Testing General Relativity with 21 cm Intensity Mapping

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Modified Gravity

- Modified gravity may explain the accelerated expansion of the universe.
- All theories are therefore tightly constrained to reproduce an expansion history not too far from ΛCDM. Have to look *beyond* background cosmology in order to distinguish models.

On sufficiently small (quasi-static) scales, we have

$$-k^2\Psi = 4\pi G a^2 \mu(a,k)\rho\Delta, \tag{1}$$

$$\Phi = \gamma(a,k)\Psi, \tag{2}$$

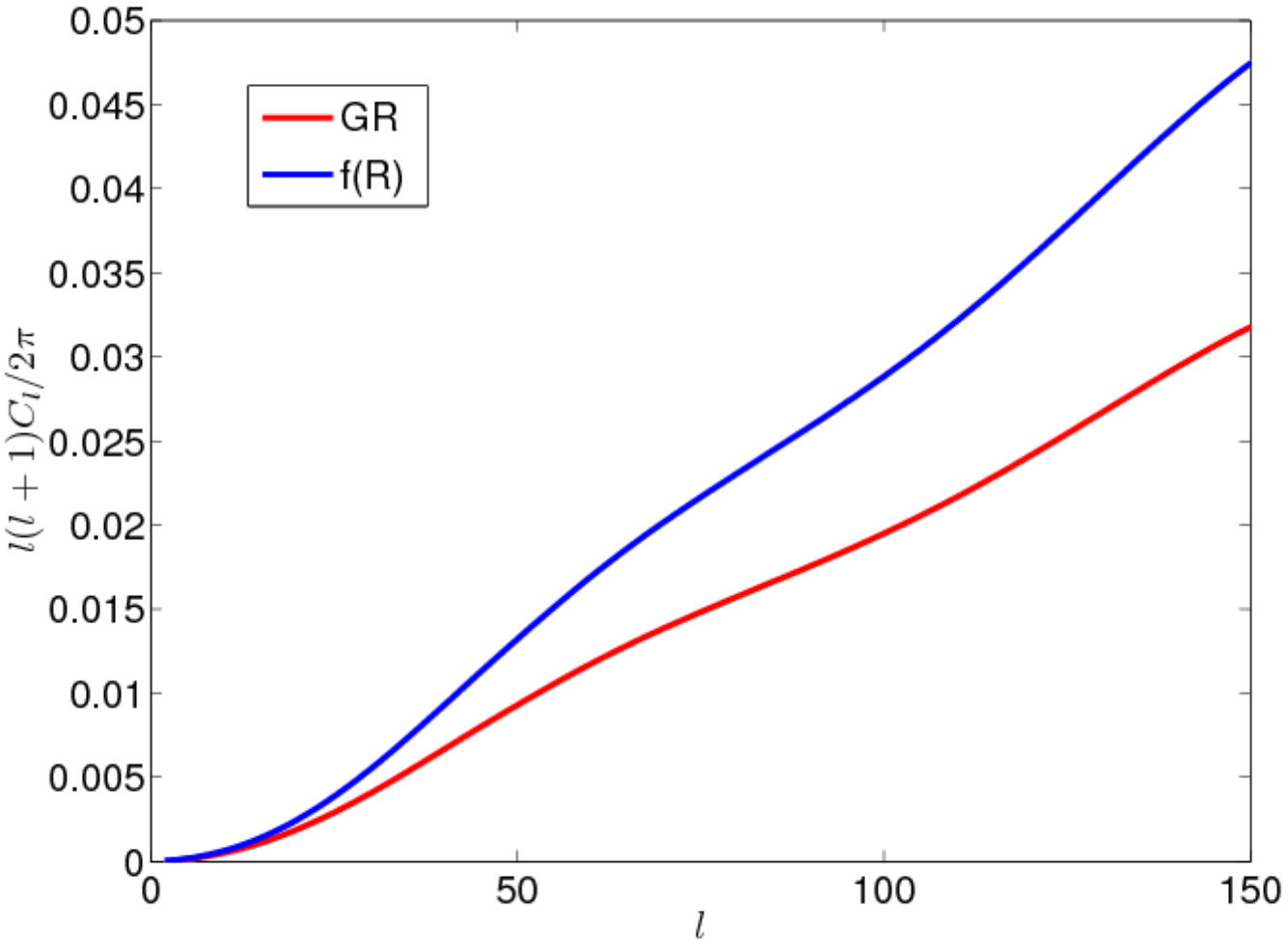
Define a third function $\Sigma = \frac{1}{2}\mu(1+\gamma)$ such that

$$\nabla^2(\Psi+\Phi) = 8\pi G a^2 \Sigma(a,k)\rho\Delta \tag{3}$$

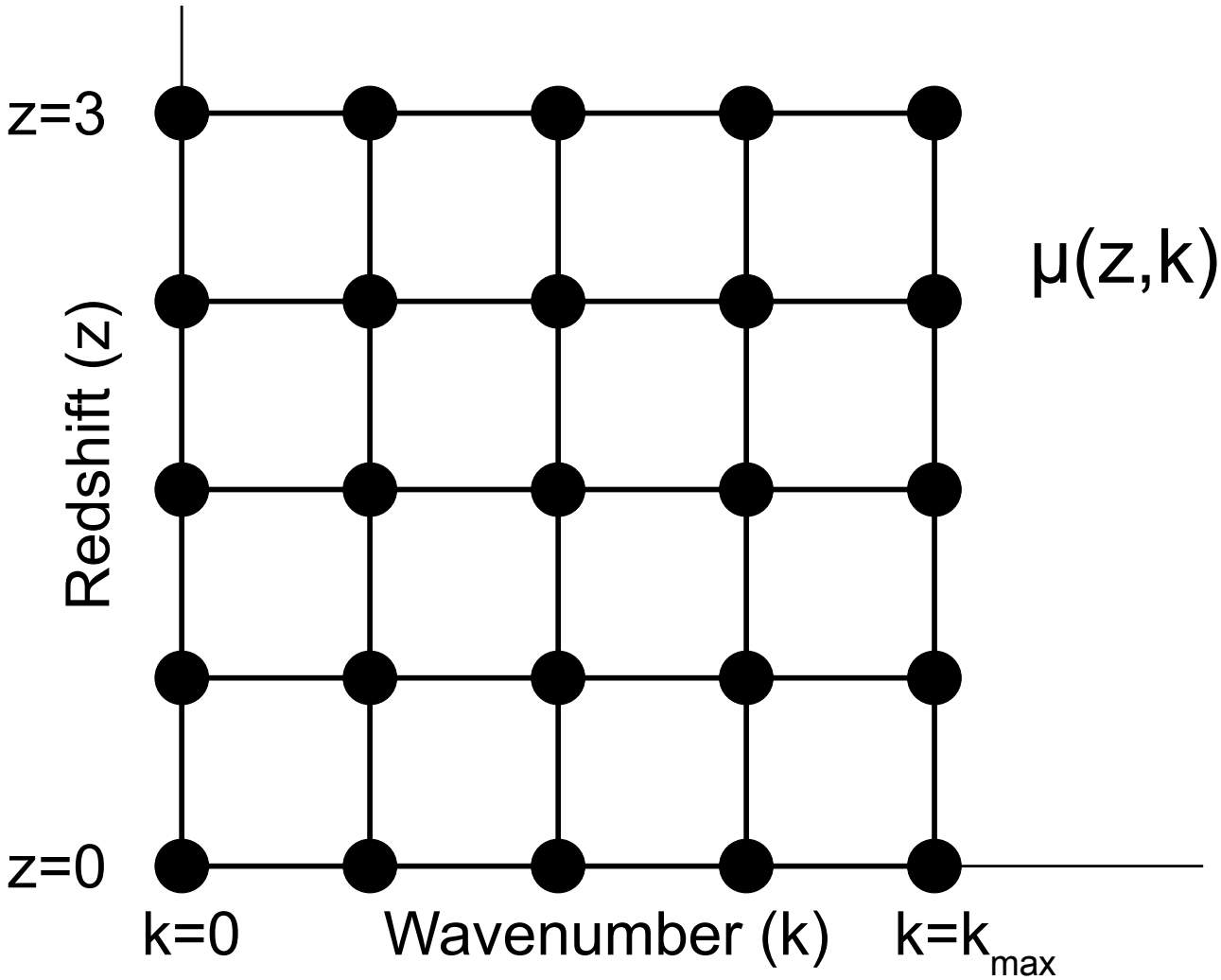
Observational Probes

- We need to measure the detailed 3D clustering of matter on linear scales to constrain μ and Σ.
- Galaxy surveys? Big, costly. Requirement of spectroscopic redshifts inevitably reduces the number of sources than can be observed.
- Weak lensing? Several large projects planned (LSST, Euclid), some years away. Difficult systematics to overcome (intrinsic shear correlations, point-spread irregularities, luminosity distribution uncertainties).
- CMB? ISW and weak lensing signal sensitive to $\Phi + \Psi$, but not so sensitive to individual potentials at late times.
- 21 cm intensity mapping

Brightness temperature angular power spectrum at $z = 0$

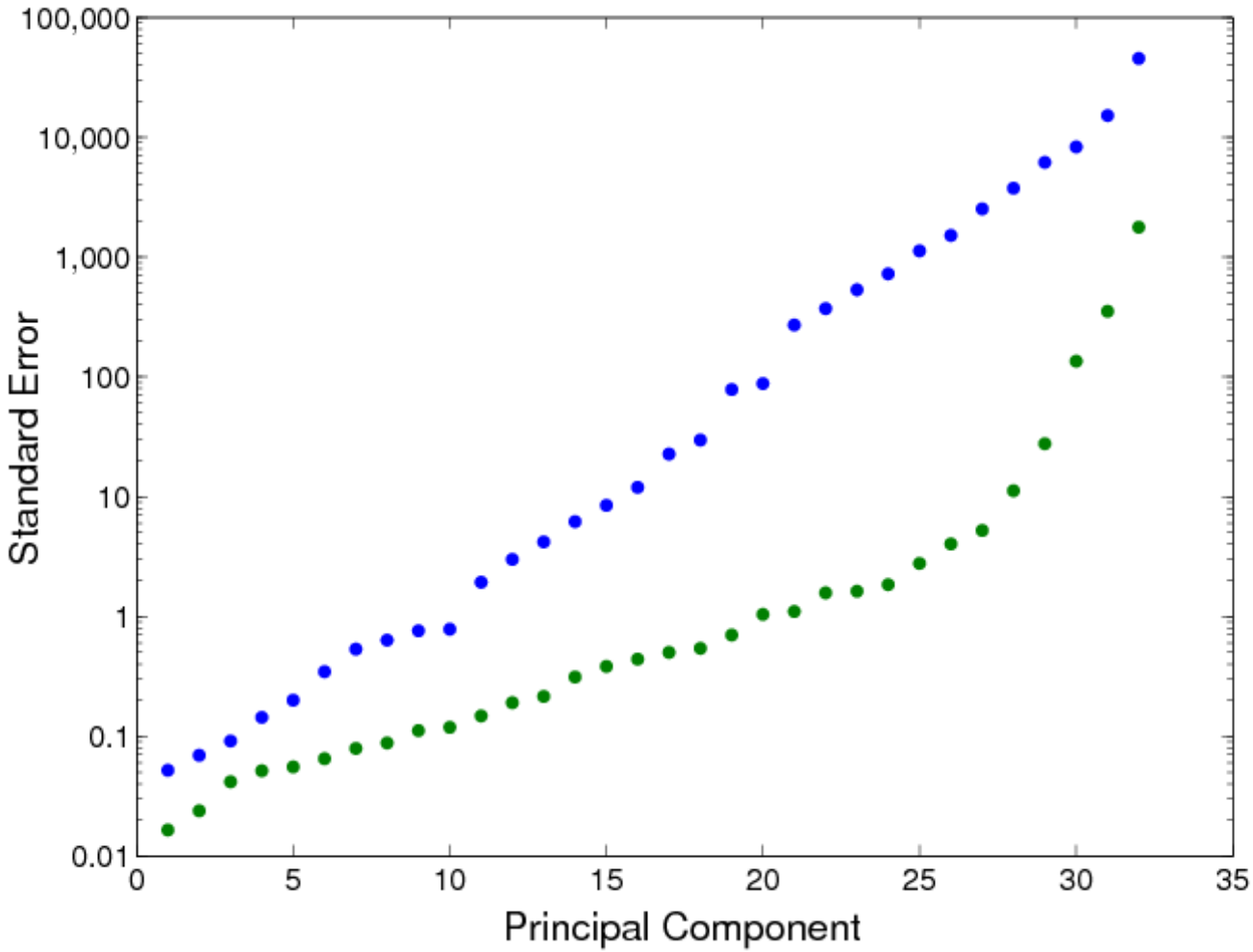


PCA



Preliminary Results: 21cm + Planck

AH, Bonvin & Challinor (in prep.)



Conclusions

- 21 cm Intensity Mapping offers a cheap and short-term method for learning about late-time structure formation.
- Can potentially learn a lot about the 3D clustering of matter, and hence learn something about gravity.
- Considerable technical challenges to be overcome, but not insurmountable.
- Preliminary results indicate that a typical experiment can constrain ~ 25 modes of the free functions introduced by modified gravity.
- Extraction of small scale information limited by the *non-linear* scale rather than the beam size at high frequencies. This is *larger* in modified gravity than in GR (Jennings et al. 2012), and presents a big obstacle in constraining scalar-tensor theories.