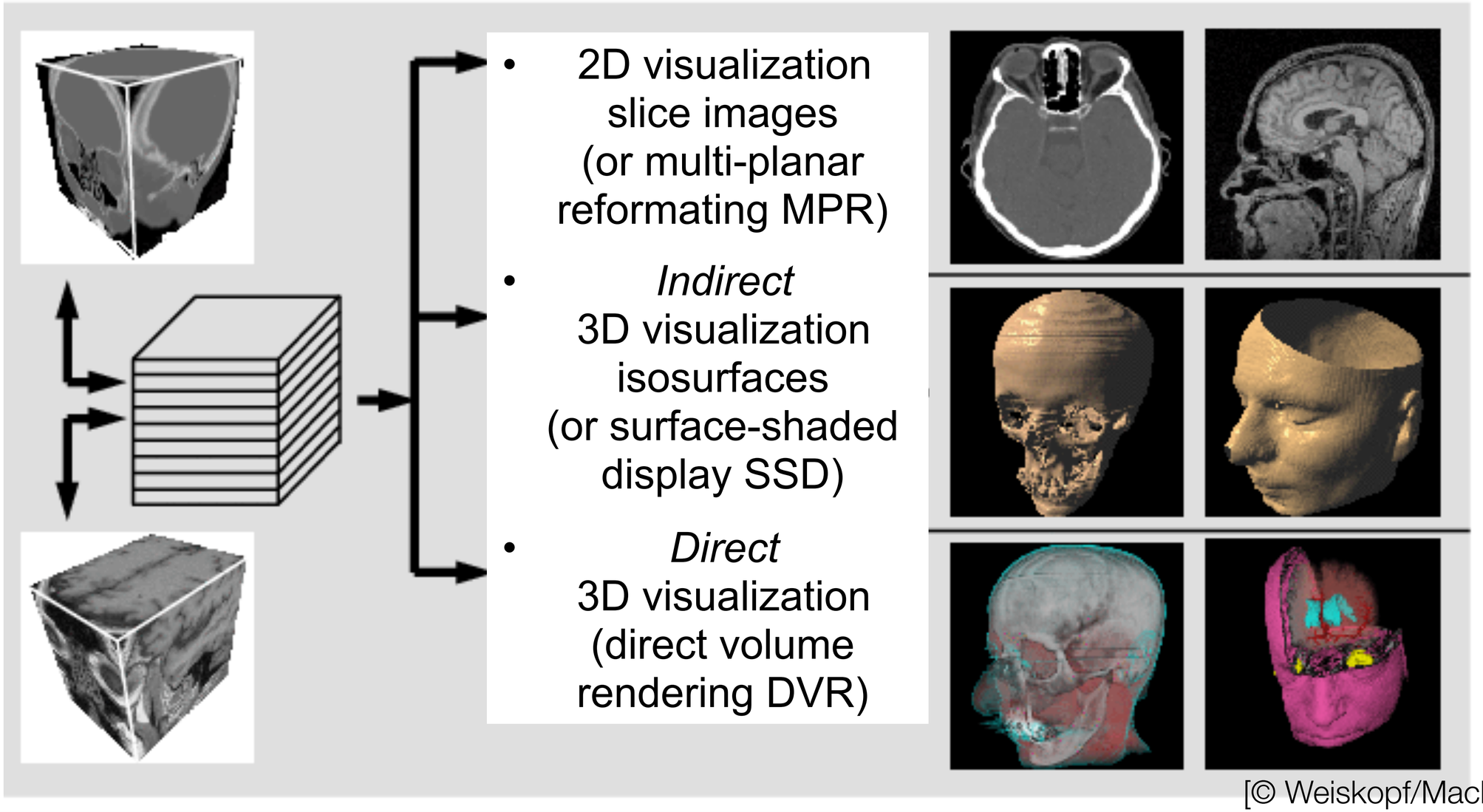
# Data Visualization (CSCI 490/680)

## Vector Fields & Text

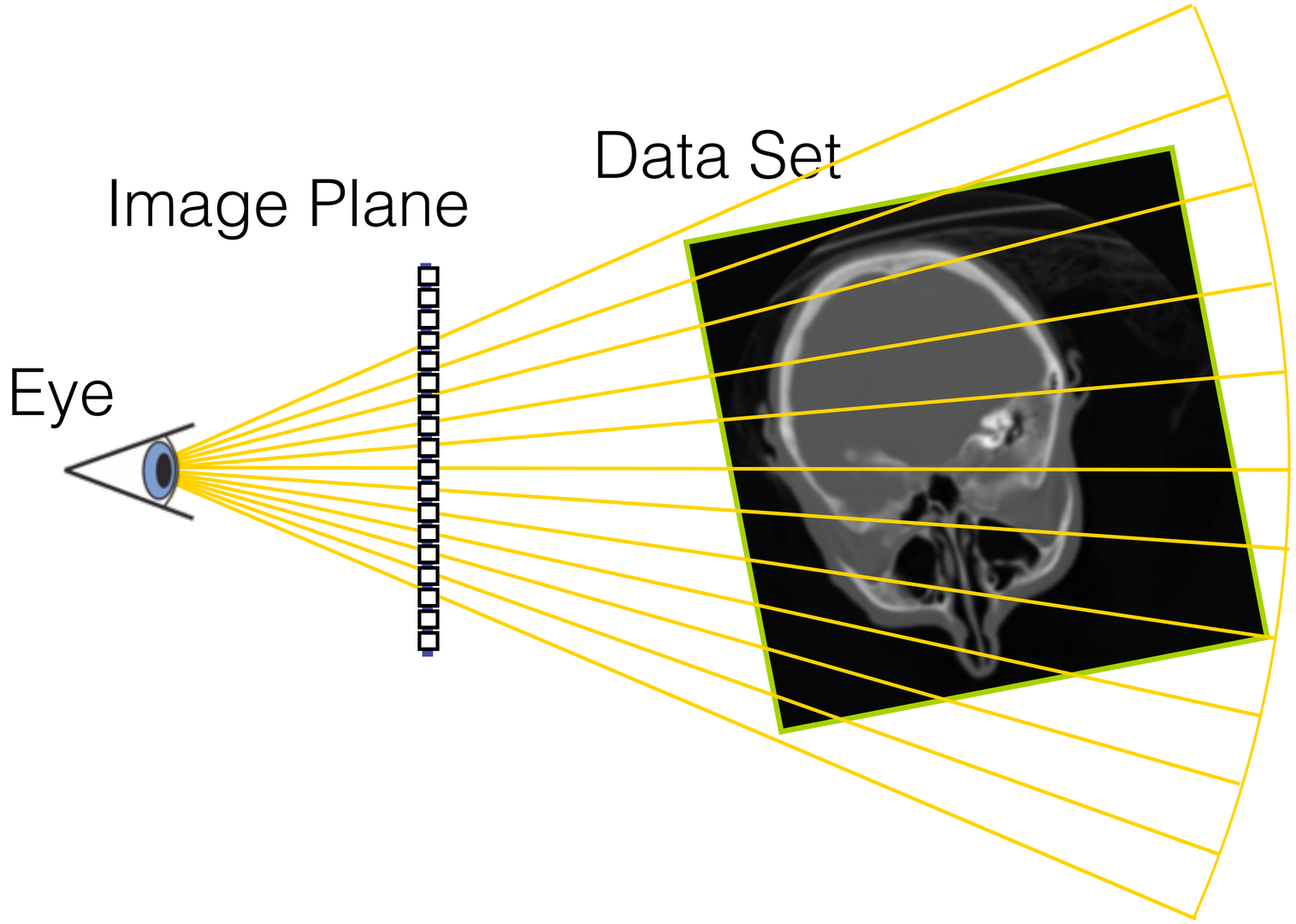
Dr. David Koop

# Visualizing Volume (3D) Data



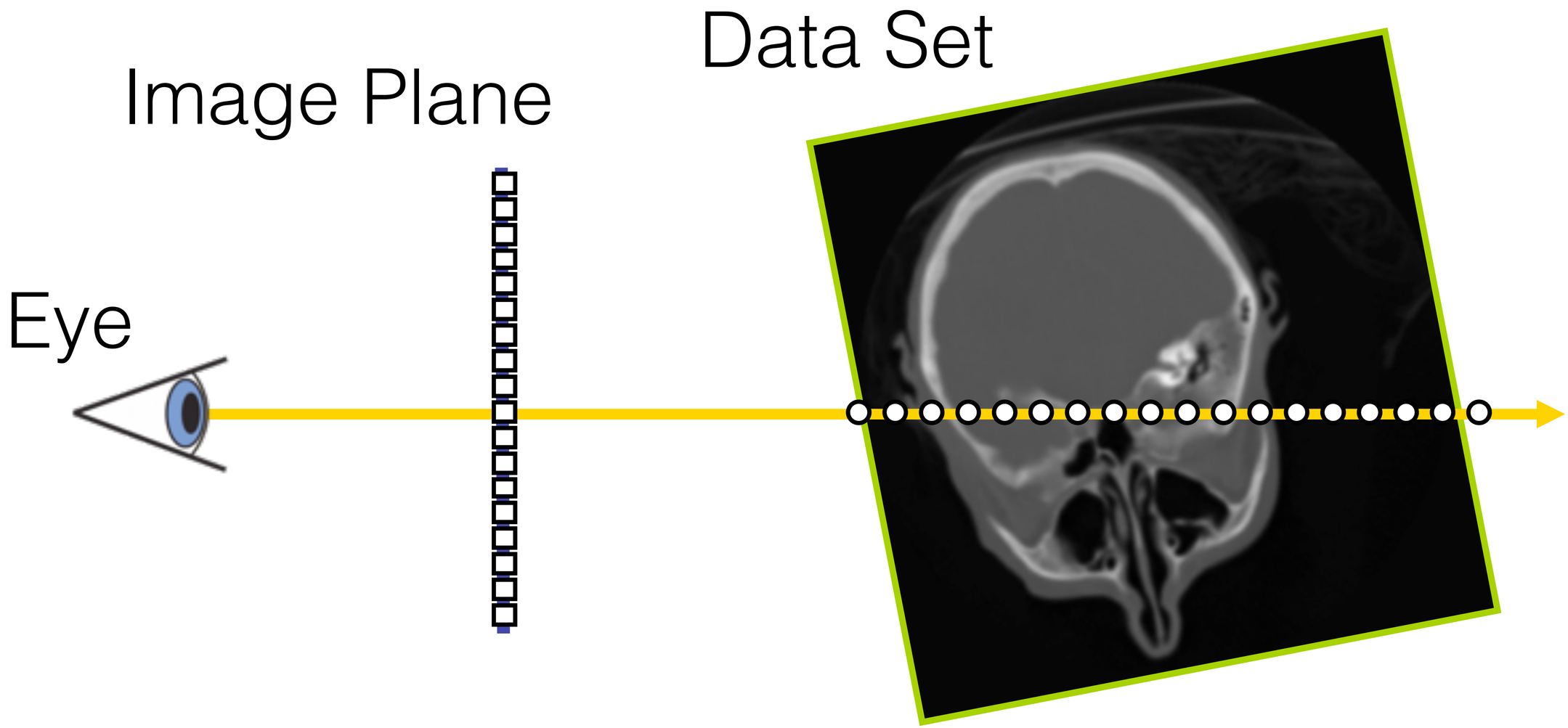

[© Weiskopf/Machiraju/Möller]

# Volume Ray Casting



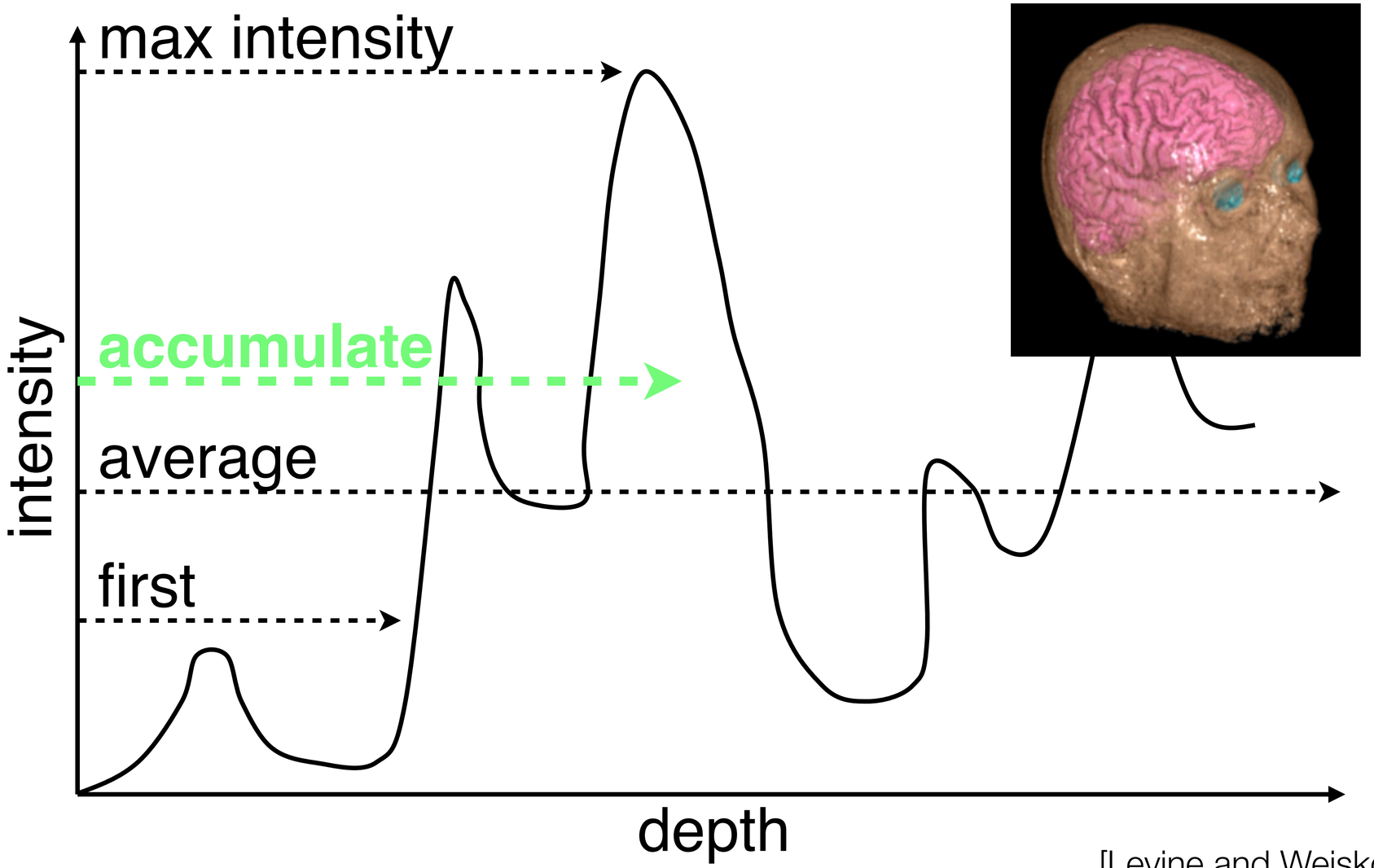

[Levine]

# Volume Ray Casting




[Levine]

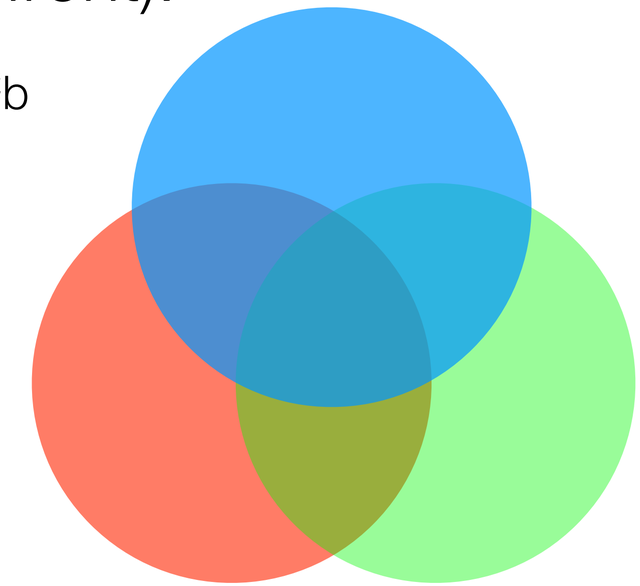
# Types of Compositing



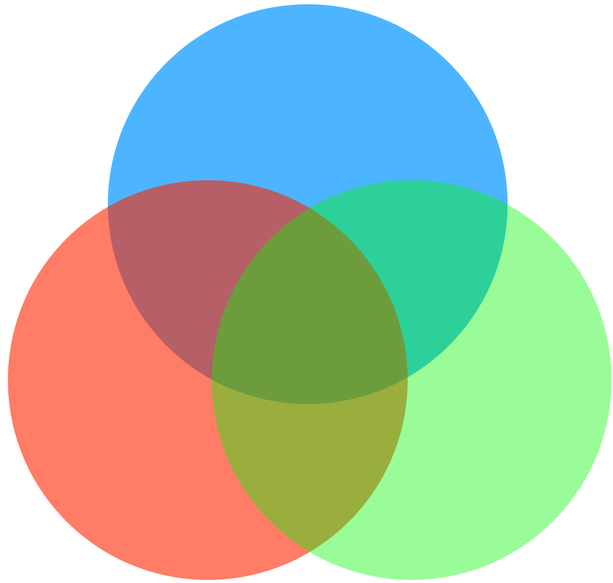

[Levine and Weiskopf/Machiraju/Möller]

# Accumulation

- If we're not just calculating a single number (max, average) or a position (first), how do we determine the accumulation?
- Assume each value has an associated color (c) and opacity (α)
- Over operator (back-to-front):
  - $c = \alpha_f \cdot c_f + (1-\alpha_f) \cdot \alpha_b \cdot c_b$
  - $\alpha = \alpha_f + (1-\alpha_f) \cdot \alpha_b$
- Order is important!



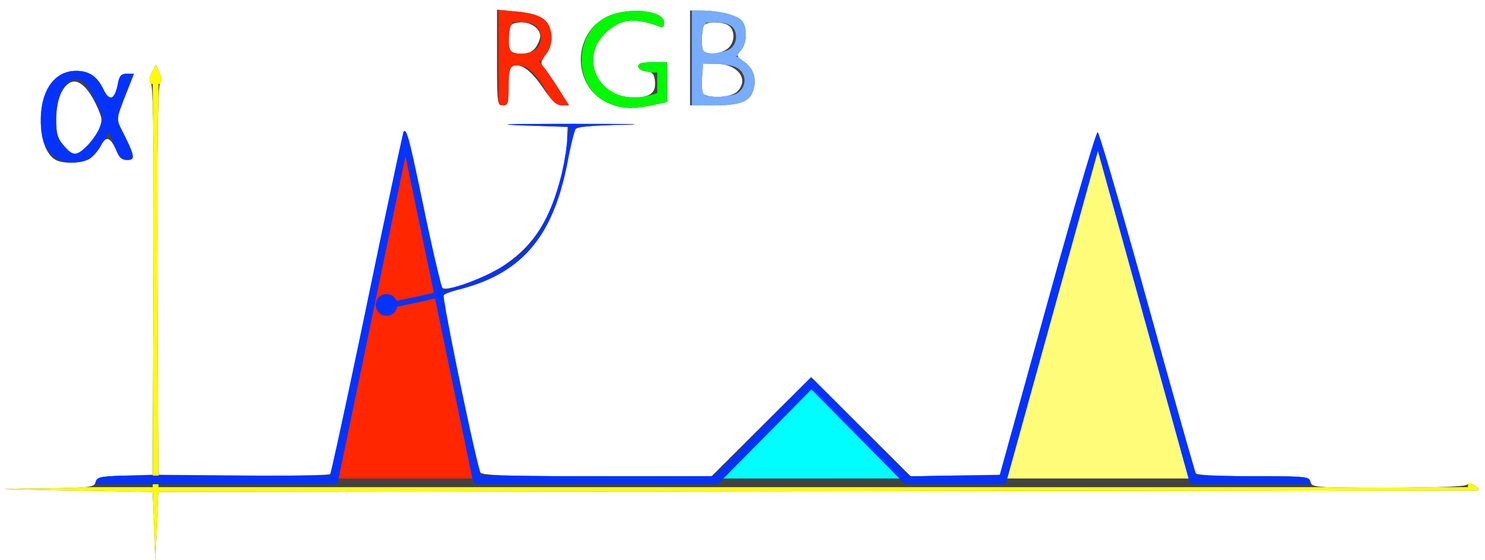
Blue Last



Blue First

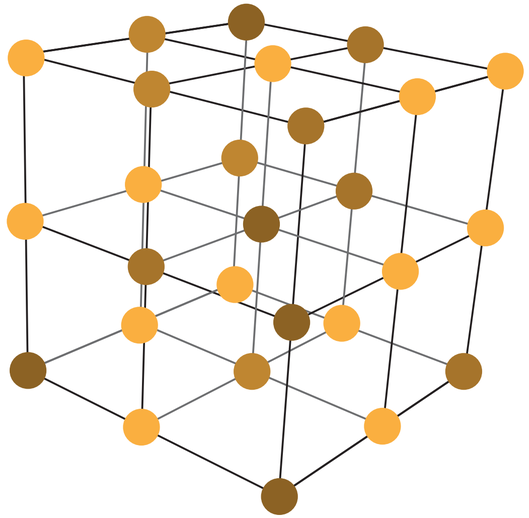
# Transfer Functions

- Where do the colors and opacities come from?
- Idea is that each voxel emits/absorbs light based on its scalar value
- …but users get to choose how that happens
- x-axis: color region definitions, y-axis: opacity



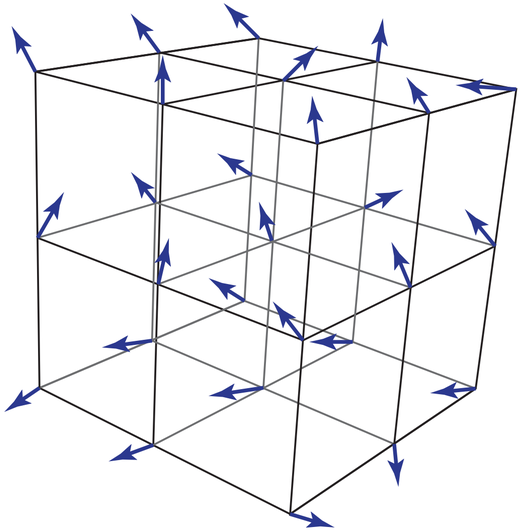

[Kindlmann]

# Fields in Visualization



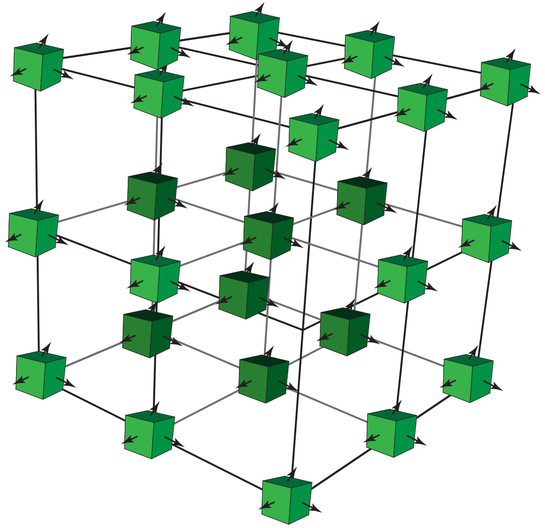
Scalar Fields

(Order-0 Tensor Fields)



Vector Fields

(Order-1 Tensor Fields)



Tensor Fields

(Order-2+)

Each point in space has an associated...

$$s_0$$

Scalar

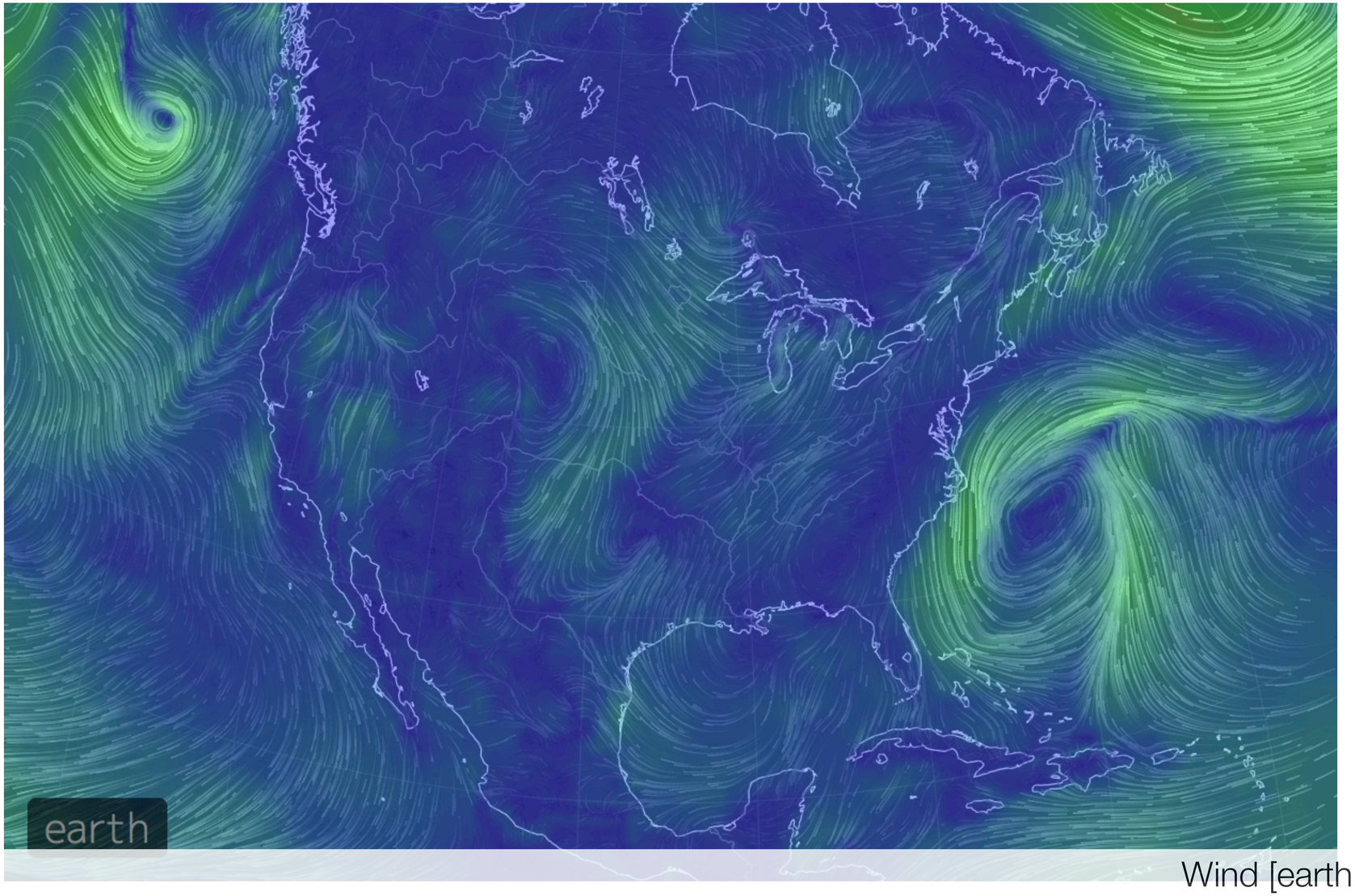
$$\begin{bmatrix} v_0 \\ v_1 \\ v_2 \end{bmatrix}$$

Vector

$$\begin{bmatrix} \sigma_{00} & \sigma_{01} & \sigma_{02} \\ \sigma_{10} & \sigma_{11} & \sigma_{12} \\ \sigma_{20} & \sigma_{21} & \sigma_{22} \end{bmatrix}$$

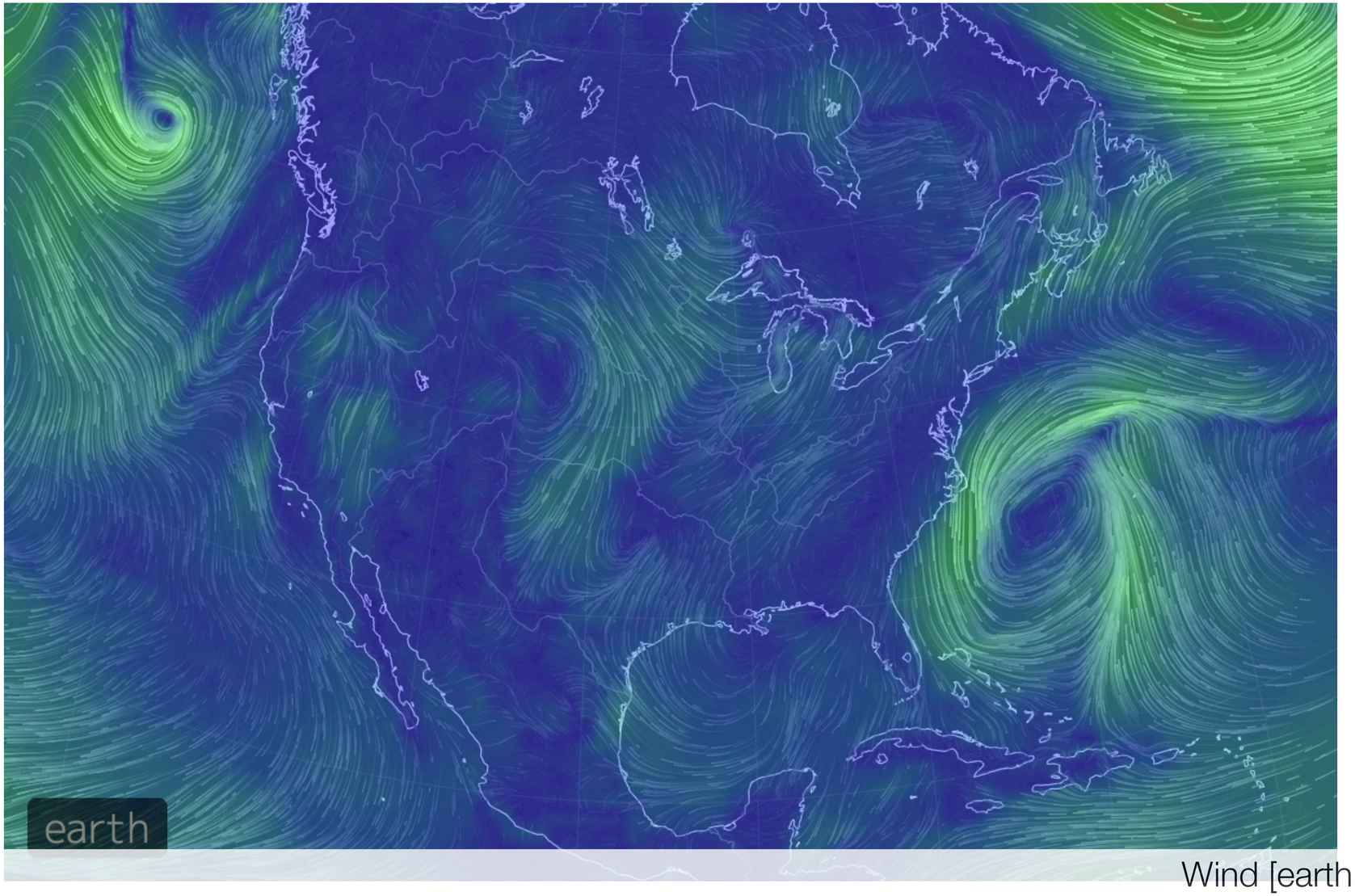
Tensor

# Vector Fields




Wind [earth.nullschool.net, 2014]

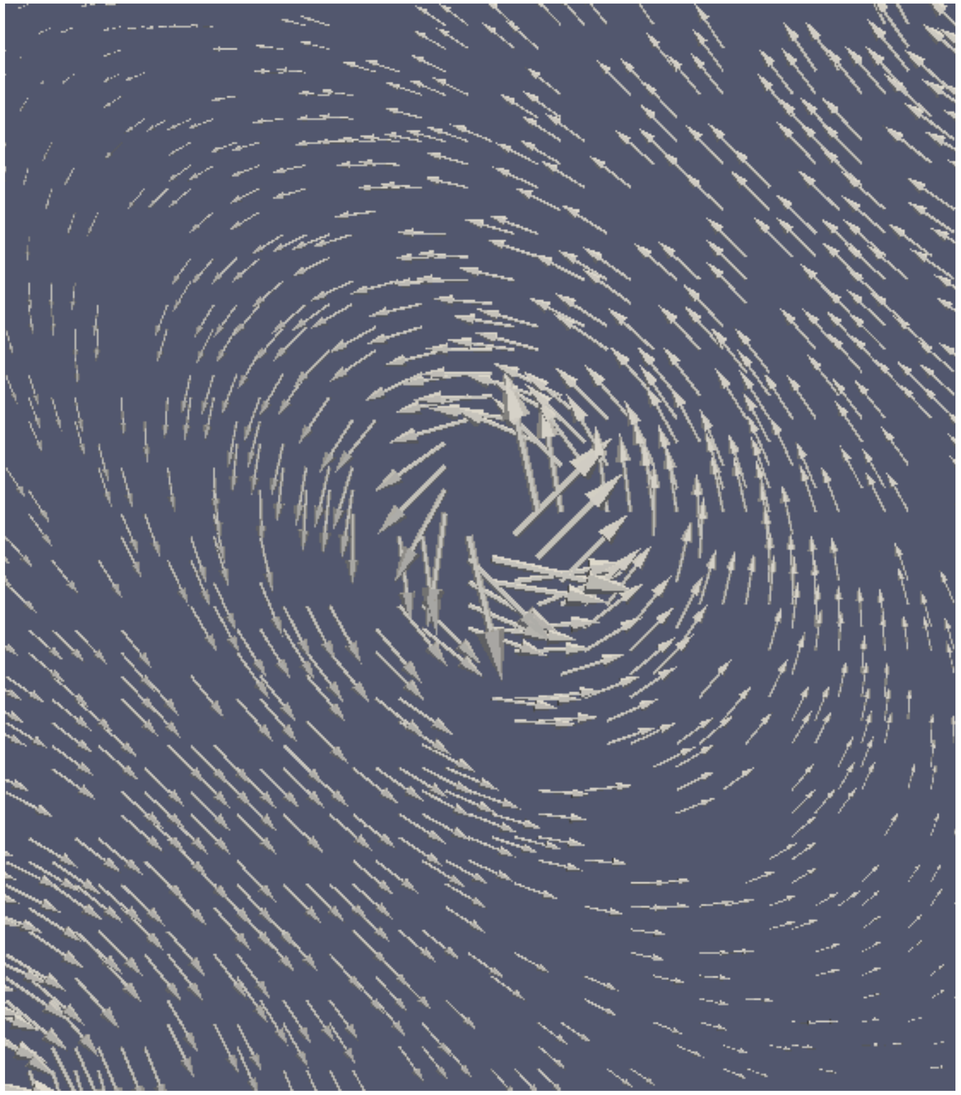
# Vector Fields




Wind [earth.nullschool.net, 2014]

# Glyphs

- Represent each vector with a symbol
- For vector fields, can encode direction, magnitude, scalar value
- Good:
  - Show precise local measures
  - Can encode scalar information as color
- Bad:
  - Possible sampling issues
  - Clutter (Occlusion): Can remove some points to help
  - Clutter is worse in higher dimensions

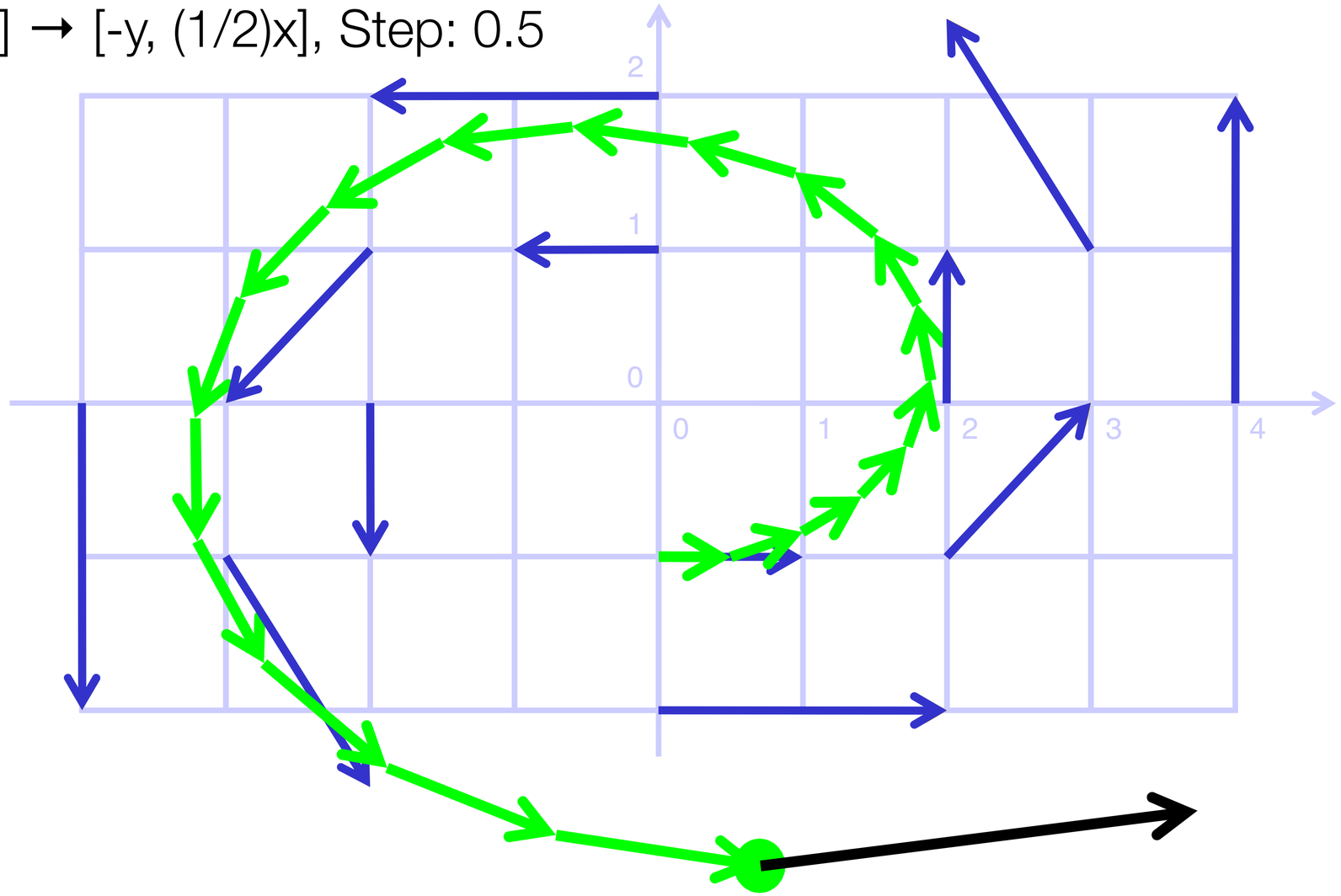


# Streamlines & Variants

- Trace a line along the direction of the vectors
- Streamlines are always tangent to the vector field
- Basic Particle Tracing:
  1. Set a starting point (seed)
  2. Take a step in the direction of the vector at that point
  3. Adjust direction based on the vector where you are now
  4. Go to Step 2 and Repeat

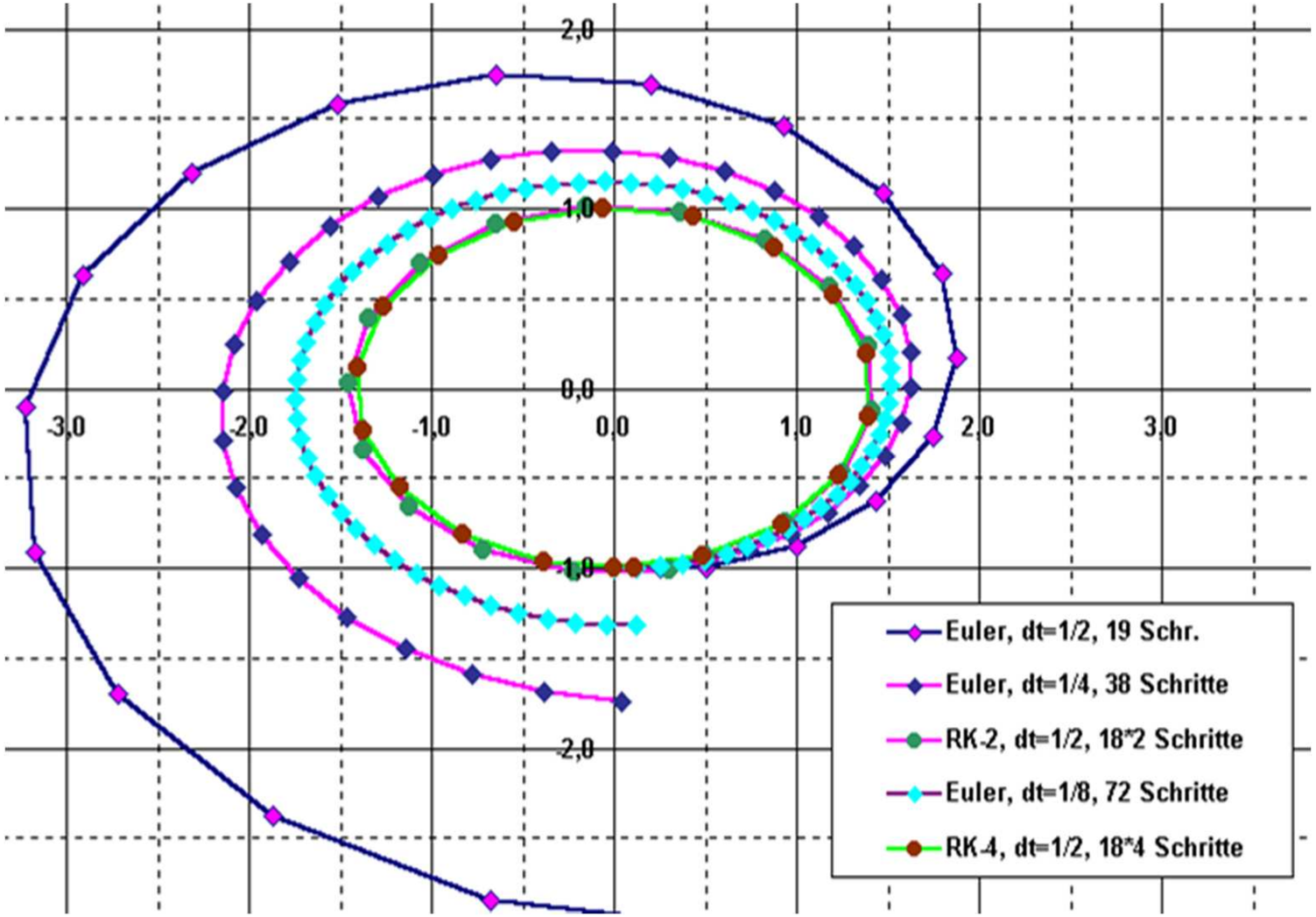
# Streamlines

[x,y] → [-y, (1/2)x], Step: 0.5




[via Levine]

# Higher-Order Interpolation Comparison




[via Levine]

# Project

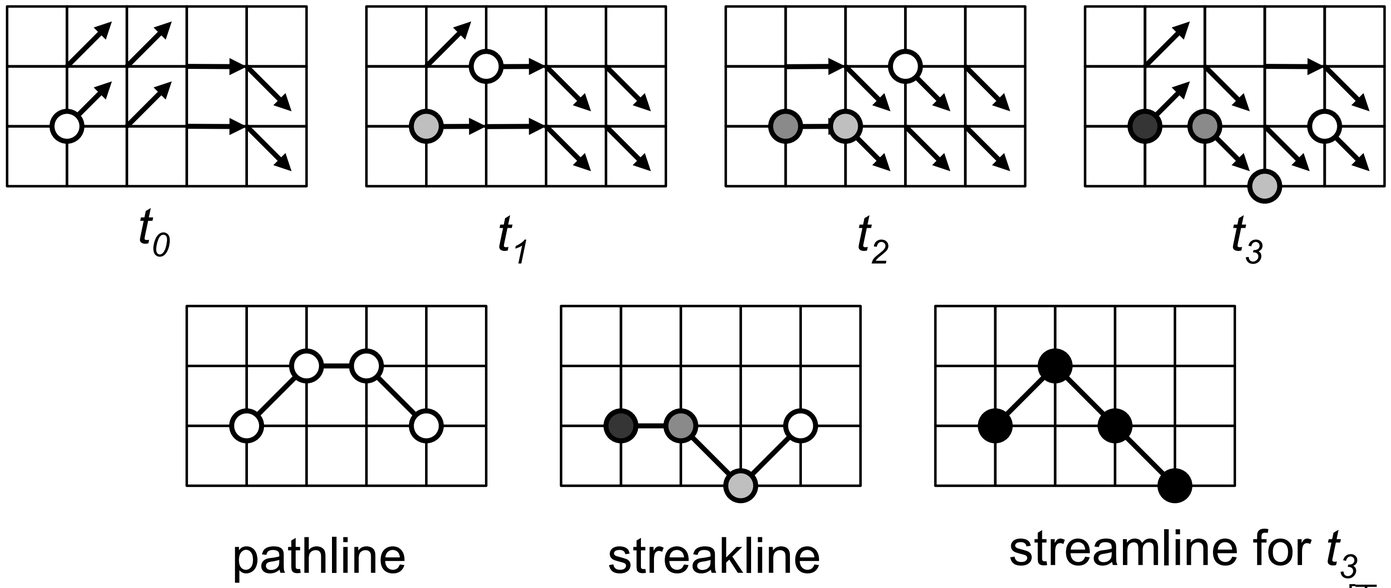
- Continue to be creative but also remember expressiveness and effectiveness
- Presentations on Dec. 5:
  - Turn in state of the visualization to Blackboard by Dec 4 at 11:59pm
  - 5 minutes per presenter
  - Showcase the visualization (not slides)
    - Brief introduction to your data and questions
    - Discuss design decisions
    - Demonstrate the interactive features of your project
  - Should run in a web browser so we will use my laptop
- Have until Dec. 6 to turn in final code and report

# Final Exam

- Thursday, Dec. 12, **10-11:50am**
- Covers all topics but emphasizes second half of the course
- Similar format as Midterm (multiple choice, free response)
- 680 Students will have a few questions related to the research papers

# Streamlines & Variants

- Steady vs. **Unsteady** flows
  - In unsteady flows, the vector field **changes** over time
- Variants: **Pathlines** and **Streaklines**




[T. Möller]

# Streamlines & Variants

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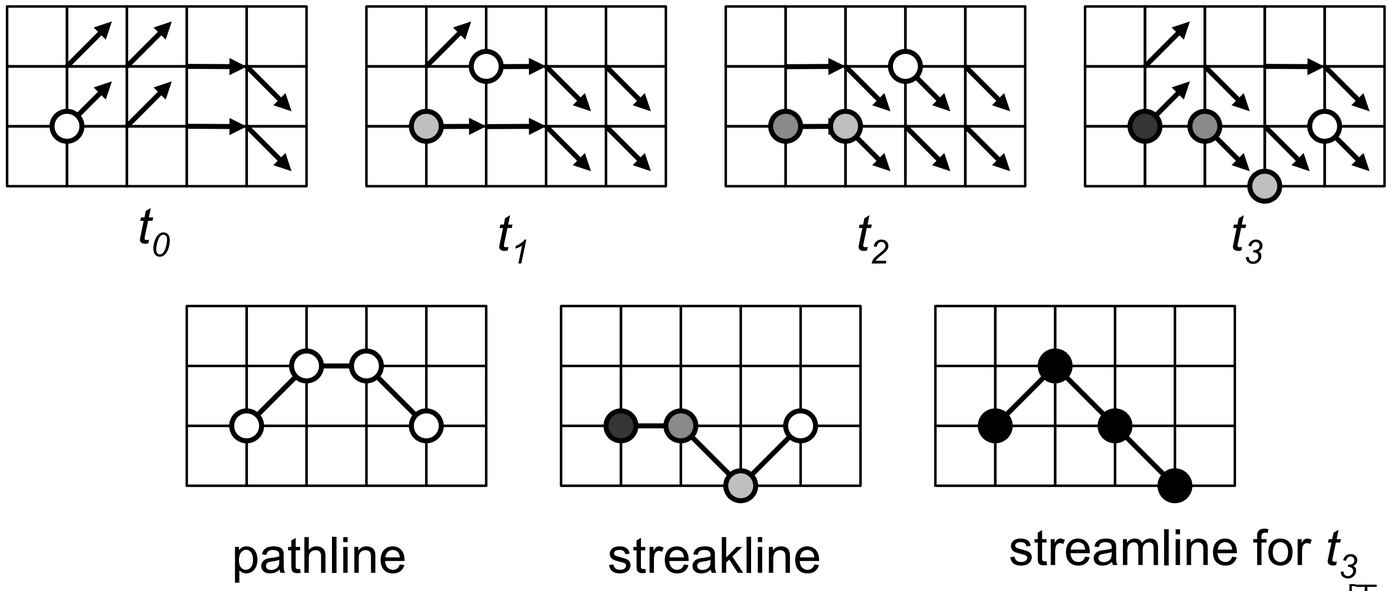
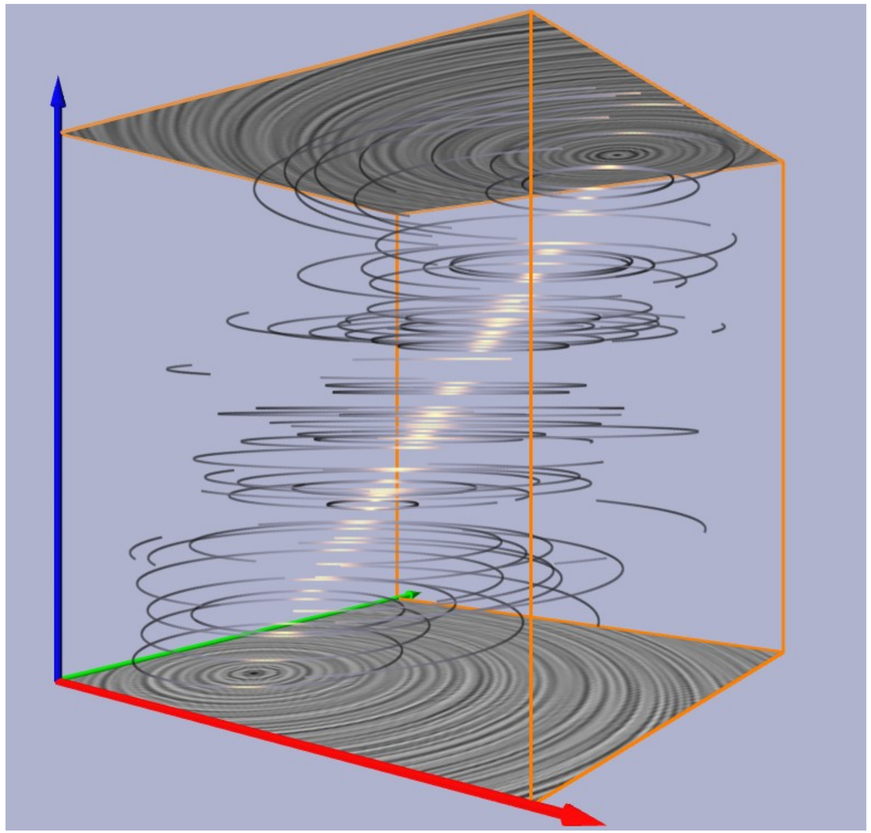


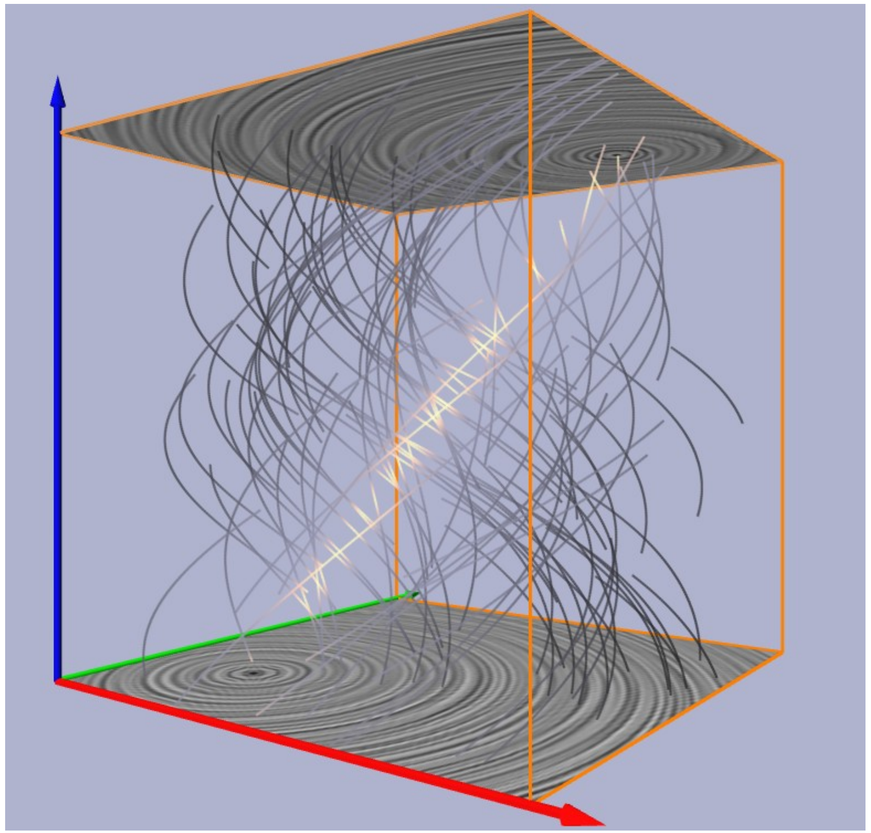

[T. Möller]

All are identical in steady flows!

# Streamlines vs. Pathlines



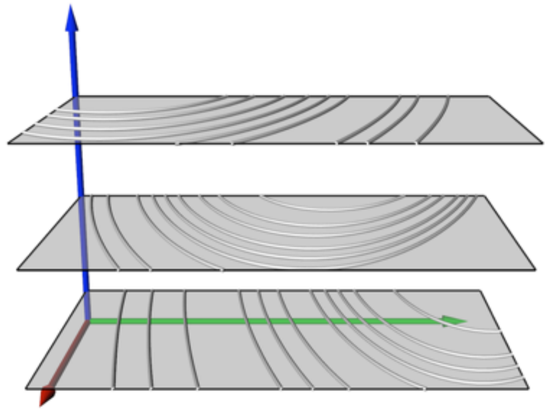
Streamlines



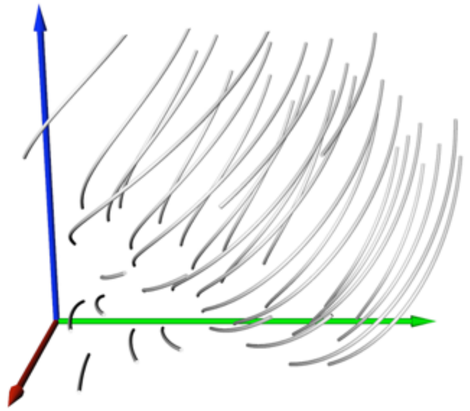
Pathlines

[Weinkauf & Theisel, 2010]

# Streaklines and timelines

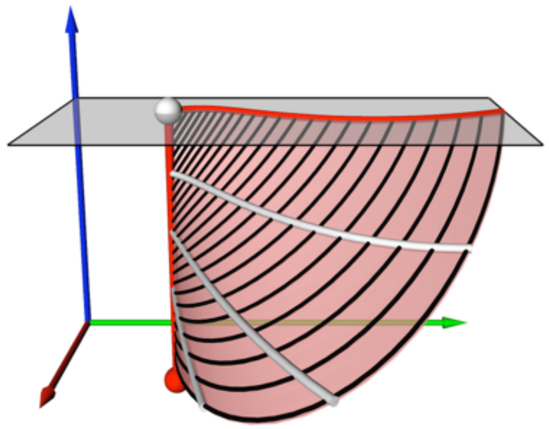


streamlines

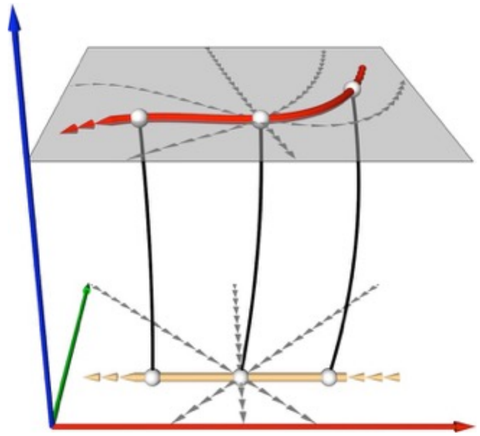


pathlines

streaklines

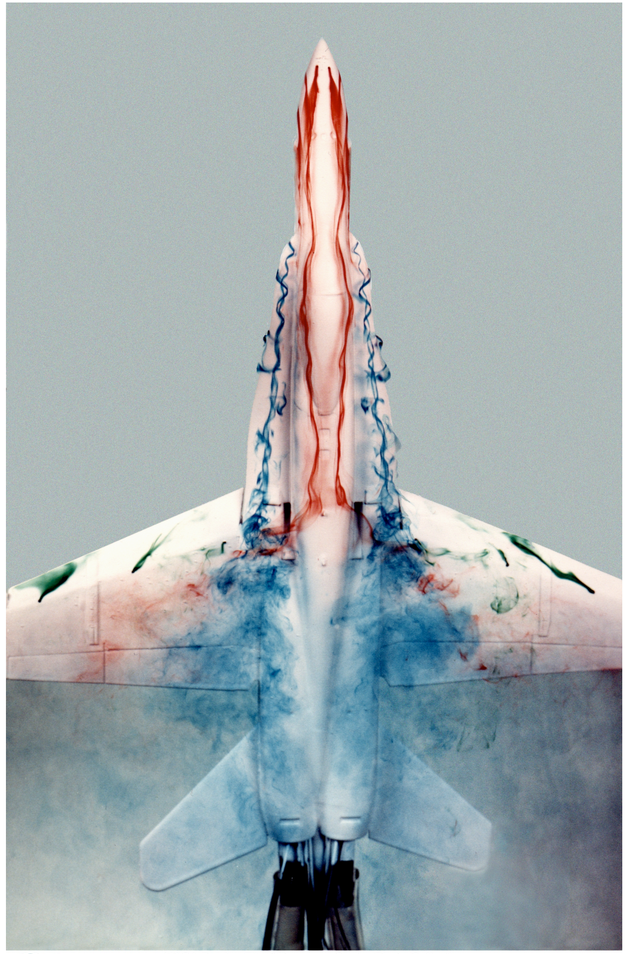


timelines



[via Levine]

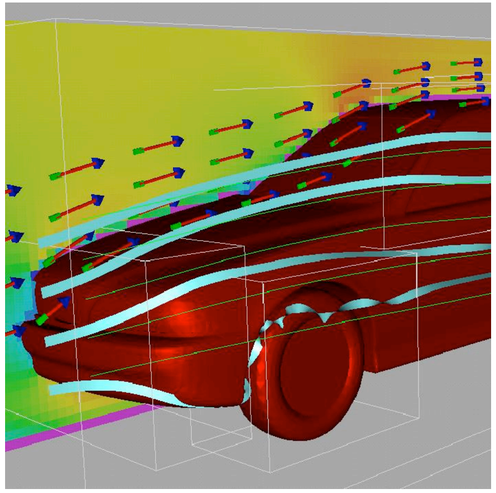
# Streamline Variants



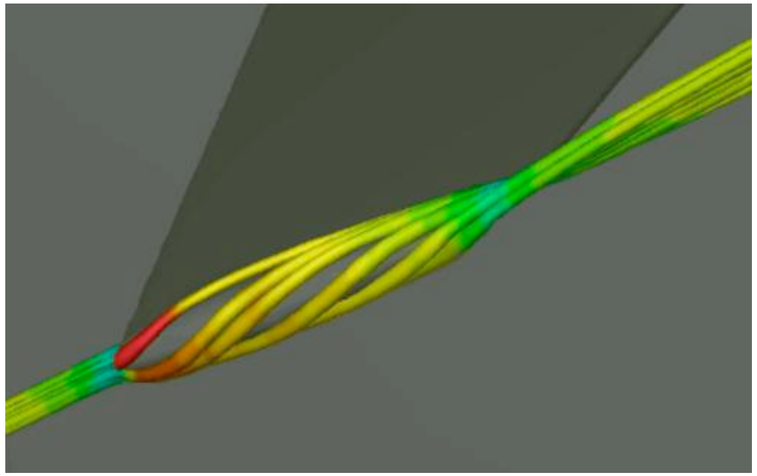
NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: ECN-33298-03 Date: 1985

1/48-scale model of an F-18 aircraft in Flow Visualization Facility (FVF)

Streaklines [NASA]

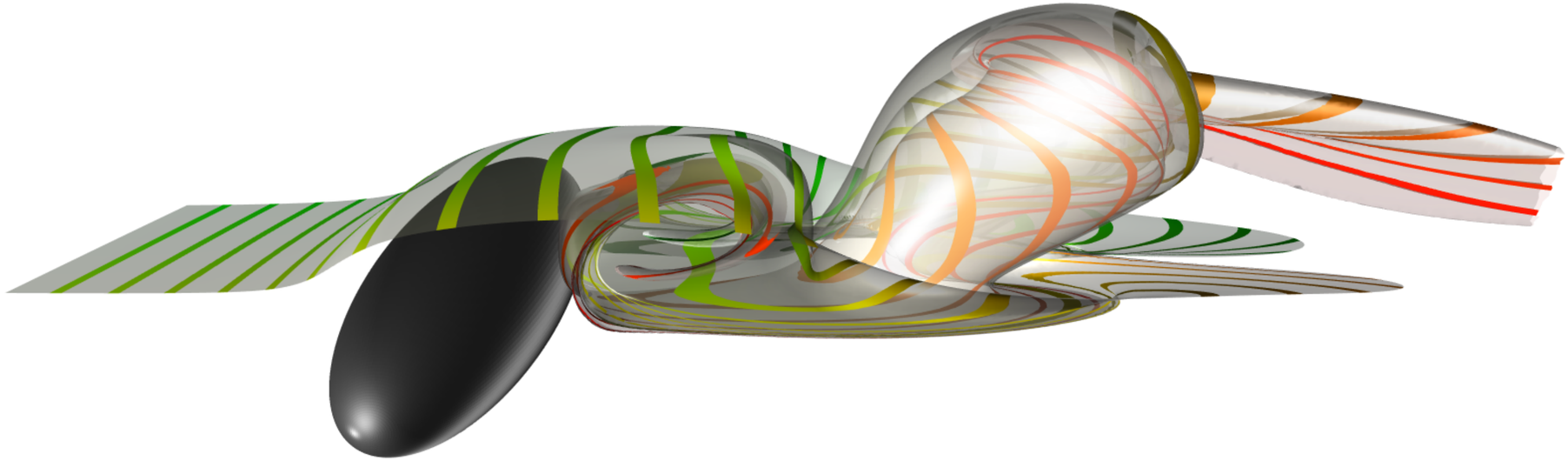


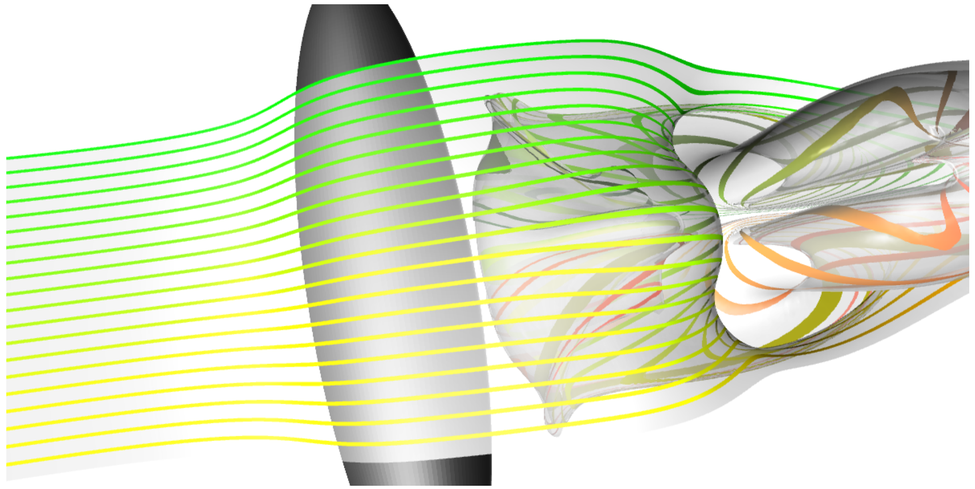
Stream Ribbons [Weiskopf/Machiraju/Möller]

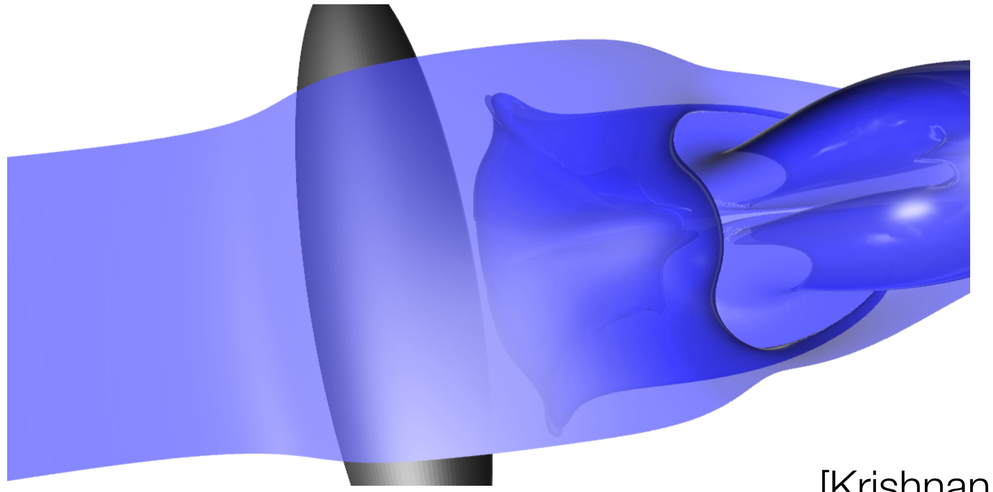


Stream Tubes [Weiskopf/Machiraju/Möller]

# Streak Surfaces

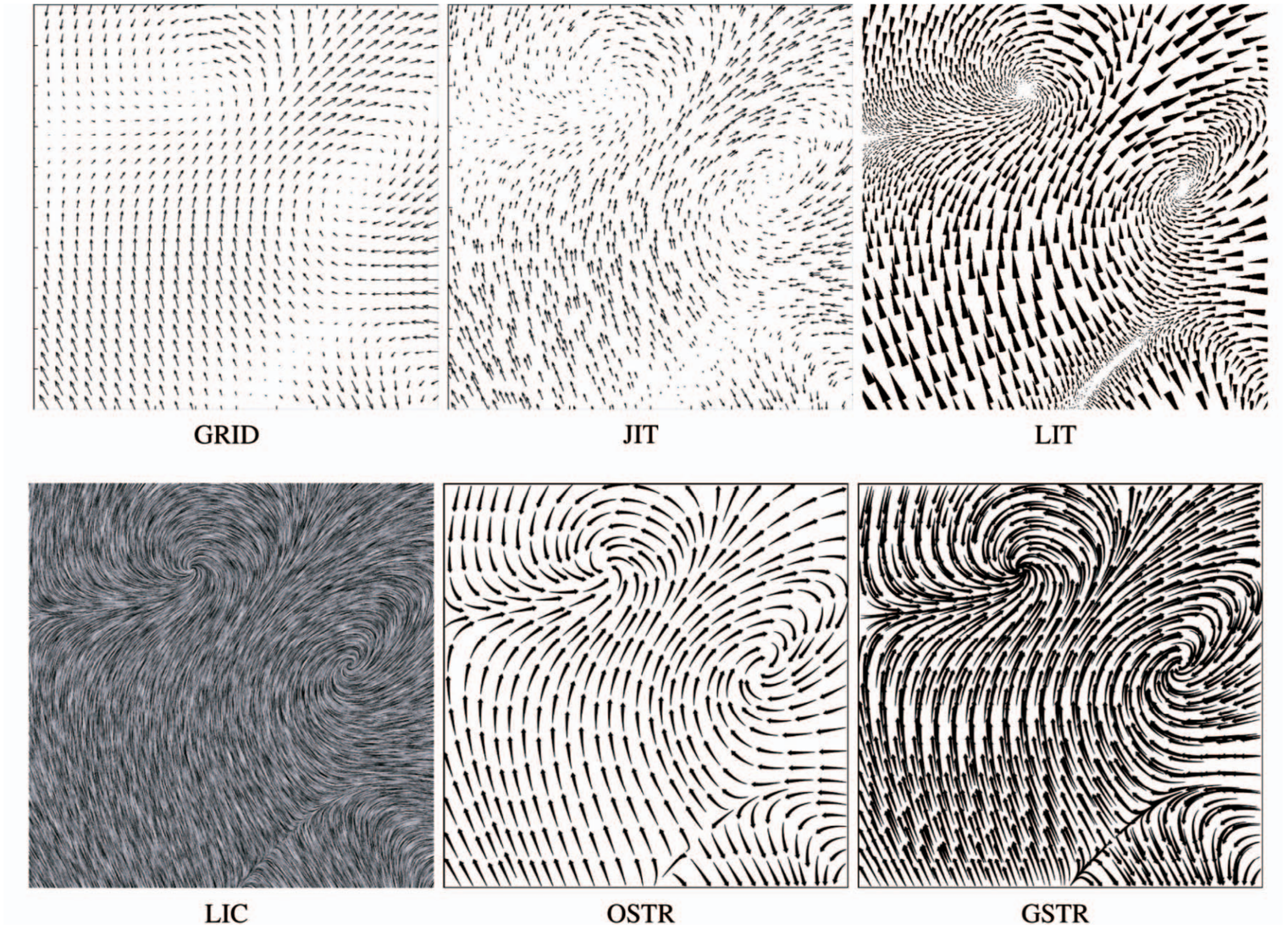






[Krishnan et al., 2009]

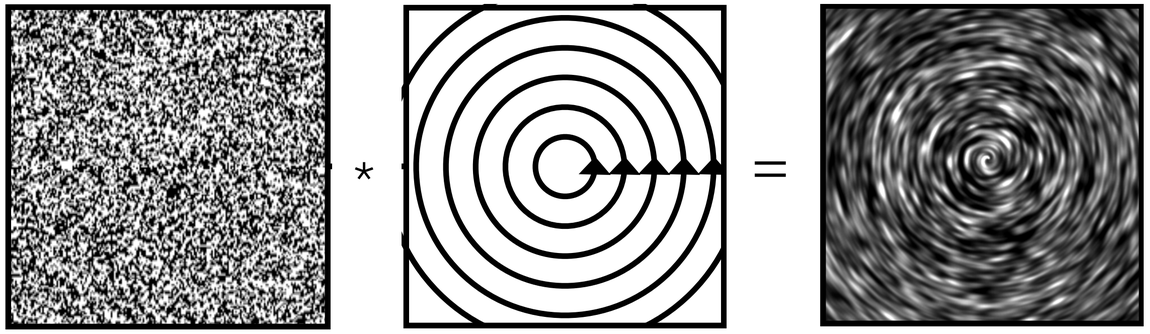
# 2D Vector Field Visualization Techniques



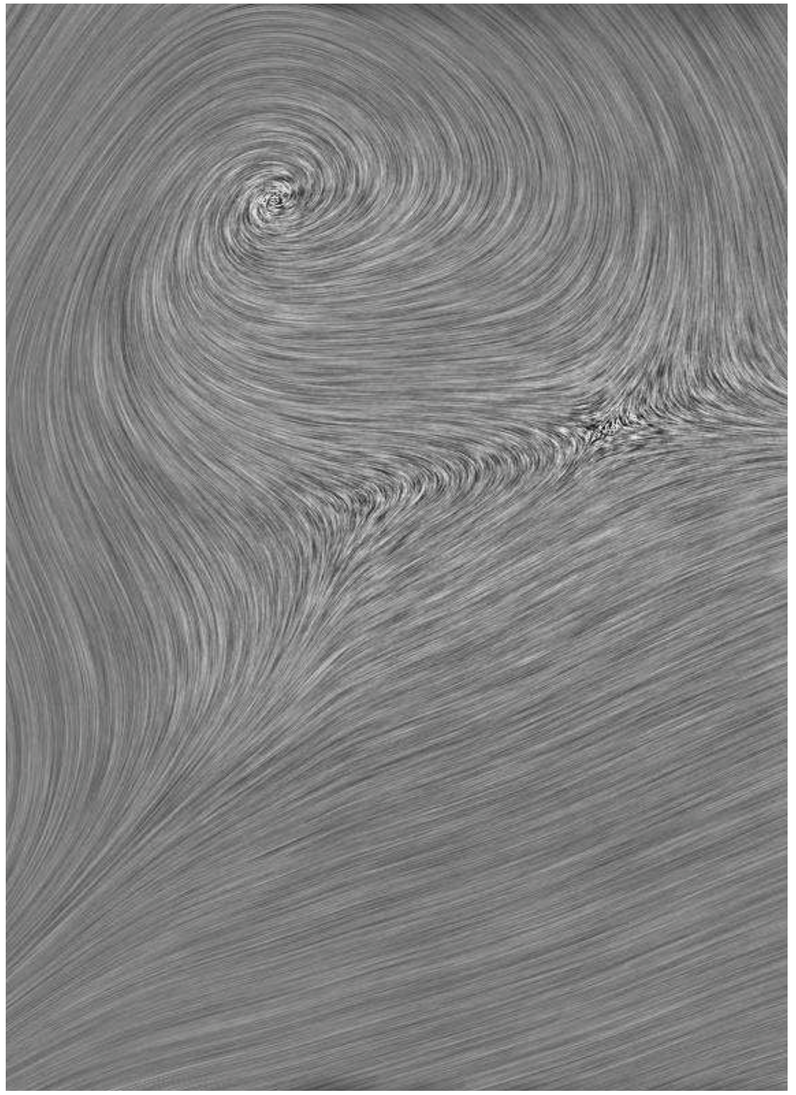

[Laidlaw et al., 2005]

# Line Integral Convolution

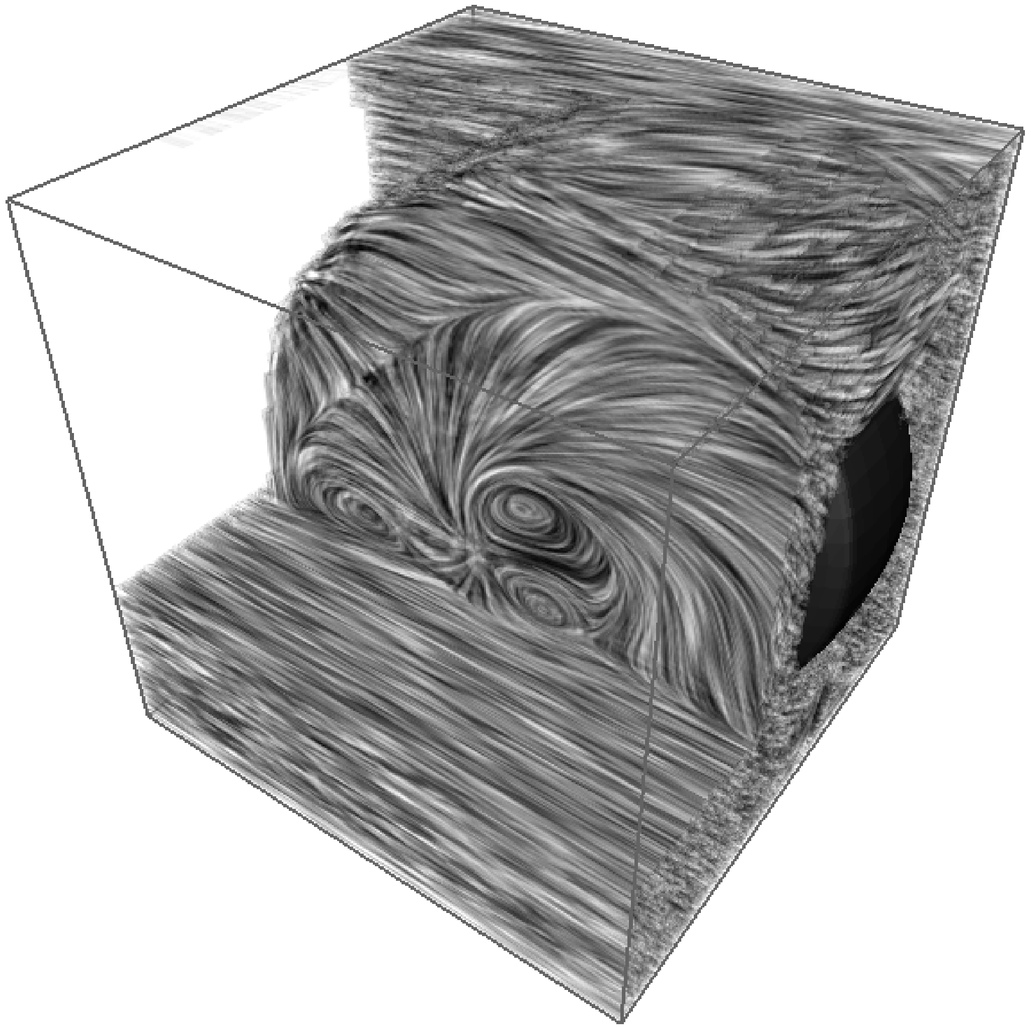
- Goal: provide a global view of a steady vector field while avoiding issues with clutter, seeds, etc.
- Remember convolution?
- Start with random noise texture
- Smear according to the vector field
- Need structured data

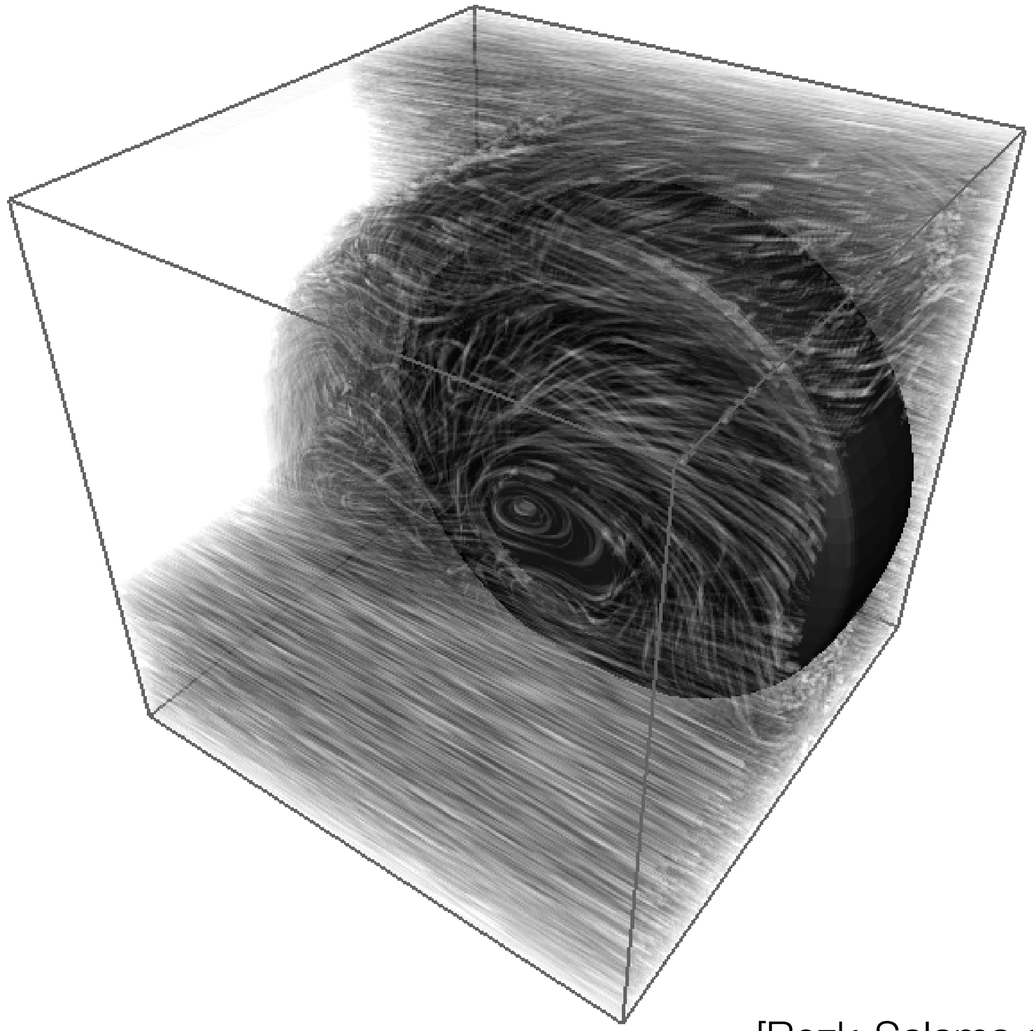


[Weiskopf/Machiraju/Möller]



# 3D LIC

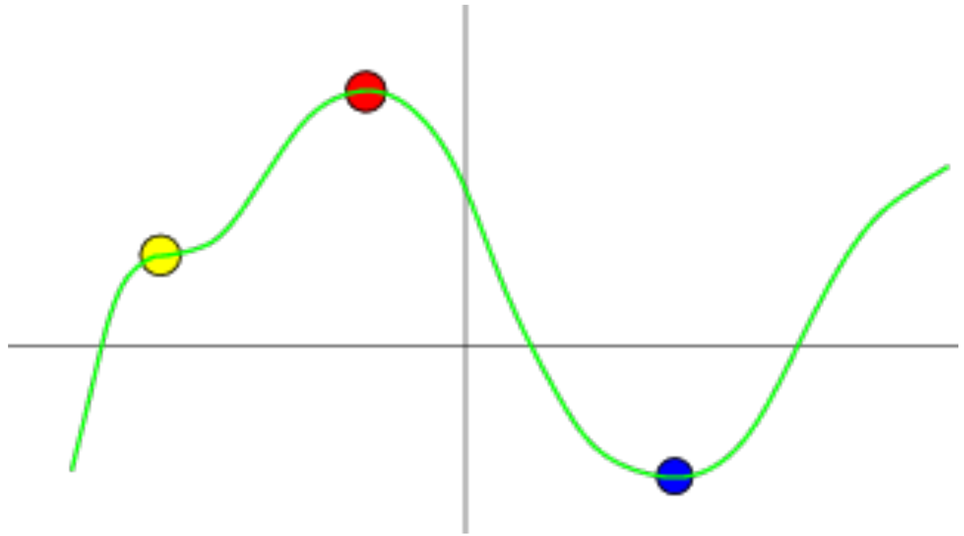




[Rezk-Salama et al., 1999]

# Critical Points

- Remember finding min/max for functions?
- Want to understand the general structure of a field, not the exact values
- Find critical points, understand there is a general trend in between
- How?
  - Derivative for functions
  - For fields…gradients



[DQ Nykamp, MathInsight]

# Topology

- The general shape of data
- Visualizations that can be "stretched" to resemble each other are topologically equivalent
- Technically, continuous transformations don't change anything
- Connect critical points to obtain a general picture of the data
- Can talk about topology in both scalar and vector fields

# 2D Scalar Field Topology


[Wikipedia]

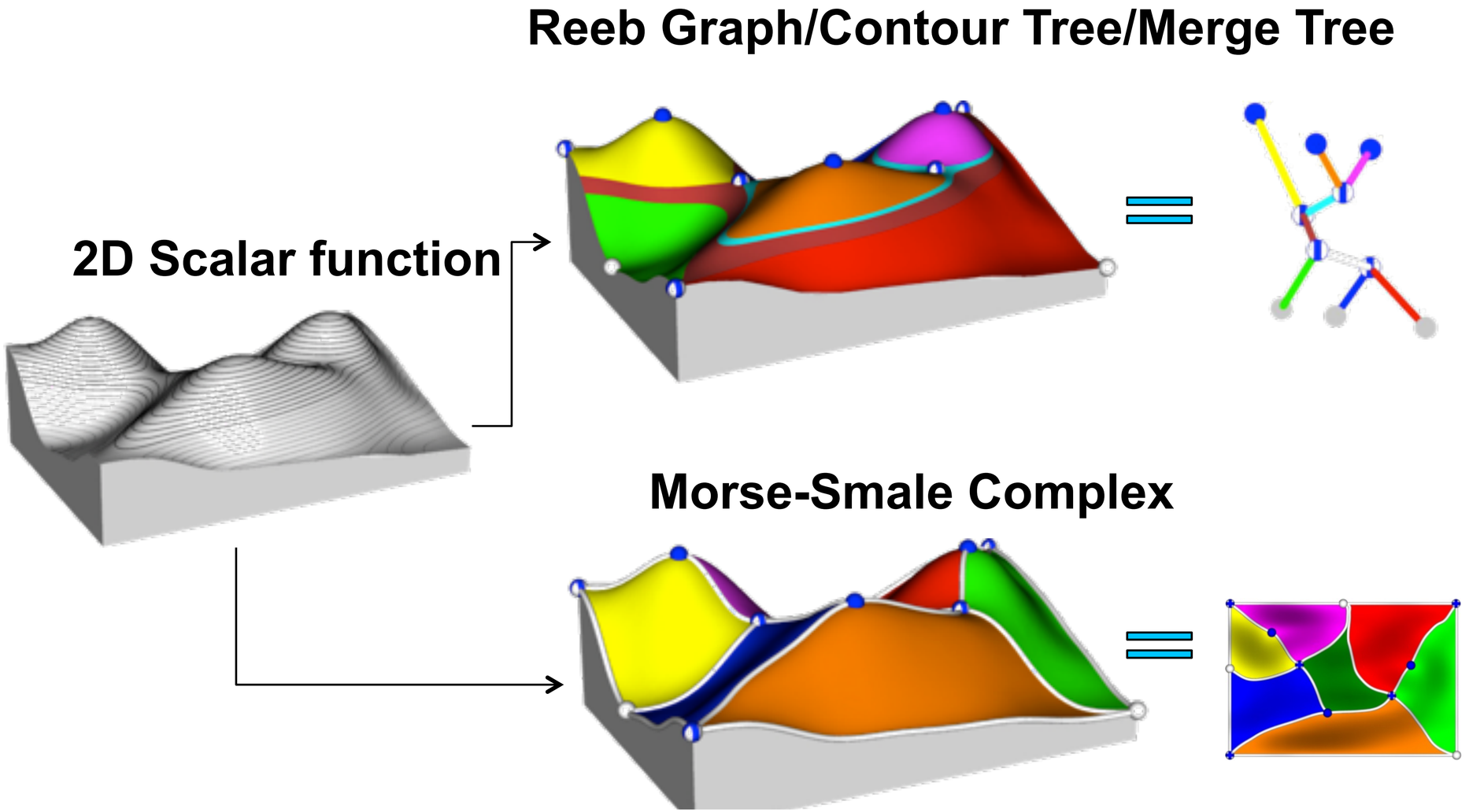
# 2D Scalar Field Topology


[Wikipedia]

# Scalar Field Topology

- Examine the gradient (changes between points on the grid) of the scalar field
- Where the gradient is zero, we have critical points (max, min, saddle)
- Can build Reeb Graph, Contour Tree, or Morse-Smale Complex from this information to show the topology (with some reasonable assumptions about how the scalar field looks)

# Scalar Field Topology




[via Levine]

# Vector Field Topology

- Instead of “guessing” correct seed points for streamlines to understand the field, try to identify structure (topology) of the field

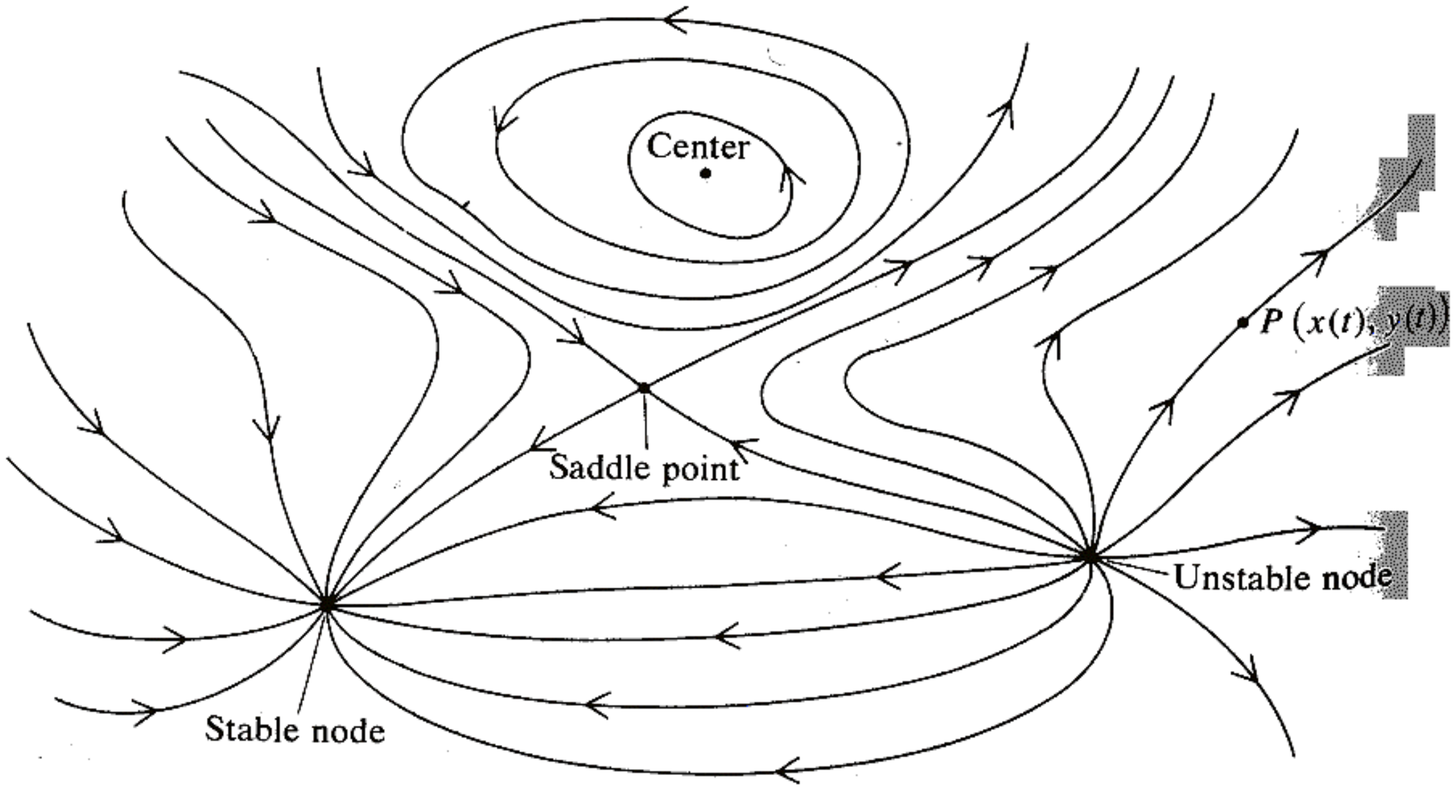
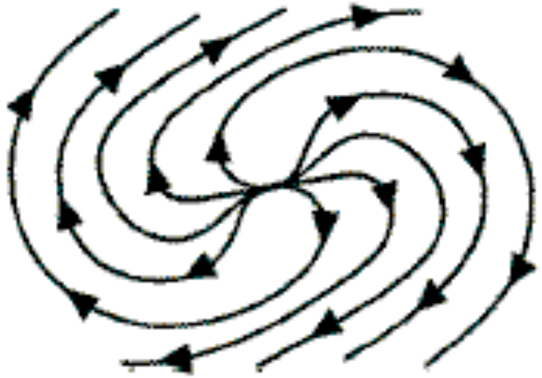


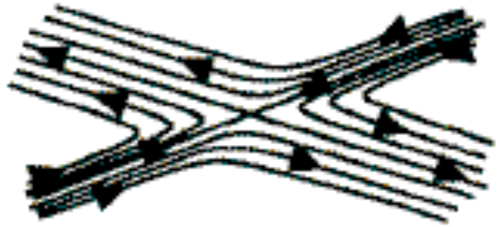

*Figure 7.1* A phase portrait.

[M. Henle]

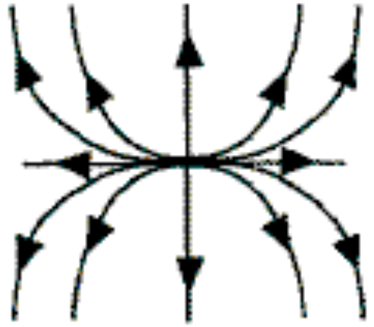
# Critical Points



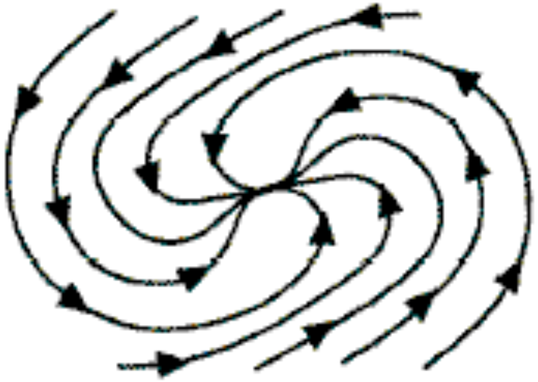
Repelling Focus
R1, R2 > 0
I1, I2 != 0



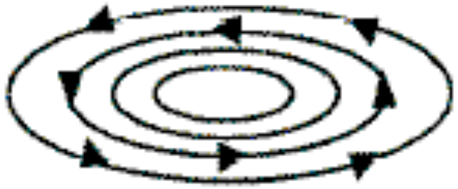
Saddle Point
R1 * R2 < 0
I1, I2 = 0



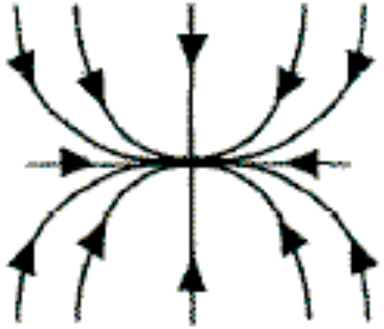
Repelling Node
R1, R2 > 0
I1, I2 = 0



Attracting Focus
R1, R2 < 0
I1, I2 != 0



Center
R1, R2 = 0
I1, I2 != 0



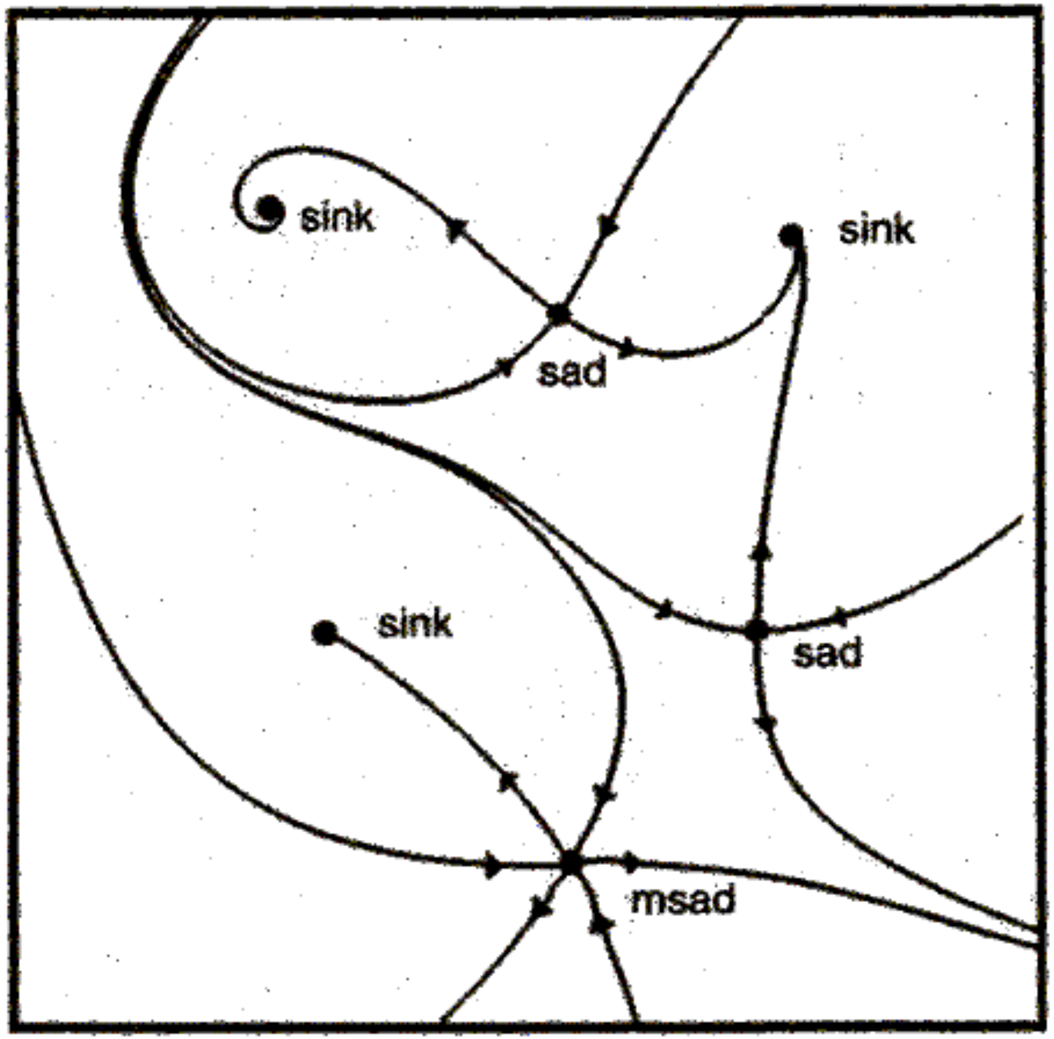
Attracting Node
R1, R2 < 0
I1, I2 = 0

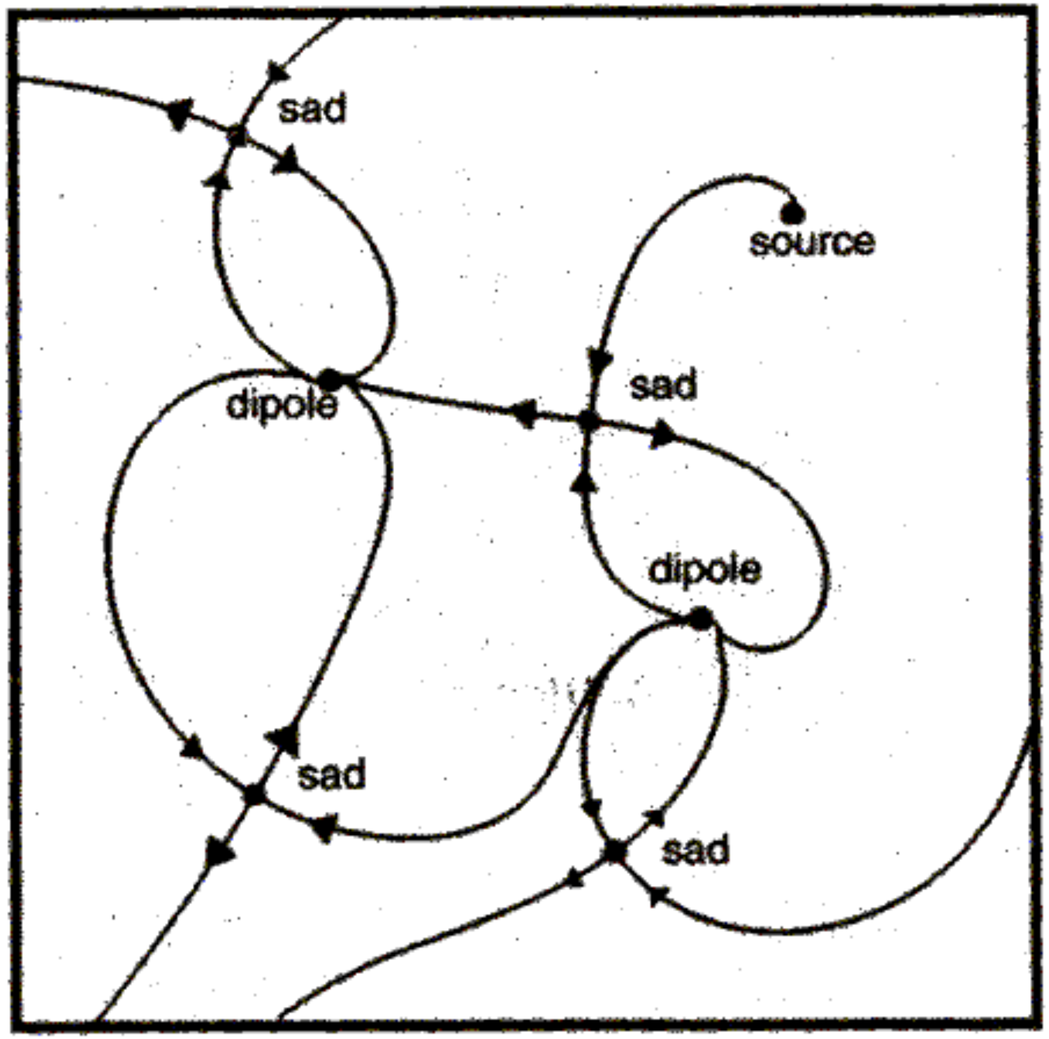
[Helman & Hesselink]

# Critical Points

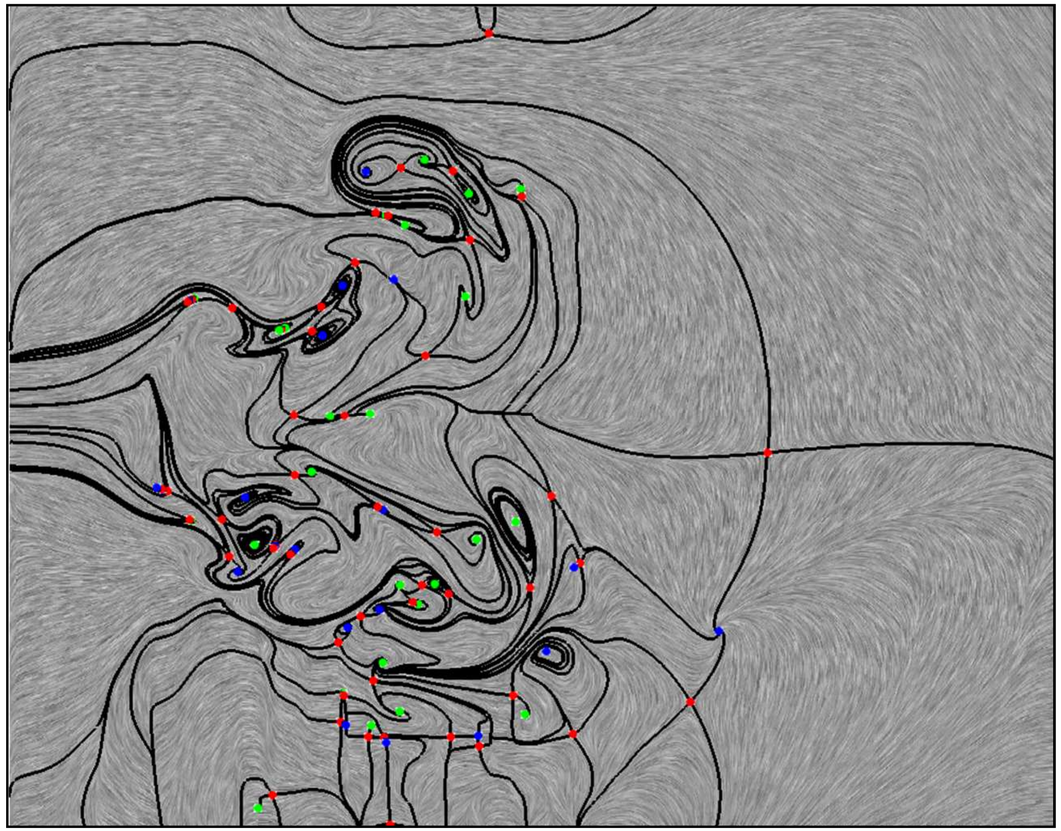
- Critical Points
  - Find where the vector field vanishes (the zero vector or undefined)
  - Attracting Nodes (Sinks), Repelling Nodes (Sources), Attracting Foci, Repelling Foci, Saddles, Centers
- How to find such points?
  - Can use a similar idea to Marching Cubes
  - Use the eigenvalues of the Jacobian matrix to classify

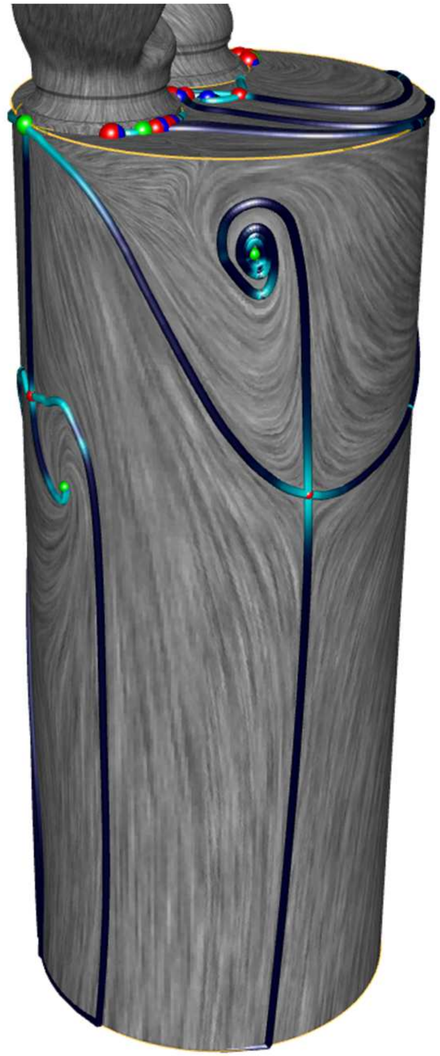
# Topological Skeleton



# More Examples





[Levine]

Text

# Text Visualization

- Why visualize text? Text is already visual, right?
- How much text? What granularity? (What is an item?)
  - Single string
  - Words/lines
  - One document
  - Multiple documents (corpus)
- Considerations:
  - Legibility
  - Variable length
  - Locality
  - Occurence

# Data Sources

- Literature: books, poetry
- Social Media: tweets, posts
- Web: Pages, posts, emails
- Code

# Tag Cloud (One Document)

- Derived data: number of occurrences of words
- Channel: Font size
- Potential problem: Think about ink…


[Scray, CC-BY-SA-3.0]

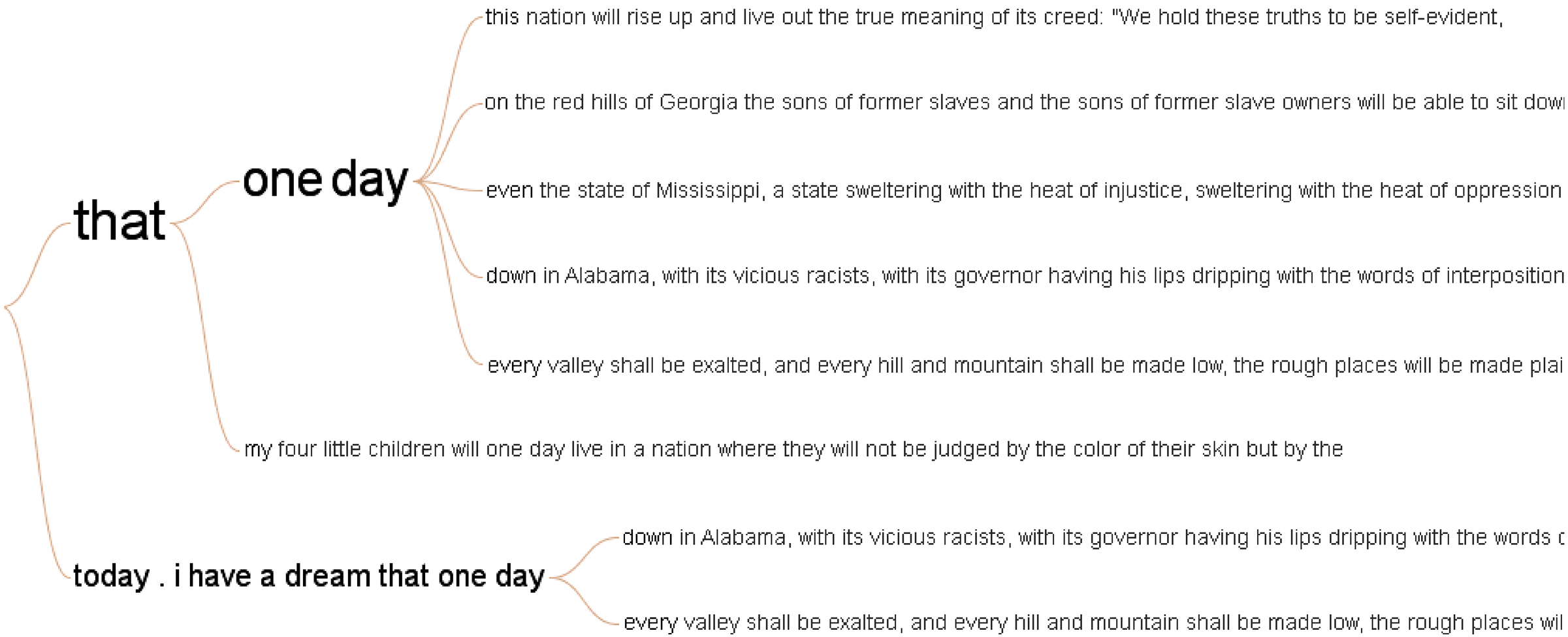
# TextArc (One Document)


[textarc.org]

# TextArc

- Three rules:
  - Show the entire text in an ellipse around the page: line-by-line and word-by-word
  - Like tag clouds, use larger font-size and brighter text for frequent words
  - Central words move to the middle (links to its mentions)

# Word Tree (One Document)

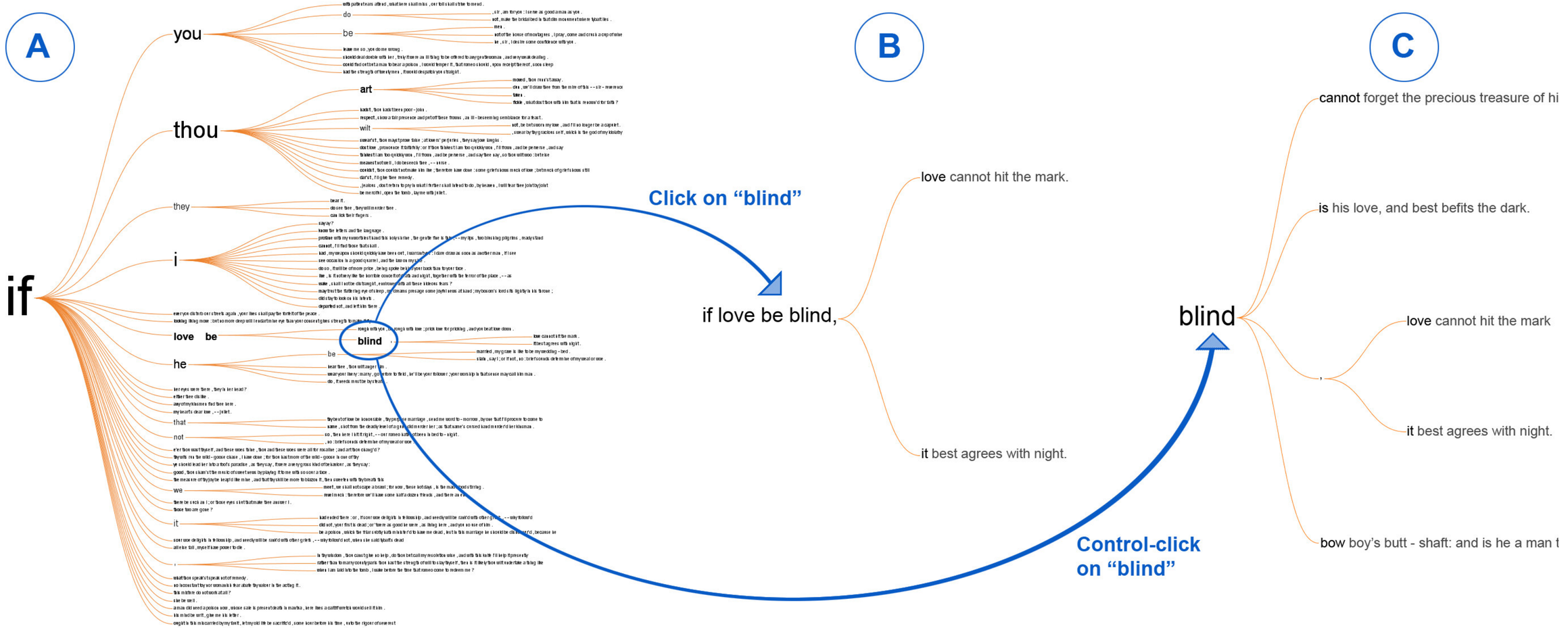



[Wattenberg & Viegas, 2007]

# Word Tree

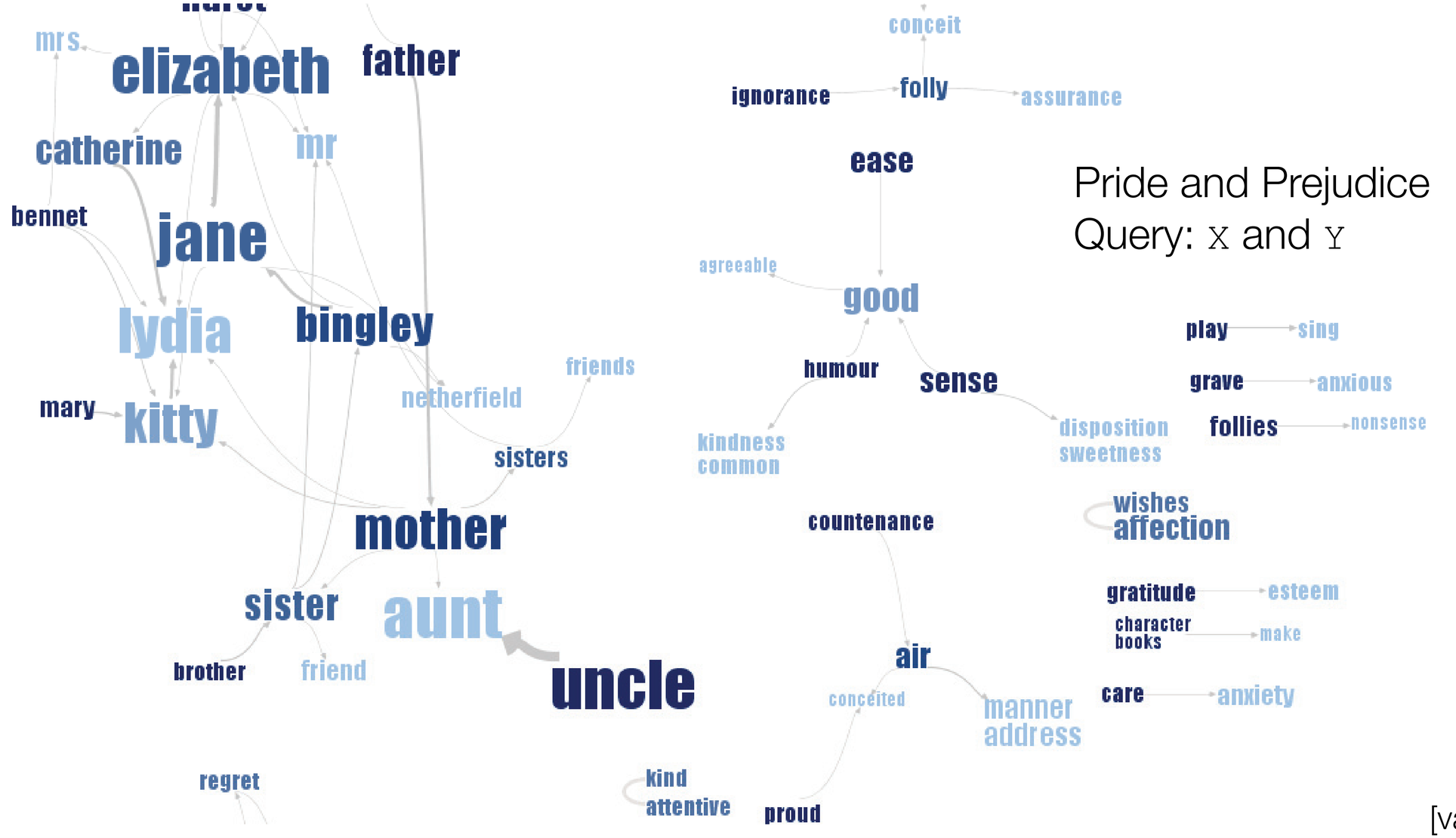
- A "Visual Concordance"
- Shows phrasing, relationships between words
- Starting point is a single word or snippet
- Branches to show common words/phrases that follow
- Goal is to show context: "keyword-in-context"

# Interaction in Word Tree




[Wattenberg & Viegas, 2007]

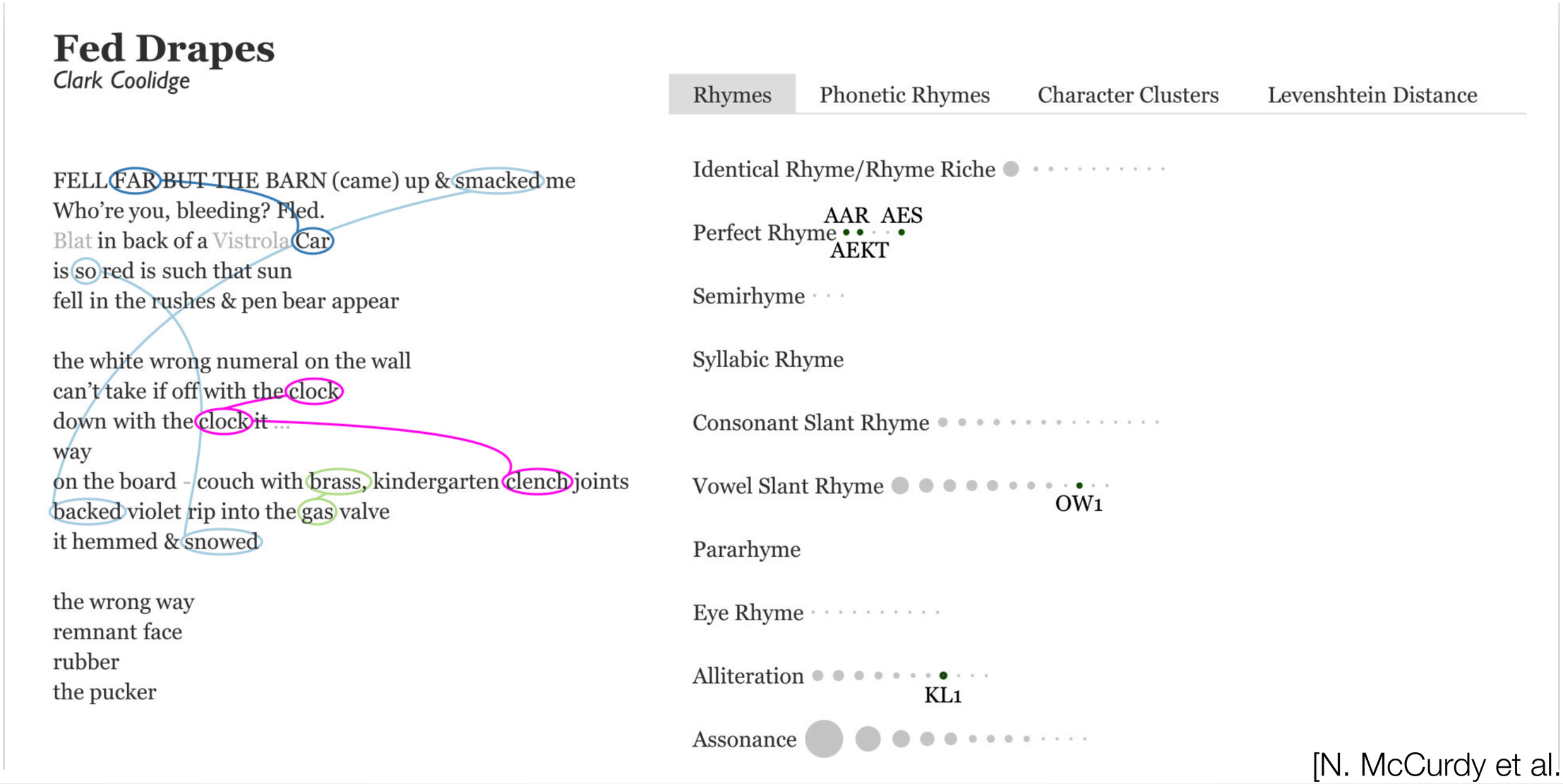
# Phrase Nets




Pride and Prejudice
Query: `X` and `Y`

[van Ham, 2009]

# Words are more than just character sequences



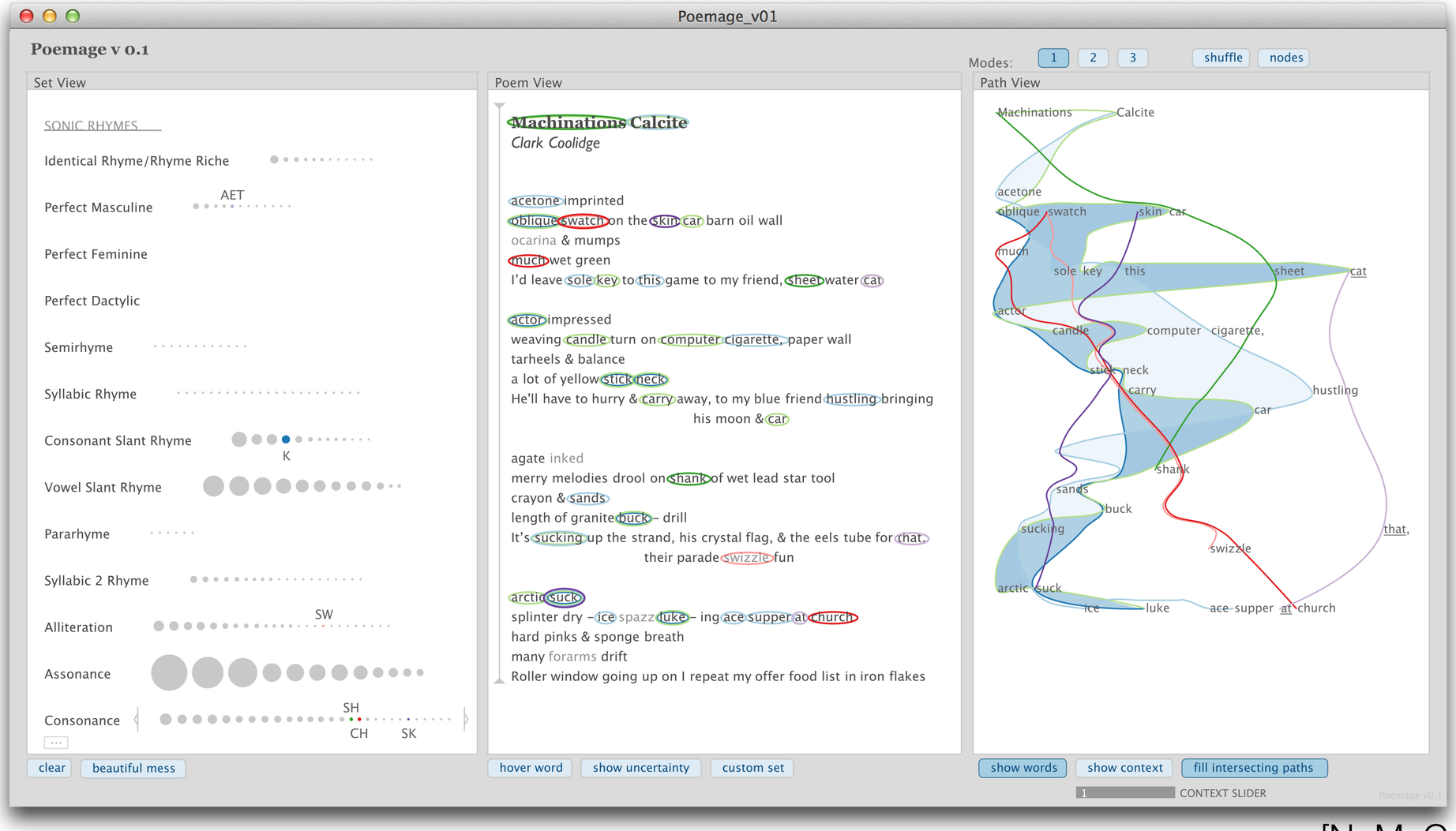

[N. McCurdy et al., 2015]

# Poemage

- Support close reading—in-depth reading to generate as much productive meaning as possible
- Search for poetic devices: affect, imagery, pun, metaphor
- Sound and linguistic devices → Rhyming
  - Identical: pare/pair
  - Perfect: picky/tricky
  - Assonance & consonance: blue/estuaries, shell/chiffon
  - Eye rhyme: cough/bough
- Support exploration: scholars do not want computers to "solve" poems

[N. McCurdy et al., 2015]

# Interface




[N. McCurdy et al., 2015]

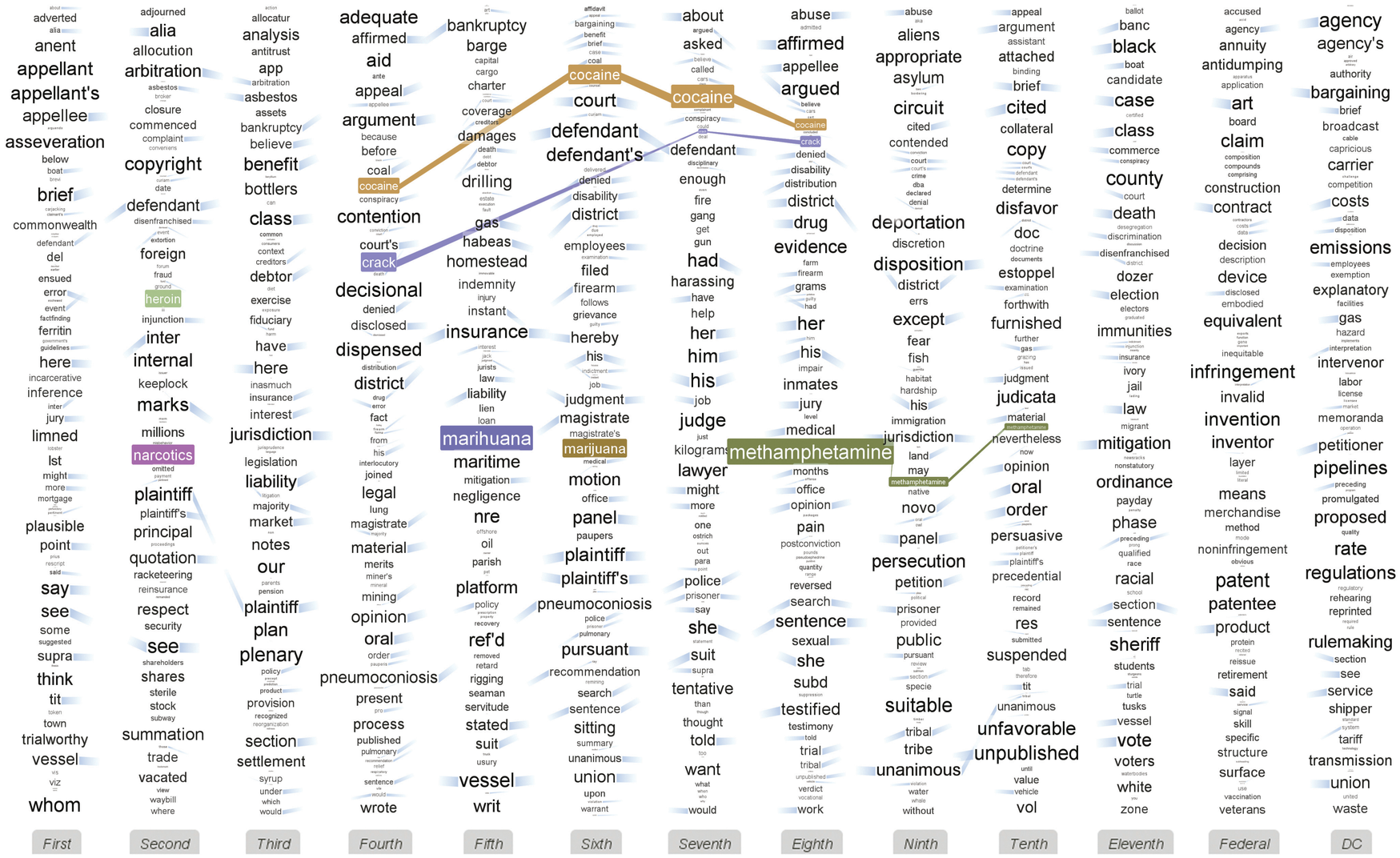
# Comparing Documents

- Word choice/usage
- Relationships
- Phrasing

# Tag Cloud (Two Documents)


[Pyrsmis, CC-BY-SA-3.0]

# Parallel Tag Clouds (Multiple Documents)




[Collins et al., 2009]

# Jigsaw (Multiple Documents)

**Visual Analytics Support for Intelligence Analysis**
**Case Study: The 9/11 Report**

Carsten Görg
Youn-ah Kang
Zhicheng Liu
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[http://www.cc.gatech.edu/gvu/ii/jigsaw/]

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