Constraints on Inflationary Physics and Dark Energy with eROSITA

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What can you do with eROSITA clusters?

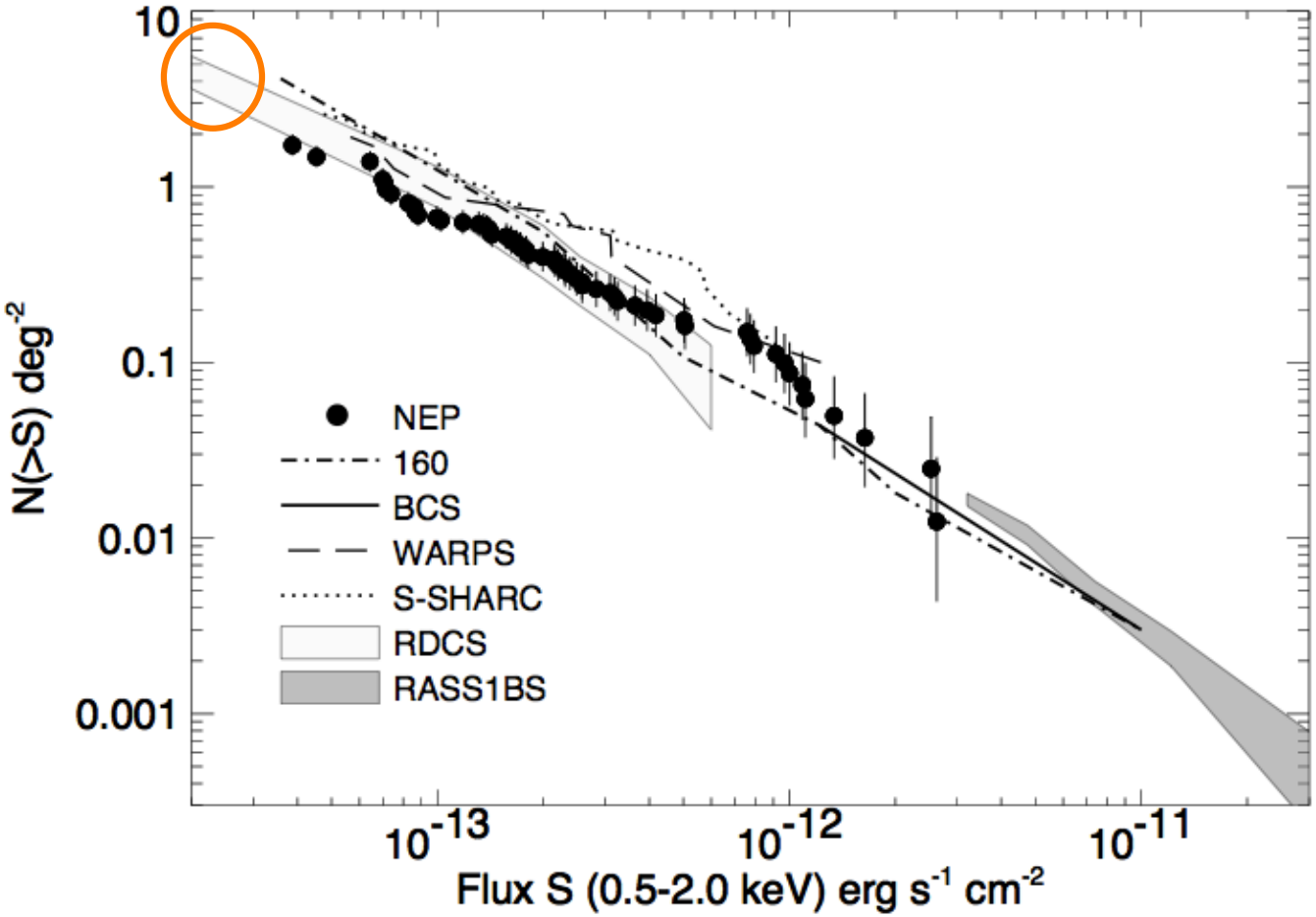
There are so many ways to do cosmology with clusters that we are spoilt with choice :

Cluster counts
2D / **3D P(k)**
BAO bumps
Evolution of cluster scaling reln
Mass/Luminosity function
Cluster gas fraction,
dA(z) from combing Xray & SZ

Each will have its own systematics. But, adding and comparing different approach gives us handle on systematics.
Also, one can simulate them with better and better details. More realistic simulations using Xray data reduction/analysis pipeline (Gus's talk)

What will be the eROSITA yield?

The answer depends on our knowledge of the cluster Xray flux - mass relation and its evolution. Prediction for eROSITA cluster numbers and especially cluster redshift distribution will be model dependent. However, the number will still be large:

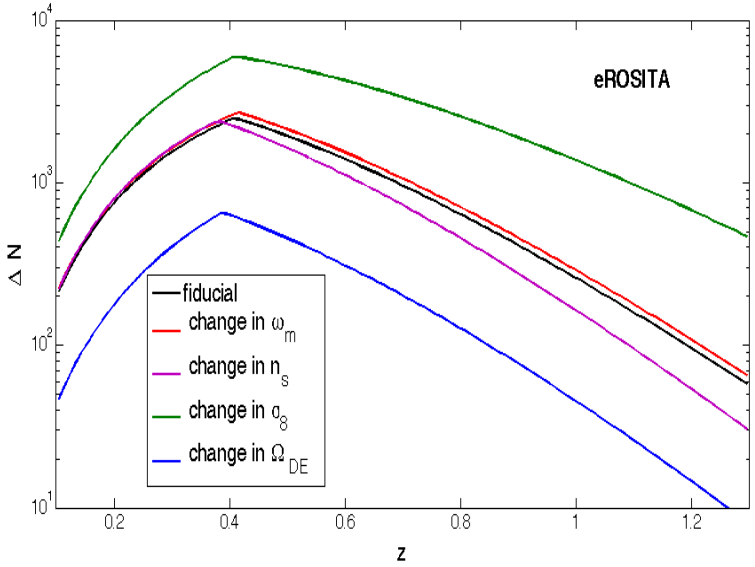


Clusters :
6e4 < N < 1.2e5

Gioia etal 2001

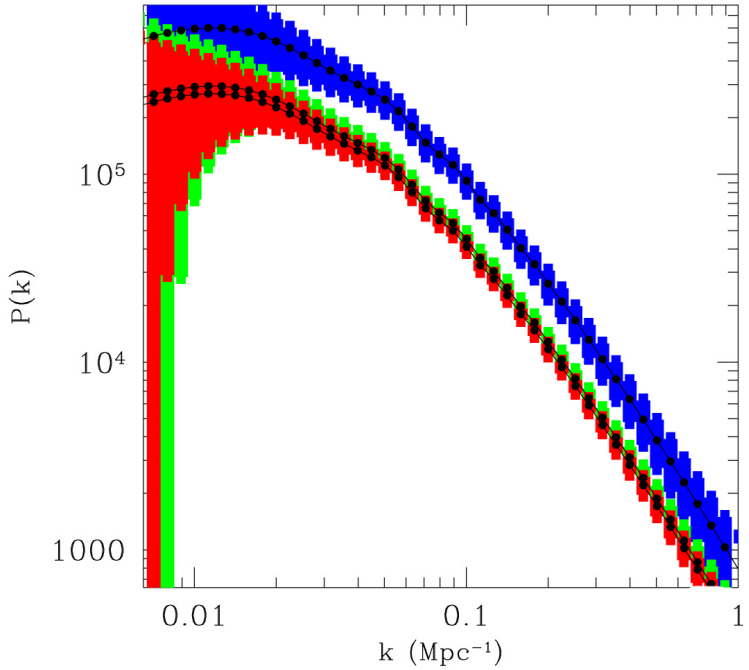
Ingredients 1 - Number Counts and P(k)

The same data (position, redshift) used for dn/dz gives P(k) - no extra obs needed



Number Counts vs redshift
(depends on cosmology)

N = 105,000, 100 photons limit
(details in Han's talk in the morning)



Average P(k) in thick z-bins

Clusters are highly biased ;
1e4 cluster ~ 1-2e5 galaxies

Scaling from Chandra data
Evolution not self-similar **(Vikhlinin 2009, Han's talk)**

Ingredients 2 - External Mass Calibration

External mass follow-up of a sub-sample is crucial for cluster cosmology.

Masses must be 'un-biased' --- These can come from Y_X, M_{gas}, or T. Best proxy should have least scatter.

Of these: M_{gas} can be found Xray flux easily in certain energy range.
It also has the least scatter with total mass (Fabjan 2011, Rasia 2011)

Mass follow-up -- a) fixes the mass-observable scaling reln
b) tests the assumption of form of scaling reln used in self-cal.

For eROSITA, with atleast 20 times more photons counts needed for Xray flux, temperatures can be measure for ~ 1000 clusters (Han's talk, 1000 photons)

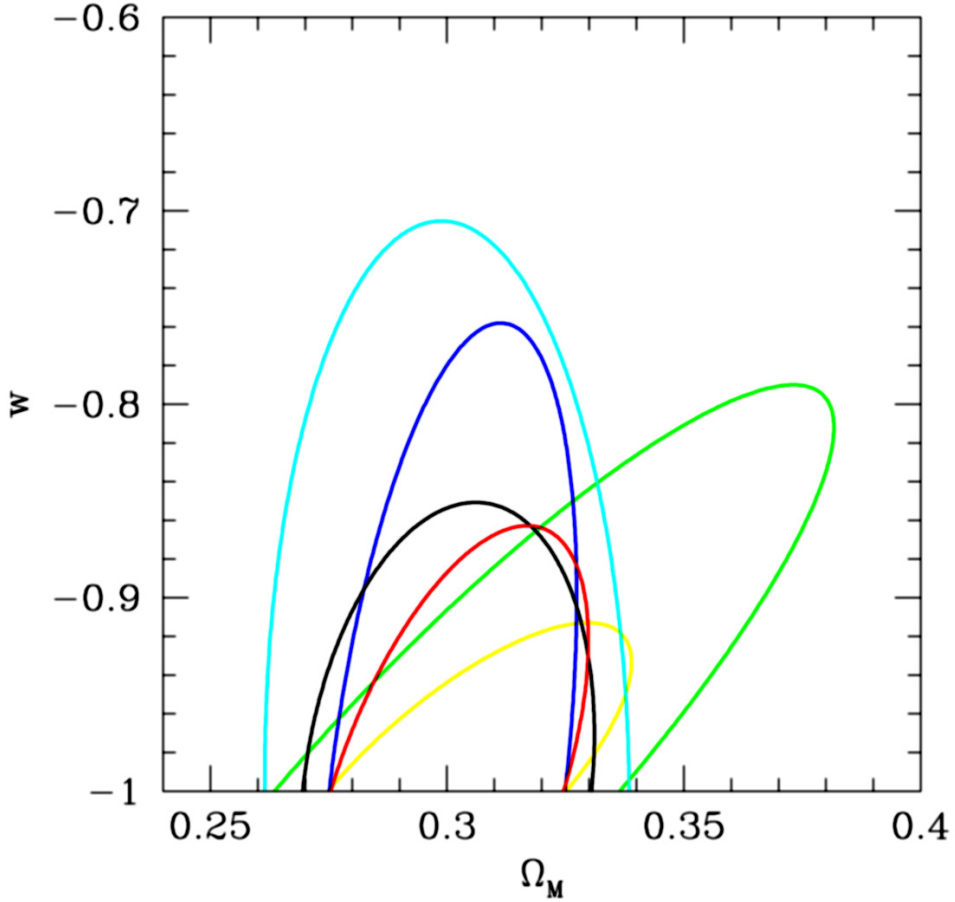
We take to follow-up scenarios :

1) 400 clusters with $\Delta M = 15\%$
2) 200 clusters with $\Delta M = 20\%$

(Note - need $\Delta M \sim 5\%$ for 600 clusters, SPT talk by Joe)

‘Self-calibration’ using Pk (internally calibrate mass)…

(SM & Mohr 2003,2004; Hu 2003, Lima & Hu 2005, Gladders etal 2007)



Example - A wide area survey with many tens of thousands of clusters.

Total Parameters : 11-13

Cosmology : 7 - 9

Cluster : 3-4

(normalization, slope, evolution,scatter)

For self-calibration to be powerful, need Pk to be well determined --- need

1) large volume (20000 sq-deg)
2) large numbers (1e5 clusters)

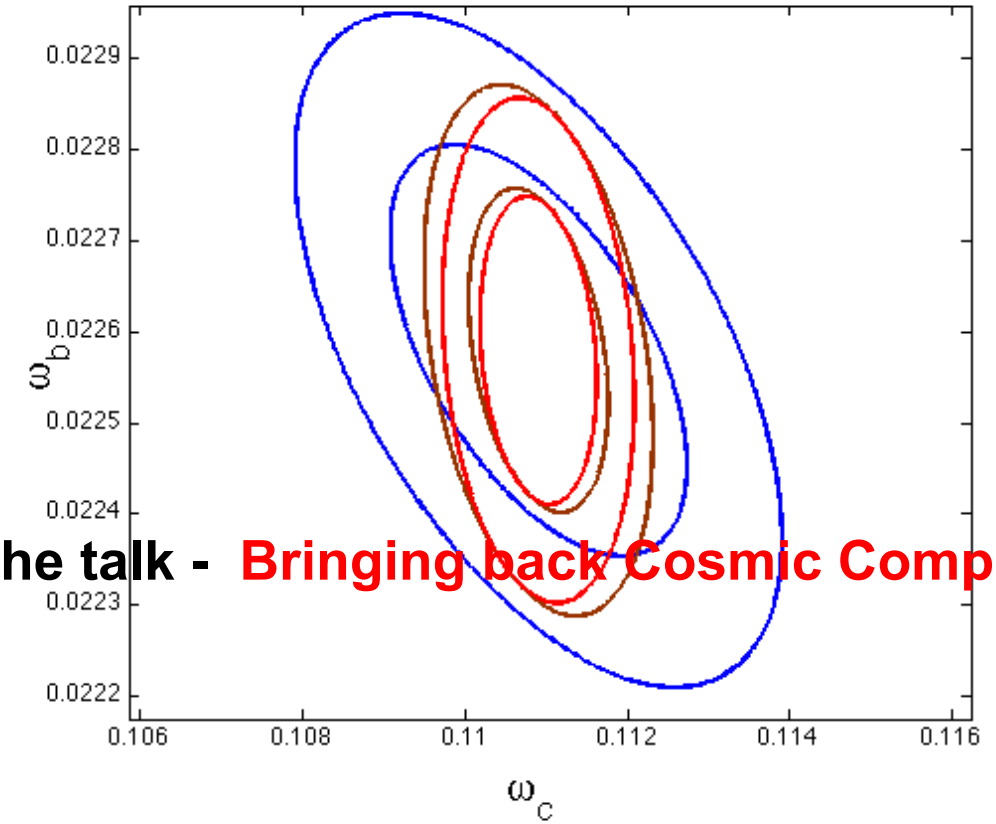
eROSITA has both!

Revival of full power of Self-Calibration

eROSITA helps tighten constraints from Planck…

Planck is the built for precision cosmology and it is hard to compete with its power to constrain cosmological parameters.

Adding eROSITA still helps a lot !

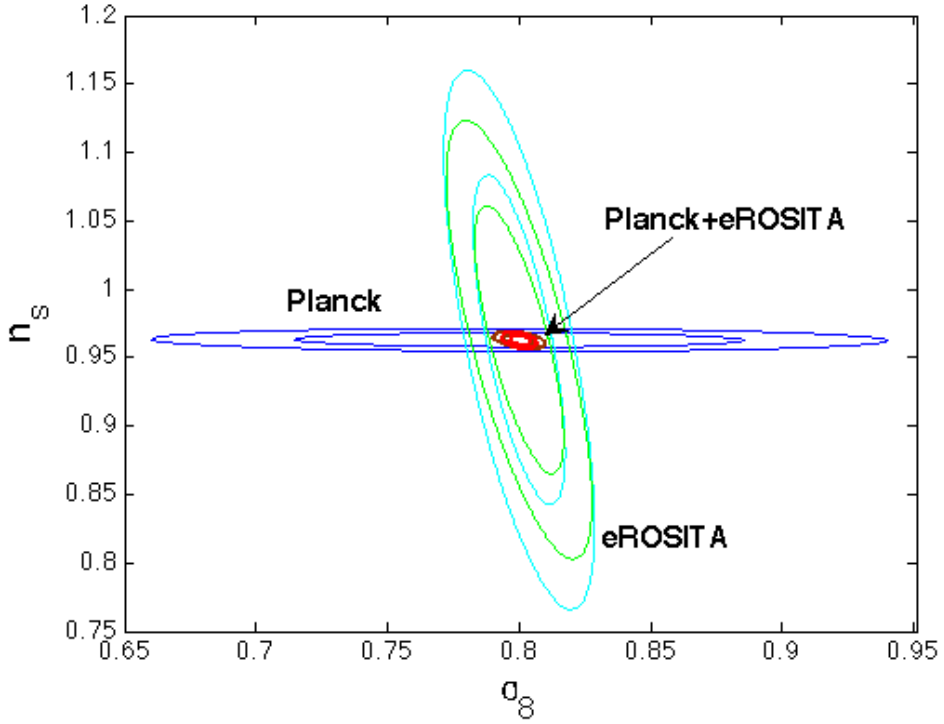


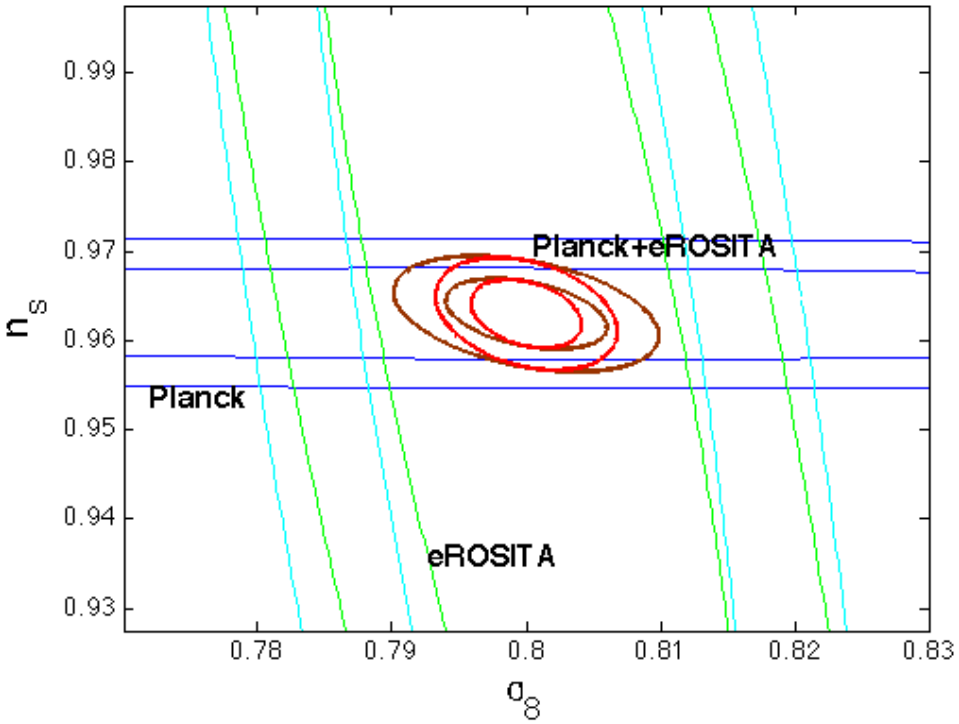
Improvement by factor of 1.5

Rest of the talk - Bringing back Cosmic Complimentarity

Improvement by factor of 2.5

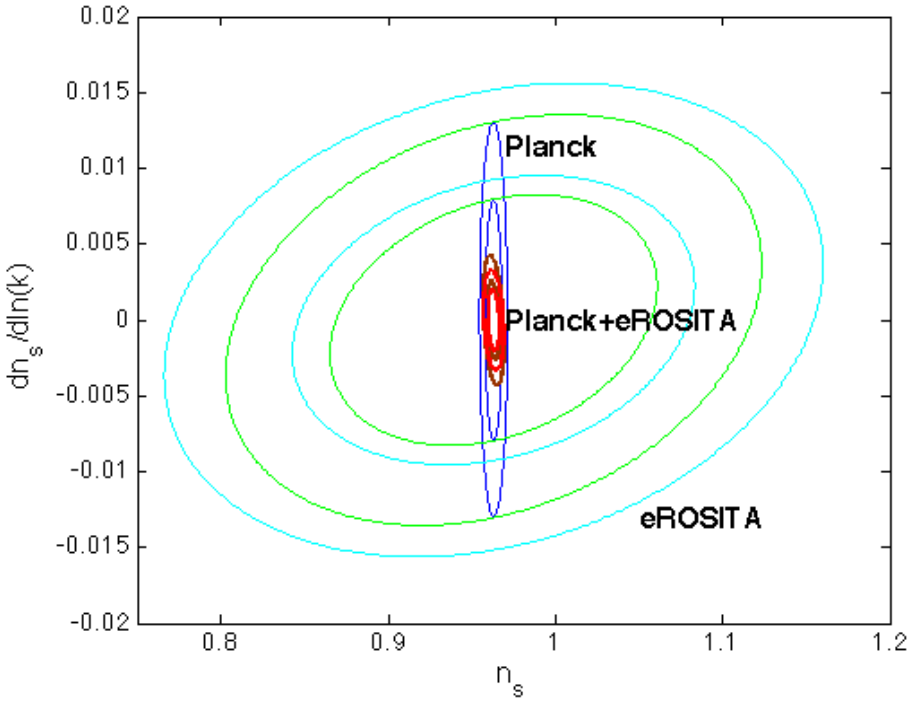
Constraints of parameters linked to Inflation - 1

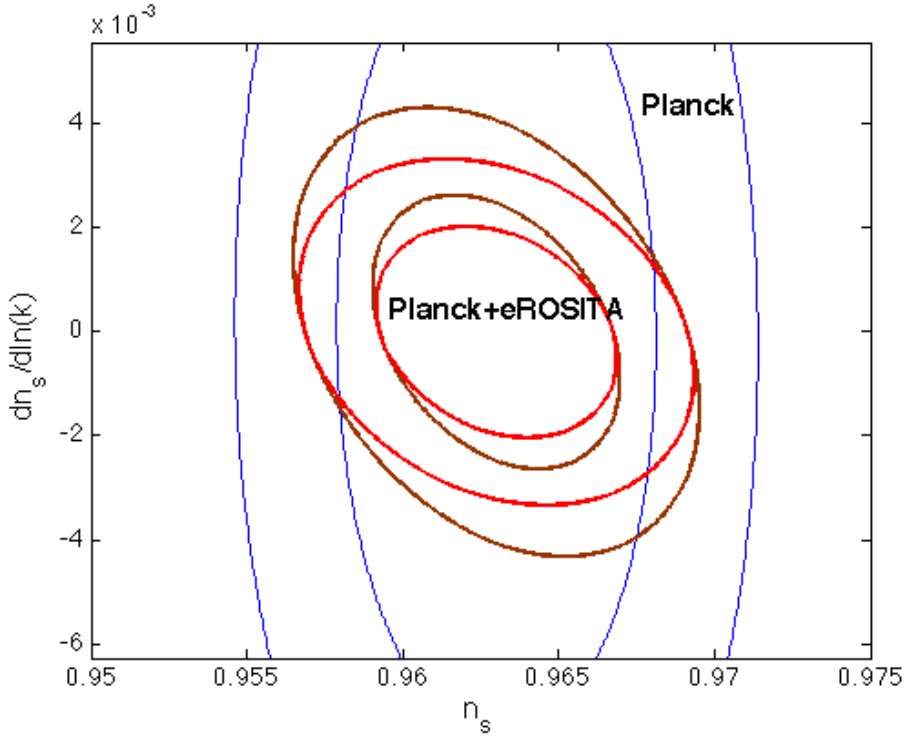




~ 30% improvement in n_s
~ order of magnitude improvement in σ_8

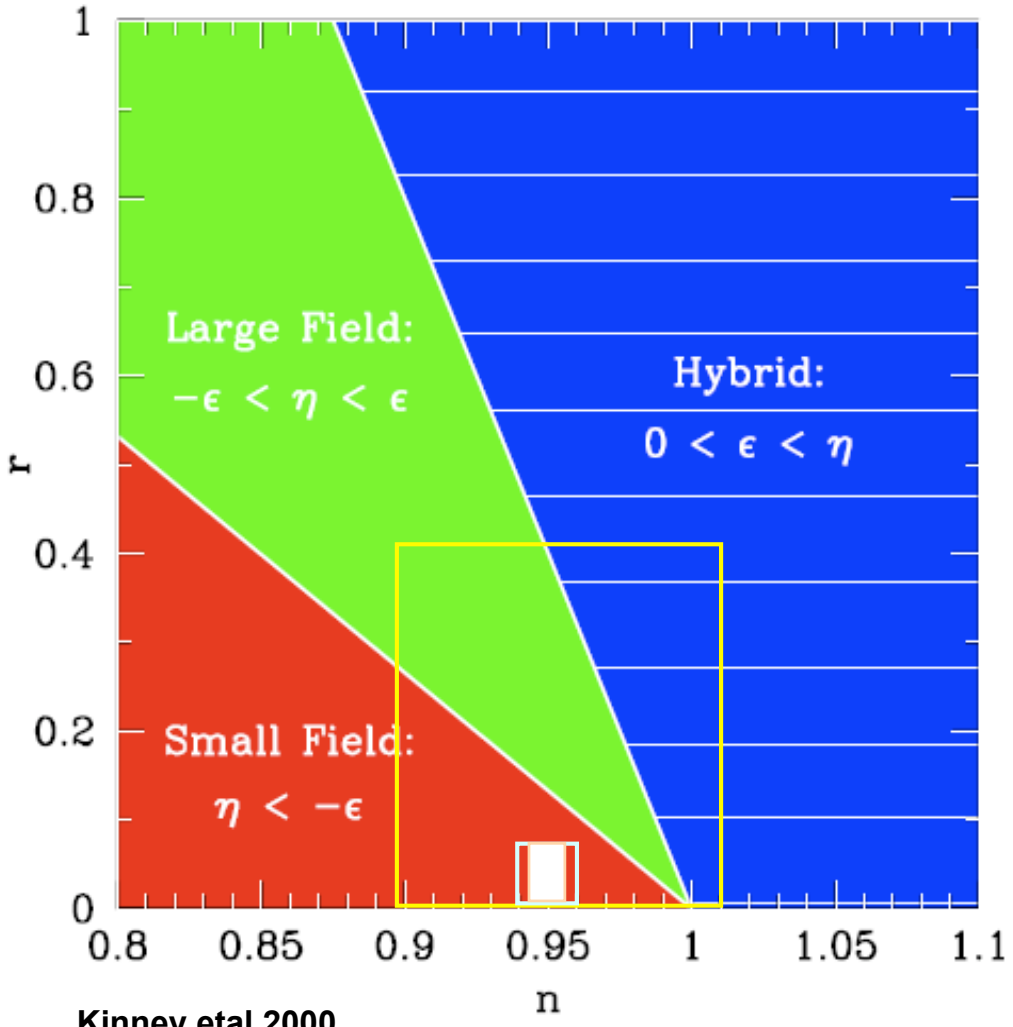
Constraints of parameters linked to Inflation - 2



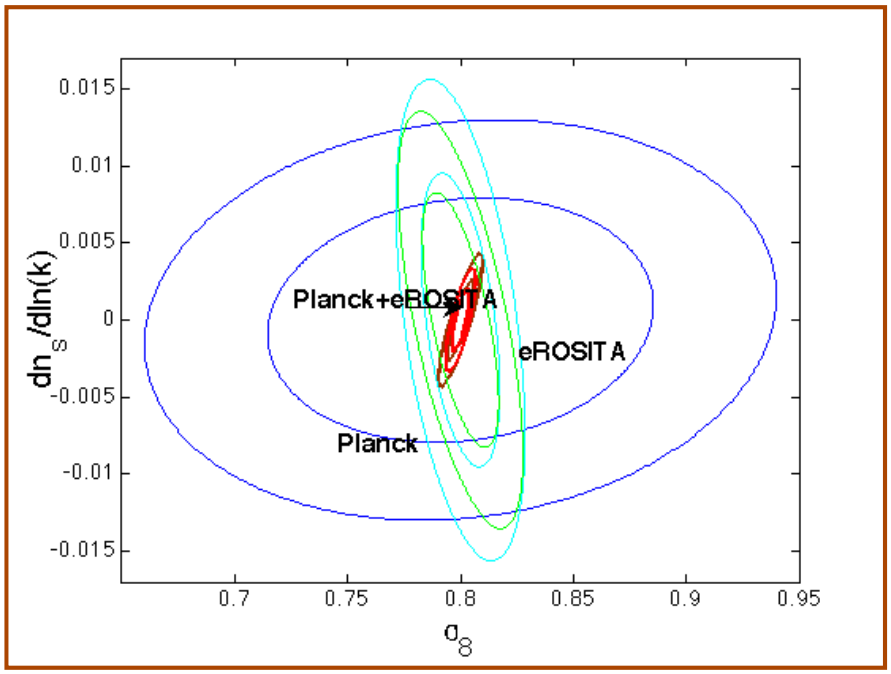


~ 30% improvement in n_s
~ 4 times improvement in $dn_s/d\ln k$

Constraints of parameters linked to Inflation - 3



Kinney etal 2000



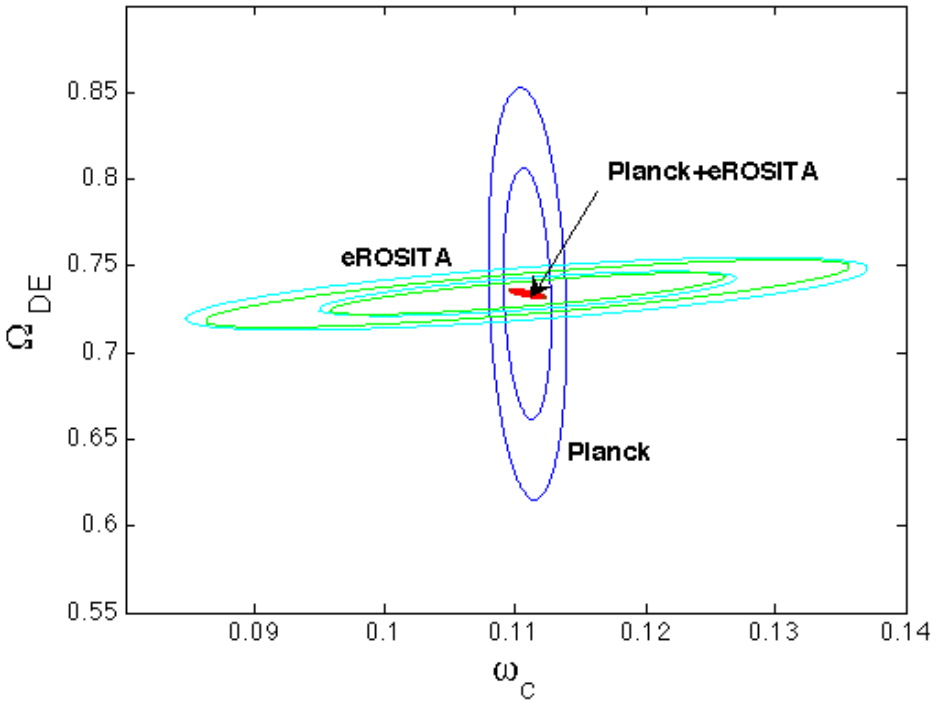
Ex - For Large field quartic potn. -

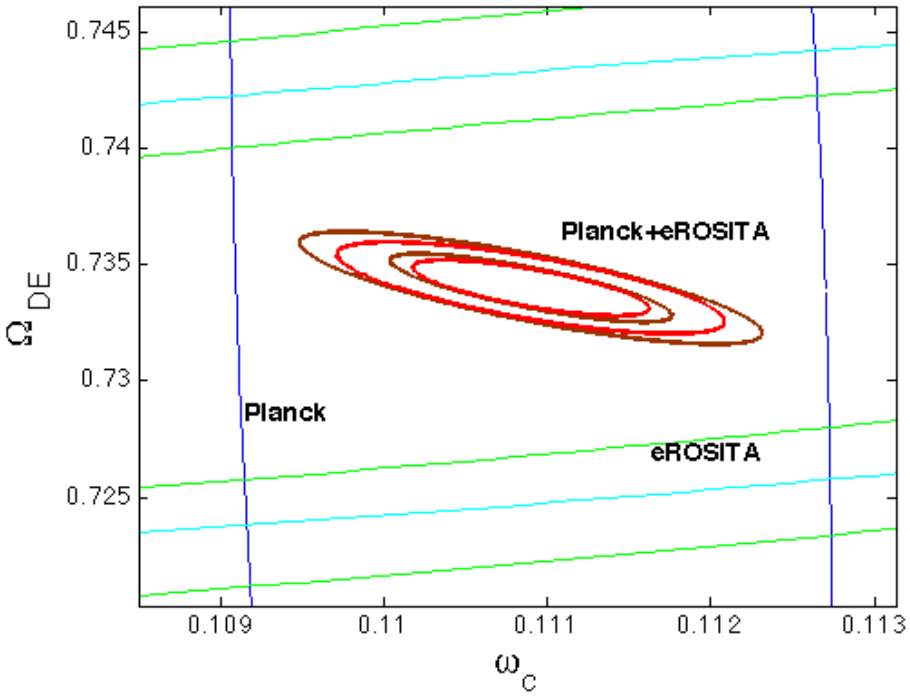
$$n_S \simeq 0.06, \quad \frac{dn_S}{d\ln k} \simeq 0.001, \quad r \simeq 0.2$$

$\Delta n_S \sim 0.003$, $\Delta dn_S/d\ln k \sim 0.0013$, $\Delta r \sim 0.025$ (with B modes, for r=0)

Constraints on *Amount* of Dark Energy

zoomed version

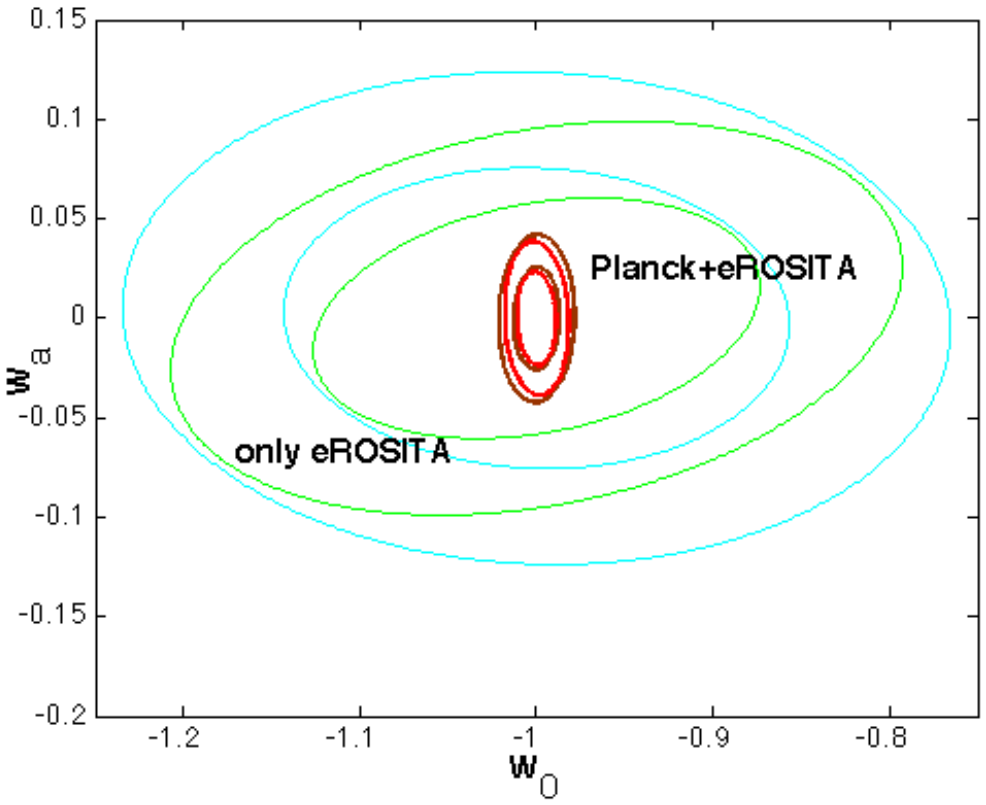




CMB by itself can poorly constrain DE, when both amount (Ω_{DE}) and nature i.e eqn state w are unknown. Tremendous improvement on adding eROSITA.

Constraint on Ω_{DE} improves by a factor of ~ 50 compared to Planck alone!!

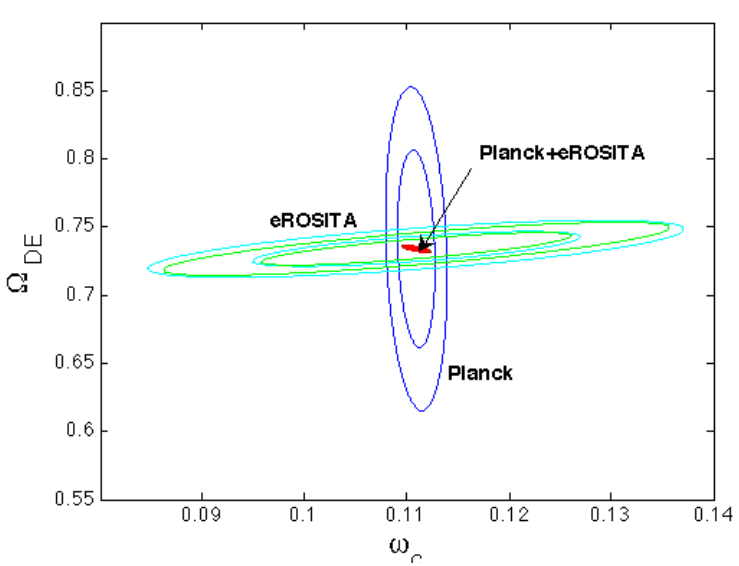
Constraints on *Nature* of Dark Energy

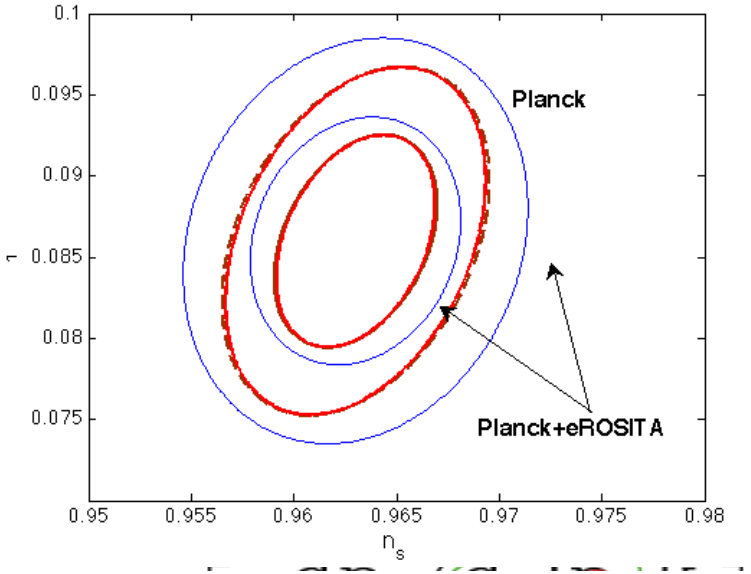


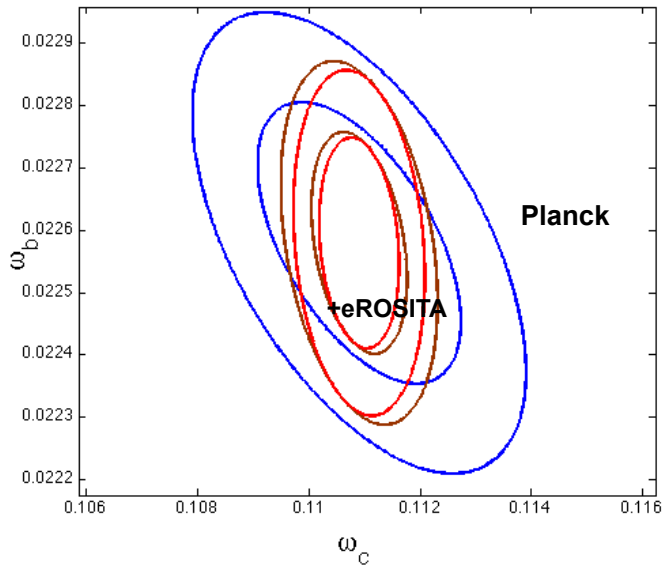
For const equation of state 'w' for DE, eROSITA improves constraints by a factor of 20!!

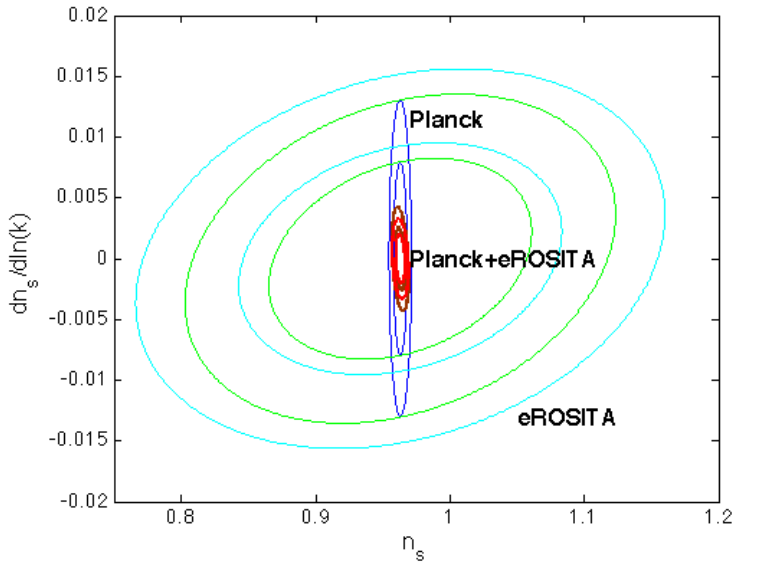
For varying 'w', CMB puts negligible constraint on the z-dependence of w. There is not much point in comparing. However, CMB helps a lot indirectly.

From **WMAP** to **Planck** to **eROSITA**









WMAP (Spergel et al., 2003)
Planck (Planck Collaboration, 2005)
eROSITA (Predehl et al., 2010)

Table of Cosmology Constraints

(marginalized over 11 parameters)

Follow-up of 400 clusters - 15% errors in mass

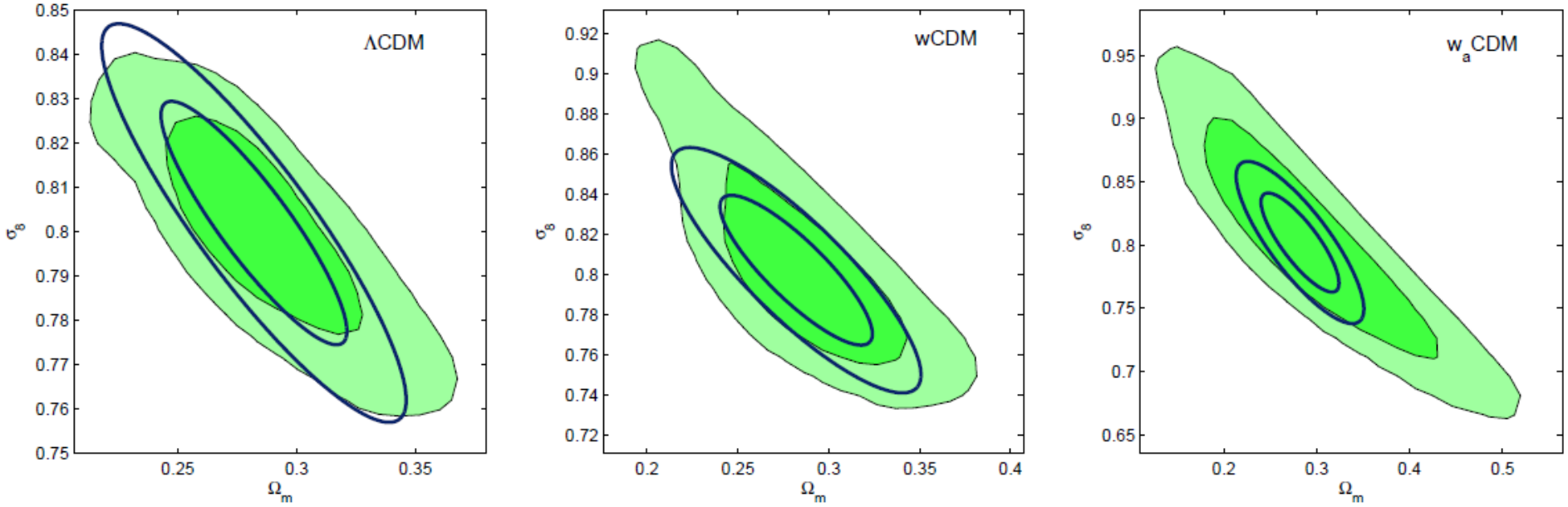
	Planck	+dndz+fup	+Pk	only clusters
wb	1.500e-04	1.200e-04	1.100e-04	5.800e-04
wc	1.210e-03	8.100e-04	4.800e-04	1.000e-02
Om_L	4.779e-02	1.767e-02	8.000e-04	7.850e-03
ns	3.380e-03	2.850e-03	2.560e-03	6.450e-02
run	5.230e-03	4.890e-03	1.340e-03	5.450e-03
s8	5.632e-02	1.447e-02	2.740e-03	1.113e-02
w0	1.759e-01	5.425e-02	7.470e-03	8.051e-02
wa	-		3.0e-02	
r	1.612e-02	1.61e-02	1.61e-02	--

Follow-up of 200 clusters - 20% errors in mass

	Planck	+dndz+fup	+Pk	only clusters
wb	1.500e-04	1.300e-04	1.200e-04	5.800e-04
wc	1.210e-03	8.700e-04	5.700e-04	1.057e-02
Om_L	4.779e-02	2.038e-02	9.800e-04	8.430e-03
ns	3.380e-03	2.920e-03	2.630e-03	7.929e-02
run	5.230e-03	5.040e-03	1.740e-03	6.290e-03
s8	5.632e-02	1.793e-02	3.990e-03	1.152e-02
w0	1.759e-01	6.430e-02	8.770e-03	9.433e-02
r	1.612e-02	1.61e-02	1.61e-02	--

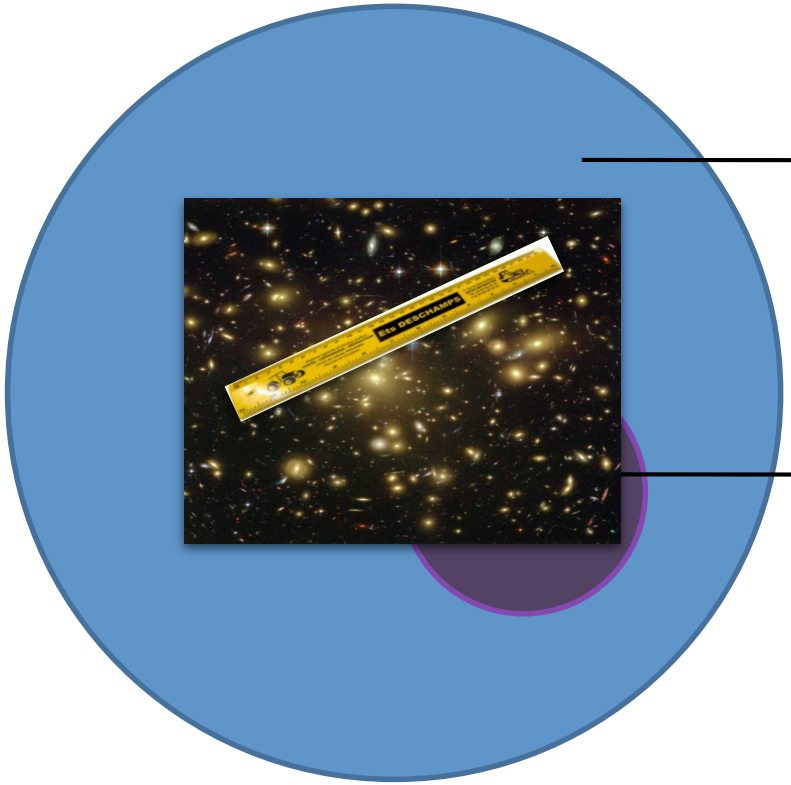
One word of caution ….

With more and more parameters (and certain parameters like w_a) , Fisher forecasts becomes more and more unreliable. Very important to do MCMC even for cluster forecasts. That's the bad news!



The good news is that addition of extra information: follow-up, Pk, CMB makes helps in 'Gaussianizing' the pdf, so mismatch is less extreme.
So that's the good news.

Use other synergies between SZ and eROSITA



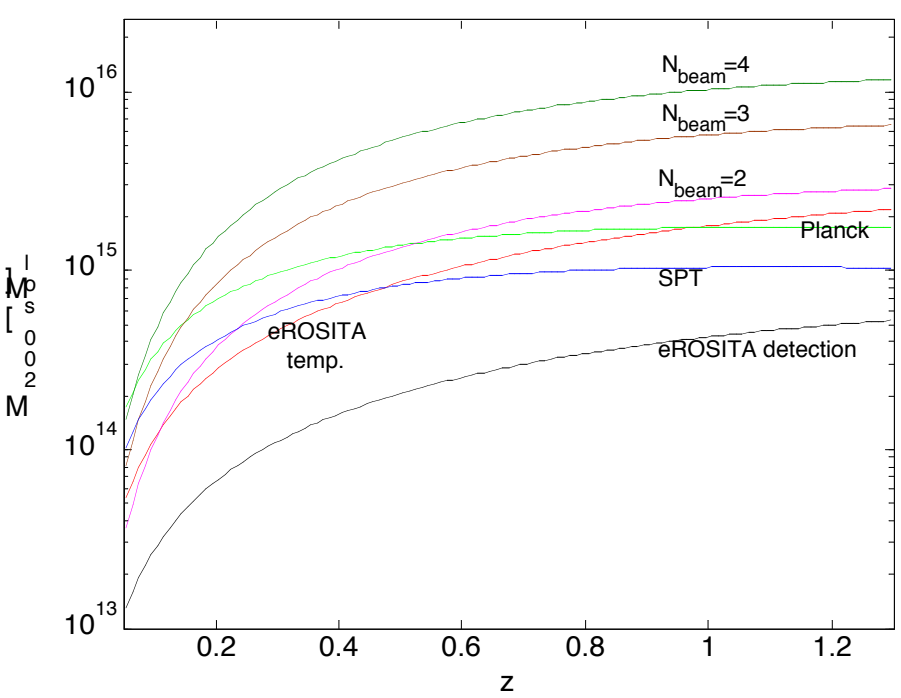
XRAY SURVEY
eROSITA .

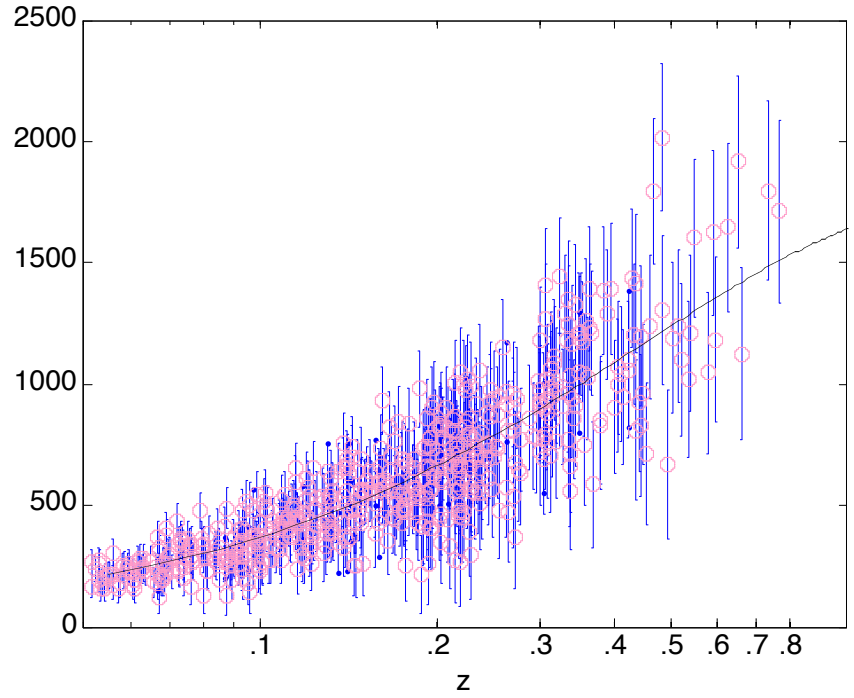
SZ SURVEY
SPT/ACT ~ 2.5 k sq. deg.
Planck ~ all sky

Find common clusters in the region of overlap between the 2 surveys.
Common clusters also ideal for Xray mass calibration (since Y-M can be compared)
--> so <T> should target these.
SZ clusters will have first go at the z's.

ESTIMATE $d_A(z)$ for each cluster.

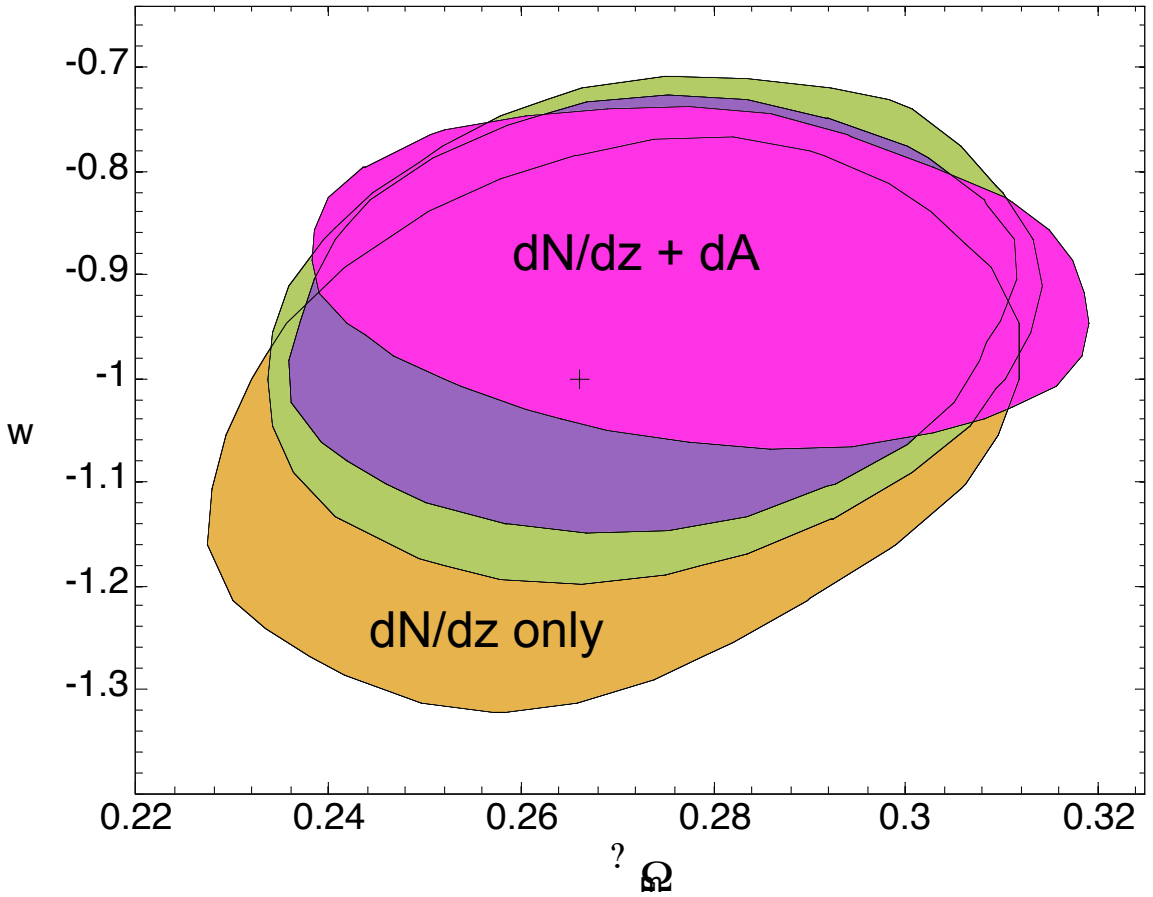
Xray+SZ survey synergy - making a mock $d_A(z)$ …





mock catalog created from **SZ + Xray** for N_{beam}=2 with **25% errors in $d_A(z)$**.

With help from eROSITA, one can improve DE constraints from Planck clusters



eROSITA, Self-Calibration and Non-Gaussianity …

Cluster Pk depends on bias.

--->Non-Gaussianity modifies large scale bias.

---> eROSITA having large volume probes large scales

---> Pk is needed for self-calibration.

Self-calibrated eROSITA clusters is ideal fro probing Non-Gaussianity.

(next in Annalisa's talk)

Conclusions

Cosmic Complimentarity comes back after a decade.
(Eisenstein etal 1998-2000, CMB+Galaxies, CMB + SNe.)
Now we have CMB + Clusters (but not just P(k)

By constraining σ_8, n_s and $dn_s/d\ln k$, eROSITA, parameter space for inflation models is greatly reduced.

By constraing WDE, w0, wa, eROSITA can heavily restrict the DE param space.

Joint clusters in Planck and eROSITA can give measurement of dA(z).

eROSITA is ideal for looking for primordial Non-Gaussianity.

THANK YOU

First eROSITA International Conference,
Garmisch -Partenkirchen, 17-20 October 2011