When Clusters Merge with Massive Halos

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University of Michigan

Sunday, June 27, 2010
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* Halo: a self-bound, quasi-equilibrium structure comprised of multiple, interacting fluids (dark matter, multi-phase baryons, and radiation) formed via gravitational collapse within a cosmic web of random noise.
* **Halo:**
  a self-bound, quasi-equilibrium structure comprised of multiple, interacting fluids (dark matter, multi-phase baryons, and radiation) formed via gravitational collapse within a cosmic web of random noise.

* **Cluster:**
  a redshift-space projection of a massive halo, *and its line-of-sight neighbors*, with the resultant system containing multiple, bright galaxies and other visible components (multi-phase baryons, non-thermal matter, etc.).
meeting topics and issues

**Cosmology**
- Optical,
- Sunyaev-Zel’dovich,
- X-ray surveys

**Astrophysics**
- AGN
- BCG’s
- galaxy evolution
- ICM evolution

**fundamental physics**
- nature of DM, DE, vacuum?
- non-GR gravity?
- non-Gaussian IC’s?
- ...

**astrophysical evolution**
- star, SMBH formation rate?
- IGM, ICM cooling, heating?
- environmental effects?
- ...

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LSS = a hierarchical web of quasi-equilibrium bound structures - halos - that emerge via gravitational amplification from a noise field imposed during an early epoch of inflation.

Halo Model's key enabling ingredients:
- space density (aka, mass function), \( n(M, z) \)
- spatial N-point correlations (e.g., 2-pt bias function), \( b(M, z) \)
- internal halo structure (kinematics, thermodynamics), \( X(r/r_\Delta, M, z) \)
halo model calibration by simulation
web-embedded halos have fuzzy topologies => variety of mass measures

\( c = 9.0 \)  \( \frac{M_{\text{of}}}{M_{\text{so}}} = 1.15 \)

\[ \frac{\rho}{\rho_c} \] vs. \( R \) [Mpc/h]
web-embedded halos have fuzzy topologies => variety of mass measures

web-embedded halos have fuzzy topologies \implies \text{variety of mass measures}

web-embedded halos have fuzzy topologies \(\Rightarrow\) variety of mass measures


is a single mass estimator optimal?

SO(\(\Delta\)) mass offers better match to cylindrical observations

\(-\ \Delta\ vs.\ mean\ matter\ density?\n\sim simple\ mass\ function\n\;virial\ scaling,\ T^{3/2} \sim M^* (1+z)\n\)

\(-\ \Delta\ vs.\ critical\ density?\n\;complex\ mass\ function\n\;virial\ scaling,\ T^{3/2} \sim M^* h(z)\n\)

FOF(\(d\)) has clean nesting properties

\(-\ no\ need\ to\ choose\ center\n\;percolation\ used\ in\ many\ other\ fields\n\)
halo space density calibration by N-body simulations

Tinker et al (2008)

\[ f(\sigma) = A \left( \frac{\sigma}{b} \right)^{-a} + 1 \] \[ e^{-c/\sigma^2} \]

22 N-body simulations with \( N \geq 512^3 \)

- 5% statistical accuracy in counts
- similarity not exact in time (need \( z \)-factors)

see also:
Sheth & Tormen 1999
Reed et al 2000
Jenkins et al 2001
Evrard et al 2002
Hu & Kravtsov 2003
Warren et al 2006
recent MICE (Marenostrum) calibration

* FOF(0.2) masses *

Crocce et al (2009)

~30% increase above log(M)~14.5
recent MICE (Marenostrum) calibration

Crocce et al (2009)

* FOF(0.2) masses *

~30% increase above log(M)~14.5

Copyright 2005. Barcelona Supercomputing Center - BSC
rank halos at fixed redshift, identify mass scale reached at fixed \(dN/dz\) (\# / sq deg / unit z)

\(\text{SO}(200\text{m})\) masses + WMAP5 cosmology

error bars based on Tinker – Jenkins calibrations
sky surface density characteristic mass scales

(rank halos at fixed redshift, identify mass scale reached at fixed dN/dz
(# / sq deg / unit z)

SO(200m) masses + WMAP5 cosmology

error bars based on Tinker – Jenkins calibrations

\[
\log \left( \frac{M_{SSD}(z)}{h^{-1} M_\odot} \right) = \log (M_c) + \log \left[ \frac{z_0^{\alpha}}{z_0^{\alpha} + z_c^{\alpha}} \right] + z_c^{2/3} - z^{2/3}
\]

<table>
<thead>
<tr>
<th>SSD (deg^{-2})</th>
<th>log M_c</th>
<th>z_c</th>
<th>(\alpha)</th>
<th>(\chi^2/\text{dof})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
<td>15.294</td>
<td>0.419</td>
<td>0.882</td>
<td>0.75</td>
</tr>
<tr>
<td>0.01</td>
<td>15.109</td>
<td>0.448</td>
<td>0.957</td>
<td>0.54</td>
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<tr>
<td>0.1</td>
<td>14.878</td>
<td>0.481</td>
<td>1.08</td>
<td>0.44</td>
</tr>
<tr>
<td>1</td>
<td>14.578</td>
<td>0.566</td>
<td>1.25</td>
<td>0.25</td>
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<tr>
<td>10</td>
<td>14.220</td>
<td>0.642</td>
<td>1.57</td>
<td>0.20</td>
</tr>
</tbody>
</table>

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sky surface density characteristic mass : variation with $w$, $\Omega_{DE}$

Green & Evrard 2010, in prep
sky surface density characteristic mass : variation with \( w, \Omega_{\text{DE}} \)

Green & Evrard 2010, in prep
THE COYOTE UNIVERSE III: SIMULATION SUITE AND PRECISION EMULATOR FOR THE NONLINEAR MATTER POWER SPECTRUM

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3 Departments of Physics and Astronomy, University of California, Berkeley, CA 94720
4 Astrophysikalisches Institut Potsdam (AIP), An der Sternwarte 16, D-14482 Potsdam
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6 T-2, Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545

Submitted to the Astrophysical Journal

ABSTRACT

Many of the most exciting questions in astrophysics and cosmology, including the majority of observational probes of dark energy, rely on an understanding of the nonlinear regime of structure formation. In order to fully exploit the information available from this regime and to extract cosmological constraints, accurate theoretical predictions are needed. Currently such predictions can only be obtained from costly, precision numerical simulations. This paper is the third in a series aimed at constructing an accurate calibration of the nonlinear mass power spectrum on Mpc scales for a wide range of currently viable cosmological models, including dark energy. The first two papers addressed the numerical challenges, and the scheme by which an interpolator was built from a carefully chosen set of cosmological models. In this paper we introduce the “Coyote Universe” simulation suite which comprises nearly 1,000 N-body simulations at different force and mass resolutions, spanning 38 wCDM cosmologies. This large simulation suite enables us to construct a prediction scheme, or emulator, for the nonlinear matter power spectrum accurate at the percent level out to \( k \approx 1 \, h \, \text{Mpc}^{-1}\). We describe the construction of the emulator, explain the tests performed to ensure its accuracy, and discuss how the central ideas may be extended to a wider range of cosmological models and applications. A power spectrum emulator code is released publicly as part of this paper.

Subject headings: methods: N-body simulations — cosmology: large-scale structure of universe
calibration or emulation?

Lawrence et al. (2009)

– 21 realizations: 16 Low + 4 Med (PM), 1 High (Gadget) for each model
– fixed 1300 Mpc volume, 11 snapshot outputs per run
calibration or emulation?

non-linear regime: emulated prediction compared to actual N-body model $P(k)$

recover accuracy better than 1% up to $k \sim 0.3 \text{ Mpc}^{-1}$ at $z<1$
calibration or emulation?

Lawrence et al. (2009)

non-linear regime: emulated prediction compared to actual N-body model $P(k)$

recover accuracy better than 1% up to $k \sim 0.3 \text{ Mpc}^{-1}$ at $z<1$

This is the future for mass function and bias estimation.
non-linear regime: emulated prediction compared to actual N-body model $P(k)$

recover accuracy better than 1% up to $k \sim 0.3 \text{ Mpc}^{-1}$ at $z<1$

This is the future for mass function and bias estimation.

What about baryon back-reaction?
galaxies in halos: SDSS HOD analysis
The Halo Occupation Distribution

\[ \langle N(M_h) \rangle = \frac{1}{2} \left[ 1 + \text{erf} \left( \frac{\log M_h - \log M_{\text{min}}}{\sigma_{\log M}} \right) \right] \left[ 1 + \left( \frac{M_h - M_0}{M_1} \right)^\alpha \right], \]

\[ \langle N(M_h) \rangle \]

\[ M_r < -22.0 \]
\[ M_r < -21.5 \]
\[ M_r < -21.0 \]
\[ M_r < -20.6 \]
### Table 3

HOD and Derived Parameters for Luminosity Threshold Samples

<table>
<thead>
<tr>
<th>$M_{\text{max}}^\text{max}$</th>
<th>$\log M_{\text{min}}$</th>
<th>$\sigma_{\log M}$</th>
<th>$\log M_0$</th>
<th>$\log M_1$</th>
<th>$\alpha$</th>
<th>$\log M_1$</th>
<th>$b_g$</th>
<th>$f_{\text{sat}}$</th>
<th>$\chi^2_{\text{dof}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-22.0</td>
<td>14.06 $\pm$ 0.06</td>
<td>0.71 $\pm$ 0.07</td>
<td>13.72 $\pm$ 0.53</td>
<td>14.80 $\pm$ 0.08</td>
<td>1.35 $\pm$ 0.49</td>
<td>14.85 $\pm$ 0.04</td>
<td>2.16 $\pm$ 0.05</td>
<td>0.043 $\pm$ 0.003</td>
<td>1.5</td>
</tr>
<tr>
<td>-21.5</td>
<td>13.38 $\pm$ 0.07</td>
<td>0.69 $\pm$ 0.08</td>
<td>13.35 $\pm$ 0.21</td>
<td>14.20 $\pm$ 0.07</td>
<td>1.09 $\pm$ 0.17</td>
<td>14.29 $\pm$ 0.04</td>
<td>1.07 $\pm$ 0.03</td>
<td>0.094 $\pm$ 0.004</td>
<td>2.3</td>
</tr>
<tr>
<td>-21.0</td>
<td>12.78 $\pm$ 0.10</td>
<td>0.68 $\pm$ 0.15</td>
<td>12.71 $\pm$ 0.26</td>
<td>13.76 $\pm$ 0.05</td>
<td>1.15 $\pm$ 0.06</td>
<td>13.80 $\pm$ 0.03</td>
<td>1.40 $\pm$ 0.03</td>
<td>0.146 $\pm$ 0.007</td>
<td>3.1</td>
</tr>
<tr>
<td>-20.5</td>
<td>12.14 $\pm$ 0.03</td>
<td>0.17 $\pm$ 0.15</td>
<td>11.62 $\pm$ 0.72</td>
<td>13.43 $\pm$ 0.04</td>
<td>1.15 $\pm$ 0.03</td>
<td>13.44 $\pm$ 0.03</td>
<td>1.29 $\pm$ 0.01</td>
<td>0.204 $\pm$ 0.009</td>
<td>2.7</td>
</tr>
<tr>
<td>-20.0</td>
<td>11.83 $\pm$ 0.03</td>
<td>0.25 $\pm$ 0.11</td>
<td>12.35 $\pm$ 0.24</td>
<td>12.98 $\pm$ 0.07</td>
<td>1.00 $\pm$ 0.05</td>
<td>12.98 $\pm$ 0.03</td>
<td>1.20 $\pm$ 0.01</td>
<td>0.218 $\pm$ 0.012</td>
<td>2.1</td>
</tr>
<tr>
<td>-19.5</td>
<td>11.57 $\pm$ 0.04</td>
<td>0.17 $\pm$ 0.13</td>
<td>12.23 $\pm$ 0.17</td>
<td>12.75 $\pm$ 0.07</td>
<td>0.99 $\pm$ 0.04</td>
<td>12.87 $\pm$ 0.03</td>
<td>1.14 $\pm$ 0.01</td>
<td>0.229 $\pm$ 0.010</td>
<td>1.0</td>
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<tr>
<td>-19.0</td>
<td>11.45 $\pm$ 0.04</td>
<td>0.19 $\pm$ 0.13</td>
<td>9.77 $\pm$ 1.41</td>
<td>12.63 $\pm$ 0.04</td>
<td>1.02 $\pm$ 0.02</td>
<td>12.64 $\pm$ 0.04</td>
<td>1.12 $\pm$ 0.01</td>
<td>0.332 $\pm$ 0.014</td>
<td>1.8</td>
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<tr>
<td>-18.5</td>
<td>11.33 $\pm$ 0.07</td>
<td>0.26 $\pm$ 0.21</td>
<td>8.99 $\pm$ 1.33</td>
<td>12.50 $\pm$ 0.04</td>
<td>1.02 $\pm$ 0.03</td>
<td>12.51 $\pm$ 0.04</td>
<td>1.09 $\pm$ 0.01</td>
<td>0.339 $\pm$ 0.015</td>
<td>0.9</td>
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<tr>
<td>-18.0</td>
<td>11.18 $\pm$ 0.04</td>
<td>0.19 $\pm$ 0.17</td>
<td>9.81 $\pm$ 0.62</td>
<td>12.42 $\pm$ 0.05</td>
<td>1.04 $\pm$ 0.04</td>
<td>12.43 $\pm$ 0.05</td>
<td>1.07 $\pm$ 0.01</td>
<td>0.320 $\pm$ 0.022</td>
<td>1.4</td>
</tr>
</tbody>
</table>

**Note.** — See § 2.3 for the HOD parameterization. Halo mass is in units of $h^{-1}M_\odot$. Error bars on the HOD parameters correspond to $1\sigma$, derived from the marginalized distributions. $M_1$, $b_g$ and $f_{\text{sat}}$ are derived parameters from the fits; $M_1$ is the mass scale of a halo that on average host one satellite galaxy above the luminosity threshold, $b_g$ is the large-scale galaxy bias factor, and $f_{\text{sat}}$ is the fraction of satellite galaxies in the sample. For all samples, the number of degrees-of-freedom (dof) is 9 (13 measured $\psi_p$ values plus the number density minus the five fitted parameters).
significant scatter in minimum mass needed to house bright galaxies - what is this telling us?

SDSS counts and clustering constraints on the Halo Occupation Distribution

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SDSS counts and clustering constraints on the Halo Occupation Distribution

Zehavi et al. 2010

significant scatter in minimum mass needed to house bright galaxies - what is this telling us?

slope of satellite number is very close to one
significant scatter in minimum mass needed to house bright galaxies - what is this telling us?

slope of satellite number is very close to one

one percent errors on bias measurement!
passive (red) galaxies dominate groups and clusters

Balogh & McGee 2010

SDSS DR6 analysis
3 different group/cluster catalogs:
   1 X-ray (HIFLUGCS, Reiprich + Boehringer 2002)
passive = red in $r-i$ and $u-g$ colors

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a multivariate Gaussian signal model
massive halo phenomenology: observable signal likelihoods

halo of mass $M$ redshift $z$

optical/lensing sub-mm X-ray

“Astrophysics for Dummies”

1. Dimensional analysis => mean relations are power-laws

2. Central Limit Theorem => deviations are log-normal
For $i^{th}$ signal, $S_i$, the mean behavior of $s_i = \ln(S_i)$ has slope $m_i$ in $\ln M$. For $N$ such signals,

$$\bar{s}(\mu, z) = m(z)\mu + b(z)$$

and the \textit{halo signal likelihood} is

$$p(s | \mu, z) = \frac{1}{(2\pi)^{N/2} |\Psi|^{1/2}} \exp\left[-\frac{1}{2} (s - \bar{s})'\Psi^{-1}(s - \bar{s})\right]$$

with \textit{covariance} of signal deviations

$$\Psi_{ij} = \left\langle (s_i - \bar{s}_i(\mu, z))(s_j - \bar{s}_j(\mu, z)) \right\rangle$$
Consider a \textit{locally} power-law mass function of slope alpha, \( n(M) \sim M^{-\alpha} \)

\[ n(\mu) = A \exp(-\alpha \mu) \quad ; \quad \alpha = \alpha(\mu, z) \]

Convolve this with the signal–mass relation, resulting in the \textit{signal space density}

\[ n(s) = \frac{A \Sigma}{(2\pi)^{(N-1)/2} |\Psi|^{1/2}} \exp \left[ -\frac{1}{2} \left( s' \Psi^{-1} s - \bar{\mu}^2(s) \frac{\Sigma^2}{\Sigma^2} \right) \right] \]

with mean mass

\[ \bar{\mu}(s) = \frac{m' \Psi^{-1} s}{m' \Psi^{-1} m} - \alpha \Sigma^2 \]

and mass variance

\[ \Sigma^2 = \left( m' \Psi^{-1} m \right)^{-1} \]
Consider a locally power-law mass function of slope alpha, $n(M) \sim M^{-\alpha}$

$$n(\mu) = A \exp(-\alpha \mu) ; \quad \alpha = \alpha(\mu, z)$$

Convolve this with the signal–mass relation, resulting in the *signal space density*

$$n(s) = \frac{A \Sigma}{(2\pi)^{(N-1)/2} |\Psi|^{1/2}} \exp\left[-\frac{1}{2} \left( s'\Psi^{-1}s - \frac{\mu^2(s)}{\Sigma^2} \right)\right]$$

with mean mass

$$\bar{\mu}(s) = \frac{m'\Psi^{-1}s}{m'\Psi^{-1}m} - \alpha \Sigma^2$$

and mass variance

$$\Sigma^2 = \left( m'\Psi^{-1}m \right)^{-1}$$

biased low by upscatter of predominant low-mass halos

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Let $r$ be correlation coeff. of $S_1$ and $S_2$ at fixed mass. Select a sample on $S_1$. Then the \{ln(mass), ln(S_2)\} likelihood is Gaussian with covariance

$$\tilde{\Psi} = \begin{bmatrix} \sigma_{21}^2 & \tilde{r}\sigma_{21}\sigma_{\mu 1} \\ \tilde{r}\sigma_{21}\sigma_{\mu 1} & \sigma_{\mu 1}^2 \end{bmatrix}$$

\[ \sigma_{21}^2 = m_2^2 \left( \sigma_{\mu 1}^2 + \sigma_{\mu 2}^2 - 2r\sigma_{\mu 1}\sigma_{\mu 2} \right) \]

\[ \sigma_{\mu i} = \sigma_i / m_i \quad \text{<- mass scatter} \]

\[ \tilde{r} = \frac{\left( \sigma_{\mu 1} / \sigma_{\mu 2} - r \right)}{\sqrt{1 - r^2 + (\sigma_{\mu 1} / \sigma_{\mu 2} - r)^2}} \]

and the $s_2$–mass scaling for $s_1$-binned samples will, in general, be biased

\[ \bar{s}_2(s_1) = m_2 \left( \bar{\mu}(s_1) + \alpha(\bar{\mu}, z) r\sigma_{\mu 1}\sigma_{\mu 2} \right) \]

\[ \frac{d\bar{s}_2}{d\bar{\mu}} = m_2 \left( 1 + (r\sigma_{\mu 1}\sigma_{\mu 2}) \frac{\partial \alpha(\bar{\mu}, z)}{\partial \mu} \right) \]

e.g.,
Rykoff et al 2008
Rozo et al 2009
Millennium Gas Simulations (MGS) support for multivariate Gaussian model

GADGET-2 resimulations of Millennium Sim. volume
- 500 Mpc/h
- 1e9 gas+DM particles
- $m_p(DM) \sim 1.4\times10^{10}$ Msun
- 25 kpc/h softening
- same cosmology as MS

Physical treatments:
- **GO**: gravity only
- **PH**: preheated gas
  - 200 keV-cm$^2$ @z=4

Hartley et al. 2008
Stanek et al. 2010
Short et al. 2010
MGS: covariance of multiple signals at fixed halo mass

preheating

gravity only

Stanek et al. 2010
effective mass scatter using pairs of signals

\[
\Sigma^{-2} = (1 - r^2)^{-1} (\sigma_{\mu_1}^{-2} + \sigma_{\mu_2}^{-2} - 2r\sigma_{\mu_1}^{-1}\sigma_{\mu_2}^{-1}).
\]

**TABLE 6**

**MASS SCATTER AT REDSHIFT ZERO** \(^a\)

<table>
<thead>
<tr>
<th>Cluster Property</th>
<th>(\sigma_{DM})</th>
<th>(T_{sl})</th>
<th>(f_{ICM})</th>
<th>(Y)</th>
<th>(L)</th>
<th>PH</th>
<th>GO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma_{DM})</td>
<td>–</td>
<td>0.12</td>
<td>0.12</td>
<td>0.075</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>(T_{sl})</td>
<td>0.10</td>
<td>–</td>
<td>0.35</td>
<td>0.050</td>
<td>0.26</td>
<td>0.12</td>
<td>0.38</td>
</tr>
<tr>
<td>(f_{ICM})</td>
<td>0.11</td>
<td>0.12</td>
<td>–</td>
<td>0.054</td>
<td>0.21</td>
<td>0.28</td>
<td>0.12</td>
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<tr>
<td>(Y)</td>
<td>0.062</td>
<td>0.069</td>
<td>0.041</td>
<td>–</td>
<td>0.056</td>
<td>0.069</td>
<td>0.075</td>
</tr>
<tr>
<td>(L)</td>
<td>0.090</td>
<td>0.10</td>
<td>0.093</td>
<td>0.066</td>
<td>–</td>
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\(^a\) The redshift zero mass scatter for each pair of signals, with the results from the PH simulation in the lower, left-hand half, and the results from the GO simulation in the upper, right-hand half, as in Figure 11. The mass scatter for the individual signal is listed on the right-hand side of the table.
effective mass scatter using pairs of signals

\[
\Sigma^{-2} = (1 - r^2)^{-1}\left(\sigma_{\mu_1}^{-2} + \sigma_{\mu_2}^{-2} - 2r\sigma_{\mu_1}^{-1}\sigma_{\mu_2}^{-1}\right).
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*The redshift zero mass scatter for each pair of signals, with the results from the PH simulation in the lower, left-hand half, and the results from the GO simulation in the upper, right-hand half, as in Figure 11.*

The mass scatter for the individual signal is listed on the right-hand side of the table.
deviations correlate with formation history

early formed quartile (~400 halos)

late formed quartile (~400 halos)

Stanek et al., in prep
from halos to clusters
DM Mass: $R_{\text{max}}=250$, $R_{\text{res}}=7$, $\text{Cen}=(0.50,0.50,0.50)$, $M_{\text{target}}=1.0 \times 10^{15}$, $M_{\text{lim}}=0$. 

B. Nord & E. Rozo

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DM Mass: $R_{\text{max}}=200$, $\text{Res}=7$, $\text{Cen}=(0.50,0.50,0.50)$, $M_{\text{target}}=1.0 \times 10^5$, $M_{\text{lim}}=0$. 
Quick Halo Sightline (QHS) approach for Monte Carlo cluster production

1. choose target mass and redshift
2. realize halos along line of sight including 2-pt clustering around target
3. dress halos with galaxies (and/or other signals)
4. analyze sky patch

Chen et al., in prep

Sunday, June 27, 2010
Quick Halo Sightline (QHS) approach for Monte Carlo cluster production

1. choose target mass and redshift
2. realize halos along line of sight including 2-pt clustering around target
3. dress halos with galaxies (and/or other signals)
4. analyze sky patch

Chen et al., in prep

Sunday, June 27, 2010
Fisher forecasts + Dark Energy Survey (DES)
value to cosmology from cluster surveys (counts + clustering)

\[
\ln M^\text{bias}(M_{\text{obs}}, z) = \ln M^\text{bias}_0 + a_1 \ln(1 + z) \\
+ a_2 (\ln M_{\text{obs}} - \ln M_{\text{pivot}}) \\
+ \sum_{i=1}^{3} b_i z^i \\
+ \sum_{i=1}^{3} c_i (\ln M_{\text{obs}} - \ln M_{\text{pivot}})^i
\]  

(3)

nuisance:

4 mass bias params

7 mass variance params

PCA analysis of DE figure of merit

Sunday, June 27, 2010
additional improvements from Mobs (observed signal) prior
An NSF/DOE-funded study of dark energy using four techniques
1) Galaxy cluster surveys (with SPT)
2) Galaxy angular power spectrum
3) Weak lensing/cosmic shear
4) SN Ia distances

Two linked, multiband optical surveys
5000 deg$^2$ grizY colors to $\sim$24$^{th}$ mag
Repeated observations of 40 deg$^2$

Development and schedule
Construction: 2007-2011
New 3 deg$^2$ camera (DECam) on Blanco 4m, Cerro Tololo
Data management system at NCSA
Survey Operations: 2012-2016
510 nights of telescope time over 5 years

Josh Frieman, Director
Fermilab, U Illinois, U Chicago, LBNL, U Michigan
CTIO/NOAO, Barcelona, UCL, Cambridge, Edinburgh
C5 Cell installed on the imager for alignment of the focal plane support plate.

Focal plate is painted black to reduce scattered light between CCDs.
Filter Changer Mechanism (FCM)
Shipping to Fermilab May 10th

Michigan filter changer completed May 2010
courtesy B. Flaugher, FNAL
testing read-out electronics

courtesy B. Flaugher, FNAL

Pin-hole camera on MCCDTV

- Using SISPI to take and assemble the images
synthetic input DECam image from N-body + ADDGALs + shapelet simulation

courtesy
H. Lin, FNAL with
M. Busha and R. Wechsler, Stanford

Sunday, June 27, 2010
proposed distributed workflows to support cosmological survey analysis

NSF Cyberinfrastructure SI2 Proposal
Software Infrastructure for Sustained Innovation
“A Cosmic Sky Machine (COSMA) for Astrophysics and Cosmology with Clusters of Galaxies”

August Evrard, University of Michigan
Andrey Kravtsov, University of Chicago
Elena Rasia, University of Michigan
Paul Ricker, University of Illinois
Risa Wechsler, Stanford University and SLAC

Stefano Borgani, dell’Universita di Trieste & INAF, Italy
Luiz DaCosta, Observatorio Nacional, Brazil
Klaus Dolag, Max-Planck-Institut fur Astrophysik
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