Intrinsic Alignments of Galaxies and Halos

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Outline

• Introduction
• Intrinsic Alignments in Illustris Simulations
• (Galaxy-Halo (Mis)Alignments in CFHTLenS: see arxiv:1507.04301)
• Summary and Outlook
LSS & Gravitational Lensing

- deflection $\alpha \rightarrow$ shift in apparent position
- differential deflection $\partial \alpha / \partial \vartheta \rightarrow$ image distortion
Correlating Image Distortions

\[ \langle \varepsilon_i^* \varepsilon_j \rangle \approx \langle \gamma^* \gamma \rangle (\vartheta) = \xi_+ (\vartheta) \approx \int d\vartheta g(\vartheta) w_+ (\vartheta, \vartheta) \]

- \( \varepsilon_i \) observed image ellipticity
- \( \gamma \) shear
- \( \xi_+ \) cosmic shear correlation function
- \( g \) geometric weight
- \( w_+ \) (projected) matter correlation function
Illustris Simulation Project

- suite of simulations:
  - box size 25 – 100 Mpc
  - mass resolution $\sim 10^6 \ M_{\text{solar}}$
  - spatial resolution: $\sim 1 \ \text{kpc}$

- various recipes for baryon physics (incl. DM only)

- using moving-mesh code Arepo (Springel 2010)
Impact of Baryons

DM + baryons

cooling, star formation

winds, SN, AGN,...
Cosmic Shear Correlations

\[ \xi_{\pm}(\theta) \text{ full/DM} \]

\[ \theta [\text{arcmin}] \]
Intrinsic Alignment

\[ \langle \epsilon_i^* \epsilon_j \rangle \approx \langle \gamma^* \gamma \rangle (\mathcal{G}) \]
Intrinsic Alignment

\[ \langle \varepsilon_i^* \varepsilon_j \rangle \approx \langle \gamma^* \gamma \rangle (\vartheta) + \langle \gamma^* \varepsilon_j^{(i)} \rangle (\vartheta) + \langle \varepsilon_i^{* (i)} \gamma \rangle (\vartheta) + \langle \varepsilon_i^{* (i)} \varepsilon_j^{(i)} \rangle (\vartheta) \]

\[ = \text{GG} + \text{GI} + \text{IG} + \text{II} \]
Intrinsic Alignment: II

on the sky:

common large-scale environment

side view:

background galaxies

z
Intrinsic Alignment: GI

on the sky:

- foreground galaxy with DM halo
- background galaxies

side view:

- observer's perspective
Galaxy Images
Galaxy Images

Gas (mass, metals)  Stars (mass, IMF, age, metals) → Transmitted projected light

Obs. mag., size, image shape
Illustris: Galaxy Sizes

$z = 0.3$

$r_{hi}[h^{-1}\text{ kpc}]$

$M_i$

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Intrinsic Alignments...
Illustris: Galaxy Ellipticities

\[ \langle \epsilon_i^2 \rangle^{1/2} = 0.15 \]
Illustris: Intrinsic Alignment: II

$z = 0.3$ II: $w_+$

$r [h^{-1} \text{ kpc}]$
Illustris: Intrinsic Alignment: GI

$w_+(r)$ vs $r$ [h$^{-1}$ kpc] for different redshifts and star formation histories.
Illustris: Intrinsic Alignment: GI

$w_{\delta+}(r)$ [$h^{-1}$ kpc]

- $z = 0.3$ GI:
  - all
  - early
  - late

$r$ [$h^{-1}$ kpc]
Illustris: Intrinsic Alignment: GI

\[ w_{\delta^+}(r) \left[ h^{-1} \, \text{kpc} \right] \]

\[ z = 0.3 \, \text{GI}: \]
- \( i \leq 20.5 \)
- \( i \leq 24.5 \)
- \( i \leq 27.5 \)
Illustris: Intrinsic Alignment: GI

\[ w_{\delta^+}(r) \] [\( h^{-1}\text{ kpc} \)]

GI: \( i \leq 24.5 \)

- \( z = 0.1 \)
- \( z = 0.3 \)
- \( z = 0.6 \)
Illustris: Intrinsic Alignment: GI

$z = 0.6 \times z = 1.0$

$\xi_+(\theta)$

$\theta$ [arcmin]
Summary

• interpreting weak lensing surveys:
  - DES, KiDS, etc. need error on prediction < few %
  - Euclid, LSST need < 1%

• impact of baryon physics:
  - ≤ 20% on matter correlations & cosmic shear corr.
  - sign & magnitude depend on scale and redshift

• intrinsic alignment of galaxies:
  - dep. on scale, redshift, galaxy properties
  - ~10% contamination for cosmic shear signal
Outlook

• to do:
  – alignment model parameters
  – test more physical alignment models (3D)
  – more/better simulations to constrain impact of baryon physics on matter distribution and intrinsic alignment
  – better (semi)analytic models
  – ...

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Thanks for Your Attention!