Introduction to Cosmology

Sergey Sibiryakov

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14 billion years of the Universe history in 3 hours

- Expansion of the Universe
- Hot Big Bang
- Inflation
Recap from lecture 1

\[ ds^2 = dt^2 - a^2(t)dr^2 \]

\[ H = \frac{\dot{a}}{a} \]

\[ H^2 = \frac{8\pi G}{3} \rho \]

Energy density

For non-relativistic matter: \[ \rho_m \propto \frac{1}{a^3} \]
Measuring cosmology with Supernovae 17

Fig. 4. Upper panel: The Hubble diagram for high redshift SNIa from both the HZSNS[83] and the SCP[77]. Lower panel: The residual of the distances relative to a $\Omega_M=0.3$, $\Omega_\Lambda=0.7$. Many of these objects are in common between the analyses of the two teams.


Discovery of accelerated expansion:

S. Perlmutter, B. Schmidt, A. Riess

2011
14 billion years of the Universe history in 3 hours

- Expansion of the Universe
- Hot Big Bang
- Inflation
CMB: perfect blackbody

A. Penzias, R. Wilson

1978

J. Mather, G. Smooth

2006

FIRAS data with 400σ errorbars

2.725 K Blackbody
Portray of the Universe in youth

Planck Collaboration: The Planck mission

Fig. 14. The SMICA CMB map (with 3% of the sky replaced by a constrained Gaussian realization).

Fig. 15. Spatial distribution of the noise RMS on a color scale of 25 $\mu$K for the SMICA CMB map. It has been estimated from the noise map obtained by running SMICA through the half-ring maps and taking the half-difference. The average noise RMS is 17 $\mu$K. SMICA does not produce CMB values in the blanked pixels. They are replaced by a constrained Gaussian realization.

for bandpowers at $\ell < 50$, using the cleanest 87% of the sky. We supplement this 'low-$\ell$' temperature likelihood with the pixel-based polarization likelihood at large-scales ($\ell < 23$) from the WMAP 9-year data release (Bennett et al. 2012). These need to be corrected for the dust contamination, for which we use the WMAP procedure. However, we have checked that switching to a correction based on the 353 GHz Planck polarization data, the parameters extracted from the likelihood are changed by less than 1.

At smaller scales, $50 < \ell < 2500$, we compute the power spectra of the multi-frequency Planck temperature maps, and their associated covariance matrices, using the 100, 143, and 217 GHz channels, and cross-spectra between these channels.

Given the limited frequency range used in this part of the analysis, the Galaxy is more conservatively masked to avoid contamination by Galactic dust, retaining 58% of the sky at 100 GHz, and 37% at 143 and 217 GHz.

interband calibration uncertainties have been estimated by comparing directly the cross spectra and found to be within $2.4 \times 10^3$ and $3.4 \times 10^3$ respectively for 100 and 217 GHz with respect to 143 GHz.
Portrait of the Universe in youth:
finer details

Planck coll. (2015)