CMB-HD: Probing Dark Matter Particle Properties with Ultra-High-Resolution CMB Lensing

Neelima Sehgal
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August 6th, 2019

Ho Nam Nguyen, NS, Mathew Madhavacheril, PRD, 2019, (arXiv:1710.03747)


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Key Question: What do matter fluctuations look like on small-scales?
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- Galaxy-galaxy strong lensing in optical and mm-wavelegths - need to disentangle complex structure of background source from substructure
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First Measurement of CMB Lensing on Halo Scales
Madhavacheril, NS, for the ACT Collaboration
PRL, 114, 2015
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3. Properties of primordial CMB are well understood
4. Sensitive to structure at higher redshifts than other gravitational lensing probes; this makes it more sensitive to FDM/WDM-type models
CMB Lensing Power Spectrum

\[ C_{nl}^{\text{nl, CDM}} \]

\[ L \]

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CMB Lensing Power Spectrum is matter power spectrum convolved with window.
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\[ C_L^{\phi \phi} = \frac{9 \Omega_m^2 H_0^4}{c^4} \int_0^{\chi_s} d\chi \left( \frac{\chi_s - \chi}{\chi^2 \chi_s} \right)^2 \frac{(1 + z)^2 P_m (k, z(\chi))}{k^4} \]
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Measured on scales $L < 3000$ so far ($k < 1 \text{ Mpc}^{-1}$)

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Want to measure scales \( L \sim 30,000 \) (\( k \sim 10 \text{ Mpc}^{-1} \) and \( M < 10^9 \text{ Msun} \))

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Contrast between CDM and models that wash out small-scale structure is larger at higher redshifts

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CMB Lensing Power Spectrum for CDM Versus FDM/WDM

\[
\frac{C_{\text{L}}^{\text{FSR, CDM}} - C_{\text{L}}^{\text{FSR, CDM}}}{C_{\text{L}}} \\
\begin{align*}
10^{-22}\text{eV FDM} \\
1\text{keV WDM}
\end{align*}
\]
CMB Lensing Power Spectrum for CDM Versus FDM/WDM

Fractional difference between FDM/WDM and CDM for the CMB lensing power spectrum

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1.) If see little deviation from pure CDM curve, that constrains both baryons and alternate DM models
2.) If see significant deviation, then can potentially use shape of curve to determine whether it is due to baryons or alternative to CDM
Dark Matter Constraints Not Degenerate with Neutrino Mass
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CMB-S4 Science Book

$\Sigma m_\nu \leq 30 \text{ meV}$

$\Sigma m_\nu \leq 60 \text{ meV}$

$\Sigma m_\nu \leq 90 \text{ meV}$

$\Sigma m_\nu \leq 120 \text{ meV}$

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Dark Matter Forecasts Using Ultra-Small-Scale CMB Lensing

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NS et al., 2019, arXiv:1903.03263

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Need camera 3 times more sensitive and with 5 times better resolution than CMB-S4

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CMB-HD is new proposed experiment

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Instrument Path

Two new 30-meter mm-wave telescopes in Atacama Desert with total sensitivity 3 times deeper than CMB-S4 == CMB-HD
Motivation of CMB-HD

**Rich Science from CMB-HD:**
- Dark Matter Properties from Small-Scale Matter Power Spectrum
- Number of Relativistic Species
- Delensing for Primordial Gravitational Waves
- Neutrino Mass
- Dark Energy
- Galaxy Cluster Astrophysics
- Galaxy Formation
- Reionization
- Planetary Studies
- Mapping Transient Sky
- Synergy with Optical Lensing Surveys
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# CMB-HD Probe of Light Particles

Table 1: Summary of CMB-HD key science goals in fundamental physics

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