National Astronomical Observatory of Japan

Rees-Sciama -- Weak Lensing Correlation

~ Non-linear study and the implications for DARK ENERGY ~

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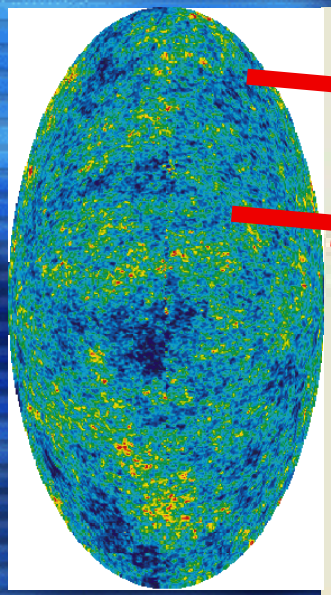
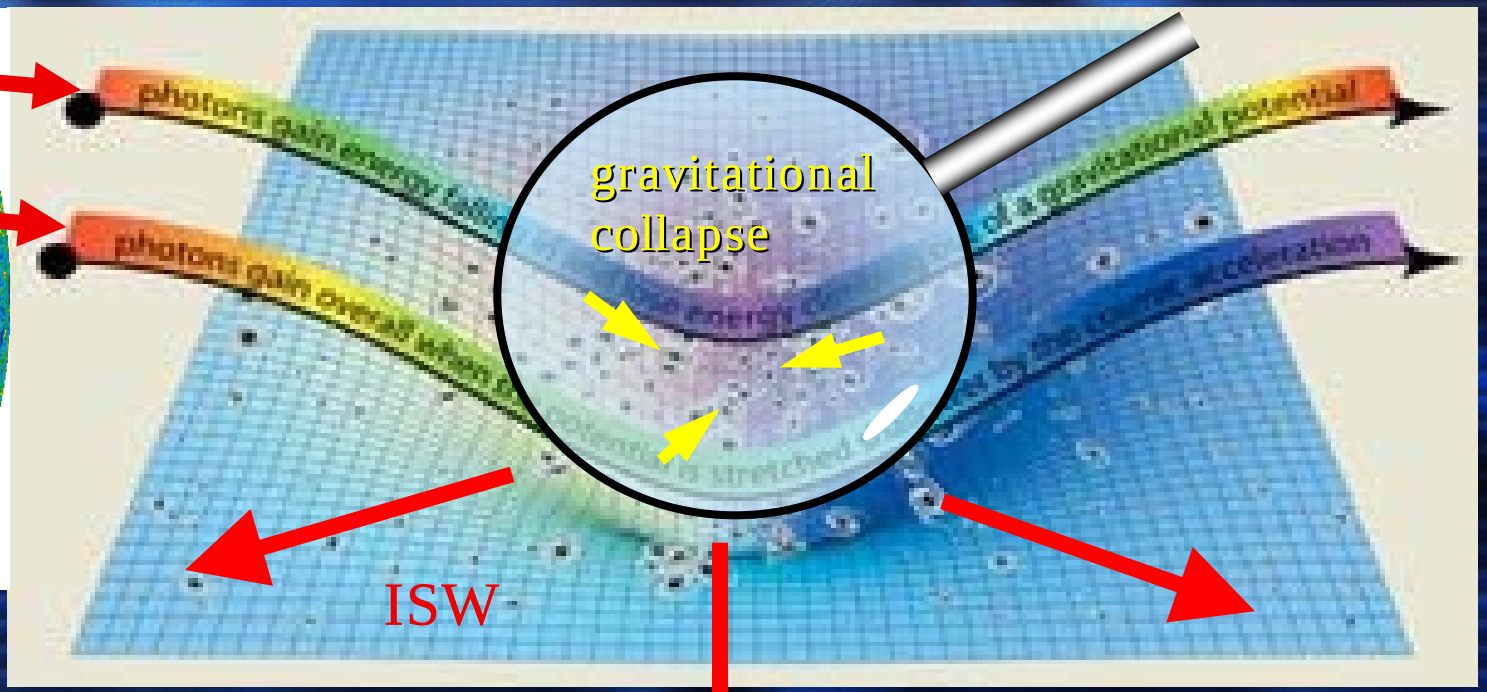
ISW and Rees-Sciama effect

$z \sim 1100$

$z < O(1)$



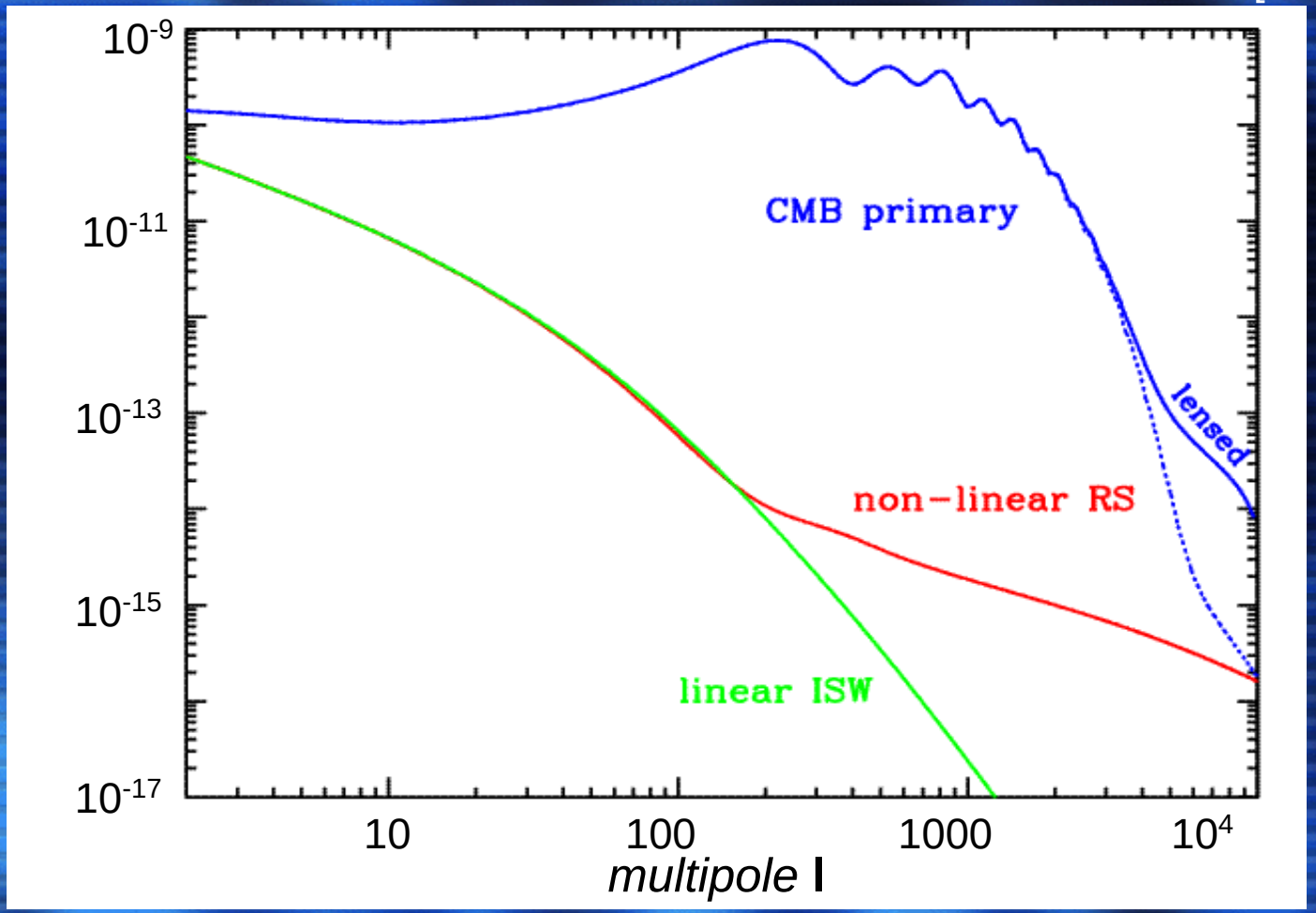


Accelerating expansion due to dark energy

$$\left(\frac{\Delta T}{T}\right)_{ISW} = \int \frac{\partial}{\partial r}\left[\Psi(\hat{n}r, r) - \Phi(\hat{n}r, r)\right] dr$$

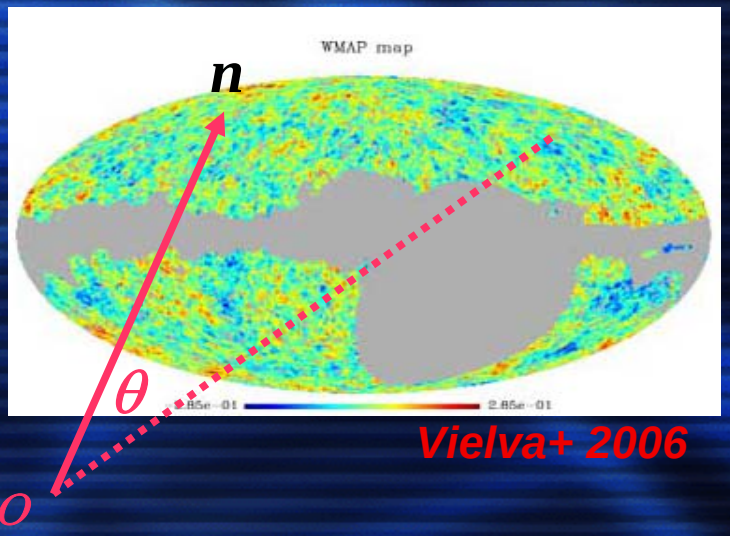
ISW/RS in the CMB spectra

- Temperature fluctuation



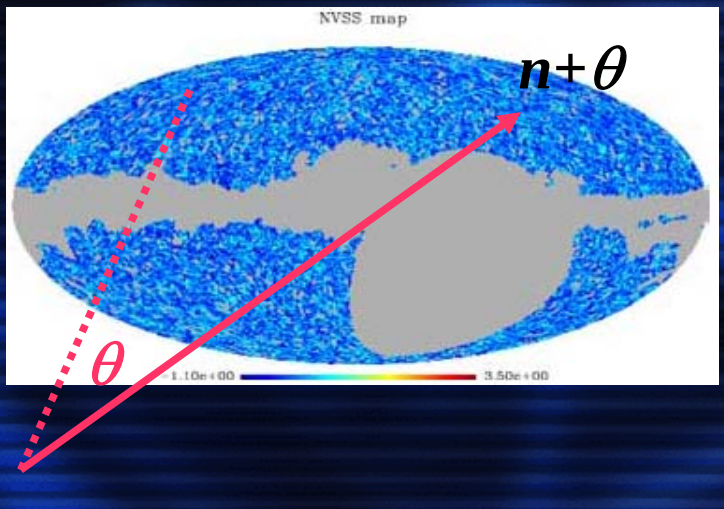
2 points statistics : Cross-Correlation of Angular Power Spectrum -CCAPS-

CMB temp. fluctuations



Vielva+ 2006

Projected density of galaxies



$$C(\theta) = \left\langle \frac{\Delta T(\hat{n})}{T} \delta(\hat{n}+\hat{\theta}) \right\rangle = \sum_{l=0}^{\infty} \frac{2l+1}{4\pi} C_l P_l[\cos(\theta)]$$

$$C_l \equiv \left\langle a_{lm}^T a_{lm}^{\delta *} \right\rangle$$

$$X(\hat{n}) = \sum_{l,m} a_{lm}^X Y_{lm}(\hat{n})$$

CCAPS

How do we treat the NLity?

- **Higher Order PT (including, renorm., resum., etc.)**
  - ○ : Easy to separate NLity ; extension of linear PT.
  - × : break down at high-k (small scale).

Makino+ 1992, Crosse+ 2006, Matsubara 2008, Taruya+ 2008 etc.

- **Halo model**
  - ○ : Physics is easy to understand.
  - × : inconsistent with N-body at int'm. scale and high z.

Seljak 2000, White+ 2001, Sheth+ 2001, 2002, Ma+ 2002 etc.

- **Fitting formulae for matter power spec.**
  - ○ : implementation is easy. Good agreement with sim.
  - × : physical interpretation is not straightforward.

Peacock+ 1996, Smith+ 2003

- **N-body simulation**
  - ○ : Minimal assumptions are required.
  - × : Time consuming. Hard to include baryon.

Springel+ 2005

~ Basic Equations ~

- Angular power spec. RS - WL

$$C_l^{\Phi'-\kappa} = 2l^2 \int dz_s \; n(z_s) \int_0^{rs} dr \; \frac{r_s - r}{r^3 r_s} P_{\Phi\Phi'}(k,r)\big|_{k=l/r}$$

- Poisson eq. with power spec. ($\Phi \rightarrow \delta$)

$$P_{\Phi\Phi'}(k,a) = \left(\frac{3\Omega_m H_0^2}{2ak^2}\right)^2 \left[P_{\delta\delta'}(k,a) - HP_{\delta\delta}(k,a)\right]$$

- Continuity eq. ($\delta' \rightarrow mv$)

$$i\delta'(\vec{k}) = kv(k)\mu + \int \frac{d^3\vec{q}}{(2\pi)^3} \delta(\vec{k}-\vec{q}) kv(\vec{q}) \mu \frac{\vec{k}\cdot\vec{q}}{q^2}$$

δ' is equivalent to the div. of momentum

RS with 3rd order standard PT

- $P_{\delta\delta}$

$$P_{\delta\delta}(k,a) = D^2(a)P_{\delta\delta}^{11}(k) + D^4(a)\left[P_{\delta\delta}^{22}(k) + 2P_{\delta\delta}^{13}(k)\right]$$

- $P_{\delta\delta'}$ (two prescriptions)

$$P_{\delta\delta'}(k,a) = \frac{1}{2}\frac{\partial}{\partial r}P_{\delta\delta}(k,a)$$

← ensemble average and time derivative can commute each other

$$P_{\delta\delta'}(k,a) = DD'P_{\delta\delta}^{11}(k) + D^3D'[P_{\theta\delta}^{13}(k) + P_{\theta\delta}^{31}(k) + P_{\theta\delta}^{22}(k) + \int\frac{d^3\vec{q}}{(2\pi)^3}\left\{B_{\delta\theta\delta}^{112}(\vec{k},\vec{q}) + B_{\delta\theta\delta}^{121}(\vec{k},\vec{q}) + B_{\delta\theta\delta}^{211}(\vec{k},\vec{q})\right\}\frac{\vec{k}\cdot\vec{q}}{q^2}]$$

using cont. eq.

→ Cont. eq. is used in Halo model (*Sheth & Cooray 2002*)

<ΦΦ'> cross correlation

ISW boost

RS evolution

N-body spec

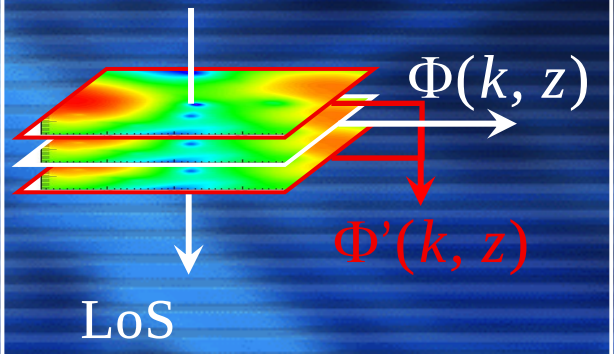
Gadget-2 code

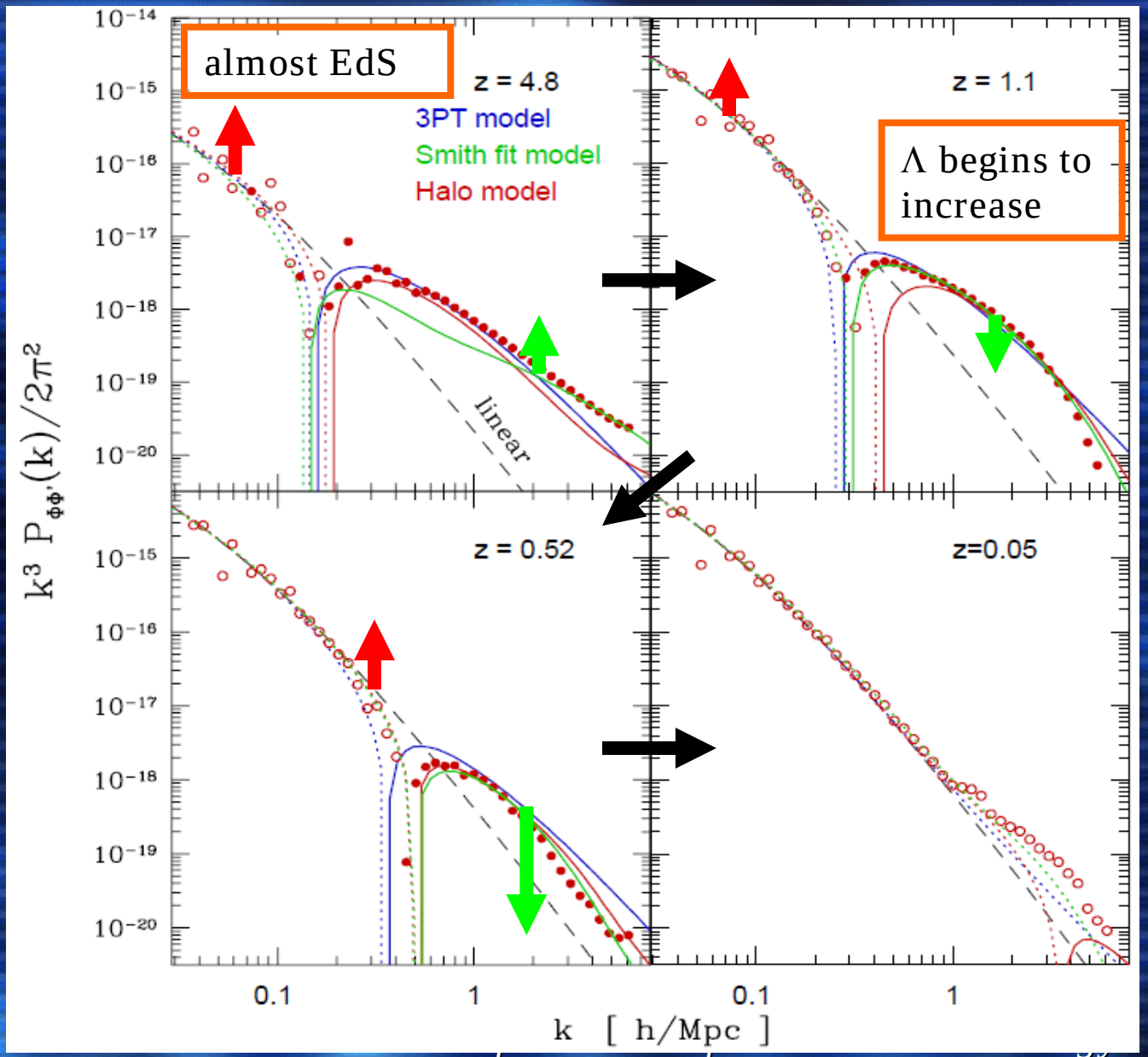
L_{box} = 200 Mpc/h

$N_{part} = 256^3$

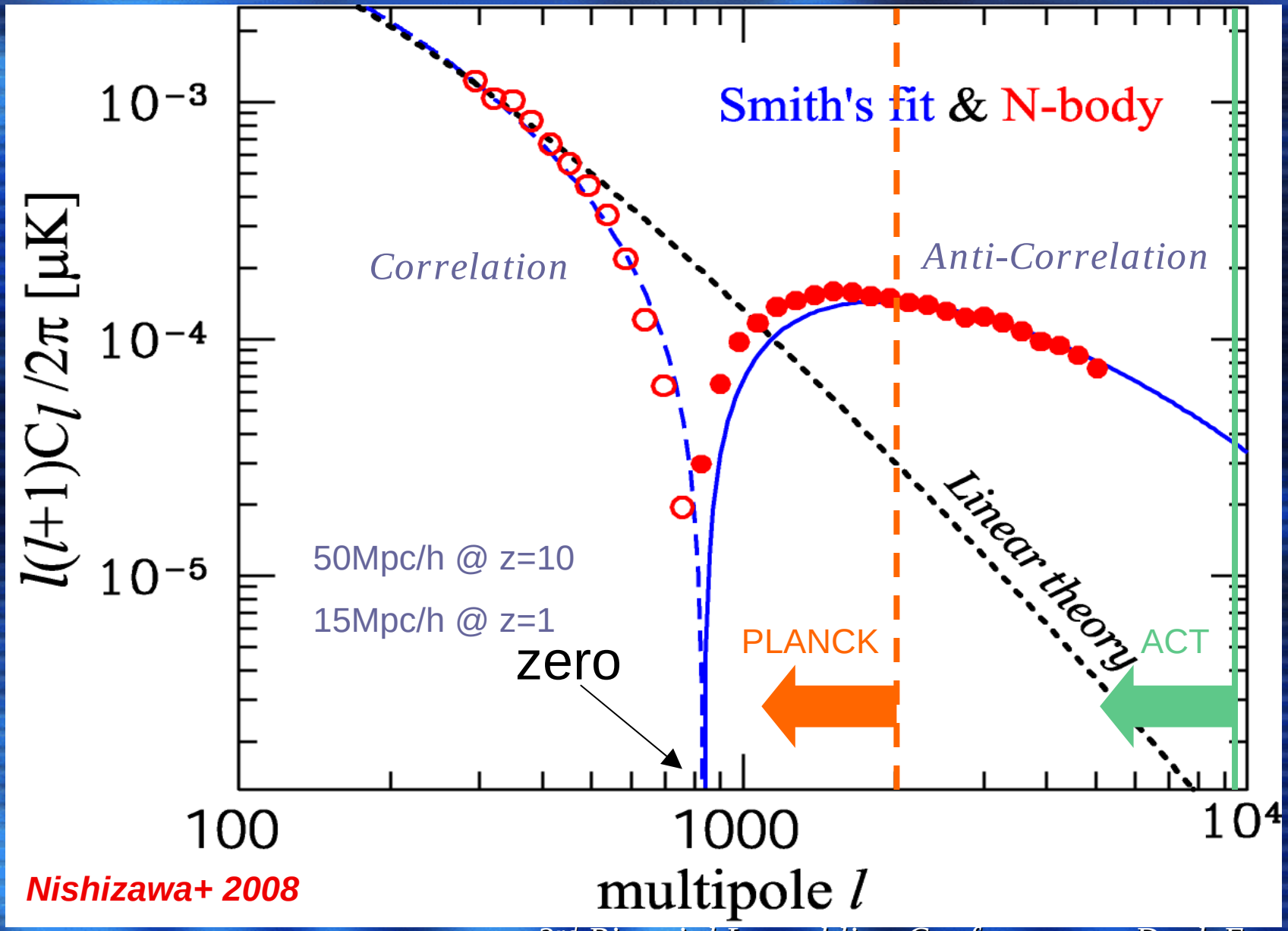
z_{range} = [10 - 0.01]

$N_{out} = 32 \times 3(z \pm \delta)$





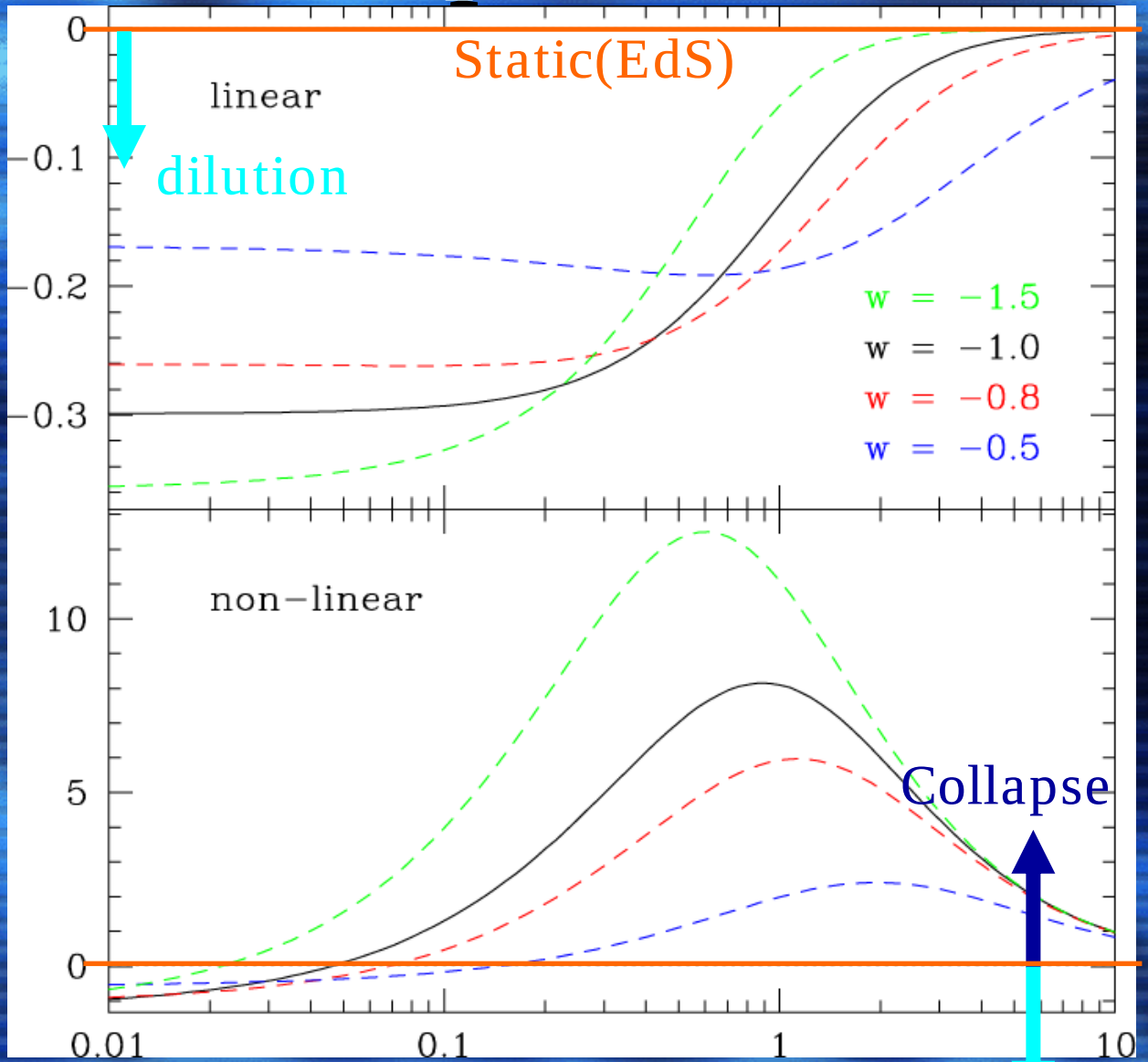
Result !!



CCAPS

Nishizawa+ 2008

Impact of w on $\langle \Phi\Phi' \rangle$



$$D^2(f-1)(1+z)^2$$

(linear PT)
Goto zero @ $\Omega_\Lambda=0$

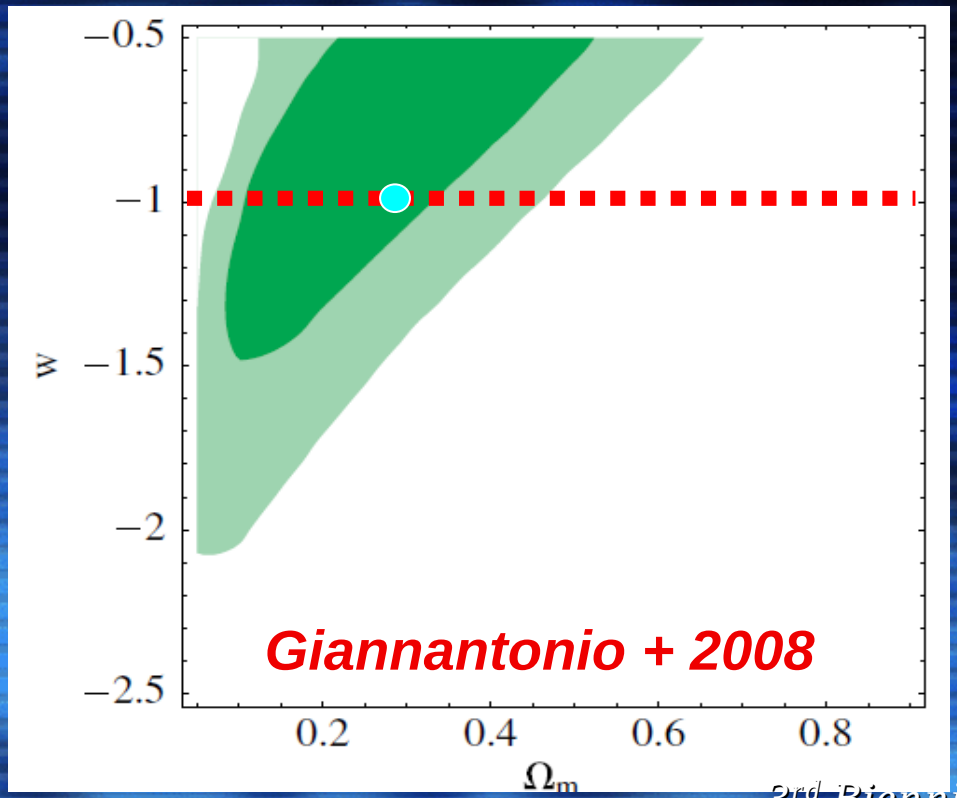
$$D^4(2f-1)H(1+z)^2$$

(3PT)
NL part
Goto zero @$\Omega_\Lambda\sim0.3$

Current Constraints from ISW

Correlating **multicolor** objects with **WMAP(3yr)**

(*Xray*(**HEAO**), *radio*(**NVSS**),
opt(**SDSS**:main,LRG,QSO),
IR(**2MASS**))

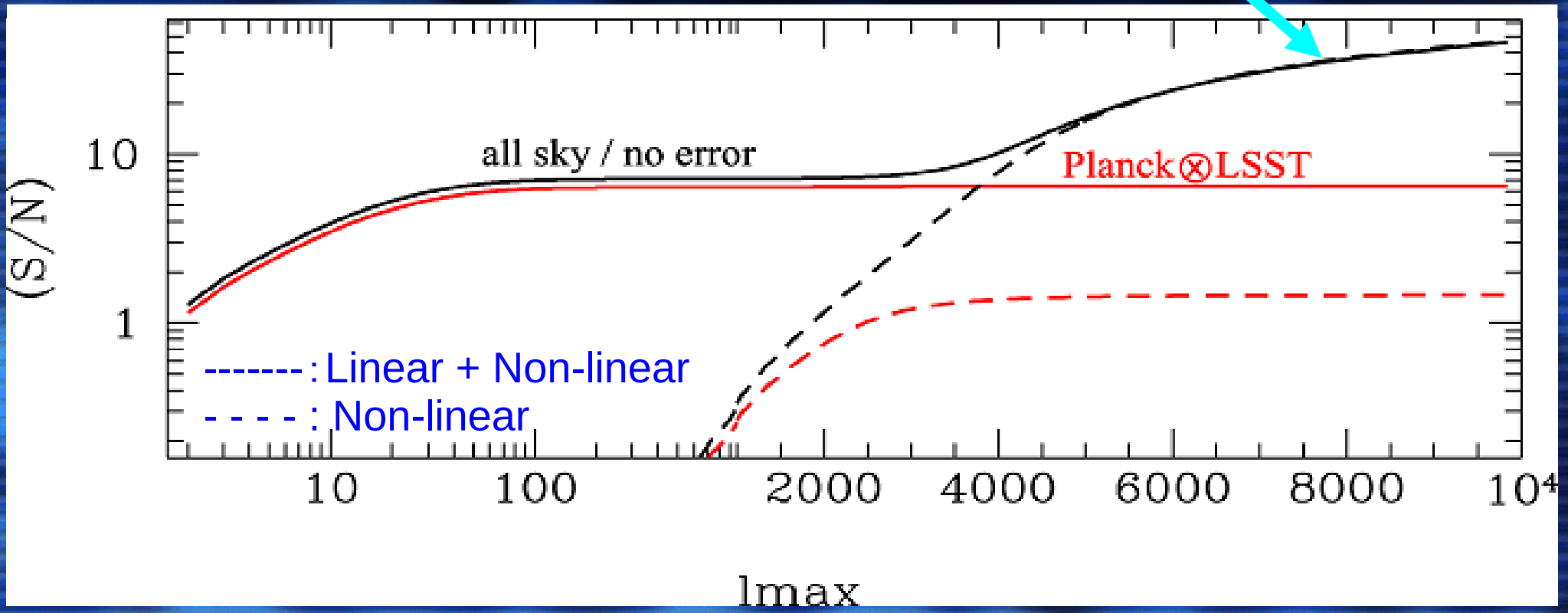


cosmological constant still survives

Detection of Φ'-κ

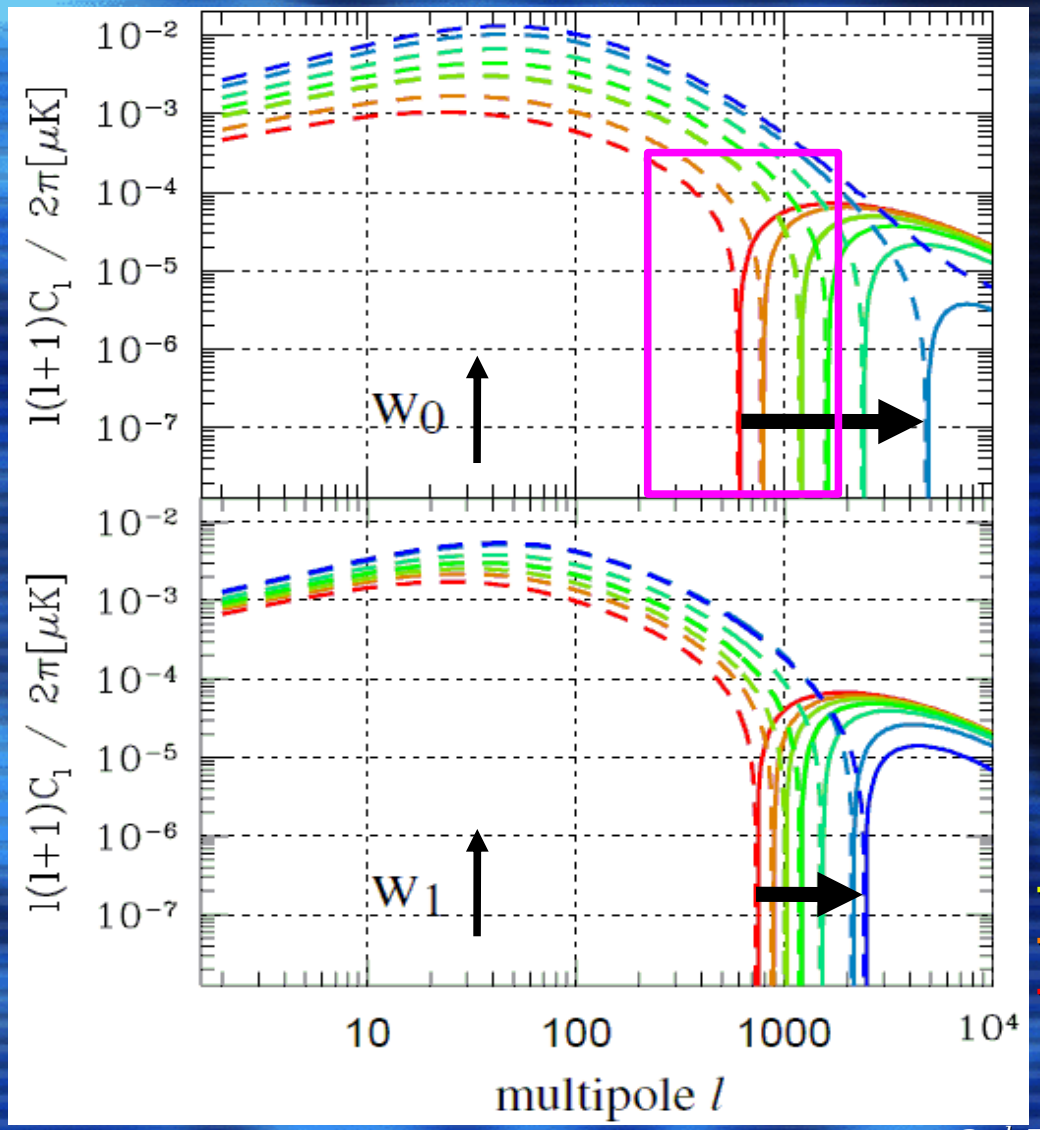
$$\left(\frac{S}{N}\right)^2 = \sum_{l=l\min}^{l\max} C_l^X \, Cov^{-1} C_l^X$$

$$Cov = \frac{C_l^X C_l^X + (C_l^{CMB} + N_l^{CMB})(C_l^\kappa + N_l^\kappa)}{f_{sky}(2l+1)}$$



Dependence on DE(Lin+NL)

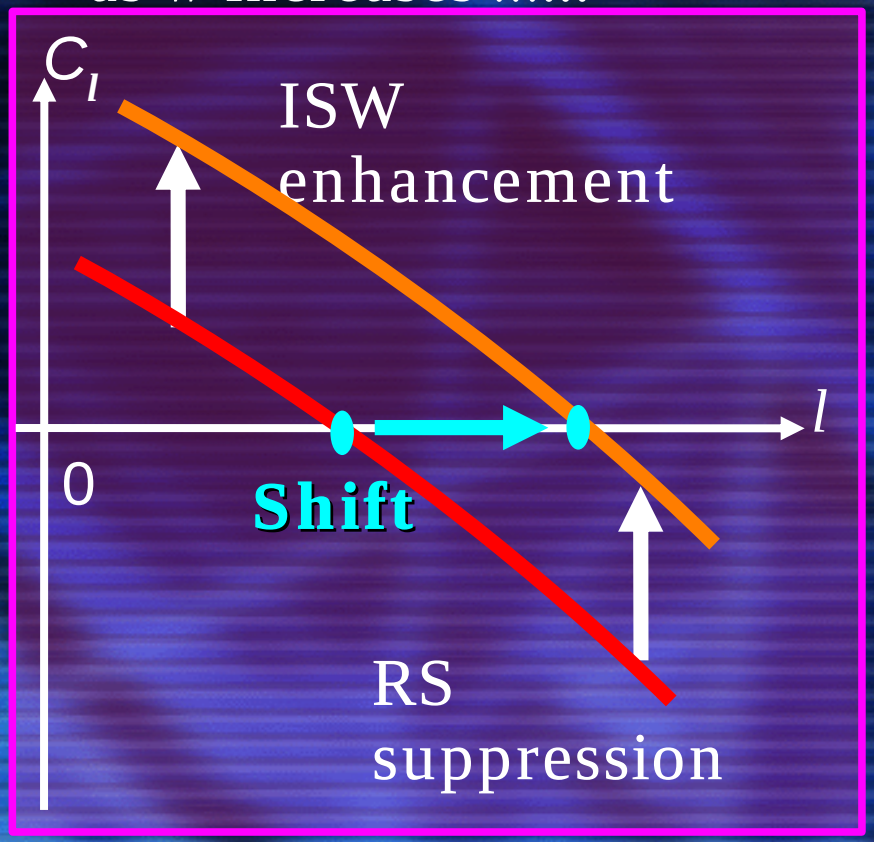
Equation of state of DE : $w \equiv p(z)/\rho(z) = w_0 + w_1(1\text{-}a)$



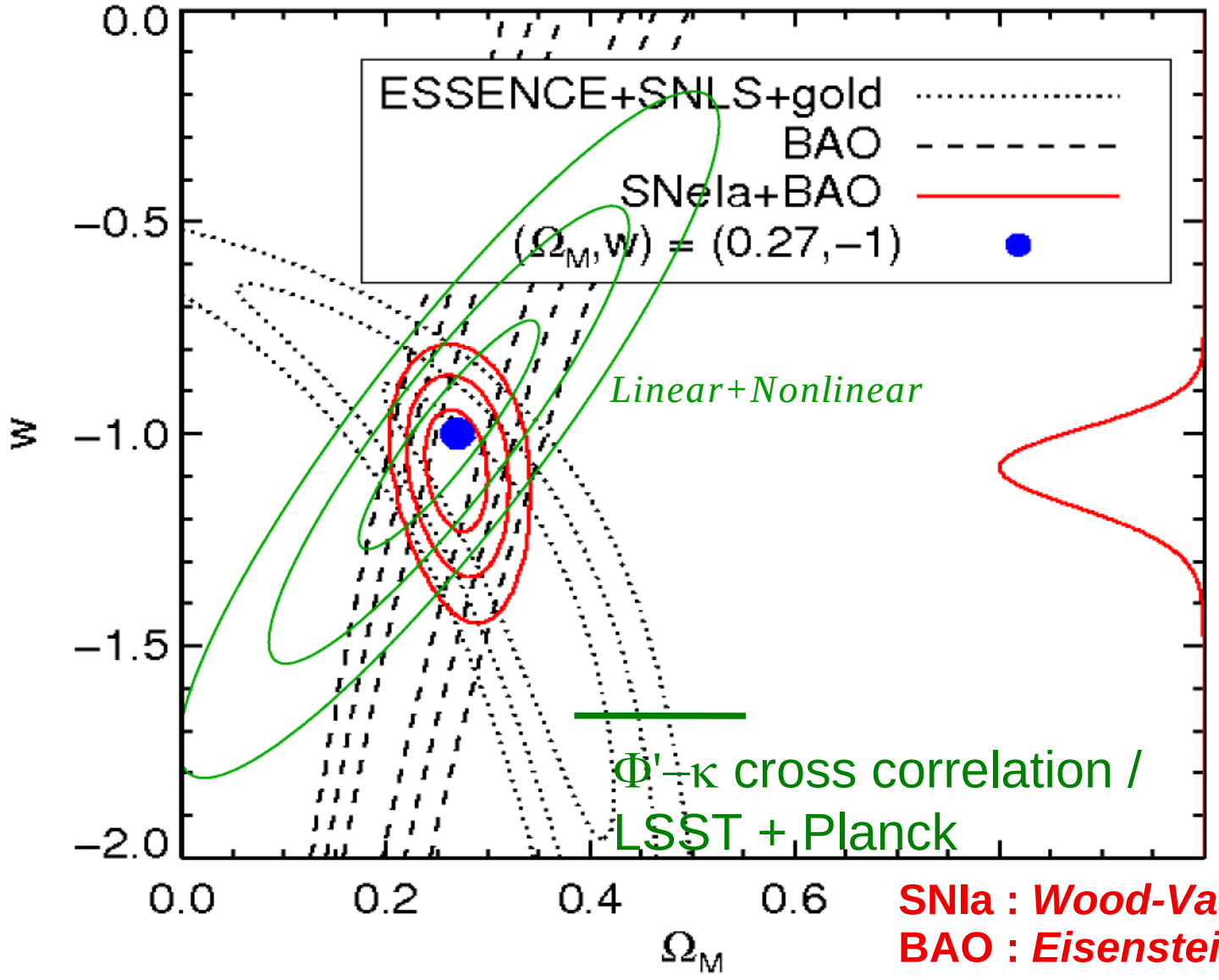
w_0: -0.1, -0.25, -0.5, -0.75, -1.0, -1.5, -2.0

w_1: 2.0, 1.0, 0.5, 0.0, -0.5, -1.0, -2.0

as w increases .....



Fisher forecast for Φ'–κ correlation



$\Omega_M + \Omega_\Lambda = 1$

SNIa : *Wood-Vasey+ 2007*
BAO : *Eisenstein+ 2005*

Energy

Conclusion

- We focus on the Cross-correlation btwn ISW/RS and WL to isolate ISW/RS effect from primary CMB temp. fluctuations.
- We compare 4 calculi of NL RS-WL correlation, 3PT, halo model, Smith's fitting and simulation. Fitting and N-body agree very well.
- Linear theory is widely used for the estimation of DE via ISW, however the NLity appears at $l>300$ we should consider about NLity for future high resolution observation.($l<2000$@Planck, $l<10^4$@ACT)
- ISW/RS-WL correlation has a zero point crossing scale ,$l\sim800$ at which the Hubble expansion balances with gravitational collapse.
- It is true that with alone, the DE constraint from ISW/RS-WL correlation is not so stringent while it's worth noting that the orientation of degeneracy btwn Ω_Λ and w differs from that via BAO/SNe.
- The systematic error from photo-z is also important for WL.