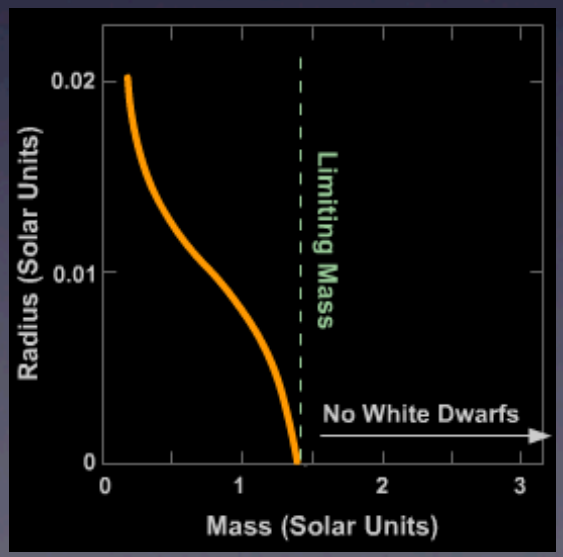
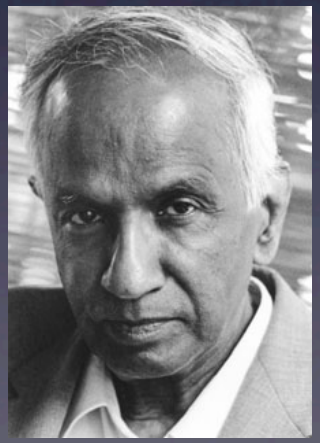
SNIa Cosmology with WISH satellite

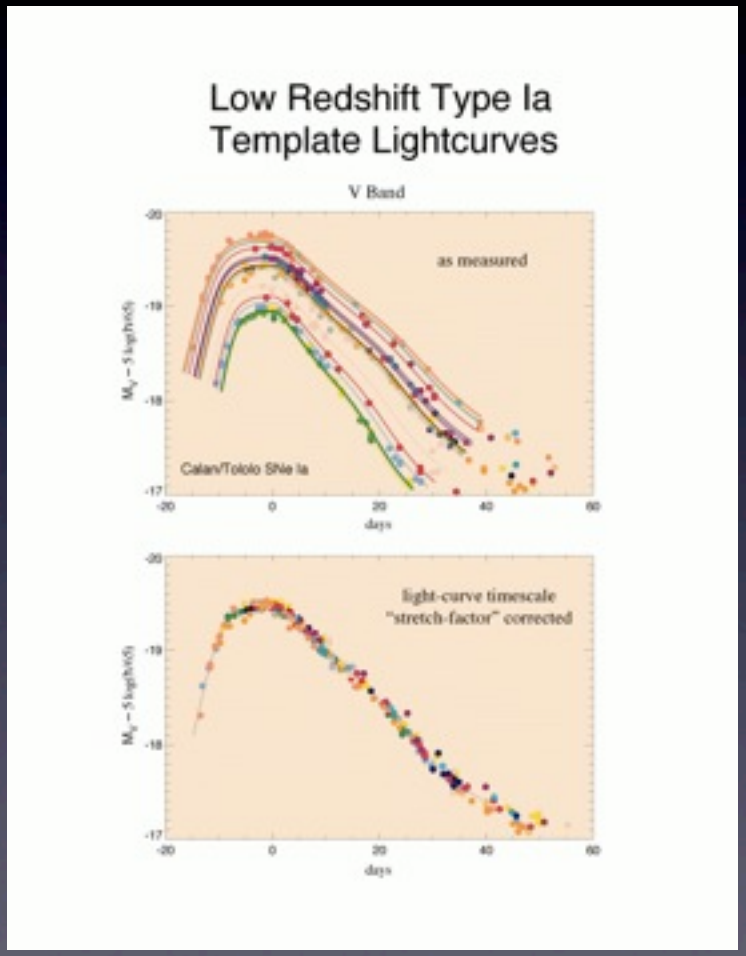
Nao Suzuki (Lawrence Berkeley Lab)

§1: Introduction to Type Ia Supernova
§2: SNIa Cosmology Today
§3: SNIa Challenges (systematic errors)
New Standard Stars for IR
§4: SNIa Cosmology with WISH

Supernova Type Ia : Standard Candle
Phillips Relation (1993)

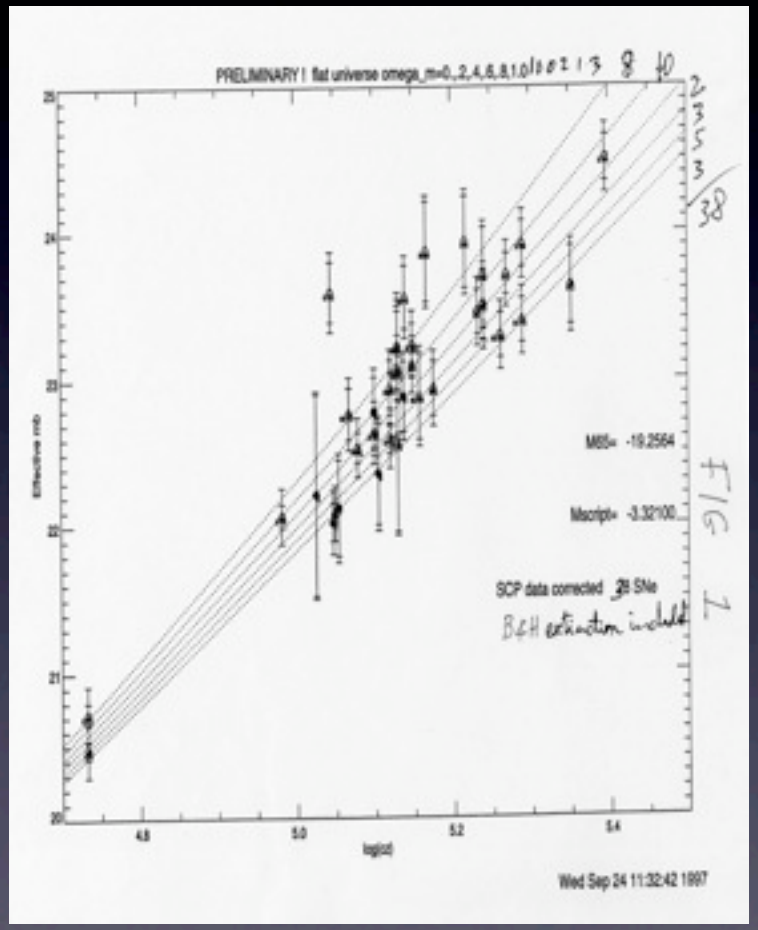




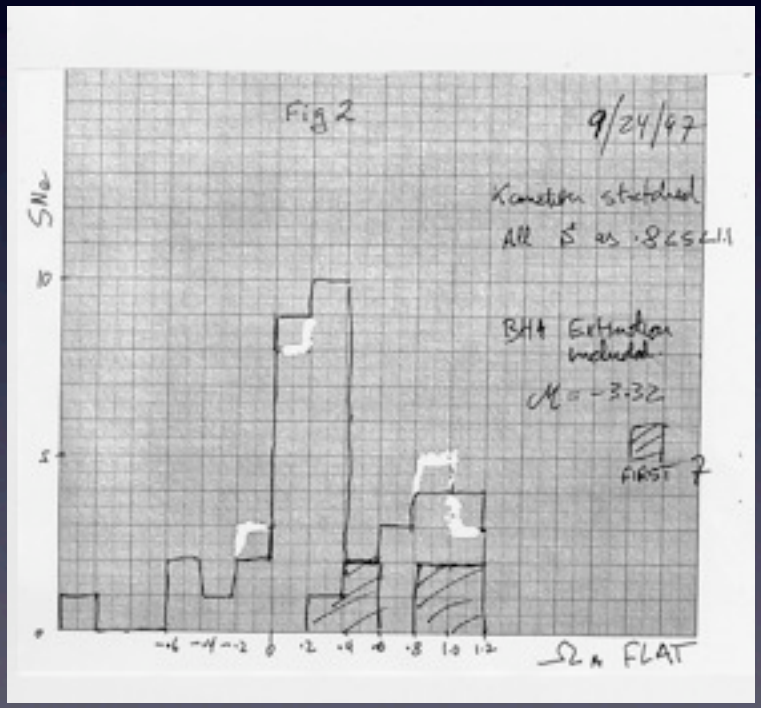


Physics Today (2003)

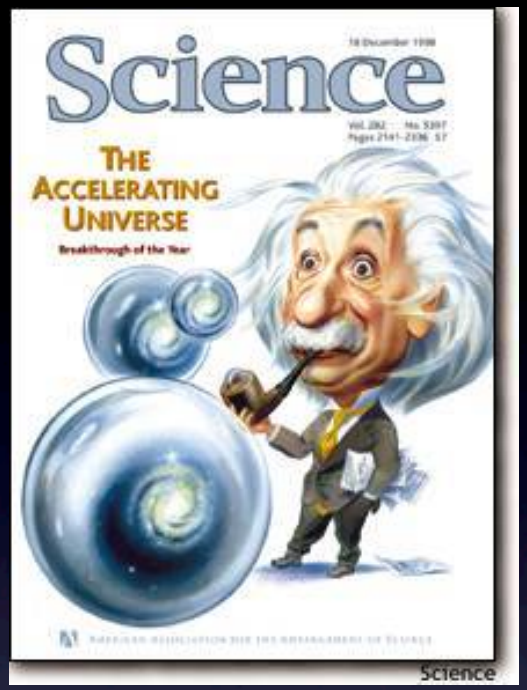
Discovery of Dark Energy (SCP 1997)

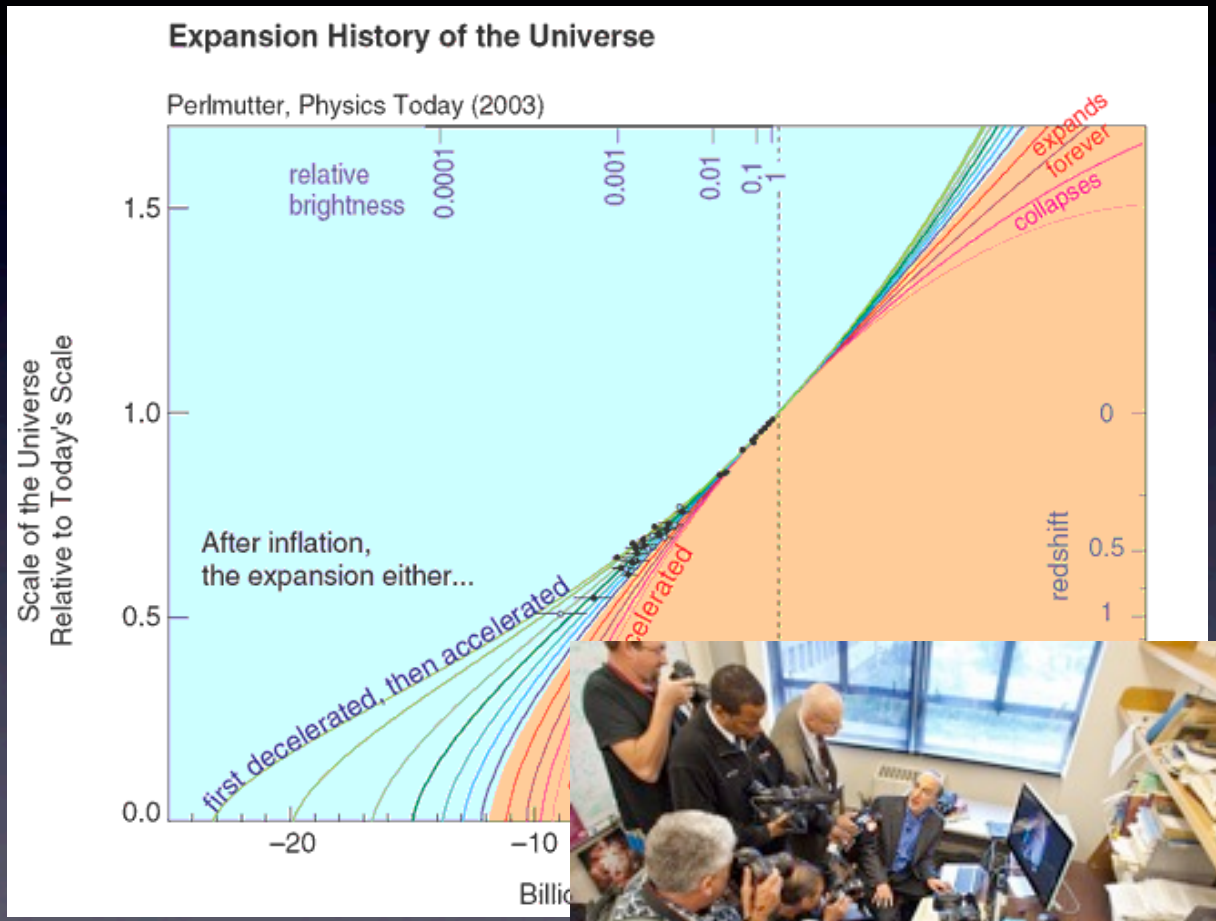


Gerson Goldhaber reported non-zero Λ on 24th in Sep '97



Accelerating Universe





HST Cluster SN Survey

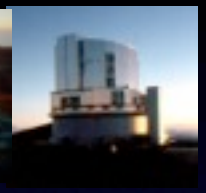
Nao Suzuki & SCP
PI: Saul Perlmutter

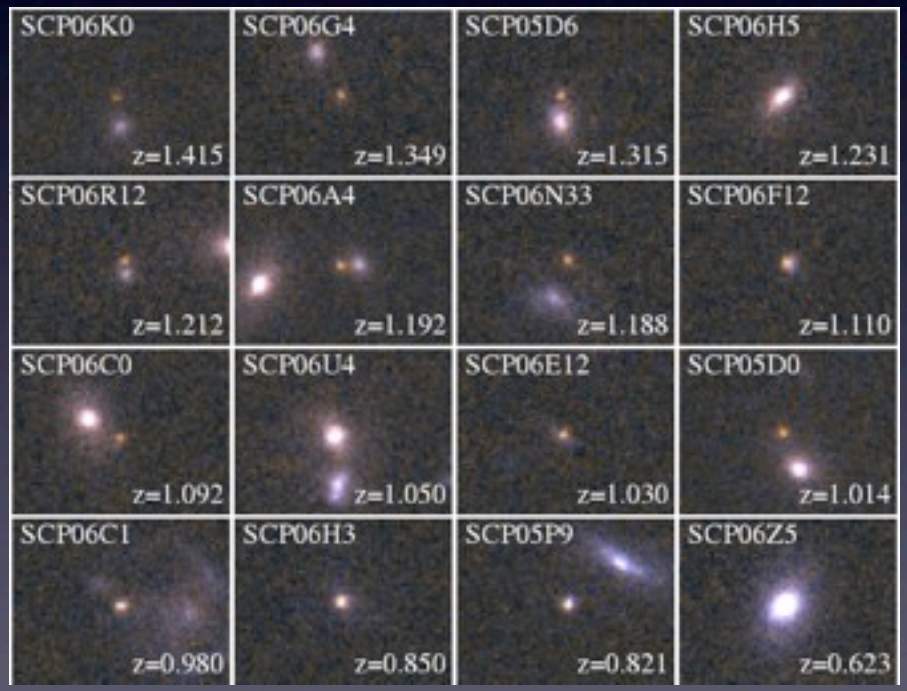
HST

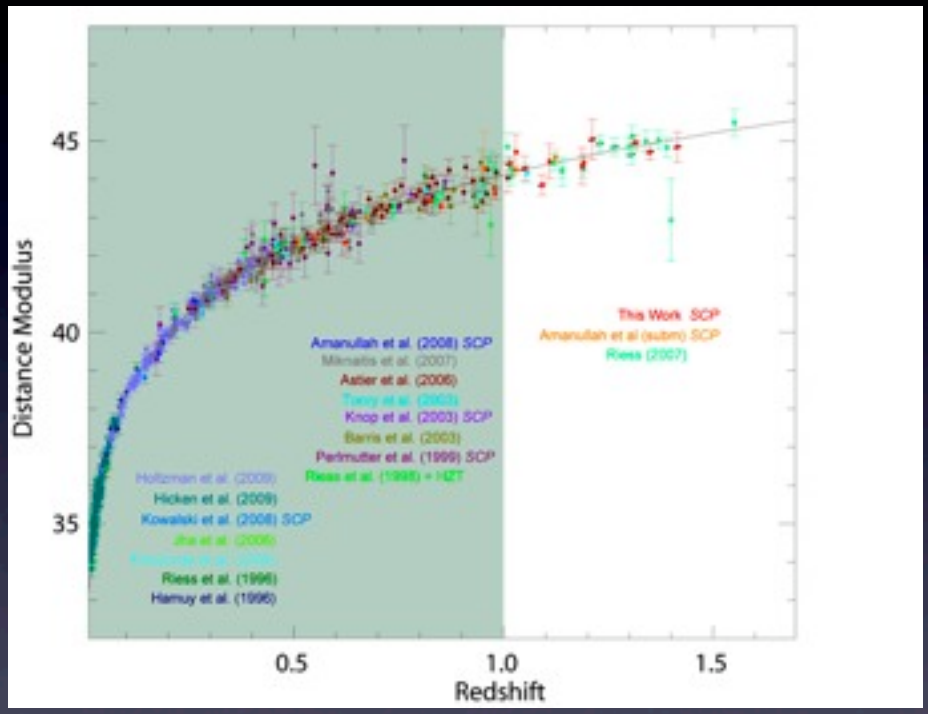
Keck

VLT

Subaru

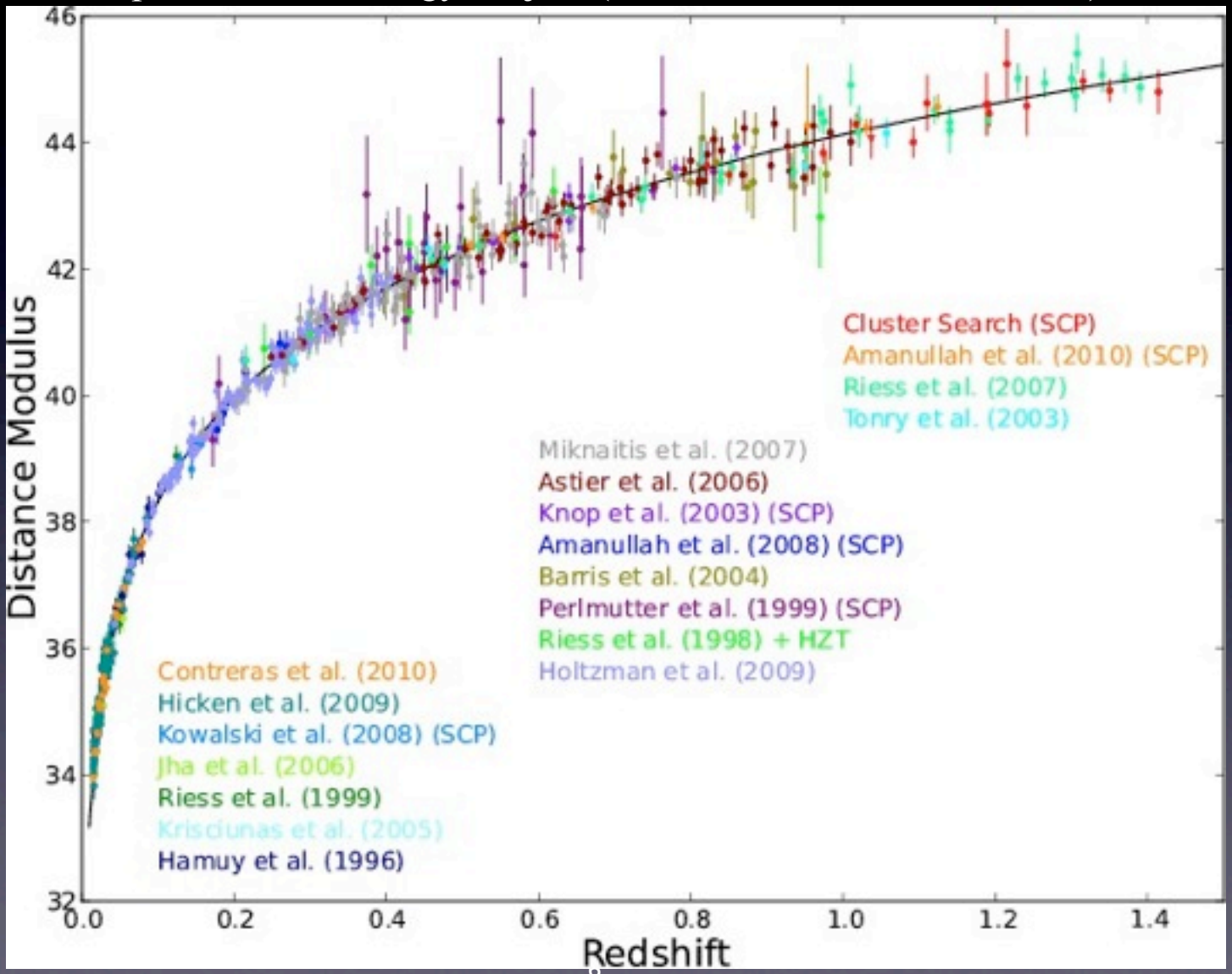






SNIa Cosmology Today (2011)

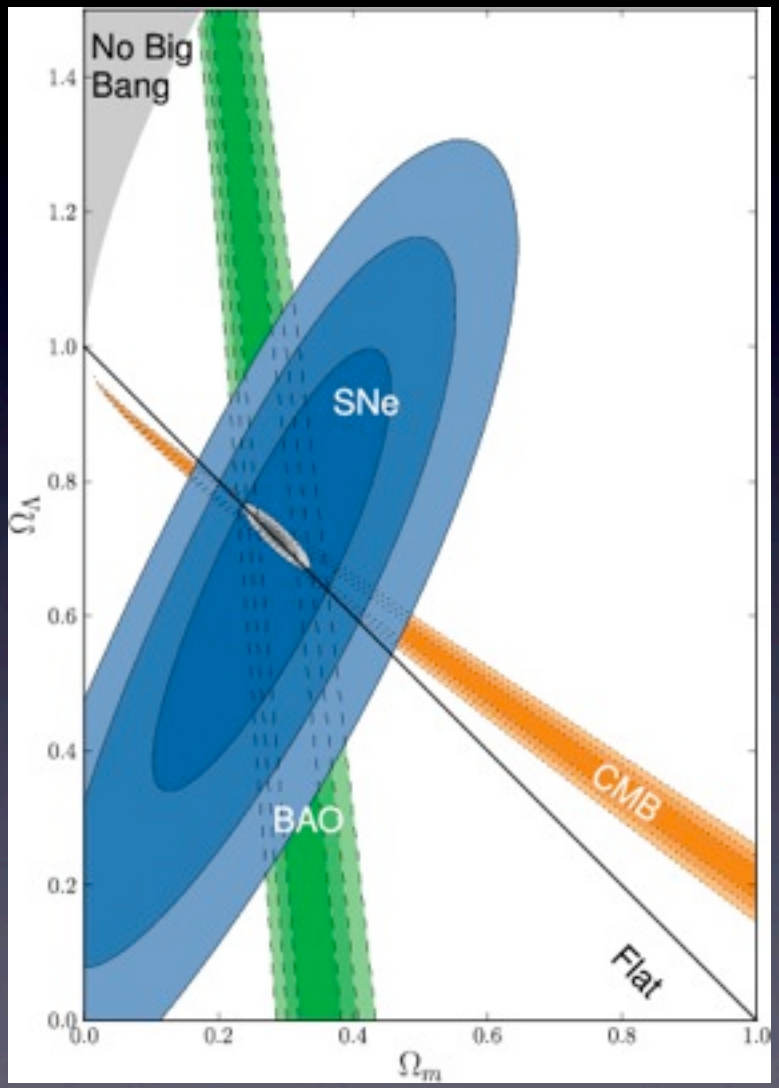
Supernova Cosmology Project (Suzuki et al. arxiv:1105.3470)



Λ Today

Combination of SNe with:
BAO (Percival et. al., 2010)
CMB (WMAP data, 2011)
For a flat Universe:

LCDM:
$\Omega_m = 0.271 \pm 0.012(\text{stat}) \pm 0.014(\text{sys})$
with curvature:
oLCDM:
$\Omega_k = 0.002 \pm 0.005(\text{stat}) \pm 0.005(\text{sys})$



w=P/ρ : equation of state
Q. Is *w* -1?

*w*CDM:

w = −1.008 ± 0.052(stat)

−1.013 ± 0.070(sys)

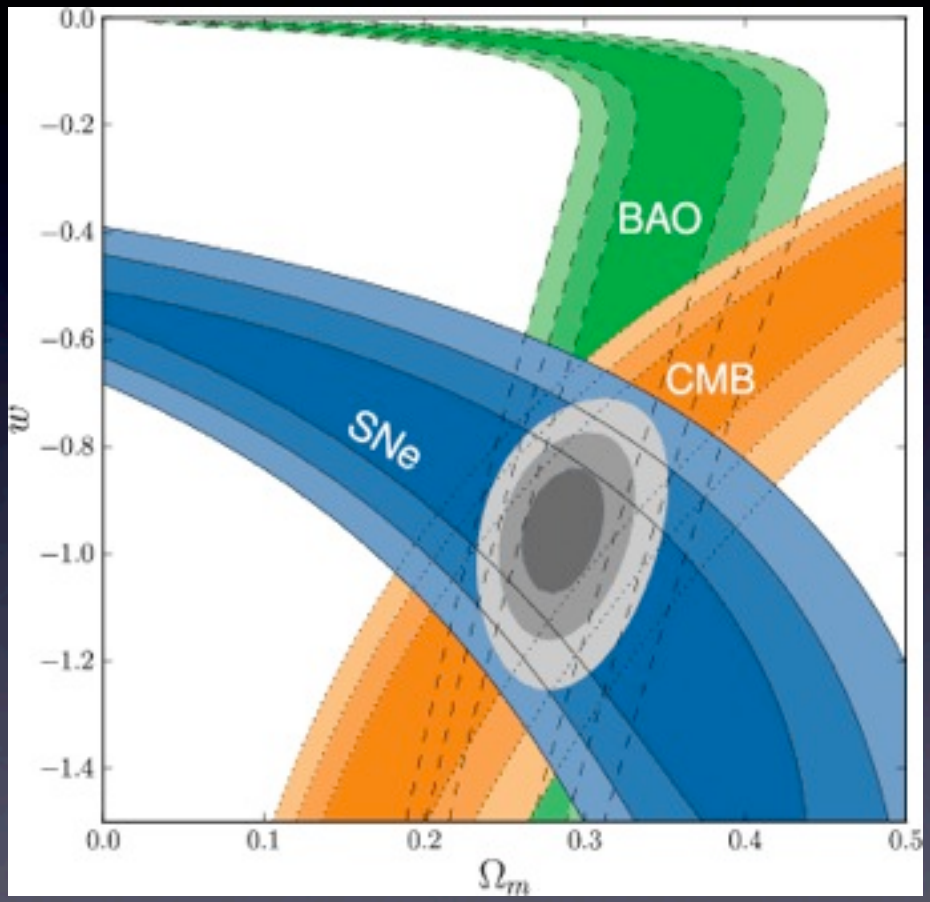
SNe + BAO + CMB

.. and allowing for curvature: owCDM

w = −1.006 ± 0.058(stat)

−1.003 ± 0.093(sys)

with systematics



- w=-1 : cosmological constant
- w=0 : matter
- w=1/3: radiation

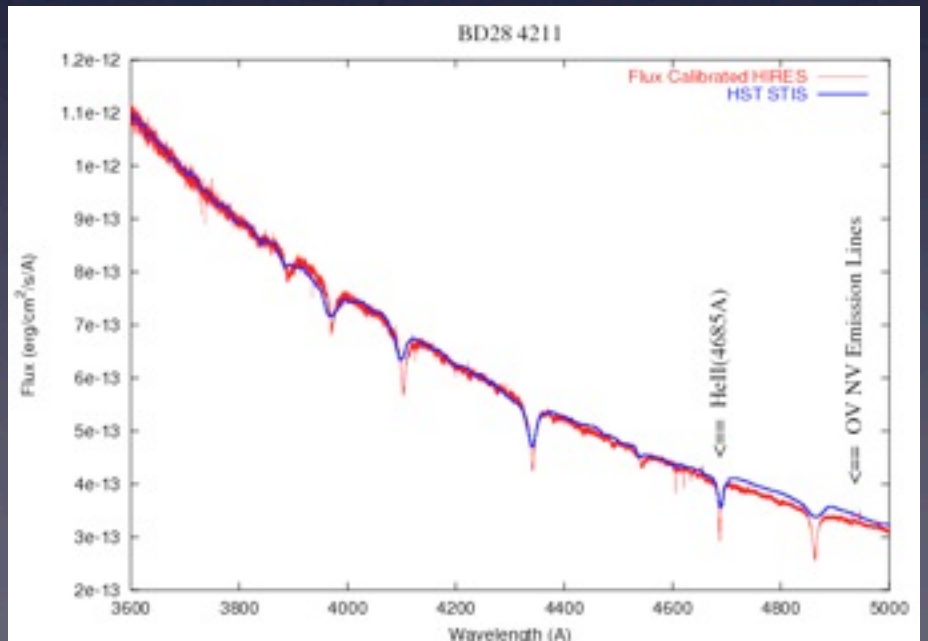
$$E \propto a^{-3(1+w)}$$

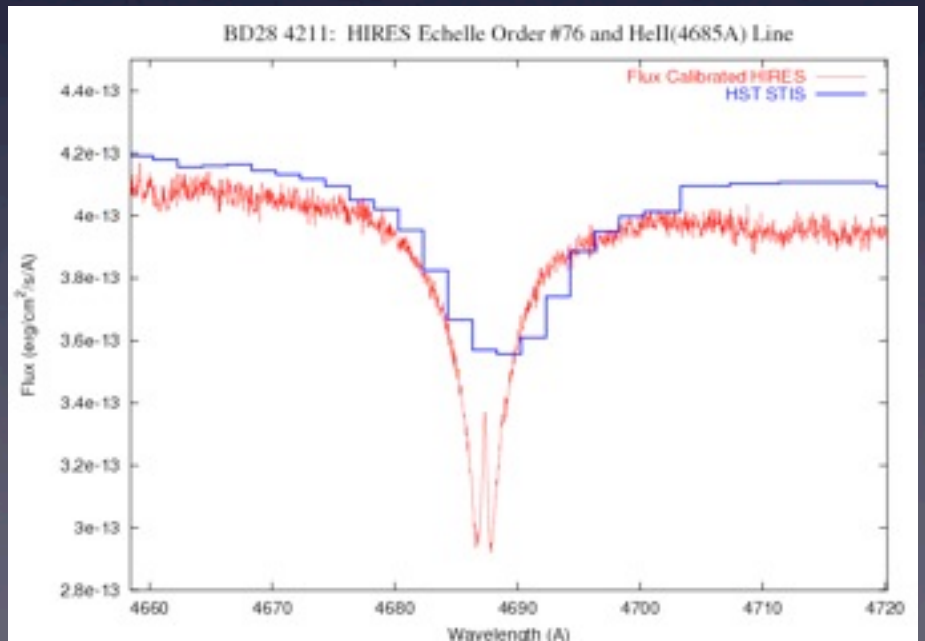
Future of SNIa Cosmology
Q: Can we Reduce Systematic Errors?

- Q1 : Observational Systematic Error => SDSS stars and Perfect Black Body stars
- Q2 : SNIa is not well understood? => Spectral Library & Simulation

The Origins of Systematic Errors Today

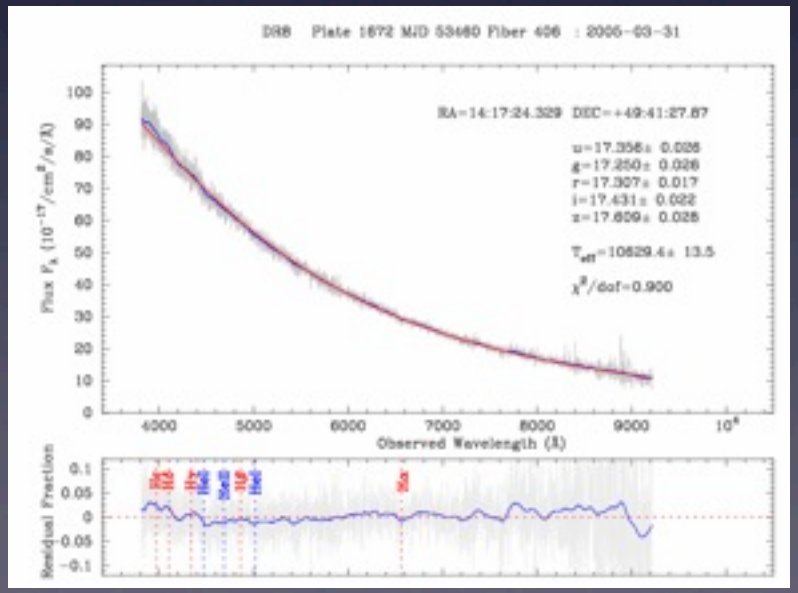
- I : Zero Point is not accurate enough (will be calibrated them with 300,000 SDSS F-stars)
- II : Standard Star Calibration (HST CALSPEC) is not accurate enough (will be replaced by DC WDs)

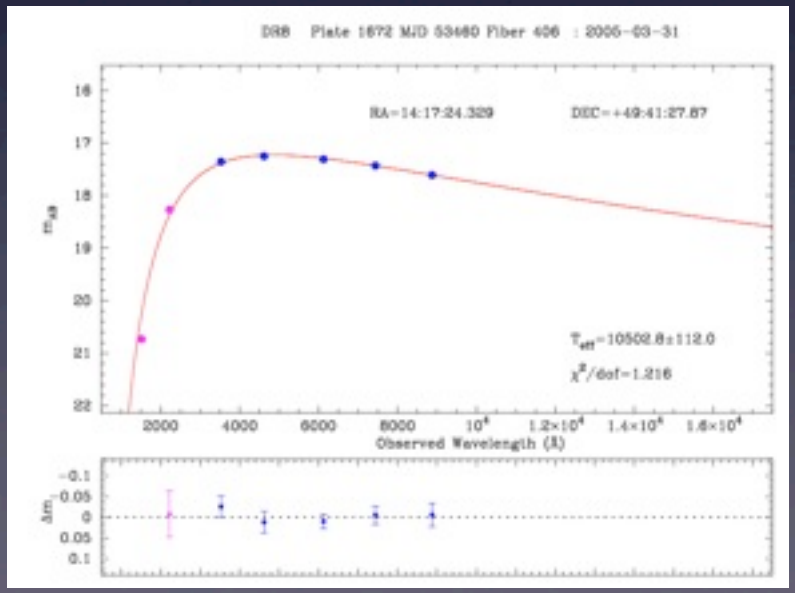


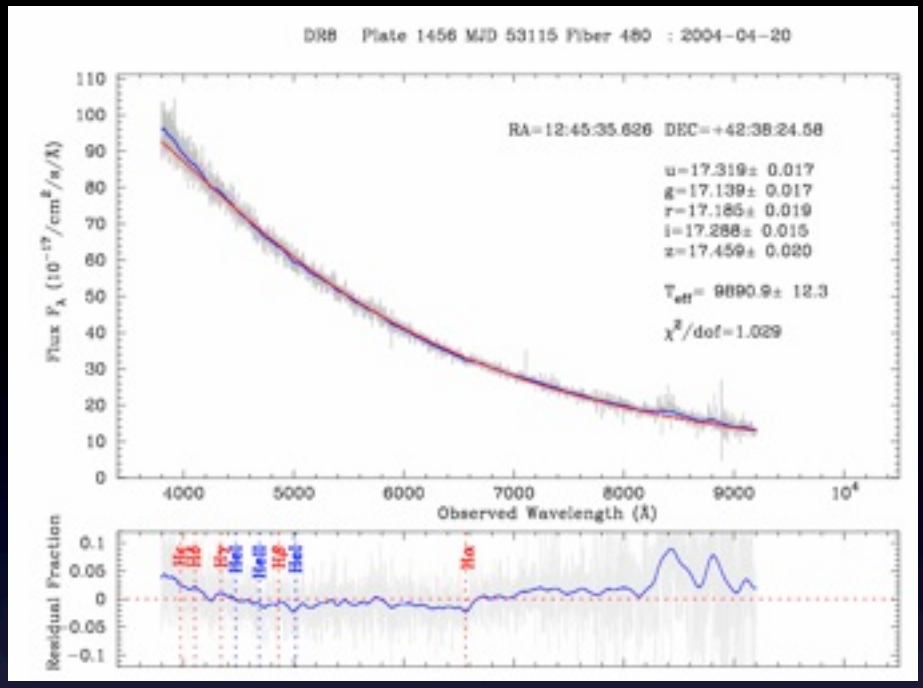


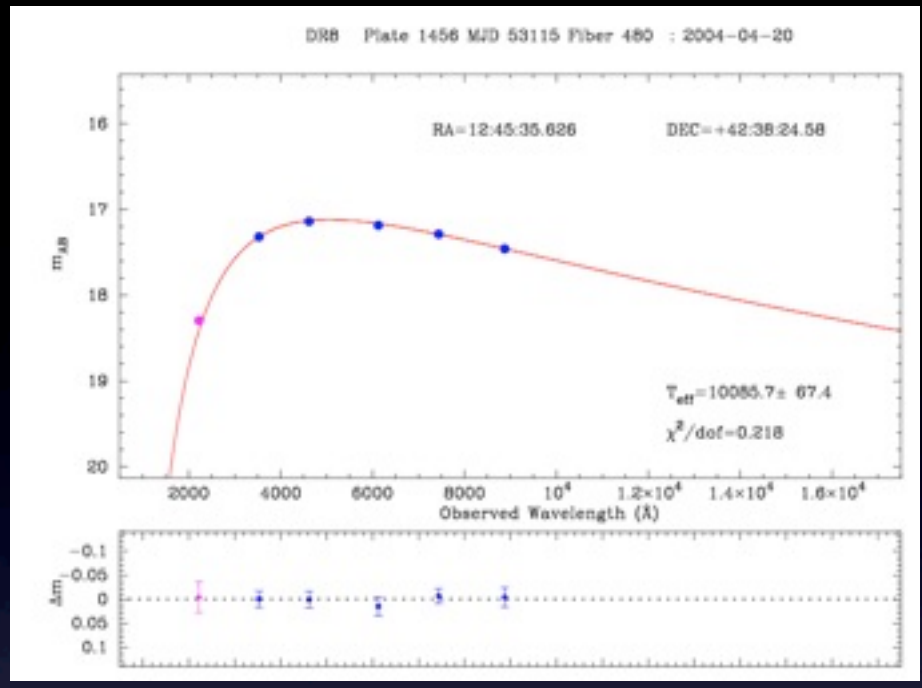
Discovery of Perfect Black Body Spectra: found as a Quasar Target Only 20 stars out of a million stars

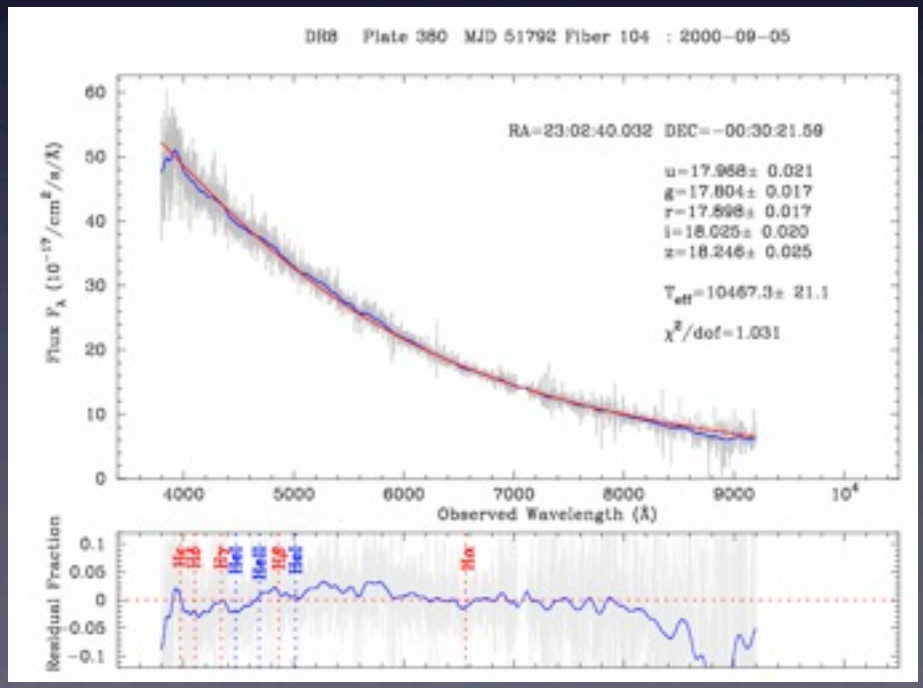
- DR8 : 605,772 stars => 5 stars
- DR9 : 110,929 stars=> 9 stars
- DR10: 81,892 stars=> 10 stars (July 2013)

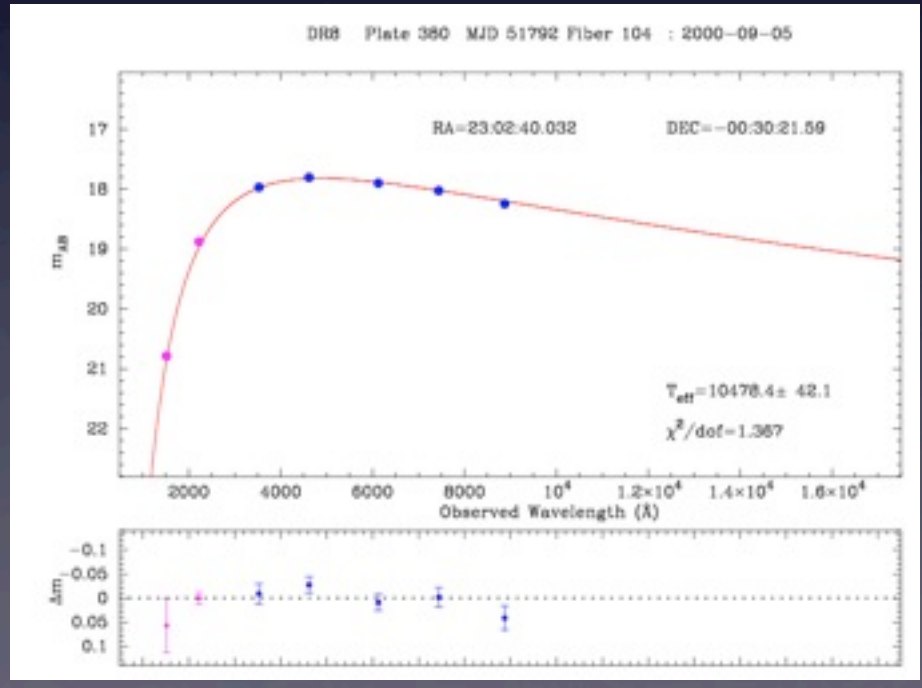




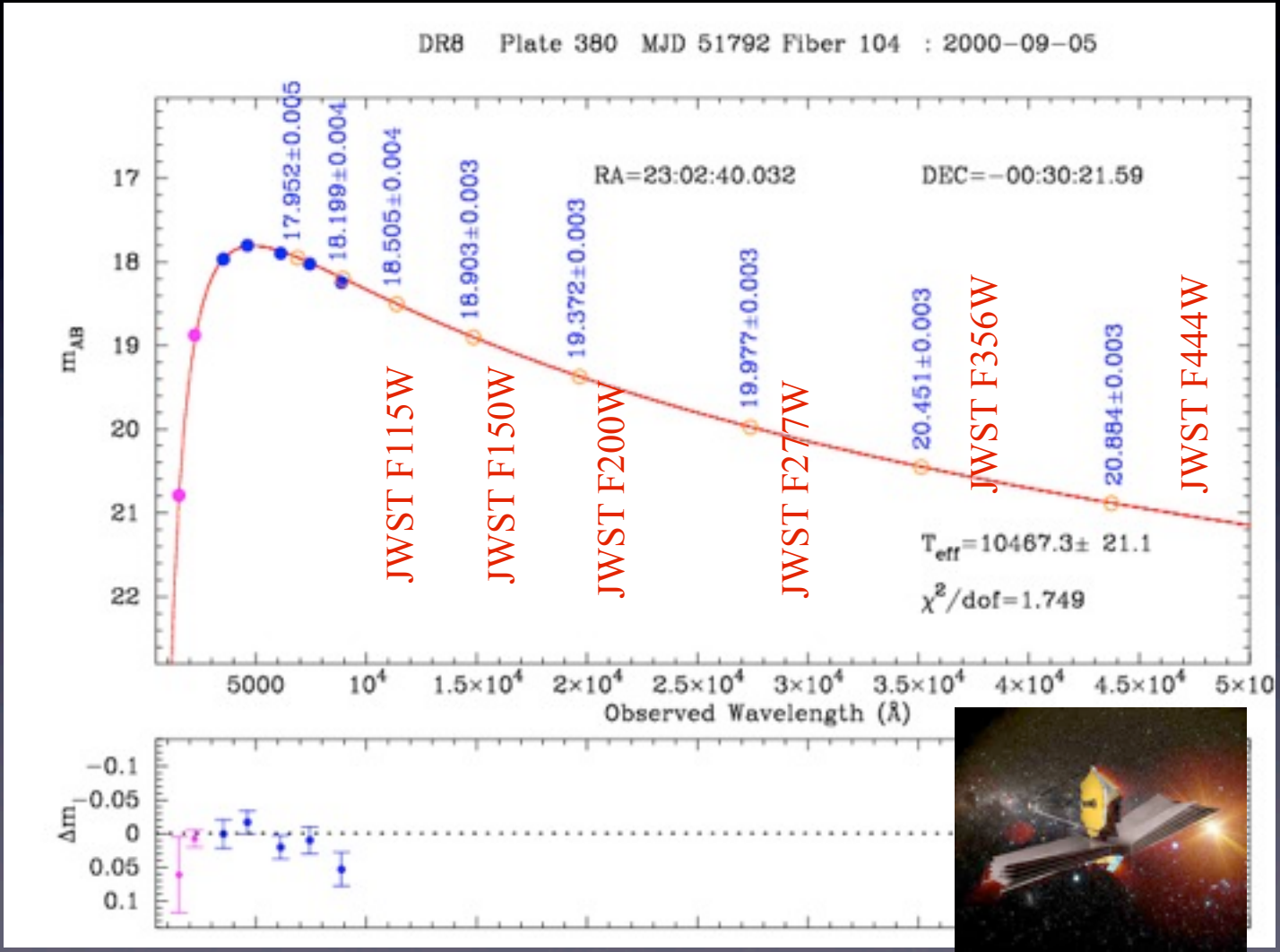

DR8 Plate 1456 MJD 53115 Fiber 480 : 2004-04-20
RA=12:45:35.626 DEC=+42:38:24.58
u=17.319± 0.017
g=17.139± 0.017
r=17.185± 0.019
i=17.288± 0.015
z=17.459± 0.020
T_{eff}= 9890.9± 12.3
χ^2/dof=1.029
Flux F_λ (10^{-17}/cm^2/s/Å)
Observed Wavelength (Å)
Residual Fraction
Hγ Hδ H7 He I H8 He I Hα


DR8 Plate 1456 MJD 53115 Fiber 480 : 2004-04-20
RA=12:45:35.626 DEC=+42:38:24.58
T_{eff}=10085.7± 67.4
χ^2/dof=0.218
m_{AB}
Observed Wavelength (Å)
Δm_i


DR8 Plate 380 MJD 51792 Fiber 104 : 2000-09-05
RA=23:02:40.032 DEC=-00:30:21.59
u=17.968± 0.021
g=17.804± 0.017
r=17.898± 0.017
i=18.025± 0.020
z=18.246± 0.025
T_{eff}=10467.3± 21.1
χ^2/dof=1.031
Flux F_λ (10^{-17}/cm^2/s/Å)
Observed Wavelength (Å)
Residual Fraction
Hγ Hδ H7 He I H8 He I Hα

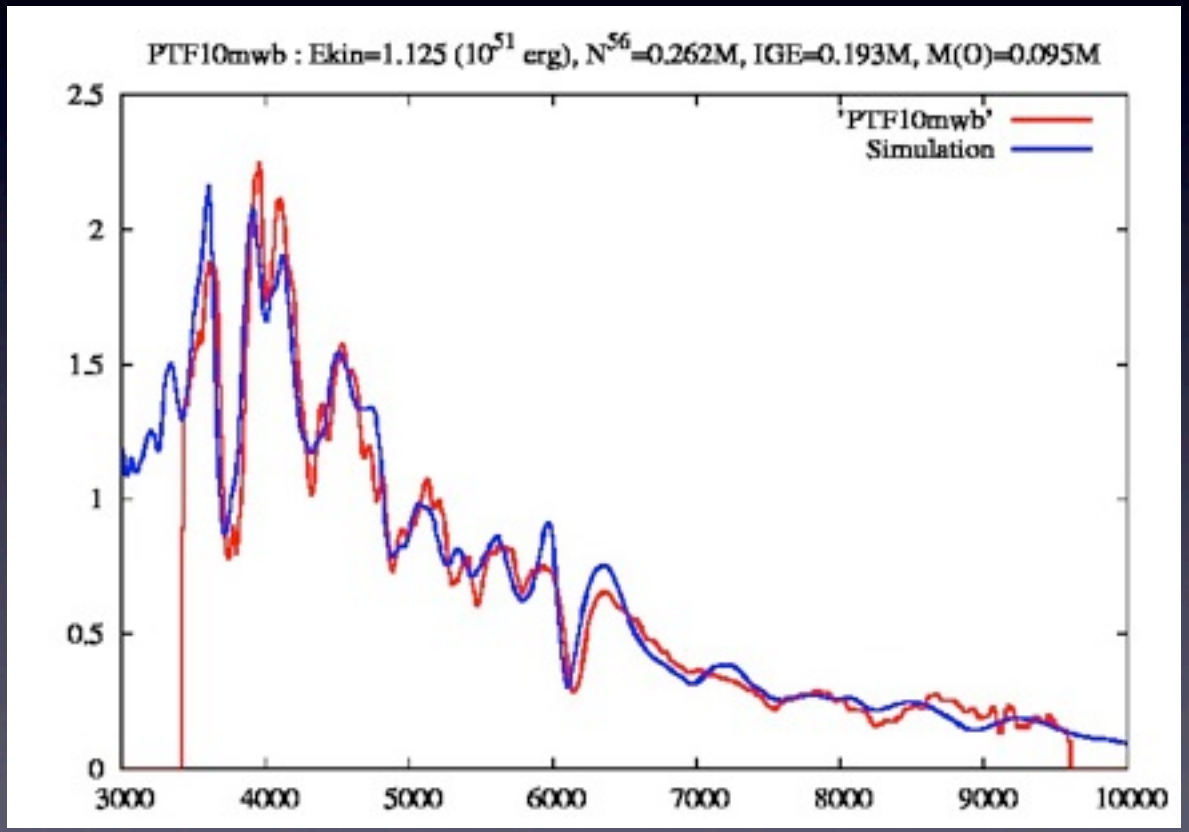

DR8 Plate 380 MJD 51792 Fiber 104 : 2000-09-05
RA=23:02:40.032 DEC=-00:30:21.59
T_{eff}=10478.4± 42.1
χ^2/dof=1.367
m_{AB}
Observed Wavelength (Å)
Δm_i

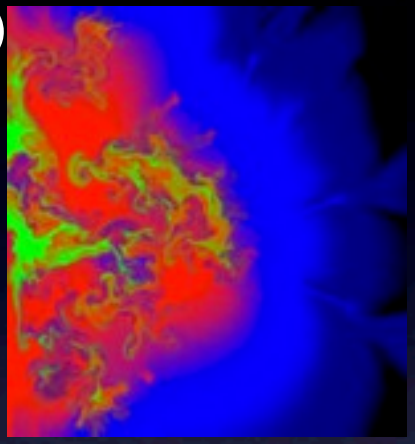
Looking at the Future with WISH/JWST
today 0.3%, but we can do 0.1%



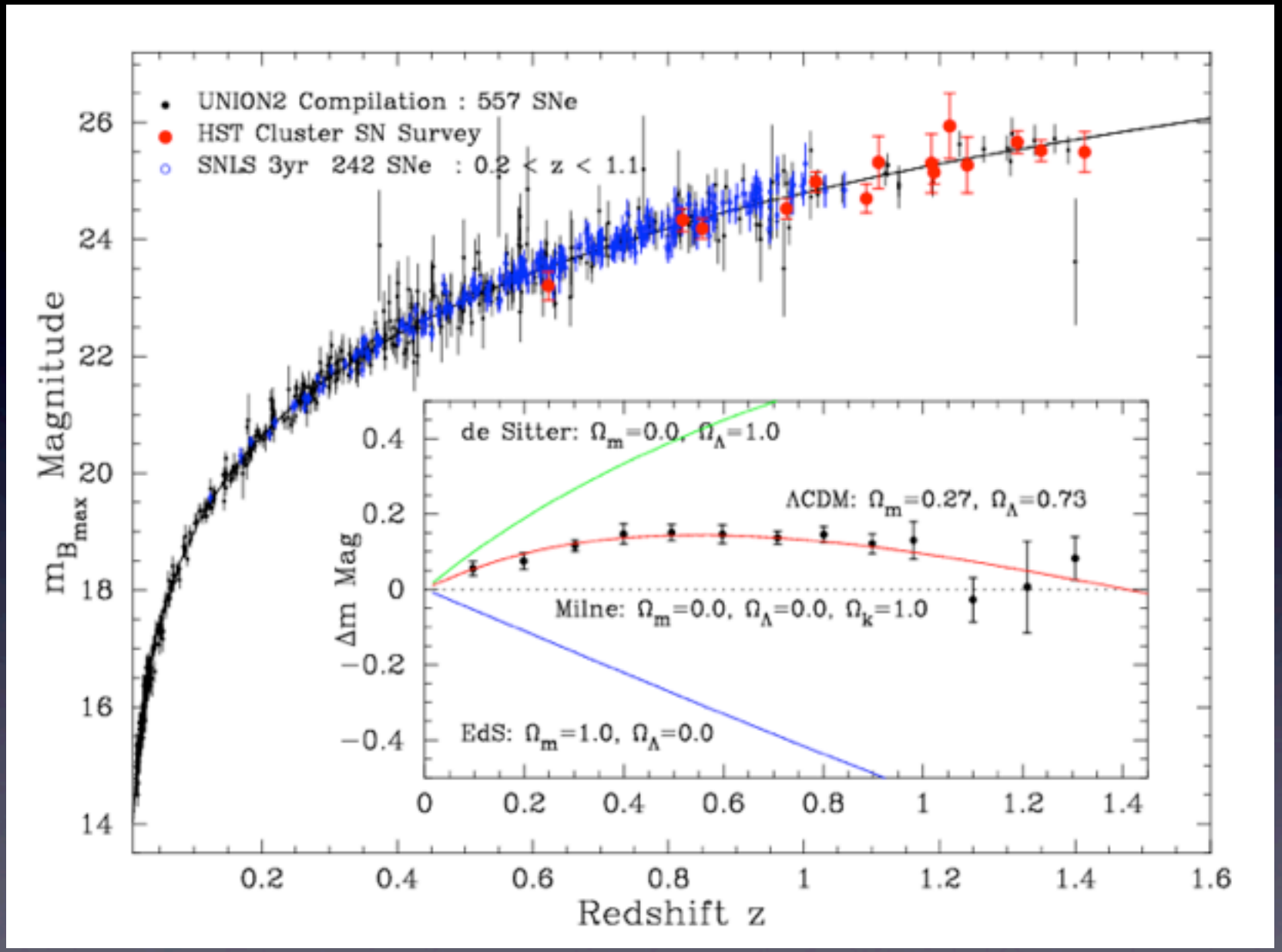
SNIa models
2D Simulation => Observation

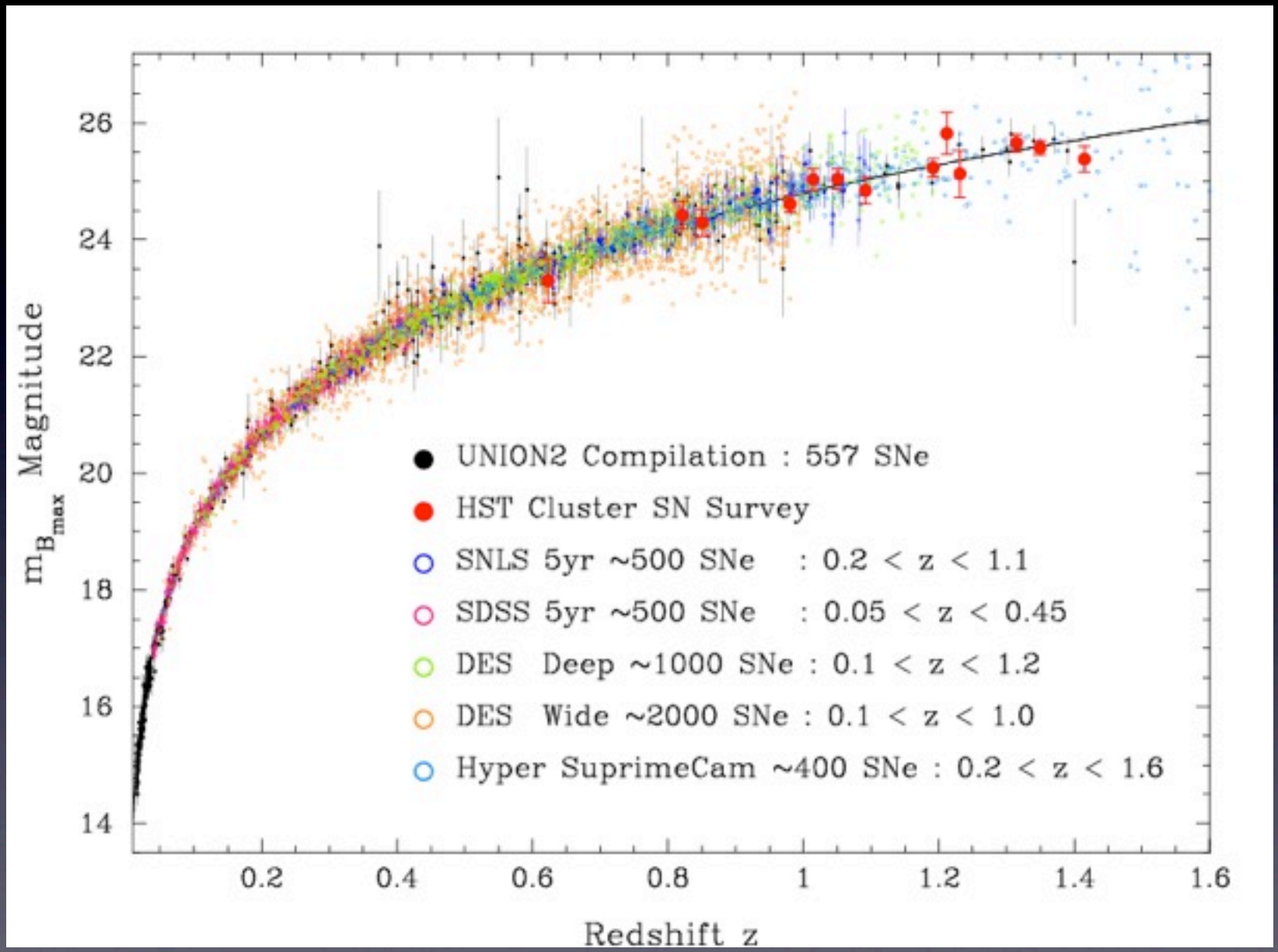
Kasen, Ropke, Woosely (2009)

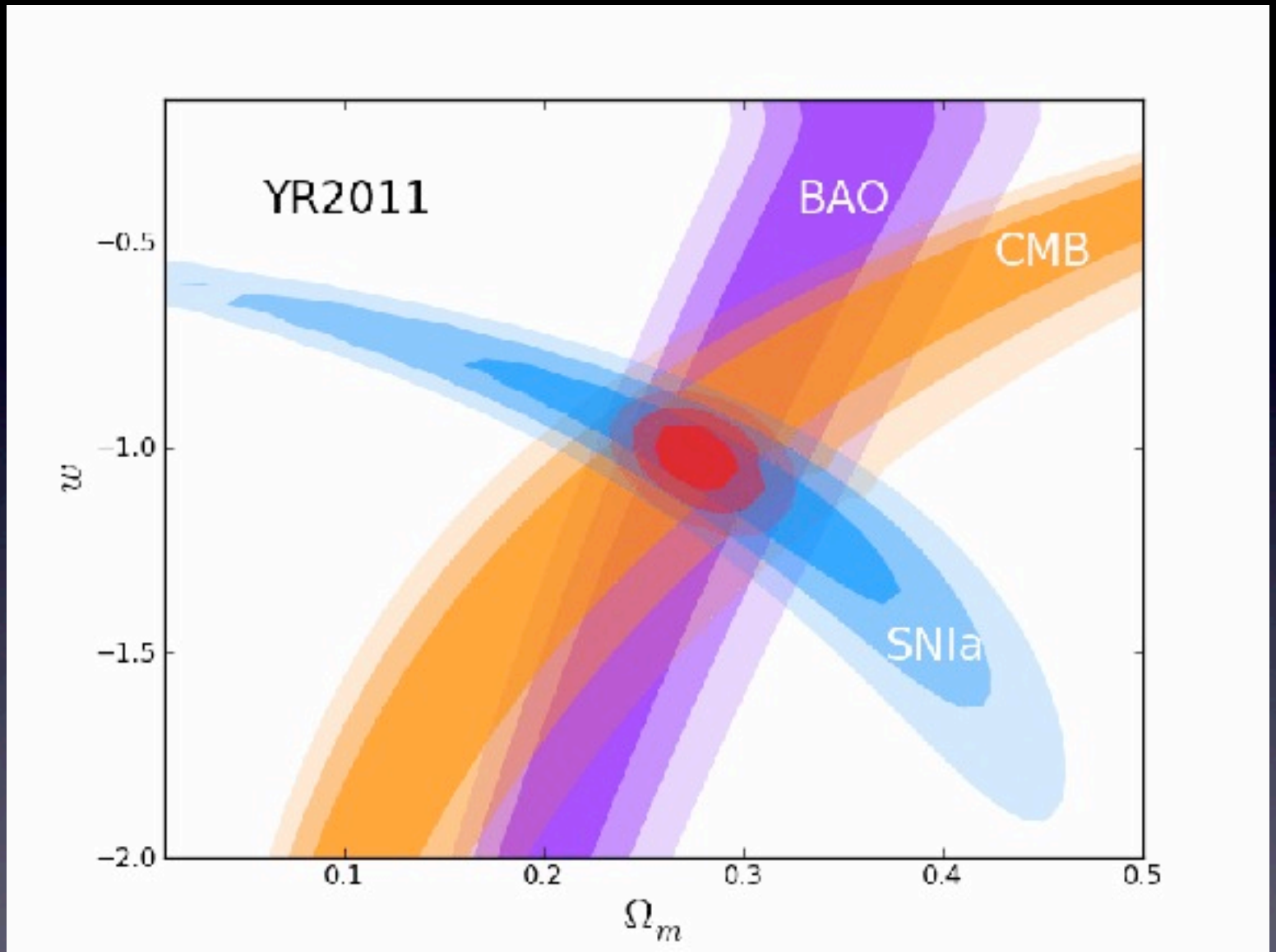


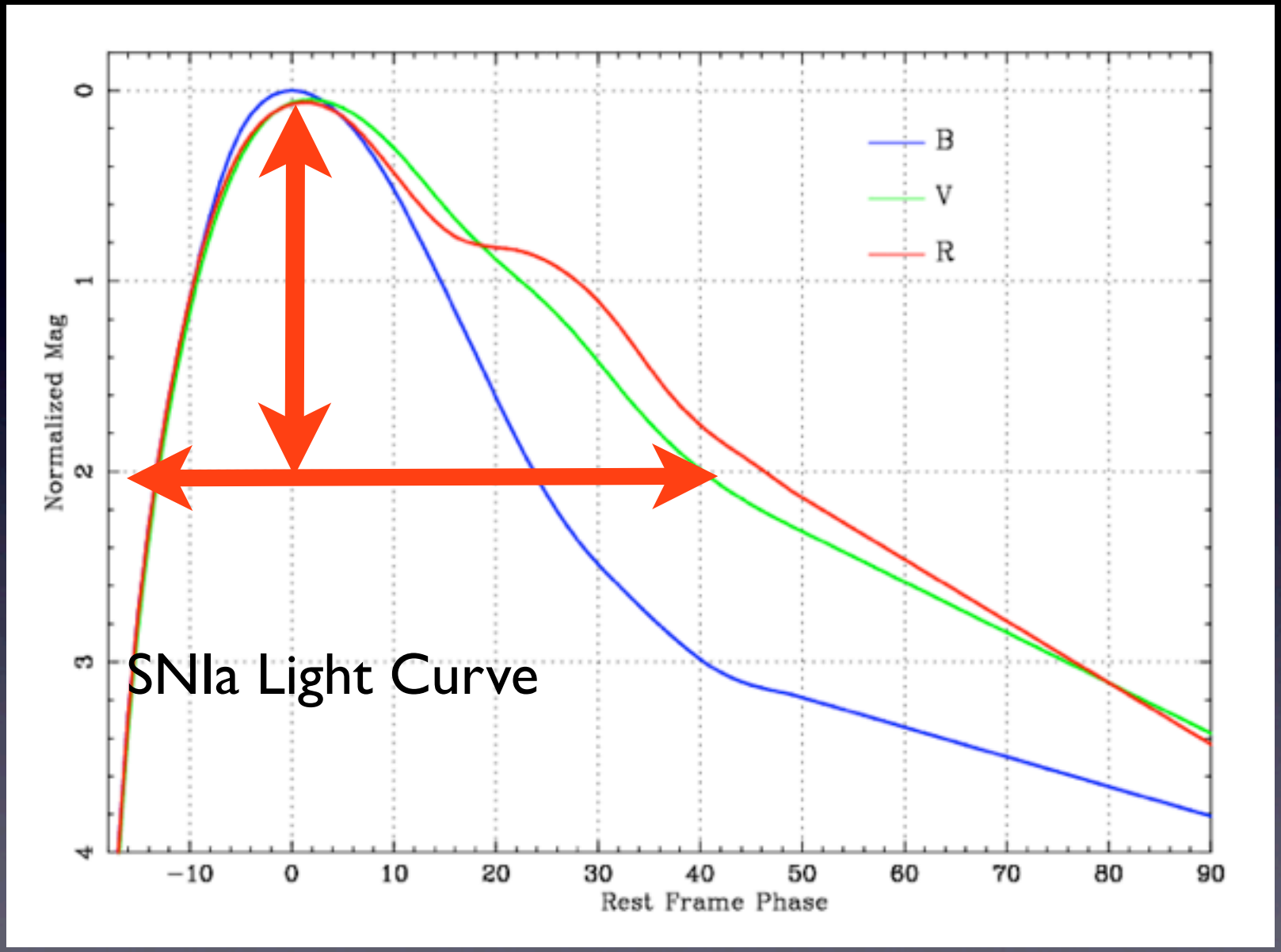


- 2D model
- 56Ni,
- Oxygen Mass,
- Carbon Mass
- Kinetic Energy
- Reproduces LTCV


UNION2 Compilation : 557 SNe
HST Cluster SN Survey
SNLS 3yr 242 SNe : 0.2 < z < 1.1
Magnitude
$m_{B_{max}}$
Redshift z
de Sitter: Ω_m=0.0, Ω_Λ=1.0
ΛCDM: Ω_m=0.27, Ω_Λ=0.73
Milne: Ω_m=0.0, Ω_Λ=0.0, Ω_k=1.0
EdS: Ω_m=1.0, Ω_Λ=0.0
Δm Mag


$m_{B_{max}}$ Magnitude
26
24
22
20
18
16
14
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Redshift z
UNION2 Compilation : 557 SNe
HST Cluster SN Survey
SNLS 5yr ~500 SNe : 0.2 < z < 1.1
SDSS 5yr ~500 SNe : 0.05 < z < 0.45
DES Deep ~1000 SNe : 0.1 < z < 1.2
DES Wide ~2000 SNe : 0.1 < z < 1.0
Hyper SuprimeCam ~400 SNe : 0.2 < z < 1.6

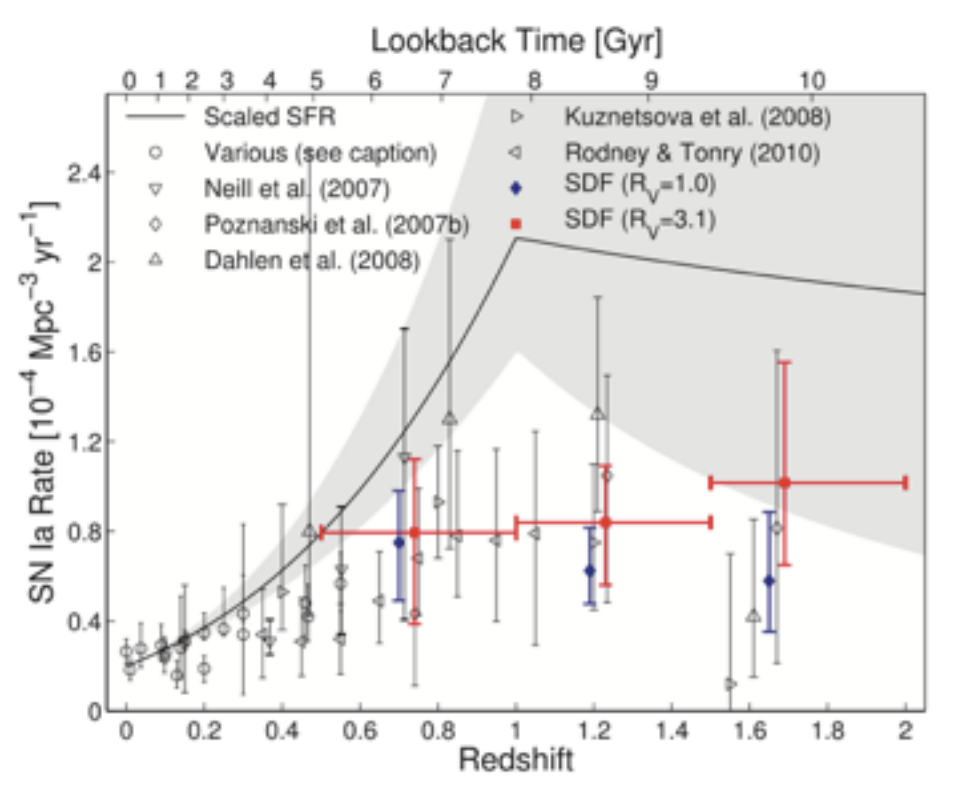

YR2011
BAO
CMB
SNIa
−0.5
−1.0
−1.5
−2.0
w
0.1
0.2
0.3
0.4
0.5
Ω_m



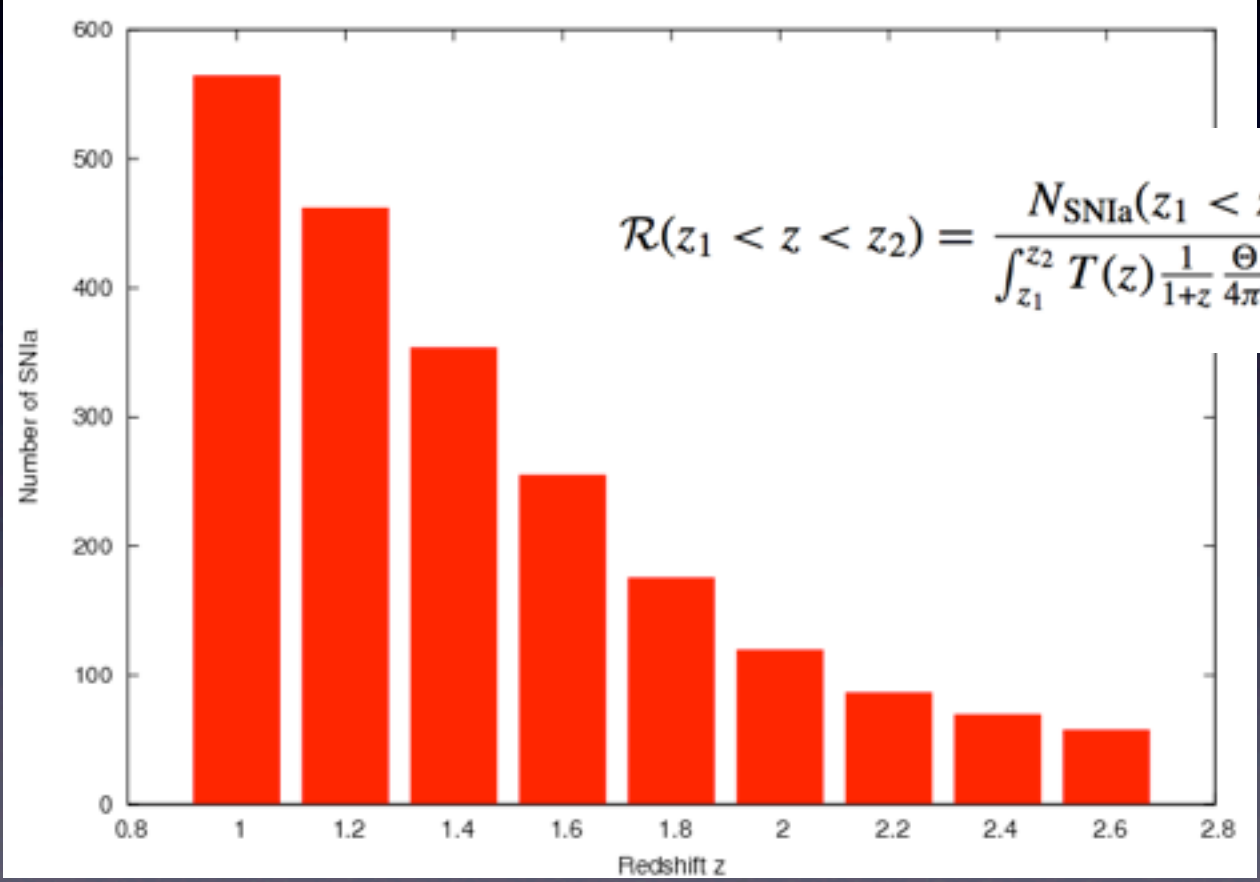
SNIa Light Curve

SNIa Rates

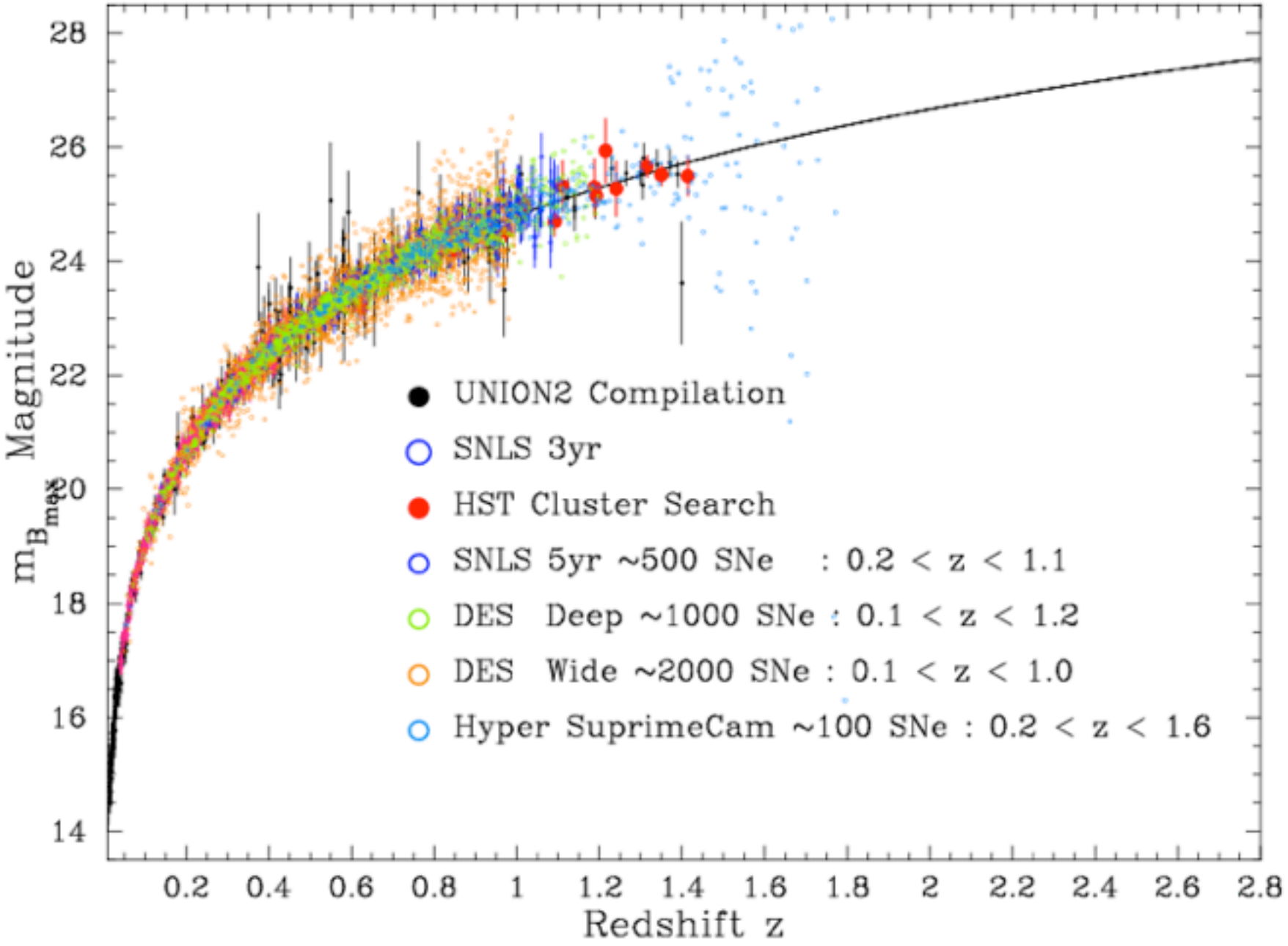
- z > 1.0 is now well understood
- (Gauer et al 2011) assume rate is constant

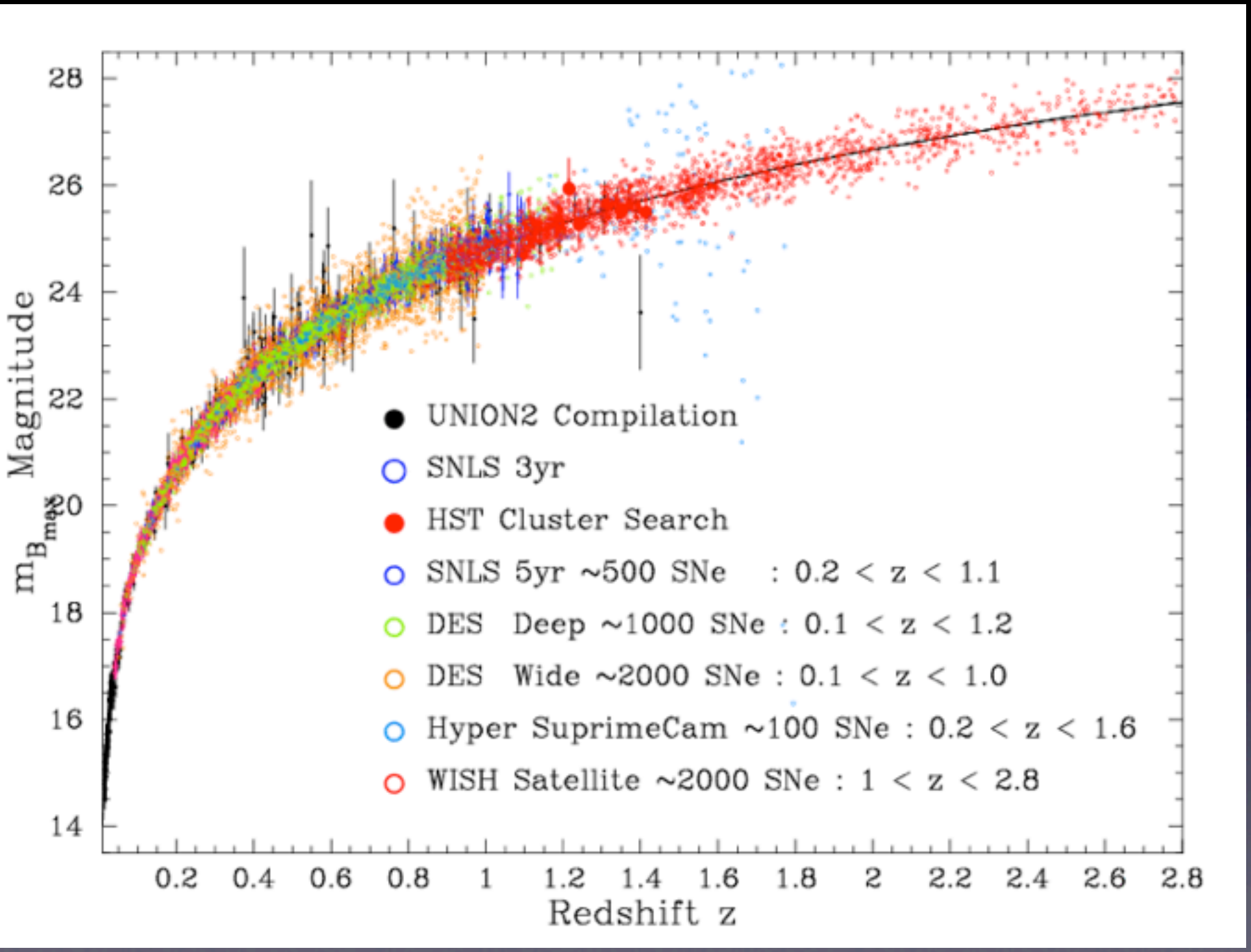


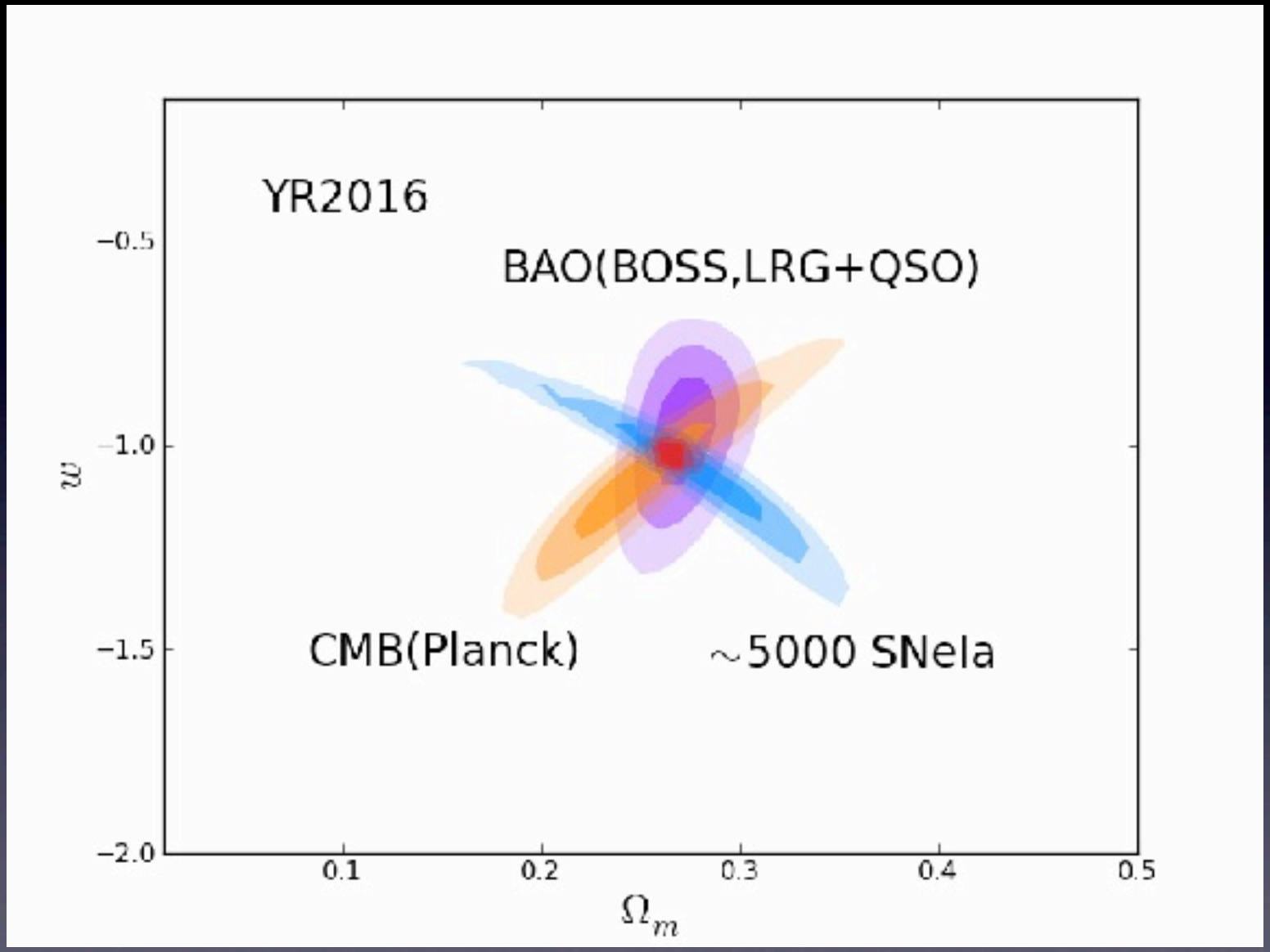
WISH SN Survey (100 deg)
2000 SNe (3-band, 30-day x 5)



$$\mathcal{R}(z_1 < z < z_2) = \frac{N_{\rm SNIa}(z_1 < z < z_2)}{\int_{z_1}^{z_2} T(z) \frac{1}{1+z} \frac{\Theta}{4\pi} \frac{dV}{dz}(z) dz},$$


Magnitude
$m_{B_{max}}$
28
26
24
22
20
18
16
14
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
Redshift z
UNION2 Compilation
SNLS 3yr
HST Cluster Search
SNLS 5yr ~500 SNe : 0.2 < z < 1.1
DES Deep ~1000 SNe : 0.1 < z < 1.2
DES Wide ~2000 SNe : 0.1 < z < 1.0
Hyper SuprimeCam ~100 SNe : 0.2 < z < 1.6


Magnitude
$m_{B_{max}}$
28
26
24
22
20
18
16
14
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
Redshift z
UNION2 Compilation
SNLS 3yr
HST Cluster Search
SNLS 5yr ~500 SNe : 0.2 < z < 1.1
DES Deep ~1000 SNe : 0.1 < z < 1.2
DES Wide ~2000 SNe : 0.1 < z < 1.0
Hyper SuprimeCam ~100 SNe : 0.2 < z < 1.6
WISH Satellite ~2000 SNe : 1 < z < 2.8


YR2016
BAO(BOSS,LRG+QSO)
CMB(Planck)
~5000 SNela
−0.5
−1.0
−1.5
−2.0
w
0.1
0.2
0.3
0.4
0.5
Ω_m

w=P/ρ : equation of state

Q. Is *w* constant over time? wa=0?

A. No clear sign of non-zero wa, yet

Dark Energy Task Force (DETF)

Figure of Merit : FoM

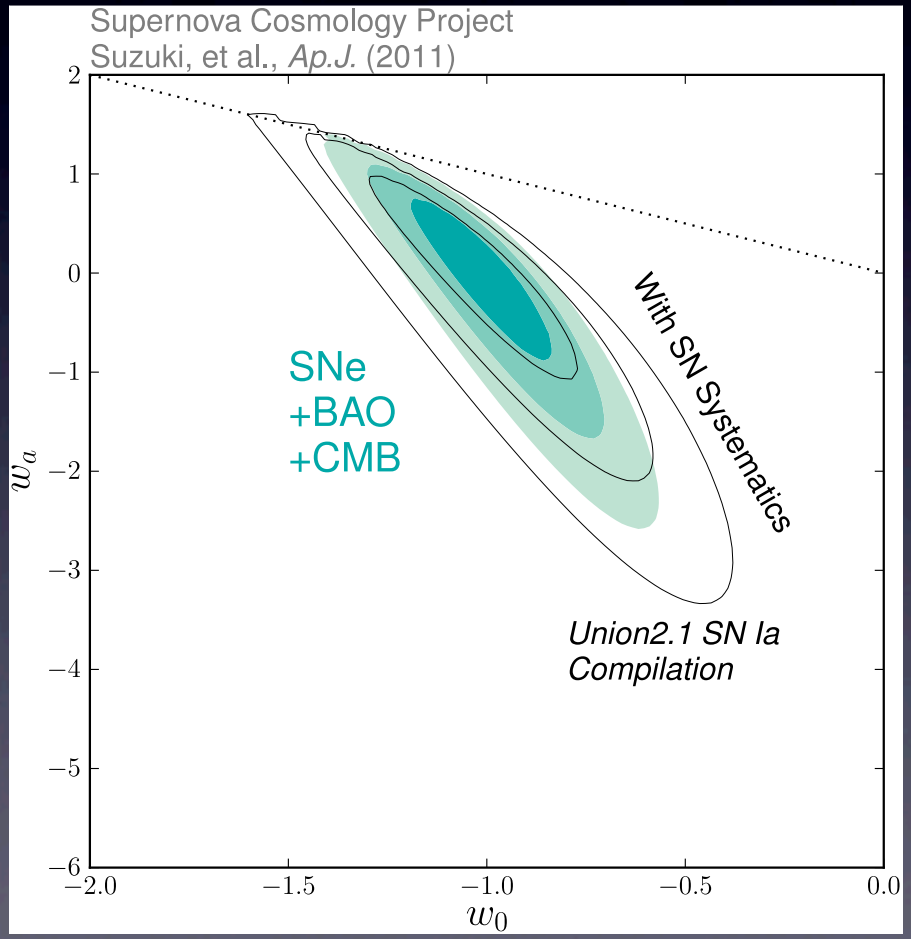
$$\frac{1}{\sigma(w_0)\sigma(w_a)}$$

$w(a)=w_0+(1-a)w_a$

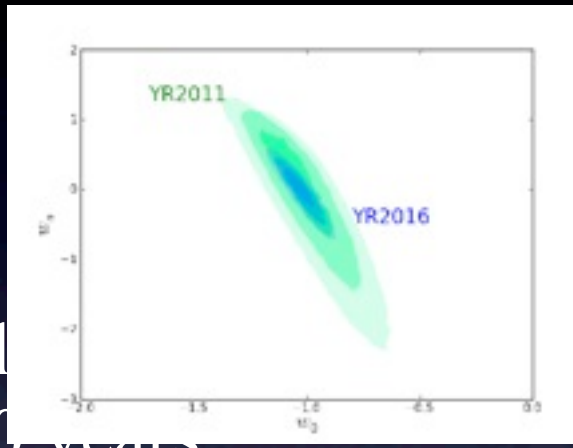
FoM=39.3(stat) 22.6(sys)

Suzuki et al 2012

SCP UNION2.1



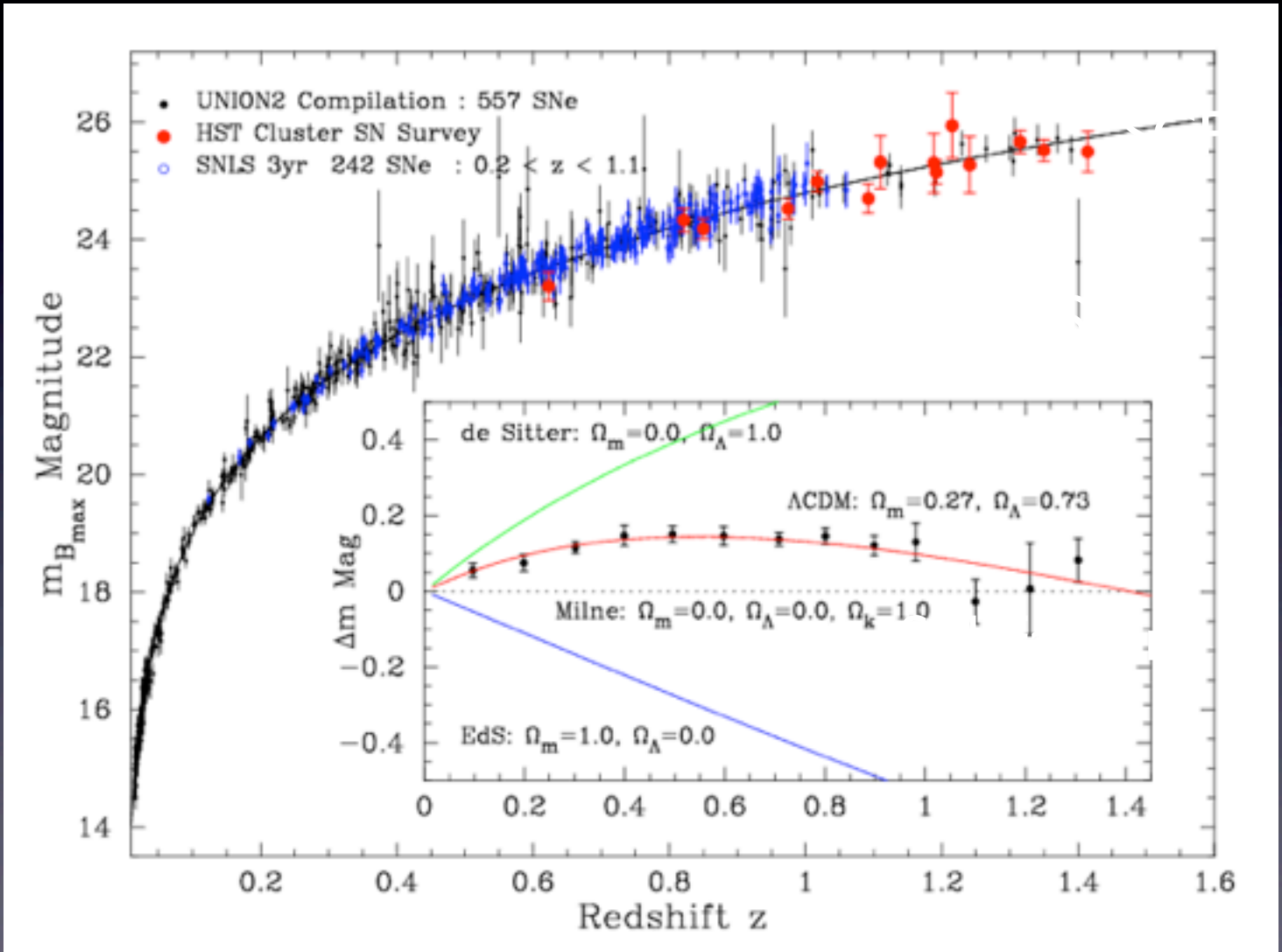
Dark Energy in 2015-2025:
Conclusion & Summary



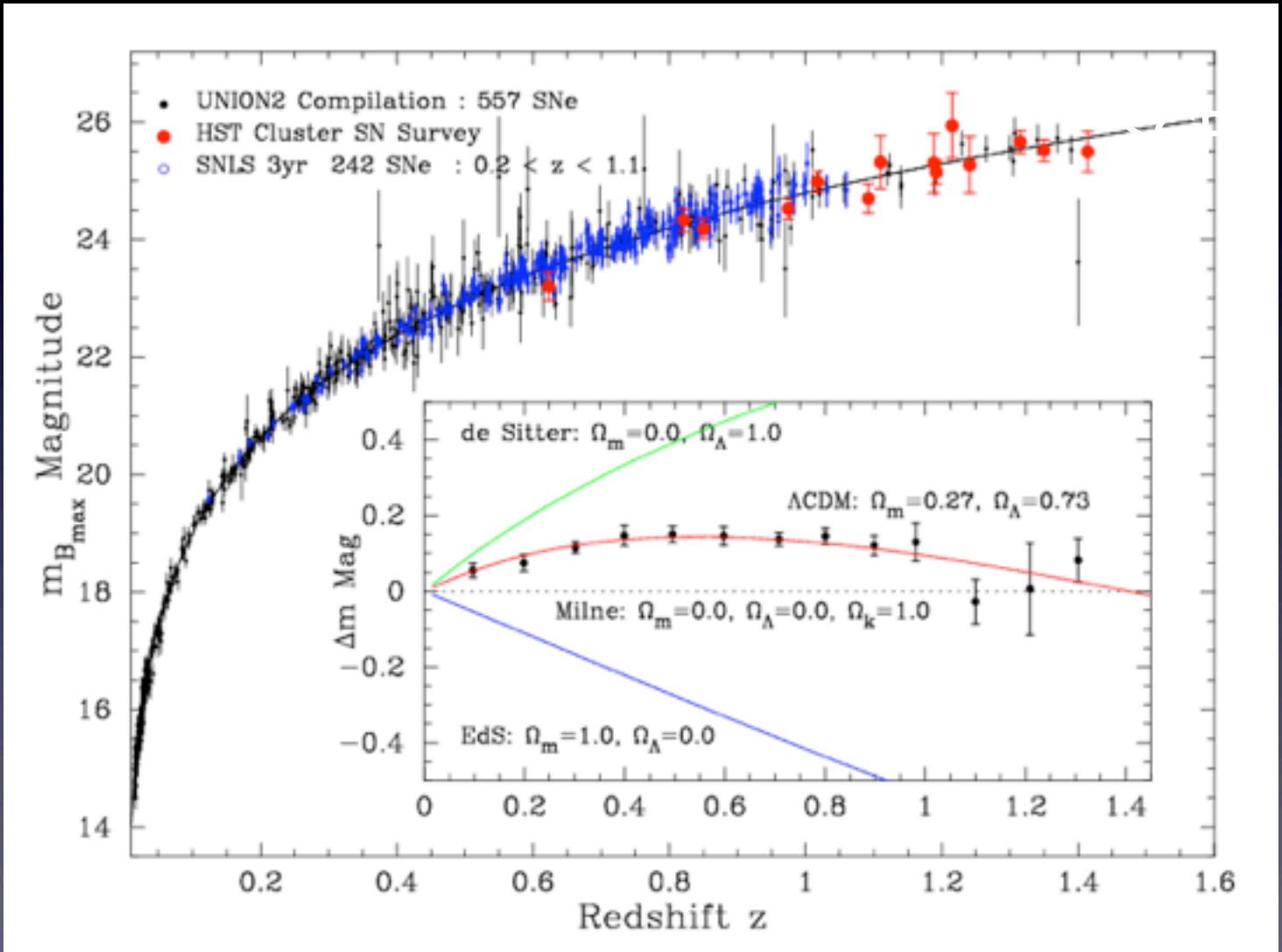
- Reducing Systematic is mandatory
- Calibration is the key
- SNIa + CMB (Planck) + BAO woul
  powerful combination in the next 10 years
- DES can find z > 1 SNe but needs z, y-band
- With WISH SNIa can lead Dark Energy Studies
- New Discoveries are yet to come (PopIII etc)
- WISH satellite can enhance FoM => 300

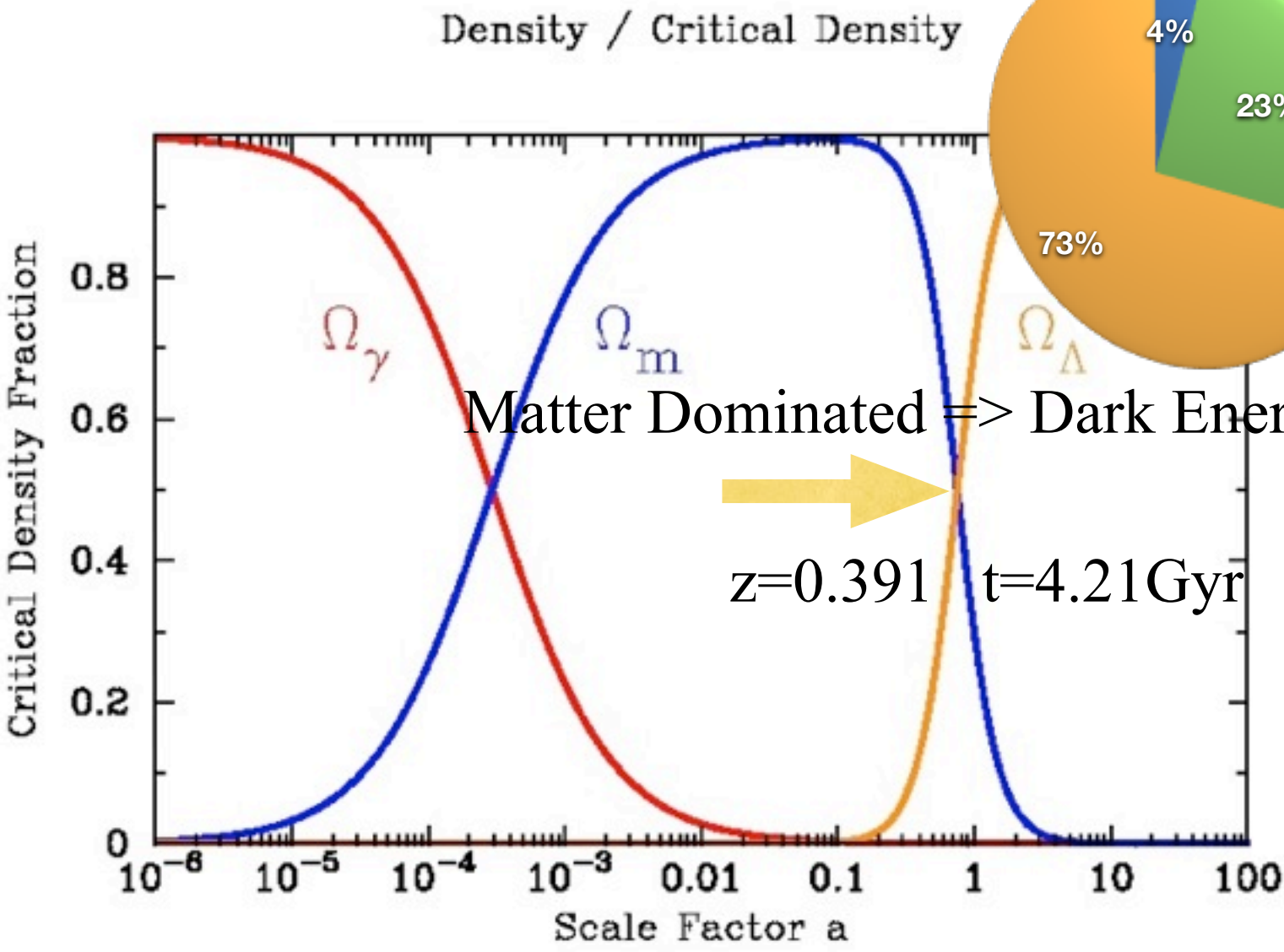
Backup Slides

SN Factory, Palomar Transient Factory (PTF), SuperNovaLegacySurvery (SNLS), Suprnova Cosmology Project (SCP)



SN Factory, Palomar Transient Factory (PTF), SuperNovaLegacySurvery (SNLS), Suprnova Cosmology Project (SCP)





Matter Dominated => Dark Energy

z=0.391 t=4.21Gyr

From Deceleration to Acceleration