Polarised Sunyaev Zeldovich Effect and the Early Universe

Julius C Wons

Cartell of Particle Physics and Cosmology Sydney
CPPC Sydney

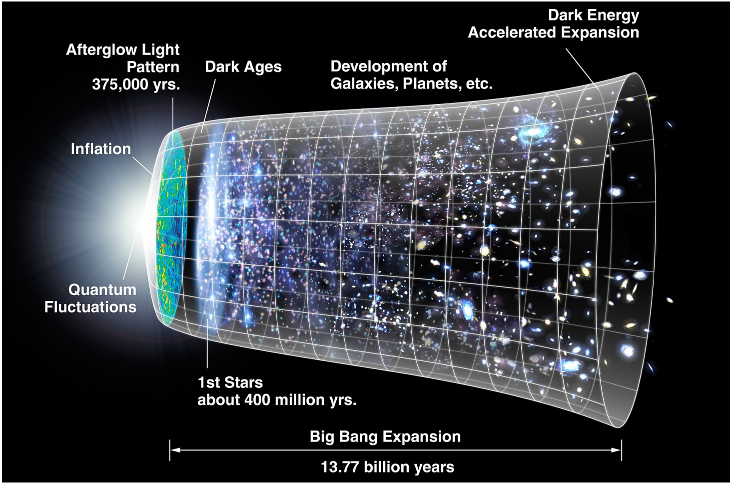
February 20, 2020

Papers

- AS Deutsch, MC Johnson, M Münchmeyer, A Terrana
  "Polarized Sunyaev Zel'dovich tomography"
  ArXiv:1705.08907

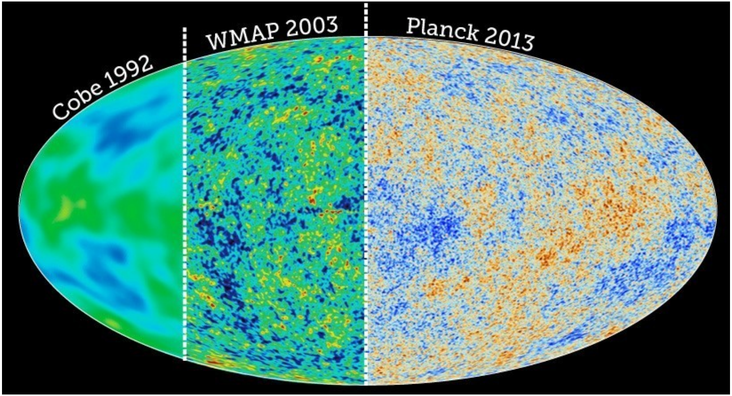
- AS Deutsch, E Dimastrogiovanni, M Fasiello, MC Johnson, M Münchmeyer
  "Primordial gravitational wave phenomenology with polarized Sunyaev Zel'dovich tomography"
  ArXiv:1810.09463

Motivation

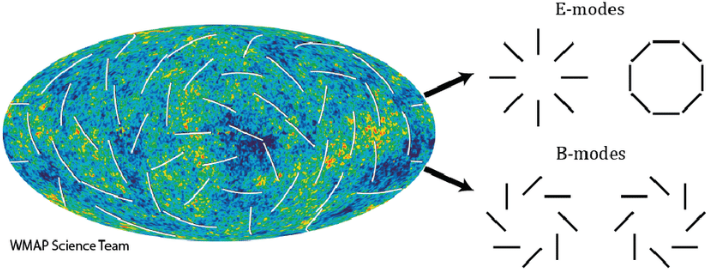


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

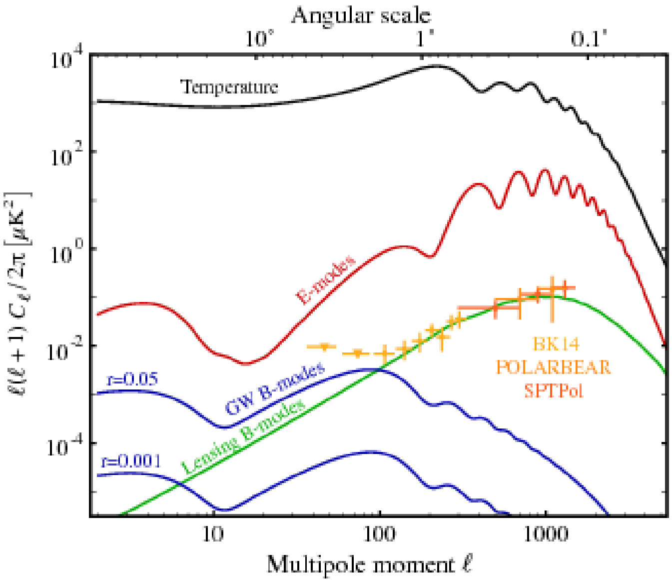
Motivation



Motivation

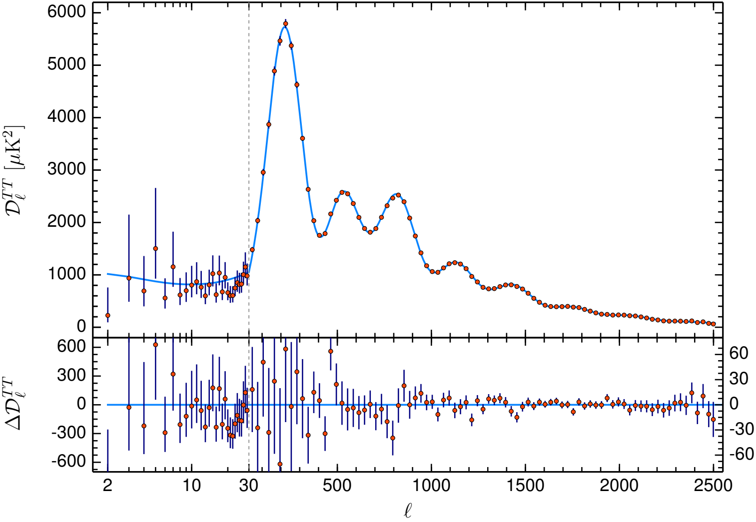


Motivation



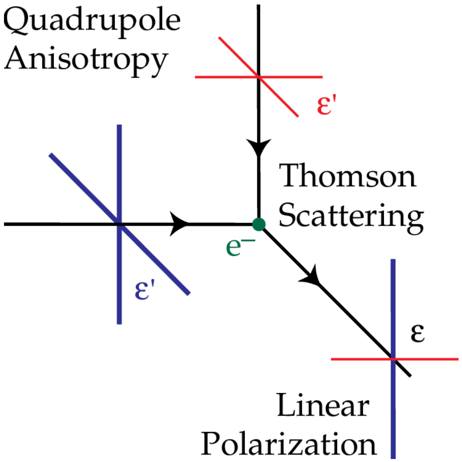
Angular scale
10°
1°
0.1°
10^4
10^2
10^0
10^{-2}
10^{-4}
$\ell(\ell+1)\,C_\ell\,/\,2\pi\,[\mu K^2]$
Temperature
E-modes
r=0.05
GW B-modes
Lensing B-modes
r=0.001
BK14
POLARBEAR
SPTPol
10
100
1000
Multipole moment ℓ

CMB



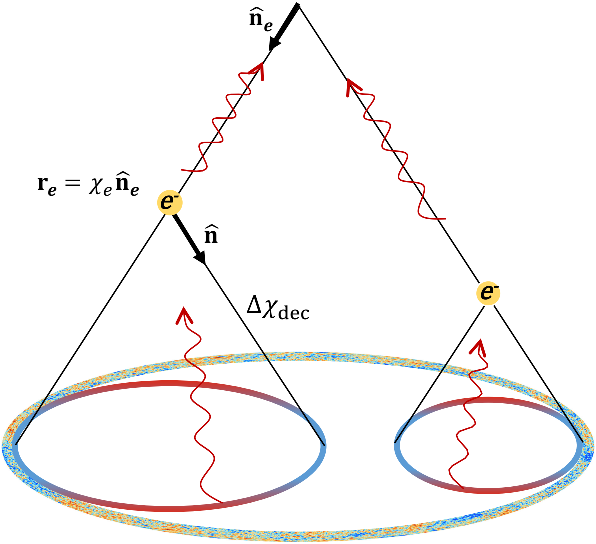
$\mathcal{D}_\ell^{TT}$ [μK^2]
6000
5000
4000
3000
2000
1000
0
$\Delta\mathcal{D}_\ell^{TT}$
600
300
0
-300
-600
60
30
0
-30
-60
2
10
30
500
1000
1500
2000
2500
ℓ

Thomson Scattering



Cross-section Thomson scattering: $\frac{d\sigma}{d\Omega} \propto |\vec{\epsilon} \cdot \vec{\epsilon}'|$

Polarised Sunyaev Zeldovic



pSZ Tomography

Polarisation via pSZ:

$$(Q \pm iU)_{\mathrm{pSZ}} = -\frac{\sqrt{6}}{10}\sigma_T \int d\chi_e a(\chi_e) n_e(\hat{n}_e, \chi_e) \tilde{q}^{\pm}_{\mathrm{eff}}(\hat{n}_e, \chi_e)$$

$$\tilde{q}^{\pm}_{\mathrm{eff}}(\hat{n}_2, \chi_e) = \sum_{m=-2}^{2} q^{m}_{\mathrm{eff}}(\hat{n}_e, \chi_e)\,{}_{\pm 2}Y_{2m}(\hat{n}_e)$$

Correlation between polarisation and matter density:

$$\left\langle (Q \pm iU)_{\mathrm{pSZ}}\, \delta(\bar{\chi}_e) \right\rangle \sim \langle \delta q^{\pm} \delta \rangle \sim q^{\pm}(\hat{n}_e, \bar{\chi}_e) \langle \delta\delta \rangle (\bar{\chi}_e)$$

pSZ Tomography

Polarisation via pSZ:

$$(Q \pm iU)_{\rm pSZ} = -\frac{\sqrt{6}}{10}\sigma_T \int d\chi_e a(\chi_e) n_e(\hat{n}_e, \chi_e) \tilde{q}^{\pm}_{\rm eff}(\hat{n}_e, \chi_e)$$

$$\tilde{q}^{\pm}_{\rm eff}(\hat{n}_2, \chi_e) = \sum_{m=-2}^{2} q^m_{\rm eff}(\hat{n}_e, \chi_e)_{\pm 2} Y_{2m}(\hat{n}_e)$$

Correlation between polarisation and matter density:

$$\Big\langle (Q \pm iU)_{\rm pSZ}\, \delta(\bar{\chi}_e) \Big\rangle \sim \langle \delta q^{\pm} \delta \rangle \sim q^{\pm}(\hat{n}_e, \bar{\chi}_e) \langle \delta \delta \rangle (\bar{\chi}_e)$$

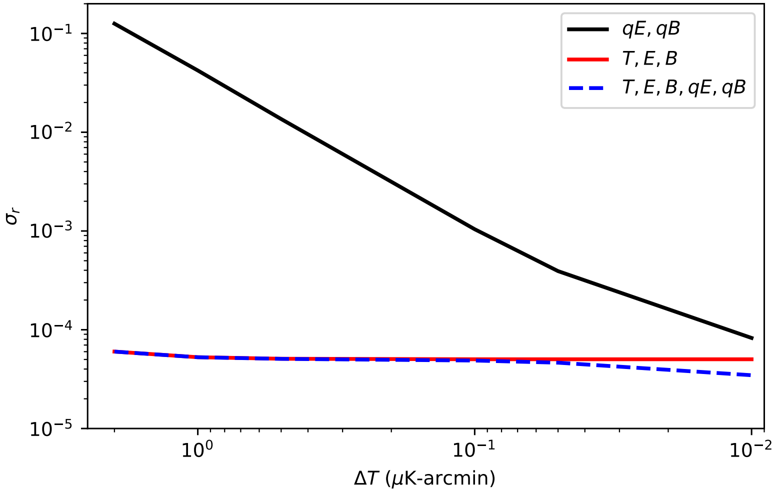
pSZ Tomography - Correlators

Write down correlation between primary CMB and reconstructed remote quadrupol field:

$a_{\ell m}^{T}$	primary CMB temperature
$a_{\ell m}^{E}$	primary E-mode polarisation
$a_{\ell m}^{B}$	primary B-mode polarisation
$a_{\ell m}^{qE}(\chi)$	E-mode remote quadrupol field
$a_{\ell m}^{qB}(\chi)$	B-Mode remote quadrupol field

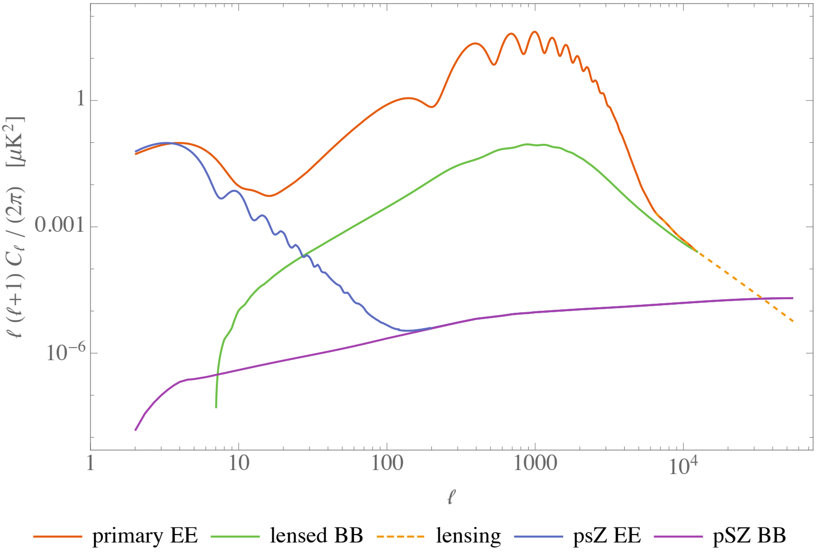
Additional information might help to constrain quantities or serve as second test of discovery.

psZ Tomography - Forecast



Expected resolution of CMB4: $1\mu K/$arcmin

Polarised Sunyaev Zeldovic



Non-Gaussanities

- Standard inflation predicts nearly Gaussian perturbations.
- Gaussian = Whole Physics/Statistics can be described by two-point correlation only
- Existence of non-Gaussanities means non-vanishing higher order correlators.
- Additional source of information about primordial physics.

Non-Gaussanities - Polarisation

$$
\begin{aligned}
B^{TTT}_{\ell_1\ell_2\ell_3} &\equiv \left\langle a^T_{\ell_1 m_1} a^T_{\ell_2 m_2} a^T_{\ell_3 m_3} \right\rangle , \\
B^{TTE}_{\ell_1\ell_2\ell_3} &\equiv \left\langle a^T_{\ell_1 m_1} a^T_{\ell_2 m_2} a^E_{\ell_3 m_3} \right\rangle , \\
B^{TET}_{\ell_1\ell_2\ell_3} &\equiv \left\langle a^T_{\ell_1 m_1} a^E_{\ell_2 m_2} a^T_{\ell_3 m_3} \right\rangle , \\
&\vdots \\
B^{EET}_{\ell_1\ell_2\ell_3} &\equiv \left\langle a^E_{\ell_1 m_1} a^E_{\ell_2 m_2} a^T_{\ell_3 m_3} \right\rangle , \\
&\vdots \\
B^{EEE}_{\ell_1\ell_2\ell_3} &\equiv \left\langle a^E_{\ell_1 m_1} a^E_{\ell_2 m_2} a^E_{\ell_3 m_3} \right\rangle .
\end{aligned}
$$

- Calculation with temperature and E-mode has been done.
- Improvement of by $\sim 25\%$ on non-Gaussanties compared to temperature only.
- Add B-modes and remote quadrupol to the correlators and make a forecast.

Conclusions

- Secondary CMB is an interesting probe of the primordial universe.
- Can help with B-mode detection and non-Gaussanities.
- Independent check of primary CMB B-modes (if detected).
- Experimental requirements extremely high.

The End