WEAK GRAVITATIONAL LENSING AND APPLICATIONS

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OUTLINE

- Weak gravitational lensing basics
- Weak gravitational lensing beyond LCDM
- Quantification of weak lensing estimator around rotating cluster halos
- Conclusion

GRAVITATIONAL LENSING BASICS

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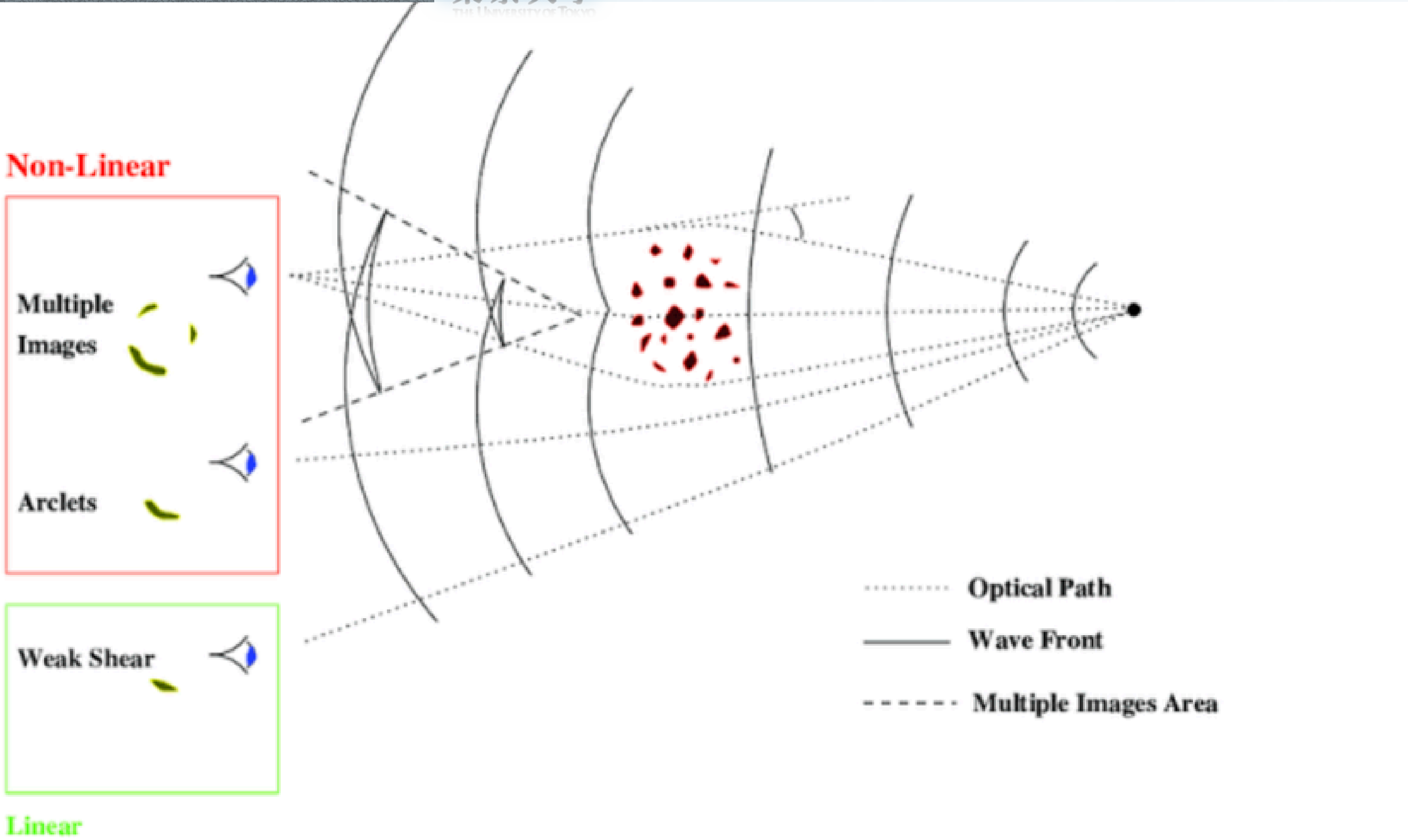
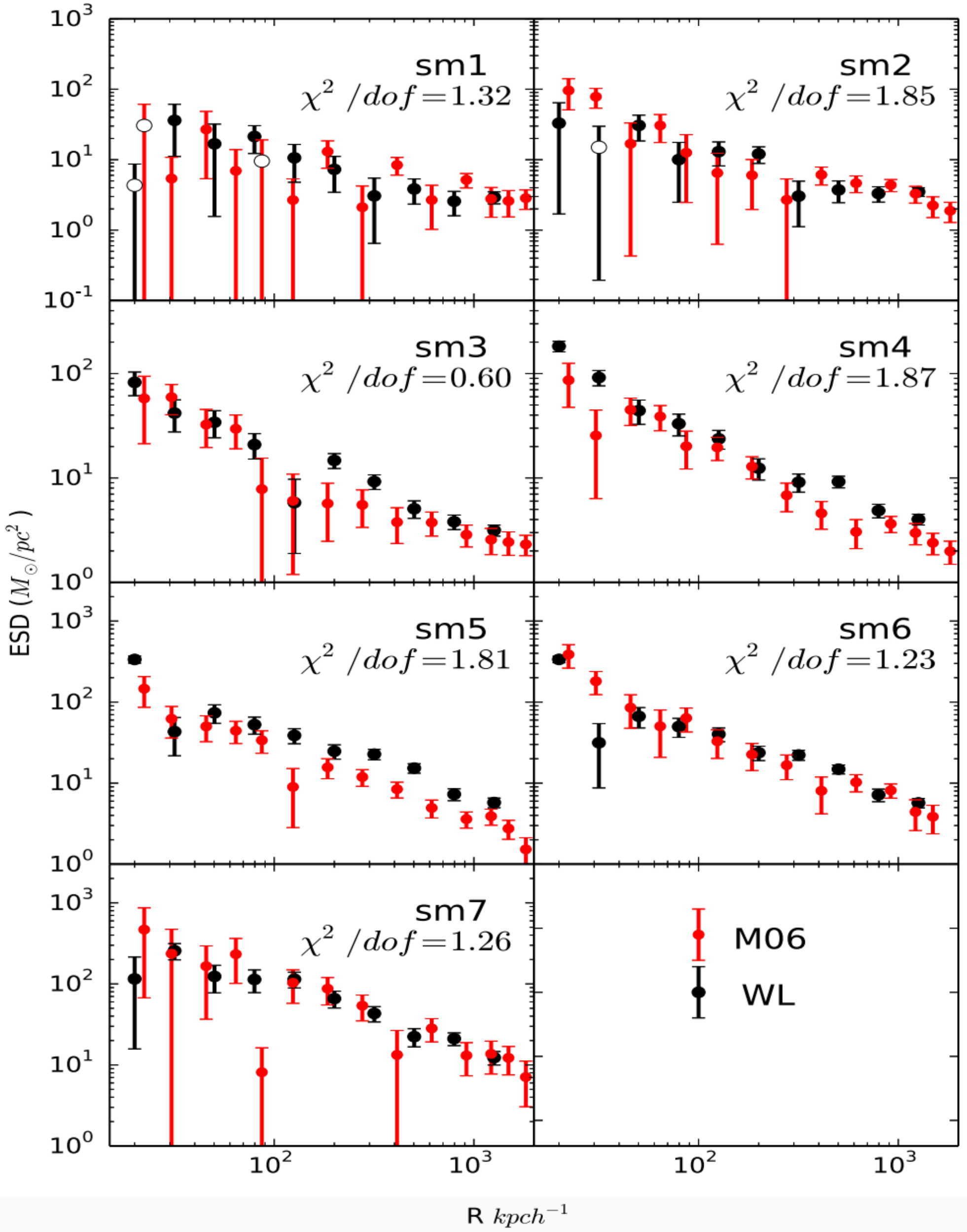
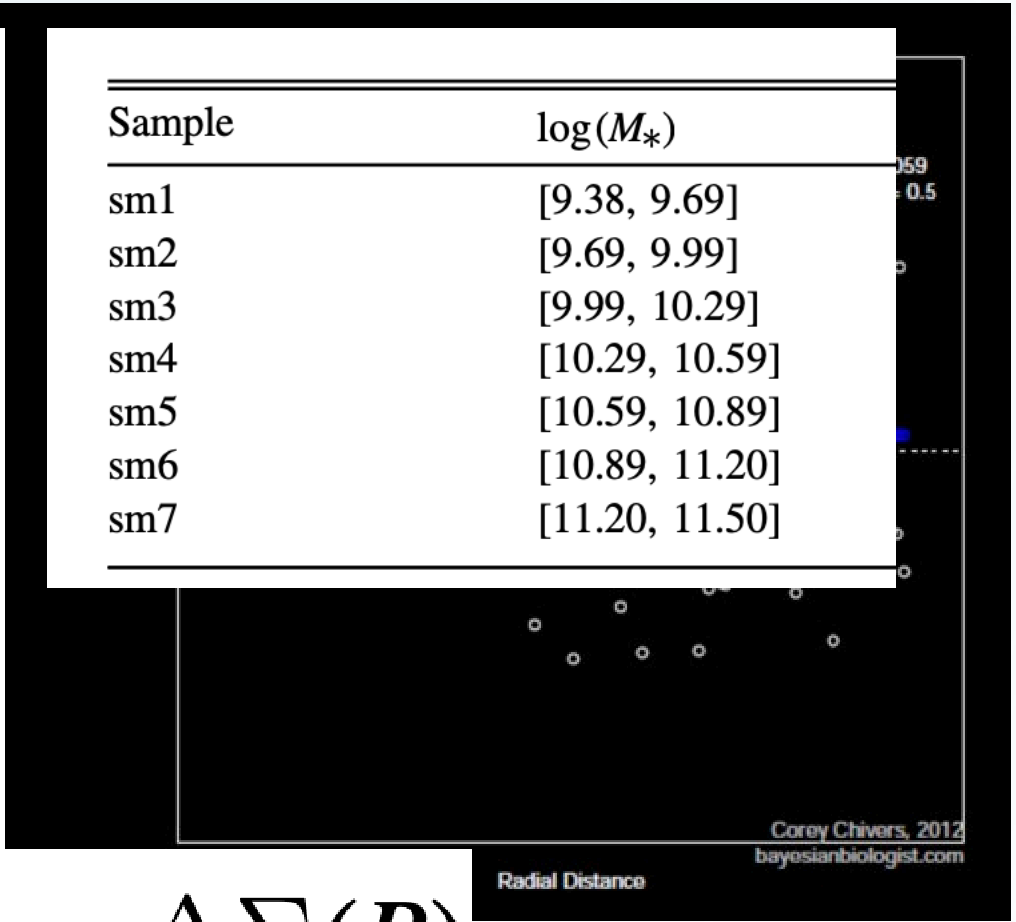


Credit: Jean-Paul Kneib https://ned.ipac.Caltech.edu/level5/Sept17/Kneib/Kneib2.html



Luo et al 2018 ApJ

Sample	$\log(M_*)$
sm1	[9.38, 9.69]
sm2	[9.69, 9.99]
sm3	[9.99, 10.29]
sm4	[10.29, 10.59]
sm5	[10.59, 10.89]
sm6	[10.89, 11.20]
sm7	[11.20, 11.50]



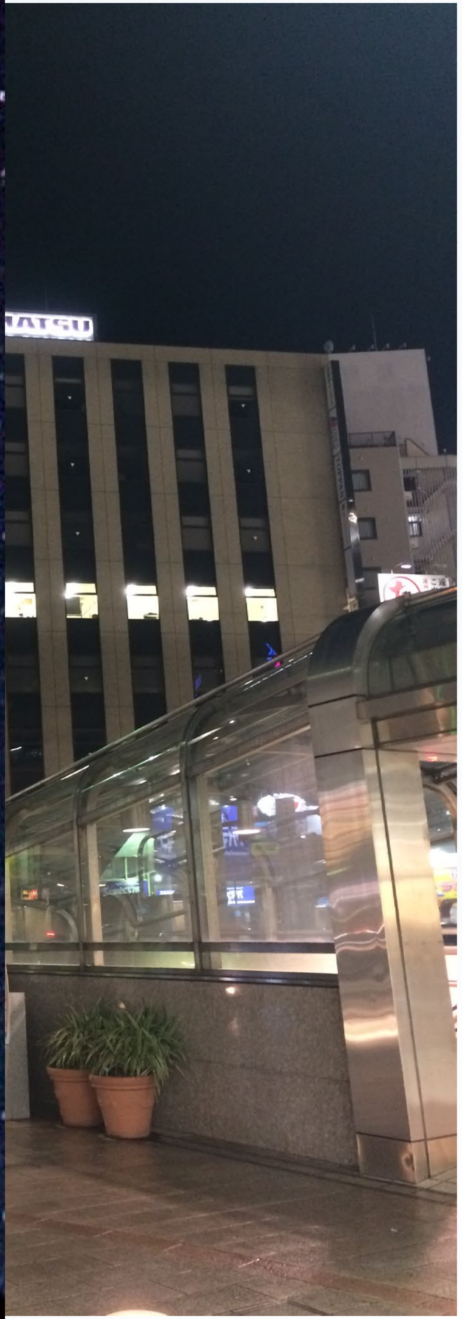
$$= \Delta\Sigma(R)$$

$$(\leqslant R) - \Sigma(R)$$

credit: CFHT website

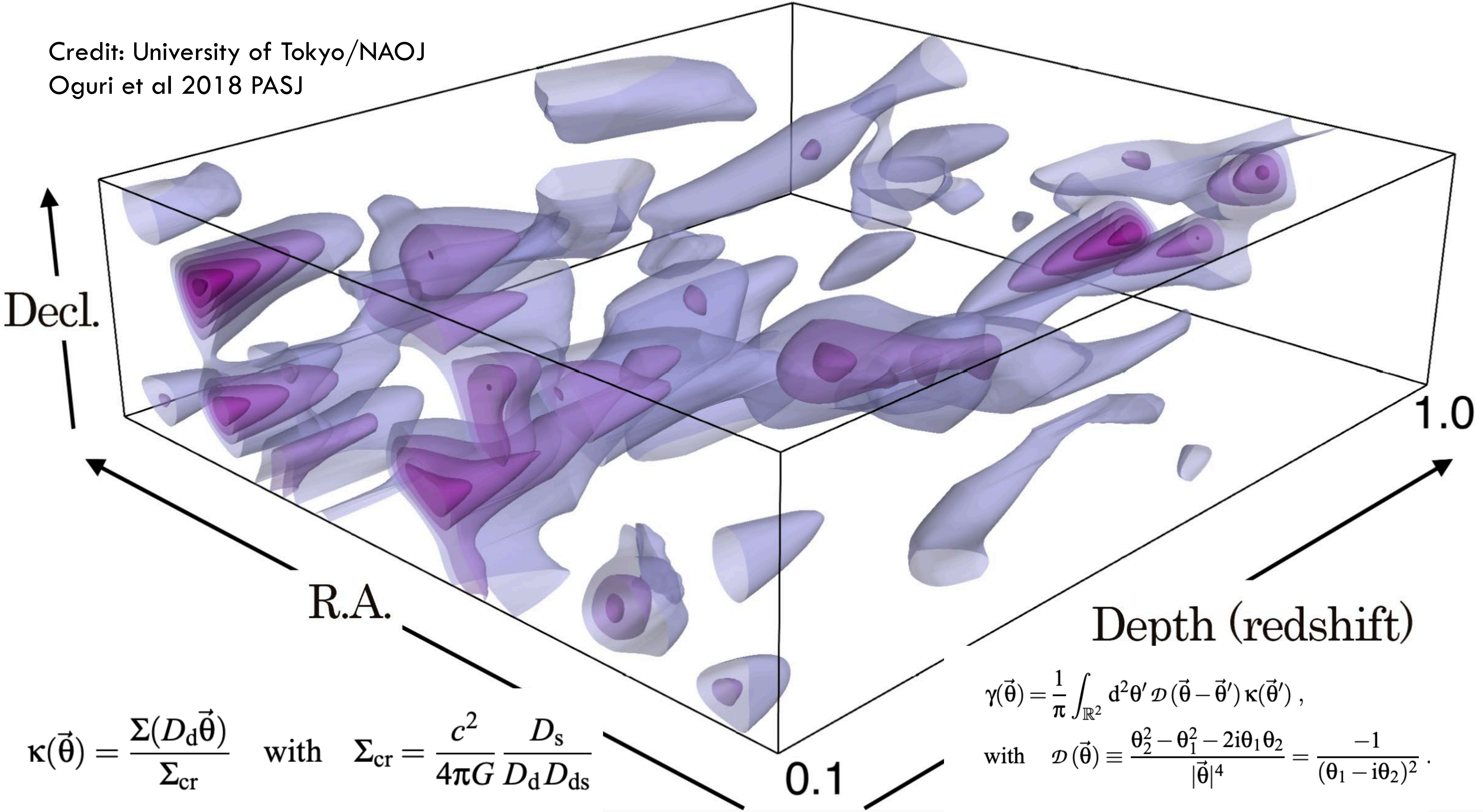
Credit: DES website

credit: LSST website



Credit: NAOJ

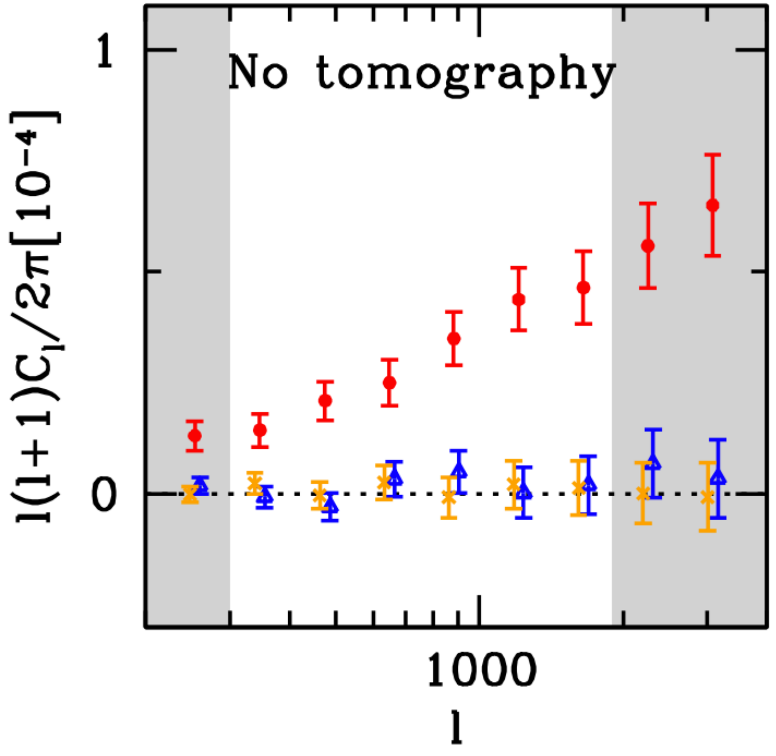
Credit: University of Tokyo/NAOJ
Oguri et al 2018 PASJ

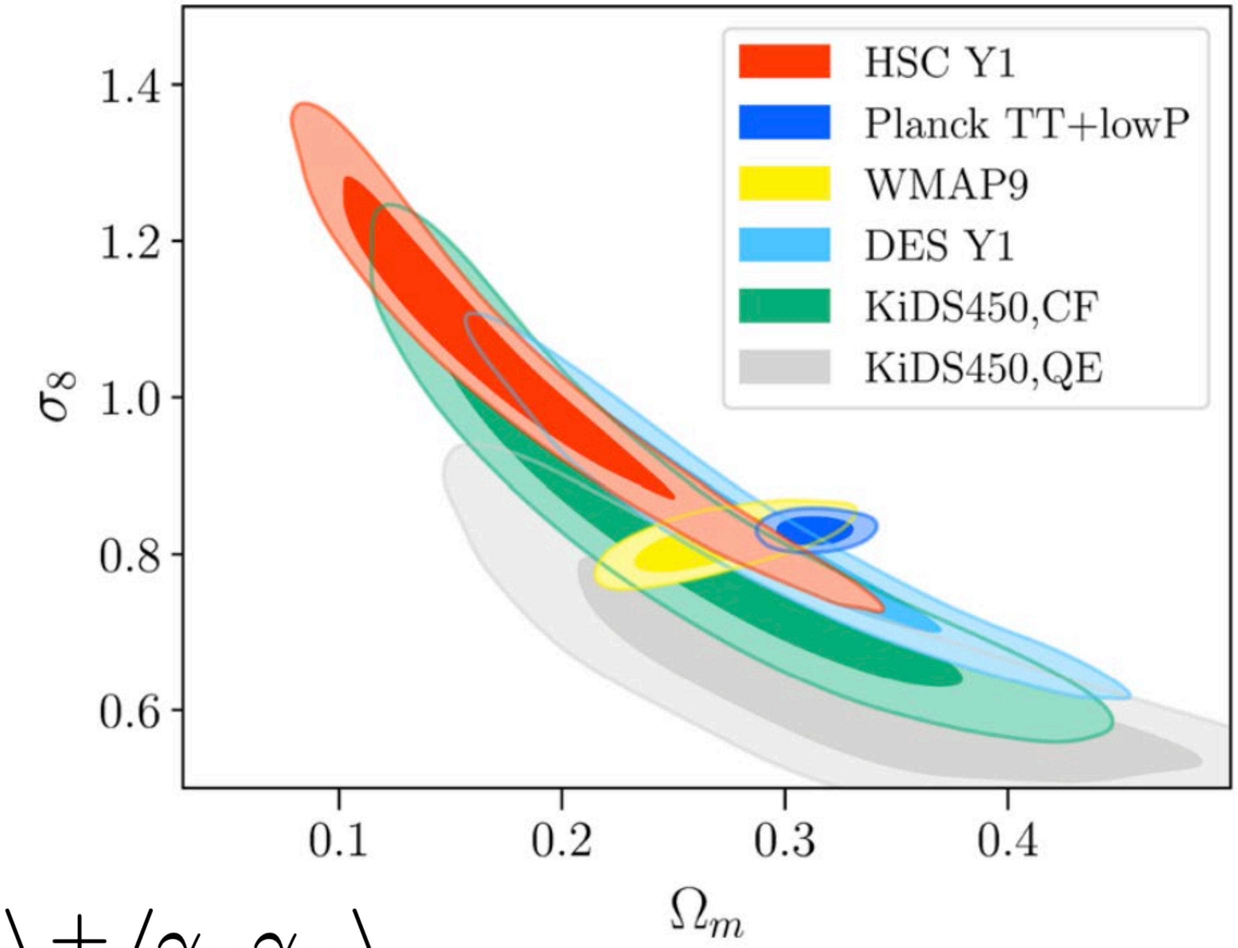


$$\kappa(\vec{\theta}) = \frac{\Sigma(D_\mathrm{d}\vec{\theta})}{\Sigma_\mathrm{cr}} \quad \text{with} \quad \Sigma_\mathrm{cr} = \frac{c^2}{4\pi G}\frac{D_\mathrm{s}}{D_\mathrm{d}D_\mathrm{ds}}$$

$$\gamma(\vec{\theta}) = \frac{1}{\pi}\int_{\mathbb{R}^2} \mathrm{d}^2\theta' \, \mathcal{D}(\vec{\theta}-\vec{\theta}') \, \kappa(\vec{\theta}') \, ,$$

$$\text{with} \quad \mathcal{D}(\vec{\theta}) \equiv \frac{\theta_2^2 - \theta_1^2 - 2\mathrm{i}\theta_1\theta_2}{|\vec{\theta}|^4} = \frac{-1}{(\theta_1 - \mathrm{i}\theta_2)^2} \, .$$



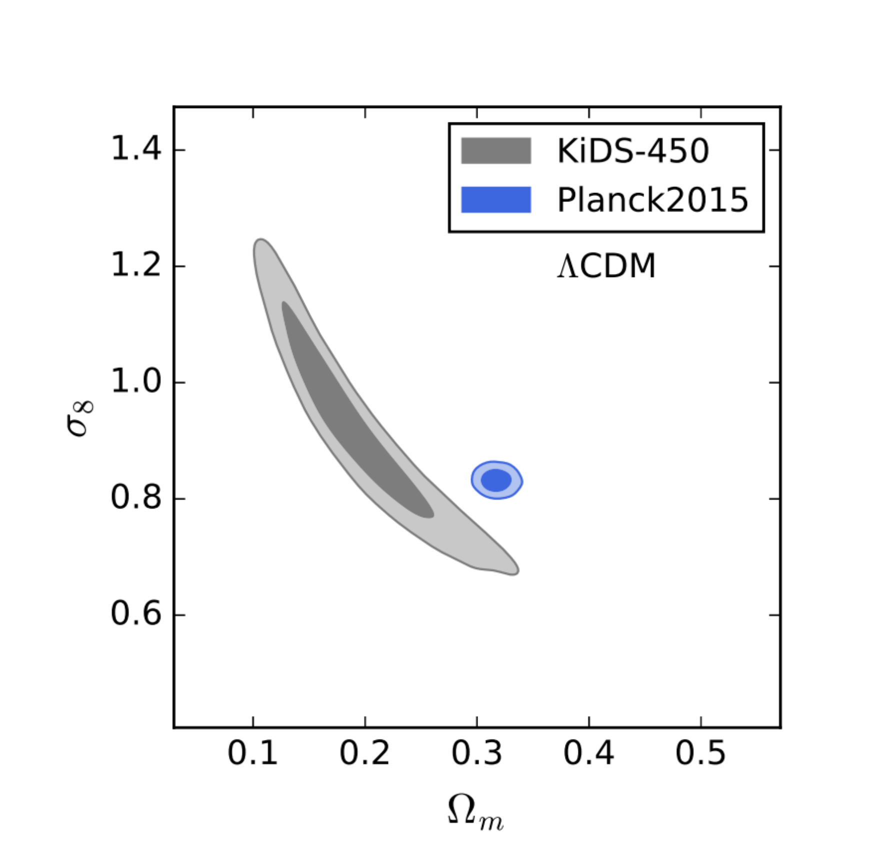


$$\xi_{\pm}(\theta) = \frac{1}{2\pi}\int d\ell\,\ell C_{\ell} J_{0,4}(\ell\theta)\quad \xi_{\pm} = \langle\gamma_t\gamma_t\rangle \pm \langle\gamma_{\times}\gamma_{\times}\rangle$$

Hikage et al 2019 PASJ

WEAK LENSING BEYOND LCDM

- Interacting dark energy and dark matter model



An et al 2017 JCAP

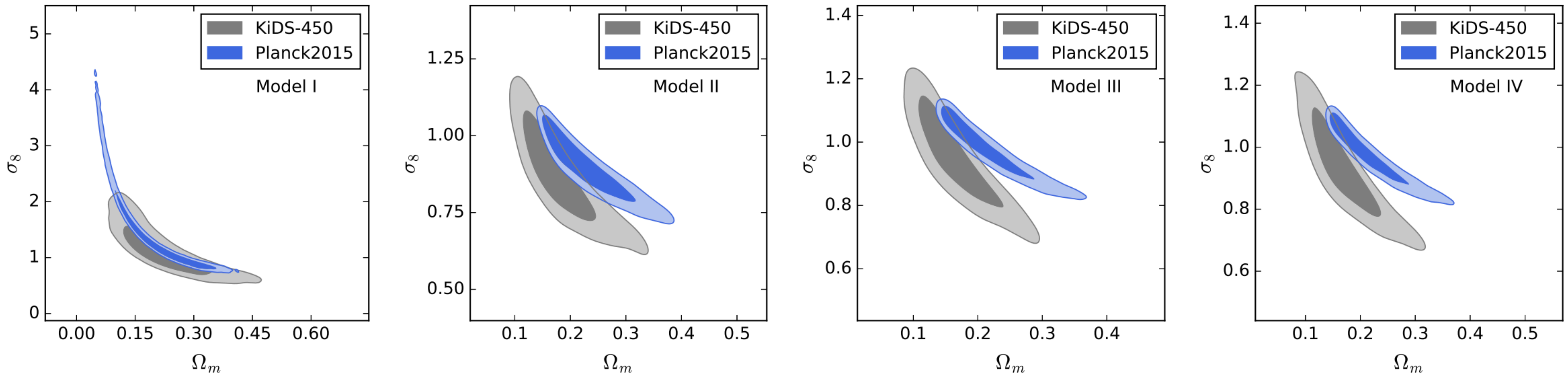
$$\dot{\rho}_c + 3\mathcal{H}\rho_c = aQ,$$

$$\dot{\rho}_d + 3\mathcal{H}(1+w)\rho_d = -aQ,$$

$$Q = 3\lambda_1 H\rho_c + 3\lambda_2 H\rho_d$$

An et al 2017 JCAP

Model	Q	w	Constraints
I	$3\lambda_2 H\rho_d$	$-1 < w < -1/3$	$\lambda_2 < 0$
II	$3\lambda_2 H\rho_d$	$w < -1$	$0 < \lambda_2 < -2w\Omega_c$
III	$3\lambda_1 H\rho_c$	$w < -1$	$0 < \lambda_1 < -w/4$
IV	$3\lambda H(\rho_c + \rho_d)$	$w < -1$	$0 < \lambda < -w/4$

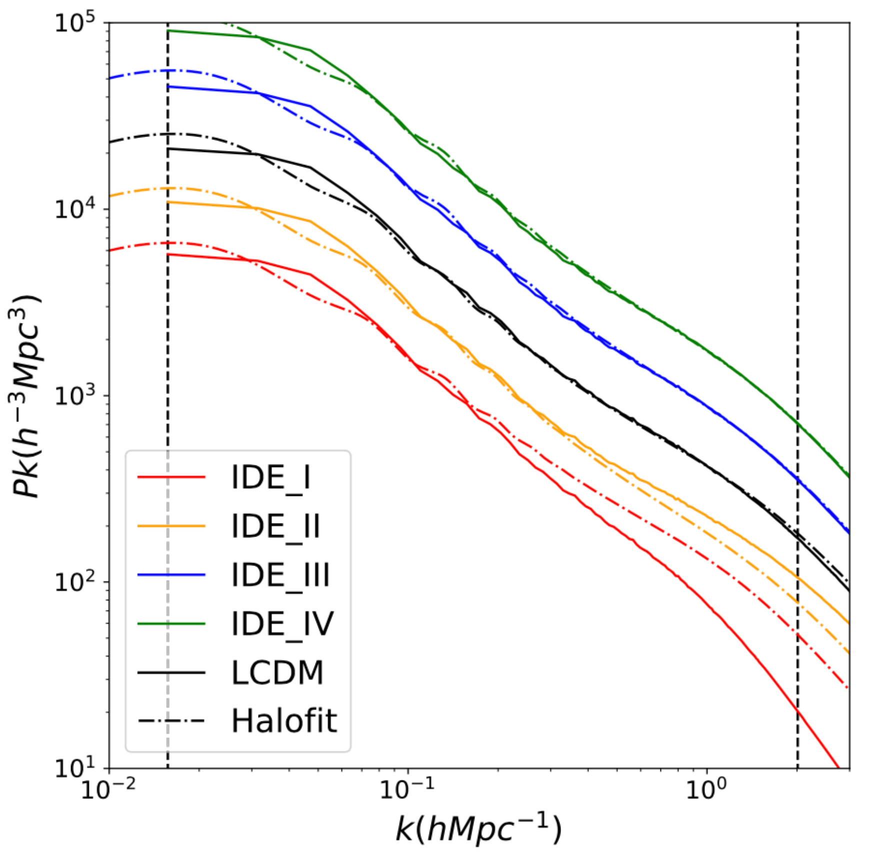


An et al 2017 JCAP

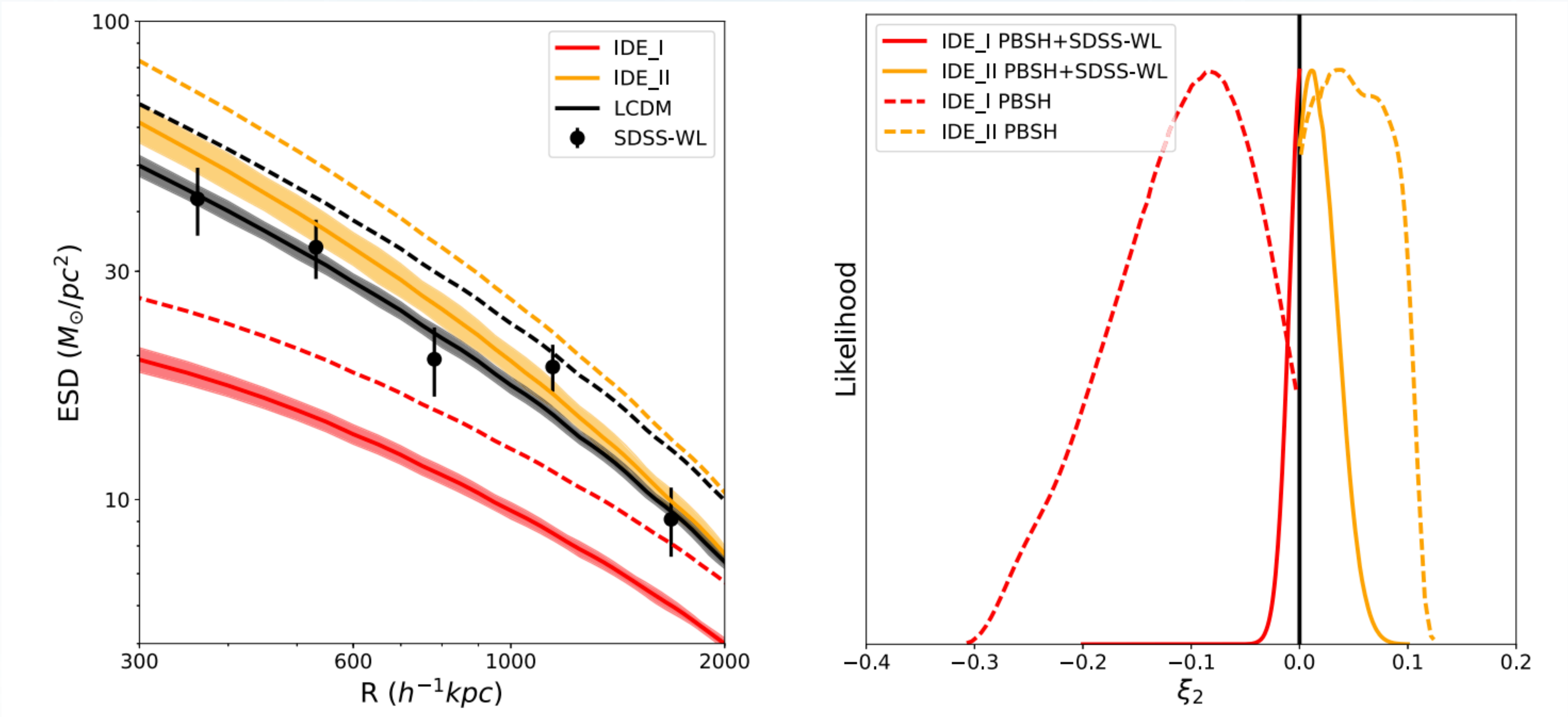
ME-GEDGET SIMULATION

Table 2
Cosmological Parameters

Parameter	IDE_I	IDE_II	IDE_III	IDE_IV	ΛCDM
$\Omega_b h^2$	0.02223	0.02224	0.02228	0.02228	0.02225
$\Omega_c h^2$	0.0792	0.1351	0.1216	0.1218	0.1198
$100\theta_{MC}$	1.043	1.04	1.041	1.041	1.04077
τ	0.08204	0.081	0.07728	0.07709	0.079
$\ln(10^{10}A_s)$	3.099	3.097	3.088	3.087	3.094
n_s	0.9645	0.9643	0.9624	0.9624	0.9645
w	−0.9191	−1.088	−1.104	−1.105	−1
ξ_1	⋯	⋯	0.0007127	0.000735	⋯
ξ_2	−0.1107	0.05219	⋯	0.000735	⋯
H_0	68.18	68.35	68.91	68.88	67.27
Ω_m	0.2204	0.3384	0.3045	0.3053	0.3156



Zhang, An, WL et al
2019 APJL

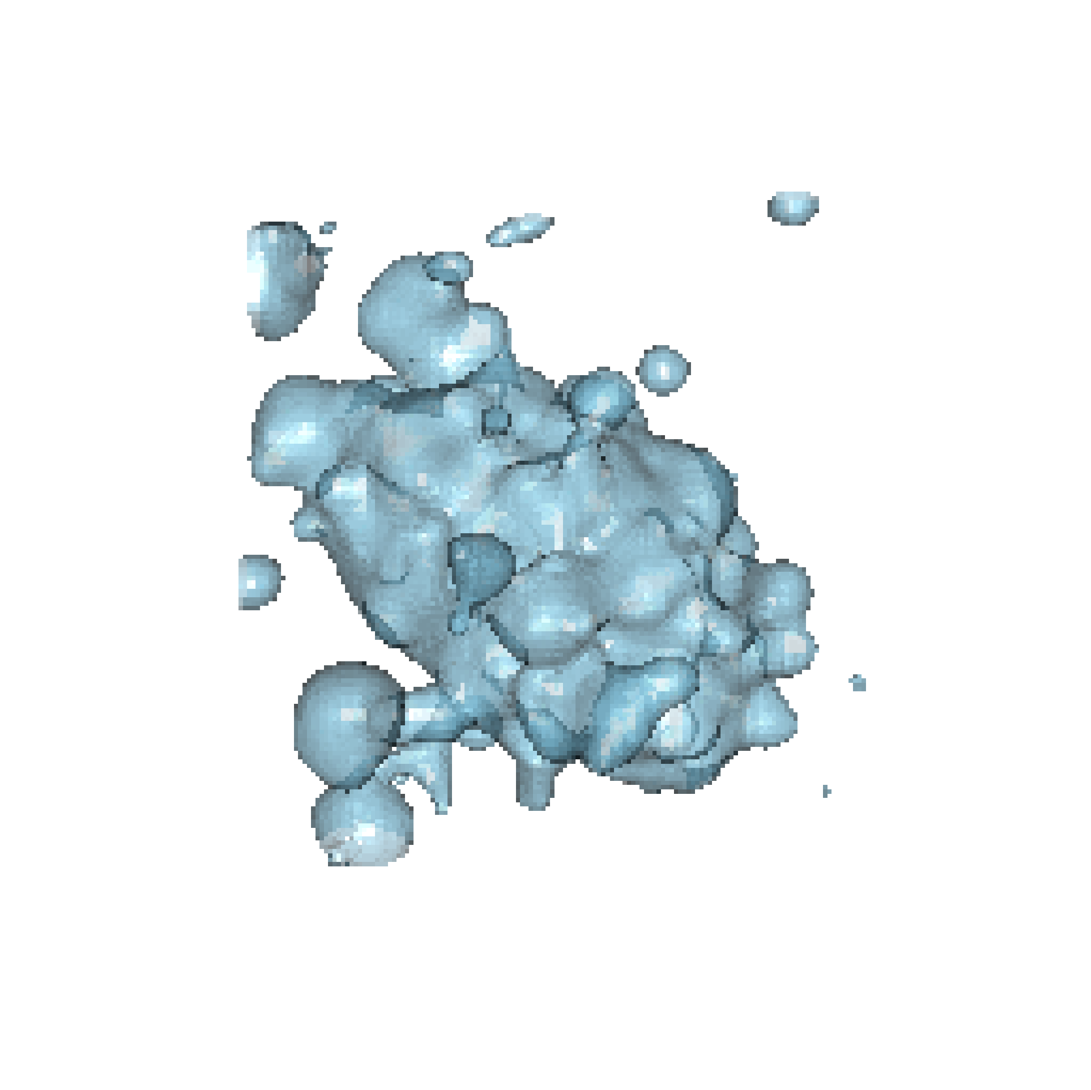


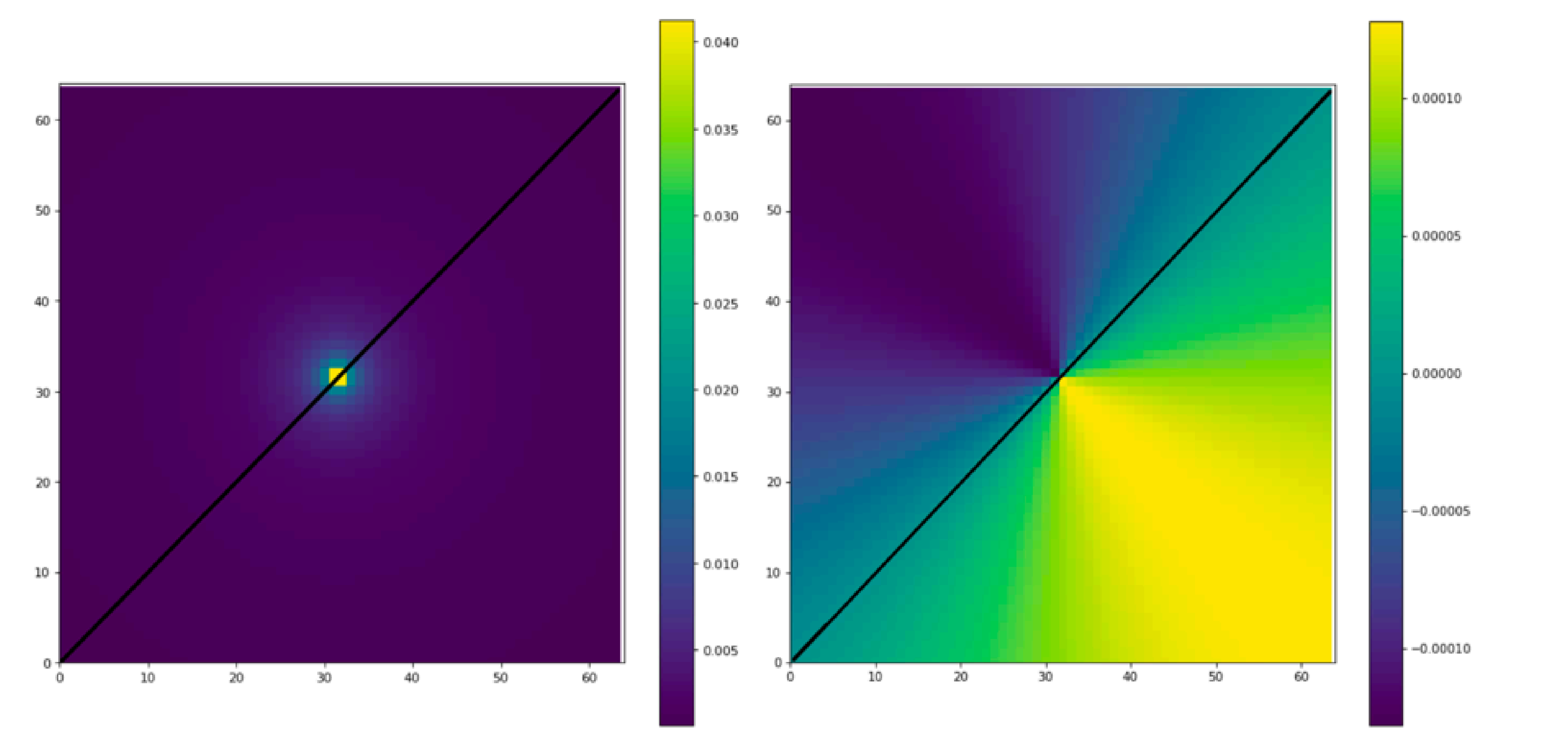
Zhang, An, Luo et al 2019 ApJL

CONCLUSION I

- Halofit can not be properly used to compute the IDE cosmology powerspectrum.
- ME-GETDGET simulation starts with IDE initial condition and simulates the IDE cosmology power spectrum while do not change the H0 significantly due to the selection of parameters.
- Combining weak gravitational lensing, we improve the constraint on IDE I by more than 12 times, IDE II by 3 times.

ROTATING CLUSTERS





$$\delta\kappa = \langle \kappa_{enhance} \rangle - \langle \kappa_{reduce} \rangle$$

Tang, Zhang, WL et al aRvix:2020 2009.12011T

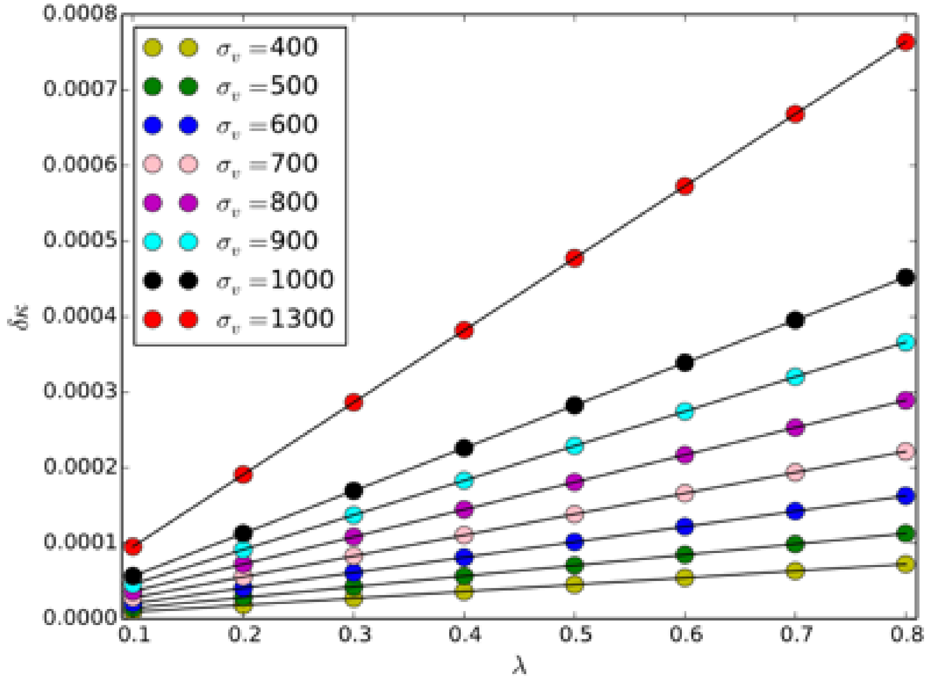
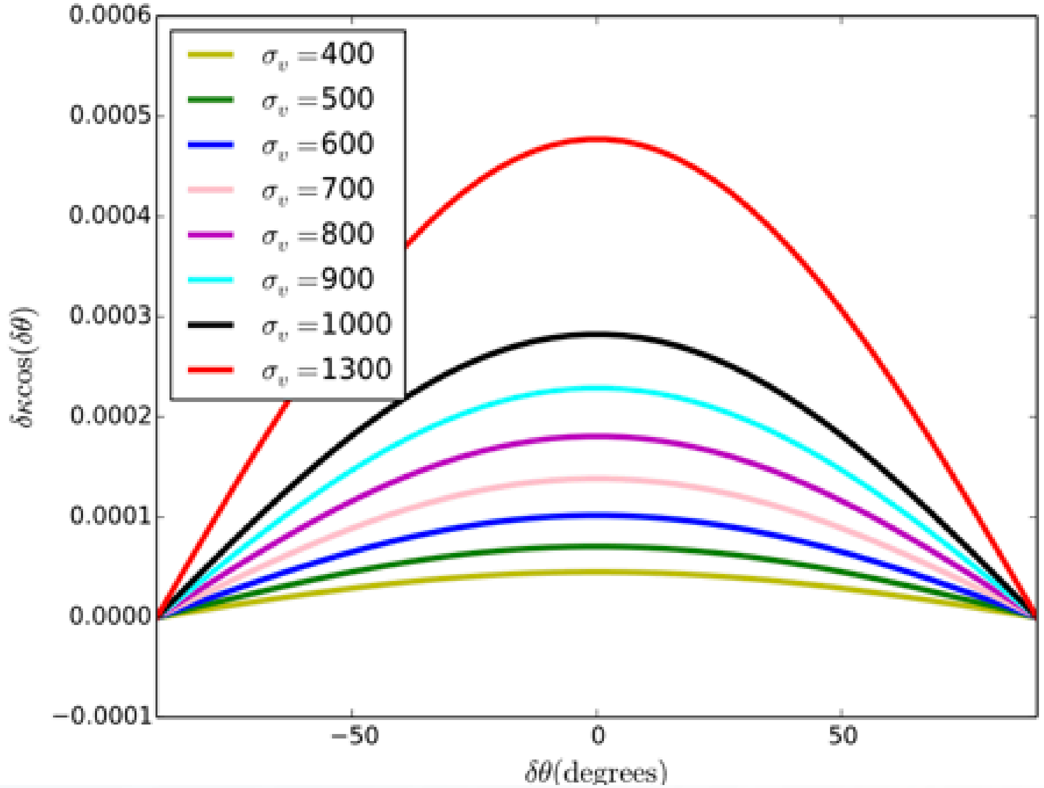


FIG. 4.— $\delta\kappa$ as a function of the fractional angular momentum parameter λ and the velocity dispersion of dark matter inside halos

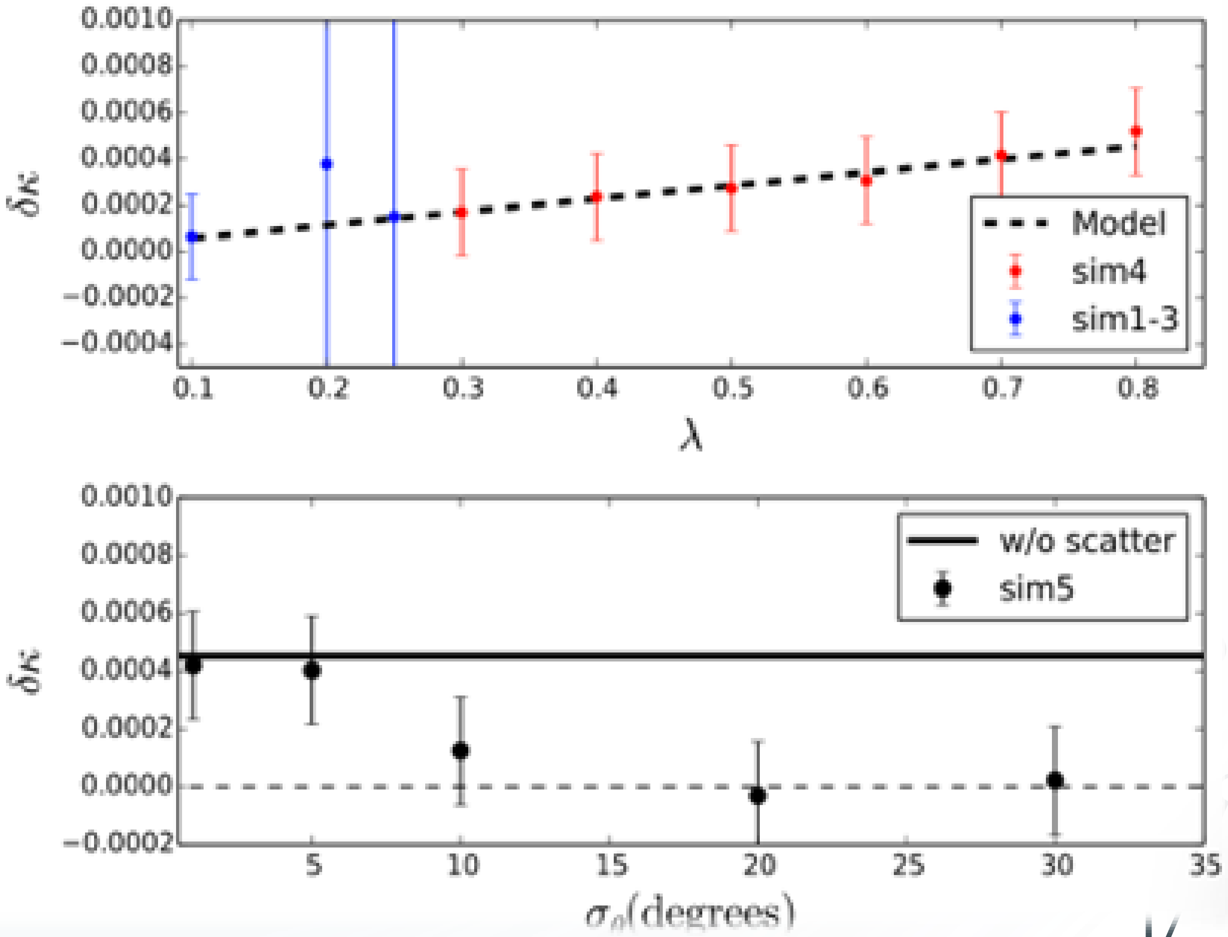


Tang, Zhang, WL et al aRxiv: 2020 2009.12011T

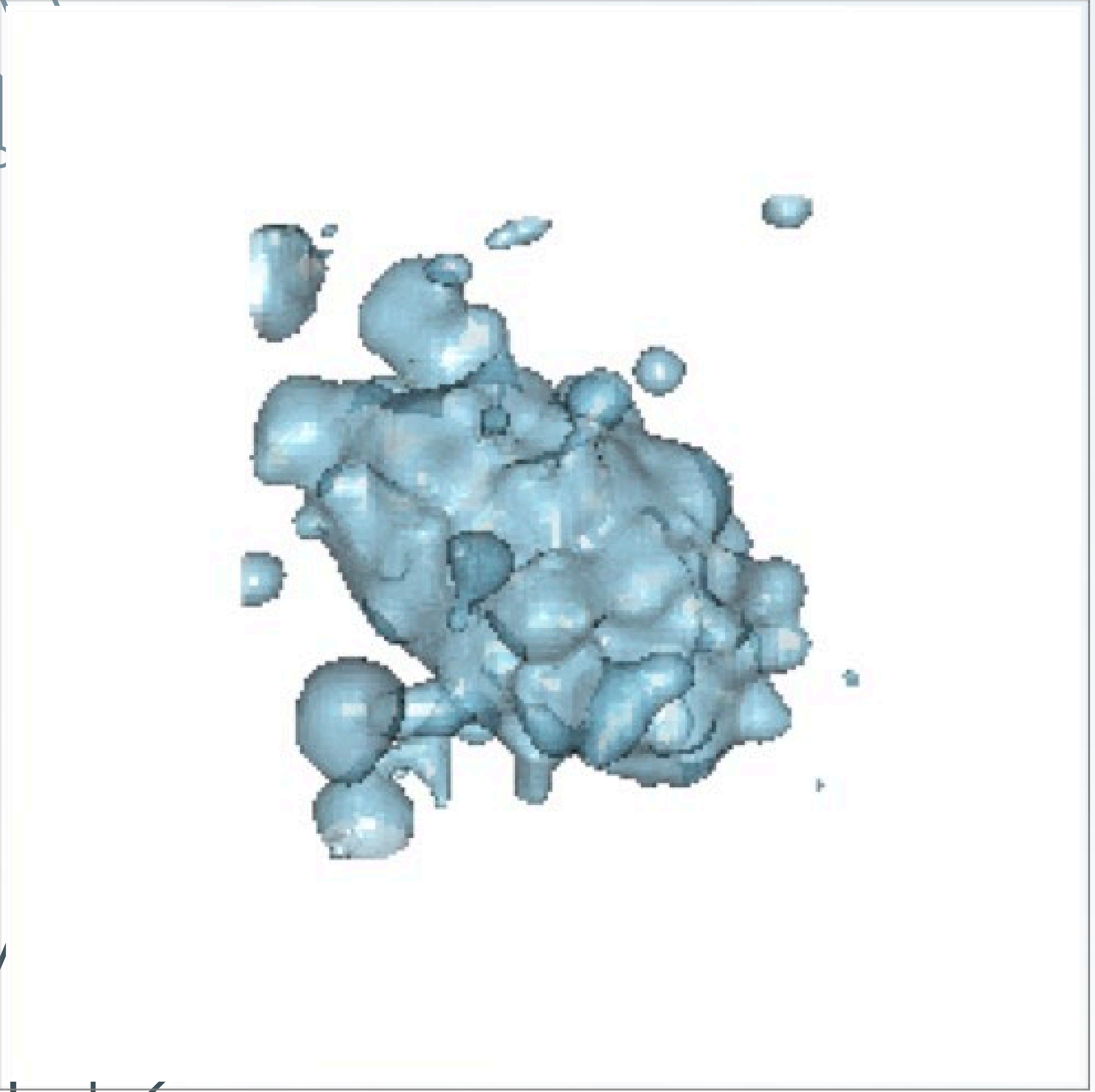
TABLE 1

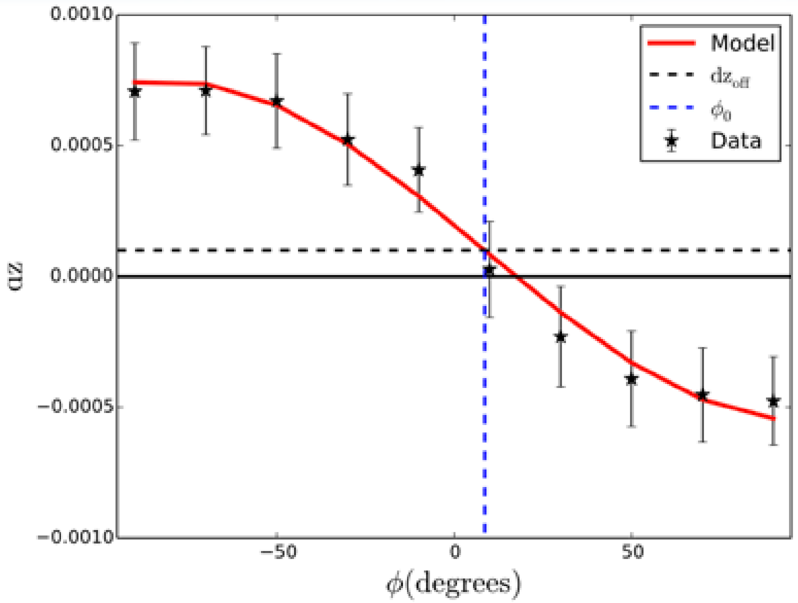
5 SUITES OF SIMULATIONS USED IN THIS WORK WITH FIXED VELOCITY DISPERSION $\sigma_v = 1000$KM/S, VARIOUS ROTATION PARAMETERS λ AND VARIOUS SCATTERS σ_θ OF MISALIGNEMENT $\delta\theta$, AND NUMBER OF SIMULATED CLUSTER HALOS.

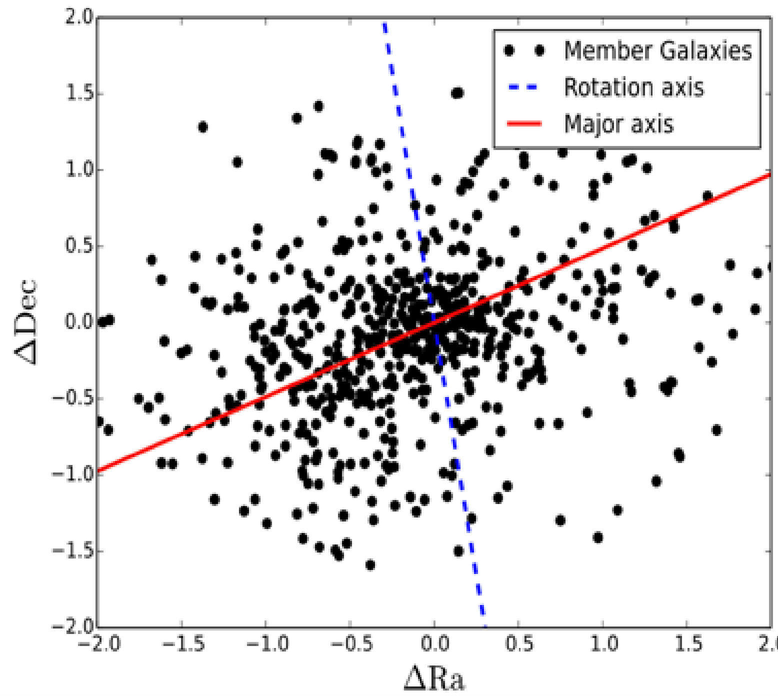
Simulation	σ_v (km/s)	λ	σ_θ(deg)	Num
Sim 1	1000	> 0.1	0.0	412
Sim 2	1000	> 0.2	0.0	13
Sim 3	1000	> 0.25	0.0	3
Sim 4	1000	0.3-0.8	0.0	400
Sim 5	1000	0.8	[1,5,10,20,30]	400



Yang, Zhang, WL et al aRxiv:2020 2009.12011T

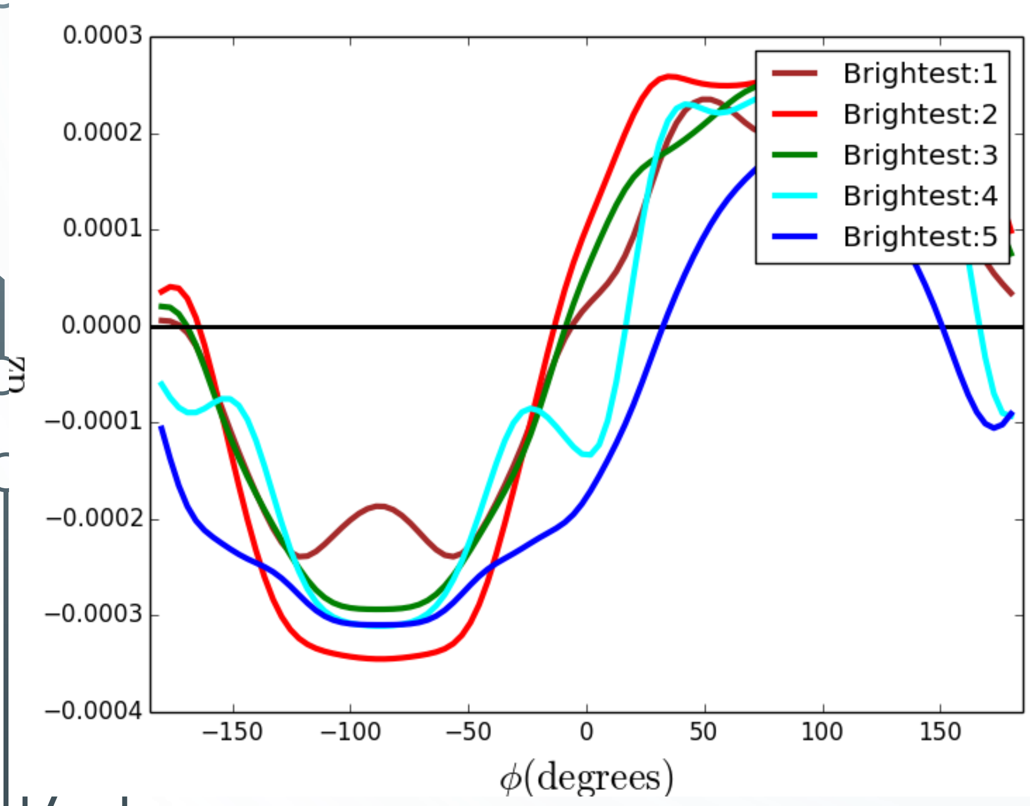


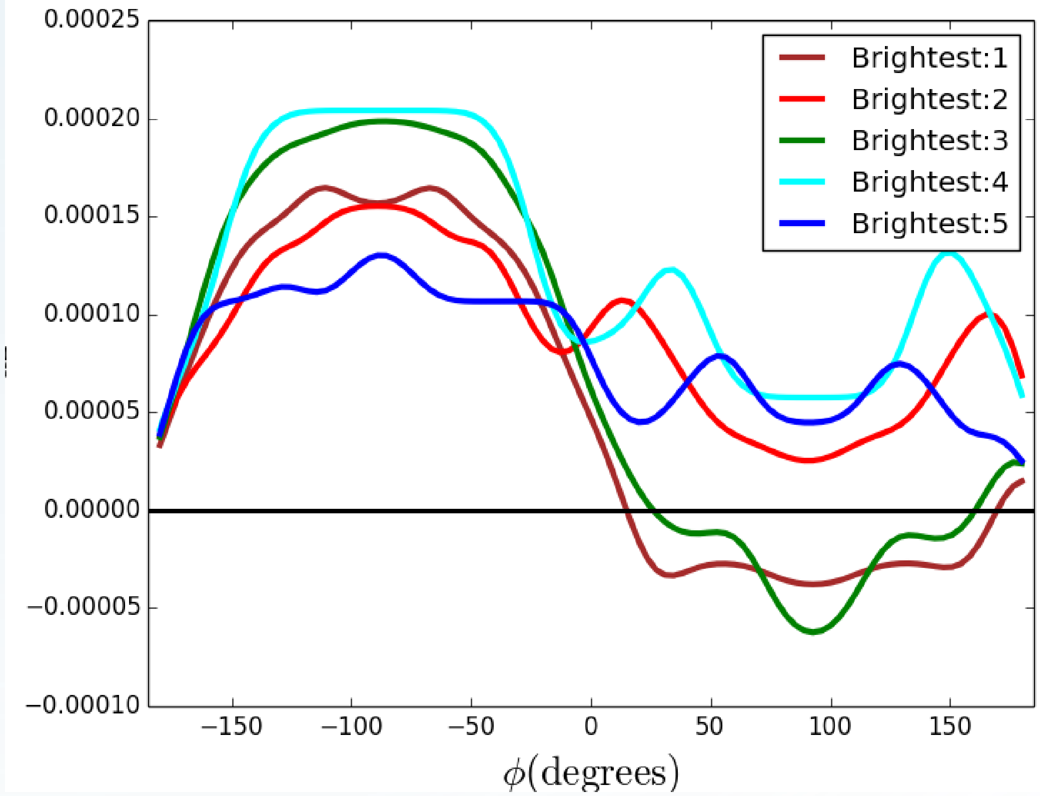

Model
dz_{off}
ϕ_0
Data
0.0010
0.0005
0.0000
−0.0005
−0.0010
dz
−50
0
50
ϕ(degrees)

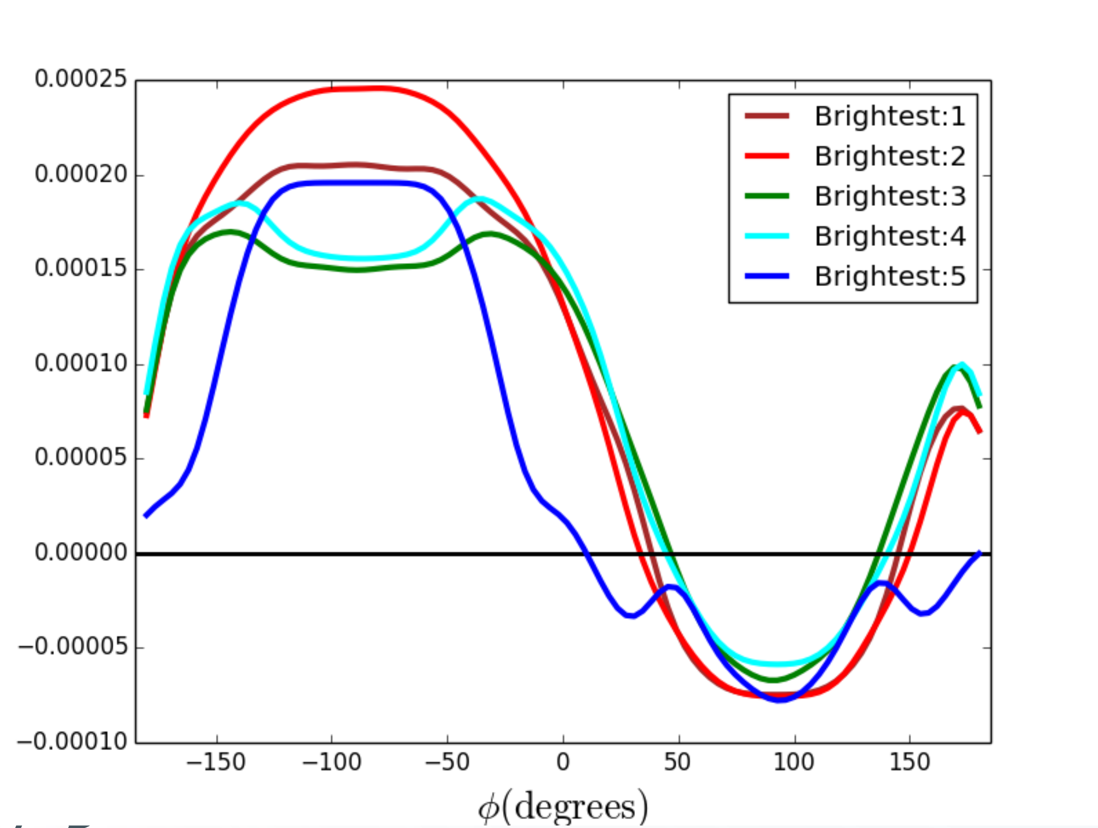
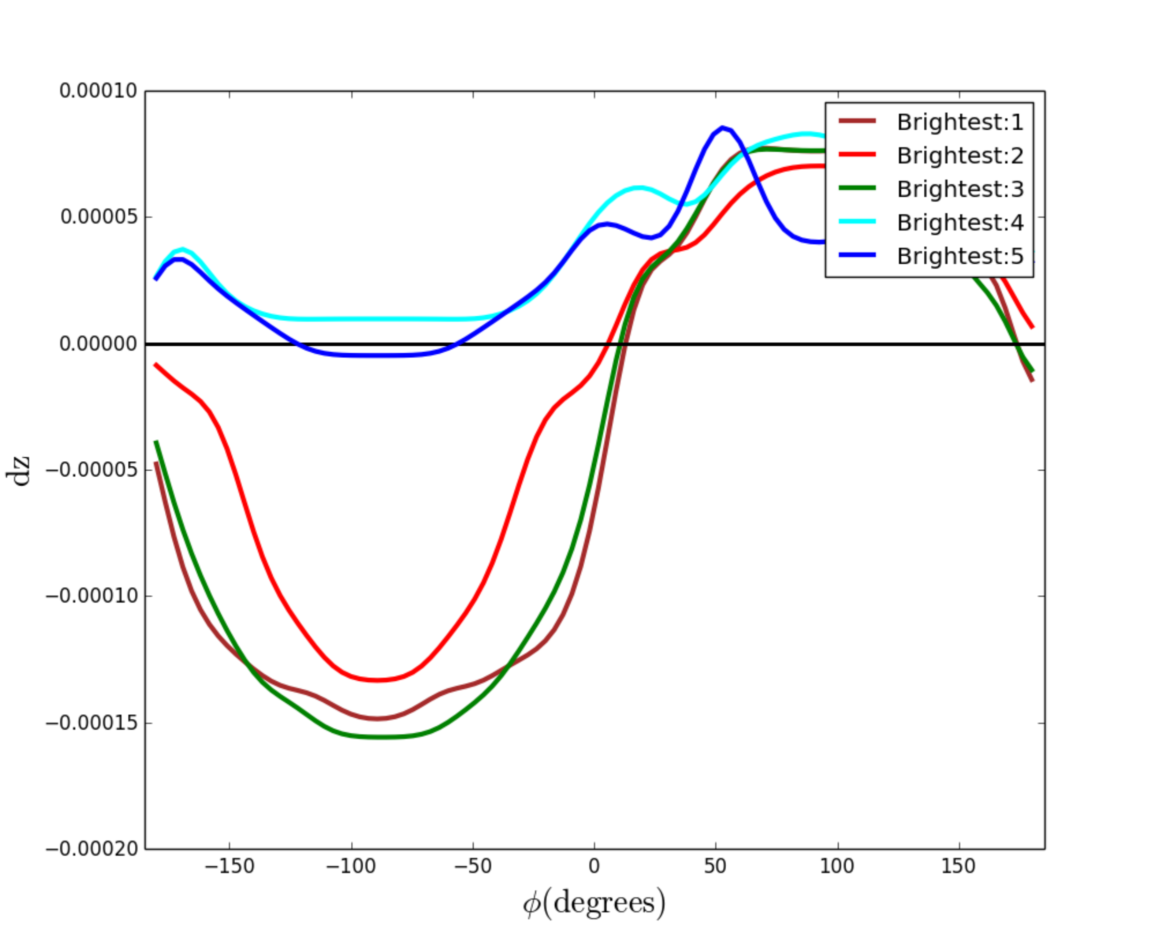

Member Galaxies
Rotation axis
Major axis
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
ΔDec
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
ΔRa

There comes more of rotating clusters

Luo et al in prep






0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
−0.00005
−0.00010
−150
−100
−50
0
50
100
150
ϕ(degrees)
Brightest:1
Brightest:2
Brightest:3
Brightest:4
Brightest:5

0.00010
0.00005
0.00000
−0.00005
−0.00010
−0.00015
−0.00020
dz
−150
−100
−50
0
50
100
150
ϕ(degrees)
Brightest:1
Brightest:2
Brightest:3
Brightest:4
Brightest:5

CONCLUSION II

- The weak lensing signals from rotating halos are very small, 2 to 3 order of magnitude smaller than that from the halo potential alone.
- From simulations, even LSST-liked survey is not sufficient to detect such signal
- However, we do find higly “impossible” rotating cluster sized halos in SDSS survey assuming the satellite rotation curve is similar to the rotation of the whole halo.
- We continue our work in another direction and try to study if satellite galaxies can be tracers of not only velocity dispersion but also rotation of dark matter halos.
- Stay tuned… …

Thank you!