Recent Cosmological Results and Future Prospects

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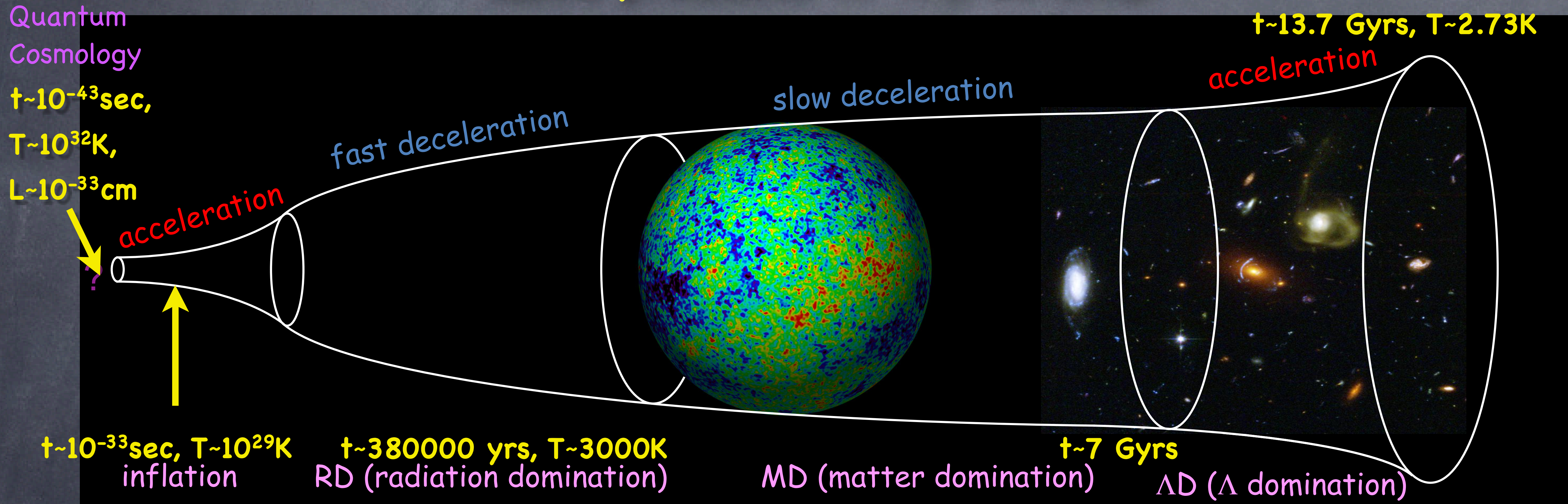
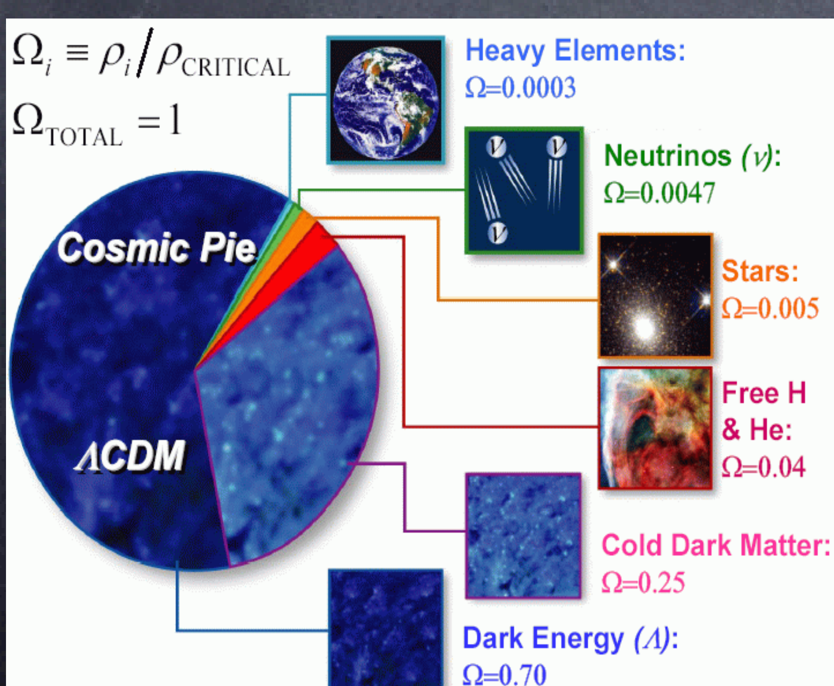
Contents of my talk

- The current Cosmological Paradigm
- Some basics of dynamical cosmology and definition of cosmological parameters
- Possible theoretical interpretations of accelerated expansion
- Major observational Cosmological Probes (geometrical & Growth of structure), recent results and future prospects.
- Our proposal to use a new tracer, alternative to SNIa, for the geometrical Cosmological probes, and preliminary results

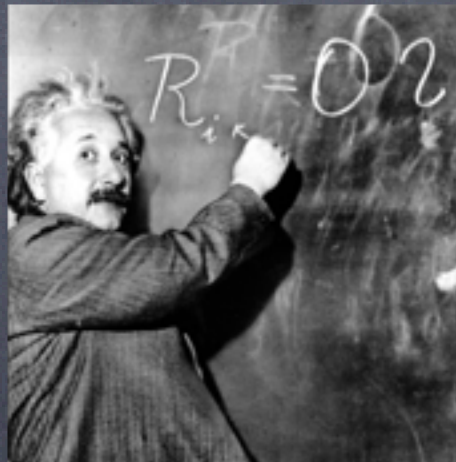
The basic Cosmological picture

The large-scale data fit extremely well a minimal Cosmological model (ΛCDM) which constitutes the current Cosmological Paradigm (with some problems in the details).





Minimal ΛCDM model is a flat, homogeneous universe with **5 components** (photons, baryons, CDM, neutrinos, Λ) and **4 stages**



A Mathematical description of our Universe

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = -\kappa T_{\mu\nu}$$

$$ds^2 = dt^2 - a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + \sin^2\theta d\phi^2)\right]$$

The 1st Friedman's eq. corresponds to Energy Conservation and is the basic eq. of the dynamical evolution of the Universe

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

In order to find how the Universe evolves we need the evolution of ρ

1st Law of Thermodynamics

$$dE + PdV = dQ = 0$$

Continuity equation

$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{P}{c^2}\right) = 0$$

$$P = w\rho c^2$$

Equation of State

cosmic density evolution

$$\rho(a) = \rho(0)\left(\frac{a}{a_0}\right)^{-3(1+w)}$$

$$w = \begin{cases} 0 & \text{matter} \\ 1/3 & \text{radiation} \\ -1/3 & k \\ -1 & \Lambda \end{cases}$$

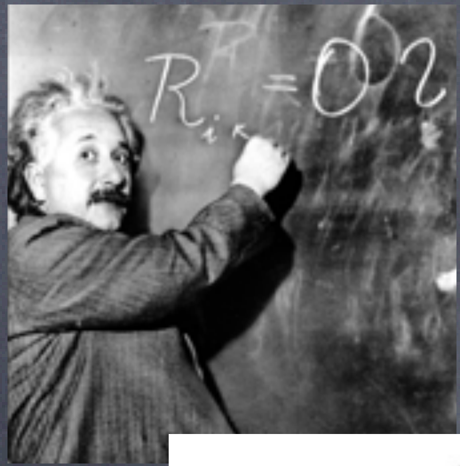
Differentiating the 1st Friedmann eq.

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3P}{c^2}\right) + \frac{\Lambda c^2}{3}$$

2nd Friedmann eq.

$$\rho + \frac{3P}{c^2} > 0 \Rightarrow w > -\frac{1}{3}$$

Condition for deceleration (as expected from self-gravity)



A Mathematical description of our Universe

A very useful representation of the source terms in the dynamical equations is that of Fluids with density ρ and pressure P.

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\left[\rho_m + \rho_k + \ldots\right]$$

$$\Omega_i(a) = \frac{\rho_i}{\rho_{\rm total}} = \frac{8\pi G\rho_i}{3H^2}$$

Useful parametrization of densities as fractional contribution to the global cosmic energy density

+

$$\rho(a) = \rho(0)\left(\frac{a}{a_0}\right)^{-3(1+w)}$$

$$\Omega_m + \Omega_k + .. = 1 \quad \forall z$$

Important relation between Ωs which just reflects mass conservation

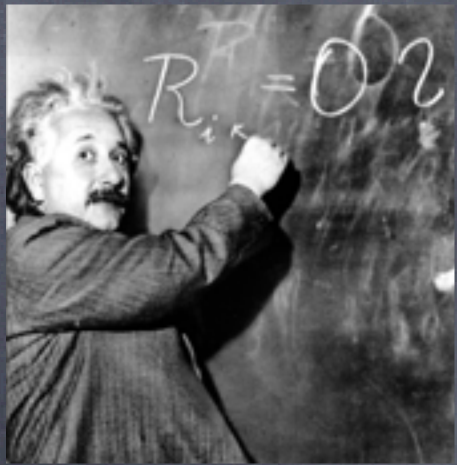
The 1st Friedmann eq. can now be written in the form (known as Hubble relation):

$$H^2(z) = H_0^2\left[\Omega_r(1+z)^4 + \Omega_m(1+z)^3 + \Omega_k(1+z)^2 + \Omega_w \exp\left(3\int_0^z \frac{1+w(x)}{1+x}dx\right)\right]$$

$$w(z) = w_0 + w_1 f(z)$$

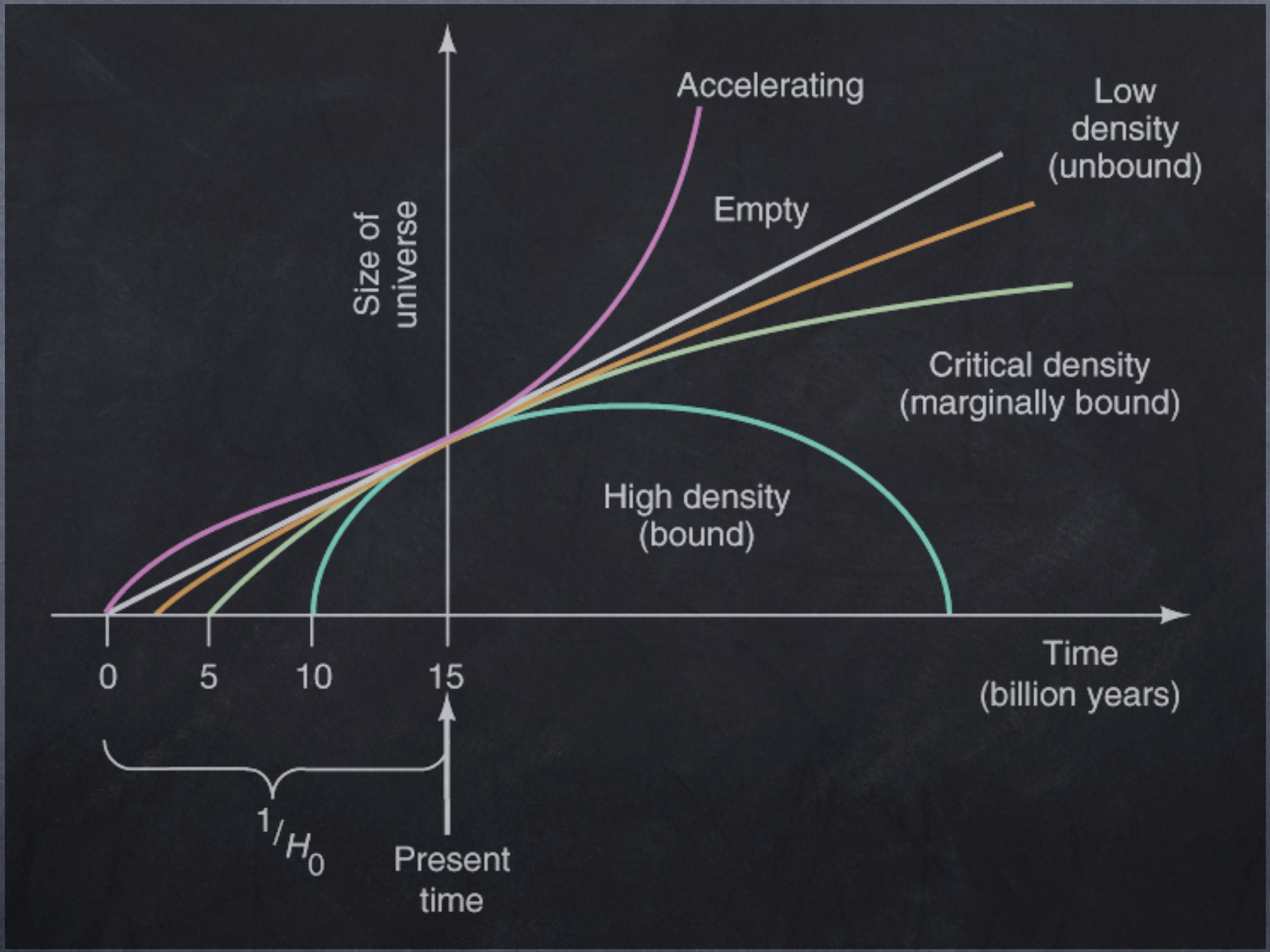
$$f(z) = z/(1+z)$$

The main Cosmological parameters that we seek to determine in order to define the Cosmic Dynamics are: H_0, Ω_m , Ω_k , Ω_w , $w(z)$



A Mathematical description of our Universe

Different combination of values of Ω_i will give you different dynamical evolution of the Universe (different age, different rate of expansion, different future)

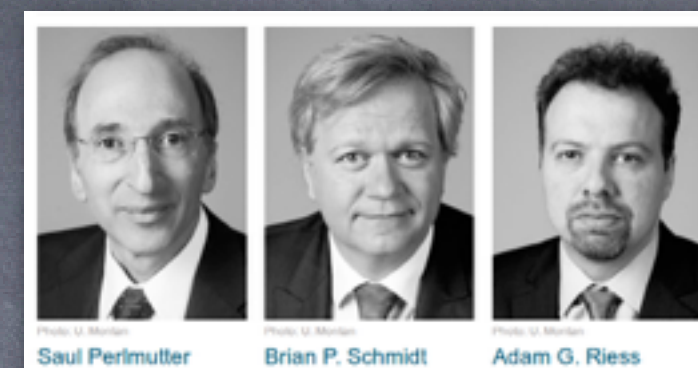


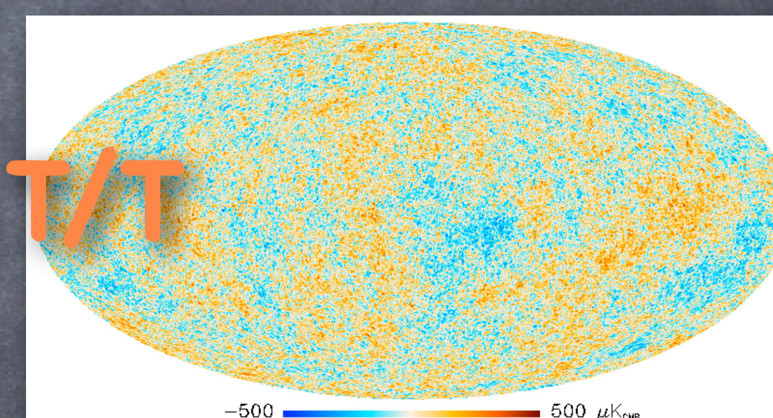
The old paradigm was that of the EdS model (Ω_m=1, Ω_k=0)… but had many-many problems (observationally Ω_m<1, Globular Cluster Age Problem, etc)

2 amazing Cosmological Observations ~10-15 years ago changed dramatically our view of Cosmology !!

1. SNIa Hubble expansion:

2011 Nobel prize !!





2. CMB Temperature anisotropies $\Delta T/T$

The Universe is spatially flat, contains baryonic and DM, and it is expanding with an accelerated paste for the last ~7 Gyr

Acceleration implies that

also flatness (CMB) implies that

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 \cancel{=} \frac{8\pi G\rho}{3} - \cancel{\frac{kc^2}{a^2}}$$

Energy conservation breaks...

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 > \frac{8\pi G}{3}\rho_m$$

and to rectify:

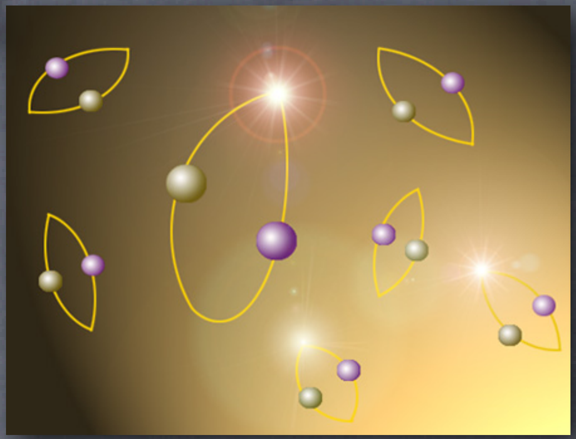
$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}(\rho_m + \rho_{\rm de})$$

Unknown fluid ("Dark Energy") component
(Λ most common case)

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G_{\rm eff}}{3}\rho_m$$

Modification of GR at Cosmological scales

Theoretical interpretation of Λ or DE

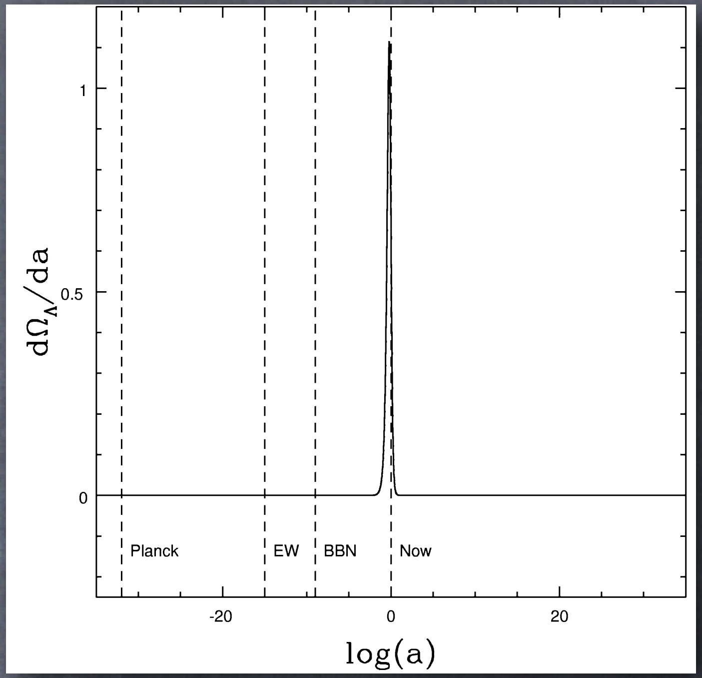


The Λ energy density has been identified as the vacuum energy density. However, this interpretation has 2 fundamental problems:

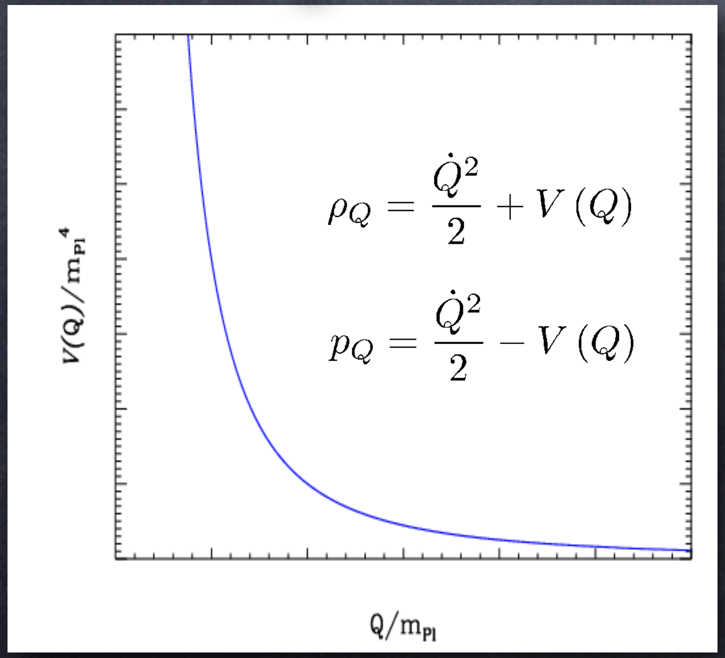
(1) FINE TUNING PROBLEM: We have from QFT that

$\rho_{vac}c^2 = 2c^7/hG^2 = 10^{111}$ J/m^3 and $\rho_\Lambda c^2 = \rho_{crit}\Omega_\Lambda c^2 = 6.22 \times 10^{-1}$ J/m^3

Obviously we get $\rho_{vac}/\rho_\Lambda \sim 10^{120}$ thus should evolve in time....



(2) COINCIDENCE PROBLEM (see Caldwell 2005): the matter energy density and the vacuum energy density are of the same order just prior to t_0, although the former is a rapidly decreasing function of time while the latter is just stationary.



Alternatives to Λ are:

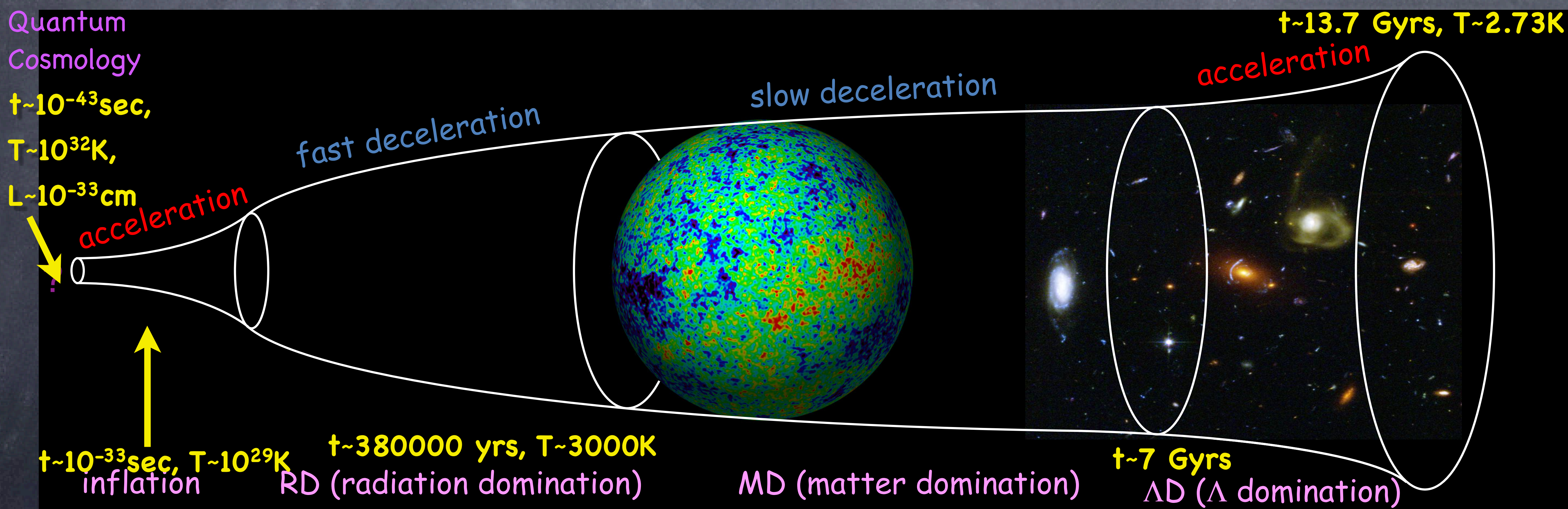
(1) a scalar field playing the role of DE ($-1<w<-1/3$), but the predicted mass of the scalar field is $m_\varphi = 10^{-33}$ eV inconceivably small for Particle Physics (Quintessence).

(2) modified gravity on Cosmological scales but many free parameters and fine-tuning.

(3) in-homogeneous Universe in large-scales (local underdensity) but fine-tuning again.

Theoretical interpretation of Λ or DE

Recently Basilakos, Lima, Sola (2013, MNRAS, PRD) proposed a new vacuum model with a strong theoretical basis (QFT in curved Space-Time) and which appears to overcome, or highly alleviating the cosmic puzzles. It is based in a decaying vacuum energy density, $\Lambda(t)$, which preserves all the nice properties of the Λ model (w=-1, fit to Hubble and CMB data) and also preserving the different stages of the cosmic evolution.



It is worth mentioning that this essay received an honorable mention in the 2013 International Essay Competition of the Gravity Research Foundation.

The Dark Energy Problem

What is DE? Λ, scalar or vector field, Λ(t), modified gravity, local underdensity ?

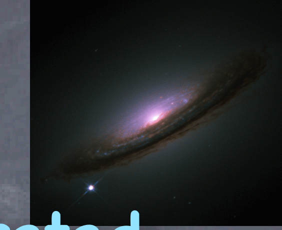
"Dark Energy" is TOP PRIORITY for future research: Outcome of 2 very extensive, recently released reports, "Report of the Dark Energy Task Force (advising DOE, NASA and NSF), Albrecht et al. (2006), and "Report of the ESA/ESO Working Group on Fundamental Cosmology", Peacock et al. (2006).

A large number of very expensive experiments (eg., Dark Energy Survey, Euclid, XXL, HETDEX, JDEM, Pan-STARRS, LSST, etc) are on their way..

COSMOLOGICAL PROBES

- Supernovea Ia (standard candles)
- CMB Temperature Fluctuations (standard ruler)
- Baryonic Acoustic Oscillations (standard ruler)
- Weak lensing (growth of structure)
- Cluster of Galaxies Physics

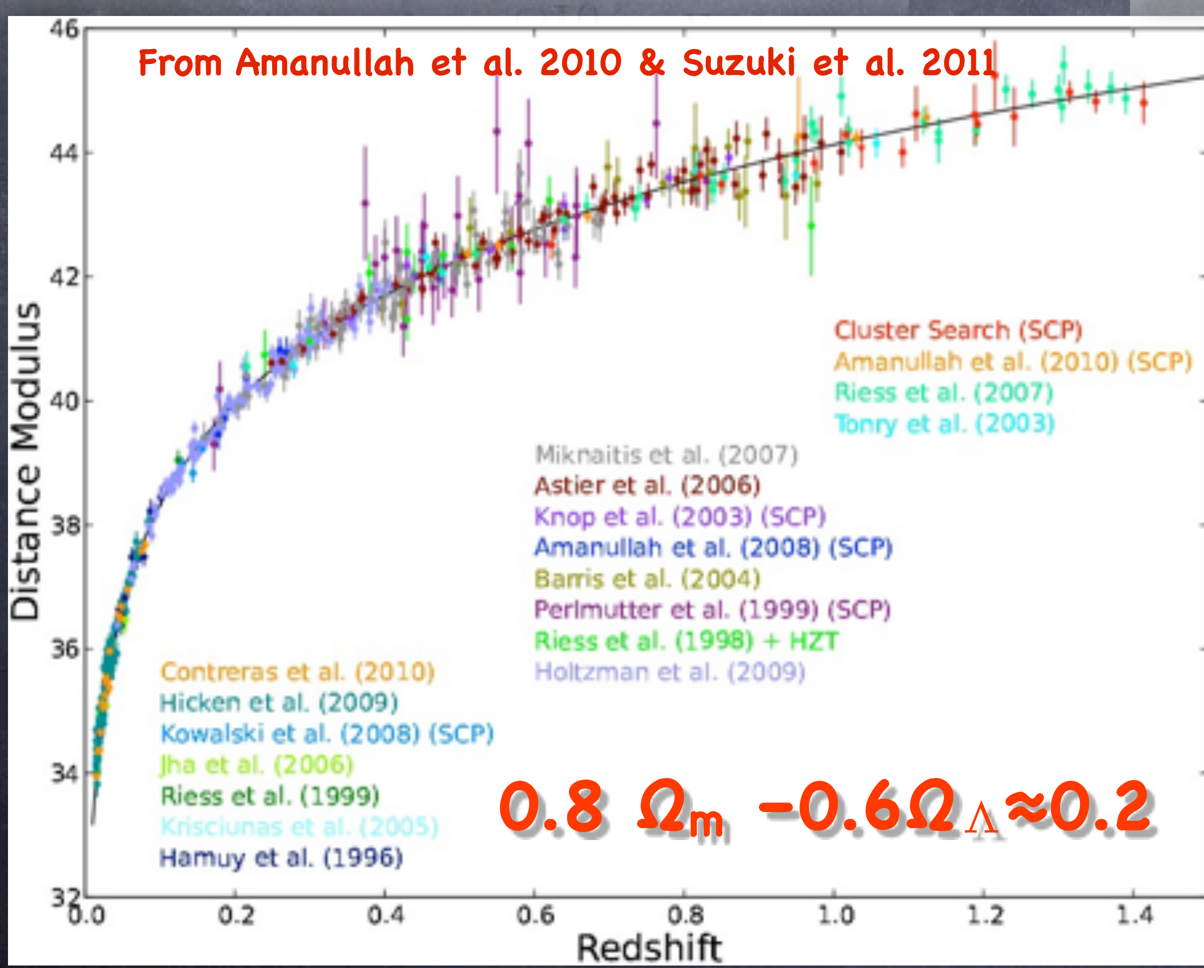
1. SNIa Hubble expansion



Type-Ia Supernovae (SNe Ia) result from explosion of White Dwarf having accreted mass from a companion star, beyond the critical Chandrasekhar limit (~ 1.4 $M_\odot$).

In 1998 two teams (Perlmutter, Riess) found that distant SNIa are dimmer than expected, a fact interpreted as being due to an accelerated expansion of the Universe. Ever since the new accumulation of data and better understanding of systematics confirm constantly this interpretation.

$$\mu = m - M = 5\log_{10} D_L + 25 \quad + \quad D_L = (1+z)\int_0^z \frac{c}{H(z)}\mathrm{d}z \longrightarrow H(z)$$



From Amanullah et al. 2010 & Suzuki et al. 2011

$0.8\ \Omega_m - 0.6\Omega_\Lambda \approx 0.2$

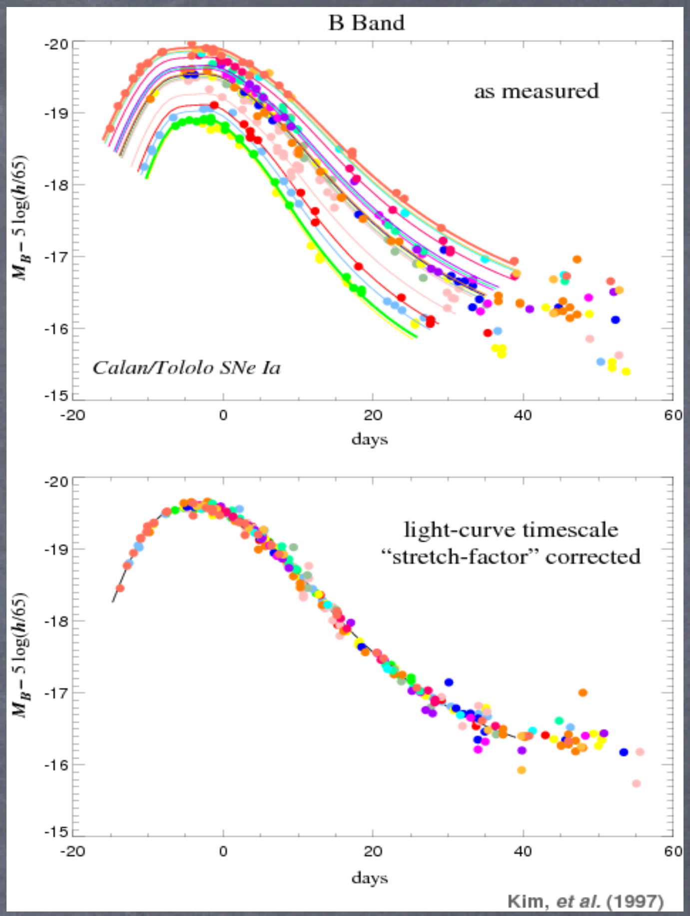
Union2: 557 SNe Ia

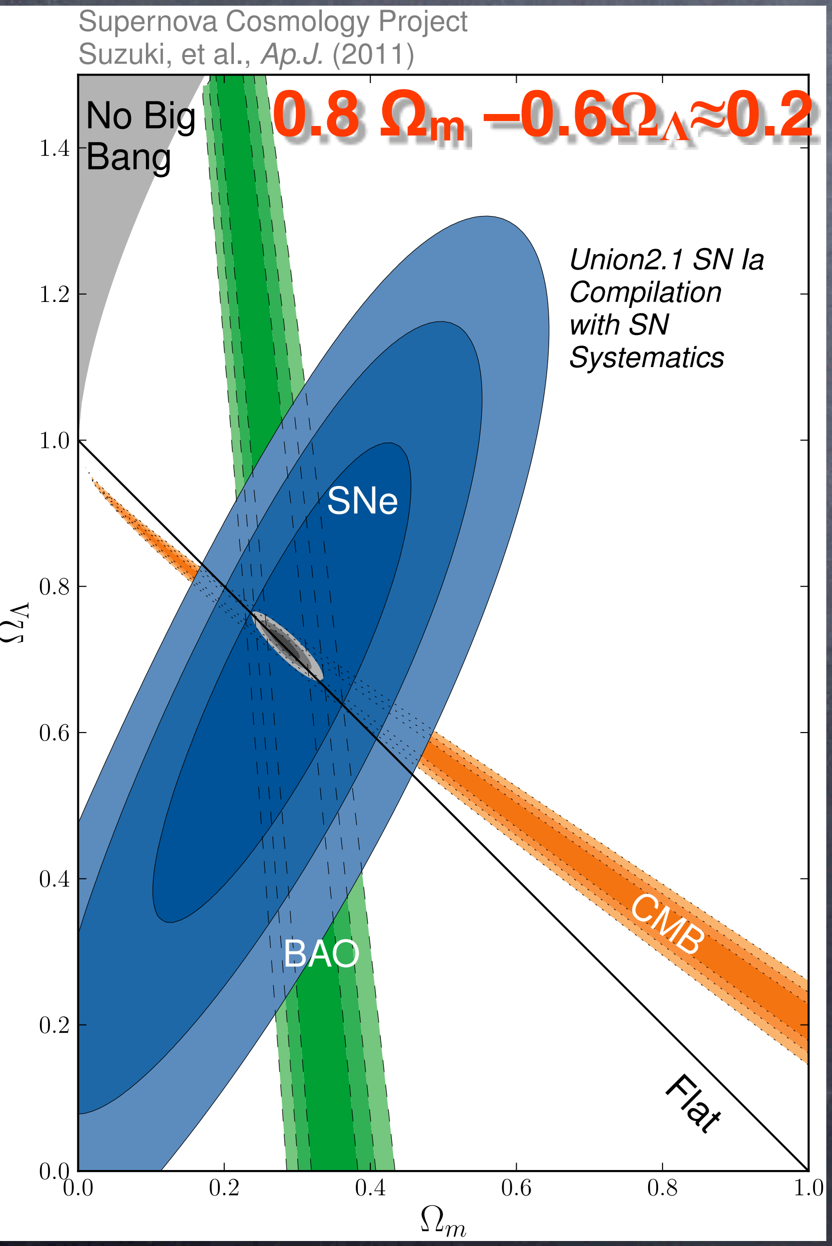
Union2.1: + 14 cluster SNe Ia (with 10 having z>1)

Suzuki et al. 2011

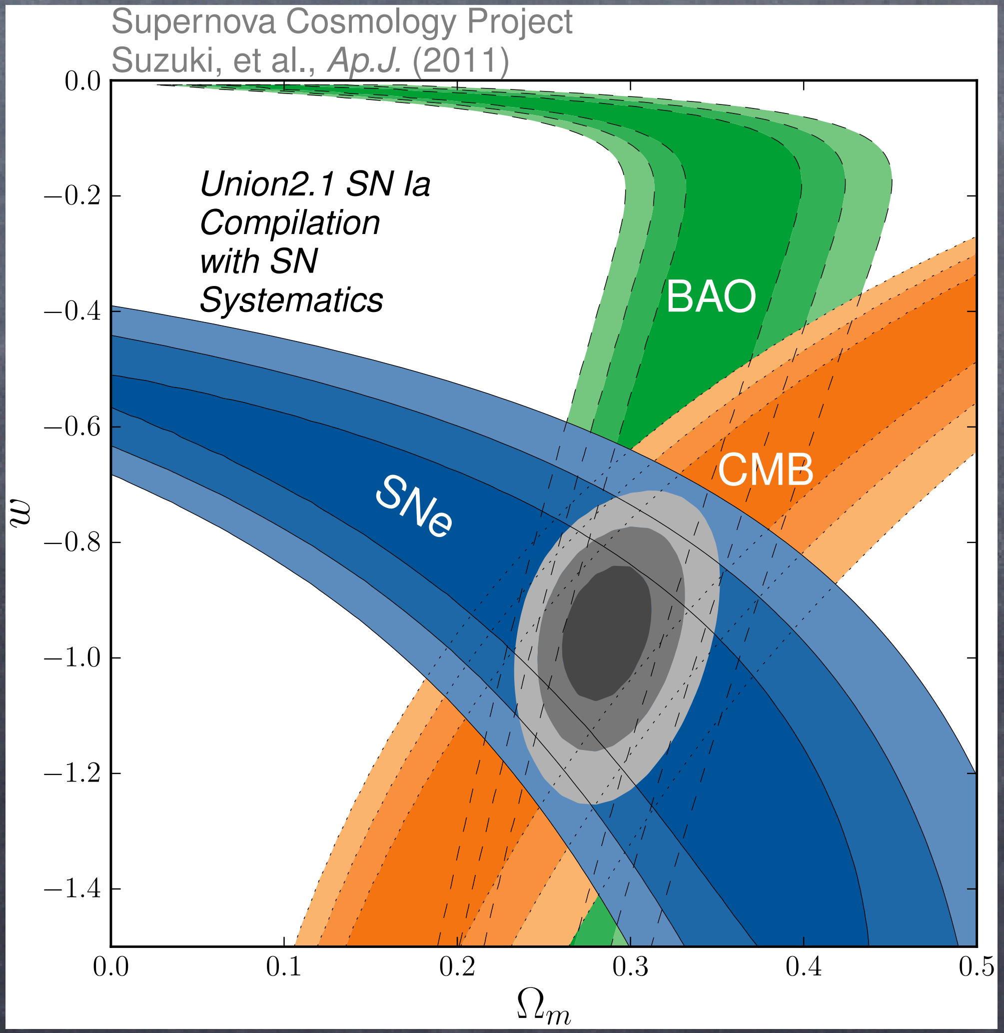
1. SNIa Hubble expansion

Systematics? Dependence on galaxy Hubble type indicates effects of absorption is important, while the change of Hubble type progenitor with z could introduce significant uncertainties in Cosmological parameters.





$0.8\,\Omega_m - 0.6\Omega_\Lambda \approx 0.2$



Only SNIa

ΛCDM: $\Omega_m = 0.295 \pm 0.041$

wCDM: $\Omega_m = 0.296 \pm 0.140$,

$w = -1.001 \pm 0.370$

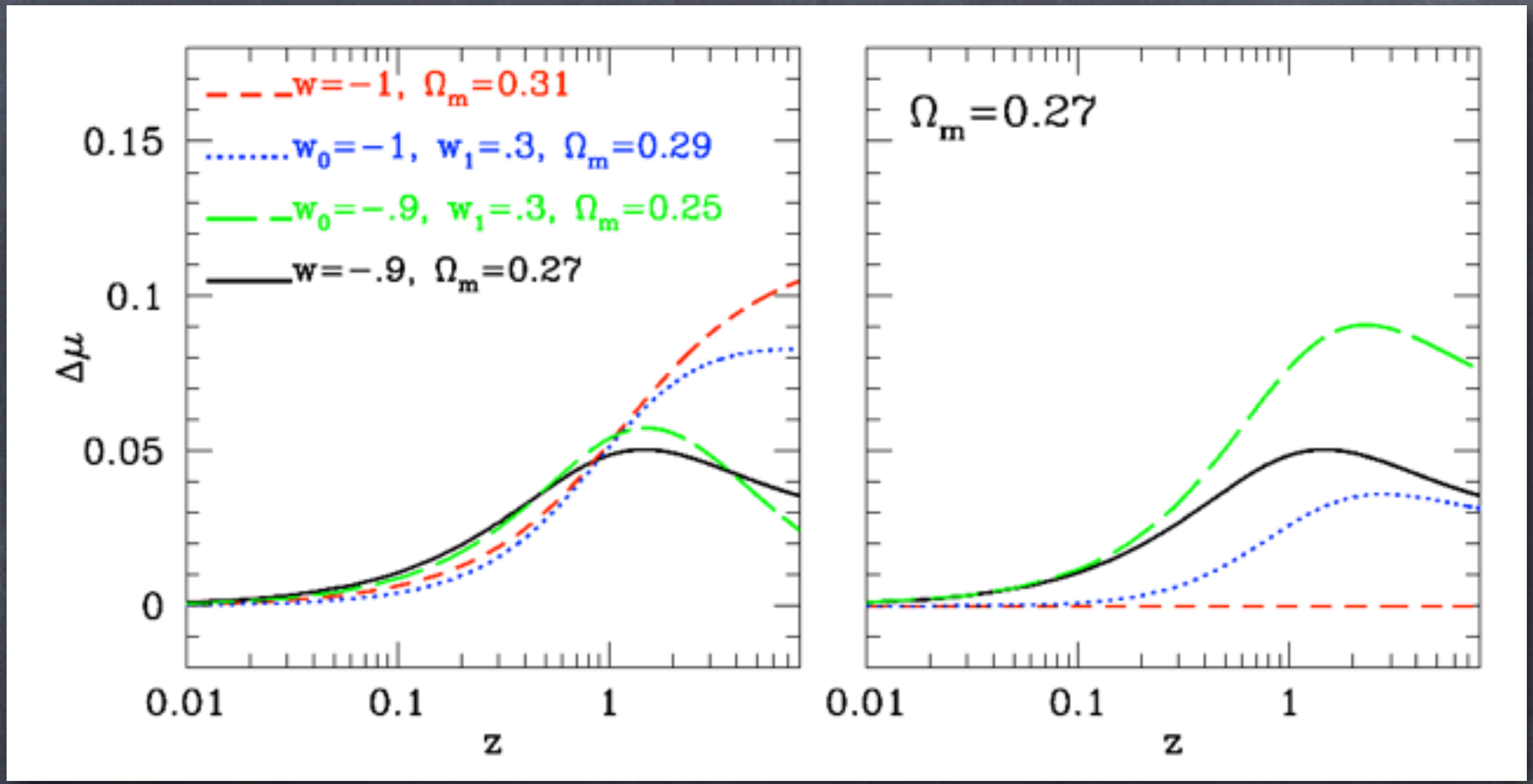
SNIa+BAO+H_0

wCDM: $\Omega_m = 0.320 \pm 0.035$,

$w = -1.097 \pm 0.100$

Suzuki et al. 2011

Severe Problem: Degeneracies of Cosmological parameters

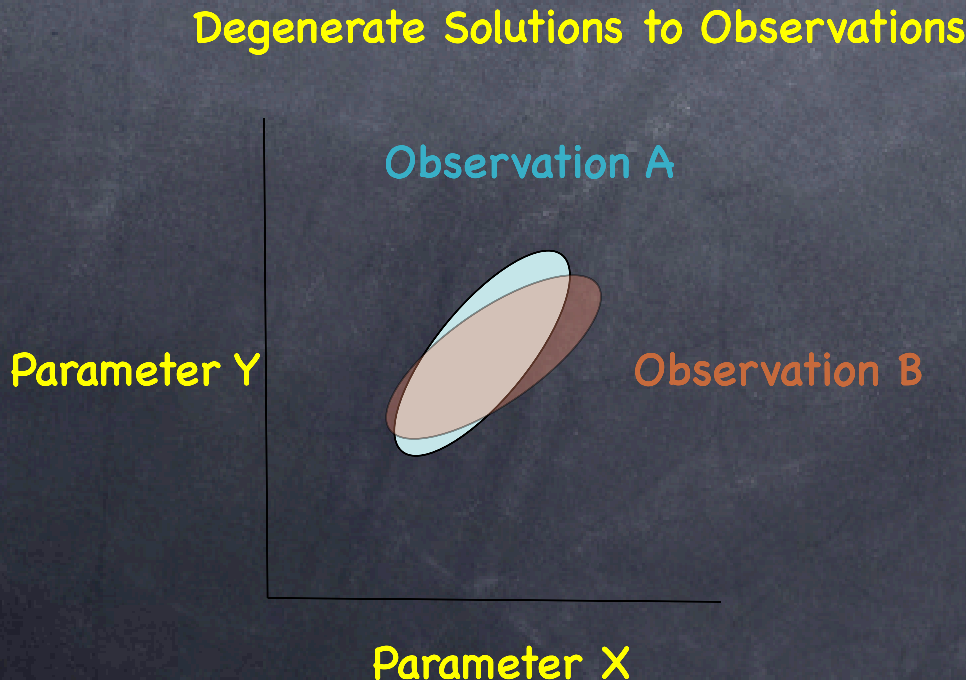


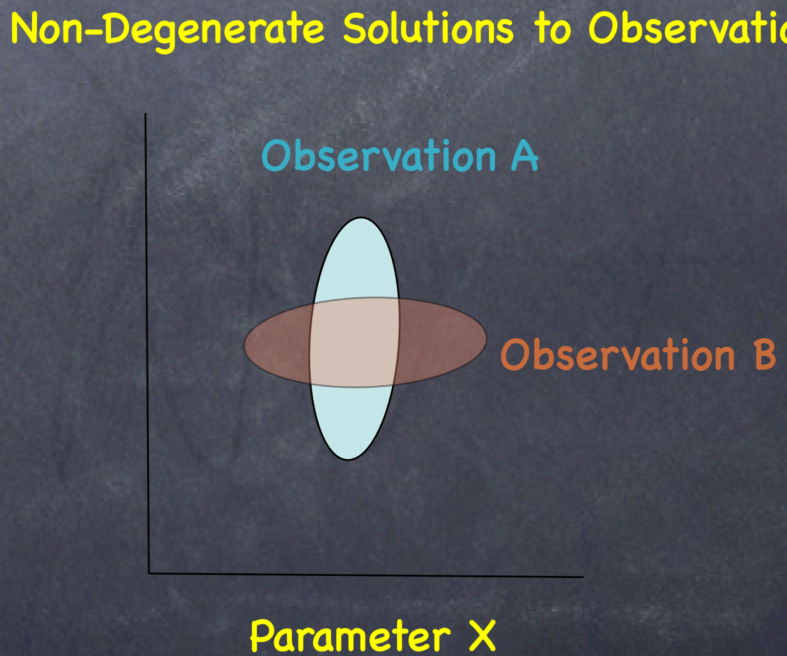
Two important observations:

(1) the largest differences between models occur at z>1.5-2, and

(2) Necessary to break degeneracies (eg., estimating independently Ω_m)

To break degeneracies it is necessary to join different Cosmological Probes in order to get useful constraints on parameters:





1. SNIa Hubble expansion: Where do we go from here and now?

TO DATE

By the end of 2013 there will be ~750 SNIa in the UNION sample

FUTURE

Ongoing Surveys:

CfA $z<0.1$

PTF (Law et al. 2009) $z<0.1$

SN factory (Aldering et al. 2002) $z<0.1$

Pan-STARRS (Kaiser 2004) $z<0.7$

DES (Bernstein 2011) $z<1.2$

Future Surveys:

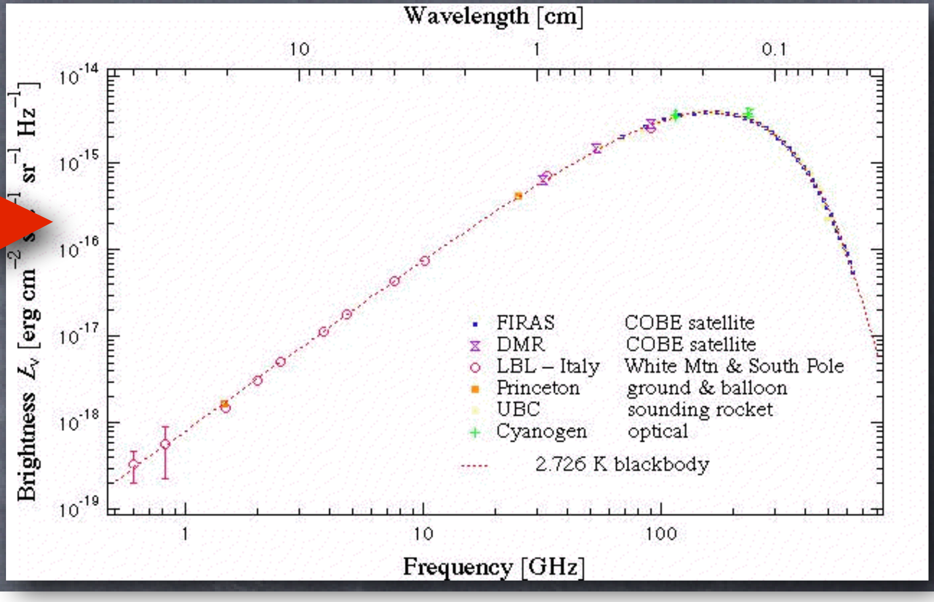
Large Synoptic Survey Telescope - LSST ($0.1<z<1.5$)

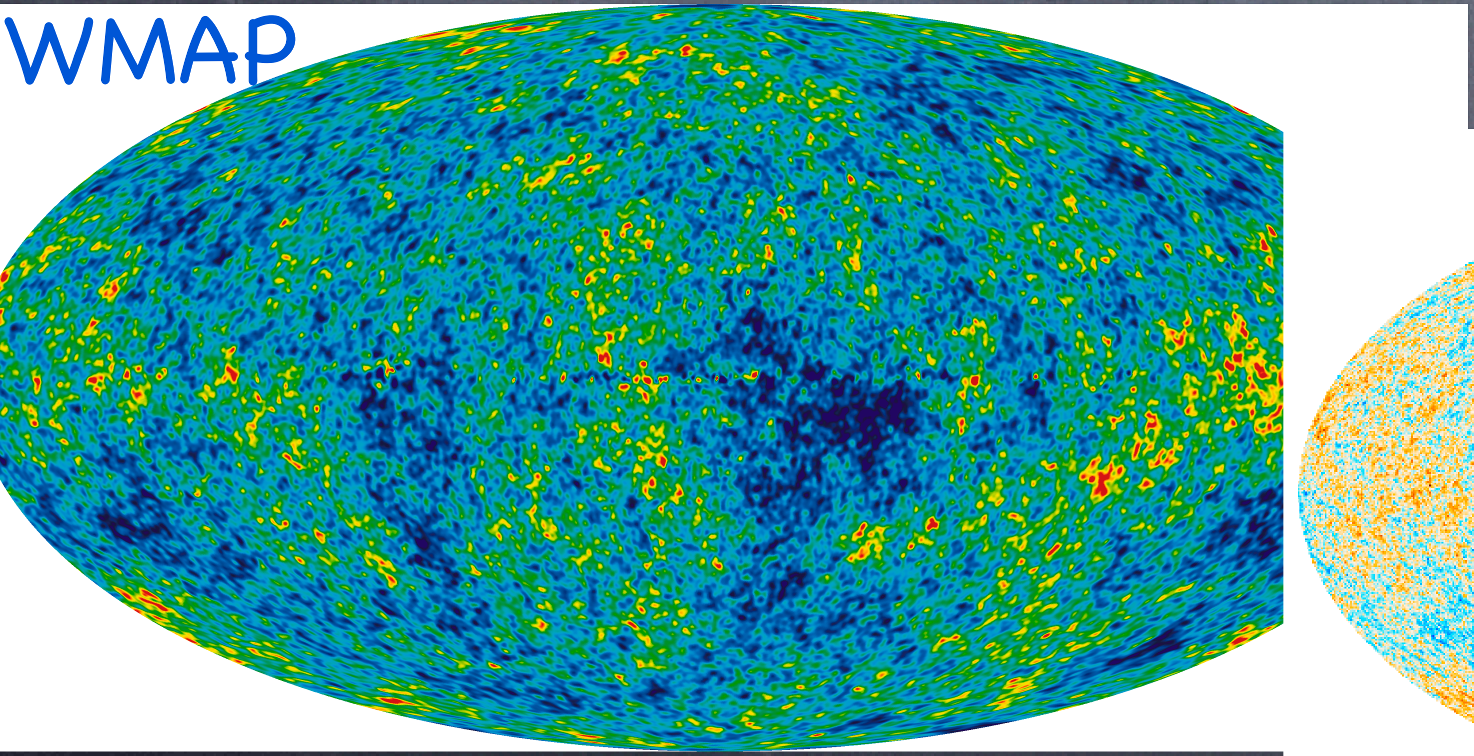
Euclid (IR follow-up of high-z SNe-Ia)

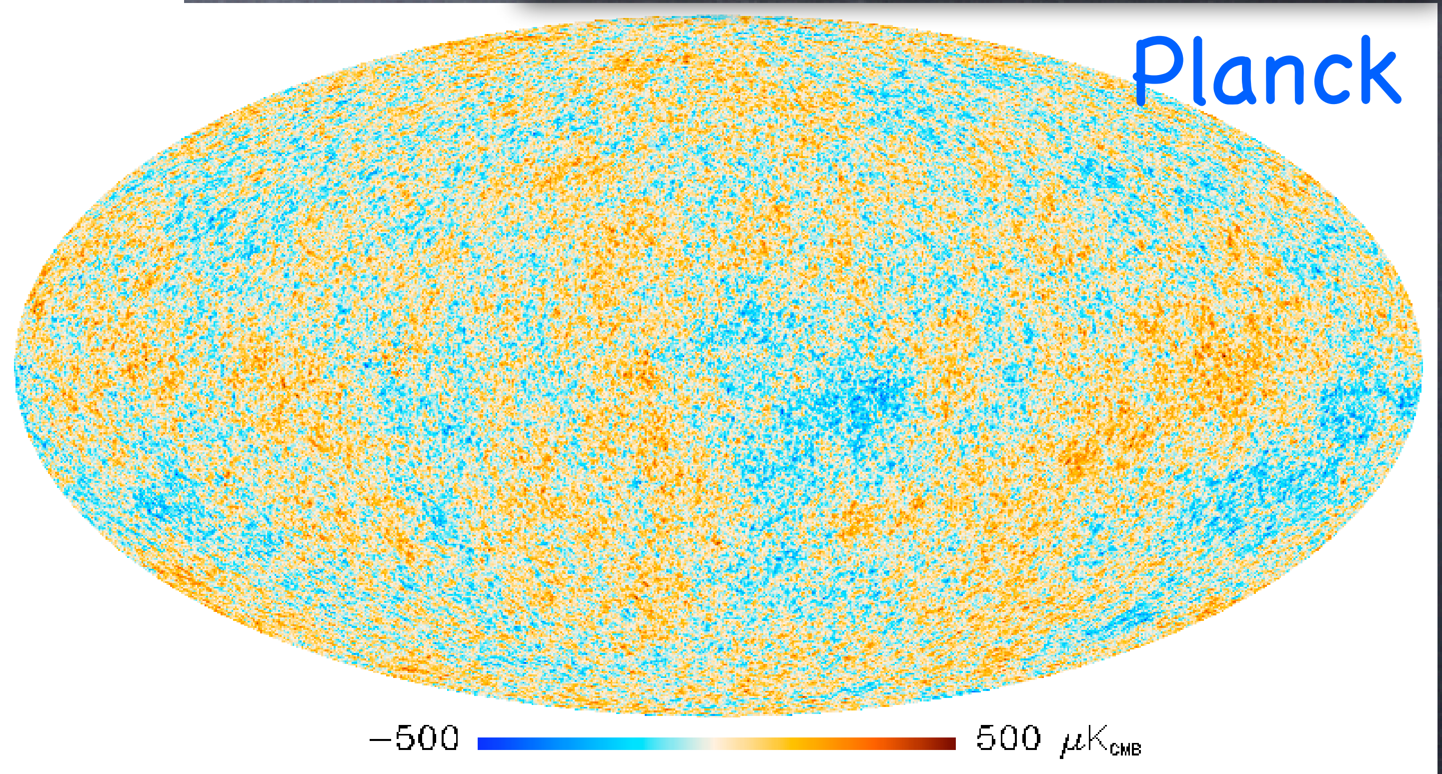
2. CMB Temperature anisotropies ΔT/T

CMB Basics: The early universe was hot, dense and opaque, with γ being scattered by free e^-, since up to T~3000K particles were ionized. As T droped, neutral hydrogen atoms formed, the γ could travel without interaction and reach observers, constituting the relic radiation that we see as the CMB.

Due to the 1100-fold expansion of the universe these photons have been red-shifted and are detected as a BB with a temperature of 2.73K

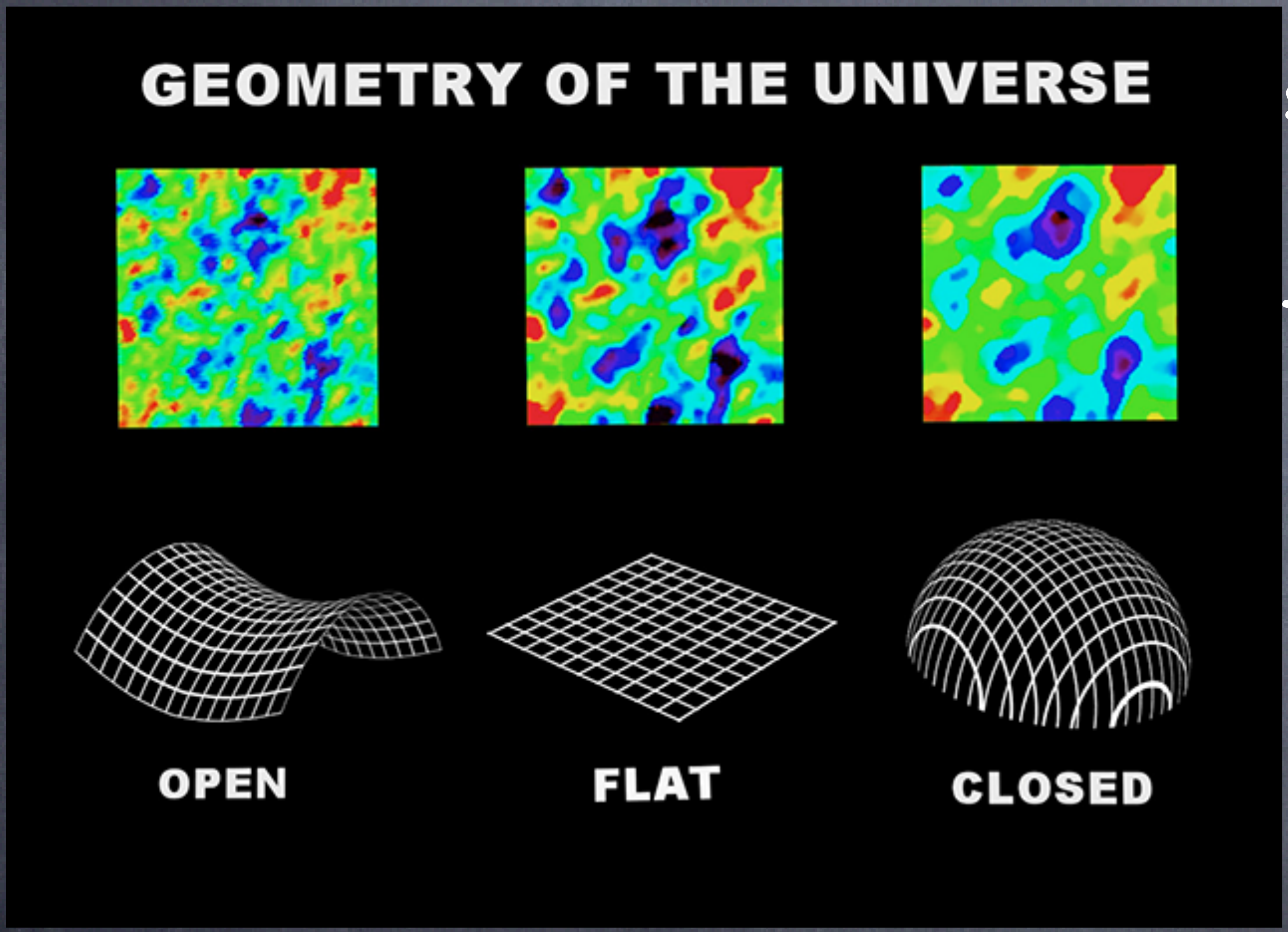






2. CMB Temperature anisotropies $\Delta T/T$

The only direct Probe of the Spatial Geometry: A characteristic physical scale (size of the sound horizon) sustains a different angular size on the last scattering surface for different spatial geometries



Spherical Harmonic expansion:

$$\Delta T/T(\theta,\varphi)=\sum a_{lm} Y_{lm}(\theta,\varphi)$$

Then the Power-Spectrum:

$$C_l=\langle|a_{lm}|^2\rangle$$

represents the amplitude of the contribution of fluctuations from different angular scales, where

$$\theta=\pi/l$$

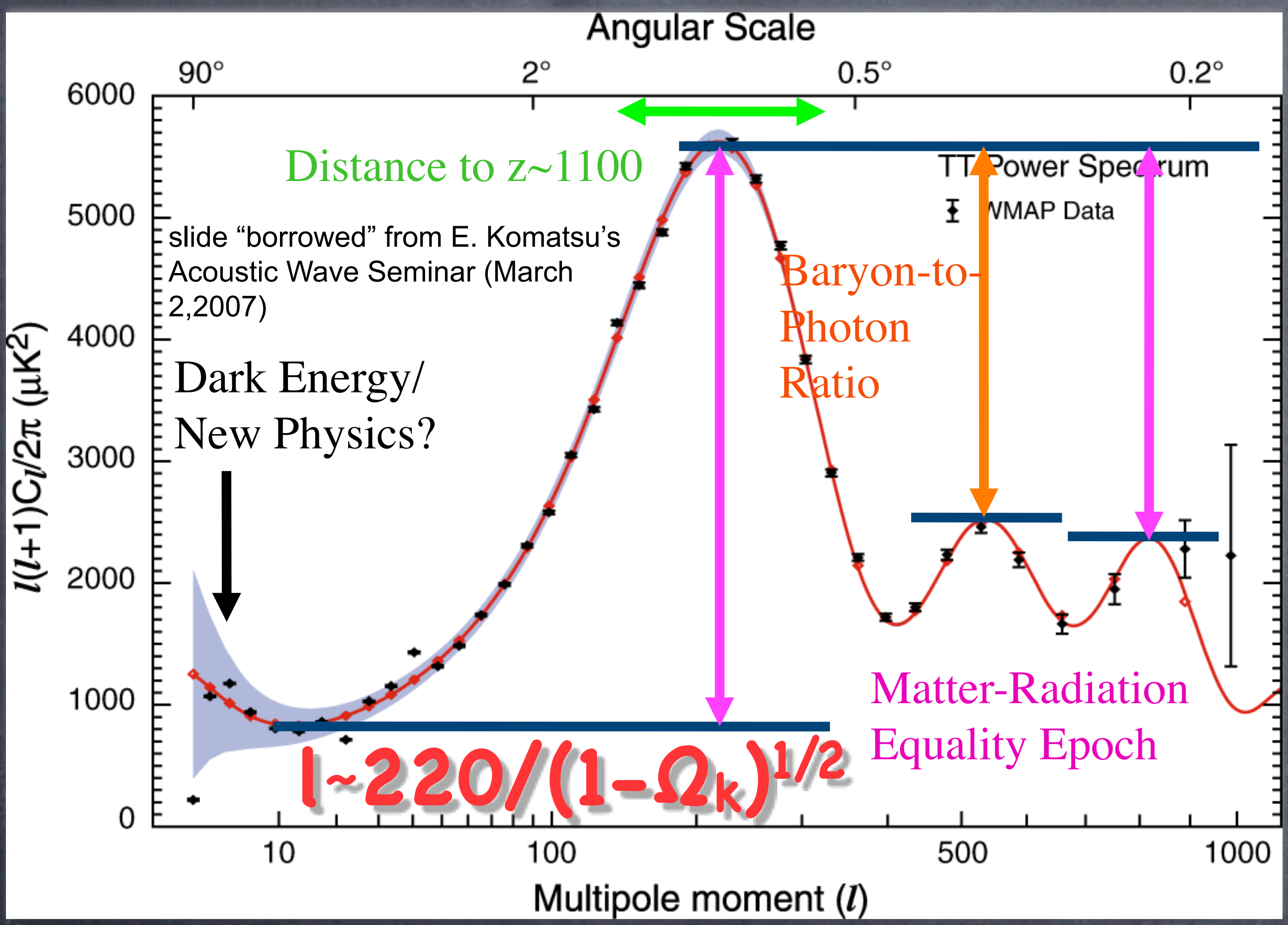
Fluctuations at $\theta<2°$ are due to the oscillations of the photo-baryonic fluid at recombination create a very strong peak in angular Power Spectrum at specific multipole which depends on spatial curvature:

$$l\sim 220/(1-\Omega_k)^{1/2}$$

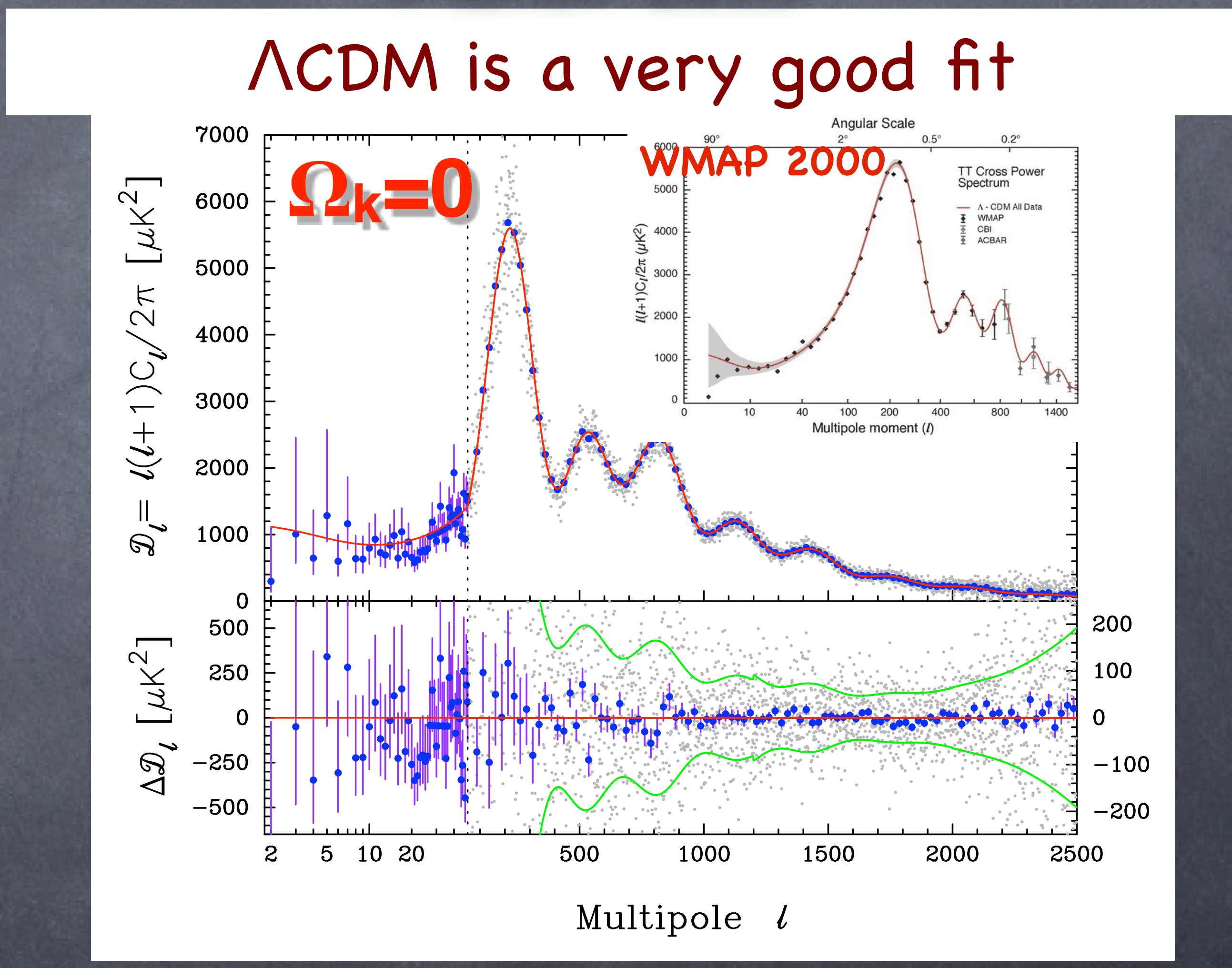
2. CMB Temperature anisotropies ΔT/T

Basic Result: The spatial curvature $\Omega_k=0$ a result provided by the 1st peak. But from the other peaks we get constraints on many other cosmological parameters.

Decomposing the peaks of C_l



Planck 2013



Only CMB ΛCDM: $\Omega_m=0.314\pm0.020$

CMB+BAO+WP wCDM: $w=-1.13\pm0.23$

Planck collaboration 2013

Comparison of 2013 WMPA9 and PLANCK ΛCDM Cosmological Parameters

6 free parameters (abundance of baryons, CDM, Λ ; amplitude and spectral index of primordial fluctuations ; epoch of reionisation due to star formation)

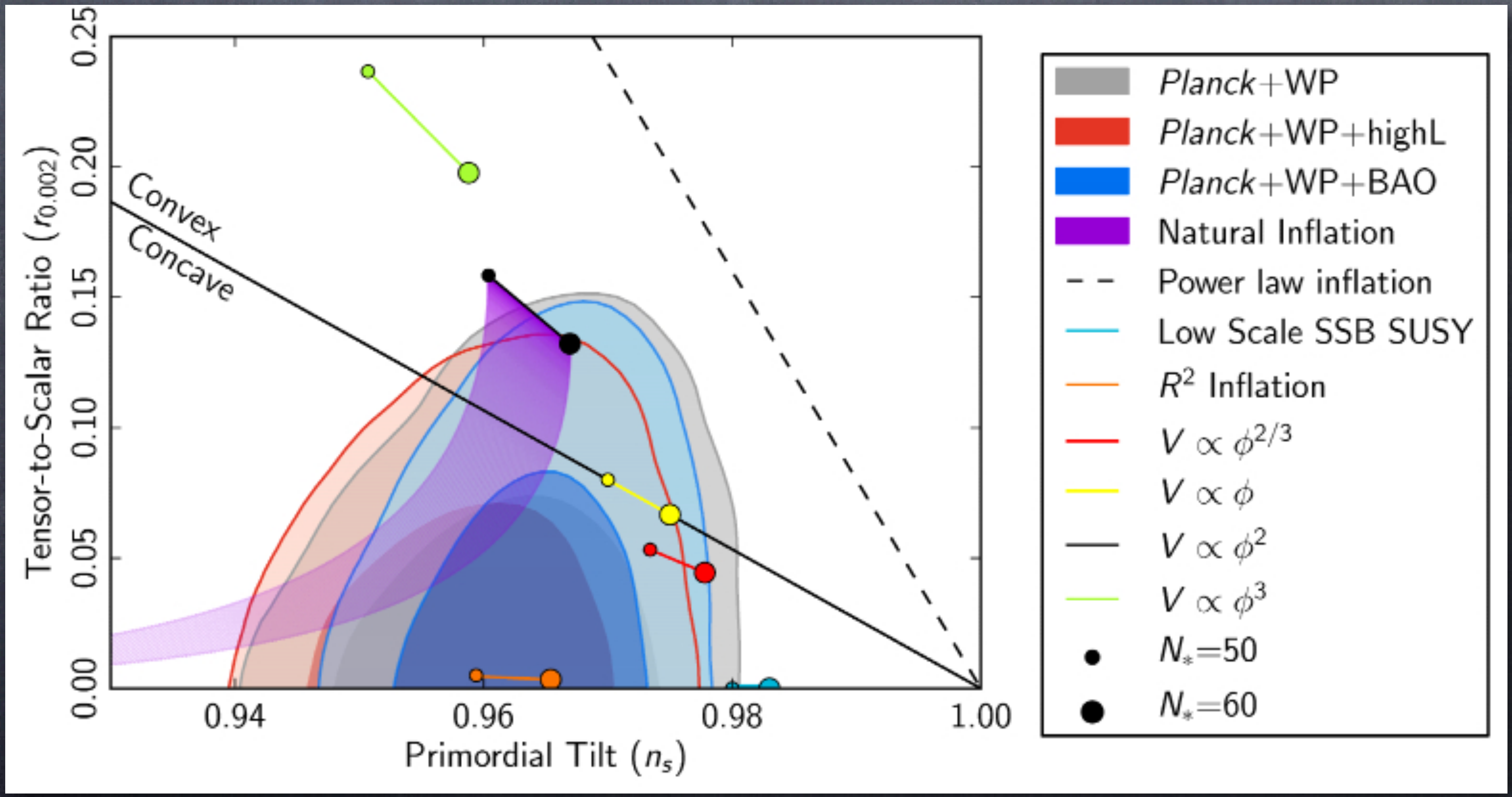
Parameters	WMAP9 2013	PLANCK 2013
Ω	0.02264±0.0005	0.02207±0.00033
Ω	0.1138±0.0045	0.1196±0.0031
n	0.972±0.013	0.9616±0.0094
τ	0.089±0.014	0.097±0.038
H	70.0±2.2	67.4±1.4
Ω	0.721±0.025	0.686±0.02

From $(\Omega_m, \Omega_\Lambda, H_0)=($**0.278, 0.722, 70.0**$)$ we have moved to $(\Omega_m, \Omega_\Lambda, H_0)=($**0.314, 0.686, 67.4**$)$ at a statistically significant level.

FUTURE: Accumulation of more data (only 1.5 year of data analysed)

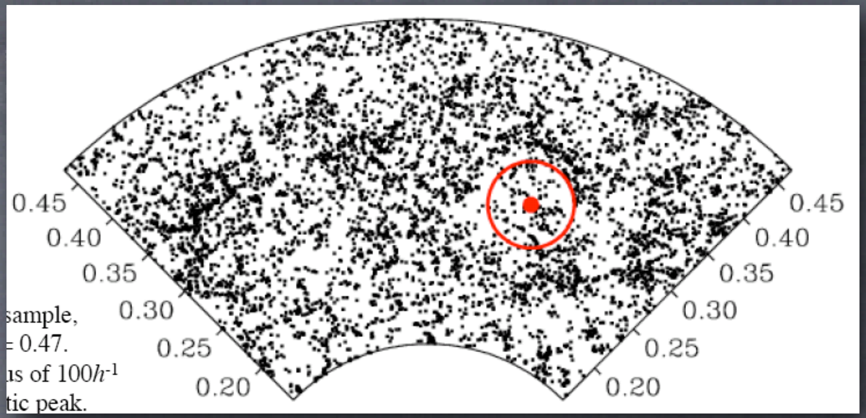
However, Planck results opened some unexpected issues regarding the Early Universe

The primordial tensor modes, if present, contribute to power-spectrum and have profound implications for Inflation. Most favorable Inflaton potentials appear to be excluded.



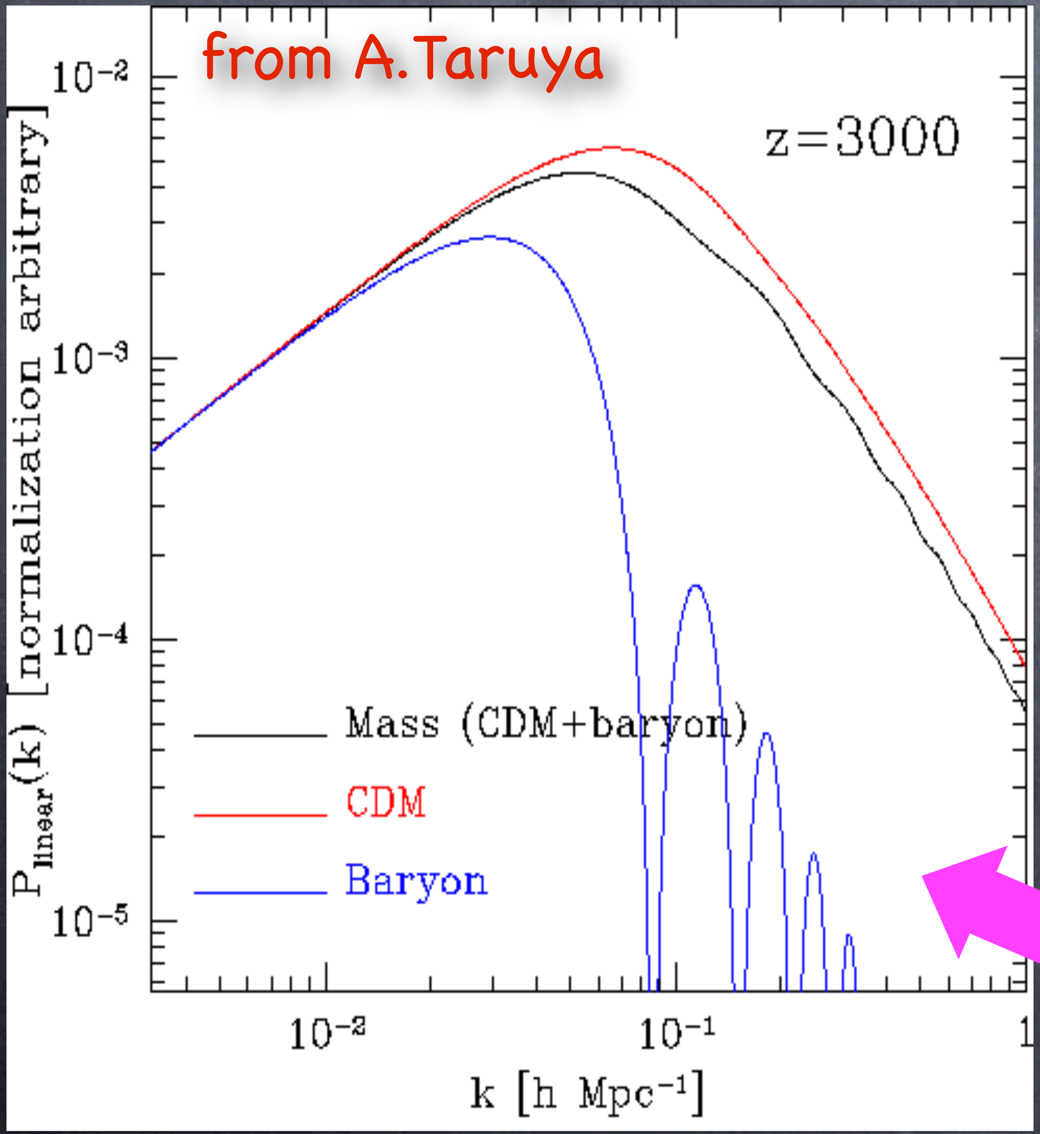
3. Baryonic Acoustic Oscillations

Acoustic oscillations of primeval baryon-photon fluid imprinted also on the clustering of large-scale structure



Typical BAO size

Power Spectrum



Physics of BAOs is well-known and unambiguous

But precision measurement of BAOs needs:

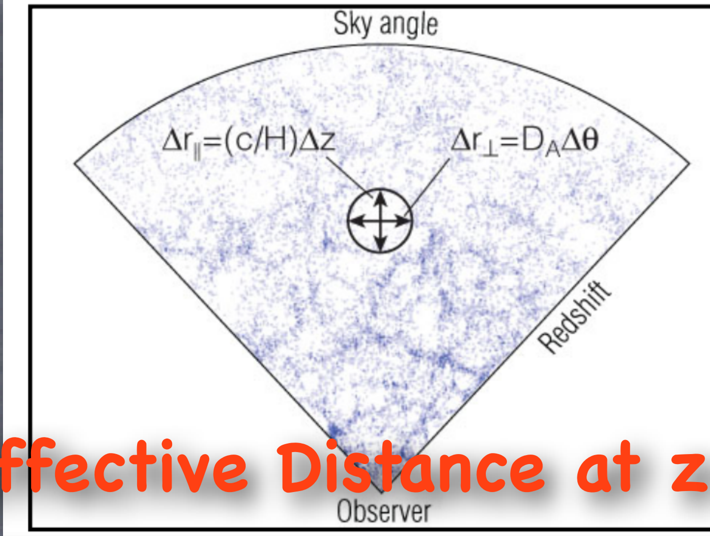
1. Accurate theoretical templates for P(k) and ξ(r)

2. Modelling systematic effects: Non-linear gravitational evolution, z-space distortions, galaxy biasing

3. Baryonic Acoustic Oscillations

Sound horizon at the time of decoupling (z~1100)

$$r_s(z_d) = \int_{z_{\rm dec}}^{\infty} \frac{c_s(z)}{H(z)} {\rm d}z = \frac{c}{\sqrt{3}} \int_0^{a_d} \frac{da}{a^2 H(a)\sqrt{1+(3\Omega_b/4\Omega_\gamma)a}}$$



Effective Distance at z*

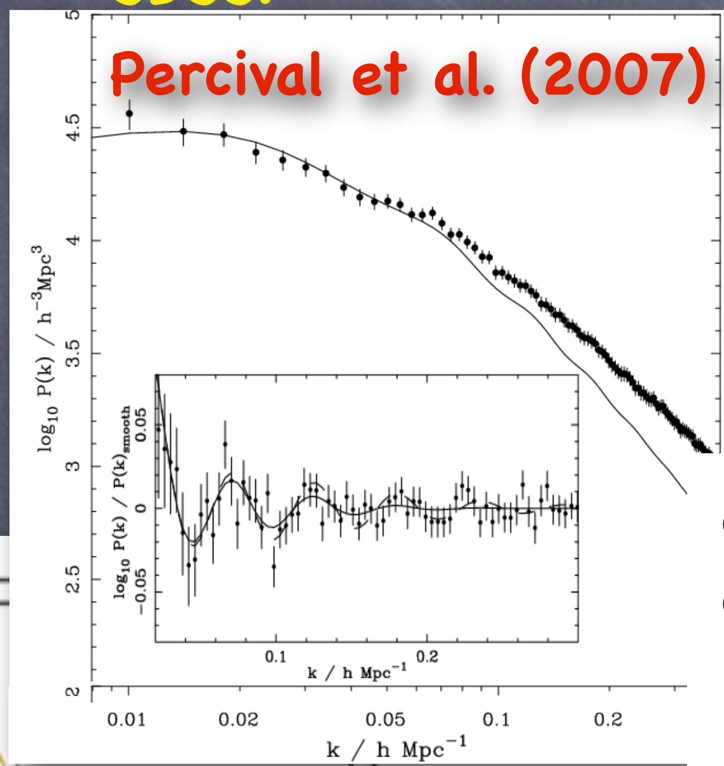
$$D_V(z) \equiv \left[(1+z)^2 D_A^2(z)\frac{cz}{H(z)}\right]^{1/3}$$

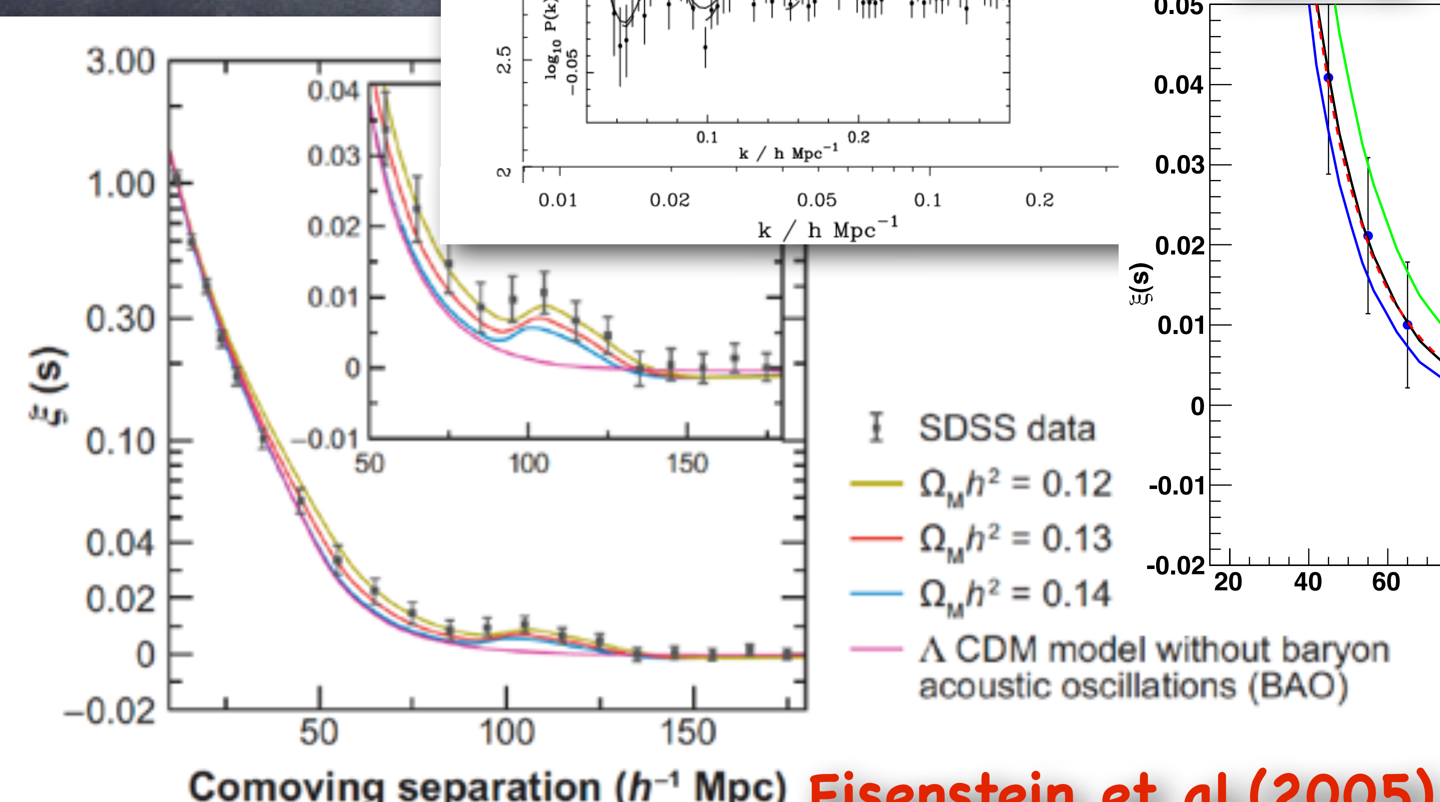
Observations provide:

$$r_s(z_{\rm dec})/D_V(z_\star) = 0.1390 \pm 0.0037$$

SDSS:

Percival et al. (2007)

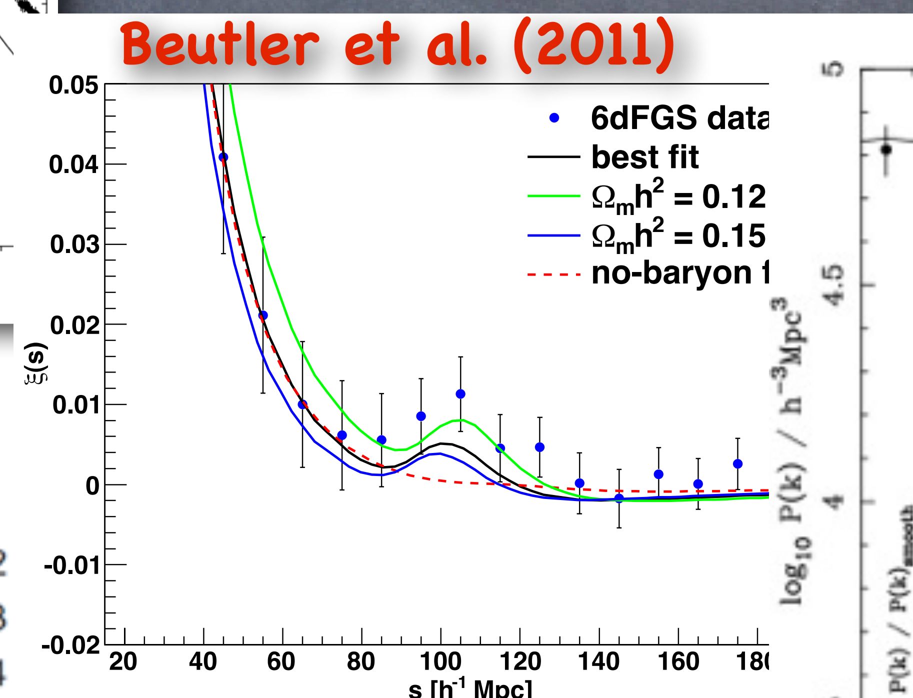




Eisenstein et al.(2005)

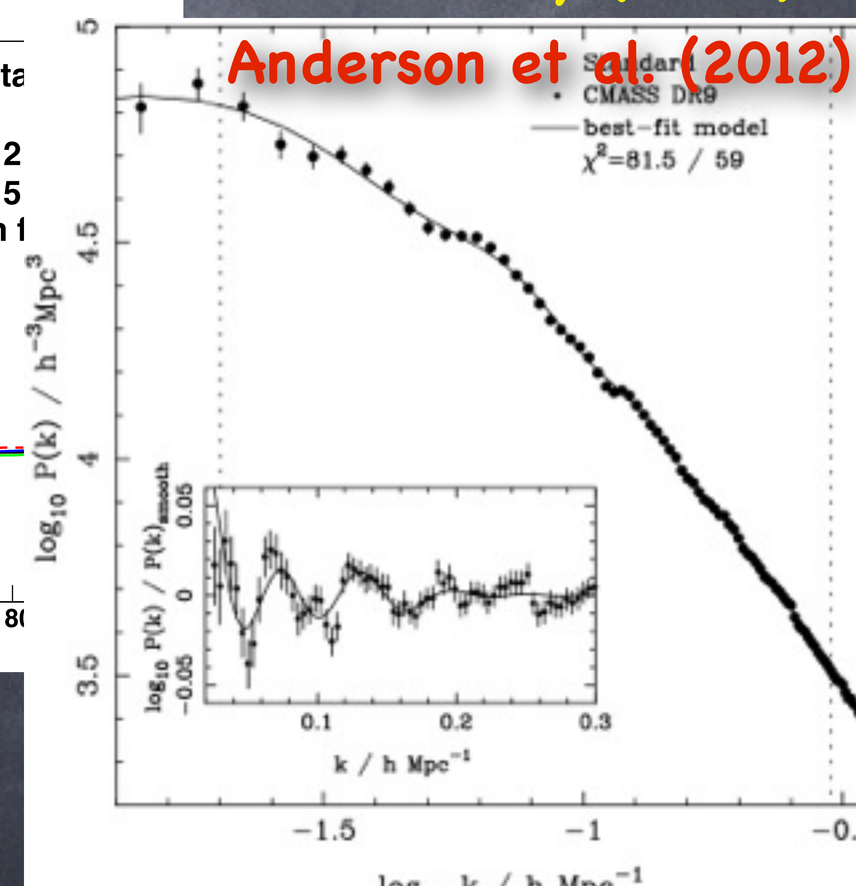
6dF survey (z~0.1):

Beutler et al. (2011)

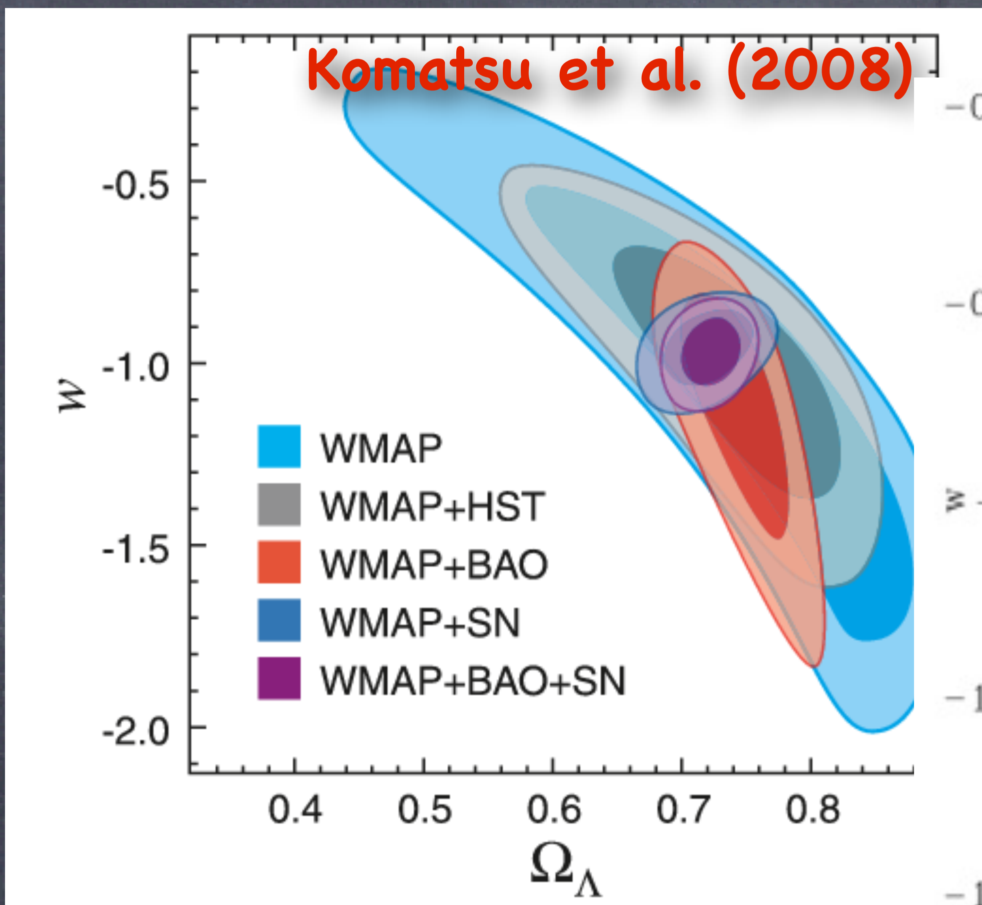


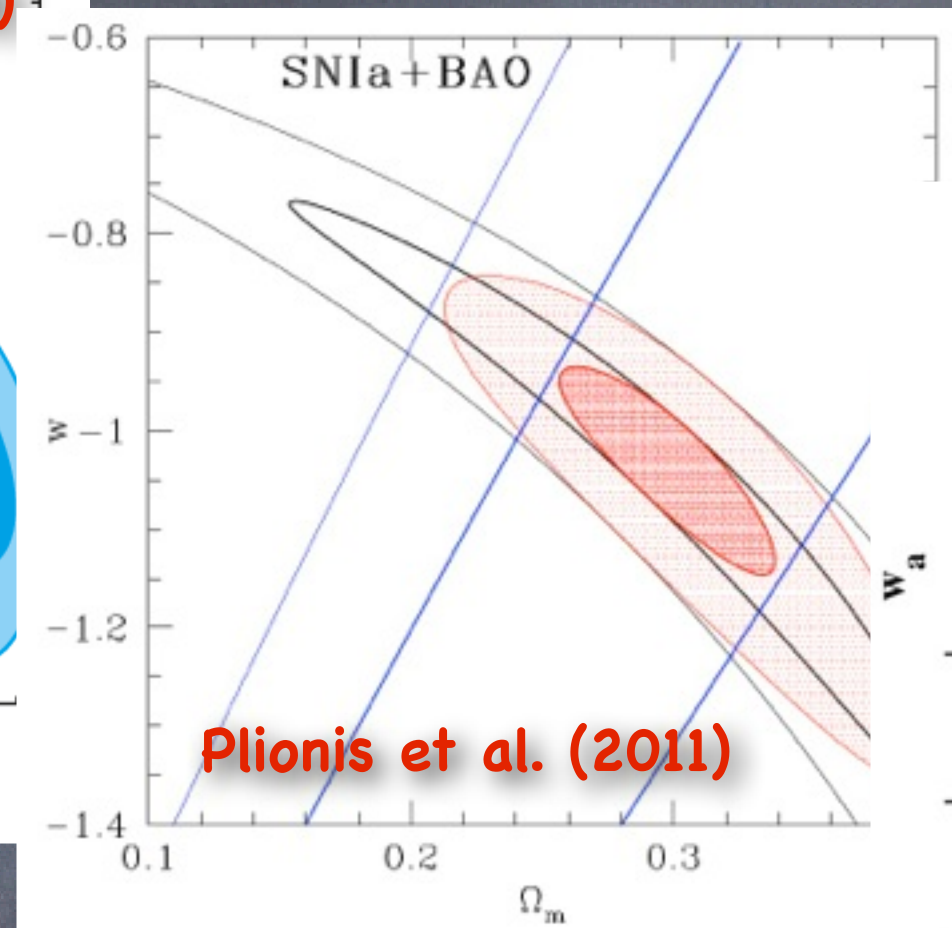
BOSS survey (z~0.6):

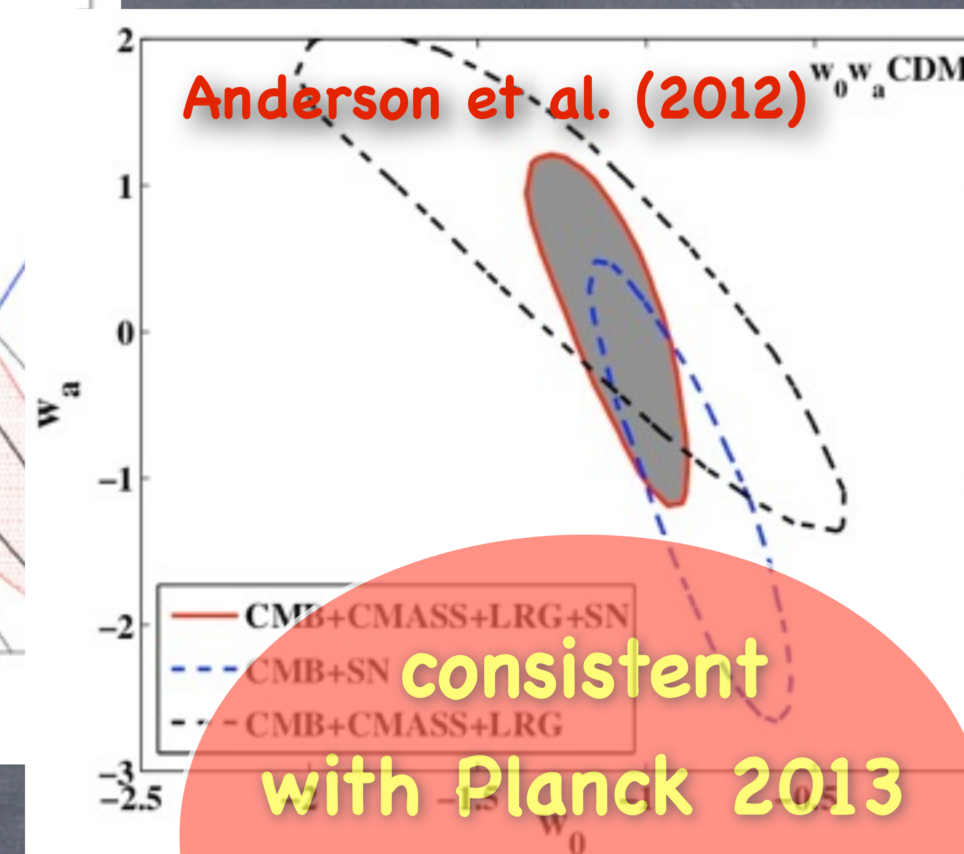
Anderson et al. (2012)



3. Baryonic Acoustic Oscillations







consistent with Planck 2013 but inconsistent with SNIa

Current results are based in SDSS/BOSS, 2dF, 6dF surveys with $V<0.7\ h^{-1}\ Mpc^3$ and $N_{gal}<6\times10^5$

This weeks joint results by Addison, Hinshaw, Halpern 2013

Only BAO

ΛCDM: $\Omega_m=0.303\pm0.040$

wCDM: $\Omega_m=0.292\pm0.043$, $w=-1.06\pm0.33$

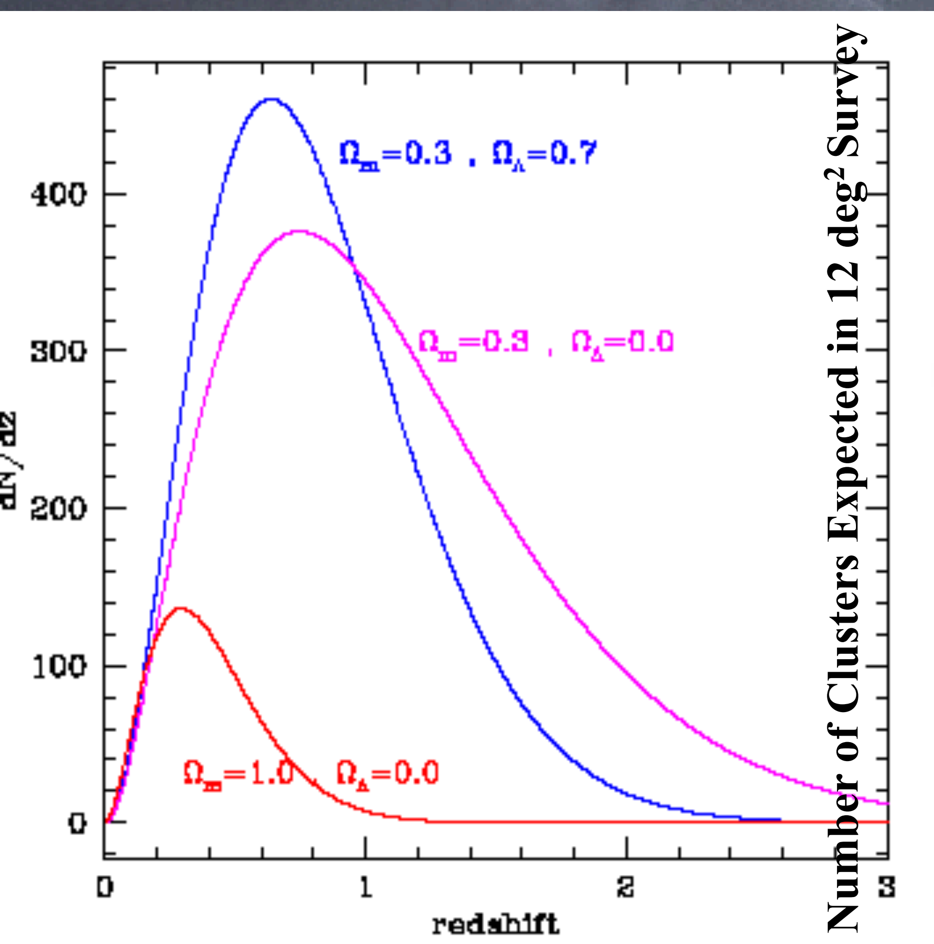
BAO+growth data

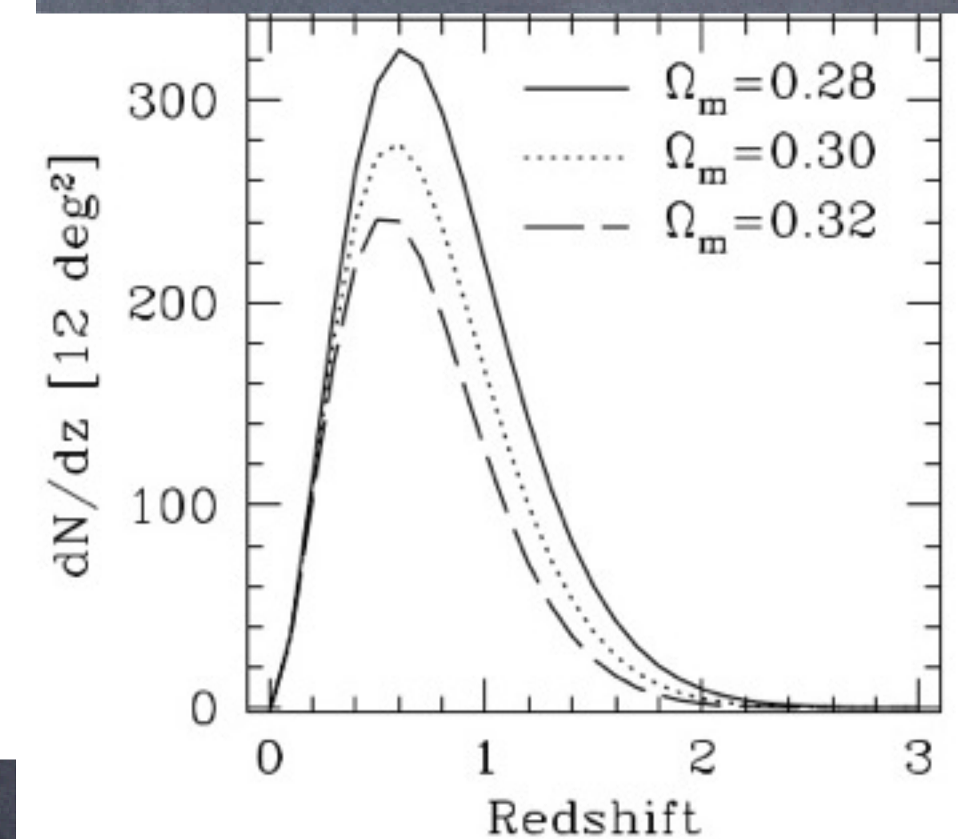
ΛCDM: $\Omega_m=0.290\pm0.019$, $H_0=67.5\pm2.8$ km/sec/Mpc

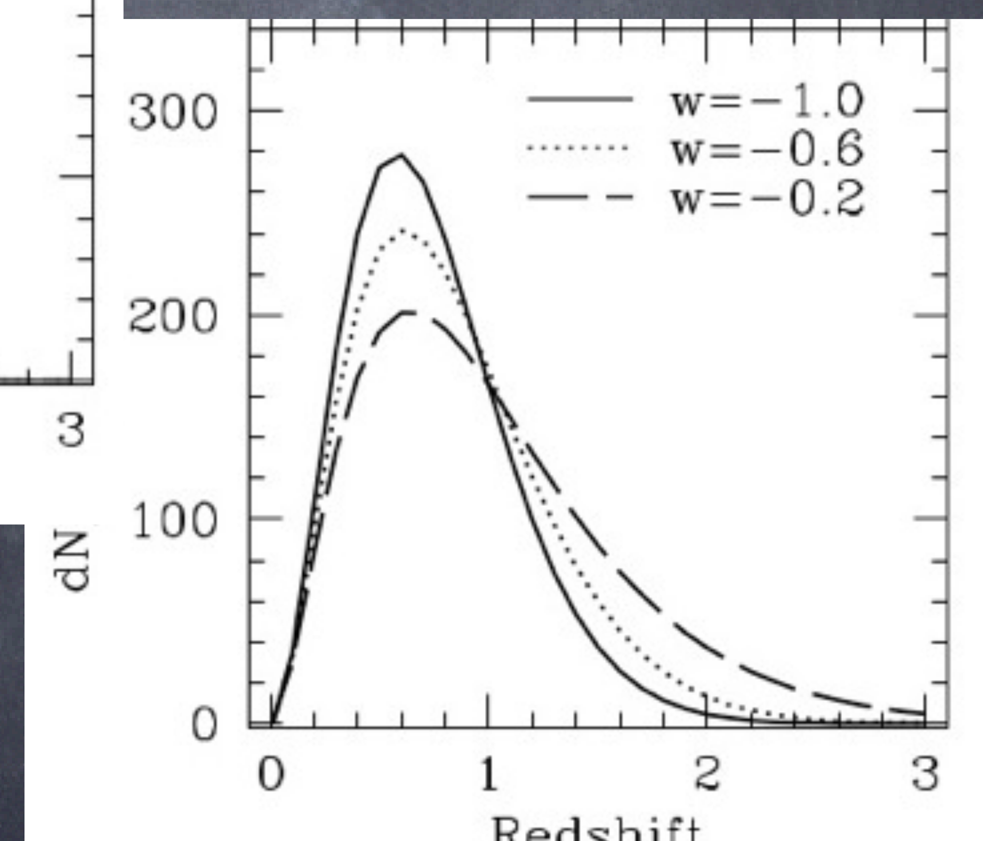
wCDM: $w=-1.14\pm0.19$

4. Clusters of Galaxies: Evolution of Cluster Abundances - Φ(M) & N(z)

Clusters of Galaxies are the largest gravitationally bound cosmic objects. The abundances of clusters as a function of redshift is a sensitive cosmological probe.







Haiman, Mohr & Holder 2001

4. Clusters of Galaxies: Evolution of Cluster Abundances - Φ(M) & N(z)

We use the Press-Schechter formalism which assumes that primordial fluctuations are described by a random Gaussian field and provides the number density of bound DM halos with masses within (M, M+δM).

$$n(M,z)dM = -\frac{\bar{\rho}}{M}\left(\frac{1}{\sigma}\frac{d\sigma}{dM}\right) f_{\mathrm{PSc}}(\sigma)dM = \frac{\bar{\rho}}{M}\frac{d\ln\sigma^{-1}}{dM} f_{\mathrm{PSc}}(\sigma)dM,$$

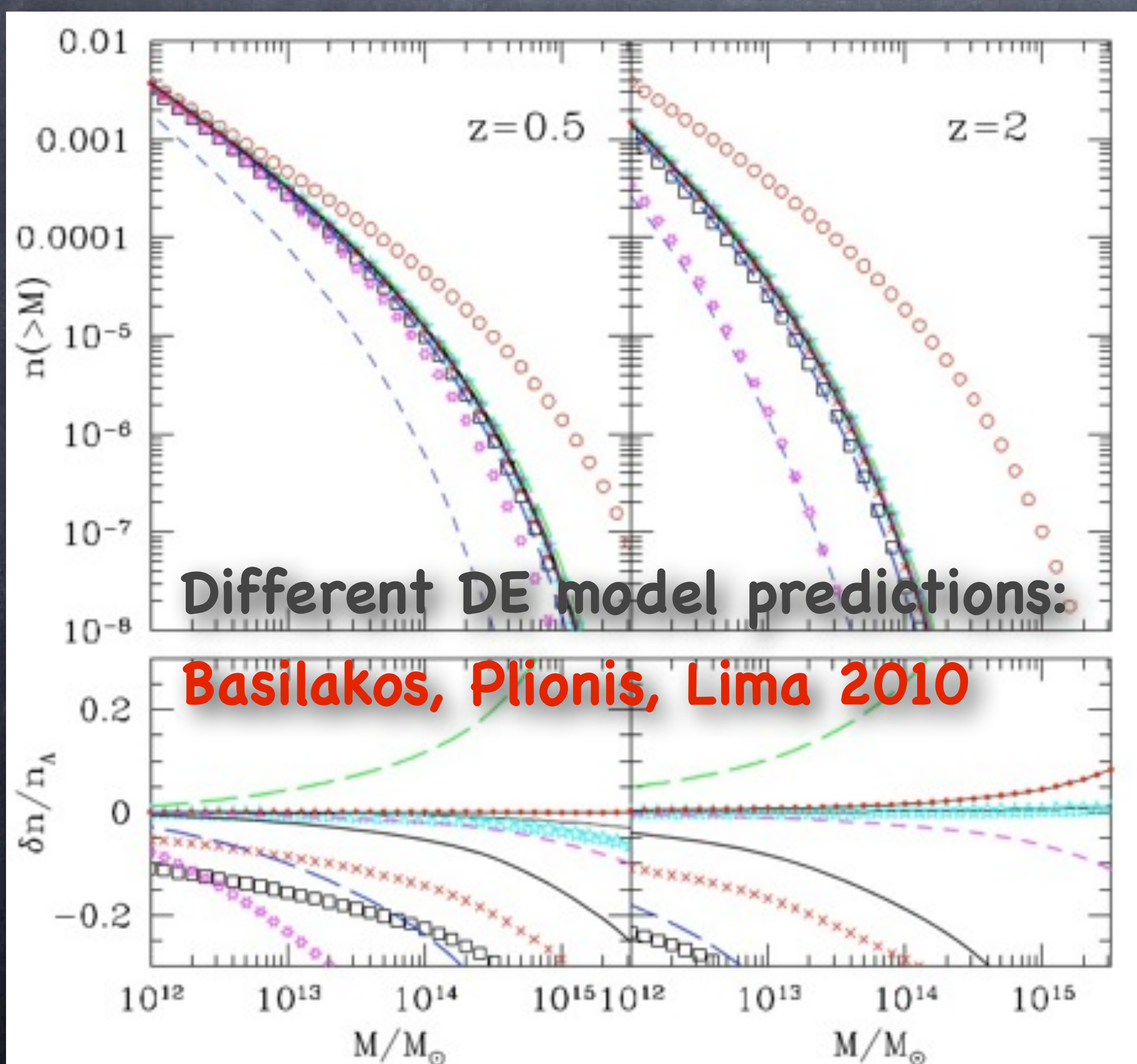
$$f_{\mathrm{PSc}}(\sigma) = \sqrt{2/\pi}(\delta_c/\sigma)\exp(-\delta_c^2/2\sigma^2)$$

We use Tinker et al (2010) f(σ)

δ_c is the linearly extrapolated density threshold above which structures collapse

$$\sigma^2(M,z) = \frac{D^2(z)}{2\pi^2}\int_0^\infty k^2 P(k) W^2(kR) dk$$

σ = mass variance of smoothed density field extrapolated at z where DM halo are identified



Different DE model predictions:

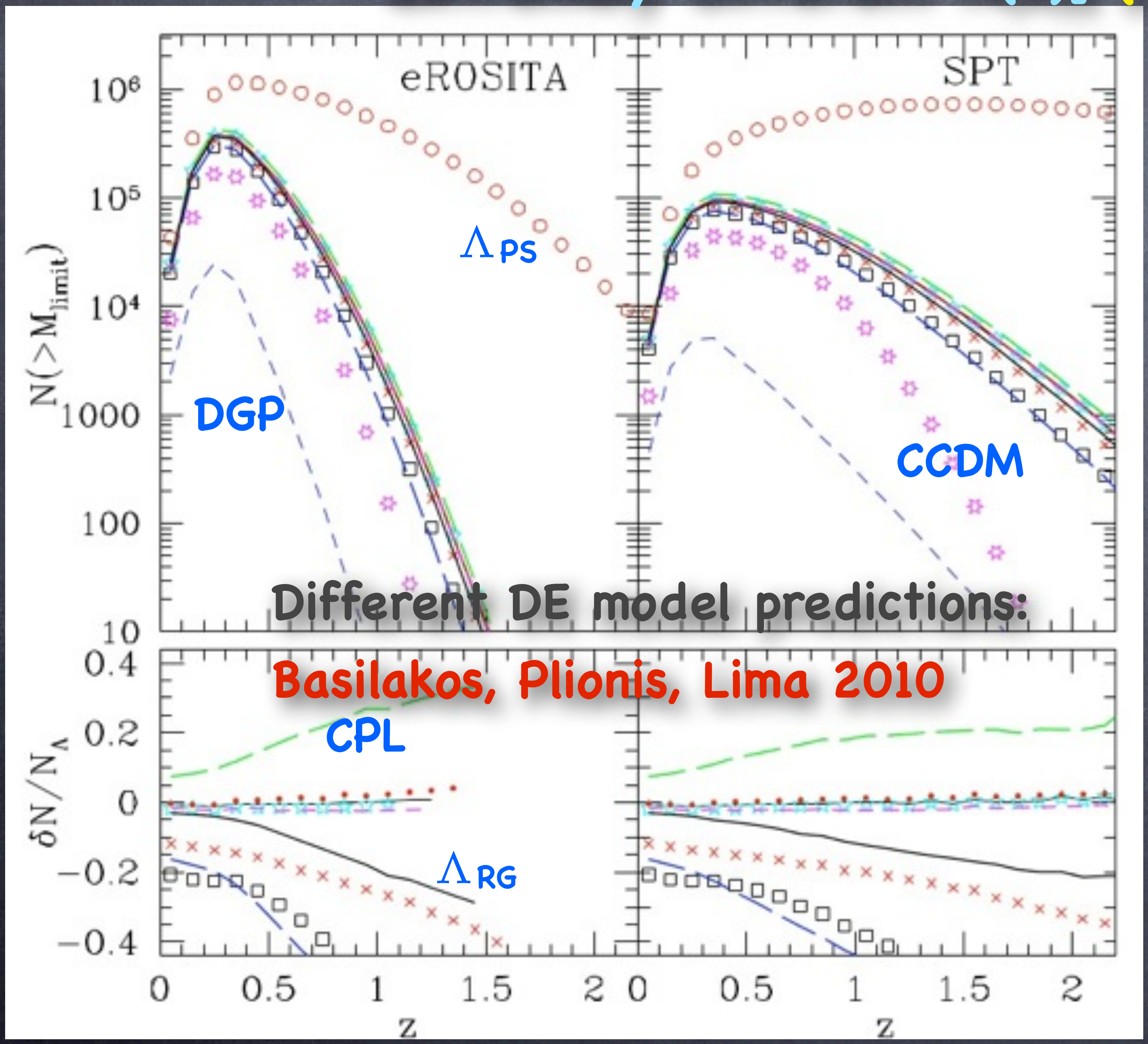
Basilakos, Plionis, Lima 2010

Sensitive to different Cosmologies through D(z) and P(k).

$$\boxed{\frac{dN(z)}{dz d\Omega} = \frac{c}{H(z)} d_A^2 (1+z)^2 \int_0^\infty dM \frac{dn(M,z)}{dM} f(M)}$$

4. Clusters of Galaxies: Evolution of Cluster Abundances - Φ(M) & N(z)

Such dynamical studies can be used also in order to test GR on large-scales, through the growth factor of matter fluctuations, D(z). Indeed here we have tested also such model [like DGP gravity, which provides extremely different N(z)] (Check talk of Pouri).



Systematics?

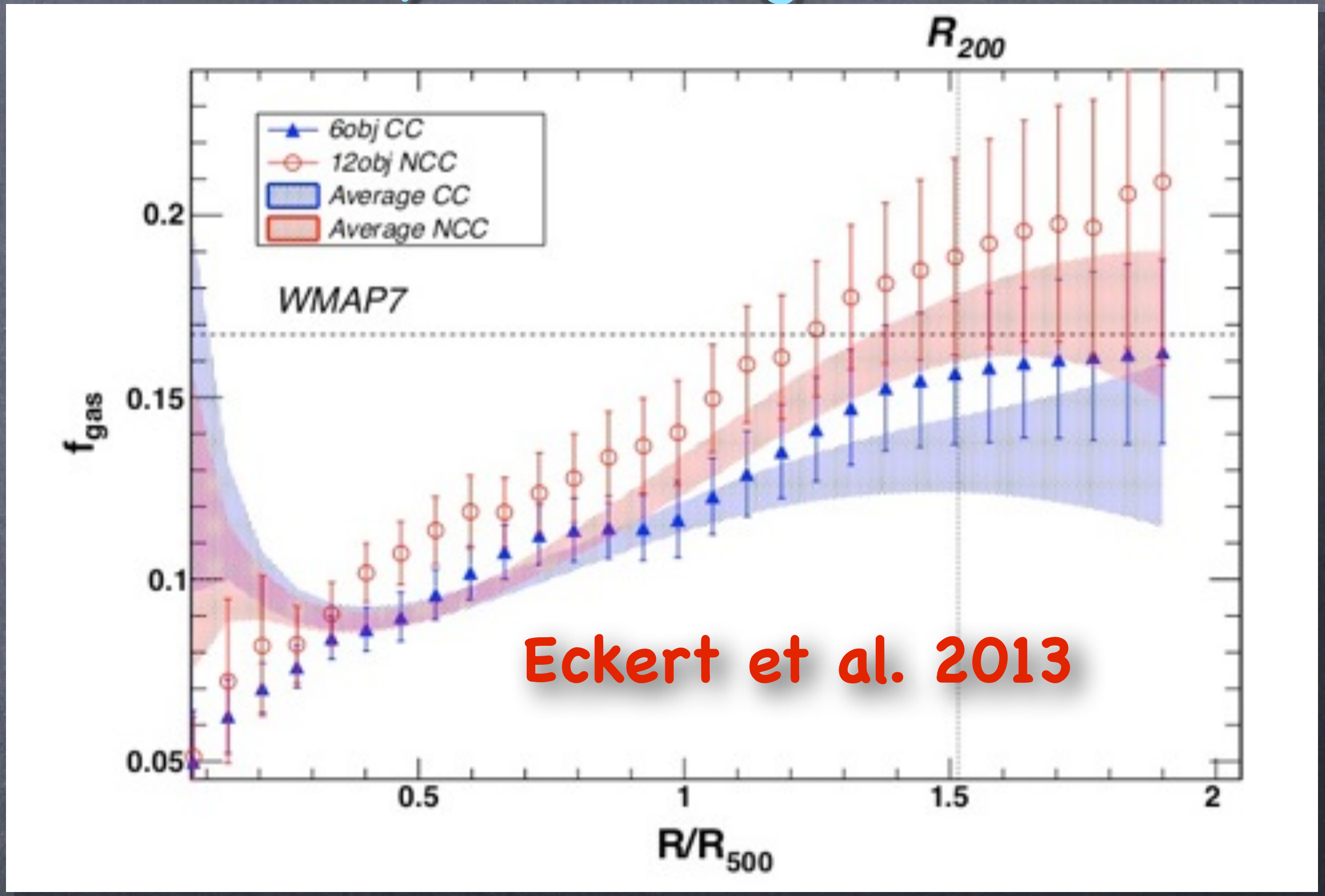
Important to include the effects of baryons in the Φ(M) since the baryonic mass fraction is on average a function of cluster total mass. The effect is changes in the normalization of Φ(M) and to a lesser degree on its slope (Balaguera-Antolínez, Porciani 2013)

4. Clusters of Galaxies: Ω_m from f_{bar}

This is an independent measurement of other cosmological parameters. Thus it can break degeneracies of other probes

BASIC HYPOTHESIS is that the DM and Baryonic mix in Clusters of galaxies corresponds to the Universal value.
Then compare estimate of Total Cluster Mass with baryonic mass (galaxies and gas) to BBPN value to get Ω_b.

First application by White et al. 1993, Nature: "The baryon content of galaxy clusters - A challenge to cosmological orthodoxy". The most recent result (Eckert et al. 2013) based on 18 local clusters common between Planck & ROSAT.



$$\left(\frac{M_b}{M_{\rm tot}}\right)_{\rm clust} = \frac{\Omega_b}{\Omega_m} = 0.166 \Rightarrow \Omega_m \simeq \frac{0.049}{0.166} \simeq 0.30$$

30% of cosmic mass-energy density is DM+Baryons

4. Clusters of Galaxies: Ω_m from M/L

This is an independent measurement of other cosmological parameters. Thus it can break degeneracies of other probes

Plionis et al. in preparation

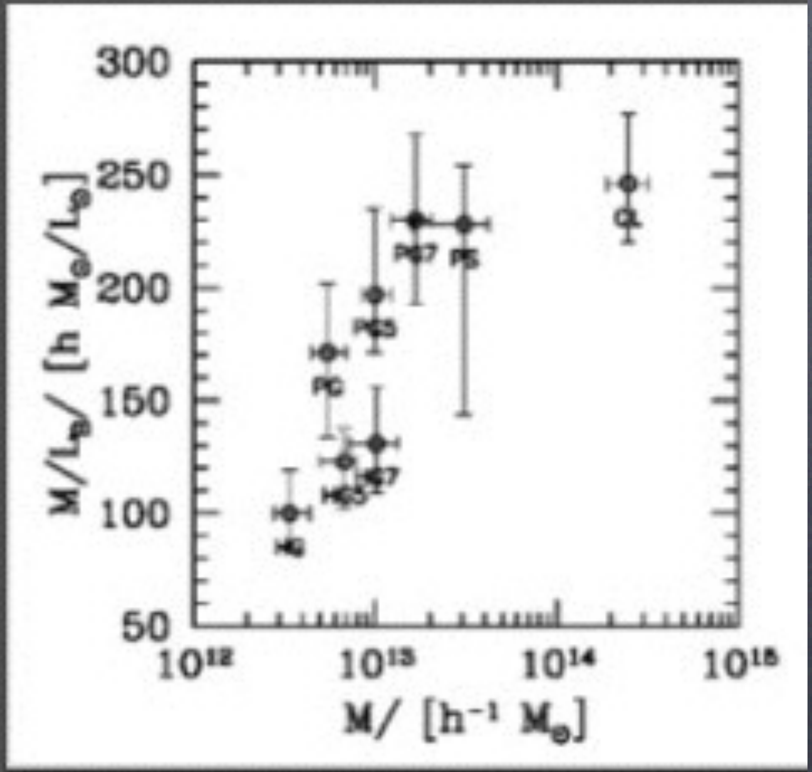
A. Determine Mass of clusters

B. Determine luminosity of clusters

Estimate Cluster galaxy luminosity function, $\Phi(L)$, integrate to low L.
Schechter Function, analytical and well behaved.

→Derive M/L for Clusters

$$\frac{M}{L} \approx 340h \frac{M_\oplus}{L_\oplus}$$



C. Determine Global M/L of Universe

→From total galaxy luminosity function, $\Phi(L)$, integrate to low luminosities. Schechter Function, analytical and well behaved.

→ Derive mean Luminosity density of Universe and then compare with mean Mass density of Universe to derive Global M/L (*SDSS, Blanton et al 2003*)

$$\Phi(L) = C\left(\frac{L}{L^*}\right)^a \exp(-L/L^*)$$

$$< L >= \int L\Phi(L)dL \propto L^*\Gamma(a+2)$$

$$\left(\frac{M}{L}\right) = \frac{\rho_0}{< L >} = \frac{\rho_{crit}\Omega_m}{< L >} \approx 1520\Omega_m h \frac{M_\oplus}{L_\oplus}$$

$$\Omega_m \approx 0.23$$

PROPOSAL FOR THE USE OF A NEW H(z) TRACER

INAOE, Aristotle Univ., Academy of Athens, Hawai, ESO
(collaborators: Terlevich, R. Terlevich, E., Plionis, M., Basilakos, S., Bressolin, F., Melnick J., Chavez, R., E. Koulouridis)

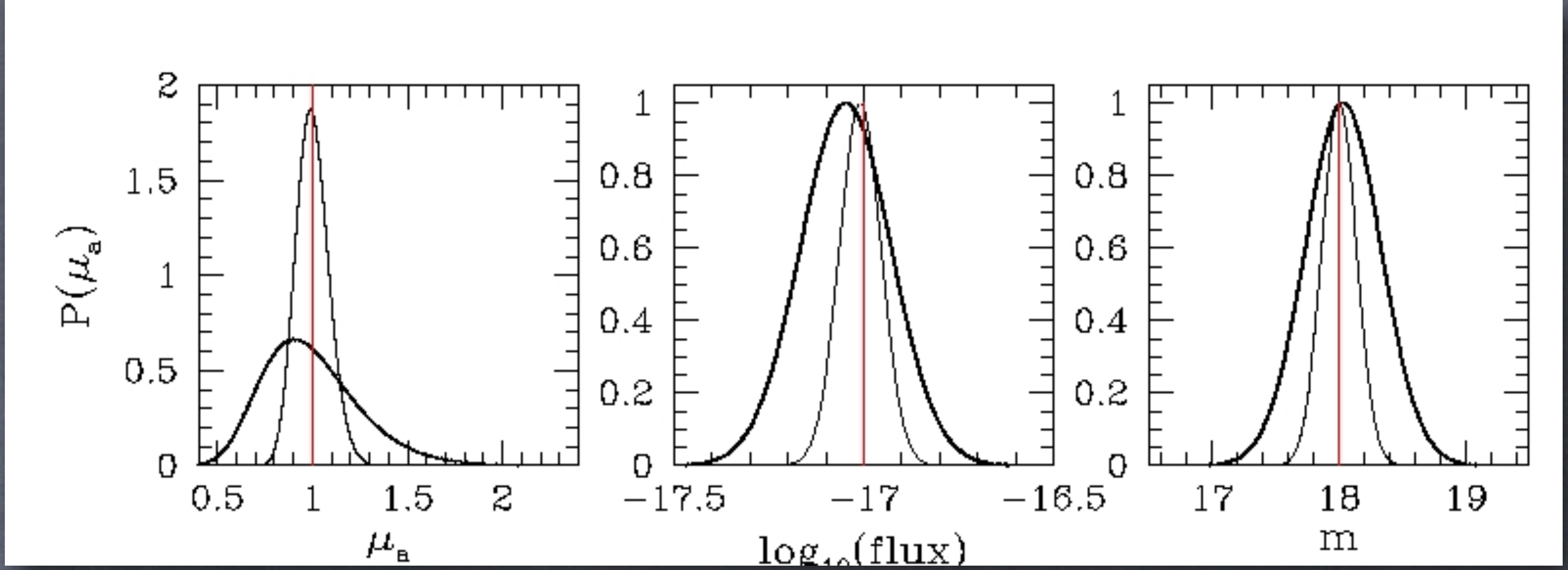
The only tracer of the Hubble relation used todate are the SNIa ($z<1.4$): Essential to verify results using alternative cosmic tracers, but also we need tracers that go deeper !

Our proposal is to use HII galaxies (**compact gals with massive burst of SF dominating total** L) and their local counterparts Giant HII regions. Optical spectra dominated by strong Balmer lines, produced by gas ionized by massive star cluster. Higher the Star cluster mass, larger the No of ionizing γ, larger the motions of the gas) ---> Tight correlation between $L(H_\beta)$ and stellar velocity dispersion, σ (Melnick & Terlevich 1981; Melnick et al. 1988; 2000).

H II Galaxies are high-z probes (more than SNIa)

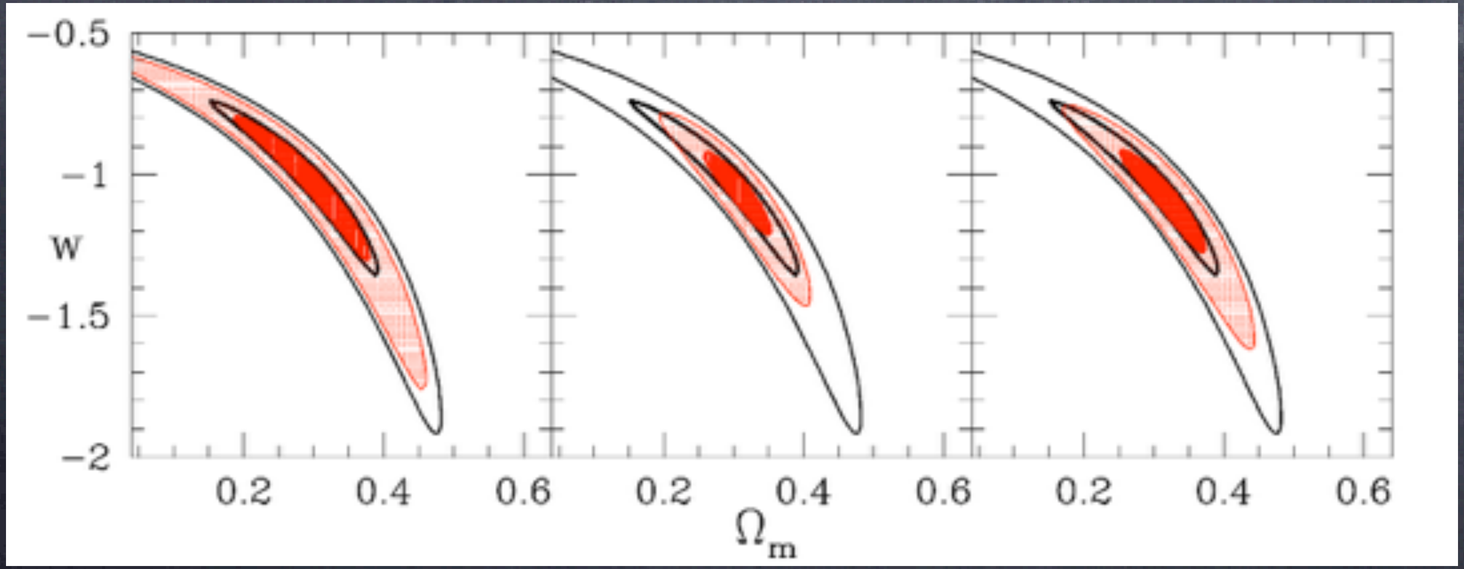
verified in detail in Plionis et al. 2011

Extensive Monte-Carlo Simulations to test methodology



Problems due to gravitational lensing

The LSS affects the propagation of light from high-z sources (eg., Holz & Wald 1998; Holz & Linder 2005; Brouzakis & Tetradis 2008). Assuming a Robertson-Walker background superimposing a locally inhomogeneous universe and taking into account both strong and weak lensing effects, results in a magnification distribution of a single source over different paths which is non-Gaussian. The magnification probability density function $P(\mu_\alpha)$ resembles a log-normal distribution with μ=0 (mean flux over all possible different paths is conserved since photon numbers are unaffected by lensing), with the mode shifted towards the de-magnified regime with a long tail to high magnification.

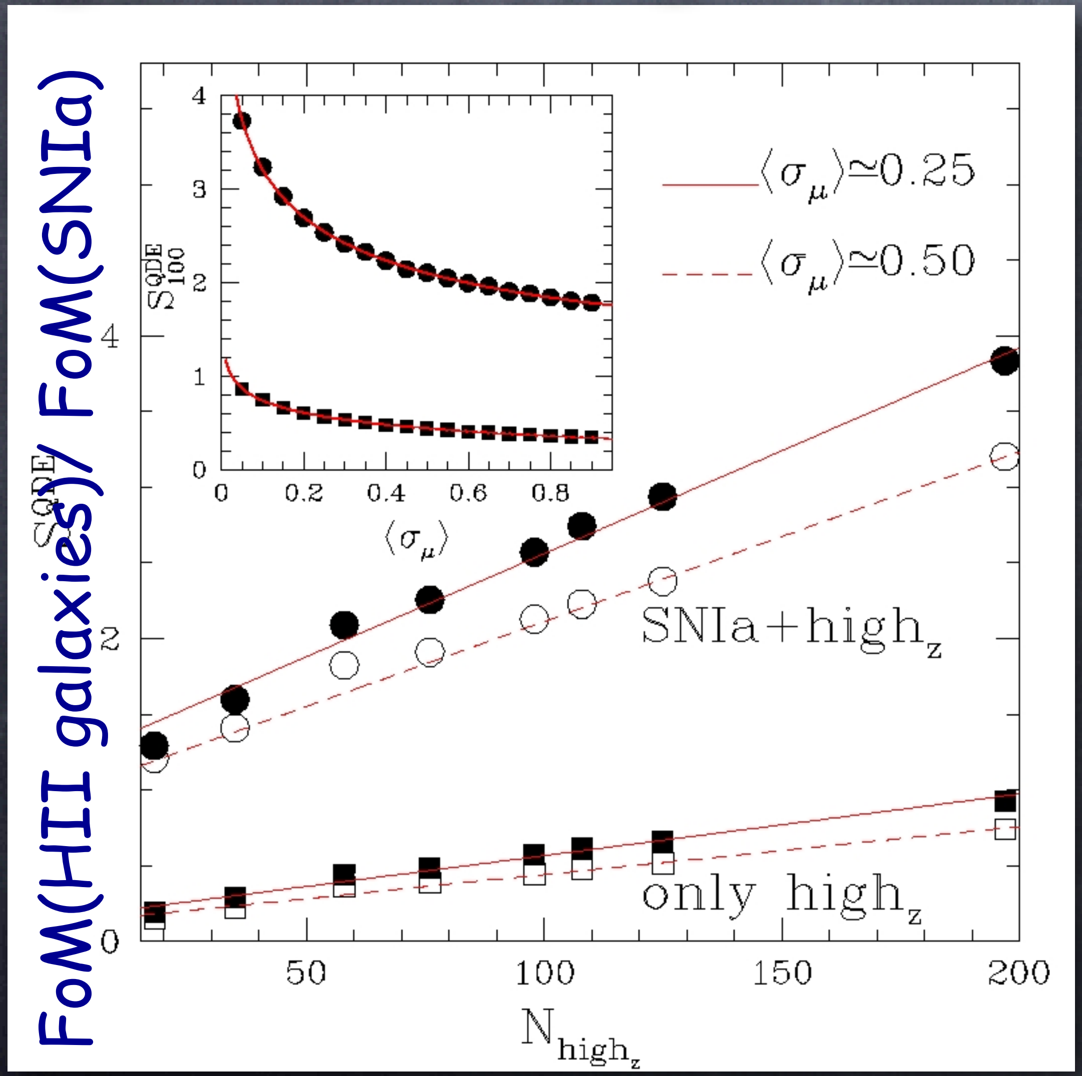


Thus most sources will be de-magnified, inducing an apparently enhanced accelerated expansion, while a few will be highly magnified.

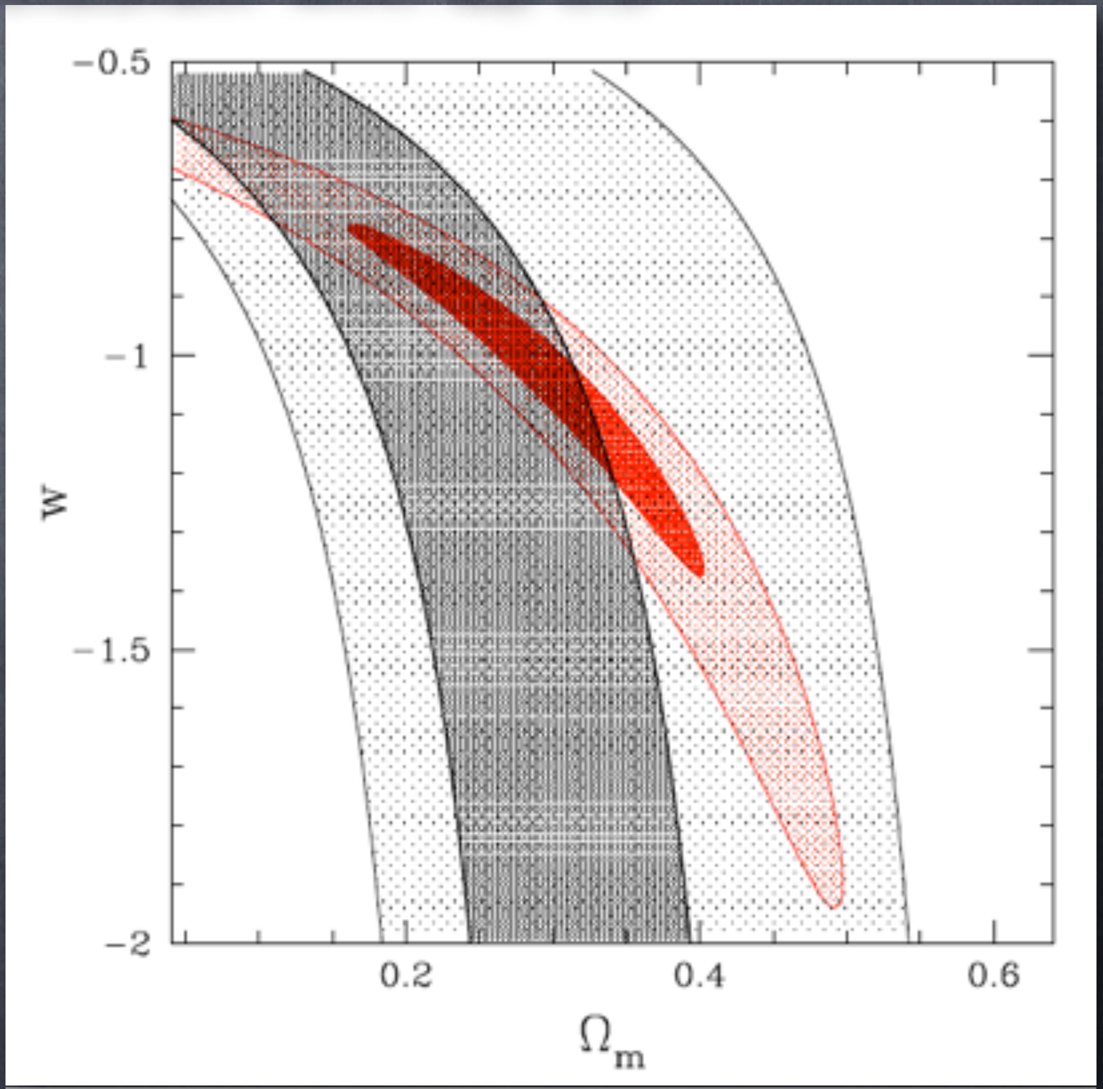
H II Galaxies are high-z probes (more than SNIa)

Plionis et al. 2011

We have performed extensive simulations to determine necessary numbers of high-z HII galaxies to be observed in order to increase the Figure of Merit by a given amount.



As a first example, we used the 15 HII galaxies of Siegel et al. (2005), our new zeropoint calibration of the L(H$_b$)-σ relation, to derive weak constraints on Ω_m but consistent with Ω_m~0.3



HII Galaxies: Low-z sample

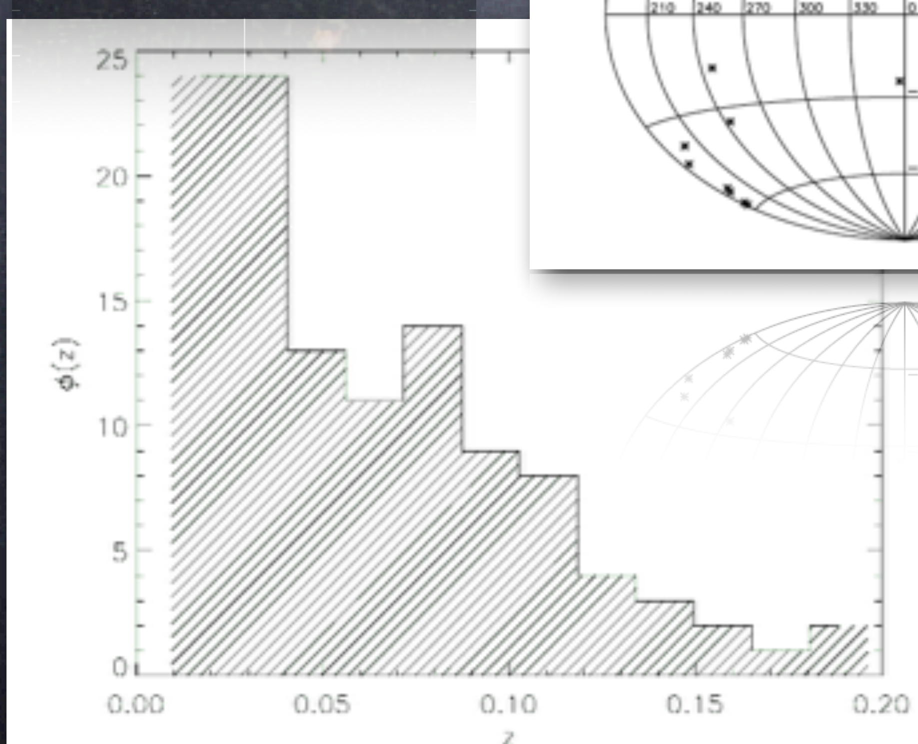
We select 128 HII galaxies from the spectroscopic DR7 SDSS catalogue within $0.01<z<0.16$
Their characteristics are: compact, with large Hβ fluxes and equivalent widths (W). The clean sample after excluding peculiar line profiles, double lines, or rotationally broaden lines is 92 HII galaxies.

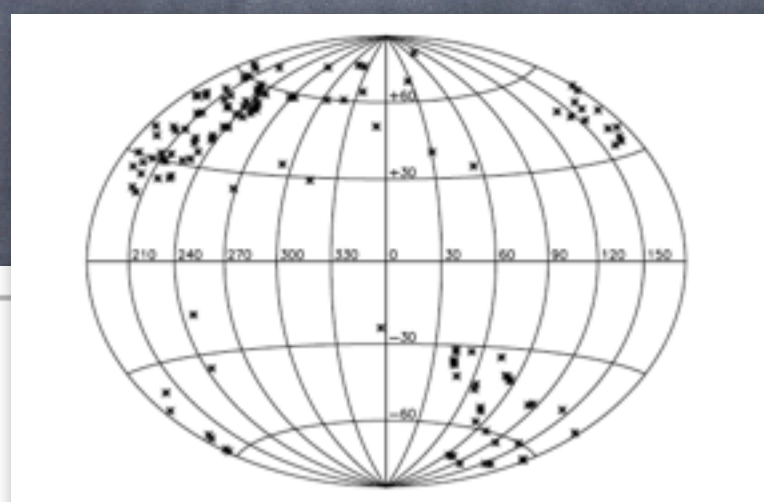
Telescopes used:

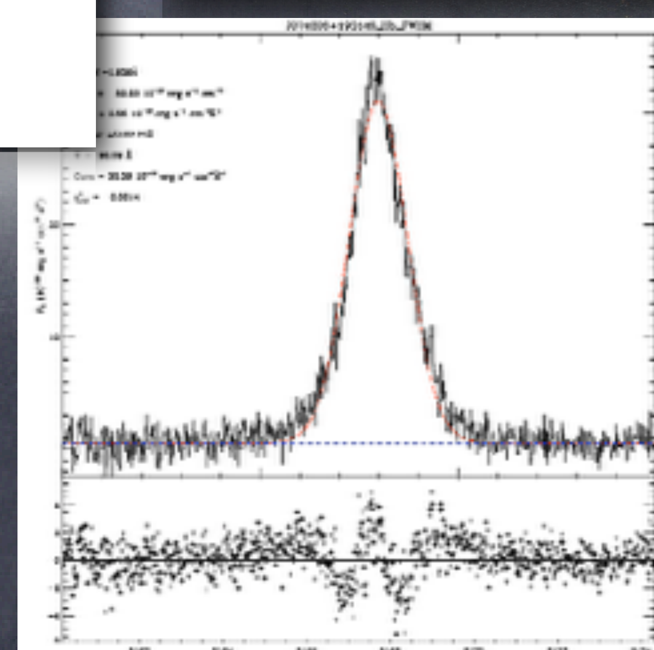
Subaru 8m (HDS),

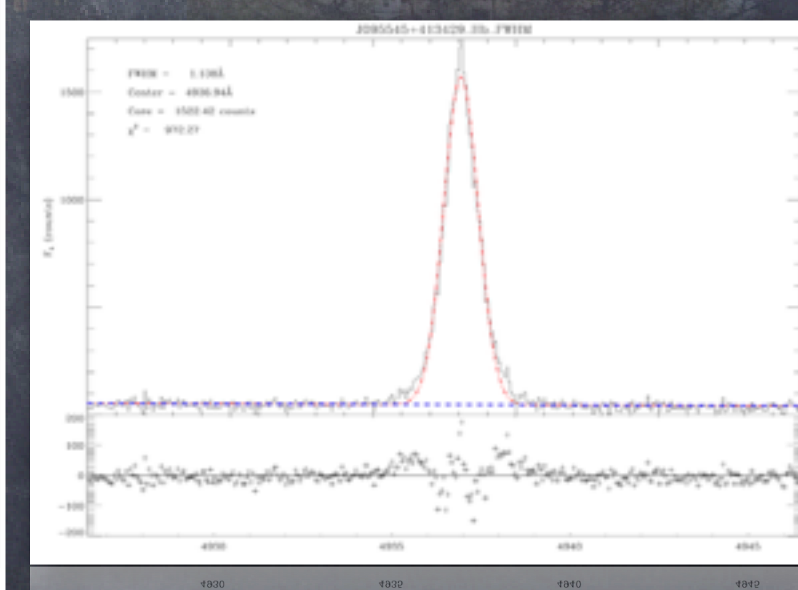
VLT 8m (UVES) to measure velocity dispersions,

SPM & Cananea 2.1m (integrated fluxes)









Measuring H_0

The Hubble Constant: Current and Future Challenges
Kavli Institute for Particle Astrophysics and Cosmology, February 2012
Sherry H. Suyu, Tommaso Treu, Roger D. Blandford, Wendy L. Freedman, ed.

The Hubble constant and new discoveries in cosmology

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Abstract.
We report the outcome of a 3-day workshop on the Hubble constant during February 6-8 2012 at the Kavli Institute for Particle Astrophysic the campus of Stanford University†. The participants met to address th Are there compelling scientific reasons to obtain more precise and more ac of H_0 than currently available? If there are, how can we achieve this go emerged from the workshop are (1) better measurements of H_0 provide constraints on dark energy, spatial curvature of the Universe, neutrino pl general relativity, (2) a measurement of H_0 to 1% in both precision and ac rigorous error budgets, is within reach for several methods, and (3) multiple determinations of H_0 are needed in order to access and control systemati

First Application: Determine H_0 within $z<0.1$ (the only alternative to SNIa)

Monthly Notices of the Royal Astronomical Society LETTERS
Mon. Not. R. Astron. Soc. (2012) doi:10.1111/j.1745-3933.2012.01299.x

Determining the Hubble constant using giant extragalactic H II regions and H II galaxies

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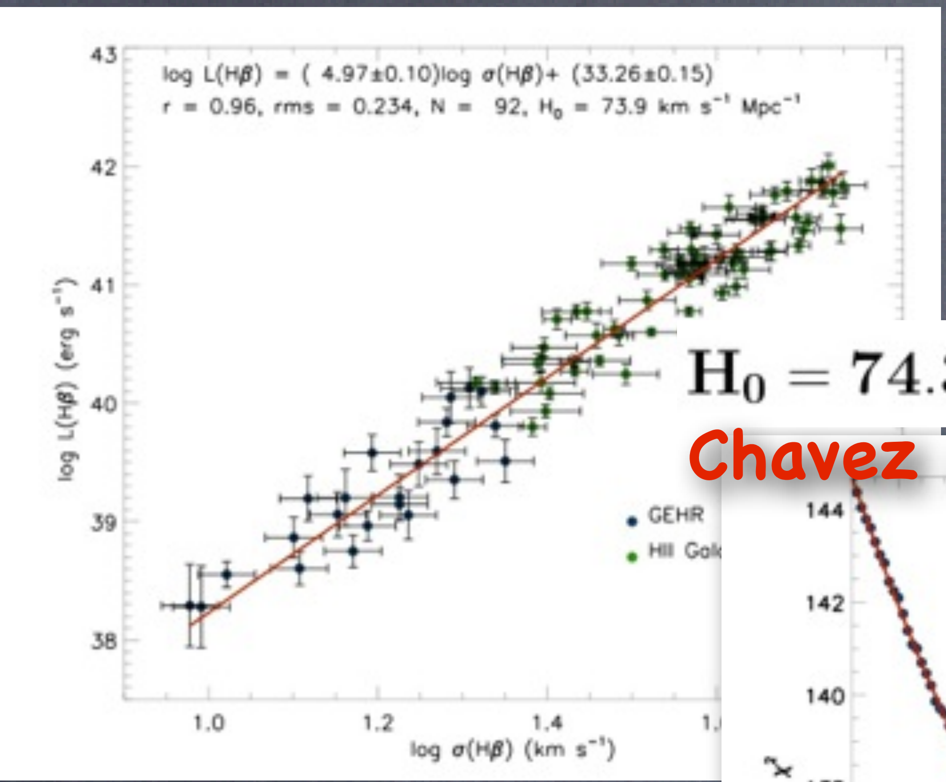
ABSTRACT
We report the first results of a long-term programme aiming to provide accurate independent estimates of the Hubble constant (H_0) using the $L(\mathrm{H}\beta)$–σ distance estimator for giant extragalactic H II regions (GEHR) and H II galaxies.

We have used Very Large Telescope and Subaru high-dispersion spectroscopic observations of a local sample of H II galaxies, identified in the Sloan Digital Sky Survey Data Release 7 (SDSS DR7) catalogue in order to redefine and improve the $L(\mathrm{H}\beta)$–σ distance indicator and to determine the Hubble constant. To this end, we utilized as local calibration or 'anchor' of this correlation GEHR in nearby galaxies which have accurate distance measurements determined via primary indicators. Using our best sample of 69 nearby H II galaxies and 23 GEHR in nine galaxies, we obtain $H_0 = 74.3 \pm 3.1$ (statistical) ± 2.9 (systematic) km s^{-1} Mpc^{-1}, in excellent agreement with, and independently confirming, the most recent Type Ia supernovae based results.

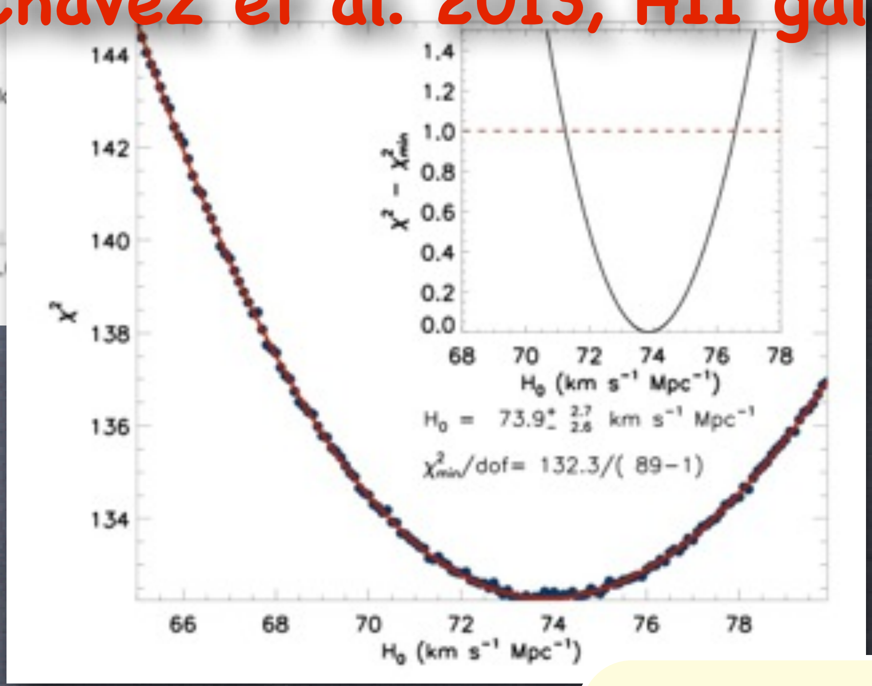
Key words: H II regions – cosmological parameters – distance scale.

Using 92 HII galaxies with z<0.1 and 23 local zeropoint calibrators (Giant HII regions with primary indicator distances) we derived the (H_β)-σ relation and H_0



$$H_0 = 74.3 \pm 4.2 \ \mathrm{km\ sec^{-1}\ Mpc^{-1}}$$

Chavez et al. 2013, HII gals



Riess et al. 2011, 600 Cepheid in 8 calibration local SNeIa:

H_0=73.8±2.4 km/sec/Mpc

Freedman et al. 2012: HST key project new Spitzer 3.6μm calibration of Cepheid distance scale:

H_0=74.3±2.2 km/sec/Mpc

Planck 2013:

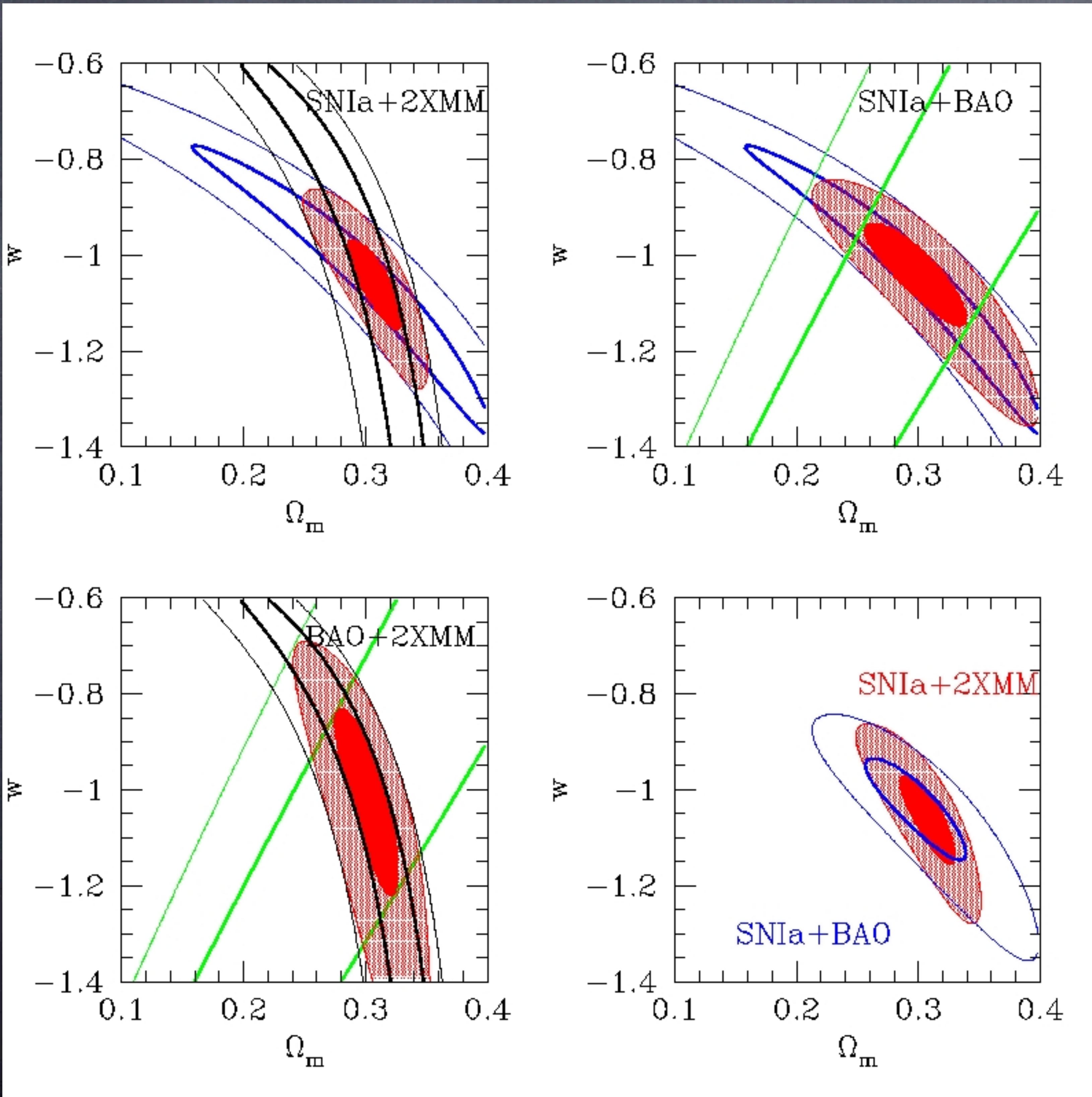
H_0=67.4±1.4 km/sec/Mpc

WMAP-9yr: Hinshaw et al. 2013

H_0=69.7±2.5 km/sec/Mpc

H_0 CONFLICT between direct methods and CMB fits!! Could it be that we live in a local underdensity ?

Our final aim is to provide DE equation of state using the joint liklehood of the Hubble expansion probe (using the alternative HII galaxies) and the clustering of X-ray AGN & Clusters of galaxies



Example of our methodology: The joint likelihood analysis, of the 2XMM clustering and the SNIa Hubble relation, and under the priors of a flat universe, h=0.704 and σ_8=0.81 provide significantly more stringent QDE constraints, as indicated by the fact that the ***Figure of Merit increases by a factor ~2,*** with respect to that of the joint SNIa-BAO analysis.

Ω_m=0.31±0.01, w=-1.06±0.05

Plionis et al. 2011

Concluding Remarks

- **The Cosmic Acceleration Problem is currently one of the most important open issues in the whole of physics**. From one side, large observational projects, missions and experiments are designed in order to measure with precision its effects on the expansion of the Universe and on the evolution of cosmic structures; from the other their are huge theoretical efforts to identify models which are physically motivated and resolve the present inconsistencies.

- **High redshift ($2<z<3.5$) Cosmological Probes are necessary** in order to obtain better constraints to the Cosmological Parameters space and distinguish among models.

- **We propose and use H II galaxies as an alternative H(z) tracer:** A first application provided **H_0=74.3 ± 3.1 (random) ±2.9 (systematic) km s^{-1} Mpc^{-1}** in excellent agreement with SNIa. A further target is to reduce uncertainty to 1% level, which is necessary for DE studies. Also a large number of high redshift H II galaxies are already catalogued, while no SNe Ia is known at such z, and these will be used to provide strong constraints in the Ω_m-w and w_0-w_a plane.