
# Challenges of a Terascale Turbulence Simulation

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# *Outline*

- Simulation
- Challenges
  - Data
  - Visualization
  - Communication
- Summary and moving forward

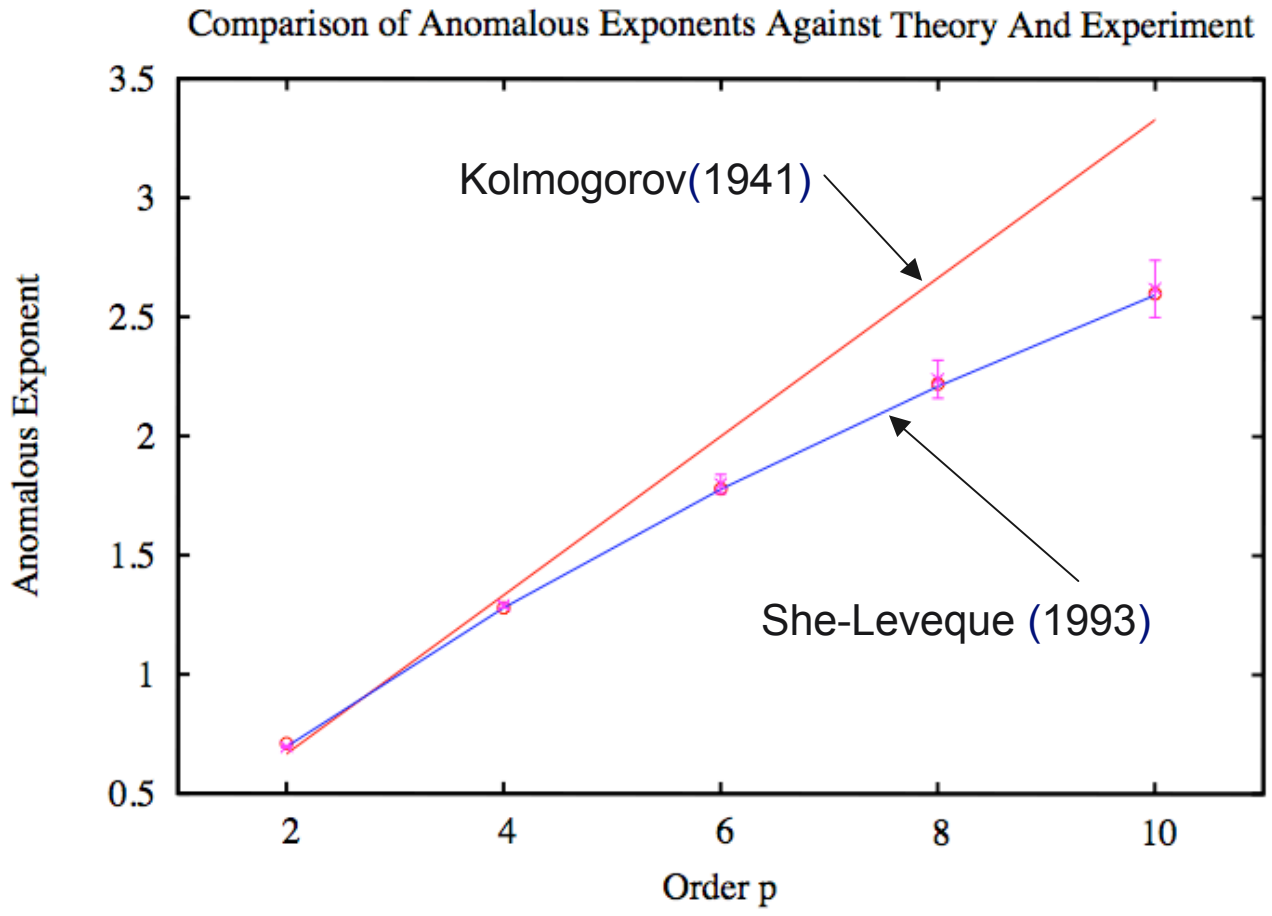
# *Simulation Introduction*

- Simulation done by ASC / Alliance Center Astrophysical Thermonuclear Flashes at The University of Chicago
- Ran on the LLNL BG/L machine during December 2005 - January 2006
- Produced 14TB of analysis data
  - 13.3 TB grid data (1 vector, 3 scalar)
  - 0.7 TB particle data (2 vectors, id)
- Produced 150TB+ of checkpoint/restart files
- Each time-step produced 32K files

# *Simulation Specifics*

- Homogeneous, isotropic compressible turbulence run with Lagrangian tracers on BG/L using FLASH 3
- Computation Size
  - $1856^3$ base grid size ($928^3$ used for analysis files)
  - $256^3$ Lagrangian tracer particles
- Computation Specifics
  - MILES-based approach solving Euler equations using PPM
  - Driven using stochastic driver (Eswaran & Pope, 1988)
  - 3D turbulent RMS Mach number = 0.3 (1D = .17) in steady-state
  - $Re_\lambda$ ~ 500 - 1000
  - Full eddy-turnover time in steady-state
- Roughly one week wall clock on 65,536 processors in CO mode

# Anomalous Scaling Exponents




Circles = Experiment
(Benzi et al, 1993)
Crosses = FLASH

# *Challenges*

- Data
  - Data transfer
  - Data storage
  - Data integrity
- Visualization
  - Real-time analysis
  - Filtering
- Communication
  - Effective communication with scientific team

# *Data Transfer*

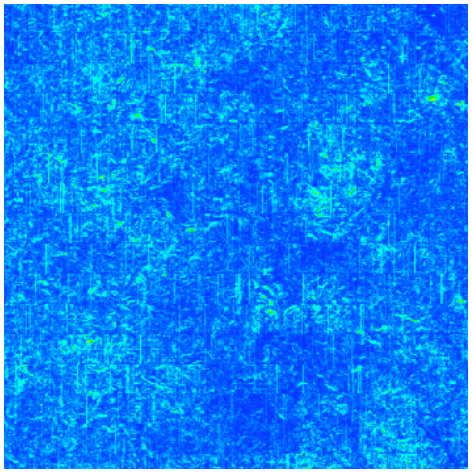
- Tarred directories to transfer as a single 18GB chunk
- GridFTP from LLNL to UC
  - Data got moved to HPSS before all could be transferred so added additional work in transfer
  - Expect scripts to manage transfers from HPSS to scratch space
  - Python scripts to manage transfers from scratch to UC
  - Screen sessions to manage overall effort
- 28 days to get 13.3 TB (grid data) to UC

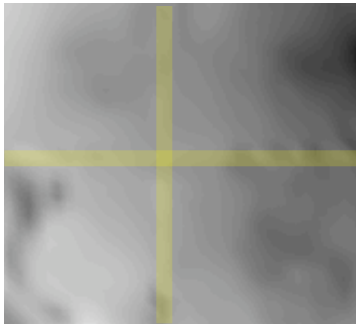
# *Data Storage*

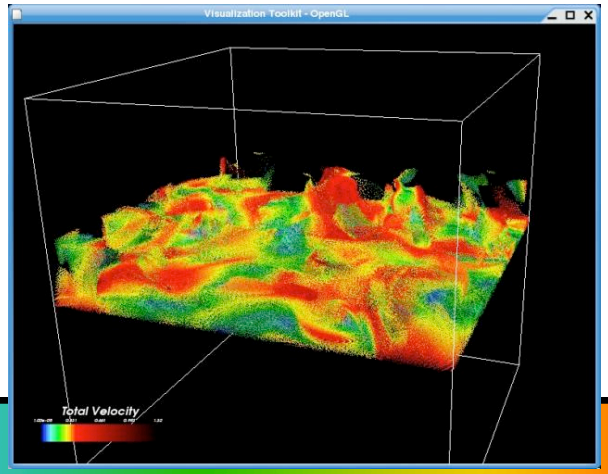
- How do you keep 14TB around?
- Represents 28% of all data the center has on disk
- Spread across multiple different volumes
- Augmented data compounds issue

# *Data Integrity*

- Whose fault is it?
- Enstrophy calculation problems
  - Calculate vorticity from analysis data
- Possible block boundary issues
  - Verify using different tools
  - Ghostcell issues
- Particle ids
  - Corrected midway through run
  - Track reconstruction





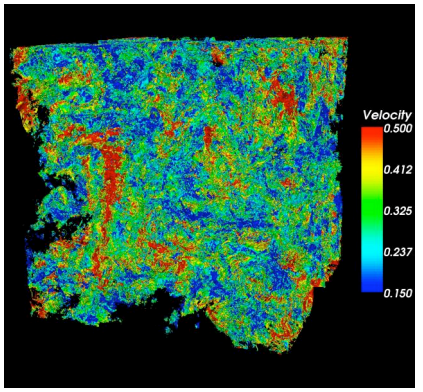


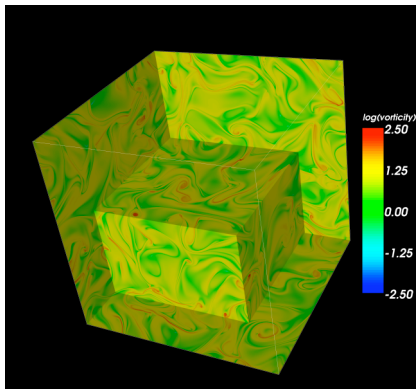
# *Visualization Tools*

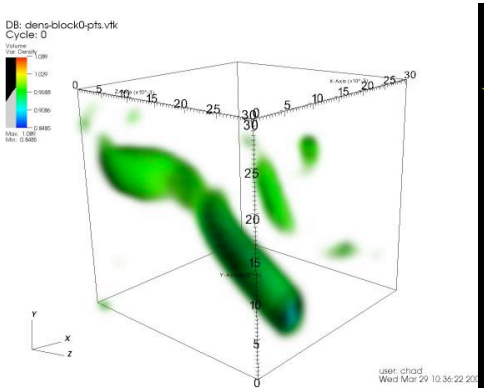
- Community tools
  - ParaView
  - VisIt
  - POVRay
- Group developed tools
  - Volume rendering
  - Particle rendering (built with vtk)

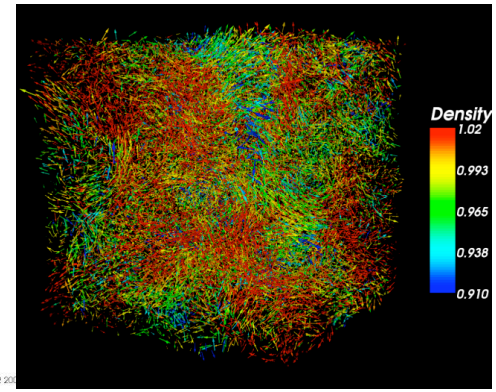
# *ParaView and VisIt*

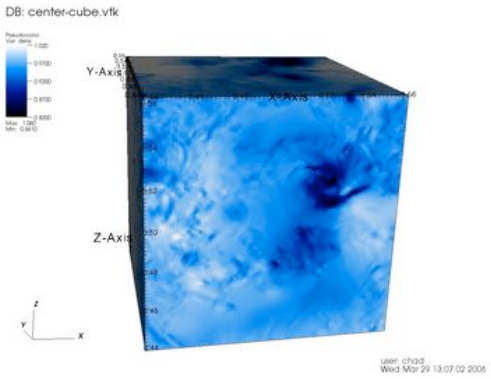
- In use by both visualization team and scientist
- Addresses real-time analysis need
  - Parallel capabilities
  - Hides complexity
  - Supports additional computation



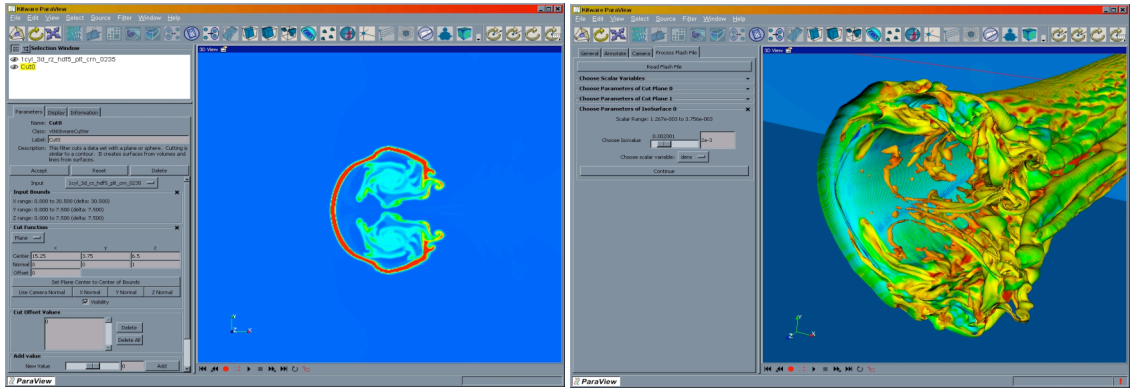



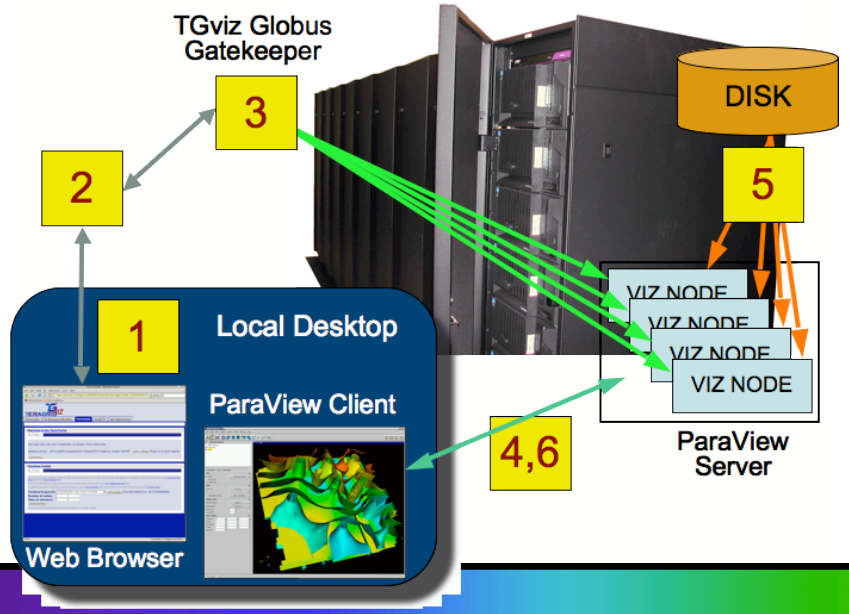



# ParaView Efforts

- Simplified interface

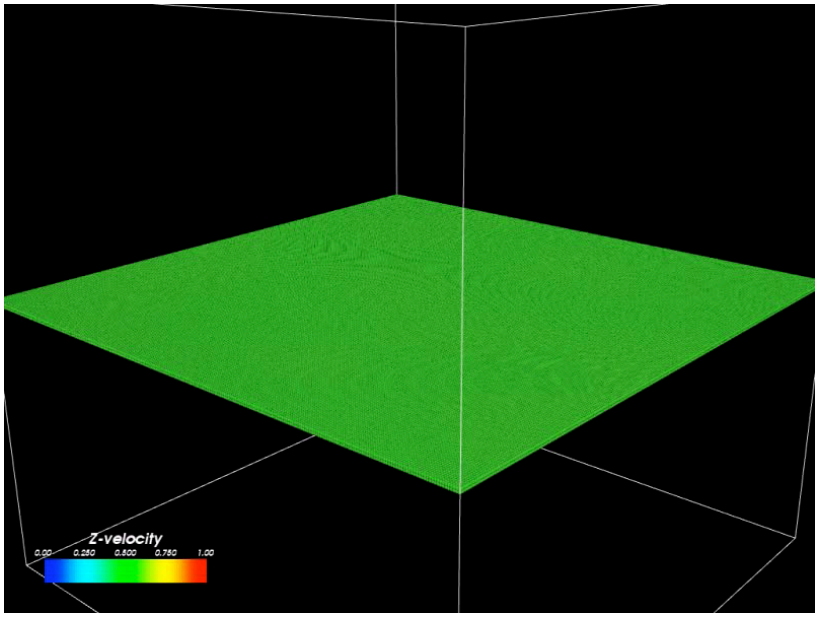


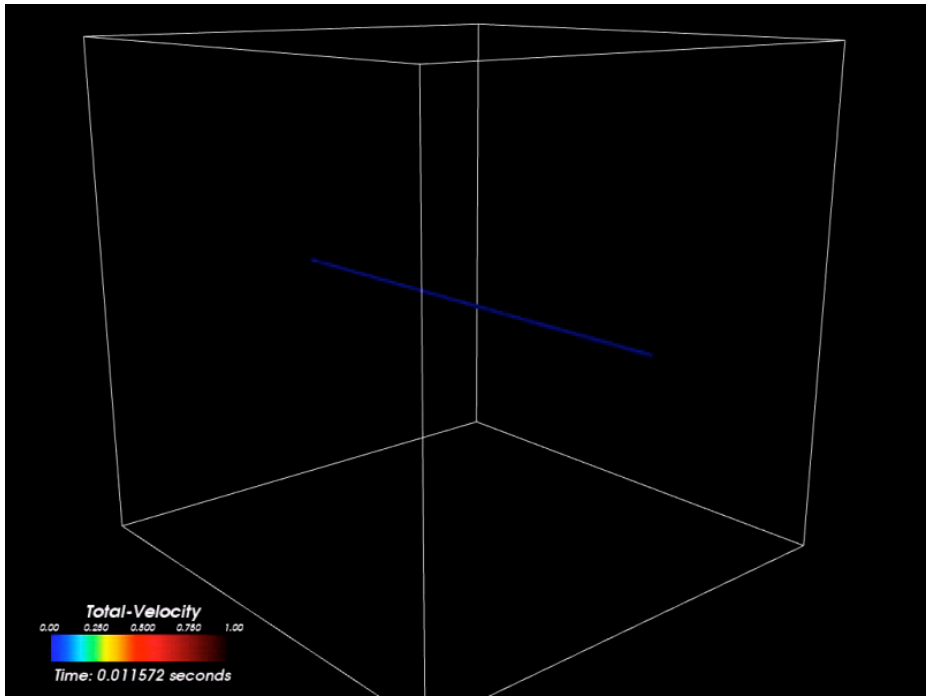
- TeraGrid visualization gateway

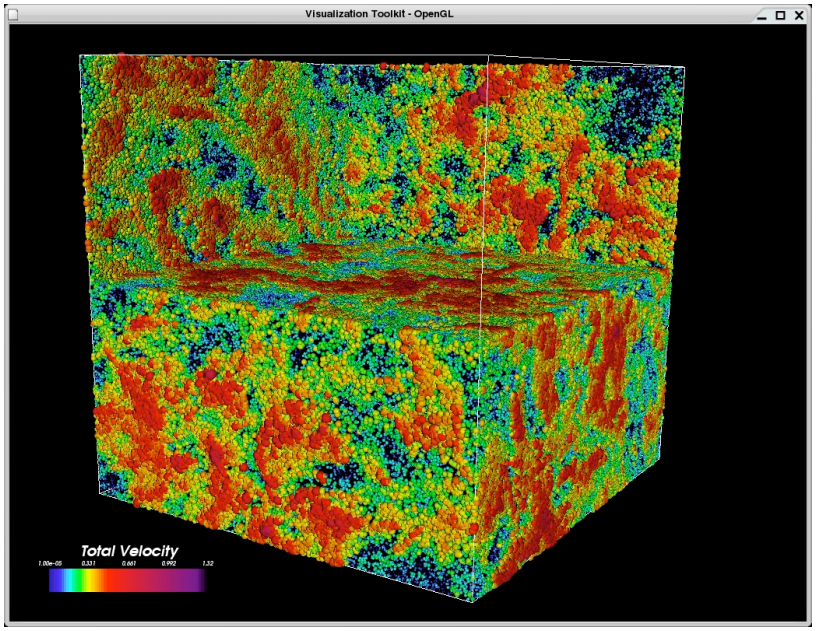


# Particle Rendering

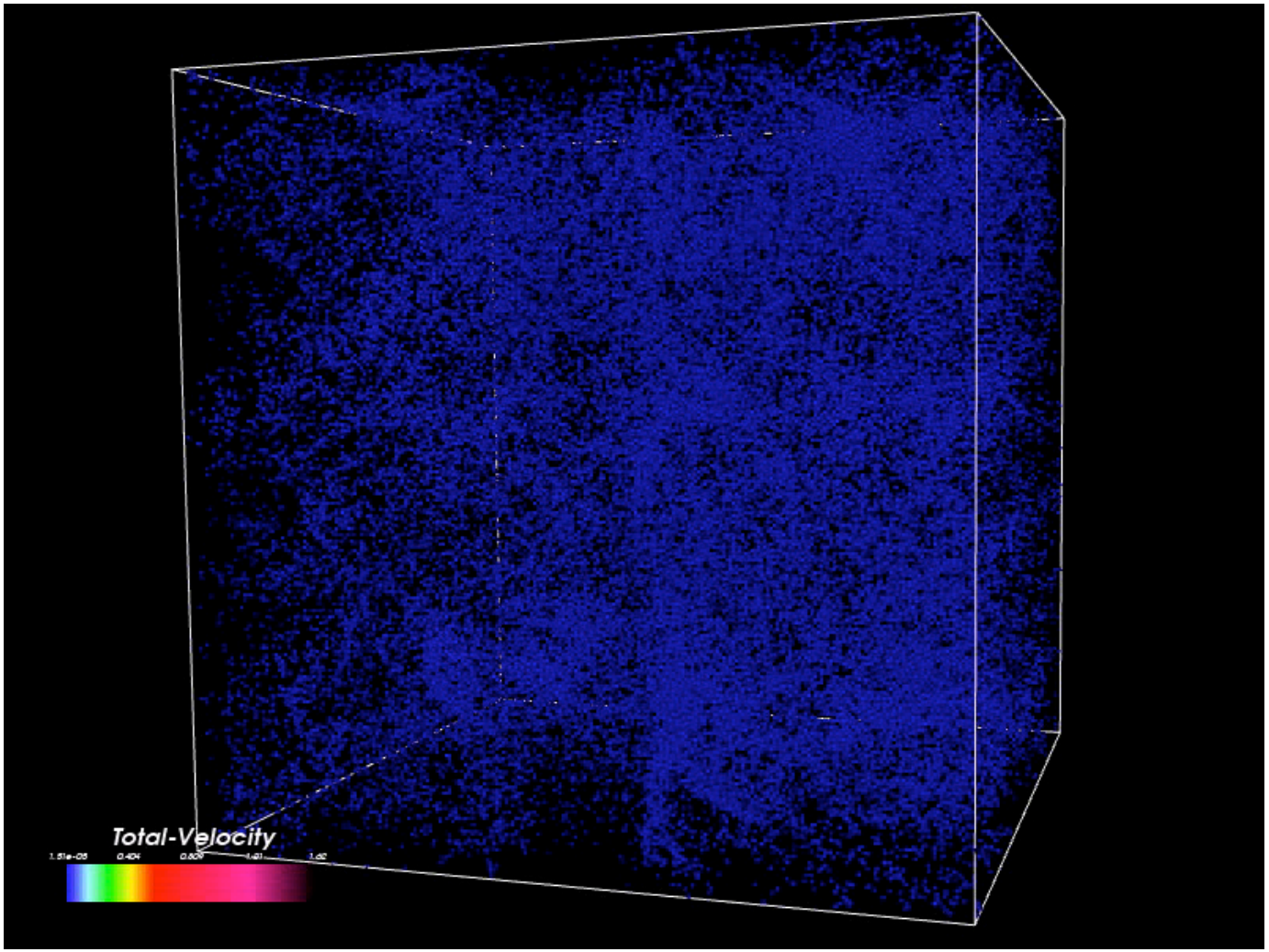
- Filtering of data
  - Geometric extraction
  - Data cuts



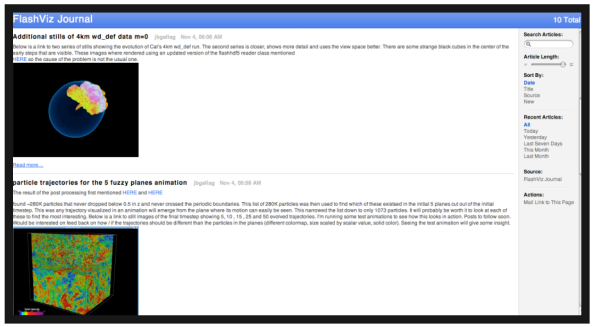



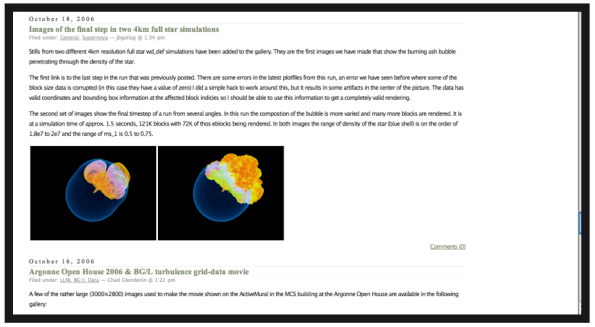
# Particle Visualization with Data Filter

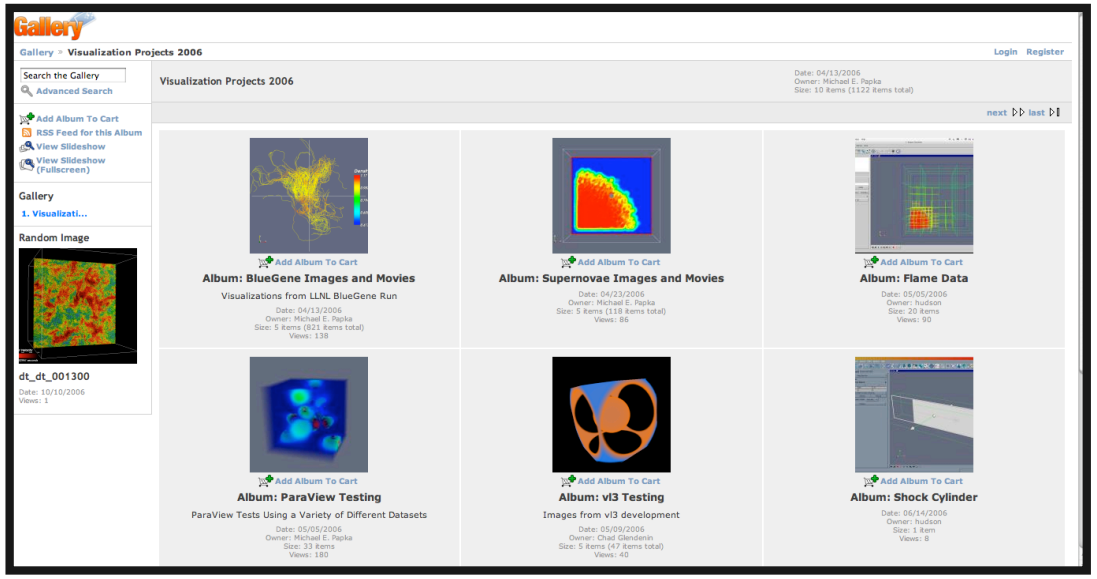


# Communication Challenges

- Keeping scientist updated
- Informing fellow team members
- Organizing results



# *Challenges - Revisited*

- Visualization component is only a fraction of the challenge
  - Usability
  - Simplification
- Data issues dominate the process
  - Location
  - State
- Communication
  - Process moving

# *Moving Forward*

`Turbulence is the most important unsolved problem of classical physics.' - Richard Feynman

- Looking at ways to make data publicly available
- Exploring integration of workflows into the process

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