Laboratório Interinstitucional de e-Astronomia (LineA)

Constructing a pipeline to constrain cosmology with galaxy clusters

LineA Webinar

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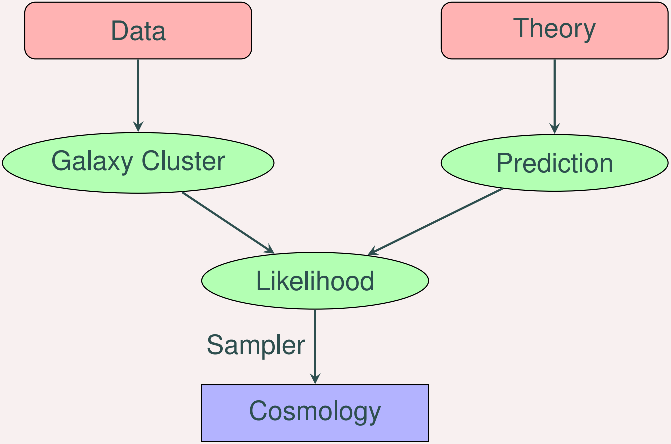
Content

Content

- The study of cosmology has experienced a rapid progress in the last few decades.
- Thanks to surveys such as WMAP (Hinshaw et al., 2013) & PLANCK (Planck Collaboration et al., 2016), the energy content of the Universe at the present epoch has been well characterized as:
  - dark energy ($\sim$ 70%)
  - dark matter ($\sim$ 25%)
  - baryonic matter ($\sim$ 5%)
- The modern approach relies on the use of large surveys using statistical quantities.
- Galaxy clusters are the largest structures in the Universe. The abundance is extremely sensitive to expansion and to growth of perturbations.

Basic Idea


Data
Theory
Galaxy Cluster
Prediction
Likelihood
Sampler
Cosmology

Einstein Equation

$$G_{\mu\nu} - \Lambda g_{\mu\nu} = 8\pi G\, T_{\mu\nu}$$

FRW Metric

$$ds^2 = dt^2 - a^2(t)\left[d\chi^2 + f^2(\chi) d\alpha^2\right]$$

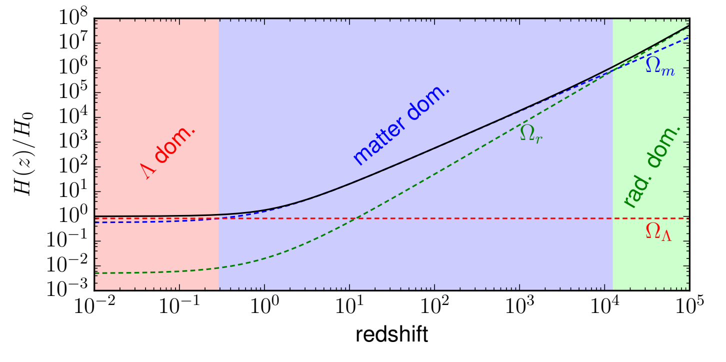
Friedmann's equations

$$H^2(a) = \frac{8\pi G}{3}\bar{\rho}(a)$$

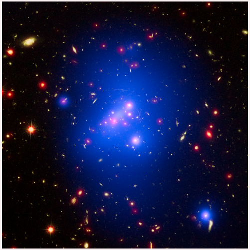
$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left[\bar{\rho}(a) + 3\bar{P}(a)\right]$$

Hubble Factor

$$H(z) = H_0\sqrt{\Omega_\Lambda + \Omega_k(1+z)^2 + \Omega_m(1+z)^3 + \Omega_r(1+z)^4}$$



- Dark Matter Halos
- Galaxy Agglomeration
- Several Observational probes (Optical, X-Ray, SZ)



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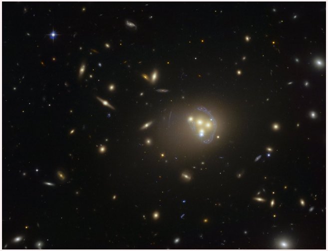

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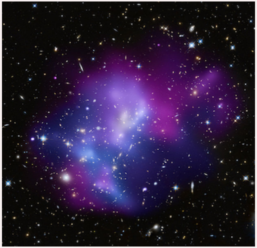

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Content

Fraction of Matter in Halos

$$F(M) = \frac{1}{\sqrt{2\pi}\sigma(M)} \int_{\delta_c}^{\infty} d\delta \exp\left[-\frac{\delta^2}{2\sigma^2(M)}\right] = \frac{1}{2}\mathrm{erfc}\left[\frac{\delta_c^2}{\sqrt{2}\sigma(\mathrm{M})}\right]$$

Press and Schechter (1974)

The differential comoving mean halo number density

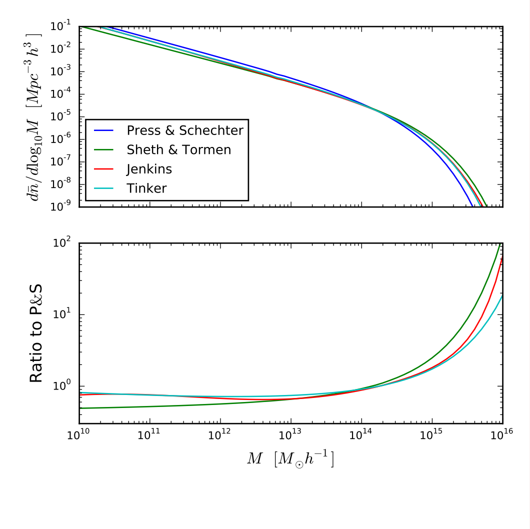
$$\frac{d\bar{n}}{d\ln M} = -\frac{\bar{\rho}_m}{M}\frac{dF}{d\ln M} = \frac{\bar{\rho}_m}{M}\frac{d\ln\sigma^{-1}}{d\ln M}\sqrt{\frac{2}{\pi}}\frac{\delta_c}{\sigma}\exp\left[-\frac{\delta_c^2}{2\sigma^2}\right]$$

$$\frac{d\bar{n}(z, M)}{d\ln M} = \frac{\bar{\rho}_m}{M}\frac{d\ln\sigma^{-1}}{d\ln M}f(\sigma)$$

Halo Abundance Formalism
Halo Mass-function

Mass-functions:

- Press and Schechter (1974) (Sphericall)
- Sheth et al. (2001) (Ellipsoidal)
- Jenkins et al. (2001) (Simulation)
- Tinker et al. (2008) (Simulation)



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Observations of Galaxy Clusters

Techniques for Detecting Clusters

- **X - ray Observations** (Evrard et al., 1996; Vikhlinin et al., 2006; Clerc et al., 2016)
- **Sunyaev-Zel'dovich Effect** (Carlstrom et al., 2002)
- **Cluster Lensing** (Dietrich and Hartlap, 2010; Marian et al., 2012; Kacprzak et al., 2016; Peel et al., 2017)
- **Optical Clusters**

Observational Effects

- Mass-Observable Relation (Lima and Hu, 2007)
- Completeness and Purity (Aguena and Lima, 2016)

$$\frac{d\bar{n}}{d\ln X}\left(\Theta_{cl}\right) = \int dV_{\Theta_h}\, \frac{d\bar{n}}{d\ln M}\left(\Theta_h\right) W_{[cl,h]}$$

- Halo Finders
- Cluster Finders

Approaches of Finders

- Friends of Friends
- Spherical Overdensity

Optical Cluster Finders

- MaxBCG
- Farrens et al. (2011)
- VT3D (Abdalla et al. - in dev.)
- redMaPPer
- VT
- WaZp

Observations of Galaxy Clusters

Observational Effects

Photometric Redshifts

$$\mathcal{P}(z^{\rm phot}) = \int_0^\infty dz\, \mathcal{P}(z) P(z^{\rm phot}|z)$$

Mass-Observable Relation

$$\frac{d\bar{n}}{dM^{\rm obs}} = \int_0^\infty dM\, \frac{d\bar{n}}{dM} P(M^{\rm obs}|M)$$

Selection Function

Completeness $c(M, z)$ and Purity $p(M^{\rm obs}, z^{\rm phot})$

Corrected Prediction

$$\bar{m}_{\alpha,i} \equiv \Delta\Omega \int_{z_i^{\rm phot}}^{z_{i+1}^{\rm phot}} dz^{\rm phot} \int dz \frac{D_A(z)^2}{H(z)} P(z^{\rm phot}|z) \int_{M_\alpha^{\rm obs}}^{M_{\alpha+1}^{\rm obs}} dM^{\rm obs} \int \frac{dM}{M} \frac{d\bar{n}}{d\ln M} P(M^{\rm obs}|M) \frac{c\,(M, z)}{p(M^{\rm obs}, z^{\rm phot})}$$

Content

Posterior

$$\mathcal{P}(\Theta|\boldsymbol{O}) \propto \mathcal{L}(\boldsymbol{O}|\Theta)\,\Pi(\Theta)$$

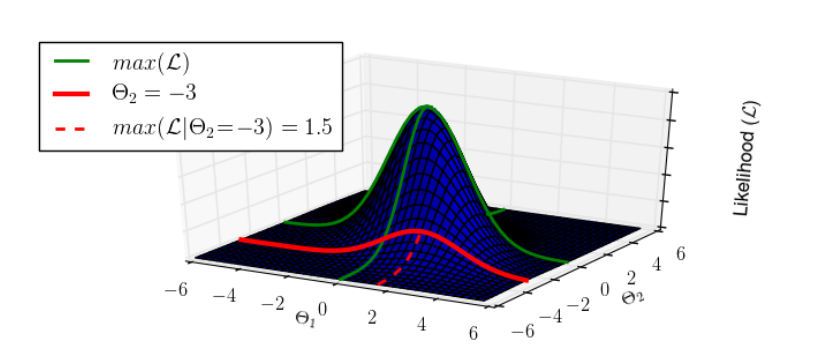
Gaussian Likelihood

$$\mathcal{L} = \frac{1}{\sqrt{2\pi\,\det\left(\boldsymbol{C}\right)}}\exp\left[\sum_{ij}\frac{\left(N_i - \bar{m}_i\right)C_{ij}^{-1}\left(N_j - \bar{m}_j\right)}{2}\right]$$

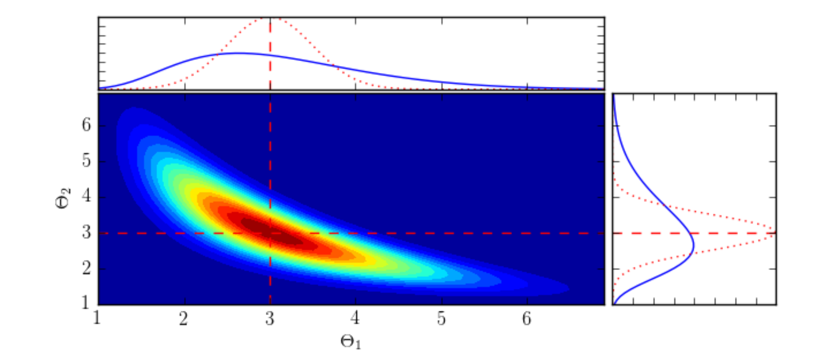
Poissonian Likelihood

$$\mathcal{L} = \sum_{i}\frac{N_i!\,\bar{m}_i^{N_i}}{\bar{m}_i}$$

$$\mathcal{L}(\Theta_1, \Theta_2) \propto \exp\left[-\frac{\Theta_1^2 + \Theta_2^2 + \Theta_1\Theta_2}{5}\right]$$



$$\mathcal{L}(\Theta_1, \Theta_2) \propto \exp\left[-\frac{(\Theta_1 - 3)^2 + (\Theta_2 - 3)^2 + (\Theta_1\Theta_2 - 9)^2}{5}\right]$$



- Assumes Gaussian distribution of the parameters
- Produces Forecasts
- Much Faster $\mathcal{O}(N_{pars})$ than sampling techniques $\mathcal{O}(10^4)$

$$F_{\alpha\beta} = -\left\langle \frac{\partial^2 \ln \mathcal{L}\left(\Theta\right)}{\partial\Theta_\alpha \partial\Theta_\beta} \right\rangle$$

Likelihoods

$$F_{\alpha\beta} = \bar{\boldsymbol{m}}_{,\alpha} \boldsymbol{S}^{-1} \bar{\boldsymbol{m}}_{,\beta}{}^T + \frac{1}{2} \mathrm{Tr}\left[\boldsymbol{S}^{-1} \boldsymbol{S}_{,\alpha} \boldsymbol{S}^{-1} \boldsymbol{S}_{,\beta}\right]$$

$$F_{\alpha\beta} = \bar{\boldsymbol{m}}_{,\alpha} \boldsymbol{M}^{-1} \bar{\boldsymbol{m}}_{,\beta}{}^T$$

$$F_{\alpha\beta} = \bar{\boldsymbol{m}}_{,\alpha} \boldsymbol{C}^{-1} \bar{\boldsymbol{m}}_{,\beta}{}^T + \frac{1}{2} \mathrm{Tr}\left[\boldsymbol{C}^{-1} \boldsymbol{S}_{,\alpha} \boldsymbol{C}^{-1} \boldsymbol{S}_{,\beta}\right]$$

- Monte Carlo Markov Chain
- Sampling from probability distributions
- Much Faster $\mathcal{O}(10^4)$ than grid $\mathcal{O}(20^{N_{pars}})$
- Does not assume Gaussianity as FM

1. From a point Θ in parameter space, propose a random step Θ_s
   (a) If $\mathcal{P}(\Theta_s) > \mathcal{P}(\Theta)$: take the step $(\Theta \rightarrow \Theta_s)$
   (b) Else: Generate a random number $R \in [0:1]$
      i. If the ratio $\mathcal{P}(\Theta_s)/\mathcal{P}(\Theta) > R$: take the step $(\Theta \rightarrow \Theta_s)$
      ii. Else: Remain at the original point Θ
2. Repeat step 1 until the distribution of the parameters converge

- Usual formulation is not parallelizable
- Parallel implementation: `emcee` (Foreman-Mackey et al., 2013)

Content

How is the cluster cosmology affected by the optical effects?

- Aguena and Lima (2016)

Survey

- flat *w*CDM with Planck 2015 cosmology $(h^2\Omega_m, h^2\Omega_b, w, A_s, n_s, \Omega_{DE})$
- priors of 1% on $(h^2\Omega_m, h^2\Omega_b, A_s, n_s)$
- area of 5000 $\deg^2$, covariance within 500 cells of 10 $\deg^2$
- $0.1 \leq z \leq 1.0$
- 7 Mass bins: $M_{th}^{\rm obs} = 10^{13.8} M_\odot/h$, $\Delta \log[M^{\rm obs}/(M_\odot h^{-1})] = 0.2$
- Mass-Observable distribution Gaussian in log space:

$$P(M^{\rm obs}|M) = \frac{1}{\sqrt{2\pi\sigma^2_{\ln M^{\rm obs}}(M)}} \exp\left[\frac{\left(\ln M^{\rm obs} - \ln M - \ln M^{\rm obs}_{bias}(M)\right)^2}{2\sigma^2_{\ln M^{\rm obs}}(M)}\right]$$

Mass-Observable

$$\ln M^{\mathrm{obs}}_{bias}(z) = A_b + n_b \ln(1+z)$$

$$\frac{\sigma^2_{\ln M^{\mathrm{obs}}}(z, M)}{0.2^2} = 1 + B_0 + B_z(1+z) + B_M \left(\frac{\ln M_s}{\ln M}\right)$$

$^*M_s = 10^{14.2} M_\odot/h$

Completeness and Purity

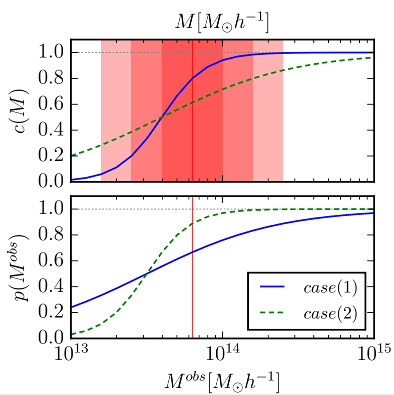
$$c(M, z) = \frac{[M/M_c(z)]^{n_c}}{[M/M_c(z)]^{n_c} + 1},$$

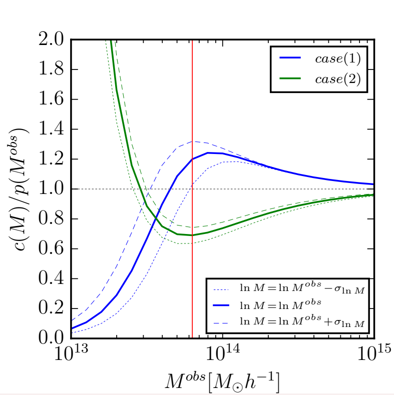
$$p(M^{\mathrm{obs}}, z) = \frac{[M^{\mathrm{obs}}/M_p^{\mathrm{obs}}(z)]^{n_p}}{[M^{\mathrm{obs}}/M_p^{\mathrm{obs}}(z)]^{n_p} + 1}$$

Possibilities of Completeness and Purity

case (1): $n_c = 3$, $n_p = 1$
case (2): $n_c = 1$, $n_p = 3$

case (0): $c(M) = 1$, $p(M^{obs}) = 1$



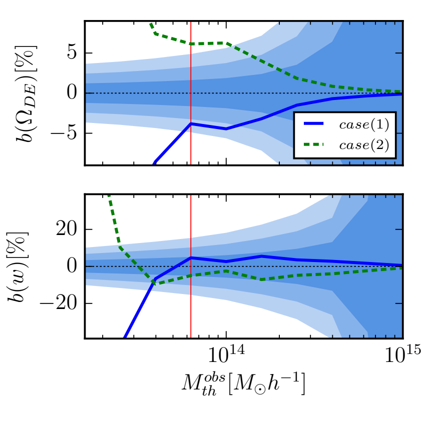


Finding Bias Limit

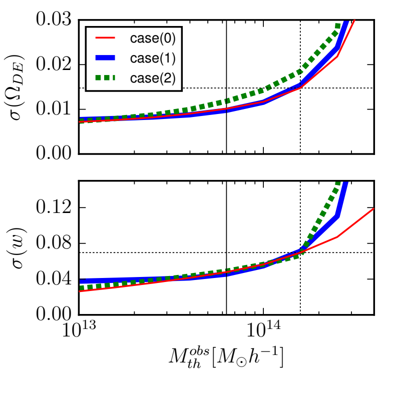
- Bias inside the constraint:

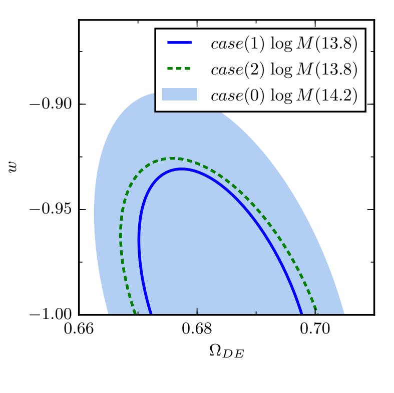
$$b(\Theta_\alpha) \leq \gamma \left(F^{-1}\right)^{1/2}_{\alpha\alpha}$$

where $\gamma = 1, 2, 3$ indicate biased predictions inside the 68, 95, 99% confidence levels.

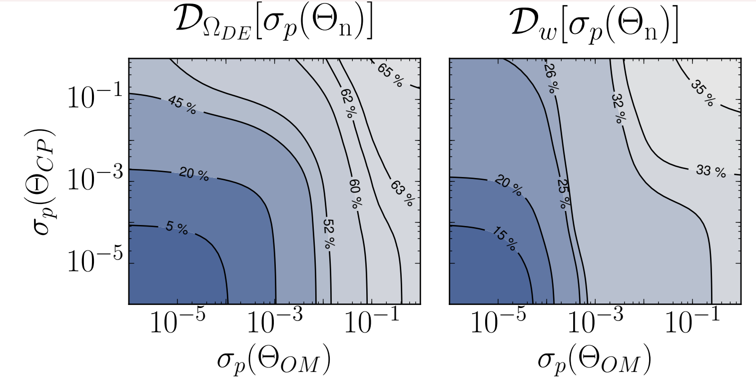


Improvements by including *CP* and Lowering M_{th}





$\Theta_{\rm OM}$	$\Theta_{\rm CP}$	$\sigma(\Omega_{\rm DE})$	$\sigma(w)$
fix	fix	0.006	0.033
free	fix	0.009	0.044
fix	free	0.009	0.042
free	free	0.010	0.046



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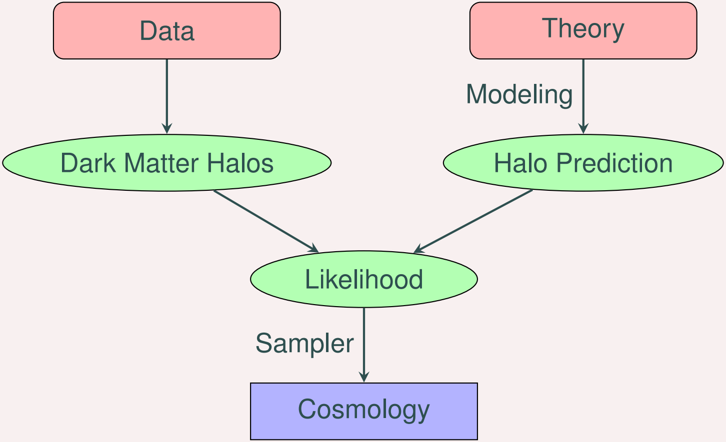
Halo Cosmology



Simulation Specifications

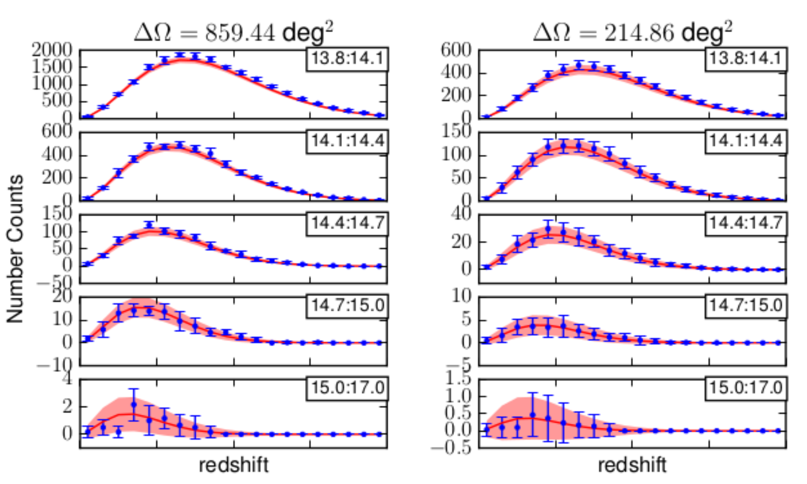
- Aardvark v1.0 catalogs of the Blind Cosmology Challenge (BCC) - DES
- DM simulation ($\sim 10,313$ deg^2, $0 < z < 2$)
- DM halos (Behroozi et al., 2013, 2012) and galaxies
- Complete above $\sim 4.5 \times 10^{13} M_\odot h^{-1}$ ($\sim 5 \times 10^{12} M_\odot h^{-1}$)
- $\sim$ 30 million halos

Theoretical Prediction Comparison

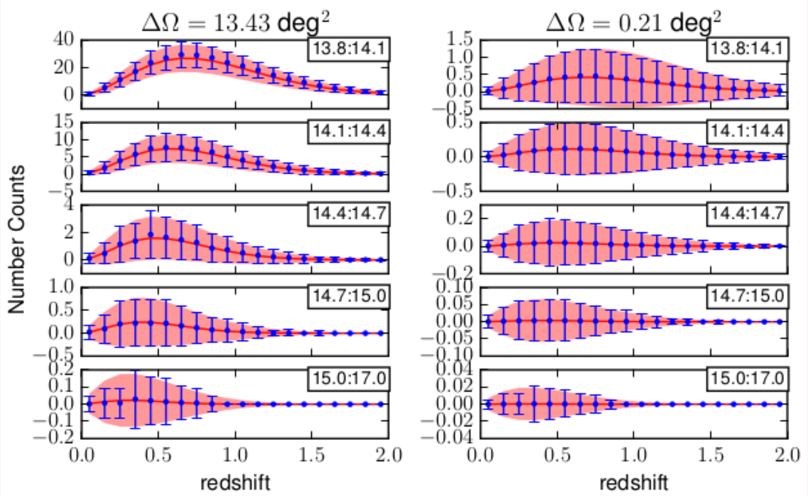
- 5 mass bins
- 20 redshift bins
- Survey was sub-divided into:
  - 12 pixels (859 deg^2)
  - 48 pixels (214 deg^2)
  - 768 pixels (13 deg^2)
  - 49152 pixels (0.21 deg^2)

Simulation Results
BCC Dark Matter Halos

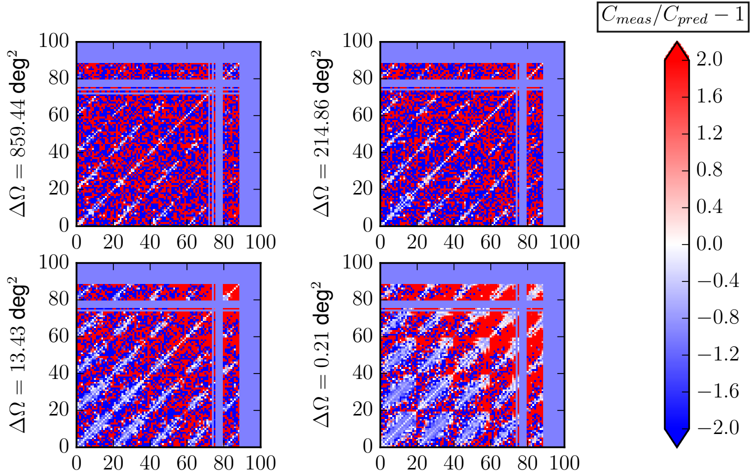
Testing Theoretical Abundance Prediction



Testing Theoretical Abundance Prediction

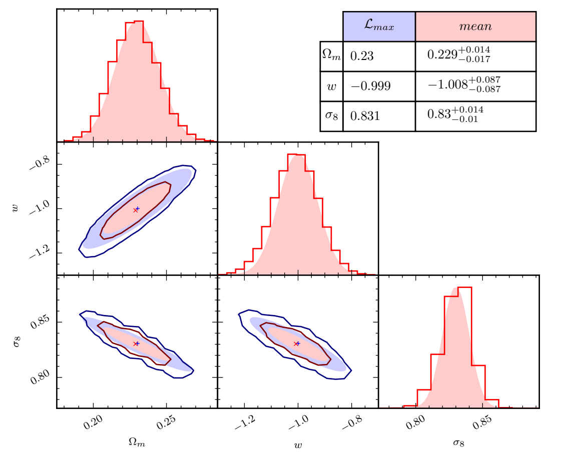


Testing Theoretical Covariance Prediction



Constraining Cosmology

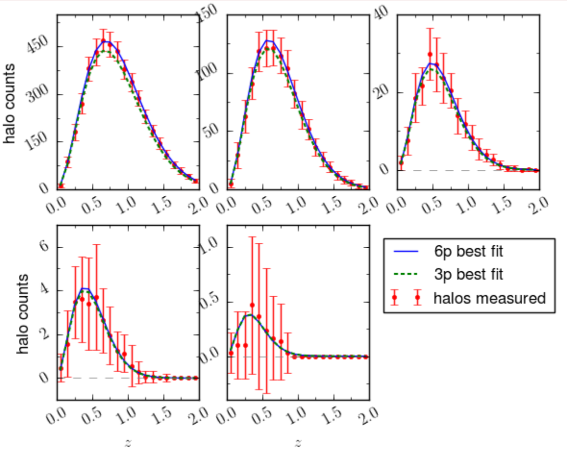
- DM Halos
- $M_{th} = 10^{13.8} M_{\odot} h^{-1}$ (5 bins)
- $0 < z < 2$ (20 bins)
- Tinker MF
- 214 deg^2
- $(h, n_s, \Omega_b) = (0.72, 0.96, 0.042)$



	$\mathcal{L}_{max}$	mean
Ω_m	0.23	$0.229^{+0.014}_{-0.017}$
w	−0.999	$-1.008^{+0.087}_{-0.087}$
σ_8	0.831	$0.83^{+0.014}_{-0.01}$

Best fit

- DM Halos
- $M_{th} = 10^{13.8} M_{\odot} h^{-1}$ (5 bins)
- $0 < z < 2$ (20 bins)
- Tinker MF
- 214 deg^2



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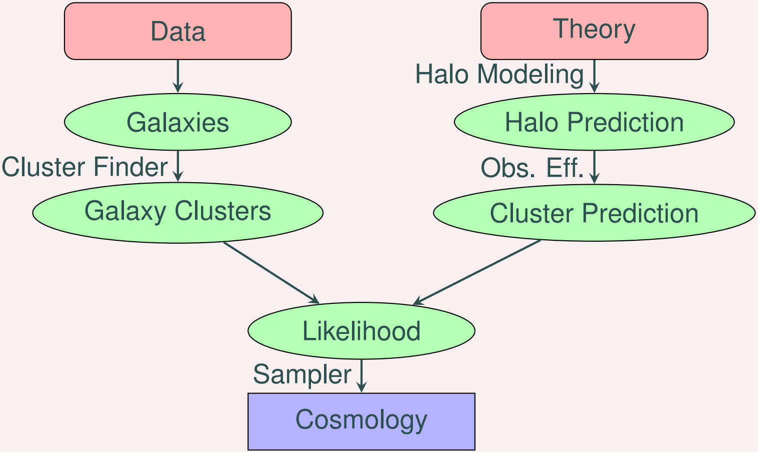
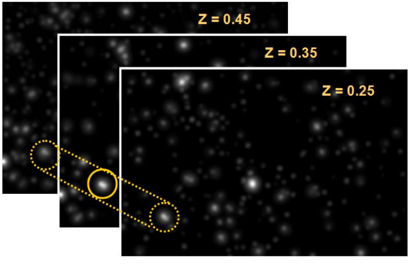
Cluster Cosmology

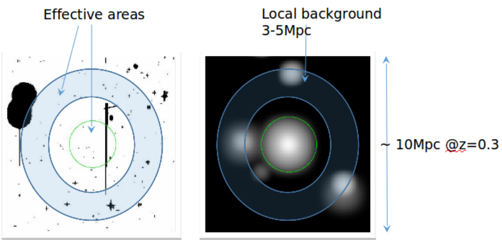


WaZp

- Wavelet z Photometric (WaZp) *cluster finder* (Dietrich et al., 2014)
- $z^{\rm phot}$ slices with overlaps
- Density in each slice is computed via wavelet transformation
- Cylinders across slices are constructed



A 3 deg² tile



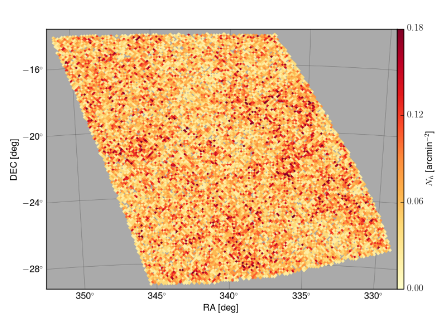
Masked regions

Galaxy density map

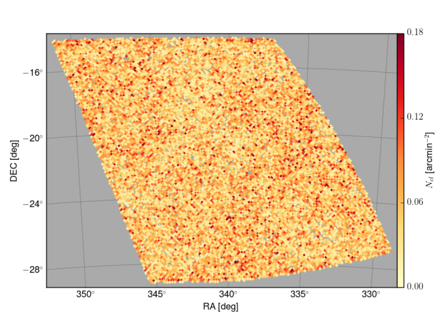
Simulation Results

WaZp clusters in BCC

- Reduced Area ($\sim 220\ \text{deg}^2$), $0.1 < z < 1.0$
- $45,677$ Halos with $M > 10^{13} M_\odot h^{-1}$
- $39,861$ Clusters with $N > 3$



Halos



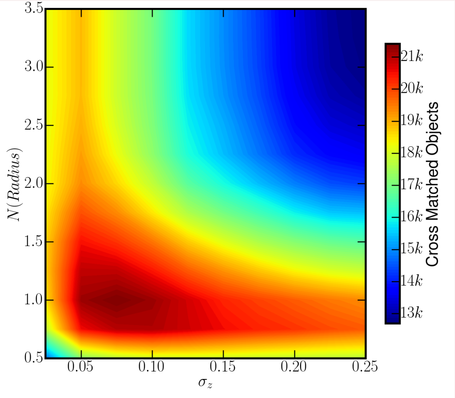
Clusters

Proximity Match

- Requirements:

$$\begin{cases} |z_{halo} - z_{cluster}| & \leq \sigma_z (1+z) * \\ \Delta\theta & \leq N\theta_R \end{cases}$$

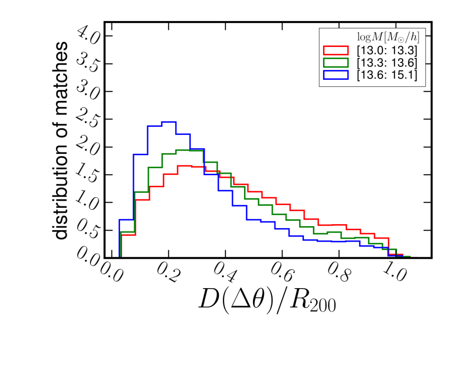
* Ilbert et al. (2006); Mazure et al. (2007); Arnouts et al. (2007); Ilbert et al. (2009)

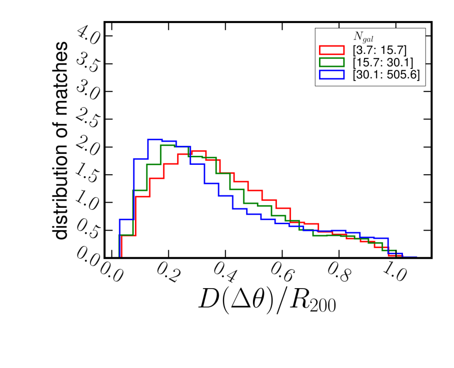


Angular Residuals

$$\Delta\theta \quad \leq N\theta_R = 2N \arcsin\left(\frac{R}{2D(z_m)}\right)$$

Mass/Richness Bins

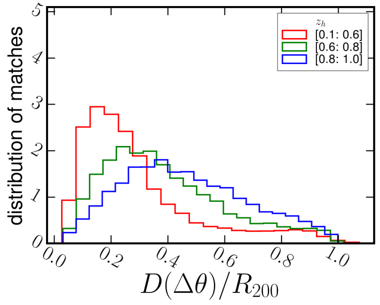


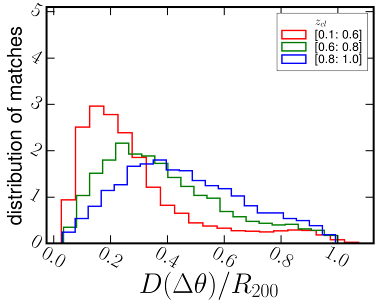


Angular Residuals

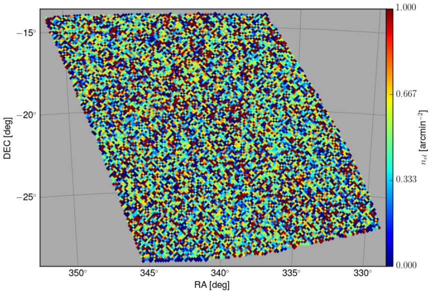
$$\Delta\theta \quad \leq N\theta_R = 2N \arcsin\left(\frac{R}{2D(z_m)}\right)$$

Redshift Bins

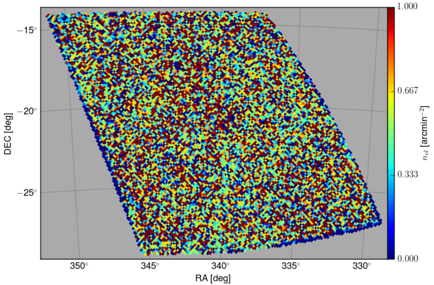




Completeness and Purity - Regions in the Sky



Completeness

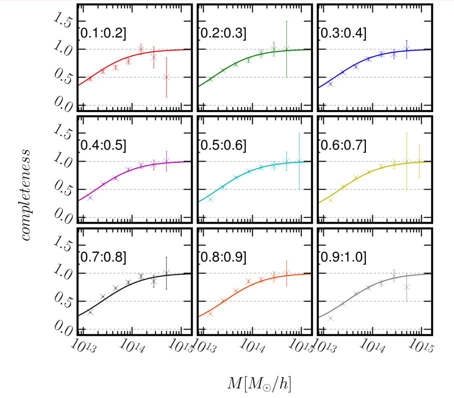


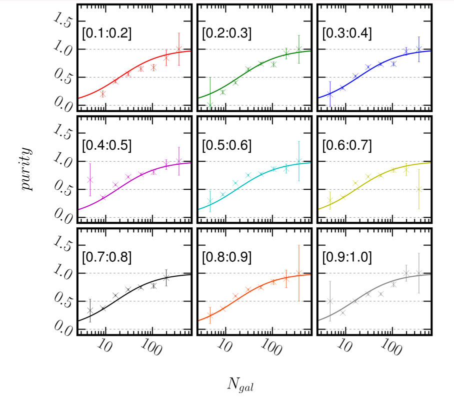
Purity

- No significant directional effects
- Small edge effects

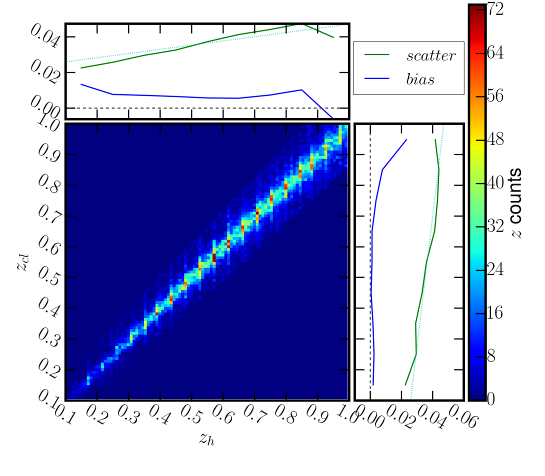
Completeness and Purity - Fit Functional Form

$$c(z, M) = \frac{[M/M_c(z)]^{n_c}}{[M/M_c(z)]^{n_c} + 1} \qquad p(M^{\rm obs}, z^{obs}) = \frac{\left[M^{\rm obs}/M_p^{\rm obs}(z^{obs})\right]^{n_p}}{\left[M^{\rm obs}/M_p^{\rm obs}(z^{obs})\right]^{n_p} + 1}$$





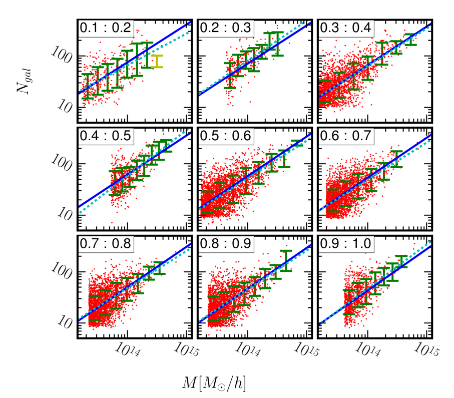
Redshift Relation

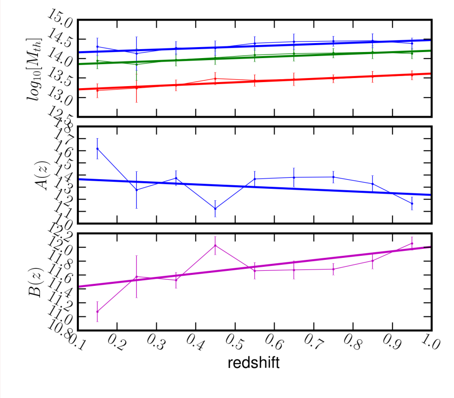


- Scatter is very small
- Test showed including $P(z^{obs}|z)$ had insignificant effect
- $P(z^{obs}|z)$ will not be considered

Mass Richness Relation

$$\log\left[\frac{M^{\rm obs}(M^{\rm cl},z)}{M_\odot h^{-1}}\right] = A(z)\ \log\left[M^{\rm cl}\right] + B(z) \qquad \begin{cases} A(z) = A_0 + A_1\ (1+z) \\ B(z) = B_0 + B_1\ (1+z) \end{cases}$$



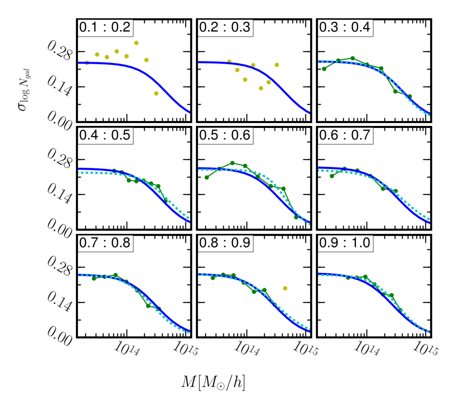


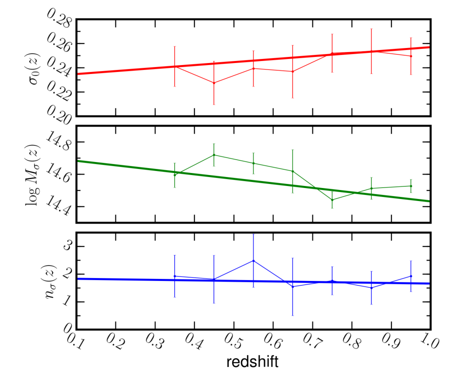
Simulation Results

WaZp clusters in BCC

$$\sigma_{\ln M^{\rm cl}}(M,z) = \frac{\sigma_0(z)}{1+\left(\frac{M}{M_\sigma(z)}\right)^{n_\sigma(z)}}$$

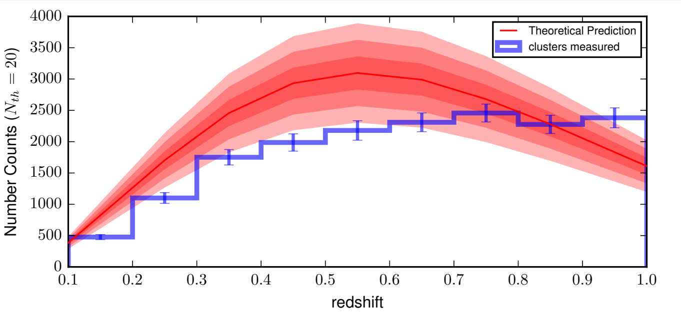
$$\begin{cases} \sigma_0(z) = \sigma_{00} + \sigma_{01}(1+z) \\ \log M_\sigma(z) = \log M_{\sigma 0} + \log M_{\sigma 1}(1+z) \\ n_\sigma(z) = n_{\sigma 0} + n_{\sigma 1}(1+z) \end{cases}$$





Theoretical Prediction

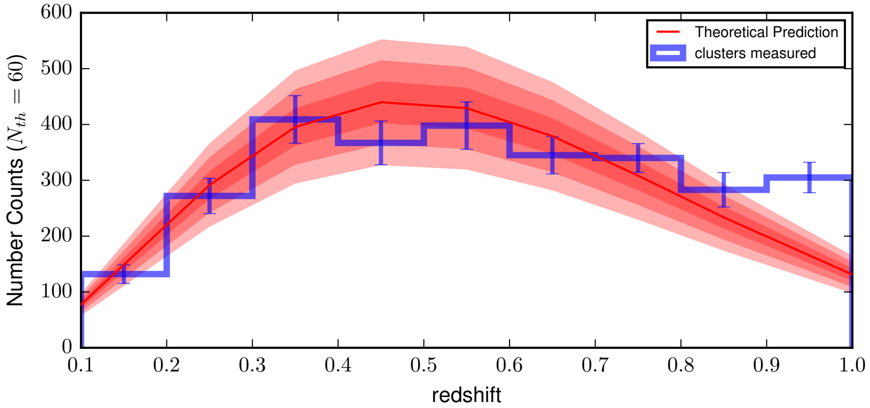
$$\bar{m}_{\alpha,i} \equiv \Delta\Omega \int_{z_i}^{z_{i+1}} dz \frac{D_A(z)^2}{H(z)} \int_{M_\alpha^{\rm obs}}^{M_{\alpha+1}^{\rm obs}} dM^{\rm obs}$$
$$\int \frac{dM}{M} \frac{d\bar{n}}{d\ln M} P(M^{\rm obs}|M) \frac{c\,(M,z)}{p(M^{\rm obs}, z^{\rm phot})}$$



Simulation Results

WaZp clusters in BCC

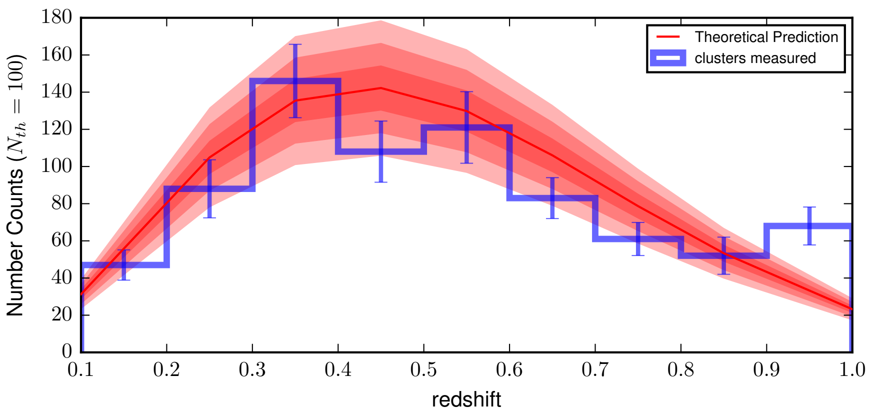
Theoretical Prediction



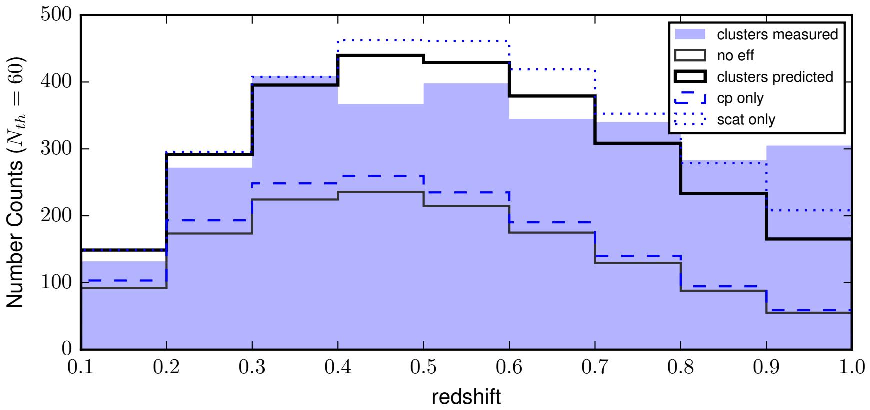
Simulation Results

WaZp clusters in BCC

Theoretical Prediction



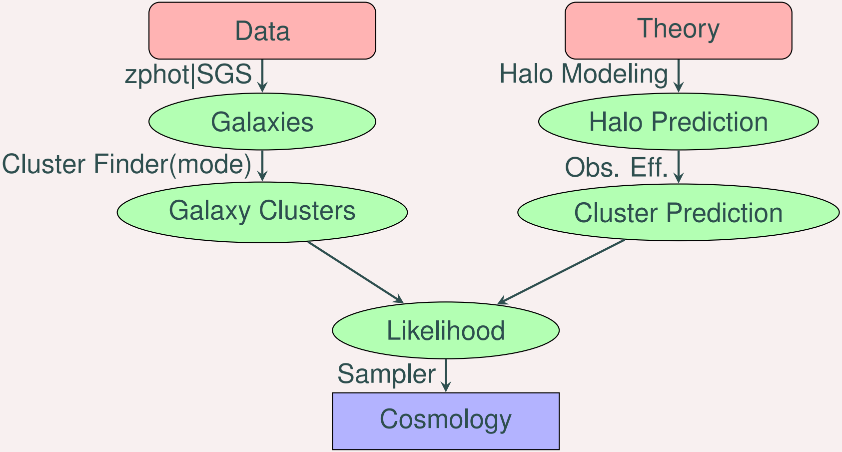
Theoretical Prediction



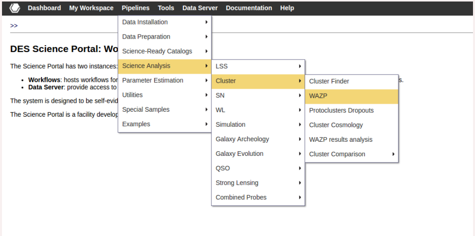
Content

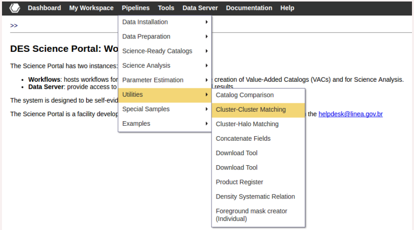
Science Portal

- There are many additional issues for galaxy cluster detection
- Collaboration from researchers of different institutes/locations



Pipelines


Dashboard
My Workspace
Pipelines
Tools
Data Server
Documentation
Help
>>
DES Science Portal: Wo
The Science Portal has two instances:
Workflows: hosts workflows for
Data Server: provide access to
The system is designed to be self-evid
The Science Portal is a facility develop
Data Installation
Data Preparation
Science-Ready Catalogs
Science Analysis
Parameter Estimation
Utilities
Special Samples
Examples
LSS
Cluster
SN
WL
Simulation
Galaxy Archeology
Galaxy Evolution
QSO
Strong Lensing
Combined Probes
Cluster Finder
WAZP
Protoclusters Dropouts
Cluster Cosmology
WAZP results analysis
Cluster Comparison


Dashboard
My Workspace
Pipelines
Tools
Data Server
Documentation
Help
>>
DES Science Portal: Wo
The Science Portal has two instances:
Workflows: hosts workflows for
Data Server: provide access to
creation of Value-Added Catalogs (VACs) and for Science Analysis.
The system is designed to be self-evid
The Science Portal is a facility develop
the helpdesk@linea.gov.br
Data Installation
Data Preparation
Science-Ready Catalogs
Science Analysis
Parameter Estimation
Utilities
Special Samples
Examples
Catalog Comparison
Cluster-Cluster Matching
Cluster-Halo Matching
Concatenate Fields
Download Tool
Download Tool
Product Register
Density Systematic Relation
Foreground mask creator (Individual)

Product Log - Matching

Utilities Cluster-Cluster Matching

Process ID: 1874

Process Summary | Results | Comments

Summary | Properties | Completeness and Purity | Centering and Redshift | Most Massive Matches

Info | Catalogs Distribution | Matched (Two Way) Distribution | Matched (Including Multiple) Distribution | Unmatched (Two Way) Distribution | Unmatched (Including Multiple) Distribution | Products

Quick Navigation

- Matching
- Footprints
- External Footprints
- Multiplicity
- Most massive

Matching ?

Component Version	V02_19_00
Matching Code Version	2.10.0

Main Info	Galaxy Clusters 3	Galaxy Clusters 18
Index Label	[1]	[2]
Total Number of Objects Used	81805	85955
Match (including Multiple)	53487	48557
Two Way Match	45194	45194

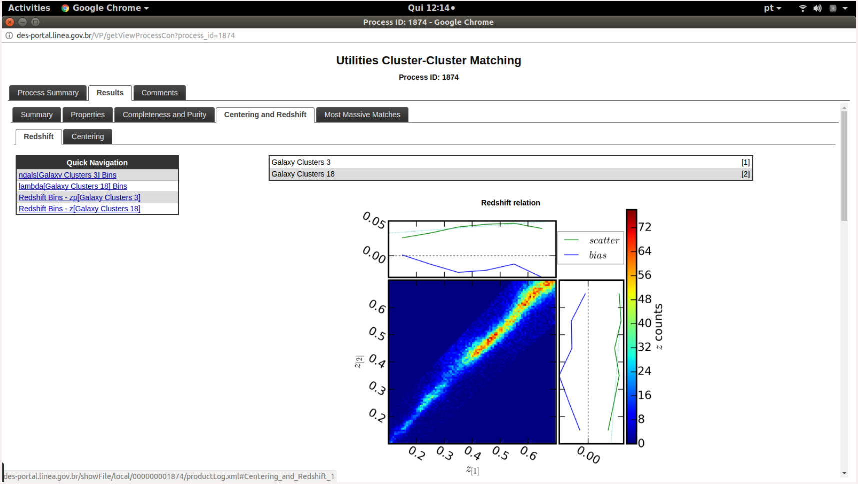
Specific Matching Types	Galaxy Clusters 3	Galaxy Clusters 18
Match (Galaxy Clusters 18 -> Galaxy Clusters 3)	46090	46090
Match (Galaxy Clusters 18 -> Galaxy Clusters 3)(Including Multiple)	52905	48050
Match (Galaxy Clusters 3 -> Galaxy Clusters 18)	46024	46024
Match (Galaxy Clusters 3 -> Galaxy Clusters 18)(Including Multiple)	52063	47992

Footprints ?

Footprint Info	Galaxy Clusters 3	Galaxy Clusters 18
Original Number of Objects in Each Catalog	140899	232400
Objects Cropped by limits	26484	128977
Objects Cropped by Galaxy Clusters 18 Footprint	32596	0
Objects Cropped by Galaxy Clusters 3 Footprint	14	17468
Footprint NSIDE	512 (~ 6.9 arcmin) - External Used [4096 (~ 51.5 arcsec)]	512 (~ 6.9 arcmin)
Footprint area	938.58 deg2 - External Used [1469.16 deg2]	951.16 deg2

des-portal.linea.gov.br/showFile/local/000000001874/productLog.xml#tabAnalysis-2

Product Log - Matching



Science Portal

Dashboard

DES Science Portal Dashboard

Release: Y1A1 Dataset: SPT

Data Instalation

Pipeline	Start	Duration	Runs	Status
QA Coadd	2016-08-24 15:11:57	02:13:45	1	🔴
Install Catalogs	2016-03-08 15:40:13	01:51:56	1	🟢
Install Mangle Mask	2016-06-10 10:21:14	05:49:15	1	🟢
Install Bright Mask	2016-06-10 10:15:36	00:01:07	2	🟢
Install Depth Maps	2016-09-20 15:46:18	01:09:07	2	🟢
Systematic Maps	2016-06-13 12:47:35	12:43:31	2	🟢
Zeropoint Correction	2017-01-18 15:47:17	05:48:03	7	🟢
Coarse Depth Map				⚪
		Total: 29:36:44		

Data Preparation

Pipeline	Start	Duration	Runs	Status
SG Separation	2017-07-06 10:41:39	02:37:33	3	🟢
Spectroscopic Sample	2017-09-14 10:35:29	00:00:26	35	🔴
Training Set Maker	2017-09-14 10:50:47	00:17:25	11	🔴
Photo-z Training	2017-07-12 15:33:23	01:30:13	17	🟢
Photo-z Compute	2017-07-28 18:43:13	03:28:14	21	🟢
Galaxy Properties				⚪
		Total: 7:53:51		

Science-ready Catalogs

Pipeline	Start	Duration	Runs	Status
Cluster	2017-09-11 10:27:48	05:04:02	18	🟢
GE				⚪
GA	2017-05-12 13:37:02	01:35:01	3	🟢
LSS	2017-06-07 16:14:24	02:42:36	3	🟢
Generic				⚪

Special Samples

Pipeline	Start	Duration	Runs	Status
ELG Sample	2017-06-07 10:26:47	00:04:25	2	🟢
RED LSS Sample	2017-06-09 15:59:29	00:06:55	3	🟢
Catalog Association				⚪

Science Workflows

Pipeline	Start	Duration	Runs	Status
ACF GE				⚪
ACF LSS	2017-06-09 11:39:57	02:12:36	1	🟢
StarHorse	2017-05-12 16:12:48	30:05:20	1	🟢
WAZP	2017-09-04 15:18:46	00:39:30	4	🟢

Parameter stimation

Utilities

Pipeline	Start	Duration	Runs	Status
Catalog Comparison	2016-08-05 14:04:35	01:08:43	5	🟢
Cluster-Cluster Matching	2017-06-15 00:27:34	06:00:45	24	🟢
Cluster-Halo Matching	2017-04-18 09:20:56	00:14:51	1	🟢
Concatenate Fields	2017-02-01 23:33:59	00:51:11	4	🟢
Download Tool	2017-09-13 13:02:01	00:00:35	30	🔴
Export Table	2017-08-29 15:03:40	38:34:42	209	🟢

Content

Conclusions

- Galaxy clusters comprise a powerful tool for constraining cosmology.
- It is extremely important to consider the observational effects.
- The proposed functional form for the corrections on the prediction agrees with simulation measurements at medium and high richnesses.
- The pipeline for halos was shown to be operating properly.
- The pipeline for clusters will be operating soon.
- We (DES-Brazil) are producing a `WaZp` catalog for the DES Y1 data in the portal.

Thank You!

Aguena, M. and Lima, M. (2016). Effects of Completeness and Purity on Cluster Dark Energy Constraints. *ArXiv e-prints*.

Arnouts, S., Walcher, C. J., Le Fèvre, O., Zamorani, G., Ilbert, O., Le Brun, V., Pozzetti, L., Bardelli, S., Tresse, L., Zucca, E., Charlot, S., Lamareille, F., McCracken, H. J., Bolzonella, M., Iovino, A., Lonsdale, C., Polletta, M., Surace, J., Bottini, D., Garilli, B., Maccagni, D., Picat, J. P., Scaramella, R., Scodeggio, M., Vettolani, G., Zanichelli, A., Adami, C., Cappi, A., Ciliegi, P., Contini, T., de la Torre, S., Foucaud, S., Franzetti, P., Gavignaud, I., Guzzo, L., Marano, B., Marinoni, C., Mazure, A., Meneux, B., Merighi, R., Paltani, S., Pellò, R., Pollo, A., Radovich, M., Temporin, S., and Vergani, D. (2007). The SWIRE-VVDS-CFHTLS surveys: stellar mass assembly over the last 10 Gyr. Evidence for a major build up of the red sequence between z = 2 and z = 1. *Astronomy and Astrophysics*, 476:137–150.

Bardeen, J. M., Bond, J. R., Kaiser, N., and Szalay, A. S. (1986). The statistics of peaks of Gaussian random fields. *Astrophysical Journal*, 304:15–61.

Baxter, E. J., Rozo, E., Jain, B., Rykoff, E., and Wechsler, R. H. (2016). Constraining the mass-richness relationship of redMaPPer clusters with angular clustering. *Monthly Notices of the Royal Astronomical Society*, 463:205–221.

Behroozi, P., Wechsler, R., and Wu, H.-Y. (2012). Rockstar: Phase-space halo finder. Astrophysics Source Code Library.

Behroozi, P. S., Wechsler, R. H., and Wu, H.-Y. (2013). The ROCKSTAR Phase-space Temporal Halo Finder and the Velocity Offsets of Cluster Cores. *Astrophysical Journal*, 762:109.

Carlstrom, J. E., Holder, G. P., and Reese, E. D. (2002). Cosmology with the Sunyaev-Zel'dovich Effect. *Annual Review of Astronomy and Astrophysics*, 40:643–680.

Clerc, N., Merloni, A., Zhang, Y.-Y., Finoguenov, A., Dwelly, T., Nandra, K., Collins, C., Dawson, K., Kneib, J.-P., Rozo, E., Rykoff, E., Sadibekova, T., Brownstein, J., Lin, Y.-T., Ridl, J., Salvato, M., Schwope, A., Steinmetz, M., Seo, H.-J., and Tinker, J. (2016). SPIDERS: the spectroscopic follow-up of X-ray selected clusters of galaxies in SDSS-IV. *Monthly Notices of the Royal Astronomical Society*, 463:4490–4515.

Cole, S. and Kaiser, N. (1989). Biased clustering in the cold dark matter cosmogony. *Monthly Notices of the Royal Astronomical Society*, 237:1127–1146.

Dietrich, J. P. and Hartlap, J. (2010). Cosmology with the shear-peak statistics. *Monthly Notices of the Royal Astronomical Society*, 402:1049–1058.

Dietrich, J. P., Zhang, Y., Song, J., Davis, C. P., McKay, T. A., Baruah, L., Becker, M., Benoist, C., Busha, M., da Costa, L. A. N., Hao, J., Maia, M. A. G., Miller, C. J., Ogando, R., Romer, A. K., Rozo, E., Rykoff, E., and Wechsler, R. (2014). Orientation bias of optically selected galaxy clusters and its impact on stacked weak-lensing analyses. *Monthly Notices of the Royal Astronomical Society*, 443:1713–1722.

Erickson, B. M. S., Cunha, C. E., and Evrard, A. E. (2011). Influence of projection in cluster cosmology studies. *Physical Review D*, 84(10):103506.

Evrard, A. E., Metzler, C. A., and Navarro, J. F. (1996). Mass Estimates of X-Ray Clusters. *Astrophysical Journal*, 469:494.

Farahi, A., Evrard, A. E., Rozo, E., Rykoff, E. S., and Wechsler, R. H. (2016). Galaxy cluster mass estimation from stacked spectroscopic analysis. *Monthly Notices of the Royal Astronomical Society*, 460:3900–3912.

Farrens, S., Abdalla, F. B., Cypriano, E. S., Sabiu, C., and Blake, C. (2011). Friends-of-friends groups and clusters in the 2SLAQ catalogue. *Monthly Notices of the Royal Astronomical Society*, 417:1402–1416.

Foreman-Mackey, D., Hogg, D. W., Lang, D., and Goodman, J. (2013). emcee: The MCMC Hammer. *PASP*, 125:306–312.

Fosalba, P., Crocce, M., Gaztañaga, E., and Castander, F. J. (2015). The MICE grand challenge lightcone simulation - I. Dark matter clustering. *Monthly Notices of the Royal Astronomical Society*, 448:2987–3000.

Hinshaw, G., Larson, D., Komatsu, E., Spergel, D. N., Bennett, C. L., Dunkley, J., Nolta, M. R., Halpern, M., Hill, R. S., Odegard, N., Page, L., Smith, K. M., Weiland, J. L., Gold, B., Jarosik, N., Kogut, A., Limon, M., Meyer, S. S., Tucker, G. S., Wollack, E., and Wright, E. L. (2013). Nine-year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Cosmological Parameter Results. *Astrophysical Journal Supplement*, 208:19.

Hoffmann, K., Bel, J., and Gaztañaga, E. (2015). Comparing halo bias from abundance and clustering. *Monthly Notices of the Royal Astronomical Society*, 450:1674–1692.

Ilbert, O., Arnouts, S., McCracken, H. J., Bolzonella, M., Bertin, E., Le Fèvre, O., Mellier, Y., Zamorani, G., Pellò, R., Iovino, A., Tresse, L., Le Brun, V., Bottini, D., Garilli, B., Maccagni, D., Picat, J. P., Scaramella, R., Scodeggio, M., Vettolani, G., Zanichelli, A., Adami, C., Bardelli, S., Cappi, A., Charlot, S., Ciliegi, P., Contini, T., Cucciati, O., Foucaud, S., Franzetti, P., Gavignaud, I., Guzzo, L., Marano, B., Marinoni, C., Mazure, A., Meneux, B., Merighi, R., Paltani, S., Pollo, A., Pozzetti, L., Radovich, M., Zucca, E., Bondi, M., Bongiorno, A., Busarello, G., de La Torre, S., Gregorini, L., Lamareille, F., Mathez, G., Merluzzi, P., Ripepi, V., Rizzo, D., and Vergani, D. (2006). Accurate photometric redshifts for the CFHT legacy survey calibrated using the VIMOS VLT deep survey. *Astronomy and Astrophysics*, 457:841–856.

Ilbert, O., Capak, P., Salvato, M., Aussel, H., McCracken, H. J., Sanders, D. B., Scoville, N., Kartaltepe, J., Arnouts, S., Le Floc'h, E., Mobasher, B., Taniguchi, Y., Lamareille, F., Leauthaud, A., Sasaki, S., Thompson, D., Zamojski, M., Zamorani, G., Bardelli, S., Bolzonella, M., Bongiorno, A., Brusa, M., Caputi, K. I., Carollo, C. M., Contini, T., Cook, R., Coppa, G., Cucciati, O., de la Torre, S., de Ravel, L., Franzetti, P., Garilli, B., Hasinger, G., Iovino, A., Kampczyk, P., Kneib, J.-P., Knobel, C., Kovac, K., Le Borgne, J. F., Le Brun, V., Fèvre, O. L., Lilly, S., Looper, D., Maier, C., Mainieri, V., Mellier, Y., Mignoli, M., Murayama, T., Pellò, R., Peng, Y., Pérez-Montero, E., Renzini, A., Ricciardelli, E., Schiminovich, D., Scodeggio, M., Shioya, Y., Silverman, J., Surace, J., Tanaka, M., Tasca, L., Tresse, L., Vergani, D., and Zucca, E. (2009). Cosmos Photometric Redshifts with 30-Bands for 2-deg^2. *Astrophysical Journal*, 690:1236–1249.

Jenkins, A., Frenk, C. S., White, S. D. M., Colberg, J. M., Cole, S., Evrard, A. E., Couchman, H. M. P., and Yoshida, N. (2001). The mass function of dark matter haloes. *Monthly Notices of the Royal Astronomical Society*, 321:372–384.

Kacprzak, T., Kirk, D., Friedrich, O., Amara, A., Refregier, A., Marian, L., Dietrich, J. P., Suchyta, E., Aleksić, J., Bacon, D., Becker, M. R., Bonnett, C., Bridle, S. L., Chang, C., Eifler, T. F., Hartley, W. G., Huff, E. M., Krause, E., MacCrann, N., Melchior, P., Nicola, A., Samuroff, S., Sheldon, E., Troxel, M. A., Weller, J., Zuntz, J., Abbott, T. M. C., Abdalla, F. B., Armstrong, R., Benoit-Lévy, A., Bernstein, G. M., Bernstein, R. A., Bertin, E., Brooks, D., Burke, D. L., Carnero Rosell, A., Carrasco Kind, M., Carretero, J., Castander, F. J., Crocce, M., D'Andrea, C. B., da Costa, L. N., Desai, S., Diehl, H. T., Evrard, A. E., Neto, A. F., Flaugher, B., Fosalba, P., Frieman, J., Gerdes, D. W., Goldstein, D. A., Gruen, D., Gruendl, R. A., Gutierrez, G., Honscheid, K., Jain, B., James, D. J., Jarvis, M., Kuehn, K., Kuropatkin, N., Lahav, O., Lima, M., March, M., Marshall, J. L., Martini, P., Miller, C. J., Miquel, R., Mohr, J. J., Nichol, R. C., Nord, B., Plazas, A. A., Romer, A. K., Roodman, A., Rykoff, E. S., Sanchez, E., Scarpine, V., Schubnell, M., Sevilla-Noarbe, I., Smith, R. C., Soares-Santos, M., Sobreira, F., Swanson, M. E. C., Tarle, G., Thomas, D., Vikram, V., Walker, A. R., Zhang, Y., and DES Collaboration (2016). Cosmology constraints from shear peak statistics in Dark Energy Survey Science Verification data. *Monthly Notices of the Royal Astronomical Society*, 463:3653–3673.

Kaiser, N. (1984). On the spatial correlations of Abell clusters. *Astrophysical Journal Letters*, 284:L9–L12.

Lacasa, F., Lima, M., and Aguena, M. (2016). Super-sample covariance approximations and partial sky coverage. *ArXiv e-prints*.

Lima, M. and Hu, W. (2007). Photometric redshift requirements for self-calibration of cluster dark energy studies. *Physical Review D*, 76(12):123013.

Marian, L., Smith, R. E., Hilbert, S., and Schneider, P. (2012). Optimized detection of shear peaks in weak lensing maps. *Monthly Notices of the Royal Astronomical Society*, 423:1711–1725.

Mazure, A., Adami, C., Pierre, M., Le Fèvre, O., Arnouts, S., Duc, P. A., Ilbert, O., Lebrun, V., Meneux, B., Pacaud, F., Surdej, J., and Valtchanov, I. (2007). Structure detection in the D1 CFHTLS deep field using accurate photometric redshifts: a benchmark. *Astronomy and Astrophysics*, 467:49–62.

Mo, H. J. and White, S. D. M. (1996). An analytic model for the spatial clustering of dark matter haloes. *Monthly Notices of the Royal Astronomical Society*, 282:347–361.

Peel, A., Lin, C.-A., Lanusse, F., Leonard, A., Starck, J.-L., and Kilbinger, M. (2017). Cosmological constraints with weak-lensing peak counts and second-order statistics in a large-field survey. , 599:A79.

Planck Collaboration, Ade, P. A. R., Aghanim, N., Arnaud, M., Ashdown, M., Aumont, J., Baccigalupi, C., Banday, A. J., Barreiro, R. B., Bartlett, J. G., and et al. (2016). Planck 2015 results. XIII. Cosmological parameters. , 594:A13.

Press, W. H. and Schechter, P. (1974). Formation of Galaxies and Clusters of Galaxies by Self-Similar Gravitational Condensation. *Astrophysical Journal*, 187:425–438.

Saro, A., Bocquet, S., Rozo, E., Benson, B. A., Mohr, J., Rykoff, E. S., Soares-Santos, M., Bleem, L., Dodelson, S., Melchior, P., Sobreira, F., Upadhyay, V., Weller, J., Abbott, T., Abdalla, F. B., Allam, S., Armstrong, R., Banerji, M., Bauer, A. H., Bayliss, M., Benoit-Lévy, A., Bernstein, G. M., Bertin, E., Brodwin, M., Brooks, D., Buckley-Geer, E., Burke, D. L., Carlstrom, J. E., Capasso, R., Capozzi, D., Carnero Rosell, A., Carrasco Kind, M., Chiu, I., Covarrubias, R., Crawford, T. M., Crocce, M., D'Andrea, C. B., da Costa, L. N., DePoy, D. L., Desai, S., de Haan, T., Diehl, H. T., Dietrich, J. P., Doel, P., Cunha, C. E., Eifler, T. F., Evrard, A. E., Fausti Neto, A., Fernandez, E., Flaugher, B., Fosalba, P., Frieman, J., Gangkofner, C., Gaztanaga, E., Gerdes, D., Gruen, D., Gruendl, R. A., Gupta, N., Hennig, C., Holzapfel, W. L., Honscheid, K., Jain, B., James, D., Kuehn, K., Kuropatkin, N., Lahav, O., Li, T. S., Lin, H., Maia, M. A. G., March, M., Marshall, J. L., Martini, P., McDonald, M., Miller, C. J., Miquel, R., Nord, B., Ogando, R., Plazas, A. A., Reichardt, C. L., Romer, A. K., Roodman, A., Sako, M., Sanchez, E., Schubnell, M., Sevilla, I., Smith, R. C., Stalder, B., Stark, A. A., Strazzullo, V., Suchyta, E., Swanson, M. E. C., Tarle, G., Thaler, J., Thomas, D., Tucker, D., Vikram, V., von der Linden, A., Walker, A. R., Wechsler, R. H., Wester, W., Zenteno, A., and Ziegler, K. E. (2015). Constraints on the richness-mass relation and the optical-SZE positional offset distribution for SZE-selected clusters. *Monthly Notices of the Royal Astronomical Society*, 454:2305–2319.

Sheth, R. K., Mo, H. J., and Tormen, G. (2001). Ellipsoidal collapse and an improved model for the number and spatial distribution of dark matter haloes. *Monthly Notices of the Royal Astronomical Society*, 323:1–12.

Sheth, R. K. and Tormen, G. (1999). Large-scale bias and the peak background split. *Monthly Notices of the Royal Astronomical Society*, 308:119–126.

Simet, M., McClintock, T., Mandelbaum, R., Rozo, E., Rykoff, E., Sheldon, E., and Wechsler, R. H. (2017). Weak lensing measurement of the mass-richness relation of SDSS redMaPPer clusters. *Monthly Notices of the Royal Astronomical Society*, 466:3103–3118.

Tinker, J., Kravtsov, A. V., Klypin, A., Abazajian, K., Warren, M., Yepes, G., Gottlöber, S., and Holz, D. E. (2008). Toward a Halo Mass Function for Precision Cosmology: The Limits of Universality. *Astrophysical Journal*, 688:709–728.

Tinker, J. L., Robertson, B. E., Kravtsov, A. V., Klypin, A., Warren, M. S., Yepes, G., and Gottlöber, S. (2010). The Large-scale Bias of Dark Matter Halos: Numerical Calibration and Model Tests. *Astrophysical Journal*, 724:878–886.

Vikhlinin, A., Kravtsov, A., Forman, W., Jones, C., Markevitch, M., Murray, S. S., and Van Speybroeck, L. (2006). Chandra Sample of Nearby Relaxed Galaxy Clusters: Mass, Gas Fraction, and Mass-Temperature Relation. *Astrophysical Journal*, 640:691–709.