Solving the Universe

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Background image courtesy of NASA: http://map.gsfc.nasa.gov/media/080997/index.html
Space!
smallest?
Subatomic particles!

Atoms are so small we can’t see them -- these particles are even smaller than that!
Opposite Extremes of Size

• Objects in the universe cover a very wide range of sizes

• So-called “fundamental particles” can’t be broken down into smaller pieces
  – Examples include electrons, quarks, and photons, but not protons or neutrons
Why Particle Physics?

• Big Bang: very hot, very dense
• Early universe: only fundamental particles existed
• Higher energy = smaller distances
Looking Back In Time

• Light travels at a fixed speed: $3 \times 10^8$ m/s
  – This means the starlight we observe was emitted a long time ago

• Higher energy = looking further back in time
  – We can look all the way back to early stages of the universe – about 380,000 years\(^1\) after the Big Bang!

Effects of Particle Interactions

- Expansion of the universe
- Formation of atoms
- Formation of galaxies and other structures
- Many other effects, including:
  - Dominance of matter over antimatter
  - Unification of forces
  - Creation/decay of exotic, never-before-seen particles
Cosmic Microwave Background

- CMB radiation
  - Doppler shifted from the visible/near infrared range\(^2\)
  - Strong evidence for the Big Bang

- Some properties:
  - Very uniform throughout the universe
  - Small variations

\(^2\) Ryden, B. *Introduction to Cosmology.* Addison Wesley (2003).
CMB Experiments

1965
Penzias and Wilson

1992
COBE

2003
WMAP

Image courtesy of NASA:
http://map.gsfc.nasa.gov/media/081031/index.html
Cosmic Inflation

- Explains why the CMB looks so uniform
- Allows for small variations
- Fixes some of the gaps in the Big Bang theory
- Theories of inflation rely heavily on particle physics

Image courtesy of NASA: http://map.gsfc.nasa.gov/media/060915/index.html
Bringing Inflation into Focus

• So far, experimental evidence allows for a wide range of theories
  – In order to understand how inflation works, we need to narrow this range

• In the end, only experimental measurements can eliminate theories
Just What Is It That I Do?

• Develop and/or modify inflationary models that fit experimental data better
• In order to do this, I:
  – Think of a model that solves the problem in question
  – Perform calculations to obtain estimates of quantities that can be measured by experiments
  – Make predictions of what should happen if the model is true
Questions