The Dark Energy Survey - Supernova Survey

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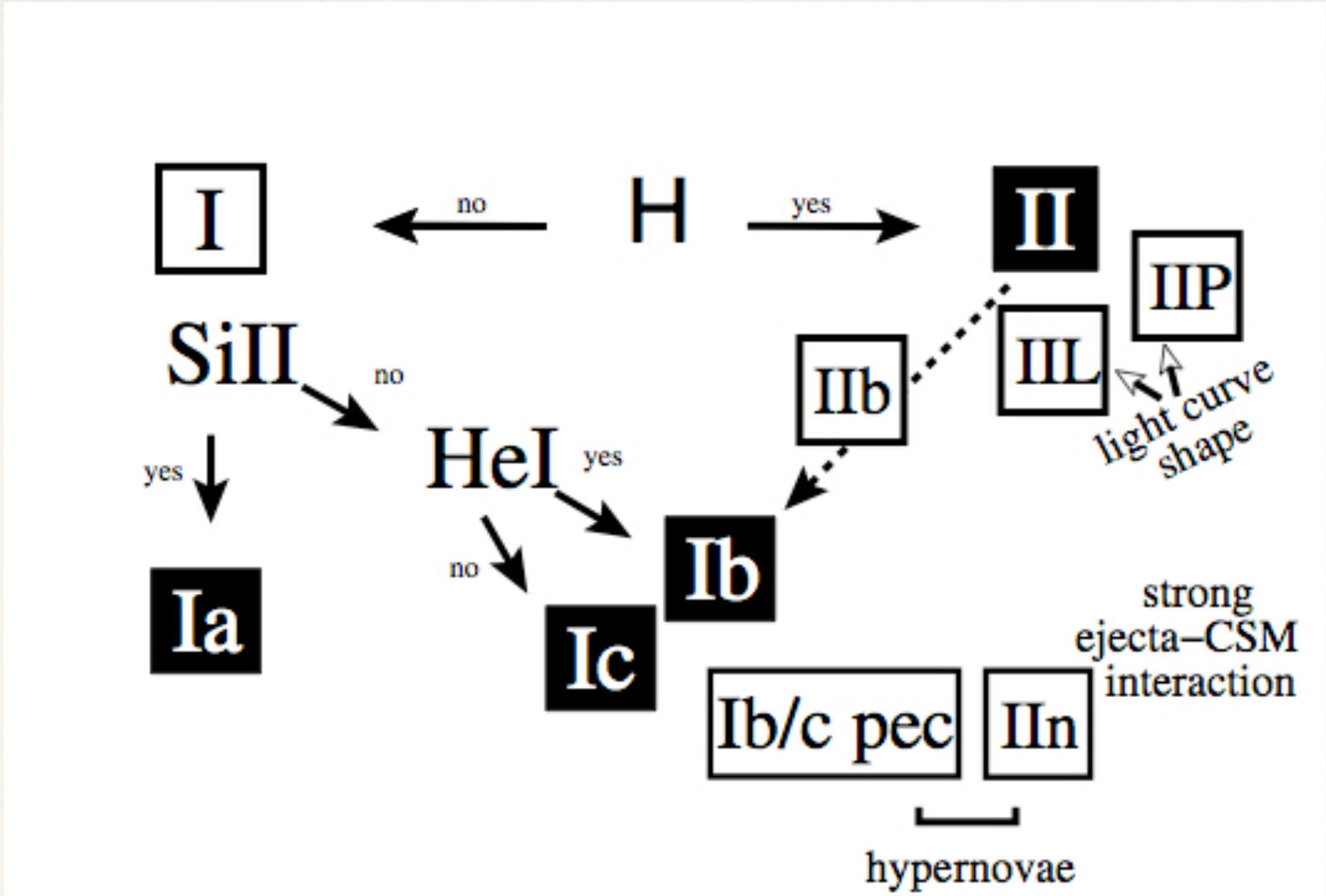
Institute for Cosmology and Gravitation
University of Portsmouth

KDUST Workshop
Institute of High Energy Physics (IHEP)
Beijing
November 7-9, 2011

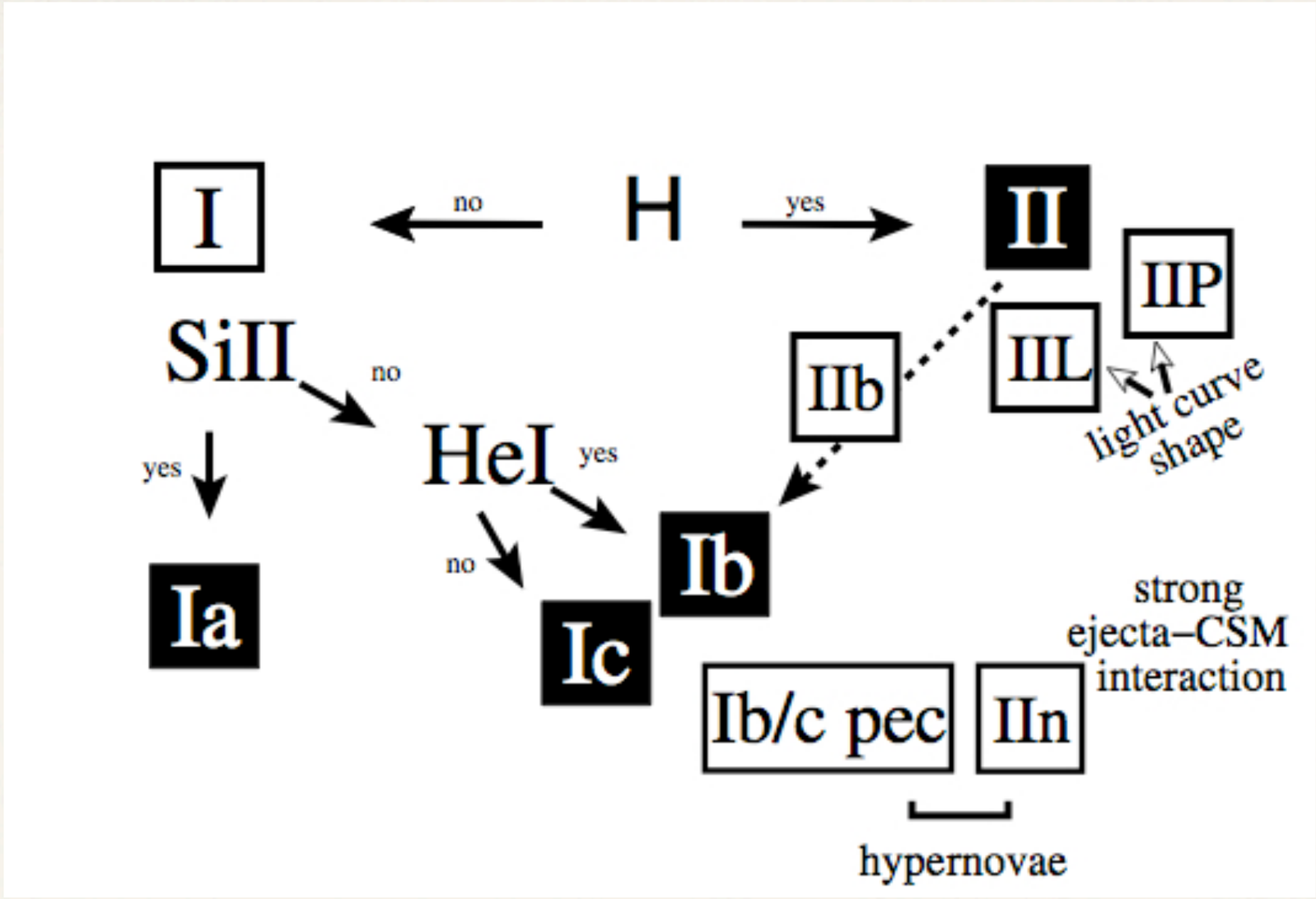
Supernova Classification



Classifications based on Spectra, Light Curves

- This makes classification *dynamic*
- New peculiar SNe (1991bg, 1991T, 2002cx) and types (ULSNe, `.Ia') continuously emerging

Supernova Classification



Turatto (2003)

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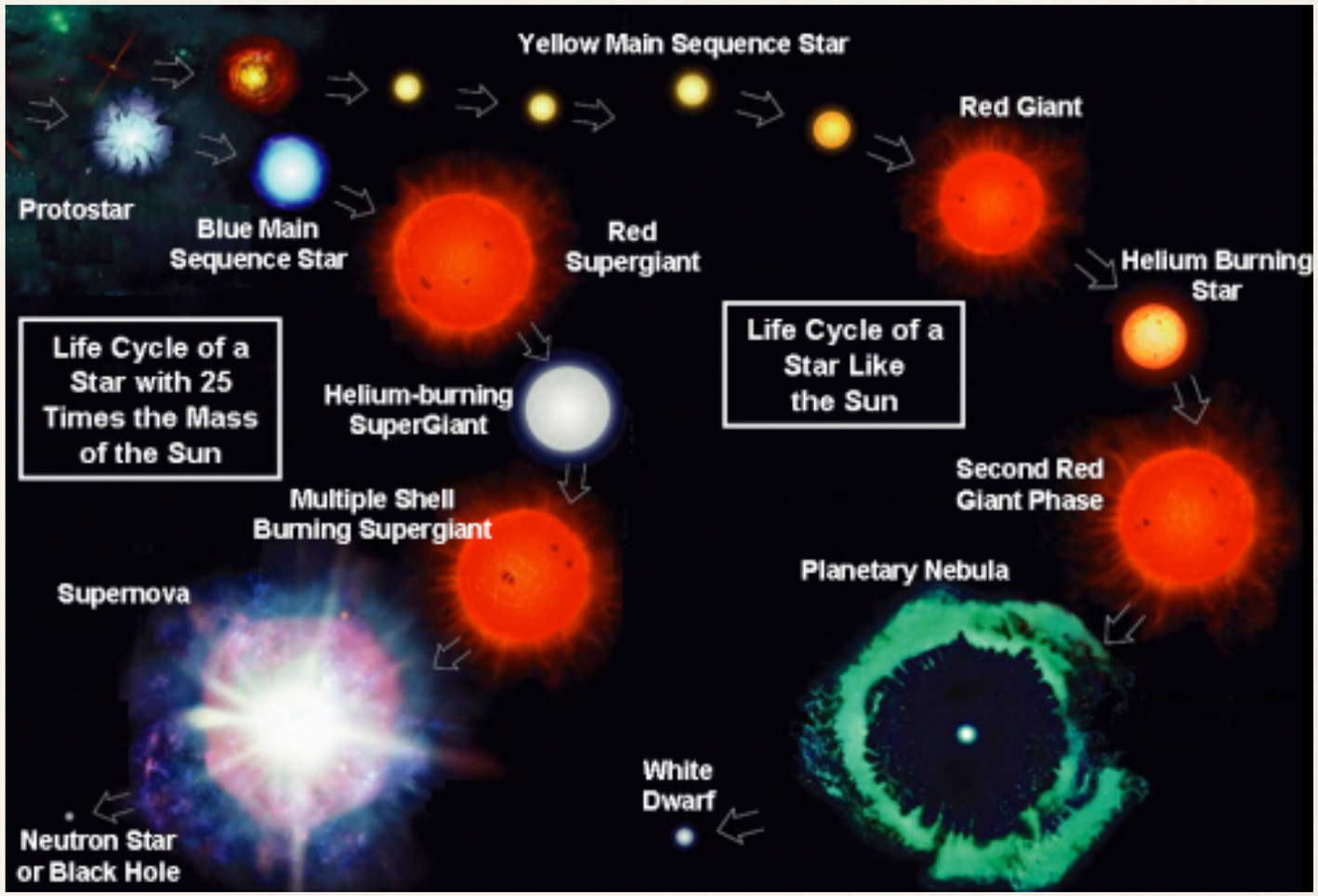
Supernova Progenitors

Type II/Ib/Ic:

- Core Collapse of Massive Star > 8 $M_\odot$
- Neutron Star or Black Hole remnant
- Only in SFG
- Dimmer, Variation of ≈5 mag in peak luminosity



Type Ia:

- Low-Mass progenitor in binary system
- Thermonuclear explosion of White Dwarf near Chandrasekhar limit
- Complete disruption; no remnant
- More luminous; little scatter (< 2 mag)

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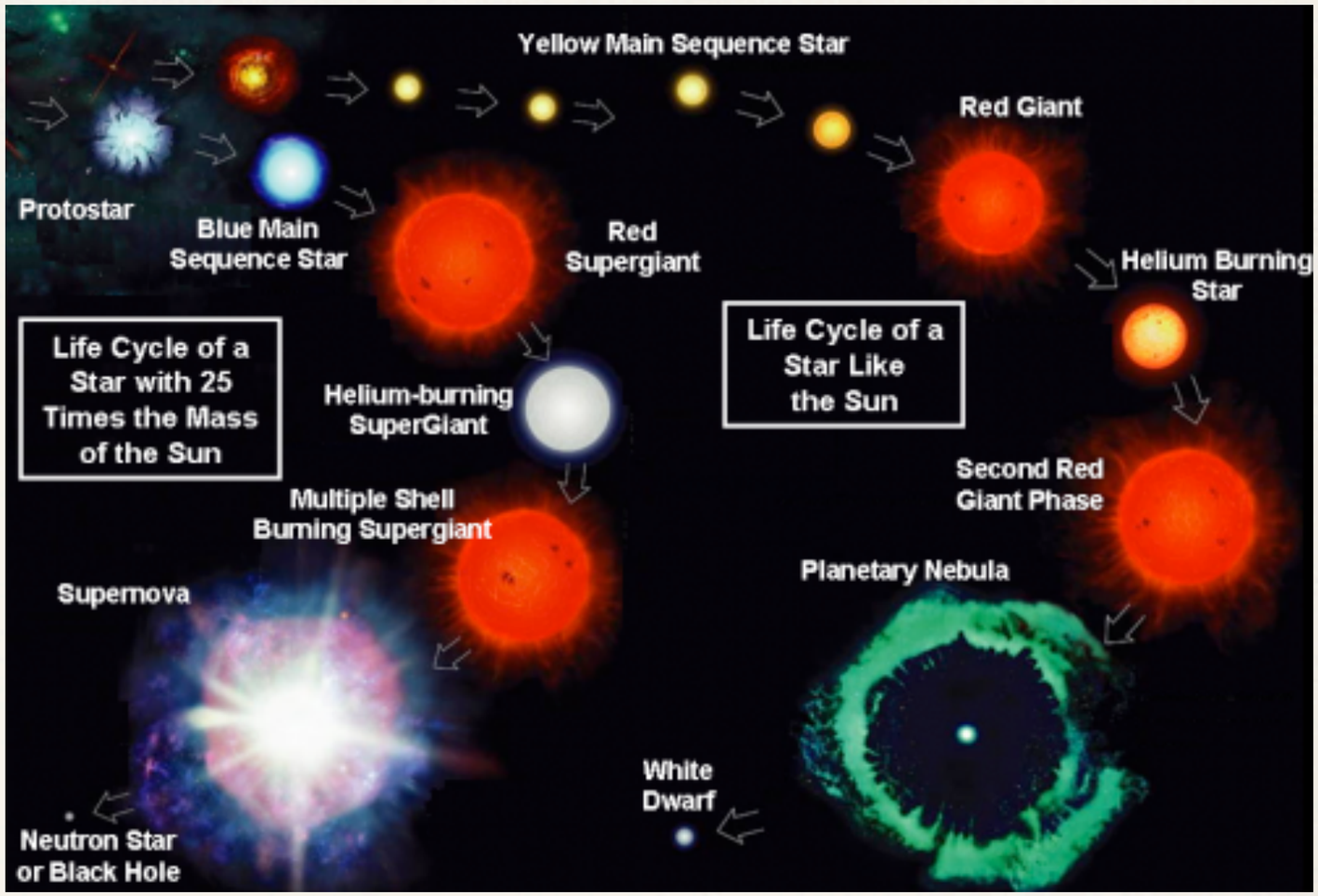

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Fast SN Cosmology Overview

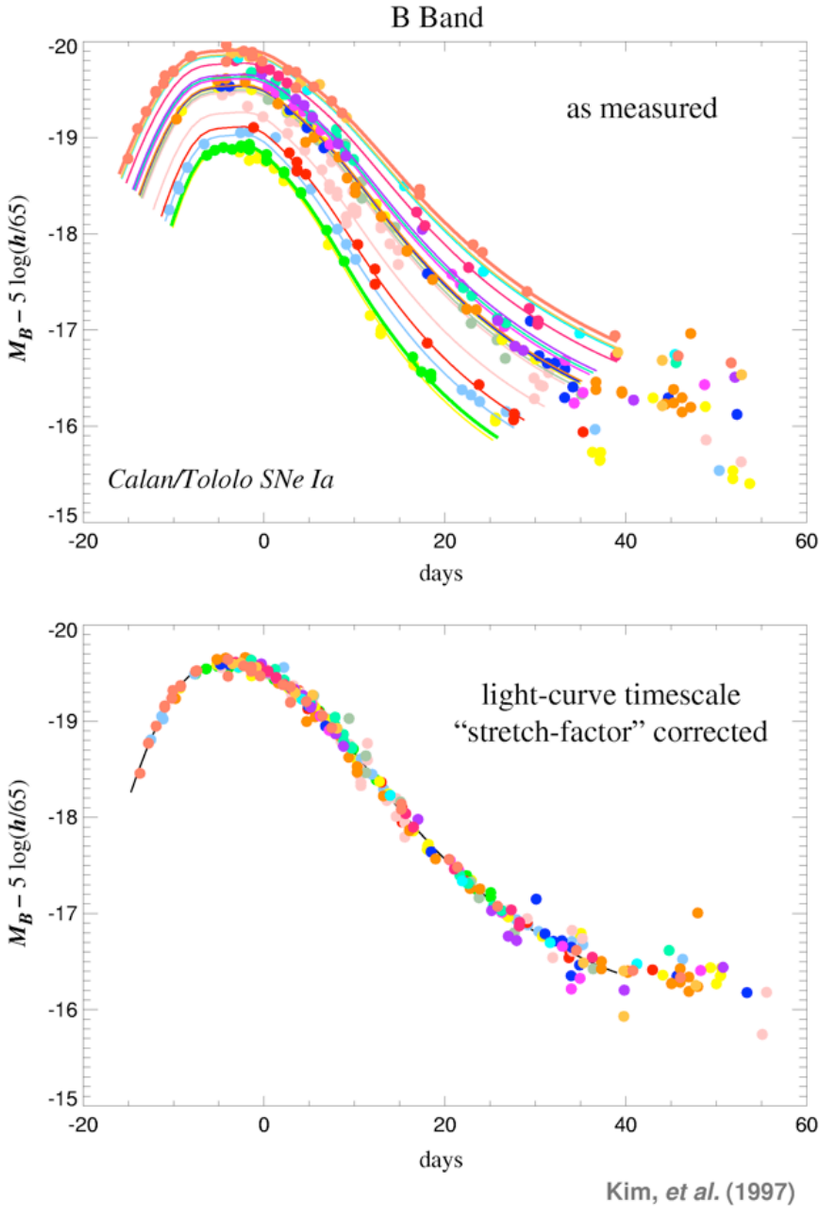
$$F = \frac{L}{4\pi\chi^2(1+z)^2} \Rightarrow D_L = (1+z)\chi(z)$$

$$\chi(z) = \frac{c}{H_0}\int_0^z \frac{dz'}{\sqrt{\Omega_M(1+z')^3+\Omega_{\rm DE}(1+z')^{3(1+w)}}}$$

$$m - M = \mu = 5\log D_L + 25 \quad [\mathrm{D_L\ in\ Mpc}]$$

$\mu \equiv$ distance modulus

The Past



SNe Ia are not standard, but standardizable

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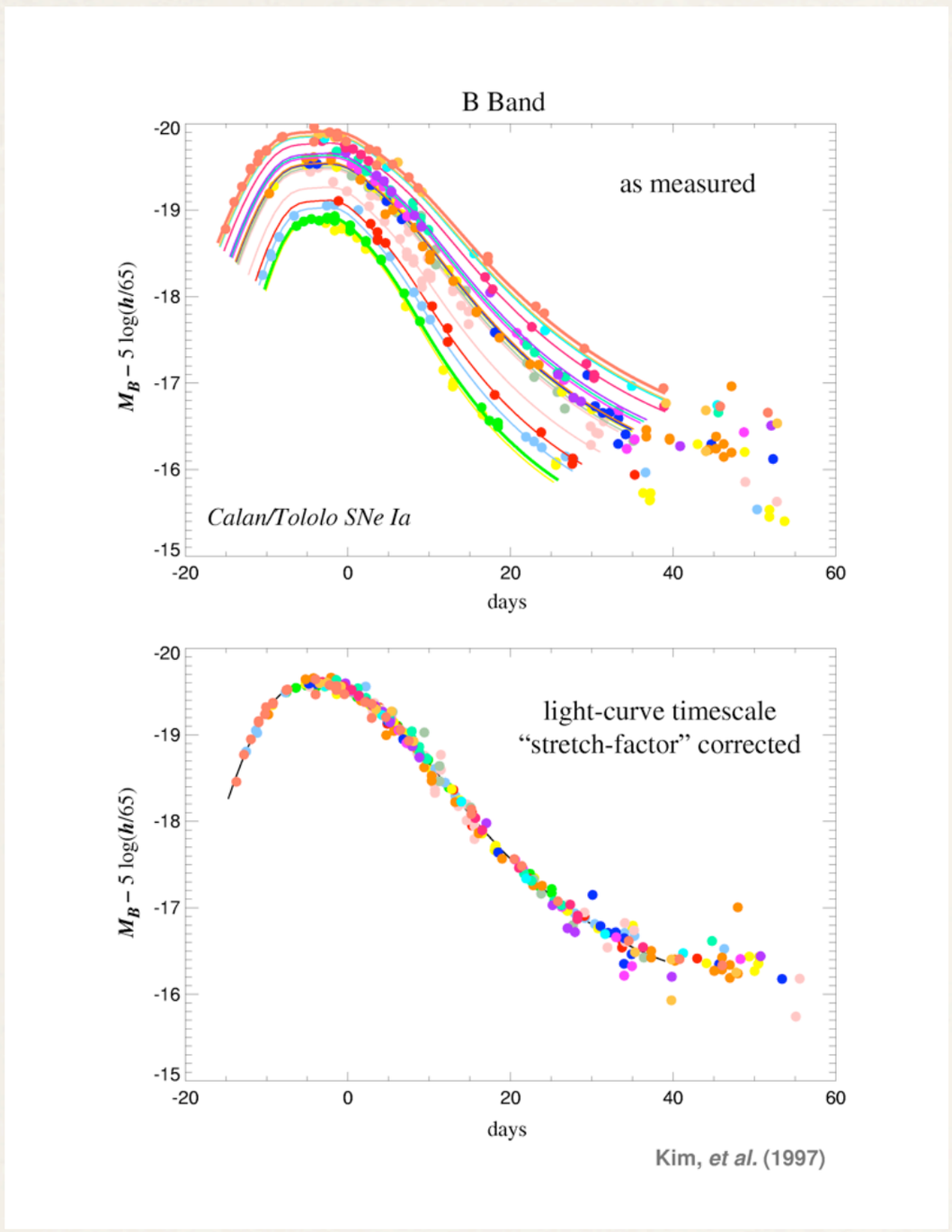

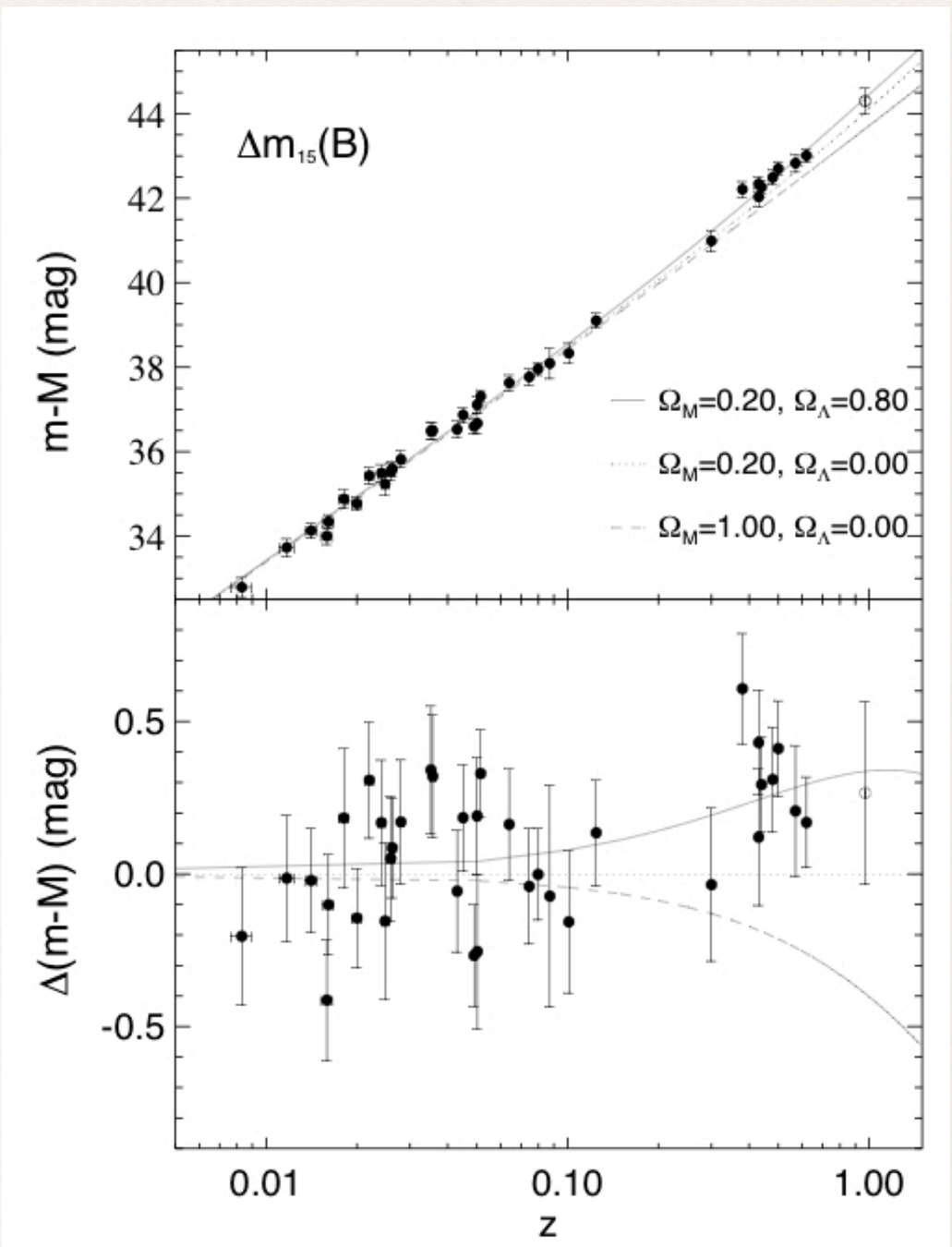

Riess et al. (98)

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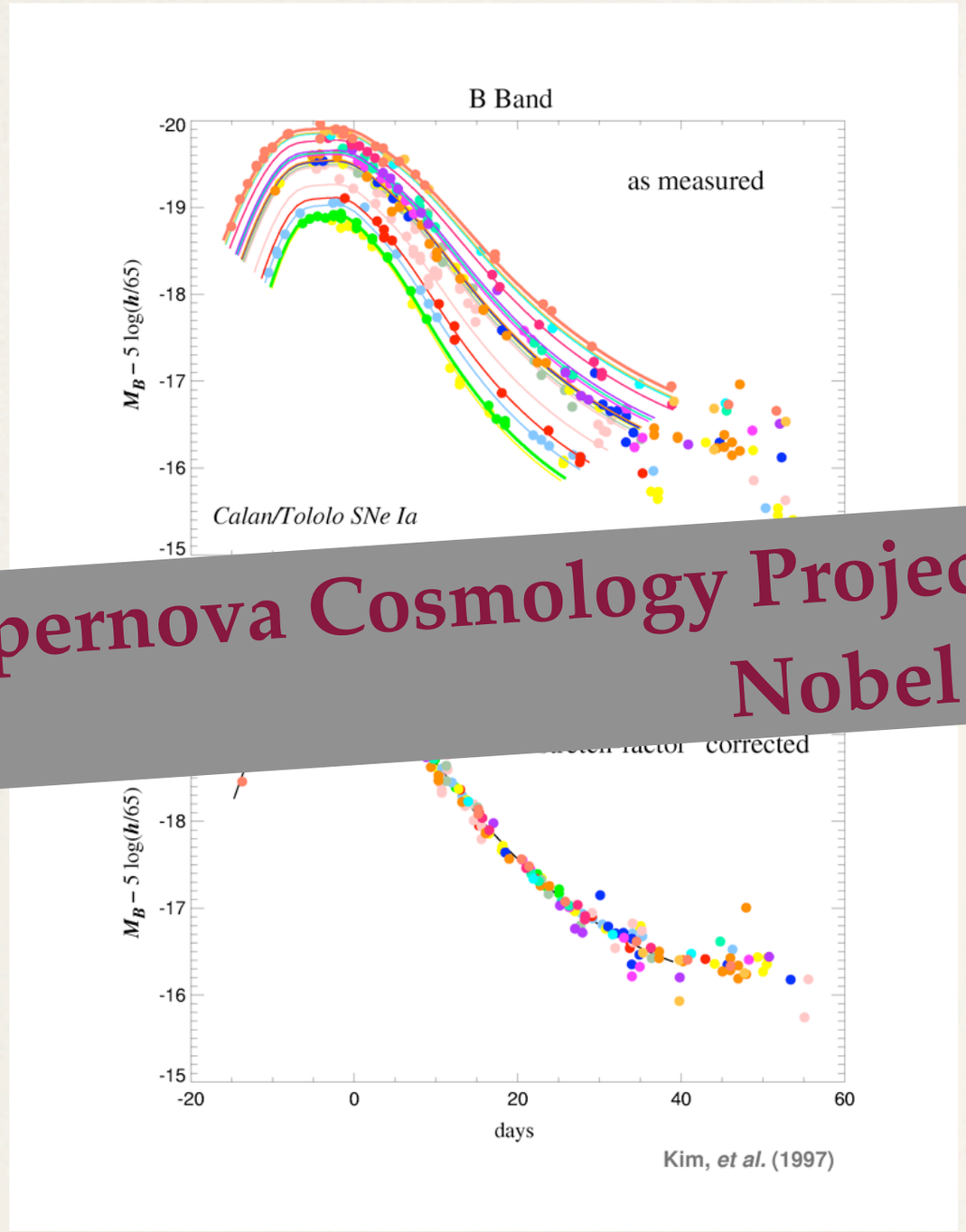
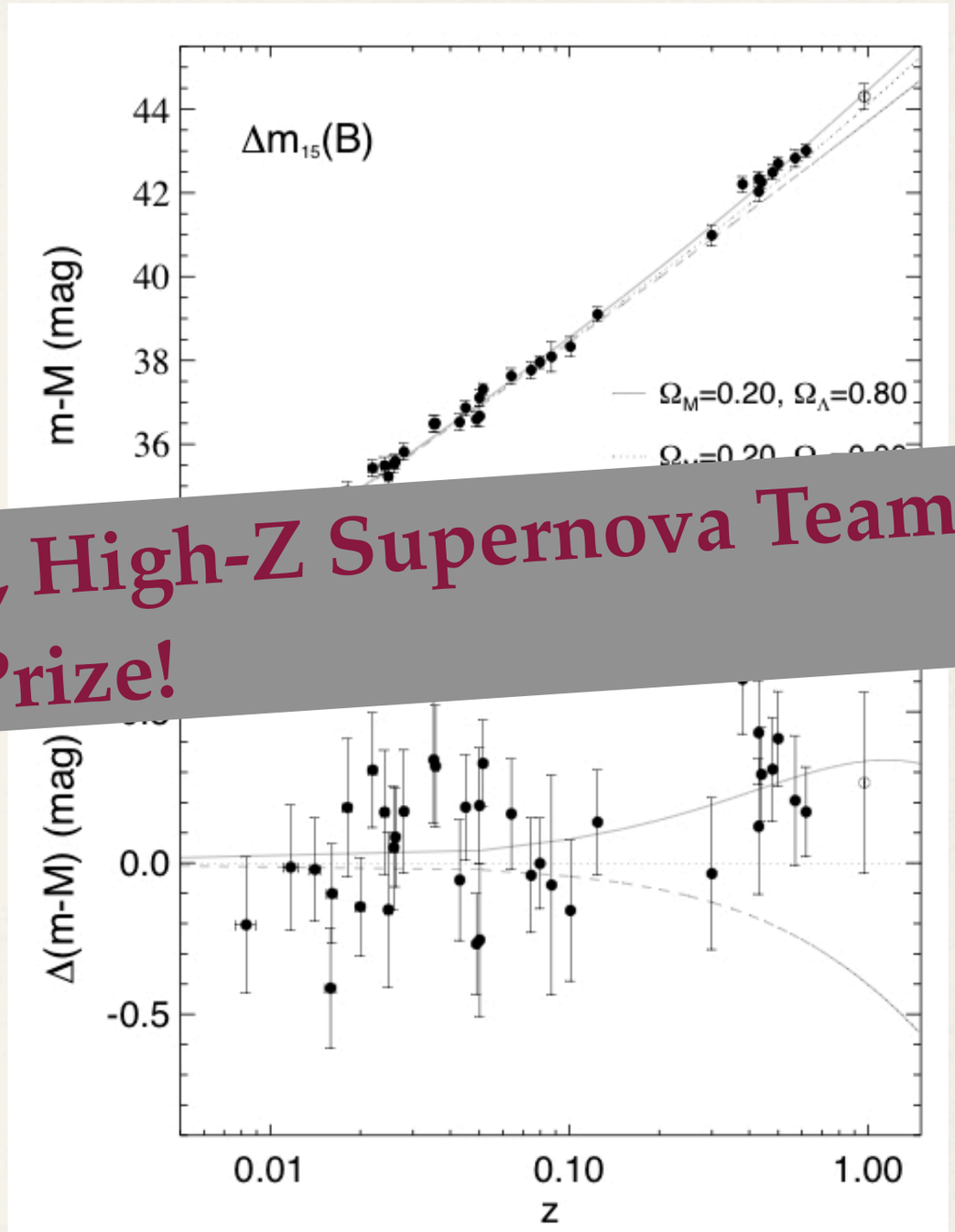




Riess et al. (98)

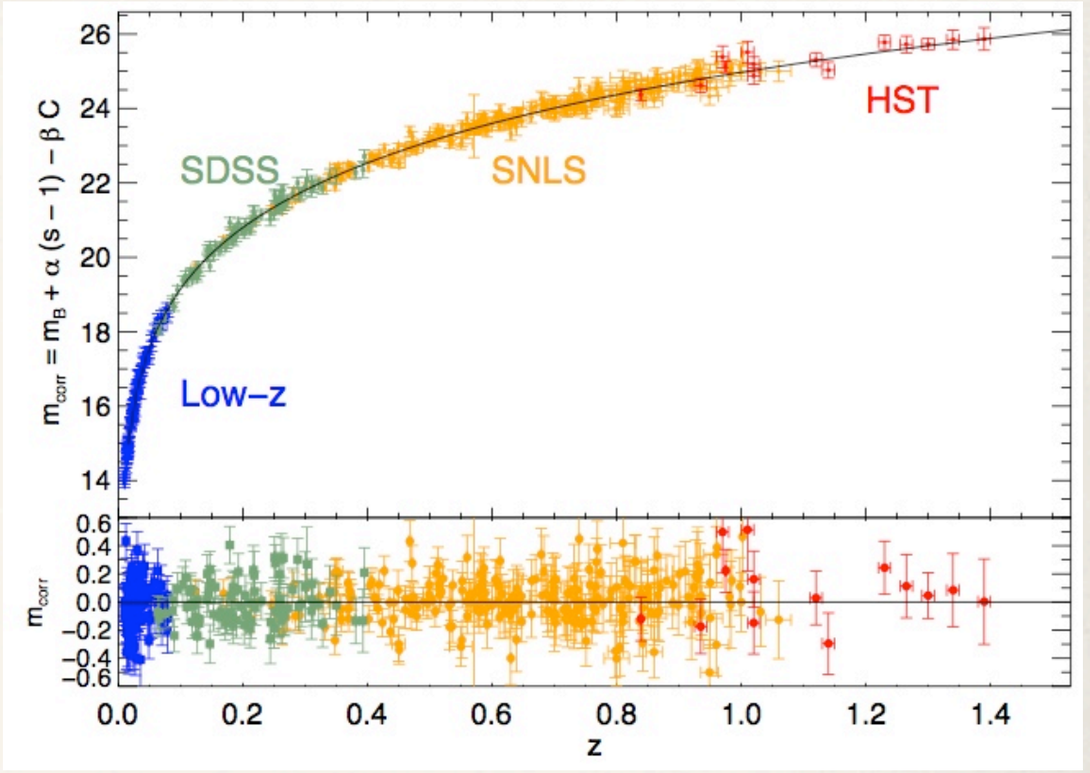
Supernova Cosmology Project, High-Z Supernova Team: Nobel Prize!

SNe Ia are not standard, but standardizable

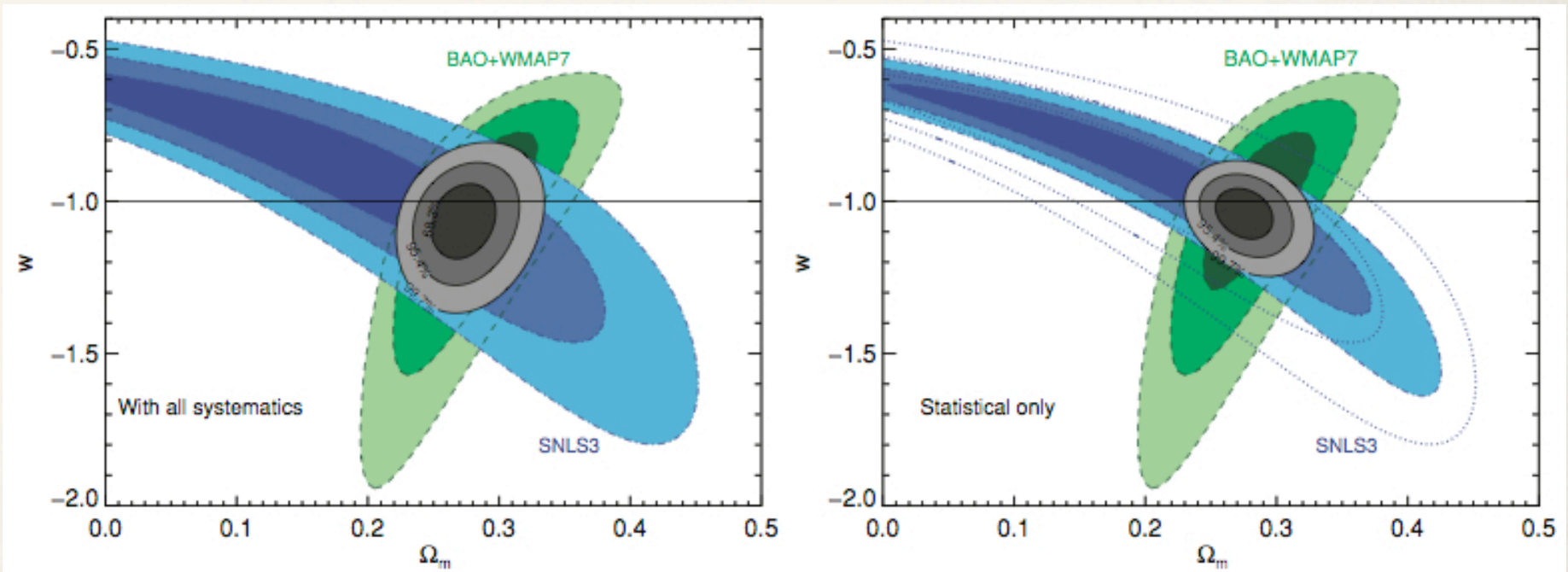
The Present

- Union 2.1 has ~580 Type Ia Supernovae at all redshifts
  - SNLS 3-year increases this number by ~170; SDSS 3-year (in prep) is another ~200

- Currently in operation: Pan-STARRS, PTF, CSP, SNF, CRTS, LOSS, ...



Conley et al. (2011)
Sullivan et al. (2011)

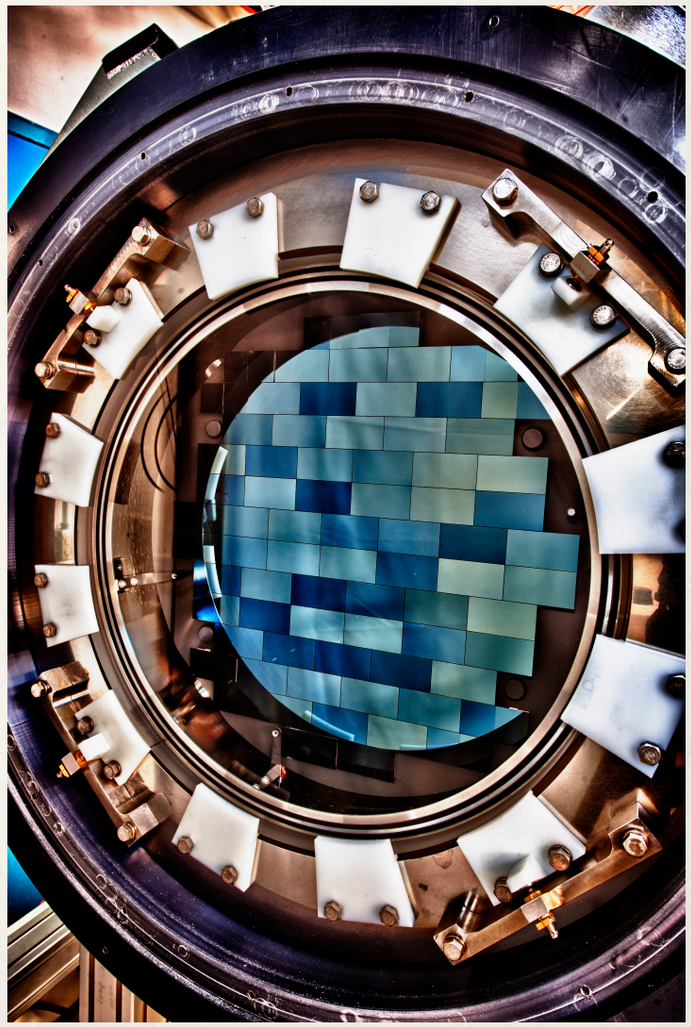


Problem for today: systematic uncertainties

Dark Energy Survey (DES)

Program: 525 scheduled nights over 5 years on the 4m Blanco telescope (CTIO) with DECam (570 Mpx, 3 deg^2 FoV)

- Large Scale Structure (LSS); Weak Lensing (WL); Galaxy Clusters (GC); Type Ia Supernovae (SNe)
- September → February; starting late 2012
- 5000 deg^2 survey to 24th mag in grizY bands (select fields imaged repeatedly for SN survey)



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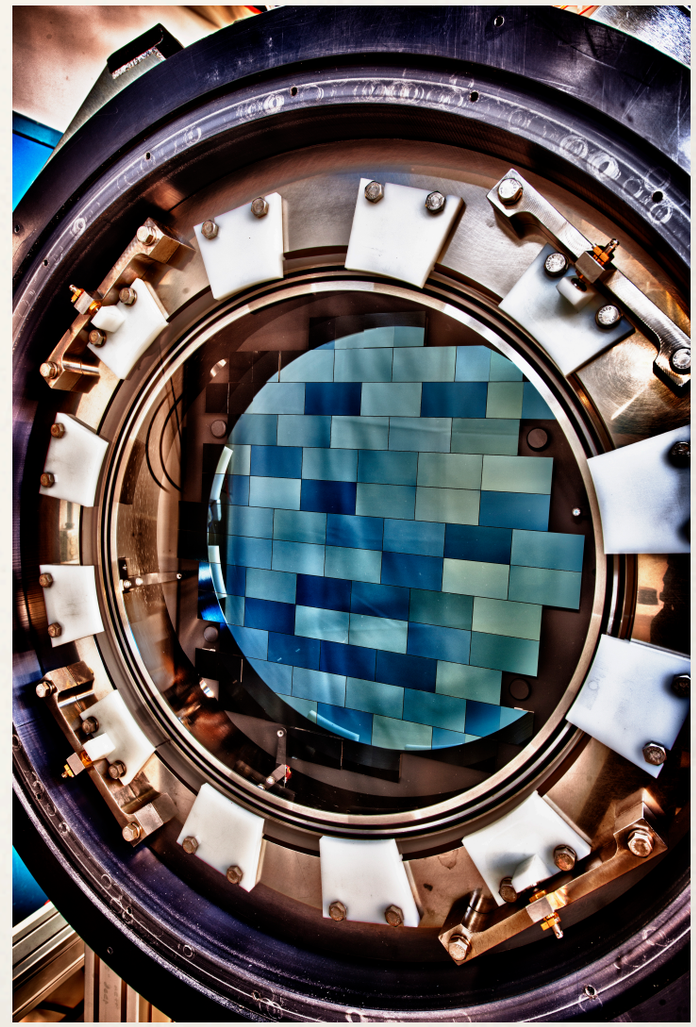


More about DES
in
Bob Nichol's Talk

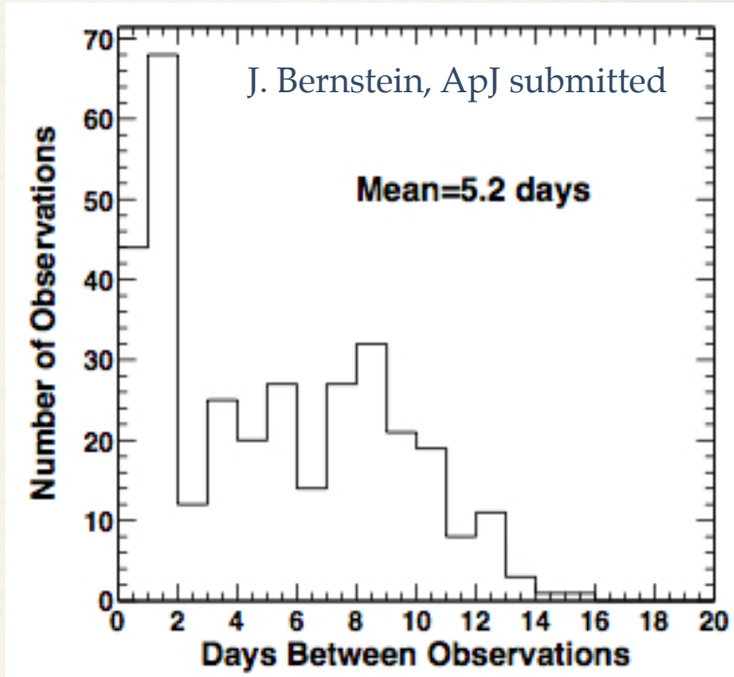
DES Supernova Survey

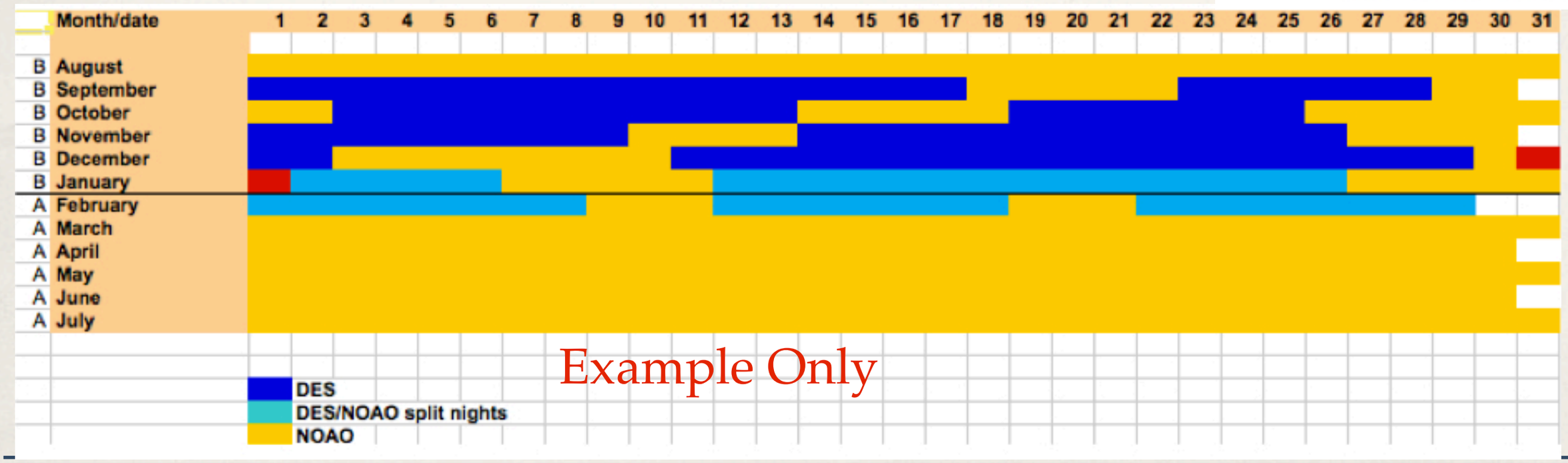
DES SN Working Group Co-Chairs: Bob Nichol (ICG) & Masao Sako (UPenn)

DARK ENERGY SURVEY

Outline

- Five (5) observing seasons of six (6) months
- ~1300 total hours of DES time; primarily non-photometric quality
  - Hard trigger after 8 days; Half-nights in January and February
- ~5 day average cadence in *griz* over 30 deg^2
- Survey Strategy: Bernstein et. al (arXiv:1111.1969)



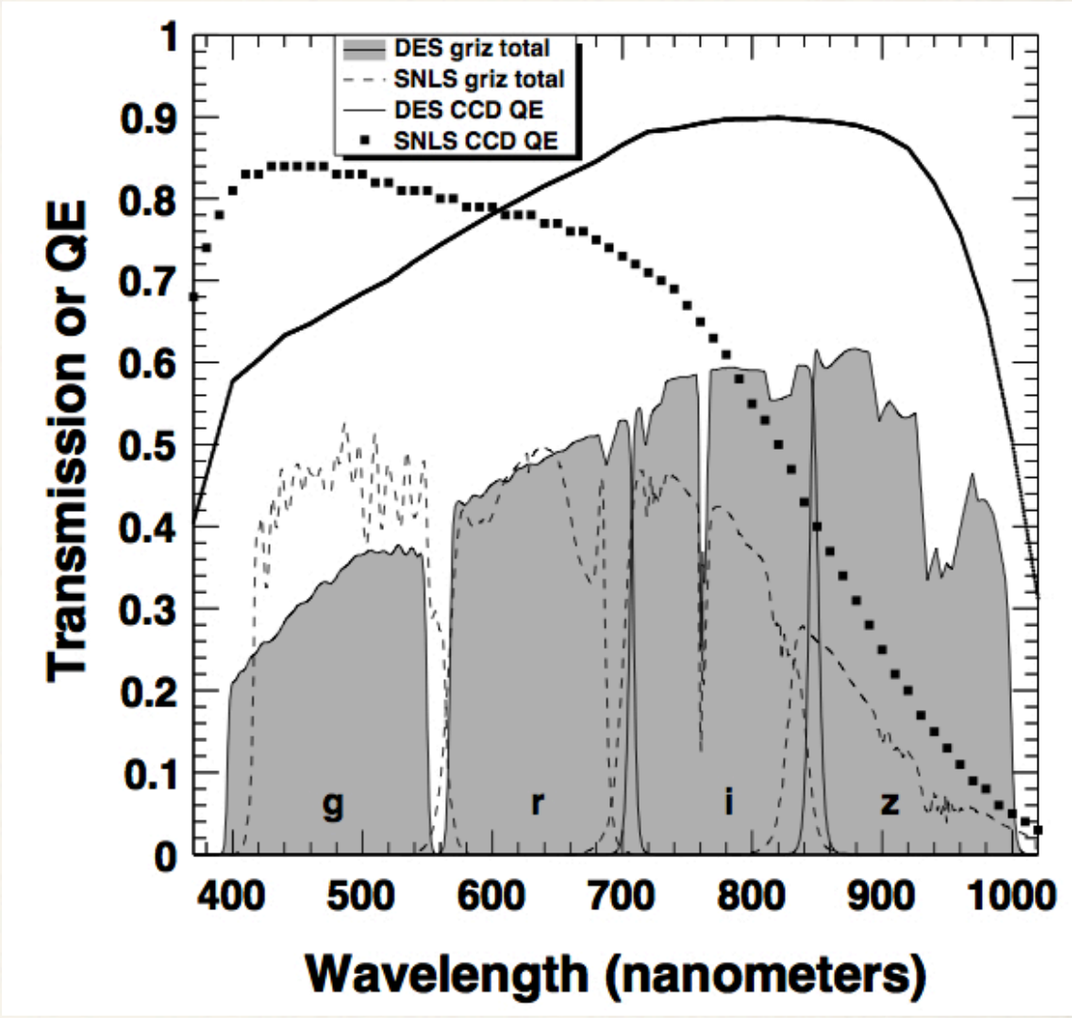


Example Only

DES Supernova Survey

- DES Photometric requirements:
  - 2% RMS photometry across entire field
  - 0.5% absolute calibration in *i*-band
  - 0.5% absolute color (*g-r, r-i, i-z)*
  - Uncertainty of 10Å on bandpass centroid

- Utilizes red-sensitive LBNL CCDs
  - z-band is much improved on SNLS, SDSS
  - allows for higher redshift detections



Bernstein et al. (2011)

DES Supernova Survey

2 deep fields, 8 shallow fields

Filter	`Deep' exposure (s)	`Deep' Limiting mag	`Shallow' exposure (s)	`Shallow' Limiting mag
g	300	25.2	175	24.9
r	1200	25.4	50	23.7
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Not all bands observed in one night

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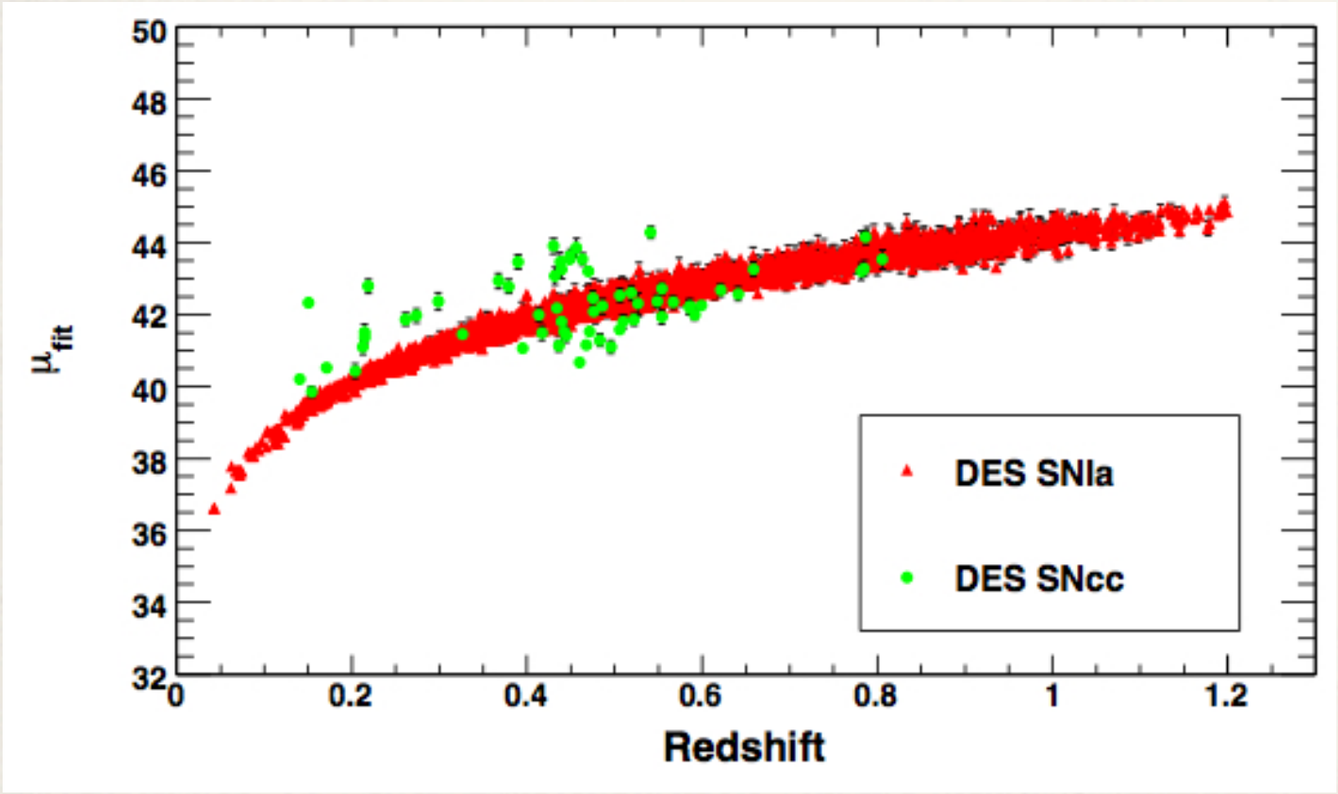

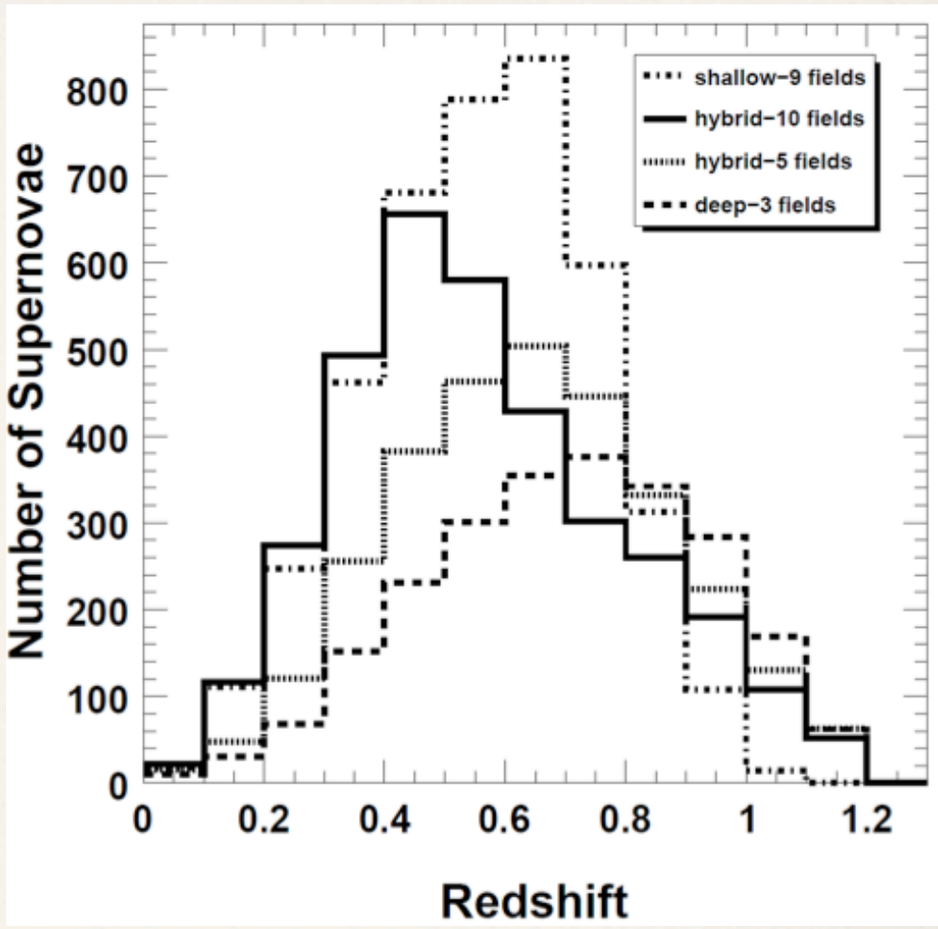

Bernstein et al. (2011)

- ~3500 `good' SNe Ia out to z ~ 1.2
  - Cuts on `good' S/N light curves are more stringent than for SDSS; useable number may be larger

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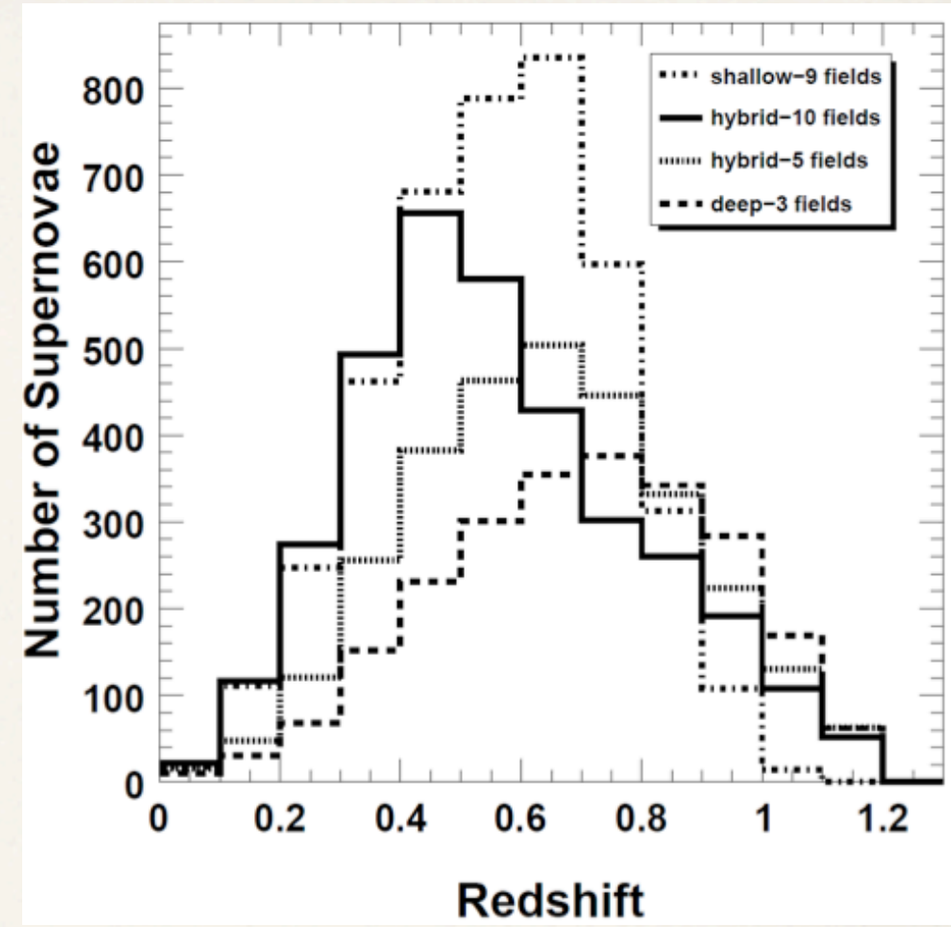

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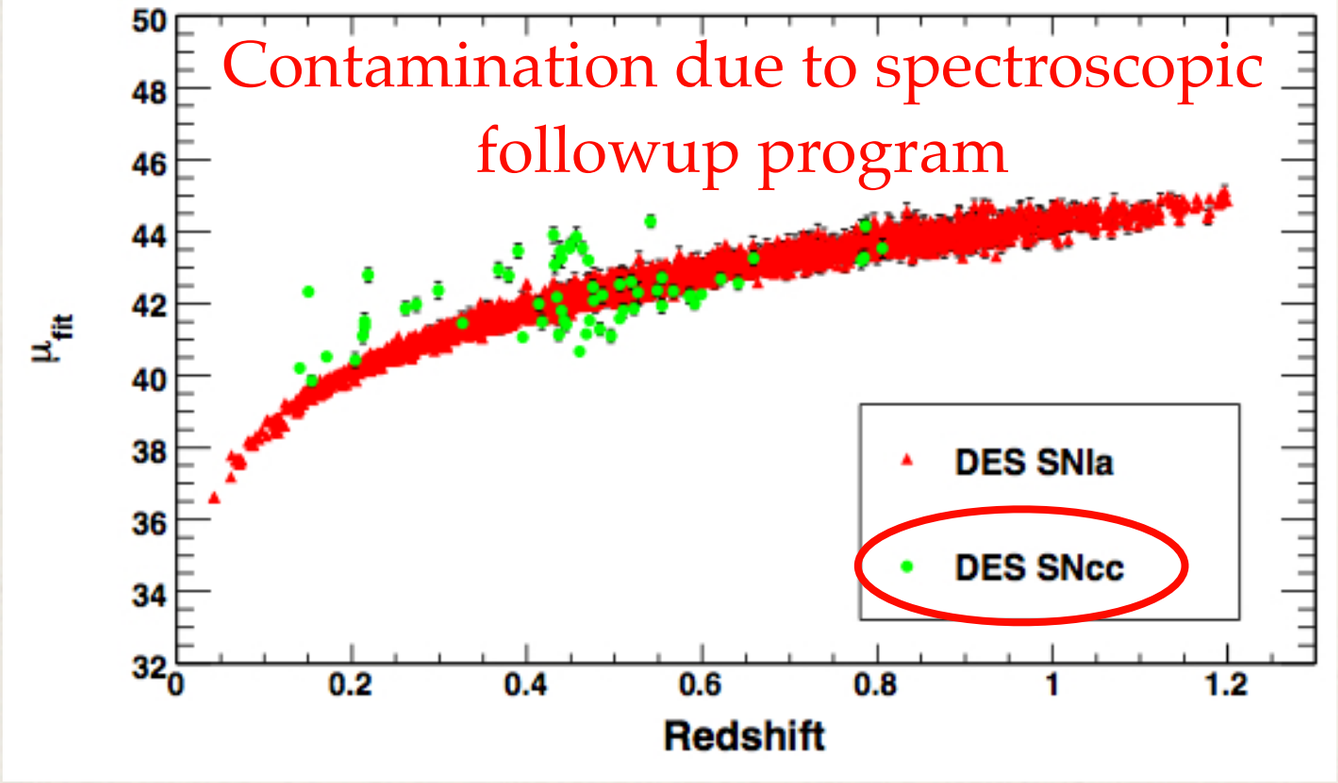

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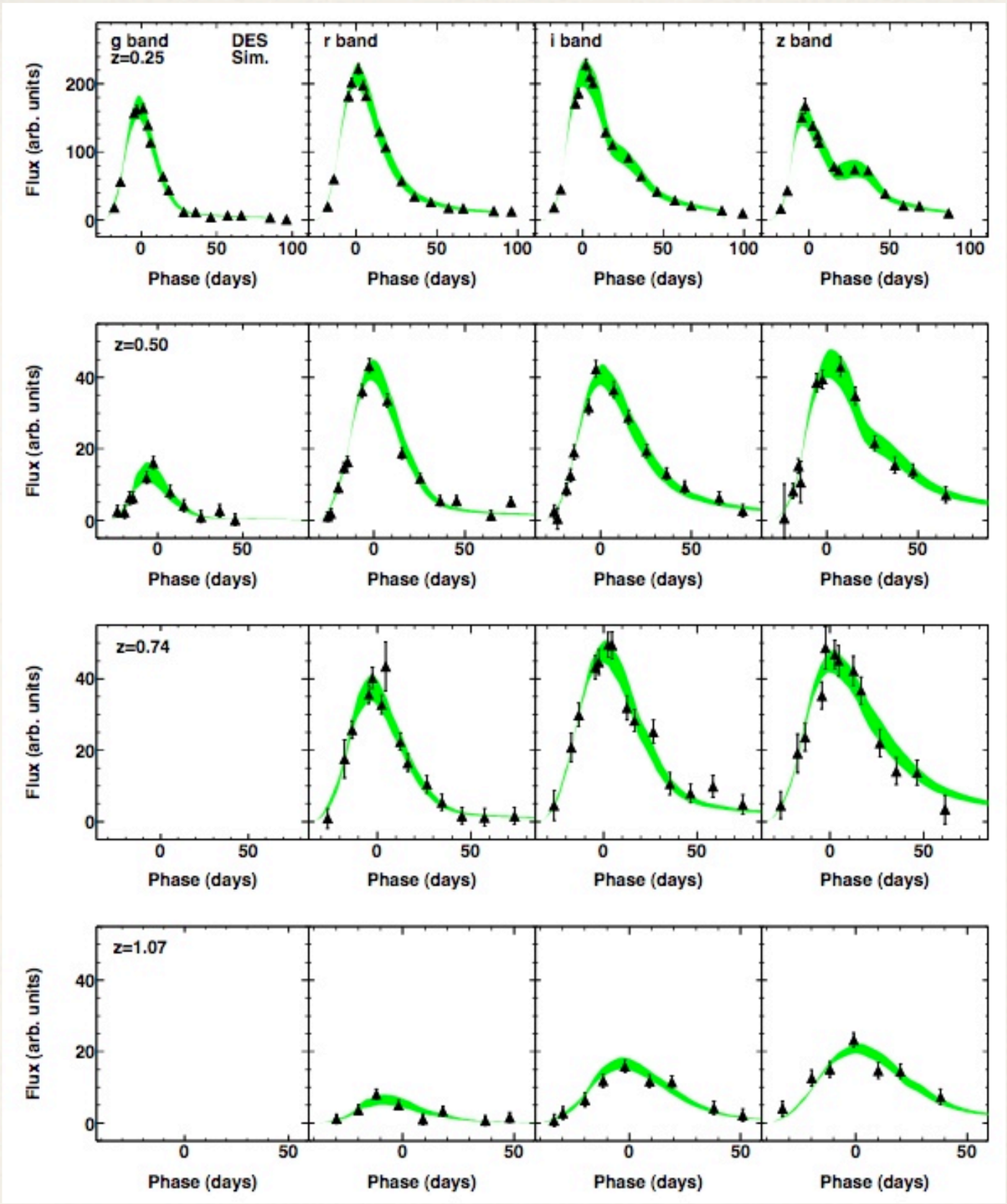
DES Simulated LC



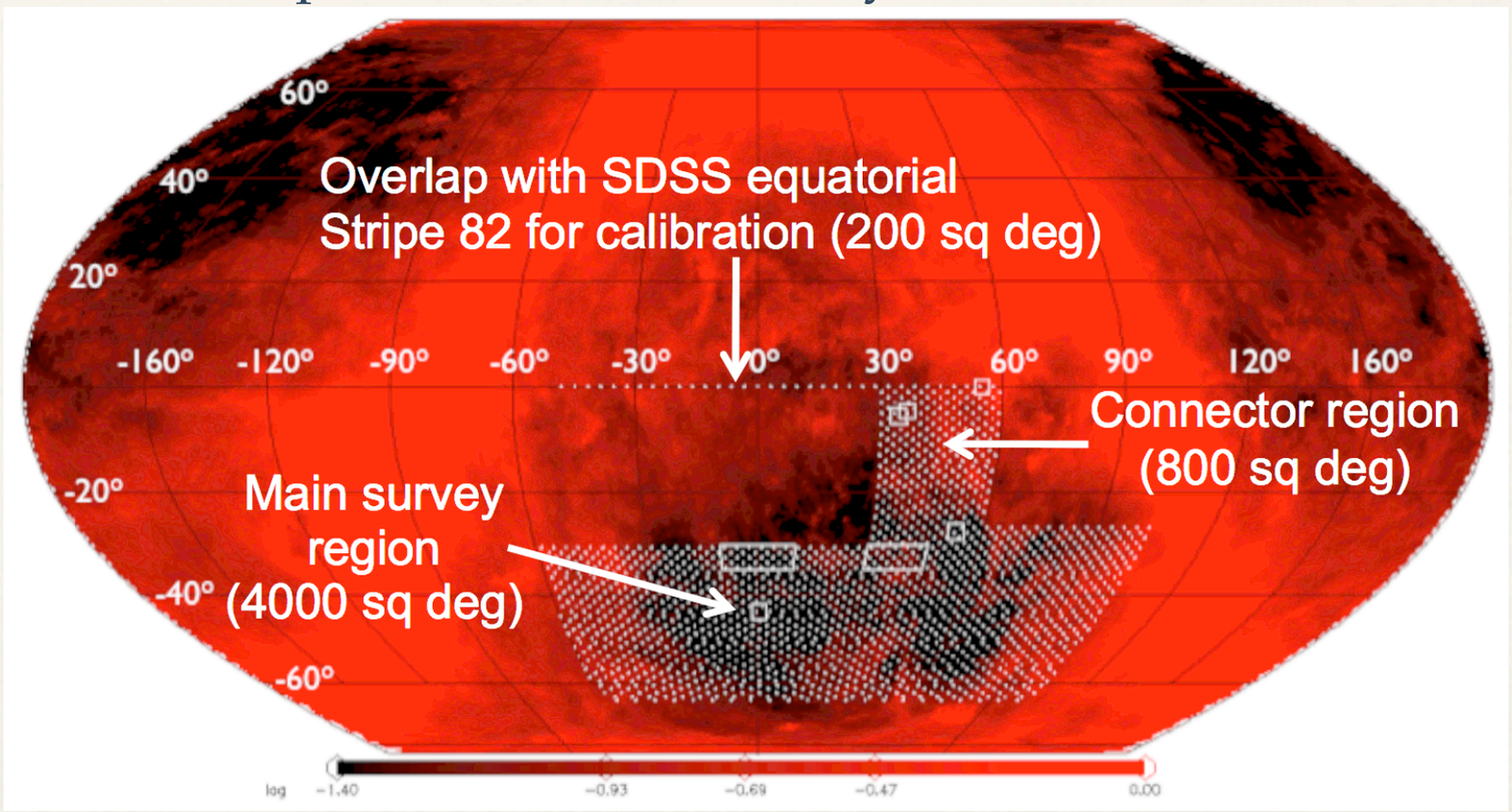
Bernstein et al. (2011)

DES SN Field Locations

Survey Field choice is not yet finalized

Criteria:

- Season-Long visibility
- Accessible by large number of spectrographs
- Low Galactic Extinction
- Part of DES calibration set / intercalibration
- Ancillary Data
- Overlap with other SN surveys



Field Ancillary Data

Current Field selection placeholders

RA, DEC

- Chandra Deep Field South (1 deep, 2 shallow) — 03:32:28, -27:48:30
  - GALEX DIS, VIDEO, VVDS, COMBO-17, SWIRE, WISE, HerMES
- SNLS/VVDS; XMM/LSS (1 deep, 2 shallow) — 02:25:59,-04:29:40
  - CFHTLS D1, VIDEO, VVDS, XMM-Newton, SWIRE, WISE, HerMES
- ELAIS-S1 (2 shallow) — 00:34:44, -43:28:12
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- Stripe 82 (RA~48 deg) (2 shallow) — 03:12:00, 00:00:00
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Which Data is useful? How much does it add?
Will upcoming projects choose OUR fields?

Currently developing FoM; should be completed soon.

Spectroscopic Challenges

`Classical' method of full spectroscopic confirmation is dead

Supernova Legacy Survey (SNLS)

Time awarded per semester (10 total)
for active SN followup

- 60 hours VLT FORS1/2
- 60 hours Gemini GMOS N/S
- 30 hours Keck LRIS

~ 1/2 year of observing on 8m spectrographs!

→ 766 spectra, 422 confirmed SNe Ia

We would have to apply for several years worth of time!

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Highly red-sensitive CCDs

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- lowers exposure time

Multiobject Spectrographs

- Allows for efficient host-galaxy spectroscopy, esp. in deep fields

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Sample	f_p >0.0	f_p >0.1
Ib/c	571	57
IIP	110	2
IIn	225	2
IIL	62	2
Total SNcc	968	63
Ia	3482	3350
Ia+SNcc	4450	3413
Sample Ia Purity	78%	98.1%

Bernstein et al. (2011)

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Photometric Typing

- Kessler et al. (2010) classifier challenge
- High efficiencies with host-z found for SNLS (Bazin et al. 2011), SDSS (Campbell et al., in prep); photo-z not accurate enough
  - Dependent on Core-collapse templates
- LSST!

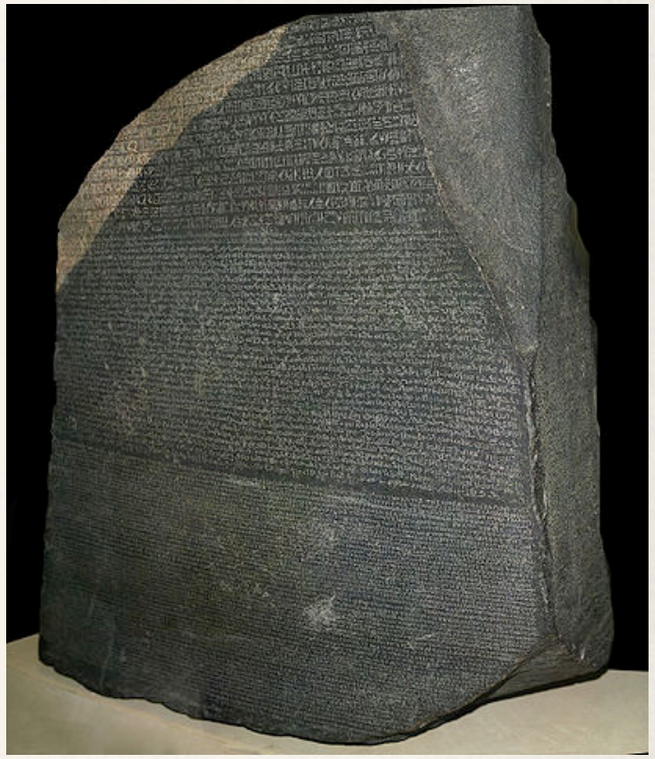
Rosetta Sample

Philosophy:

Obtain high-quality data sets for a subsample of observed SNe spanning the entire redshift range

Use Rosetta Sample to train typer; quantify bias

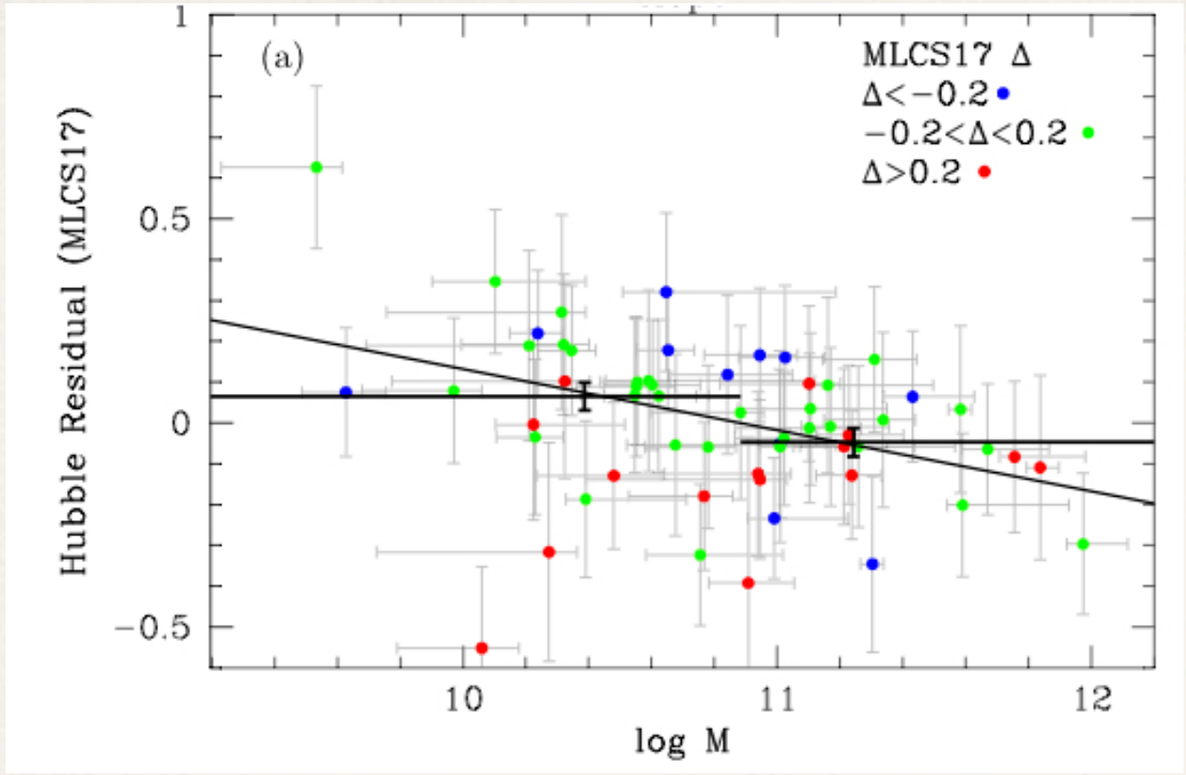
	Baseline	Rosetta
Photometry	Moderate S/N Optical Only	High S/N NIR + optical
SN Spectral Features	None	Yes
Host Galaxy Properties	Photometric DES+Ancillary	Spectroscopic
Redshift	Host	Host + SN

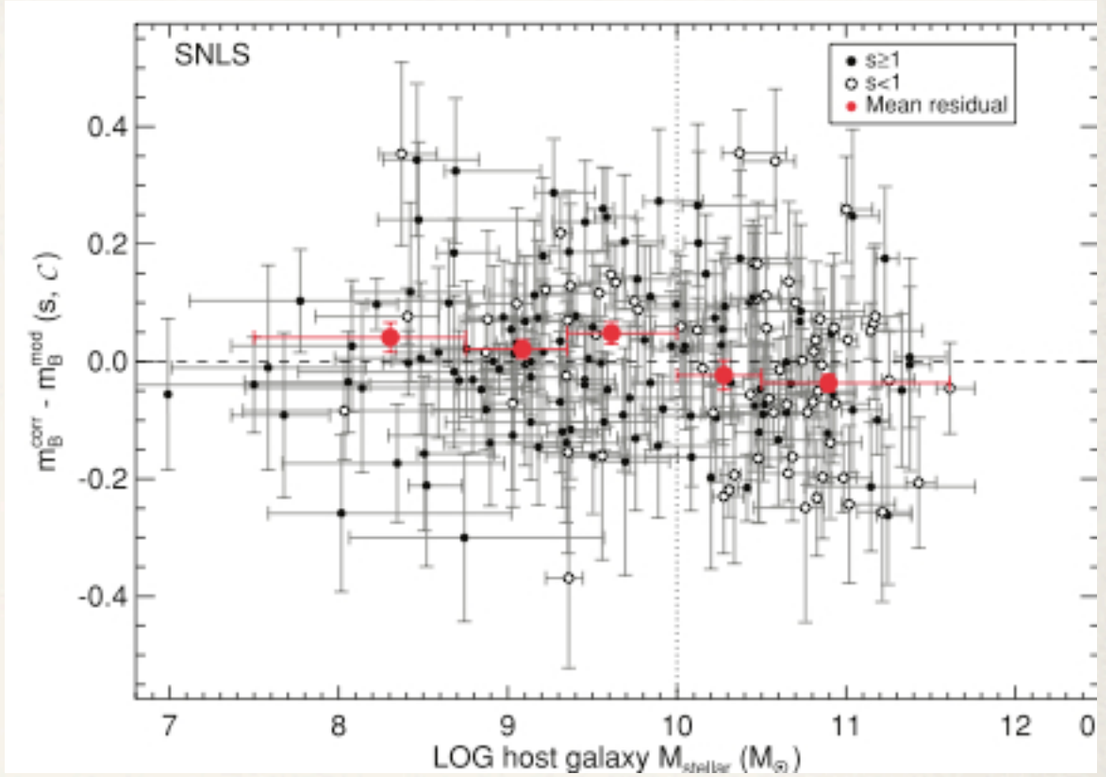


"Rosetta Stone is 2200 year old text including both Greek and Egyptian hieroglyphs"

- SNe in the NIR display the same dispersion as *corrected* optical LCs
  - small VIDEO sample at $z < 0.3$
- Bailey Ratio (642/443); Chotard et al. (2011)

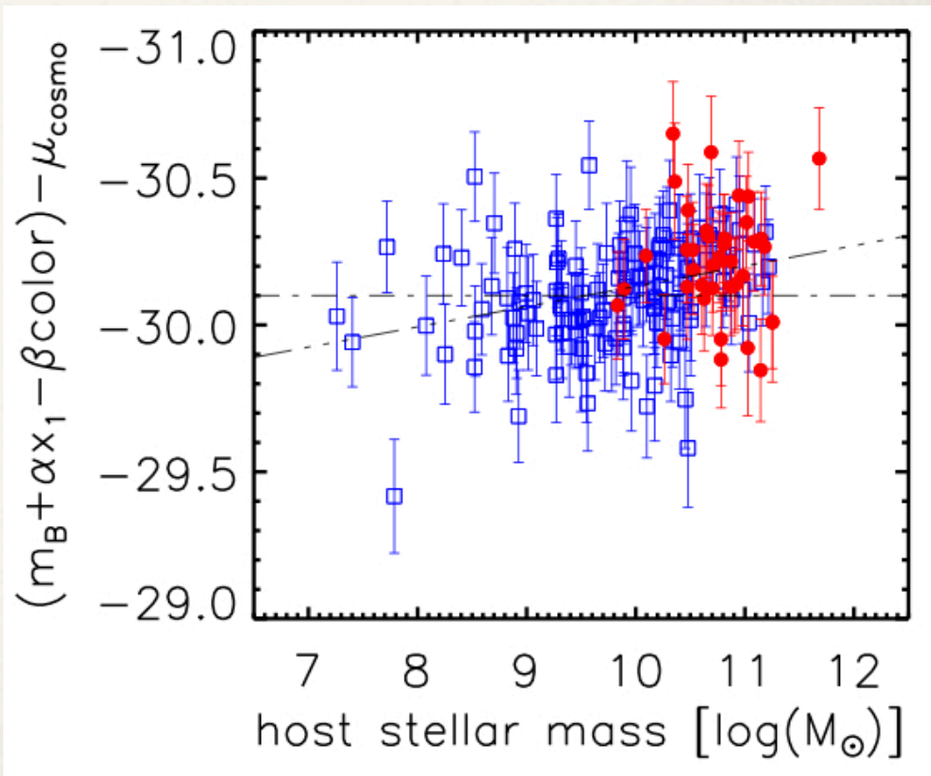
Host Galaxy - SN Ia correlation





Clockwise: Kelly et al. (2010), Sullivan et al. (2010), Lampeitl et. al (2010)

AFTER correcting for light curve shape and color,
Hubble Residuals correlate with Host Mass



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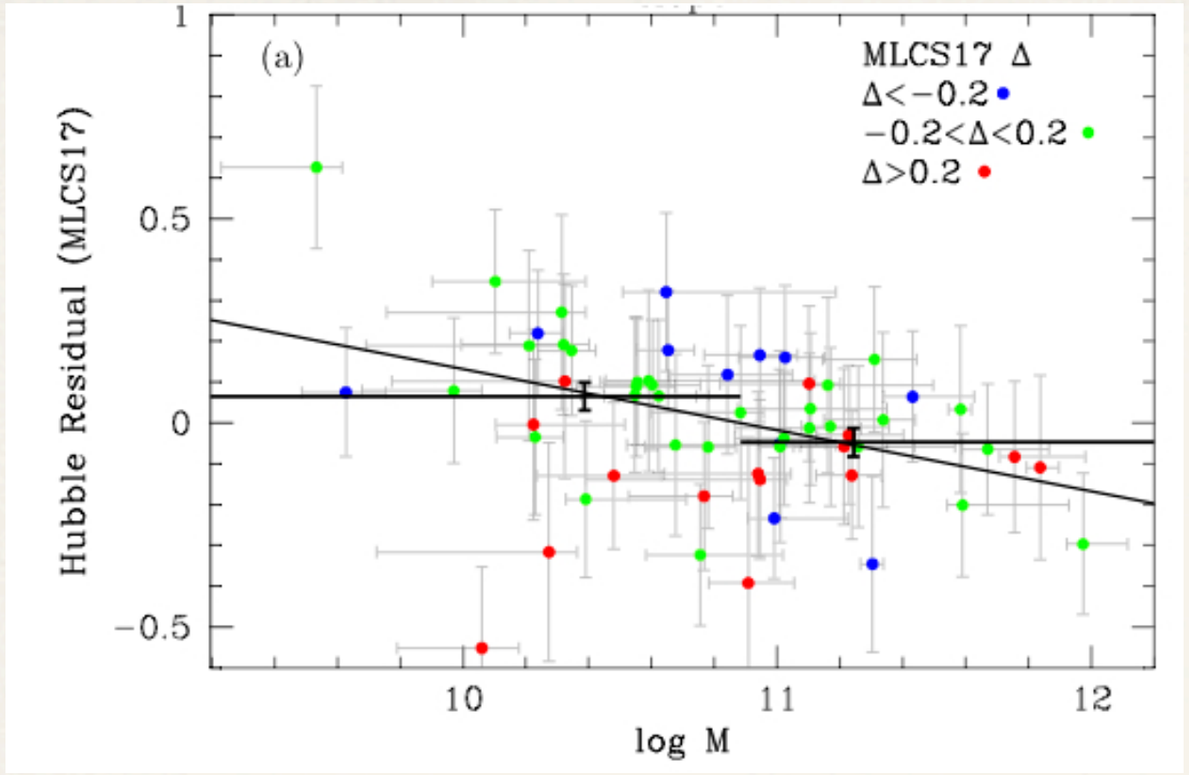

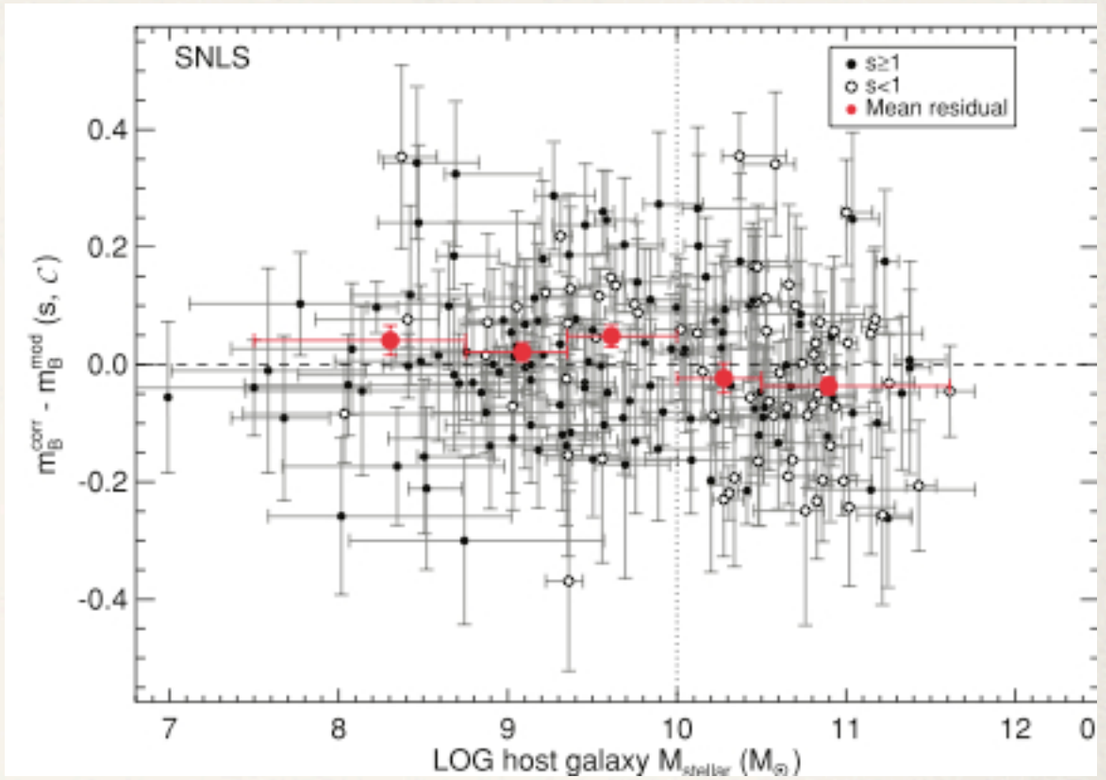

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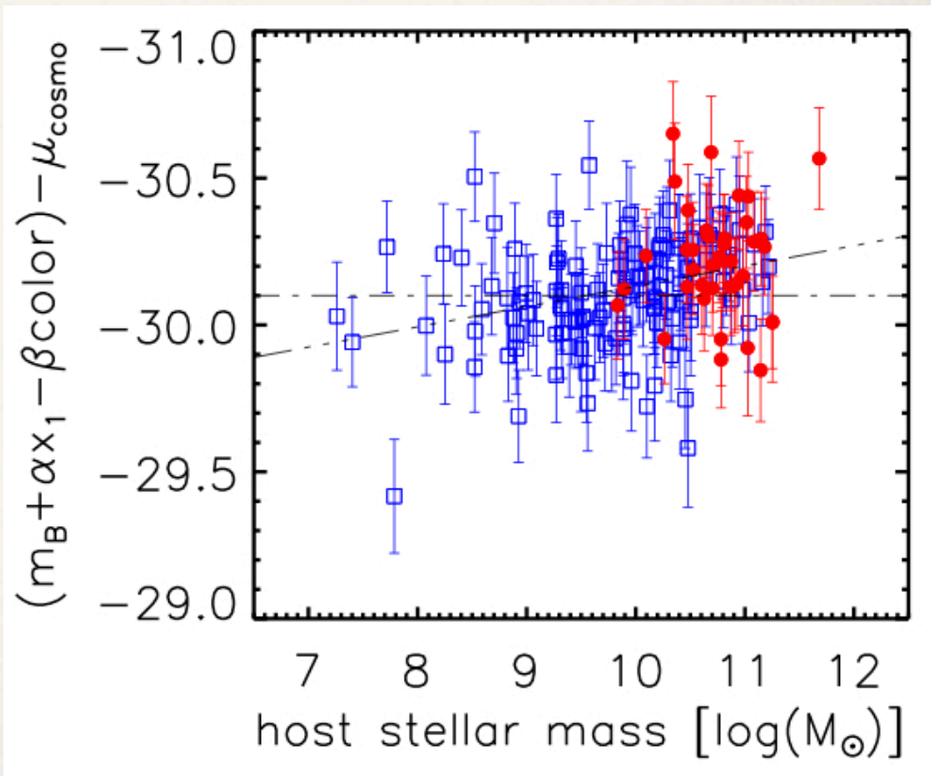
Two Questions:
To what extent? And why?



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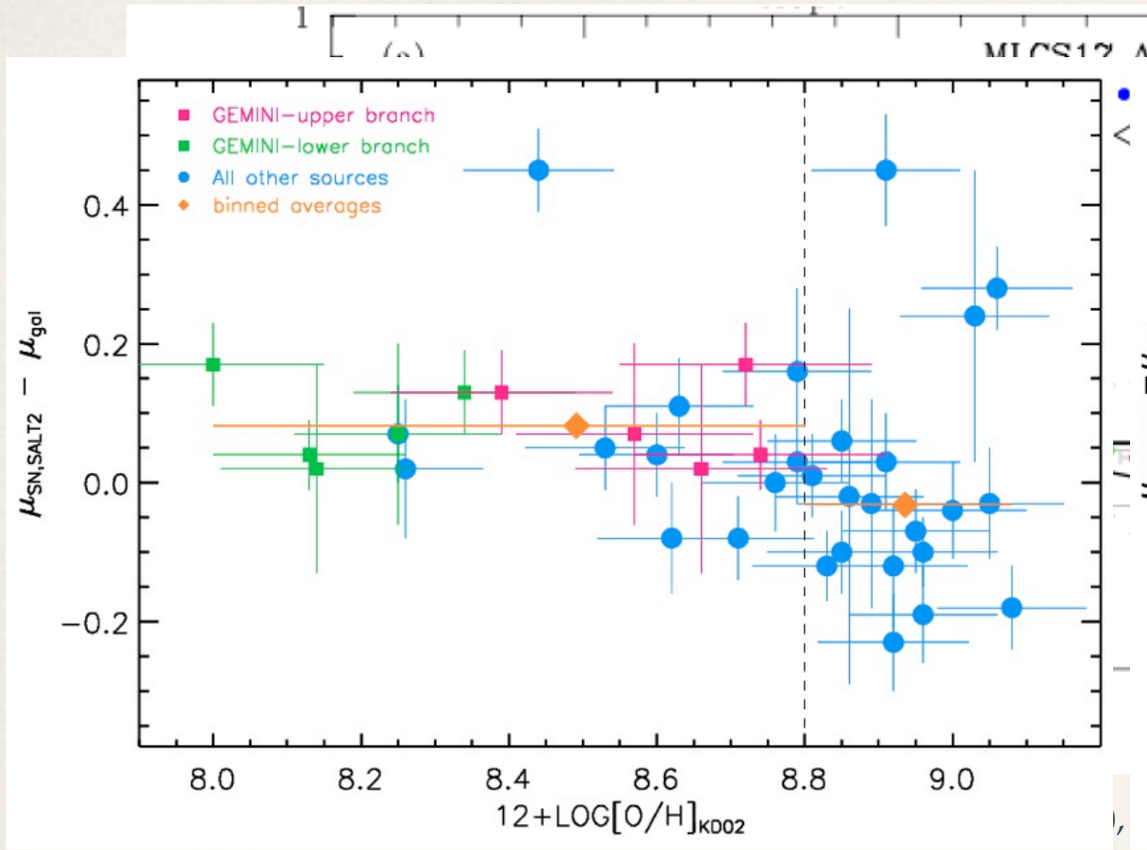

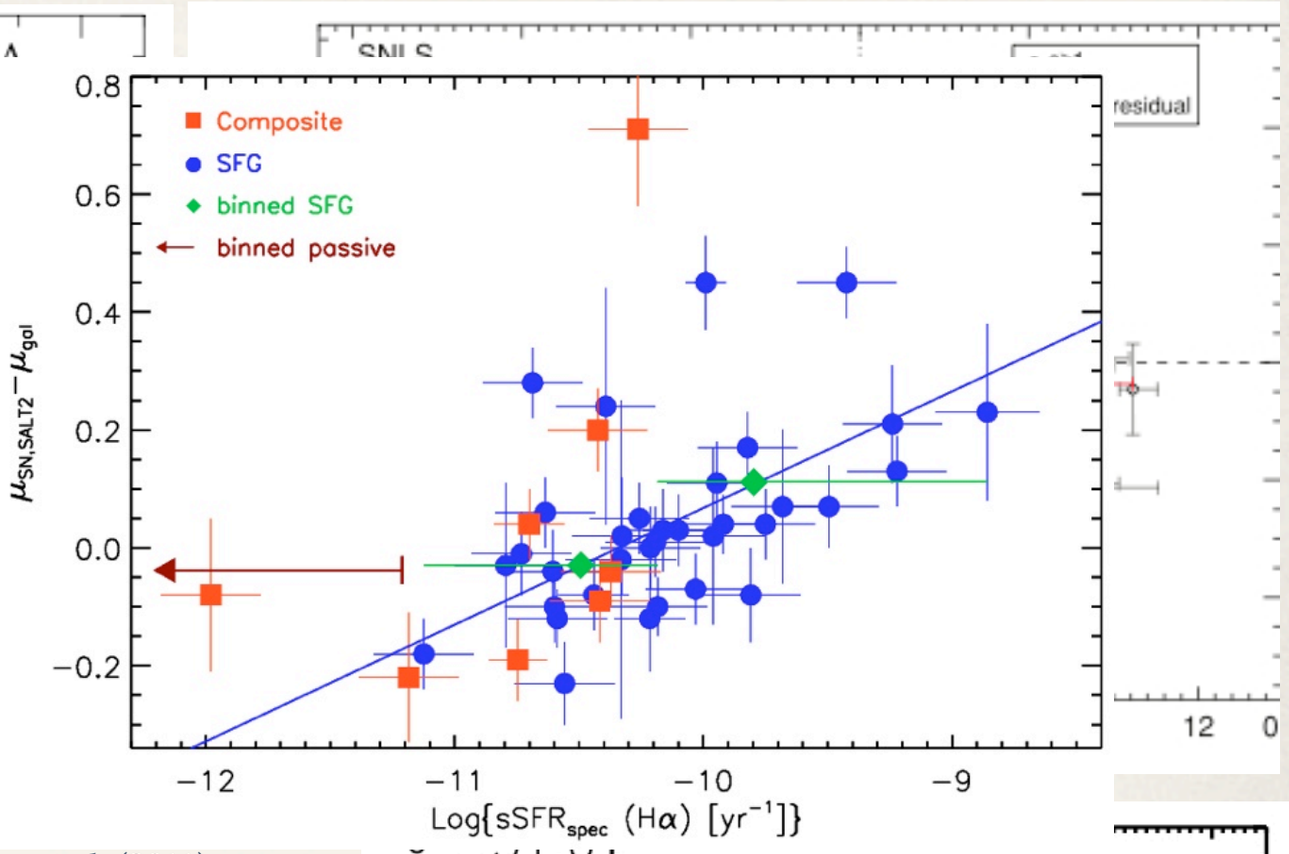

D'Andrea et al. (2011)

Progenitor metallicity or age?
(all evolve with redshift!)

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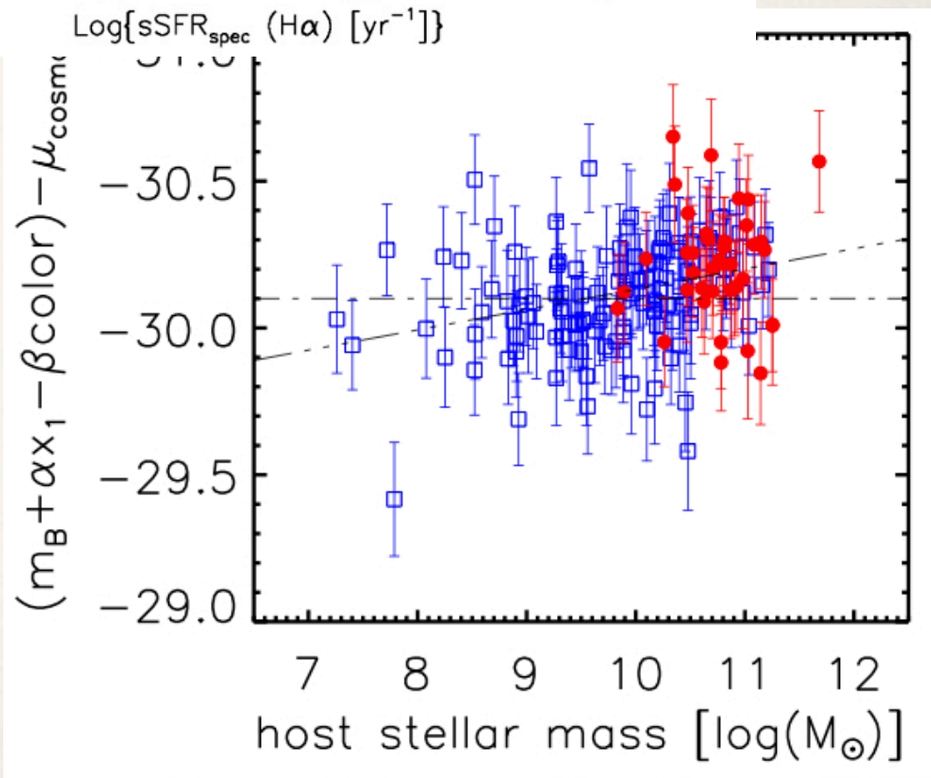

Host Galaxy Importance

SNLS 3 year paper (Conley et al. 2011)
Host Galaxy Mass corrections included in cosmology

"It seems likely that the true relationship is both more complex and more continuous, but the current data do not require a more sophisticated model. Therefore, we adopt this approach here."

"The final effects [of host galaxy mass] ... are one of the larger contributions to our final uncertainty budget (much less than calibration, however). If we do *not* apply this correction, as in all previous analyses, but apply the difference purely as a systematic uncertainty, *the effect is approximately the same size as all other uncertainties (statistical and systematic) combined*."
[Second emphasis added]

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DES SN Community Workshop

October 12-13, 2011
University of Pennsylvania, Philadelphia
(right after DES Collaboration Meeting

To help spread ideas on the direction of SN cosmology,
and to figure out how DES can best help that future.

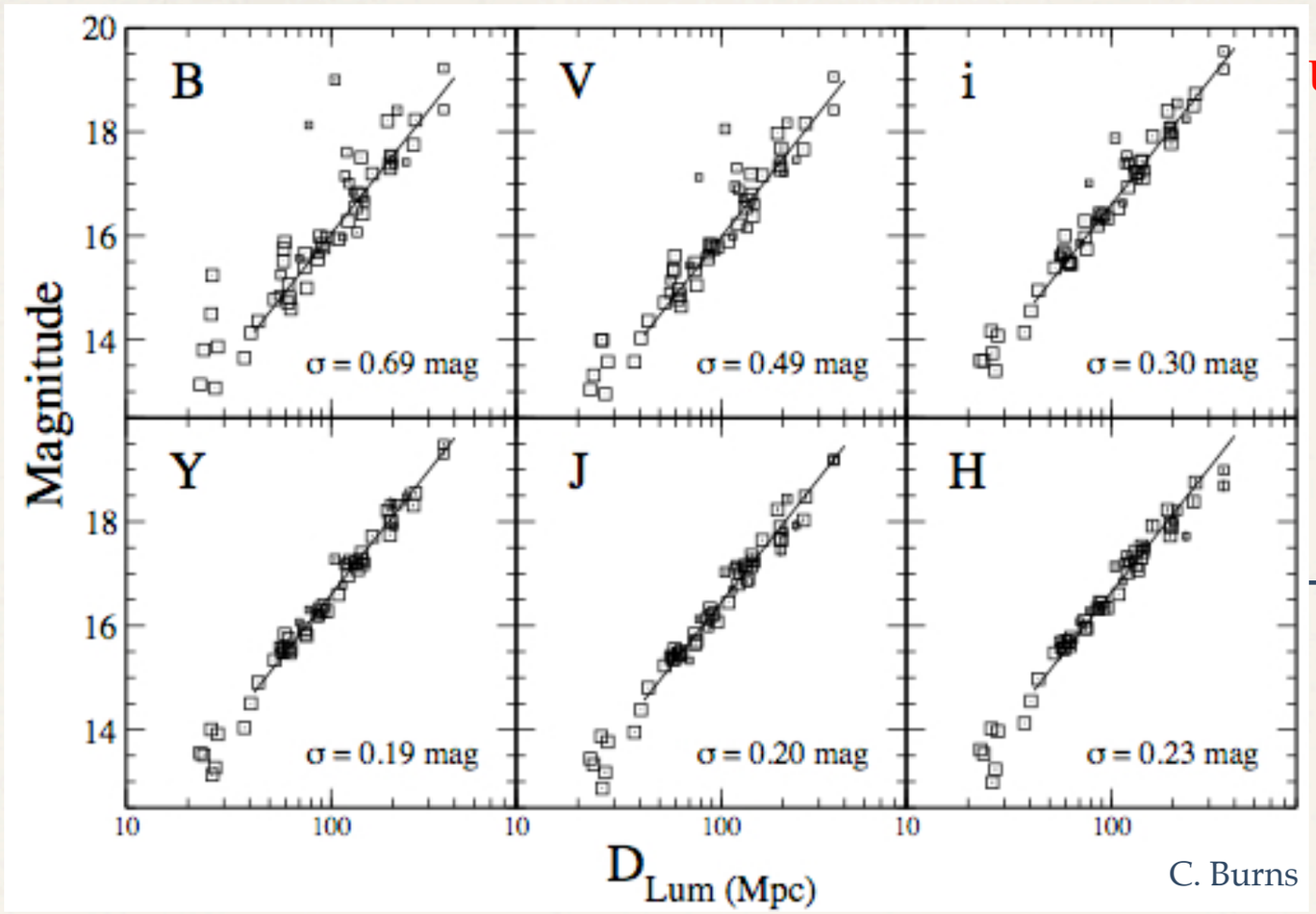
Also to gauge interest in spectroscopic coordination with outside groups
e.g., non-Ia followup

Participants

Raul Abramo
Greg Aldering
Pierre Astier
Kyle Barbary
Bruce Bassett
Edo Berger
Chris Burns
Heather Campbell
Enrico Cappellaro
Brian Connolly
Chris D'Andrea
John Fischer
Josh Frieman
Ariel Goobar
Or Graur
Ravi Gupta
Bill Hanlon
Saurabh Jha
Rick Kessler
Alex Kim
Kevin Krisciunas
Steve Kuhlmann
Chris Lidman
John Marriner
Tom Matheson
Jennifer Mosher
Bob Nichol
Ribamar Reis
Adam Riess
Steve Rodney
Masao Sako
Dan Scolnic
Chris Smith
Mat Smith
Rollin Thomas
Josiah Walton
Michael Wood-Vasey
Naoki Yasuda

DES SN Community Workshop

October 12-13, 2011
University of Pennsylvania, Philadelphia
(right after DES Collaboration Meeting



C. Burns

Systematic change included	FoM with systematic
None	228
Filter zeropoint shift	157
Inter-calibration	188
Filter λ shift	179
Core collapse misid.	226
R_V and τ_{A_V}	128
Total without R_V and τ_{A_V}	124
Total with R_V and τ_{A_V}	101

Bernstein et al. (2011)

Raul Abramo
Greg Aldering
Pierre Astier
Kyle Barbary
Bruce Bassett
Edo Berger
Chris Burns
Heather Campbell
Enrico Cappellaro
Brian Connolly
Chris D'Andrea
John Fischer
Josh Frieman
Ariel Goobar
Or Graur
Ravi Gupta
Bill Hanlon
Saurabh Jha
Rick Kessler
Alex Kim
Kevin Krisciunas
Steve Kuhlmann
Chris Lidman
John Marriner
Tom Matheson
Jennifer Mosher
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DES Wrap

- Spectroscopic plan is being fully developed (Alex Kim, C.D). Preparation for first proposals in March
- Field locations will be finalized soon (~ month).
- Data pipeline: NCSA* is in charge of imaging pipeline; image subtraction. SN WG produces templates, runs candidate identification software + `human pipeline'
  [lots of experience from SDSS]
  - *National Center for Supercomputing Applications; University of Illinois at Urbana-Champaign
- Note: Different burn-in from SDSS. No galaxy templates; variable star catalog. Mini pre-survey to help.

KDUST/AST3

DES SN program ends February 2017; misses KDUST?

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AST3 unable to observe DES SN fields during search season?

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AST3 unable to observe DES SN fields during search season?

BUT - DECam is a community instrument!

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Cosmology with AST3 (low-z) + DES (high-z), with cross-calibration done as a community proposal for a small DECam survey during Chilean winter?

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Cosmology with AST3 (low-z) + DES (high-z), with cross-calibration done as a community proposal for a small DECam survey during Chilean winter?

Thank you!