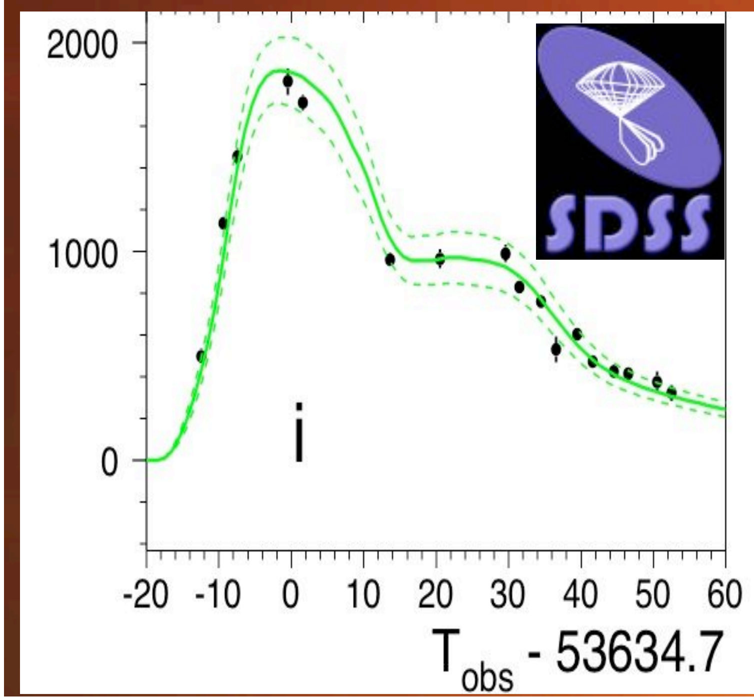
Kavli Institute for Cosmological Physics at the University of Chicago

Results from the SDSS-II Supernova Survey



R.Kessler

University of Chicago

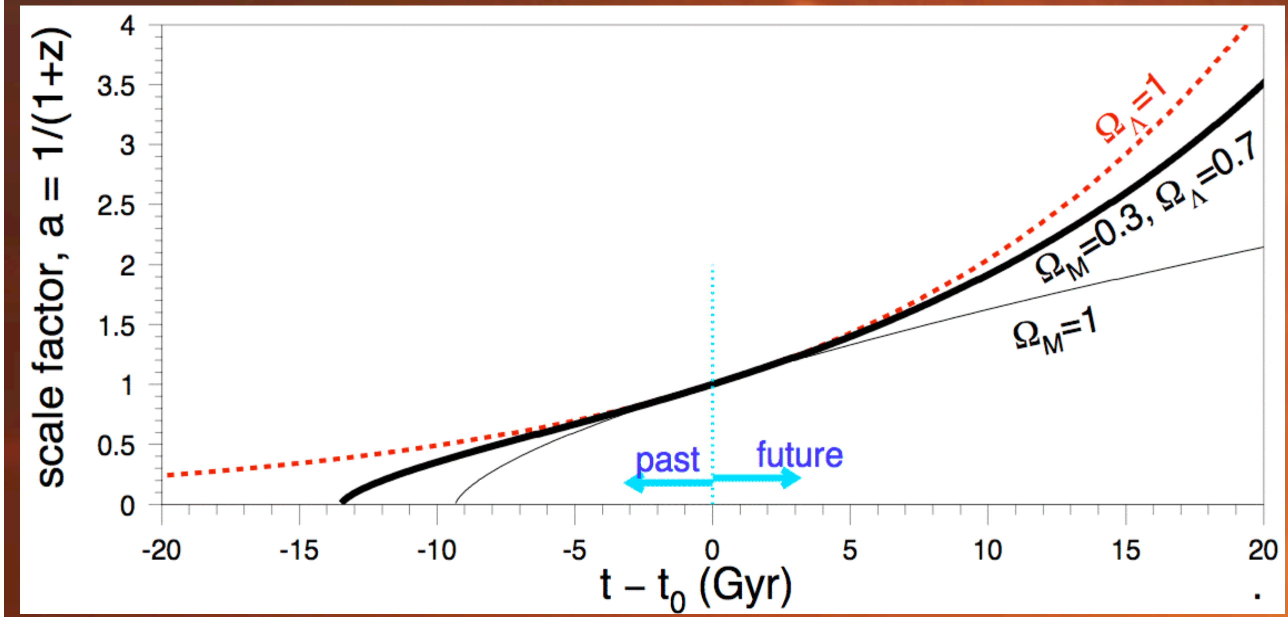
Sep 14, 2009

Paris-Berkeley Dark-Energy Workshop

Outline

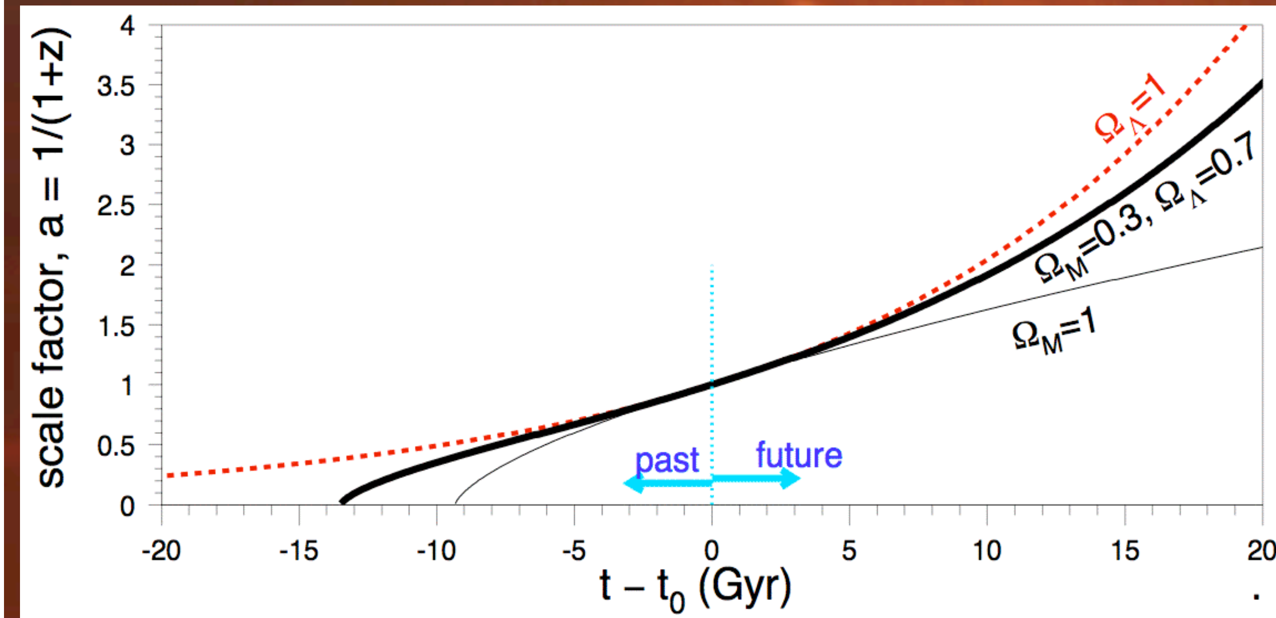
- Overview of SDSS-II Survey
- Analysis with existing Light curve fitters: MLCS & SALT2
- Calibration
- Results & Comparisons (arXiv:0908.4274)
- Systematics Issues
- Future Prospects

Hubble Diagram Basics

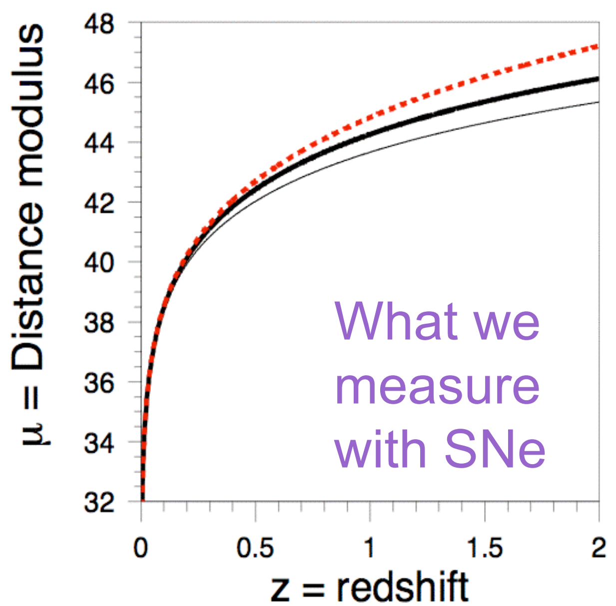


Expansion history depends on Ω_Λ and Ω_M

Hubble Diagram Basics



Expansion history depends on Ω_Λ and Ω_M



mag = $-2.5\log(\mathscr{L}/4\pi d_L^{\,2})$.

$d_L = (1+z) \int dz/H(z,\Omega_M,\Omega_\Lambda,w)$
for flat universe.
Distance modulus: $\mu=5\log(d_L/10\text{pc})$

The SDSS-II SN Team

The Sloan Digital Sky Survey-II Supernova Survey: Technical Summary

AJ 135, 338 (2008)

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SDSS-II Supernova Survey:
Sep 1 - Nov 30, 2005-2007

(1 of 3 SDSS-II projects for 2005-2008)

GOAL:

Few hundred high-quality type Ia SNe lightcurves in redshift range 0.05-0.4

SAMPLING:

~300 sq deg in ugriz (3 million galaxies every two nights)

SPECTROSCOPIC FOLLOW-UP:

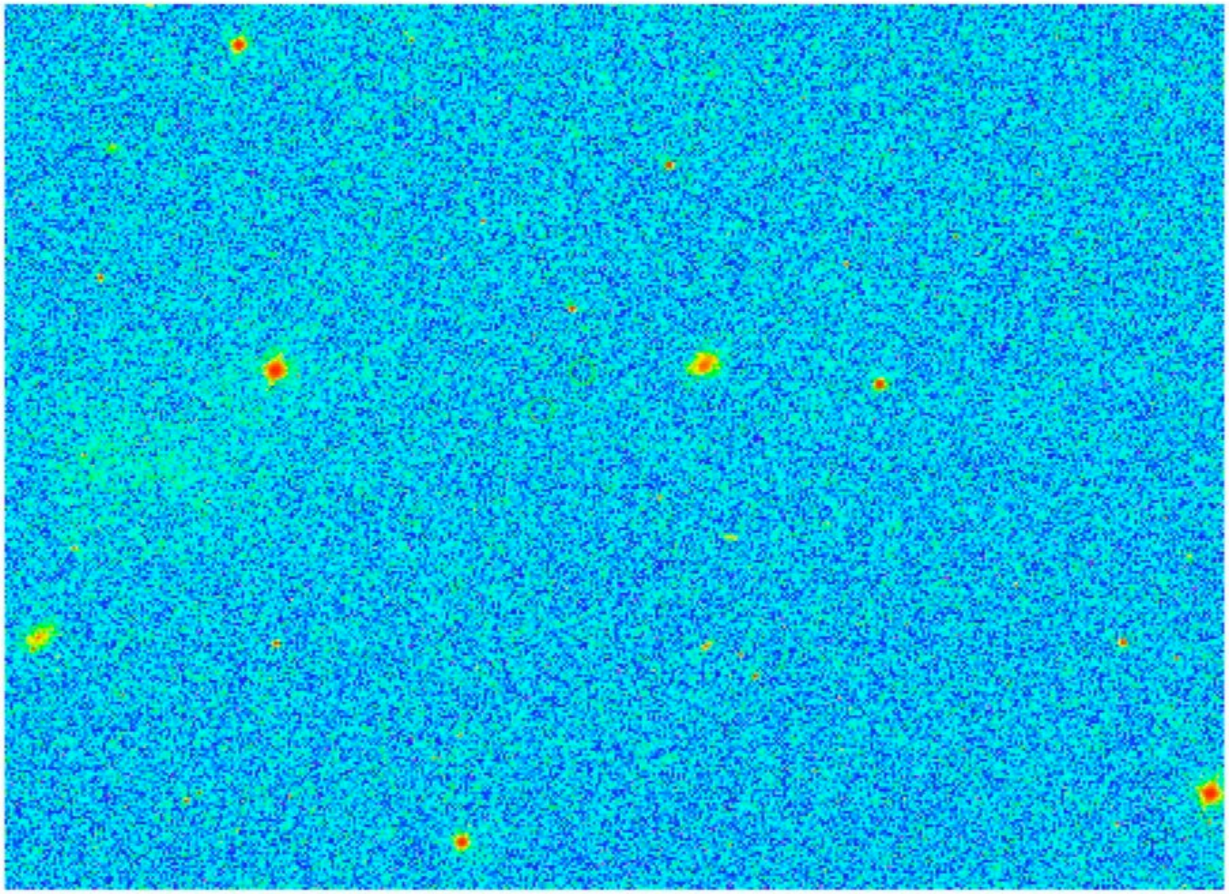
HET, ARC 3.5m, MDM, Subaru, WHT, Keck, NTT, KPNO, NOT, SALT, Magellan, TNG

SDSS Data Flow

One full night collects 800 fields (ugriz per field) ➪ 200 GB

Advances in computing & software allows searching 150 sq deg in less than 24 hours.

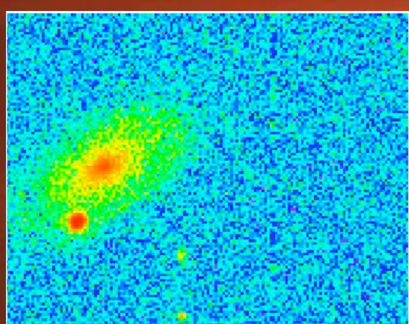
one raw g-field (0.2 sq-deg)



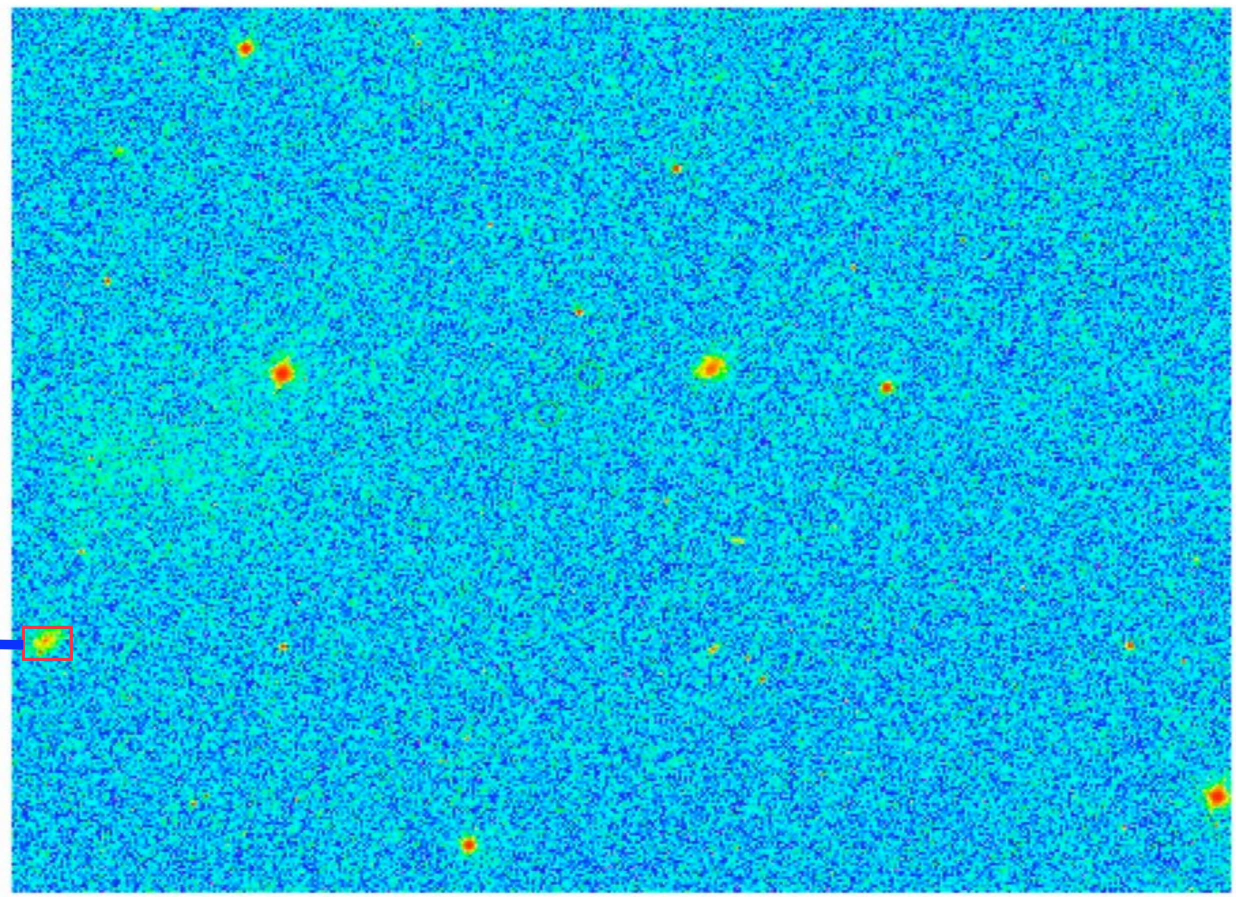
SDSS Data Flow

One full night collects 800 fields (ugriz per field) ➪ 200 GB

z = 0.045



one raw g-field (0.2 sq-deg)

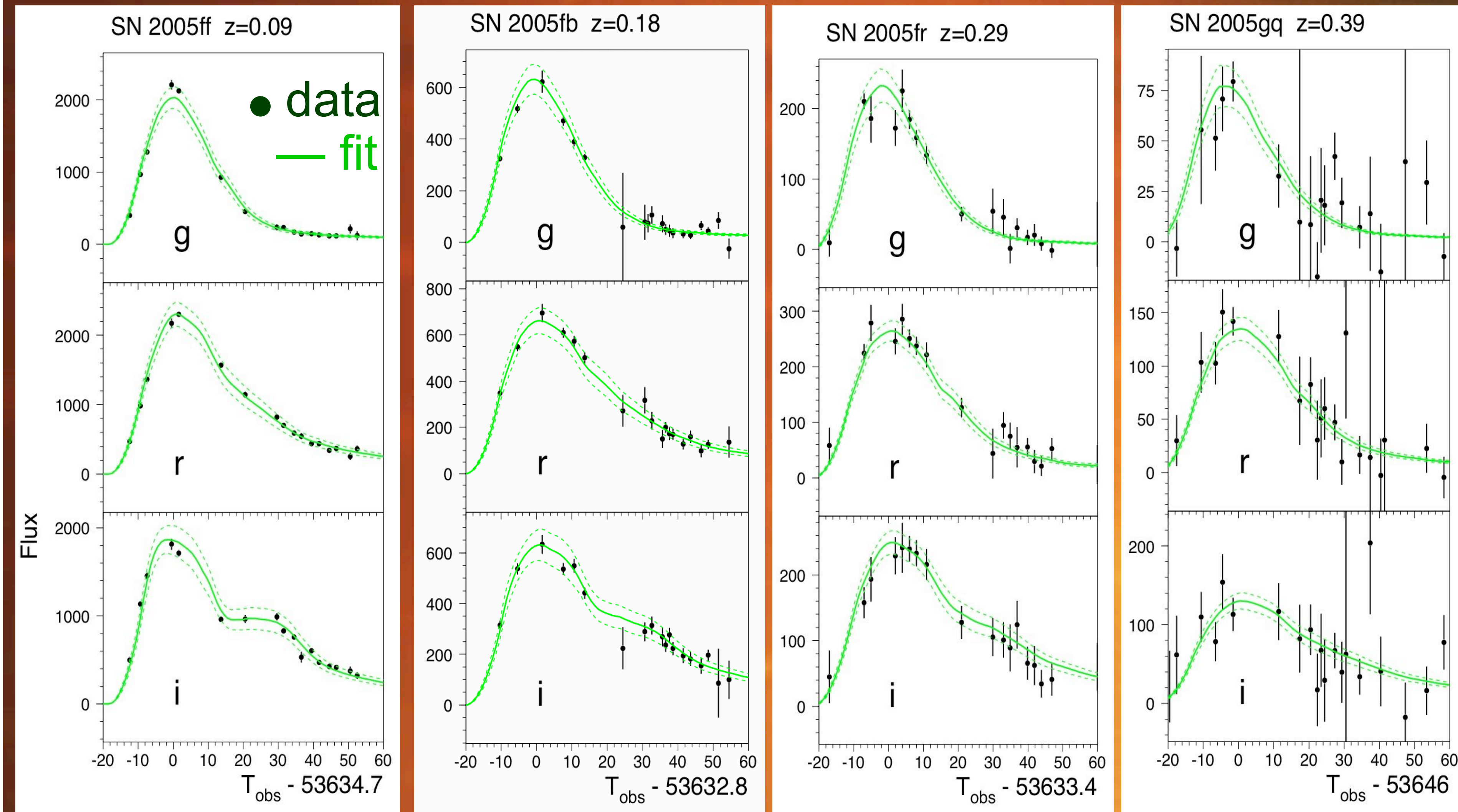


SDSS-II SN Stats (3 seasons)

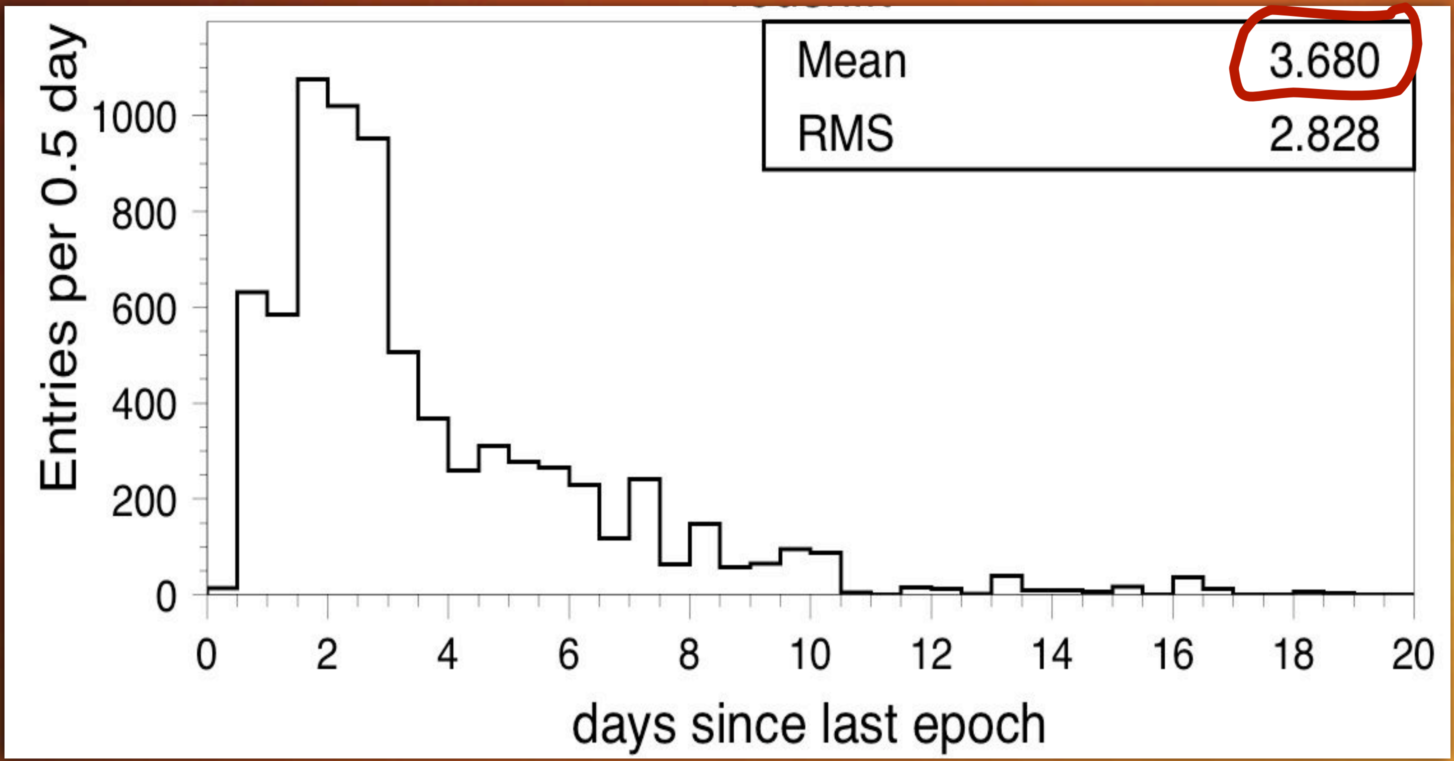
- Spectroscopic confirmation for **~500** SNe Ia
- Host-galaxy redshifts for additional **~300** photometrically ID'ed SNe Ia
- **~1700** photometrically ID'ed SN Ia: will get host-galaxy redshifts from SDSS-III (few % of fibers)
- This talk: cosmology results using **103** SNe (after cuts) from first season (Fall 2005).
- **78** Spectroscopically confirmed non-Ia (58 Type II, 8 Ib, 12 Ic)

SDSS **gri** Light Curves:

$\langle N_{measure} \rangle$ = 48 per SN

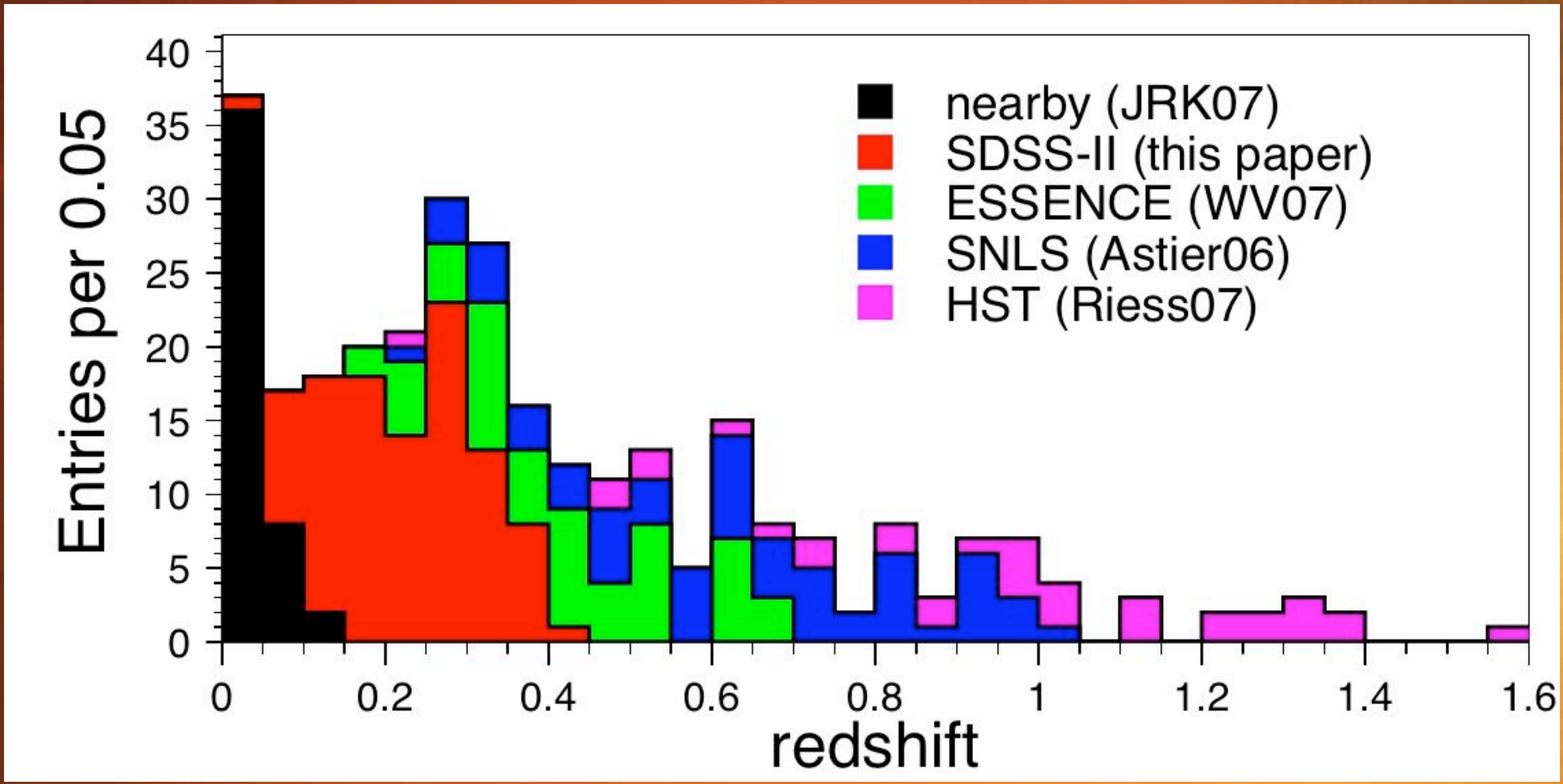


SDSS-II Survey Cadence



Redshift Distribution

(SDSS SNe fill redshift gap: 0.05 - 0.4)



Analysis with available light curve fitters:

- **MLCS**:
  - assumes color variations are ONLY from host-galaxy extinction.
  - Prior enforces positive extinction: $A_V > 0$

- **SALT2**:
  - color variations are not untangled from SN and host-galaxy extinction
  - no prior (bluer is always brighter)

Analysis with available light curve fitters:

- **MLCS** (Jha,Riess,Kirshner 2007):
  same method, but re-written with significant improvements to implementation

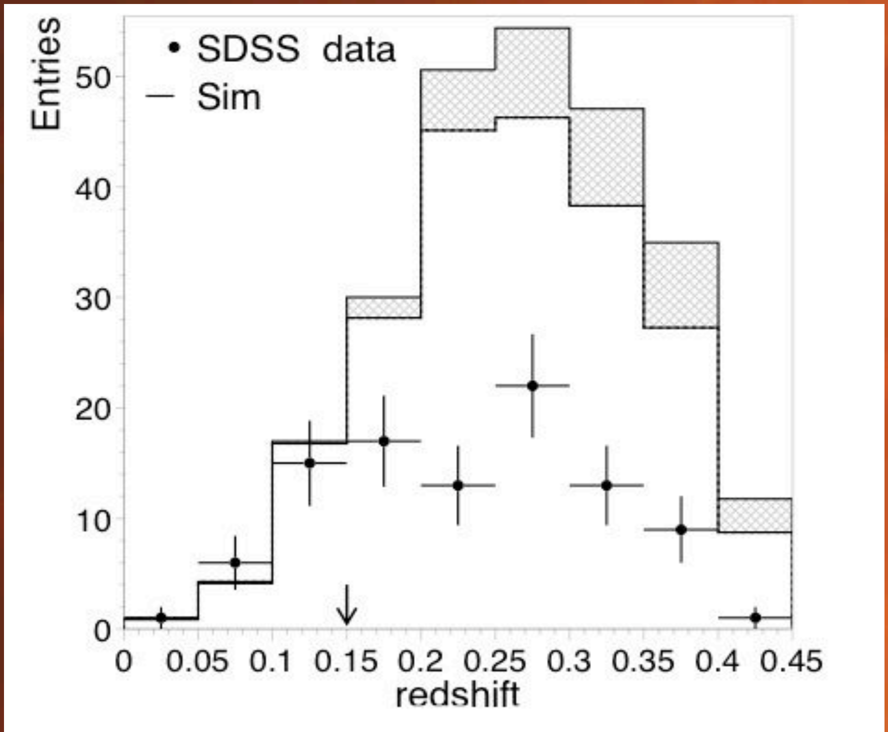
- **SALT2** (Guy et al.,2007):
  use code as-is, but retrained spectral surfaces with our UBVRI filter shifts for nearby sample (instead of those in Astier 2006)

Changes in MLCS Implementation

(no changes in training or philosophy)

- Host galaxy dust properties are measured with SDSS Sne (instead of assumptions)
- Account for spectroscopic efficiency in fitting prior ➜ big effect at high-z end of each survey
- Fit in flux (not mag)

Measurement of Dust Properties with SDSS-II



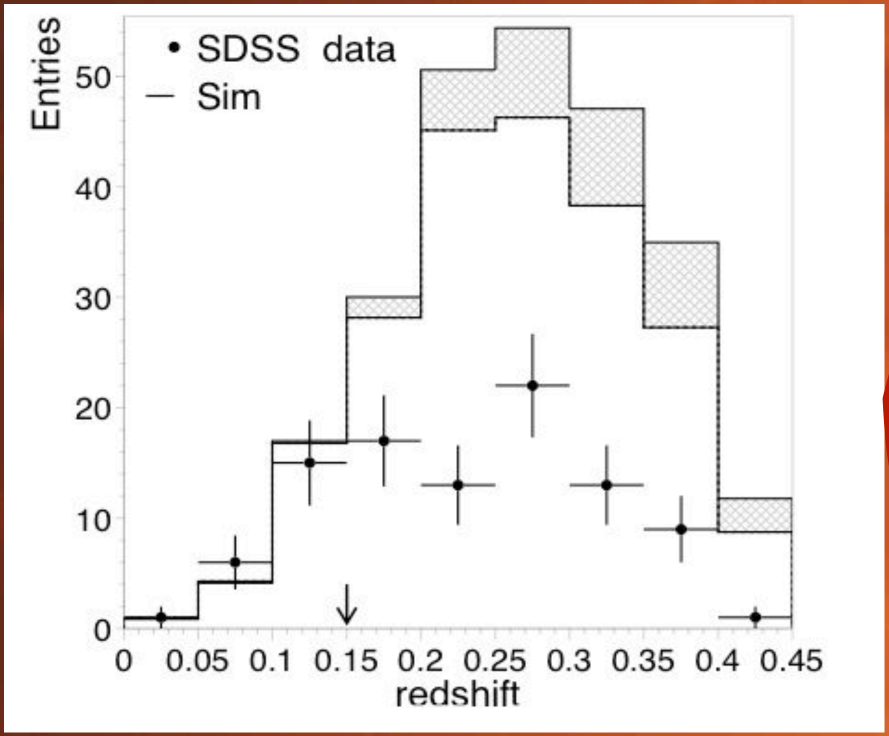
PROBLEM: Spec-confirmed SN Ia sample has large (spectroscopic) inefficiency

MLCS framework

Confirmed SNe on average are **BLUER and BRIGHTER** than parent population

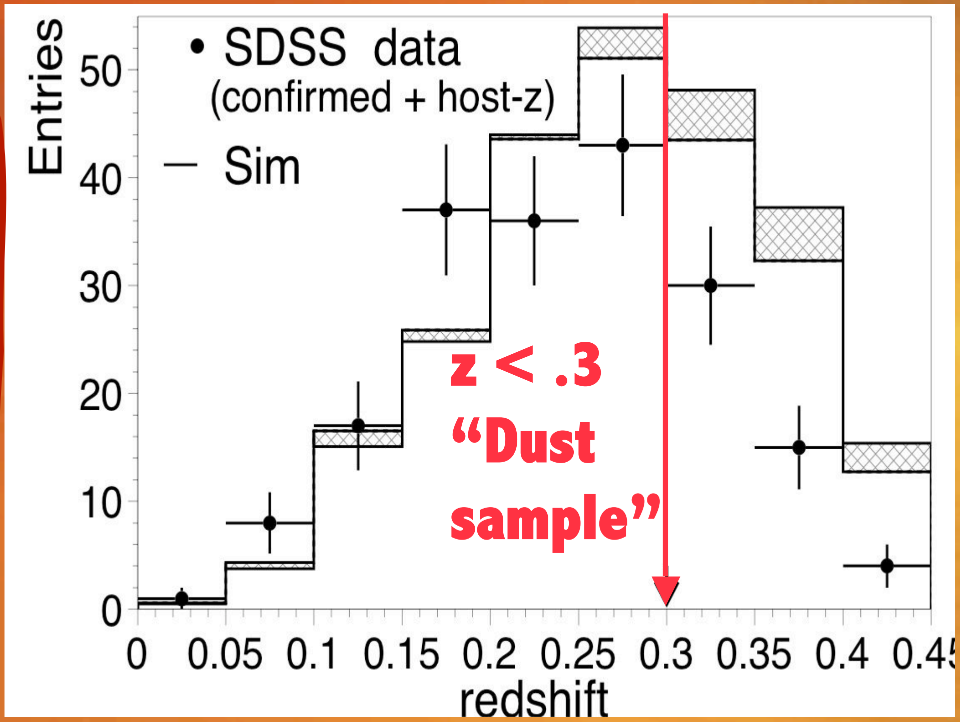
→ biased dust properties (R_V, A_V profile)

Measurement of Dust Properties with SDSS-II



PROBLEM: Spec-confirmed SN Ia sample has large (spectroscopic) inefficiency.

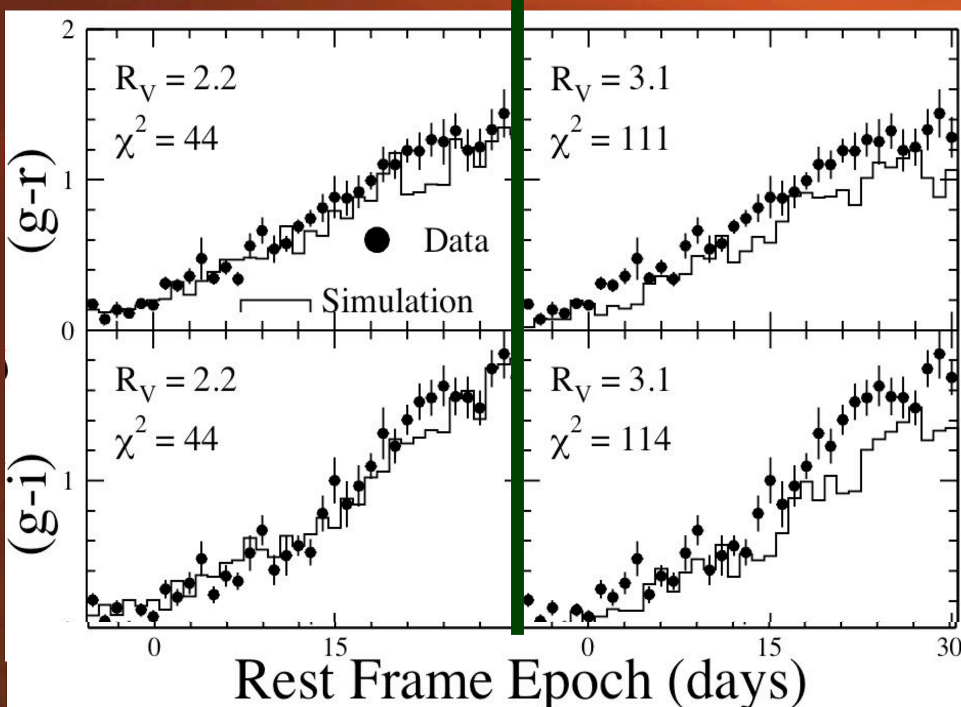
SOLUTION: include photometric SNe Ia with host-galaxy redshift: 155 with z < 0.3



Dust Properties with SDSS-II

R_V = 2.2 ± 0.5 in simulation matches observed colors

R_V = 3.1 in simulation => Poor match

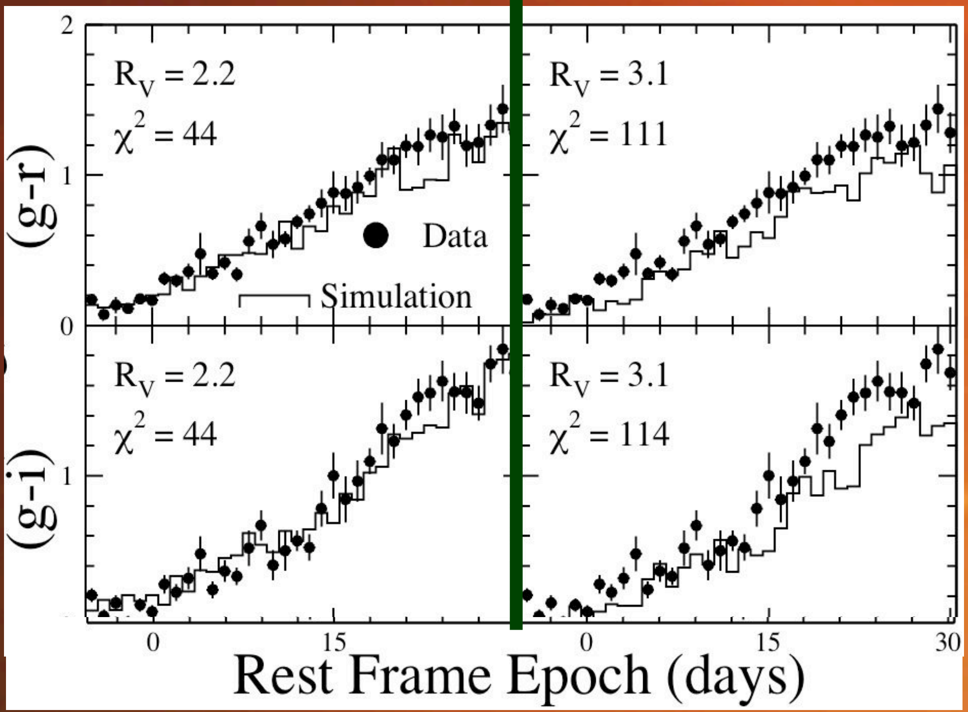


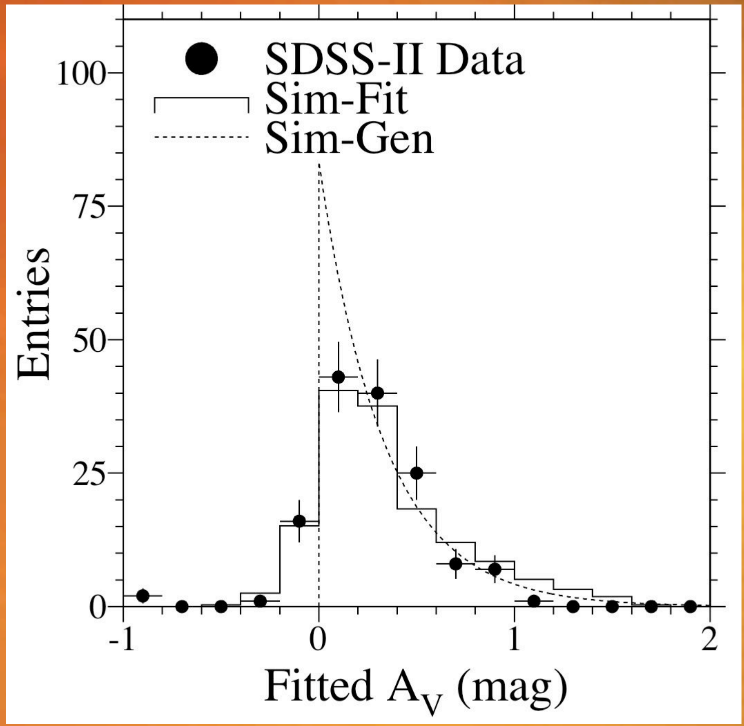
Dust Properties with SDSS-II

RV = 2.2 ± 0.5
in simulation
matches
observed
colors

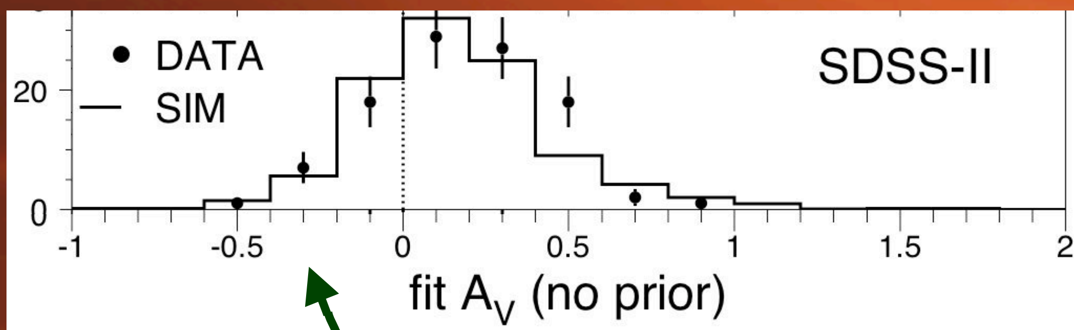
R_V = 3.1
in simulation
=>
Poor match

Exponential
A_V profile in sim
matches fit-A_V
profile in data



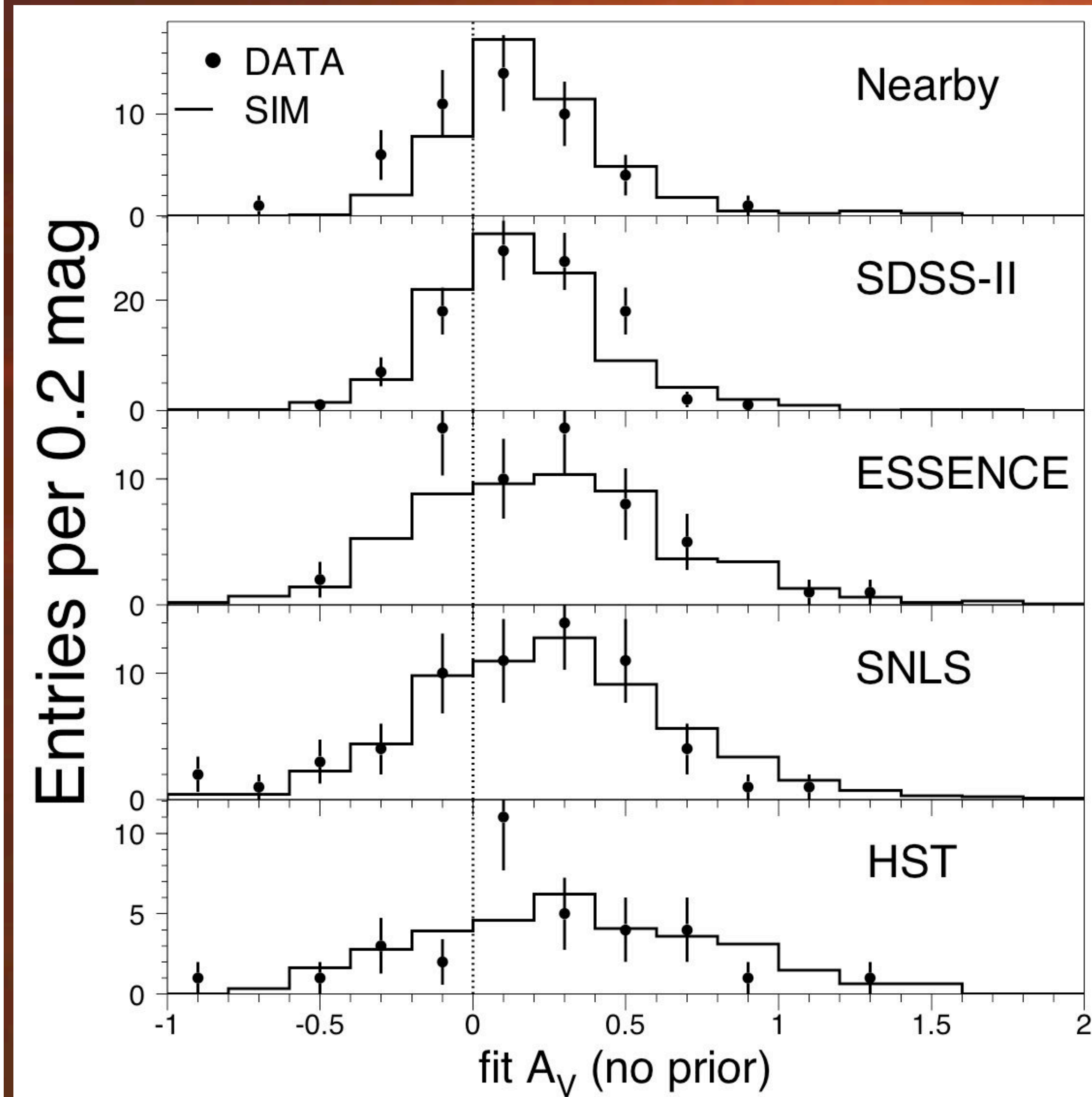


A_V with Flat Prior



$A_V > 0$
generated
in simulation
➔
describes
fitted $A_V < 0$
with no prior
➔
consistent with
MLCS interp
of SNe bluer
than template

A_V with Flat Prior



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of SNe bluer
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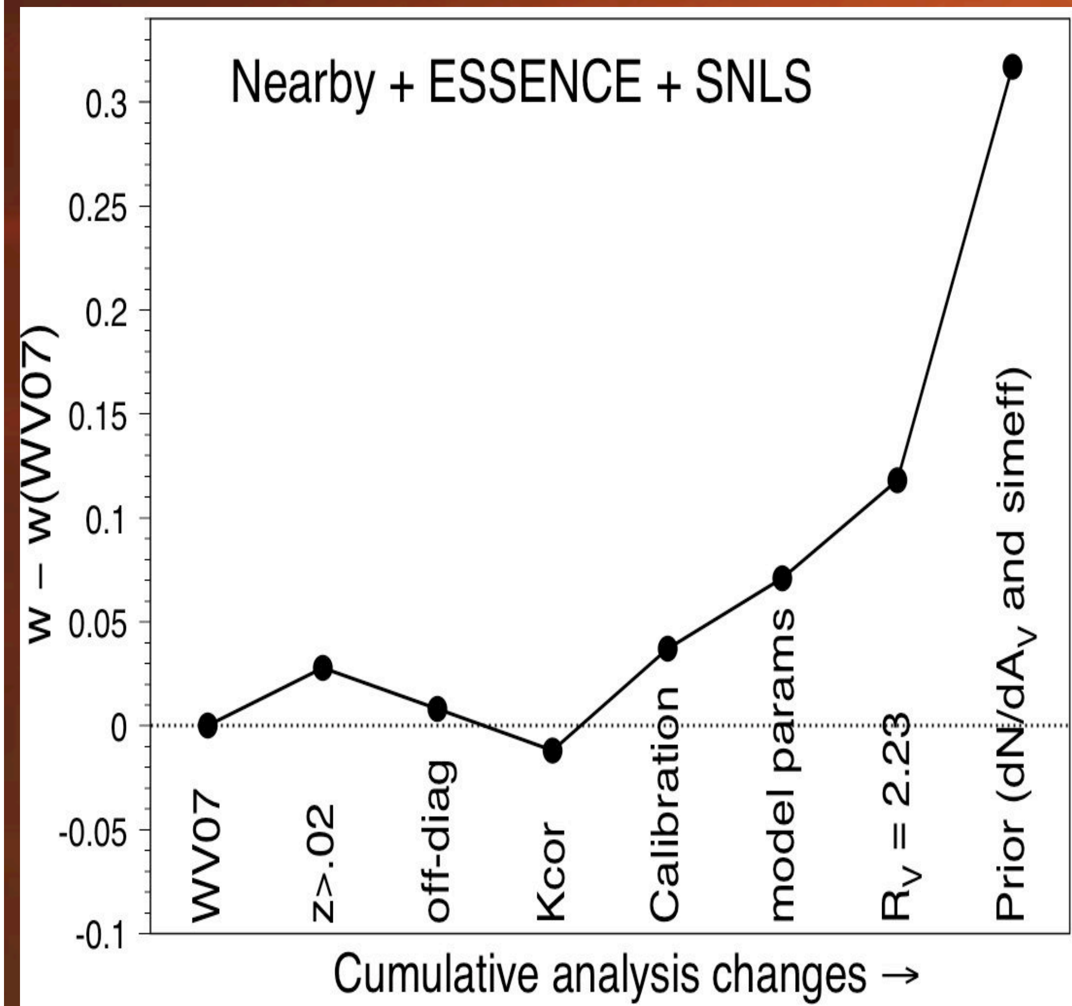
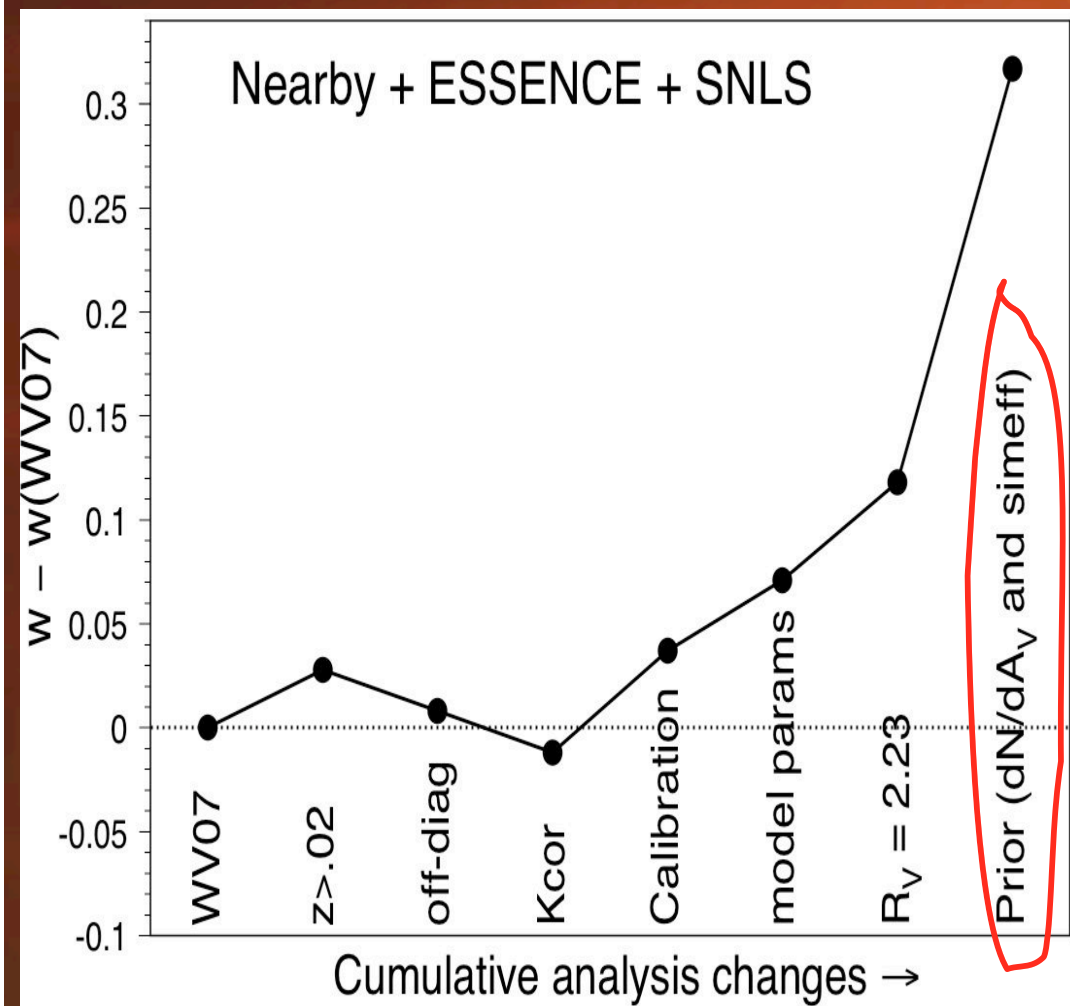
Impact of MLCS Changes (dw ~ 0.3 compared to WV07)

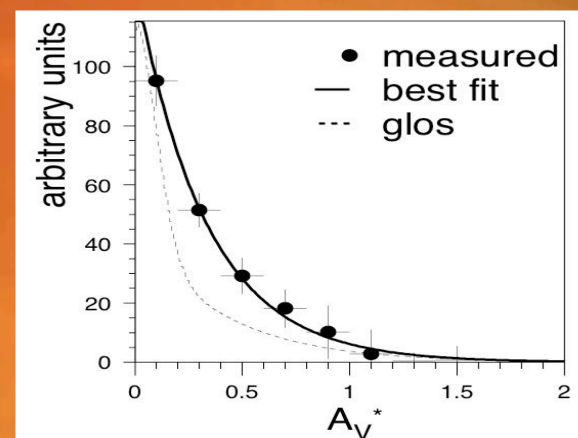


Wood-Vasey Et al, 2007: previous MLCS - based analysis from ESSENCE collaboration

Impact of MLCS Changes (dw ~ 0.3 compared to WV07)



1. Measured R_V =2.2(5) (instead of assuming 3.1)
2. Measured A_V profile (instead of assuming glos)



3. Include spectroscopic efficiency in prior (instead of ignoring it)

Calibration

- Use **BD+17** as primary refernce (crosscheck with Vega is consistent)
- SDSS **AB offsets** from HST standard solar analogs

- **Nearby UBVRI**: Bessell90 filter response + color transformation determined from Landolt standards with HST spectra (App B of 0908.4274)
- Crosscheck with shifted UBVRI filters is consistent (shift defined to have zero color transformation)

Calibration Details

AB offsets

Table 1: AB offsets and central wavelength uncertainties for the SDSS filters.

SDSS filter	AB offset (mag) and its uncertainty[a]	uncertainty (Å) on central wavelength
u	-0.037 ± 0.014	8
g	$+0.024 \pm 0.009$	7
r	$+0.005 \pm 0.009$	16
i	$+0.018 \pm 0.009$	25
z	$+0.016 \pm 0.010$	38

[a]Errors account for uncertainties in the central wavelengths of the SDSS filters.

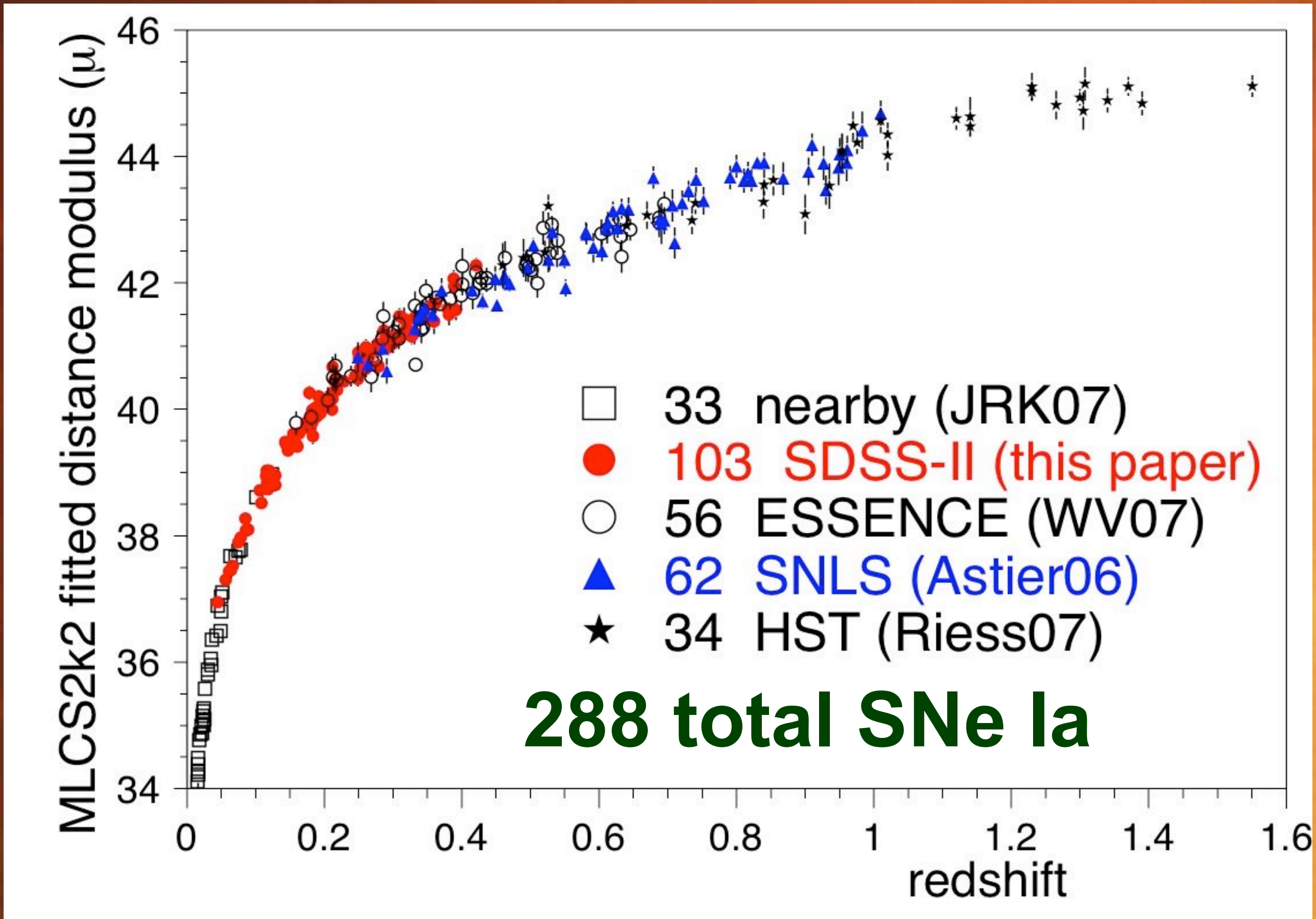
Bessell filter shifts

Table 21: Wavelength shifts for the Bessell (1990) filters.

	filter shift in Å for:	
Bessell filter	HST standards	Astier et al. (2006)
U	$+13 \pm 4$	–
B	-15 ± 4	-41
V	$+12 \pm 6$	-27
R	$+7 \pm 9$	-21
I	-45 ± 21	-25

Results ...

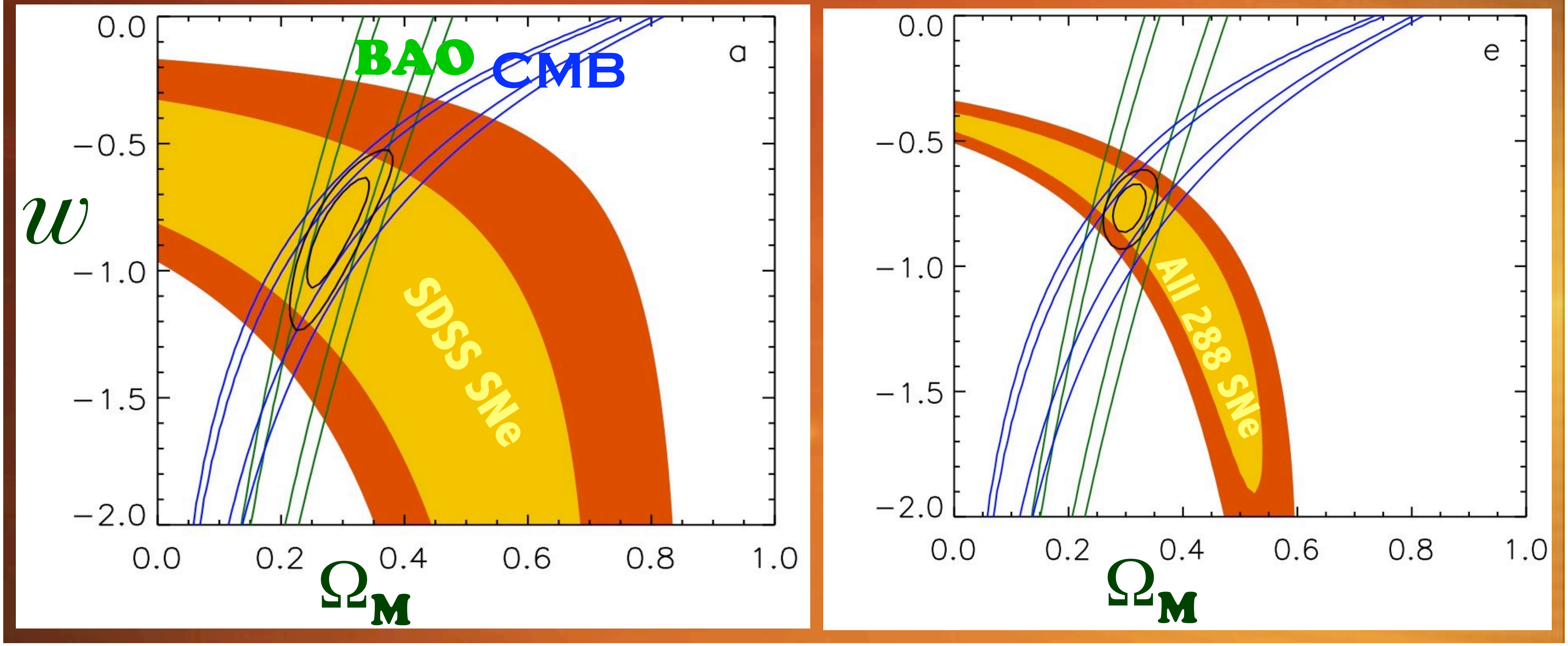
Combine SDSS SNe with Published Samples



Cosmology Fit

- Priors: BAO, CMB, flat universe
- Float w and Ω_M

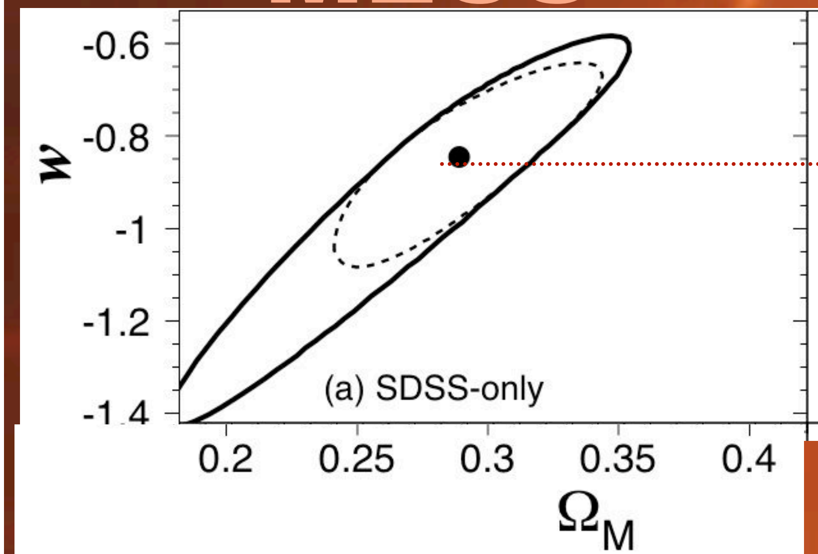
68% + 95% stat-error contours (MLCS)



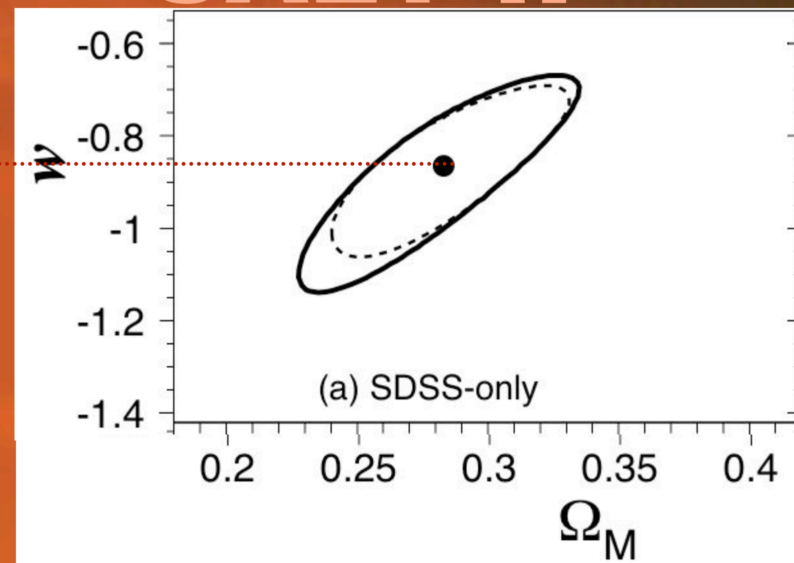
Results:

— total error
- - stat error

MLCS



SALT-II

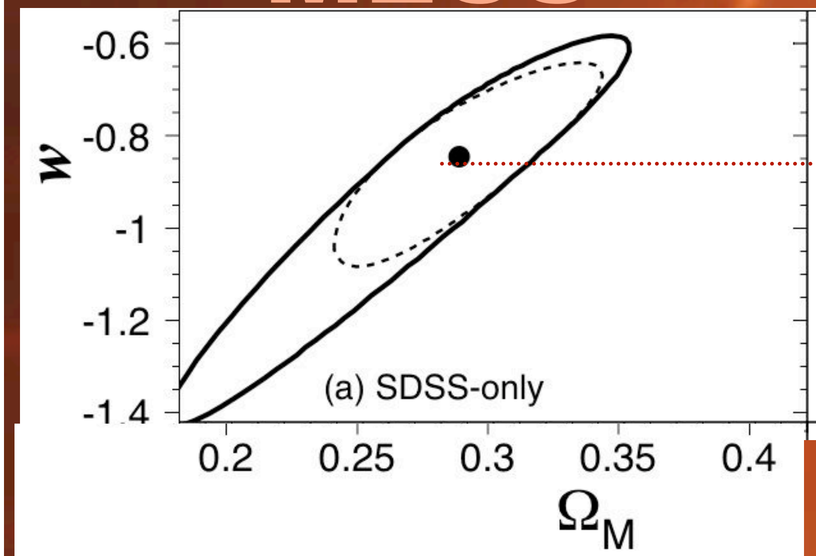


good agreement

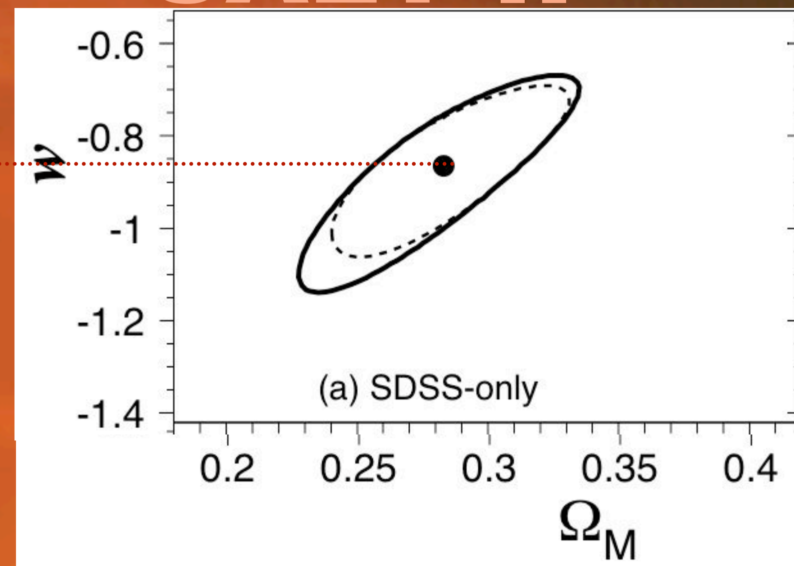
Results:

— total error
- - stat error

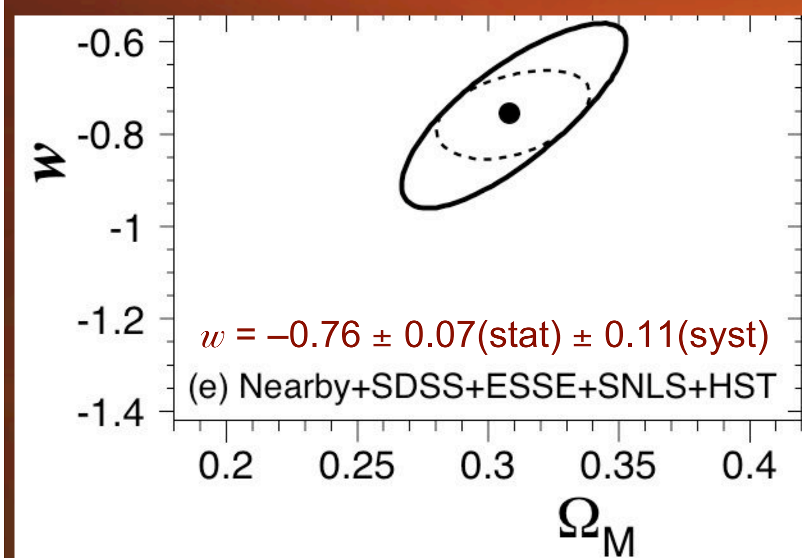
MLCS



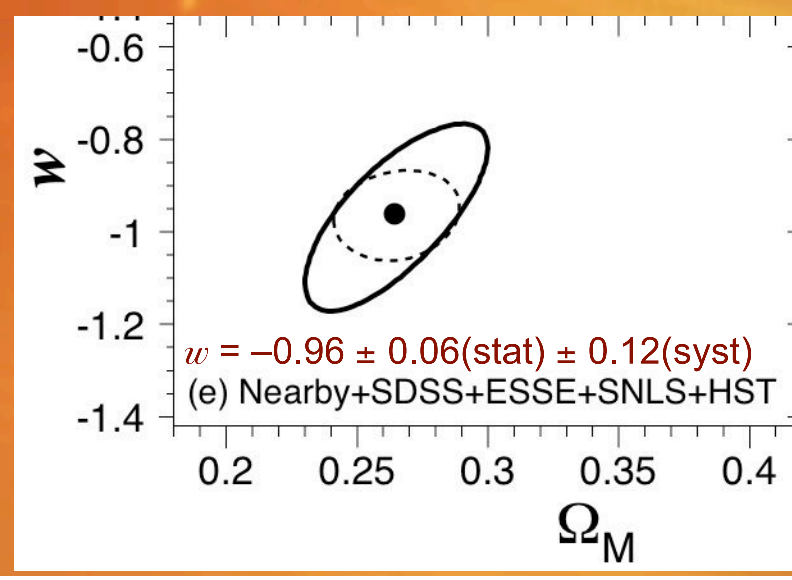
SALT-II



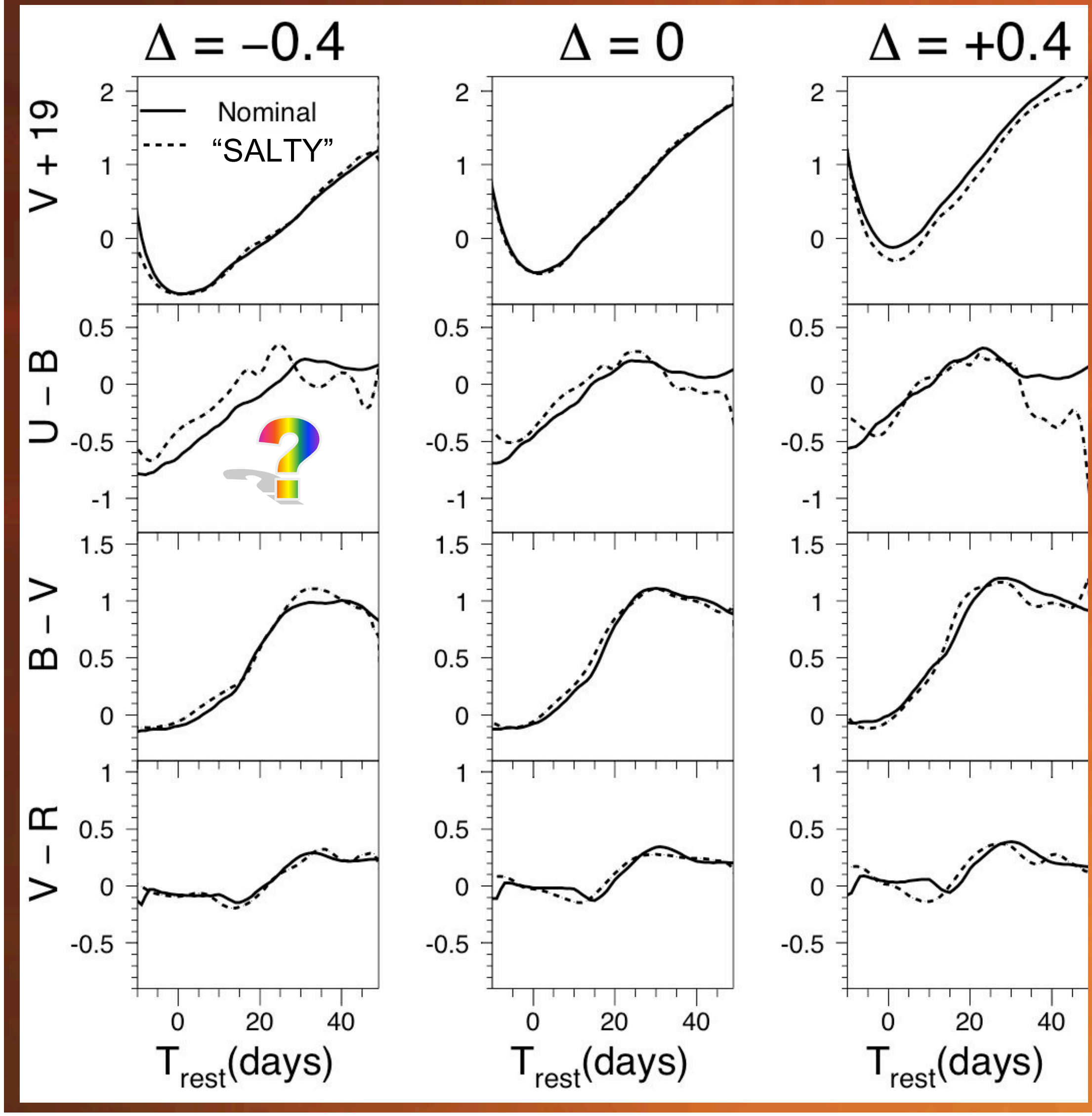
good agreement



Δw ~.2



Tracing the SALT2 - MLCS Discrepancy

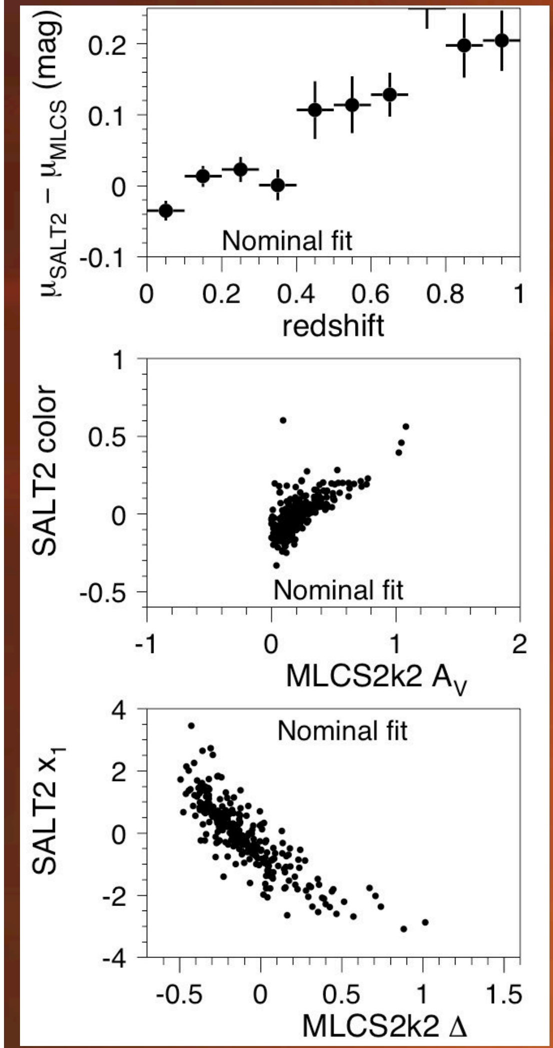


Translate SALT2 SED surface (λ vs. Trest) into "SALTY" MLCS model parameters; i.e., train MLCS with SALT2 SED surface.

↓

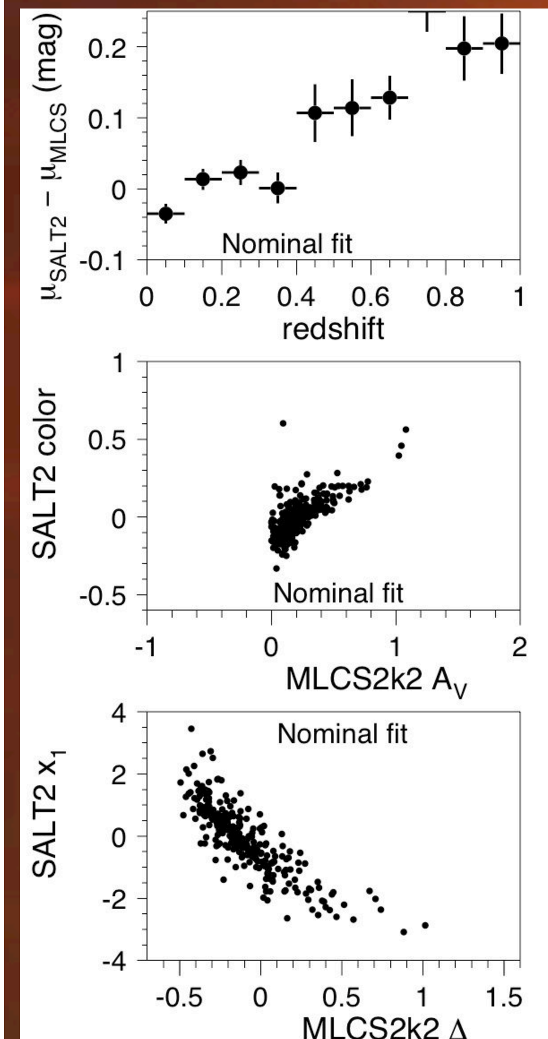
UV region is most discrepant

Tracing the SALT2 - MLCS Discrepancy



SALT2
vs.
Nominal MLCS

Tracing the SALT2 - MLCS Discrepancy



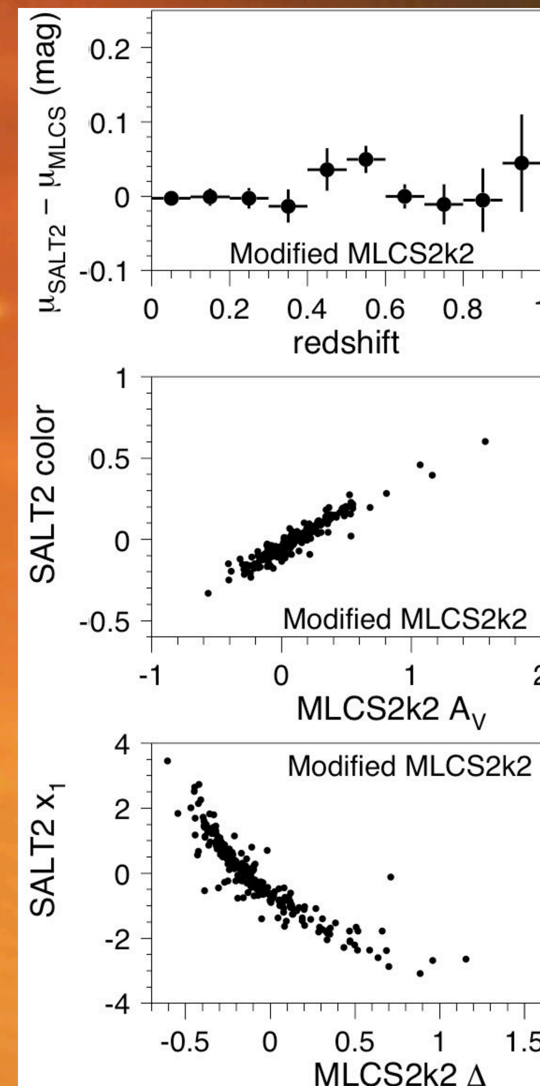
SALT2

vs.

Nominal MLCS

vs.

SALTY MLCS



Tracing the SALT2 - MLCS Discrepancy

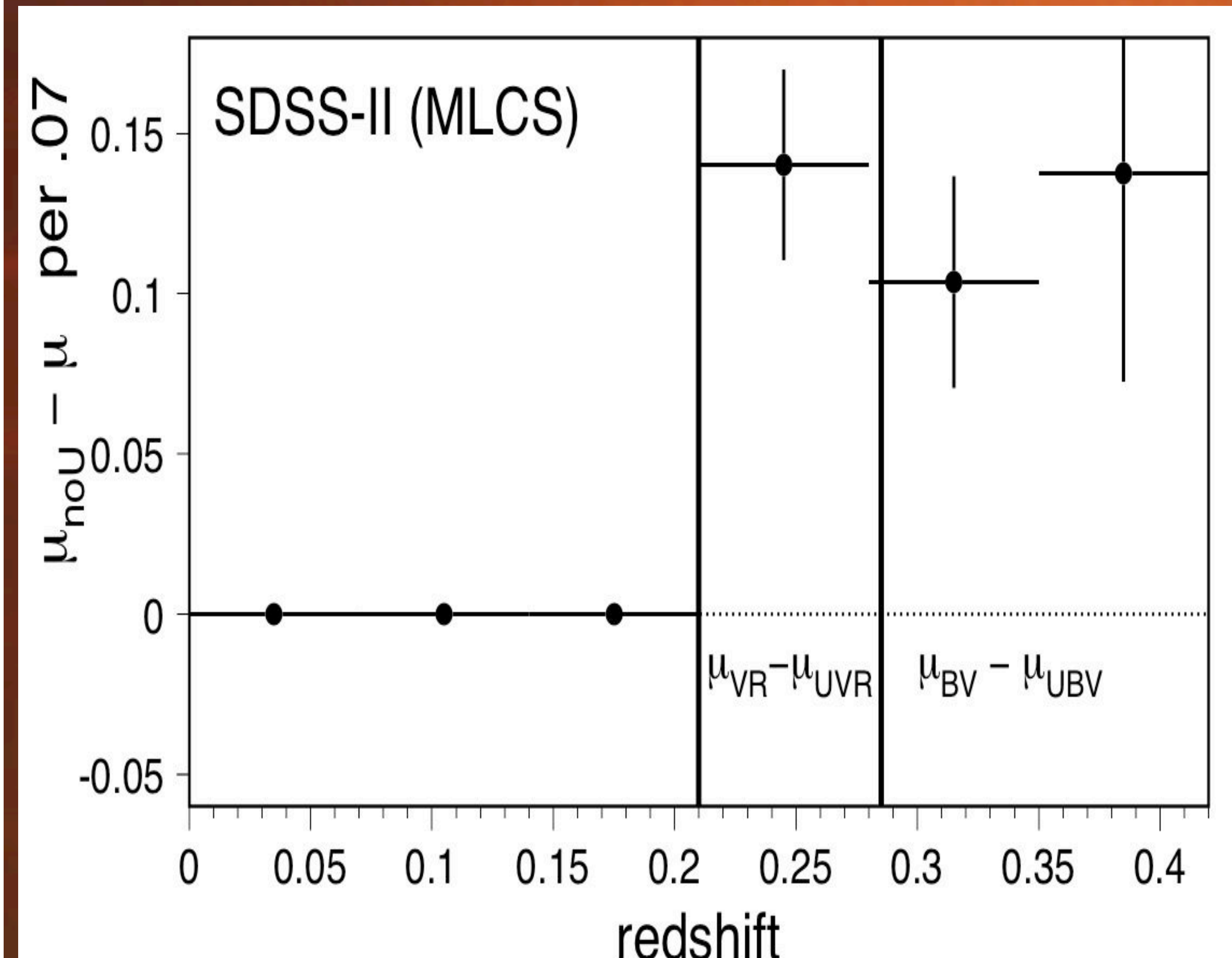
- Using SALTY-MLCS and removing A_V prior (i.e, allow A_V <0) → w shifts by –0.2 and agrees with SALT2 result.

- Either change alone makes small change in w: need both changes

- This test does not suggest that either method is right or wrong; only illustrates sources of discrepancy.

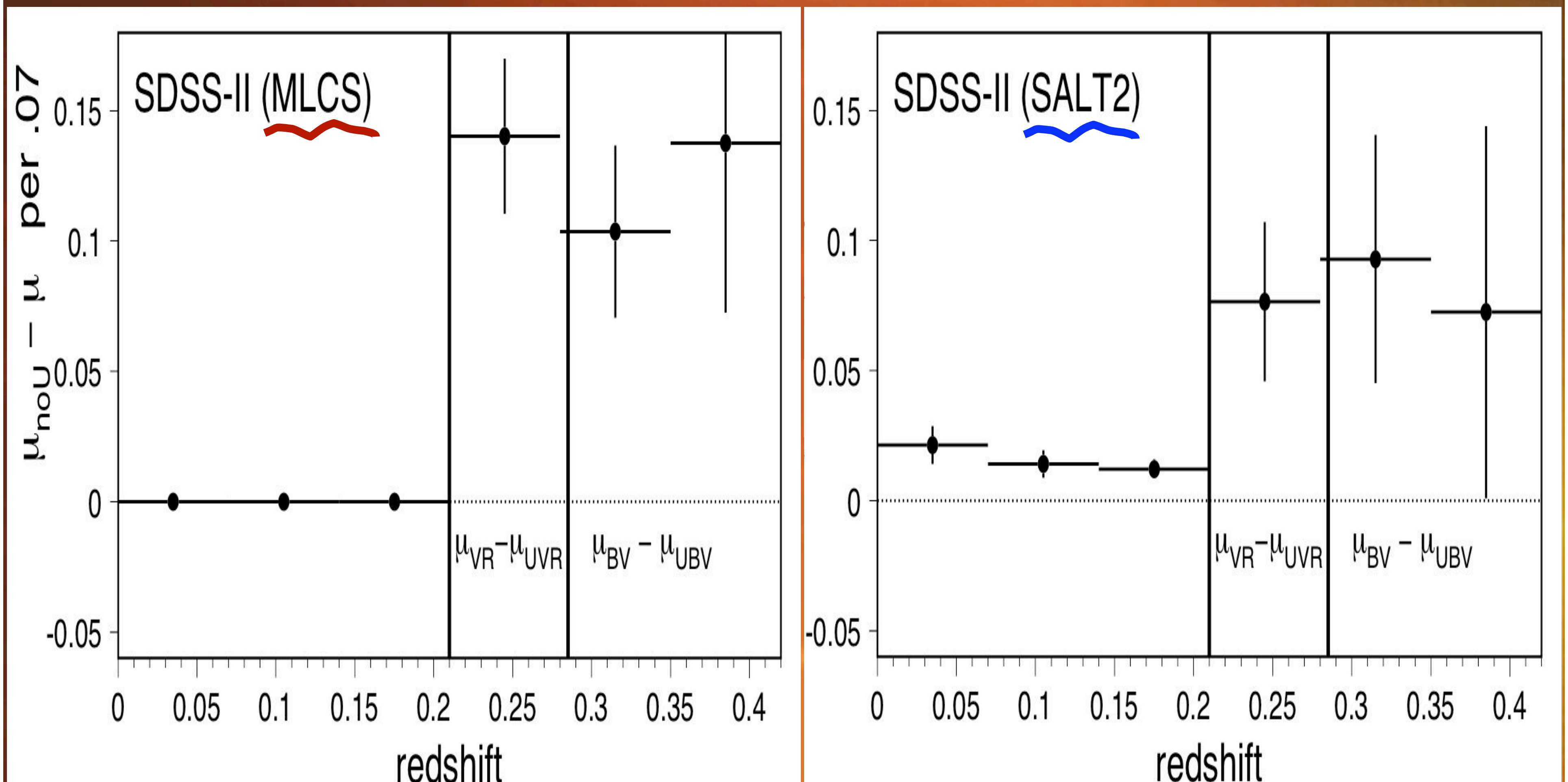
Systematics Issues

Large U-band Systematic for SDSS SNe

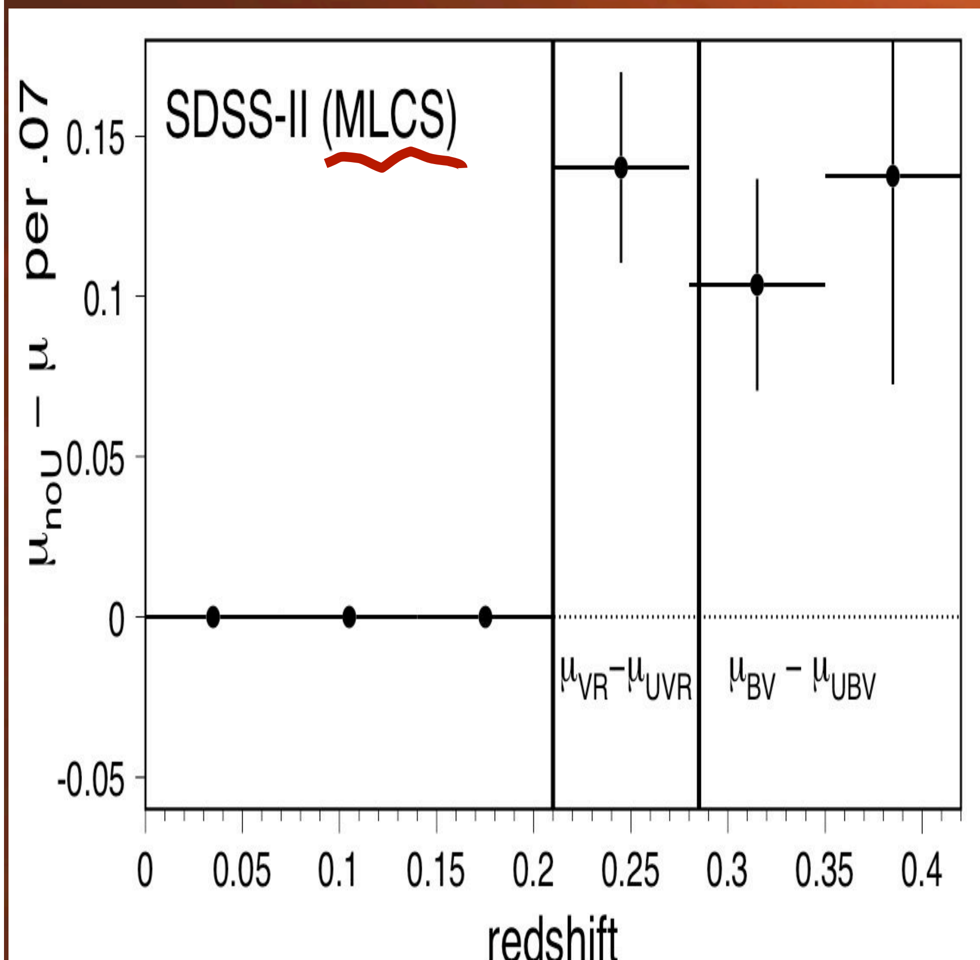


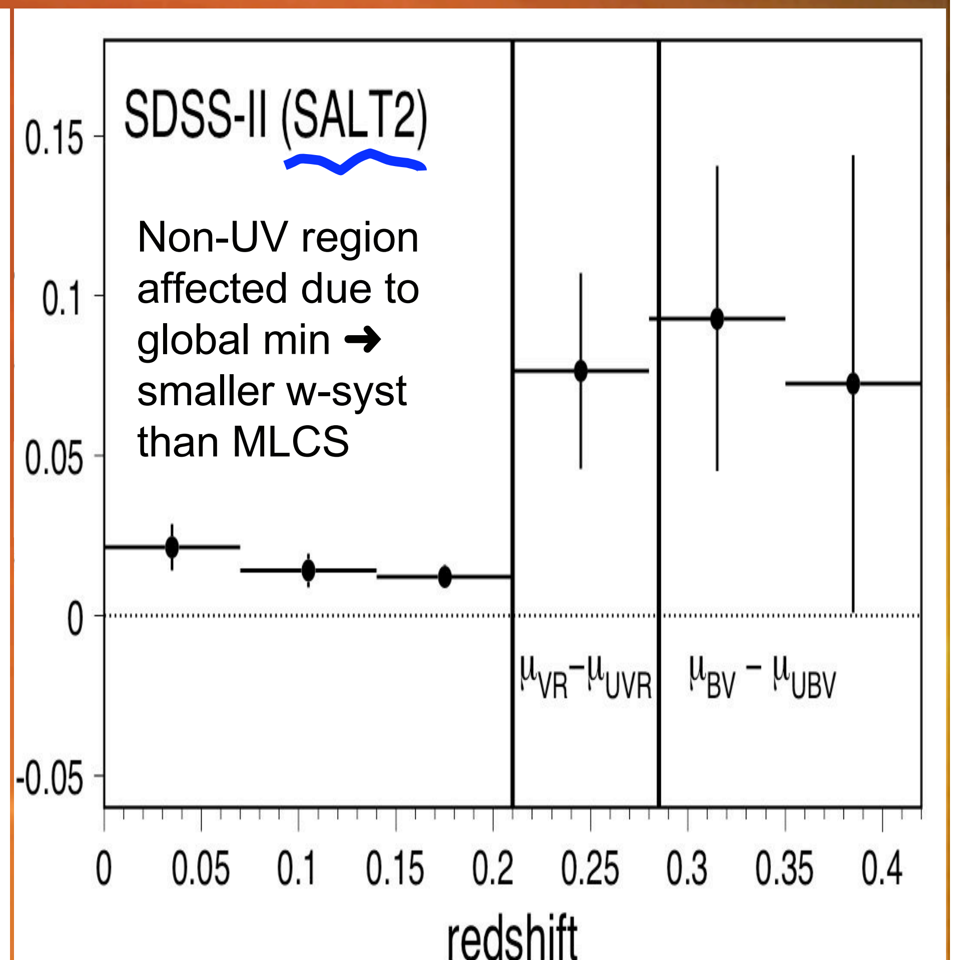
Source of largest systematic error.

Large U-band Systematic for SDSS SNe



Large U-band Systematic for SDSS SNe





UV-region

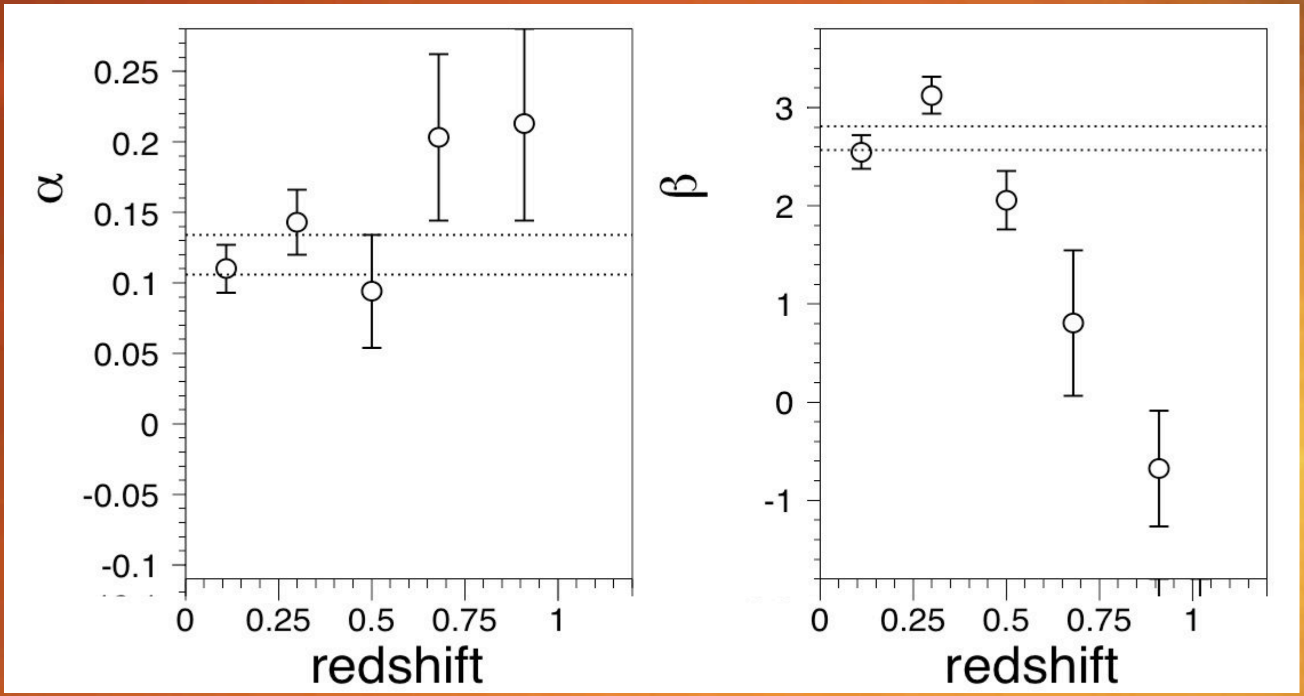
- Evidence points to problem with rest-frame UV in Nearby ($z < 0.1$) sample.
- MLCS is more sensitive (than SALT-II) to nearby UV because MLCS uses *only* nearby SNe for training.

- SDSS SN sample ideally suited to study rest-frame UV region:
- ✿ few dozen SNe with **u** → **UV** ($z < 0.1$)
  ✿ 200 SNe with **g** → **UV** ($z > 0.2$)
  ✿ with host-galaxy redshifts ($r_{gal} < 21.5$) from SDSS-III, perhaps double !

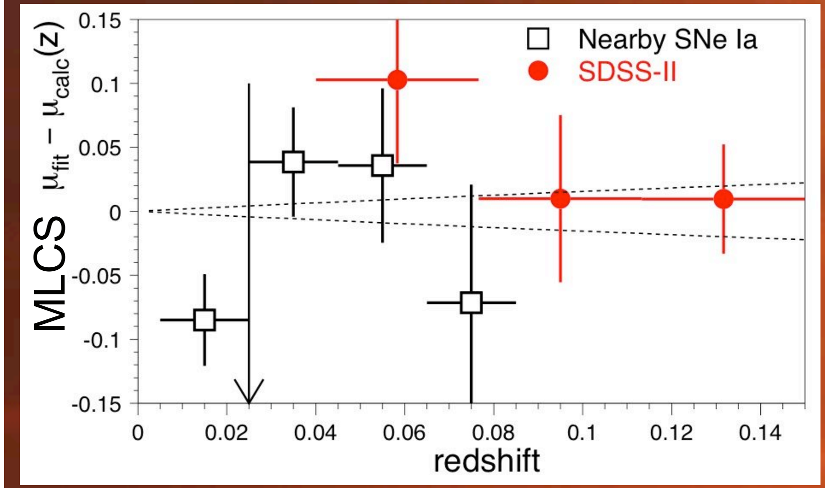
SALT-II redshift dependence

Intrinsic SN mag = M + α(stretch) – β(color)

Fit in separate redshift bins with cosmology (w, Ω_M) fixed to values from global fit.



Hubble Bubble ?



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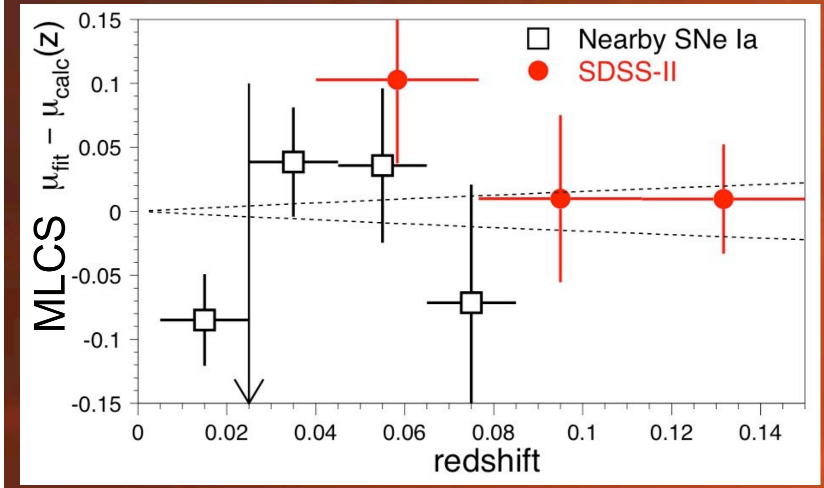
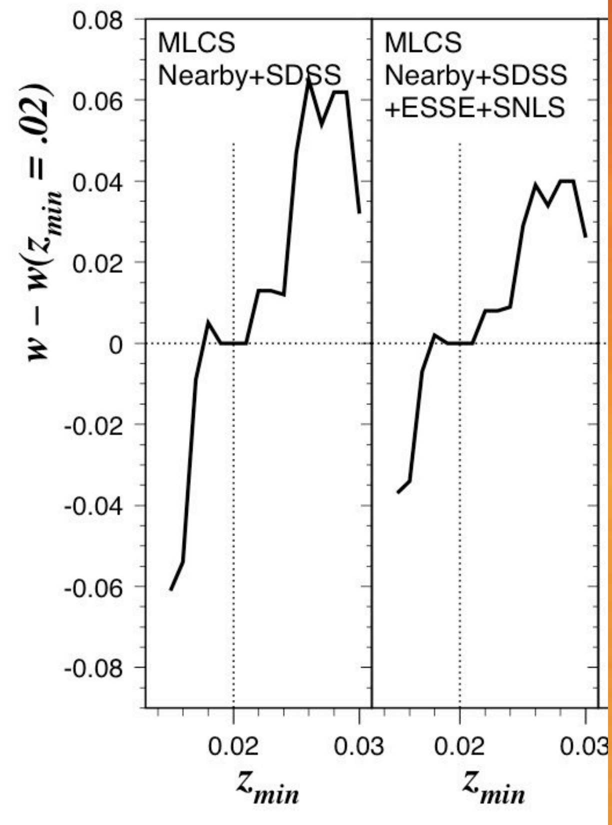
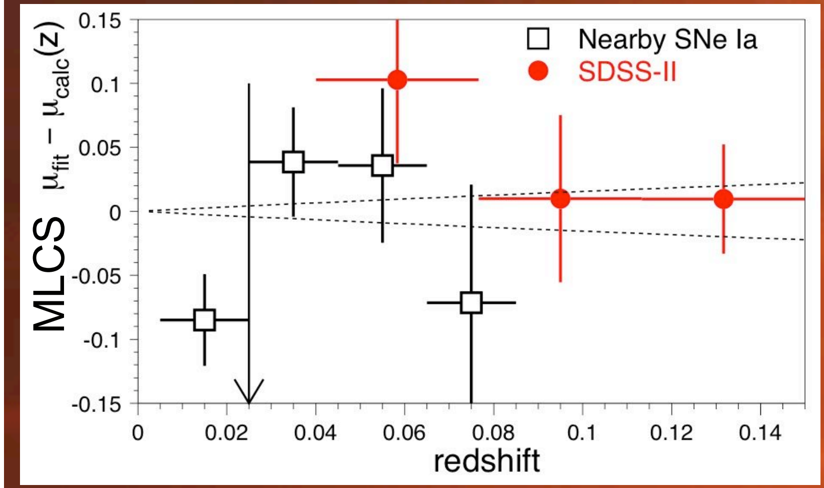
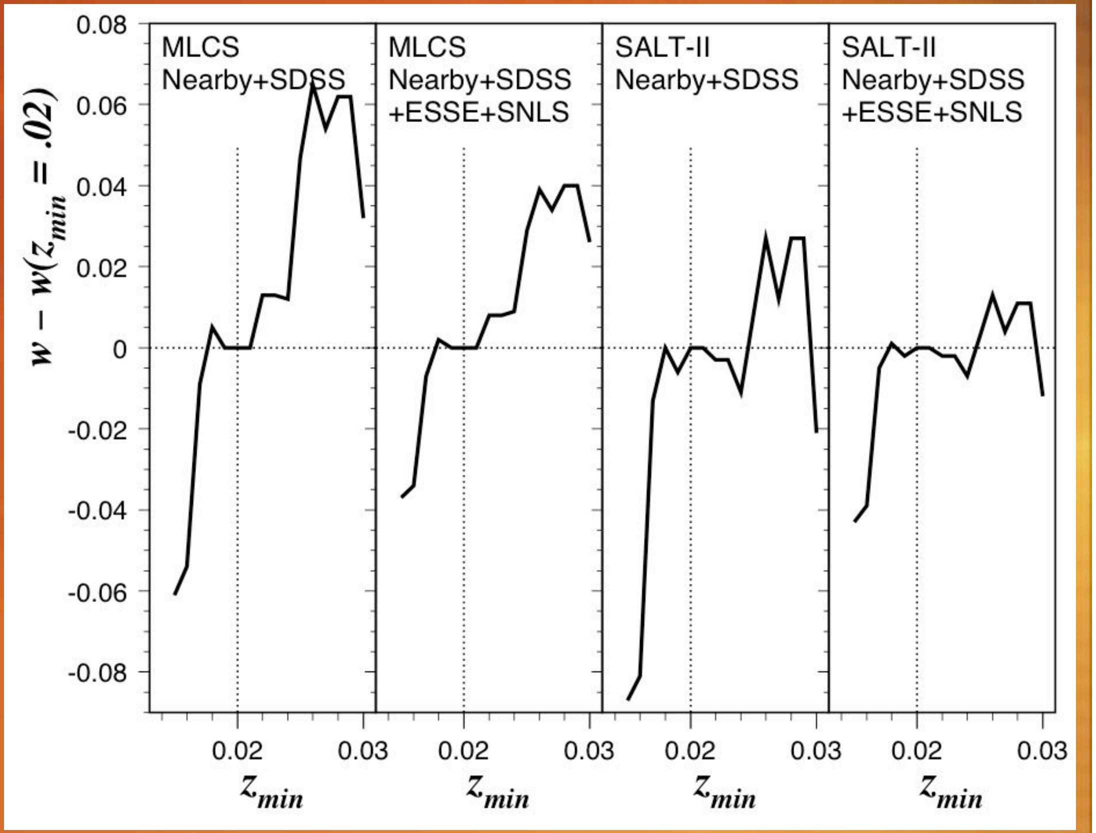




Hubble Bubble ?





δw_{syst} = .03 - .06

Summary

- Cosmology analysis of 1st season SDSS SNe Ia is finished;

  unresolved issues ➜ systematic errors
- “improved” MLCS and “standard” SALT-II give discrepant results for w: traced to UV model and assumption of color variations.
- UV model problem very clear with SDSS SNe; dominates systematic error.
  SDSS data ideal to study UV region.
- Still working to obtain a nearly “complete” SDSS SN sample that includes photometrically ID’ed SNe with host-galaxy redshifts (from SDSS-III).