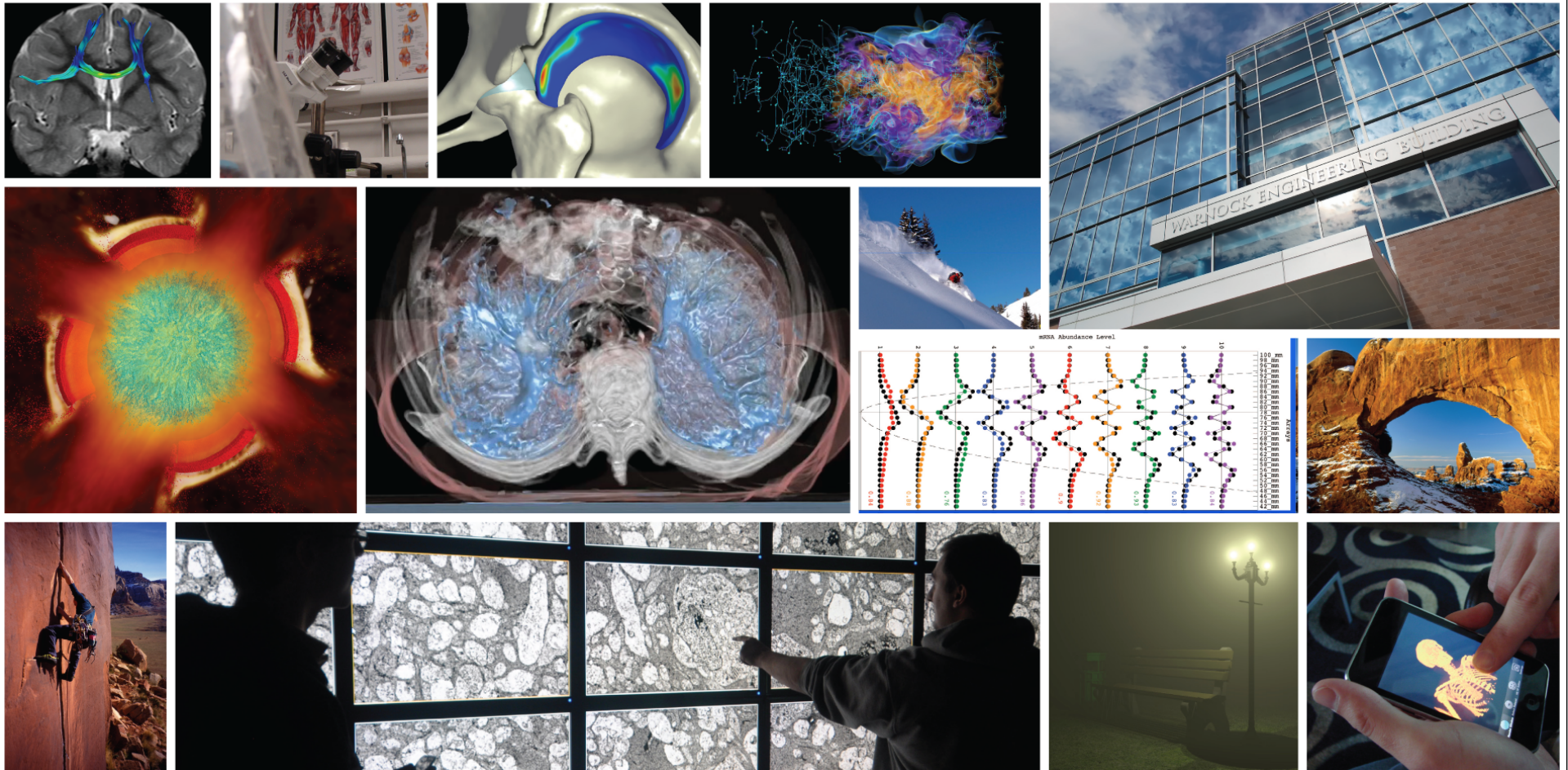


# Large Scale Visual Analysis



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



# History of Computer Graphics at 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

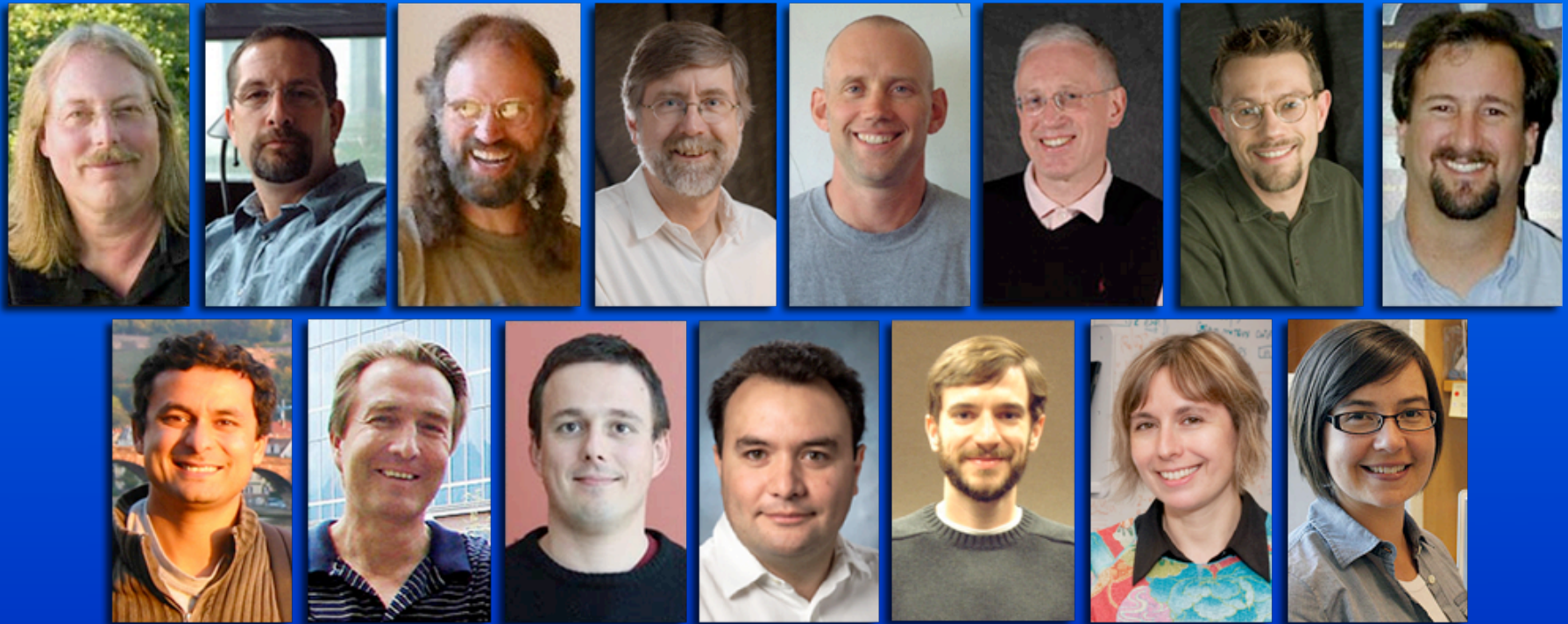
**12. Allen Ashton**  
 -Word Perfect  
 -My CFO Founder

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



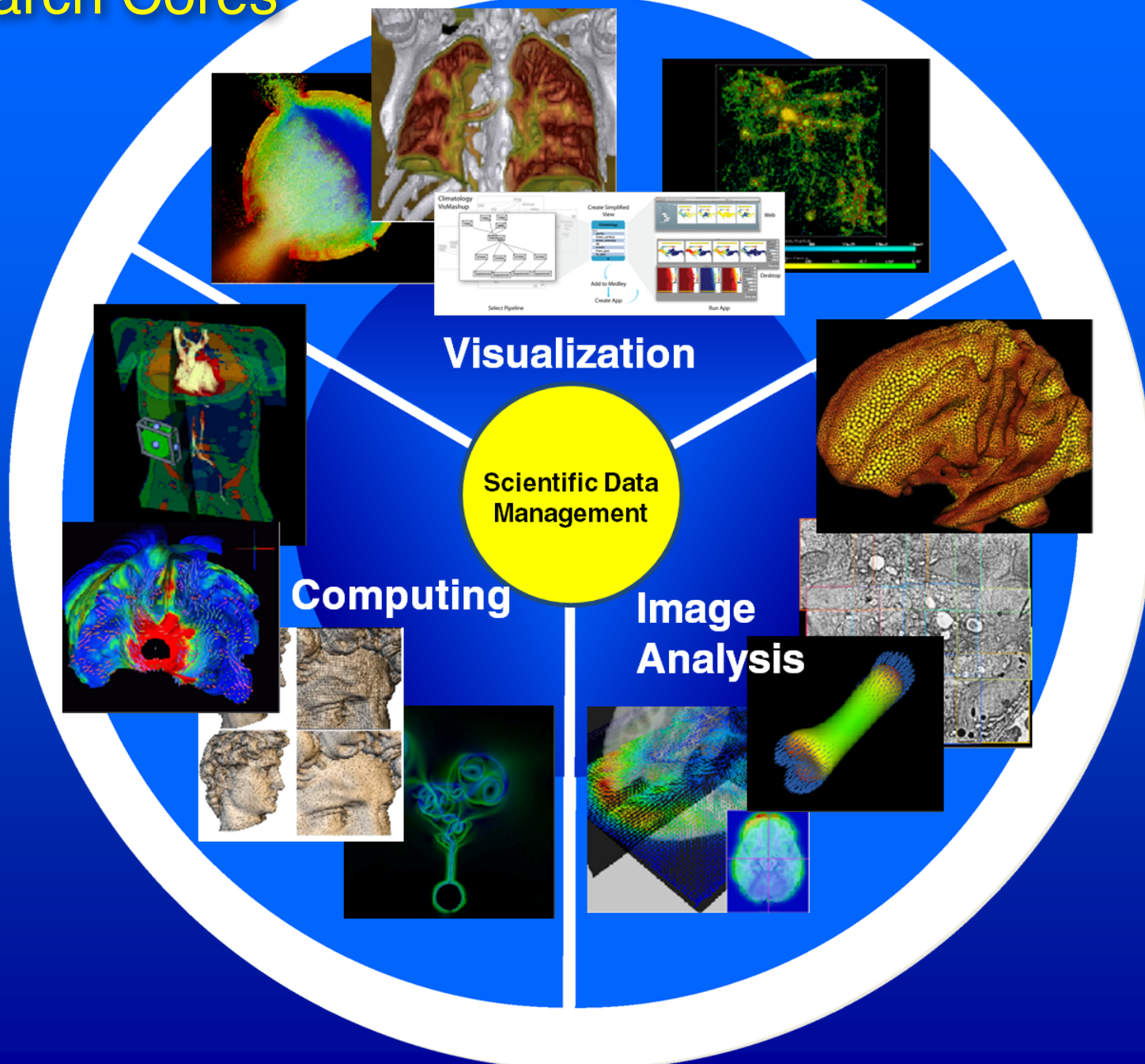
# SCI Institute Faculty

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# Research Cores





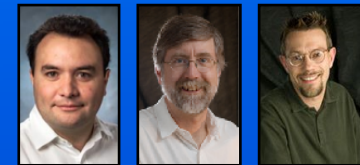
# Research Centers We Direct



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



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



**Utah Center for Neuroimage Analysis**



**UTAH** Center for  
Computational Earth Sciences



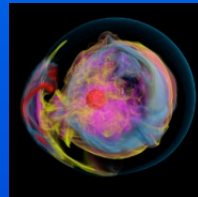
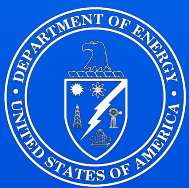


# Research Centers We are Affiliated With

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## SDAV

Scalable Data Management, Analysis  
and Visualization

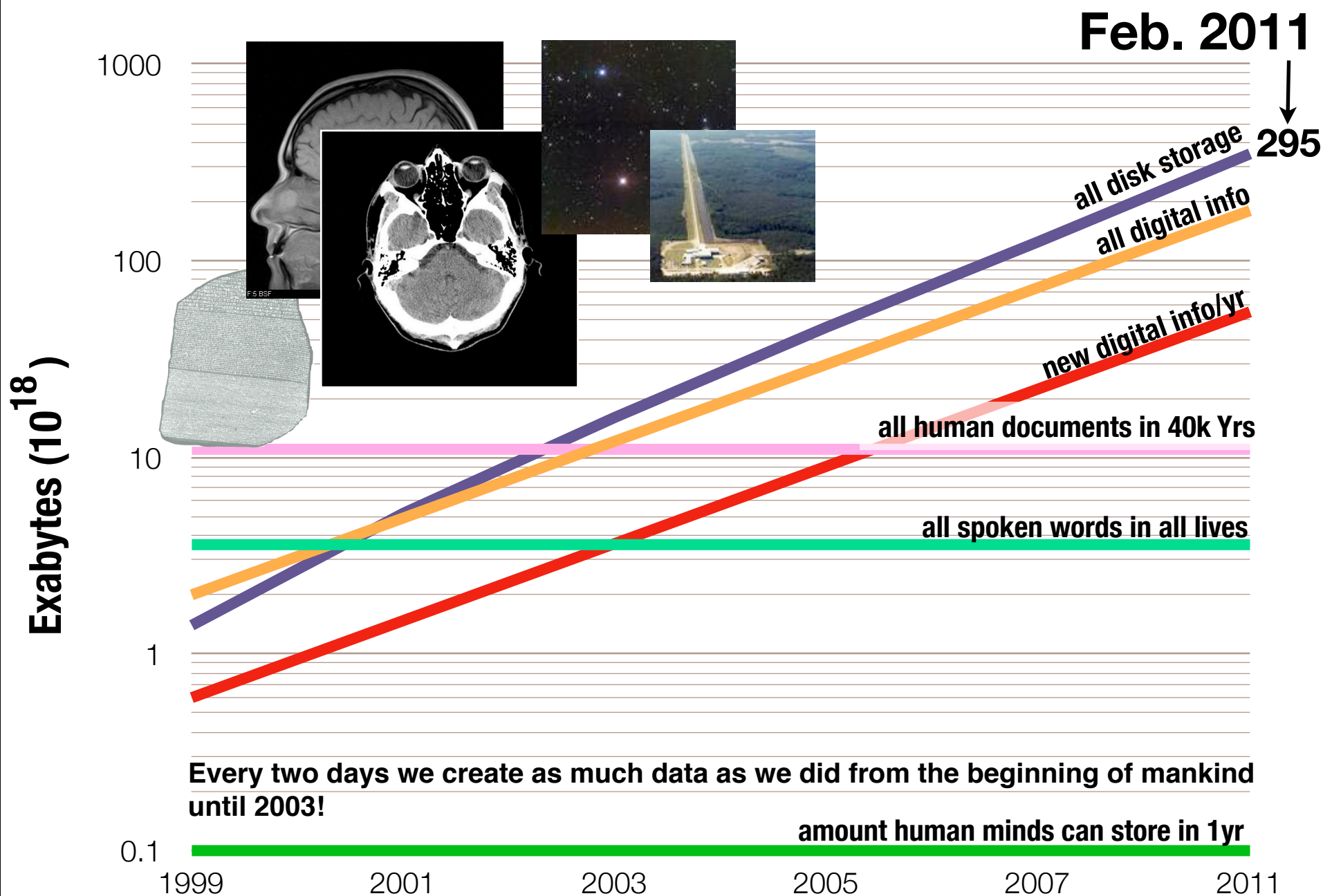


NIH NAMIC



IAMCS  
Institute for Applied Mathematics  
and Computational Science





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

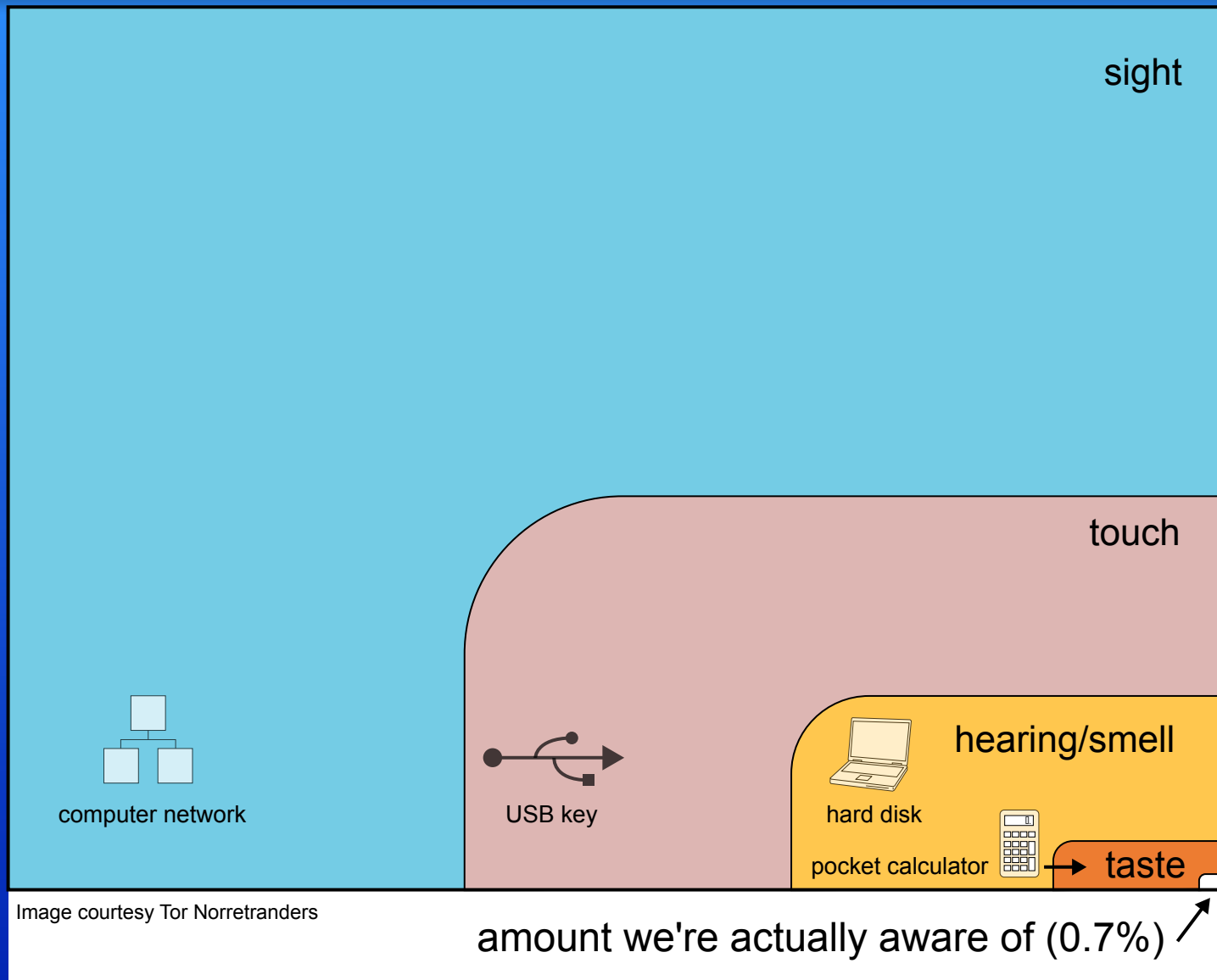
In 2005, there were **400,246,300,201** trees on Earth

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

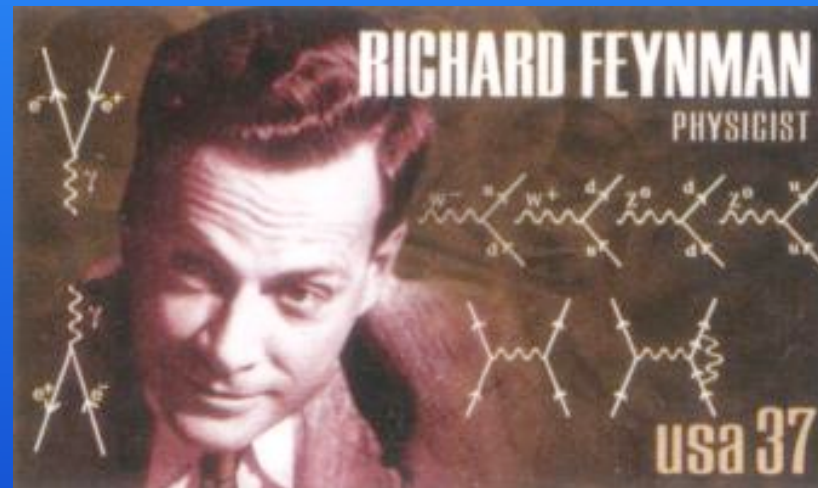
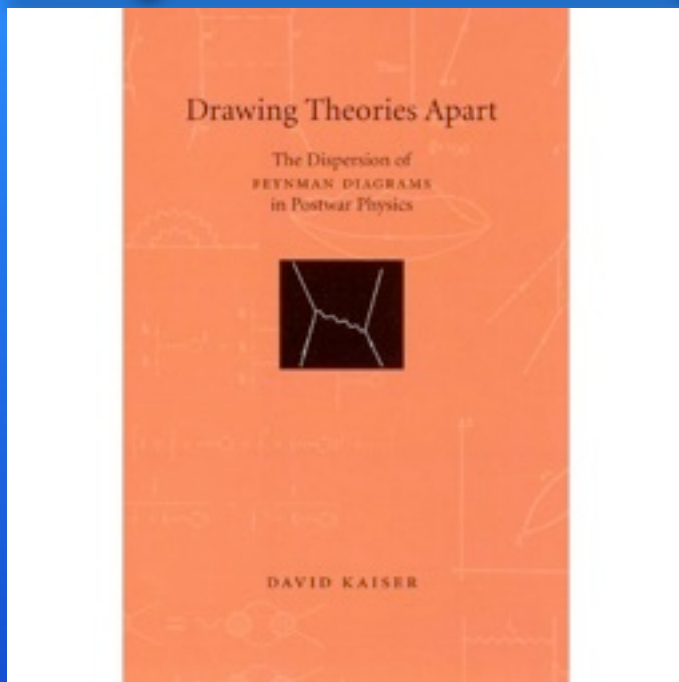
Sources: <http://www.whatsabyte.com/> and <http://wiki.answers.com>



# 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."

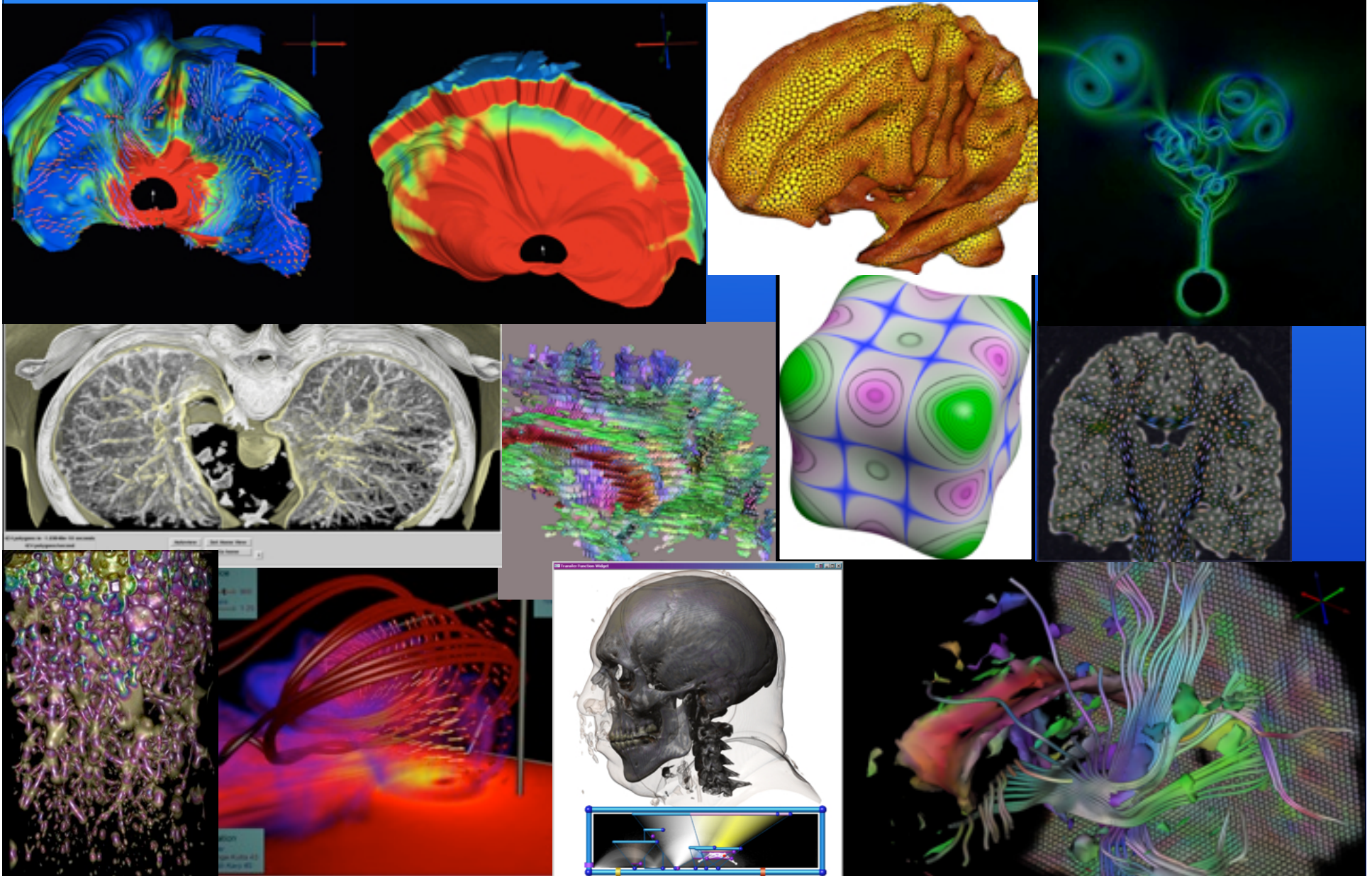
James Gleick, *The Life and Science of Richard Feynman*, Vintage Books, New York, 1992.

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Scientific Computing and Imaging Institute, University of Utah



# New Visualization Techniques



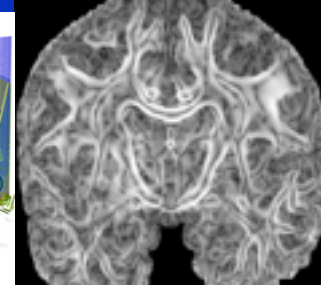
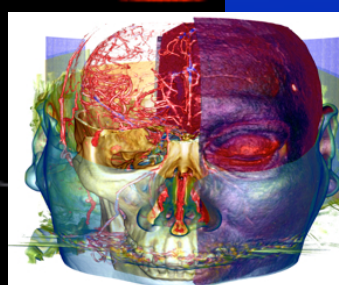
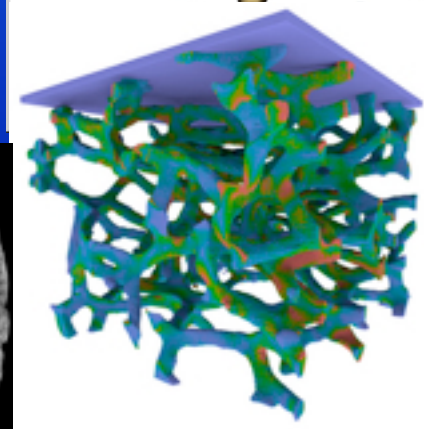
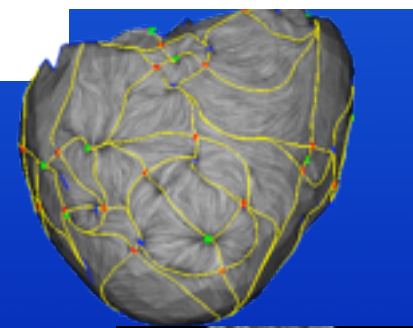
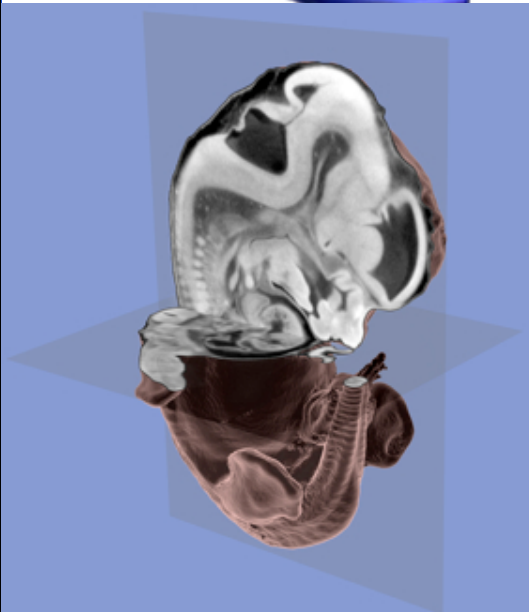
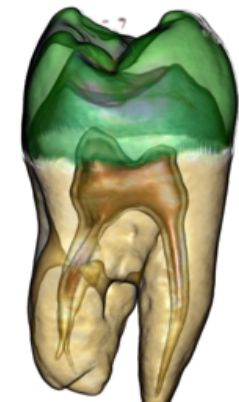
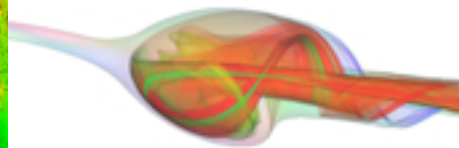
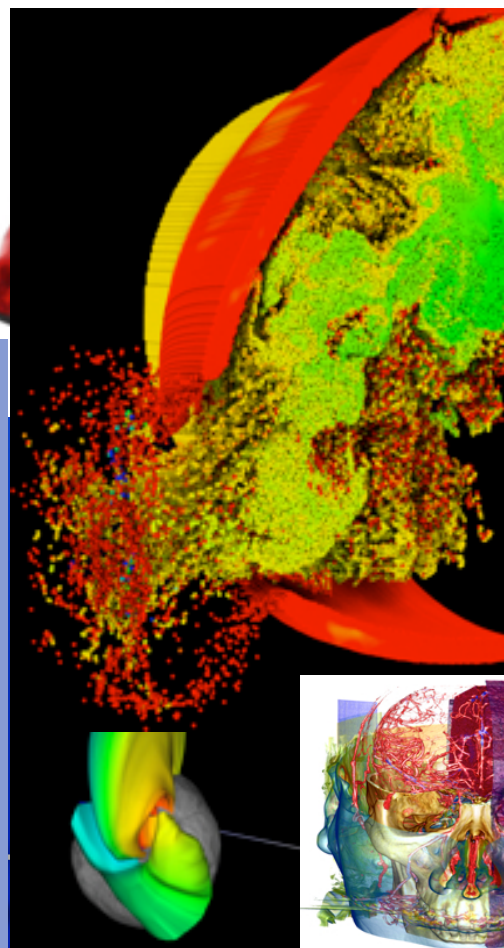
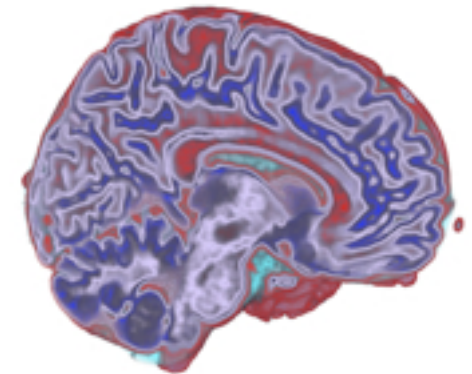
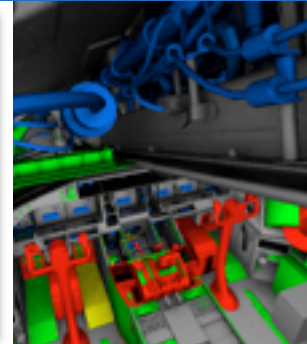
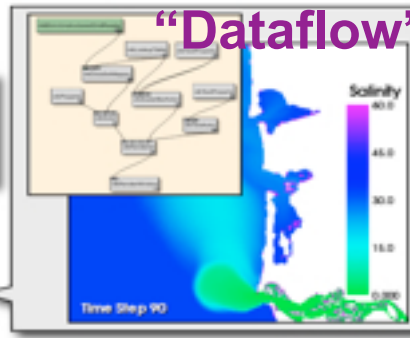


# More New Visualization Techniques

“VisTrail”

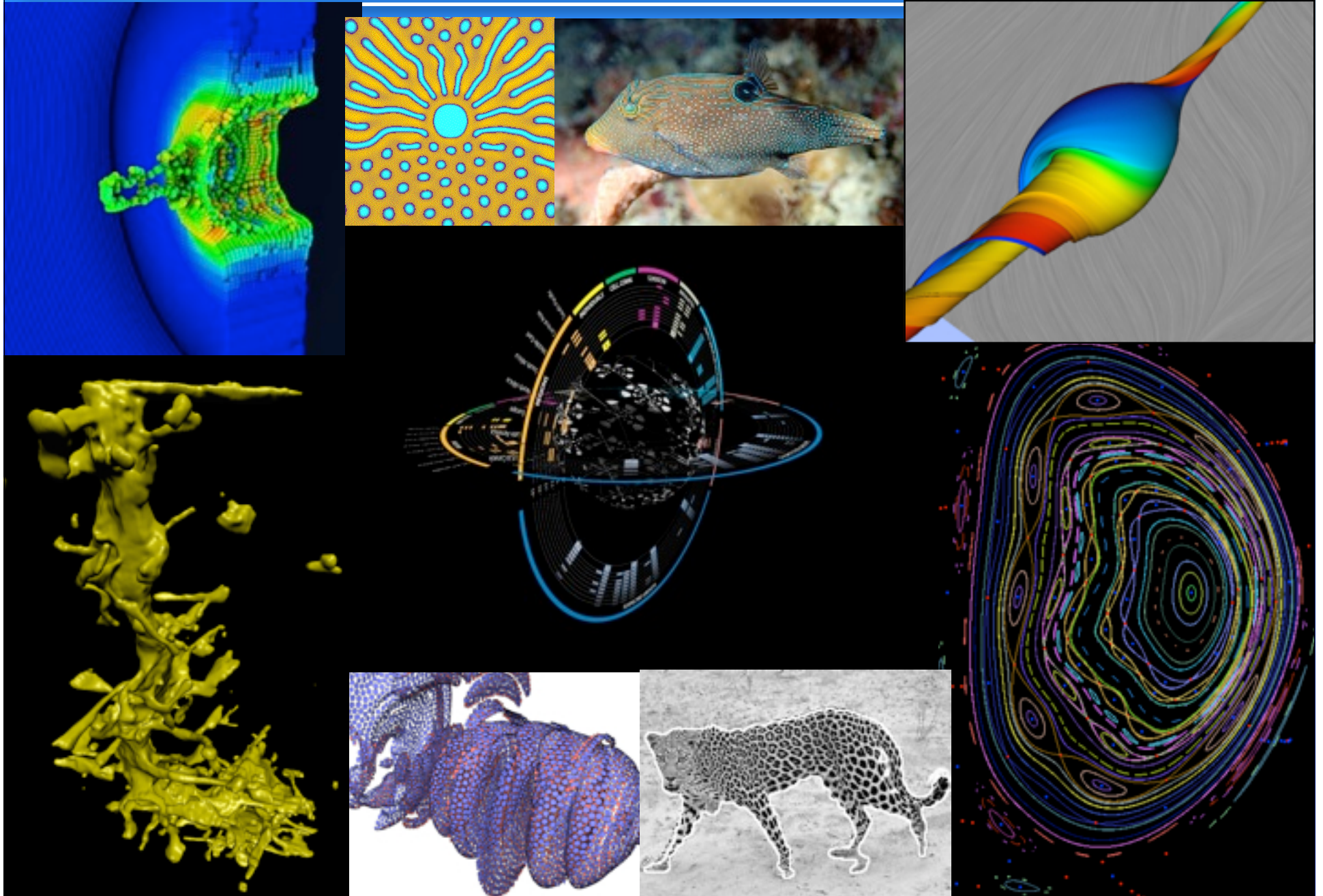


“Dataflow”

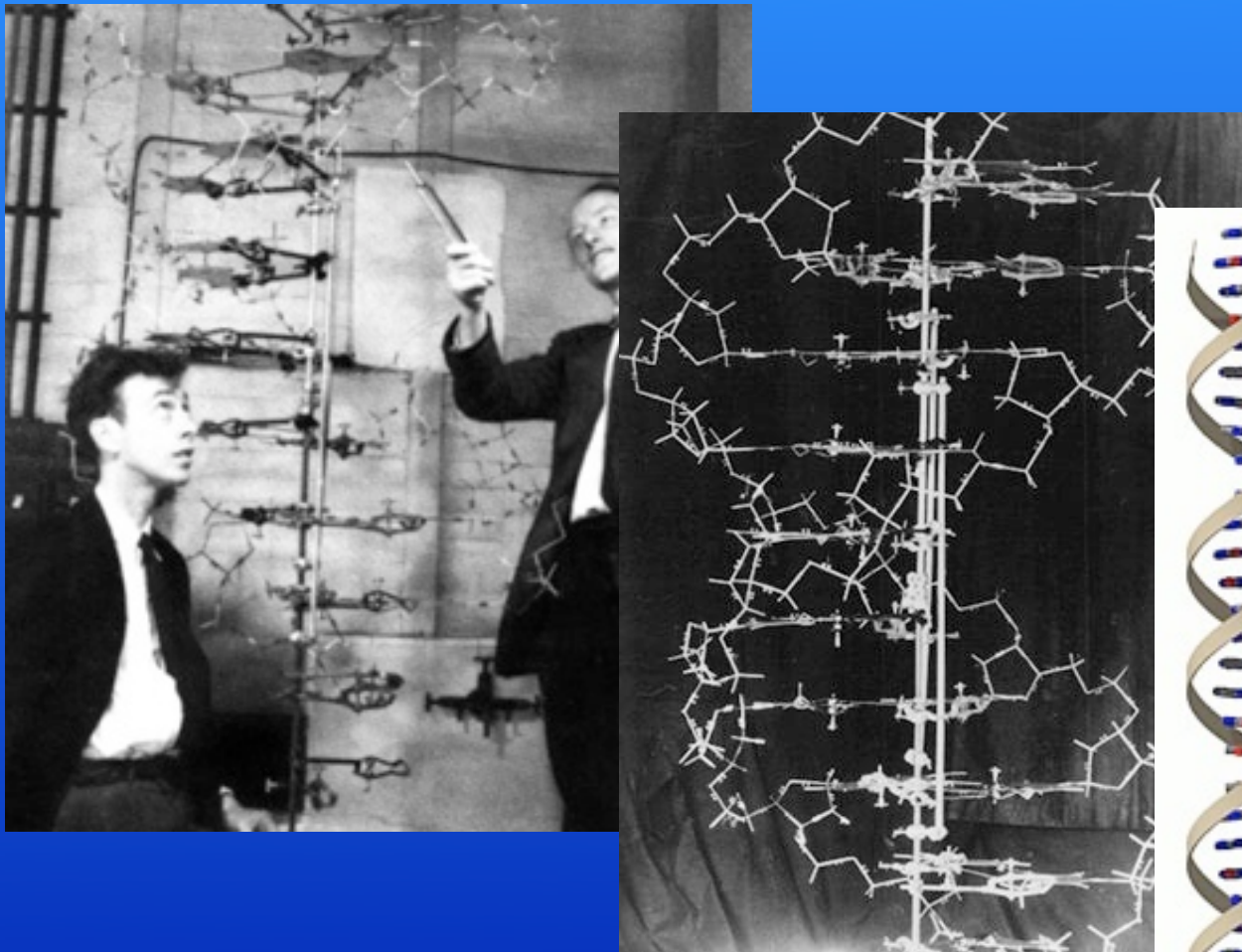




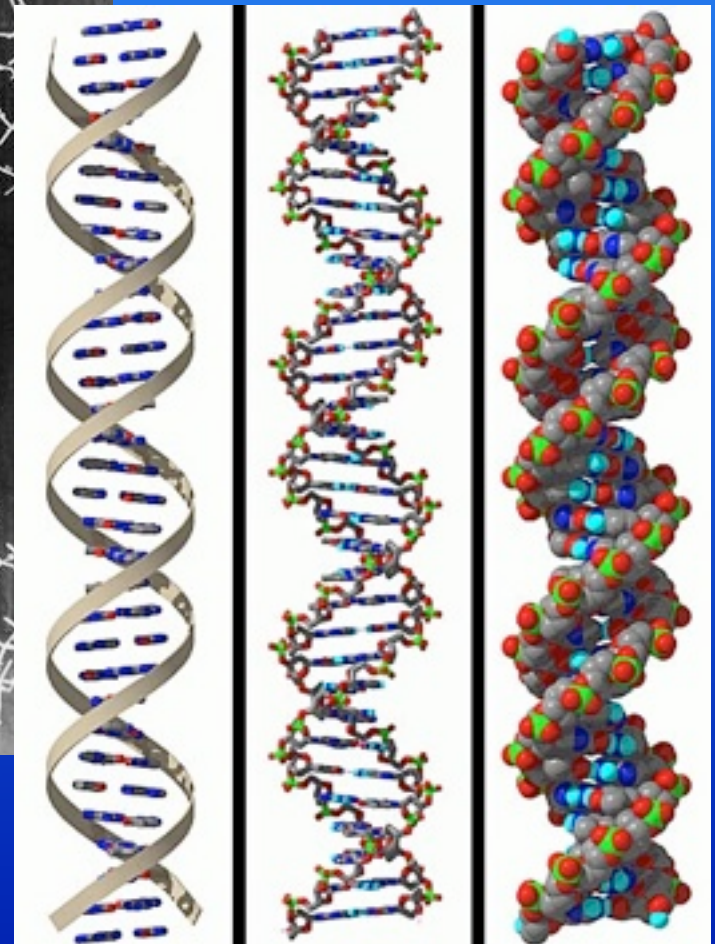
# Even More New Visualization Techniques



# Watson and Crick - DNA



James Watson and Francis Crick - 1953  
Nobel Prize - 1962  
X-ray diffraction data from Maurice Wilkins  
and Rosalind Franklin





# Mario Capecchi - Nobel Prize 2007

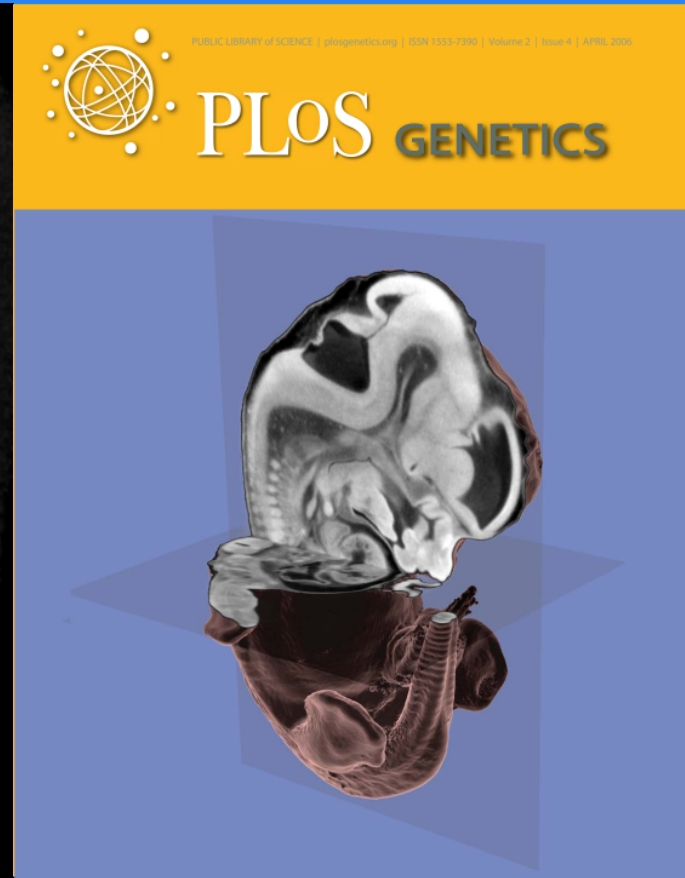
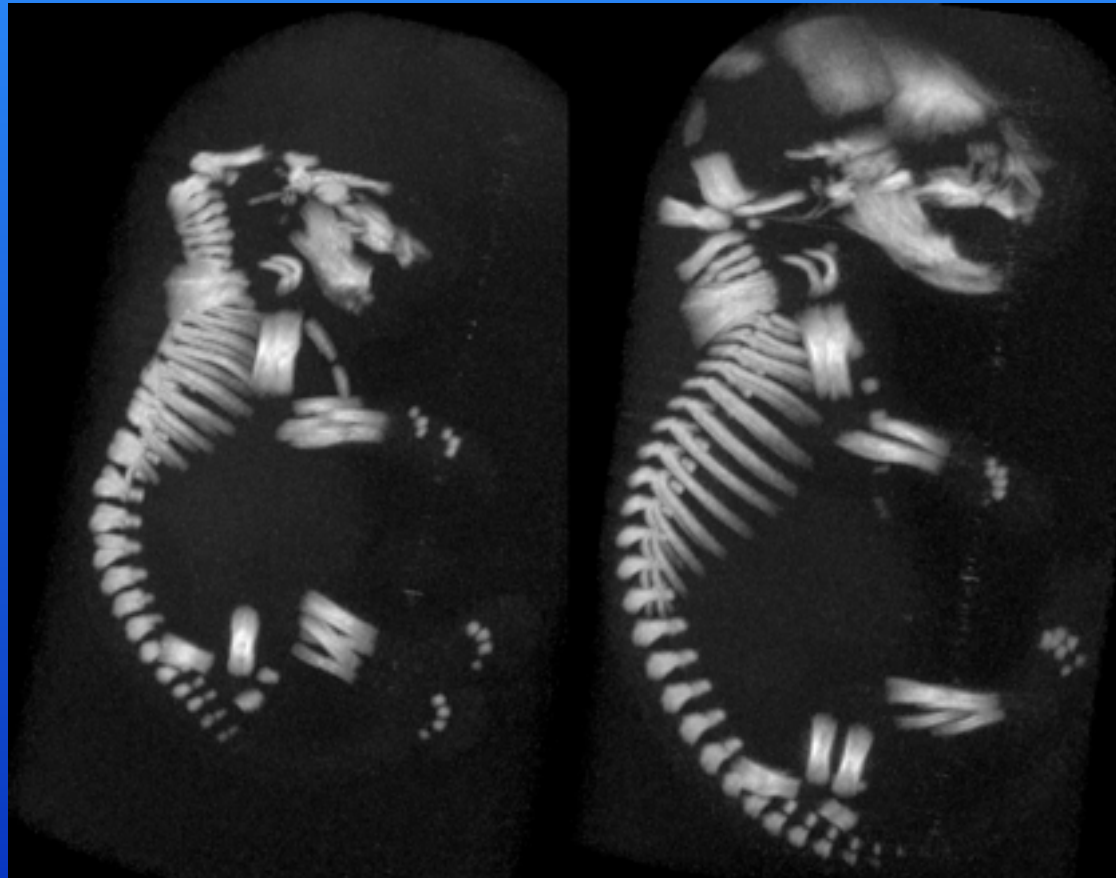


Mario R. Capecchi, Ph.D., distinguished professor of human genetics and biology at the University of Utah's Eccles Institute of Human Genetics has won the 2007 Nobel Prize in Physiology or Medicine.

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Scientific Computing and Imaging Institute, University of Utah

# Image Based Phenotyping

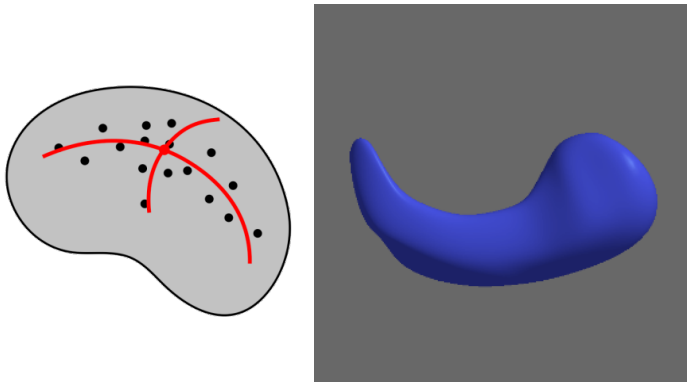


J.T. Johnson III, M.S. Hansen, I. Wu, L.J. Healy, C.R. Johnson, G.M. Jones, M.R. Capecchi, C. Keller.  
"Virtual Histology of Transgenic Mouse Embryos for High-Throughput Phenotyping,"  
In PLoS Genetics, Vol. 2, No. 1, pp. 471-477. April, 2006.

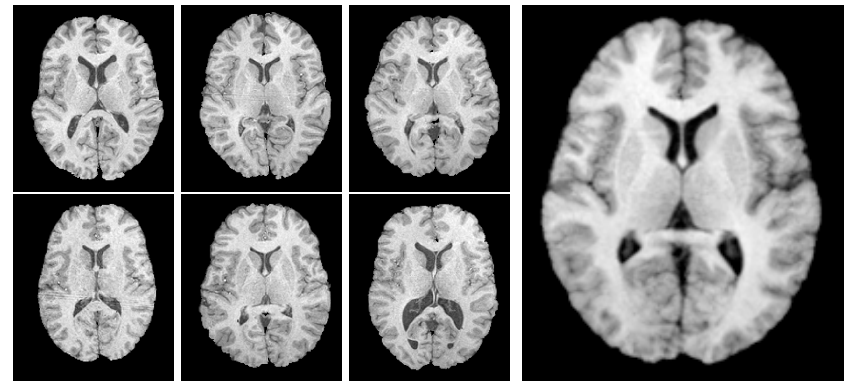
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Scientific Computing and Imaging Institute, University of Utah

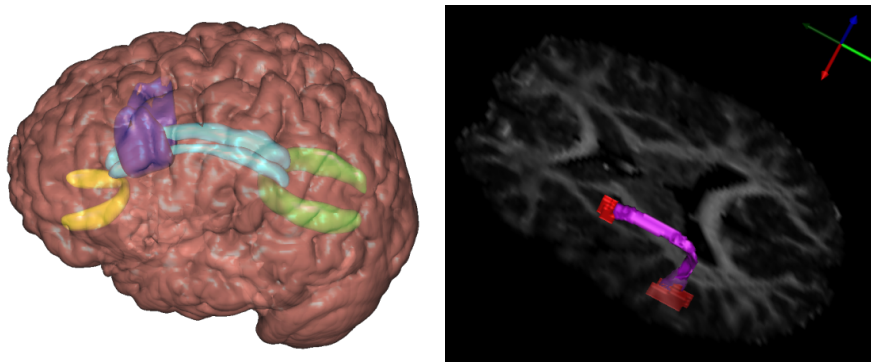
# Statistics of Shape, Connectivity, and Function



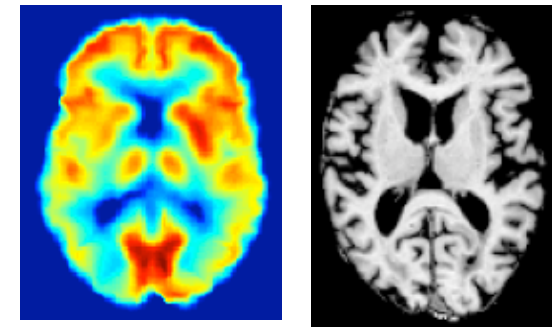
**Computational Statistics  
in Nonlinear Spaces**



**Anatomical shape averaging  
and variability**



**Diffusion Tensor Image Analysis  
Autism project**



**Combined PET + MRI analysis  
Alzheimer's disease project**



# GPUs for Scientific Computing



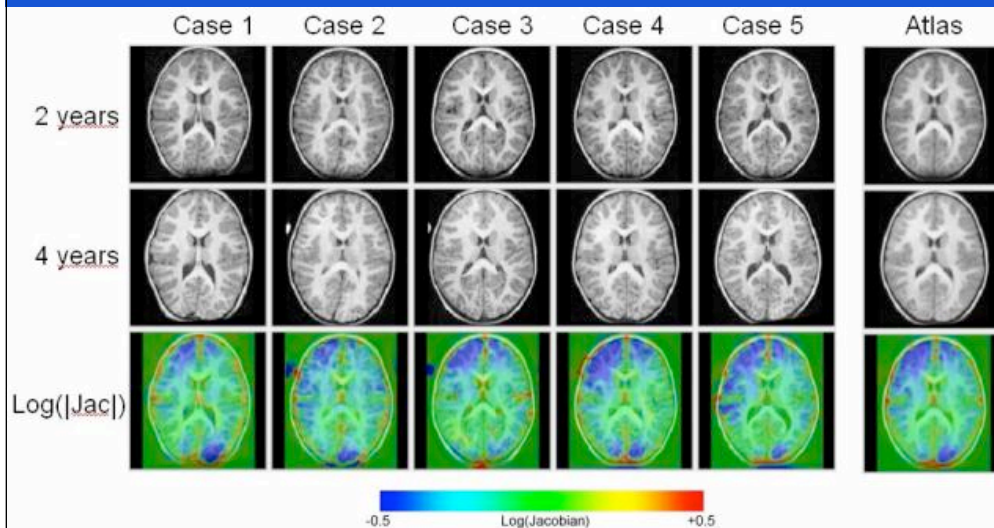
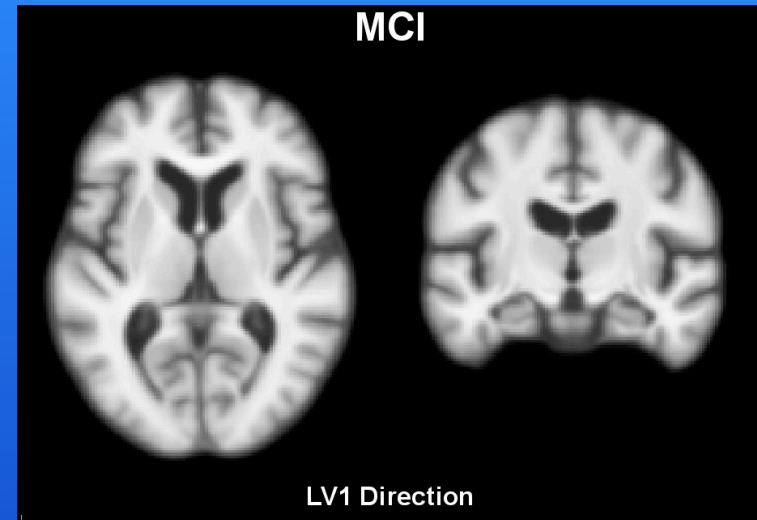
FOR IMMEDIATE RELEASE:

## **NVIDIA RECOGNIZES UNIVERSITY OF UTAH AS A CUDA CENTER OF EXCELLENCE**

*University of Utah Latest in a Growing List of Exceptional Schools Demonstrating  
Pioneering Work in Parallel Computing*

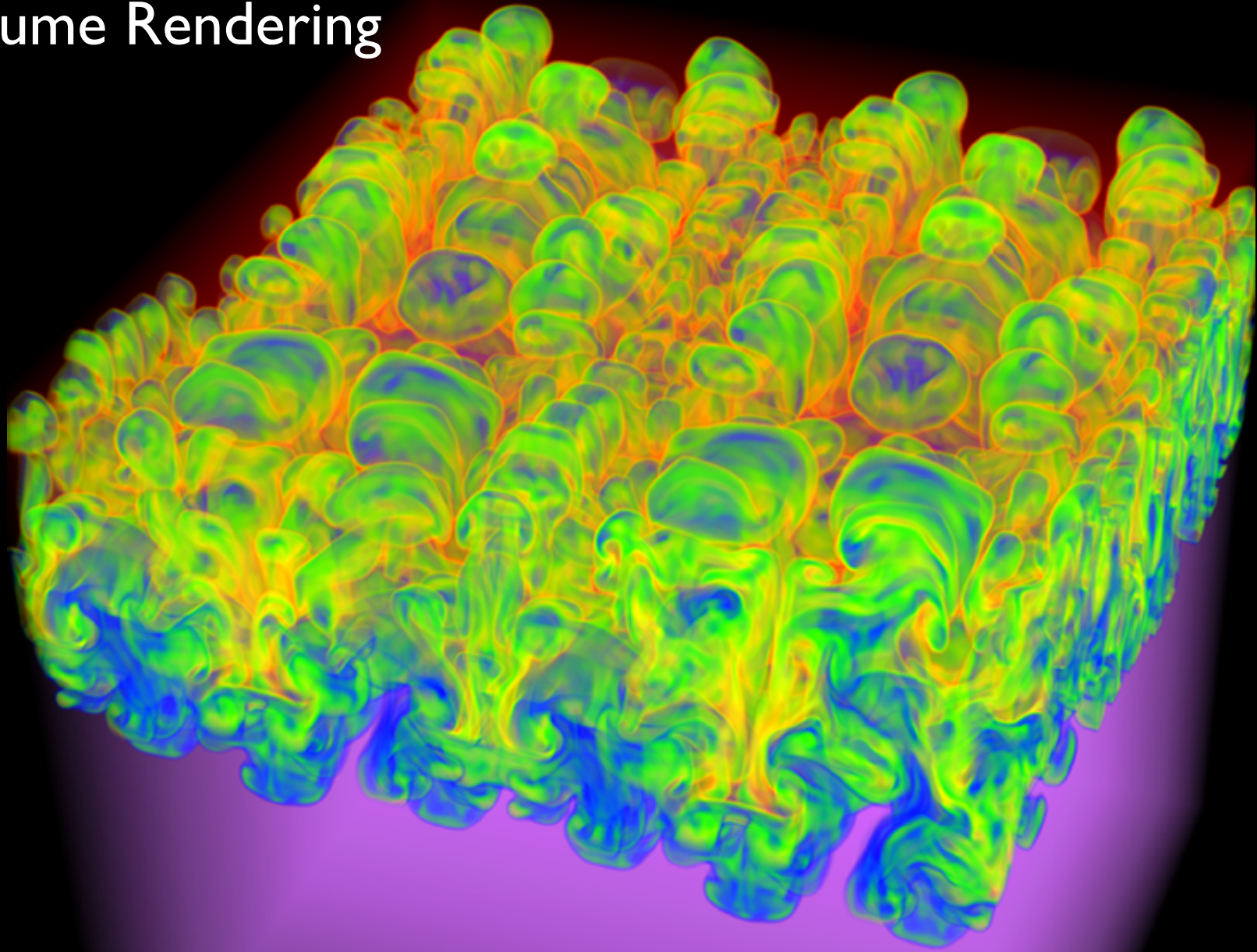
**SANTA CLARA, CA & SALT LAKE CITY, UT —JULY 31, 2008—**NVIDIA

Corporation, the worldwide leader in visual computing technologies, and the University of Utah today announced that the university has been recognized as a CUDA Center of Excellence, a milestone that marks the beginning of a significant partnership between the two organizations.



## Scientific Computing and Imaging

# Volume Rendering

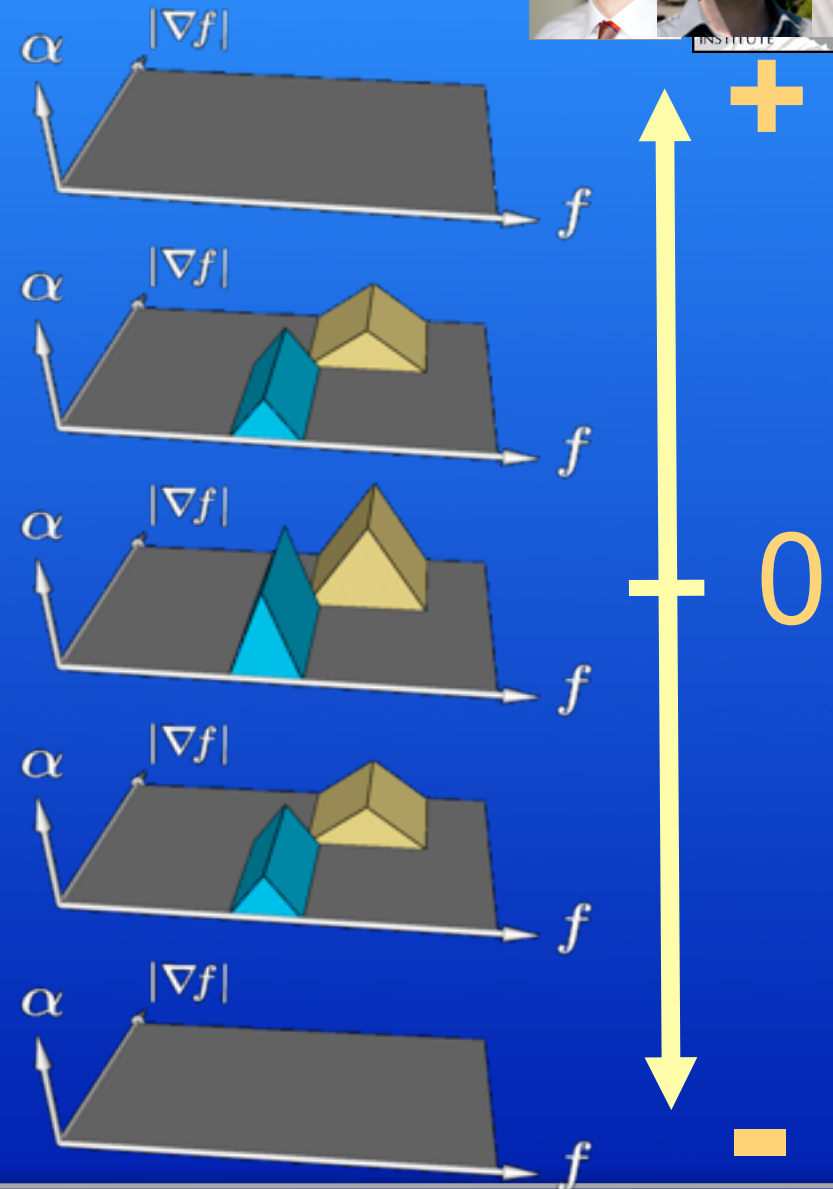




# Multi-Dimensional Transfer Function



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

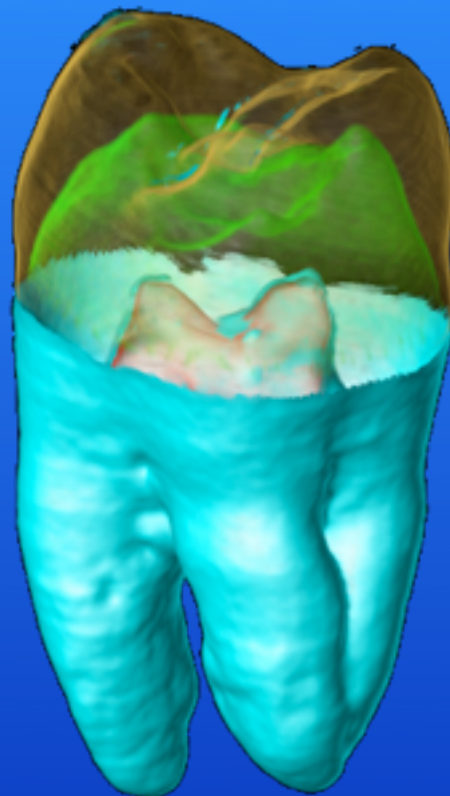




# Volume Rendering



enamel /  
background



dentin / background



dentin / enamel



dentin / pulp

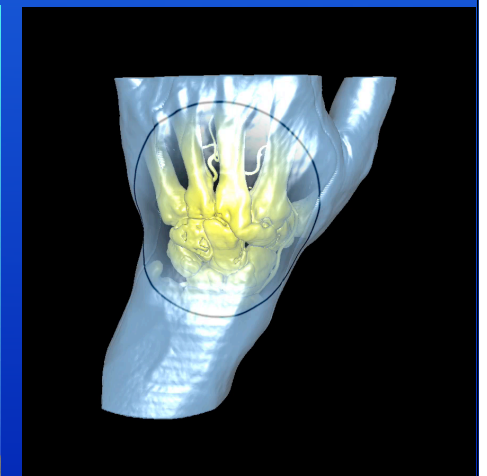
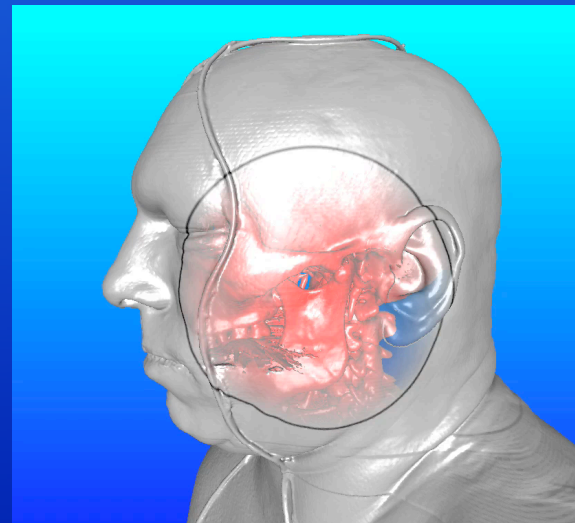
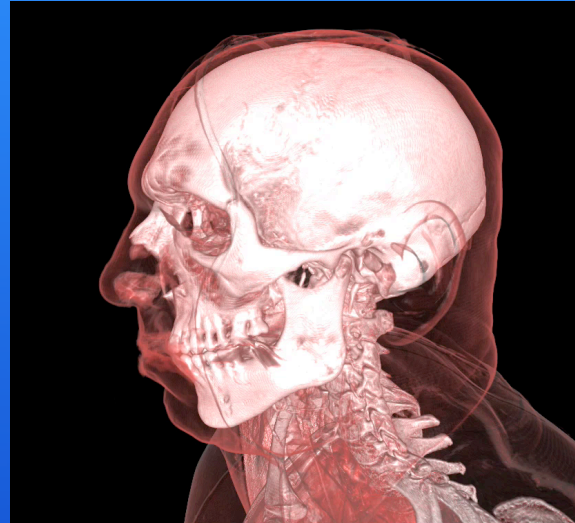
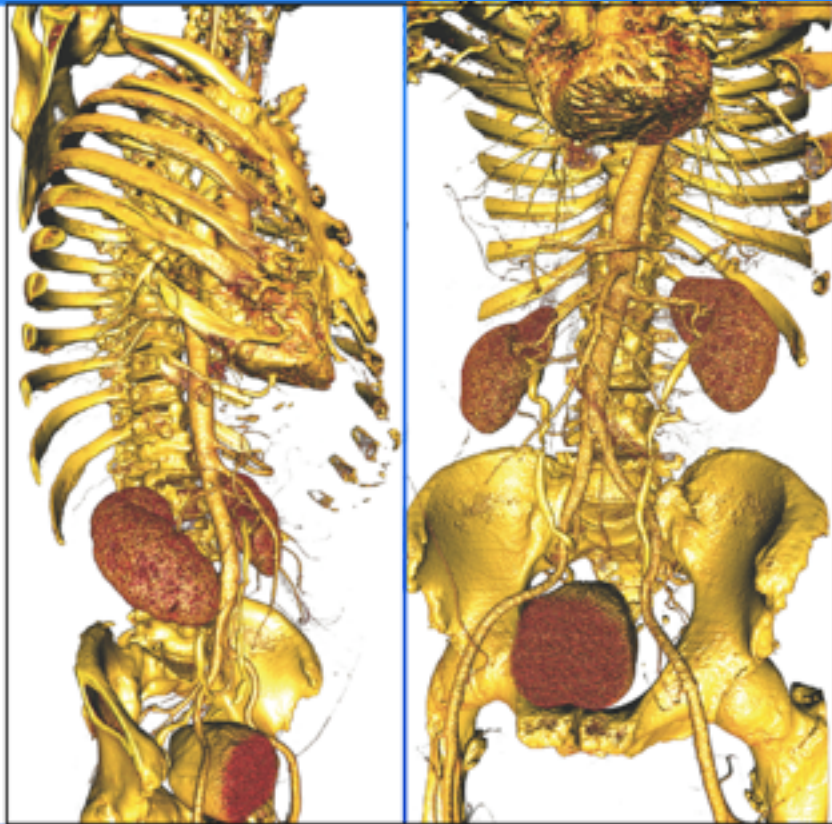


**1D: not possible**

**2D: specificity not as good**

Computing and Imaging Institute, University of Utah

# ImageVis3D



Scientific Computing and Imaging Institute, University of Utah



# ImageVis3D and Tuvok

## IO

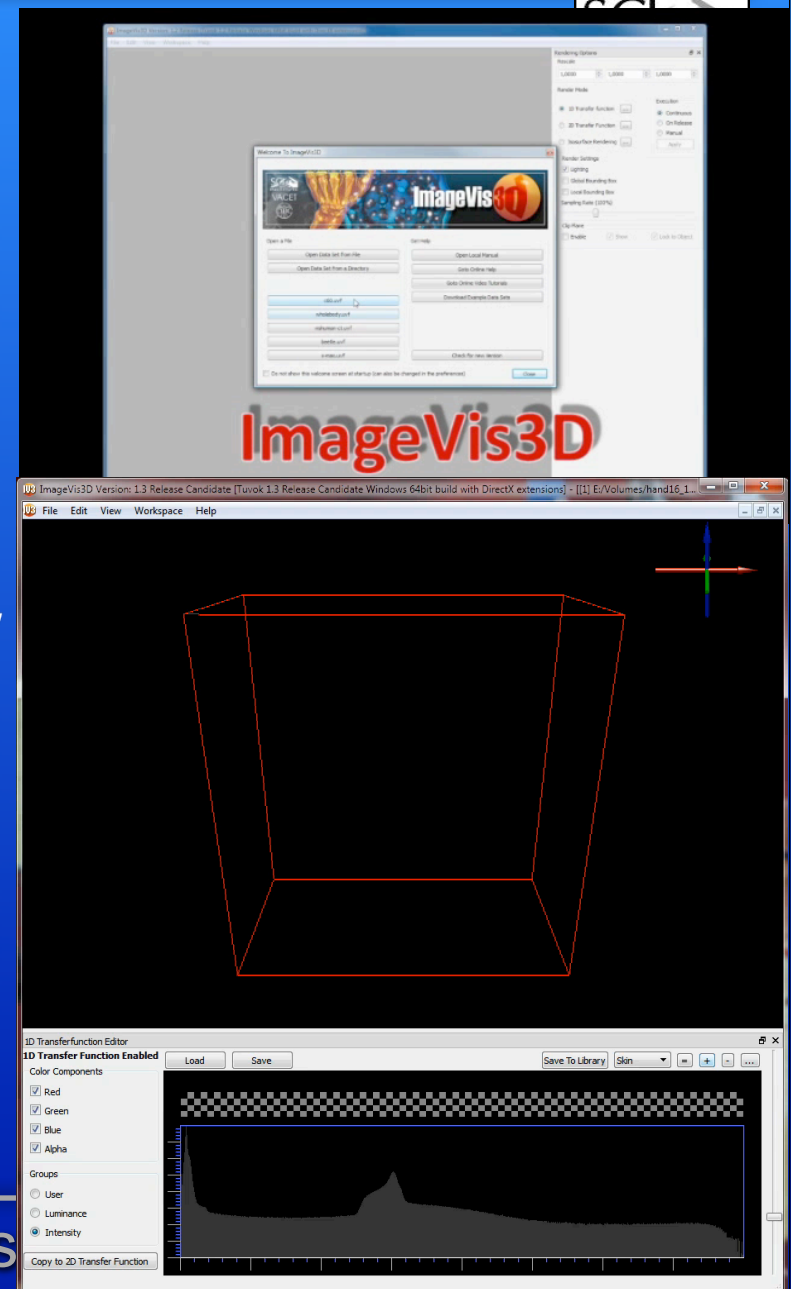
- Understands various file formats including DICOM
- Reads and handles data of up to 18 EB
- Provides Bricking and LoD computations

## Renderer

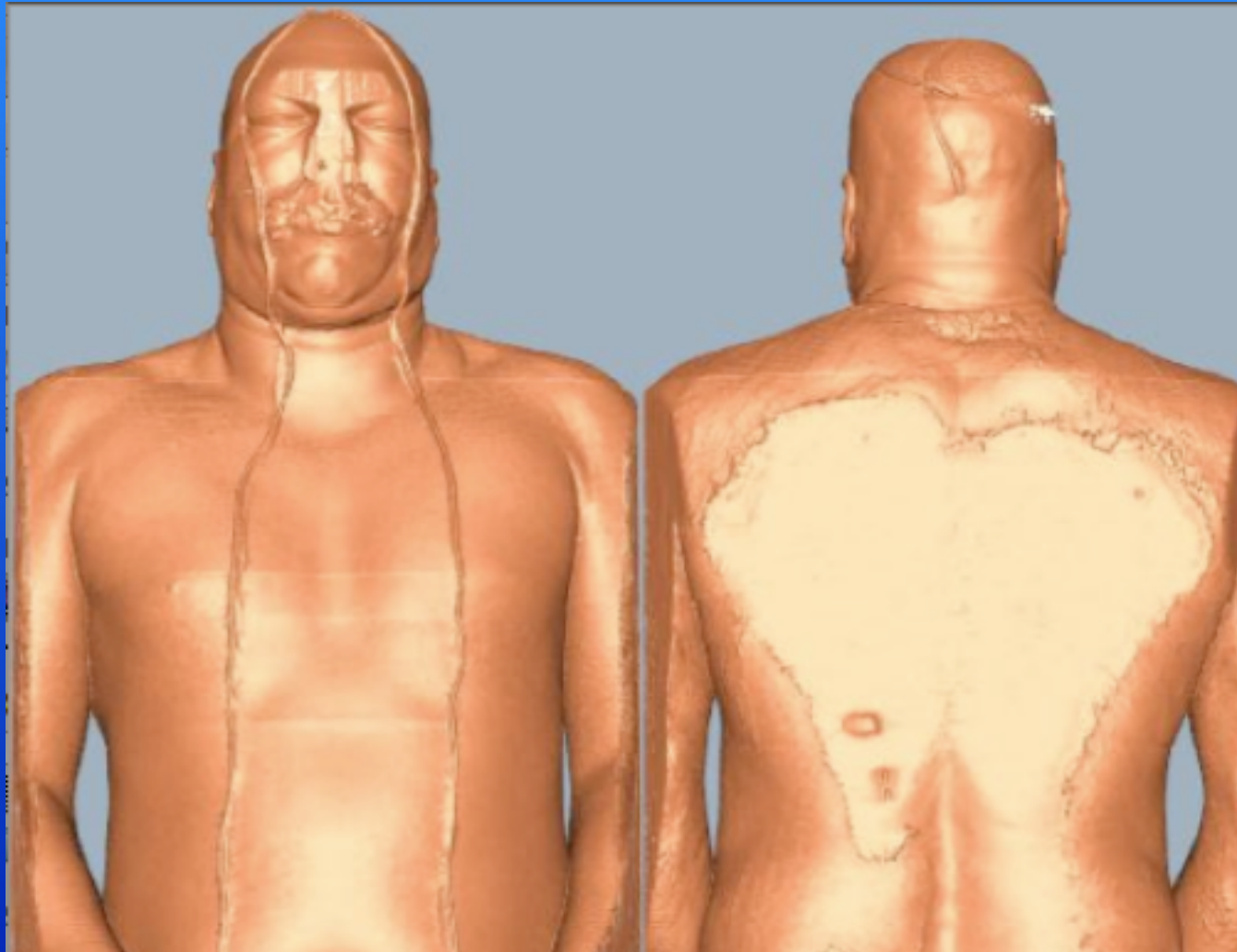
- Supports Raycasting and Slicing
- Supports 1D, 2D TFs, Isosurfacing, and ClearView
- Provides extensive support for older hardware

## General

- Cross platform
- Intuitive and Configurable UI
- Supports multiple windows
- Open Source - MIT License



# NIH Visible Male



Scientific Computing and Imaging Institute, University of Utah



# Visible Human - High Resolution



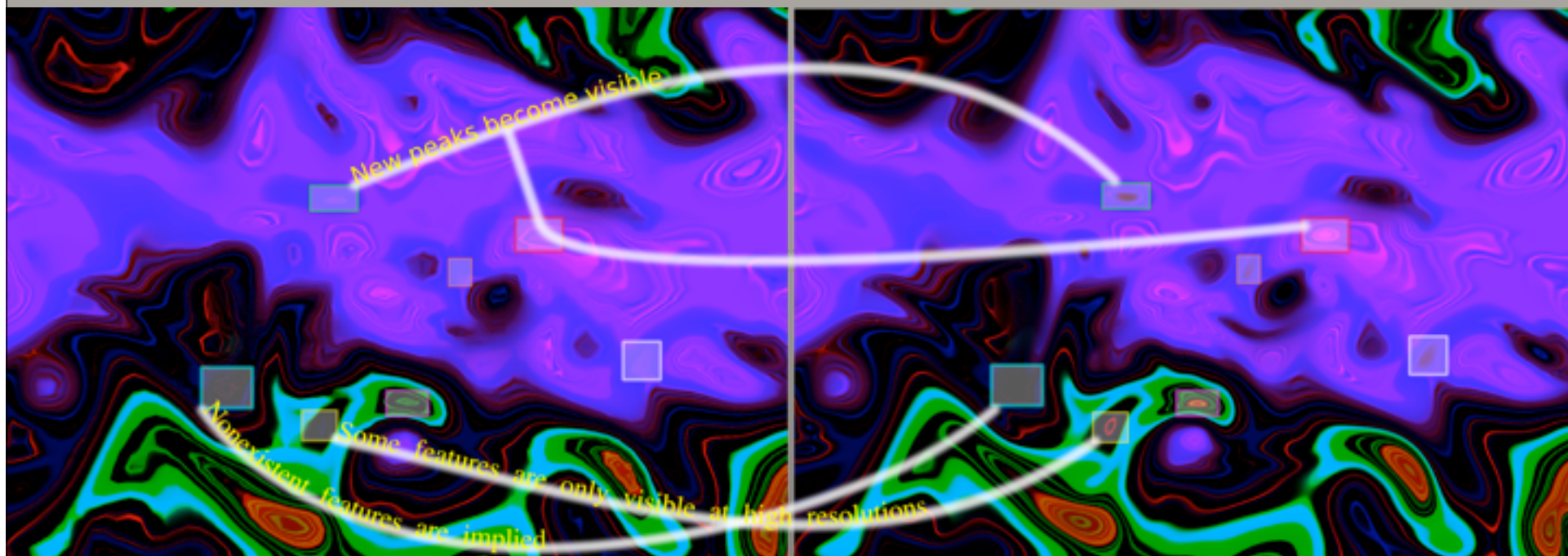
Scientific Computing and Imaging Institute, University of Utah



# 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.”

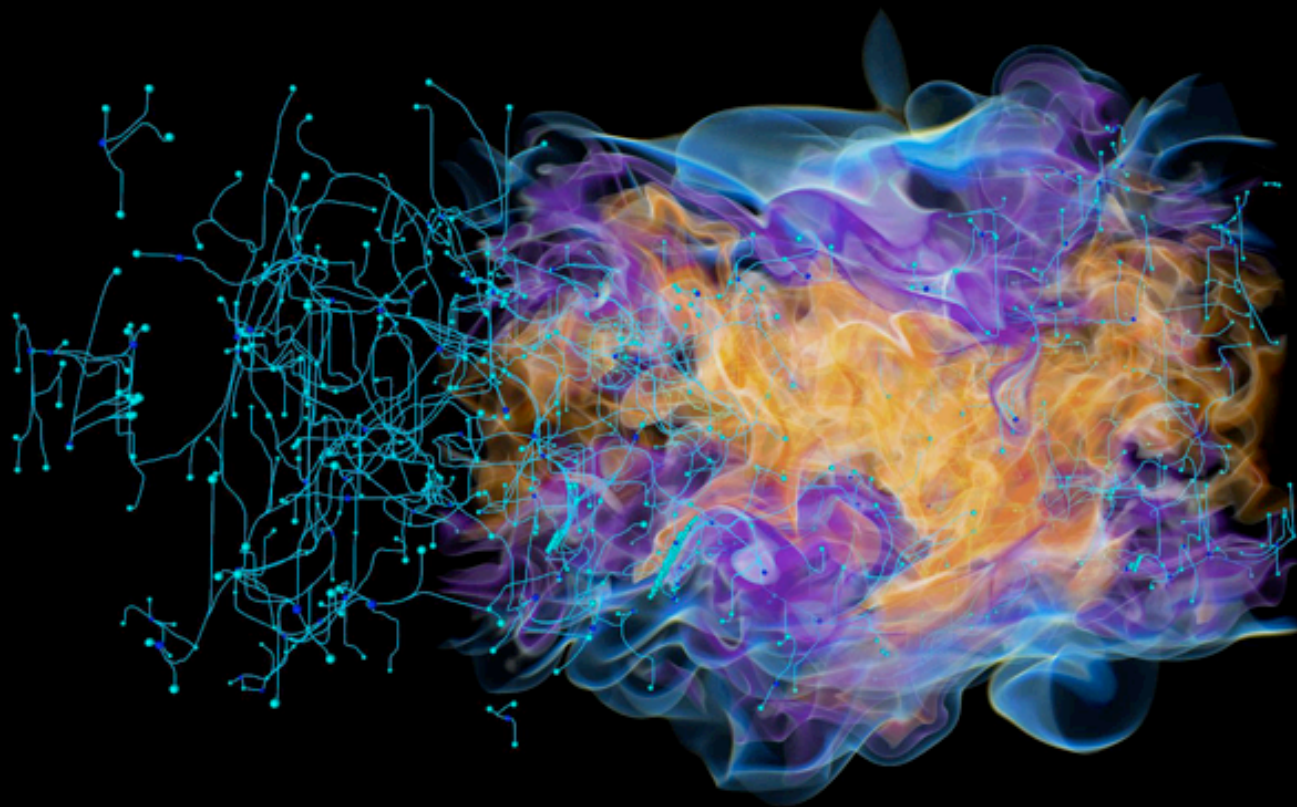
Jacqueline Chen, Sandia National Laboratories



Lower Resolution

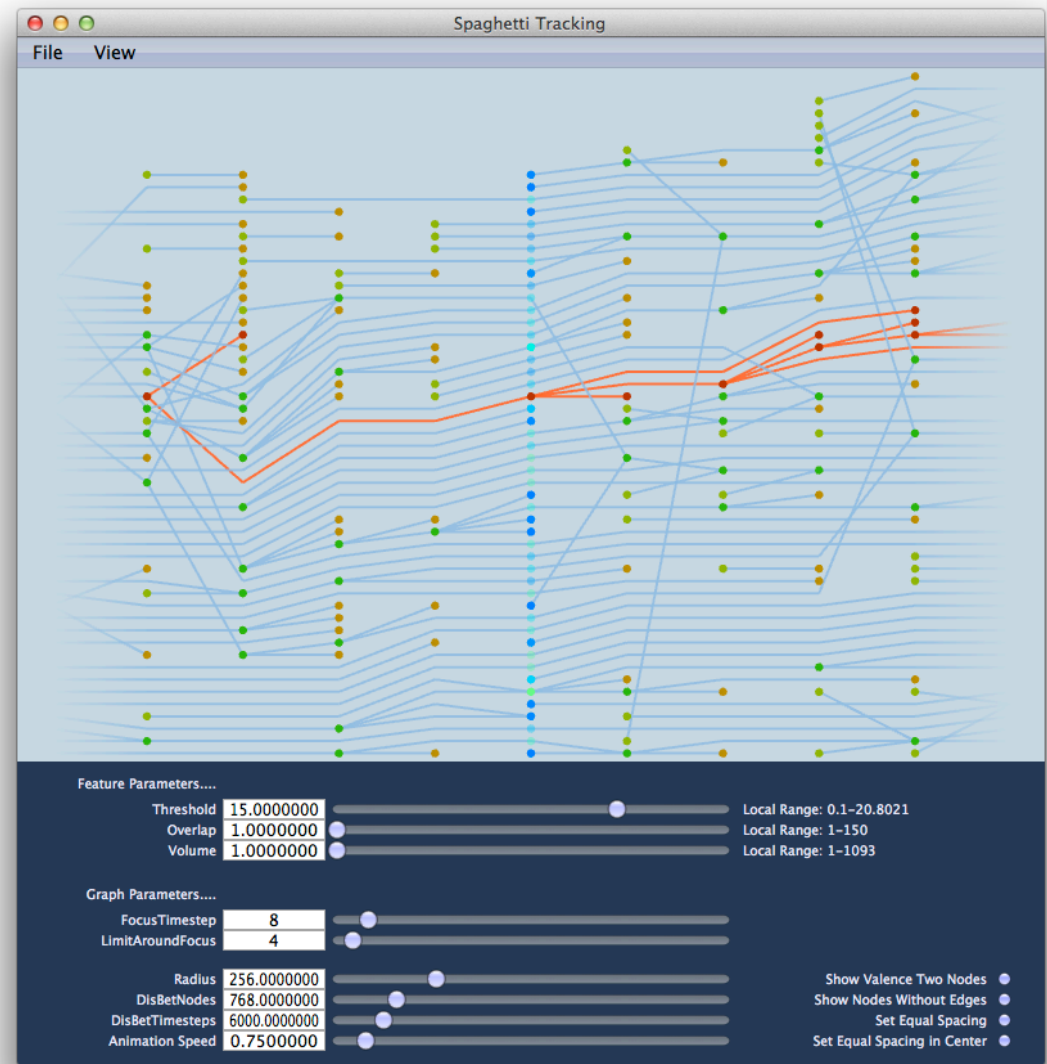
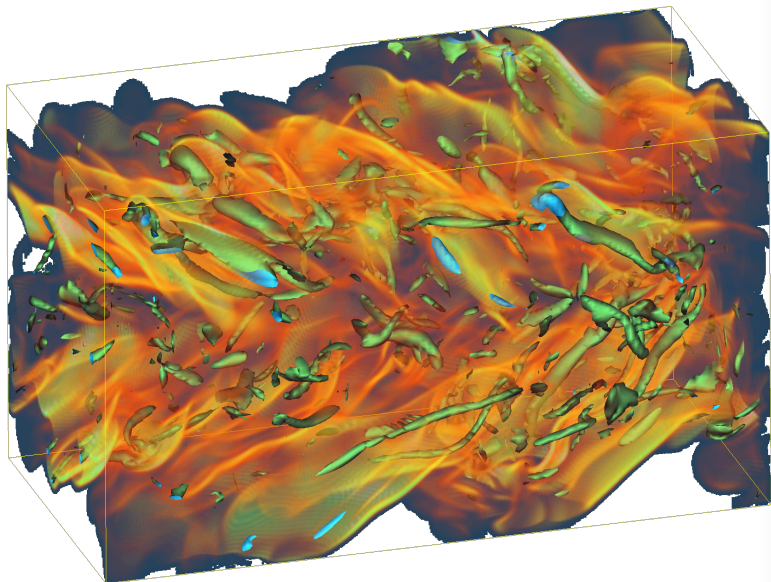
High Resolution





# Topological Analysis of Massive Combustion Simulations

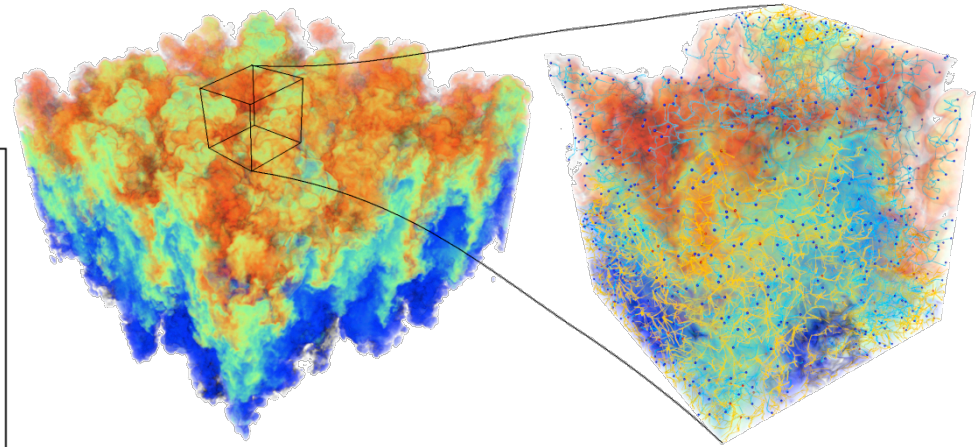
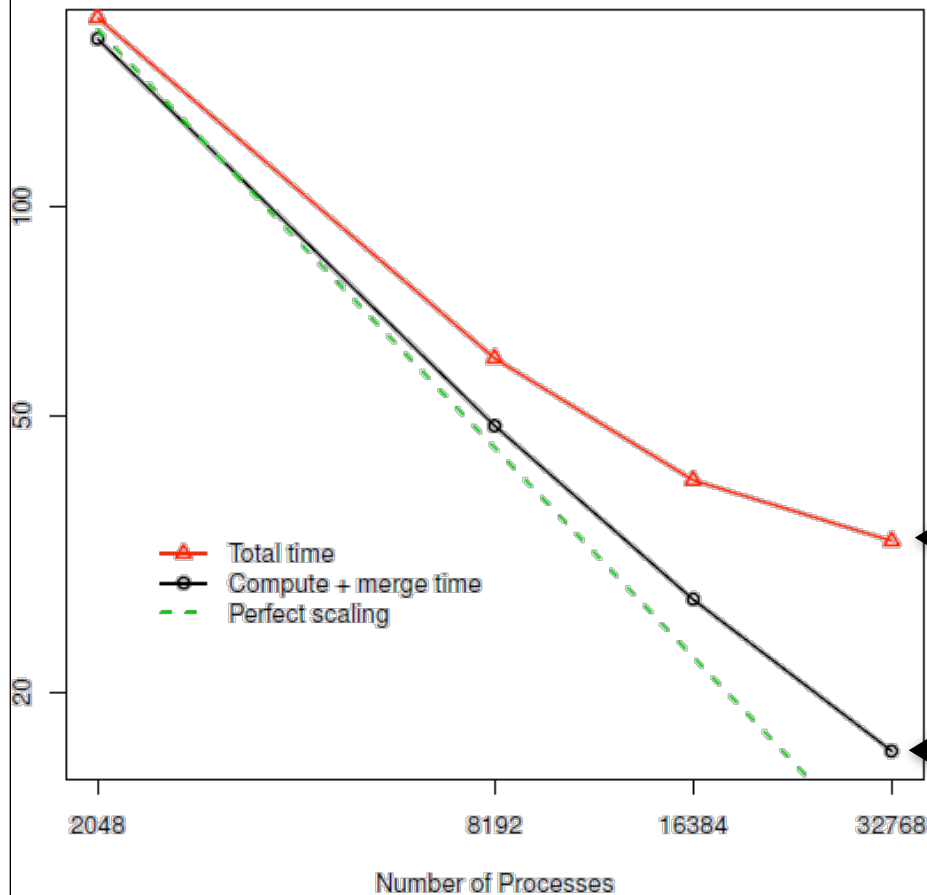
- Non-premixed DNS combustion (J. Chen, SNL): Analysis of the time evolution of extinction and reignition regions for the design of better fuels





# New Parallel Topological Computations Achieve High Performance at Scale (see session 11)

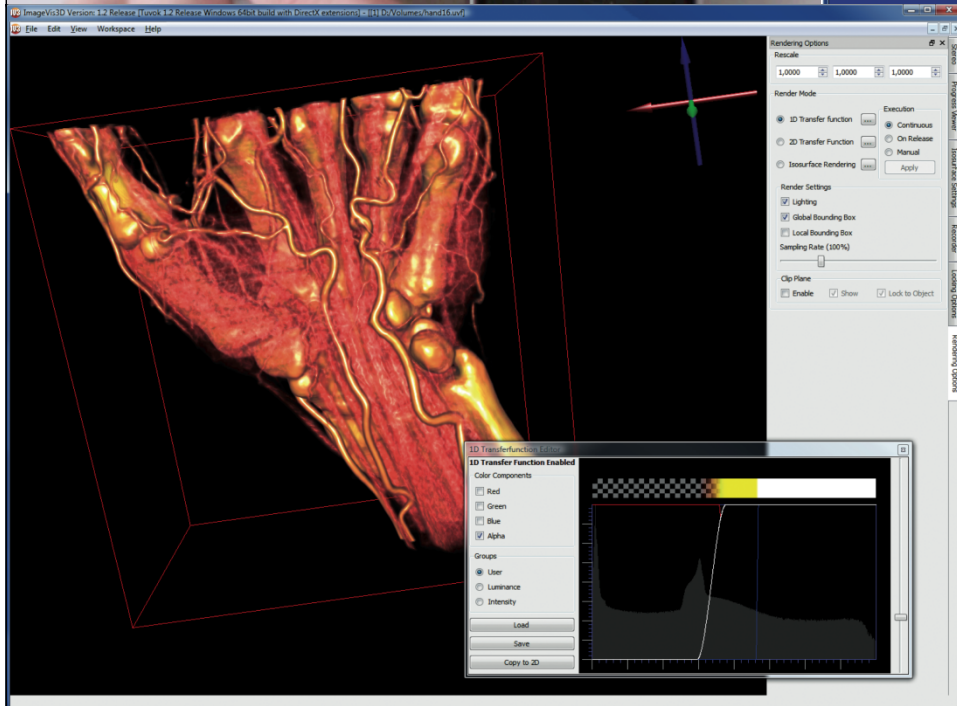
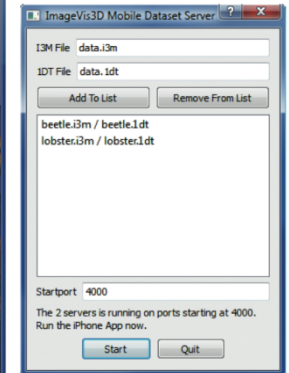
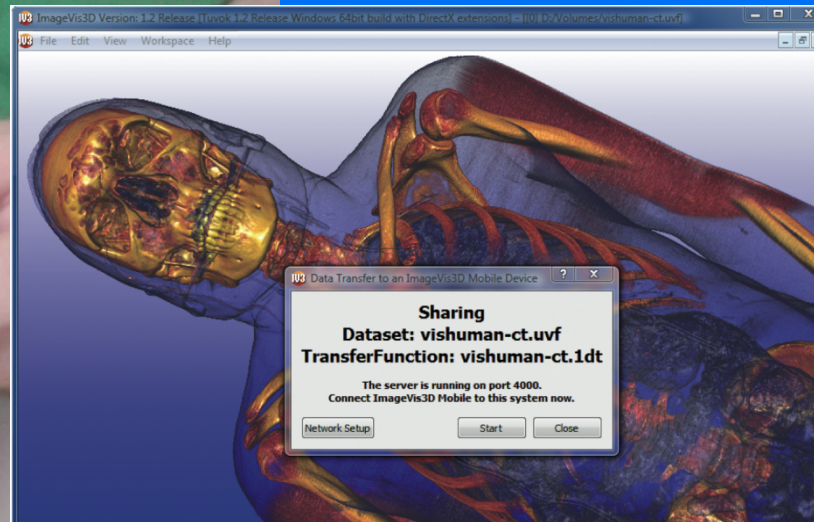
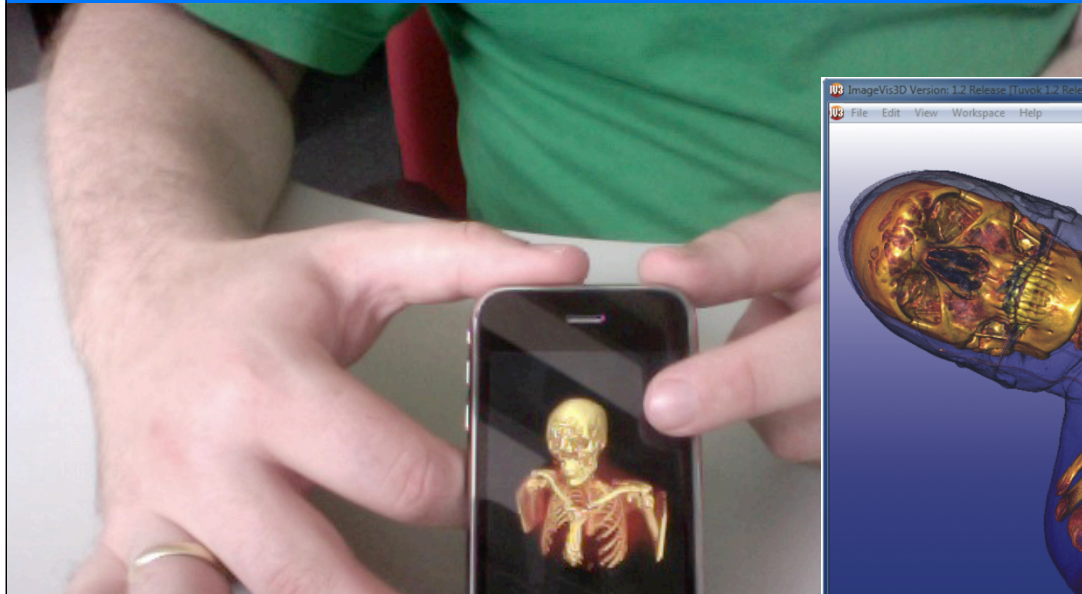
Total & Compute+Merge Time For Rayleigh–Taylor Mixing



Computation + I/O

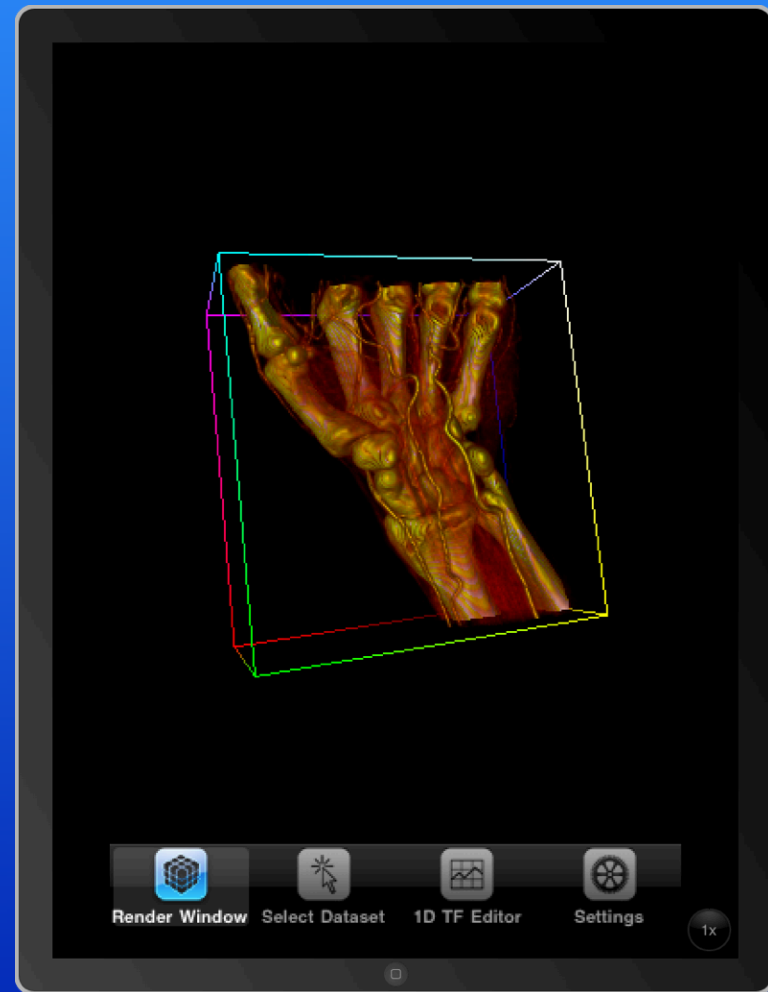
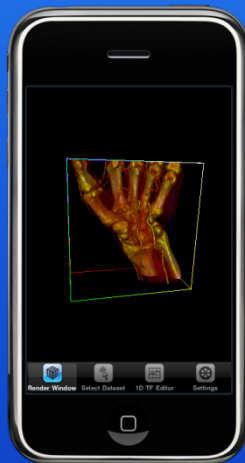
Pure Computation

# ImageVis3D - Mobile



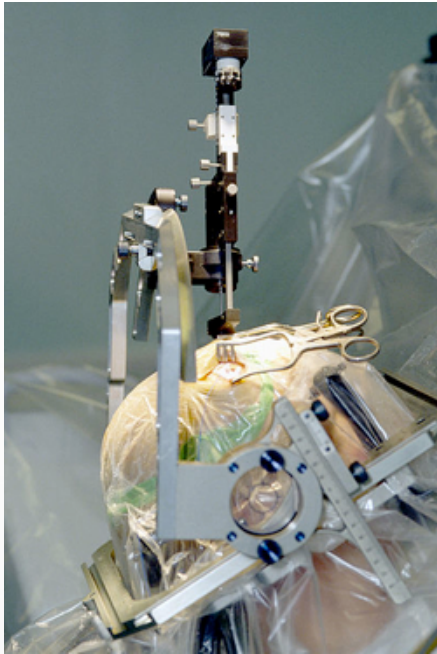


# ImageVis3D Mobile

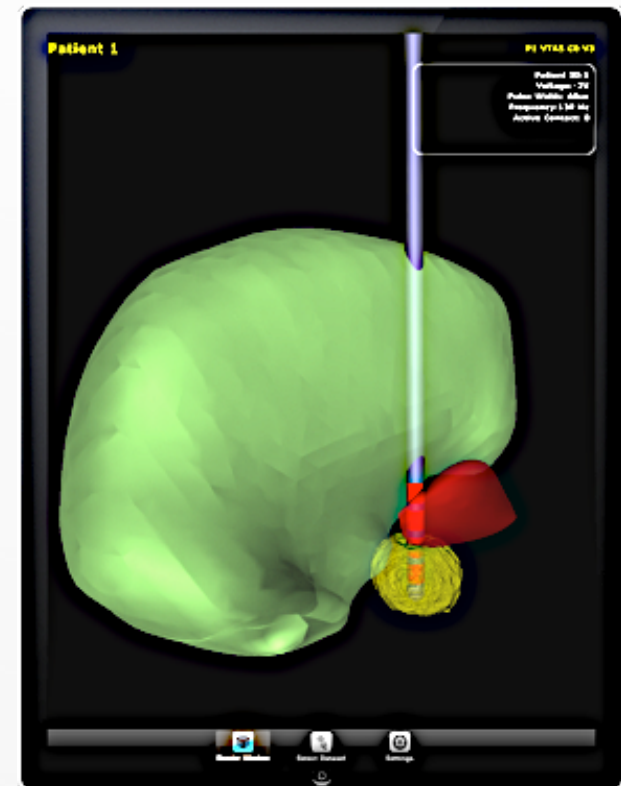


# ImageVis3D Mobile DBS App

Introduction



Deep Brain Stimulation  
DBP: Chris Butson

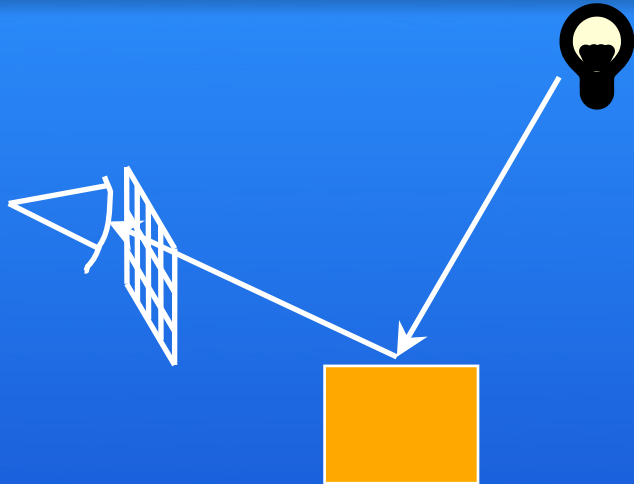


C. Butson, G. Tamm, S. Jain, T. Fogal and J. Krüger  
"Evaluation of Interactive Visualization on Mobile  
Computing Platforms for Selection of Deep Brain  
Stimulation Parameters" *IEEE Transactions on  
Visualization and Computer Graphics*, 2012 (in  
press).





# Parallel Rendering - Ray Tracing



Scientific Computing and Imaging Institute, University of Utah

# Rendering Algorithms

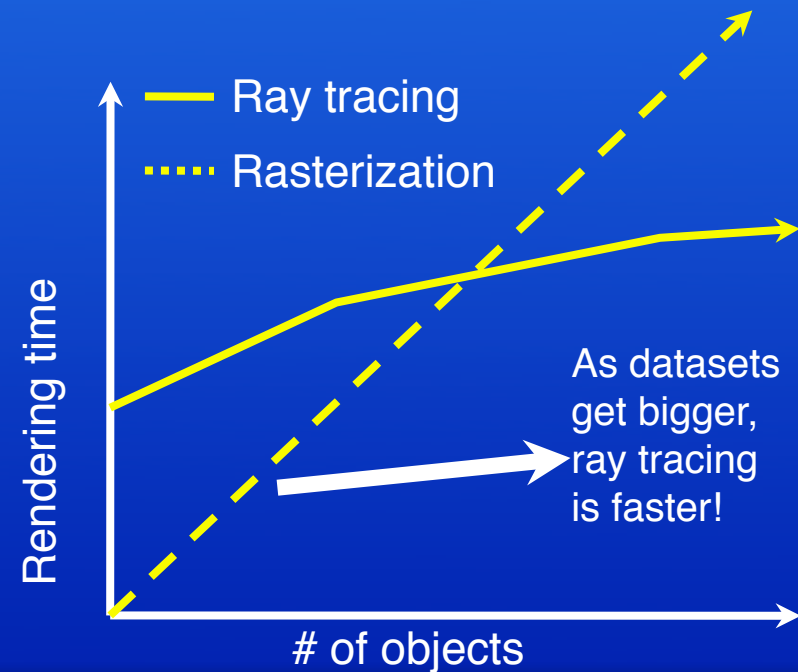
Basic idea: modeling the physics of light

## Rasterization (Z-buffer)

- Invented at U of U in 1974
- Hardware in every modern PC
- High interactivity, increasing quality

## Ray tracing

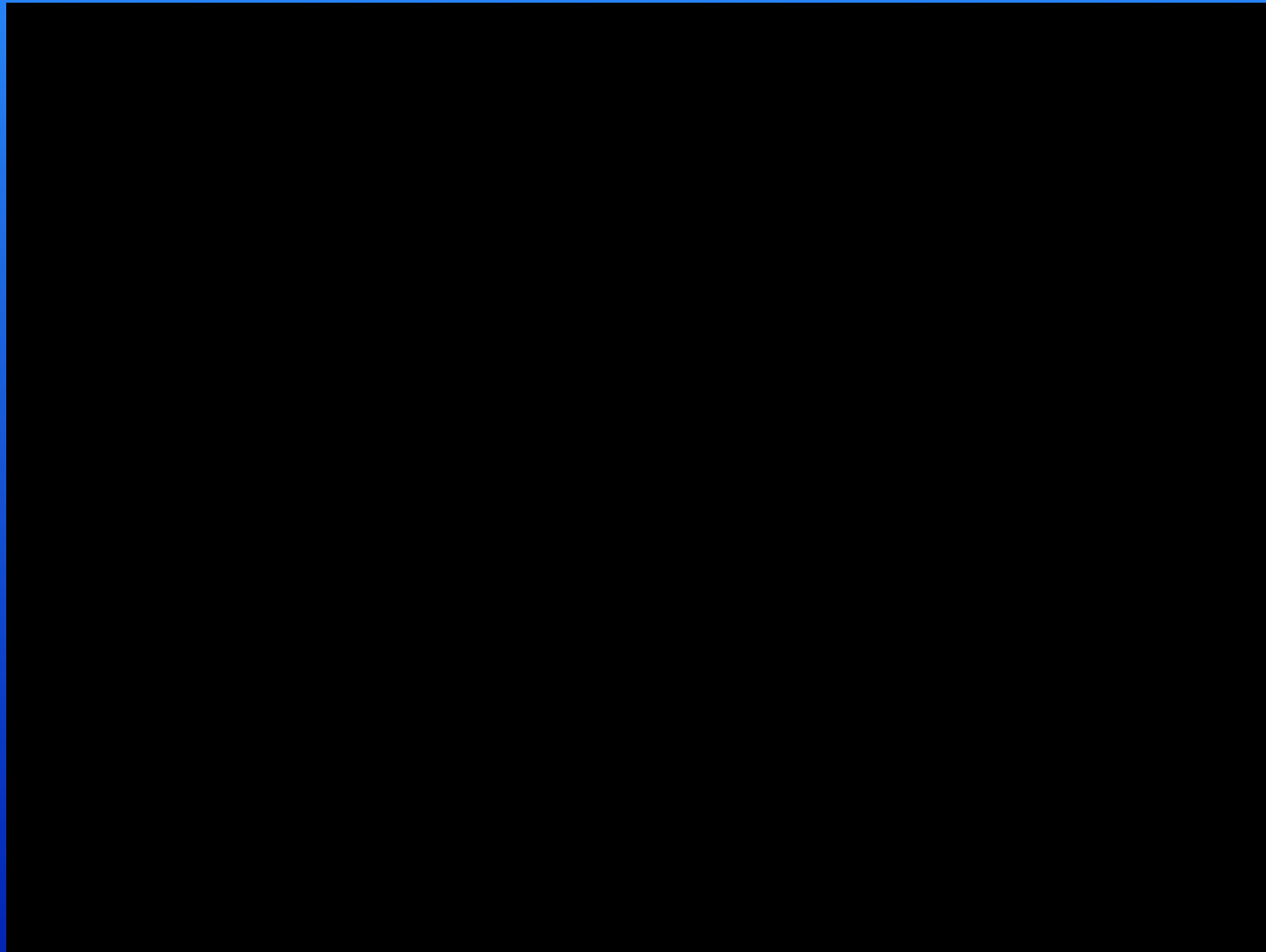
- Whitted 1980
- High quality, increasing interactivity





# 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**

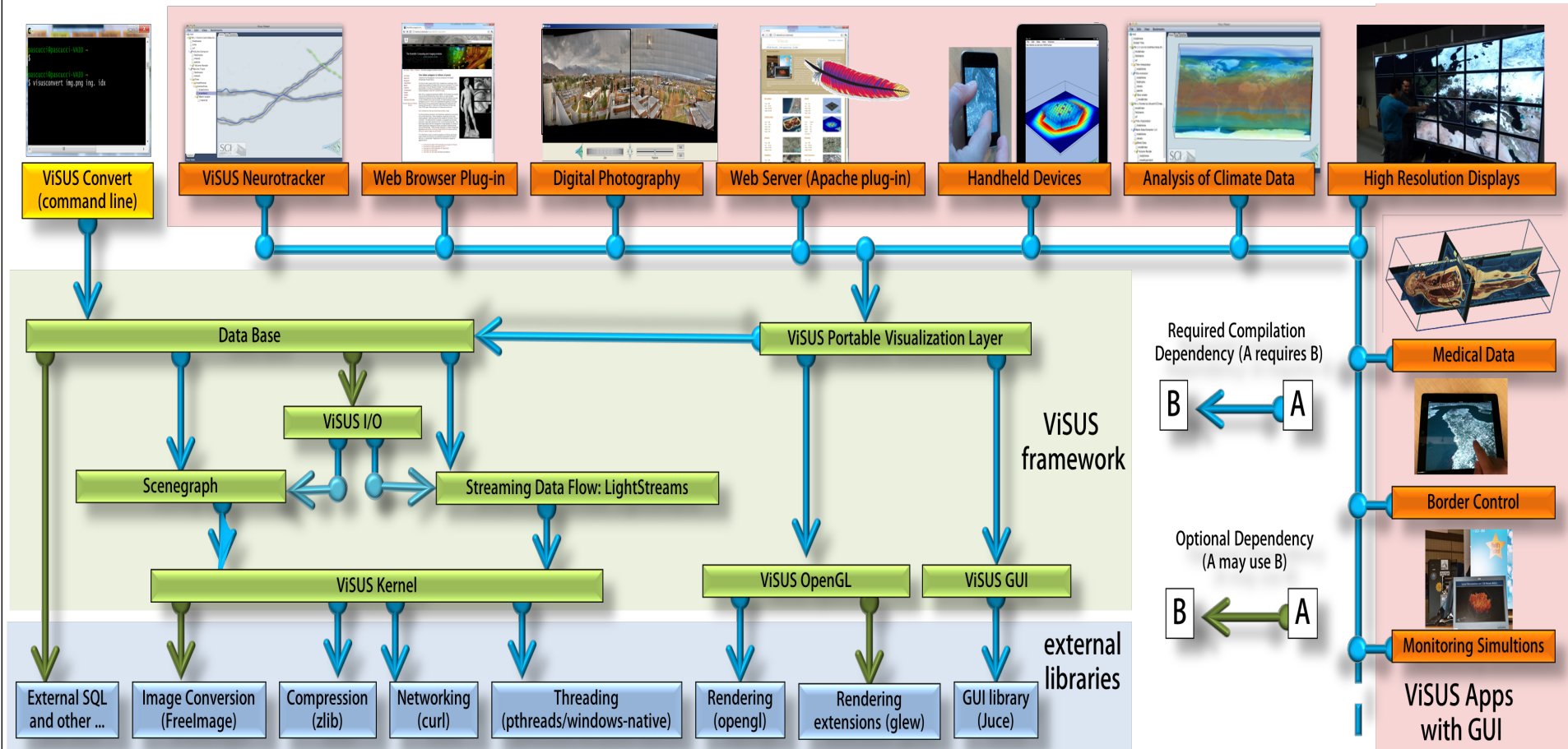
Welcome to the first  
gigapixel, multi-view  
rendering of

The Digital Michelangelo  
Project's David



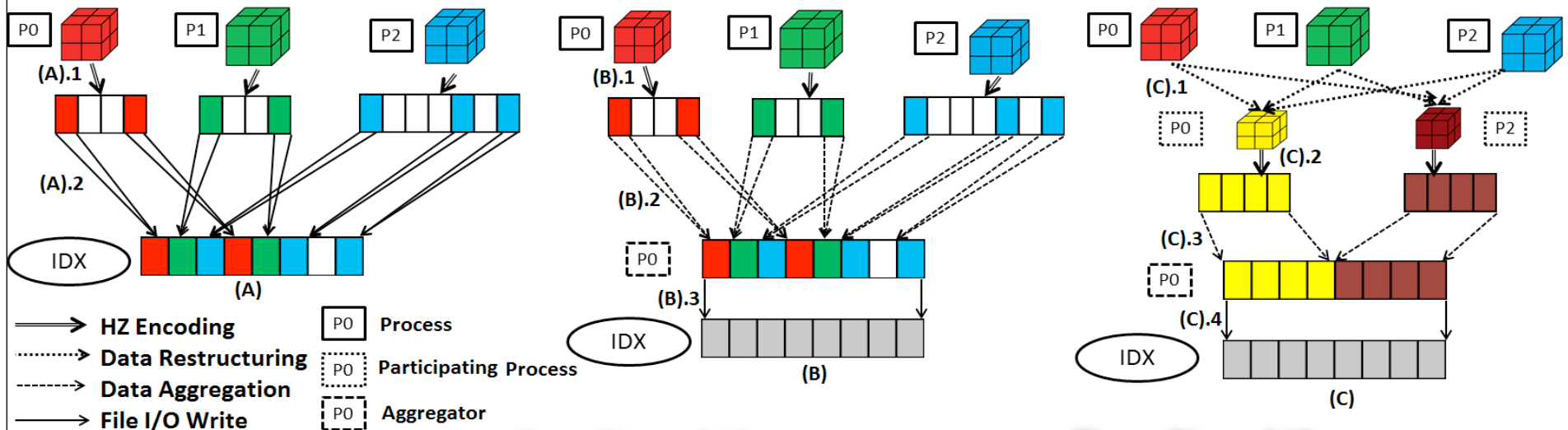
Scientific Computing and Imaging Institute, University of Utah

# ViSUS Framework for Scalable Data





# The ViSUS Parallel I/O Infrastructure (PIDX) Adopts a 3-Phase Data Transfer Model



## One-Phase I/O:

**(A).1** HZ encoding of irregular data set leads to sparse data buffers interleaved across processes.

**(A).2** I/O writes to underlying IDX file by each process, leading to a large number of small accesses to each file.

## Two-Phase I/O:

**(B).1** HZ encoding of irregular data set leads to sparse data buffers interleaved across processes.

**(B).2** Data transfer from in-memory HZ ordered data to an aggregation buffer involving large number of small sized data packets.

**(B).3** Large sized aligned I/O writes from aggregation buffer to the IDX file.

## Three-Phase I/O:

**(C).1** Data restructuring among processes transforms irregular data blocks at processes P0, P1 and P2 to regular data blocks at processes P0 and P2.

**(C).2** HZ encoding of regular blocks leading to dense and non-overlapping data buffer.

**(C).3** Data transfer from in-memory HZ ordered data to an aggregation buffer involving fewer large sized data packets.

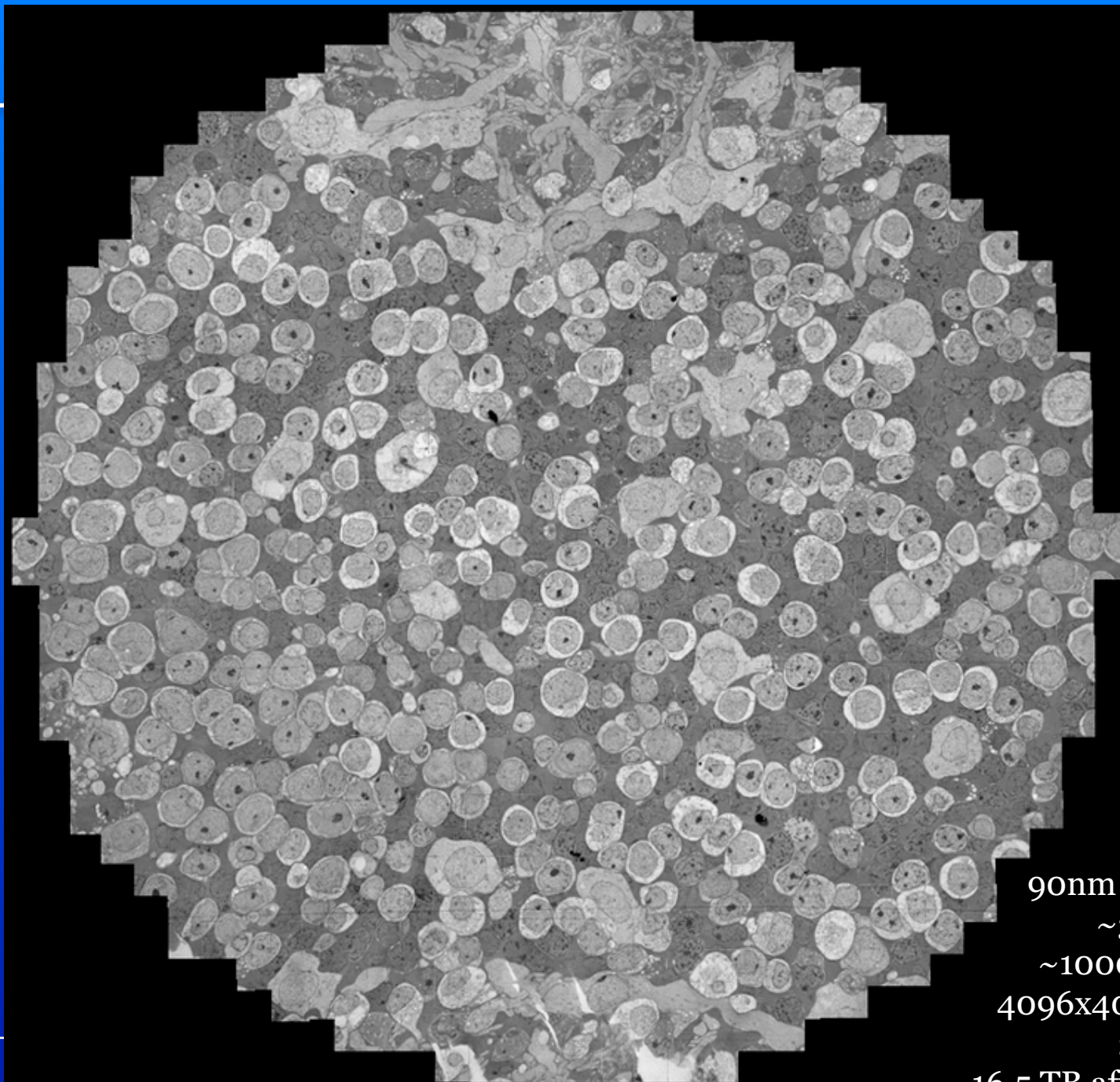
**(C).4** I/O writes from aggregation buffer to a IDX file.

# Large Scale Galaxy Simulation



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

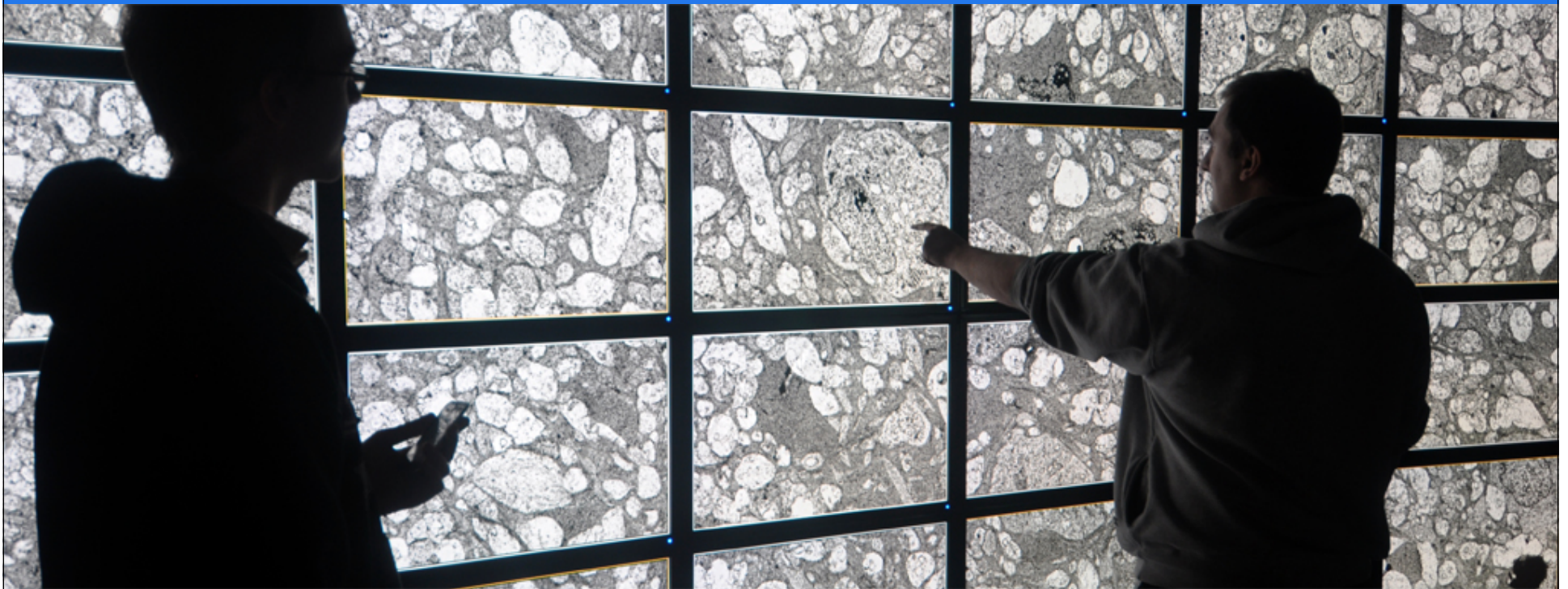


# Antony van Leeuwenhoek (1632-1723)



*... 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**

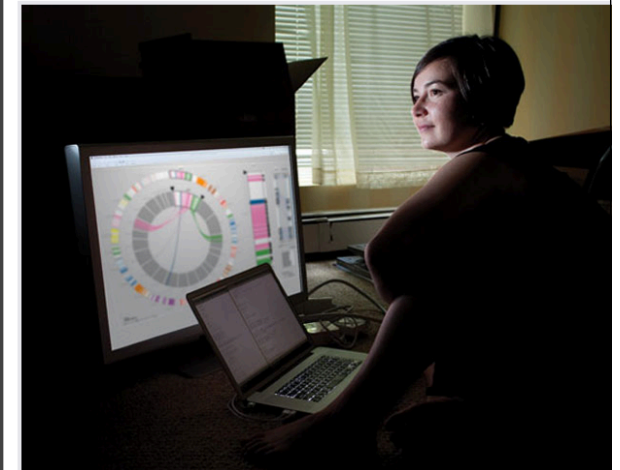


# PROBLEM-DRIVEN VISUALIZATION RESEARCH *for biological data*

- target specific biological problems
- close collaboration with biologists
- rapid, iterative prototyping
- focus on genomic and molecular data

tr35 Technology Review's annual list of 35  
**INNOVATORS**  
UNDER 35

Miriah Meyer, 34  
Extending data visualization to biology  
University of Utah



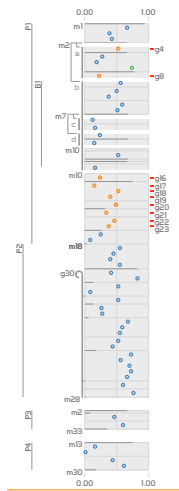


M. Meyer et al., EuroVis 2010.

# Pathline

## PATHLINE

PATHWAY METRIC OVERVIEW



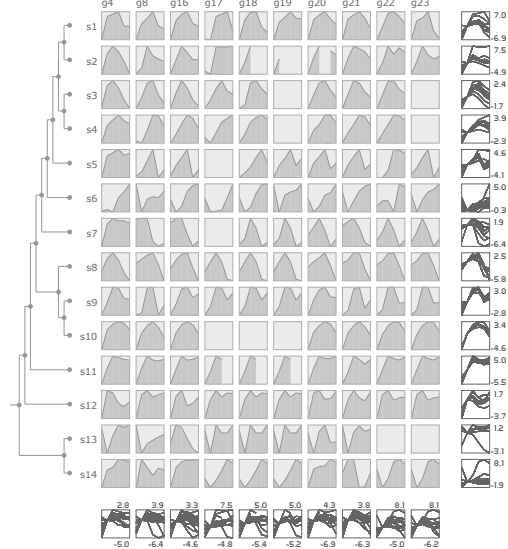
KEY Genes: forward, reverse, bidirectional  
Metabolites: Metrics, PearsonRL

SPECIES

CURVEMAP

A TOOL FOR COMPARATIVE FUNCTIONAL GENOMICS

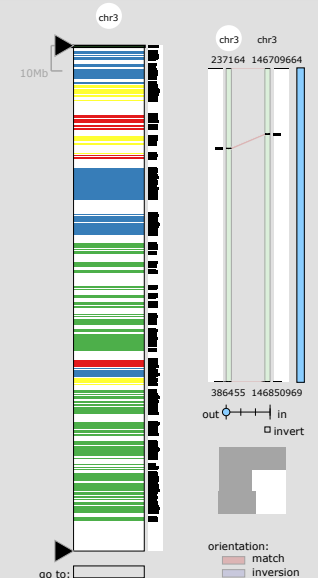
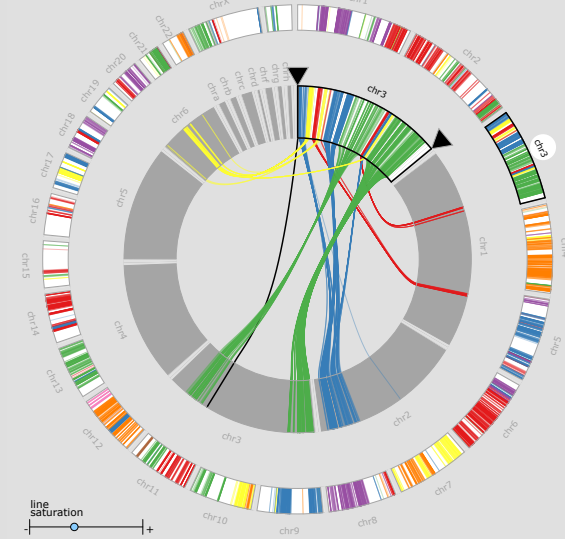
OVERLAYS



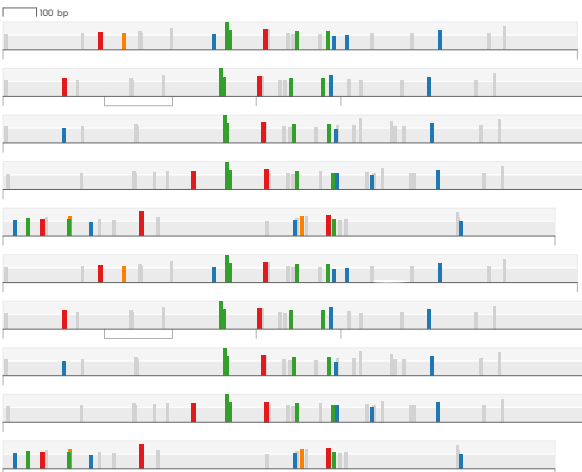
# MizBee

M. Meyer et al., InfoVis 2009.

source: Human  
destination: Lizard



Regions



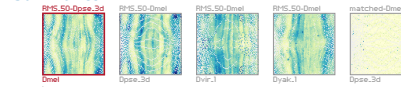
Alignment

Site types

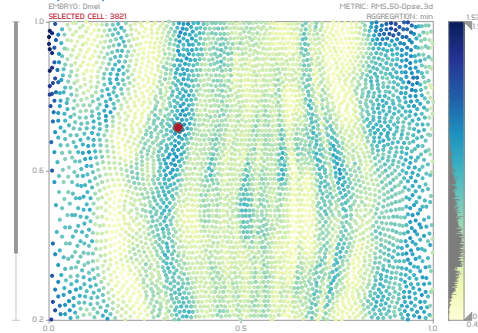
class1, class2, class3, class4, class5, class6, class7, class8, class9

clear

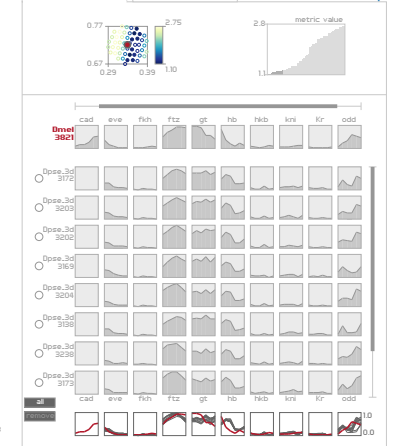
Summaries



Embryo Map



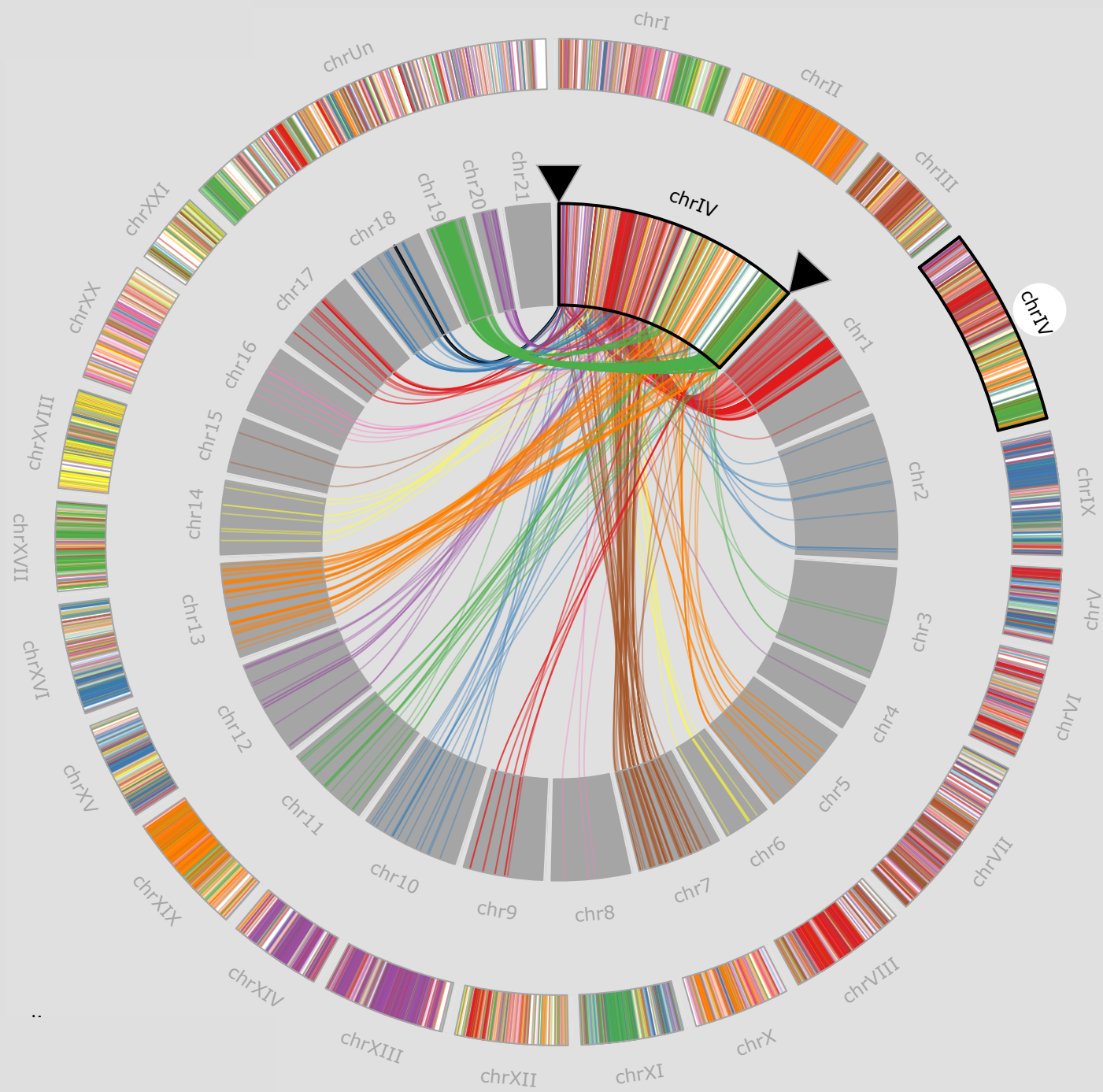
REGISTRATION GROUP CREATED GROUP Curvemap

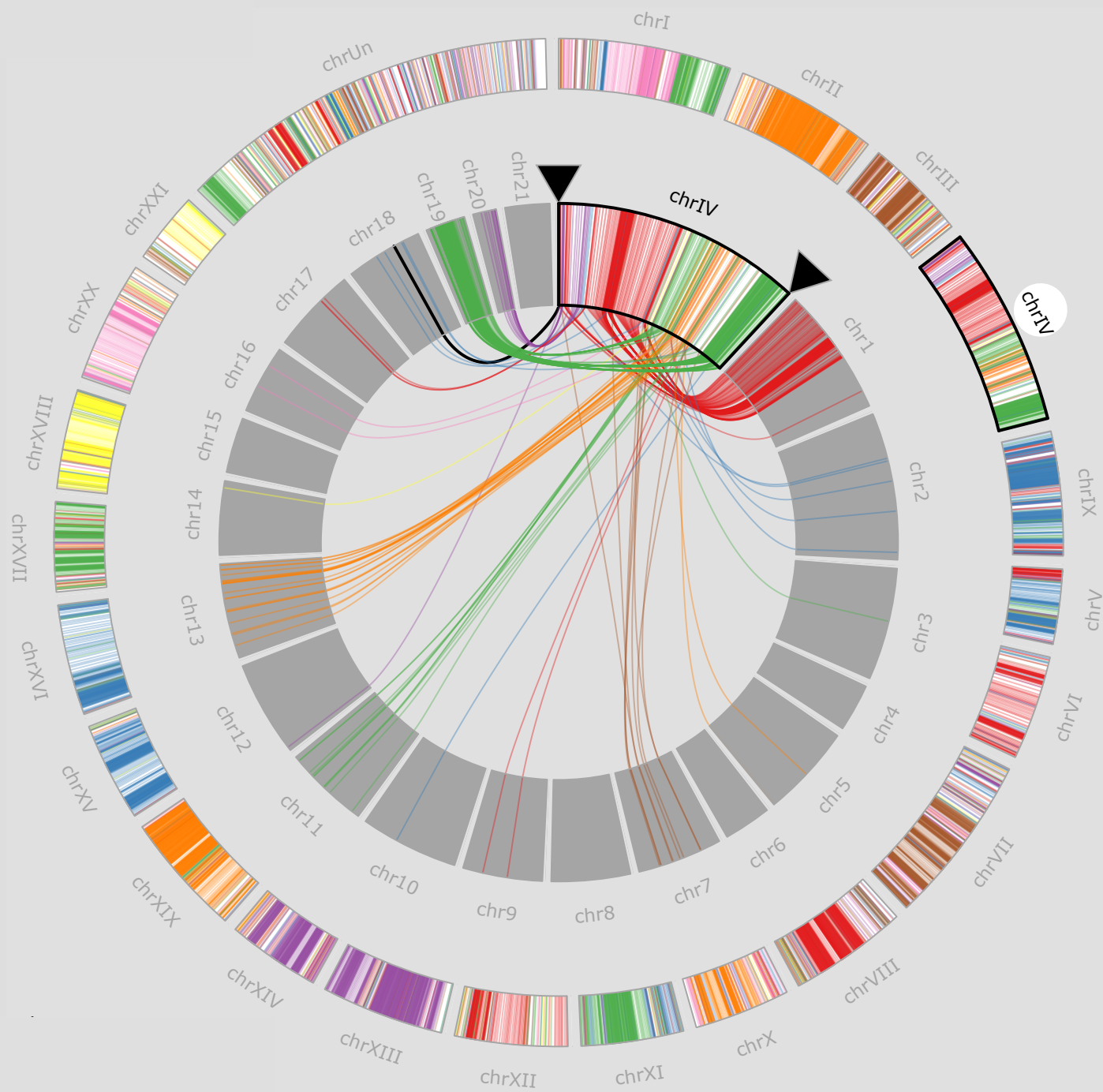


# InSite

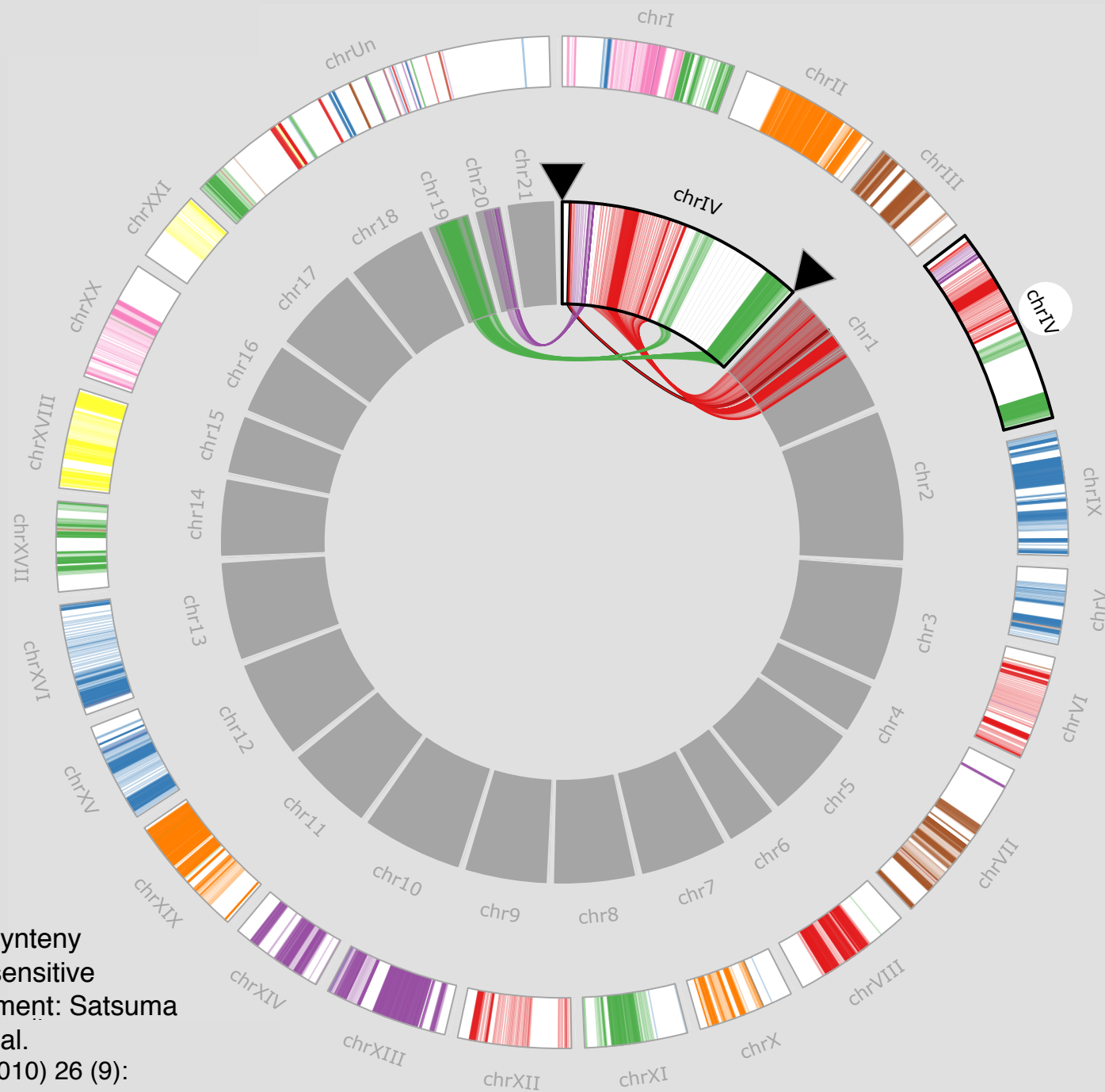
# MulteeSum

M. Meyer et al., InfoVis 2010.









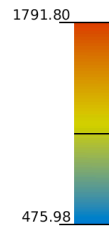
Genome-wide synteny  
through highly sensitive  
sequence alignment: Satsuma  
M. Grabherr, et al.  
Bioinformatics (2010) 26 (9):  
1145-1151.

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



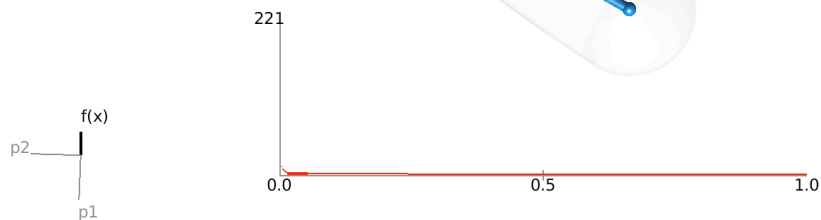
Local Extinction

Value: 1066.76  
Input std: 0.61  
Density: 0.0004

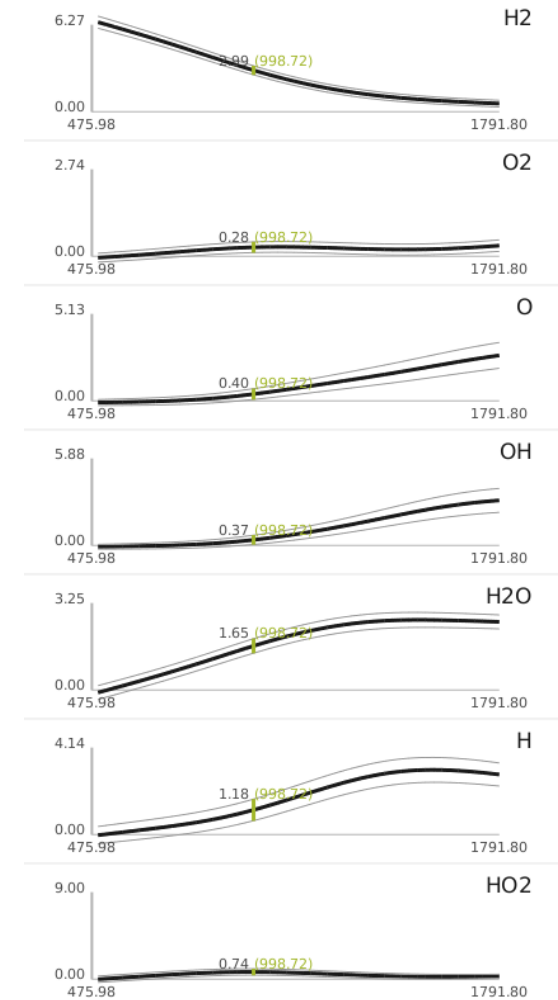


Pure Oxidizer

Pure Fuel



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

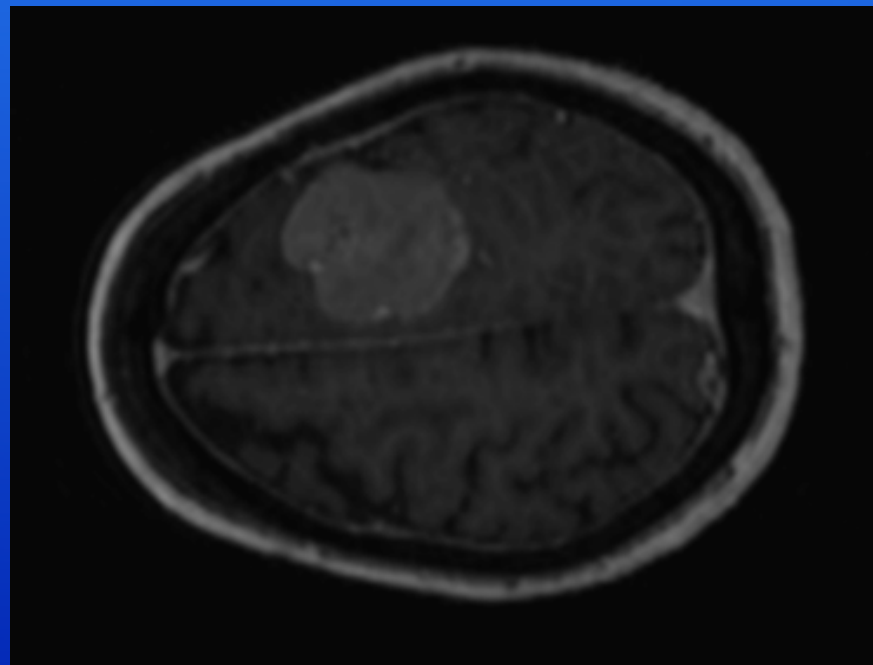
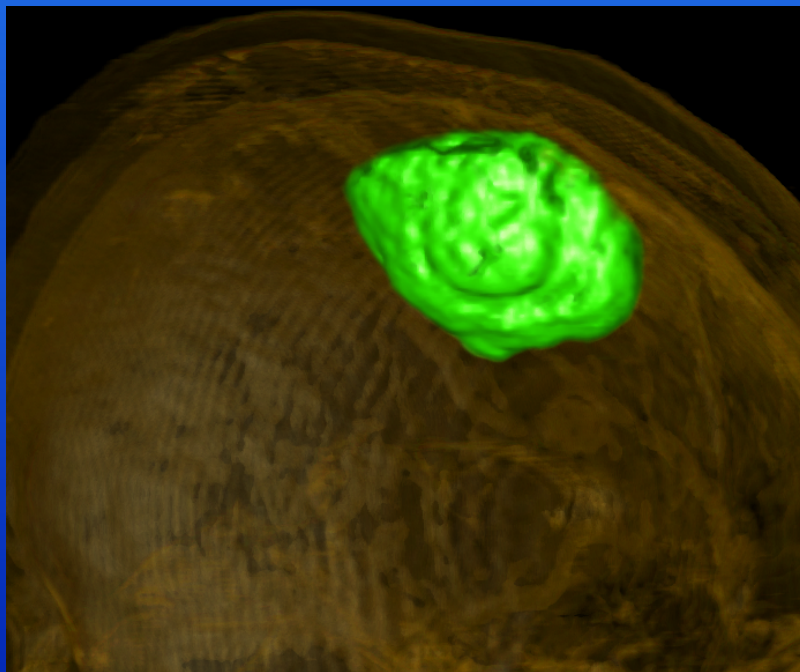
**Output:** Temperature



# Uncertainty Visualization



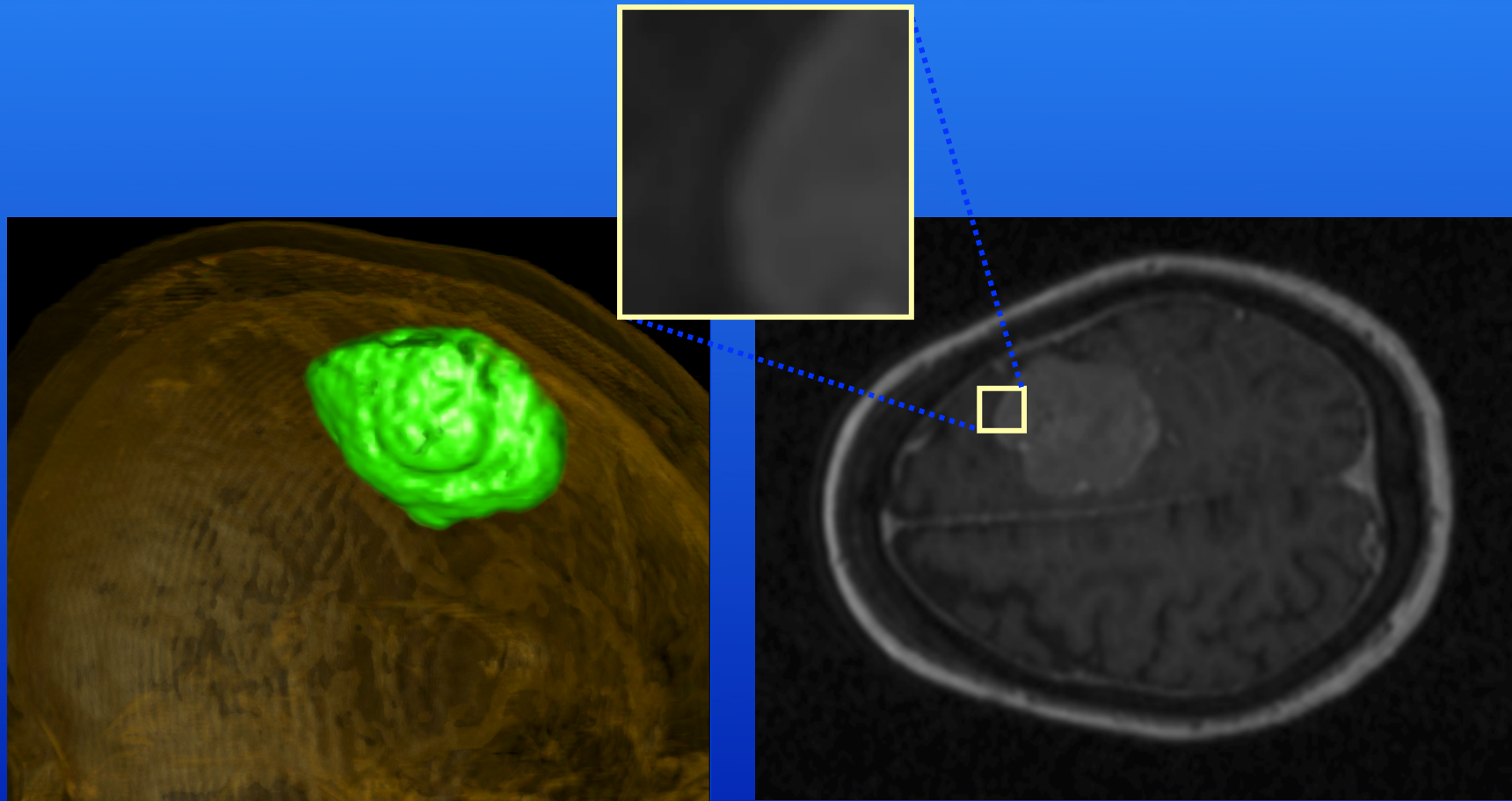
**When is the last time you've seen an error bar in a 3D visualization?**



# Uncertainty Visualization

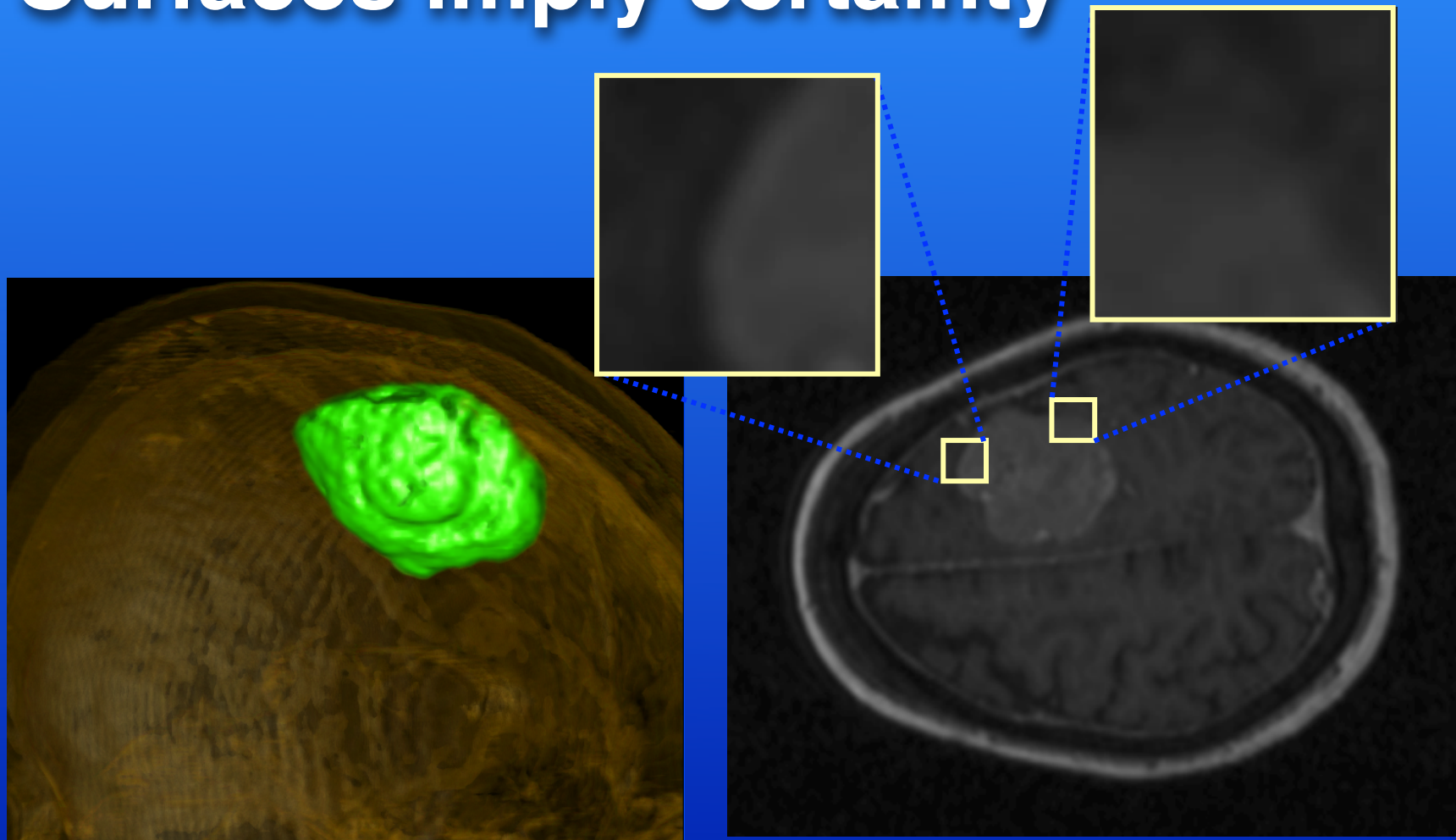


## Surfaces imply certainty



# Uncertainty Visualization

## Surfaces imply certainty

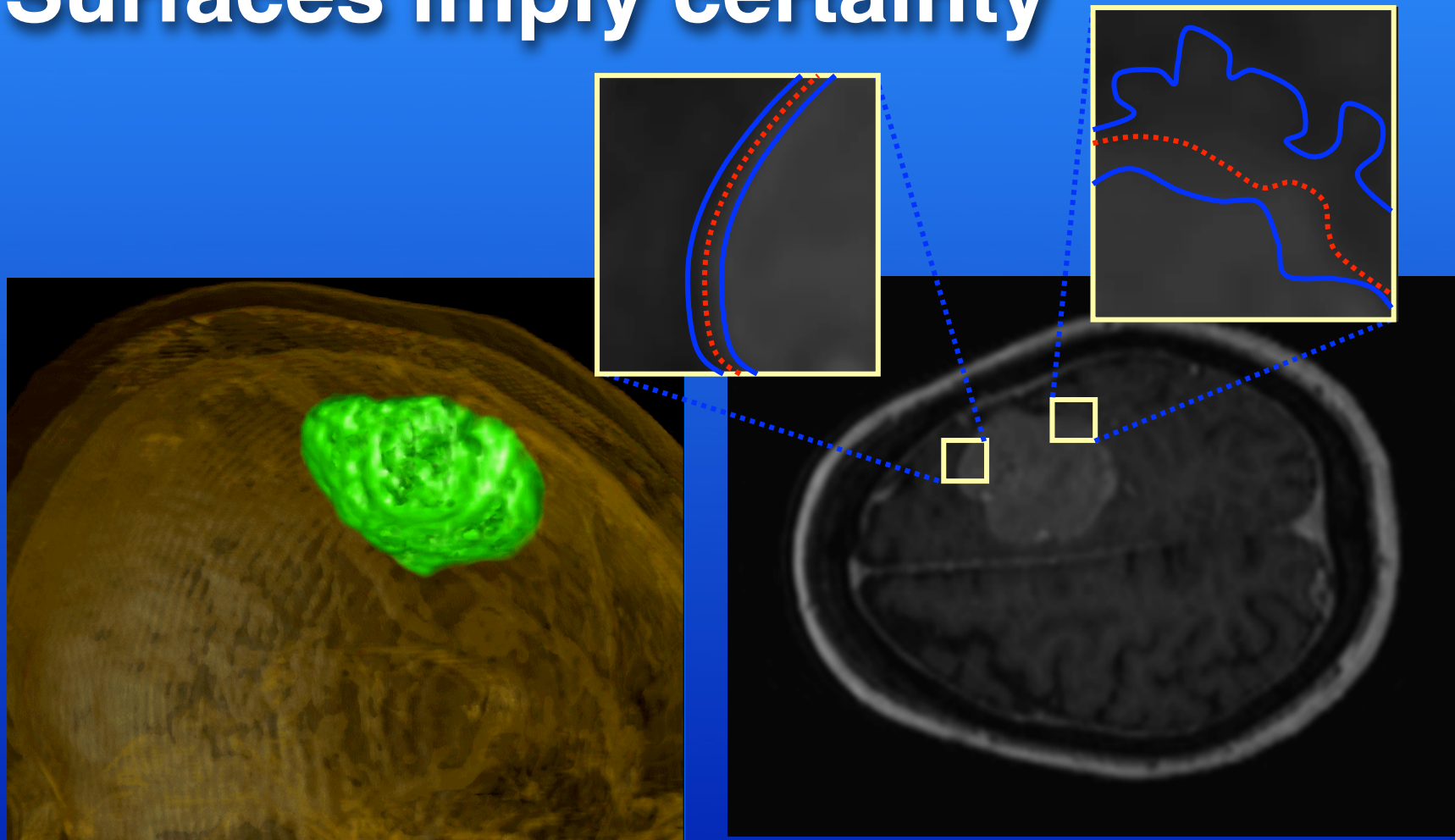




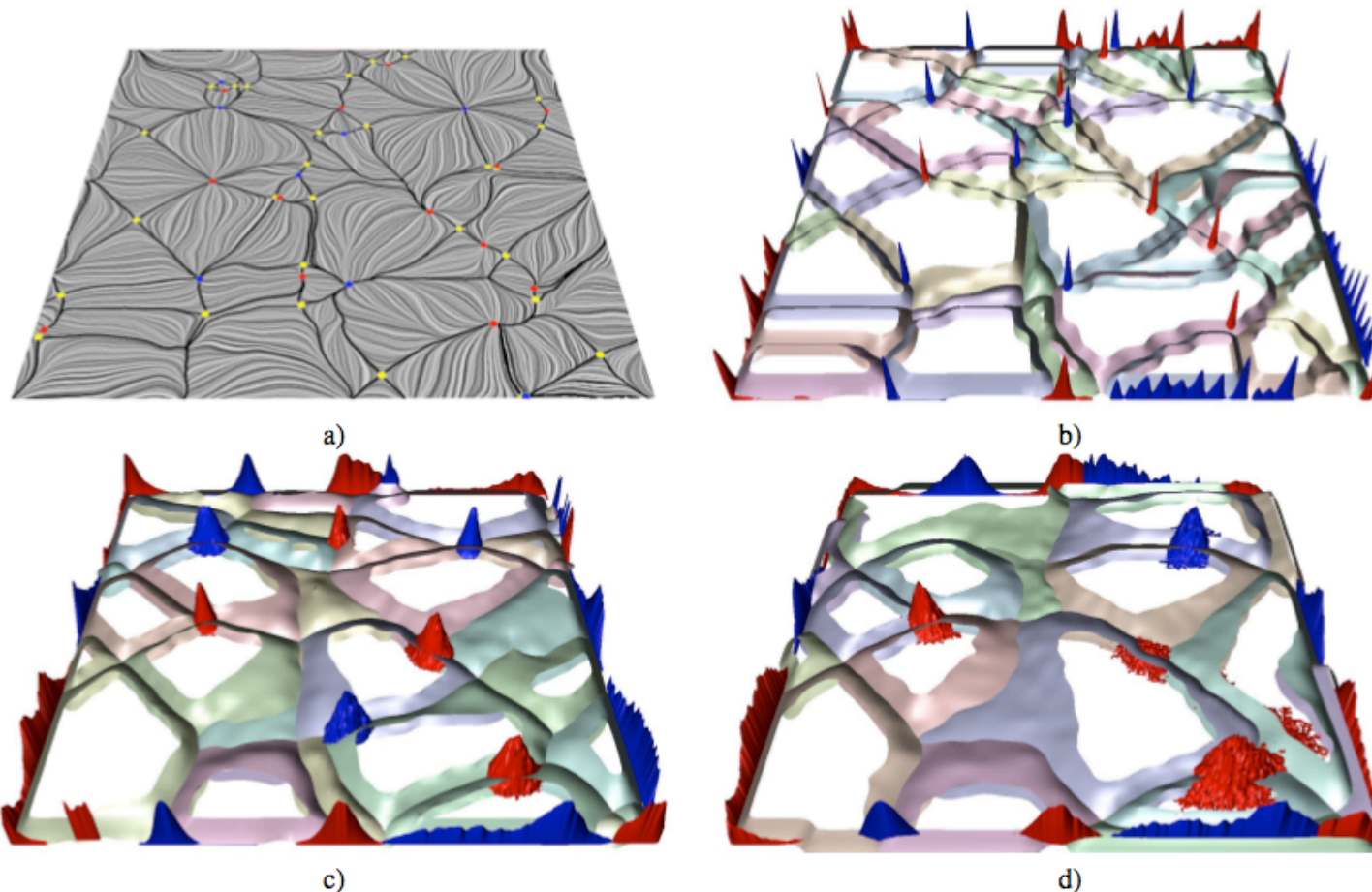
# Uncertainty Visualization



## Surfaces imply certainty



# Topological Uncertainty

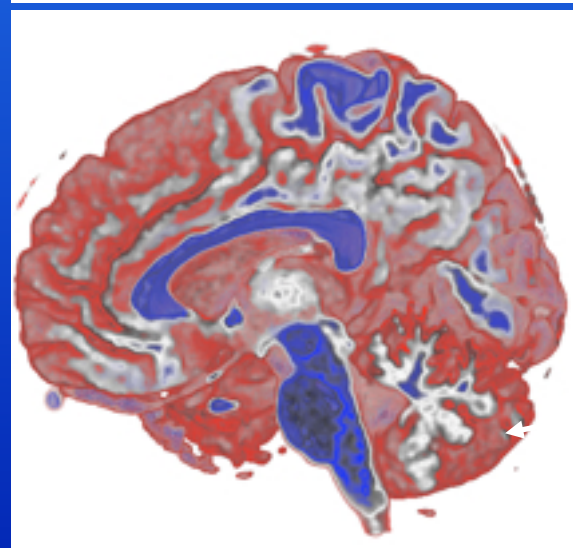
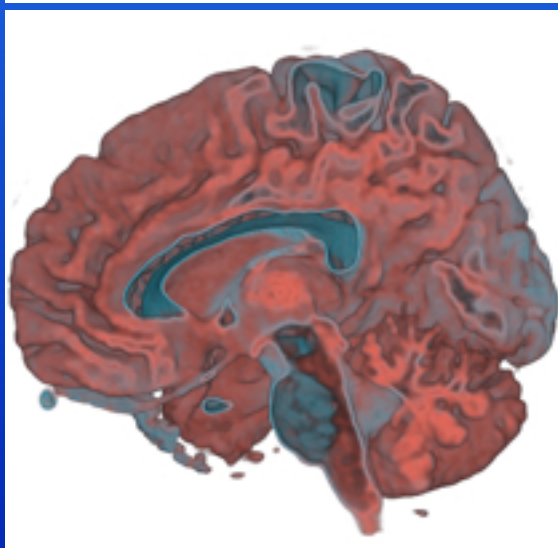
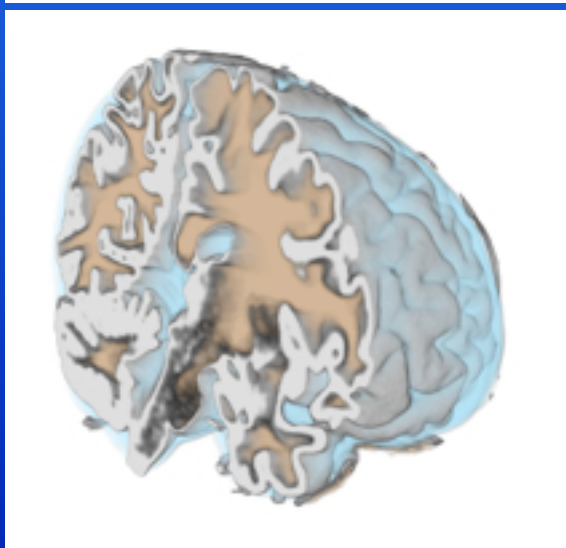
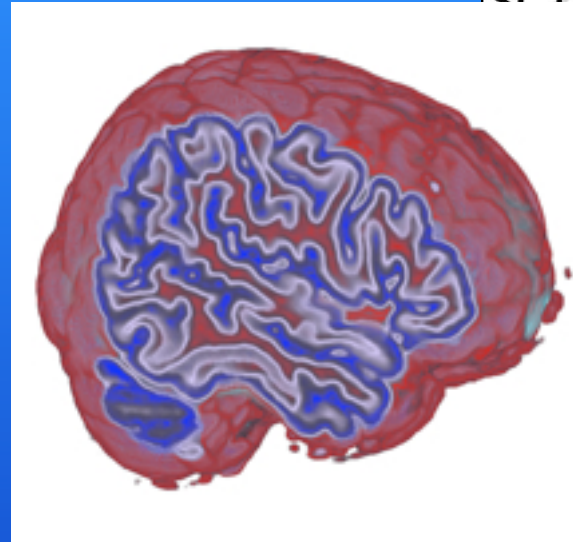
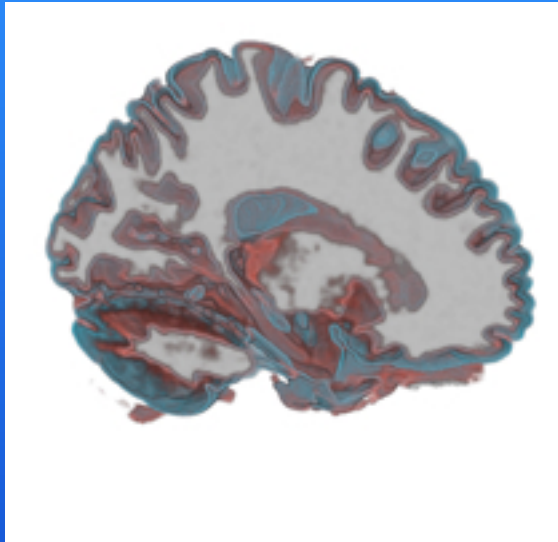
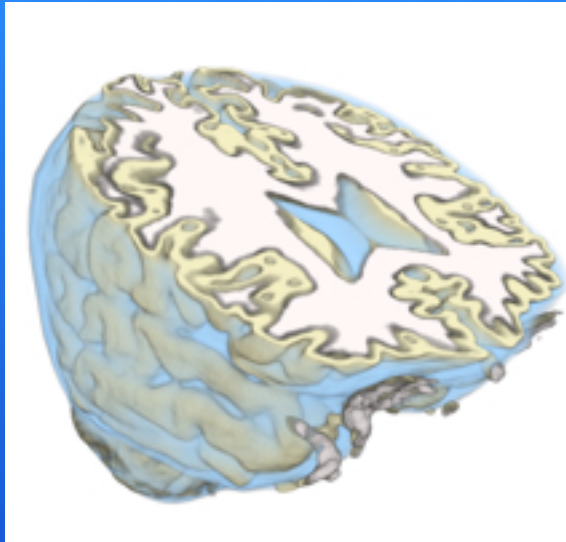


**Figure 6:** Increasing the uncertainty of a random vector field: a) certain topology of mean vector field; b)  $\|\mathbf{T}\|_F = 0.2$ ; c)  $\|\mathbf{T}\|_F = 2.0$ ; d)  $\|\mathbf{T}\|_F = 5.0$ .

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



# Visualizing Uncertainty



Fuzzy

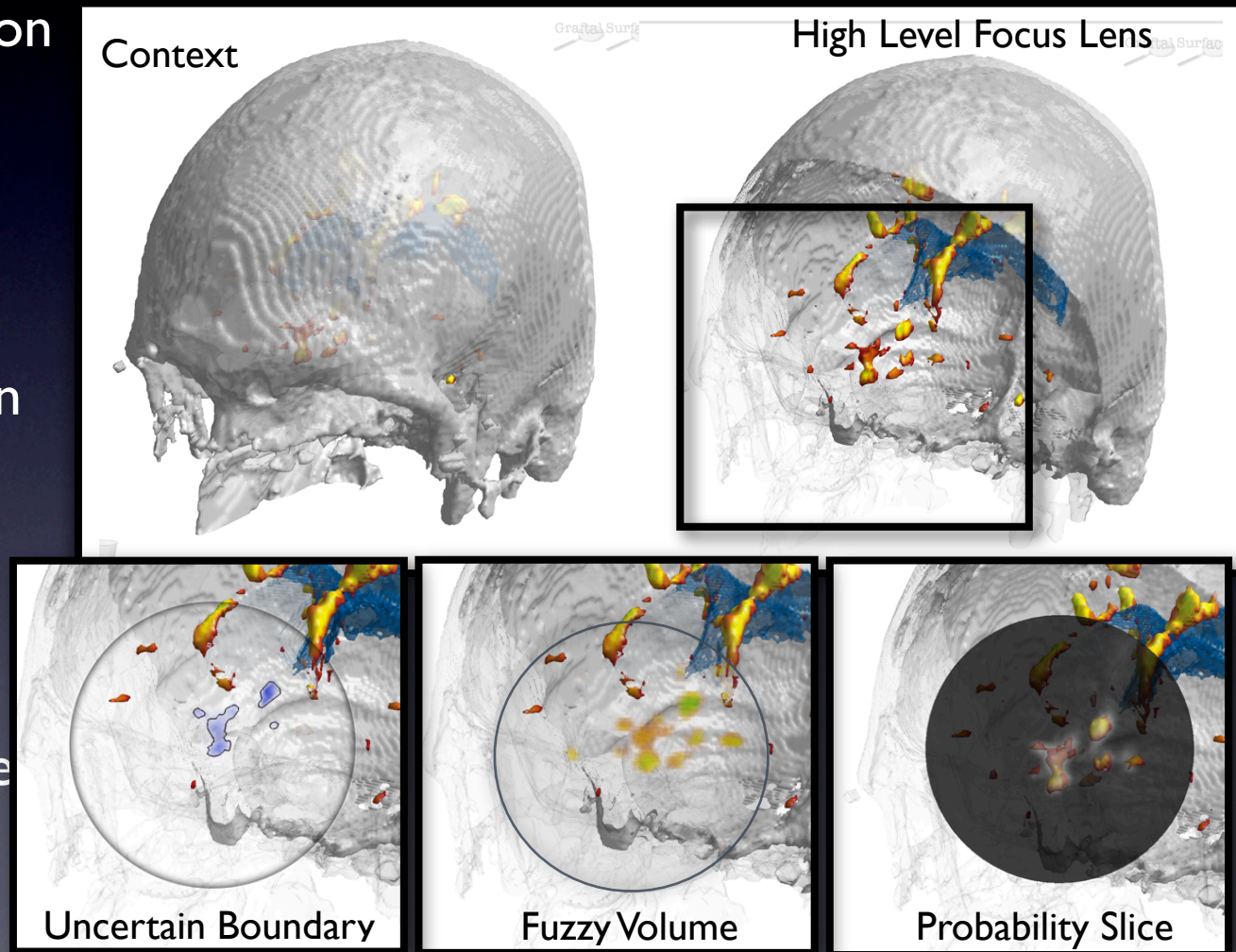
Sensitivity

Confidence



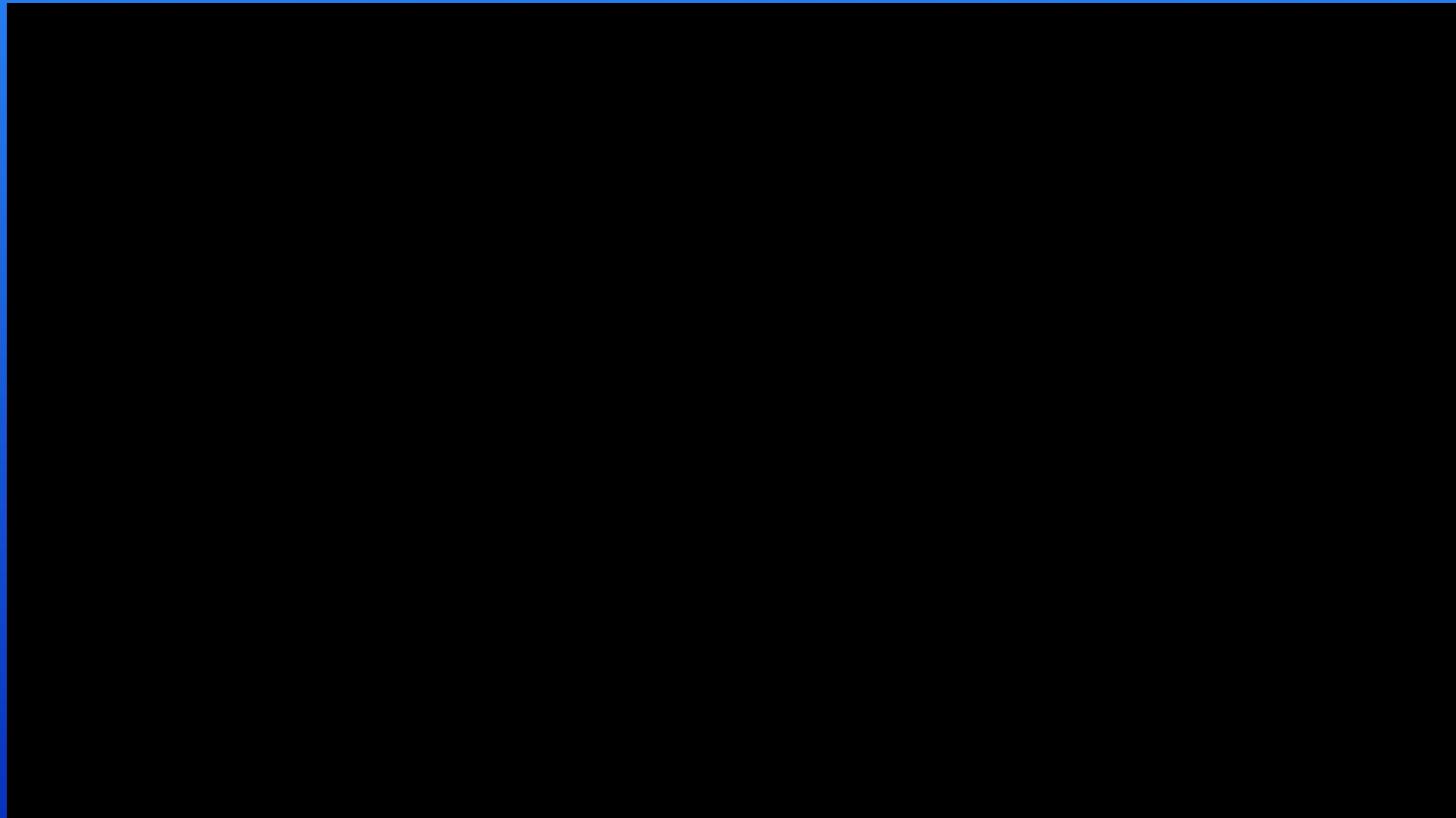
# QuizLens: A Multi-lens approach for uncertainty exploration

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



# Scientific Computing and Visualization

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Scientific Computing and Imaging Institute, University of Utah



# The SCI Institute





# Productivity Machines







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Salt Lake City, Utah

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**NSF**

**Utah Centers of Excellence**

**KAUST**



# More Information

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