Gravitational Lensing, Baryons, and Intrinsic Alignments

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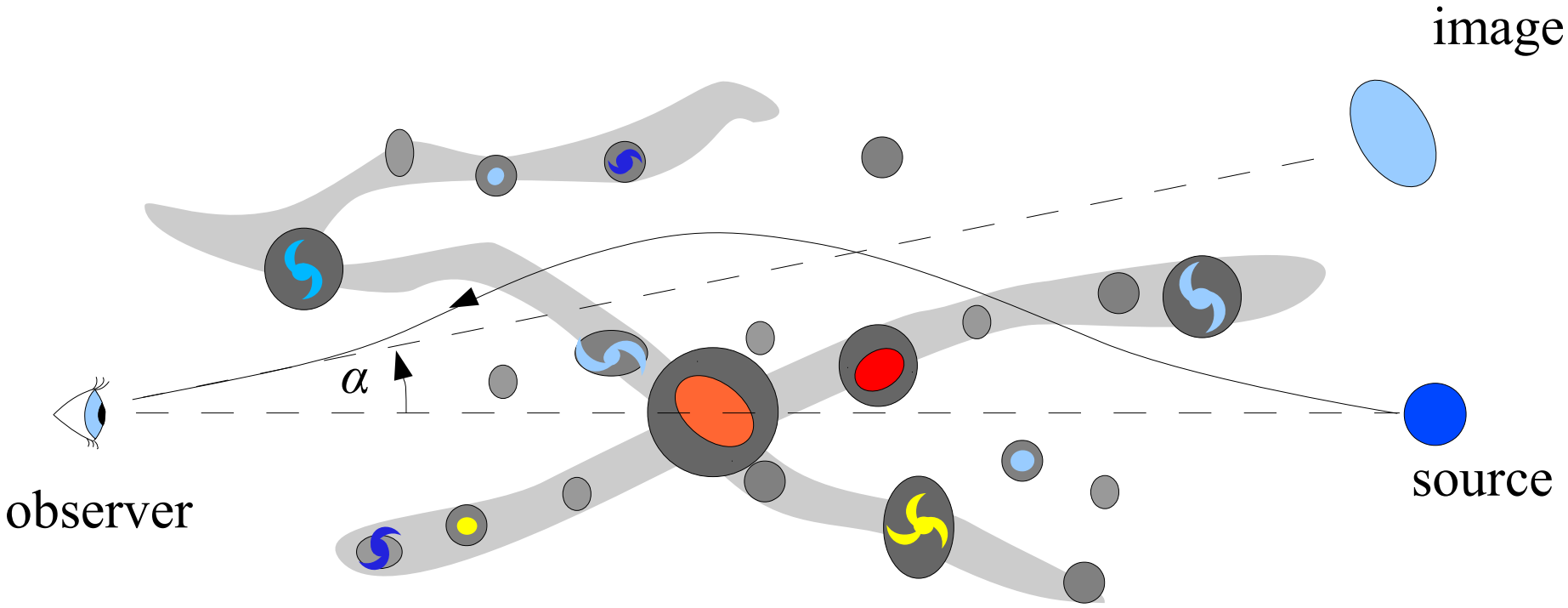
Outline

- Motivation
- Baryon physics impact on matter distribution
- Intrinsic alignments
- Summary and Outlook

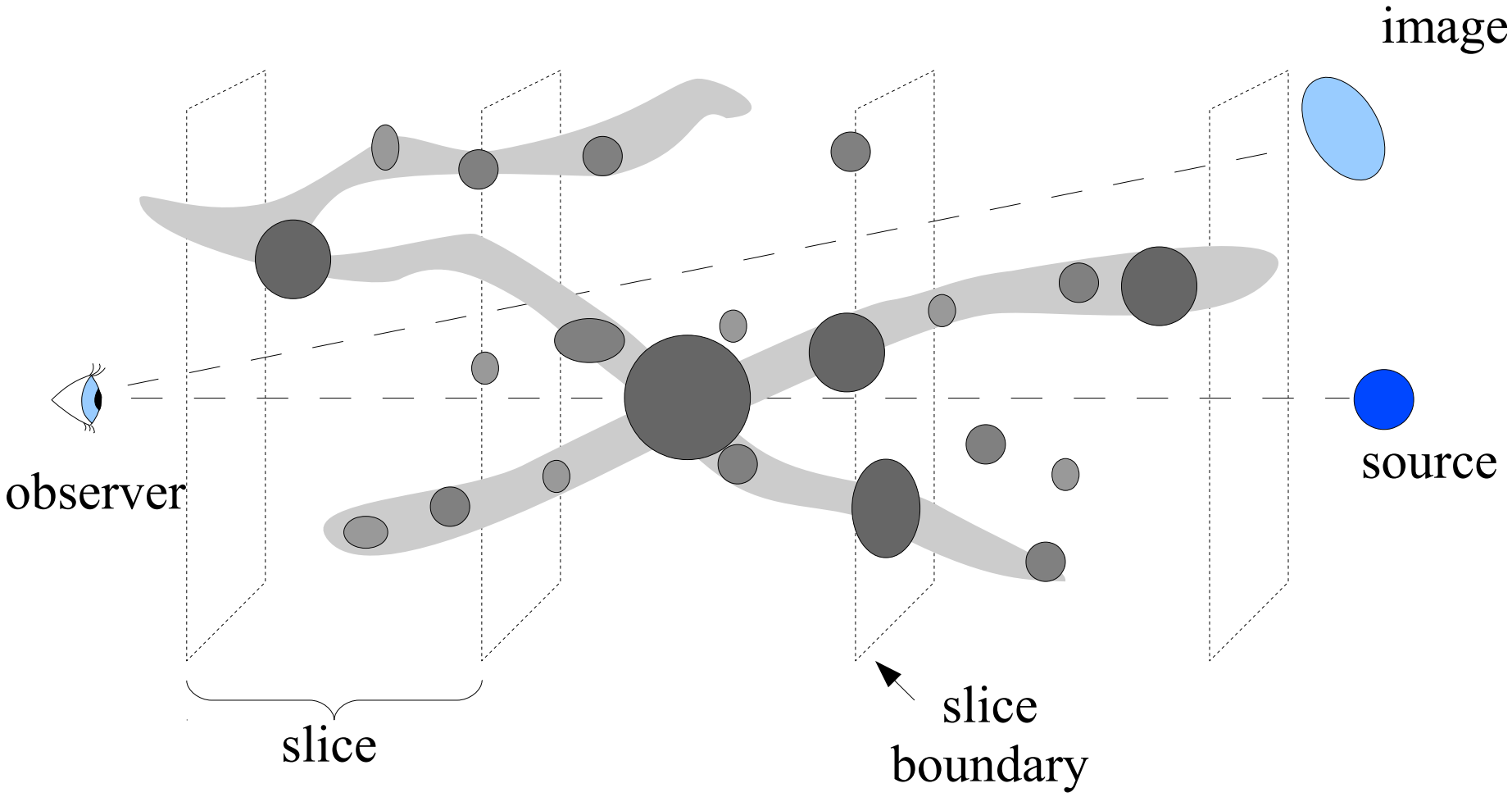
Motivation

Gravitational Lensing

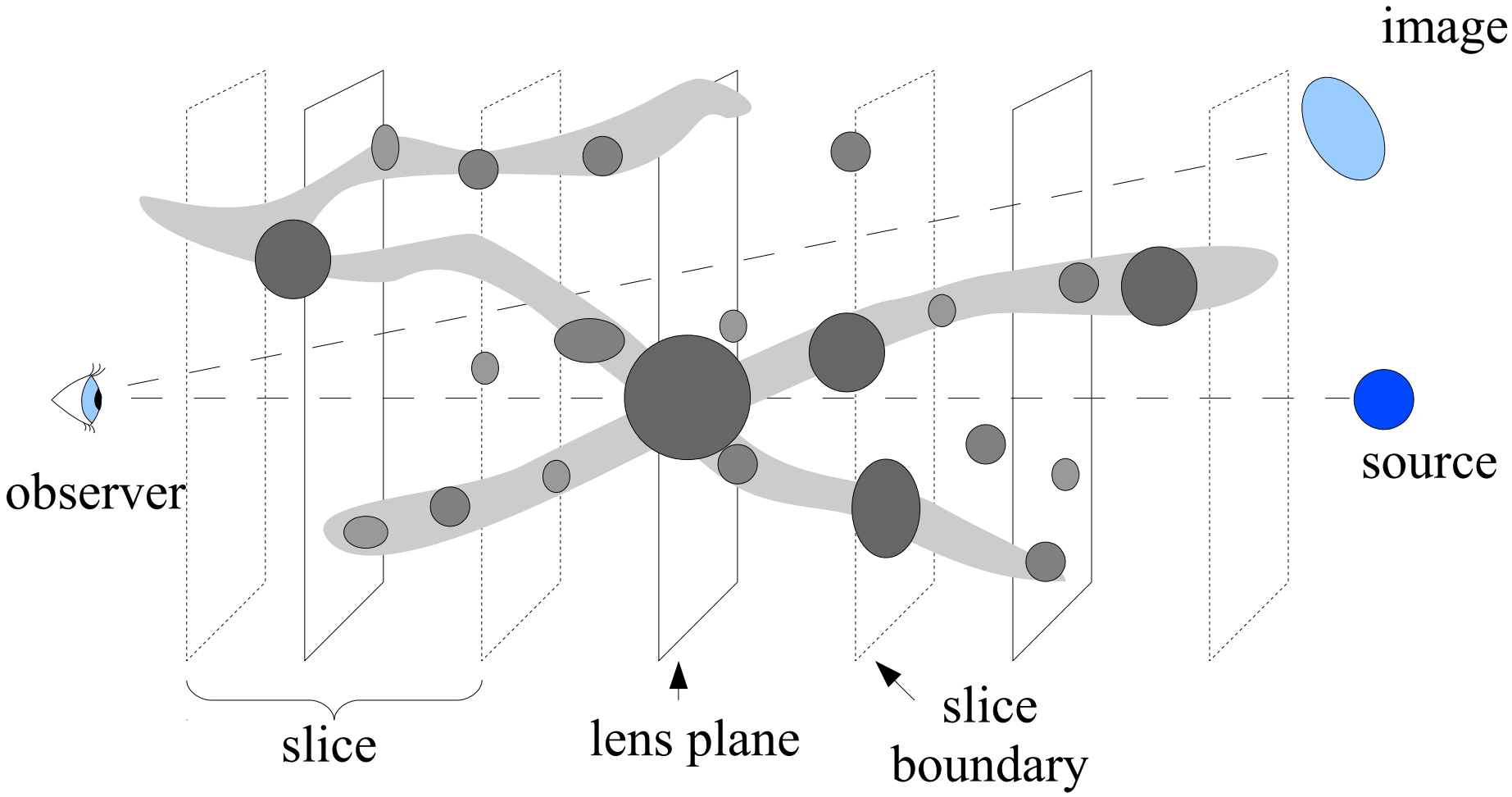


- deflection $\alpha \rightarrow$ shift in apparent position
- differential deflection $\partial\alpha/\partial\vartheta \rightarrow$ image distortion

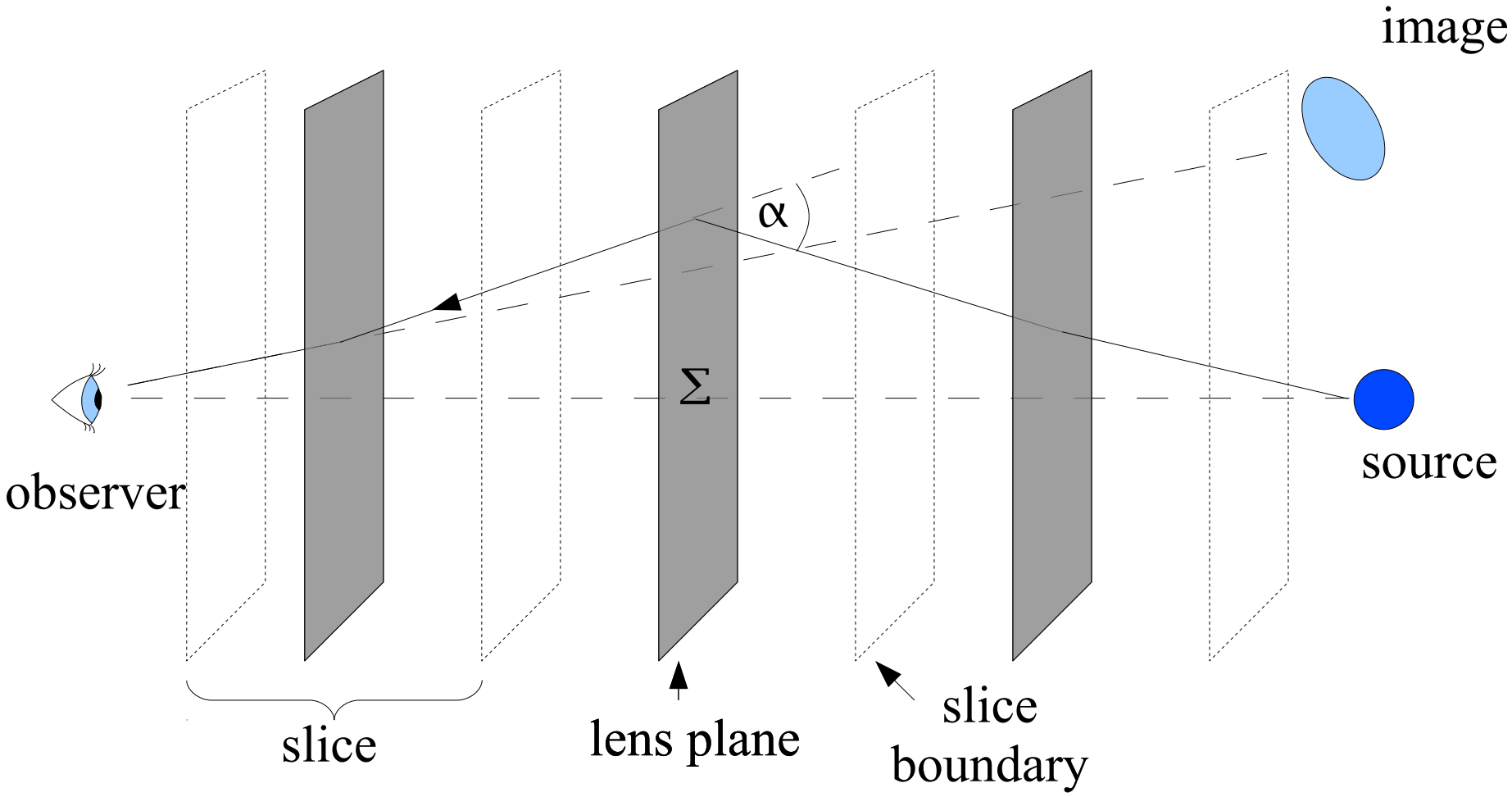
Multiple-Lens-Plane Approximation



Multiple-Lens-Plane Approximation

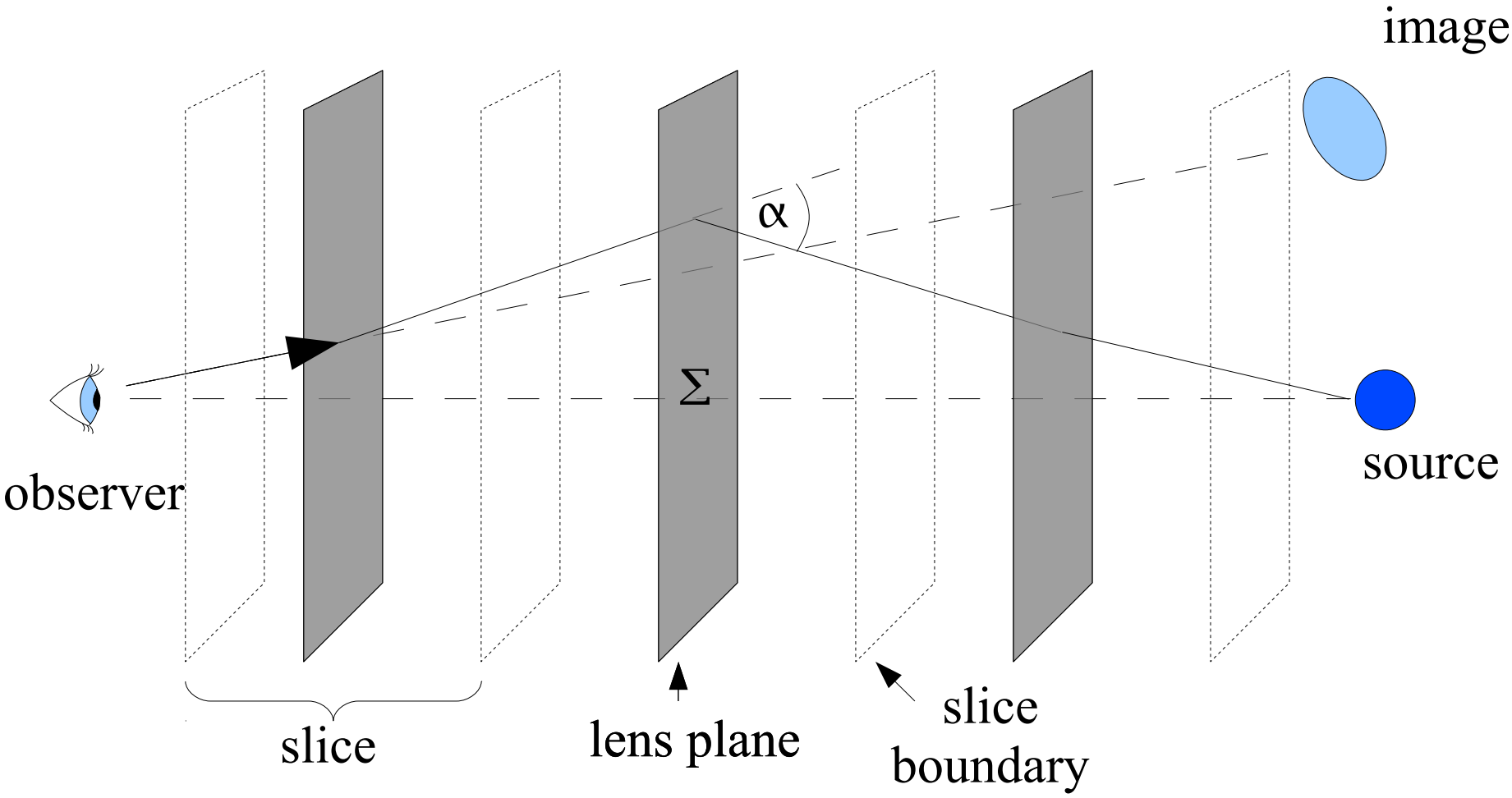


Multiple-Lens-Plane Approximation



$$\Psi = \left(\nabla^2\right)^{-1}\Sigma \;\Rightarrow\; \alpha = \nabla\Psi$$

Multiple-Lens-Plane Approximation



$$\Psi = (\nabla^2)^{-1}\Sigma \;\Rightarrow\; \alpha = \nabla\Psi$$

Lensing Simulations

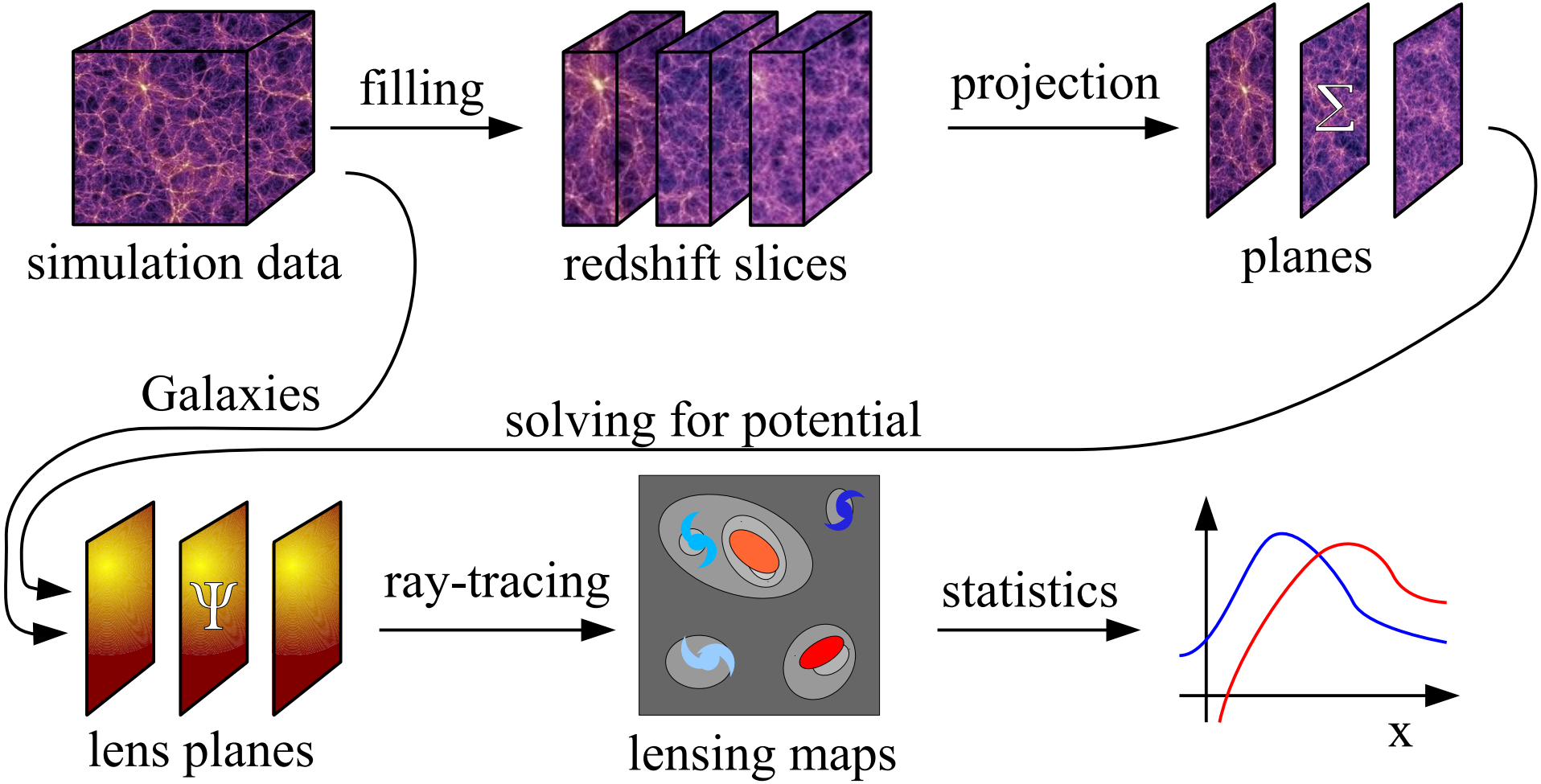
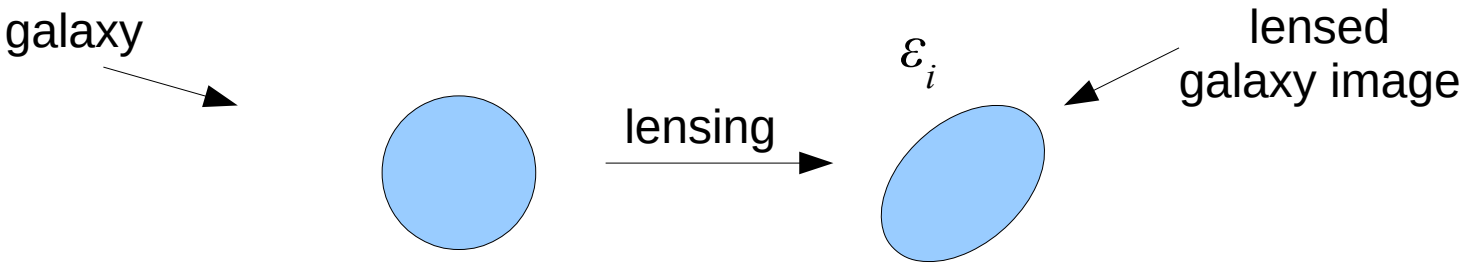


Image Distortions



$$\varepsilon_i \approx \gamma$$

- ε_i observed galaxy image ellipticity
- γ shear ~ differential deflection $\partial\alpha/\partial\vartheta$

Image Distortions: Ellipticity

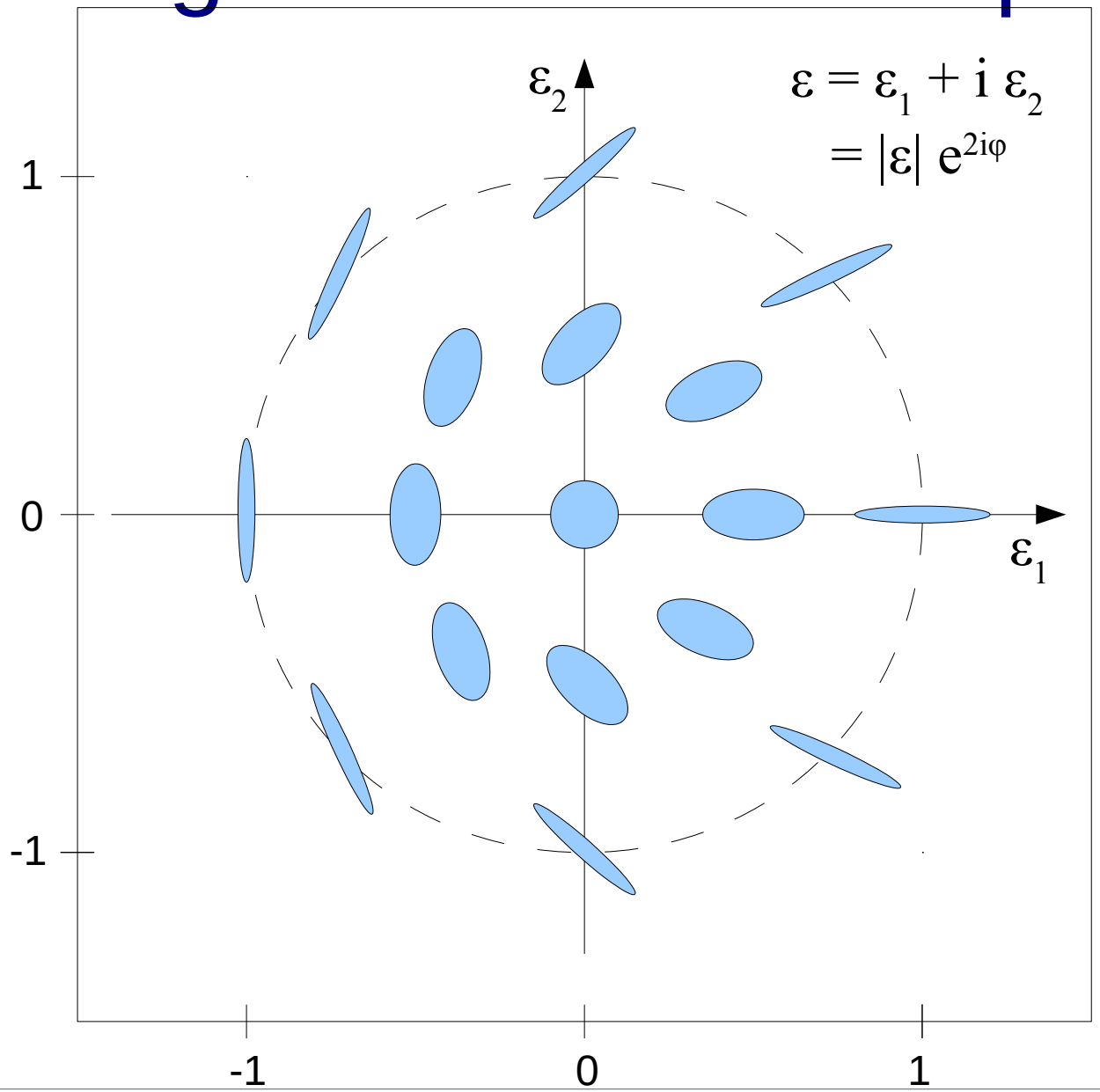
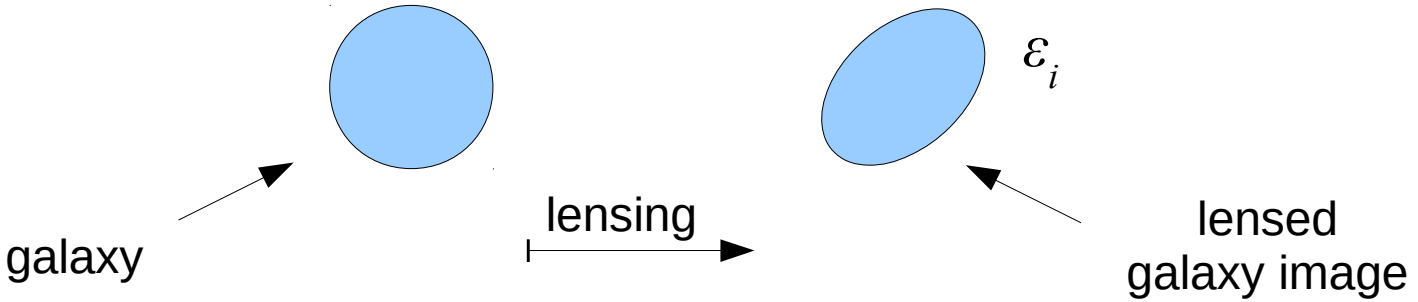


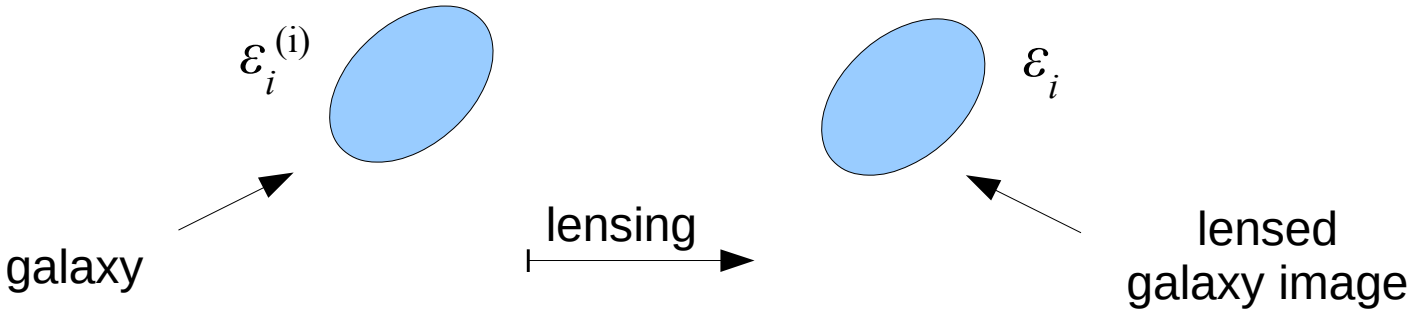
Image Distortions



$$\varepsilon_i \approx \gamma$$

- ε_i observed image ellipticity
- γ shear

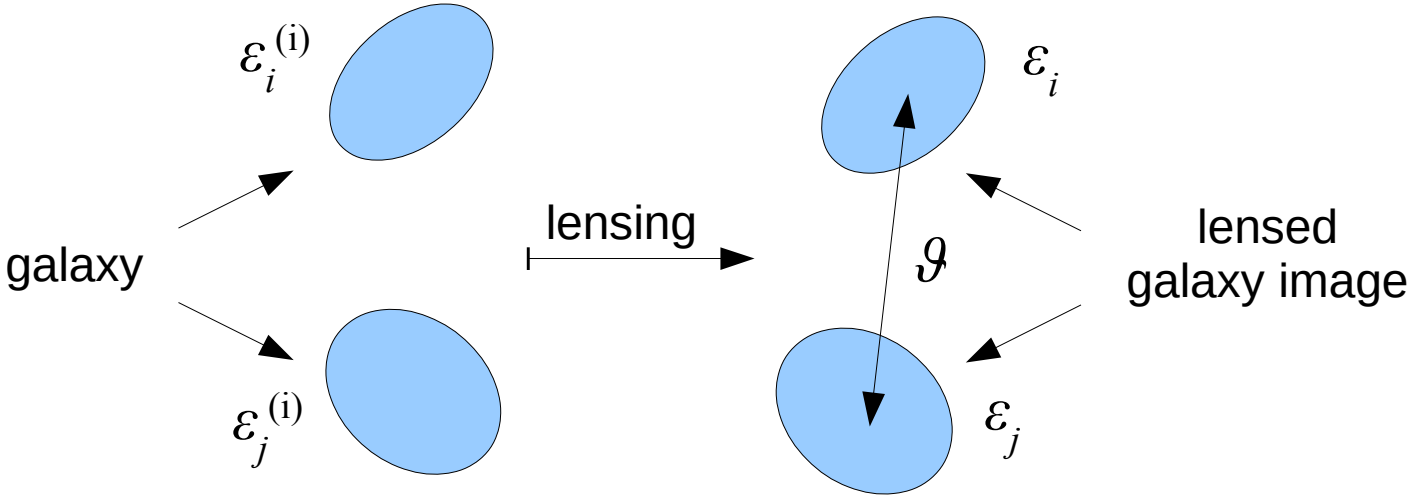
Image Distortions



$$\varepsilon_i \approx \gamma + \varepsilon_i^{(i)}$$

- ε_i observed image ellipticity
- γ shear
- $\varepsilon_i^{(i)}$ intrinsic ('true') galaxy ellipticity $\gg \gamma$

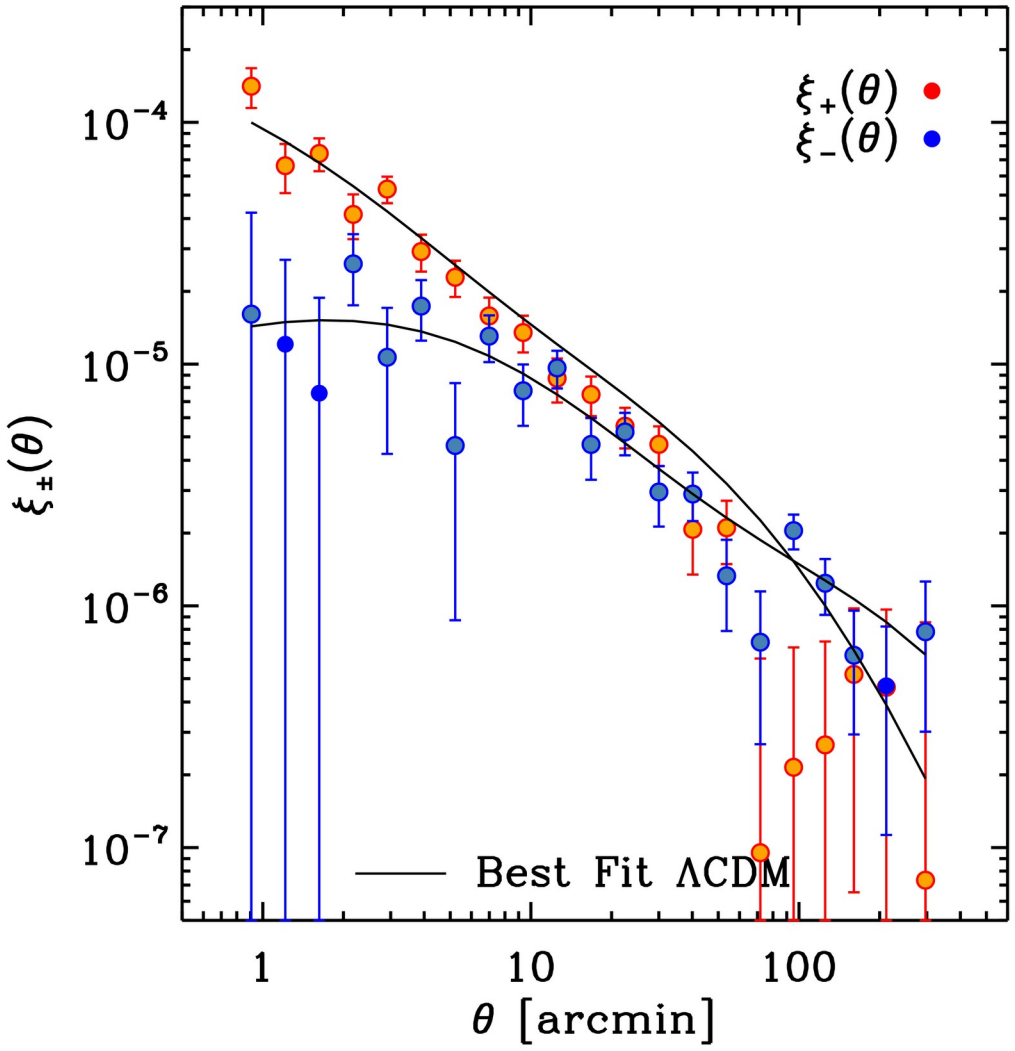
Correlating Image Distortions

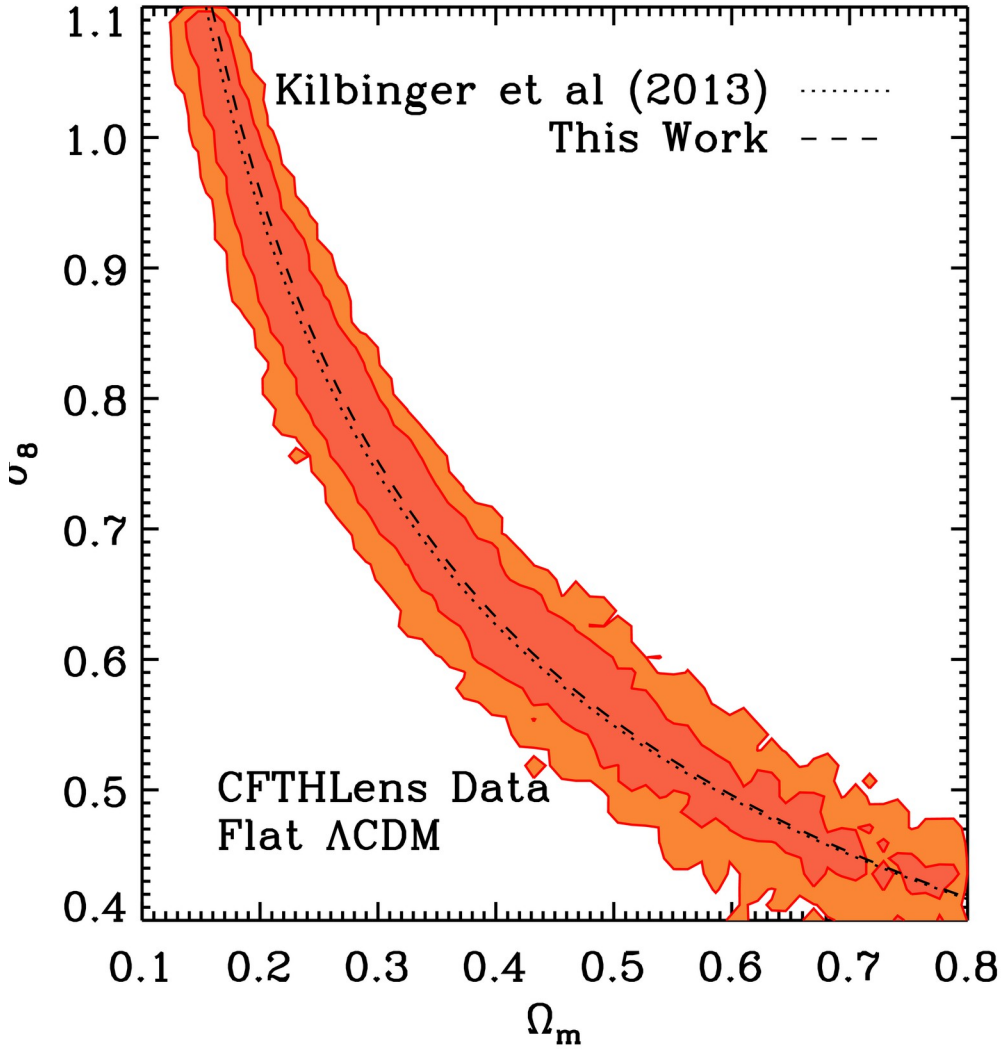


$$\langle \varepsilon_i^* \varepsilon_j \rangle \approx \langle \gamma^* \gamma \rangle(\vartheta) = \xi_+(\vartheta) \approx \langle \kappa \kappa \rangle(\vartheta) \approx \int dz\, g(z)\, w_{\delta+}(f_K(z)\vartheta, z)$$

- ε_i observed image ellipticity
- γ shear
- ξ_+ shear correlation function
- κ convergence
- $w_{\delta+}$ projected matter correlation

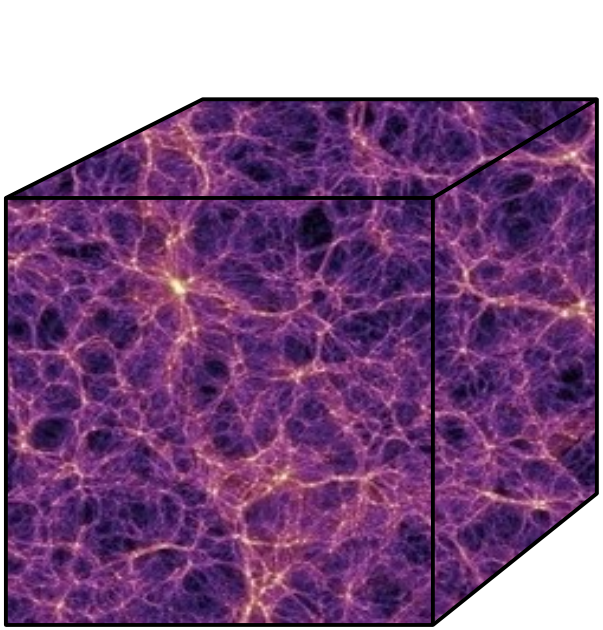
Cosmic Shear Correlations in CFHTLenS



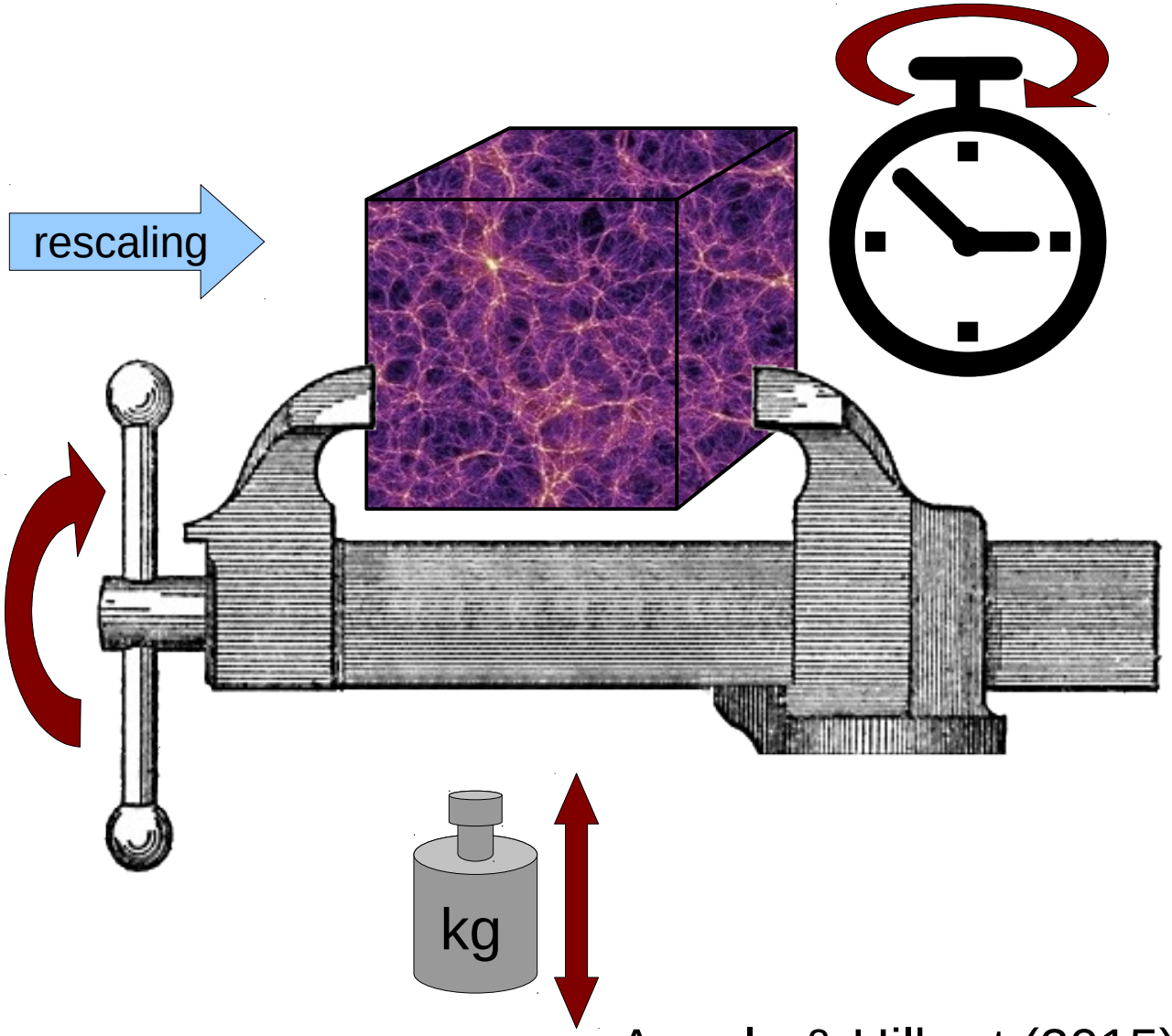


Angulo & Hilbert (2015)

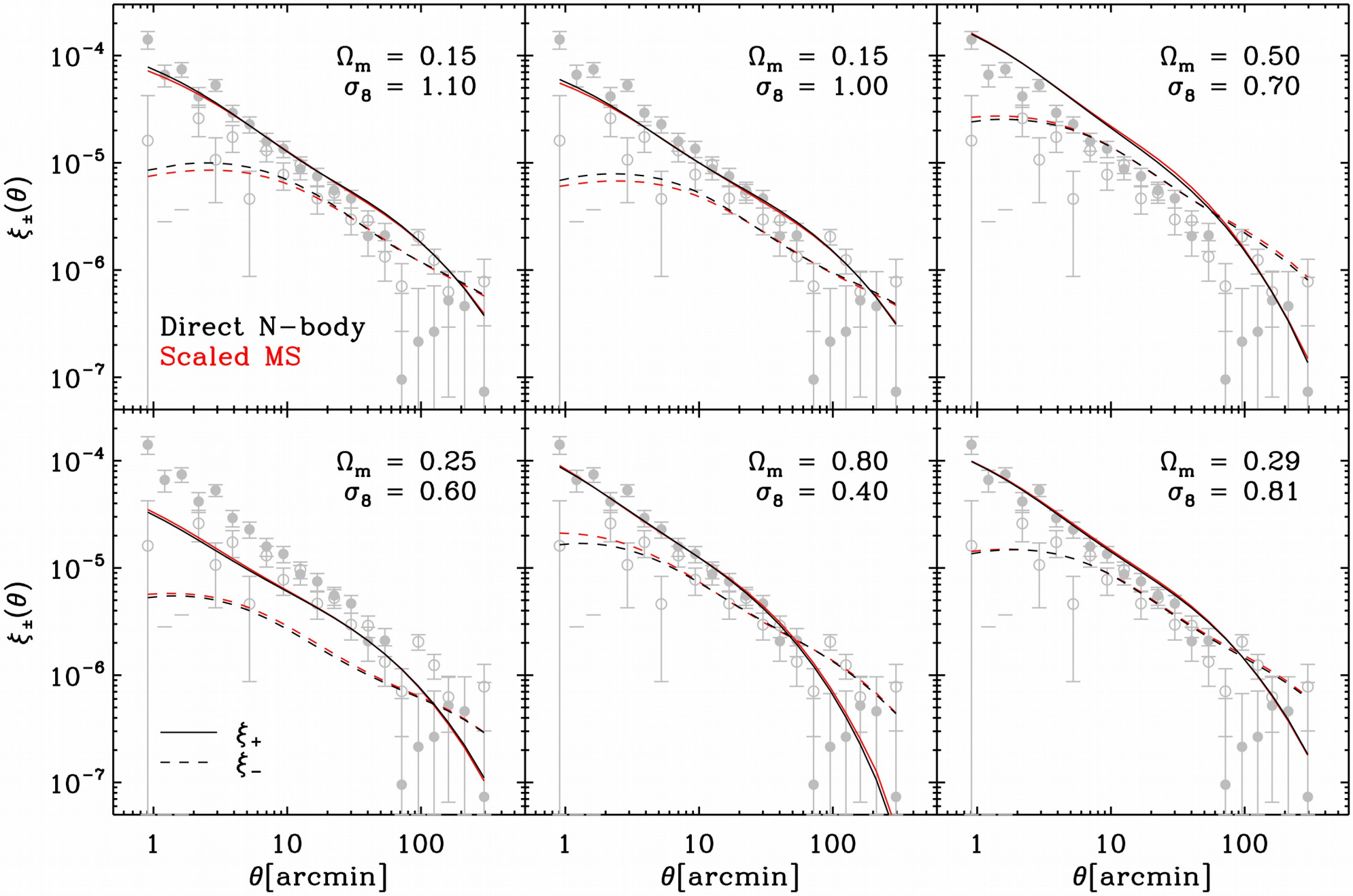
Cosmology Scaling



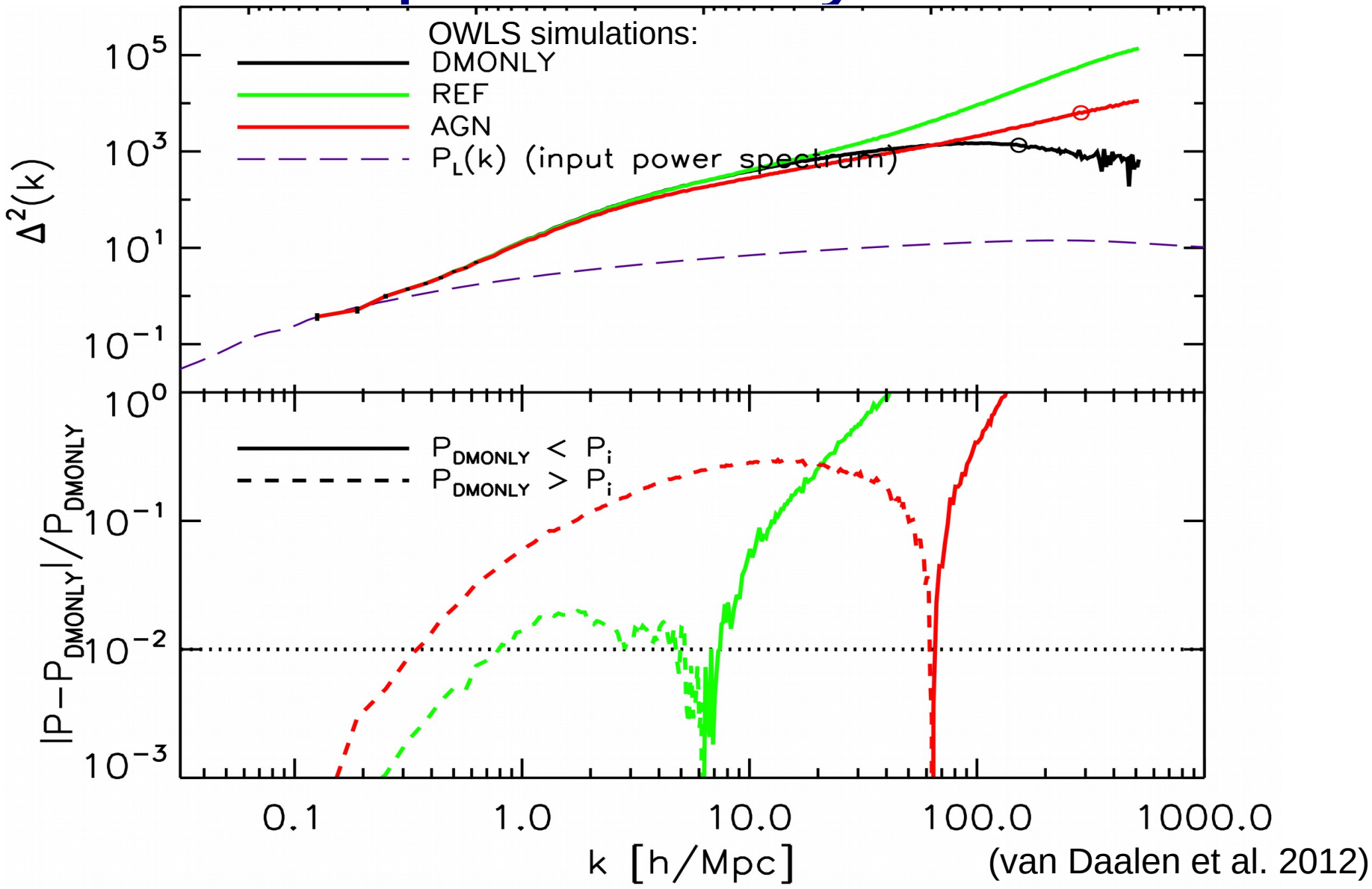
simulation data



Angulo & Hilbert (2015)

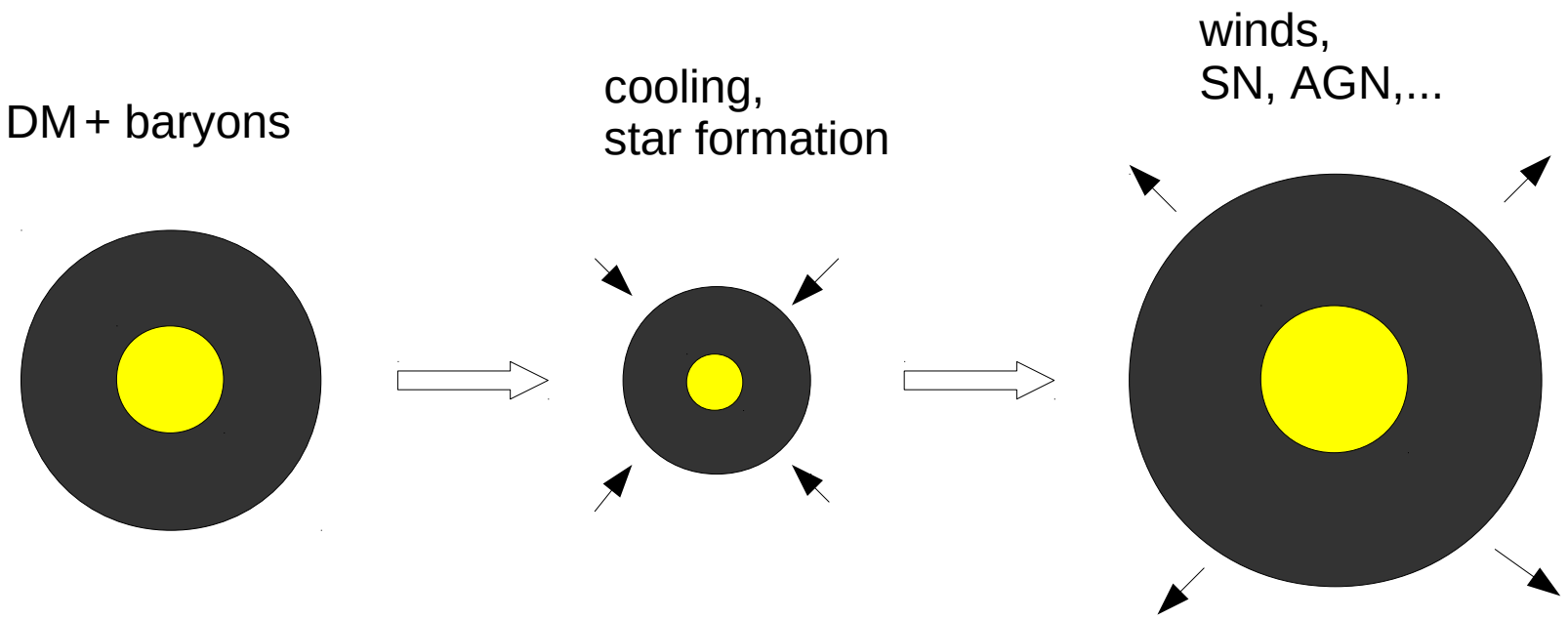

Ω_m = 0.15
σ_8 = 1.10
Ω_m = 0.15
σ_8 = 1.00
Ω_m = 0.50
σ_8 = 0.70
Ω_m = 0.25
σ_8 = 0.60
Ω_m = 0.80
σ_8 = 0.40
Ω_m = 0.29
σ_8 = 0.81
Direct N−body
Scaled MS
ξ_+
ξ_-
$\xi_{\pm}(\theta)$
θ[arcmin]
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
10
100

Impact of Baryons



(van Daalen et al. 2012)

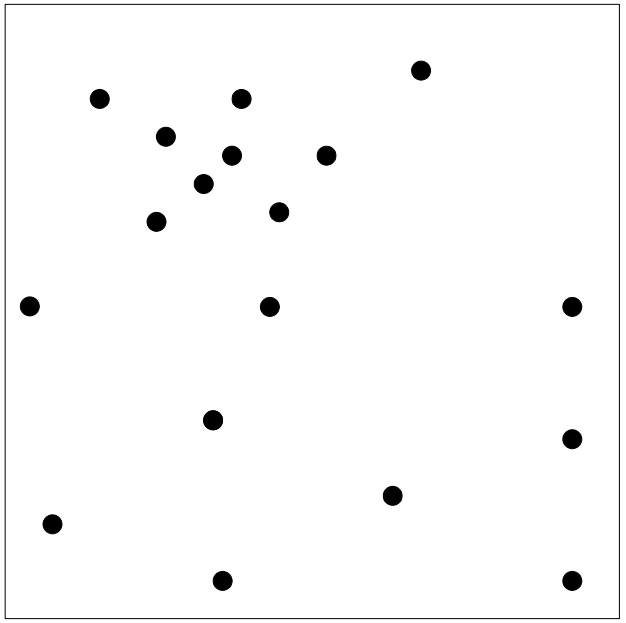
Impact of Baryons



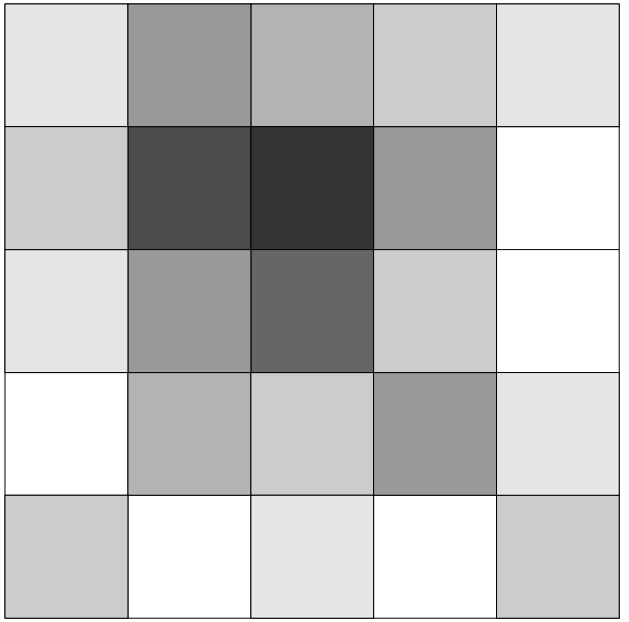
Illustris Simulation Project

- suite of simulations
  - box size 25 Mpc - 100 Mpc
  - mass resolution ~ 10^6 $M_{\odot}$
  - spatial resoluton ~1 kpc
- various recipes for baryonic physics (incl. DM-only)
- uses moving-mesh code Arepo (Springel 2010)

Structure Formation Simulations



N-body / SPH

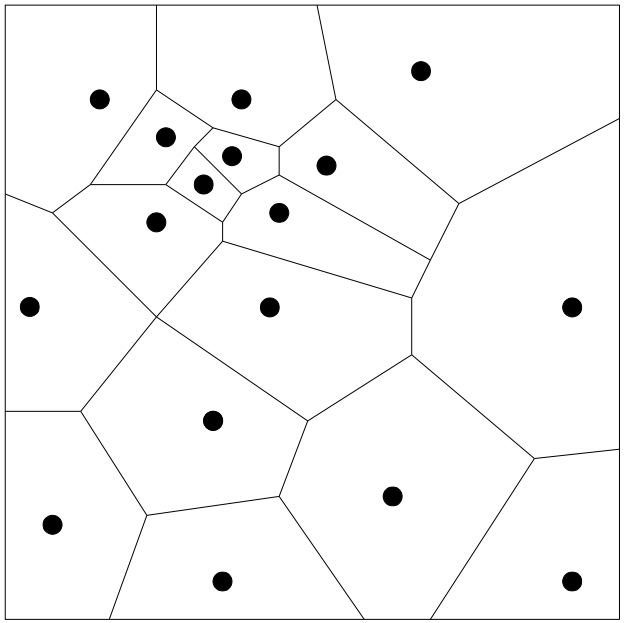


Hydro Mesh

Arepo

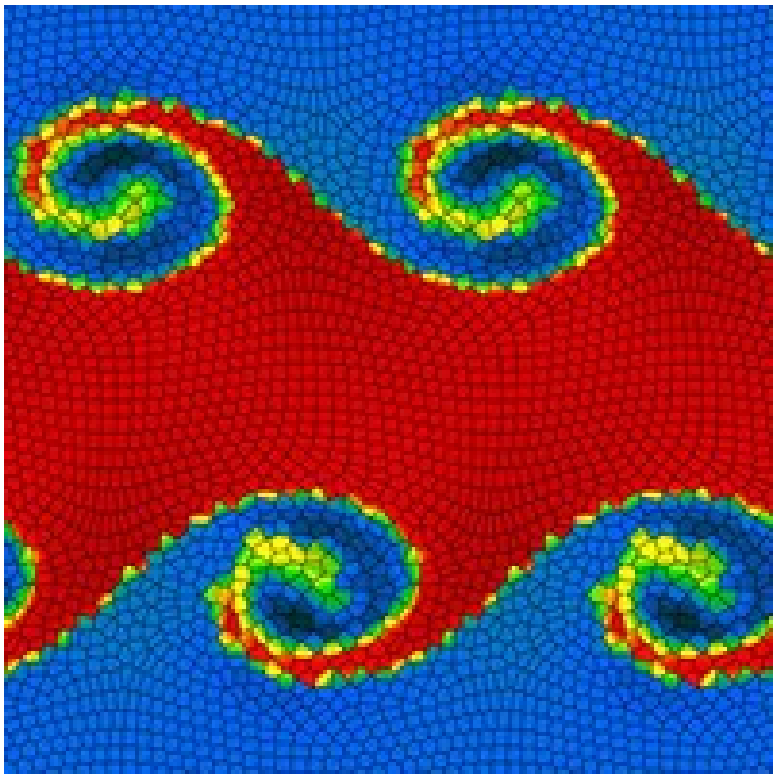
N-body / SPH

Hydro Mesh

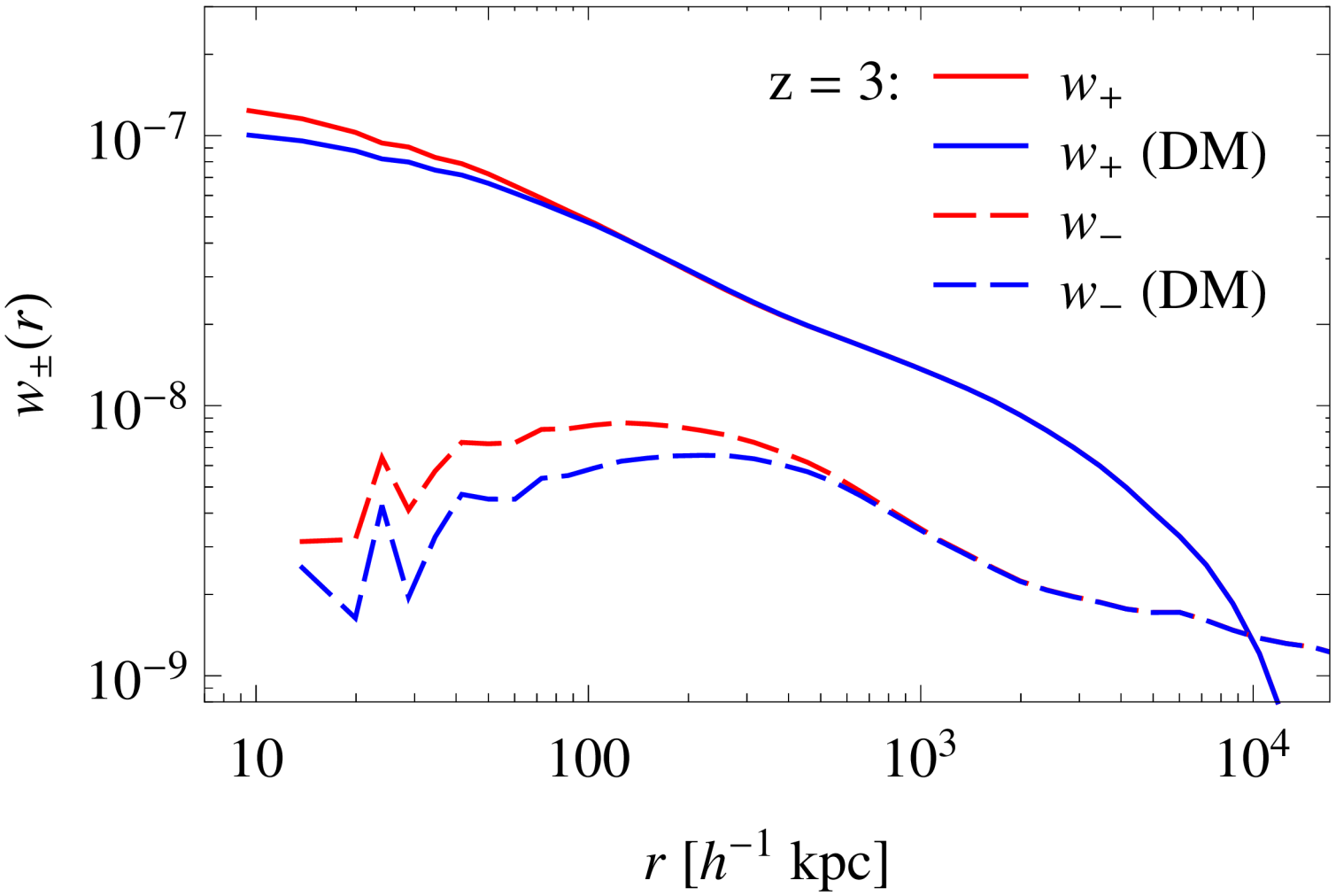


hybrid particle - mesh

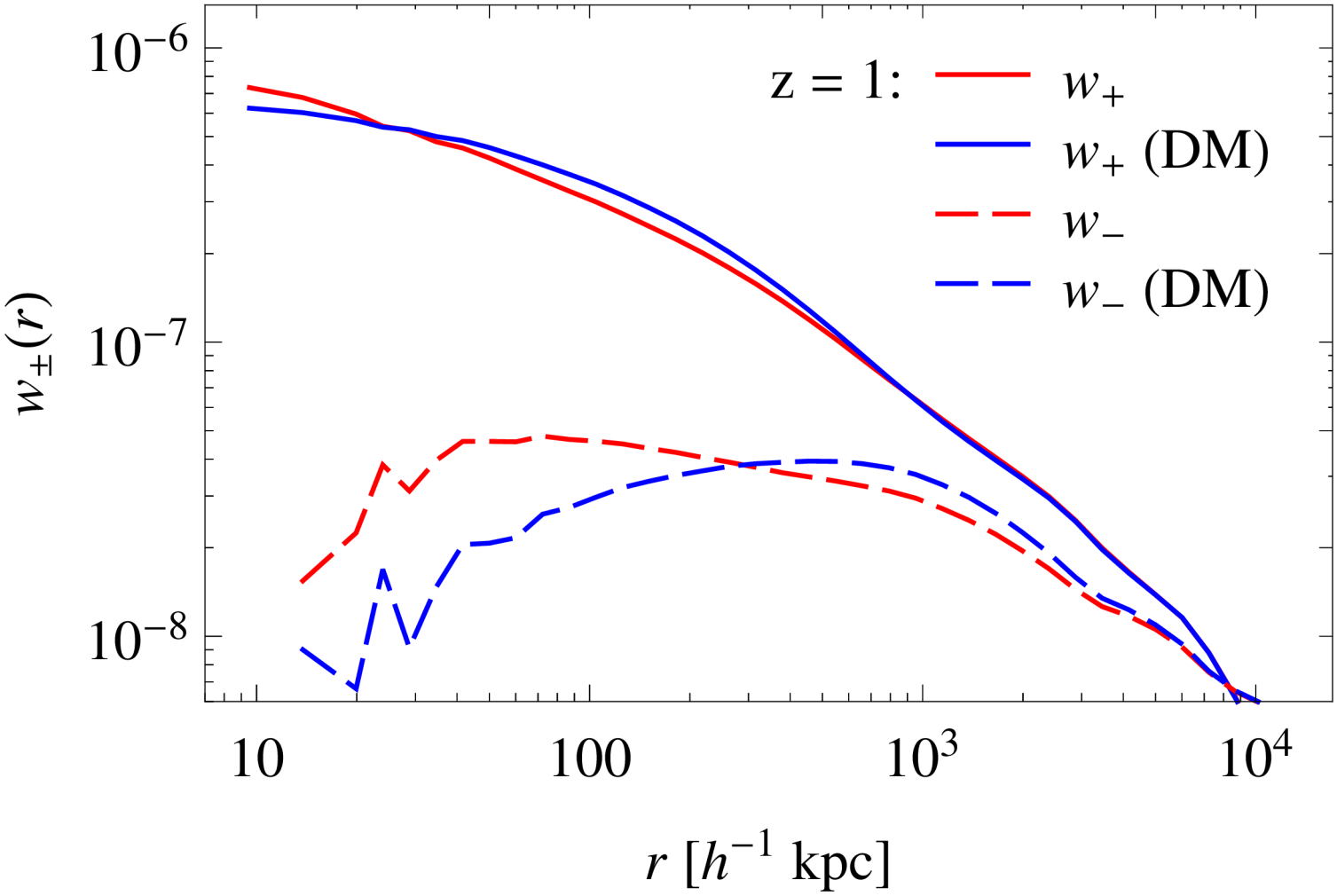
Arepo



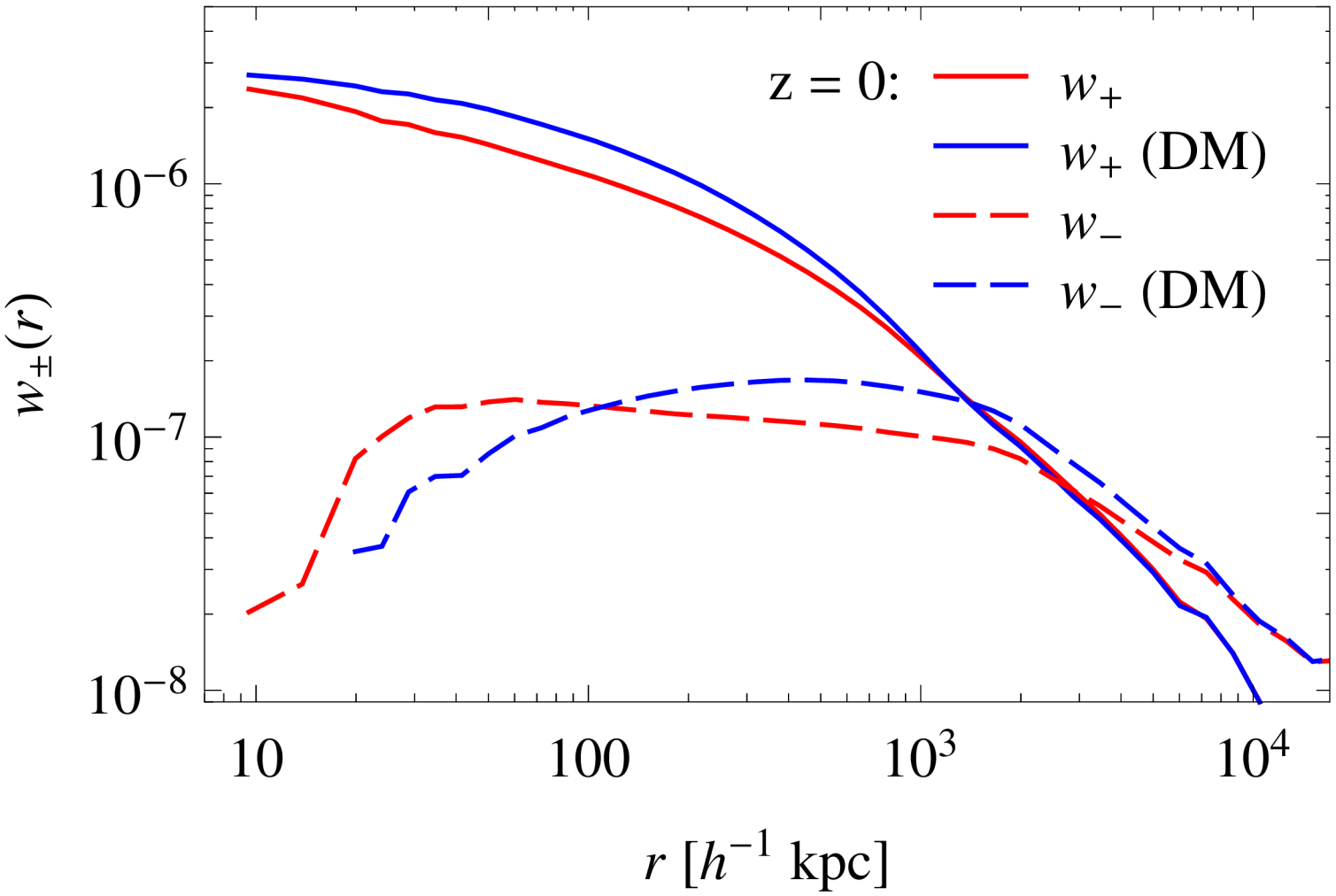
Impact of Baryons



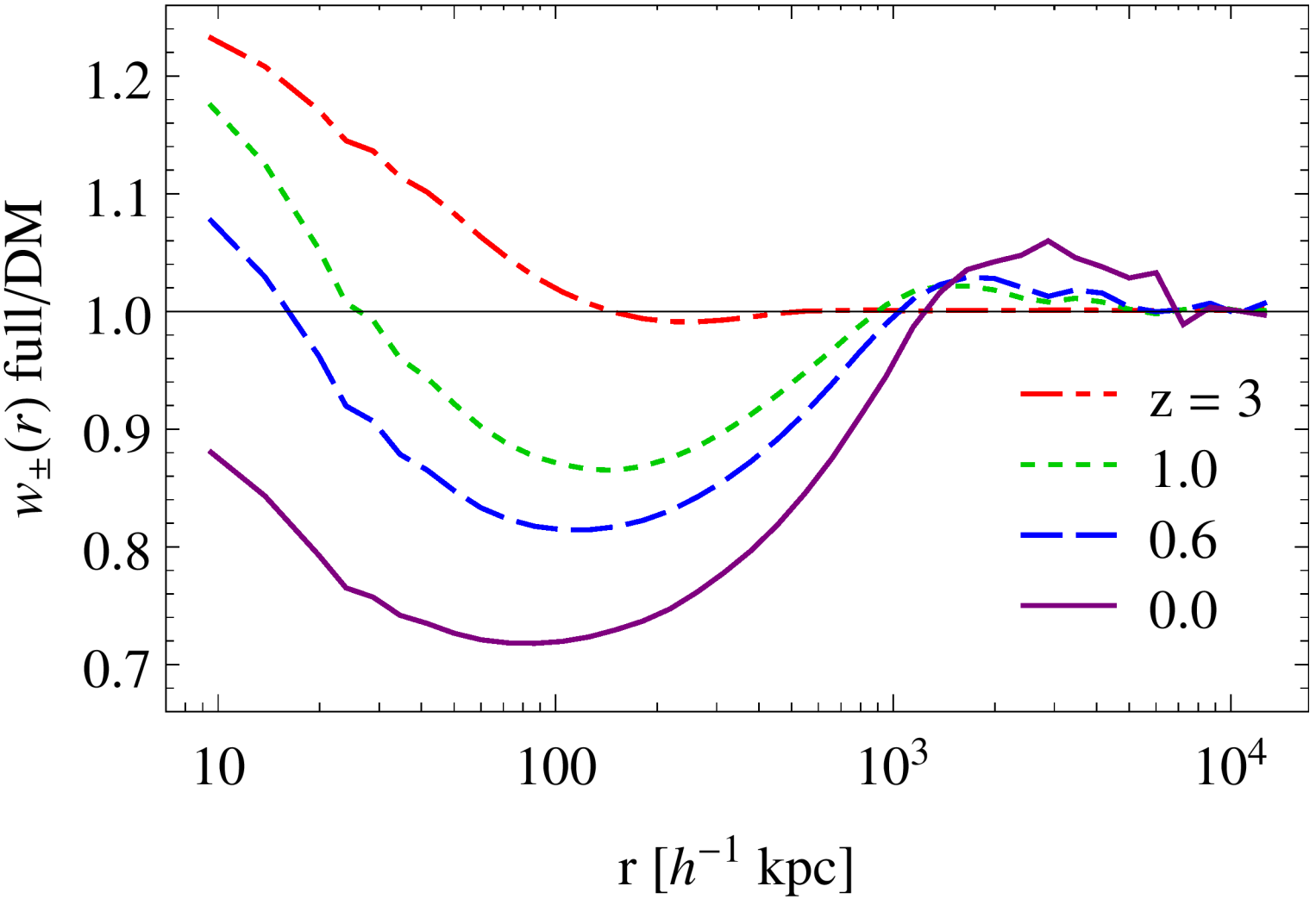
Impact of Baryons



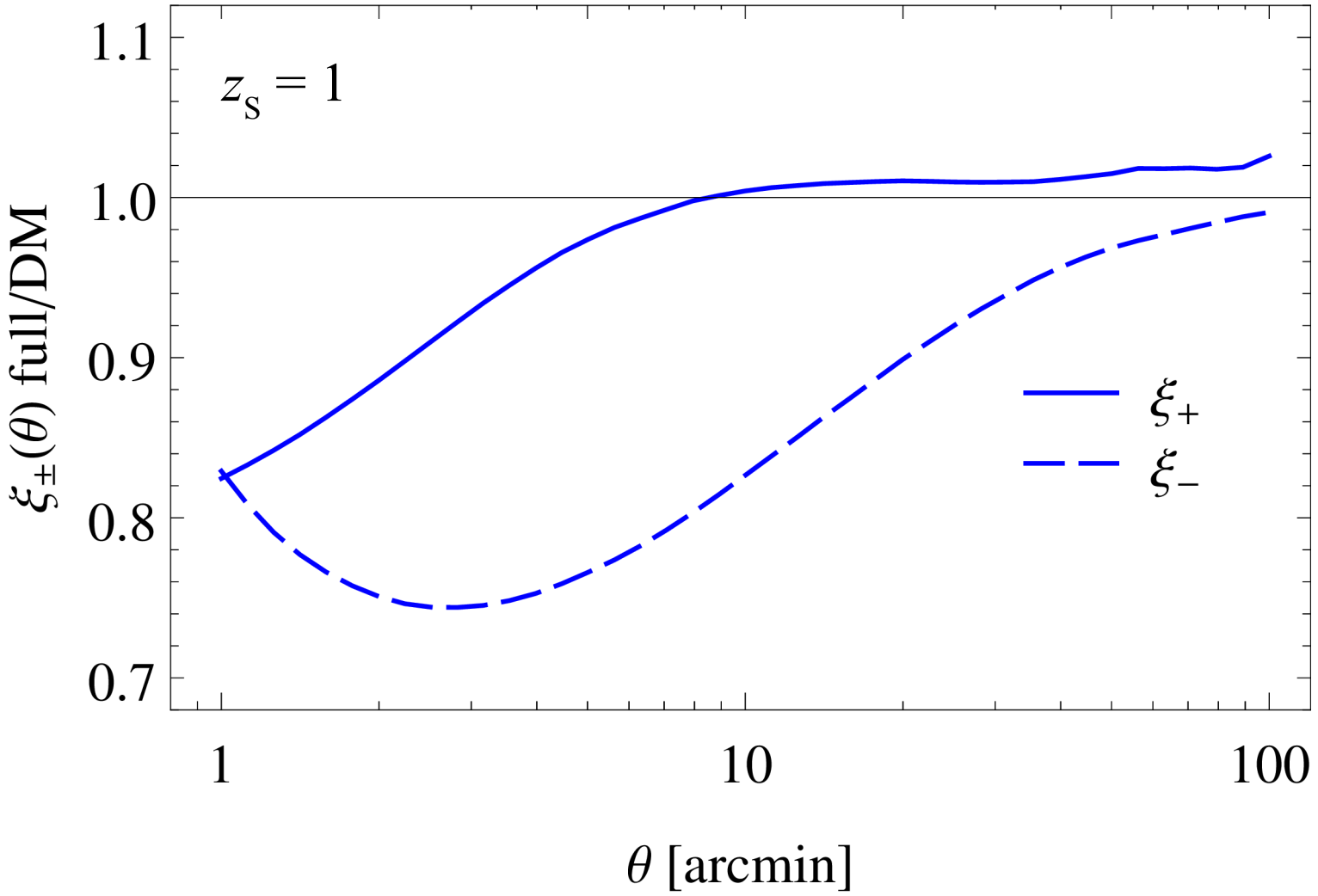
Impact of Baryons



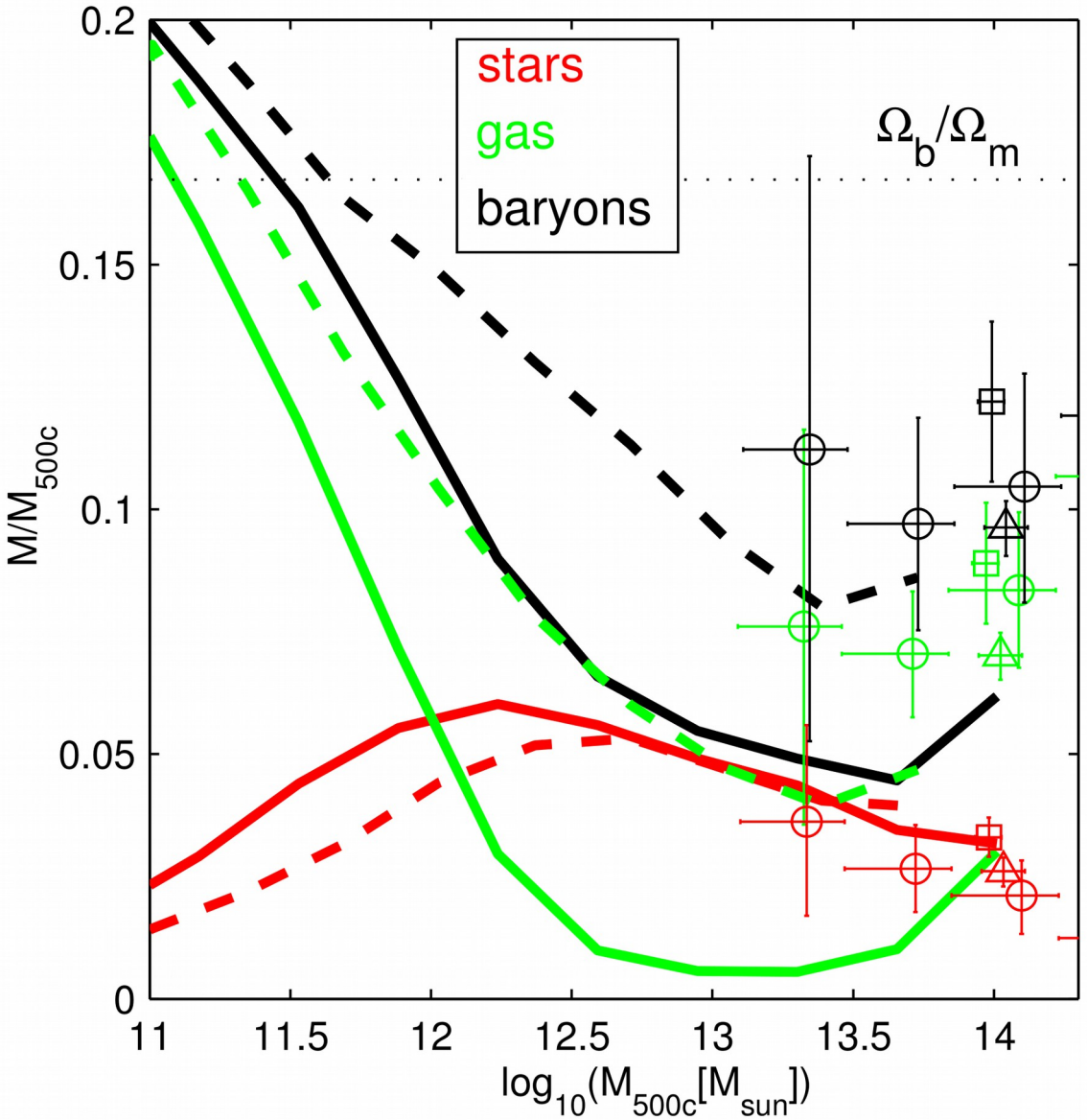
Impact of Baryons



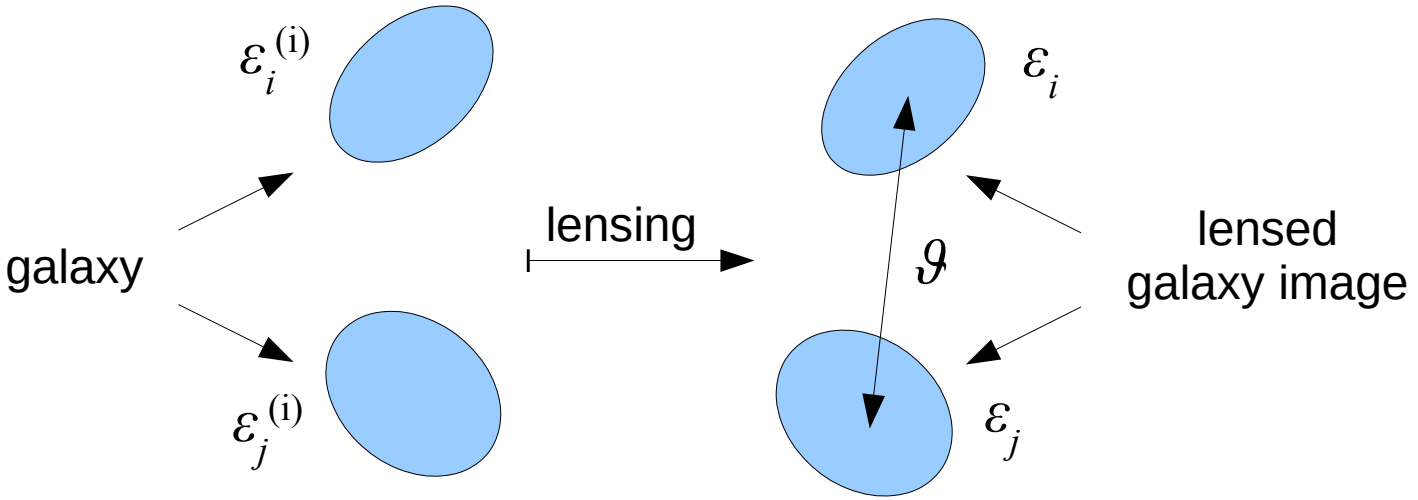
Impact of Baryons



Impact of Baryons



Intrinsic Alignments

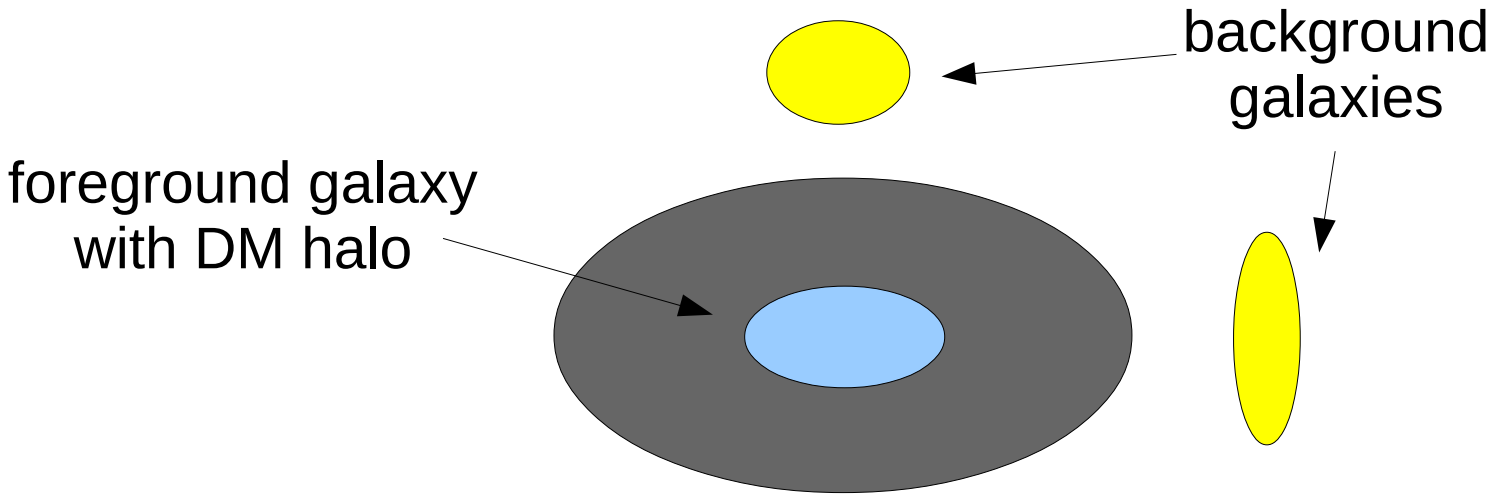


$$\langle \varepsilon_i^* \varepsilon_j \rangle \approx \langle \gamma^* \gamma \rangle(\vartheta) + \langle \varepsilon_i^{(i)*} \gamma \rangle + \langle \gamma^* \varepsilon_j^{(i)} \rangle + \langle \varepsilon_i^{(i)*} \varepsilon_j^{(i)} \rangle$$

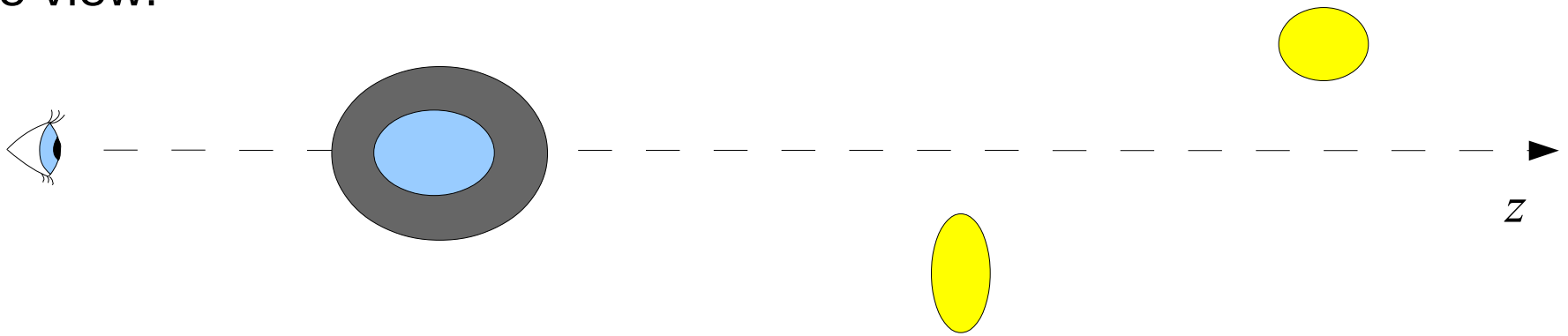
$$= \text{GG} + \text{IG} + \text{GI} + \text{II}$$

Intrinsic Alignments: GI

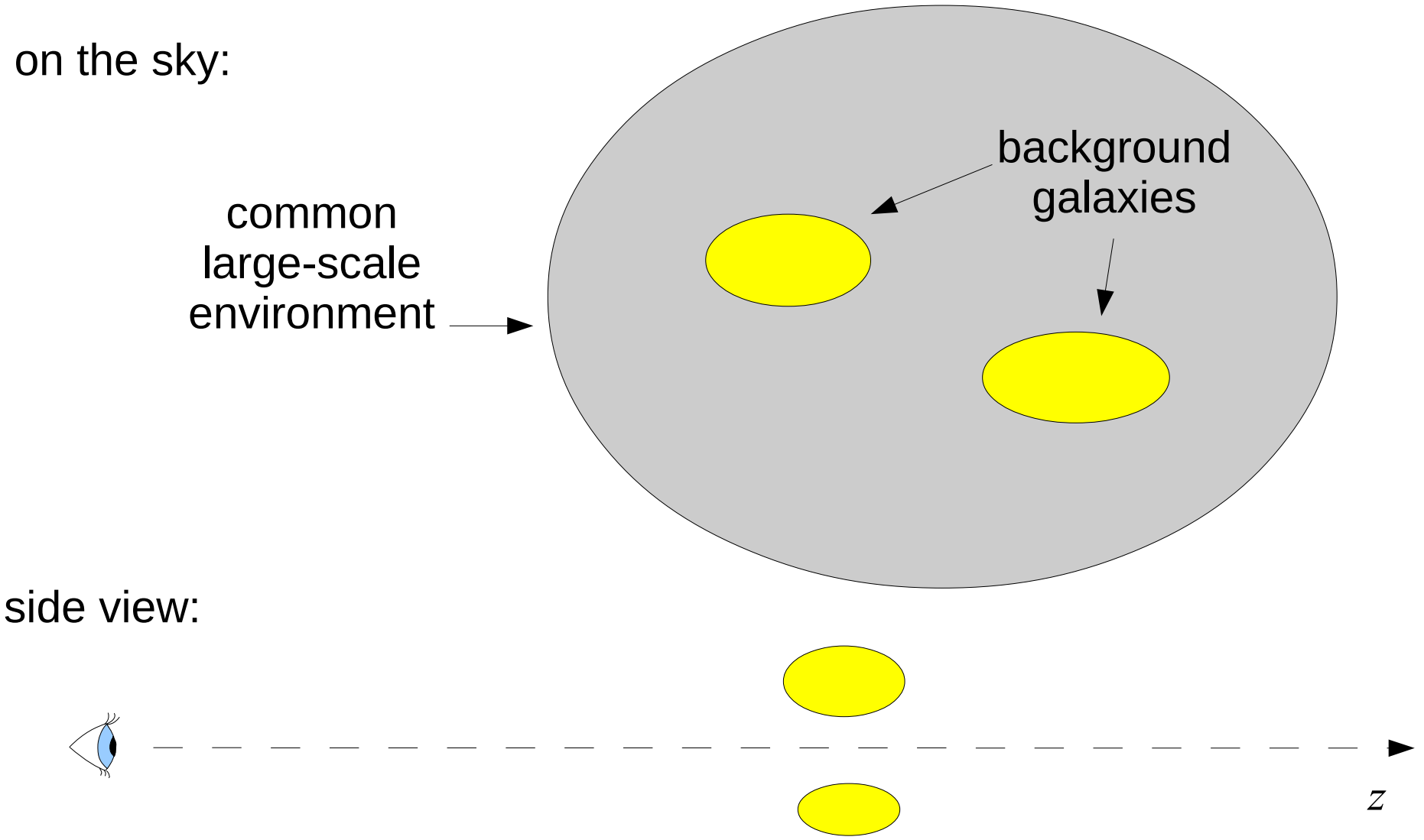
on the sky:



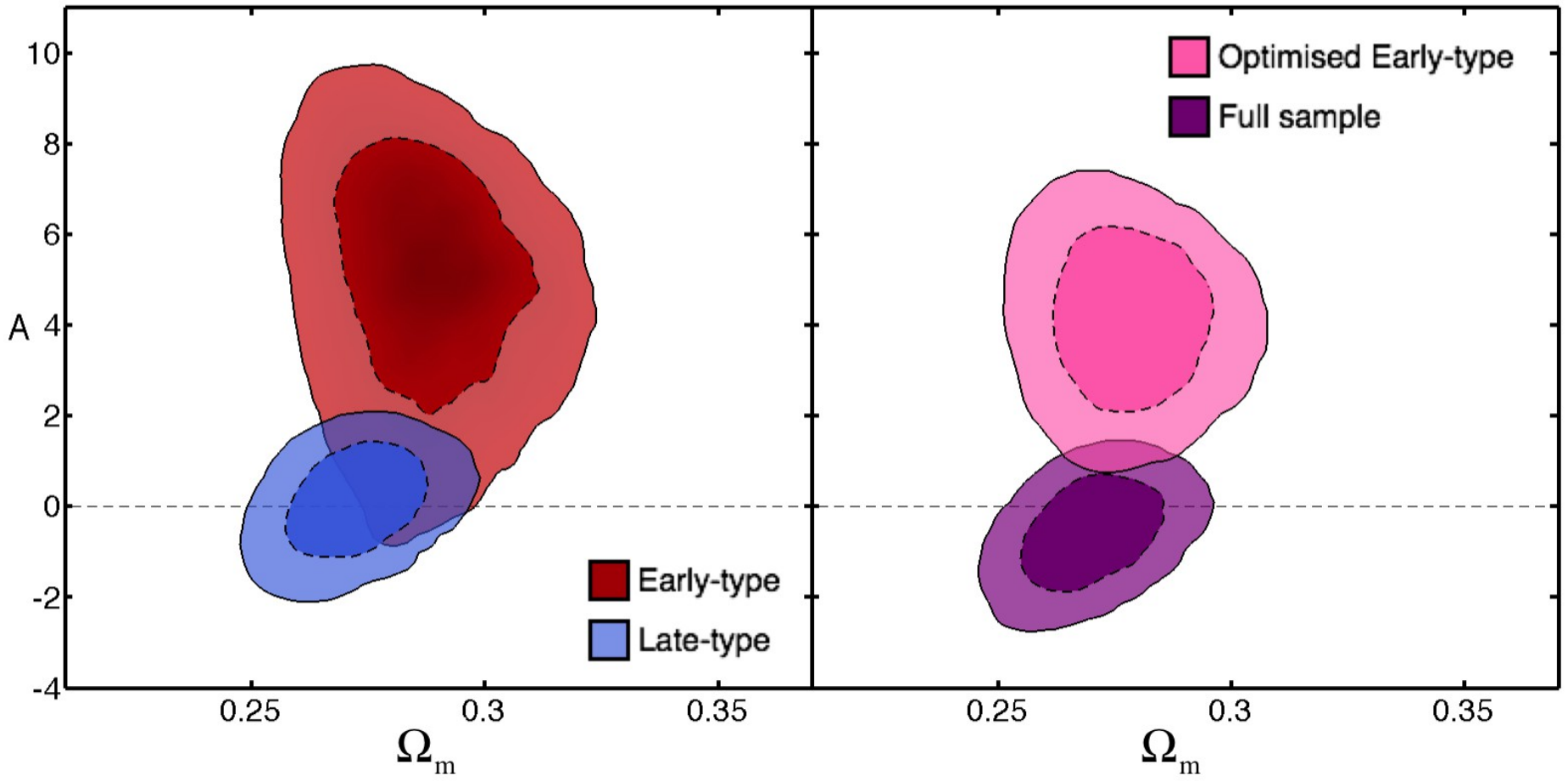
side view:



Intrinsic Alignments: II

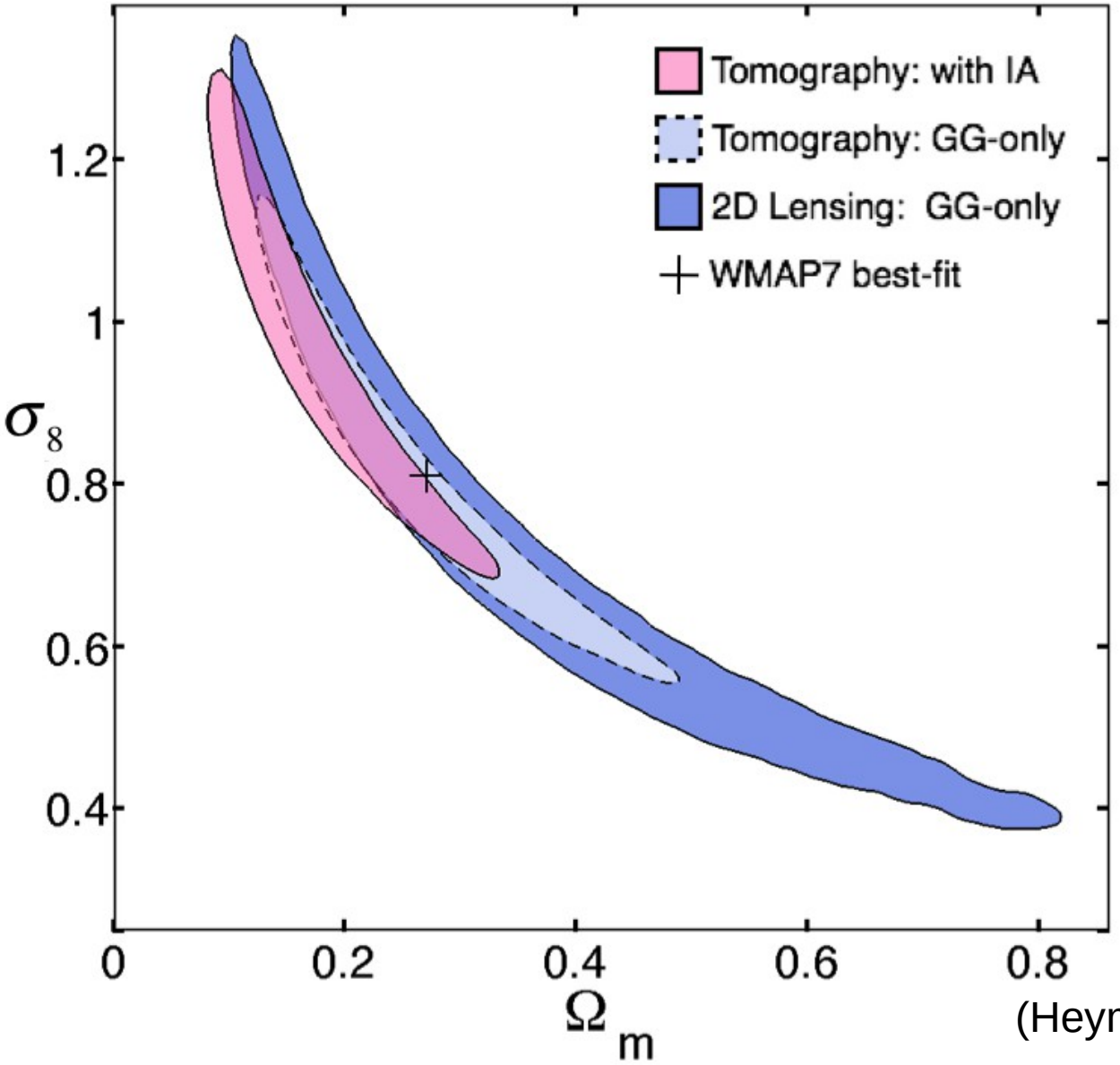


Intrinsic Alignment in CFHTLS



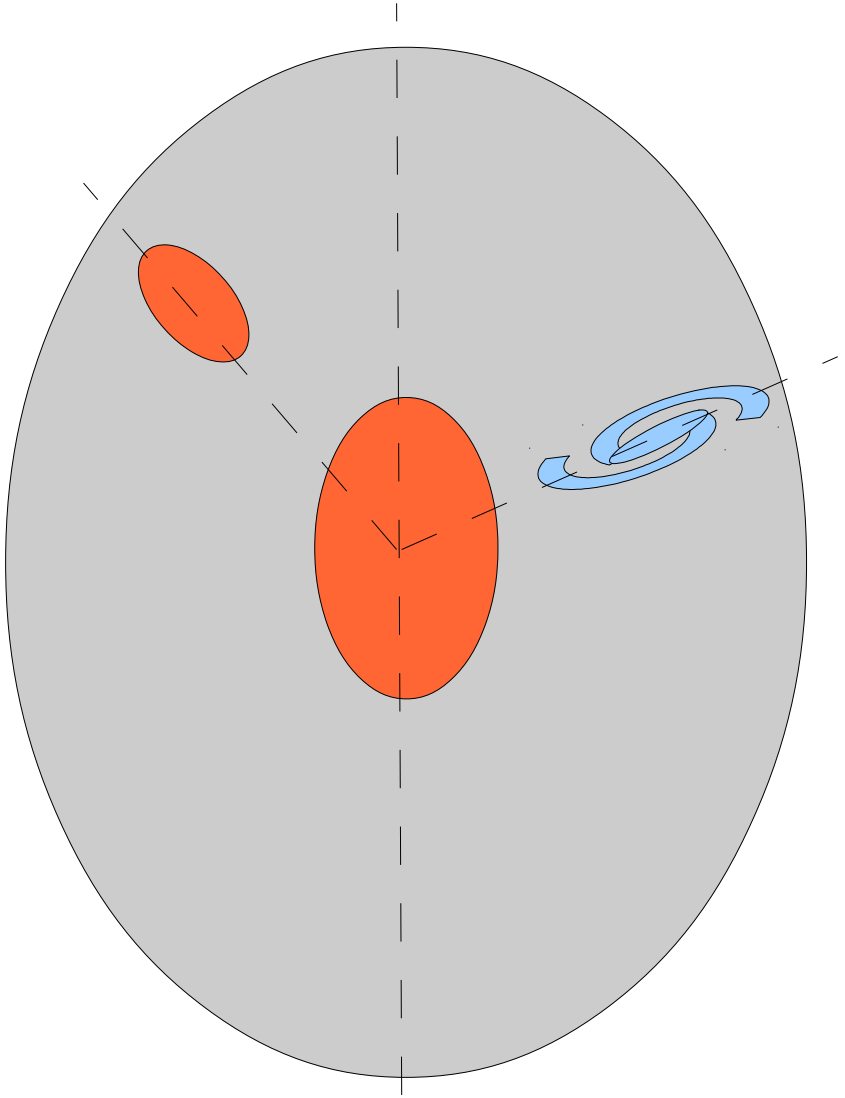
(Heymans et al. 2013)

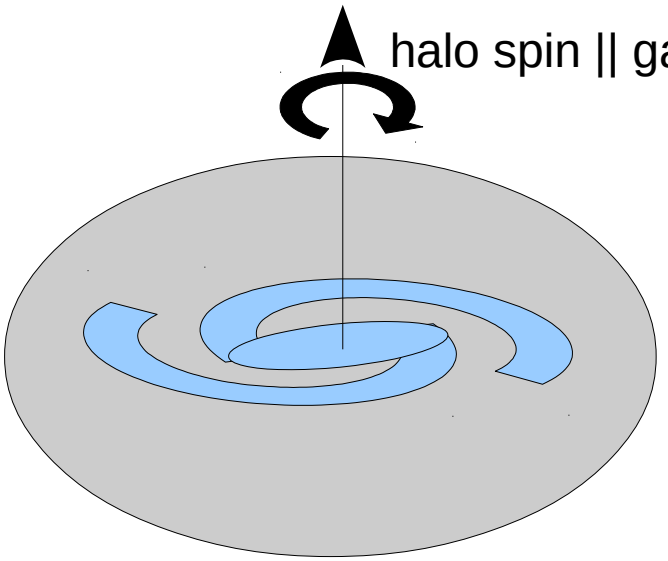
Intrinsic Alignment in CFHTLS



(Heymans et al. 2013)

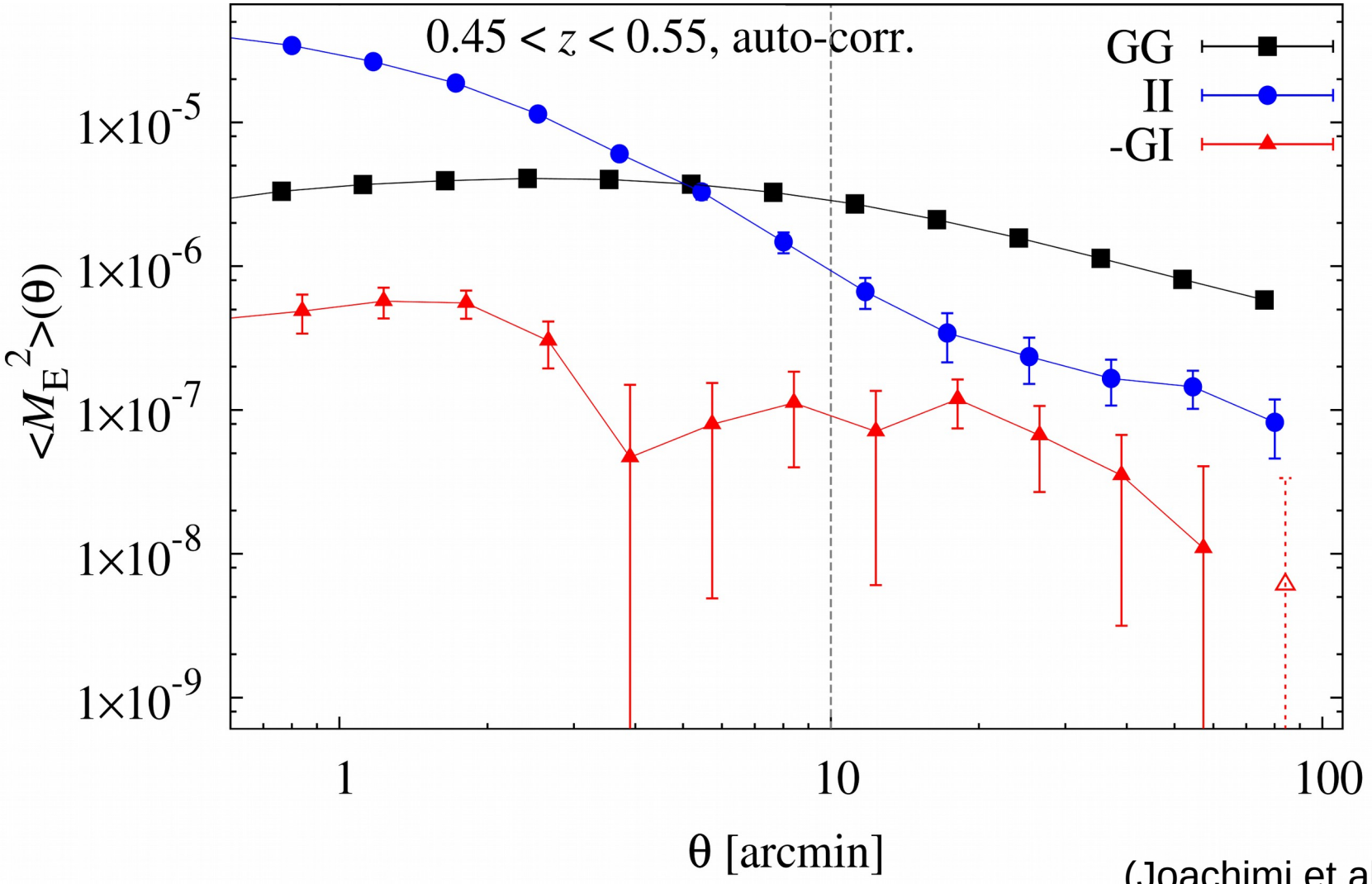
Intrinsic Alignment Models for Millennium Run





(Joachimi et al. 2013)

Euclid-like Survey



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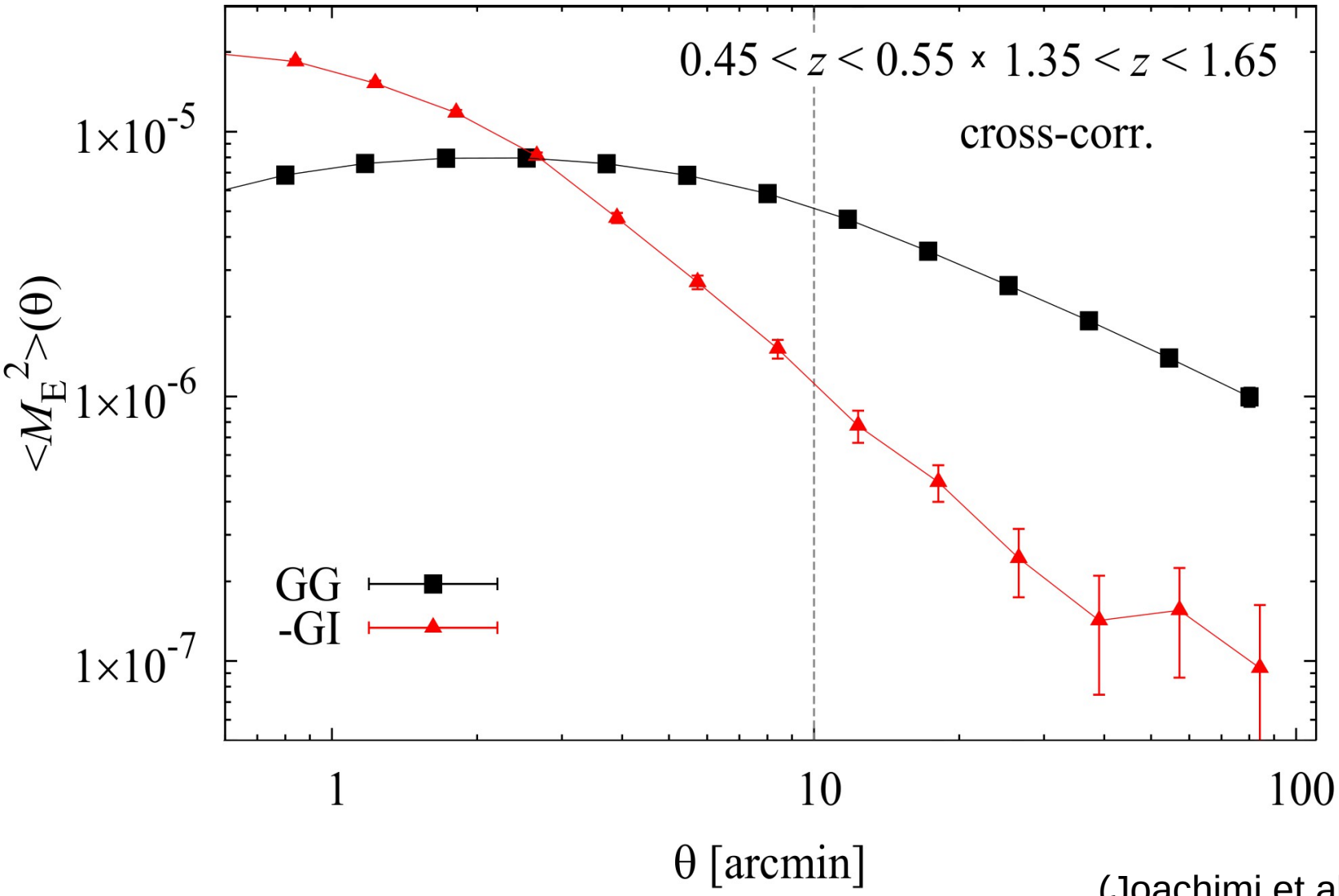
Euclid-like Survey



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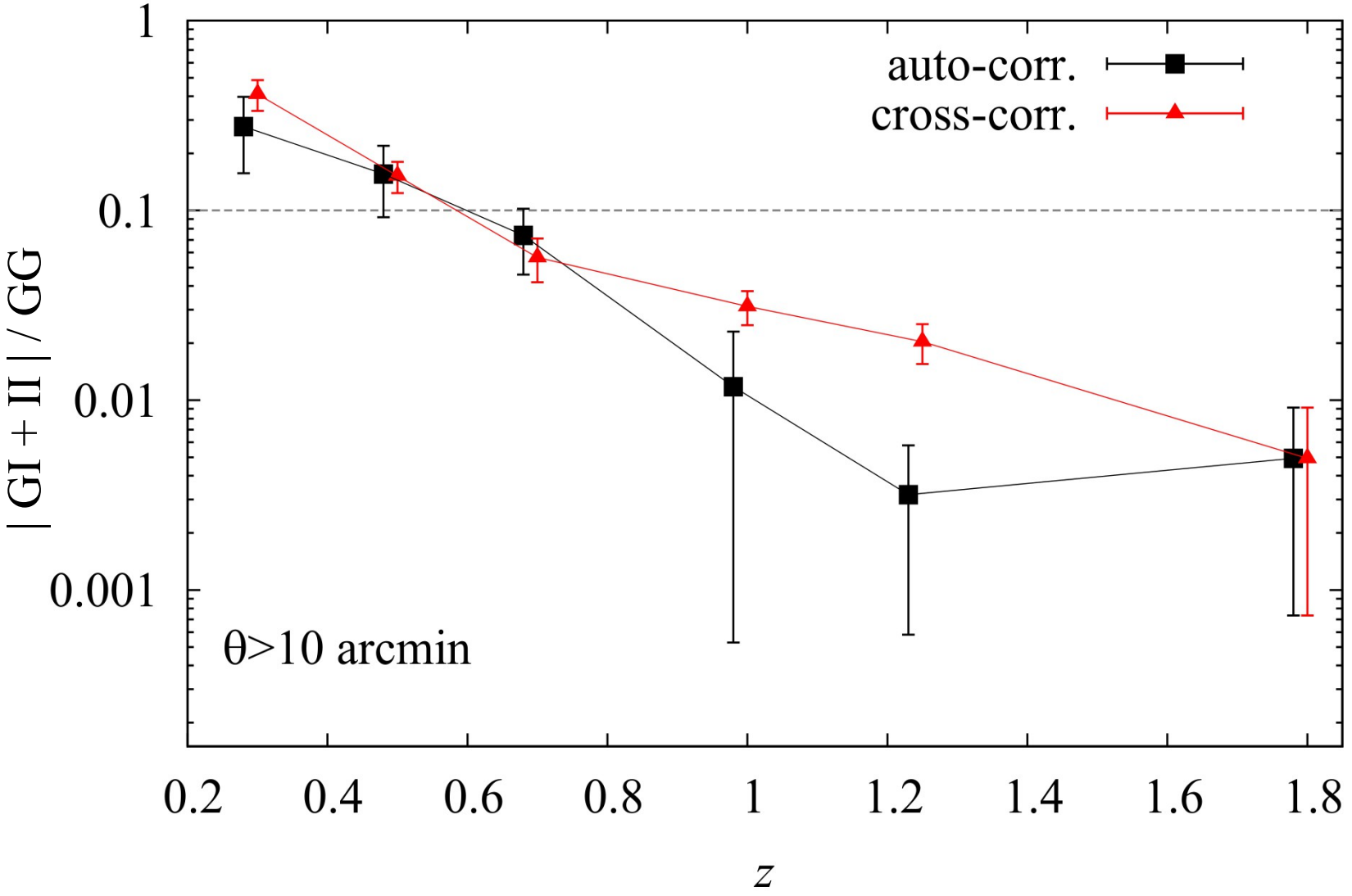
Euclid-like Survey



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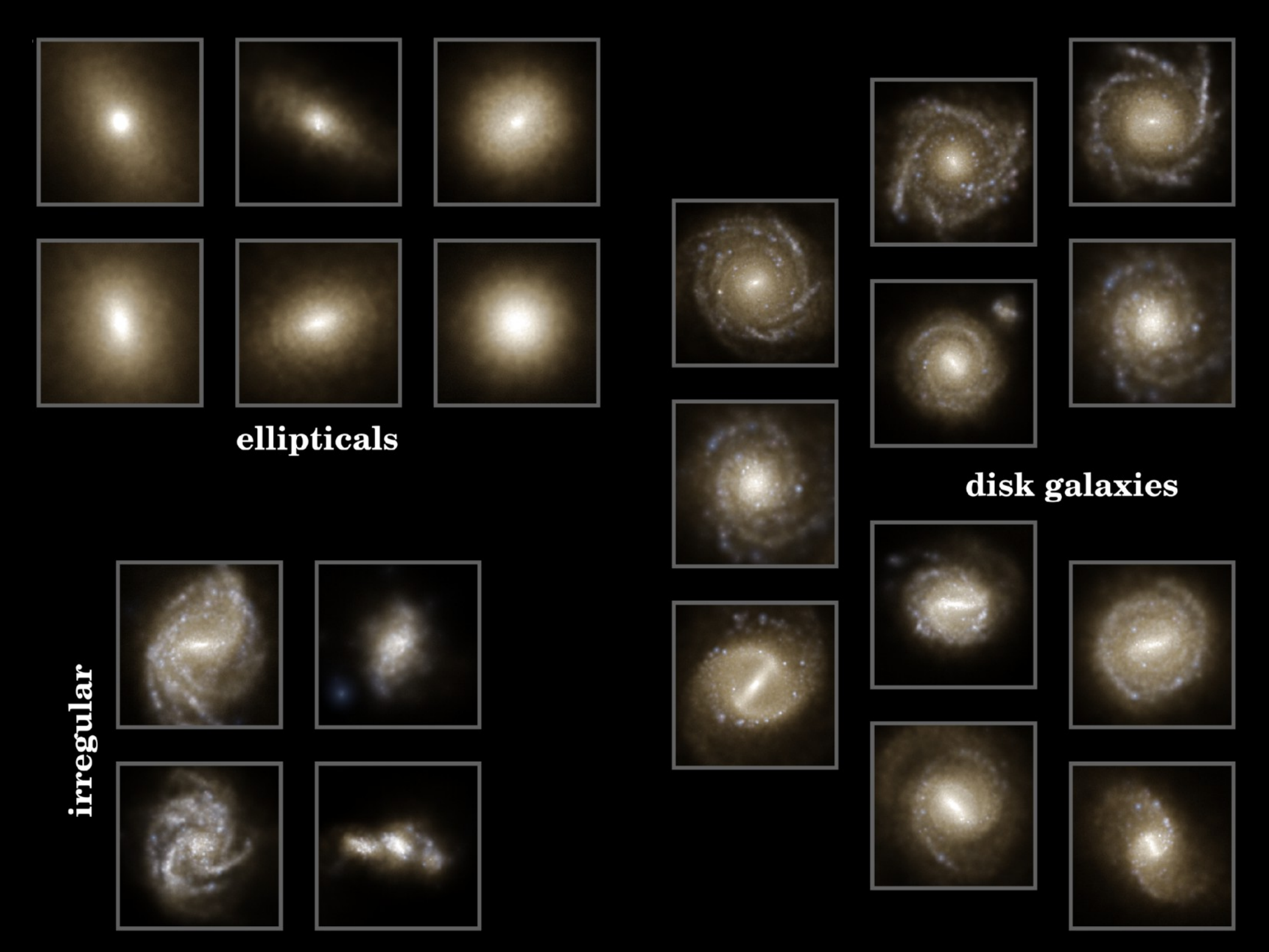
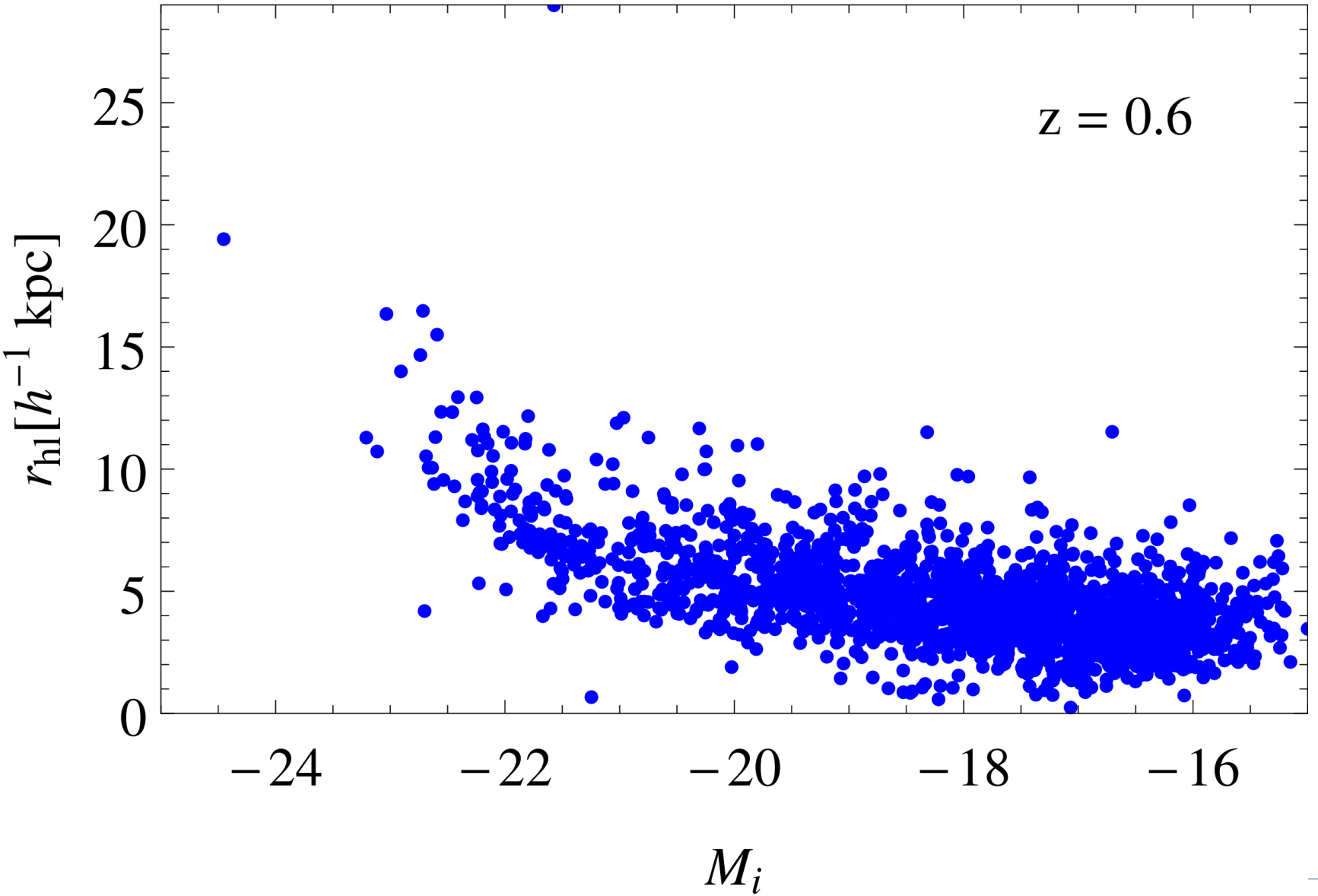
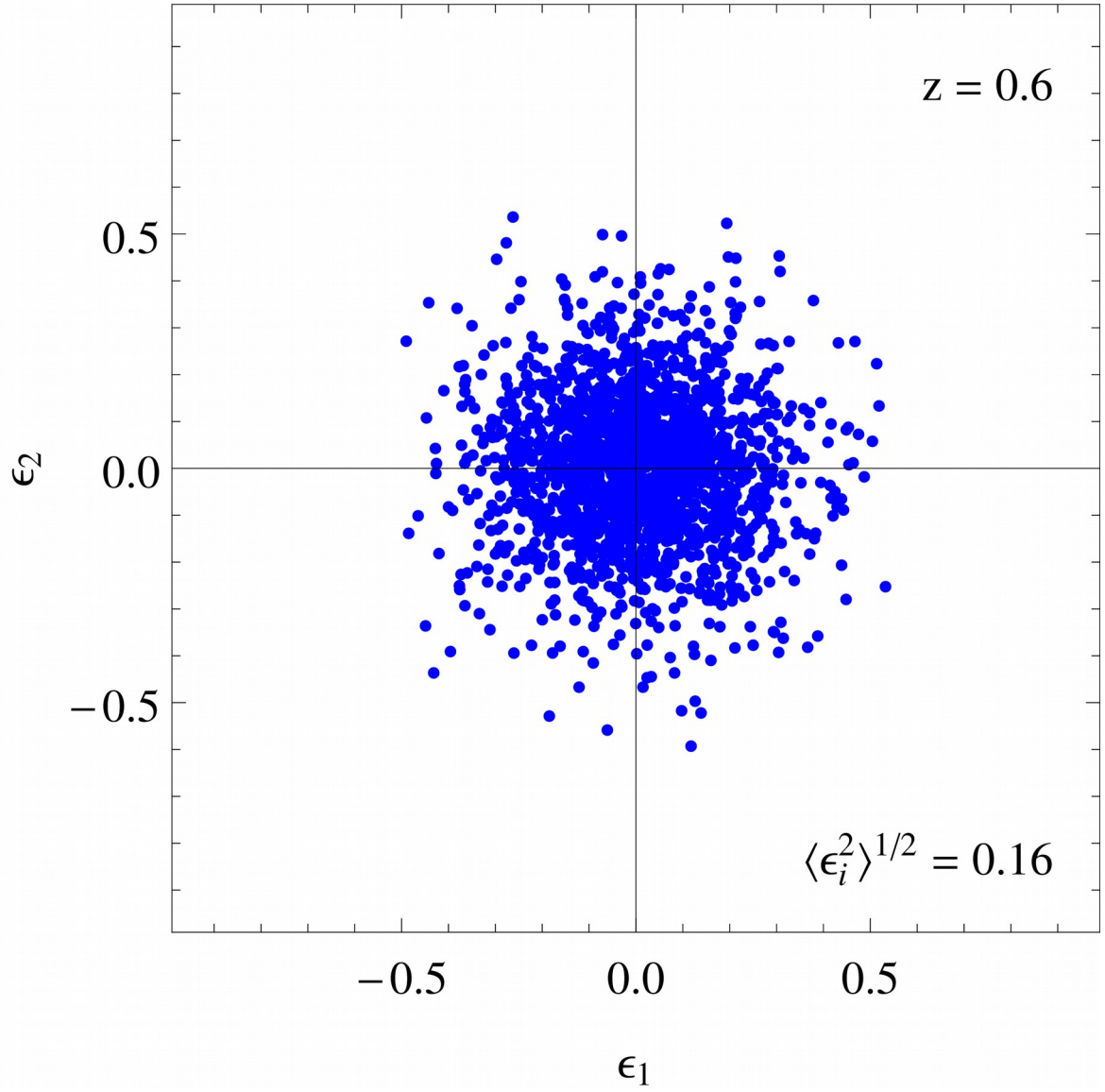

ellipticals
disk galaxies
irregular

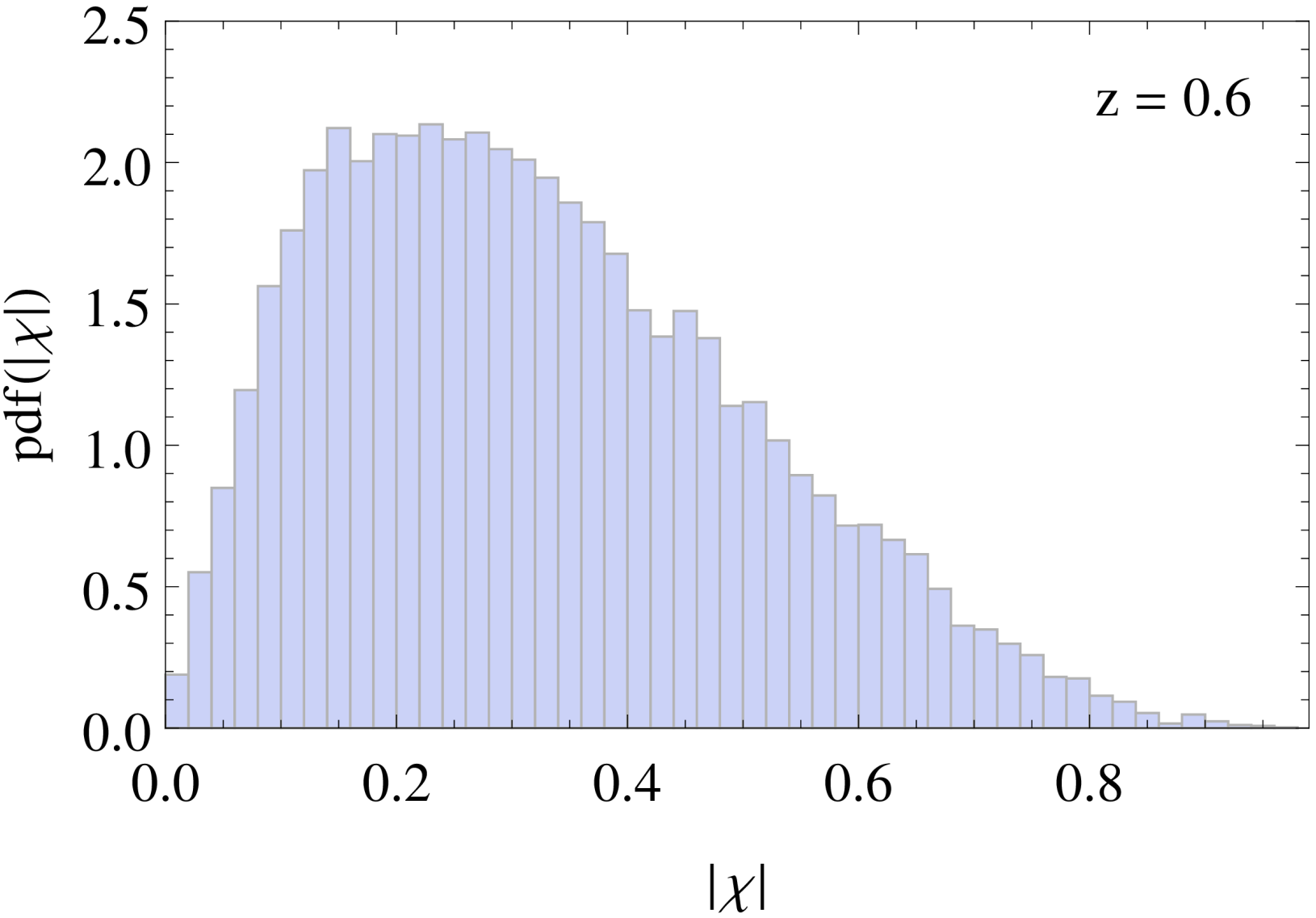
Illustris Galaxy Sizes



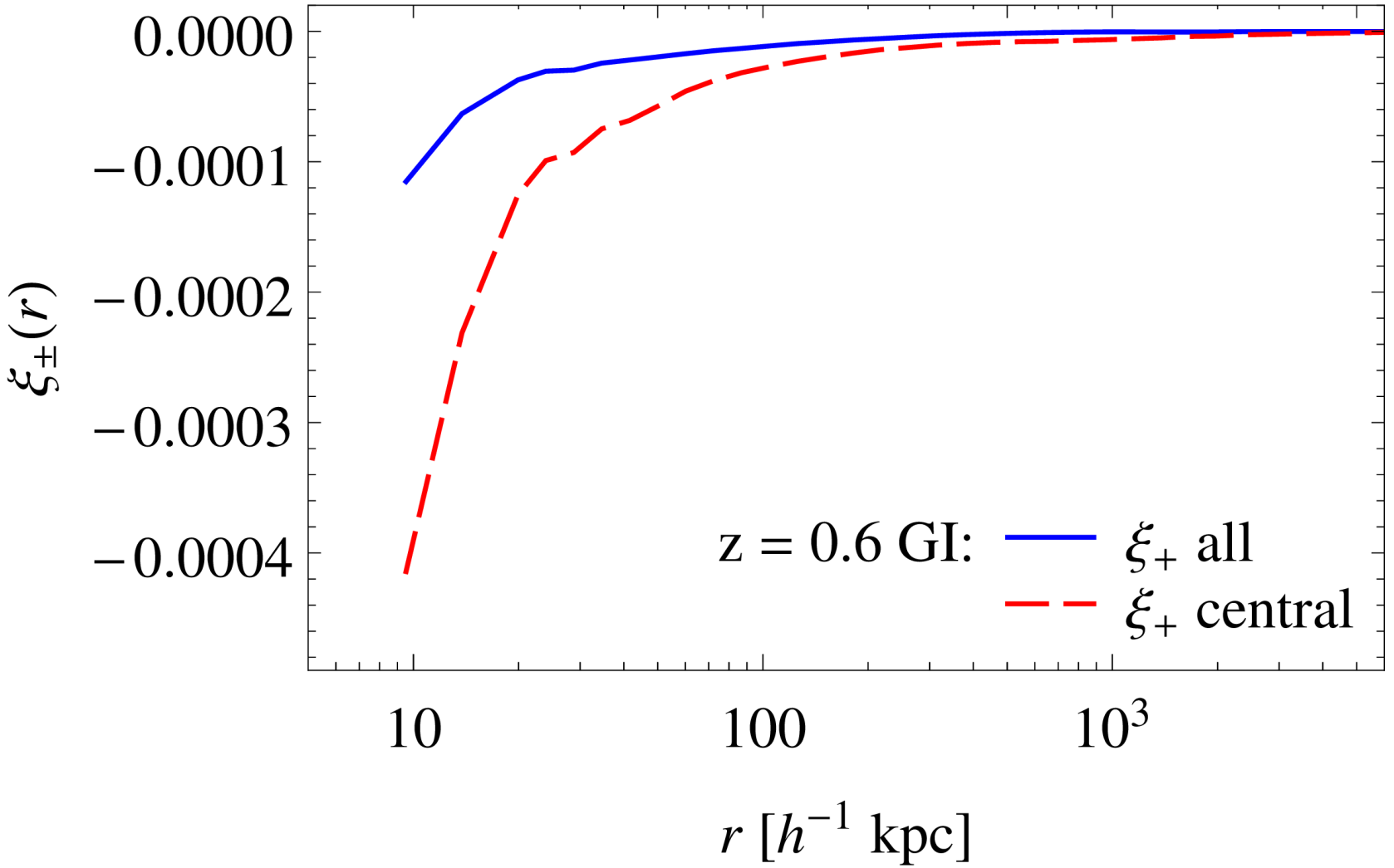
Illustris Galaxy Ellipticities



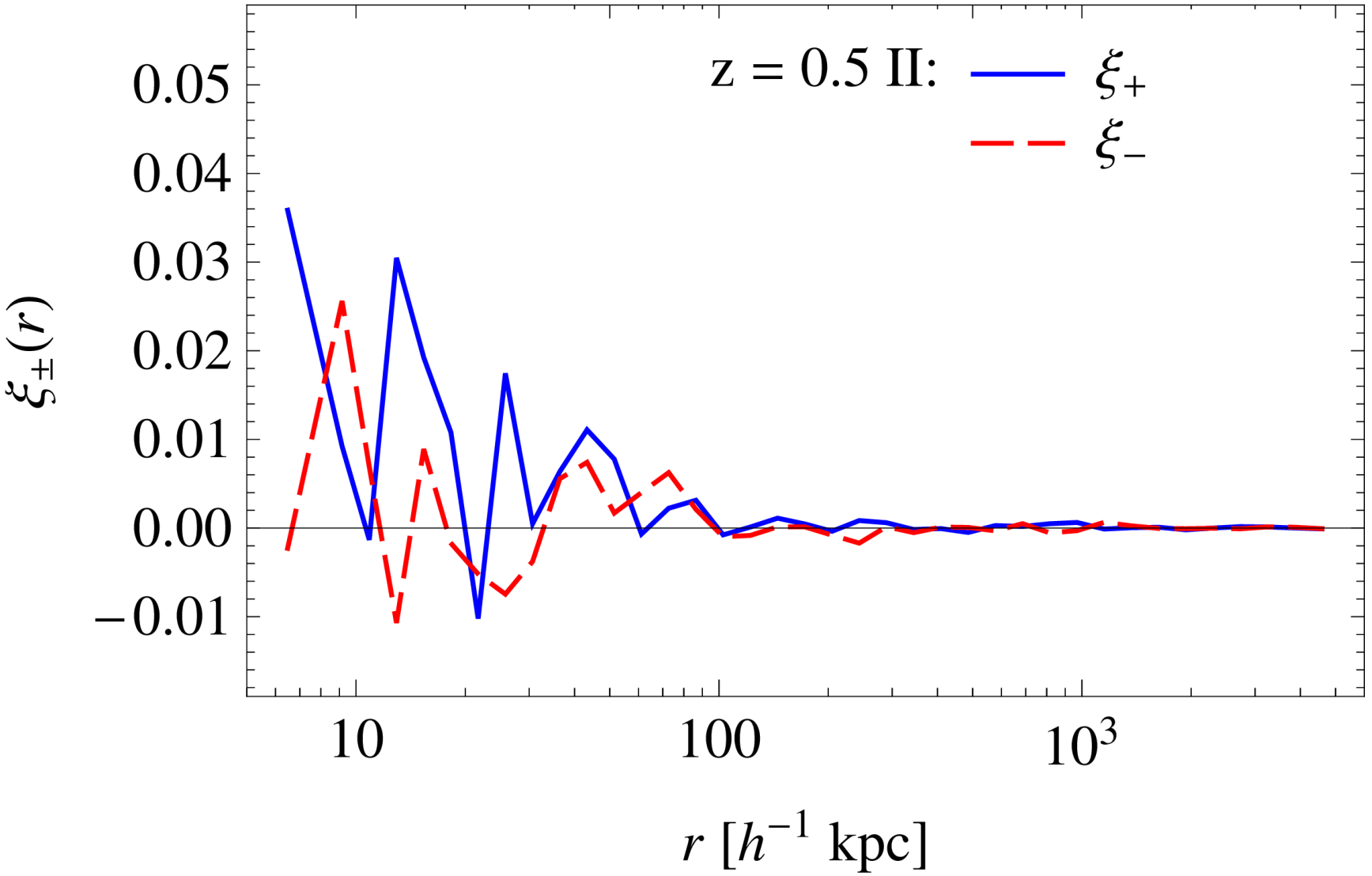
Illustris: Galaxy Ellipticities



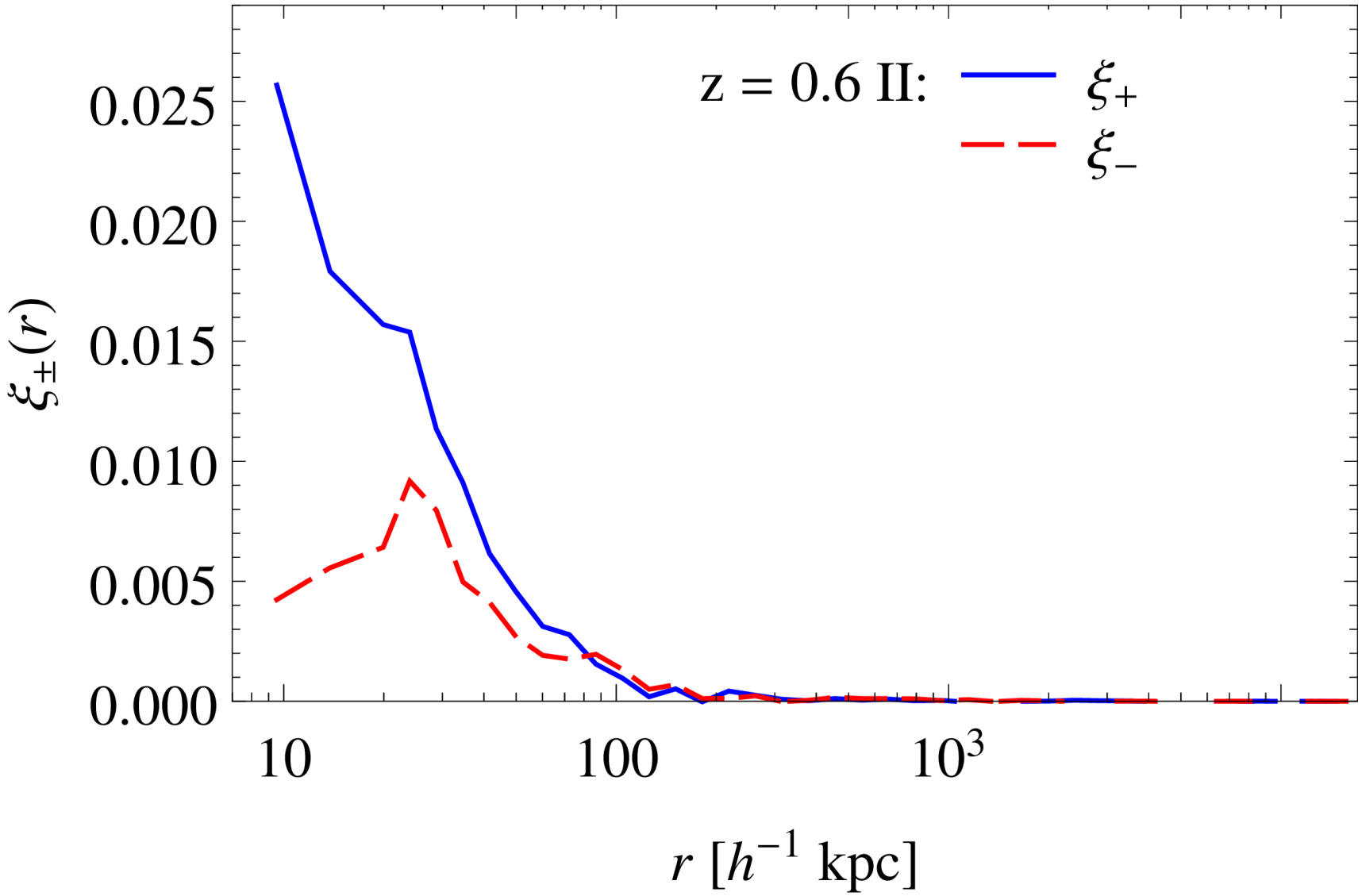
Illustis Intrinsic Alignment: GI



Illustris Intrinsic Alignment: II



Illustris Intrinsic Alignment: II



Summary

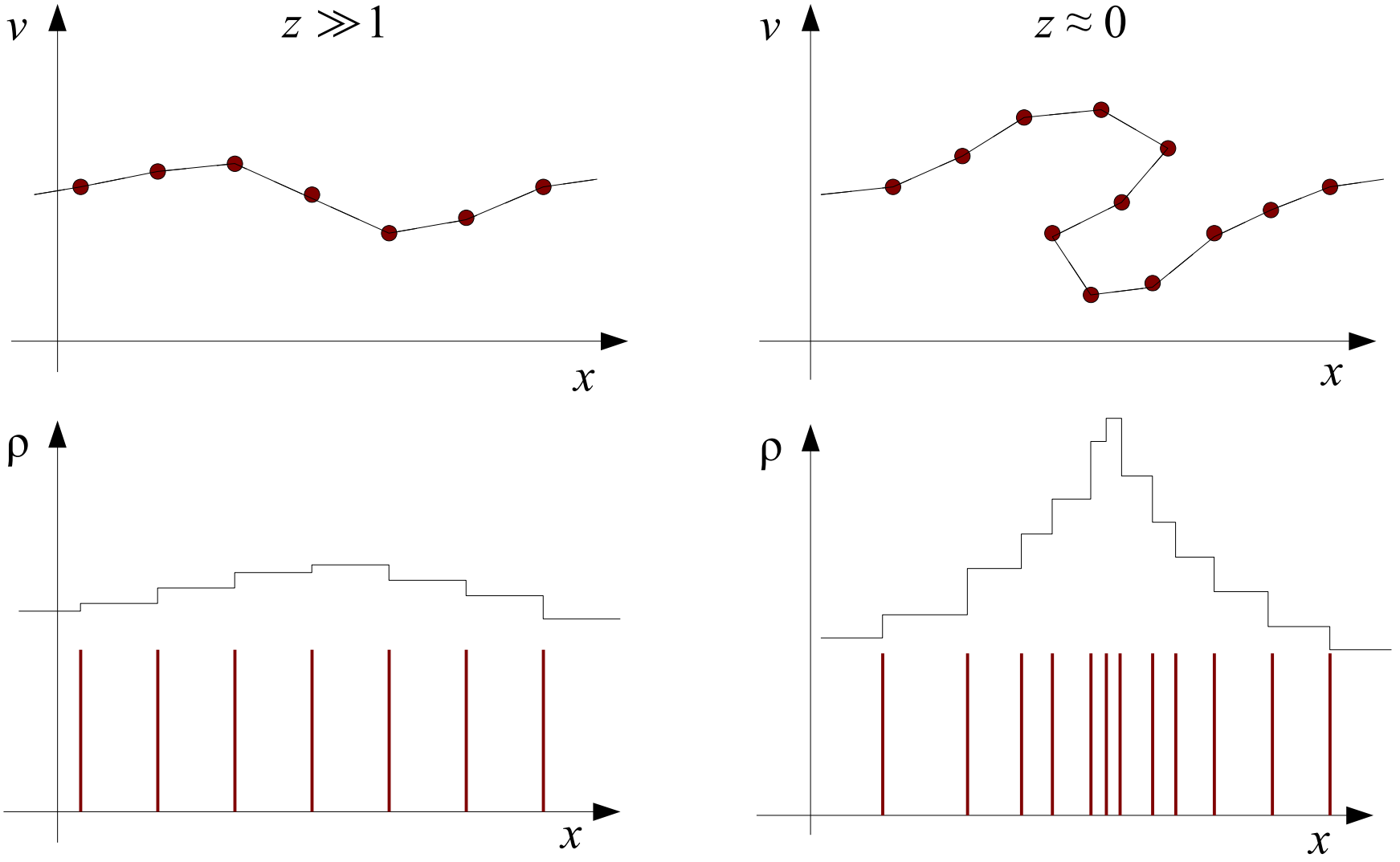
- impact of baryons:
  - effects on matter correlations/cosmic shear
  - Illustris: impact <~20%
  - sign/magnitude depends on ang. scale and redshift
- intrinsic alignment:
  - intrinsic galaxy shape correlation contaminates cosmic shear
  - impact on cosmic shear surveys ~10%
  - signal depends on galaxy properties, redshift,...
  - II signal noisy

Outlook

- to do:
  - prediction of baryon impact on cosmic shear tomography
  - prediction of IA signal for future WL surveys
  - test/improve galaxy characterization
  - test parametrizations of baryon impact
  - test alignment theories
  - …

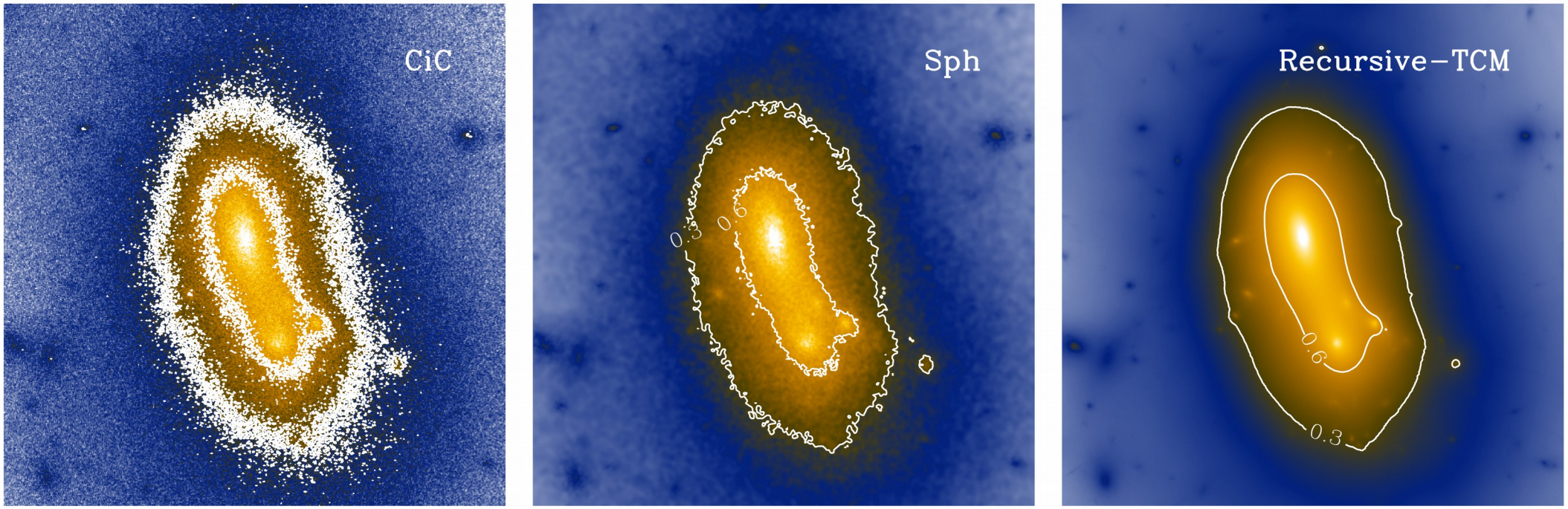
Outlook: New Methods

DM Phase Space Sheet



Abel et al. (2012)

Comparison: Convergence



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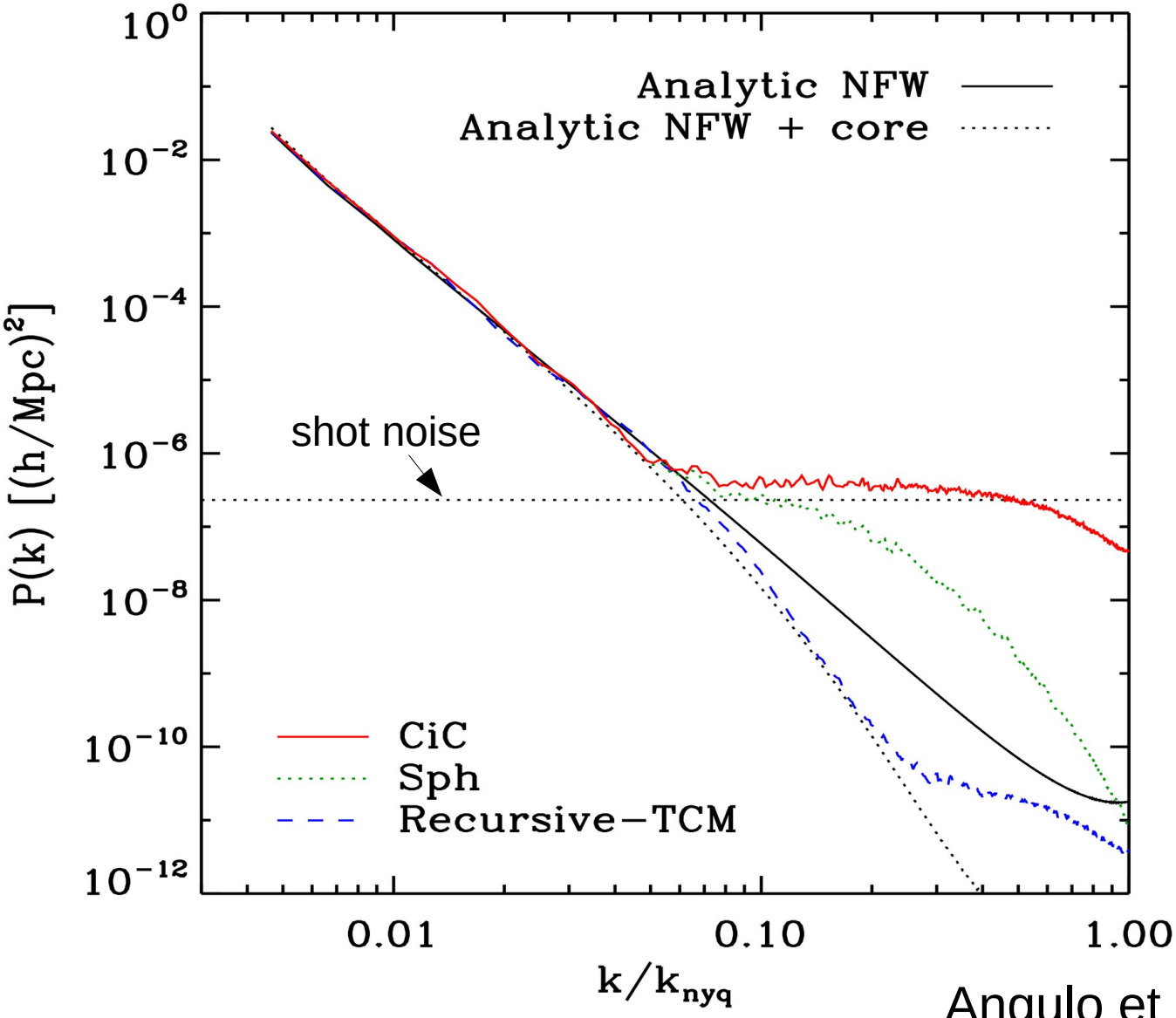
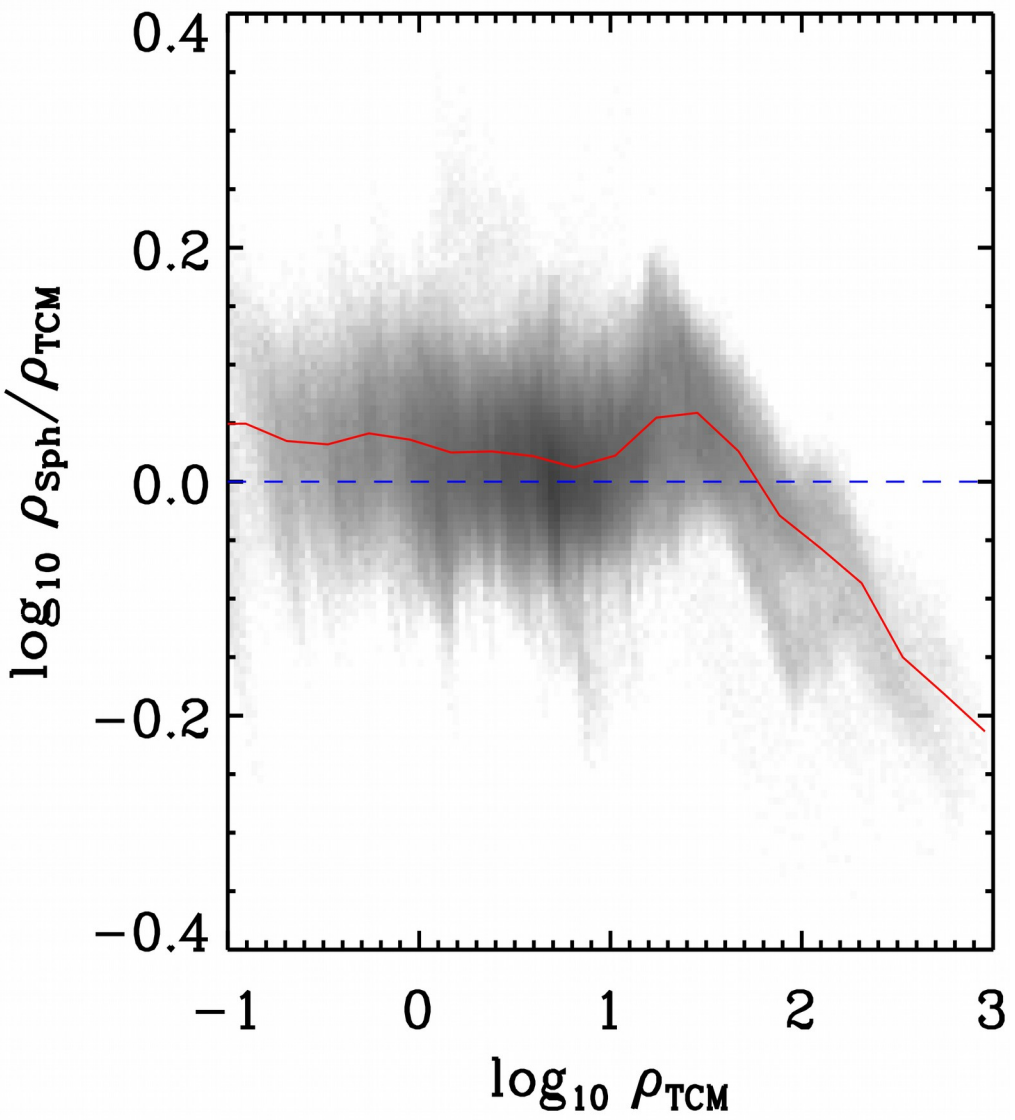
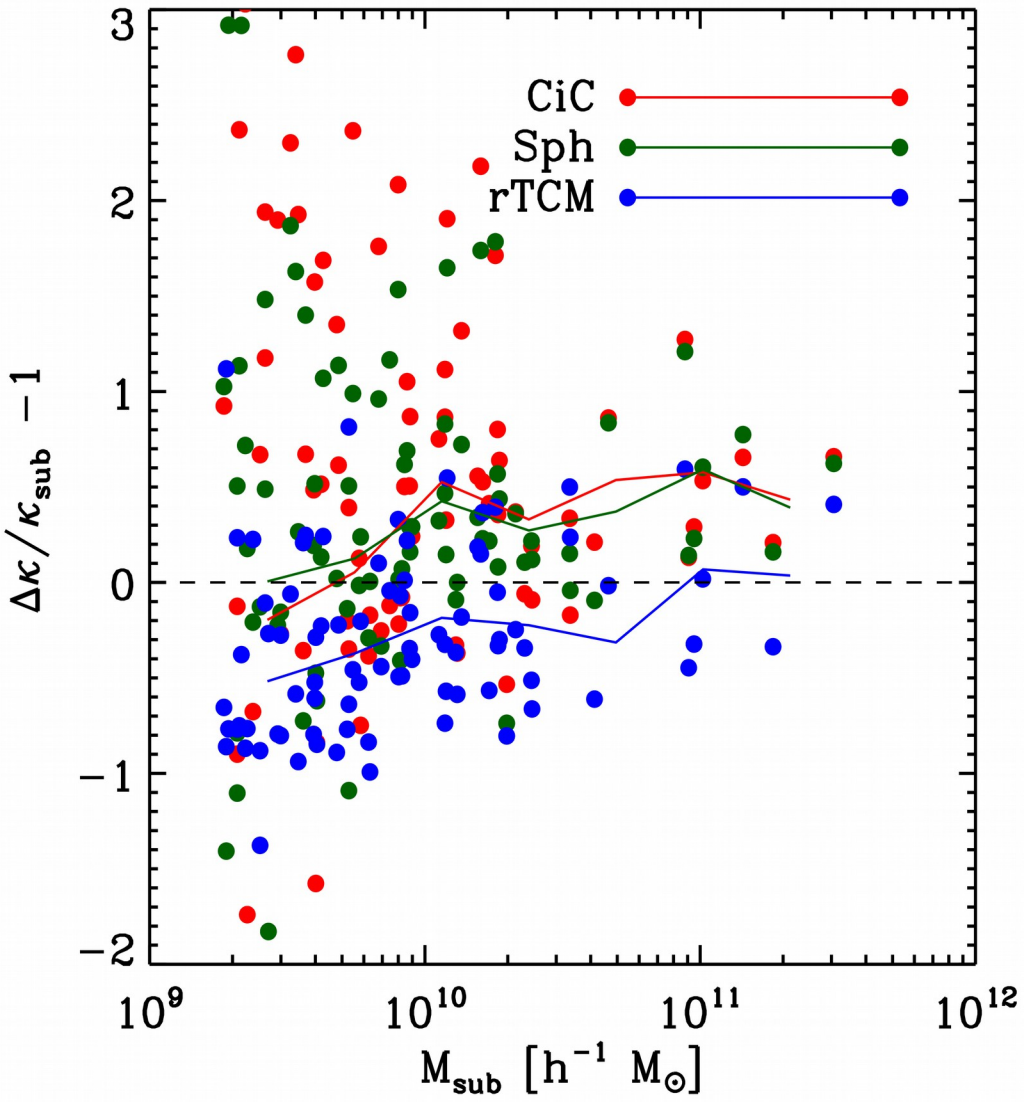


Angulo et al. (2014)

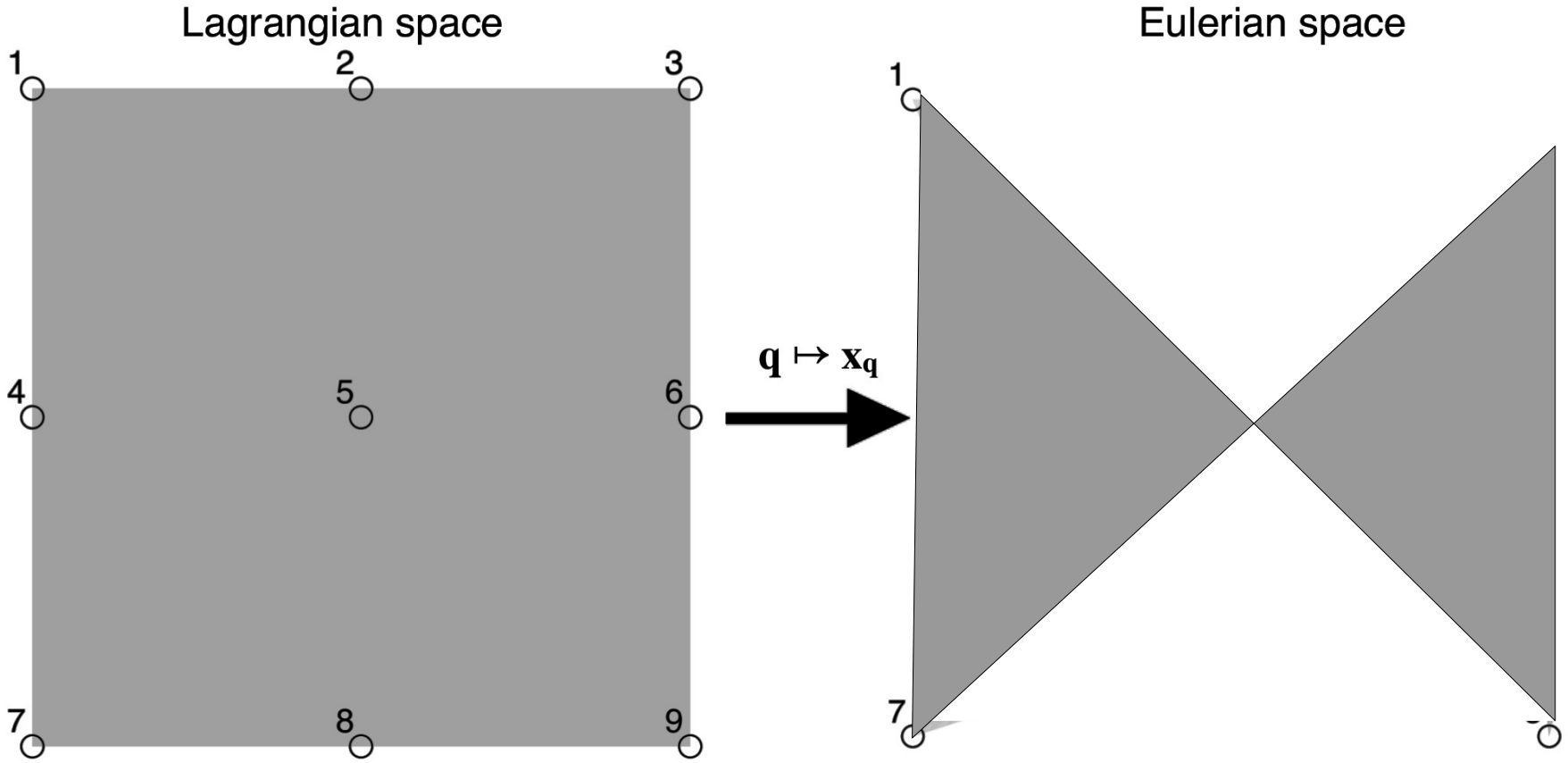
Problem: Bias





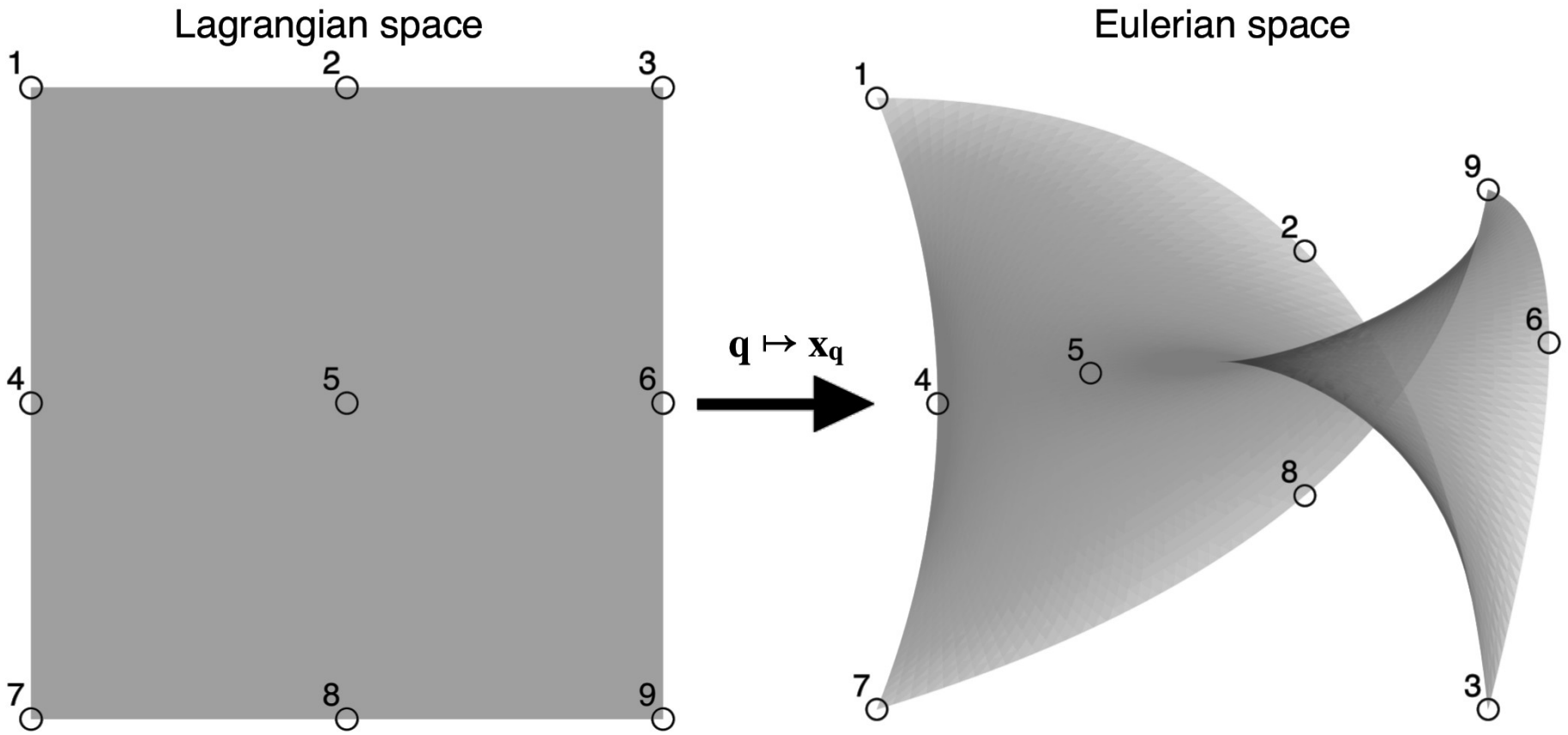
Angulo et al. (2014)

Solution (?): Better Interpolation



Hahn & Angulo (2015)

Solution (?): Better Interpolation



Hahn & Angulo (2015)

Thanks
for
Your Attention!