CS49000-VIZ - Fall 2020

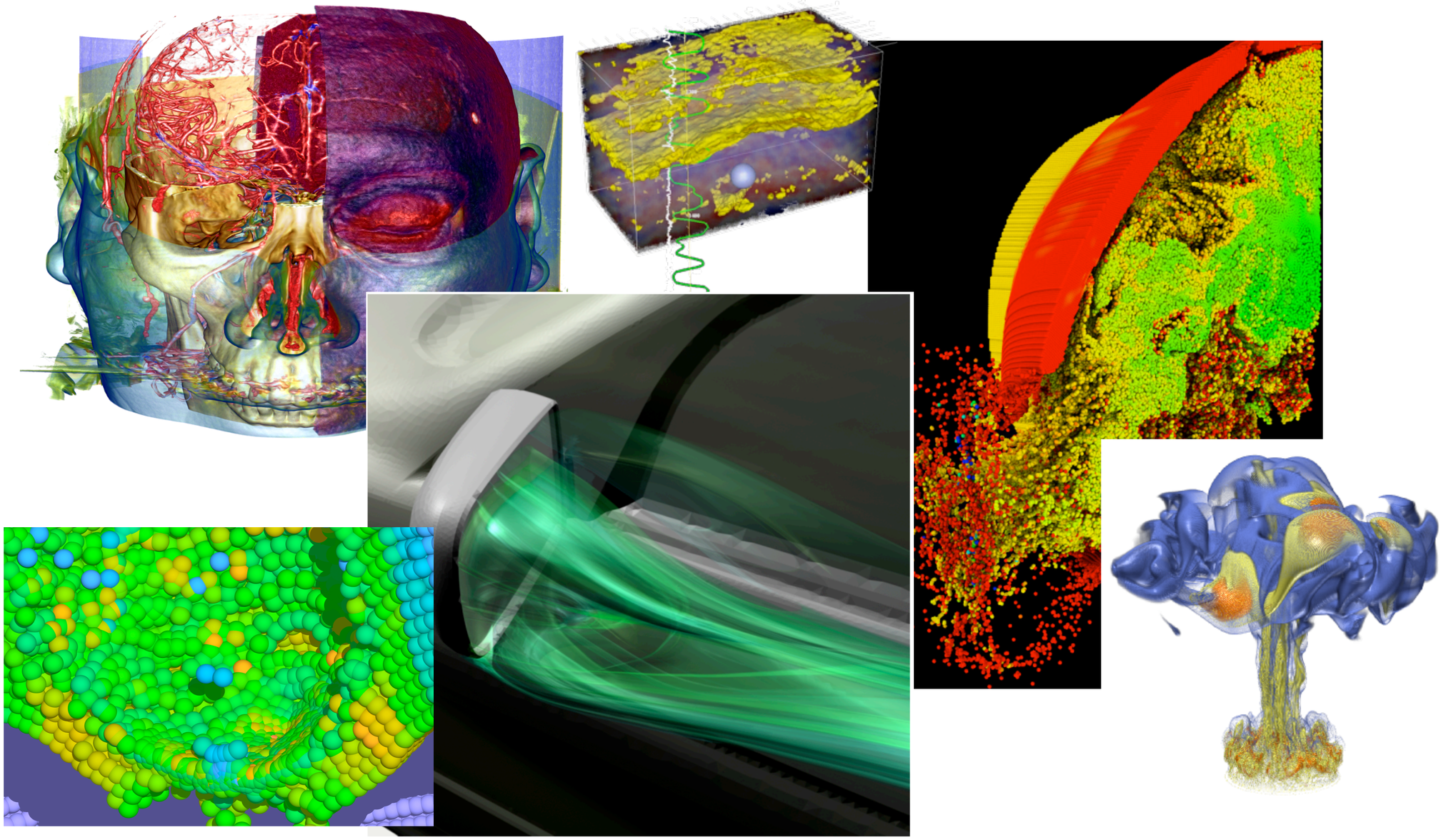
Introduction to Data Visualization

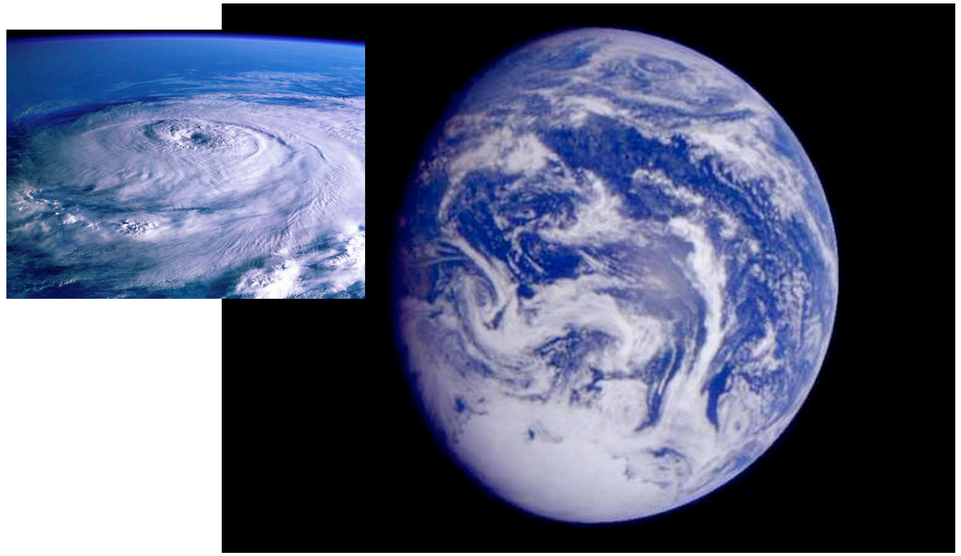
Scientific Visualization

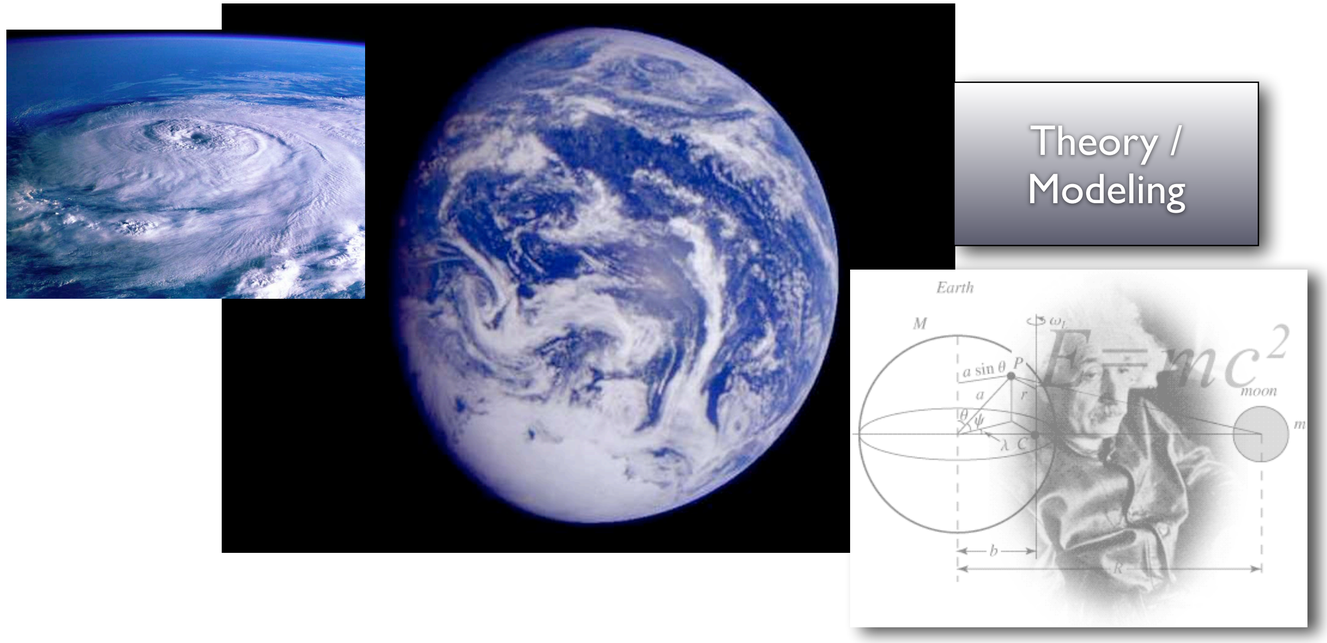
Lecture 17

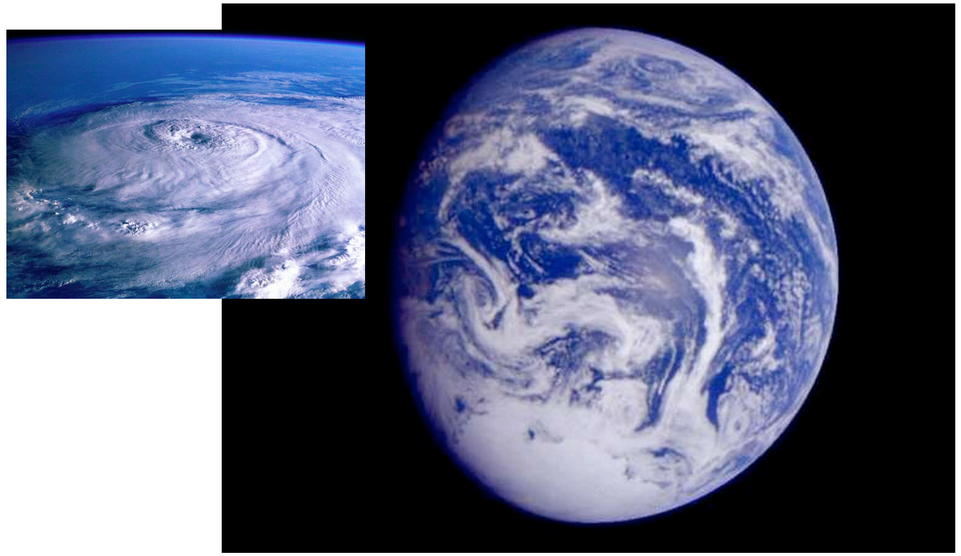
November 10, 2020

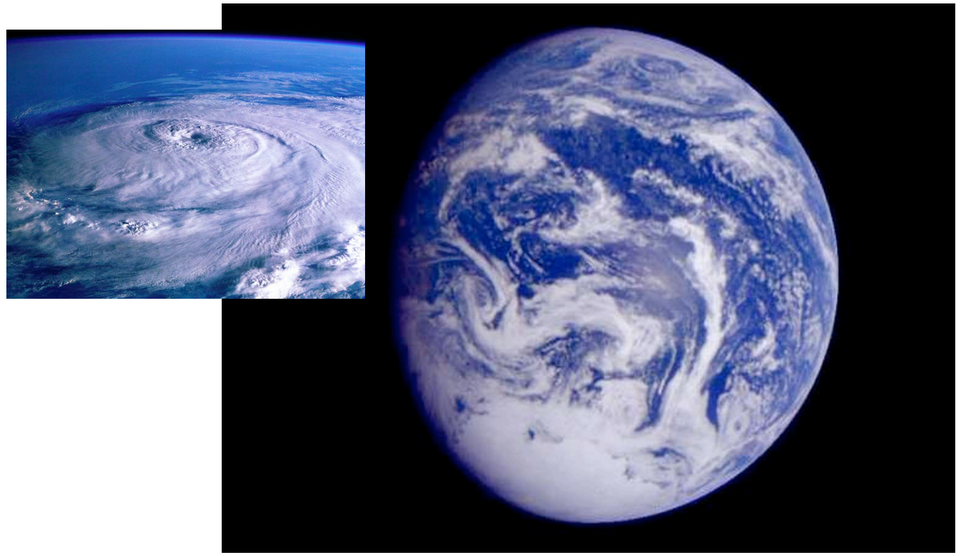
What is Sci Vis?



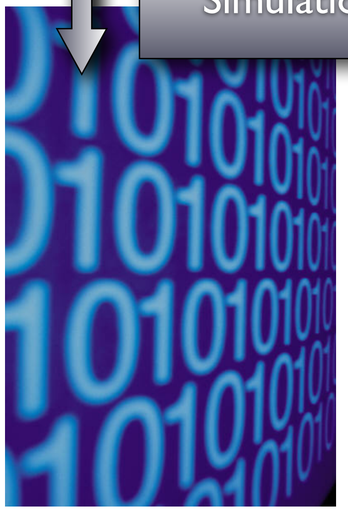


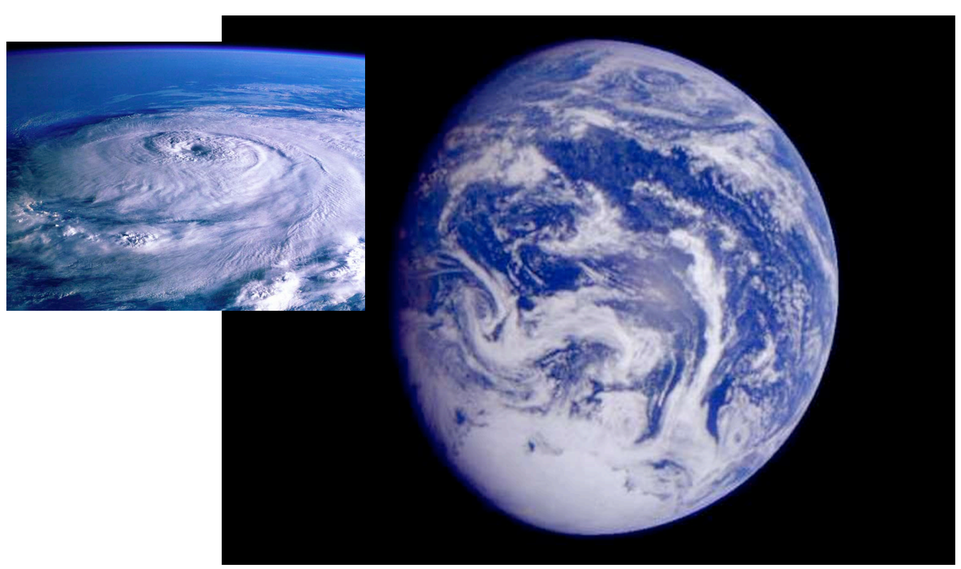

Theory /
Modeling
Earth
M
ω_i
$a \sin\theta$
P
a
r
θ
ψ
λ
C
b
moon
m
R
$E = mc^2$



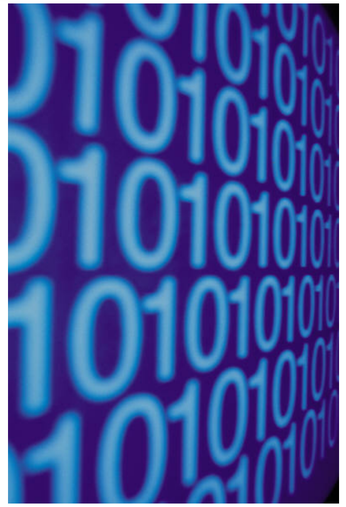


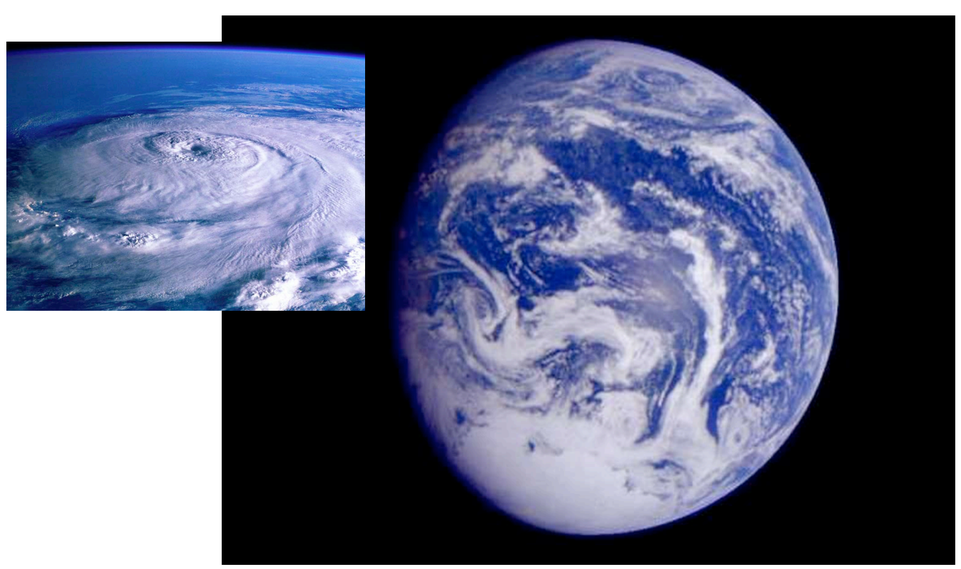
Simulation

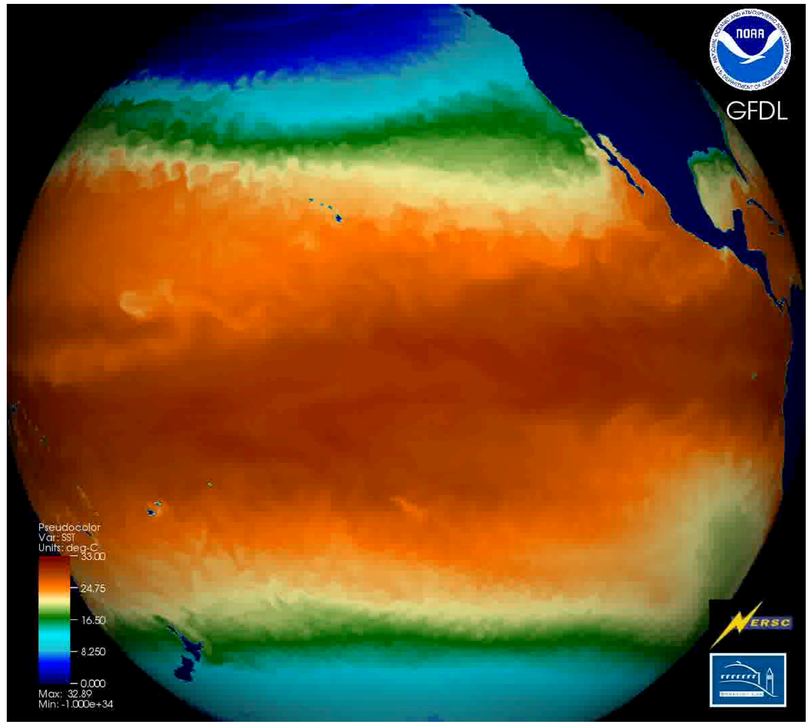




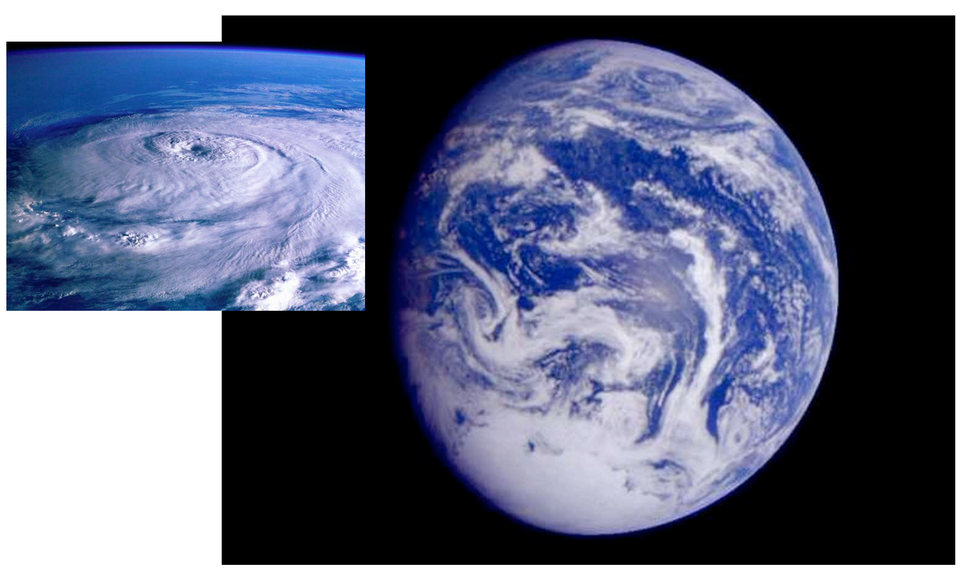
Experiment / Measures

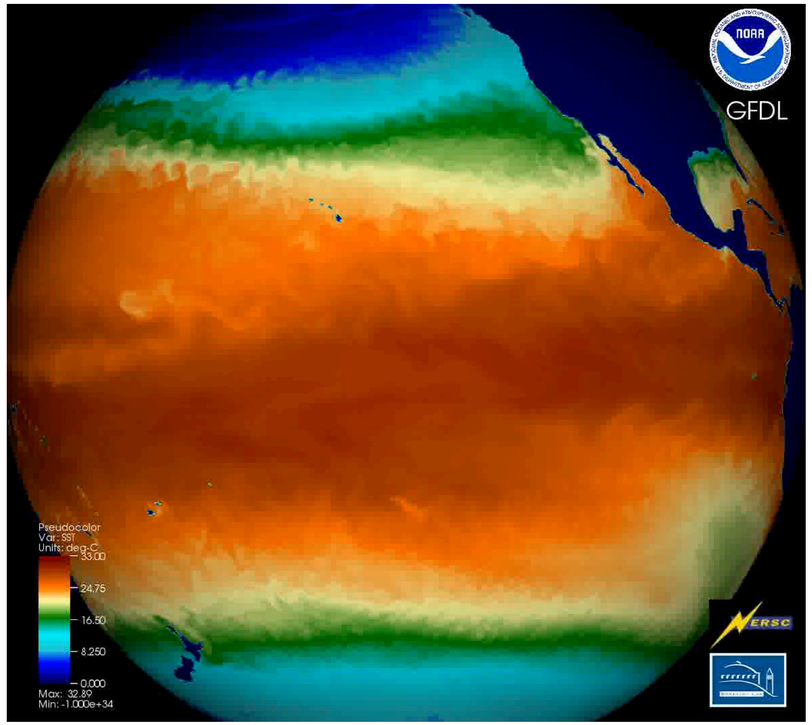






Visualization





Visualization

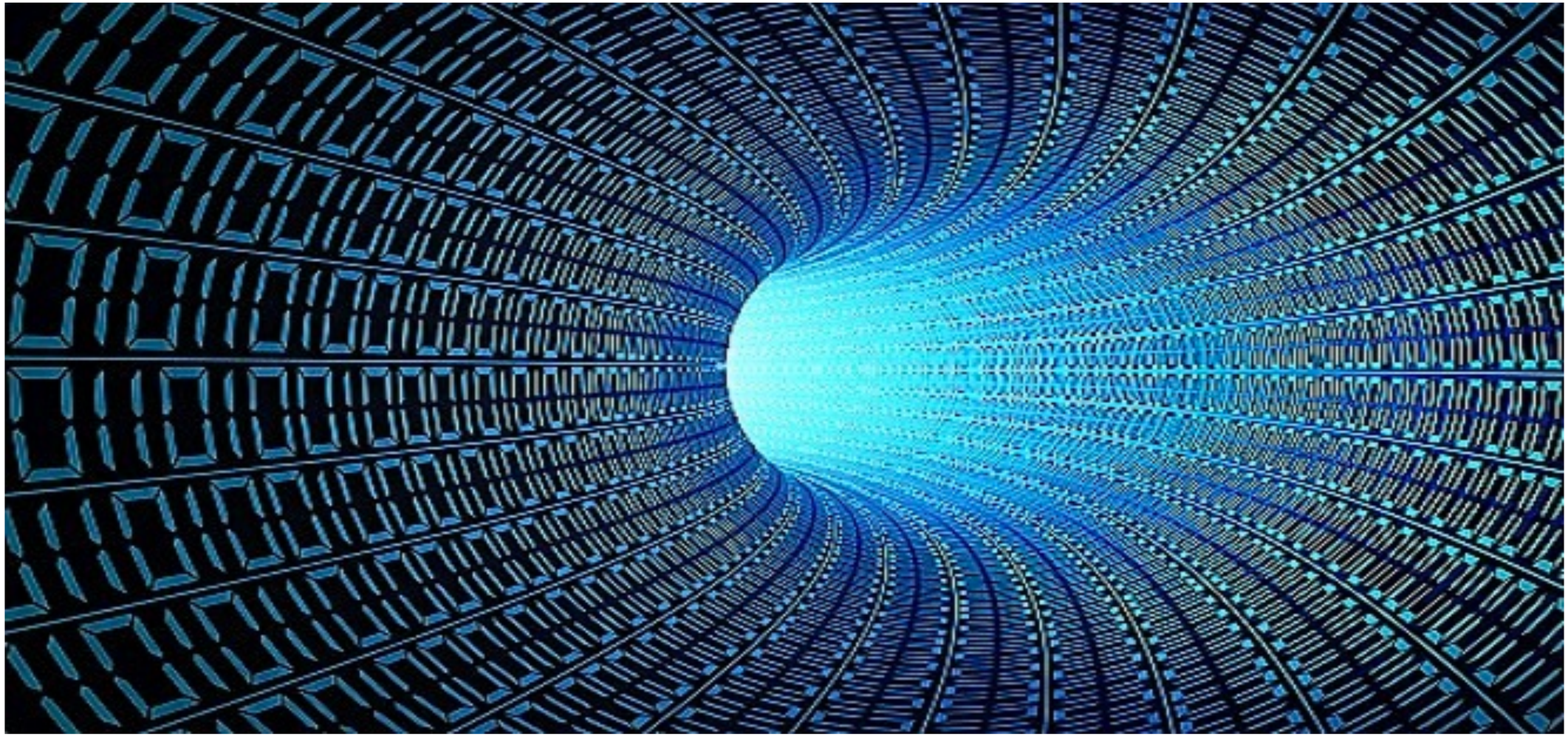
What is Sci Vis?

A hybrid and collaborative discipline

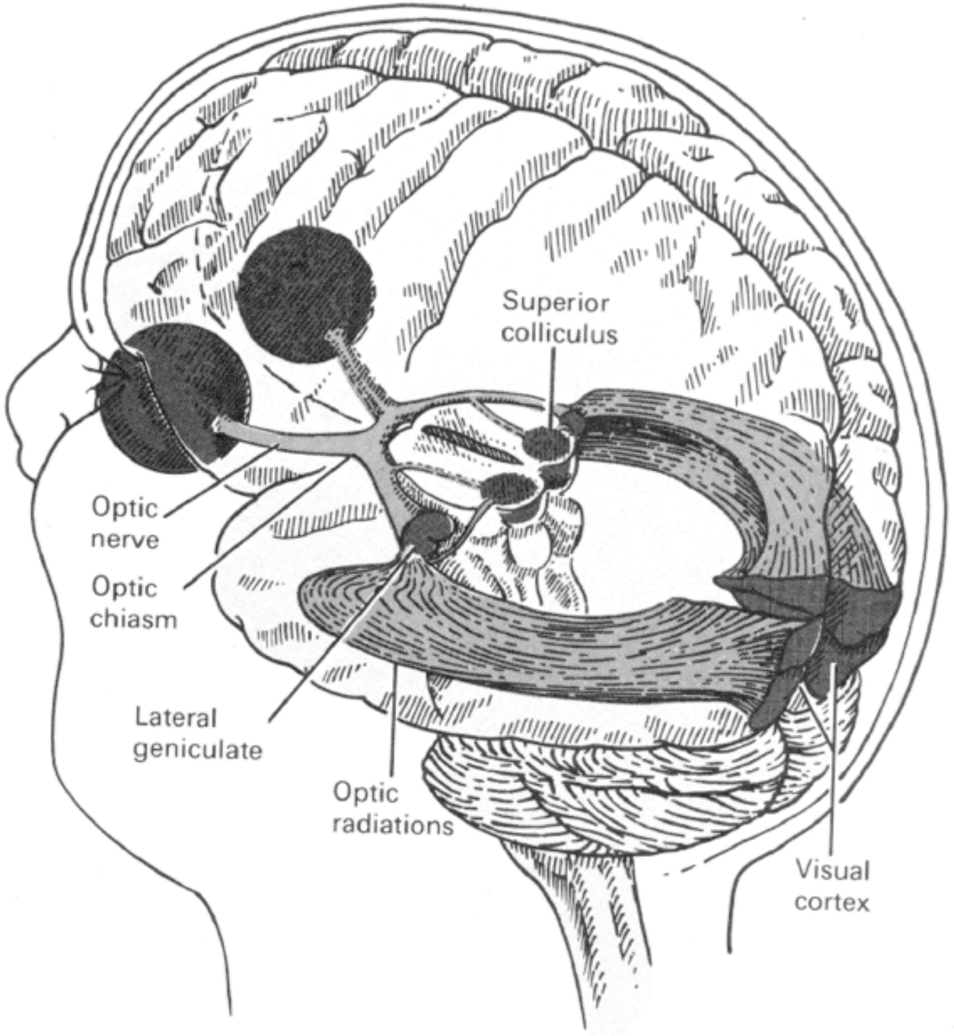
- Computer graphics
- Numerical analysis
- Image/signal processing and pattern recognition
- Scientific computing
- Art and design
- Psychophysics
- …

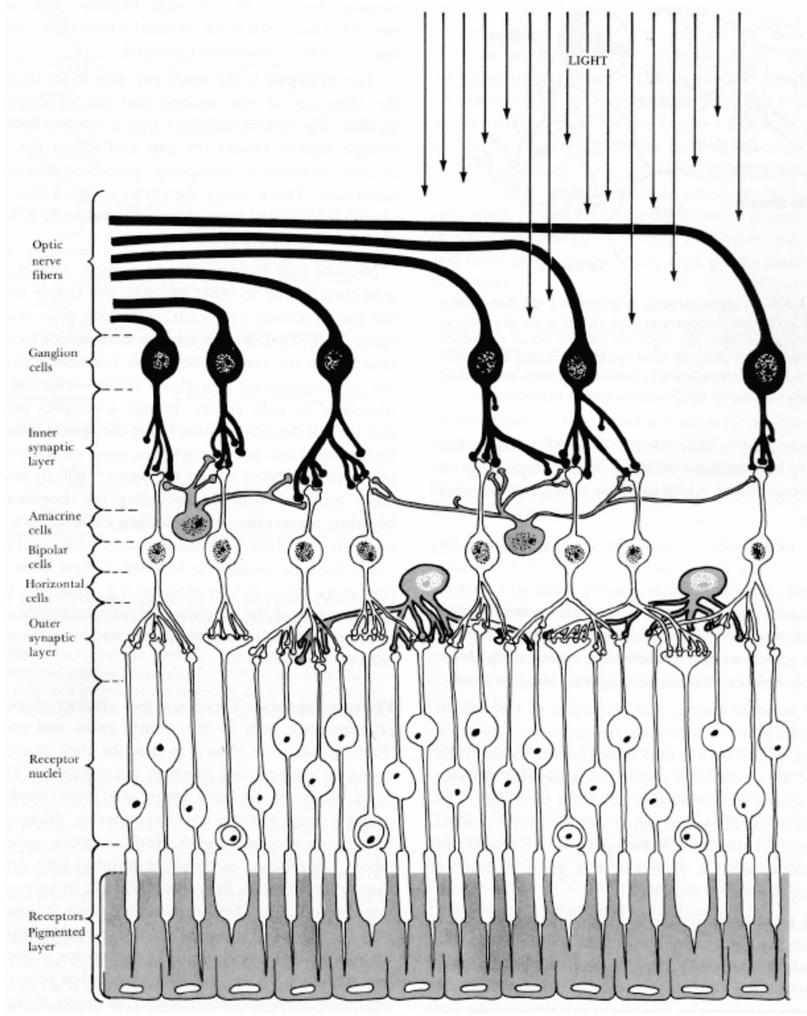
Why Visualize?

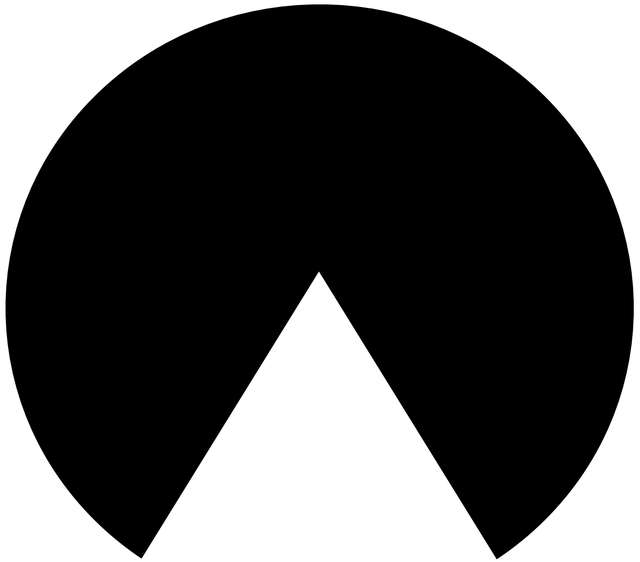
Information Explosion

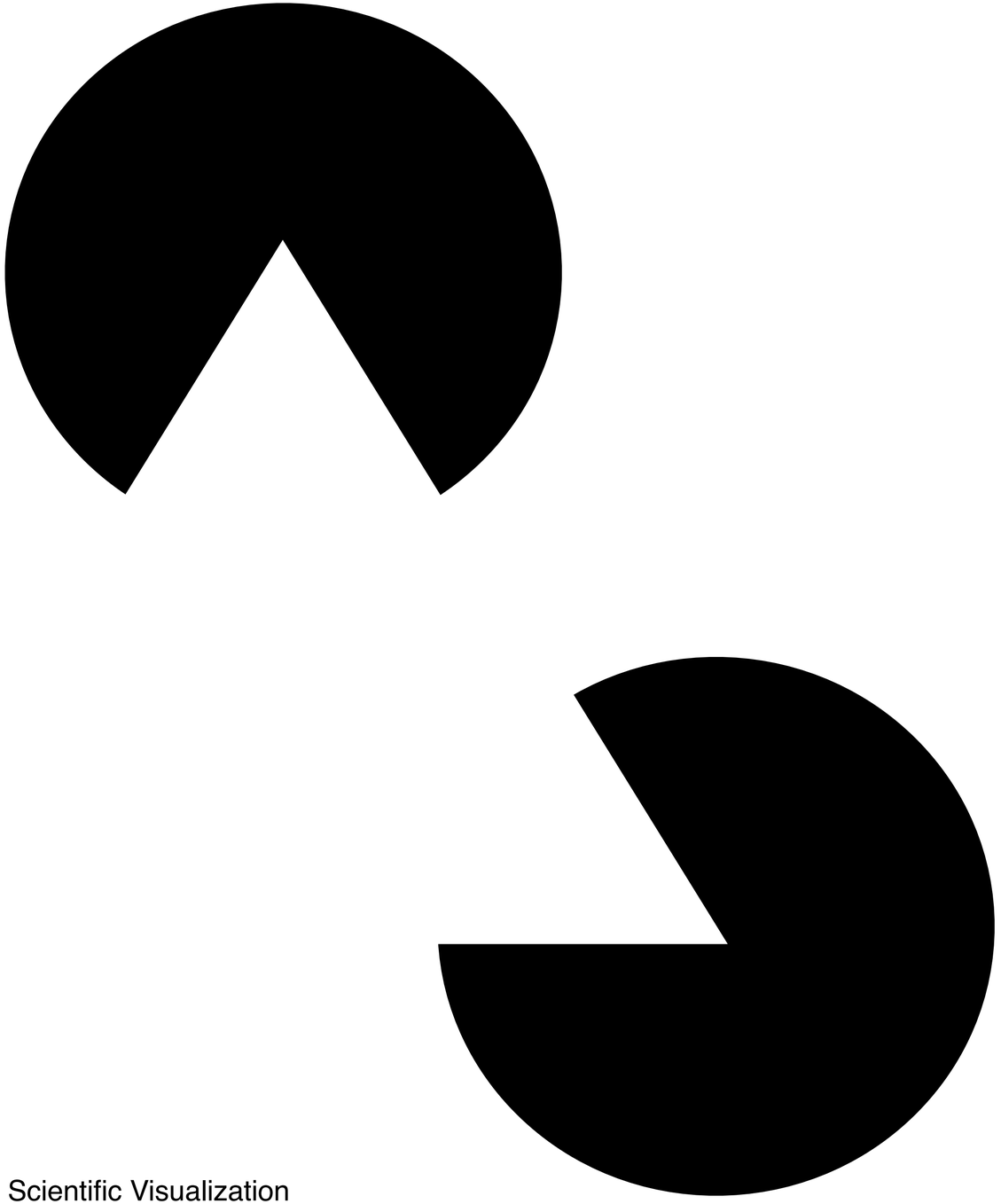


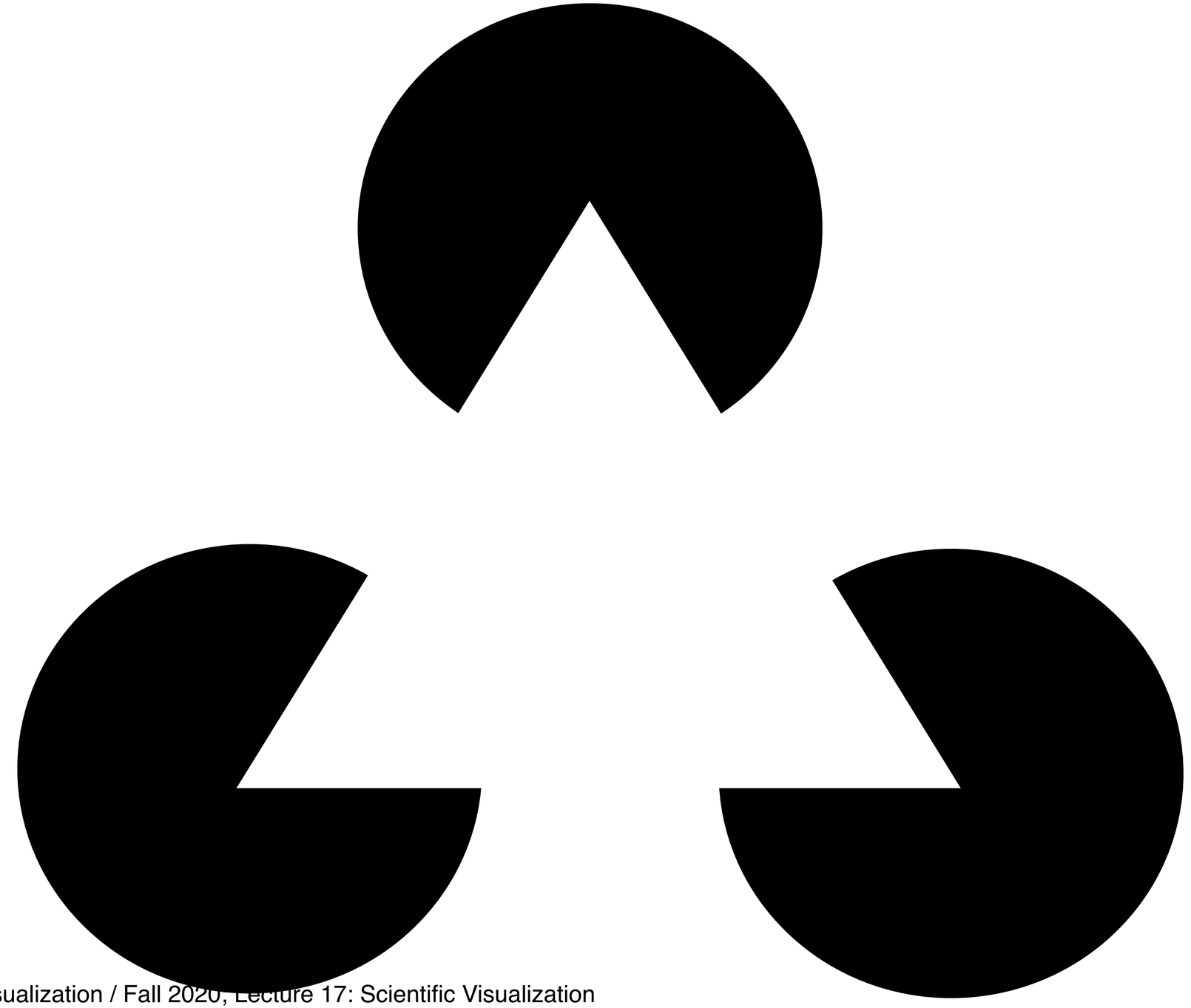
Visual System

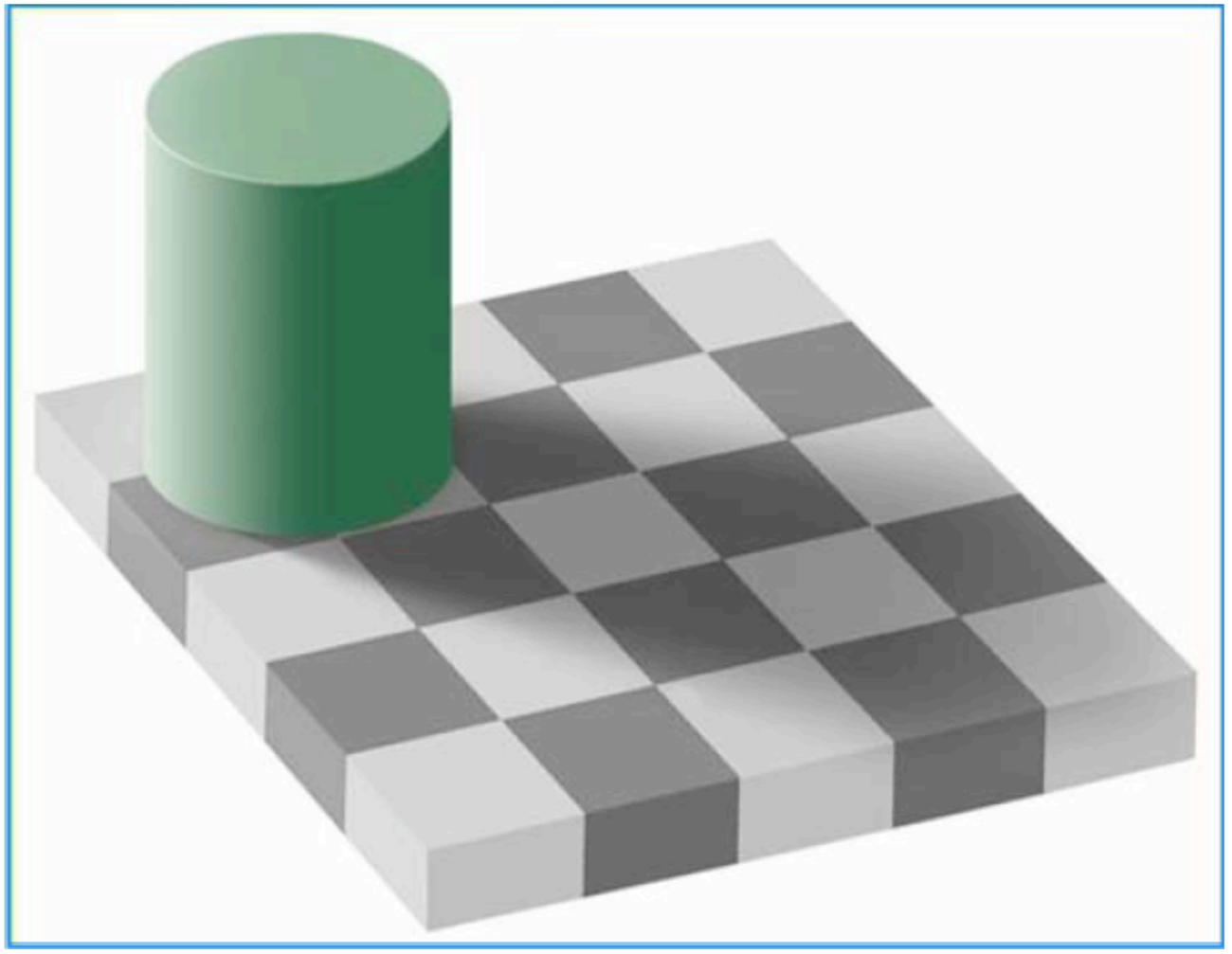


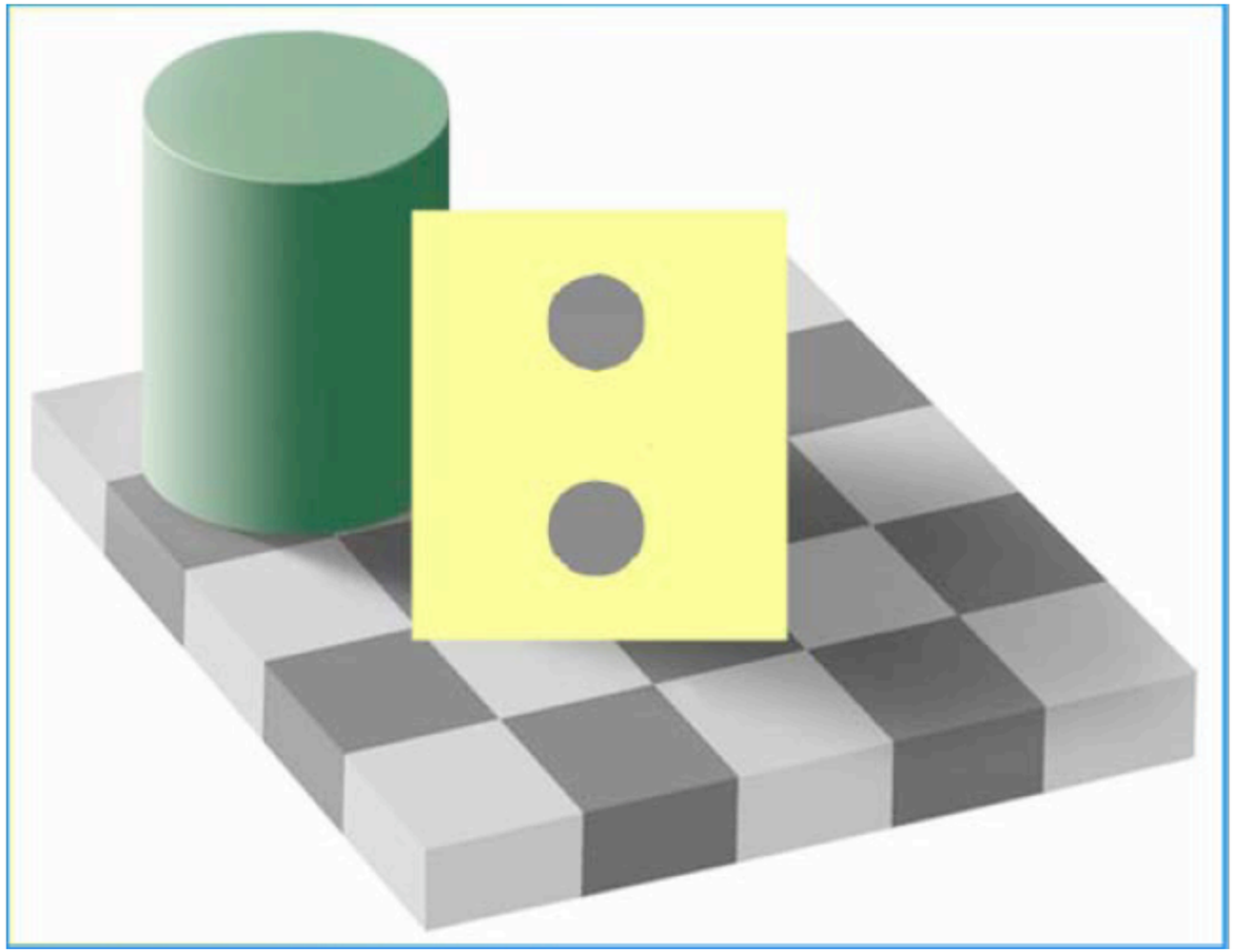


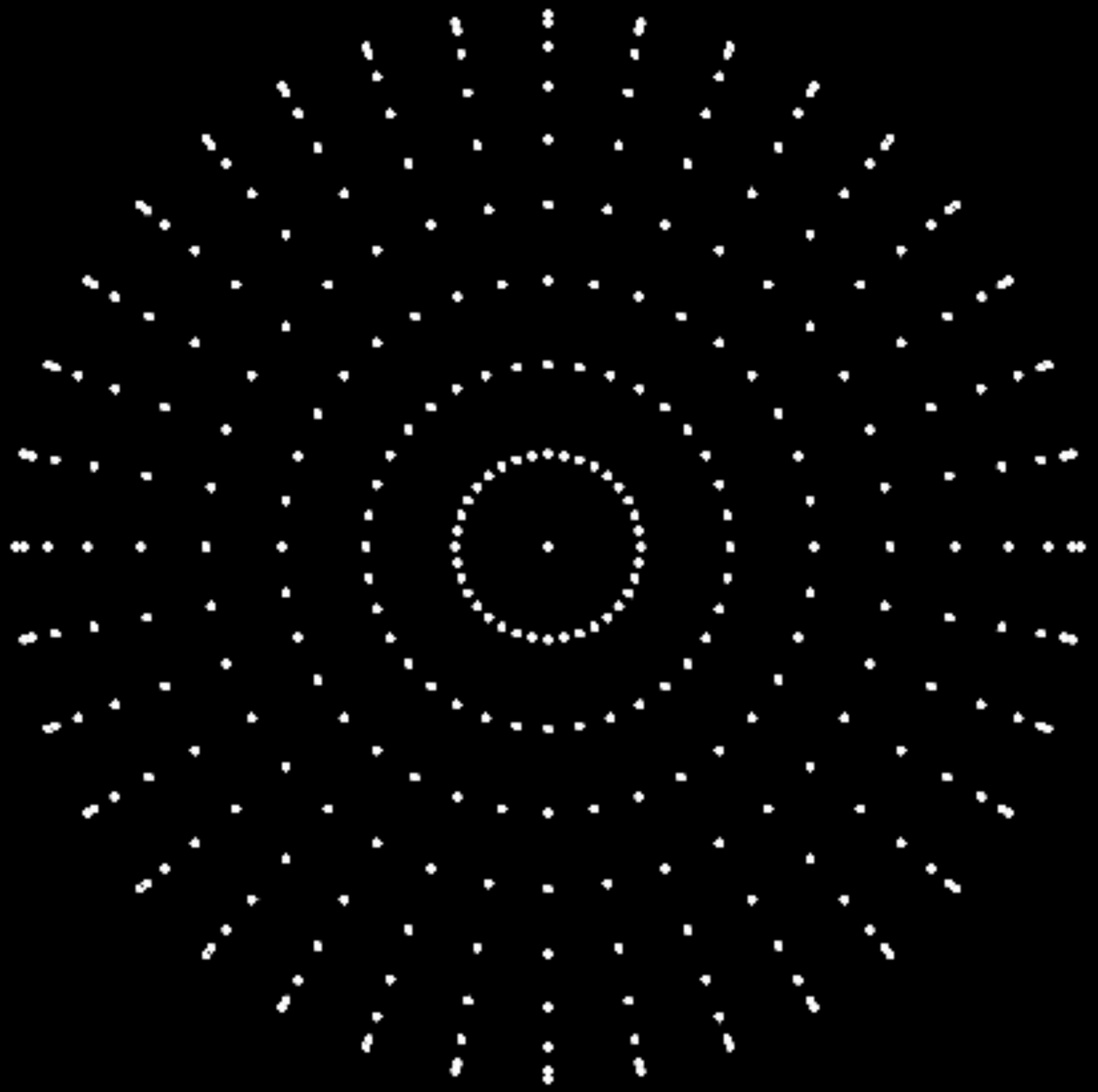


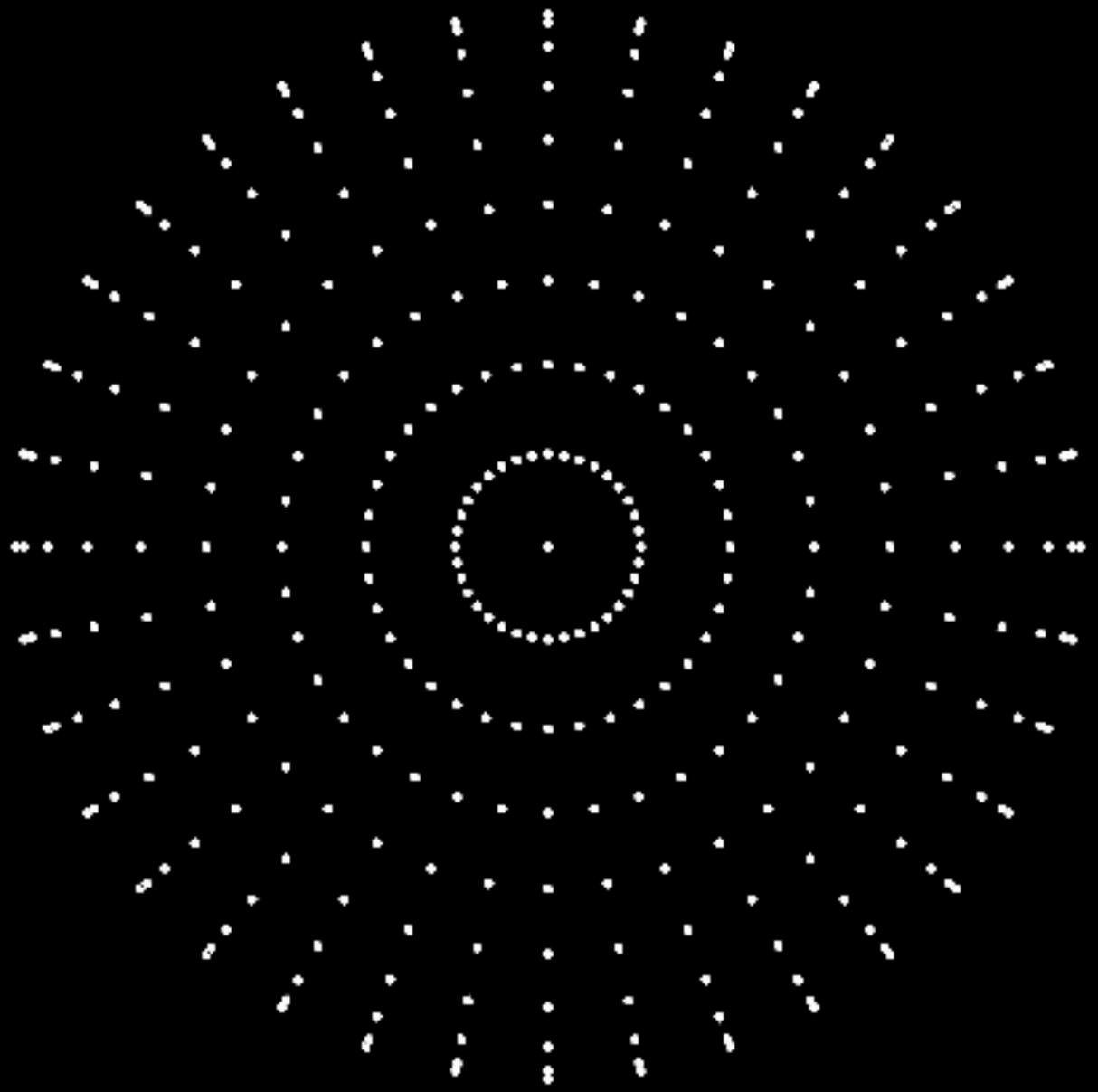






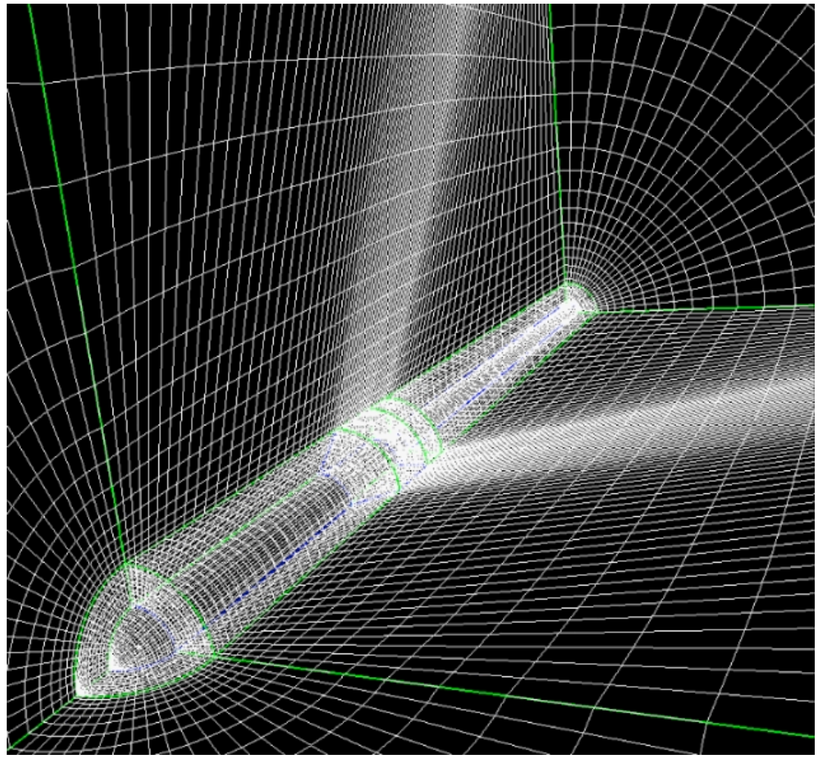


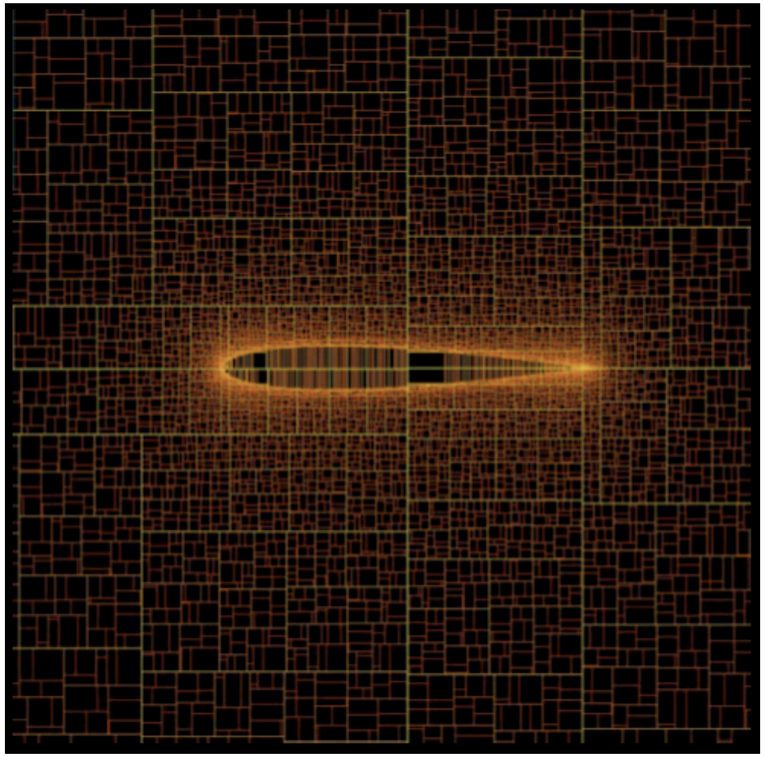




Spatial Data Structures

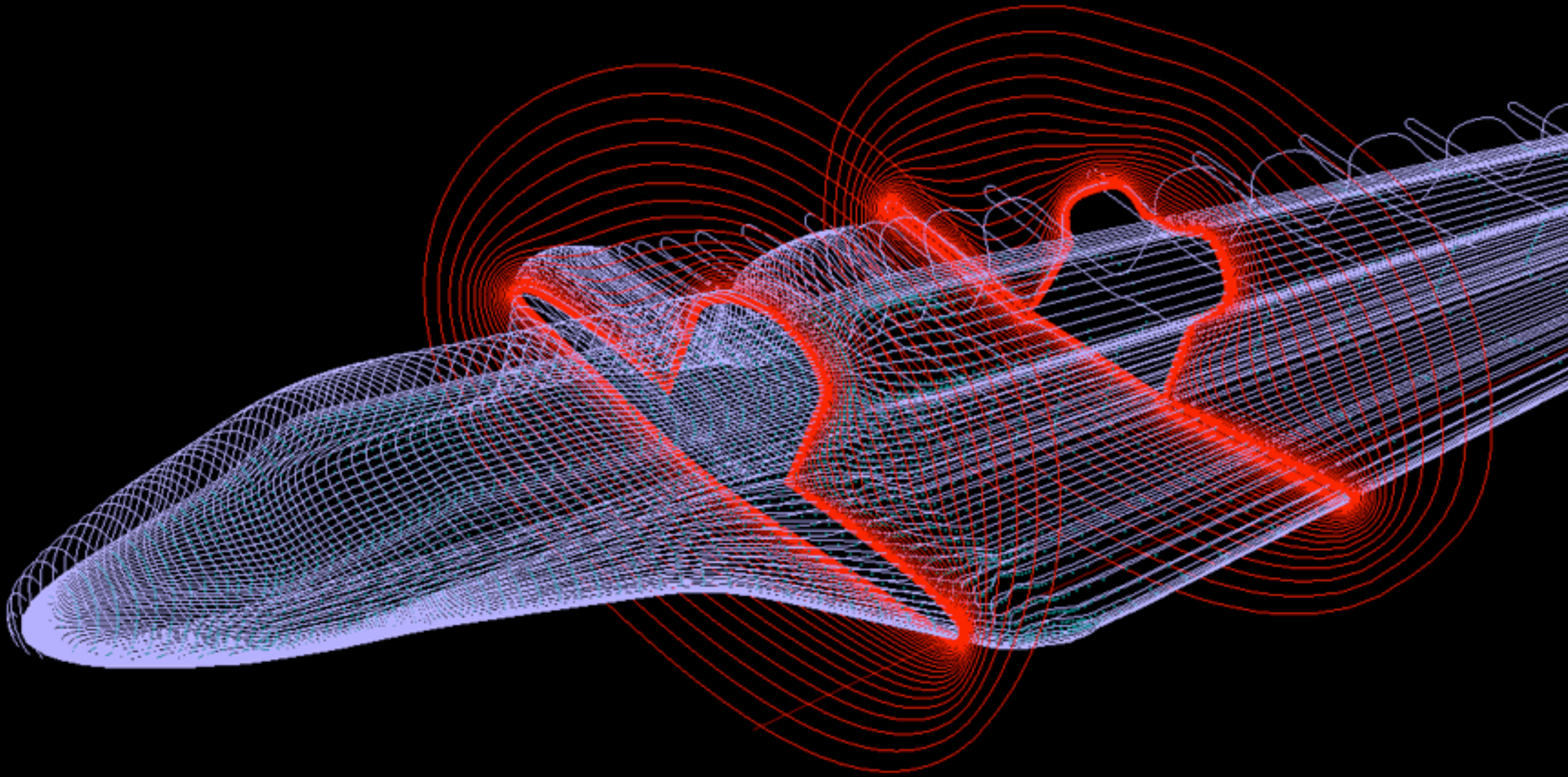
Data representation and processing

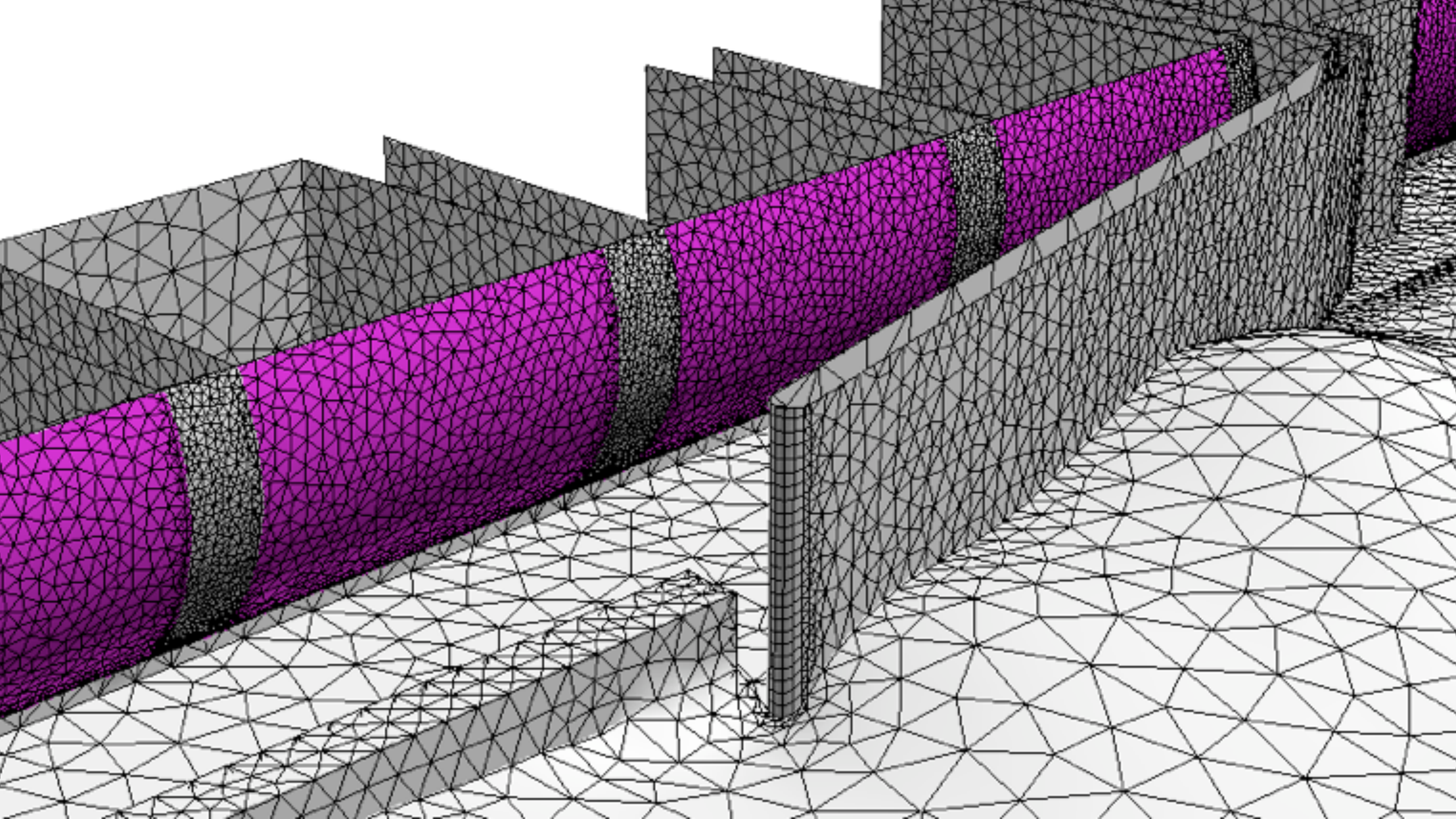


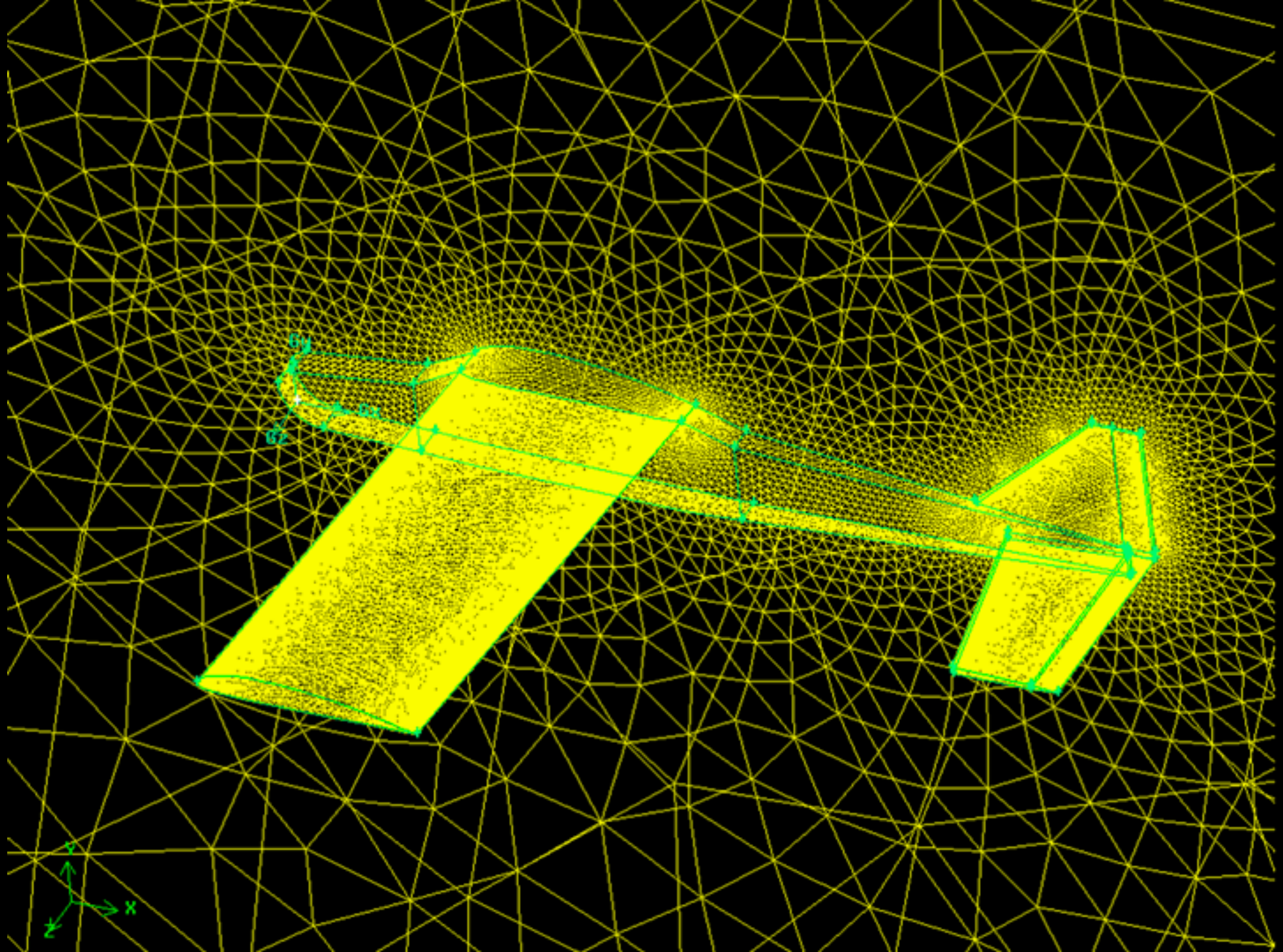


Interpolation

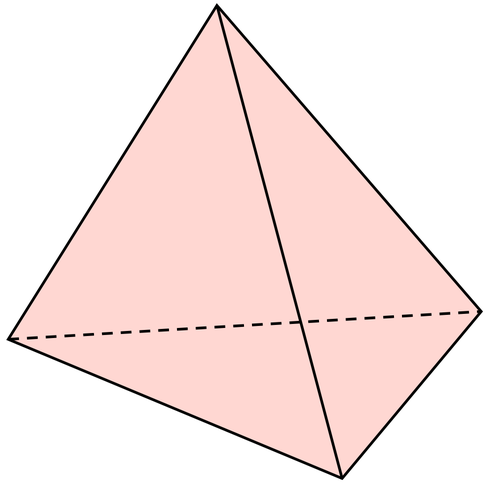
- **Input:** discrete samples of continuous quantities + mesh
- **Goal:** smooth reconstruction of those quantities from samples
- **Interpolation:** cell-wise functions



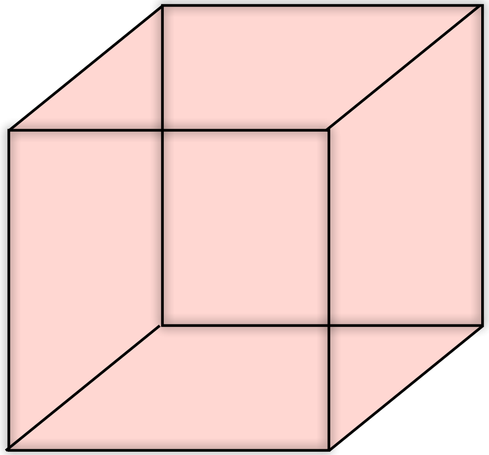



Y
X
Z

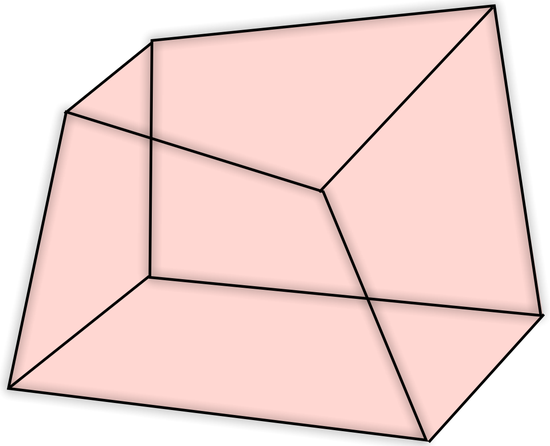
Cells



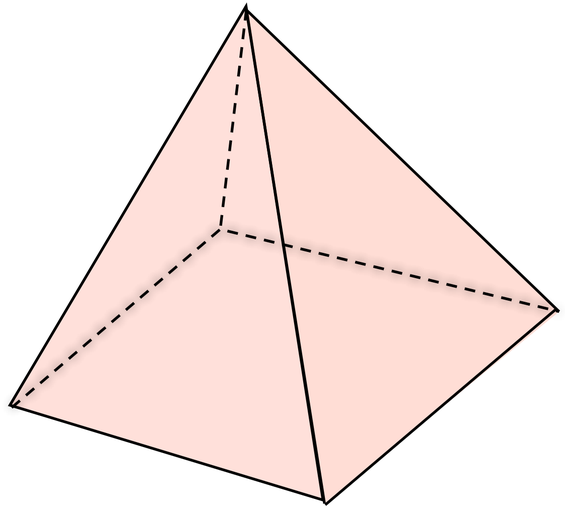
tetrahedron



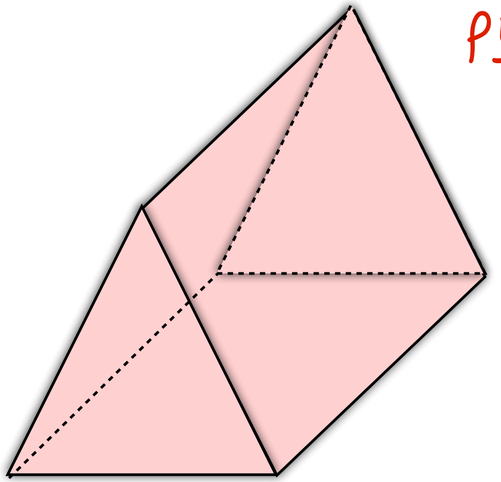
voxel



hexahedron

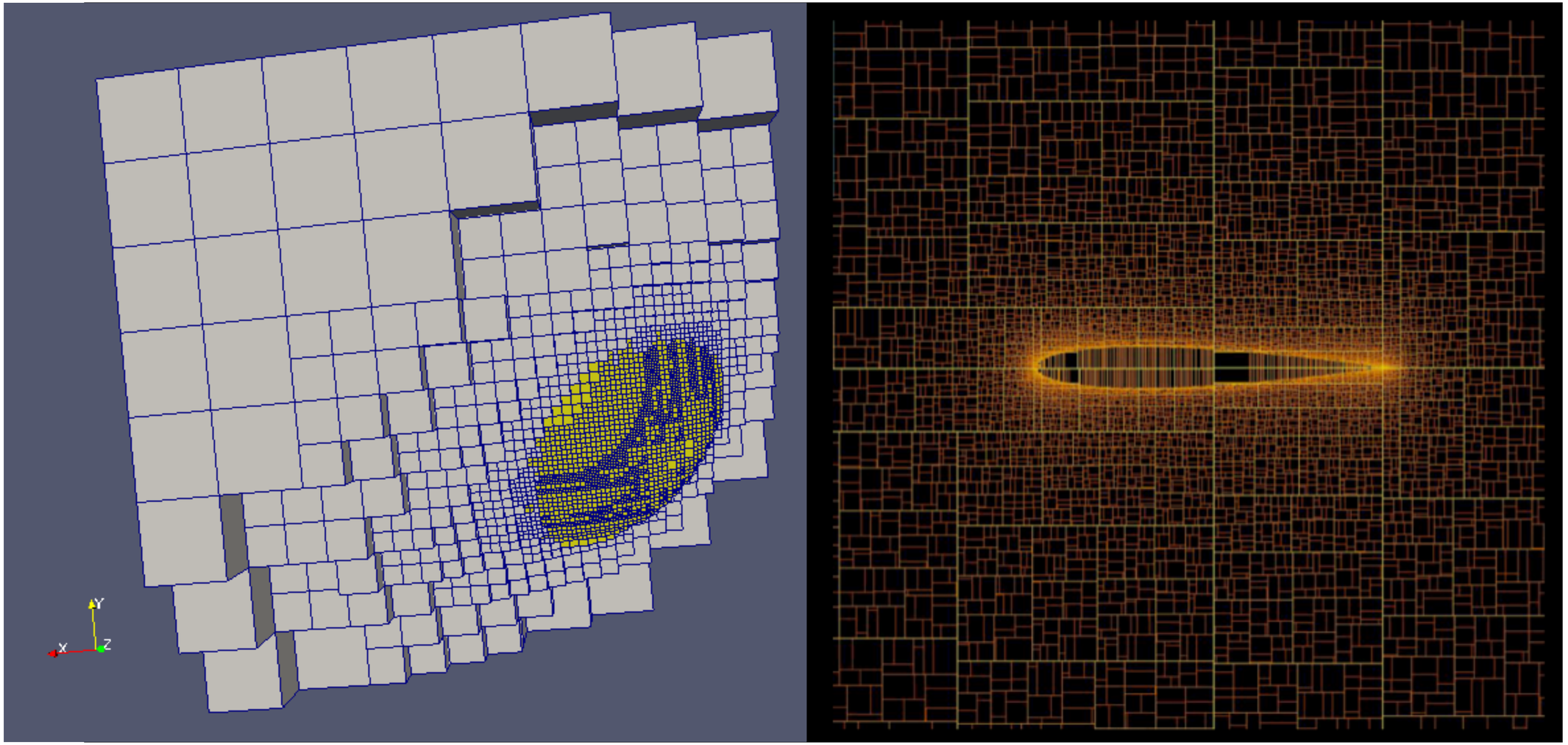


pyramid



prism

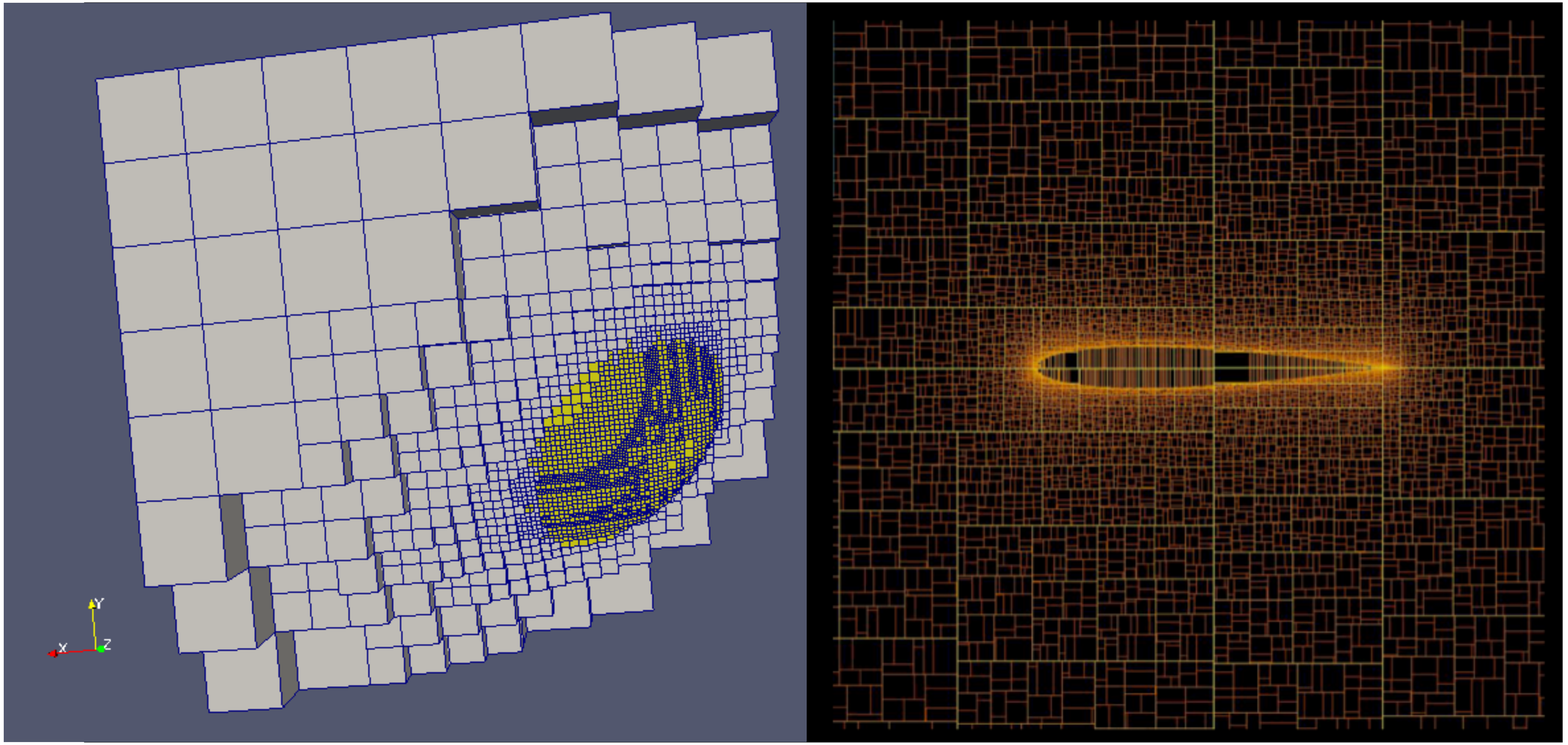
Spatial Queries



Octree

kd-tree

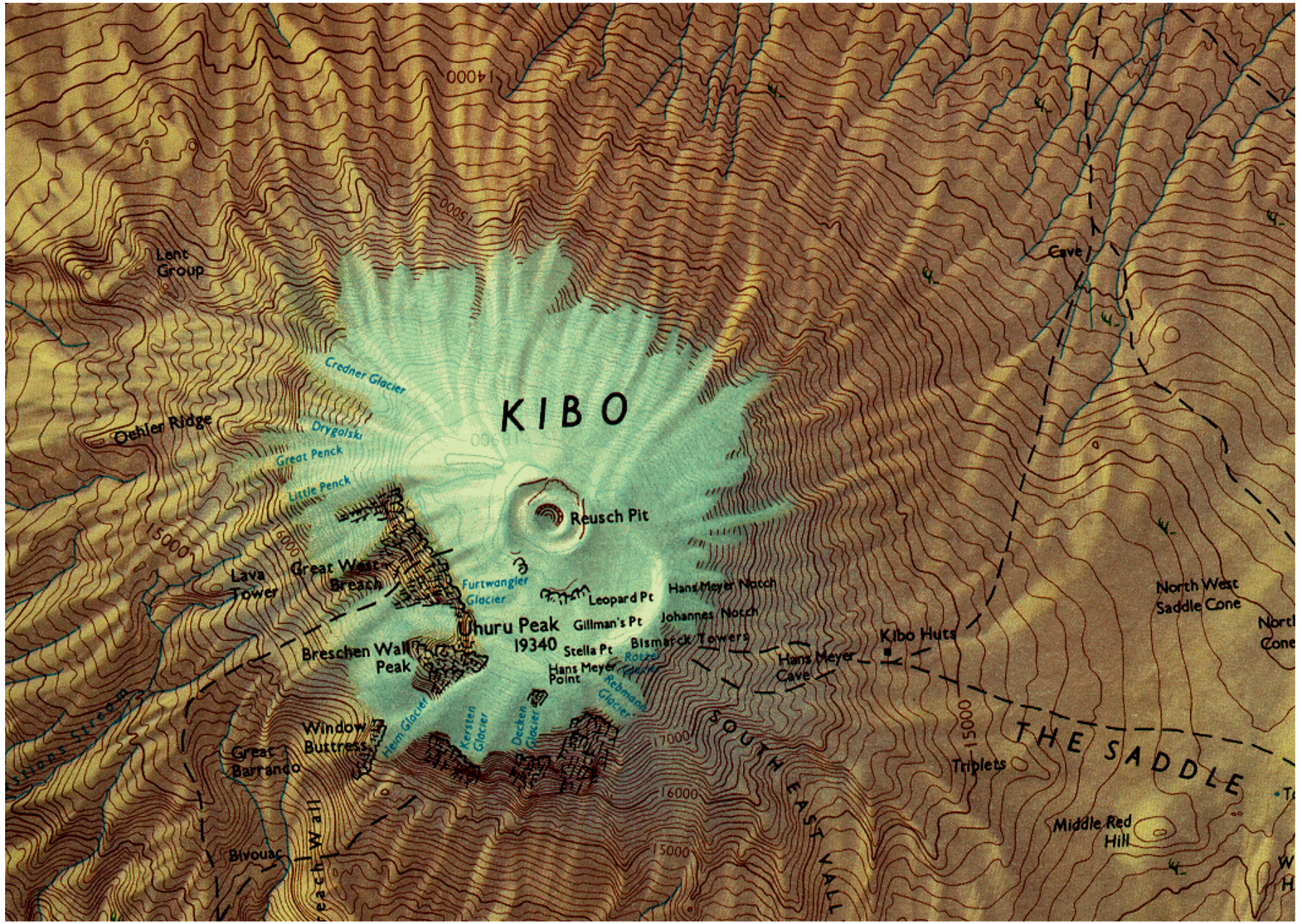
Spatial Queries



Octree

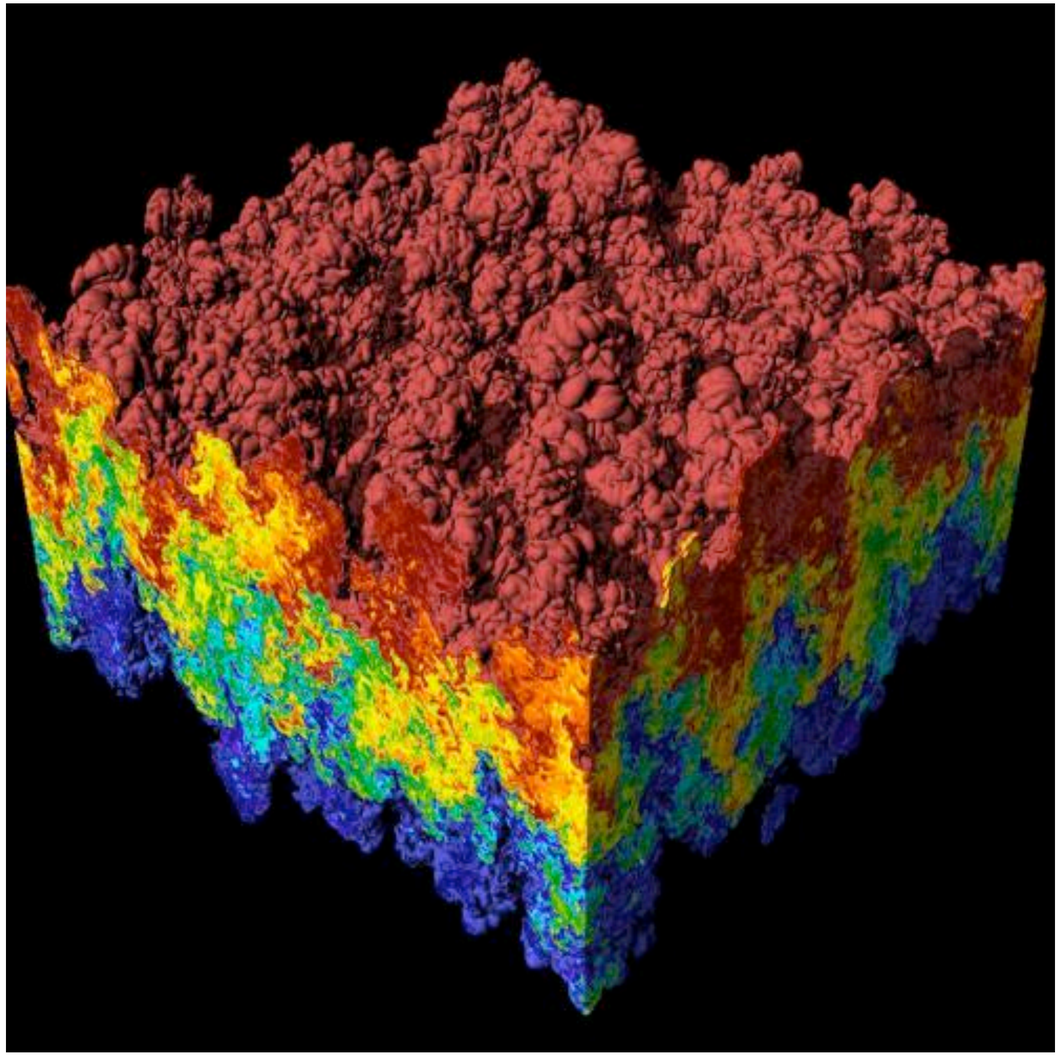
kd-tree

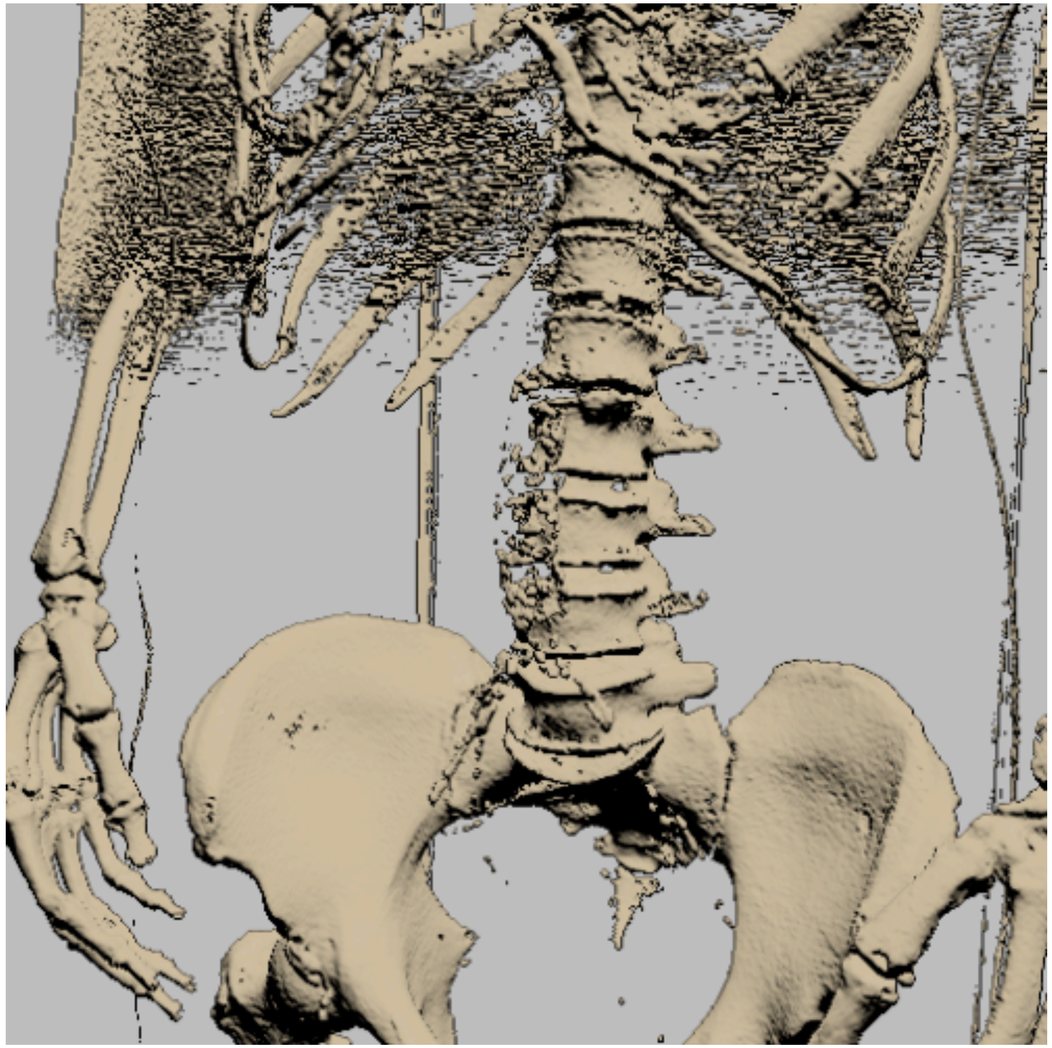
Scalar Visualization in 2D



isocontours

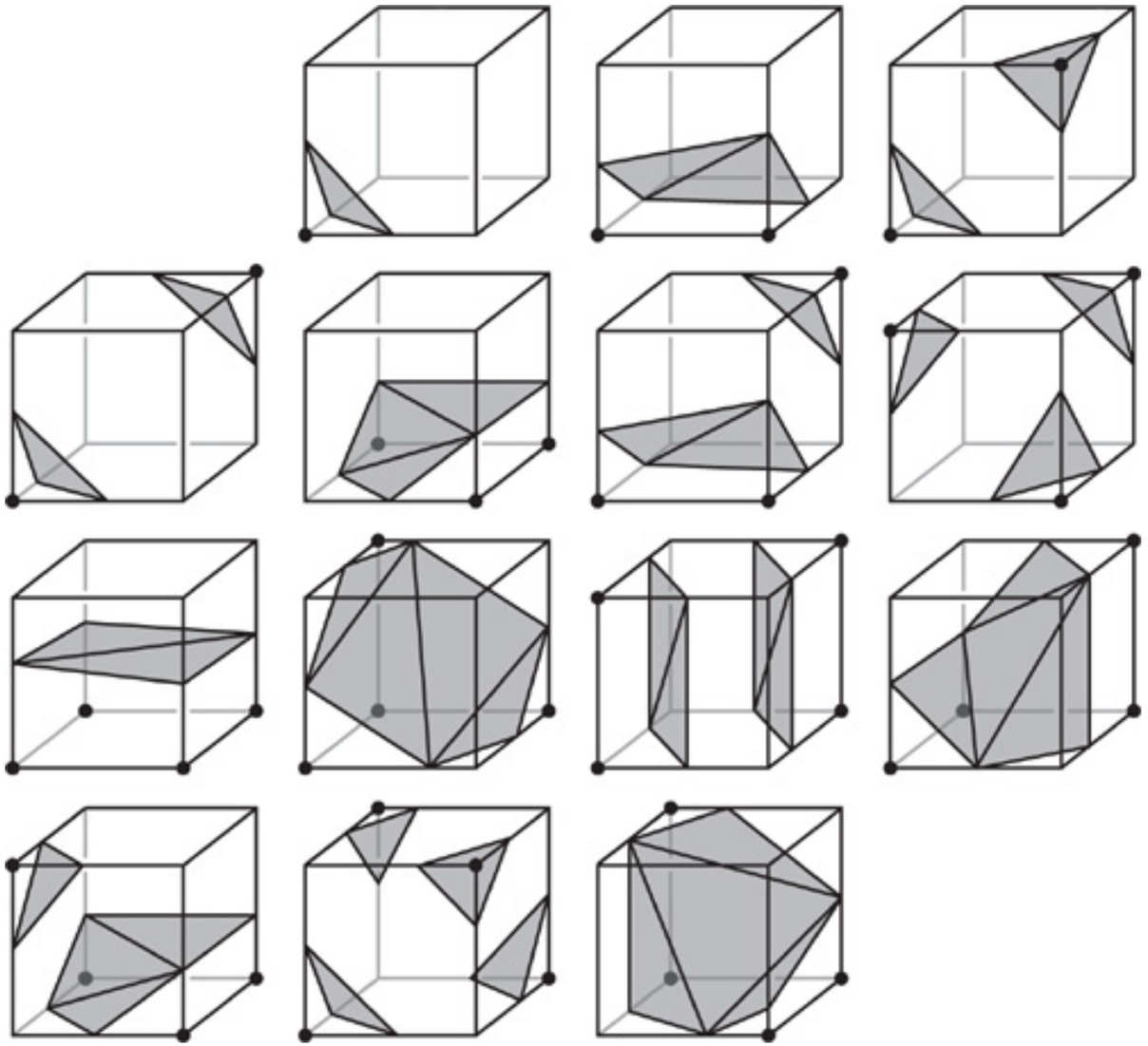
Scalar Visualization in 3D



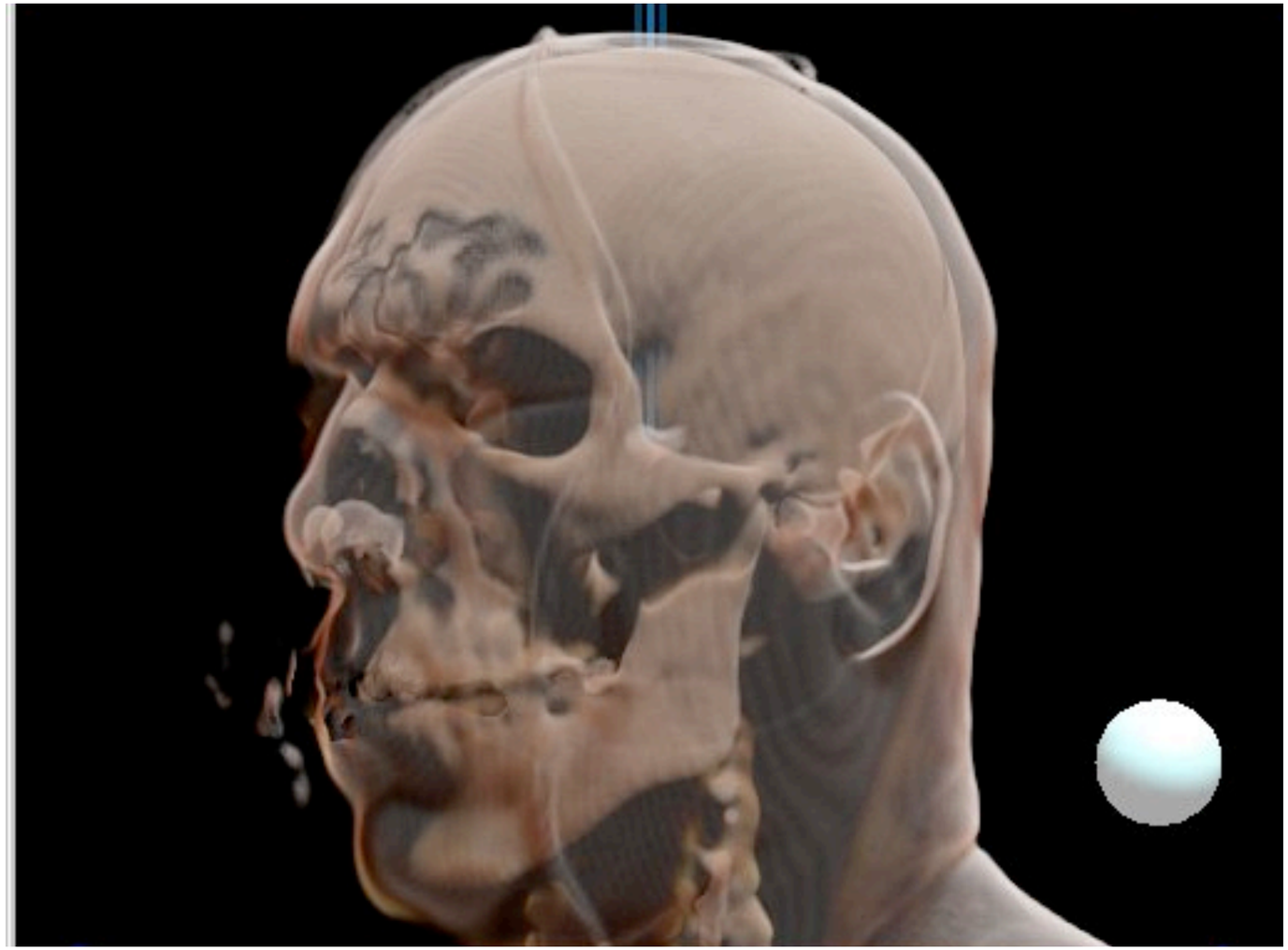


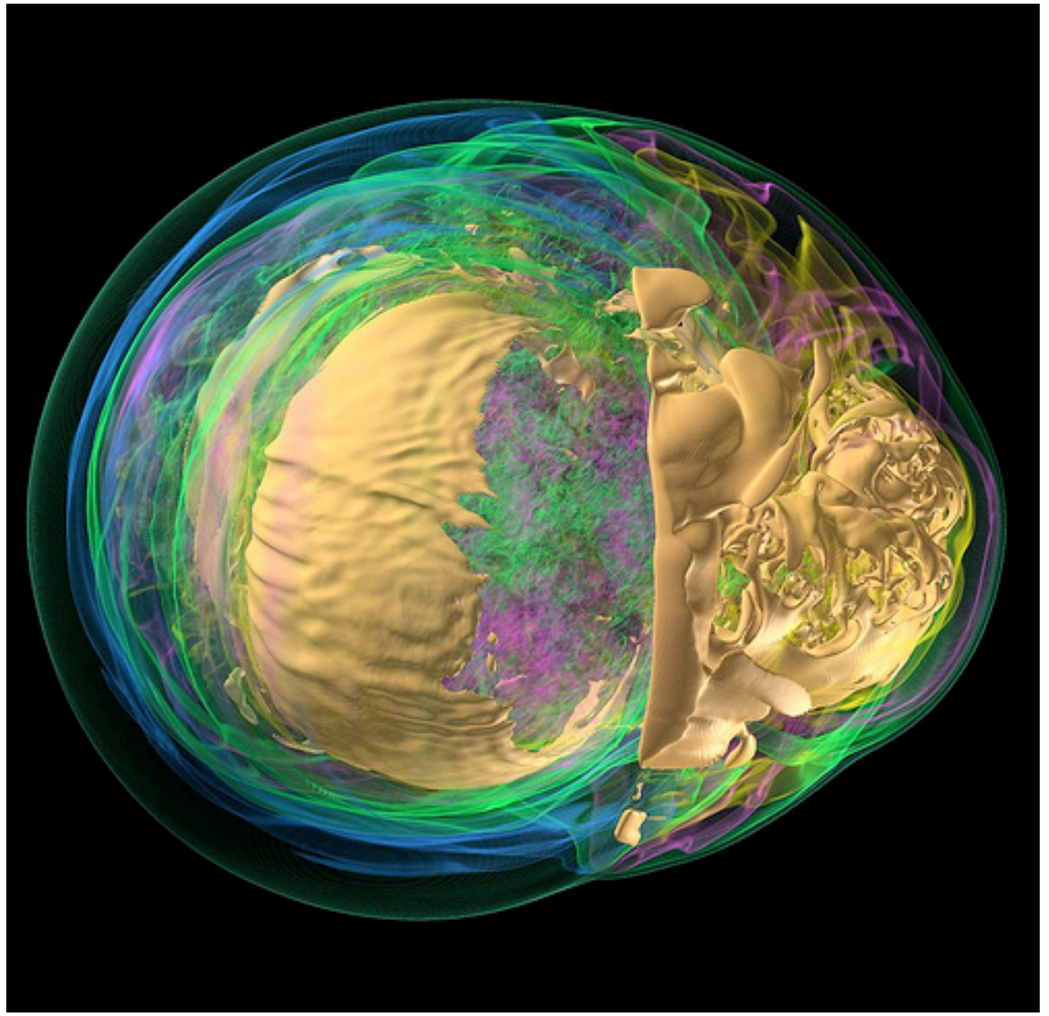
isosurfaces

Marching Cubes



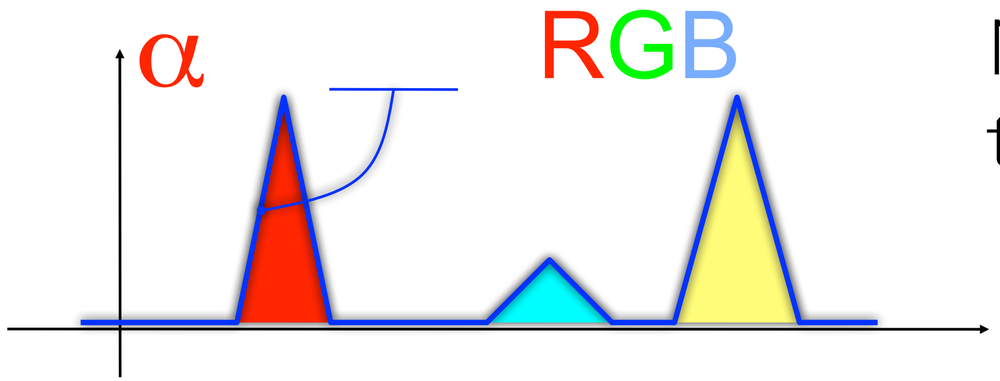
Scalar Visualization in 3D





direct volume rendering

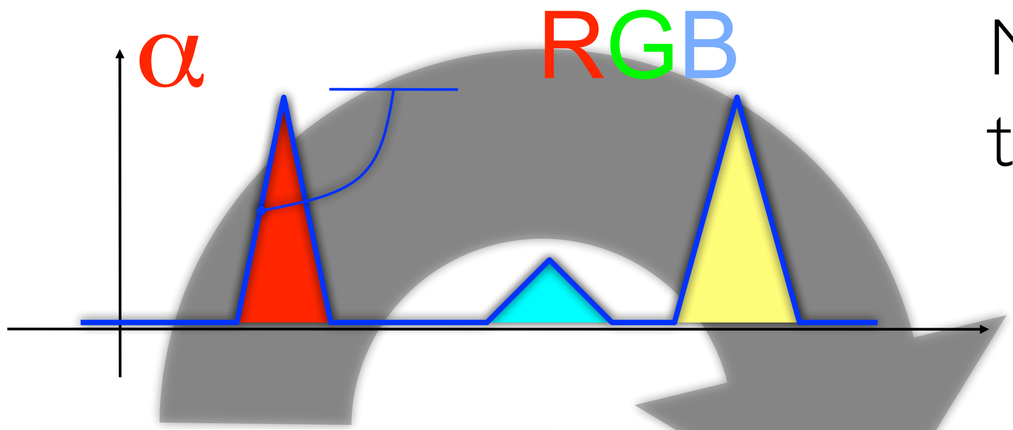
Transfer Functions (TFs)



Map data value *f*
to color and opacity

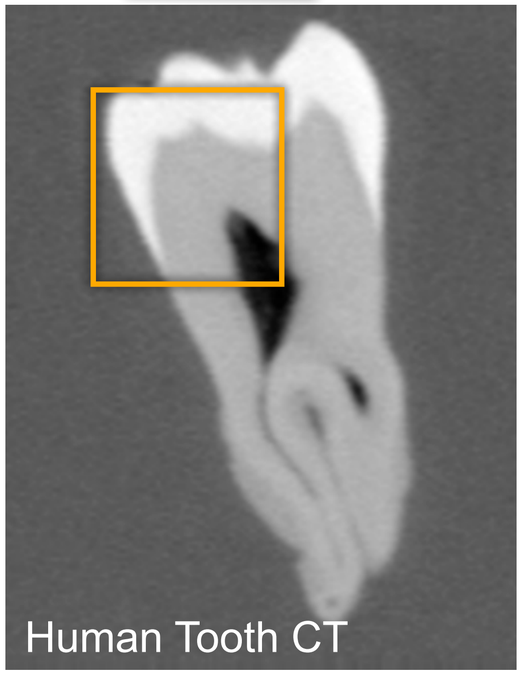
f

Transfer Functions (TFs)

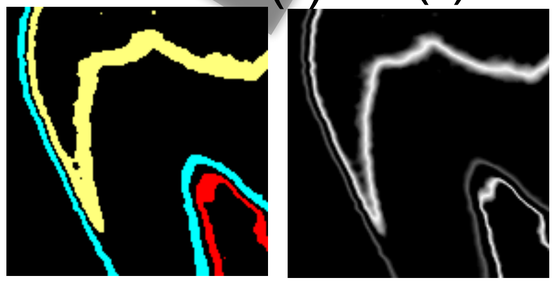


Map data value *f*
to color and opacity

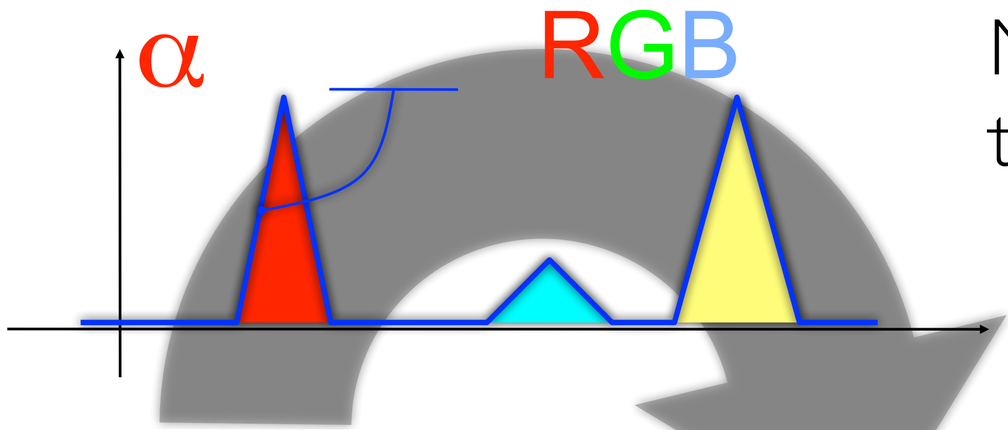
f



RGB(***f***) α(***f***)

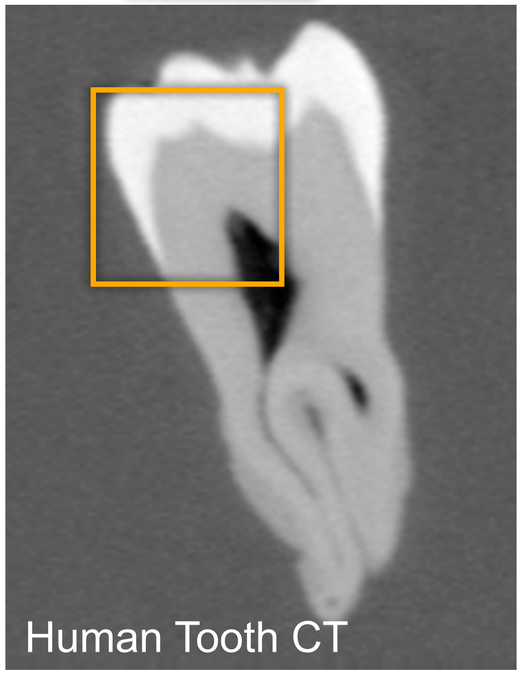


Transfer Functions (TFs)

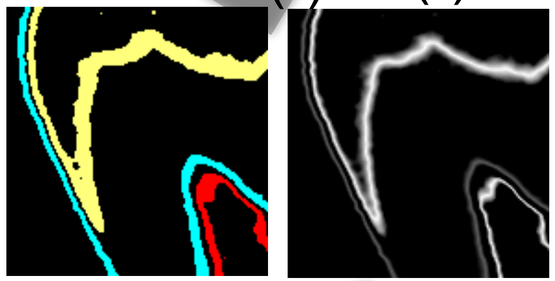


Map data value *f*
to color and opacity

f

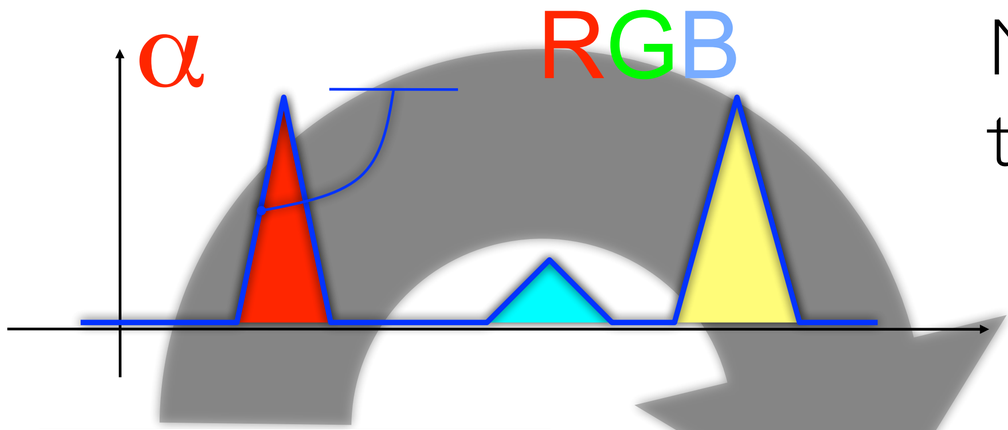


RGB(***f***) α(***f***)

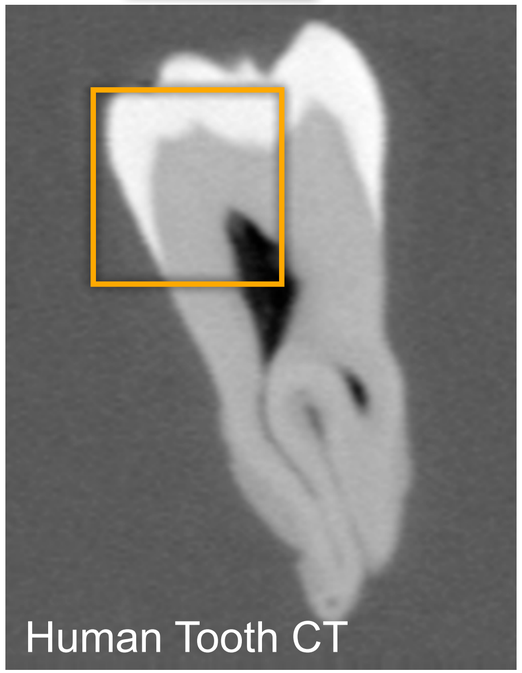


Shading,
Compositing…

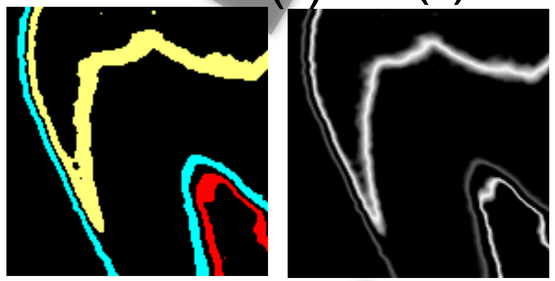
Transfer Functions (TFs)



Map data value *f*
to color and opacity



RGB(***f***) α(***f***)



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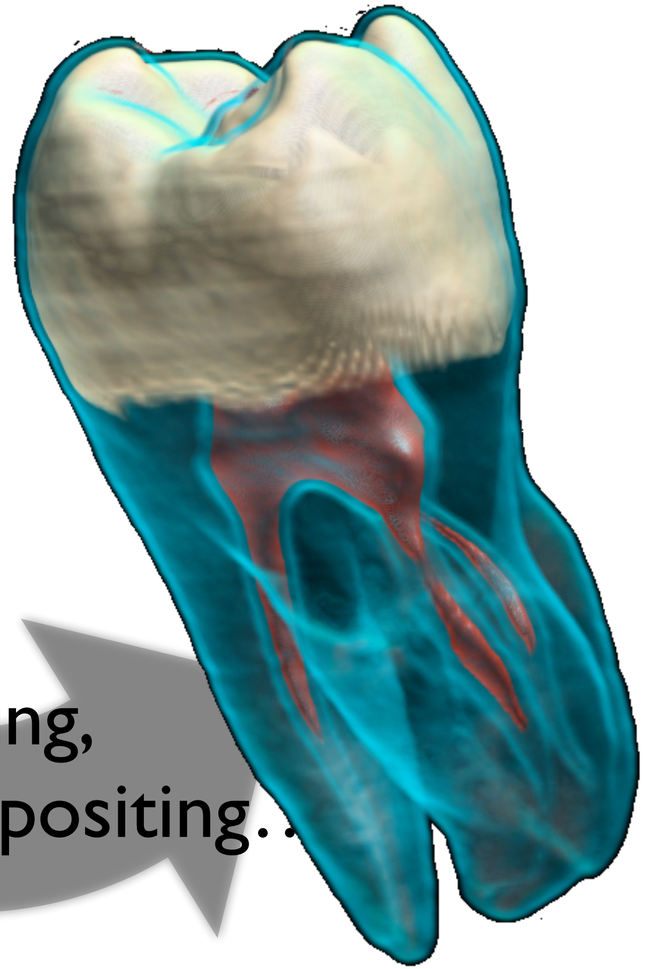
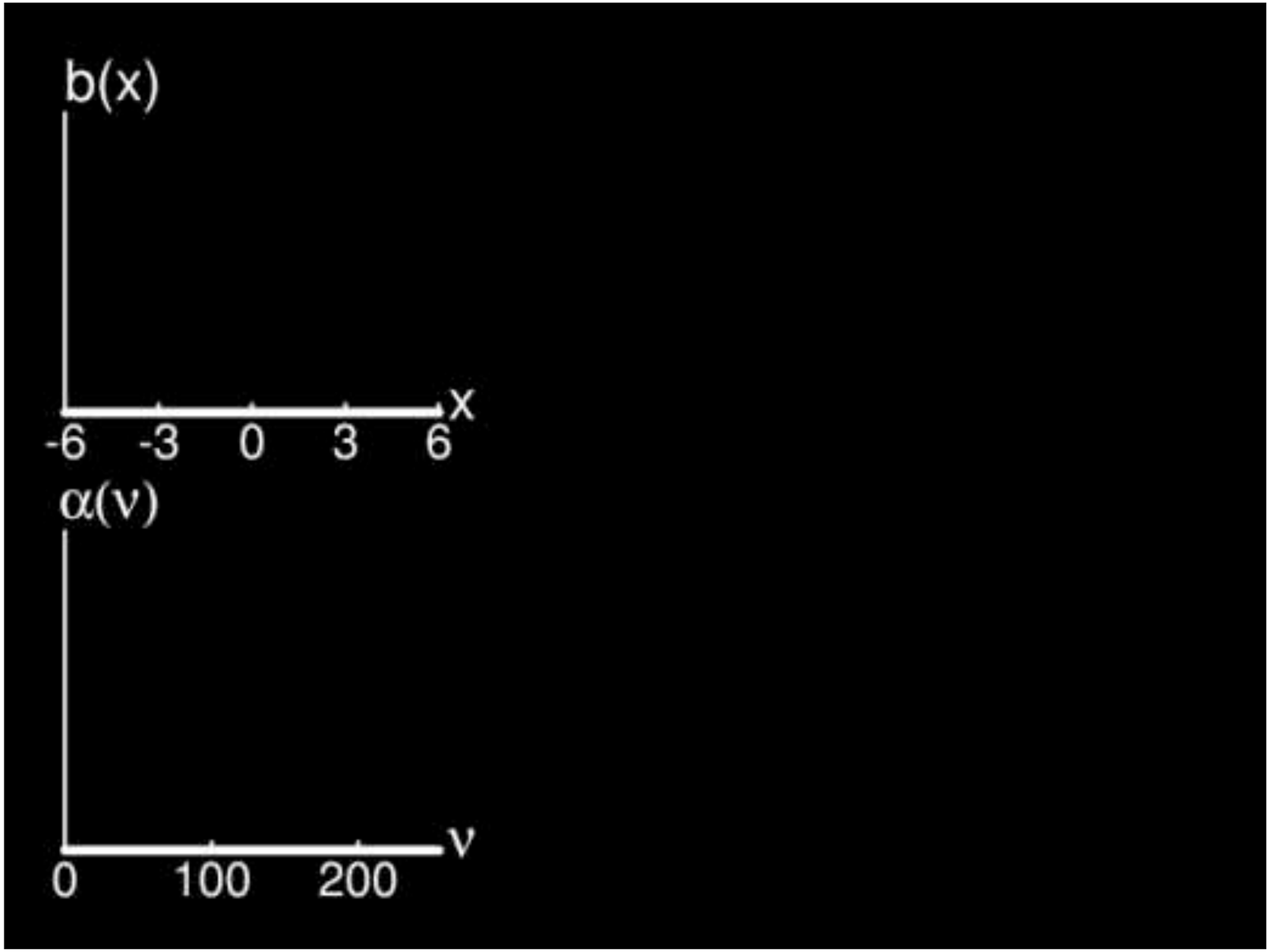
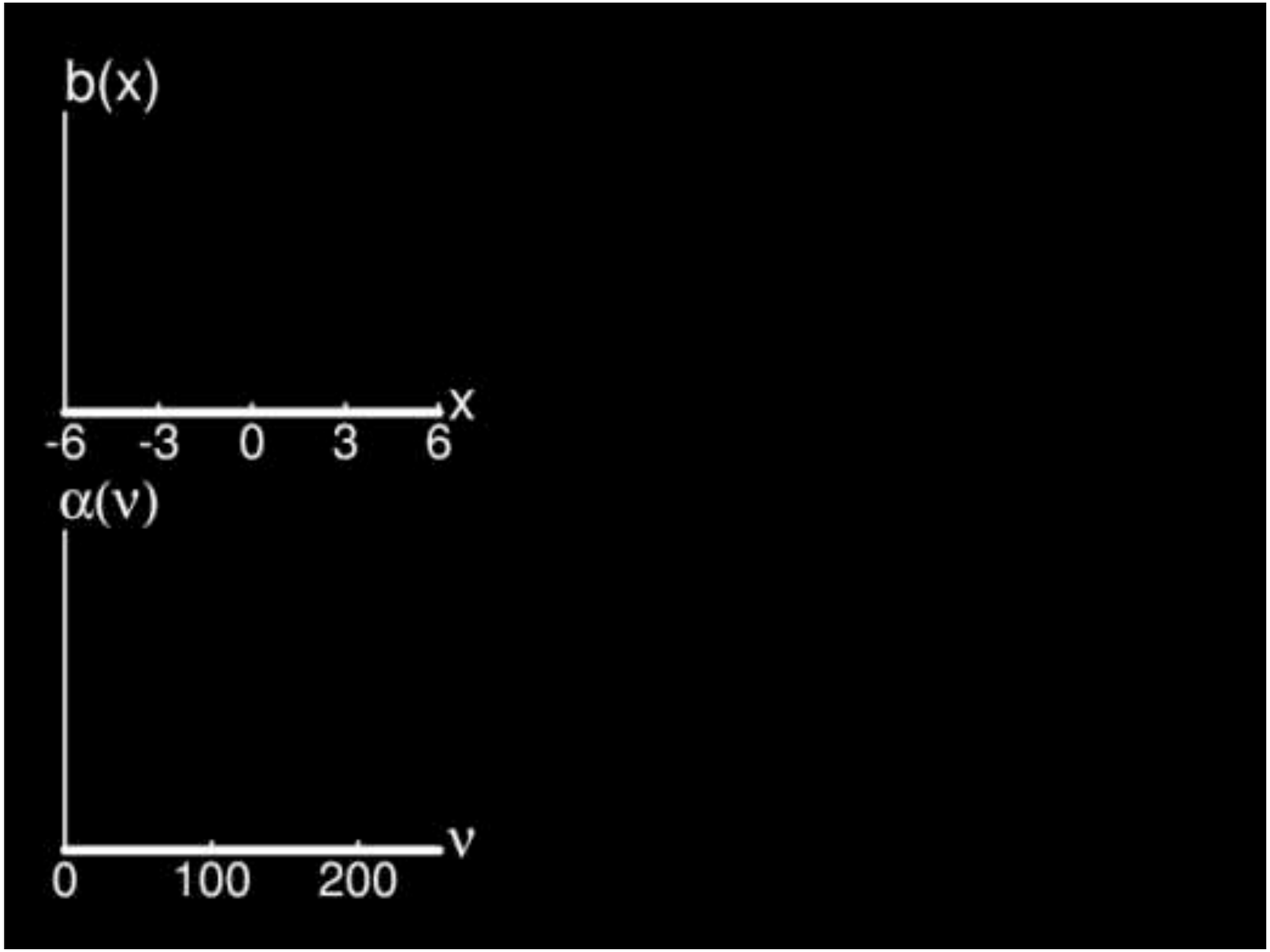


Shading,
Compositing…

Scalar Visualization in 3D

direct volume rendering


b(x)
x
-6
-3
0
3
6
α(ν)
ν
0
100
200

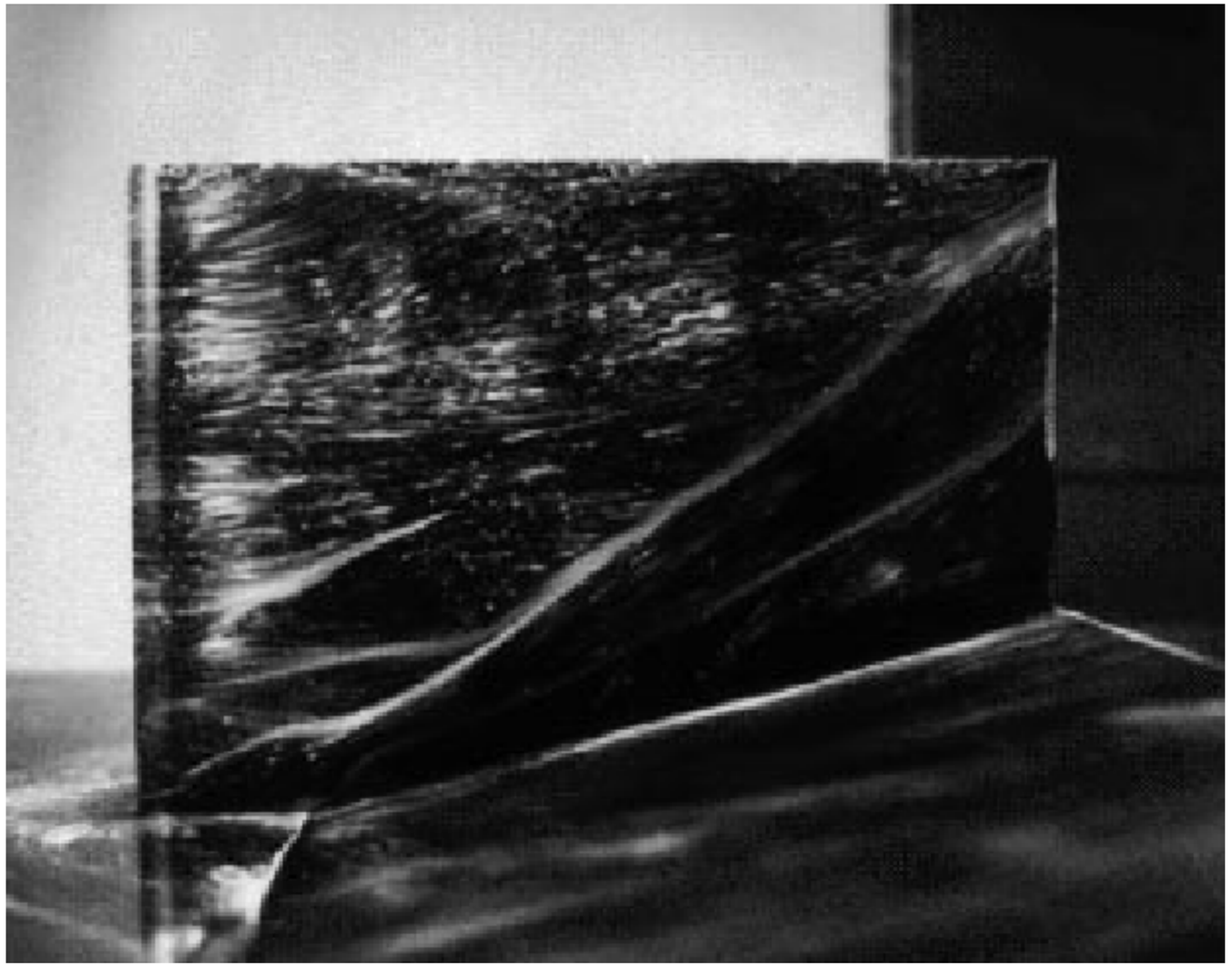

b(x)
x
-6
-3
0
3
6
α(ν)
ν
0
100
200

Origins of Flow

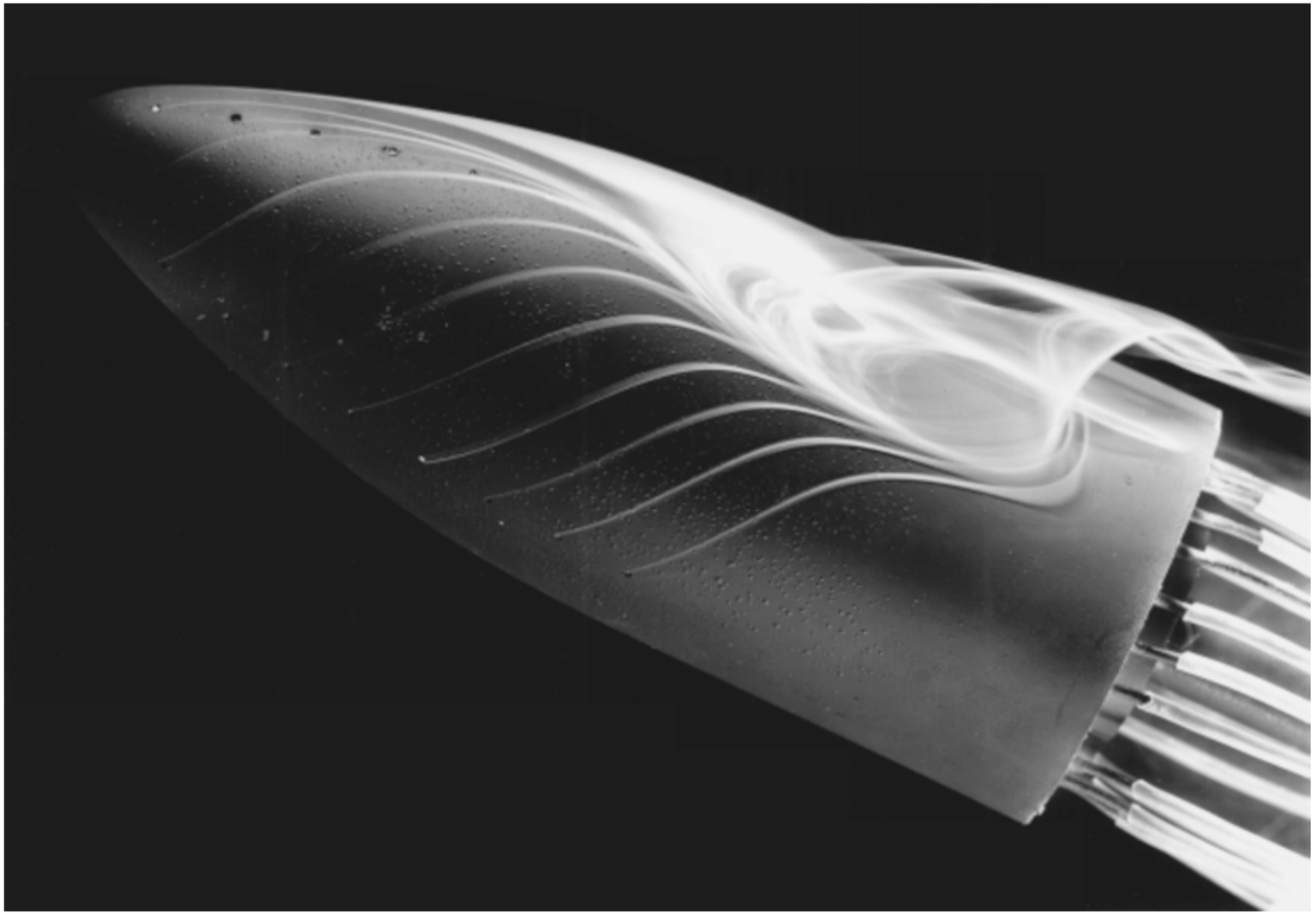
- Rich field of Fluid Flow Visualization (experimental)

da Vinci

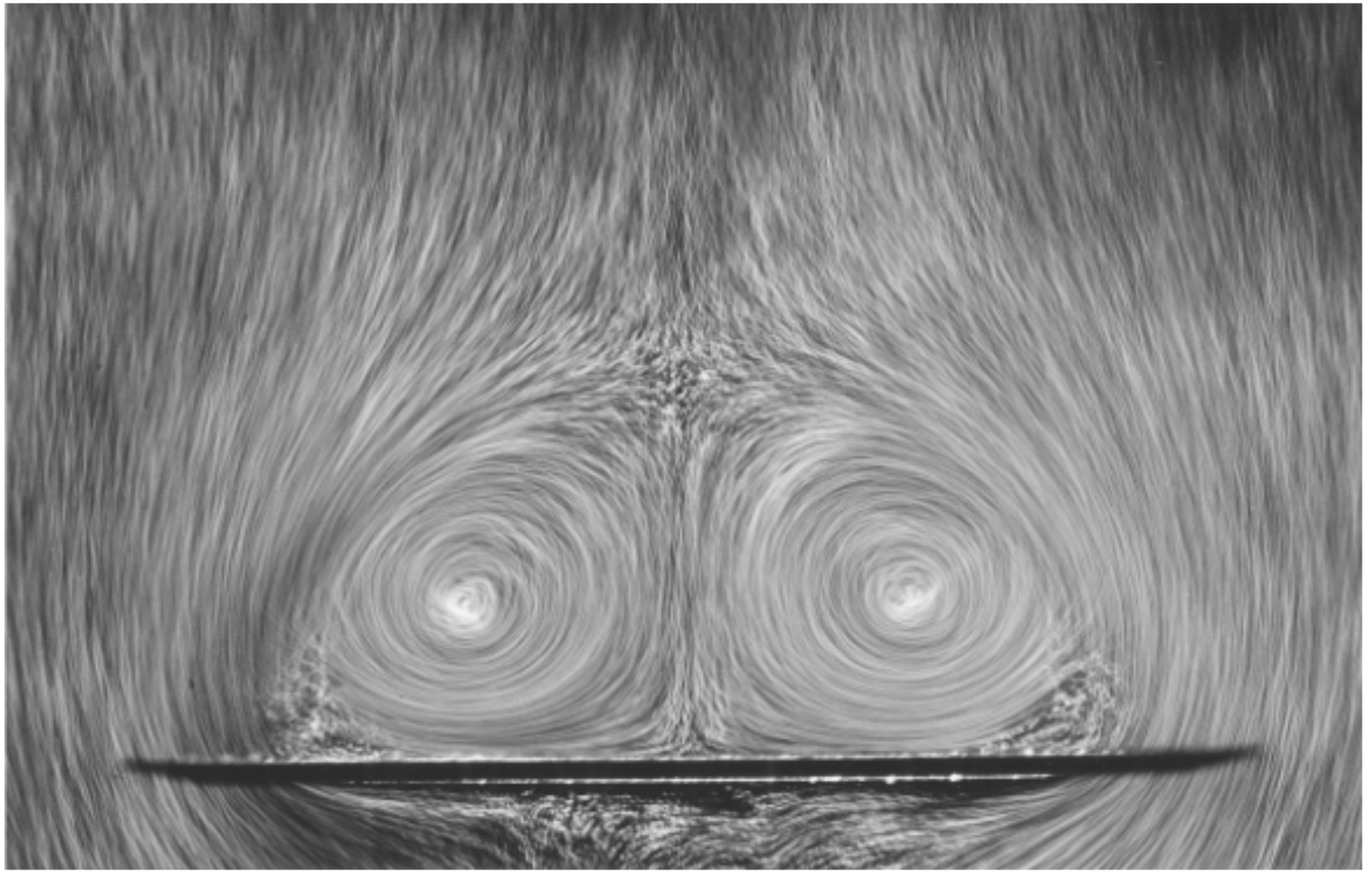
Experimental Flow



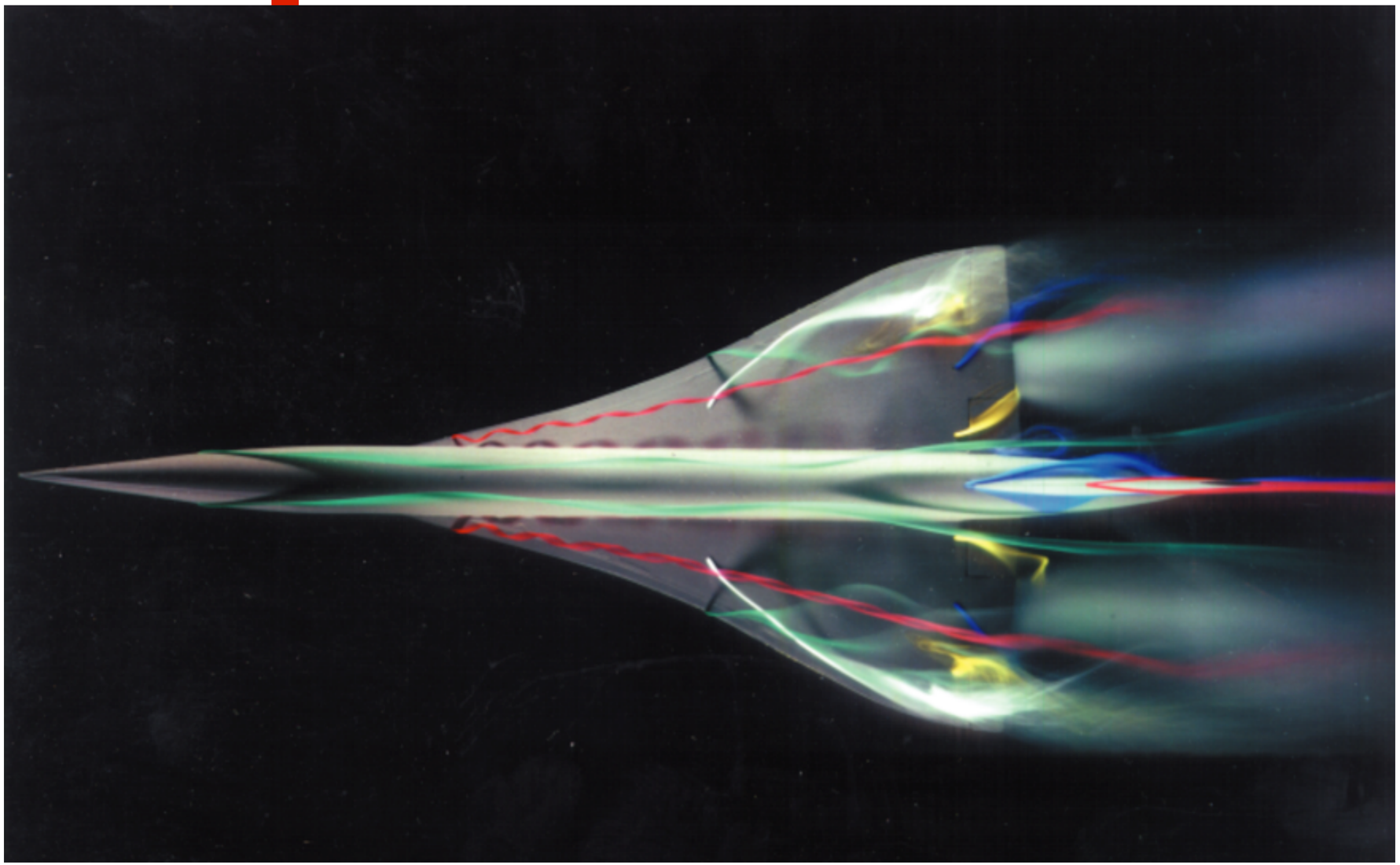
Experimental Flow



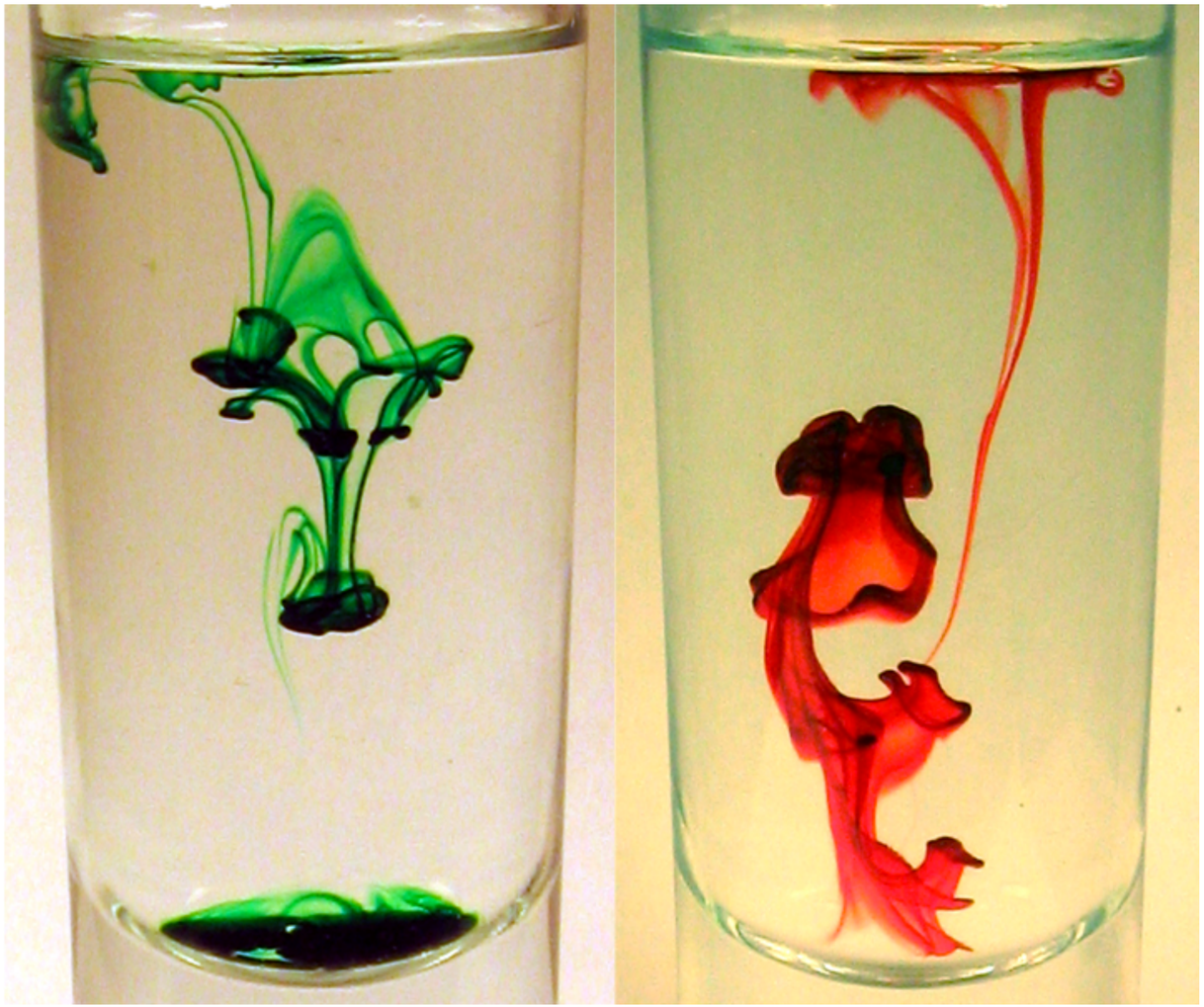
Experimental Flow



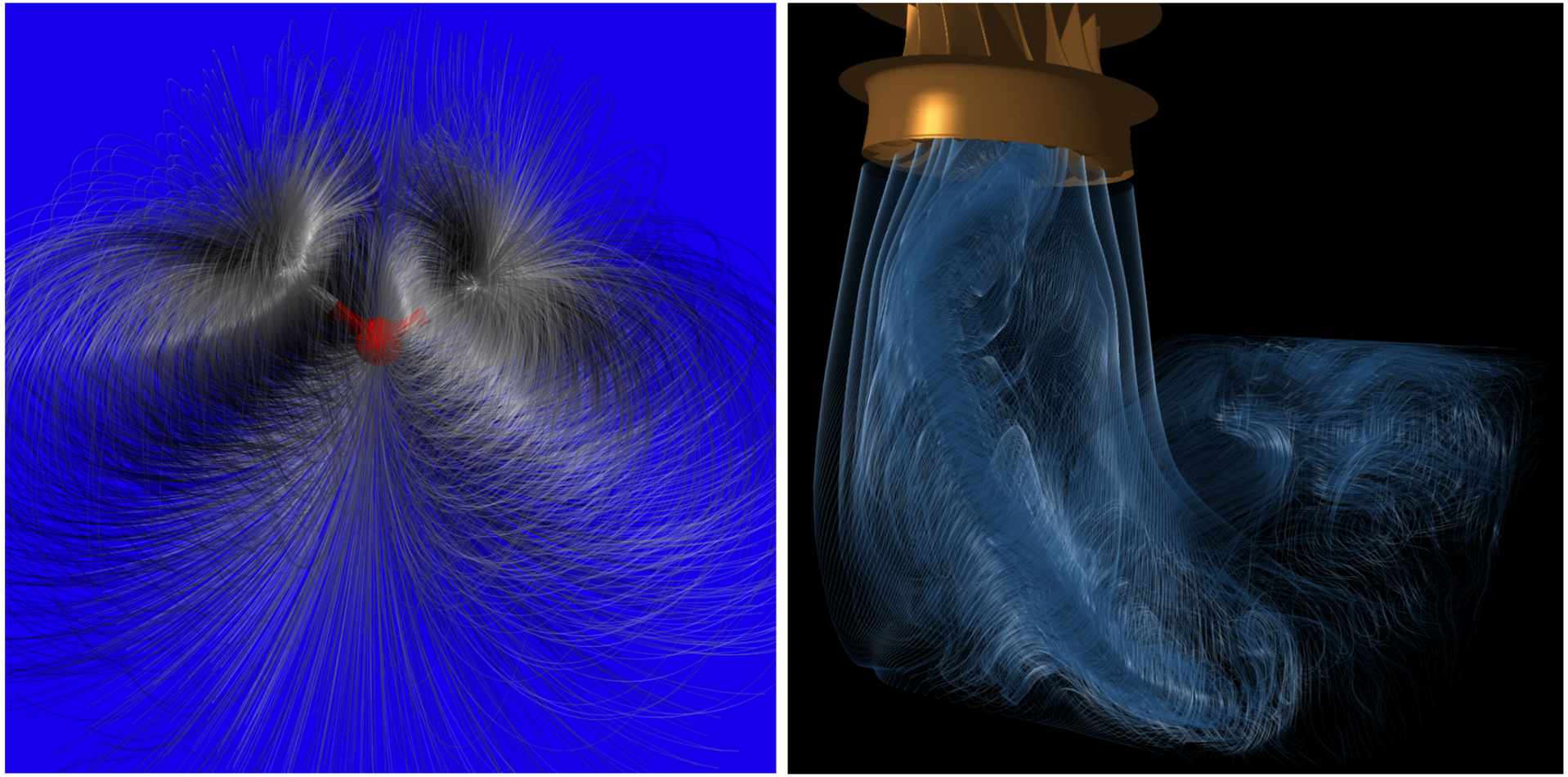
Experimental Flow



Experimental Flow

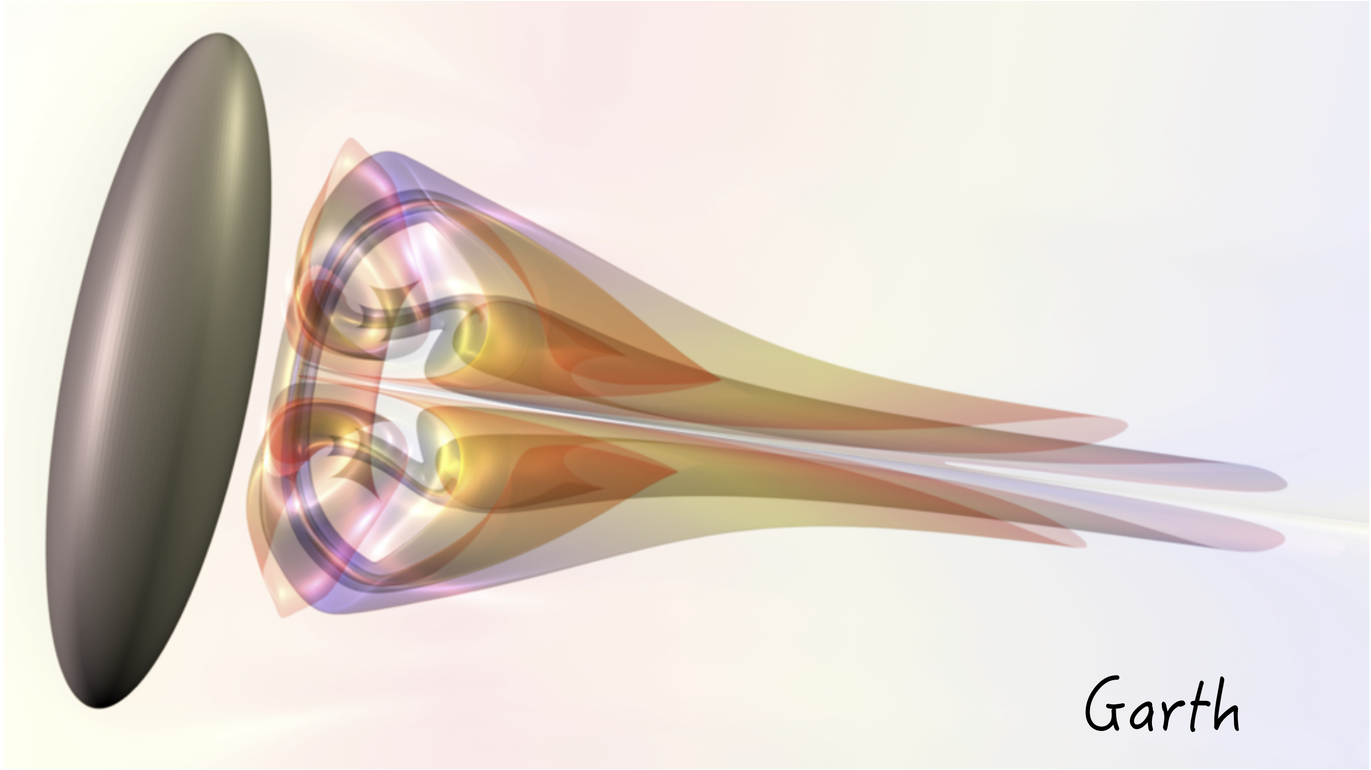


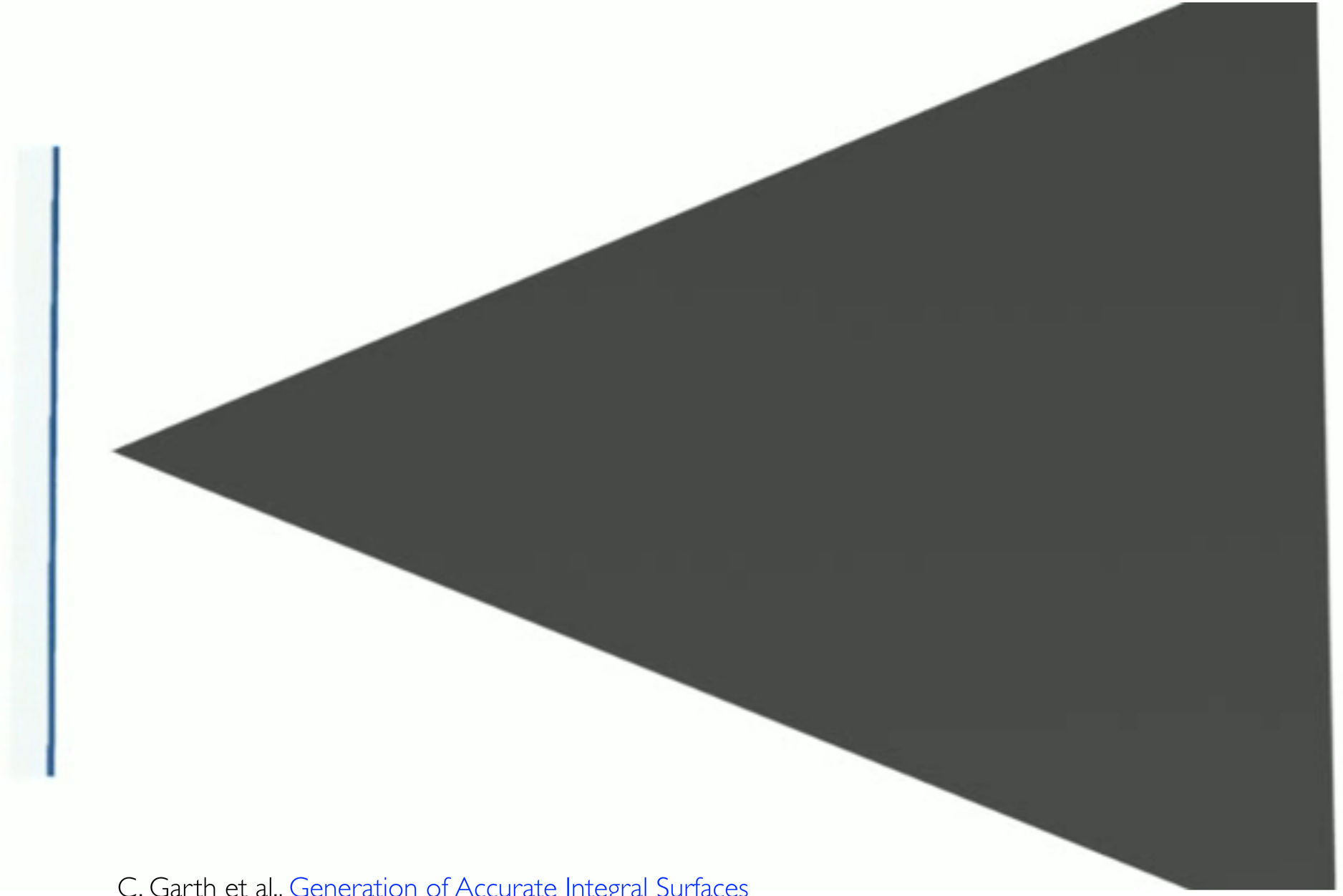
Illuminated



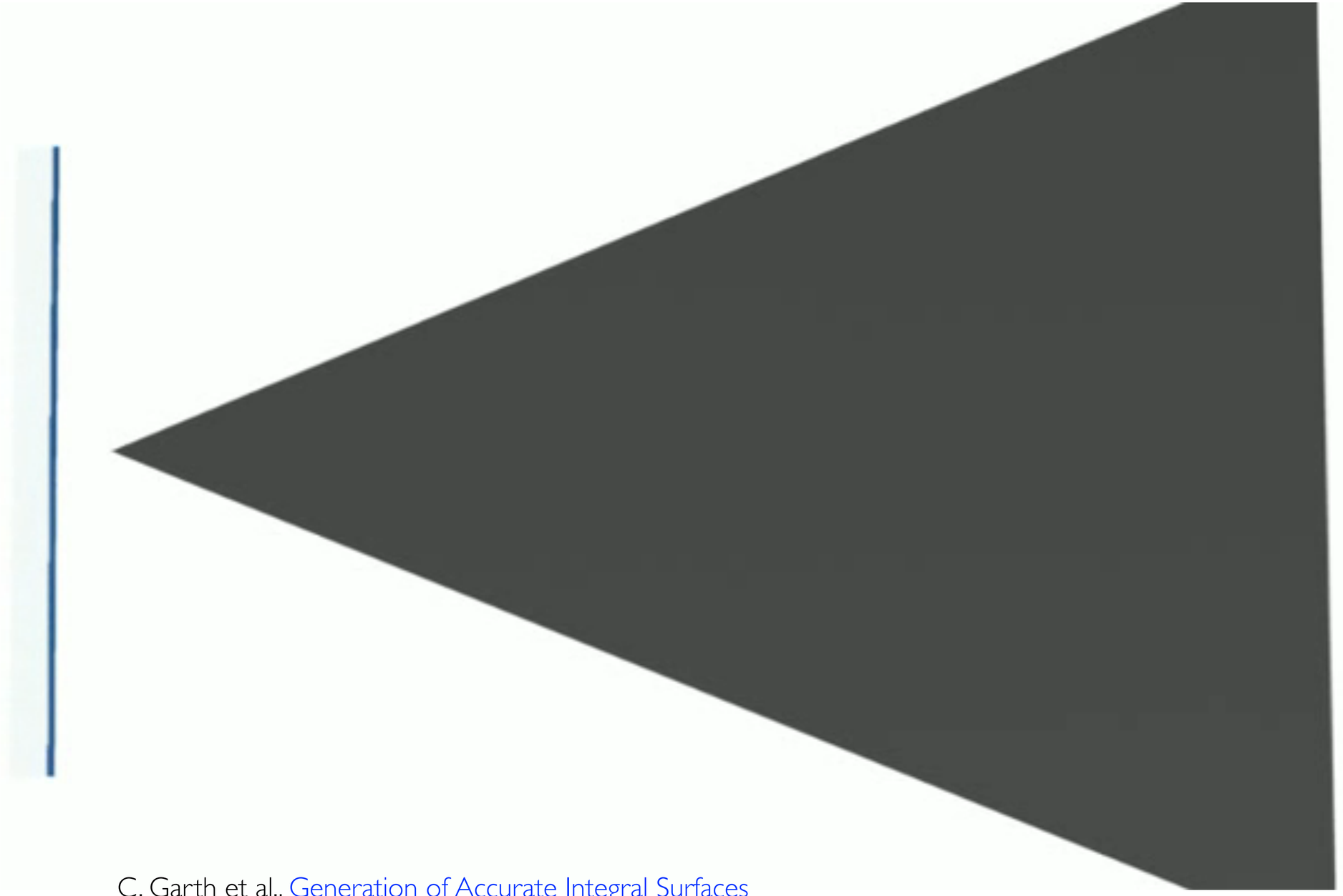
Illuminated Streamlines Revisited. Mallo, Peikert, Sigg, Sadlo, IEEE Vis 2005

Vector Visualization
Streamlines / Stream surfaces



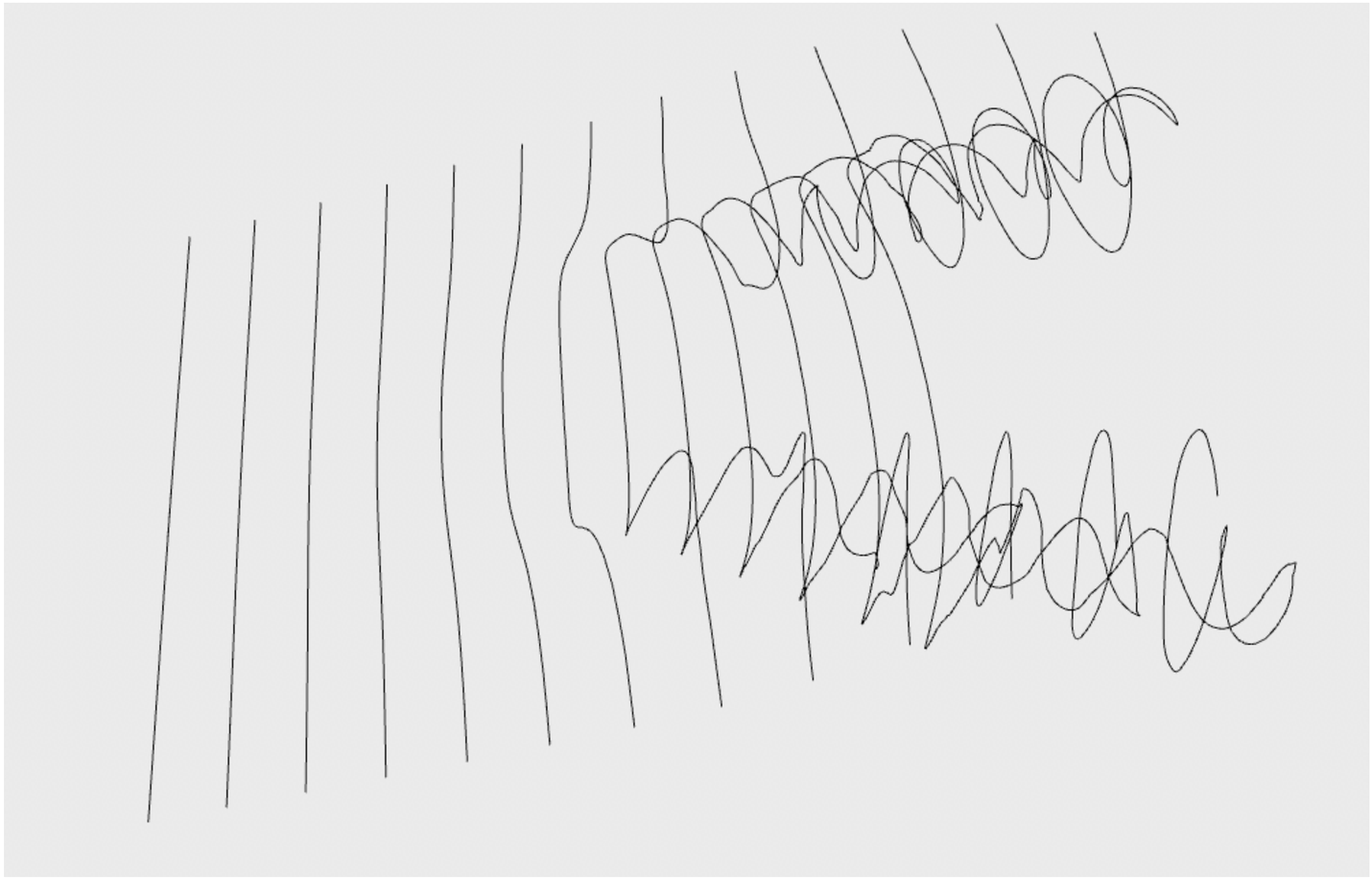


C. Garth et al., Generation of Accurate Integral Surfaces in Time-Dependent Vector Fields. IEEE Visualization 2008



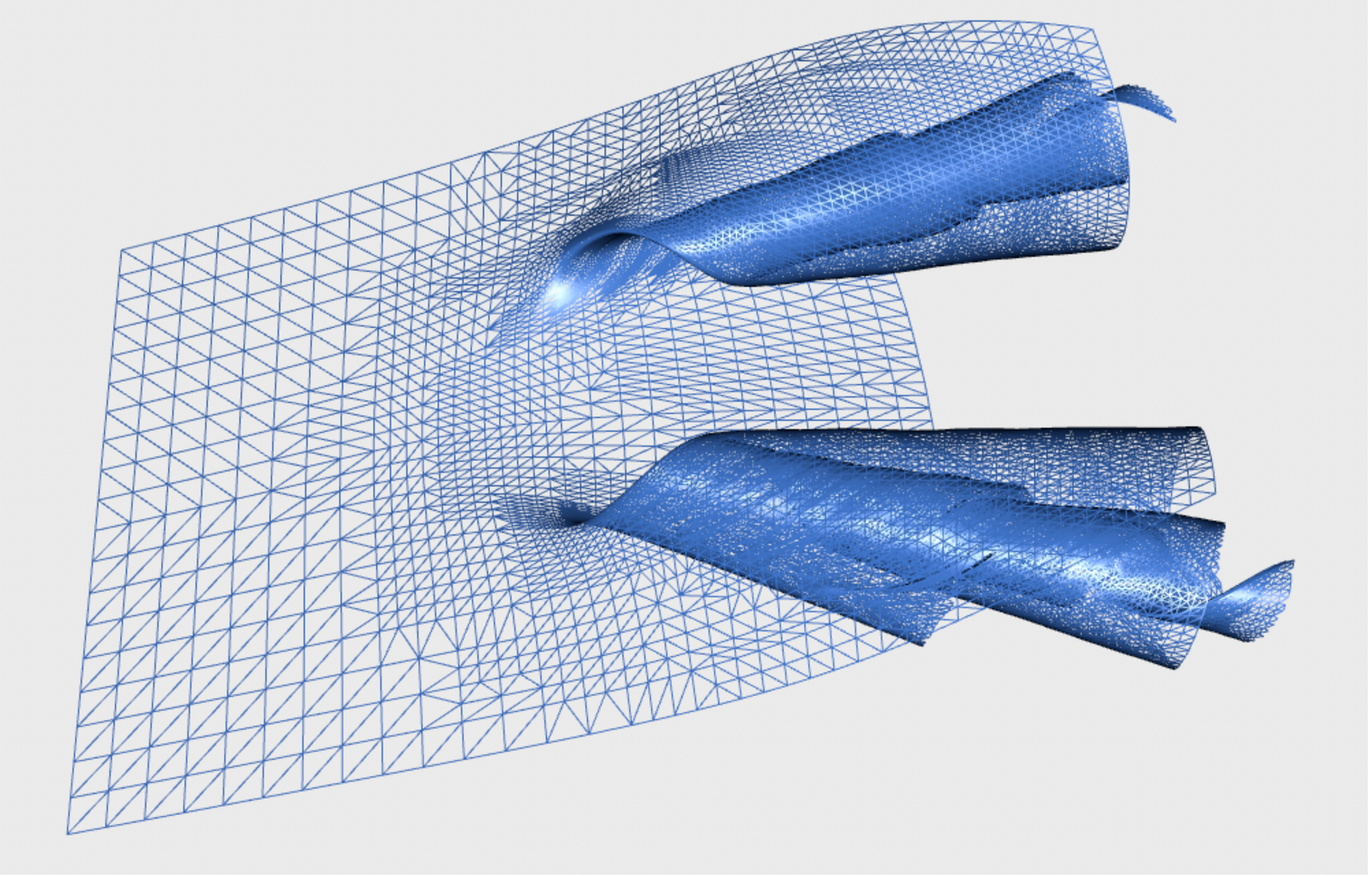
C. Garth et al., Generation of Accurate Integral Surfaces in Time-Dependent Vector Fields. IEEE Visualization 2008

Path Surface

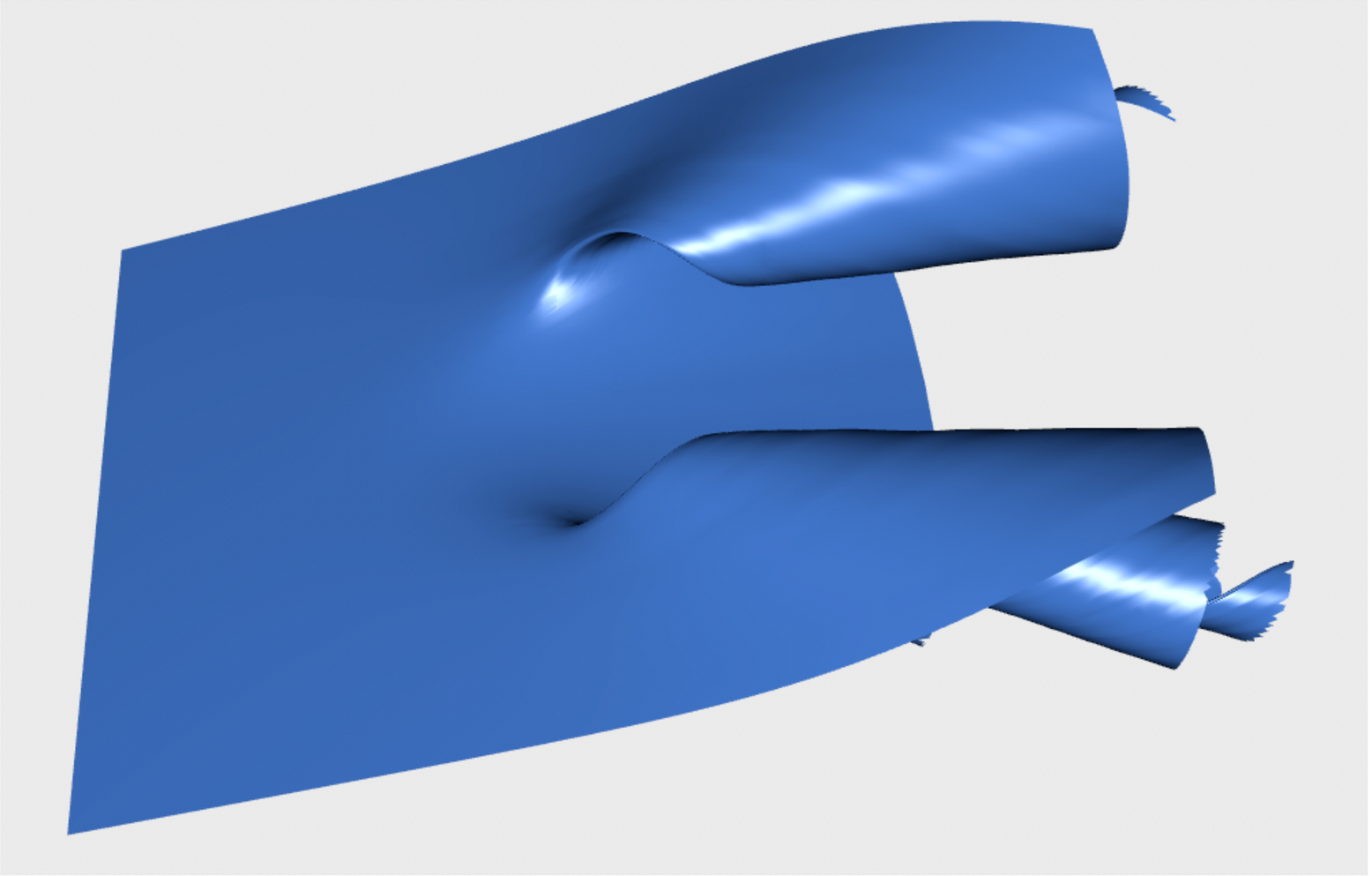


C. Garth et al., Generation of Accurate Integral Surfaces in Time-Dependent Vector Fields. IEEE Visualization 2008

Path Surface



Path Surface



Texture Mapping on Path Surfaces

Vortex formation behind an ellipsoid (2.6e6 cells, 400 timesteps)

Texture Mapping on Path Surfaces

Vortex formation behind an ellipsoid (2.6e6 cells, 400 timesteps)

Texture Mapping

Vortex formation behind an ellipsoid (2.6e6 cells, 400 timesteps)

Comparative visualization of vortex formation

steady simulation

unsteady simulation

Texture Mapping

Vortex formation behind an ellipsoid (2.6e6 cells, 400 timesteps)

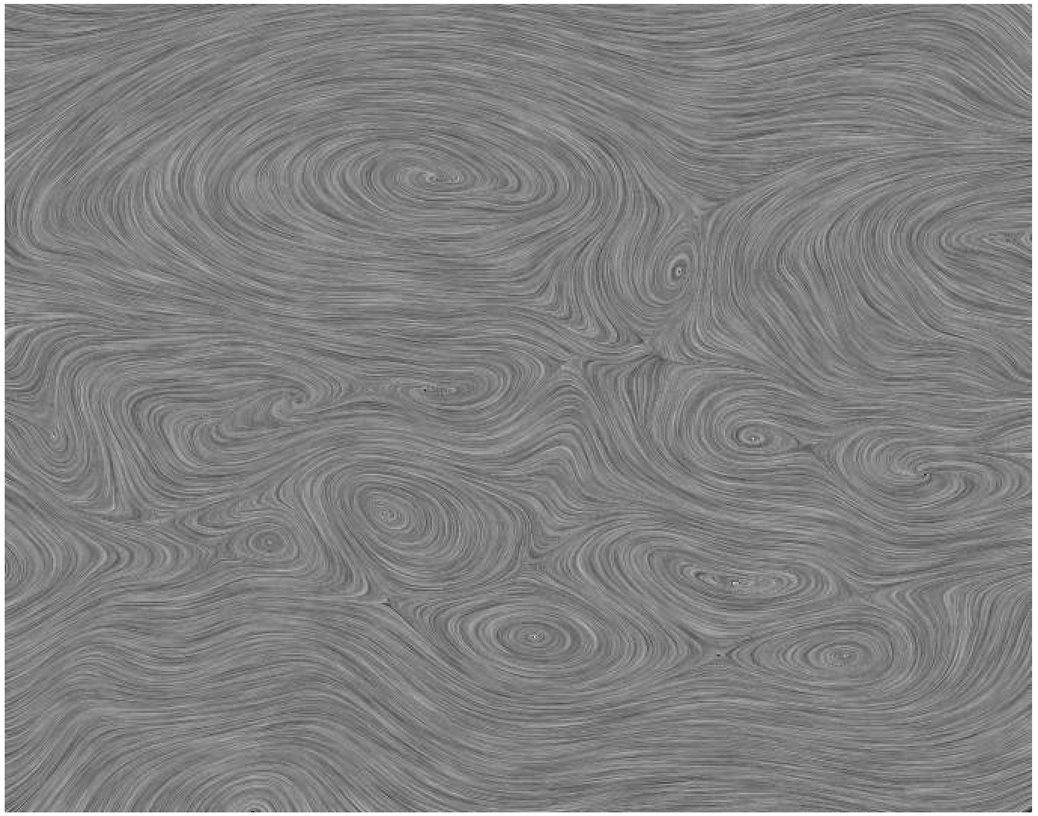
Comparative visualization of vortex formation

steady simulation

unsteady simulation

Dense Flow Vis

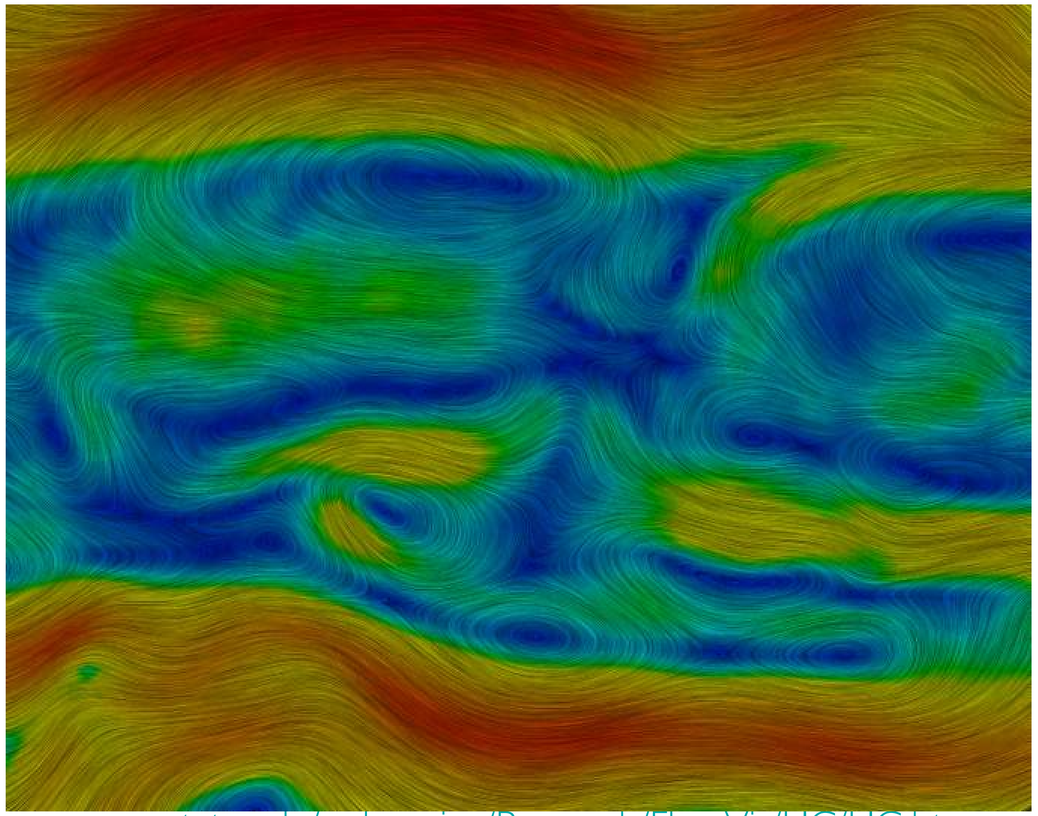
- Basic LIC



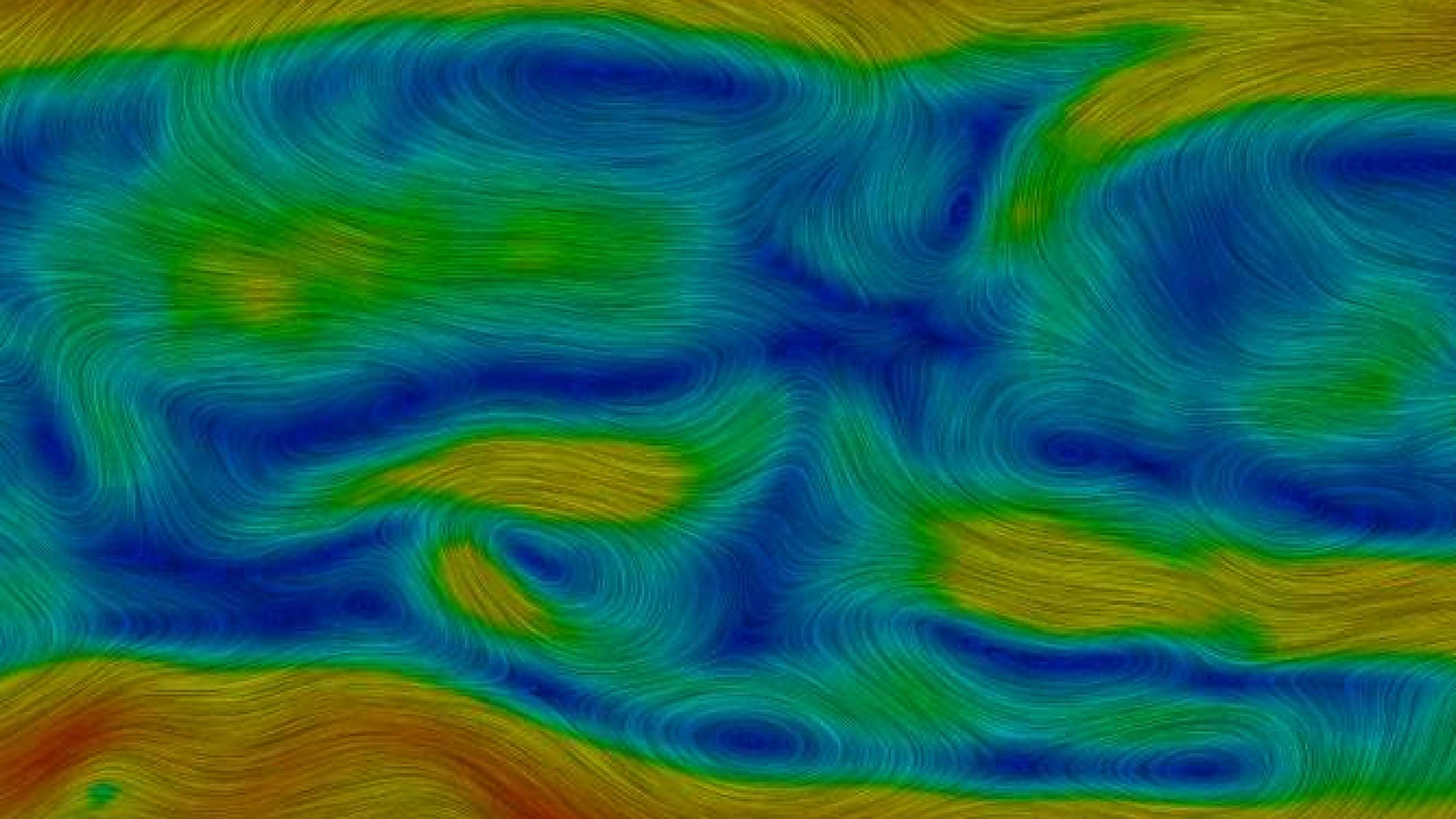
http://www.erc.msstate.edu/~zhanping/Research/FlowVis/LIC/LIC.htm

Dense Flow Vis

+ Color coded vector field magnitude

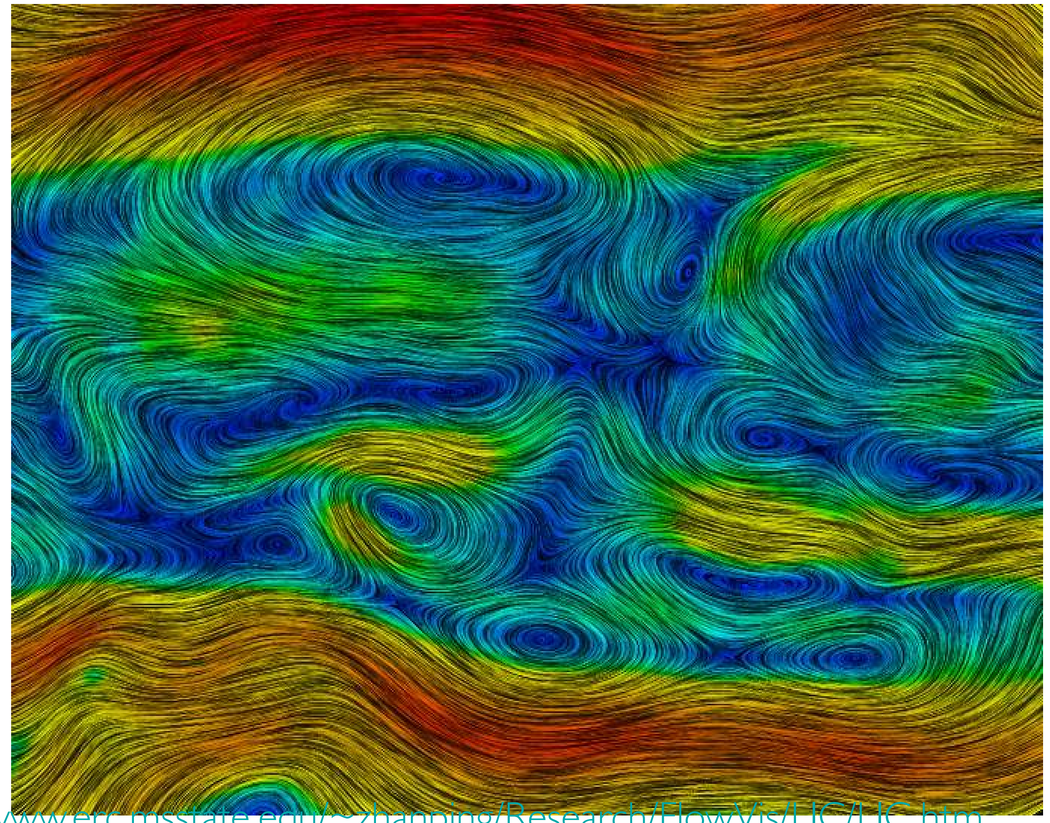


http://www.erc.msstate.edu/~zhanping/Research/FlowVis/LIC/LIC.htm



Dense Flow Vis

+ Histogram equalization



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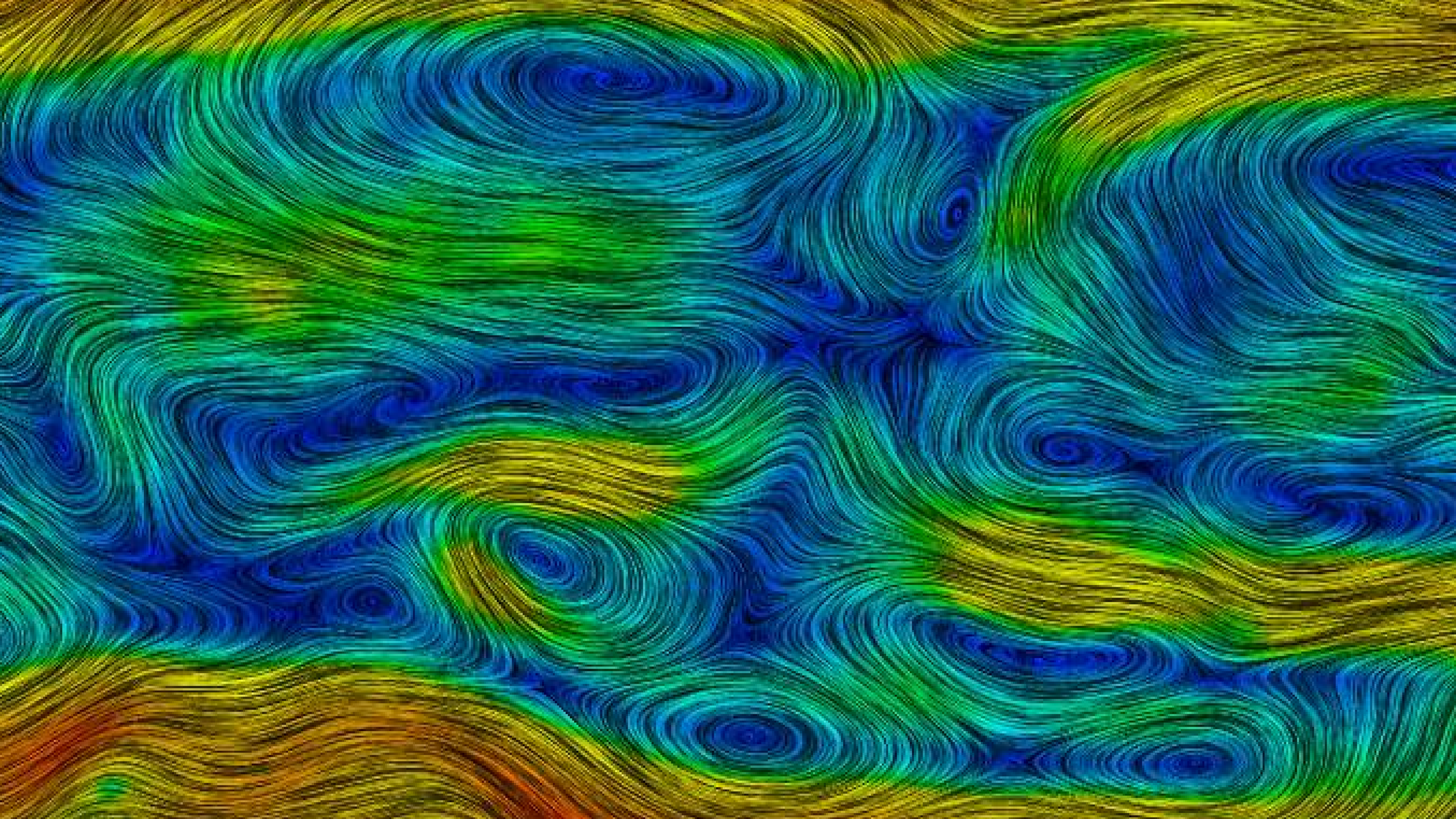
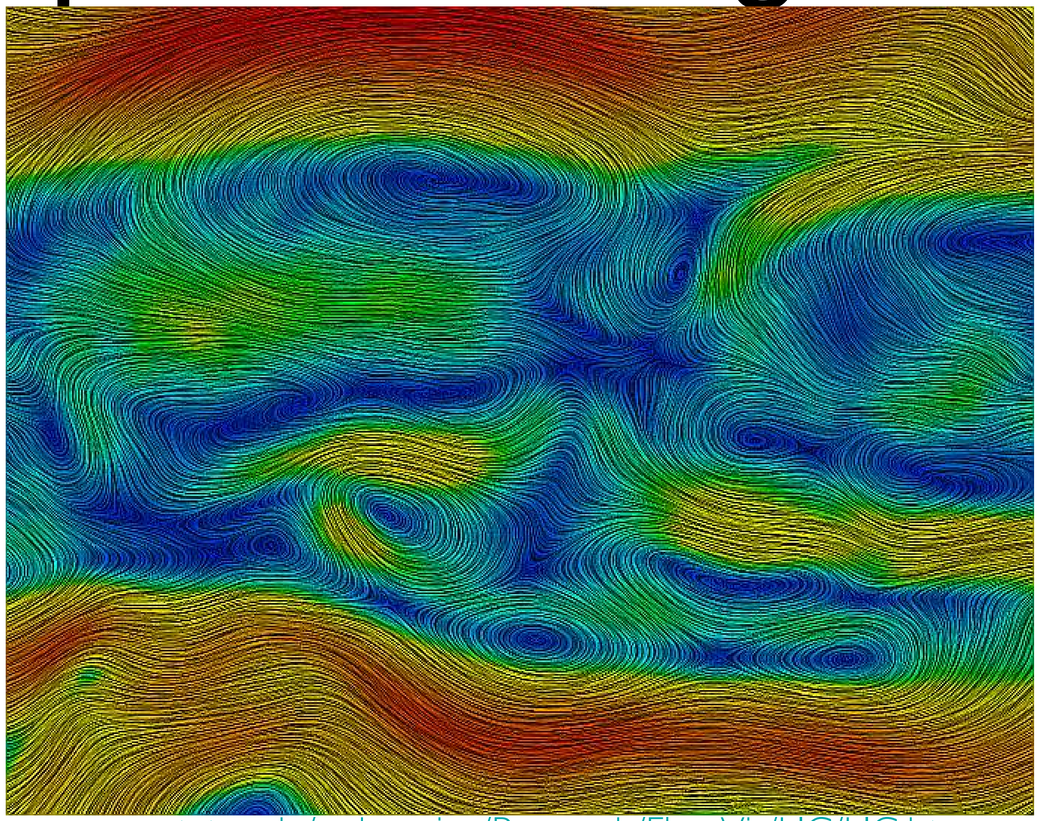


Dense Flow Vis

+ High-pass filtering



http://www.erc.msstate.edu/~zhanping/Research/FlowVis/LIC/LIC.htm

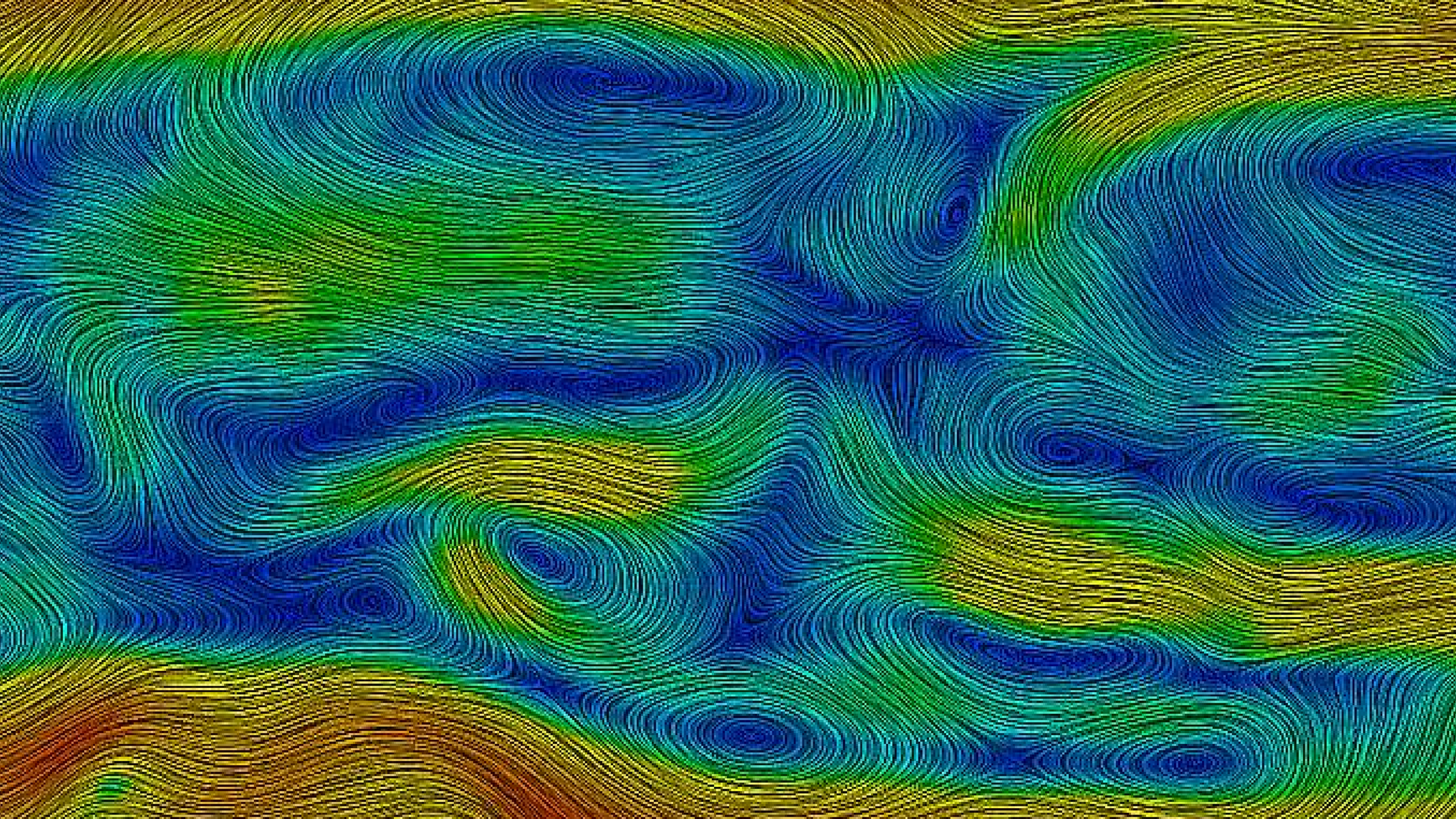
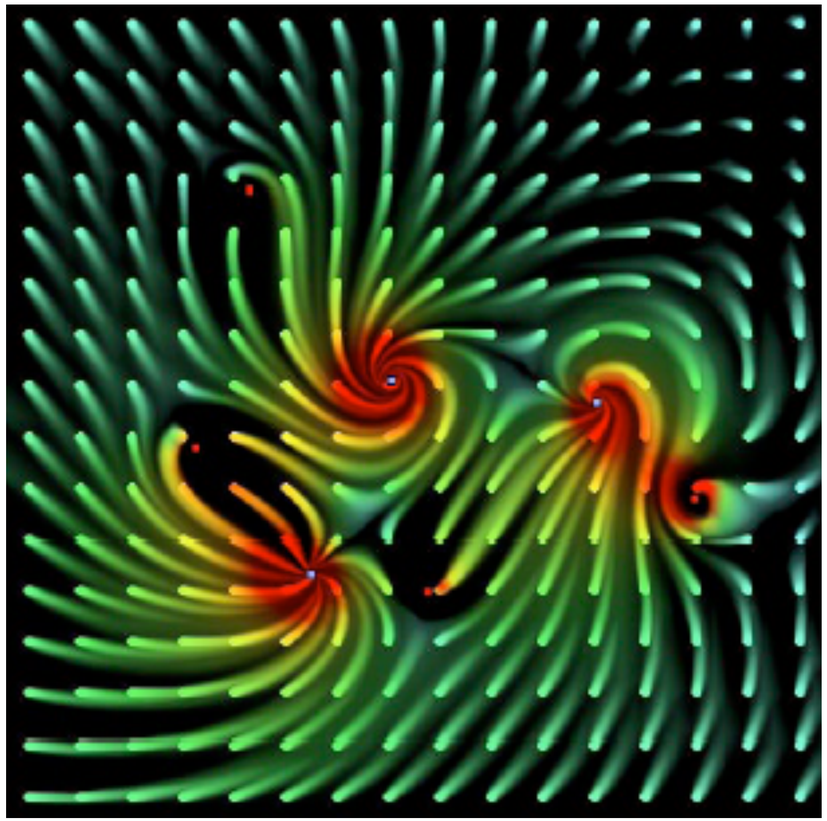
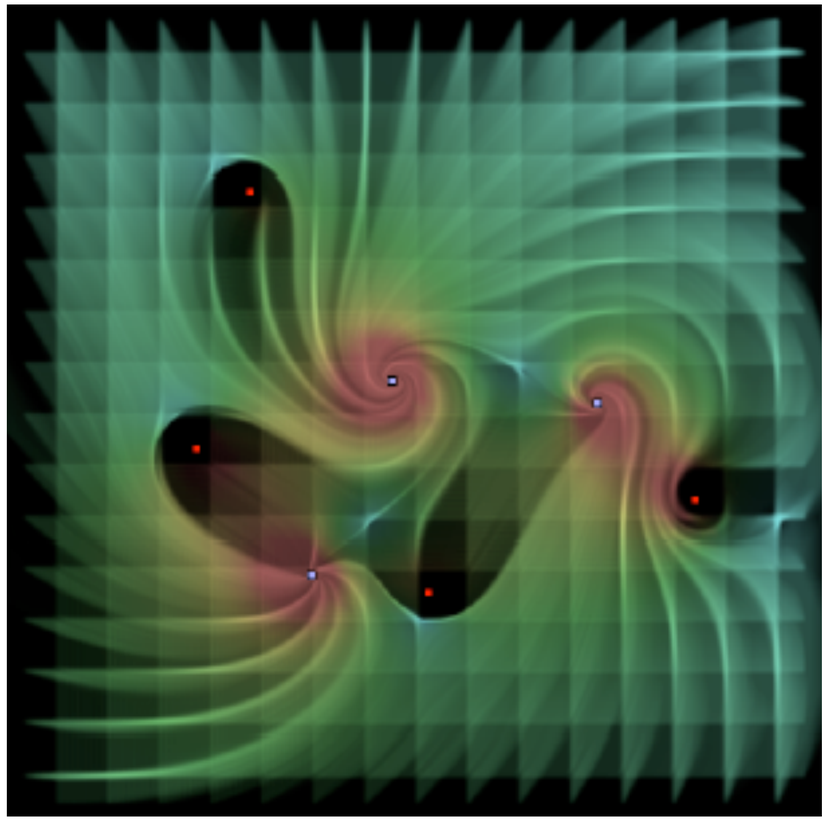


Image-based Flow Vis





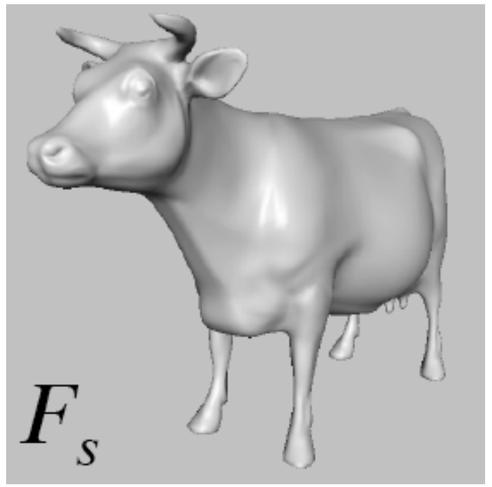
J. Van Wijk, Image Based Flow Visualization, ACM SIGGRAPH 2002

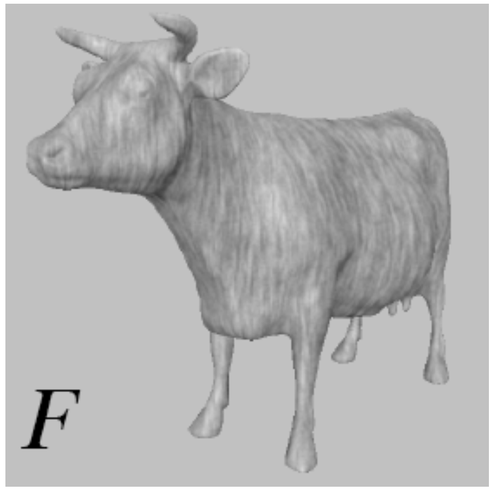
IBFV for Surfaces

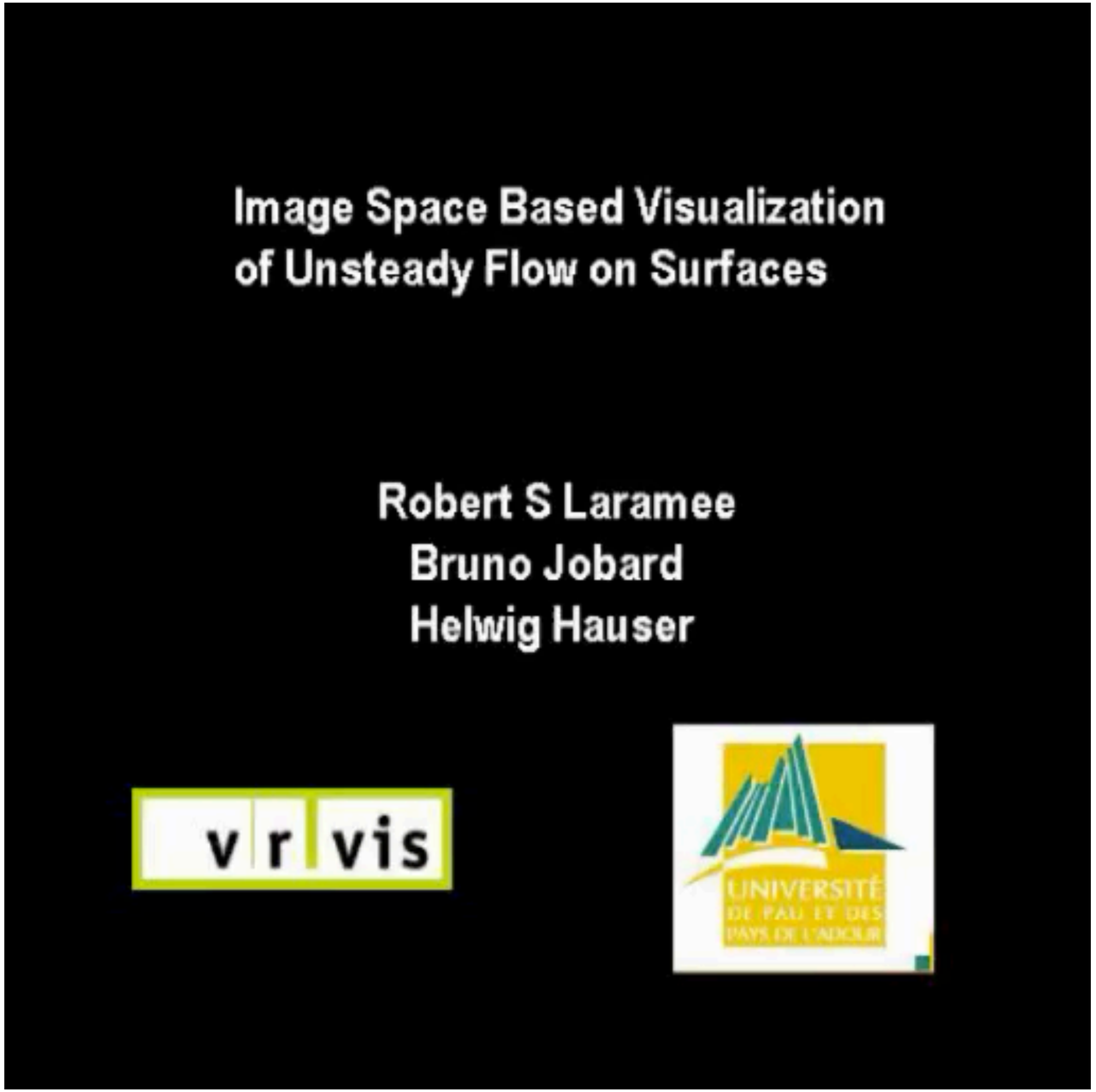
- Additional cue for surface shape obtained by blending shaded surface

$$F(\mathbf{x}', k) = \beta F_t(\mathbf{x}', k) + (1 - \beta) F_s(\mathbf{x}', k)$$

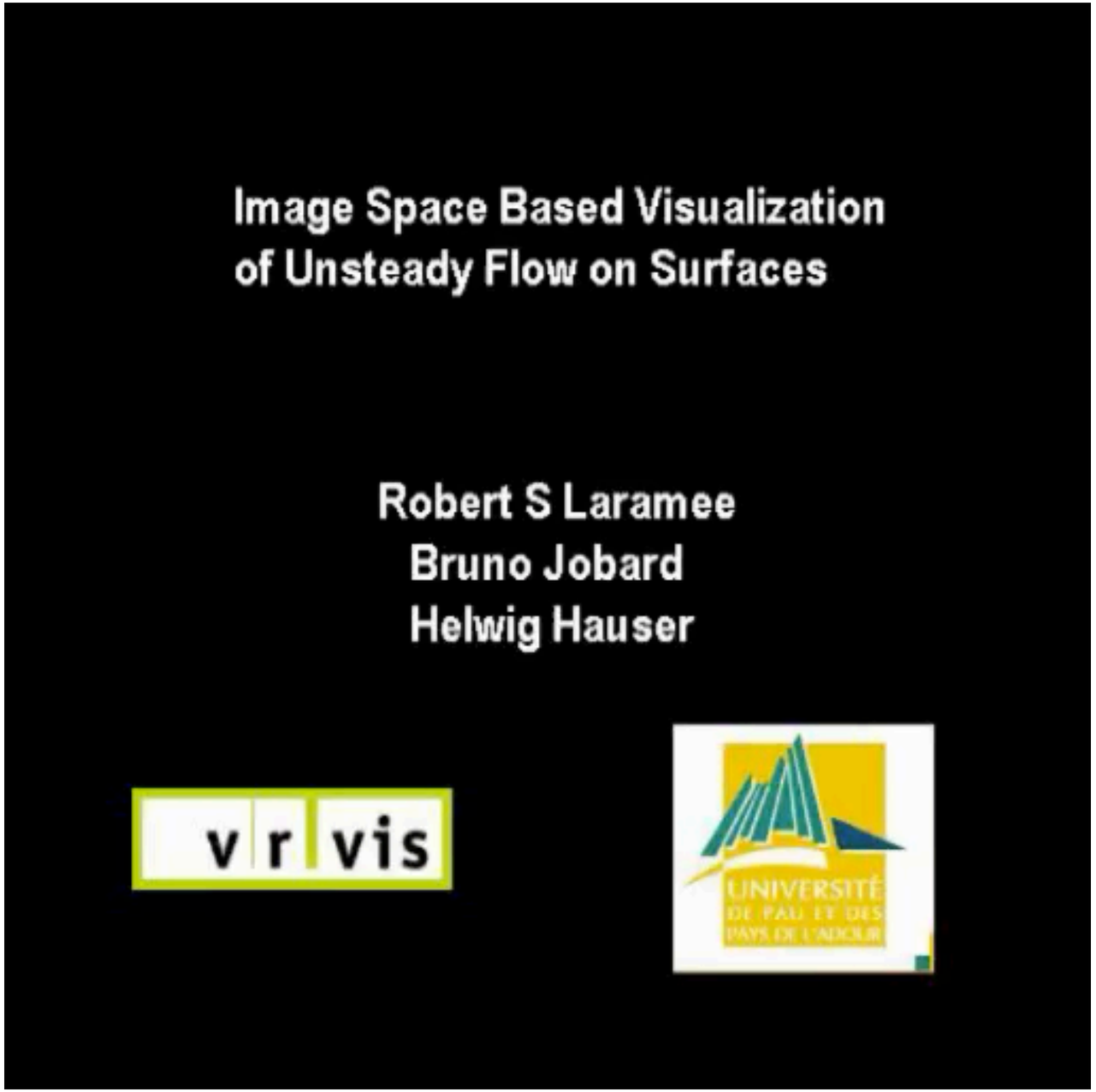
shaded







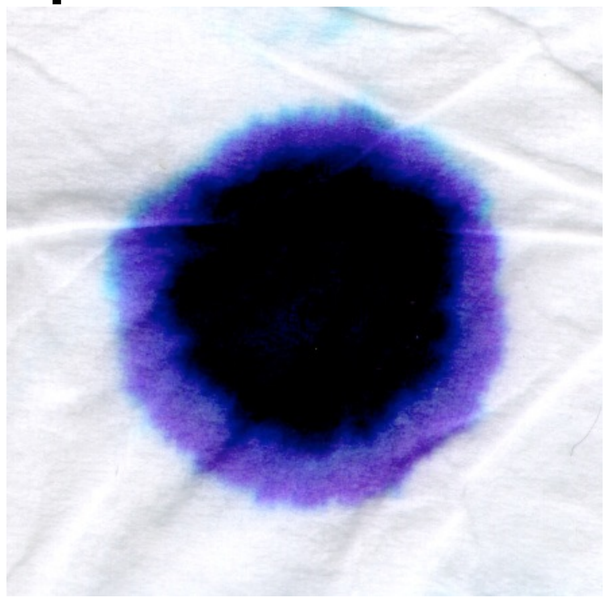
R. Laramee, B. Jobard, H. Hauser, Image Space Based Visualization of Unsteady Flows on Surfaces, IEEE Visualization 2003



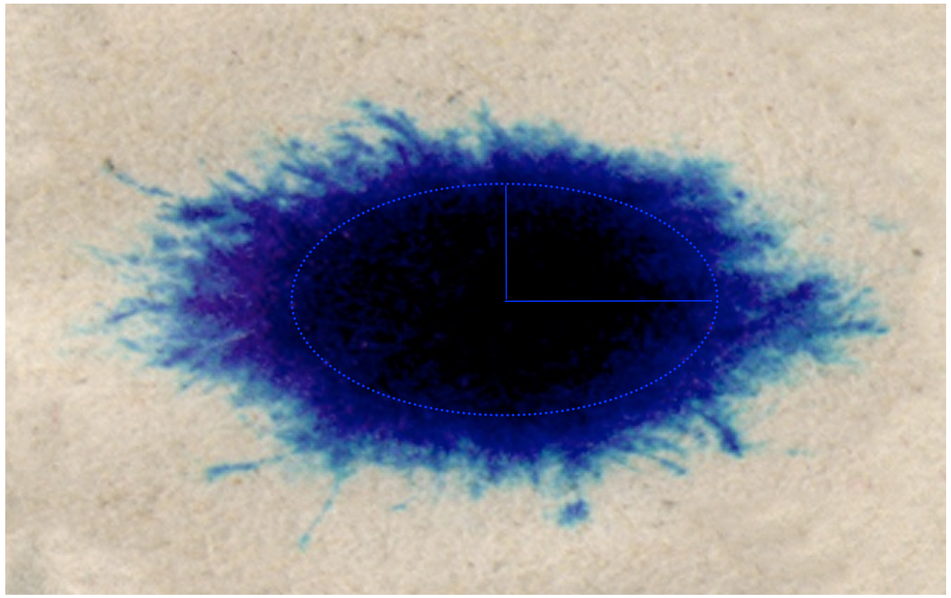
R. Laramee, B. Jobard, H. Hauser, Image Space Based Visualization of Unsteady Flows on Surfaces, IEEE Visualization 2003

Tensors

- Anisotropy characterizes tensor shape
- Example: ink diffusion

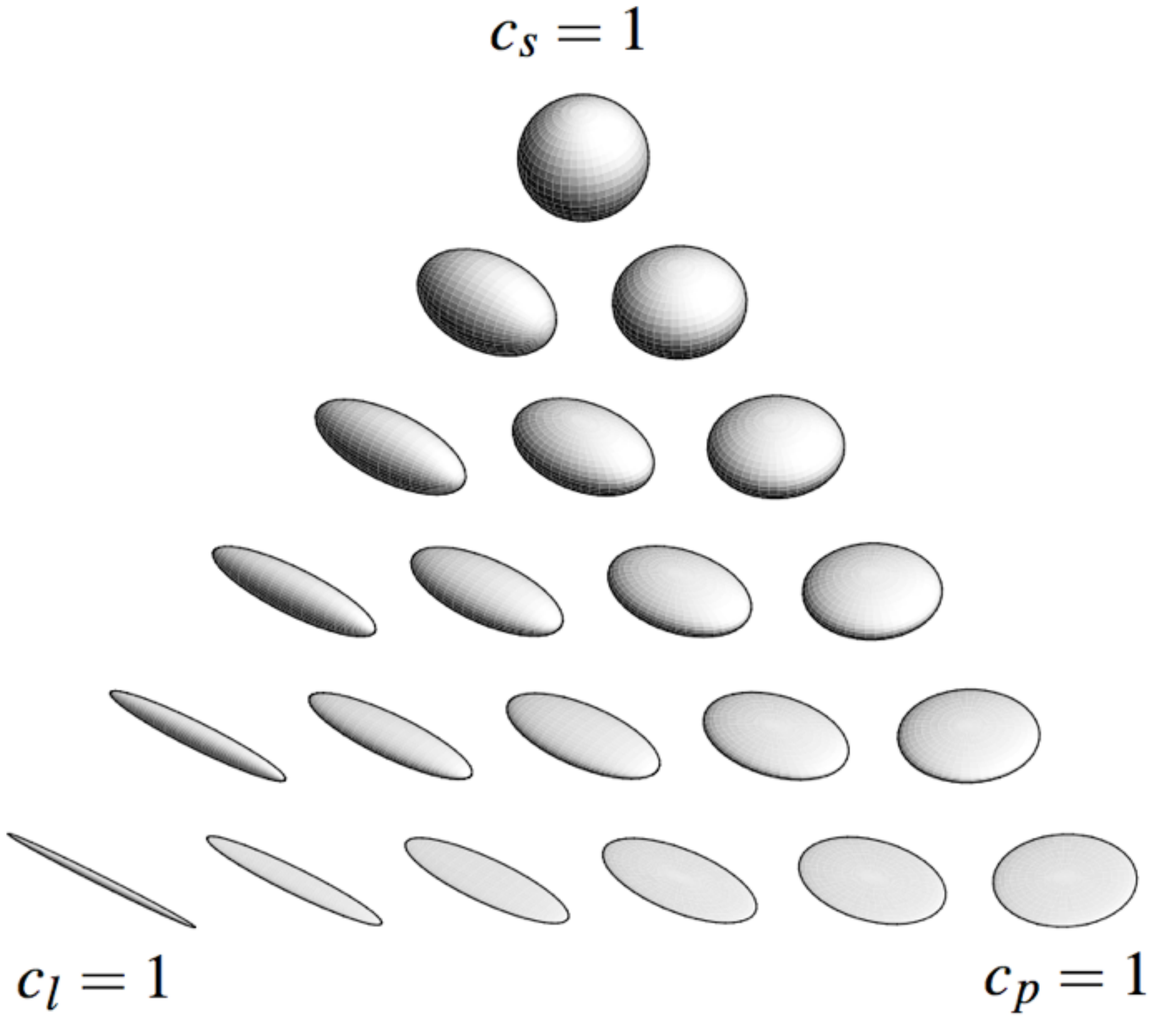


Kleenex



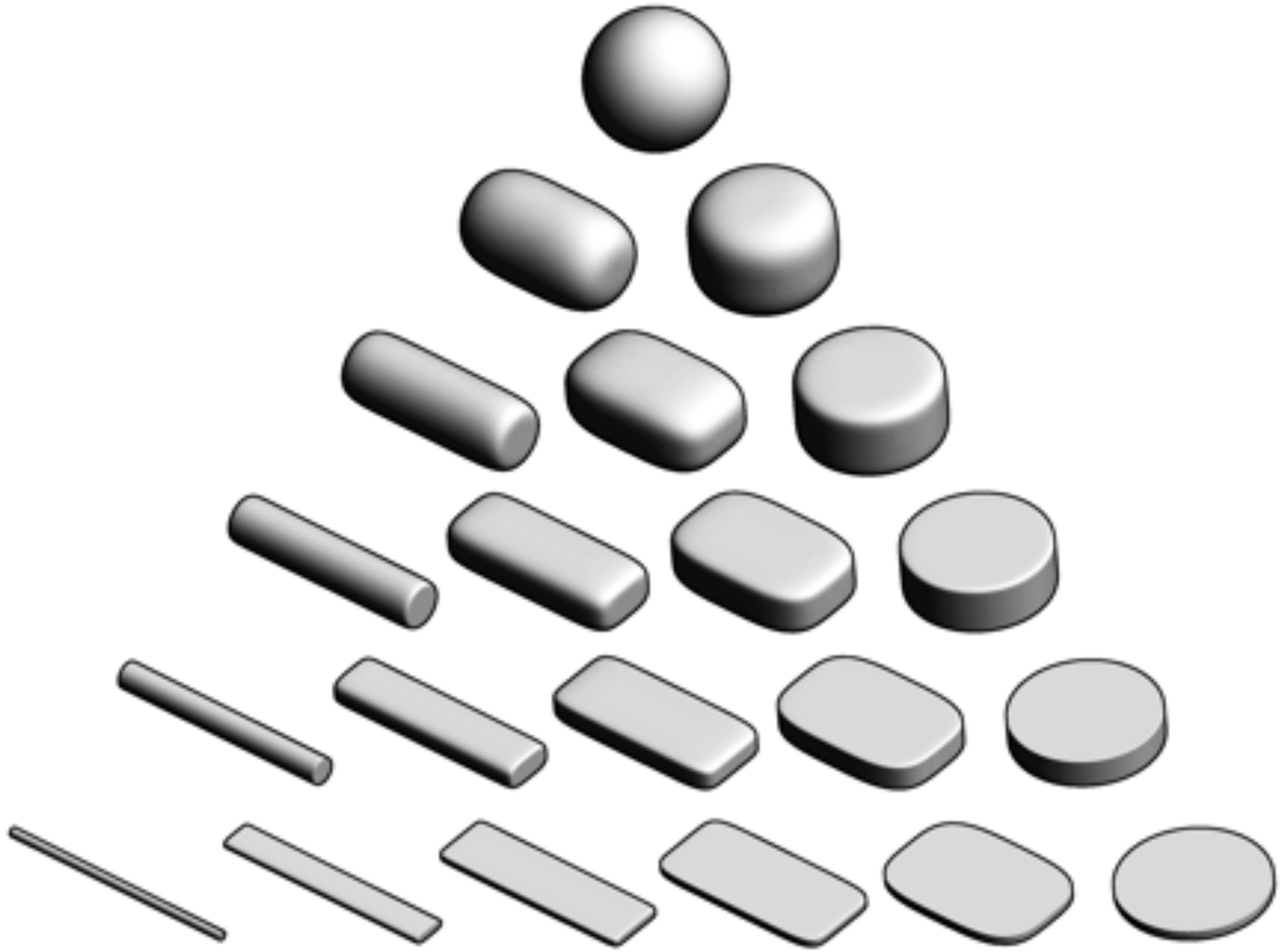
Newspaper

Symmetric Tensor

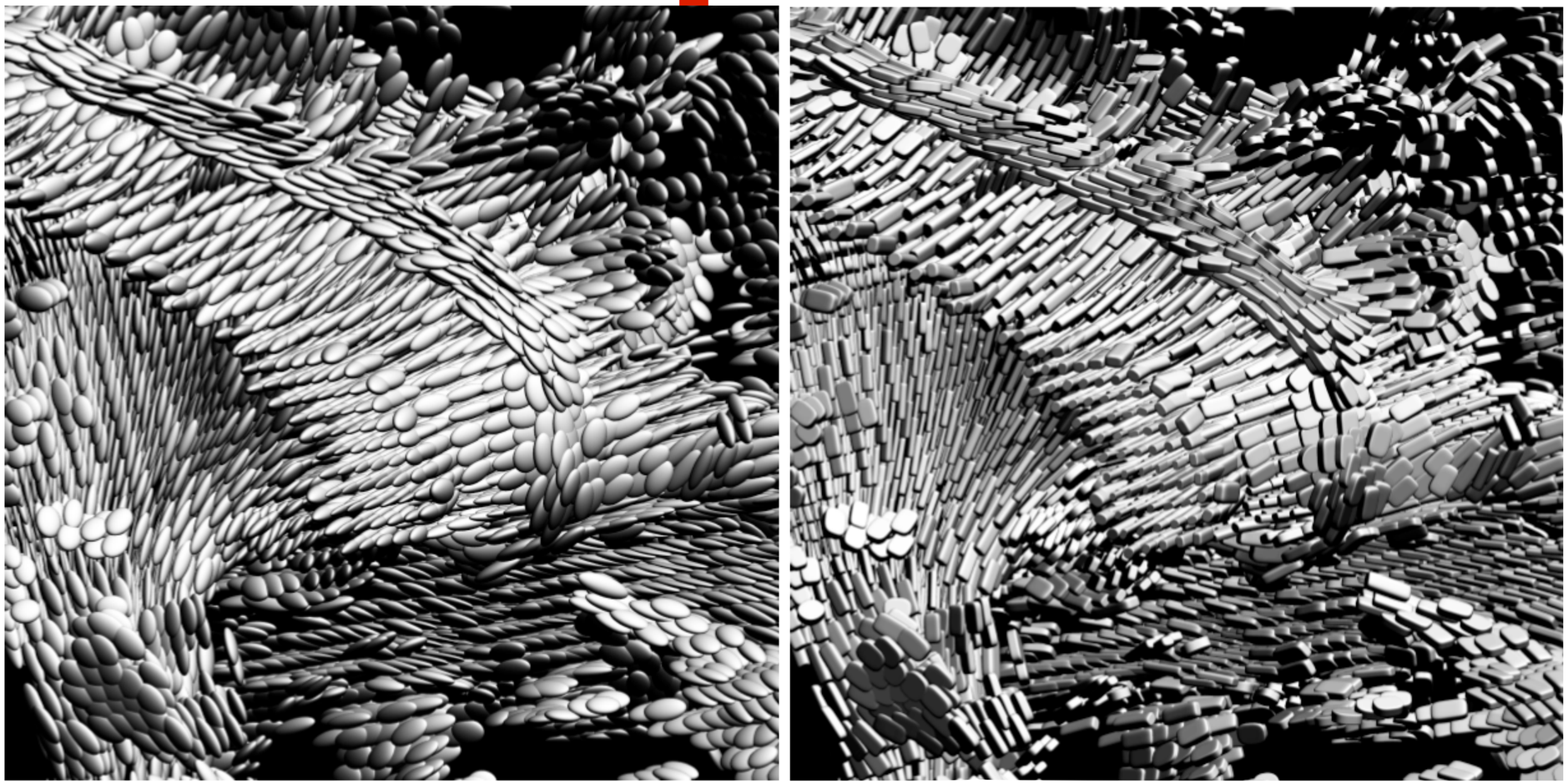


Superquadric Tensor

- Superq

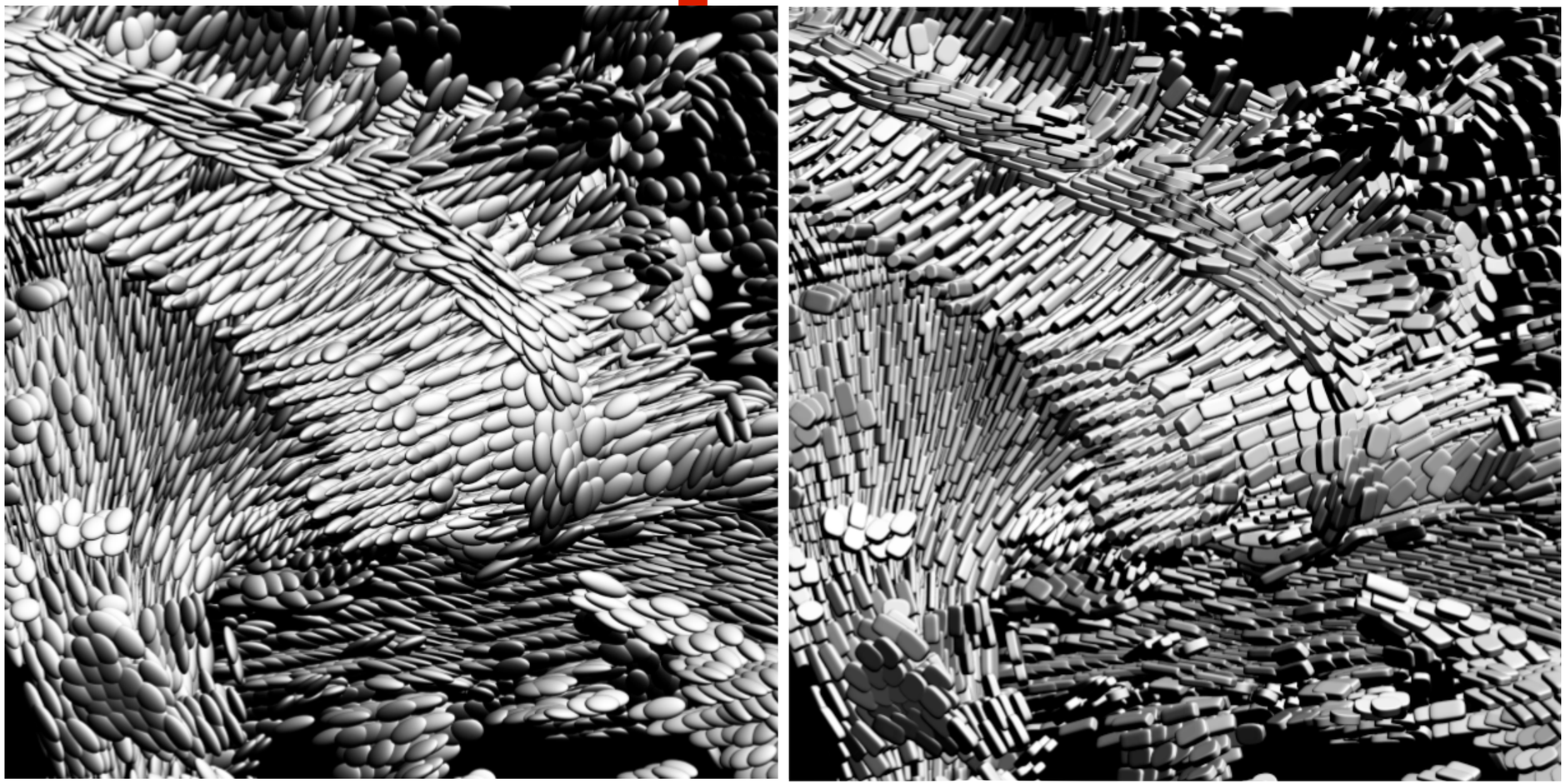


Comparison



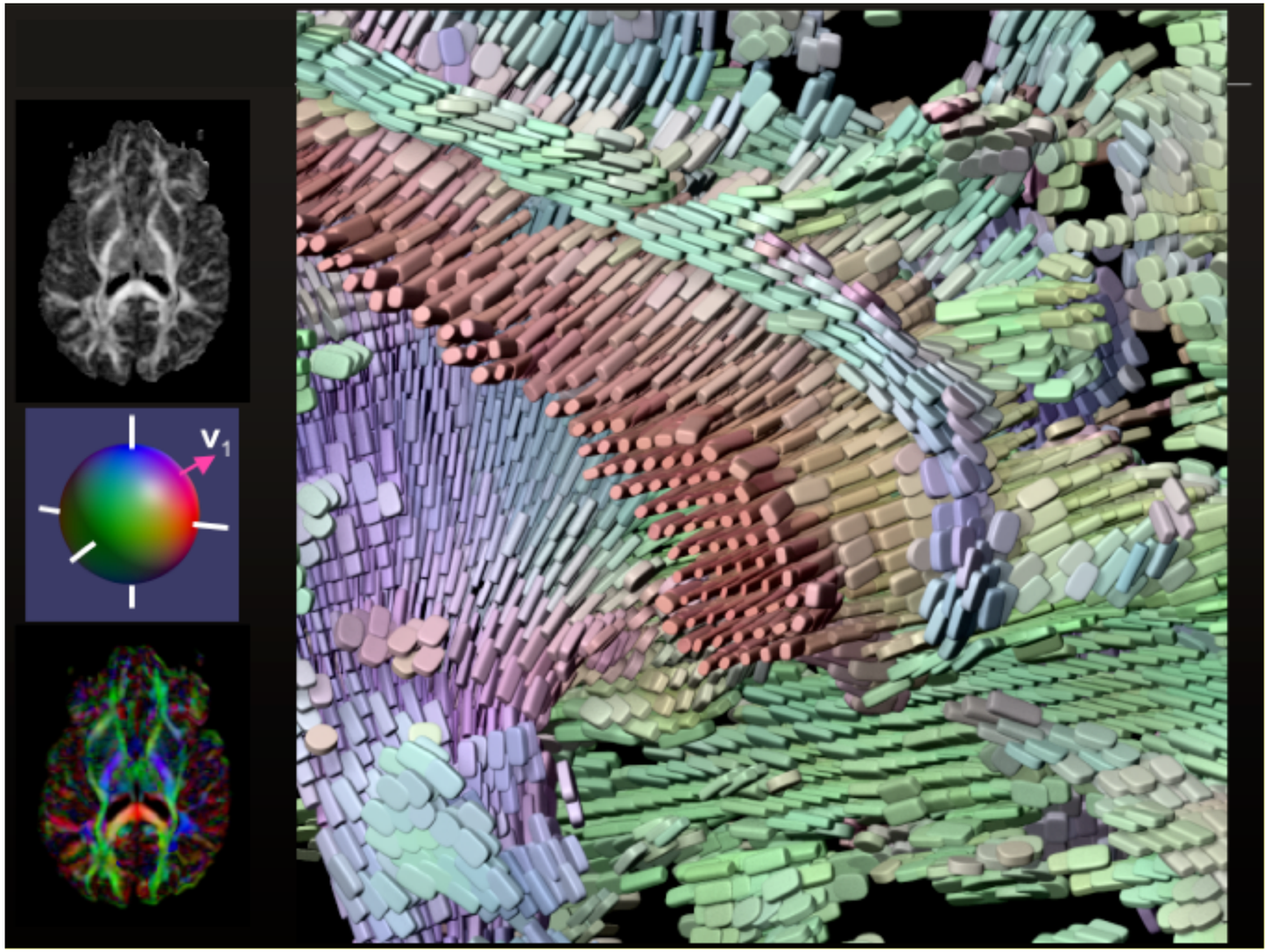
G. Kindlmann, *Superquadric Tensor Glyphs*,
Joint Eurographics/IEEE VGTC Symposium on Visualization 2004

Comparison

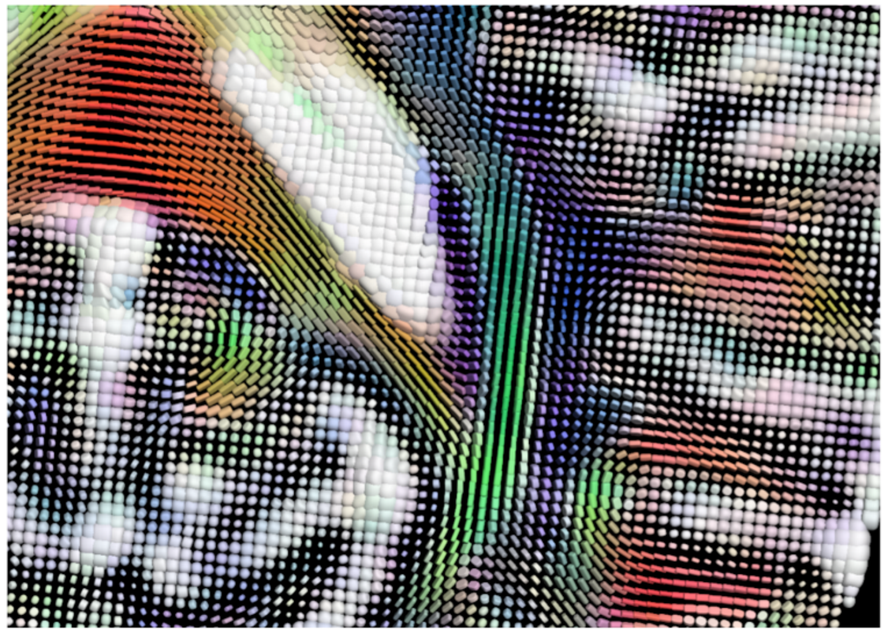


G. Kindlmann, *Superquadric Tensor Glyphs*,
Joint Eurographics/IEEE VGTC Symposium on Visualization 2004

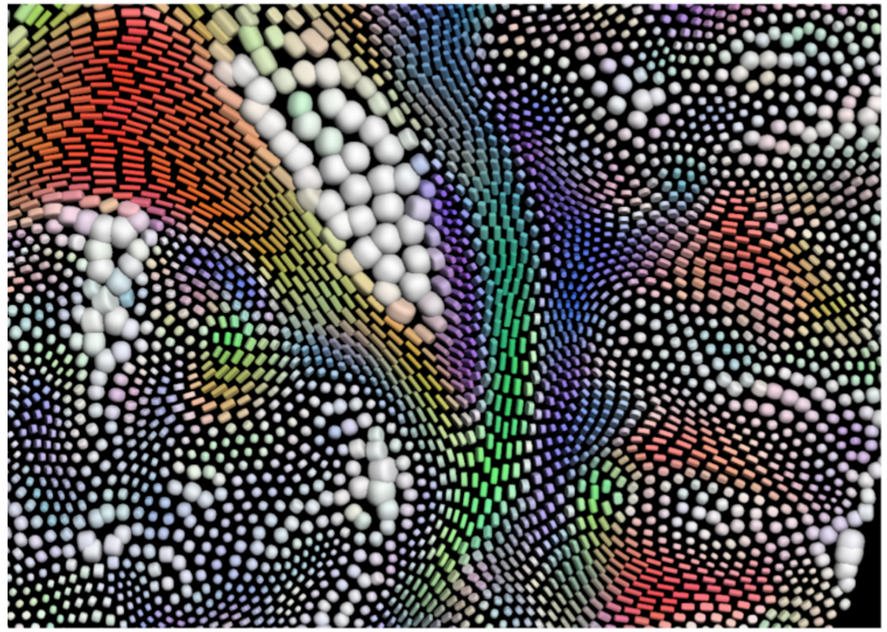
Symmetric Tensor



Glyph Packing



Regular grid

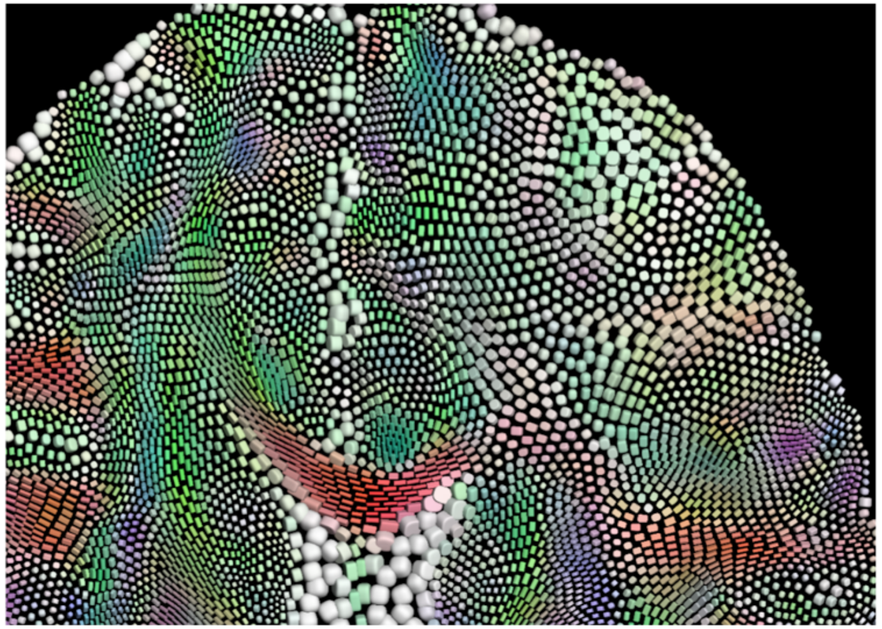


Glyph packing

G. Kindlmann and C.-F. Westin, *Diffusion Tensor Visualization with Glyph Packing*, IEEE Visualization 2006

Glyph Packing

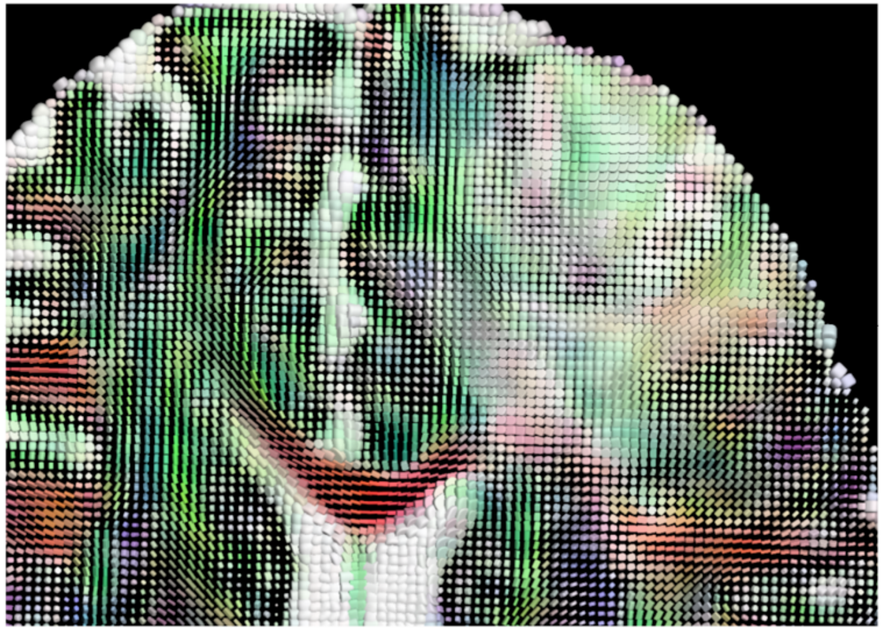
Regular grid



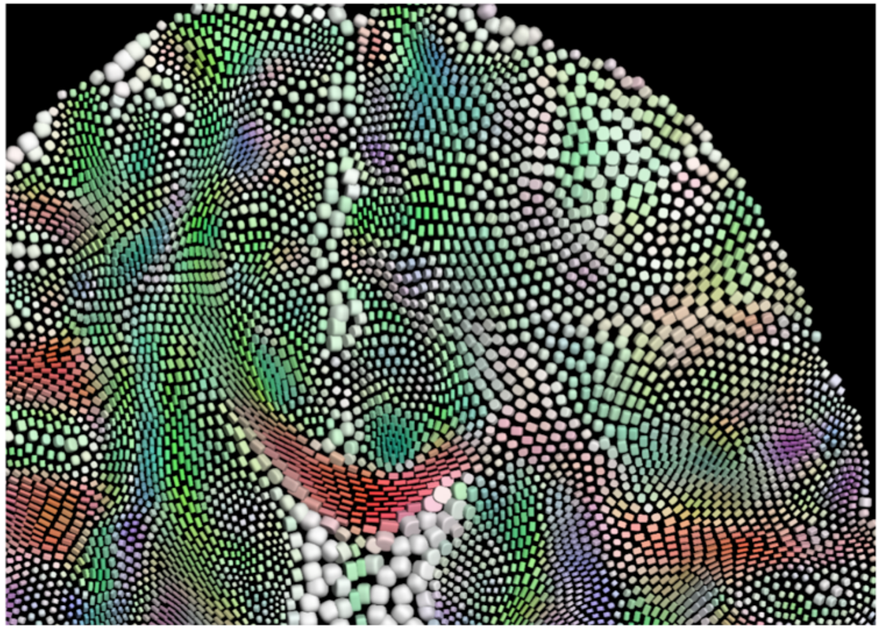
Glyph packing

G. Kindlmann and C.-F. Westin, *Diffusion Tensor Visualization with Glyph Packing*, IEEE Visualization 2006

Glyph Packing



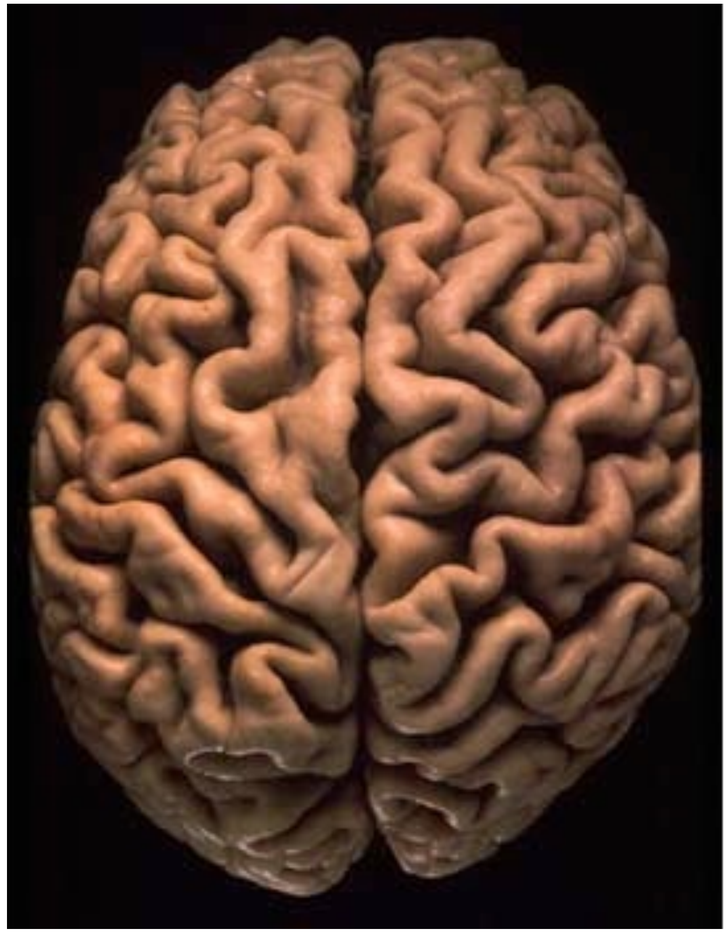
Regular grid

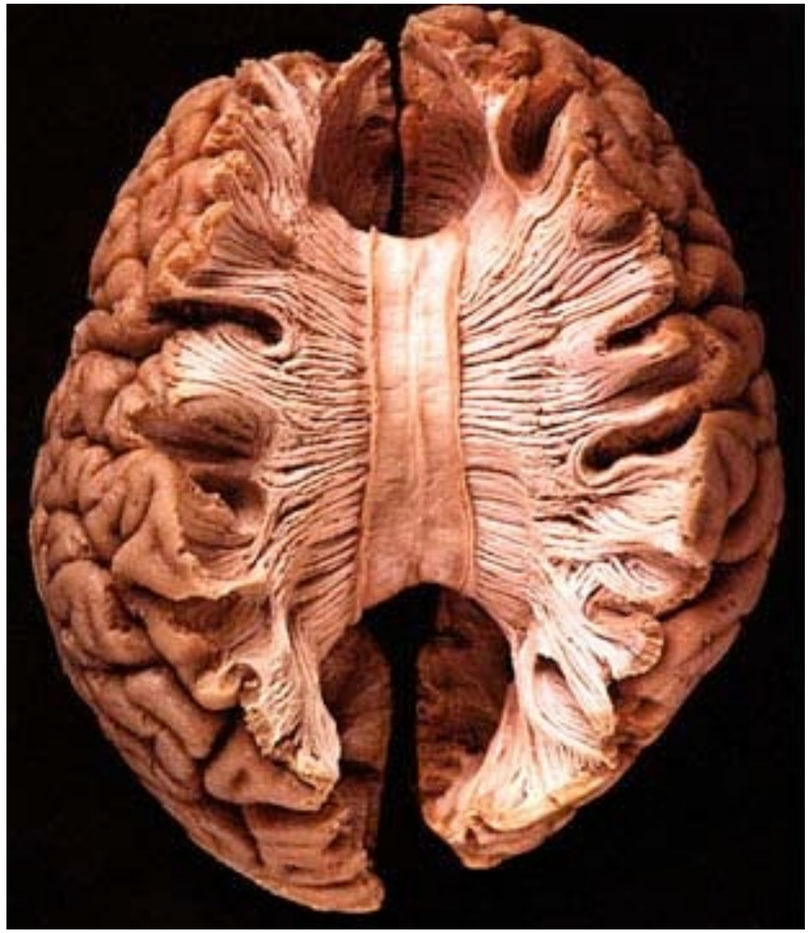


Glyph packing

G. Kindlmann and C.-F. Westin, *Diffusion Tensor Visualization with Glyph Packing*, IEEE Visualization 2006

Brain Structure - Fiber



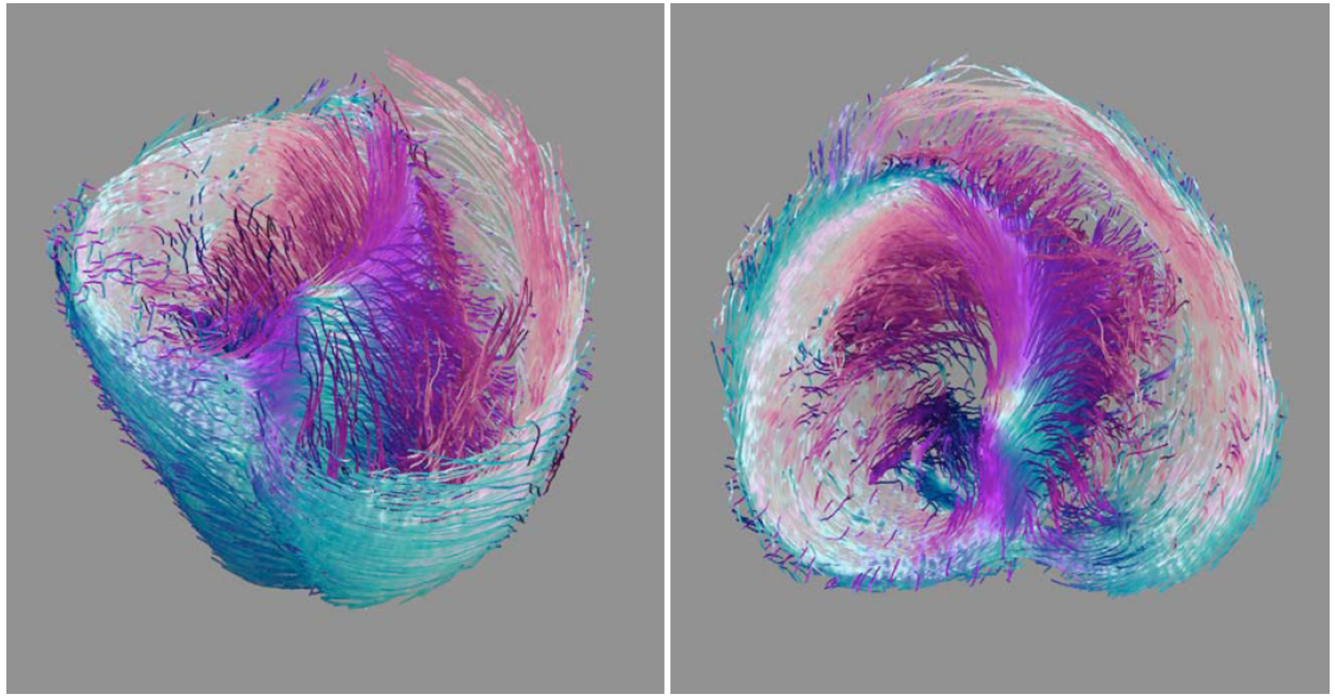


Diffusion Tensor

Diffusion Tensor

Fiber Tracing

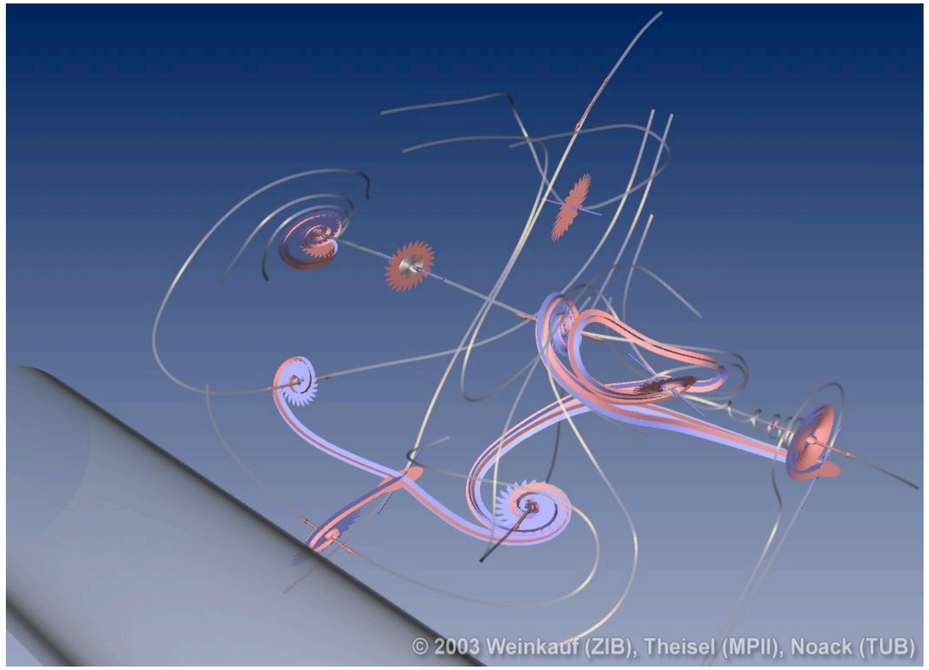
- Heart

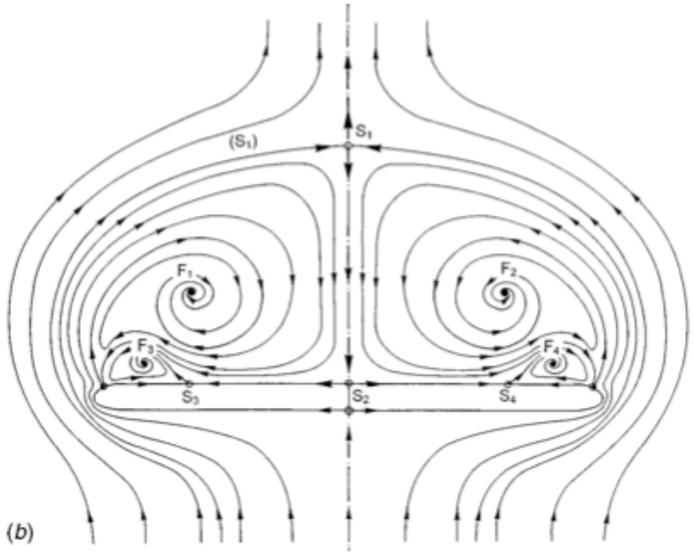


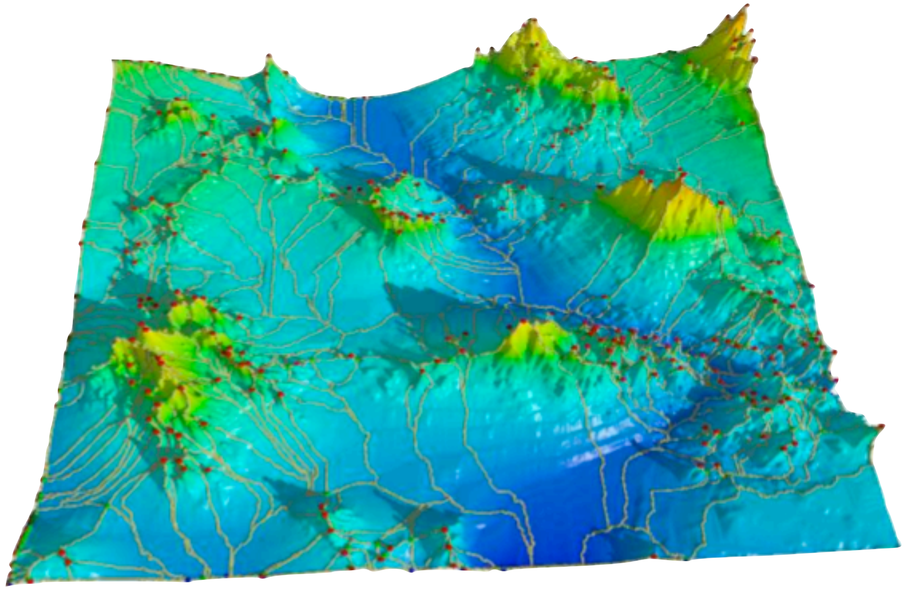
L. Zhukov, A. Barr,
Heart Fiber Reconstruction from Diffusion Tensor MRI,
IEEE Visualization 2003

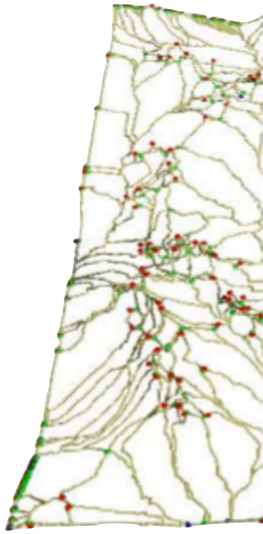
Some Visualization Research Topics

Topological Methods

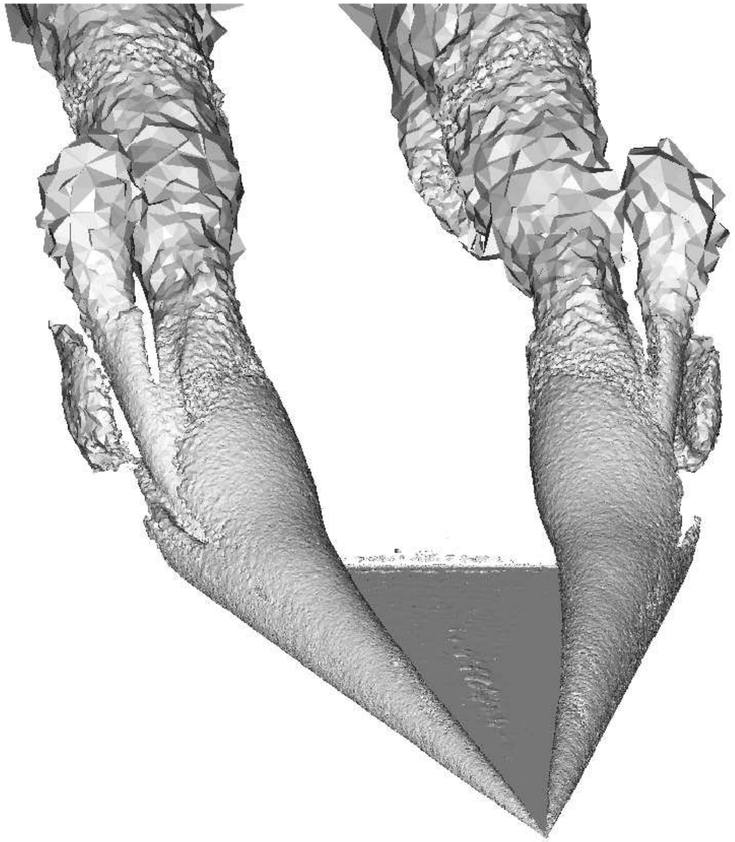


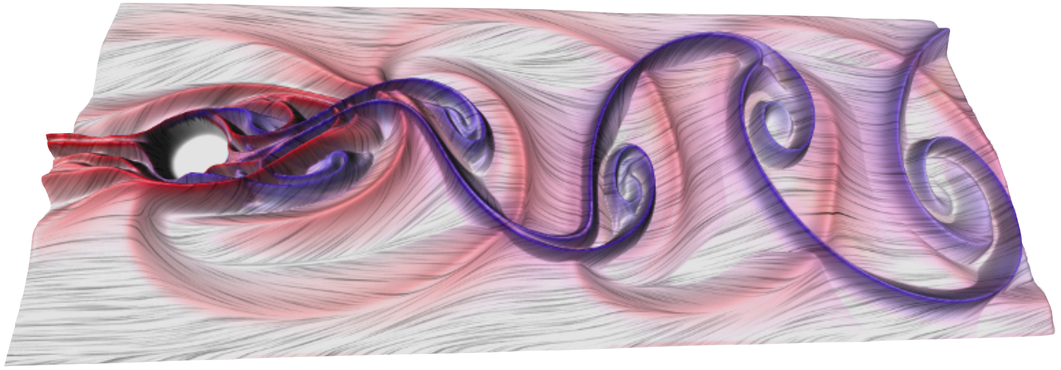




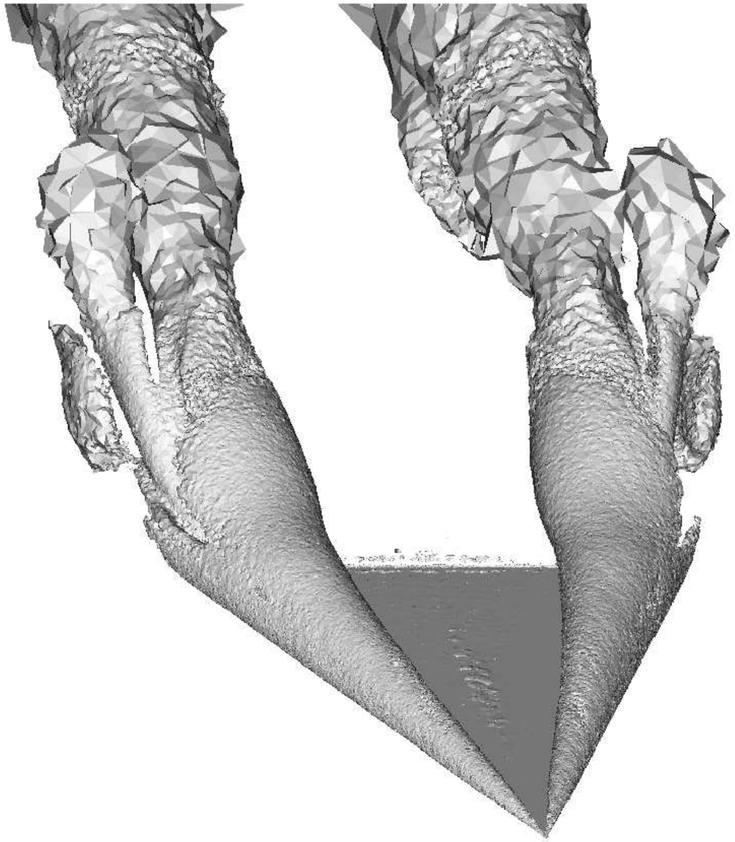


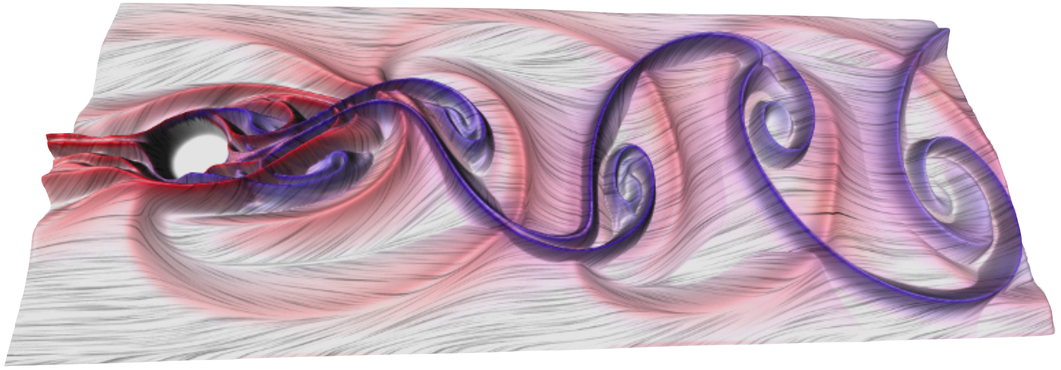
Flow Analysis



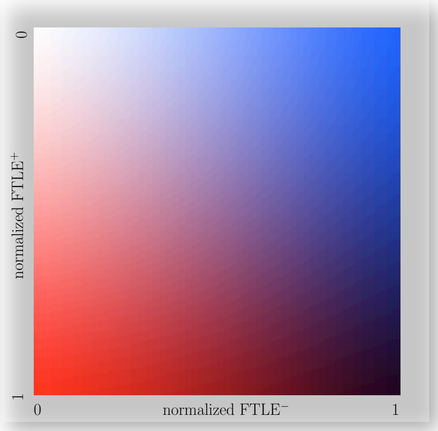


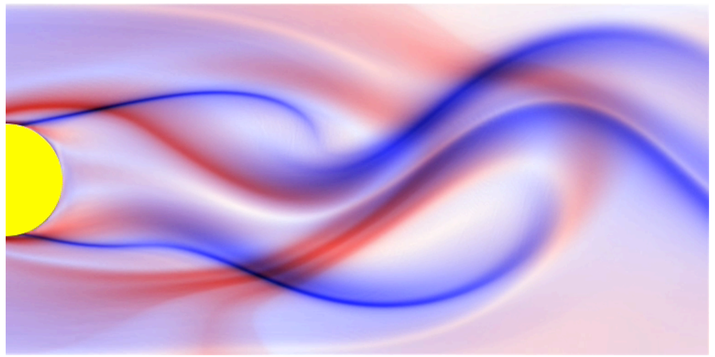
Flow Analysis





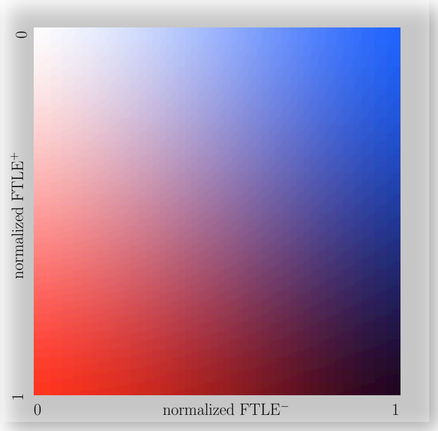
Lagrangian

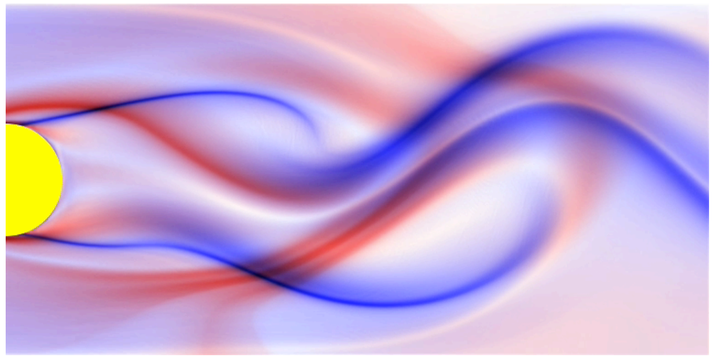




von Kármán vortex street

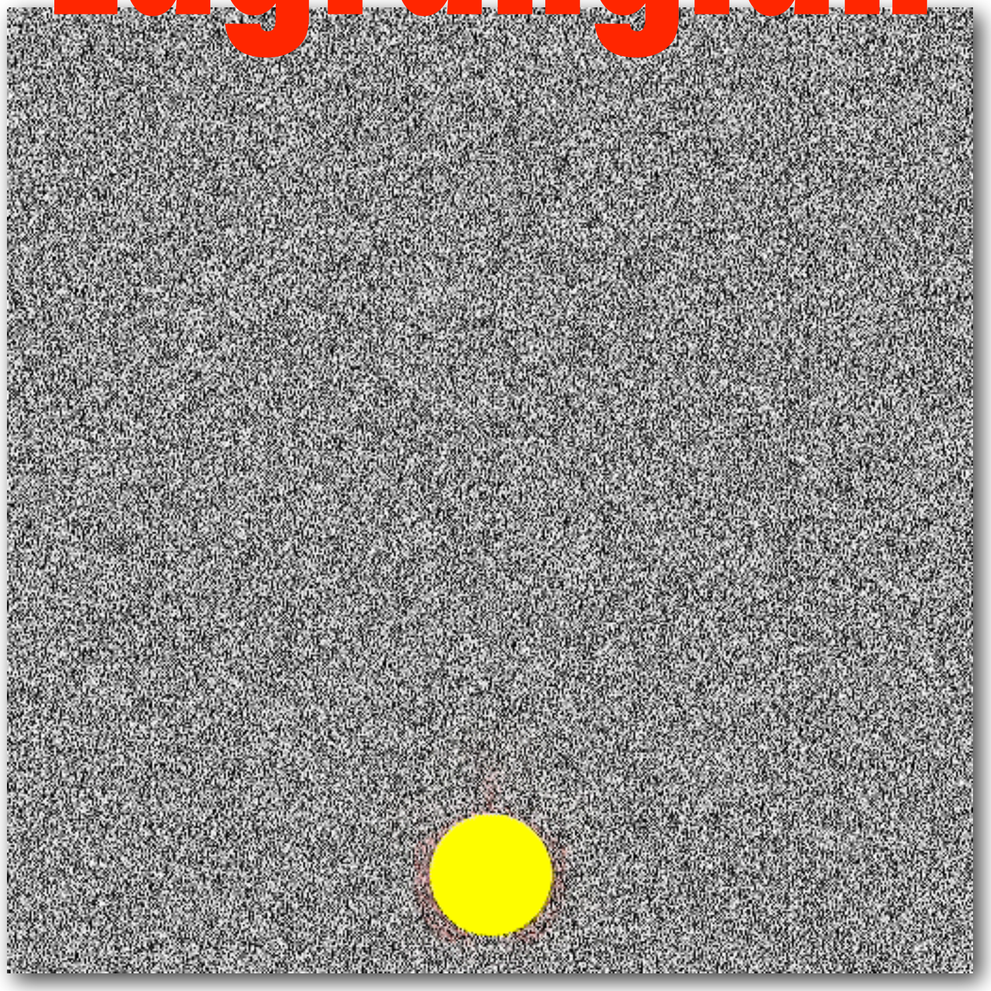
Lagrangian



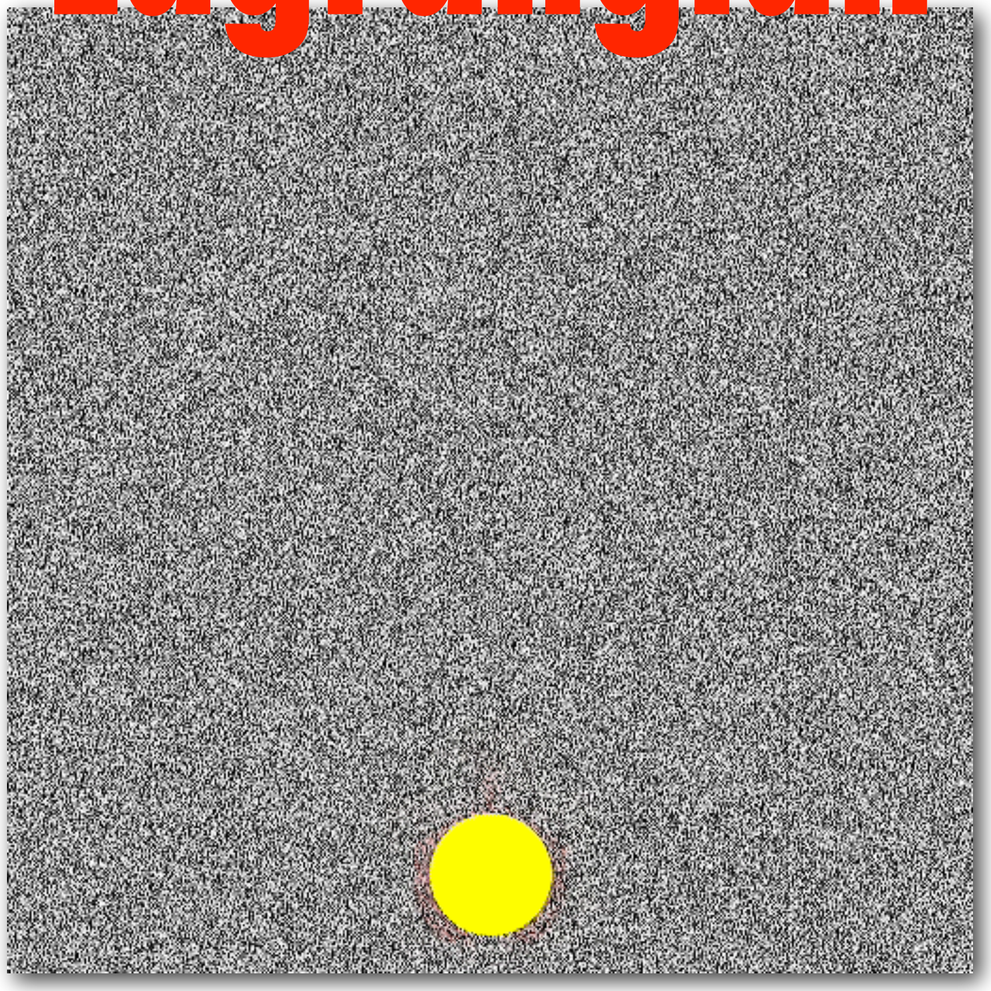


von Kármán vortex street

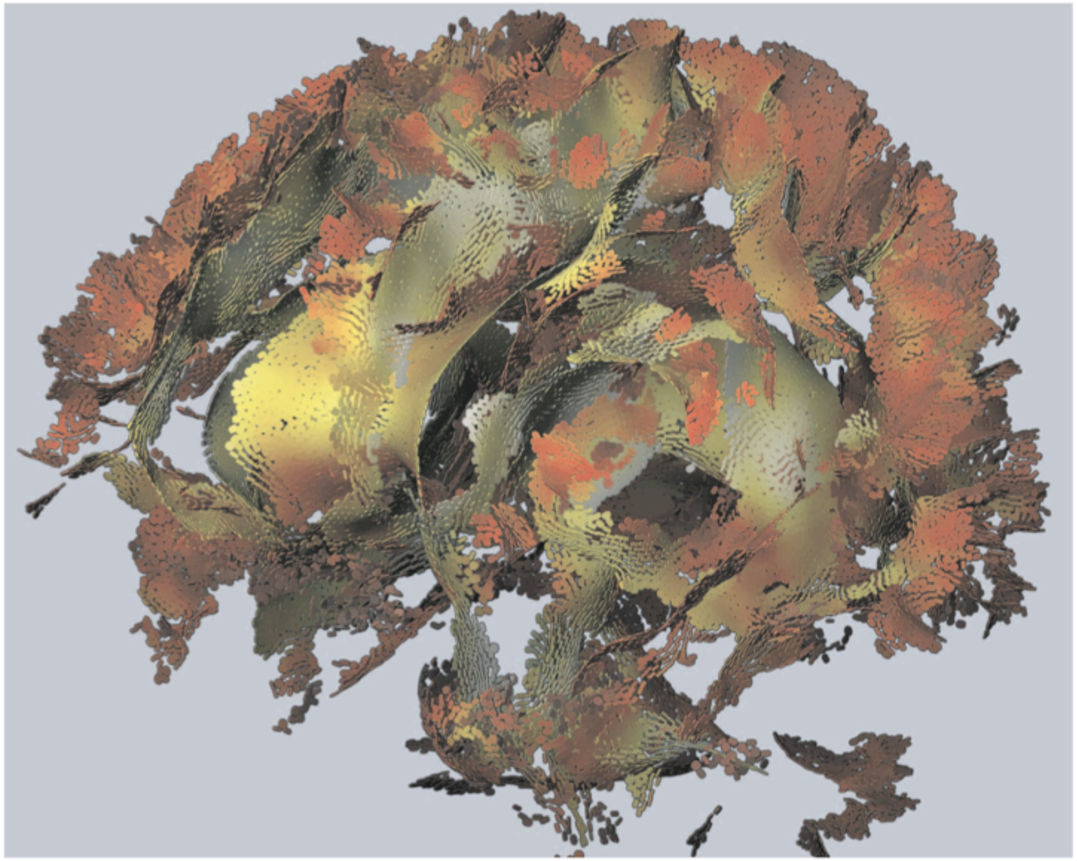
Lagrangian

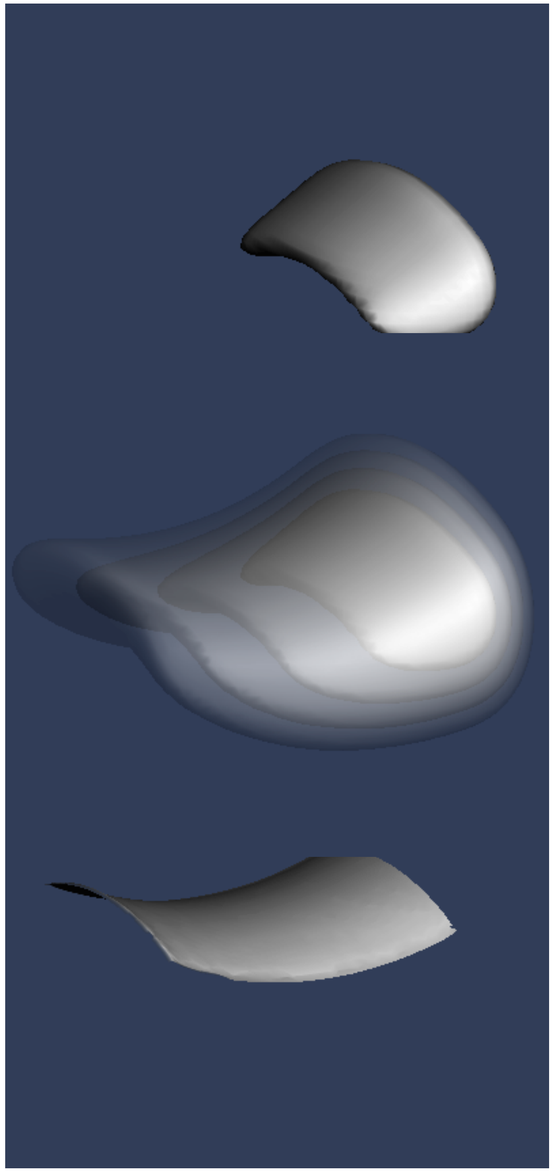


Lagrangian

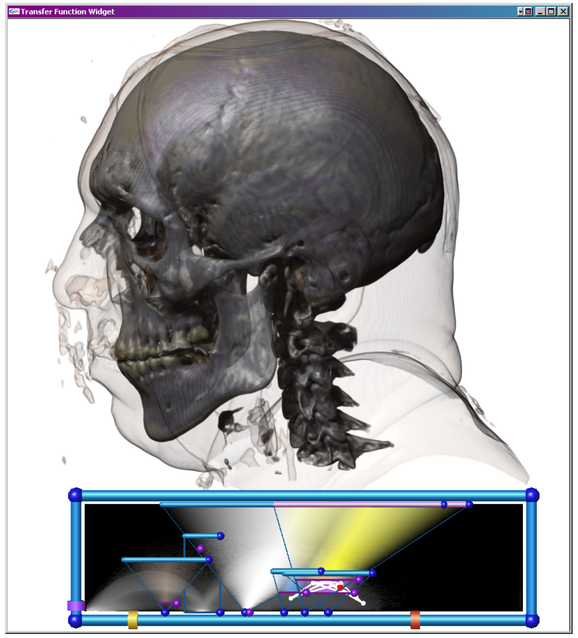


Ridges / Salient





Biomedical



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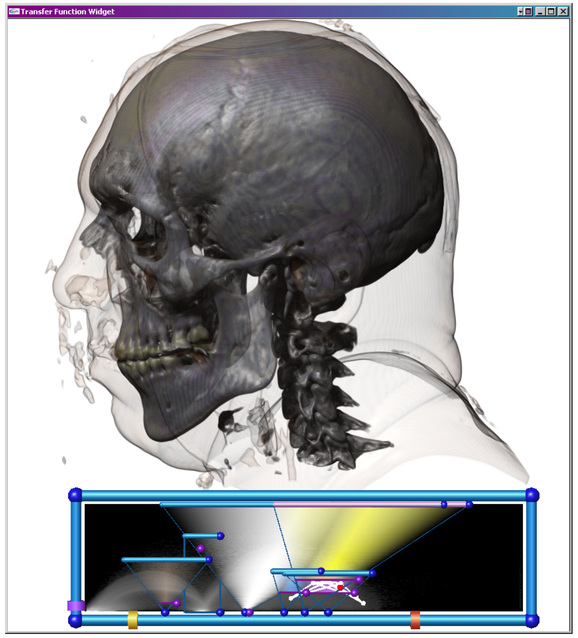
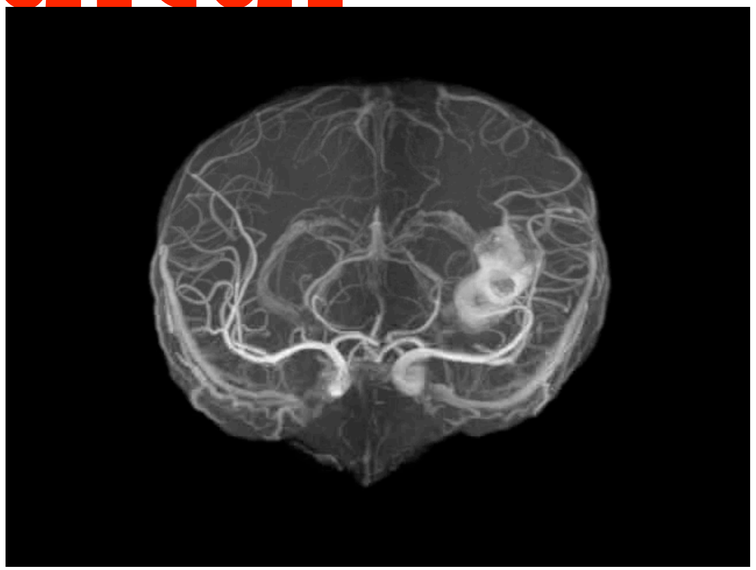
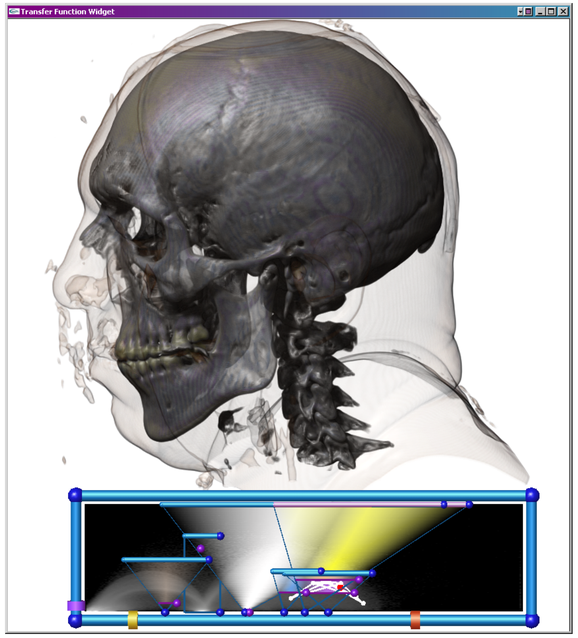


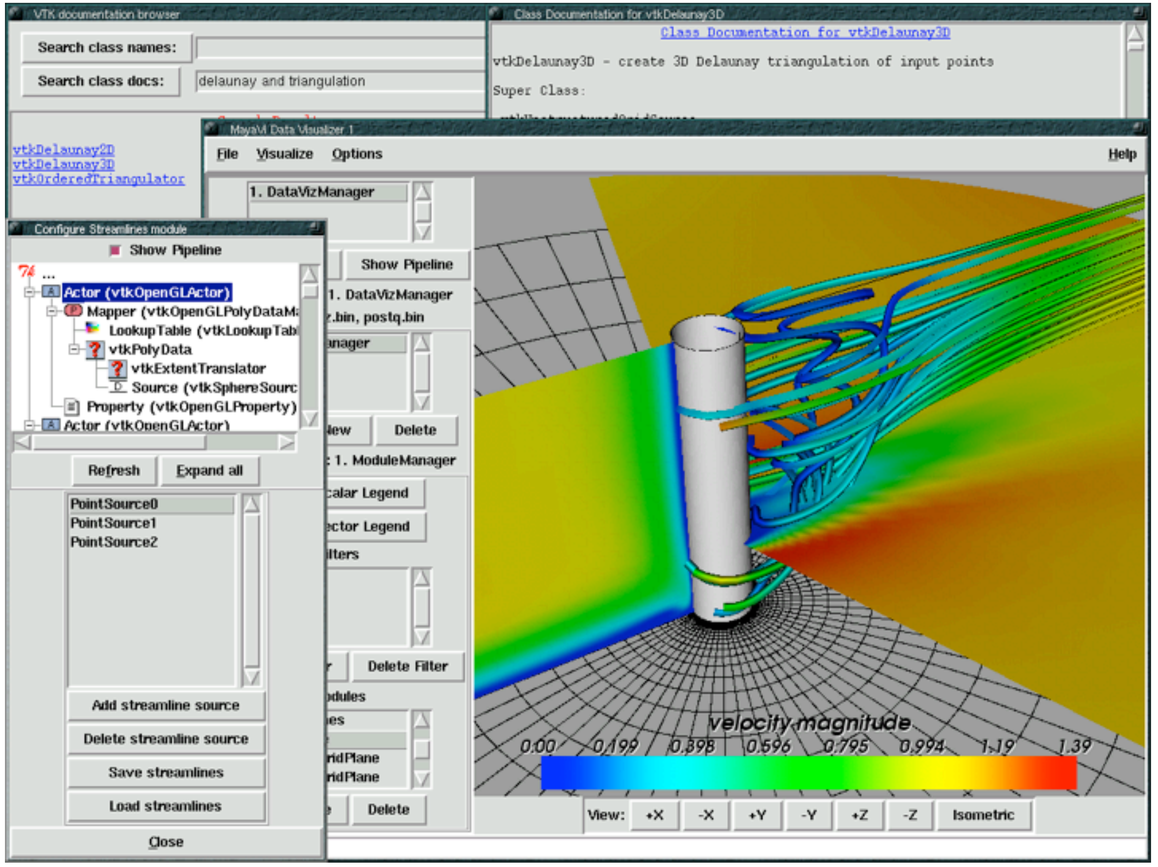
Biomedical



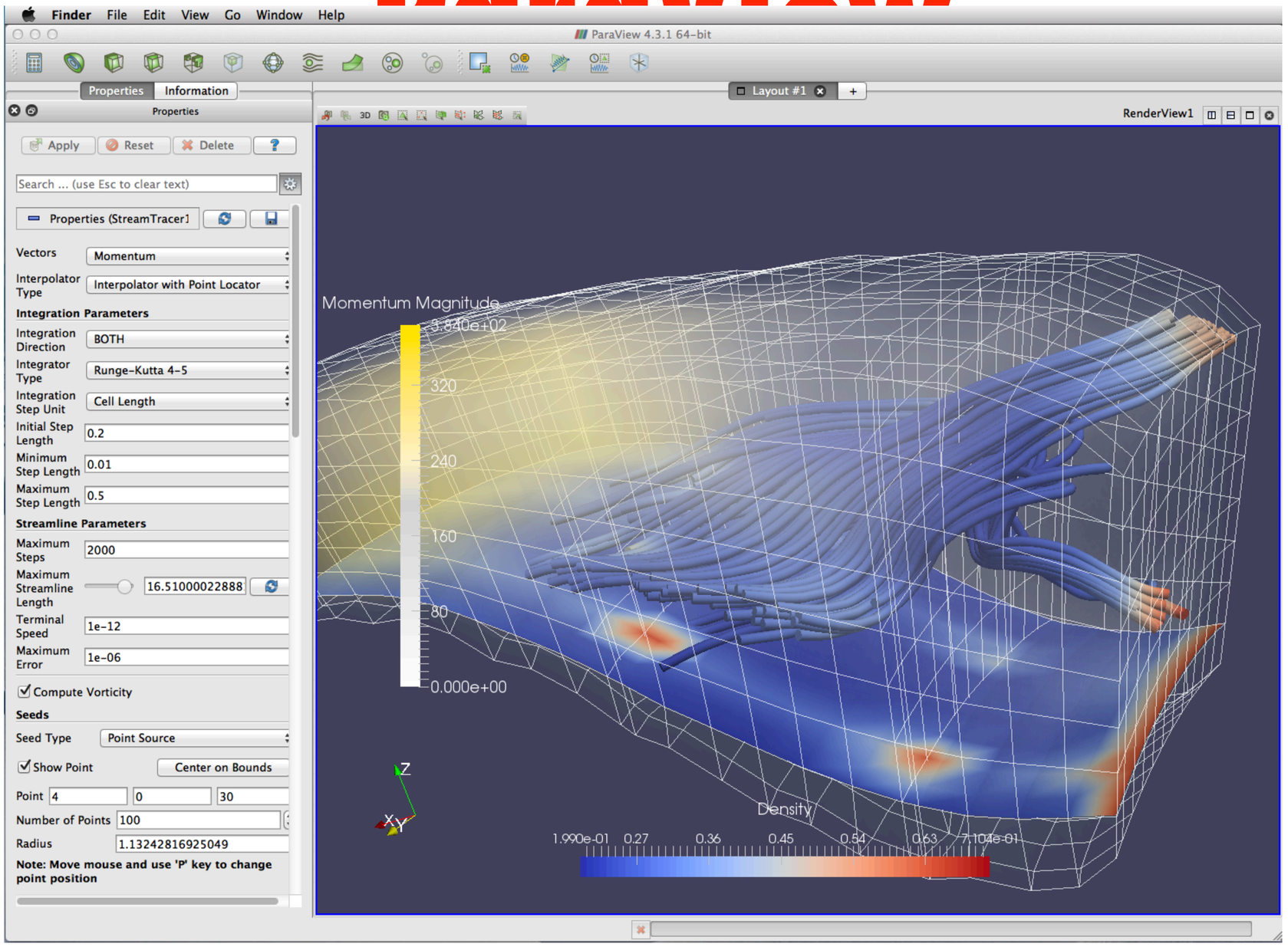


Visualization Tools

- VTK via Tcl/Tk



ParaView


Finder File Edit View Go Window Help
ParaView 4.3.1 64-bit
Properties Information
Properties
Apply Reset Delete
Search ... (use Esc to clear text)
Properties (StreamTracer)
Vectors Momentum
Interpolator Type Interpolator with Point Locator
Integration Parameters
Integration Direction BOTH
Integrator Type Runge-Kutta 4-5
Integration Step Unit Cell Length
Initial Step Length 0.2
Minimum Step Length 0.01
Maximum Step Length 0.5
Streamline Parameters
Maximum Steps 2000
Maximum Streamline Length 16.51000022888
Terminal Speed 1e-12
Maximum Error 1e-06
Compute Vorticity
Seeds
Seed Type Point Source
Show Point
Center on Bounds
Point 4 0 30
Number of Points 100
Radius 1.13242816925049
Note: Move mouse and use 'P' key to change point position
Layout #1
RenderView1
Momentum Magnitude
3.840e+02
320
240
160
80
0.000e+00
Z
Xy
Density
1.990e-01 0.27 0.36 0.45 0.54 0.63 7.104e-01