Cosmic Magnification and the ISW effect - New Rules for High-Redshift Observations

Marilena LoVerde, Lam Hui, Enrique Gaztanaga

Columbia University, Institut de Ciències de l'Espai

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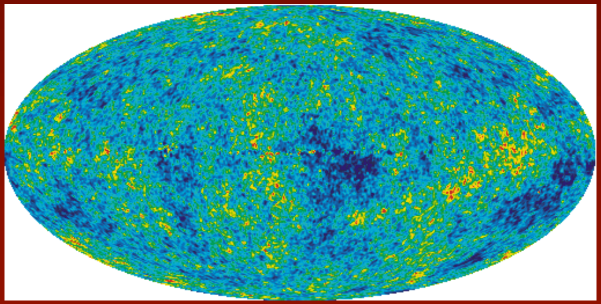
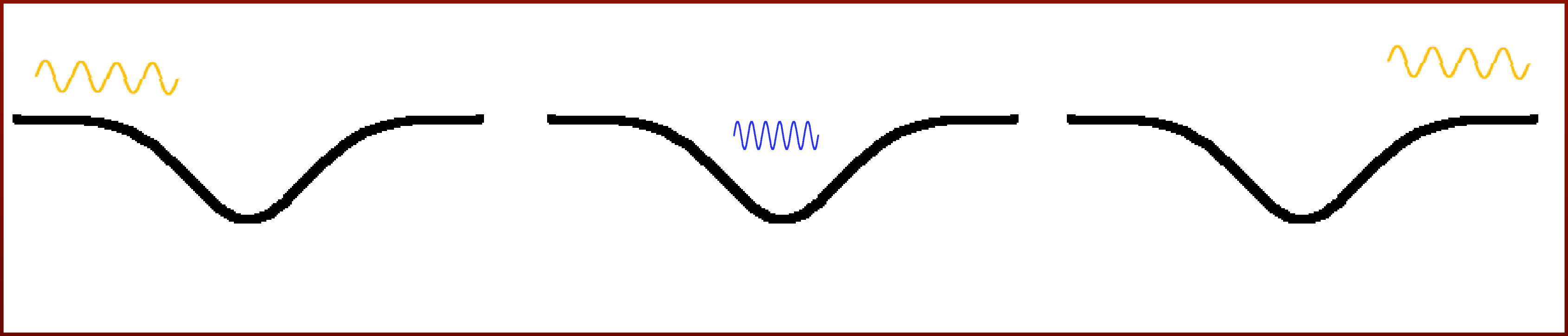
Integrated Sachs-Wolfe effect





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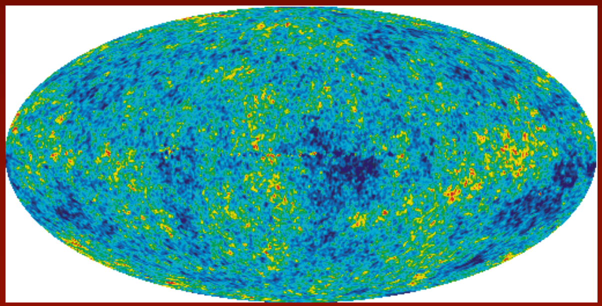
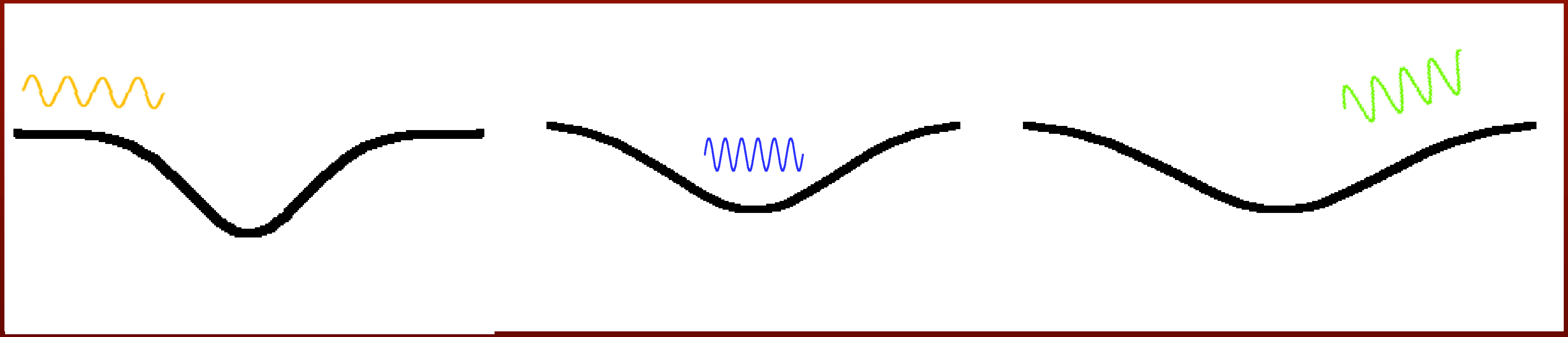
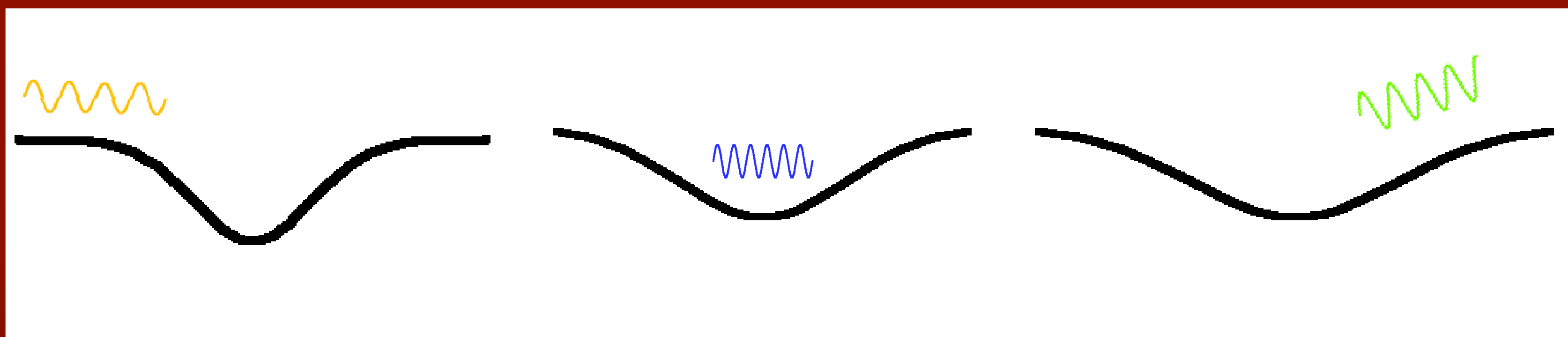




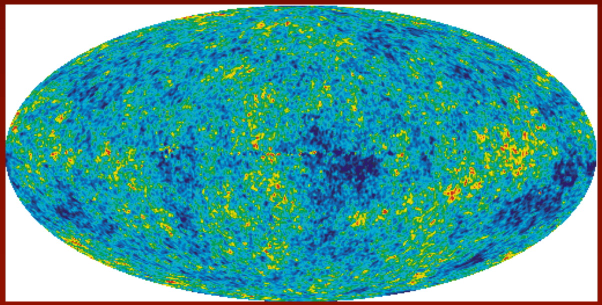
Integrated Sachs-Wolfe effect

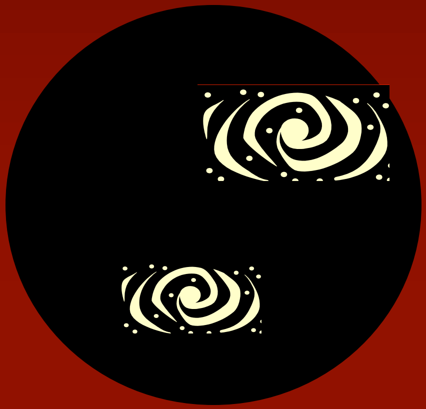
If, $\Omega_m \neq 1$ gravitational potentials decay



This leads to a secondary anisotropy in the microwave background, which is a signature of dark energy domination

ISW from cross-correlation

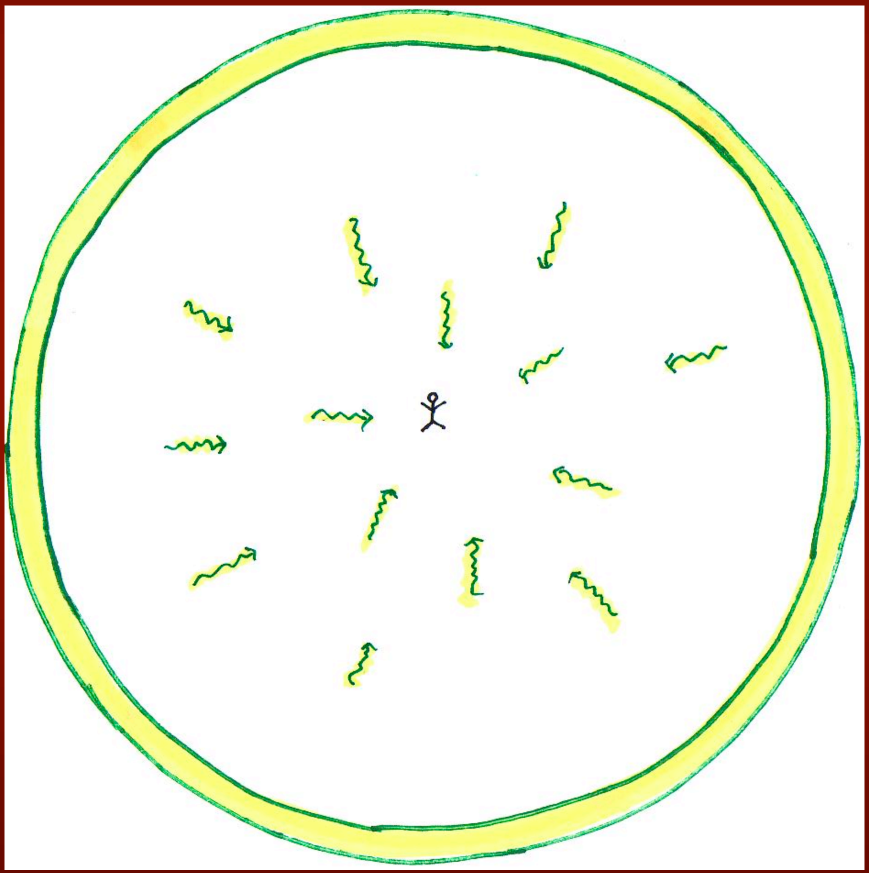




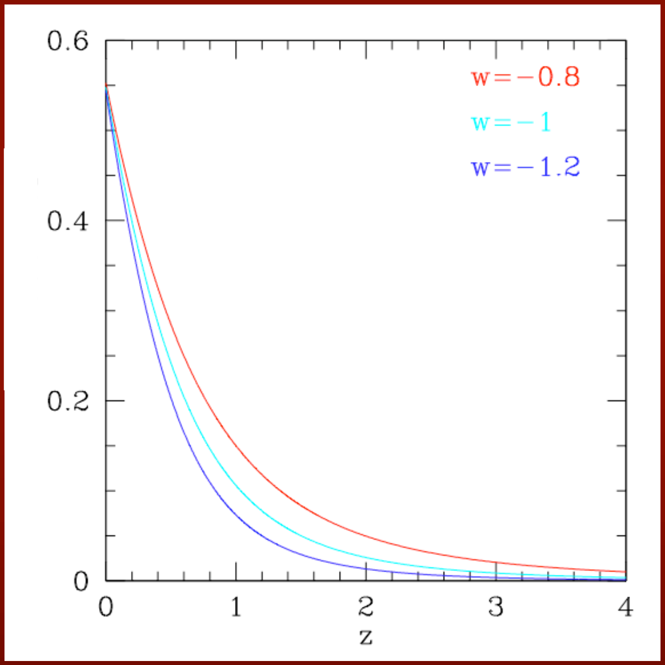
Only photons passing through grav. potentials during dark energy era experience ISW

→ correlation between LSS and CMB

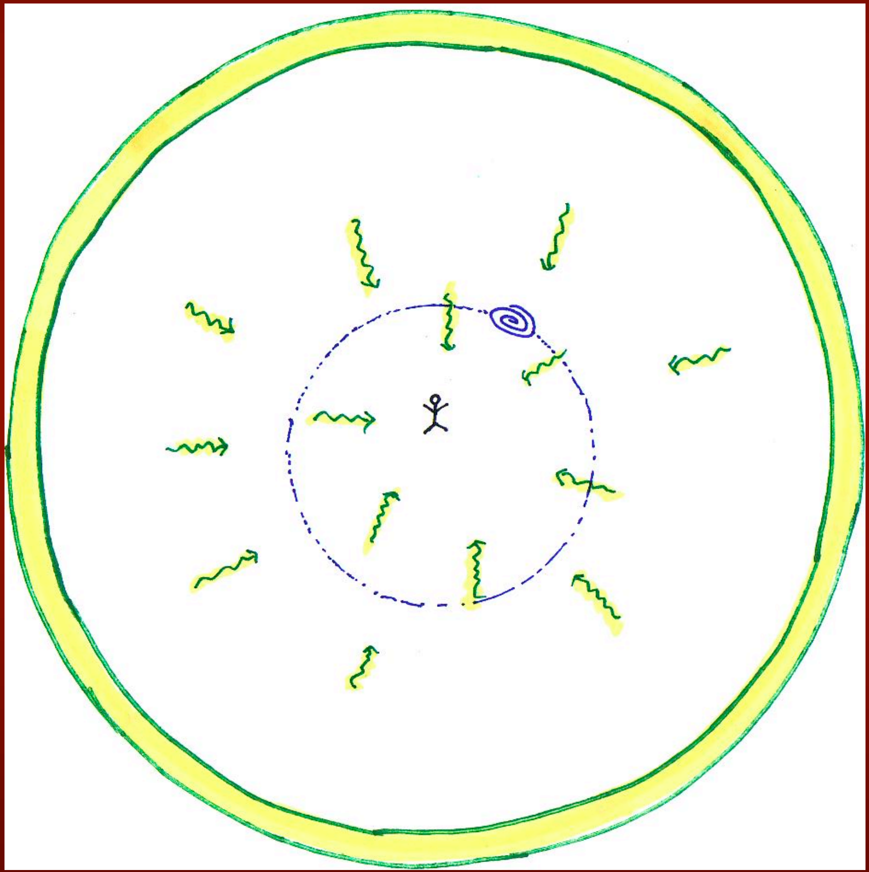
ISW from cross-correlation



Growth rate: d/dz[D(z)(1+z)]



ISW from cross-correlation



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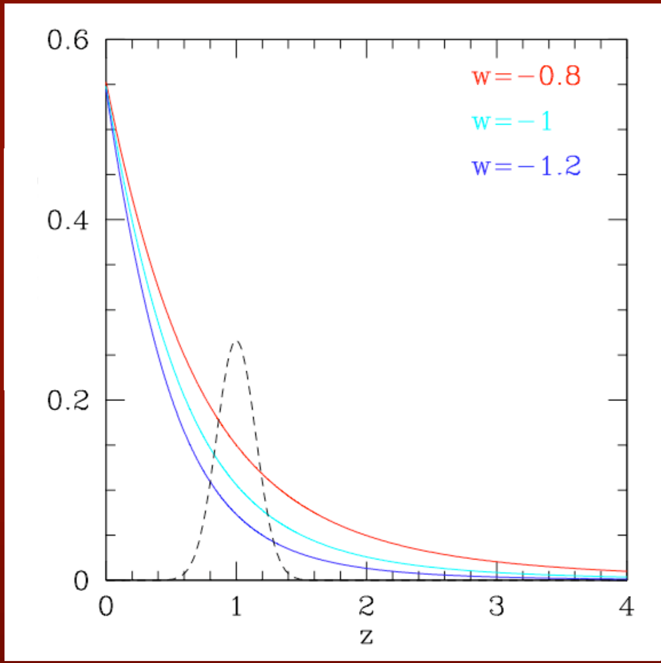
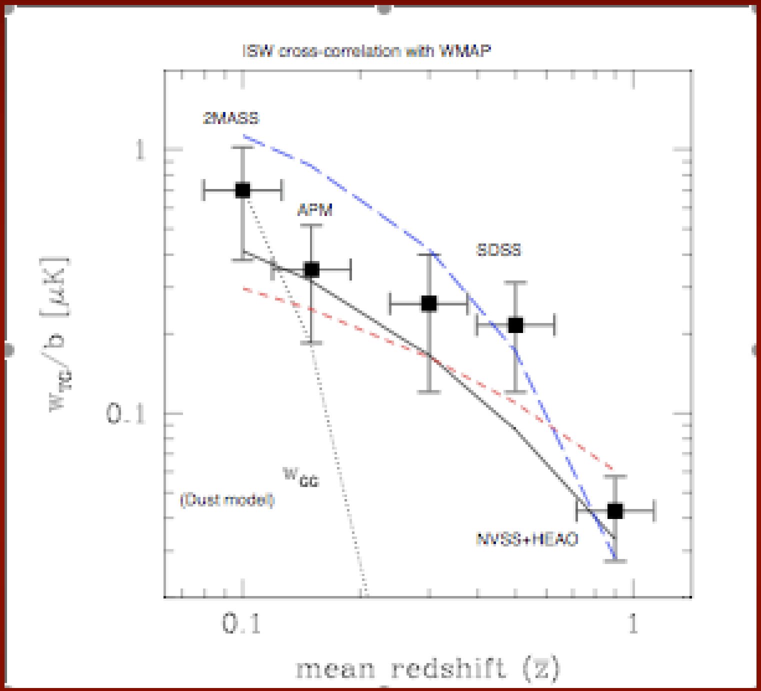
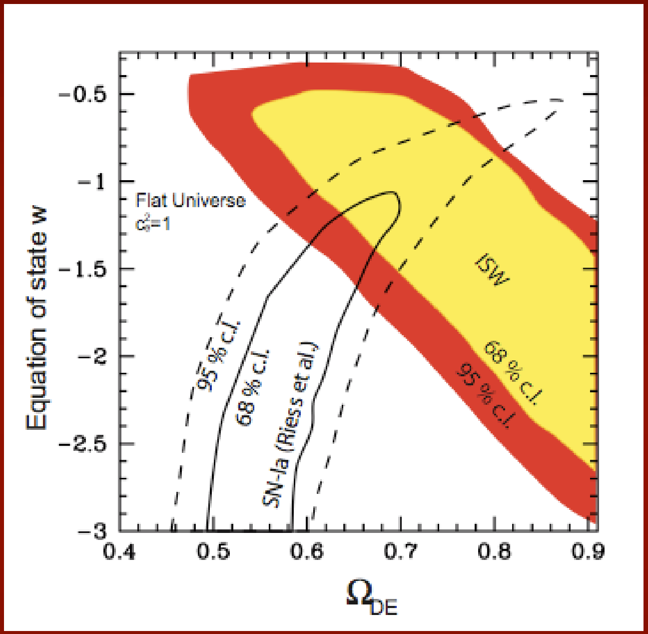


ISW measurements



Gaztanaga et al 2004



Corasaniti et al 2004

Boughn and Crittenden 2004; Nolta et al 2004;
Fosalba and Gaztanaga 2004; Fosalba, Gaztanaga and Castander 2003;
Scranton et al 2003; Afshordi, Loh, Strauss 2004; Cabre et al. 2006;
Giannantonio et al 2006; Pietrobon, Balbi, Marinucci 2006

So,

$$\langle \Delta T \delta n(z_0) \rangle$$

Cross-correlation tells us about growth rate of large-scale structure at z_0

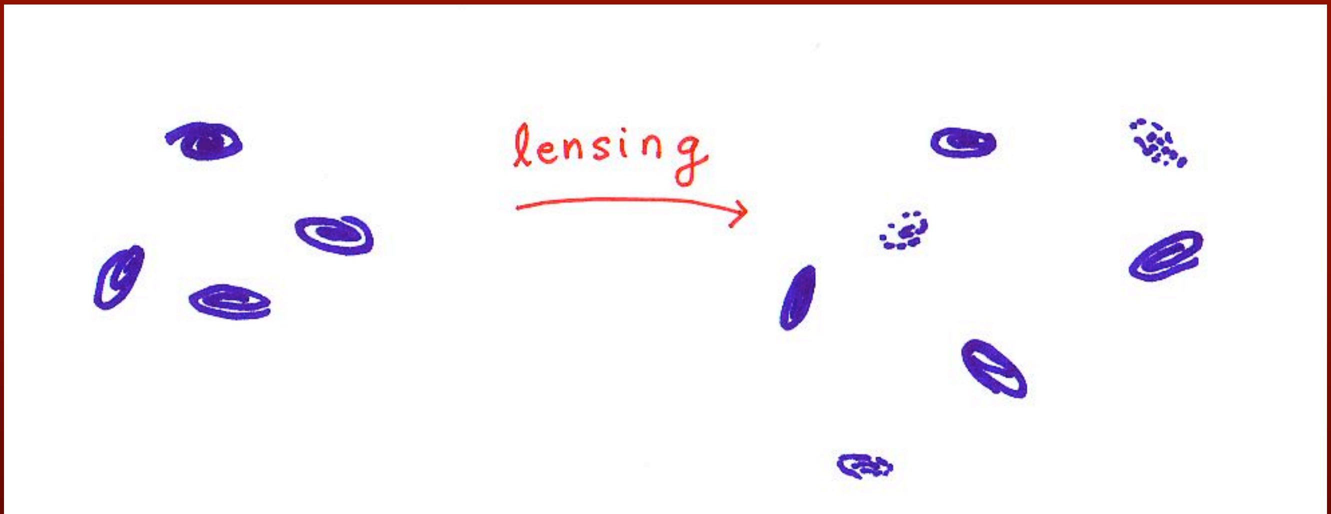
The growth rate of structure tells about matter contents, eg dark energy.

But, at high redshifts gravitational lensing may become important.

Lensing magnification:

1. Increases the area, *decreasing* the galaxy overdensity δn

2. Brightens sources promoting intrinsically faint objects above m_{lim}, *increasing* δn



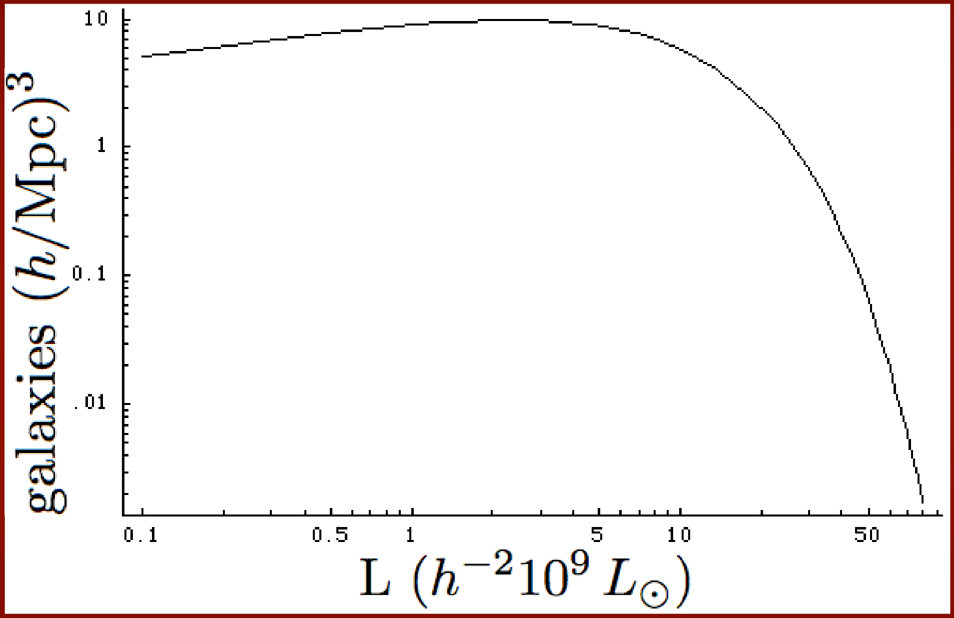
Broadhurst, Taylor, Peacock 1996

Together these corrections are called

Magnification Bias

The change in δ**n** depends on:

$$s = \frac{d}{dm}\left[\log N(m)\right]$$



$$\left(\begin{array}{c} N(m) = \#\ \text{of galaxies in a survey} \\ \text{with limiting mag. m} \end{array} \right)$$

Broadhurst, Taylor, Peacock 1996

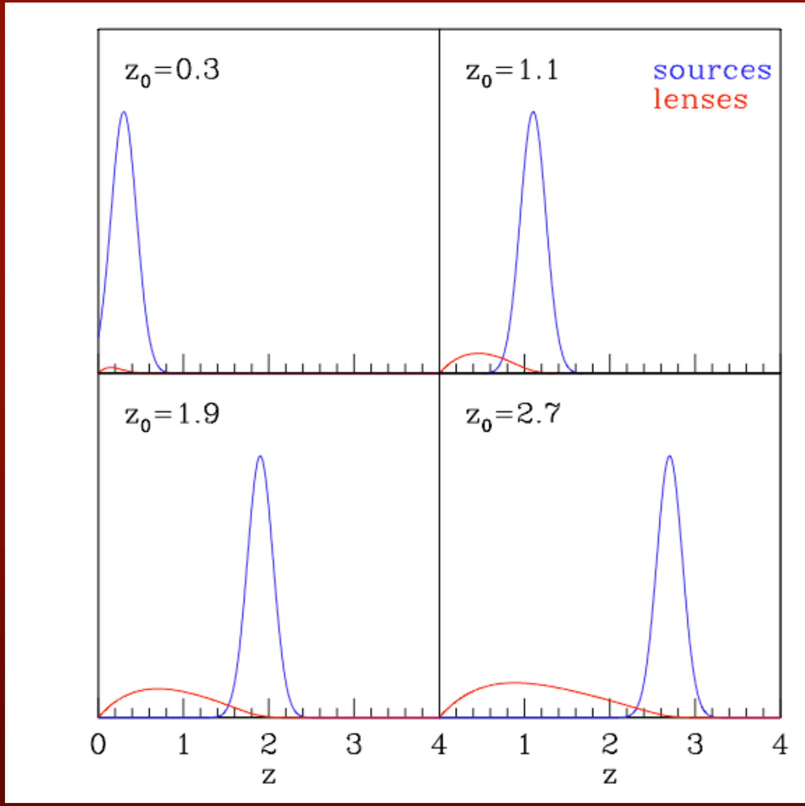
Magnification bias

The measured fluctuation is a sum of two terms:

$$\delta n = \delta n_g + \delta n_\mu$$

$$\delta n_g \propto \int dz \,(\text{selection function})\, \frac{\delta\rho}{\rho}(z)$$

$$\delta n_\mu \propto \int dz \,\frac{H_0^2}{cH(z)} (\text{lensing efficiency})(1+z)\, \frac{\delta\rho}{\rho}(z)$$



On the next slide I've added d/dz[D(z)(1+z)] (dashed line) to the previous plots to illustrate how the source and lens terms are unequally sampled in cross-correlation. So even though the magnification term is smaller then the galaxy term, the magnification-temperature correlation can be larger than the galaxy-temperature correlation.

Magnification bias

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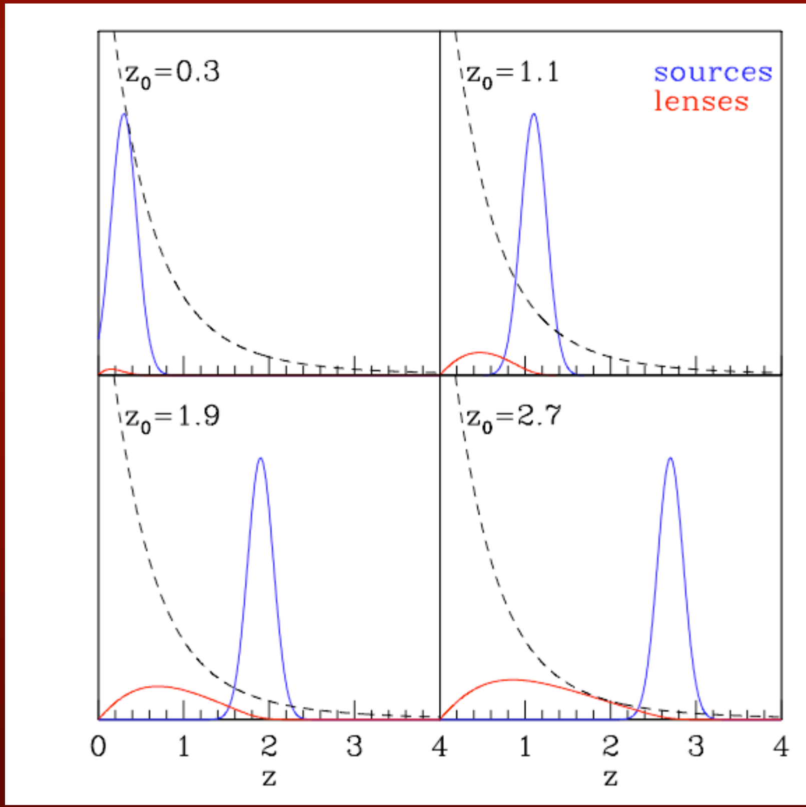


So with magnification bias,

$$\langle \Delta T \delta n(z_0) \rangle = \langle \Delta T \delta n_g(z_0) \rangle + \langle \Delta T \delta n_\mu(z_0) \rangle$$

- has info about structure growth at redshift of sample
- $\propto$ galaxy bias

- tells about growth rates at lens redshifts
- $\propto$ (2.5s-1)

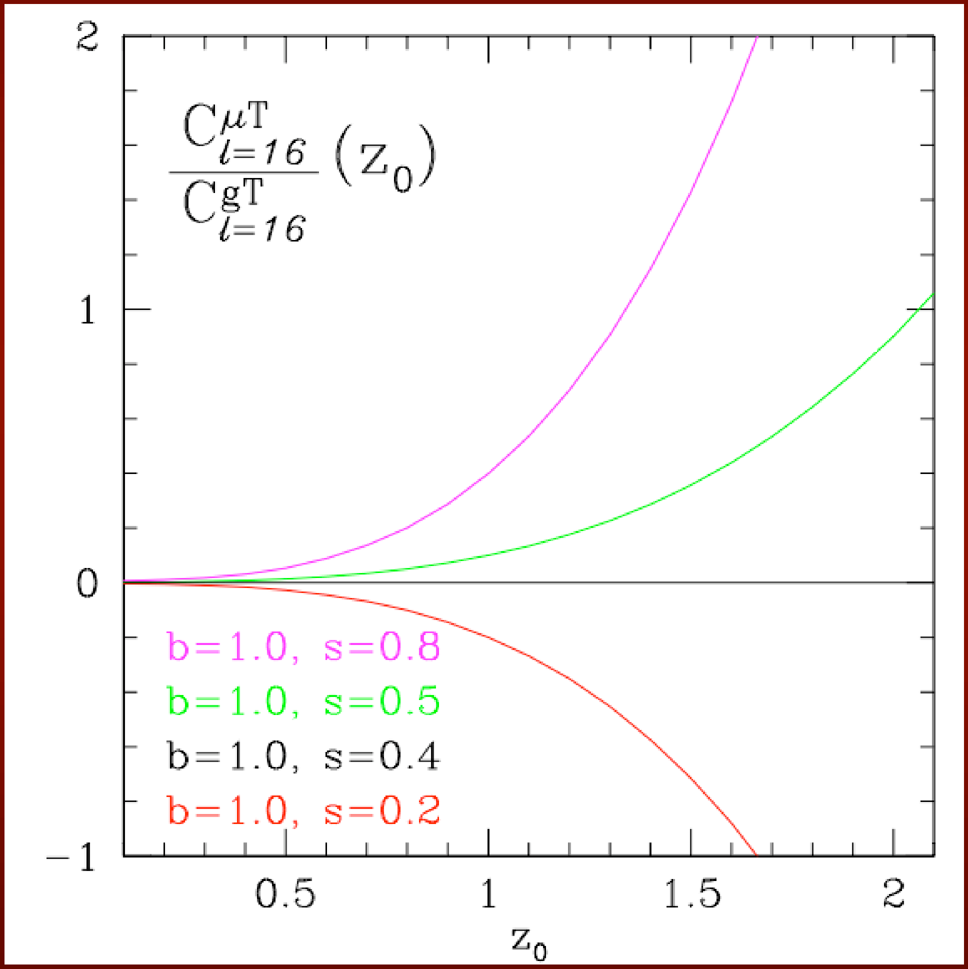
  s = d log(N(m))/dm

Relative magnitude of the two terms is redshift, scale and galaxy population dependent

Questions:

- How big is the effect?
- Does this alter dark energy measurements?
- Can it provide new information?

How big is the effect?



- Magnitude and sign depend strongly on galaxy sample

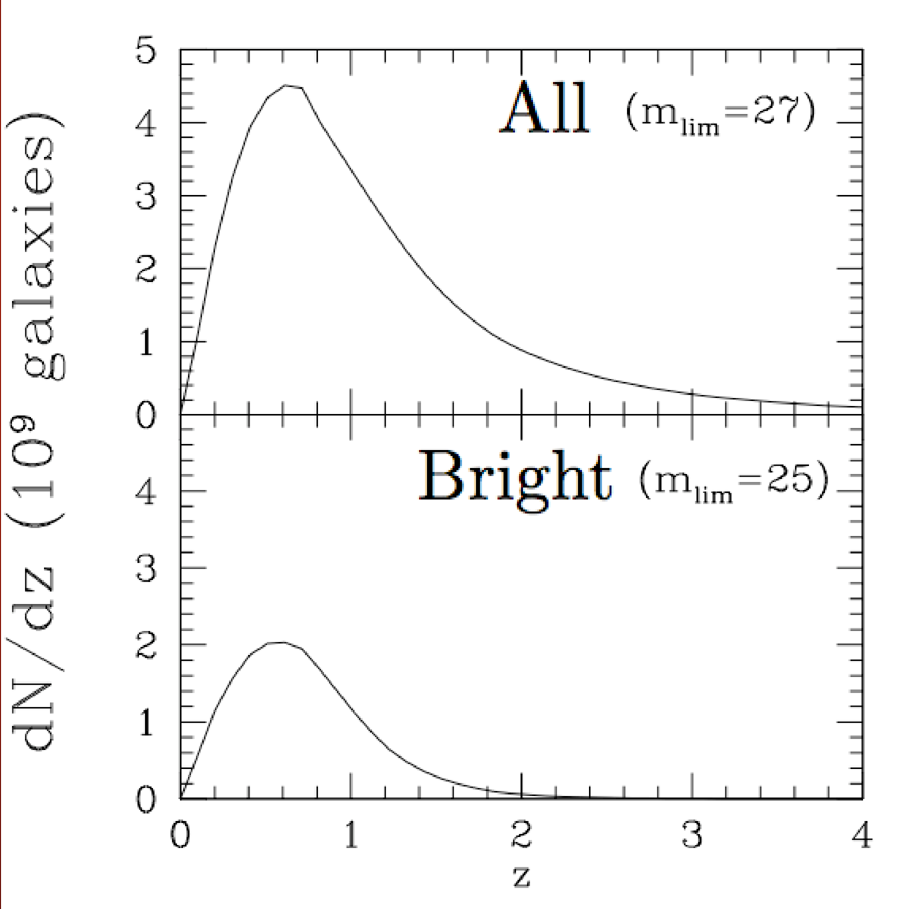
LSST-like survey with two galaxy samples

<u>All</u>: fainter, large sample defined by $m_{lim}(I)=27$

<u>Bright</u>: bright sample defined by $m_{lim}(I)=25$

$f_{sky} = 0.5$

Use redshift dependent luminosity functions of Gabasch et al. A &A 2006



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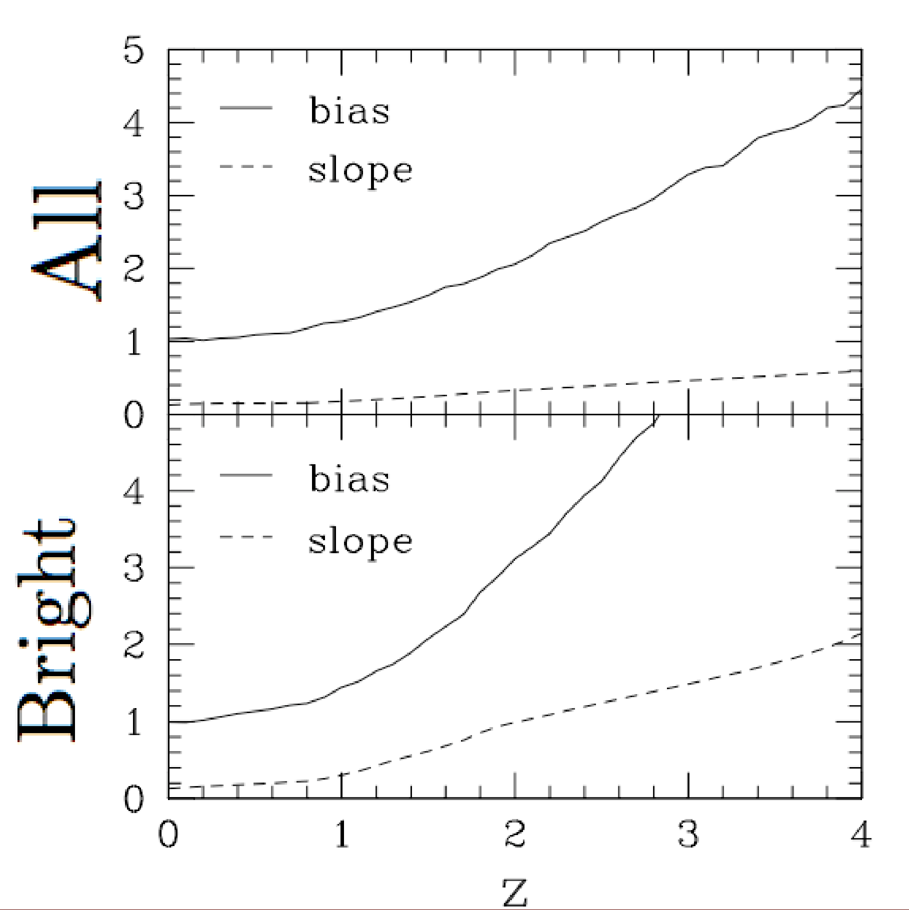


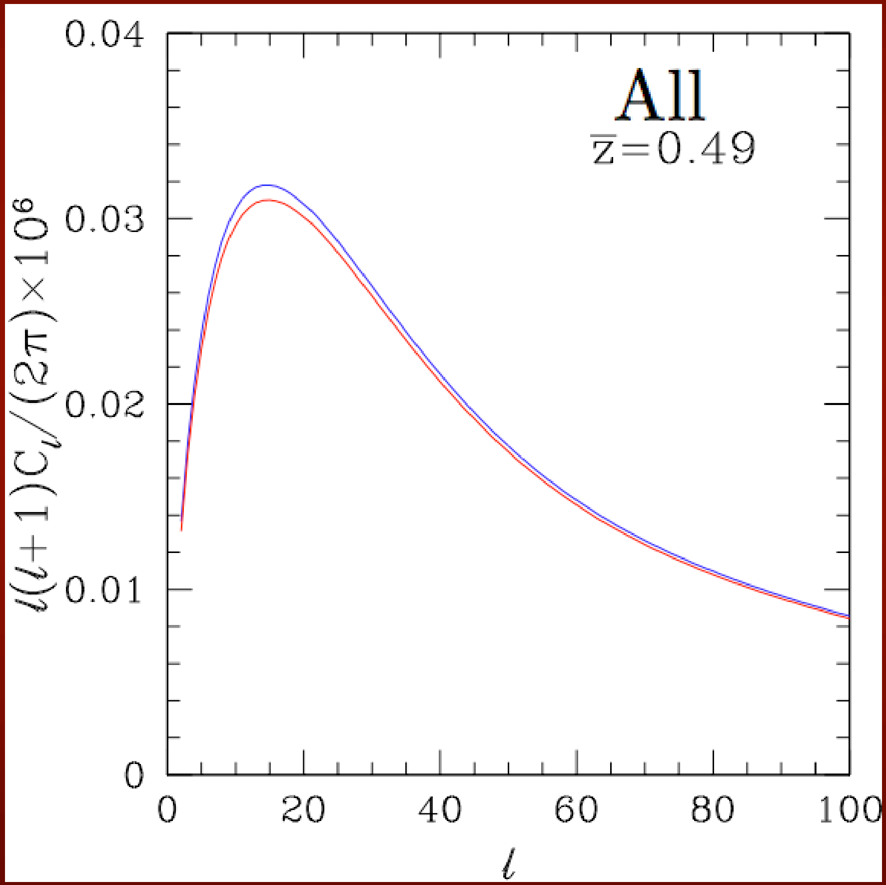
Use redshift dependent luminosity functions of Gabasch et al. A &A 2006

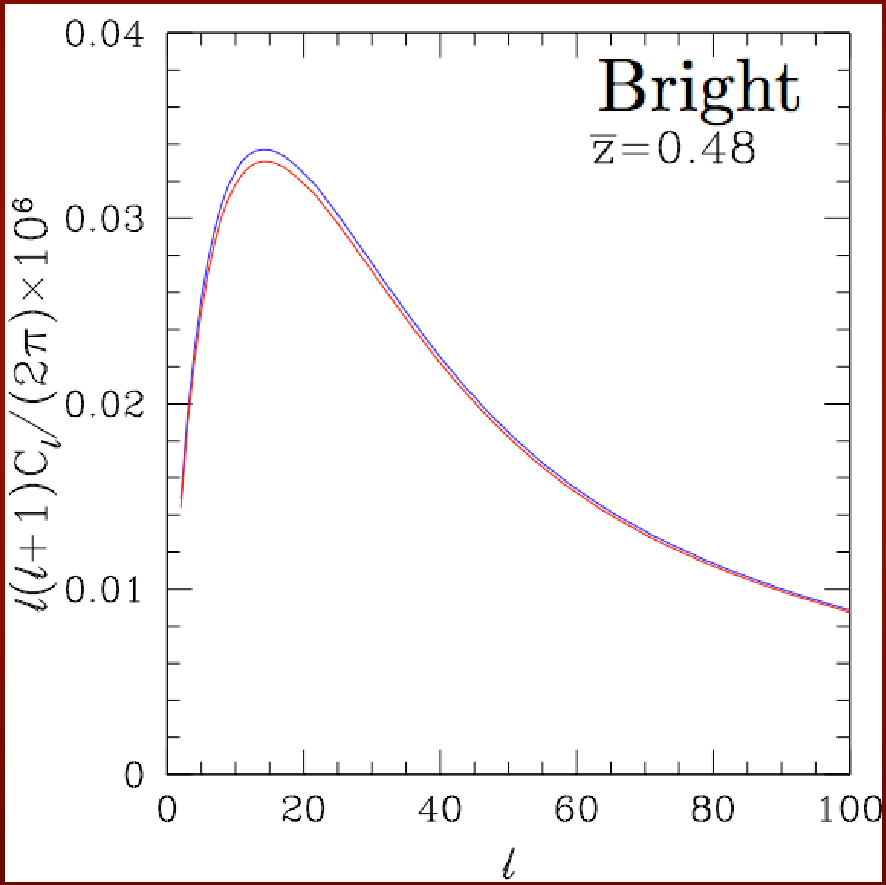
Bias - use number matching technique of Kravtsov et al. Ap. J 2004
+ Sheth and Tormen mass function and halo bias

We divide each sample into redshift bins of $\Delta z \sim 0.8$ and calculate the galaxy-temperature and net galaxy-temperature plus magnification-temperature cross-correlation for each redshift bin.

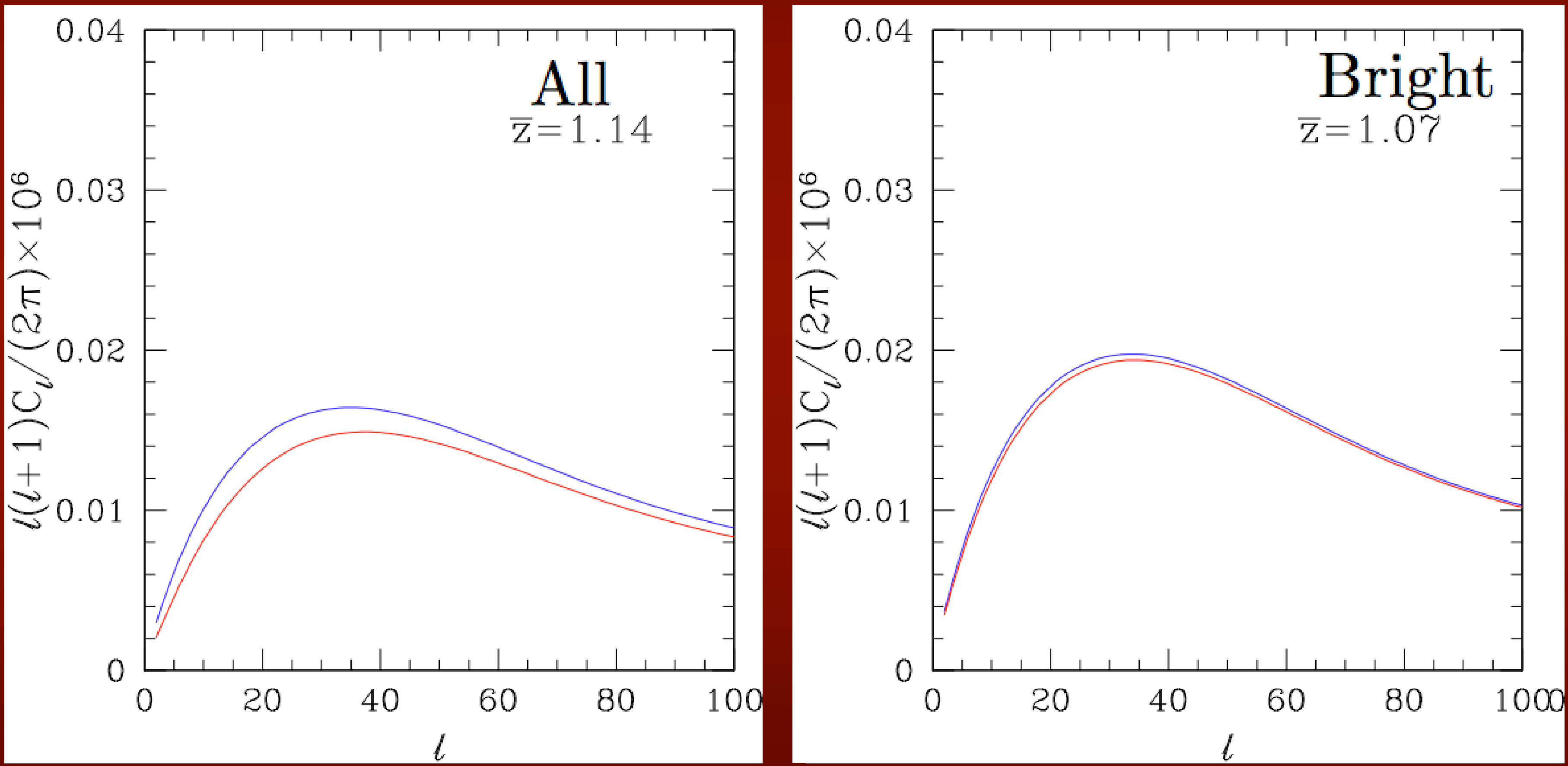
Results:

$$\frac{\ell(\ell+1)}{2\pi}C_\ell^{gT} \qquad \frac{\ell(\ell+1)}{2\pi}(C_\ell^{gT}+C_\ell^{\mu T})$$





Results: $\frac{\ell(\ell+1)}{2\pi}C_\ell^{gT}$ $\frac{\ell(\ell+1)}{2\pi}(C_\ell^{gT}+C_\ell^{\mu T})$



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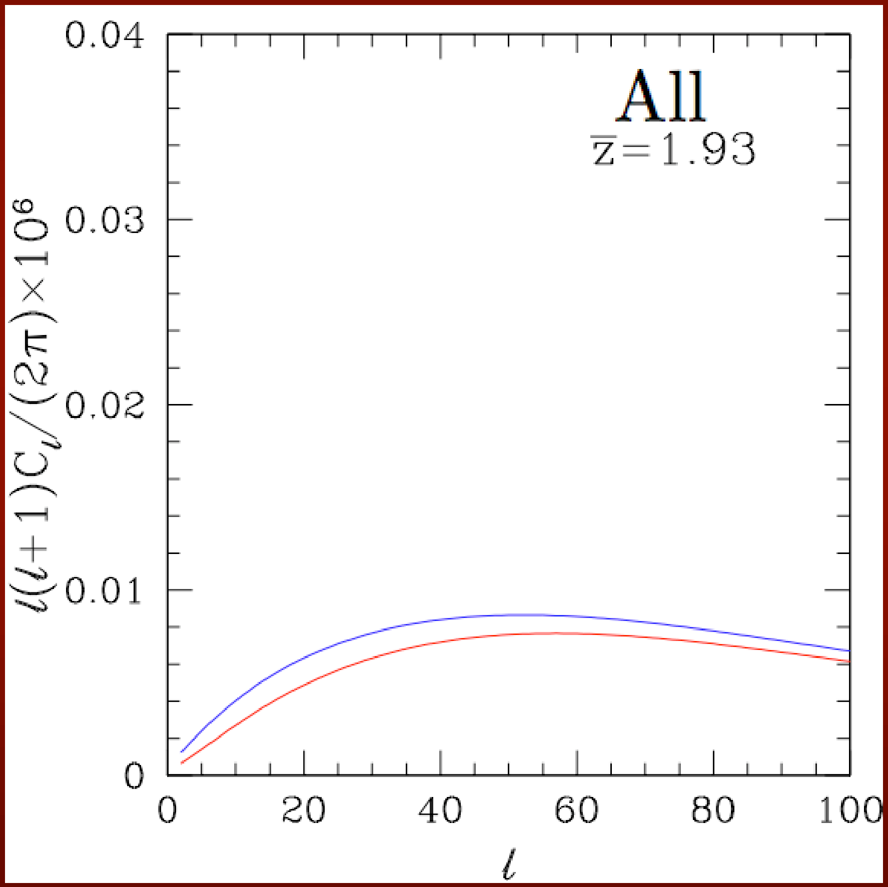

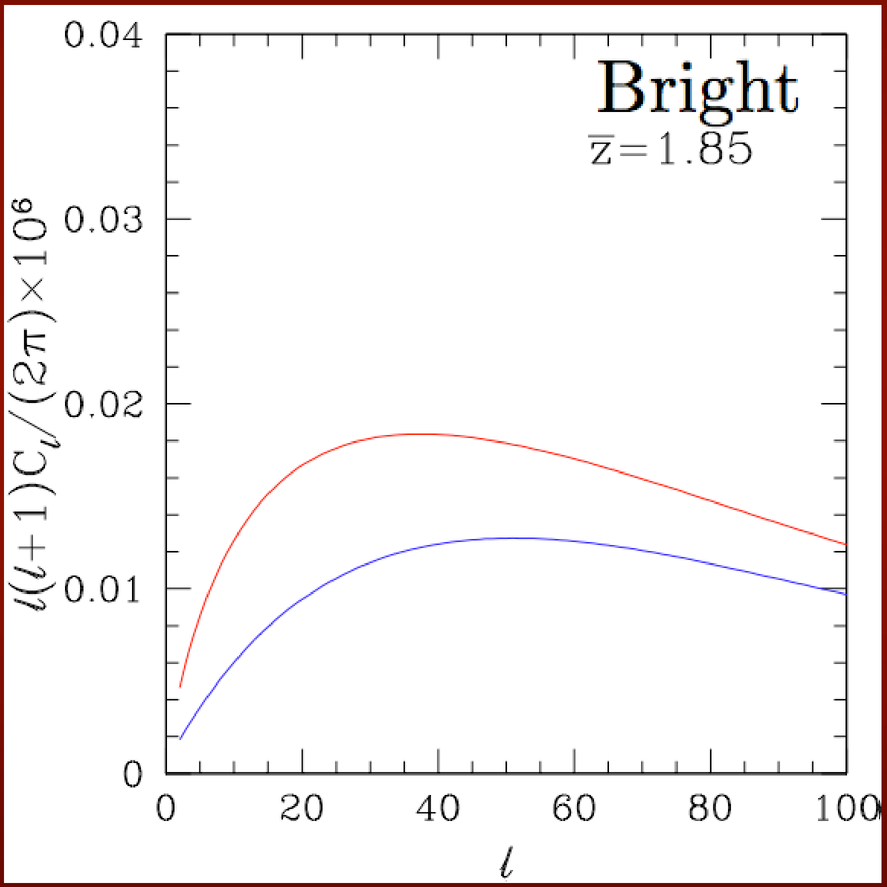

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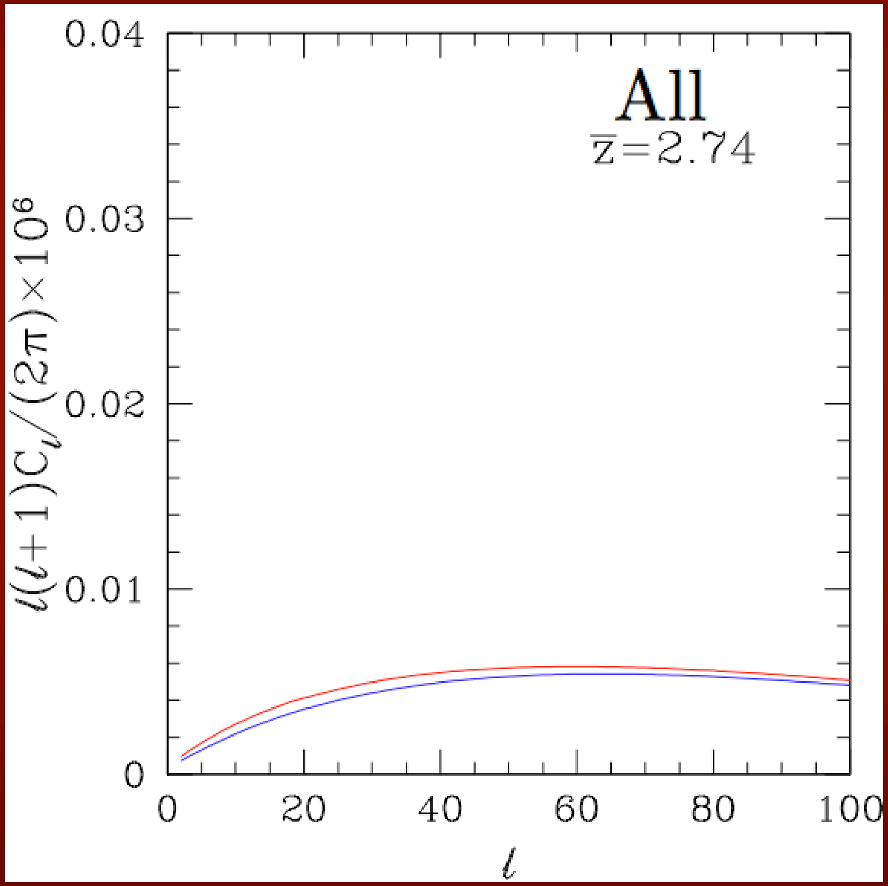
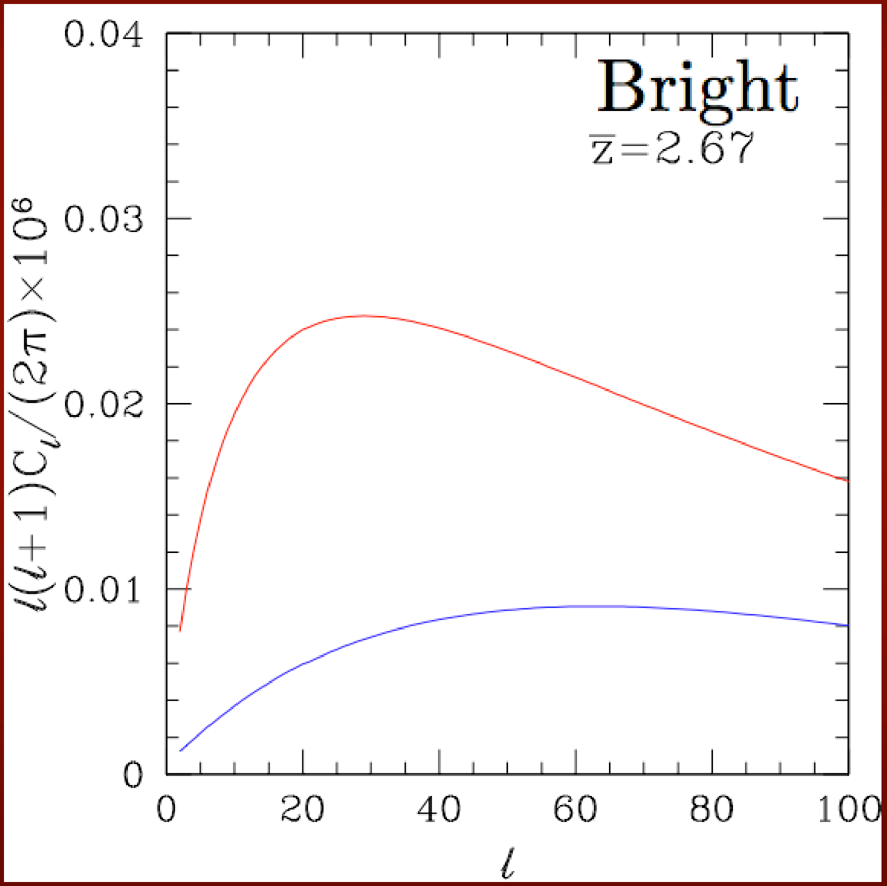
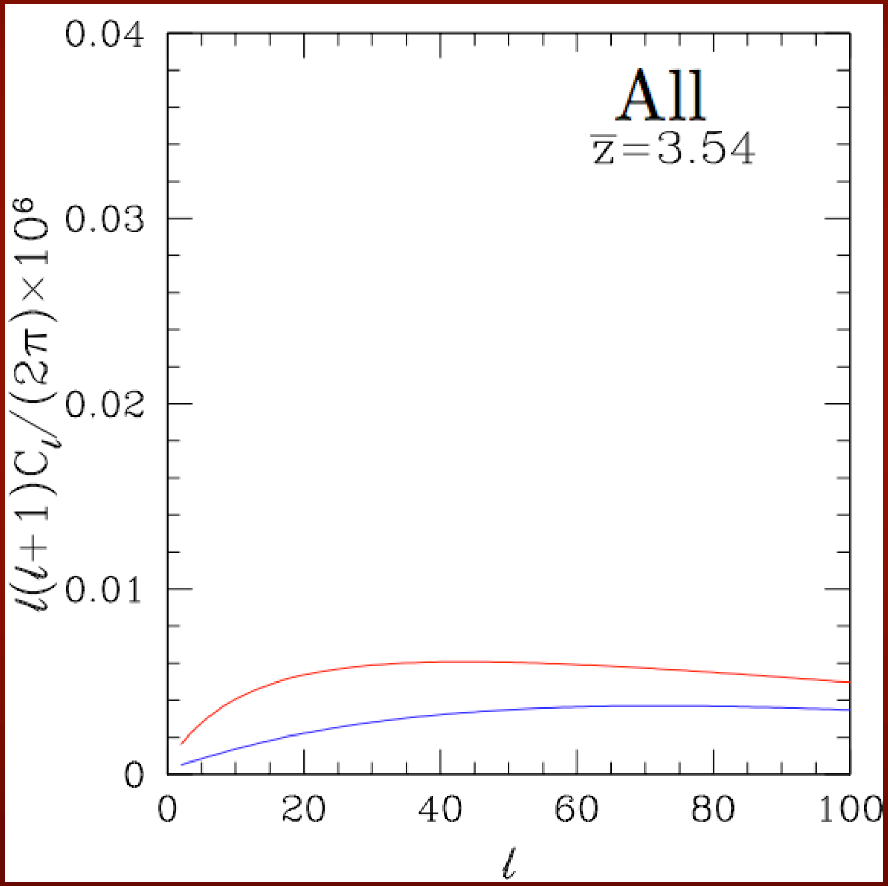
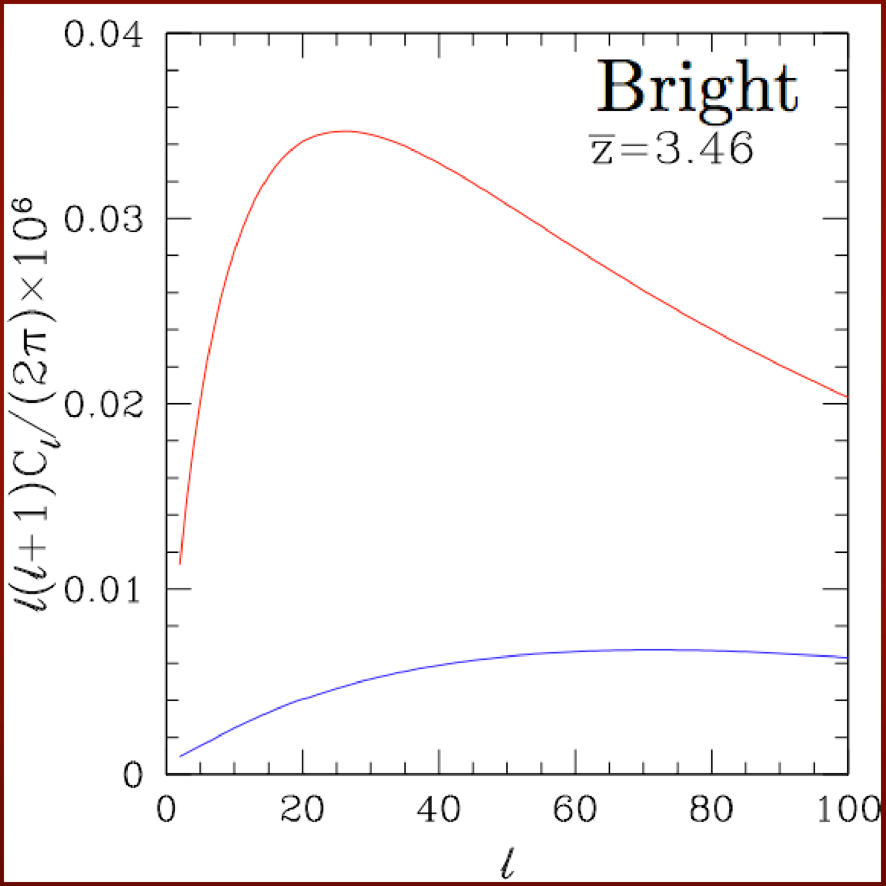




Results: $\frac{\ell(\ell+1)}{2\pi} C_\ell^{gT}$ $\frac{\ell(\ell+1)}{2\pi} (C_\ell^{gT} + C_\ell^{\mu T})$

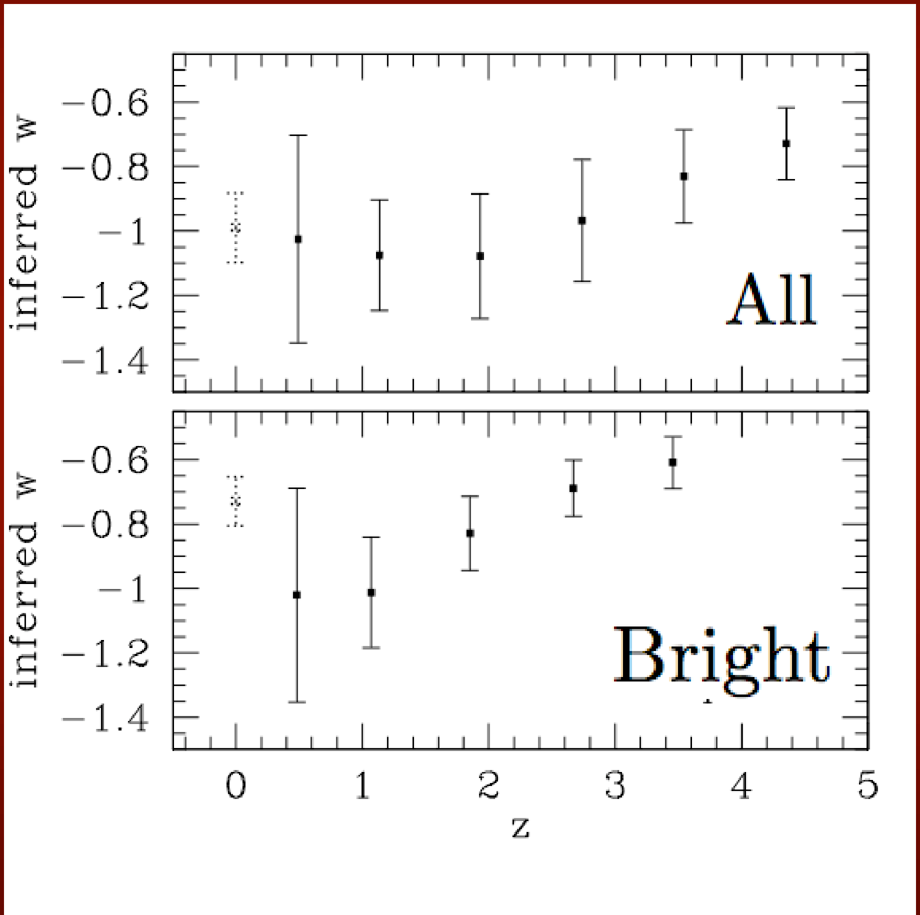




- The magnification-temperature signal *is* large

- What are the consequences of neglecting it?

Thought Experiment:



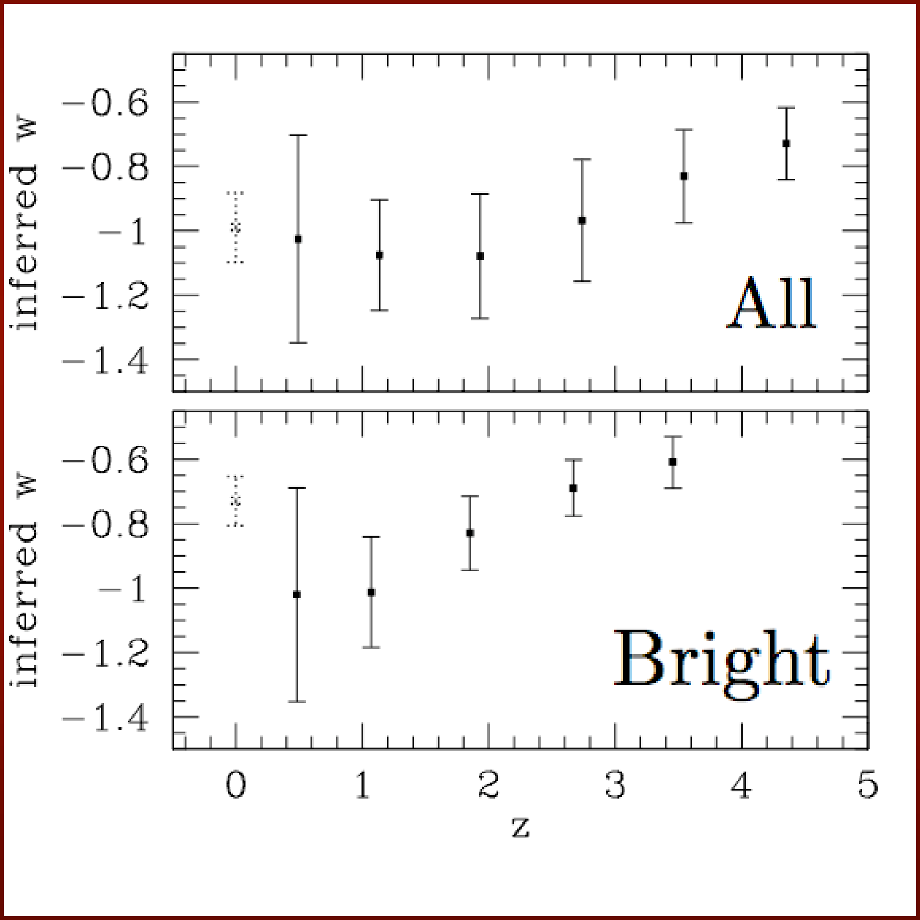
$$w = P_{DE}/\rho_{DE}$$

The thought experiment supposes the universe is ΛCDM (w=-1) but that magnification is neglected when fitting the cross-corr. data e.g. we fit to a model with only galaxy-temperature correlation

Use 5% priors on $\Omega_m h^2$, $\Omega_b h^2$, h, σ_8

10% on $b(z_0)$, 2% on n_s

Thought Experiment:



$$w = P_{DE}/\rho_{DE}$$

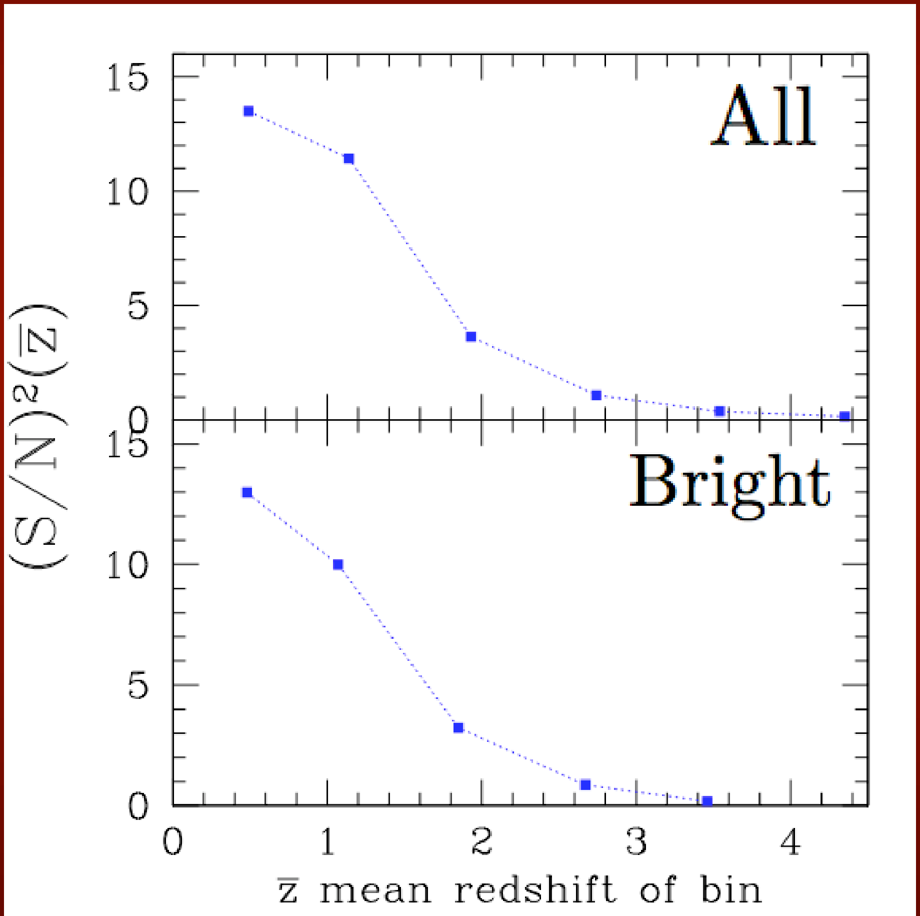
Can hugely bias results!

Use 5% priors on $\Omega_m h^2$, $\Omega_b h^2$, h, σ_8
10% on $b(z_0)$, 2% on n_s

- Magnification bias *is* a large systematic

- Can this systematic be turned into a signal?

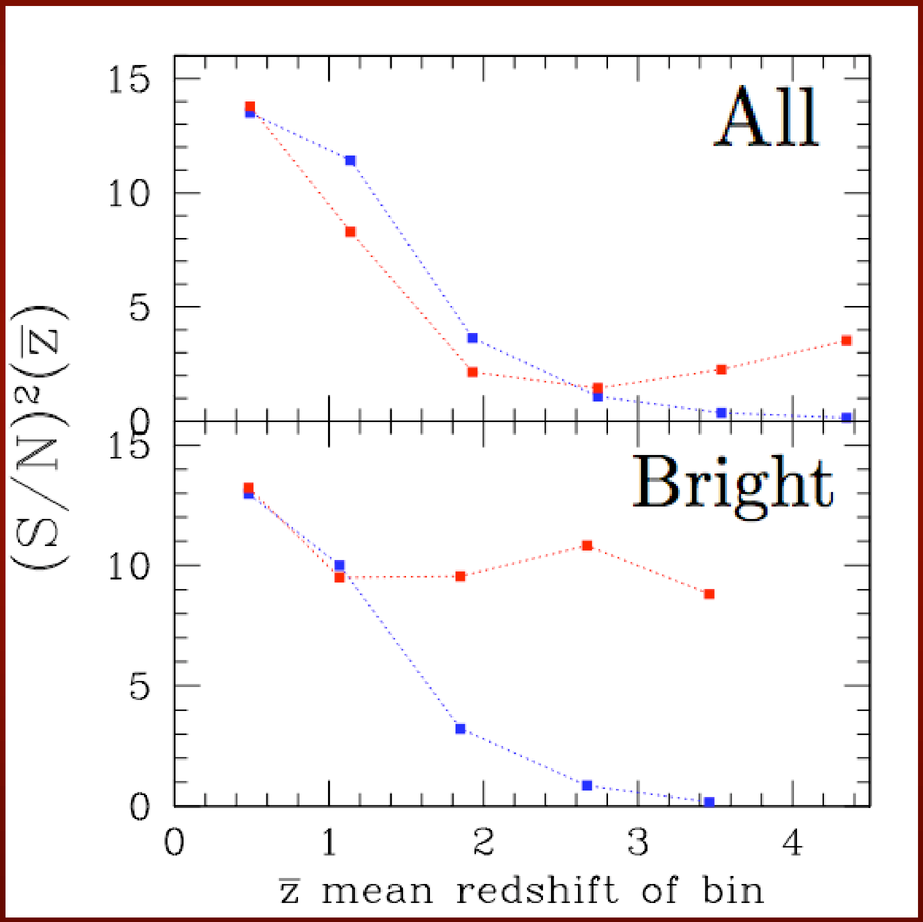
More Information?



The points show the signal to noisein each redshift bin if there is no magnification (as if s=0.4)

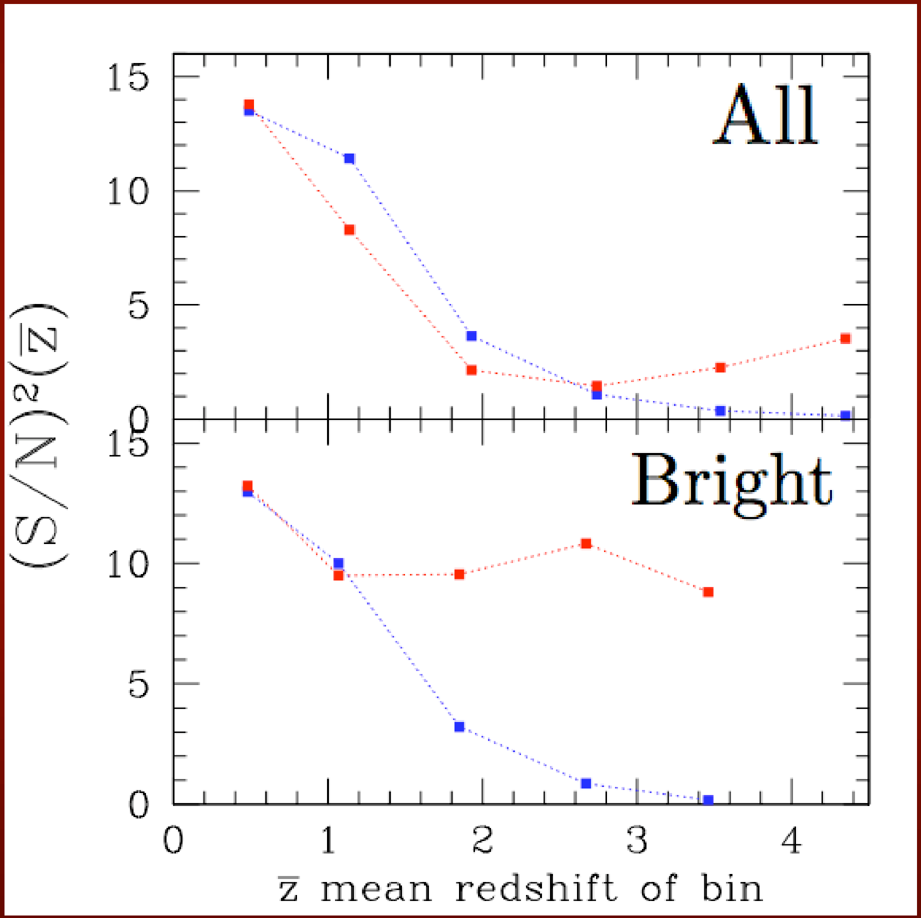
The next slide will show the signal to noise for each redshift bin including the predicted magnification bias (red curves)

More Information?



Large signal to noise out to high redshifts!

More Information?

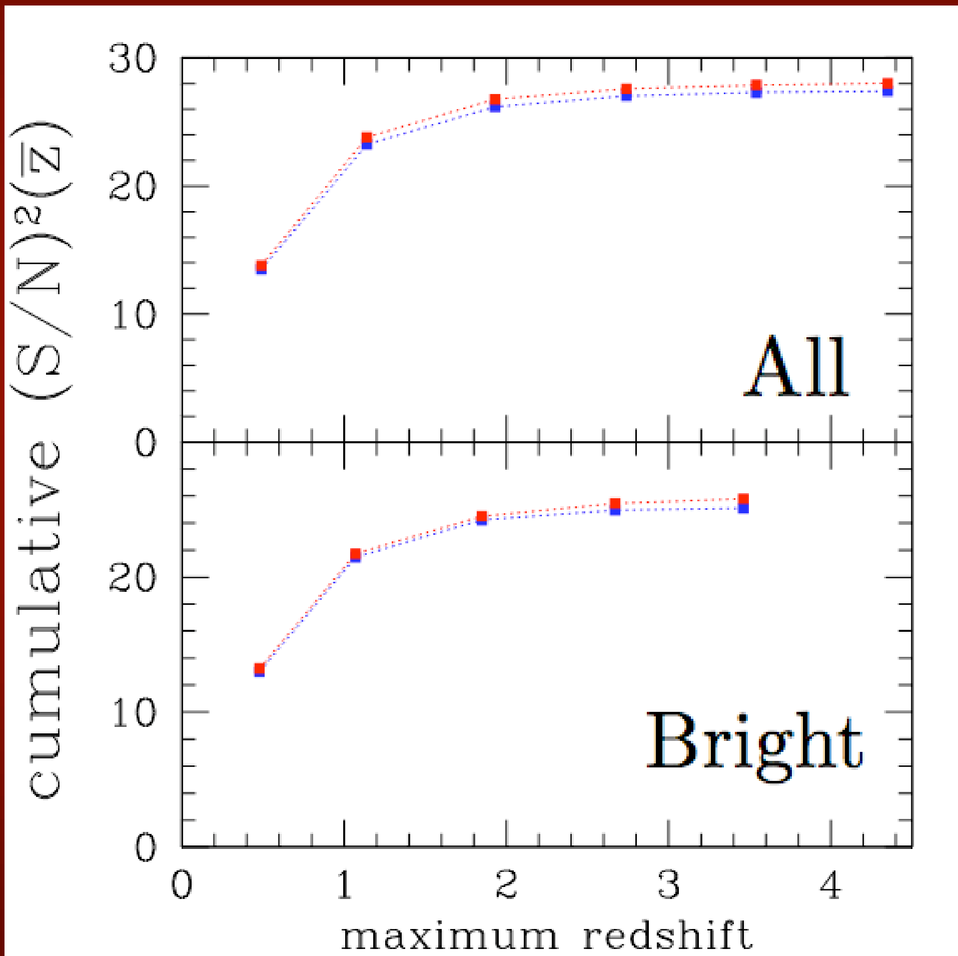


Large signal to noise out to high redshifts!

but

high-z strongly correlated with low-z

More Information?

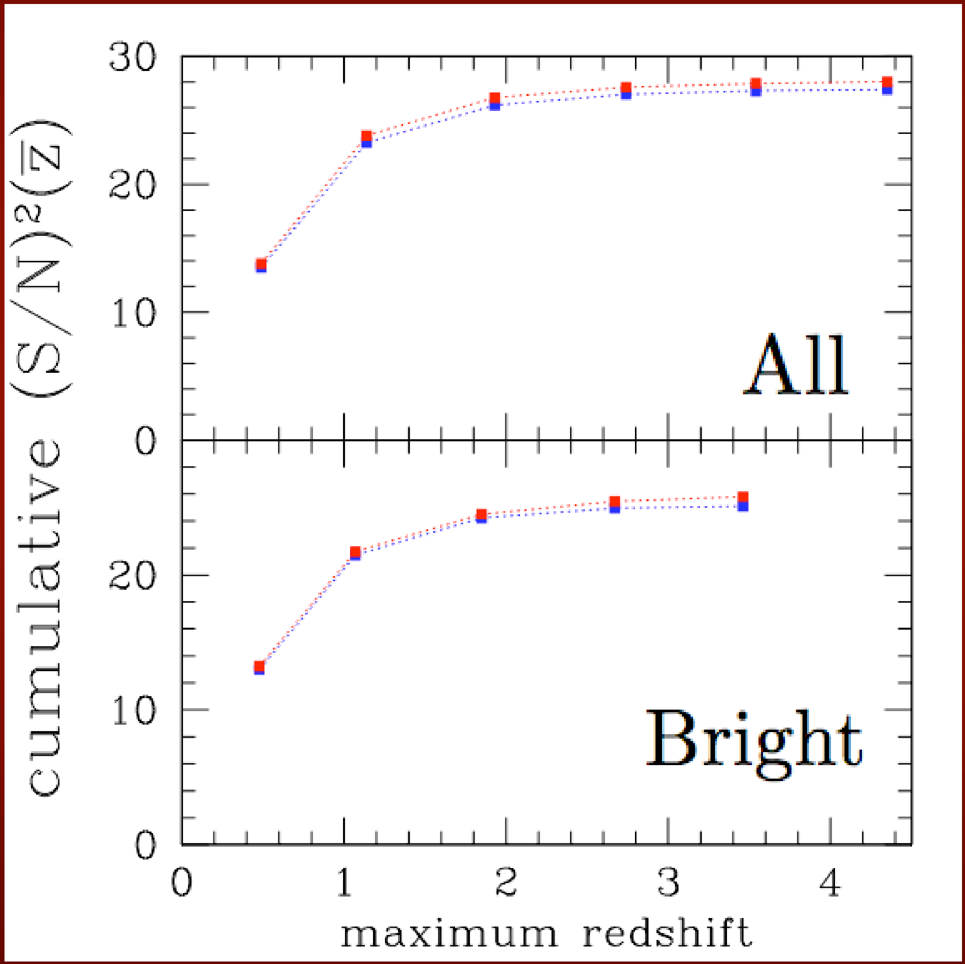


On a bin-by-bin basis S/N is larger

But the cumulative S/N is about the same

This is the signal to noise as a function of the maximum redshift bin used in the analysis

~~More Information~~



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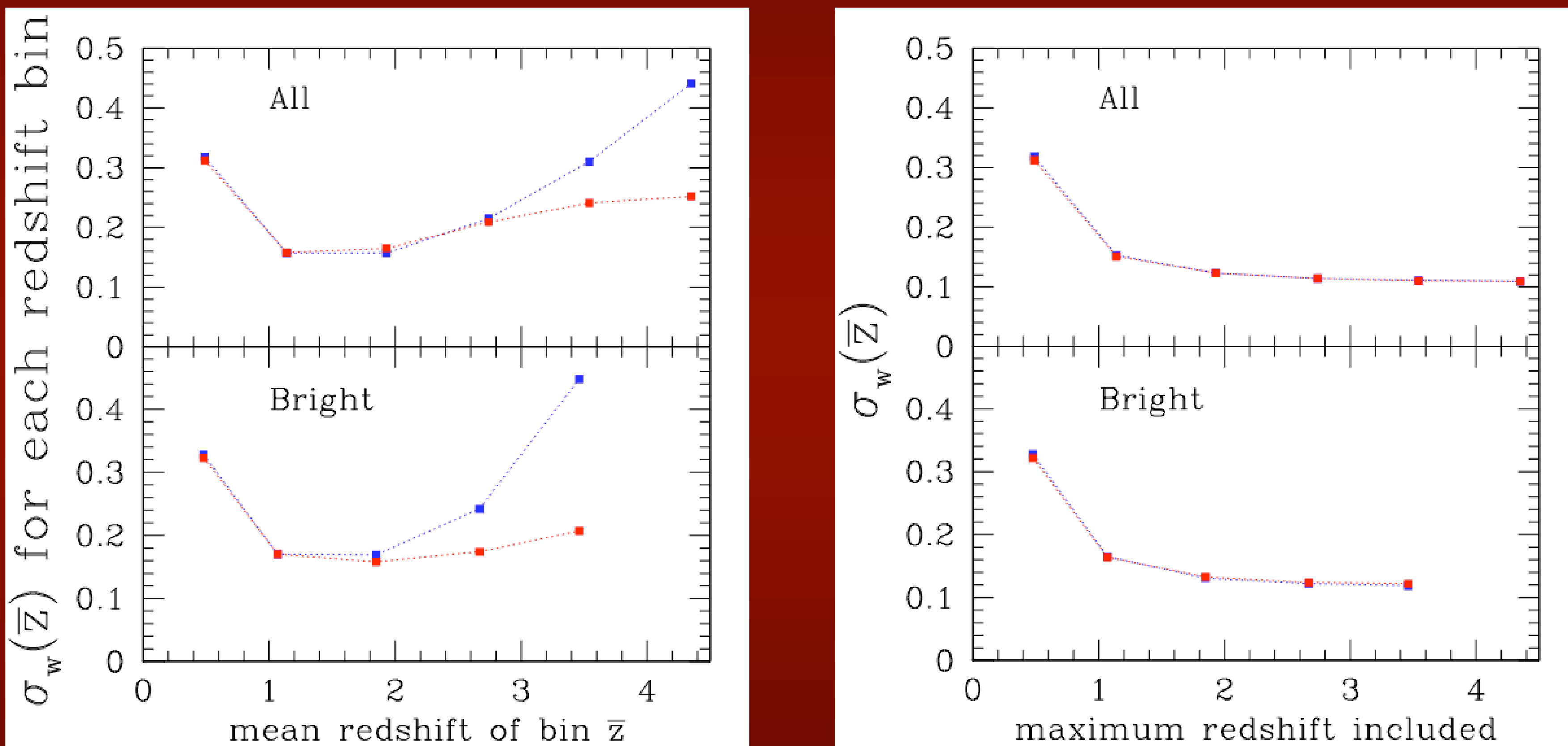
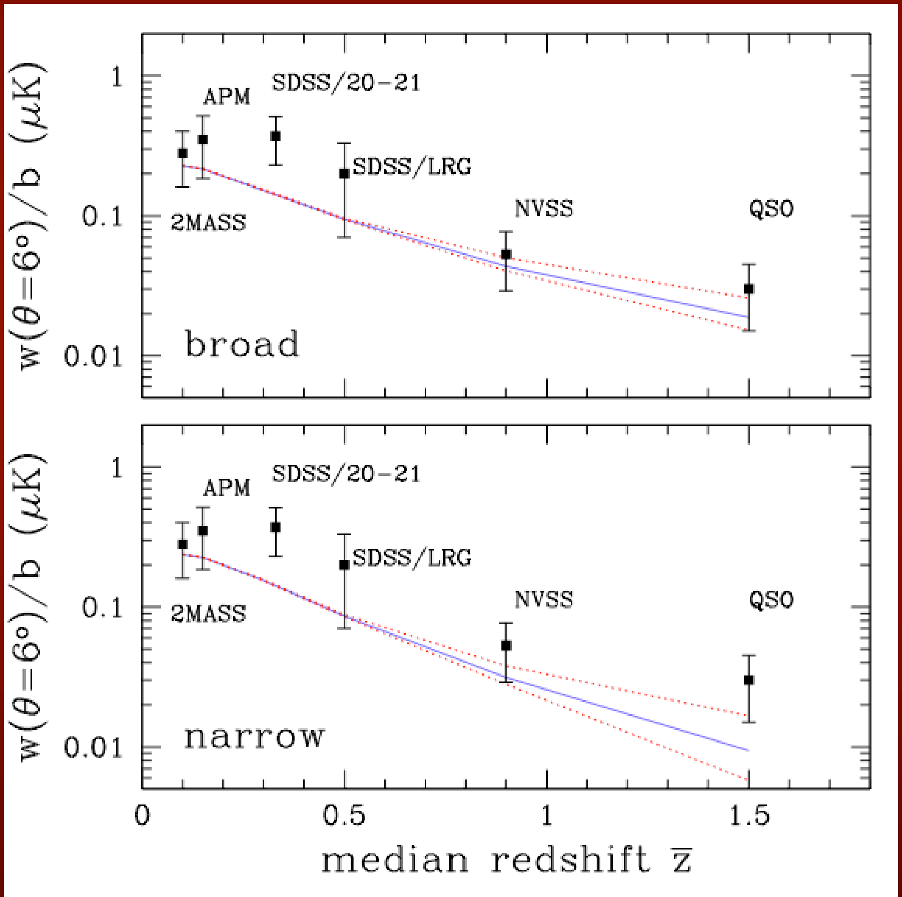


This is the error on w in each redshift bin (left panel) and as a function of the maximum redshift bin used (right). blue=no mag., red=including mag.

Mag.-bias and Existing ISW Measurents?

The blue curve is the no magnification case, the red curves show magnification for s=0.8 (upper red) and s=0.2 (lower red). 'broad' means a broader ($\Delta z \sim 1$) source dist. Is used, 'narrow' means a narrower ($\Delta z \sim 0.3$-0.5) is used for calculating $w(\theta)$. The broad falls off more slowly because it is still sampling low-z sources at high-z.



Conclusions

- Magnification bias *does* significantly alter the ISW cross-correlation signal
- If not taken into account incorrect conclusions about cosmological parameters may be reached
- The magnification signal remains large at high-z opening up a new window for high-z ISW measurements

  <u>but</u>

  high-z measurements highly correlated w/low-z ones, so not expected to provide much new information
- The magnification signal doesn't depend on galaxy bias so it may be a more accurate tracer of $\delta(z)$

Further Questions:

- How should a galaxy sample be chosen to optimize the information provided by galaxy-temperature and magnifcation-temperature correlations?
- If we account for magnification bias, how should the redshift distribution be chosen to optimize the information learned from ISW?