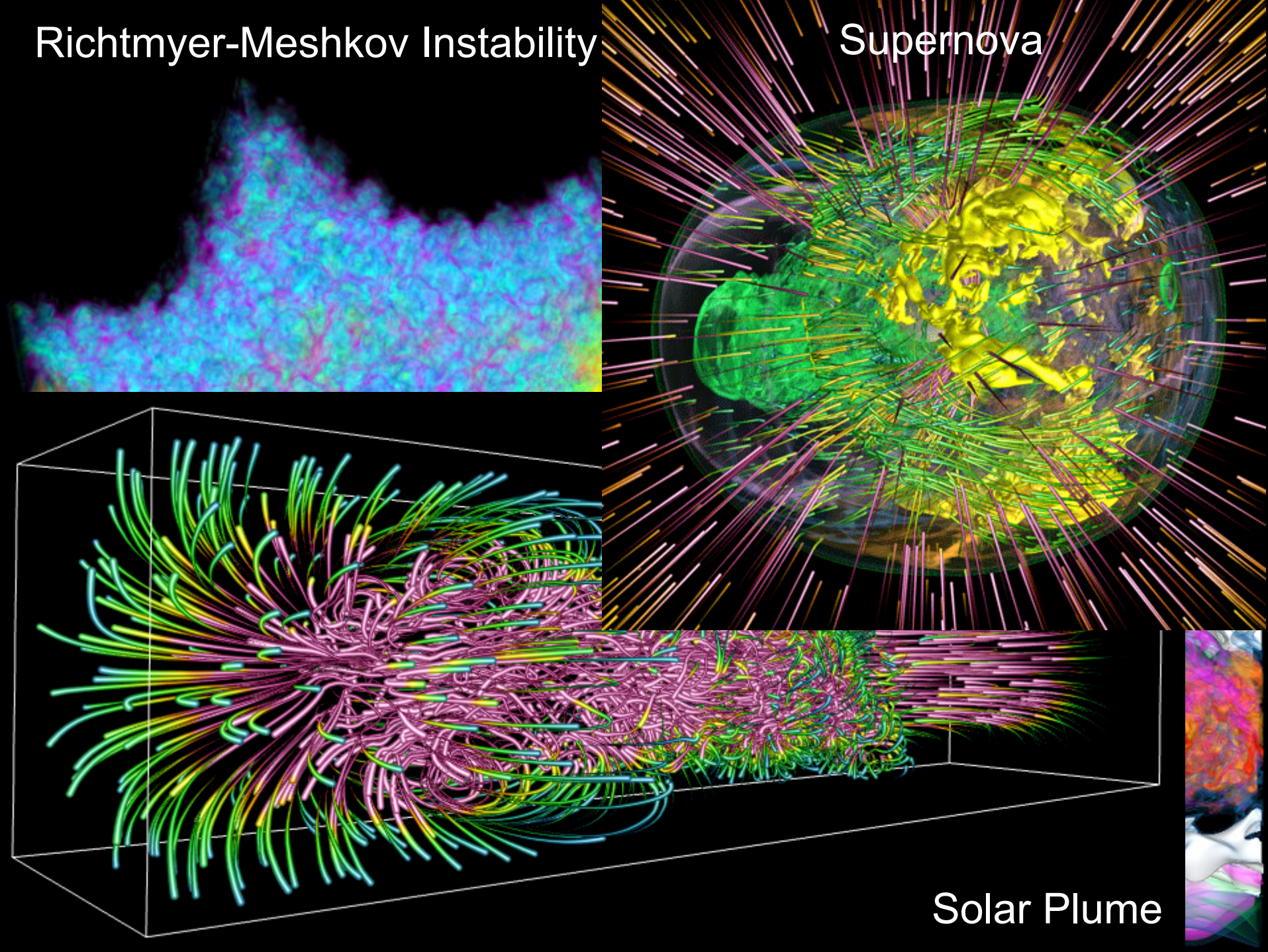
http://iusv.org/
http://vidi.cs.ucdavis.edu/

Enabling User Interfaces for Time-Varying Data Analysis and Visualization

Chaoli Wang

CScADS Summer Workshops
31 Jul 2008


Richtmyer-Meshkov Instability
Supernova
Solar Plume

Introduction

- Large-scale scientific simulation data
  - Spatial, temporal, and variable domains
  - Sizes of data increase dramatically
- New techniques to data analysis and visualization
  - Seeing previously unseen
  - Interactive visual exploration and analytics
  - Propel scientific discoveries

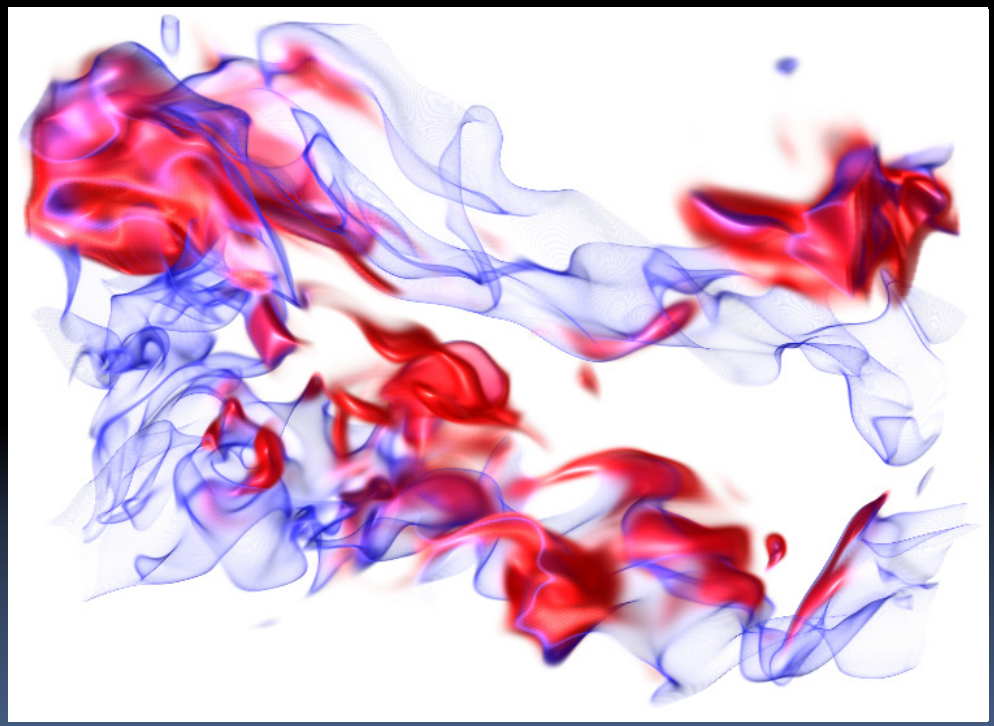
Outline

- A tri-space interface for time-varying, multivariate volume data visualization
- A system for exploring time-varying, multivariate fusion particle data
- Multiple views for uncertainty visualization of cosmological particle data

Tri-Space UI for TVMV Data Visualization

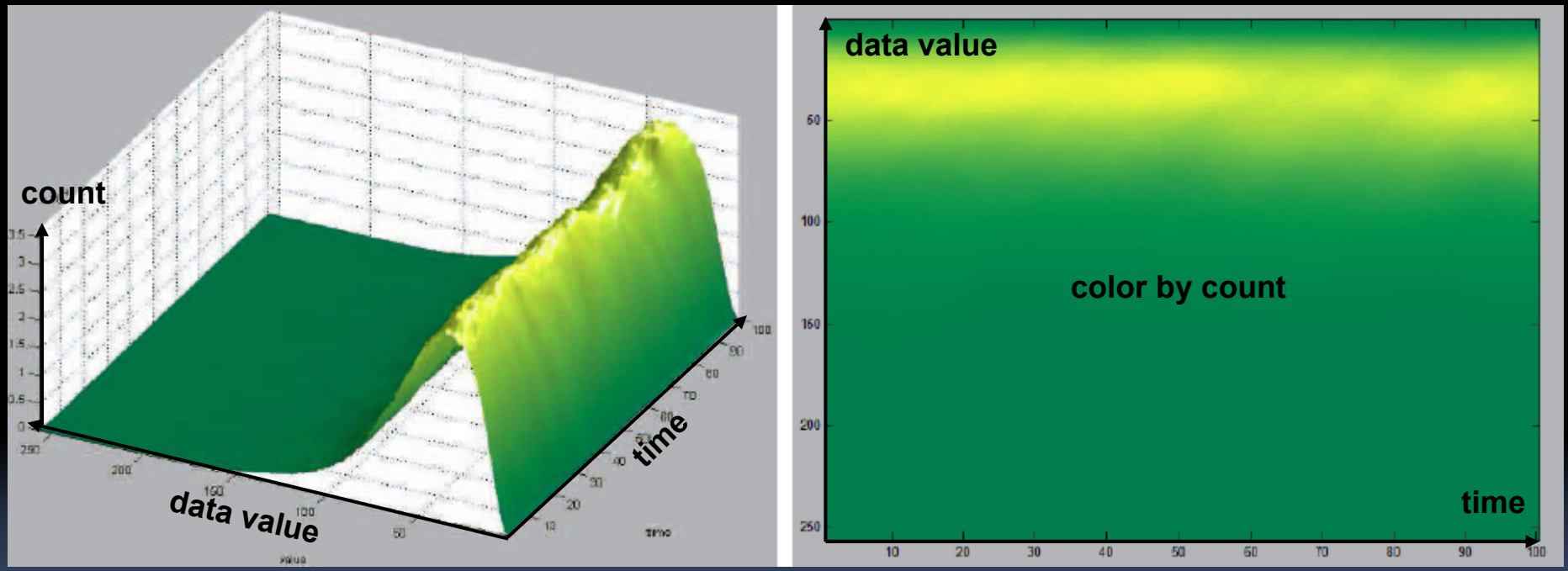
- A tri-space visual interface that allows the user to explore
  - Spatial, temporal, and variable domains
  - Spatial view – volume rendering
  - Temporal view – time histogram
  - Variable view – parallel coordinate
  - All views are linked together in the visual exploration

Spatial View



- Hardware-accelerated volume rendering
  - GPU raycasting
- Support multivariate data
  - Linearly blend opacity-weighted color

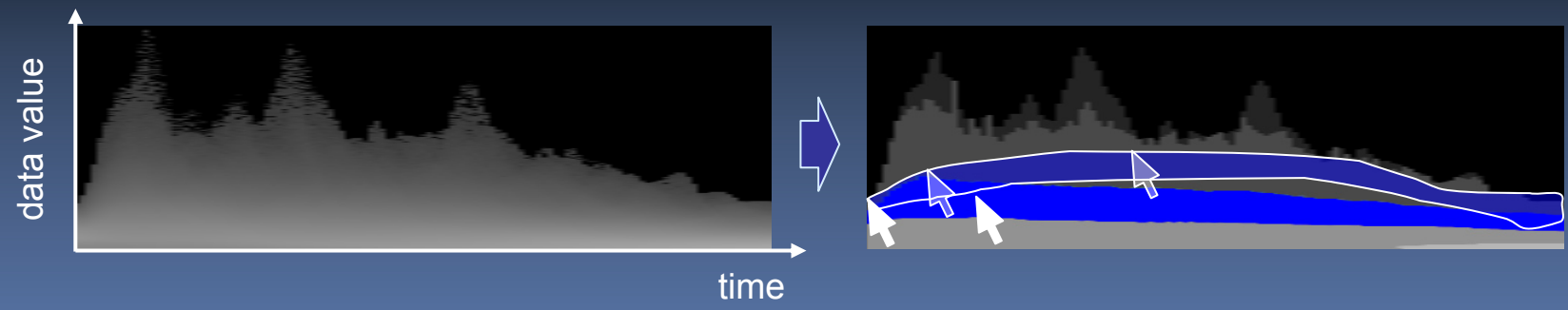
Temporal View – Time Histogram



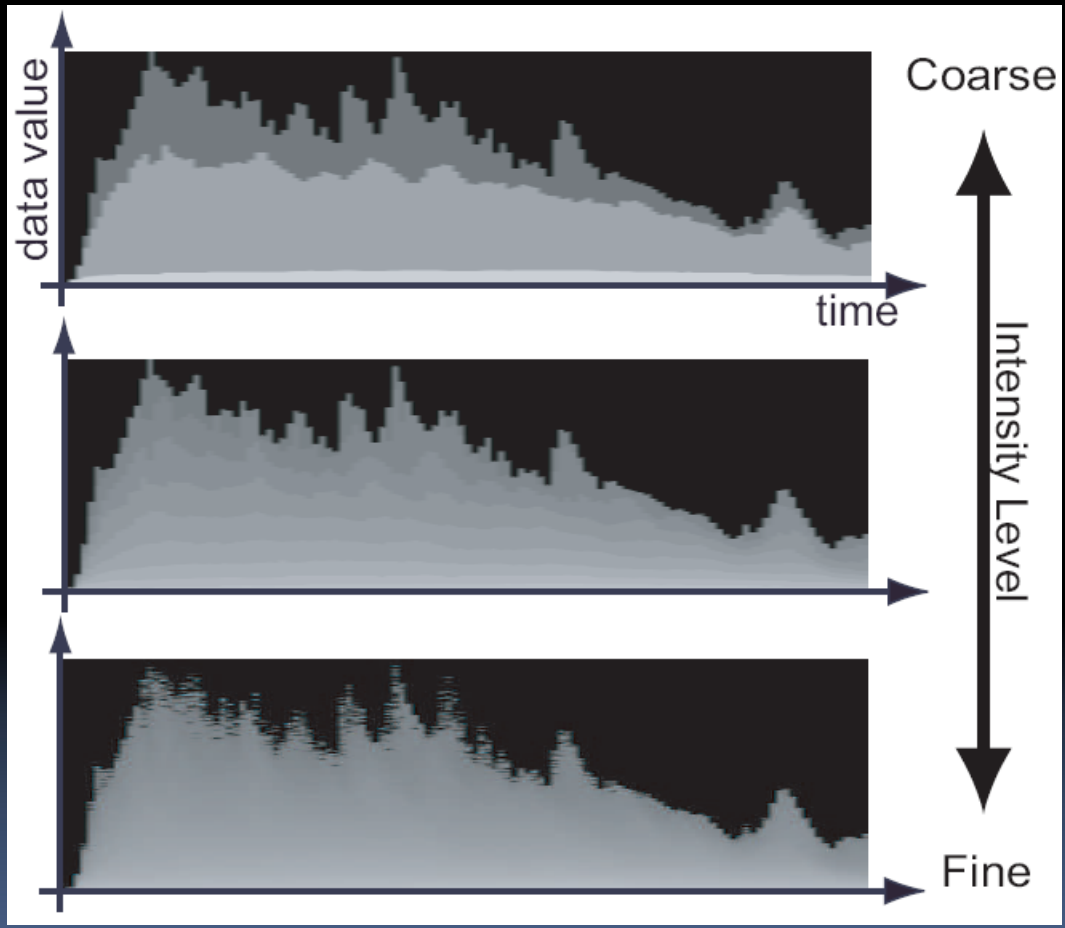
- Time histogram displayed as a 3D height field (left) or a 2D image (right)

Time Histogram for Classification

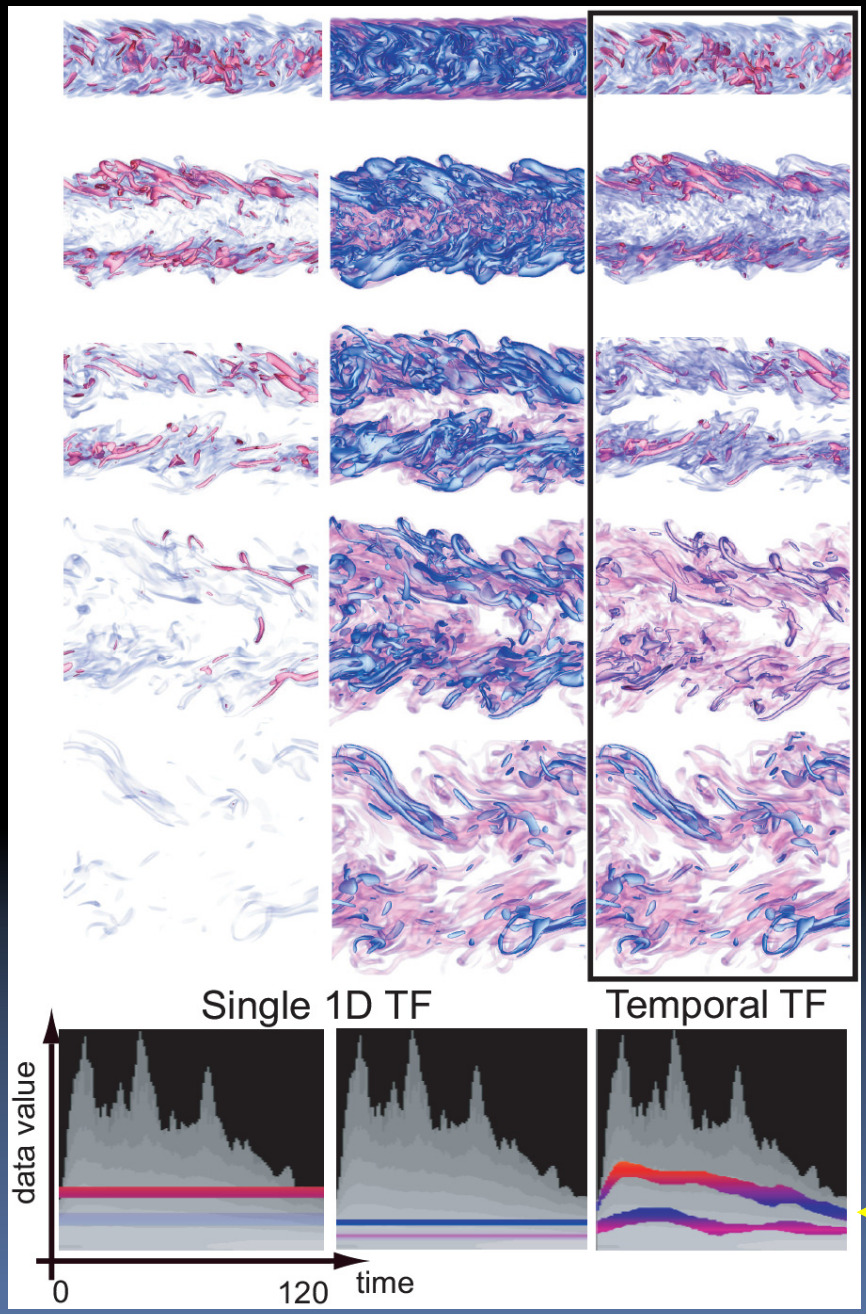
- Traditional trial-and-error approach
  - Time consuming and non-trivial
- Our method
  - Set mapping function from count to color
  - Quantize into the user-specified number of clusters
  - Specify transfer function by clicking one of the clusters or manually drawing a region



Time Histogram for Classification



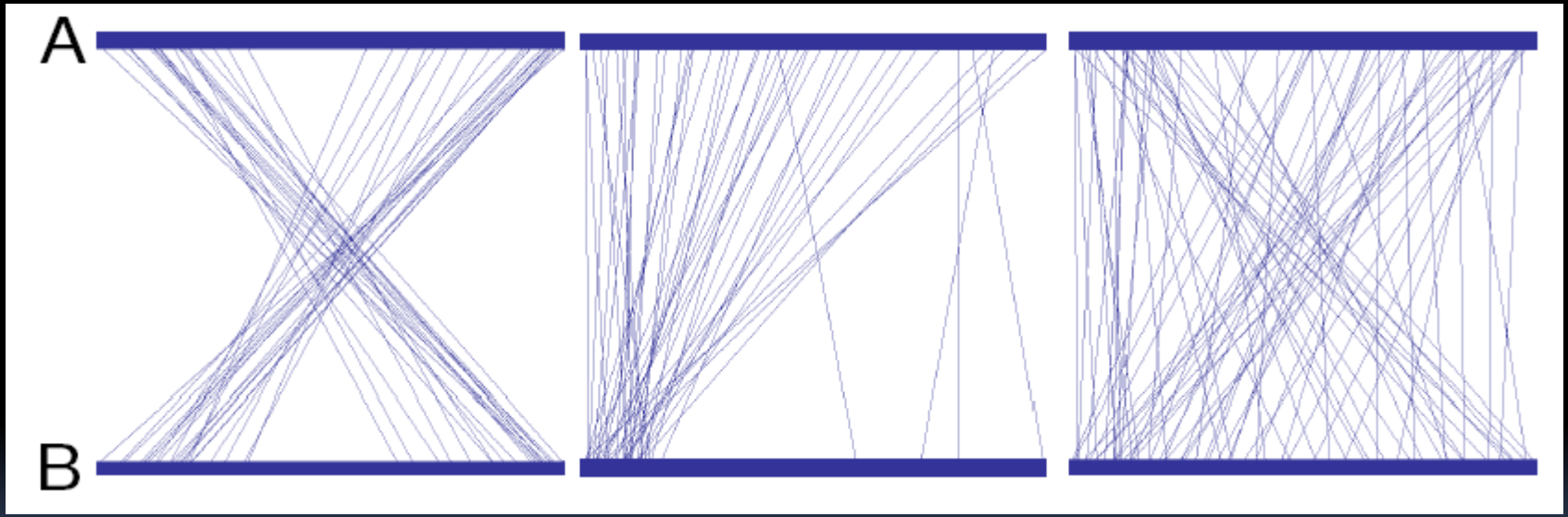
- Coarse to fine classification through adjusting histogram display mapping and the granularity of quantization



- Classification of the vorticity magnitude, time-histogram classification is able to show the vorticity structures from all time steps

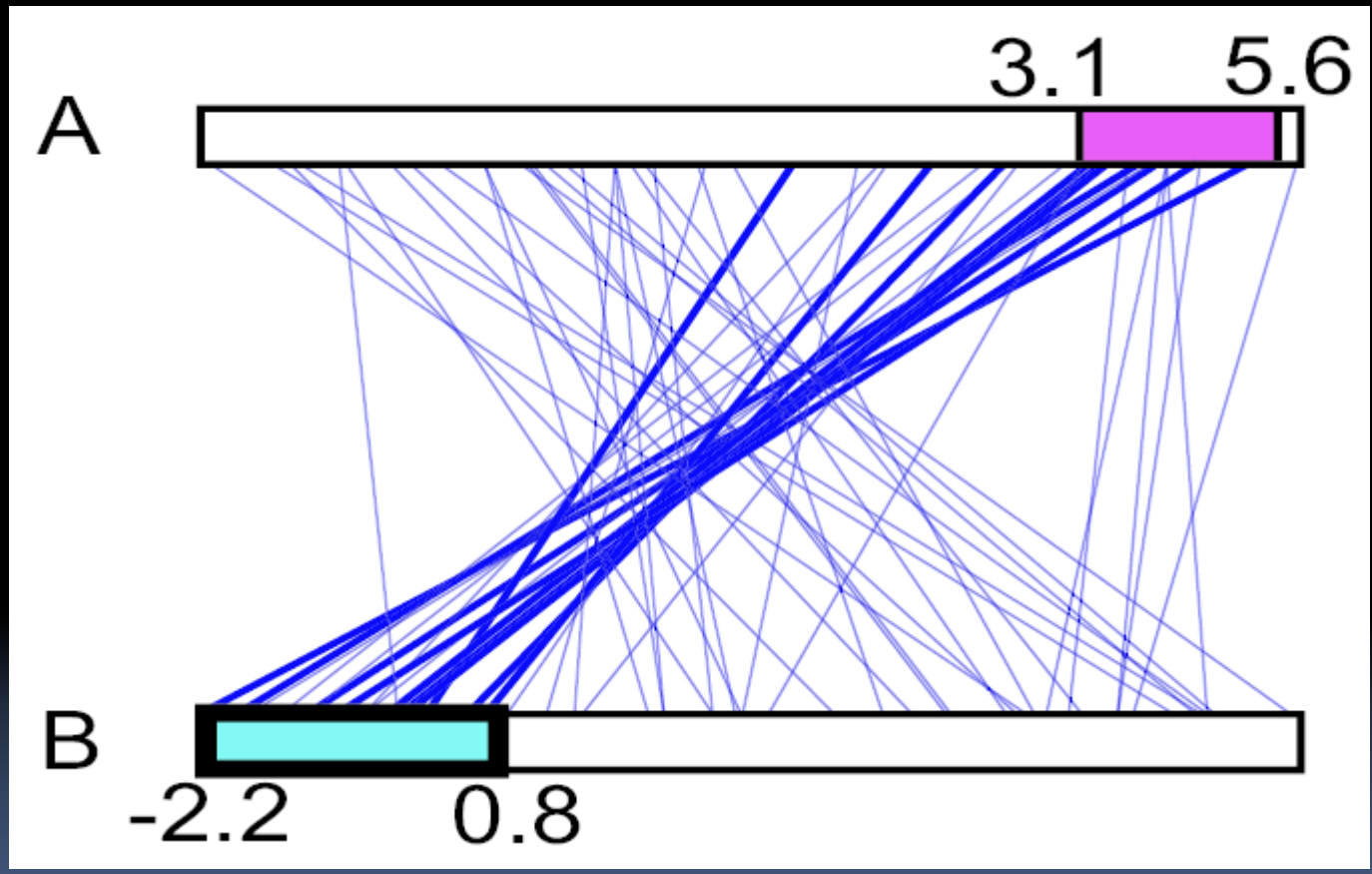
static color assignment

Variable View



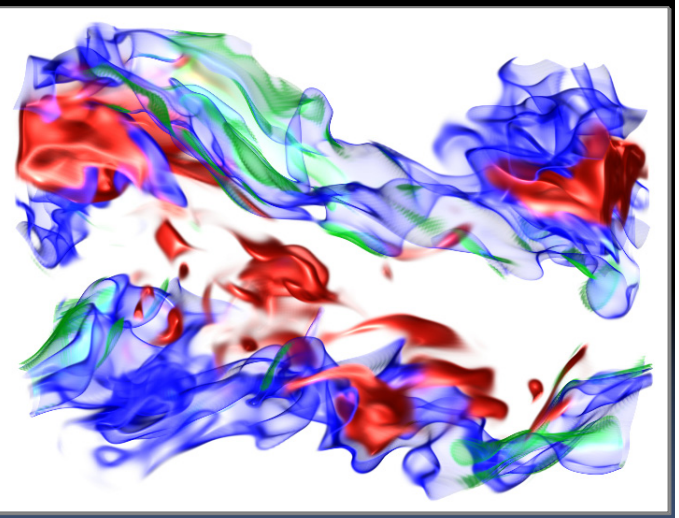
- Parallel coordinate showing variables A and B with negative correlation (left); strong correlation of A and lower values of B (middle); no obvious correlation (right)

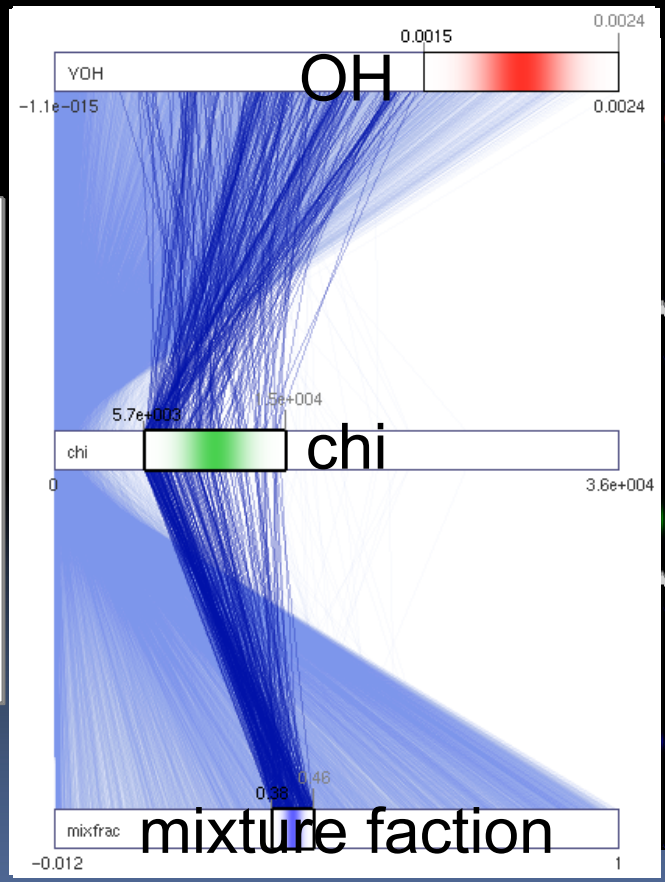
Variable View – Brushing

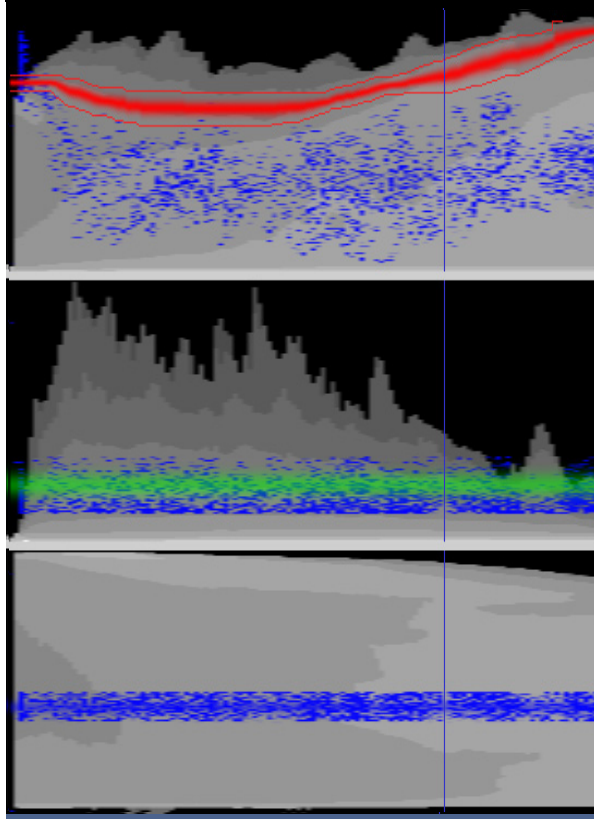


- Transfer function widgets on the parallel coordinate

Examples




0.0024
0.0015
VOH
OH
-1.1e-015
0.0024
5.7e+003
chi
0
3.6e+004
0.38
0.46
mixfrac
mixture faction
-0.012
1

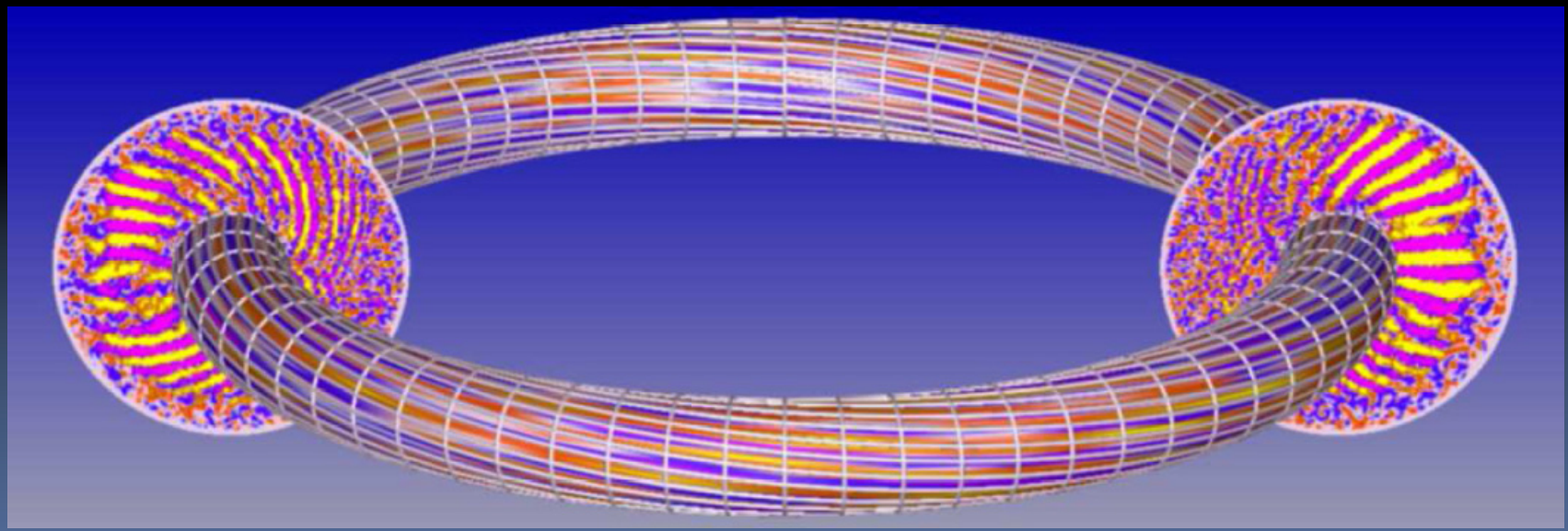


Outline

- A tri-space interface for time-varying, multivariate volume data visualization
- A system for exploring time-varying, multivariate fusion particle data
- Multiple views for uncertainty visualization of cosmological particle data

Gyrokinetic Particle Simulations

- Study anomalous energy transport associated with plasma microturbulence
  - Use the torus for plasma confinement
  - Up to 1 billion particles
  - Time-varying, multivariate particle data

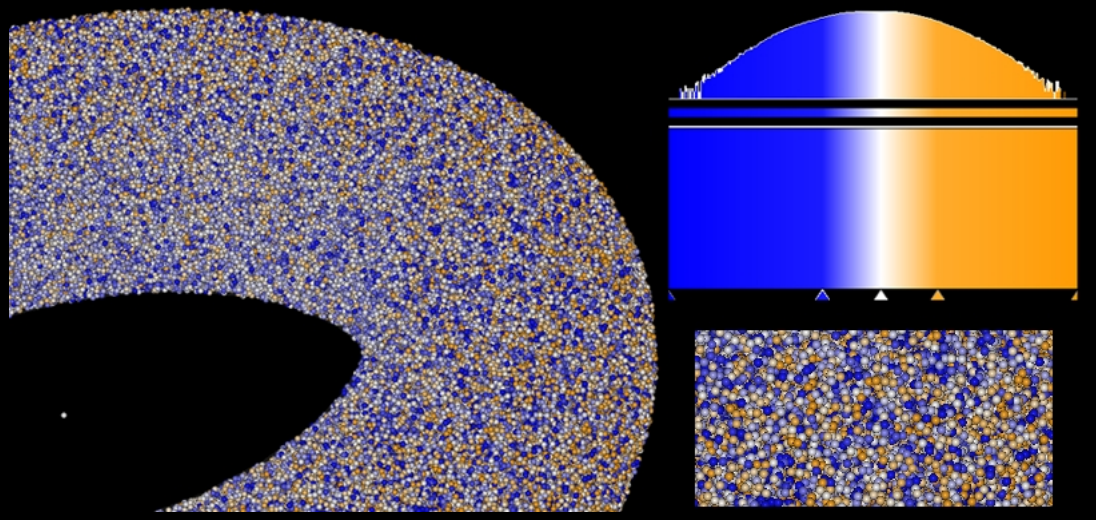


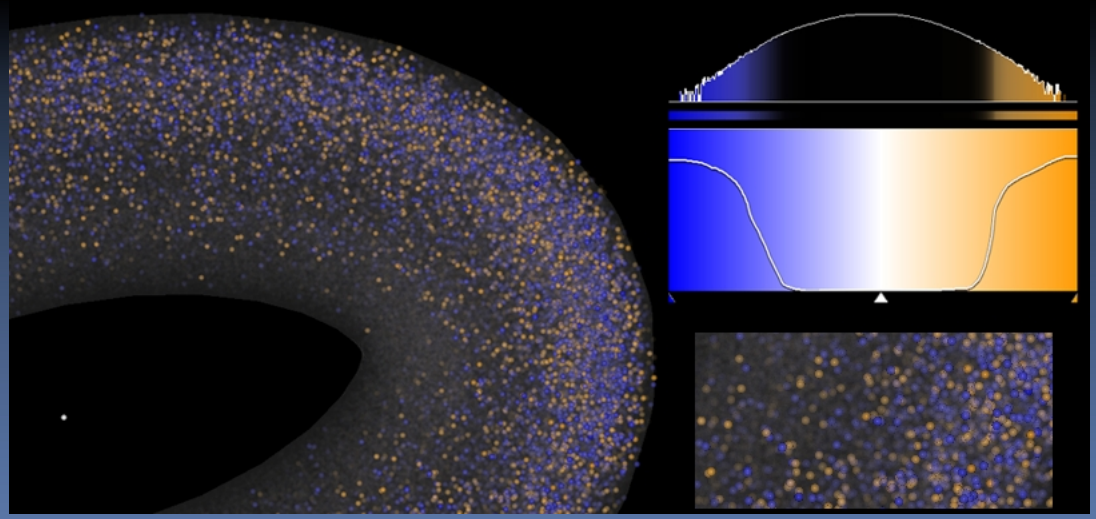
Tokamak – a machine producing a toroidal magnetic field for confining a plasma

Integrated Approach for Visualizing Fusion Data

- Variable view
  - Show relationships and trends among variables
  - Provide the interface for data selection
- Physical view
  - Show spatial representation of the data
  - Display particle visualization results
    - Particle rendering
    - Pathline rendering
- Both views are linked together

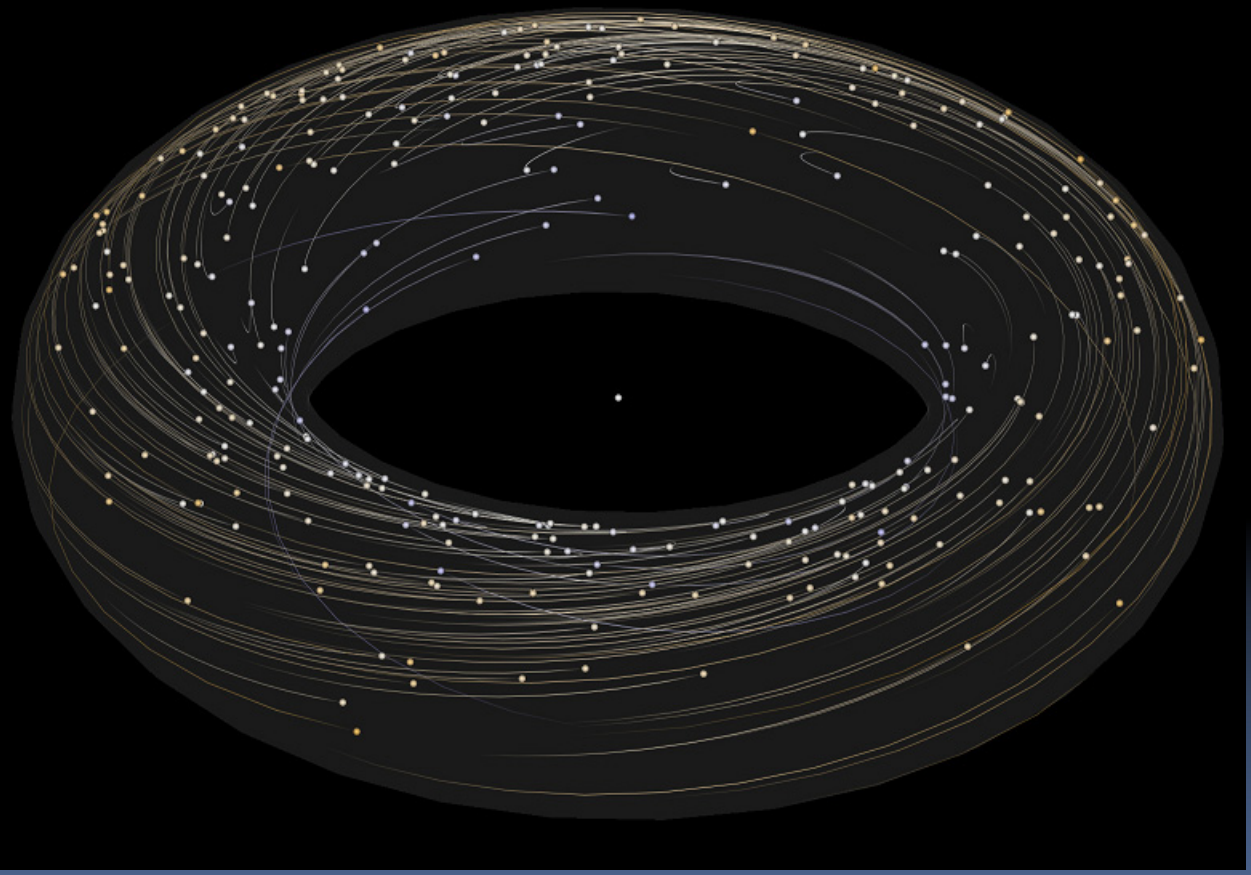
Particle Rendering





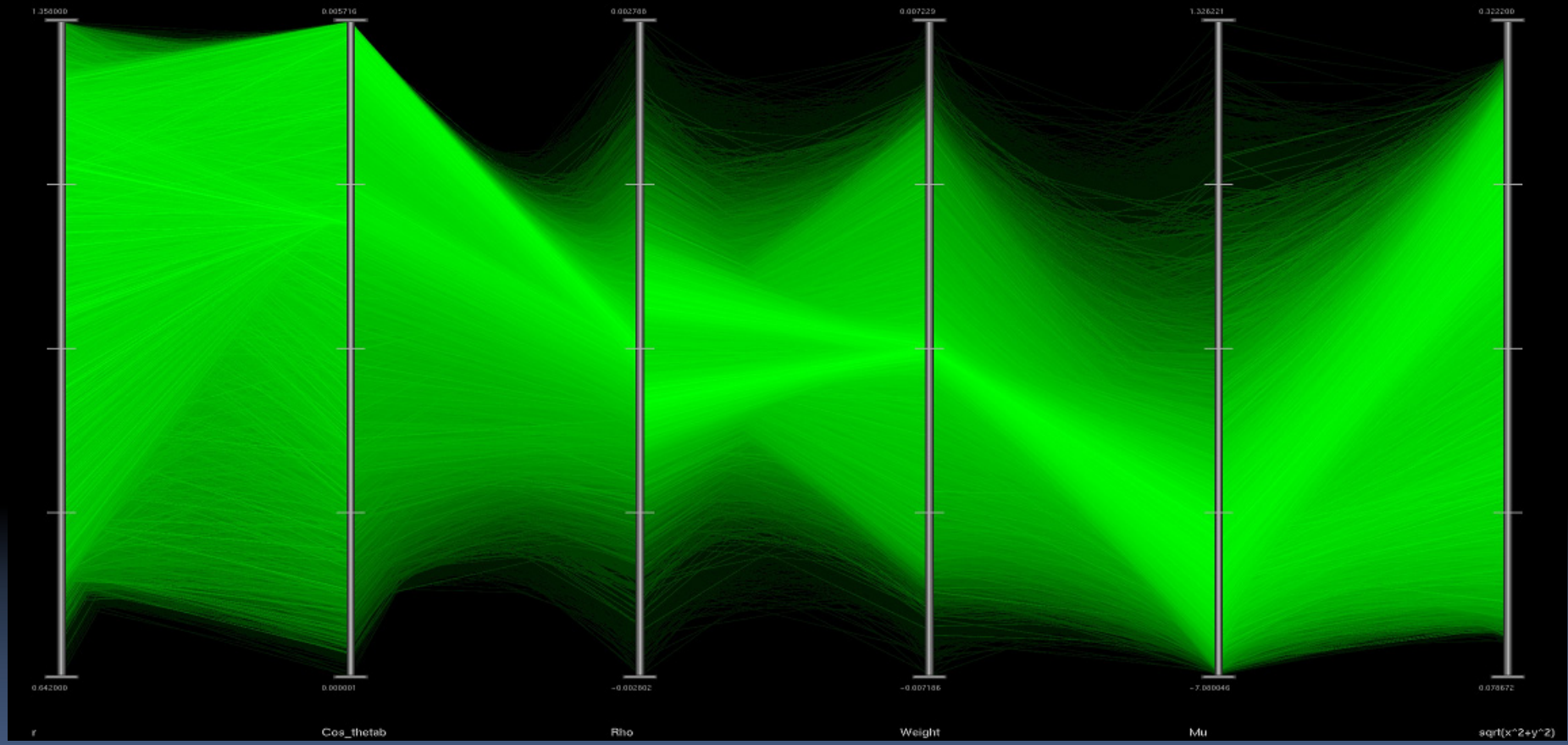
- Particles – GPU shaded 3D spherical glyphs
- Color and opacity – mapped from a selected variable
  - Parallel velocity
    - Blue (negative)
    - White (zero)
    - Orange (positive)

Pathline Rendering



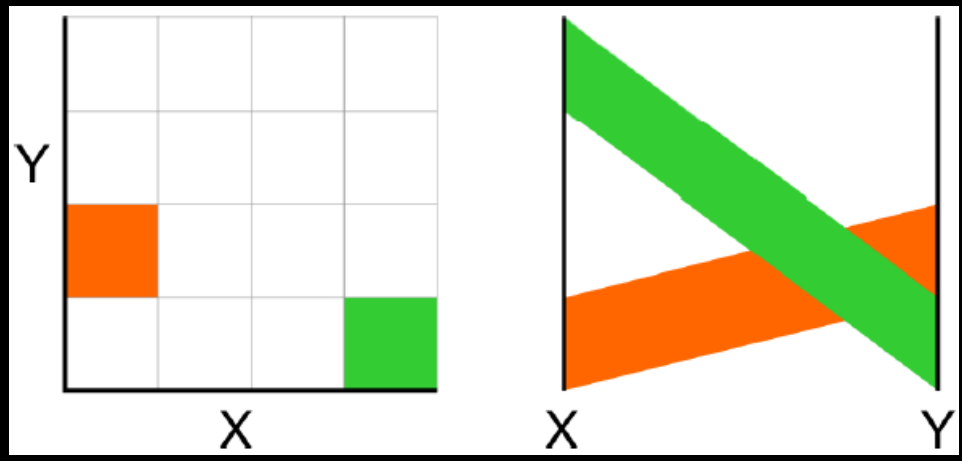
- Pathlines – illuminated, colored lines
  - Time-dependent changes of value and location
  - Color at each location used the same scalar mapping from the transfer function

Parallel Coordinate



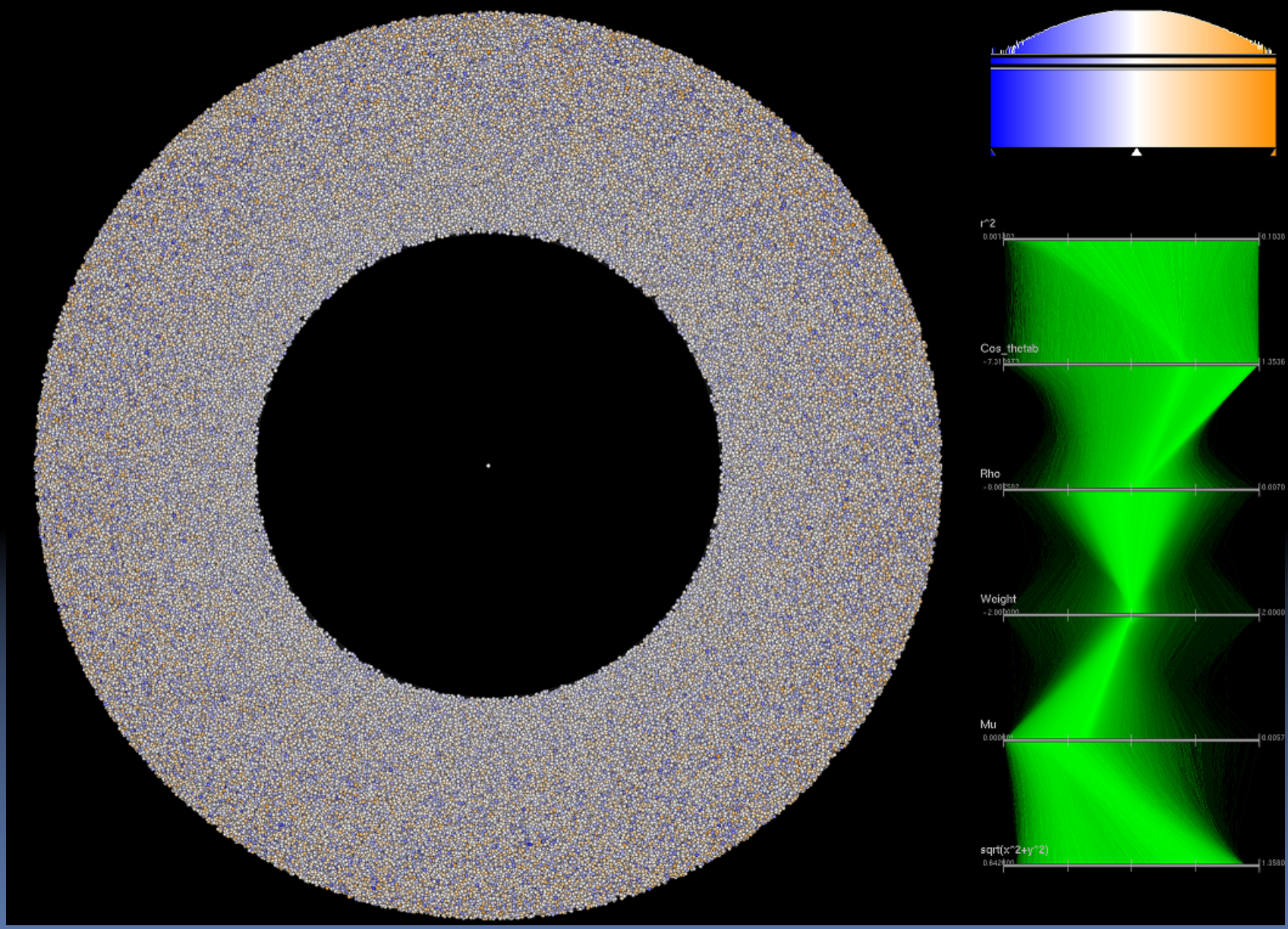
- Shows relationships between multiple variables
- Serves as an interface for particle selection

Over Saturation – Bin Map

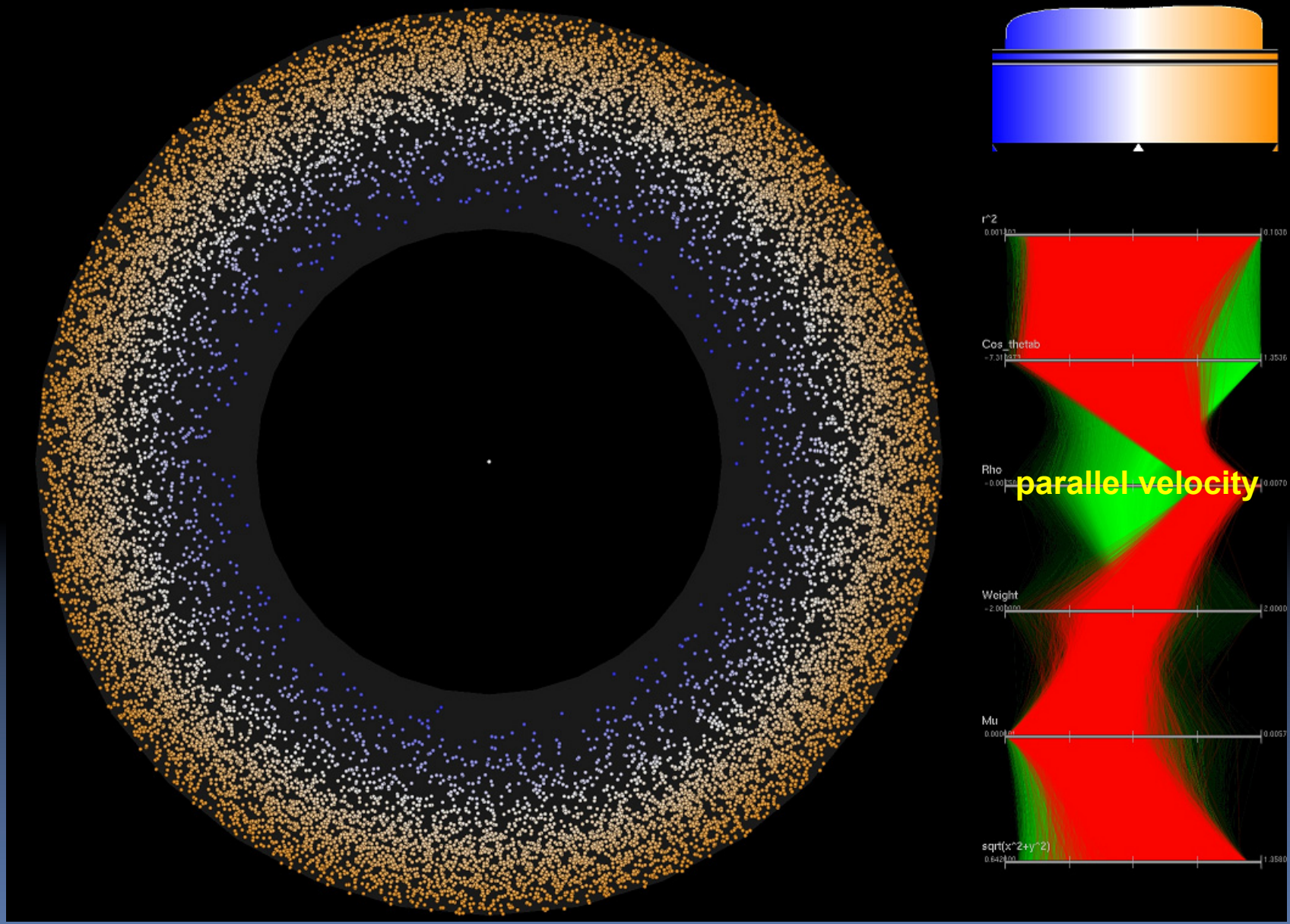


- Created for every pair of axes on the parallel coordinate
- A 2D histogram recording the frequency of lines between locations
- Render a global overview of the data
  - More contextual information
  - Independent of the size of data
  - W/O heavy memory demand

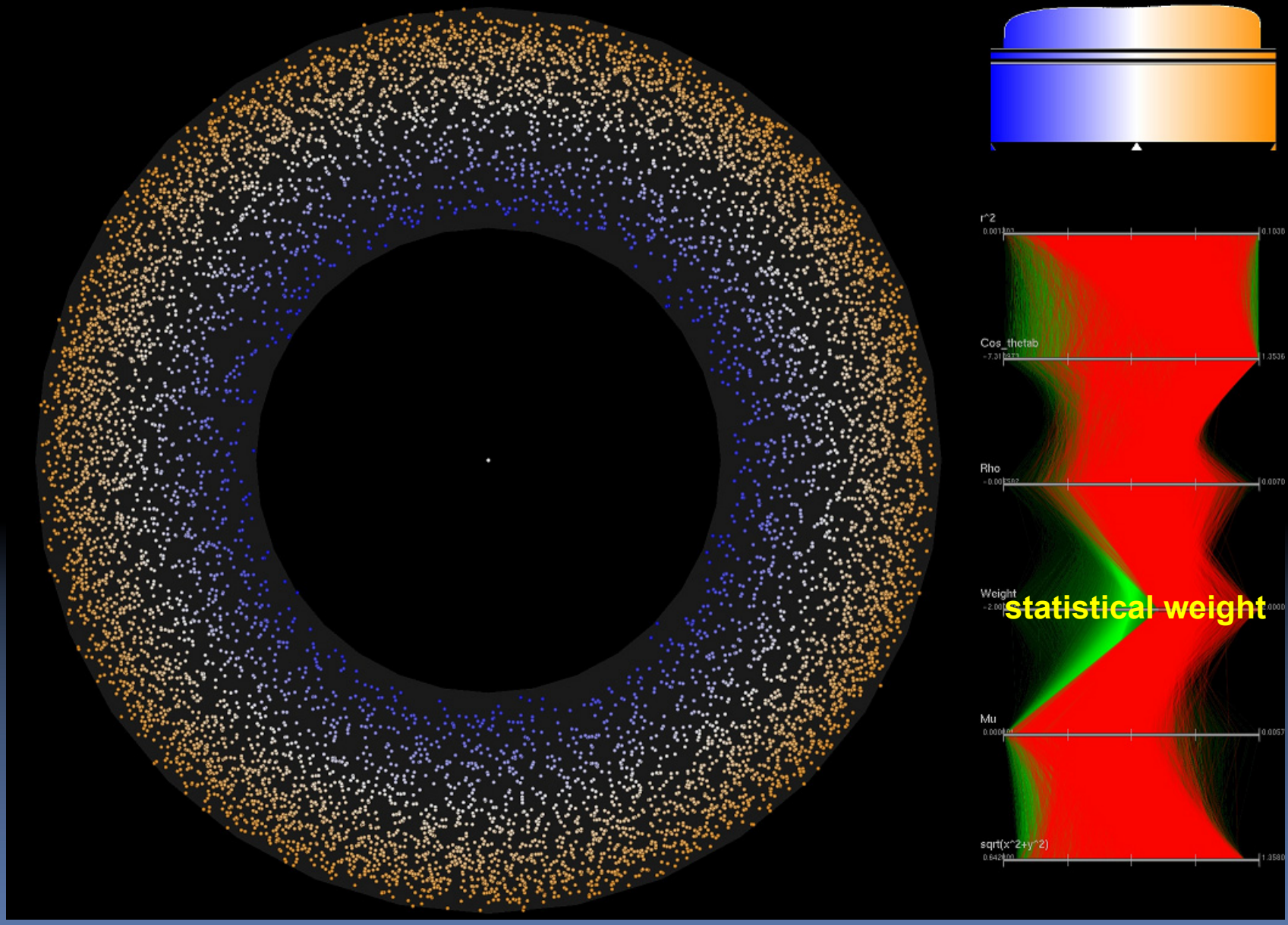
Particle Selection – 1M Particles



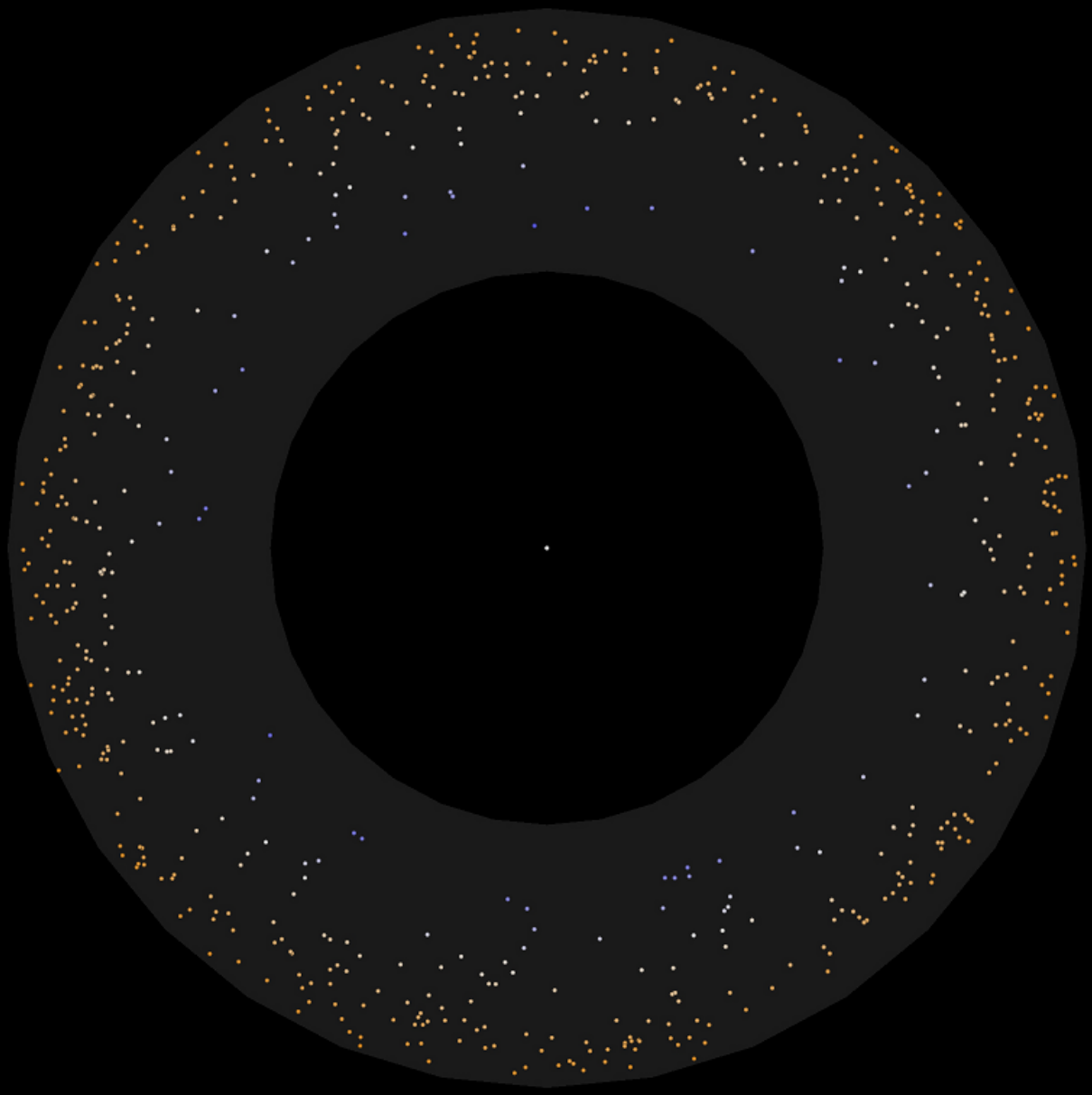
Particle Selection – High Positive Velocity

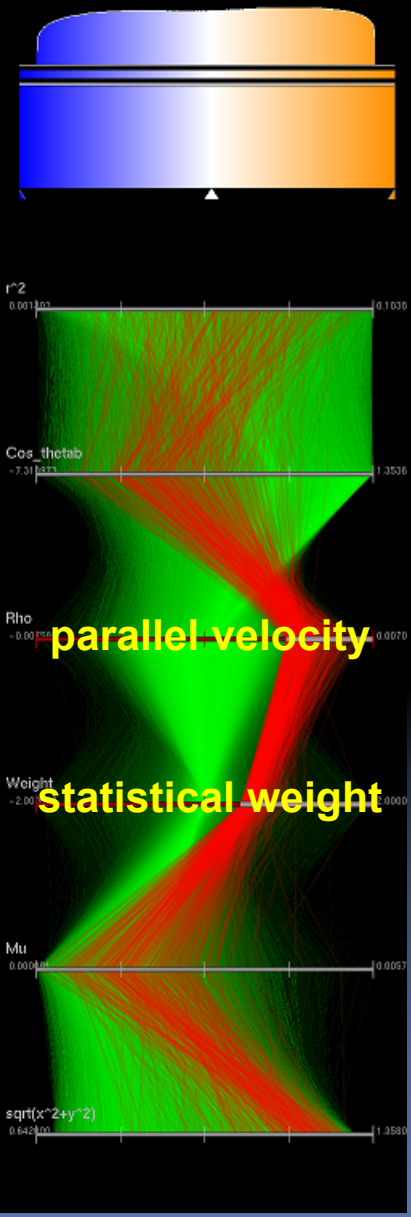


Particle Selection – High Positive Weight



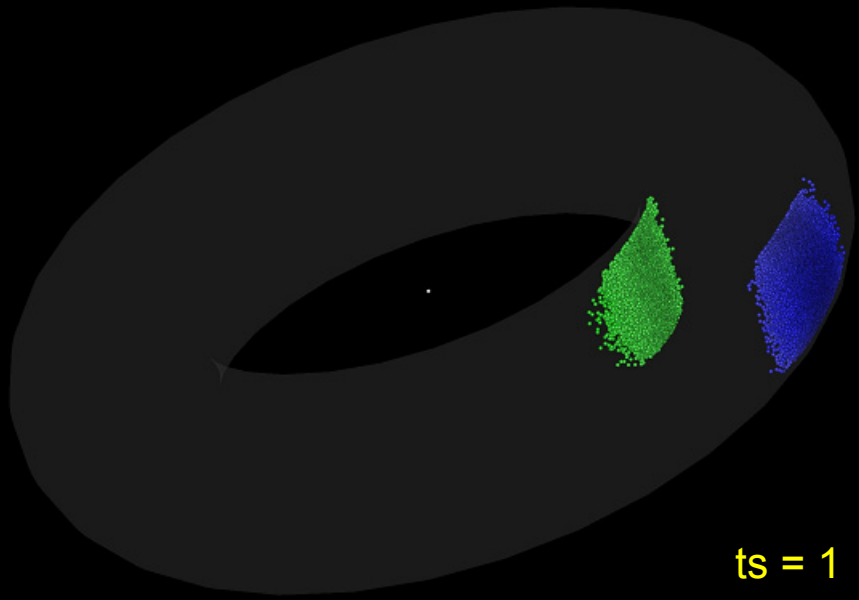
Particle Selection



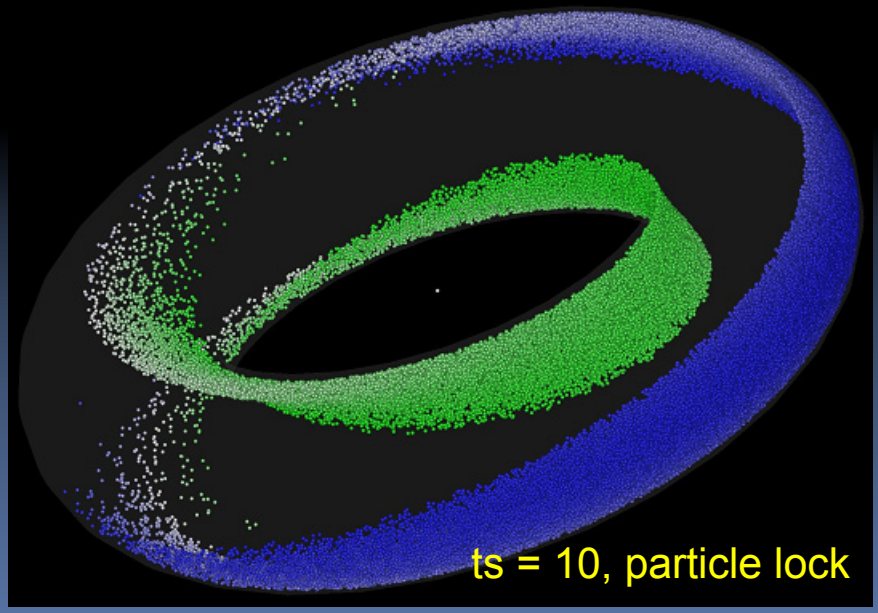


Selection Locking

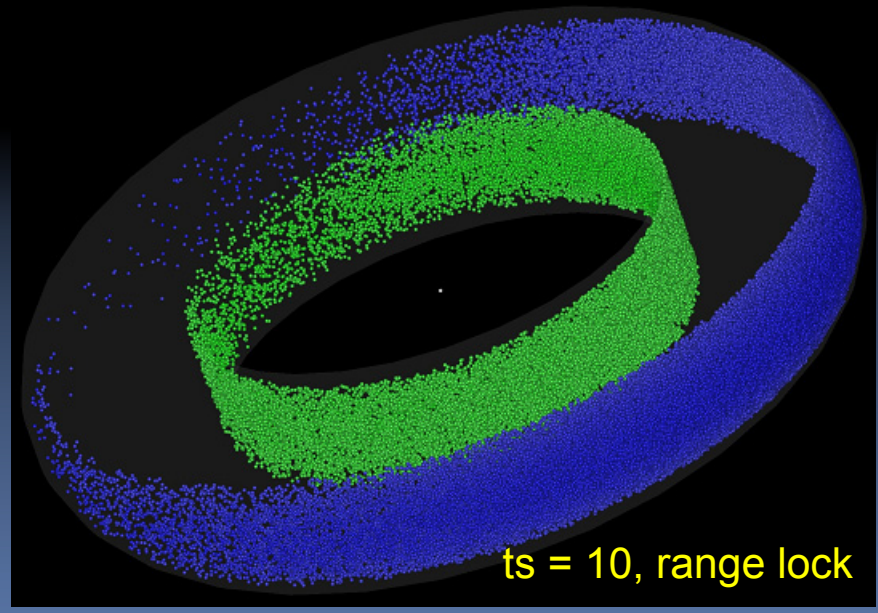
- Particle lock
  - Particles selected at a time step are kept as focus over other time steps
- Range lock
  - Ranges of data values selected are a time step are enforced over other time steps



ts = 1



ts = 10, particle lock

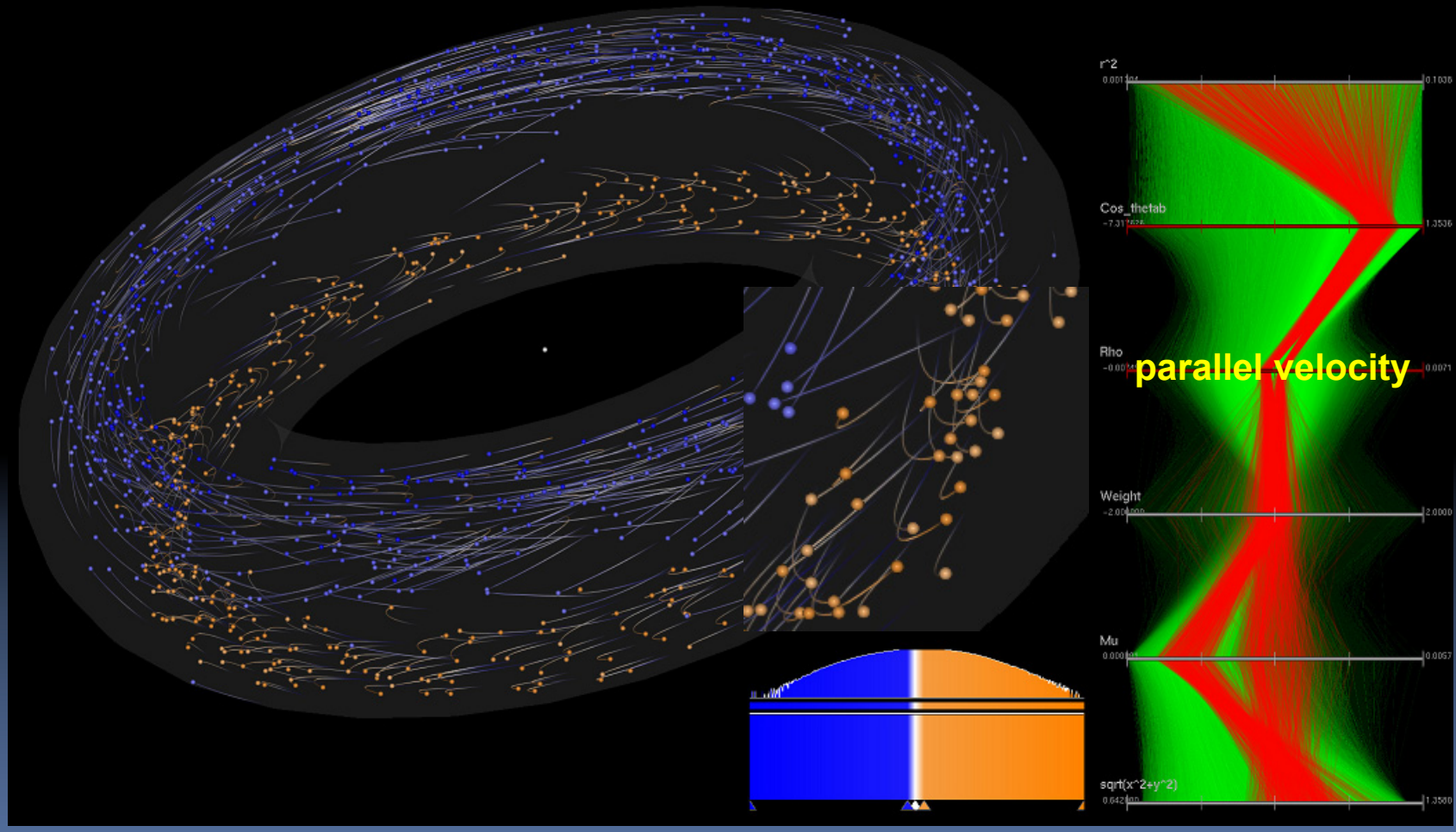


ts = 10, range lock

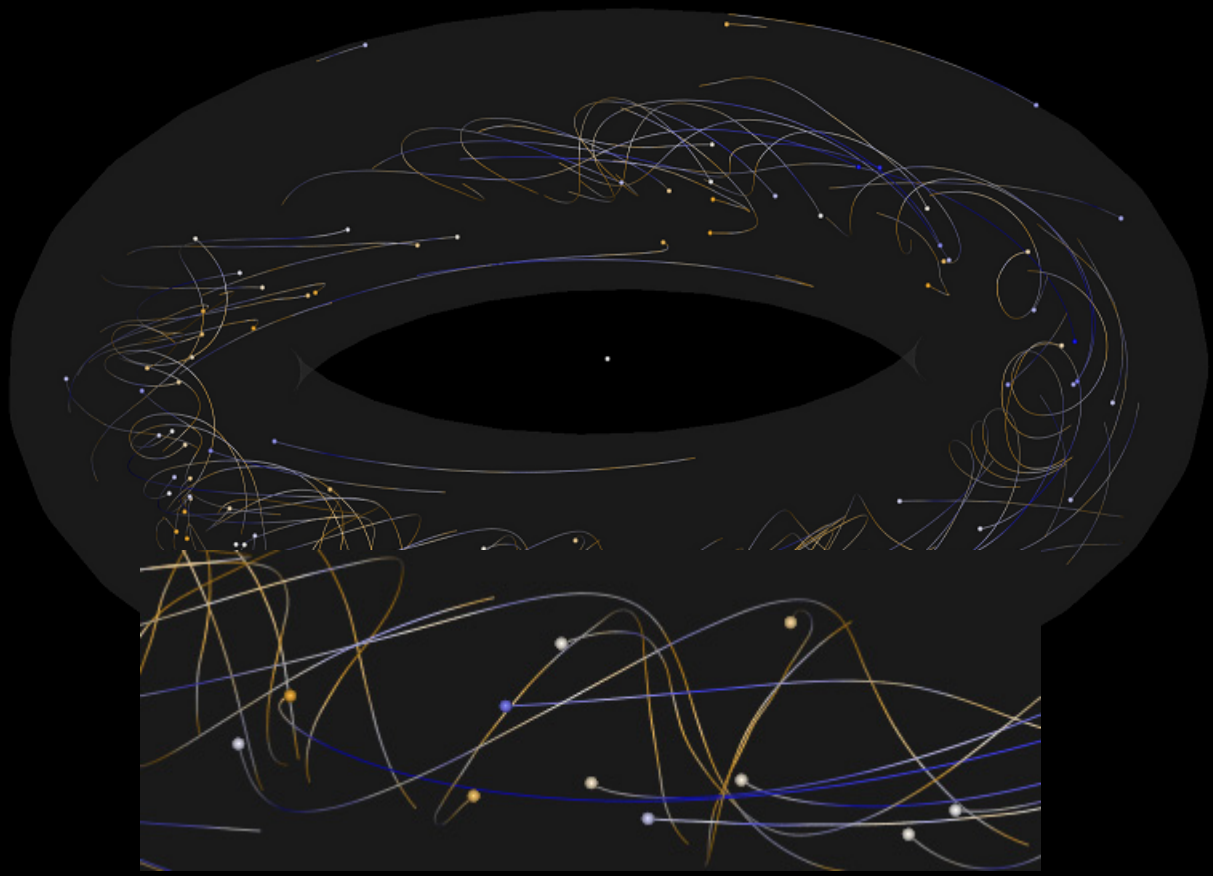
Trapped Particles

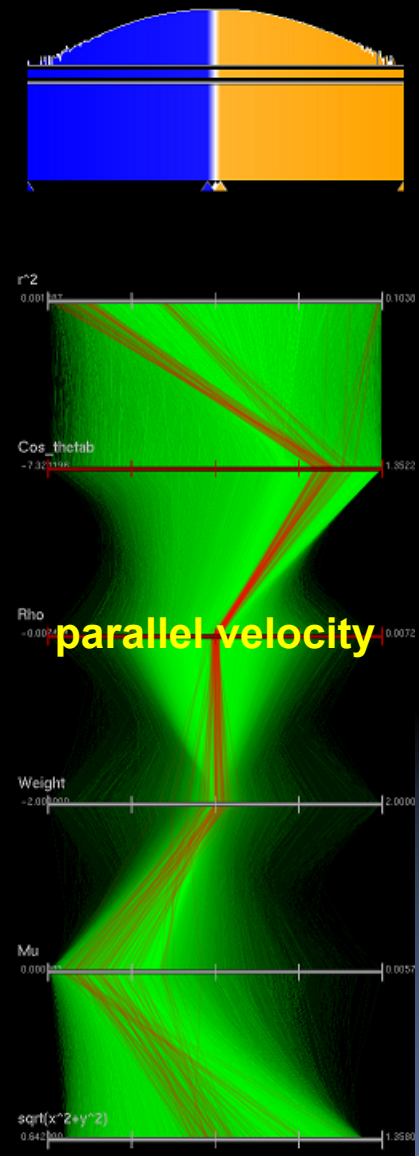
- Particles trapped due to turbulent flow
  - Turn around and change directions
  - Parallel velocity changes sign
- Have a much greater impact on transport than passing particles
- Isolate trapped particles using the parallel coordinate and trace their paths

Trapped Particles



Trapped Particles

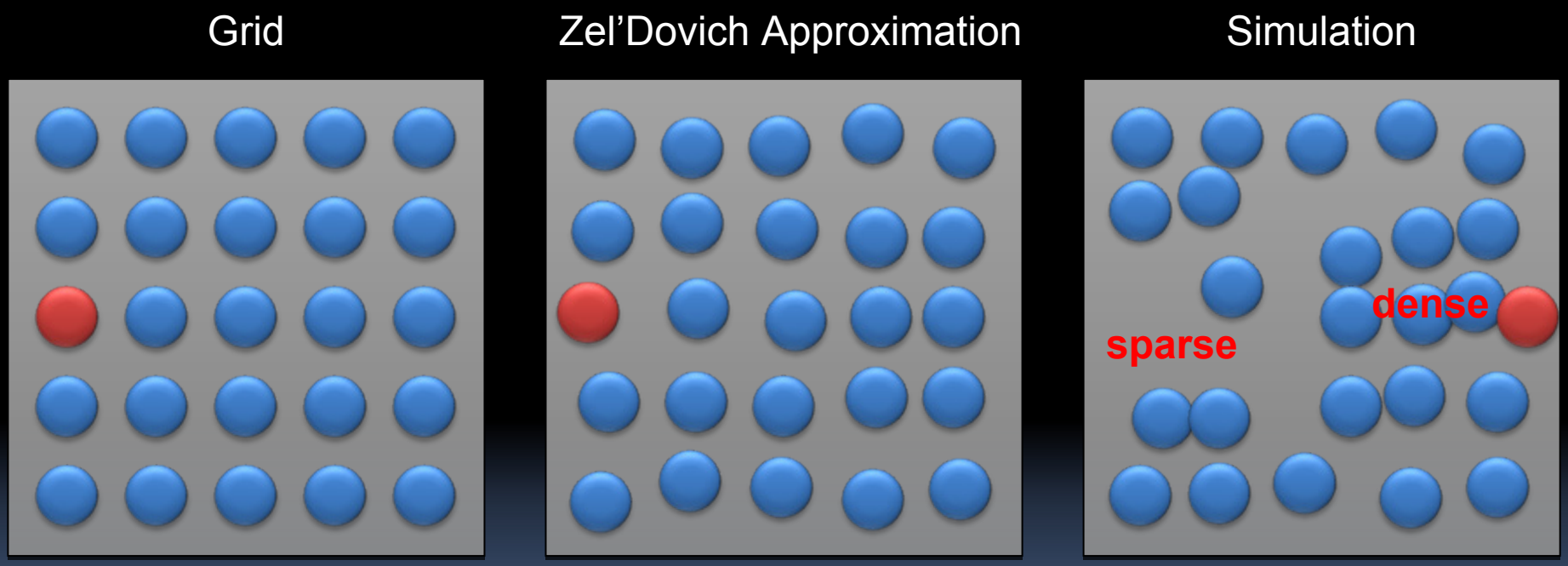




Outline

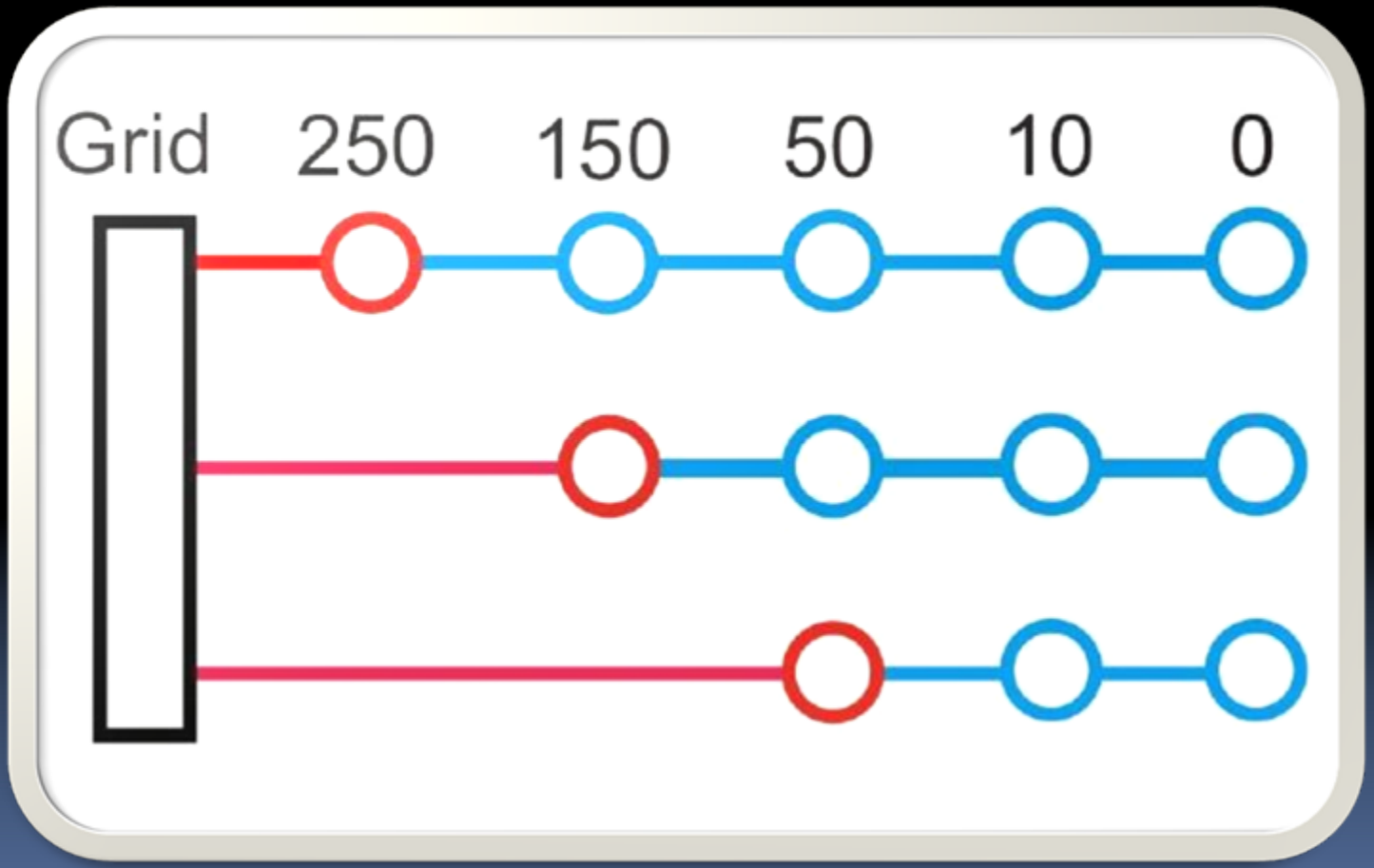
- A tri-space interface for time-varying, multivariate volume data visualization
- A system for exploring time-varying, multivariate fusion particle data
- Multiple views for uncertainty visualization of cosmological particle data

Cosmological Simulation



Time-varying, multivariate cosmological particle data

Zel'Dovich Approximations



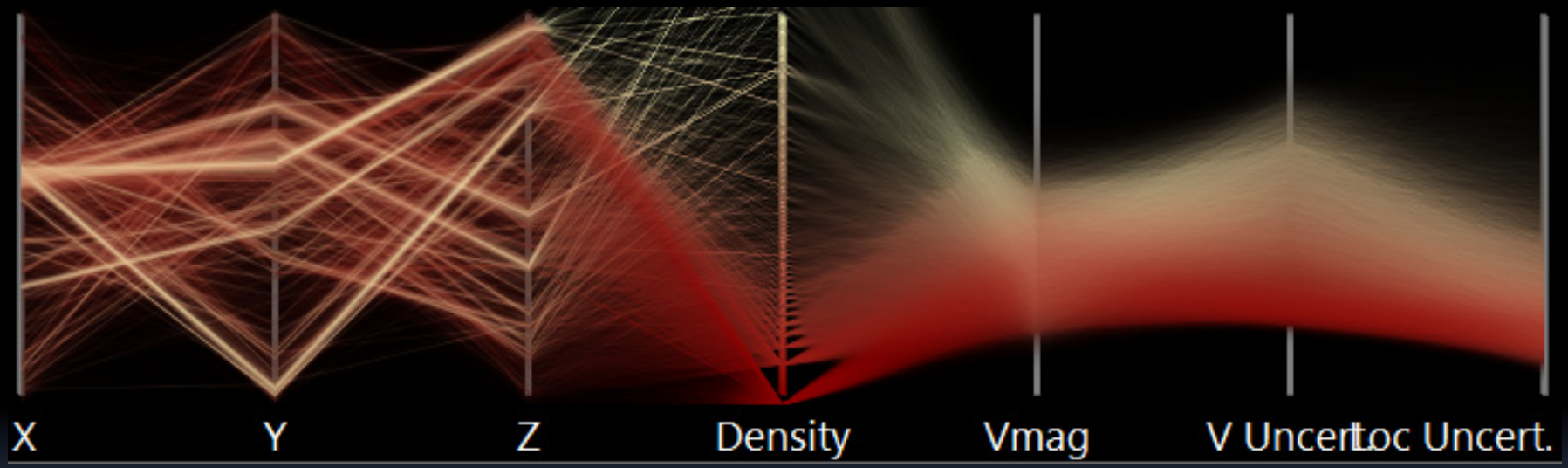
Cosmological Simulation

- Source of uncertainty
  - Different simulation codes used to compute inter-particle forces
    - Hierarchical sampling of the system phase space distribution function
    - Simplify by distance
- Variables
  - Positional dimensions
  - Velocity components and magnitude
  - Positional and velocity uncertainty

Visualization Consideration

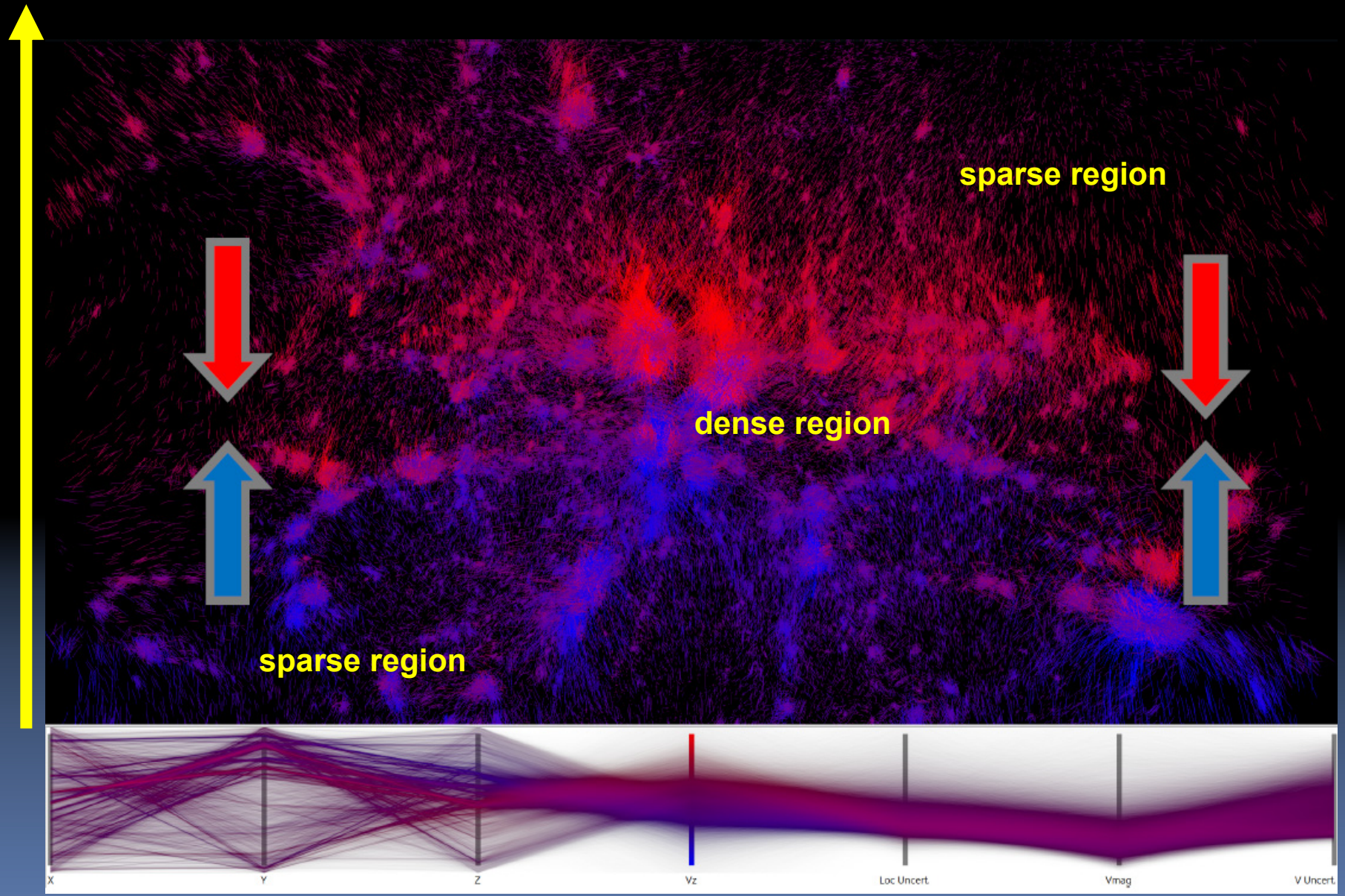
- Particle clusters
  - Highly dense region – cluster
  - Highly sparse region – void
  - Filament
- Different simulations have the same general structure but varying locations and densities
- Extremely close proximity in dense clusters
  - Voxelizing is not desirable
  - Render particle as line segment
    - Center – particle location
    - Length – particle velocity

Parallel Coordinate

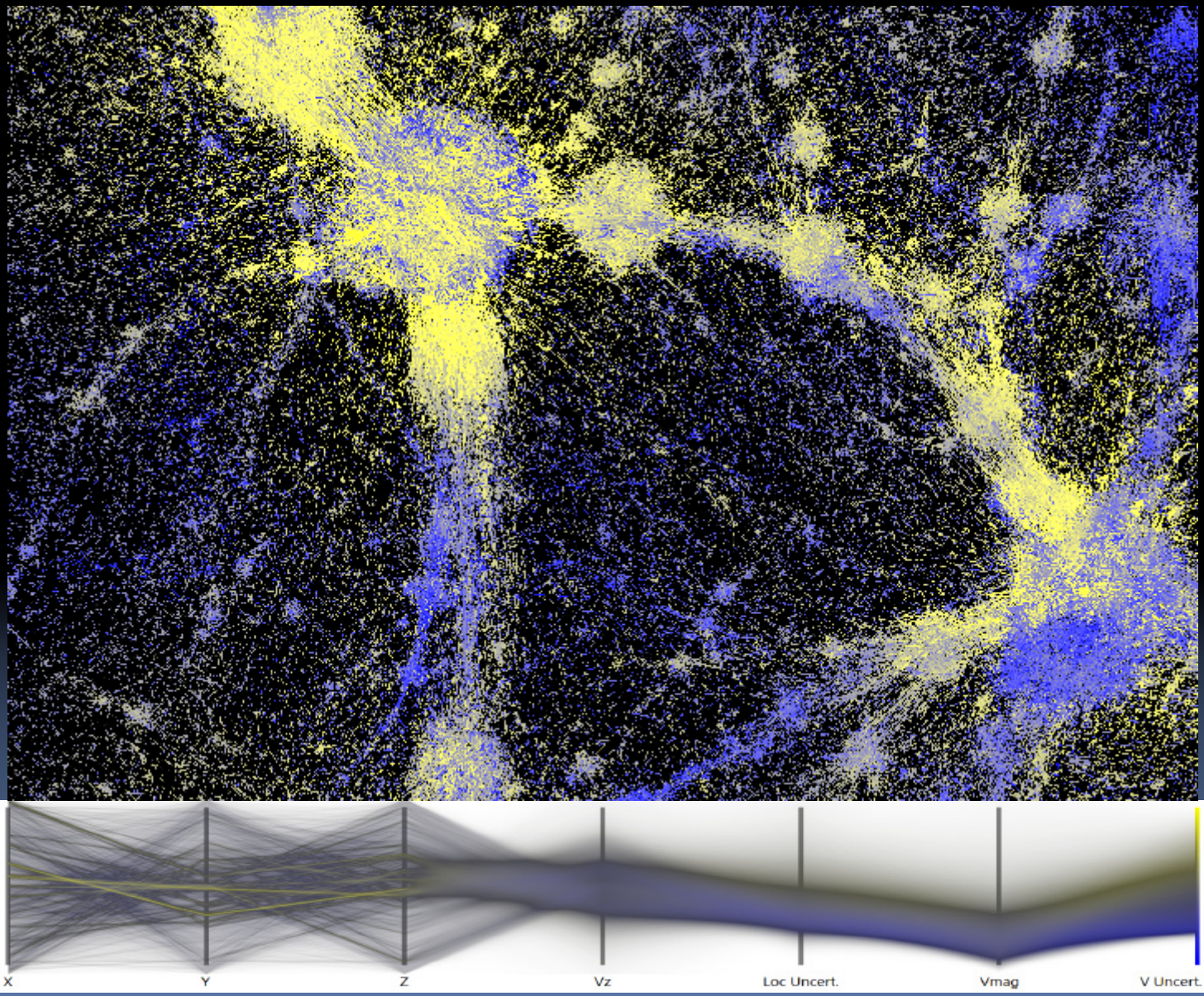


Color by variable

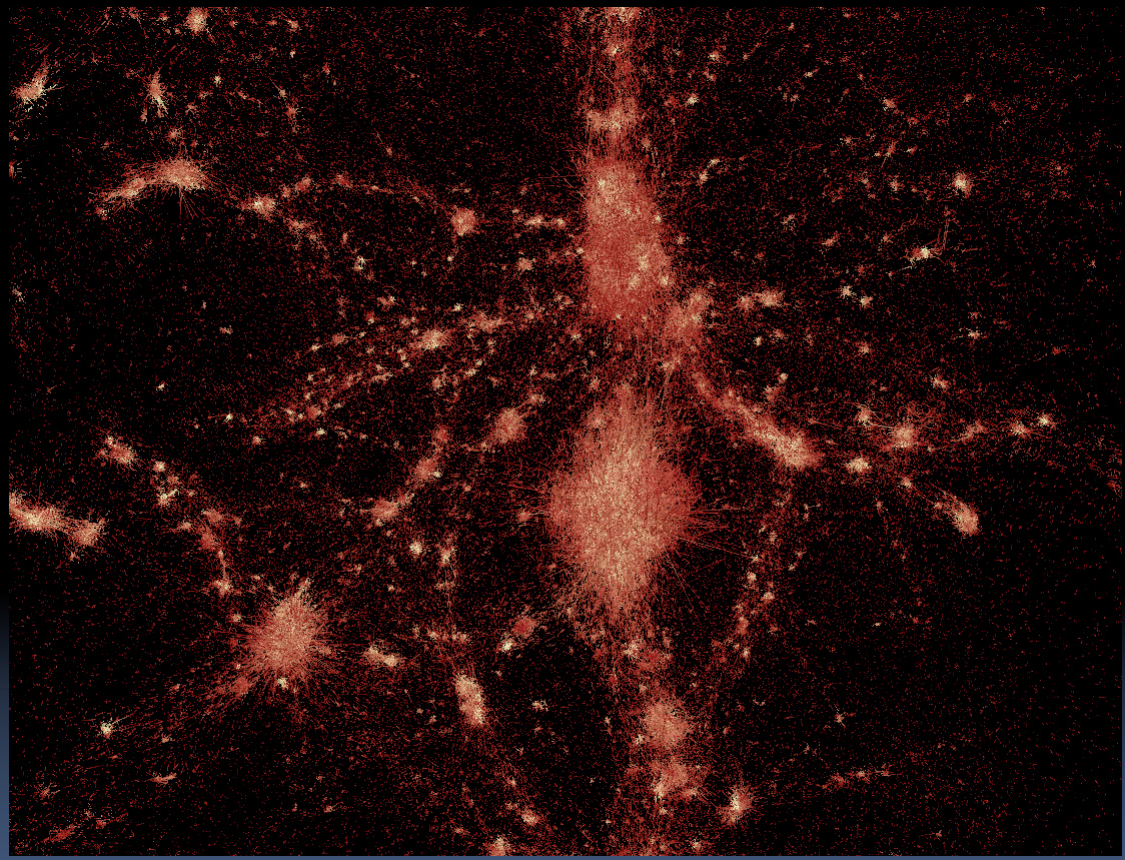
Color by Velocity

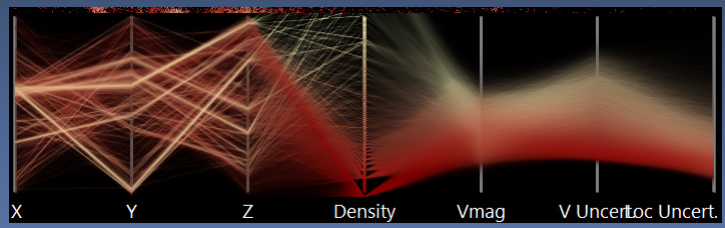


Color by Difference/Uncertainty



Multiple Views





Summary

- Application-driven user interface design
- Handle large-scale data sets
  - Time-varying, multivariate
- Leverage InfoVis techniques for SciVis
  - Multiple coordinated views
  - Parallel coordinate is powerful for multivariate visualization

References

- H. Akiba, N. Fout, K.-L. Ma, Simultaneous Classification of Time-Varying Volume Data Based on the Time Histogram, *Proc. EuroVis* 2006.
- H. Akiba, K.-L. Ma, A Tri-Space Visualization Interface for Analyzing Time-Varying Multivariate Volume Data, *Proc. EuroVis* 2007.
- H. Akiba, K.-L. Ma, J. H. Chen, E. R. Hawkes, Visualizing Multivariate Volume Data from Turbulent Combustion Simulations, *IEEE Computing in Science & Engineering*, Mar./Apr. 2007.
- C. Jones, K.-L. Ma, A. Sanderson, L. R. Myers Jr., Visual Interrogation of Gyrokinetic Particle Simulations, *Journal of Physics: Conference Series*, vol. 78, 2007.
- C. Jones, K.-L. Ma, S. Ethier, W.-L. Lee, An Integrated Exploration Approach to Visualizing Multivariate Particle Data, *IEEE Computing in Science & Engineering*, Jul./Aug. 2008.
- S. Haroz, K.-L. Ma, K. Heitmann, Multiple Uncertainties in Time-Variant Particle Data, *Proc. PacificVis* 2008.
- S. Haroz, K. Heitmann, Seeing the Differences between Cosmological Simulations, *IEEE Computer Graphics and Applications*, Sep./Oct. 2008.

Acknowledgements

- Hiroshi Akiba, Chad Jones, Steve Haroz (UC Davis)
- Jacqueline H. Chen, Evatt R. Hawkes (SNL)
- Stéphane Ethier, Wei-Li Lee (PPPL)
- Katrin Heitmann (LANL)
- National Science Foundation
  - CCF-0634913, IIS-0552334, CNS-0551727, OCI-0325934, CCF-9983641, and CCF-0222991
- Department of Energy
  - The SciDAC program with Agreement No. DE-FC02-06ER25777, DE-FC02-01ER41202, and DE-FG02-05ER54817

Thank you