Rees-Sciama Effect of Super Structures

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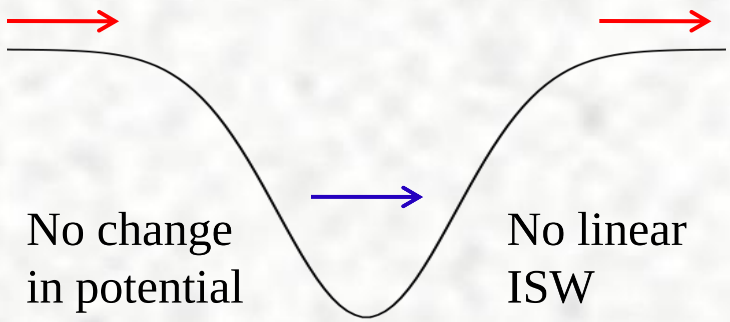
Integrated Sachs—Wolfe Effect

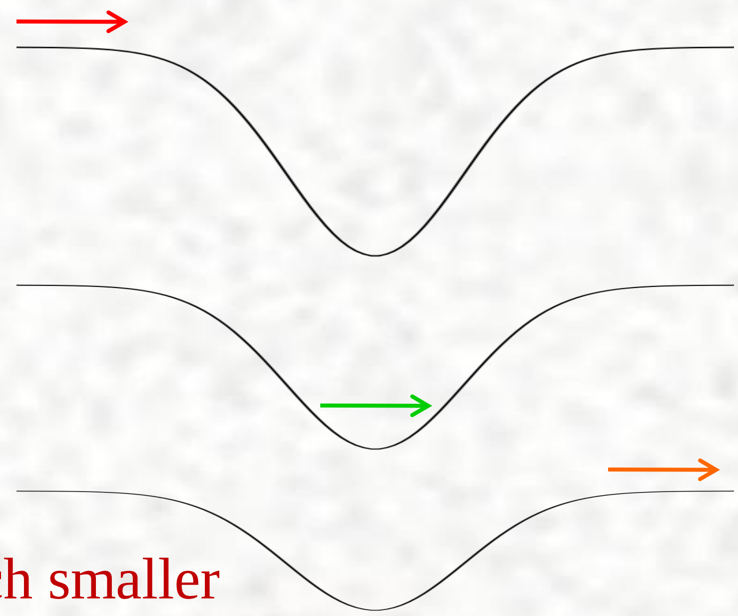


$$\Delta T_{\mathrm{ISW}} \approx \int d\tau \frac{d\phi}{d\tau}$$

$$\frac{d\phi}{d\tau} \approx a\phi(\mathbf{x}) \frac{d}{d\tau} \frac{D(a)}{a}$$

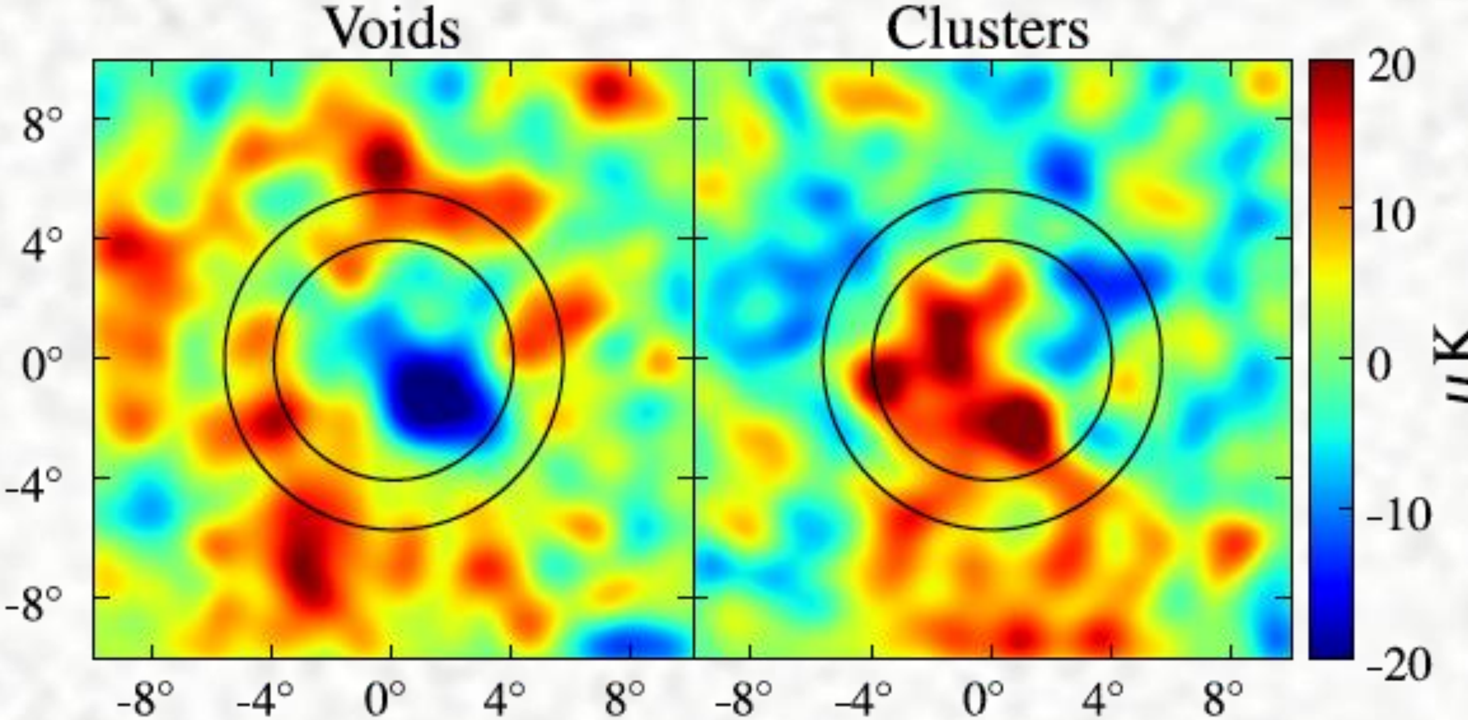
There is no linear ISW effect in an EdS universe, because $D(a)=a$. Need to break $D=a$

- with extra component(s) e.g., dark energy, or
- go nonlinear (Rees—Sciama effect).



The RS effect is expected to be much smaller than the linear ISW effect in ΛCDM.

ISW Effect of Super Structures



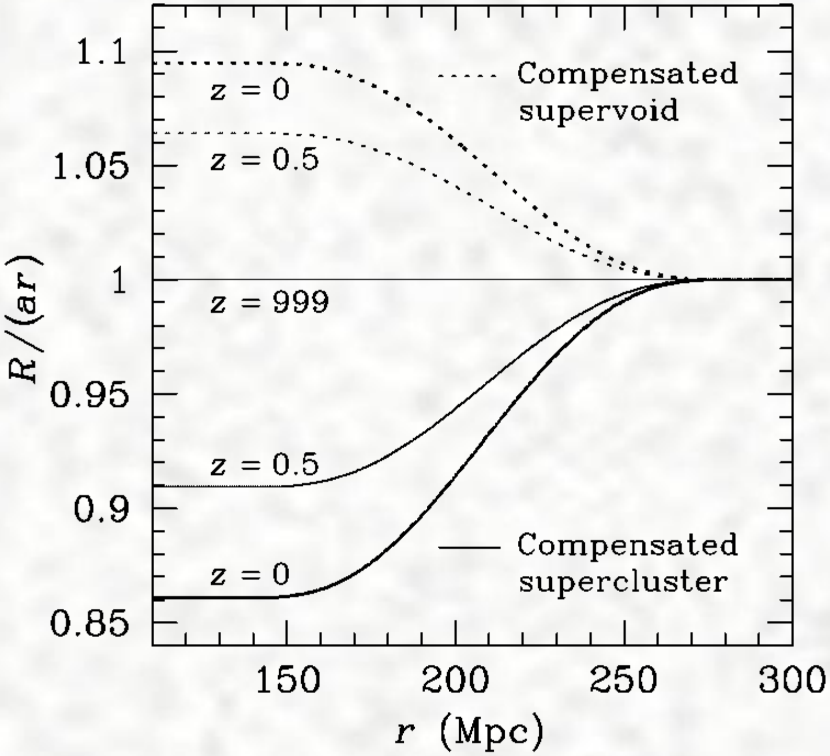
Granett, Neyrinck, & Szapudi (2008): stacked CMB temperature maps behind super structures in the SDSS LRG sample at z~0.5. Inner radius ~100 Mpc/h; temperature difference ~10μK at 4-σ.

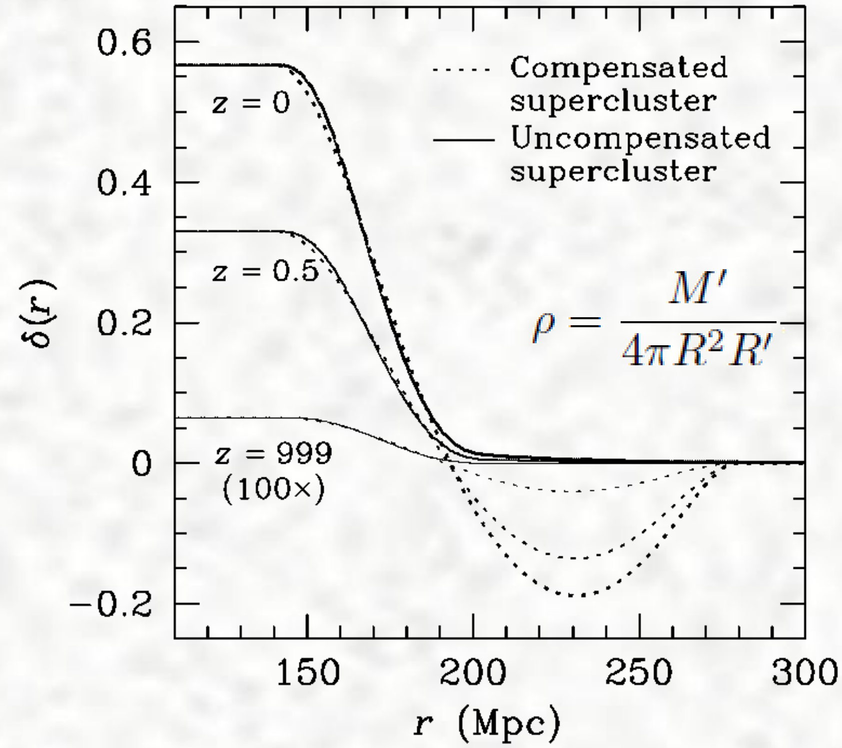
Studying the RS Effect with the LTB Model

$$ds^2 = -dt^2 + \frac{R'^2(t,r)dr^2}{1 - K(r)r^2} + R^2(t,r)d\Omega^2$$

$$\dot{R}^2(t,r) = \frac{2GM(r)}{R(t,r)} - K(r)r^2$$

$$\ddot{R} = -\frac{GM}{R^2}$$





$$\rho = \frac{M'}{4\pi R^2 R'}$$

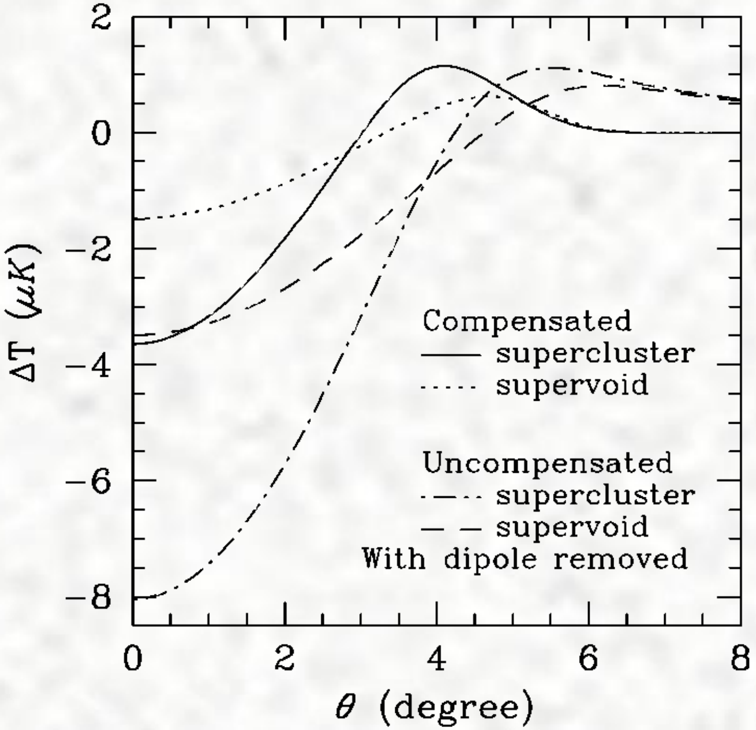
Initial condition:

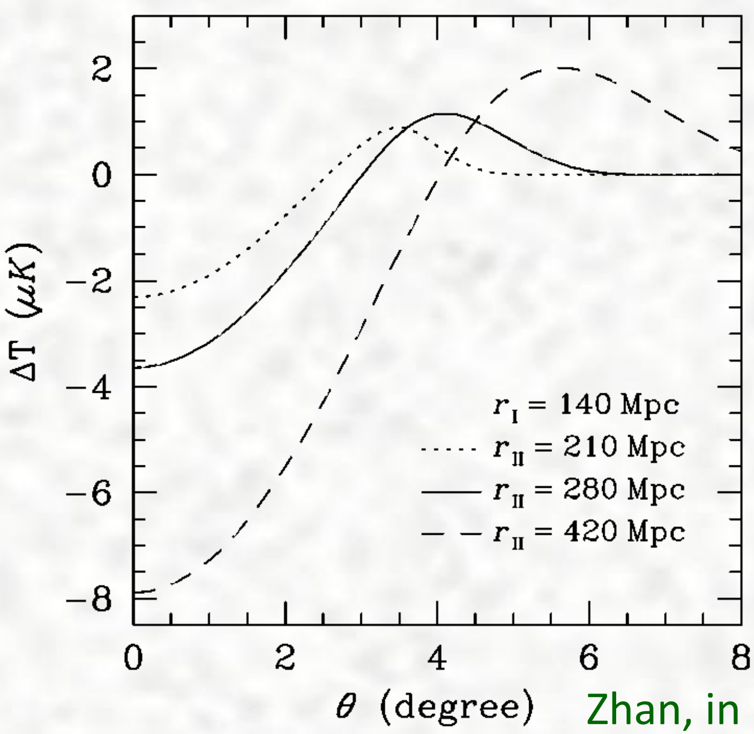
$$R(t_i, r) = a_i r \quad \text{and} \quad \dot{R}(t_i, r) = a_i H_i r$$

Ray tracing:

$$\frac{d^2 x^\mu}{dv^2} + \Gamma^\mu_{\alpha\beta} \frac{dx^\alpha}{dv} \frac{dx^\beta}{dv} = 0$$

RS Effect of Super Structures





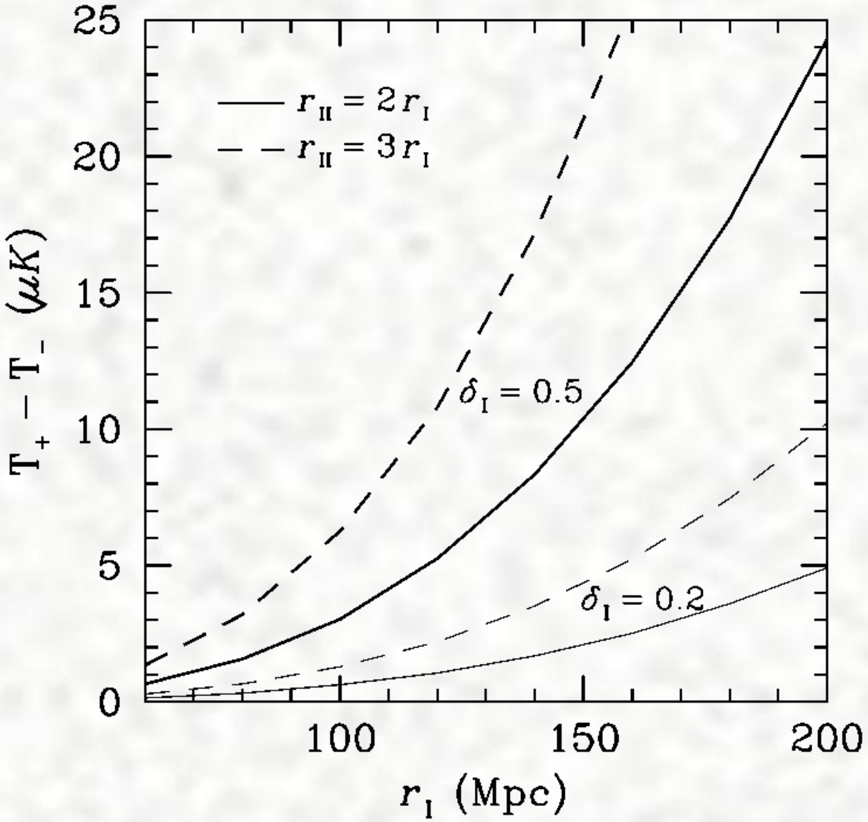
Zhan, in prep

Rees—Sciama effect of superclusters (central overdensity δ=0.36 at z=0.5) and supervoids (δ=-0.19) with inner radii of 100Mpc/h.

For the uncompensated super structures, the dominant feature is a dipole due to the observer's infall /outflow, which is subtracted.

Unlike the ISW effect, the RS effect is always a temp. decrement in the center and a slight increase in the surrounding. The amplitude is not small.

RS Effect of Super Structures

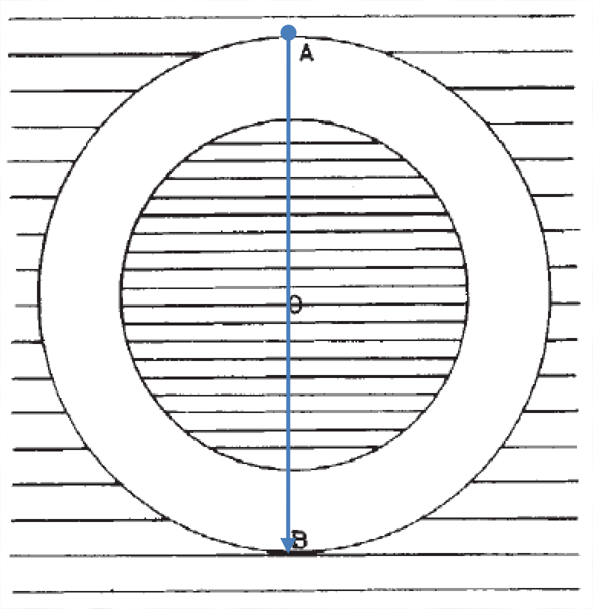


The peak-to-trough temperature difference. The dependence on the central overdensity of the structure is quite nonlinear, even though the overdensity is not very large. The temperature difference is also a fast-rising function of the size of the super structure.

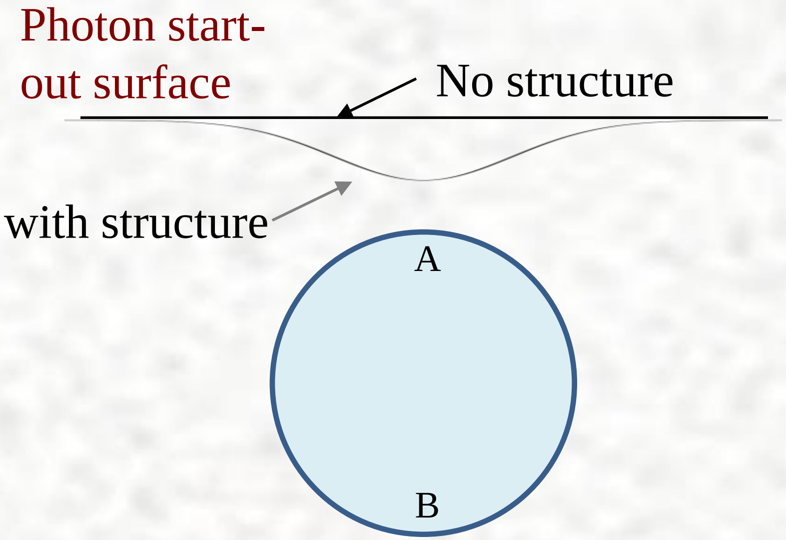
Two Views of the RS Effect

Rees & Sciama (1968)

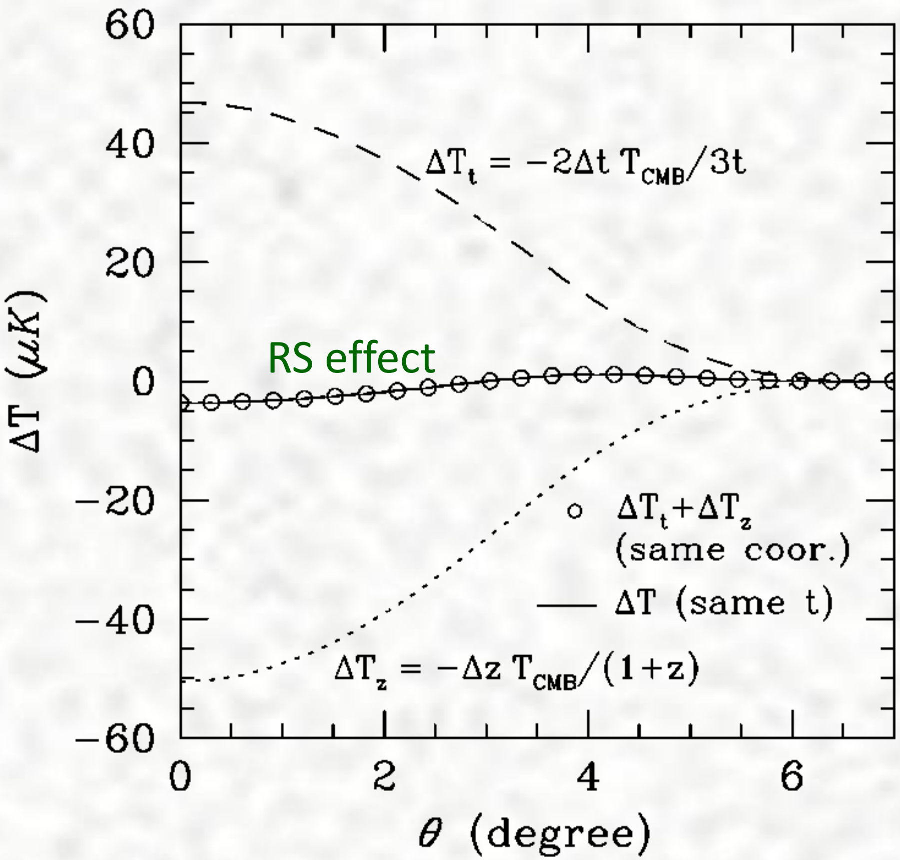
Photons from the same coordinate A to B with or without structure. Two effects: 1) redshift of photon due to deeper potential, and 2) time delay means earlier & hotter CMB.



CMB photons started out at the same time (e.g., instantaneous recombination) and are observed at the same time. However, the observed photons would start out from different locations with or without the structures. There is only a redshift effect in this case.

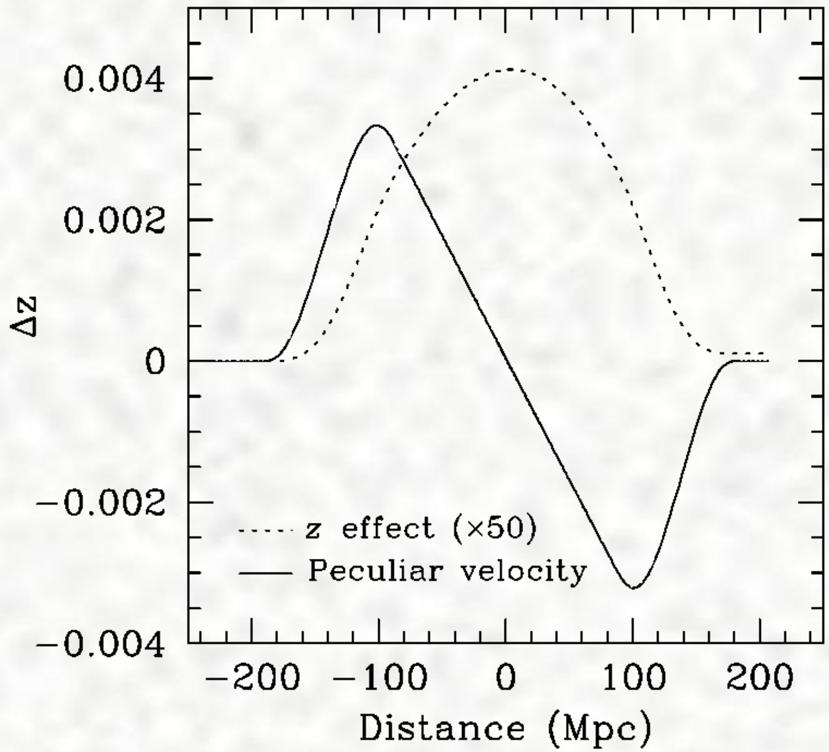


Two Views of the RS Effect



The two view of the Rees—Sciama Effect are equivalent. Note however that the redshift effect and the time-delay effect of photons started out from the same location are ten times larger than the net effect. This suggests a potentially significant effect on galaxy redshifts.

Effect of Structure Evolution on Galaxy Redshifts



Dotted line: increase in galaxy redshifts due to the evolution of the supercluster (multiplied by 50).

Solid line: peculiar velocity effect along the line-of-sight.

Evolution of structure has a small effect on galaxy redshifts but can be significant compared to peculiar velocities.

Summary

- The Rees—Sciama effect can be significant compared to the linear ISW effect caused by dark energy.
- Evolving structures have an effect on galaxy redshifts that can be significant compared to galaxy peculiar velocities.