Upcoming S-Z Surveys

Probing <u>both</u> cosmology and cluster physics

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What's this talk about?

This talk is not only about how much cosmology can we do with SZ surveys. Its about what chance we have in doing cosmology with SZ surveys.
(Upcoming surveys: APEX-SZ, SPT, ACT , Planck)

SZ has strong cosmological dependence. It has dependence on gas physics as well. Question is can we separate the two?

Using *multiple* information we can hope to do *both* at the same time.

The classical dN/dz test

Clusters detected over some flux limit in SZ surveys + The redshifts of the clusters from Optical/IR followup = cluster redshift distribution

(cosmology cluster physics)

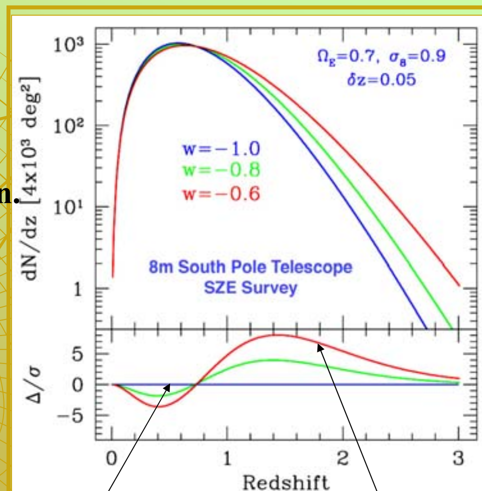
Sensitivity of Cluster Redshift Distribution to Dark Energy Equation of State

dN/dz probes:

1) volume-redshift relation
2) abundance evolution
3) cluster structure & evolution.

Increasing w keeping Ω_E fixed has The following effects:

- **it decreases volume surveyed**
- **It decreases growth rate of density perturbations**

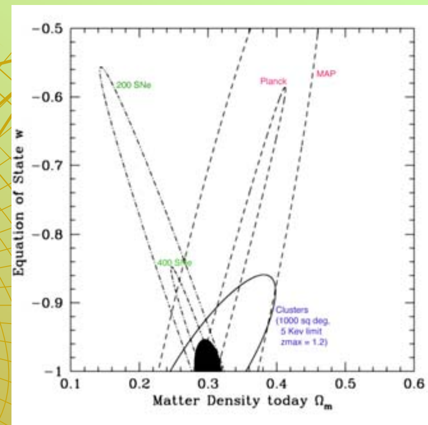


Volume effect Growth Effect

Fig courtesy Joe Mohr

Potential for different methods to constrain `w’

- Large yield cluster surveys are *complimentary* to CMB and Sne constraints on `w’.
- The constraints are *orthogonal.* Rather we *may* have some choices to make the constraints from clusters be orthogonal to those from others.
- The constraints are definitely *competetive* (with clusters alone).
- The best results (1-2 % level) constraint on `w’ can only be achieved if *all are combined*.



from Levine etal, 2002

Cluster Scaling Relations

Tight scaling relations in cluster properties exist both in observations and in hydro simulations of structure formation- clusters can be well modeled theoretically

These scaling relations appear to persist at intermediate redshift in observations and in simulations (even at high z)

Precision cosmology requires mass-observable relationships and models for their evolution that have systematic biases at the 5% - 10% level (or smaller).

Existence of tight scaling relations (10-20% scatter) means halo mass can be predicted with reasonably good accuracy from simple observables. Calibrating mass-observable relationships likely requires multiple mass estimators (i.e. weak lensing, hydrostatic, dynamical.

Problem: No observations agree on scaling relns (say M-T). They don’t agree with theory either !

Self-Calibration in SZ surveys

- **Two surveys, the South Pole Telescope Survey and the Planck all sky survey (yielding > 20,000 clusters), contain enough information to constrain the interesting cosmological parameters and solve for the structure of galaxy clusters simultaneously!**
- **Assumptions required:**
  1. **Hierarchichal structure formation is correct**
  2. **A mass-X-ray luminosity relation exists (or a mass-SZE luminosity relation exists)**
  3. **Crude redshift estimates are available for each cluster detected in the survey**

SM & J. Mohr 2003a

Survey	Ω_m	Ω_{tot}	w	σ_8	h	n	Ω_b	Norm	Slope
Priors		**flat**			**0.07**	**0.050**	**0.004**		
Planck	**0.017**	**-**	**0.075**	**0.013**	**0.053**	**0.041**	**0.004**	**24%**	**~2%**
SPT	**0.024**	**-**	**0.062**	**0.013**	**0.047**	**0.048**	**0.004**	**21%**	**~2%**

$$f_x(z)4\pi d_L^2 = AM^\beta E^2(z)$$

Self-calibrating character of cluster surveys was first shown by Jose Diego et al in an analysis of local cluster data. Levine et al. applied it to large temp limited cluster surveys.

Will *Self-Calibration* survive ?

- **We have assumed the scaling relations to be non-evolving in redshift.**
- **What if they evolve? (for ex:, non-gravitational processes at higher redshifts can modify these relations.)**

If so, then mass estimate of a cluster with a particular flux at redshift z **is less accurate**

$$f_x(z)4\pi d_L^2 = AM^\beta E^2(z)(1+z)^\gamma$$

Net Result : Uncertainties in `w' grow by factor of ~ 3-5

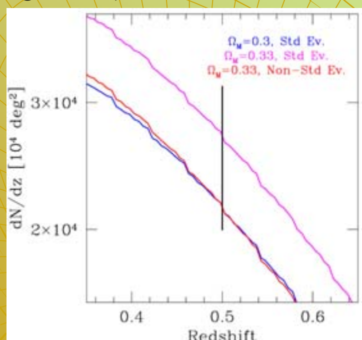
SM & J. Mohr, 2002a

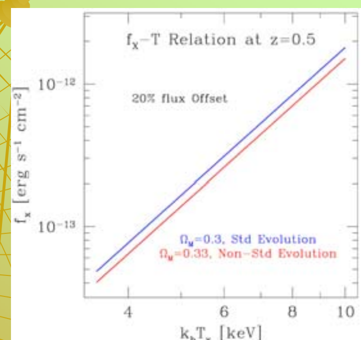
Survey	Ω_m	Ω_{to}	w	σ_8	h	n	Ω_b	Norm	Slope	γ
Priors		**flat**			**0.07**	**0.050**	**0.004**			
SPT	**0.024**	**-**	**0.068**	**0.013**	**0.062**	**0.048**	**0.004**	**21%**	**~1%**	
	0.025	-	0.182	0.019	0.062	0.048	0.004	24%	~1%	55%
Planck	**0.017**	**-**	**0.075**	**0.013**	**0.053**	**0.041**	**0.004**	**24%**	**~2%**	
	0.018	-	0.387	0.015	0.057	0.043	0.004	26%	~2%	50%

Scaling Relations Evolution & Followup

Introducing a non-standard evolution model to offset a change of $\delta\Omega_m$=0.03 leads to a 20% offset in the X-ray flux- temperature (fx-Tx) relationship for the clusters in this z=0.5 redshift bin.

Assuming scatter in Lx-T of 50%, the 200 clusters with measured Tx in this redshift bin would provide enough information to discern this shift with great confidence (~6σ significance).





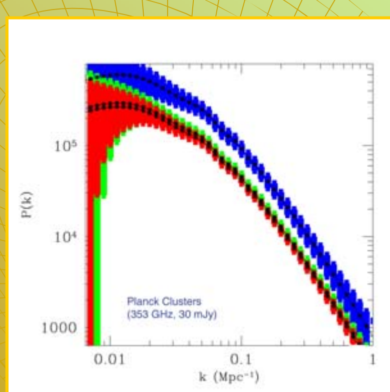
Joe Mohr

A mass followup of **as small as 100 clusters** **from the survey sample, can have *dramatic results.***

Power Spectrum of the Cluster Sample

Power spectrum of dark matter density fluctuations P(k)

- **Clusters are biased: 20,000 clusters comparable to ~2-5x10^5 galaxies**
- **Bias gives a handle on the underlying masses**



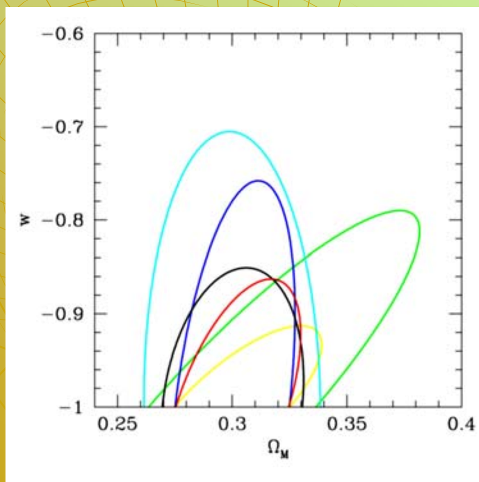
SM & J.Mohr 2003b

From redshift surveys, we will get P(k) *for free* !

Unfortunately, only P(k) gives almost no constraints on `w'. Combined with CMB priors, one can constraint w ~ 25-30%

Things become *interesting* when dn/dz and P(k) are combined.

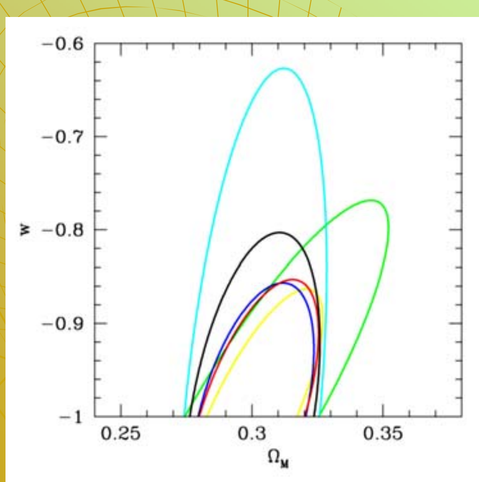
Prospects for SPT Cluster Survey



SM & J Mohr, 2003b

Follow-up helps a lot followed by P(k)

Prospects for Planck Cluster Survey



P(k) helps more than follow-up !

How well do we get `w' ?

1σ error around w=-1, normalized over 9 other parameters

Survey	On its own	+ P(k)	+100 clusters follow-up	+ Both
SPT	0.18	0.16	0.06	0.035
Planck	0.39	0.10	0.12	0.041

Reality:
1)scatter not accounted for
2) w(z) should have been taken
3)very sensitive to flux lims
and ofcourse
4)will we get all the clusters?
……….

And what about cluster physics ?

If we add cosmological information from WMAP/Planck
1σ error around w=-1, normalized over 9 other parameters

	M-T Norm	M-T slope	Evolution
SPT/Planck	~20 %	~ 1-2%	20-50%
SPT/Planck (strong prior on cosmo)	< 10 %	< 1%	~ 10%

This is far better than what targetted observations give us !!

To Conclude

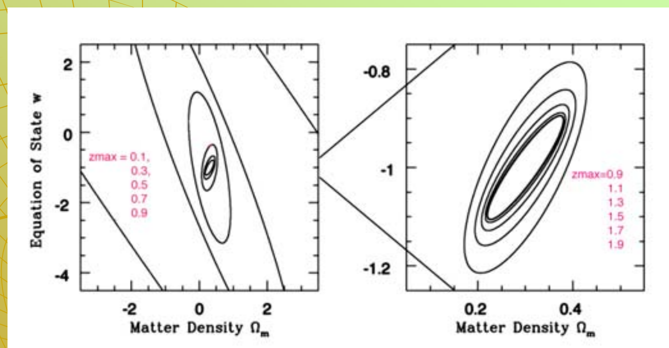
- We must look at both cosmology and cluster physics in tandem if we want to probe either of the two with cluster surveys.
- If we add multiple information from cluster surveys and `some bit of followup', then we can get `impressive' constraints on cluster structure and evolution.
- And ofcourse, we can hope to do `precision' cosmology as well.

Planned Optical and Near-IR Surveys: Photo-z's

- Photometric redshifts
  - Estimate R=V=25 to get photo-z's out to z=1 (80% sample)
  - Require near-IR photometry for accurate photo-z's beyond z=1 (20% sample)
- Survey speeds:
  - 45 dark nights/100deg^2 at 67% efficiency on CTIO 4m w/Mosaic (or 2.5m w/1deg^2 camera)
- Large solid angle surveys planned (PRIME, VST, VISTA and SNAP wide)
  - We are exploring collaborations to ensure that planned, large solid angle surveys cover our SPT survey region

Courtesy : Joe Mohr

Cluster Surveys: Dancing Ellipses



- Punchine : One may be ambitious enough to construct cluster surveys to be most complimentary to CMB & SN