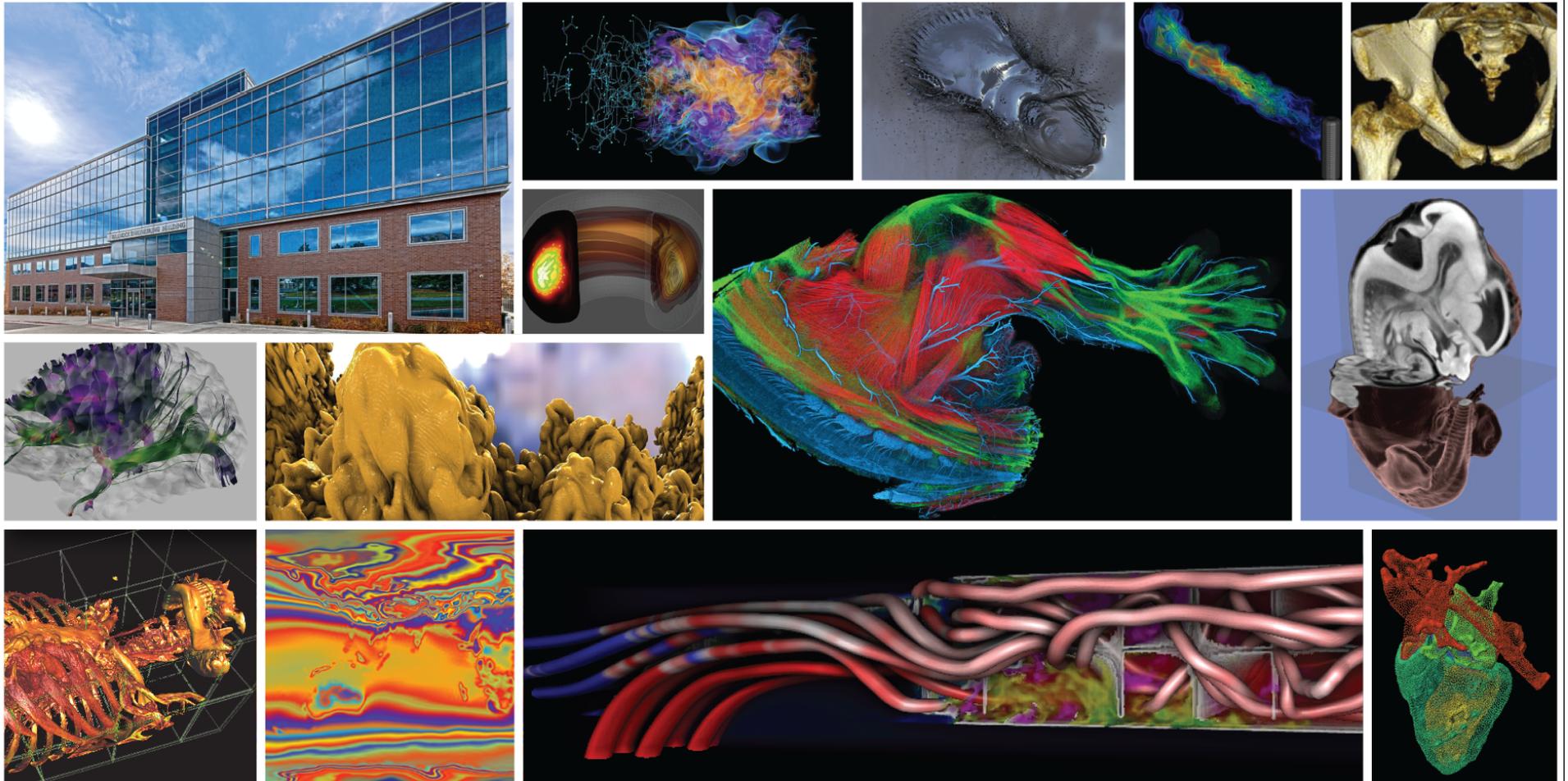


# Large-Scale Visual Analysis



**Chris Johnson**  
**Scientific Computing and Imaging Institute**  
**University of Utah**

# History of Computer Graphics in Utah



**1, 2. David Evans /Ivan Sutherland**  
-Founded CS Dept at the UofU in 1968  
-Ivan Sutherland - Turing award  
-Founded Evans & Sutherland Company

**3. John Warnock**  
-Worked at Evans & Sutherland  
-Founded Adobe  
-Hidden Line Removal Algorithm  
-Helped invent Postscript @ Adobe

**4. Tom Stockham**  
-Known for work in Signal Processing  
-Helped to invent the CD Player

**5. Ed Catmull**  
-Worked at Lucas Film  
-Co-Founded Pixar  
-President of Disney Animation Studios  
-Chair of CoE External Advisory Board

**6. Alan Kay**  
- Personal Computer  
-Turing Award Winner  
-Object Oriented Languages

**7. Jim Kajiya**  
-VP Research at Microsoft

**8. Jim Clark**  
-Founded SGI, Netscape, Healtheon  
- Work in Geometry Pipelines

**9. Jim Blinn**  
-Invented Blinn-Phong Shading Model

**10. Nolan Bushnell**  
-Invented Pong  
-Founded Atari

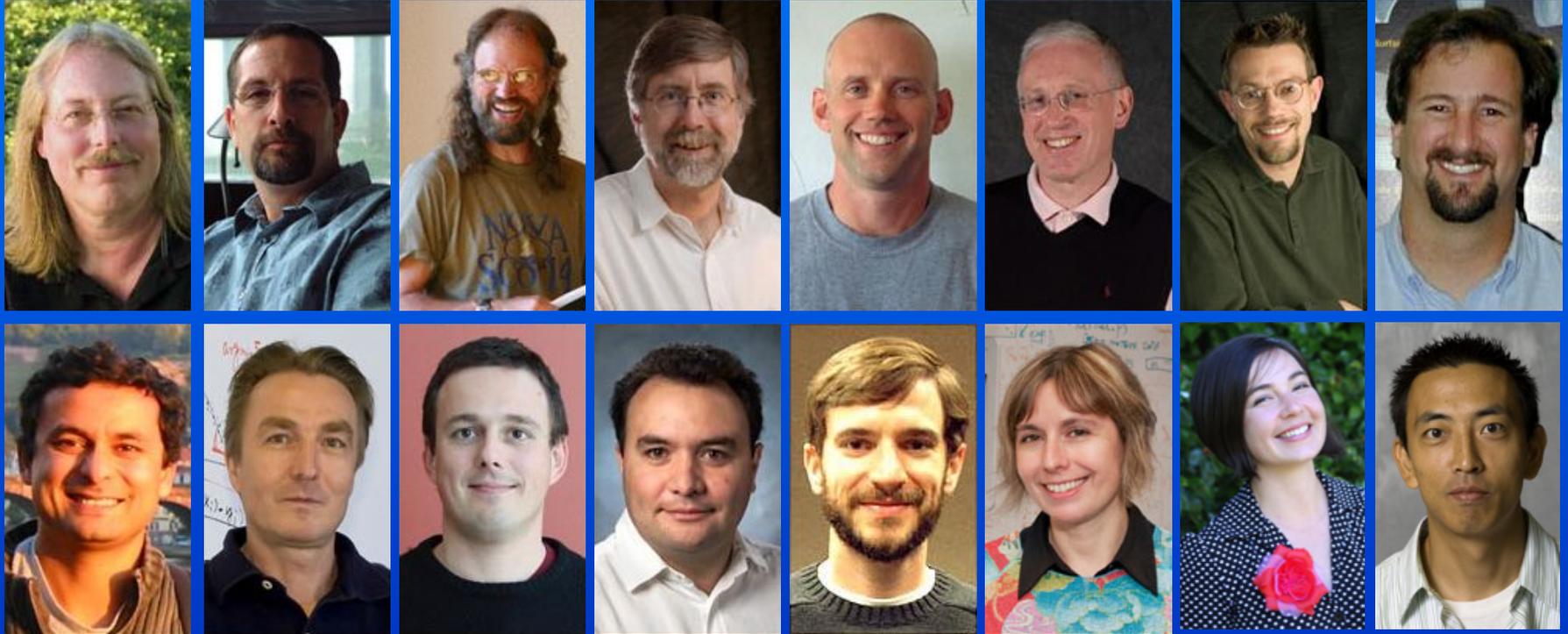
**11. Henri Gouraud**  
-Invented Gouraud Shading Model

**12. Allen Ashton**  
-Word Perfect  
-My CFO Founder

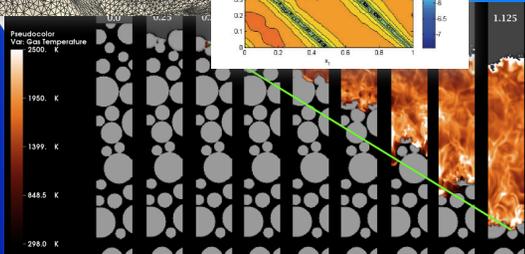
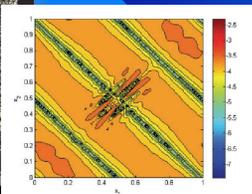
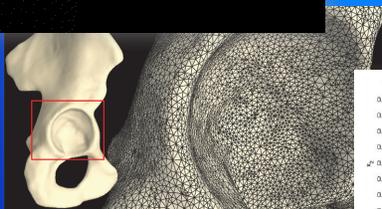
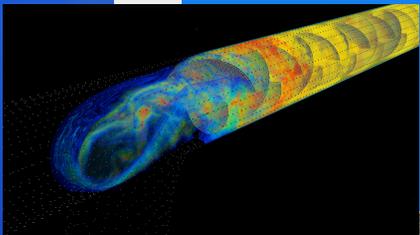
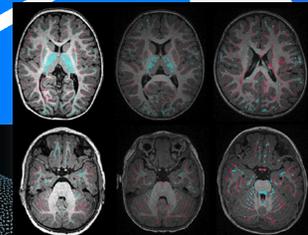
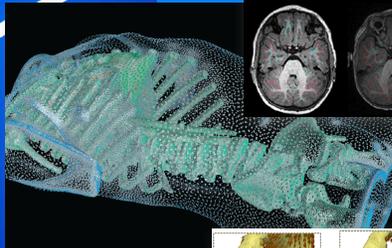
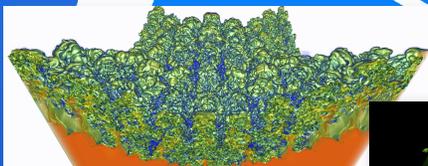
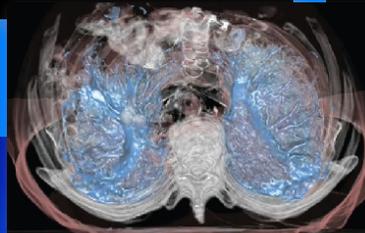
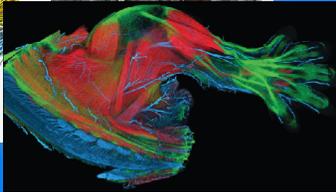
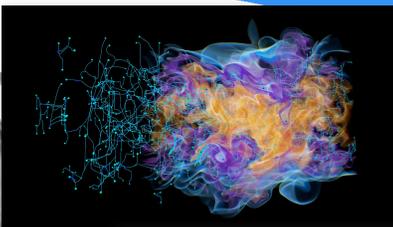
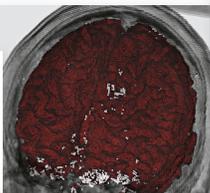
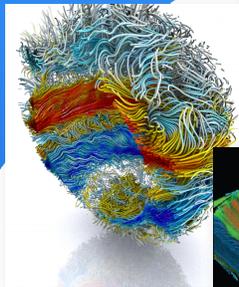
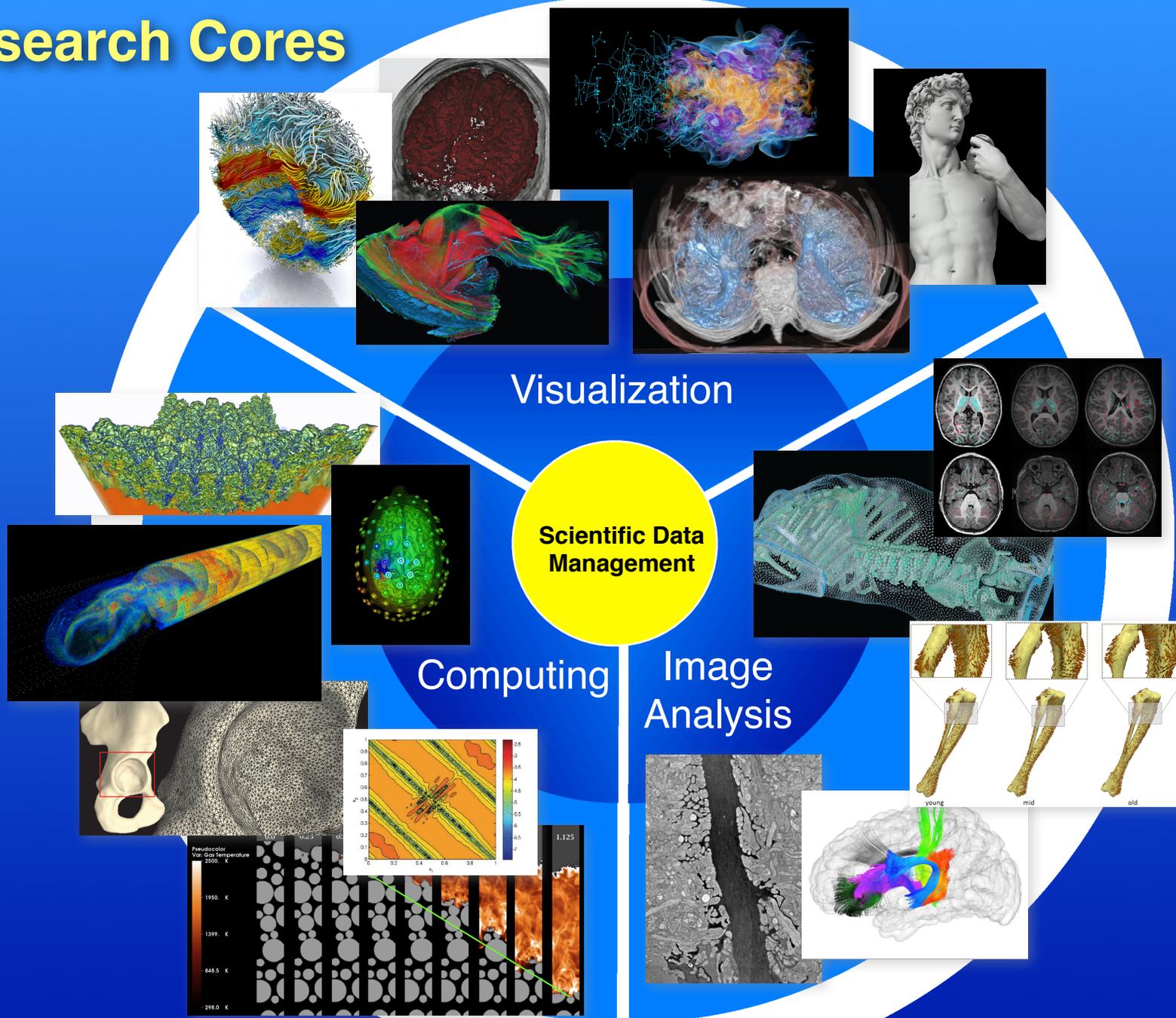
**13. Bui Tuong Phong**  
-Invented Phong Reflection and Shading Models

# SCI Institute Faculty

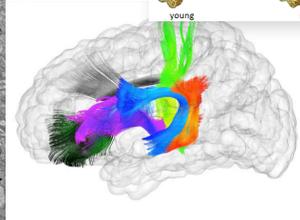
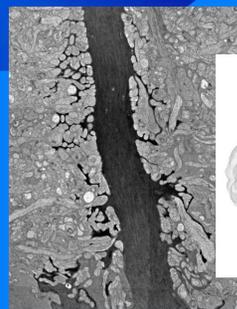
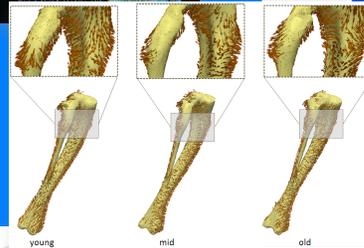
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# Research Cores



**Image Analysis**

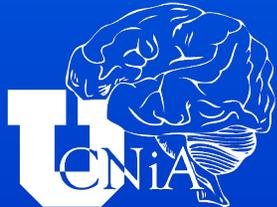




# Centers We Direct



**NIH/NIGMS Center for Integrative Biomedical Computing**



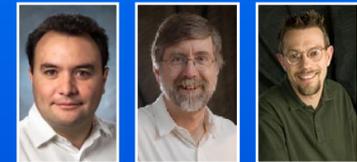
**Utah Center for Neuroimage Analysis**



**UTAH Center for Computational Earth Sciences**



**Center for Extreme Data Management, Analysis, and Visualization**



**NVIDIA CUDA Center of Excellence** at the  
The Scientific Computing and Imaging Institute



**CDE<sub>3</sub>M** Alliance for Computationally-guided  
Design of Energy Efficient  
Electronic Materials

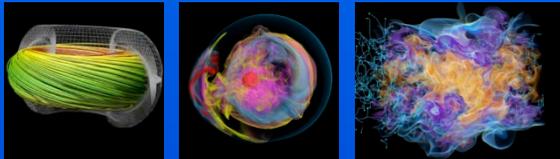


# National Centers We are Affiliated With

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## SDAV

Scalable Data Management, Analysis  
and Visualization



NIH NAMIC



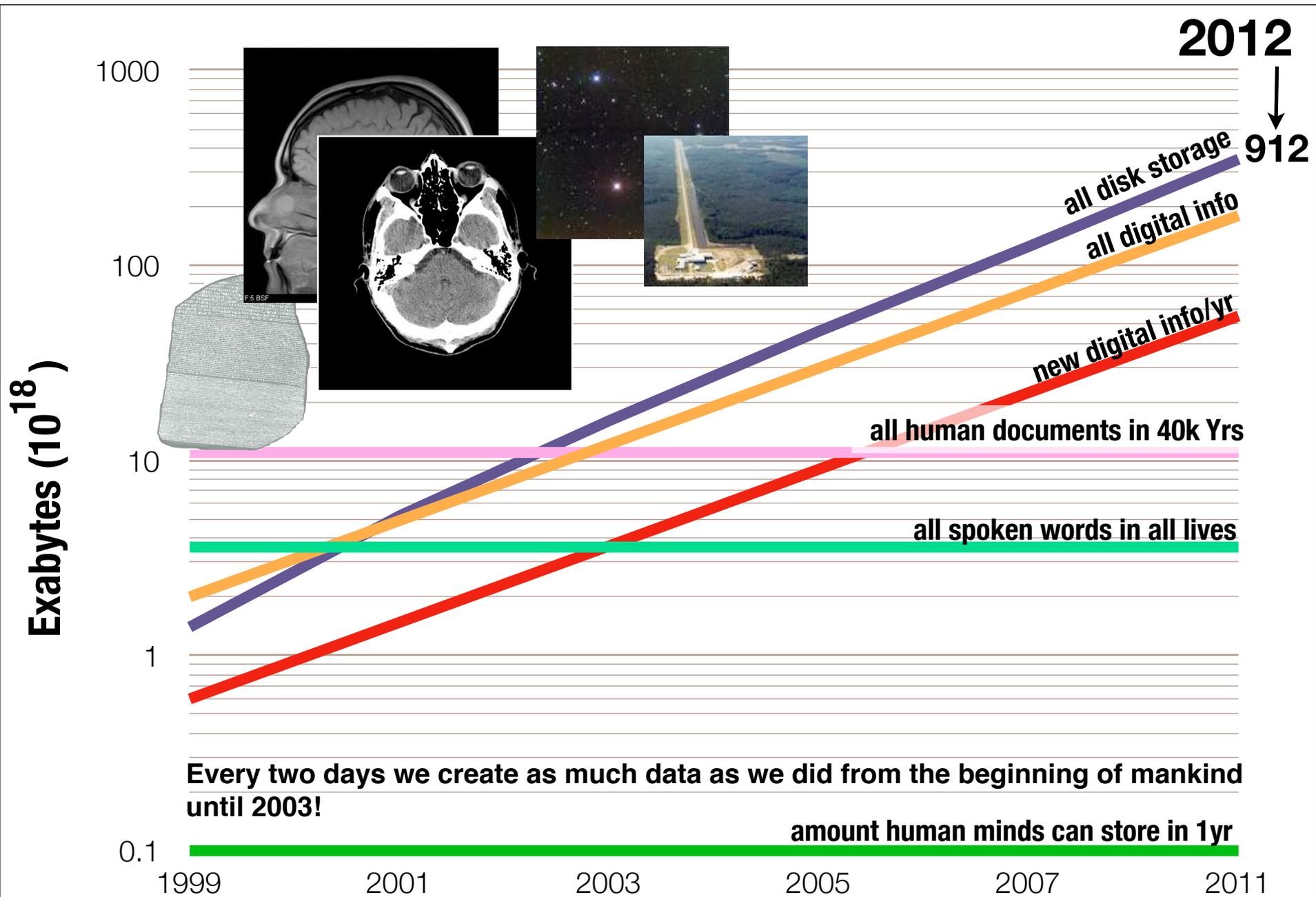
IAMCS  
Institute for Applied Mathematics  
and Computational Science

CDC Decision-Support  
for Infectious Disease  
Epidemiology



# EXACT

Center for Exascale Simulation  
of Combustion in Turbulence



Sources: Lesk, Berkeley SIMS, Landauer, EMC, TechCrunch, Smart Planet

# How Much is an Exabyte?



How many trees does it take to print out an Exabyte?

1 Exabyte = 1000 Petabytes = could hold approximately 500,000,000,000,000 pages of standard printed text

It takes one tree to produce **94,200** pages of a book

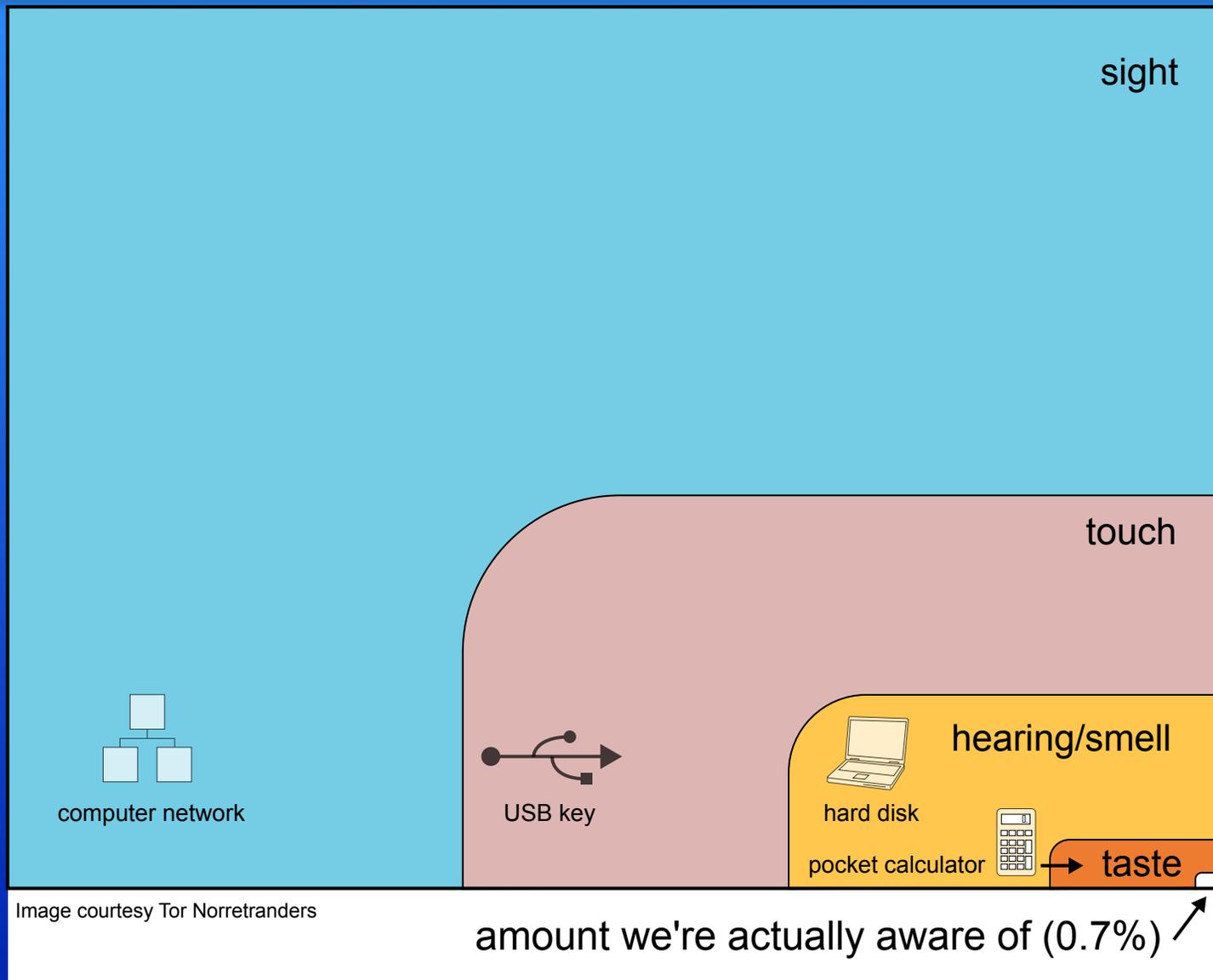
Thus it will take **530,785,562,327** trees to store an Exabyte of data

In 2005, there were **400,246,300,201** trees on Earth

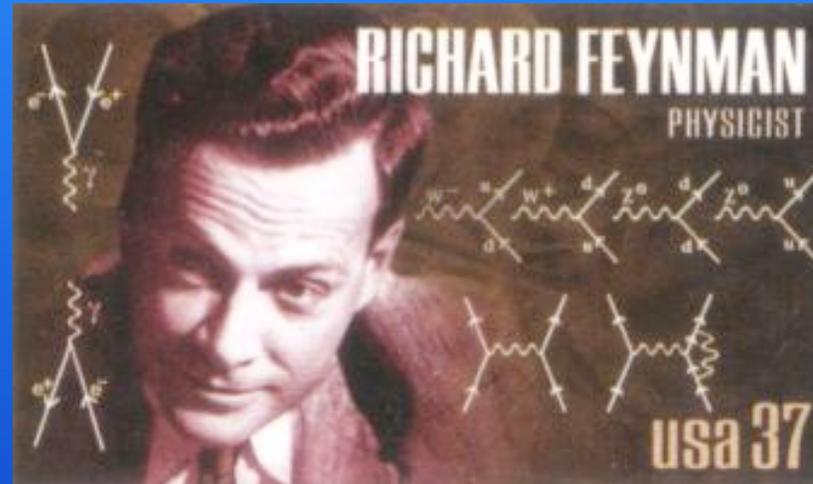
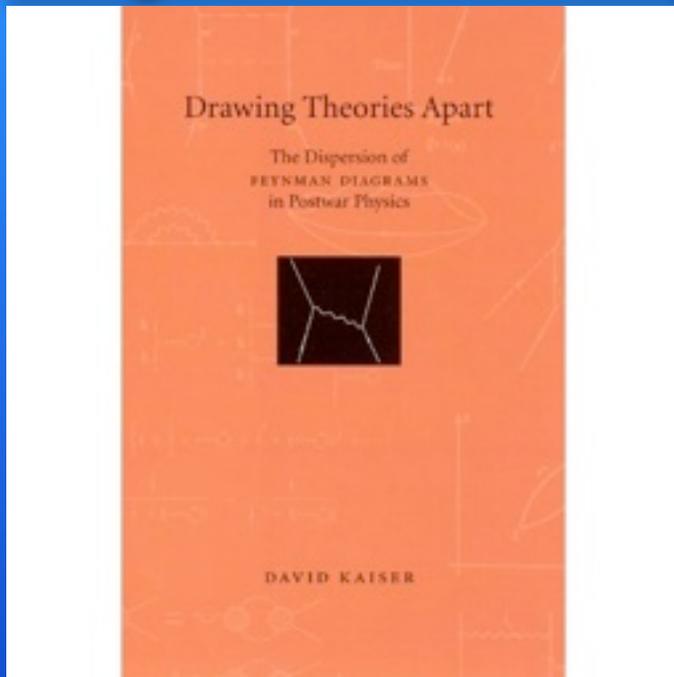
We can store **.75** Exabytes of data using all the trees on the entire planet.

Sources: <http://www.whatsabyte.com/> and <http://wiki.answers.com>

# Brain Information Bandwidth



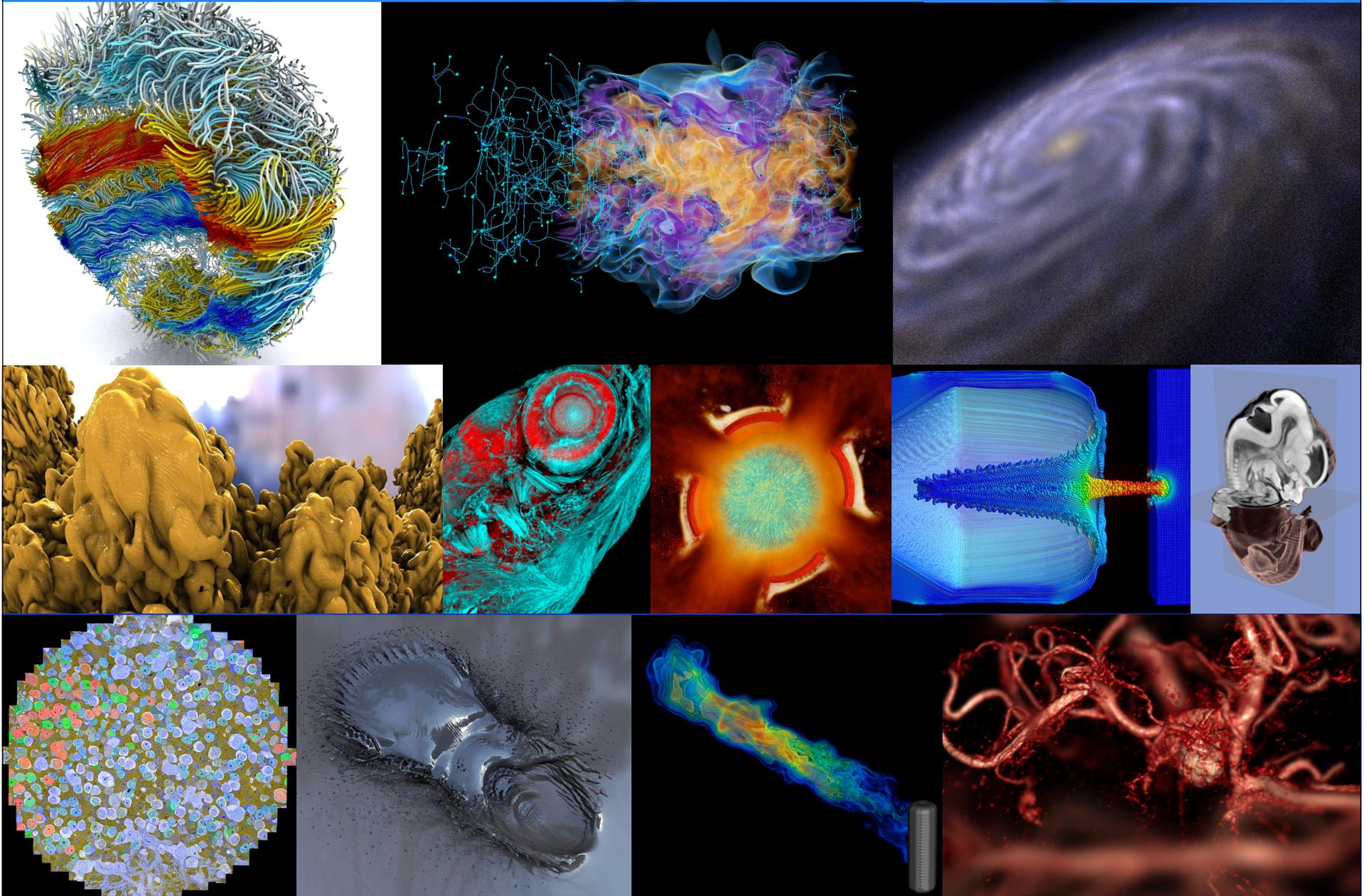
# Feynman Diagrams

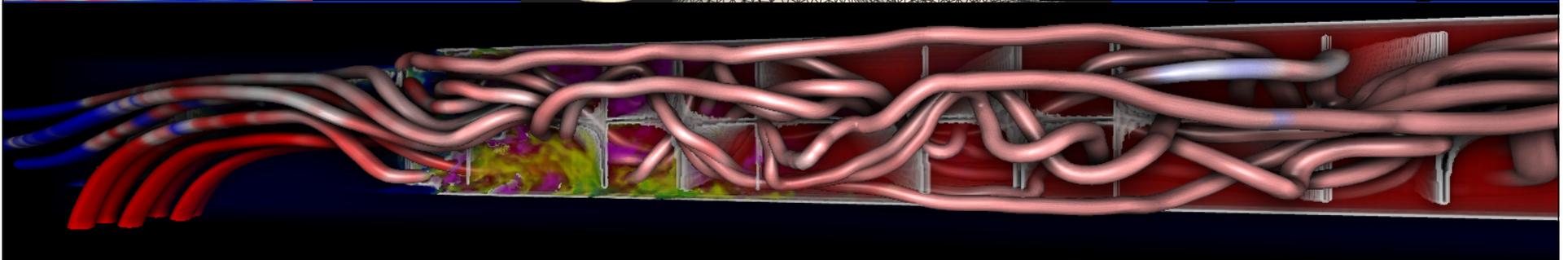
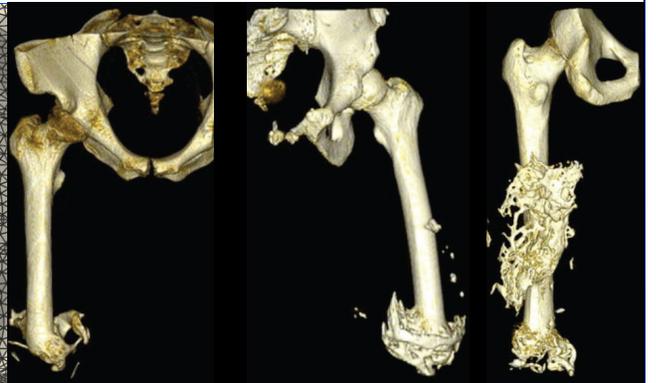
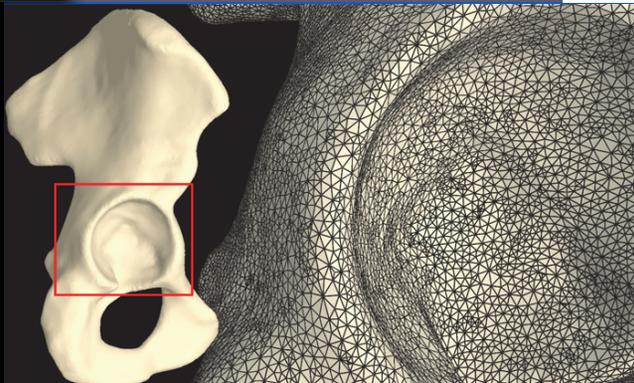
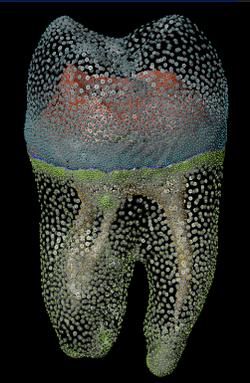
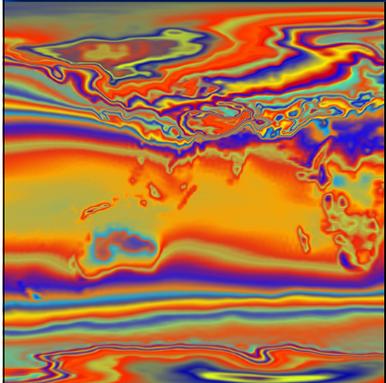
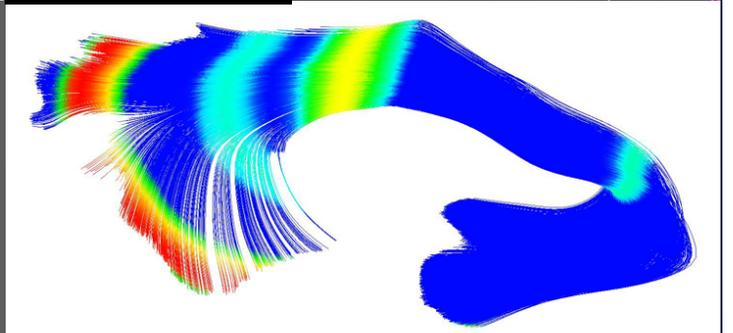
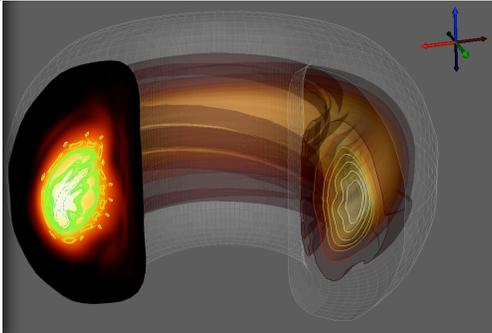
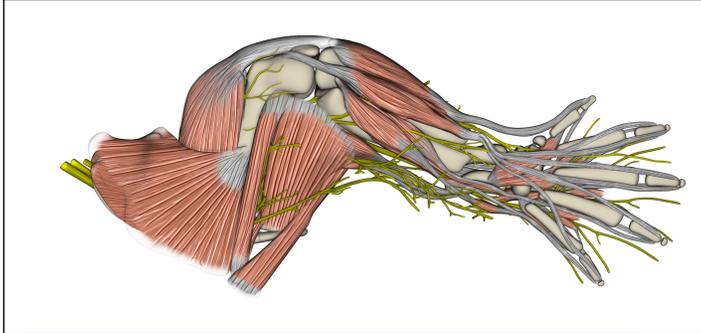
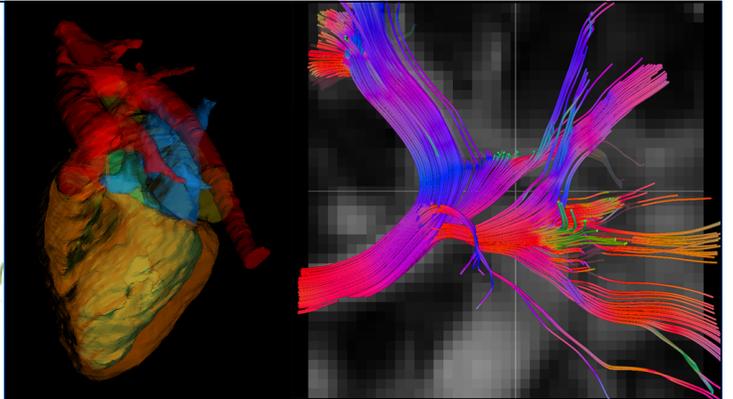
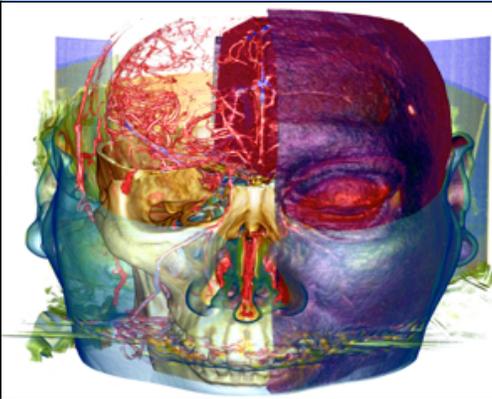
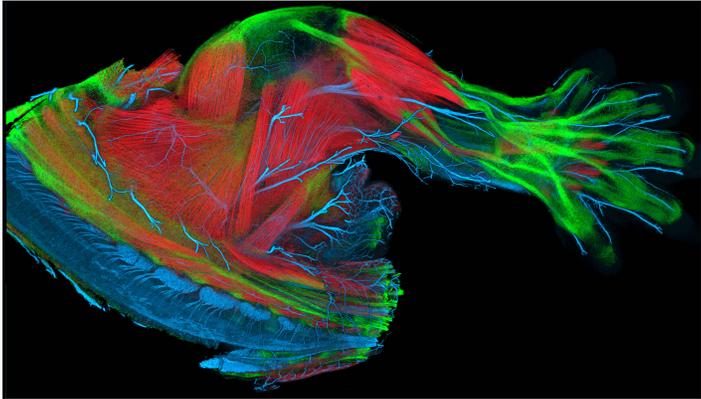


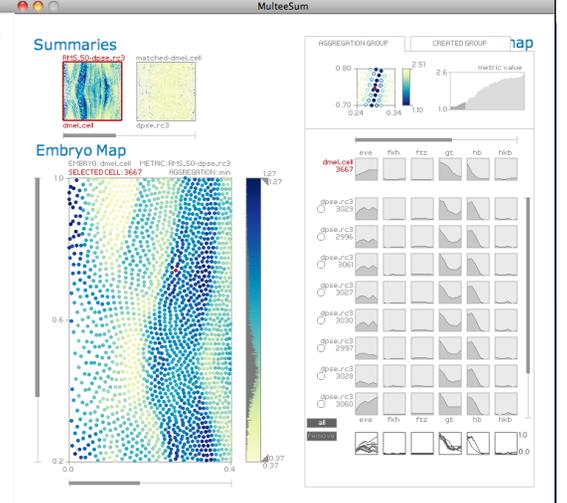
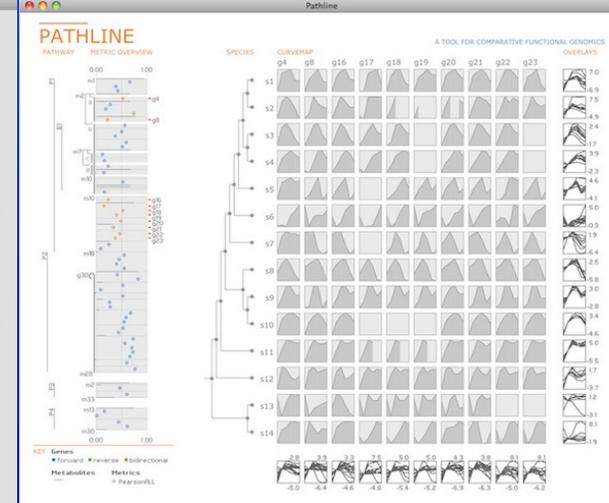
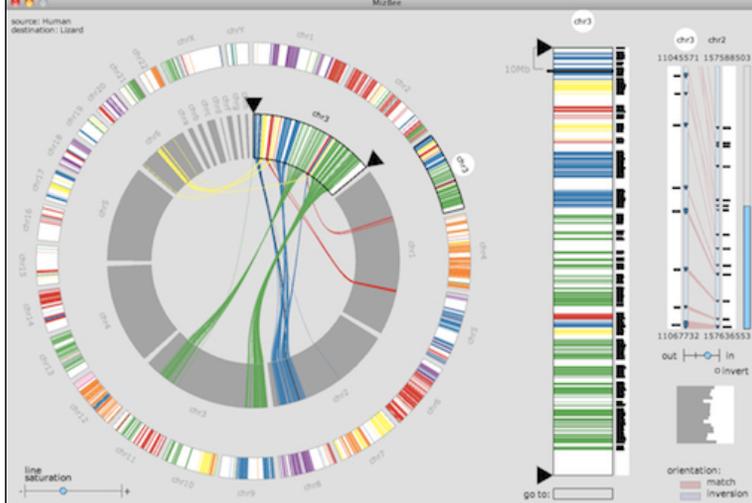
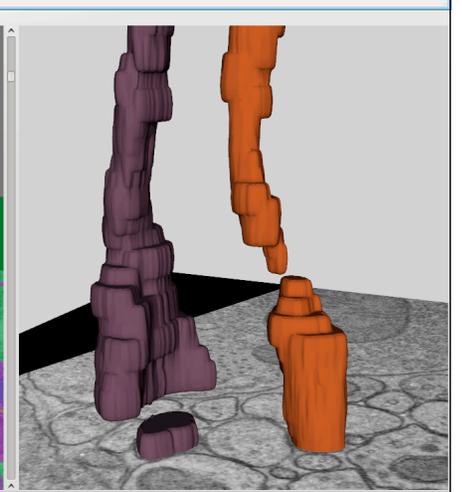
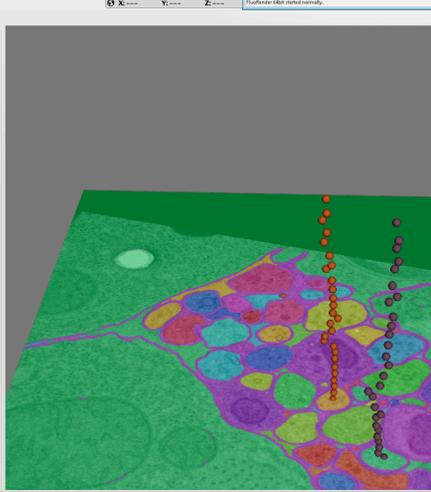
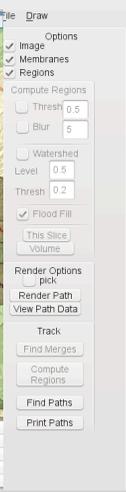
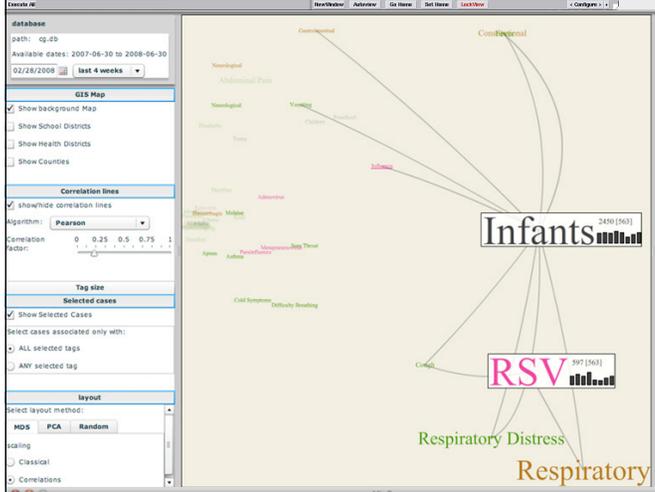
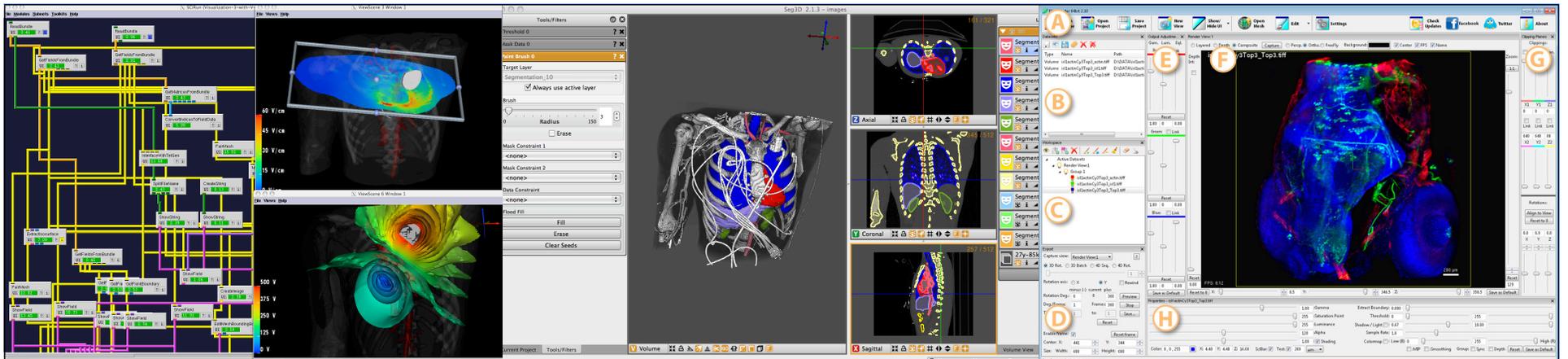
Feynman: “What I am really try to do is bring birth to clarity, which is really a half-assedly thought-out-pictorial semi-vision thing. I would see the jiggle-jiggle-jiggle or the wiggle of the path. Even now when I talk about the influence functional, I see the coupling and I take this turn - like as if there was a big bag of stuff - and try to collect it in away and to push it. It's all visual. It's hard to explain.”

James Gleick, *The Life and Science of Richard Feynman*, Vintage Books, New York, 1992.

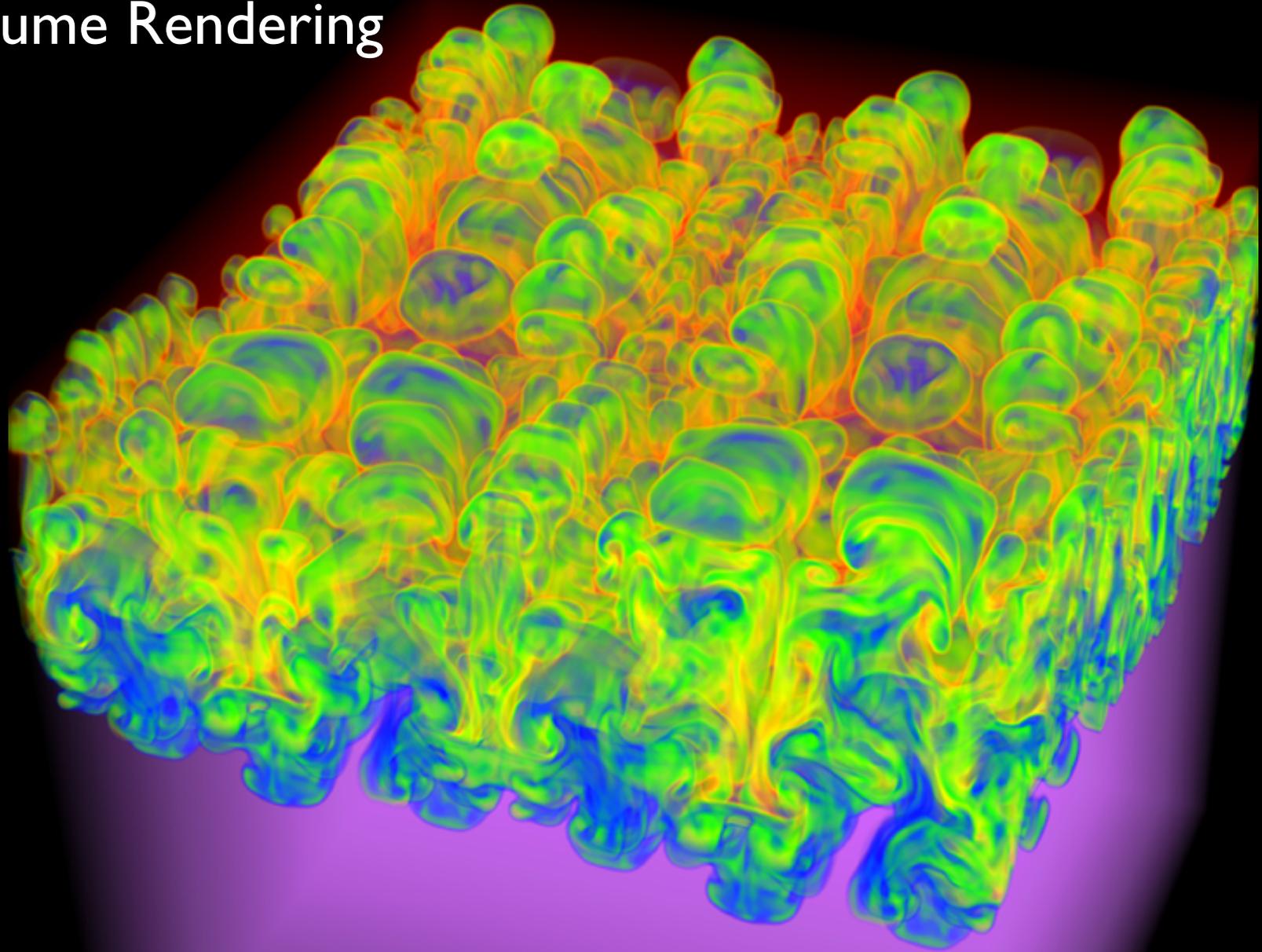
# New Visual Analysis Techniques



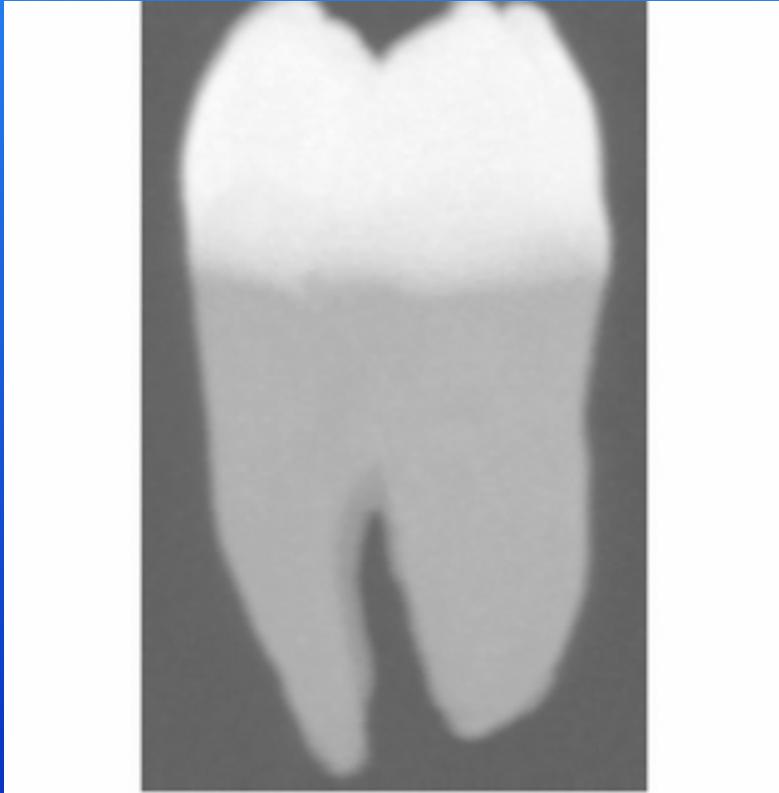




# Volume Rendering



# Volume Rendering

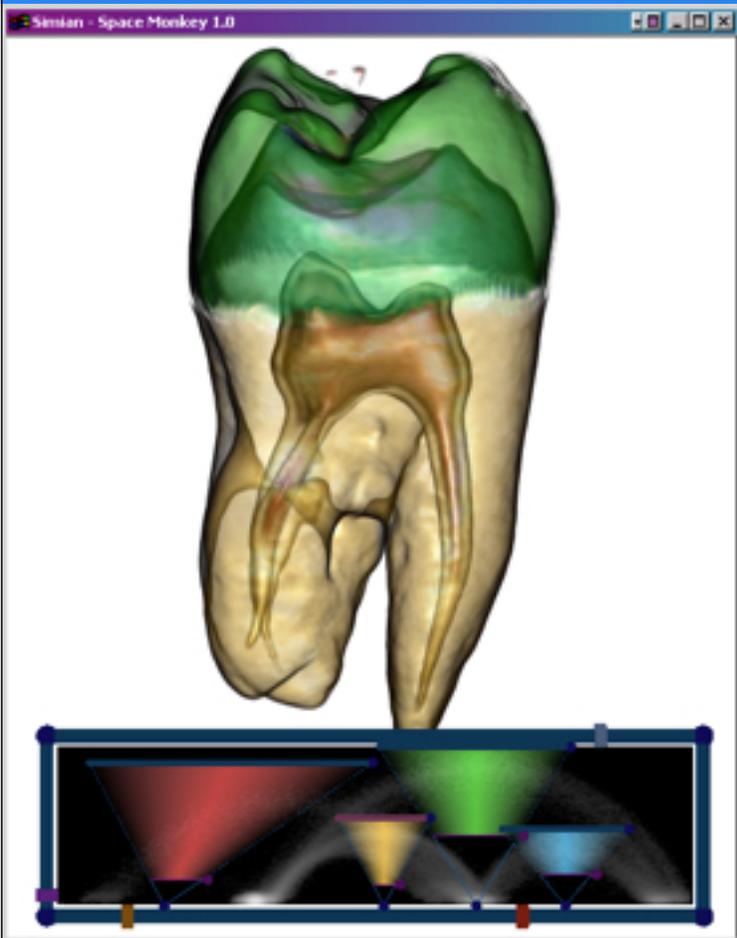


**Maximum Intensity Projection (MIP)**

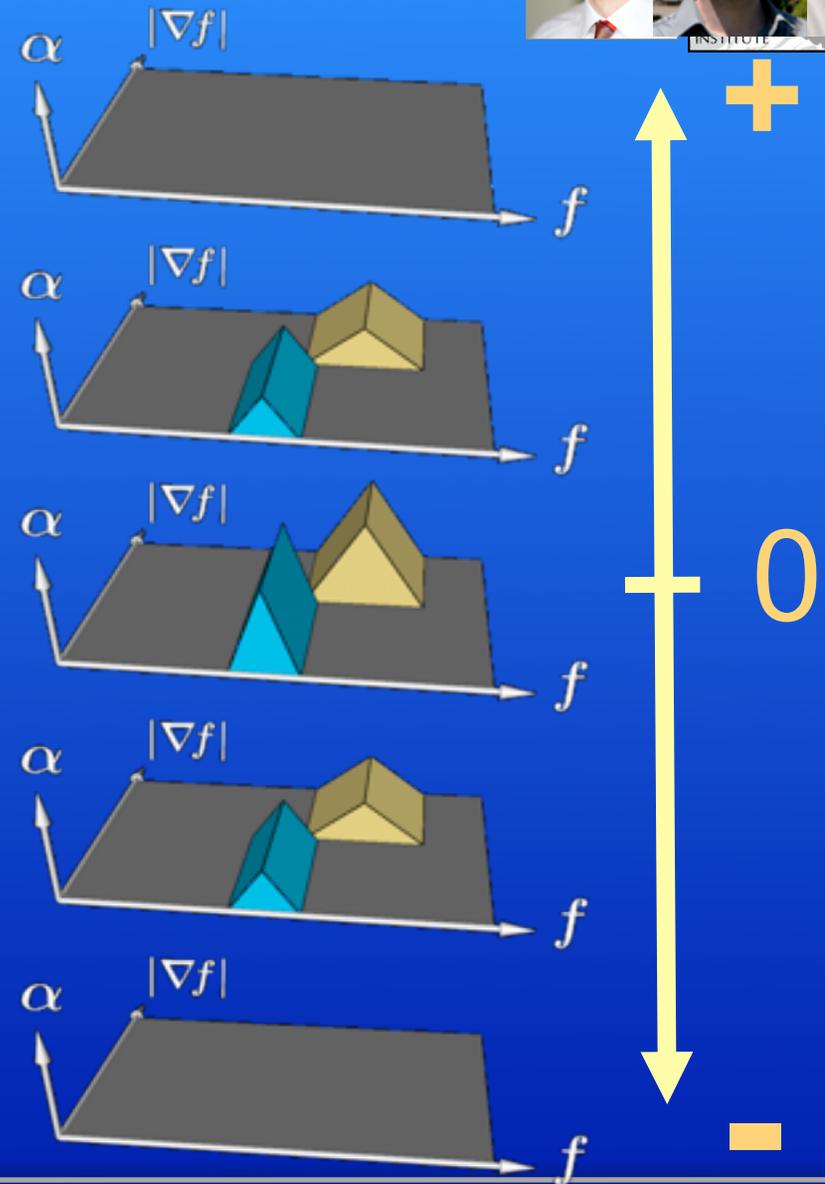


**Full Volume Rendering**

# Multi-Dimensional Transfer Function



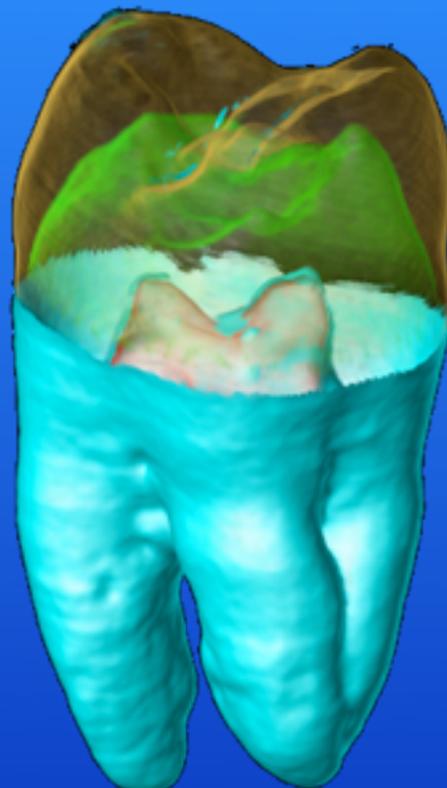
$$\text{RGB} \alpha(f, |\nabla f|, D^2_{\nabla f} f)$$



# Volume Rendering



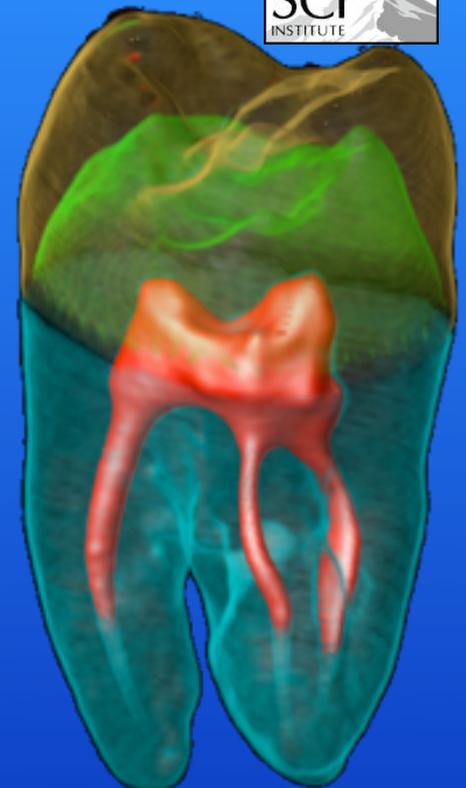
enamel /  
background



dentin / background



dentin / enamel



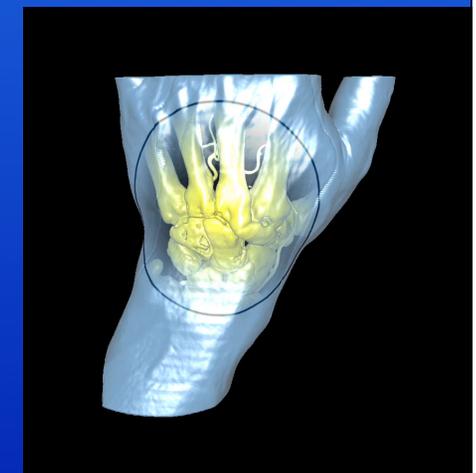
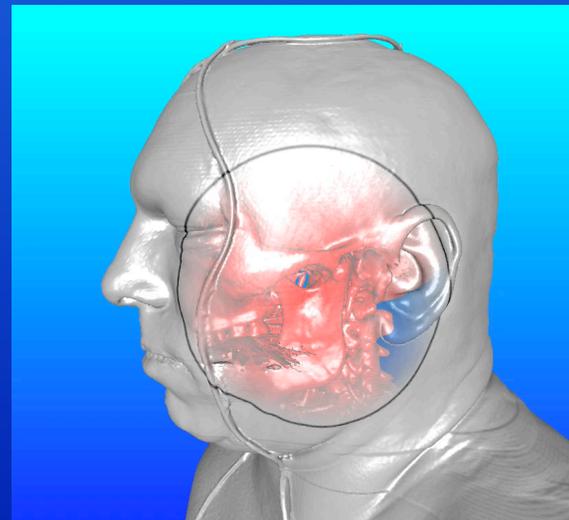
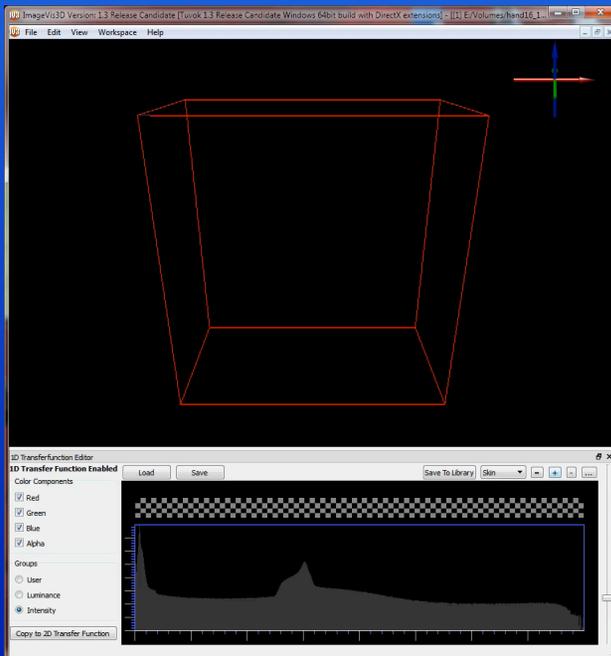
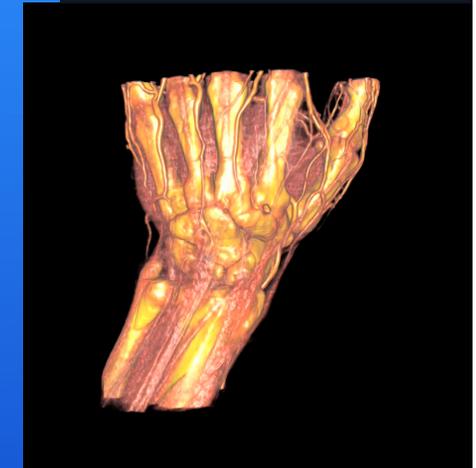
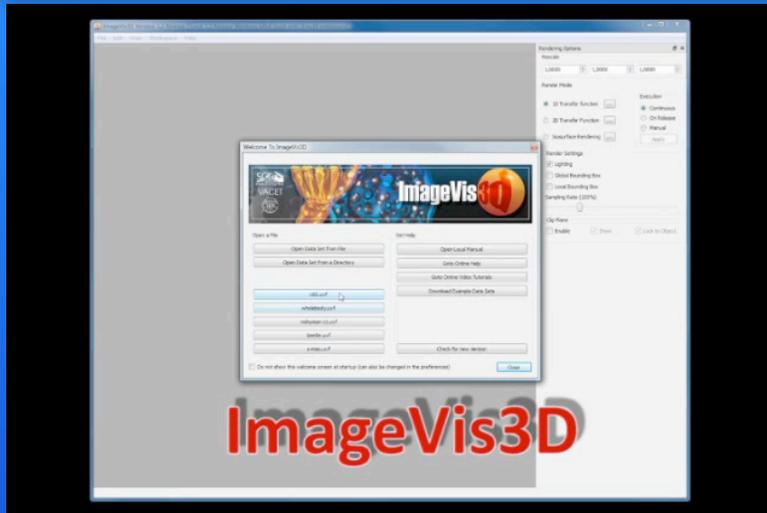
dentin / pulp



**1D: not possible**

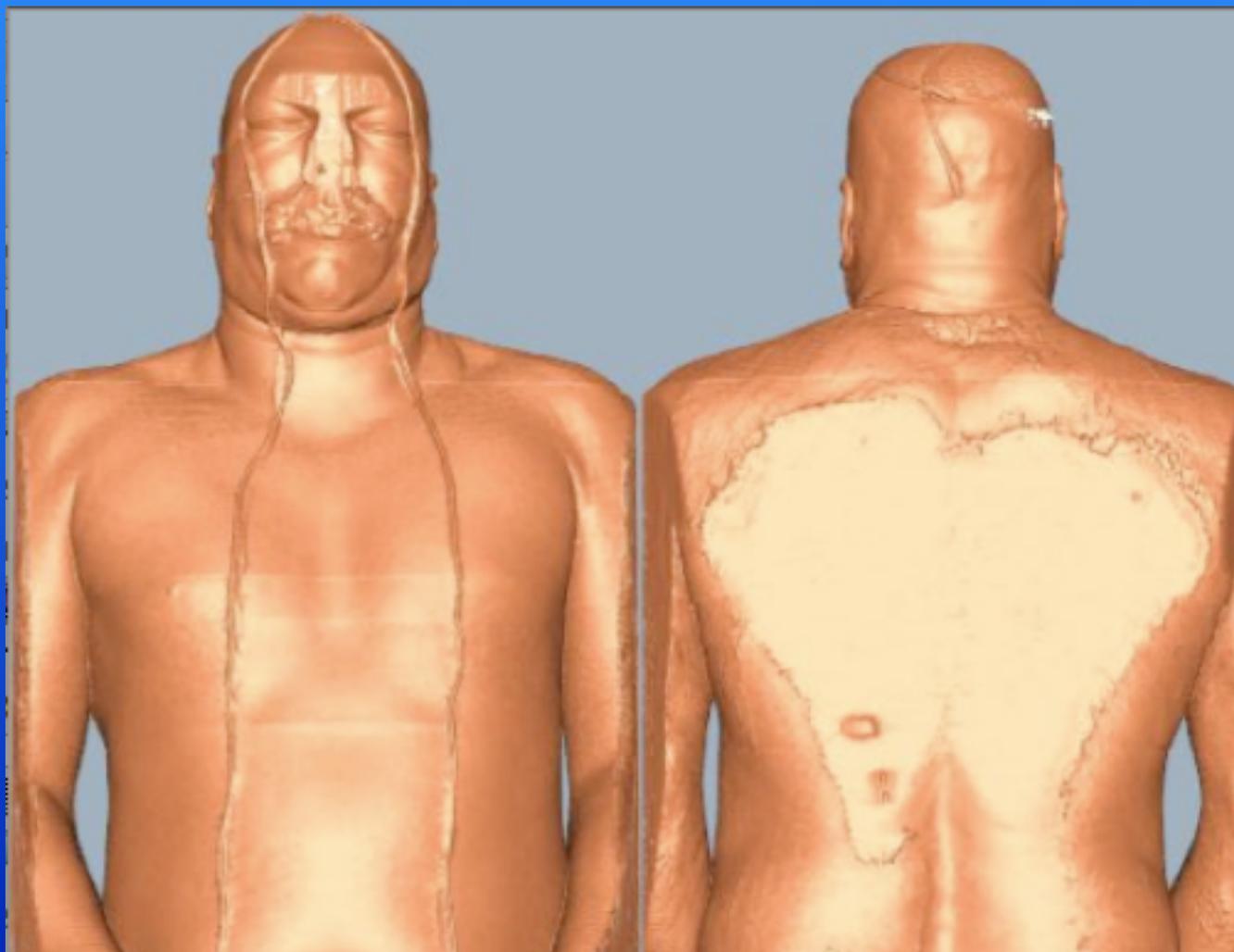
**2D: specificity not as good**

# Volume Visualization



Scientific Computing and Imaging Institute, University of Utah

# NIH Visible Male



Scientific Computing and Imaging Institute, University of Utah

# Visible Human - High Resolution



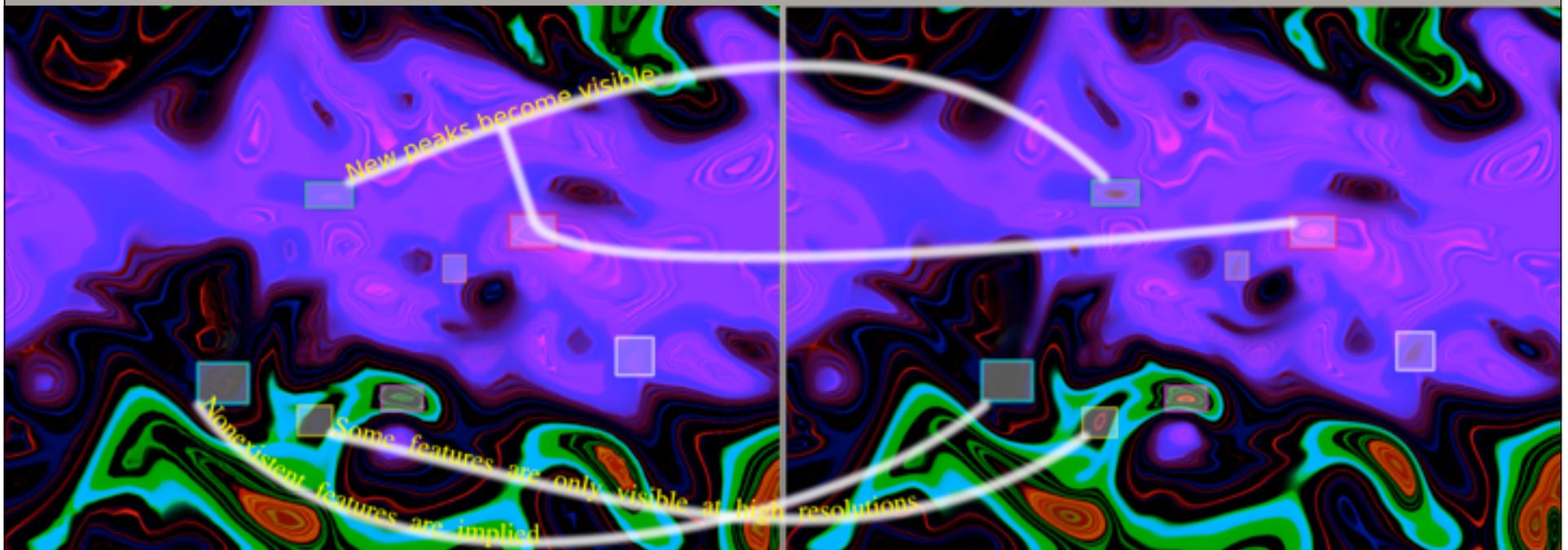
Scientific Computing and Imaging Institute, University of Utah



## The Need for High Resolution Visualization

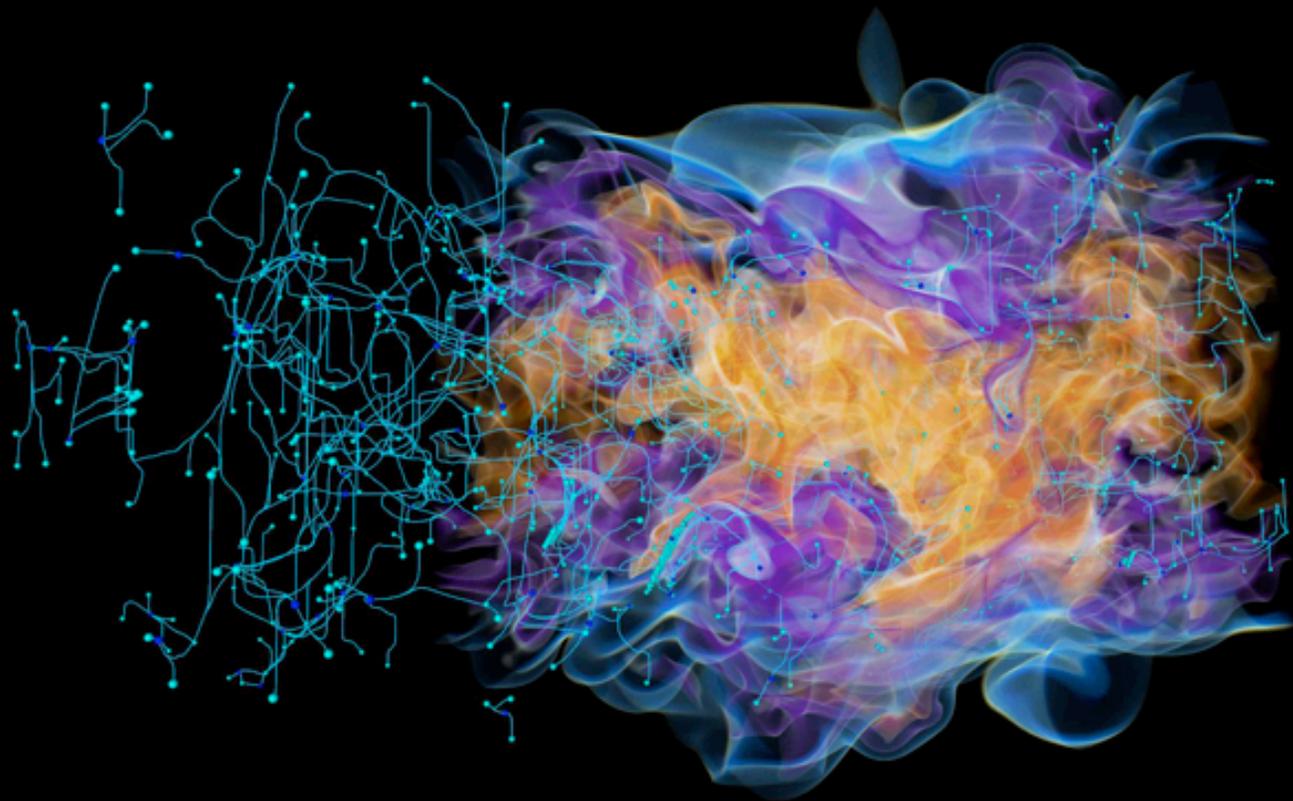
“...the data show for the first time how detailed transport and chemistry effects can influence the mixing of reactive scalars. It may be advantageous to incorporate these effects within molecular mixing models. It is worth noting that at present it is impossible to obtain this type of information any other way than by using the type of highly resolved simulation performed here.”

Jacqueline Chen, Sandia National Laboratories



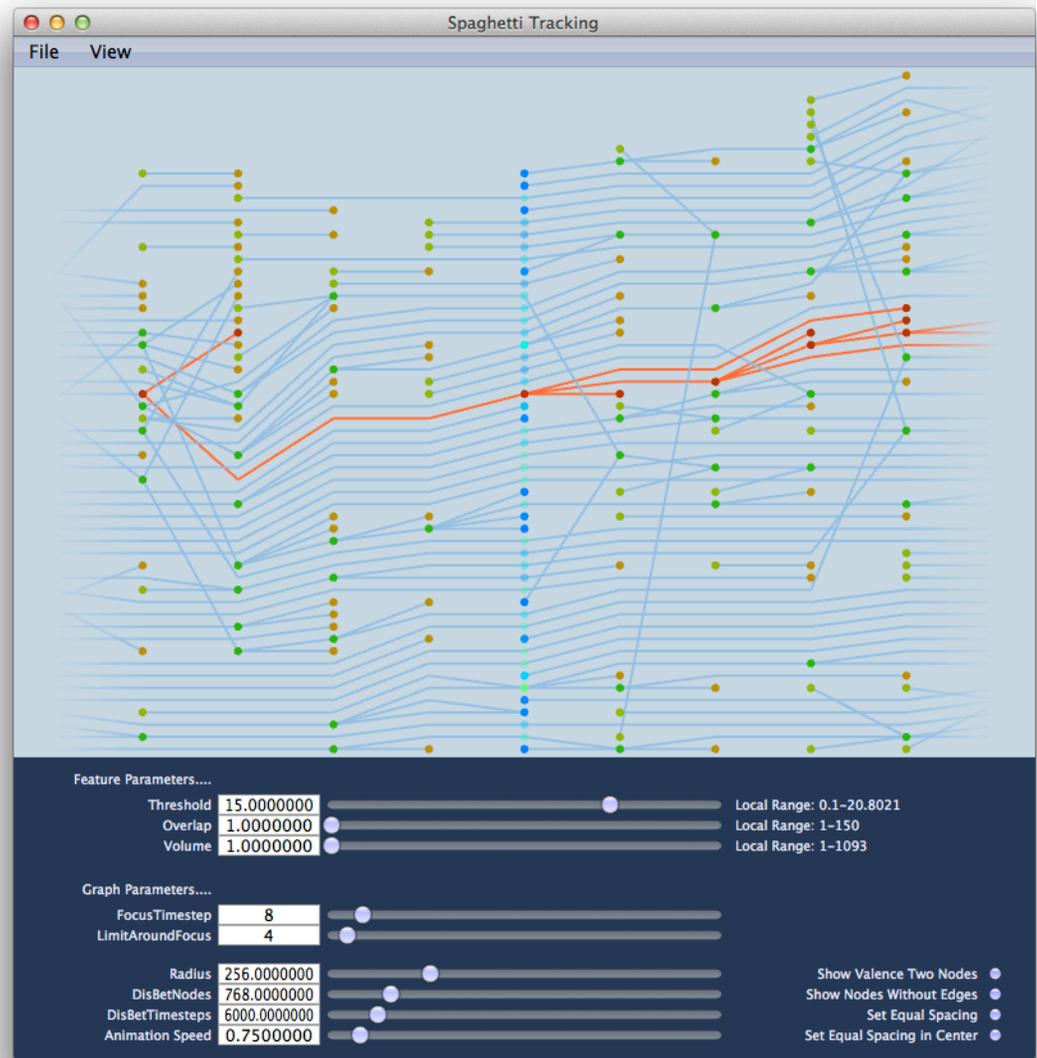
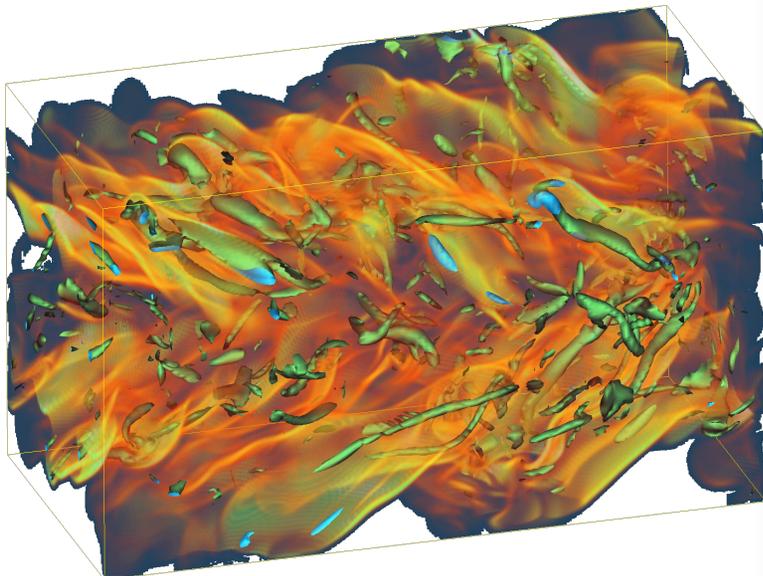
Lower Resolution

High Resolution



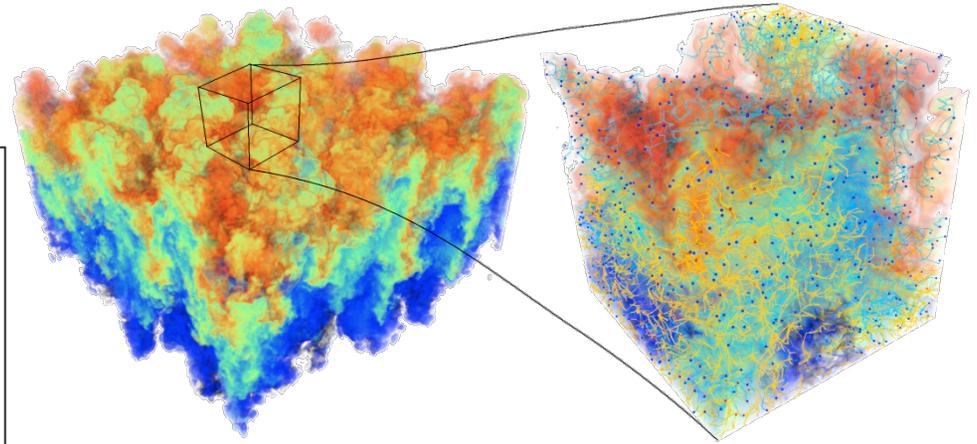
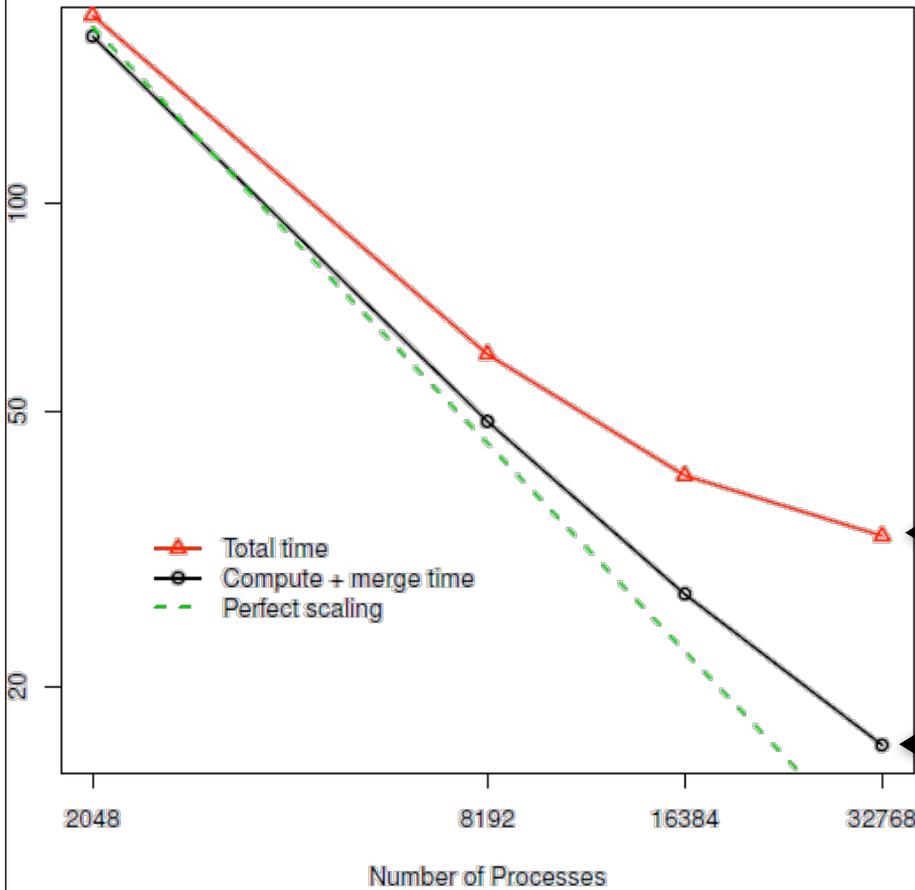
# Topological Analysis of Massive Combustion Simulations

- Non-premixed DNS combustion (J. Chen, SNL): Analysis of the time evolution of extinction and reignition regions for the design of better fuels



# New Parallel Topological Computations Achieve High Performance at Scale

Total & Compute+Merge Time For Rayleigh–Taylor Mixing



Computation + I/O

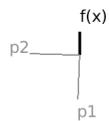
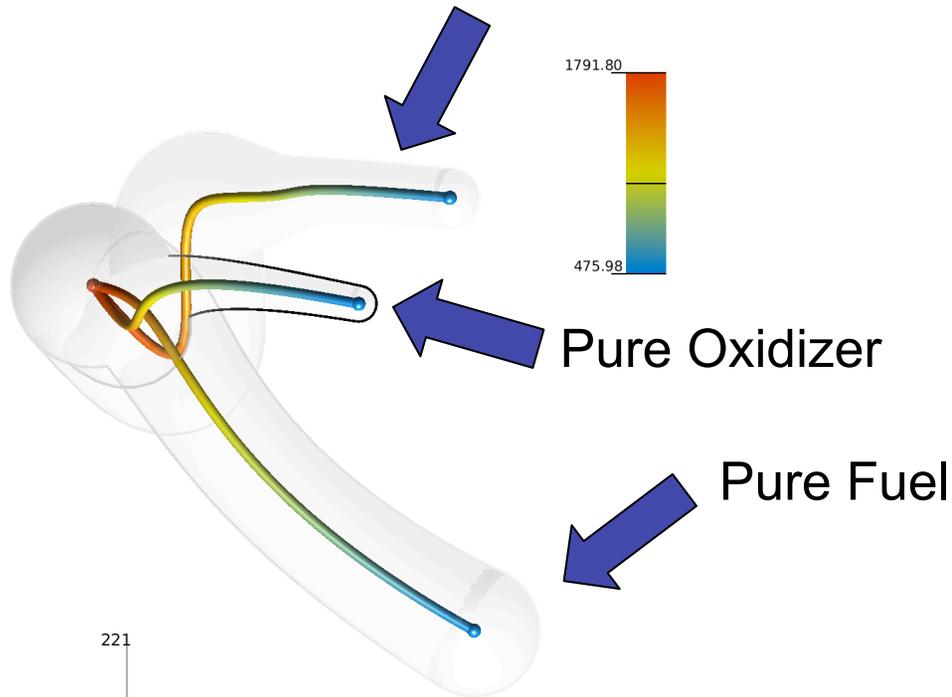
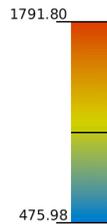
Pure Computation

# Visualization of 10D Combustion Simulation of Jet CO/H<sub>2</sub>-Air Flames

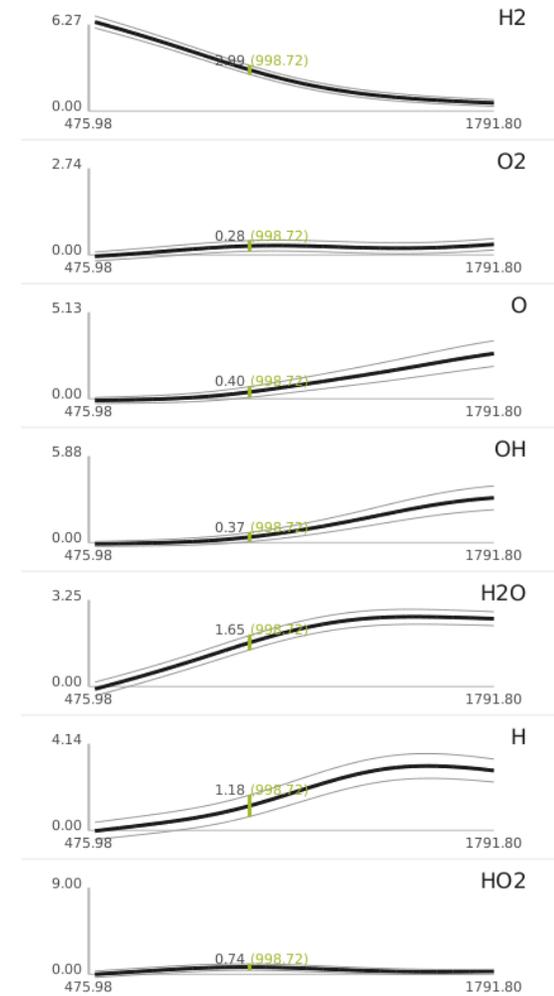


Local Extinction

Value: 1066.76  
Input std: 0.61  
Density: 0.0004



10 dimensional data set describing the heat release wrt. to various chemical species in a combustion simulation





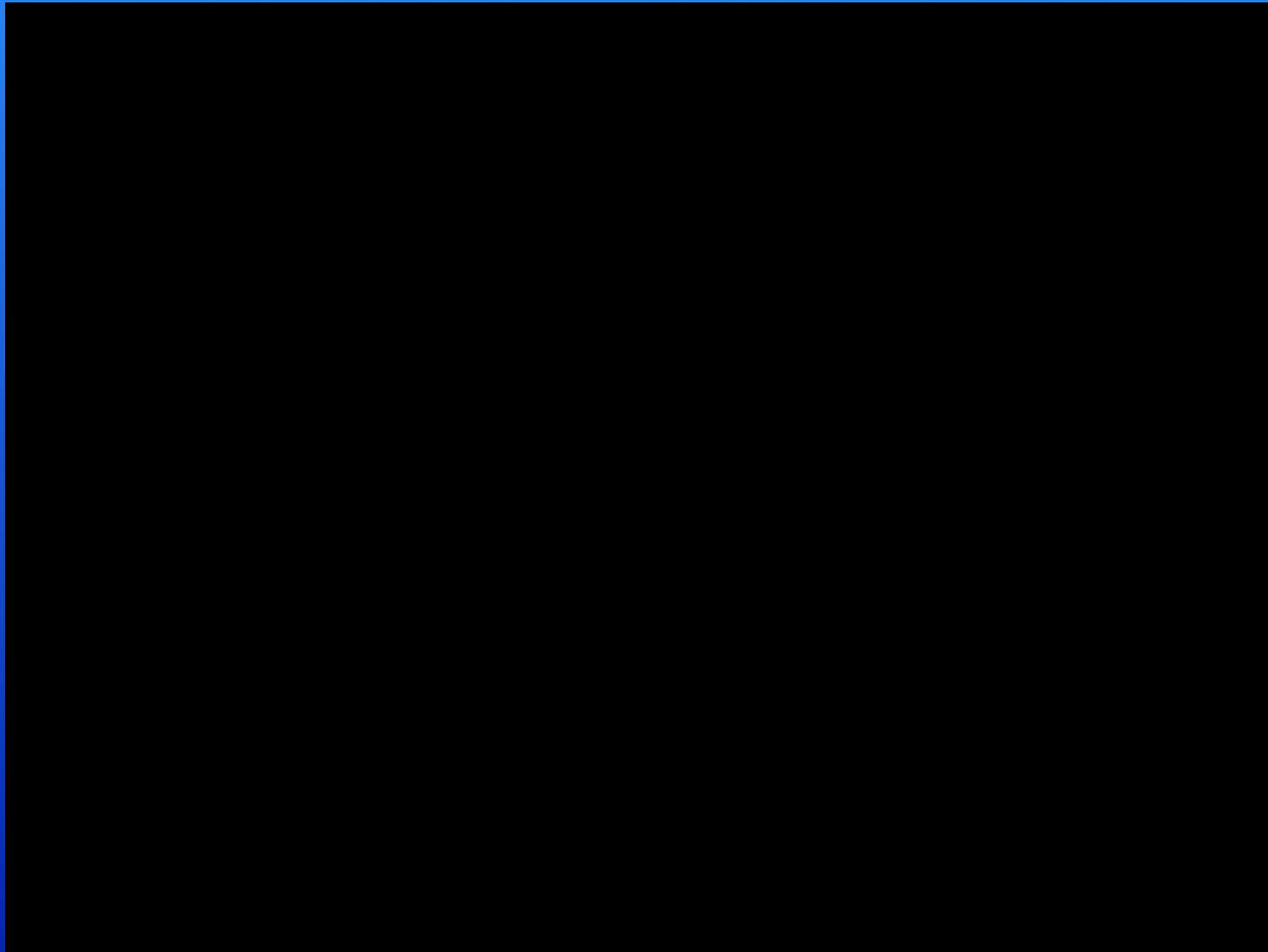
## Combustion Simulation of Jet CO/H<sub>2</sub>-Air Flames

**Input:** Composition of 10 chemical species

**Output:** Temperature

# Michelangelos David

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Scientific Computing and Imaging Institute, University of Utah

# Michelangelo David - Part 2



**One billion polygons  
to billions of pixels**

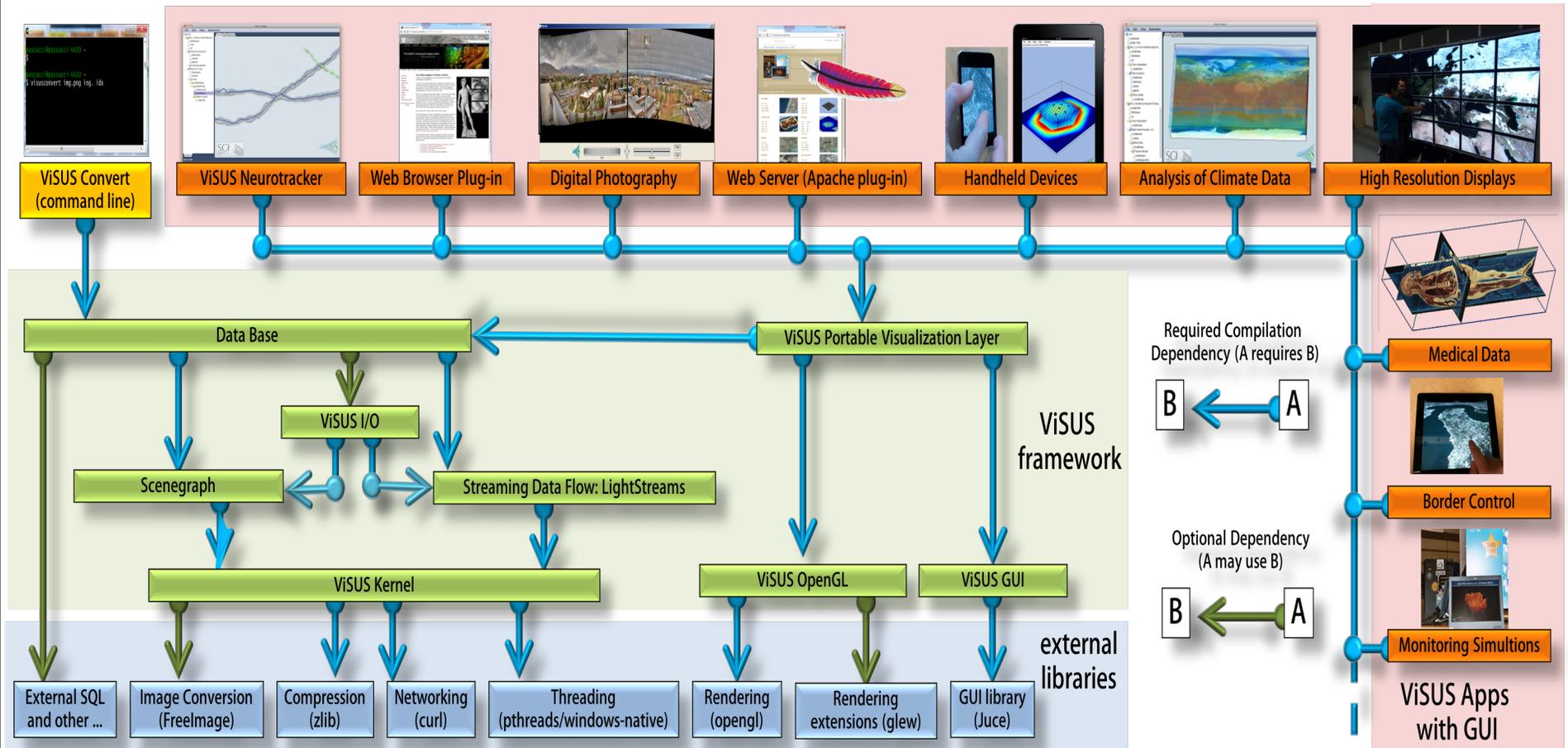
Welcome to the first  
gigapixel, multi-view  
rendering of

The Digital Michelangelo  
Project's David



Scientific Computing and Imaging Institute, University of Utah

# ViSUS Framework for Scalable Data

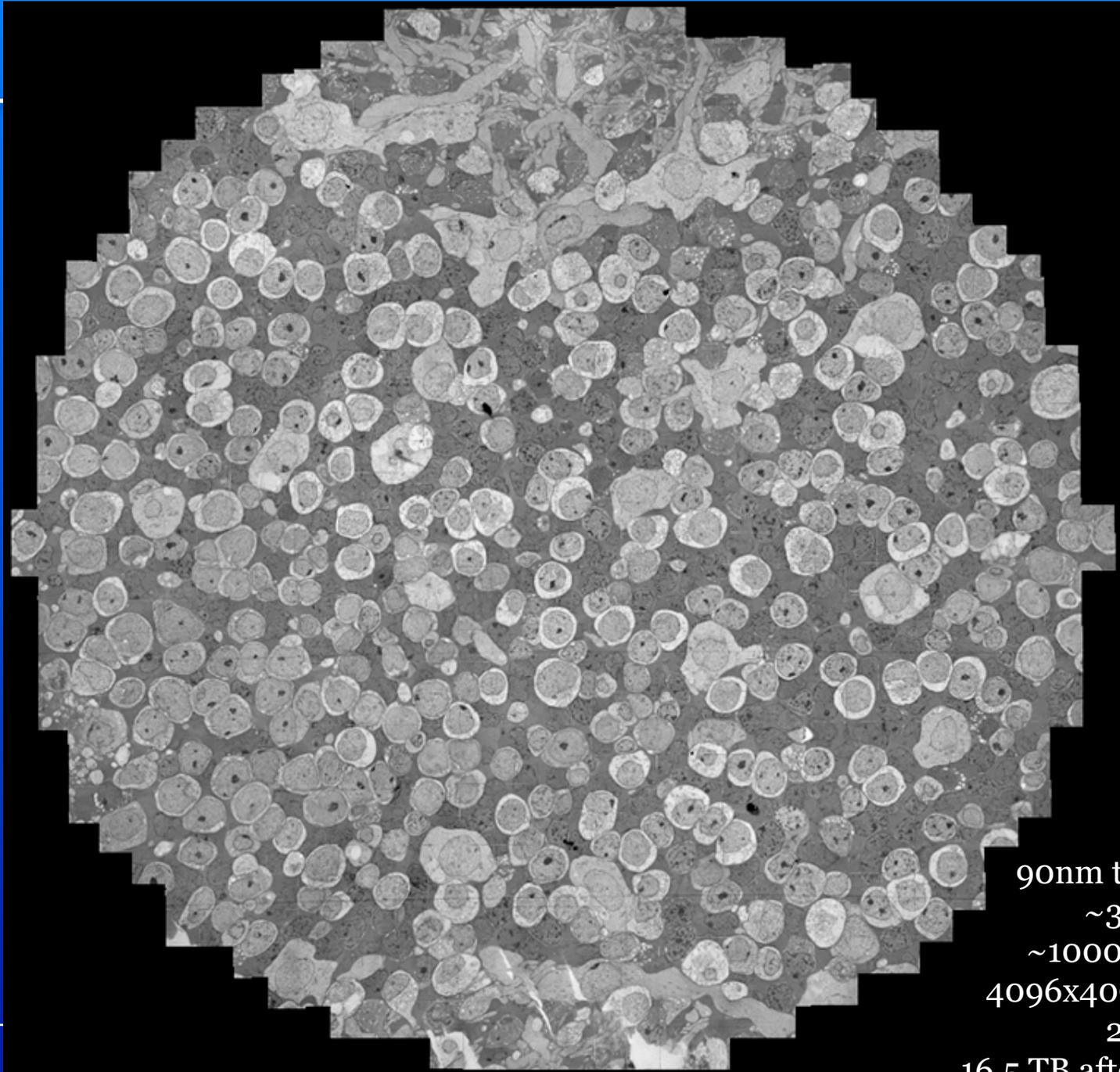


# Large Scale Galaxy Simulation



**GALAXY SPIRAL  
ARM FORMATION**

Scientific Computing and Imaging Institute, University of Utah



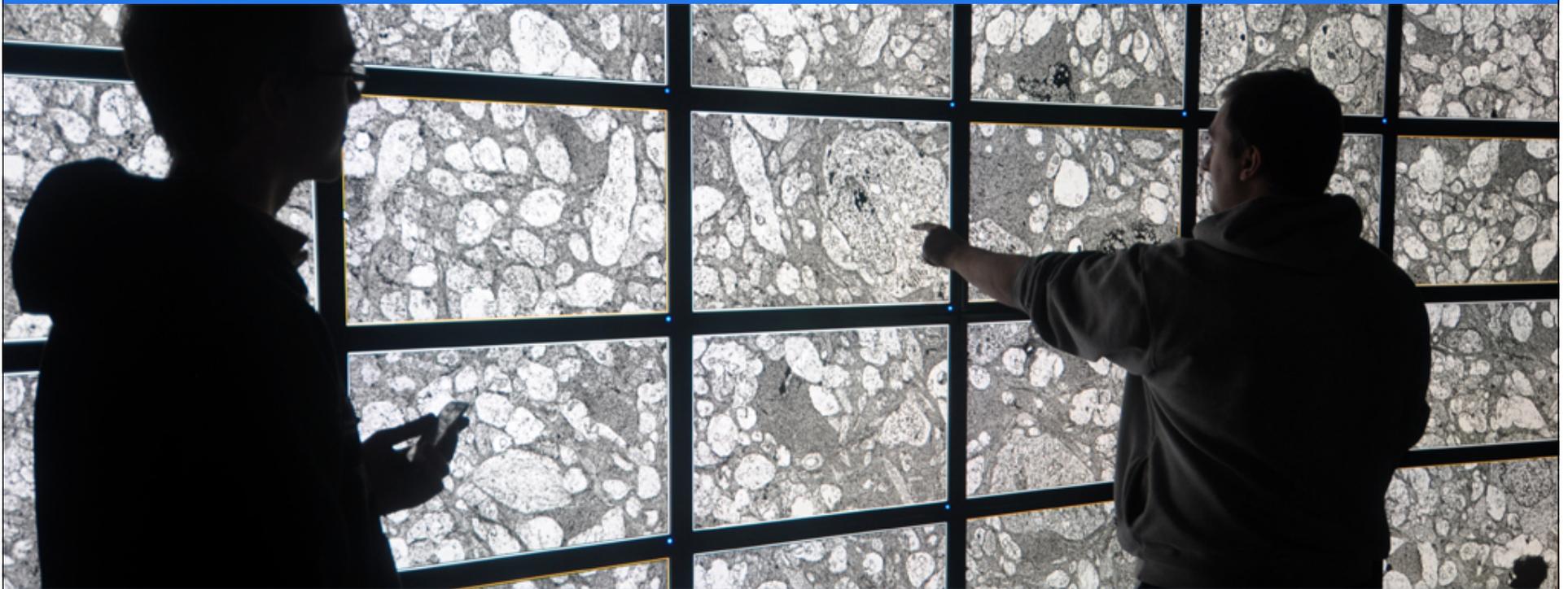
341 Sections  
90nm thick sections  
~32GB/Section  
~1000 tiles/section  
4096x4096 pixels/tile  
2.18  $\mu$ m/Pixel  
16.5 TB after processing

# Antony van Leeuwenhoek (1632-1723)



*... my work, which I've done for a long time, was not pursued in order to gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than in most other men. And therewithal, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed thereof.*

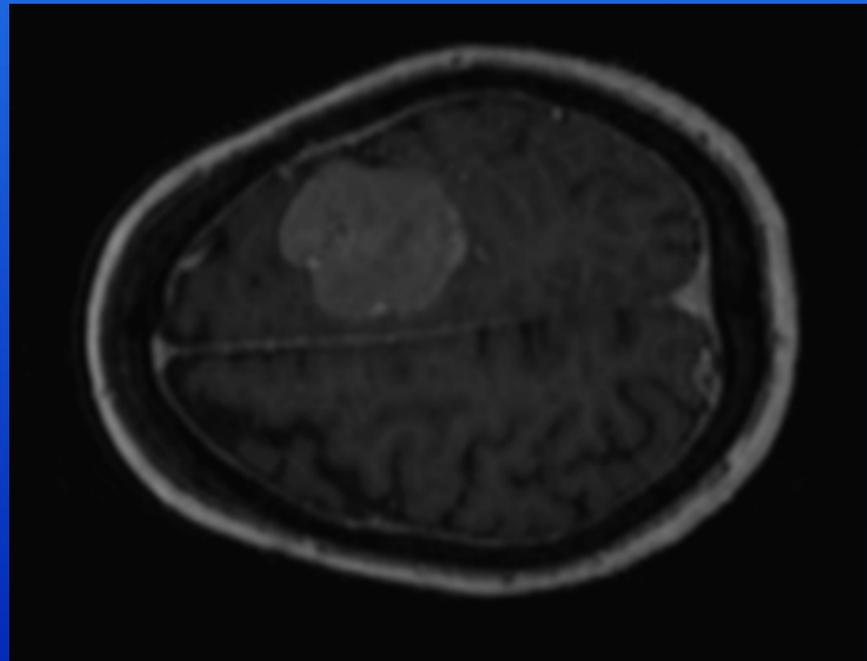
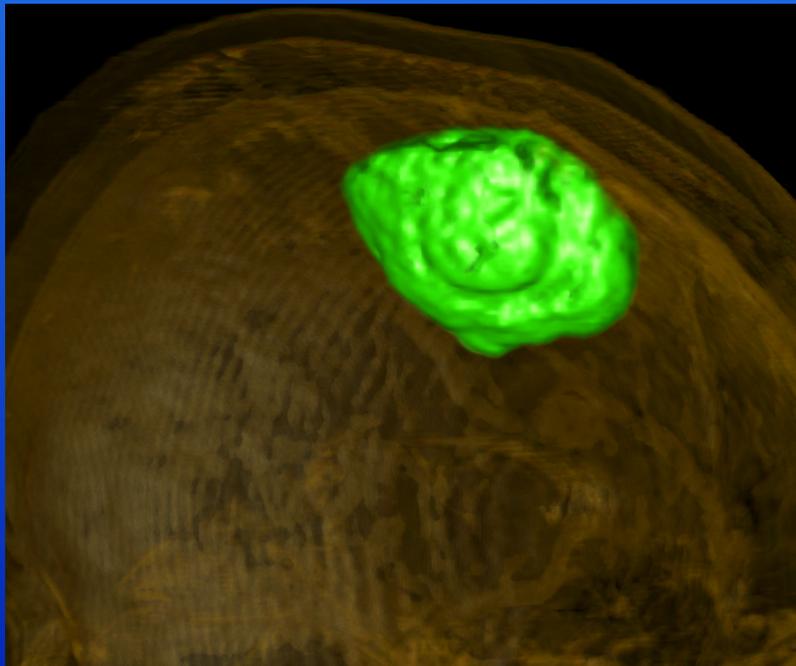
**Antony van Leeuwenhoek. Letter of June 12, 1716**



# Uncertainty Visualization



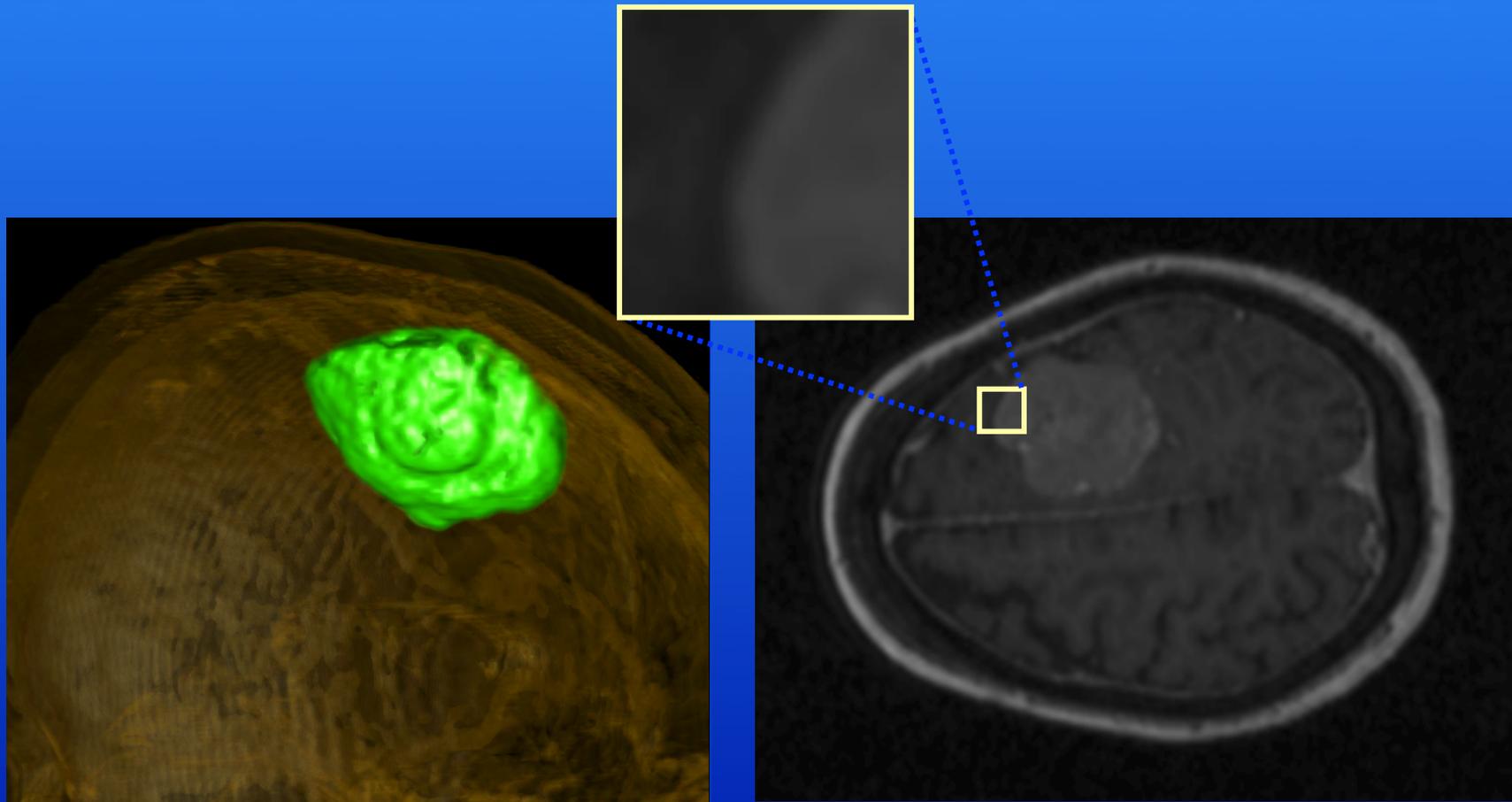
When is the last time you've seen an error bar in a 3D visualization?



# Uncertainty Visualization

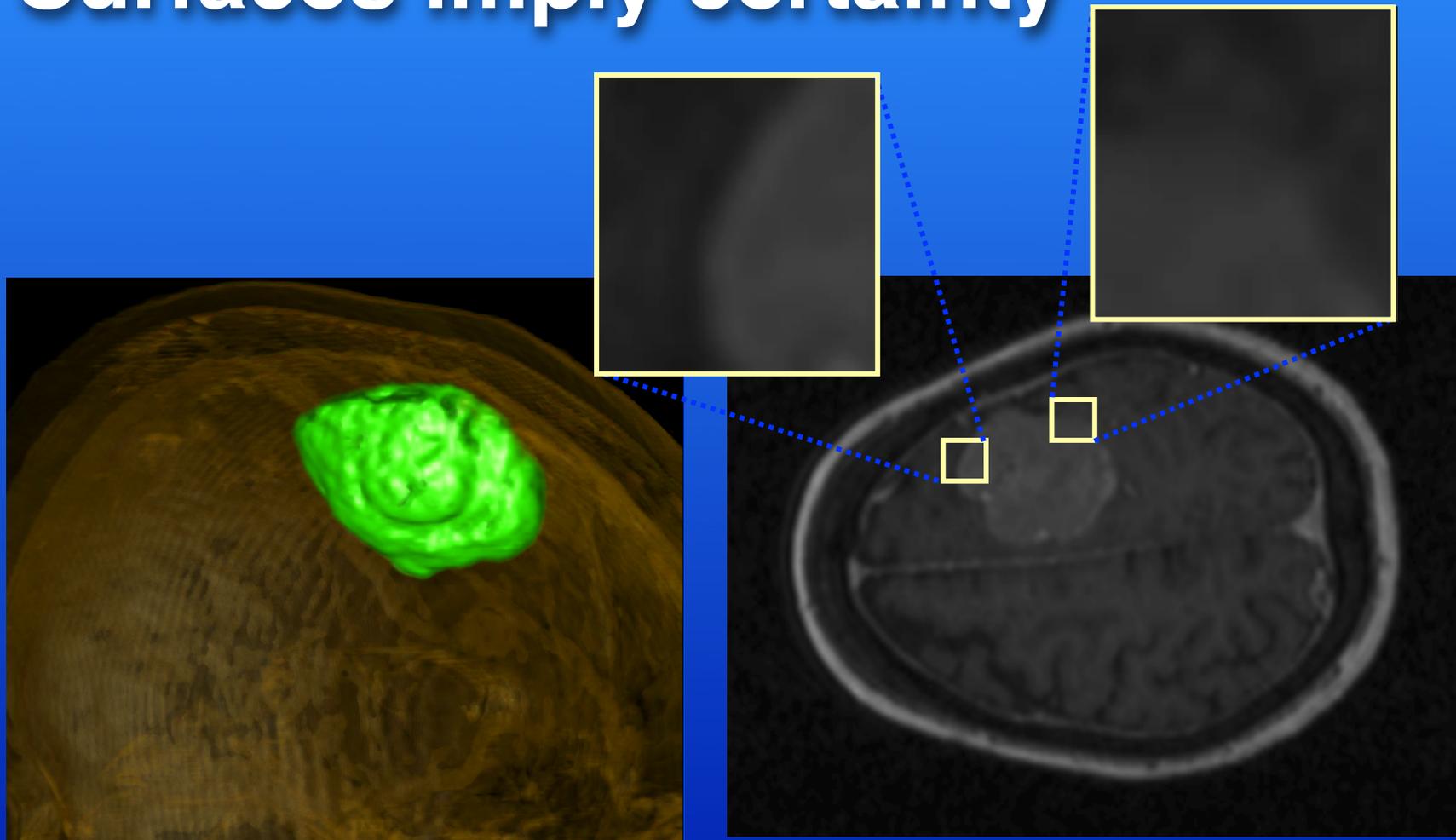


## Surfaces imply certainty



# Uncertainty Visualization

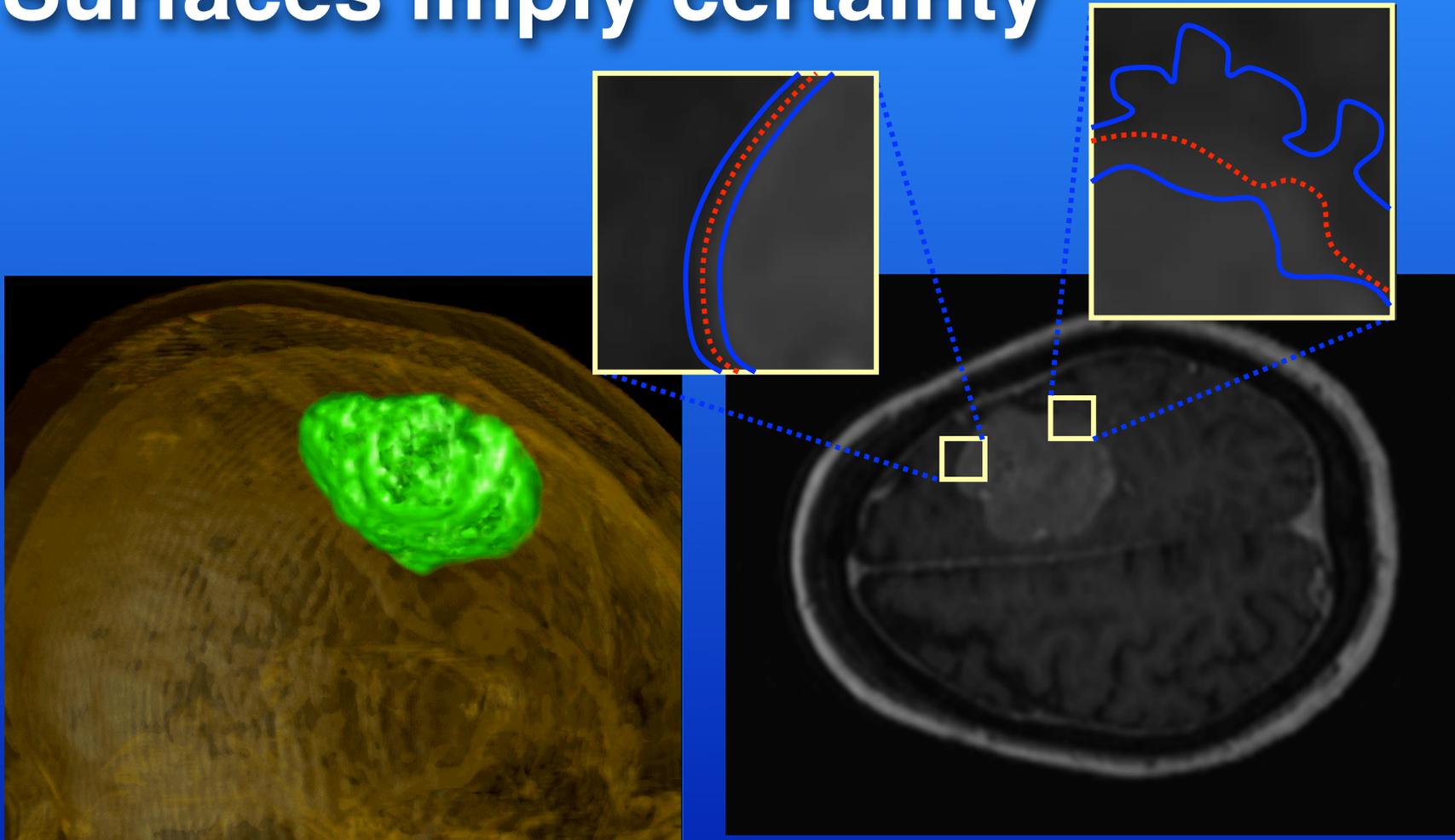
## Surfaces imply certainty



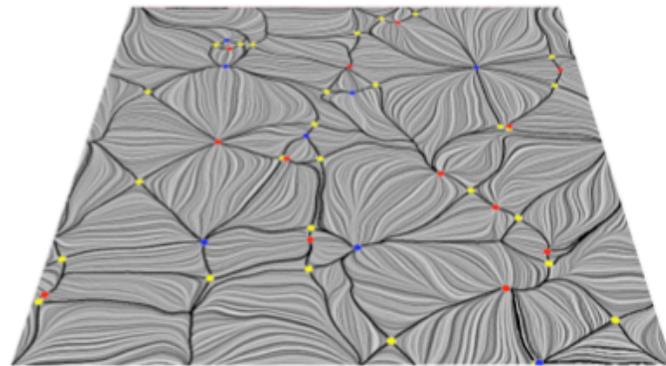
# Uncertainty Visualization



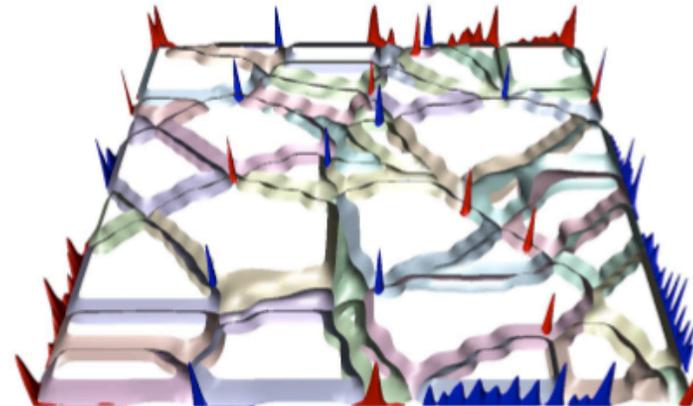
## Surfaces imply certainty



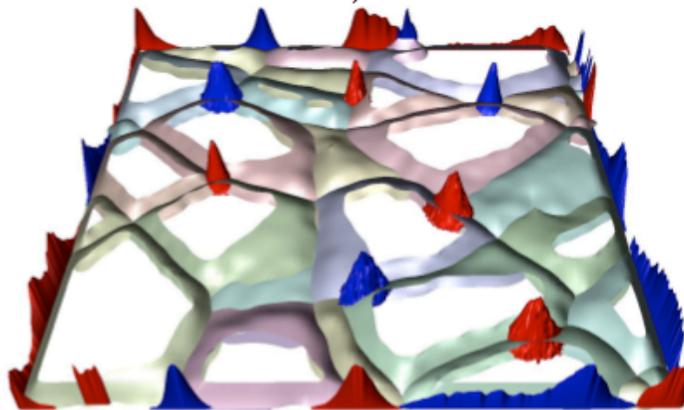
# Topological Uncertainty



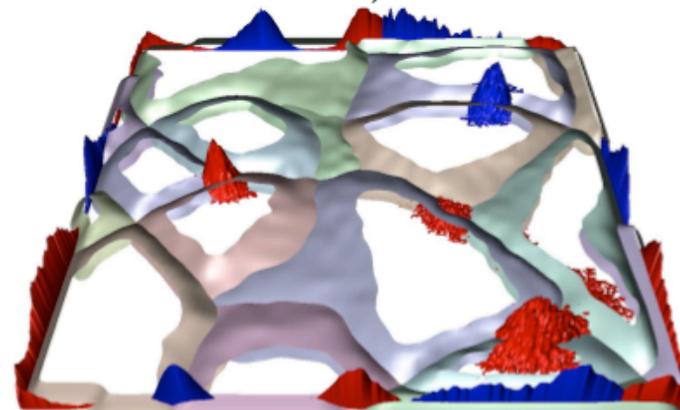
a)



b)



c)

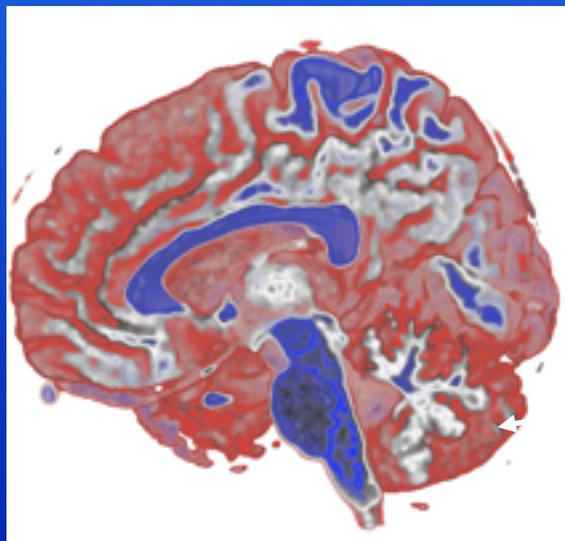
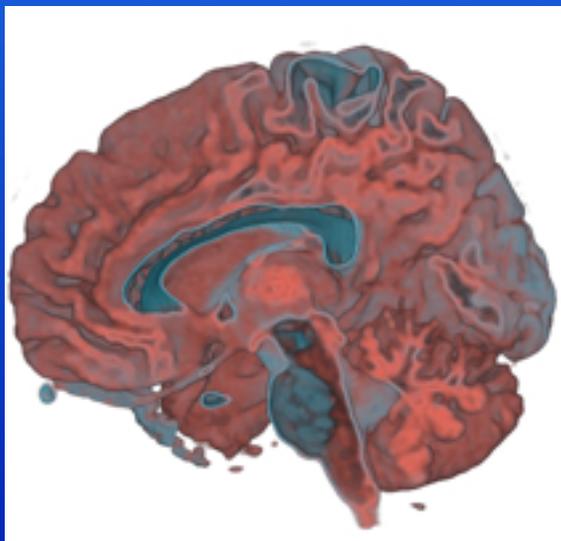
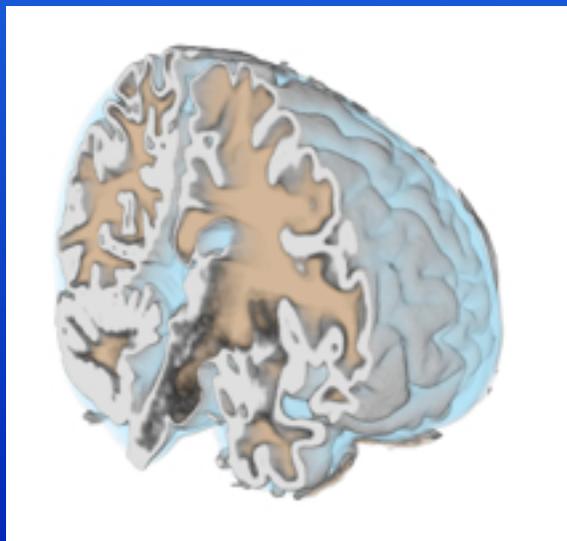
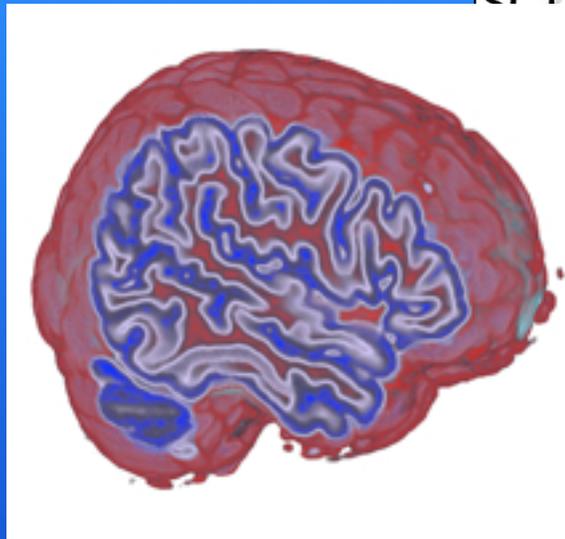
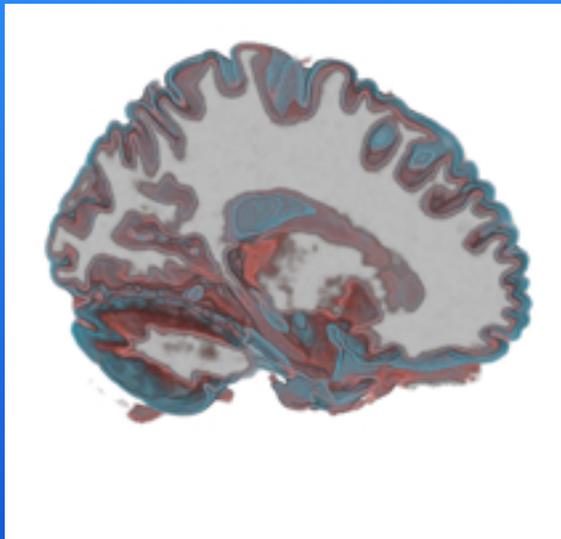
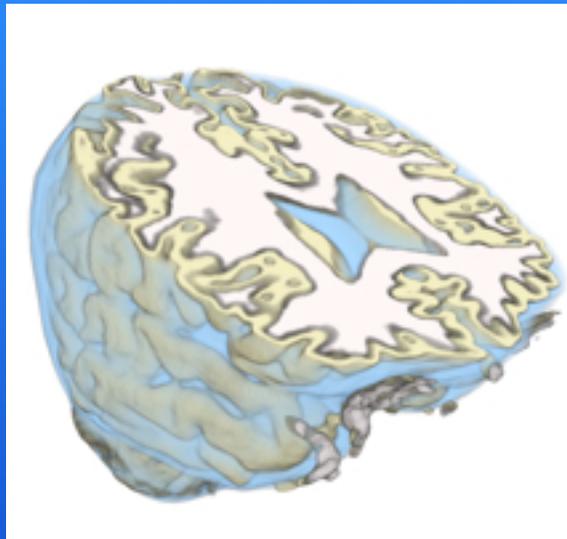


d)

**Figure 6:** Increasing the uncertainty of a random vector field: a) certain topology of mean vector field; b)  $\|\mathbf{T}\|_F = 0.2$ ; c)  $\|\mathbf{T}\|_F = 2.0$ ; d)  $\|\mathbf{T}\|_F = 5.0$ .

M. Otto, T. Germer, H.C. Hege, H. Theisel. Uncertain 2D Vector Field Topology. In *CGF*, 29(2), 2010.

# Visualizing Uncertainty



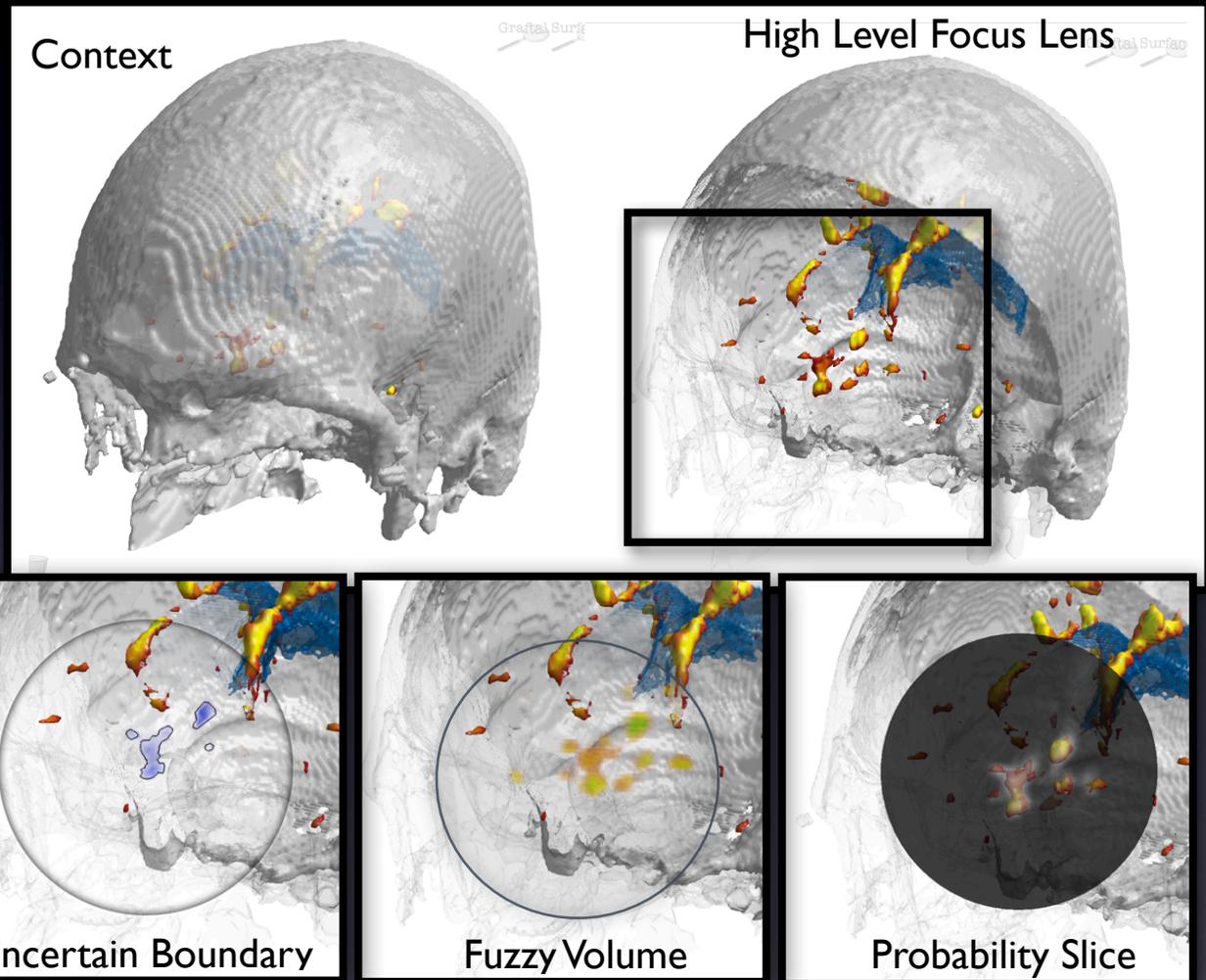
Fuzzy

Sensitivity

Confidence

# QuizLens: A Multi-lens approach for uncertainty exploration

- Global information important for qualitative evaluation & context
- Local information necessary for quantitative understanding
- Interchangeable lenses to explore various data characteristics



# The SCI Institute



# Productivity Machines



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**DOE SciDAC and NETL**

**NSF**

**Utah Centers of Excellence**

**KAUST**

# More Information

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