Nobel Prize in Physics

2006

Discovery of the black-body form and anisotropy of the cosmic microwave background radiation

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17.10.2006
**COSMIC BACKGROUND EXPLORER (COBE)**

- NASA’s satellite launched on 18.11.1989
- First satellite dedicated to cosmology
- Received data 4 years
- Instruments:
  - **DMR (Differential Microwave Radiometers)** to map the cosmic microwave background radiation precisely
  - **FIRAS (Far-Infrared Absolute Spectrophotometer)** to compare the spectrum of the cosmic microwave background radiation with that from a precise black-body
  - **DIRBE (The Diffuse Infrared Experiment)** to search for and measure the cosmic infrared background radiation
**Black-body Radiation**

- **Absorbs all electromagnetic radiation that falls onto it**
- **No radiation passes through it and none is reflected**
- **Not really black: radiates every possible wavelength of energy**

The amount and type of electromagnetic radiation they emit is directly related to their temperature.

Formulated by Max Planck in 1901

\[
I(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{kT}} - 1}
\]
Cosmic Microwave Background (CMB)

- First discovered in 1965 by Penzias and Wilson
- Remnant of Big Bang
- CMB observed now was photons from the time of recombination
- Expansion of the space caused photons to redshift
RESULTS OF COBE

- Picture from the time of recombination ($T = 10^4 K = 0.86$ eV, $T = 300000$ yr after Big Bang)
- Anisotropy can be seen
- Variation of ~30 microK from average of 2.7 K
Four Year Data

COBE - DMR Map of CMB Anisotropy
Four Year Results

North Galactic Hemisphere  South Galactic Hemisphere

$-100 \mu K$  $+100 \mu K$
BLACK-BODY FORM OF CMB SPECTRUM

- **First evidence of spectrum being blackbody form**
- **Theoretical curve and measured data with in perfect match**
- **Corresponds to blackbody radiation in temperature of 2.725 +/- 0.002 K**
WHAT WE GAINED

• GRAVITATIONAL FORCES DUE TO ANISOTROPY ARE LARGE ENOUGH TO PRODUCE THE OBSERVED CLUSTERING

• DATA AGREES WITH THEORIES OF THE EXISTENCE OF DARK MATTER/ENERGY

• BEST EVIDENCE FOR THE HOT BIG BANG MODEL OF THE UNIVERSE SO FAR
Remarks

• **WMAP measured CMB with higher accuracy in 2003**

• **Future measurements:**
  - *Early neutrinos?*
  - *Gravitational waves?*

• **Questions? Comments?**
KEEP WATCHING THE SKIES