Impact of calibration on SNe-Ia luminosity distance precision

Journées LSST montpellier

Marc Betoule

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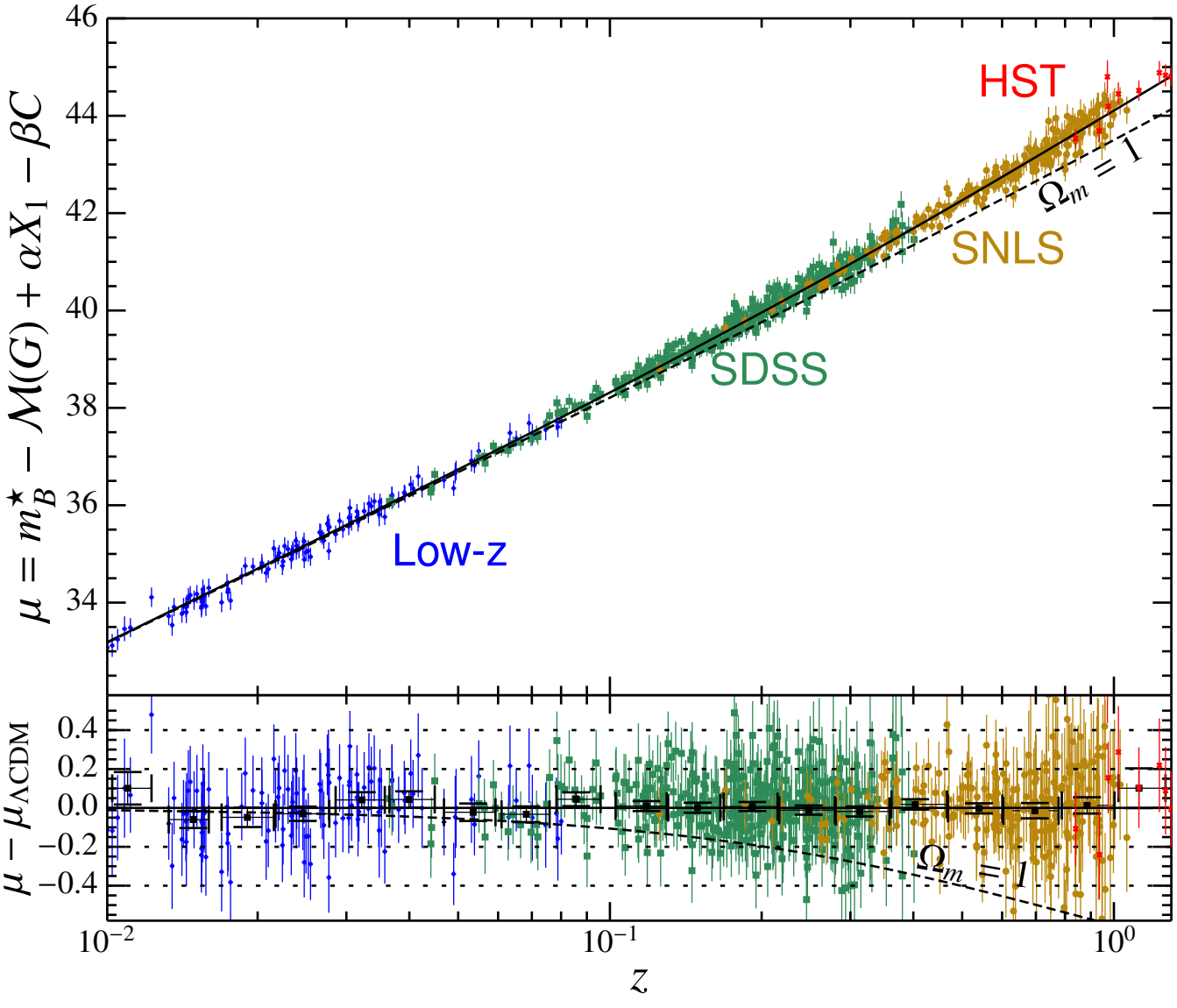
PARIS

The distance-redshift relation: probe for dark energy



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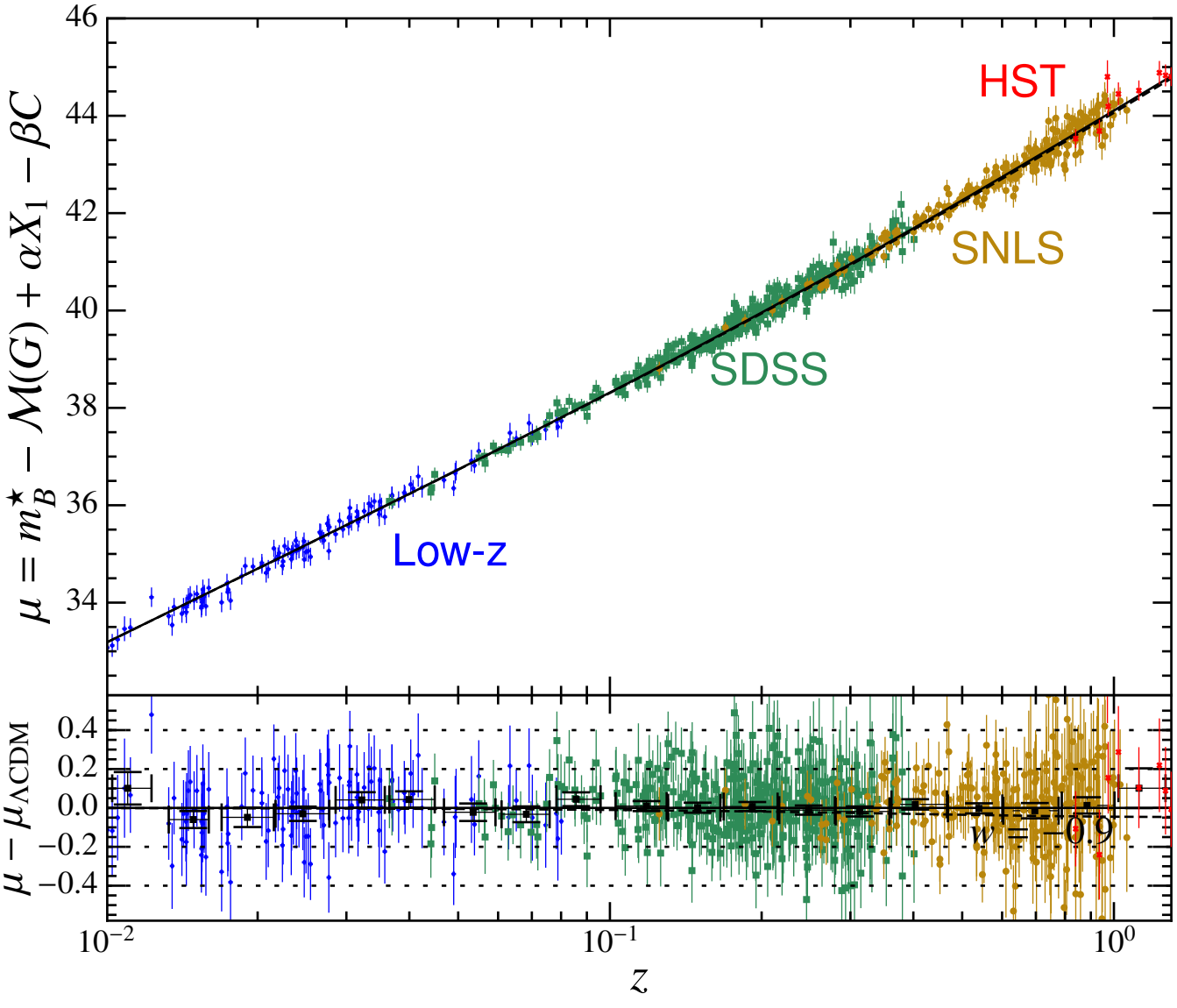
The distance-redshift relation: probe for dark energy



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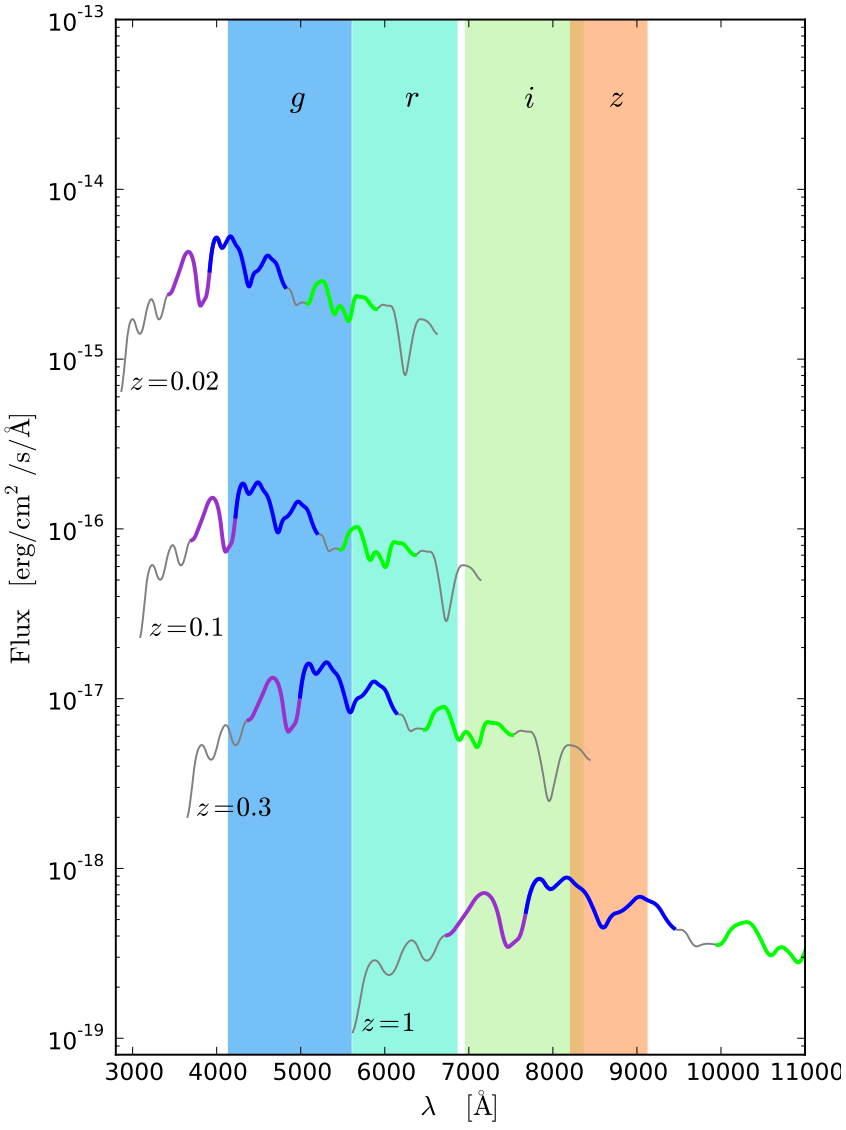
Measuring supernovae fluxes . . . and colors



$$\mu \approx m_B^* - [M + 3(m_B^* - m_V^*)]$$

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Photometric calibration

Consider the following model for broadband measurements:

$$\phi = \int T(\lambda) S(\lambda; \theta) d\lambda + n$$

- $S(\lambda; \theta)$ Parametric model of object SED
- $T(\lambda)$ Intrument band transmission
- n Centered random variable
- ϕ Measured broadband flux

Errors on $T(\lambda)$ translates to errors on θ

Typical requirement is that noise remains the first source of uncertainty

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Error modes in transmission

Normalisation $\int T(\lambda)d\lambda$

Change at different time scales

- At short time scales (Between two exposures):
  - Atmospheric extinction/PSF variation
- At longer time scales:
  - Changes in instrument transmission (mirror, coatings . . .)

Mean wavelength $\int \lambda T(\lambda)d\lambda$

- At short time scale (night): atmospheric transmission (Water / ozone)
- At longer time scale: filter aging, Spectrometer calibration

SN spectra are smooth $\rightarrow$ following orders negligible

Requirements for SNe Ia

1) Individual measurements not impaired by the transmission determination

$$\sigma(Z_p) \leq \sigma(n)$$

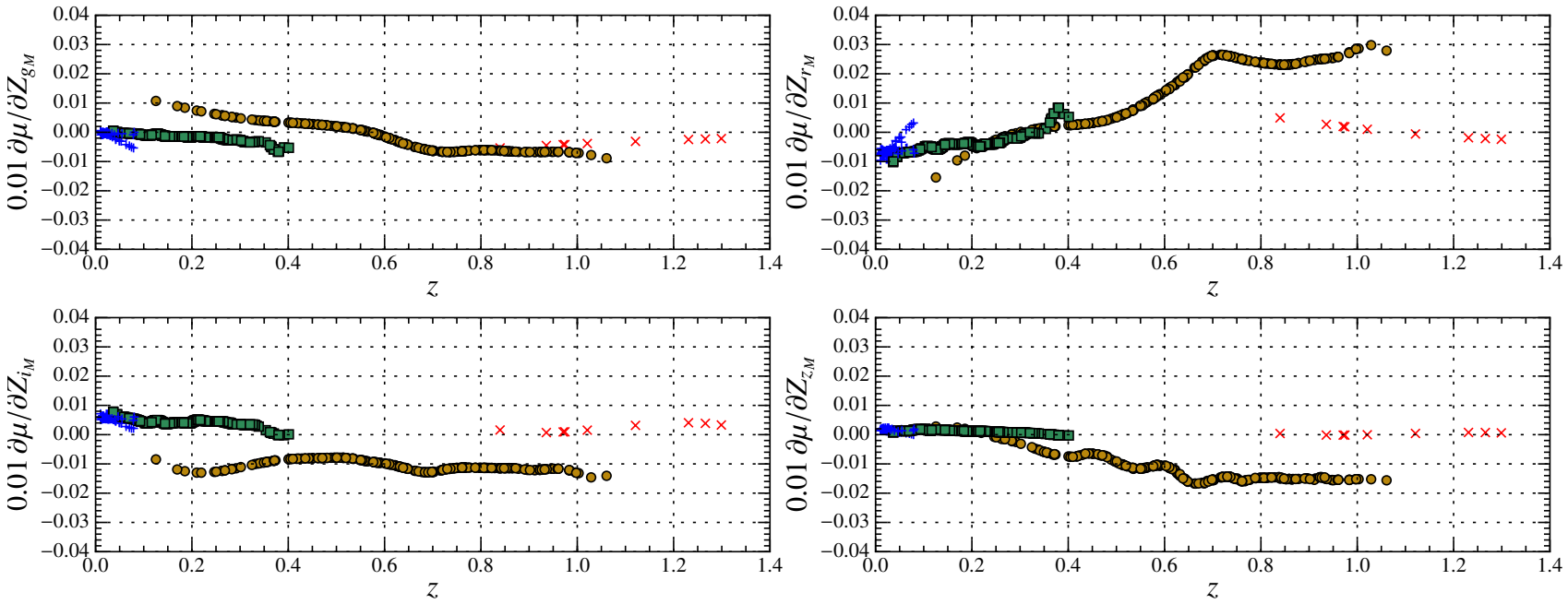
Not a problem for a rolling search

2) Average distance measurement not impaired by the average transmission determination

- Already requires an accurate knowledge of the mean passband
- LSST: 1000 SNe $\rightarrow$ 10000 SNe

Error modes in JLA (lowz + SDSS + SNLS): $\sim$ 700 SNe

Effect of a 1% ZP error in each of the MegaCam bands:



We are mostly sensitive to color evolution

- Changing r changes $(g-r)-(r-i)$: 1% $\rightarrow$ 2% on w

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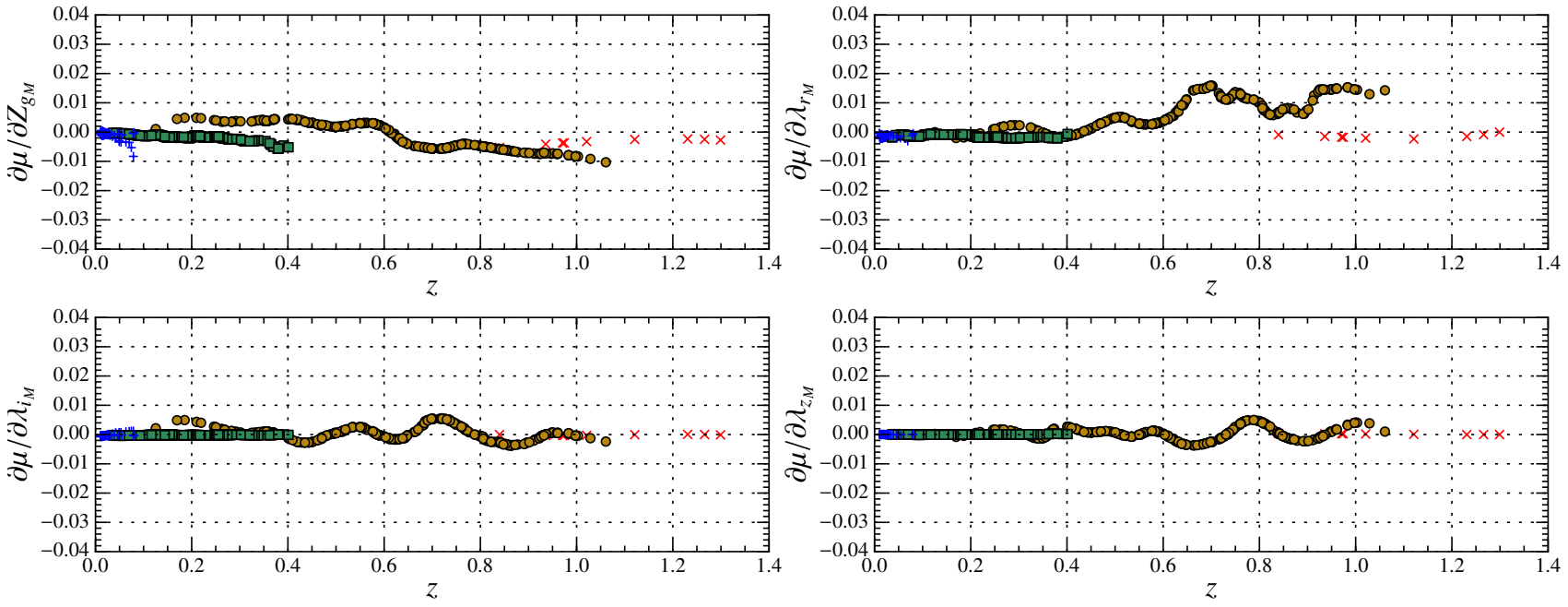
Effect of a 1~nm MW error in each band:



- Sensitive to color differences between the calibration standard and the SN

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What about SNe in LSST ?

Depends on the survey design . . .

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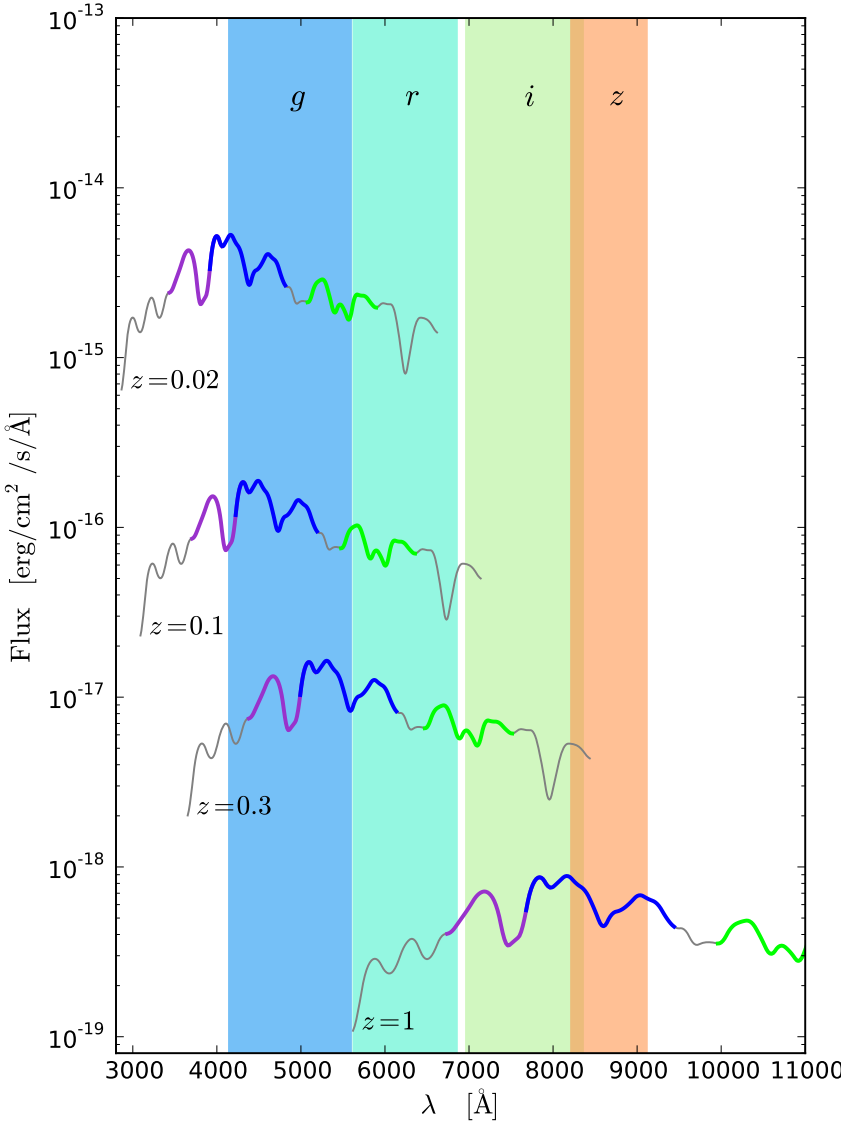
What wavelength range ?



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Astier et al. (2014)

Conservative hypothesis

- 3 bands in the rest-frame $380 < \lambda < 700$

Consequently:

- $z < 0.95$
- 8800 high-z / 8000 low-z
- Minimize sensitivity to calibration uncertainties

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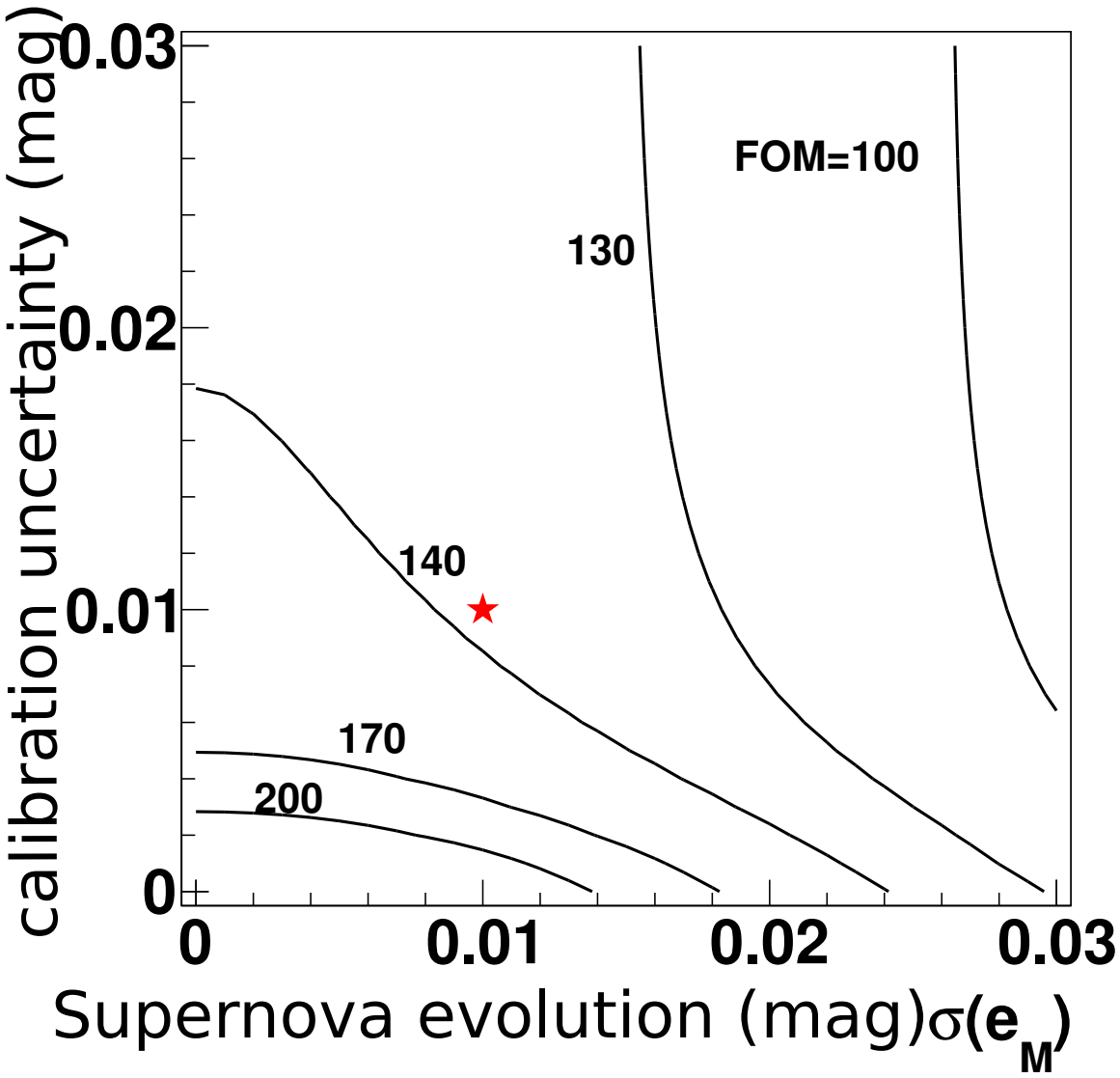
Predicted FOM:



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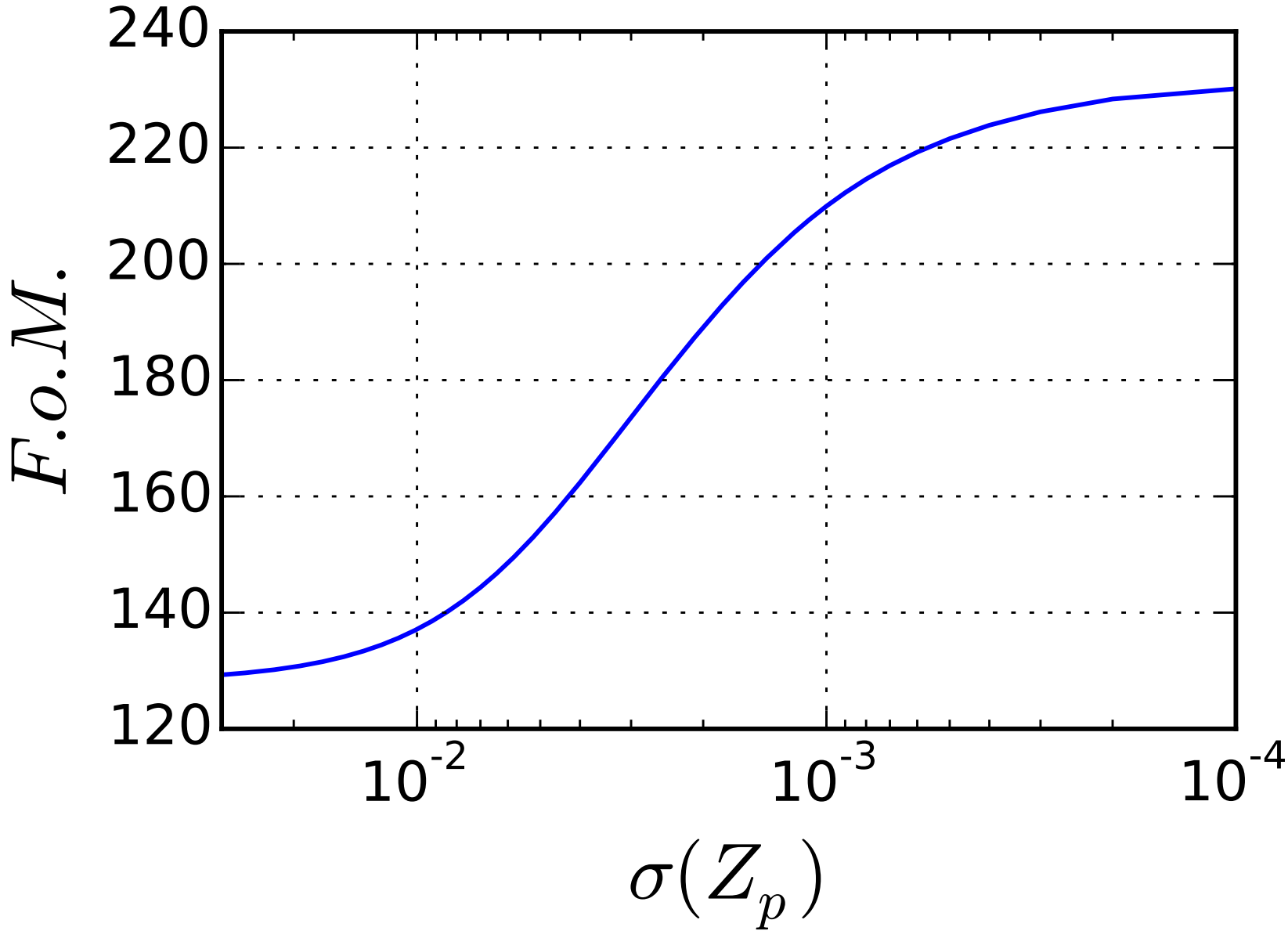
Courtesy of P. Astier

Target accuracy



Conclusion

Critical:

- Accurate average passband
- Accurate relative normalization

Not as critical:

- Survey uniformity (time/area)

Not important

- Overall flux-scale

Target accuracy is $\sim 1 mmag$, requires progress on:

- Calibration standards
- Transfer accuracy
- Instrument knowledge (passbands at a few Angstrom and monitoring)
- Atmospheric transmission knowledge

The Regnault's law of MegaCam calibration accuracy