Cosmological Constraints from Cluster Mass-to-Galaxy Number Ratio

Jeremy Tinker
Erin Sheldon, Eduardo Rozo
Idit Zehavi, David Weinberg
Risa Wechsler, Ben Koester
Clusters as a Cosmology Tool

- “Largest bound objects”
  - Largest: unbiased relative to universal M/L
  - Bound: we can measure their masses
- Method for measuring $m_m$
  
  
  \[ W_m = \langle M/L \rangle_{cl} \sigma \left( r_{lum} / r_{crit} \right) \]

- Low values of $m_m \sim 0.15-0.2$
  - Are they really unbiased?
The amount of light per halo depends on matter clustering. Lower $m_8$ = lower cluster M/L.

HOD+SDSS =

$\langle M/L_{18} \rangle = 577 \frac{N^m_{m_8=0.95}}{0.3}$

• Red-sequence cluster finder, z<0.3. (Koester et al 2007a,b. 734-330-9074)
• Stack in bins of richness N200.
• Masses from weak lensing (Sheldon et al)
• Instead of M/L, use $M/N$. 

![Graph showing the relationship between $(M/N_{\text{gal}})/(\rho_c/n_{\text{gal}})$ and $N_{200}$]
Both models match $M/N + n_{\text{gal}}$.

- Low $m_m$ has too few satellites.
- High $m_m$ has too many.
- Slope of $N(M)$ helps constrains $m_8$.

$M_r <- 19.5$ sample
Thanks a lot, Sloan. Now I actually have to worry about systematics in my model.

No longer sample variance limited.

- Can we use the HOD as a cosmological tool?
- Primary assumption is that galaxy content (ie, N) depends only on halo mass.
- Test this assumption with clustering stats that probe different $m$.
Does halo occupation depend on environment?

Two $M_r<-19$ models.

Cyan: $P(N|M)$
standard HOD.

Gold: $P(N|M,m)$
galaxy formation less efficient at low densities.
Use voids to test the HOD

These two models produce the same 2-pt clustering.

Large difference in the voids--halo occupation changed from high-m to low-m
• Points: DR4 measurements.
• Blue Curves: HOD predictions.
• Green curves: mHODs
• Luminosity depends only on M, not on halo environment.

Parameters and Priors

- 3 HOD parameters ($M_{\text{sat}}$, $M_{\text{cut}}$, $m_{\text{sat}}$)
  - $m_m$ and $m_8$.
- $n_s=0.96+/-0.02$ and $h_0=0.72+/-0.04$ (~WMAP5 priors).
- Uncertainties in HOD modeling:
  - 5% halo mass function (Tinker et al 08)
  - 5% halo bias function (in prep)
  - 15% scale-dependent bias (in prep)
  - Galaxy concentrations free ($c_{\text{gal}}/c_{\text{halo}}>0.2$)
- Uncertainties in mass-richness relation
  - Eduardo Rozo et al (in prep)
Results

\begin{align*}
\langle N \rangle_M & = \text{best-fit model} \\
\text{MAXBCG} \\
\frac{(M/N) \div (\rho_c/n_{gal})}{\Omega_m = 0.27, \sigma_8 = 0.73, \alpha_{sat} = 0.92}
\end{align*}

\begin{align*}
M_{200, c} [h^{-1} M_\odot] & \\
N_{200} & = 10^1, 10^2, 10^3, 10^4, 10^5 \\
10^{11} & \leq M_{200, c} [h^{-1} M_\odot] \leq 10^{15} \\
\text{DR7} & \\
\text{best-fit model} &
\end{align*}

\begin{align*}
w_p(r_p) [h^{-1} \text{Mpc}] & = 100, 10, 1, 0.1 \\
r_p [h^{-1} \text{Mpc}] & = 10, 1, 0.1
\end{align*}
Parameter Constraints

**Blue**: $1+2m$ contours.

**Green**: make $n_s/h_0$ priors flat over 4-m range.

**Low-$\Omega_m$ limit**: shape of $w_p$.

**Low-$\Omega_\delta$ limit**: shape of $N(M)$. 
Parameter Constraints

**Blue**: 1+2m contours.

**Green**: make $n_s/h_0$ priors flat over 4-m range.

**Low-$\Omega_m$ limit**: shape of $w_p$.

**Low-$\Omega_\Theta$ limit**: shape of $N(M)$.
• Work in progress, but…
  – HOD is a viable tool for cosmology.
  – For measured M/N+\(w_p\), there exists a unique cosmology that fits all data.
  – In good agreement with CMB.

• Miscentering correction for galaxies.
• Use N(R) profiles to constrain \(c_{gal}\).
• Repeat on higher luminosity samples.