Commentary on CMB lensing

Commentator: Alan Heavens, University of Edinburgh
Talk by Ethan Anderes
SCMA V, Penn State
June 2011
CMB Lensing – context

- Deflection by intervening matter distorts the Cosmic Microwave Background
- Lensing causes measurable effects in e.g. the power spectrum of T and E & B polarisation
- CMB is the single most important observable for telling us about cosmology
B-mode polarisation

- ‘Smoking gun’ for inflation, and gives information on energy scale of inflation
- Lensing distorts E-modes (from Thomson scattering) into B-modes on small scales
- Need to understand and correct for/model

Lewis & Challinor

Hu and Okamoto

Hu & Okamoto (2001)
Robust physics, statistics

- Lensing physics is well-understood.

\[ \phi(x) = \frac{2}{c} \int_0^{z_{CMB}} \frac{dz}{H(z)} \left[ \frac{r(z_{CMB}) - r(z)}{r(z_{CMB}) r(z)} \right] \Phi(r(z)) \]

- Almost all of the effect comes from linear perturbations, which are (very close to) a random gaussian field.

- The unlensed CMB physics is well-understood, and it is (very close to) a random gaussian field, and is at a known \( z \).

- Complications: foregrounds, non-stationary and correlated noise, asymmetric beams, holes in map...
Treatments

- Statistical (e.g. compute the effect on T power spectrum; trispectrum). Typically translating from theory to observational space

- Reconstruction. Anderes' approach. Measure and undo the lensing

- Quadratic estimators exist (estimate harmonic coefficients of lensing field - hence global)
Effects

- The typical shift is rather small – 3 arcminutes (potential $\sim 10^{-5}$; $\sim 50$ deflections)
- On small scales there is very little intrinsic power in the primary CMB
- The correlation length of the shifts is rather large – 10 degrees
Effects

- Quadratic estimator and others are global
- Determine the field locally to avoid some complications (Anderes’ approach)
- For gaussian CMB and gaussian lensing potential, we can write down exactly what the probability of a given observed map is
- Susceptible to Bayesian inference approaches
Issues

- Reconstruction of simulated fields is quite impressive, but not perfect
- Statistical properties of the reconstruction
- Any artefacts from stitching together local maps?
- Sensitivity to systematics? e.g. striping
- Nonlinear terms in expansion in lensing potential?

\[ \Theta(x + \nabla \psi) = \Theta(x + \nabla \Theta \cdot \nabla \psi + \nabla_a \psi \nabla_b \psi \nabla_{ab} \Theta/2 + \ldots) \]