

Let there be light: the Big Bang

Lecture 3 - October 15th, 2011

This lecture's subject is the earliest moments of the Universe after Inflation ends, when the Universe was very hot -- far above 10¹⁰ Kelvin. In practice, a very hot Universe is one in which all manner of crazy things can happen, because many reactions and interactions need a lot of energy to take place. In today's Universe, we can only get so much energy inside of particle accelerators like Fermilab or CERN's Large Hadron Collider. During the Big Bang, these collisions happened everywhere!

We can divide the physics of the Big Bang into three kinds:

- 1. Observational facts matched with well understood theory, e.g. nucleosynthesis
- 2. Observational facts with as-yet uncertain theory, e.g. matter / antimatter asymmetry, dark matter creation
- 3. Theoretical ideas awaiting observational tests, e.g. cosmic strings and magnetogenesis

We will discuss each of these in today's lecture.

Some key concepts for today:

- The Universe "banged" into a *very* hot state, and has been cooling down since the Big Bang. An expanding Universe is a cooling-off Universe.
- Nuclear physics is very well understood on Earth, which is why we can do such precise calculations about the nuclear reactions that happened during the first 20 minutes of the Universe's existence.



Paul Dirac, who predicted antimatter before it was observed

- Anti-matter may *sound* exotic, and it isn't something we run into on a day-to-day basis, but by now it is an old and well-understood commodity that we can readily make and do experiments on.
- The early Universe was hot enough that the reactions that took place then were at even higher energies than the particle annihilations at the Large Hadron Collider!
- We hope to find remnants of the early Universe in today's observations to learn about fundamental physics.
- There is still a lot of uncertainty about what exactly happened during the Big Bang.



Agreement between predictions of nucleosynthesis and observations



How cosmic strings can cause gravitational lensing