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# Lensing Application II: Cross– correlate with other tracers of large—scale structure

- Lensing generated by large—scale structure over a wide range of redshifts between here and last—scattering with peak contribution near z ~
  Therefore correlates with many other tracers of this large—scale structure.
- Far—infrared background (and its fluctuations) also arises over a wide range of redshifts.
  Fluctuations can be related to those of the dark matter via a halo model.





## Lensing Application III: Study evolution of growth factor from z=1100 to z=0.5 to 3

- Primary CMB measurements will provide high—precision measurement of fluctuation amplitude at z=1100.
- Lensing power spectrum can provide high—precision measurement of fluctuation amplitude averaged over z=0.5 to 3.
- Combine to study evolution, constrain dark energy





#### Secondary CMB





Lloyd Knox, UCD (KITP New Cosmology Conference 8/20/02)

Measuring  $v_{pec}$  with the SZ effectsSpectral distortion characterized by Compton y parameter $y = \frac{k\sigma_T}{m_ec^2} \int dlT_e(l)n_e(l) \Box \tau \frac{kT_e}{m_ec^2}$  $\frac{\Delta I_v}{I_v} = yf(x)$ ;  $x = \frac{hv}{kT_{CMB}}$ As  $x \to 0, f(x) \to -2$ Kinetic $\frac{\Delta I_v}{I_v} = -\frac{v}{c}\tau x \frac{e^x}{e^x - 1} \to (\frac{\delta T}{T})_{sz} = -\frac{v}{c}\tau$ Combine to get velocity: $v/c = -\frac{kT_e}{m_ec^2} \frac{(\delta T/T)_{sz}}{y}$ Sunyaev & Zeldovich 1980

# Applications of Peculiar Velocities

- I) Gravitational Potential Reconstruction (i.e., POTENT on 60 Mpc to Gpc scales)
- II) Two—point correlation as function of redshift (to constrain cosmological parameters)
- III) Velocity—ISW correlation (dependent on dark energy parameters)

Dore, Knox and Peel astro-ph July 2002

### Peculiar Velocity Application I: $\Phi(r,\hat{\theta})$ Reconstruction

• For shallow survey (0.2 < z < 0.4) there are 360 clusters with  $M > 10^{14} h^{-1} M_{\text{p}}$  per 100 sq. degrees.

• Assume can achieve 100 km/s error on every cluster with in solid angle  $\theta^2$ .

• Can reconstruct every mode in the survey with wavelength greater than  $\sim 60$ Mpc with S/N > 1. Note: If can achieve 100 uK rt-sec on kinematic SZ then need ~3 months to do every cluster in SDSS photometric survey (0.2 < z < 0.4).

Iolder (2002), Nagai et al. (2002)

### Some uses of the potential map

- Cross—correlate density map with galaxies, groups, galaxy clusters, quasars, ... to learn about galaxy formation, etc.
- Make constrained realizations to compare simulations to reality on object—by—object basis
- Cross—correlate with CMB temperature maps on large—angular scales (ISW effect) a la Boughn, Crittenden and Turok.













# Conclusion

The CMB will continue to play a key role in the confrontation between cosmological theory and observation through the next decade.