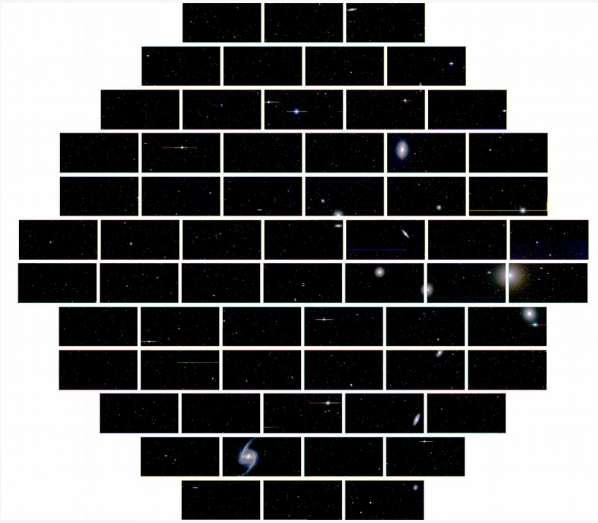
Galaxy Mock Catalogs for the Dark Energy Survey



by Santiago Ávila

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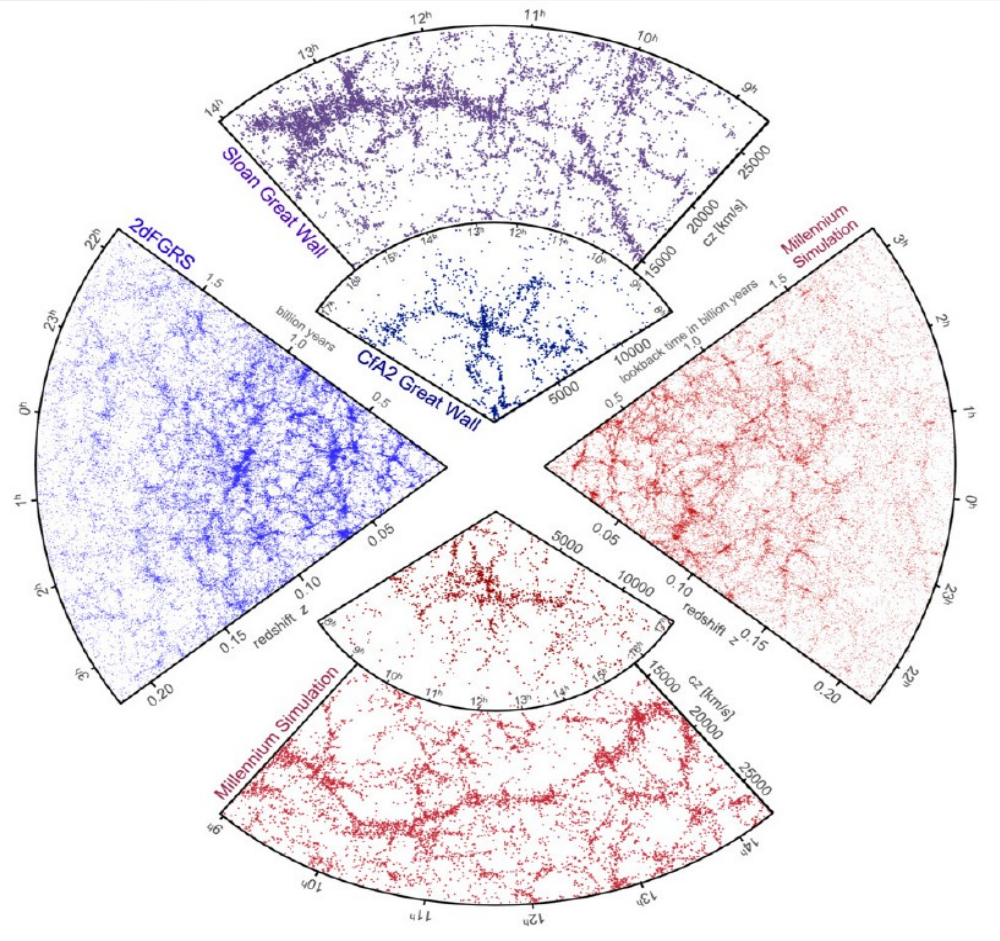
Instituto de Física Teórica UAM-CSIC

27th of June, 2016
Madrid

Mock catalogues

- Mock catalogues:
  theoretical conterpart to LSS observations



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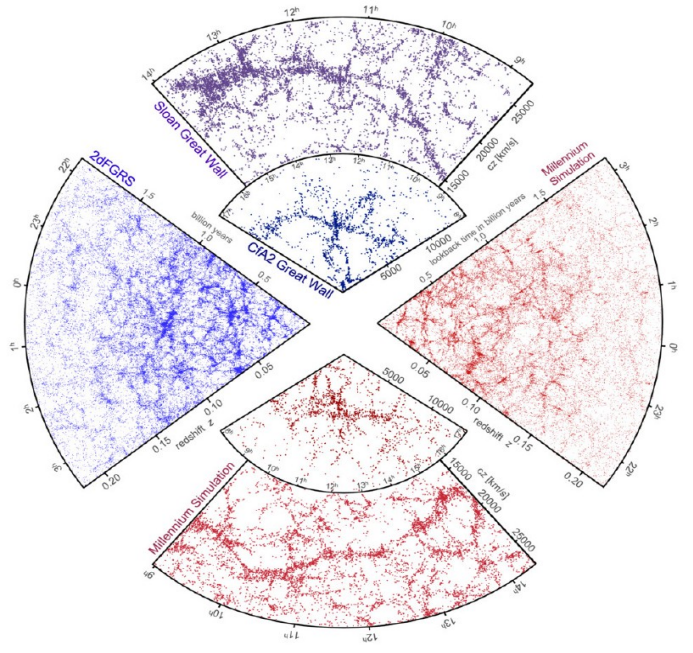

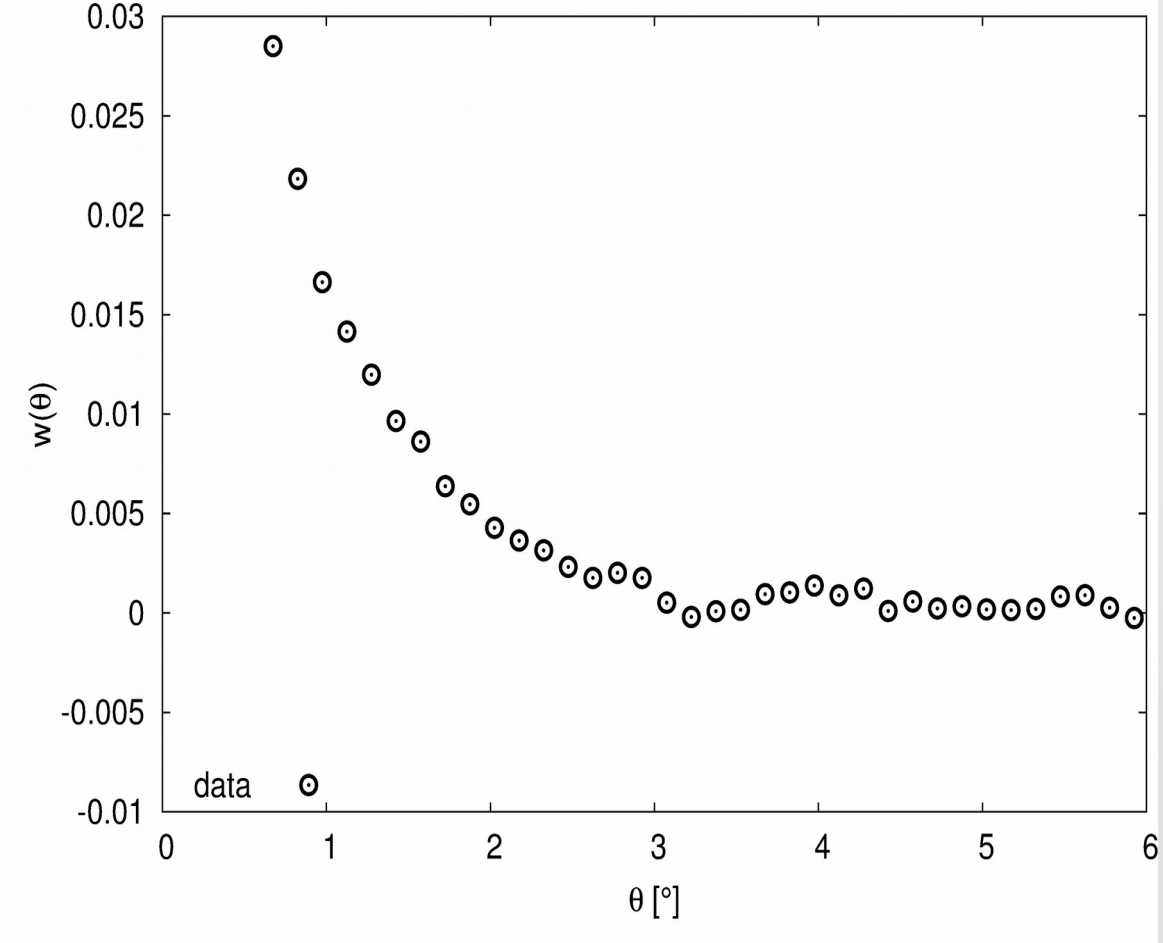

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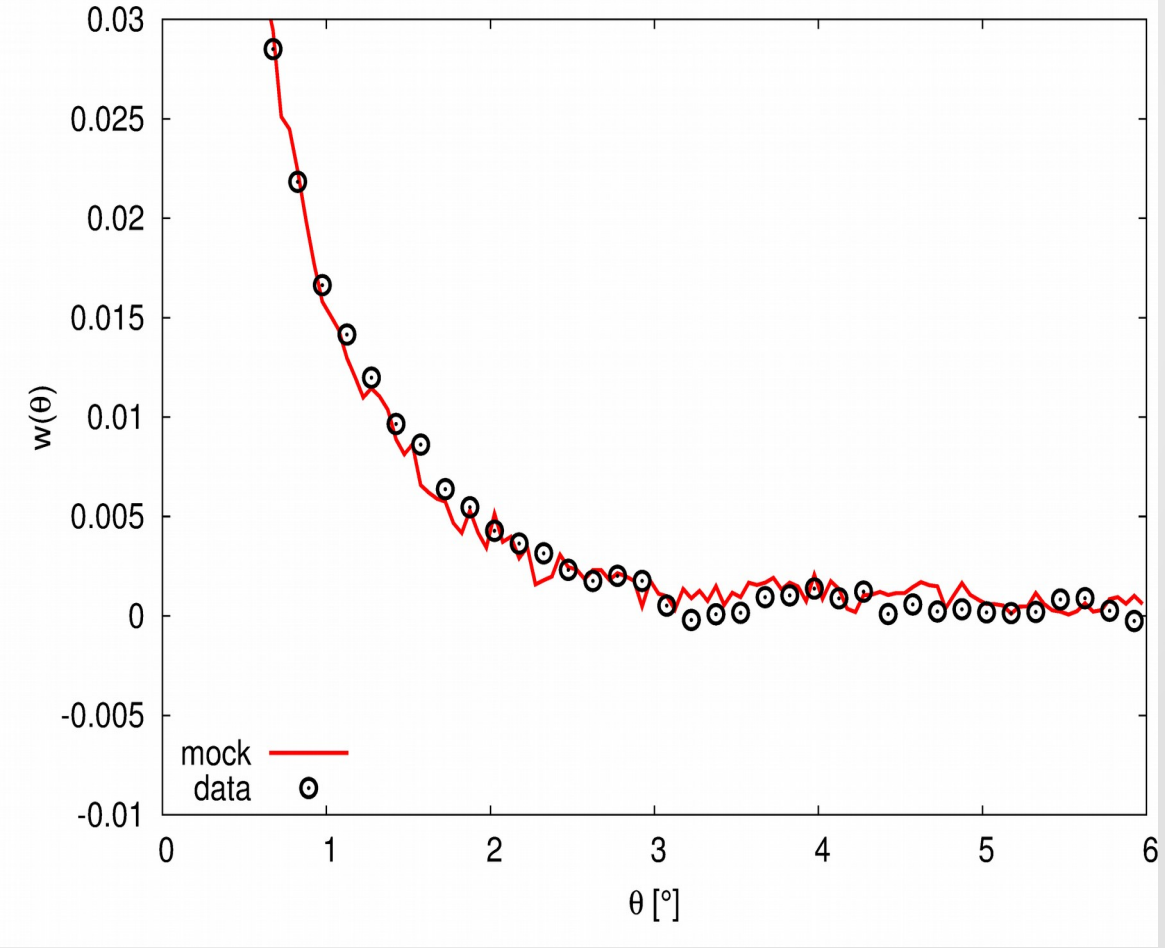
  - agree?
  - detection?



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- Statistical answer,
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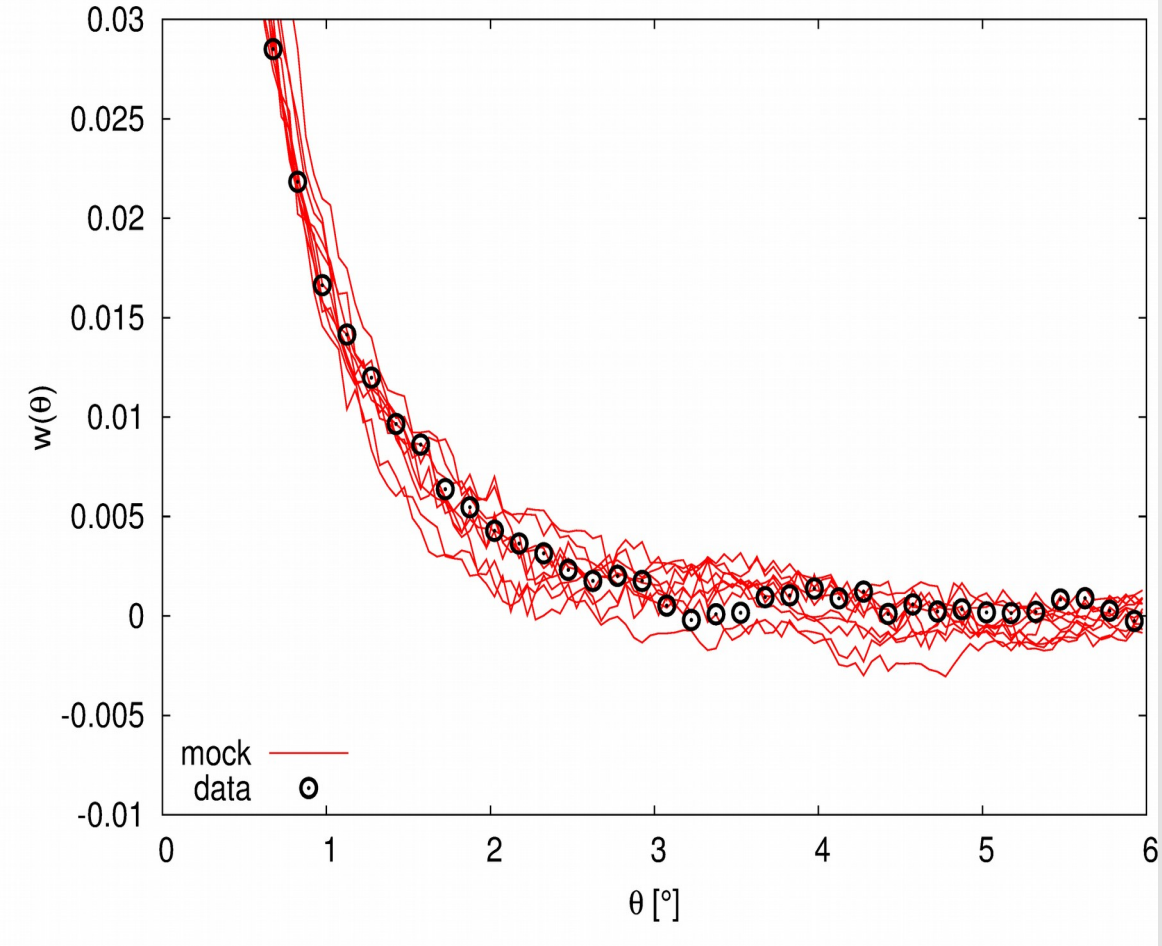

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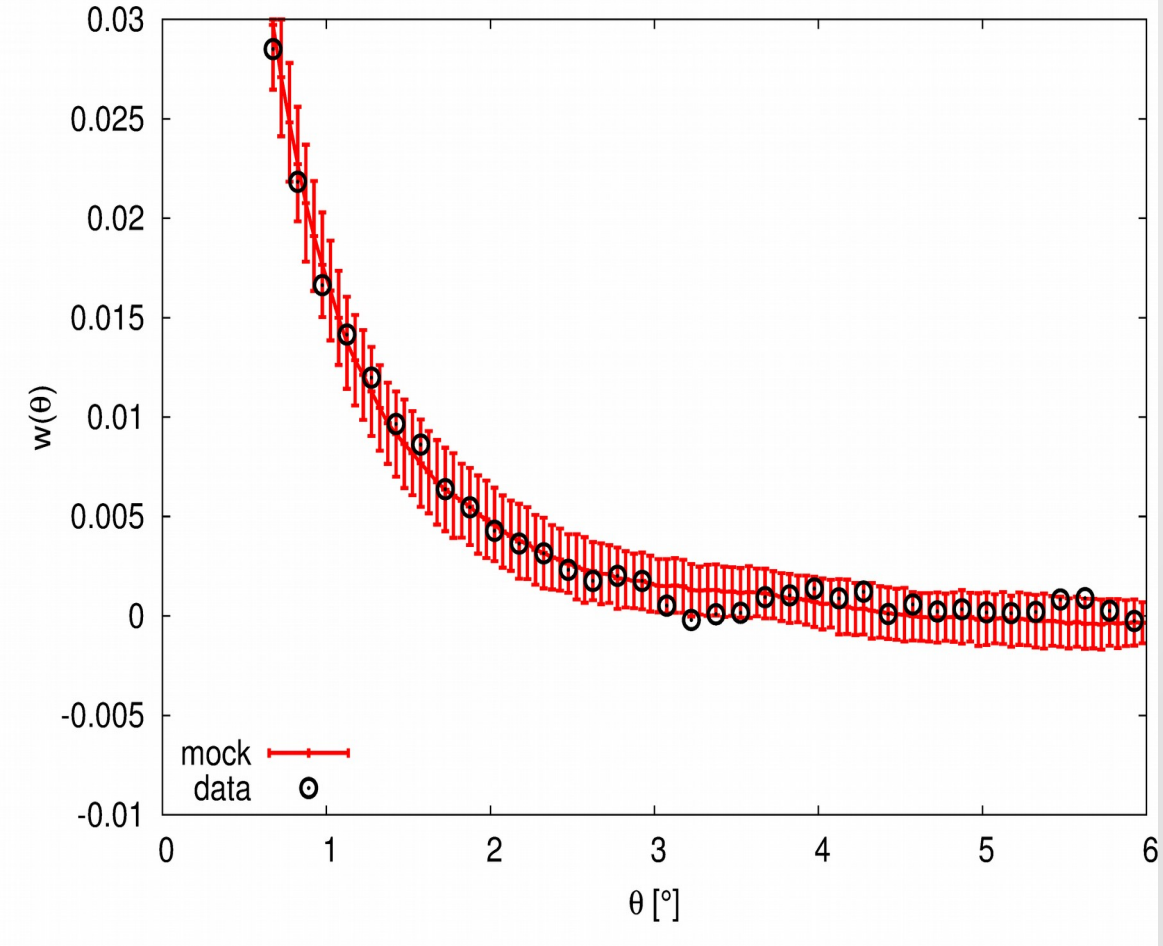

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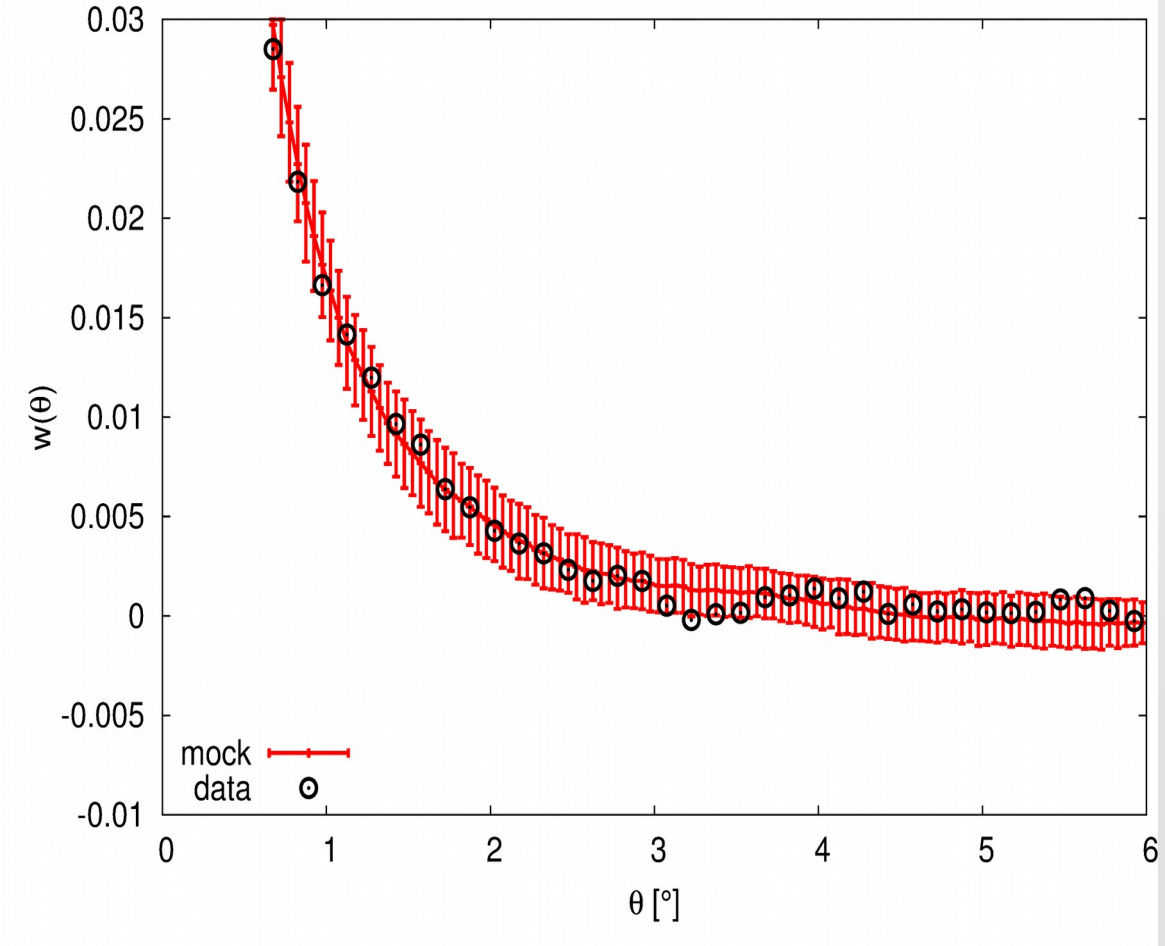

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  of experiments
  - Error bars
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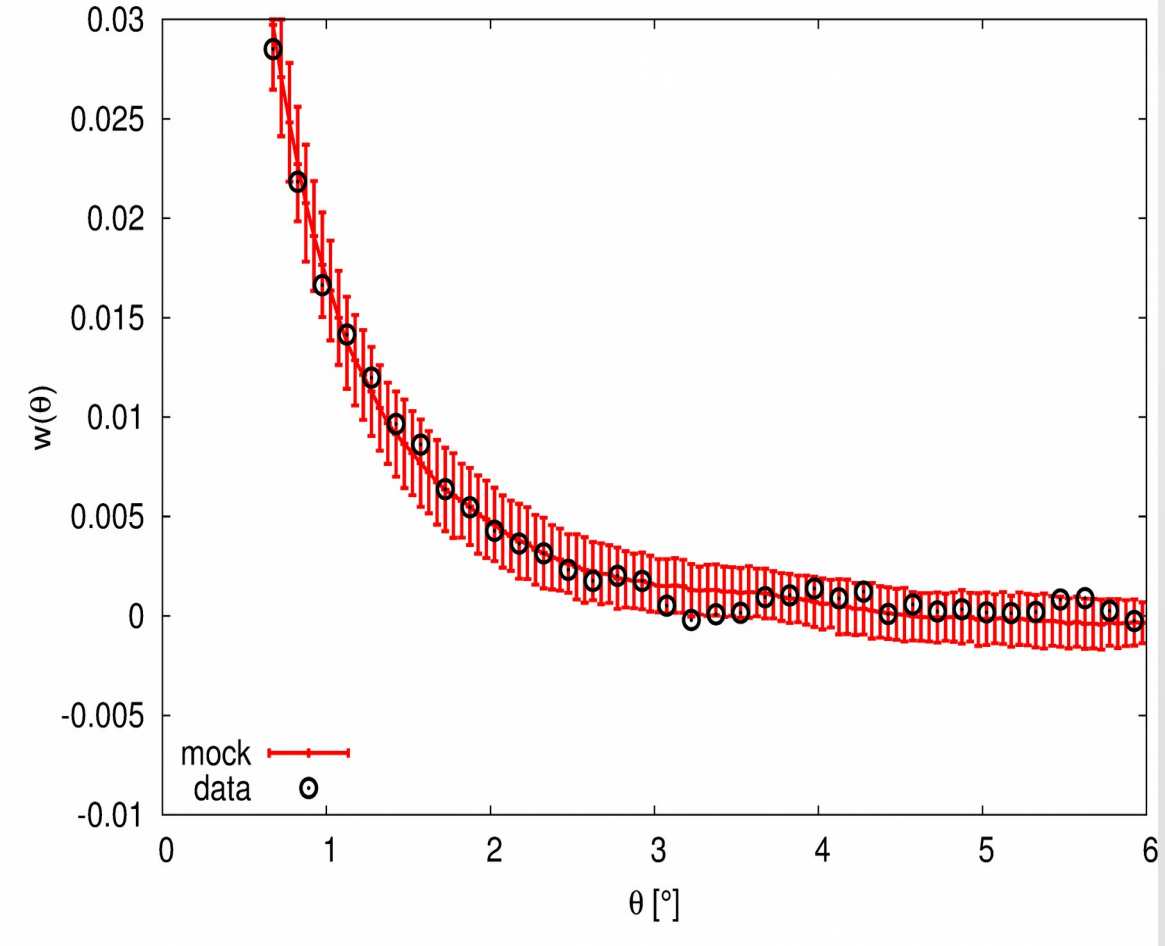
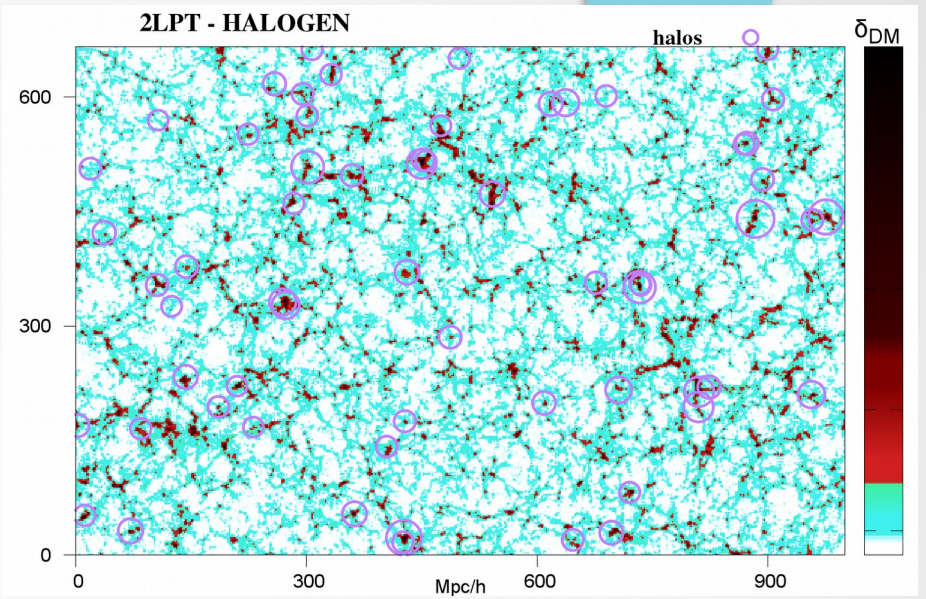
  - Systematics
- Need 100s to 1000s:
  - Unfeasible with N-Body sims.
  - Need: Approximate methods

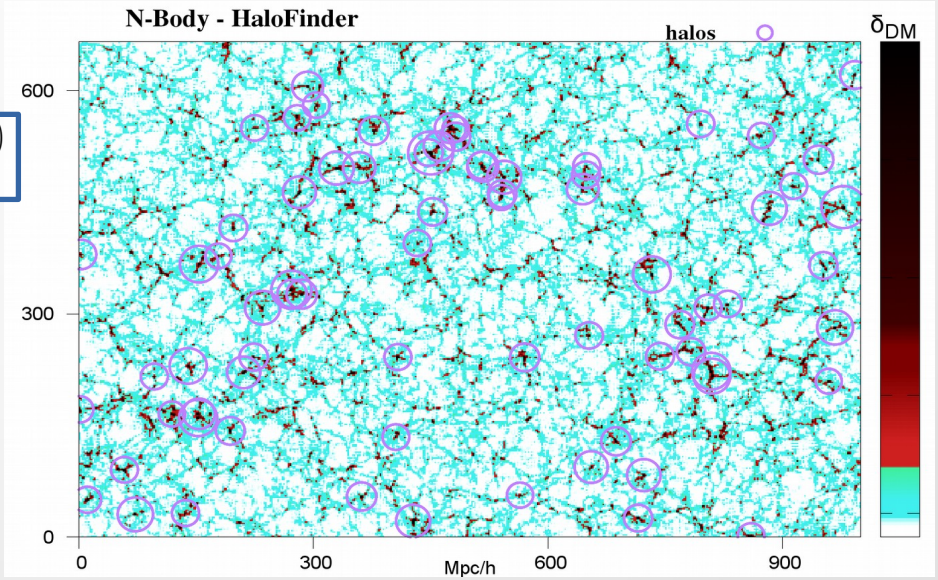


HALOGEN: description

HALOGEN (Ávila et al 2015)

- A public tool to generate halo catalogs.
- ~10^{3-5} times faster than a N-Body Simulation.
- Designed to:
  - · Reproduce the Halo Mass Function
  - · Obtain the correct 2-point Statistics
- Consists of 4 steps:
  1. 2LPT → $\rho_{DM}(\vec{x})$
  2. Analytic Halo Mass Function → M^{i}_{halo}
  3. Place halos stochastically with correct bias: $P_{cell} \propto \rho_{cell}^{\alpha(M_{halo})}$
  4. Velocity bias. $\vec{v}_h = f_{vel}(M_{halo})\vec{v}_p$

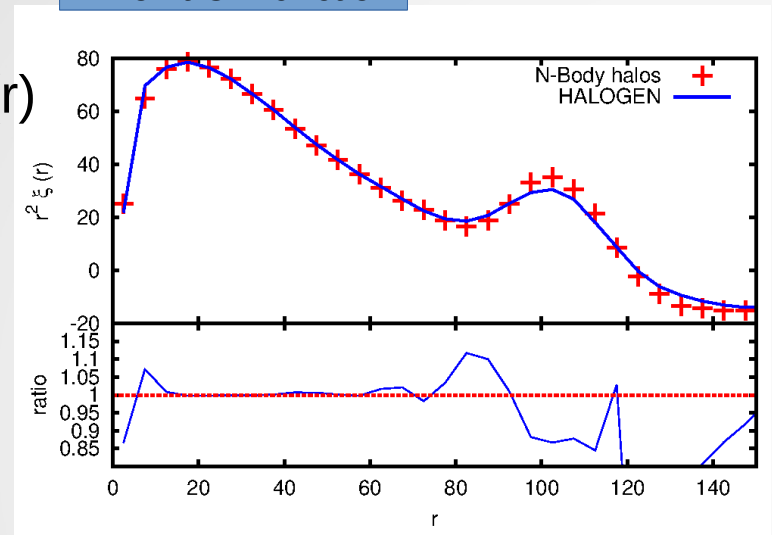




HALOGEN: Results

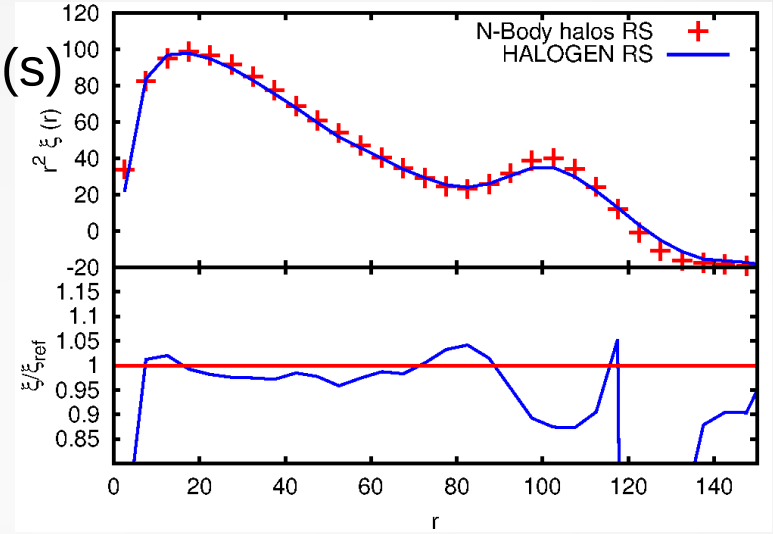
2-Point C. Function

ξ(r)



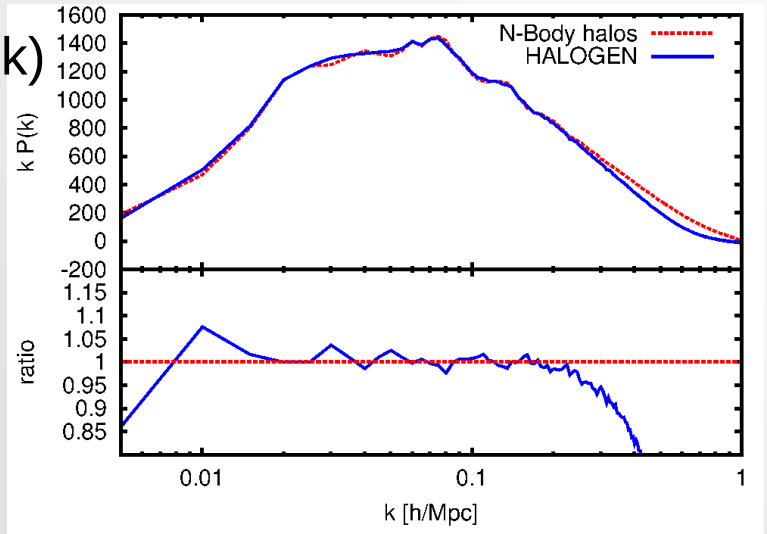
2-Pt w/ Redshift Space Distorsions

ξ(s)

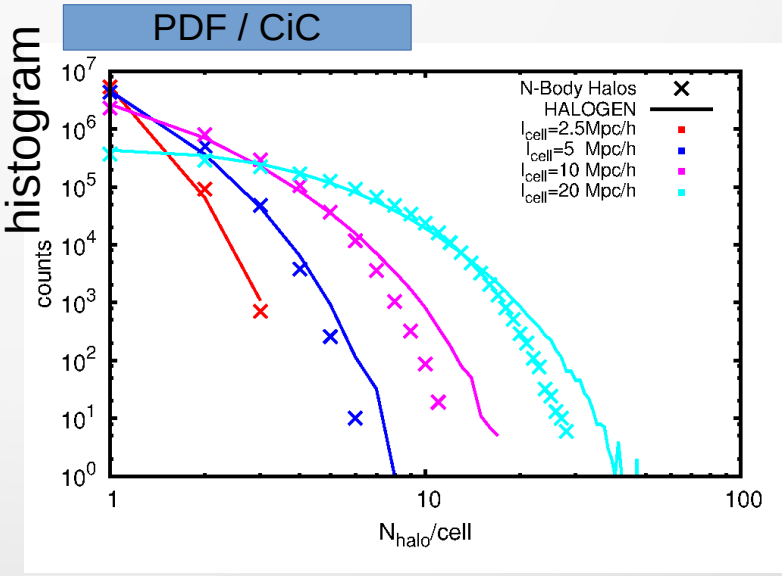


Power Spectrum

P(k)



PDF / CiC



Dark Energy Survey (DES)

- A Photometric galaxy survey that will observe
  - 5000 deg^2
  - 200 million galaxies up to z~1.4

THE DARK ENERGY SURVEY

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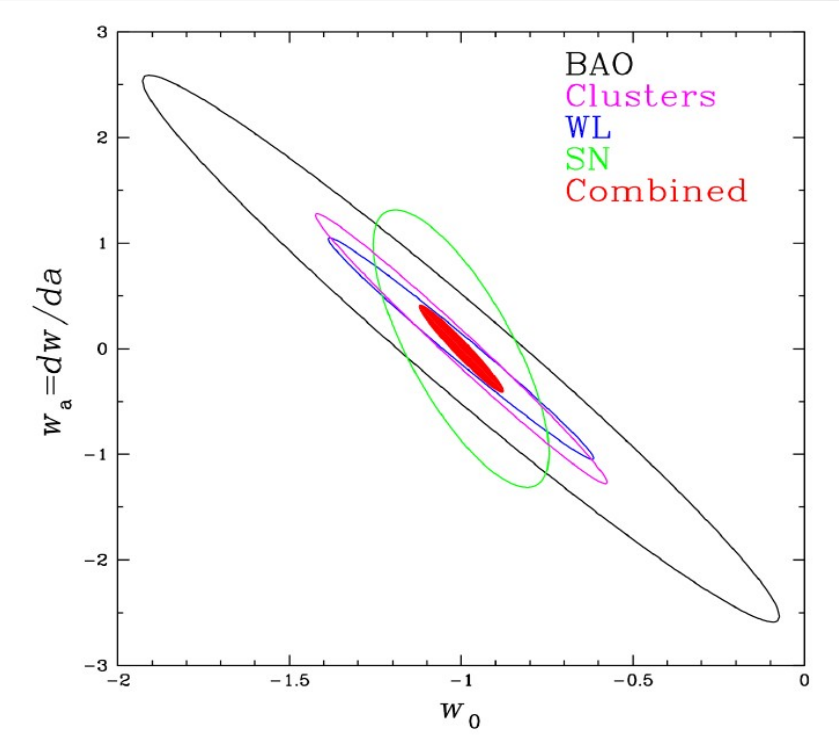
- 4 Dark Energy probes:
  - Baryonic Acoustic Oscillations
  - Type Ia Supernova
  - Cluster Counts
  - Weak Lensing



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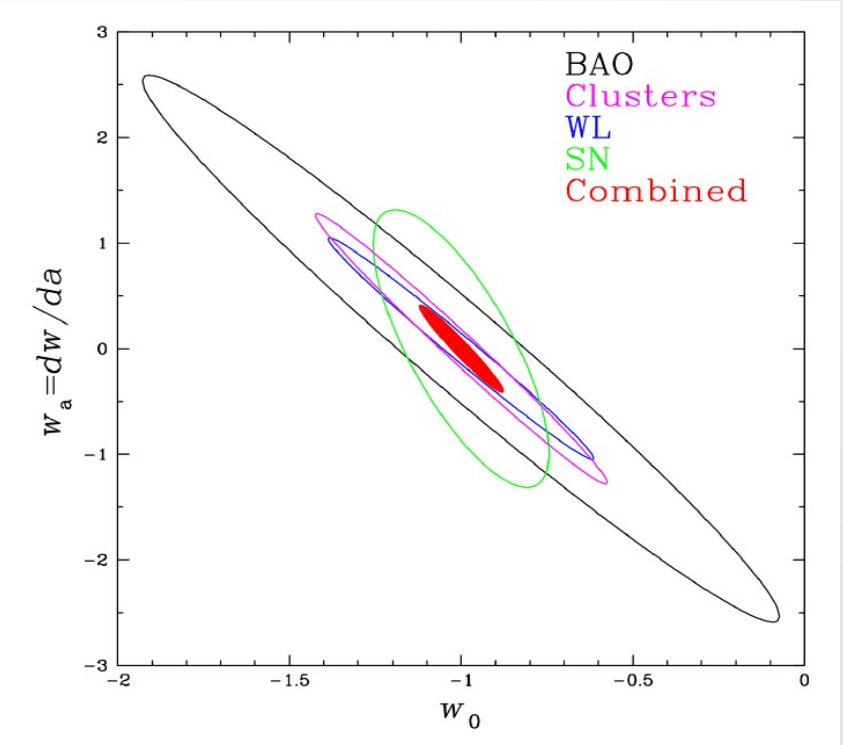
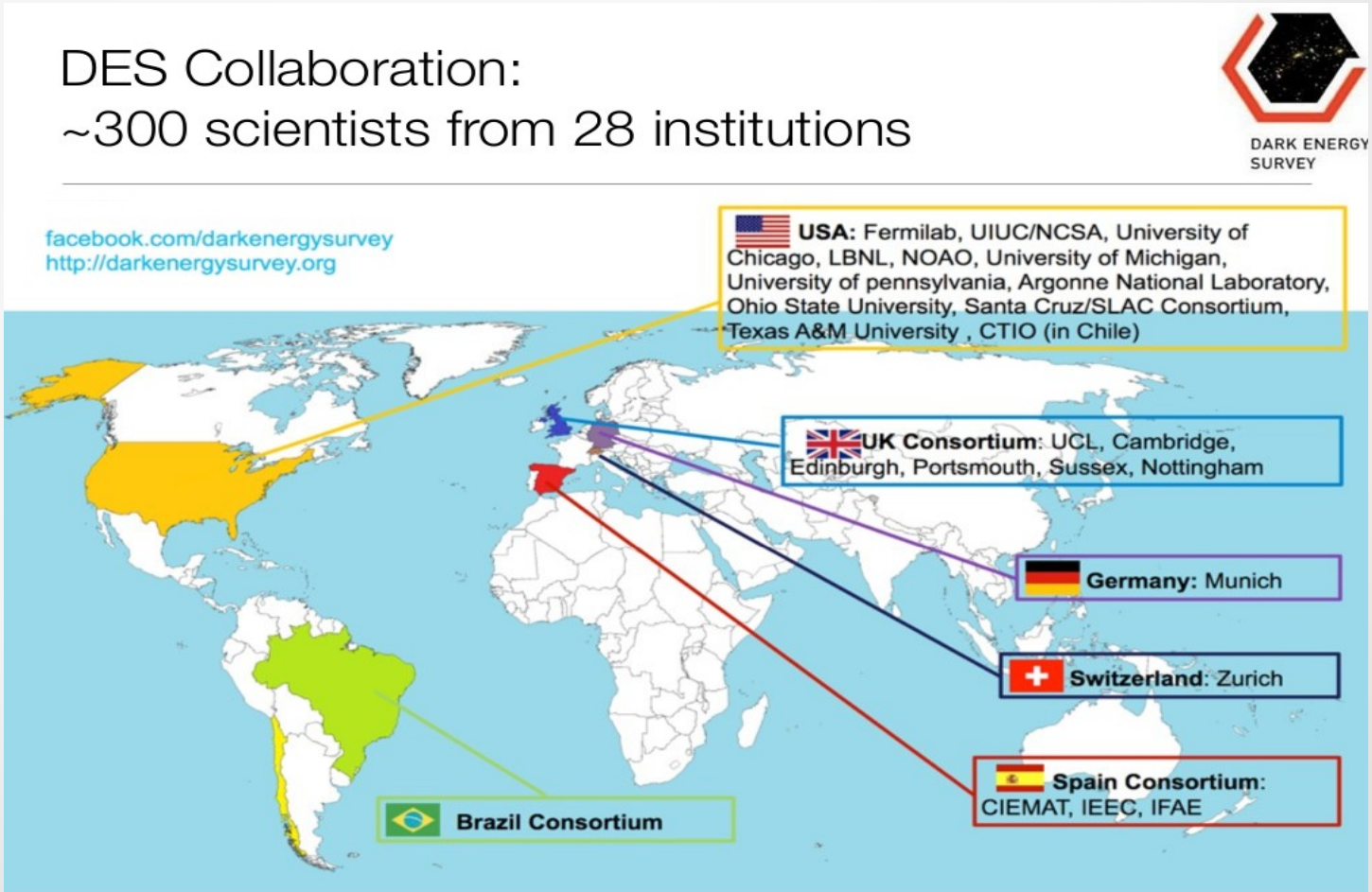
  - Type Ia Supernova
  - Cluster Counts
  - Weak Lensing
- Also valuable many other astrophysical studies (1601.00329)



Dark Energy Survey

- International Consortium



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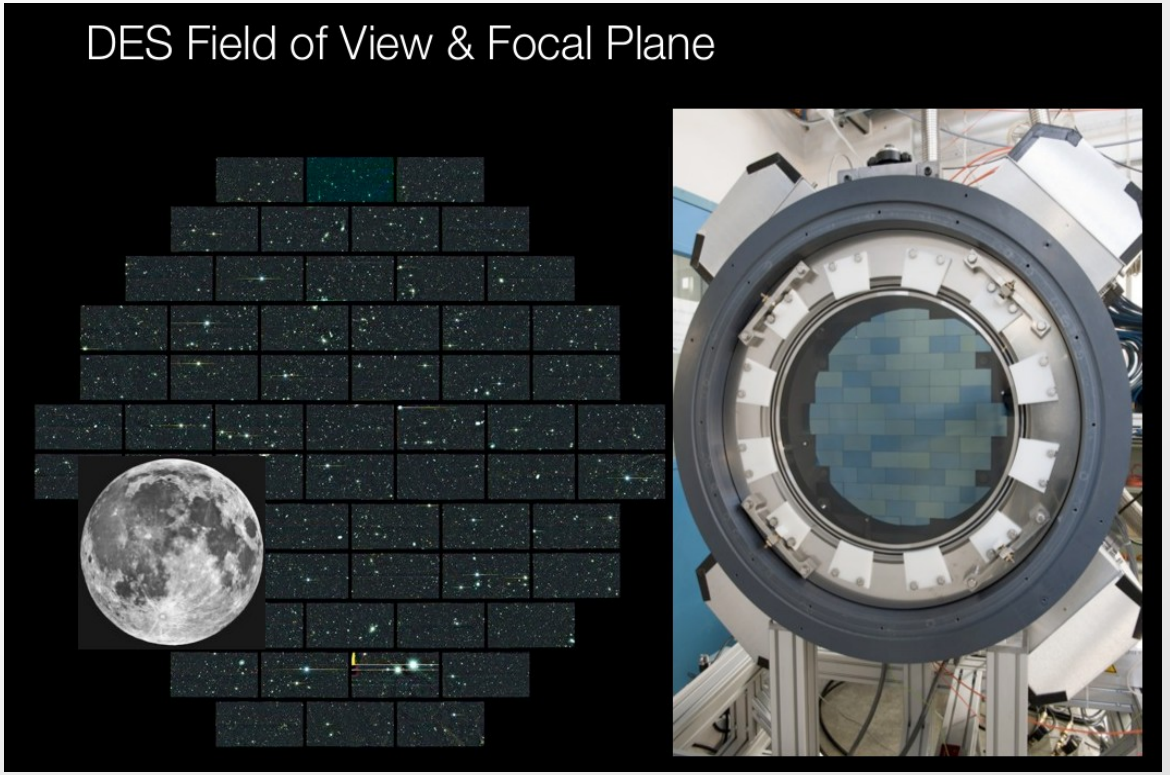
- Camera: DEcam



Dark Energy Survey

- International Consortium
- Telescope: Blanco 4-meter teslecope
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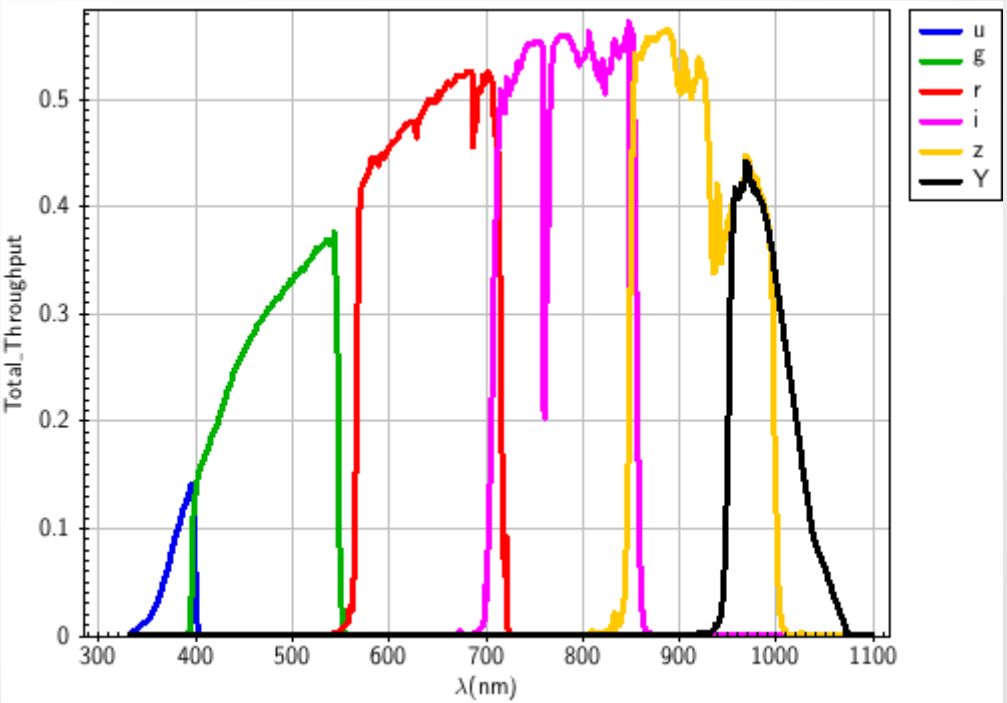
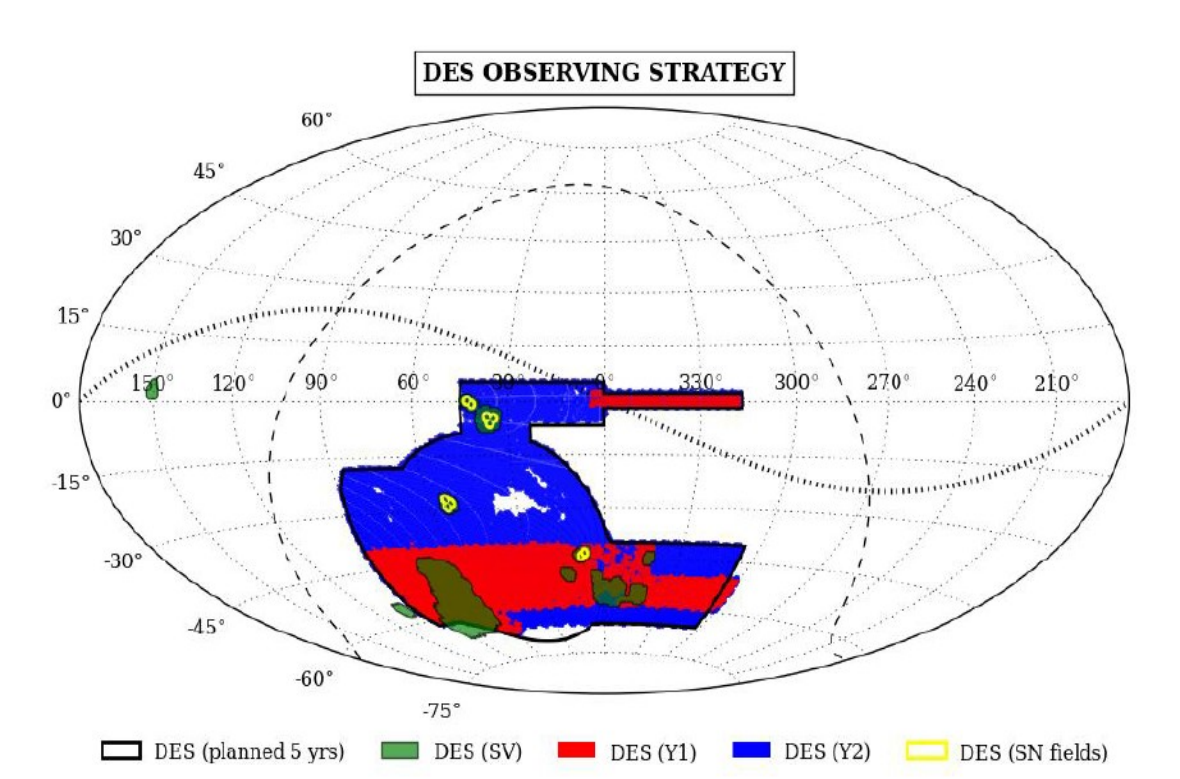
- Camera: DEcam
- Photometry with 5 filters



Dark Energy Survey

- International Consortium
- Telescope: Blanco 4-meter teslecope
  in Cerro Tololo Inter-American Observatory, Chile
- Camera: DEcam
- Photo-z: 5 filters
- 5 years, 5000deg^2
  m_i<24 → z~1.4,

  200 million galaxies



Year-1 LSS sample

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- Trade-off between:
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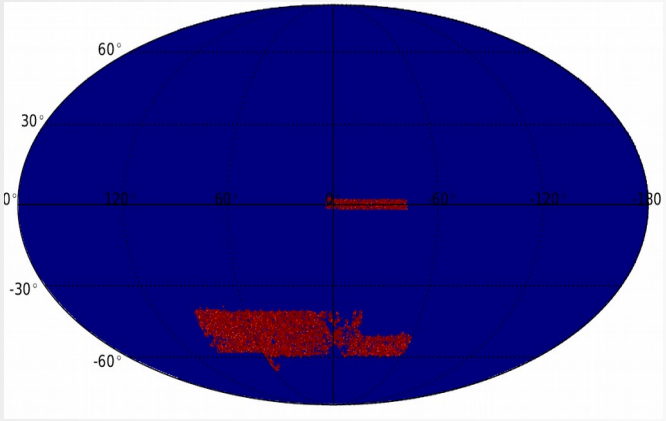
- Selection:
  - Completeness: $17.5 < m_i < 22$
  - z- dependent flux: $m_i < 19 + 3z_{\rm ph}$
  - Red sample: $(m_i - m_z) + 2(m_r - m_i) < 1.7$

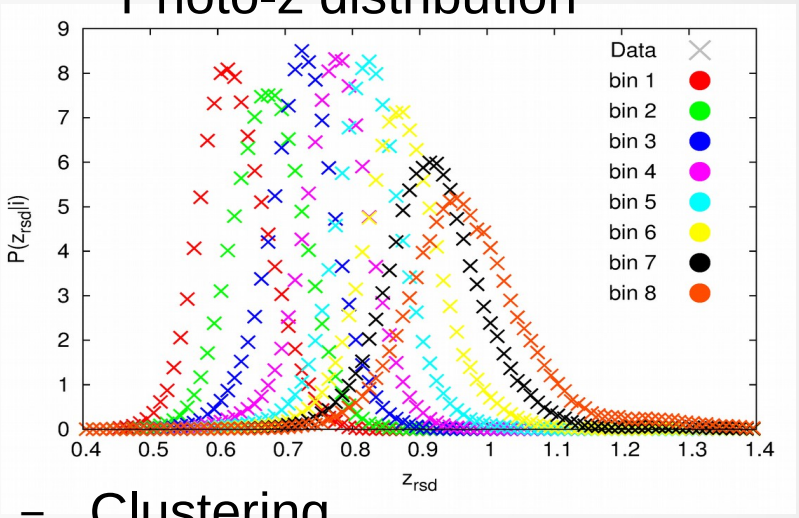
(Crocce et al. In prep.)

Year-1 LSS sample

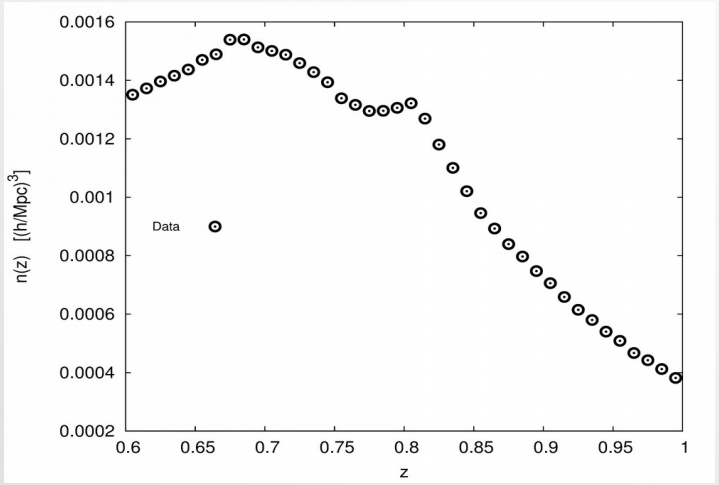
- We aim at reproducing 4 properties:
  - Footprint



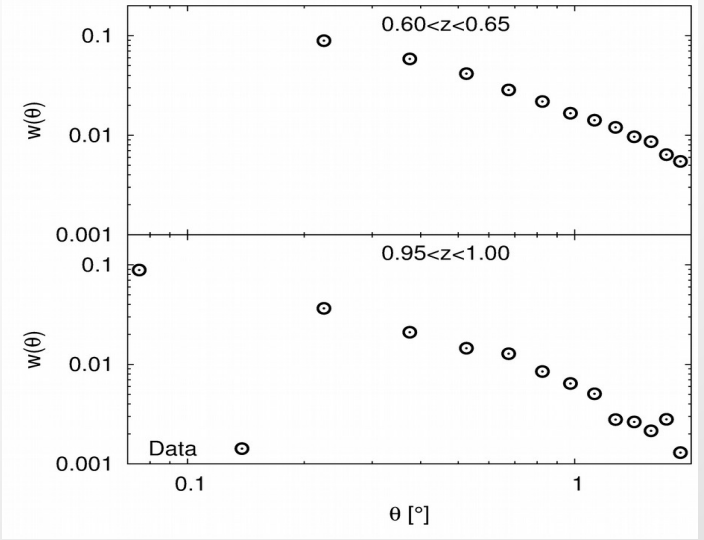
  - Photo-z distribution



  - Number density



  - Clustering



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  - Number density
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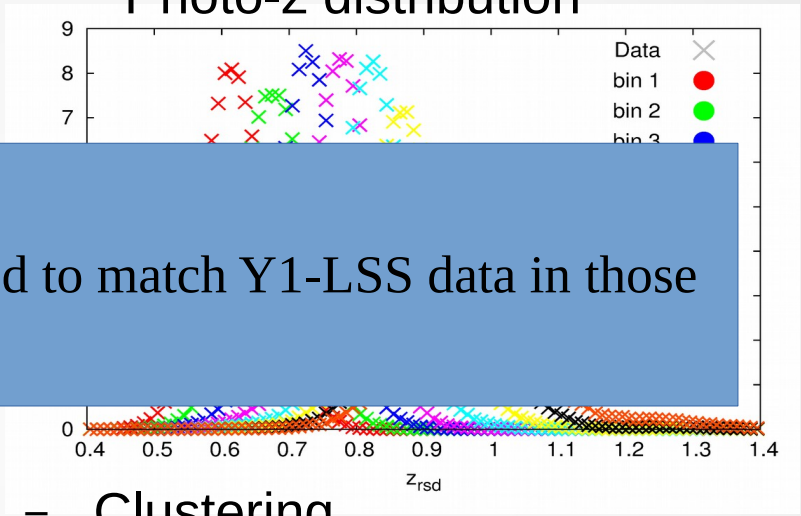
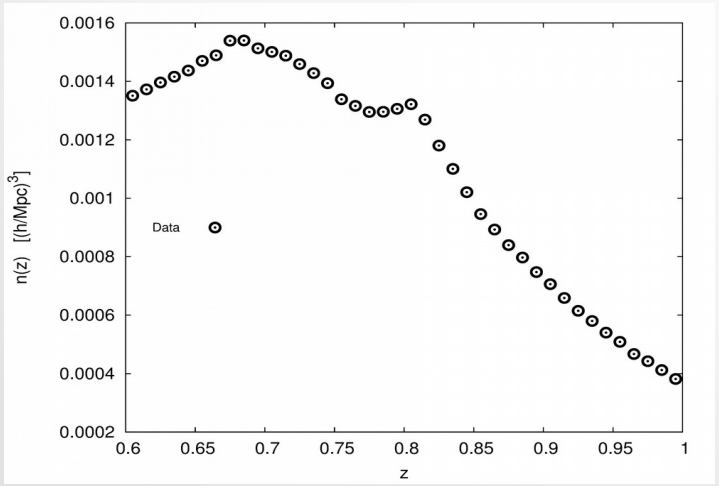
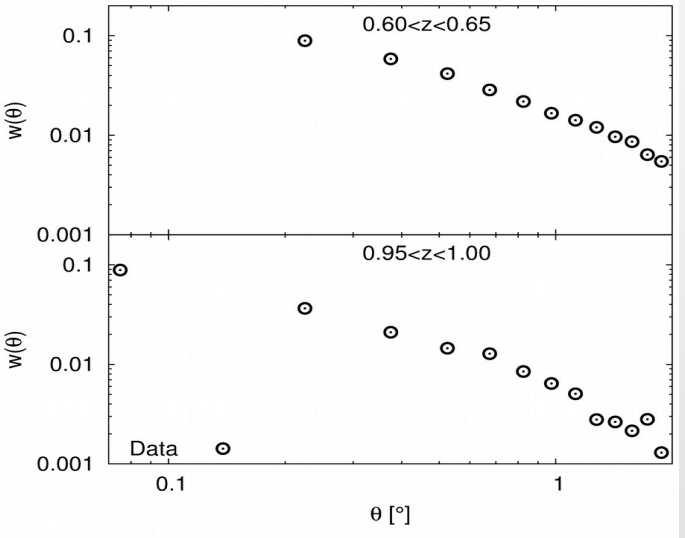


HALOGEN-lamps:
Galaxy mock catalogues created to match Y1-LSS data in those four properties





Year-1 LSS sample

- We aim at reproducing 4 properties:
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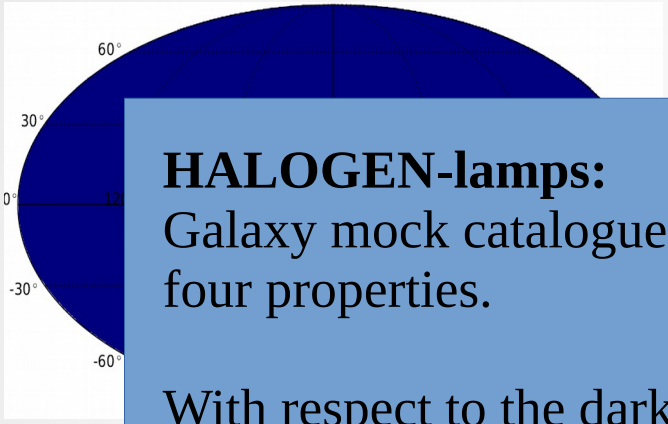
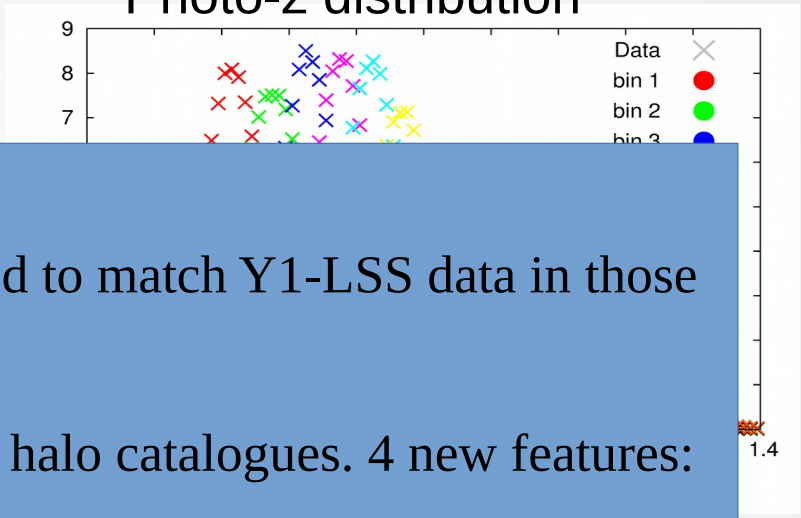
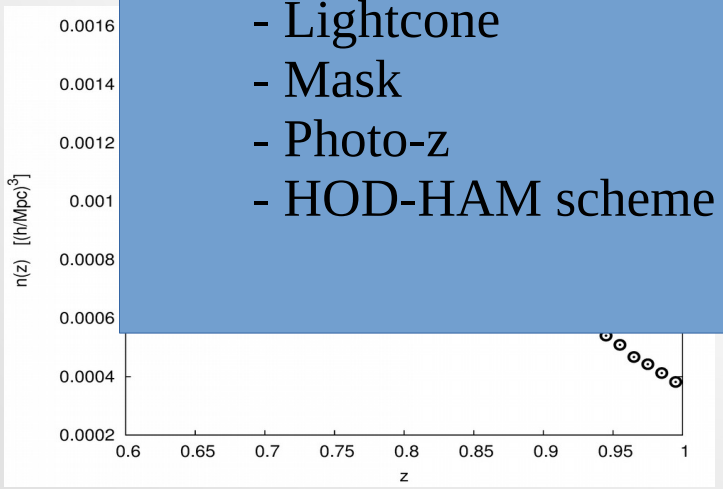
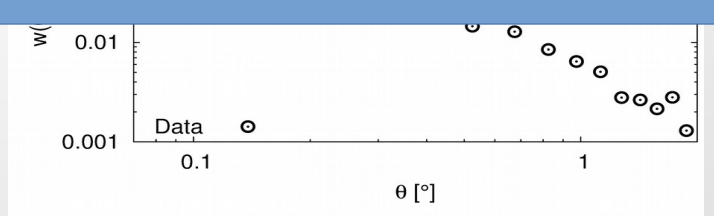
  - N









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Galaxy mock catalogues created to match Y1-LSS data in those four properties.

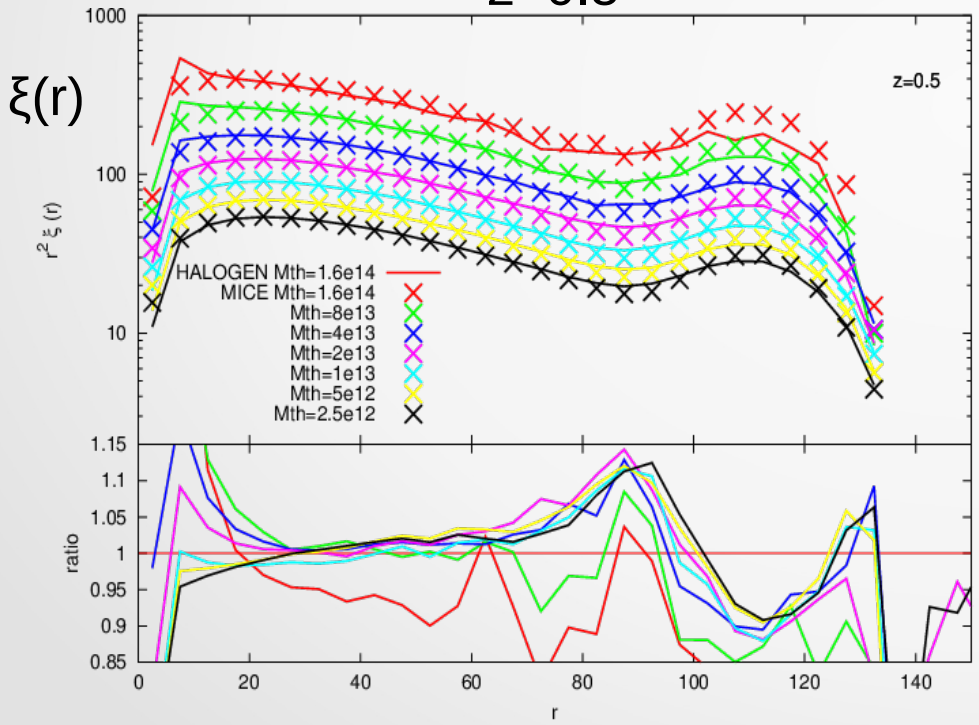
With respect to the dark matter halo catalogues. 4 new features:

- Lightcone
- Mask
- Photo-z
- HOD-HAM scheme

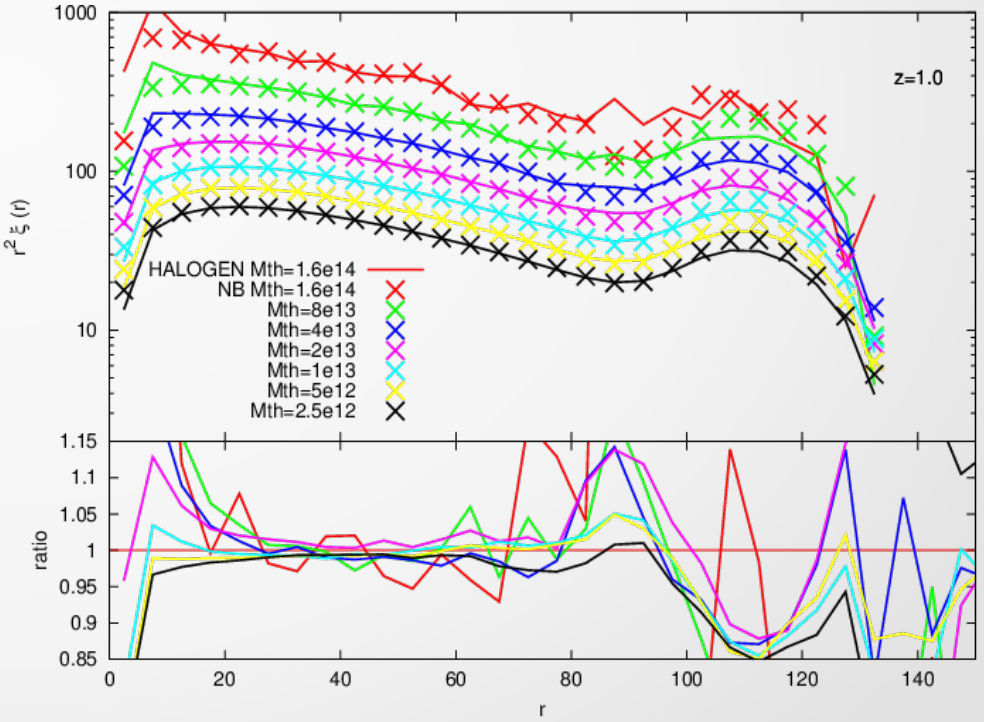
HALOGEN: halo catalogs

- Clustering is fitted to a N-Body Simulation (MICE):
  - At different snapshots
  - As a function of mass

z=0.5

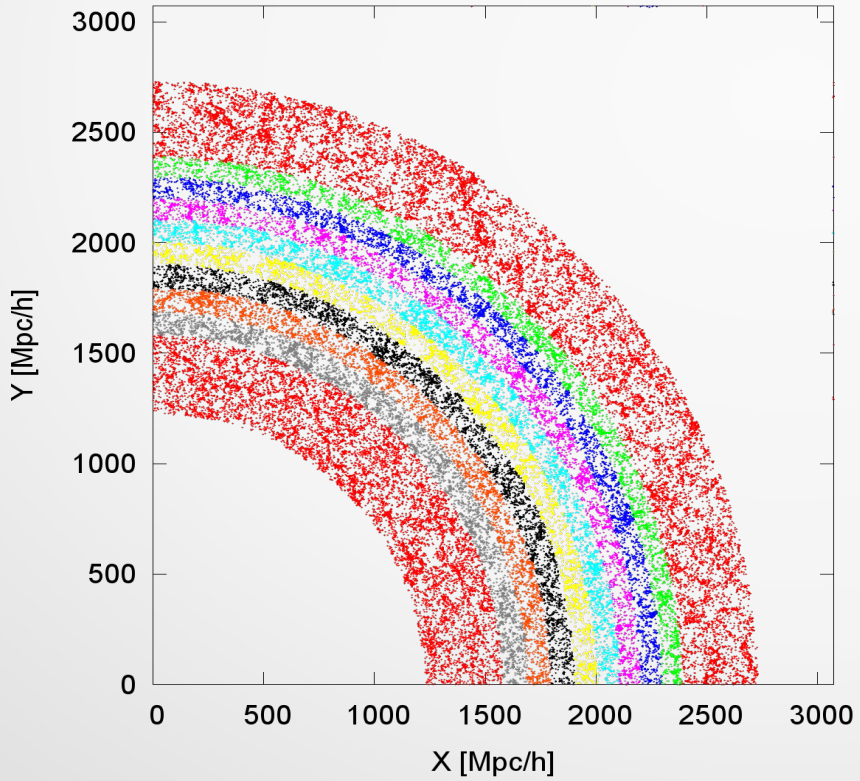


z=1.0



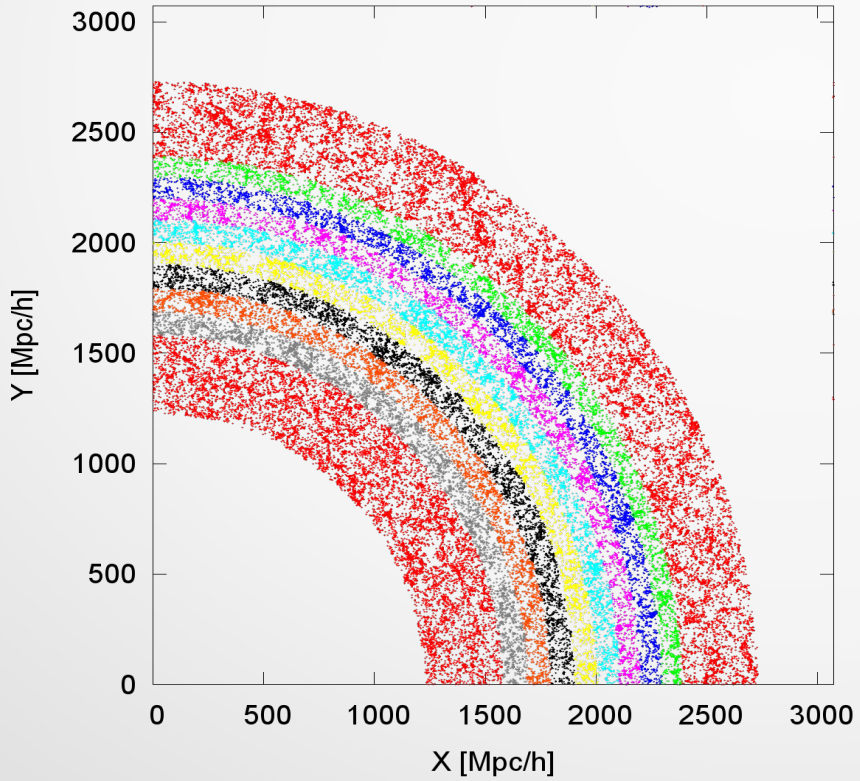
Lightcone

- HALOGEN parameters interpolated at intermediate snapshots
- Observer placed at the corner of the box
- Lightcone from superposition of z-shells



Lightcone

- HALOGEN parameters interpolated at intermediate snapshots
- Observer placed at the corner of the box [X, Y, Z] → [RA, DEC, z_{rsd}]
- Lightcone from superposition of z-shells

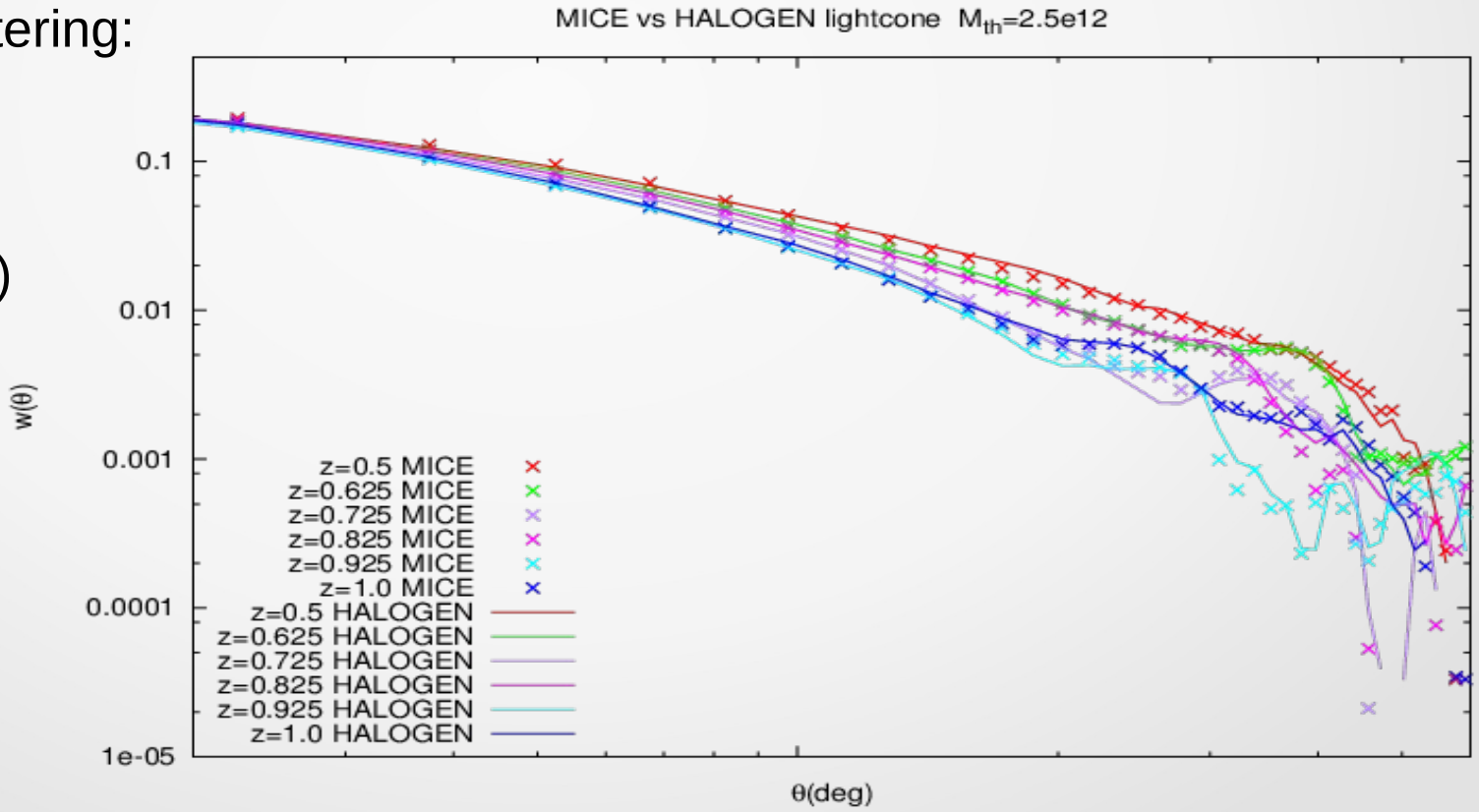


Combination of position, velocity and time: include RSD

Lightcone

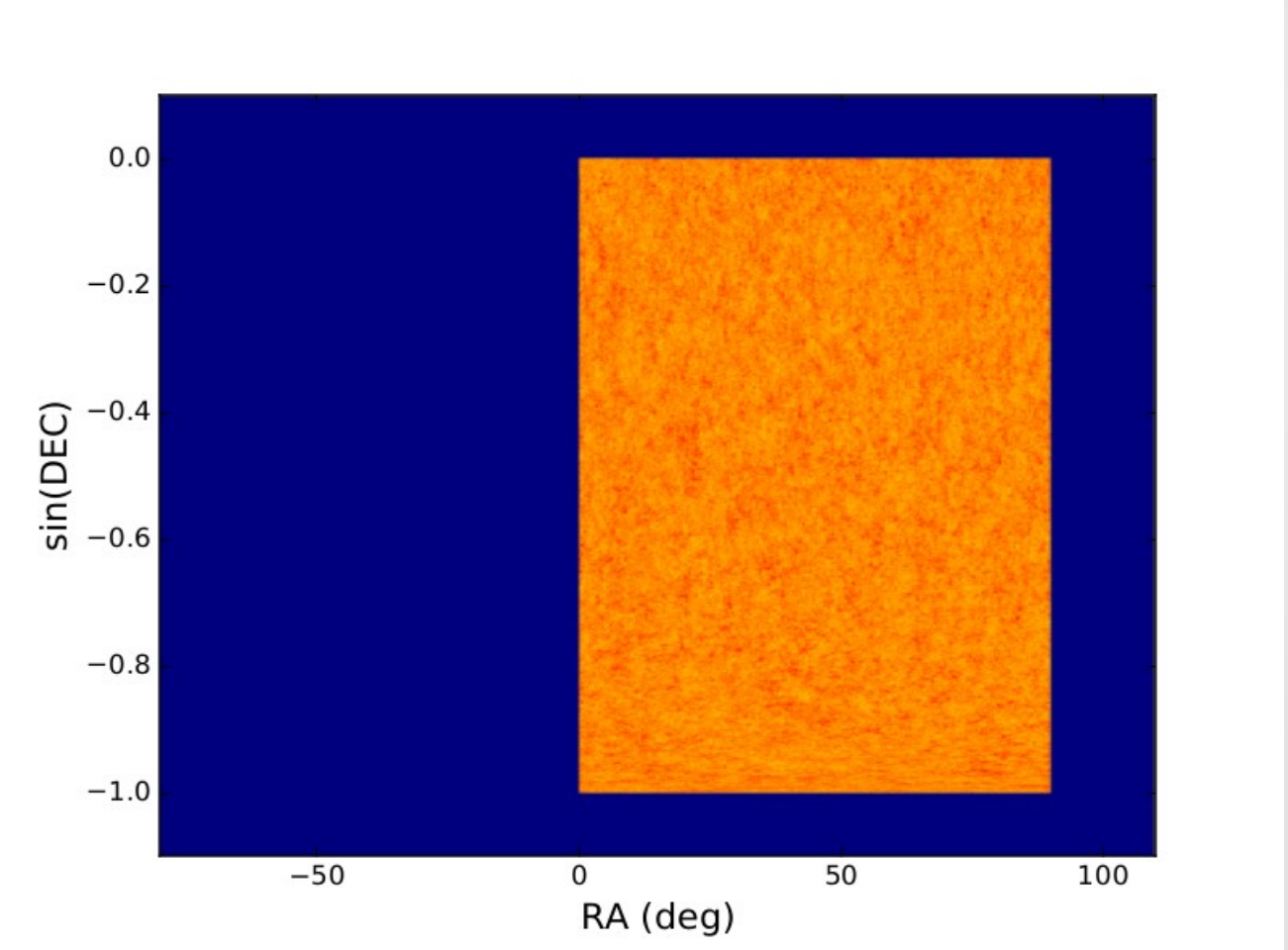
- HALOGEN parameters interpolated at intermediate snapshots
- Observer placed at the corner of the box [X, Y, Z] → [RA, DEC, z_{rsd}]
- Lightcone from superposition of z-shells
- Angular Clustering:

w(θ)



Mask

- The mask does not fit in an octant
- We need to generate the mask from 3 patches



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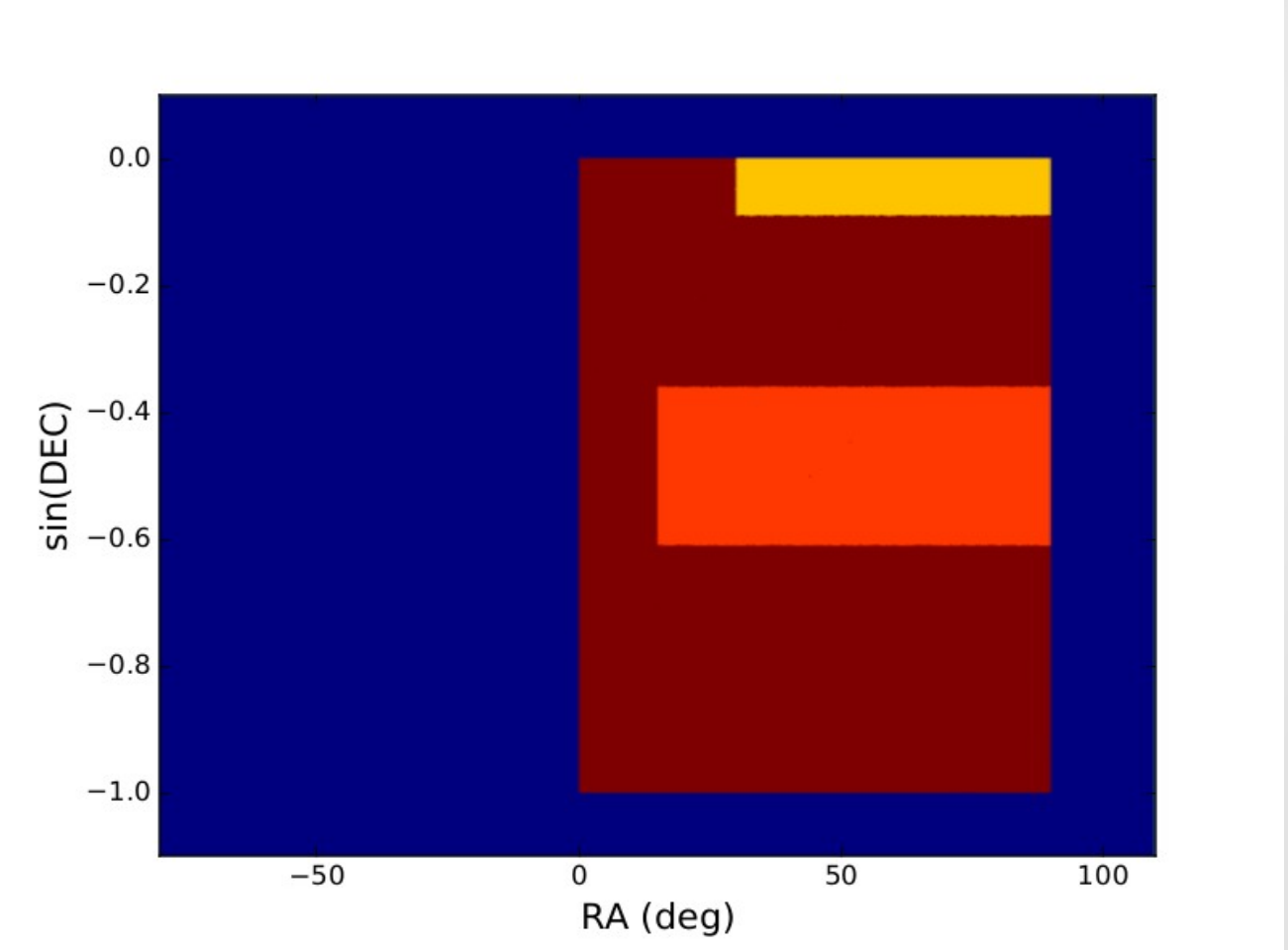

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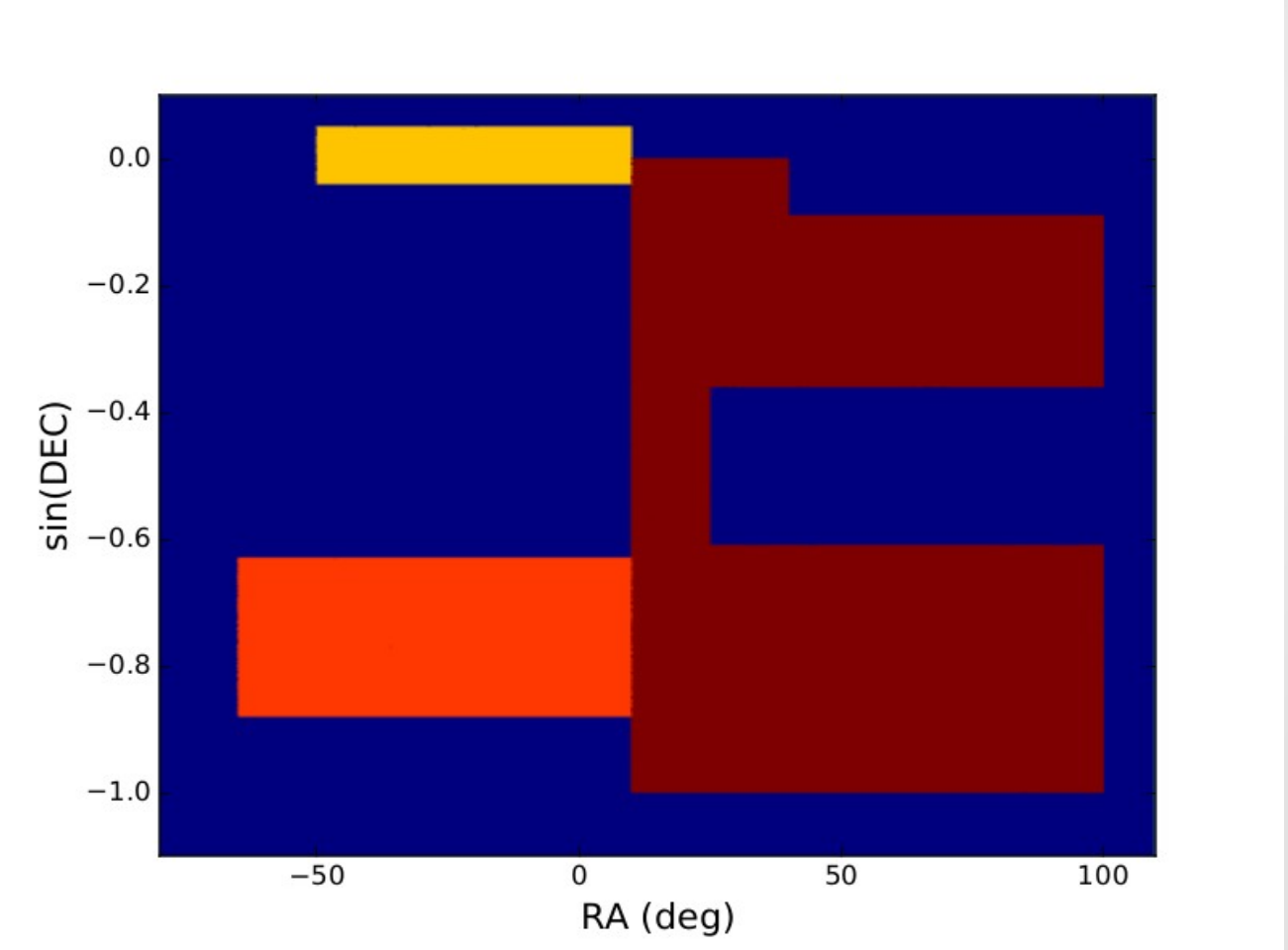

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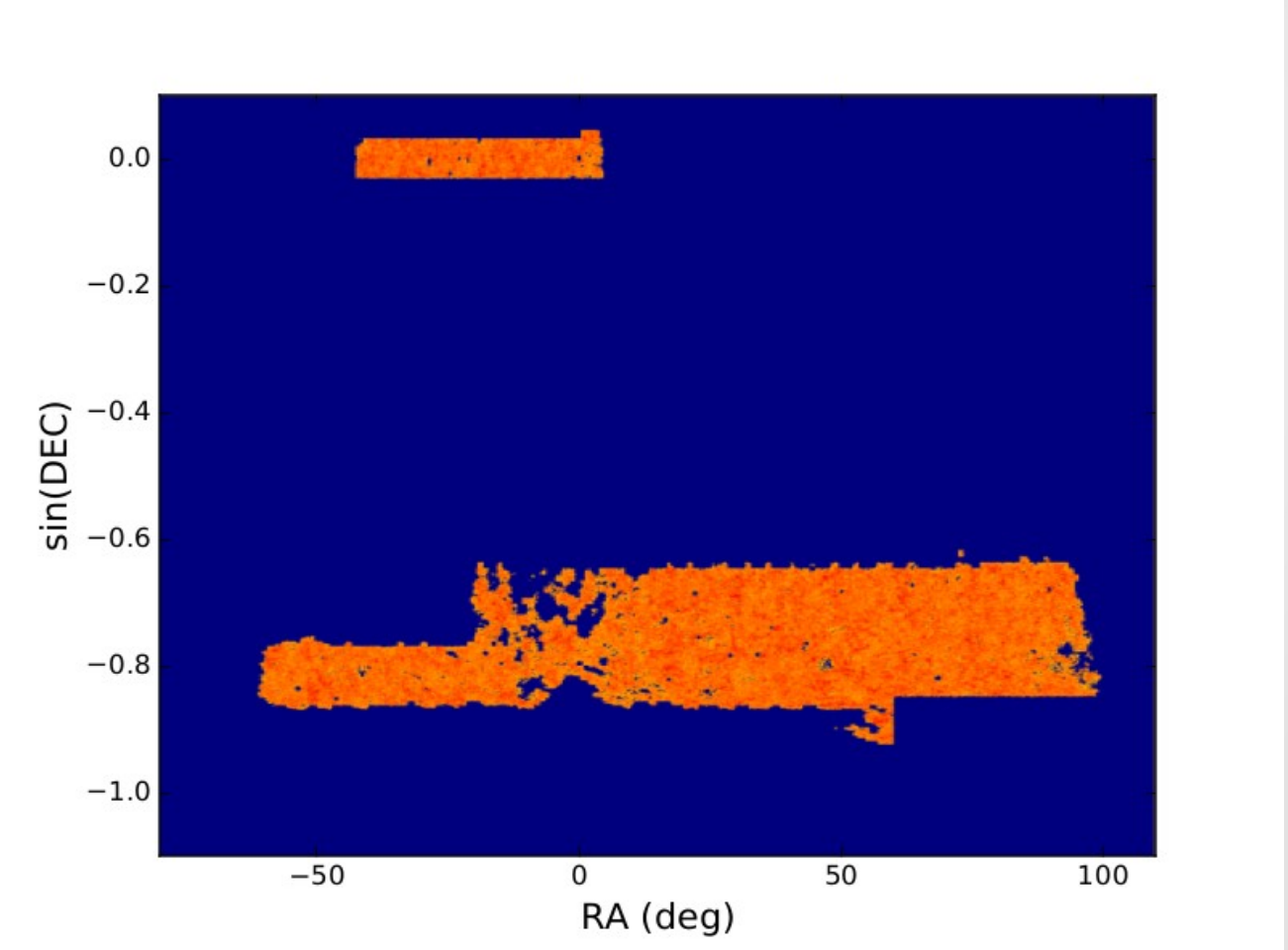

Year-1 LSS sample

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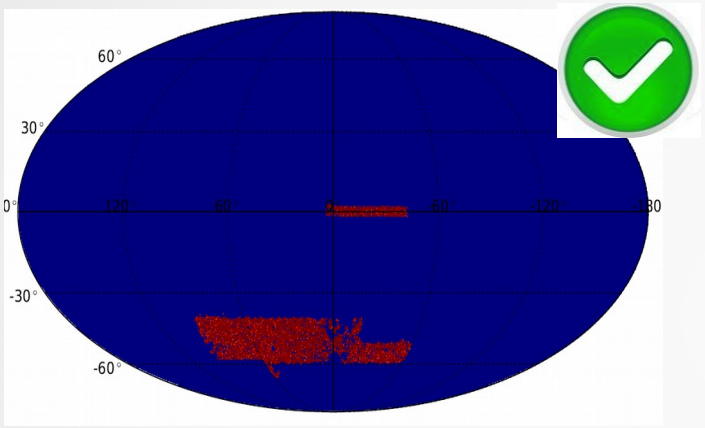
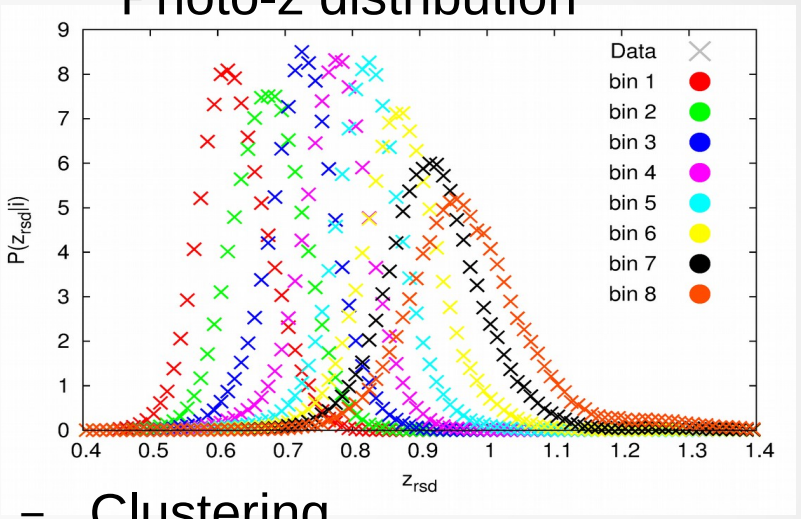
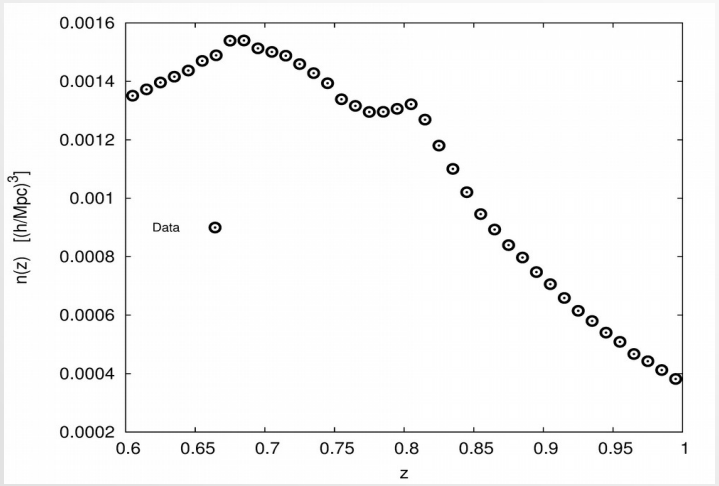
  - Footprint



  - Photo-z distribution



  - Number density



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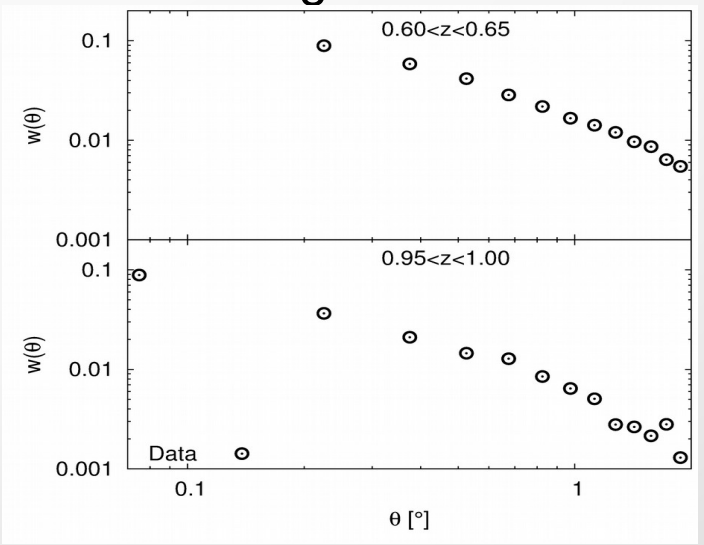

HALOGEN lamps: photo-z

- Photo-z (z_{ph}): Estimation of z_{rsd} (BPZ, Benítez et al. 2004)

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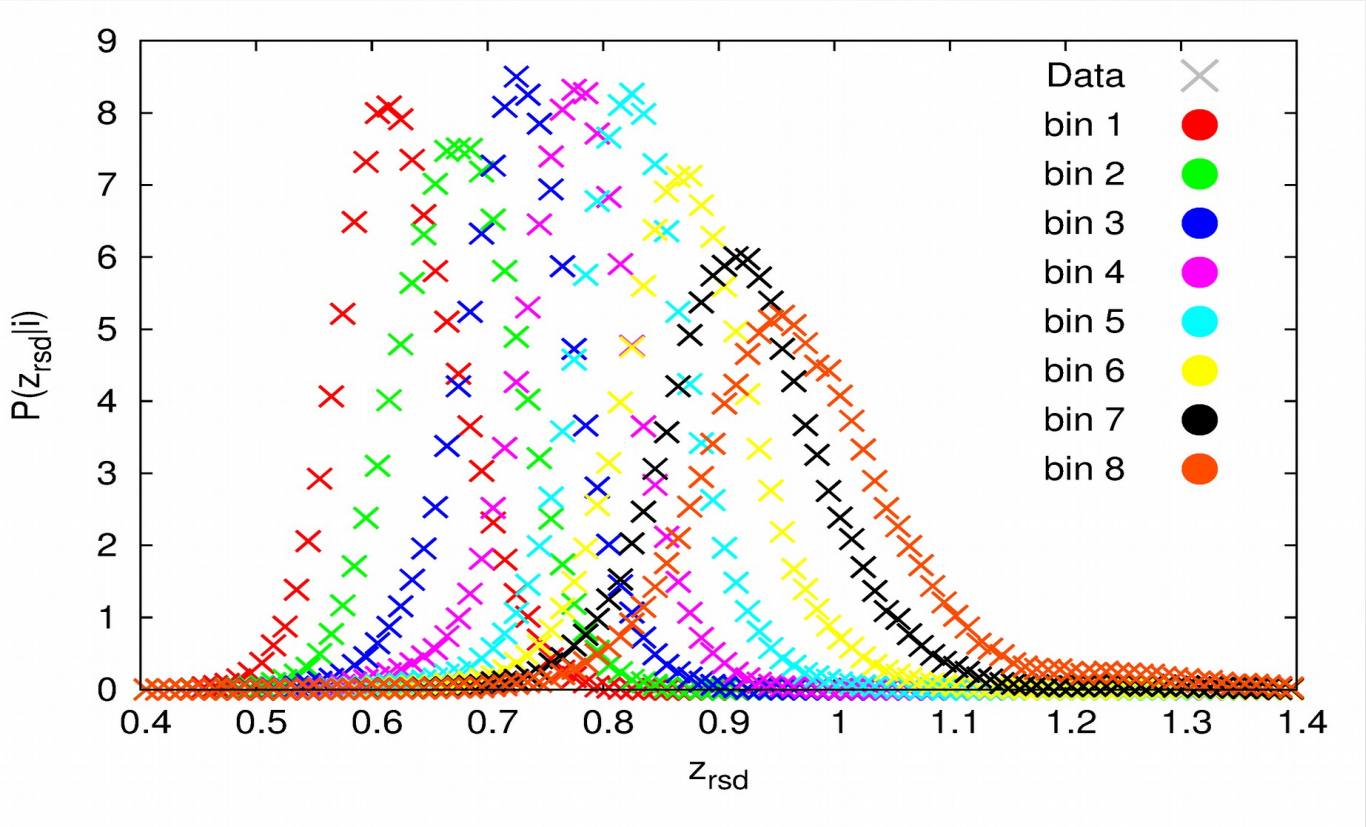
- 8 photo-z bins (i) between 0.6 and 1.0
- $P(z_{rsd}|i)$: the true ***z*** distribution within bins.



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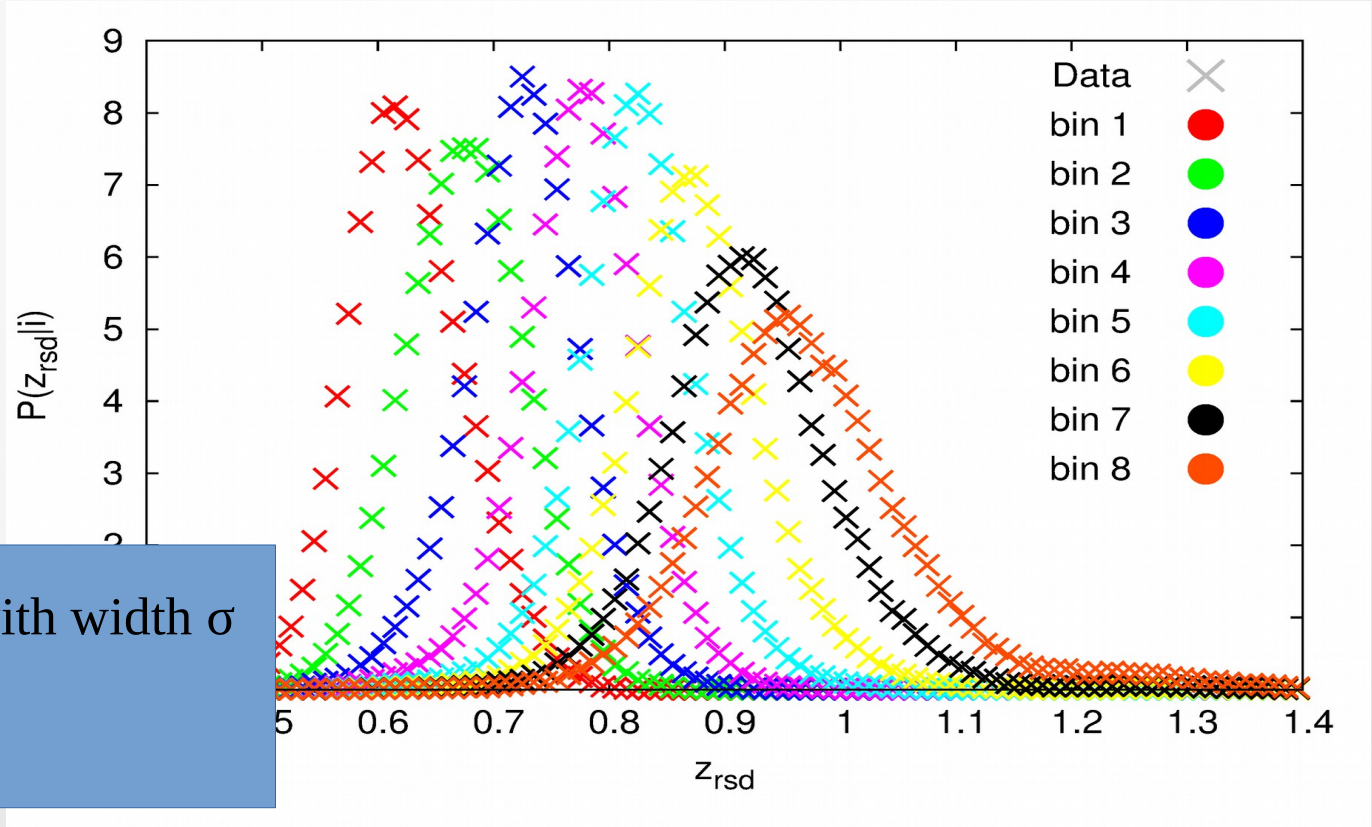

$P(z_{rsd}|i)$ ~ gaussians with width σ

σ/(1+z) ~ constant

HALOGEN lamps: photo-z

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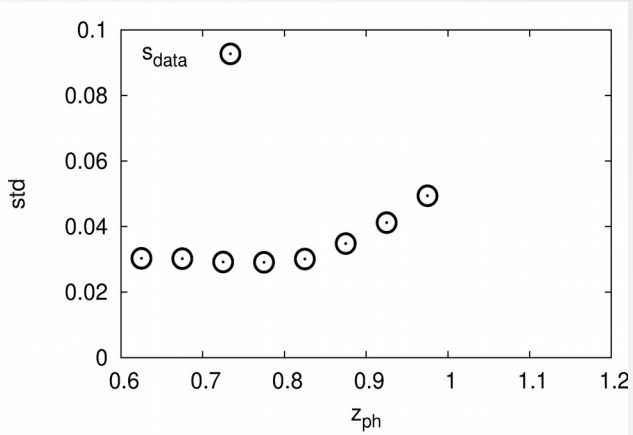

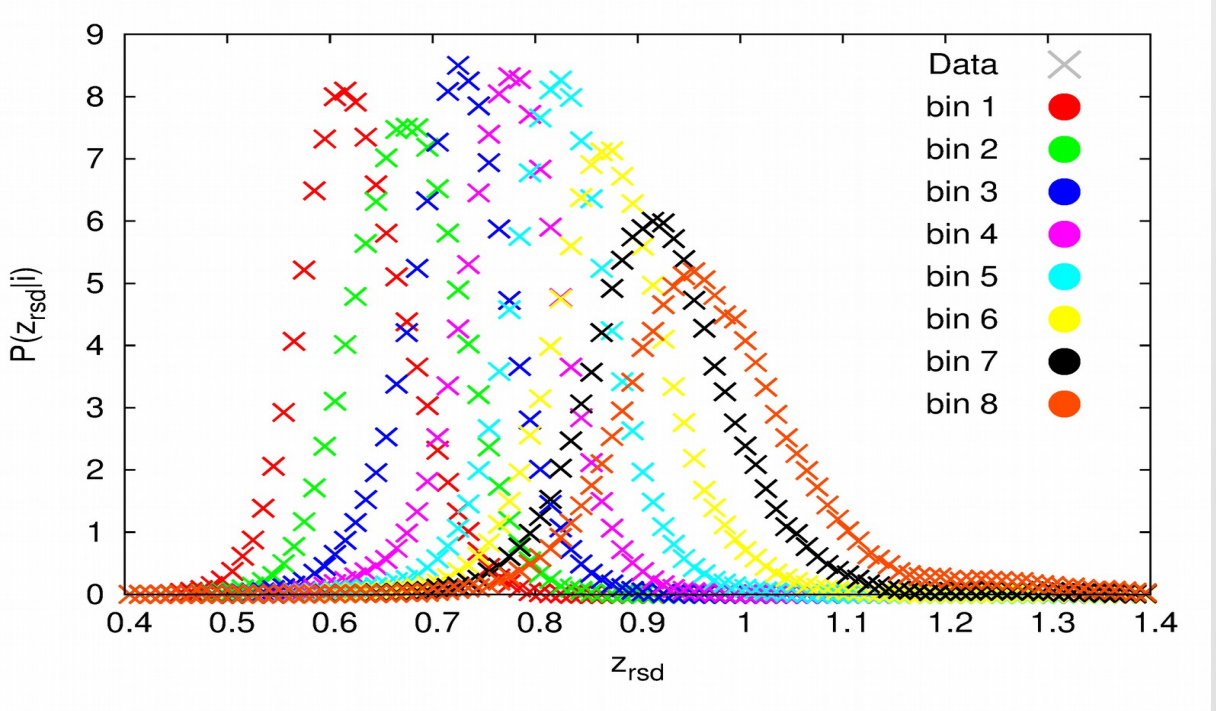

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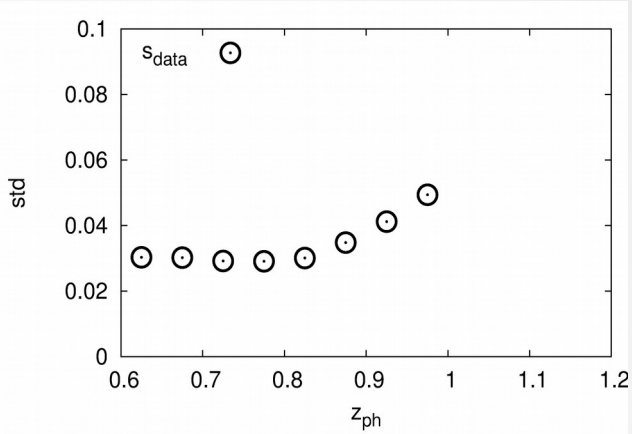

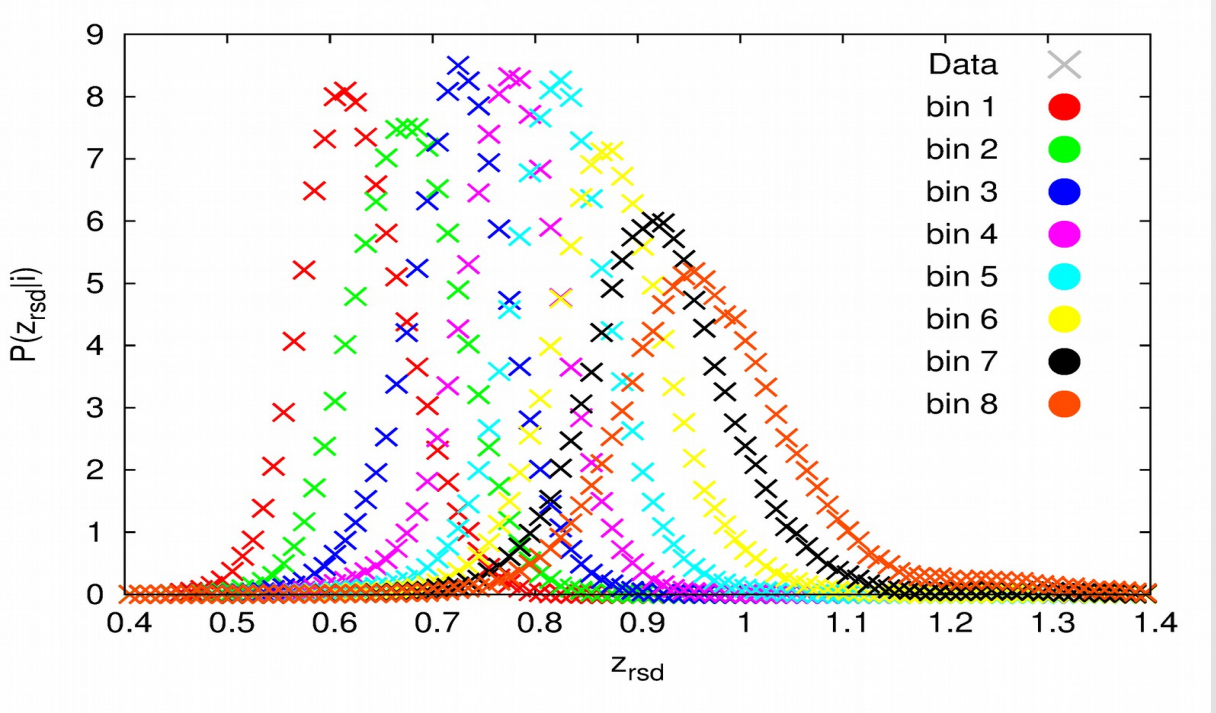

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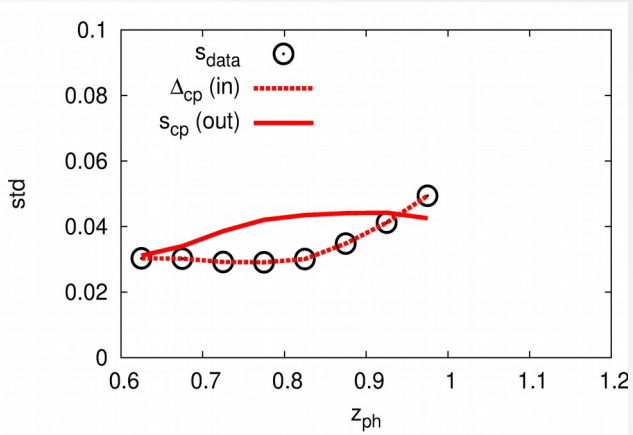

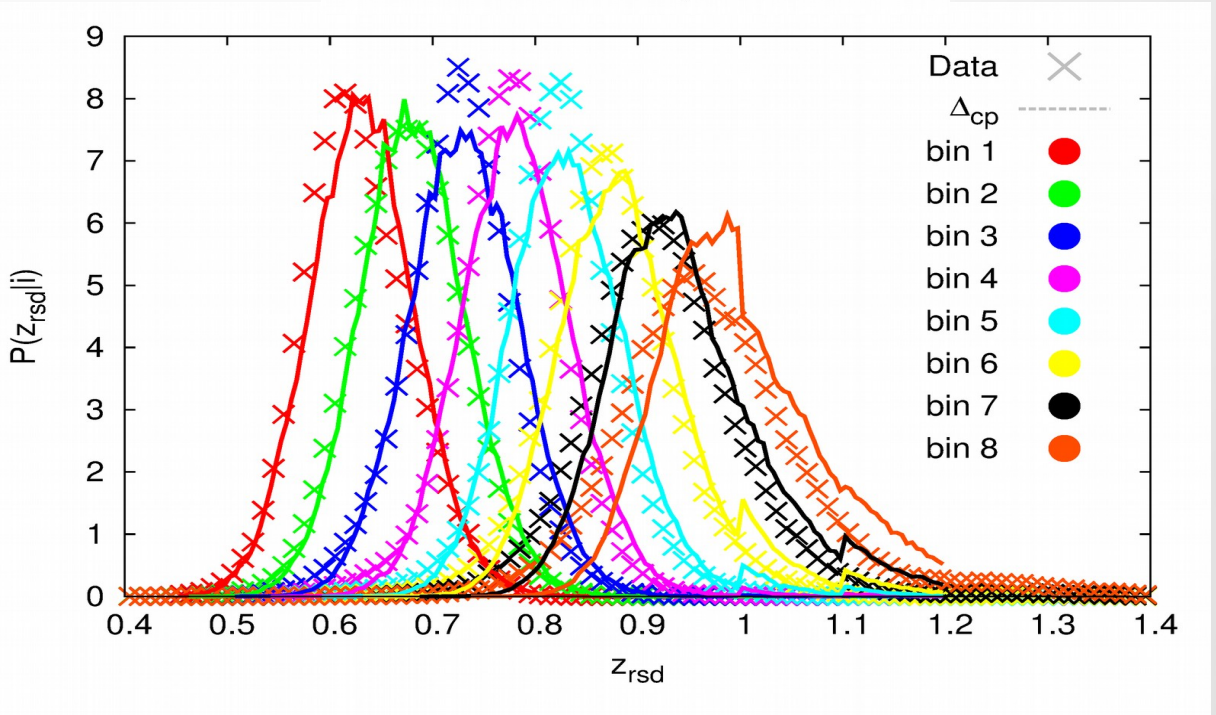

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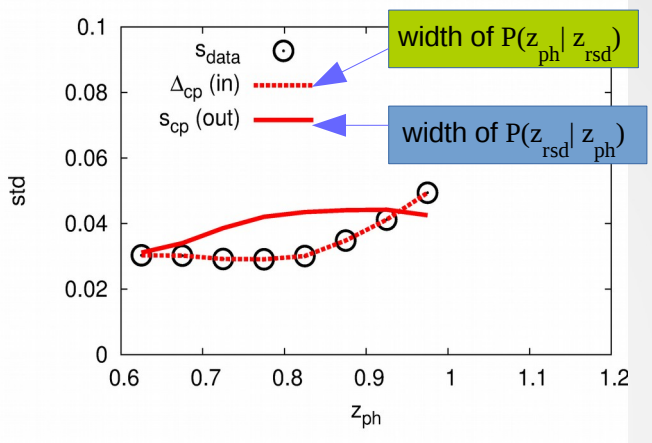

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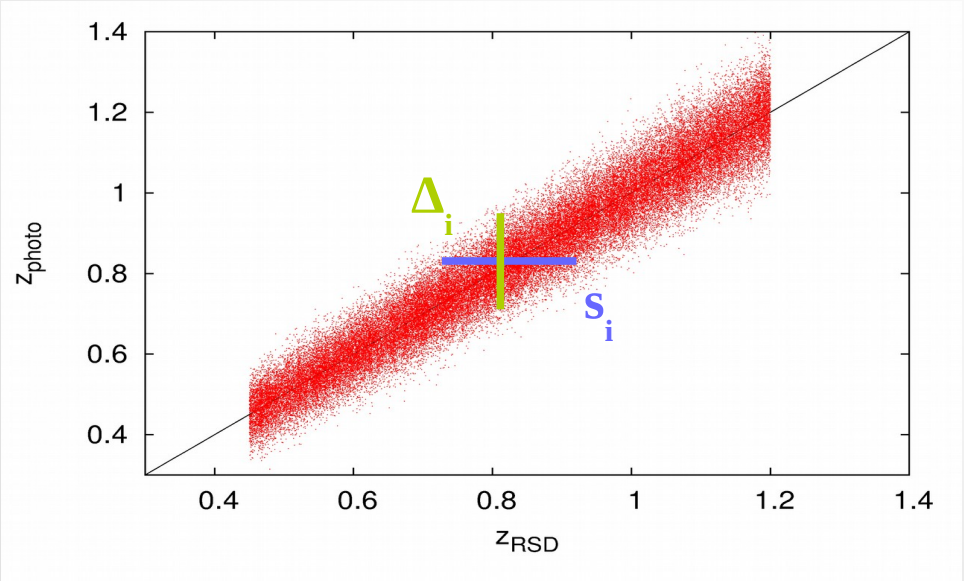

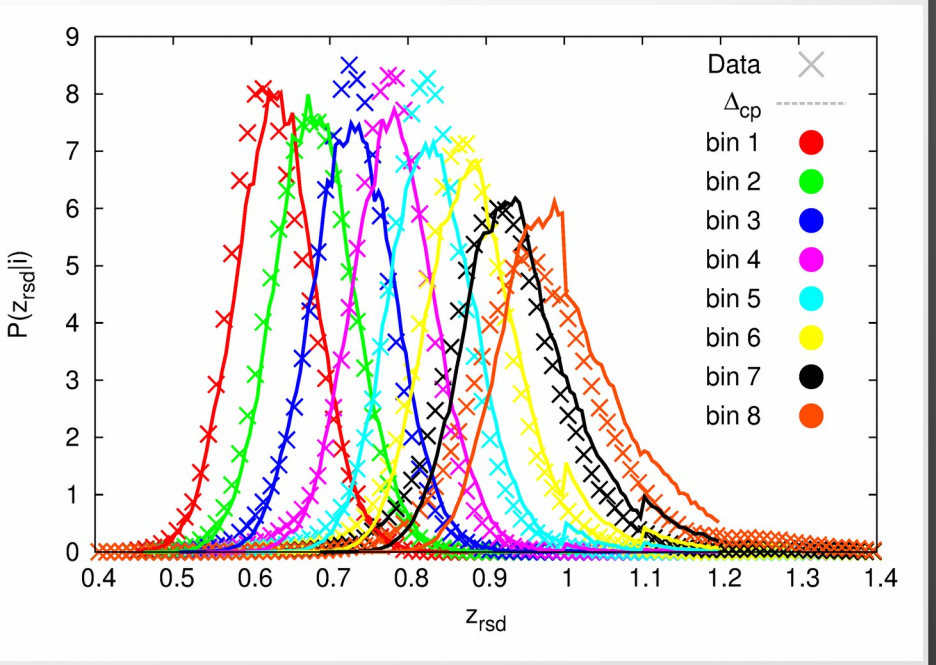

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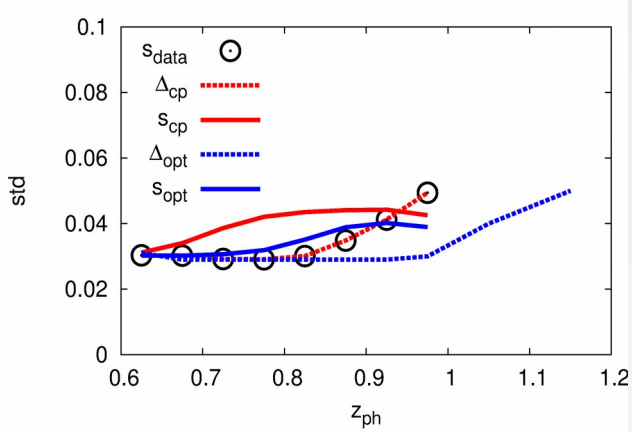

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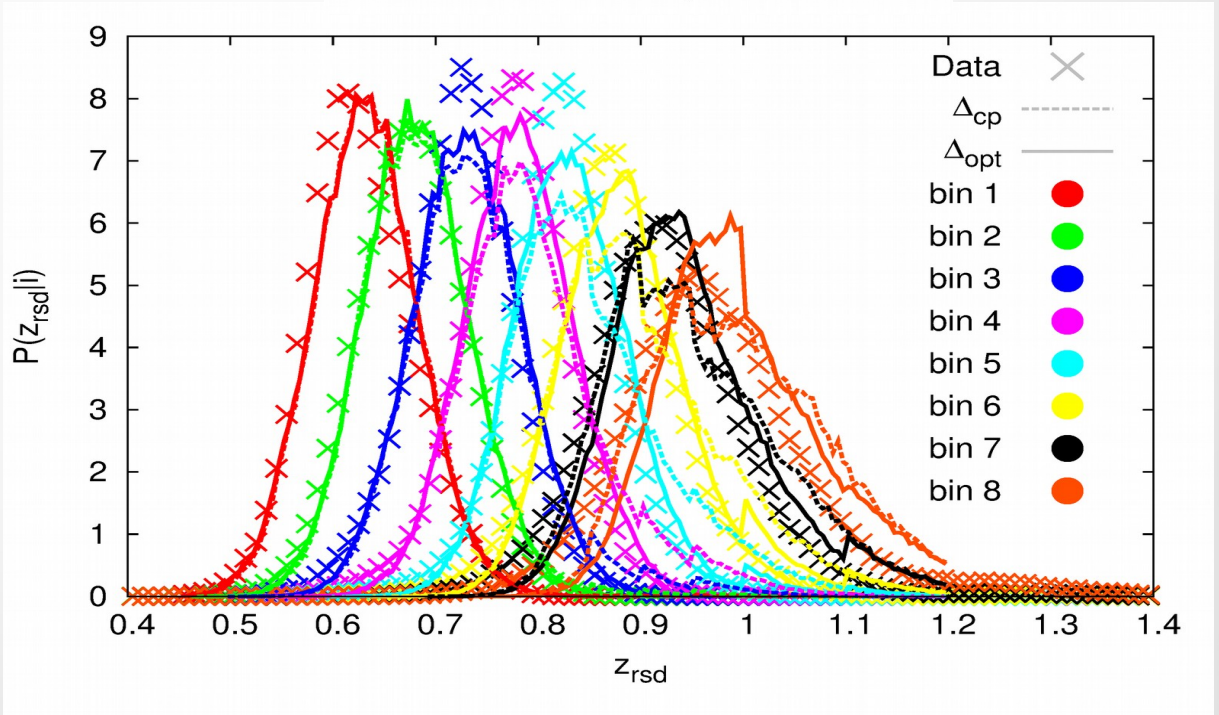

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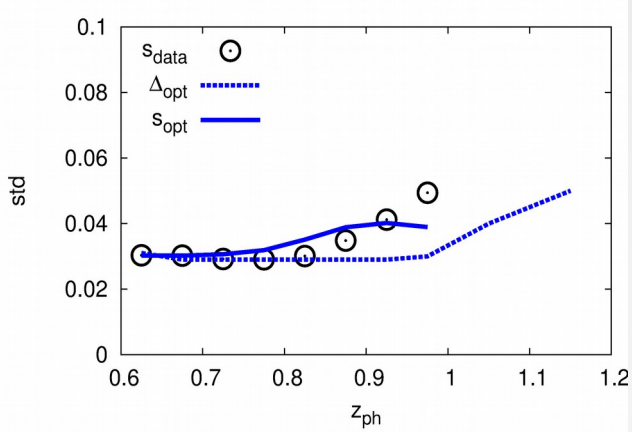

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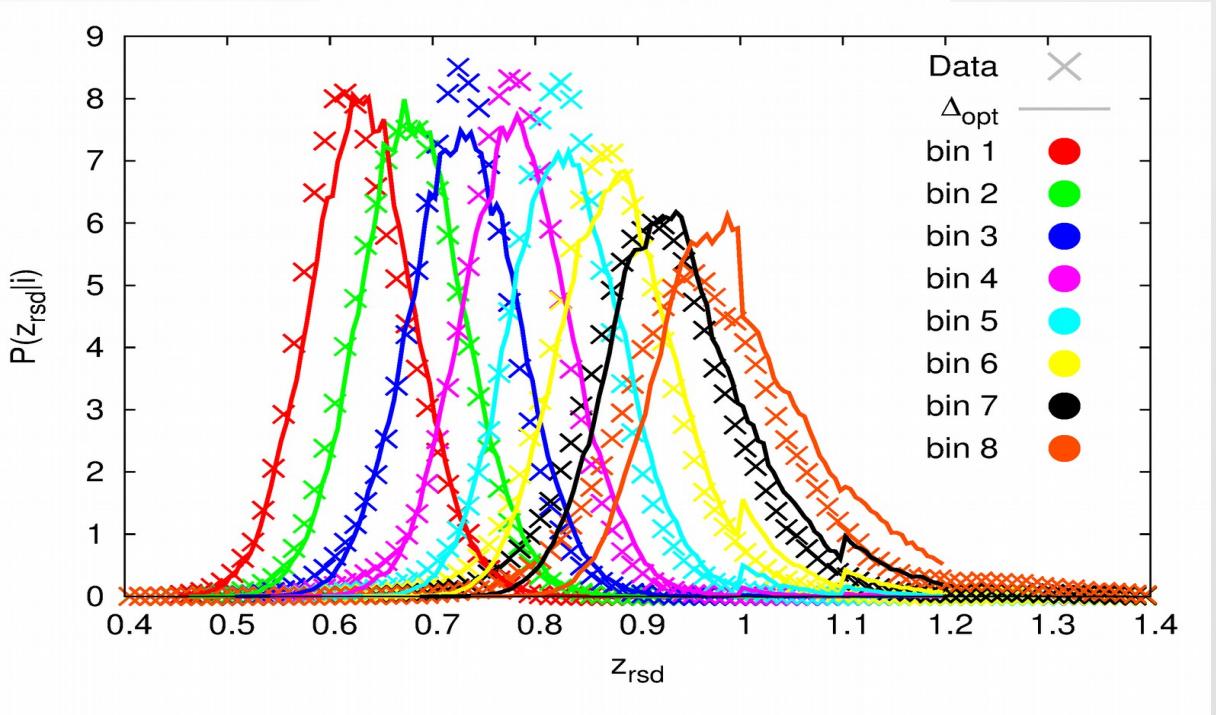

Year-1 LSS sample

- We aim at reproducing 4 properties:
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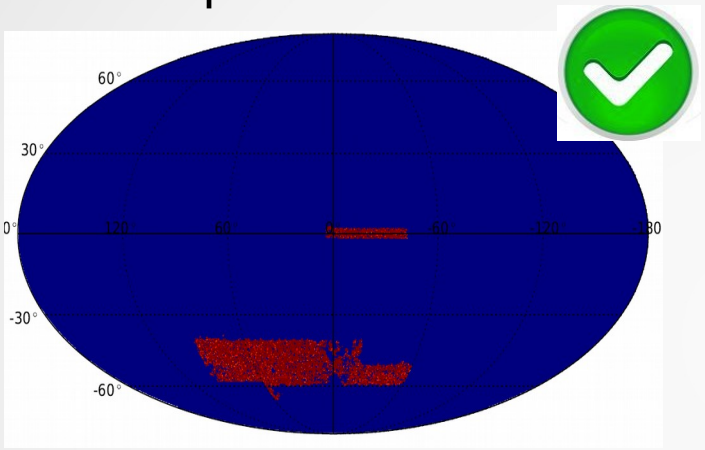

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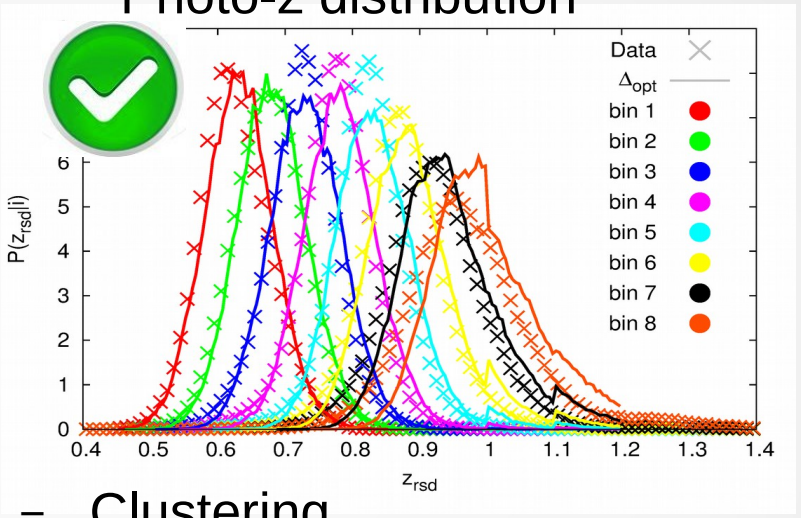
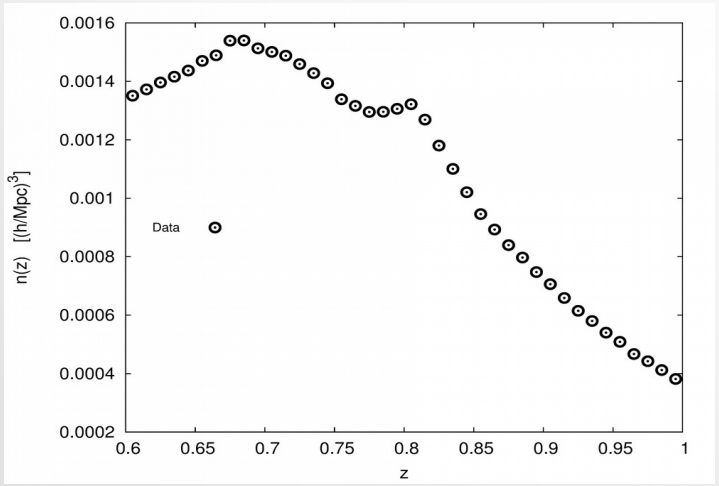


  - Number density



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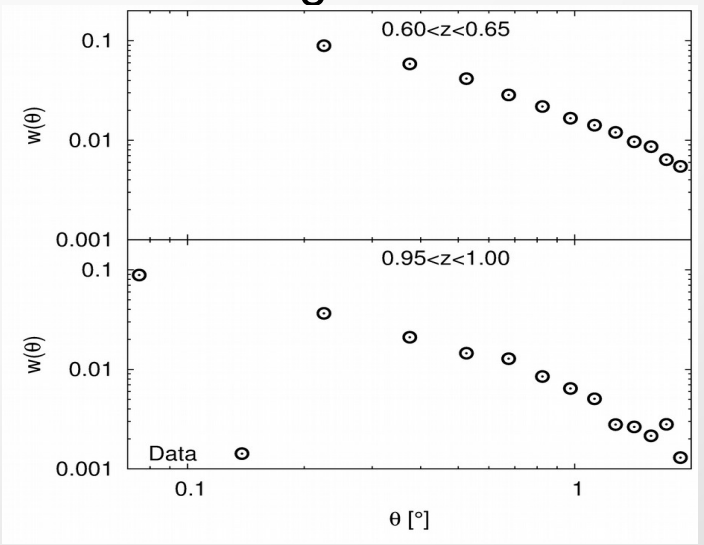

HALOGEN lamps: n(z)

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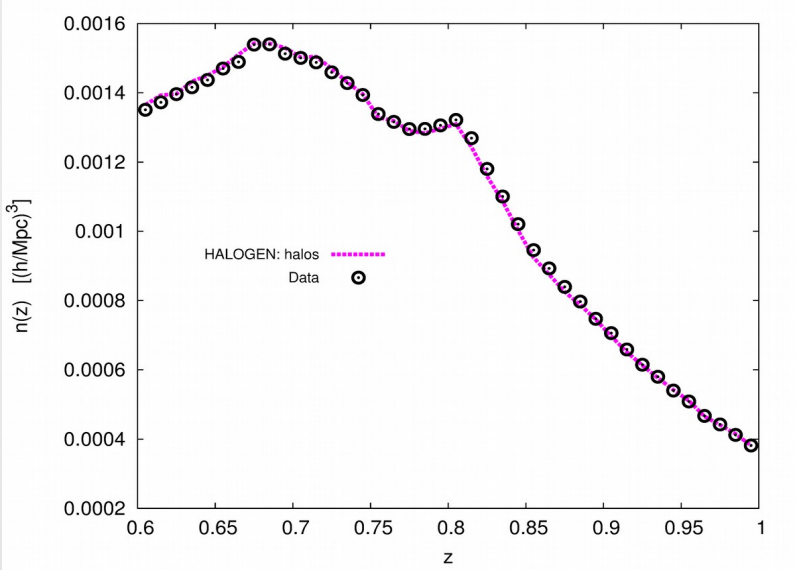

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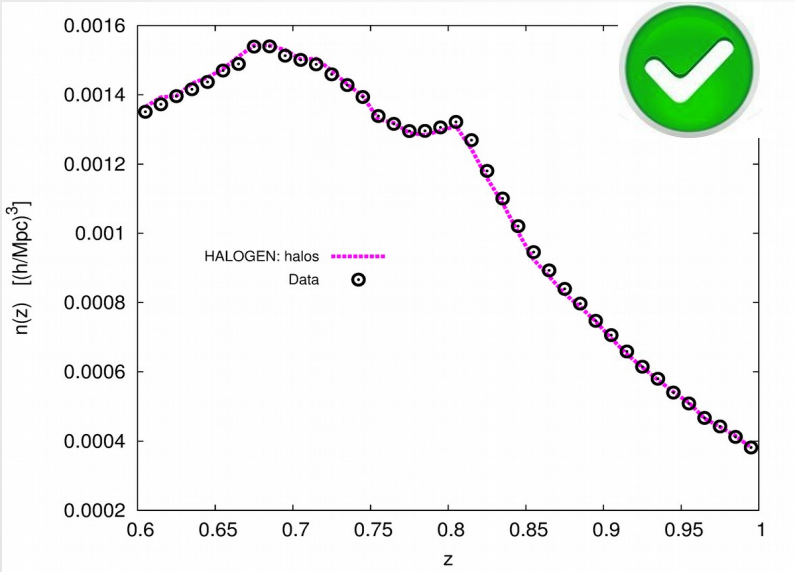

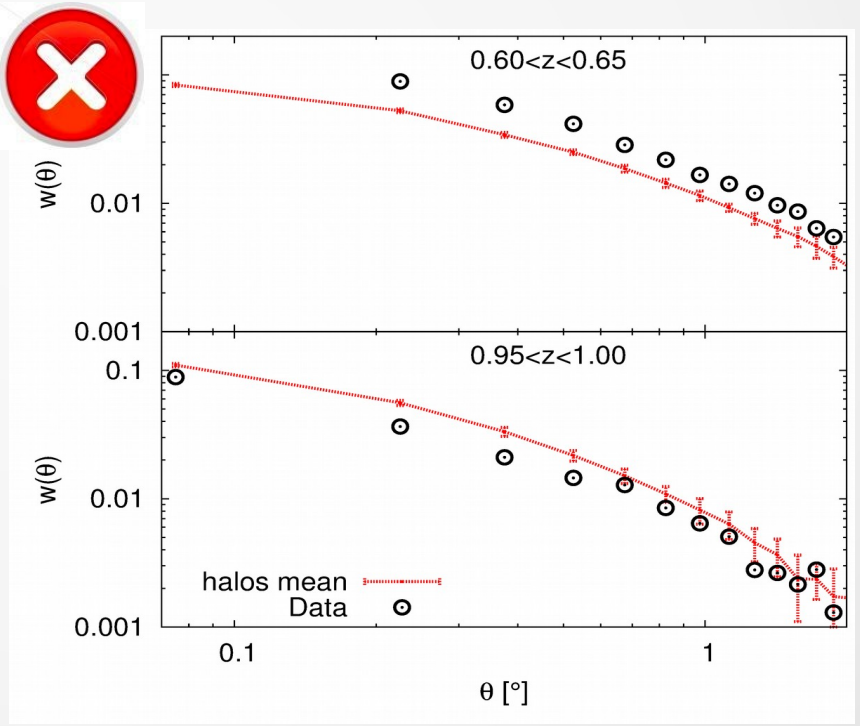

HALOGEN lamps: HOD-HAM

- **Halo Ocupation Distribution** (HOD) (Jing98, Peacock00, Berlind02, Zehavi11, Carretero15, ...)
  - Halos can host more than one galaxy
  - More massive halos host more galaxies
    → Massive halos overrepresented
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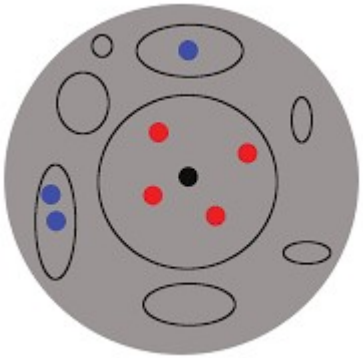

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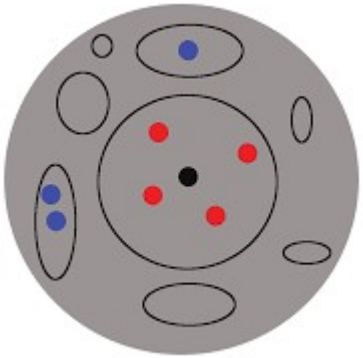

- A 1-param. HOD:

$$N_{\rm sat}(M_h) = R_{\rm Poisson}\left(\frac{M_h}{M_1}\right)$$

- Assign $M_{gal}=M_h$
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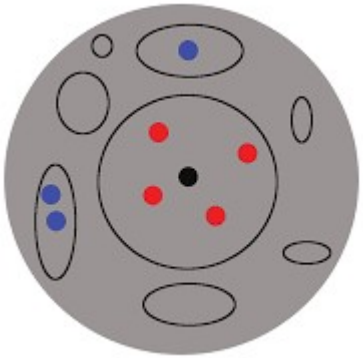

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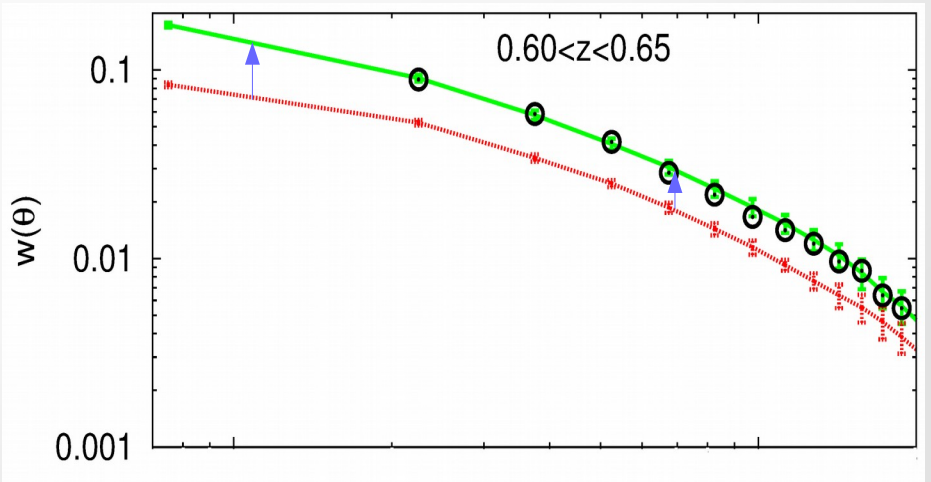
- M_1 controls the bias:



HALOGEN lamps: HOD-HAM

- **Halo Abundance Matching** (HAM) (Conroy06, Behroozi10, Trujillo-Gomez11, Guo16)
  - Reality:
    Scatter between Mass and Luminosity
  - Add scatter to mocks:

$$\log M^{\rm gal} = \log M_{\rm h} + \gamma \cdot R_{\rm gauss}(0,1)$$

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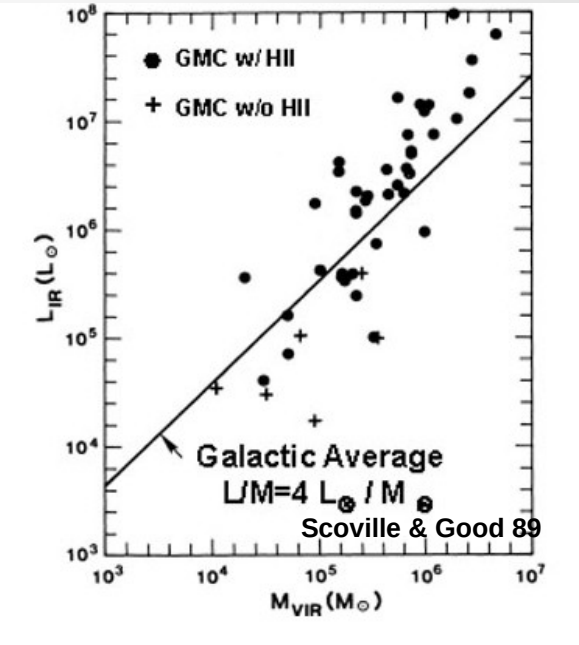

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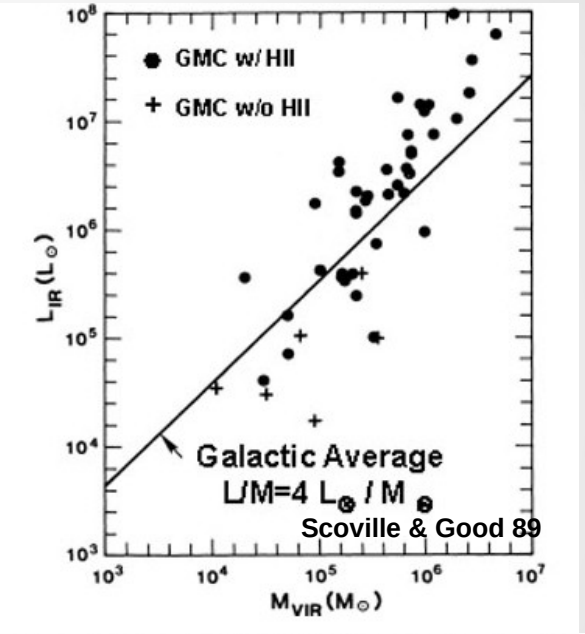
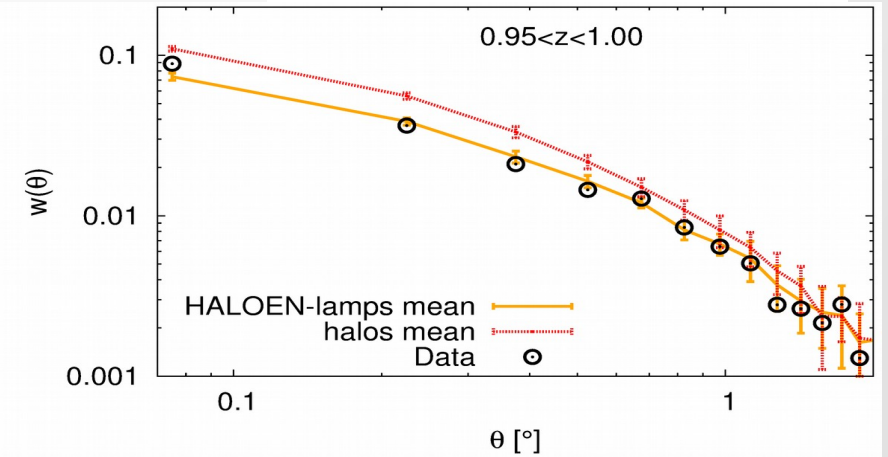
  - Mix of masses → mix bias
    → reduce bias

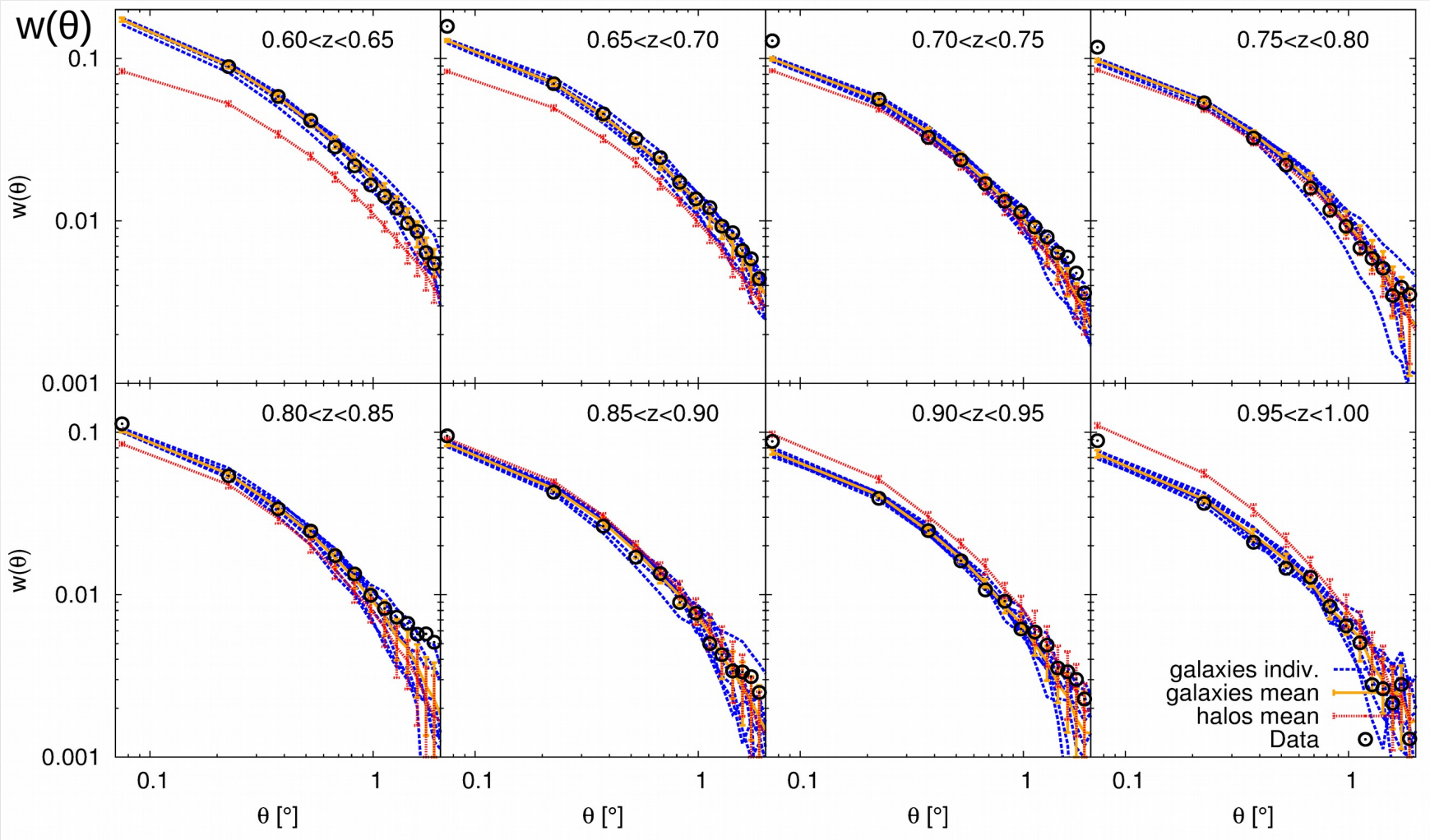




HALOGEN lamps: HOD-HAM

- We adapt M_1 /γ to increase/deacrease the bias:

bin-i	1	2	3	4	5	6	7	8
$\log_{10}(M_1^i)$	13.4	13.6	14.2	14.5	14.0	–	–	–
γ^i	–	–	–	–	–	2.6	2.6	3.5



Y1-LSS sample: mock catalogs

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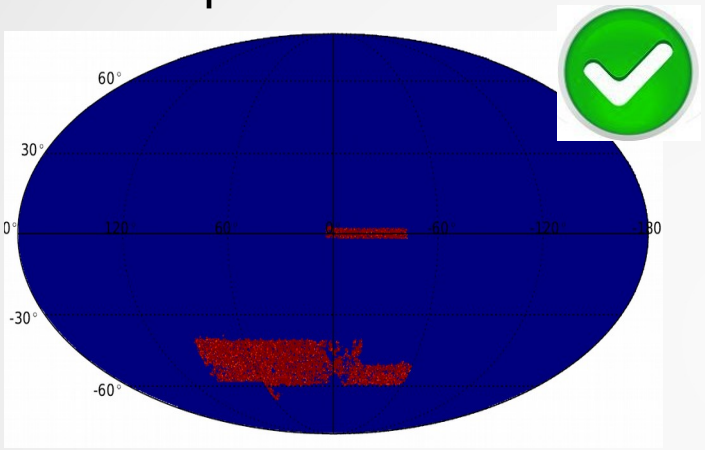

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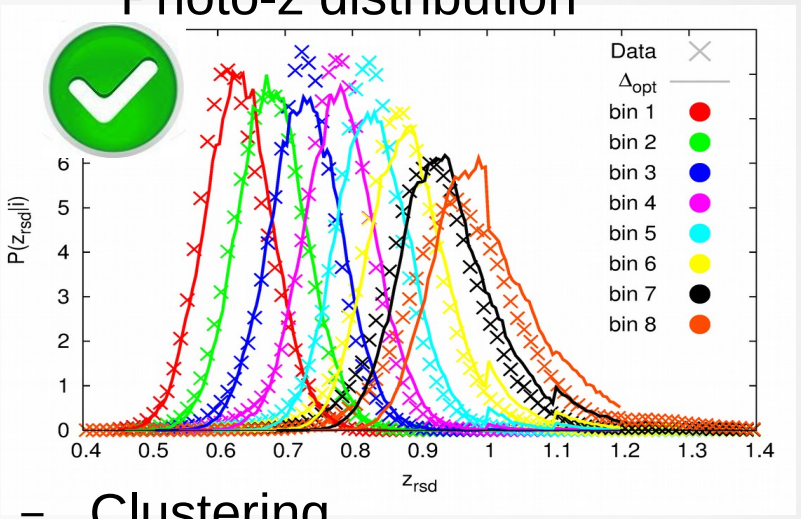

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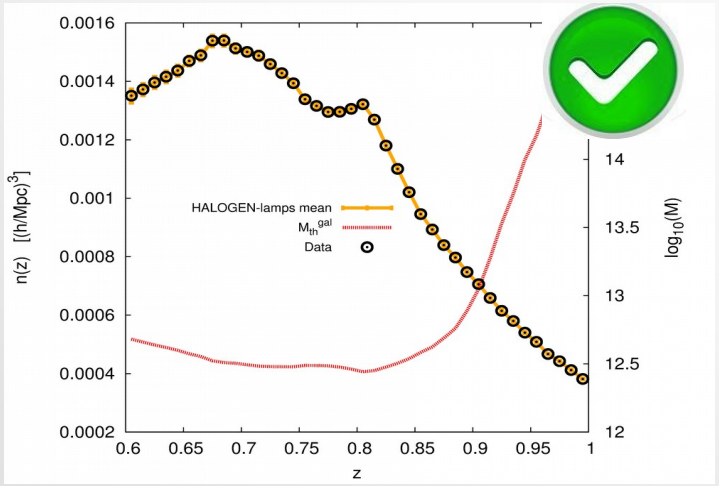

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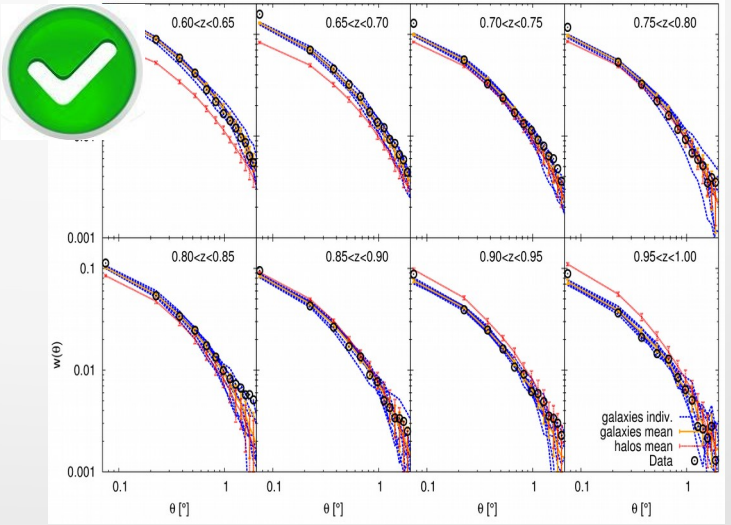


Applications

- Optimise Metholodogy
- Gain Modelling Insight
- Estimate uncertainties

Applications

- Optimise Methodology: extracting BAO

  From the original catalog
  what is the best way to extract χ_{BAO} ?

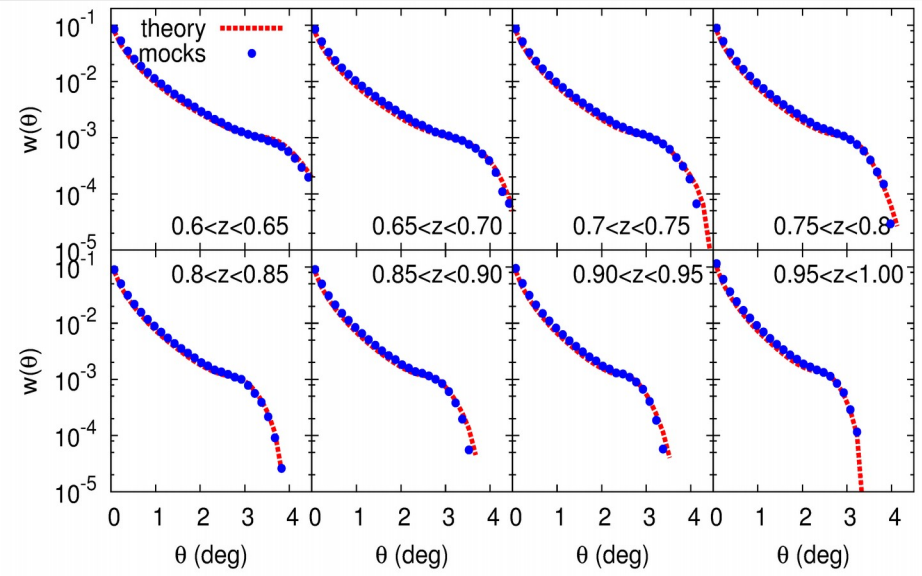
  - Binning (in θ, z_{ph} , ...)
  - Space (θ, r, k, C_l, …)
  - Fitting procedure / model.

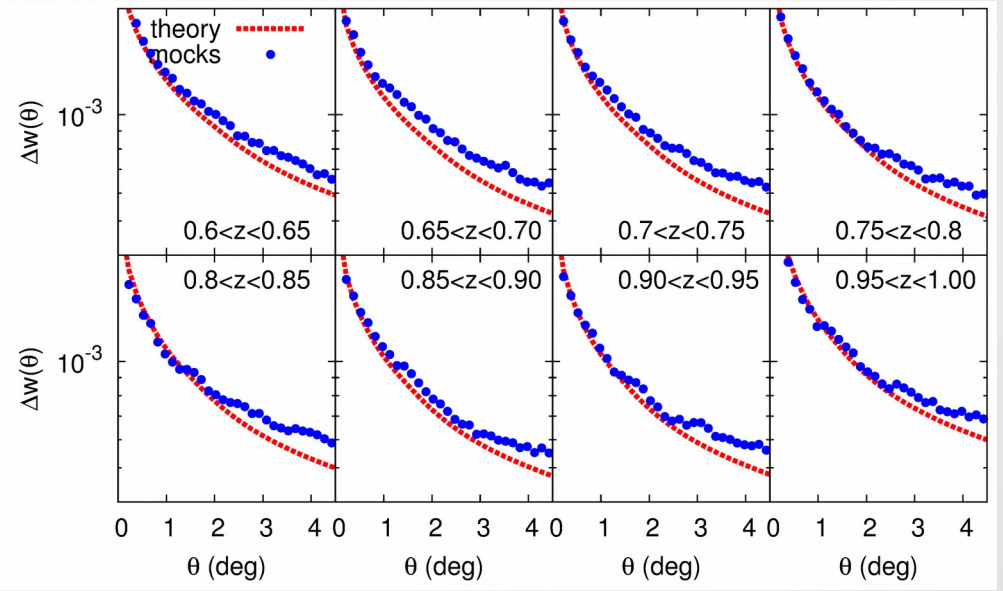
  → Test statistically in the mock catalogues

  Answer: Sanchez et al. in prep.

Modelling insight

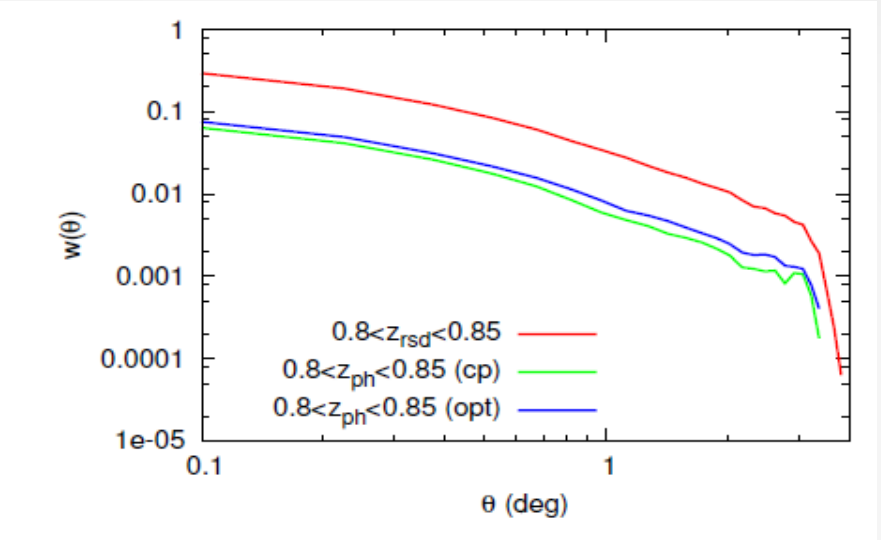
- Comparison with theory (from Crocce11)
  - Mean w(θ)
  - Error Δw(θ)



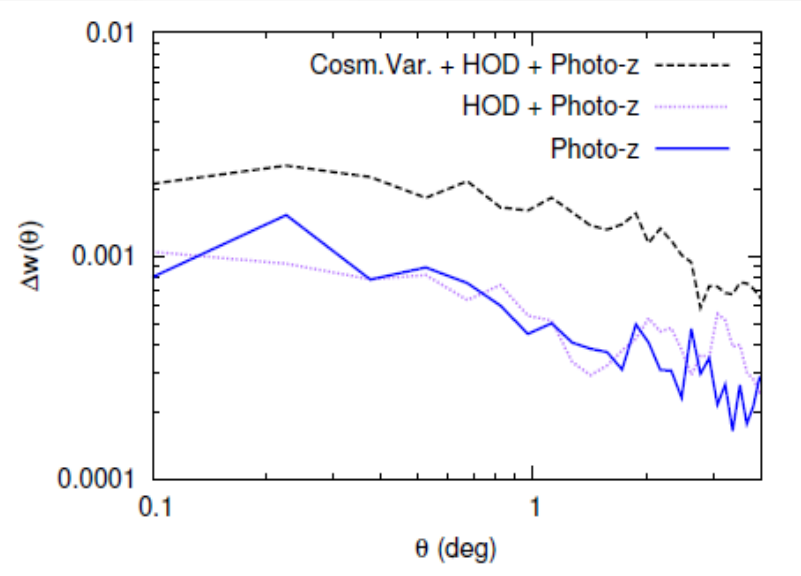


Modelling insight

- Effect of photo-z

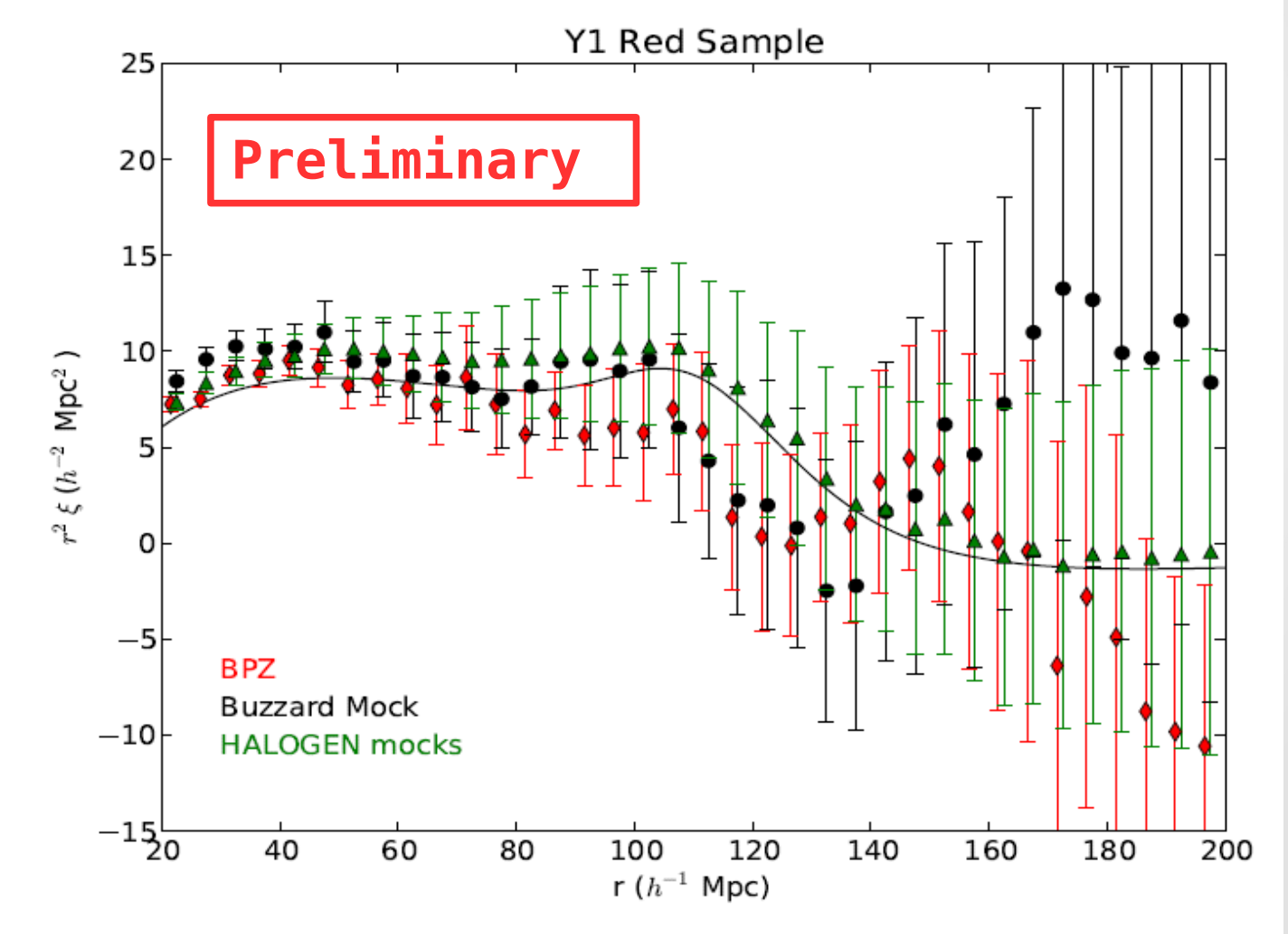


- Error introduced by
  - Photo-z
  - HOD
  - Cosmic Variance



Estimating Uncertainties

- Error bars of clustering ξ(r)
- Eventually
  $\Delta\chi^2_{BAO}$



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