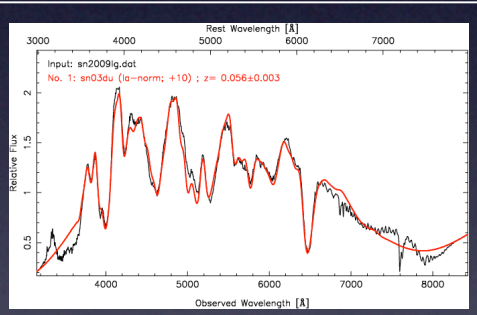
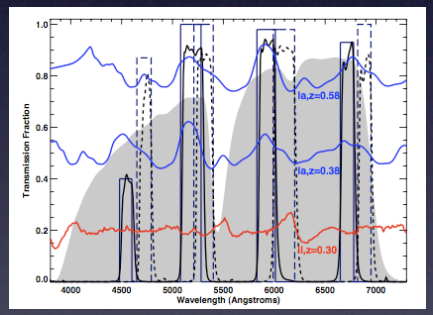
Three Methods of SNe Ia Classification for PS1 and DES

Dan Scolnic, Adam Riess, Steve Rodney, JHU

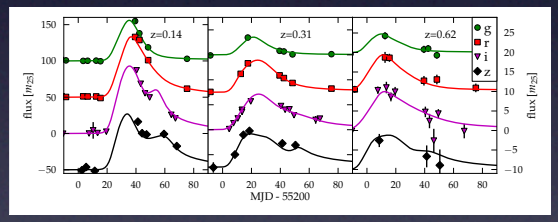
Spectroscopic



SNACC



Photometric



PS1 Papers:

Rest, 2011

Scolnic, 2011

Scolnic,Brout,Stafford, 2011

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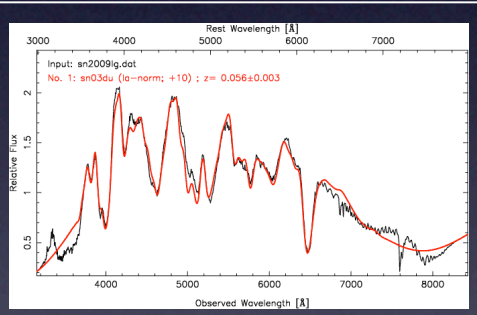

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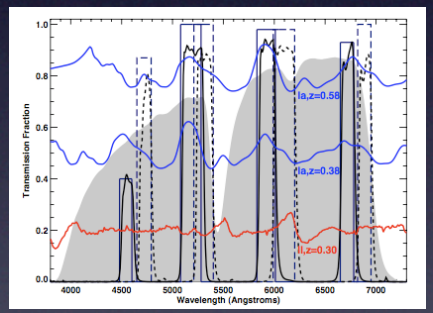

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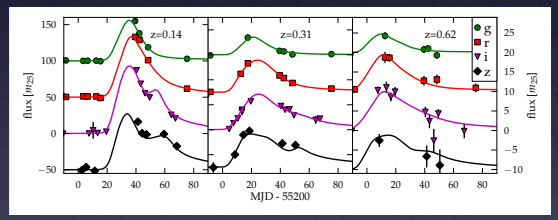


(R~1000) high R

(R~30)

(R~5) low R

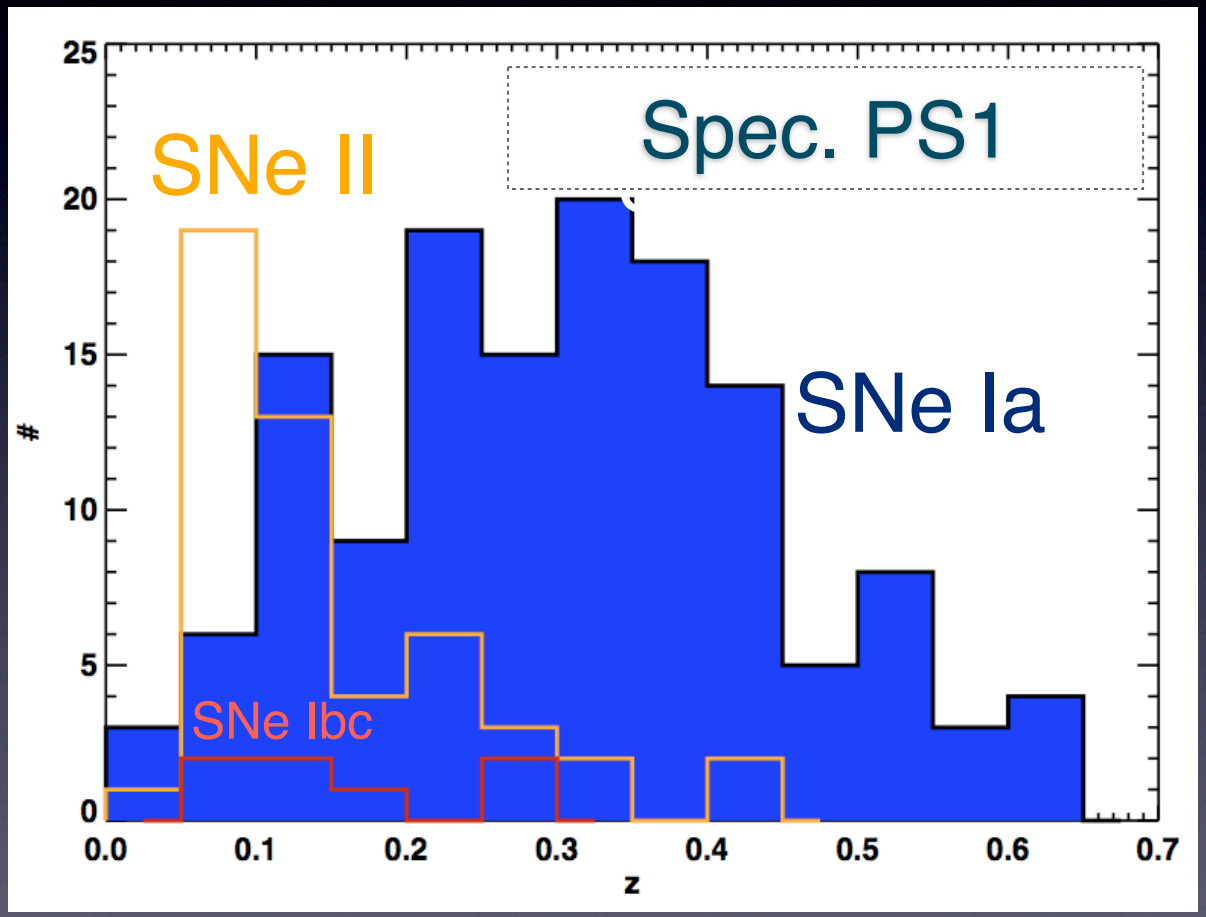
The spectral resolution:

$R=\lambda / \Delta\lambda$

Spectroscopic Follow-up Is Limited/Biased

For PS1:

- ~2300 likely SNe
- Spec: 10% of sample
  - 200 SNe.
  - 140 SNe Ia
  - 110 useful for cosmology.
- MMT,GMOS,Magellan,APO
- Spec. sample has >S/N, good sampling...
- 1 hour per spectrum

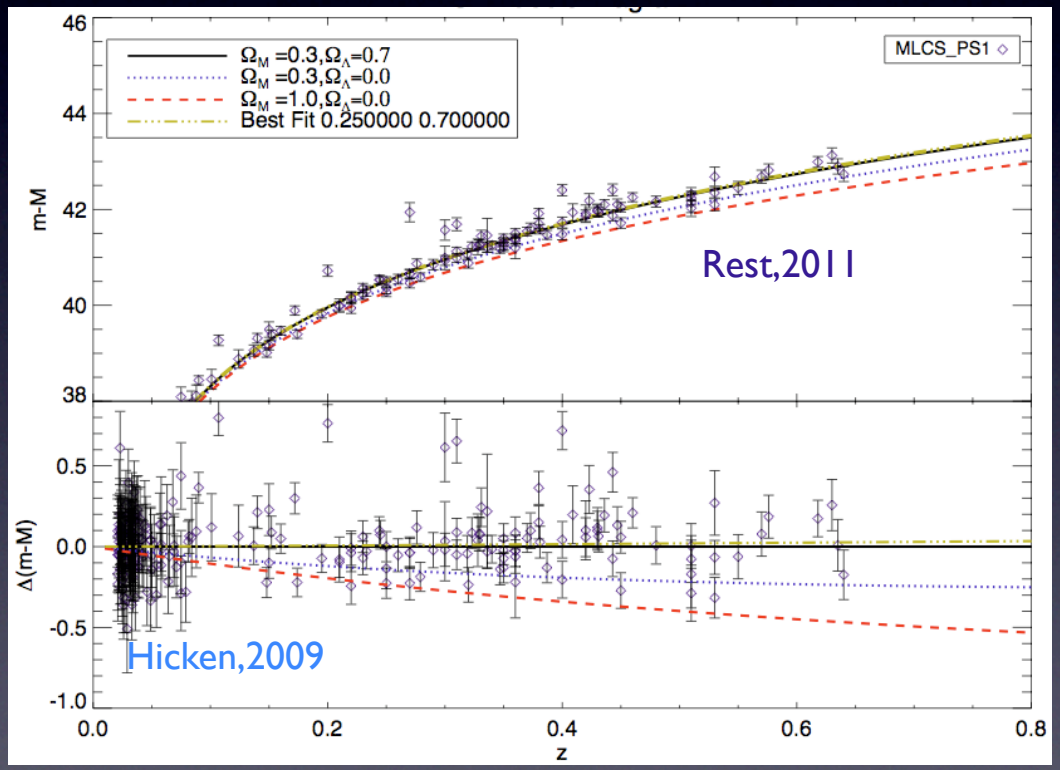


How to use Limited Spectroscopic Follow-up for Cosmology

For PS1:

- On pace to 300 SNe Ia, confirmed
- 0.05<z<0.65
- In future, will have own low-z sample

- Spectra are expensive
- Consider TACs approval (Incremental progress hard to show)
- Representative vs. Specific Sample vs. Training



How well does photometric classification work?

SNIa	CC
122	39
?	?
244	78
2000	1436

For PS1, we analyze 4 Sets:

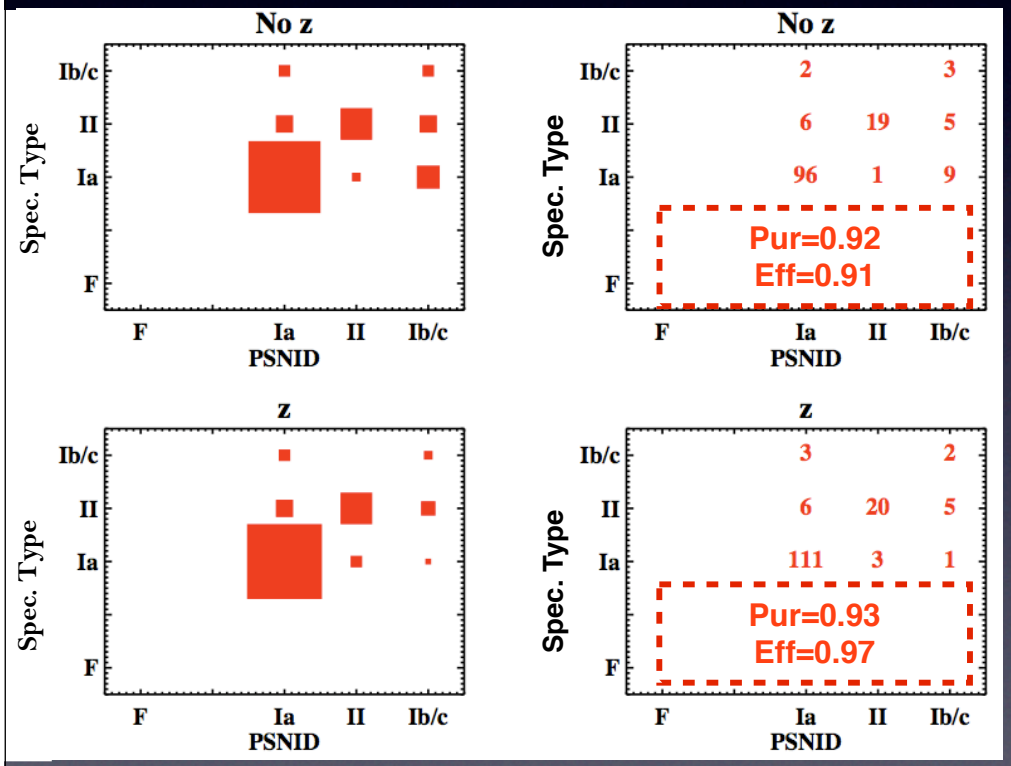
PS1 Spec. Set: Selection Bias: > S/N, >rad. sep., >samp.
PS1 Full Set: Everything. 2260 SNe
Sim. PS1 Spec. Set: SNANA Sim. Best Match Set
Sim. PS1 Full Set: Full SNANA Sim.

Using light curve quality cuts for all sets.

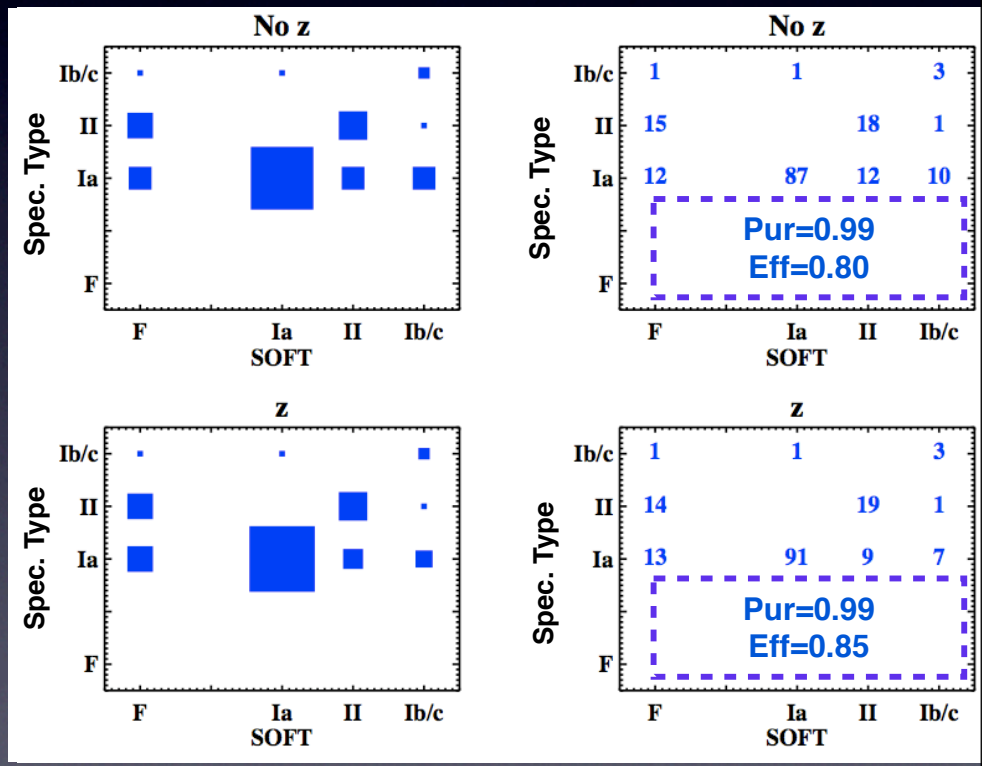
Methods: SOFT (Rodney), PSNID (Sako), SNLS Color Cuts (Bazin)

The Photometric Classification (w/wo z) of PS1 Spectroscopic Set has purity in 90s

PSNID



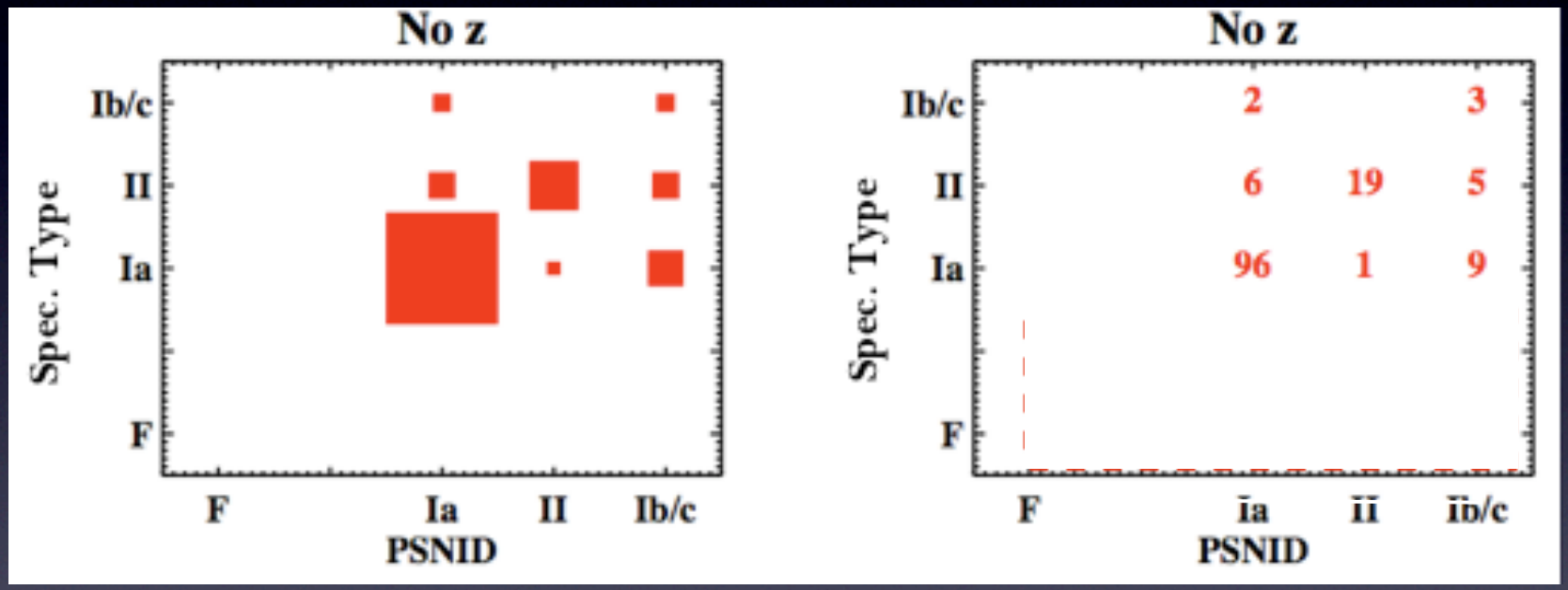
SOFT



$P>0.9$,
$X^2<1.6$

Purity is very high
Redshift Prior does not significantly help.
> S/N, better sampling, not representative of full set

The Photometric Classification (w/ wo z) of PS1 Spectroscopic Set has purity in 90s

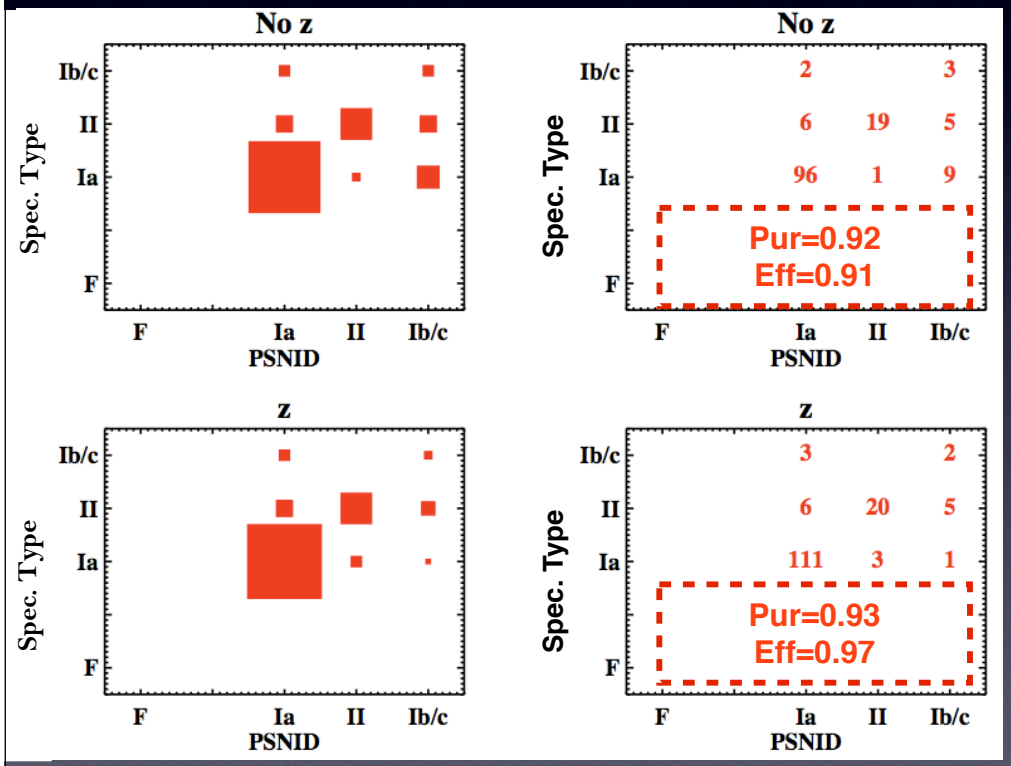


Ideally, only boxes along diagonal
Worst is if small boxes everywhere

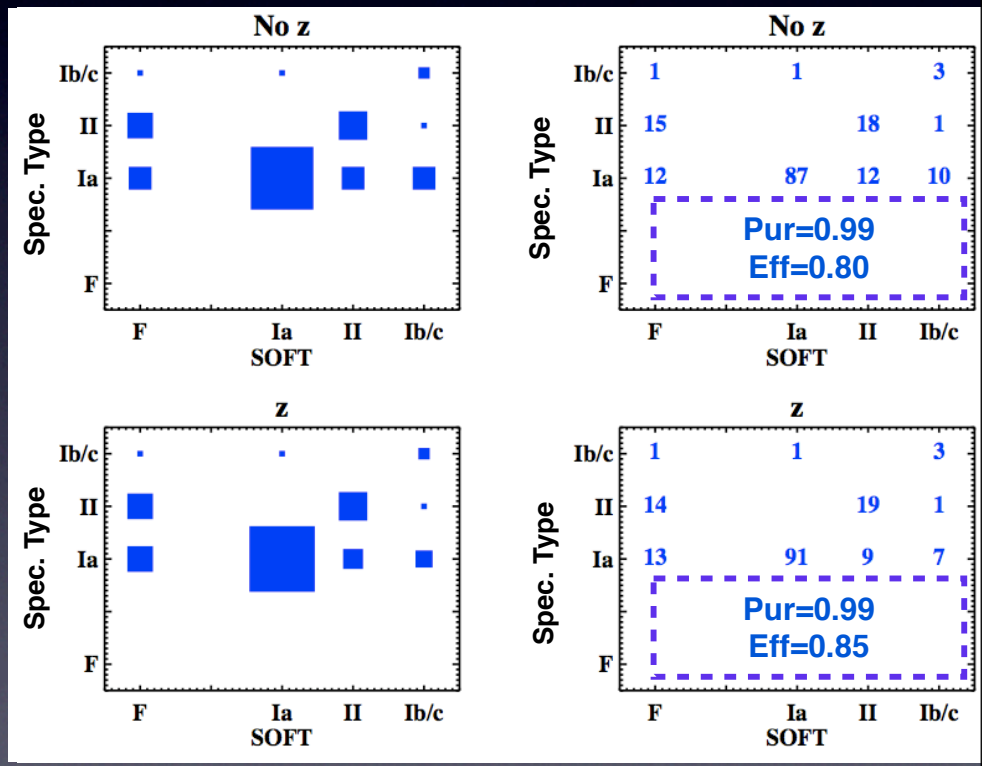
$$\text{Pur} = \frac{N_{Ia}^{true}}{N_{Ia}^{true} + N_{Ia}^{false}} \qquad \text{Eff} = \frac{N_{Ia}^{true}}{N_{Ia}^{total}}$$

The Photometric Classification (w/wo z) of PS1 Spectroscopic Set has purity in 90s

PSNID



SOFT



$P>0.9$,
$X^2<1.6$

Purity is very high
Redshift Prior does not significantly help.
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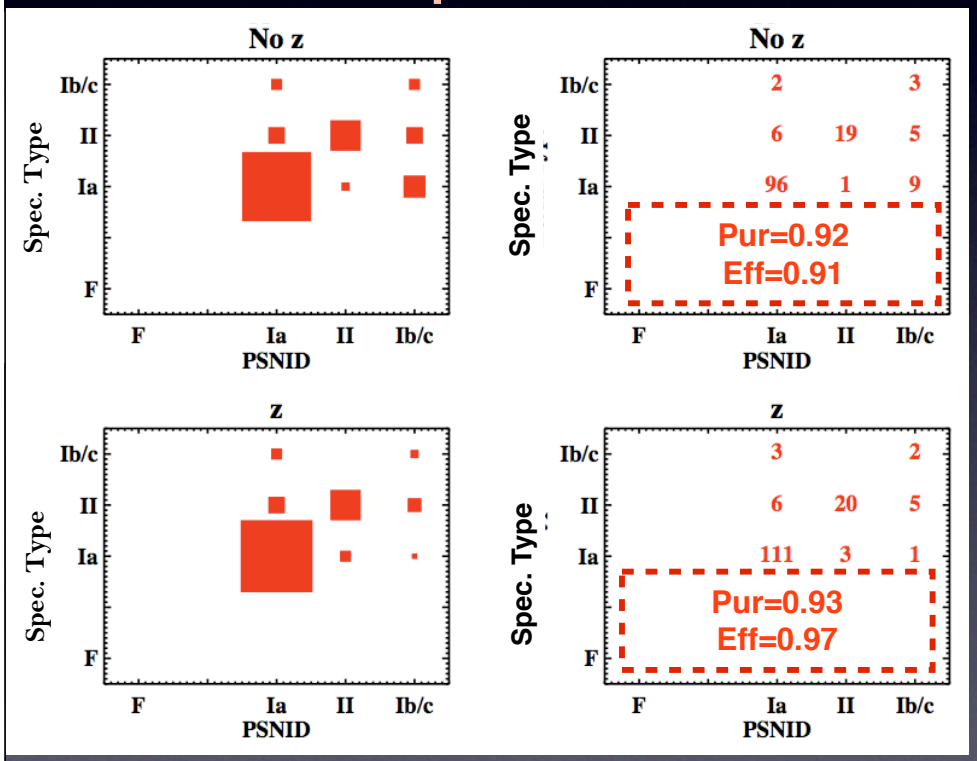
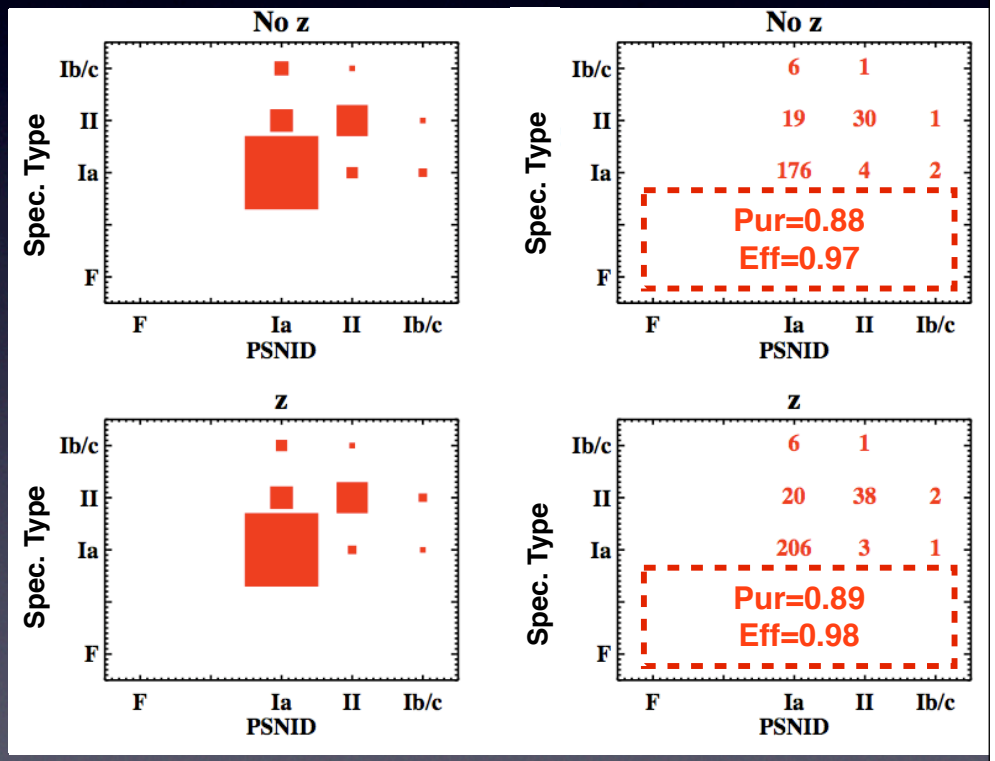
Simulating spec. set reproduces phot. class. results, Purity=89%-93%

PSNID: Spec. PS1 Set



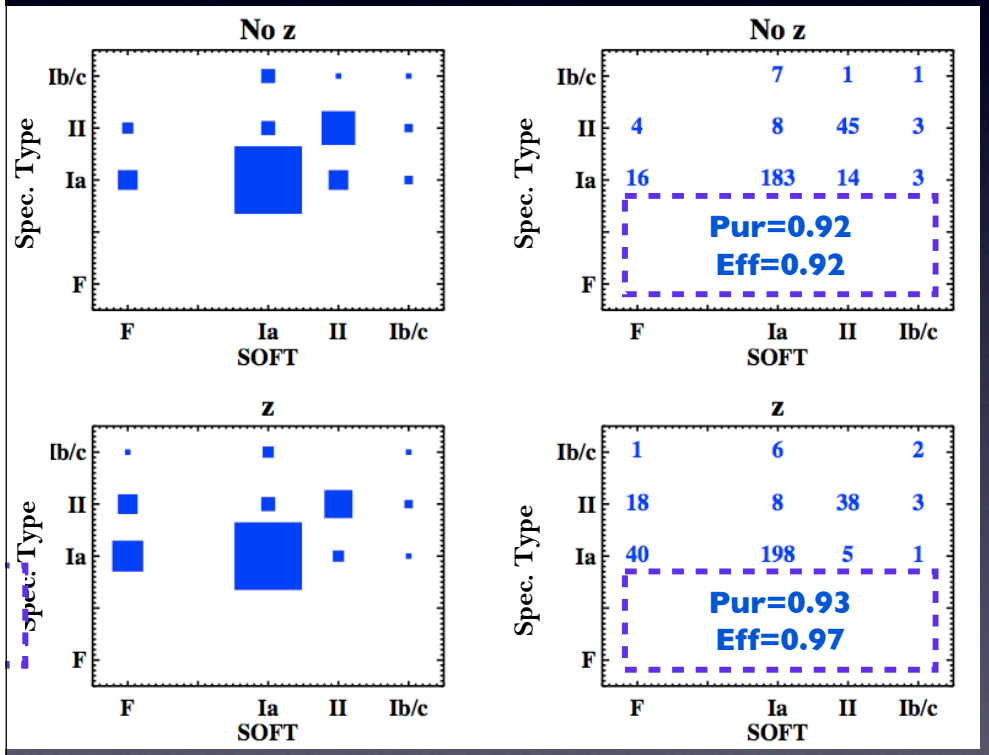
PSNID: Sim. Spec. PS1 Set



Simulated comparable, slightly worse, than Real.
Efficiency improves with host galaxy prior.

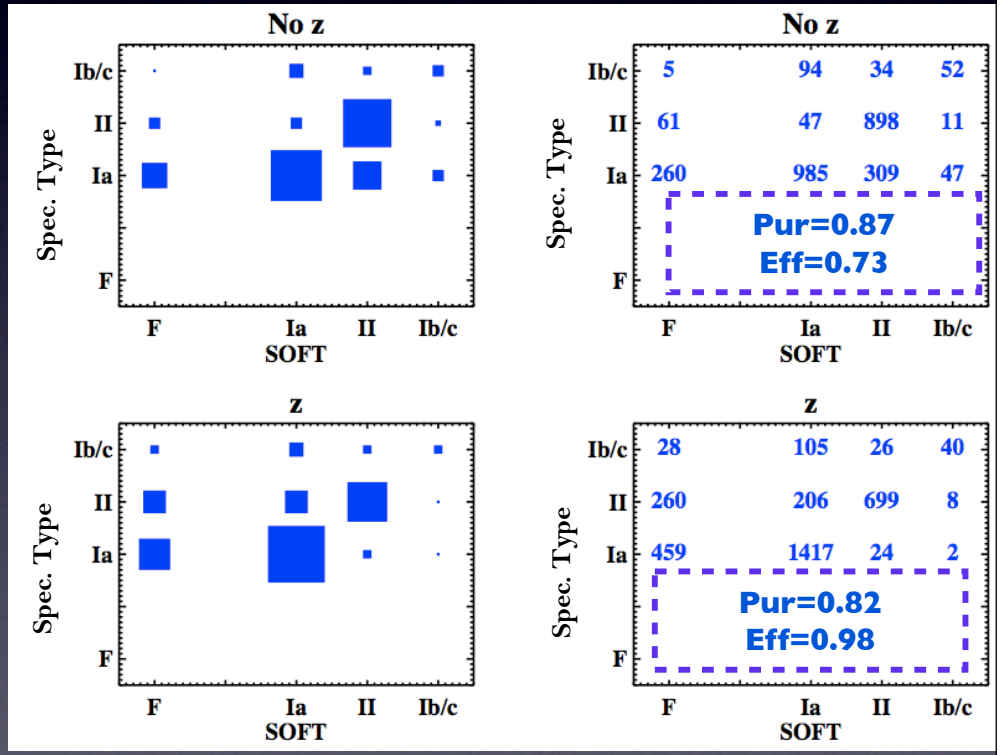
Simulating the Full Set of SNe, Purity drops to 5-11%

SOFT: Sim. Spec. Conf. PS1 Set



SOFT: Sim. Full PS1 Set

- higher # SNe II / # SNe Ia, lower S/N



We could extrapolate success of classifiers

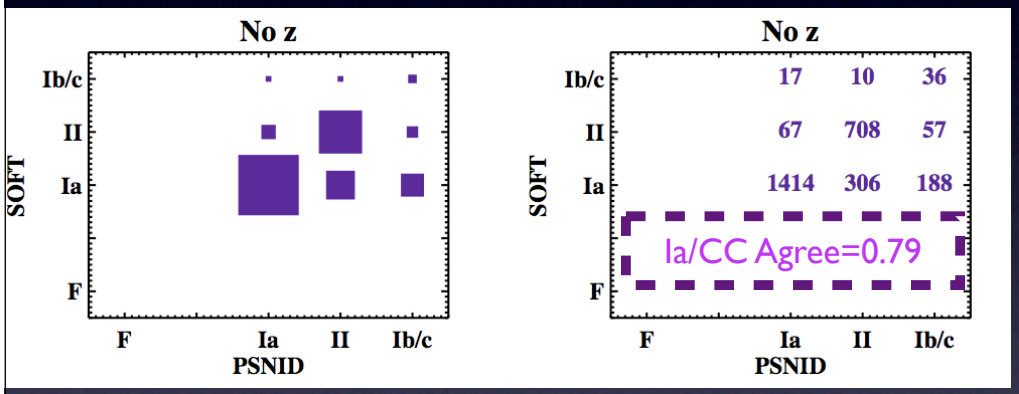
(Purity,Eff)

	PSNID (z)	PSNID (no-z)	SOFT (z)	SOFT (no-z)
PS1 Spec.	93%,97%	92%,91%	98%,85%	99%,80%
Sim PS1 Spec.	89%,98%	88%,97%	93%,97%	92%,92%
Sim Full PS1	83%,97%	83%,79%	82%,98%	87%,73%

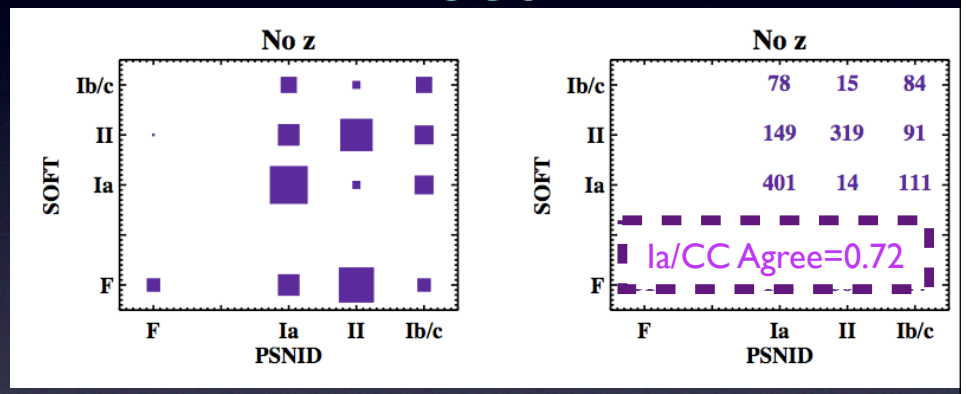
to full PS1 set, however...

We See Lower Classifier Agreement in Reality

PSNID v. SOFT: Sim. Full PS1 Set



PSNID v. SOFT: Full PS1 Set



Simulations overestimate agreement of classifiers
More SNe II in Full PS1 Set or More non-SNe in Full PS1 set

Using SNLS Color Cuts gives high purity, but lower efficiency

(Purity,Eff)	PSNID	SOFT	SNLS Color
PS1 Spec	93%,96%	99%,76%	97%,85%
Sim Spec PS1	89%,98%	93%,97%	95%,79%
Sim Full PS1	83%,97%	82%,98%	93%,73%

Bazin et al. 2011 (requiring redshift):

x_1,c
g-i
r-z
i-z

Color

PSNID		Ia
	Ia	250
	CC	75

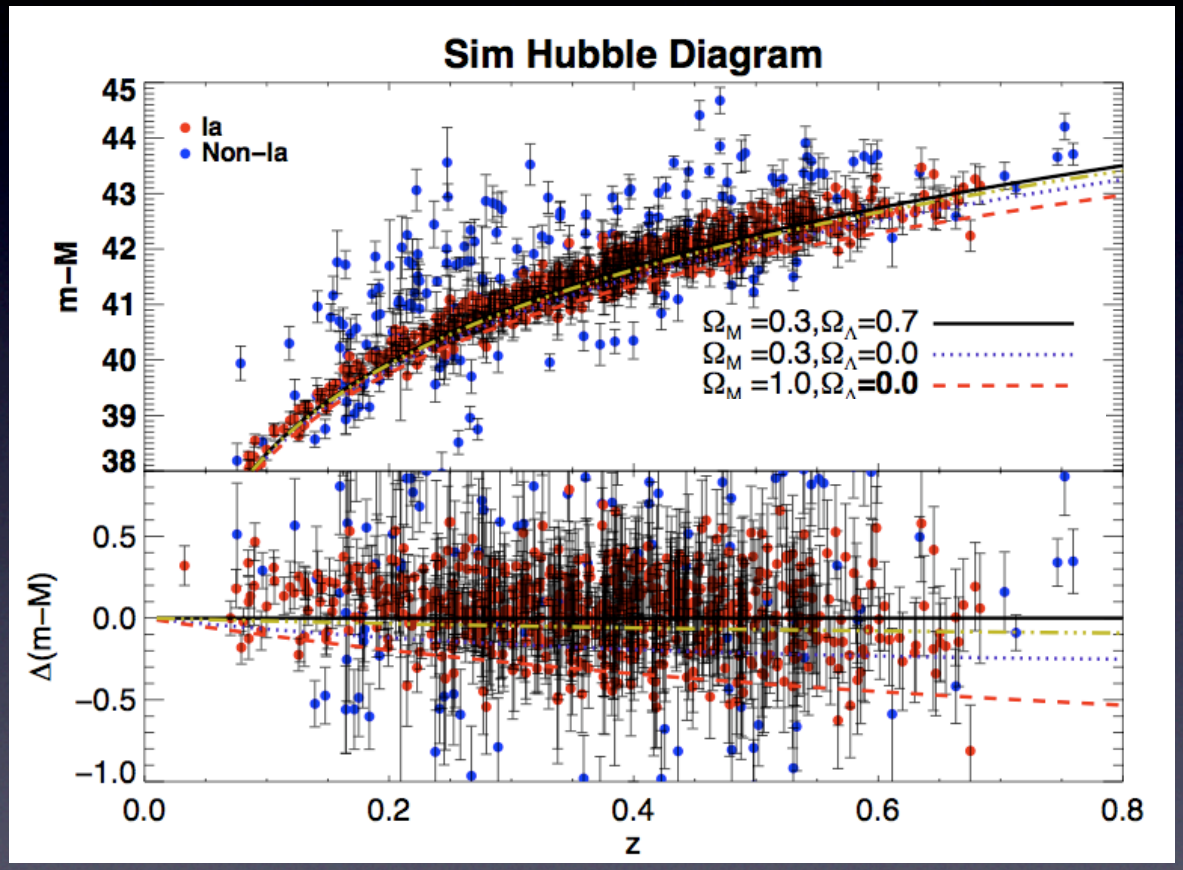
77% agree

Color

SOFT		Ia
	Ia	171
	CC	40

81% agree

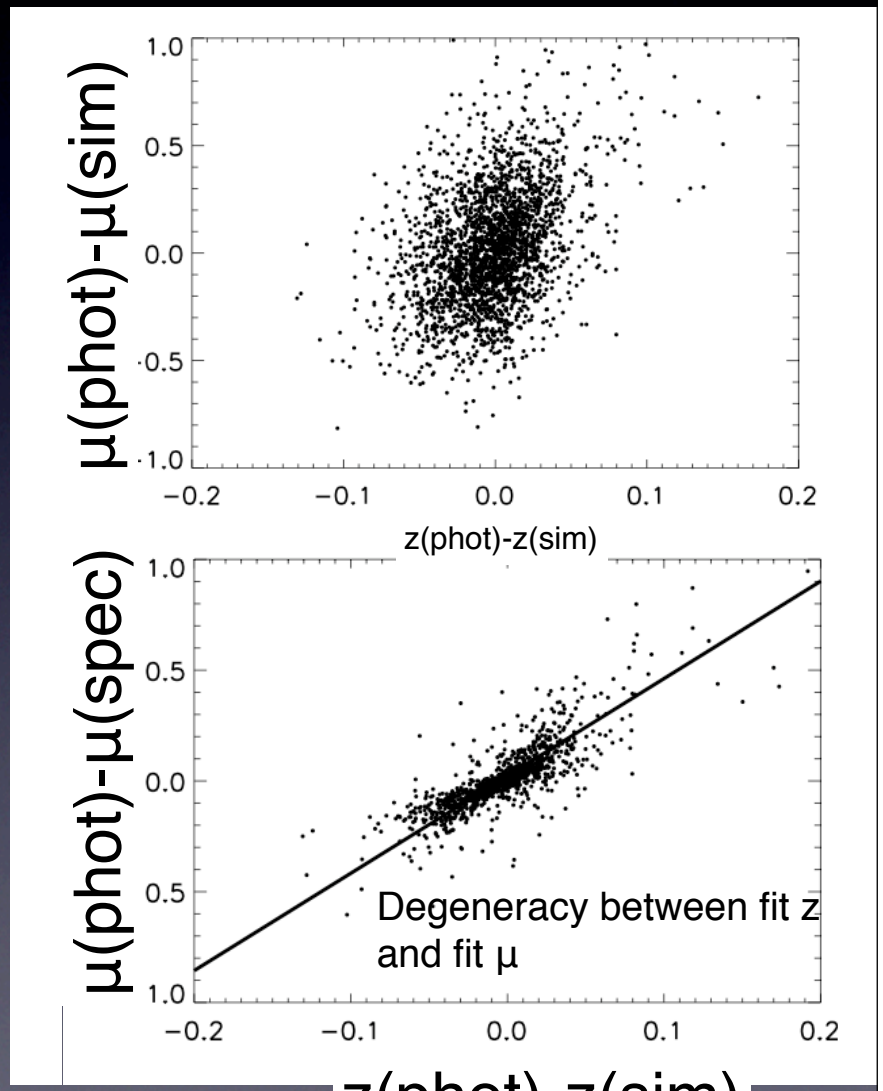
The goal is to use photometric sample of SNe Ia for cosmology



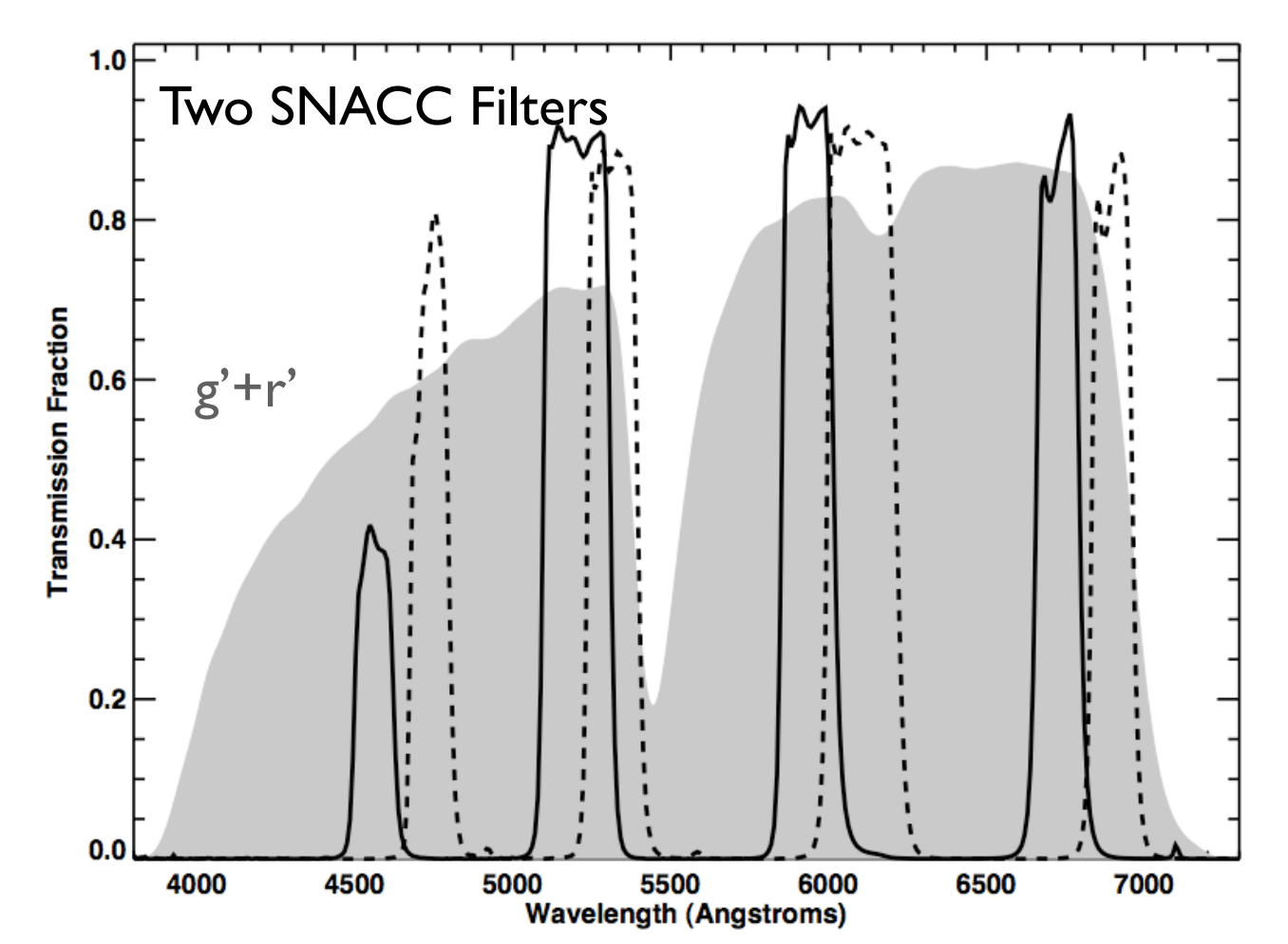
We can use Bayesian analysis, but...

Using SN Photometric Redshifts Degrades Cosmology

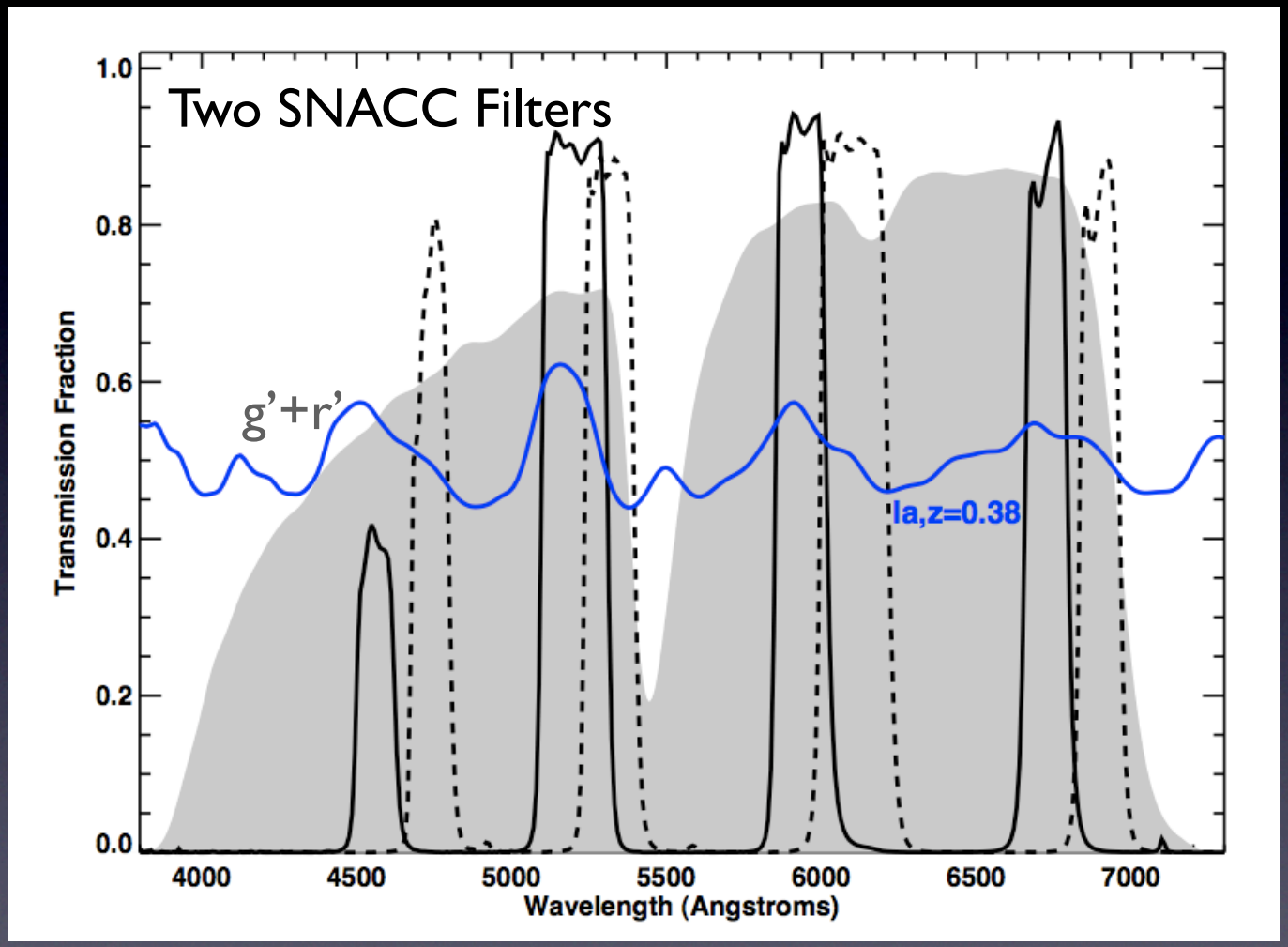
- $\sigma_z/(1+z)=0.03$
- $\sigma_z \sim 0.04 \Rightarrow .17$ mag error in μ.
  3x more SNe needed with photo-zs than spec-zs for similar cosmology constraint
- >20% no clear host galaxy (McCrum,PS1,2011)
- Need closer to spectroscopic accuracy, i.e. host galaxy spec. z



Presenting An Intermediate R Solution: SNACC filters

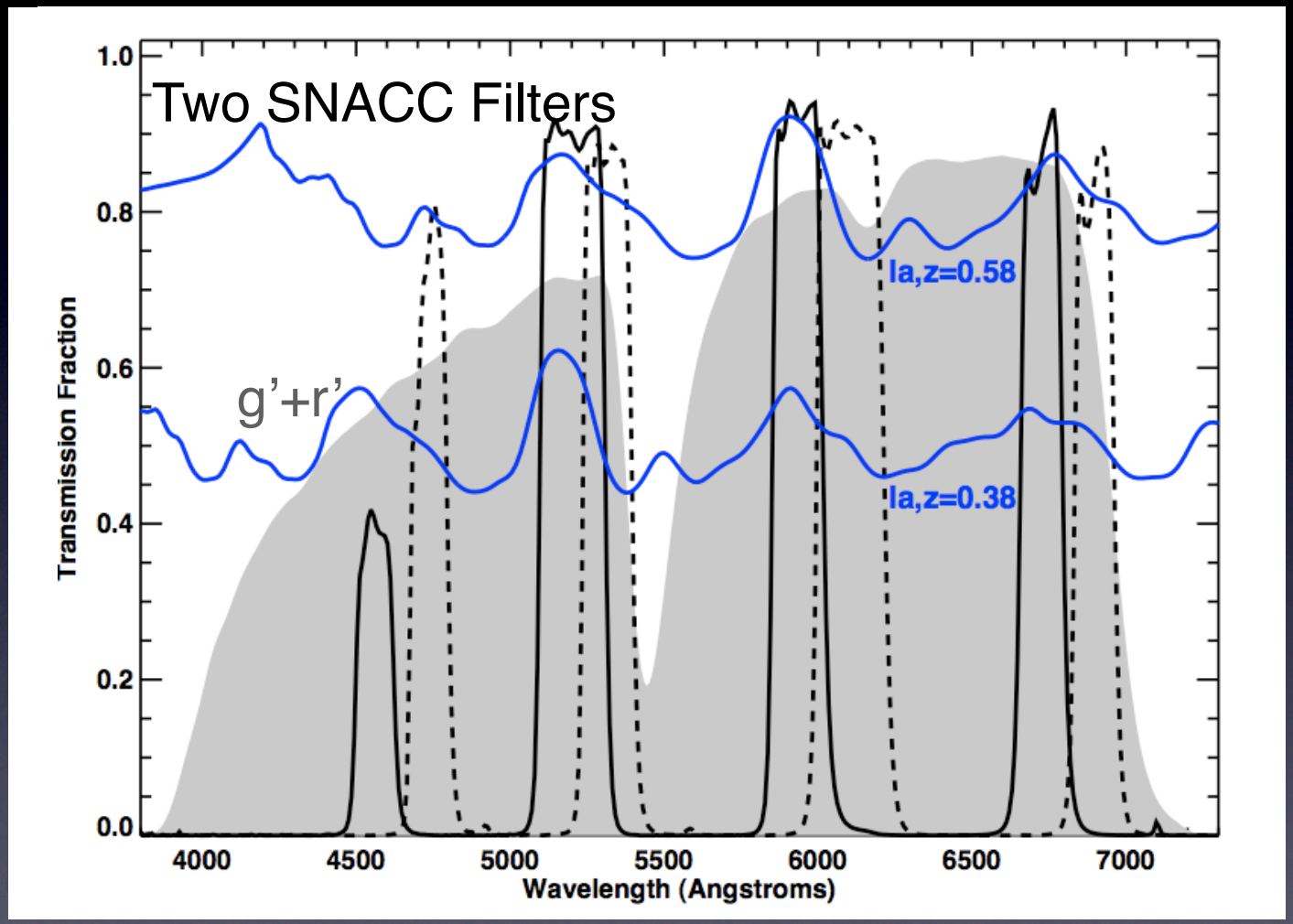


Presenting An Intermediate R Solution: SNACC filters



Teeth align with spec. features

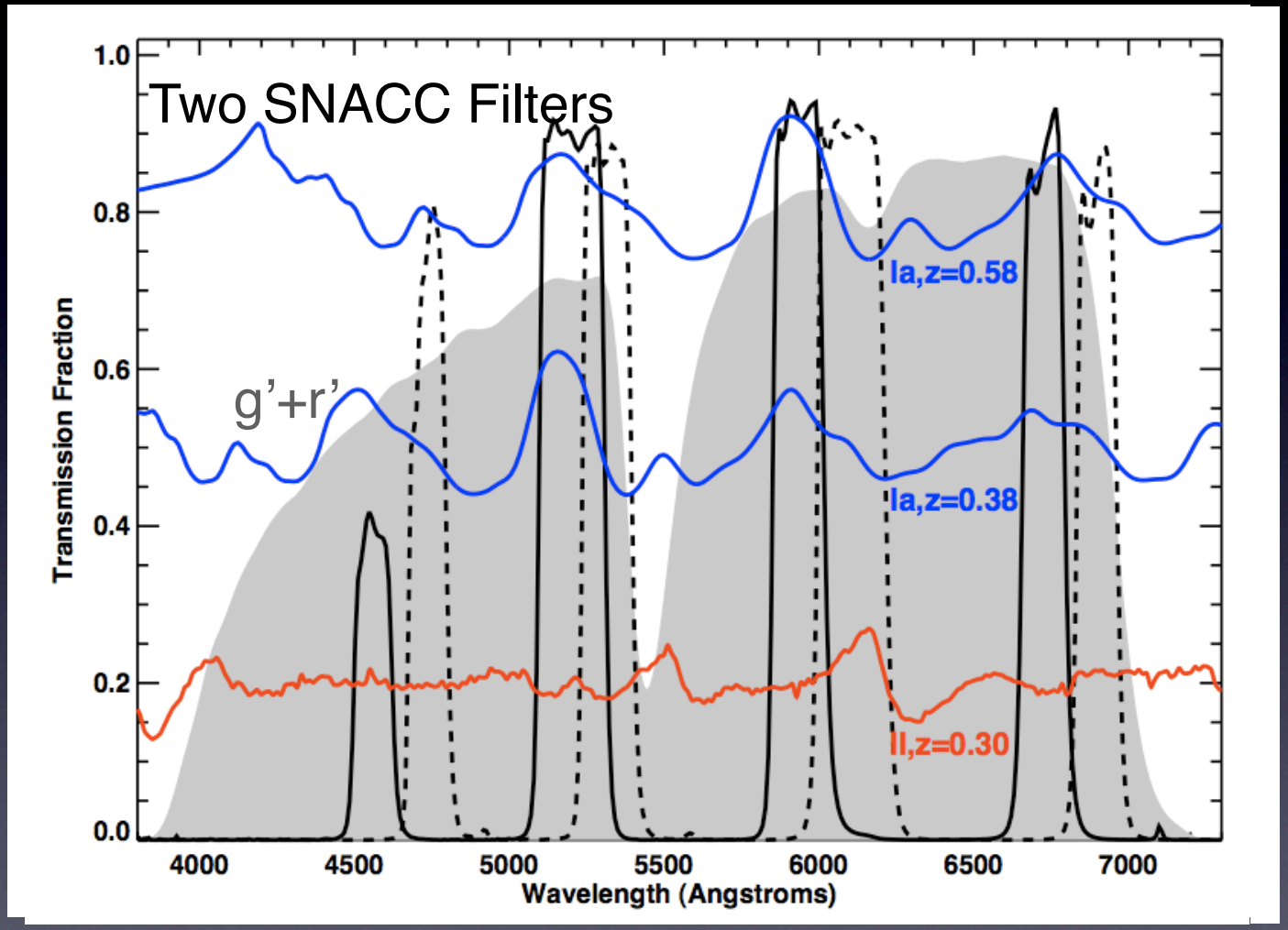
Presenting An Intermediate R Solution: SNACC filters



Redshift Periodicity $\Delta z=0.2$ (Works 3 loops around)

Teeth align with spec. features

Presenting An Intermediate R Solution: SNACC filters

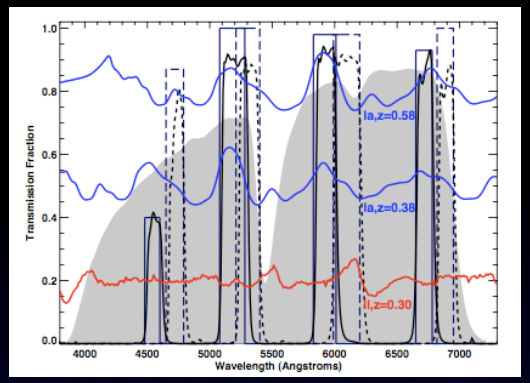


Redshift Periodicity $\Delta z=0.2$ (Works 3 loops around)

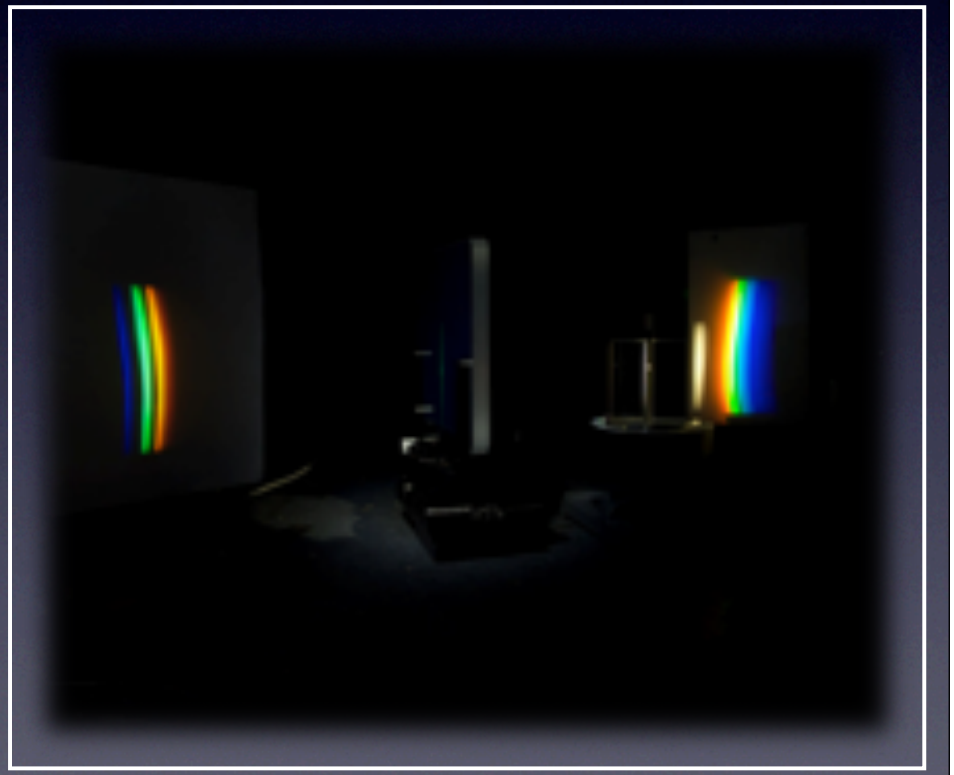
Teeth align with spec. features

SNe II - No Correlation

PS1/Subaru SNACC observing Program



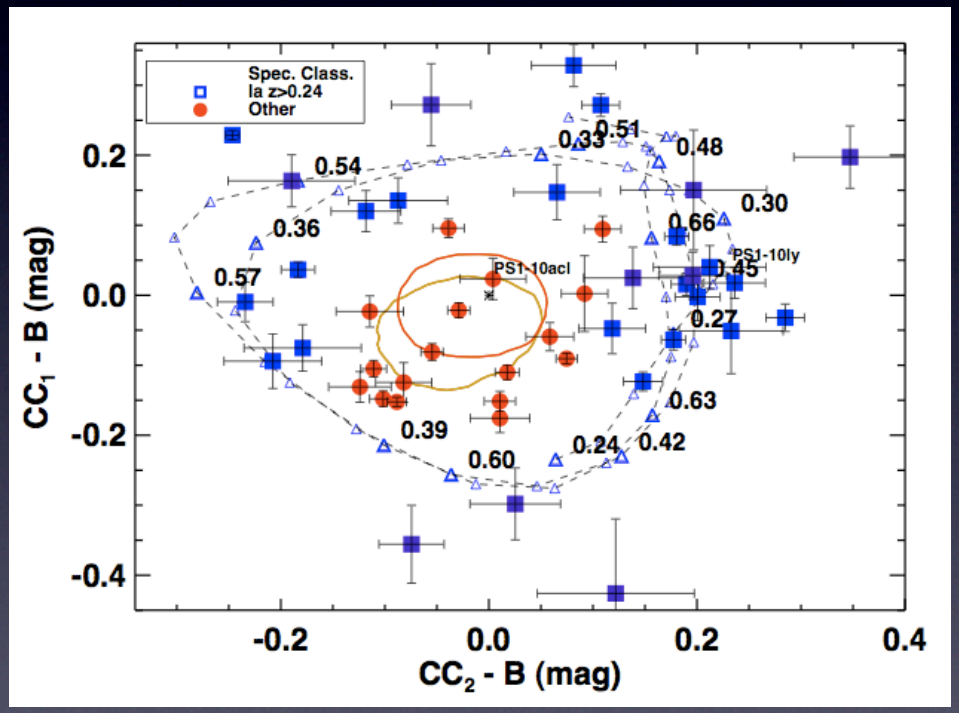
- 2 'Comb Filters' on SuprimeCam
- 600 Angstrom equivalent width, 60% of broadband filter.
- 4 minutes per image, high S/N
- Multiplex ~ 10 SNe Ia per 1 deg^2
- 165 SNe followed-up, 5.5 nights (limited by available targets)



SNACC Classifications are Better than Photometric, ~95%

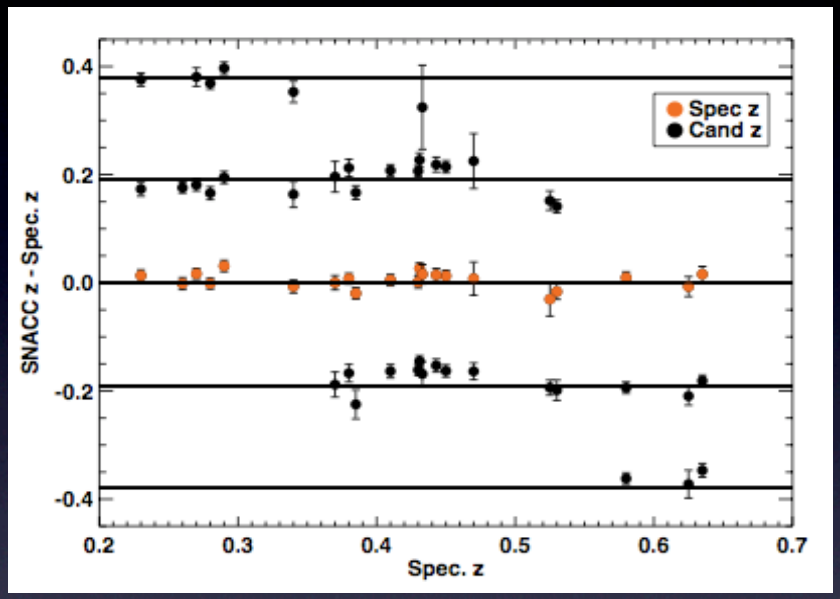
(Purity,Eff)	SNACC
Simulated	95%,99%
Confirmed	95%,83%

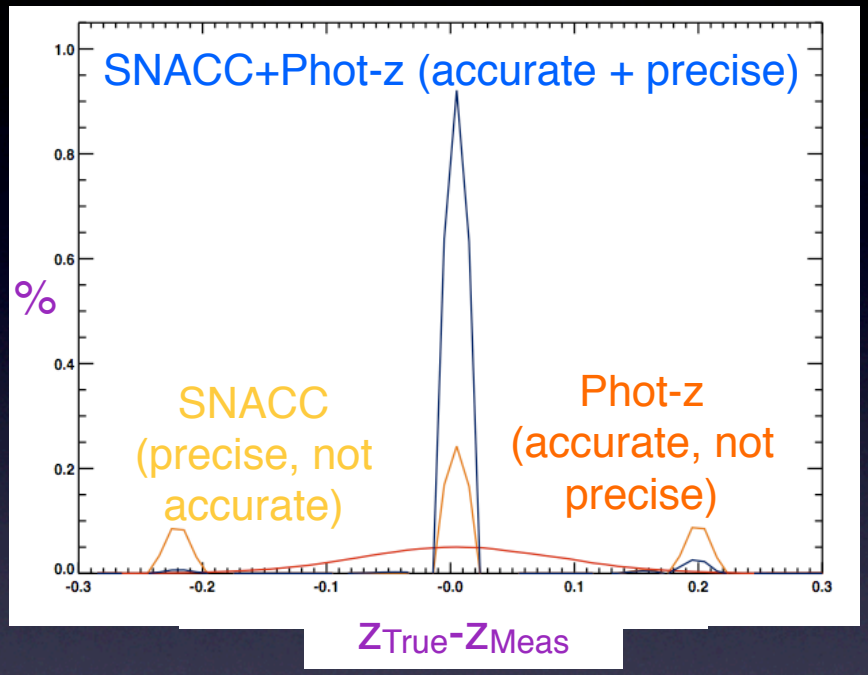
For Spec. Verified Candidates:



- SNACC 95% compared to Photometric ~83%
- Low S/N degrades efficiency, not purity
- With host galaxy spec-z, purity improves to 99%

SNACC provides High Precision Redshifts with breakable degeneracy.





- With photo-z, have accurate and precise redshift, $\sigma_z \sim 0.01$, better than photometric
- Can still use Bayesian analysis, infer accurate cosmology

The Operational Advantages of SNACC:

- Speed (Just 30% slower than broadband, 10x faster than spectroscopic)
- Makes use of cross correlation with spectral features
- Insensitive to reddening, because unlike colors, measurement comes from spectral features not continuum
- Independent of light curve data, fits
- Measurements derived from image subtraction reduce surface brightness bias compared to spectroscopy

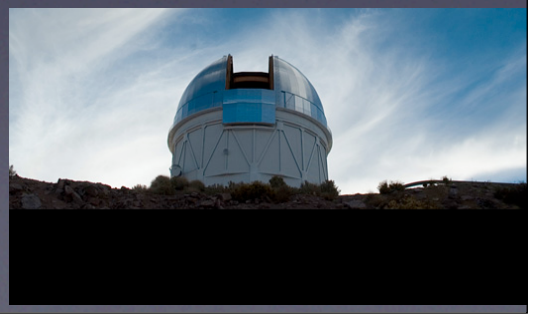
Possible SNACC Filter Use for DES

- ~1 observation per field per month catches most SNe. Need to sample in (-10 days,10 days)*(1+z)
- Observe whole field - unbiased sample
- 225 s x 2 filters=450s.450sx 5 fields=2250s.2250sx1 per month

~0.5 hour per month

- Tuned to 0.3<z<0.8 (or 0.4 < z<0.9 ...)
- Could be accomplished in small fraction of 10% public time

DARK ENERGY SURVEY



Summary

- Spectroscopic -Expensive, Need to choose between subsamples
- Photometric - Purities ~ mid 80s% for full set, need host galaxy redshifts
- SNACC - Hybrid, 95% purity, advantage if on DES

Should do all of the above.