

# Introduction to ParaView

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# Contents

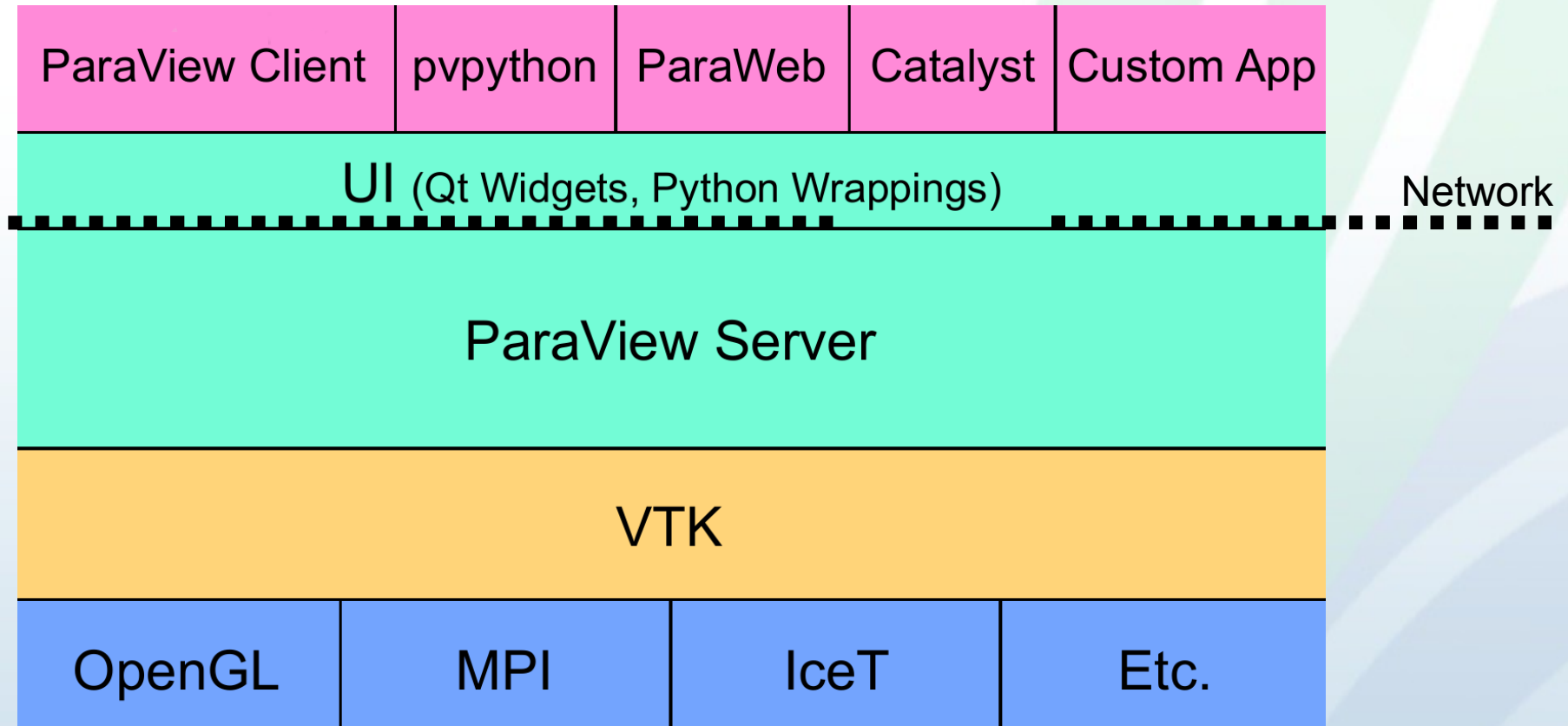
- ParaView description, architecture and history
- User interface: the Pipeline Browser and the Object Inspector. ParaView objects: Filters, Representations and Views. Finding Data and Selection.
- Running ParaView in parallel.
- Hands-on practice: vector visualization, data analysis

# What is ParaView?

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

- **Application** - you don't have to write any code to analyze your data
- **Architecture** - designed to be extensible if you want to code  
Custom apps, plugins, python scripting, Catalyst, ParaViewWeb
- **Open-source** – BSD 3-clause license
- **Display** - excels at traditional scientific vis qualitative 3D rendering
- **Analysis** - data drill down through charts, stats, all the way to values
- **ParaView** – parallel - scales from notebooks to world's largest supercomputers

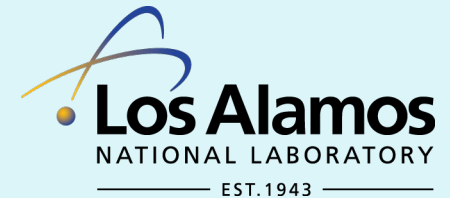
# ParaView Architecture



# History

[http://www.paraview.org/Wiki/ParaView\\_Release\\_Notes](http://www.paraview.org/Wiki/ParaView_Release_Notes)

- 1999 LANL/Kitware project (via ASCII Views)
  - Build an end user tool from VTK (TCL-TK interface)
  - Make VTK scale
  - October 2002 first public release, version 0.6
- 2002-2005 Versions 0.6 through 2.6
  - Continued growth under DOE Tri Labs, Army Research Lab and various other partnerships
- September 2005 ParaQ project started
  - Sandia, Kitware and CSimSoft
  - Make ParaView easier to use (Qt interface)
  - Add quantitative analysis
  - May 2007 version 3.0 released
- Continuing to evolve
  - 3.2, 3.4, 3.6, 3.8, 3.10, 3.12, 3.14, 3.98
  - 4.0.1, 4.1, 4.2, 4.3.1 (January 2015)



# User Interface

Menu Bar

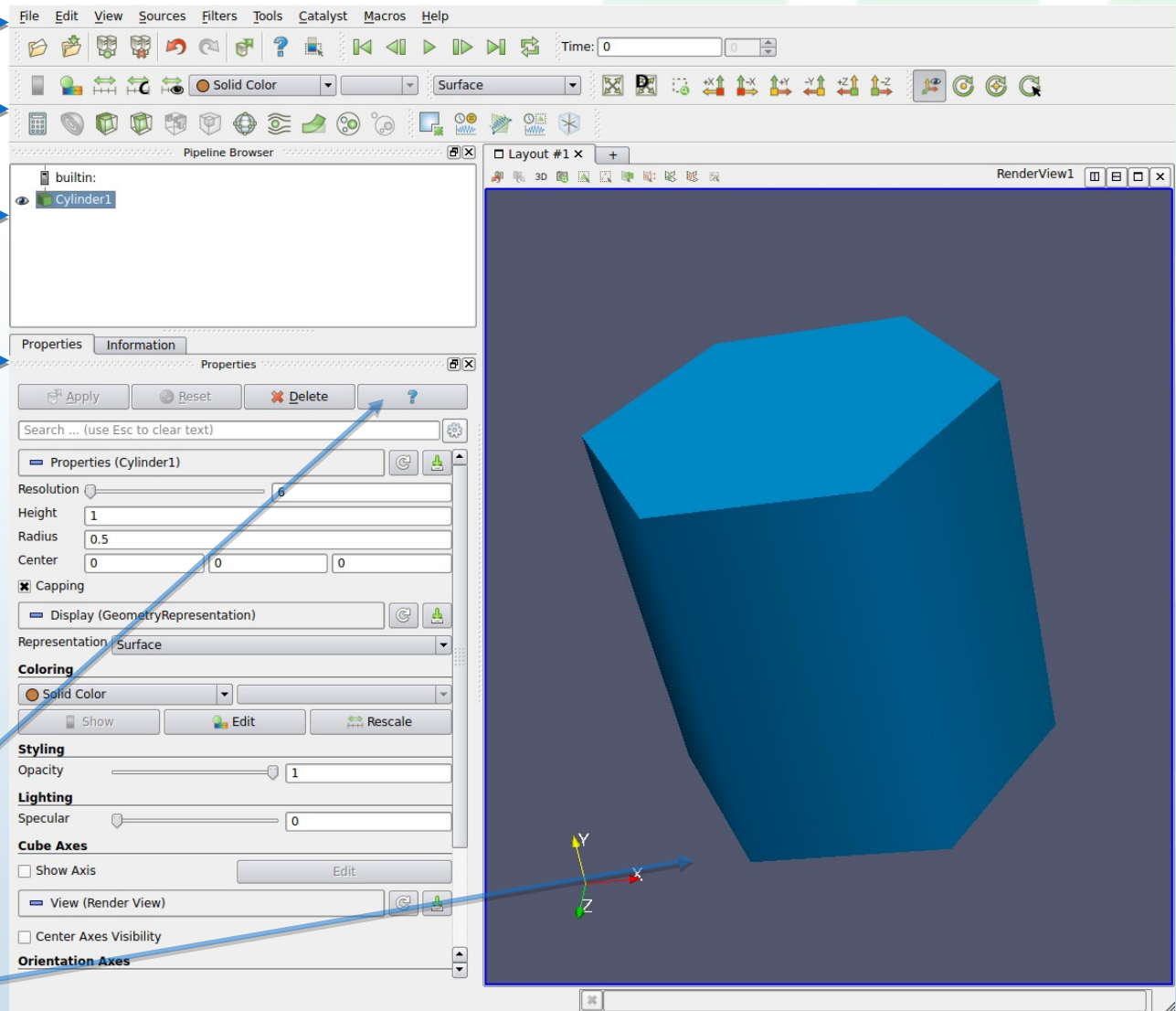
Toolbars

Pipeline Browser

Object Inspector  
Properties  
Properties  
Display  
View  
Information

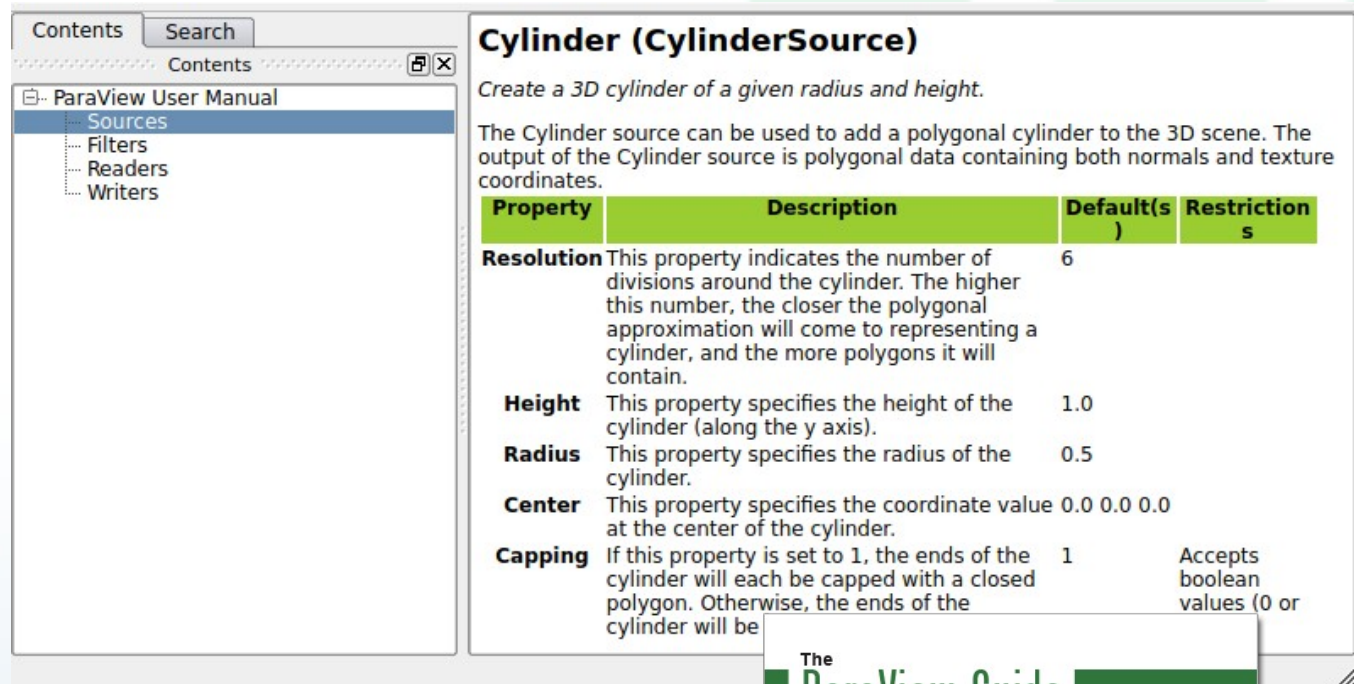
Online help

View(s)



# Help

- Online help



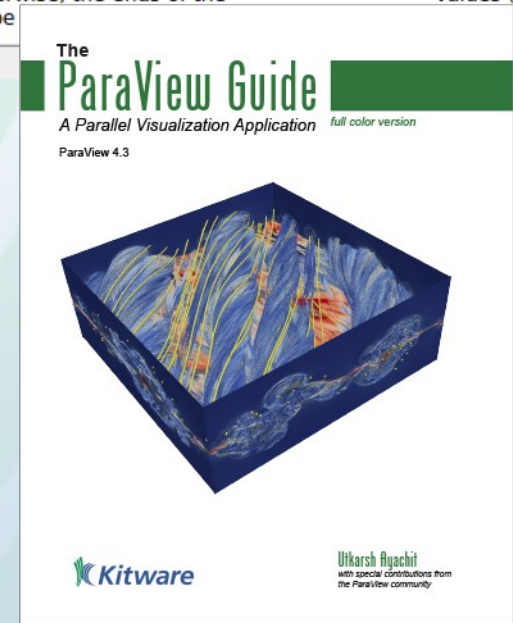
The screenshot shows the ParaView User Manual interface. On the left, a 'Contents' pane lists 'Sources', 'Filters', 'Readers', and 'Writers'. The 'Cylinder (CylinderSource)' section is selected. The main pane displays the title 'Cylinder (CylinderSource)', a brief description 'Create a 3D cylinder of a given radius and height.', and a table of properties.

**Cylinder (CylinderSource)**  
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
<b>Resolution</b>	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	
<b>Height</b>	This property specifies the height of the cylinder (along the y axis).	1.0	
<b>Radius</b>	This property specifies the radius of the cylinder.	0.5	
<b>Center</b>	This property specifies the coordinate value at the center of the cylinder.	0.0 0.0 0.0	
<b>Capping</b>	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 1)

- The ParaView Guide (262 pages)
- The ParaView Tutorial
- ParaView Mailing Lists
- ParaView Wiki
- <http://www.paraview.org/documentation/>





# How to Use ParaView

1. Read in data: File → Open, hit **Apply**
  - Over 100 file formats supported
  - Help/Readers - readers compiled in
2. Add a filter to process data:
  - Tune filter properties, hit **Apply**
  - Repeat Step 2 as needed
3. Tune Display (for all Filter, View pairs) and View (for all Views) parameters
4. Save datasets, rendered results (screenshot or animation) or application state

Edit → Undo



**Filter** = an object that operates on data: reads its inputs and produces one or more outputs

**Reader** = reads a file and produces an output

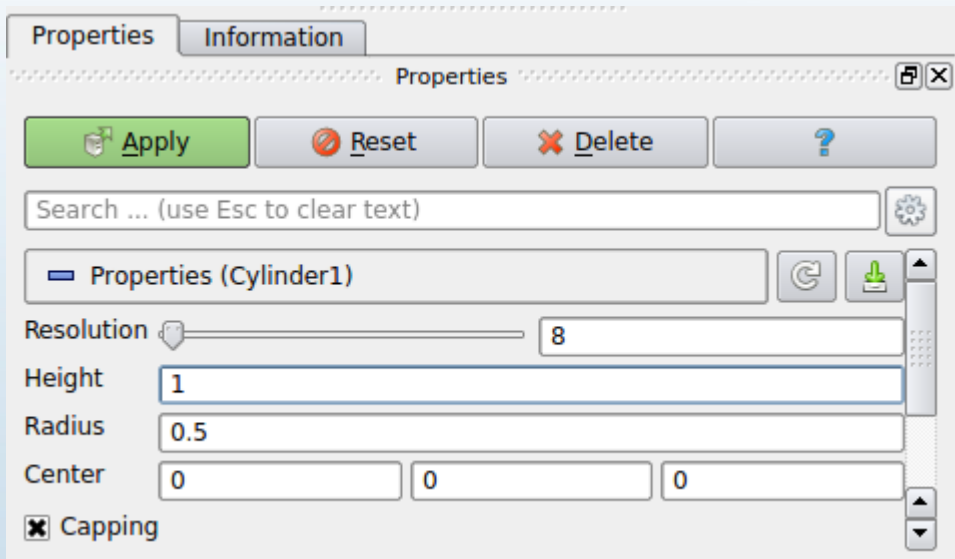
**Source** = produces an output (Cylinder)

**Pipeline object** = a filter, reader or source

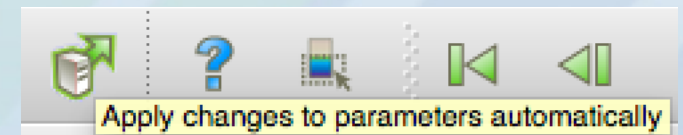


# Filter Properties and the Apply Button

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

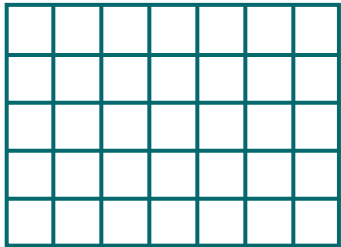


Toggle auto  
apply

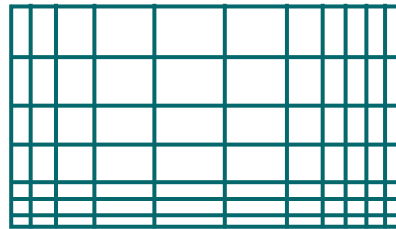


# ParaView Dataset Types

**vtkImageData**



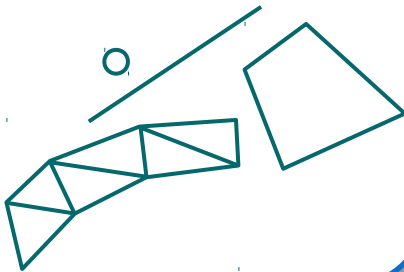
**vtkRectilinearGrid**



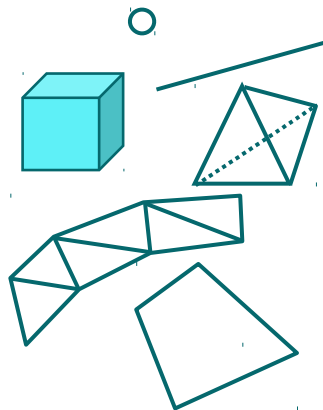
**vtkStructuredGrid**



**vtkPolyData**



**vtkUnstructuredGrid**



Multi-blocks

AMR

Time-varying  
data

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

# 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

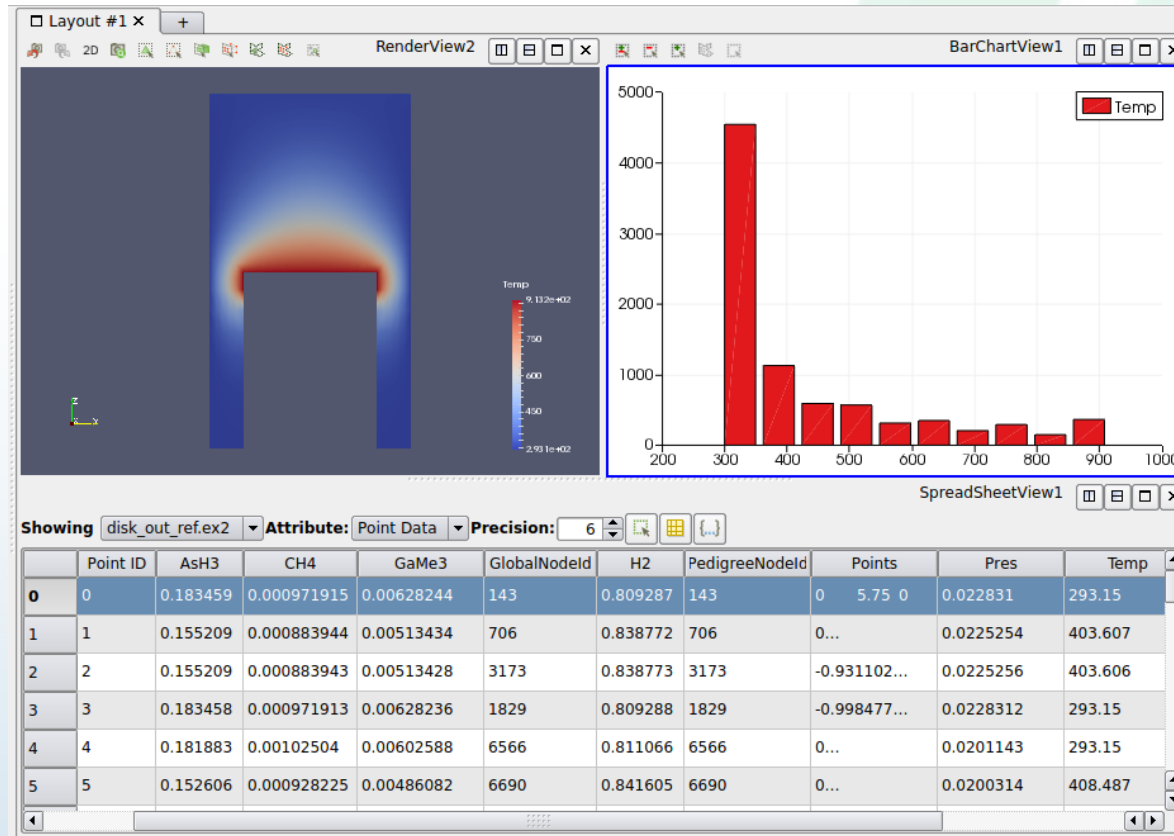
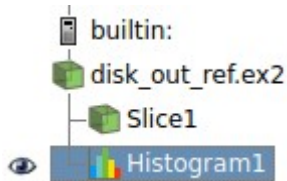
The screenshot shows the 'Information' tab of the Object Inspector. It displays the following sections:

- Data Hierarchy:** A tree view showing the dataset structure. The 'Multi-block Dataset' is expanded, showing 'Element Blocks' (containing 'Unnamed block ID: 1 Type: HEX' and 'Unnamed block ID: 2 Type: HEX'), 'Face Blocks', 'Edge Blocks', 'Element Sets', 'Side Sets', 'Face Sets', and 'Edge Sets'.
- Statistics:** A summary of the dataset's properties.
  - Type: Unstructured Grid
  - Number of Cells: 4800
  - Number of Points: 6724
  - Memory: 1.4 MB
- Data Arrays:** A table listing the data arrays with their names, data types, and ranges.
- Bounds:** A summary of the spatial bounds of the dataset.
- Time:** A table showing the temporal domain with indices and values.

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]

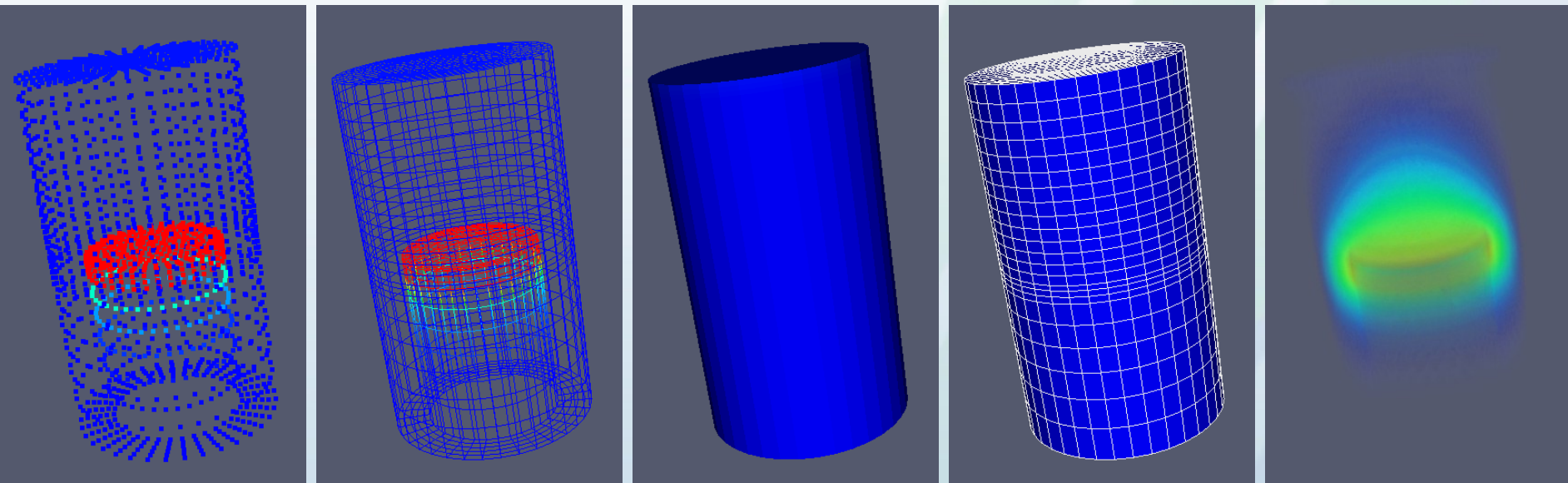
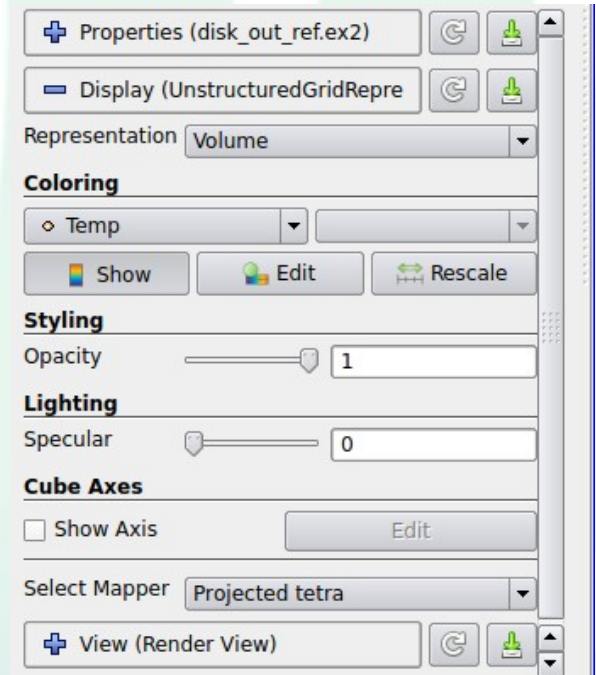
Index	Value
0	0
1	0.000100074
2	0.000199905
3	0.000299964
4	0.000400087
5	0.000499919
6	0.000599935
7	0.000700049
8	0.000800035
9	0.000900061

# Multiple Views



# Display Properties

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



13 Points

Wireframe

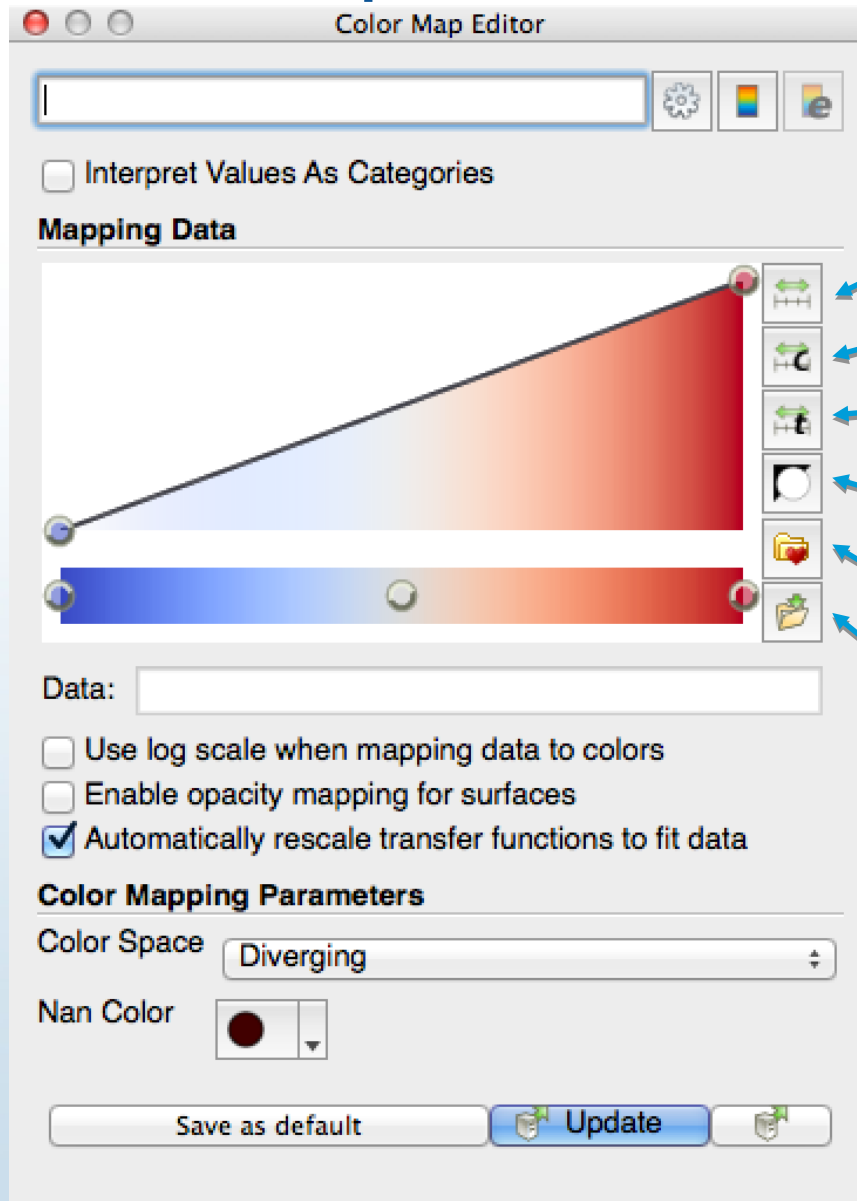
Surface

Surface  
with Edges

Volume  


# Color Map Editor

Mapping  
Scalar Range – Color Palette



Rescale to data  
range

Rescale to custom  
range

Rescale to data  
range over all  
time-steps

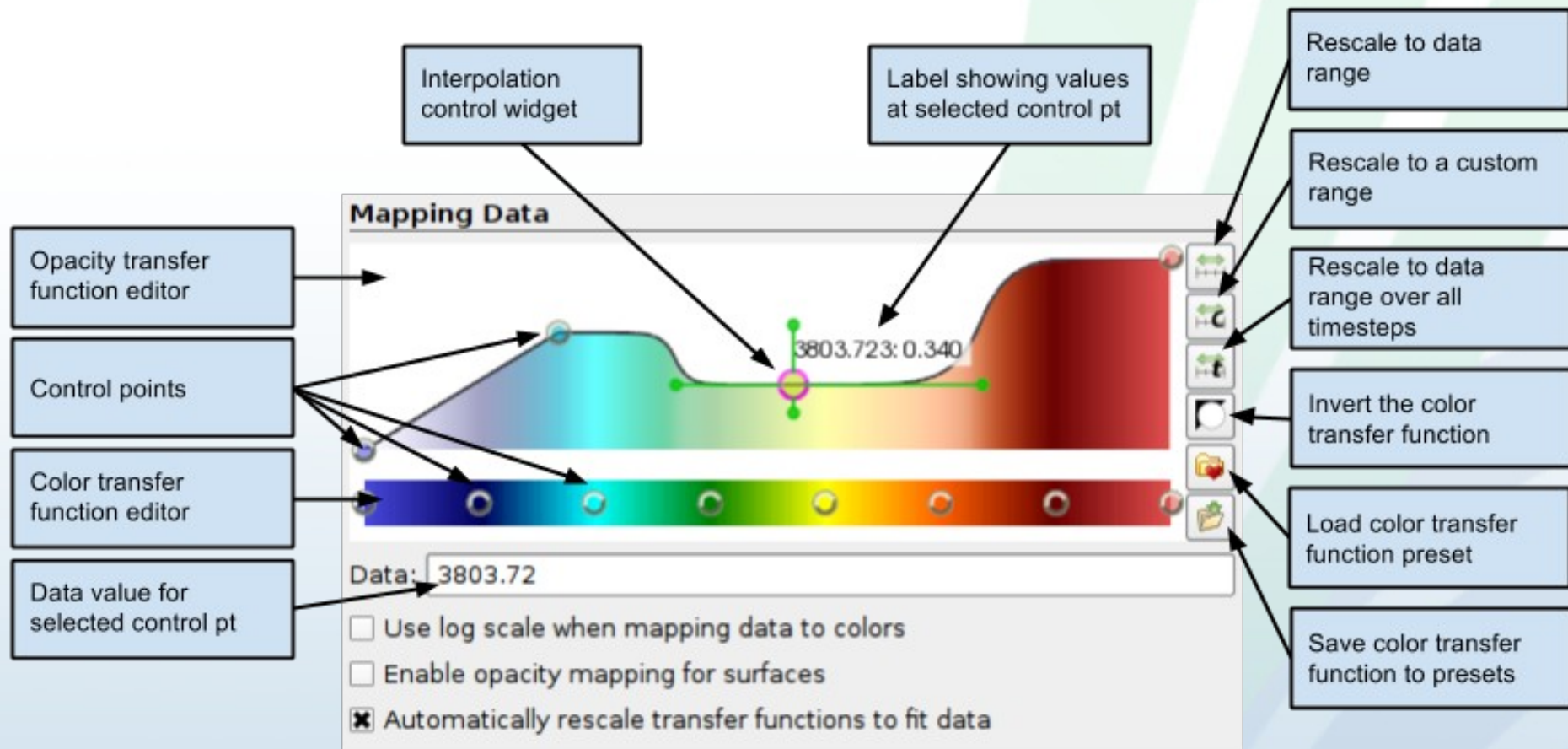
Invert the  
transfer function

Choose preset

Save to preset



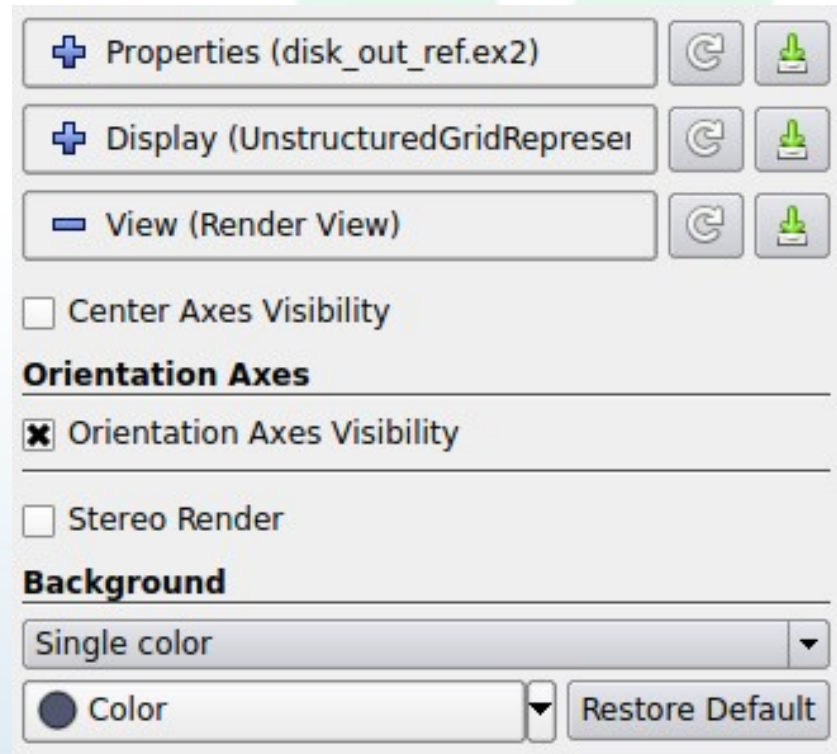
# Color Map (Transfer Function) Editor





# View Properties

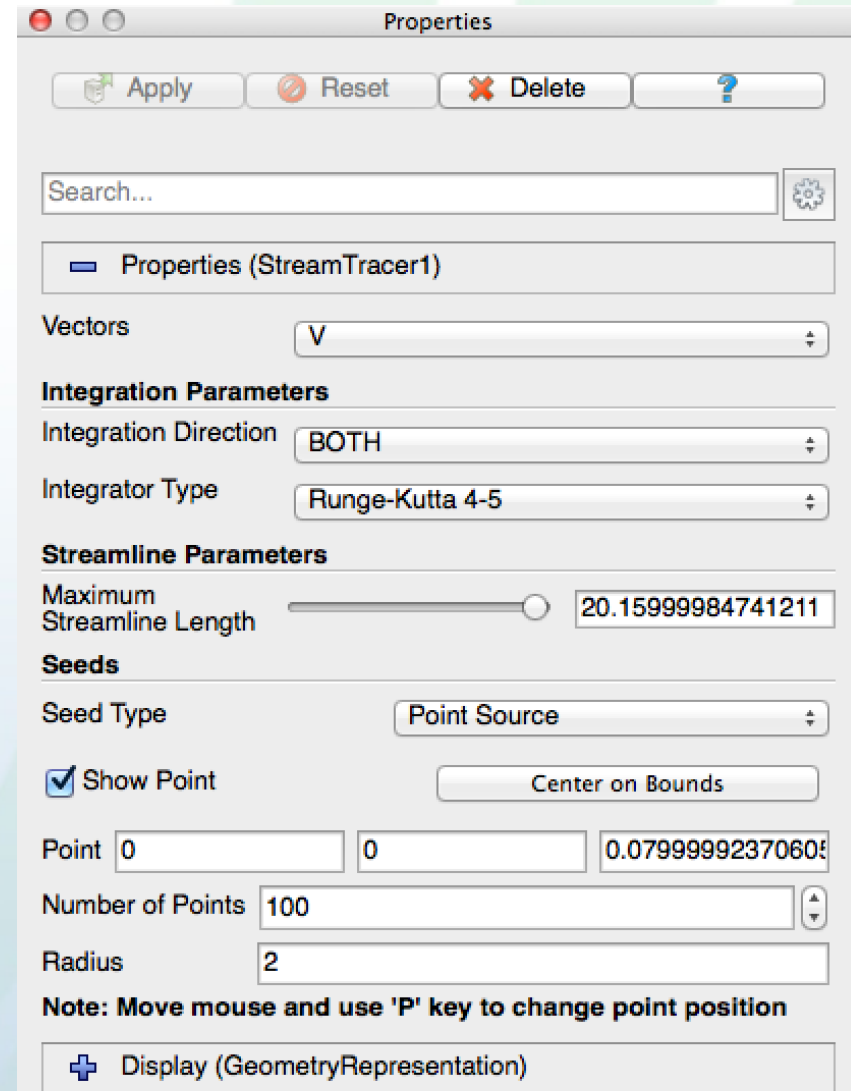
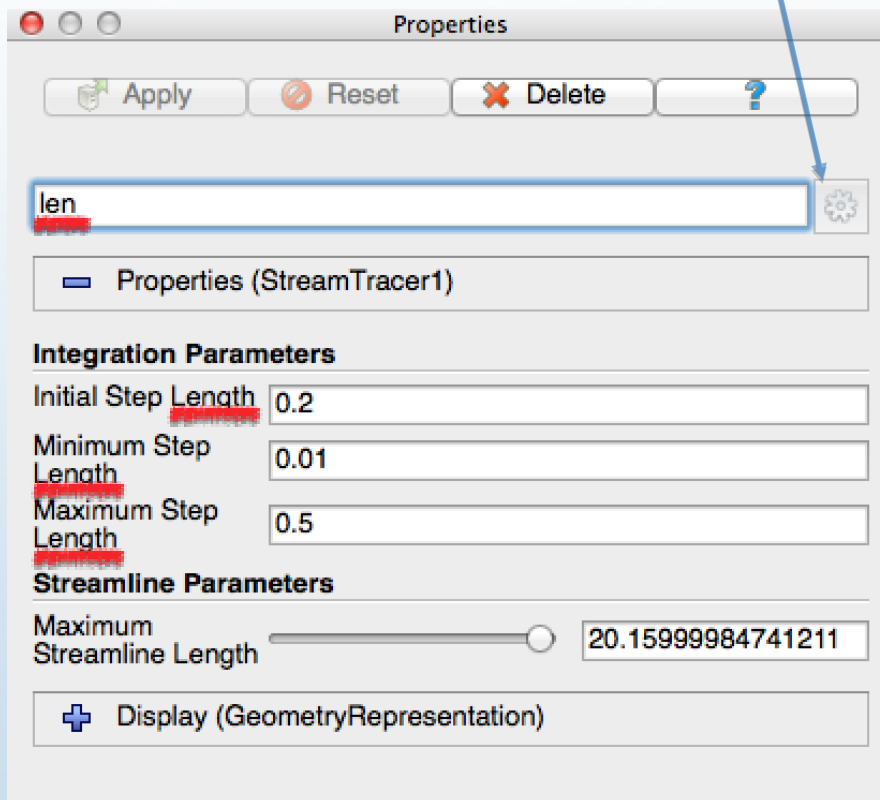
Properties associated with the Active View



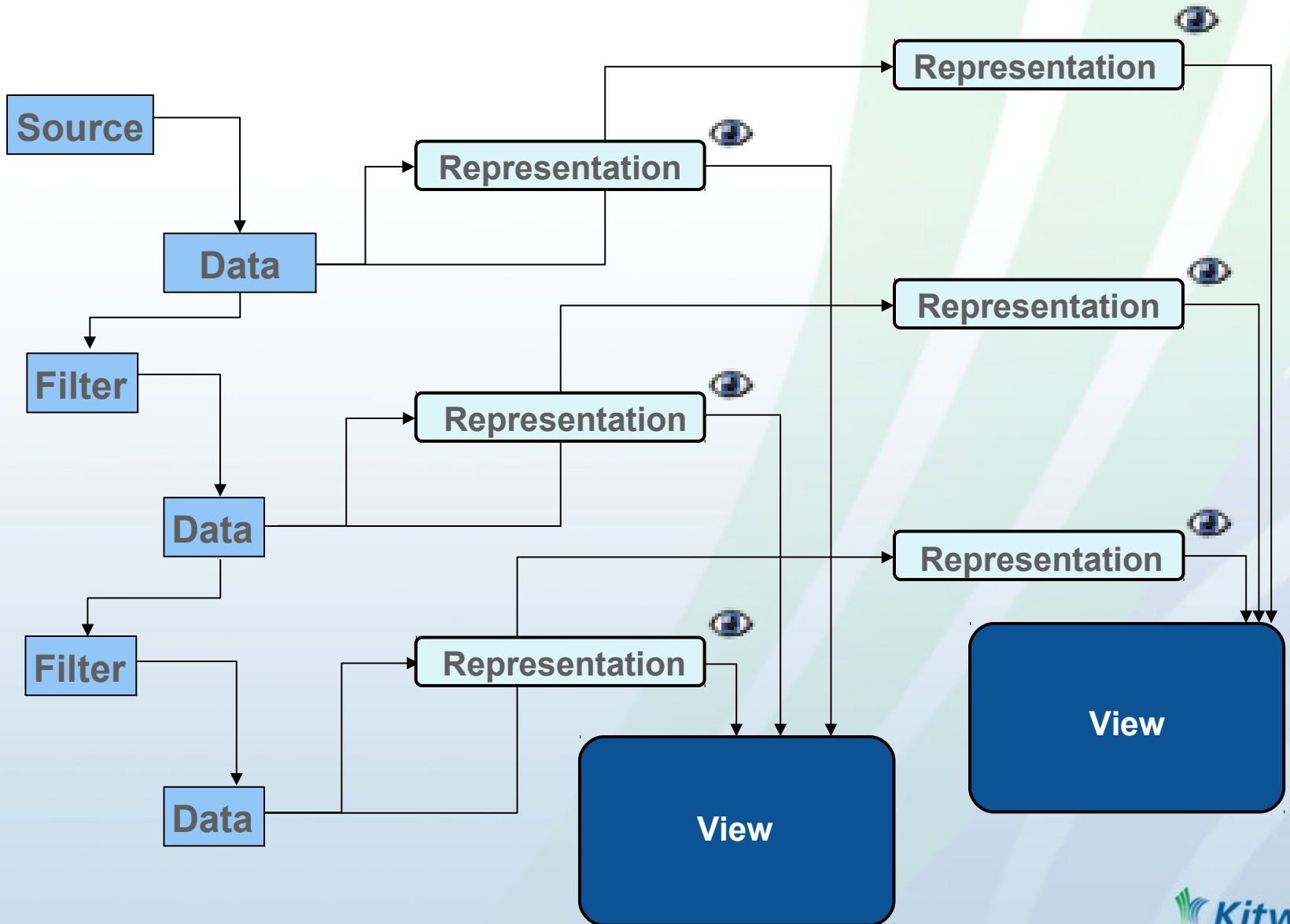
# Find properties (for Filters, Displays and Views)

- Search for properties
- Toggle on/off advanced properties

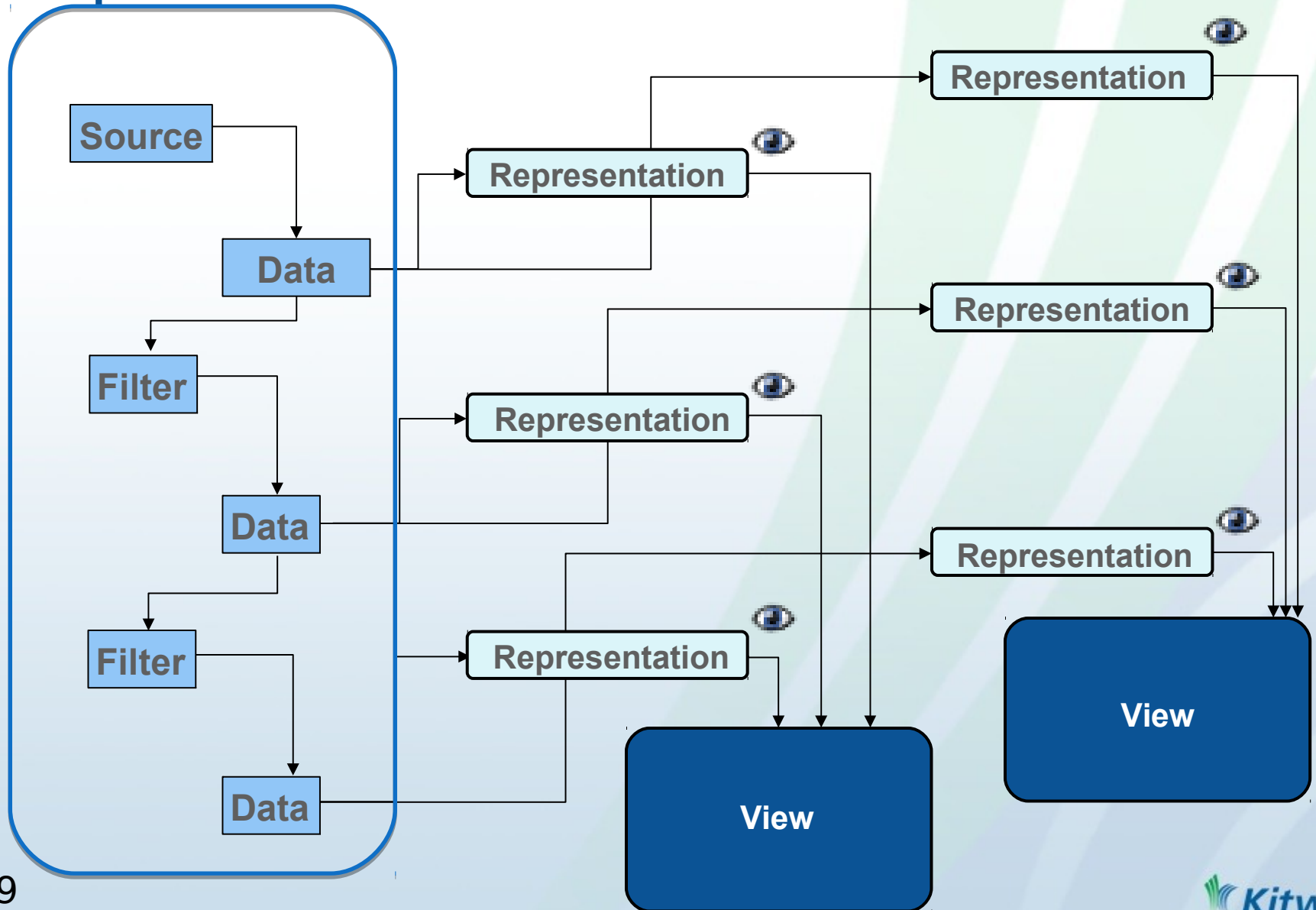
Advanced Properties



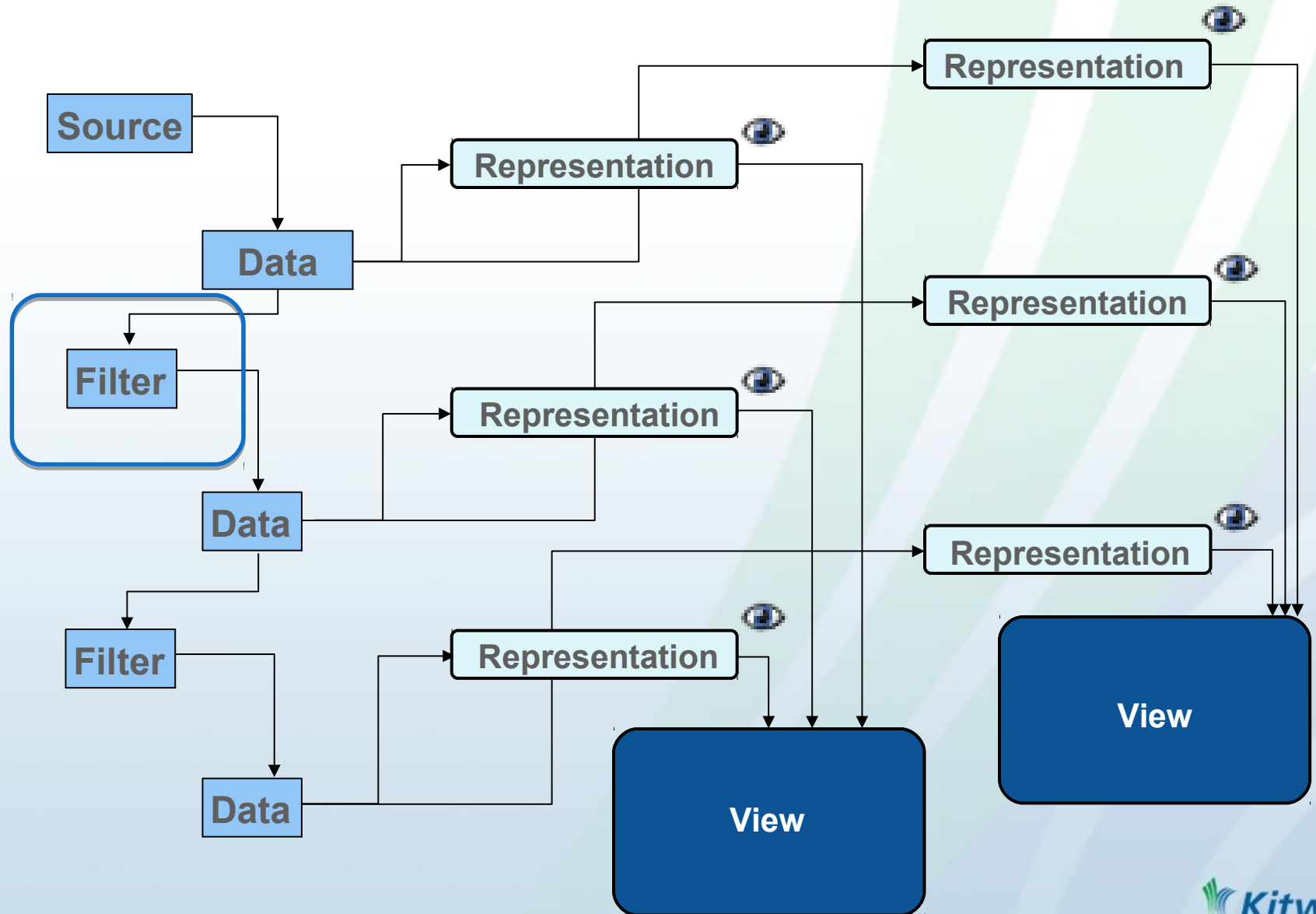
# Multi-View Visualization Pipeline



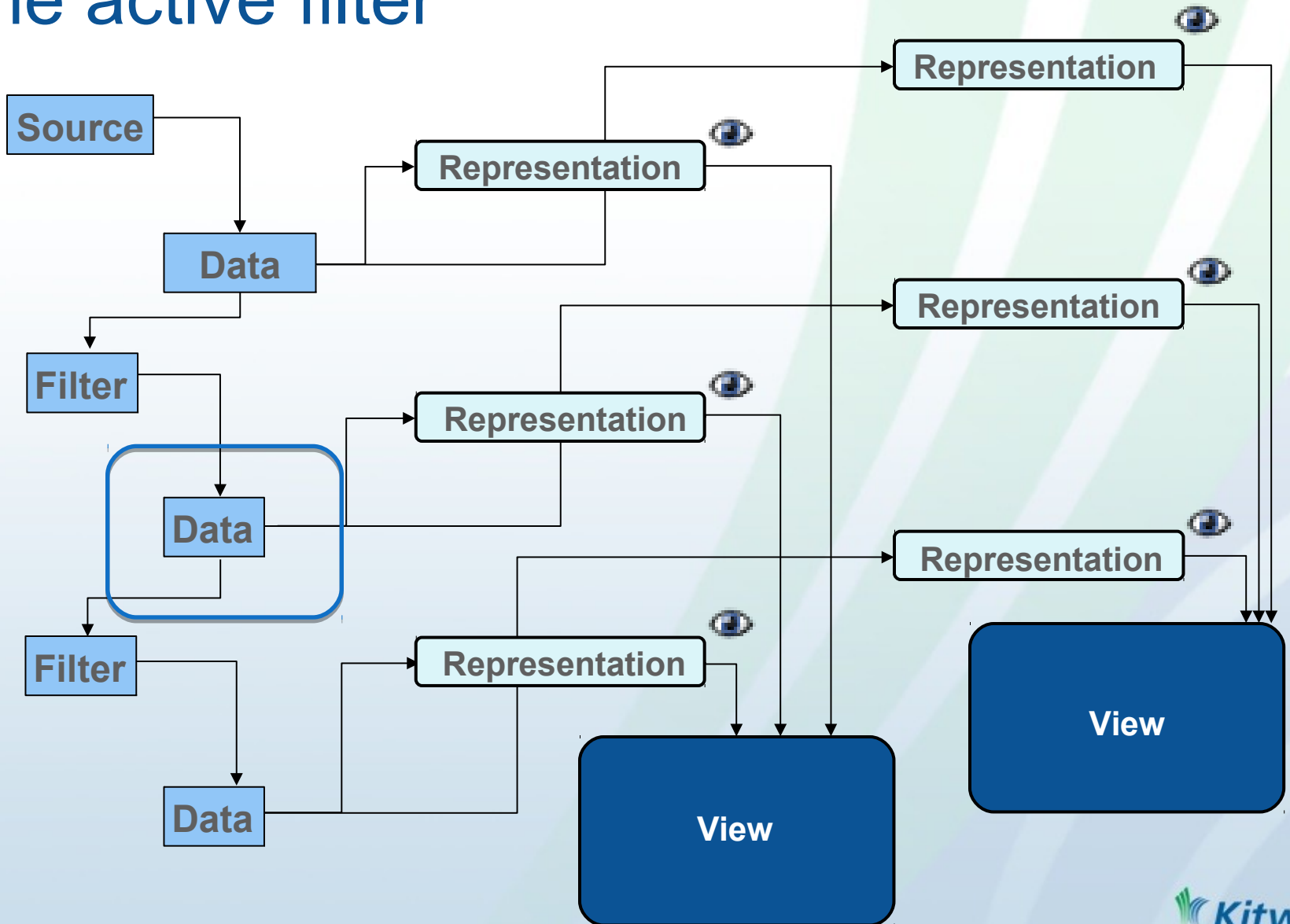
# Pipeline Browser



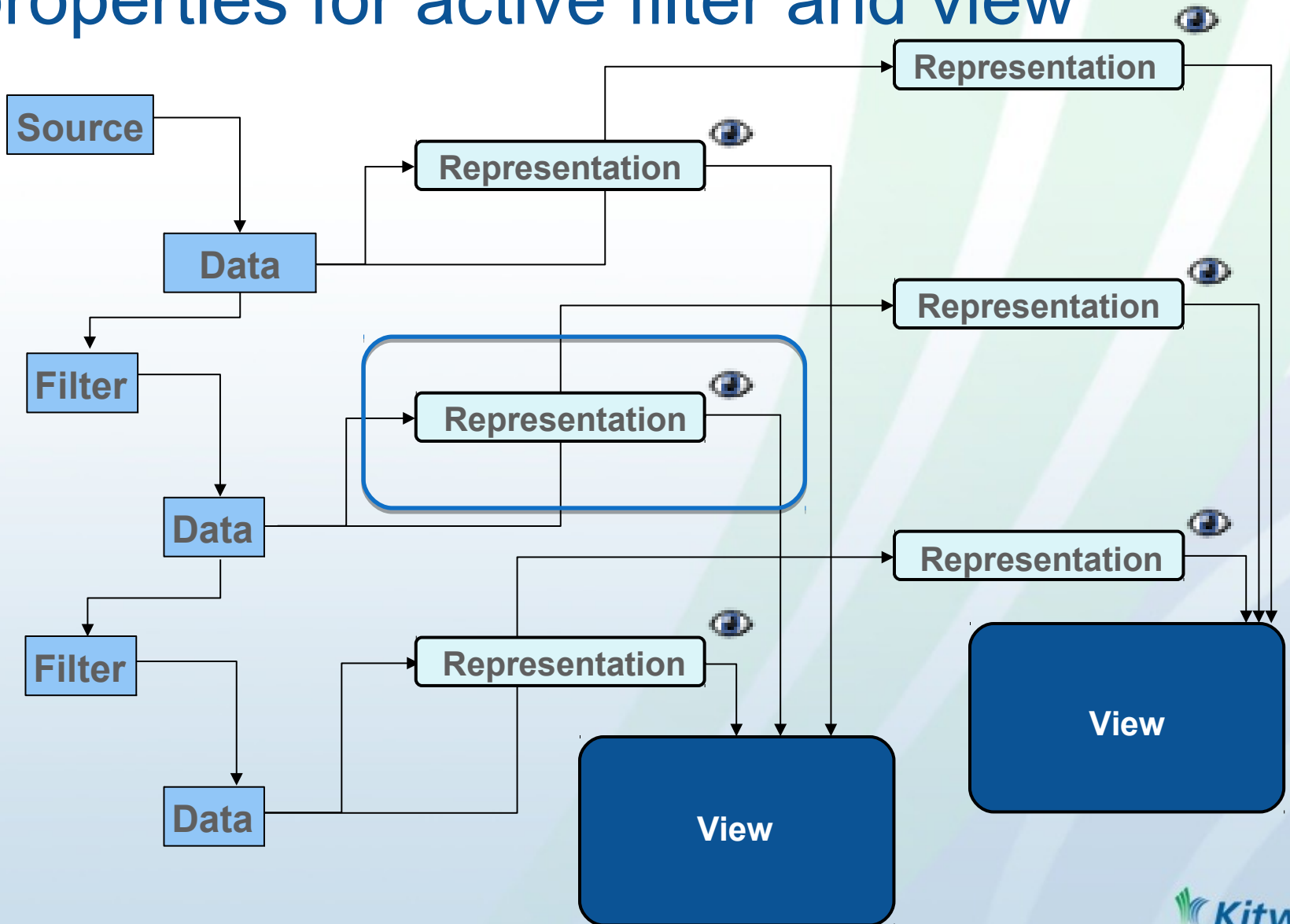
# Filter Properties – acts on active filter



# Information Tab – shows output data for the active filter

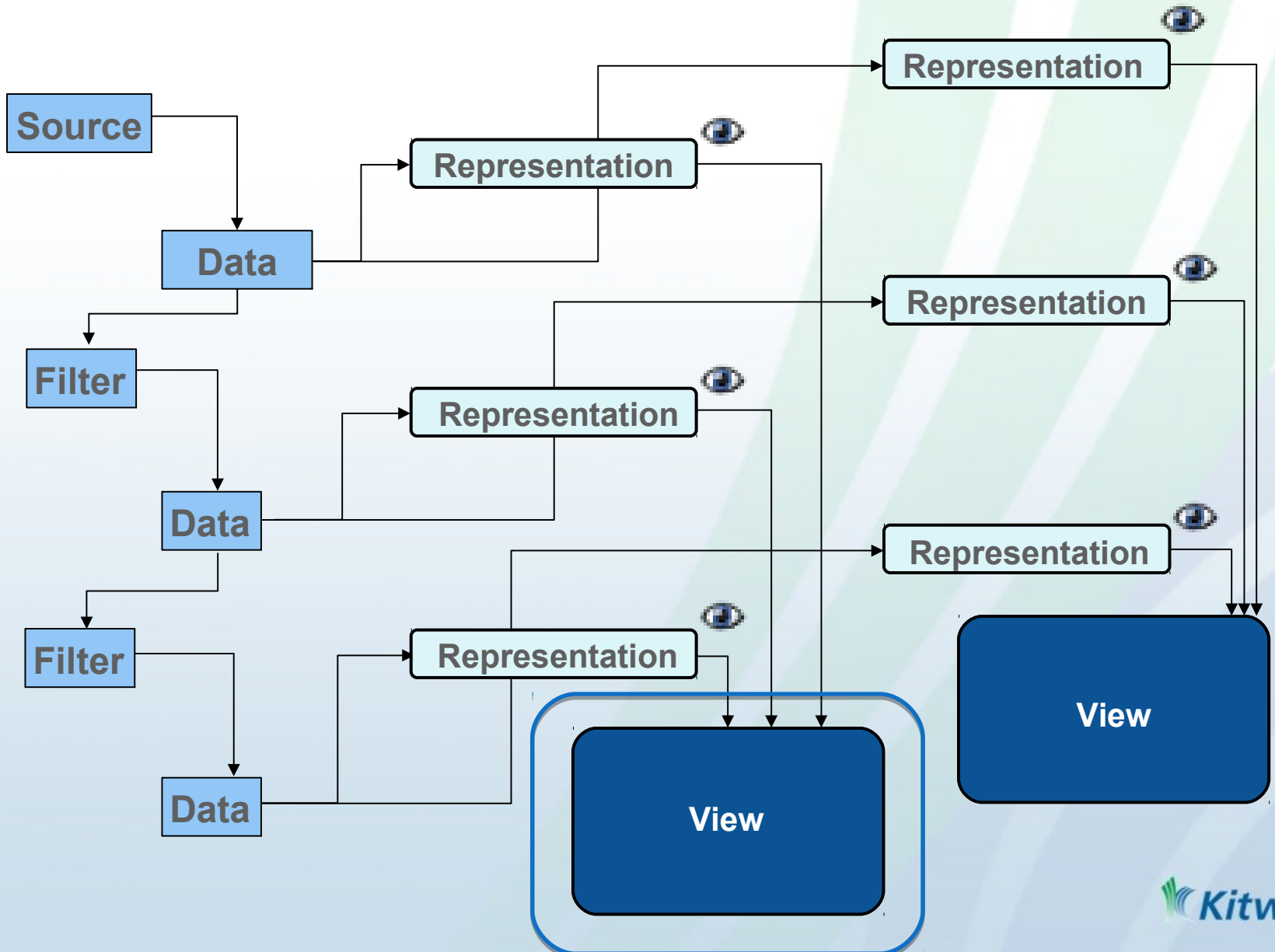


# Display Properties – representation properties for active filter and view





# 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'. There is a 'Block ID' dropdown set to 'is' and a 'Run Selection Query' button. Below this is the 'Current Selection (can.ex2 : 0)' section, which 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. To the right of the table is a 'Selection Display Properties' section with buttons for 'Selection Color', 'Cell Labels', 'Point Labels', 'Freeze Selection', 'Extract Selection', 'Plot Selection Over Time', and 'Close'. The background shows a 3D surface plot with a color scale for EQPS values ranging from -0.000e+00 to 2.894e+00. The plot shows a blue surface with a pink wireframe overlay.

	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



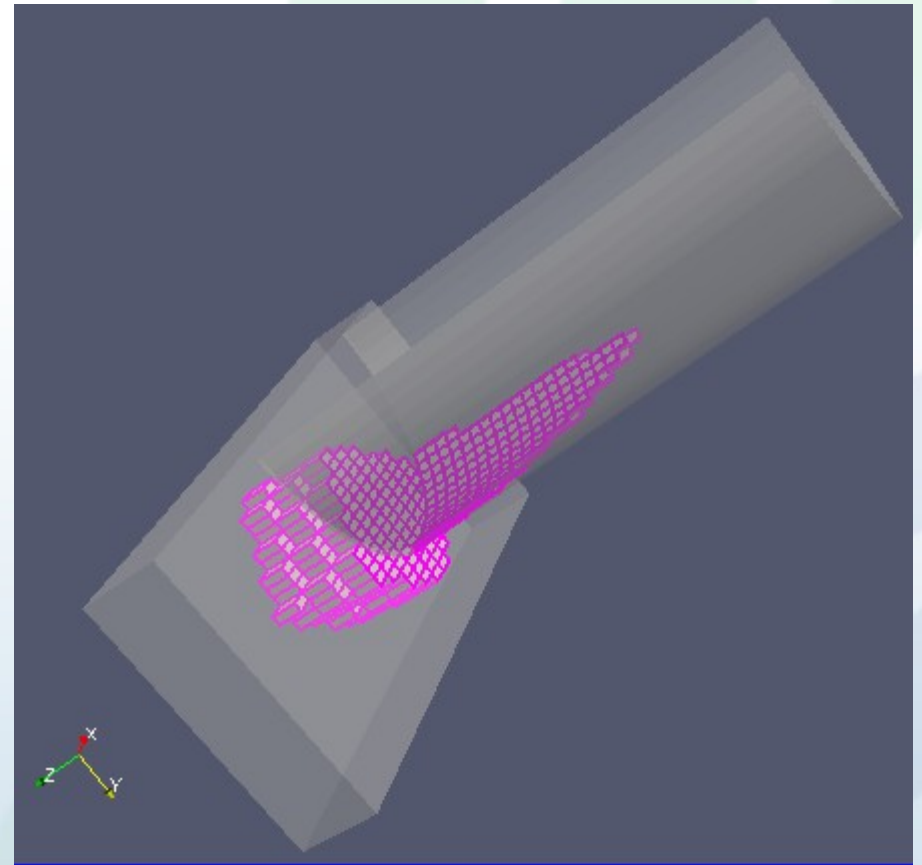
- ‘Select Points On’ to get nearest points



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



- ‘Select Points Through’ for selecting points inside a frustum



# Exporting data, images, sessions

- 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
  - Screen shot, either selected view or all
  - Export visible scene 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 session later

# What to Expect from Parallel Processing

Serial + Parallel = 1 (percentage that you cannot/can parallelize)

- Amdahl's Law

$$\text{Speedup}(\text{CPUs}) = \frac{1}{\text{Serial} + \frac{\text{Parallel}}{\text{CPUs}}}$$

aka Strong scaling

If data size is fixed, don't expect great scalability.

More processors != faster

- Gustafson's Law

$$\text{Speedup}(\text{CPUs}) = \text{CPUs} * \frac{\text{Parallel}}{\text{Parallel} + \text{Serial}}$$

aka Weak scaling

As data size grows, you must have more resources.

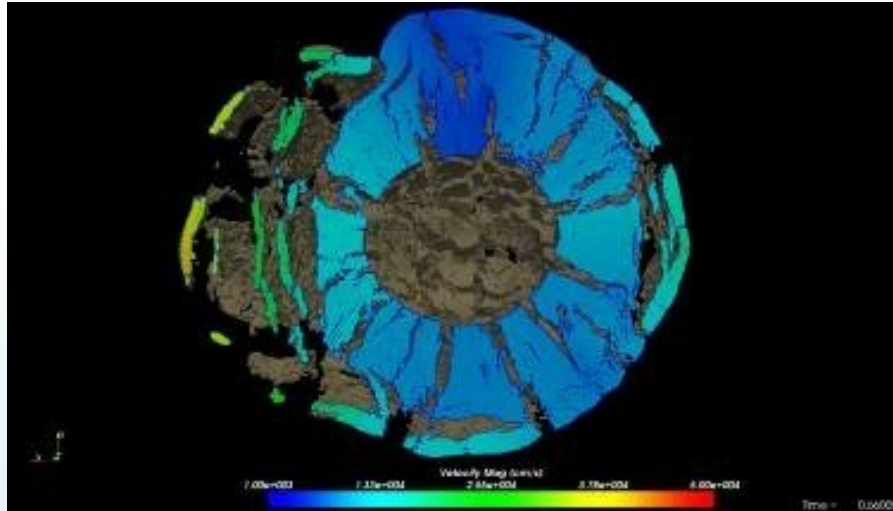
More disk and IO = higher resolution possible

# What to Expect from Parallel Processing

- Parallel  $\neq$  Faster
- Parallel  $\rightarrow$  Larger Problem Size

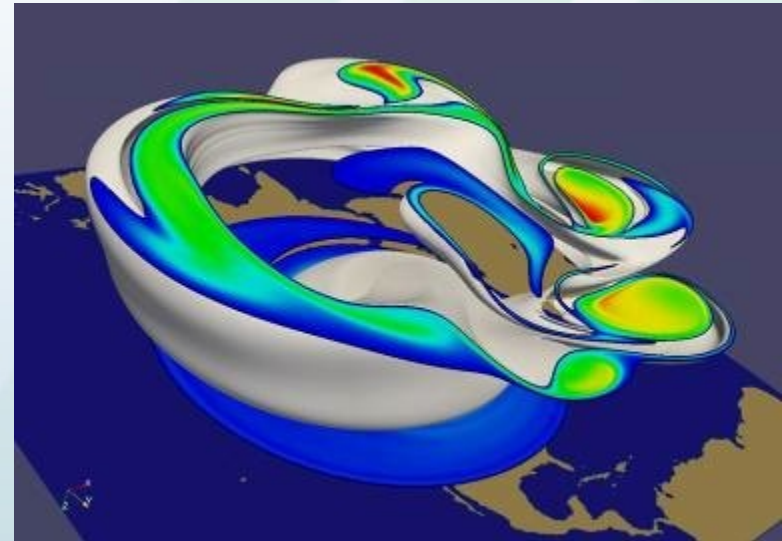


# Large Data processed by ParaView

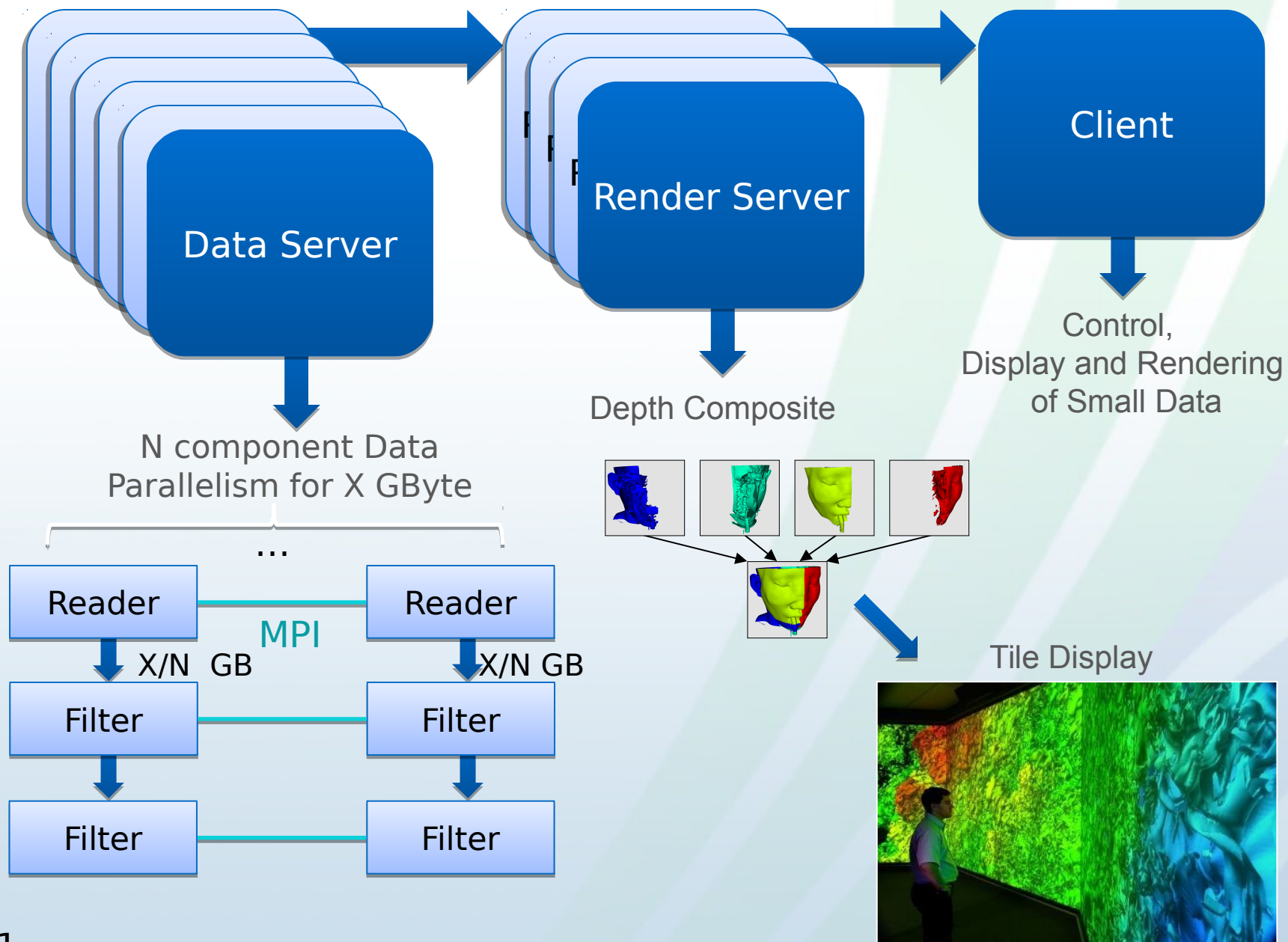


1 billion cell asteroid  
detonation simulation



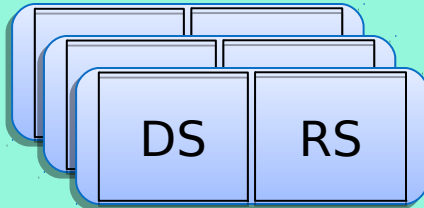
**½ billion cell  
weather  
simulation**



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 &amp;;</code> <code>paraview # 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

# Connecting to a Server

- Follow instructions at <http://www.alcf.anl.gov/user-guides/paraview-cooley>
- File → Connect

Configuration	Server
Cooley	cs://cc010.cooley.pub.alcf.anl.gov:8000

Buttons: Add Server, Edit Server, Load Servers, Save Servers

Configuration Dialog:

Name: Cooley

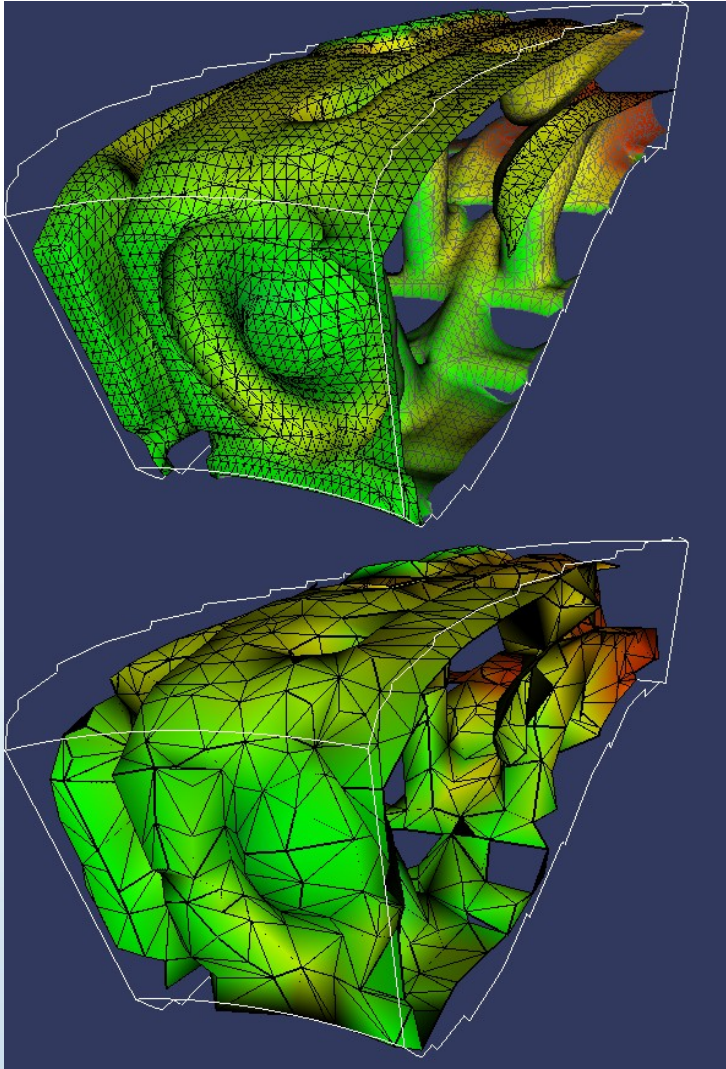
Server Type: Client / Server

Host: cc010.cooley.pub.alcf.anl.gov

Port: 8000

Buttons: Configure, Cancel

# Level of Detail – Maintain Interactivity

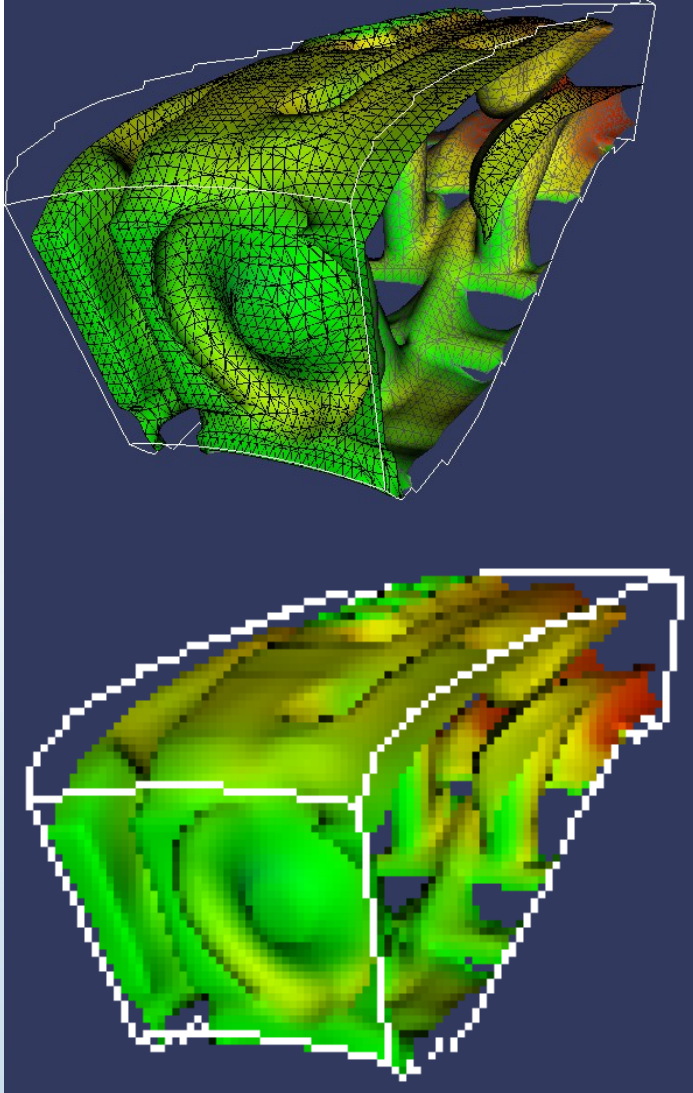


## Type 1: Geometrically based

- Edit → Settings → Render View →
- LOD threshold = 0.1
- Down-samples geometry while interacting



# Level of Detail – Maintain Interactivity



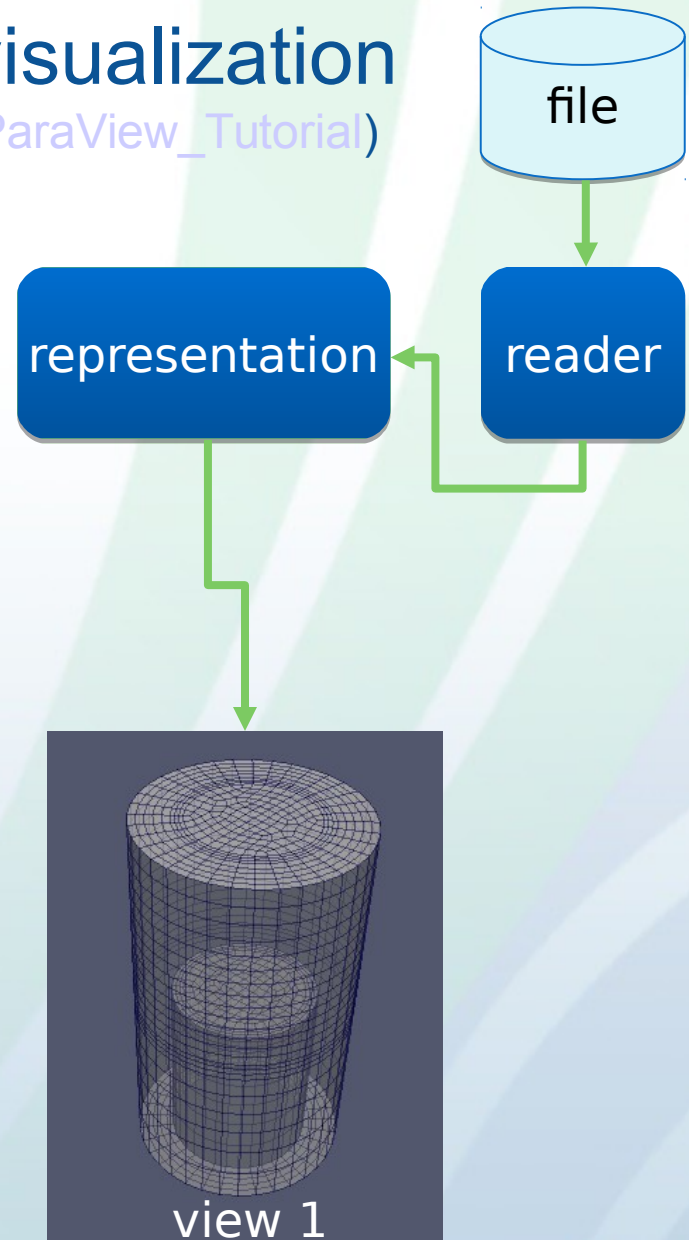
## Type 2: Image Based

- Edit → Settings → Render View →
- Remote Render Threshold = 0.1
- Image Reduction Factor = 10
- Down-samples pixels while interacting

# Hands on practice: vector visualization

(see also [http://www.paraview.org/Wiki/The\\_ParaView\\_Tutorial](http://www.paraview.org/Wiki/The_ParaView_Tutorial))

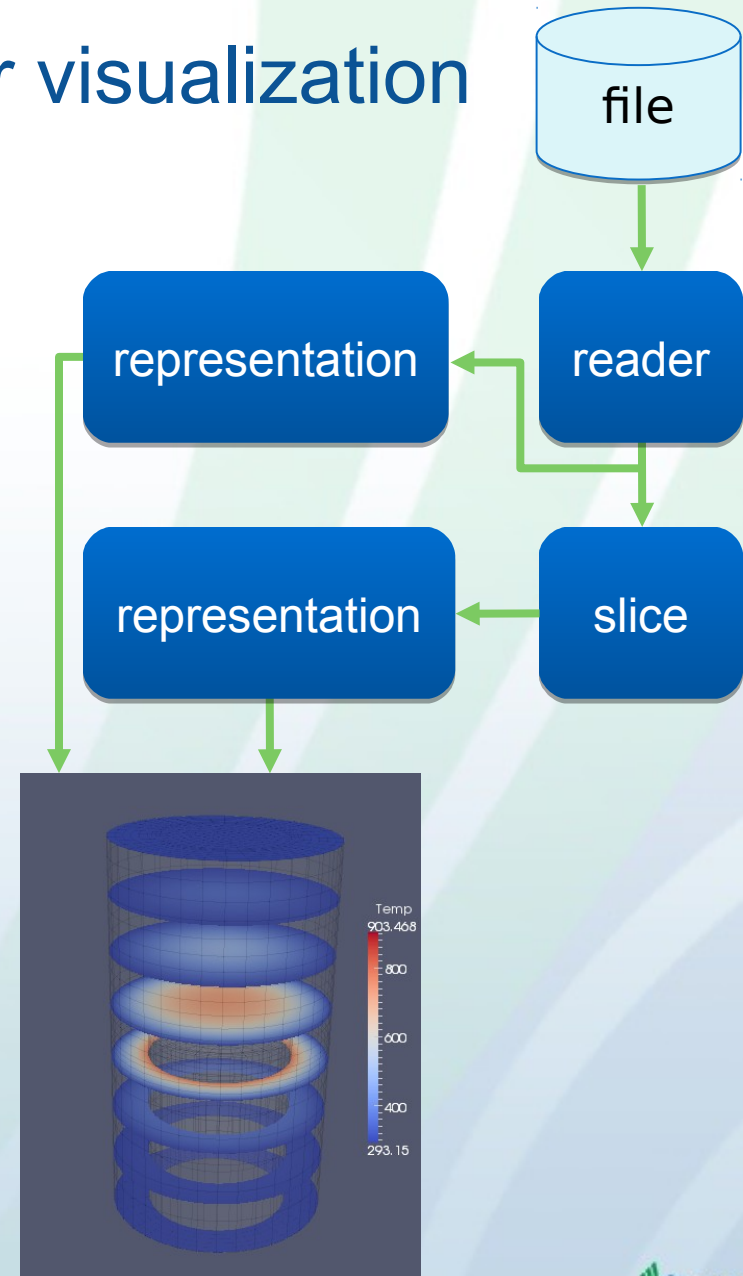
- Load disk\_out\_ref.ex2
  - An exodus format file
  - Enable all variables
- Information tab
  - Multi-block (group of datasets)
  - Not time varying
  - Roughly 8000 cells and points, 2MB
  - 11.5 units in diameter, 20 units in height
- Show as surface with edges to see structure
- Set opacity to 0.5
- Looks like a cylinder with a recess





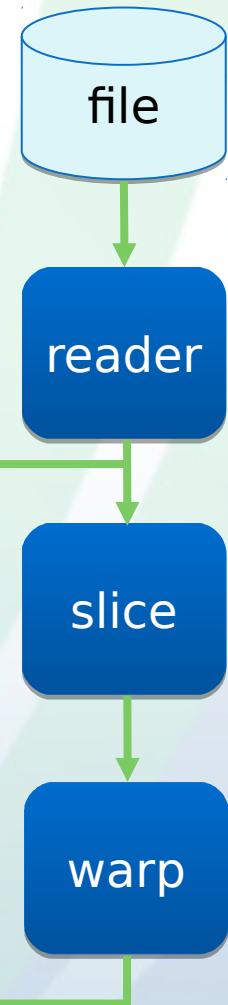
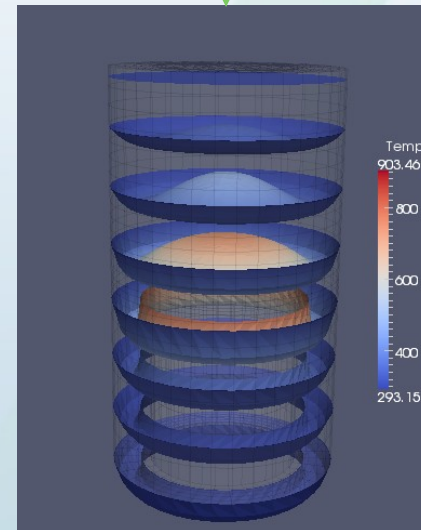
# Hands on practice: vector visualization

- Apply slice filter
  - Align with z and use 10 offset values
- Color by Temp
- Show temp color key
- Adjust opacity of reader(0.1) and slice(1.0) so that you can see temperature variation clearly



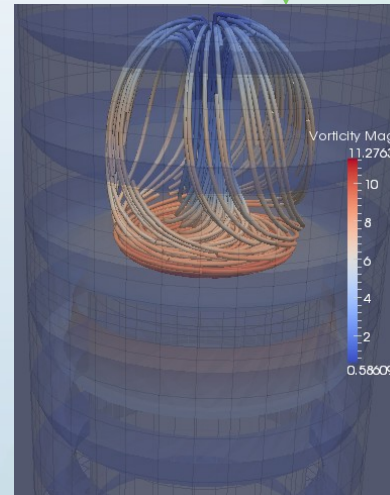
# Hands on practice: vector visualization

- Apply warp filter
  - Warp slices along  $V$  vector field with a scale factor of 0.1
- Compare with display of slice
  - note see how vector field pushes up in center and down further out
  - We are seeing convection of a heated gas, it rises at the heat source



# Hands on practice: vector visualization

- Change warp opacity to .2
- Apply streamline filter
  - Starts from seed points and advects along vector field to show you vector flow
- Apply tube filter
  - Gives infinitely thin streamlines extent so we can see them well
- Set opacity to 1.0 and color by vorticity
  - We are seeing rotation
  - A heated plate is spinning in gas
- Manipulate streamline's seed points

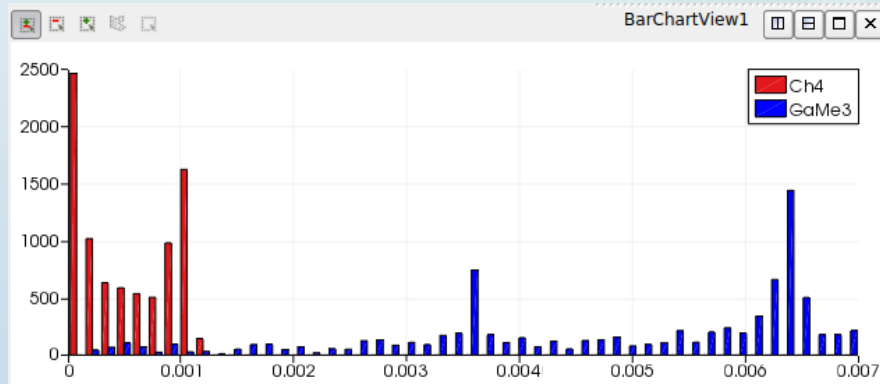
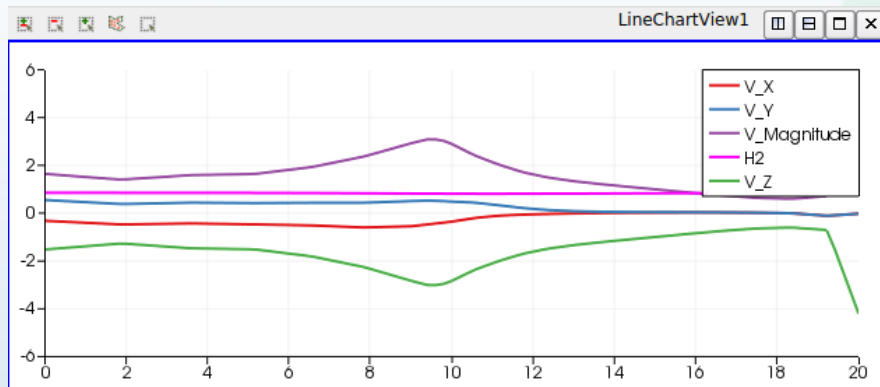


# Putting it together: data analysis

SpreadSheetView1

Showing: disk\_out\_ref.ex2 Attribute: Point Data Precision: 6

	Block Number	Point ID	AsH3	CH4	GaMe3	GlobalNo
0	2	0	0.183459	0.000971915	0.00628244	143
1	2	1	0.155209	0.000883944	0.00513434	706
2	2	2	0.155209	0.000883943	0.00513428	3173
3	2	3	0.183458	0.000971913	0.00628236	1829
4	2	4	0.181883	0.00102504	0.00602588	6566
5	2	5	0.152606	0.000928225	0.00486082	6690



reader

view 2

plot over  
line

view 3

histogram

view 4

Thank You.  
Questions?