Introduction to Cosmology

Sergey Sibiryakov
14 billion years of the Universe history in 3 hours

- Expansion of the Universe
- Hot Big Bang
- Inflation
Hot Universe in brief

- $p + e \rightarrow n + \nu$
- $e^+ + e^- \rightarrow 2\gamma$
- $p + n \rightarrow D + \gamma$
- $D \rightarrow \ldots \rightarrow ^4\text{He}$
- $p^+ + e^- \rightarrow H + \gamma$
- $He^{2+} + 2e \rightarrow He + n\gamma$

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1s</td>
<td>1 MeV</td>
<td>$n, \nu$ decoupling</td>
</tr>
<tr>
<td>0.5 min</td>
<td>0.5 MeV</td>
<td>$e^+e^-$ annihilation</td>
</tr>
<tr>
<td>4.5 min</td>
<td>70 keV</td>
<td>nucleosynthesis</td>
</tr>
<tr>
<td>0.4 Myr</td>
<td>3 eV</td>
<td>RDMD transition</td>
</tr>
<tr>
<td>14 Gyr</td>
<td>2.7 K</td>
<td>recombination</td>
</tr>
<tr>
<td>today</td>
<td></td>
<td>CMB</td>
</tr>
</tbody>
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Abundances of $^4\text{He}, D, ^7\text{Li}$
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CMB anisotropies

Planck coll. (2015)
CMB anisotropies

\[ \Delta D_{TT}^\ell \quad \Delta D_{TE}^\ell \quad \Delta D_{EE}^\ell \]

\[ D_{TT}^\ell \quad D_{TE}^\ell \quad D_{EE}^\ell \]

\[ \ell \]

Planck coll. (2018)
Where the next breakthrough?

Wanted: BSM physics

- Dark matter
- Baryogenesis
- Inflation, reheating

Conceptual

- Why cosmological constant is so small?
- What was before inflation?
- Why quantum mechanics works for the whole Universe?