What we can/cannot do with cosmic number magnification

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Gravitational lensing
Lensing distortions

\[ A(\boldsymbol{\theta}) = \frac{\partial \boldsymbol{\beta}}{\partial \boldsymbol{\theta}} \]

Jacobi matrix:

\[ \mu(\boldsymbol{\theta}) = \frac{1}{[(1 - \kappa(\boldsymbol{\theta}))^2 - \gamma^2(\boldsymbol{\theta})]} \]

Magnification factor:
Outline

1. Magnification bias and comparison to shear
2. Number density cross-correlation formalism
3. Cosmic number magnification covariance matrix
4. Signal-to-noise and dark energy figure of merit
5. Conclusions
\[ d\Omega_{\text{obs}} = \mu \, d\Omega \]
\[ f_{\text{obs}} = \mu \, f_0 \]
Magnification bias

\[ N_{\text{obs}}(> f) = \frac{1}{\mu} N_0 \left( > \frac{f}{\mu} \right) \]

Using the logarithmic slope of the source number counts \( \alpha \)

\[ \frac{N_{\text{obs}}}{N_0} (< m) = \mu^{\alpha - 1} \]
First cosmic magnification detection

Scranton et al. (2005)

+ Hildebrandt et al. (2009, 2011 & 2013), Ménard et al. (2010), Wang et al. (2011)
+ tomography in Morrison et al. (2012)
Magnification raw comparison with shear

**PROS**

- no need for PSF shape correction
- no intrinsic alignments
- usable with unresolved sources and different population types
- high-redshift populations

**CONS**

- at a given redshift (when shot noise dominated): 
  \[ (S/N)_{\text{shear}} \sim 2 - 5 (S/N)_{\text{mag}} \]
- need more accurate photo-z’s
- rely on precise calibration of the number counts
  - very sensitive to the completeness
- sensitive to dust extinction
LSST key figures for magnification

- 20,000 deg$^2$ coverage
- 6 photometric bands - $u, g, r, i, z, y$
- $i < 24.5$ for a single exposure
- $i < 27.5$ expected for complete survey (10 years)
- Number density of galaxies
  $n \sim 45$ arcmin$^{-2}$
Source density gain from SDSS to LSST
Source density gain from SDSS to LSST

courtesy S. Mei
Number density cross-correlation

We define the number density cross-correlation power spectrum

\[ w_{\delta_n \delta_n}^{(ij)}(\theta) = \int \frac{d^2 \ell}{(2\pi)^2} e^{-i \ell \cdot \theta} P_x^{(ij)}(\ell) \]

\[ P_x^{(ij)}(\ell) = P_{gg}^{(ij)}(\ell) + P_{gm}^{(ij)}(\ell) + P_{gm}^{(ji)}(\ell) + P_{mm}^{(ij)}(\ell) + P_{sn}^{(ij)} \]

- **intrinsic clustering**
- **galaxy-lensing**
- **lensing-lensing**
- **shot noise**

The respective contribution of these phenomena to the cross-correlation power spectrum depends on the redshift distribution of populations \( i \) and \( j \).
Tomographic distribution for this work

**LSST**

$i$-mag $< 27.5$

simple tomographic redshift distribution with **non overlapping** redshift bins

average number density of galaxies

$n = 45$ arcmin$^{-2}$
Fisher matrix formalism

The Fisher matrix for the power spectrum $P_x$ reads:

$$F_{\alpha\beta} = \sum_{\ell} \sum_{i,j;i',j'} \frac{\partial P_{x}^{(ij)}(\ell)}{\partial p_{\alpha}} C_{ij i' j'}^{-1}(\ell) \frac{\partial P_{x}^{(i' j')}(\ell)}{\partial p_{\beta}}$$

where the associated Gaussian covariance matrix is:

$$C_{ij i' j'}^{-1}(\ell) = \text{Cov} \left[ P_{x}^{(ij)}(\ell), P_{x}^{(i' j')}(\ell') \right]$$

$$= \frac{1}{2 \ell \Delta \ell f_{\text{sky}}} \left[ P_{x}^{(ii')}(\ell) P_{x}^{(jj')}(\ell) + P_{x}^{(ij')}(\ell) P_{x}^{(ji')}(\ell) \right]$$
Covariance of magnification signal

\[ C_{ijij}^{-1}(\ell) = \frac{1}{2 \ell \Delta \ell f_{\text{sky}}} \left[ P_{\times}^{(ii)}(\ell) P_{\times}^{(jj)}(\ell) + P_{\times}^{(ij)}(\ell)^2 \right] \]

\[ z_i = 0.3 \]
\[ z_j = 1.1 \]

non overlapping

intrinsic clustering
galaxy-lensing
lensing-lensing
shot noise
Covariance of magnification signal

\[ C_{ijij}^{-1} (\ell) = \frac{1}{2 \ell \Delta \ell f_{sky}} \left[ P^{(ii)}(\ell) P^{(jj)}(\ell) + P^{(ij)}(\ell)^2 \right] \]

\[ \text{z}_i = 0.3 \]

non overlapping

intrinsic clustering

galaxy-lensing

lensing-lensing

shot noise
Most of the signal comes from the non-linear scales
Cosmological constraints on $w_0-w_a$

$$p_{DE} = w(z) \rho_{DE}$$

$$w(z) = w_0 + w_a \left( \frac{z}{1 + z} \right)$$

Constraints for 5 tomographic bins with cross-correlation only

FoM $\sim 1$
Conclusions

- Cosmic number magnification is not competitive with cosmic shear for cosmological constraints, passed the shot noise regime (confirmed by Duncan et al. 2013)

- However cosmic magnification
  - can provide an estimator of the lensing potential at redshifts where the shape cannot be measured
  - is able to break the mass-sheet degeneracy (see e.g. Umetsu et al. 2011)
  - can help measure the dust and various astrophysical observables using cross-correlation
  - get information on the galaxy bias