A two component cluster survey as an efficient Cosmological probe

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Surveys dealing with Clusters

(slide courtesy S. Majumdar)

Many Surveys (**ongoing/finished, approved, proposed**)
….. for potential cluster studies:

Red Sequence Cluster Survey
Spitzer adaptation of the RCS
South Pole Telescope
APEX-SZ
Atacama Cosmology Telescope
Blanco Cosmology Survey
Sunyaev-Zeldovich Array
XMM-LSS Serendipitous Survey
XMM-Cluster Survey

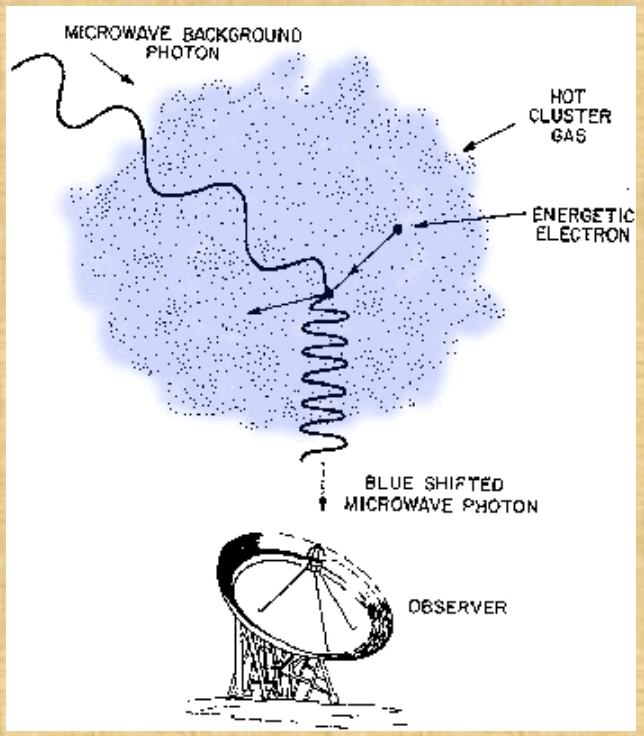
Pan-Starrs
Dark Energy Survey
Large Synoptic Survey Telescope
eROSITA
Planck

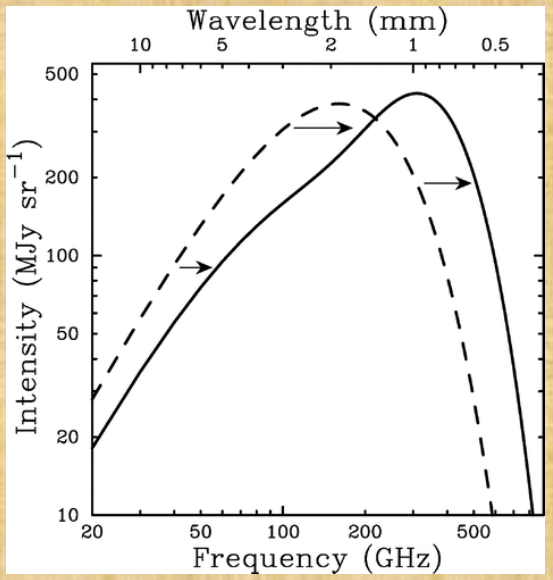
Dark Universe Explorer
Spitzer Legacy Extremely Wide Survey
Cluster Imaging Experiment
Cluster Cosmology Atacama Telescope
Constellation-X
X-Ray Evolving Universe Spectroscopy

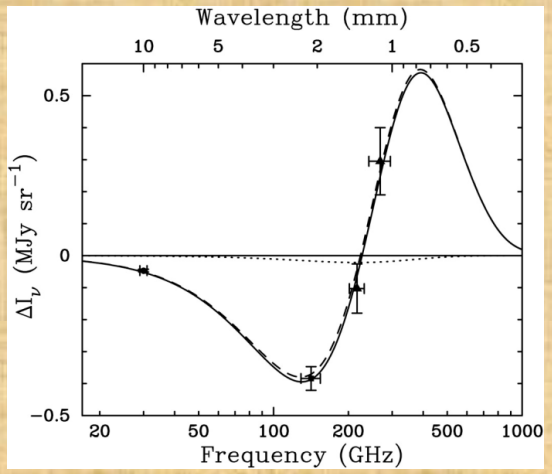
Outline

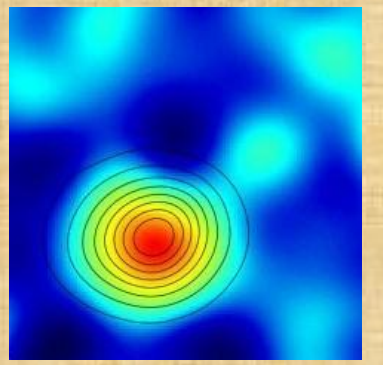
1. Detecting clusters in CMB (SZ effect).
2. Clusters as Cosmological probes.
3. Using Deep + Wide Survey to break degeneracy & tighten cosmological constraints.
4. Results & Conclusion

Observing Clusters in CMB
The Sunyaev Zeldovich Effect









$$\Delta I_{SZE} \propto \int n_e \frac{k_B T_e}{m_e c^2} \sigma_T dl$$

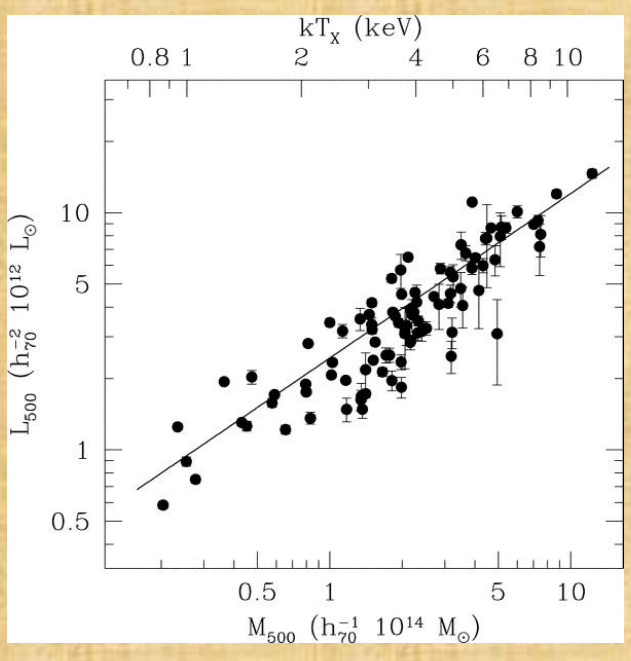
Using cluster number counts as probes of Cosmology

$$\frac{dN}{dz}(z) = \Delta\Omega \frac{dV}{dz d\Omega}(z) \int_{M_{\rm lim}(z)}^{\infty} \frac{dn(M,z)}{dM}$$

need to convert: $M -> observable$.... scaling relation

eg: $\Delta I \sim \frac{A M_{200}^{\alpha} E^{2/3}(z)(1+z)^{\gamma}}{d_A^2(z)}$

Mass observable scatter ?



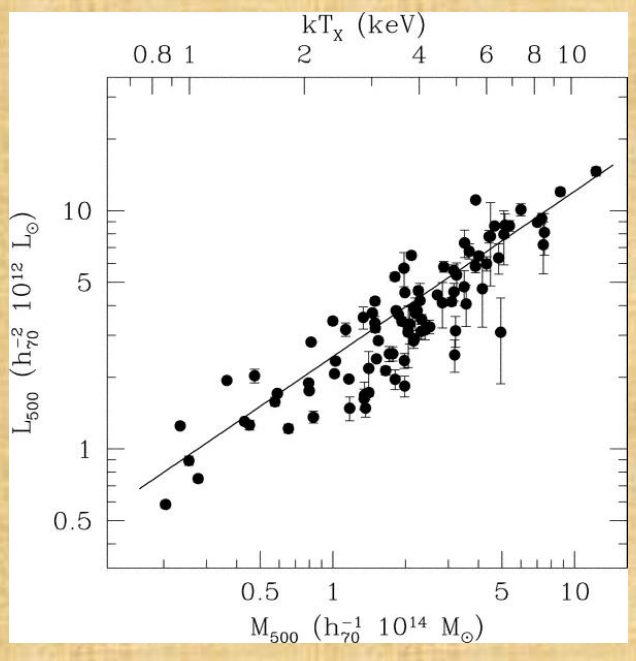
Using cluster number counts as probes of Cosmology

$$\frac{dN}{dz}(z) = \Delta\Omega \frac{dV}{dz d\Omega}(z) \int_0^\infty \frac{dn(M,z)}{dM} f(M,z) dM$$

need to convert: $M -> observable$.... scaling relation

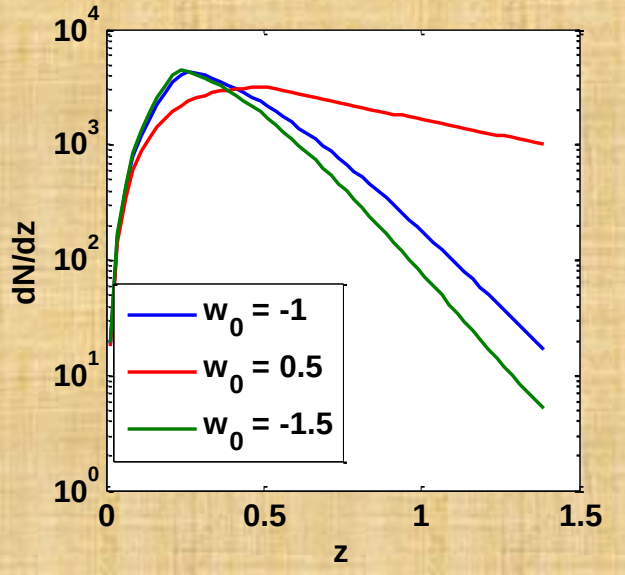
eg: $\Delta I \sim \frac{A M_{200}^{\alpha} E^{2/3}(z)(1+z)^{\gamma}}{d_A^2(z)}$

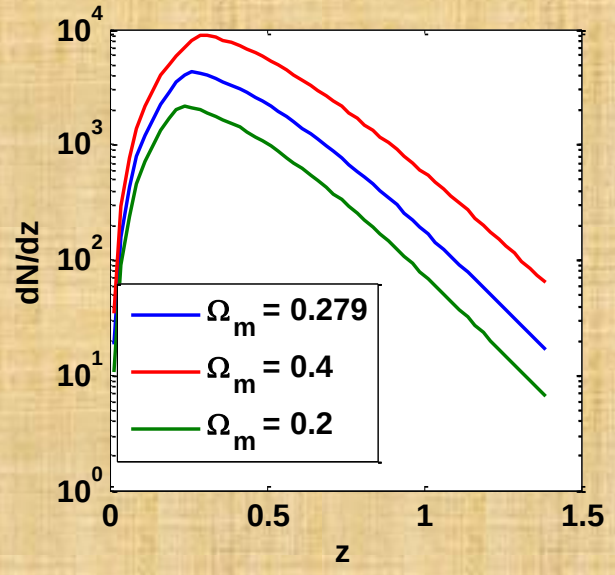
$f(M,z)$ can account for scatter

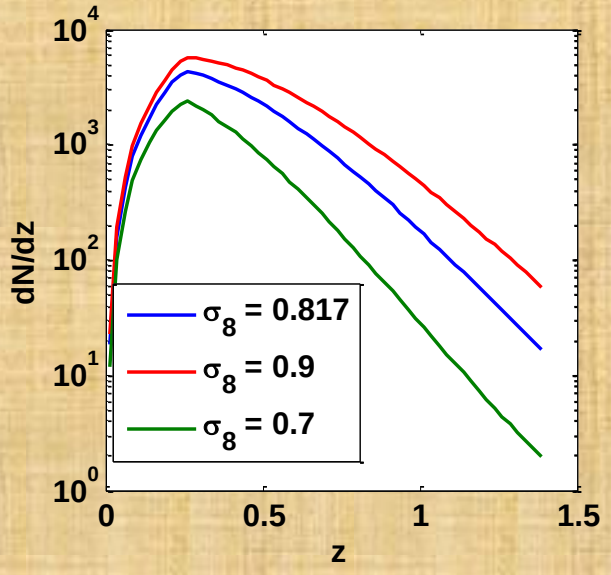


Cosmology with Clusters

1. Sensitive to expansion history & growth of perturbations. Constraints on DE (w).
2. Very sensitive to σ_8 & Ω_m.





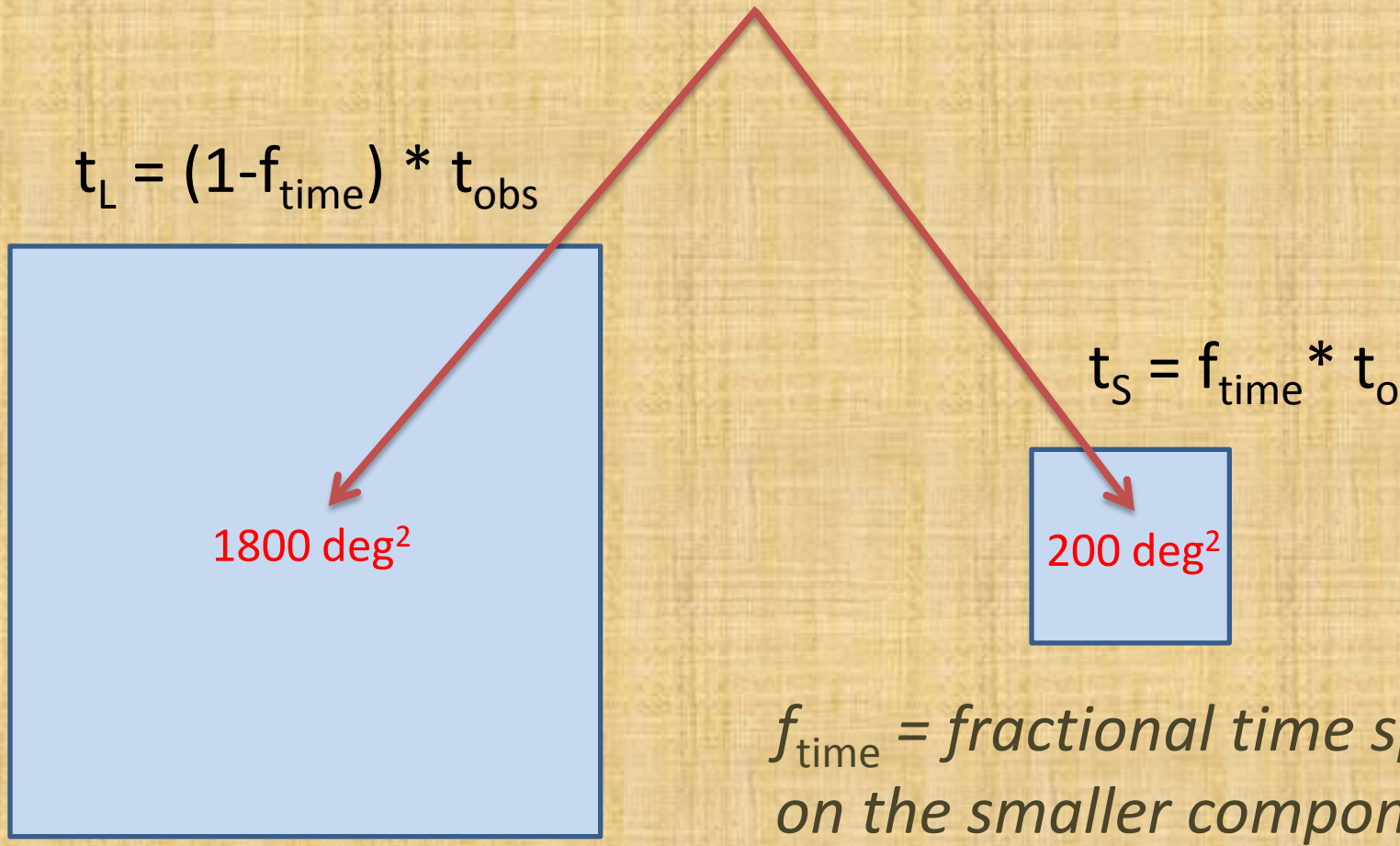


Need for Self-calibration ?

1. Theoretical understanding of cluster physics is not complete, cannot predict values of scaling parameters.
2. Large **degeneracy** between scaling & cosmological parameters; **dilutes** cosmological constraints.
3. Need to break this degeneracy using **extra information** – follow up observations, Clustering information, SZ Power spectrum, etc.
4. We propose a **2-component survey** to **break the degeneracy**.

What is a 2-component survey ?

ACT - 2000 deg^2 survey with t_{obs} ~ 10^7 s



f_{time} = fractional time spent on the smaller component.

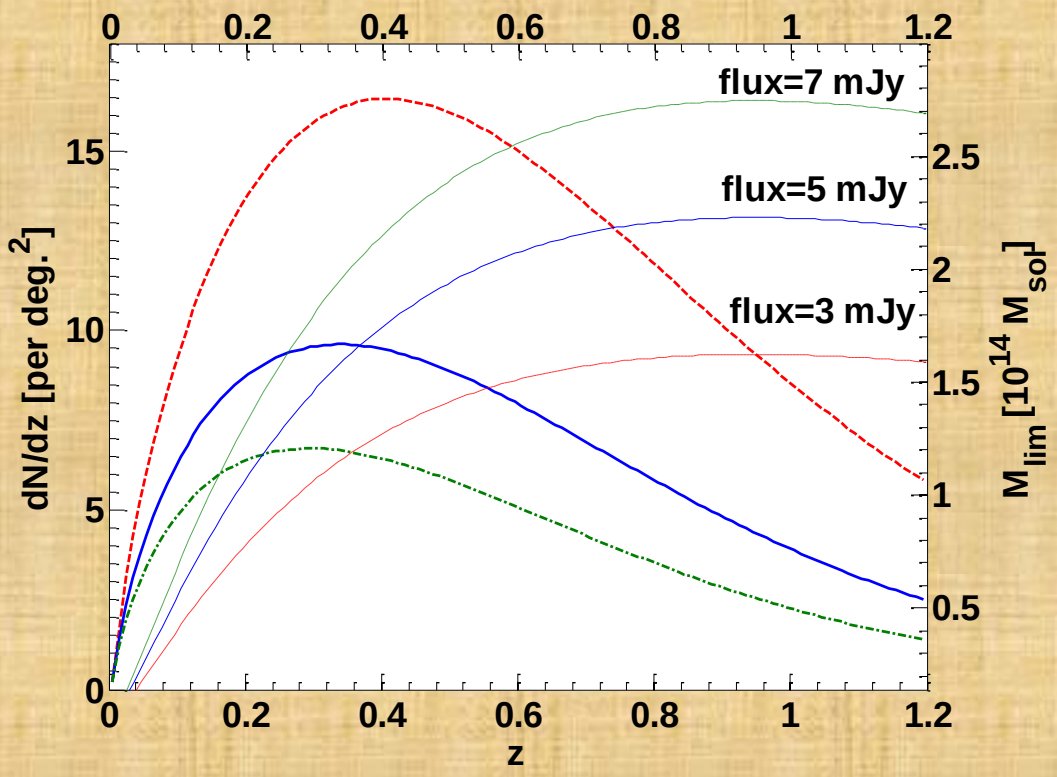
Understanding the flux sensitivity of a survey

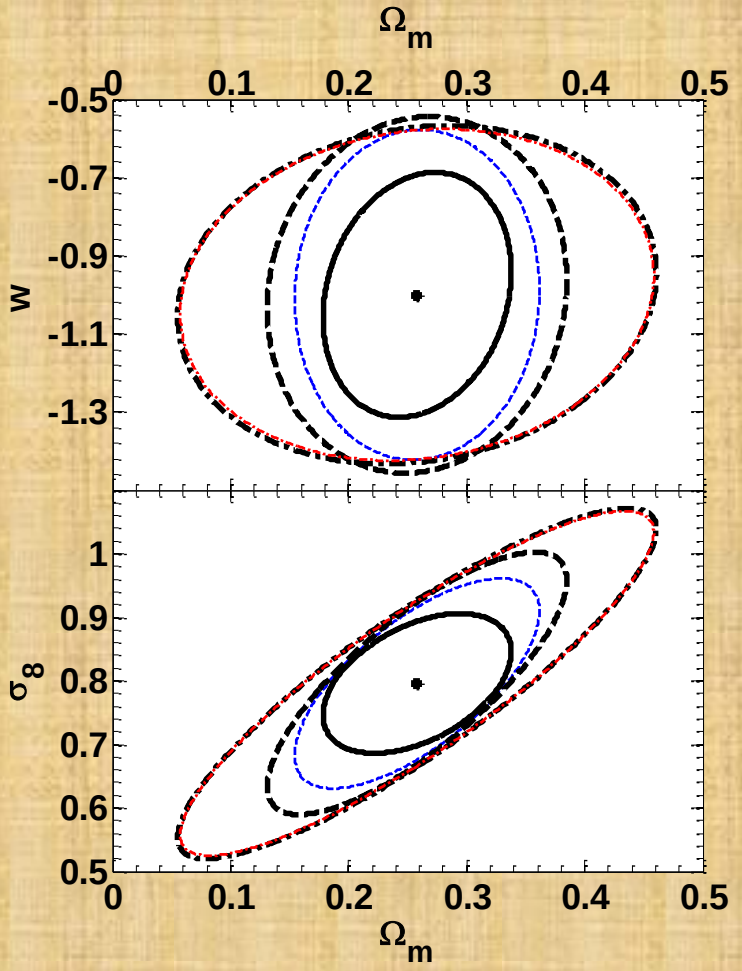
- The flux sensitivity of an SZ survey depends on – f_{sz} , N_{dect} , θ_{fwhm} , NET(σ) , t_{obs}, area
- The limiting flux is given by,

$$\Delta T = \frac{1}{\sqrt{N_{\mathrm{detc}}}} \frac{\sigma}{\sqrt{t_{\mathrm{pix}}}} \qquad t_{\mathrm{pix}} = \frac{t_{\mathrm{obs}}}{\mathrm{area} / \theta^2_{\mathrm{fwhm}}} \qquad \Delta I(\nu, T) = \frac{\delta I(\nu, T)}{\delta T} \Delta T$$

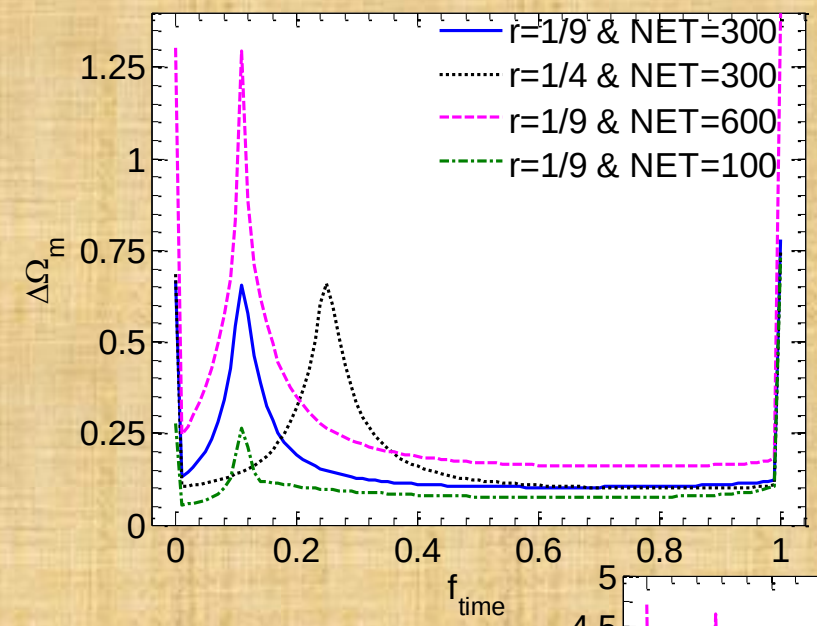
- Scanning a smaller area, for a larger time improves the flux sensitivity,
- Survey becomes ***Deeper !***

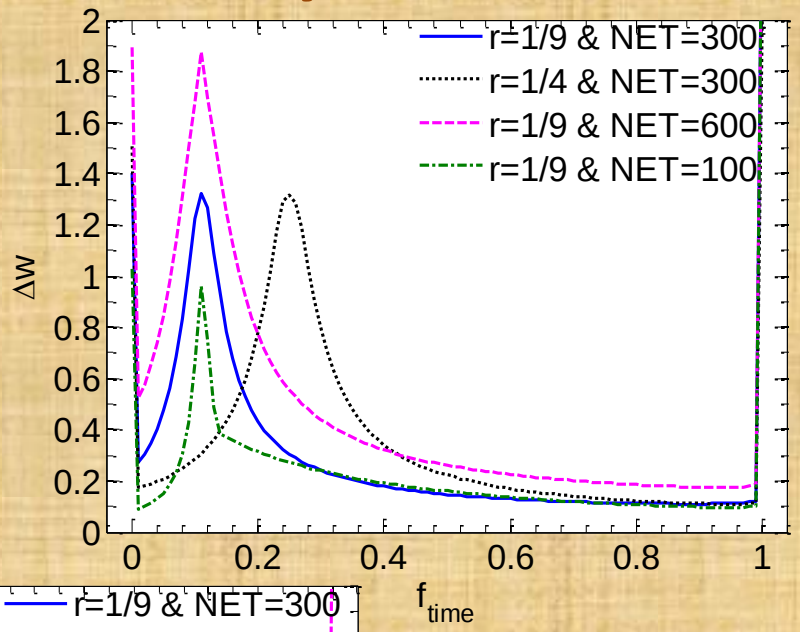
Breaking parameter degeneracy with a 2-component survey

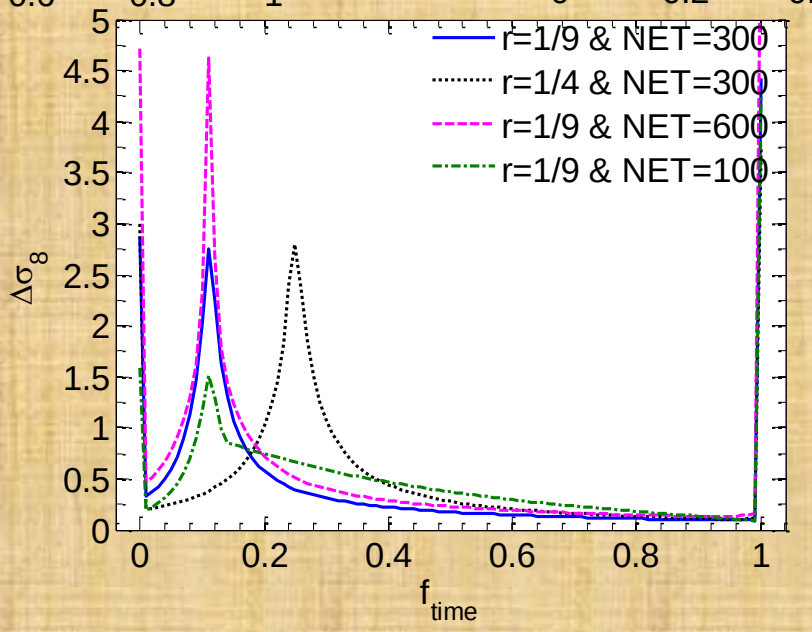




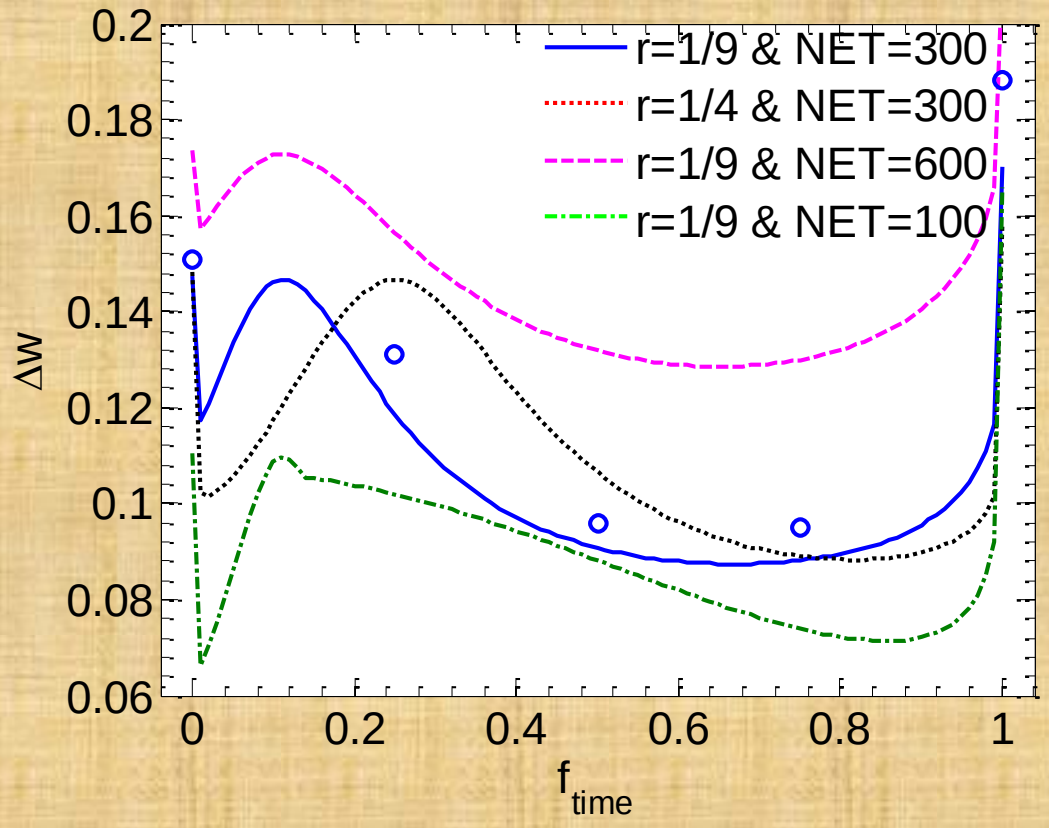
Constraints from only dn/dz

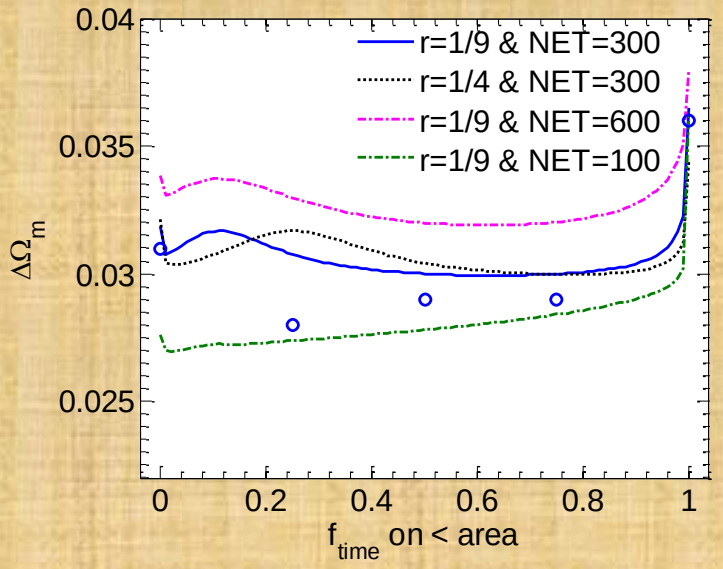


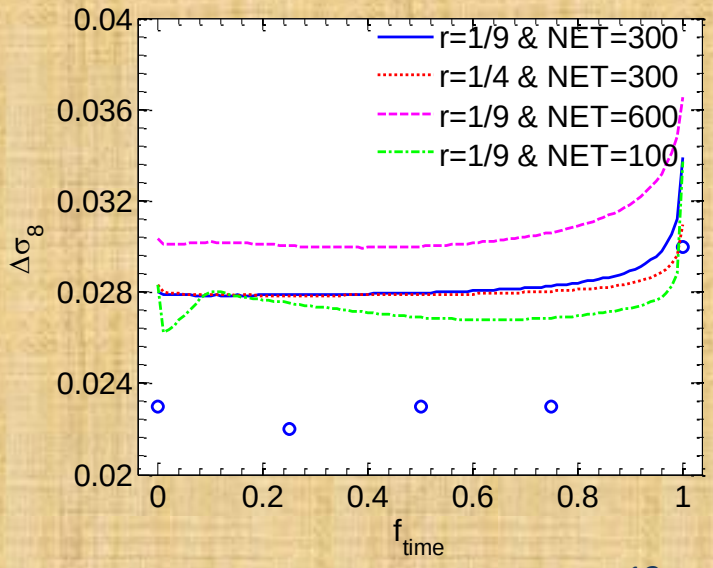




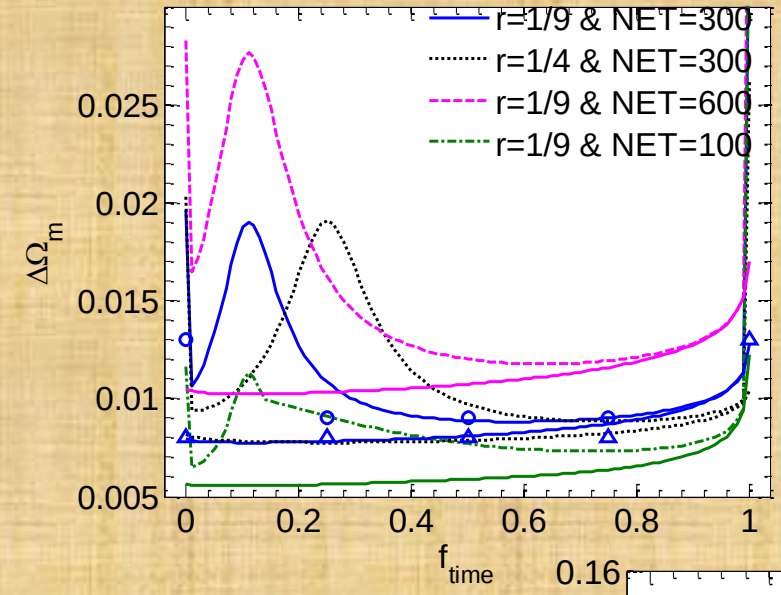
Constraints from dn/dz + followup

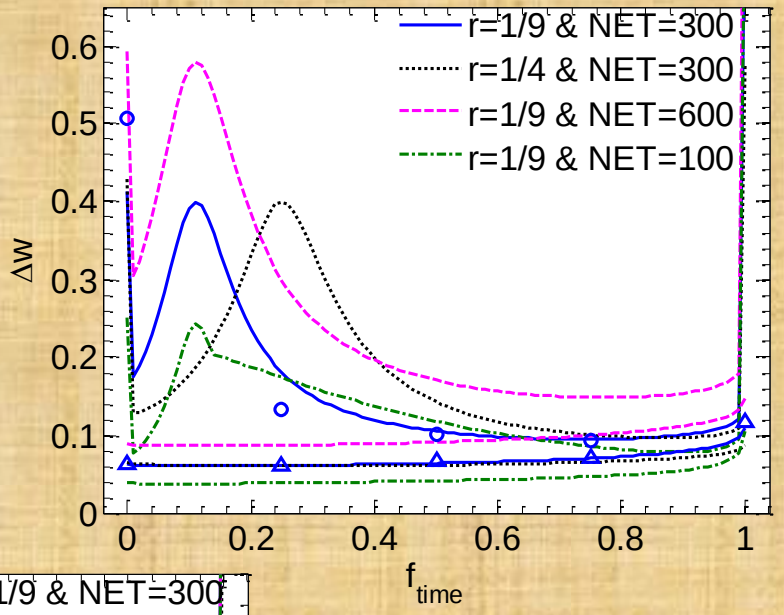


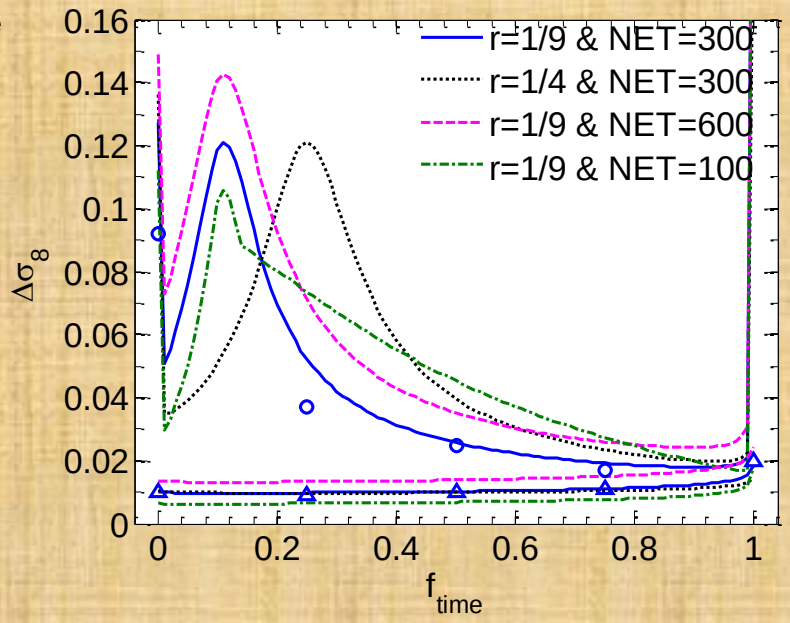




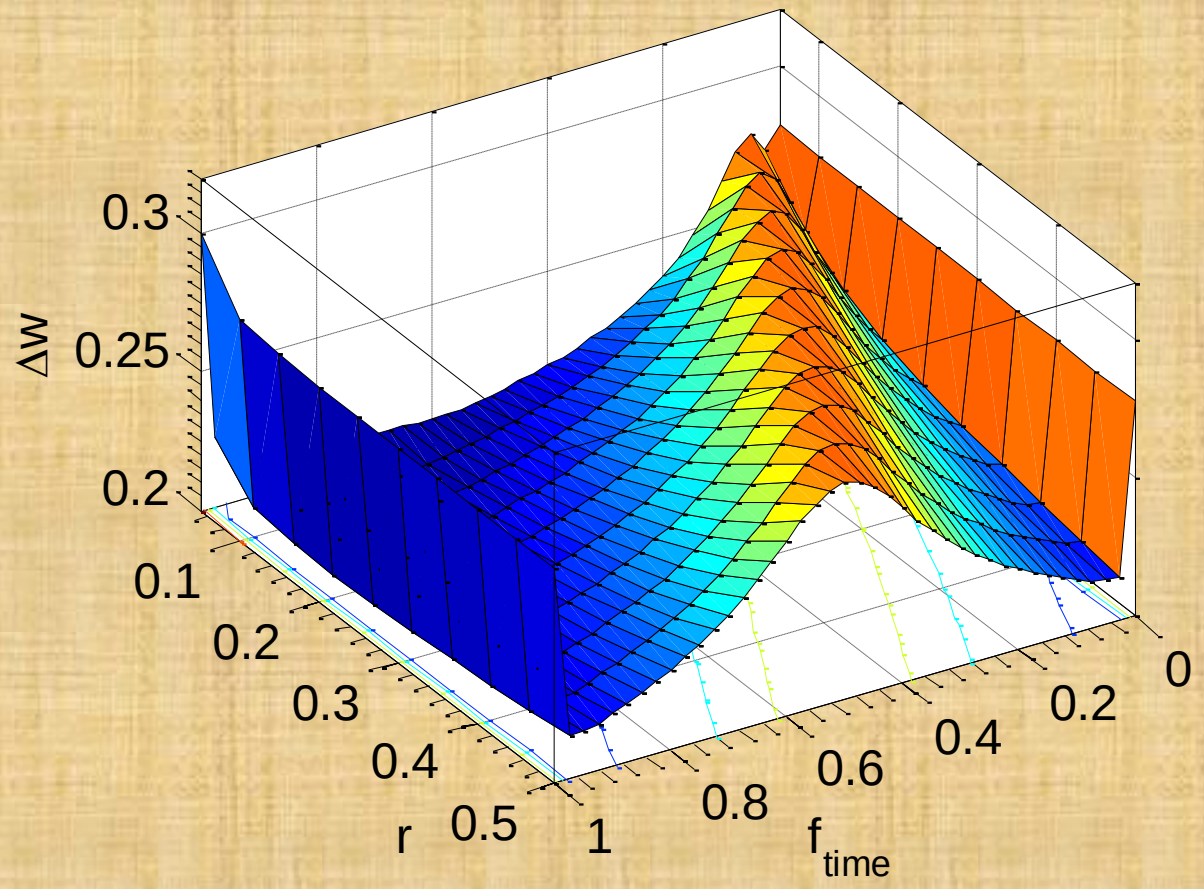
Known Scaling, Unknown Evolution







Varying the ratios of areas



Results

	dn/dz	dn/dz + follow up	2 – comp* dn/dz
Ω_m	0.772	0.032	0.105
w	1.406	0.147	0.115
σ_8	3.311	0.028	0.116
	A, α - fixed	**A, α , γ - fixed**	**2 – comp* A, α - fixed**
Ω_m	0.019	0.008	0.009
w	0.400	0.060	0.095
σ_8	0.121	0.010	0.019

Known Scaling, Unknown Cluster Evolution

* $f_{time} = 0.75$

Conclusions

1. The **degeneracy directions** of a deep and wide survey are very **different**.
2. Having a Deep + Wide survey is very effective at **breaking the degeneracy** between Cosmology and cluster physics.
3. Even with a **low yield**, **tight constraints** may be obtained on Ω_m, w & σ_8 for surveys like the ACT & SPT.
4. Constraints are **comparable** to those from a **follow up** survey.
5. Tight constraints on w even when the cluster Evolution is unknown.
6. ***No Extra observational effort or cost !!***