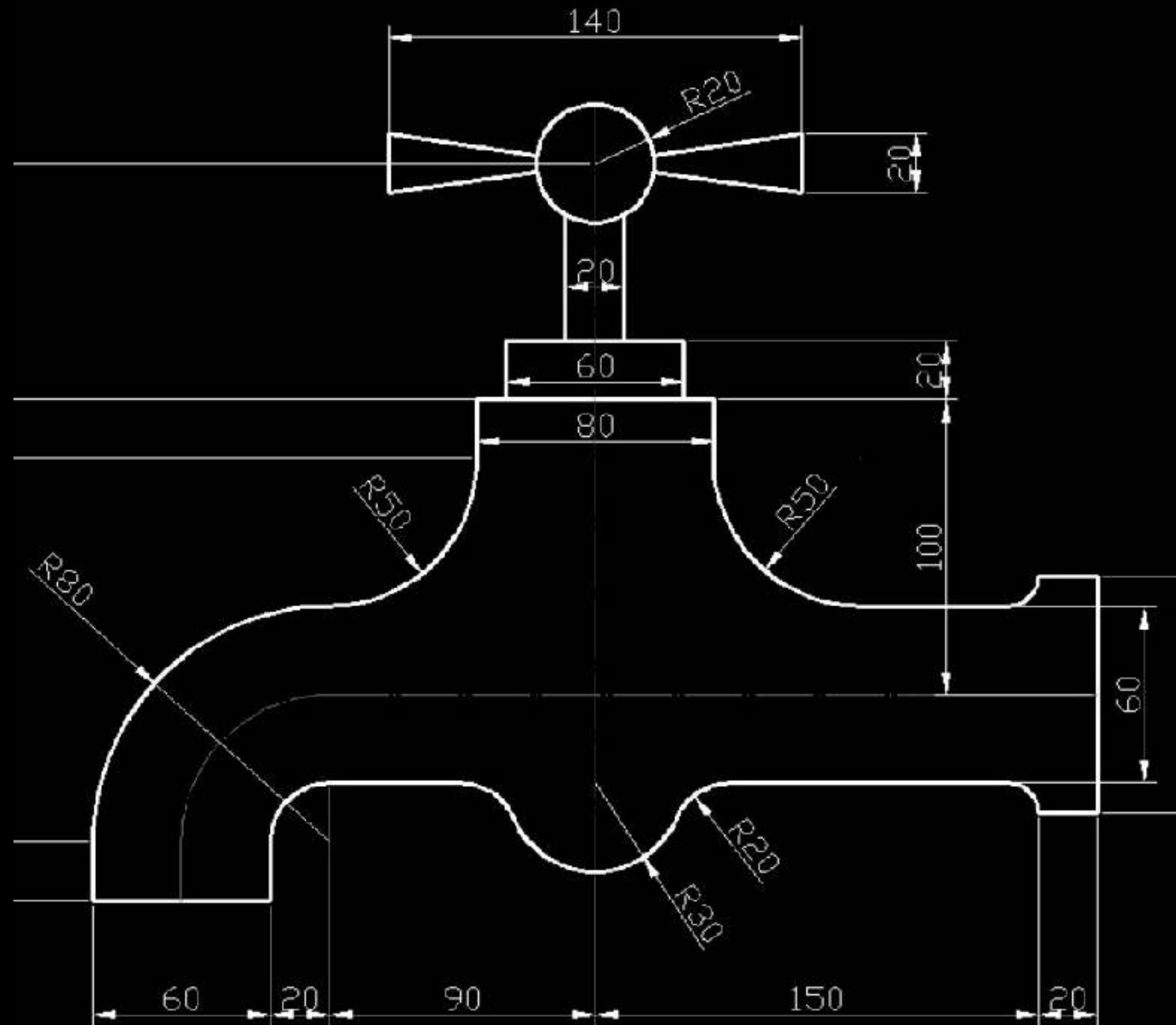# Introduction to volume rendering

Paul Bourke

2D drafting/drawing
Points + lines + curves + primitives (circle, rectangle …)
Describes boundaries

2D image
Pixels
Describes the interior of a rectangle, a texture

2D drawings are constructed by various geometric primitives, but isn't suited to representing an image (except inefficiently as a very large number of coloured squares)

3D modelling
Points + lines + faces + texture + primitives (sphere, box …)
Describes surfaces

Volumeric, 3D image
Voxels
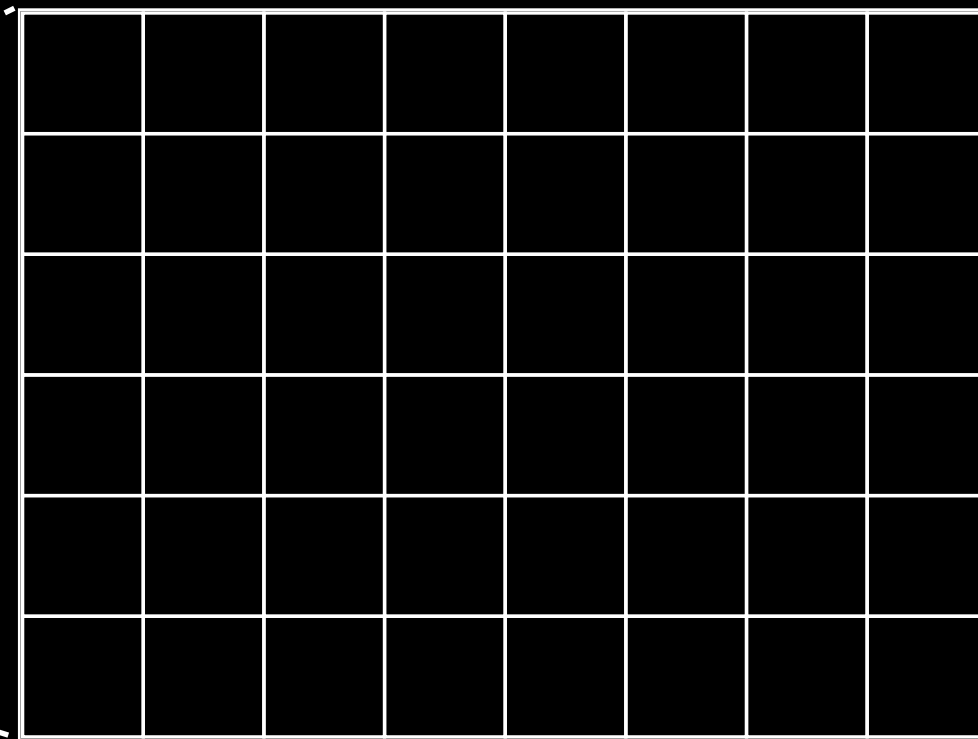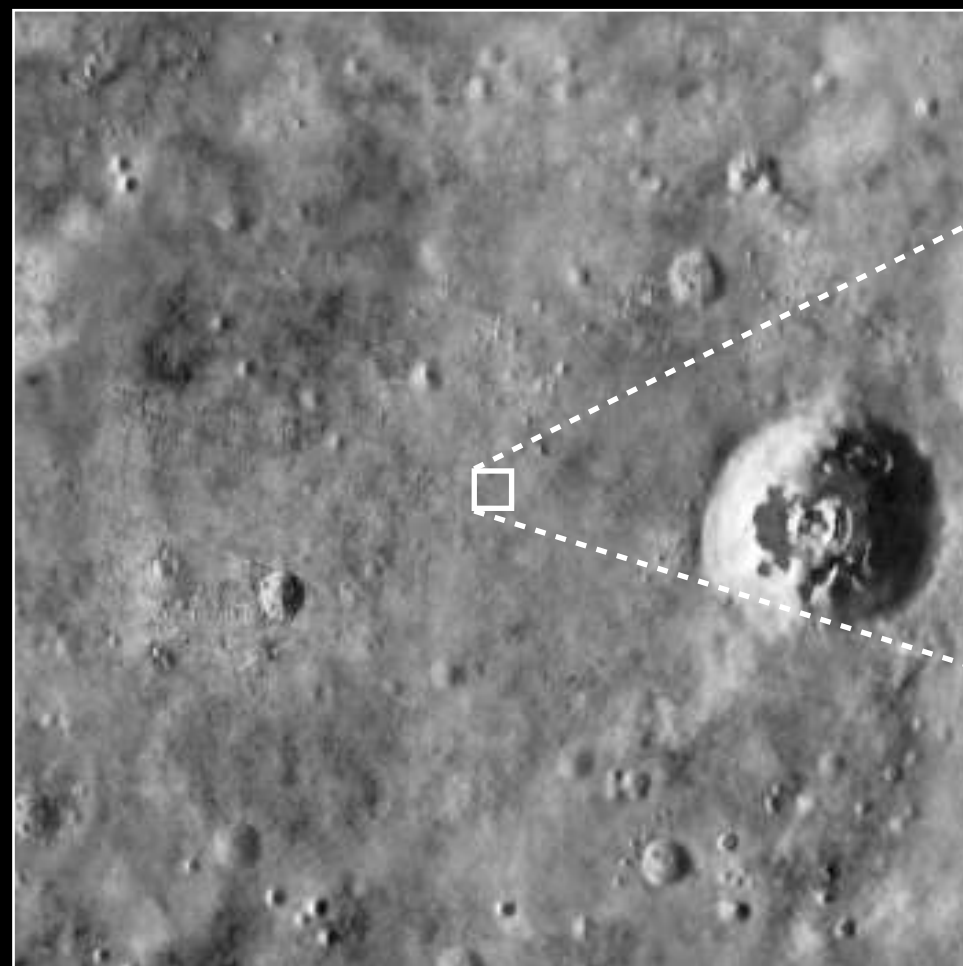**Describes interiors**

**Empty on the inside**

Full on the inside

3D models are constructed by various geometric primitives, but not suited to representing a volume (except inefficiently as a very large number of coloured cubes)

A digital image contains some quantity sampled on a regular grid on a 2D plane.

In a volumetric dataset there is some quantity sampled on a regular 3D grid. Each cell is called a VOXEL (VOlumetric piXEL)
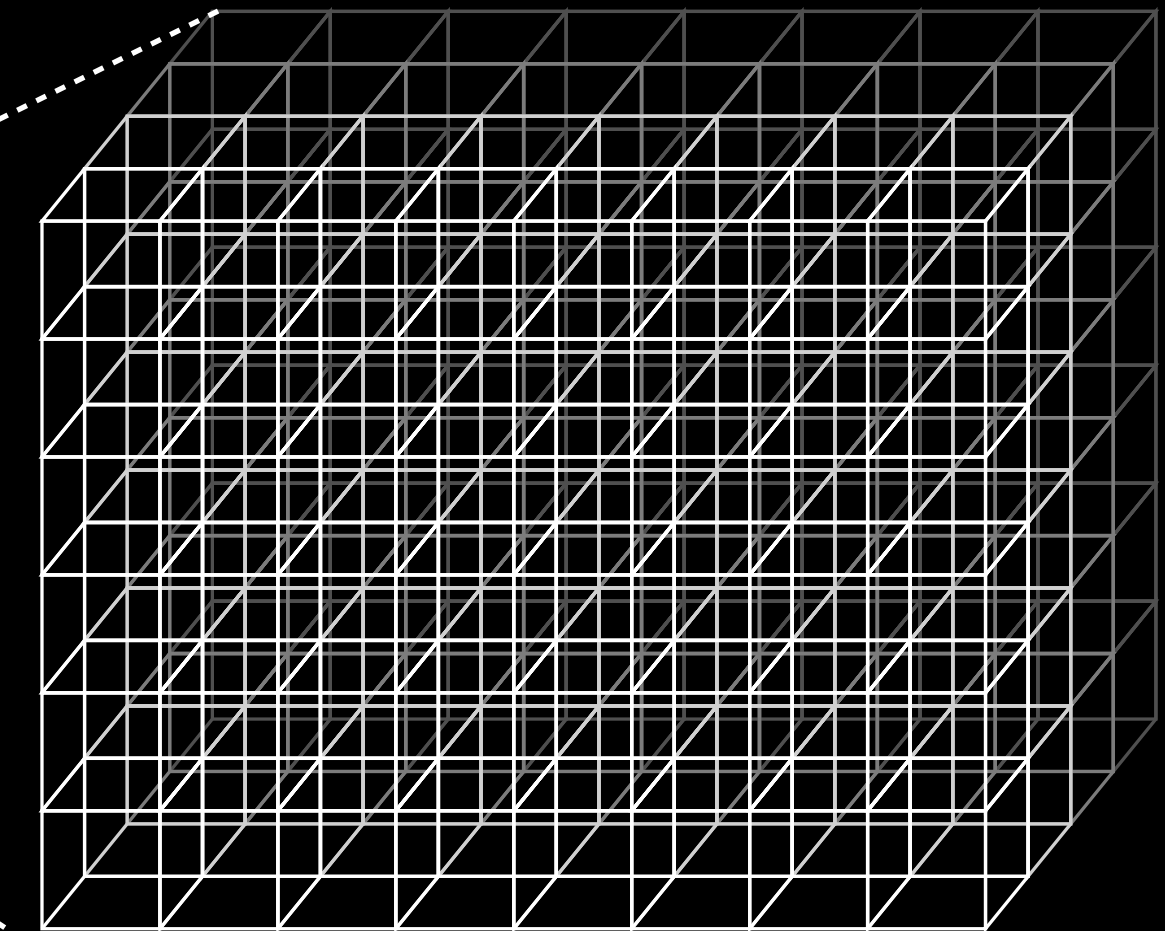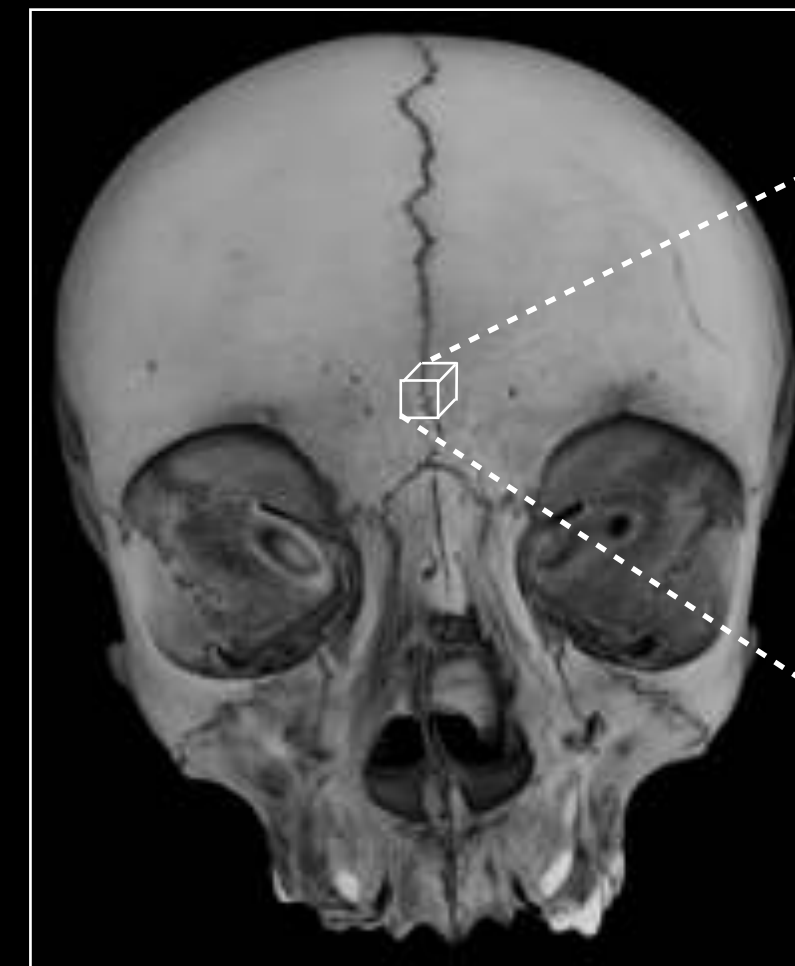
In each case the value in the pixel or voxel is mapped onto colour and opacity.

Wide range of applications

- Very common form of data in the sciences.

- Traditionally one thinks about medical data, for example MRI.
  Other scanning and 3D imaging technologies include CT (MicroCT) and CAT scans.

- Volumetric data also arises from many numerical simulations.
  Quite common in physics (simulations) and engineering (finite element calculations).

- In scanned volumetric datasets the quantity per voxel depends on the scanning technology. For example: MRI essentially gives water content, CT gives density.

- For volumetric datasets derived from simulation there can be multiple variables per voxel.
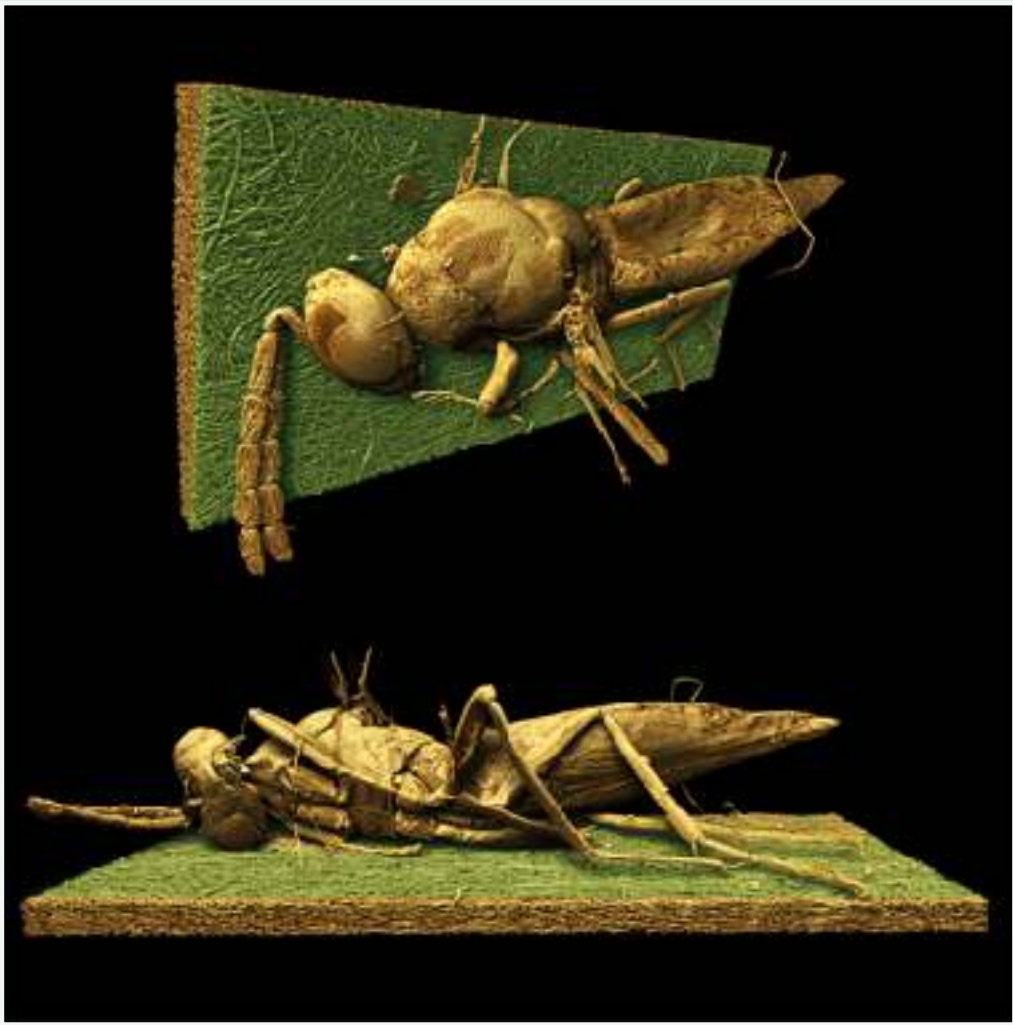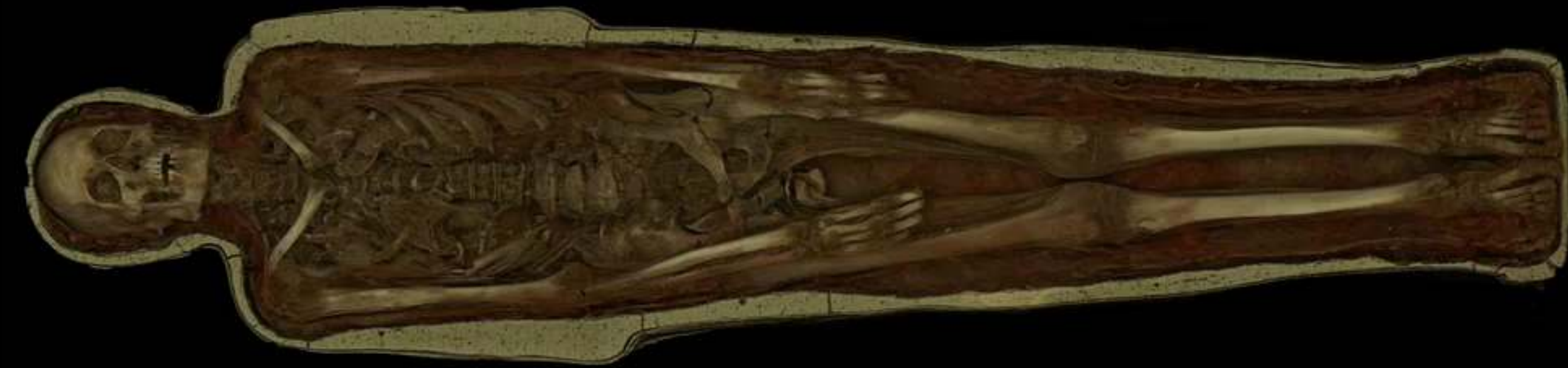
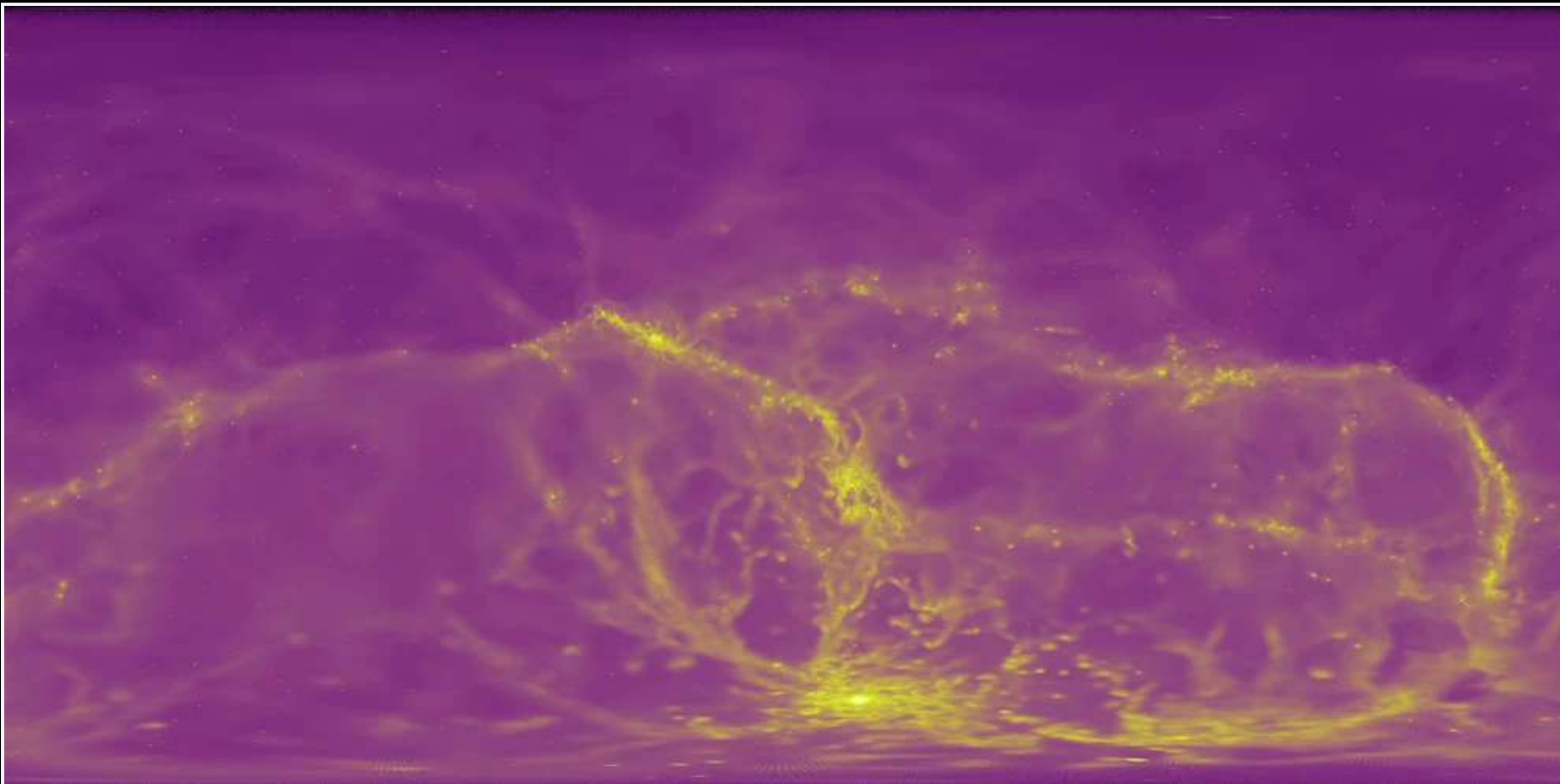**Medical research (MRI)**

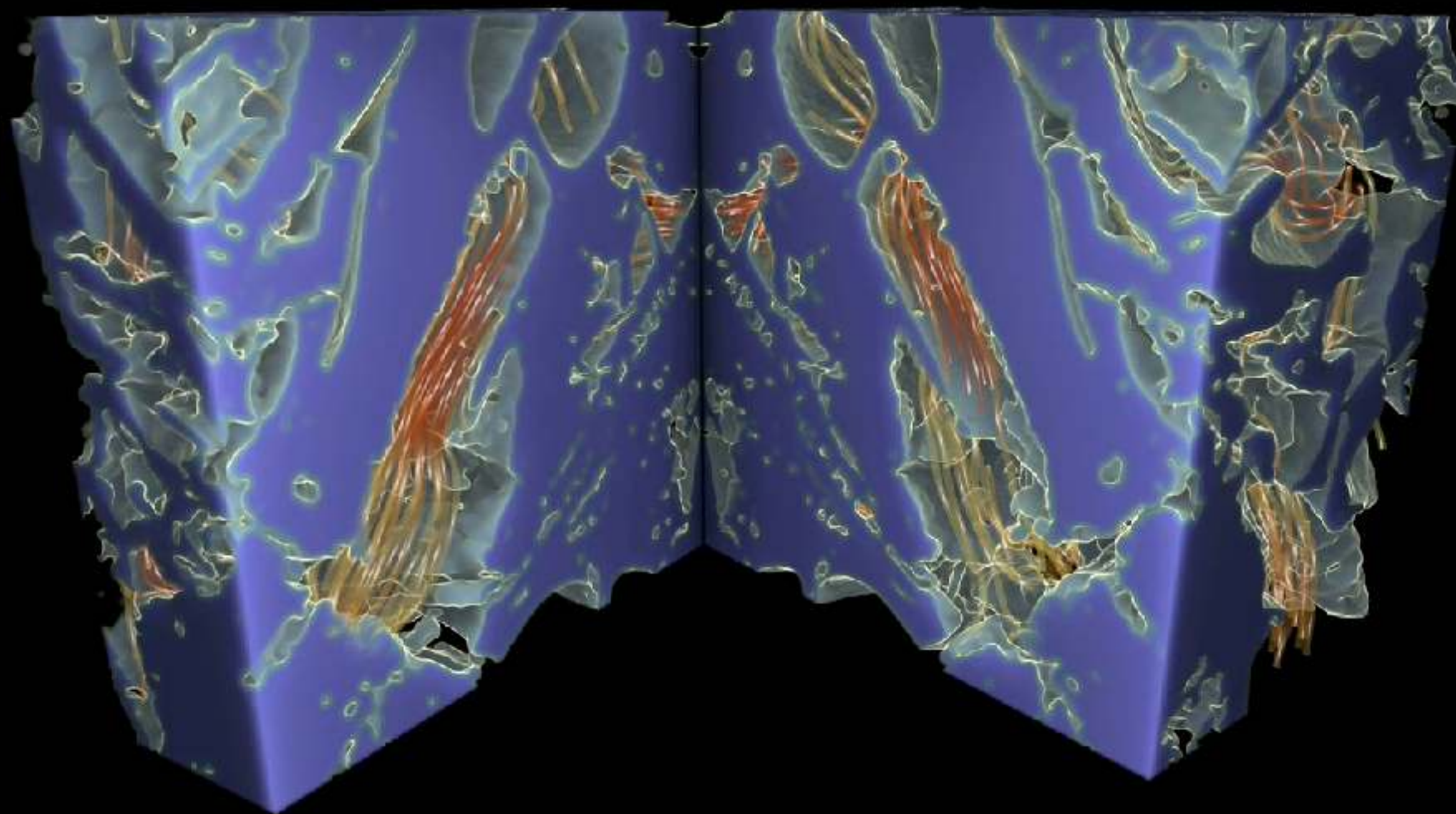**Geology (CT)**
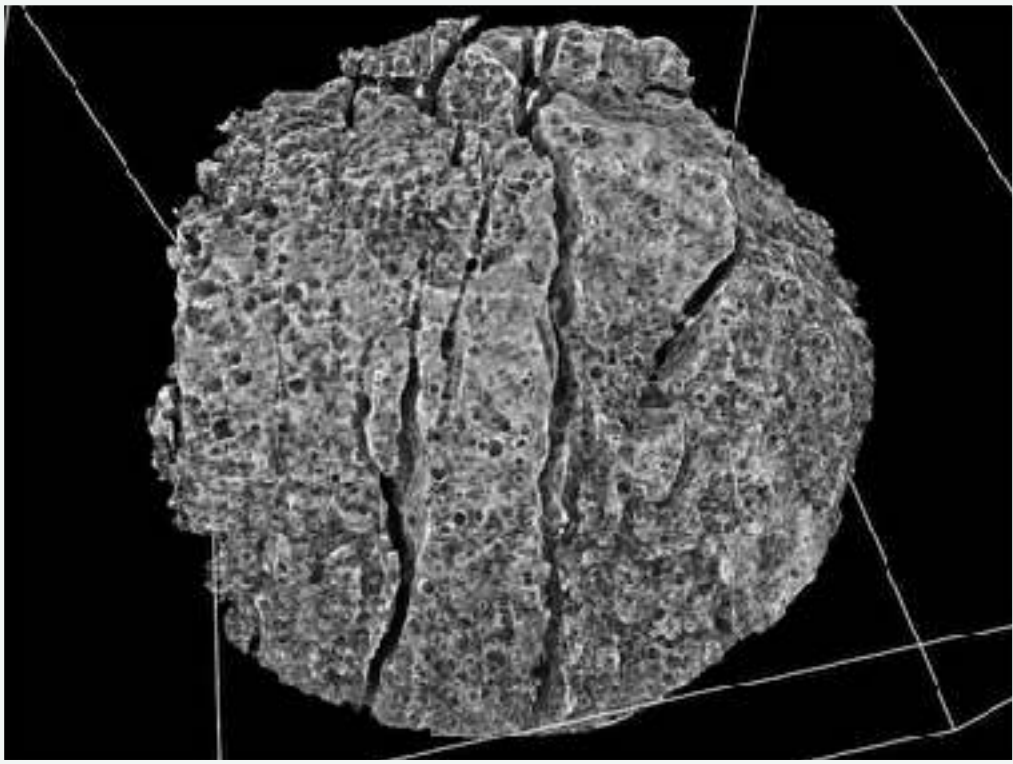
Entomology
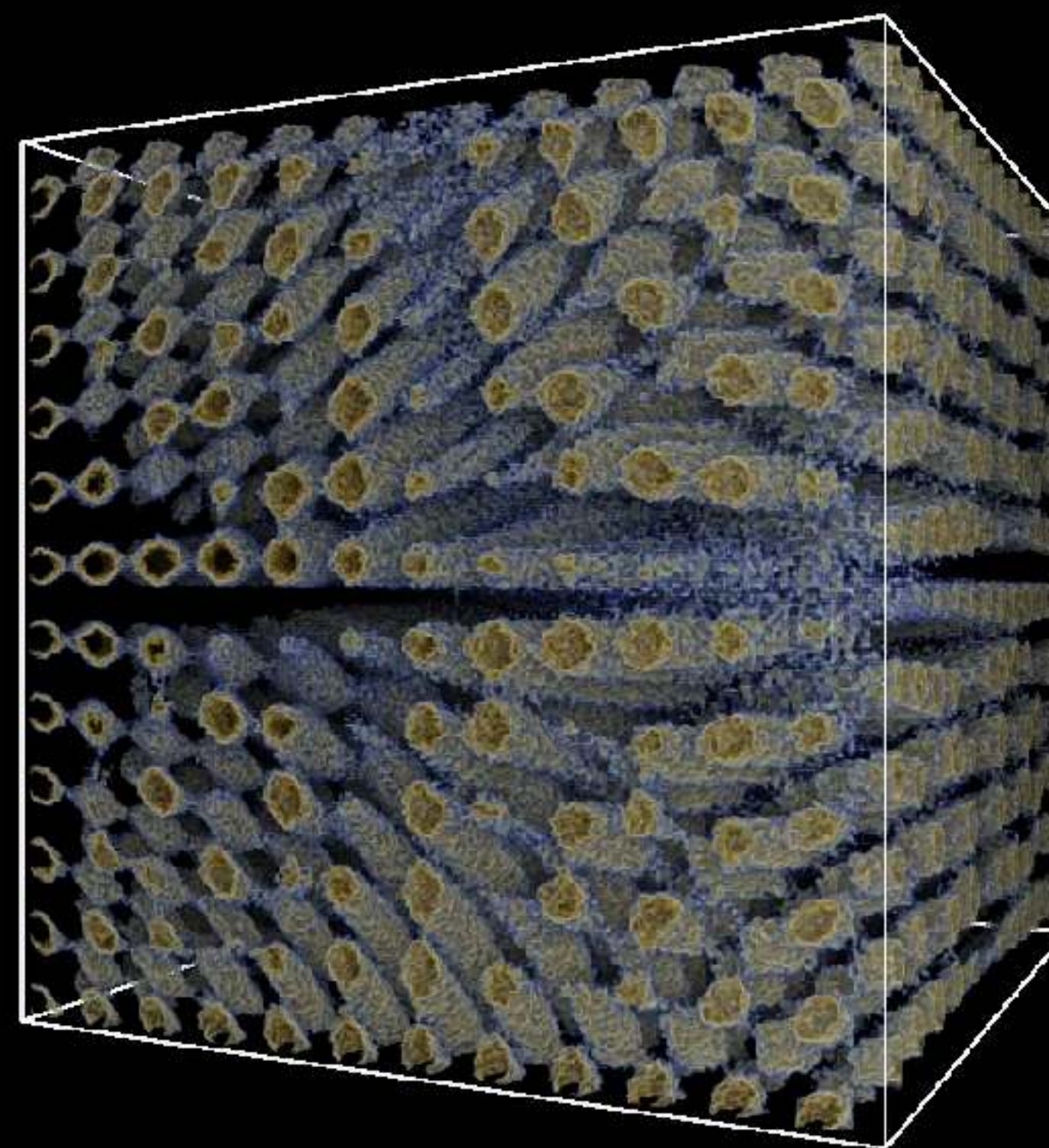
Rabbits liver, medical research

Egyptology

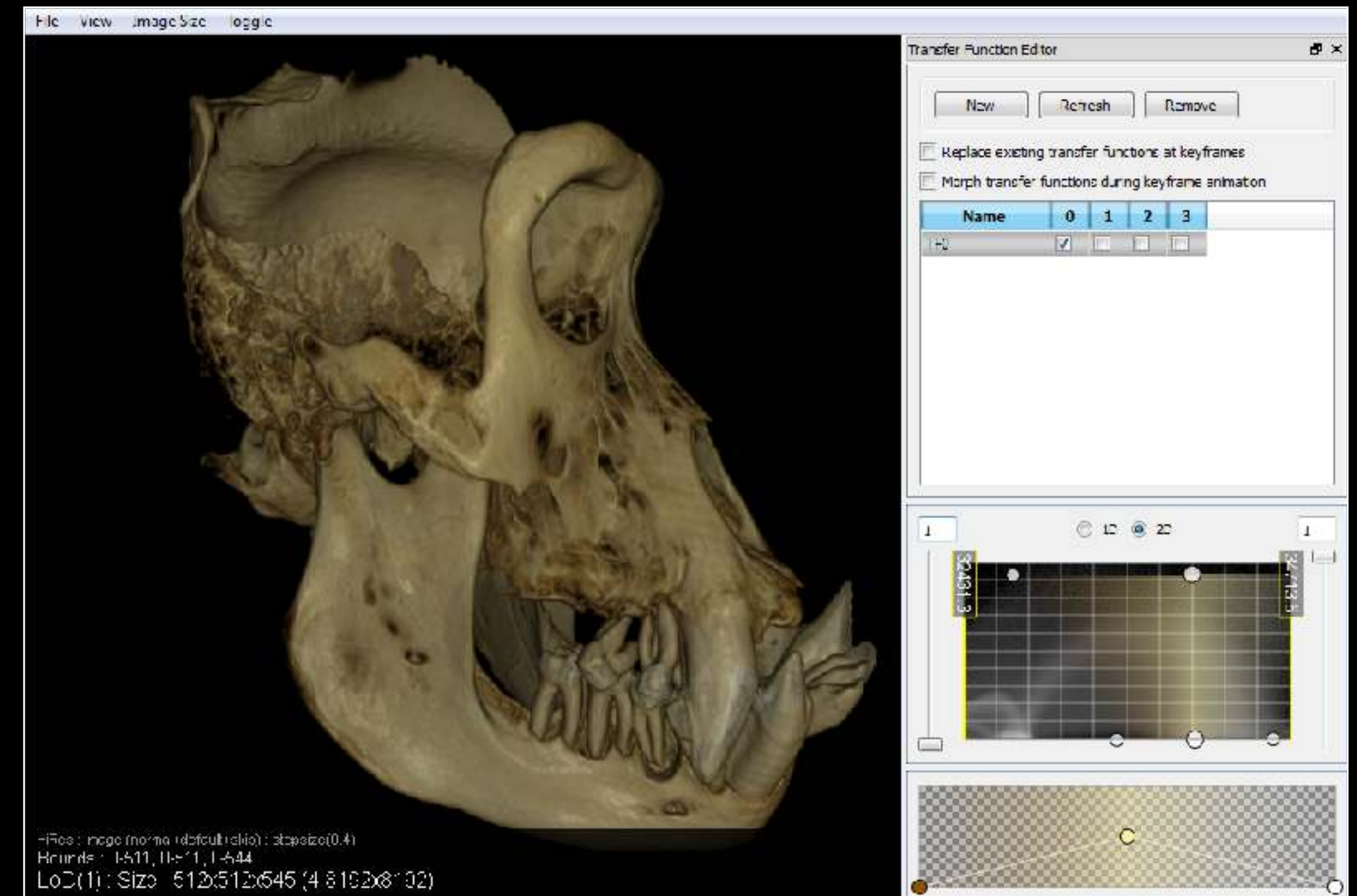**Astrophysics**
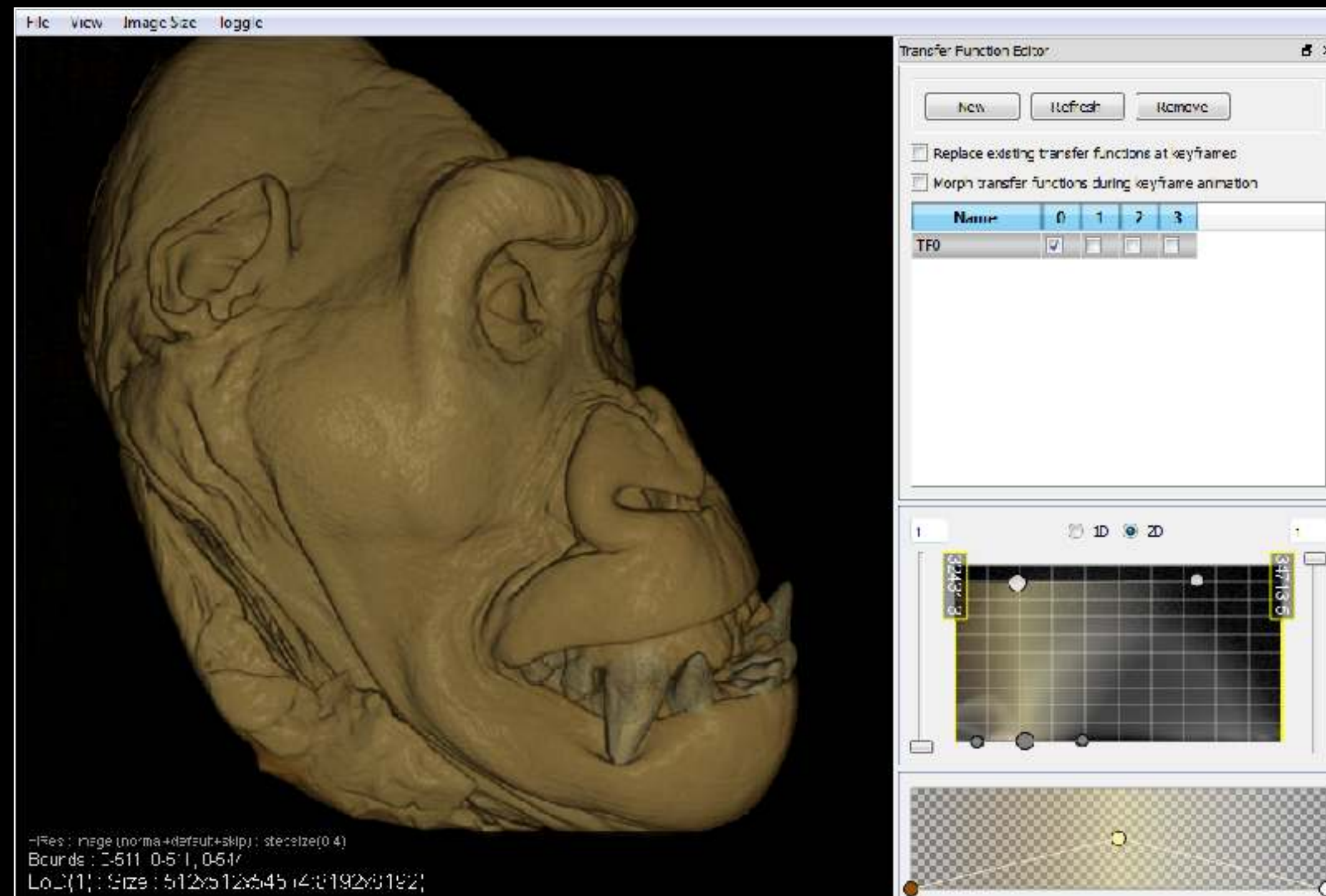
Fluid flow in porous material, geology
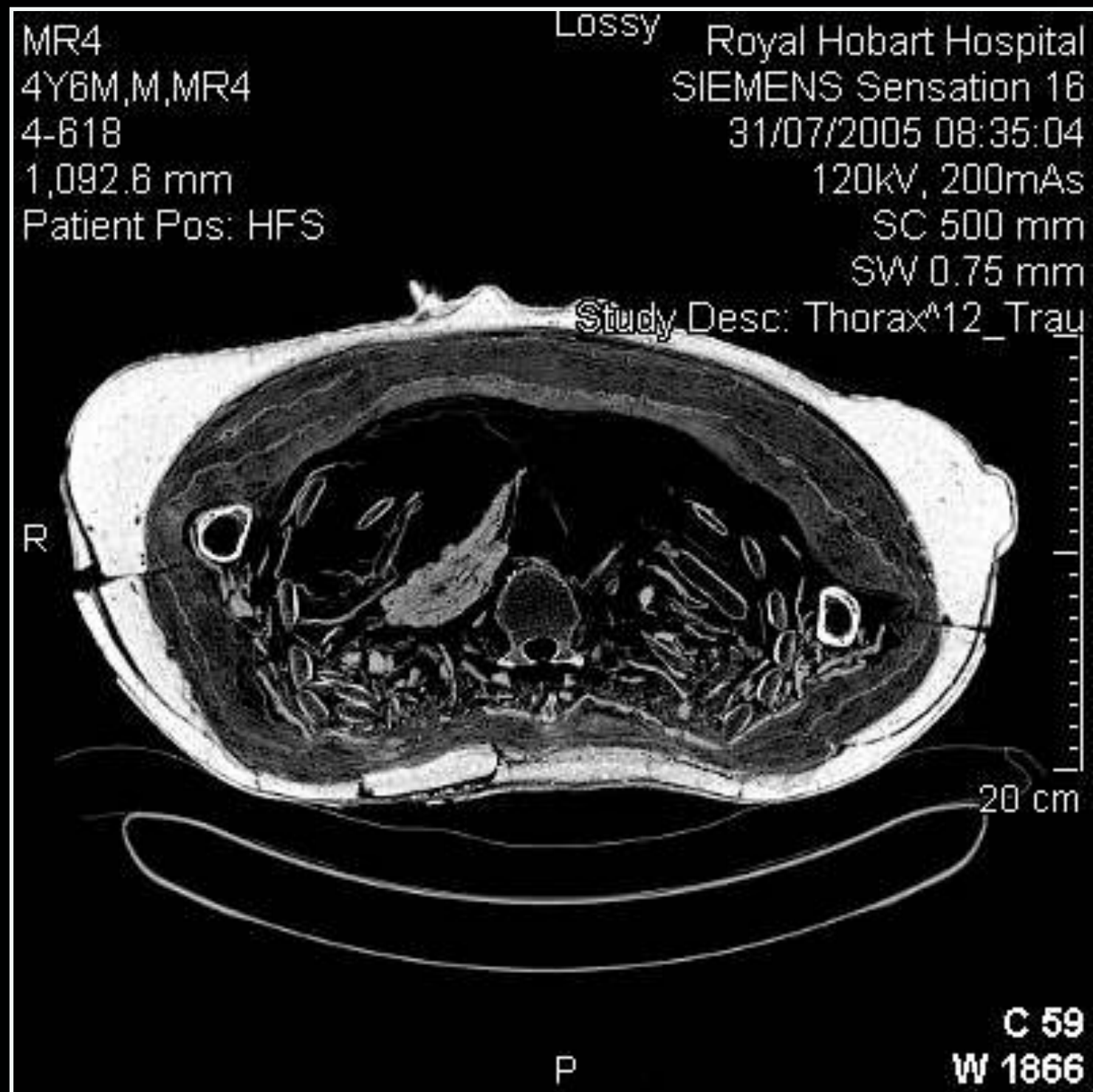
Standing waves, nano-science

Volumetric visualisation is the process of exploring and revealing the structure/interior of a volumetric dataset. The general approach involves a mapping between voxel values and colour/opacity.

Same data but different mappings

3D scanners typically create multiple 2D sections (bottom left).
Voxels are not always cubes, often the within slice resolution is higher than between slice resolution.

MR4
4Y6M,M,MR4
4-618
1,092.6 mm
Patient Pos: HFS

Lossy Royal Hobart Hospital
SIEMENS Sensation 16
31/07/2005 08:35:04
120kV, 200mAs
SC 500 mm
SW 0.75 mm
Study Desc: Thorax^12_Trau

R

20 cm

C 59
P   W 1866

Slice data from the CT scanner   **Volume visualisation**
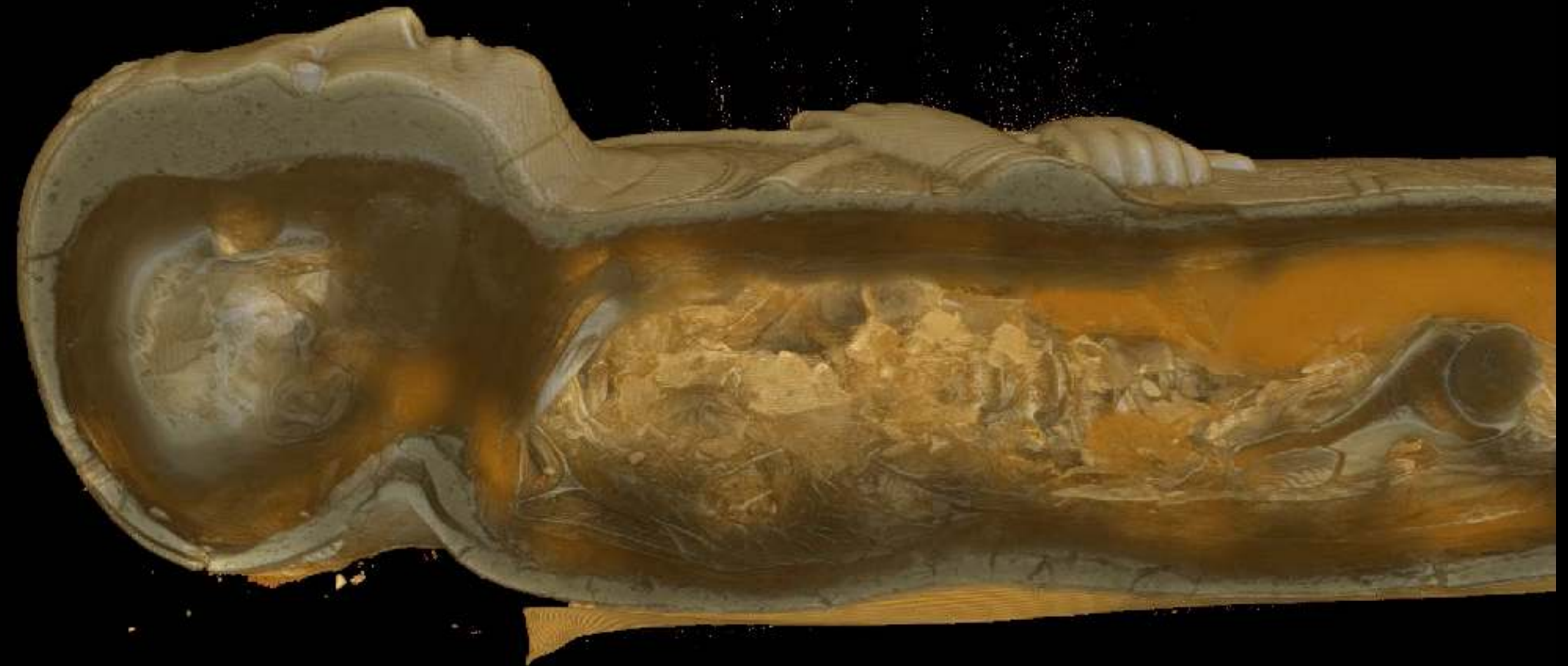
The details of the user interfaces vary but
key is how to specify the mapping from
voxel value to colour and opacity.

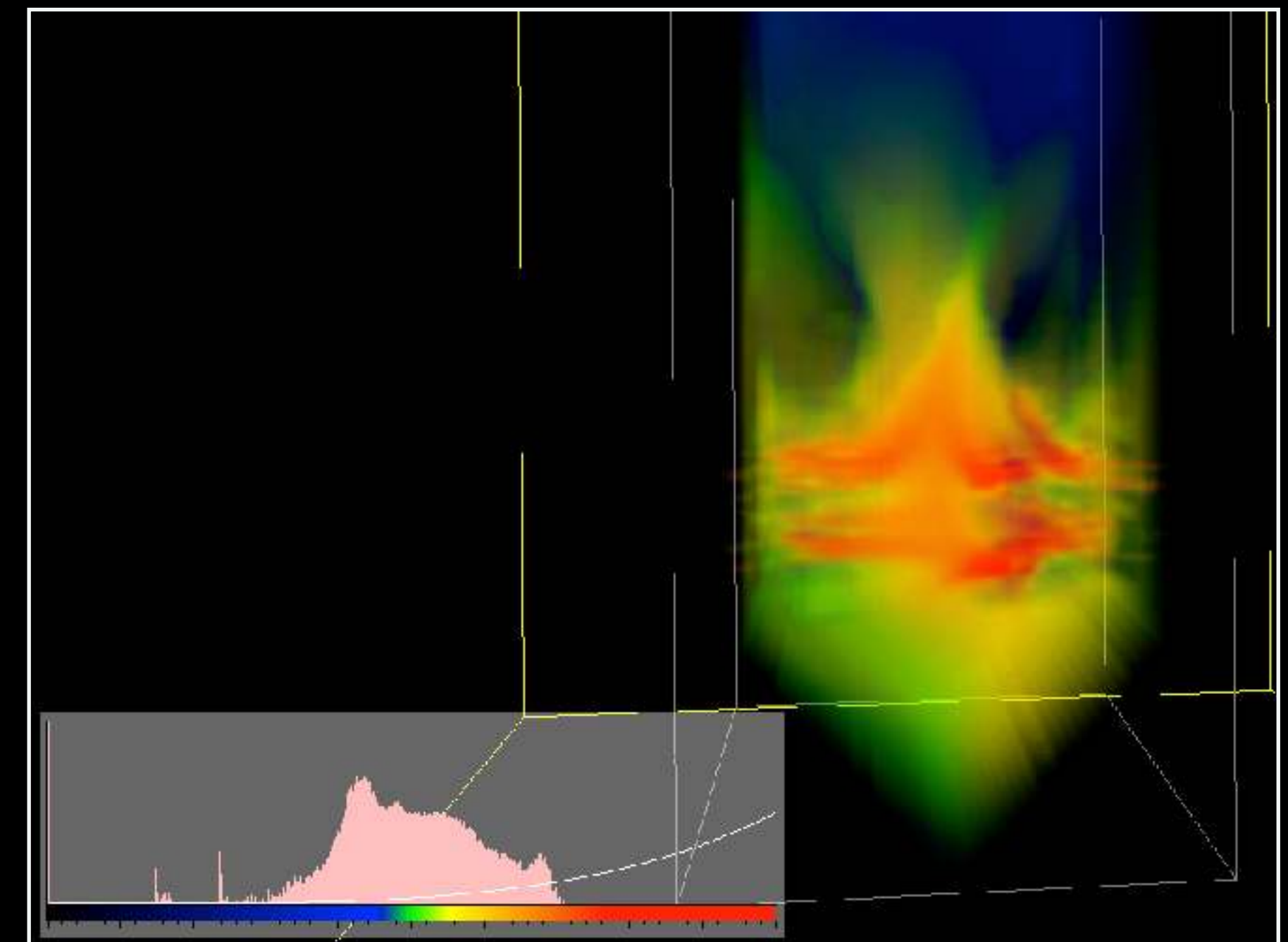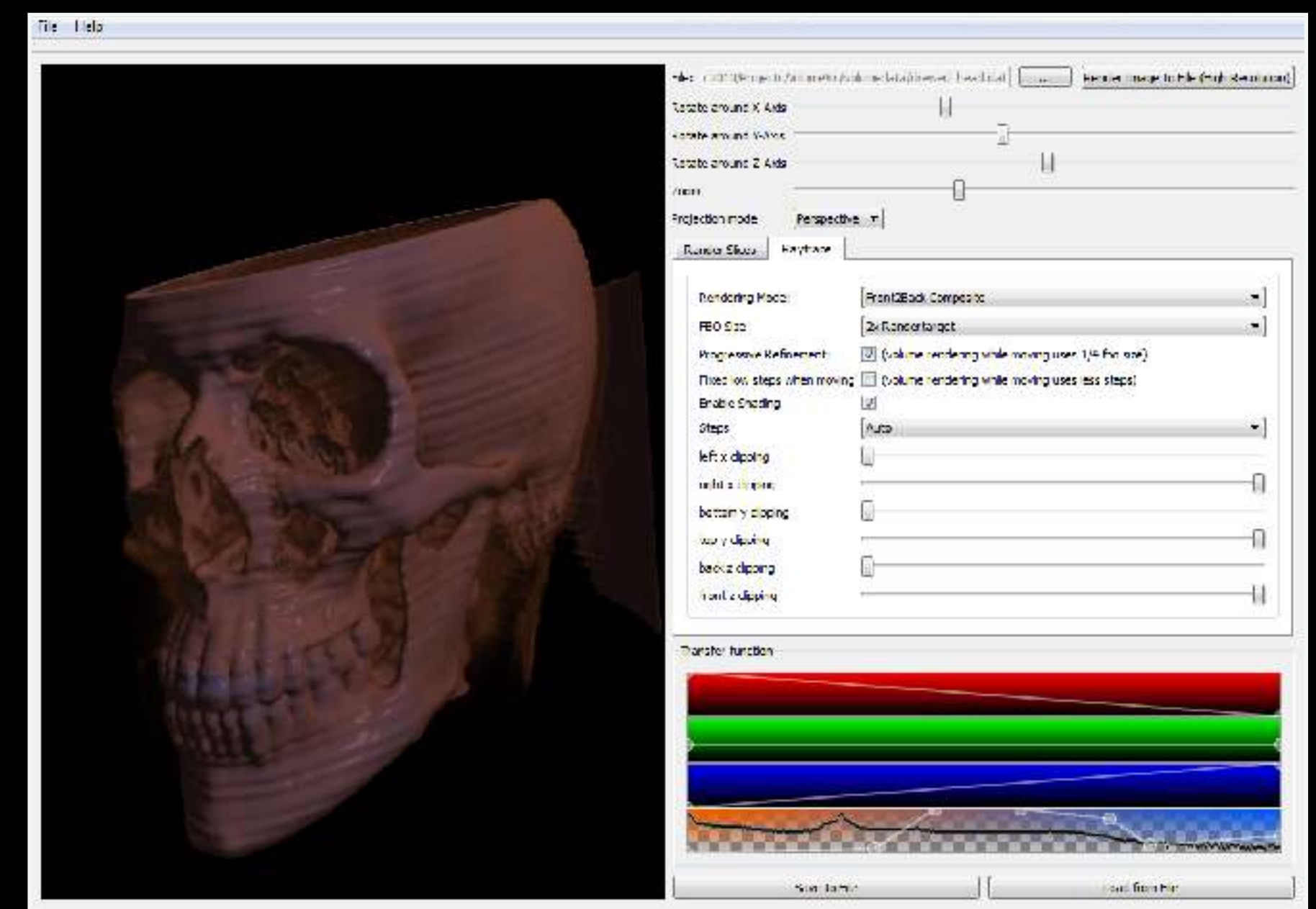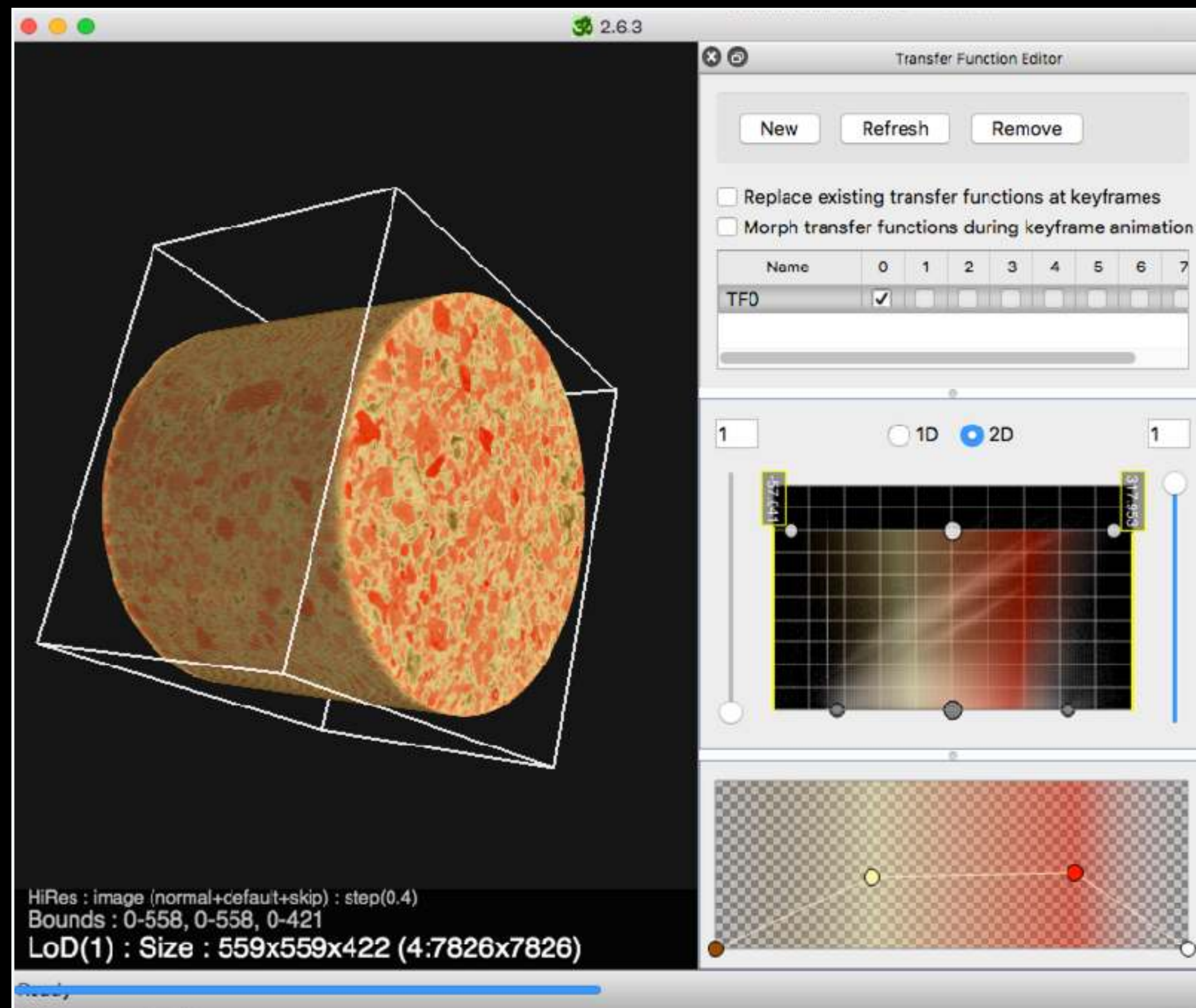# Data formats

- Medical scanners (and others) generally create DICOM files.
  These are one file per slice but also contains metadata, for example, scanner make/model, date, scanner settings, size of the voxels in world units, subject identifiers, operator name, institution … and so on.

- Other sources of volumetric data just provide the slices in some more standard image format, for example, jpg, tiff, png …

- There are some single file containers for the whole volume.
  Typically they have a header giving at least the number of voxels on each axis, the size of the voxels in world units, and the size of the items per voxel (eg; byte, short, int …)

- No good standards though, many people fall back to a single raw file and the above documented externally.

Additional notes

- Voxels are rarely cubes except for volumetric data from physics or engineering simulations. Scanners typically create a higher density within each slice compared to the density between slices.

- Voxels are usually all the same size except for some physics and engineering simulations where it may be desirable to have a higher density of voxels in important regions.

- The most common voxel values are single bytes (256 states) or unsigned short integers. But can also be floating point and sometimes can be actual colour values (eg: sliced and photographed objects).

- Researchers have always, since the start of volumetric data visualisation, created volumes at a resolution that is hard to visualise interactively … despite the advances in realtime computer graphics on the GPU.

Demonstration

Dristhi

Means "vision" or "insight" in Sanskrit

Developed at the Australian National University by Ajay Limaye