Weak lensing and intrinsic size and magnitude correlations

Robert Crittenden
Institute of Cosmology and Gravitation
University of Portsmouth

ICG Portsmouth

Work with Sandro Ciarlariello, F Pace

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Weak gravitational lensing

Our best means of mapping the dark matter distribution

- Shearing of observed galaxy shapes
  - Measurements of the shear field
  - Stacking on galaxies or clusters (‘galaxy-galaxy lensing’)
- Modulating the density of galaxies
  - Two compensating effects
  - Introduce correlations between near and background objects (e.g. quasars)
- Magnifying the observed size of objects
- Magnifying the observed flux of objects

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- **Magnifying the observed size of objects**
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Menard et al 2010, Huff & Graves 2011, Schmidt et al. 2011

Bartelmann et al. 1996,Heavens et al 2013, Casaponsa et al 2013, Alsing et al. 2014

Effects of magnification

Magnifying the observed size of objects

$$r_O = r_I(1+\kappa) \qquad r \equiv \sqrt{A}$$

$$\lambda_O \simeq \lambda_I + \kappa \quad \lambda \equiv \ln(r/r_*)$$

Magnifying the observed flux and magnitudes of objects

$$F_O = F_I(1+2\kappa)$$

$$\ln(F_O/F_*) \simeq \ln(F_I/F_*) + 2\kappa$$

$$m_O = m_I + q\kappa \qquad q \equiv -5\log_{10} e \simeq -2.17$$

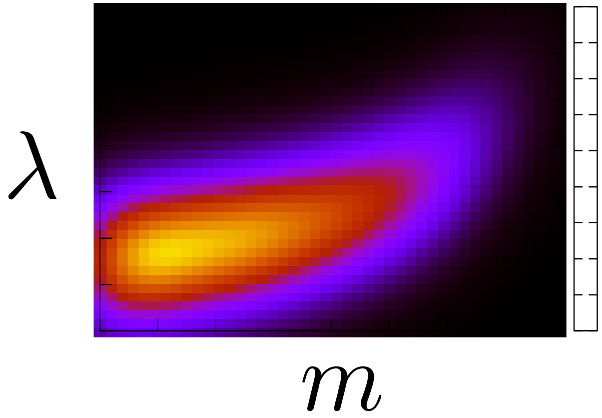
Effect on a population

Magnification can pull in objects into the sample, meaning that the effect on sample mean properties can be reduced

Population responsivities:

$$\langle \lambda_O \rangle = \langle \lambda_I \rangle + \eta_\lambda \kappa$$

$$\langle m_O \rangle = \langle m_I \rangle + \eta_m \kappa$$



Point estimators for local convergence:

$$\hat{\kappa}_\lambda = (\lambda - \langle \lambda \rangle)/\eta_\lambda$$

$$\hat{\kappa}_m = (m - \langle m \rangle)/\eta_m$$

Schmidt et al. 2009
Schmidt et al. 2011

Intrinsic correlations

There may well be other physical effects that can cause the sizes and magnitudes to be correlated.

These can lead to systematics in the interpretation of the sizes and magnitudes, just as for galaxy shapes.

$$\hat{\kappa} = \kappa + \kappa_I$$
$$\langle \hat{\kappa}\hat{\kappa} \rangle = \langle \kappa\kappa \rangle + 2\langle \kappa\kappa_I \rangle + \langle \kappa_I\kappa_I \rangle$$

Just as for shape correlations, there are potentially intrinsic correlations and cross correlations with the magnification.

It is essential to understand and quantify these intrinsic correlations in order to interpret the size and magnitude data.

Modeling intrinsic correlations

Our primary assumption is that the sizes and luminosities of galaxies correlate with their total mass, using a halo model to estimate the correlations of the mass properties.

We also build on numerical 'abundance matching' studies to infer how the properties correlate with mass, as well as the scatter in these relations.

Mass-size (Kravtsov 2013)

$$r_{1/2} = 0.015 R_{200}$$

Mass-Luminosity (Vale & Ostriker 2008)

$$L = L_0 \frac{(M/M_0)^a}{(1 + (M/M_0)^{bk})^{1/k}}$$

Halo model elements

We build on the halo model, dividing galaxies into central galaxies surrounded by a halo satellite galaxies:

- Halo mass function n(M, z) (Sheth & Tormen 1999)
- Sub-halo mass function dN(m, M, z)/dm (Giocoli 2010)
  - Proportional to M, with M dependent cutoff
- NFW halo profile (Navarro, Frenk & White, 1996)
- Biased halo two-point correlation function (using the bias model of Sheth & Tormen 1999)

$$\xi_{hh}(r, M_1, M_2) = b(M_1, z_1)b(M_2, z_2)\xi_{linear}(r)$$

Two point correlation functions

To compare to the lensing signal, we must calculate the two point correlations of the intrinsic term, and their correlations with the lensing field.

Generally, the halo model implies:

$$P(k) = P_{1h}(k) + P_{2h}(k)$$

Particularly at high redshift, the typical galaxy sample is dominated by central galaxies, and the most relevant term is the two-halo contribution.

In this case, the two halo power spectrum is simply proportional to the linear power spectrum:

$$P_{2h}(k) = b^2_{\kappa_I,c} P_{linear}(k)$$

Size bias

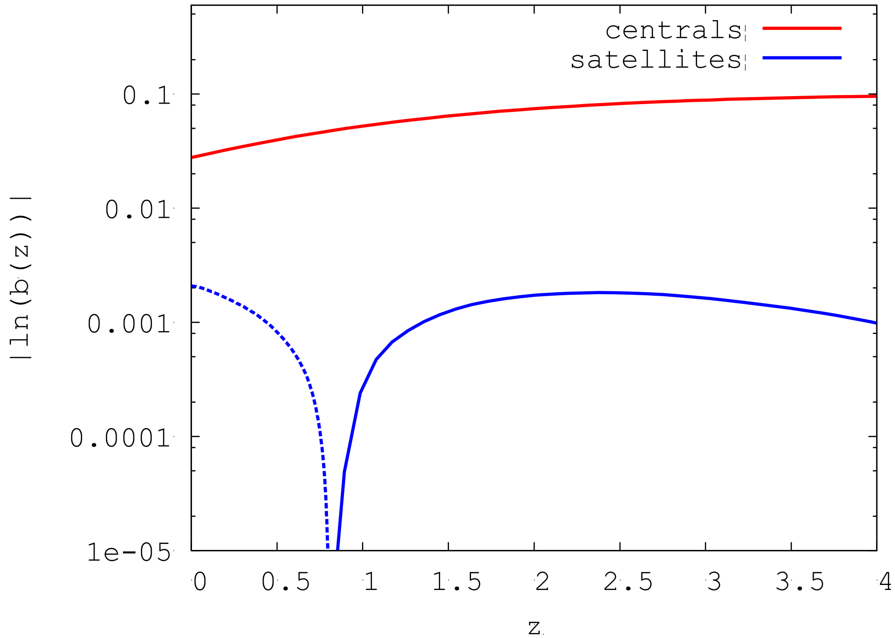
The two point correlations depend primarily on the 'size bias,' the bias weighted by the convergence estimator.

$$b_{\kappa_I,c} = n_g^{-1} \int dM n(M) b(M) \kappa_I(M)$$

$$\kappa_I = (\lambda(M) - \langle\lambda\rangle)/\eta_\lambda$$

Zero if b(M) is constant!

Requires that the more massive halos cluster differently than the less massive ones, but this is generally expected.



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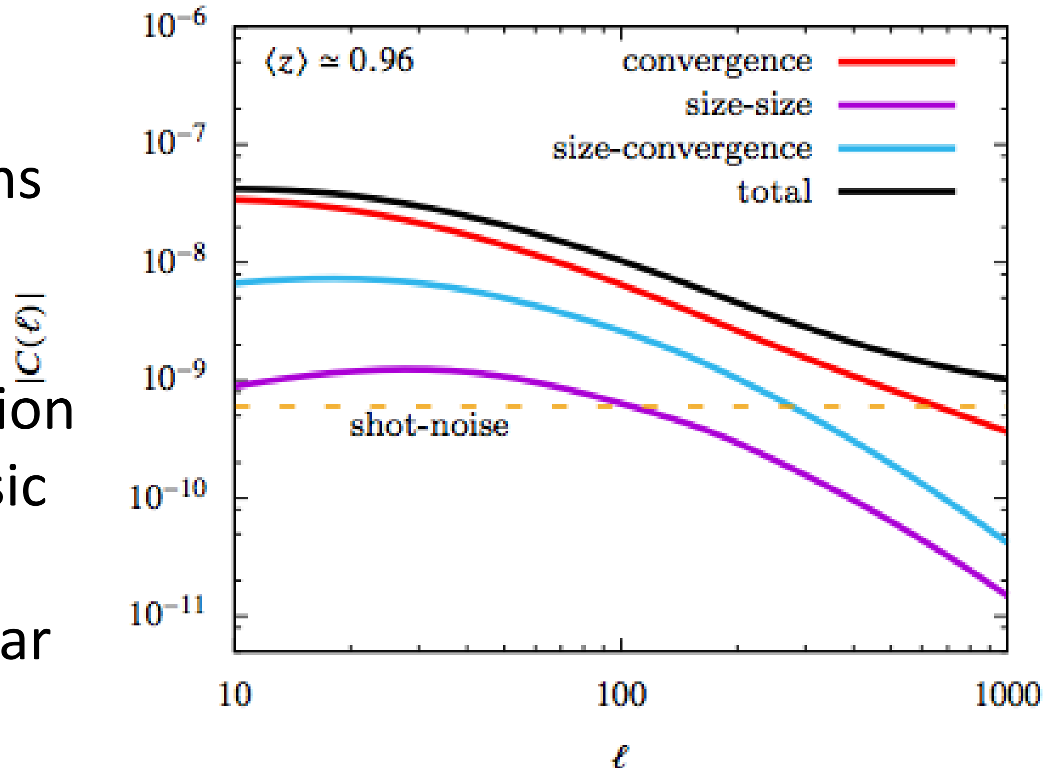
Euclid-like survey

We can calculate the amplitude of the signal for size estimator for convergence, using Euclid-like observations.

For such a deep survey, the intrinsic-intrinsic correlations are suppressed.

However, the cross correlation between lensing and intrinsic signals is still significant, as large as 30% on small angular scales. This would lead to significant parameter biases if not corrected for.



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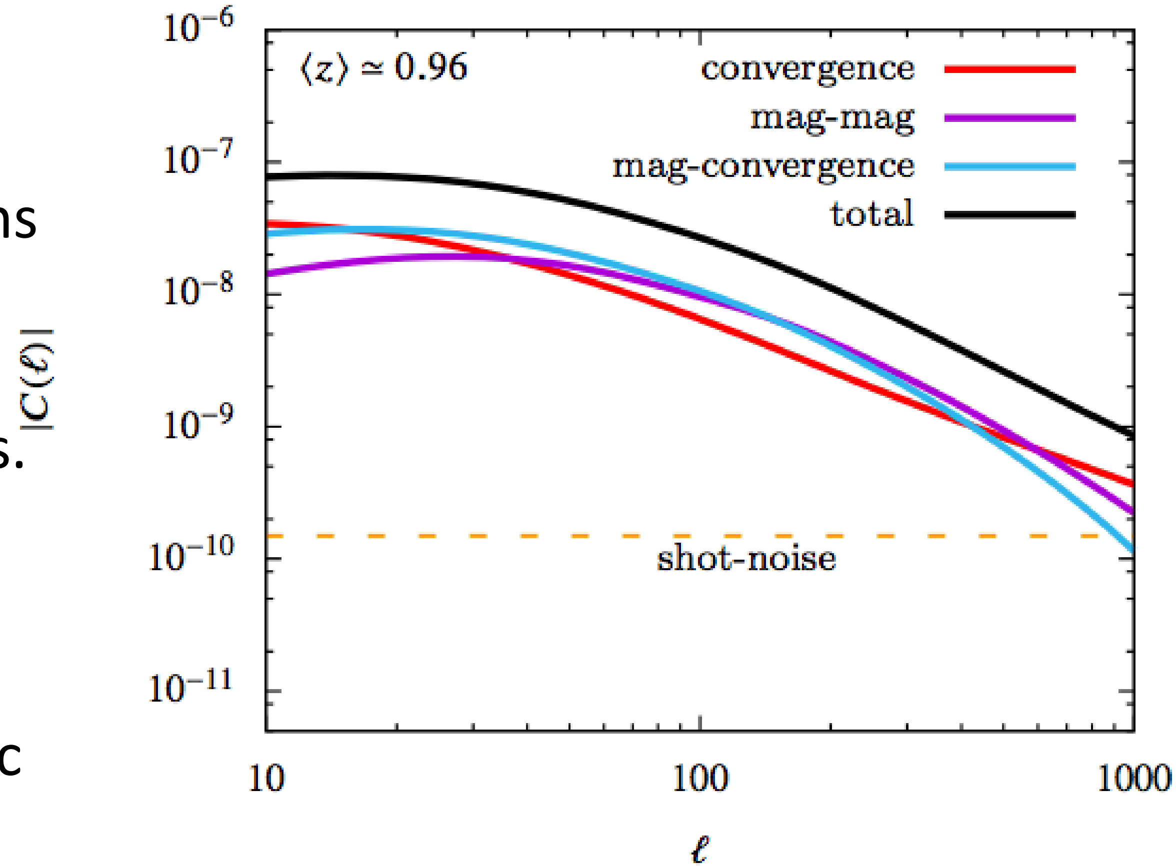
Including magnitudes

The noise properties can be improved by including magnitude and size information together with an optimal weighting.

However, work in progress suggests that the intrinsic correlations are even more important for magnitude correlations.

Potentially consistency of estimators could be used to test for intrinsic effects?



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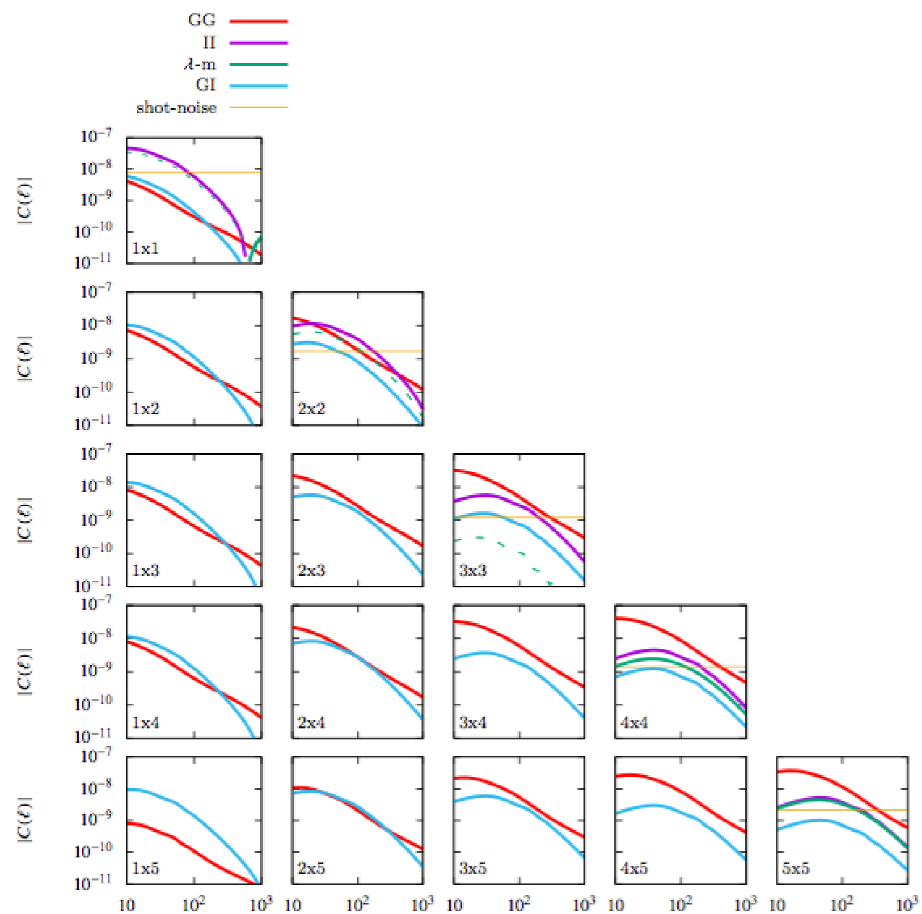
Tomography

Our models indicate that intrinsic correlations can dominate the cosmological signal in tomographic studies.

Like intrinsic alignments, the intrinsic-intrinsic (II) term can dominate in narrow bins, particularly at low redshift.

Similarly, the GI contributions, where background lensing correlates with foreground galaxy properties, can be a significant contaminant.



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Conclusions

- Size and flux magnification can provide complementary information to galaxy shear, though with larger noise.
- In principle, many systematics should be independent. However, like intrinsic alignments, intrinsic size and magnitude correlations are expected to exist.
- As size and magnitude correlate with the underlying mass, their correlations can arise at first order when the bias is mass dependent.
- Our preliminary study, based on the halo model, suggests that intrinsic correlations are an important systematic that must be accounted for, particularly at low redshift and in tomographic studies.