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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Spectroscopic

SNACC

Photometric

(R~1000)

high R

(R~30)

The spectral resolution:

\[ R = \frac{\lambda}{\Delta \lambda} \]
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

Hicken, 2009
Rest, 2011
How well does photometric classification work?

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

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

\[
\text{Pur} = \frac{N_{\text{Ia}}^{\text{true}}}{N_{\text{Ia}}^{\text{true}} + N_{\text{Ia}}^{\text{false}}}
\]
\[
\text{Eff} = \frac{N_{\text{Ia}}^{\text{true}}}{N_{\text{Ia}}^{\text{total}}}
\]
The Photometric Classification (w/wo z) of PS1 Spectroscopic Set has purity in 90s

Purity is very high
Redshift Prior does not significantly help.
> S/N, better sampling, not representative of full set
Simulating spec. set reproduces phot. class. results, Purity=89%-93%

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

SOFT: Sim. Full PS1 Set

<table>
<thead>
<tr>
<th>Spec. Type</th>
<th>No z</th>
<th>Z</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Ib/c</td>
<td>7</td>
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</table>

Pur=0.92
Eff=0.92

Pur=0.93
Eff=0.97

Pur=0.87
Eff=0.73

Pur=0.82
Eff=0.98
We could extrapolate success of classifiers

<table>
<thead>
<tr>
<th></th>
<th>PSNID (z)</th>
<th>PSNID (no-z)</th>
<th>SOFT (z)</th>
<th>SOFT (no-z)</th>
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<tbody>
<tr>
<td>PSI Spec.</td>
<td>93%,97%</td>
<td>92%,91%</td>
<td>98%,85%</td>
<td>99%,80%</td>
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<tr>
<td>Sim PSI Spec.</td>
<td>89%,98%</td>
<td>88%,97%</td>
<td>93%,97%</td>
<td>92%,92%</td>
</tr>
<tr>
<td>Sim Full PSI</td>
<td>83%,97%</td>
<td>83%,79%</td>
<td>82%,98%</td>
<td>87%,73%</td>
</tr>
</tbody>
</table>

(Purity, Eff)

To full PSI set, however...
We See Lower Classifier Agreement in Reality

PSNID v. SOFT: Sim. Full PS I Set

PSNID v. SOFT: Full PS I Set

Simulations overestimate agreement of classifiers
More SNe II in Full PS I Set or More non-SNe in Full PS I set
Using SNLS Color Cuts gives high purity, but lower efficiency

Bazin et al. 2011 (requiring redshift): \( x_1, c, g-i, r-z, i-z \)

<table>
<thead>
<tr>
<th>(Purity, Eff)</th>
<th>PSNID</th>
<th>SOFT</th>
<th>SNLS Color</th>
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<tbody>
<tr>
<td>PS1 Spec</td>
<td>93%, 96%</td>
<td>99%, 76%</td>
<td>97%, 85%</td>
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<tr>
<td>Sim Spec PS1</td>
<td>89%, 98%</td>
<td>93%, 97%</td>
<td>95%, 79%</td>
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<tr>
<td>Sim Full PS1</td>
<td>83%, 97%</td>
<td>82%, 98%</td>
<td>93%, 73%</td>
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<table>
<thead>
<tr>
<th>Color</th>
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<tbody>
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<td>la 250</td>
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<tr>
<td>la</td>
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<tr>
<td>SOFT</td>
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<td>la</td>
<td>171</td>
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<tr>
<td>CC</td>
<td>40</td>
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</table>

77% agree

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

- $\sigma_z/(1+z)=0.03$

- $\sigma_z \sim 0.04 \Rightarrow 0.17$ mag error in $\mu$
  
  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

Degeneracy between fit $z$ and fit $\mu$: $\mu_{(\text{phot})} - \mu_{(\text{sim})}$ vs. $z_{(\text{phot})} - z_{(\text{sim})}$
Presenting An Intermediate R Solution: SNACC filters
Presenting An Intermediate R Solution: SNACC filters

Two SNACC Filters

Teeth align with spec. features
Presenting An Intermediate R Solution: SNACC filters

Two SNACC Filters

g’+r’

Redshift Periodicity Δz=0.2 (Works 3 loops around)

Teeth align with spec. features
Presenting An Intermediate R Solution: SNACC filters

Two 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%

<table>
<thead>
<tr>
<th>(Purity, Eff)</th>
<th>SNACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulated</td>
<td>95%, 99%</td>
</tr>
<tr>
<td>Confirmed</td>
<td>95%, 83%</td>
</tr>
</tbody>
</table>

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

For Spec. Verified Candidates:
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
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.