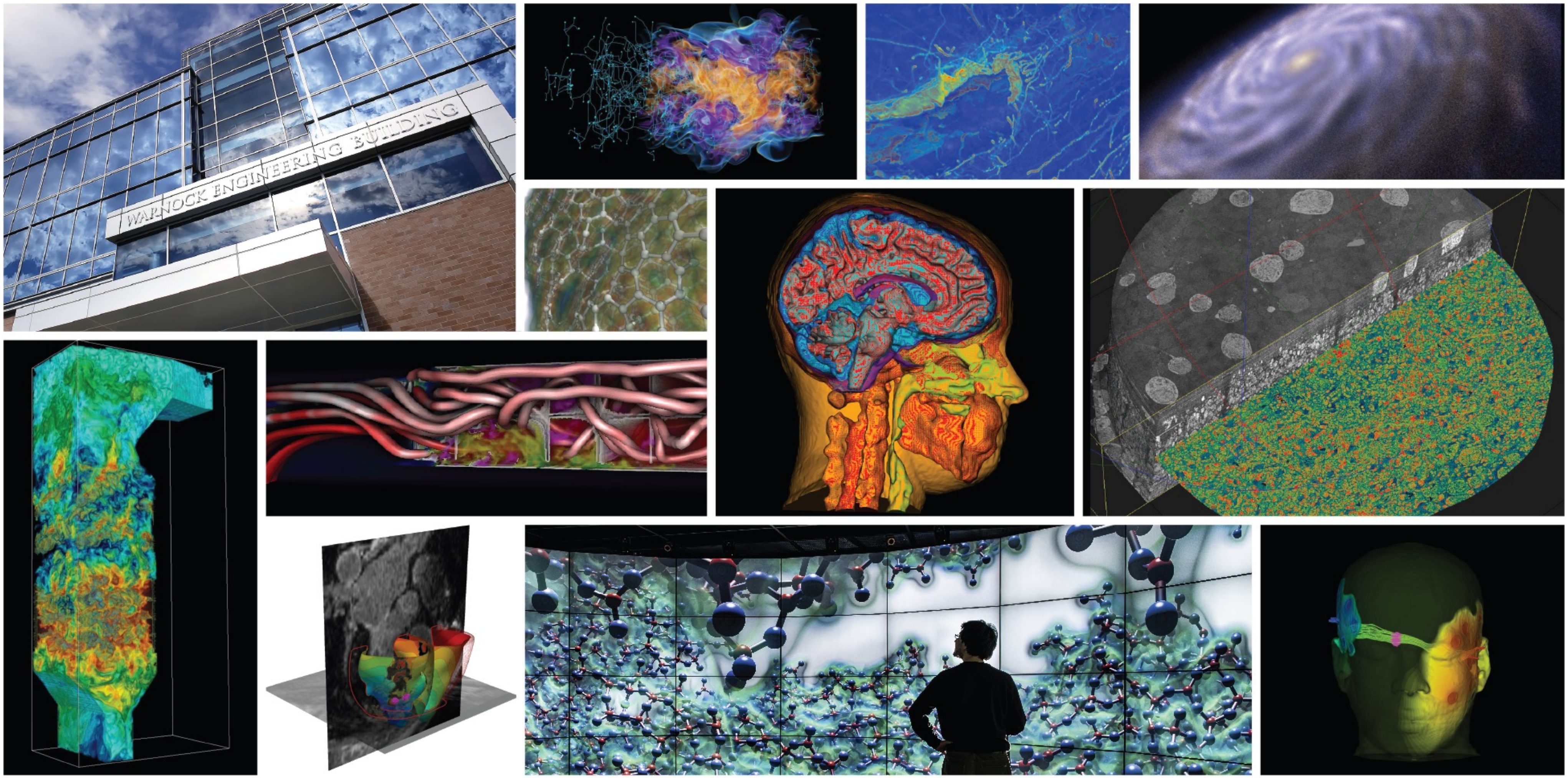
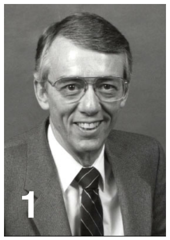
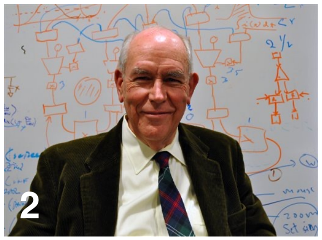
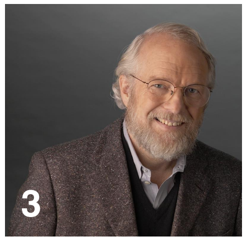
# Large-Scale Visual Analysis in the Age of Data

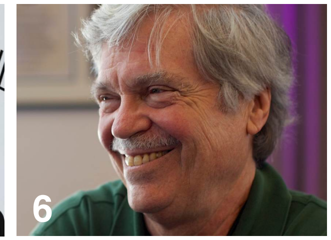


# Computer Graphics at Utah










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

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

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

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

**8. Jim Kajyia**
- Rendering Equation
- VP Research at Microsoft

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

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

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

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

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

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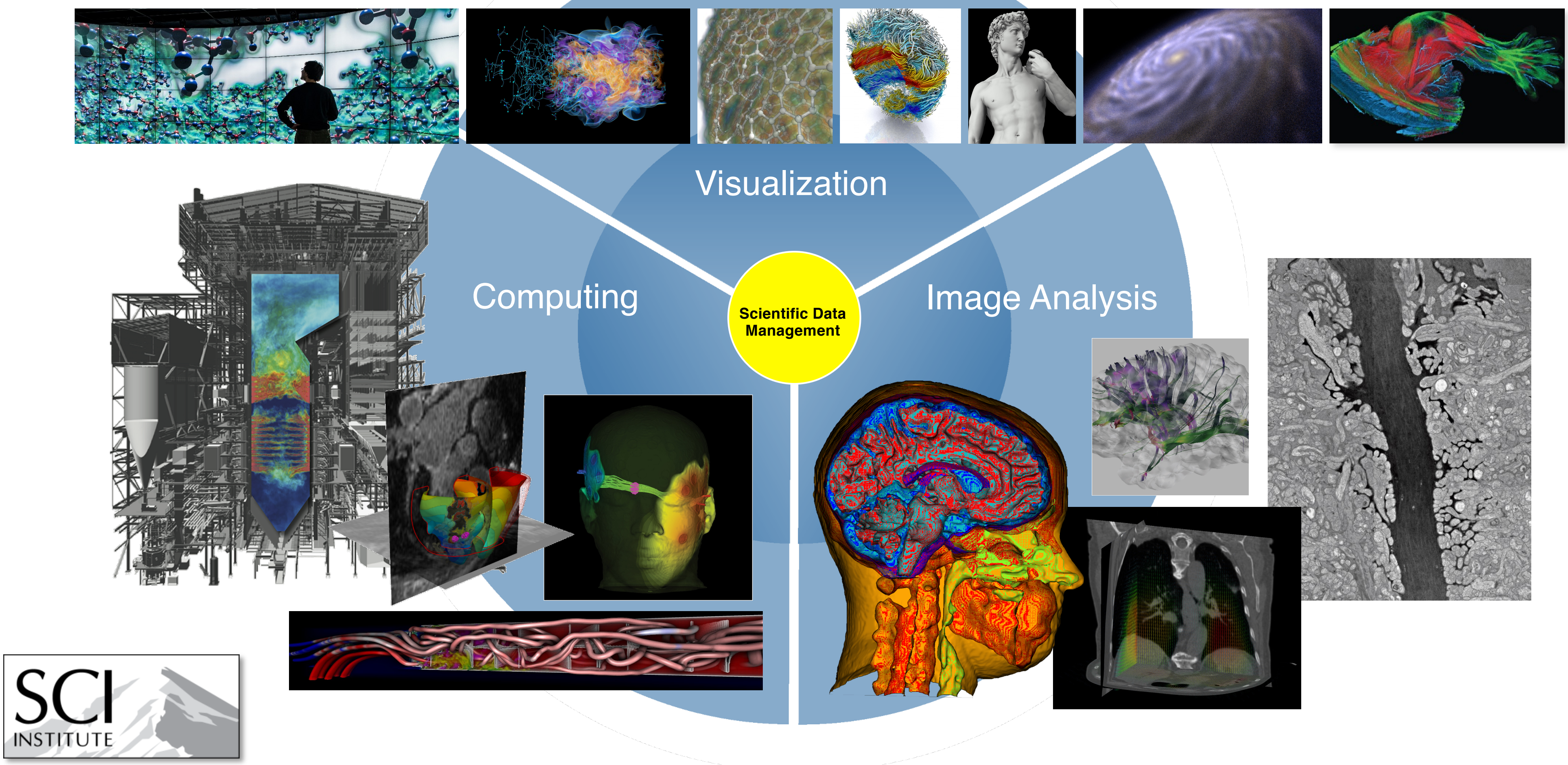
# Research Cores



# Research Centers at SCI

CIBC NIH/NIGMS Center for Integrative Biomedical Computing

CI Compass NSF Cyberinfrastructure Center of Excellence

intel OneAPI Center of Excellence

intel Graphics and Visualization Institute

NVIDIA GPU CENTER OF EXCELLENCE

CEDMAV Center for Extreme Data Management, Analysis, and Visualization

NSDF National Science Data Fabric

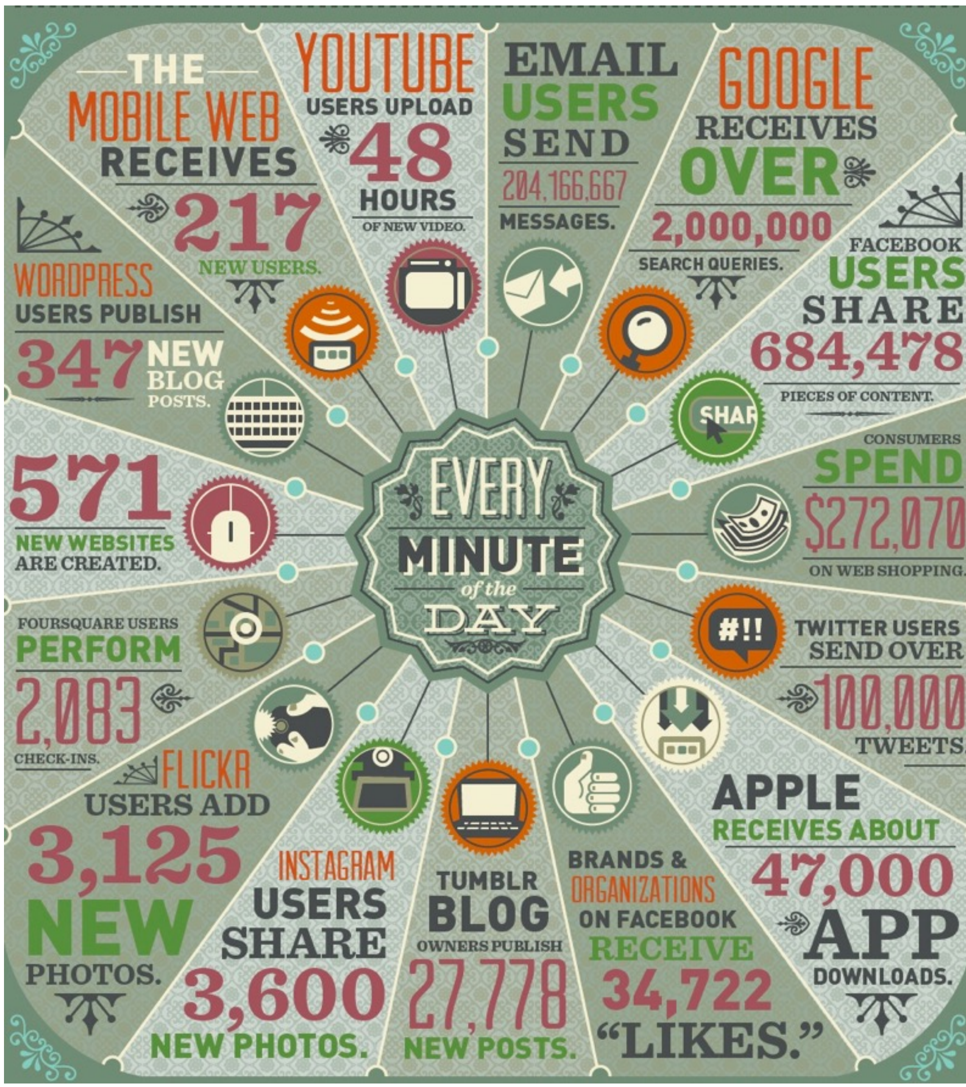
UTAH Center for Computational Earth Sciences

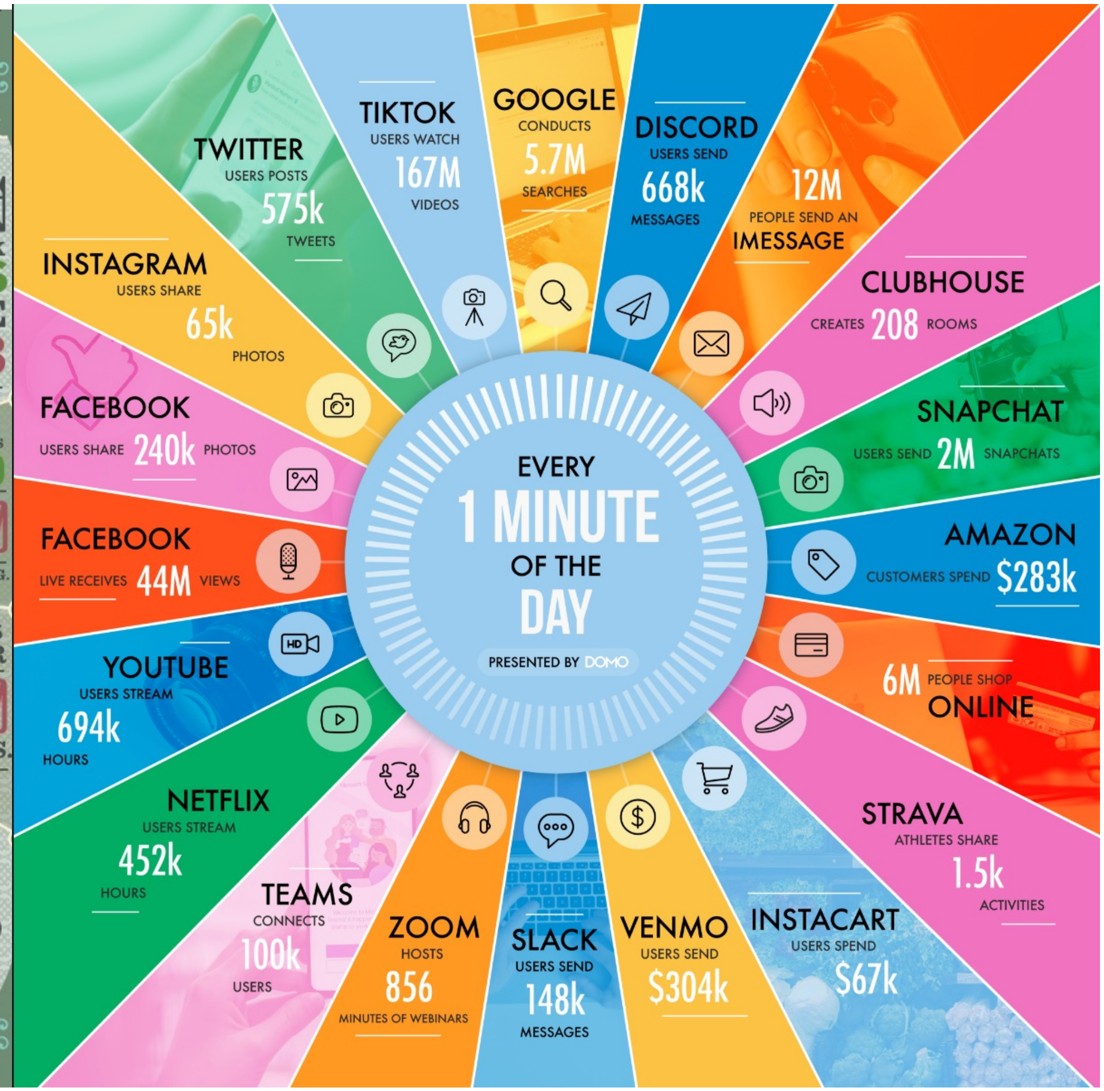
Carbon Capture Multidisciplinary Simulation Center

$CDE_3M$ Alliance for Computationally-guided Design of Energy Efficient Electronic Materials

THE UNIVERSITY OF UTAH®

SCI www.sci.utah.edu


EVERY MINUTE of the DAY
THE MOBILE WEB RECEIVES 217 NEW USERS.
YOUTUBE USERS UPLOAD 48 HOURS OF NEW VIDEO.
EMAIL USERS SEND 204,166,667 MESSAGES.
GOOGLE RECEIVES OVER 2,000,000 SEARCH QUERIES.
FACEBOOK USERS SHARE 684,478 PIECES OF CONTENT.
CONSUMERS SPEND $272,070 ON WEB SHOPPING.
TWITTER USERS SEND OVER 100,000 TWEETS.
APPLE RECEIVES ABOUT 47,000 APP DOWNLOADS.
BRANDS & ORGANIZATIONS ON FACEBOOK RECEIVE 34,722 "LIKES."
TUMBLR BLOG OWNERS PUBLISH 27,778 NEW POSTS.
INSTAGRAM USERS SHARE 3,600 NEW PHOTOS.
FLICKR USERS ADD 3,125 NEW PHOTOS.
FOURSQUARE USERS PERFORM 2,083 CHECK-INS.
571 NEW WEBSITES ARE CREATED.
WORDPRESS USERS PUBLISH 347 NEW BLOG POSTS.


EVERY 1 MINUTE OF THE DAY
PRESENTED BY DOMO
TWITTER USERS POSTS 575k TWEETS
TIKTOK USERS WATCH 167M VIDEOS
GOOGLE CONDUCTS 5.7M SEARCHES
DISCORD USERS SEND 668k MESSAGES
12M PEOPLE SEND AN IMESSAGE
CLUBHOUSE CREATES 208 ROOMS
SNAPCHAT USERS SEND 2M SNAPCHATS
AMAZON CUSTOMERS SPEND $283k
6M PEOPLE SHOP ONLINE
STRAVA ATHLETES SHARE 1.5k ACTIVITIES
INSTACART USERS SPEND $67k
VENMO USERS SEND $304k
SLACK USERS SEND 148k MESSAGES
ZOOM HOSTS 856 MINUTES OF WEBINARS
TEAMS CONNECTS 100k USERS
NETFLIX USERS STREAM 452k HOURS
YOUTUBE USERS STREAM 694k HOURS
FACEBOOK LIVE RECEIVES 44M VIEWS
FACEBOOK USERS SHARE 240k PHOTOS
INSTAGRAM USERS SHARE 65k PHOTOS

# Brain Information Bandwidth

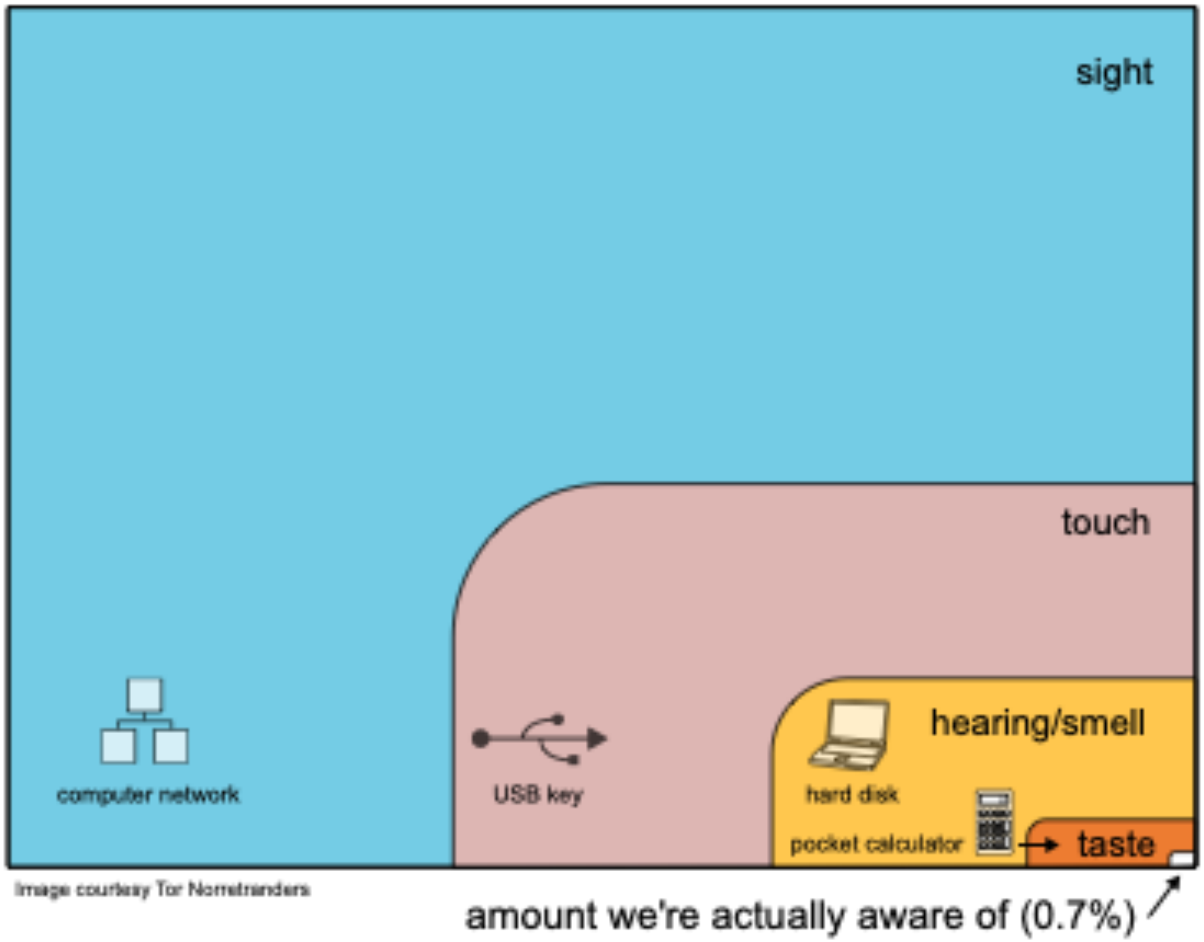
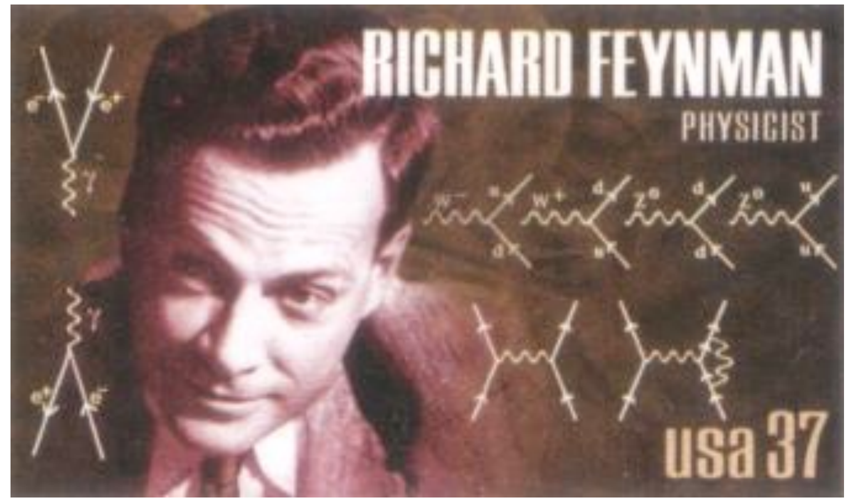
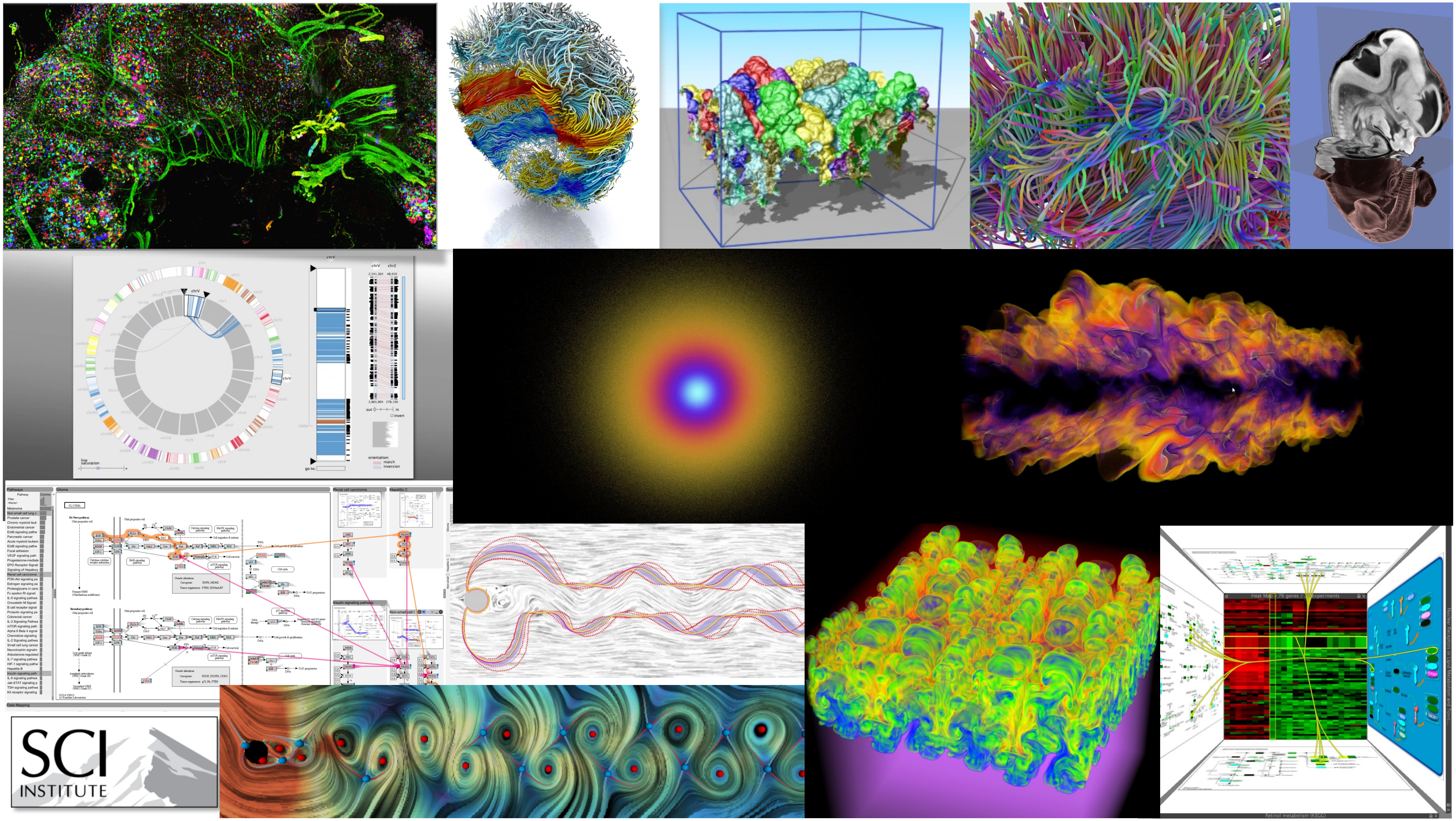


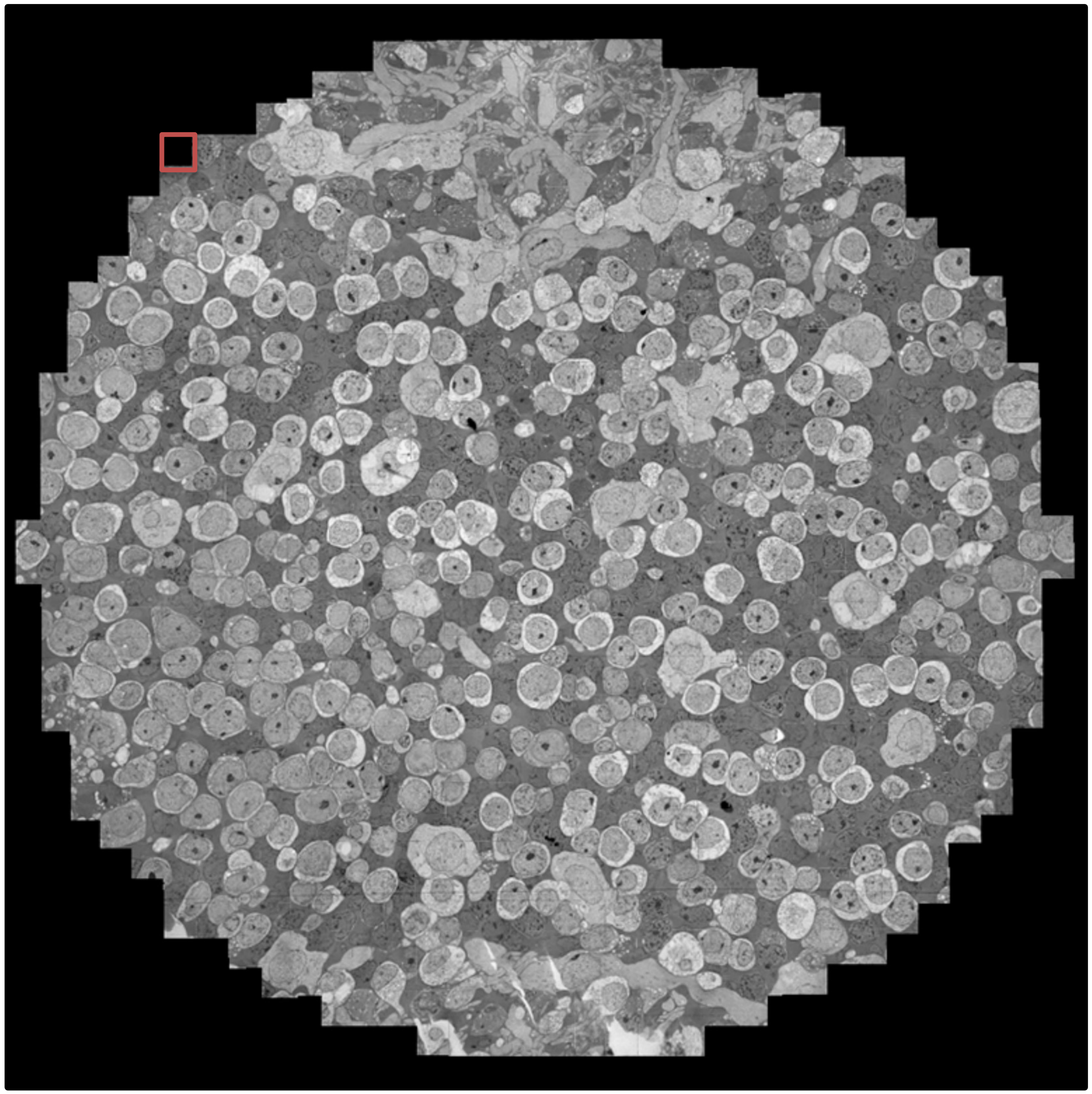

Image courtesy Tor Nørretranders

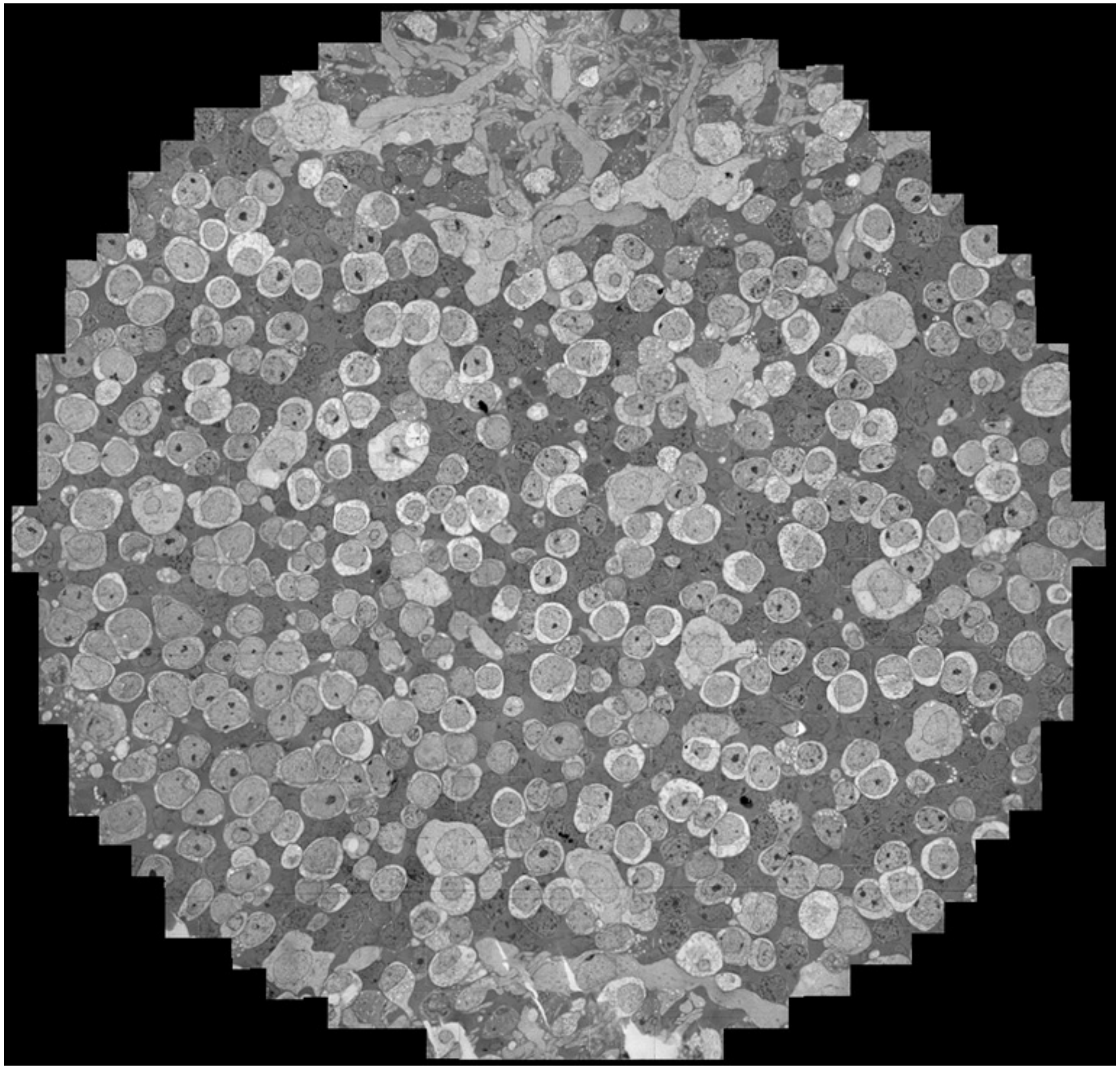
# Feynman Diagrams




- 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.







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

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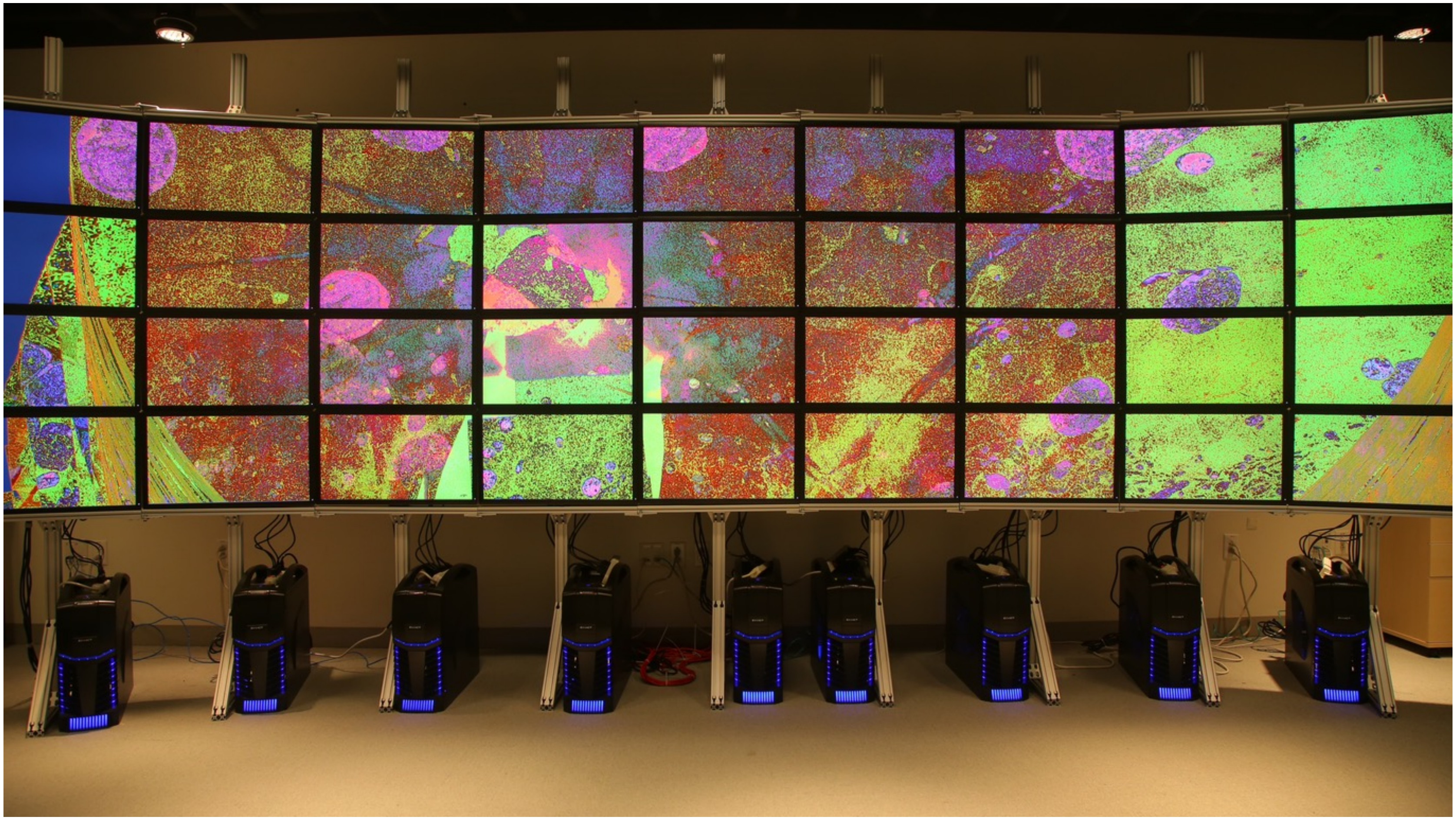

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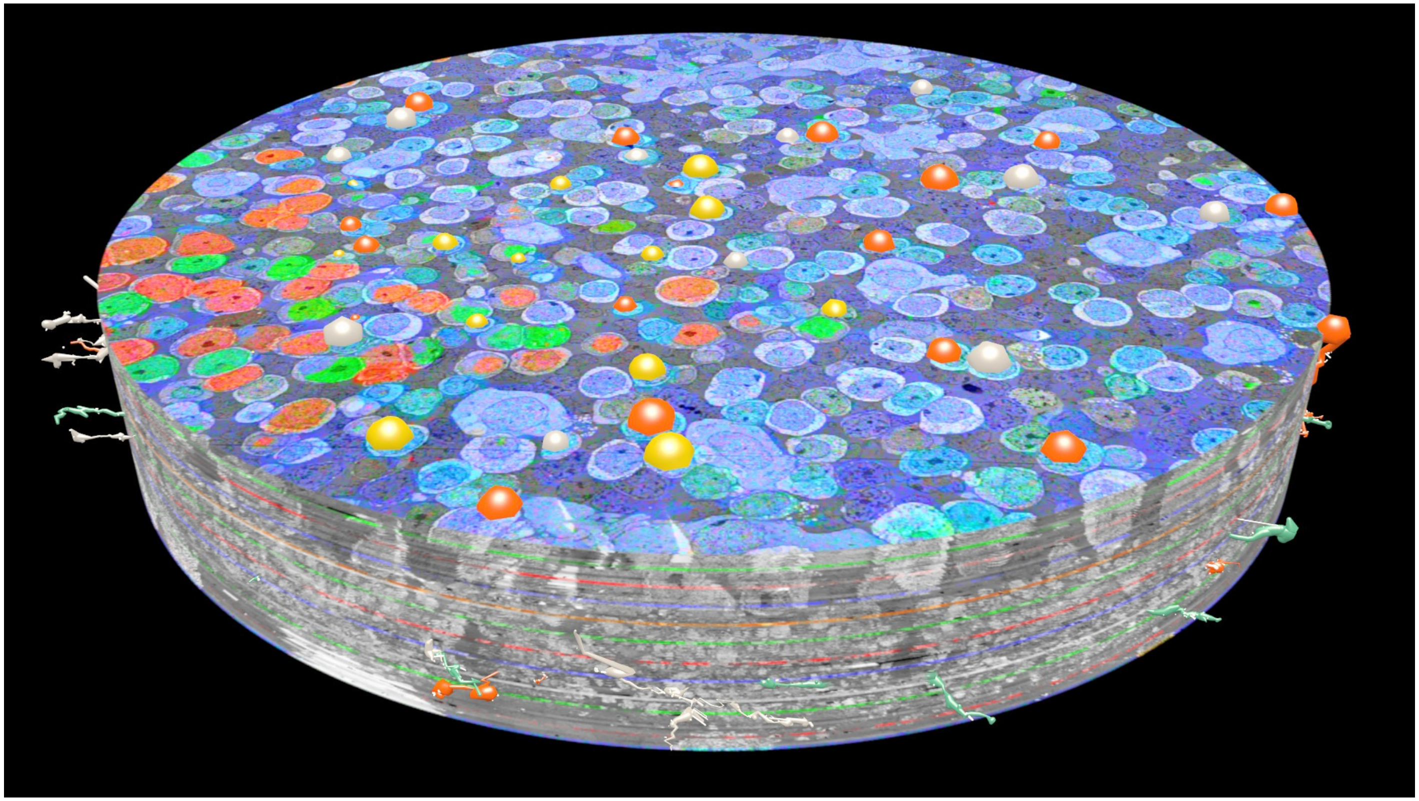
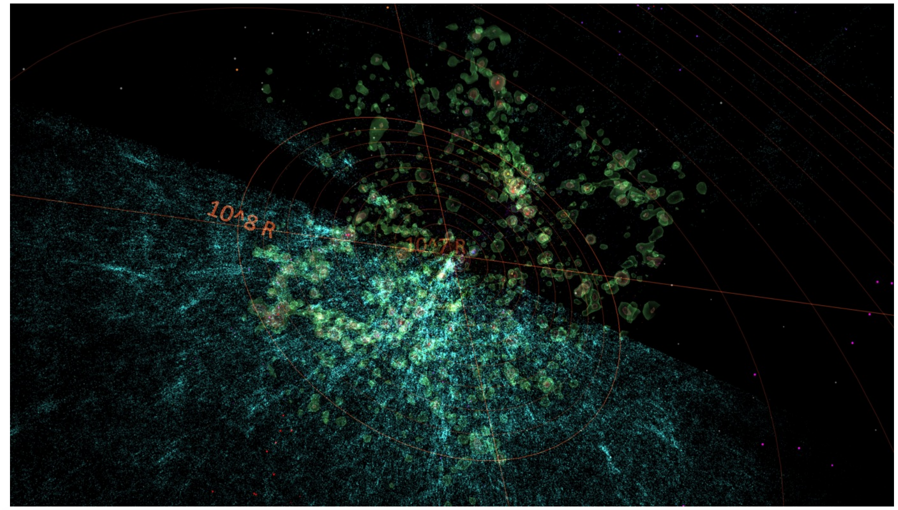
# Connectome

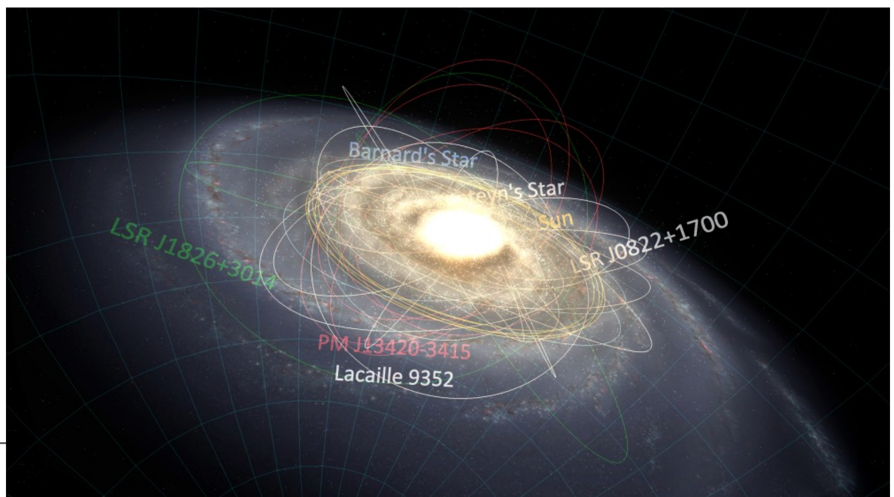


# OpenSpace

**Platform for:**

- **Visualization Research**
- **Space & Astro Research**
- **Science Communication**

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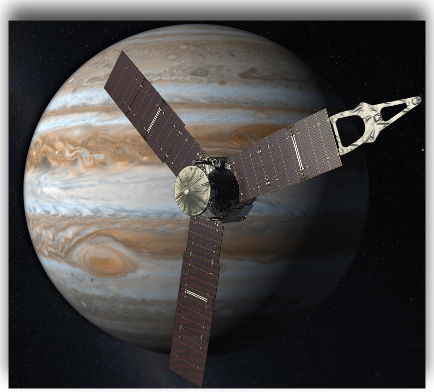
# OpenSpace Team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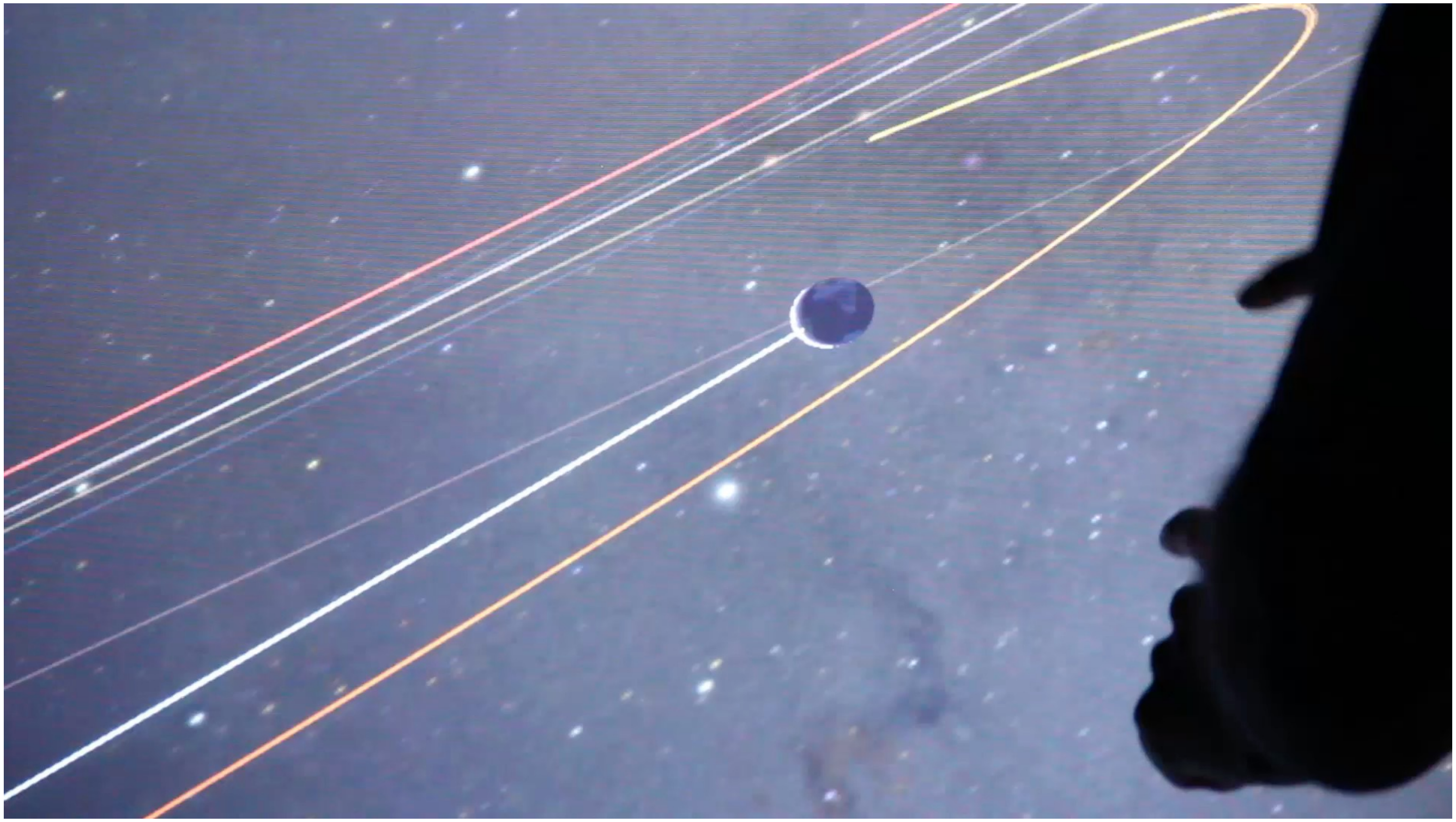
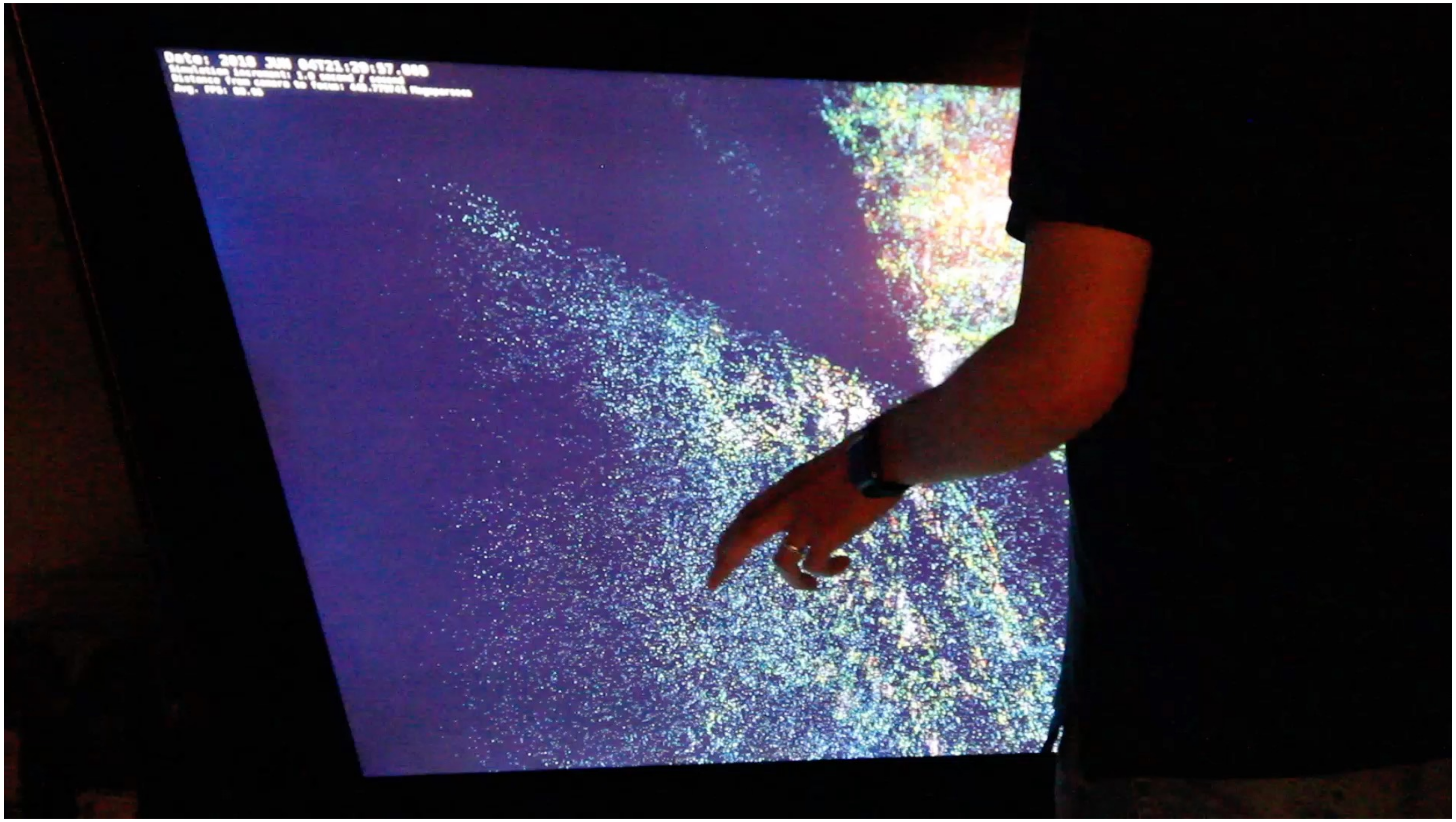
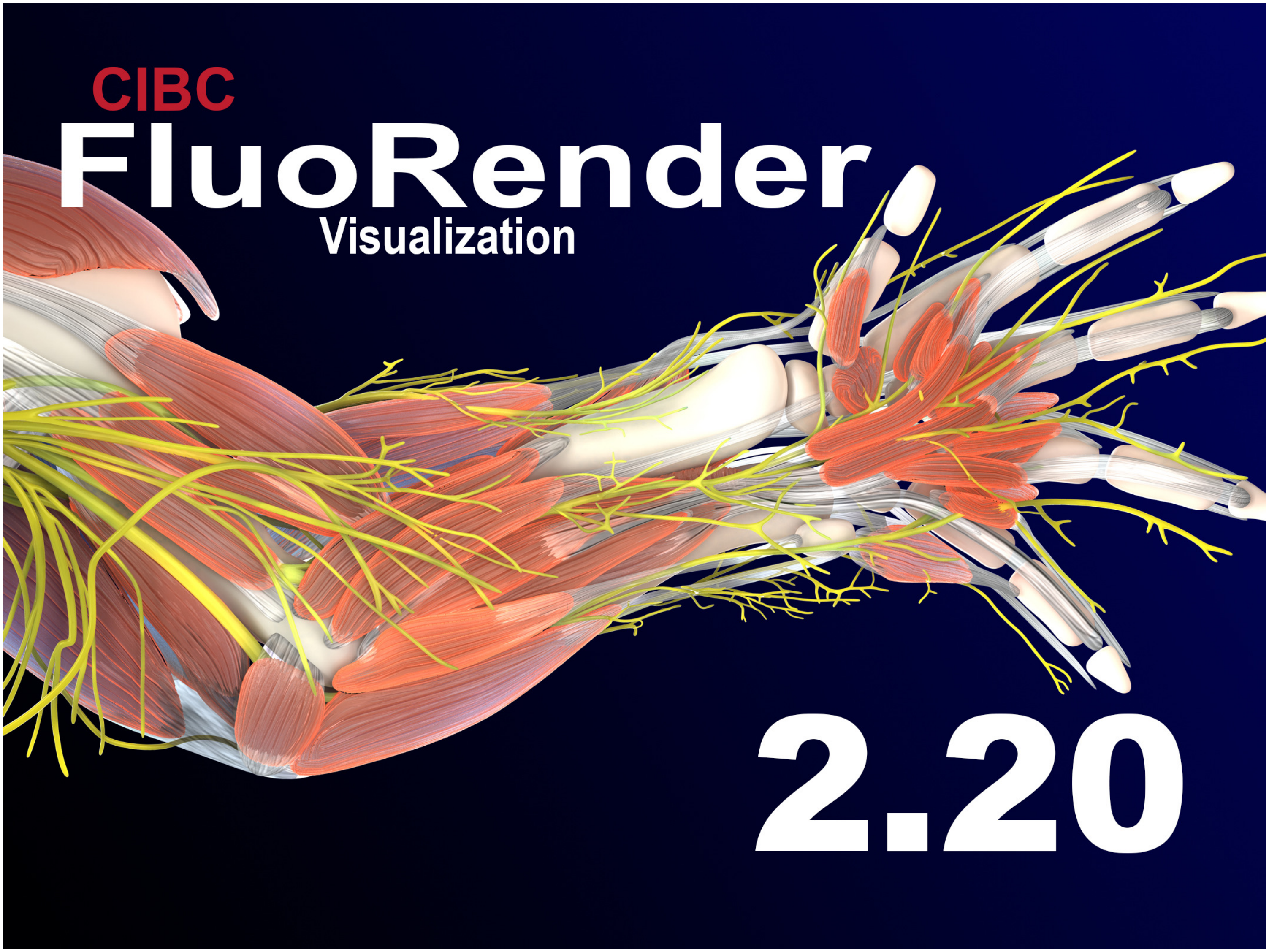
http://openspaceproject.com





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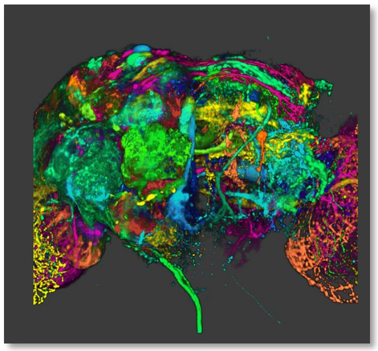
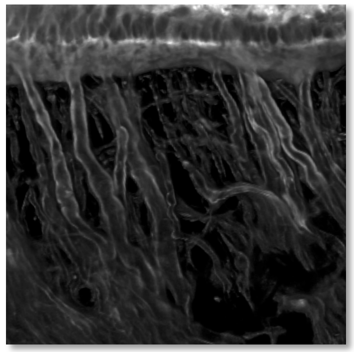
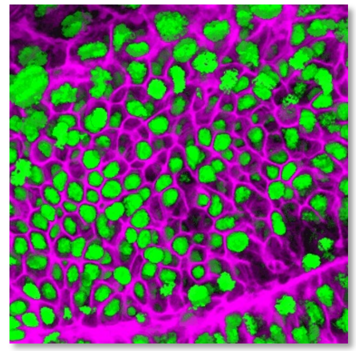
# FluoRender Capabilities



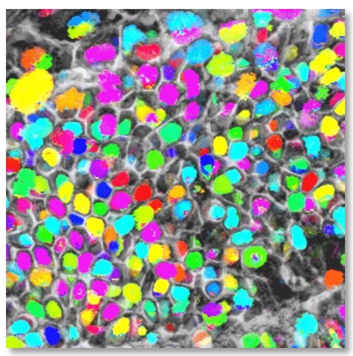
Multichannel visualization



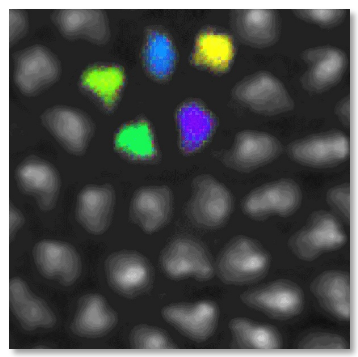
Interactive segmentation



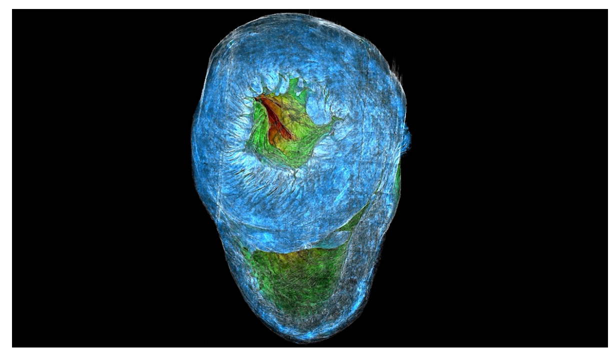
4D scan visualization



Auto segmentation on GPU



Tracking



Large-Scale Data

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# FluoRender

# PROBLEM-DRIVEN VISUALIZATION RESEARCH *for biological data*

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

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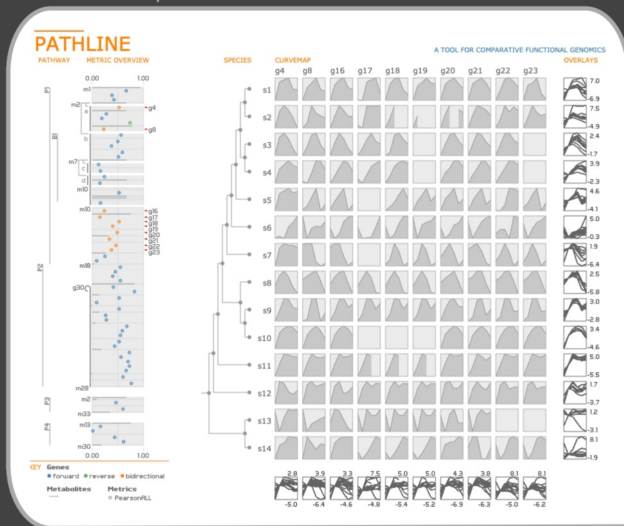
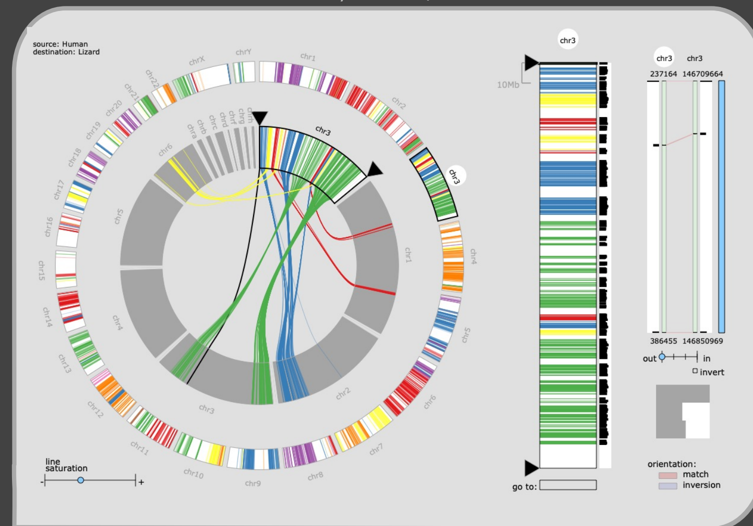
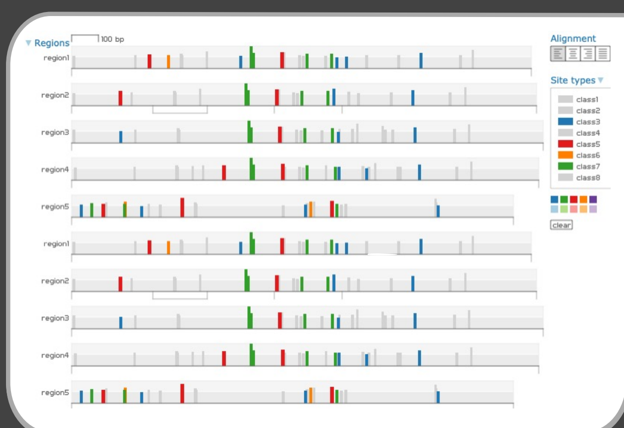
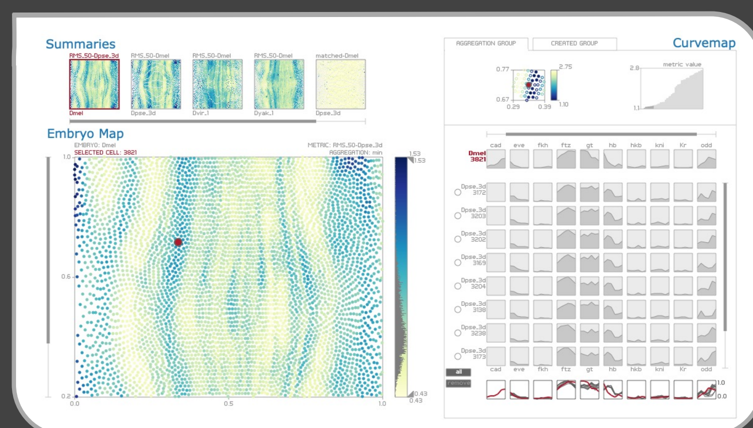
M. Meyer et al., EuroVis 2010. **Pathline**




**MizBee** M. Meyer et al., InfoVis 2009.




**InSite**

**MulteeSum** M. Meyer et al., InfoVis 2010.

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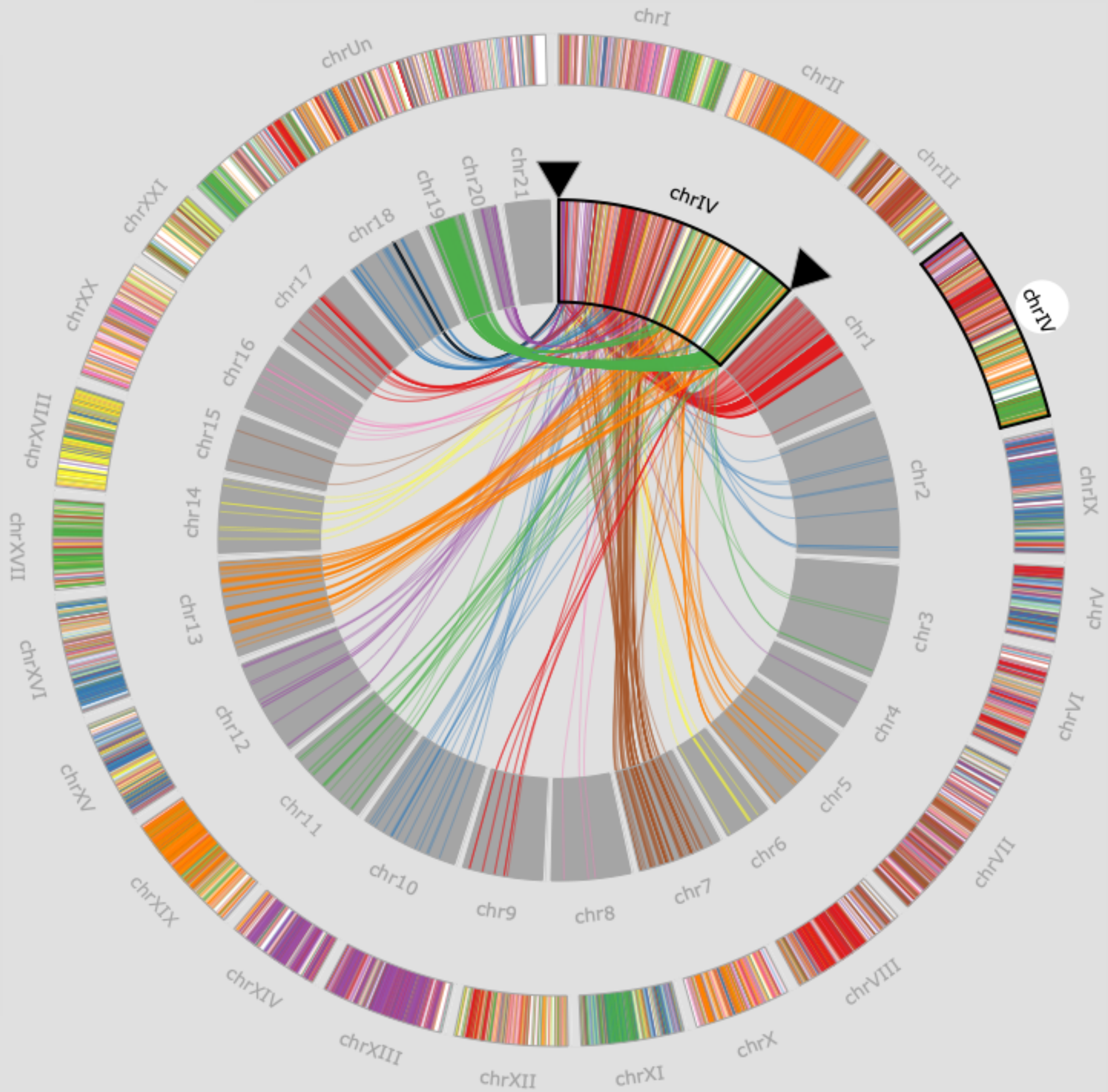


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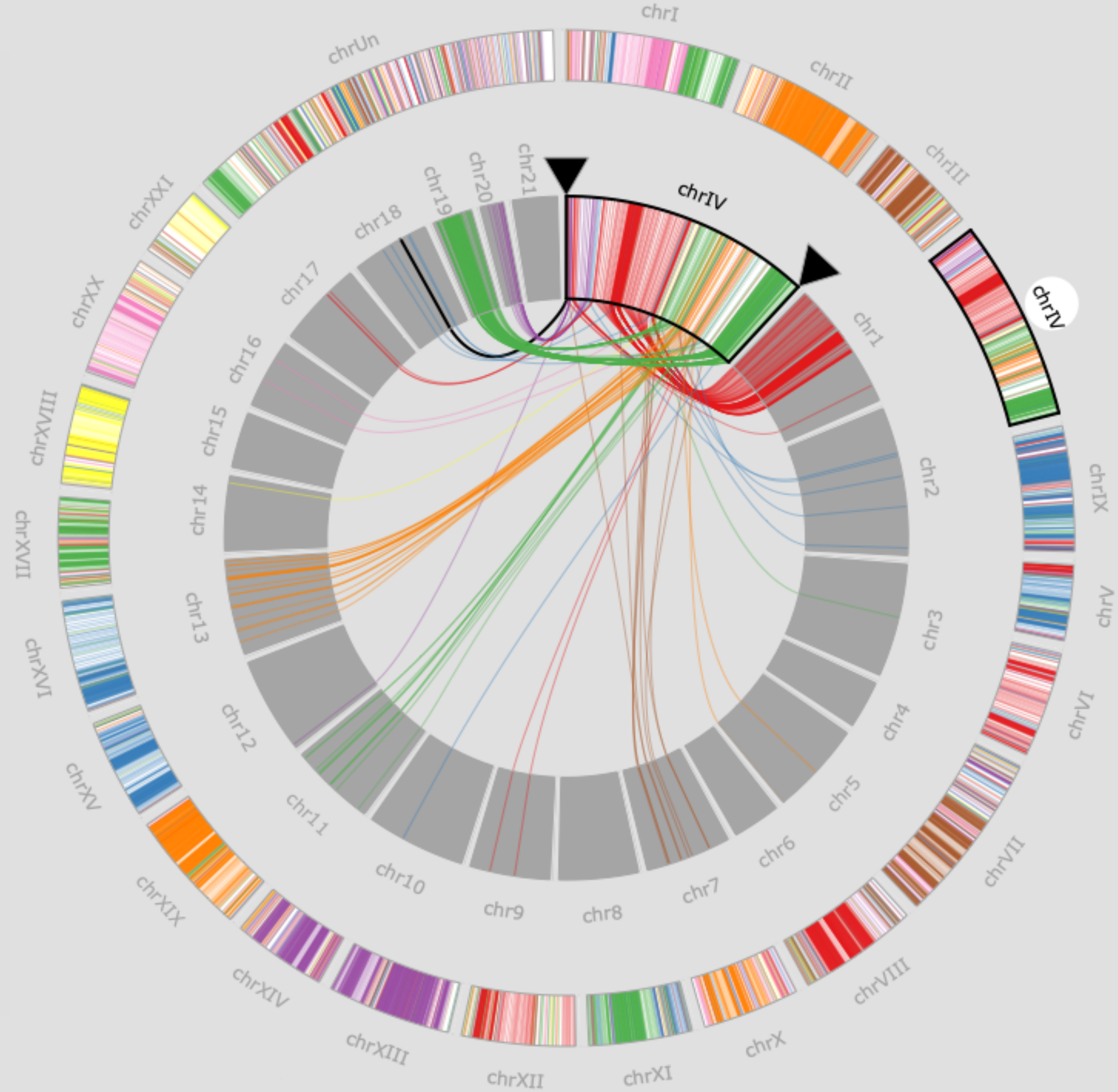
chrI
chrII
chrIII
chrIV
chrIX
chrV
chrVI
chrVII
chrVIII
chrX
chrXI
chrXII
chrXIII
chrXIV
chrXIX
chrXV
chrXVI
chrXVII
chrXVIII
chrXX
chrXXI
chrUn
chrIV
chr1
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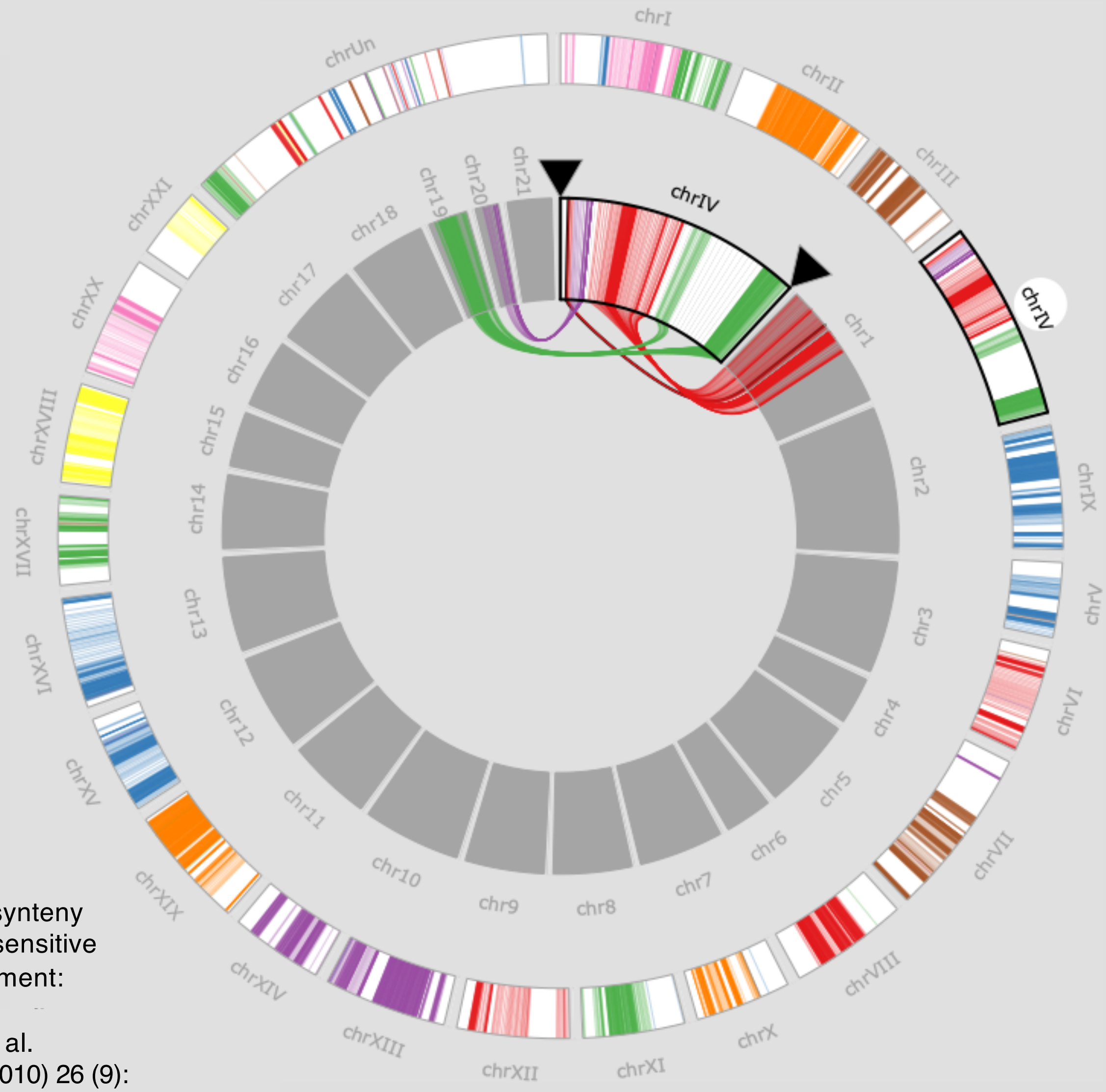
chr21




Genome-wide synteny through highly sensitive sequence alignment: Satsuma

M. Grabherr, et al.
Bioinformatics (2010) 26 (9): 1145-1151.

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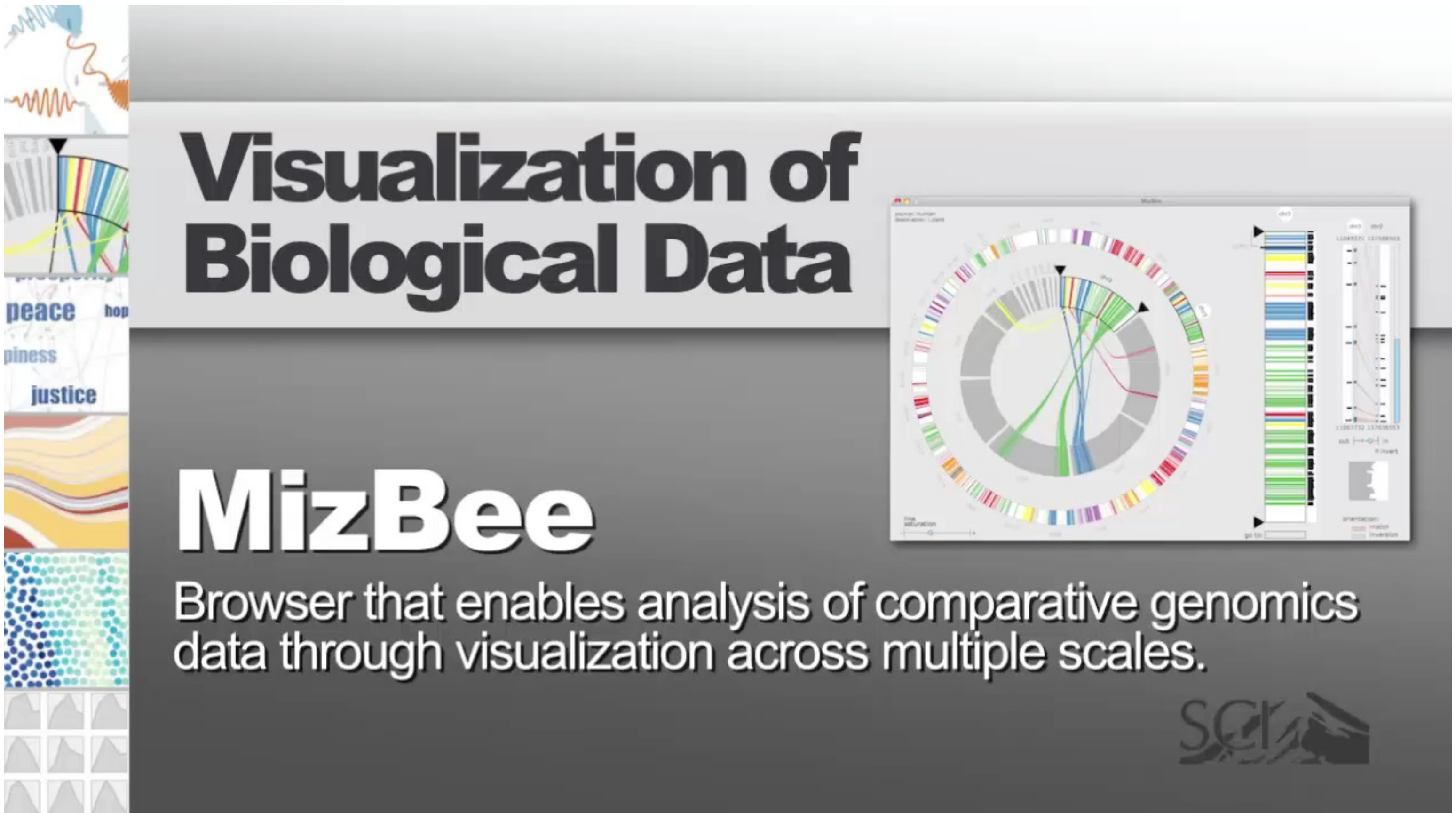
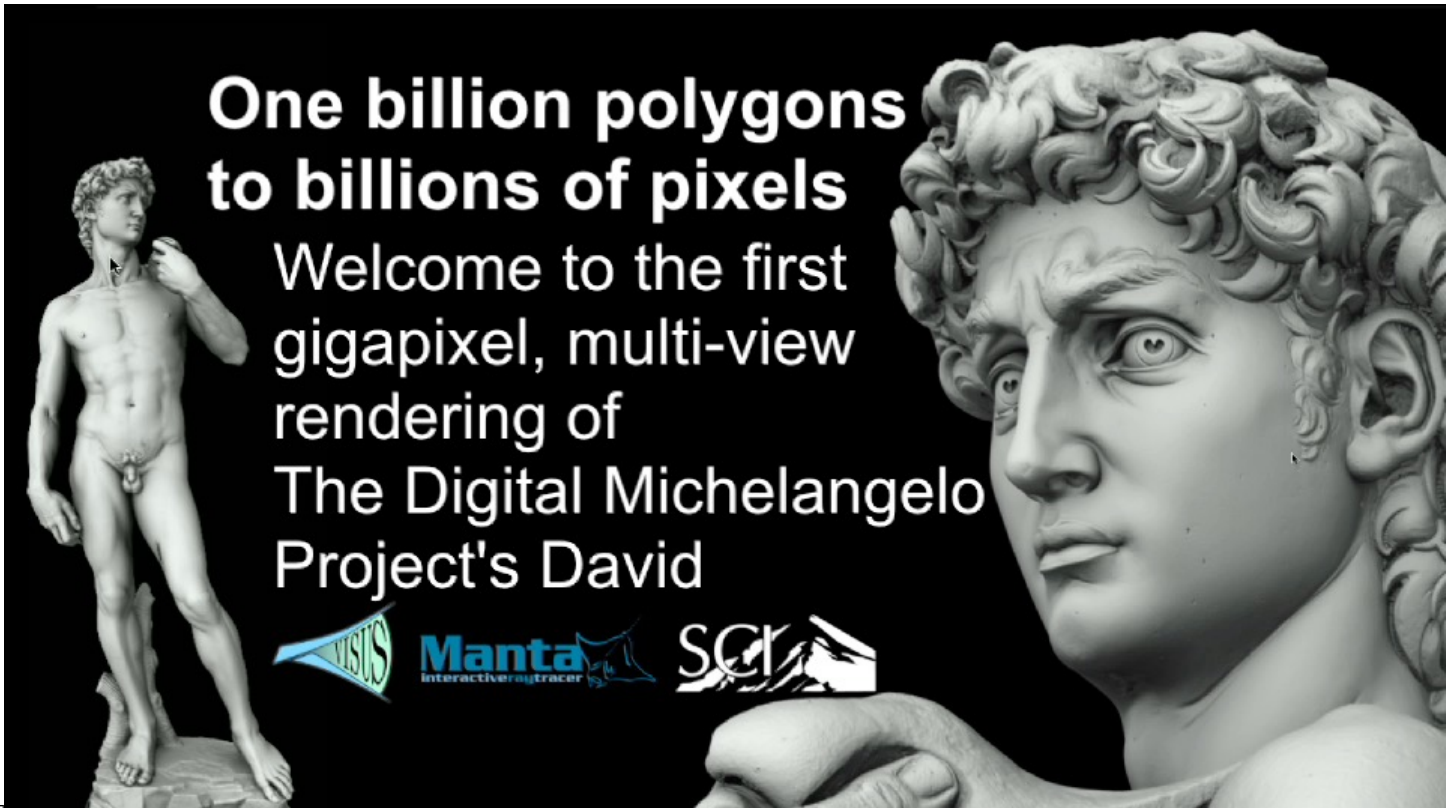

Visualization of Biological Data
MizBee
Browser that enables analysis of comparative genomics data through visualization across multiple scales.
peace
piness
justice

# Michelangelo's David

# Michelangelo's David - Part 2

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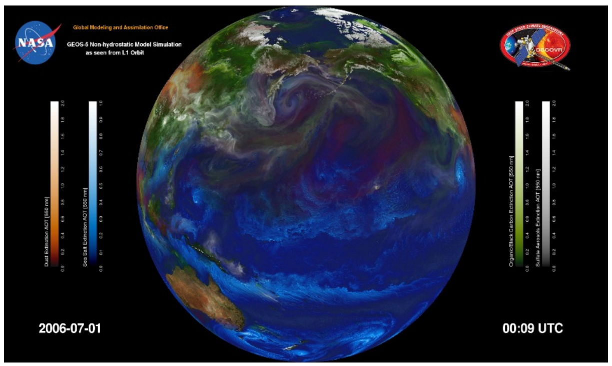
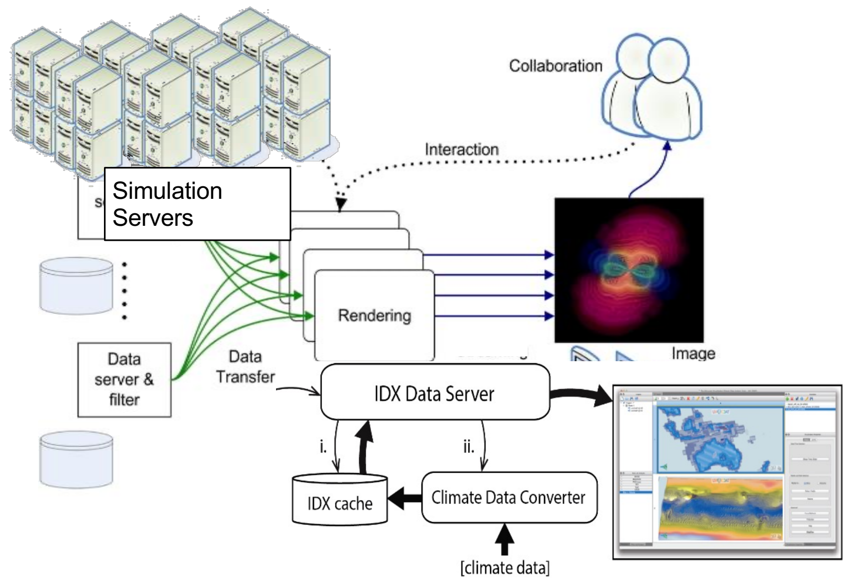
# Scalable Deployment: Exploration of 3.5PB of NASA Weather/Climate Data in Real Time

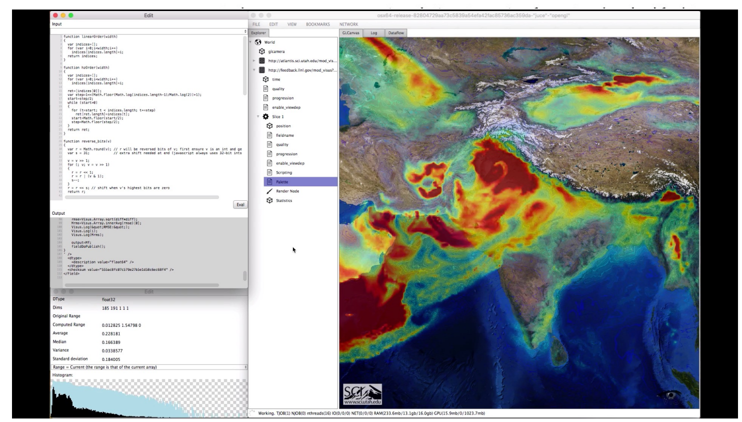
Workflow
- *Data creation*
- *Data Management*
  - Processing
  - Analysis
  - Visualization

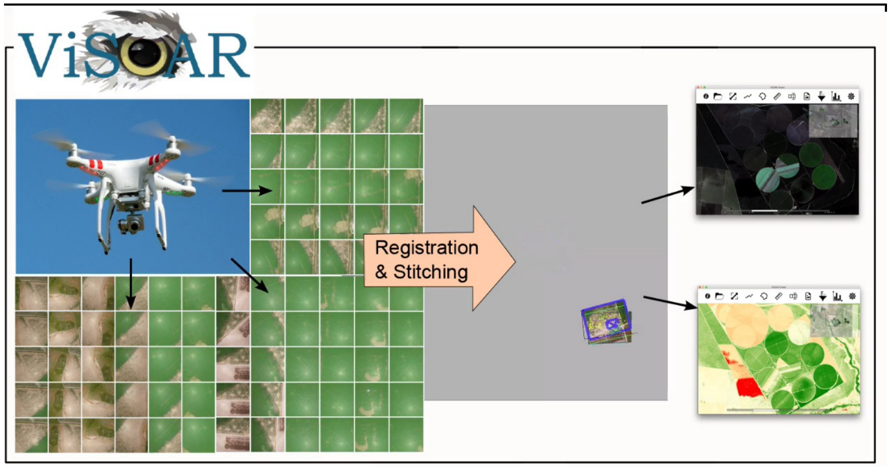


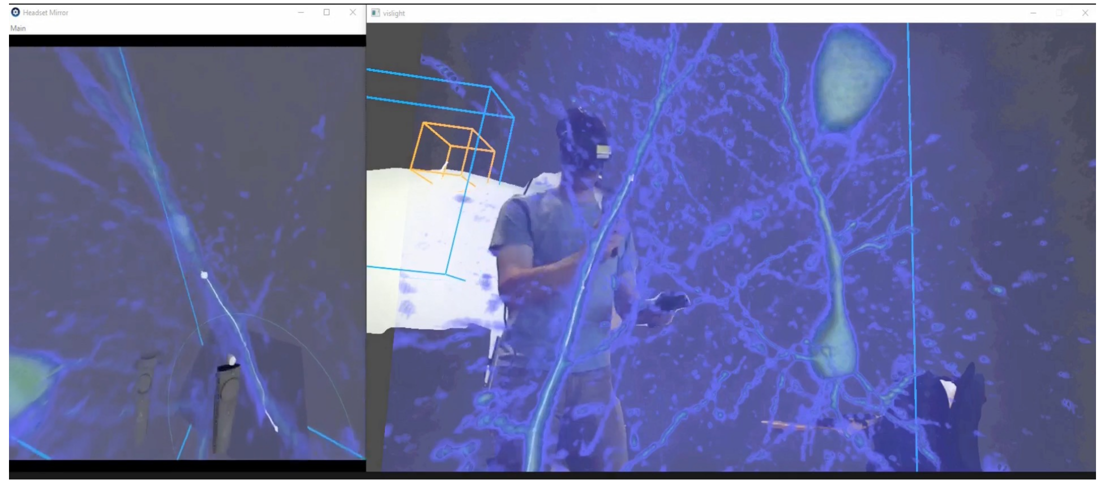

- 7km GEOS-5 "Nature Run"
- 1 dataset, 3.5 PB
- theoretically: openly accessible
- practically: precomputed pics

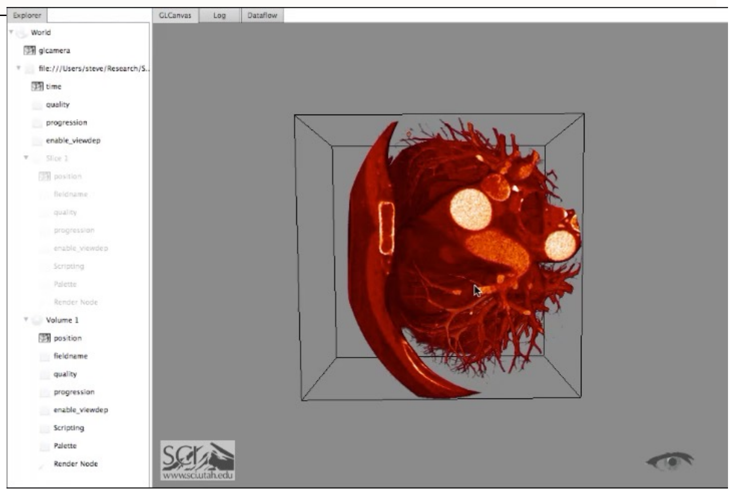
Distributed Resources
- 3.5 PB of *data store in NASA*
- *Primary ViSUS server in LLNL*
- *Secondary ViSUS server in Utah*
- *Clients connect remotely*
- *Work without additional HPC resources*




ViSOAR
Registration & Stitching




Explorer
GLCanvas
Log
Dataflow
World
glcamera
time
quality
progression
enable_viewdep
Volume 1
position
fieldname
quality
progression
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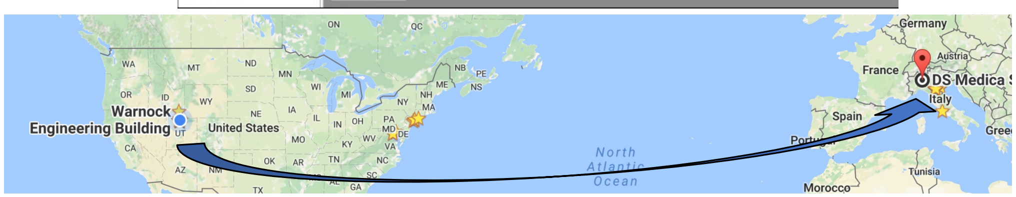
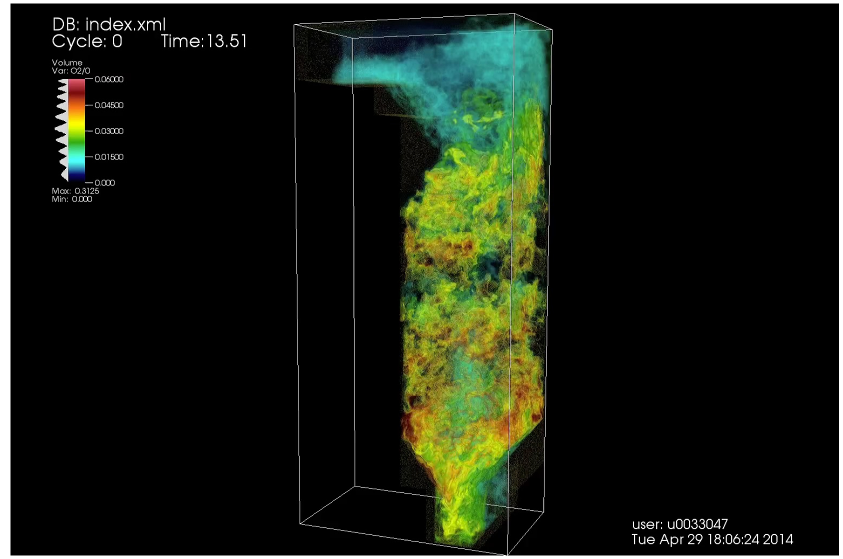
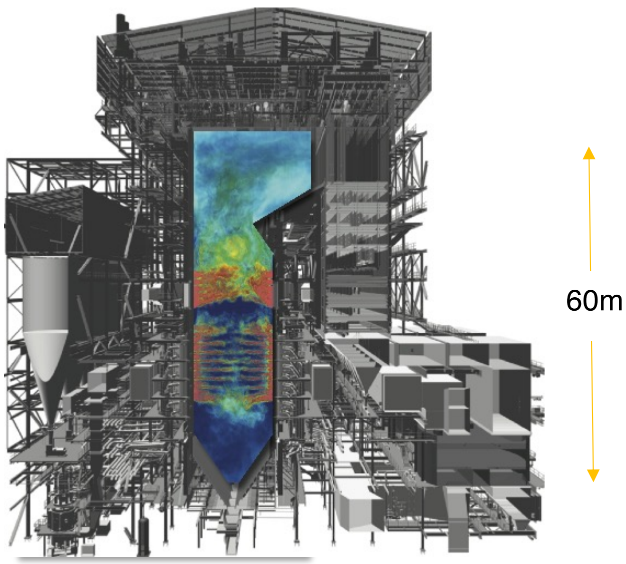
Scripting
Palette
Render Node


Warnock
Engineering Building
United States
North
Atlantic
Ocean
Germany
Austria
France
DS Medica
Italy
Spain
Morocco
Tunisia

# DOE PSAAP2 Simulations of GE Clean(er) Coal Boilers

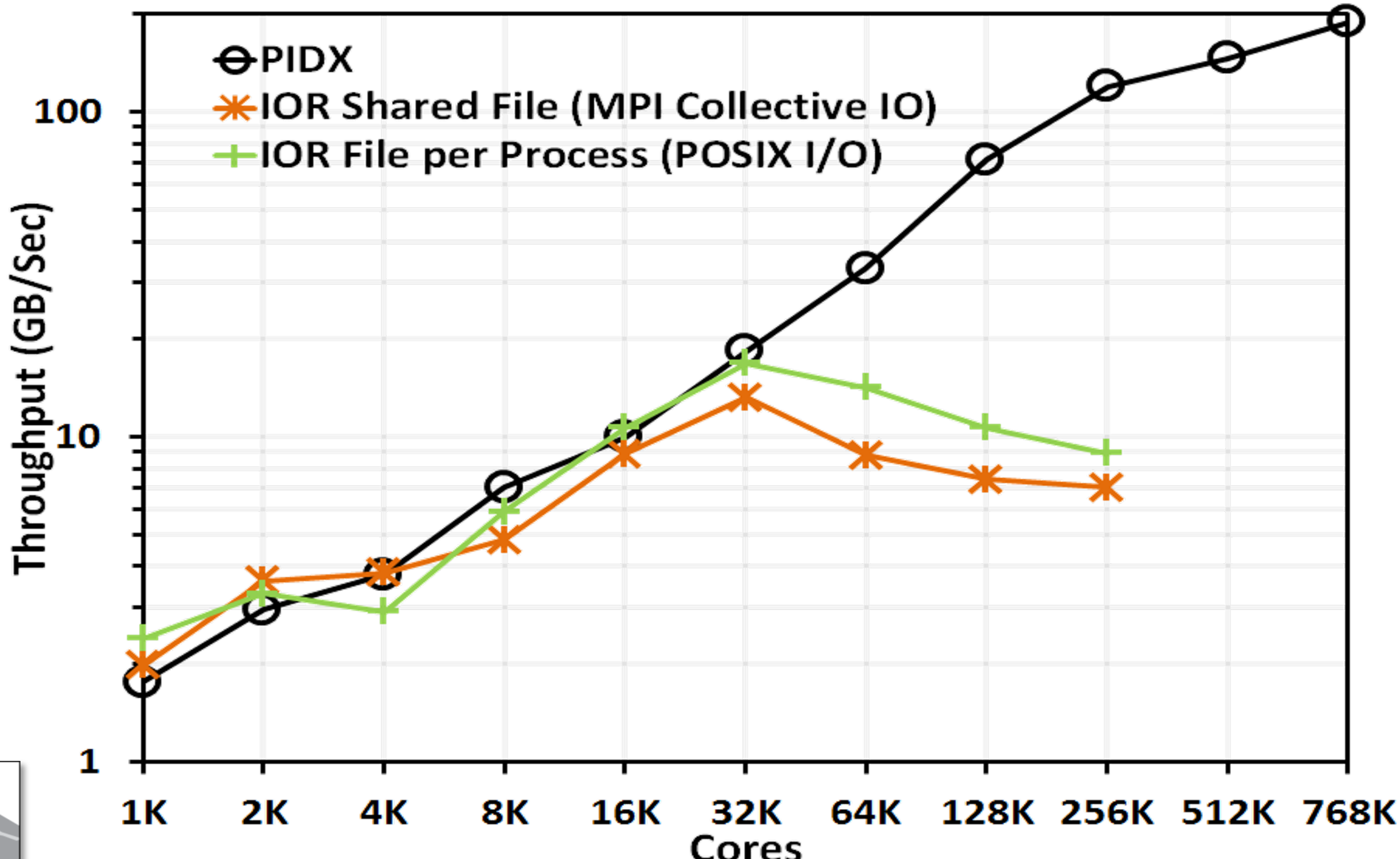
- Large scale turbulent combustion needs mm scale grids 10^14 mesh cells 10^15 variables (1000x more than now)
- Structured, high order finite-volume discretization
- Mass, momentum, energy conservation
- LES closure, tabulated chemistry
- PDF mixing models
- DQMOM (many small linear solves)
- Uncertainty quantification




- Low Mach number approx. (pressure Poisson solve up to 10^12 variables. 1M patches 10 B variables
- Radiation via Discrete Ordinates – many hypre solves Mira (cpus) or ray tracing Titan (gpus strong and weak scaling via AMR).
- FAST I/O needed PIDX for scalability

# High Performance Data Movement for Real-Time Monitoring of Large Scale Simulations

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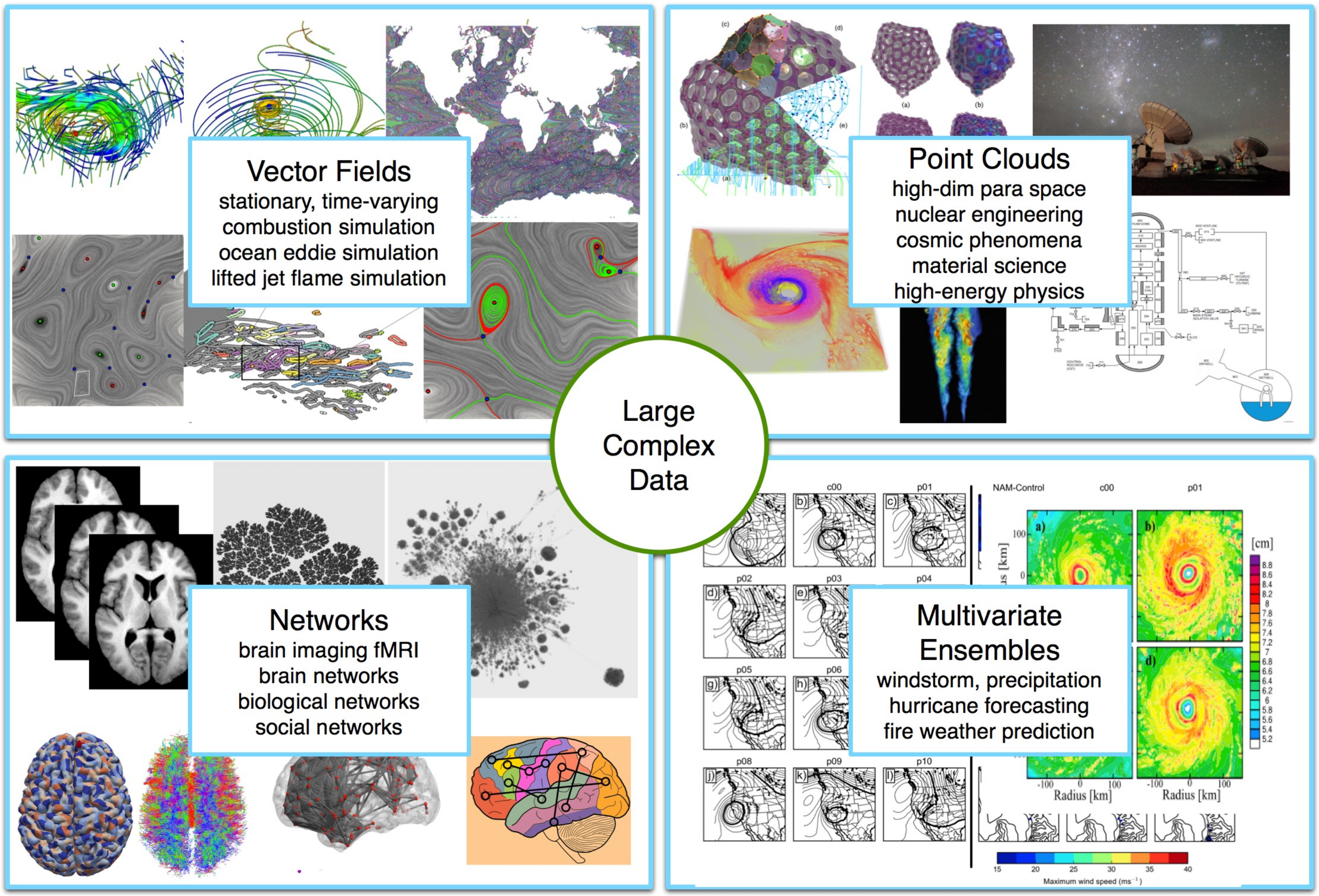
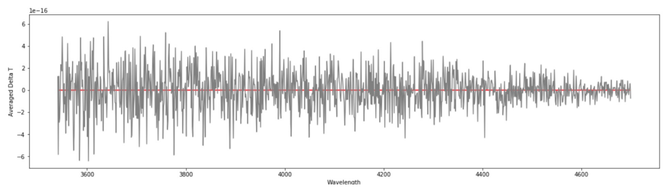
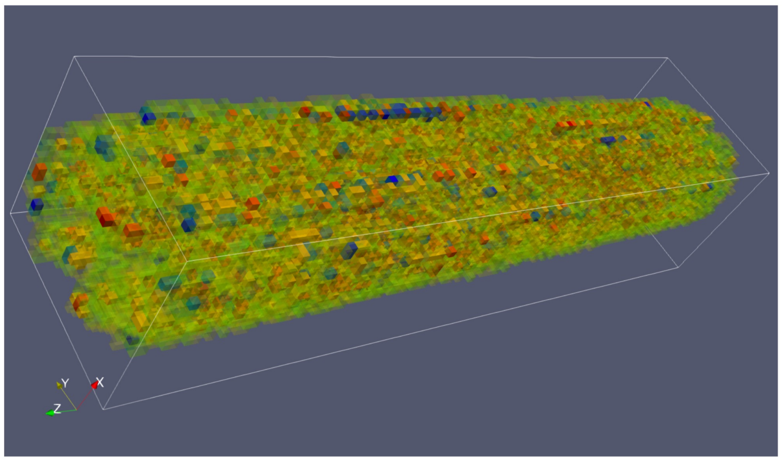
# Topological Data Analysis and Visualization

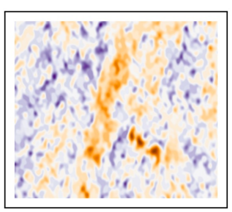


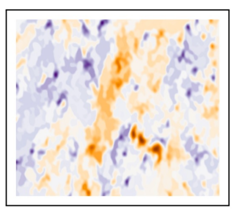
# Topological Data Analysis for Astronomical Data Cubes

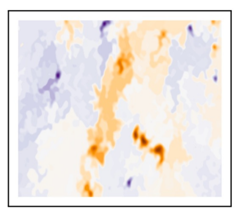


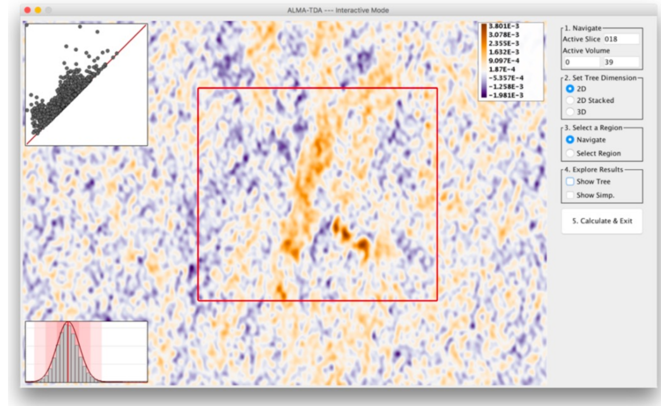



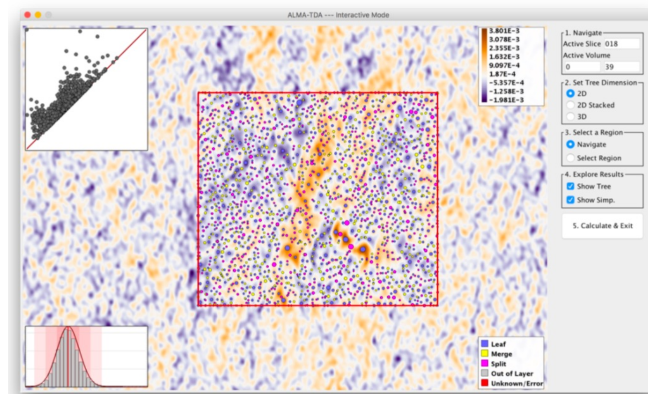

Analysis of cosmic voids










Using Contour Trees in the Analysis and Visualization of Radio Astronomy Data Cubes

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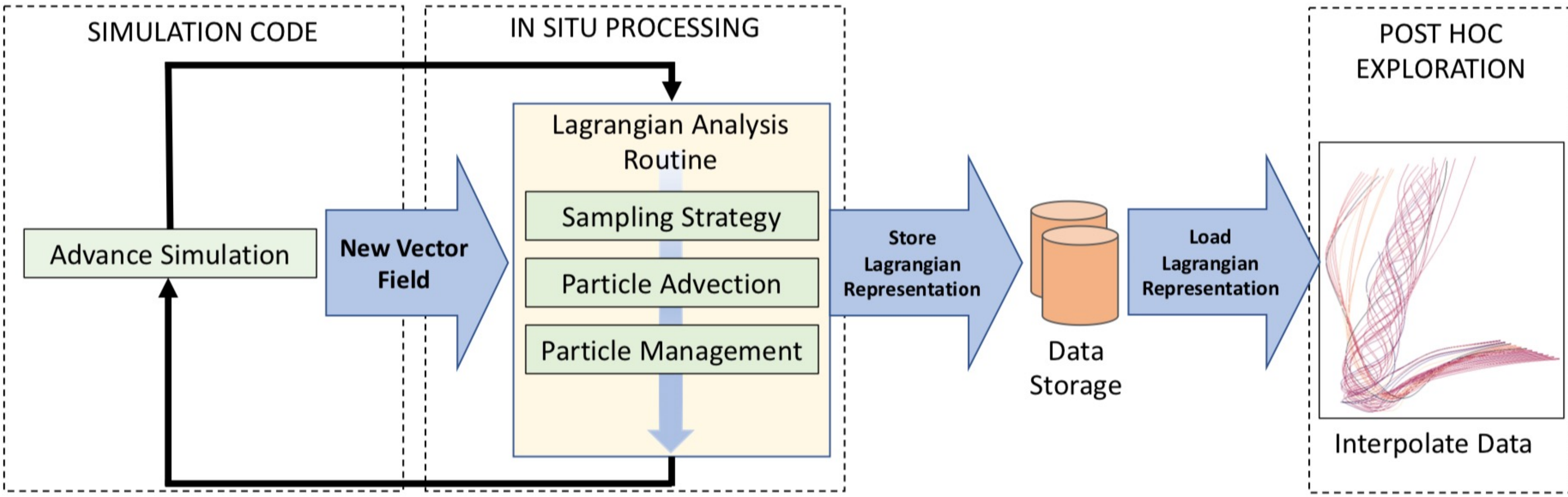
Yulong Liang, Vikranta Kamble, Helion Dumas Desbourboux, Lin Yan, Mengjiao Han, Kyle Dawson, Nicholas Boardman, Gail Zasowski, Anil Seth, Joel Brownstein, Paul Rosen, Juna A. Kollmeier, Guillermo Blanc, **Bei Wang**

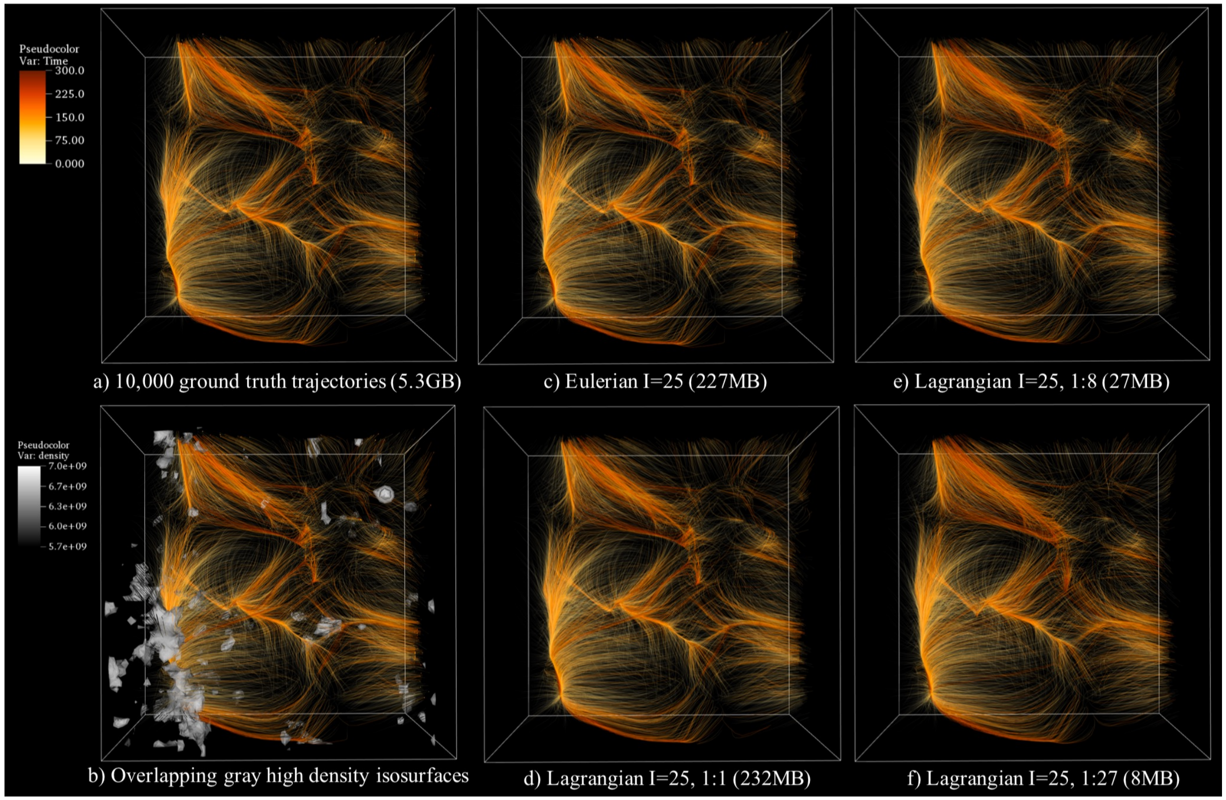
# In Situ Lagrangian Analysis




S. Sane, C.R. Johnson, H. Childs. Investigating the Use of In Situ Reduction via Lagrangian Representations for Cosmology and Seismology Applications. *International Conference on Computational Science 2021*. **Best Paper Award**.

S. Sane, A. Yenpure, R. Bujack, M. Larsen, K. Moreland, C. Garth, C. R. Johnson, and H. Childs. Scalable In Situ Computation of Lagrangian Representations via Local Flow Maps. *Eurographics Symposium on Parallel Graphics and Visualization (EGPGV) 2021*. **Best Paper Award**.

# In Situ Lagrangian Analysis

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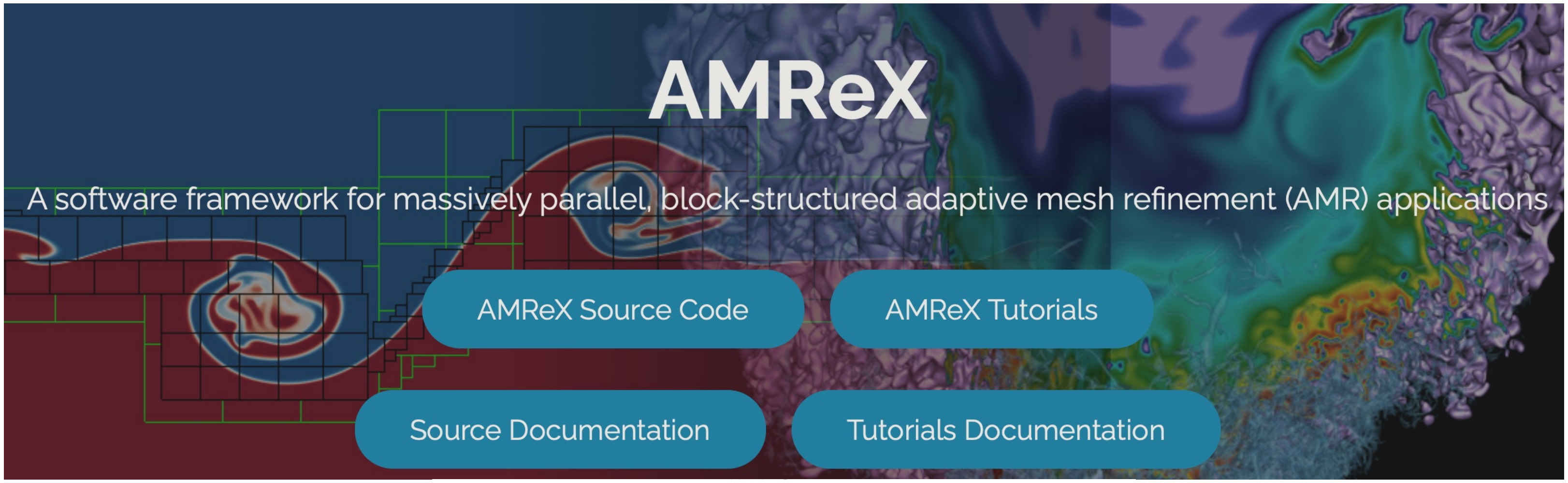
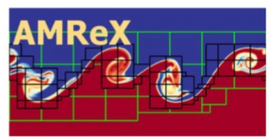
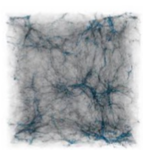
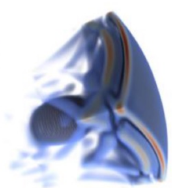


Nyx
INT-179



WarpX
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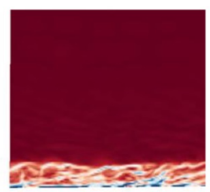

AMRWind
INT-1350

Pele
INT-133

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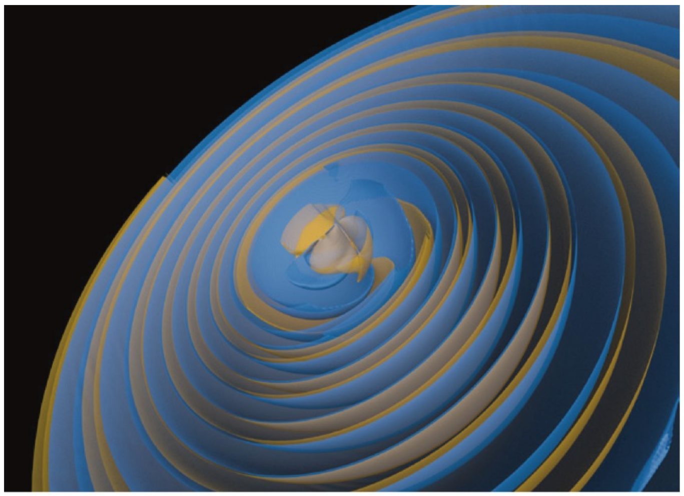
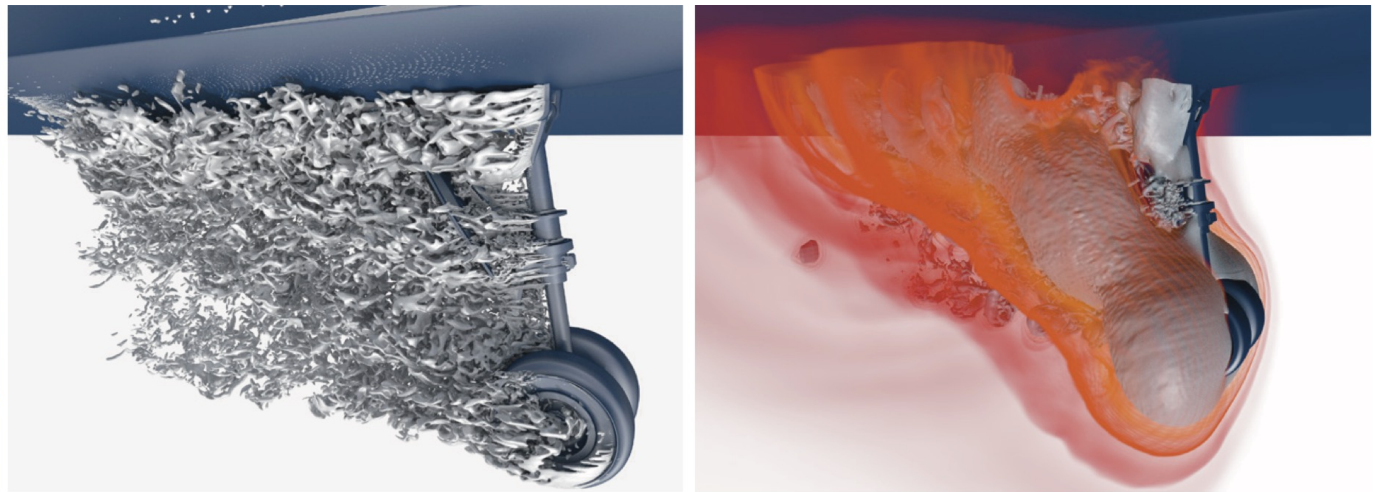
Ascent

# AMR Visualization



Colliding Black Holes



NASA Exajet Landing Gear

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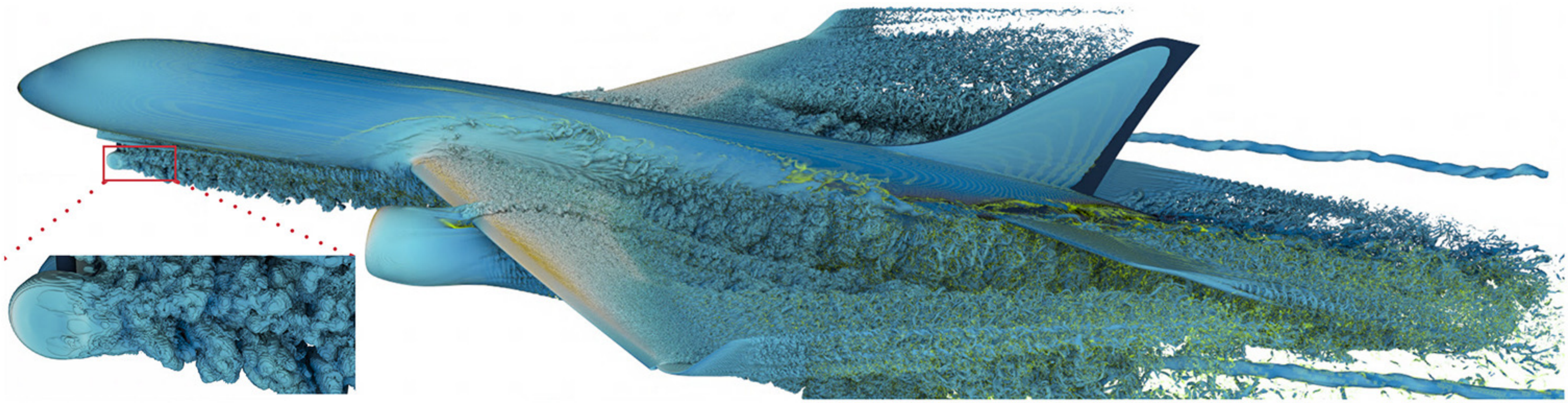
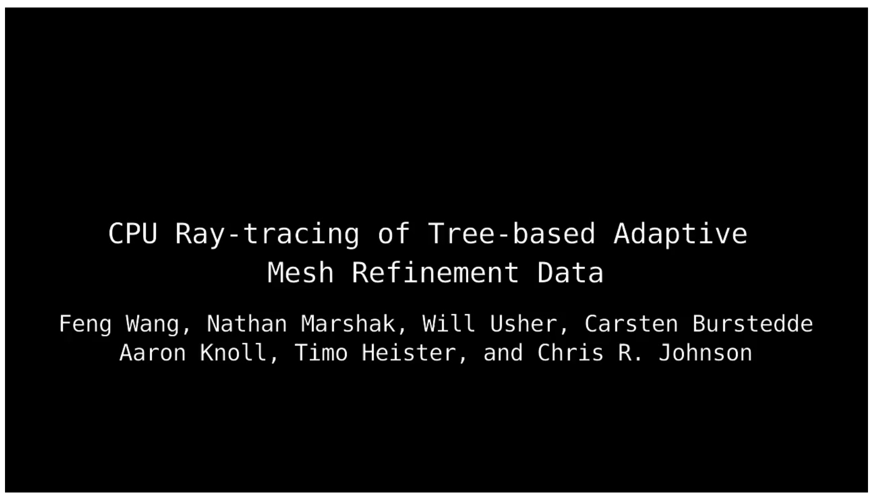
F. Wang, I. Wald, Q. Wu, W. Usher, C. R. Johnson. **"CPU Isosurface Ray Tracing of Adaptive Mesh Refinement Data,"** In *IEEE Transactions on Visualization and Computer Graphics*, Vol. 25, No. 1, IEEE, pp. 1142-1151. Jan, 2019.






F. Wang, N. Marshak, W. Usher, C. Burstedde, A. Knoll, T. Heister, C. R. Johnson. **"CPU Ray Tracing of Tree-Based Adaptive Mesh Refinement Data,"** In *Eurographics Conference on Visualization (EuroVis) 2020*, Vol. 39, No. 3, 2020.

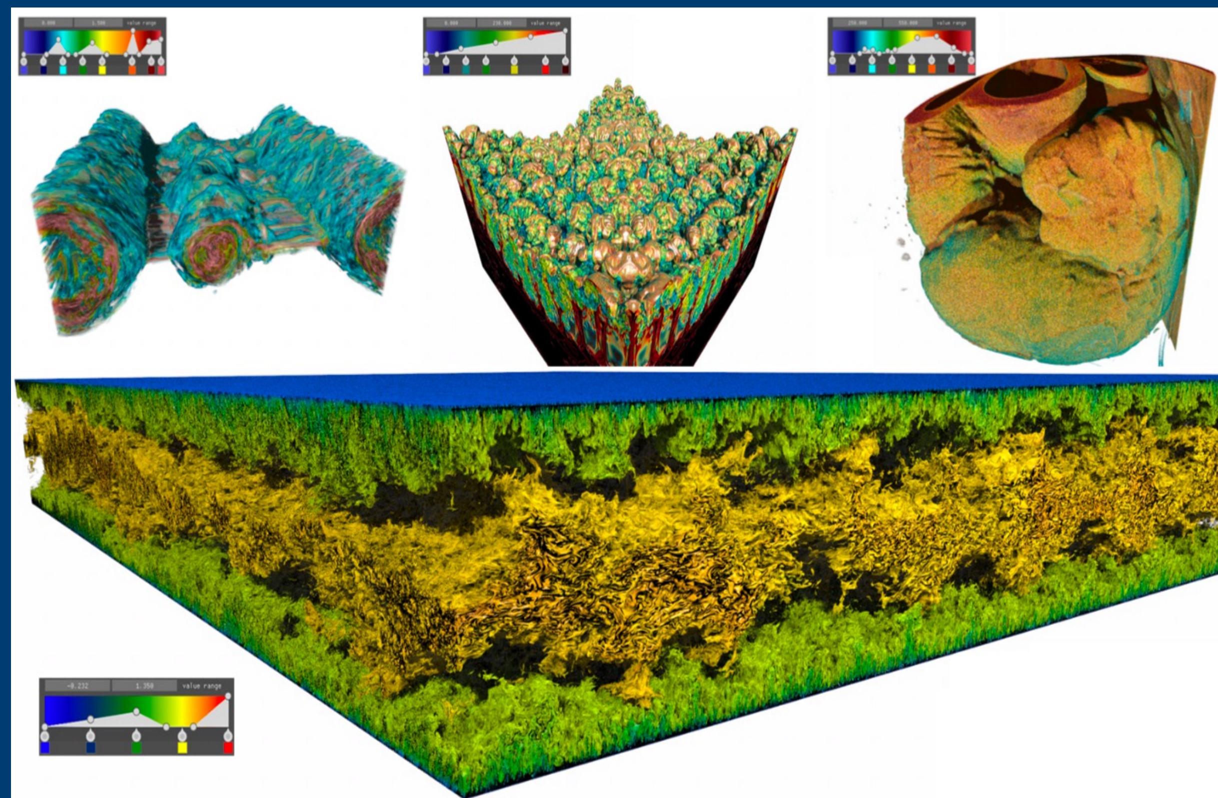
# Bricktree for Large-scale Volumetric Data Visualization

- Interactive visualization solution for large-scale volumes in OSPRay

+ Quickly loads progressively higher resolutions of data, reducing user wait times

- Bricktree – a low-overhead hierarchical structure allows for encoding a large volume into multi-resolution representation

- Rendered via OSPRay module



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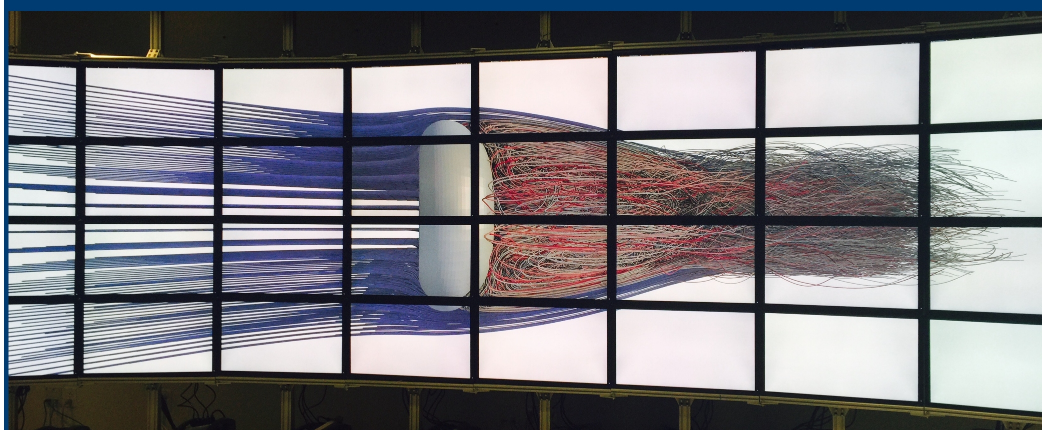
F. Wang, I. Wald, and C.R. Johnson. Interactive Rendering of Large-Scale Volumes on Multi-Core CPUs *IEEE Symposium on Large Data Analysis and Visualization 2019*, pp. 27-36, 2019.

# Display Wall Rendering with OSPRay

+ Software infrastructure that allows parallel renderers (OSPRay) to render to large-tiled display clusters.
+ Decouples the rendering cluster and display cluster
+ Lightweight, inexpensive and easy to deploy options via Intel NUC + remote rendering cluster



Streamlines computed on flow past a torus

300M triangle isosurface on the Richtmeyer Meshkov

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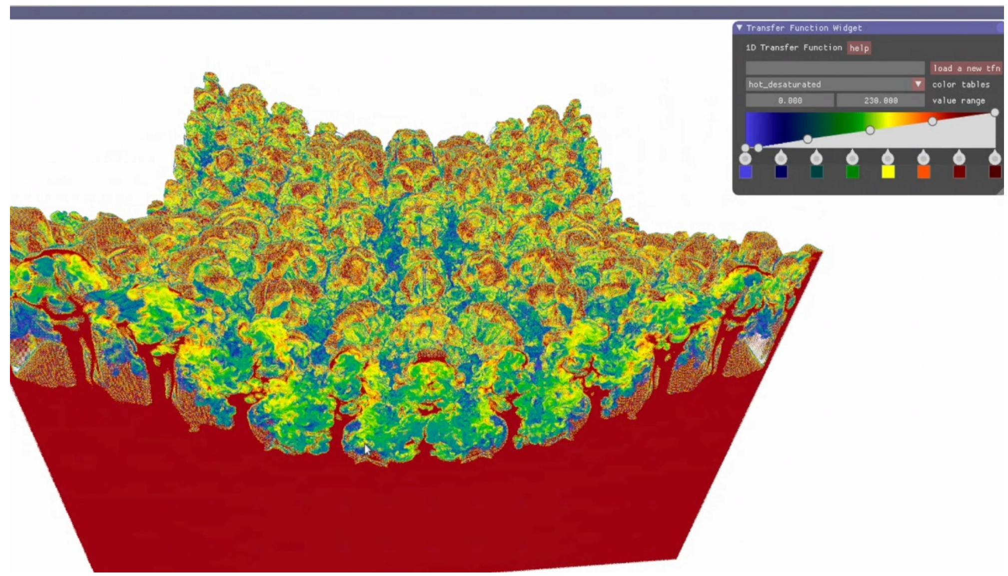
M. Han, I. Wald, W. Usher, N. Morrical, A. Knoll, V. Pascucci, and C.R. Johnson. A Virtual Frame Buffer Abstraction for Parallel Rendering of Large Tiled Display Walls. *IEEE Visualization 2020*,

# Ray-guided Progressive Rendering

Progressive sampling

- Hierarchical representation
- On-demand loading
- Independent data-streaming threads
- Visualize coarse data as a approximate and gradually refine it

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# Interactive Streamline Exploration and Manipulation using Deformation

Xin Tong[1], John Edwards[2], Chun-Ming Chen[1],
Han-Wei Shen[1], Chris R. Johnson[2], Pak Chung Wong[3]
[1]The Ohio State University
[2]Scientific Computing and Imaging Institute, University of Utah
[3]Pacific Northwest National Laboratory

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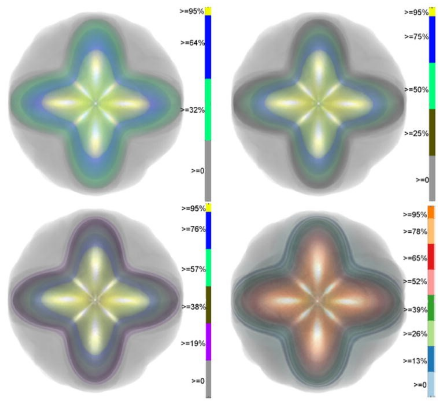
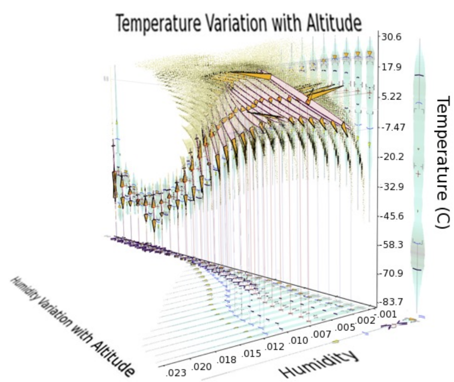
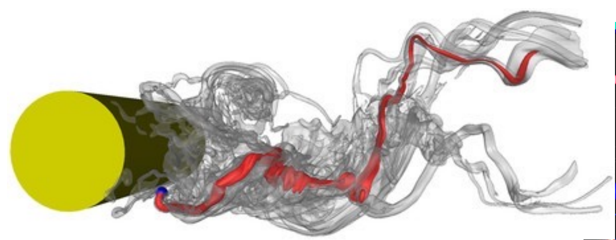
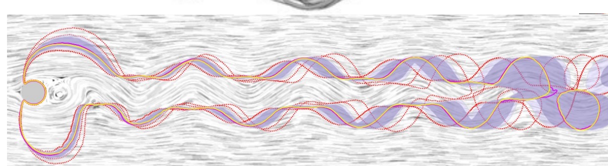
# Uncertainty Visualization

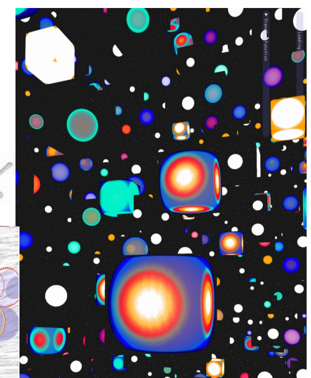
When is the last time you've seen an error bar on an isosurface?

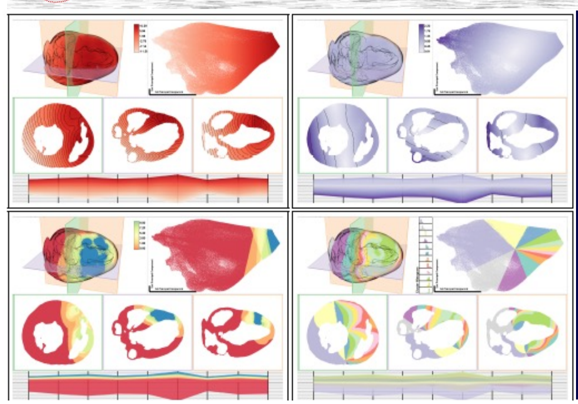


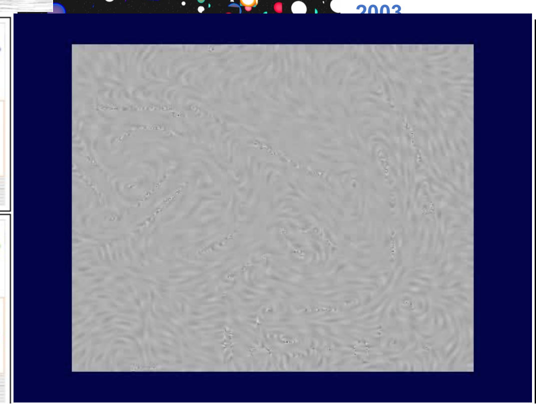


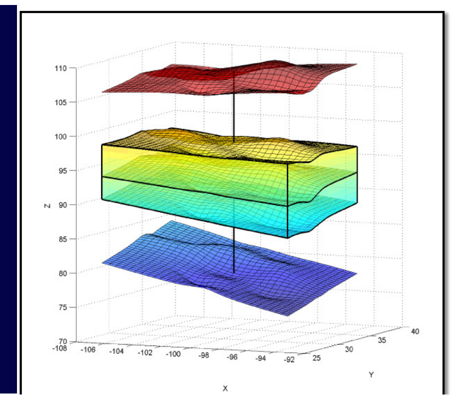














G.P. Bonneau, H.C. Hege, C.R. Johnson, M.M. Oliveira, K. Potter, P. Rheingans, T. Schultz. "Overview and State-of-the-Art of Uncertainty Visualization," In *Scientific Visualization: Uncertainty, Multifield, Biomedical, and Scalable Visualization*, Edited by M. Chen and H. Hagen and C.D. Hansen and C.R. Johnson and A. Kauffman, Springer-Verlag, pp. 3-27. 2014.

M.G. Genton, C.R. Johnson, K. Potter, G. Stenchikov, Y. Sun. "Surface boxplots," In *Stat Journal*, Vol. 3, No. 1, pp. 1-11. 2014.

K. Potter, P. Rosen, C.R. Johnson. "From Quantification to Visualization: A Taxonomy of Uncertainty Visualization Approaches," In *Uncertainty Quantification in Scientific Computing*, IFIP Series, Vol. 377, Springer, pp. 226-249. 2012.

K. Potter, A. Wilson, P.-T. Bremer, D. Williams, C. Doutriaux, V. Pascucci, C.R. Johnson. "Ensemble-Vis: A Framework for the Statistical Visualization of Ensemble Data," In *Proceedings of the 2009 IEEE International Conference on Data Mining Workshops*, pp. 233-240. 2009.

C.R. Johnson, A.R. Sanderson. "A Next Step: Visualizing Errors and Uncertainty," In *IEEE Computer Graphics and Applications*, Vol. 23, No. 5, pp. 6-10. September/October, 2003.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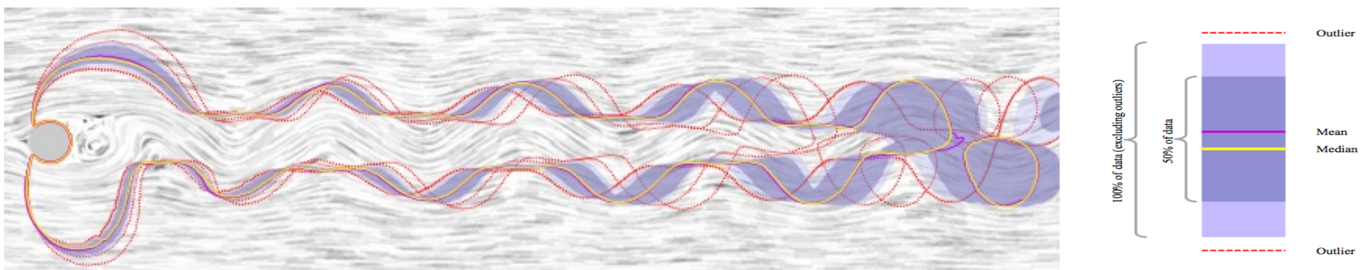
# Contour Box Plots

$$S \in \mathrm{sB}\left(S_1,\ldots S_j\right) \iff \bigcap_{k=1}^{j} S_k \subset S \subset \bigcup_{k=1}^{j} S_k.$$





Whitaker, Mirzargar, Kirby, *IEEE Transactions on Visualization and Computer Graphics*, Vol. 19, No. 12, pp. 2713--2722, 2013.

M.G. Genton, C.R. Johnson, K. Potter, G. Stenchikov, Y. Sun. "Surface boxplots," In *Stat Journal*, Vol. 3, No. 1, pp. 1-11. 2014.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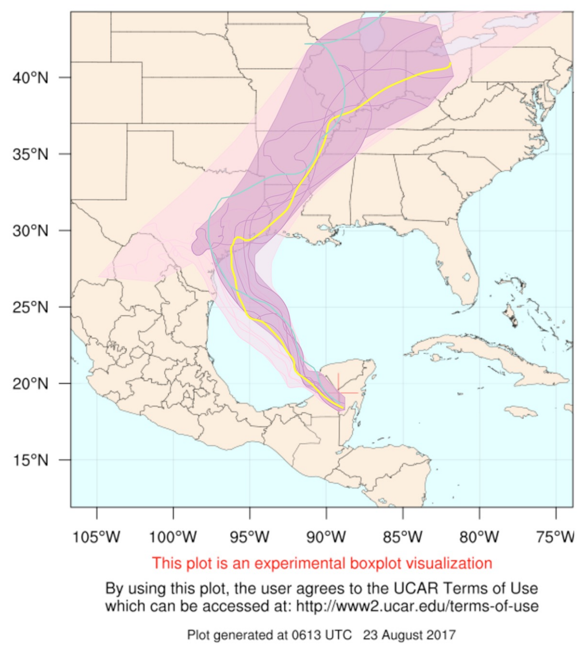
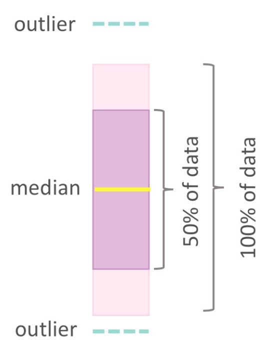
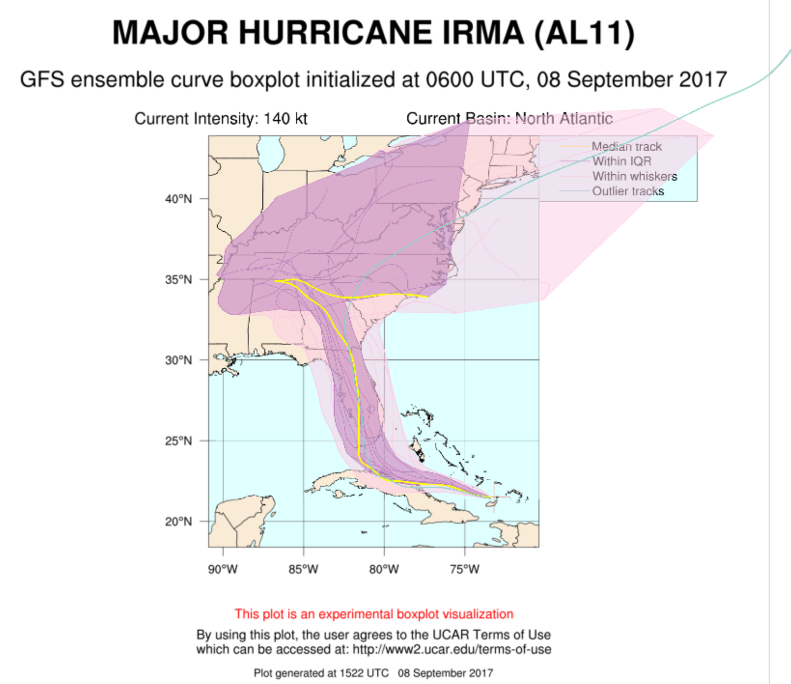
# Ensemble Curved Boxplot

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**M. Mirzargar, R. Whitaker, R. M. Kirby. "Curve Boxplot: Generalization of Boxplot for Ensembles of Curves," IEEE Transactions on Visualization and Computer Graphics, Vol. 20, No. 12, IEEE, pp. 2654-63. December, 2014.**

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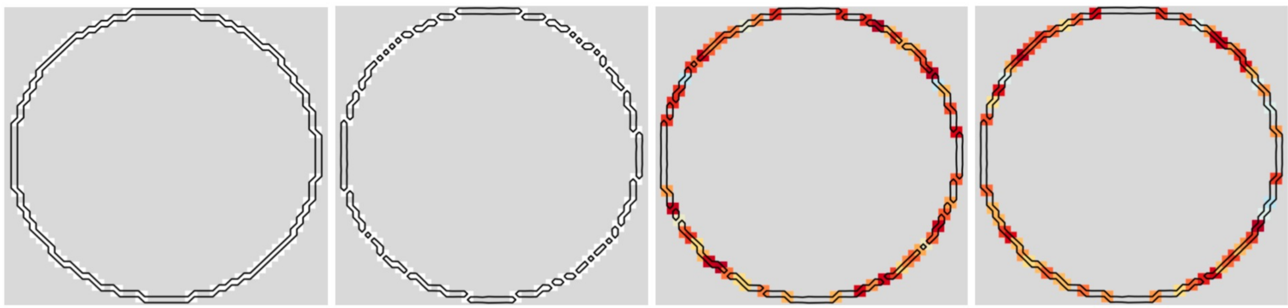
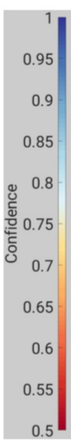
# Probabilistic Asymptotic Decider for Topological Ambiguity Resolution in Level-Set Extraction for Uncertain 2D Data

Tushar Athawale and Chris R. Johnson



(a) The isocontour topology in the (b) The asymptotic decider in the mean (c) The probabilistic midpoint decider (d) The probabilistic asymptotic decider

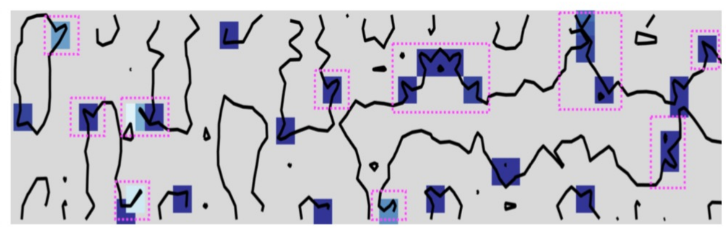



I. The probabilistic midpoint decider

II. The probabilistic asymptotic decider

(a) The temperature field

I. The probabilistic midpoint decider



II. The probabilistic asymptotic decider

(b) The velocity field for the Kàrmàn vortex street

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# Uncertainty Visualization of the Marching Squares and Marching Cubes Topology Cases - VIS 2021

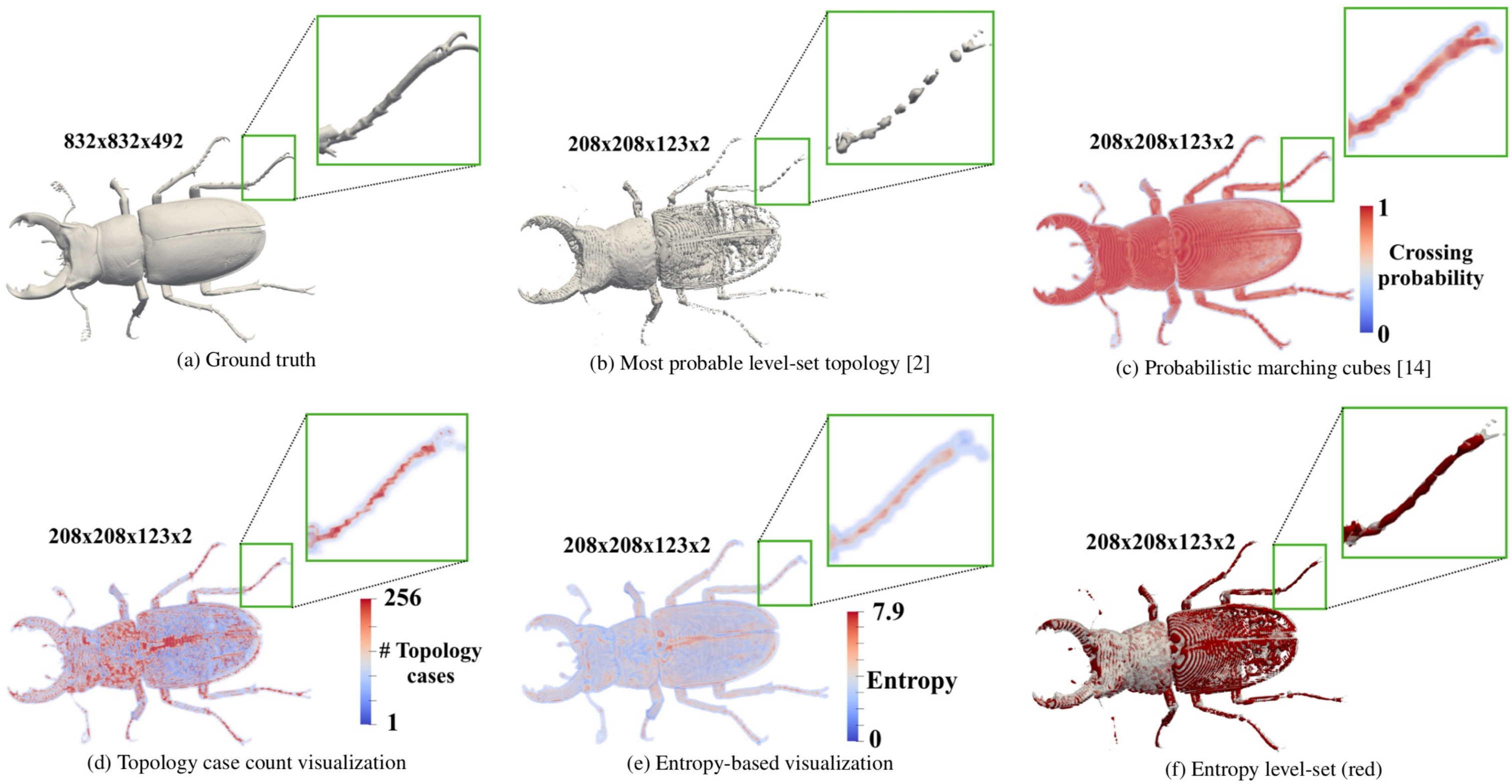


Figure 5: Uncertainty visualizations for the stag beetle [21] hixel dataset at $k = 900$. The noise in the data results in breaking of the beetle leg in image (b). In probabilistic marching cubes, it is difficult to distinguish between the regions of high and topological uncertainty, which is easier using our visualizations in images (d-f). The relatively high sensitivity of the beetle leg topology to noise is detected in images (d-f) by the red regions. In image (f), the most probable level-set (gray) is overlaid with the entropy volume level-set (red) for entropy isovalue 5.

# Productivity Machines


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