The removal of shear-ellipticity correlations from the cosmic shear signal

Nulling intrinsic alignment

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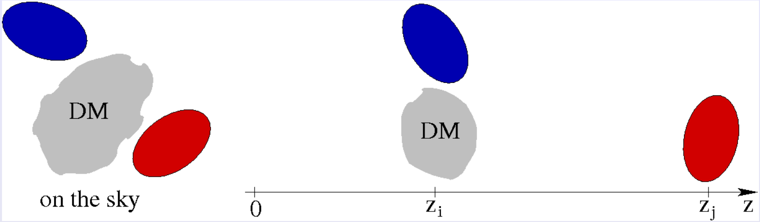
Intrinsic alignment of galaxies



$$\langle \epsilon_i \epsilon_j \rangle = \langle \gamma_i \gamma_j \rangle + \langle \epsilon_i^s \epsilon_j^s \rangle + \underbrace{\langle \gamma_i \epsilon_j^s \rangle + \langle \epsilon_i^s \gamma_j \rangle}$$

GG II GI

	systematic	*geometric method of elimination*
II	intrinsic ellipticity correlations	use redshift information to remove physically close galaxy pairs *(King & Schneider 02, 03; Heymans & Heavens 03)*
GI	shear-ellipticity correlations	use GI redshift dependence to null signal *(Hirata & Seljak 04; Joachimi & Schneider 08)*

Nulling DM contributions

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Projected surface mass density:

$$\kappa^{(j)}(\boldsymbol{\theta}) = \frac{3H_0^2\Omega_{\rm m}}{2c^2} \int_0^{\chi_{\rm hor}} \mathrm{d}\chi \, \frac{g^{(j)}(\chi)\,\chi}{a(\chi)} \, \delta\,(\chi\,\boldsymbol{\theta}, \chi) \qquad \text{(flat Universe)}$$

$$g^{(j)}(\chi) \rightarrow \tilde{g}^{(i)}(\chi) = \int_{\chi}^{\chi_{\rm hor}} \mathrm{d}\chi' B^{(i)}(\chi') \left(1 - \frac{\chi}{\chi'}\right) \qquad \text{new lensing efficiency}$$

No contributions from matter at $\hat{\chi}_i$ if the constraint $\tilde{g}^{(i)}(\hat{\chi}_i) = \int_{\hat{\chi}_i}^{\chi_{\rm hor}} \mathrm{d}\chi\; B^{(i)}(\chi) \left(1 - \frac{\hat{\chi}_i}{\chi}\right) = 0$ is fulfilled

Introduce new power spectrum:

$$\Pi^{(i)}(\ell) := \int_0^{\chi_{\rm hor}} \mathrm{d}\chi\; B^{(i)}(\chi)\; P_\kappa(z(\hat{\chi}_i), z(\chi), \ell)$$

analogous definitions for two-point real-space measures

New cosmic shear measures

$$\Pi^{(i)}(\ell) \approx \sum_{j=i+1}^{N_z} B^{(i)}(\chi(z_j))\, P_\kappa^{(ij)}(\ell)\, \chi'(z_j)\, \Delta z_j \equiv \sum_{j=i+1}^{N_z} T_{[1]\,j}^{(i)}\, P_\kappa^{(ij)}(\ell)$$

Rewrite constraint with same approximation and $T_{[0]\,j}^{(i)} := 1 - \frac{\hat{\chi}_i}{\chi(z_j)}$:

$$\tilde{g}^{(i)}(\hat{\chi}_i) \approx \sum_{j=i+1}^{N_z} B^{(i)}(\chi(z_j)) \left(1 - \frac{\hat{\chi}_i}{\chi(z_j)}\right) \chi'(z_j)\, \Delta z_j \equiv \sum_{j=i+1}^{N_z} T_{[1]\,j}^{(i)} T_{[0]\,j}^{(i)}$$

Construct more new power spectra by

$$\Pi_{[q]}^{(i)}(\ell) = \left(\vec{T}_{[q]}^{(i)} \cdot \vec{P}^{(i)}(\ell)\right) \text{ where } \left(\vec{T}_{[q]}^{(i)} \cdot \vec{T}_{[r]}^{(i)}\right) = 0 \;\forall\; r = 0, \ldots, q-1$$

Create set of $\vec{T}_{[q]}^{(i)}$ by means of Gram-Schmidt orthogonalization $\rightarrow$ results in orthogonal transformation matrix

$$\boldsymbol{T}^{(i)} := \left(\vec{T}_{[0]}^{(i)}, \ldots, \vec{T}_{[N_z-i-1]}^{(i)}\right)$$

Data transformation

$$\vec{\Pi}^{(i)}(\ell_m) = \boldsymbol{T}^{(i)}\ \vec{P}^{(i)}(\ell_m)\ \ \forall\, i, m \quad \text{with } \boldsymbol{T}^{(i)} \text{ orthogonal}$$

i.e. nulling can be understood as a *rotation* of the set of $\left\{\vec{P}^{(i)}(\ell_m)\right\}$ into $\left\{\vec{\Pi}^{(i)}(\ell_m)\right\}$

In $\left\{\vec{\Pi}^{(i)}(\ell_m)\right\}$ the first component for each bin (i) does not fulfill the constraint and is thus contaminated by the GI signal. $\longrightarrow$

If these components are removed, the transformed data vector is free from GI, at the price of losing information.

If the weighting is combined with a data compression algorithm, one can reduce the number of new power spectra to one per bins (i), ℓ_m.
(Joachimi & Schneider 08)

Fisher matrix analysis

Statistical analysis with the Fisher matrix: *(e.g. Tegmark et al. 1997)*

$$F_{\mu\nu} = \sum_{\alpha,\beta=1}^{N_P} \frac{\partial P_{\mathrm{f}\alpha}}{\partial p_\mu} \left(C_P{}^{-1} \right)_{\alpha\beta} \frac{\partial P_{\mathrm{f}\beta}}{\partial p_\nu}$$

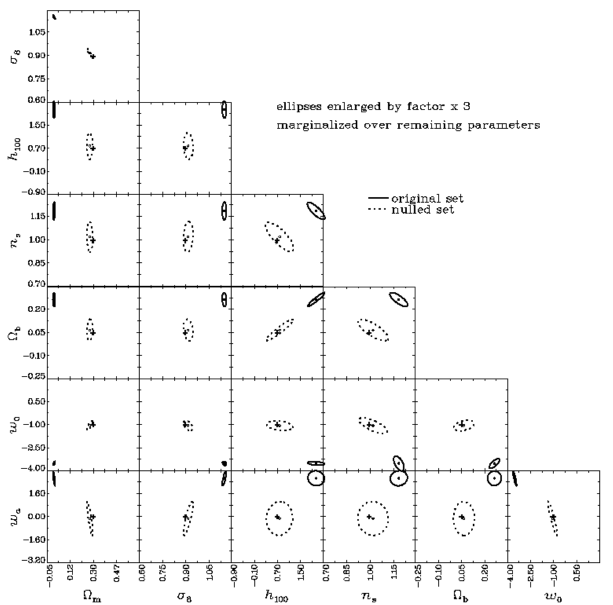
Bias formalism: *(e.g. Huterer & Takada 2005)*

$$b_{p_\mu} \equiv \Delta p_\mu = \sum_\nu \left(F^{-1} \right)_{\mu\nu} \sum_{\alpha,\beta=1}^{N_P} P_{\mathrm{sys}\,\alpha} \left(C_P{}^{-1} \right)_{\alpha\beta} \frac{\partial P_{\mathrm{f}\beta}}{\partial p_\nu}$$

Fisher matrix for parameter-dependent data transformation $\boldsymbol{T}(\vec{p})$:

- likelihood transform yields extra $|\det \boldsymbol{T}|^{-1}$ $\rightarrow$ extra terms in $F_{\mu\nu}$
- derivation of $F_{\mu\nu}$ modified since data vector itself becomes $\vec{p}$-dependent (in addition to mean vector)
- covariance depends on $\vec{p}$ even if original C does not

Performance of nulling



Parameters:

$\{\Omega_m, \sigma_8, h_{100}, n_s, \Omega_b, w_0, w_a\}$

$w(a) = w_0 + w_a(1 - a)$

flat Universe

Signal:

tomographic shear power spectra *(Smith et al. 03)*

non-linear PS

$N_z = 10$, $N_\ell = 100$

Systematic:

GI simplified linear alignment toy model *(Hirata & Seljak 04, Bridle & King 07)*

Performance of nulling

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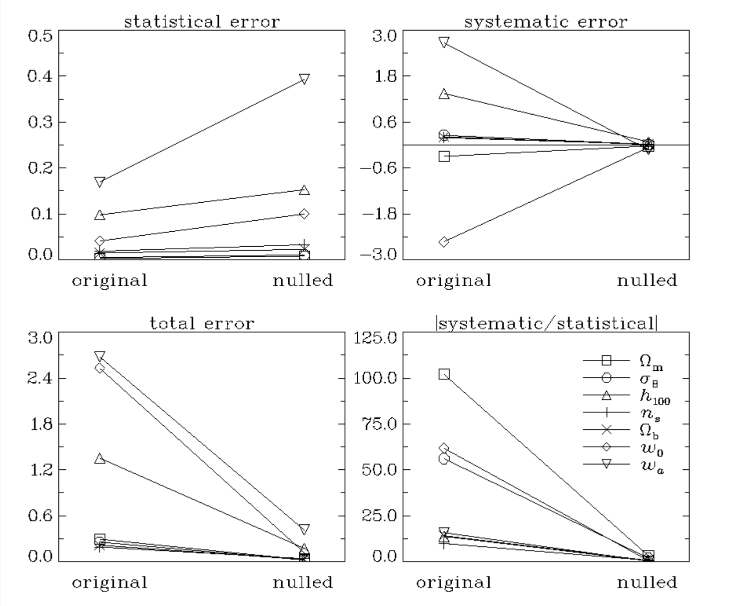

Conclusions & Outlook

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- nulling largely removes shear-ellipticity correlations from the cosmic shear signal
- statistical errors on cosmological parameters are moderately increased; mean square error decreases strongly
- nulling does not rely on an intrinsic alignment model
- to work efficiently, precise redshift information is needed

Next steps:

- assess requirements on photometric redshifts
- find optimal way of nulling in case of limited knowledge about systematic signal
- extend method to three-point shear statistics