



# Type Ia supernovae selection and forecast of cosmology constraints for the Dark Energy Survey



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**Astroparticle Physics**

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**Type Ia supernovae selection and forecast of cosmology constraints for the Dark Energy Survey**

Eda Gjergo<sup>1,2,\*</sup>, Jefferson Duggan<sup>3</sup>, John D. Cunningham<sup>4,5</sup>, Steve Kuhlmann<sup>6</sup>, Rahul Biswas<sup>7</sup>, Eve Kovacs<sup>8</sup>, Joseph P. Bernstein<sup>9</sup>, Harold Spinka<sup>9</sup>

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<sup>2</sup>Illinois Institute of Technology, Dept. of Physics, 3541 S. Maryland Ave., Chicago, IL 60607, USA  
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**ABSTRACT**

We present the results of a study of selection criteria to identify Type Ia supernovae photometrically in a simulated broad sample of Type Ia supernovae and core-collapse supernovae. Our simulated sample is a realization of the expected view of the Dark Energy Survey. This is the first broad and secure Type Ia supernova sample ever compiled and used to help separate the Type Ia supernovae from the core-collapse sample. The light curves (LC) from the Figure of Merit (FoM) (modified to include core-collapse supernovae) are used to discriminate among the various selection criteria. This study of various selection criteria for Type Ia supernovae candidates in the DE is an essential step in our understanding of the Figure of Merit. Different factors that contribute to the Figure of Merit are detailed. With our analysis methods, both SALT2 and SALT2+SNCC figures of merit improve with higher selection cuts and higher purity, peaking at 98% purity.

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**Importance of study:**

- Future supernovae surveys will be largely or entirely photometric.
- How to correctly distinguish SNIa from Core Collapse using photometry?
- Trade-off between efficiency and purity

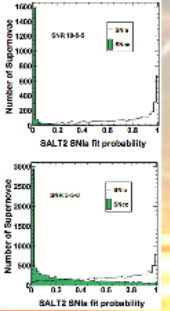
**Conclusions of study:**

- A purity of 98% optimizes the supernovae sample that constrains cosmology

### How do we select our sample?

- Simulation done in SNIANA, K. Kasater et al., PASP 121 (2009) 1028-1035.
- Templates of both Type Ia SNe (SNIa) and Core-collapse SNe: Ibc, IIc, IIIc, IIn (SNCC). These follow the fractions from W. Li et al., MNRAS 412 (2011) 1441-1472.
- We select the supernovae with a signal-to-noise ratio as defined in the table below
- We compare our simulated sample to a SNIa light curve model, SALT2, Guy et al., (2007), and we keep the SNIa with fit probability > 0.1

LCID	Signal
2 Filter: i+g+R+Z+Y	SNIa 2-2-0
3 Filter: i+g+R+Z+Y	SNIa 3-3-0
4 Filter: i+g+R+Z+Y	SNIa 4-4-0
5 Filter: i+g+R+Z+Y	SNIa 5-5-0
6 Filter: i+g+R+Z+Y	SNIa 6-6-0



### Figure of Merit (FoM)

Below: Figure of Merit as advocated in Dark Energy Task Force (DETF). Constrains the values of  $w_0$  and  $w_0$  parameters that model the time dependency of Dark Energy.

Albrecht et al. (2006)

MFC: CL, Modulus Only  
 MFC: CL, Stars, Flux

DETF Stage 9 Prior

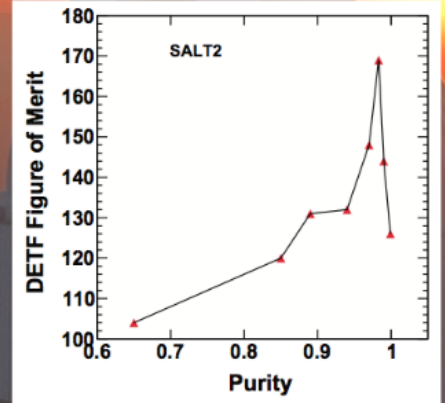
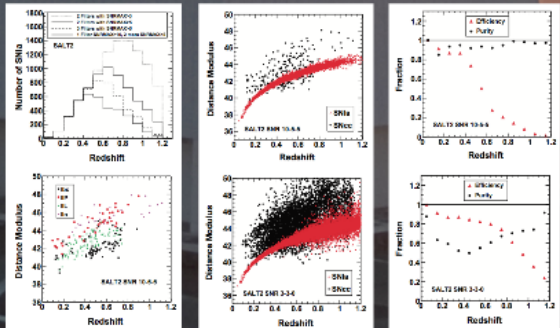
**What affects the FoM:**

- Number of Supernovae
- Distance Modulus error
- Core Collapse contamination

\*F is the Fisher Matrix, a statistical tool  
 L is the probability distribution

$$L(\mu|\theta) = \Theta = (\mu_0, w_0, \Omega_m, \Omega_b, \dots)$$

$$F = \frac{\partial^2 (-\ln L)}{\partial \theta_i \partial \theta_j}$$

$$FoM \propto \frac{1}{\text{Area}_{95\%}}$$






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 We present the results of a study of selection criteria to identify Type Ia supernovae photometrically in a simulated broad sample of Type Ia supernovae and core-collapse supernovae. Our simulated sample is a realization of the expected view of the Dark Energy Survey. By using our model and various Type Ia supernovae models we compare and used to help separate the Type Ia supernovae from the core-collapse sample. The figure shows the Figure of Merit (FoM) (modified to include core-collapse supernovae) is used to discriminate among the various selection criteria. This study of various selection criteria for Type Ia supernovae candidates in the DES to evaluate core-collapse contamination using the Figure of Merit. Different factors that contribute to the Figure of Merit are detailed. With our analysis methods, both SALT2 and SALT2+SNR improve with higher selection cuts and higher purity, yielding a 98% purity.

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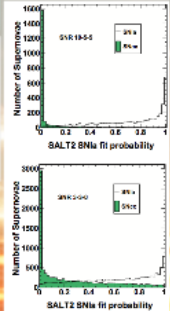
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Case	Signal
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2 Filter: i+g+R+Z+Y	SNIa 5-5-0
1 Filter: i+g+R+Z+Y	SNIa 5-5-5
1 Filter: SNIaMAX	i+g+R+Z+Y



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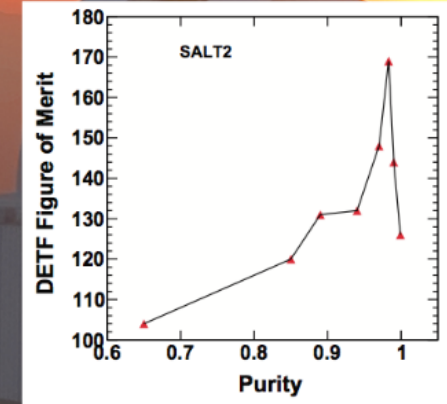
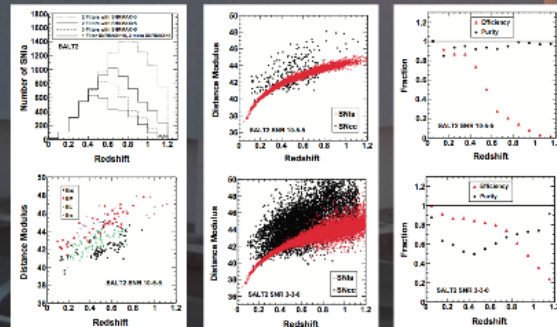
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$$FoM \propto \frac{1}{\text{Area}_{90\%}}$$


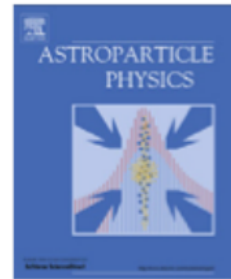
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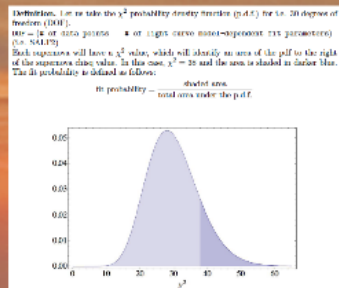
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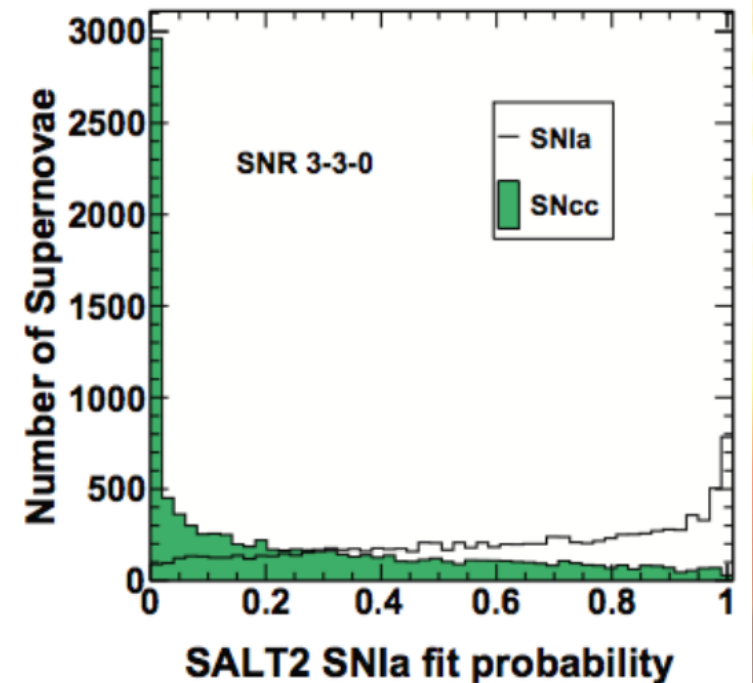
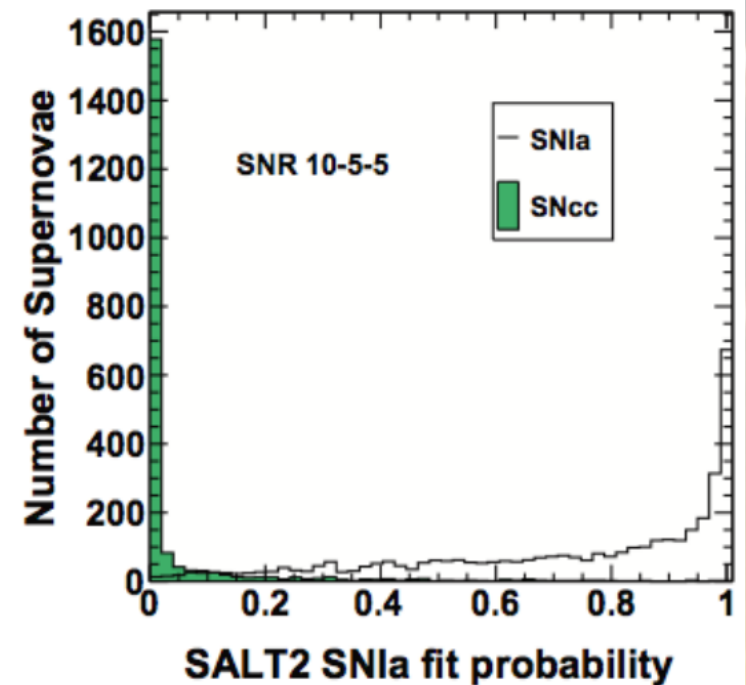


# How do we select our sample?

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Cuts	Symbol
2 filters with SNRMAX $\geq 3$	SNR-3-3-0
2 filters with SNRMAX $\geq 5$	SNR-5-5-0
3 filters with SNRMAX $\geq 5$	SNR-5-5-5
1 filter SNRMAX $\geq 10$ , 2 more filters SNRMAX $\geq 5$	SNR-10-5-5

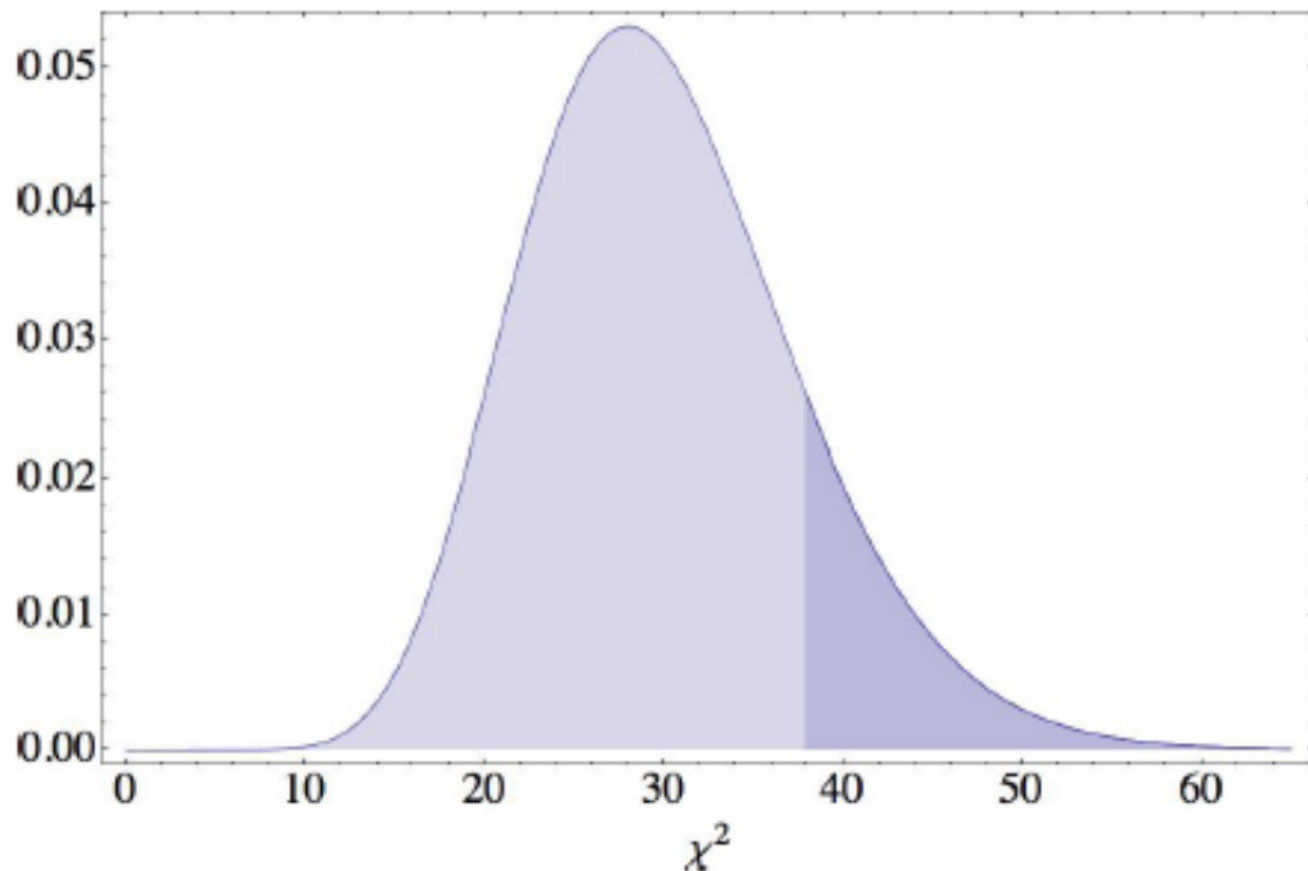


**Definition.** Let us take the  $\chi^2$  probability density function (p.d.f.) for i.e. 30 degrees of freedom (DOF).

DOF = (# of data points - # of light curve model-dependent fit parameters)  
(i.e. SALT2)

Each supernova will have a  $\chi^2$  value, which will identify an area of the pdf to the right of the supernova  $\chi^2$  value. In this case,  $\chi^2 = 38$  and the area is shaded in darker blue. The fit probability is defined as follows:

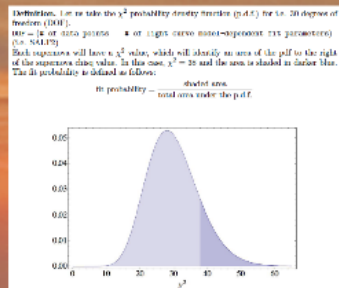
$$\text{fit probability} = \frac{\text{shaded area}}{\text{total area under the p.d.f.}}$$



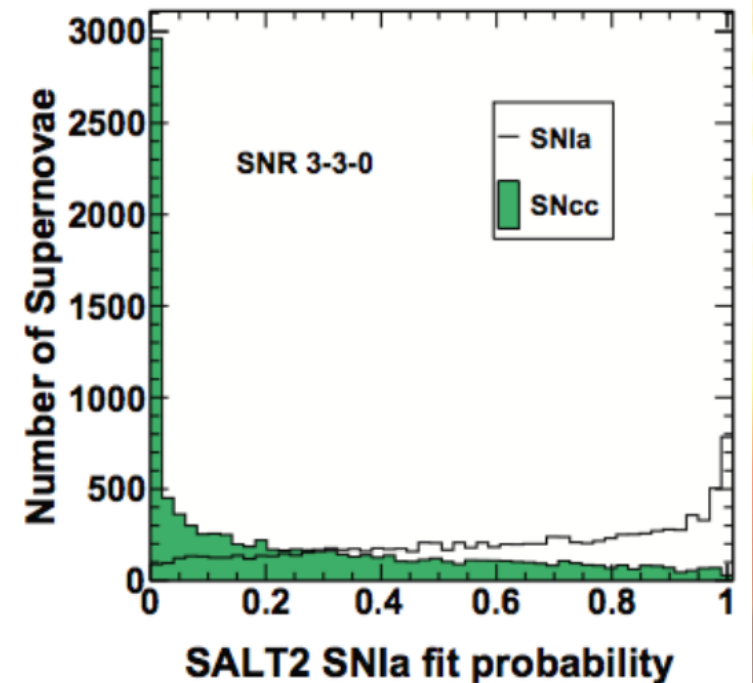
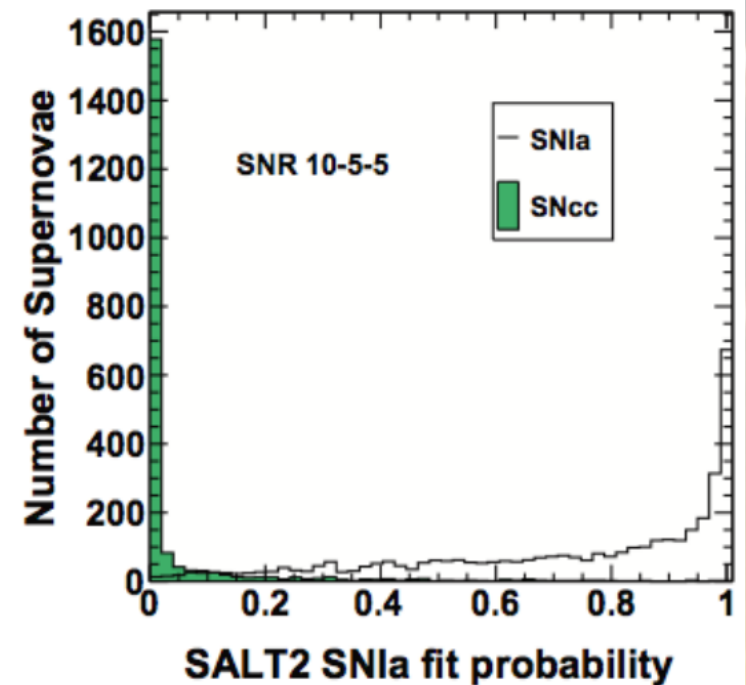


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1 filter SNRMAX $\geq 10$ , 2 more filters SNRMAX $\geq 5$	SNR-10-5-5

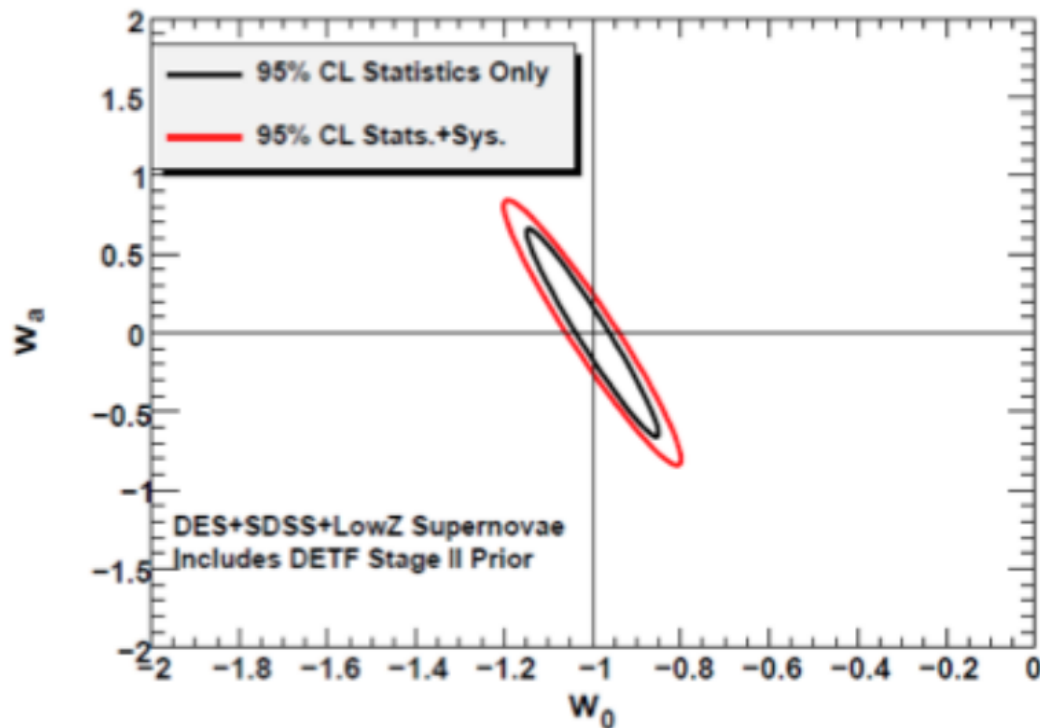


$$w(z) = w_0 + \frac{w_a}{1+z}$$

# Figure of Merit (FoM)

Below: Figure of Merit as advocated in Dark Energy Task Force (DETF). Constrains the values of  $w_a$  and  $w_0$ , parameters that model the time dependency of Dark Energy.

Albrecht et al. (2006)



## What affects the FoM:

- Number of Supernovae
- Distance Modulus error
- **Core Collapse contamination**

- F is the Fisher Matrix, a statistical tool
- L is the probability distribution

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

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

$$FoM \propto \frac{1}{Area_{ellipse}}$$



## CPL parametrization

M. Chevallier, D. Polarski, Int.

J. Mod. Phys. D 10 (2001) 213–223. <astro-ph/0009008>.

$$w(z) = w_0 + w_a \frac{z}{1+z}, \text{ where}$$

$$z = \frac{\lambda_{\text{observed}}}{\lambda_{\text{emitted}}} - 1 = \text{redshift}$$

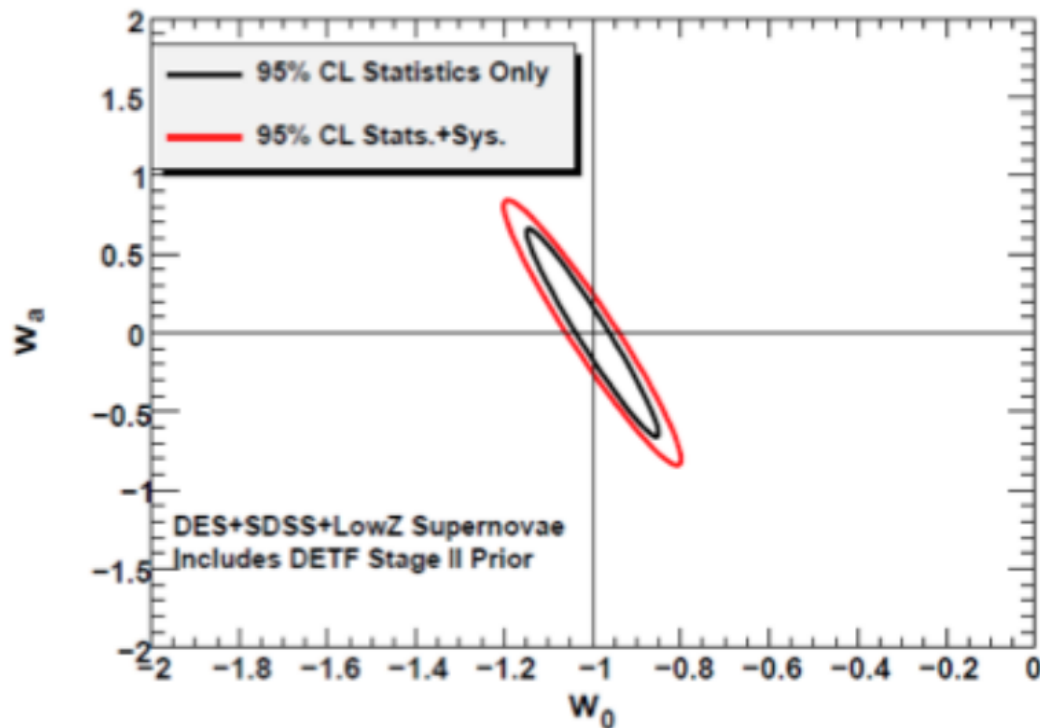
$$w = \frac{p}{\rho} = \frac{\text{pressure}}{\text{density}}$$

$$w(z) = w_0 + \frac{w_a}{1+z}$$

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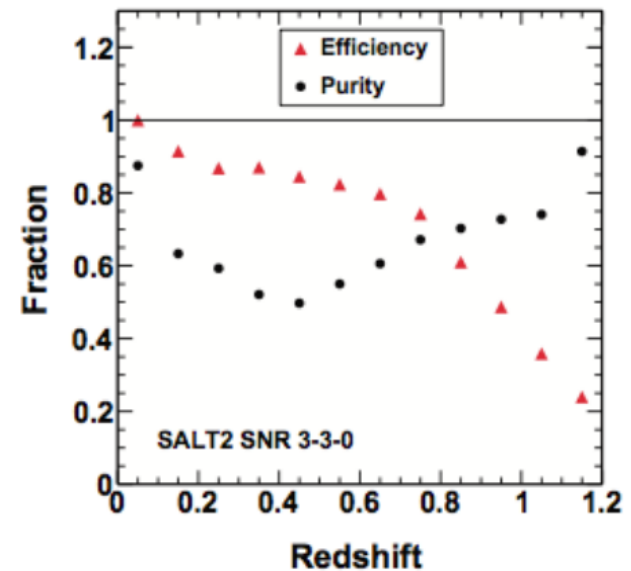
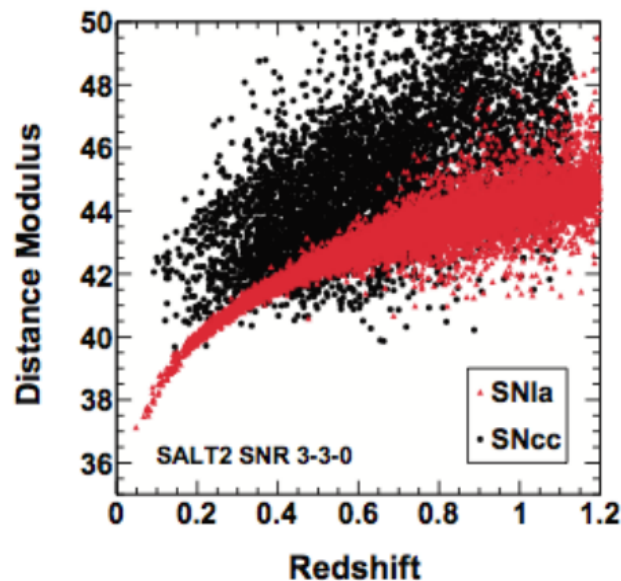
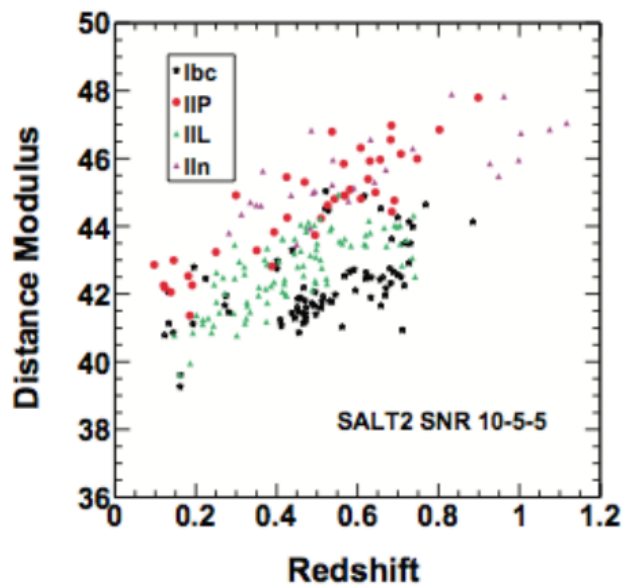
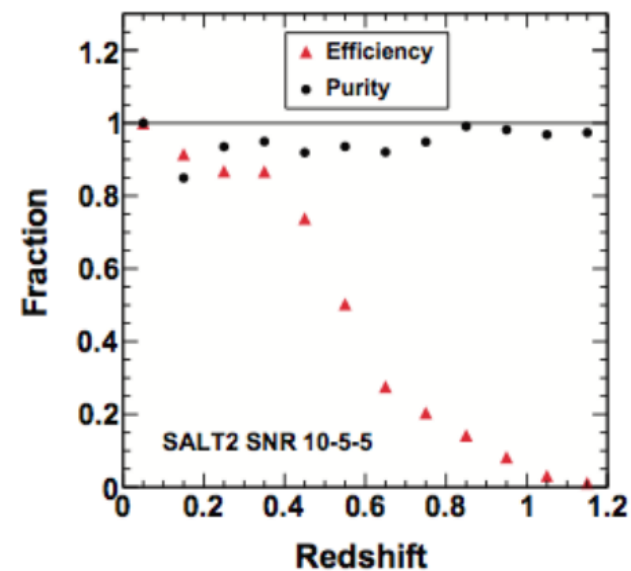
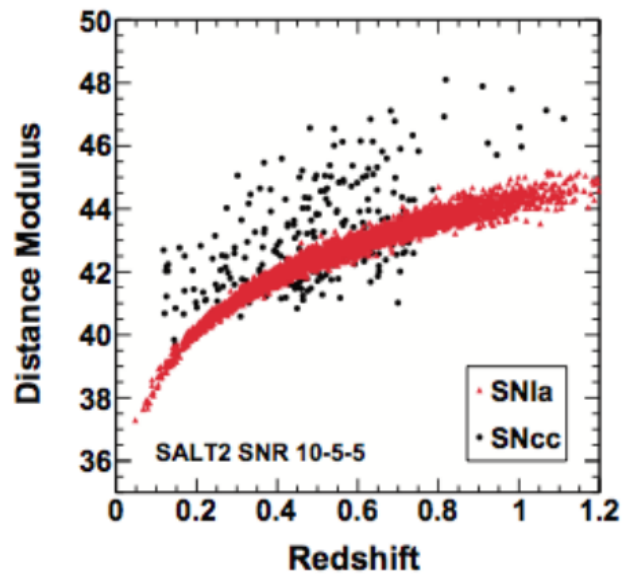
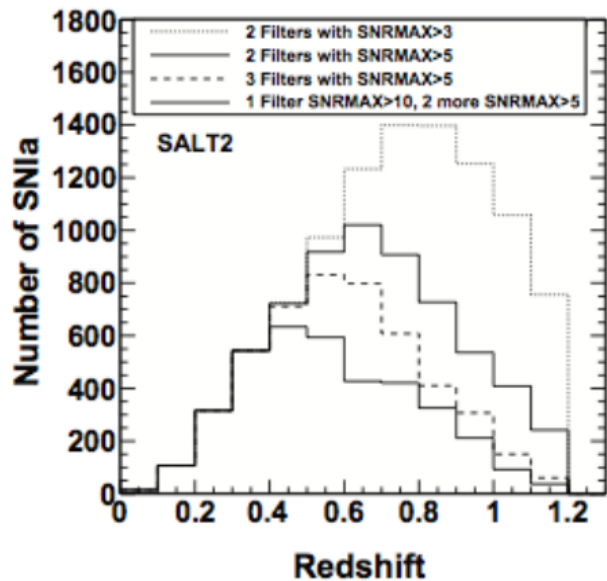
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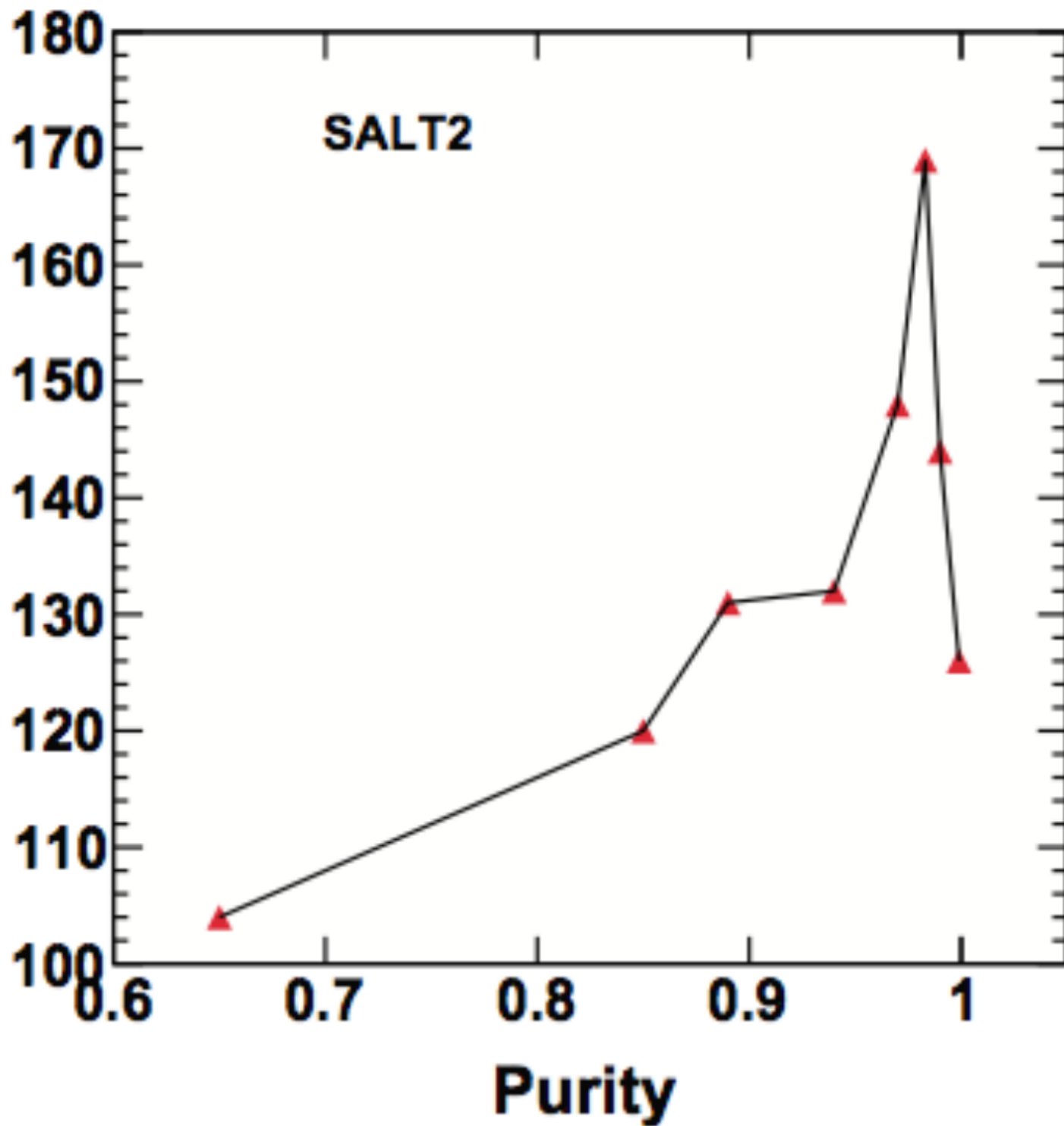
$$F \approx \left\langle \frac{\partial^2 (-\ln L)}{\partial \theta_i \partial \theta_j} \right\rangle;$$

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**DETF Figure of Merit**







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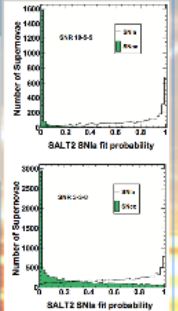
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Code	Symbol
2 Filter: $z < 0.3$ SNR: 20.0	SNIa 2-2-0
3 Filter: $z < 0.3$ SNR: 15.0	SNIa 3-3-0
4 Filter: $z < 0.3$ SNR: 10.0	SNIa 4-4-0
5 Filter: $z < 0.3$ SNR: 5.0	SNIa 5-5-0
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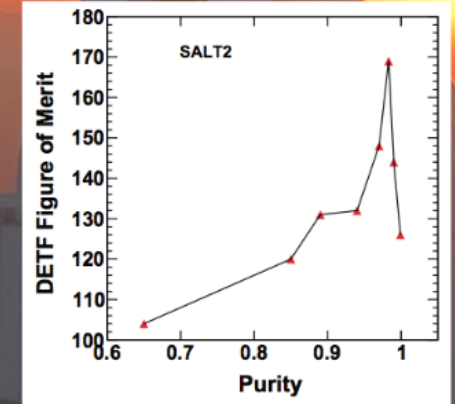
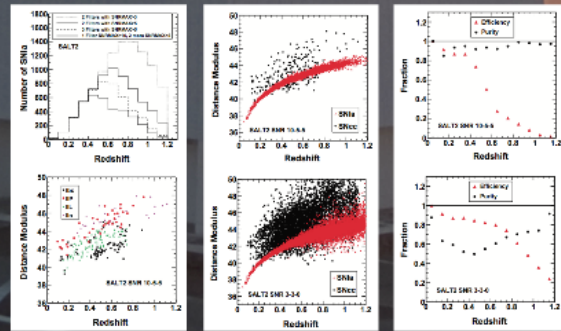
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