INTRODUCTION TO SCIENTIFIC VISUALIZATION & WITH VISIT

Amit Chourasia

San Diego Supercomputer Center, UCSD

Tutorial material: https://goo.gl/y1FTAS

Hands on requirements

Tutorial material: https://goo.gl/y1FTAS

1. Computer + mouse with scroll wheel (laptop trackpads are difficult to use for 3D navigation)
2. **VisIt software** VisIt software version 3.0 must be installed. Download executable/ binary version for your operating system from here https://wci.llnl.gov/simulation/computer-codes/visit/executables

3. Download sample data from here https://wci.llnl.gov/content/assets/docs/simulation/computer-codes/visit/visit_data_files.tar.gz

4. Comet host profile http://users.sdsc.edu/~amit/comet/visit3.0.x-comet-host-profile.zip

Reference

VisIt class material and manuals https://wci.llnl.gov/simulation/computer-codes/visit/manuals

INTENDED AUDIENCE LEVEL

Beginner for visualization

Data sharing session will be useful for all level attendees

LECTURE/DEMO OUTCOME

Jump start attendees with visualization

- Provide understanding of standard visualization techniques,
- Application scenarios
- Best practices
- Gain proficiency in creating sophisticated visualizations using VisIt
- Conduct remote visualization on Comet.
- Learn to use SeedMe platform for data and visualization sharing.

Tutorial material: https://goo.gl/y1FTAS

TUTORIAL AGENDA & GOALS

Session 1 (40 mins) - Lecture

Visualization concepts

Visualization use cases

Best practices in visualization

Session 2 (40 mins) – Hands on

Introduction to VisIt software - Perform basic tasks in VisIt

BREAK

Session 3 (50 mins) – Hands on

Perform sophisticated tasks with VisIt

Session 4 (20 mins) – Hands on

Remote visualization with VisIt on Comet cluster at SDSC (Training accounts will be provided)

COMMON MISCONCEPTIONS

- I am not an artist thus can't do viz
- Viz is an art, not science or engineering
- Viz is a one time task
- Viz SU's are insignificant
- Viz is useful only for presentation/communication

SESSION 1: VISUALIZATION FUNDAMENTALS

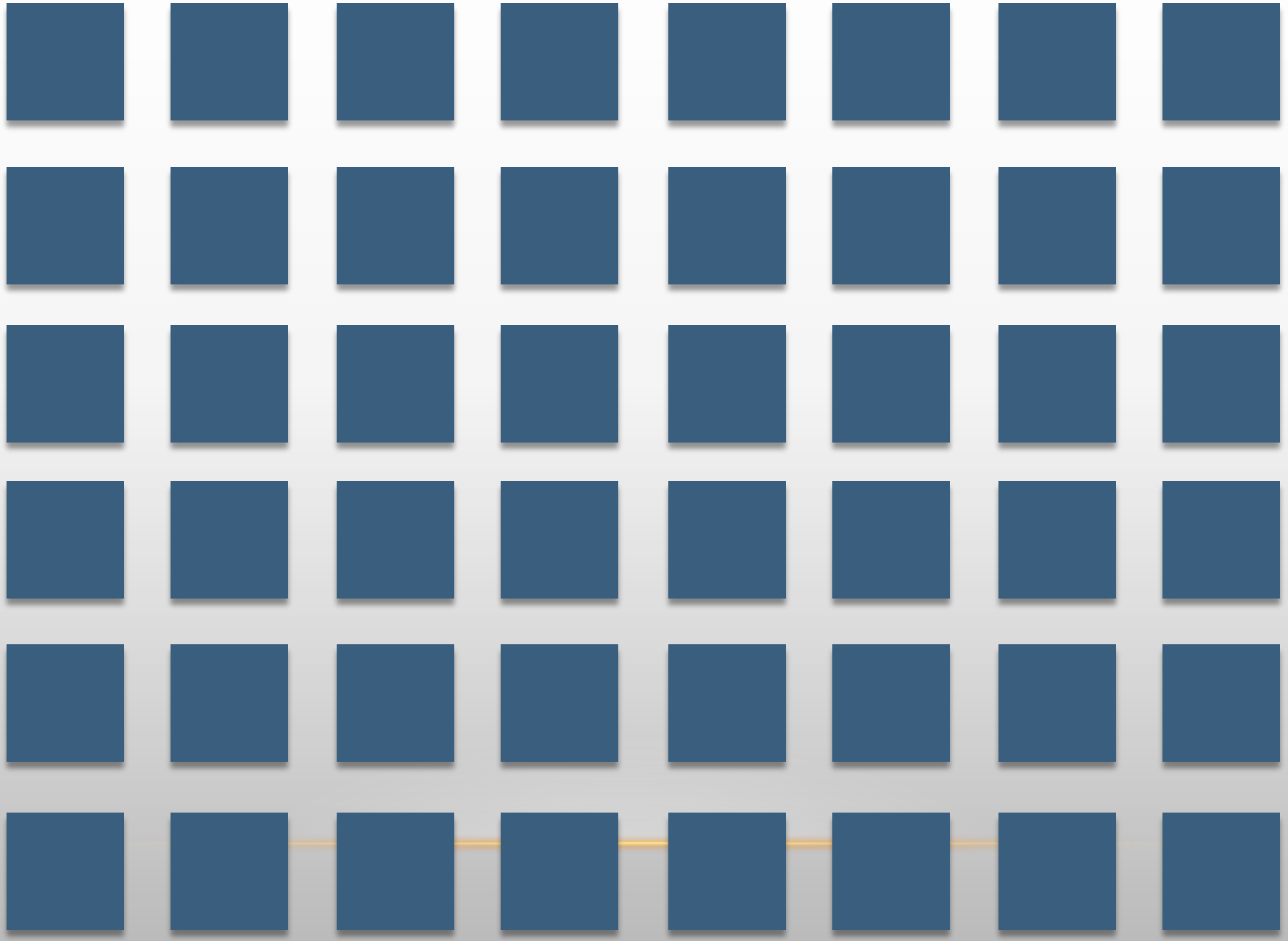
Why should you care about visualization?

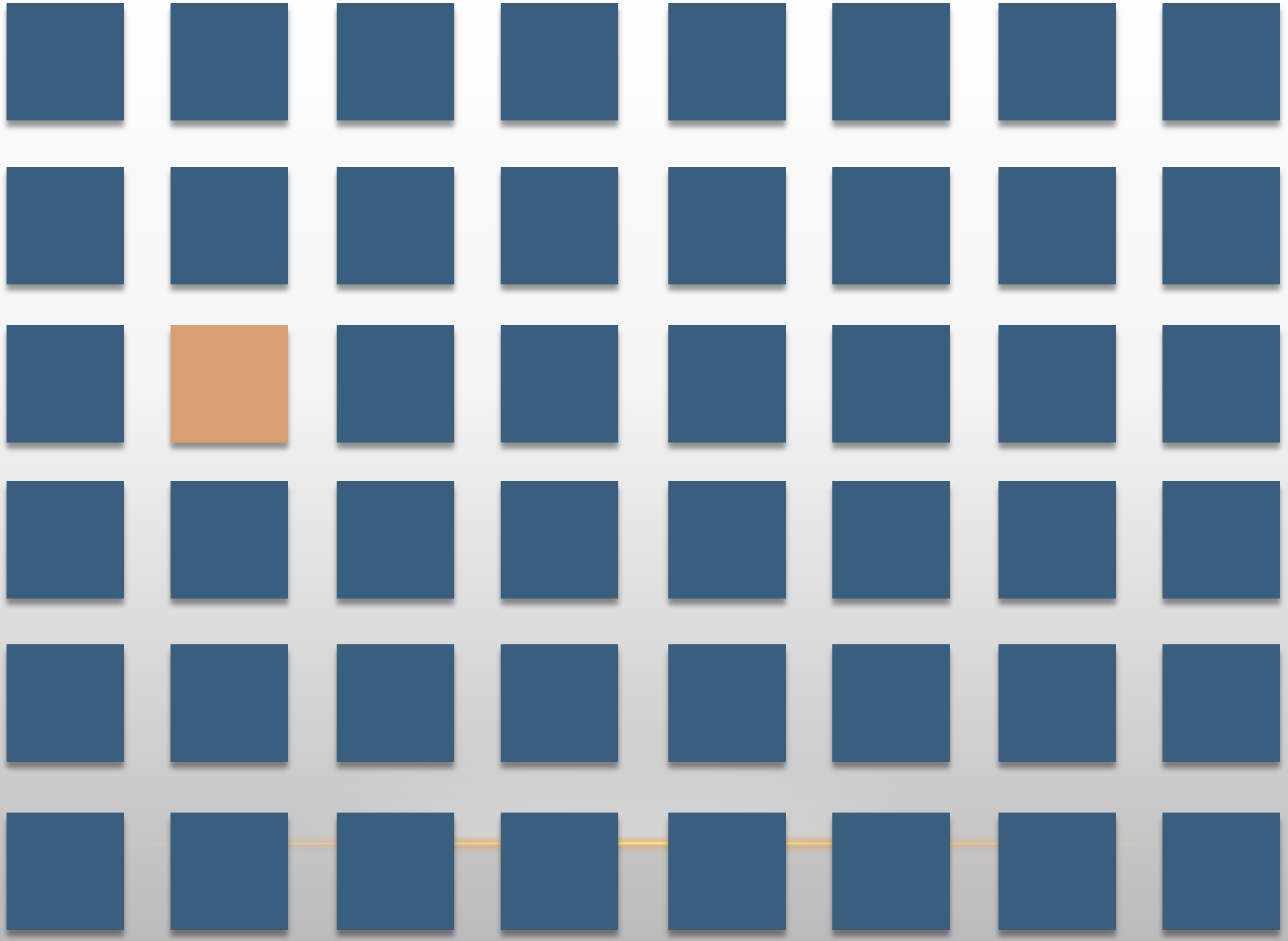
HOW MANY 3'S IN FIRST 350 NUMBERS OF PI?

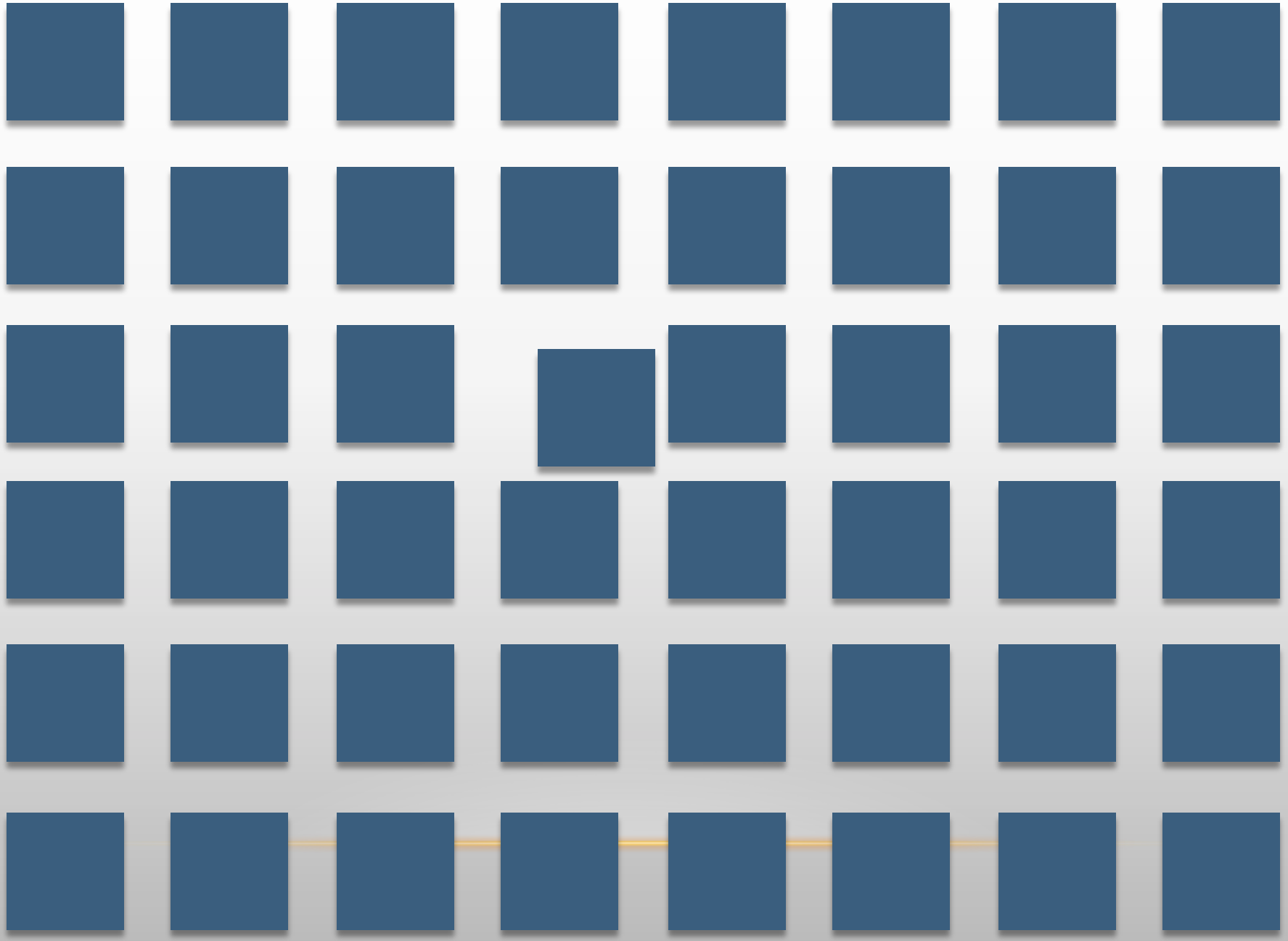
3.14159265358979323846264338327950288419716939937510582097494459230781640628620
89986280348253421170679821480865132823066470938446095505822317253594081284811174
50284102701938521105559644622948954930381964428810975665933446128475648233786
78316527120190914564856692346034861045432664821339360726024914127372458700660631
5588174881520920962829254091715364 3

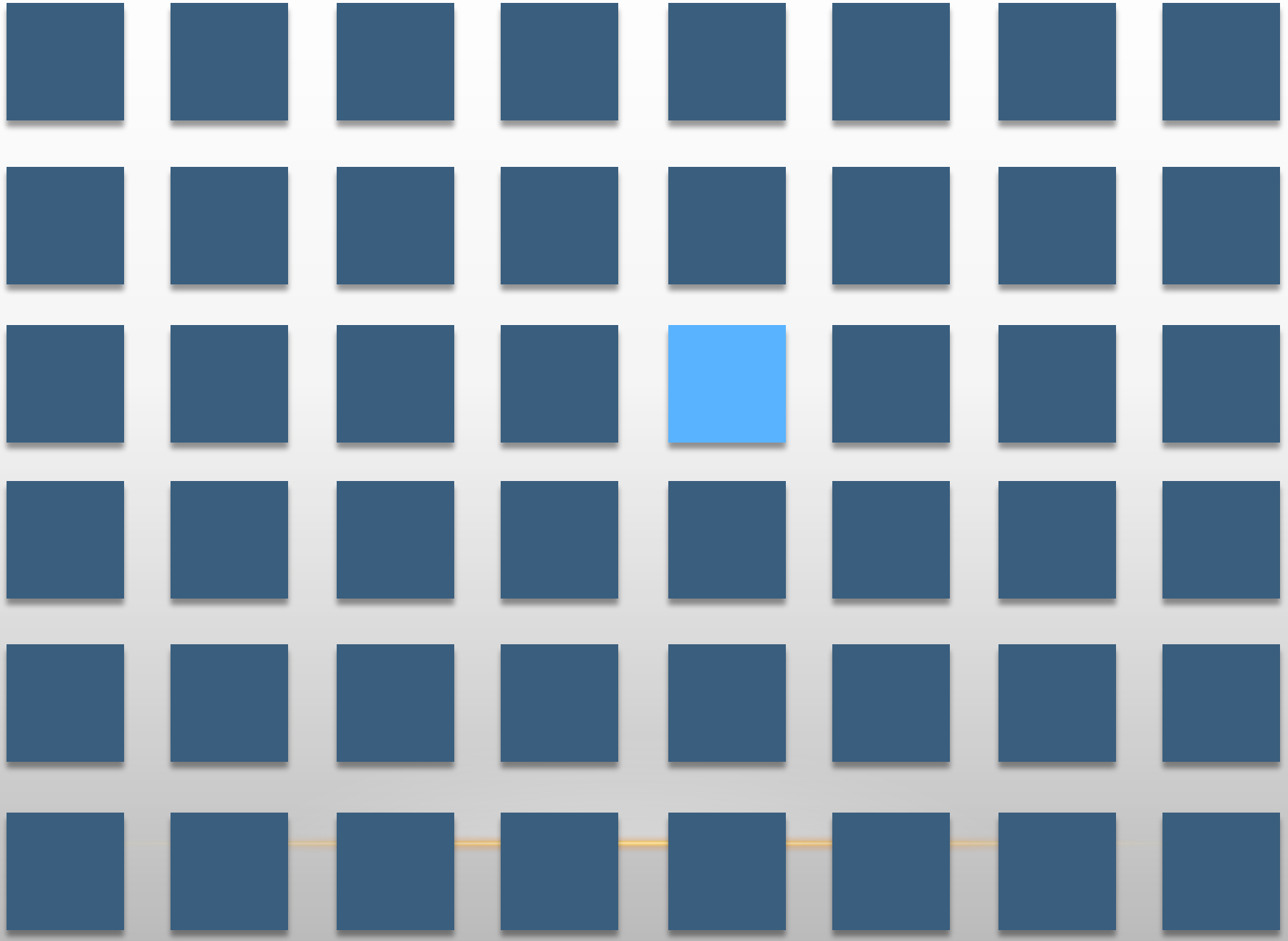
HOW MANY 3'S IN FIRST 350 NUMBERS OF PI?

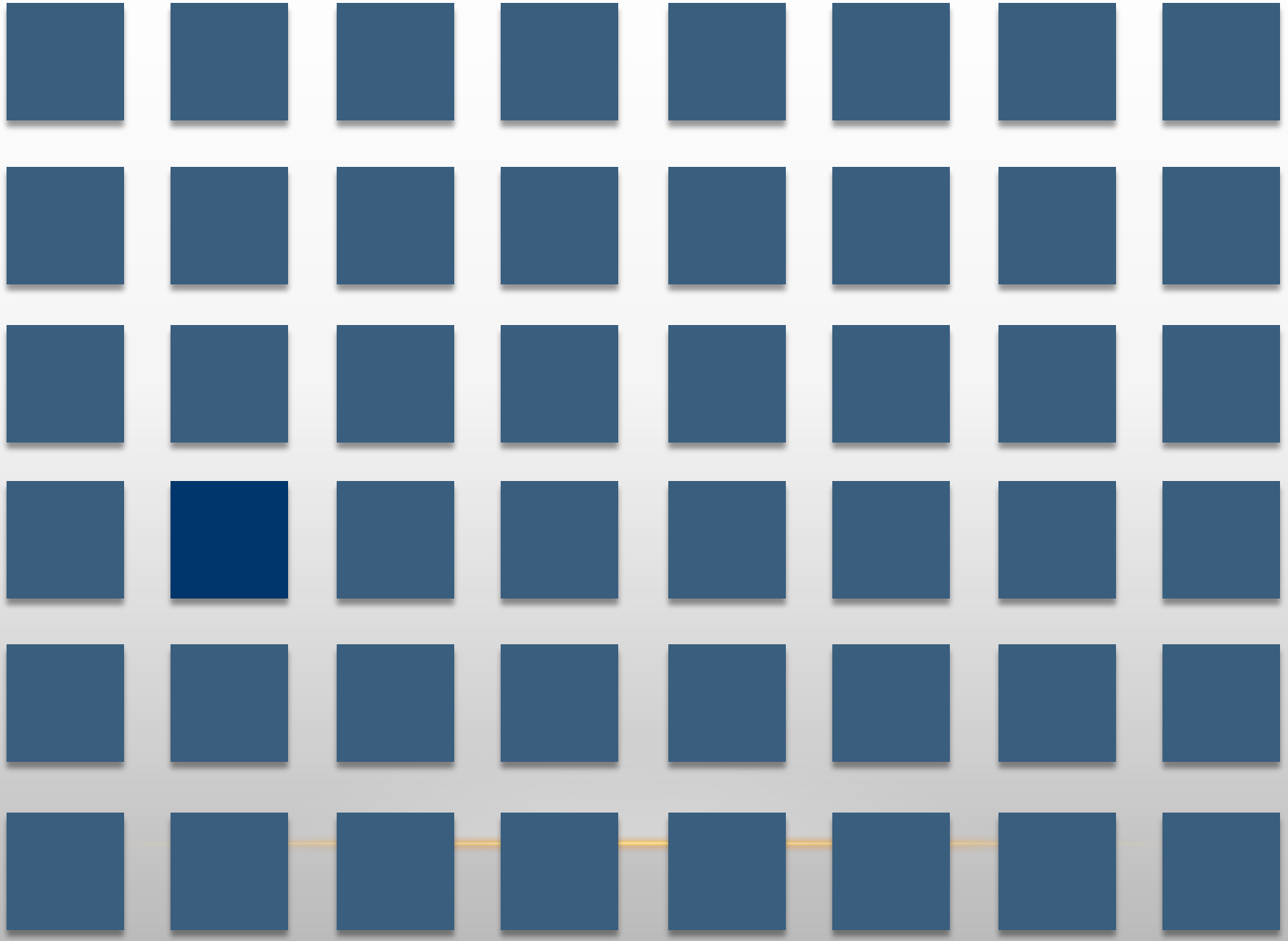
Total 33

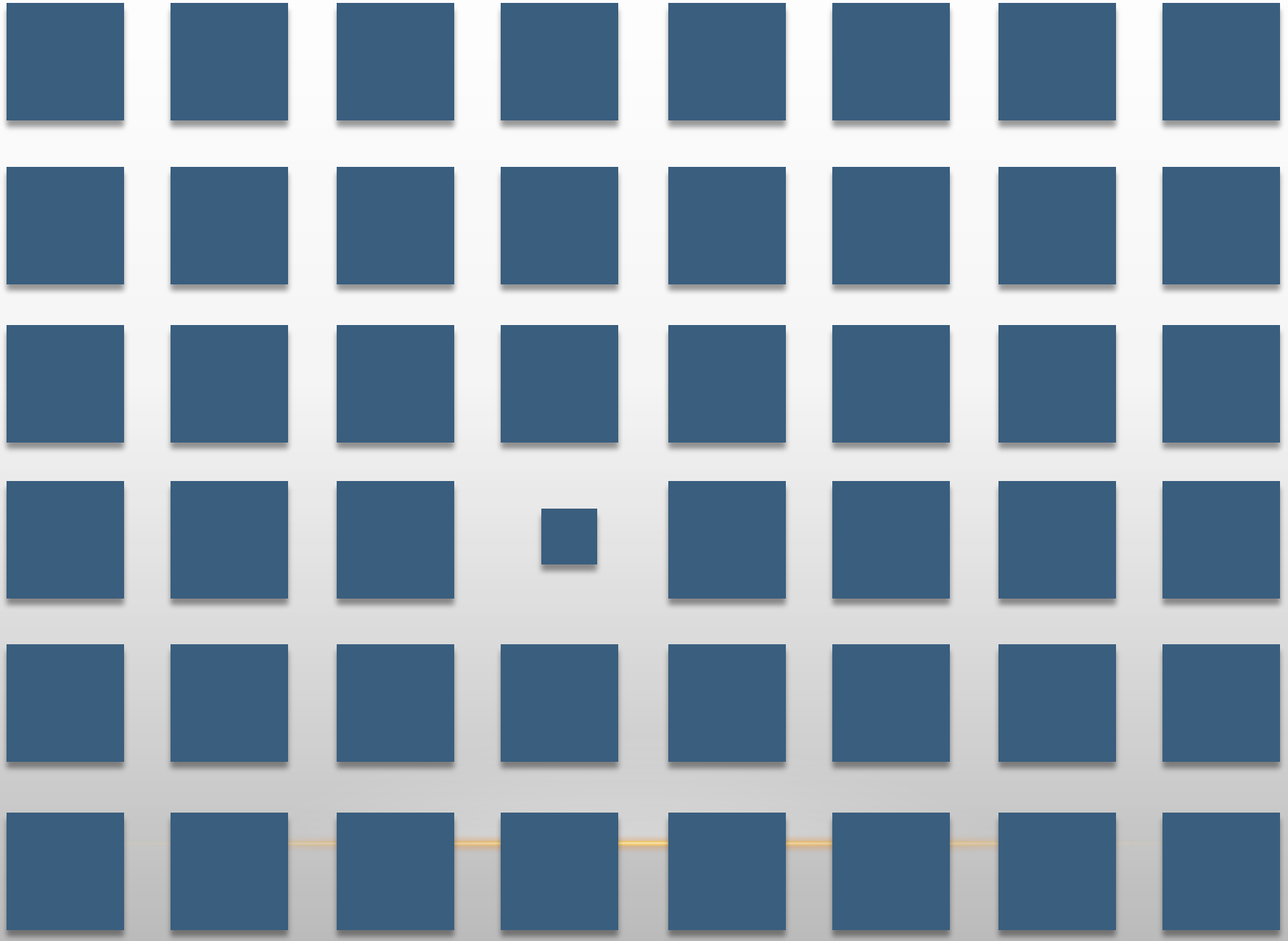


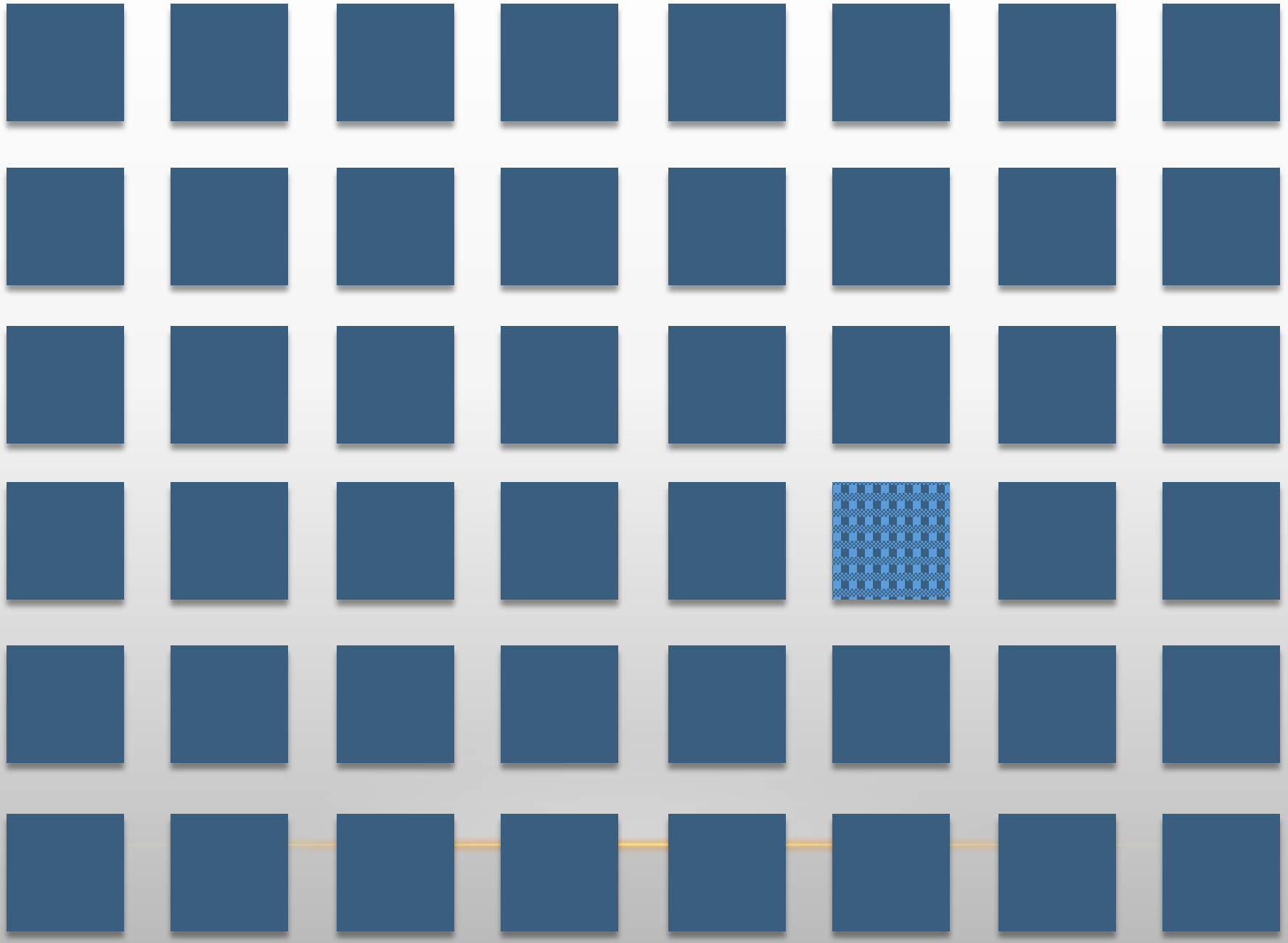


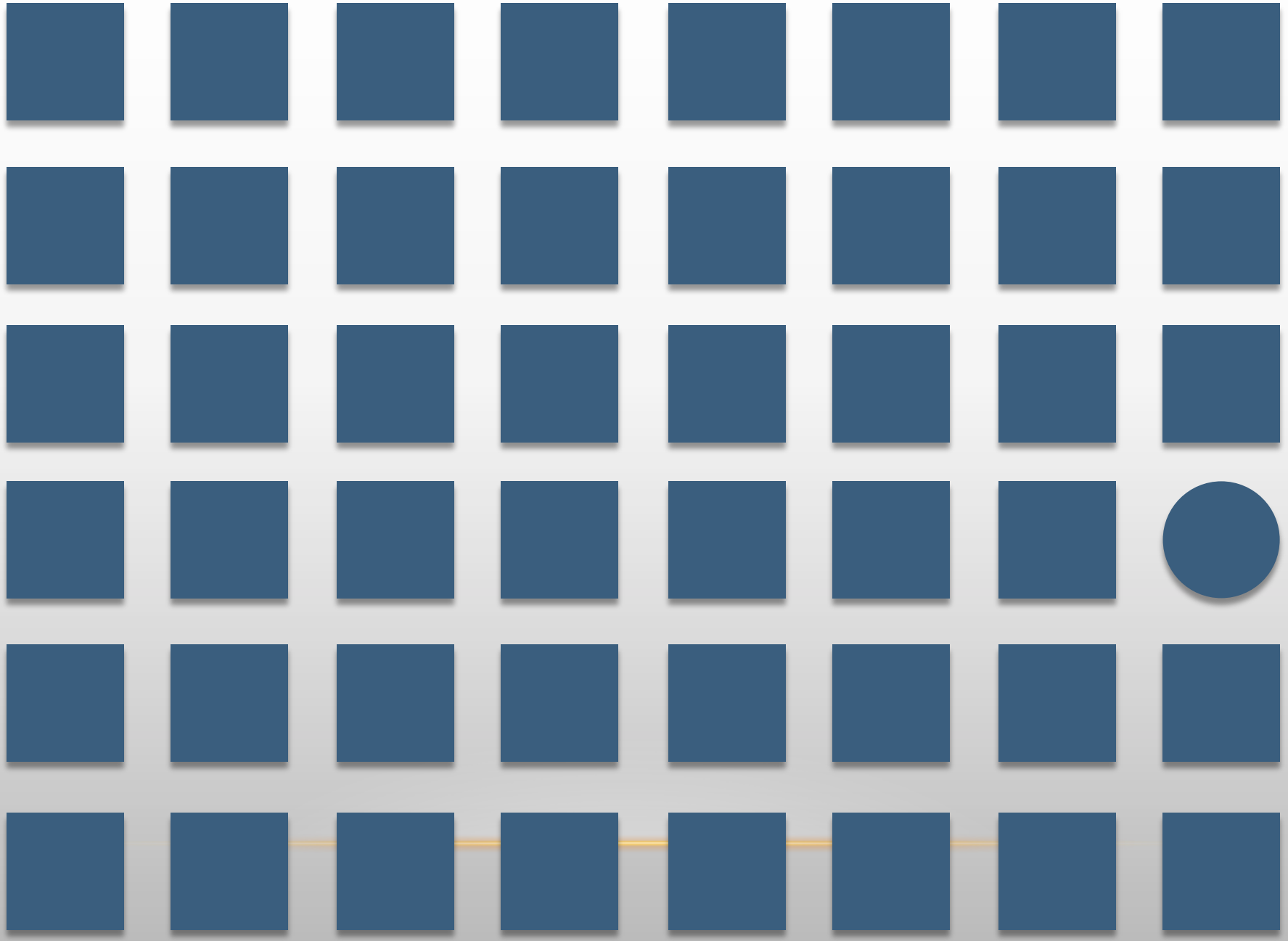












What did you observe?

PREATTENTIVE PROCESSING

Unconsciously gathering information from the environment

Preattentive Attributes(partial list):

position, orientation, scale

color, brightness, saturation

shape, texture

WHAT IS SCIENTIFIC VISUALIZATION?

Working Definition

Visually gaining/extracting insight from a scientific **data** using computational methods

Or

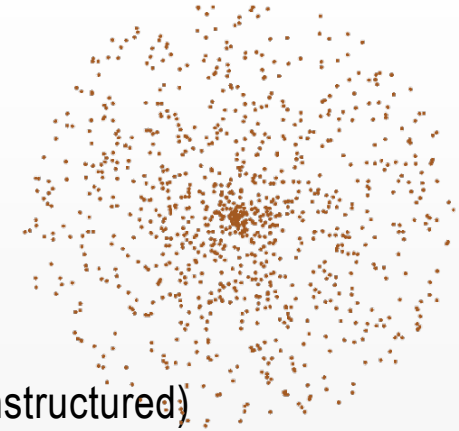
Creating a visual representation of **data** using algorithms

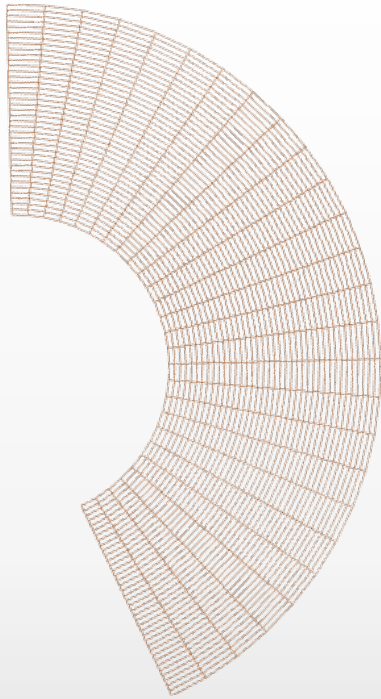
Trivia

Are charts visualizations?

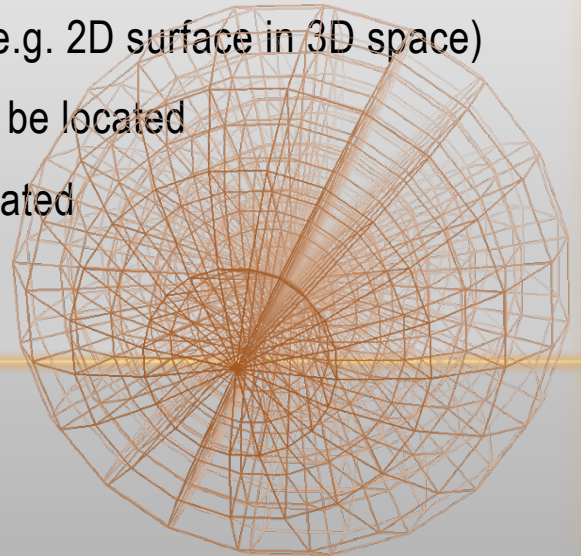
Are illustrations visualizations?

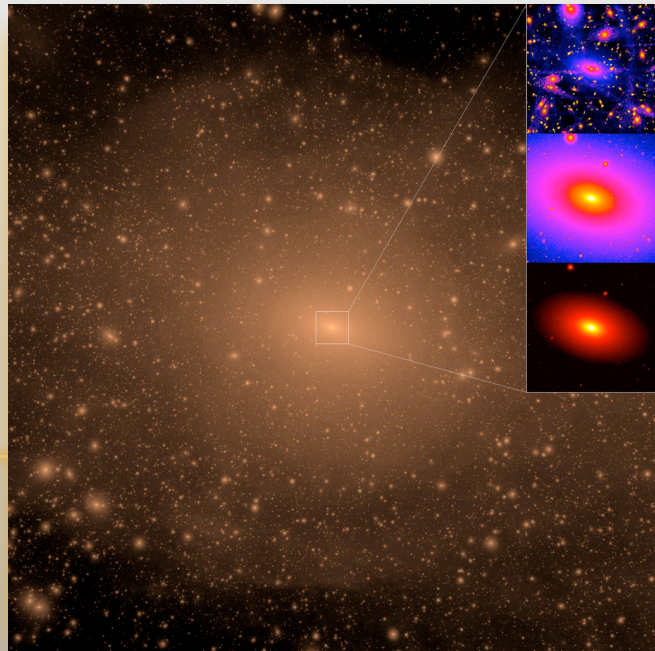
DATA





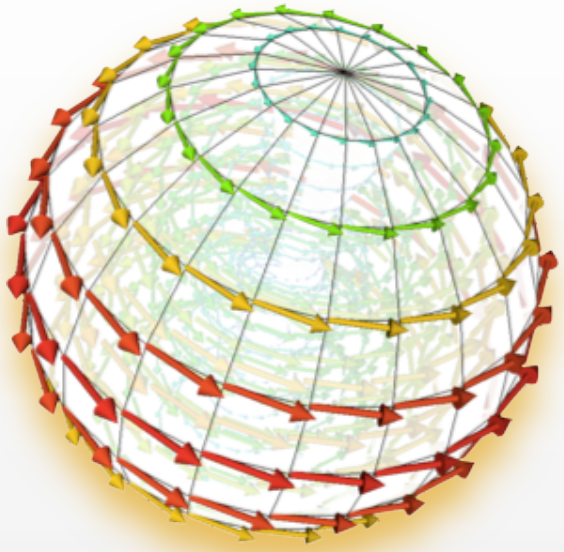
- Data
  - High Dimensional (structured and Unstructured)
  - Mesh
- Meshes Discretizes space into points and cells
  - 1D, 2D, 3D
  - All of these over time (up to 4D)
  - Can have lower-dimensional meshes in a higher-dimensional space (e.g. 2D surface in 3D space)
  - Provides a place for data to be located
  - Defines how data is interpolated



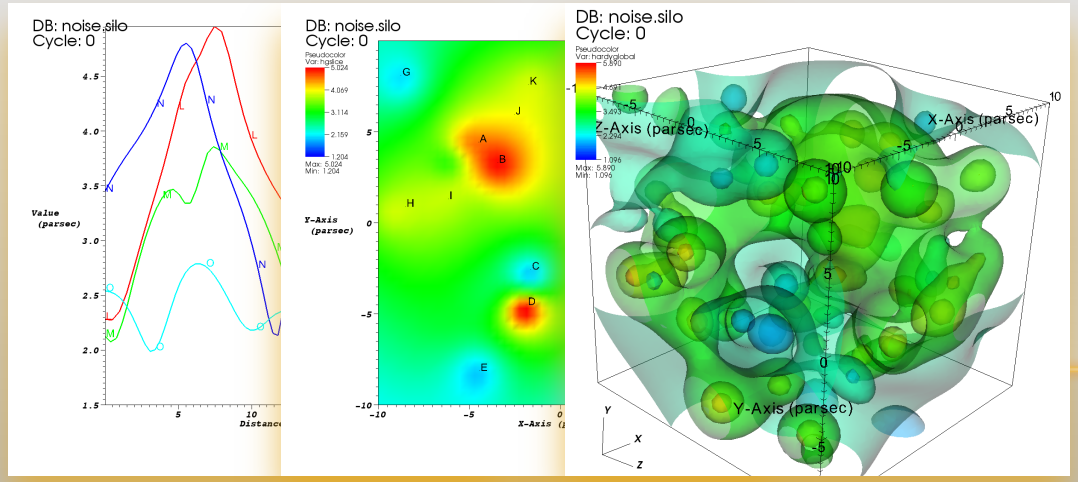


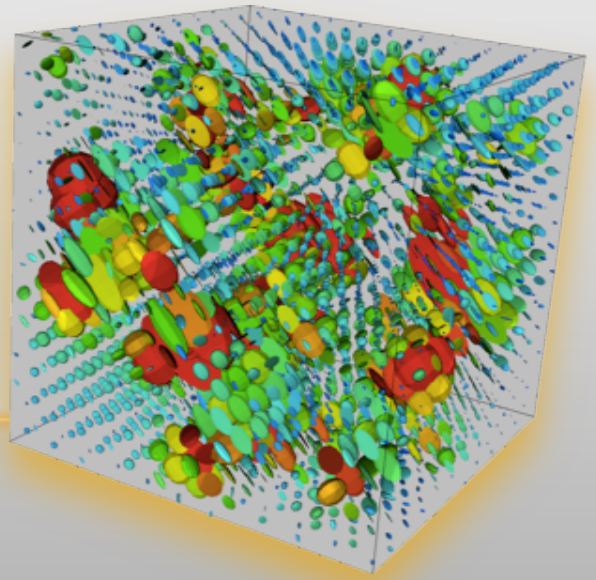
Slide: Courtesy of Sean Ahern, NICS

VARIABLES



- Scalars, Vectors, Tensors
- Sits on points or cells of a mesh
  - Points: linear interpolation
  - Cells: piecewise constant
- Could have different dimensionality than the mesh (e.g. 3D vector data on a 2D mesh)





Slide: Courtesy of Sean Ahern, NICS

MOTIVATION FOR VISUALIZATION

Create visual representations based on underlying data that are

- Concise (Yes)
- Unambiguous (Preferably)
- Intuitive (Trainable)
- Interactive (Desirable)
- Scalable (We wish)

VISUALIZATION BUILDING BLOCKS

Viz Elements

- Glyphs (e.g. Alphabets, Arrows)
- Lines
- Triangles
- Voxels* (volume element)

*Cannot be directly represented on displays

Viz Attributes

- Transforms (Position, Rotation, Scale)
- Color
- Opacity

View Attributes

- Viewpoint
- Projection (Orthographic, Perspective)
- Canvas

Viz Reinforcement

- Texture
- Light
- Distortion (e.g. displacement)
- Motion (e.g. Camera, time steps)
- Filter (e.g. threshold, resample, subset, slice, clip)
- Add Context (e.g. Connectivity, Map Overlay)

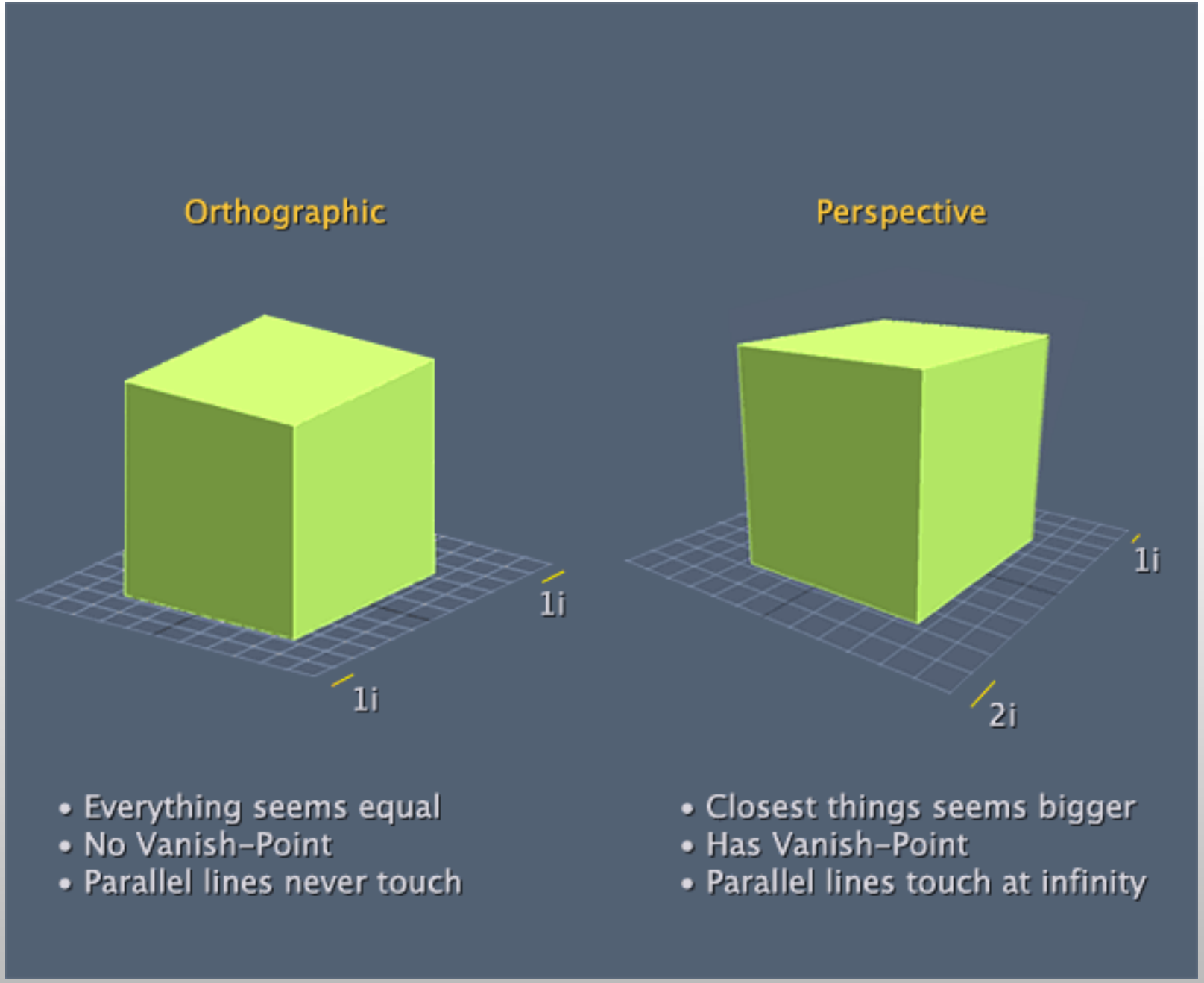


Image Credit: Diney Bomfim - http://blog.db-in.com/cameras-on-opengl-es-2-x/

VISUALIZATION TECHNIQUES

VISUALIZATION TECHNIQUES

- **COLOR MAP (Pseudocolor)***
- **CONTOURS***, **ISOSURFACE*** AND EXPLICIT GEOMETRY
- **VOLUMETRIC***
- STREAMLINES
- LINE INTEGRAL CONVOLUATION
- GLYPHS
- TOPOLOGICAL (advanced)
- **PARALLEL COORDINATES***, NETWORKS, ETC

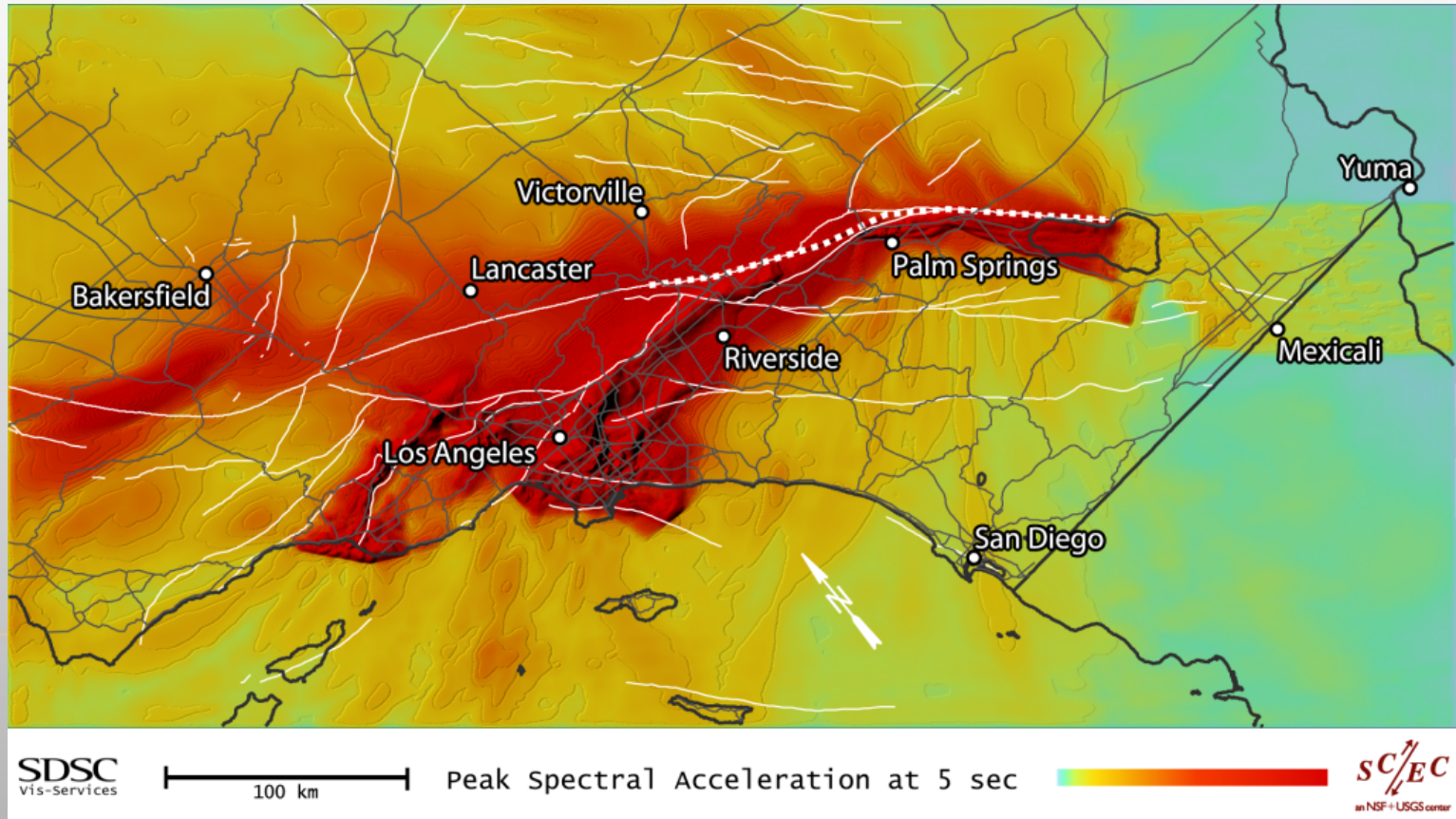
* We will create these plots using Parview and VisIt in hands on session.

VIZ TECHNIQUES: COLOR MAP (PSUEDOCOLOR PLOT)

Process: Map scalar data to a color table

Utility: To investigate range of data

Fast and great for Error Diagnostic and Visual Validation



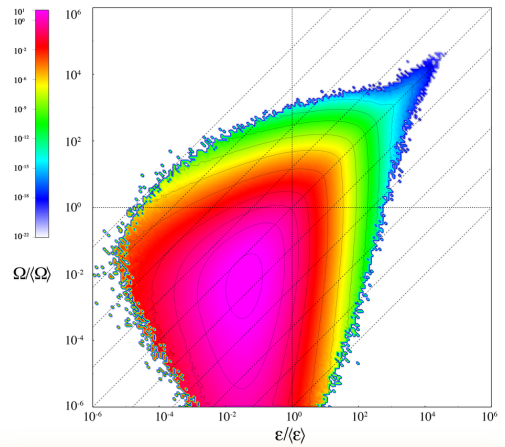
VIZ TECHNIQUES: GEOMETRIC

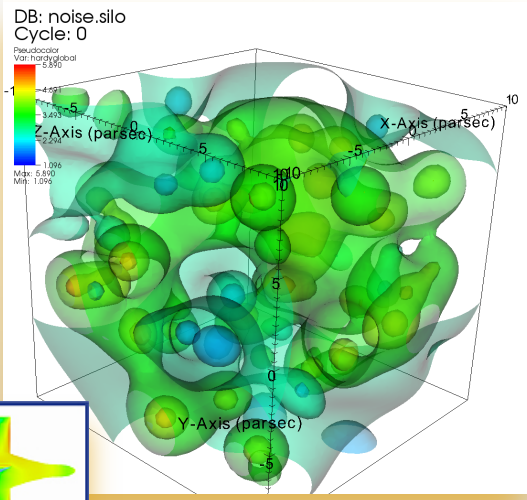
Process & Utility: Identify regions of same scalar value

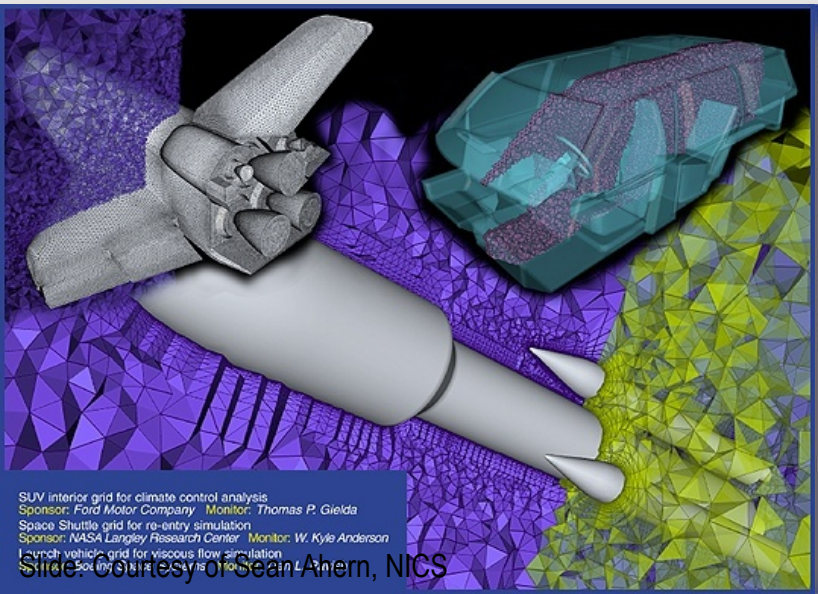
2D: Contours

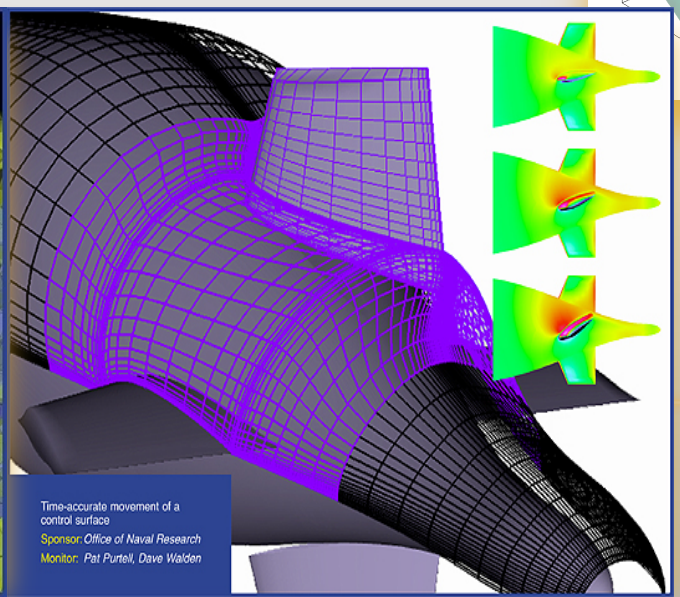
3D: Isosurface (Marching cubes, Marching tetra)

Process: Draw Explicit Geometry (Tri Mesh, Tet Mesh)









Slide: courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: VOLUMETRIC

Process: Volumetrically map scalar data to a transfer function (Color + Opacity)

Utility: To investigate interior/density of scalar volumetric data

Results are very sensitive to

- Transfer Function
- Sampling Interval
- Output Resolution

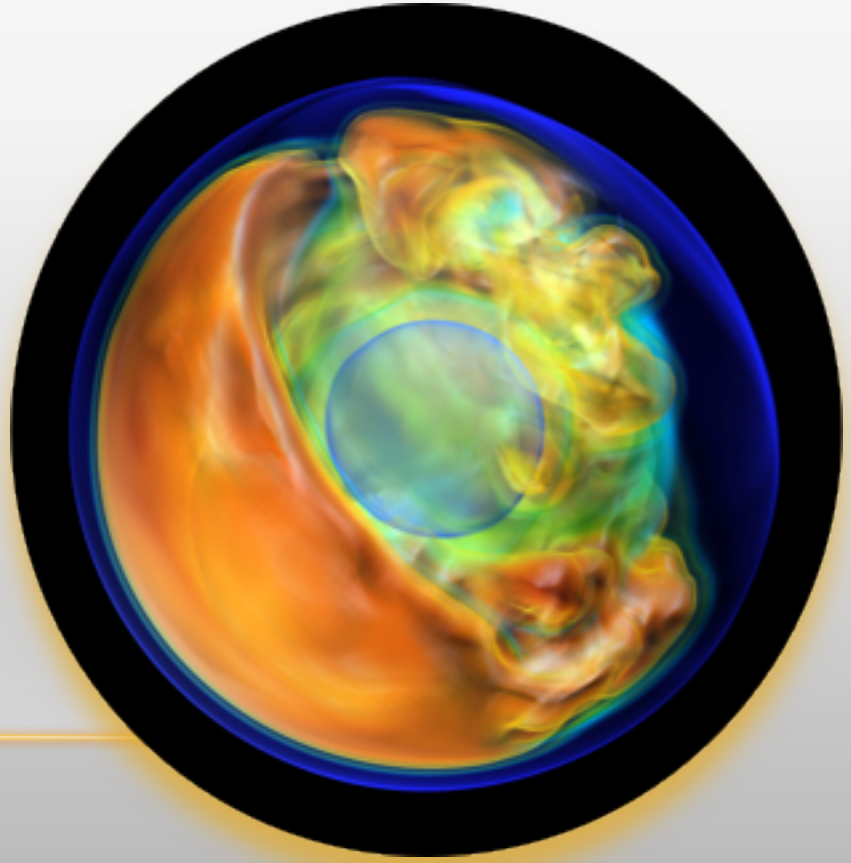


Image: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: STREAMLINES

Process: Find curves that are instantaneously tangent to the velocity vector of the flow

Utility: To investigate nature of flow

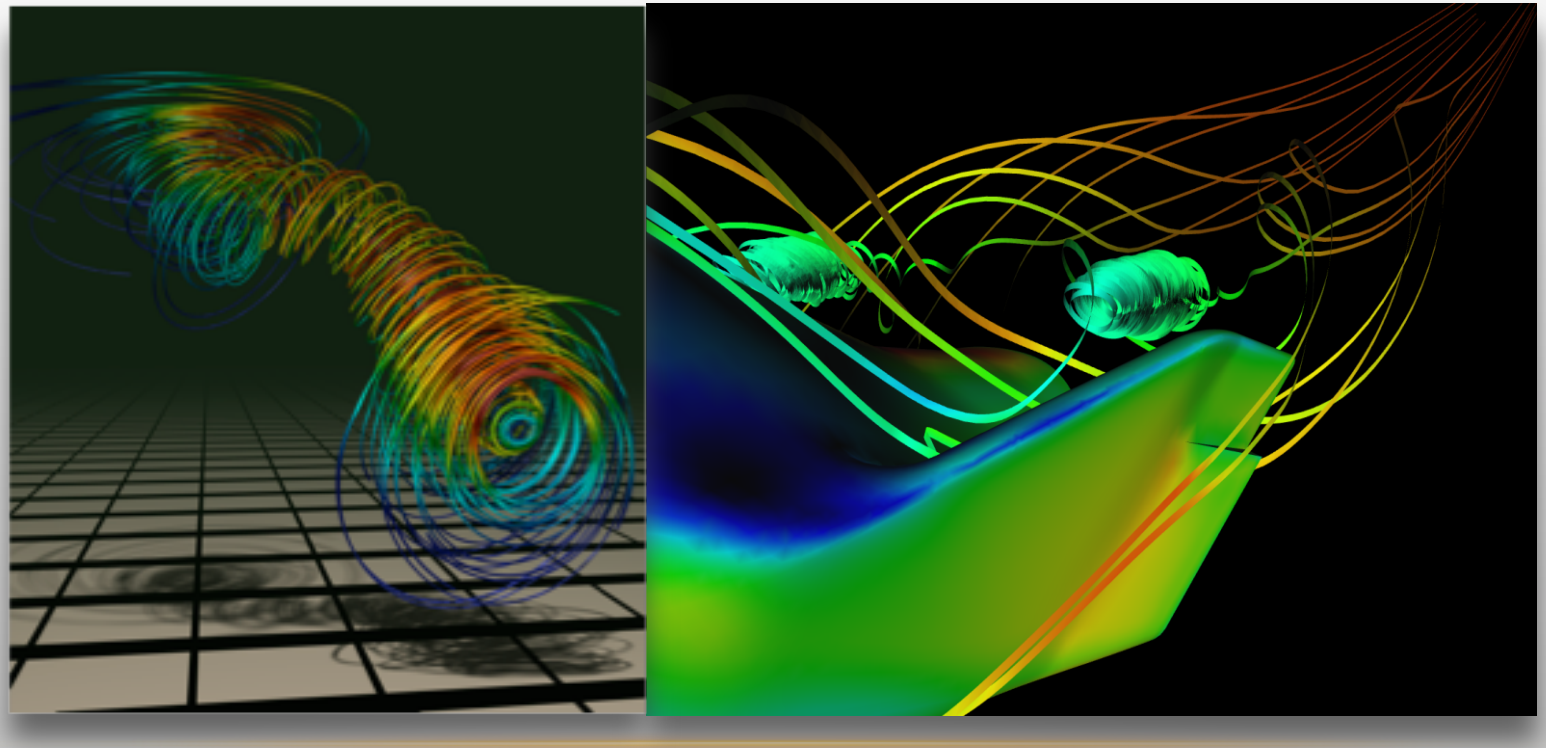
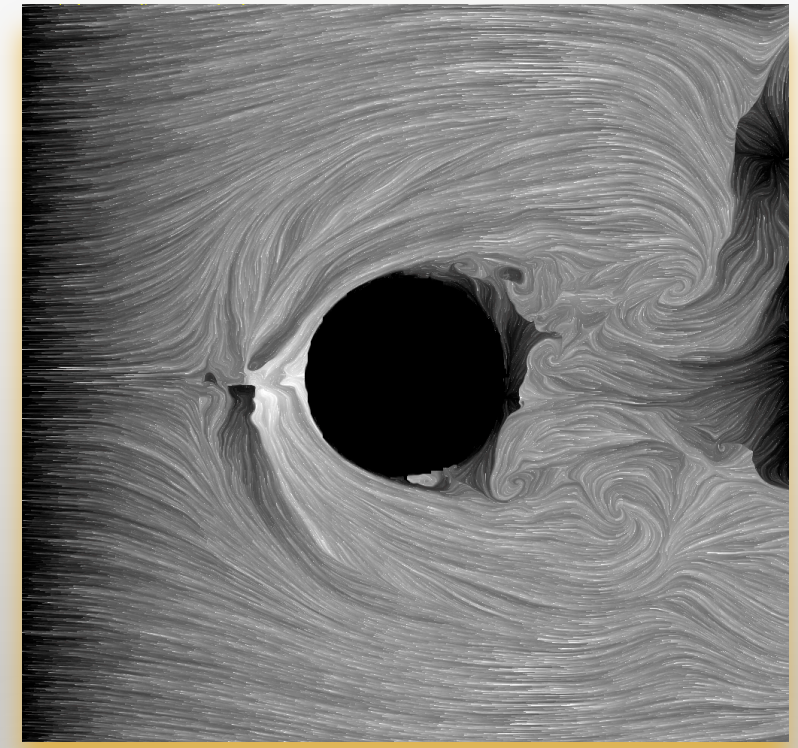


Image: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: LIC

Line Integral Convolution

Utility: To investigate nature of flow

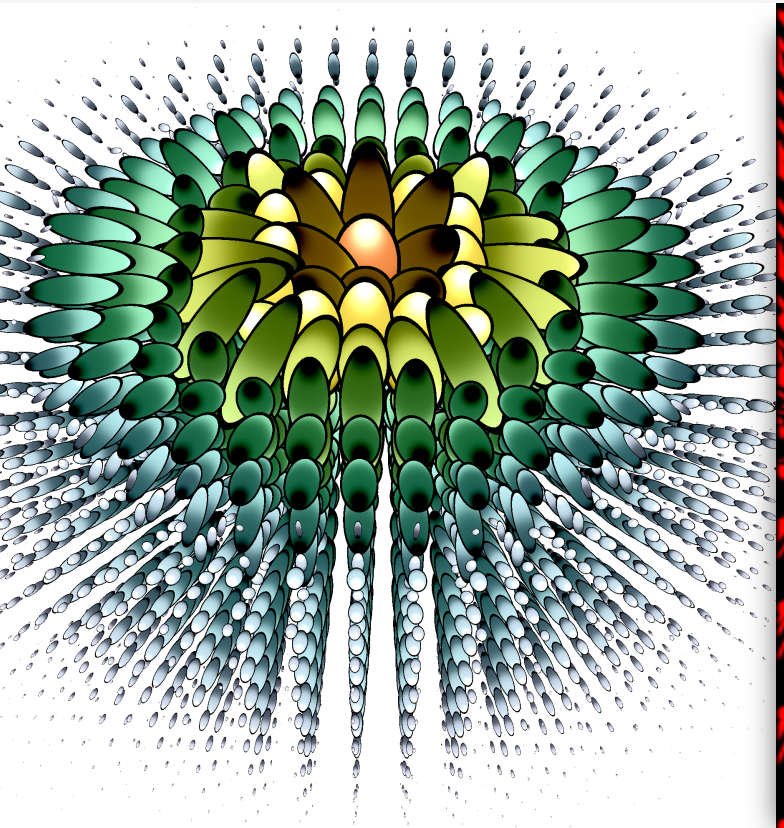


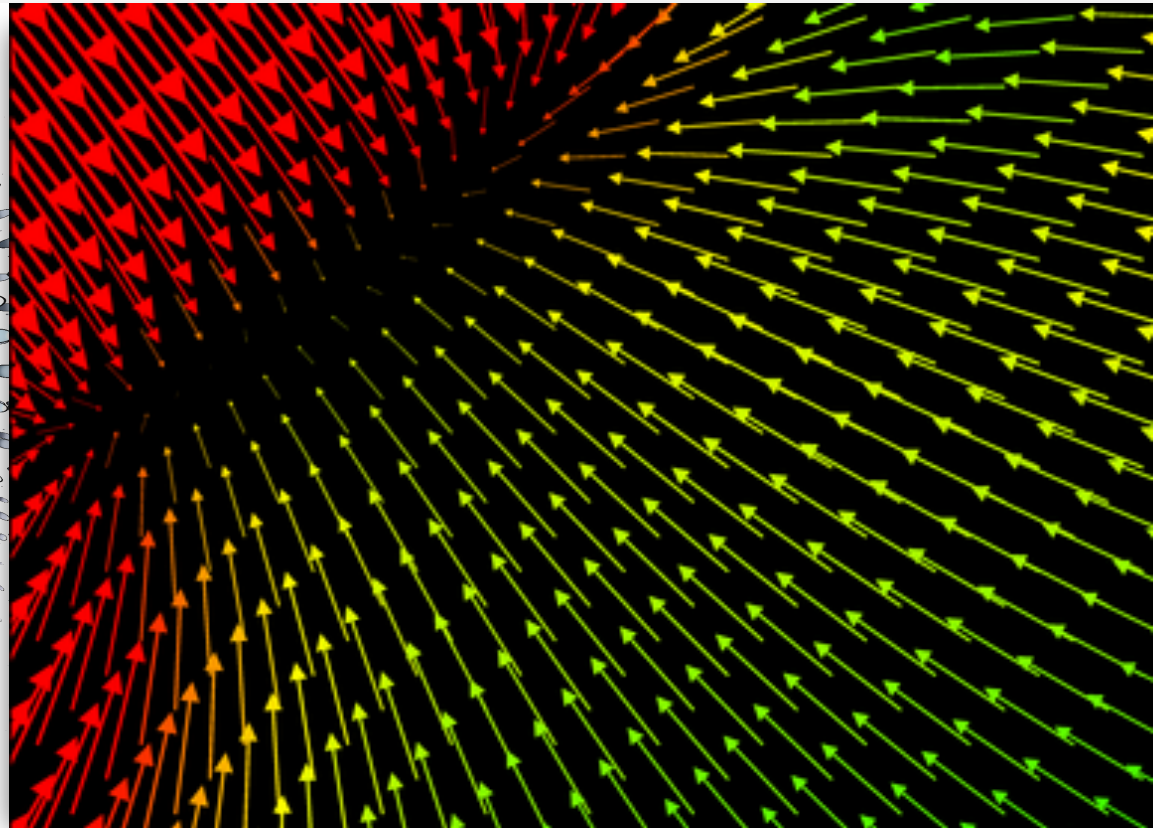
Image/movie: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES:
GLYPHS

Map the scalar or vector data to a shape

Utility: To investigate flow of vector data or distribution of scalar/vector data

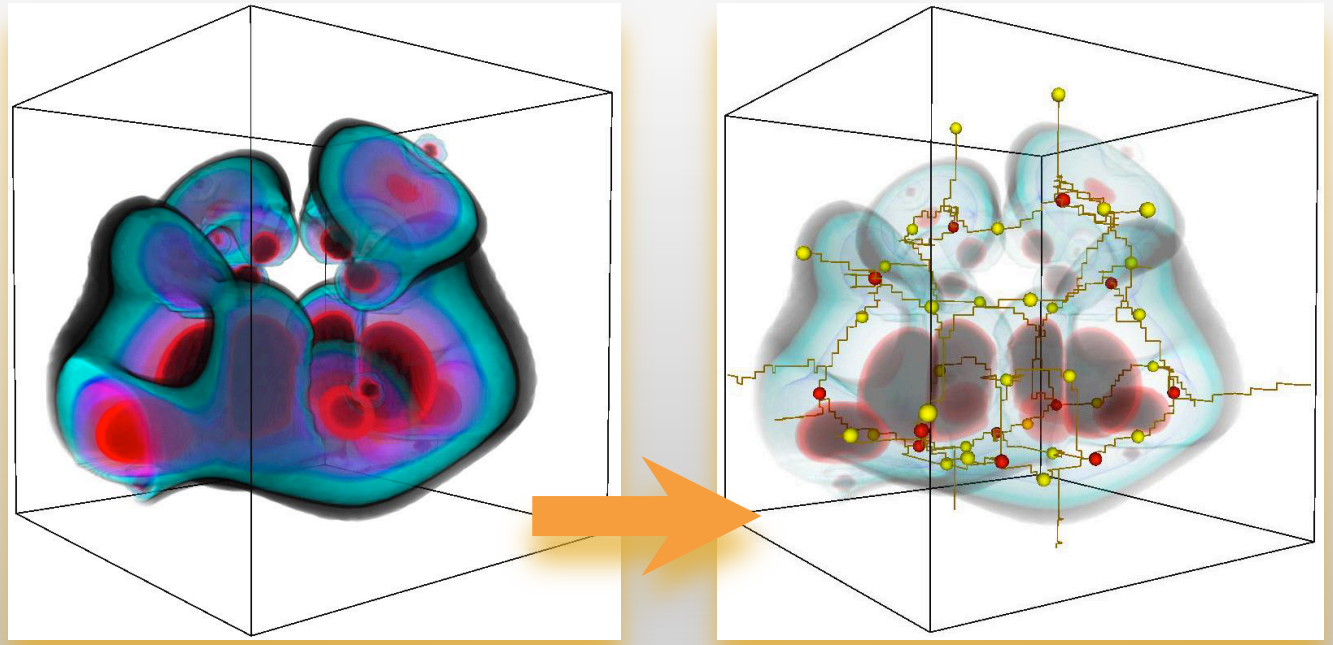




VIZ TECHNIQUES: TOPOLOGICAL

Process: Compute topology of underlying data

Utility: To investigate local maxima, minima saddle points, etc



Images: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: TENSOR ANALYSIS

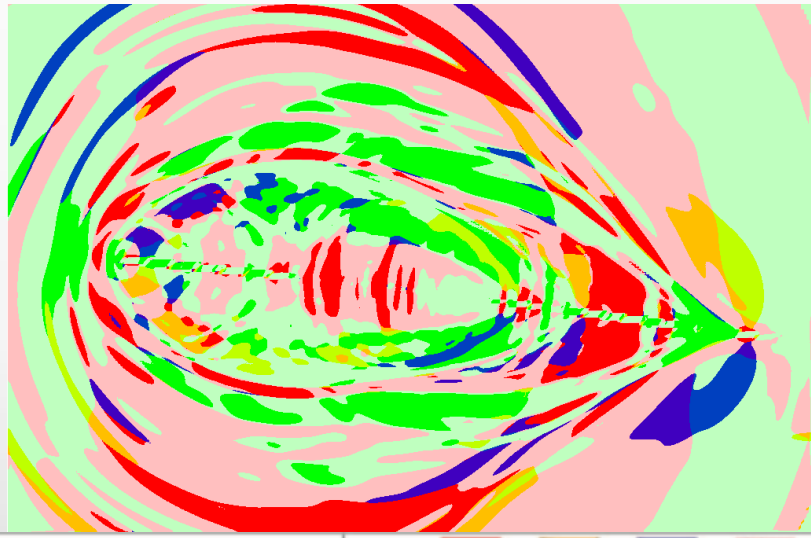
References

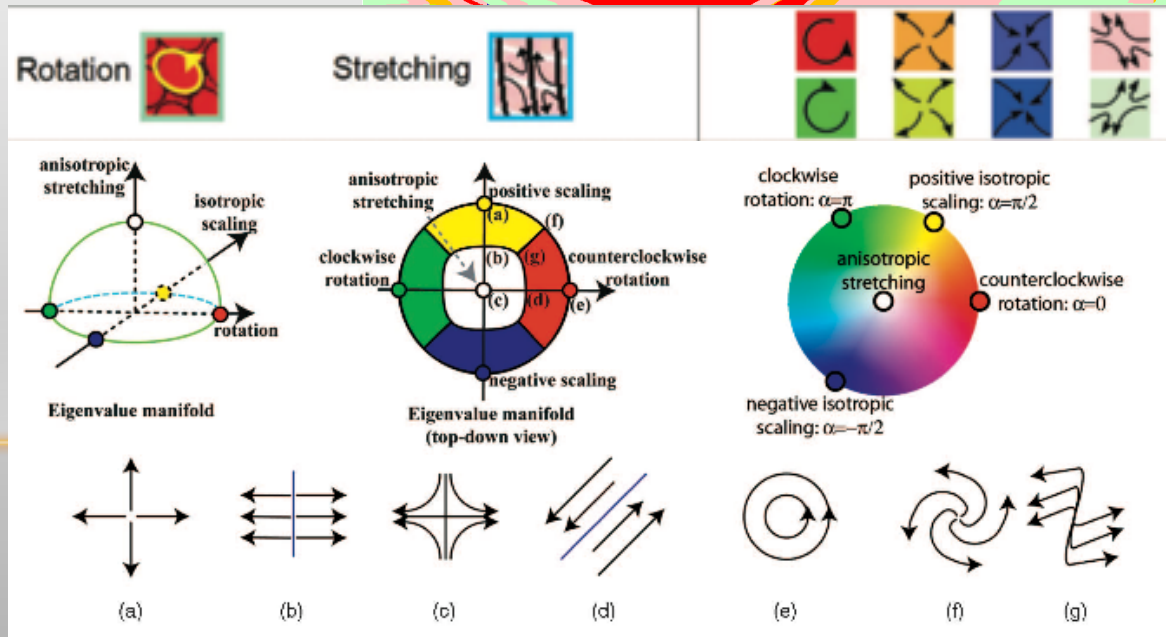
Asymmetric Tensor Analysis for Flow Visualization

Eugene Zhang, Harry Yeh, Zhongzang Lin, and Robert S. Laramee

Asymmetric Tensor Field Visualization for Surfaces

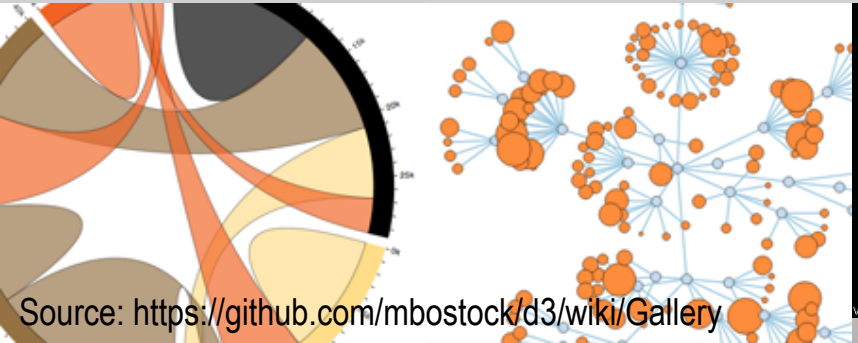
Guoning Chen, Darrel Palke, Zhongzang Lin, Harry Yeh, Paul Vincent, Robert S. Laramee and Eugene Zhang

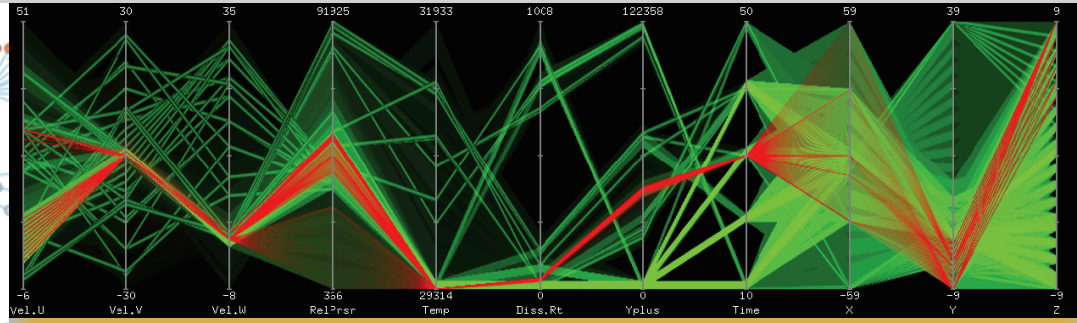




OTHER VIZ TECHNIQUES

- **Parallel Coordinates**
- Chord
- Tree (e.g. Dendograms, Sunbursts, Treemaps, etc)
- Many others



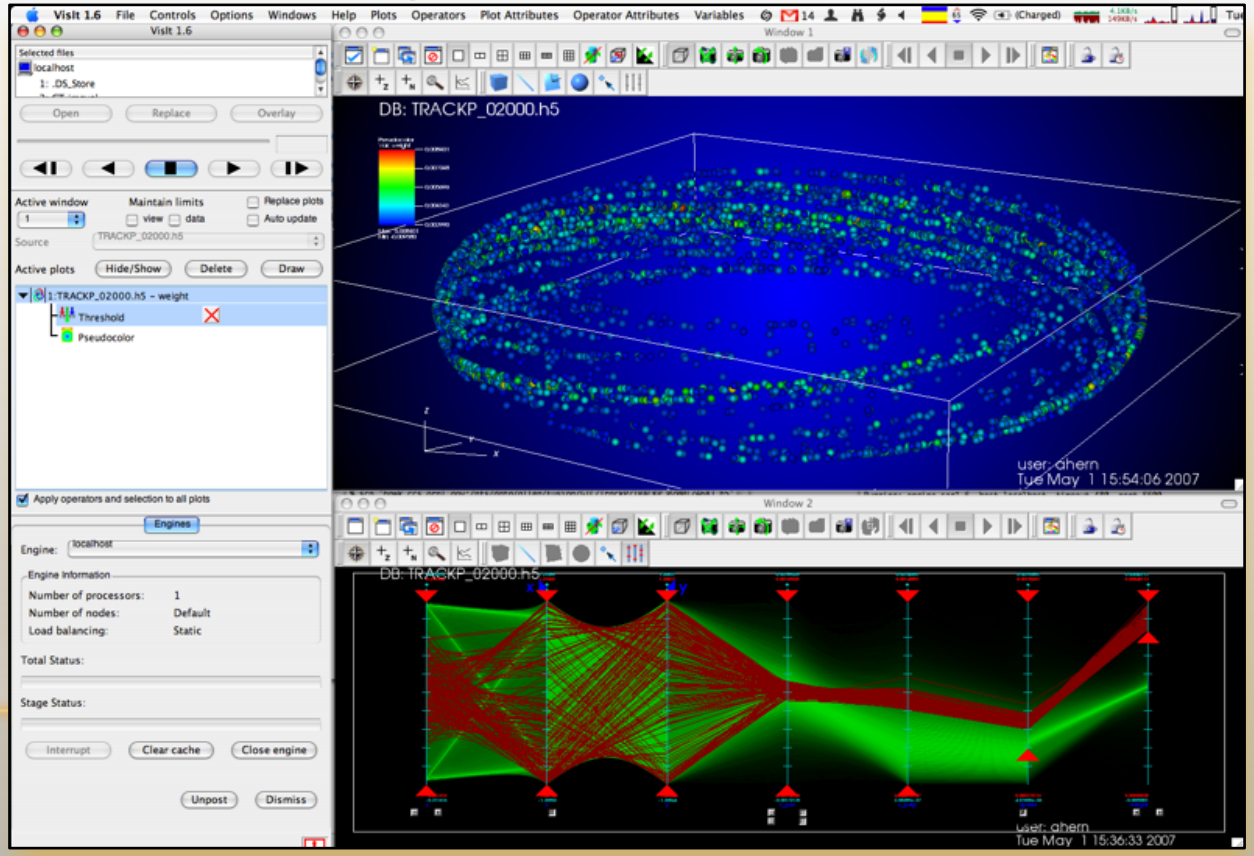


Source: https://github.com/mbostock/d3/wiki/Gallery

HIGH-DIMENSIONAL VISUALIZATION

Parallel coordinates summarize high-dimensional information

Utility: To find trends and relationships



VISUALIZATION APPLICATIONS

- Communication
- Confirmation
- Inspection and Exploration

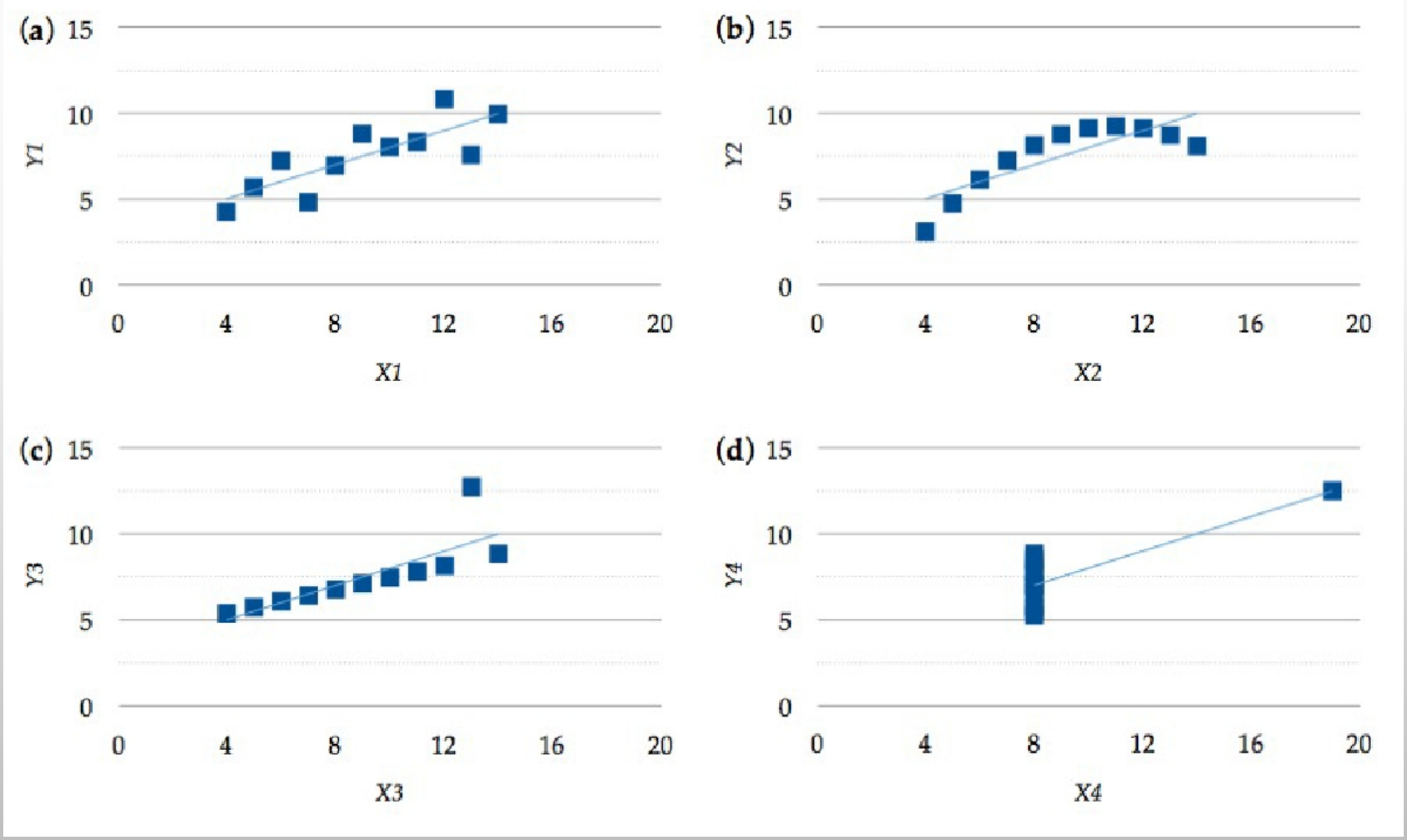
APPLICATION OF VIZ -CONFIRMATION

X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	Y_4
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

mean(X) = 9, var(X) = 11, mean(Y) = 7.5, var(Y) = 4.12,
cor(X,Y) = 0.816, linear regression lineY = 3 + 0.5*X

Anscombe 1973, The American Statistician

Anscombe's Quartet

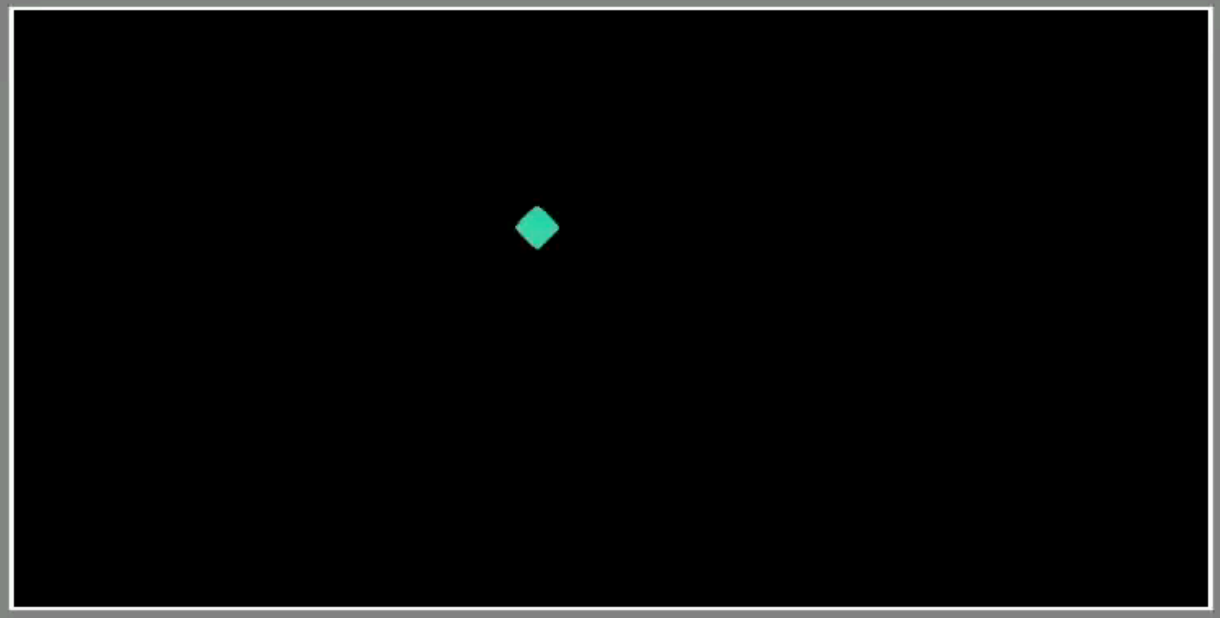


Slide: Courtesy of N Gehlenborg & M Meyer / Bio-IT World 2011

APPLICATION OF VIZ
- INSPECTION AND EXPLORATION

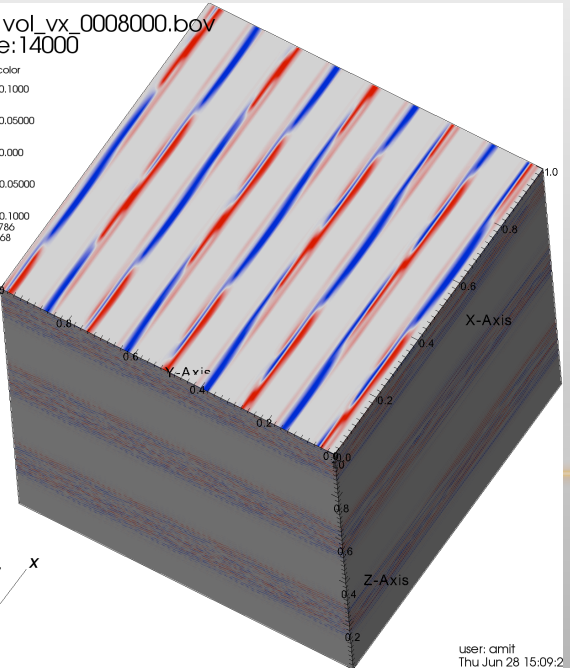
SALIENT APPLICATIONS OF VISUALIZATION

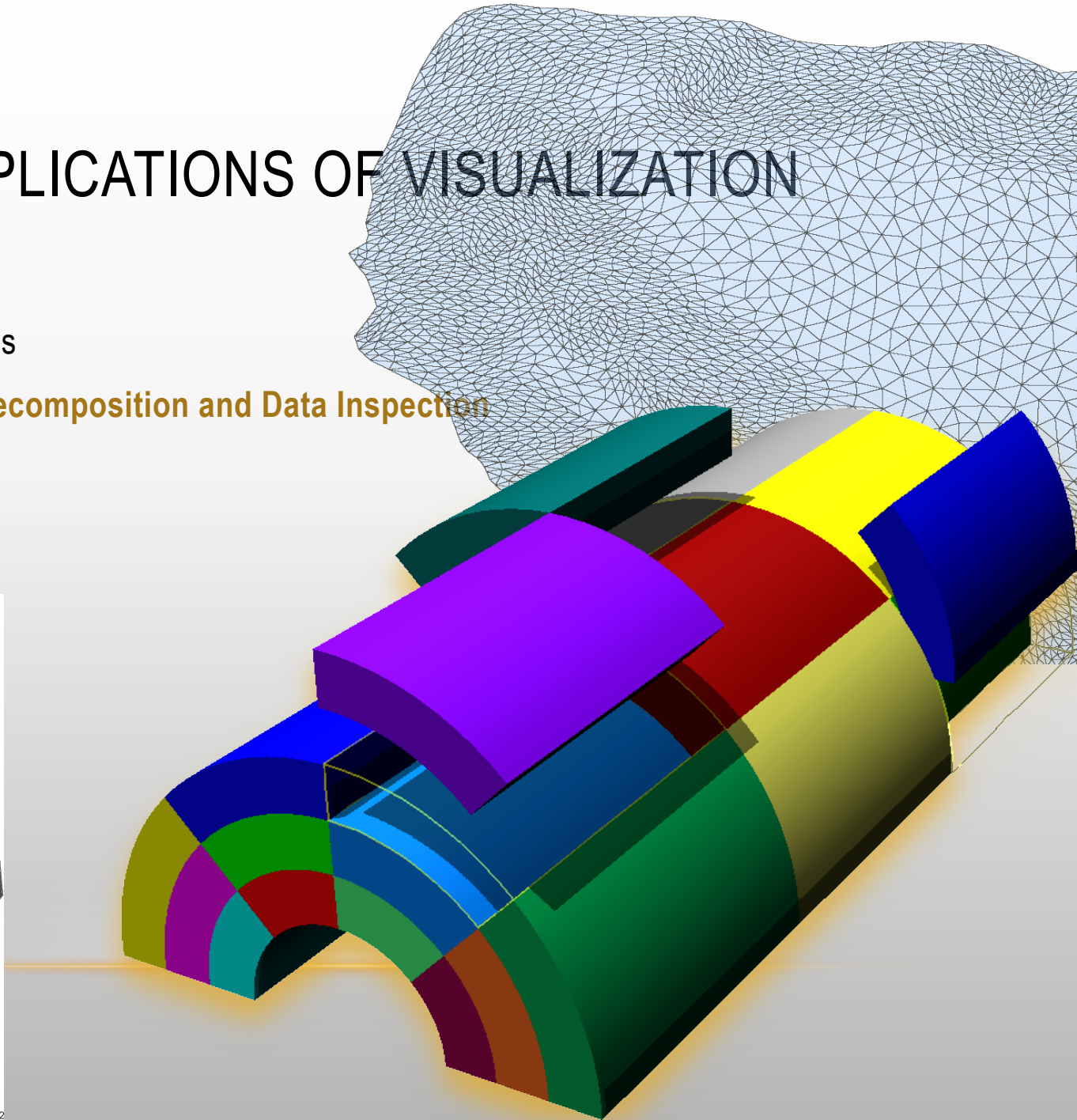
- **“nan” Inspection**
- **Boundary Conditions**



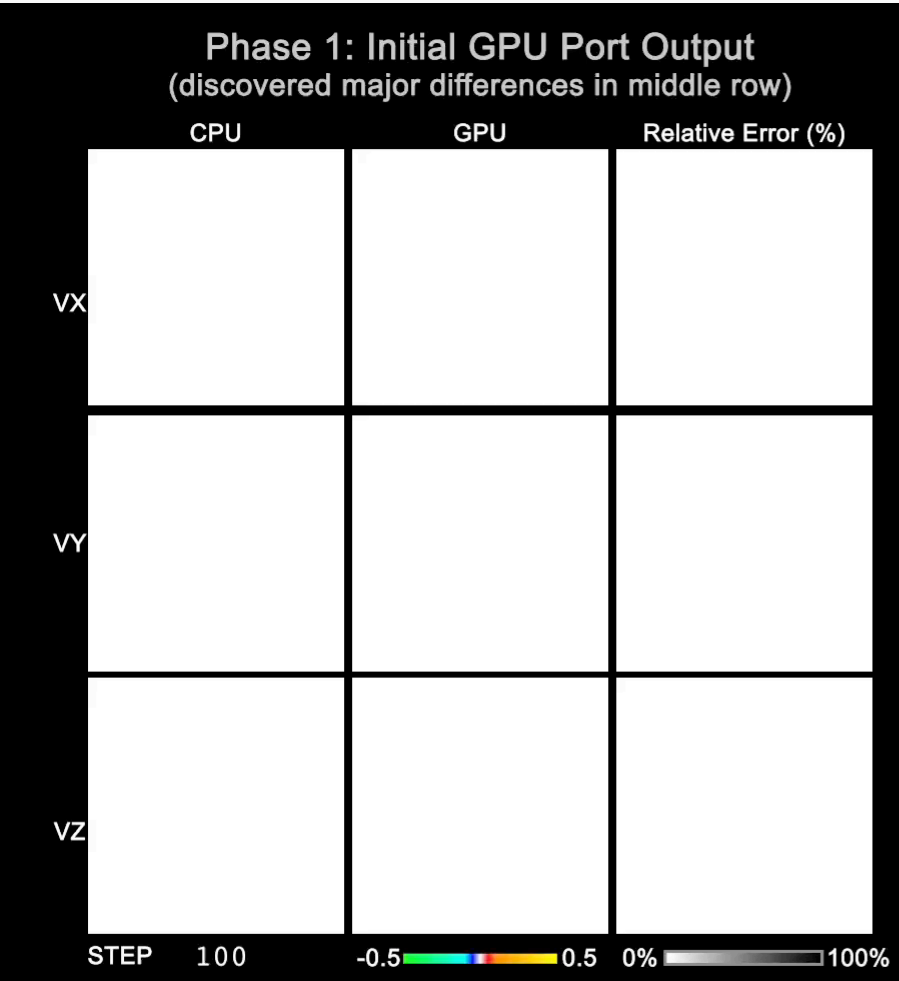
SALIENT APPLICATIONS OF VISUALIZATION

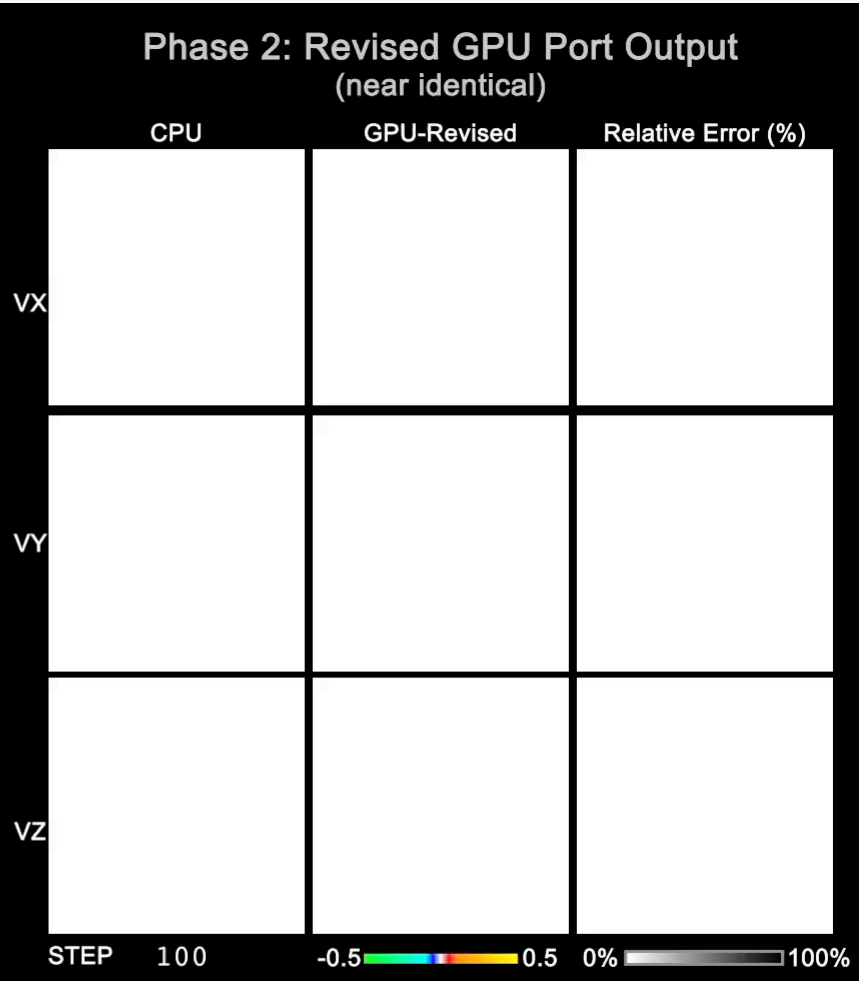
- “nan” Inspection
- Boundary Conditions
- **Mesh Topology, Decomposition and Data Inspection**





SALIENT APPLICATIONS OF VISUALIZATION

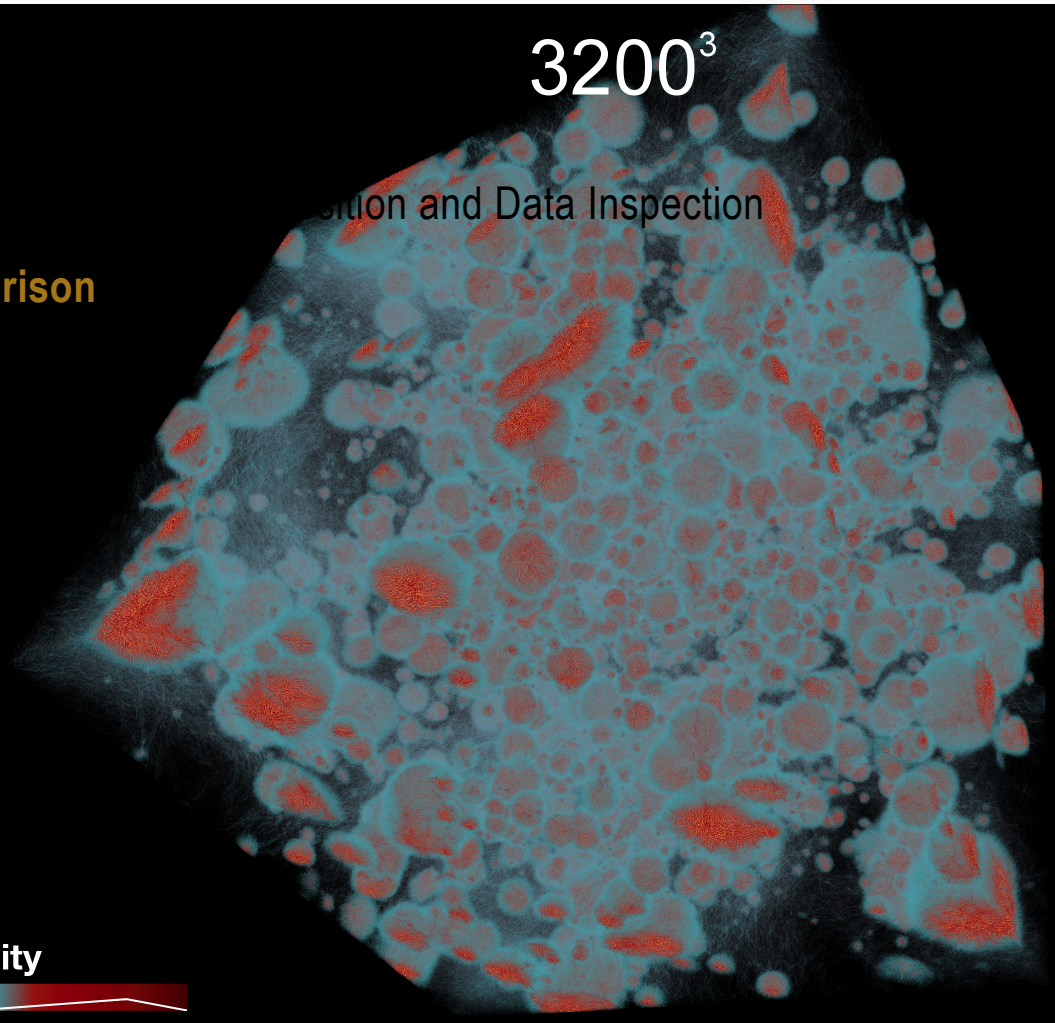




SDSC

SALIENT APPLICATIONS OF VISUALIZATION

- 3200^3
- ...tion and Data Inspection
- **Comparison**



Density

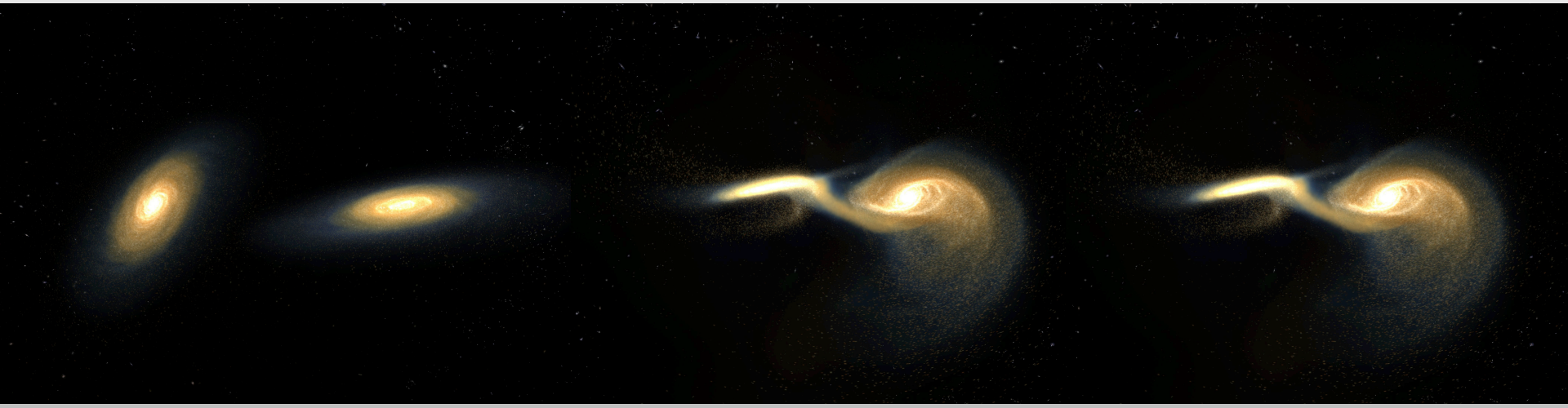
Non-Radiative No Difference Radiative

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

Argonne
NATIONAL LABORATORY

SALIENT APPLICATIONS OF VISUALIZATION

- “nan” Inspection
- Boundary Conditions
- Mesh Topology, Decomposition and Data Inspection
- Comparison
- **Collisions and Mergers**



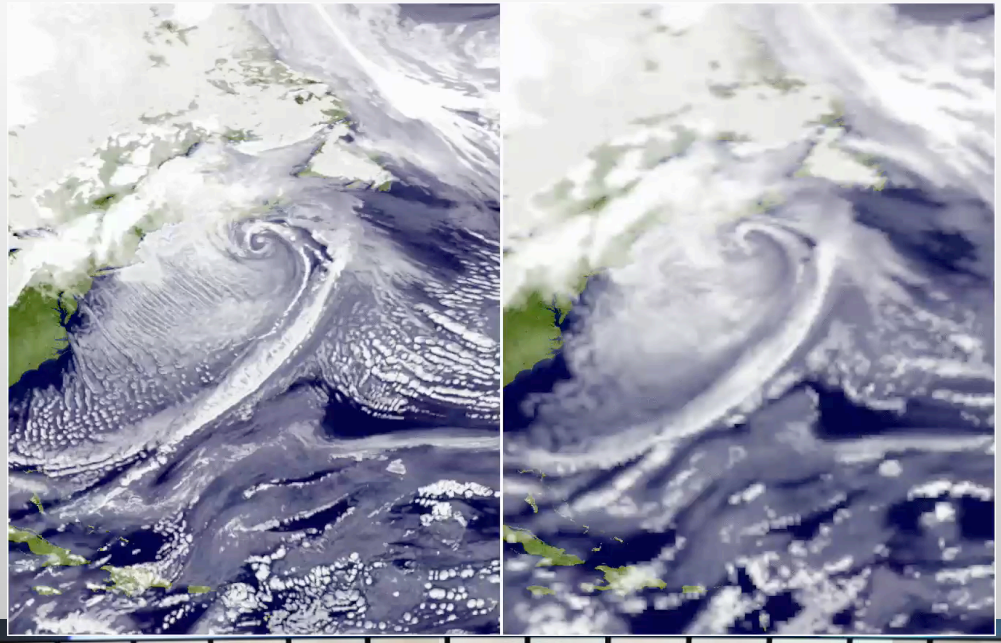
“Deep Sea Adventure” CalTech, NCSA, ADLER PLANETARIUM

SALIENT APPLICATIONS OF VISUALIZATION

SCEC
an NSF+USGS center
SDSC

DISPLAYING DATA

- High resolution devices (latest tablets and laptops)
- High resolution monitors (30” flat panels, 4 megapixel, 2500x1600)
- Tile Displays (array of monitors)

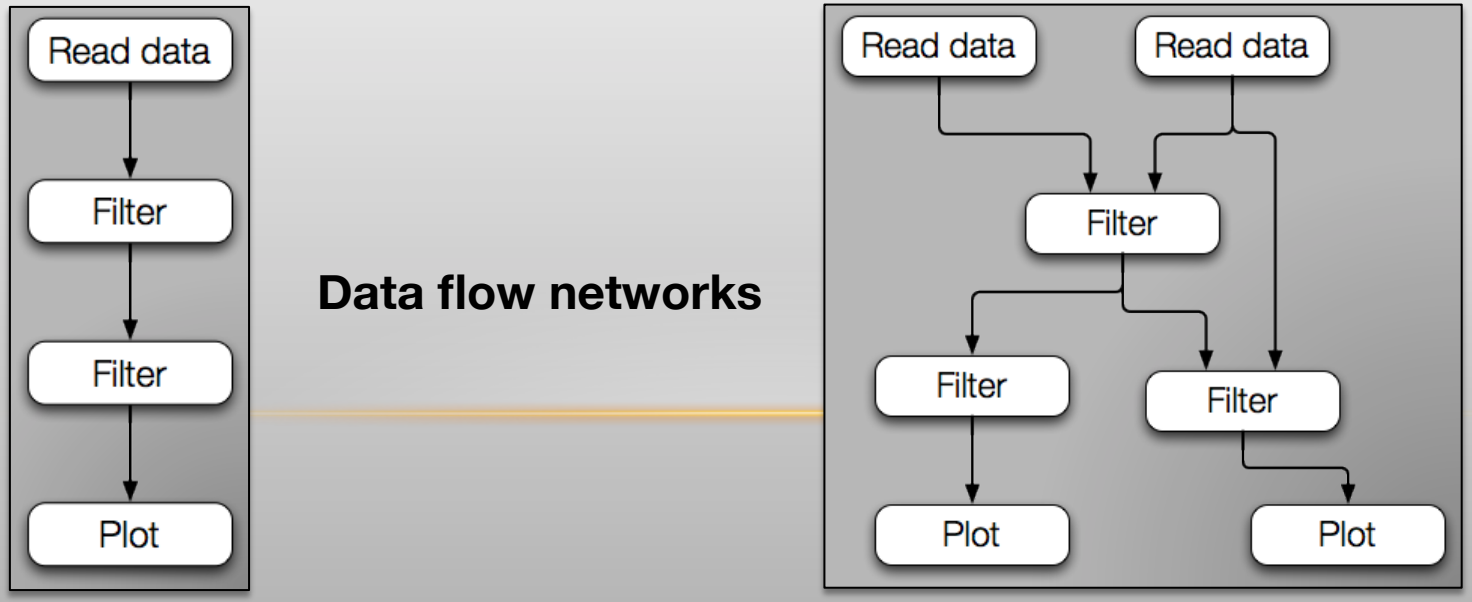


Slide: Courtesy of Sean Ahern, NICS

MISCELLANEOUS

FLOW NETWORKS (PIPELINES)

- Data reading: NetCDF, HDF, text, CSV, PDB
- Data operations: Slicing, resampling, mesh transforms
- Data plotting: Pseudocolor, isosurface, volume rendering



BEST PRACTICES

- Colors
  - Parsimony of color, Grey scale can be excellent at many things
  - Don’t use rainbow color map: http://blog.visual.ly/rainbow-color-scales/
  - Good Color map design:
    - colorbrewer2.org (excellent)
    - kuler.adobe.com
    - Use HSV color scale for color map design and interpolation
- Always include a legend
- Visualizations have their own unpredictable life cycle. Writing non technical captions will help you extremely in long run.
- Carefully set sampling, interpolation and seeds
- Write data in parallel read friendly format
- Reduce/Minimize Data Movement: Visualize as close to the data as possible

VIZ MODES

- Post Visualization (after the simulation)

  Pros:

  - Maximum flexibility
  - Operational simplicity

  Cons:

  - Data reload
  - Time consuming
  - Delayed access to results
- Co-located Visualization (during simulation but on different nodes)
- In-Situ Visualization (during simulation on same nodes)

  Pros:

  - Enables swift visual validation of results
  - Least/moderate data movement/replication

  Cons:

  - Difficult implementation
  - Additional complexity an longer runtime
  - Fixed visualization outputs

VIZ LIMITATIONS

- Domain knowledge
- Interpolation
- Multivariate data
- Temporal coherence
- Precision loss (compression)
- Perceptual issues (color blindness)
- Personal bias (author & viewer)

VIZ MISCONCEPTIONS (BUSTED)

- I am not an artist thus can't do viz (Stick around. Try again and ask for help this time)
- Viz is an art not science (Viz is driven by algorithms, some very sophisticated)
- Viz is a one time task (Viz is a process like any other analysis)
- Viz is useful only for communication (Think about error and diagnostics)
- Viz SU's are insignificant (Welcome to Viz World)

REQUESTING HELP

- Submit tickets at XSEDE
- Request Extended Collaborative Support Service (ECSS) with your allocation

  ECSS Provides collaborative expertise on your research work in several areas

  - Performance Tuning
  - Scaling
  - Visualization
  - etc

SESSION 2: VISUALIZATION WITH VISIT (HANDS ON)

VISIT SOFTWARE

Originally developed at LLNL (2000 onwards), now a community effort

Strengths

- Cross Platform
- Open and freely available
- Versatile (supports many mesh types, reads over 100 data formats)
- Local, Remote, Client-Server
- Supports large data (scalable)
- Interactive, Command Line & Batch
- Extensible via C++, Java & Python

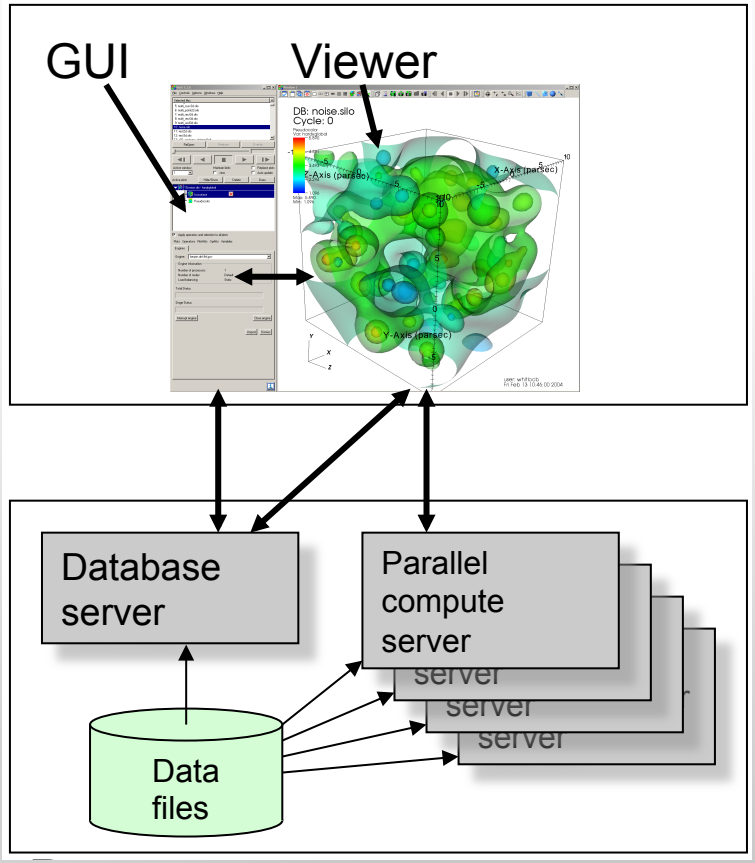
Source code, executable and documentation available at http://www.llnl.gov/visit

Trivia: VisIt name is play on words "**Vis**ualize **It**"

VISIT ARCHITECTURE

Four Main Components

- GUI (main window)
- Viewer (visualization or plot window)
- Database server
- Compute engine



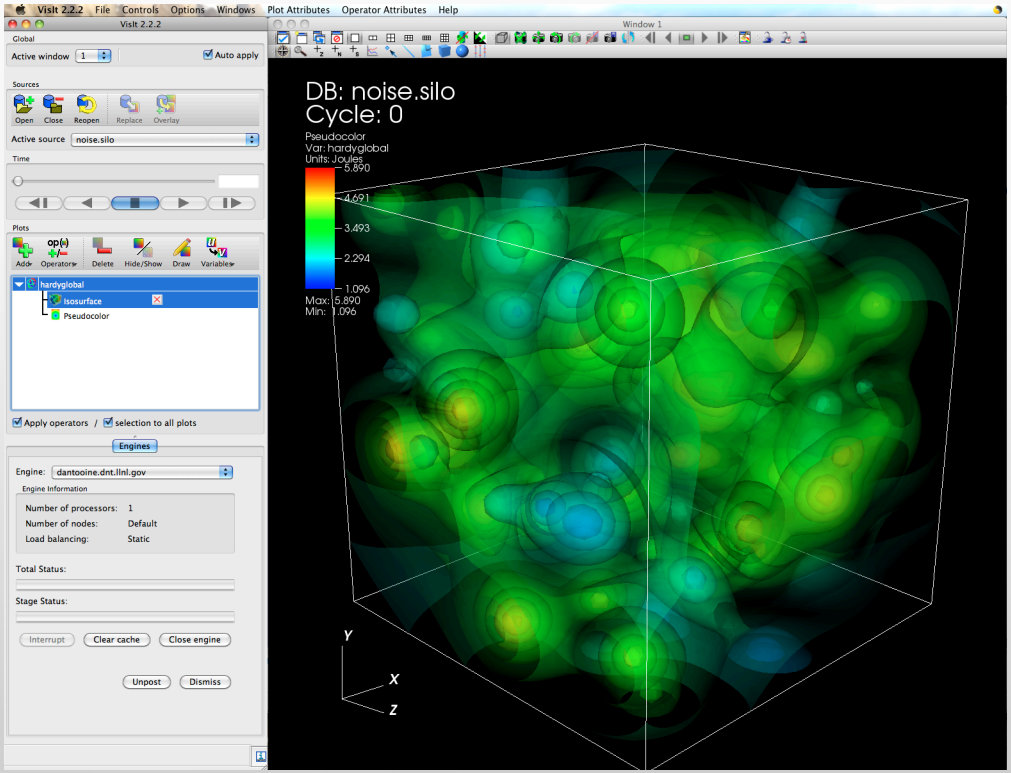
VISIT'S MAIN WINDOWS

GUI

- Select files to visualize
- Create and manage plots
- Set plot attributes
- Add operators
- Set look and feel for visualization

Viewer

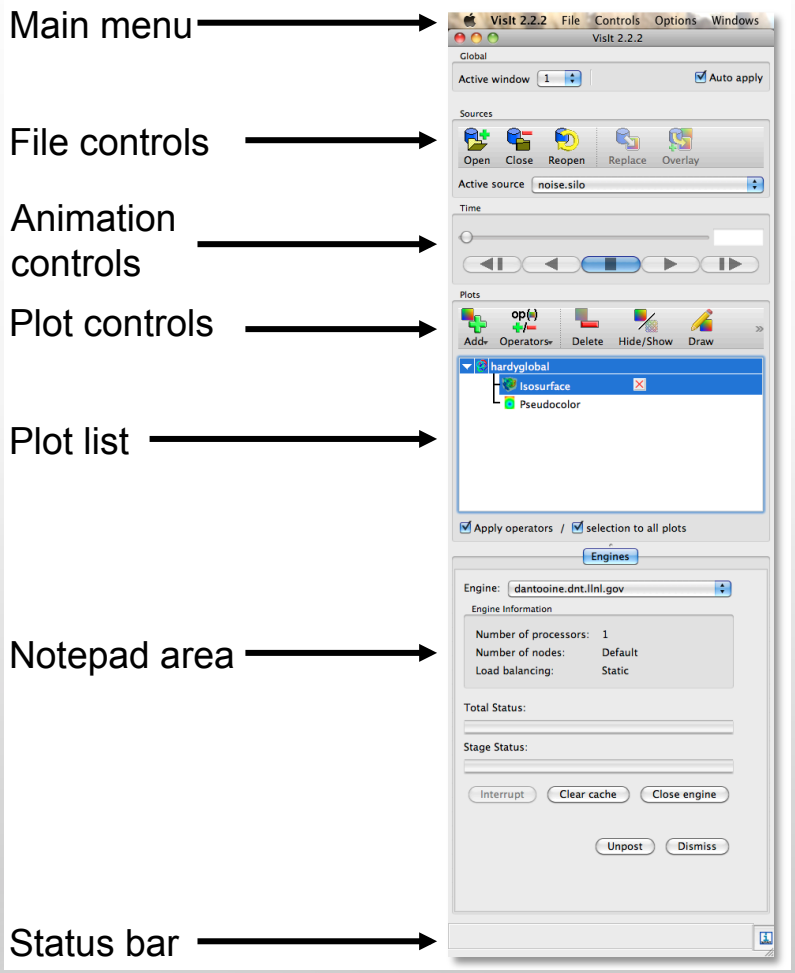
- Viewer windows, or vis windows, display all of the data being visualized
- Mouse navigation
- Up to 16 vis windows
- Popup menu
- Toolbars



MAIN WINDOW

GUI or Main window

- Open files
- Access other controls
- Set time state
- Create and manage plots
- Display plot progress



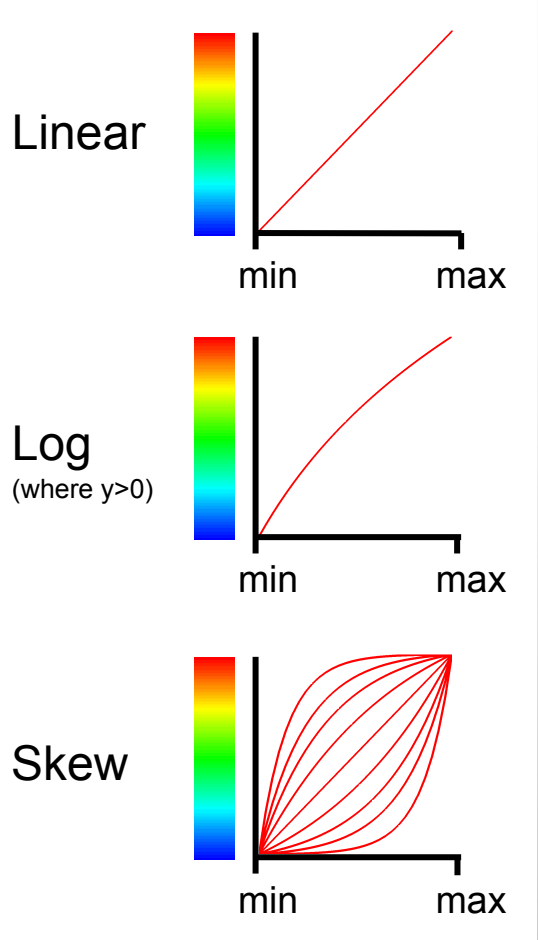
VISUALIZATION RECIPE FOR VISIT

1. Open database (file or set of files)
2. Create a plot
3. Set plot attributes
4. Apply operators to plot to modify data
5. Set operator attributes
6. Change refine view

SCALING OPTIONS IN VISIT

Scaling tells VisIt how to map values to color

- Linear scaling maps data range evenly to color range
- Log scaling assigns more low data values to color range (Values must be > 0)
- Skew scaling can assign either high or low values to color range using a skew factor



SESSION 3: REMOTE VISUALIZATION VISIT ON COMET (HANDS ON)

TEST ACCESS TO COMET

SSH to Comet

% ssh USERNAME@comet.sdsc.edu

% module list

Note: VisIt does not use default modules on Comet

USING VISIT IN COMMAND LINE OR BATCH MODE ON COMET

Make sure that **gnu** and **openmpi_ib** modules are loaded

source /etc/profile.d/modules.sh

module unload intel

module unload mvapich2_ib

module load gnu

module load openmpi_ib

module list

VISIT PATH ON COMET

/share/apps/compute/visit

Find versions of visit installed on Comet
Server -Client compatibility
3.0.x - 3.0.x
2.9.x - 2.9.x

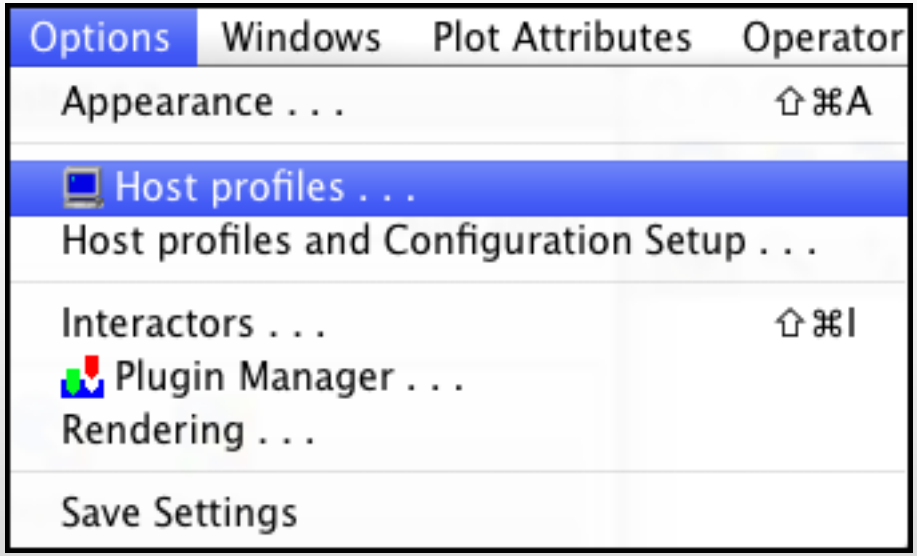
Bank/Account/Allocation: gue998

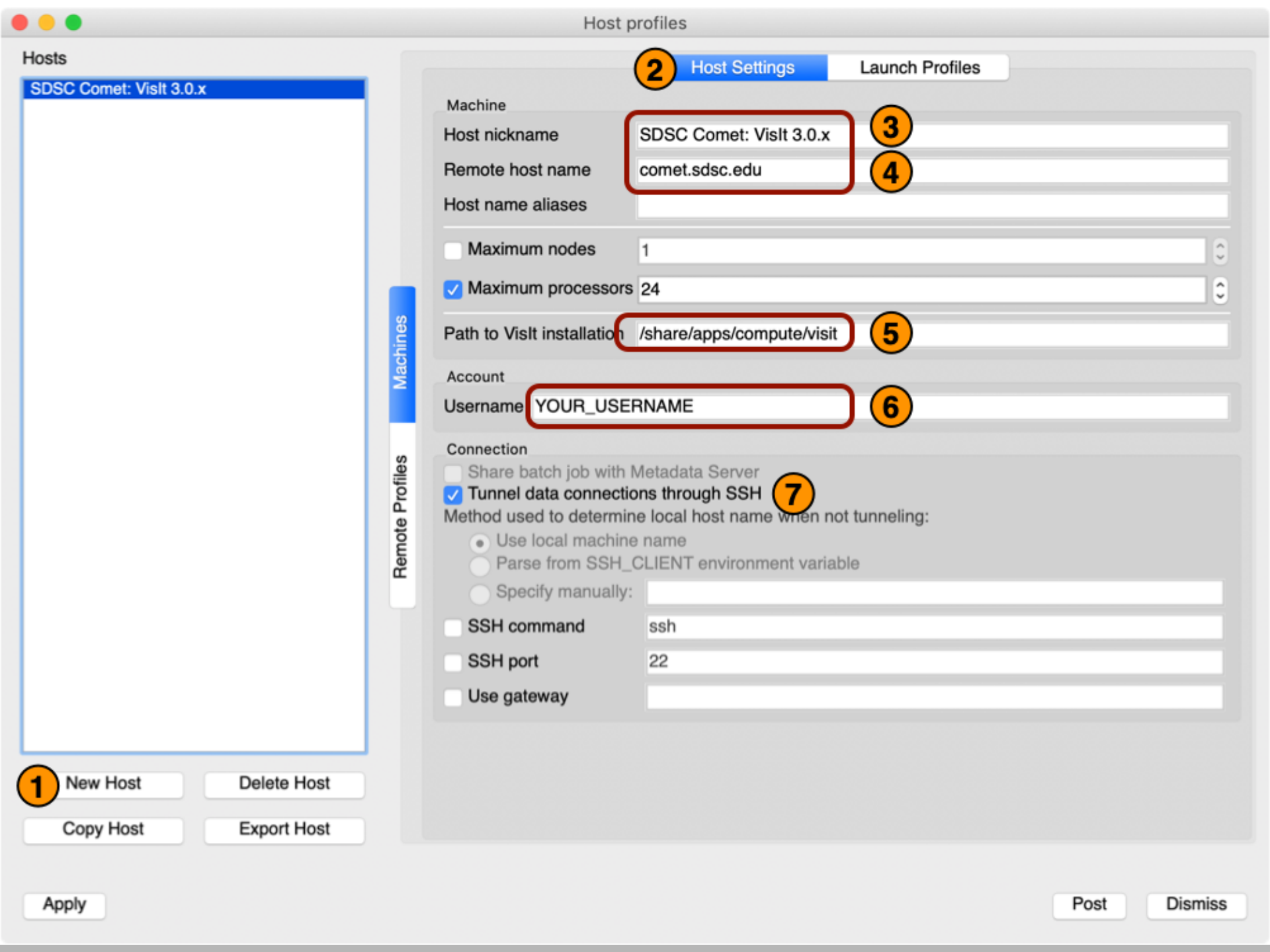
USING VISIT ON COMET

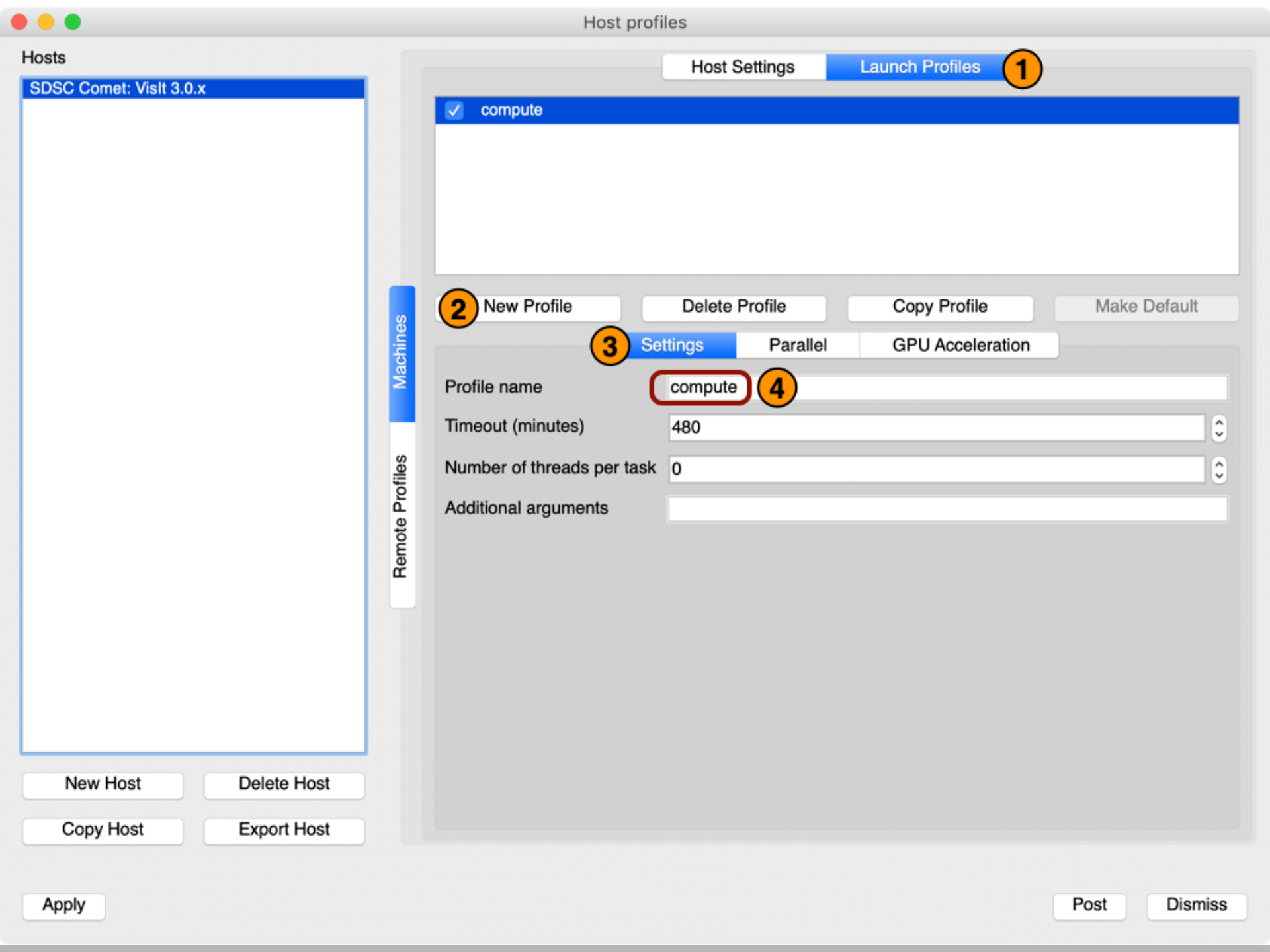
Create Host Profile for Comet in Visit
Connect and use Visit in server client mode

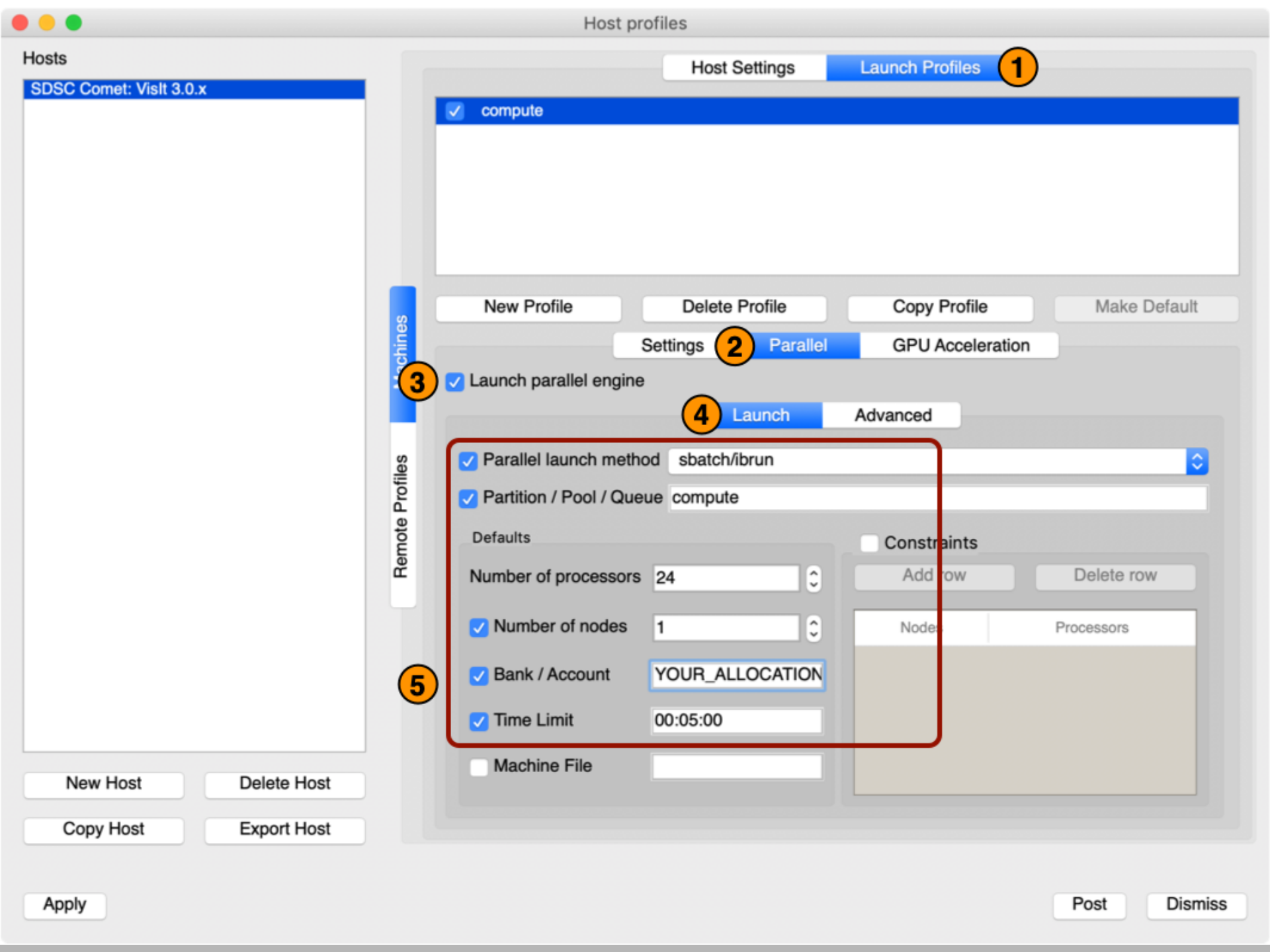
Documentation
https://www.sdsc.edu/support/user_guides/tutorials/visit_on_comet.html

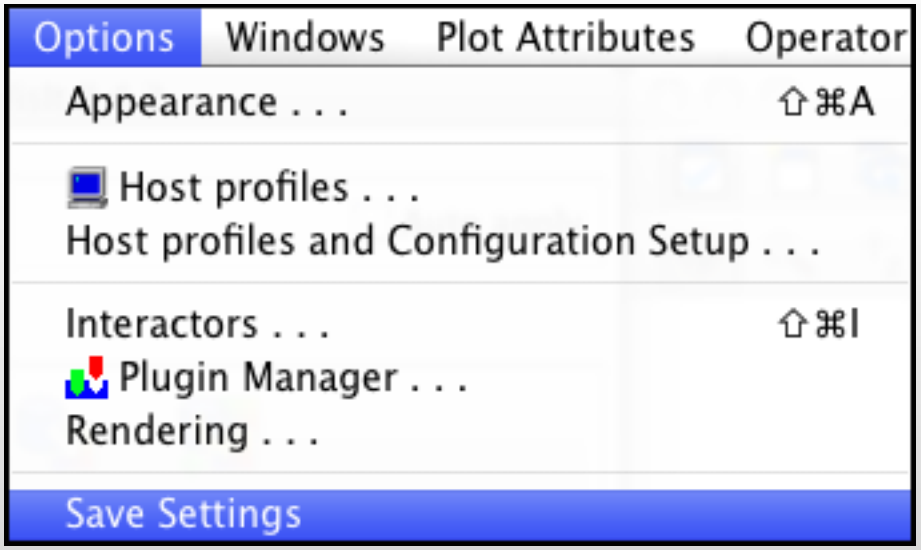
CREATE COMET HOST PROFILE IN VISIT




Host profiles
Hosts
SDSC Comet: VisIt 3.0.x
1
New Host
Delete Host
Copy Host
Export Host
Machines
Remote Profiles
2
Host Settings
Launch Profiles
Machine
Host nickname
SDSC Comet: VisIt 3.0.x
3
Remote host name
comet.sdsc.edu
4
Host name aliases
Maximum nodes
1
Maximum processors
24
Path to VisIt installation
/share/apps/compute/visit
5
Account
Username
YOUR_USERNAME
6
Connection
Share batch job with Metadata Server
Tunnel data connections through SSH
7
Method used to determine local host name when not tunneling:
Use local machine name
Parse from SSH_CLIENT environment variable
Specify manually:
SSH command
ssh
SSH port
22
Use gateway
Apply
Post
Dismiss


Host profiles
Hosts
SDSC Comet: VisIt 3.0.x
New Host
Delete Host
Copy Host
Export Host
Machines
Remote Profiles
Host Settings
Launch Profiles
1
compute
2
New Profile
Delete Profile
Copy Profile
Make Default
3
Settings
Parallel
GPU Acceleration
Profile name
compute
4
Timeout (minutes)
480
Number of threads per task
0
Additional arguments
Apply
Post
Dismiss


Host profiles
Hosts
SDSC Comet: VisIt 3.0.x
New Host
Delete Host
Copy Host
Export Host
Apply
Host Settings
Launch Profiles
1
compute
New Profile
Delete Profile
Copy Profile
Make Default
Machines
Remote Profiles
Settings
2
Parallel
GPU Acceleration
3
Launch parallel engine
4
Launch
Advanced
Parallel launch method
sbatch/ibrun
Partition / Pool / Queue
compute
Defaults
Number of processors
24
Number of nodes
1
5
Bank / Account
YOUR_ALLOCATION
Time Limit
00:05:00
Machine File
Constraints
Add row
Delete row
Nodes
Processors
Post
Dismiss


Options
Windows
Plot Attributes
Operator
Appearance . . .
⇧⌘A
Host profiles . . .
Host profiles and Configuration Setup . . .
Interactors . . .
⇧⌘I
Plugin Manager . . .
Rendering . . .
Save Settings

Continued Self Study

Complete the VisIt class and exercises provided here

https://wci.llnl.gov/simulation/computer-codes/visit/manuals

More documentation

http://www.visitusers.org/index.php?title=User_Documentation

Sign up for VisIt users list. (Ask for help and help others)

https://elist.ornl.gov/mailman/listinfo/visit-users