galaxy ellipticities as cosmological probes

workshop: gravity on the largest scales

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outline

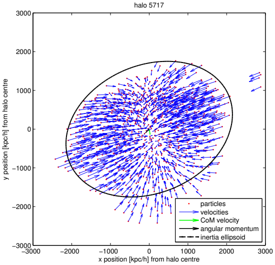
weak cosmic shear and intrinsic alignments

- weak lensing shear: projected tidal field along the line of sight
- combines information about growth, geometry and statistics
- Euclid: measures shear with up to 1000σ of significance
  - precision determination of cosmological parameters
  - investigation of models of gravity on large scales
- assumption: uncorrelated intrinsic shapes $\rightarrow$ **not true**
- intrinsic alignments: correlations between shapes of galaxies
  - galaxy formation process and angular momentum generation
  - interaction of galaxies with local tidal fields
- properties:
  - small scale phenomena
  - statistics not easy to derive
  - contamination of lensing surveys at the 10%-level
  - generation of shear B-modes (most important effect!)
  - cross correlation with weak lensing shear

alignment models: many questions

1. quadratic alignments → for spirals and spheroids?
   - tidal shearing generates halo angular momentum
   - symmetry axis of the stellar disk aligns
   - ☺ theory well developed, perturbative process
   - ☹ overestimates signal, baryonic physics poorly understood
2. linear alignments → for ellipticals?
   - tidal shear distorts the stellar ellipsoid
   - leakage of the stars into the direction of tidal shear distortion
   - ☺ theory reasonably well to handle, alignments found in CFHTLenS
   - ☹ GI-alignments
3. accretion models
   - halo alignment due to anisotropic accretion on halos along filaments
4. vorticity alignments
   - alignment of haloes with local vorticity field

tidal torquing simulations



particle velocities around a forming halo

- non-minimal coupling of haloes to the tidal shear field
- angular momentum $L_i \propto \epsilon_{ijk} I_{jl} \partial^2_{lk} \Phi$
- analytic treatment possible, tidal shear correlation functions

theory of quadratic alignments

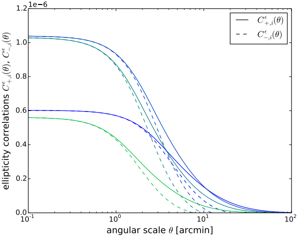
- halo angular momentum $\vec{L}$ generated by tidal shearing $\partial^2_{ij}\Phi$
- effective description with a conditional probability $p(\vec{L}|\partial^2_{ij}\Phi)\mathrm{d}\vec{L}$
- angular momentum direction tilts the disk and changes complex ellipticity $\epsilon = \epsilon_+ + \mathrm{i}\epsilon_\times$:

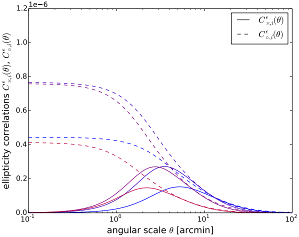
$$\epsilon_+ = \frac{\hat{L}_y^2 - \hat{L}_x^2}{1 - \hat{L}_z^2} \quad \text{and} \quad \epsilon_\times = 2\frac{\hat{L}_x\hat{L}_y}{1 + \hat{L}_z^2}$$

  with the angular momentum direction $\hat{L} = \vec{L}/L$
- prediction of 4 ellipticity spectra: $C_E(\ell)$, $C_B(\ell)$, $C_C(\ell)$ and $C_S(\ell)$ including correlations of the scalar ellipticity $|\epsilon| = \sqrt{\epsilon_+^2 + \epsilon_\times^2}$ and cross-correlation with the E-mode, analogy to CMB polarisation

disk orientation

intrinsic ellipticity correlations

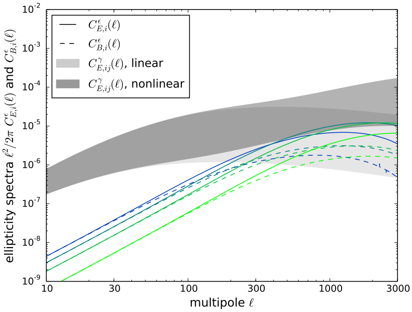




angular ellipticitiy correlation functions $C^{\epsilon}(\theta)$

- angular ellipticity correlation functions, for Euclid tomography

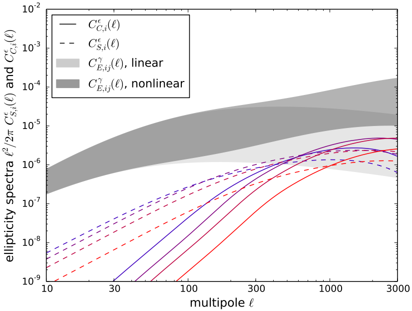
intrinsic ellipticity E- and B-mode



ellipticity spectra $C^{\epsilon}_{E}(\ell)$ and $C^{\epsilon}_{B}(\ell)$

- tomographic spectra for Euclid
- small scale correlations, similar to linear lensing, smaller than nonlinear lensing in all bins

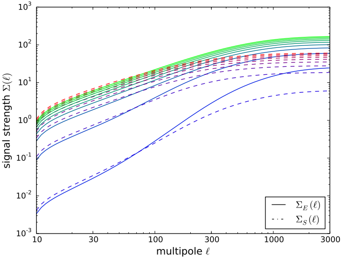
intrinsic ellipticity C- and S-mode



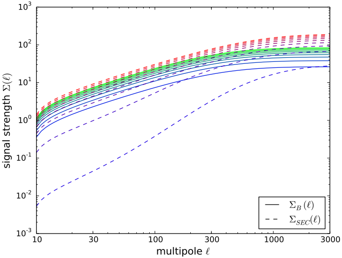
ellipticity spectra $C^{\epsilon}_{S}(\ell)$ and $C^{\epsilon}_{C}(\ell)$

- tomographic spectra for Euclid
- 2 new observables, spectra similar, cross-spectrum steeper at low ℓ

observability of the ellipticity spectra



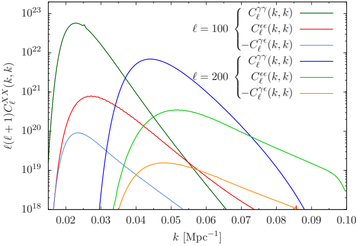
s/n-ratio E and S alone



s/n-ratio ESC combined, B

- all 4 spectra are observable with Euclid, tomography boosts signal
- measurement of the alignment parameter with percent accuracy

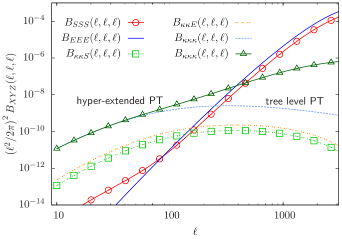
3d ellipticity alignments



3d intrinsic alignment and lensing spectra $C_\ell^{\epsilon}(k,k)$

- incorporate intrinsic alignments into the 3d weak lensing formalism
- for quadratic (theory) and linear (theory and numerics) alignments

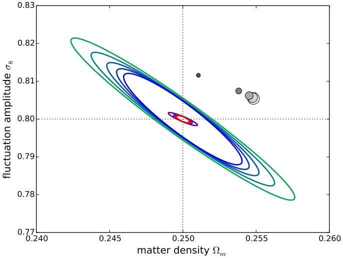
ellipticity bispectra



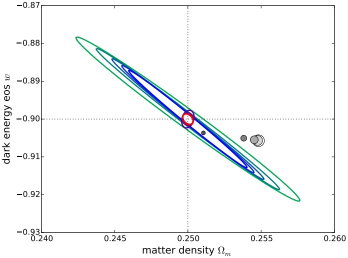
ellipticity bispectra $B_{XZY}(\ell,\ell,\ell)$, equilateral configuration

- ellipticity bispectra, linear alignment model
- different configuration dependence compared to lensing
- surprisingly strong, confirms Elisabetta Semboloni's results on simulations

parameter estimation biases



Ω_m-σ_8-plane



Ω_m-w-plane

- Euclid weak lensing survey, up to 6 bins
- estimation biases are significant

summary

- resonable understanding of linear and quadratic alignments
  - spectra (tomographic, 3d) and bispectra
  - intrinsic ellipticity spectra can be measured with Euclid
  - parameter estimation biases significant
- mechanisms for tidal interaction are understood
- formation of stellar component/baryonic physics difficult

current developments

alignments as cosmological probes, relation between tidal fields and ellipticity distribution (for different galaxy types), GI-alignments, more elaborate alignment models, simulations

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