DARK ENERGY: MULTIPROBES ANALYSIS and CONSISTENCY CHECK

Main people involved: Charling TAO , ZHANG XinMin, André TILQUIN , QIAN Zuxuan , **ZHAO Gongbo** , **XIA Junqing** , FAN Zuhui , **SUN Lei,** Jean Marc VIREY , **LI Hong** , Zhu Zhonghong , Christian MARINONI , Jean Paul KNEIB, Stephanie JOUVEL, *QIN Bo* . *DENG Jinsong , CHAO Wu , ZHOU Xu , WANG Xiaofeng*

CPPM/CPT/IHEP/LAM/PKU/NAOC/Tsinghua U/Beijing Normal U. + collaborators

Outlook

- The cosmology group inside FCPPL
- Introduction to cosmology and dark energy
- The 4 main probes: principle
- Summary of our main papers
- Work in progress on probe combination
  - Frequentist and data grid
  - Consistency check
- Summary

Cosmology group in FCPPL

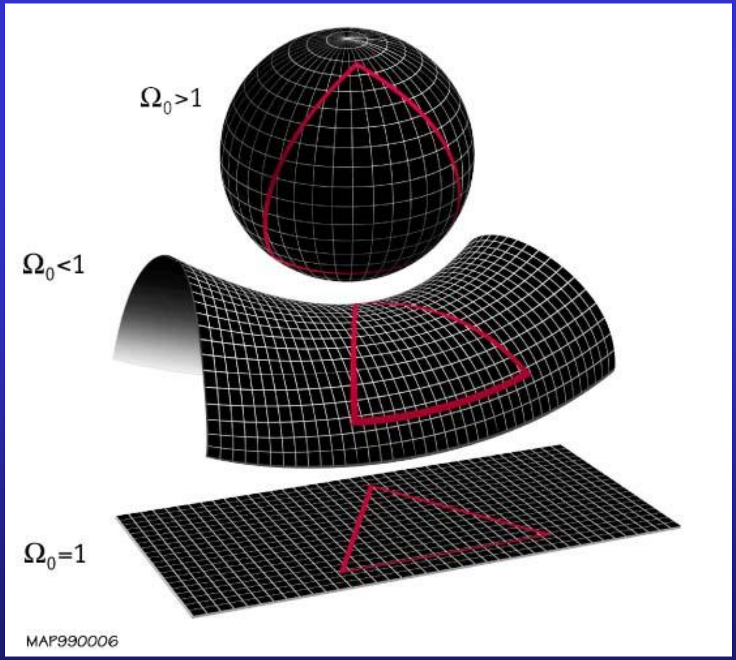
- Main topic is cosmology (dark energy/ dark matter)
  - Phenomenology
  - Data analysis : combinations and systematic studies
  - Datagrid: ESR and EUCHINA VO
  - SN
- 7 labs:
  - 5 in Beijing: IHEP+PKU+NAOC+Tsinghua U.+Beijing Normal U.
  - 2 in Marseille: CPPM+CPT
- One join thesis between CPPM and PKU: SUN Lei
- Some long term missions every year:
  - ½ year in CPPM : Sun Lei
  - 1 months in CPPM : Pr QIN Bo, DENG Jinsong
  - 3+2+2(1)+1 months in Beida and IHEP : Charling Tao, Zuxuan Qian and myself

Introduction to cosmology

Cosmology based on :

Cosmological principal :Homogenous and isotropic Universe

General relativity: $G_{\mu\nu}$ +☹$g_{\mu\nu}$ = $8\pi G T_{\mu\nu}$



Energy content: $\Omega = \rho/\rho_c$

Equation of state: $w(z)=p/\rho$

Matter (Ω_m) :	w =0
Radiation (Ω_r) :	w = 1/3
Cosmological cste (Ω_Λ):	w=-1
Dark energy (Ω_X) :	w(z)

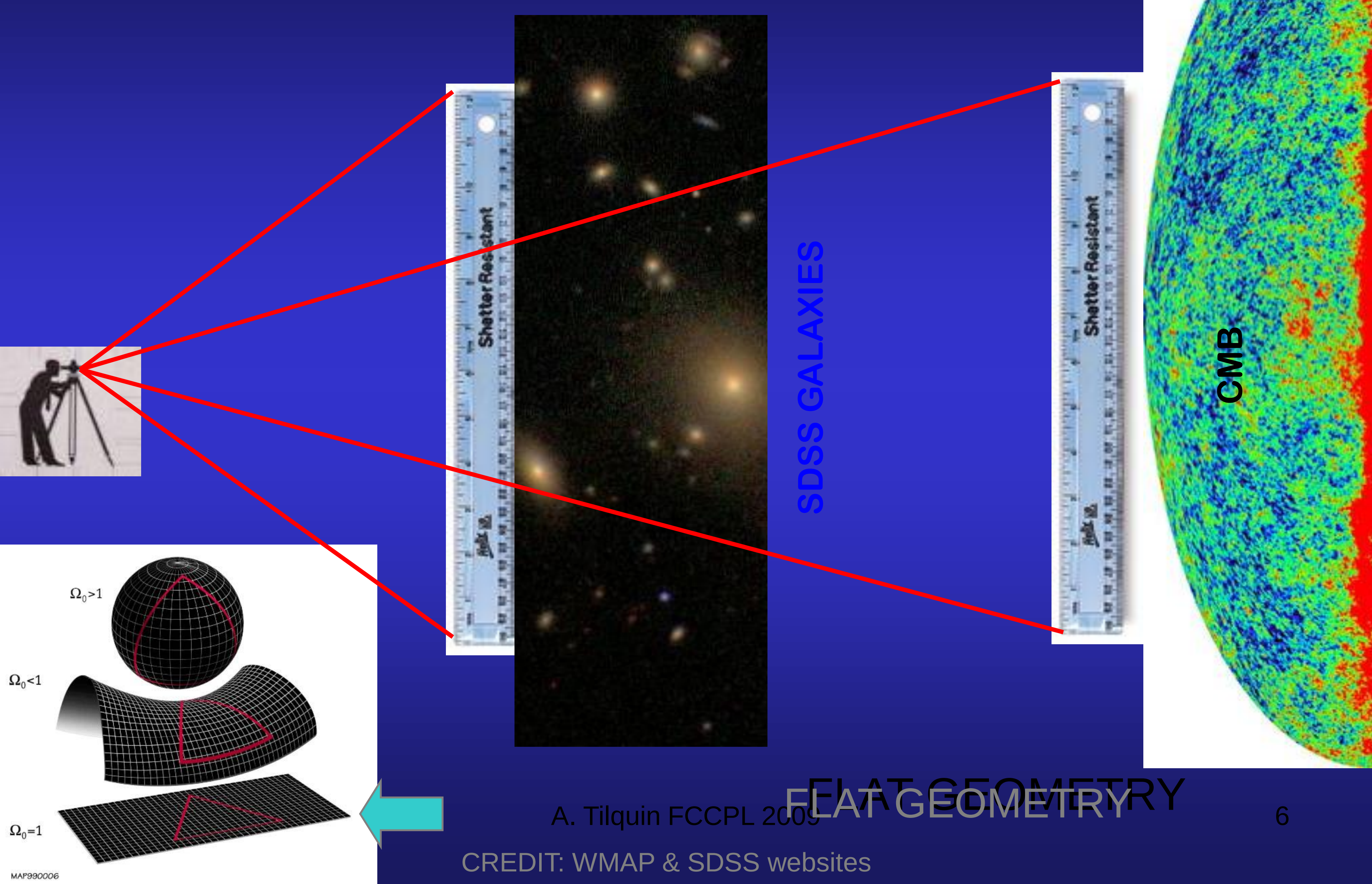
$$\Omega_T = \Omega_m + \Omega_r + \Omega_X$$

Few words about Dark Energy

- 70% of dark energy in our Universe
- Expansion of Universe is accelerating:
  - Left hand side:
    - ☹ is a new constant of nature
    - It acts like a long range repulsive force : $F_{☹}$✪ -☹r
  - Right hand side
    - New field(s) with negative pressure : w = p/❒<0
    - Characterized by equation of state:

$$w(z) = w_0+w_a.z/(1+z)$$

Looking back in time in the Universe



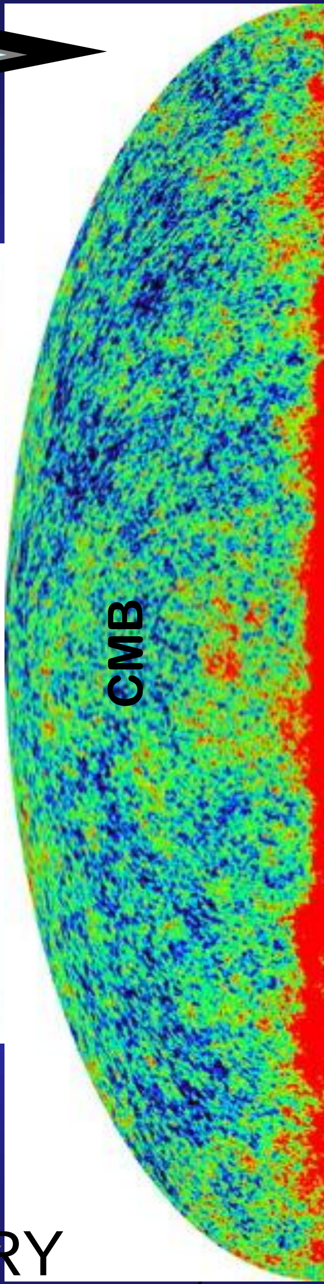
FLAT GEOMETRY

FLAT GEOMETRY

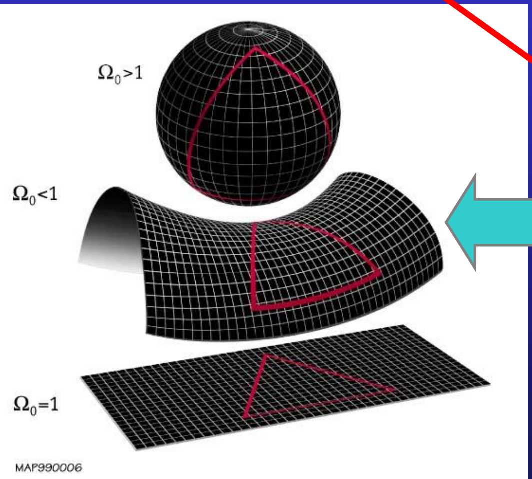
CREDIT: WMAP & SDSS websites

Looking back in time in the Universe

SDSS GALAXIES



CMB



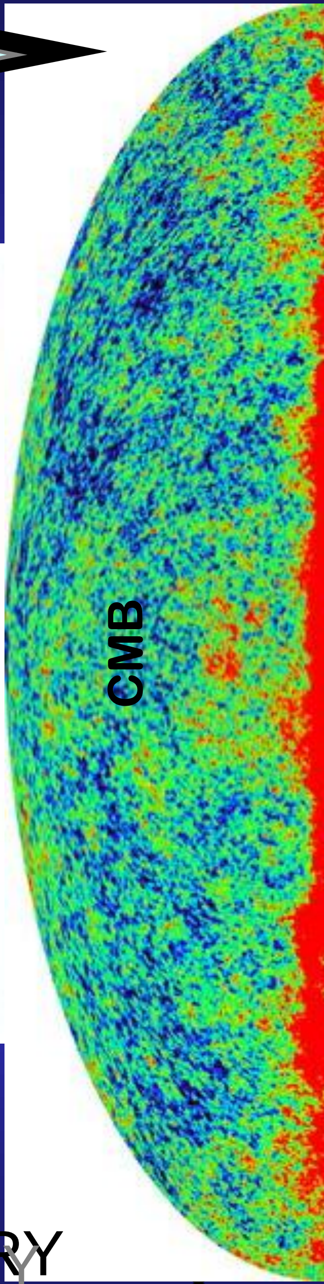
FLAT GEOMETRY

OPEN GEOMETRY

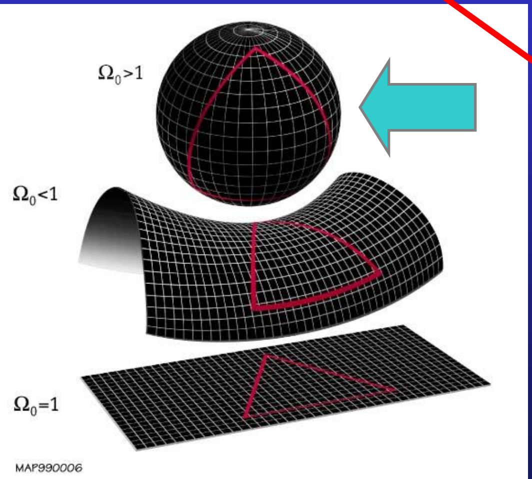
CREDIT: WMAP & SDSS websites

Looking back in time in the Universe

SDSS GALAXIES



CMB

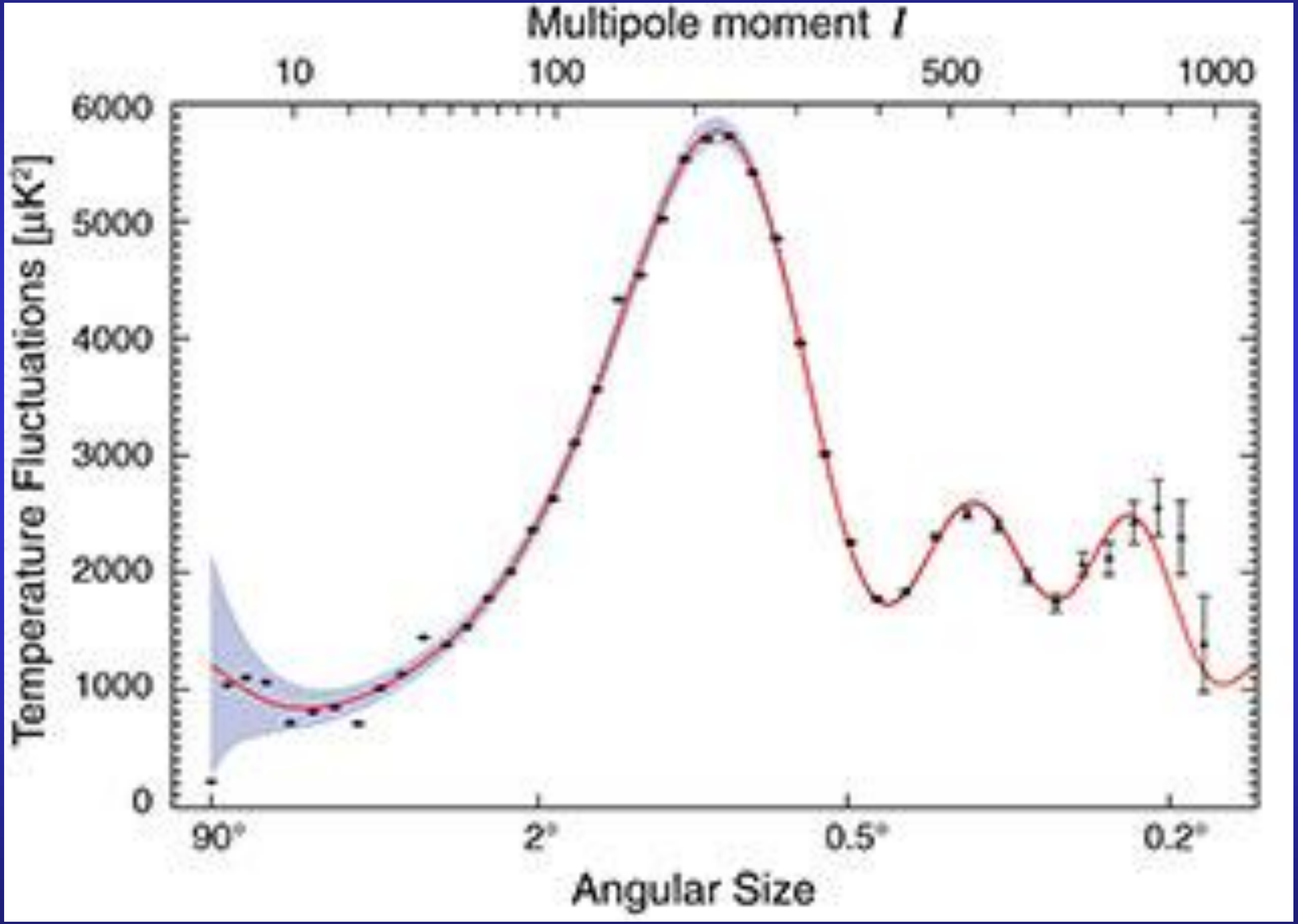


FLAT GEOMETRY

CLOSED GEOMETRY

CREDIT: WMAP & SDSS websites

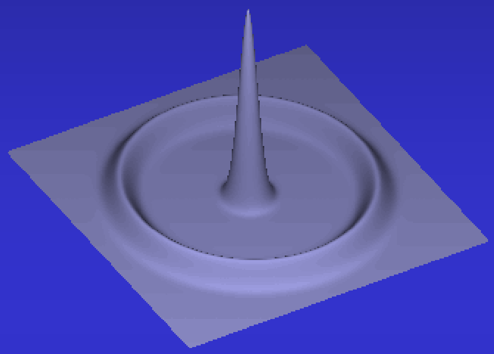
Temperature correlation

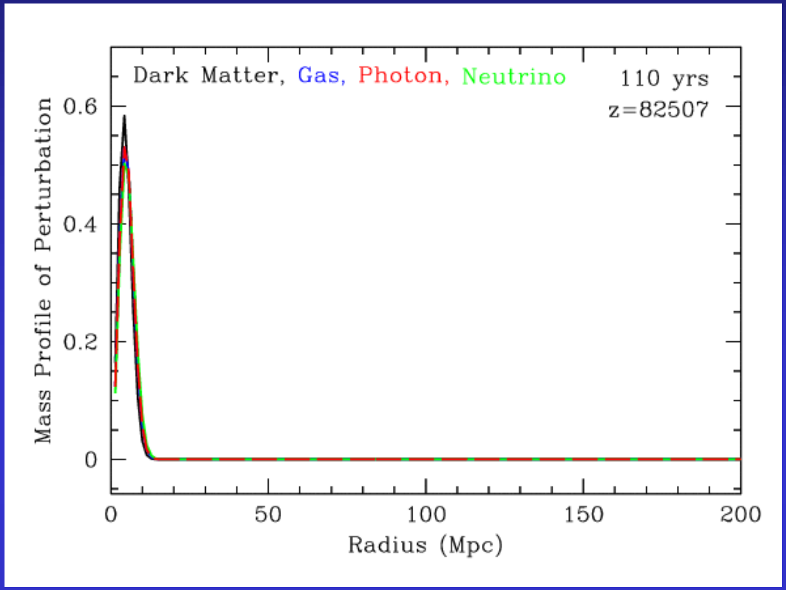


Baryonic oscillations from last scale structures

Wayne Hu

D. Eisenstein/CMBFast





Weak leftover from oscillations have been observed in galaxy distributions. For a flat Universe, one expects:

$$\lambda_s = \frac{1}{H_0 \Omega_m^{1/2}} \int_0^{a_r} \frac{c_s}{(a + a_{eq})^{1/2}} da \quad = 150 \text{ Mpc}$$

Peebles & Yu 1970; Sunyaev & Zel'dovich 1970

Confirmed at 3-4σ by 2dF (Cole et al) and SDSS (Eisenstein et al) 2005

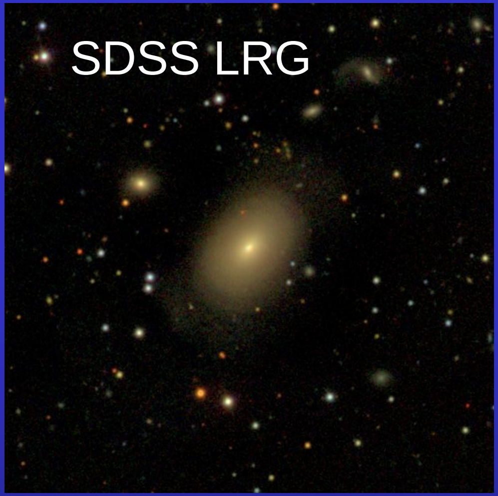
Baryonic Oscillations: SDSS Luminous Red Galaxies Correlations

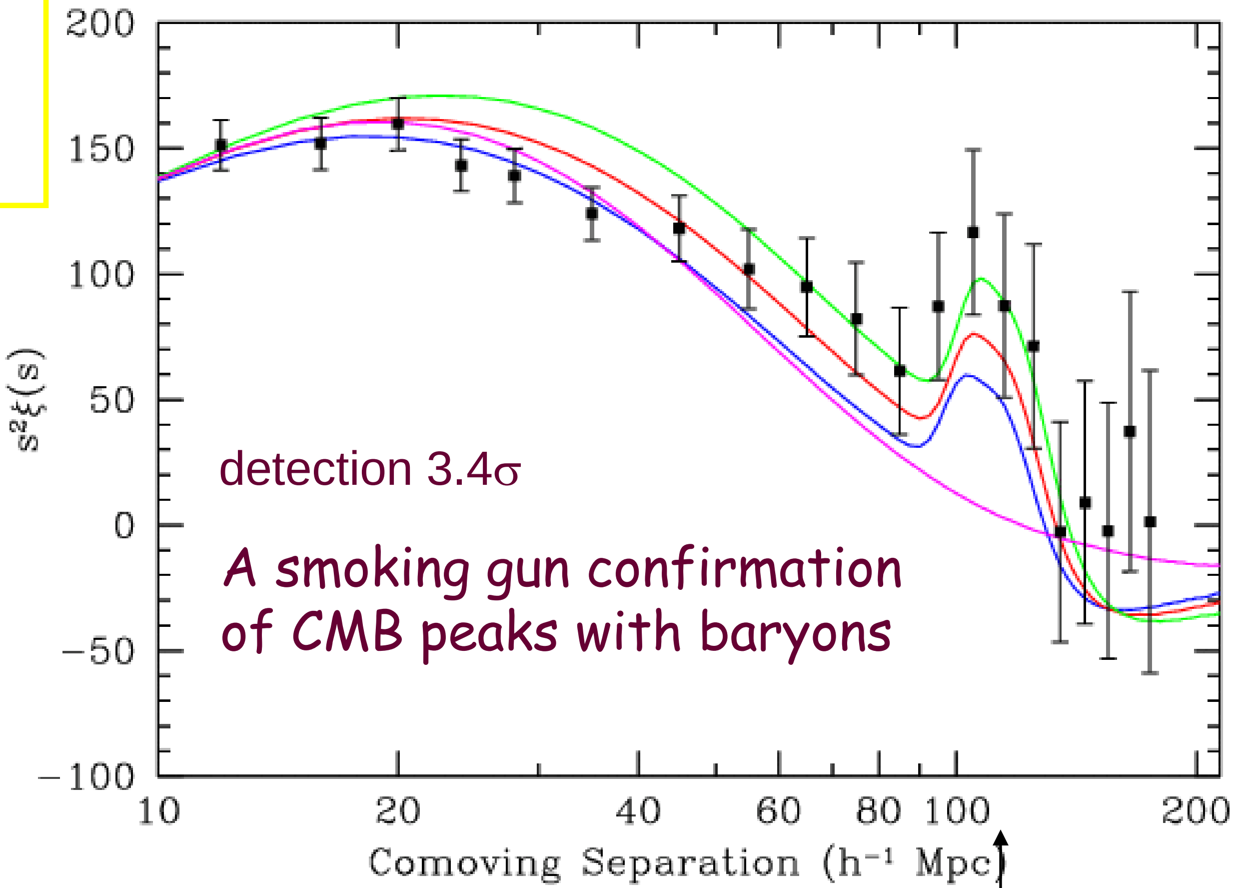
Eisenstein et al. 2005

46,700 LRGs 3816 deg^2

$0.16<z<0.47$

$0.72h^{-3}Gpc^3$



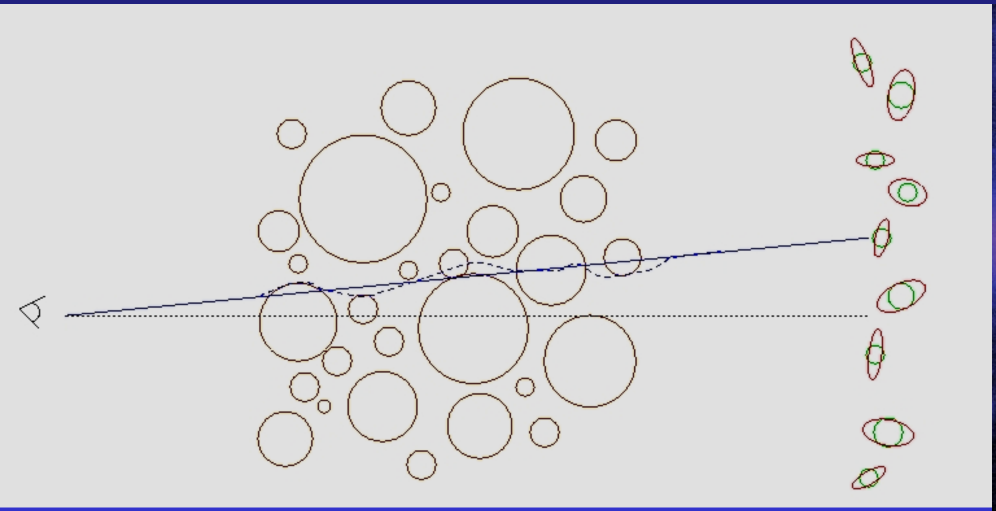


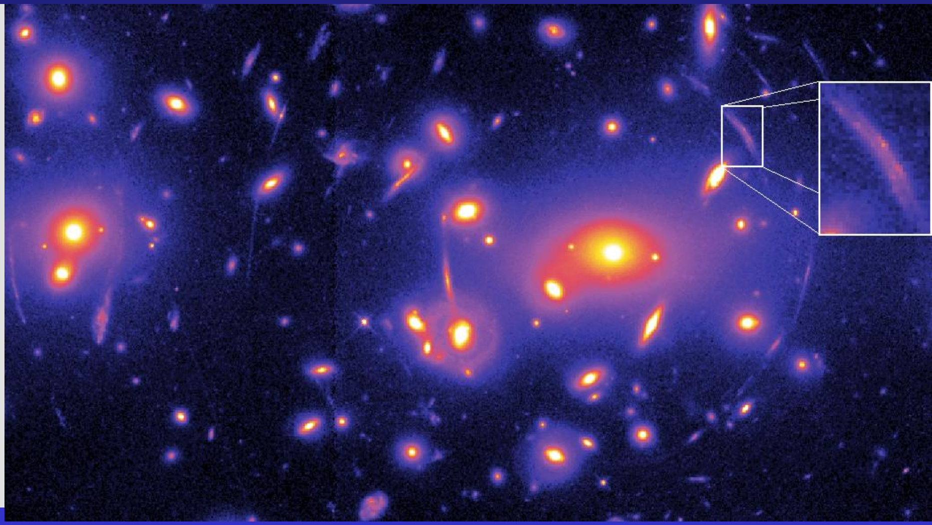
For a flat Universe

$$\lambda_s = \frac{1}{H_0 \Omega_m^{1/2}} \int_0^{a_r} \frac{c_s}{(a + a_{eq})^{1/2}} da \quad = 150 \text{ Mpc}$$

Precise Determination Ω_M

"Weak Lensing"





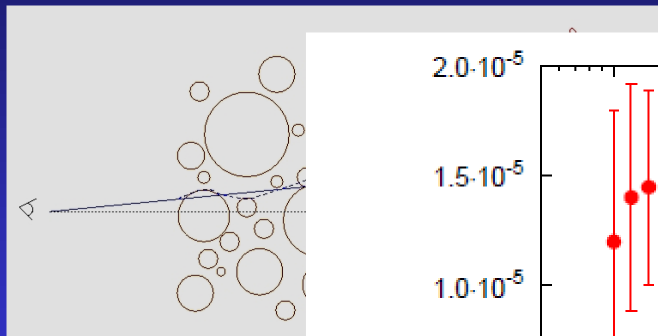
Deformation matrix:

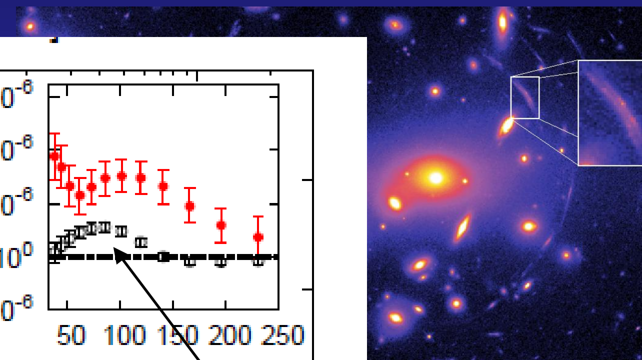
$$\Psi_{ij} = \frac{\partial \delta\theta_i}{\partial \theta_j} = \int dz\, g(z) \frac{\partial^2 \Phi}{\partial\theta_i \partial\theta_j}$$

→ Direct measurement of mass distribution

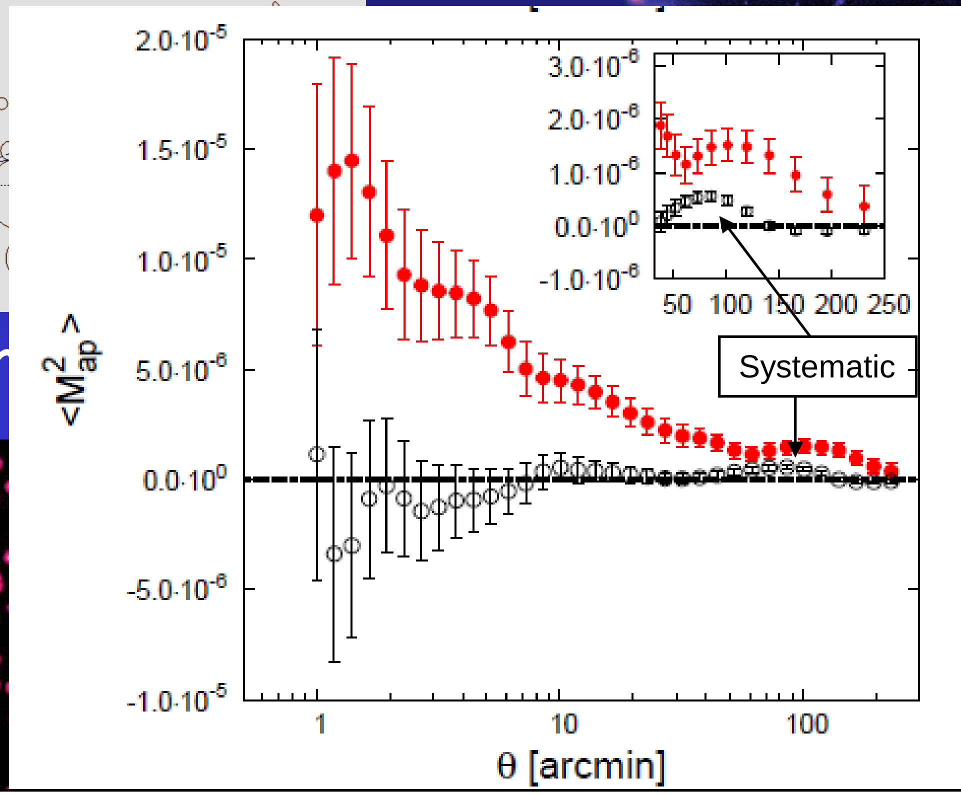
→ Other methods measure distribution of light

“Weak Lensing”

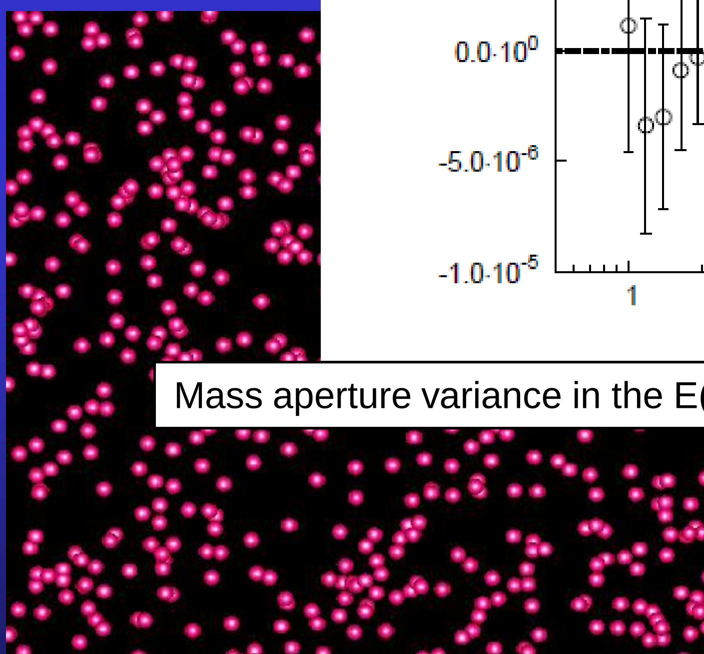


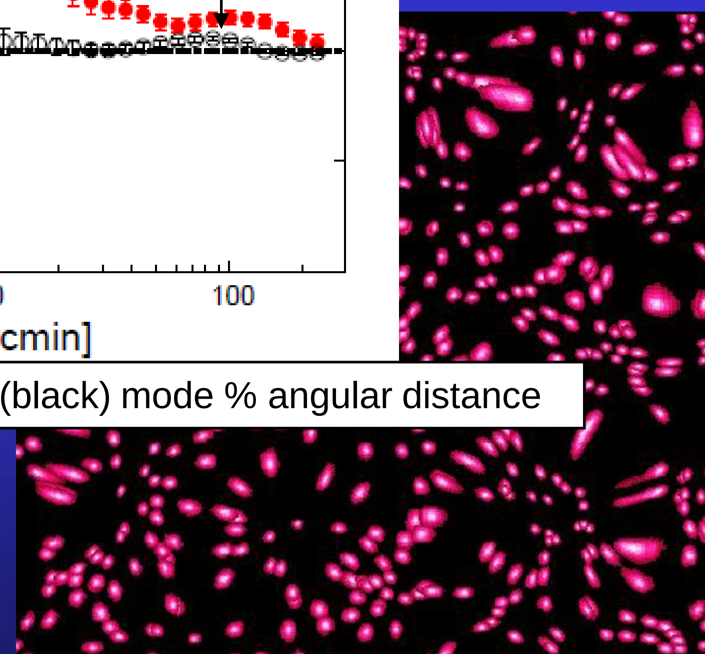


Distorsion



Mass aperture variance in the E(red) and B(black) mode % angular distance

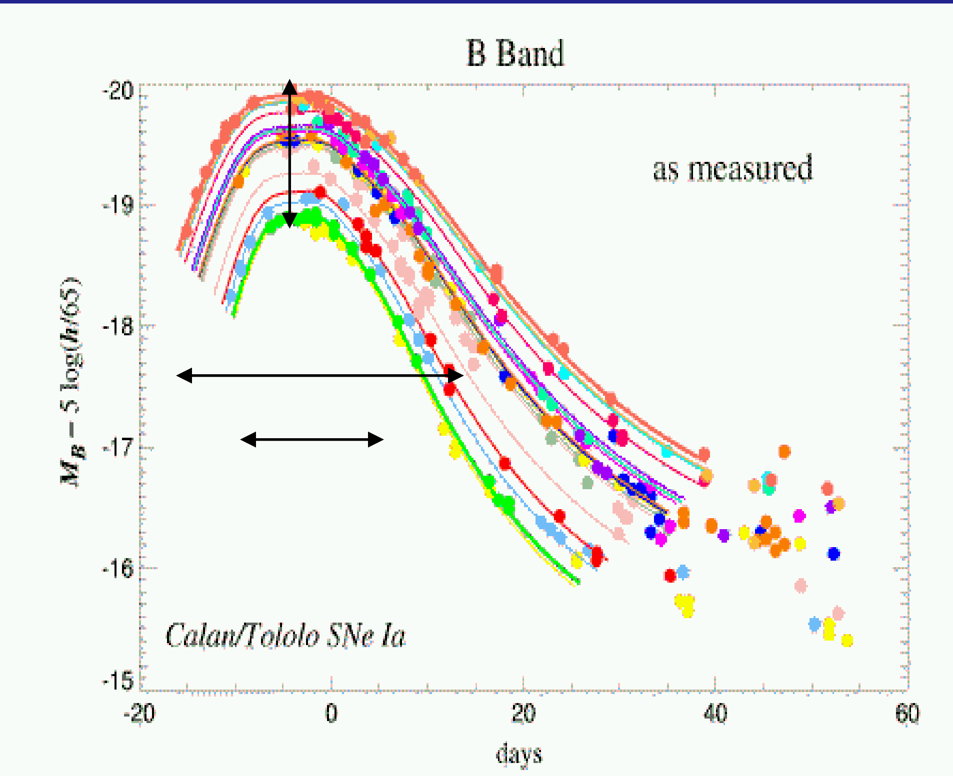


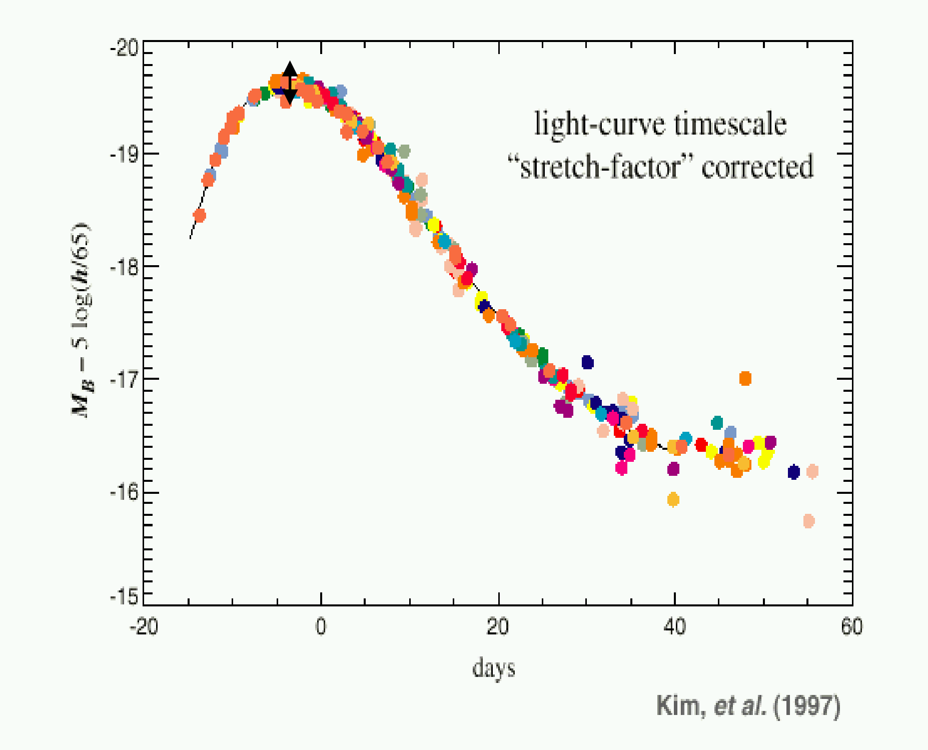


without lensing

Lensing effect

SN 1a are not standard candle but are standardisable to some level





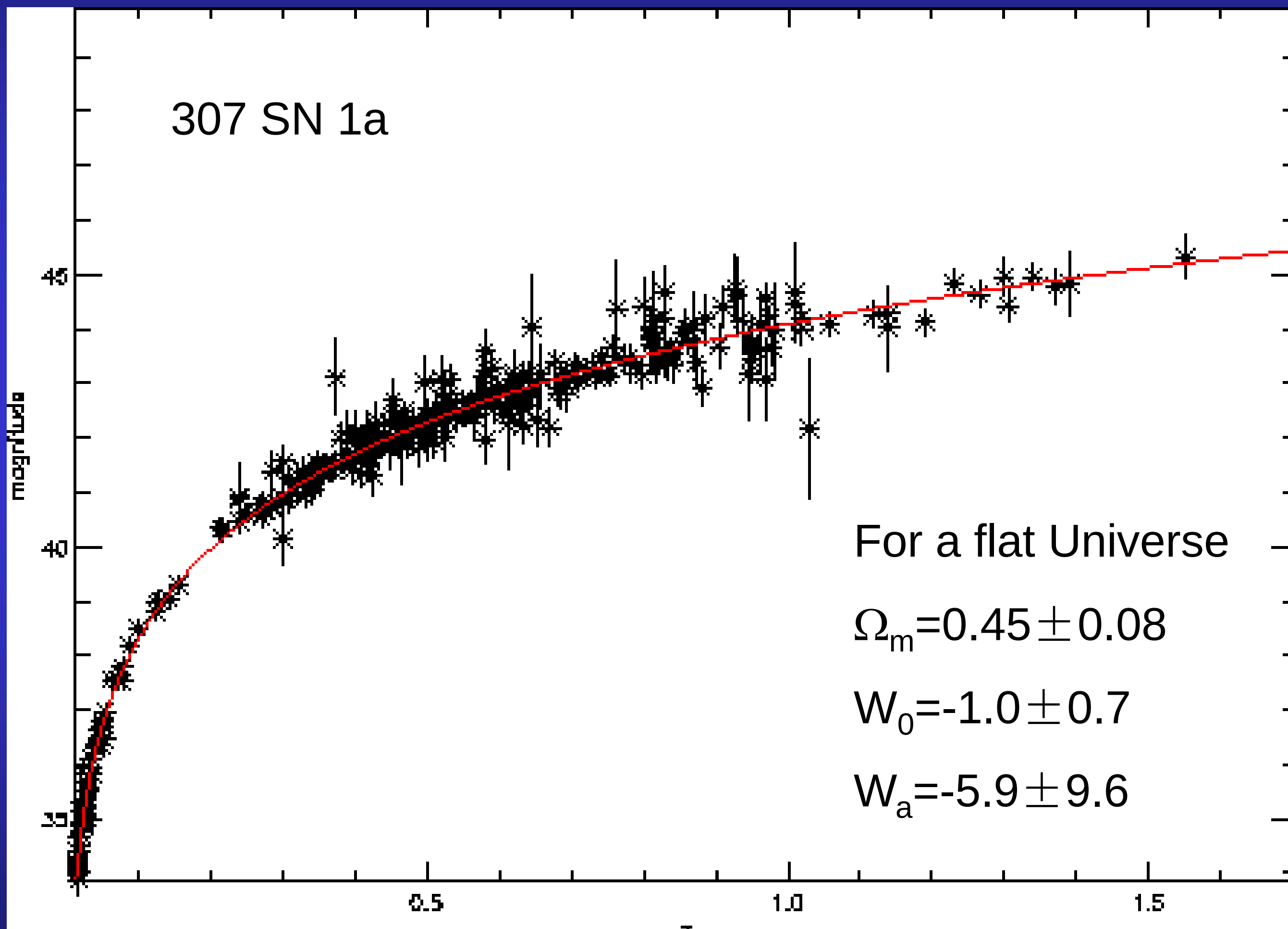
before: m_B

after, eg, stretch : correction

$m_{Bcor} = m_B - \alpha\,(s-1)$

Direct measurement of the scale factor with distance: Hubble diagram

Hubble diagram: Union data set



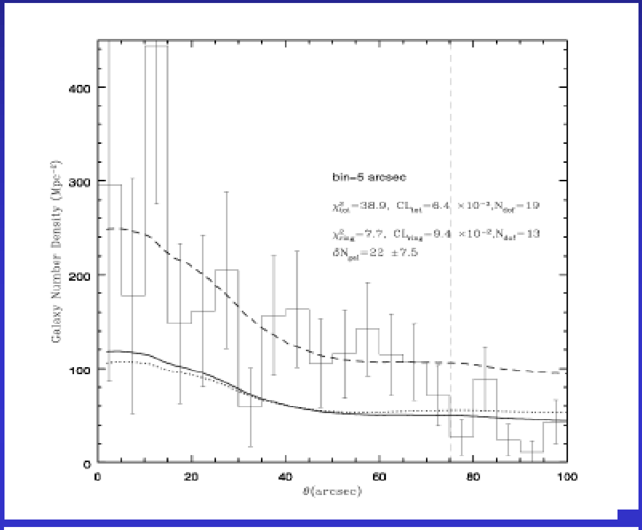
"Galaxy Distribution as a Probe of the Ringlike Dark Matter Structure in the Galaxy Cluster CL 0024+17"

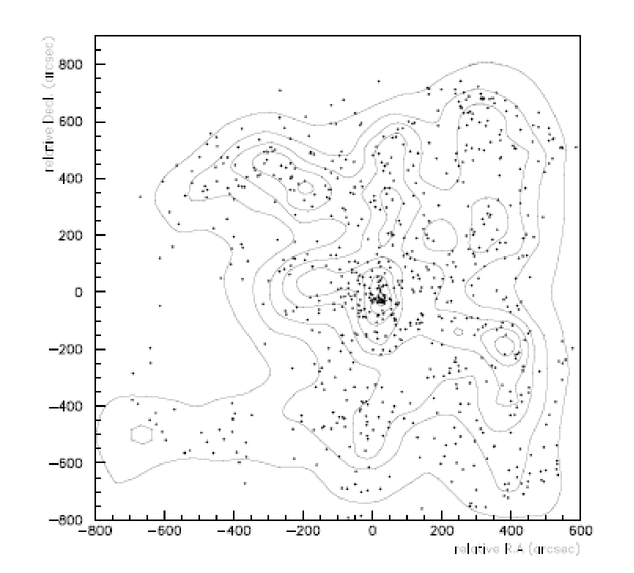
Bo Qin, Huan-Uan Shan,Andre Tilquin

- By using weak and strong lensing, dark matter density profile has been reconstructed and shows a ring like structure (Jee et al. 2007)

- Our paper shows that galaxies do not exhibit such a structure as expected.

- Using a simulation technique taking into account the completeness of galaxies sample from Czoske et al (2007) catalog exclude such a structure at a 99.6% confidence level.





“Catastrophic Photo-z Errors and the Dark Energy Parameter Estimates with Cosmic Shear”

Lei Sun, Zu-Hui-Fan, Charling Tao, J-P Kneib, Stephanie Jouvel, Andre Tilquin

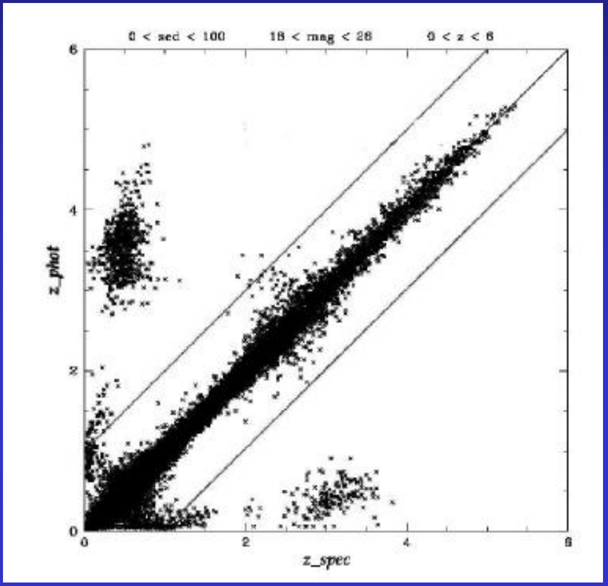
- Future large WL survey need a good measurement of galaxies redshift: use of photometric redshift estimate (9 filters)

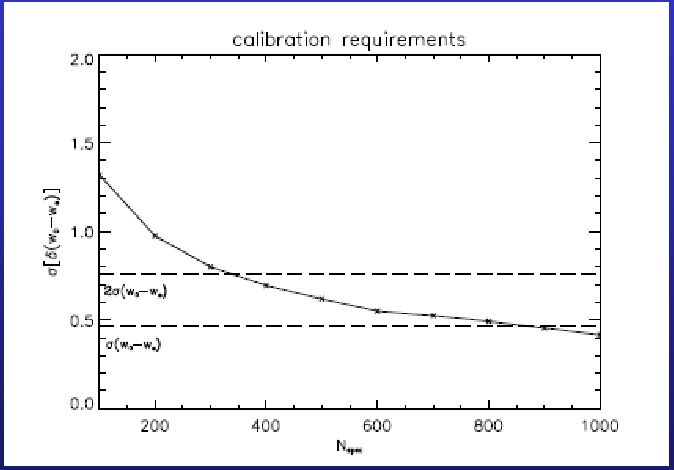
- Mis-identification of the Lyman(1200) and 4000 Å break leads to catastrophic error.

- A f_{cata} of 1% leads to systematic biases on w_0 and w_a

- In this paper we estimate the number of galaxies spectra $3<z_{phot}<4$ needed to calibrate the catastrophic contamination (f_{cata})

- For a survey of 1000 deg^2 (10000 deg^2) the number of spectra is 800 (8000).

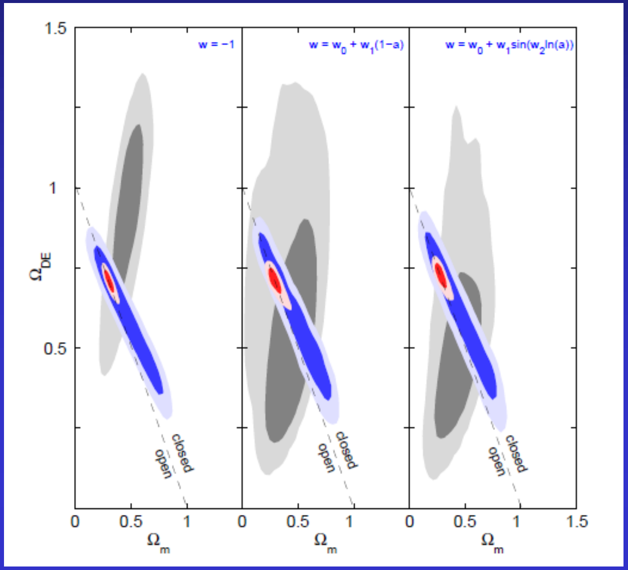


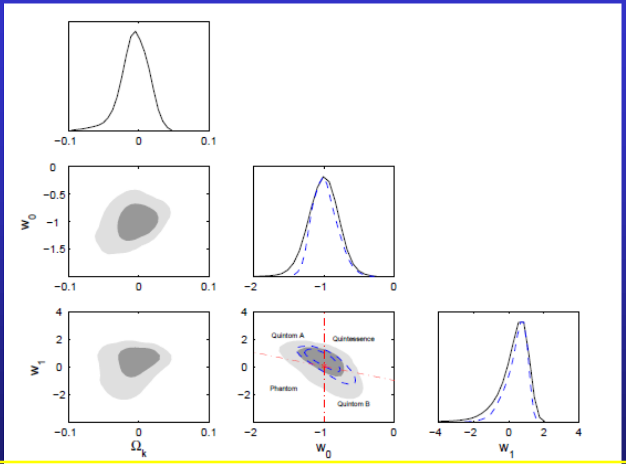


"Probing for Dynamics of Dark Energy and Curvature of Universe with Latest Cosmological Observations"

Gong-Bo Zhao, Jun-Qing Xia, Hong Li, Charling Tao, Jen-Marc Virey, Zong-Hong Zhu, Ximmin Zhang

- Try to constraint in the same time curvature and dark energy
- Using WMAP 3 years, Large Scale Structure and 182 Supernova: MCMC and dark energy perturbation: $|\Omega_k|<0.06$ at 2σ
- Assuming a flat Universe doesn't change drastically equation of state parameters measurement:
  - Non flat:: $w_0 = -1.06^{+0.44}_{-0.39}$; $w_a = 0.94^{+0.28}_{-2.93}$
  - Flat: $w_0 = -1.15^{+0.54}_{-0.12}$; $w_a = 1.02^{+0.15}_{-2.10}$

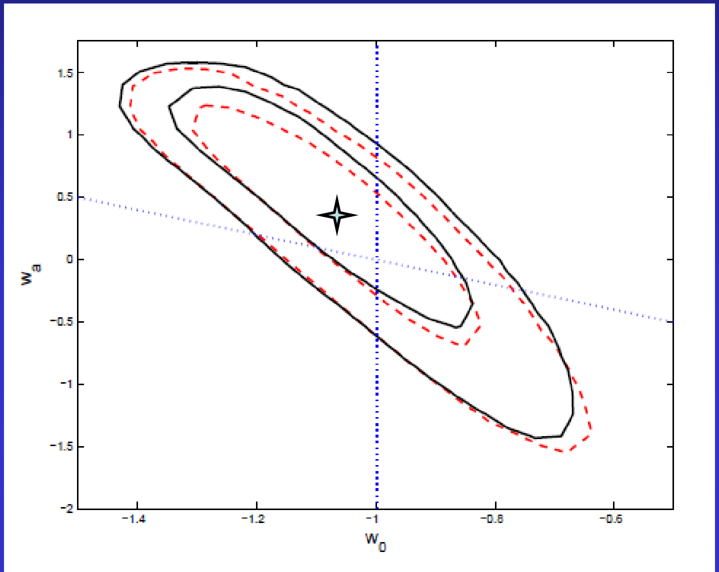




Results confirmed by simulation studies from Marseille groups (CPPM+CPT): "On the determination of curvature and dynamical Dark Energy » by J.-M. Virey, D. Talon-Esmieu, A. Ealet, P. Taxil, A. Tilquin

Constraining Cosmological Parameters with Observational Data Including Weak Lensing Effects

Hong Li, Jie Liu, Jun-Qing Xia, Zu-Hui Fan, Charling Tao, Andre Tilquin, Xinmin Zhang

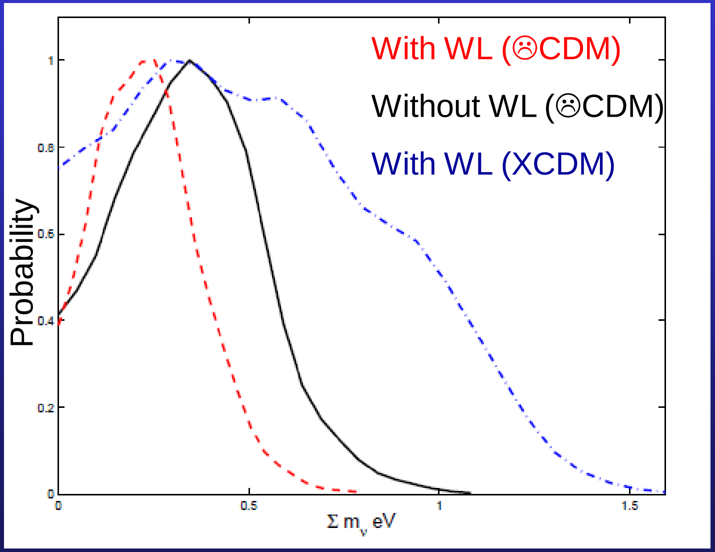


- Study of cosmological implications of the 100 deg^2 Weak Lensing Surveys (CFH,RCS,Virmos-Descart, GaBoDS)

- Combined with WMAP5, BAO (SDSS) and Union SN set (307 Sn z<1.7). MCMC method+DE perturbation.

- Some improvement adding weak lensing (red dashed) on equation of state. Minimum value slightly in agreement with Quitom model (-1.06,0.38)

- Improvement of 0.2 eV on the total neutrino mass:
  - ♦m▪<0.47eV(95%CL) for ☹CDM
  - ♦m▪<1.11eV(95%CL) for XCDM



Work in progress about full combination

- Different statistical approach
  - Frequentist statistic
  - Use of datagrid: ESR and EUCHINA
- A little bit larger weak lensing survey
  - 135 $degre^2$
- Exploring all possible combinations for consistency check and systematic
  - Dark energy perturbation
  - SN evolution and bias

Which statistic: Freqentist

- Statistic based on the log likelihood: $\chi^2(\Omega_i, w_0, w_a, \ldots)$
- Minimum using the gradient method: ☆χ^2/☆Ω_i=0

  Iterative numerical resolution:

$$\left(\Omega_i - \Omega_i^o\right) = -\left(\left.\frac{\partial^2 \chi^2}{\partial \Omega_k \partial \Omega_i}\right|_{\Omega_k^o}\right)^{-1} \left.\frac{\partial \chi^2}{\partial \Omega_k}\right|_{\Omega_k^o}$$

- Contour: Solving the equation $\chi^2_m = \chi^2_{min} + s^2$

  Marginalization obtained by minimization:

  $$\chi^2_m(w_0, w_a) = \chi^2_{min}(\Omega_i \mid w_0, w_a)$$

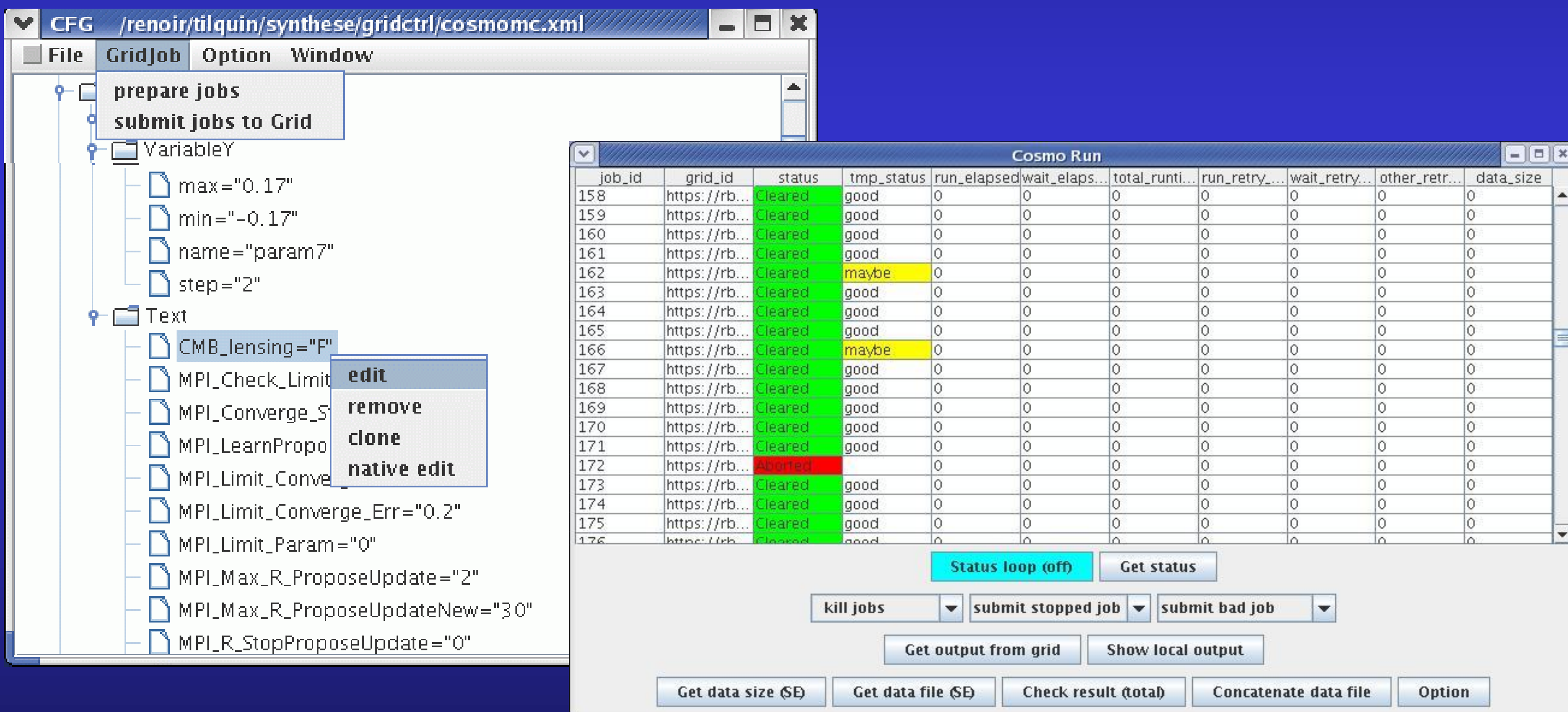
  The contour is constructed by minimizing χ^2 over Ω_I on a grid of points in w_0, w_a (minimum 20*20). Iso-χ^2 are constructed using interpolation.

Because we are using full simulation (2 mn of CPU to compute a χ^2 with cmbeasy), each contour is 1-2 years of computing.

=> Datagrid: ESR and EUCHINA

EGEE graphical interfaces

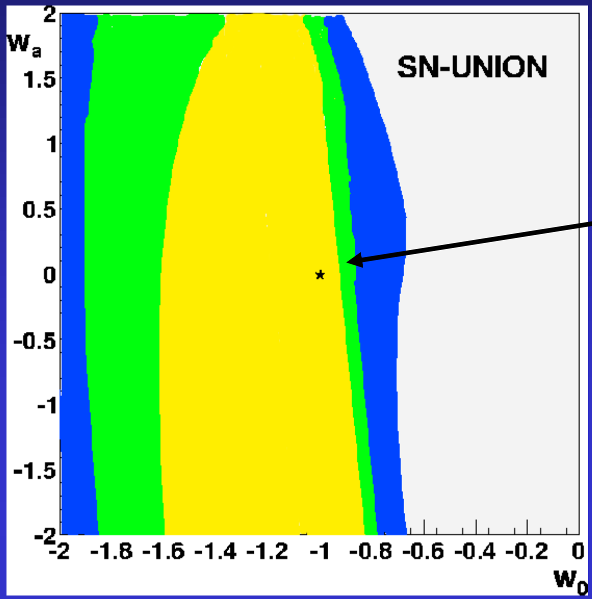
- 2 graphical interfaces has been developed to construct, submit and control jobs.: Thanks to Zuxuan Qian (CPPM) who wrote these 2 interfaces and installed datagrid for ATLAS in IHEP and PKU.

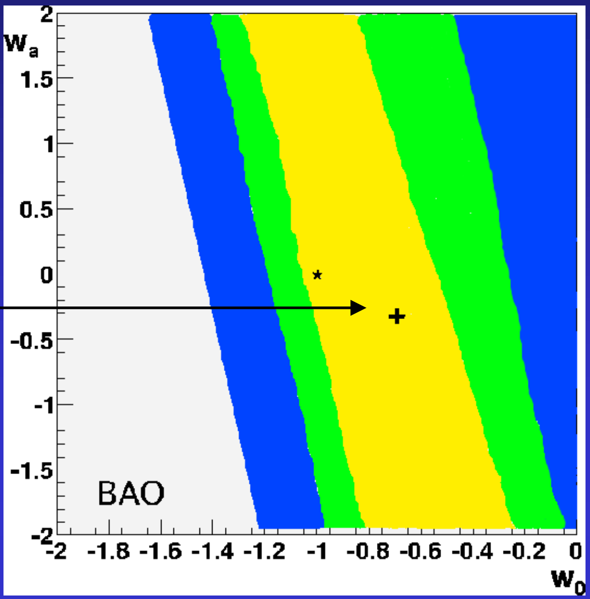


Combinations summary:

- Use:
  - WMAP 5 years
  - BAO Eisentein 2005
  - Weak Lensing (4 surveys, 132 square degree)
  - Union SN data set : 307 SN from z = 0 to 1.55
- Fitted parameters:
  - Ω_b, Ω_{CDM}, h, n_s, τ, σ_8,bao_{bias},m_s, w_0, w_a
  - Flat Univers
  - No dark energy perturbation yet
- About 12 years of computing on a single CPU!

w_0,w_a individual contour (Ω_T=1)





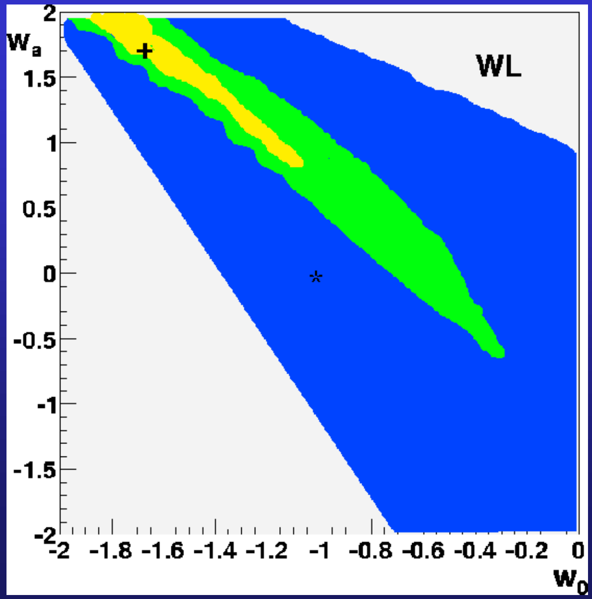
☹CDM

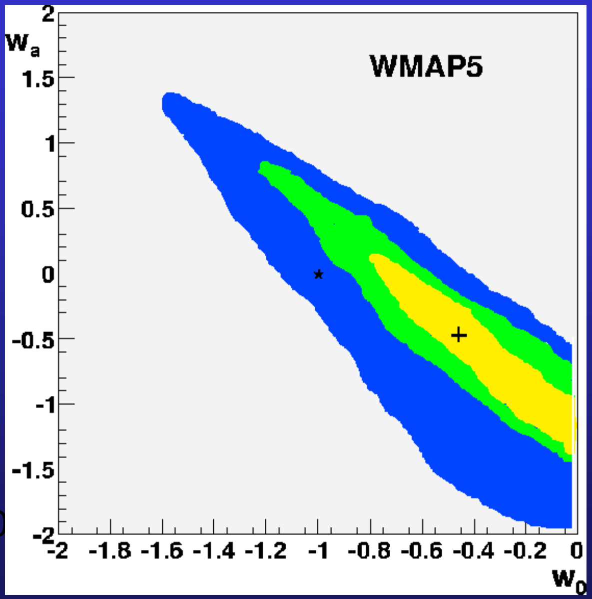
Min.

39% CL

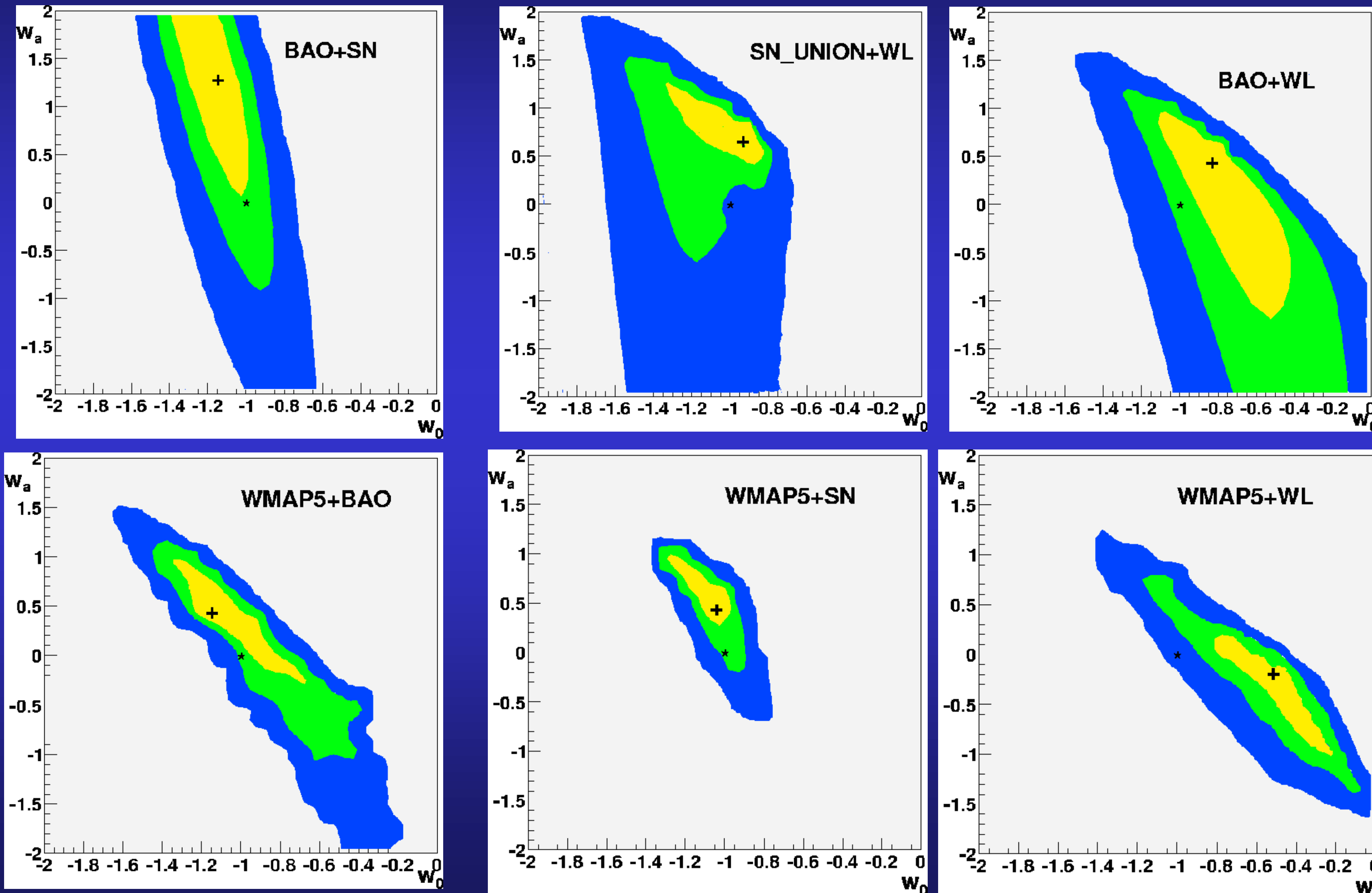
68% CL

95% CL

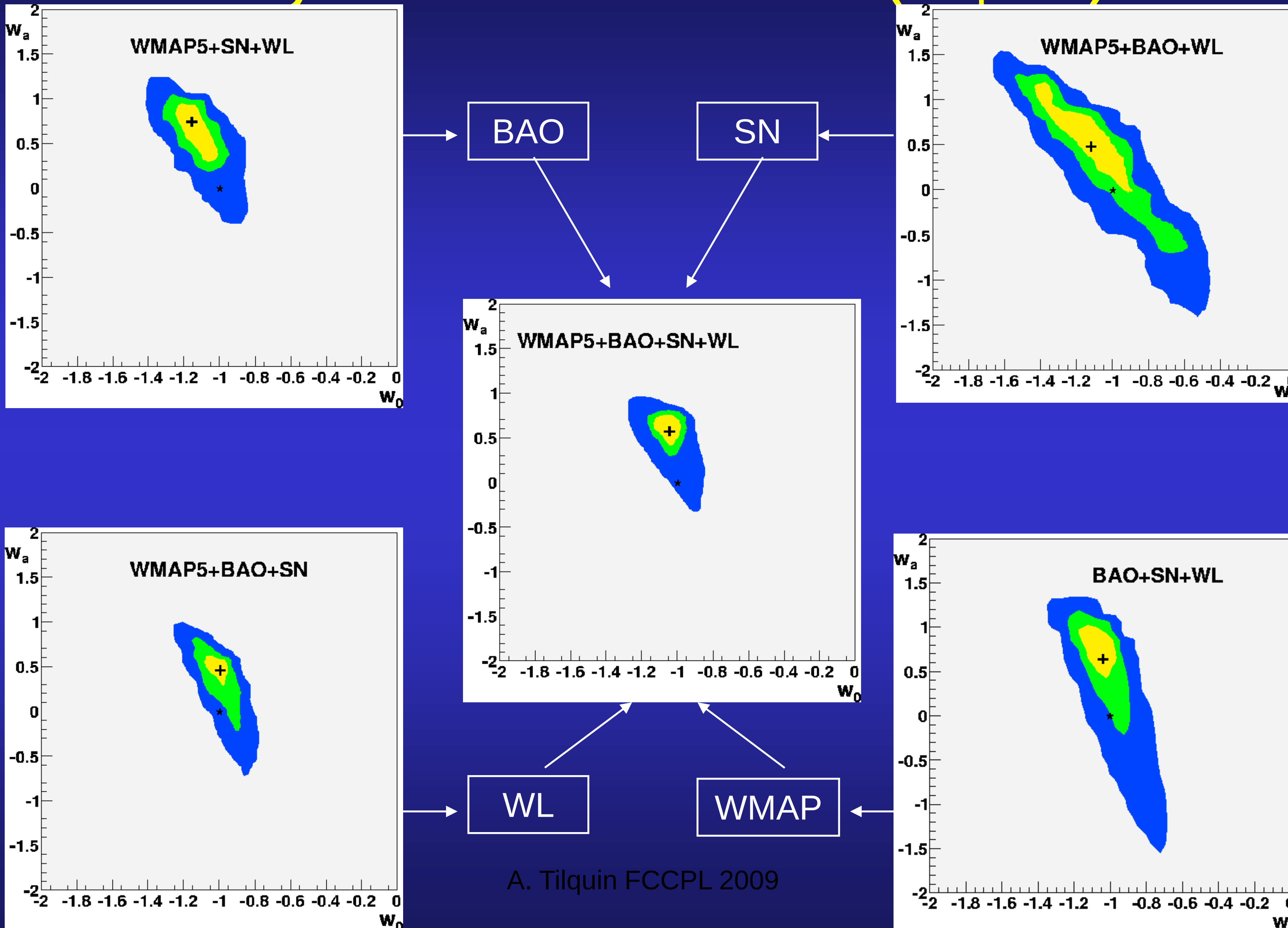




2 by 2 combinations (Ω_T=1)



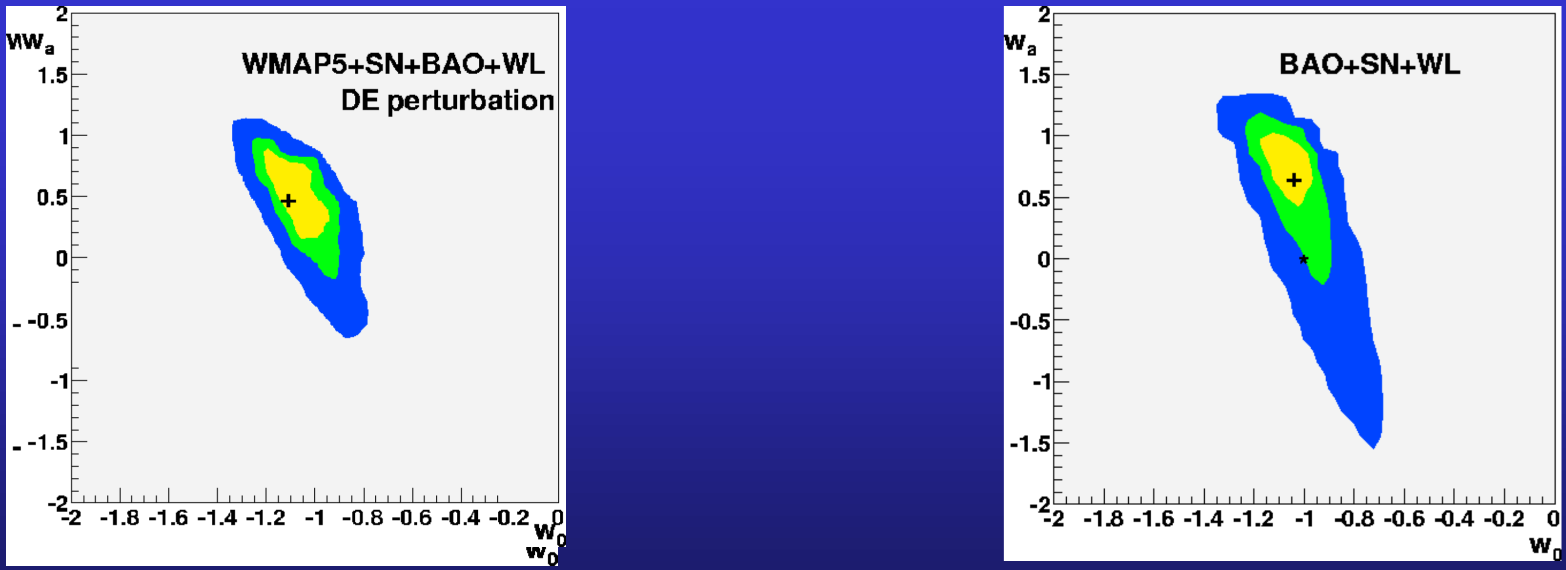
3 by 3 combinations (Ω_T=1)



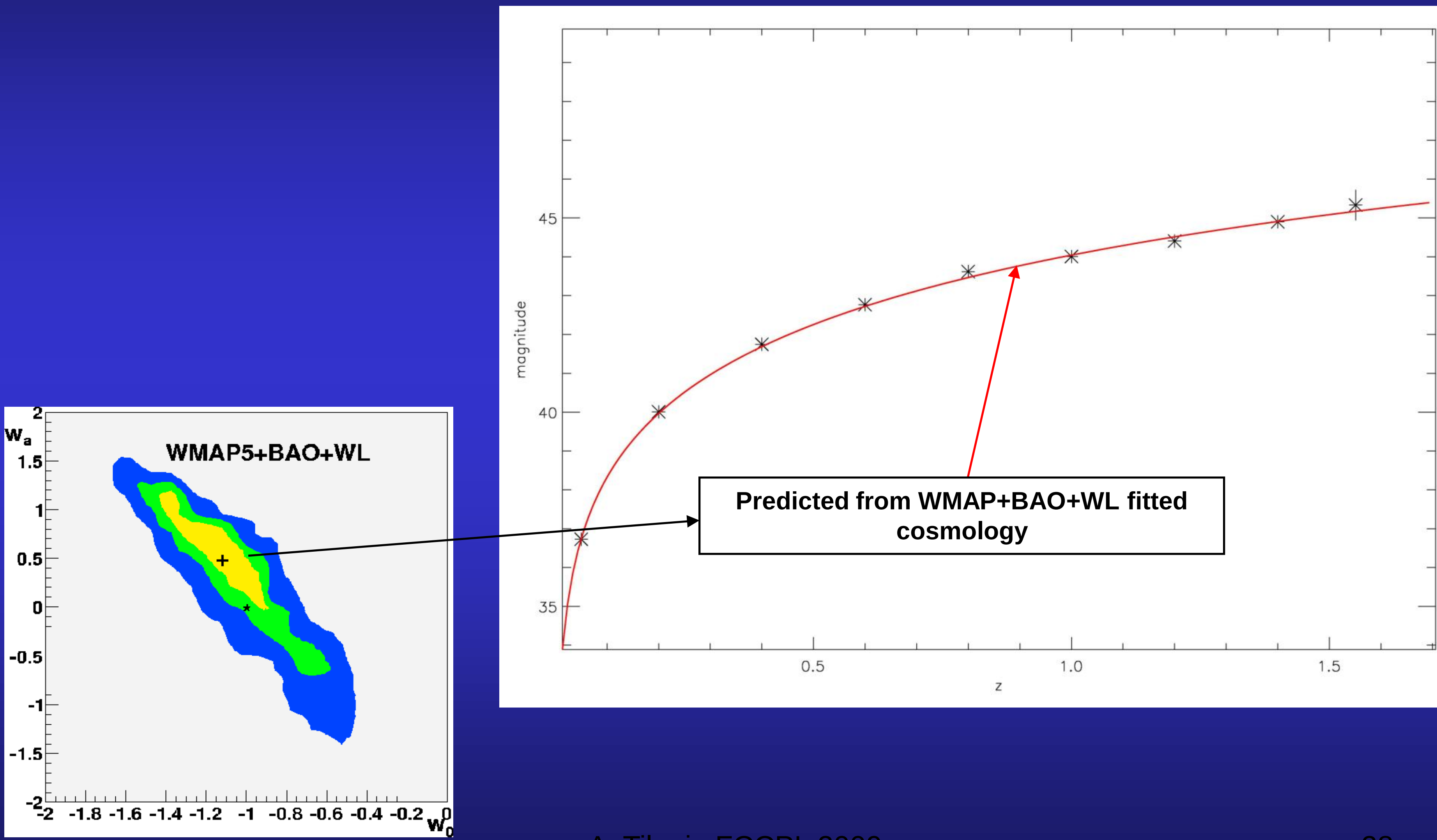
A. Tilquin FCCPL 2009

Dark energy perturbation

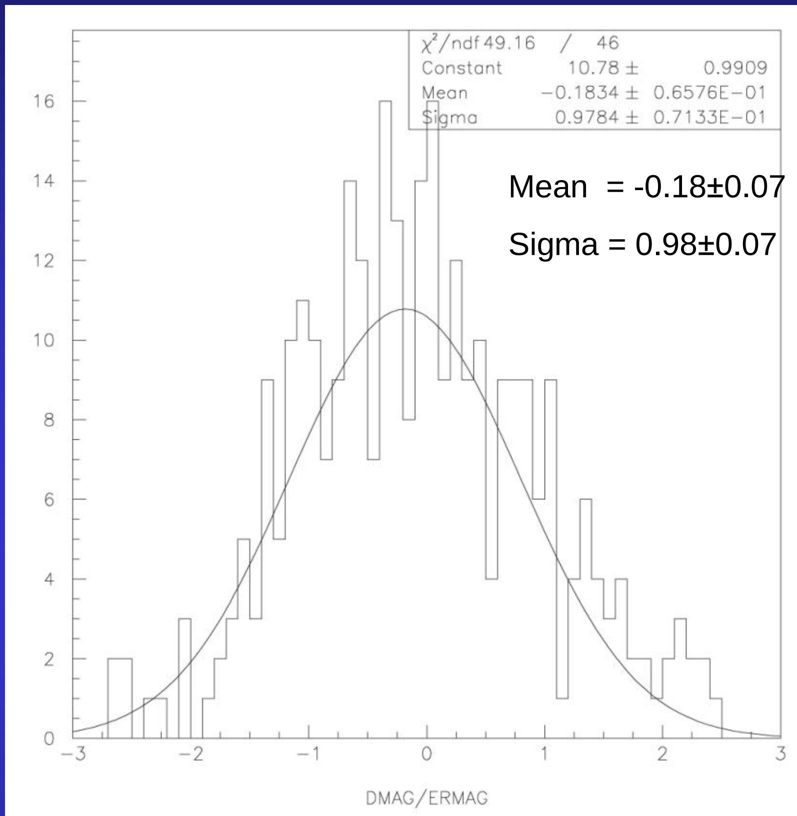
- Dark energy perturbation has important effect on CMB
- Effect on Weak Lensing and BAO expected to be small.
  - Should be estimated : work in progress

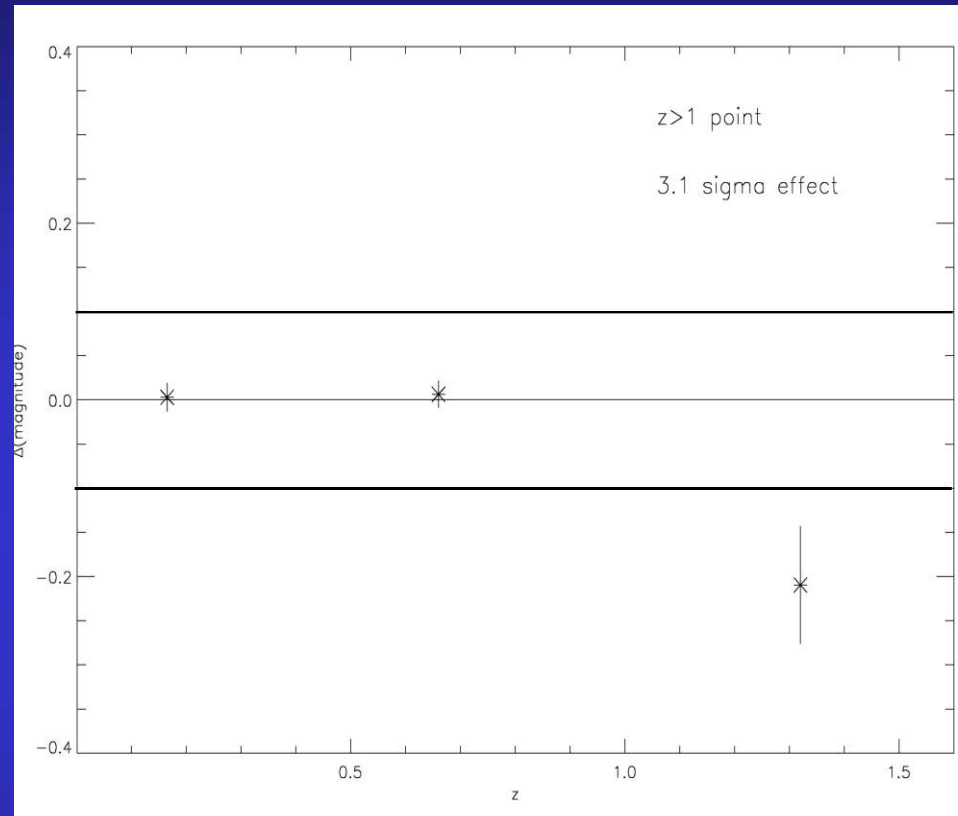


SN Fit WITH WMAP+BAO+WL



SN pull and evolution: work in progress





(mag_sn – mag_predict)/ermag

SN a little bit too bright at high z (<5%)

•No significant evolution seen: ☟mag<0.1 for z<1

•SN a little bit too bright at z>1 (HST) : Evolution ? Malmquist bias ? Gqlqctic subtraction

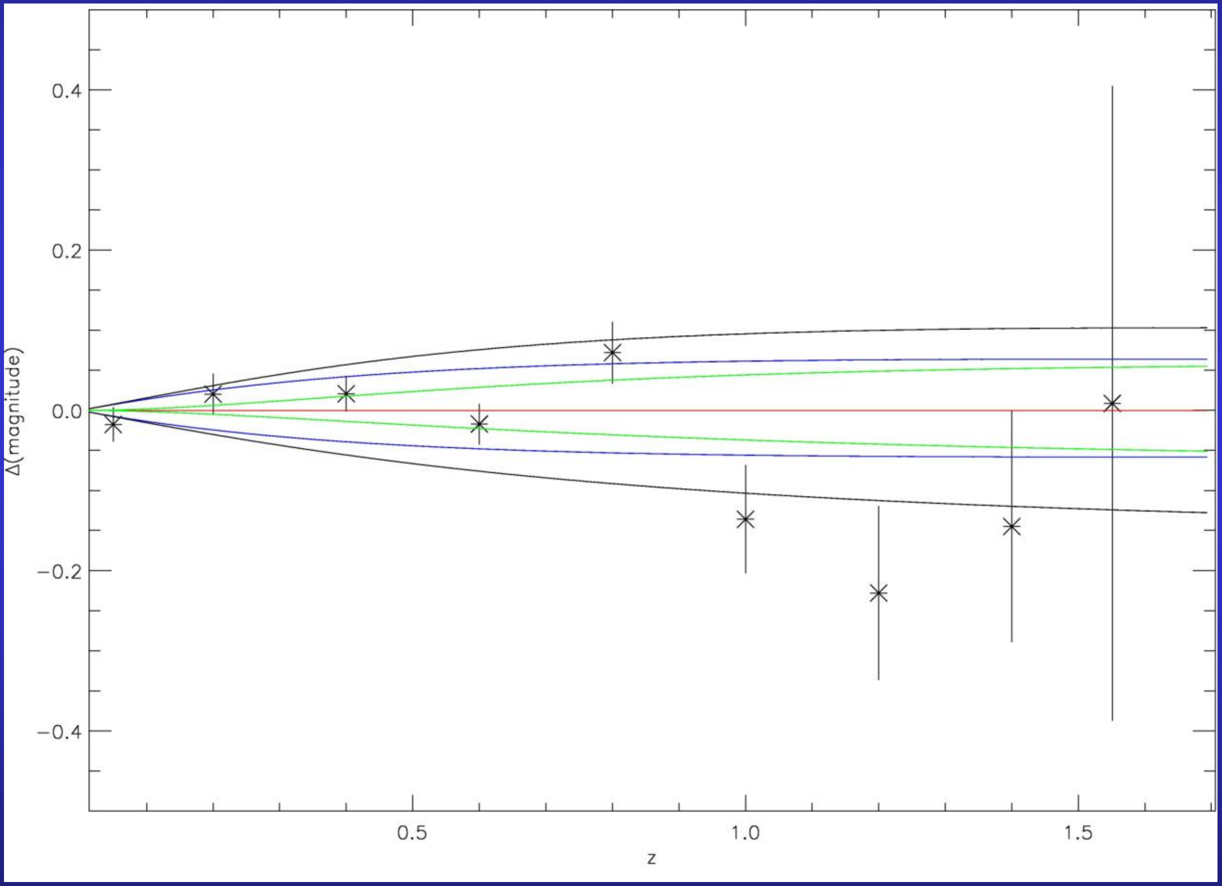
Summary

- Interesting results have been obtained by the Cosmology group in FCPPL
- The full combination (MCMC or Frequentist) of cosmological probes give precise statistical results on dark energy equation of state parameters.
- Systematic errors and bias studies are starting:
  - By using simulation : catastrophic error on photo-z
  - By using data : SN evolution or Malmquist bias.

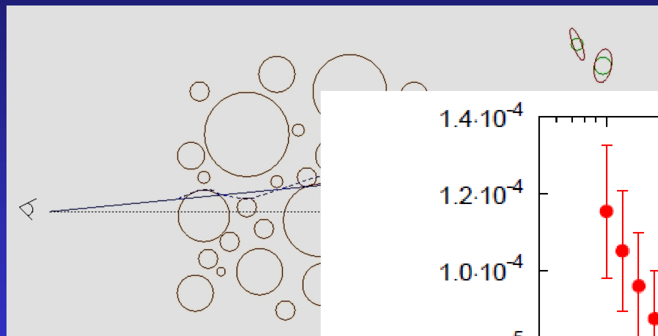
Prospective:

- Reproduce the SN analysis with other probes
- Add new probes (Clusters counting, galaxies diameter..)
- Try to address modified gravity models…
  - Growth factor
  - Luminosity/diameter distances

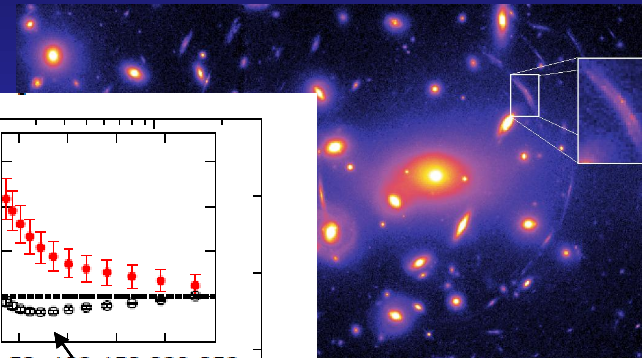
Spare



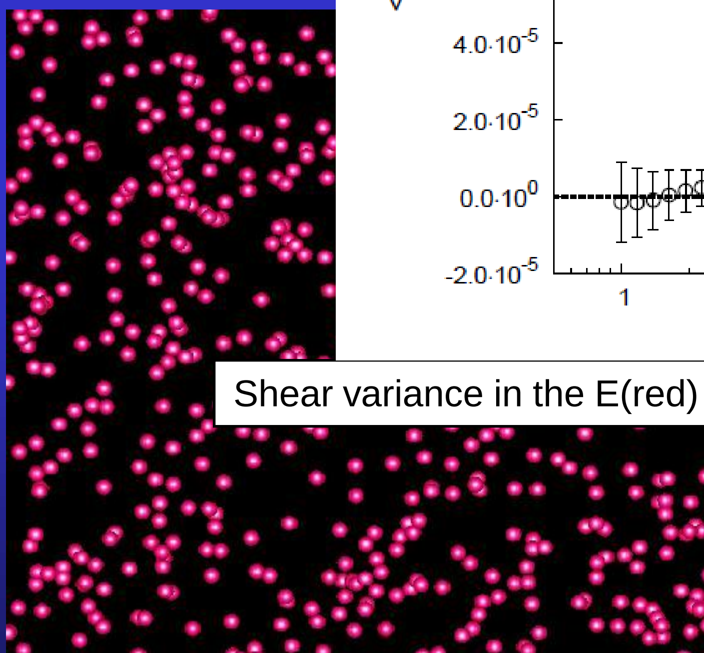
"Weak Lensing"

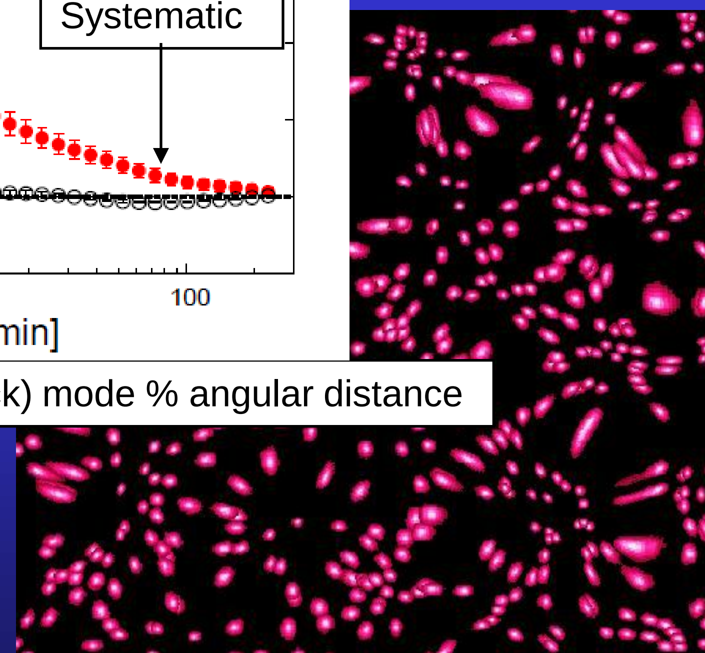


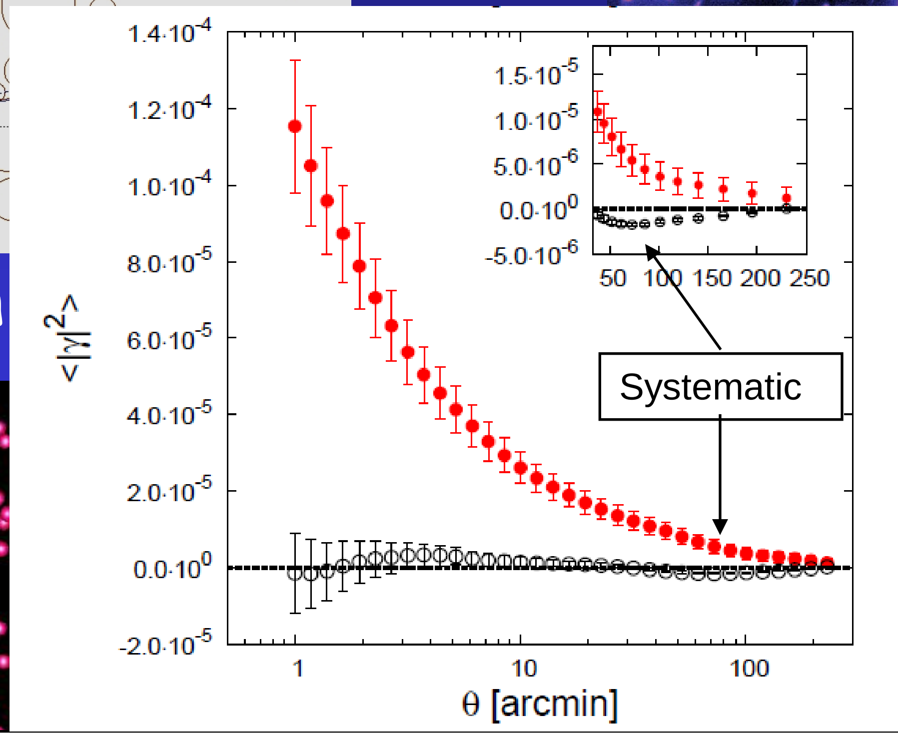
Distorsion



...er







Shear variance in the E(red) and B(black) mode % angular distance

without lensing

Lensing effect