A New Window into Stochastic Gravity Waves

Aditya Rotti

Supervisor: Tarun Souradeep

Indo-UK Meet
11th August 2011
The Current Landscape

Cosmic Gravity wave background

No Probe
Lensing

Cluster Lenses Locate Most Distant Sources

- ~300 thousand years since Big Bang (z=1100)
- ~500 million years since Big Bang (z=10)
- ~2.1 billion years since Big Bang (z=3)
- ~11.2 billion years since Big Bang (z=0.18)
- ~13.4 billion years since Big Bang (z=0)

Kneib & Ellis with Caltech Digital Media Center
Lensing

Direction of photon arrival changed

\((\theta_0, \phi_0) \rightarrow (\theta_0 + \delta \theta, \phi_0 + \delta \phi)\)

Let \(\Delta\) denote the displacement on the sphere.

\[
\Delta_a = - \sum_{lm} \left( h_{lm}^+ Y_{lm:a} + h_{lm}^\times Y_{lm:b} \epsilon^b_a \right)
\]

Angular power spectrum of photon displacements

\[
C_l^{h^+} = \frac{1}{2l + 1} \sum_{m=-l}^{m=l} \langle h_{lm}^+ h_{lm}^{+*} \rangle \quad \text{Gradient spectrum}
\]

\[
C_l^{h^\times} = \frac{1}{2l + 1} \sum_{m=-l}^{m=l} \langle h_{lm}^\times h_{lm}^{\times*} \rangle \quad \text{Curl spectrum}
\]
Lensing induces power transfer between the two polarization spectra

\[
\begin{pmatrix}
\tilde{C}^{EE}_l \\
\tilde{C}^{BB}_l
\end{pmatrix} =
\begin{pmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{pmatrix}
\begin{pmatrix}
C^{EE}_l \\
C^{BB}_l
\end{pmatrix}
\]

Lensing Kernel

\[
C^{\tilde{E}}_l = C^E_l - (l^2 + l - 4) R C^E_l + \frac{1}{2(2l + 1)} \sum_{l_1 l_2} \left[ C^{h\times}_{l_1} \left( 2 F^\oplus_{ll_1 l_2} \right)^2 + C^{h\times}_{l_1} \left( 2 F^{\otimes}_{ll_1 l_2} \right)^2 \right] \left[ (C^E_{l_2} + C^B_{l_2}) + (-1)^L (C^E_{l_2} - C^B_{l_2}) \right]
\]

\[
C^{\tilde{B}}_l = C^B_l - (l^2 + l - 4) R C^B_l + \frac{1}{2(2l + 1)} \sum_{l_1 l_2} \left[ C^{h\times}_{l_1} \left( 2 F^\oplus_{ll_1 l_2} \right)^2 + C^{h\times}_{l_1} \left( 2 F^{\otimes}_{ll_1 l_2} \right)^2 \right] \left[ (C^E_{l_2} + C^B_{l_2}) - (-1)^L (C^E_{l_2} - C^B_{l_2}) \right]
\]
Hints !!

- Current lensing considerations are only due to scalar perturbations.
- The scalar power spectrum is already well measured.
- A huge difference between current upper limits on the BB spectra and the expected signal.
Hints!!

QUAD/BICEP

The graph shows the multipole $\ell$ versus $\ell(\ell+1) C_{\ell}/2\pi (\mu K^2)$, with expected lensed BB spectra indicated. The figure also highlights the question mark (?), suggesting an area of interest or a point of uncertainty in the data.
Just a Reminder

Toy model:

\[ C_{\ell}^{h\otimes} = C_{\ell}^{h\oplus} \]

Power Spectrum of the projected lensing potential \( C_{\ell}^{\psi\psi} \)

Scalar Perturbations (LSS)

Tensor Perturbations (Gravity Waves)
A Comparison: GW more efficient!
Can we constrain Gravitational Waves Power Spectra?

Gravitational waves!!
GW Power Spectra \iff Deflection Power Spectra

\[ C^h_{\ell} = \frac{\pi}{l^2(l+1)^2} \frac{(l+2)!}{(l-2)!} \int d^3k P_T(k, z) |T_{eff}|^2 \]

C. Li and A. Cooray, PRD 74, 023521(2006)

\( P(k) = \text{Constant} \)

GW sourced at different \( z \)
Constraining the deflection power spectra

Sensitivity of the lensed BB spectra to the deflection angular power spectra !!

The **best constraints** on the deflection power in the specific bins will come from the measurements of the $C_{\ell}^{BB}$ spectra at the location of the respective peaks.

RMS deflection power is kept constant:

$$\langle \alpha^2 \rangle = \frac{1}{4\pi} \sum_l l(l+1)(2l+1)C_{\ell}^{h\otimes}$$

$R = 1.9 \times 10^{-4}$

Scalar Perturbations
Constraints on the GW power spectra.

Preliminary Results
A New Window into Gravitational Waves!!

\[ k = 0.001 - 1 \text{ Mpc}^{-1} \quad \rightarrow \quad 10^{-16} - 10^{-14} \text{ Hz} \]

Vol 460 | 20 August 2009 | doi:10.1038/nature08278
Summary:

• Tensors are more efficient at transferring power from EE $\rightarrow$ BB spectra.
• From current and future experiments which will measure the CMB polarization spectra, it will be possible to put constraints on the Gravitational Waves spectra.
• This probe provides a new window into Gravitational Waves which has not been previously explored.

Thank you for your attention 😊