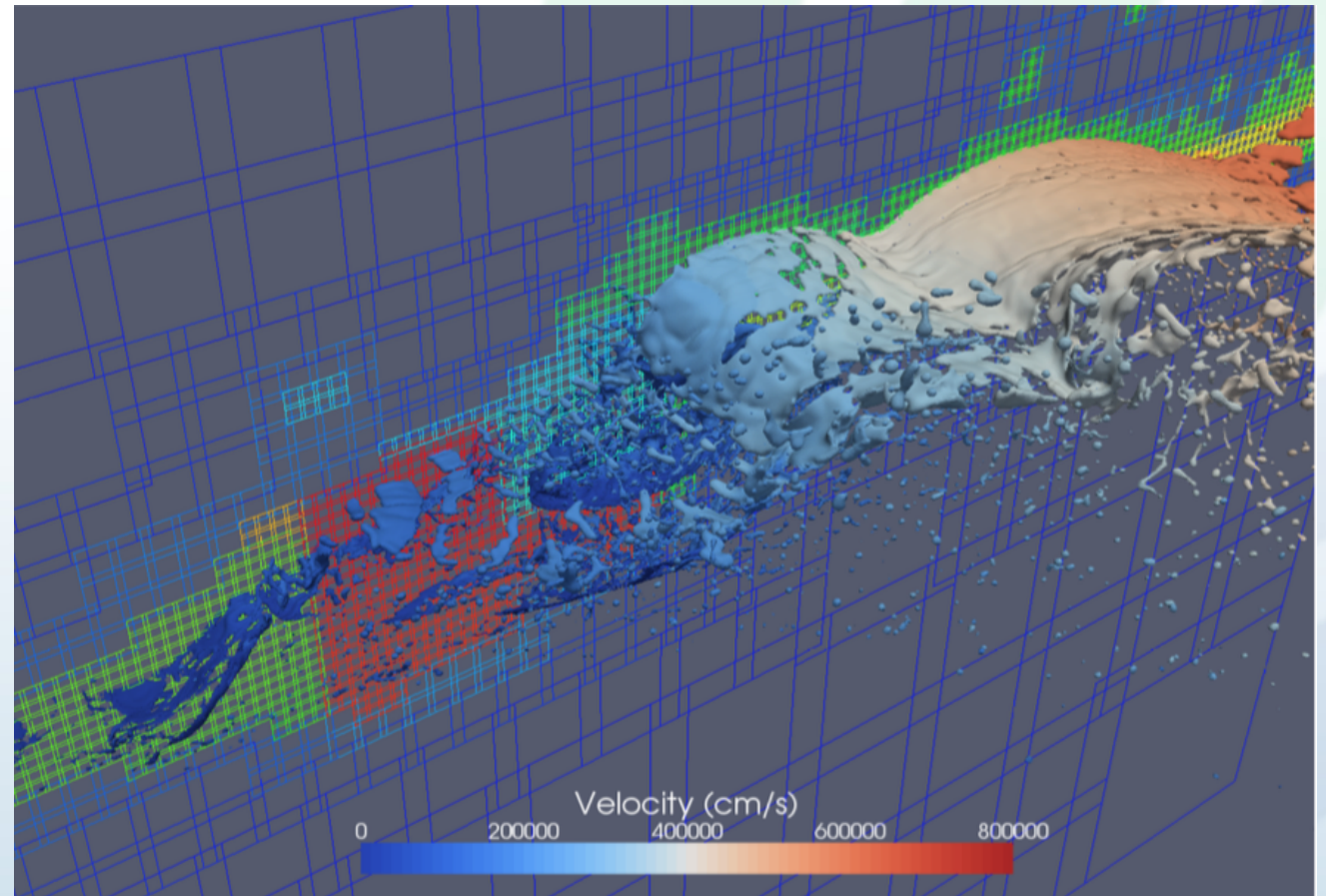


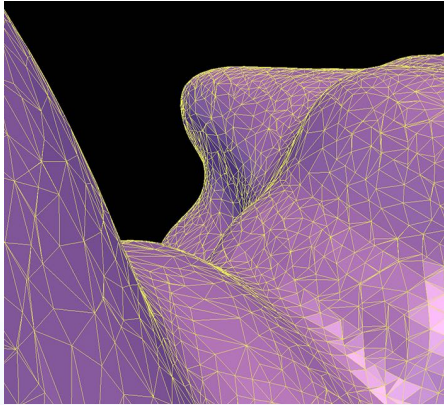
Large Scale Visualization with ParaView

Dan Lipsa
Staff R&D Engineer

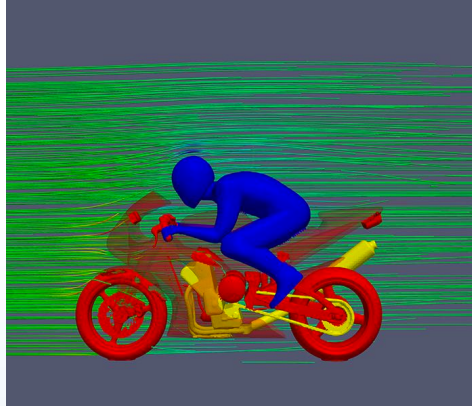


CTH Simulation with billions of cells visualized with ParaView. ParaView Tutorial.

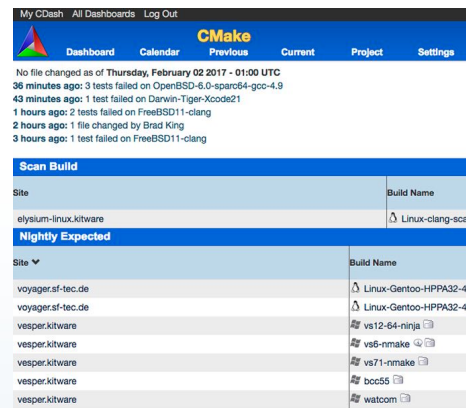
Kitware Inc.



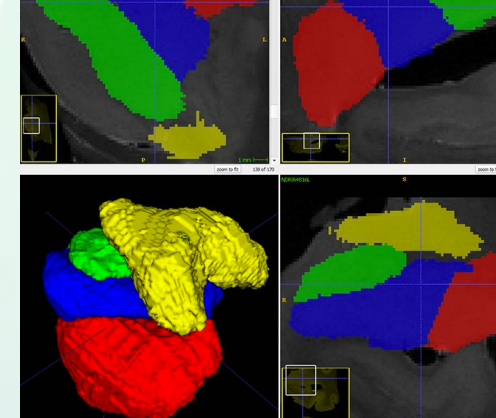
VTK



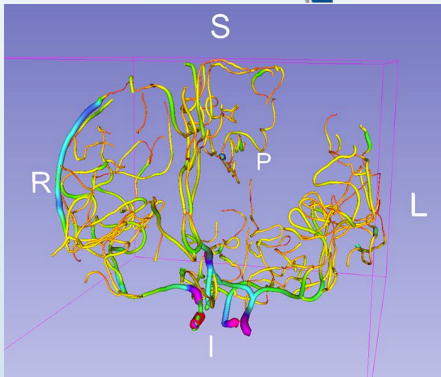
ParaView



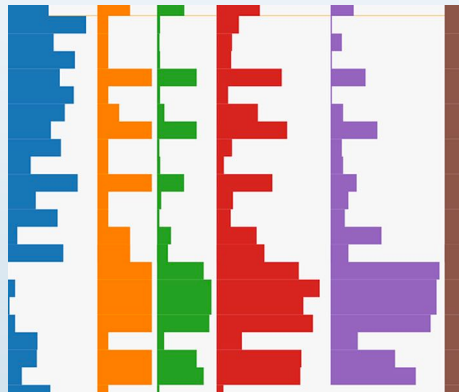
CMake



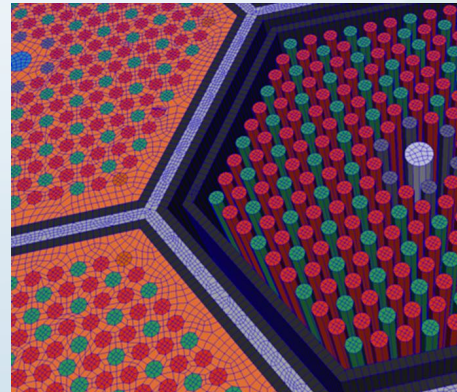
itk



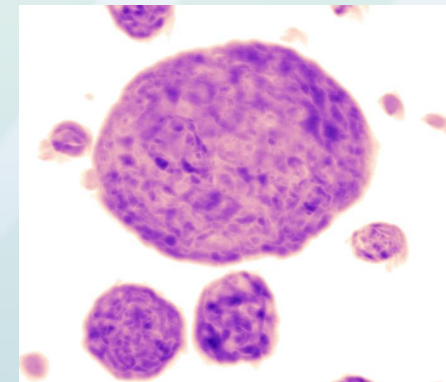
3DSlicer



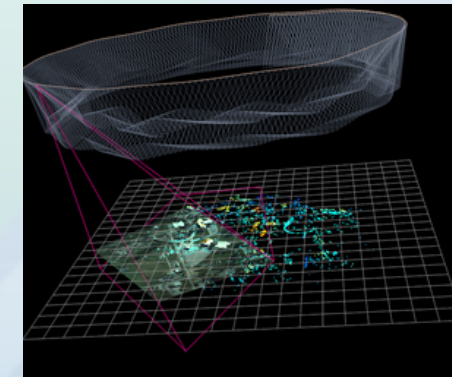
Resonant



CMB



tomviz



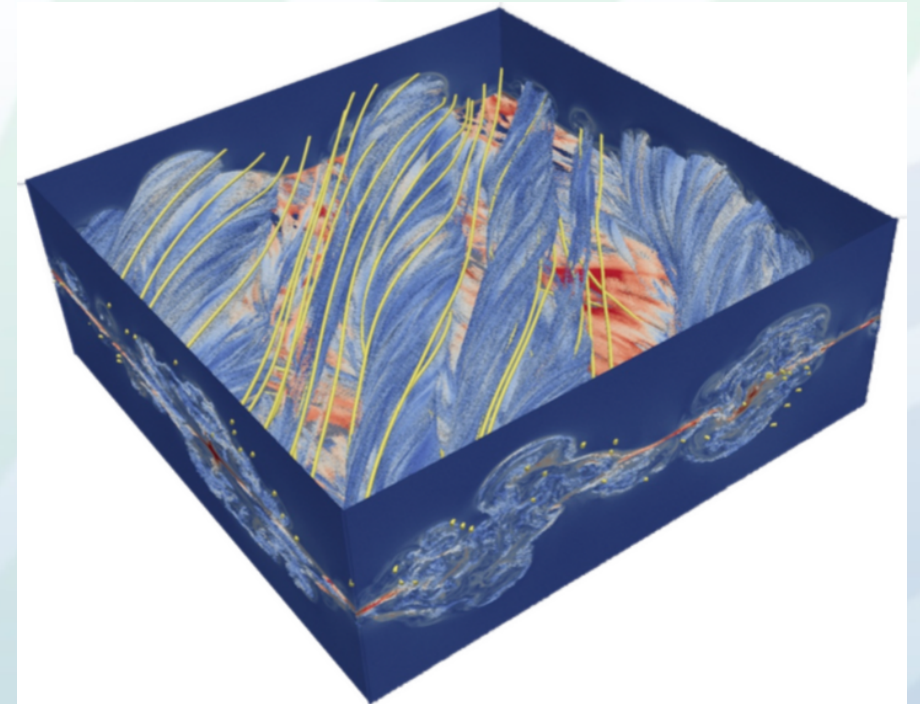
KWIVER

Kitware

Contents

- What is ParaView?
- User interface: the Pipeline Browser and the Object Inspector: Filters, Representations and Views. Finding Data and Selection.
- Running ParaView in parallel.
- ParaView Tutorial: Ex 2.1-2.xx

Install ParaView 5.4.0
Windows: Install PuTTY
Mac OS: Install XQuartz



VPIC simulation with 3.3 billion structured cells. Image courtesy of Bill Daughton, LANL

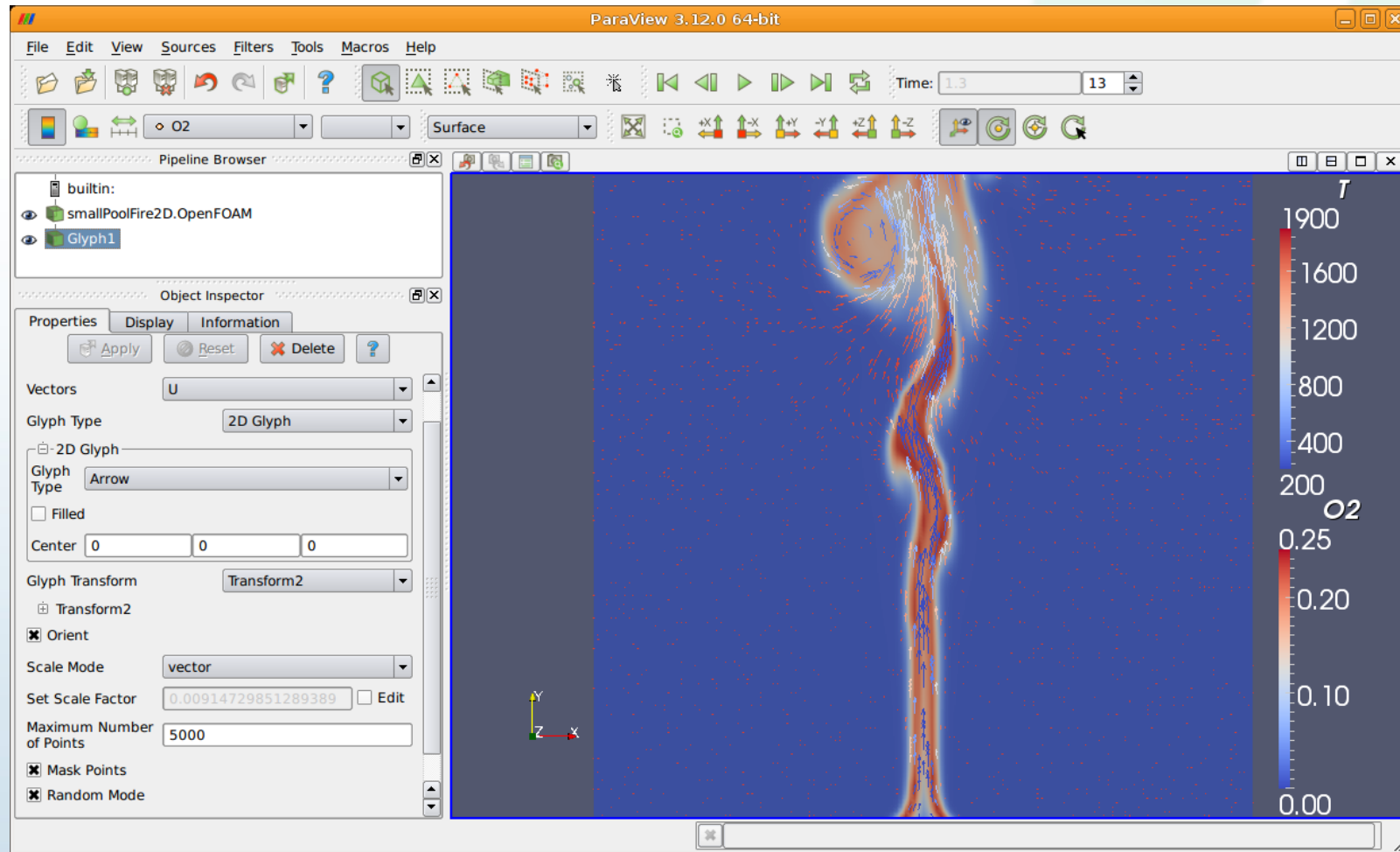
What is ParaView?

An **open-source application** and **framework** for **display** and **analysis** of scientific datasets.

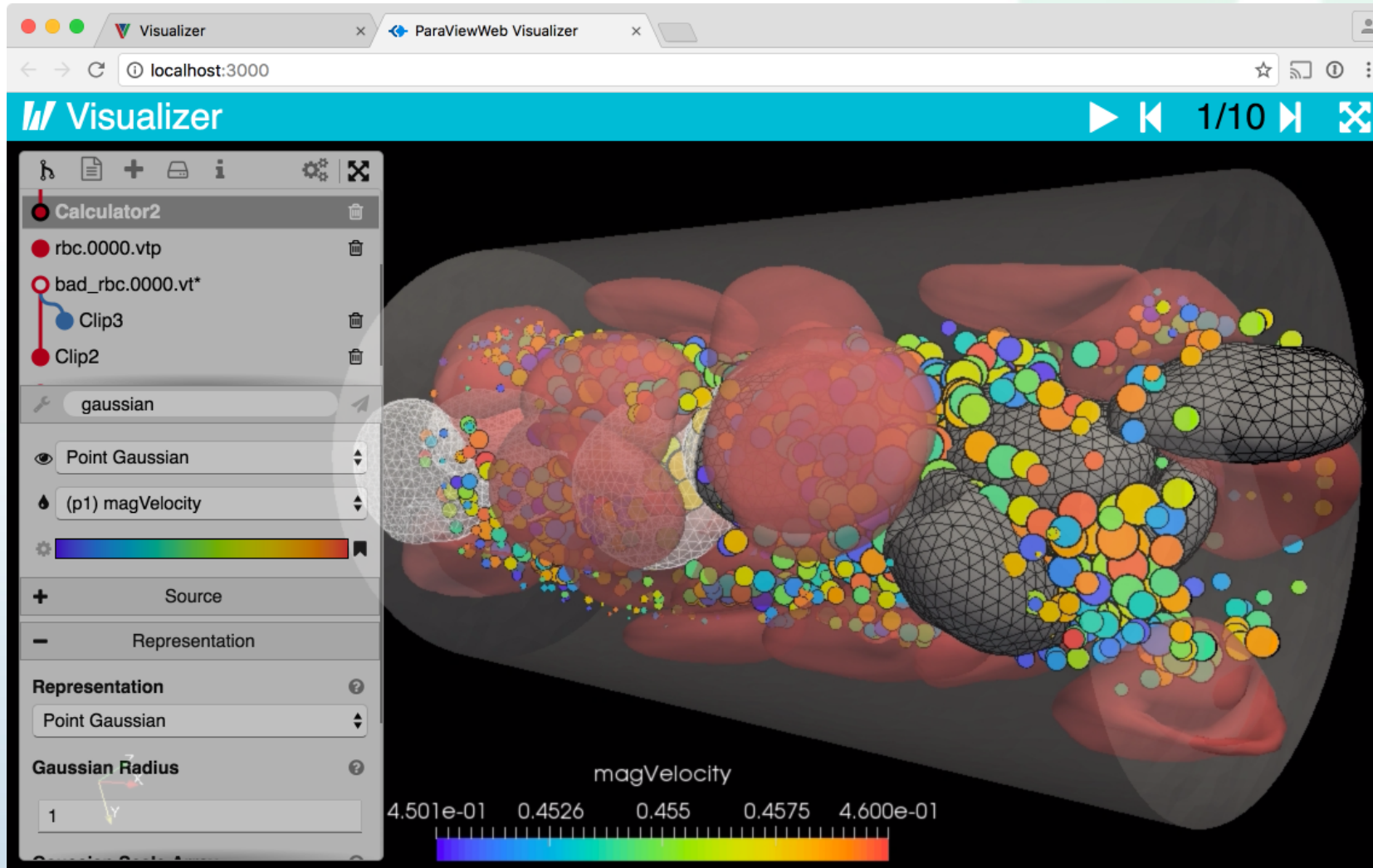


Record setting in-situ simulation run:
First in-situ run to exceed one million MPI processes.

ParaView on the Desktop



ParaView on the Web

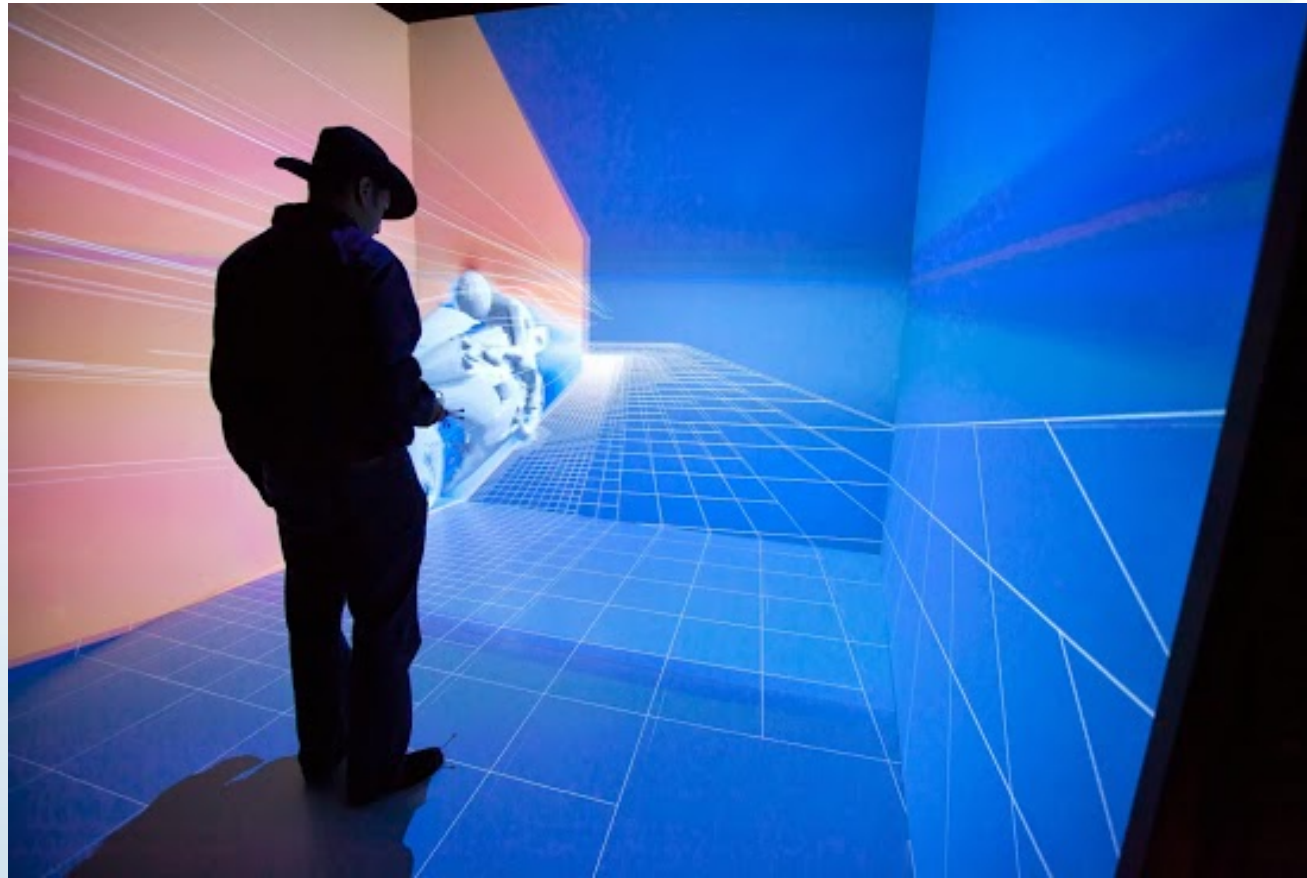


ParaView Scripting - Python



Python scripts can control ParaView with or without the GUI in order to create reproducible and customizable visualizations.

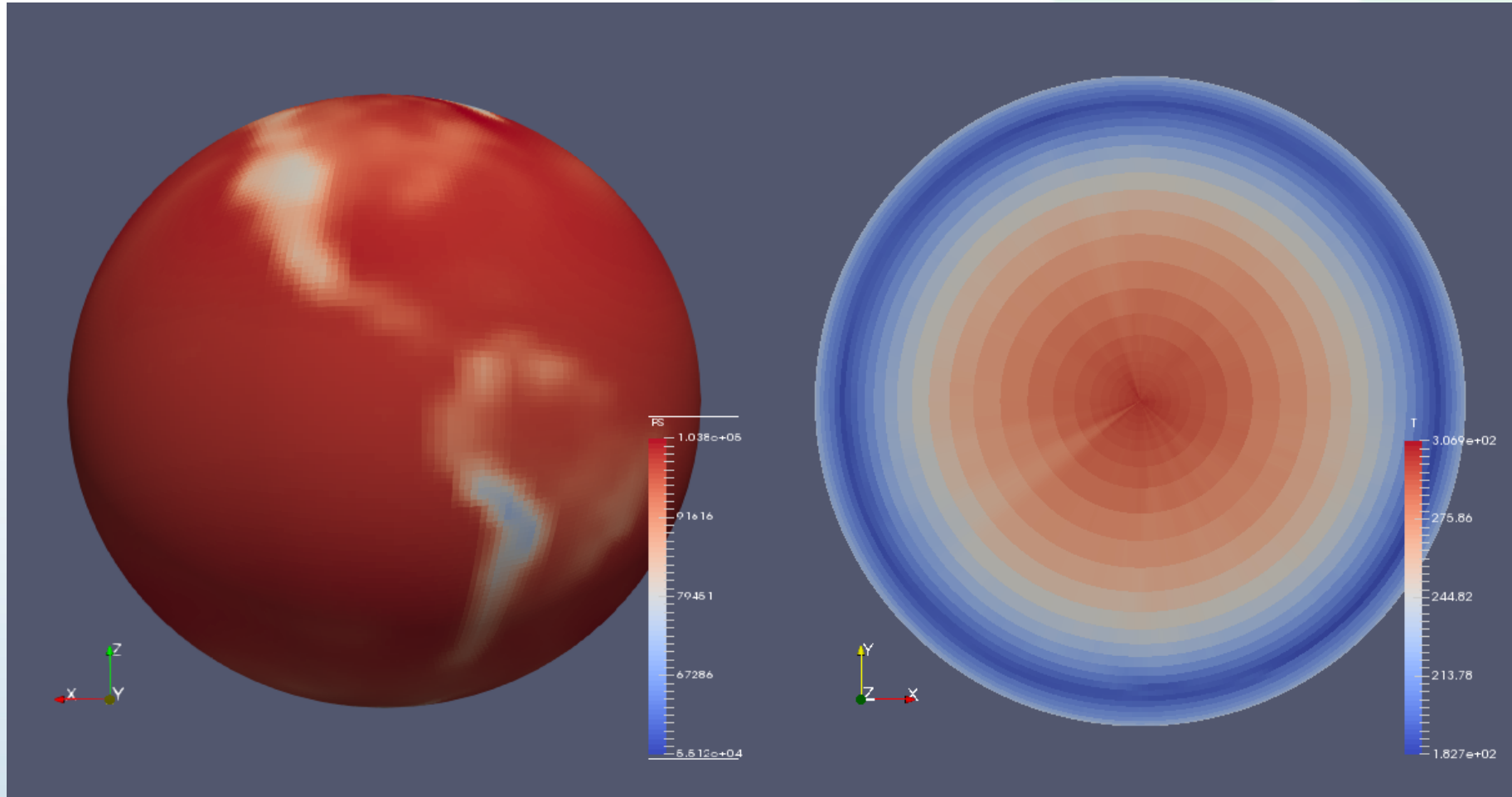
ParaView Immersive



ParaView for HPC

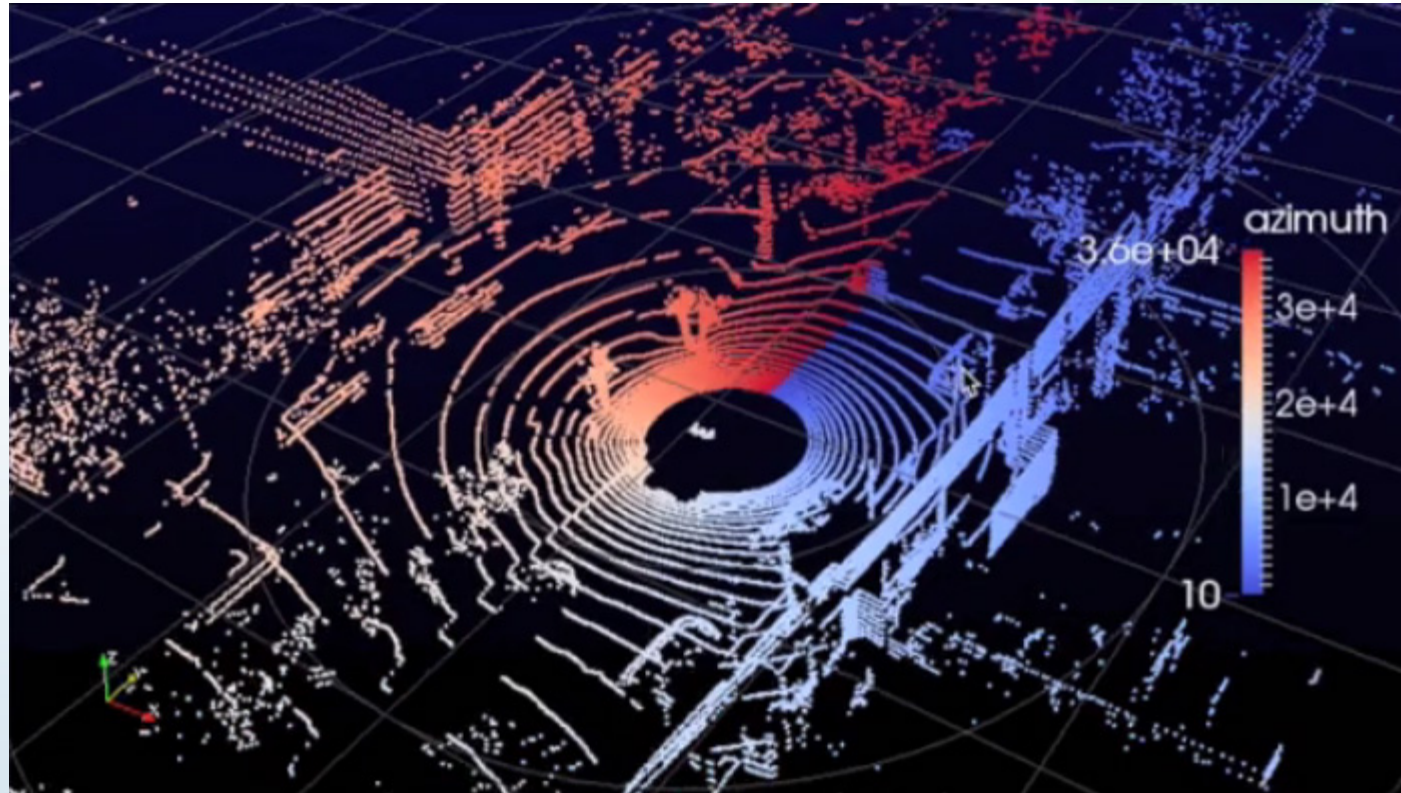


ParaView InSitu (ParaView Catalyst)



Community Atmosphere Model (CAM5) 2D (PS) 3D data (T), Spectral Element dynamic module.

ParaView Custom Application: VeloView



Visualization of 3D LIDAR data.

User Interface

Menu Bar

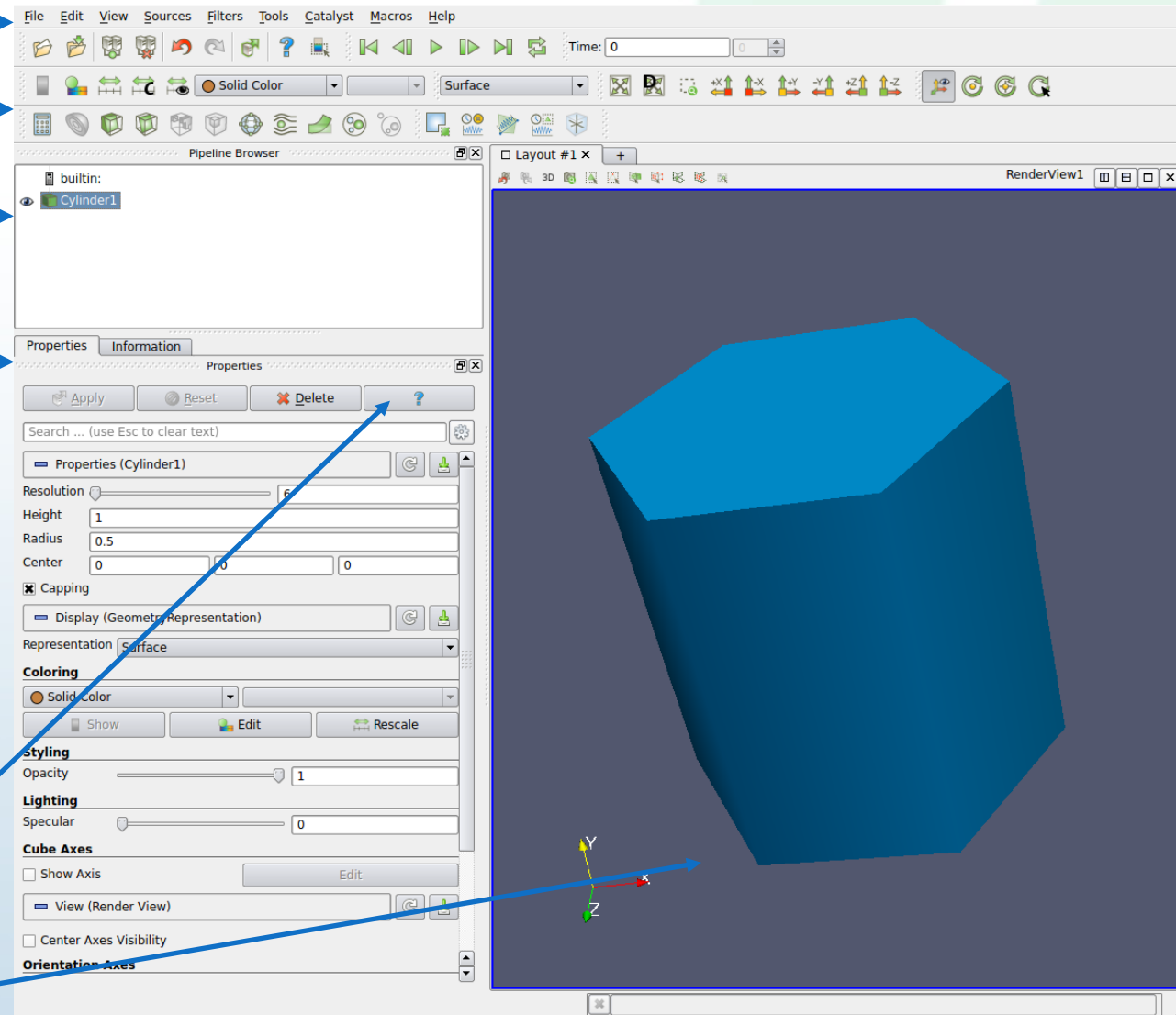
Toolbars

Pipeline Browser

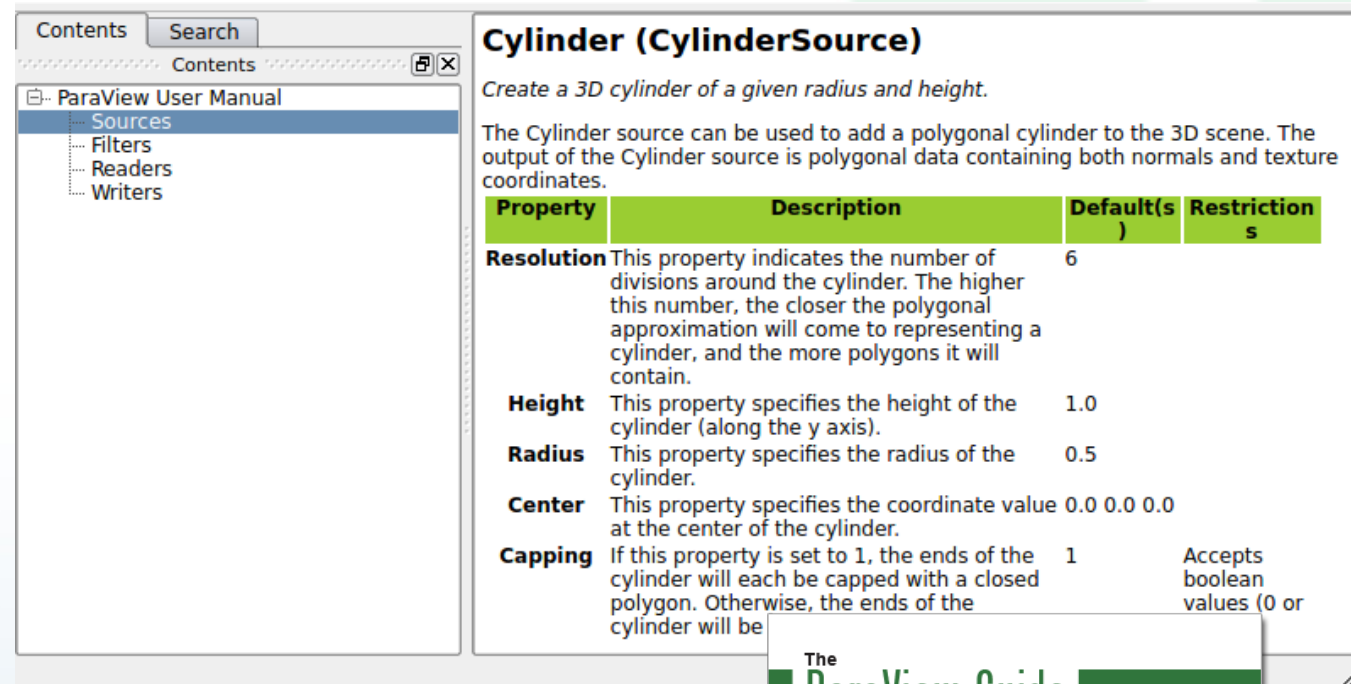
Object Inspector
Properties Tab
Properties
Display
View
Information Tab

Filter reference

View(s)



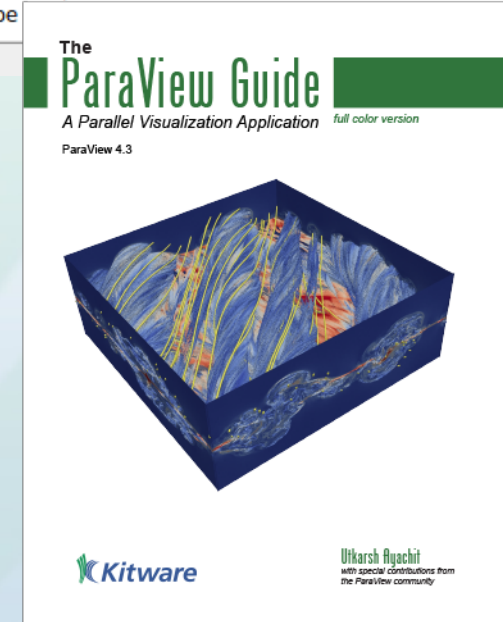
Help



The screenshot shows a web browser window displaying the ParaView User Manual. The left sidebar contains a 'Contents' menu with links to 'Sources', 'Filters', 'Readers', and 'Writers'. The main content area is titled 'Cylinder (CylinderSource)' and includes a description: 'Create a 3D cylinder of a given radius and height. The Cylinder source can be used to add a polygonal cylinder to the 3D scene. The output of the Cylinder source is polygonal data containing both normals and texture coordinates.'

Property	Description	Default(s)	Restrictions
Resolution	This property indicates the number of divisions around the cylinder. The higher this number, the closer the polygonal approximation will come to representing a cylinder, and the more polygons it will contain.	6	
Height	This property specifies the height of the cylinder (along the y axis).	1.0	
Radius	This property specifies the radius of the cylinder.	0.5	
Center	This property specifies the coordinate value at the center of the cylinder.	0.0 0.0 0.0	
Capping	If this property is set to 1, the ends of the cylinder will each be capped with a closed polygon. Otherwise, the ends of the cylinder will be	1	Accepts boolean values (0 or

- Getting Started With ParaView
- The ParaView Guide
- Filter Reference
- The ParaView Tutorial
- Example Visualizations
- ParaView Mailing Lists
- ParaView Wiki
- <http://www.paraview.org/documentation/>



How to Use ParaView

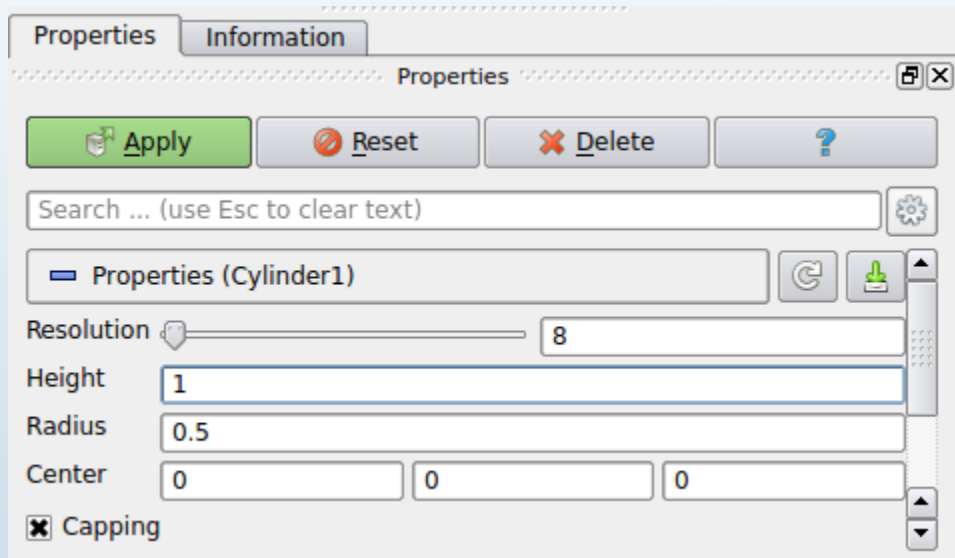
1. **Read in data:** File → Open
 - Tune **reader properties** Apply
 - Over 100 file formats supported
2. **Add a filter** to process data:
 - Change **Filter properties** Apply
 - **Repeat Step 2** as needed Edit → Undo
3. Modify **Display properties**
4. Tune **View properties**
5. Save datasets, rendered results (screenshot or animation) or ParaView state

Filter (Pipeline object) = an algorithm that operates on data
Reader, Writer, Source

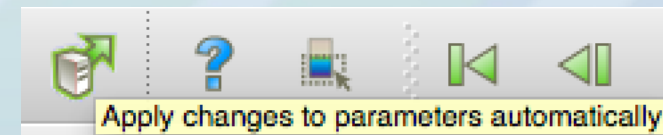


Filter Properties and the Apply Button

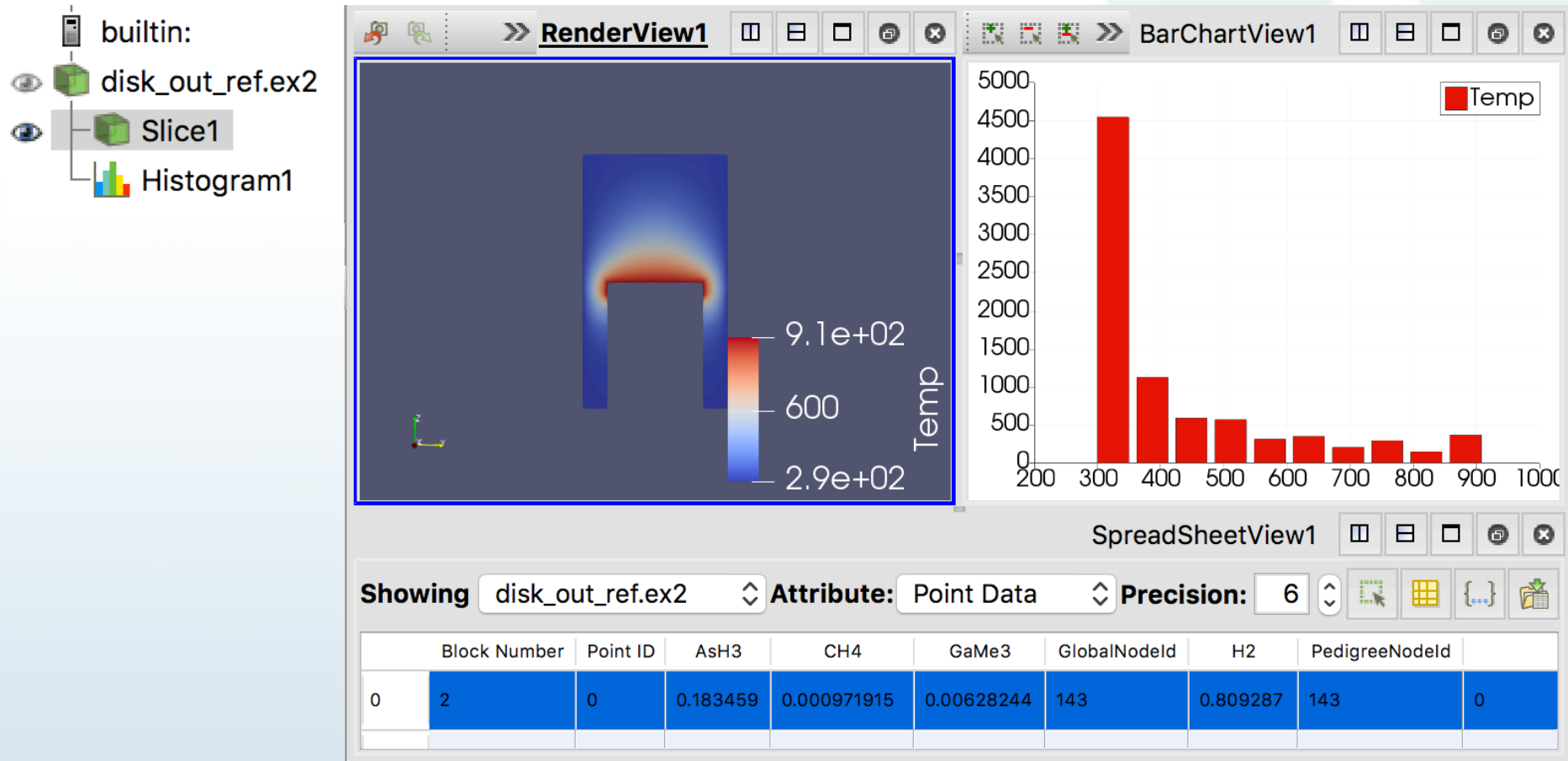
- Active Filter properties
- ParaView is meant to process large data – it might take a long time when changing a filter property.



Toggle auto apply

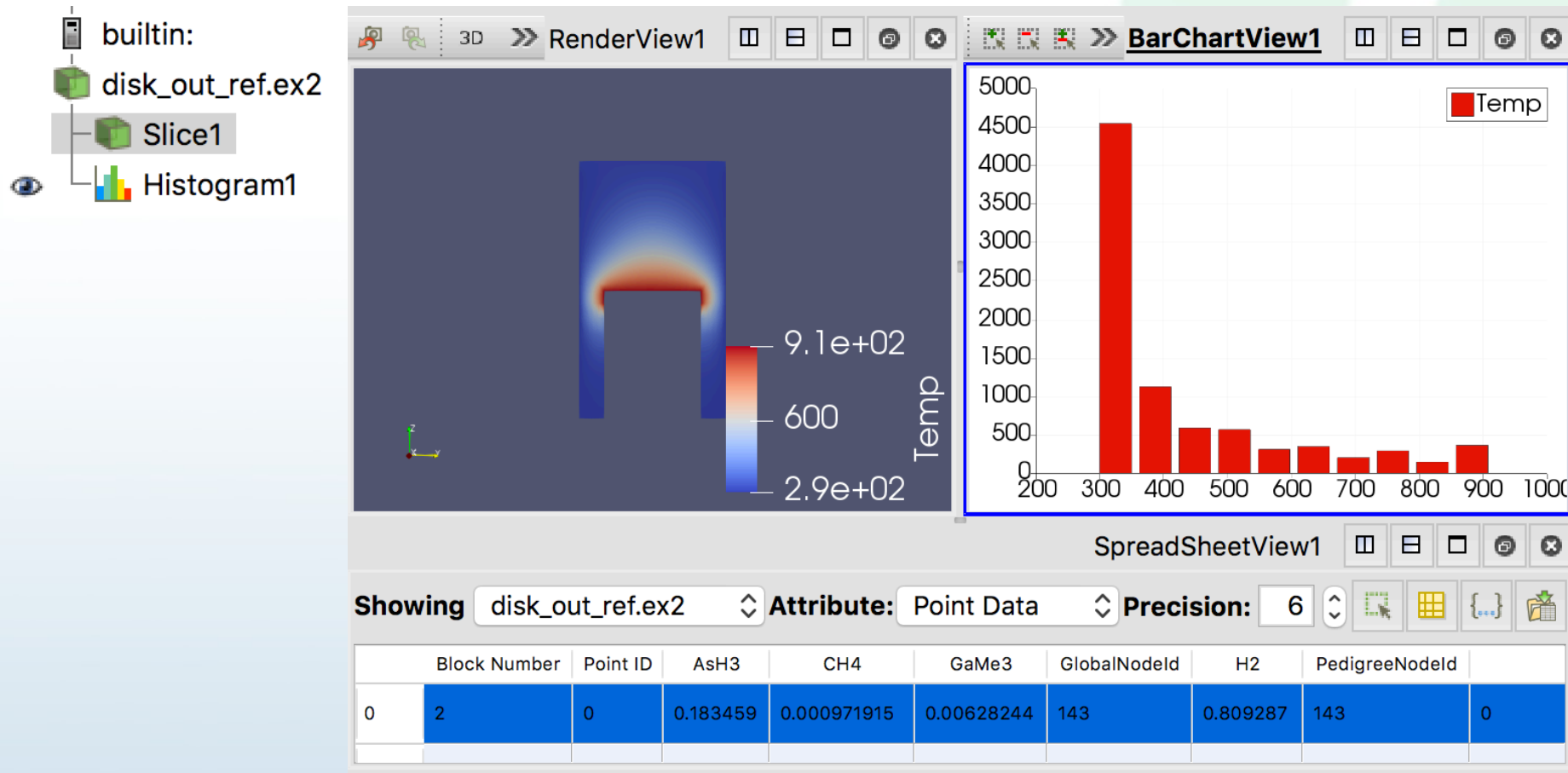


Multiple Views – Render View Active

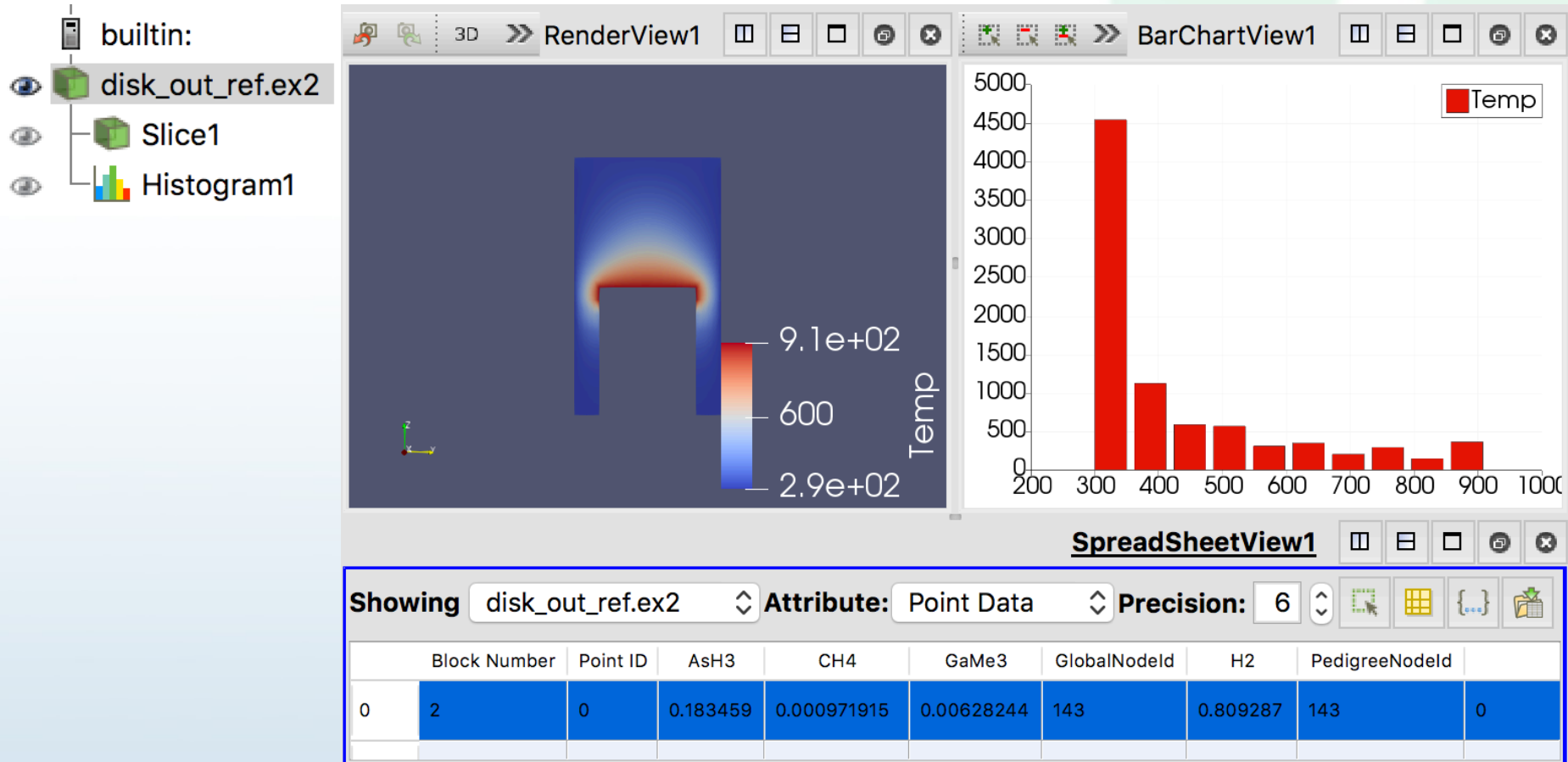


- Buttons: Split (Vertical, Horizontal), Maximize, Restore, Close

Multiple Views – BarChartView Active

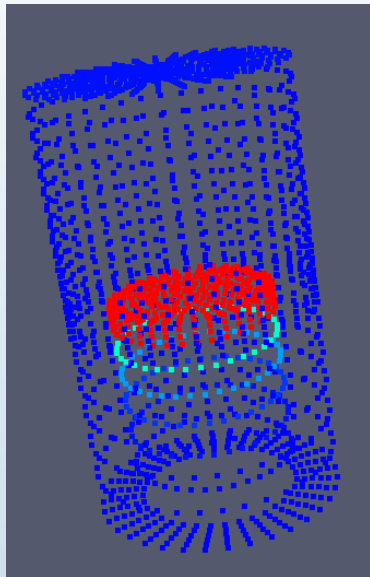
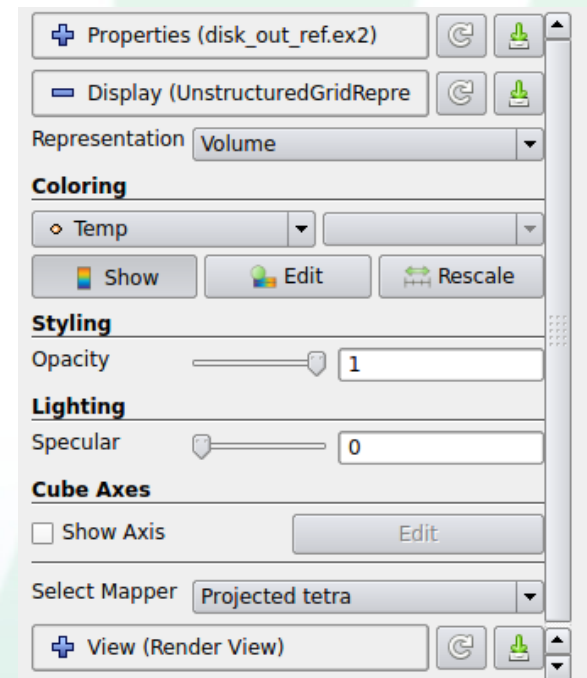


Multiple Views – Spreadsheet Active

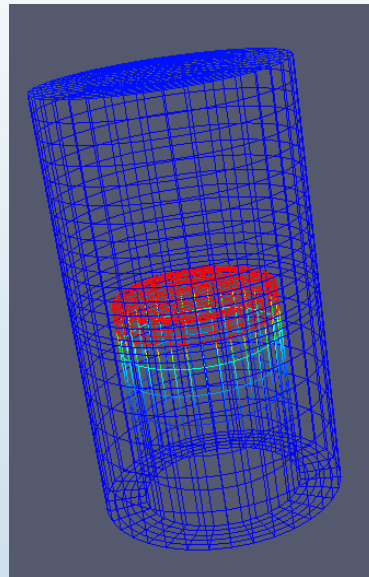


Display Properties

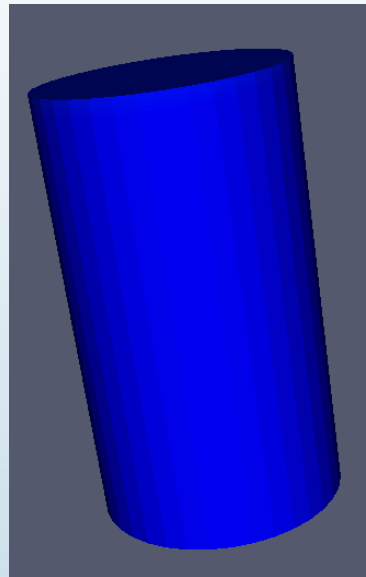
- **A Representation** (a display): object that stores visual characteristics a data set in a view
- Display Properties are associated with the Active Filter and Active View.



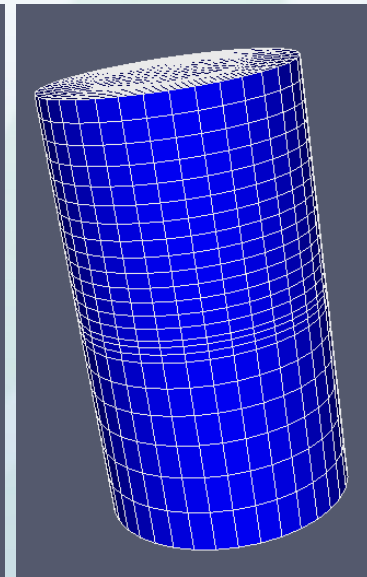
Points



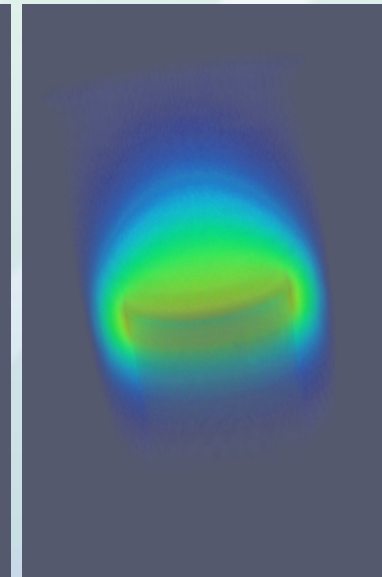
Wireframe



Surface

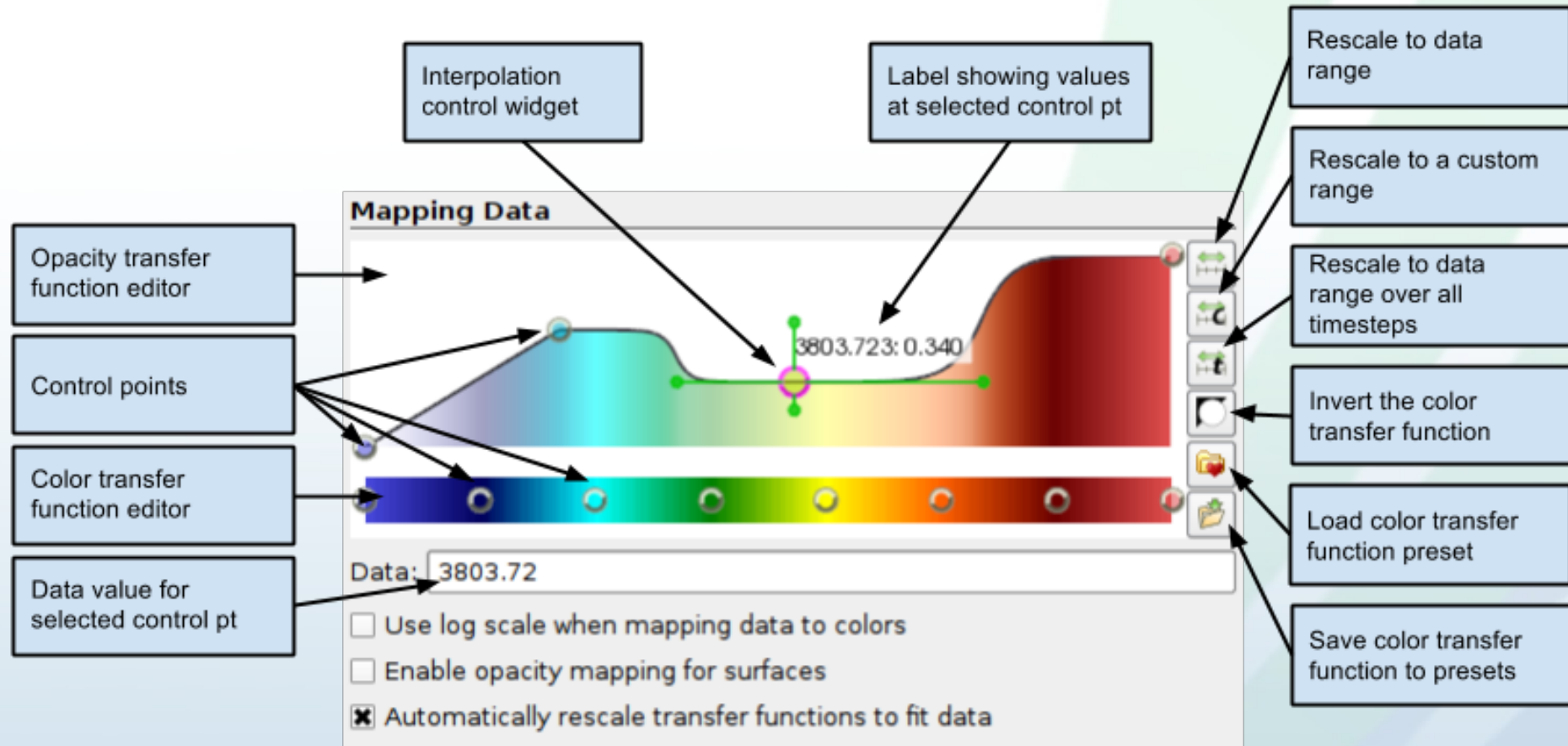


Surface
with Edges



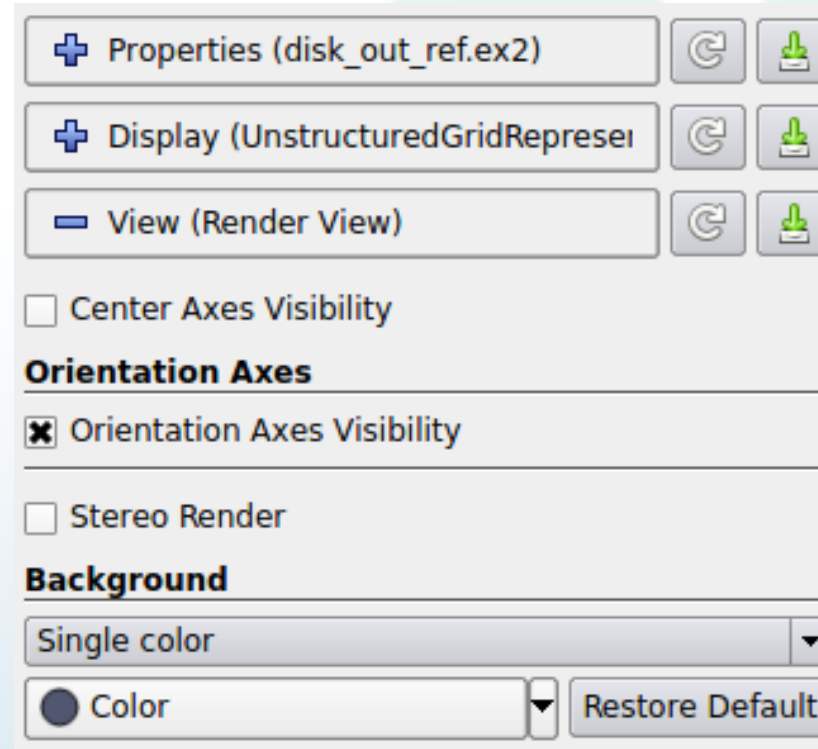
Volume

Color Map (Transfer Function) Editor



View Properties

Properties associated with the Active View



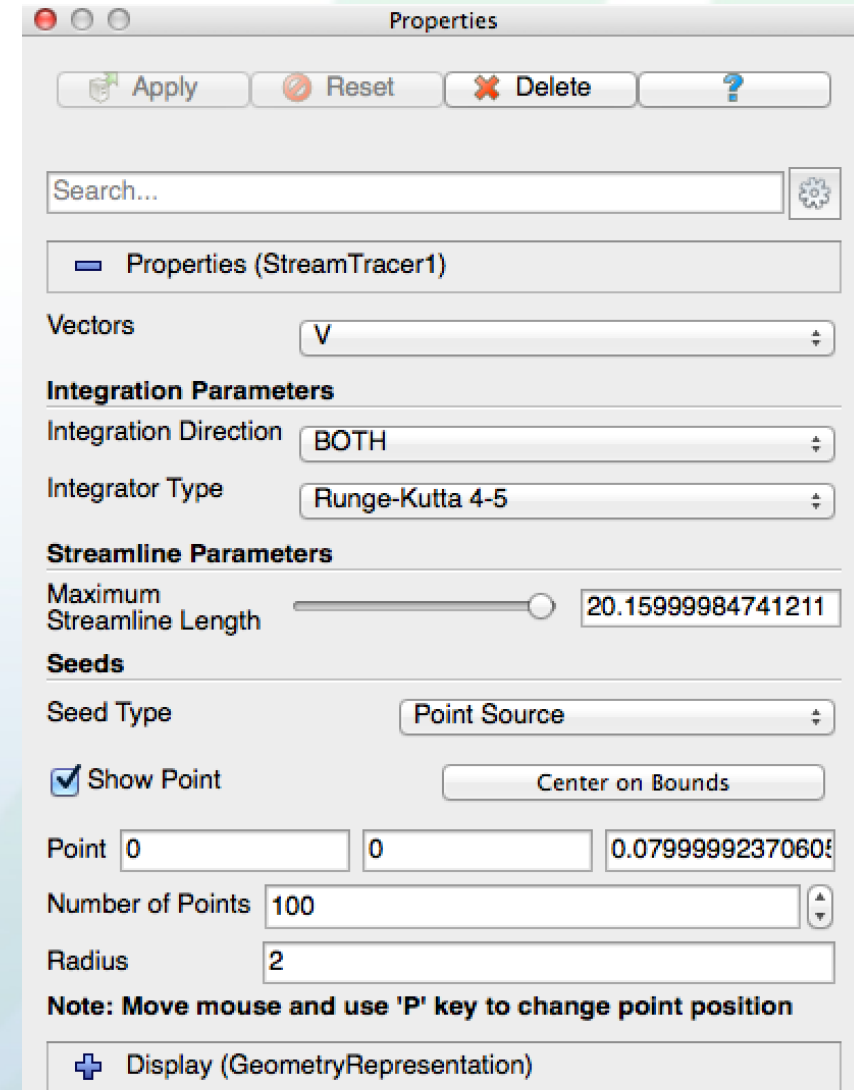
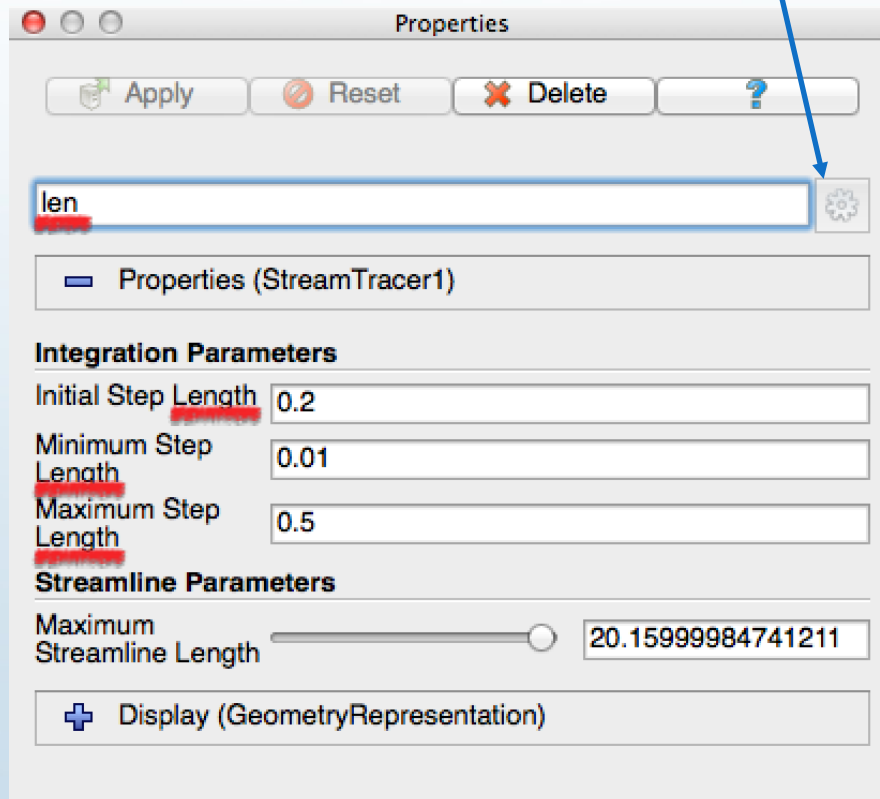
The screenshot shows a 'View Properties' dialog box with the following elements:

- A list of three items: 'Properties (disk_out_ref.ex2)', 'Display (UnstructuredGridReprese...', and 'View (Render View)'. Each item has a plus icon on the left and refresh and save icons on the right.
- A checkbox for 'Center Axes Visibility' which is currently unchecked.
- A section header 'Orientation Axes'.
- A checkbox for 'Orientation Axes Visibility' which is checked (indicated by an 'x' in the box).
- A checkbox for 'Stereo Render' which is unchecked.
- A section header 'Background'.
- A dropdown menu for 'Single color'.
- A color selection area with a dark blue circle and the label 'Color'.
- A 'Restore Default' button.

Find properties (for Filters, Displays and Views)

- Search for properties
- Toggle on/off advanced properties

Advanced Properties



Object Inspector Information Tab

- Information about the Active Filter's output
- Dataset Type
- Size (Bytes, #points, #cells)
- Geometric bounds
- Structured bounds
- Arrays:
 - Name
 - Association 🟡=point, 🟠=cell)
 - Data Type
 - Data Ranges (and scalar/vector)
- Temporal Domain

Information

Data Hierarchy

- Multi-block Dataset
 - Element Blocks
 - Unnamed block ID: 1 Type: HEX
 - Unnamed block ID: 2 Type: HEX
 - Face Blocks
 - Edge Blocks
 - Element Sets
 - Side Sets
 - Face Sets
 - Edge Sets

Statistics

Type: Unstructured Grid
Number of Cells: 4800
Number of Points: 6724
Memory: 1.4 MB

Data Arrays

Name	Data Type	Data Ranges
ACCL	double	[0, 0], [0, 0], [0, 0]
DISPL	double	[0, 0], [0, 0], [0, 0]
GlobalNodeId	idtype	[1, 6724]
PedigreeNodeId	idtype	[1, 6724]
VEL	double	[0, 0], [0, 0], [0, 0]
EQPS	double	[0, 0]
GlobalElementId	idtype	[1, 4800]
ObjectId	int	[1, 1]
PedigreeElementId	idtype	[1, 4800]
KE	double	[1.46764e+06, 2.96e+06]

Bounds

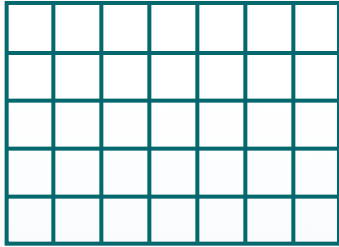
X range: -5.2 to 5.2 (delta: 10.4)
Y range: 0 to 5.2 (delta: 5.2)
Z range: -15 to 0 (delta: 15)

Time

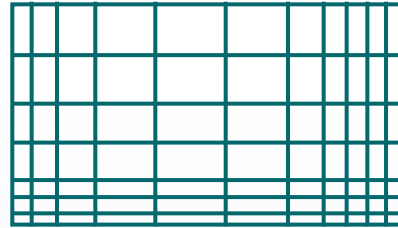
Index	Value
0	0
1	0.000100074
2	0.000199905
3	0.000299964
4	0.000400087
5	0.000499919
6	0.000599935
7	0.000700049
8	0.000800035
9	0.000900061

ParaView Dataset Types

vtkImageData



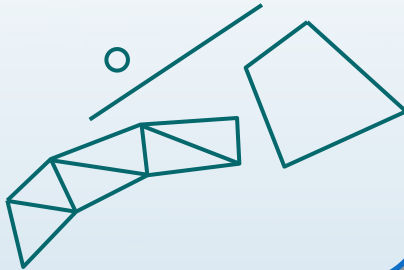
vtkRectilinearGrid



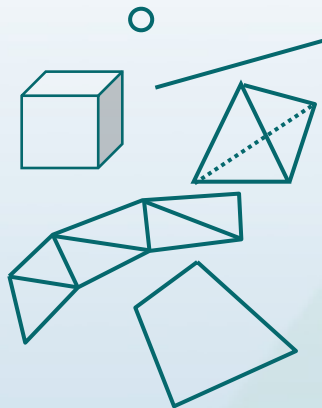
vtkStructuredGrid



vtkPolyData



vtkUnstructuredGrid



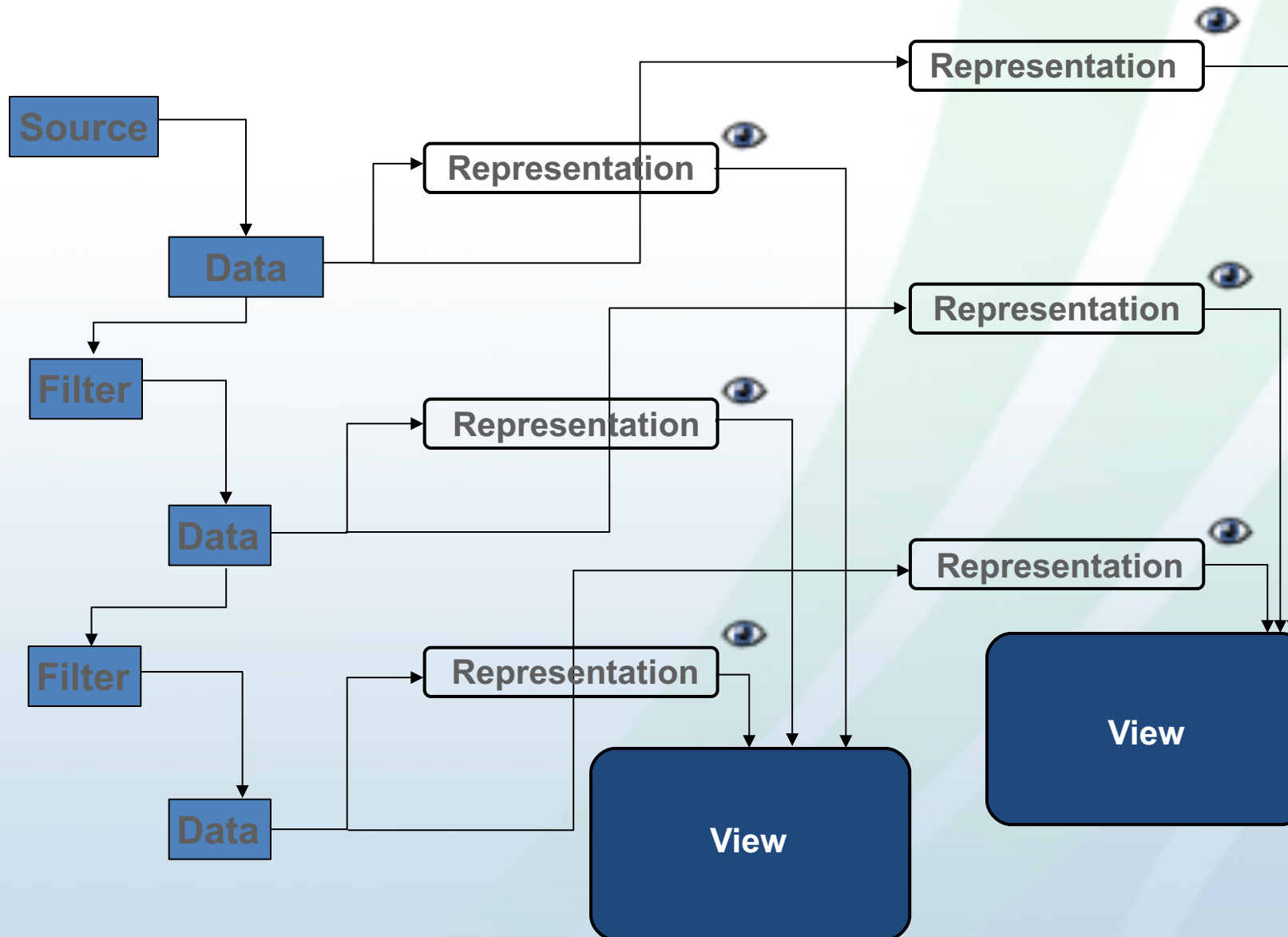
Multi-blocks

AMR

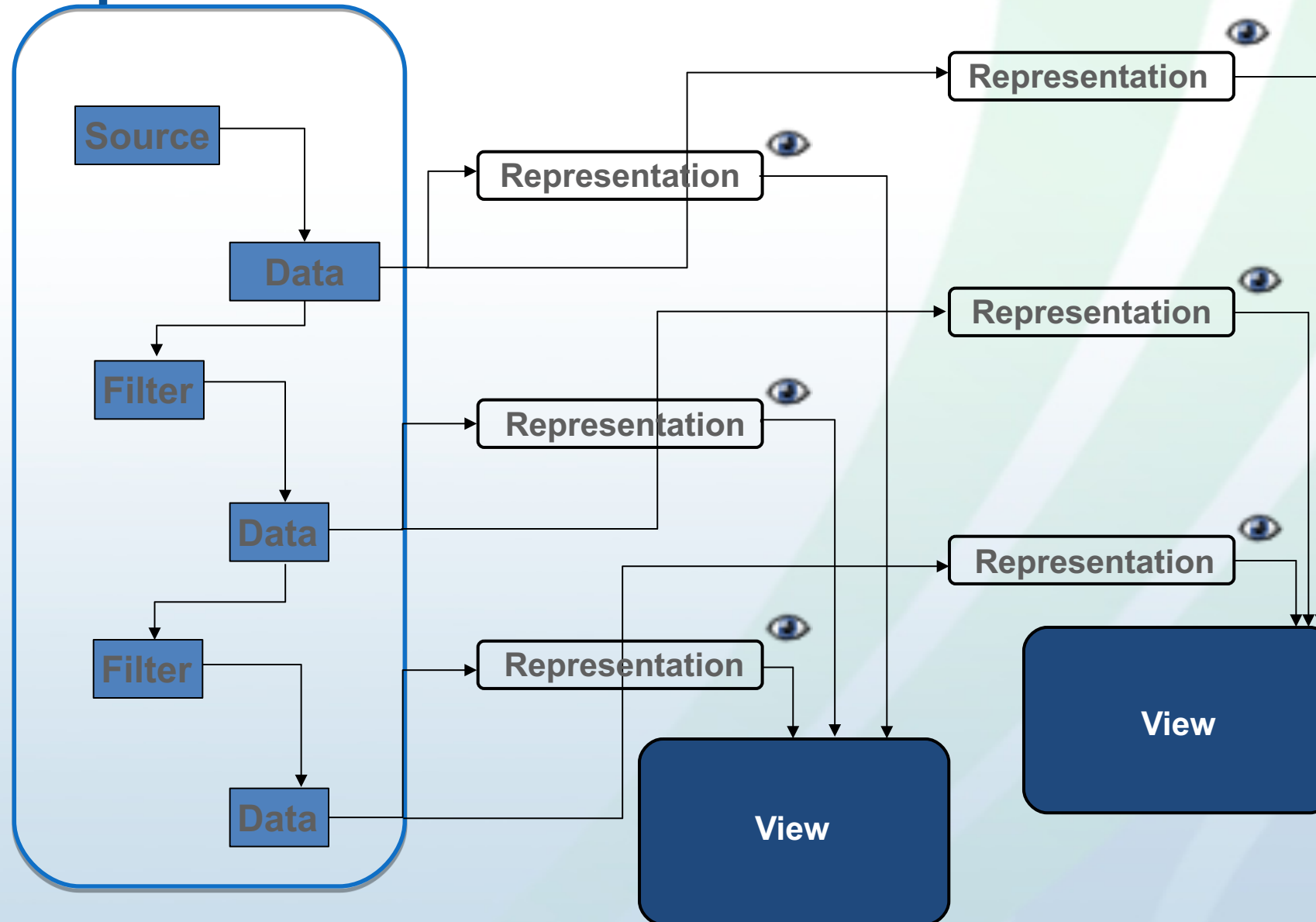
Time-varying data

- points, cells
- values associated points and/or cells: scalars, vectors, tensors

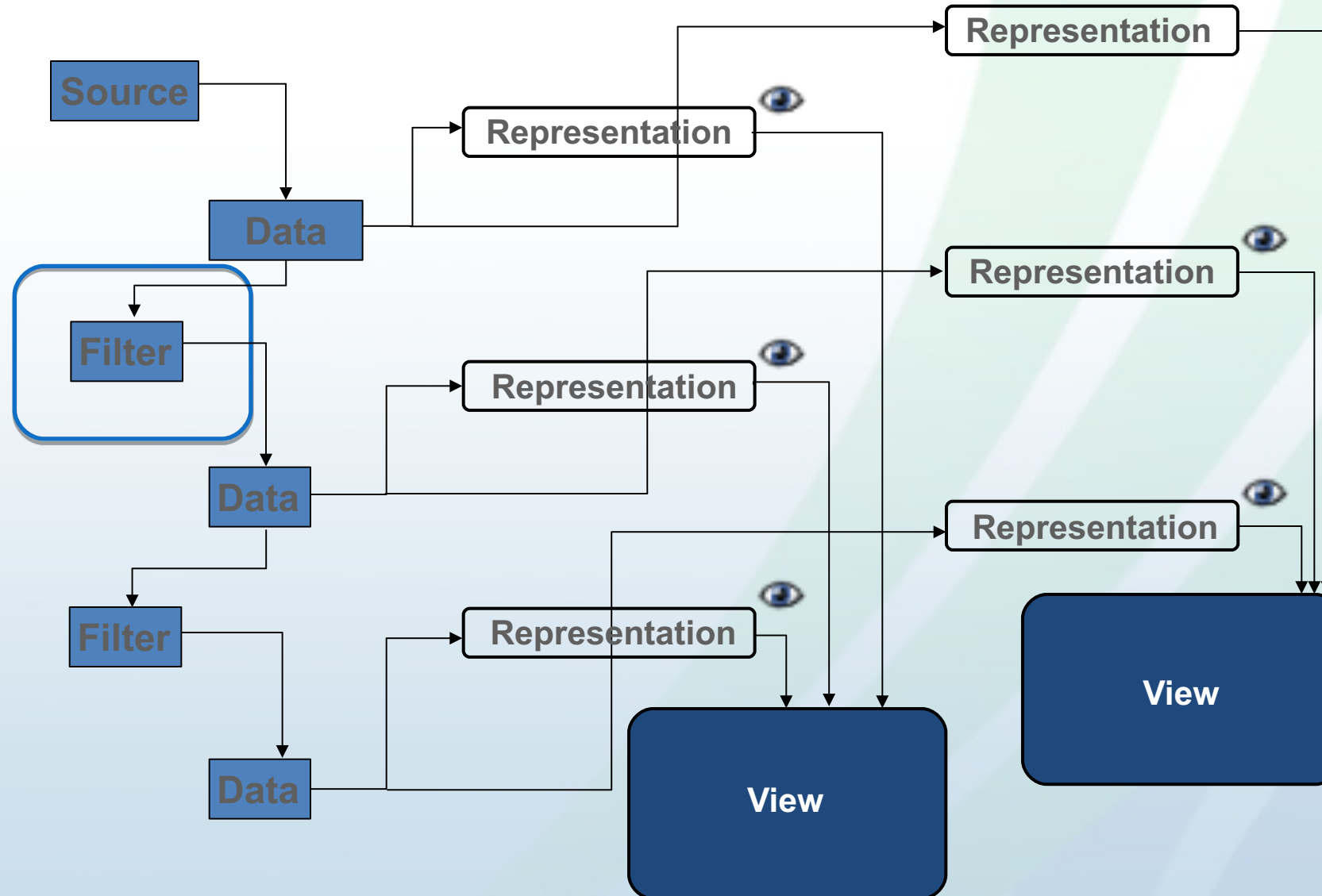
Multi-View Visualization Pipeline



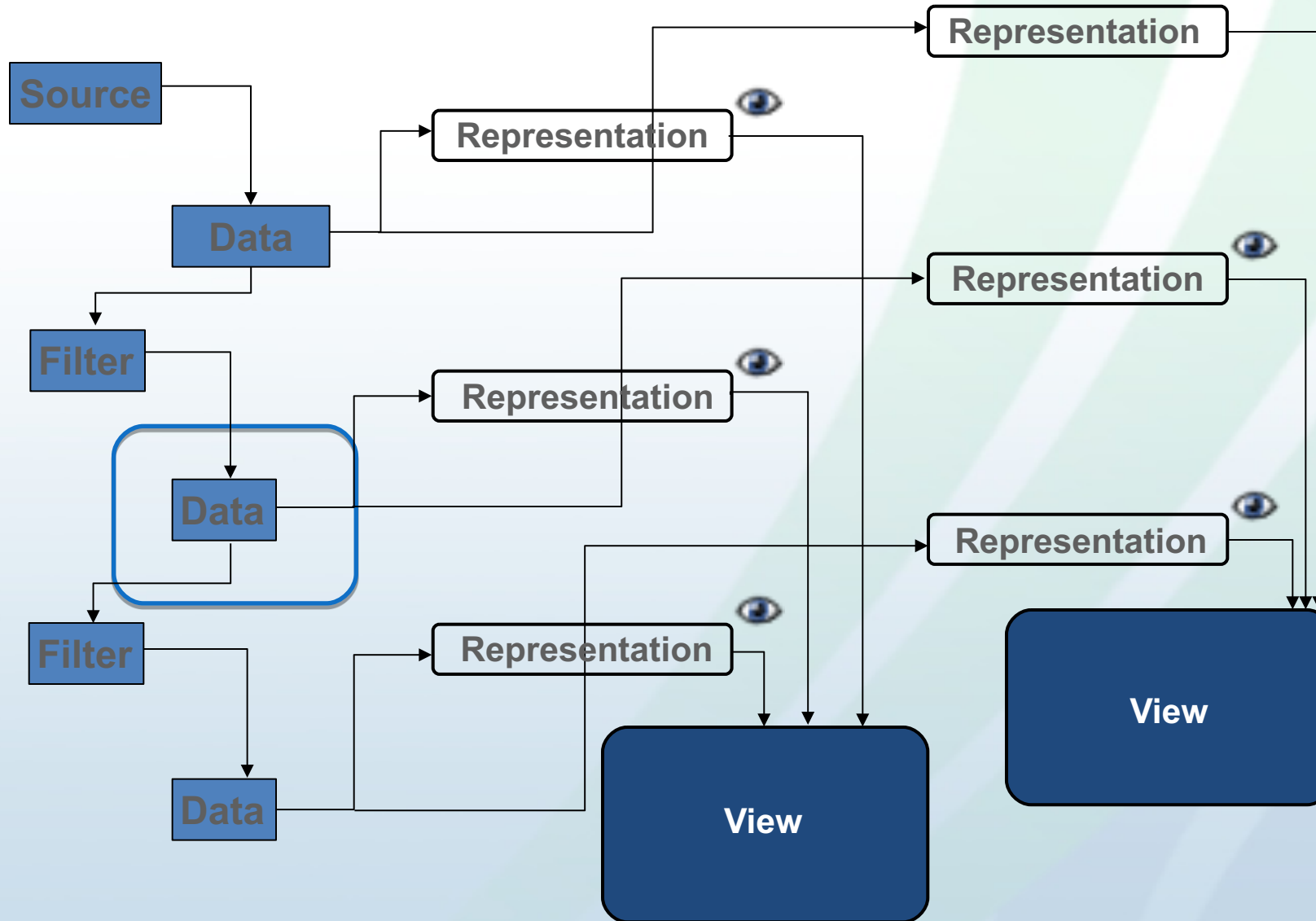
Pipeline Browser



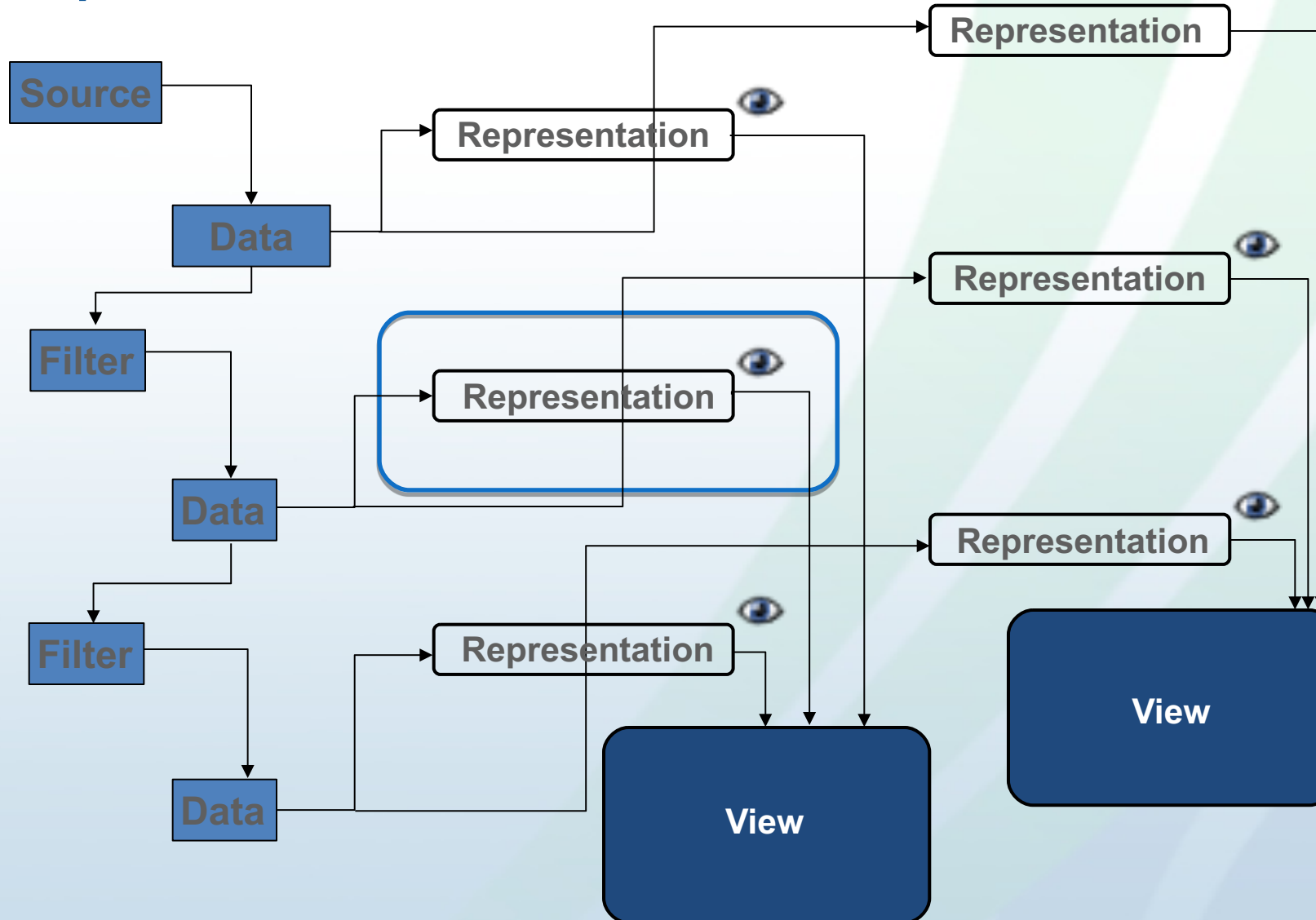
Filter Properties – acts on active filter



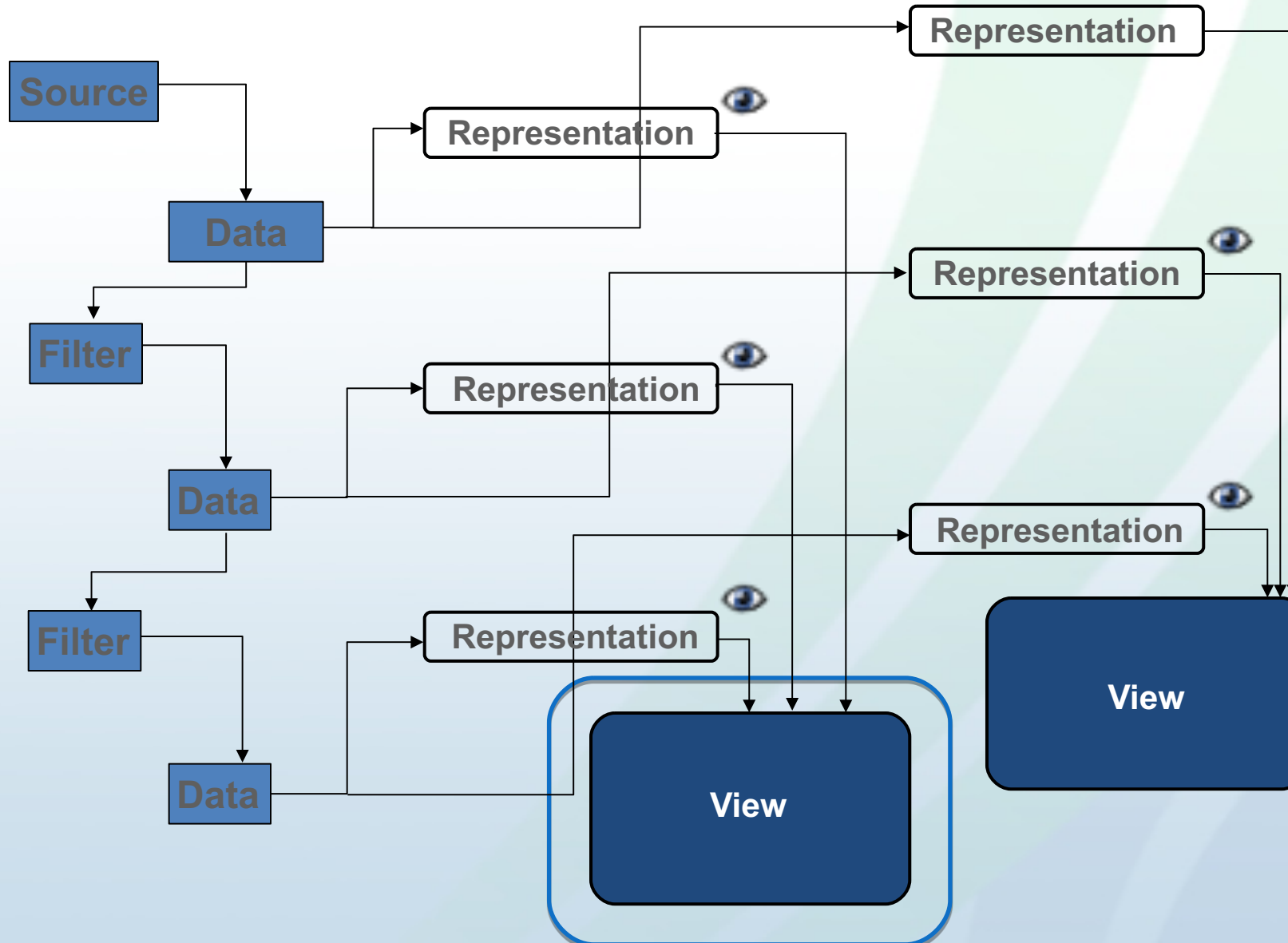
Information Tab – shows output data for the active filter



Display Properties – representation properties for active filter and view



View Properties – acts on active view



Filters

- Filters Menu
 - Recent
 - Common
 - Data Analysis
 - Statistical
 - Temporal
 - Alphabetical
- Quick Launch
 - PC/Linux
 - *CTRL-Space*
 - Mac
 - *ALT-Space*
- Apply Undo/Redo



Calculator



Glyph



Contour



Stream Tracer



Clip



Warp By Vector



Slice



Group Datasets



Threshold



Extract Group



Extract
Subset

Query Data by Attributes Values – Find Data Dialog

The screenshot shows the 'Find Data' dialog box in a software application. The dialog is titled 'Find Data' and has a 'Create Selection' section. In this section, the 'Find' dropdown is set to 'Cell(s)', the 'from' dropdown is set to 'can.ex2', and the 'EQPS' dropdown is set to 'is >= 1.5'. Below this, there is a 'Block ID' dropdown set to 'is' and a 'Run Selection Query' button. The 'Current Selection (can.ex2 : 0)' section shows a table of results. The table has columns for Block Number, Cell ID, Cell Type, EQPS, and Global ID. The table contains three rows of data. Below the table, there is a 'Selection Display Properties' section with a 'Selection Color' dropdown set to 'Cell Labels', a 'Point Labels' dropdown, and buttons for 'Freeze Selection', 'Extract Selection', 'Plot Selection Over Time', and 'Close'. The background of the application shows a 3D surface plot with a color scale for EQPS values ranging from 0.000e+00 to 2.894e+00. The surface plot is titled 'RenderView1'.

	Block Number	Cell ID	Cell Type	EQPS	Global ID
0	2	35	Hexahedron	1.97048	36
1	2	36	Hexahedron	1.51309	37
2	2	75	Hexahedron	2.13094	76

Query Data Visually - Selection

- Visually select interesting data shown in all compatible views can then label, extract etc



- ‘Select Cells On’ to get nearest cells



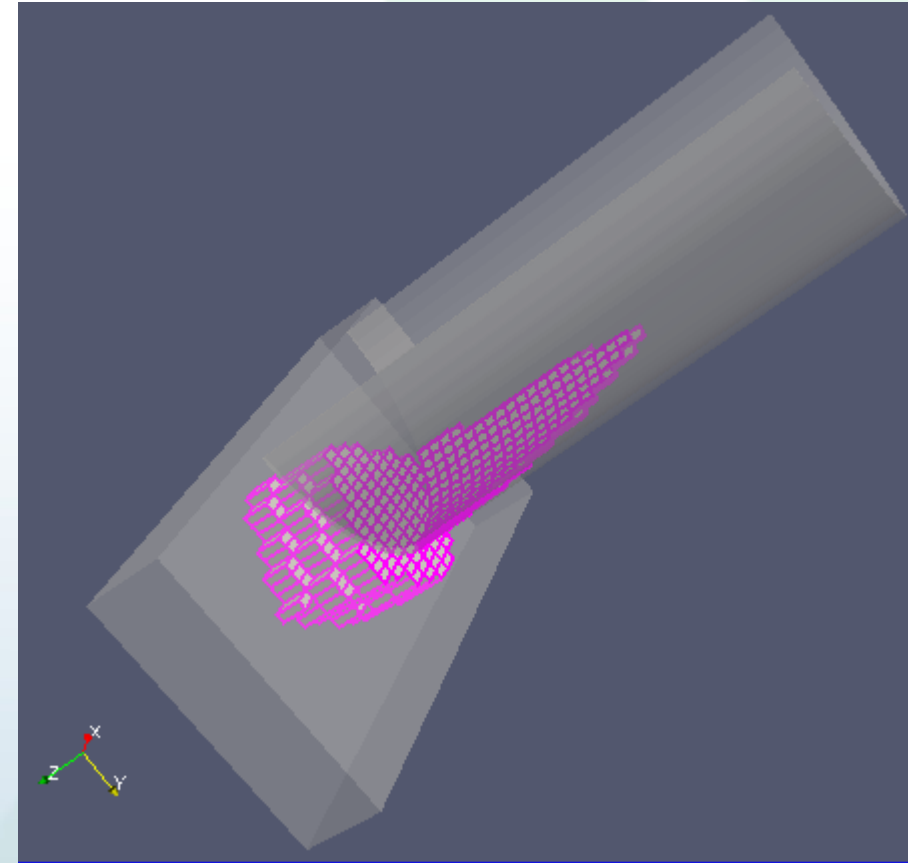
- Select Points On’ to get nearest points



- ‘Select Cells Through’ to get all cells intersecting a frustum

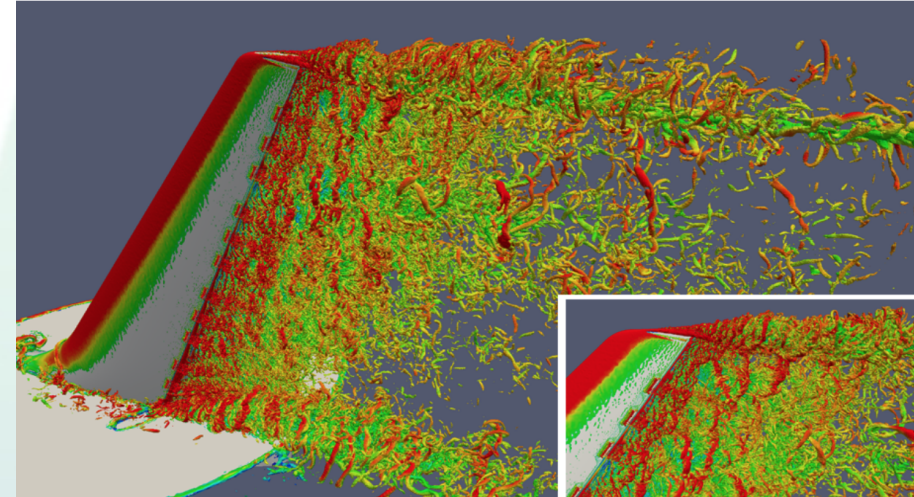


- ‘Select Points Through’ for selecting points inside a frustum
- Select Points/Cells With Polygon
- Select Block
- Interactive Select Point/Cells
- Hover Points/Cells



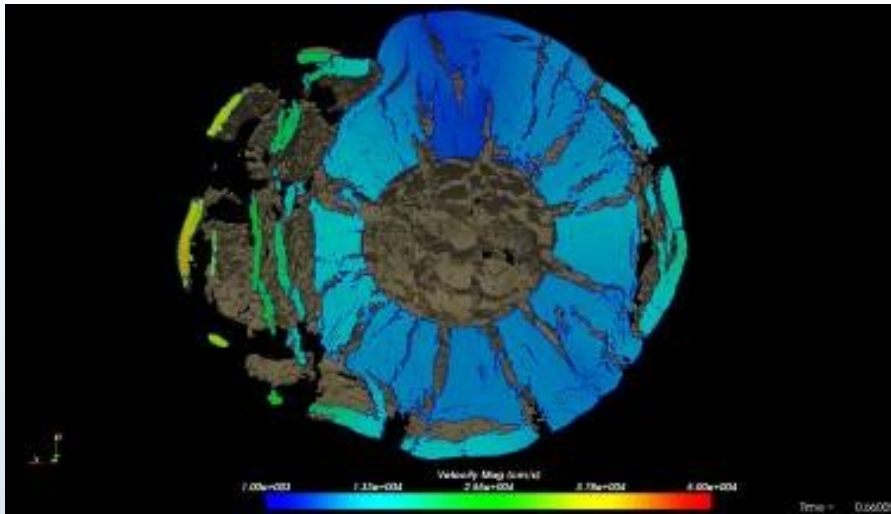
Exporting data, images, state

- File → Save *
 - Active filter's **data**, prompted for file format
 - List of file formats given in help primarily kitware
 - formats + exodus, ensight, xdmf/hdf5, csv
 - **Screenshot** (image)
 - In a format for **high quality rendering**
 - eps, pdf, ps, svg, pov, vrml, webgl, x3d, x3db
 - **Movie**
 - Image sequence, avi, ogg, ffmpeg → avi
 - **State**
 - for restoring ParaView state later

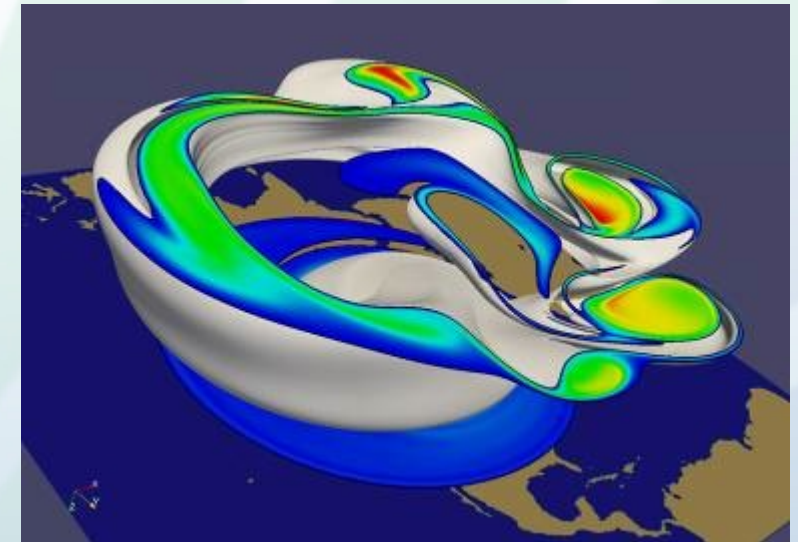


In-situ vis. 1.3 billion cells, 256K MPI processes, Image courtesy of Michel Rasquin, ANL

Large Data processed by ParaView

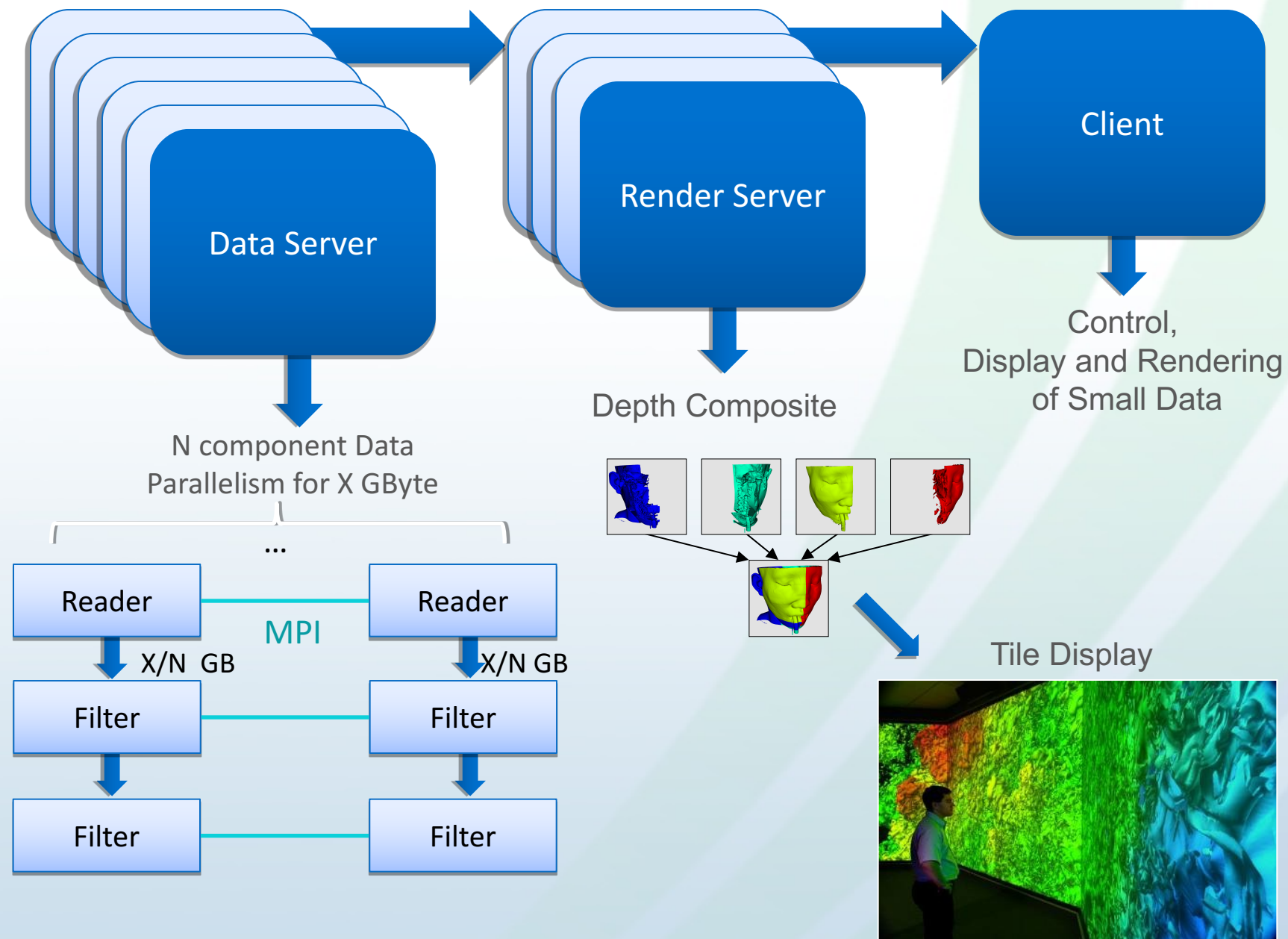


1 billion cell asteroid
detonation simulation






1 billion cell
weather simulation

source: Sandia National Lab



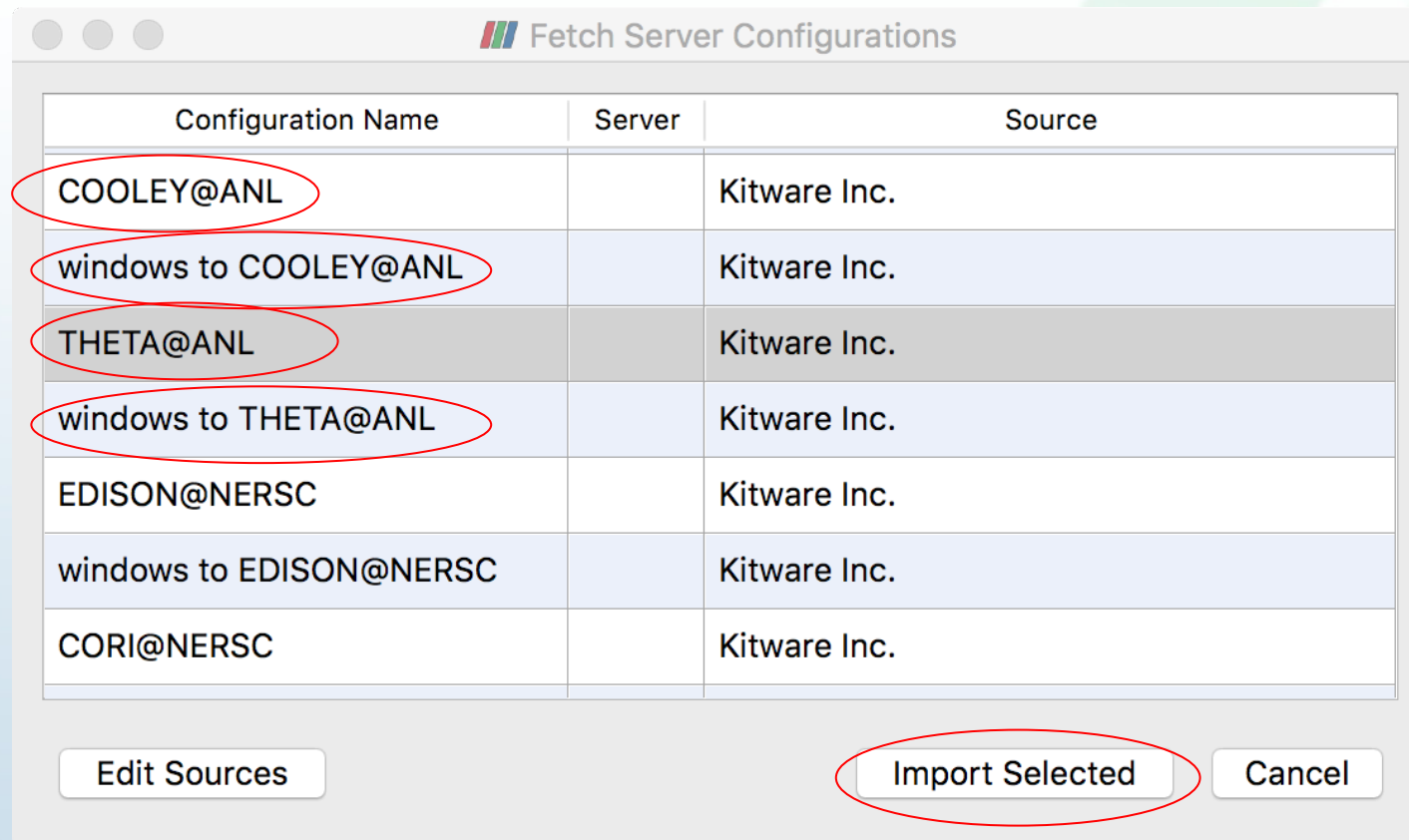
ParaView's Running Modes

Builtin aka Standalone aka Serial		all components within one process (client may be GUI or pvpython) <code>paraview pvpython</code>
Combined Server		data processing and parallel rendering in MPI job of combined processes. control from TCP connected client. <code>mpiexec -n x pvserver & paraview #</code> <code>or pvpython #+ Connect</code>
Batch		server is an MPI job which directly runs a python script <code>mpiexec -n x pvbatch \</code> <code>vis_script.py</code>

DS = data server
RS = render server

Fetch Server Configuration

- File > Connect > Fetch Servers



Connect

Mac Os: Install Xquartz

Connection Options for "COOLEY@ANL"

Xterm executable	/opt/X11/bin/xterm	...
SSH executable	ssh	...
Remote machine	cooley.alcf.anl.gov	
Username	danlipsa	
ParaView version	v5.4.0	
Client port	11111	^v
Server port	42844	^v
Number of nodes to reserve	2	^v
Number of minutes to reserve	10	^v
Account	ATPESC2017	
Queue	training	
Job name	paraview_server	

Cancel OK

Connect

Windows: Install PuTTY

Connection Options for "windows to COOLEY..."

SSH executable ...

Remote machine

Username

ParaView version

Client port

Server port

Number of nodes to reserve

Number of minutes to reserve

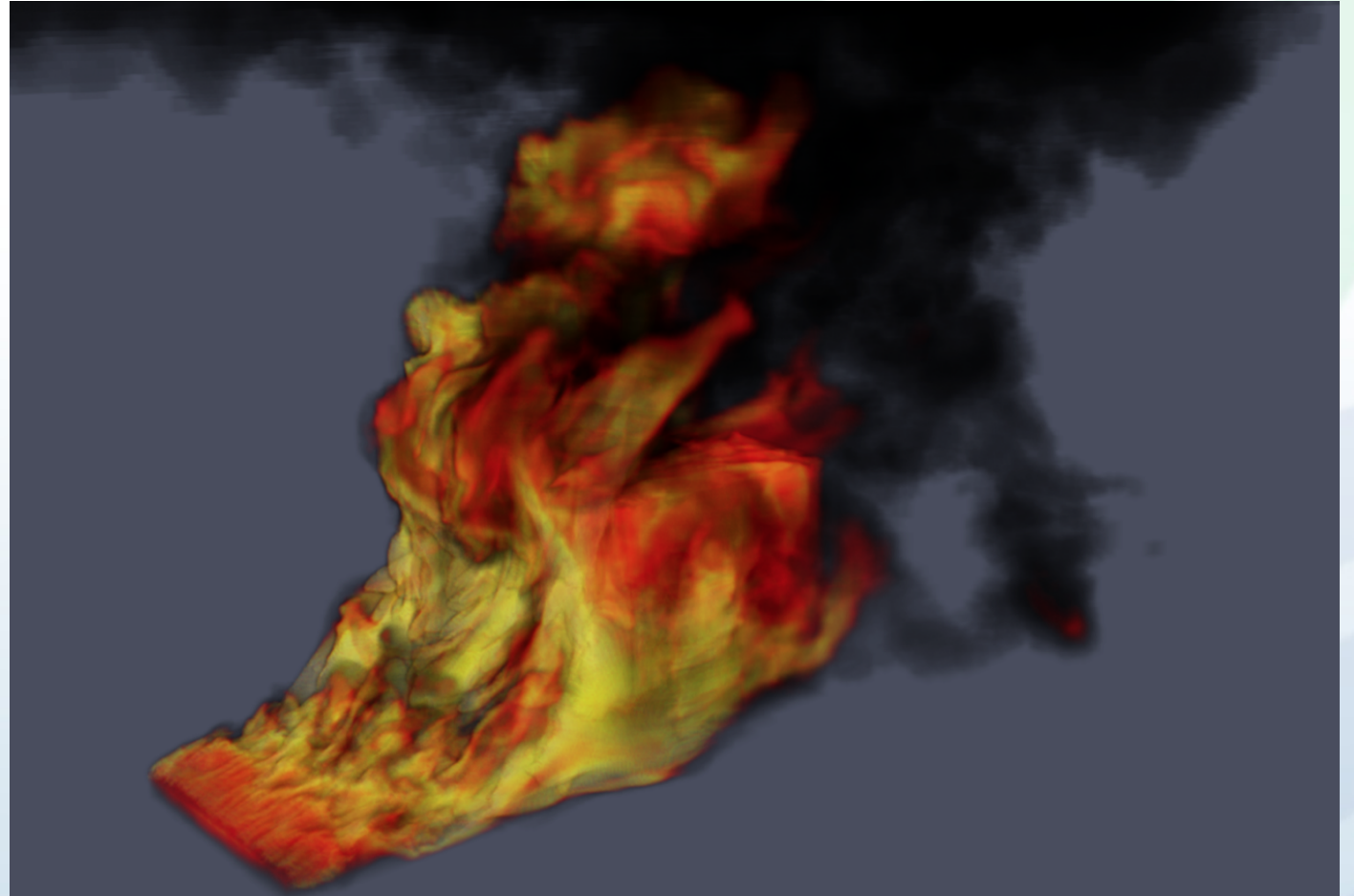
Account

Queue

Job name

ParaView Tutorial

Help > ParaView Tutorial
Exercises 2.1 – 2.36



Syrinx-Calore simulation with 10 million unstructured hexahedra cells. ParaView Tutorial.