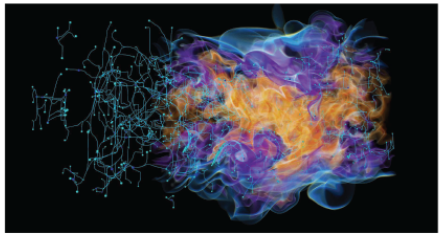
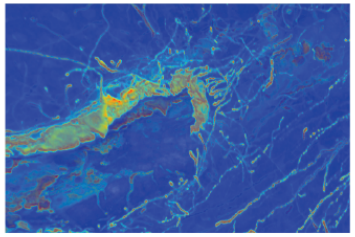
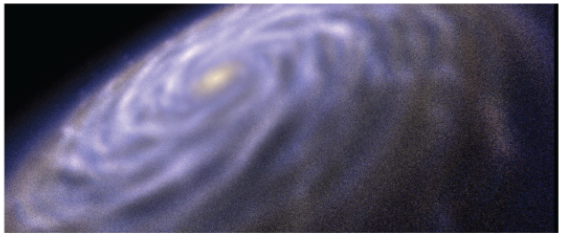
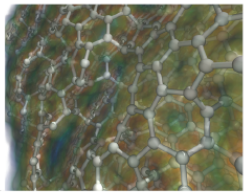
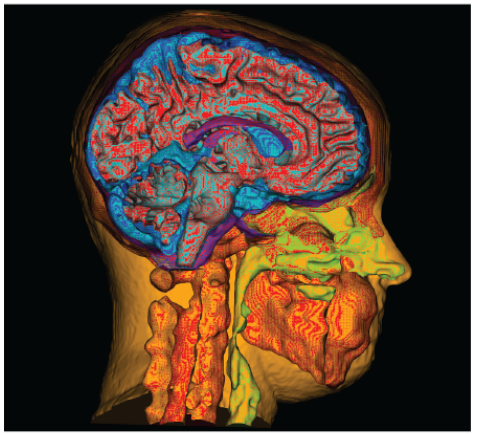
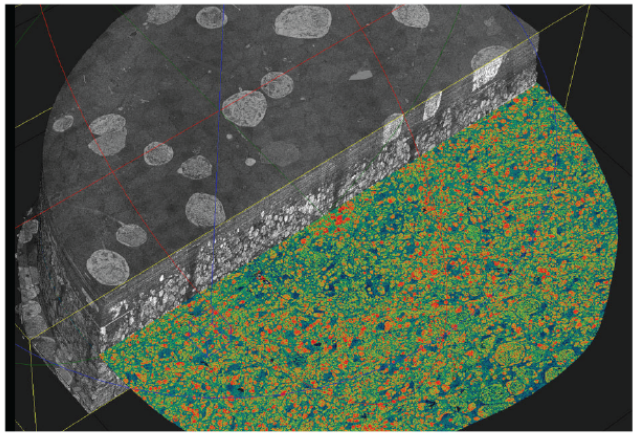
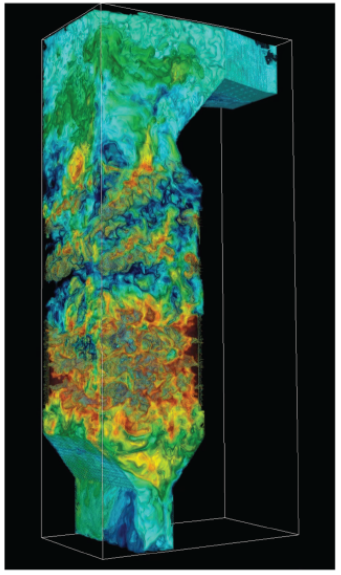
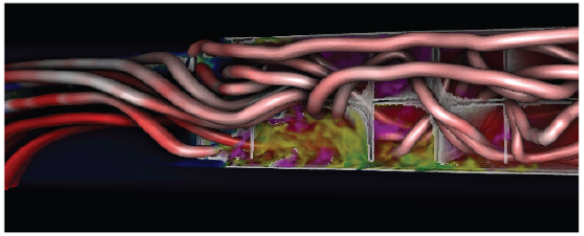
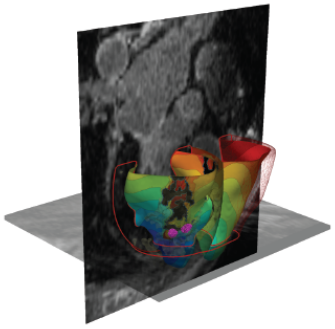
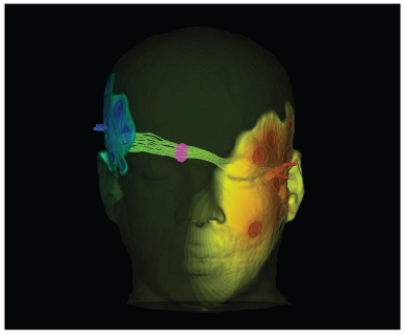
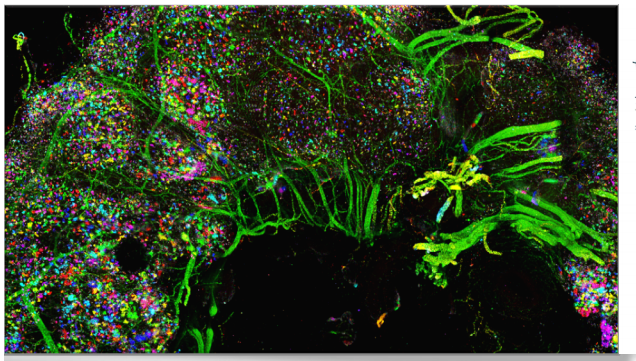
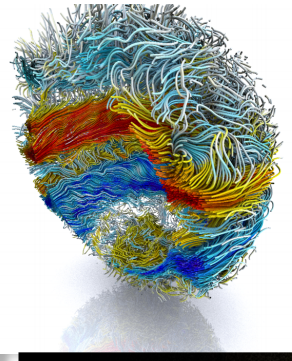
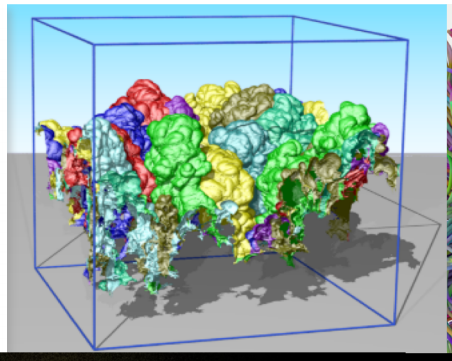
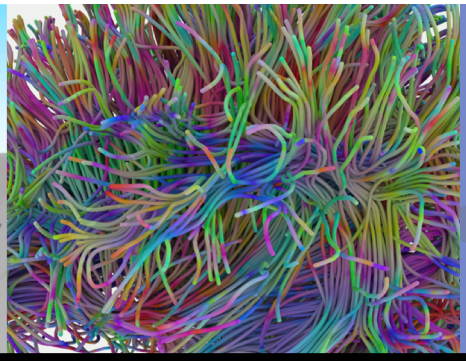
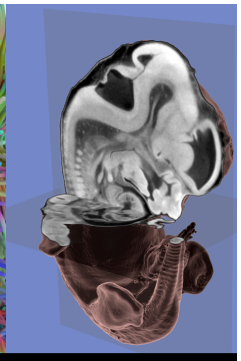
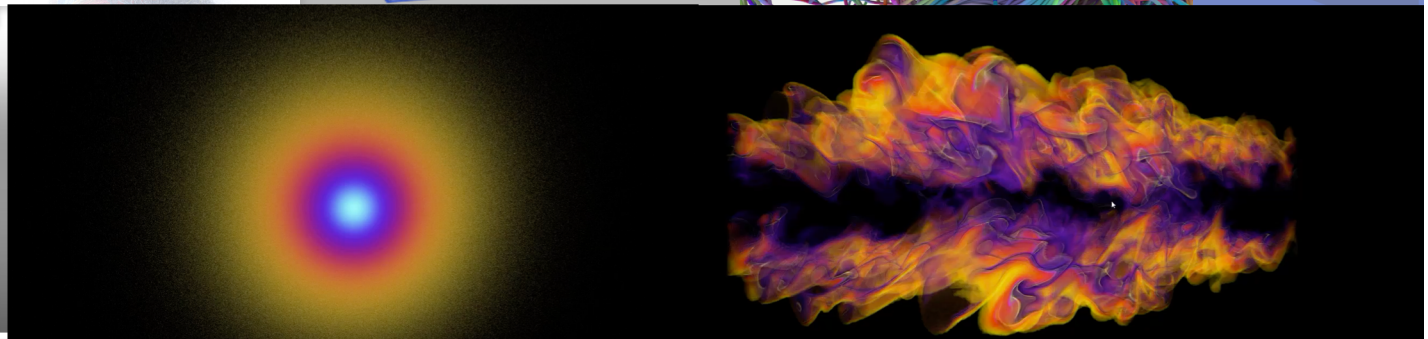
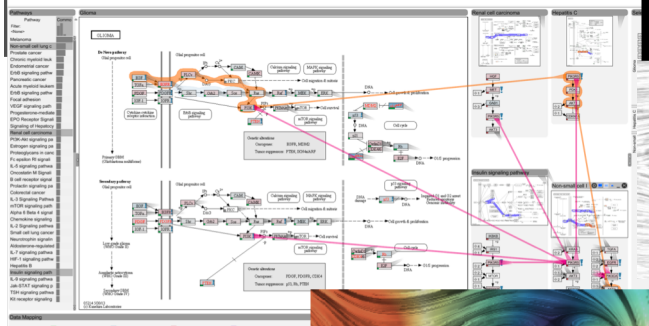
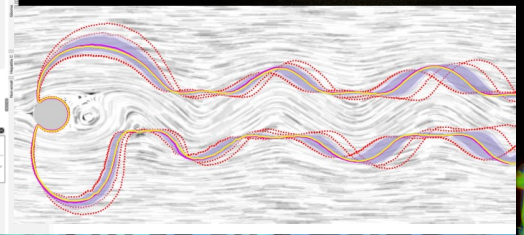
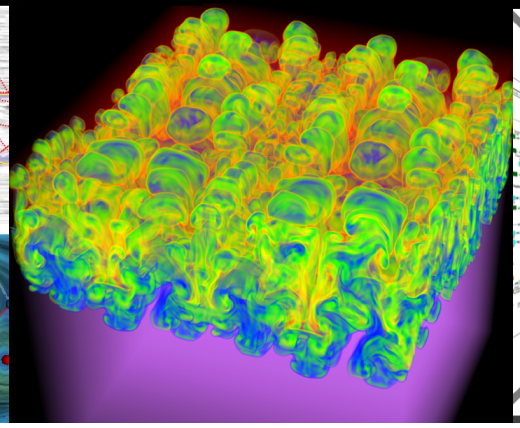
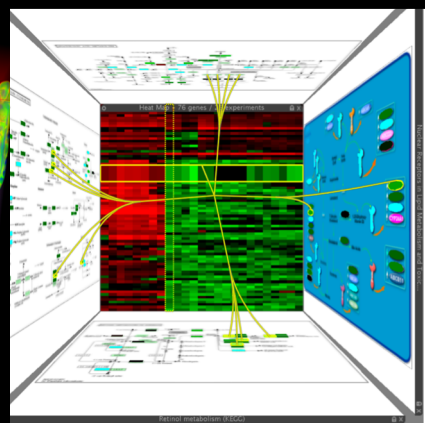
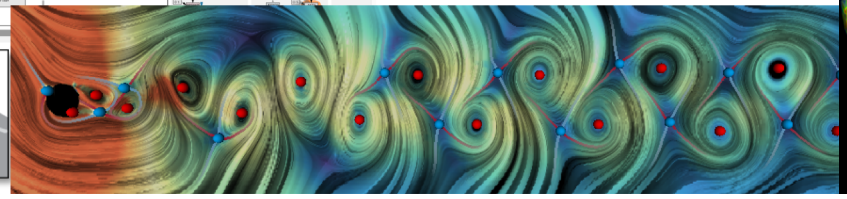
Visual Analysis Challenges in the Age of Data



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Large-Scale Visualization Challenges

Analysis

Scalability

Users and Usability

Large-Scale Visualization Challenges

Analysis

- High Order Simulation
- Uncertainty Quantification and Visualization
- Topological Data Analysis

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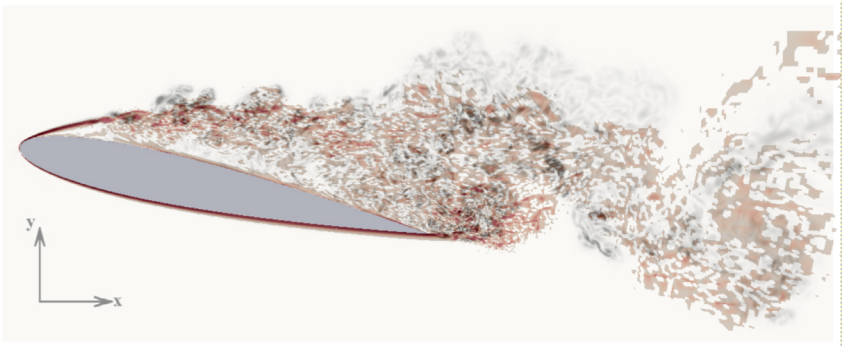
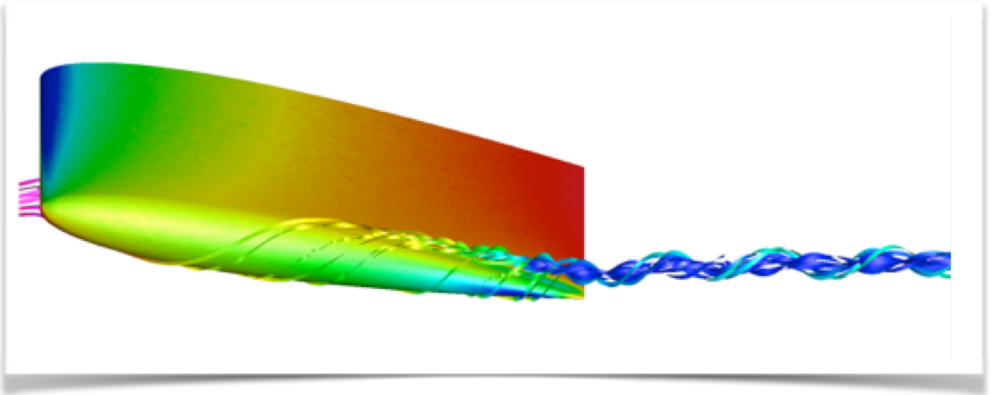
Formula-1 Racing & Simulation



Nektar++: an open-source scalable C++ software library for high-order Finite Element methods.

See: www.nektar.info



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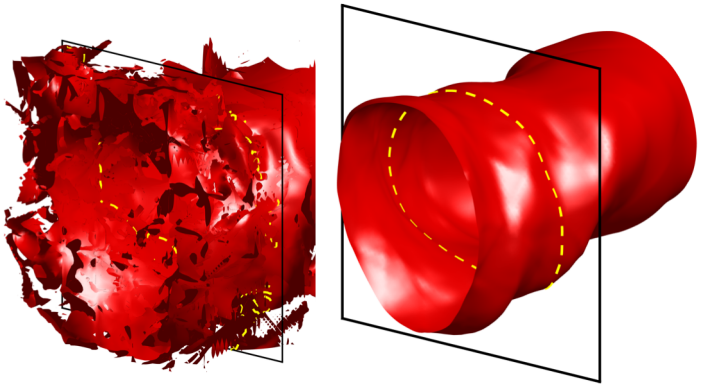
Mike Kirby and Spencer Sherwin

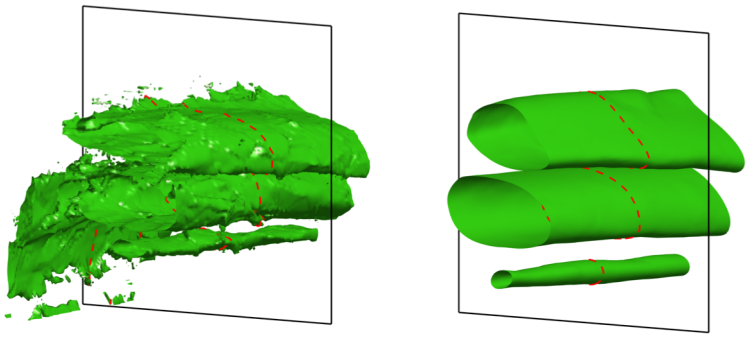
Filtering for High-Order FEM Visualization



FEM Vorticity

LSIAC Filtered Vorticity

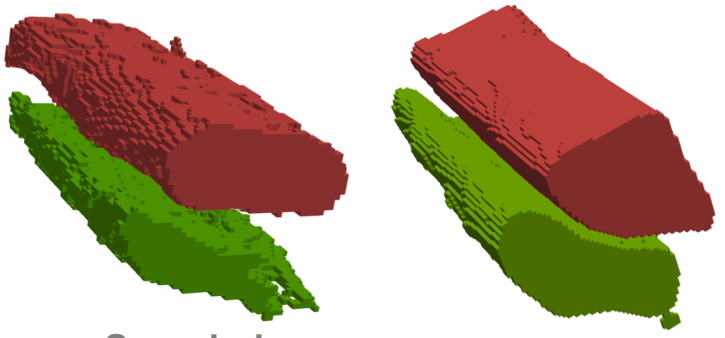
Counter-Rotating Vortex Vorticity



Sampled

LSIAC Filtered

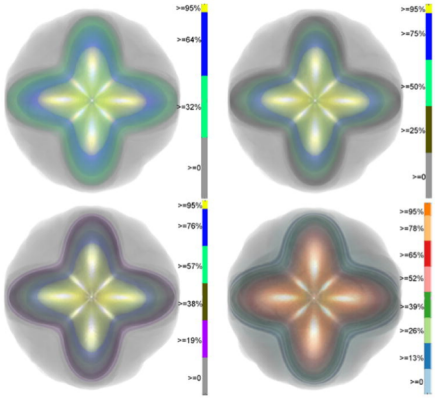
Topological Analysis of Fields

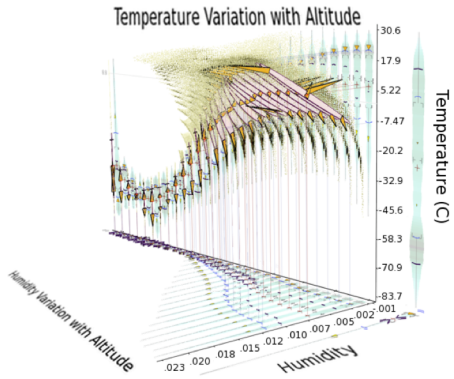


Sampled

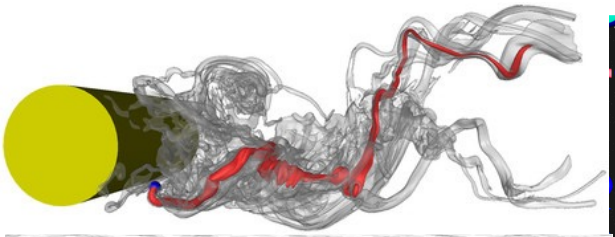
LSIAC Filtered

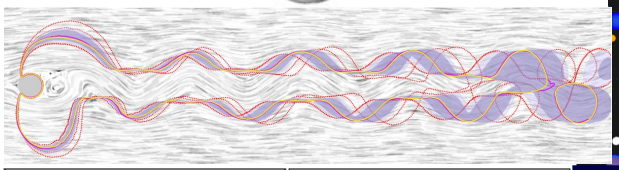
Uncertainty Visualization

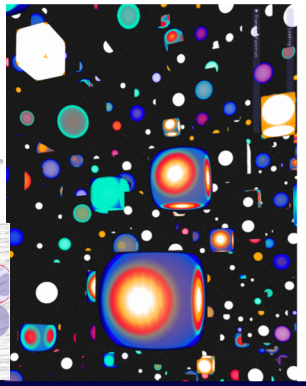


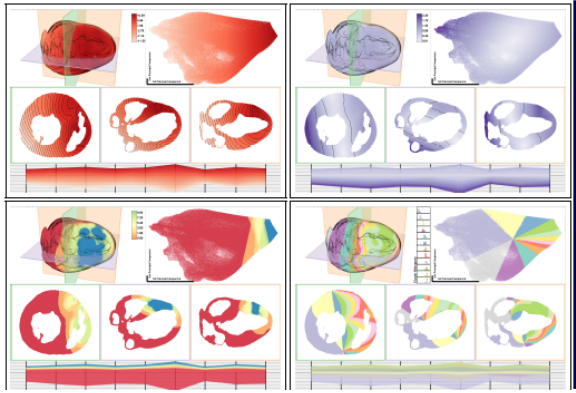


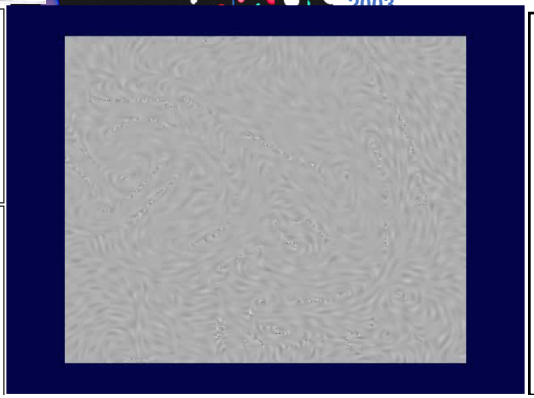
When is the last time you've seen an error bar on an isosurface?

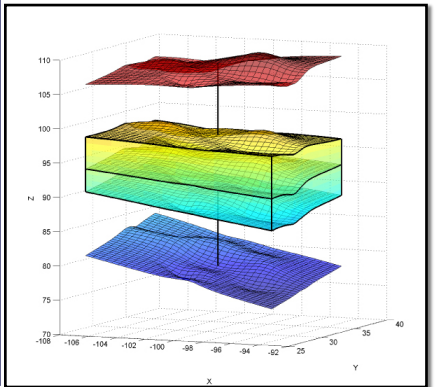












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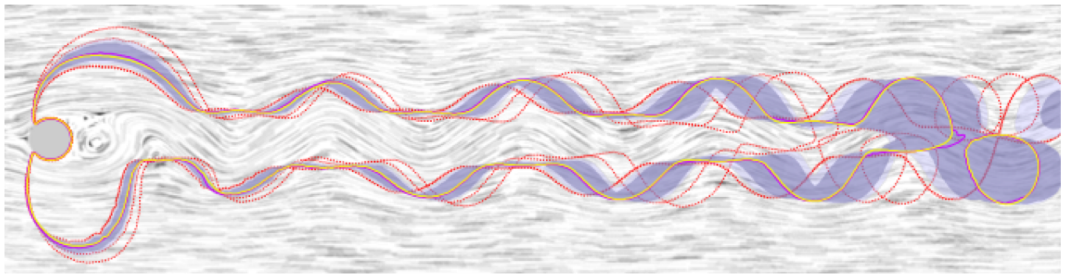
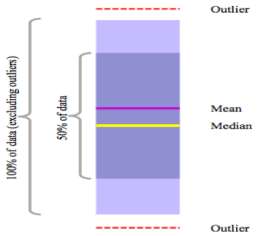
Contour Box Plots

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





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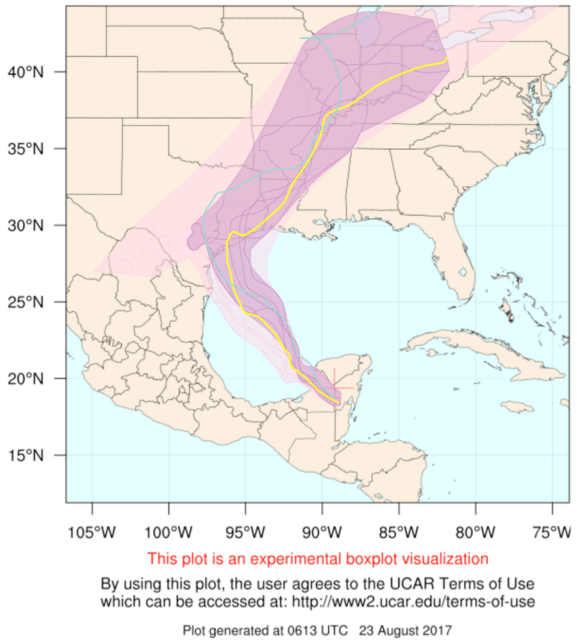
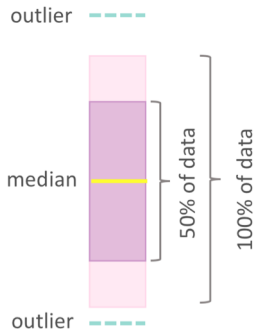
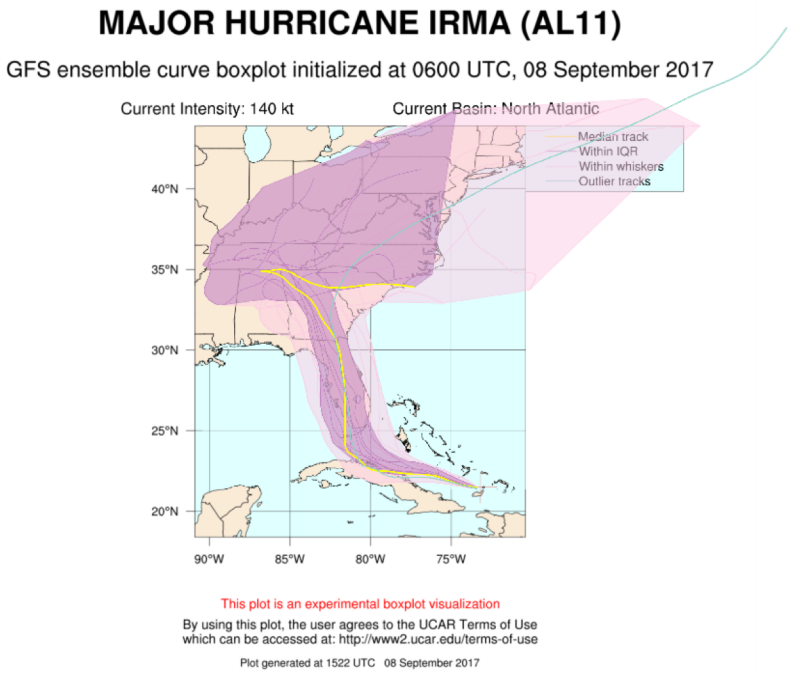
Ensemble Curved Boxplot







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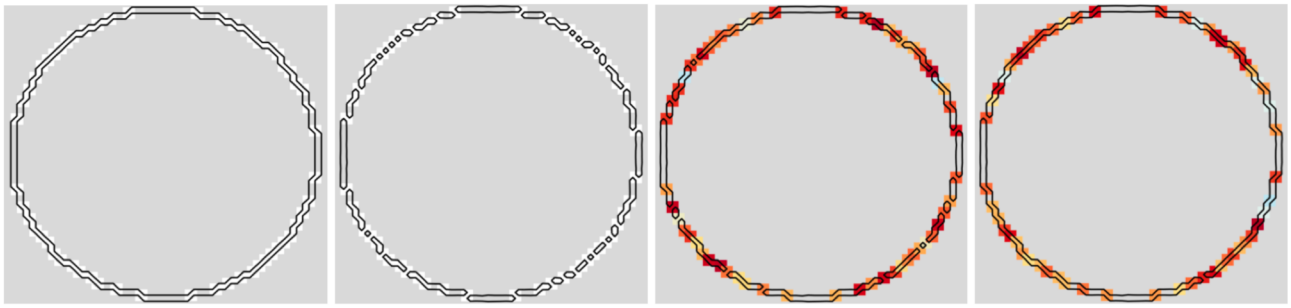
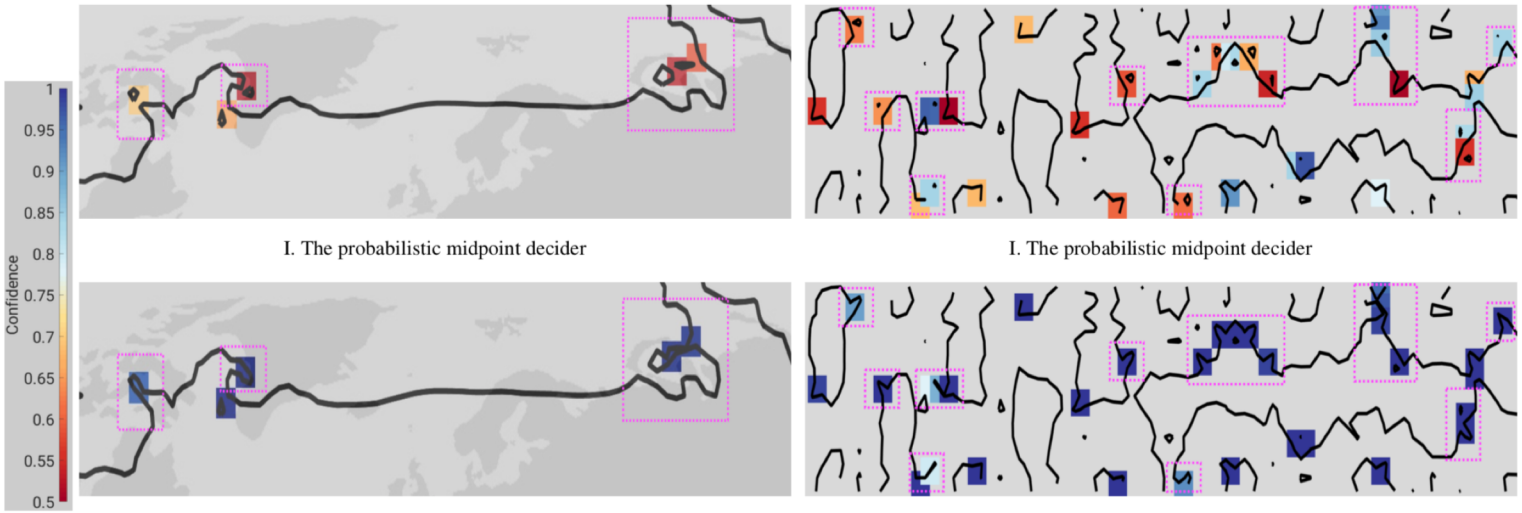
Probabilistic Asymptotic Decider for Topological Ambiguity Resolution in Level-Set Extraction for Uncertain 2D Data

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

I. The probabilistic midpoint decider

II. The probabilistic asymptotic decider

II. The probabilistic asymptotic decider

(a) The temperature field

(b) The velocity field for the Kàrmàn vortex street

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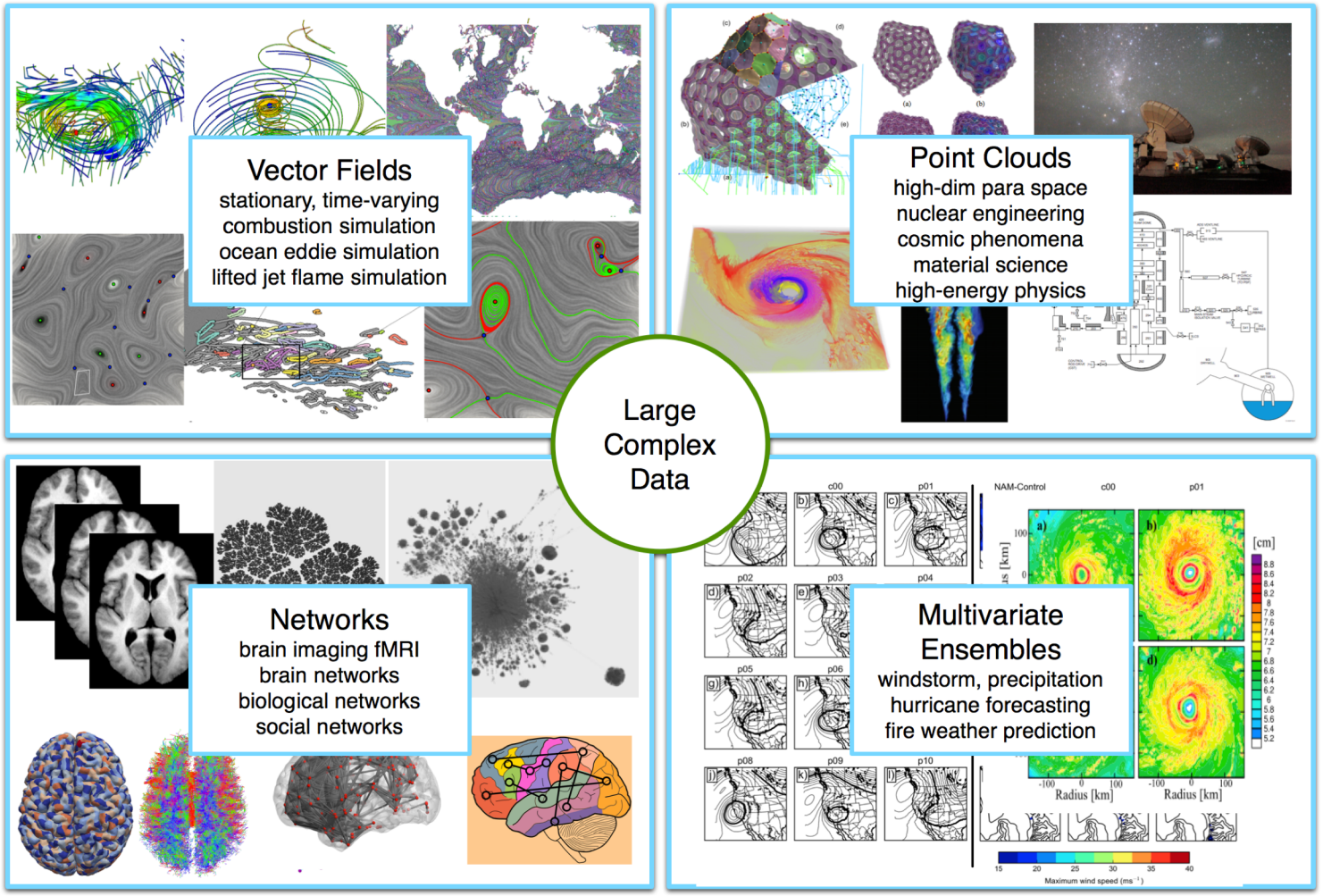
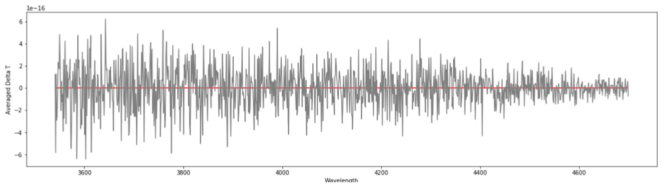
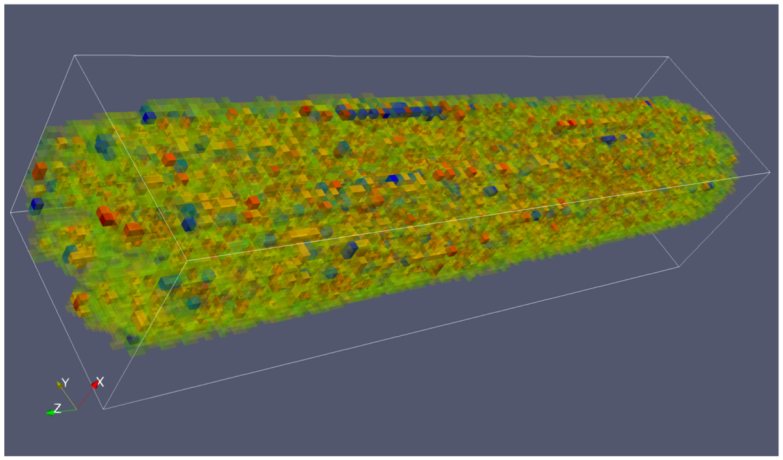
Topological Data Analysis and Visualization

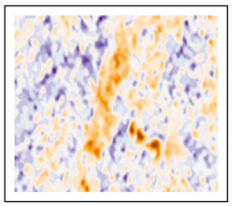


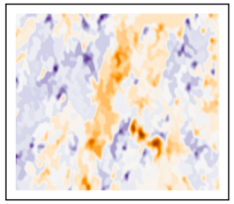
Topological Data Analysis for Astronomical Data Cubes

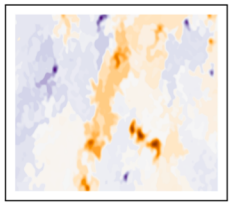


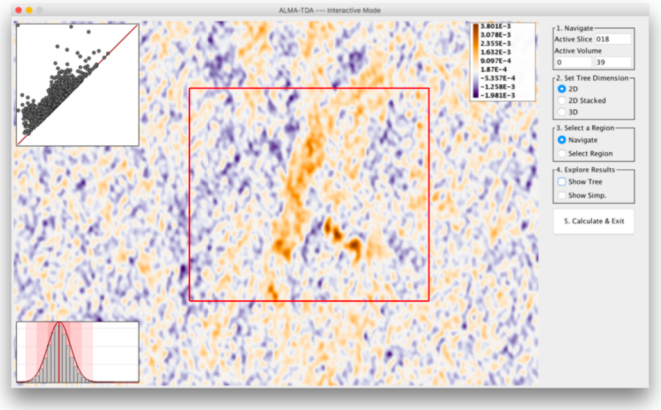


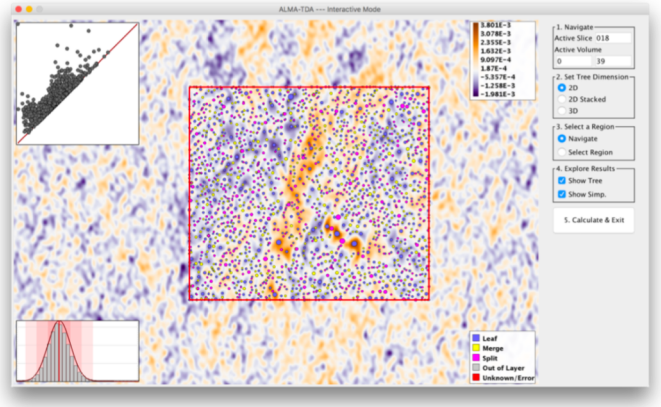
Analysis of cosmic voids











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

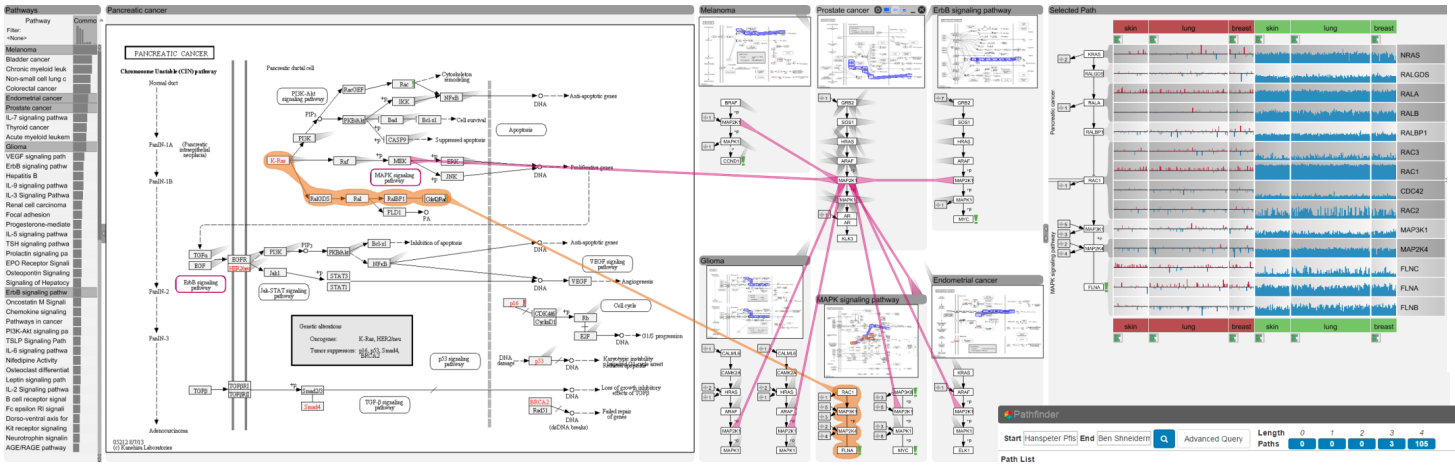
Yulong Liang, Vikranta Kamble, Helion Dumas Desbourboux, Lin Yan, Mengjiao Han, Kyle Dawson, Nicholas Boardman, Gail Zasowski, Anil Seth, Joel Brownstein, Paul Rosen, Juna A. Kollmeier, Guillermo Blanc, **Bei Wang**

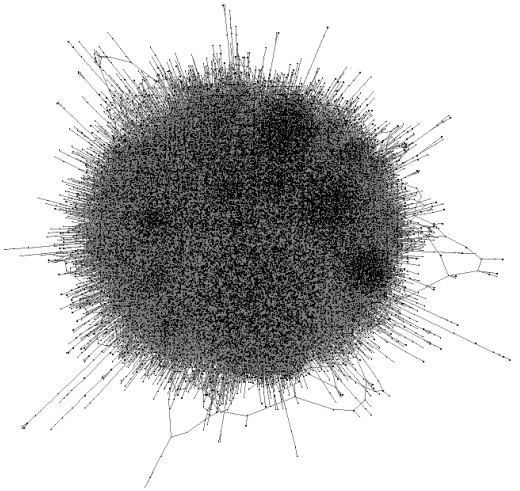
Large-Scale Visualization Challenges

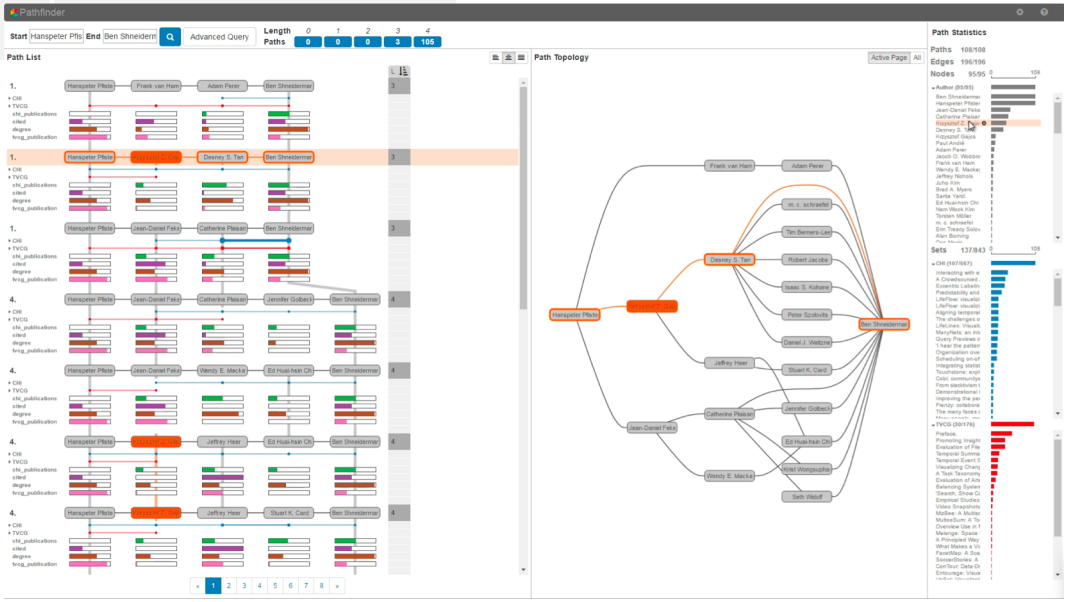
Scalability

- High Dimensional Visualization
- In Situ and Streaming Visualization
- Hierarchy

Large Multivariate Networks







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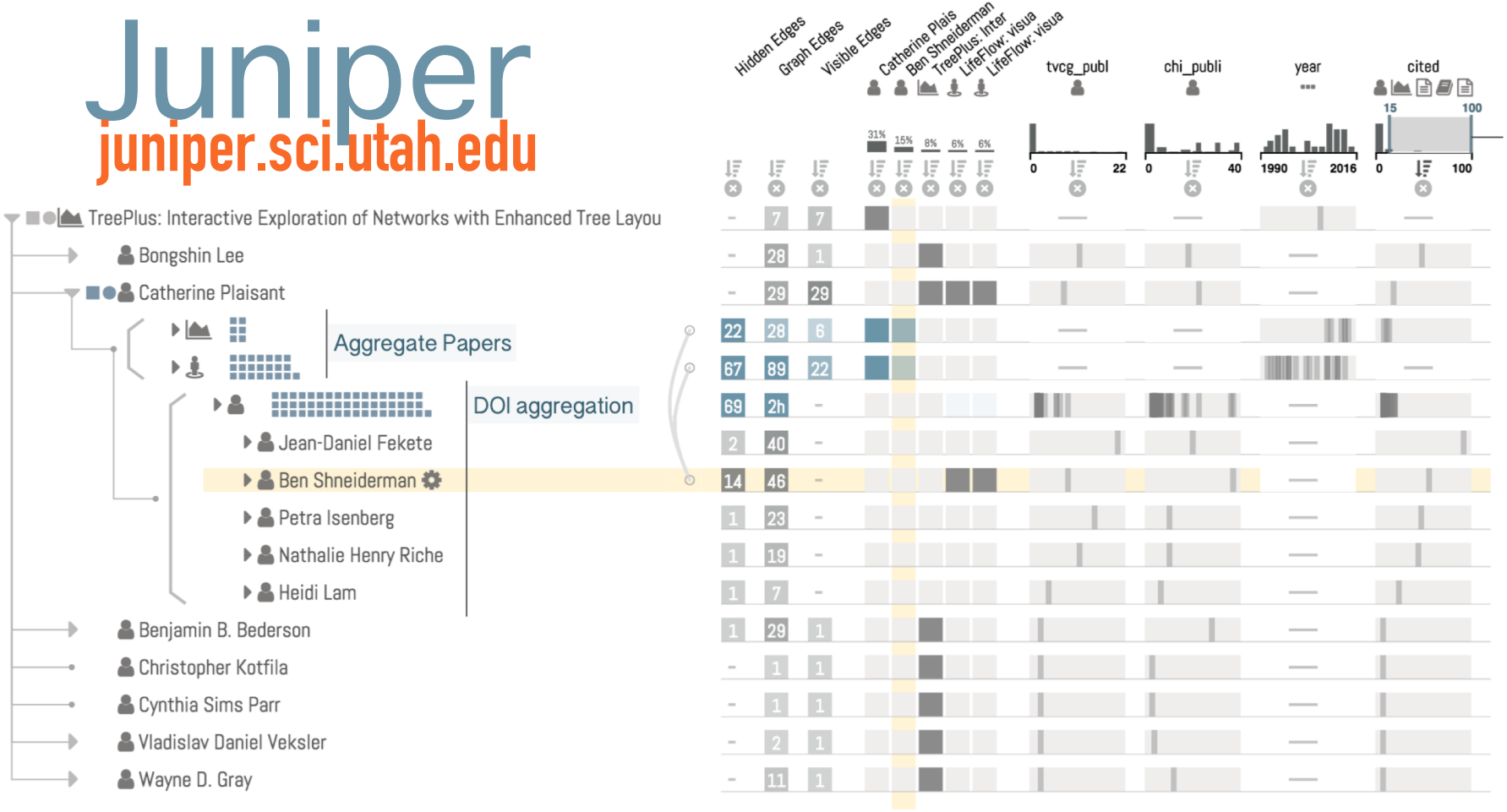
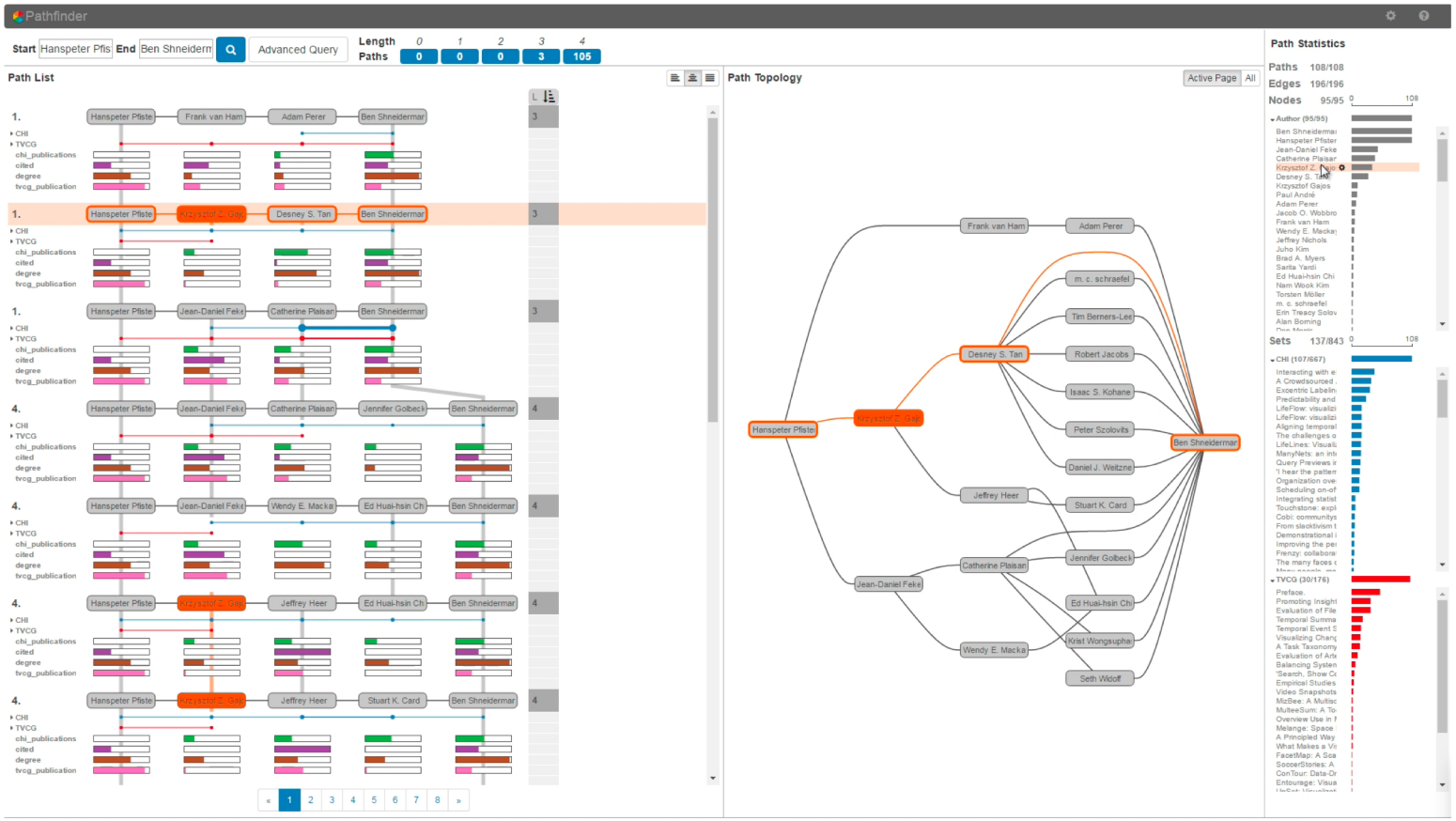


Pathfinder: Visual Analysis of Paths in Graphs

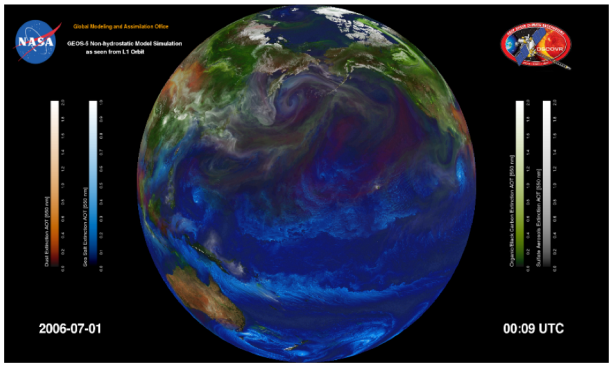


C. Partl, S. Gratzl, M. Streit, A. Wassermann, H. Pfister, D. Schmalstieg, A. Lex. **"Pathfinder: Visual Analysis of Paths in Graphs,"** In *Computer Graphics Forum (EuroVis '16)*, Vol. 35, No. 3, pp. 71-80, 2016.

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

Workflow

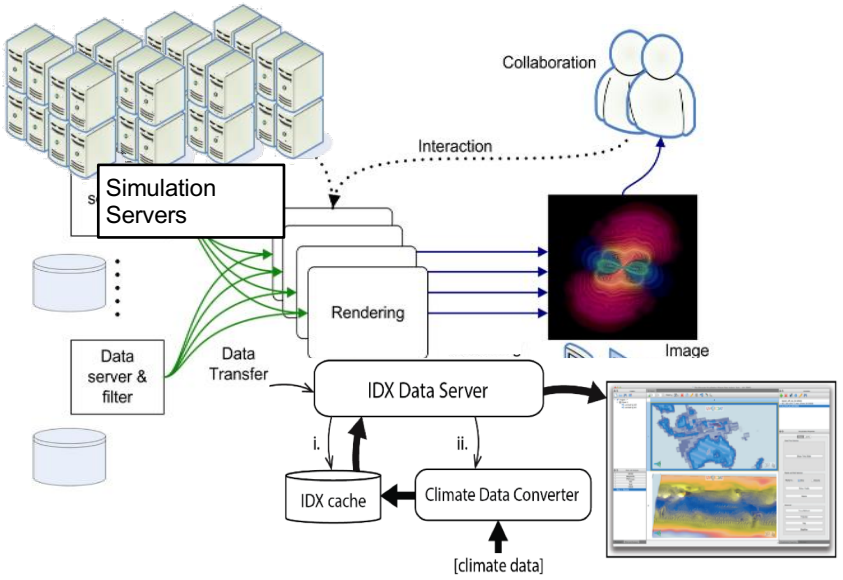
- *Data creation*
- *Data Management*
  - Processing
  - Analysis
  - Visualization

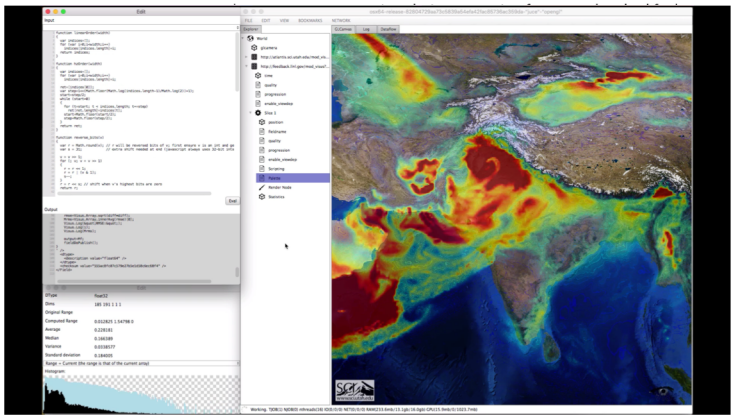


- 7km GEOS-5 “Nature Run”
- 1 dataset, 3.5 PB
- theoretically: openly accessible
- practically: precomputed pics

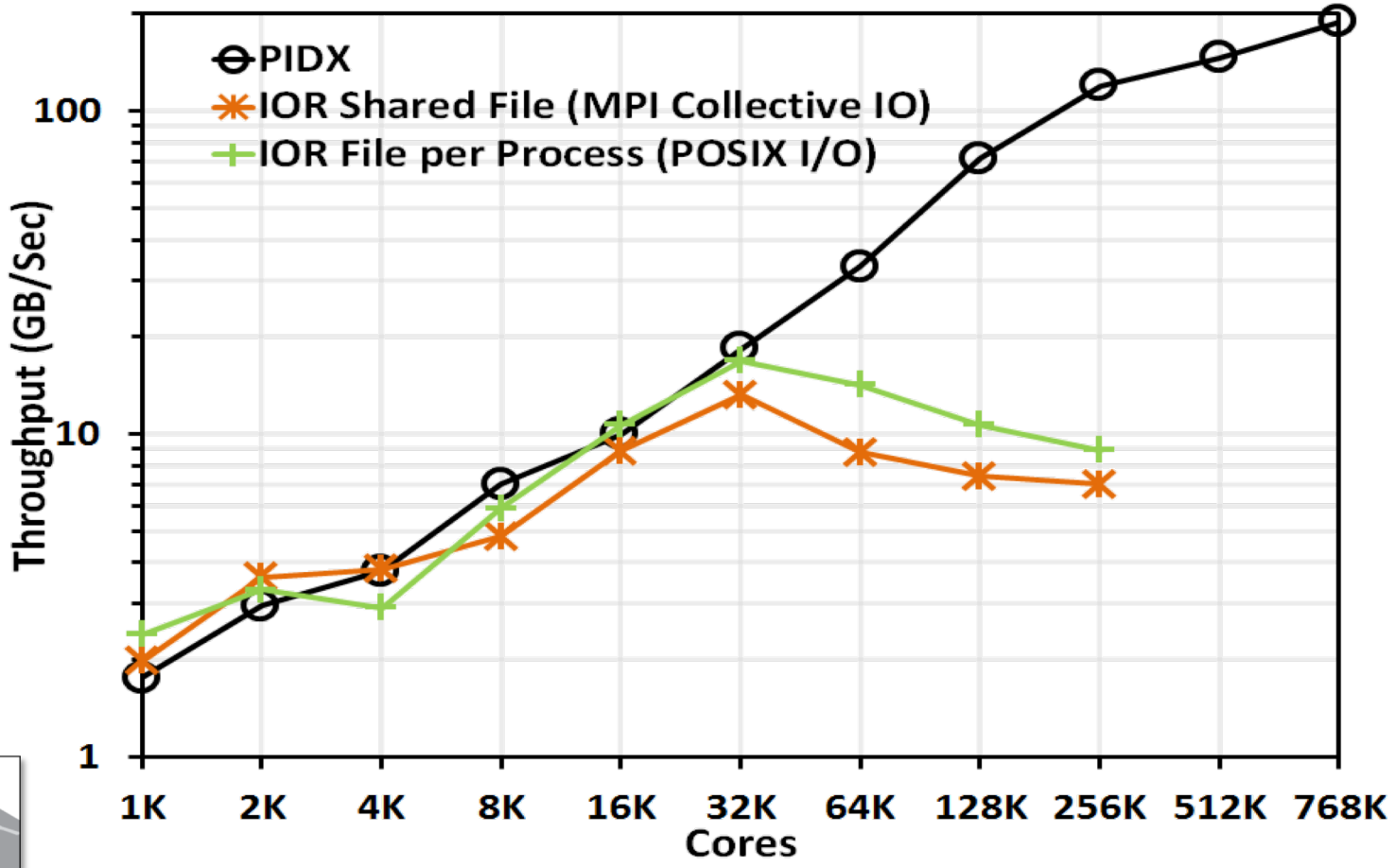
Distributed Resources

- 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*





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



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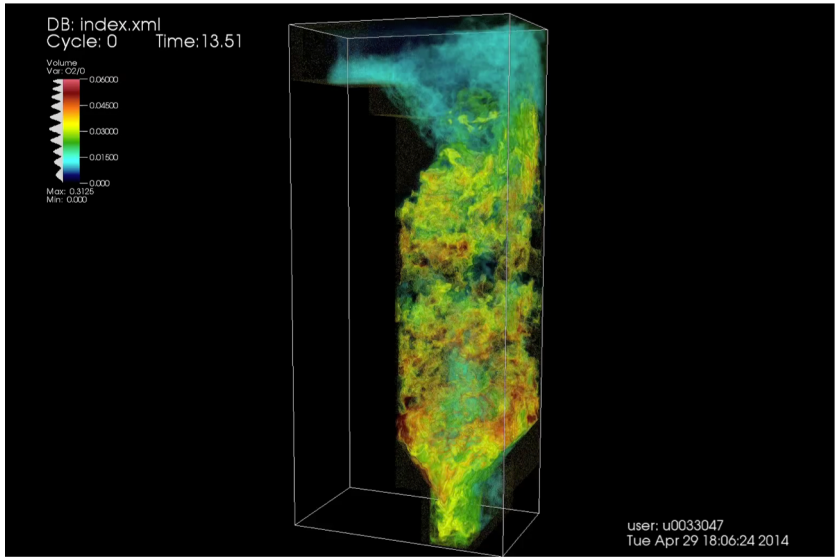
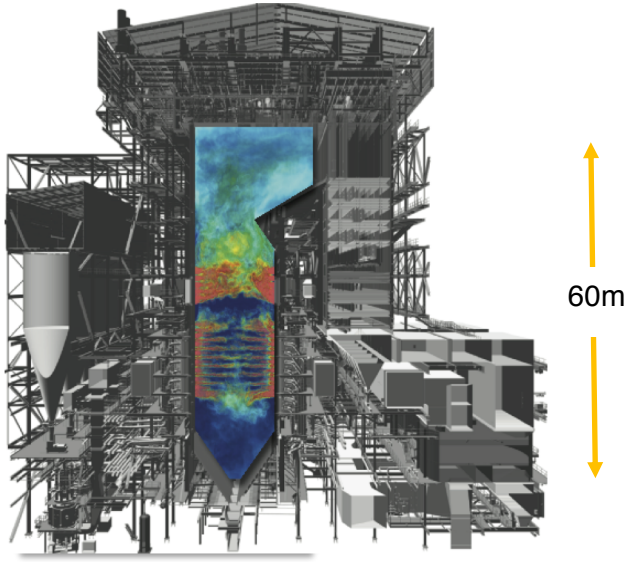
DOE PSAAP2 Simulations of GE Clean(er) Coal Boilers

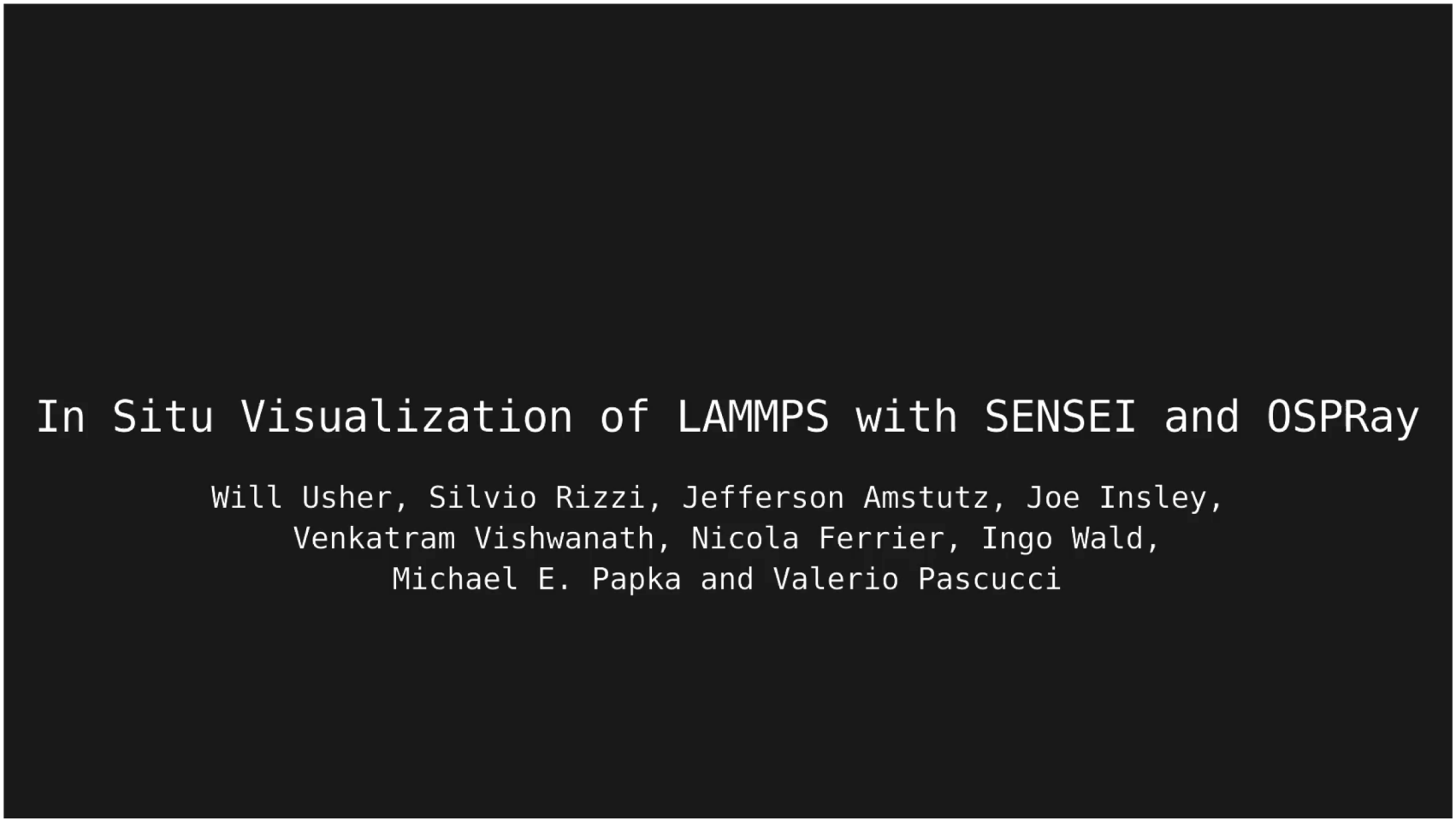
- Large scale turbulent combustion needs mm scale grids
  10^14 mesh cells 10^15 variables (1000x more than now)
- Structured, high order finite-volume discretization
- Mass, momentum, energy conservation
- LES closure, tabulated chemistry
- PDF mixing models
- DQMOM (many small linear solves)
- Uncertainty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

LAMMPS In-Situ Rendering with OSPRay



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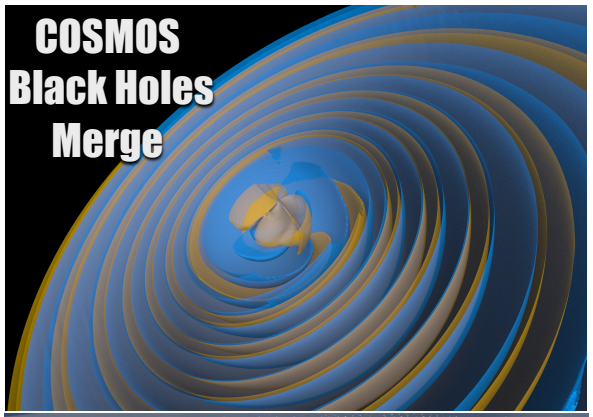
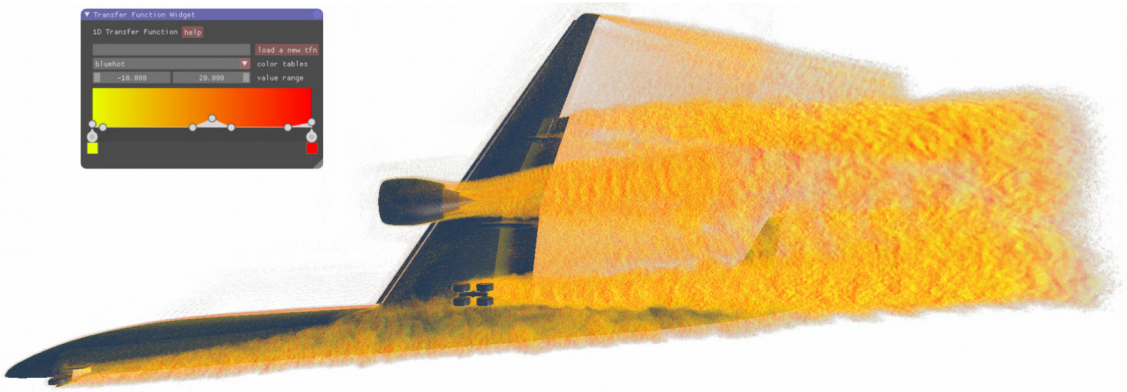
AMR Data Visualization

- Block-structured AMR



NASA LandingGear

- Tree-based (unstructured) AMR



NASA Exajet

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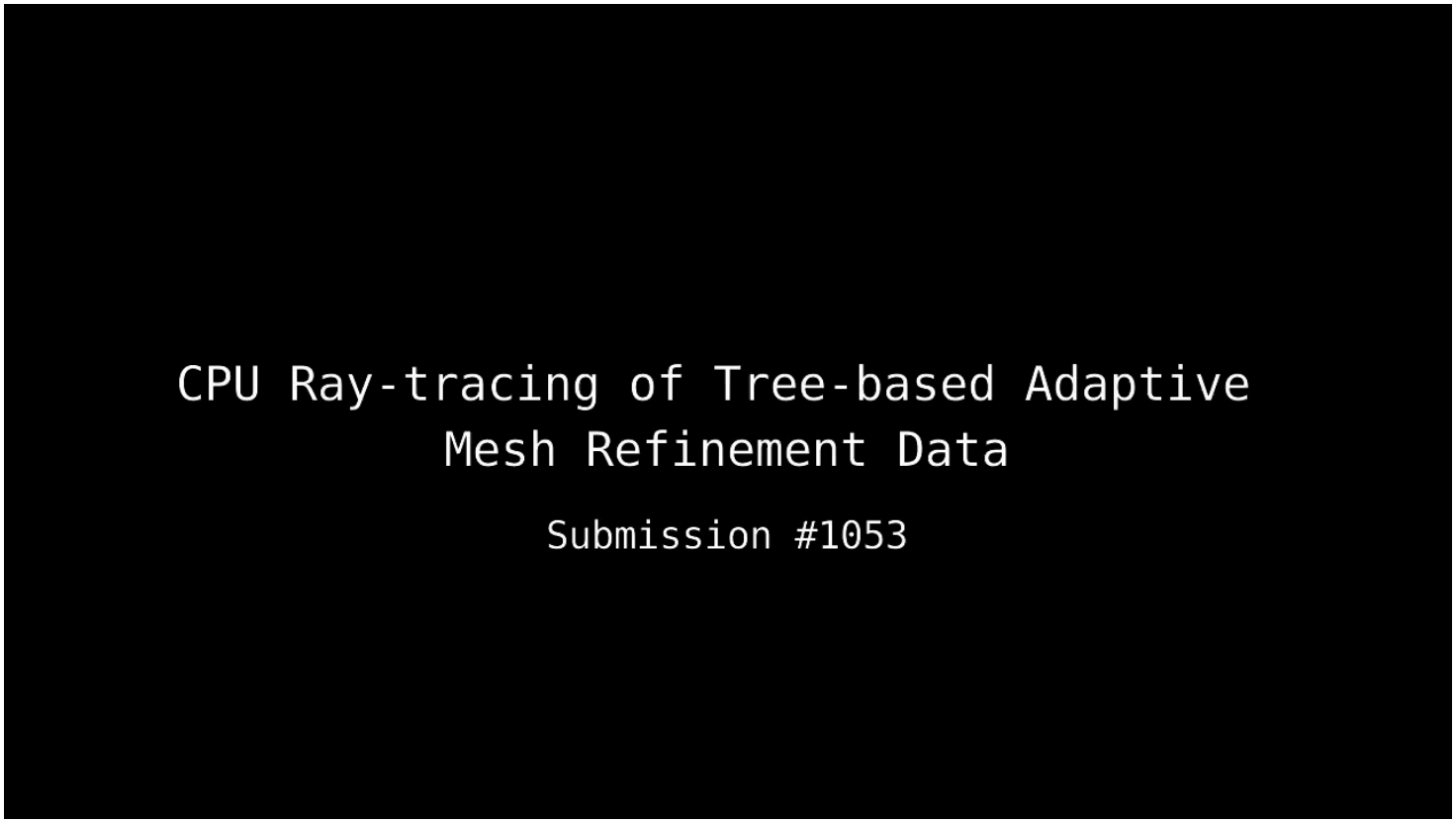
NASA Exajet - 1.3B Cells



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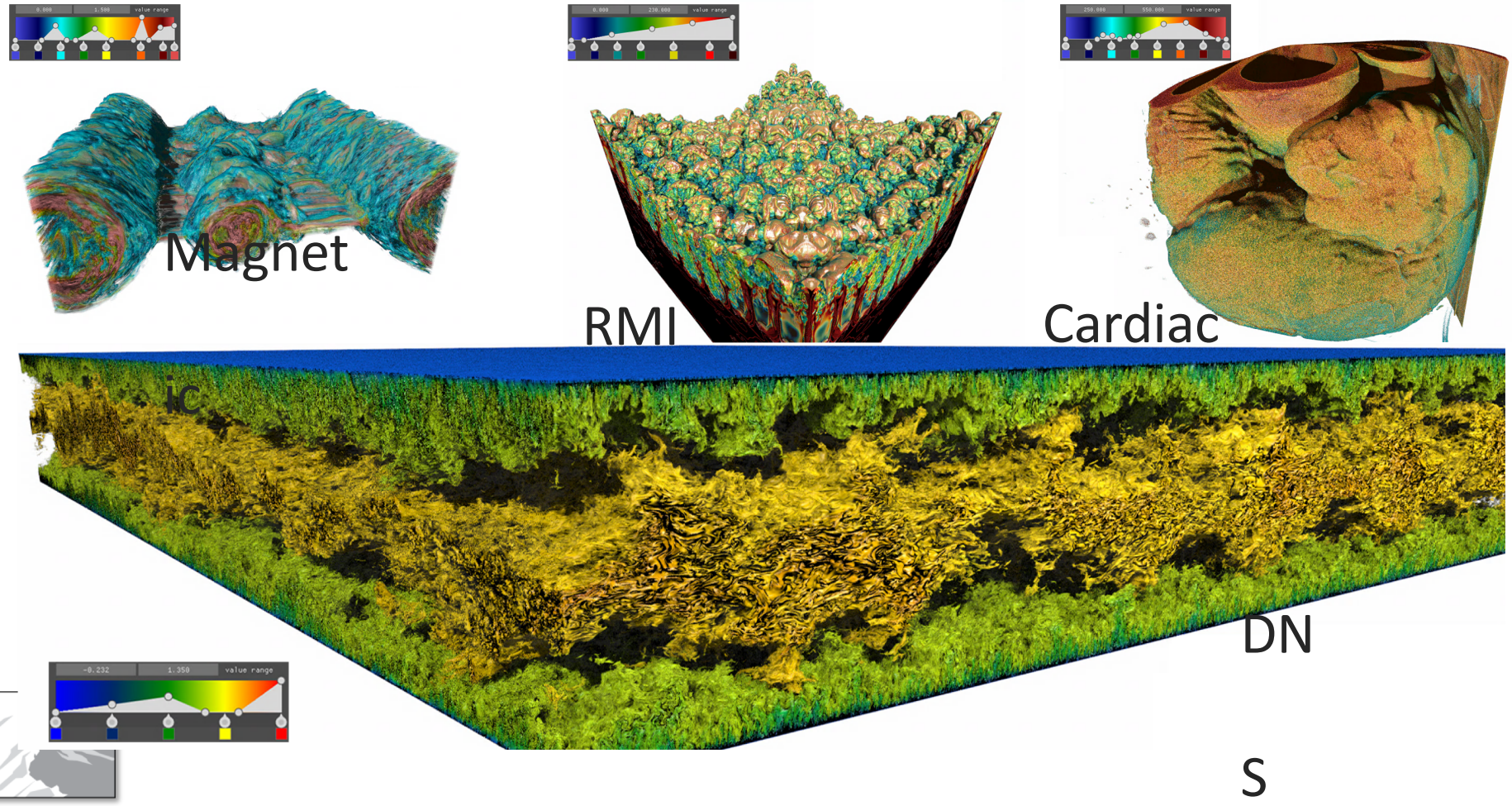
Interactive Visualization of Large-Scale Datasets



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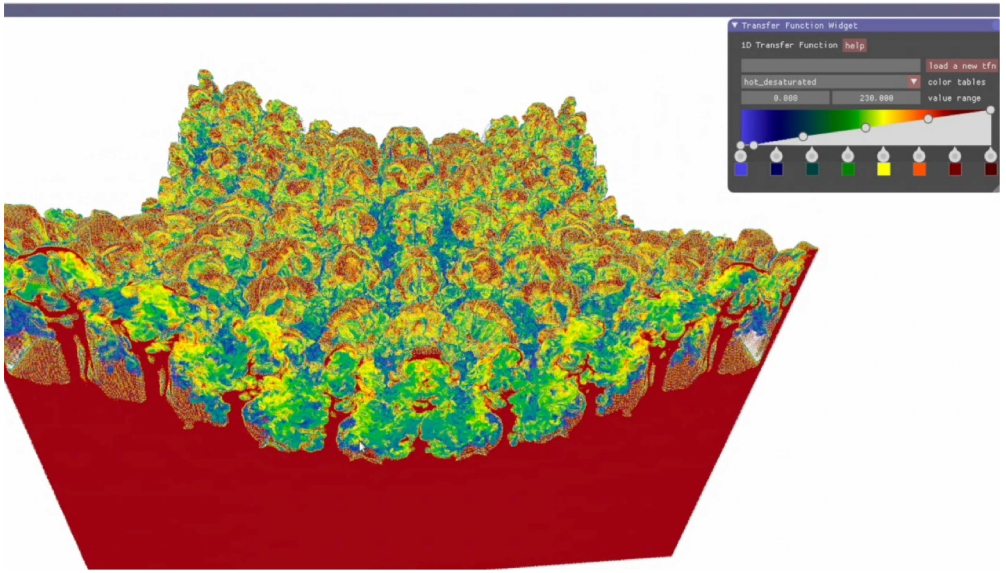
Ray-guided Progressive Rendering

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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Large-Scale Visualization Challenges

Users and Usability

- Interactivity
- Collaboration
- Design
- Reproducible Visualization

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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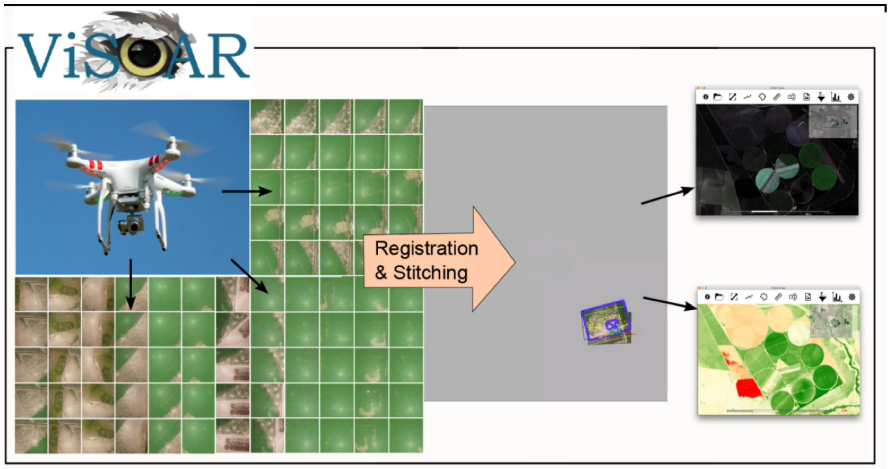
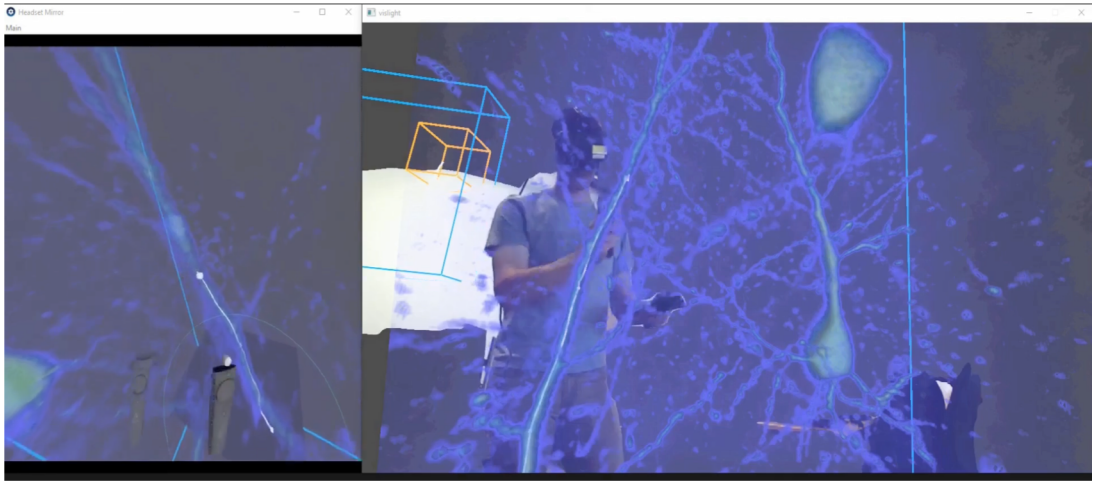
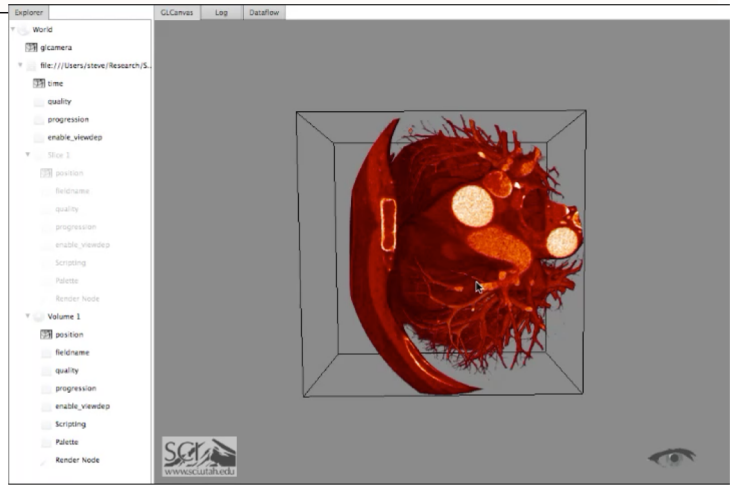
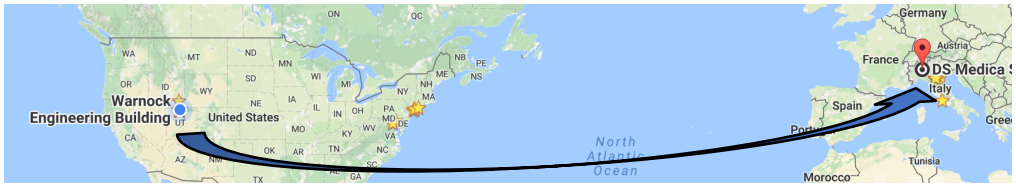

ViSOAR
Registration
& Stitching



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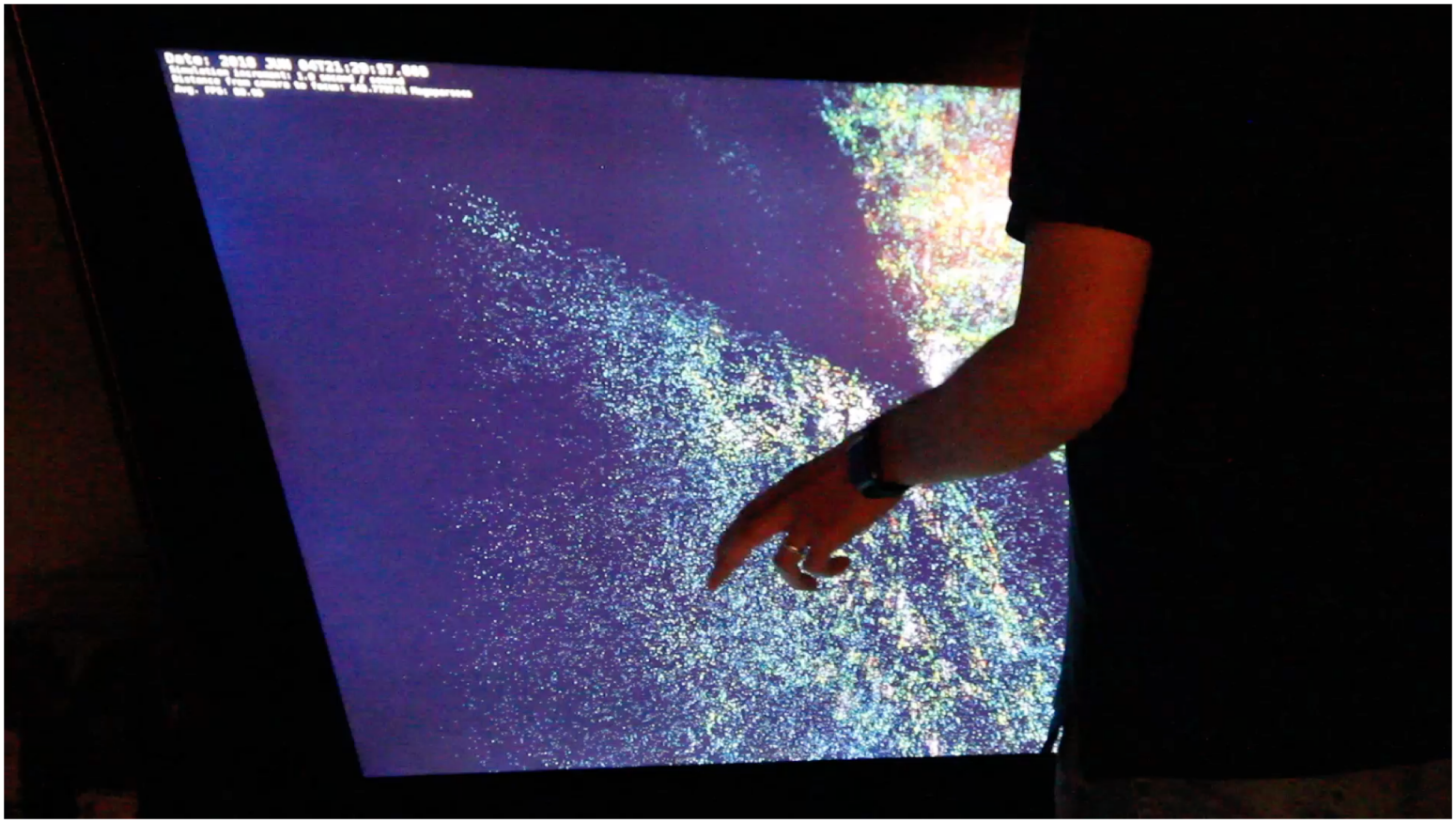
http://openspaceproject.com



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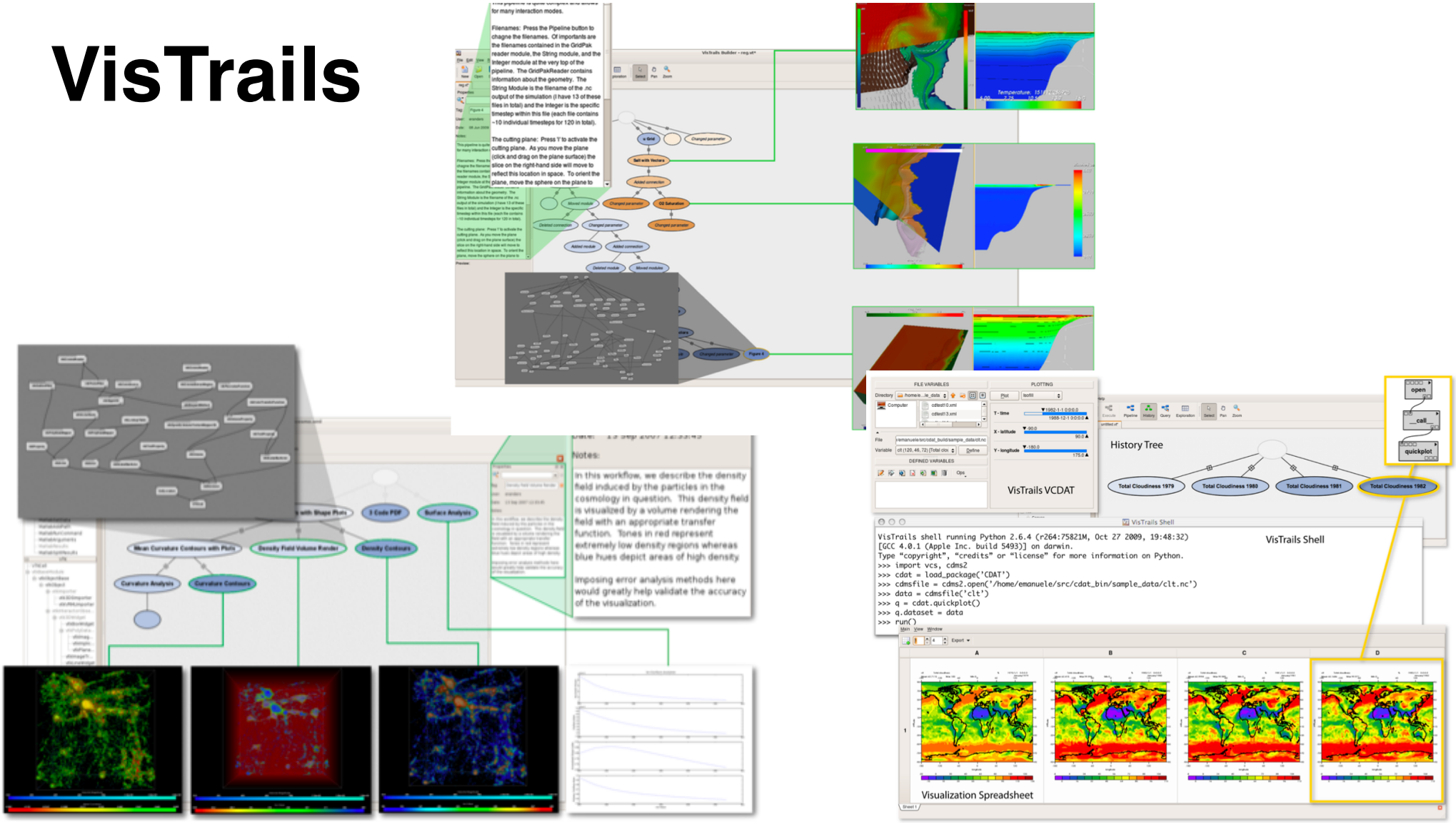
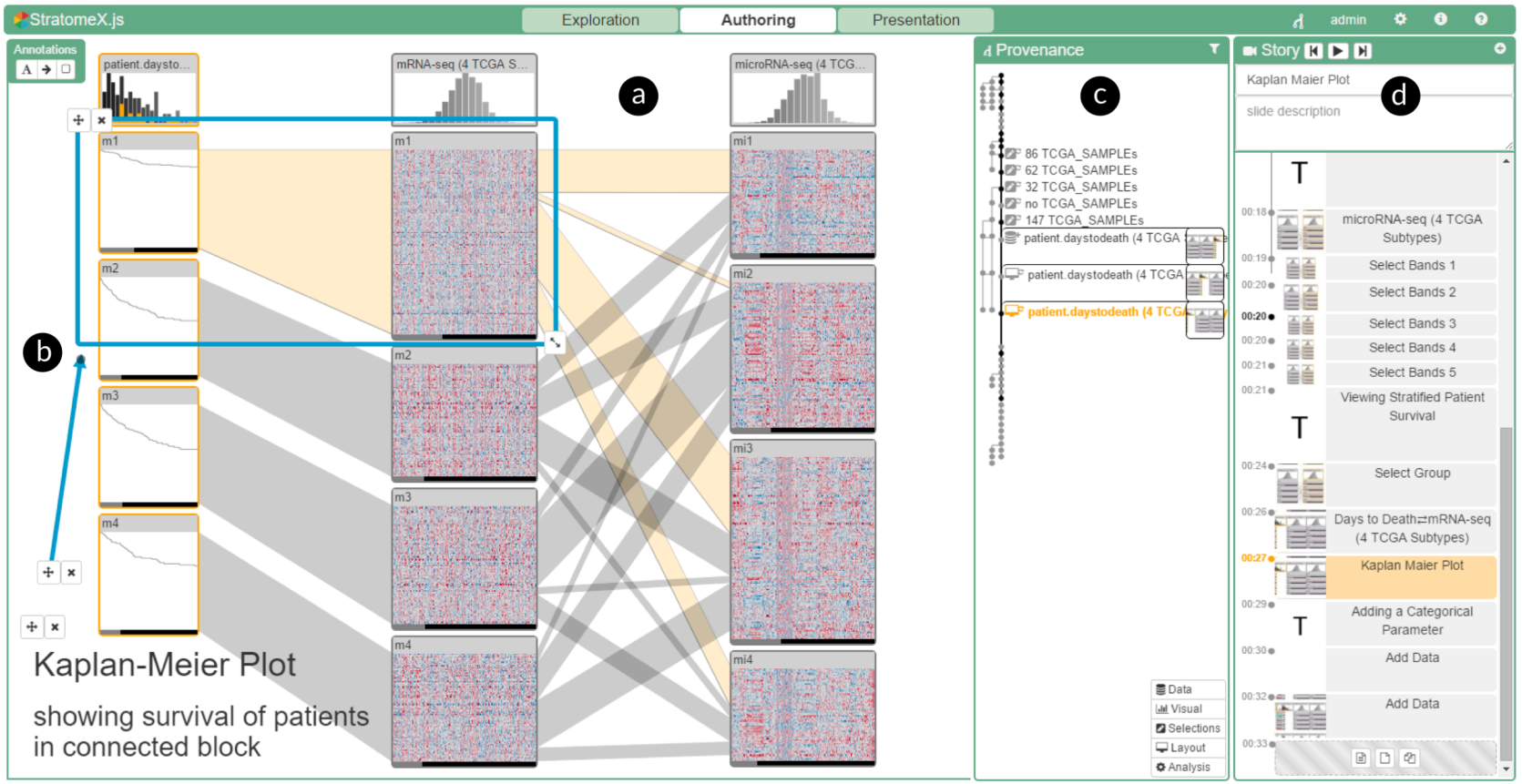
VisTrails


Notes:
In this workflow, we describe the density field induced by the particles in the cosmology in question. This density field is visualized by a volume rendering the field with an appropriate transfer function. Tones in red represent extremely low density regions whereas blue hues depict areas of high density.
Imposing error analysis methods here would greatly help validate the accuracy of the visualization.
VisTrails VCDAT
History Tree
Total Cloudiness 1979
Total Cloudiness 1980
Total Cloudiness 1981
Total Cloudiness 1982
open
__call__
quickplot
VisTrails Shell
VisTrails shell running Python 2.6.4 (r264:75821M, Oct 27 2009, 19:48:32)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin.
Type "copyright", "credits" or "license" for more information on Python.
>>> import vcs, cdms2
>>> cdat = load_package('CDAT')
>>> cdmsfile = cdms2.open('/home/emanuele/src/cdat_bin/sample_data/clt.nc')
>>> data = cdmsfile('clt')
>>> q = cdat.quickplot()
>>> q.dataset = data
>>> run()
Visualization Spreadsheet

Reproducibility in Computational Workflows



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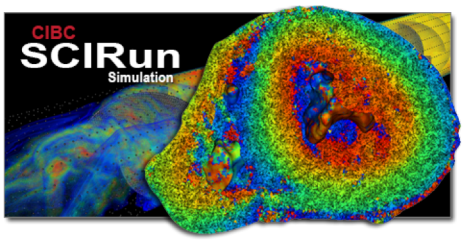
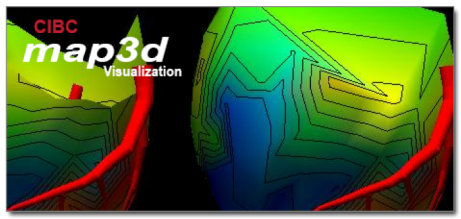
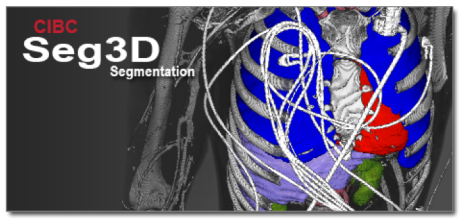
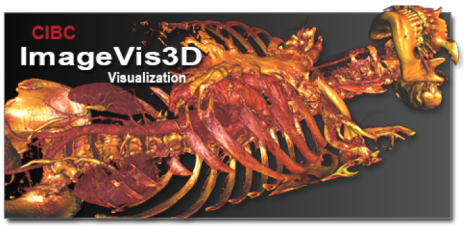
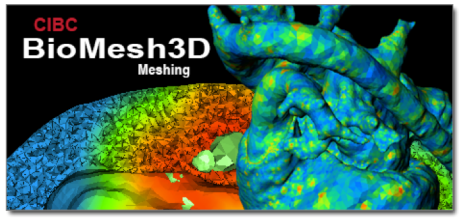
NIH Center Software

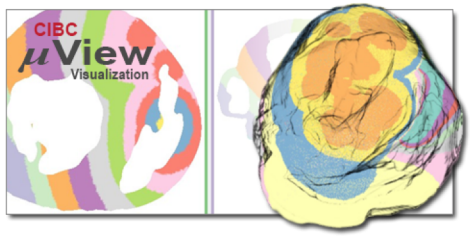












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Acknowledgments

NIH/NIGMS Center for Integrative Biomedical Computing

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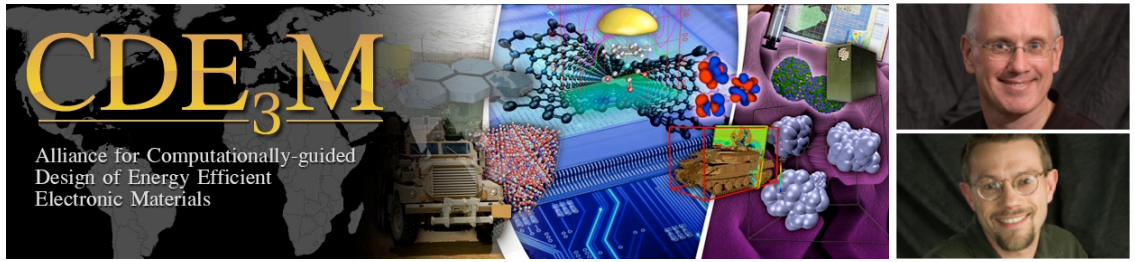
intel Graphics and Visualization Institute

Utah Center for Computational Earth Sciences
at the Scientific Computing and Imaging Institute

CDE$_3$M
Alliance for Computationally-guided Design of Energy Efficient Electronic Materials



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