High-z Massive Clusters and Alternative Cosmological Models

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Outline

- General idea and technique
- ΛCDM vs. VDE: some results
- Final remarks

The idea

- Using high-z galaxy clusters to constrain cosmology is a recent idea
- For instance:

  Coupled dark energy [Baldi, Pettorino 2010],

  Non gaussianity [Hoyle, Verde, Jimenez 2011],

  Vector dark energy [Carlesi et al. 2011]

...and many more (sorry if I didn't mention your work!)

Current observations

- XMMU J2235.3-2557 ($z = 1.38$, $M = 7.3 \times 10^{14} M_{\odot}$), [Jee et al. 2009]
- SPT-CL J0546-5345 ($z = 1.07$, $M = 7.95 \times 10^{14} M_{\odot}$), [Brodwin et al. 2010]
- SPT-CL J2106-5844 ($z = 1.18$, $M = 1.27 \times 10^{15} M_{\odot}$), [Foley et al. 2011]

The idea

1. Initial gaussian fluctuations

2. Perturbations evolve and collapse

3. Clusters size and number at every z depends on *1.* and *2.*

How to constrain

- Many possible approaches
- Extreme value statistics, monte carlo, number density integration...
- Results agree only qualitatively

Our Approach

Cumulative Mass Functions

- Press-Schechter (1974):

$$N(>M) \propto \nu e^{\frac{\nu^2}{2}}$$

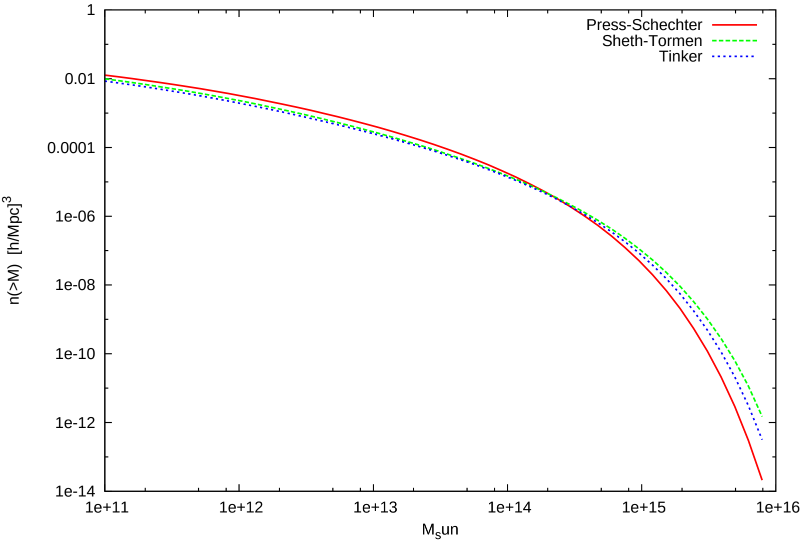
- Sheth-Thormen (1999):

$$N(>M) \propto a\nu(1 + \left(\frac{1}{\nu}\right)^c)e^{\frac{\nu^2}{2}}$$

- Tinker (2008):

$$N(>M) \propto A\nu(1 + \left(\frac{\sigma_M}{b}\right)^c)e^{\frac{-c}{\sigma_M^2}}$$

Mass functions



Our approach

- Compute the cumulative mass function $N(> M)$ at different zs
- Cumulative number density $n(> M, z)$
- Integrate over comoving volume (survey volume): $\int n(> M, z) dV_c(z)$

The VDE Model

The VDE model

- Vector-tensor action [1]:

$$S = \int d^4x\sqrt{-g}\left(-\frac{R}{16\pi G} - \frac{1}{2}\nabla_\mu A_\nu \nabla^\mu A^\nu + \frac{1}{2}R_{\mu\nu}A^\mu A^\nu\right)$$

- G only dimensional scale in the model
- No free parameters
- No potential terms [2]

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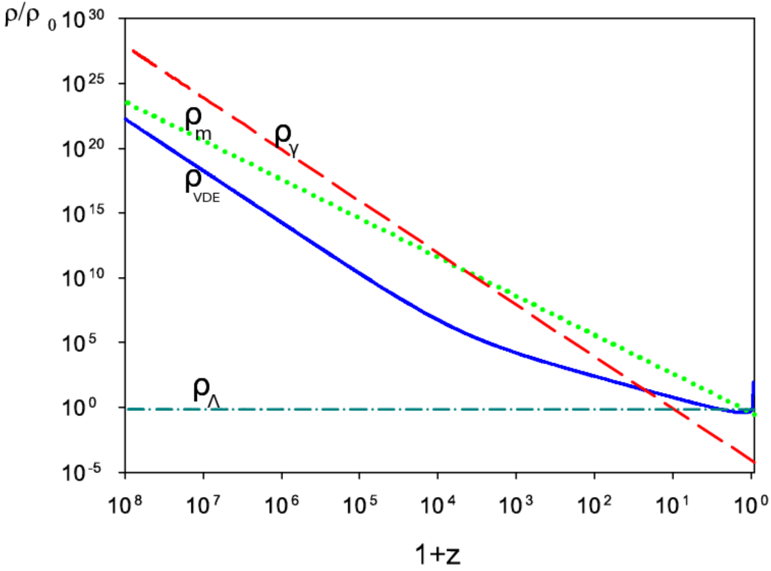
[1] **J.Beltrán, A.L.Maroto, PRD 78, 063005, 2008**
[2] **Kieselev, Armendariz '04; Boehmer, Harko '07; Mota, Koivisto '07**

Energy densities



ΛCDM vs. VDE cosmology

Parameter	VDE	ΛCDM
Ω_M	0.388	0.27
ω_0	-3.53	-1
Ω_{DE}	0.612	0.73
h	0.62	0.7
σ_8	0.83	0.8

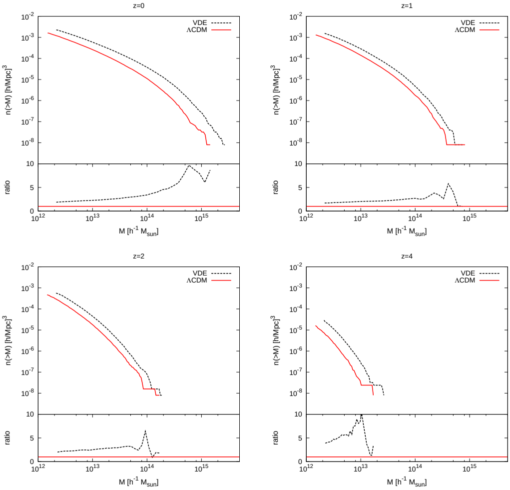
Mass Functions Computation

Free/model dependent parameters $\rightarrow$ Tune the CMF using N-body:

Simulation	N particles	Box Size	$M_{particle}$	Ω_M	σ_8
ΛCDM-1	512^3	500 Mpc h^{-1}	6.95×10^{10}	0.27	0.79
ΛCDM-2	512^3	1000 Mpc h^{-1}	5.55×10^{11}	0.27	0.79
VDE-1	512^3	500 Mpc h^{-1}	1.00×10^{11}	0.38	0.83
VDE-2	512^3	1000 Mpc h^{-1}	8.02×10^{11}	0.38	0.83

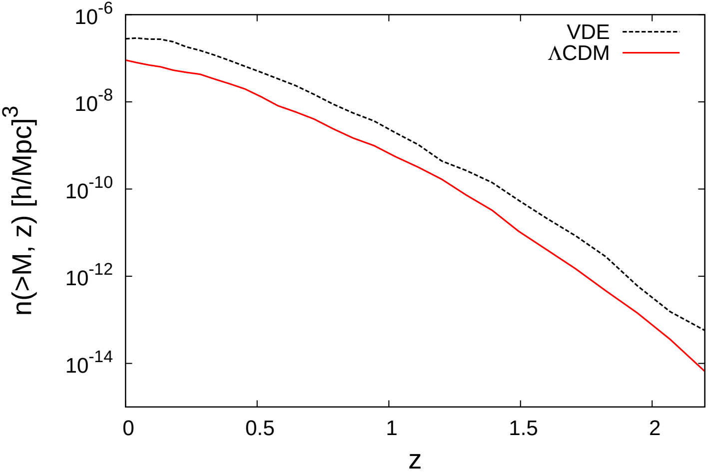
N-bodies mass functions are box-size limited

Cumulative mass function at z=0,1,2,4



Number Density

We use *Sheth-Tormen* to compute $n(> M_0, z)$ ($M_0 = 5 \times 10^{14}$):



Expected number of clusters

- Compute $n(> M_0, z)$ for different M_0s and different models (VDE, ΛCDM)
- Integrate n over comoving volume V_c:

$$dV_c(z) = D_H \frac{(1+z)^2 D_A}{E(z)} d\Omega dz$$

- Obtain expected number of objects $M > M_0$

Results

$M[10^{14} M_{\odot}]$	Δz	$\Omega_{\rm survey}[deg^2]$	$N_{\Lambda \rm CDM}$	$N_{\rm VDE}$
> 10	> 1	2500	0.007	0.02
> 7	> 1	2500	0.03	0.31
> 5	$1.38 - 2.2$	11	0.005	0.06

- Extremely low number expected in ΛCDM
- Probabiliy substantially enhanced in VDE

Conclusions

- Powerful and general method
- Mass function parametrization dependent
- Observational tensions with ΛCDM
- Need for new cosmology?