Challenges of low and intermediate redshift supernova surveys

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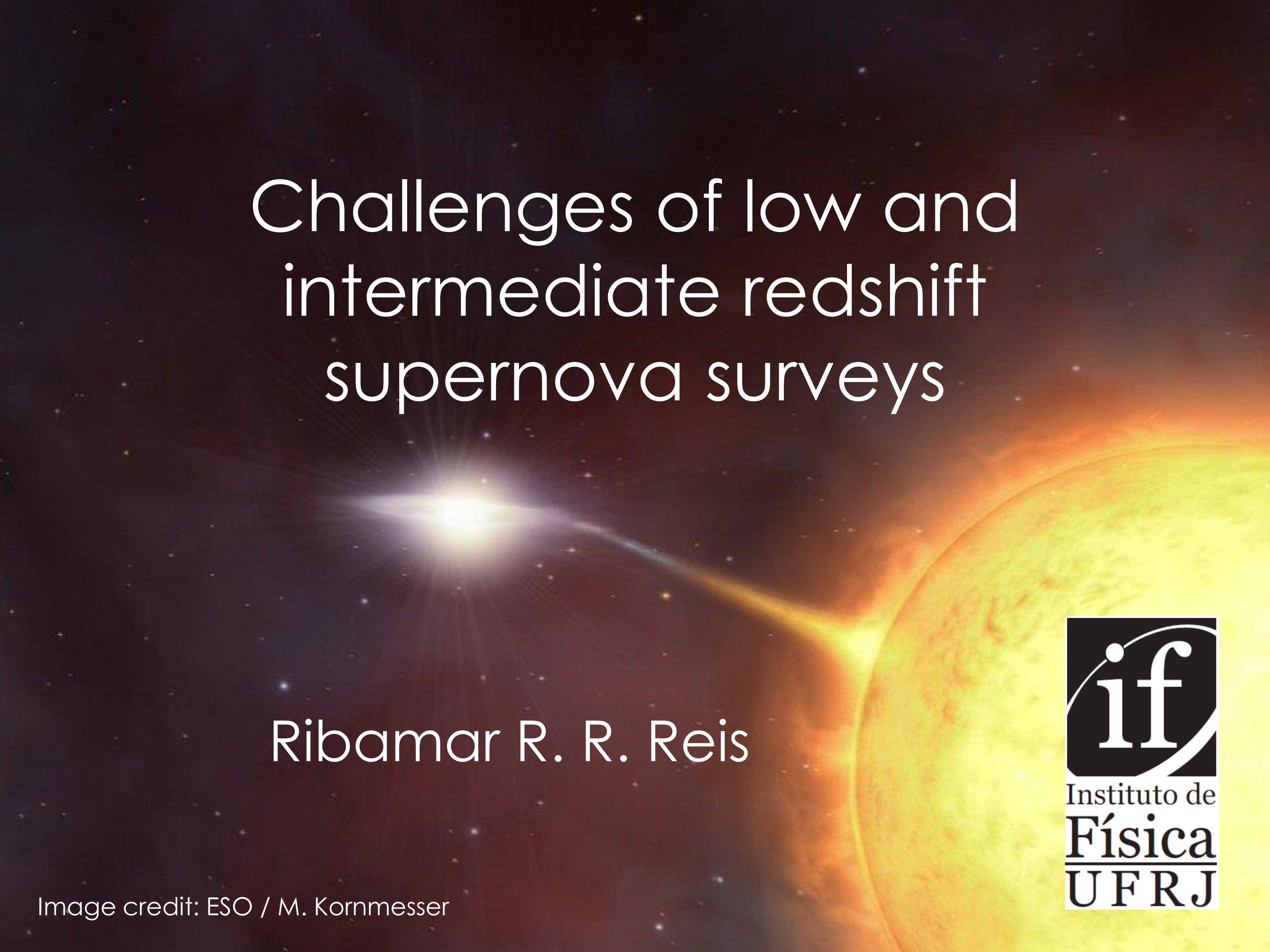


Image credit: ESO / M. Kornmesser

Introduction

Type Ia supernovae (SNeIa) are thermonuclear explosions of CO white dwarfs (WD) in binary systems.

Bright ($M \approx -19.5$, $L \approx 10^{43}$ ergs/s).

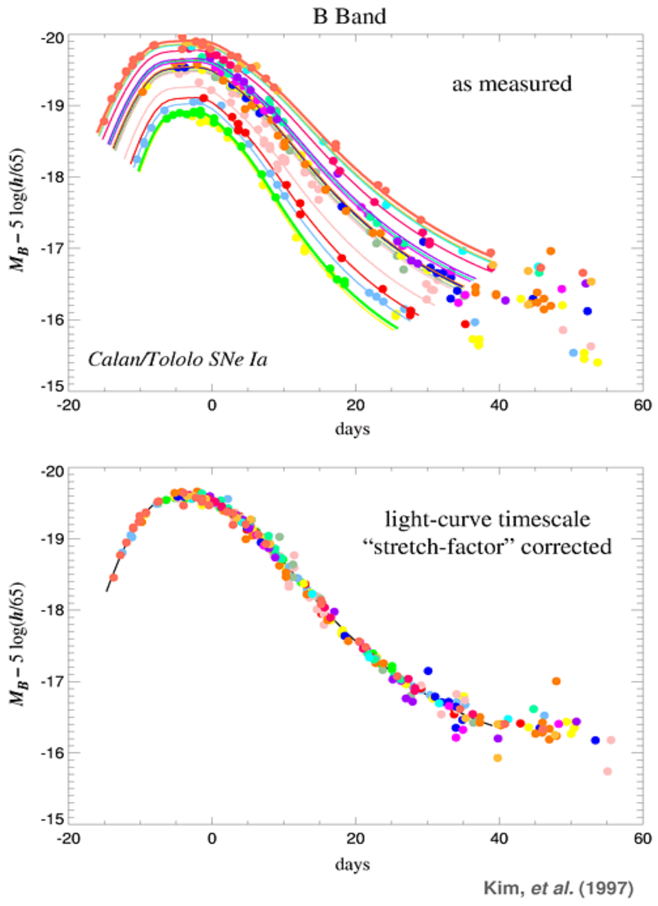
Homogeneous class (the WD is expected to explode at ~1.4 solar masses).

It takes place in all types of galaxies.

Good candidate for standardizable candle.

Identified via spectrum. Photometric identification introduces contamination. Purity and completeness depend on the number of filters and wavelength coverage.

Introduction



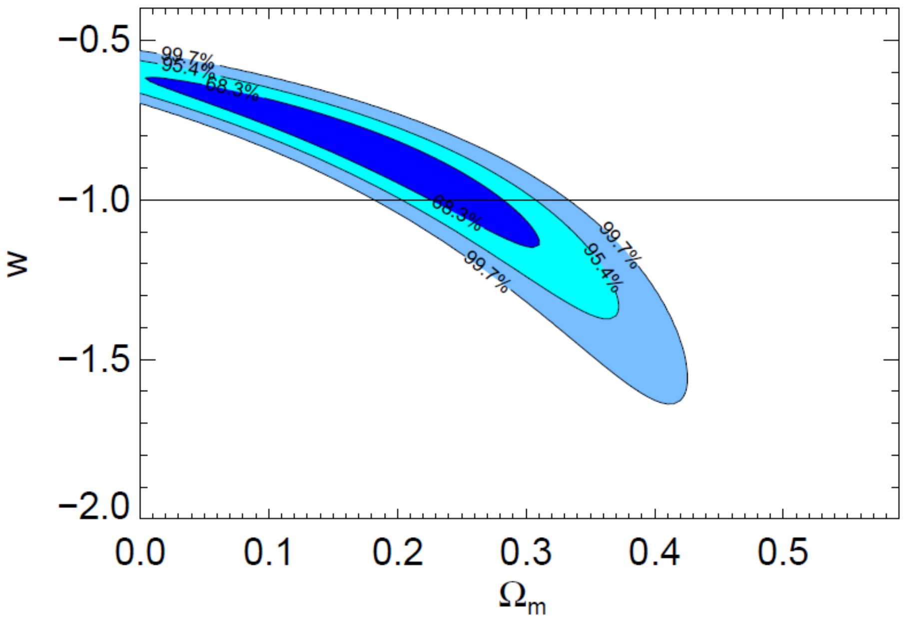
- SNeIa are not standard candles.
- They can be standardized.
- Empirical correlations: Brighter-Broader-Bluer.
- Different recipes available: light curve fitters.
- Examples: Multicolor Light Curve Shape (MLCS2k2) and Spectral Adaptive Lightcurve Template (SALT2)

Introduction

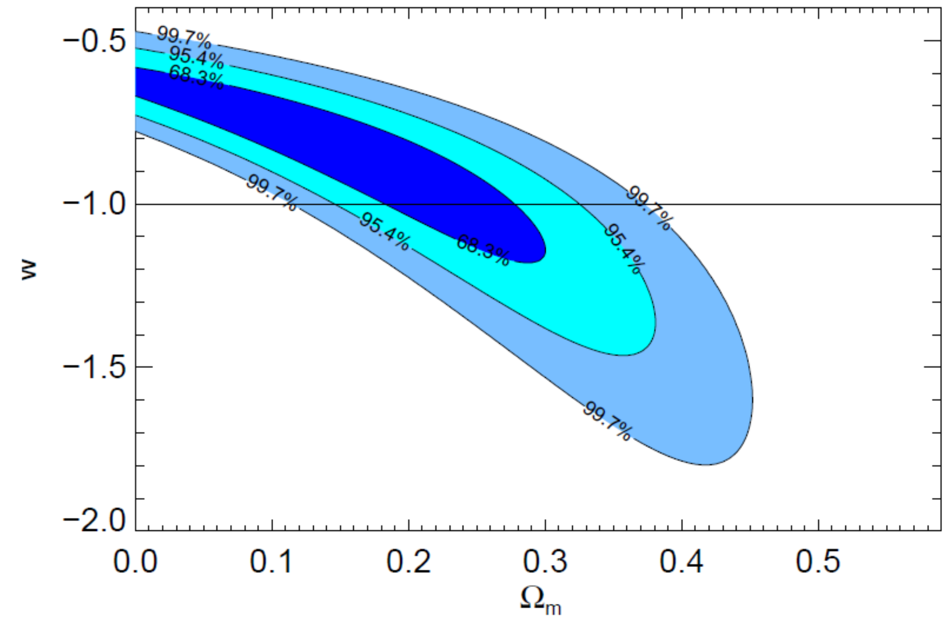
Conley et alii, 2011

$$\frac{H}{H_0}(z,\theta) = \Omega_m(1+z)^3 + (1-\Omega_m)(1+z)^{3(1+w)}$$

SDSS(1year)+SNLS(3 years)+HST+Nearby SNeIa



Statistical



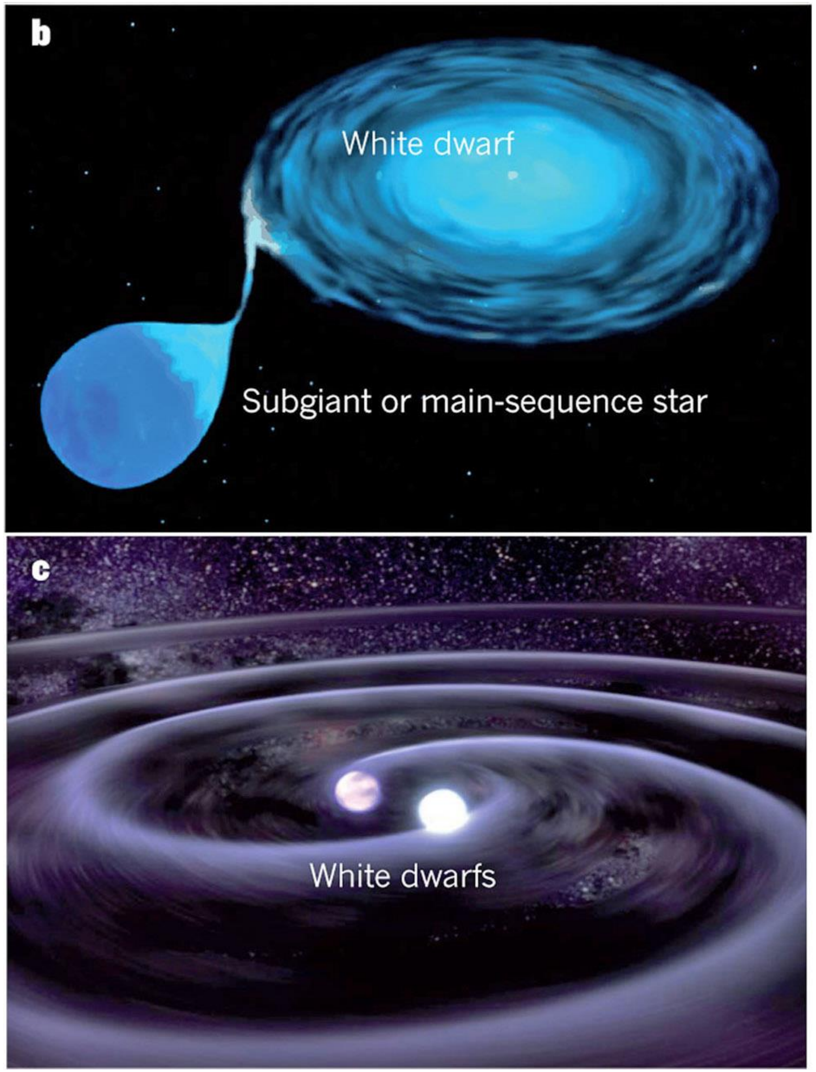
Statistical + systematic

Introduction

Various potential systematics (Knights *et alii*, 2013):

- Peculiar velocities;
- Photometric redshift;
- Filters errors;
- Template errors;
- Observational conditions;
- Combining data from different surveys/telescopes;
- Gravitational lensing;
- Dust extinction;
- Host galaxies properties;

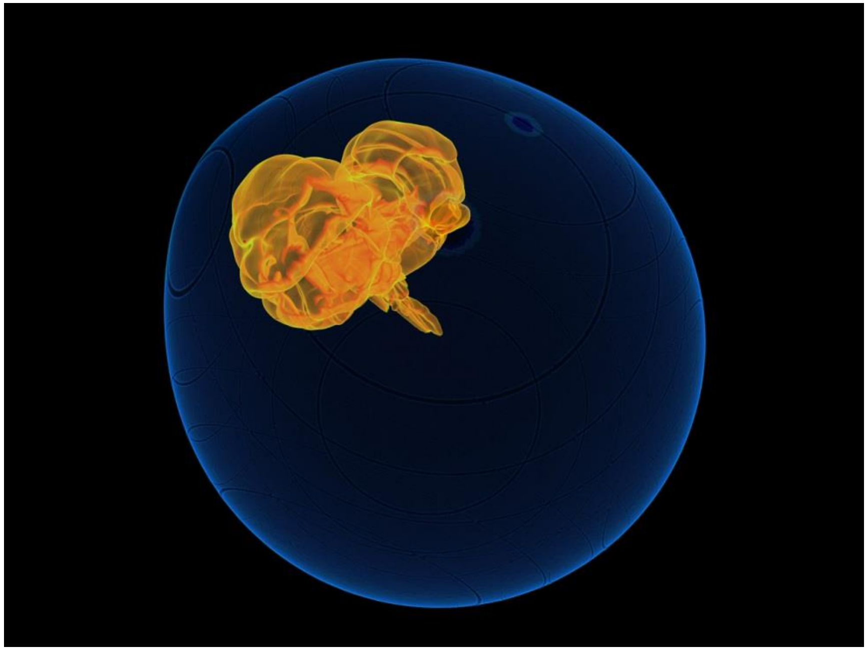
Progenitor system



- What is the white dwarf companion?
  - *single degenerate*: WD + MS/RG
  - *double degenerate*: WD + WD
- There are evidences for a *double degenerate* contribution:
  - *delay time distribution*
  - Absence of hydrogen lines in nebular spectra
  - Absence of X-ray emission in elliptical galaxies

http://www.toomanyparsecs.info/2012/05/studying-type-ia-supernova-progenitors.html

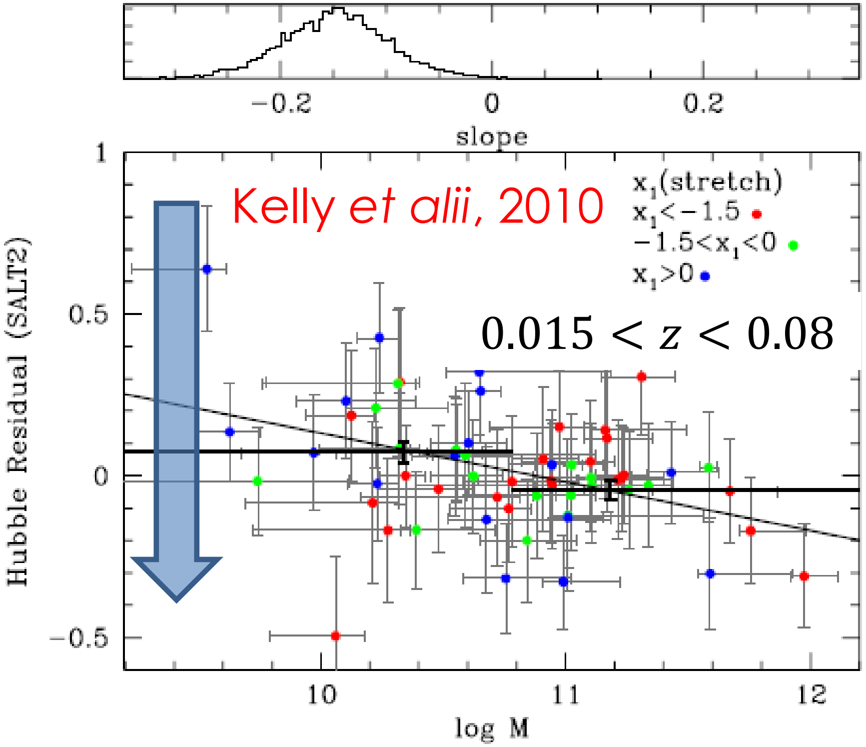
Explosion mechanism

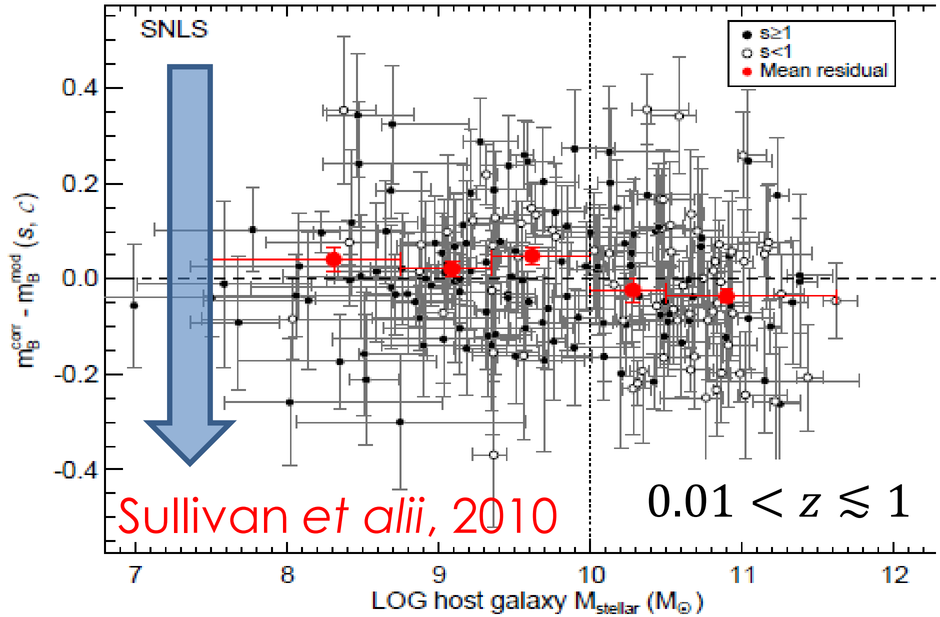


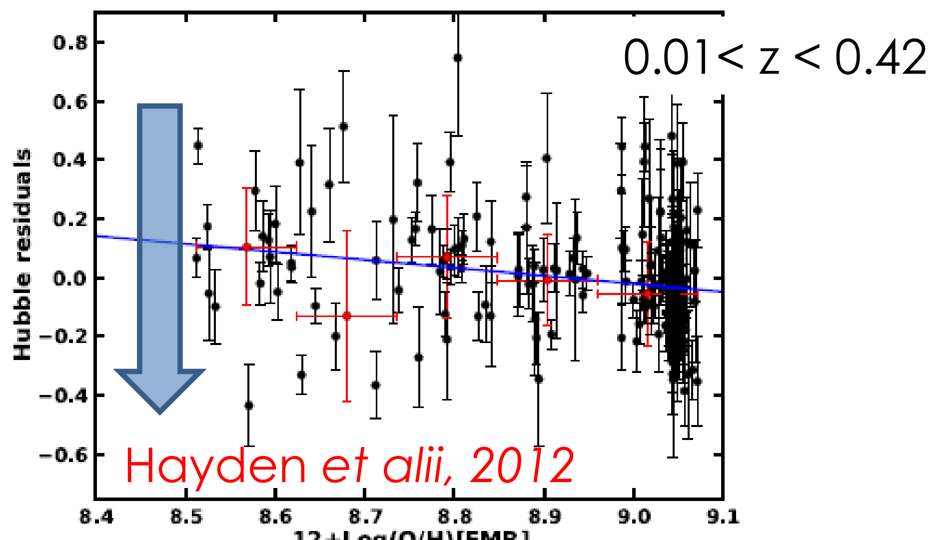
DOE NNSA ASC/Alliance Flash Center at the University of Chicago

- Pure detonation produces iron group elements mainly
- Pure deflagration tends to result in sub luminous events
- Current solution: Deflagration to Detonation Transition (DDT). What triggers the detonation?
- Simulations indicate that the explosion is asymmetric. Observed flux could depend on the line of sight.

Host galaxy properties







Fundamental Metallicity Relation

$$12 + \log(O/H) = f(\log M_* - \alpha \log SFR)$$

Host extinction/Color

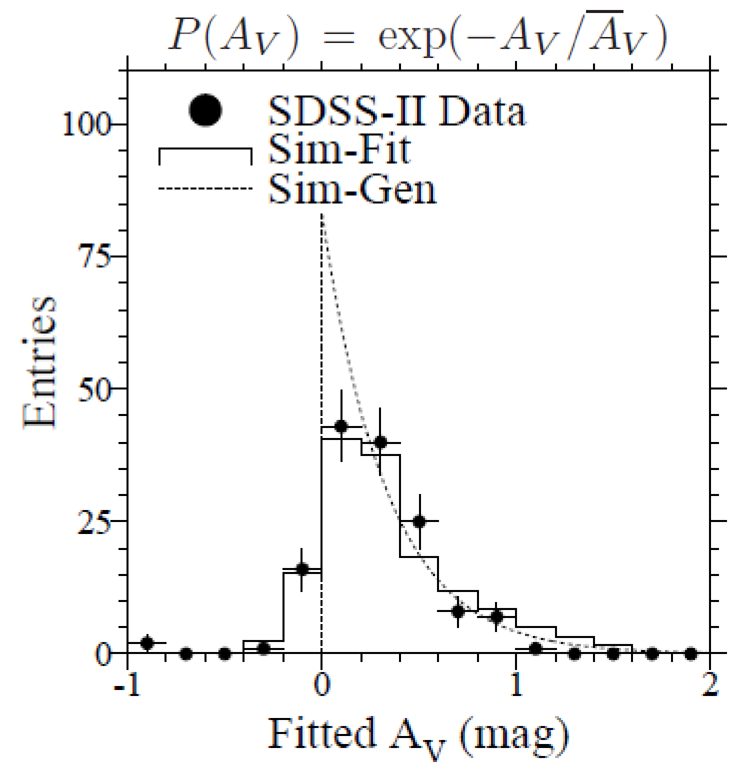
$$X_{\mathrm{host}}^{e,f'} = \zeta^{e,f'}(a^{f'} + b^{f'}/R_V)A_V \quad R_V = A_V/E(B-V)$$

$R_V = 3.1$ Milky Way

$$R_V = 2.18 \pm 0.14_{\mathrm{stat}} \pm 0.48_{\mathrm{syst}}$$
$$\overline{A}_V = 0.358 \pm 0.026_{\mathrm{stat}} \pm 0.068_{\mathrm{syst}}$$

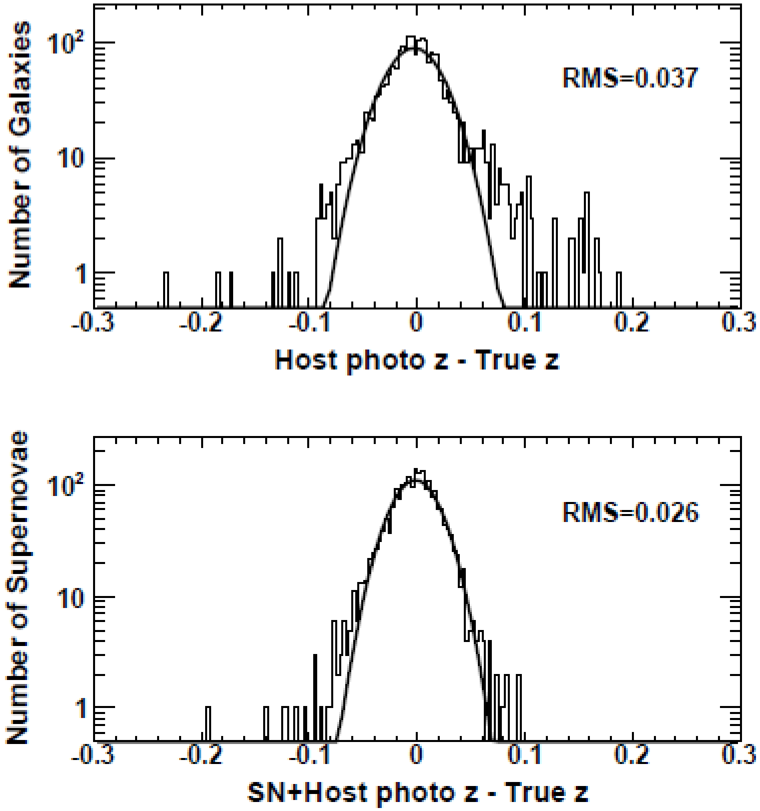
Kessler *et alii*, 2009

- If the color smearing model is a good description for the SNeIa intrinsic colors, then the parameter β from SALT2 could be biased low (Kessler *et alii*,2009).
- If SNeIa colors were dominated by normal dust extinction SALT2-like fitters would be capable to reproduce MLCS2k2 assumptions. This discrepancy suggest this is not the case (Conley *et alii*, 2011)



Photometric typing and redshift estimation

Sample	f_p >0.0	f_p >0.1	Tot. simulated
Ib/c	571	57	53514
IIP	110	2	107210
IIn	225	2	6940
IIL	62	2	14976
Tot. SNcc	968	63	182640
Ia	3482	3350	18695
Ia+SNcc	4450	3413	201335
Ia Purity	78%	98.1%	n/a



Simulations for DES (Bernstein *et alii*, 2012)

Javalambre Physics of the Accelerating Universe Astrophysical Survey

- Brazil-Spain Collaboration.
- 8600 squared degrees in 55 filters of ~145 A, 100 A spaced, plus 4 broad band filters.
- 2,5 m telescope + 5 squared degrees camera, 1.2 Gpix, dark site ~0.7 arcsec seeing: Javalambre in Teruel, Spain.
- Start in 2015 and finish in 2021.
- Main objective: measuring radial BAO up to z~1.6.

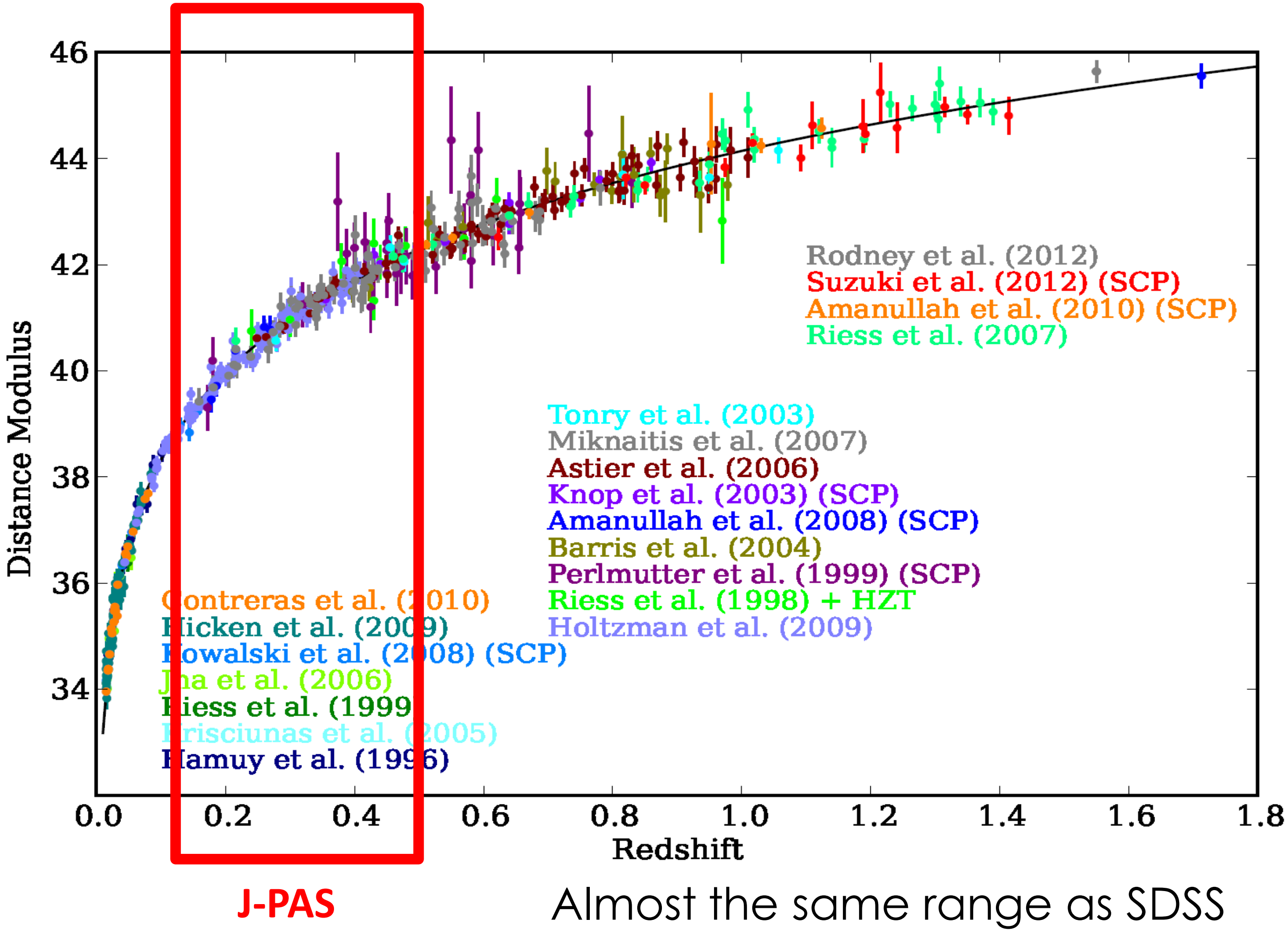
http://j-pas.org

J-PAS supernova survey

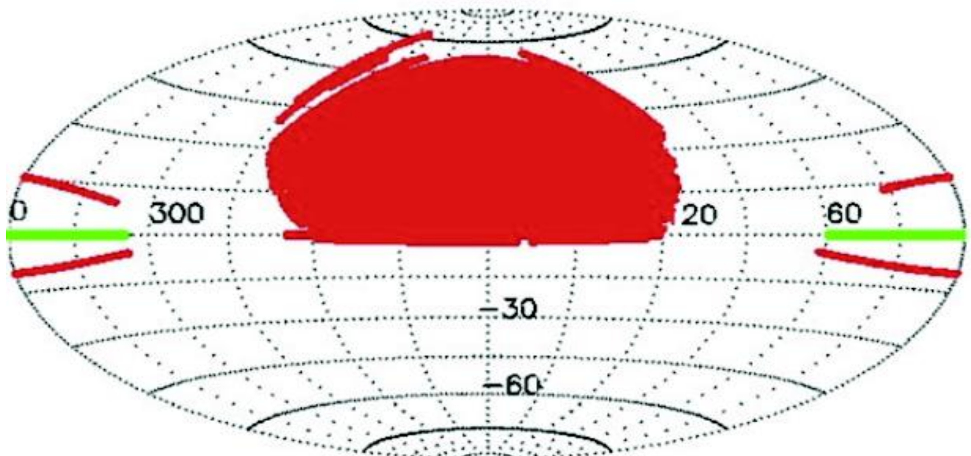
Researchers: Ribamar Reis, Masao Sako, Raul Abramo, Ioav Waga, Maurício Calvão, Richard Kessler, Miguel Perez-Torres;
Post-docs and students: **Beatriz Siffert**, **Henrique Xavier**, Marcelo Vargas dos Santos;

- Intermediate redshift survey ($z<0.5$);
- Higher precision in photometric redshift , ~ 0.003(1+z) for galaxies;
- Lower contamination from photometric typing ~1%;
- Better characterization of Host properties;
- Lots of color indicators to describe host extinction;
- Rates estimates for all types.

Rubin et al. ApJ 763 (2013)



Almost the same range as SDSS

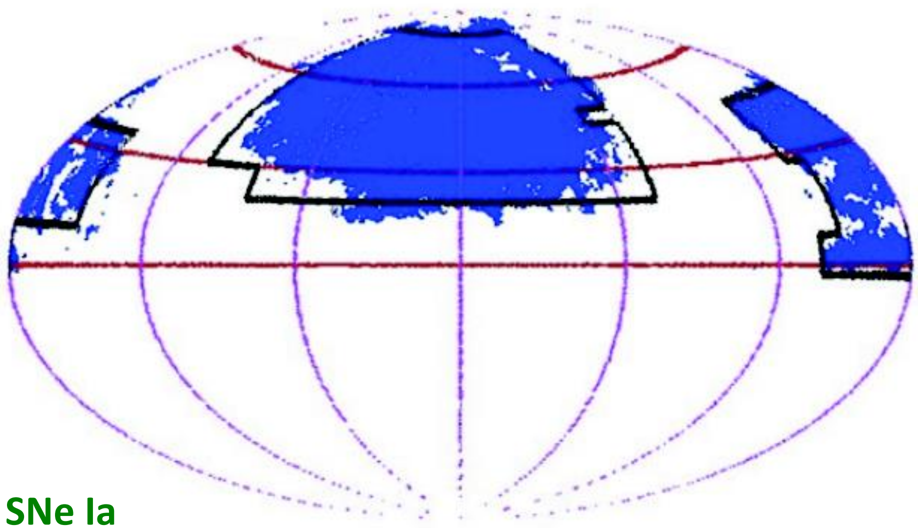


SDSS

8400 deg^2

SNe Ia: 250 deg^2

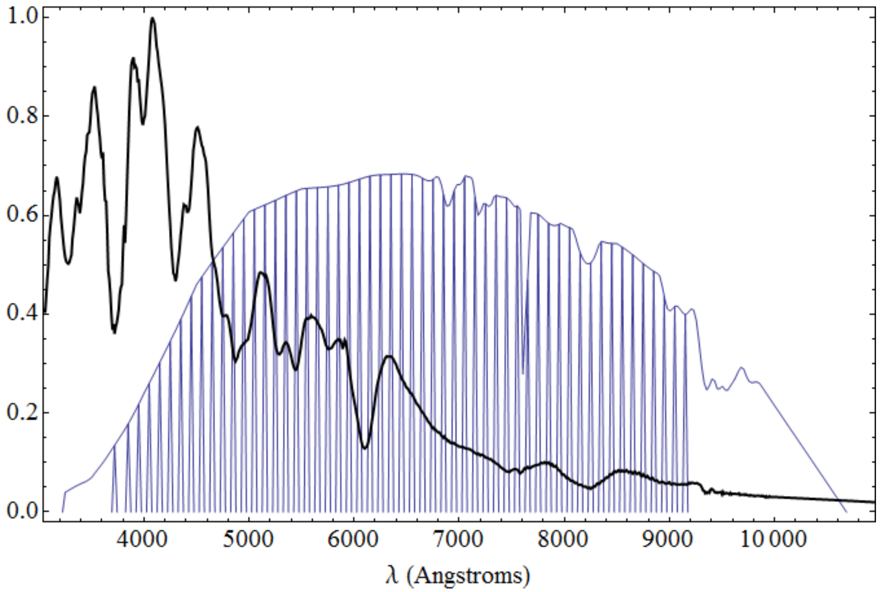
~ 500 SNe Ia

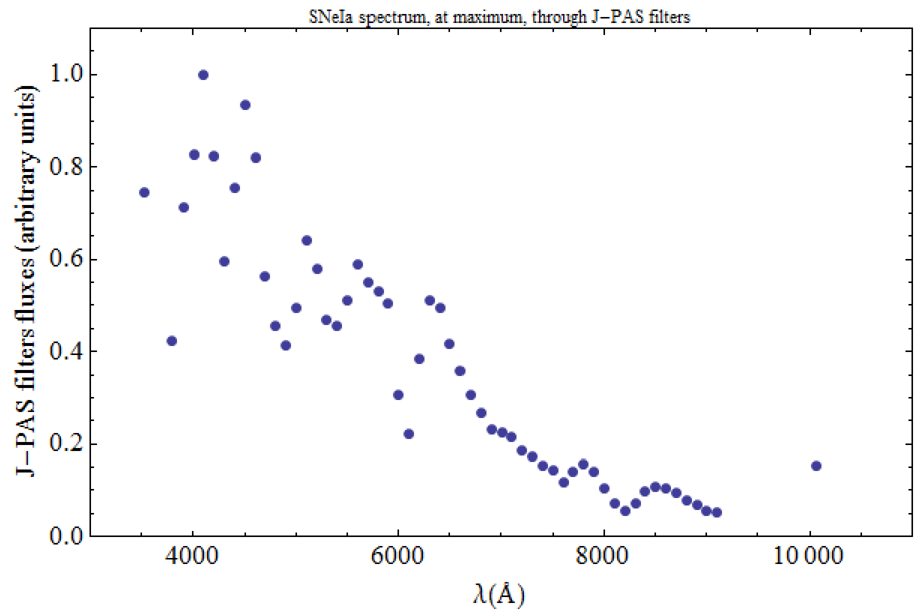


J-PAS

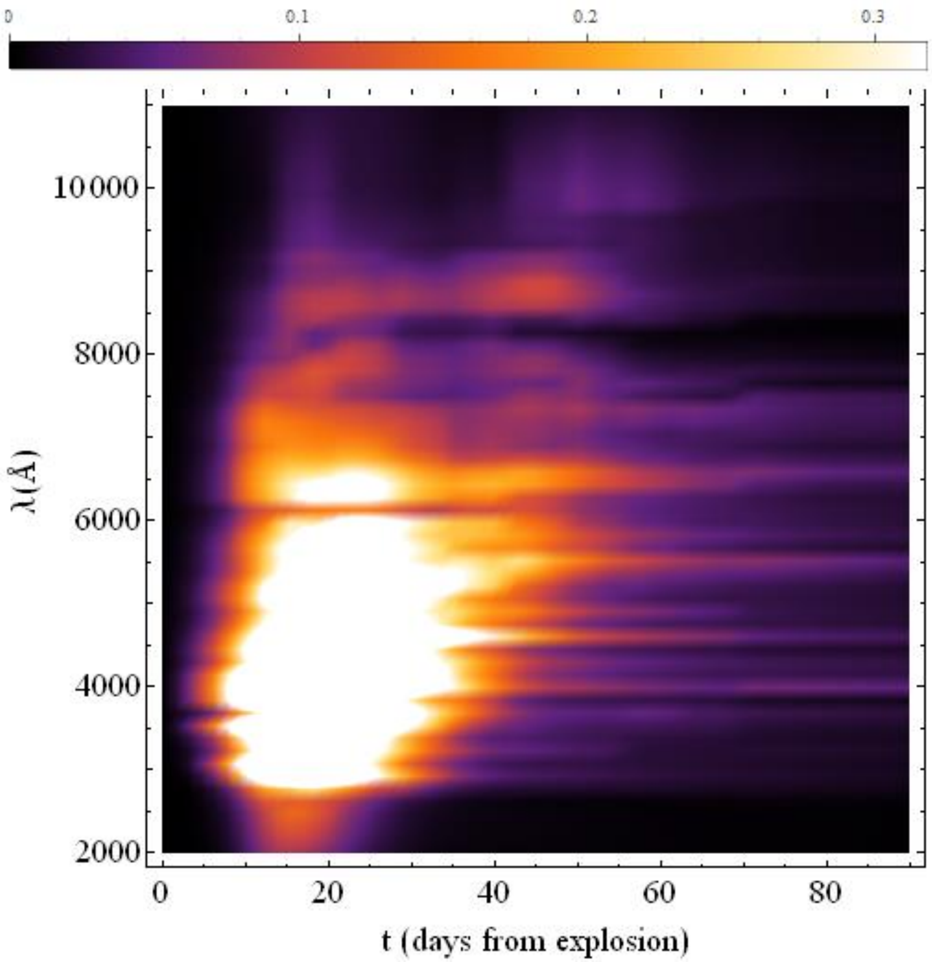
8600 deg^2

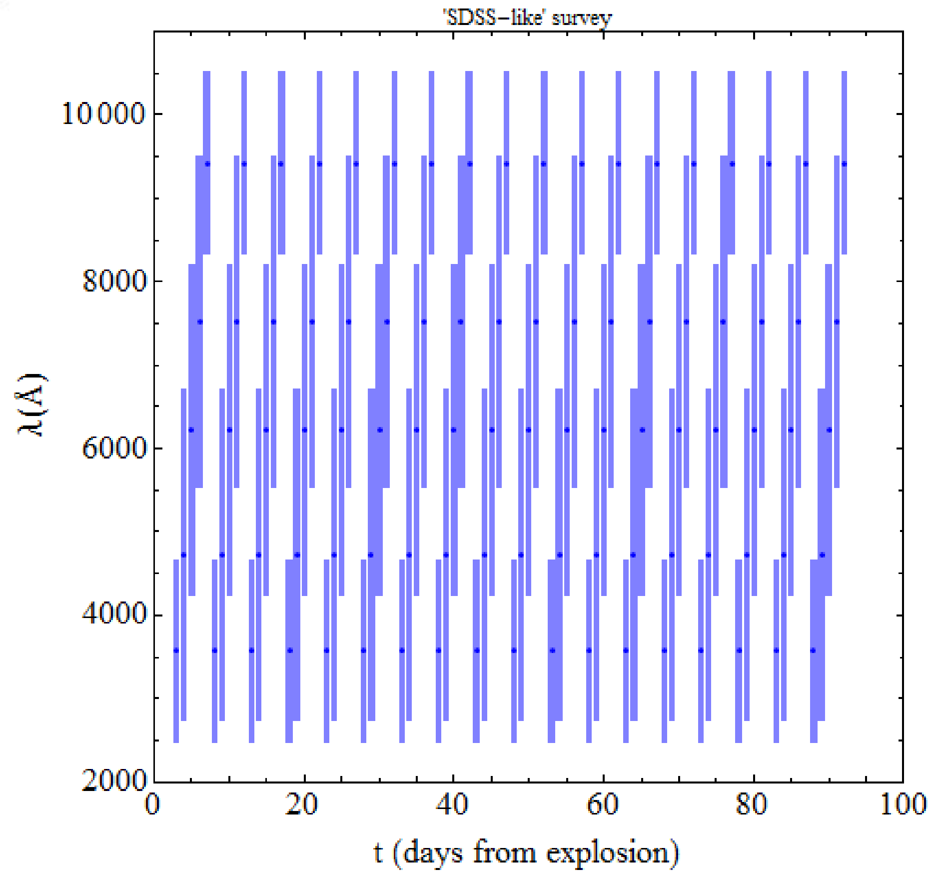
~ 6000 SNe Ia



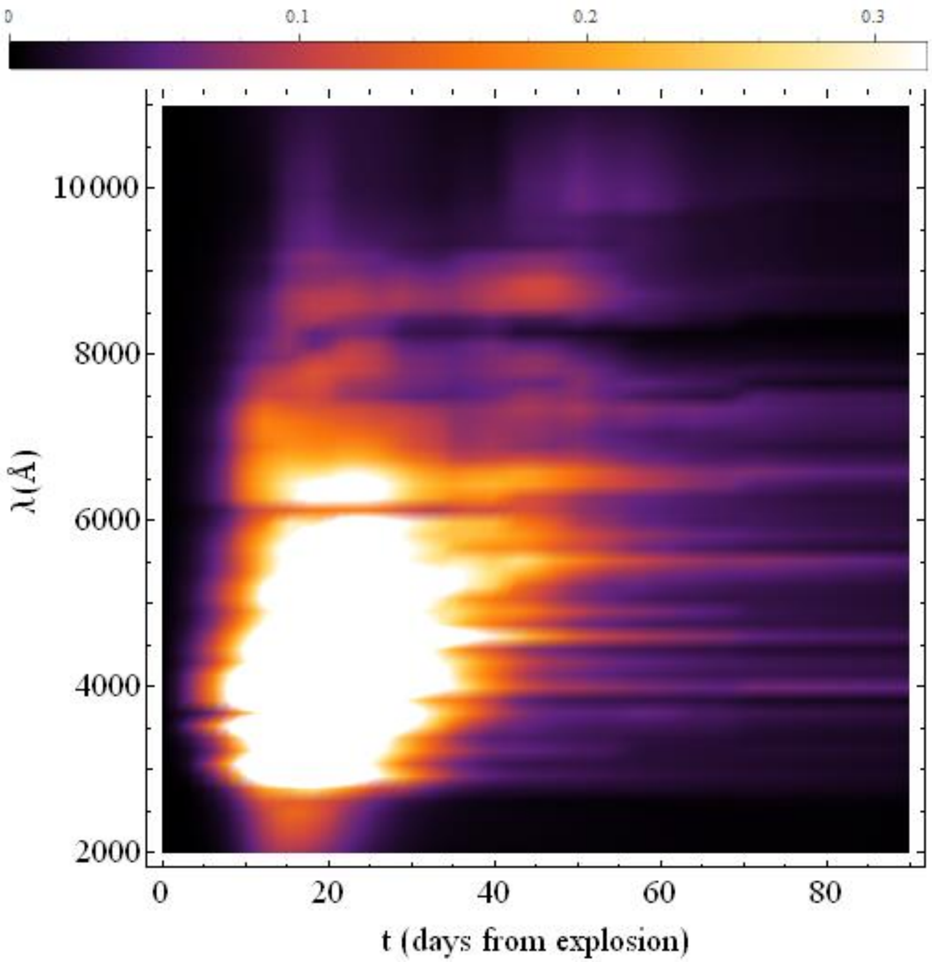


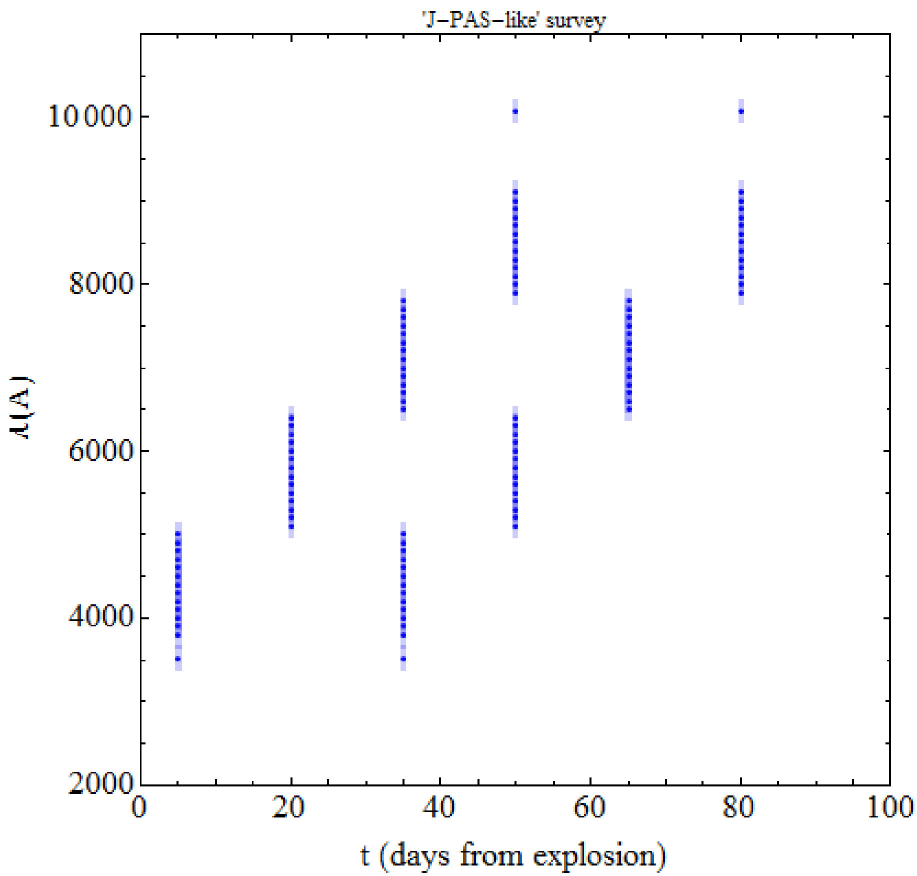
Narrow band filters allow us to probe the broad features of a SNeIa spectrum, considering observations in all filters in a night. But we cannot observe in all filters at once, using J-PAS.





Assuming a cadence of 5 days in 5 filters: 90 observations at most



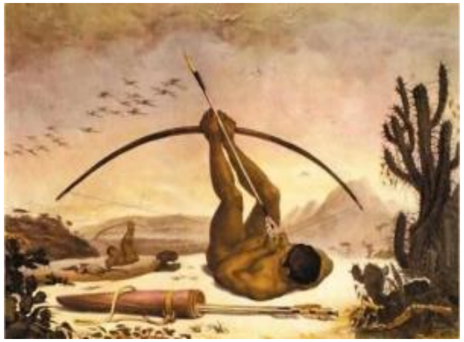


Assuming 2 observations in each filter: 112 observations at most

Conclusion

- SNeIa are an important observable for dark energy studies;
- Current and future projects are expected to find thousands of new supernovae;
- We are limited by a number of systematics;
- In order to improve the accuracy and precision in the determination of cosmological parameters we need a better understanding of various features of these objects;

Join us!



The astrophysics, relativity and cosmology group at the Federal University of Rio de Janeiro works in various subjects:

- Type Ia supernovae
- Weak lensing
- Baryon Acoustic Oscillations
- Constraints to cosmological models
- Photometric redshift
- Inflation
- Dark energy
- Dark matter
- Modifications of General Relativity
- Fractal cosmology
- Econophysics
- Inhomogeneous and/or anisotropic cosmological models
- Transplanckian physics
- Propagation and scattering of waves in curved spaces
- Students and post-docs are welcome

ARCOS – Astrophysics, Relativity e Cosmology
http://arcos.if.ufrj.br

BACKUP SLIDES

Multicolor Light Curve Shape (MLCS2k2)

Description from Joshua Frieman

Riess, *et al* 96, 98; Jha, *et al* 2007

MLCS2k2 Light-curve Templates in rest-frame $j=UBVRI$; built from ~100 well-observed, nearby SNe Ia

Δ <0: bright, broad

Δ >0: faint, narrow, redder

time-dependent model "vectors" trained on Low-z SNe

observed passband

$$m^{i}_{\text{mod}}(t-t_0) = \mu + M^{j}(t-t_0) + P^{j}(t-t_0)\Delta + Q^{j}(t-t_0)\Delta^2 + K^{ij}(t-t_0) + X^{j}_{host}(t-t_0) + X^{i}_{MW}(t-t_0)$$

fit parameters

Time of maximum   distance modulus   host gal extinction   stretch/decline rate

Spectral Adaptative Light curve Template (SALT2)

Description from Joshua Frieman

Guy, *et al* 05,08

Fit each light curve using rest-frame *spectral* surfaces:

$$\frac{dF_{\rm rest}}{d\lambda}(t,\lambda) = x_0 \times [M_0(t,\lambda) + x_1 \times M_1(t,\lambda)] \times \exp[c \times CL(\lambda)]$$

light-curve shape

color term

Light curves fit individually, but distances only estimated globally:

$$\mu_i = m^*_{B_i} - M + \alpha \cdot x_{1,i} - \beta \cdot c_i$$

Global fit parameters, determined *along with* cosmological parameters by fit to Hubble diagram (so in principle you should not use SALT distance tables to test some other cosmological model)

Differences from MLCS: not trained just on low-redshift data; flat priors on model parameters; color variations *not* assumed only from dust. *If* dust, then $\beta = R_V + 1$.