
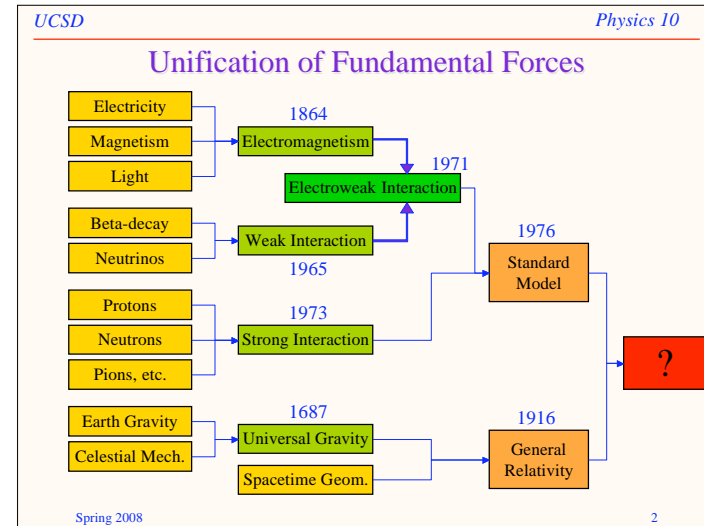


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The Frontiers of Physics
 Where we're going, why, and what's at the end?



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So What's Left to Learn?

- Are quarks, leptons, force carriers *really* fundamental?
- Why are there 3 “generations” of particles?
- What determines the *masses* of these objects?
 - Seem randomly arranged
- Why is the Universe dominated by matter?
 - Rather than photons (energy), for example
 - And why does matter dominate over antimatter?
- How many dimensions are there?
 - Feels like 3; GR says 4, Superstring theory wants 11!
- How does gravity fit into this scheme?!
 - Can it be unified with other fundamental forces?
- What is the nature of the vacuum?
 - Seething energy, repulsive on large scales

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What's the Nature of the Vacuum?

- What's going on when there is nothing there?
- Quantum Mechanics says the vacuum is a turmoil of continuous production and annihilation of particle-antiparticle pairs

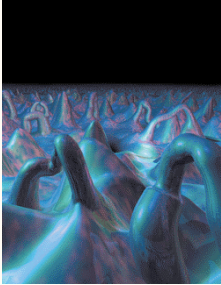
“borrowed” energy ↔ antielectron (positron)
↔ electron ↔ “returned” energy

What impact does this sea of “virtual particles” have on the expansion of the Universe? Is this related to Dark Energy?

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The Seething, Frothy, Energetic Vacuum



Scientific American; Steven Weinberg

This is one artist's view of the vacuum turmoil of particle creation/annihilation at the Planck scale, and the associated loopy, foamy curvature of space resulting from the process.

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So We've Come Full Circle

- Physics on the most microscopic of scales influences the eventual fate of the Universe
- While the last Century has seen remarkable progress in increasing our fundamental understanding of Nature, there remain stark open questions
- Much of our progress has involved insights into the nature of space and time
 - prediction: future progress will re-define these concepts

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The Amazing Twist

- Lots of parameters in physics have to be “fine-tuned” to promote (allow) life
 - gravitational strength
 - enough to form stars/galaxies; not too much or re-collapse
 - amount of dark energy (too much is a huge problem)
 - electromagnetic strength
 - sets how atoms are built and interact
 - initial “seed” density fluctuations
 - too much: get only black holes
 - too little: don't get stars/galaxies
 - strength of strong nuclear force and mix of particles
 - need to be able to form stable atomic nuclei

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So why did physics end up “just right”

- Could it have come out a different way?
 - can there be a different set of laws?
 - can the constants like G , k , h we've seen vary?
- Are there perhaps other instances of universes that are incredibly inhospitable to life?
 - as would naturally happen in inflationary models of the universe
- Are we special, lucky, or here because we're here?

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Possible “Explanations”

- Supernatural Entity set it all up
 - essentially, God
- Physics is unique and *must* work this way to be self-consistent
 - a unique theory of physics: the ultimate unified theory
- It could have been any type of universe, but we wouldn’t be here to muse about it if it *weren’t* conducive to life
 - anthropic (human-centric) reasoning

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So what can physics say?

- About God?
 - Nothing. Not the domain of science
- About a Unique Physics?
 - the goal of many physicists: explain with no wiggle room why things *have* to work out this way
 - but if the only physics possible is one that allows life...
- About anthropic reasoning?
 - more than you’d think
 - as we understand how our universe came to be, we are being driven to the idea that ours may not be the only one
 - imagine gazillions of separate universes
 - now the odds aren’t as tall for making a lively one
 - and of course we’re going to occupy *that* one!

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A looming philosophical battle for physics

- Old-school physics believes in a drive toward unification
 - Einstein spent most of his professional career in this pursuit
 - Success in the 60’s and 70’s fueled this belief
- Anthropic support is growing
 - Partly fueled by new surprises in cosmology (dark energy, etc.)
 - Ironically, string theory—meant to be the final theory of everything (TOE)—has opened this door the widest
 - current trend is that there may be as many as 10^{500} ways to formulate physics in 11 dimensions
 - Assisted by increasing evidence for inflationary epoch in expansion history of the universe
- Either way, at the moment, it’s a *religious* choice
 - until one or the other is supported by experiment, it’s only a hunch

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The end of physics?

- We will *never* know all the answers
- Better said, there will *always* be new questions
 - will we ever truly know *what* mass is? energy? space? time?
 - will we ever know why all of this is here at all?
- It’s conceivable that physics will peter out at the borders of philosophy
 - where physicists (and certainly experiments) lose interest
- But there is always more to be learned in the study of complexity
 - applications, technology, chemistry, biology, etc.

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Show your gratitude...

- If you like the demos, send a quick e-mail to the demo folks (Jeff Patterson and Brad Hanson) to let them know you appreciate the availability and quality of the demos (and how it helped your learning):
 - demo@physics.ucsd.edu

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References and Assignments

- References
 - *The Elegant Universe*, by Brian Greene
 - *The Cosmic Landscape*, by Leonard Susskind
- Assignments
 - Last Q/O due Fri. 6/06, by midnight
 - still opportunity for late submission through time of the final exam
- Announcements
 - Final Exam Fri. June 13, 3:00–6:00, WLH 2005
 - bring light-red half-sheet scantron, #2 pencil, calculator
 - Study guide posted online
 - **Study sessions in Solis 104: Wed. 8–10 PM, Thu. 8–10 PM**

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