DES – Type Ia SNe Selection Part 2: Figure of Merit for Cosmology Constraints

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Outline

- Definition of Figure of Merit (FoM) from the *Dark Energy Task Force*
- Factors affecting the FoM
- Hubble scatter plots for Ia and Core Collapse
- FoM Results for a range of SNR cuts, and for MLCS and SALT
Figure of Merit (FoM)

- $L$ is the probability distribution of SN Ia
- $F$ is the Fisher Matrix, a statistical tool

$L(\mu|\Theta); \quad \Theta = (w_0, w_a, \Omega_\Lambda, \Omega_k, ...)$

$F \approx \left\langle \frac{\partial^2(-\ln L)}{\partial \theta_i \theta_j} \right\rangle$

$FoM \propto \frac{1}{\text{Area}_{\text{ellipse}}}$

Left: 95% confidence contour: constrains the values of $w_a$ and $w_0$, parameters that model the time dependency of Dark Energy. The FoM is proportional to the reciprocal of the ellipse area.
Factors contributing to the FoM

- Number of Supernovae
- Distance Modulus error
- Core Collapse contamination
  - How? Fitting $\left\langle \mu_{\text{cc}} \right\rangle - \left\langle \mu_{\text{Ia}} \right\rangle$ in $z$ bins
  - $f_{\text{cc}} \rightarrow$ probability that SN is CC, i.e. (1-purity)
  - We use 100% of the value of $f_{\text{cc}}$ as its uncertainty, this uncertainty is used as a prior for the FoM.

Signal to Noise ratio cuts affect all of the above
Hubble scatter plots

SALT simulations with SALT fits

SNR 5_5_5

SN Ia and SN Core Collapse

SN Core Collapse Types

<table>
<thead>
<tr>
<th>SN Type</th>
<th>$M_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIP</td>
<td>$-15.66 \pm 0.16$</td>
</tr>
<tr>
<td>Ib/c</td>
<td>$-16.09 \pm 0.23$</td>
</tr>
<tr>
<td>IIL</td>
<td>$-17.44 \pm 0.22$</td>
</tr>
<tr>
<td>IIln</td>
<td>$-16.86 \pm 0.59$</td>
</tr>
</tbody>
</table>

Li et. Al. (2011a), R-band magnitudes
FoM vs Number of SN

Blue dots:
DES SNe + stage II + Planck priors
Sqrt(N) fit

Purple dots:
DES SNe Ia (FoM x1000)
Linear fit

Num SN
Average mu error for Ia and CC

MLCS sim and fit

SNR_10_5_5

SNR_3_3_0

CC mu reported error ~ 2 times Ia error

CC mu reported error ~ 4 times Ia error
FoM scaling mu error x2 or x4

- FoM decreases from 250 to 188 with mu err x2
- FoM decreases from 250 to 133 with mu err x4

(SNR_10_5_5 – la only)
## FoM vs fpMLCS cut

<table>
<thead>
<tr>
<th>SNRMAX cuts</th>
<th>ID algorithm</th>
<th>FoM SNIa only</th>
<th>FoM SNIa and SNCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR-3-3-0</td>
<td>$f_p$MLCS&gt; 0.05</td>
<td>332.8</td>
<td>139.2</td>
</tr>
<tr>
<td>SNR-3-3-0</td>
<td>$f_p$MLCS&gt; 0.1</td>
<td>316.4</td>
<td>137.2</td>
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<tr>
<td>SNR-3-3-0</td>
<td>$f_p$MLCS&gt; 0.2</td>
<td>306.2</td>
<td>136.7</td>
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<tr>
<td>SNR-10-5-5</td>
<td>$f_p$MLCS&gt; 0.05</td>
<td>251.7</td>
<td>238.3</td>
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<tr>
<td>SNR-10-5-5</td>
<td>$f_p$MLCS&gt; 0.1</td>
<td>250.4</td>
<td>244.9</td>
</tr>
<tr>
<td>SNR-10-5-5</td>
<td>$f_p$MLCS&gt; 0.2</td>
<td>247.5</td>
<td>245.0</td>
</tr>
</tbody>
</table>

| Table 5. The Dark Energy Task Force Figure of Merit is presented for a variety of MLCS fit probability selection criteria. |  |

**FoM is fairly insensitive to precise fpMLCS cut**
Example: scaling of FoM, including CC

- **SNR_3_3_0** – loosest cuts (MLCS)
  - FoM for Ia (only) = 303
  - FoM for Ia + CC (with Ia mu error) = 354
  - FoM for Ia + CC (no systematics) = 316
  - FoM for Ia + CC + CC systematics = 137

- Dispersion in mu of CC is not included in DETF FoM. Our plan is to change the intrinsic dispersion amount to match the total sample Ia +CC RMS. This will increase our sensitivity to purity.
Overall, FoM is extremely sensitive to purity.
For example for MLCS, 97% → 91% change in purity is a drop of 61 in FoM.
Comparable to largest systematic uncertainty in Bernstein et al. (2011).
Additional variables to improve purity

• SALT color
• SALT $x_1$
• Hubble residuals
SALT color

10_5_5

3_3_0
SALT $x_1$

10_5_5

3_3_0

![Histograms](image-url)
SALT $x_1$ vs color

SNR_3_3_0

- SNIa
- SNCC
Would like to apply a cut that is very insensitive to cosmology (next slide...).
If we trust the Ia widths from the simulation, cutting at peak ± 1 mag in each bin would be insensitive to cosmology and efficient.
Conclusions

• In our analysis, the DETF Figure of Merit drops quickly for purities below 95%.
• SALT fitting allows more core collapse SNe to have decent fit probabilities, leading to lower purities than MLCS.
• Additional cuts being investigated to improve purities.