Integrated Sachs-Wolfe

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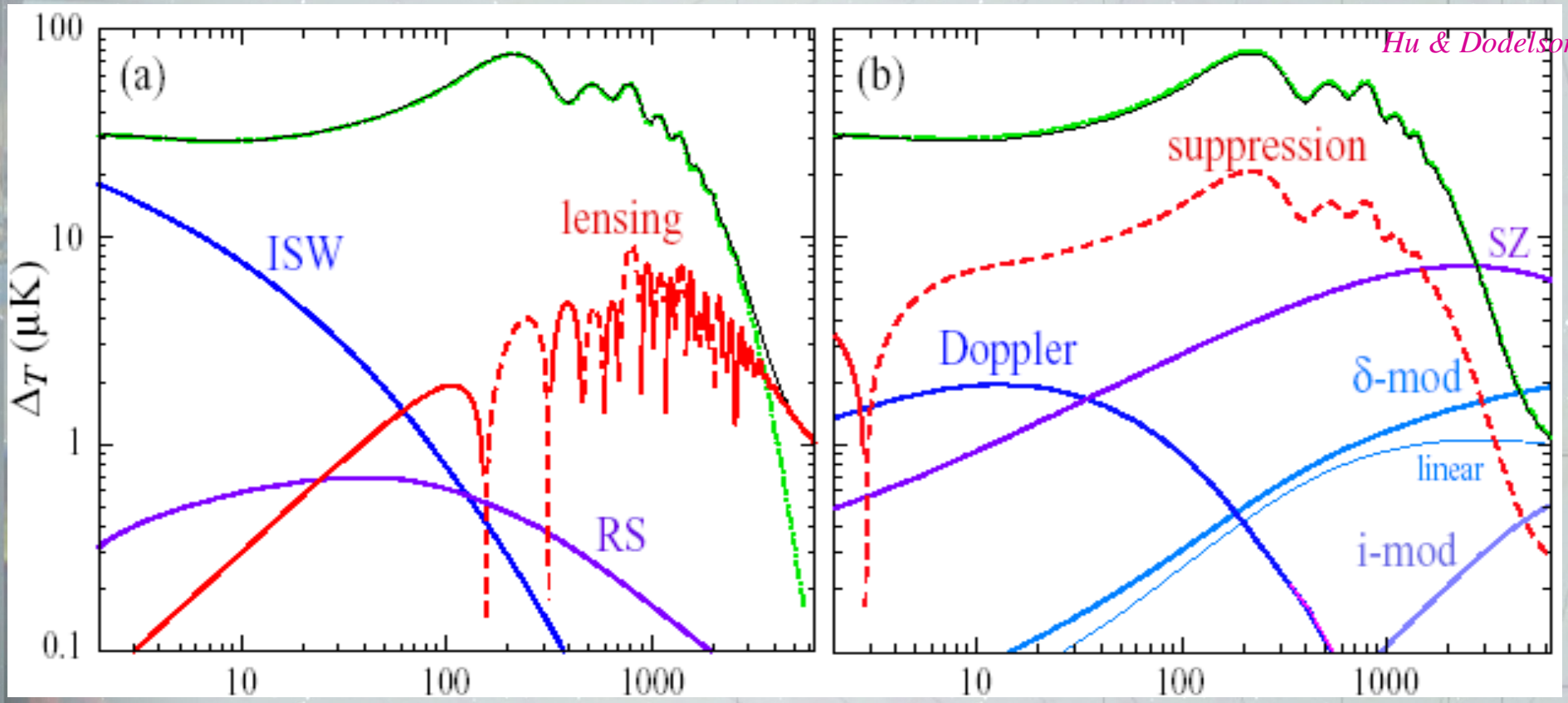
For EIC-WG: M. Douspis, A. Rassat, A. Refregier, J. Weller, NA

Secondary effects of the CMB



Gravitational effects

Scattering effects

Integrated Sachs-Wolfe

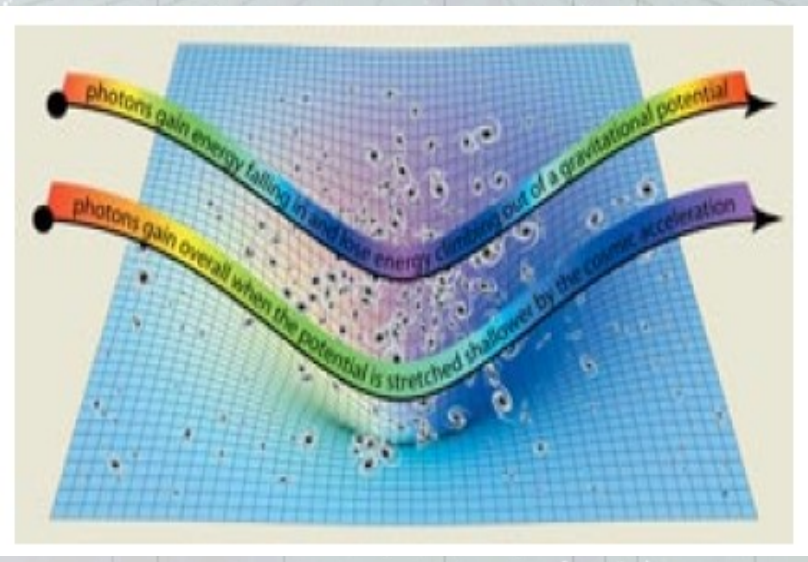
Source of CMB secondary anisotropies (low z, large scales)

$$\frac{\Delta T_{\rm ISW}}{T}(\hat{n}) = -2\int_0^{r_0} dr\,\dot{\Phi}(r,\hat{n}r)$$

$$\dot{\Phi} \equiv \partial/\partial z[(1+z)D(z)] \equiv \partial g/\partial z$$

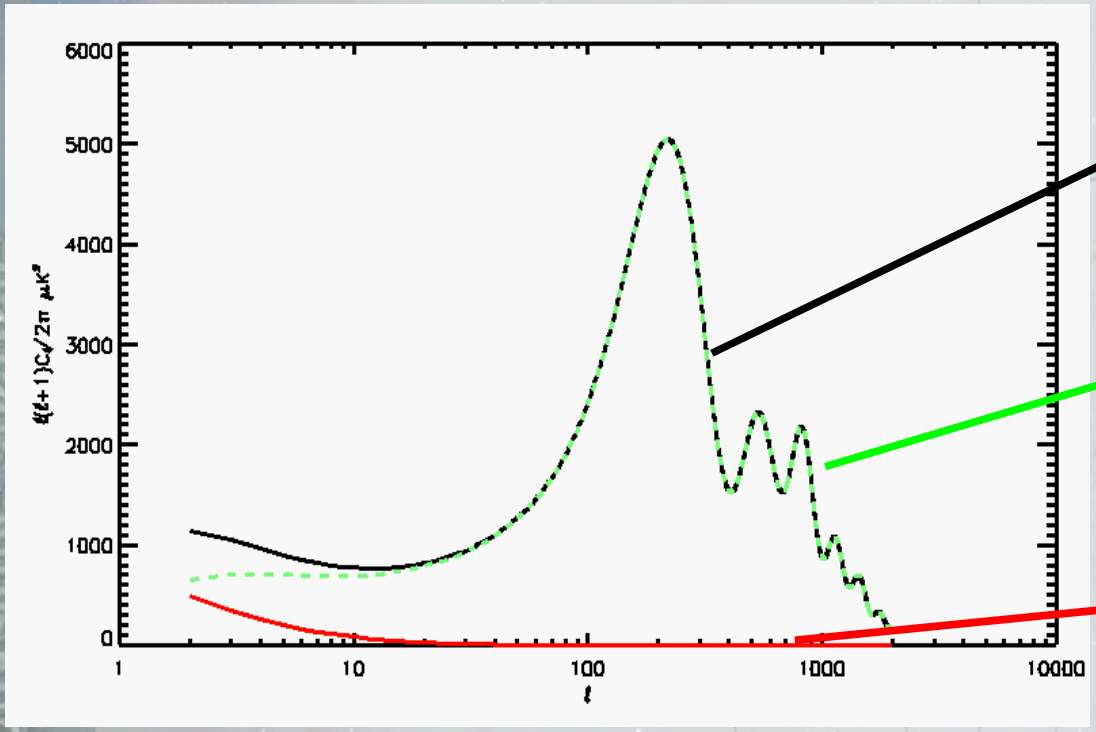
$$g(z) \equiv f\left[\Omega_m(z), E(z)\right]$$ **growth factor**

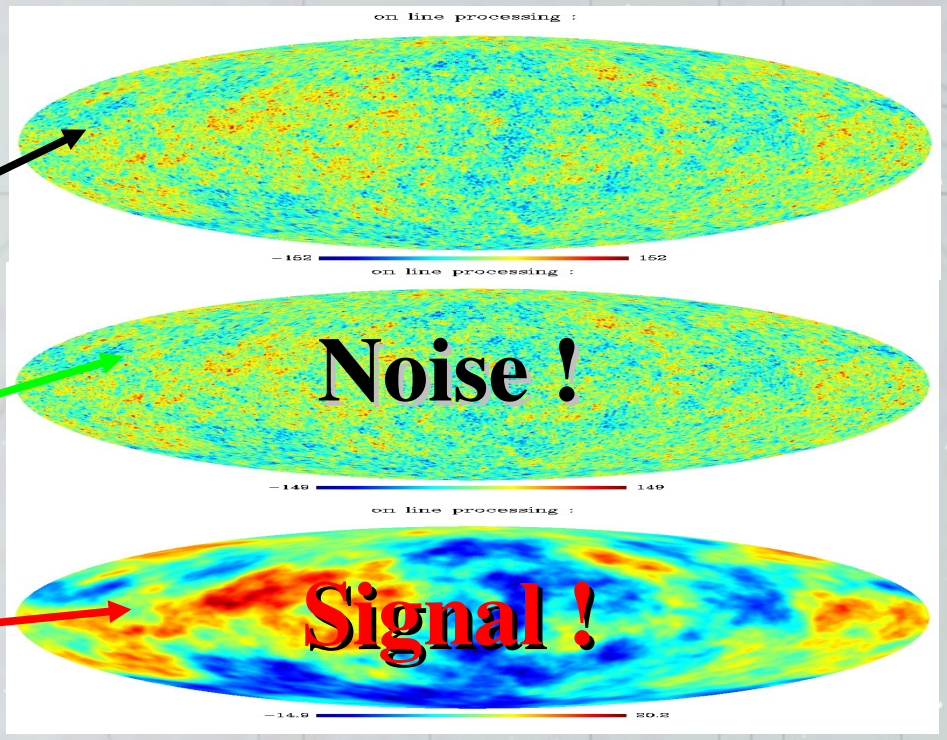
$$E(z)^2 \equiv \Omega_{\rm m}(1+z)^3 + \Omega_{\rm K}(1+z)^2 + \Omega_{\rm DE}(1+z)^3 \exp[3\int_0^z dz'\, w(z')/(1+z')]$$



→ **test growth of structures**
→ **test DE nature and evolution**
→ **test GR**

ISW





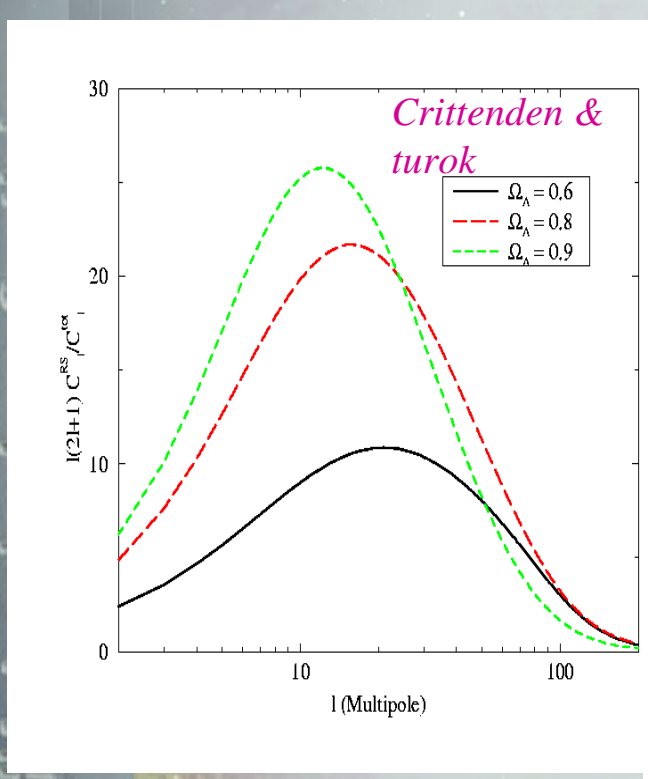
Limitation: cosmic variance!!!!

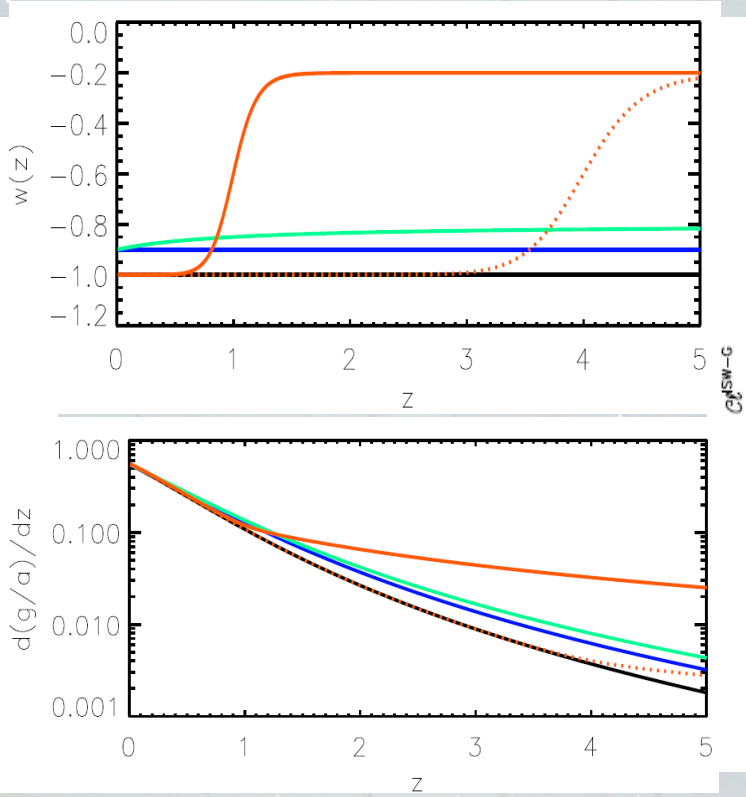
Poisson equation links Φ with matter distribution: Potentiels responsible for ISW are associated with LSS (galaxies/QSO/etc)

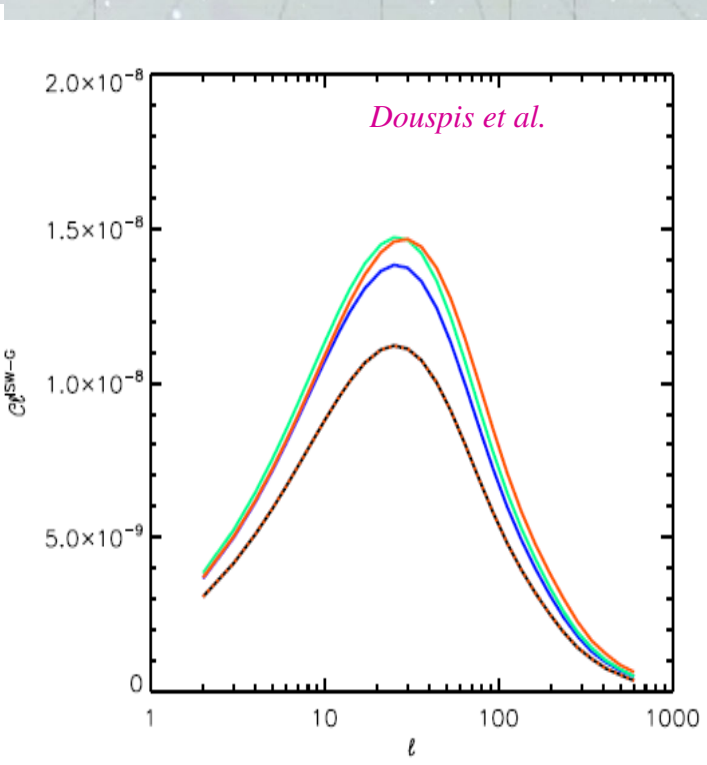
Correlation between CMB and LSS

Objectives: DE

Correlation with LSS to test different cosmologies





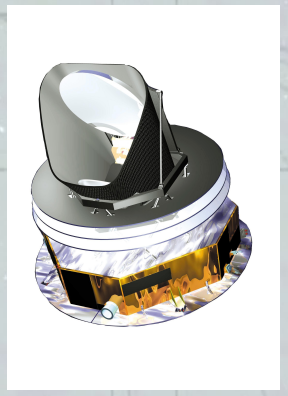


Power spectrum of the correlation CMB/galaxies

$$C_l^{\mathrm{ISW-G}} = \frac{2}{\pi}\int \mathrm{d}k\, k^2 P_{\delta\delta}(k) I_l^{\mathrm{ISW}}(k) I_l^{\mathrm{G}}(k)$$

Constraints of ISW on DE

Fisher matrix analysis EIC & Planck (z_m=0.9, f_{sky}=0.5, nbar=40) **:**



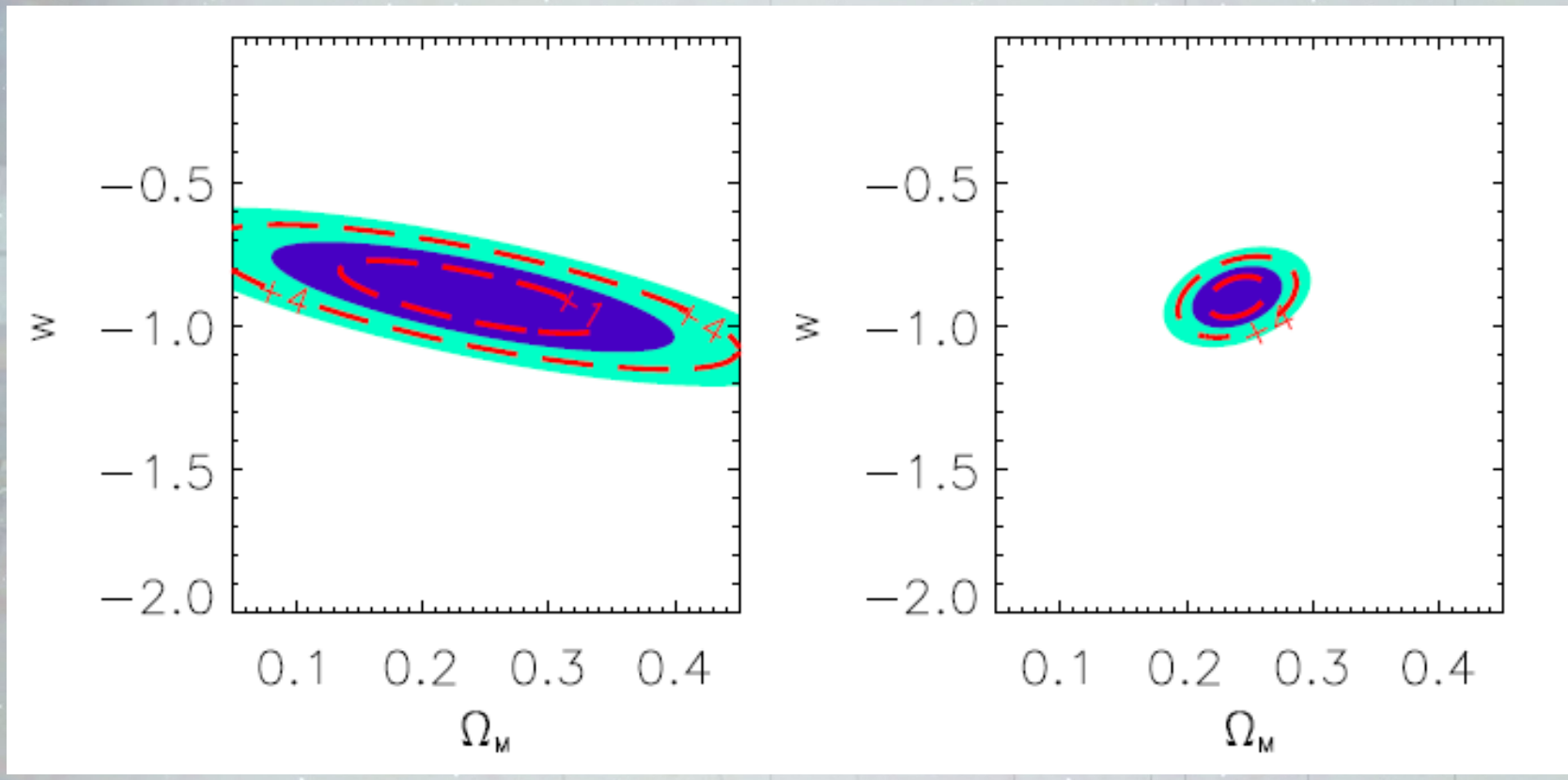
$$F^{i,j} = f_{sky}^{c} \sum_{l} (2l+1) \frac{\partial C_l^{\mathrm{ISW-G}}}{\partial \Theta_i} \, cov^{-1}(l) \, \frac{\partial C_l^{\mathrm{ISW-G}}}{\partial \Theta_j}$$

$$cov(l) = \left[C_l^{\mathrm{ISW-G}}\right]^2 + \left(C_l^{\mathrm{ISW}} + N_l^{\mathrm{CMB}}\right)\left(C_l^{\mathrm{G}} + N_l^{\mathrm{G}}\right)$$

$$\Theta = (H_0, \Omega_{\mathrm{b}}, \sigma_8, n_{\mathrm{s}}, \Omega_{\mathrm{DE}})$$

+ w ou (w_0,w_a) or a_t

DE constraints:Fisher matrix analysis

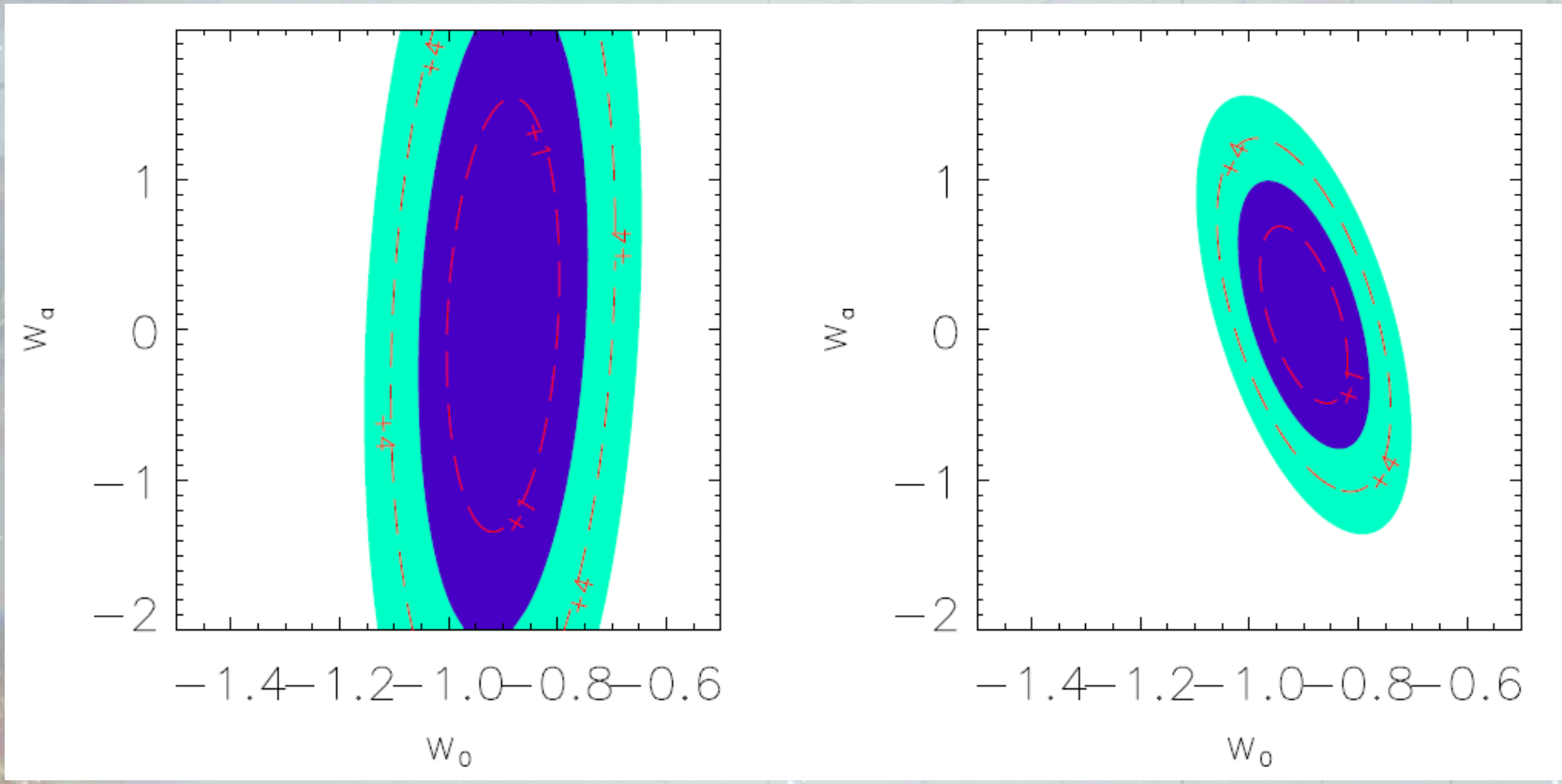


CMB (T)

CMB (T) + ISW

Douspis, et al 2008

DE constraints:Fisher matrix analysis



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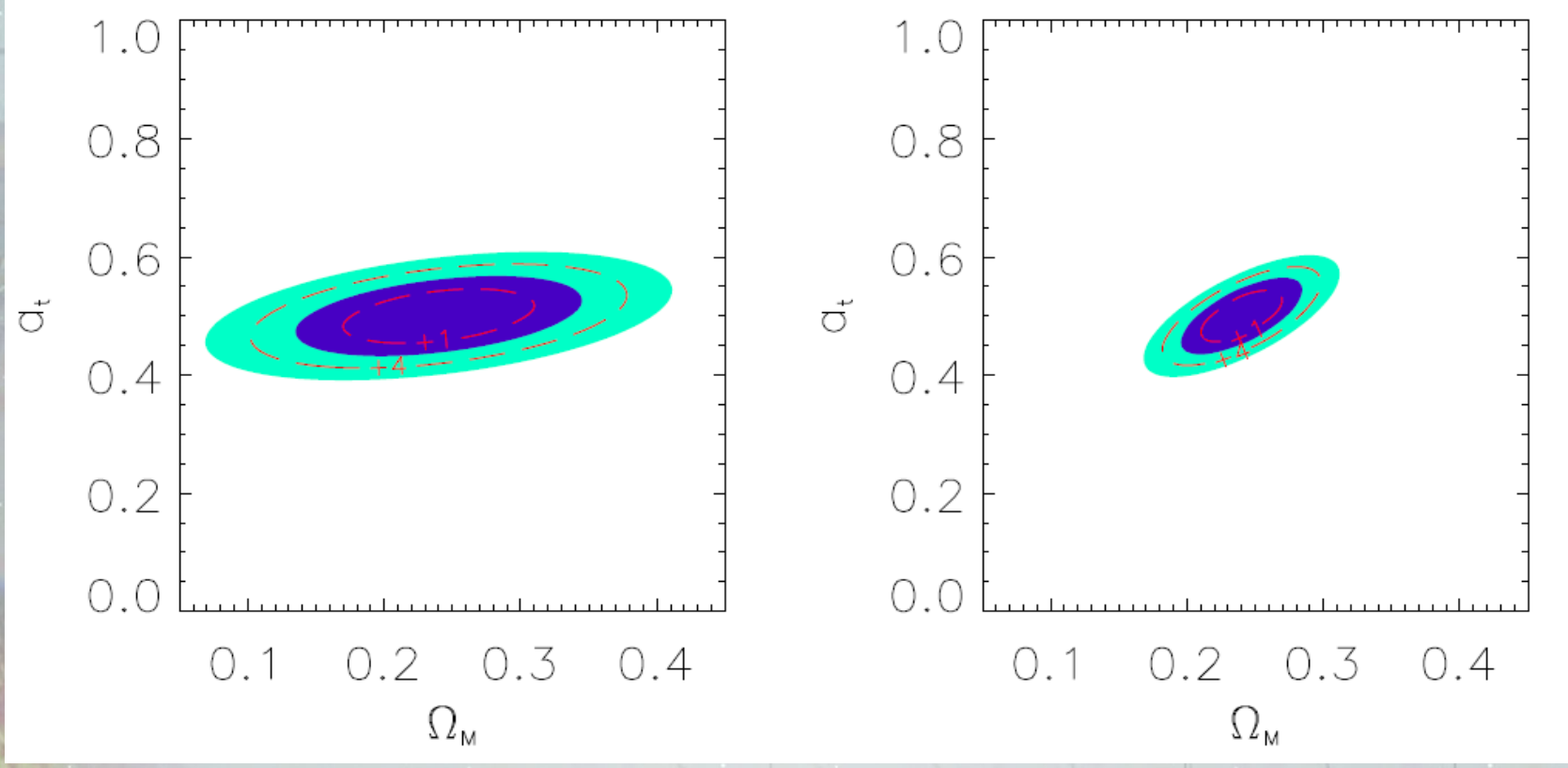
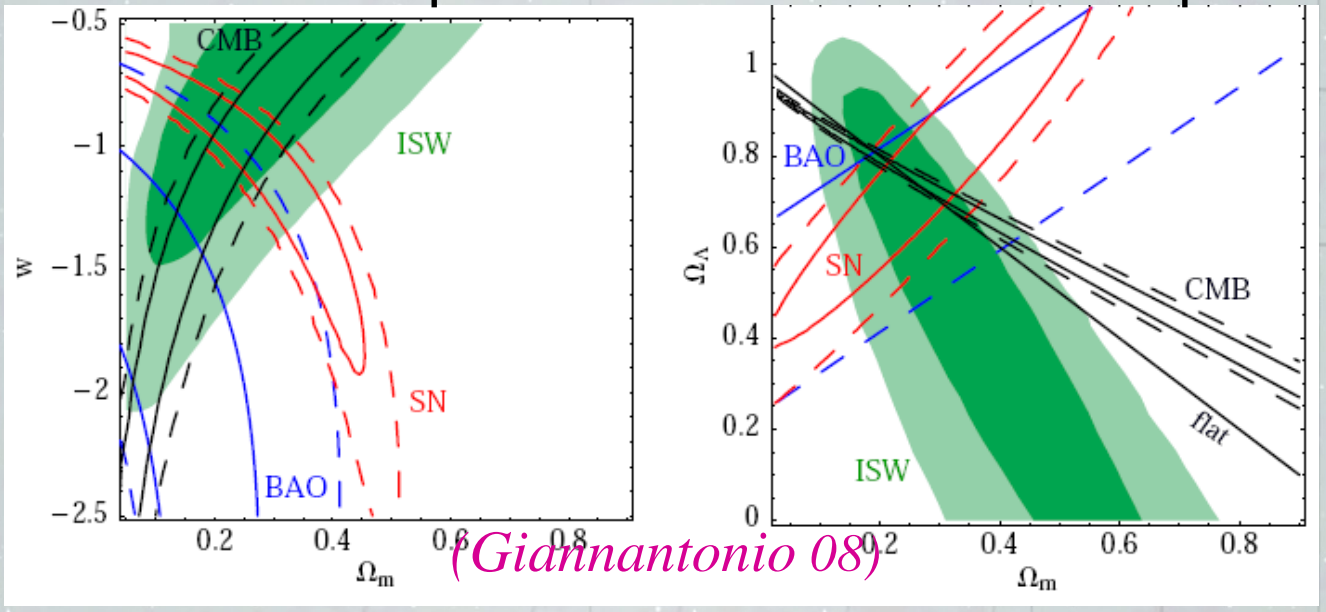


CMB (T)

CMB (T) + ISW

Douspis, et al 2008

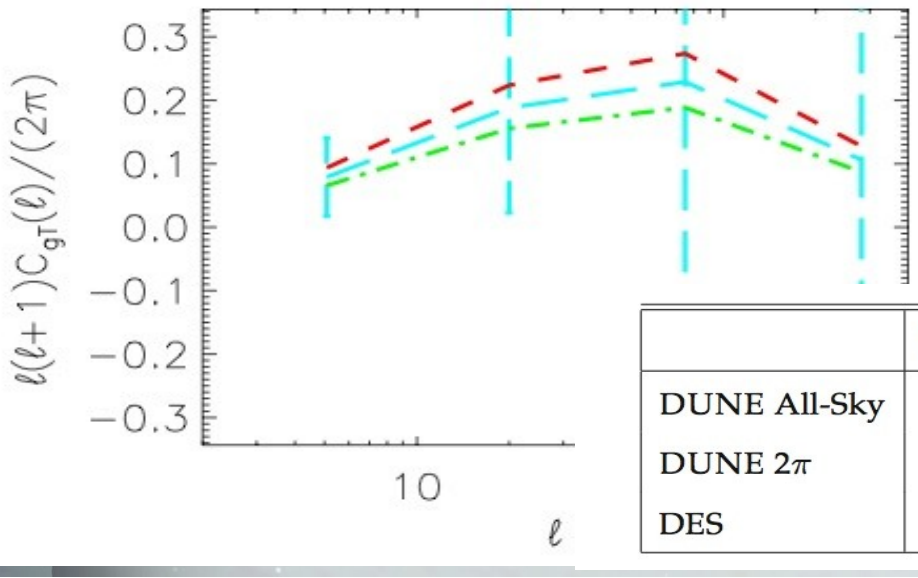
Combination of probes in flat and curved space



(Giannantonio 08)

Test of GR

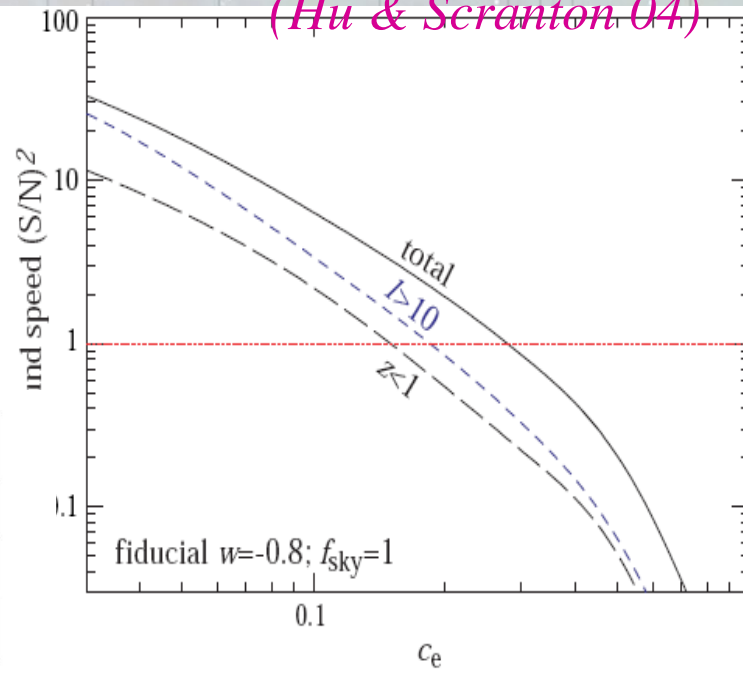
(Rassat 07)



	$\Omega_\Lambda = 0.75$	$\Omega_\Lambda = 0.90$
DUNE All-Sky	18%	8%
DUNE 2π	25%	12%
DES	54%	28%

Test of clustered DE

(Hu & Scranton 04)

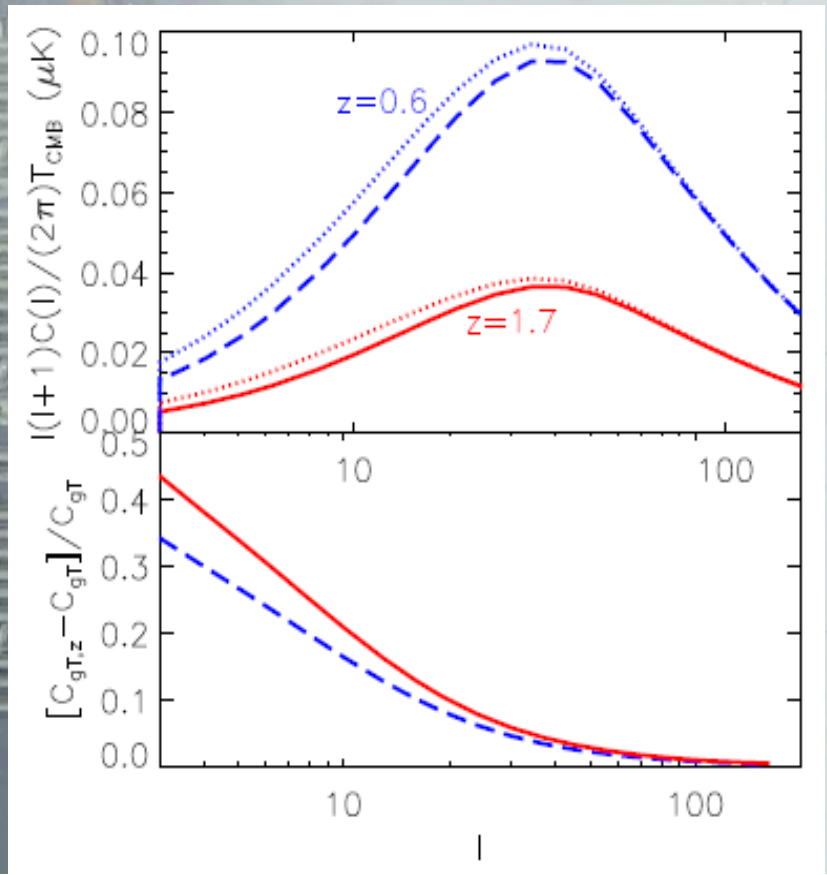


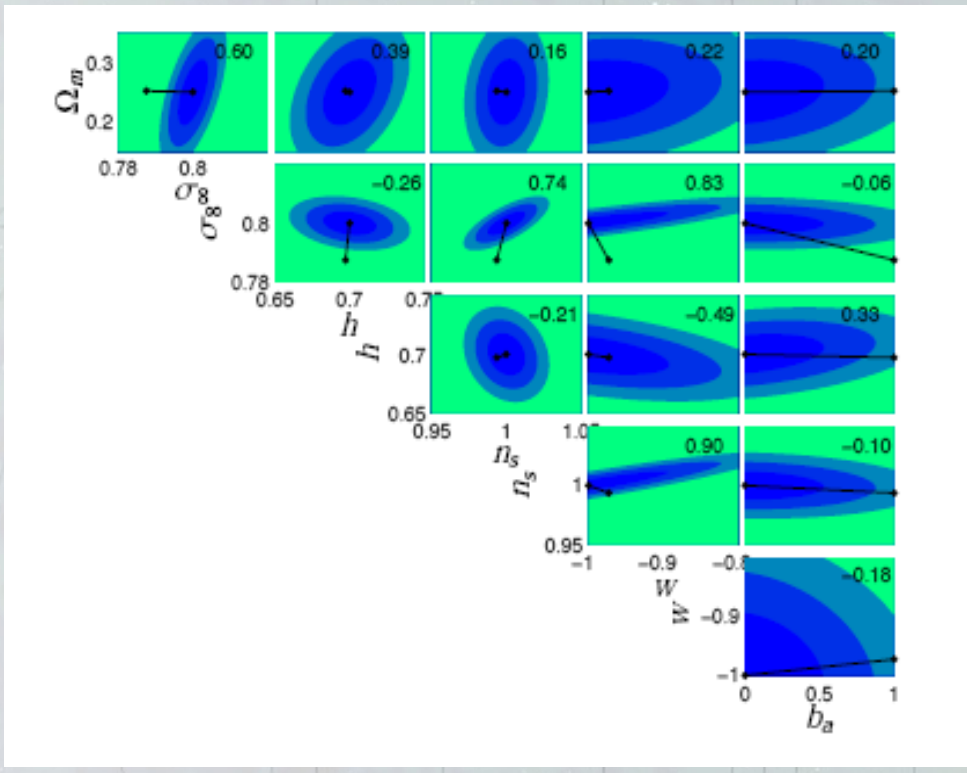
Some words of caution

Linear bias evolution

➞ suppressed power at large scales
=> biases on the cosmological parameters

Schaefer et al. 09





Redshift distortions

➞ increased amplitude for ISW
=> when neglected DE overestimated
=> inclusion is an additional cosmological information

Rassat 09

Cross-correlation

Detections at 2-4 σ

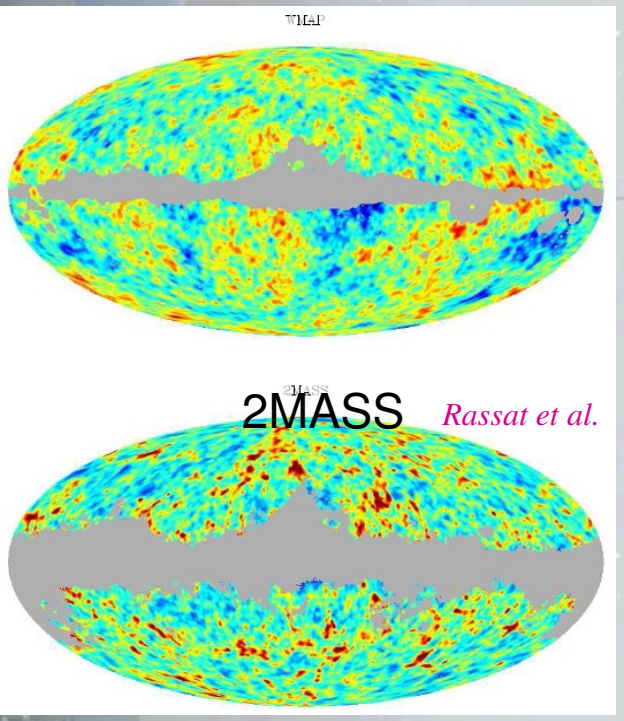
- **X-ray background** *(Boughn & Crittenden)*
- **SDSS quasars** *(Giannantonio et al.)*
- **Radio galaxies**:
  - NVSS confirmed by Nolta et al

  (WMAP collaboration)
  - Wavelet analysis: higher significance

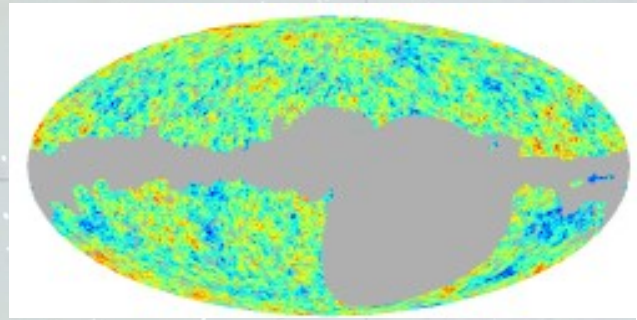
  (Vielva et al. McEwan et al.)

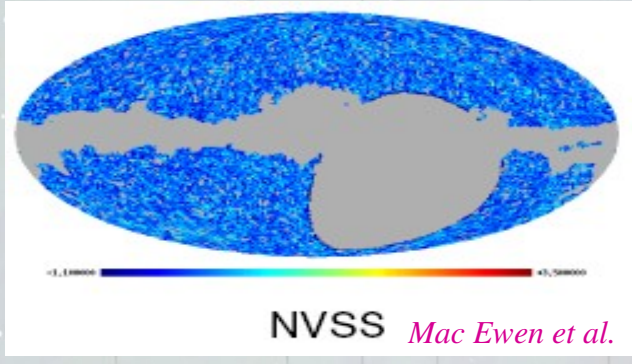
  FIRST radio galaxy survey *(Boughn et al.)*
- **Infrared galaxies**:
  - 2MASS near infrared survey
  - *(Afshordi et al.,Rassat et al.)*
- **Optical galaxies**:
  - APM survey *(Folsalba & Gaztanaga)*
  - Sloan Digital Sky Survey *(Scranton et al., Cabre et al.)*
  - Band power analysis of SDSS data *(Pamanabhan, et al.)*

Cross-correlations

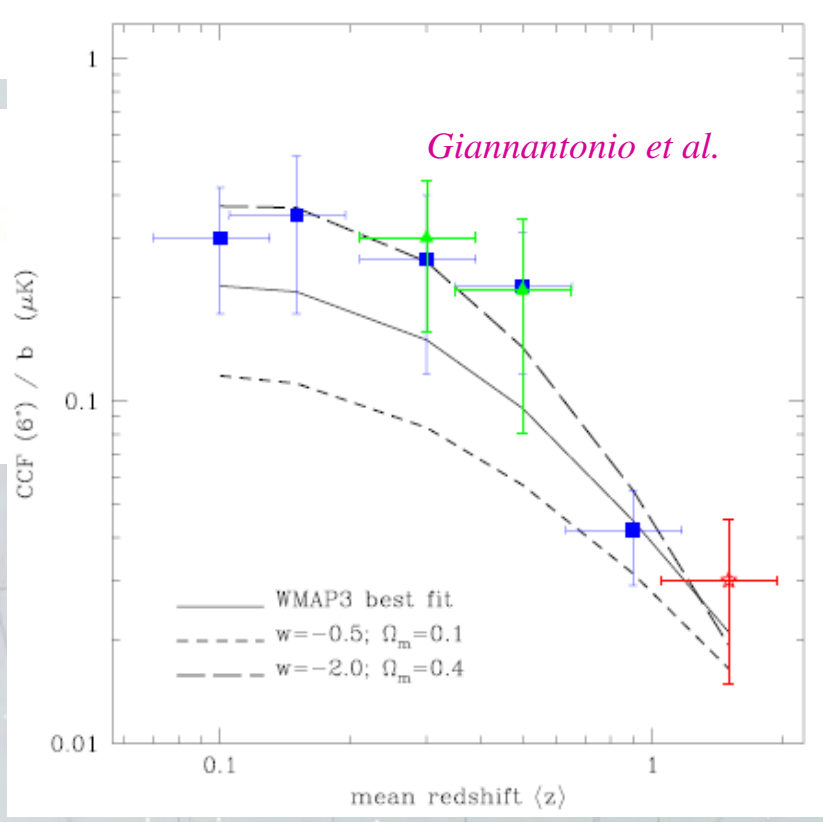


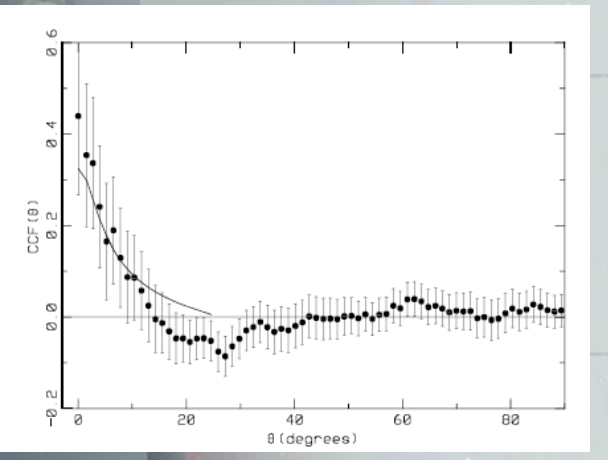
Rassat et al.

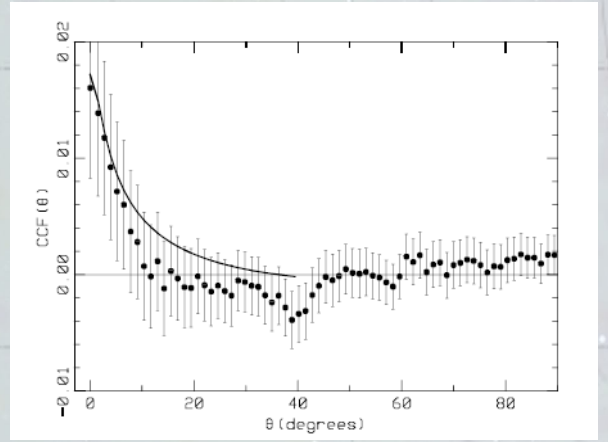




Mac Ewen et al.







Requirements & optimisation

A clean as large as possible CMB map → Planck :-)

Signal-to-noise analysis

$$\left(\frac{S}{N}\right)^2 = f_{sky}^c \sum_{l=l_{min}}^{l_{max}} (2l+1) \frac{\left[C_l^{ISW-G}\right]^2}{\left[C_l^{ISW-G}\right]^2 + \left(C_l^{ISW} + N_l^{ISW}\right)\left(C_l^{G} + N_l^{G}\right)}$$

$C_l^{ISW} \equiv C_l^{CMB}$ $\quad N_l^{G} \equiv \frac{1}{N}$

Key parameters:

- **Common sky fraction: f_{sky}**
- **Depth, median redshift: z_m**
- **Number of galaxies per arcmin²: $\overline{N}$**

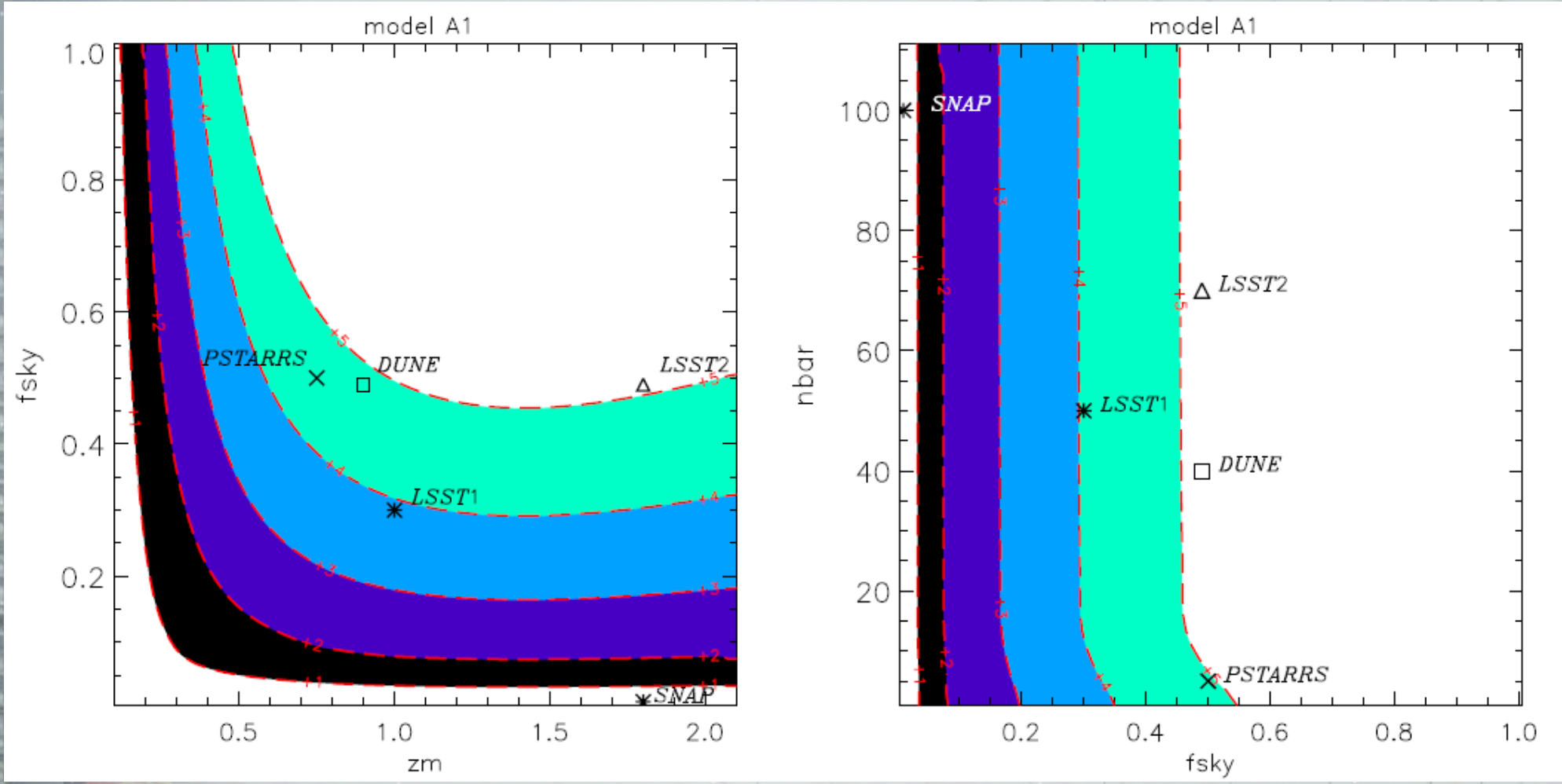
4 scenarios: different DE

- Λ , $w=-1$
- $w=-0.9$
- $w=-0.9+0.1\ z/1+z$
- $w=-1.0 \rightarrow -0.2$ **kink**

Douspis et al. 2008

Requirements & optimisation

LCDM



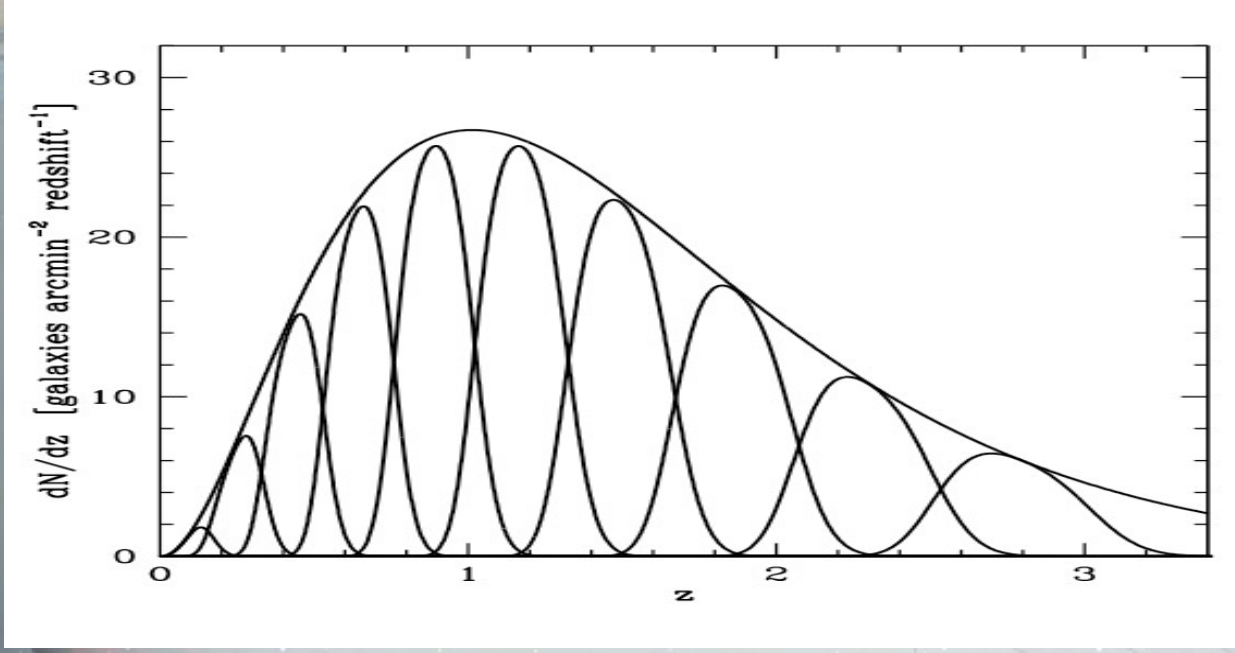
$Z_m > 0.8$, $f_{sky} > 0.4$, nbar > 10/arcmin^2

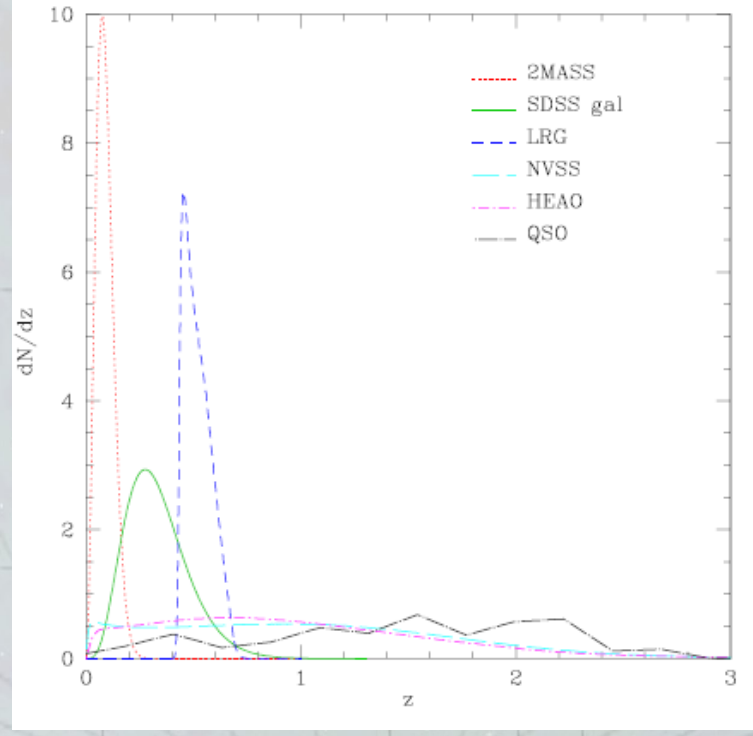
Requirements & optimisation

Limitation: CMB

Cross-correlation at different redshifts

- **Use different surveys** *(Giannantonio et al 2008)*
- **Sample the survey in bins: tomography**





Ongoing: Douspis, Rassat

Conclusions

Objectives:

- **Constraints on $w_{DE}(z)$**
- **Test of GR and clustered DE**
- **Improving cosmological constraints**
- **Information on the bias**

Mission requirements:

- **$f_{sky} > 0.4$, $n_{gal} >$ few/arcmin^2, $z_{med} \sim 0.9$, $\delta z \rightarrow$ needs of primary probes (WL)**
- **Compelling with WL requirements**