Photometric calibration of the wide field imager MegaCam with the demonstrator SNDice

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Azores School on Observational Cosmology
September 2011

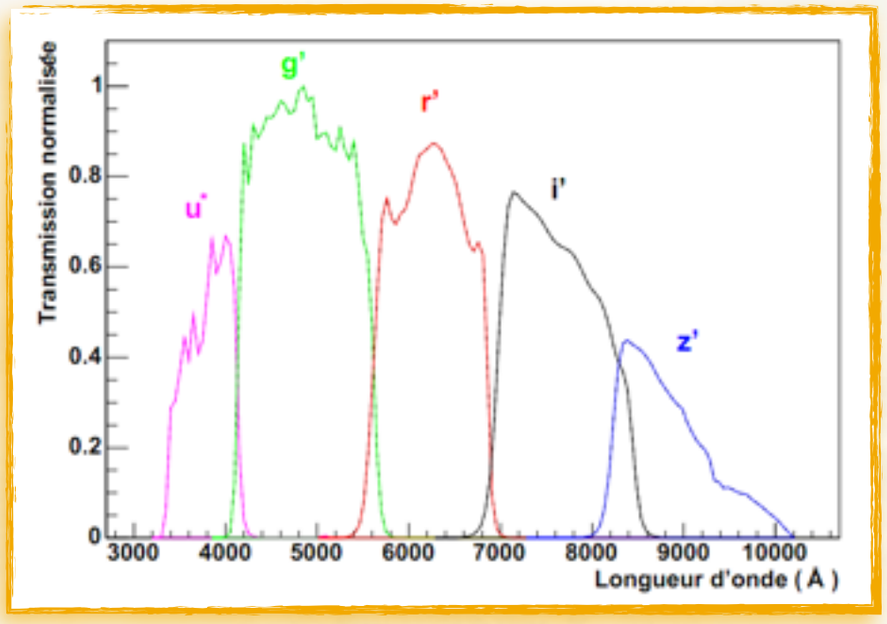
Outline

- ✓ Cosmology with Type Ia Supernovae (SNe Ia)
- ✓ Recent SNe Ia results:
  Supernovae Legacy Survey (SNLS) 3 years data release
- ✓ The SNDice Project
- ✓ Data Analysis
- ✓ Outlook

Supernovae Legacy Survey (SNLS)

- ✓ Photometric survey @ CFHT Hawaii (40 nights/year from 2003 to 2008)
- ✓ Four fields ~ 1 deg^2
- ✓ g, r, i, z bands
- ✓ MegaCam imager

- ✓ Spectroscopic survey for identification of SNe Ia and redshift (VLT, Keck, Gemini)

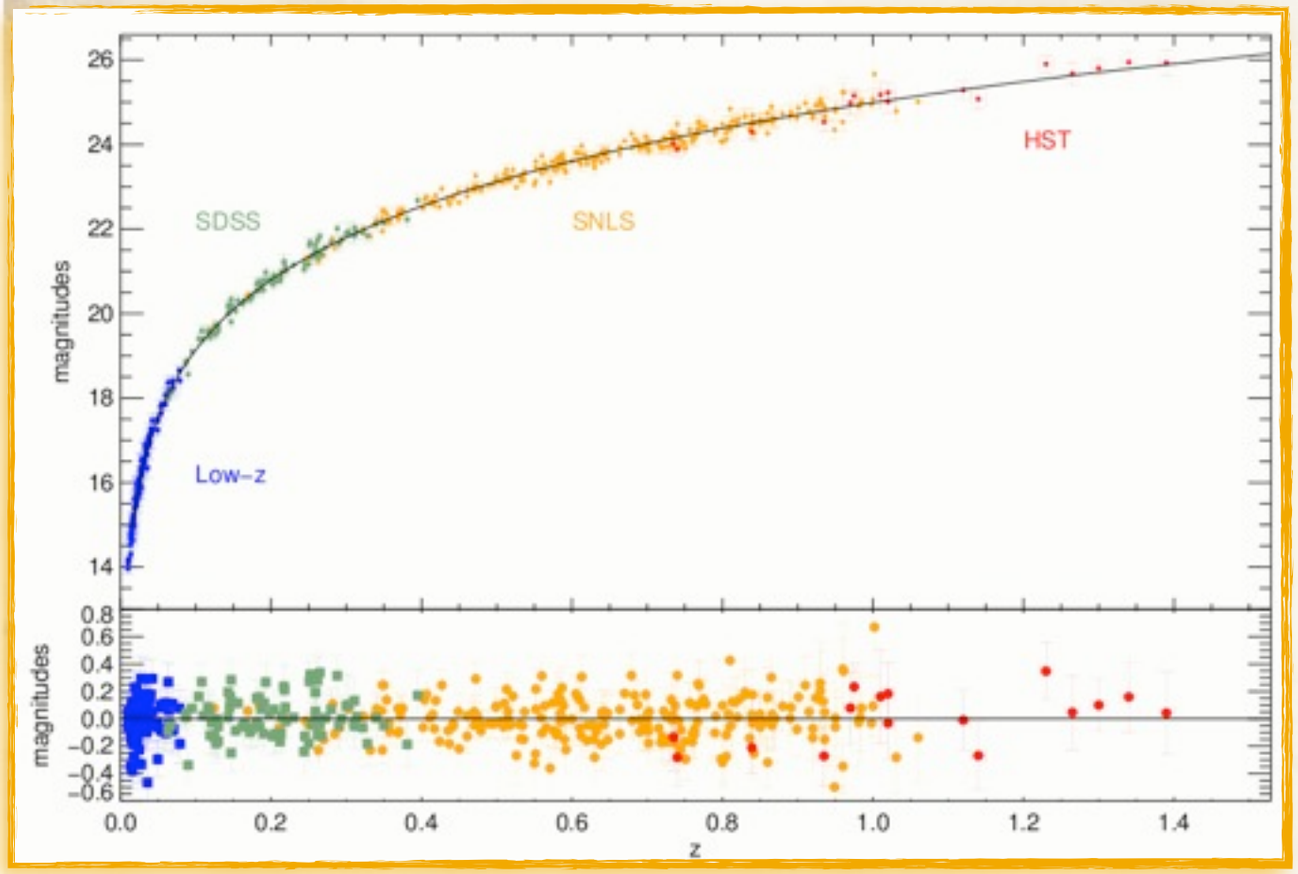


~ 450 confirmed SNe Ia

0.15 < z < 1.1

Supernovae Legacy Survey (SNLS)

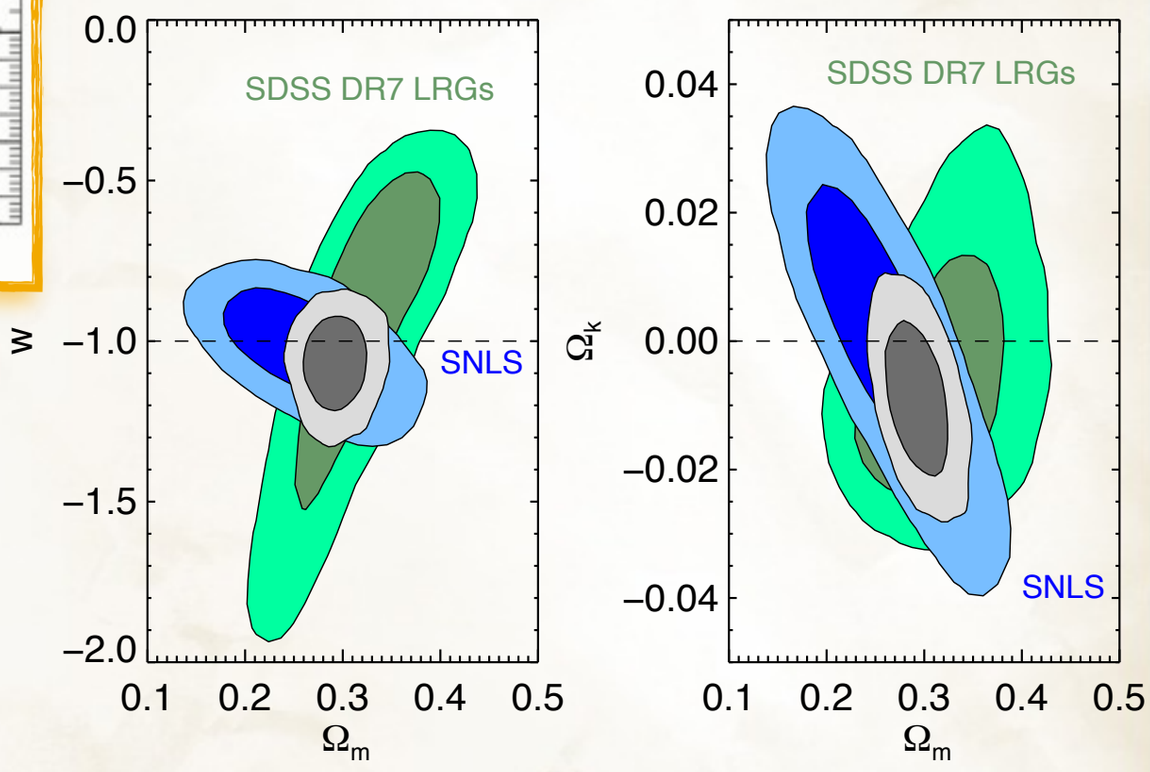
Hubble Diagram from (Conley, et al. 2011)



Both near and distant objects needed to distinguish between models

Degeneracy in the measurement of parameters

COMBINATION OF SEVERAL COSMOLOGICAL PROBES

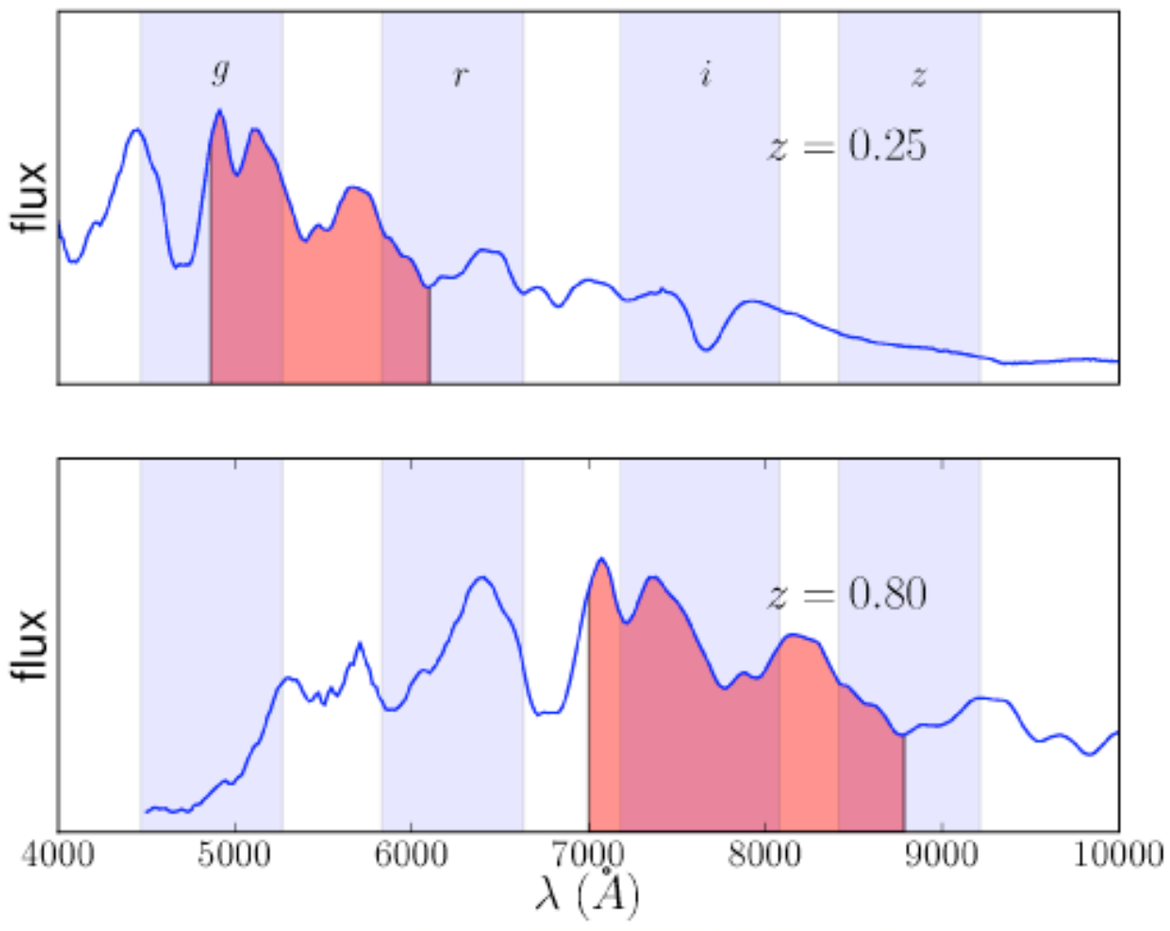


(Sullivan, et al. 2011)

Why is it a Difficult Business?

COMPARISON NEAR TO FAR OBJECTS:

1. At the same phase after explosion
2. In the same rest-frame passbands



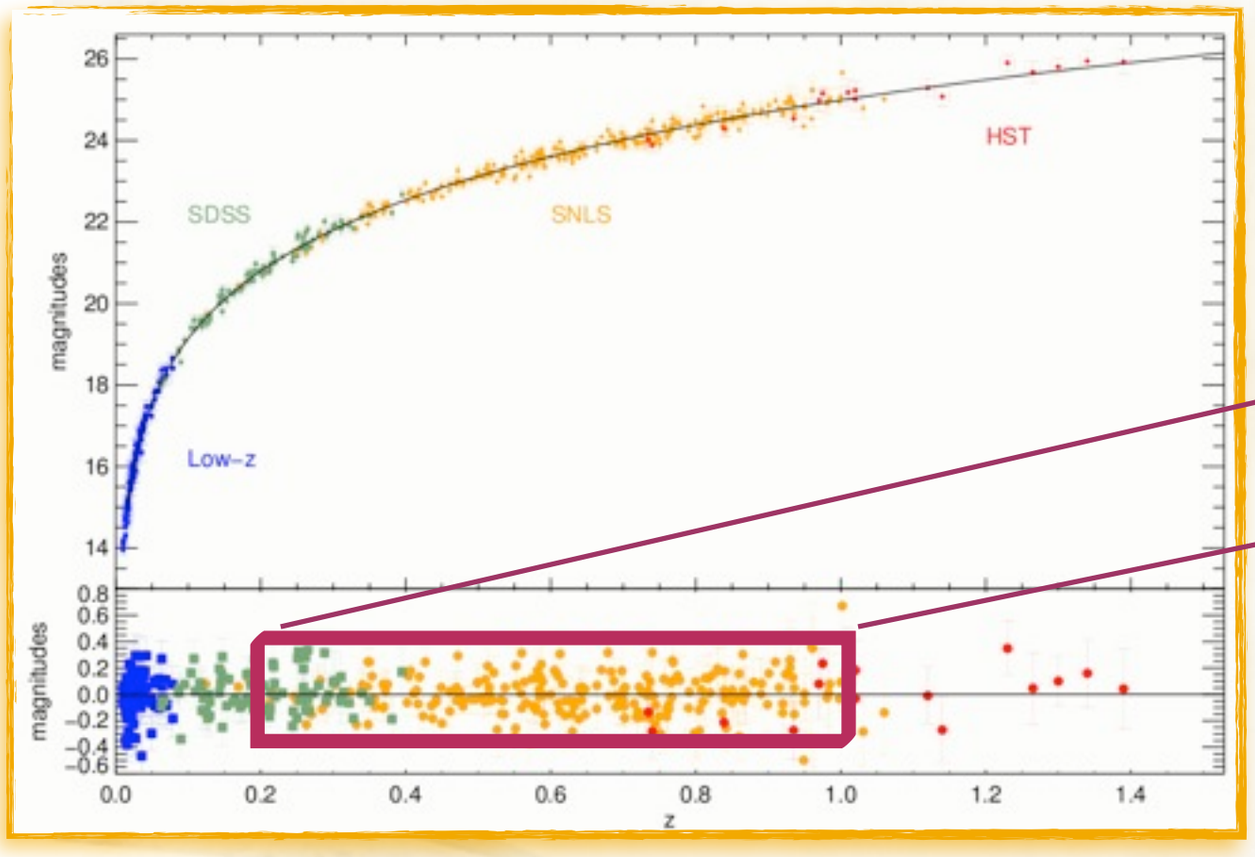
WE NEED:

- ✓ SN Ia spectral model at different phases
- ✓ Flux intercalibration of the imager passbands

Recent results: SNLS3 (1)

DATA

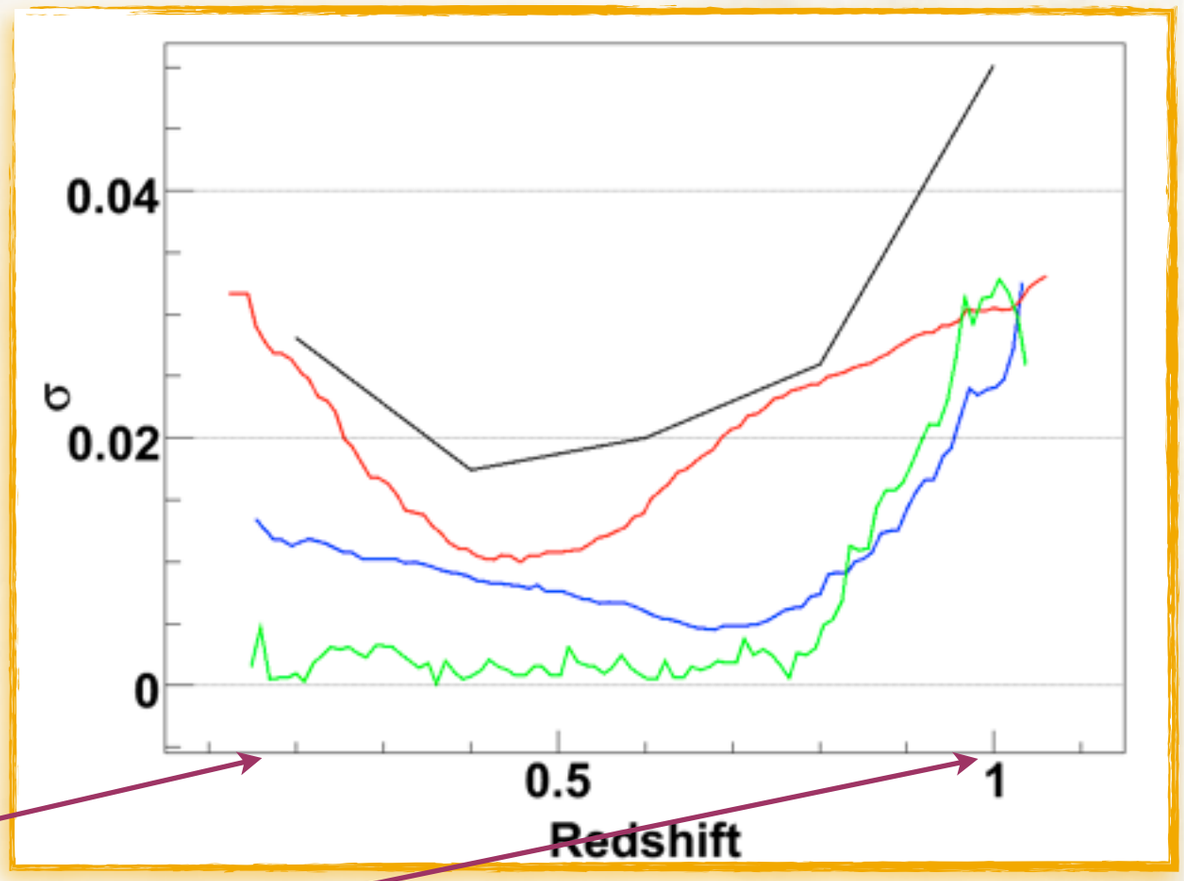
SNe Ia	number
Low z	123
SDSS-7y	93
SNLS-3y	242
HST	14



Hubble Diagram from (Conley et al.,2011)

(Guy et al.,2010) for SNLS3 data only

UNCERTAINTY ON DISTANCE ESTIMATES



- ✓ Statistical uncertainty
- ✓ Calibration
- ✓ Finite training sample
- ✓ Residual scatter model

Recent results: SNLS3 (2)

(Conley et al.,2011)

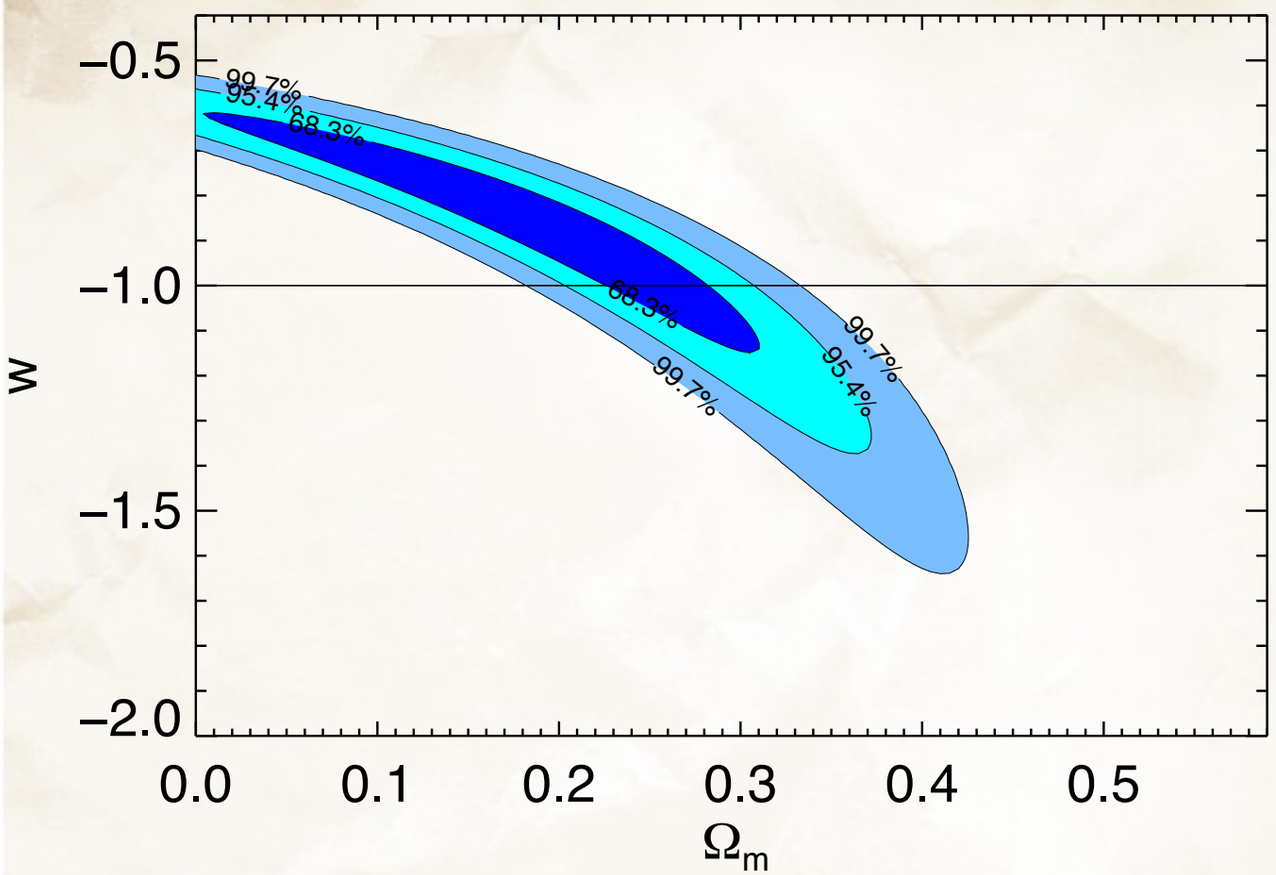


Table 7: Identified systematic uncertainties

Description	Ω_m	w	Rel. Area [a]
Stat only	$0.19^{+0.08}_{-0.10}$	$-0.90^{+0.16}_{-0.20}$	1
All systematics	0.18 ± 0.10	$-0.91^{+0.17}_{-0.24}$	1.85
Calibration	$0.191^{+0.095}_{-0.104}$	$-0.92^{+0.17}_{-0.23}$	1.79
SN model	$0.195^{+0.086}_{-0.101}$	$-0.90^{+0.16}_{-0.20}$	1.02
Peculiar velocities	$0.197^{+0.084}_{-0.100}$	$-0.91^{+0.16}_{-0.20}$	1.03
Malmquist bias	$0.198^{+0.084}_{-0.100}$	$-0.91^{+0.16}_{-0.20}$	1.07
non-Ia contamination	$0.19^{+0.08}_{-0.10}$	$-0.90^{+0.16}_{-0.20}$	1
MW extinction correction	$0.196^{+0.084}_{-0.100}$	$-0.90^{+0.16}_{-0.20}$	1.05
SN evolution	$0.185^{+0.088}_{-0.099}$	$-0.88^{+0.15}_{-0.20}$	1.02
Host relation	$0.198^{+0.085}_{-0.102}$	$-0.91^{+0.16}_{-0.21}$	1.08

(Conley et al.,2011)

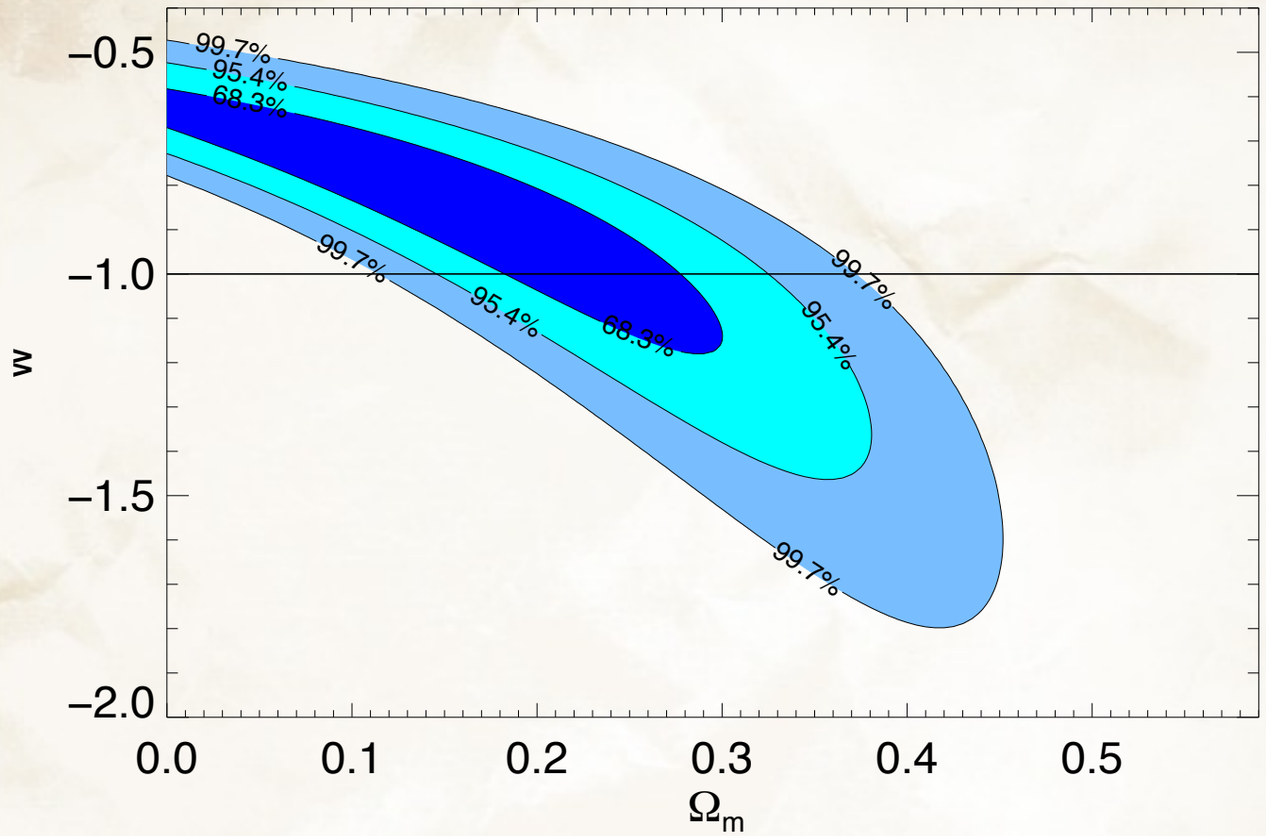
$$w = -0.91^{+0.16}_{-0.20}(\text{stat})^{+0.07}_{-0.14}(\text{sys})$$

Ellipse relative areas:

- ✓ Stat only= 1
- ✓ Syst tot = 1.85
- ✓ Calibration = 1.79

Recent results: SNLS3 (2)

(Conley et al.,2011)



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Ellipse relative areas:

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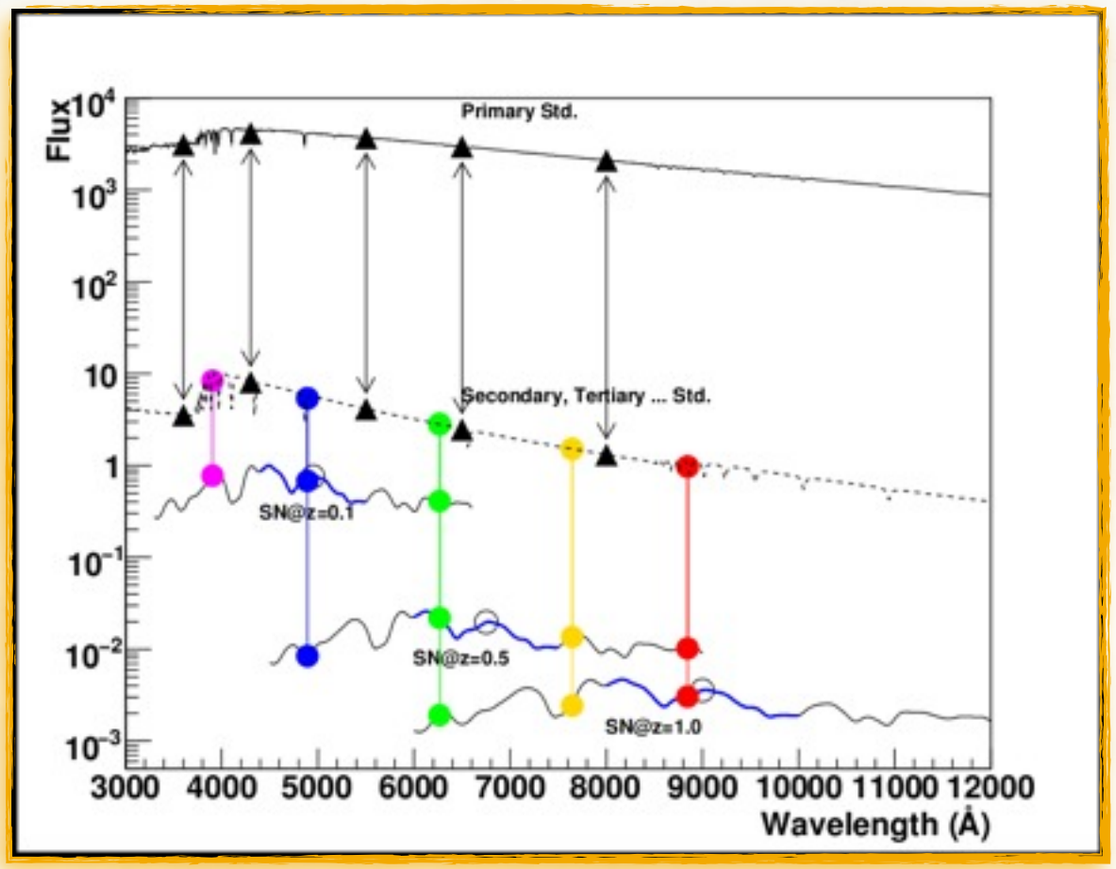
How can we improve SNLS measurements?

✓Direct observation of primary standards with MegaCam

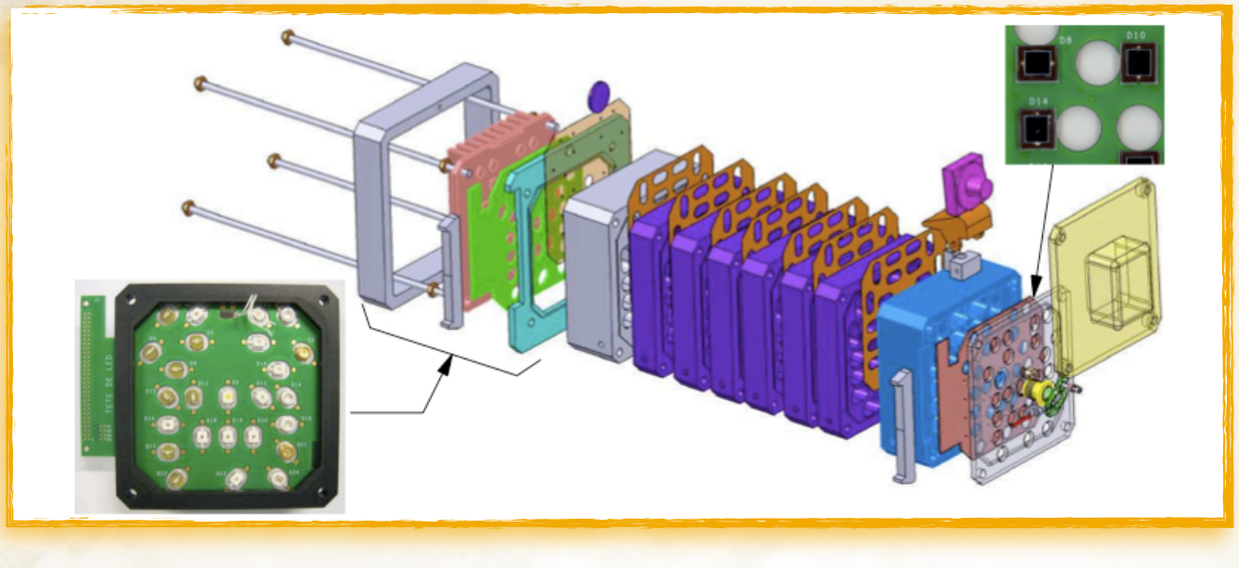


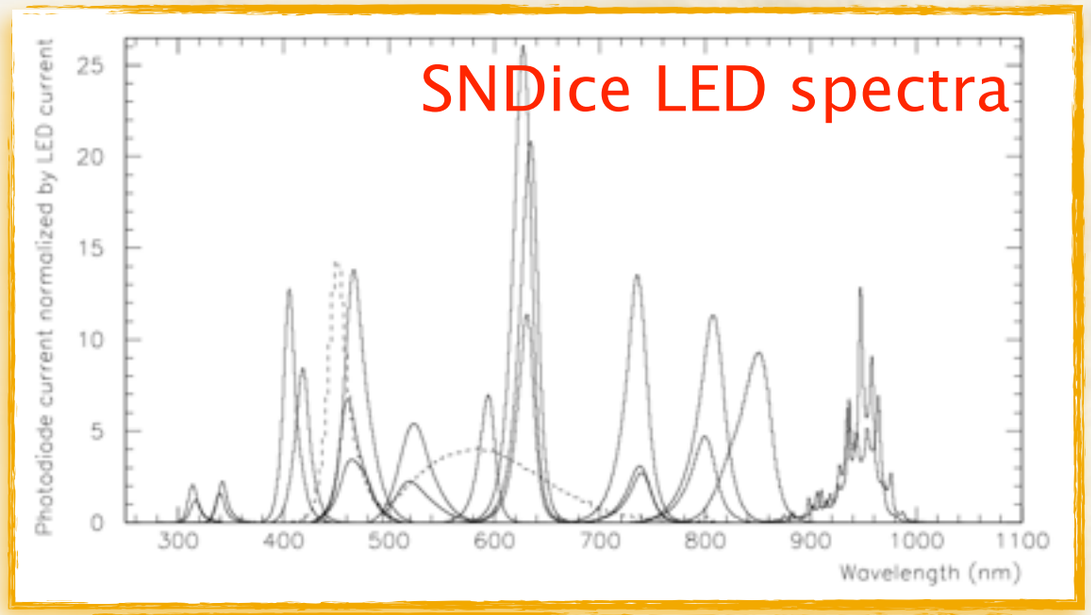
✓New data set of low-z SNe Ia observed in the same filter system

✓Project of instrumental calibration with calibrated light sources: LASERS (Stubb et al., 2006) , LEDs (SNDice @ LPNHE)

The SNDice Project

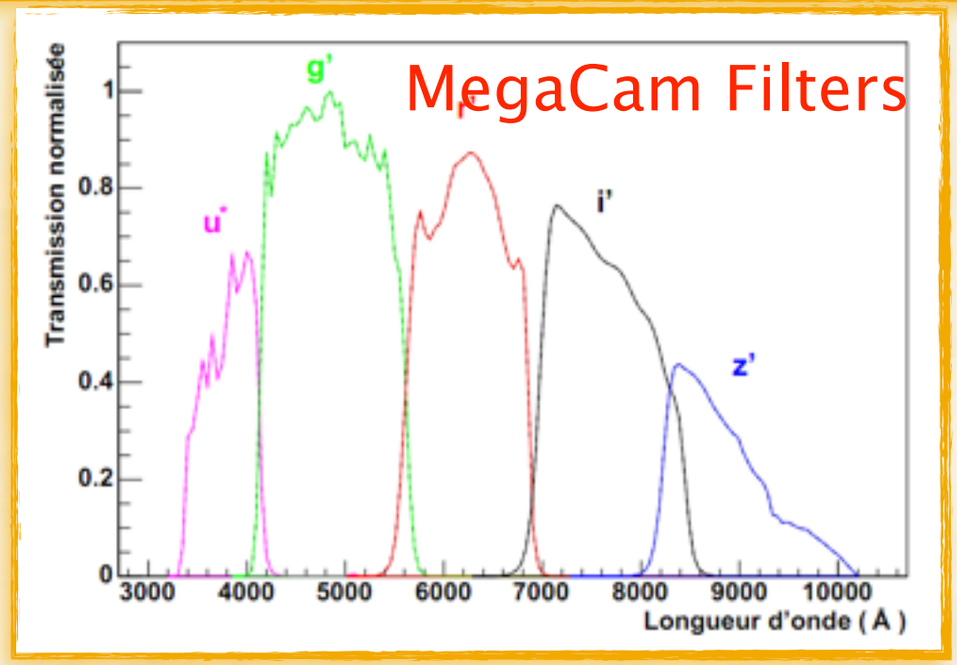
Designed and built @ LPNHE





✓ 24 LEDs: narrow spectra from IR to UV

✓ Absolute reference for flux measurement (LED fluxes absolutely calibrated using a photodiode – precision 10^{-4})



Optimized to study MegaCam imager

SNDice Applications

✓ Study of the MegaCam readout electronics:

→ stability, determination of amplifier gains

✓ Monitoring of camera performances:

→ CCD quantum efficiency, mirror reflectivity, optical transmission

✓ Study of the uniformity of the imager photometric response:

→ flat field optimisation

✓ Intercalibration of passbands

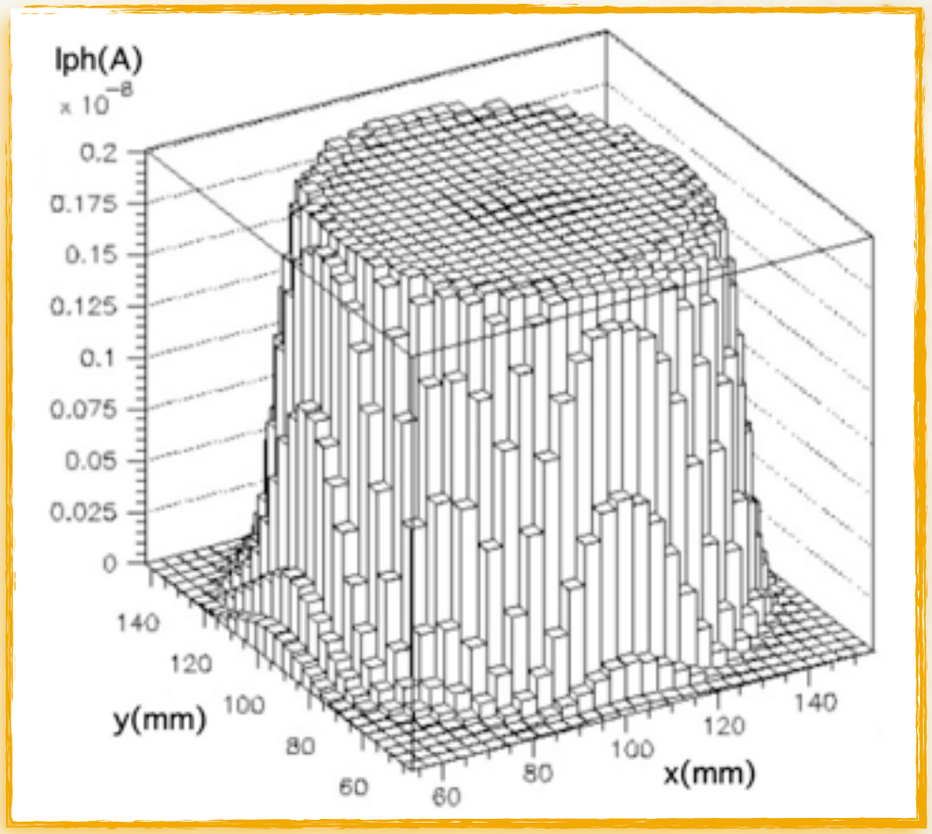
Test bench activities @ LPNHE

CALIBRATION AND STUDY OF THE STABILITY OF THE LIGHT SOURCE ITSELF

✓ Mapping of each LED beam (uniform @ 10^{-4} level)

✓Study of the emission stability vs time

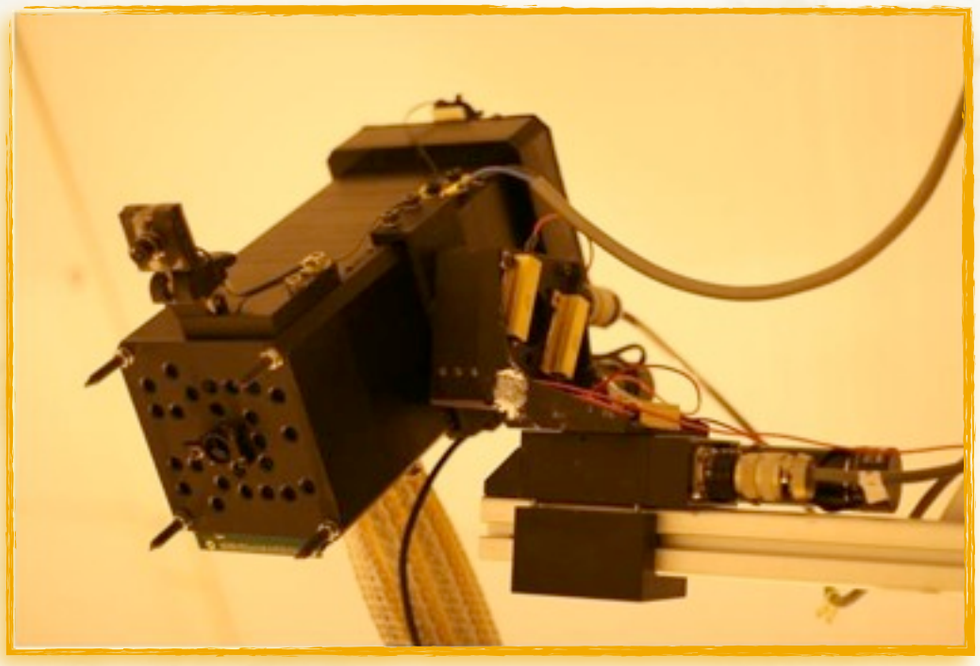
✓ Variation of each LED spectrum with temperature

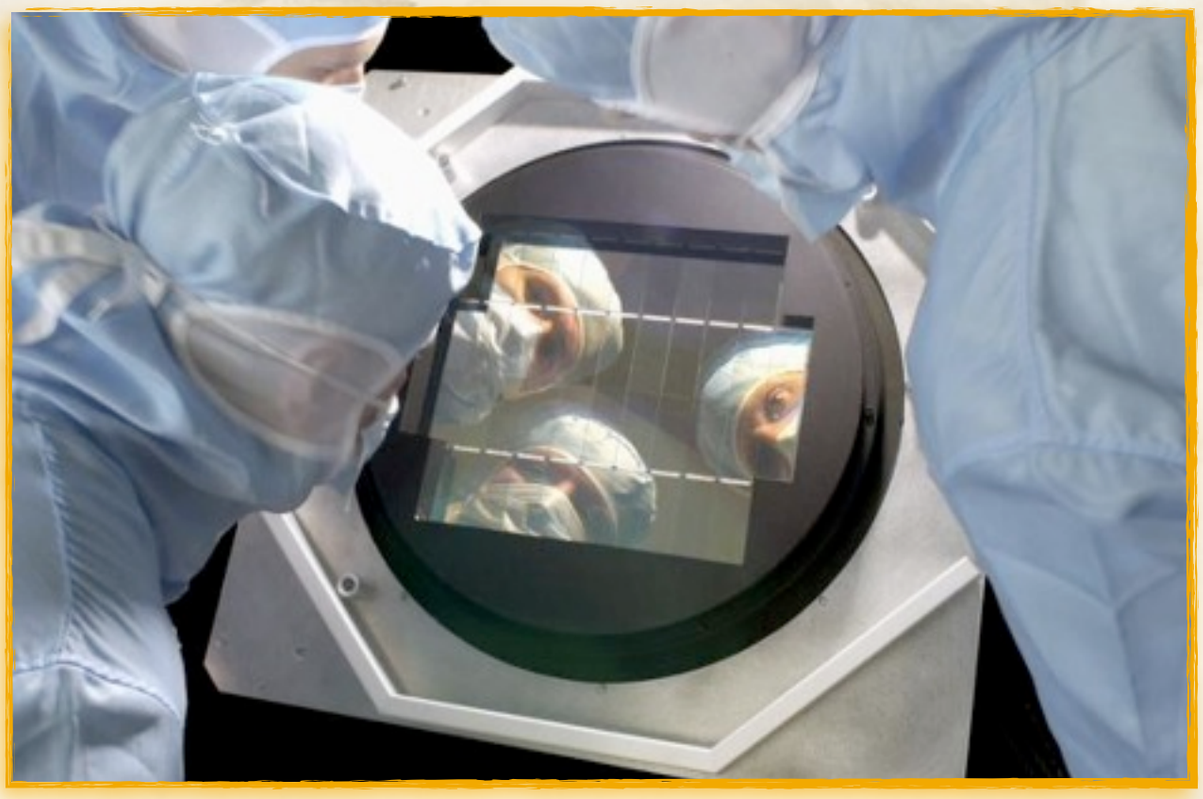


(Juramy, et al. 2008)

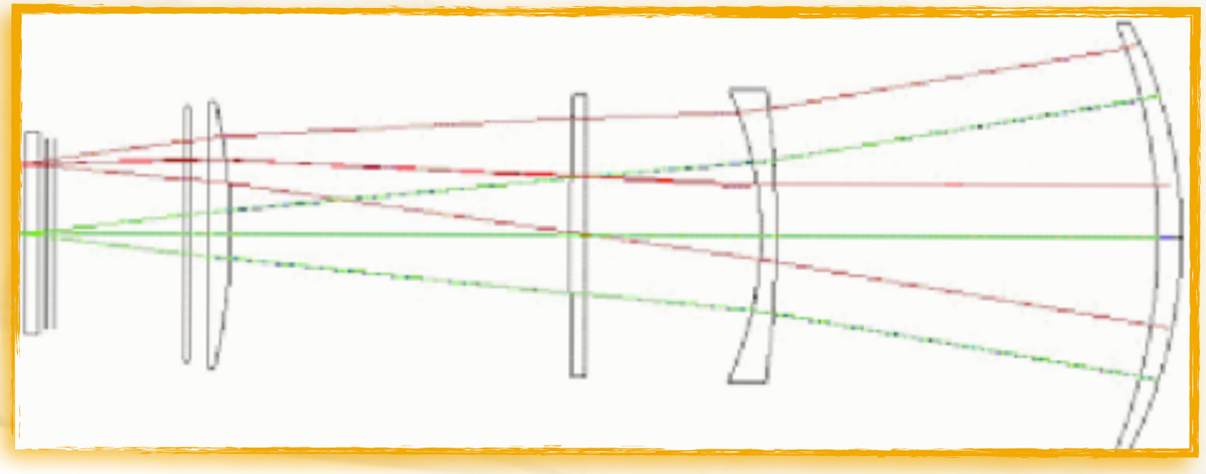
Installation @ CFHT

Configuration SNDice-MegaCam in the CFHT enclosure





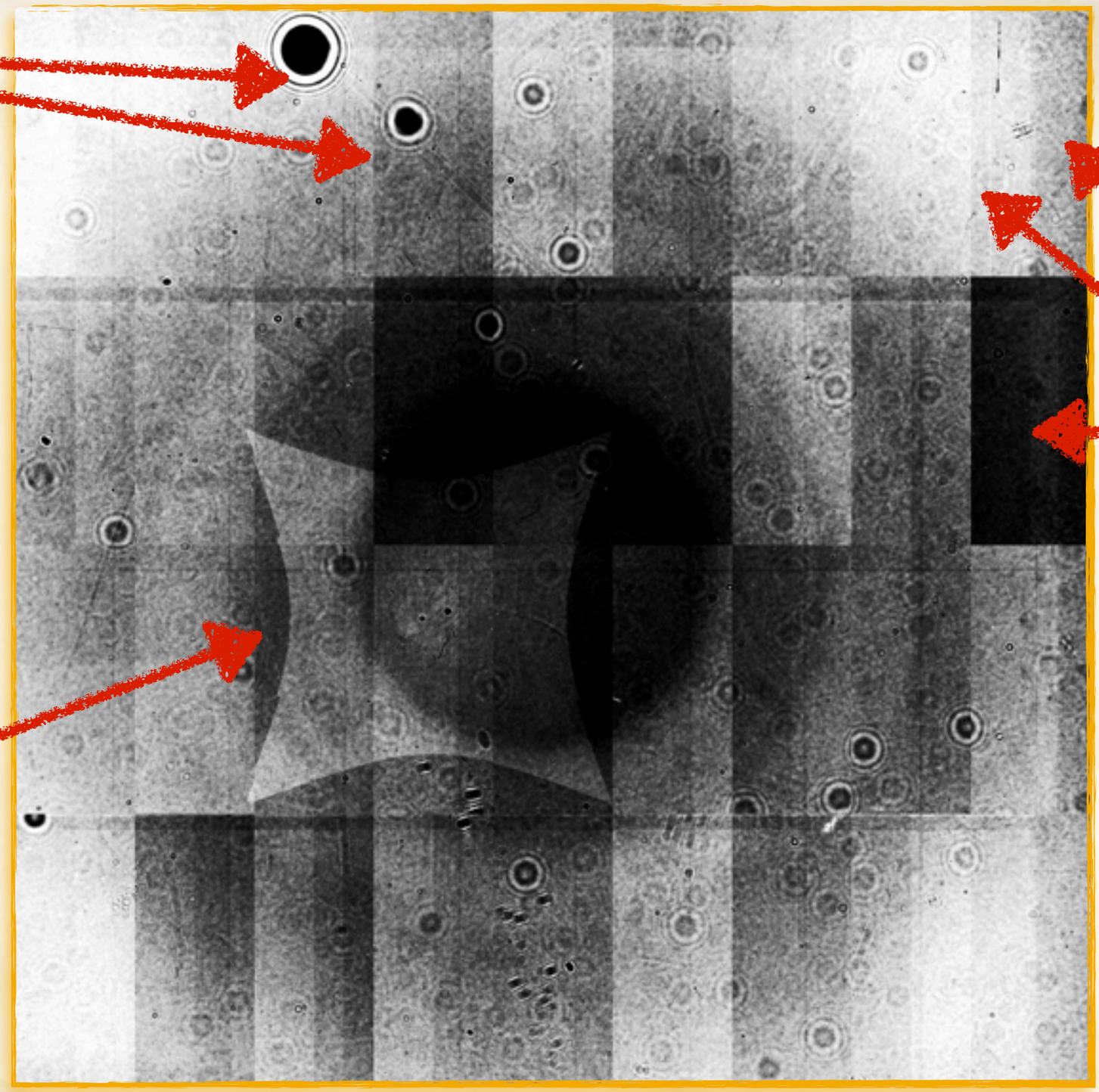
36 CCDs 2k x 4k , 72 amp.



- ✓ Field 1 deg^2
- ✓ Angular res. 1pix = 0.187”
- ✓ Wide Field Corrector 4 lens

SNDice Exposure

Dust/ defects in the optical path



Gain variations

Reflection within the optics

Instrument Model

$$\Phi_{\mathrm{ADU}} = g_{\mathrm{amp}} \int \varepsilon(\lambda) \cdot \mathrm{T}(\lambda) \cdot \mathrm{S}(\lambda)\,\mathrm{d}(\lambda)$$

Gain
(readout electronics)

CCD QE

Normalized
transmission
(continous)

LED
Spectrum
(measured)

We want to determine: GAINS, CCD QE and TRANSMISSIONS (optics and mirror)

Gains and Quantum Efficiencies

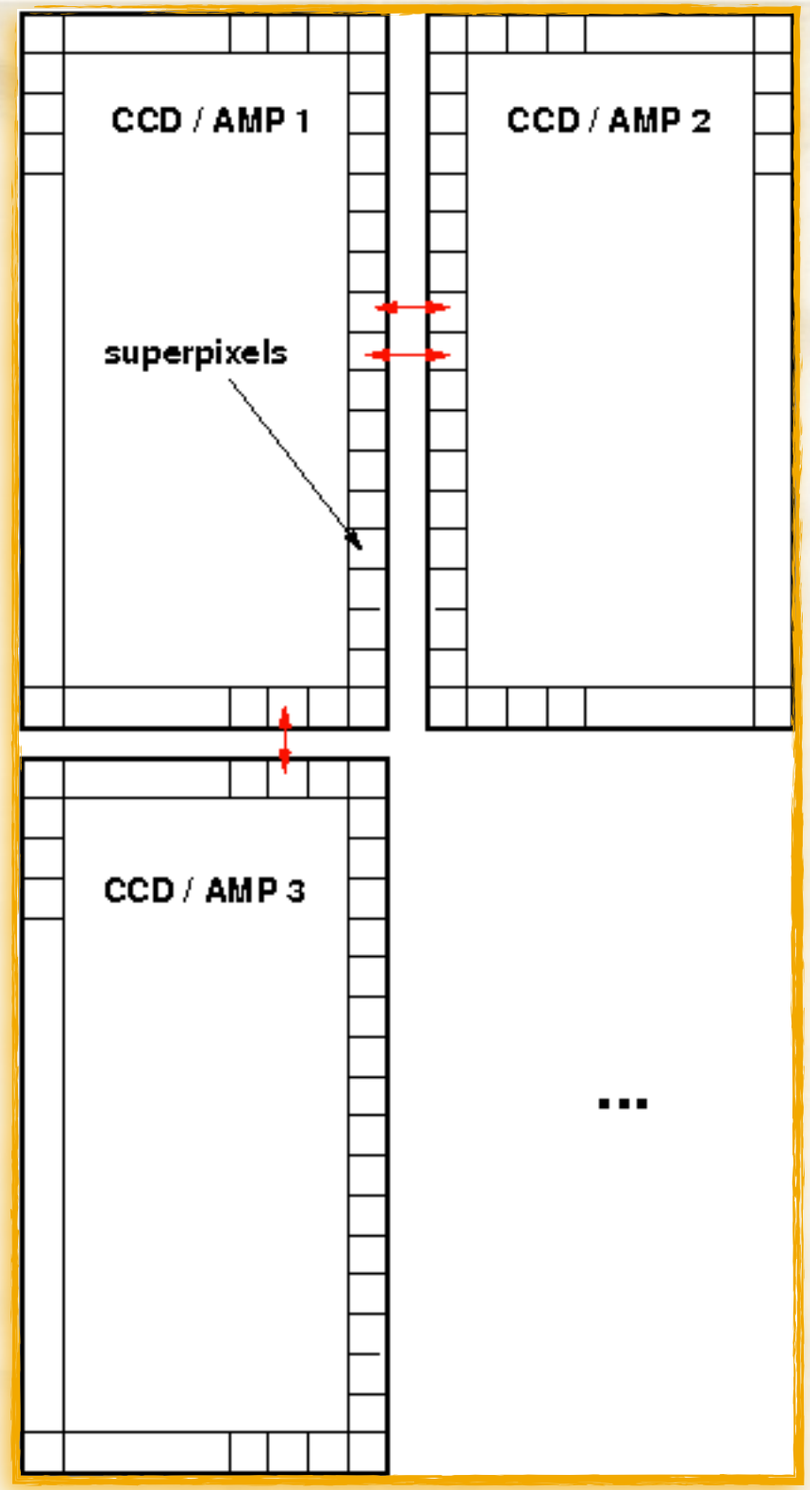
✓ We can determine the gain times CCD QE ratios from one amplifier to another:

$$g_1 \Phi_1 = g_2 \Phi_2$$

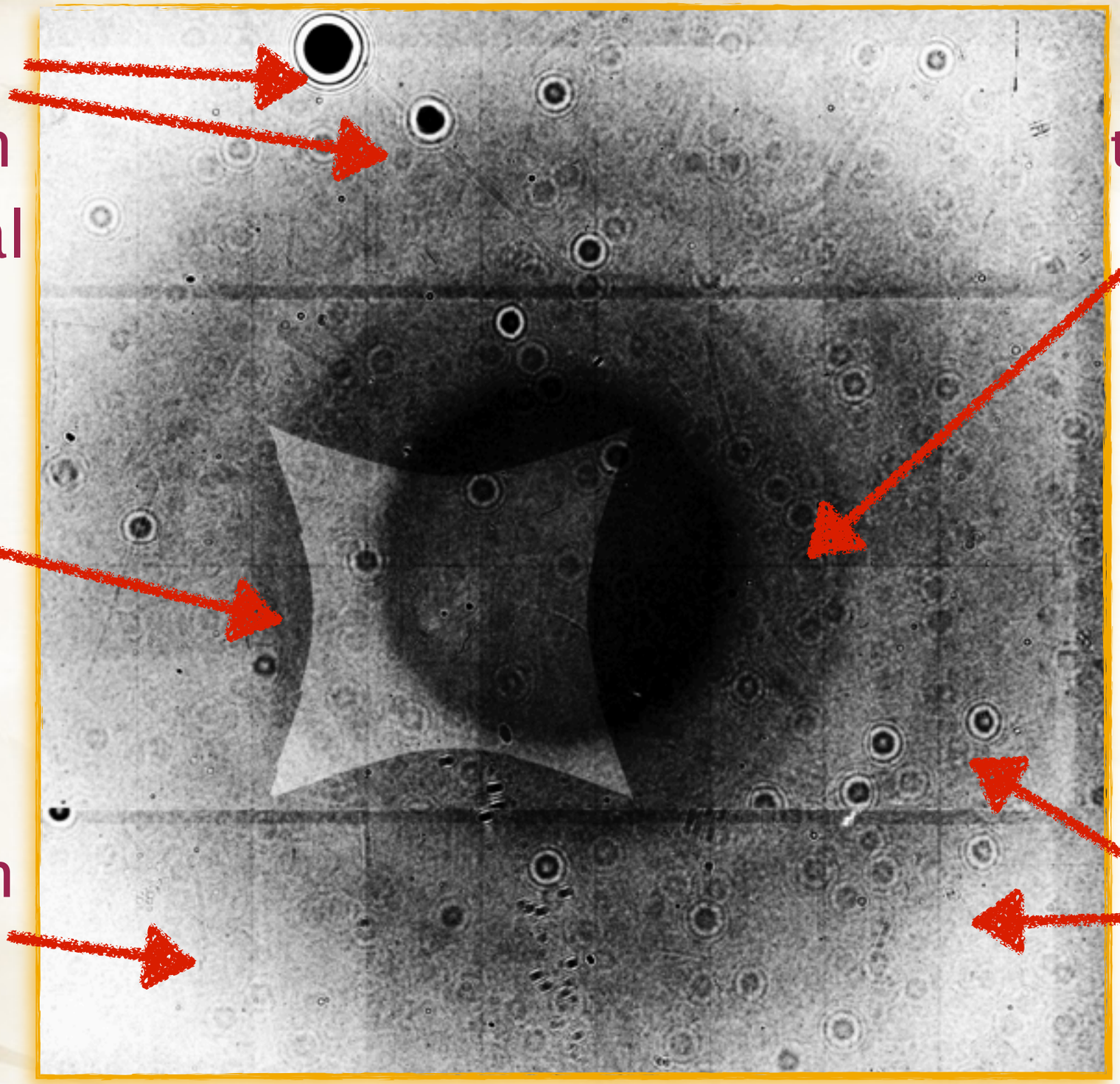
✓ If we consider all the neighboring superpixel pairs:

$$\chi^2 = \sum_p w_p (g_{ip} \Phi_{ip} - g_{jp} \Phi_{jp})^2$$

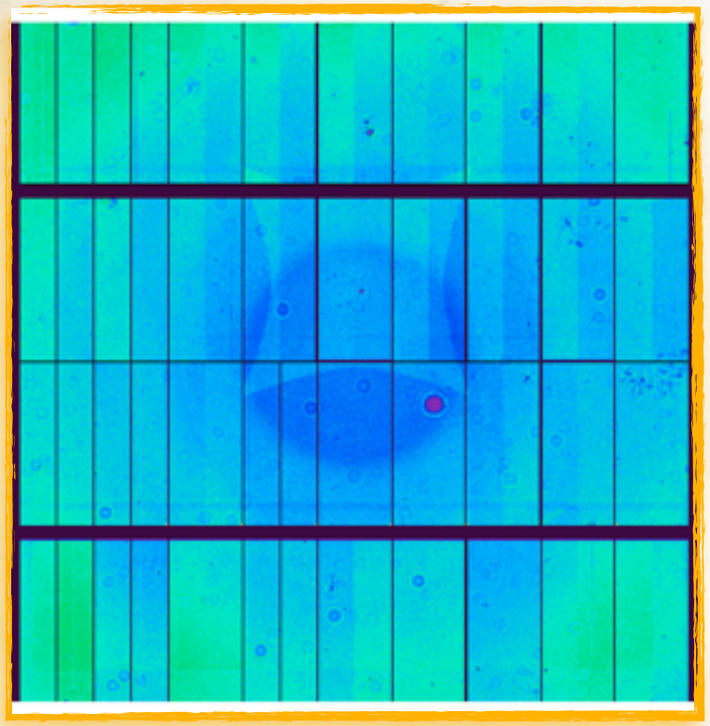
→ 71 INDIPENDENT VALUES



SNDice Exposure (2)



Data Analysis

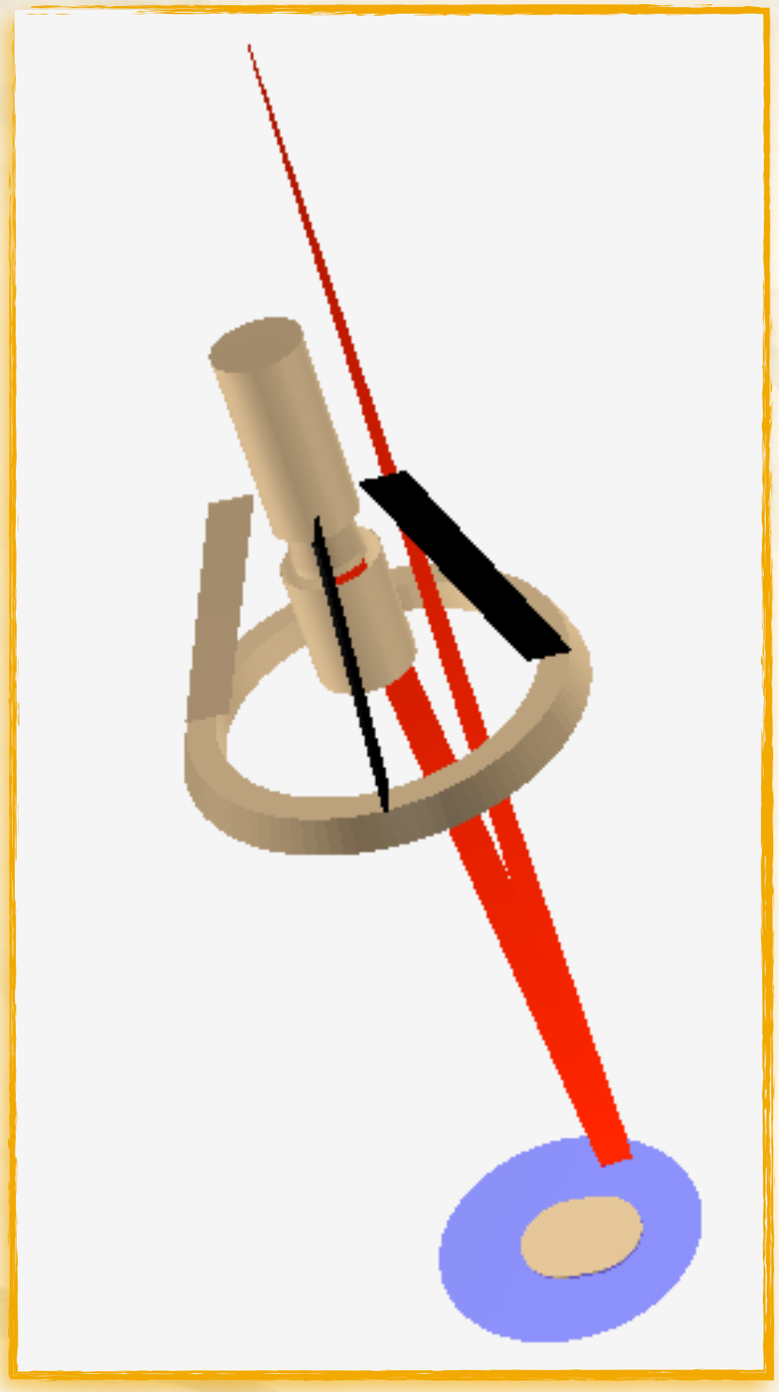


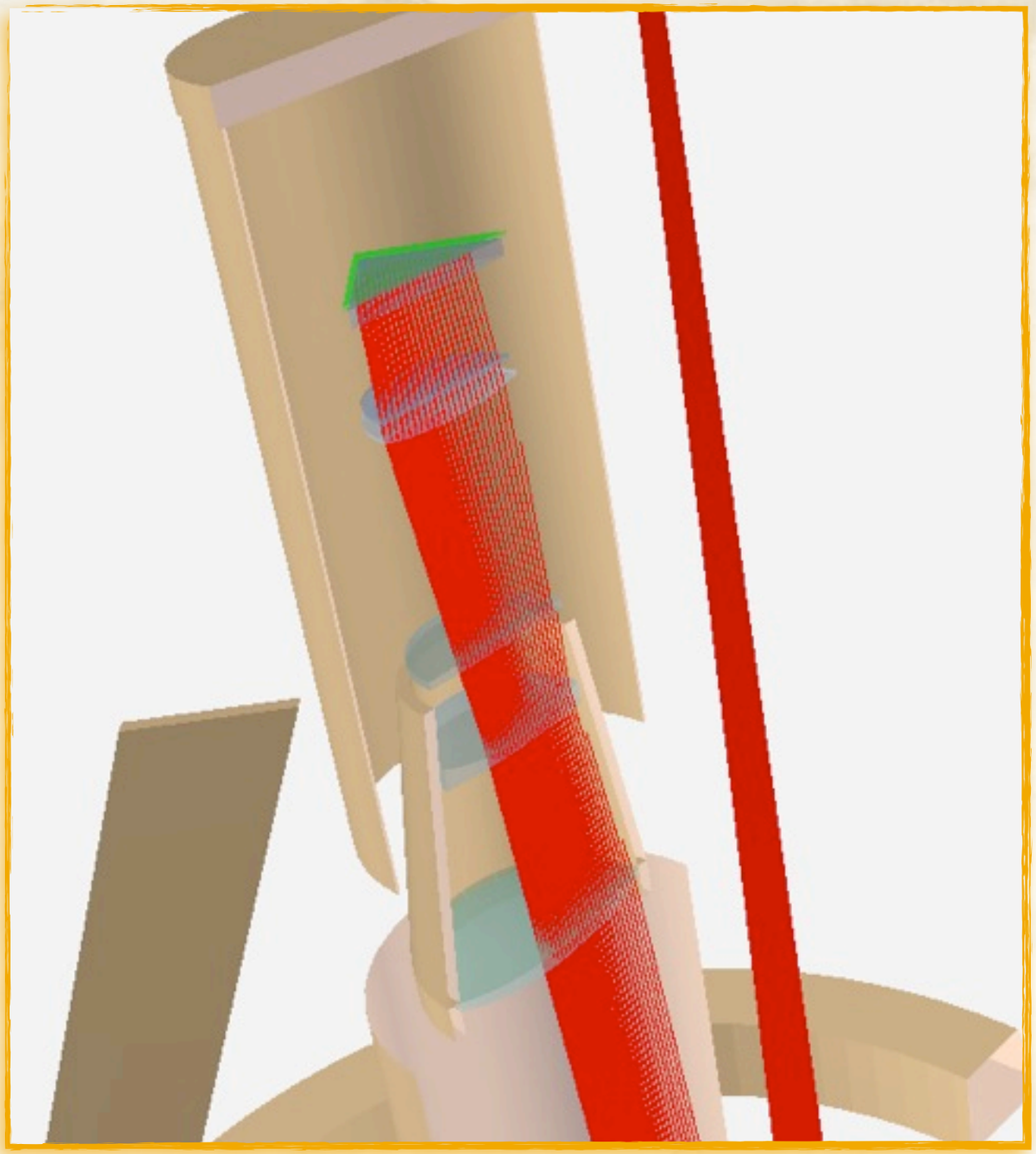
MegaCam CALIBRATION

SNDice IMAGES

Telescope model and illumination simulation

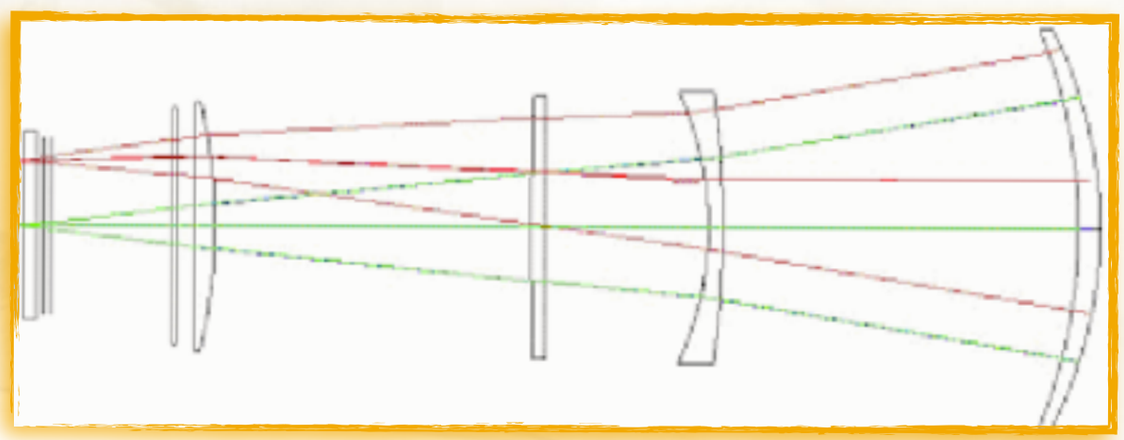
Simulation of SNDice-MegaCam system





Simulation of focal plane illumination

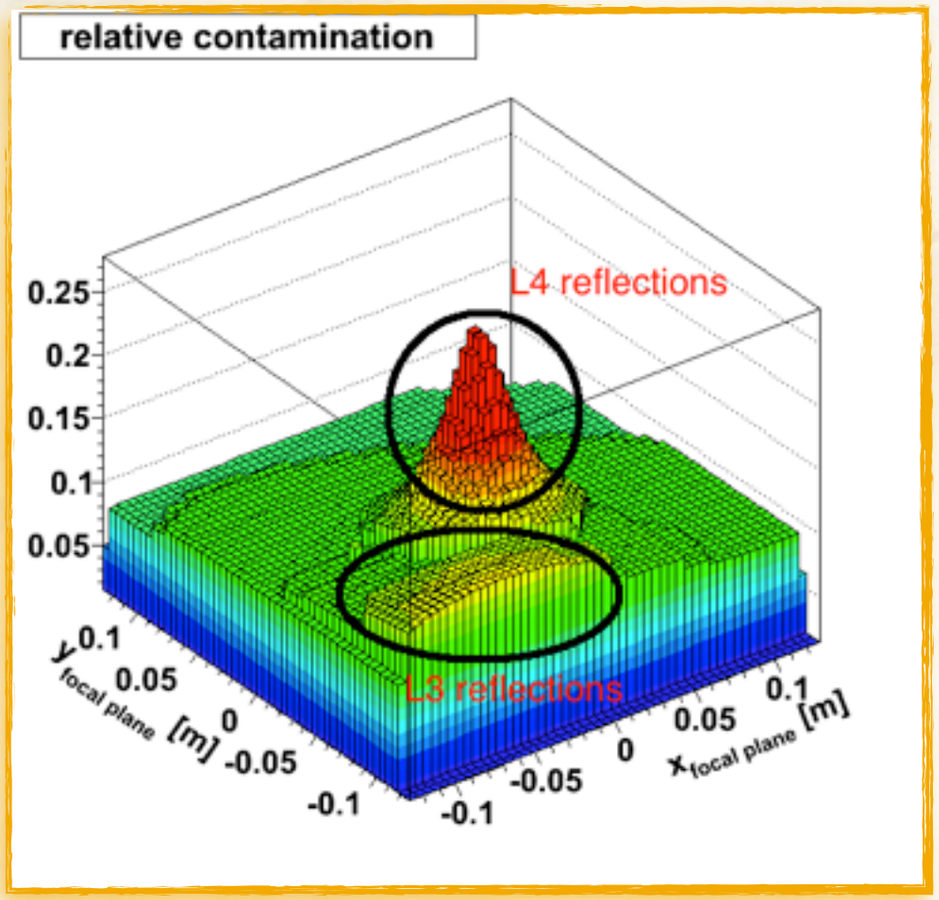
Stars seen by MegaCam



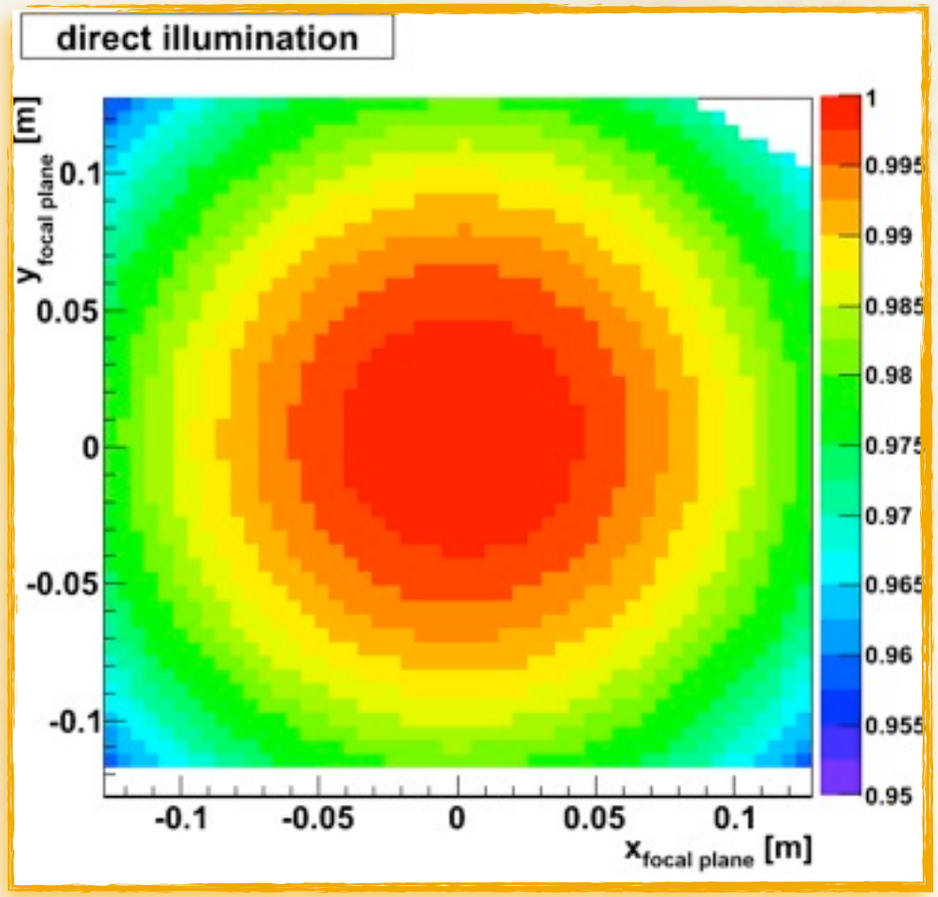
Goal: TO GET RID OF INTERNAL REFLECTIONS FROM OPTICS

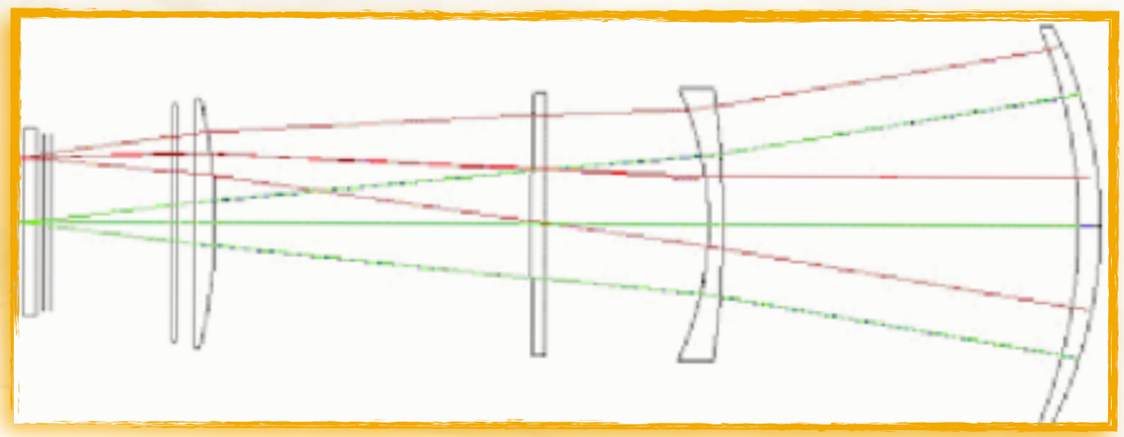
Simulation of focal plane illumination

Simulated star



Direct light contribution

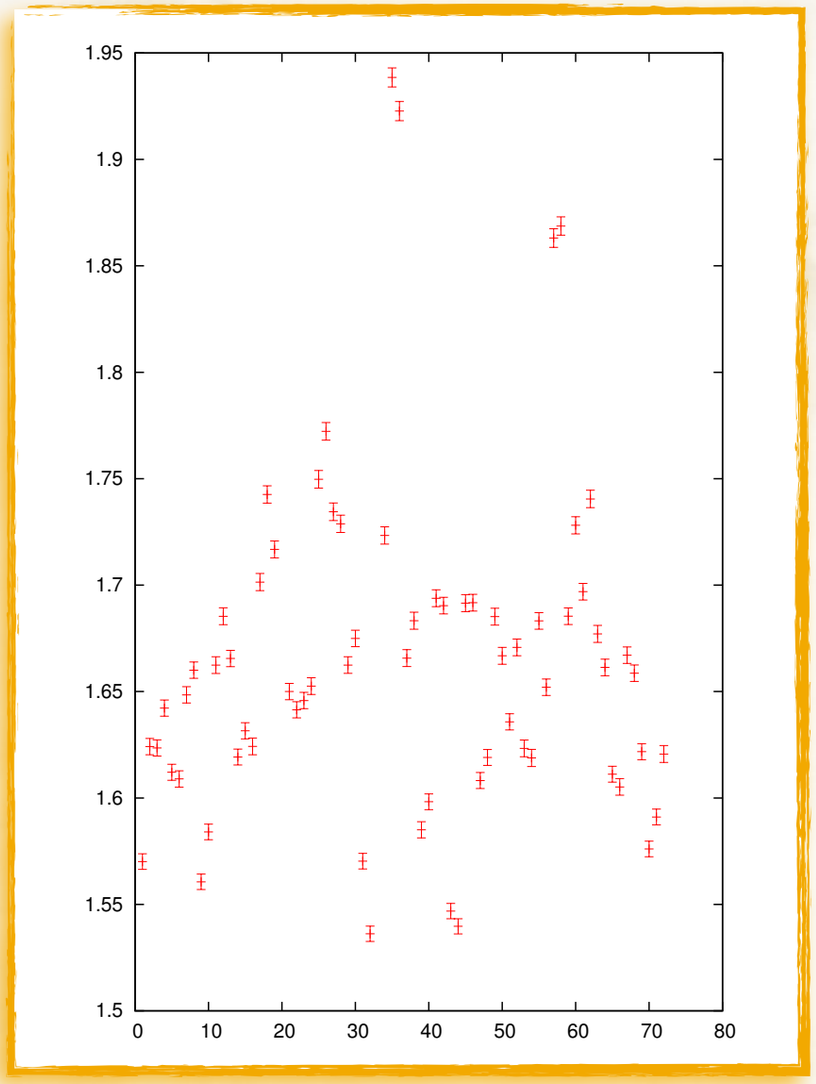


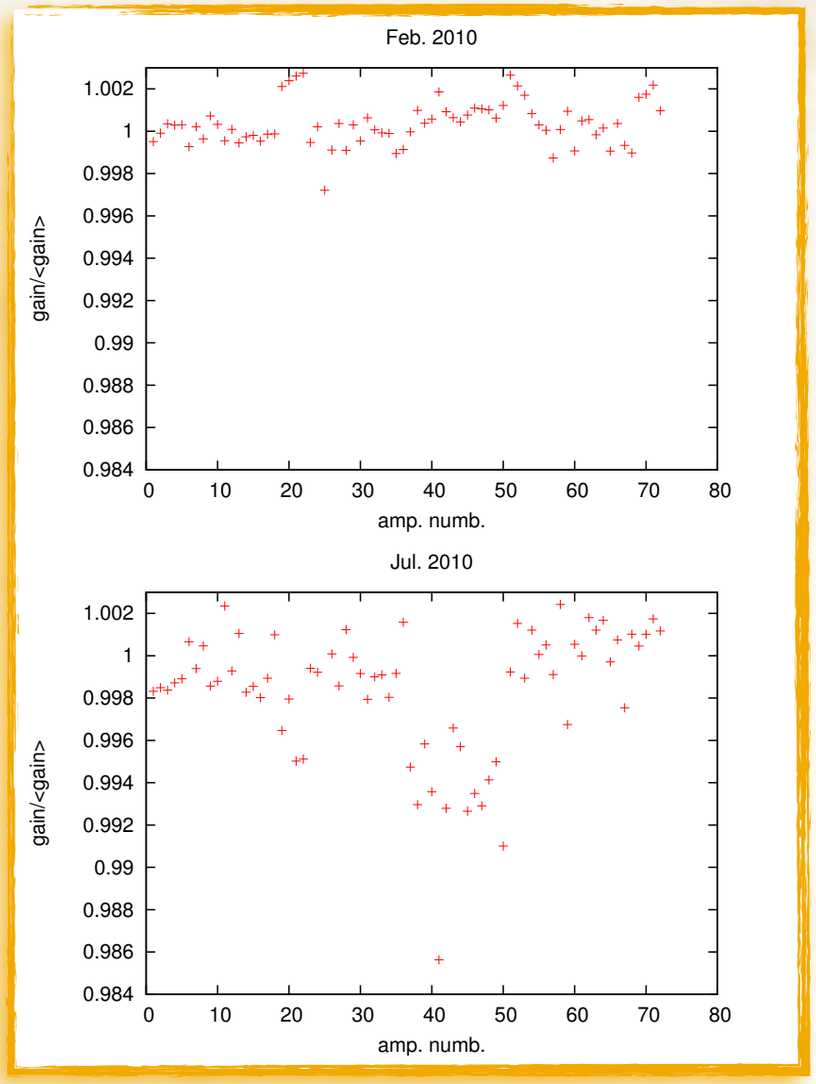


Goal: TO GET RID OF INTERNAL REFLECTIONS FROM OPTICS

Electronic Gain Determination

STABILITY CHECK OVER ONE YEAR OF DATA AQUISITION





Poissonian dist

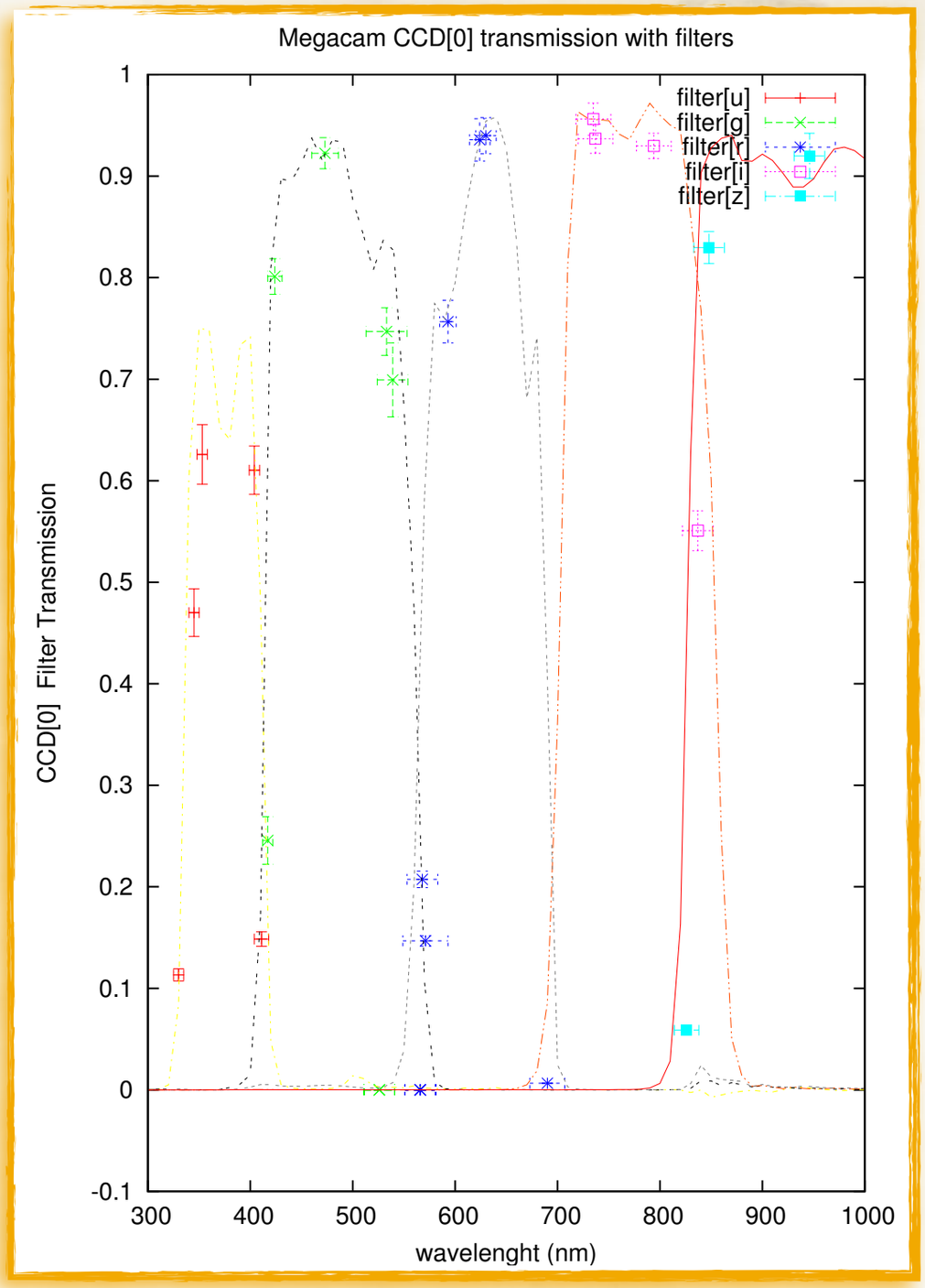
$$\Phi_{\mathrm{ADU}} = g_{\mathrm{amp}} \cdot N_{\gamma}$$

FIXED

A. Guyonnet's Thesis

Study of Passbands

Filters transmission (CCD0)



A. Guyonnet's Thesis

Ongoing analysis

✓ Determination of the absolute passband transmission (A. Guyonnet's Thesis)

✓ Optimization of the new flat-fielding technique

✓ Test bench acquisition at low temperatures

✓ A new prototype SKYDice for the SkyMapper Telescope (Australia)

Thanks for your attention!