Cosmological Constraints from SNLS/SDSS: Pushing down the Systematics

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on behalf of the SNLS/SDSS JLA collaboration

LPNHE

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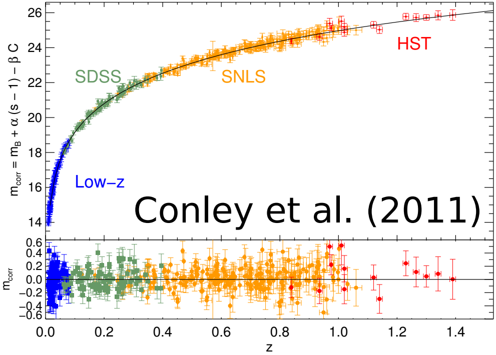
Cosmology with SNe-Ia



1. Redshift measurement
2. Apparent flux measurement
3. Standardization

$\downarrow$

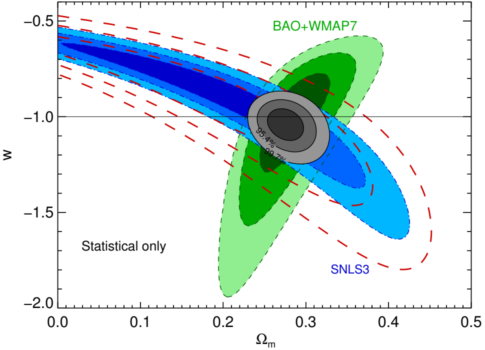
distance luminosity ratios

Probe of the expansion history at late time

- Independent of the CMB
- Very complementary for dark energy studies

$$d_L(z) = (1+z)\frac{c}{H_0}\int dz\left(\Omega_m(1+z)^3 + \Omega_x(1+z)^{3(1+w)}\right)^{-1/2} \quad \text{with: } w = \frac{p_x}{\rho_x}$$

SNLS3 and measurement systematics

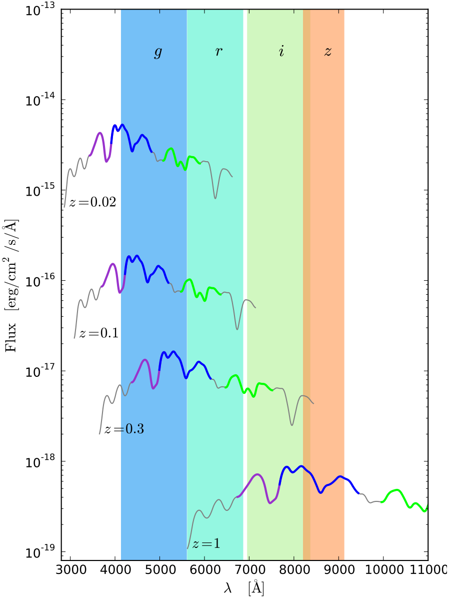


SNLS3 Analysis (Guy et al. 2010, Conley et al. 2011, Sullivan et al. 2011)

- Systematic uncertainties: half of the error budget
- Mostly photometric calibration

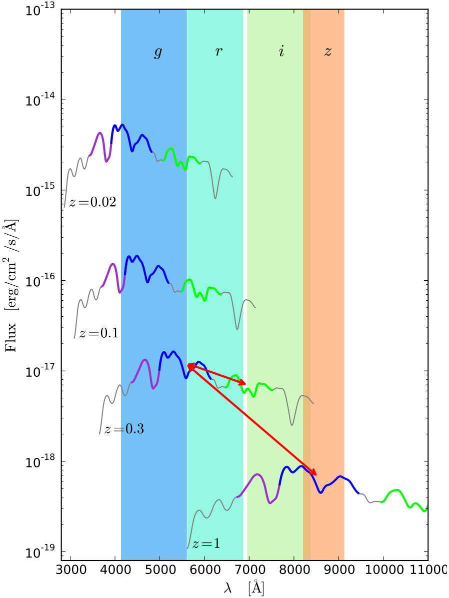
Highest priority: tackling measurement systematics

The measurement basics



Required ingredients

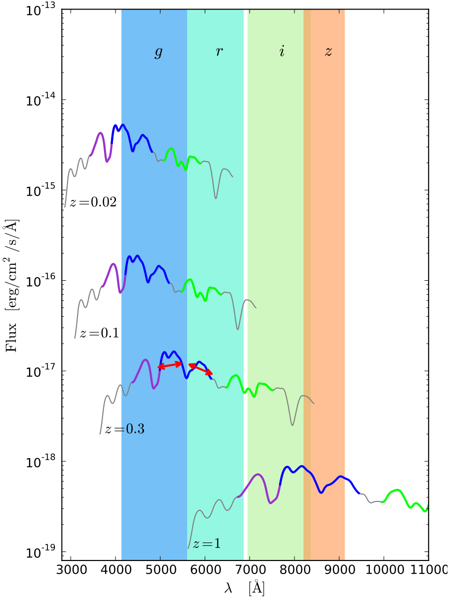
The measurement basics



Required ingredients

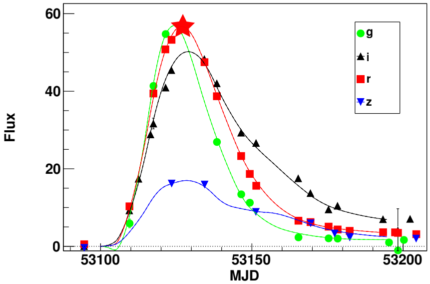
- Being able to measure flux ratios between different observer-frame band
  $\rightarrow$ inter-calibration

The measurement basics



Required ingredients

- Being able to measure flux ratios between different observer-frame band
  $\rightarrow$ inter-calibration
- Being able to interpolate in time and wavelength
  $\rightarrow$ Light-curve model



Working on measurement systematics

SNLS/SDSS collaboration: Joint Light-curve Analysis

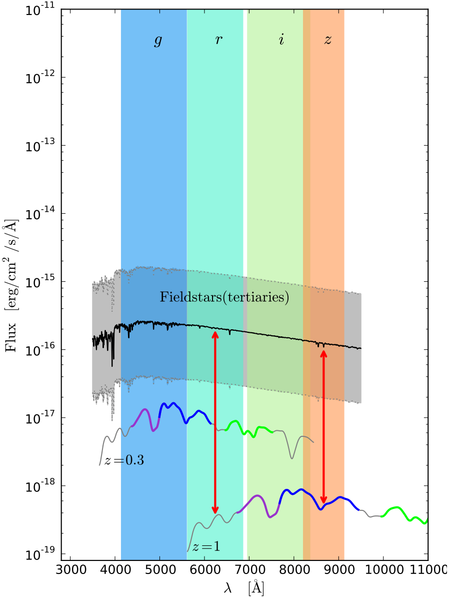
- Transverse WG joining the two main SNe-Ia surveys
- Started in June 2010
- Share data, code and expertise

Two main axes:

- Photometric calibration
  - Joint calibration paper — *Betoule et al. (2013), A&A 552*
  - Blind in regard to cosmology
  - Concluded at the end of 2012
- Model systematics
  - intrinsic dispersion of SNe-Ia — *Kessler et al. (2013), ApJ 764*
  - light-curve fitter biases — *Mosher et al. (in prep.)*

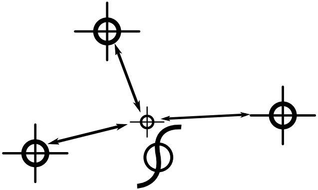
Outline

What is calibration ?



I) Characterization of the instrument response

- Enable measurement of **flux ratios** in a single image



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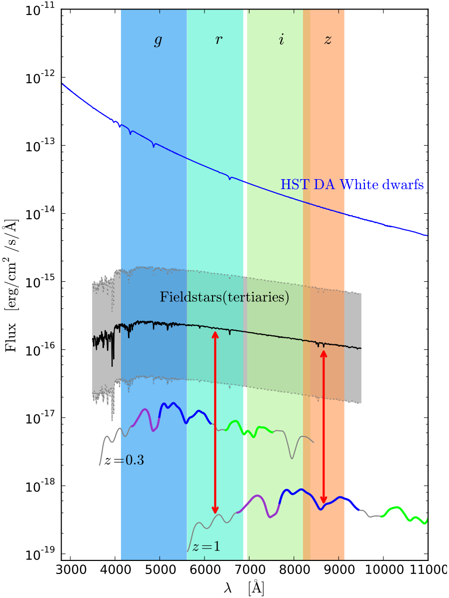

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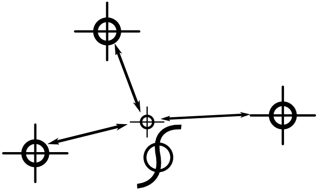

II) Calibration transfer

- HST standard stars as primary calibration source
- Enable comparison of flux in different bands/instruments

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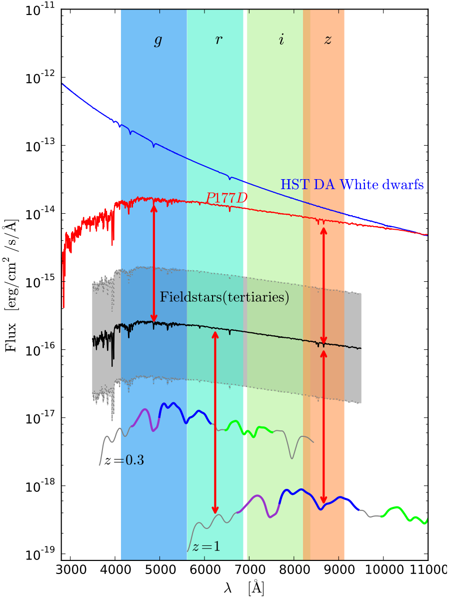

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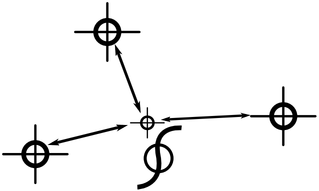

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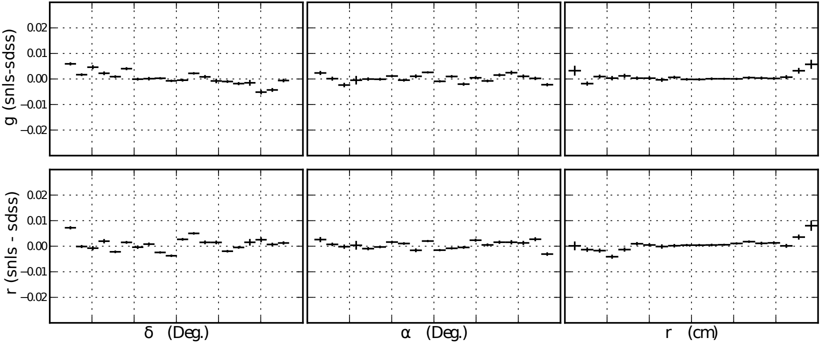
- HST standard stars as primary calibration source
- Enable comparison of flux in different bands/instruments

Result I: “Flat-fielding” 2 wide-field camera at 0.3%

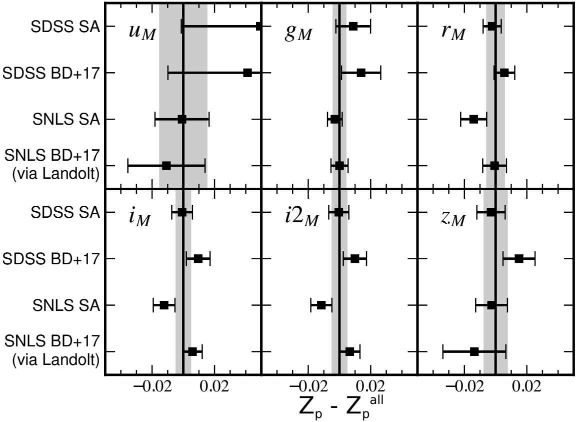
Comparison of SDSS/SNLS photometry



- SNLS and SDSS flat-fields obtained independently
- Achievement of wider interest (e.g. Photo-z)

Result II: $\sim$ 0.5% accuracy in absolute calibration

Short and redundant paths for calibration transfer



New data

- Direct observation of HST stars
- Direct SNLS/SDSS cross-calibration

Enable:

- Comparison of several paths
- 0.3% accuracy in *gri*

Final uncertainty dominated by HST calibration

In Summary

New SNLS and SDSS calibration

- More robust
- More accurate

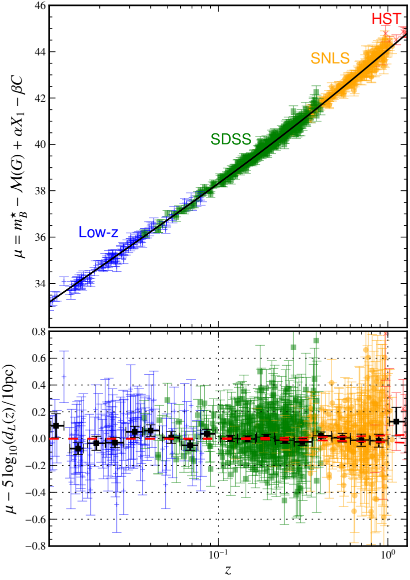
Changes at the percent level

band	g	r	i	z
ΔZ_{SNLS} (mmag)	-12.9	-0.9	1.3	-17.9
ΔZ_{SDSS} (mmag)	-4.0	0.0	0.0	-6.0

Thanks to

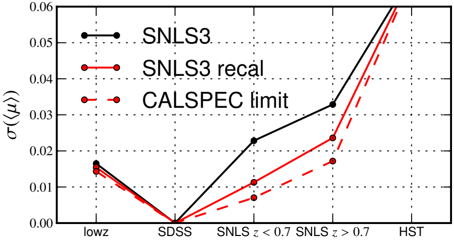
- New and better calibration data
- Correction of instrumental effects
  - filter aging
  - improved flat-fielding
  - PSF size variation (with color, flux ...)

The recalibrated JLA Hubble diagram



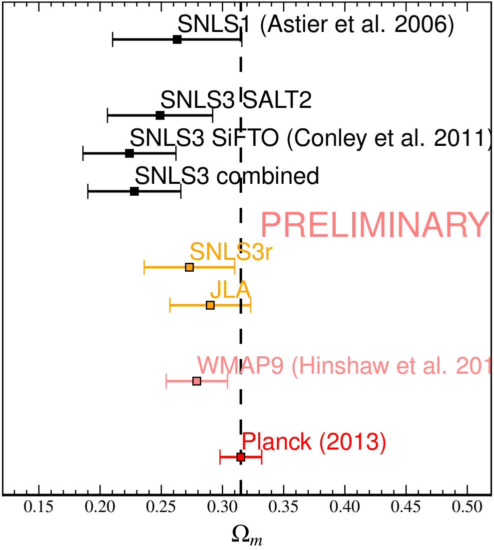
- Low-z+SNLS3+SDSS3+HST
- SNLS and SDSS sample firmly tied together by the joint calibration

Impact of recalibration on the uncertainty in distance ratios



- Dominated by the uncertainty on HST calibration

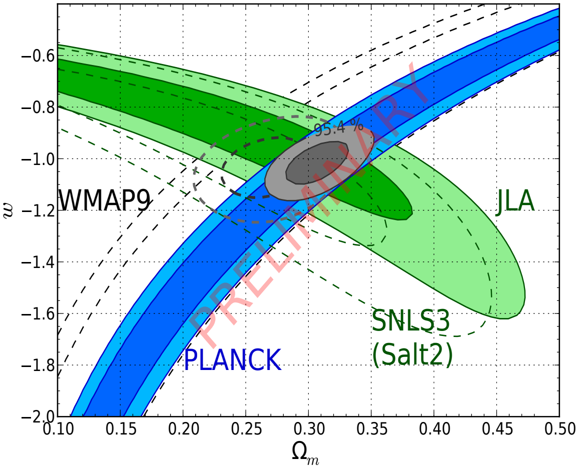
ΛCDM constraints



SNe-Ia/CMB tension on the Ω_m measurement noticed in Planck papers

- No need for new physics
- Solvable in:
  - SALT2/SiFTO differences
  - Calibration changes

Dark Energy constraints in combination with CMB (flat universe)



- Improved CMB constraints from Planck
- Improvement on SNe-Ia systematics from the JLA work
- Accuracy on *w* reaches 5.6%
- Compatible with a cosmological constant

Conclusion

Current SNe-Ia data do not require anything else than ΛCDM

- Improved accuracy on photometric calibration
- Best constraints on w from the combination of CMB+BAO+JLA: 5.6%
- Paper in prep.

Going further with SNe-Ia

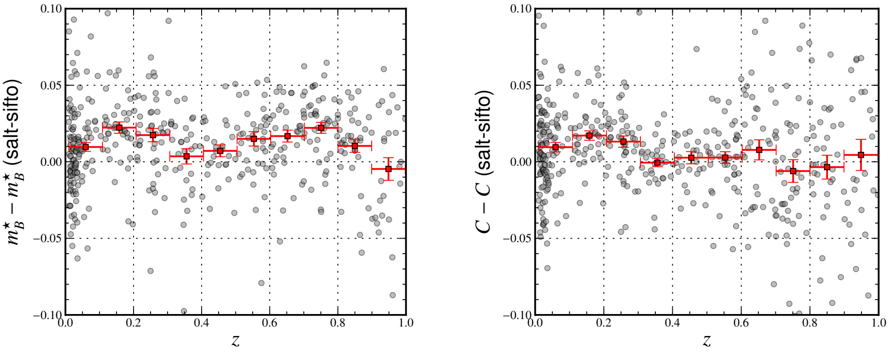
- Forthcoming new data
  - SNLS5 spectroscopic sample close to ready
  - New low-z data available
- Important pending questions
  - Supernovae evolution
  - Nature of the color law and its variations
  - Nature of the luminosity-host properties relation
- Upcoming surveys (DES, LSST, EUCLID) with important improvements
  - wider-deeper $\rightarrow$ increased statistic
  - Infrared photometry
  - Associated with instrumental calibration projects

THANK YOU

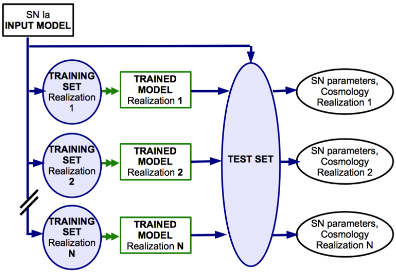
Error estimate: Comparing SALT2 and SiFTO (SNLS3)

More physical assumptions / less free parameters in SiFTO

- Stretch model
- Based on a spectral template, recalibrated with few parameters.



Testing SALT2 with simulations (Mosher et al. in prep.)



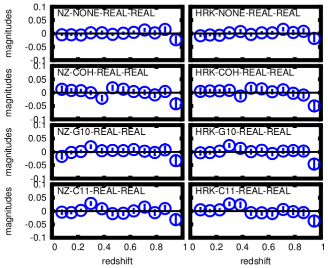


Fig. 22.—: Hubble residual bias plots are shown for all eight Guy10-model based trainings applied to REAL test data. Plot labels indicate the input model and training type.

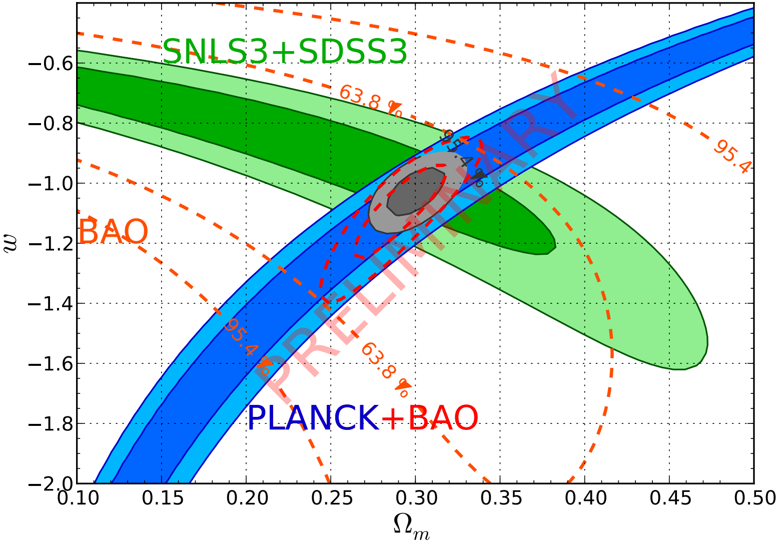
Adress concerns such as

- Is the method flexible enough to fit different models
- How much bias is introduced by regularization for missing data
- Dependencies on assumptions on the intrinsic variability

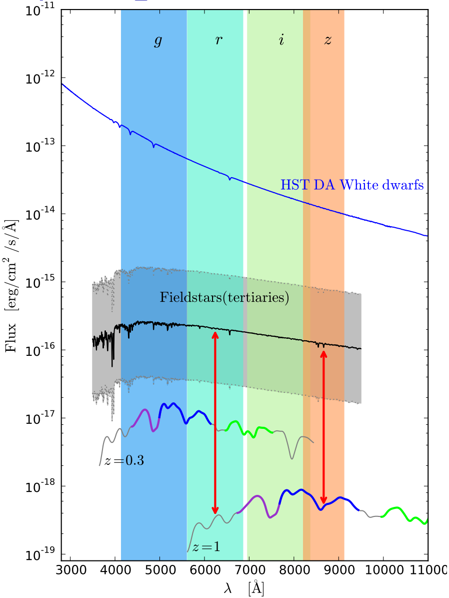
Preliminary results: General validation of the method

- Bias on distance modulii at the 2% level ($\sim 2\times$ smaller than the Salt/Sifto difference)

Combination with latest CMB results and BAO



Improving calibration accuracy in a joint analysis



choosing good references

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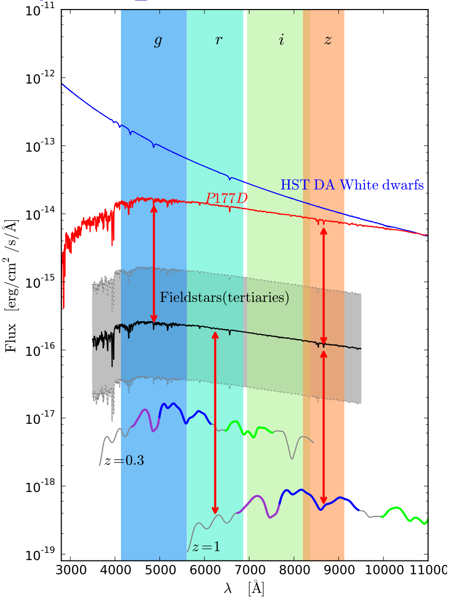

choosing good references

- "Observable" to ease the transfer

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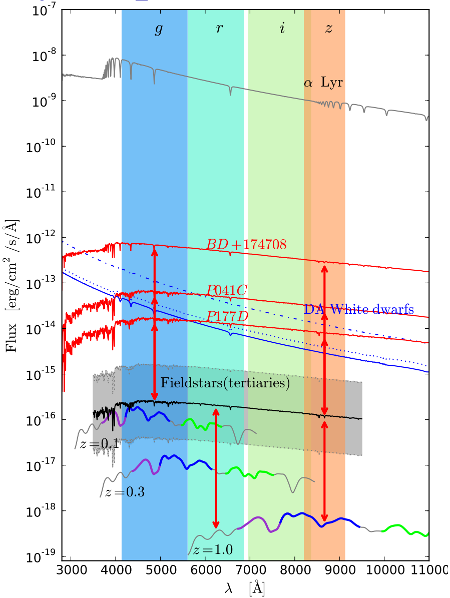

choosing good references

- "Observable" to ease the transfer
- "Red" to minimize instrumental systematics

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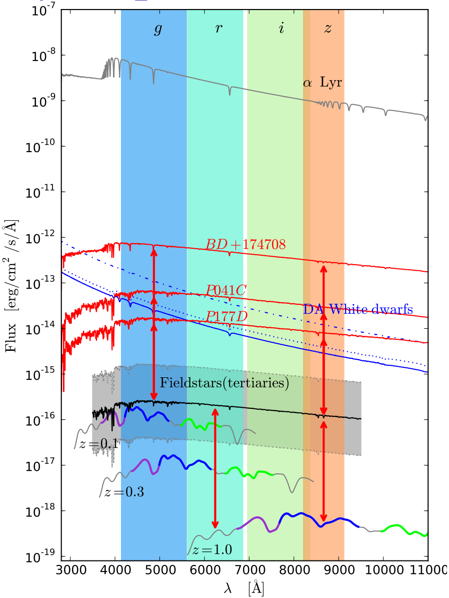

choosing good references

- "Observable" to ease the transfer
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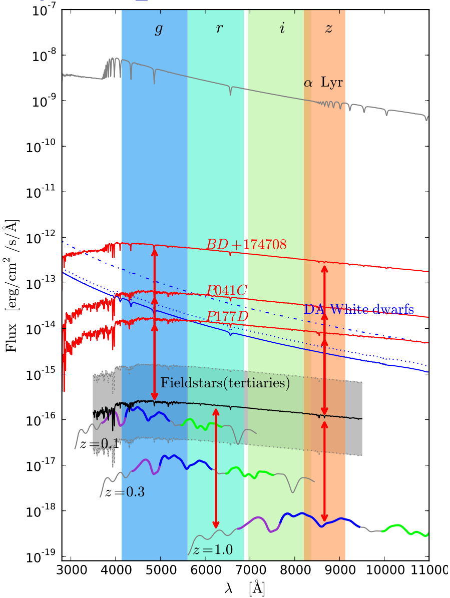
Improving the transfer accuracy

- Smart observation design

Improving calibration accuracy in a joint analysis



choosing good references

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Improving the transfer accuracy

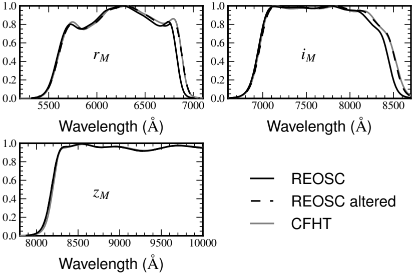
- Smart observation design

Discovering and correcting new "small" instrumental effects

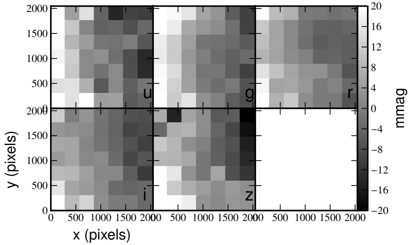
- Many show up around 1%

Adressing new small effects

- Filter aging

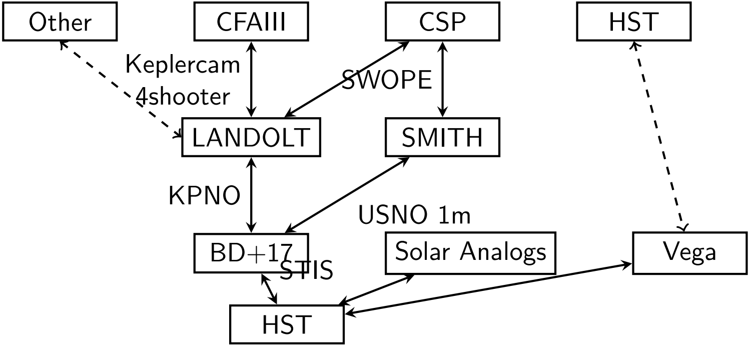


- SDSS PT flat-fielding error



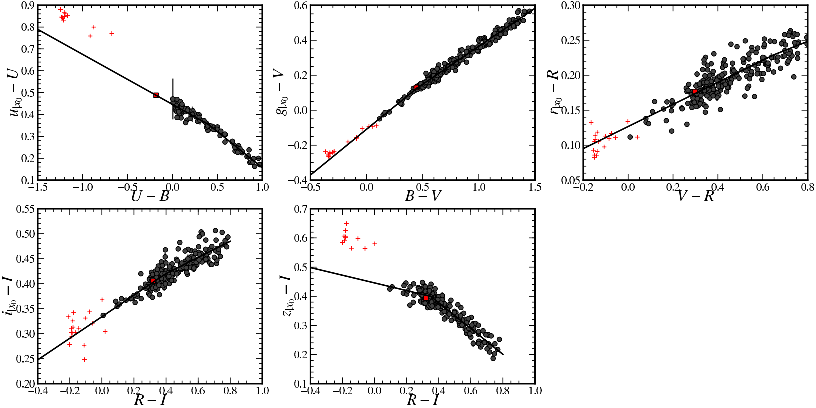
- Better understanding of fine photometry effects
  - Aperture corrections
  - Background residuals
  - PSF variations

Calibration overview

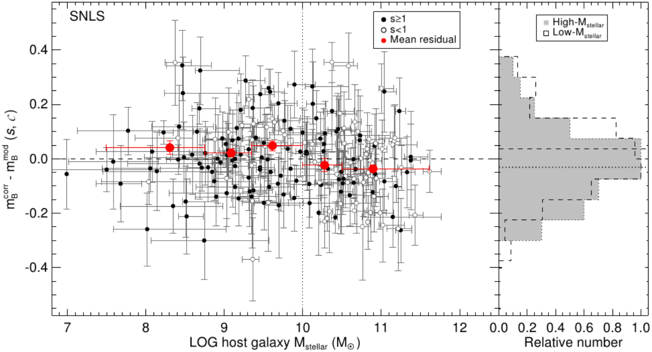


- well understood
- reasonably well understood (color transformation of the standard star + internal systematics)
- recipe taken from C11

BD17



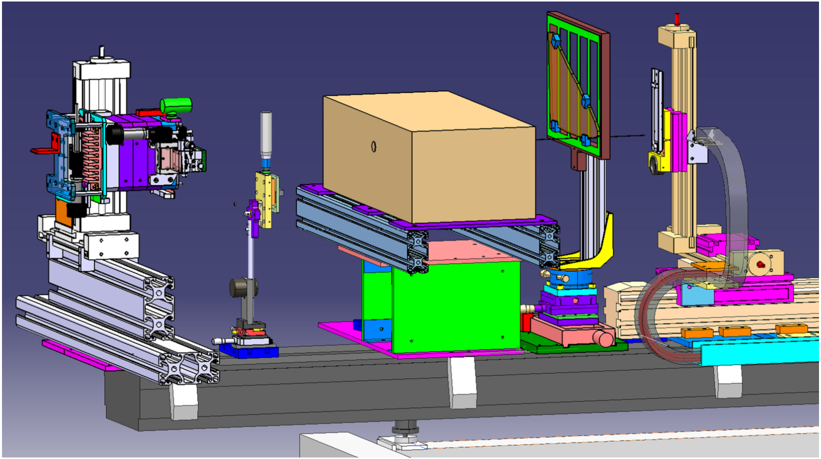
Relation to the host Galaxy properties (e.g. Sullivan et al. 2010)



- SNe-Ia in massive (older) hosts appears in average brighter at 4σ

Solution: Add the host properties as an observable in the cosmological fit.

New MegaCam filter measurements



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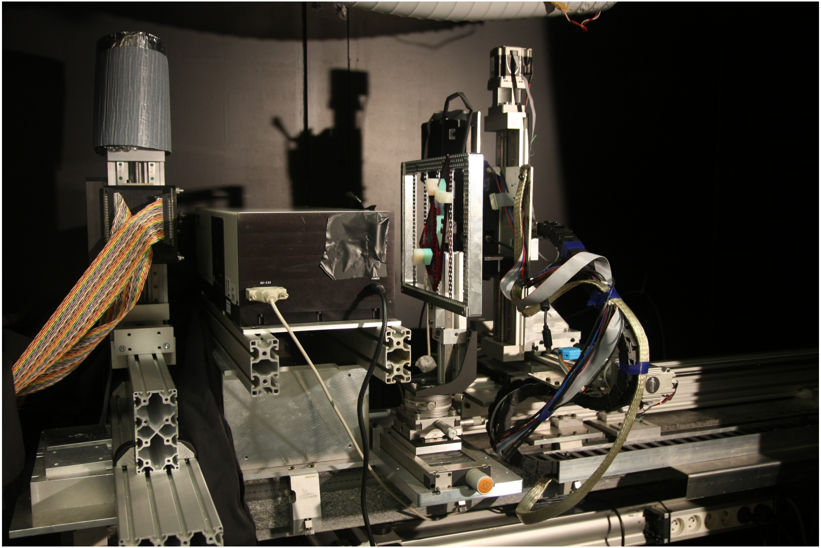

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