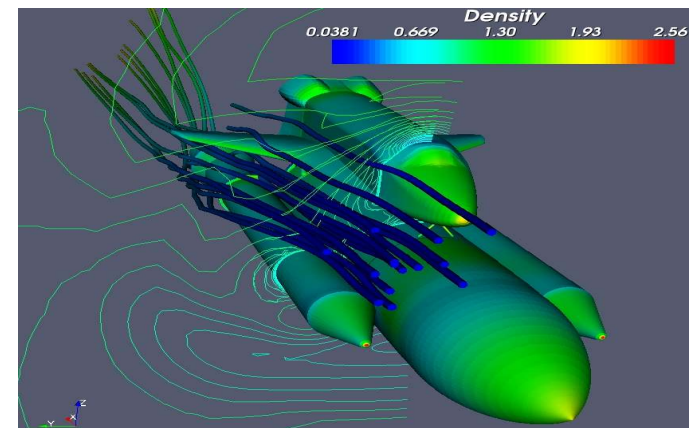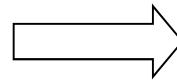# Visualization

The one with pictures …

Outline

- Goals of visualization

- Its role in the simulation chain

- Common types of visualization in CFD

- ParaView demo

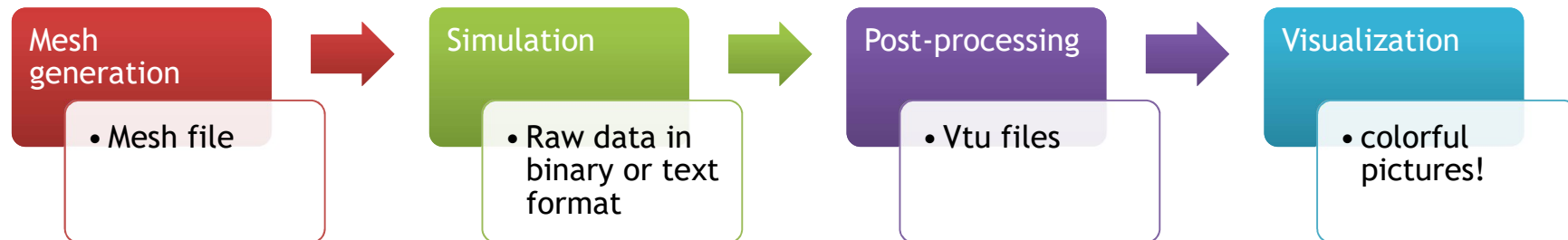- ParaView hands-on session

Goal of visualization

- Numerical value → graphical representation
  - Color, dots, line, surface …
- Raw data → meaningful values in physics
  - Gradient, vorticity …
- Better analysis
  - Error calculation; comparison; making video

Its role in the simulation flow chart

Mesh generation		Simulation		Post-processing		Visualization
• Mesh file	→	• Raw data in binary or text format	→	• Vtu files	→	• colorful pictures!

Common types of plots in CFD

- Mesh preview
- XY plots
- Contour plots
- Vector and streamline plots
- Scatter plots

Type of mesh

Unstructured mesh
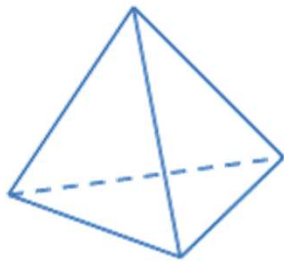
Structured mesh

Tetrahedron
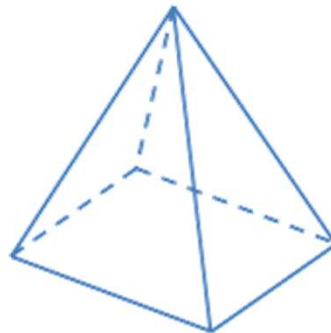
Pyramid
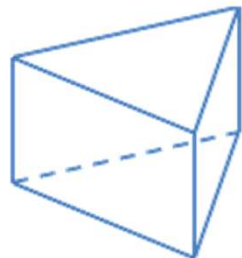
Triangular Prism
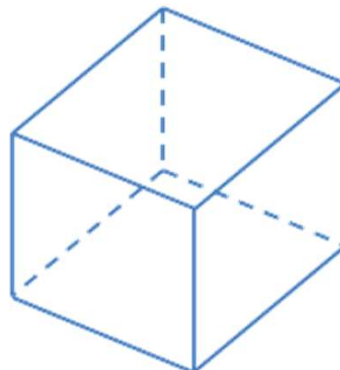
Hexahedron
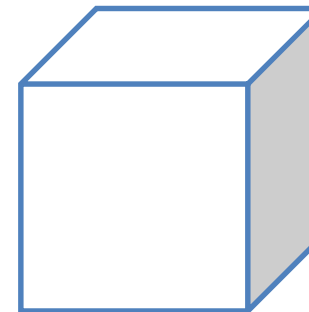
voxel

Unstructured Mesh
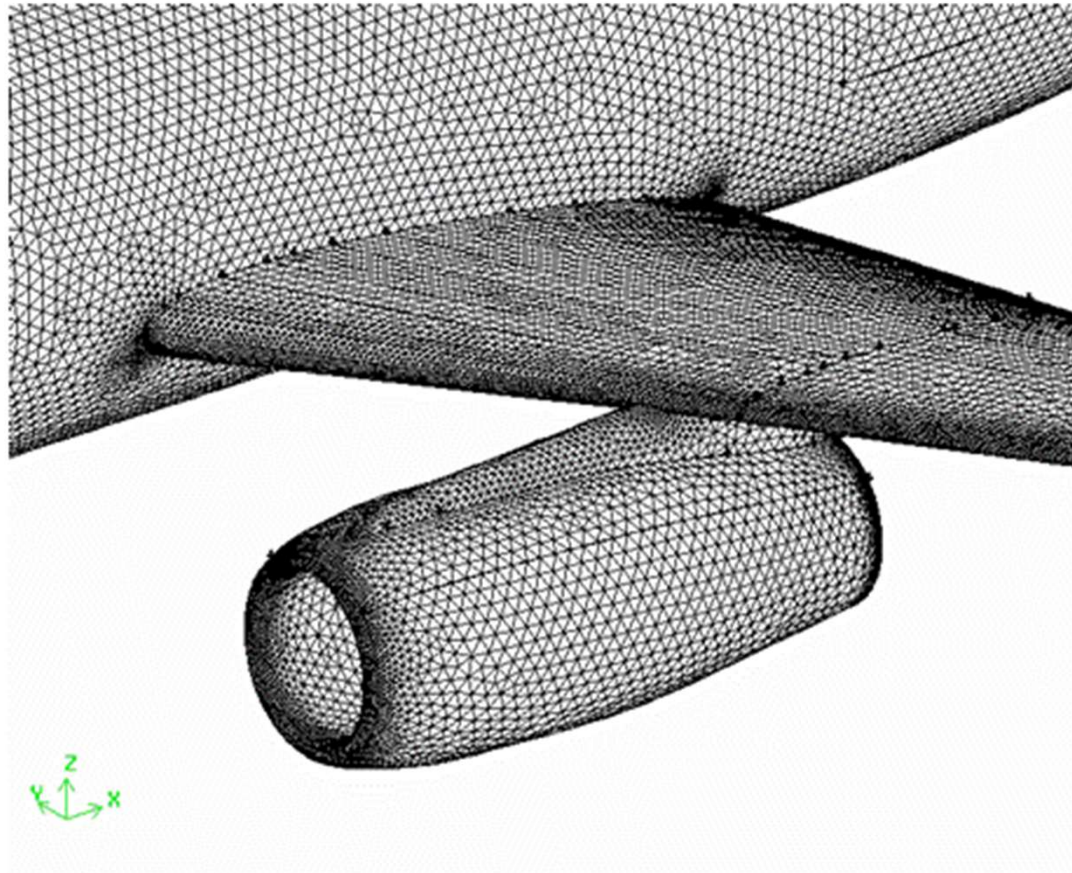
Voxel mesh
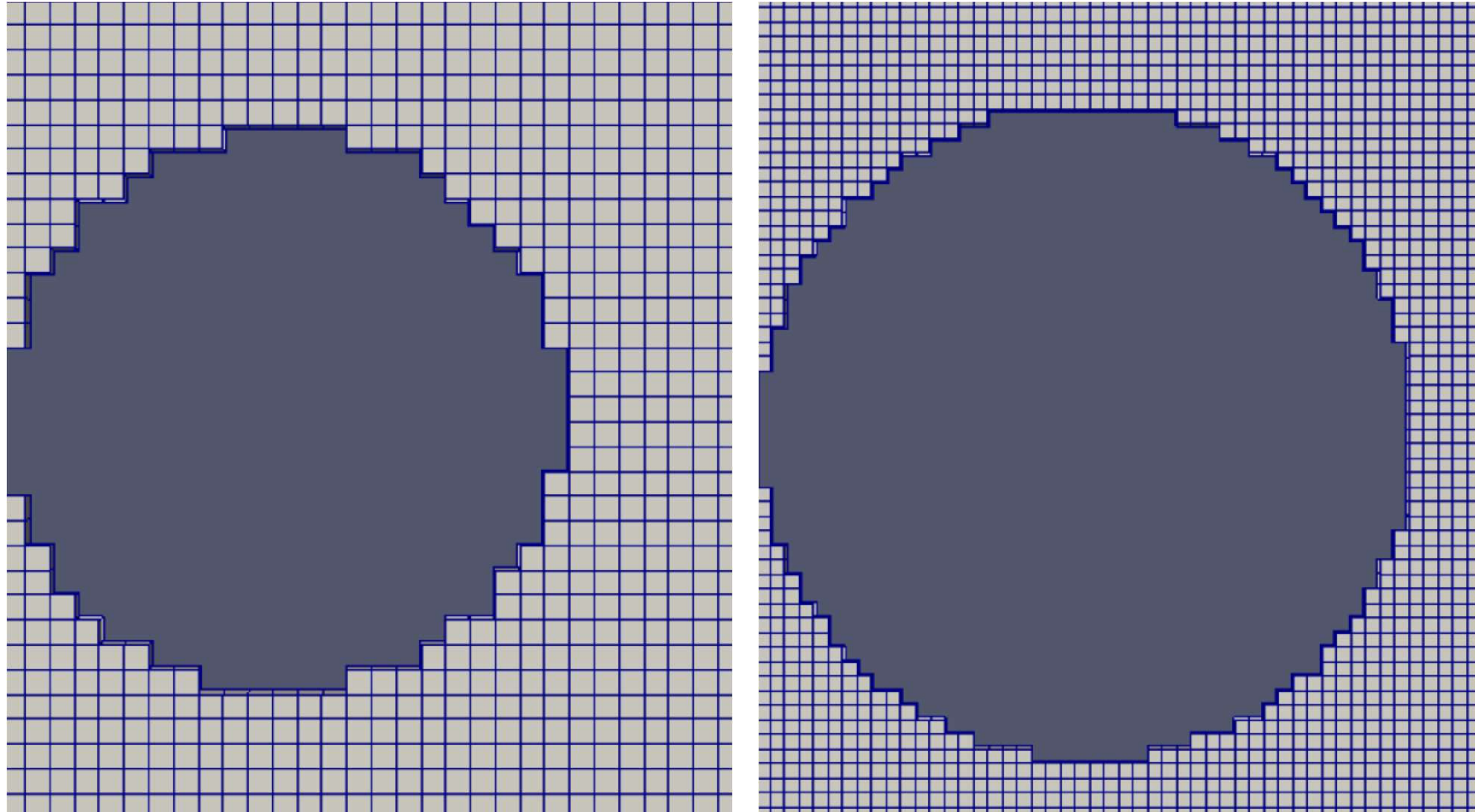
XY plots

- Two-dimensional graph, represents one dependent variable versus another independent variable. (y versus x)
  - Velocity on a line (spatial)
  - Pressure on a point over time (temporal)
- Most simple, but precise quantitative way to present numerical data.

Pressure versus position X

Pressure Drop along Channel 2D
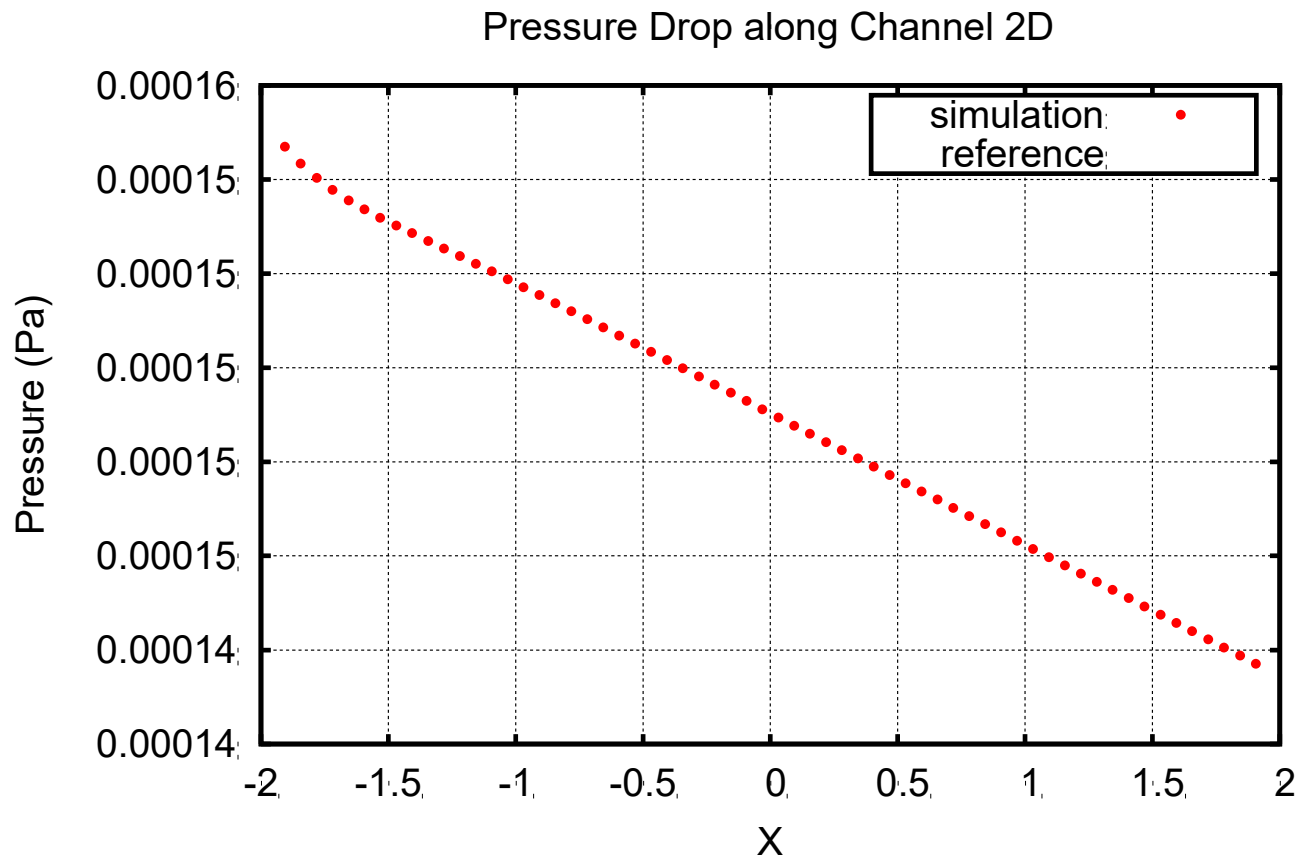
Velocity versus position Y

Velocity across Channel 2D
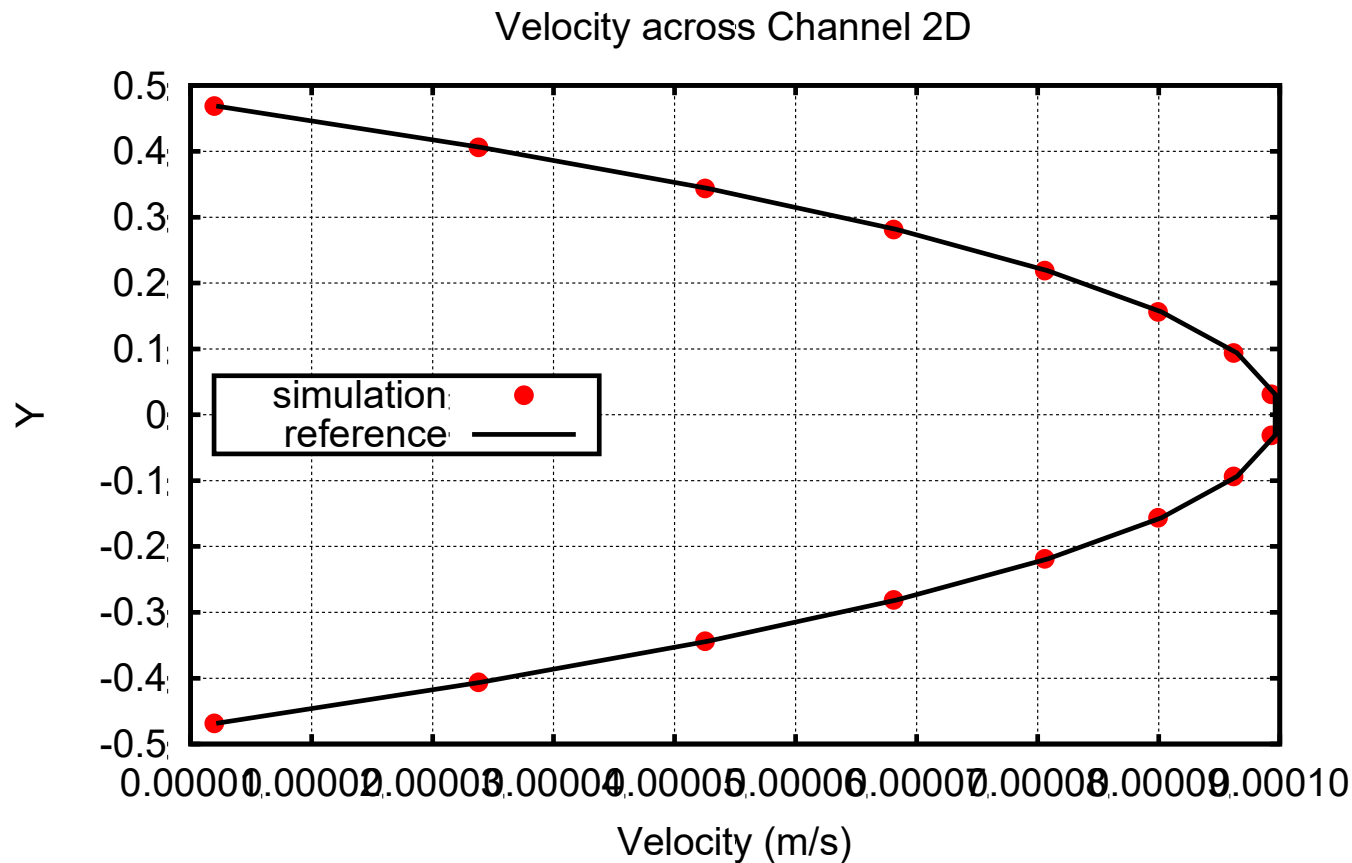
Pressure over time

Pressure over time on a probe point
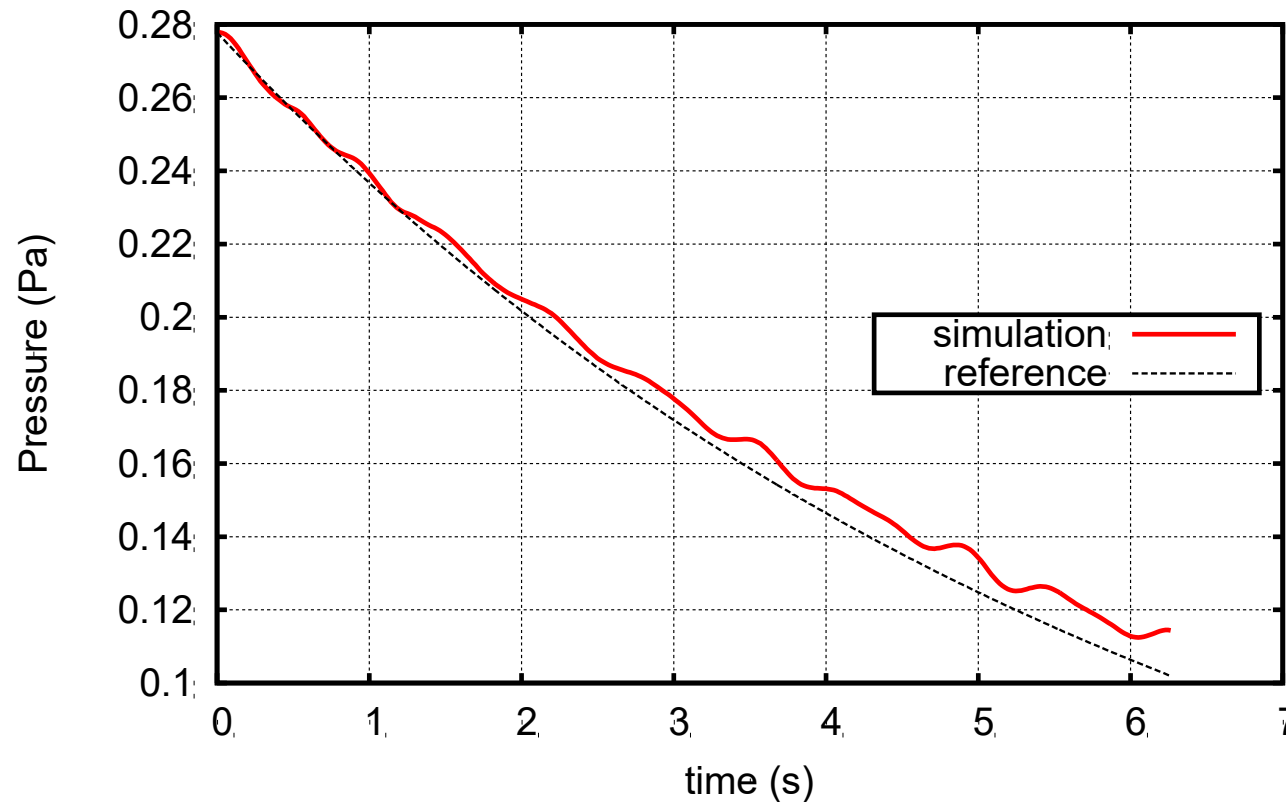
Contour plots

- A contour line is a line, along which some property is constant.

- The difference between the quantitative value of the variable from one contour line to an adjacent contour line is held constant.

Pressure contour for 2D channel flow over cylinder
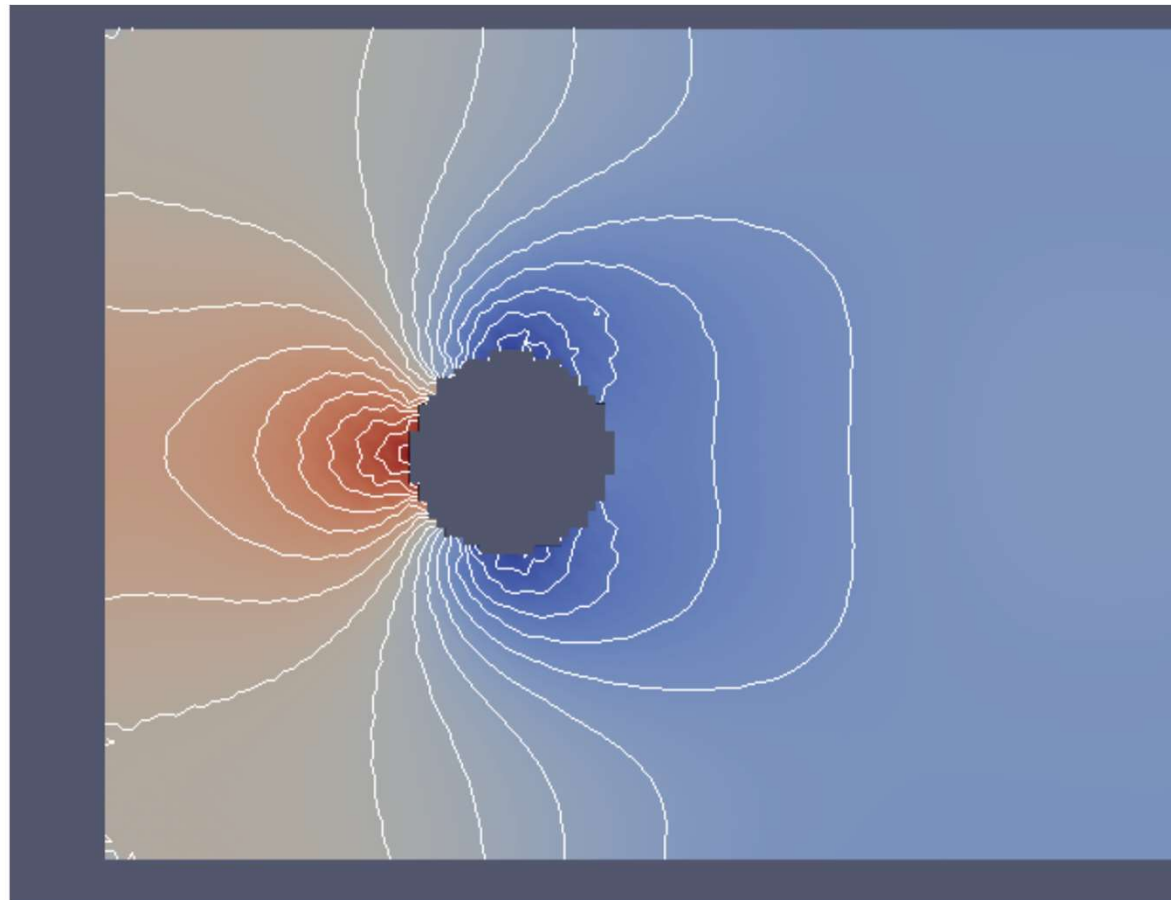
Vector plots

- Use arrow to display vector quantity (in CFD, usually velocity) showing both magnitude and direction.

- Magnitude of the quantity can be represented by color or size of arrow.

- A good way to examine the velocity field.

Velocity vector for 2D channel flow over a cylinder

Velocity vector for 2D channel flow over a cylinder
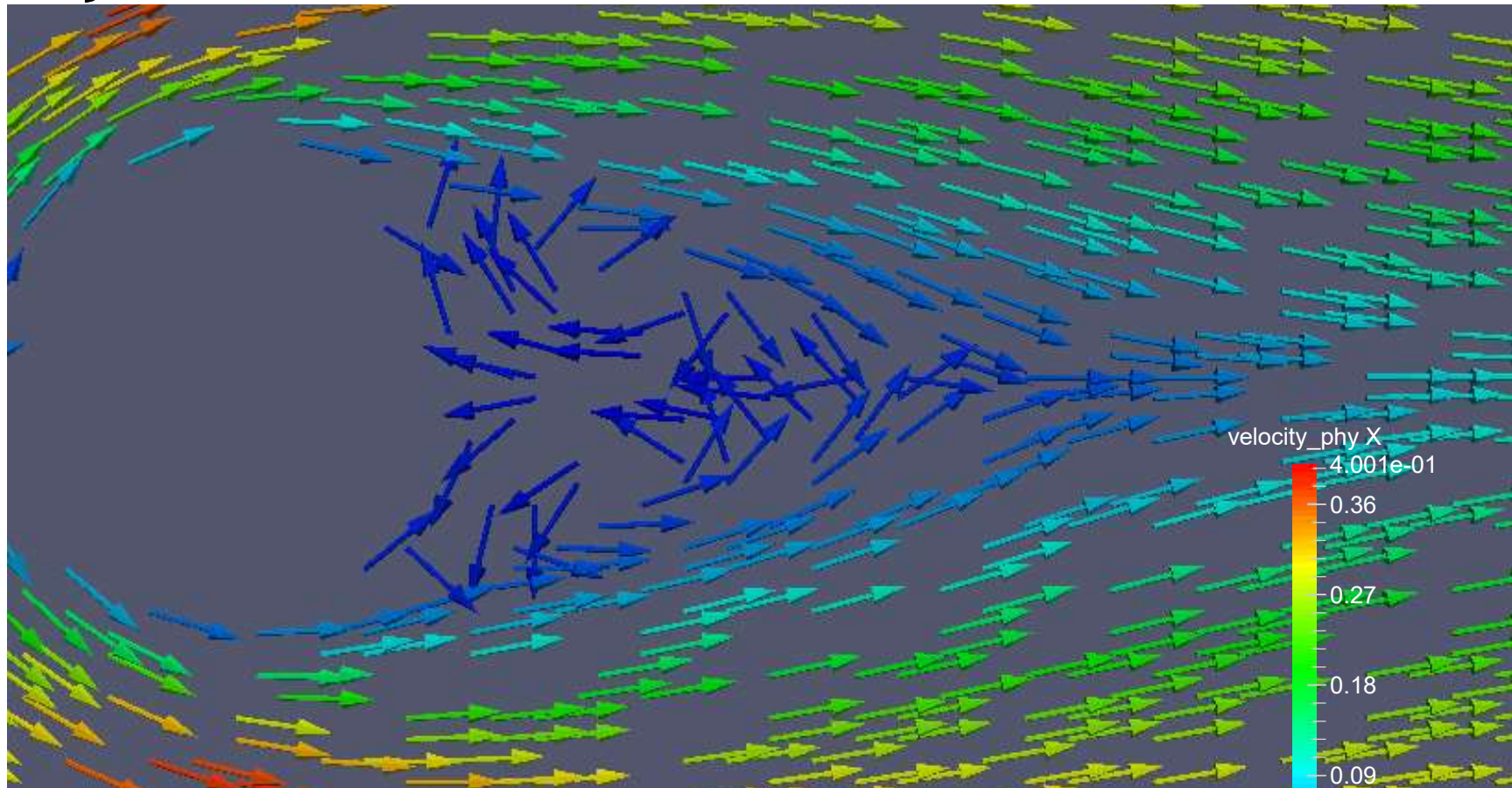
Streamline plots

- <u>Streamlines</u> are a family of curves that are instantaneously tangent to the velocity vector of the flow.

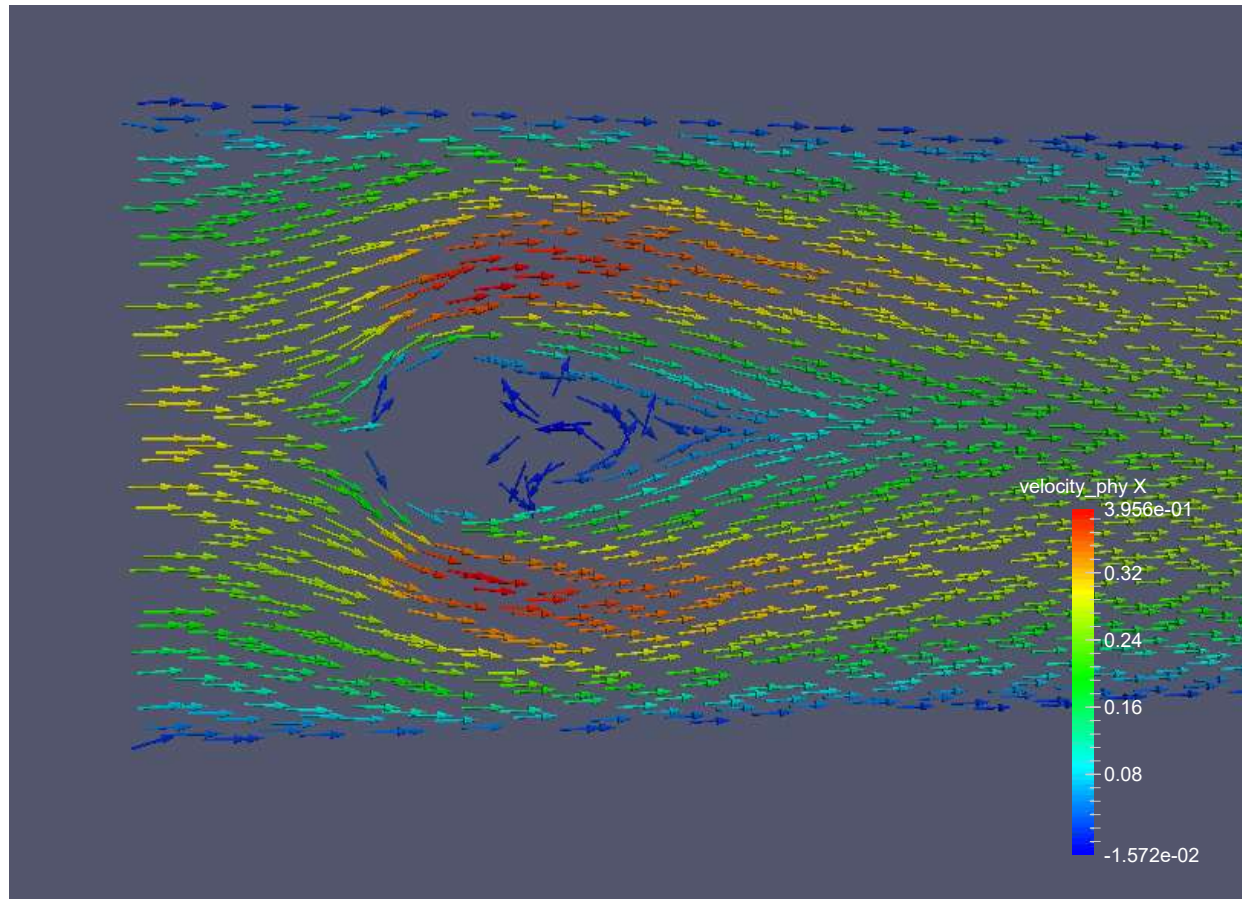- <u>Pathlines</u> are the trajectories that individual fluid particles follow. These can be thought of as "recording" the path of a fluid element in the flow over a certain period.

- For steady flow, these two types of lines coincide.

Streamline for 2D channel flow over a cylinder
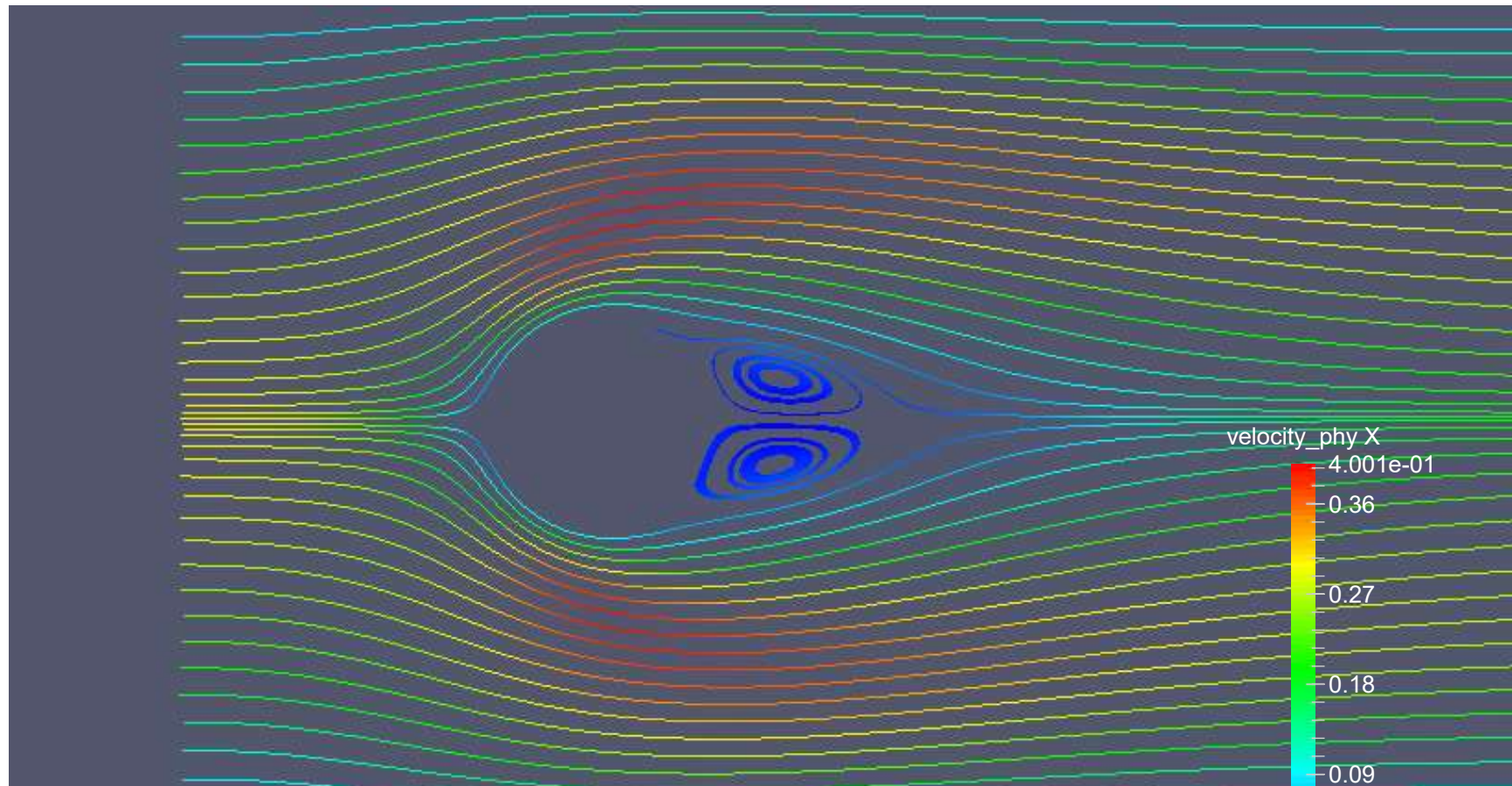
Composite plots (pressure + velocity)

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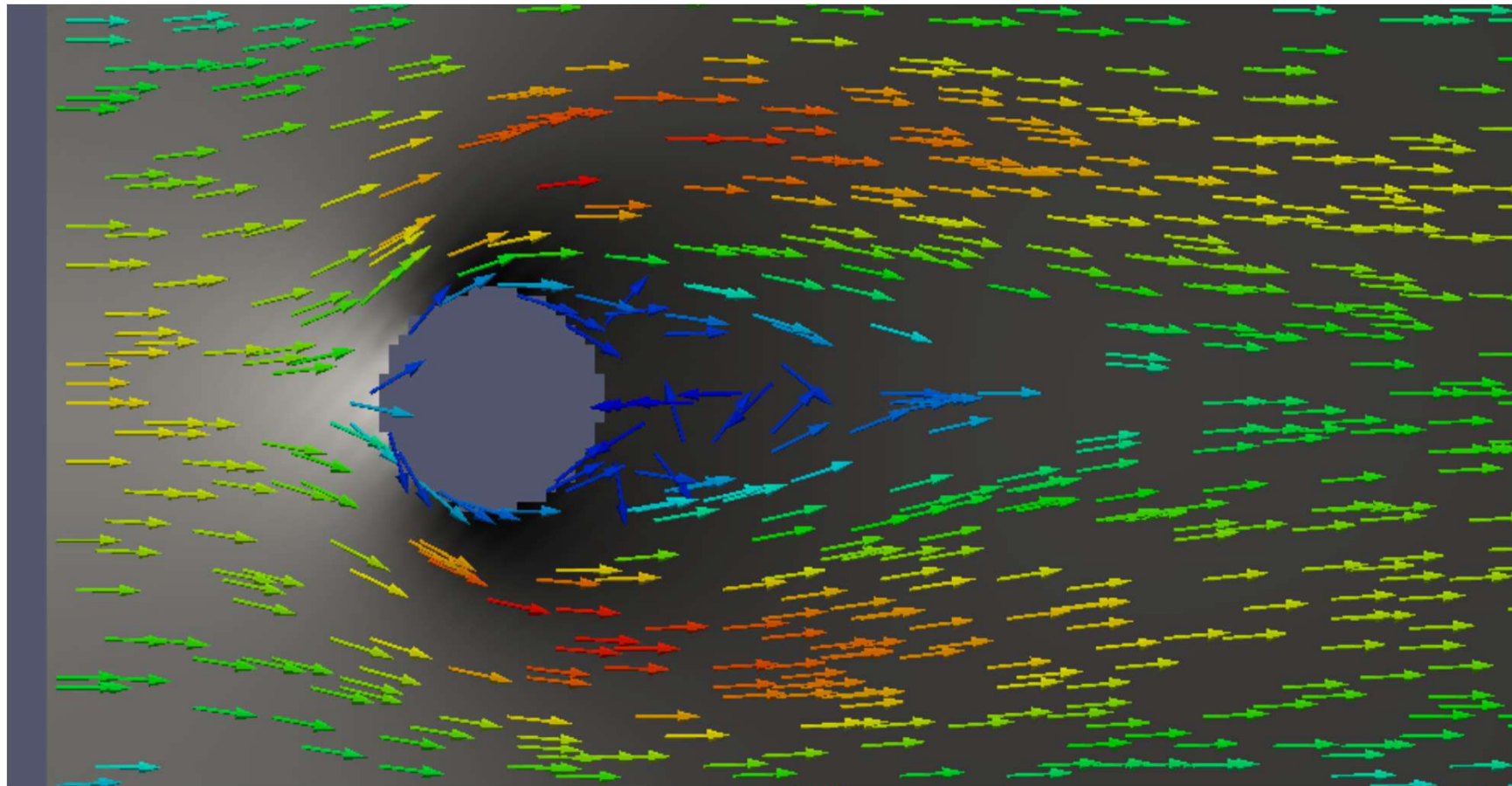
Visualization software

- Gnuplot: A very powerful and free command-line plotting tool.

- ParaView: A powerful open-source visualization tool.

- VisIt: Another powerful open-source visualization tool that can run on parallel systems.

- Tecplot 360: CFD & Numerical Simulation Visualization Software

ParaView

- www.paraview.org
- Open-source, multi-platform visualization application
- Good for general purpose, rapid visualization
- Built upon the Visualization ToolKit (VTK) library.
  - Old ascii format (vtk)
  - New XML-based format (vtu)
- Supports a wide variety of data types, time series.
  - Structured grids, unstructured grids
- Supports many visualization algorithms
  - Isosurfaces, cutting planes, streamlines…