

# Physics 102 - September 9, 2009

▀ Readings on BlackBoard

▀ Reserves list

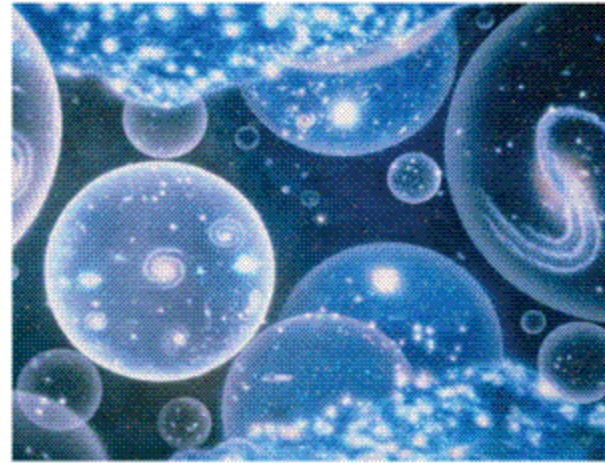
▀ Recitations begin next week

☹ Wed Noon - 1:50 Section Saga

currently trying M-Th 7-9 pm

▀ Calculator

Last Time



Manly's Populist  
Multiverse Taxonomy

J. Bann/SPL  
Nature.com

6 classes

Space Separated

Time Separated

Space + Time Separated

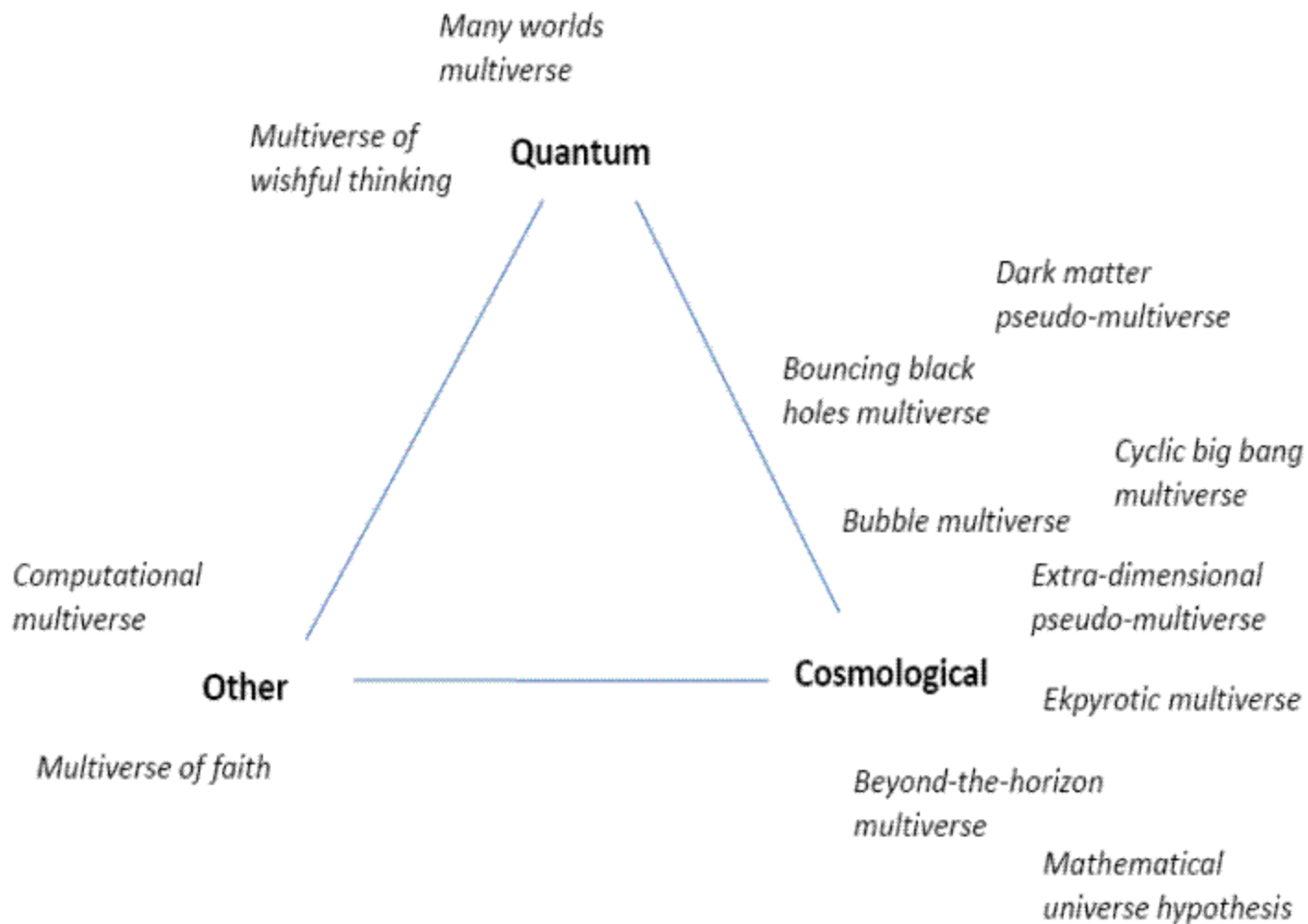
Faith-Based Separation

Dimensionally Separated

Pseudo-Multiverses

12 multiverse concepts (might be many versions)

Whirlwind descriptions in document  
on BlackBoard



*Beyond-the-horizon  
multiverse*      *Dark matter  
pseudo-multiverse*

*Many worlds  
multiverse*      *Bouncing black  
holes multiverse*

**scientific**

*Cyclic big bang  
multiverse*      *Extra-dimensional  
pseudo-multiverse*

**Based on science but reputable experts  
argue over the degree to which the  
multiverse hypothesis is testable**

**nonscientific**

*Bubble multiverse*

*Multiverse of faith*

*Computational  
multiverse*

*Mathematical  
universe hypothesis*

*Multiverse of  
wishful thinking*

*Ekpyrotic multiverse*



Max Tegmark

Cosmologist, currently prof at MIT

// 4 level multiverse Taxonomy  
Separated via degree  
of abstraction

Cosmetologist

### Level 1: Regions beyond our cosmic horizon

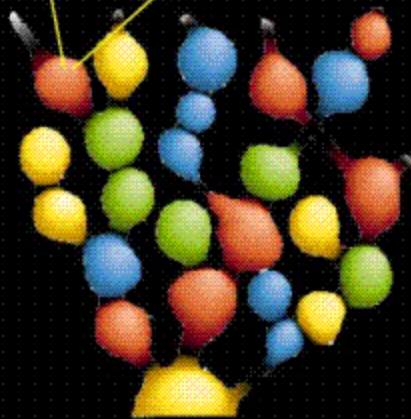
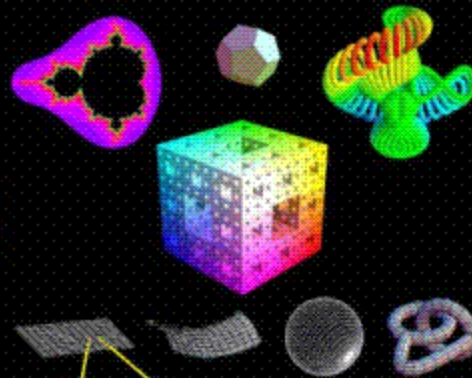
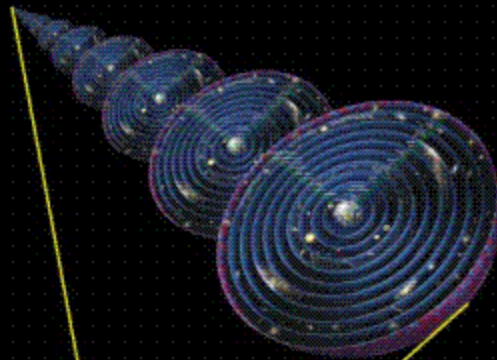
**Features:** Same laws of physics, different initial conditions  
**Assumptions:** Infinite space, ergodic matter distribution  
**Evidence:**

- Microwave background measurements point to flat, infinite space; large-scale smoothness
- Simplest model

### Level 4: Other mathematical structures

**Features:** Different fundamental equations of physics  
**Assumption:** Mathematical existence = physical existence  
**Evidence:**

- Unreasonable effectiveness of math in physics
- Answers Wheeler-Hawking question: "why these equations, not others?"



### Level 2: Other post-inflation bubbles

**Features:** Same fundamental equations of physics, but perhaps different constants, particles and dimensionality  
**Assumption:** Chaotic inflation occurred  
**Evidence:**

- Inflation theory explains flat space, scale-invariant fluctuations, solves horizon problem and monopole problems and can naturally explain such bubbles
- Explains fine-tuned parameters

### Level 3: The Many Worlds of Quantum Physics

**Features:** Same as level 2  
**Assumption:** Physics unitary  
**Evidence:**

- Experimental support for unitary physics
- AdS/CFT correspondence suggests that even quantum gravity is unitary
- Decoherence experimentally verified
- Mathematically simplest model

# The Human Experience

Time  $\sim$  milliseconds to 100 years or 1000's of years

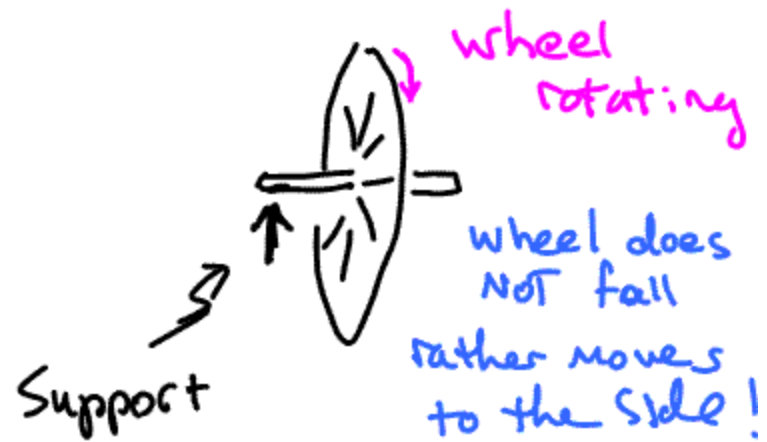
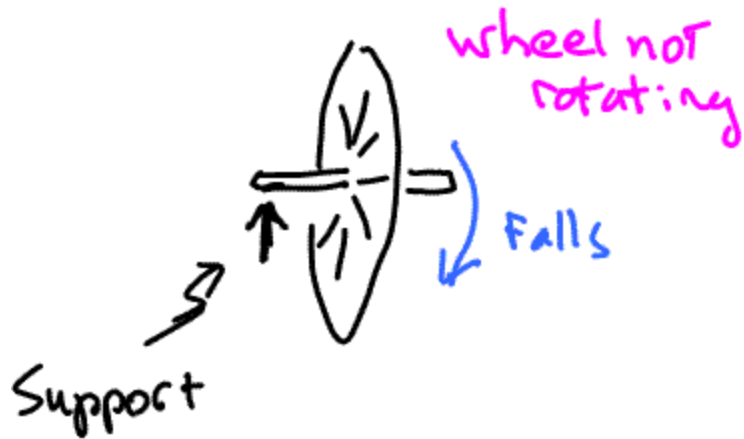
DISTANCE  $\sim$  millimeters to 1000 kilometers

Mass  $\sim$  milligrams to tons

human experience is small fraction of  
scales seen in the universe  
might expect things to be "strange" at new scales

However if you do careful observations... even at "human" scales nature has some surprises

### bicycle wheel demo



Surprise!



See java applet at

<http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html>

## Length:

Distance	Length (m)
Radius of visible universe	$1 \times 10^{26}$
To Andromeda Galaxy	$2 \times 10^{22}$
To nearest star	$4 \times 10^{16}$
Earth to Sun	$1.5 \times 10^{11}$
Radius of Earth	$6.4 \times 10^6$
Sears Tower	$4.5 \times 10^2$
Football field	$1.0 \times 10^2$
Tall person	$2 \times 10^0$
Thickness of paper	$1 \times 10^{-4}$
Wavelength of blue light	$4 \times 10^{-7}$
Diameter of hydrogen atom	$1 \times 10^{-10}$
Diameter of proton	$1 \times 10^{-15}$

# Time:

Interval	Time (s)
Age of universe	$5 \times 10^{17}$
Age of Grand Canyon	$3 \times 10^{14}$
32 years	$1 \times 10^9$
One year	$3.2 \times 10^7$
One hour	$3.6 \times 10^3$
Light travel from Earth to Moon	$1.3 \times 10^0$
One cycle of guitar A string	$2 \times 10^{-3}$
One cycle of FM radio wave	$6 \times 10^{-8}$
Lifetime of neutral pi meson	$1 \times 10^{-16}$
Lifetime of top quark	$4 \times 10^{-25}$

# Mass:

Object	Mass (kg)
Milky Way Galaxy	$4 \times 10^{41}$
Sun	$2 \times 10^{30}$
Earth	$6 \times 10^{24}$
Boeing 747	$4 \times 10^5$
Car	$1 \times 10^3$
Student	$7 \times 10^1$
Dust particle	$1 \times 10^{-9}$
Top quark	$3 \times 10^{-25}$
Proton	$2 \times 10^{-27}$
Electron	$9 \times 10^{-31}$
Neutrino	$1 \times 10^{-38}$

# Kinematic Variables

$x \equiv$  position

$\Delta \equiv$  "change in"

$$v \equiv \frac{\Delta x}{\Delta t} \equiv \frac{\text{change in position}}{\text{change in time}} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

Average Speed

$\Delta t \rightarrow 0$   $\hookrightarrow$  instantaneous speed

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

Add direction

Speed  $\rightarrow$  Velocity

Velocity is speed plus direction

Speed is magnitude of velocity

$$\frac{\Delta v}{\Delta t} \equiv \text{Average Acceleration} \equiv a$$

$$x, v, a, t$$

kinematic variables

If we know  $x, v, a$  for object as a function of time — we know all about the motion of that particle!