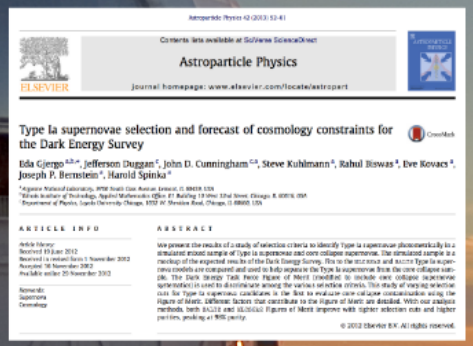
# Type Ia supernovae selection and forecast of cosmology constraints for the Dark Energy Survey


Astroparticle Physics

Contents lists available at SciVerse ScienceDirect

Astroparticle Physics

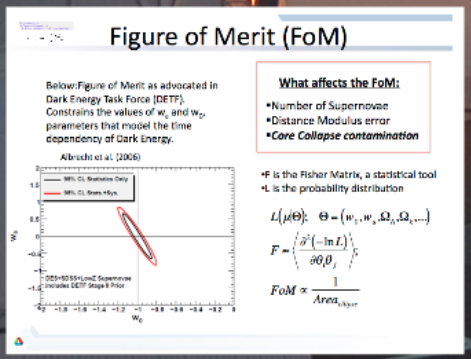
journal homepage: www.elsevier.com/locate/astropart

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

Eda Gjergo, Jefferson Duggan, John D. Cunningham, Steve Kuhlmann, Rahul Biswas, Eve Kovacs, Joseph P. Bernstein, Harold Spinka

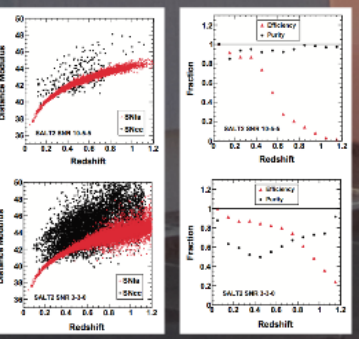
ARTICLE INFO

ABSTRACT



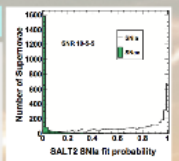

Importance of study:
- Future supernovae surveys will be largely or entirely photometric.
- How to correctly distinguish SNIa from Core Collapse using photometry?
- Trade-off between efficiency and purity

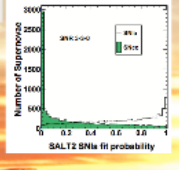
Conclusions of study:
- A purity of 98% optimizes the supernovae sample that constrains cosmology

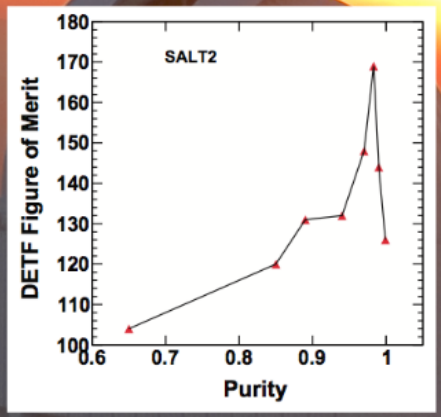



## How do we select our sample?

- Simulation done in SNANA, R. Kessler et al., PASP 121 (2009) 1028–1035.
- Templates of both Type Ia SNe (SNIa) and Core Collapse SNe: Ib/c, IIP, IIL, 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 SNe with fit probability > 0.1

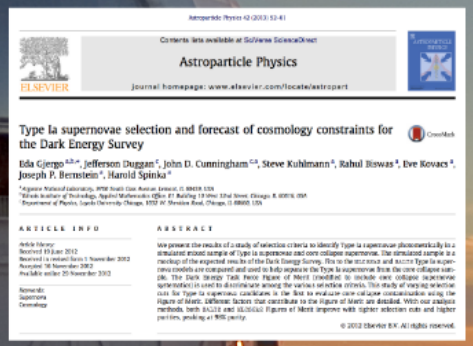




E. Gjergo et al. / Astroparticle Physics 42 (2013) 52–61

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


Astroparticle Physics

Contents lists available at SciVerse ScienceDirect

Astroparticle Physics

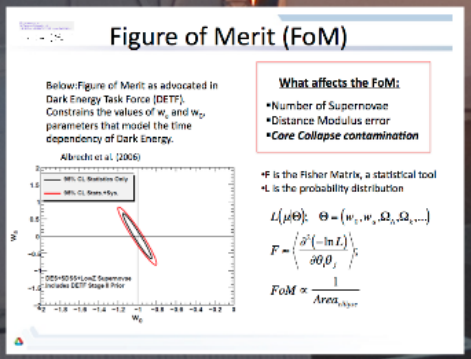
journal homepage: www.elsevier.com/locate/astropart

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

Eda Gjergo, Jefferson Duggan, John D. Cunningham, Steve Kuhlmann, Rahul Biswas, Eve Kovacs, Joseph P. Bernstein, Harold Spinka

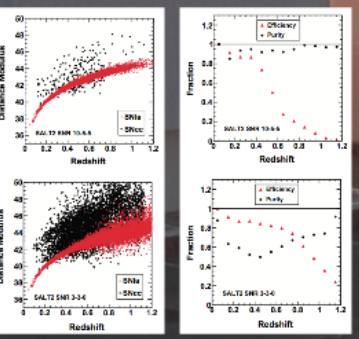
ARTICLE INFO

ABSTRACT



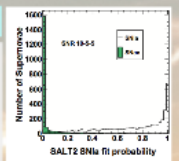

Importance of study:
- Future supernovae surveys will be largely or entirely photometric.
- How to correctly distinguish SNIa from Core Collapse using photometry?
- Trade-off between efficiency and purity

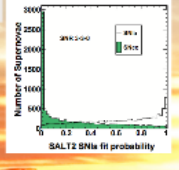
Conclusions of study:
- A purity of 98% optimizes the supernovae sample that constrains cosmology

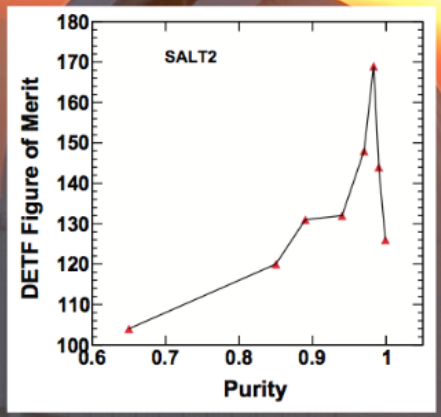



## How do we select our sample?

- Simulation done in SNANA, R. Kessler et al., PASP 121 (2009) 1028–1035.
- Templates of both Type Ia SNe (SNIa) and Core Collapse SNe: Ib/c, IIP, IIL, 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 SNe with fit probability > 0.1


E. Gjergo et al. / Astroparticle Physics 42 (2013) 52–61

Astroparticle Physics 42 (2013) 52–61

Contents lists available at SciVerse ScienceDirect

Astroparticle Physics

journal homepage: www.elsevier.com/locate/astropart

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

Eda Gjergo [a,b,*], Jefferson Duggan [c], John D. Cunningham [c,a], Steve Kuhlmann [a], Rahul Biswas [a], Eve Kovacs [a], Joseph P. Bernstein [a], Harold Spinka [a]

[a] Argonne National Laboratory, 9700 South Cass Avenue, Lemont, IL 60439, USA
[b] Illinois Institute of Technology, Applied Mathematics Office, E1 Building 10 West 32nd Street, Chicago, IL 60616, USA
[c] Department of Physics, Loyola University Chicago, 1032 W. Sheridan Road, Chicago, IL 60660, USA

ARTICLE INFO

*Article history:*
Received 19 June 2012
Received in revised form 1 November 2012
Accepted 16 November 2012
Available online 29 November 2012

*Keywords:*
Supernova
Cosmology

ABSTRACT

We present the results of a study of selection criteria to identify Type Ia supernovae photometrically in a simulated mixed sample of Type Ia supernovae and core collapse supernovae. The simulated sample is a mockup of the expected results of the Dark Energy Survey. Fits to the MLCS2k2 and SALT2 Type Ia supernova models are compared and used to help separate the Type Ia supernovae from the core collapse sample. The Dark Energy Task Force Figure of Merit (modified to include core collapse supernovae systematics) is used to discriminate among the various selection criteria. This study of varying selection cuts for Type Ia supernova candidates is the first 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 MLCS2k2 Figures of Merit improve with tighter selection cuts and higher purities, peaking at 98% purity.

Importance of study:

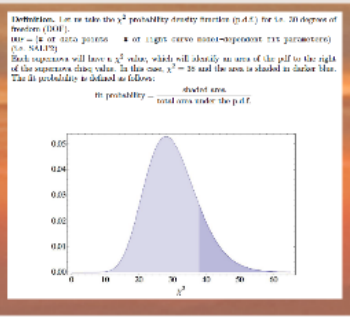
- Future supernovae surveys will be largely or entirely photometric.
- How  to correctly distinguish SNIa from Core Collapse using photometry?
- Trade-off between efficiency and purity

Conclusions of study:

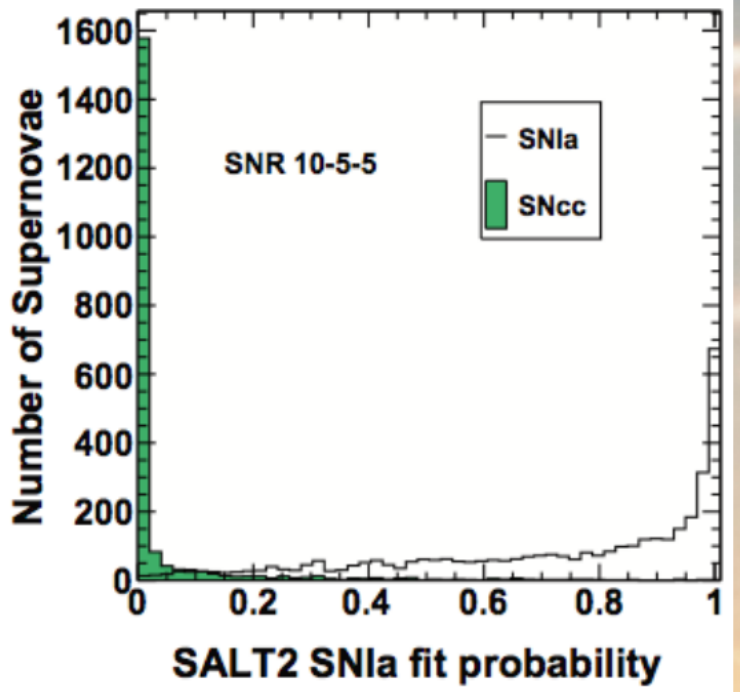
- A purity of 98% optimizes the supernovae sample that constrains cosmology

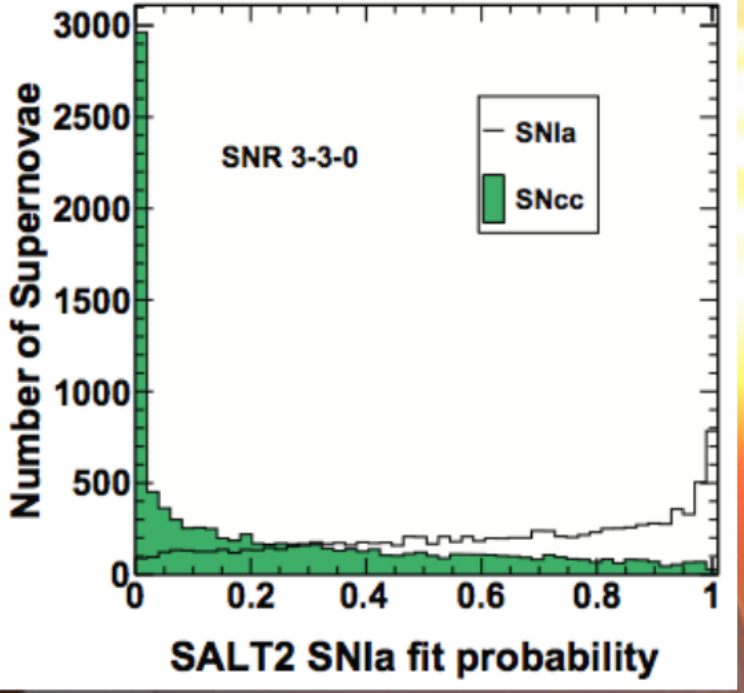
# *How do we select our sample?*

- Simulation done in SNANA, R. Kessler et al., PASP 121 (2009) 1028–1035.
- Templates of both Type Ia SNe (SNIa) and Core Collapse SNe: Ib/c, IIP, IIL, 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 SNe with fit probability > 0.1



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



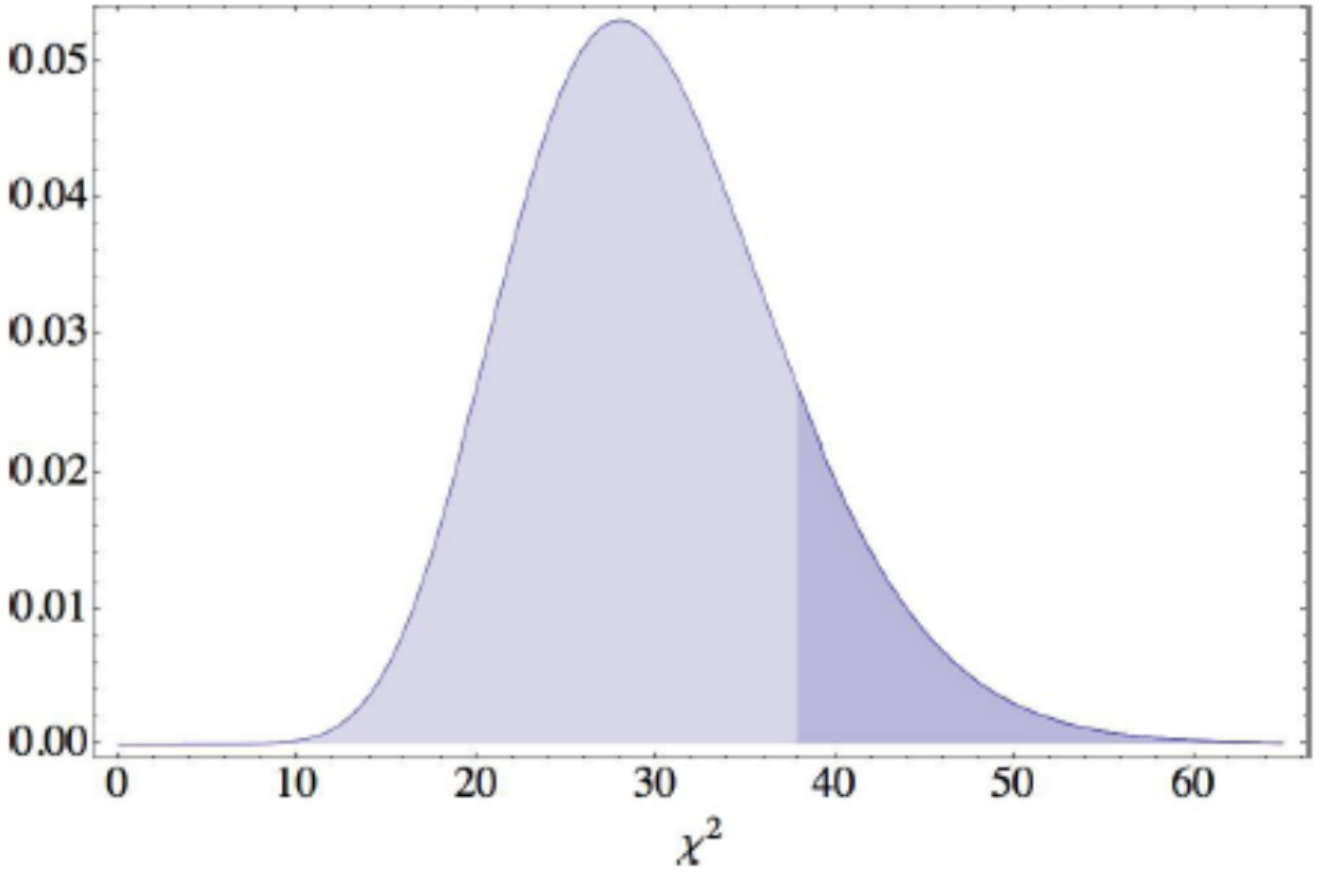



**Definition.** Let us take the $\chi^2$ probability density function (p.d.f.) for i.e. 30 degrees of freedom (DOF).

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

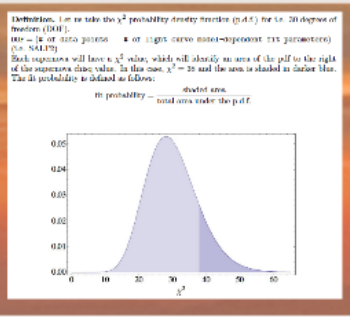
Each supernova will have a $\chi^2$ value, which will identify an area of the pdf to the right of the supernova chisq value. In this case, $\chi^2 = 38$ and the area is shaded in darker blue. The fit probability is defined as follows:

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

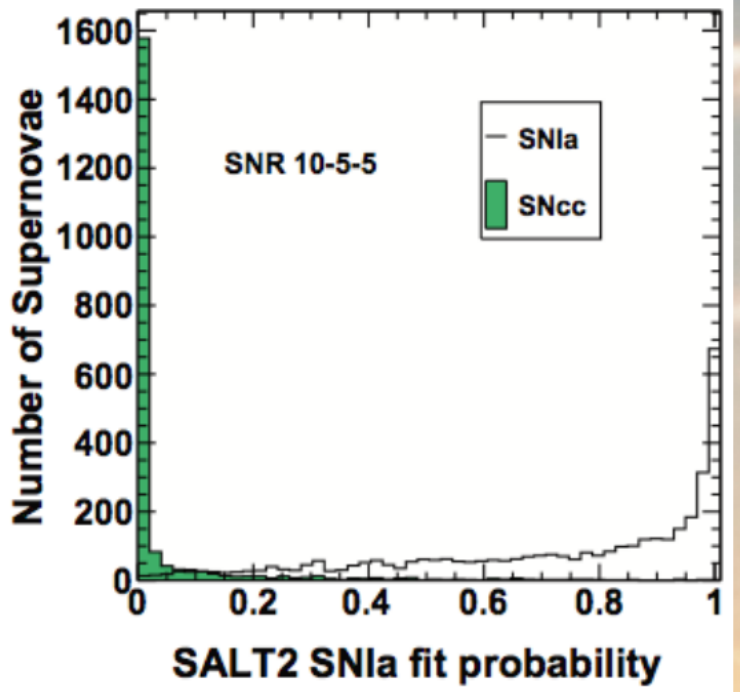


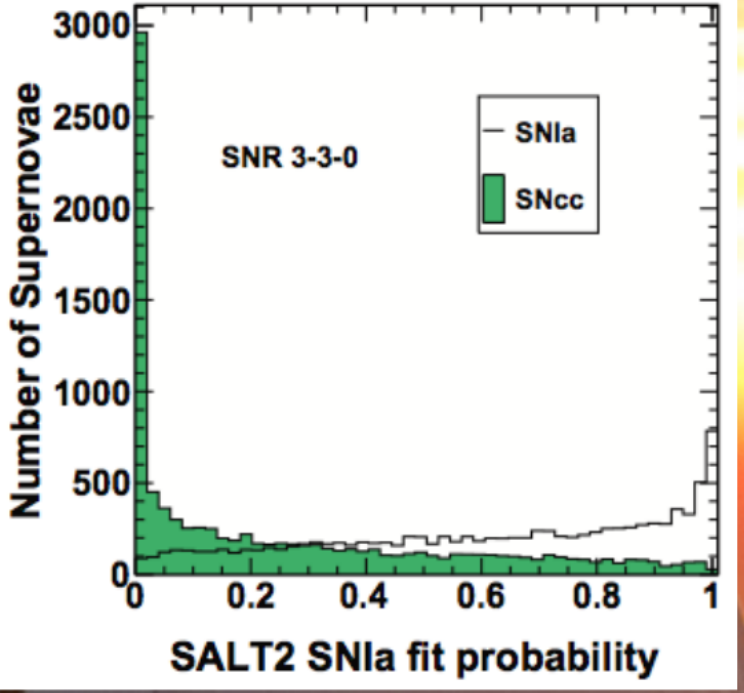
# *How do we select our sample?*

- Simulation done in SNANA, R. Kessler et al., PASP 121 (2009) 1028–1035.
- Templates of both Type Ia SNe (SNIa) and Core Collapse SNe: Ib/c, IIP, IIL, 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 SNe with fit probability > 0.1



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



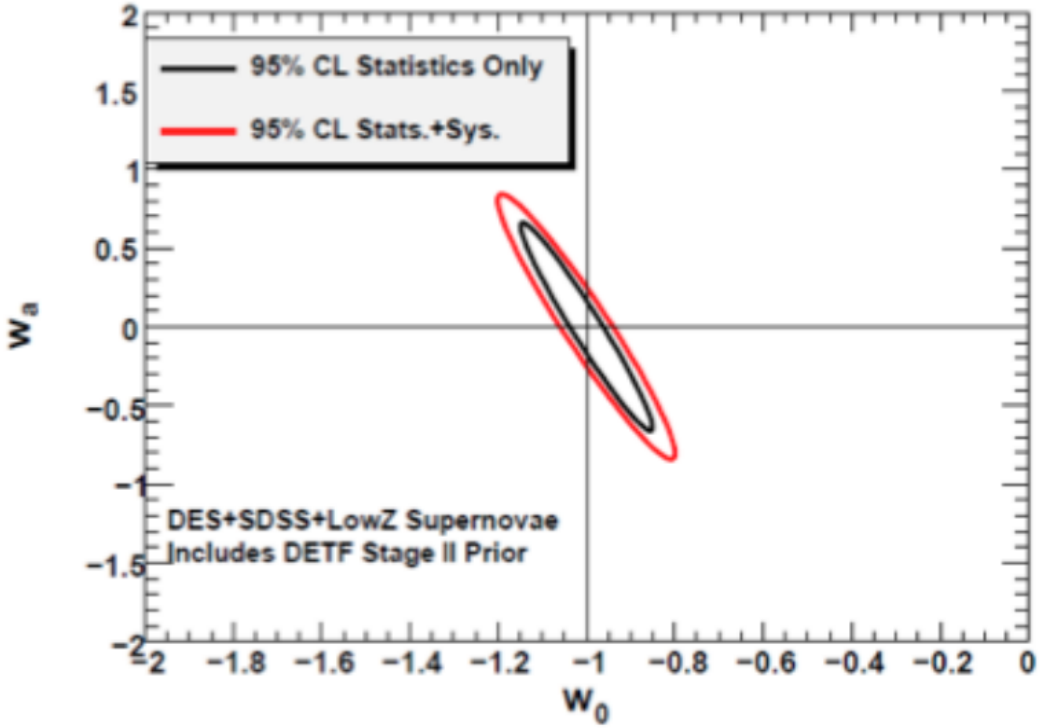



CPL parametrization
M. Chevallier, D. Polarski, Int.
J. Mod. Phys. D 10 (2001) 213-223, <astro-ph/0009008>.

# 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

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

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

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

CPL parametrization

M. Chevallier, D. Polarski, Int.

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

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

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

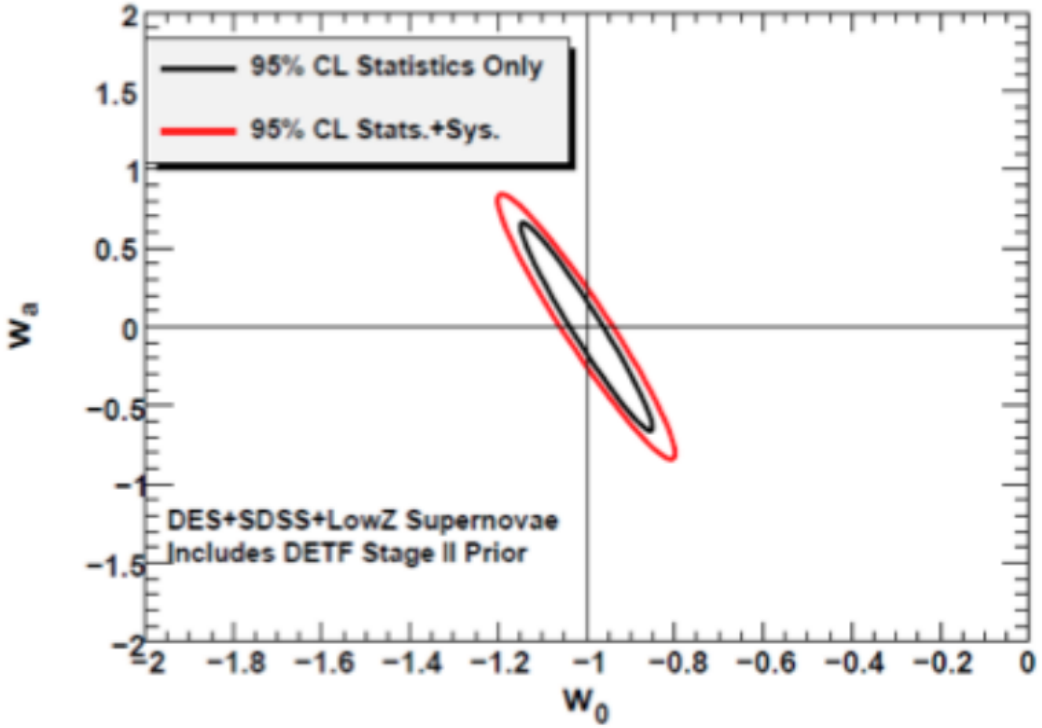
$$w = \frac{p}{\rho} = \frac{pressure}{density}$$

CPL parametrization
M. Chevallier, D. Polarski, Int.
J. Mod. Phys. D 10 (2001) 213-223, <astro-ph/0009008>.

# 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:**

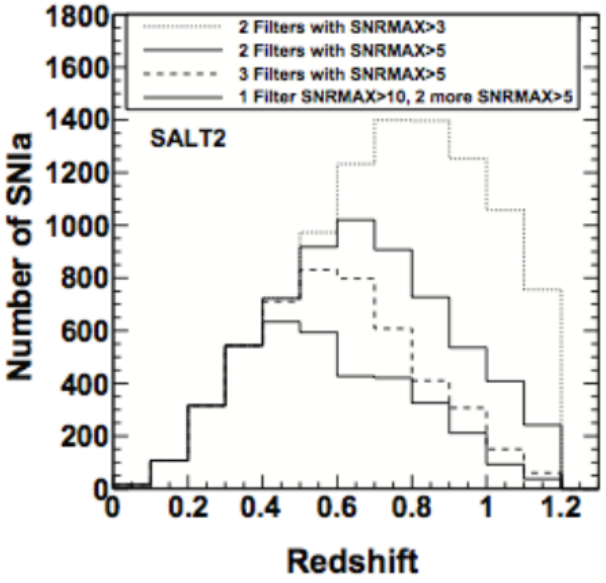
- Number of Supernovae
- Distance Modulus error
- ***Core Collapse contamination***

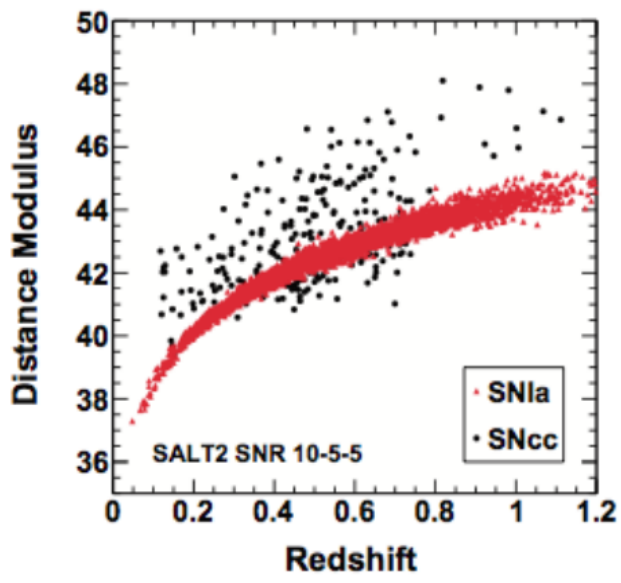
- F is the Fisher Matrix, a statistical tool
- L is the probability distribution

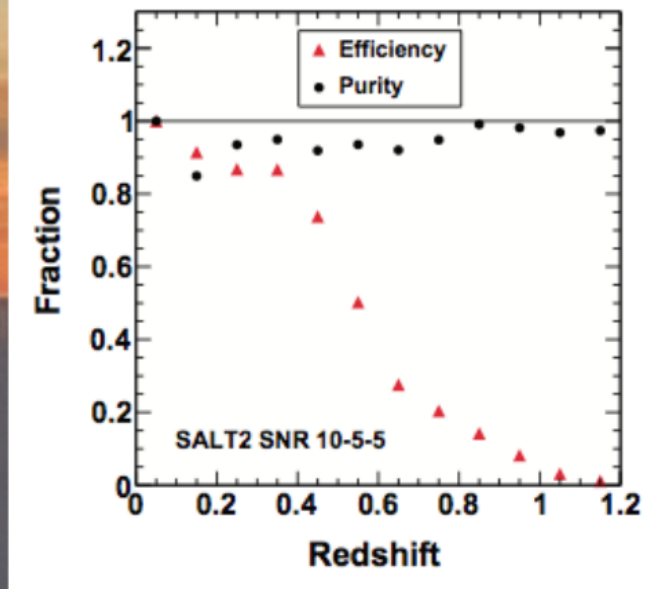
$$L(\mu|\Theta); \quad \Theta = (w_0, w_a, \Omega_\Lambda, \Omega_k, \ldots)$$

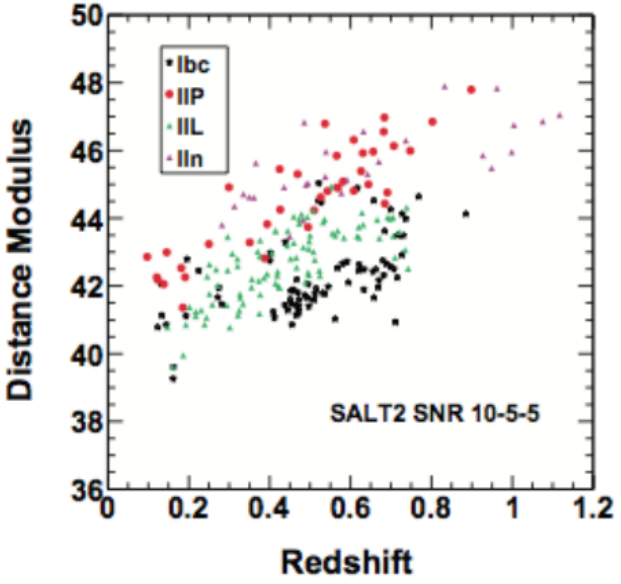
$$F \approx \left\langle \frac{\partial^2(-\ln L)}{\partial\theta_i\theta_j} \right\rangle;$$

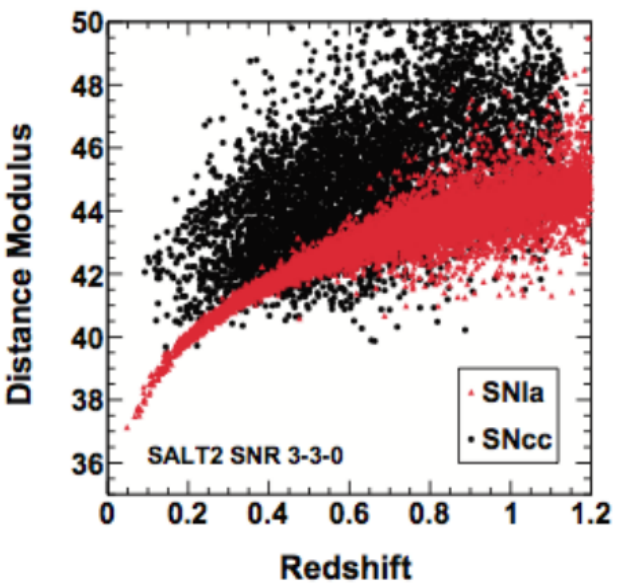
$$FoM \propto \frac{1}{Area_{ellipse}}$$

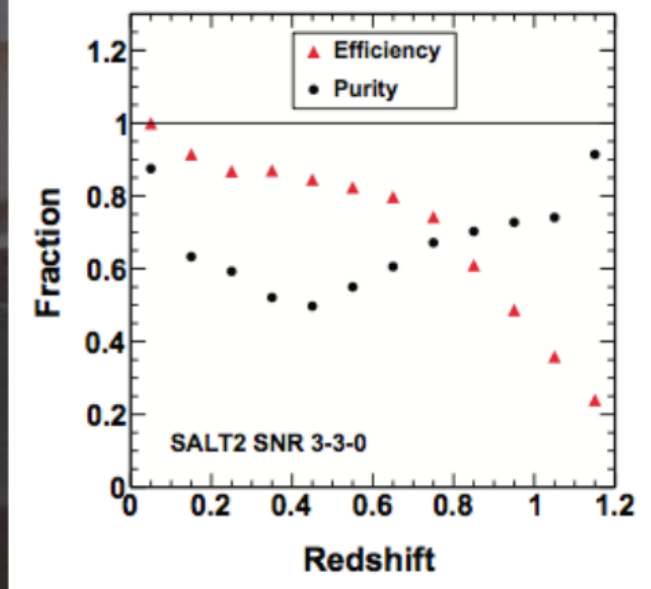

2 Filters with SNRMAX>3
2 Filters with SNRMAX>5
3 Filters with SNRMAX>5
1 Filter SNRMAX>10, 2 more SNRMAX>5
SALT2
Number of SNIa
Redshift

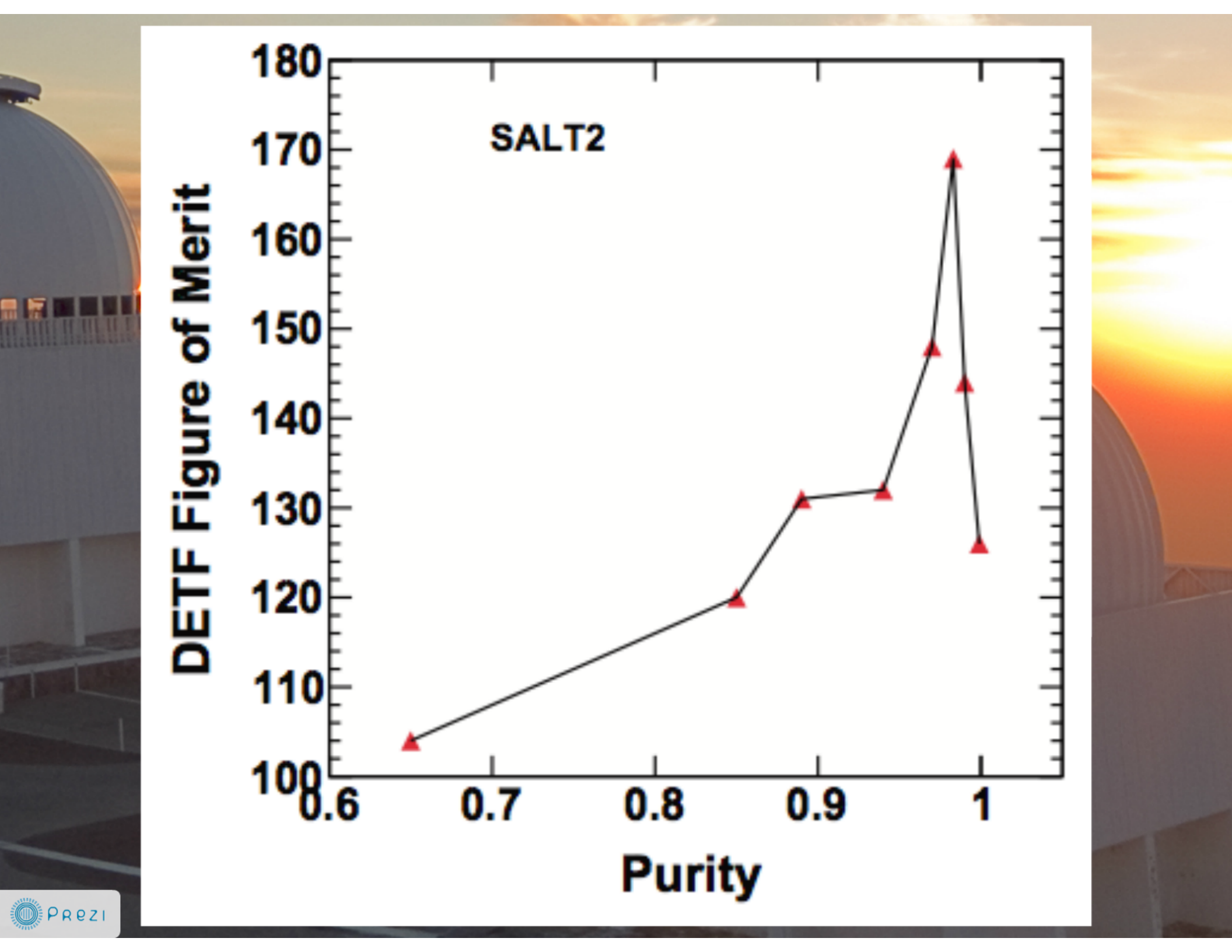

SNIa
SNcc
SALT2 SNR 10-5-5
Distance Modulus
Redshift


Efficiency
Purity
SALT2 SNR 10-5-5
Fraction
Redshift

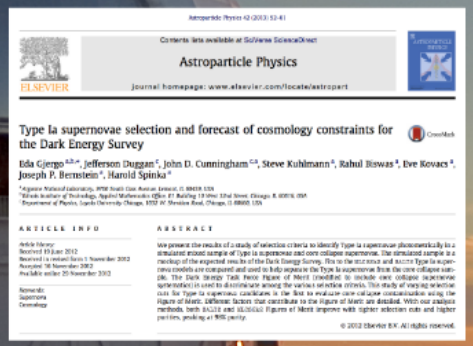

Ibc
IIP
IIL
IIn
SALT2 SNR 10-5-5
Distance Modulus
Redshift


SNIa
SNcc
SALT2 SNR 3-3-0
Distance Modulus
Redshift


Efficiency
Purity
SALT2 SNR 3-3-0
Fraction
Redshift


SALT2
DETF Figure of Merit
180
170
160
150
140
130
120
110
100
0.6
0.7
0.8
0.9
1
Purity

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


Astroparticle Physics 42 (2013) 52–61

Contents lists available at SciVerse ScienceDirect

Astroparticle Physics

journal homepage: www.elsevier.com/locate/astropart

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

Eda Gjergo[a,b,*], Jefferson Duggan[c], John D. Cunningham[c,1], Steve Kuhlmann[a], Rahul Biswas[a], Eve Kovacs[a], Joseph P. Bernstein[a], Harold Spinka[a]

ARTICLE INFO

ABSTRACT

We present the results of a study of selection criteria to identify Type Ia supernovae photometrically in a simulated mixed sample of Type Ia supernovae and core collapse supernovae. The simulated sample is a mockup of the expected results of the Dark Energy Survey. Fits to the SDSS-II and SNLS Type Ia supernova models are compared and used to help separate the Type Ia supernovae from the core collapse sample. The Dark Energy Task Force Figure of Merit (modified to include core collapse supernovae contamination) is used to discriminate among the various selection criteria. This study of varying selection cuts for Type Ia supernova candidates is the first 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 SIFTO Figures of Merit improve with tighter selection cuts and higher purities, peaking at 98% purity.

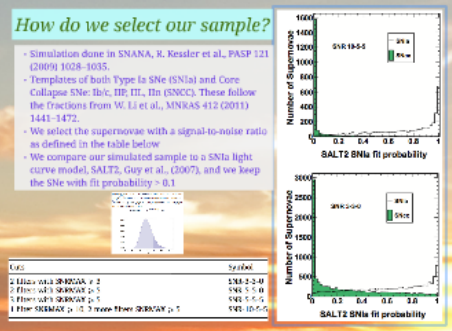
© 2012 Elsevier B.V. All rights reserved.

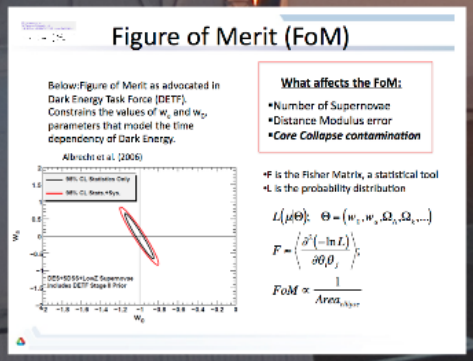
Importance of study:

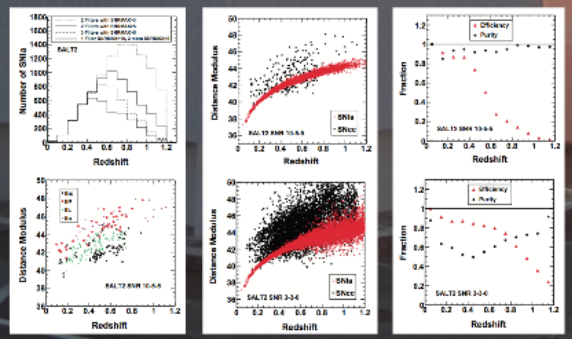
- Future supernovae surveys will be largely or entirely photometric.
- How to correctly distinguish SNIa from Core Collapse using photometry?
- Trade-off between efficiency and purity

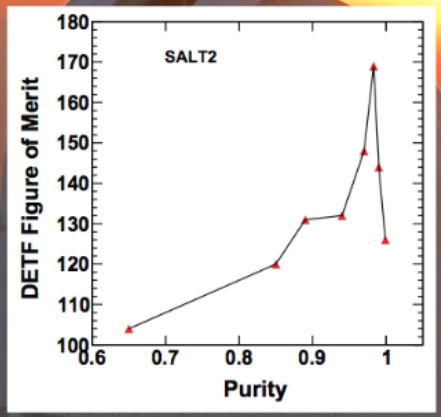
Conclusions of study:

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




E. Gjergo et al. / Astroparticle Physics 42 (2013) 52–61