The Quantum Dynamics of Shape

A New Starting Point for Quantum Gravity

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and

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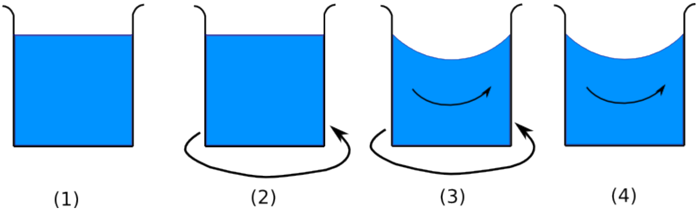
May 1, 2010

What do we really know about reality?

How can our physical theories reflect that?

Outline

Newton's Bucket



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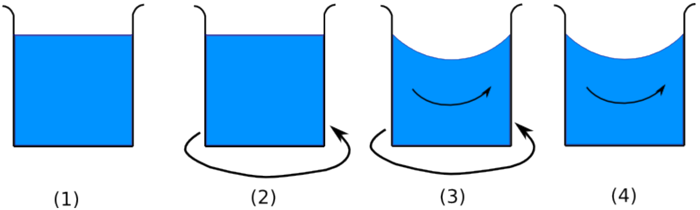

	1	2	3	4
Relative Motion	NO	YES	NO	YES
Absolute Motion of H_2O	NO	NO	YES	YES
Shape of H_2O	FLAT	FLAT	CURVED	CURVED

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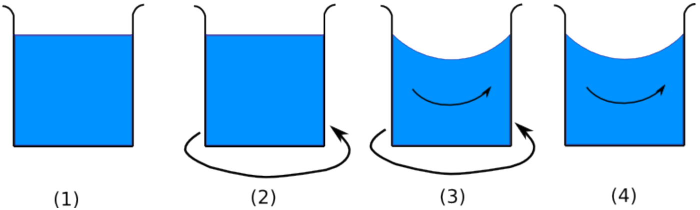

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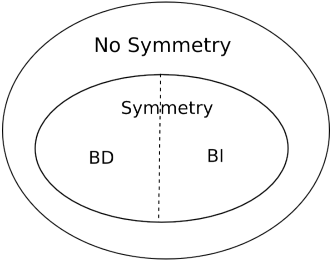
Proof of Absolute Space!!

Relational/Absolute $\Rightarrow$ Different Predictions

Symmetries vs Backgrounds

Definitions

- Symmetry $\equiv$ Equations are invariant.
- Relational $\equiv$ Physical Laws are invariant.



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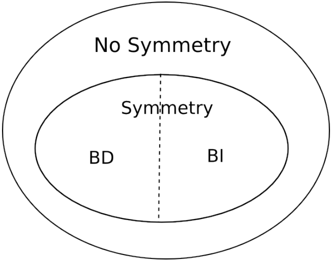
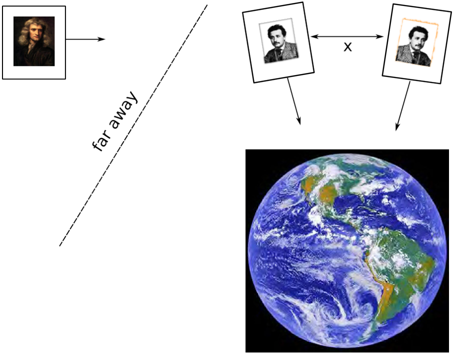


Mach's Argument

Backgrounds emerge when many heavy objects (eg, galaxies) are present.

→ Related to Hilbert spaces of quantum theories!

Equivalence Principle and Curvature



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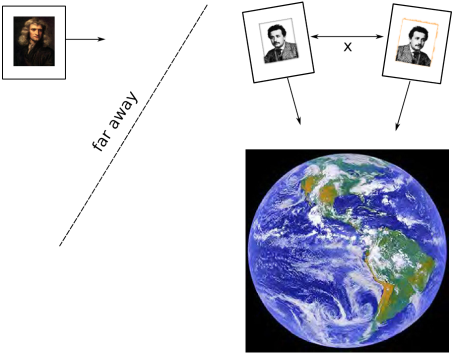

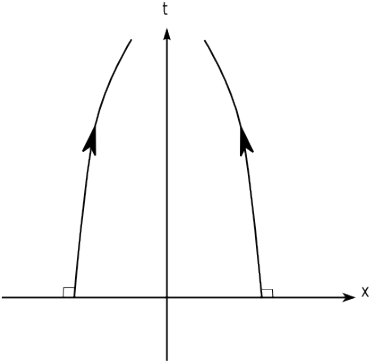

$\because$ Parallel straight lines converge

$\Rightarrow$ **spactime is curved!**

Newton vs Einstein

Two key OBSERVED differences:

1. Special Relativity
   - No action at a distance.
   - Lorentz transformations

Newton vs Einstein

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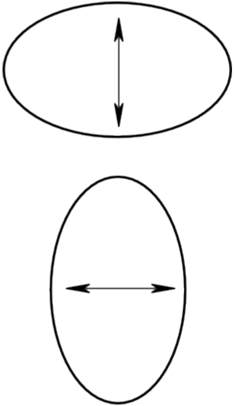
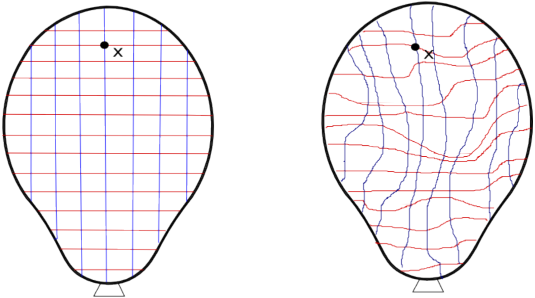
1. Special Relativity
   - No action at a distance.
   - Lorentz transformations
2. Spin 2 particle
   - Mercury's Orbit
   - Gravity wave polarization



Part 1: The Variables (Kinematics)



Rules for painting lines:

1. number of dim = number of lines
2. No lines of the same color can cross
3. Draw enough for desired resolution

metric vs geometry

Part 2: Symmetry

Variables are painted lines!

Key Idea

- Symmetry: eq'ns $\longrightarrow$ independent of how you paint. (Need differential geometry)
- Relational: physics $\longrightarrow$ independent of how you paint. (Need best matching)

True degree of freedom: geometry!

Part 3: Dynamics

"Conservation of Energy" $\Rightarrow$ $\boxed{K + V = E}$

Geometry Dynamics (Geometrodynamics)

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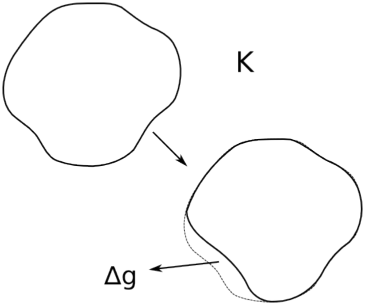
Geometry Dynamics (Geometrodynamics)

- $K \equiv$ Rate of change of geometry ($K \sim v^2$, where $v = \frac{\Delta g}{\Delta t}$)



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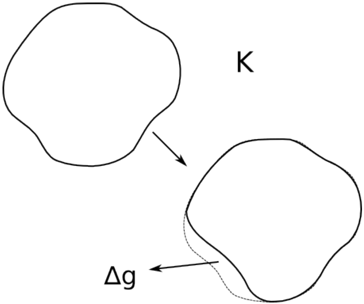

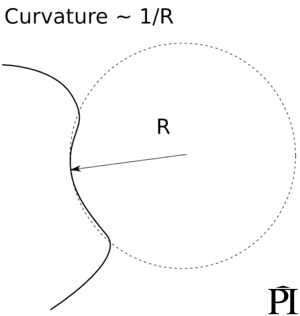

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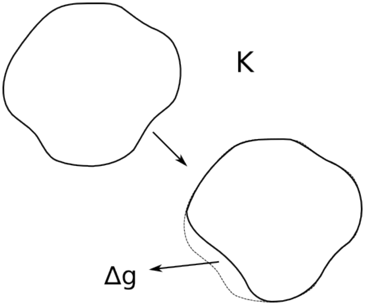
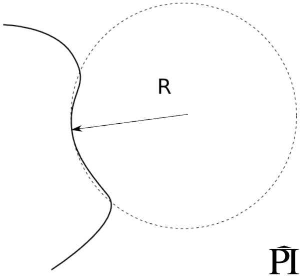
- $E \equiv$ cosmological constant

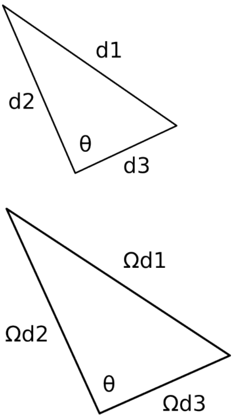


Curvature ~ 1/R



Geometry vs Shape Part 1: Size

Rescale:



Only angles and ratios of lengths are measurable.
Ratios of Lengths:

$$\frac{d_1}{d_2} = \frac{\Omega d_1}{\Omega d_2}, \text{ etc...} \tag{1}$$

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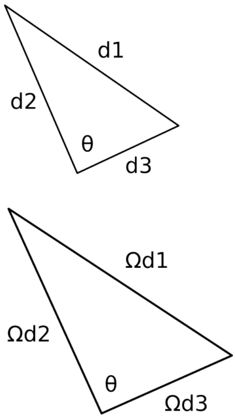

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Ratios of Lengths:

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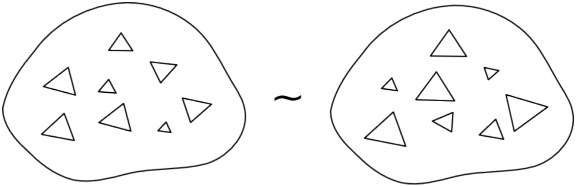
Angles:

$$\cos\theta = \frac{1}{2}\frac{d_2^2 + d_3^2 - d_1^2}{d_2 d_3} = \frac{1}{2}\frac{(\Omega d_2)^2 + (\Omega d_3)^2 - (\Omega d_1)^2}{(\Omega d_2)(\Omega d_3)} \tag{2}$$

$\therefore$ d_1/d_2, θ, etc... are unchanged!

Geometry vs Shape Part 2: LOCAL Size



Only LOCAL shapes are measured!

Problem

Local size not measurable.
GR depends on scale. Why?

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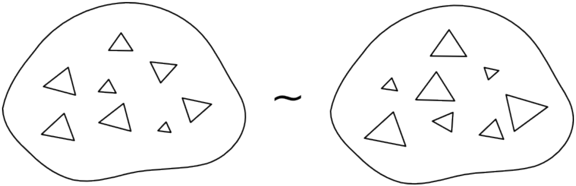

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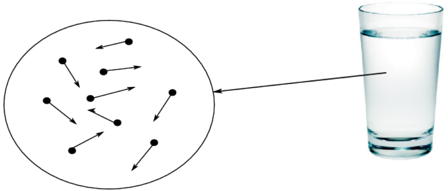
Solution?

Find a local scale independent theory (using best matching).

$\Rightarrow$ Shape Dynamics

Statistical Smoothing

Physics is possible because we can "smooth–out" fine details.



The Good, the Bad, and the Ugly

- Good: micro–physics averages out.
- Bad: micro destroys macro.
- Ugly: averaging doesn't work.

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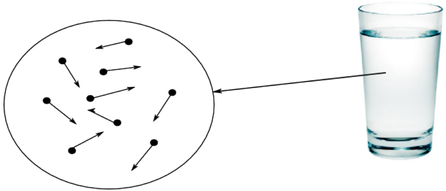

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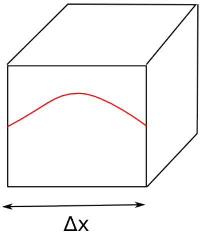
GR is Bad and Ugly!!

Why GR is bad: A Particle in the *Smallest* Box



Longest wavelength photon:

$$\lambda = 2\Delta x \quad \Rightarrow \quad f = \frac{c}{2\Delta x} \tag{3}$$

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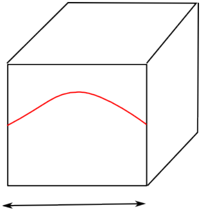

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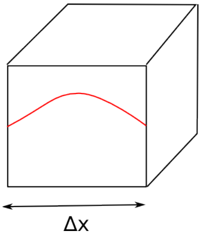

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Gravity: (Black hole radius)

$$R_{\text{BH}} = \frac{2mG}{c^2} = \frac{2EG}{c^4} \tag{5}$$

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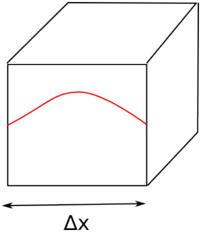

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If $\Delta x \sim R_{\mathrm{BH}}$ then $\Delta x = \sqrt{\frac{\hbar G}{c^3}} \equiv$ Plank length.

Local Scale Symmetry Saves the Day

Waves with $\lambda <$ Plank length create black holes!
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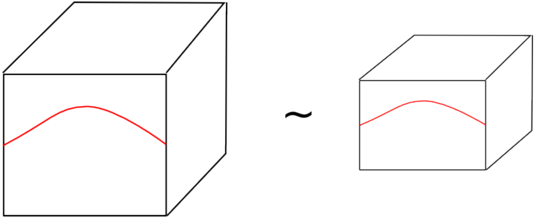
Local scale invariance:



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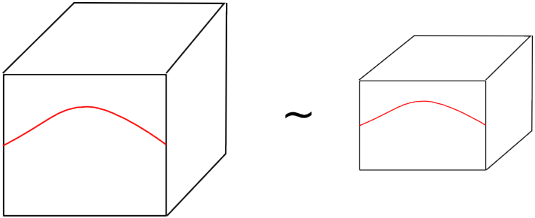


Plank length is meaningless!

Alternatives: string theory, LQG, etc...

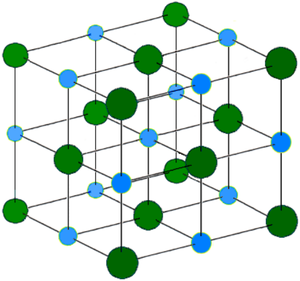
Phase Transitions: Water

Symmetries can be "broken" at low energy!

High Energy (Liquid)

Uniform Distribution → symmetry

Low Energy (Solid)

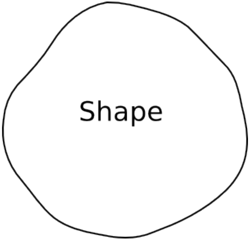


Latice → broken symmetry

Phase Transitions: Geometry

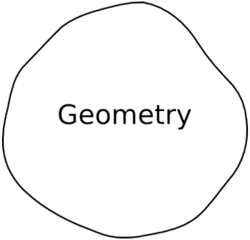
In Quantum Shape Dynamics, I expect scale symmetry will be broken.

High Energy



Gravity $\longrightarrow$ QSD

Low Energy



Gravity $\longrightarrow$ GR

Conclusions

Summary:

- Symmetry $\neq$ Relational (Background Independence)
- Equivalence Principle $\rightarrow$ curved spacetime
- Gravity $=$ dynamic geometry (energy balance)
- Coordinate dependence is relational
- Scale dependence is NOT!
- Shape Dynamics might tame ∞'s?!

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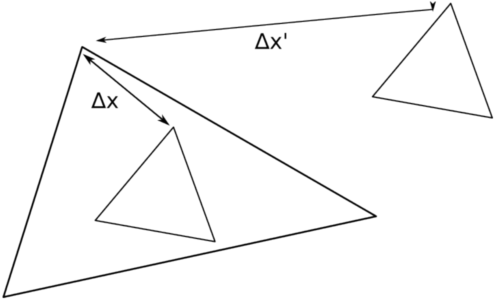
Disclaimer

Shape dynamics is not yet a complete theory! There are still many unresolved question.
If we knew what we were doing, it wouldn't be called research!

Bonus Slides: Best Matching – The Idea

What is the “difference” between 2 shapes?



$$\Delta S^2 = \sum_I (\Delta x)^2 \qquad (6)$$

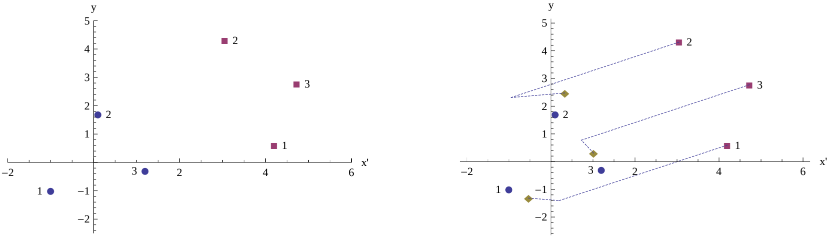
Or,

$$(\Delta S')^2 = \sum_I (\Delta x')^2 ? \qquad (7)$$

Ambiguity in coordinates?

Bonus Slides: Best Matching

Solution: *minimize* ΔS by shifting coordinates!
$\Rightarrow$ Best Matching



Newton's Laws $(F(= \nabla V) = ma) \longrightarrow \min(V \cdot \Delta S)$ for all t.