Photometric Classification and Redshift Estimation of LSST SNe

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Outline

- Photometric classification using SN colors and Bazin parameters
- Photo-z estimation using SALT2 model with nested sampling
- Hubble Diagram fitting

Photometric classification using SN colors

- General function (Bazin func) fit to obtain peak mags and calculate colors (in adjacent bands, i.e. u-g, g-r, r-i, i-z, z-Y) – model-independent characterization of SN light curves

$$f(t) = A\frac{\exp^{-(t-t_0)/t_{\rm fall}}}{1+\exp^{-(t-t_0)/t_{\rm rise}}} + B$$ (Bazin et al. 2009)

- Random Forest classification algorithm

  17 features: 5 colors +

  12 Bazin parameters:

  $$6\ t_{{\rm fall},f}\ +\ 6\ t_{{\rm rise},f}\ (f = {\rm u, g, r, i, z, Y})$$

- No redshift given for classification

  (0.01<z<1.2 in simulation)

Bazin fit details

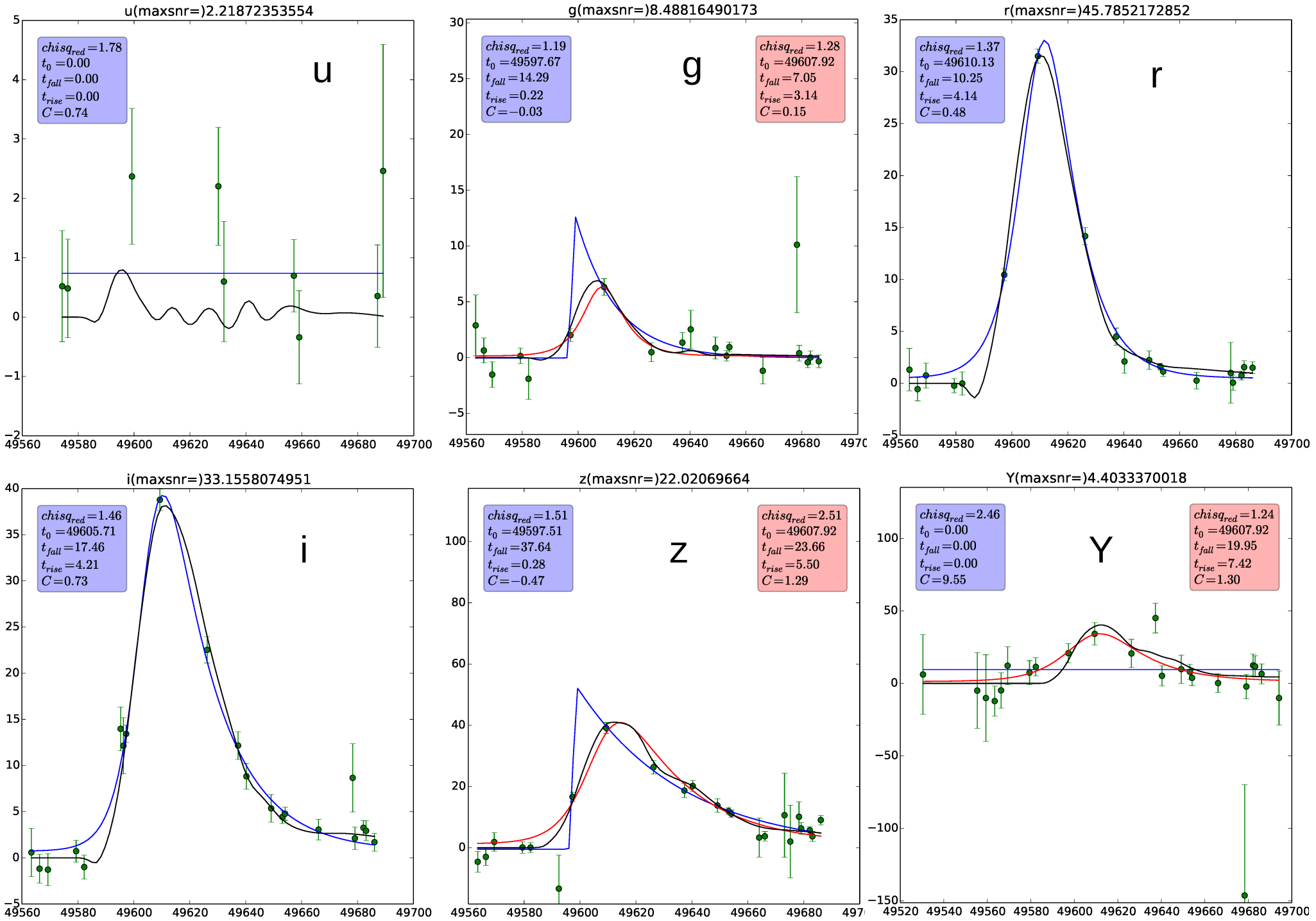
- For SNRmax<=5, $f(t) = B$

  SNRmax>5, $f(t) = A\frac{\exp^{-(t-t_0)/t_{\rm fall}}}{1+\exp^{-(t-t_0)/t_{\rm rise}}} + B$

- 2-step fit

	1st step		2nd step	
	ini	limits	ini	limits
A	flux at peak	[0,inf]	flux at peak	[0,inf]
t_0	time at peak	[-inf,inf]	median(t_0)	fixed
t_{fall}	15	[0,inf]	median(t_{fall})	[1,inf]
t_{rise}	5	[0,inf]	median(t_{rise})	[1,inf]
B	0	[-inf,inf]	0	[-inf,inf]

- Selection cuts on Bazin parameters and χ^2



Blue: 1st Bazin fit Red: 2nd Bazin fit Black: SALT fit

Selection Cuts Summary

	Ia	II	Ibc
Total Before any cuts	199400	1941000	
Max SNR > 5 for 3 bands	62147 (0.31)	67631 (0.035)	14468 (0.007)
1 point before and 2 after the peak[1] for 3 bands , 1 of which has SNR>5	48298 (0.24)	54900 (0.028)	11468 (0.006)
bazin fit success[2] (all 6 bands)	48157 (0.24)	52341 (0.027)	11310 (0.006)
bazin cuts[3]	26615 (0.13)	7959 (0.004)	4354 (0.002)
mag_err < 2 + have I-band peak[4]	24800 (0.12)	6230 (0.003)	3735 (0.002)
Final Fraction[5]	0.713	0.179	0.107

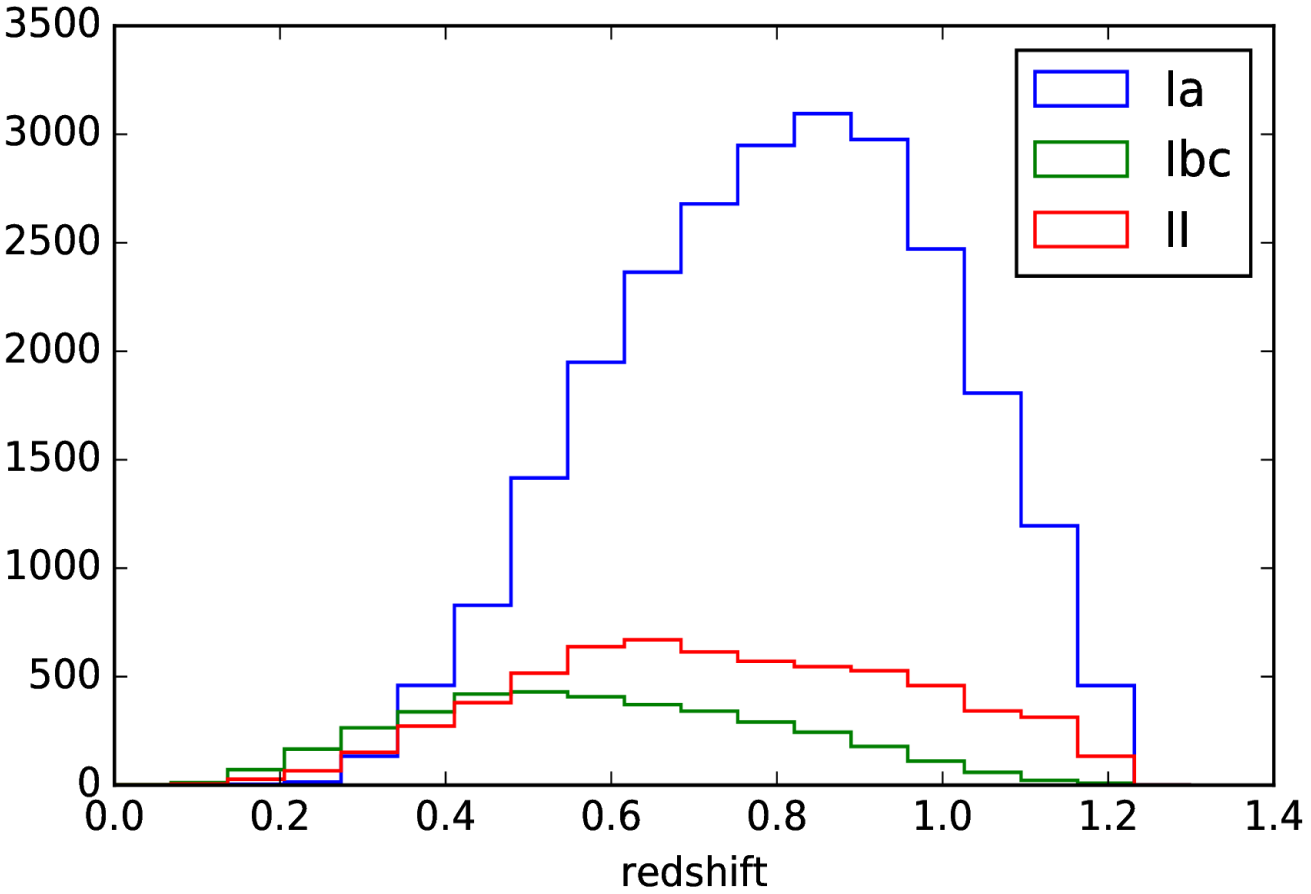
Notes:
1. here “peak” refers to the highest flux point in the raw light curve whose SNR is greater than the median SNR of that band
2. here “success” refers to any fit that returns a set of values (does not return a “failure” by the curvefit program), whether they are in a reasonable range or not
3. detailed in the next slide
4. This is set as quality cuts in the analytic photoz estimator; it may or may not be necessary
5. Fraction of types in the final sample (added up to 1)

Bazin Parameter Cuts

	Ia	II	Ibc
Cuts during bazin fit:			
SNR>5 for 3 bands + 1 point before peak, 2 point after peak + bazin fit success	48157 (100%)	52341 (100%)	11310 (100%)
Cuts for bazin parameters:			
t_rise > 1, t_rise not close to 1 (tolerance = 0.01)	40336 (84%)	34161 (65%)	8319 (74%)
-20<C<20	38316 (80%)	17438 (33%)	6228 (55%)
Reduced chisq < 10	36040 (75%)	16307 (31%)	5995 (53%)
t_fall < 150	33579 (70%)	13037 (25%)	5742 (51%)
t_rise < t_fall	31247 (65%)	11200 (21%)	5219 (46%)
A < 5000	31190 (65%)	11171 (21%)	5207 (46%)
A_err < 100	27805 (58%)	9611 (18%)	4627 (41%)
t0_err < 50	27544 (57%)	9120 (17%)	4567 (40%)
t_fall_err < 100	26825 (56%)	8077 (15%)	4390 (39%)
t_rise_err < 50	26615 (55%)	7960 (15%)	4354 (38%)
Y-A, u-A < 1000	26615 (55%)	7959 (15%)	4354 (38%)
For photoz:			
Magerr<2 + has I-peak			

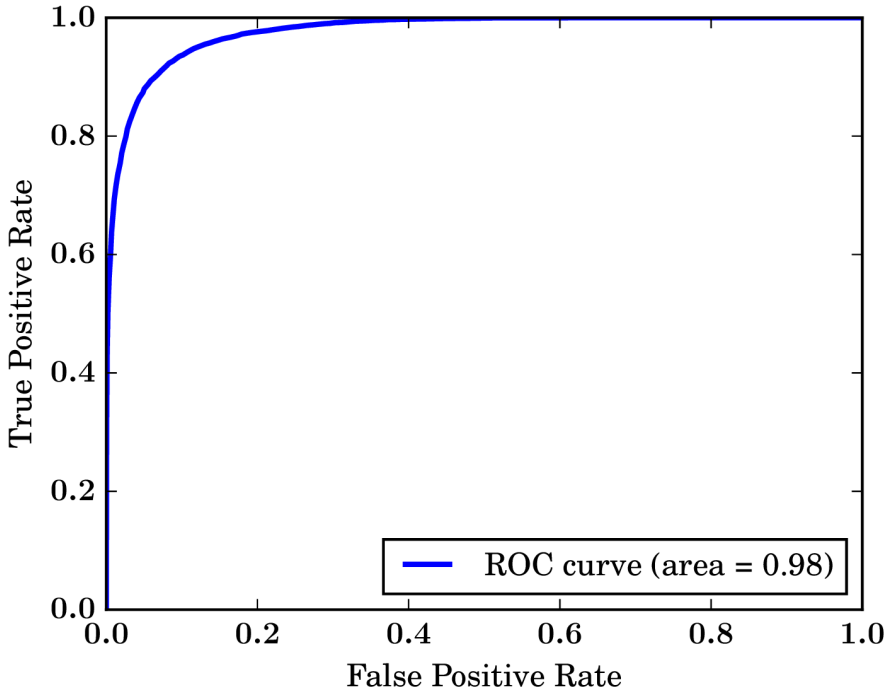
Redshift distribution

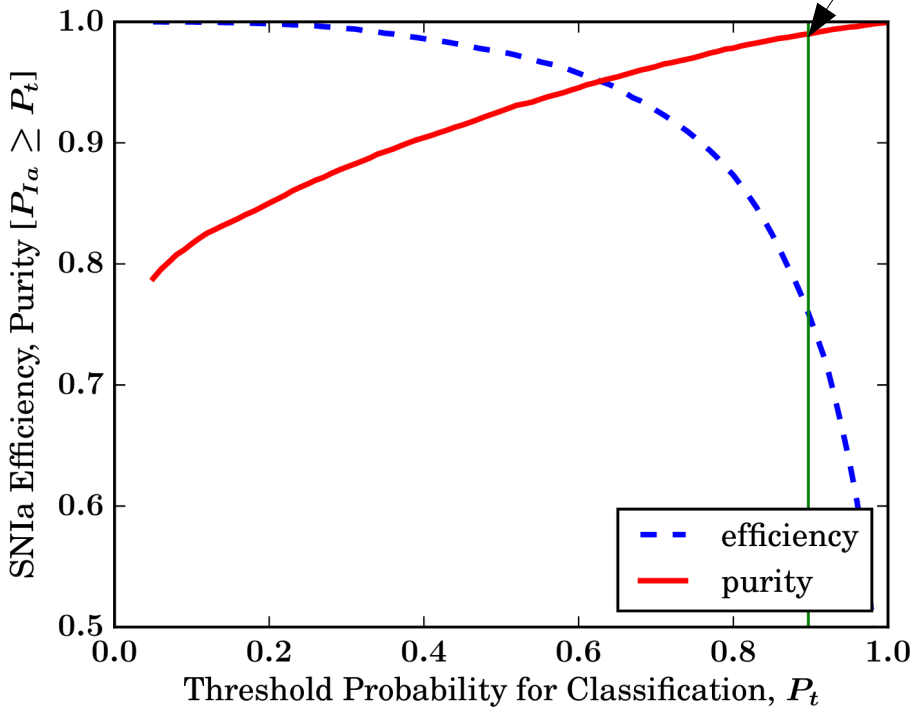
(before classification)



Classification results

ML codes in Gupta et al. 2016
by Argonne Group (Ravi Gupta, Eve Kovacs, Steve Kuhlmann)





	Predicted Class		
Actual Class		P	N
	P	TP	FN
	N	FP	TN

$$\mathrm{TPR} = \frac{\mathrm{TP}}{\mathrm{TP+FN}} \qquad \mathrm{efficiency} = \frac{\mathrm{TP}}{\mathrm{TP+FN}}$$

$$\mathrm{FPR} = \frac{\mathrm{FP}}{\mathrm{FP+TN}} \qquad \mathrm{purity} = \frac{\mathrm{TP}}{\mathrm{TP+FP}}$$

Photo-z estimation

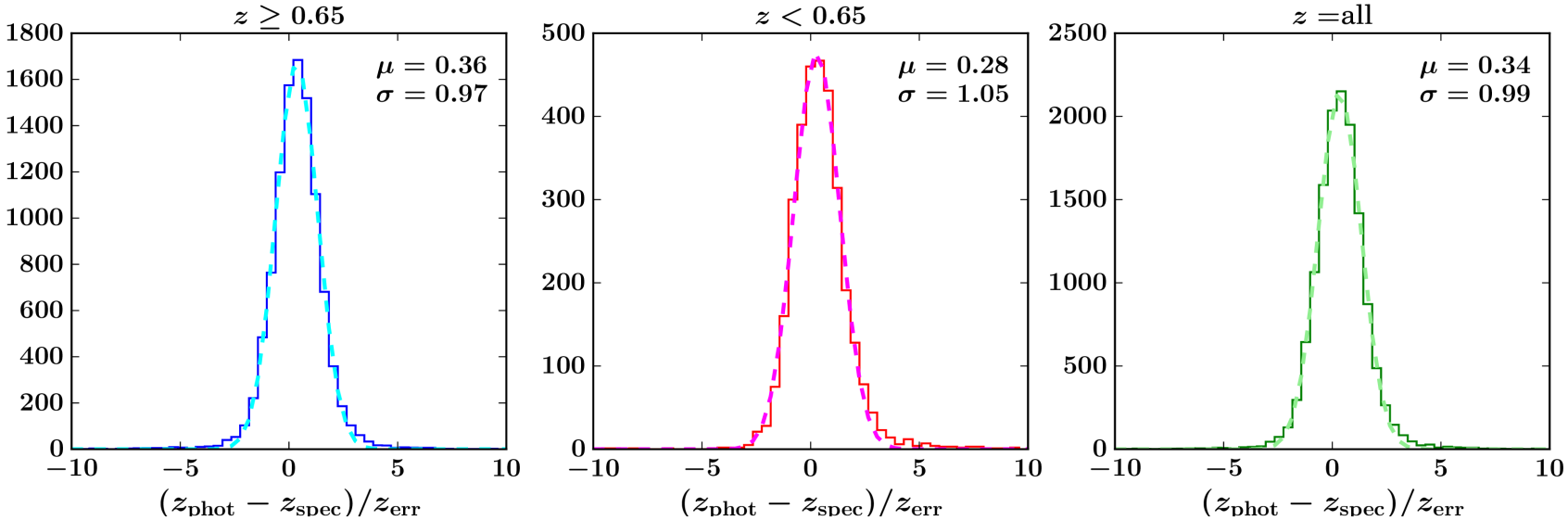
- Fit SALT2 parameters and photo-z in SNCosmo using nested sampling

  2-stage fit:

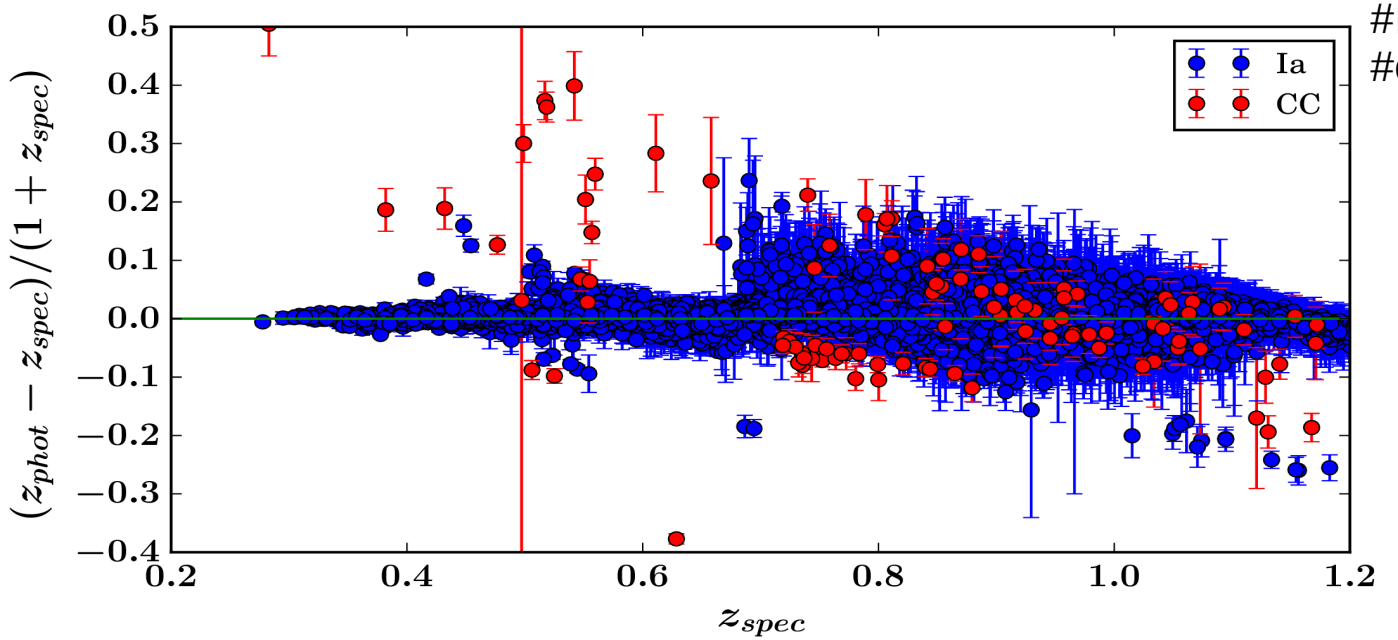
	Model -cov	x_0	t_0	x_1	c	z
1st fit	**Off**	**SNcosmo "guess_ampl-itude"**	**$[t_{min}-15, t_{max}+15]$**	**[-5,5]**	**[-0.5,0.5]**	**[0.01,1.2]**
2nd fit	**On**	**SNcosmo "guess_ampl-itude"**	**$[t_0-3\sigma, t_0+3\sigma]$**	**$[x_1-3\sigma, x_1+3\sigma]$**	**$[c-3\sigma, c+3\sigma]$**	**$[z-10\sigma, z+10\sigma]$**

Photo-z errors

SN-only photo-z, no host prior

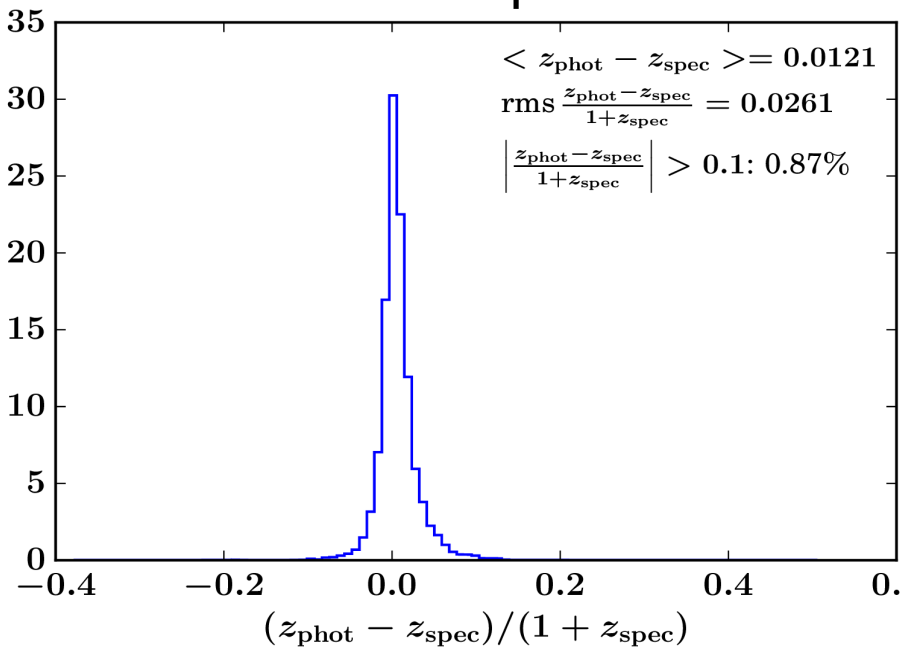


(χ^2cut: χ^2/d.o.f<1.5
#Ia cut out: 109 (0.8%)
#cc cut out: 24 (20%))

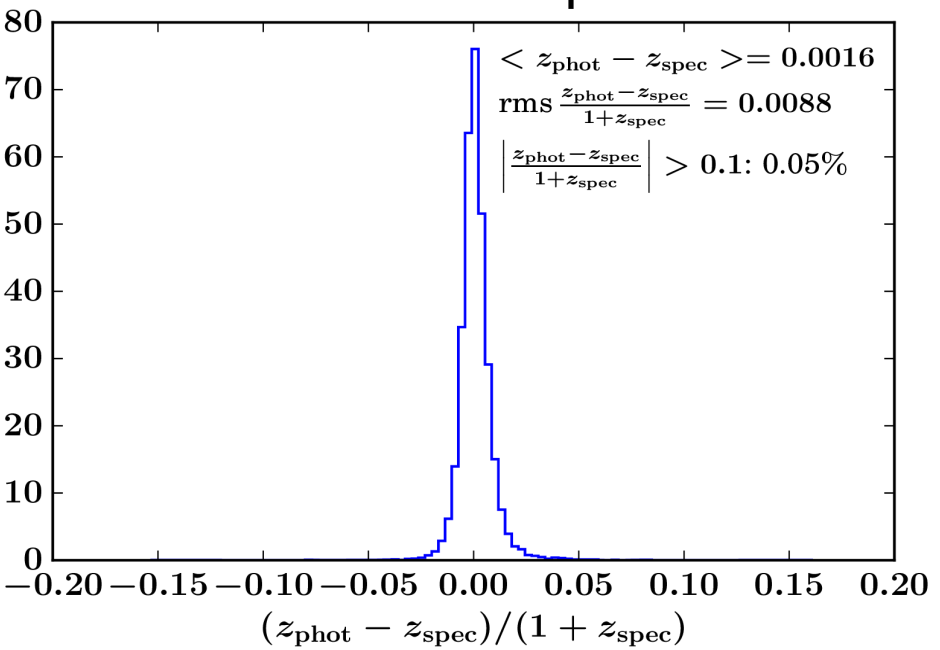


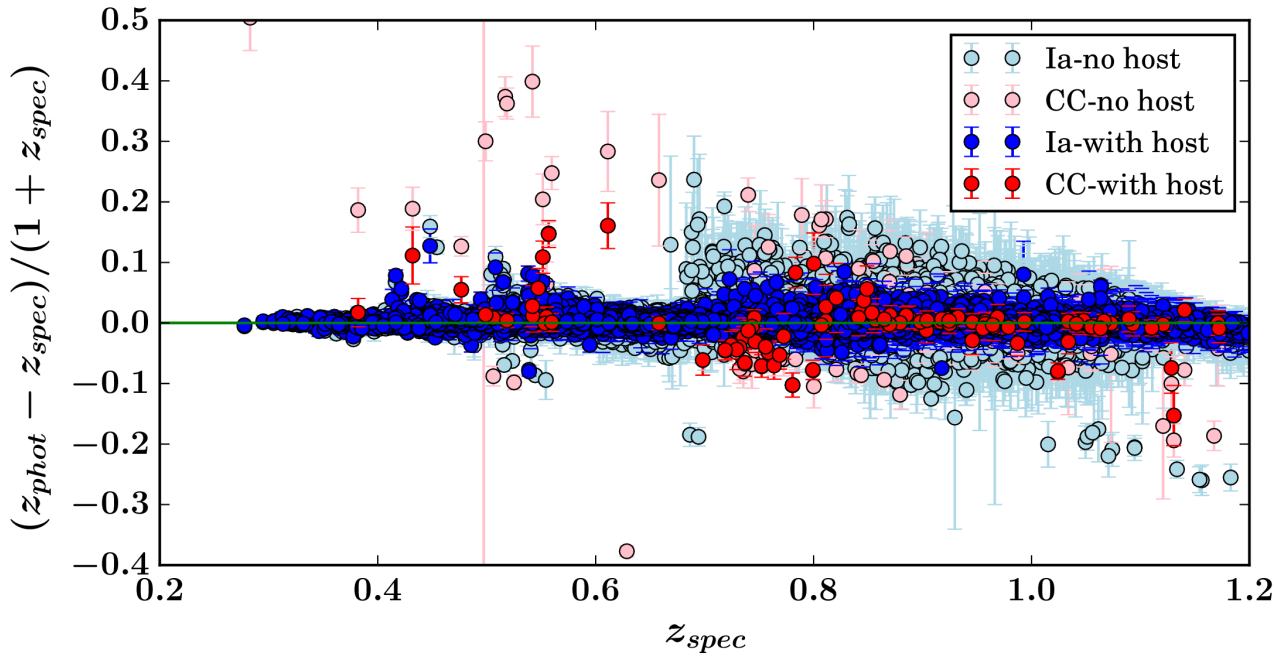
Host Priors

No host prior



With host prior



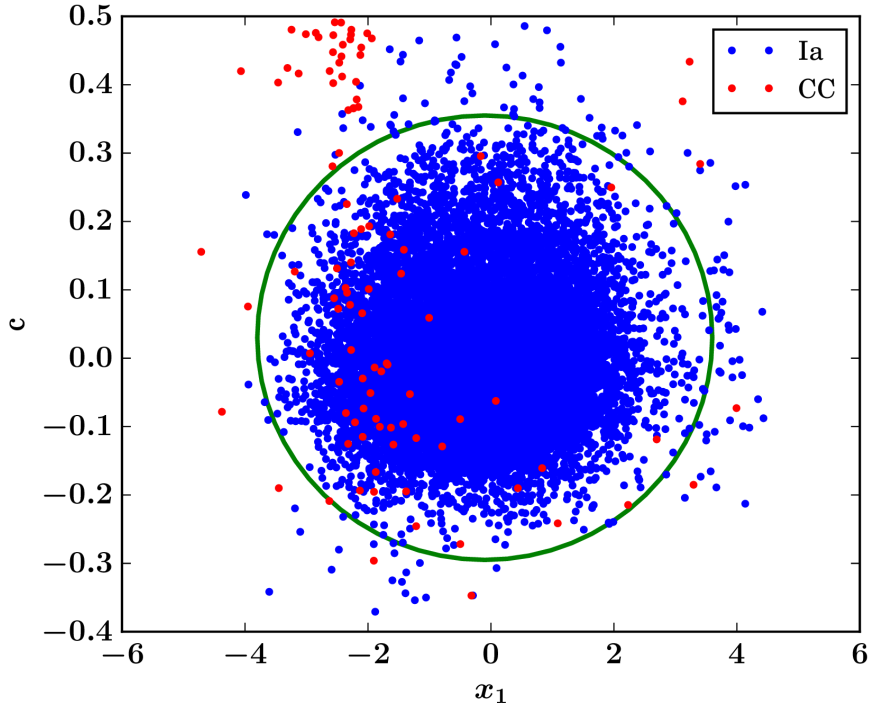


Note: the host-galaxy errors may be too optimistic...

(χ^2cut: χ^2/d.o.f<1.5
#Ia cut out: 112 (0.8%)
#cc cut out: 32 (25%))

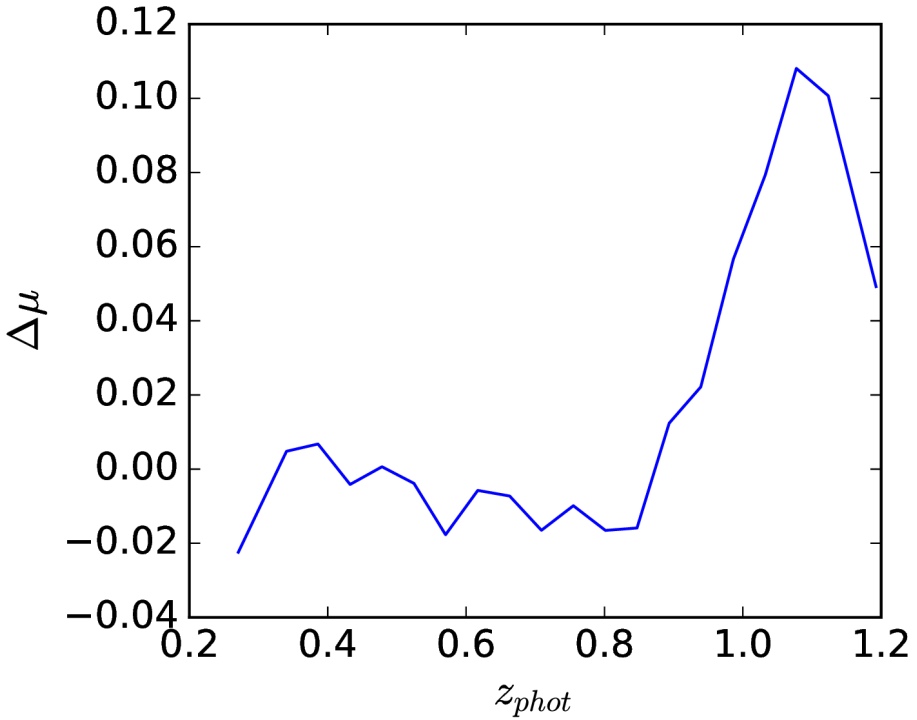
Hubble Diagram

- Ellipse cut:

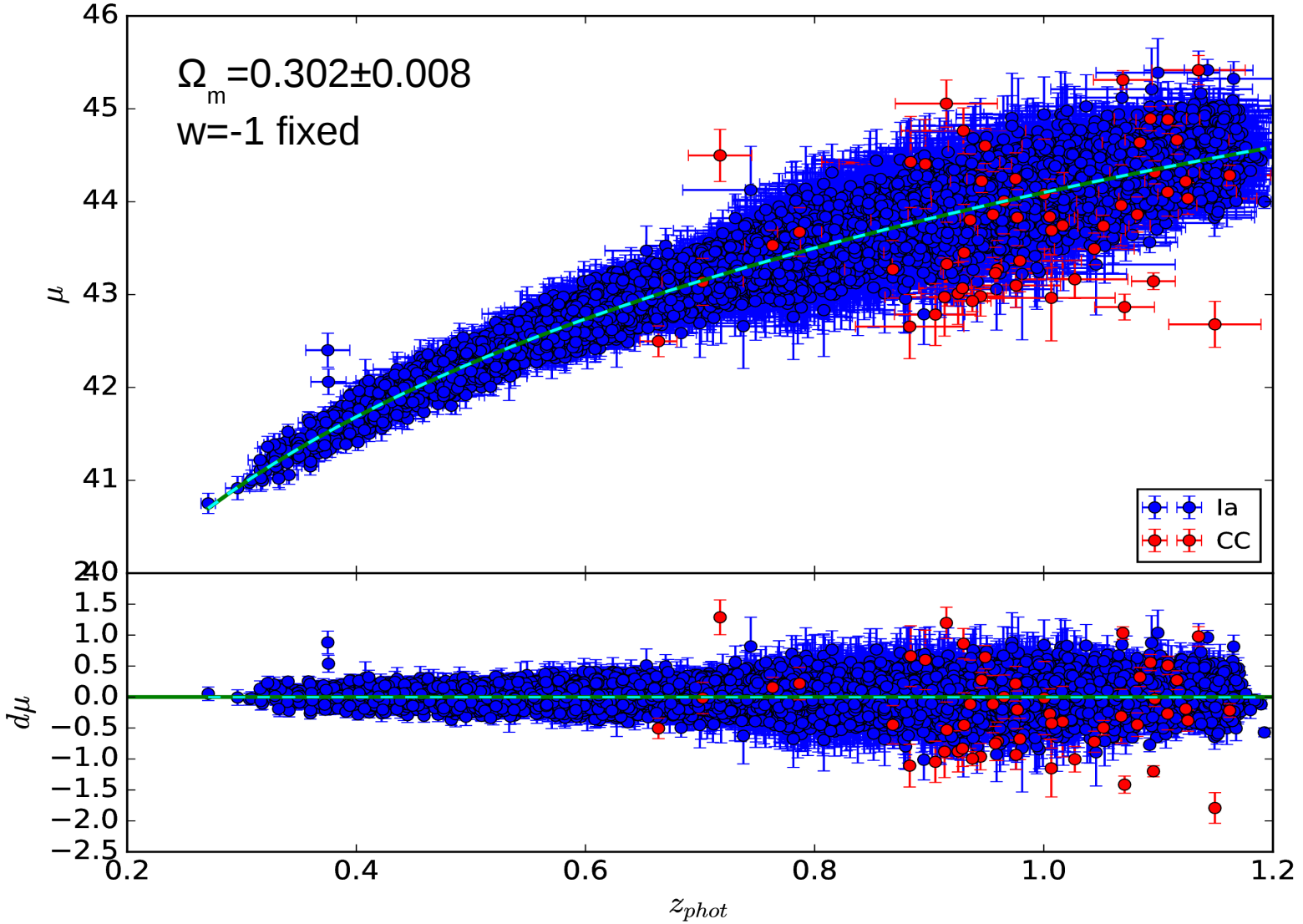


- Bias after ellipse cut :

$$\Delta\mu = \mu_{fit} - \mu_{true}$$



Hubble Diagram



Summary

- SN classification using SN colors and Bazin parameters:

  AUC=0.98, purity=99% with efficiency=76%

- SN photo-z estimation using SALT2 with nested sampling (Sncosmo):

  better photo-z error (sigma((z_phot-z_true)/z_err)~1)

  rms (z_phot-z_true)/(1+z_true) = 0.026 no host

  = 0.008 with host

- Fit ΛCDM (sim Ω_m=0.3): Ω_m=0.302±0.008 (stat only)

Backup slides...

SALT2 parameter bias