ...	NC File

File name: reticulite.pvl.nc    NetCDF Files (\*.pvl.nc)

Open Cancel



3:55 PM  
24/11/2009



Recycle Bin



F-PROT Antivirus f...



FileZilla Client



Drishti-1.0



Volumetric examples

Drishti Launcher

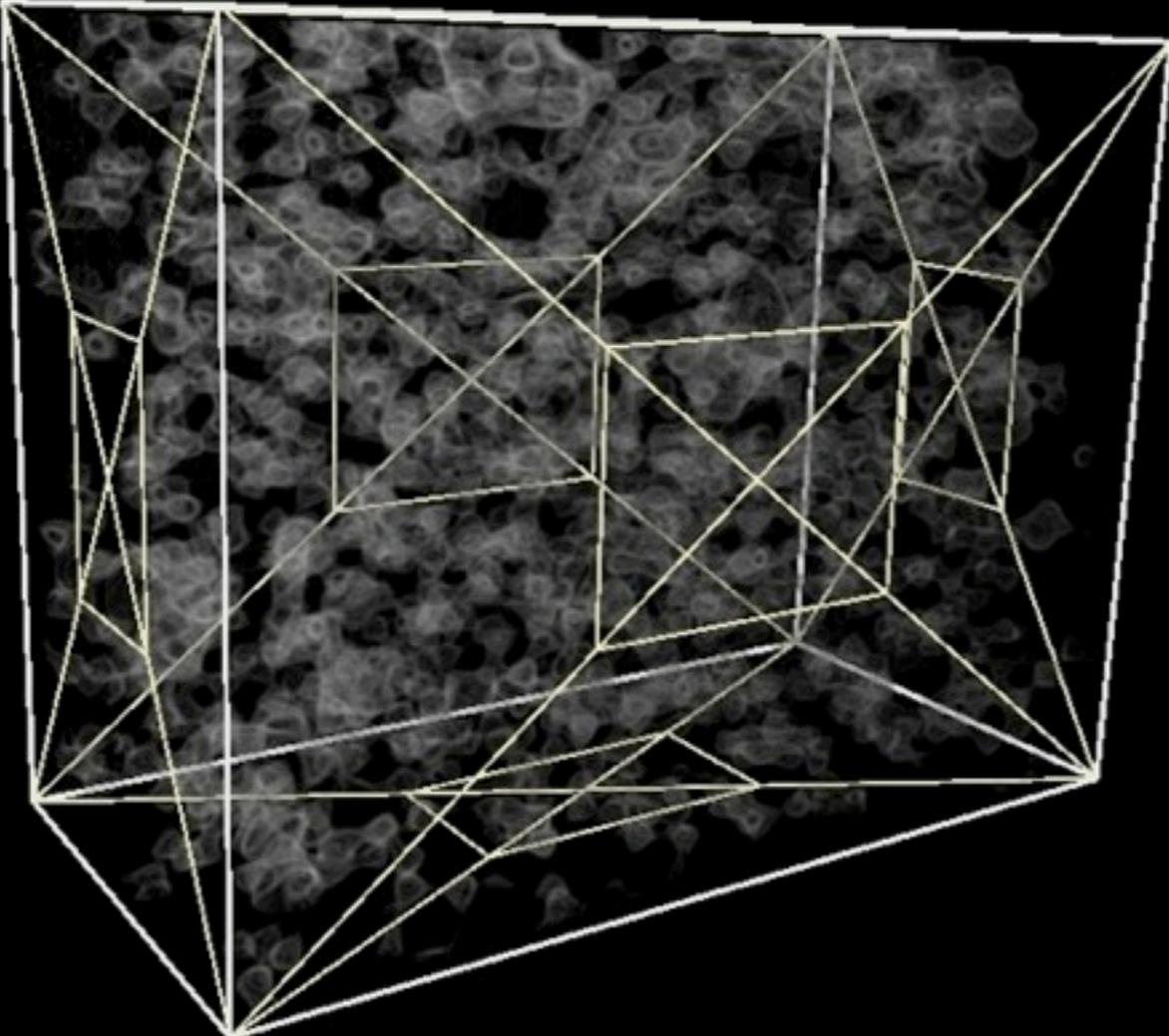
Stereo    ॐ    ॐ    ॐ    ॐ    ॐ

Render    Prithvi    Import    Paint    Composite

Create an initial transfer function

Drishti - Volume Exploration and Presentation Tool

File View Image Size Toggle Help



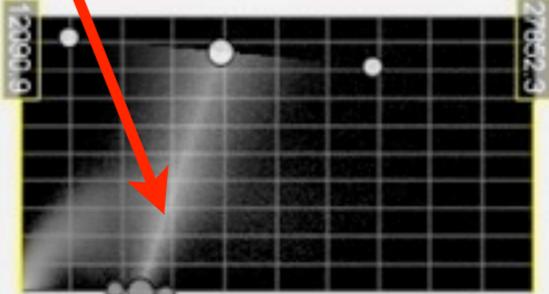
LowRes : stepsize = 0.7 : 1 1 1  
 Bounds : 0-123, 0-97, 0-62  
 Selected SubVolume Size : 124x98x63 - (128x128x64)

Transfer Function Editor

New Refresh Remove

Replace existing transfer functions at keyframes  
 Morph transfer functions during keyframe animation

Name	0	1	2	3
TF 0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

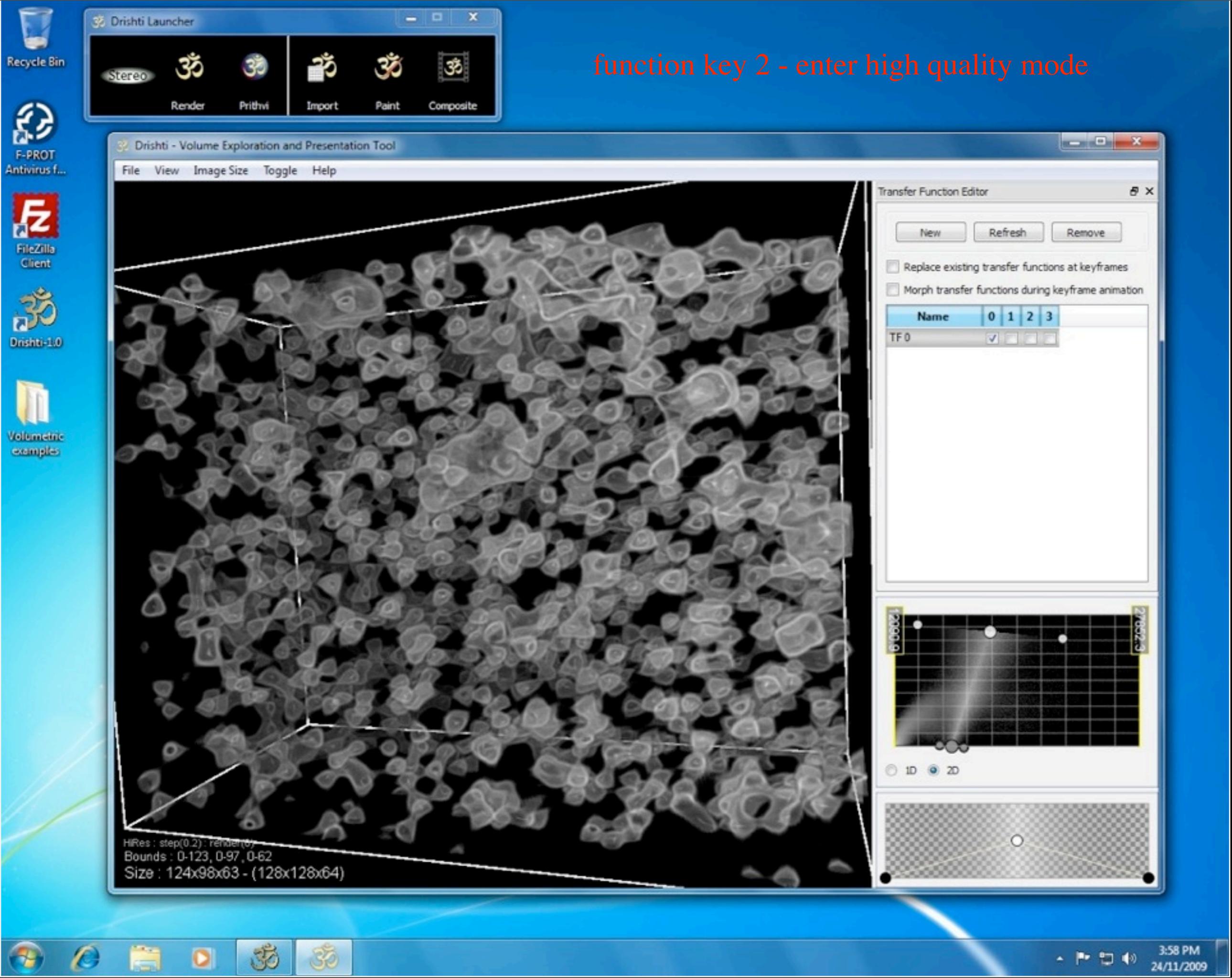


1D 2D



3:57 PM 24/11/2009

function key 2 - enter high quality mode



Drishti - Volume Exploration and Presentation Tool

File View Image Size Toggle Help

Transfer Function Editor

New Refresh Remove

Replace existing transfer functions at keyframes

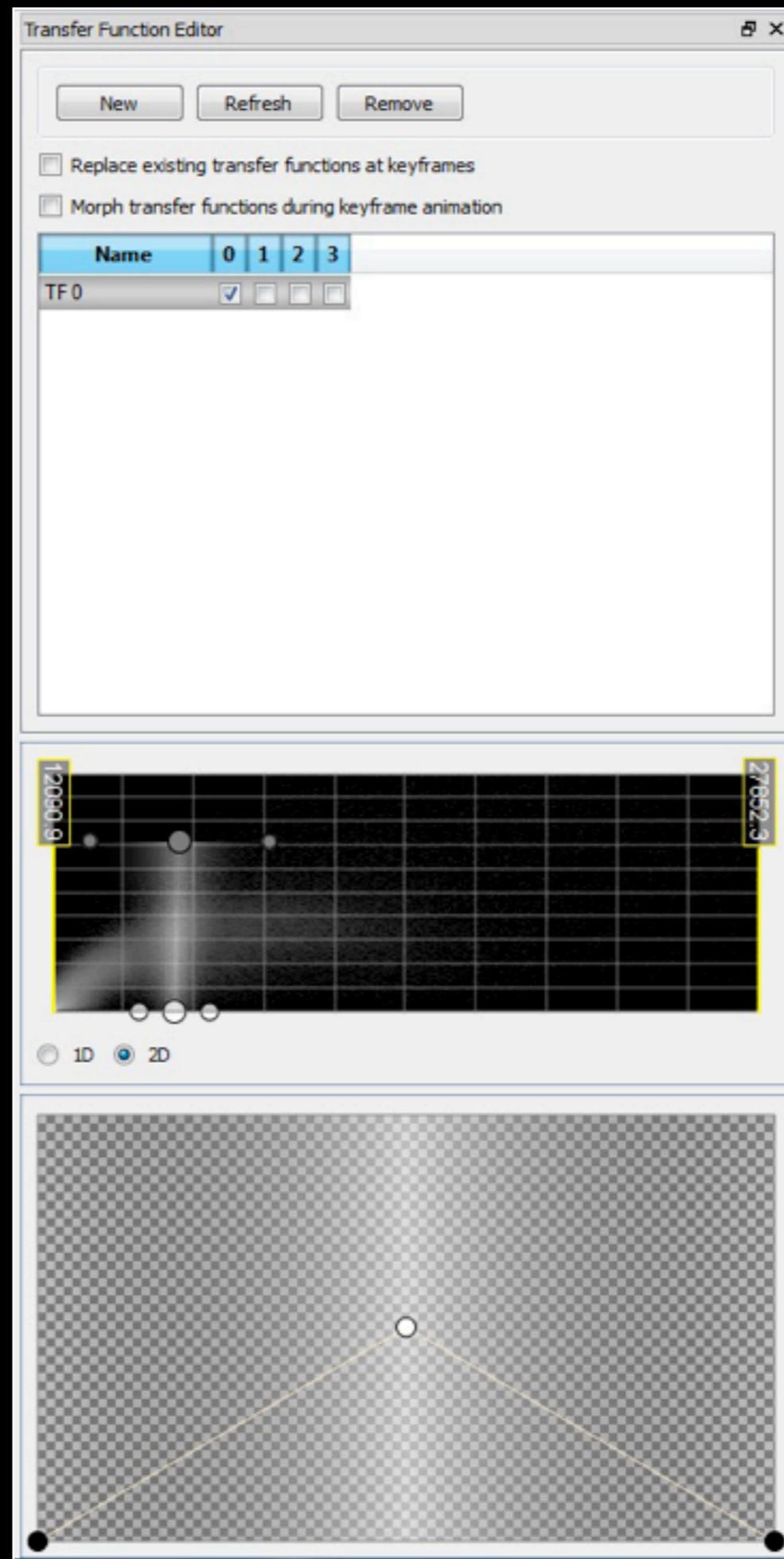
Morph transfer functions during keyframe animation

Name	0	1	2	3
TF 0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12000-0 27000-3

1D 2D

HiRes : step(0.2) : render(0)  
Bounds : 0-123, 0-97, 0-62  
Size : 124x98x63 - (128x128x64)



Transfer function list

Voxel value and gradient histogram

← Shift-left click to drag control with constraints

← Left mouse - add node  
← Right mouse - delete node

Control point colour and opacity

← Double click node to change colour

Preferences

Tab 1 Axis Labels Stereo Tag Colors

Texture Memory Size 512 Mb

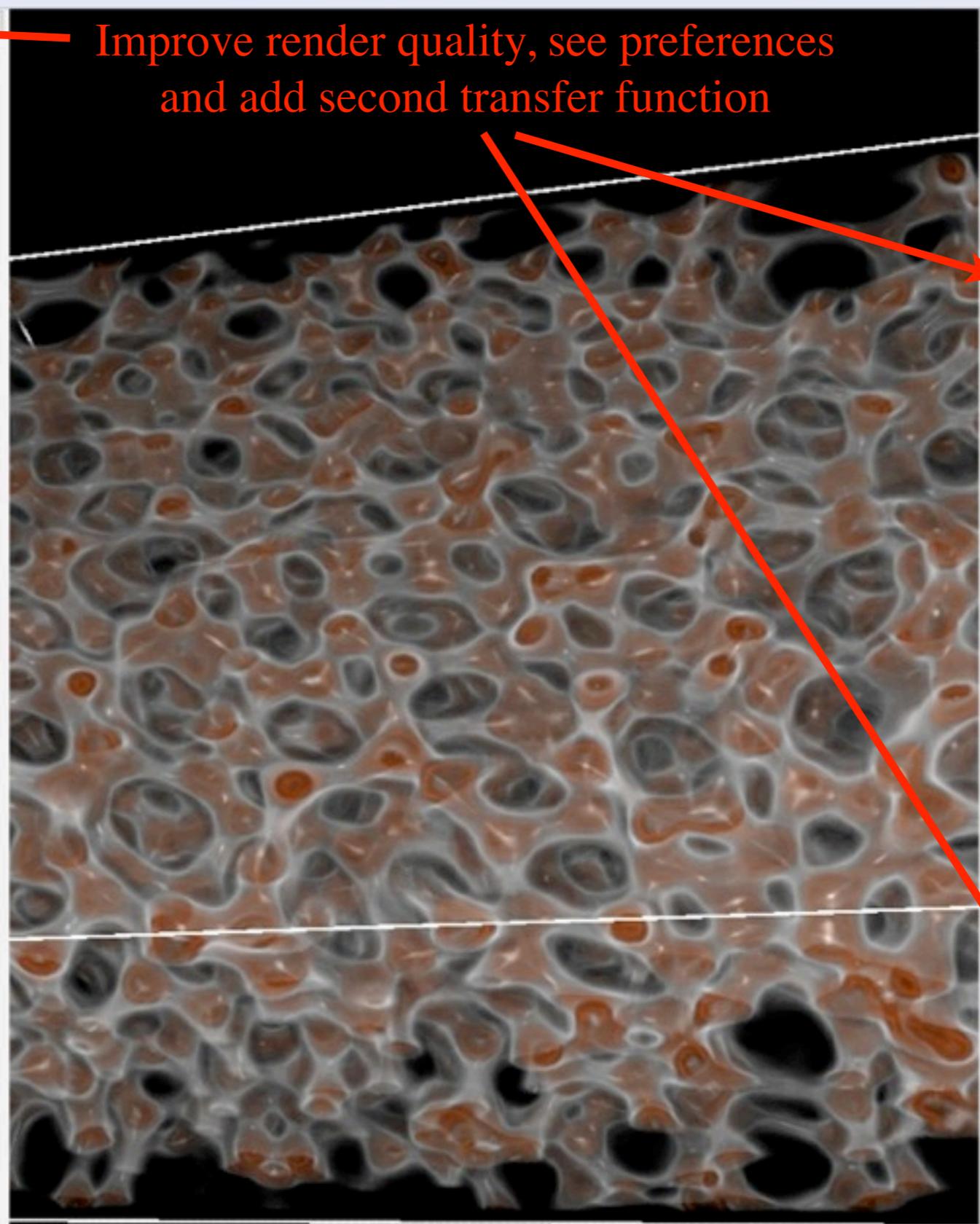
3D Texture Size Limit 1024^3

Image Quality

Still

Drag

Background Color



Improve render quality, see preferences and add second transfer function

Transfer Function Editor

New Refresh Remove

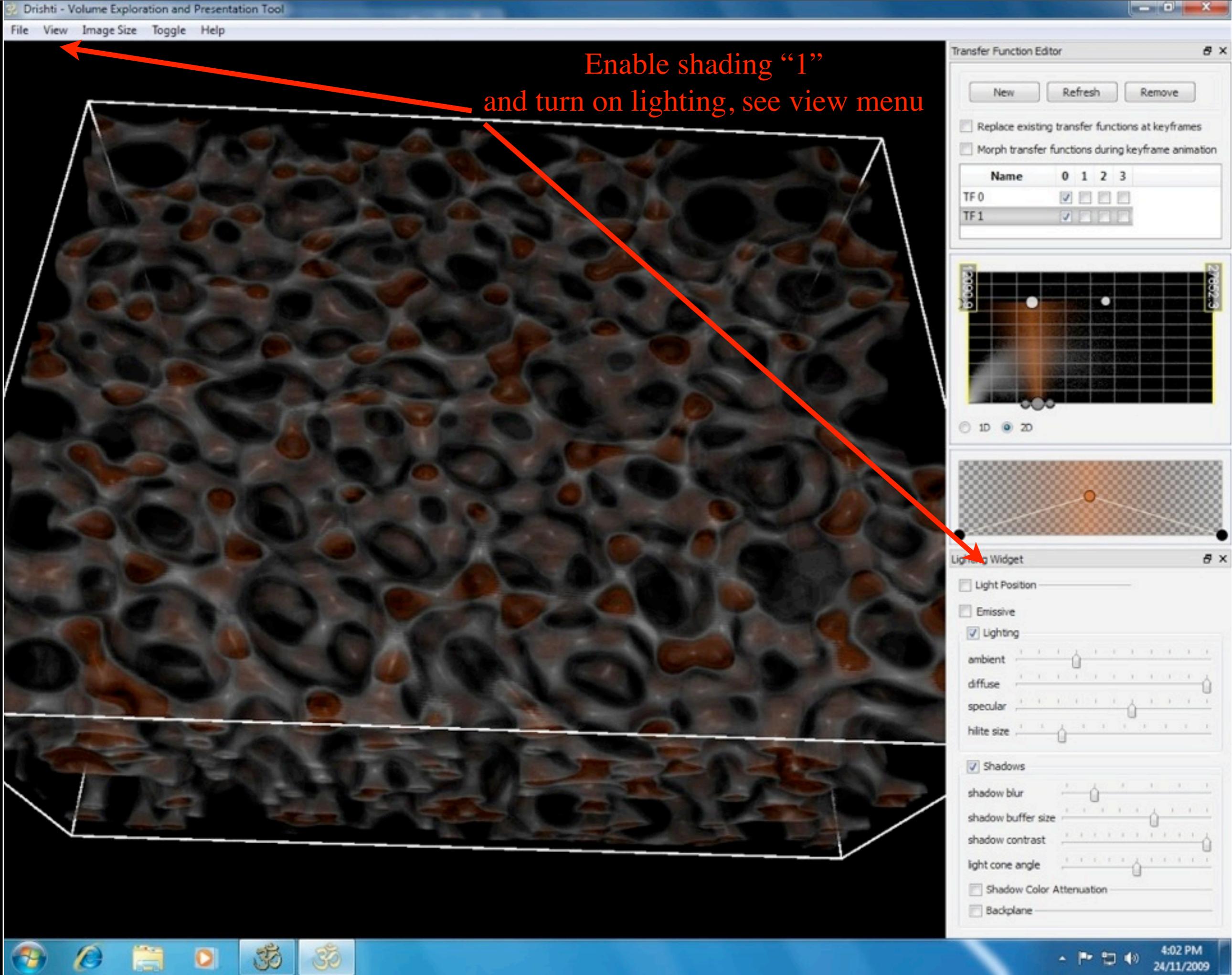
Replace existing transfer functions at keyframes

Morph transfer functions during keyframe animation

Name	0	1	2	3
TF 0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TF 1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1D 2D

HRes : step(0.2) : render(0)  
 Bounds : 0-123, 0-97, 0-62  
 Size : 124x98x63 - (128x128x64)



# Drishti - Command subset

- Within the 3D window
  - left mouse button rotates camera
  - right mouse button pans (translates) camera
  - middle mouse button (wheel) zooms camera
  - f2 toggles between high resolution and preview mode
  - “1” (digit one) toggles between shaded and non shaded
  - alt “s” creates a screen snapshot from the main window
  - “c” adds a clip plane
  - “v” toggles visibility of clip planes
  - “b” toggles the bounding box
  - “a” toggles axes
  - “?” toggles the volume information text
- Within the transfer function window
  - left mouse adds a node or moves an existing node
  - shift-left mouse button moves a node with constraints
  - right mouse button removes a node
  - double left button click open colour selector

