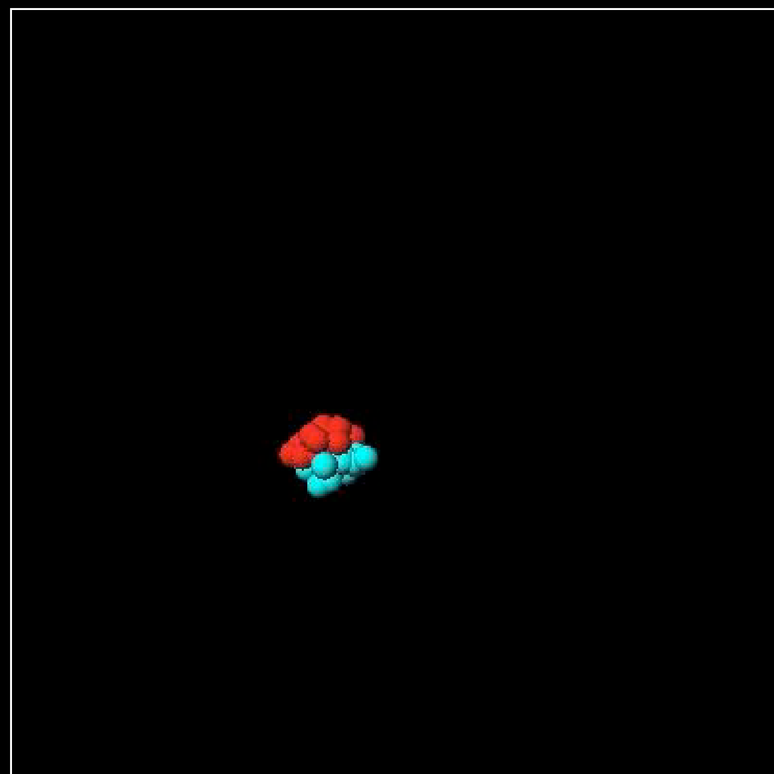
A Glider For Every Graph

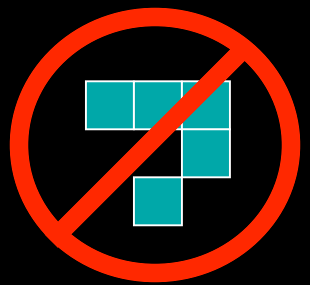


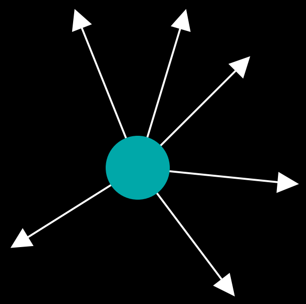
Alexander Lamb

(alex.lamb@gmail.com)

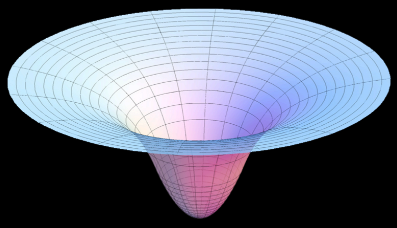
The Challenge!

- Rotationally-invariant, straight-line motion across a discrete medium
  - A pattern that can move in any direction
  - An algorithm that doesn't change with angle





- A medium that behaves like space
  - Should support relativisitic curvature
  - Should be flexible and dynamic
  - Should have no preconceived orientation



The Motivation

- What's the payoff?
  - A simple approximation to a physical particle
  - A step towards a discrete, deterministic, Turing-Machine-equivalent model of nature
- Why describe motion specifically?
  - Starting point for analyzing physical systems

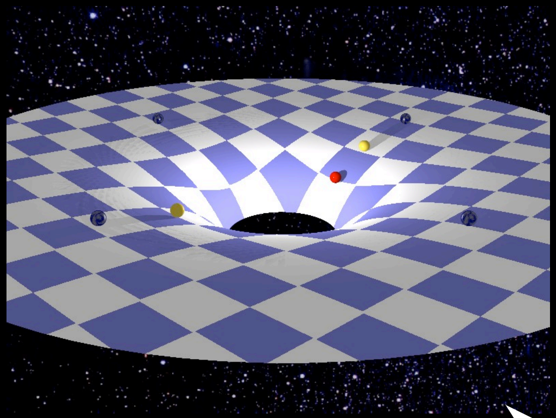
$$\frac{dx}{dt}$$

- Why rotational invariance in a dynamic medium?
  - That's what we see

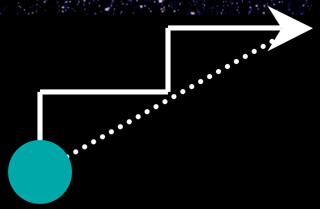
Overview

- What others have done
- What I have done
  - Choice of medium
  - A pseudo-particle algorithm to traverse it
- Examination of results
  - With a metric to test straightness
- Exploration of proposed method’s potential

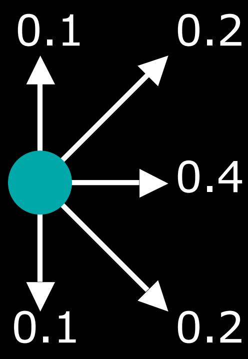
What's Been Done?



- Compound motion on regular grid defines direction
  - Change of angle isn't smooth
  - No curvature
    - Tim Tyler, finitenature.com

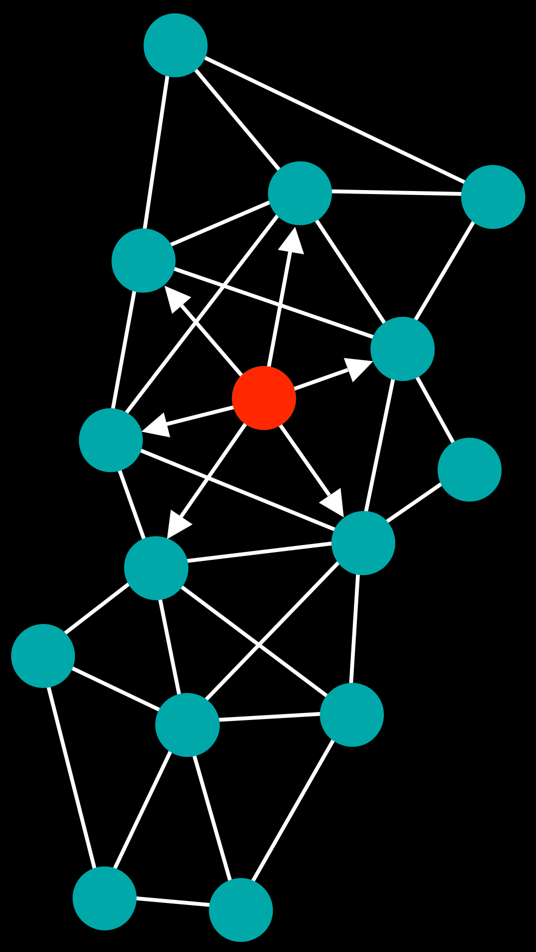


- Probability as direction
  - Replaces continuous motion with continuous probability
  - Preconceived orientation required
    - Ed Hanna, arXiv:cs/0607018v2 [cs.CE]



Our Discrete Medium

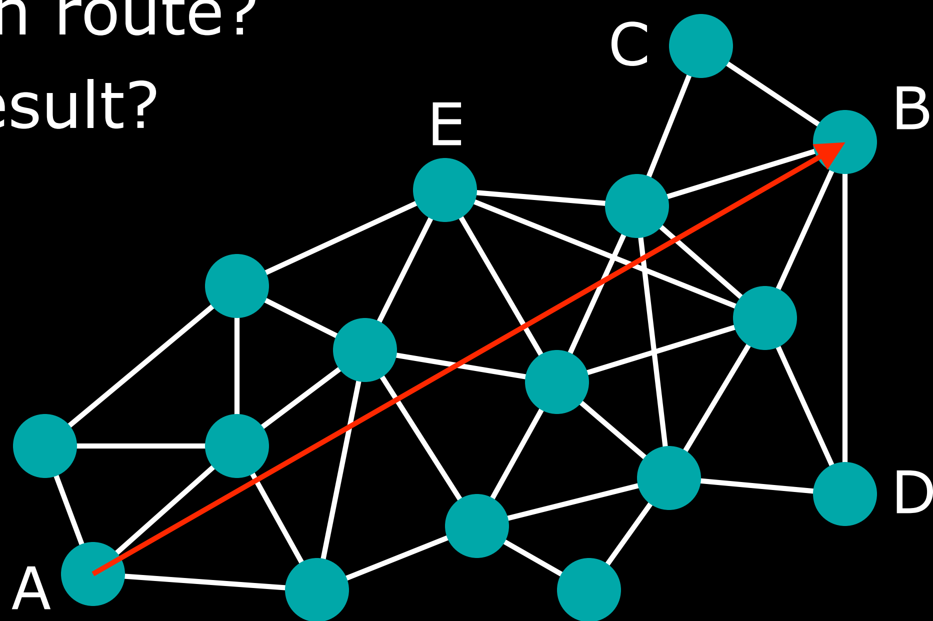
- Irregular Directed Graphs
  - No preferred directions
  - Minimal data at each node
  - Directed links add room for subtlety later



- Graph Recipe:
  - Give many nodes random coordinates in a fixed area
  - Connect each node to all others within threshold distance d
  - Hide coordinates

What is Straight?

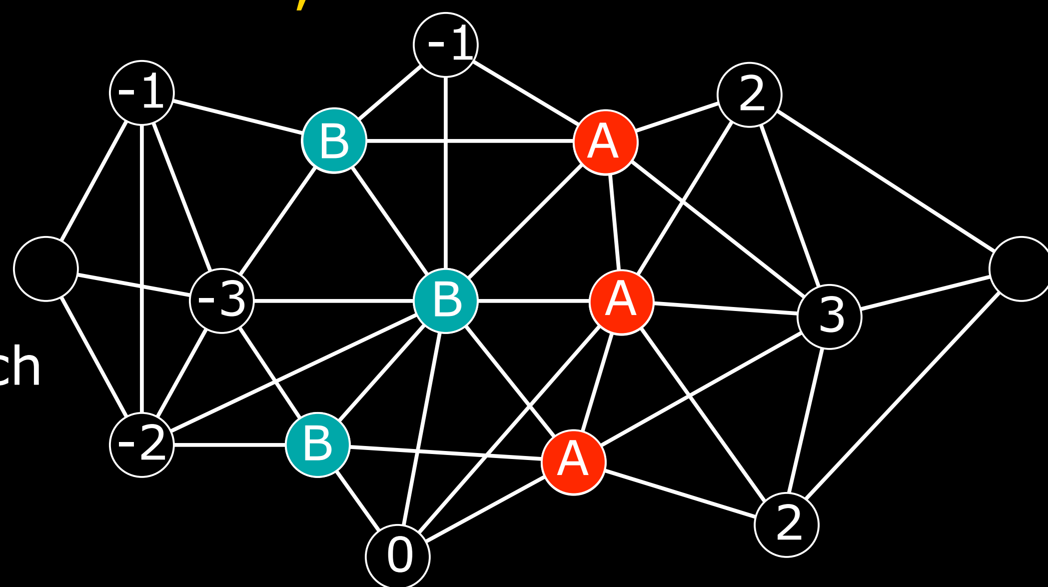
- Shortest distance between two points…
  - Via which route?
  - Which result?



Could be in a space with any dimensionality

The Jellyfish Algorithm

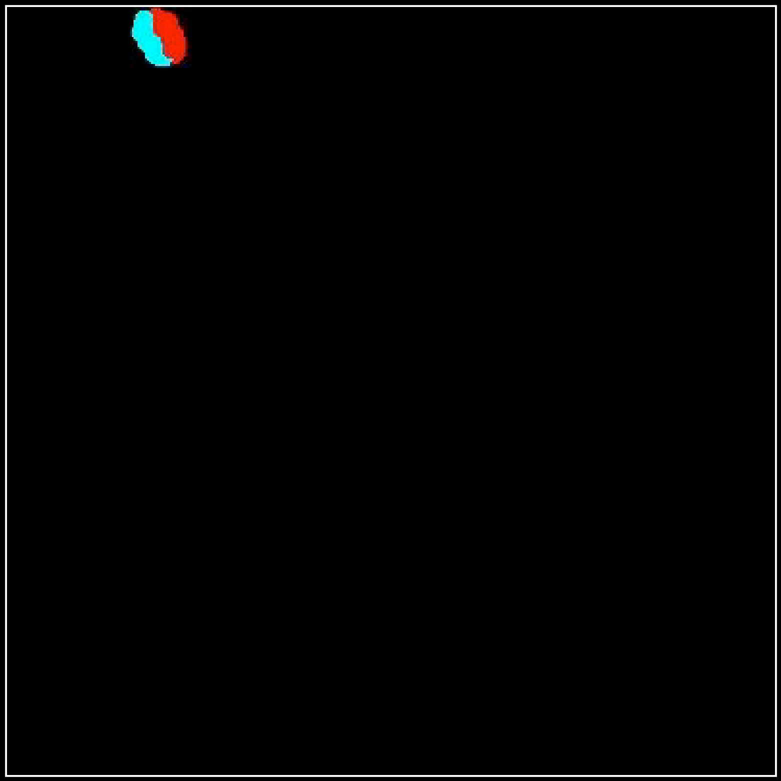
- Two sets of nodes, size n: A & B
- For every neighbor of $A \cup B$, allocate a score
  - Add one for each adjacent element of A
  - Subtract one for each adjacent element of B



- New B = A
  New A = top scoring n neighbors

For each neighbor node x, score is: $|A \cap \text{neighbors}(x)| - |B \cap \text{neighbors}(x)|$

Jellyfish in Action

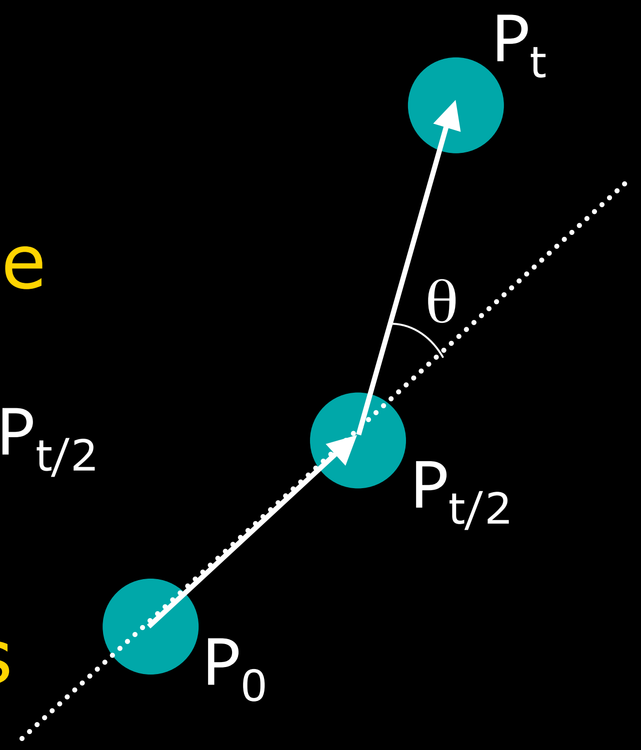


100K graph nodes not shown, 50 nodes in A, 50 in B

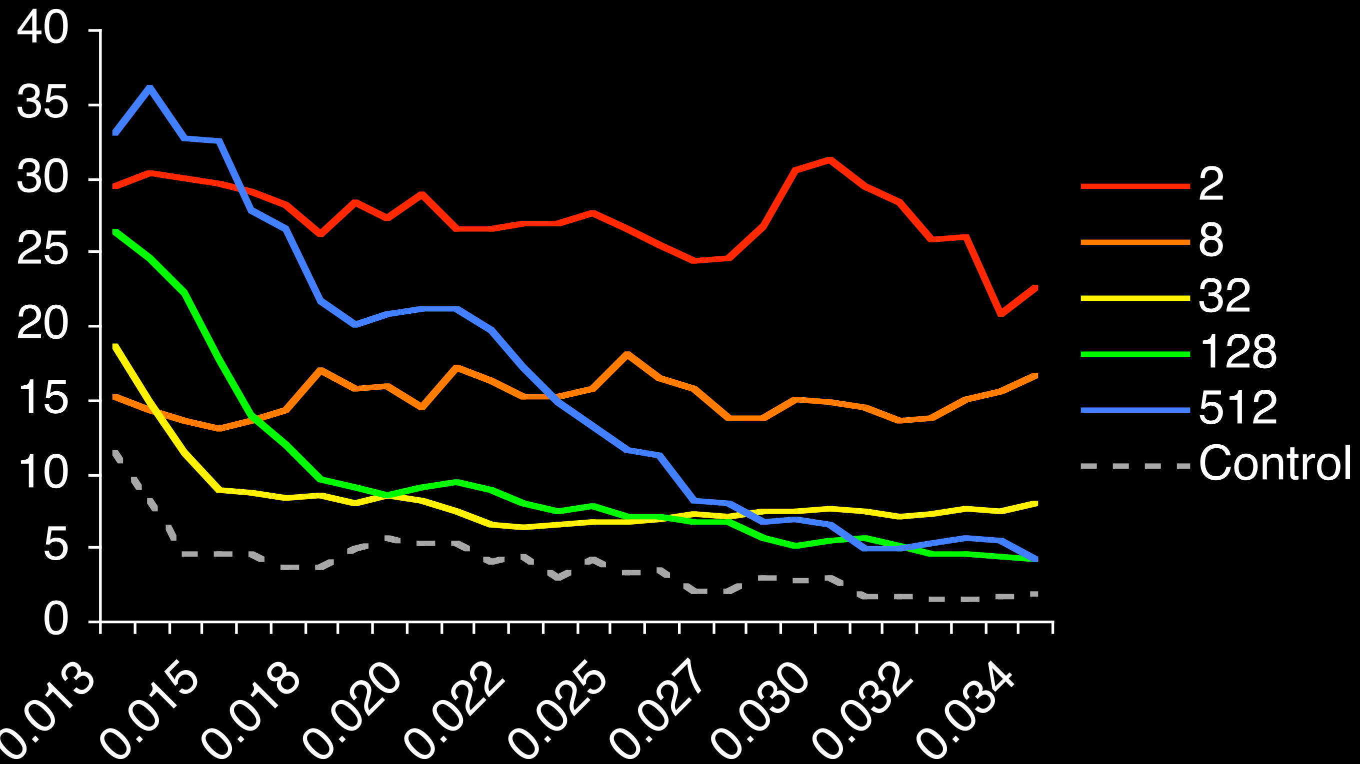
Straightness dependent on graph conditions!

Quantifying Straightness

- Want a metric that ignores changes over short distances
  - Angles at short distances are guaranteed!
- Measure direction change over time
  - Compare $P_{t/2}$- P_0 with P_t- $P_{t/2}$
  - We know the real angles!
- Average over many runs

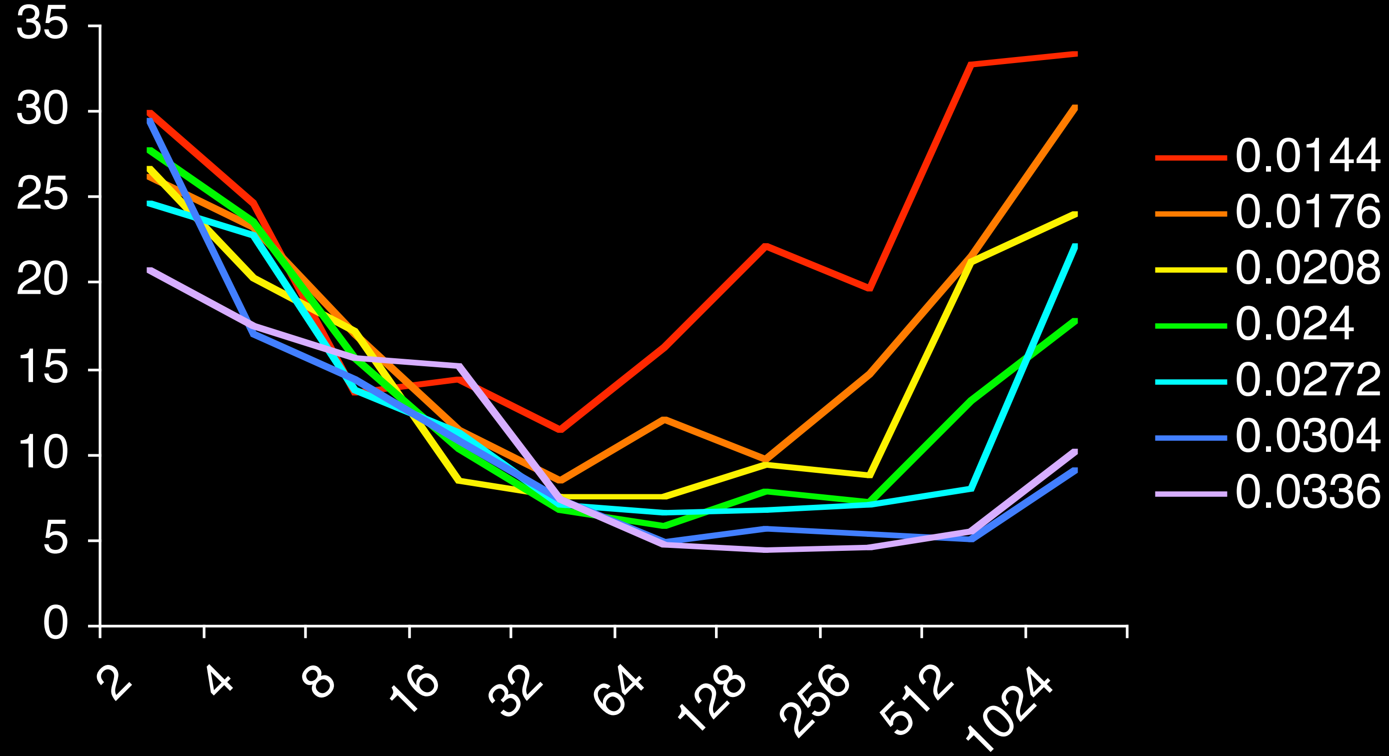


Angular Deviation with Particle Size



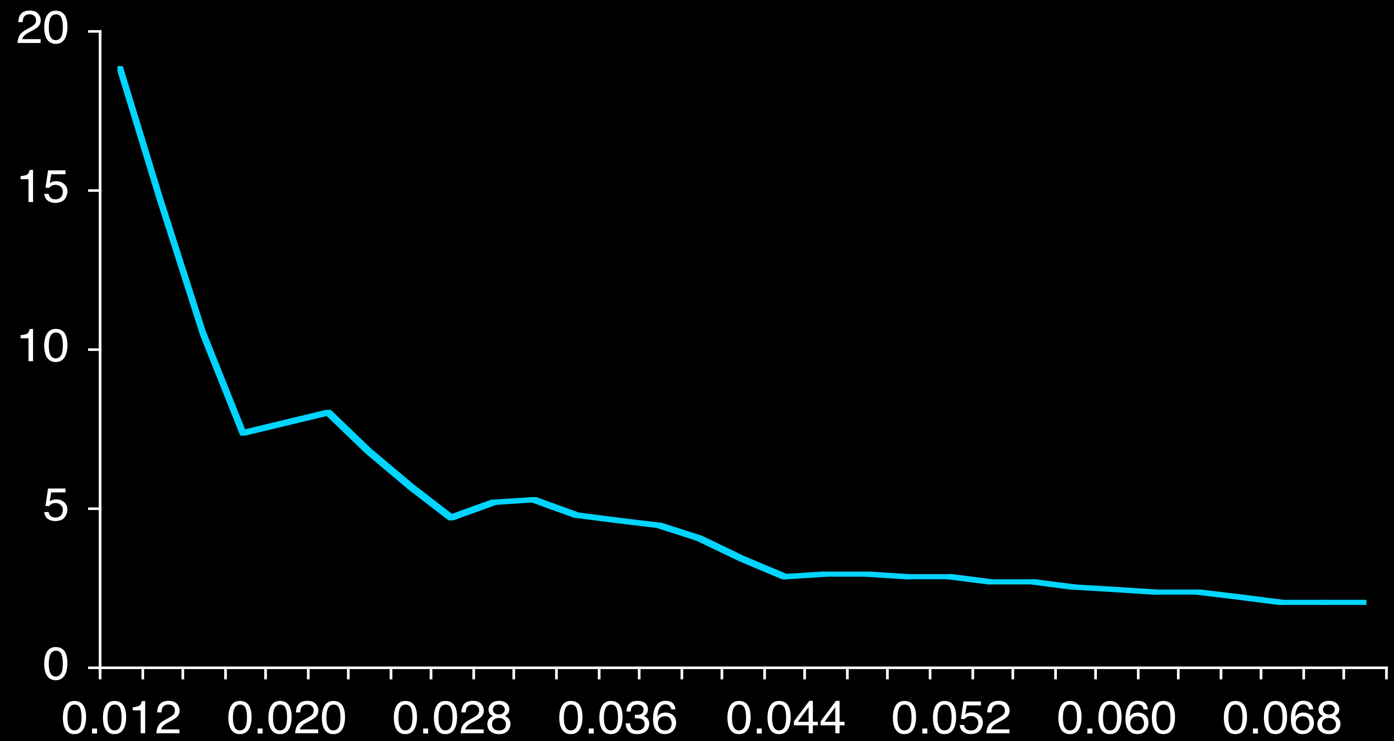
Angular deviation for different set sizes with varying connection density

Angular Deviation with Connection Density



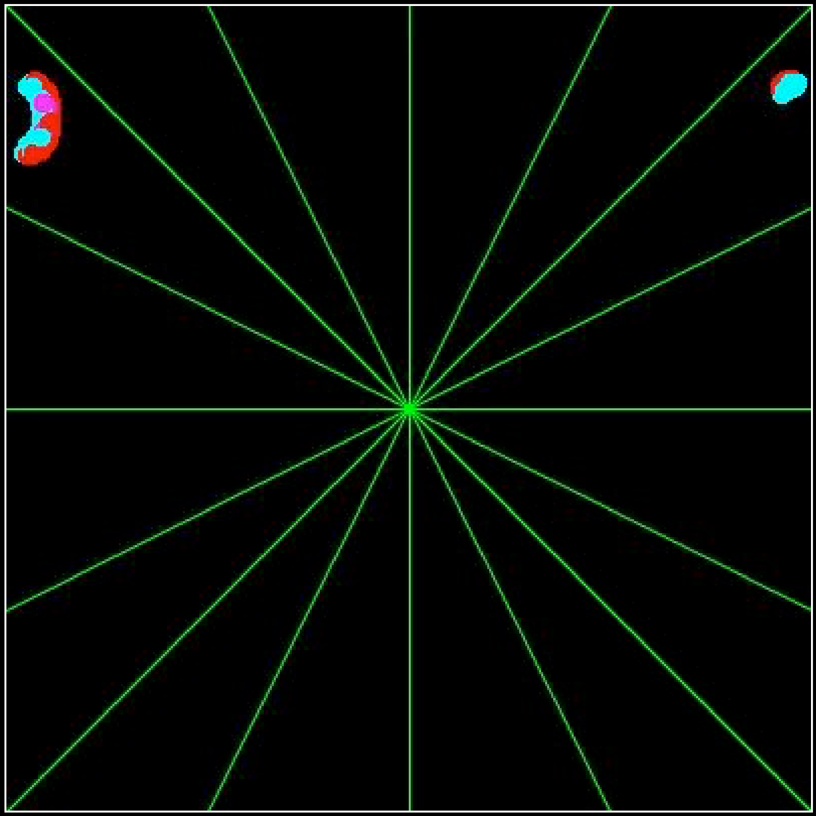
Angular deviation for different connection densities with varying particle size

Angular Deviation For Optimum Particles



Angular deviation for set size (mean neighbors)/2 with varying connection density

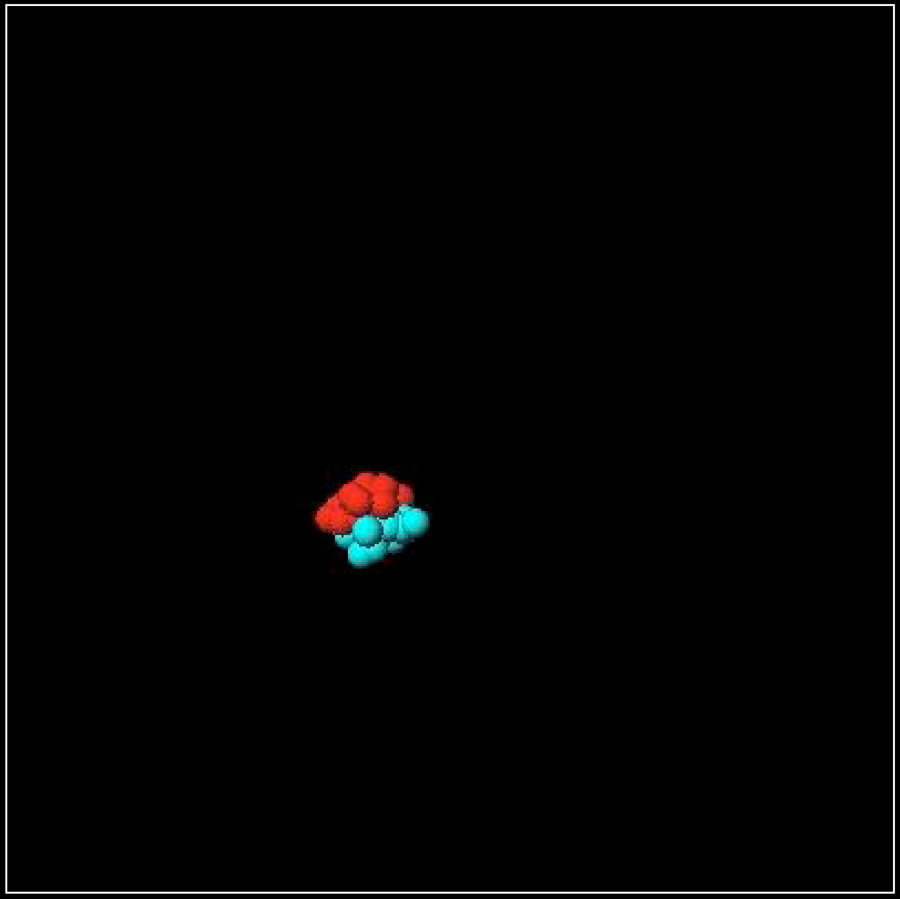
Did Irregular Graphs Help?



Yes!

Regular graphs bend the direction of flight for every algorithm tested

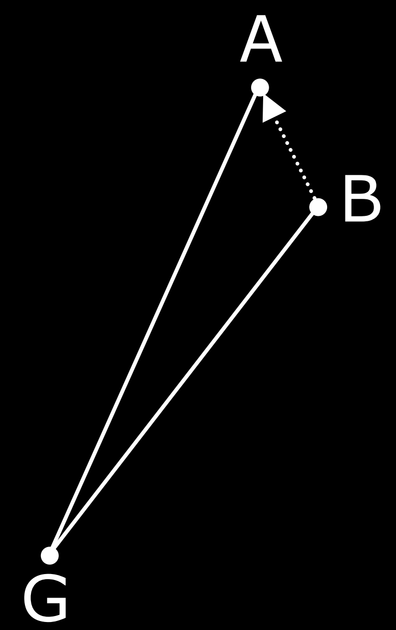
Adding Dimensions



Not a
problem

Variable Curvature: A Potential

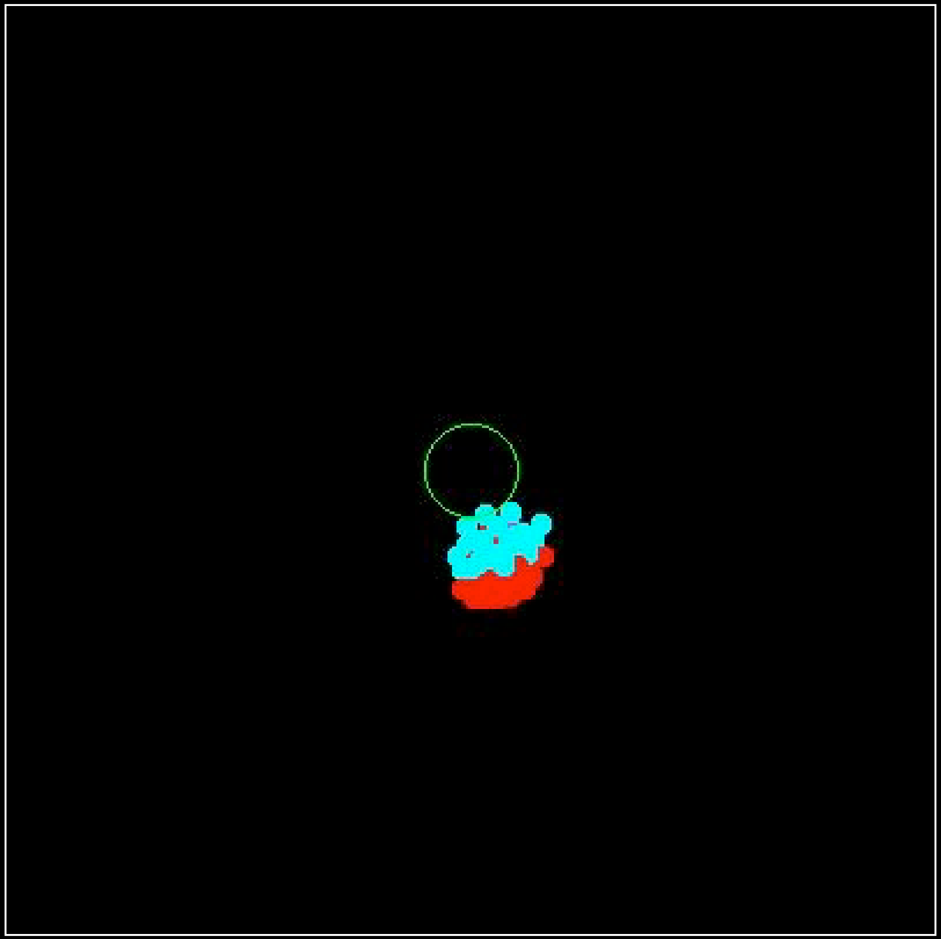
- Try for a force that goes as $1/r^2$
- Build graph by linking based on probability P_L as well as radius threshold
- For any two nodes, P_L depends on relative distance from G
- Links more likely to be added that point toward G



$$P_L = 0.5 - \frac{GB-GA}{2t(1 + GA + d)^2}$$

t = threshold dist. d = damping func.

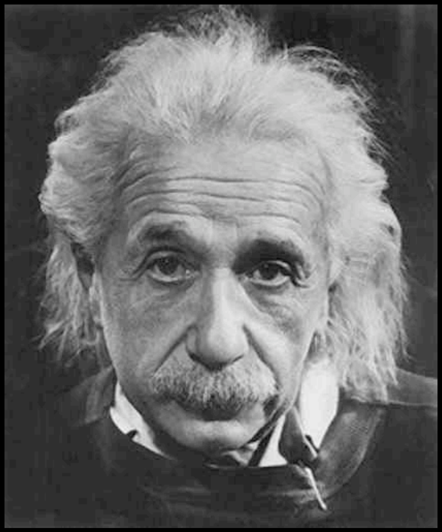
Jellyfish in Orbit



Slightly exotic orbits chosen on purpose!

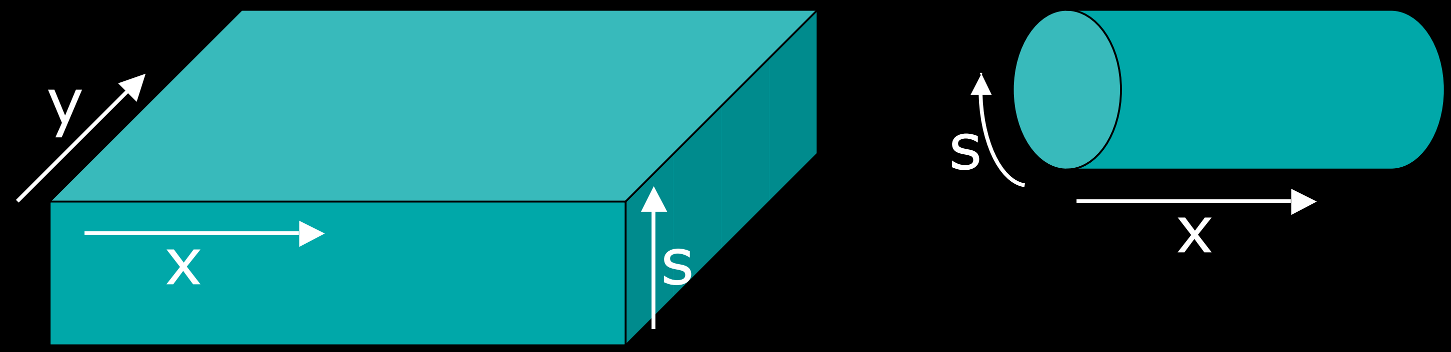
How Far Can We Stretch?

- Exploring the Potential of Jellyfish:
  - Special Relativity
  - Quantum-Wave Behavior



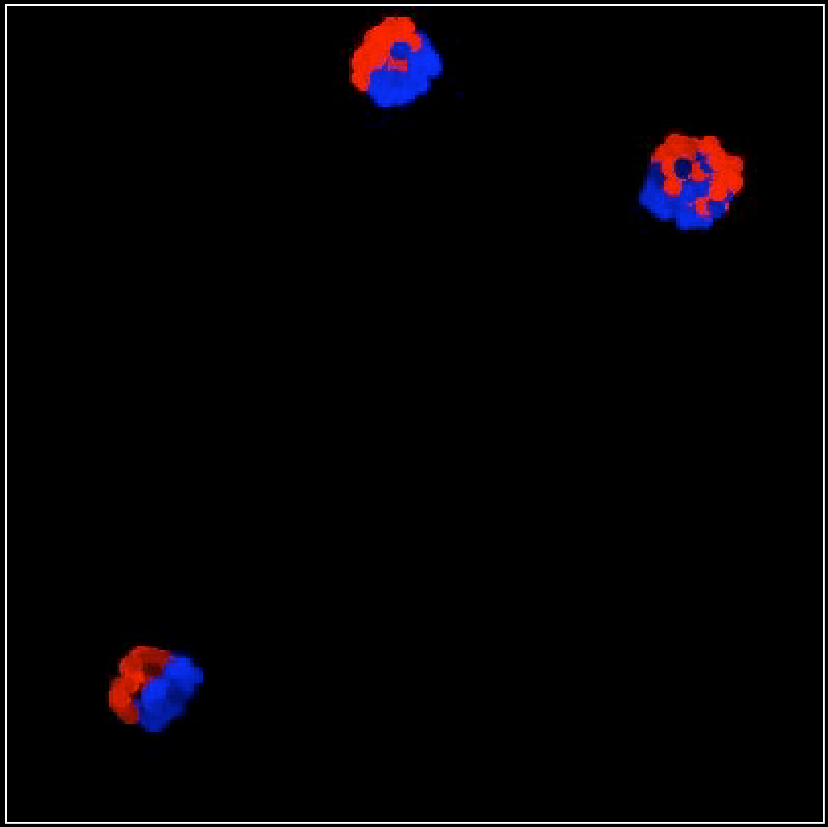
Special Relativity - Part One

- Let's borrow a trick from Kaluza-Klein Theory
- $s^2 = t^2 - x^2 - y^2 - z^2$, so add an axis for s



- KK Theory is defunct, but we're just exploring 🙂

Special Relativity - Part Two

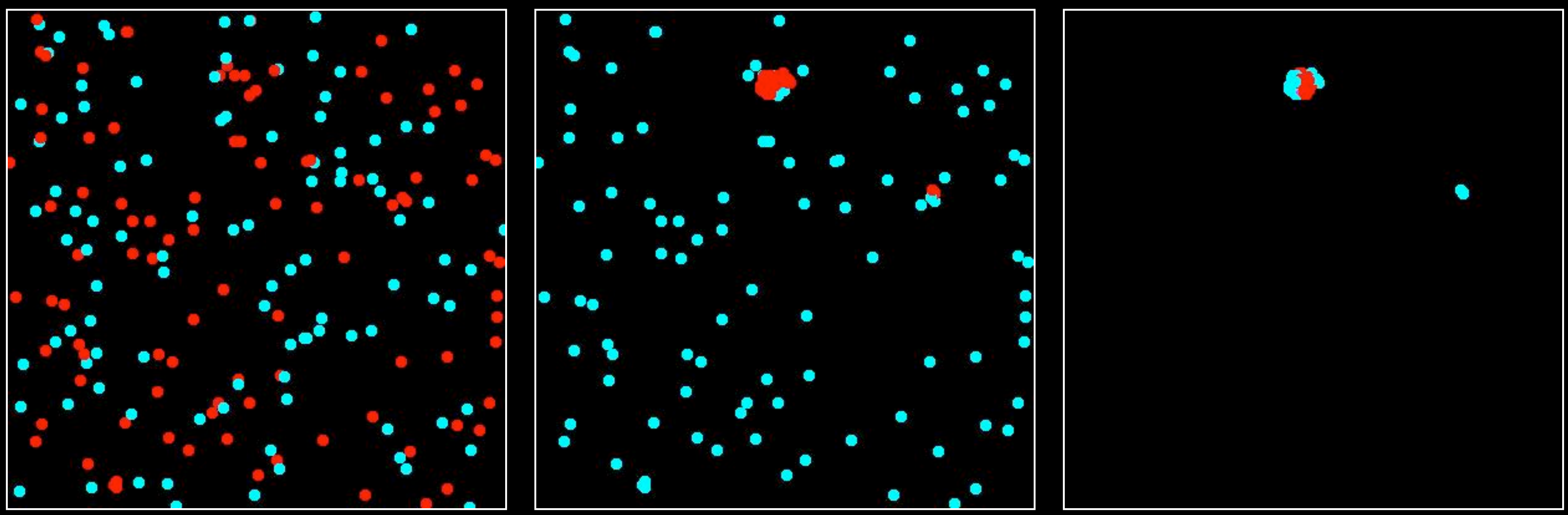


Without interaction, demonstration is incomplete

However, particles conform to Lorentz metric

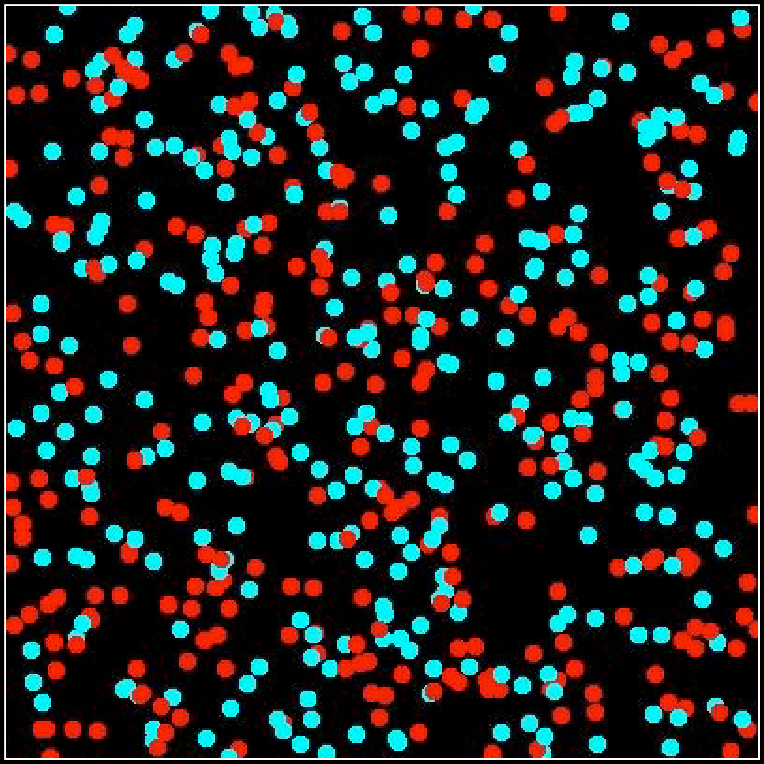
Quantum Behavior - Part One

Look what happens when we start Jellyfish



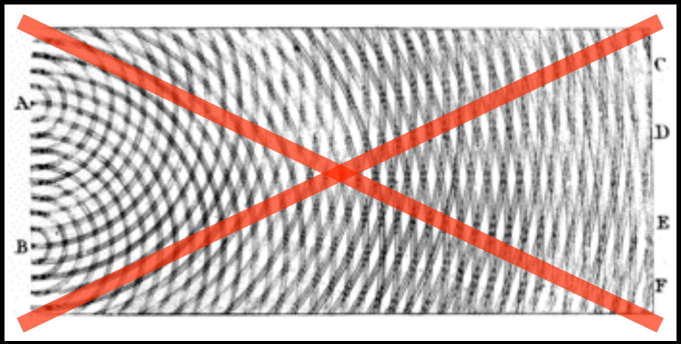
Quantum Behavior - Part Two

Look what happens when Jellyfish divides



Using coarse graph here to highlight effect

What Can't Jellyfish Do?



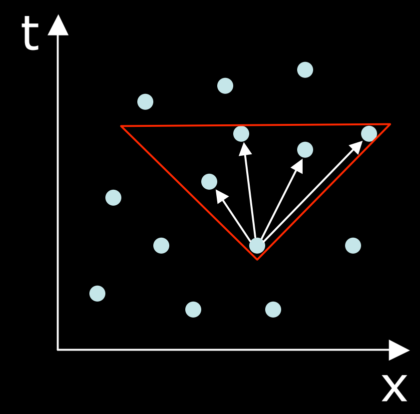
- No self-interference
- No wavelength
- Background dependent
  - Worse: dependent on canned dimensions
- Monolithic Algorithm
  - Unlike CAs
- No motion across trivalent graphs

Conclusions

- Irregular graphs worked well
  - Denser graphs improved performance
- We approximated straight-line motion
  - Though never perfectly
- We don’t have a digital photon yet
  - But we do have a test particle
- Reach of digital physics extended
  - Very well placed to explore further

Next Steps

- Background Independence
  - Nodes in spacetime 🙂
  - Graph deformation by particle
  - Jellyfish as nodes 🙂



- Algorithm extension
  - Interaction 🙂 🙂
  - QM behavior: polarization, spin, all paths, etc
  - Improved relativity
- Generalizing and searching the rule-space
  - Break Jellyfish into simple operations on node sets 🙂

Thank You!

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Gabriel Hare (UCSC, Physics Dept.)
Andrew Cotton-Clay (UC Berkeley, Math Dept.)
Sean Halle (UCSC, CS Dept.)
Lucas Winstrom (UCSC, Physics Dept.)

alex.lamb@gmail.com

Video Samples

Motion in 2D
http://www.youtube.com/watch?v=Y_yCxcjYPmo

Motion in 3D
http://www.youtube.com/watch?v=3w4A6m26WI4

Deflection by regular graphs
http://www.youtube.com/watch?v=Me6K4weLS5c

Geodesic motion
http://www.youtube.com/watch?v=n3jnKejhX-Q

Relativistic motion
http://www.youtube.com/watch?v=ggd8Z1fZwTA

Quantum-like collapse
http://www.youtube.com/watch?v=qUrqKhBwjGw