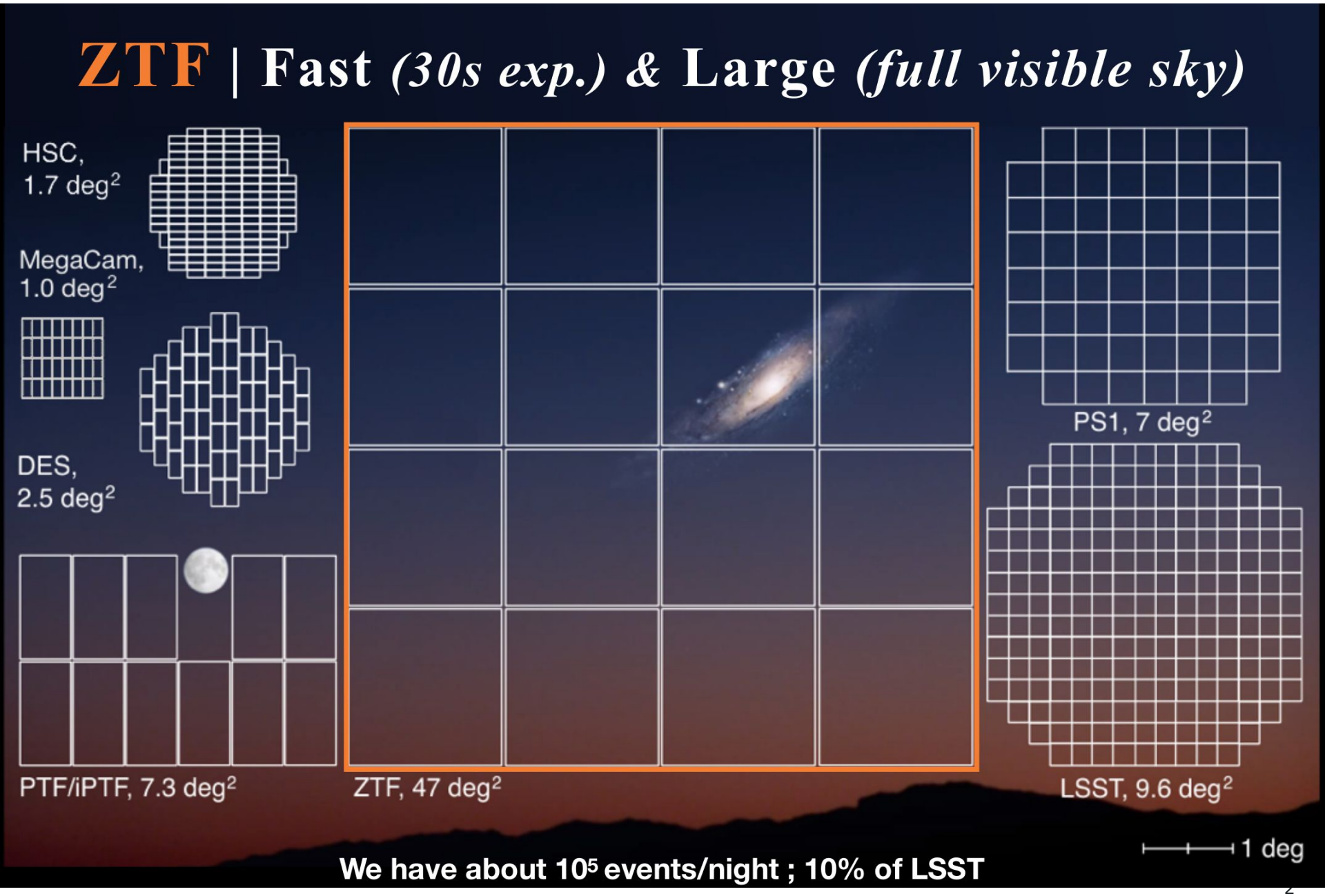
ZTF calibration work

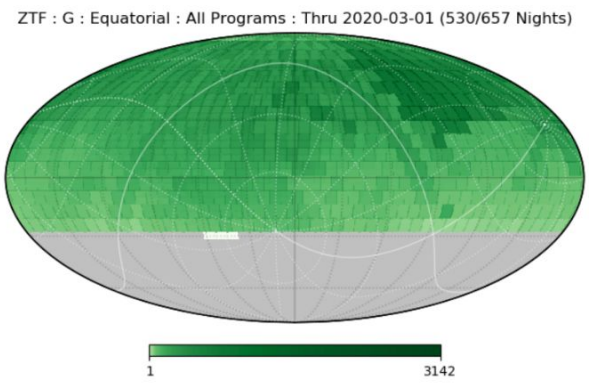
N. Regnault & ZTF IN2P3 participation group.

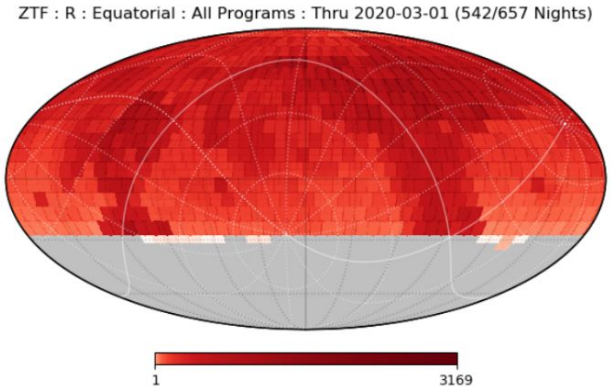
ZTF | Fast *(30s exp.)* & Large *(full visible sky)*

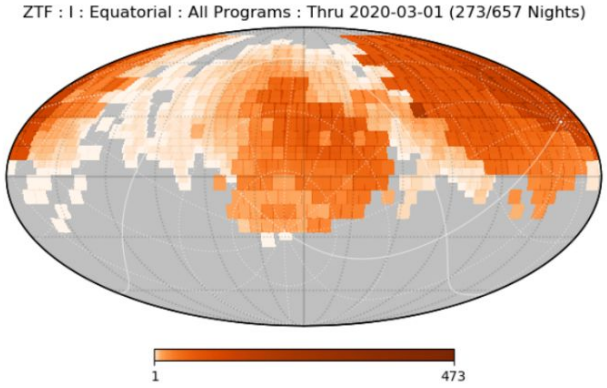


We have about 10^5 events/night ; 10% of LSST

Survey of the full northern sky

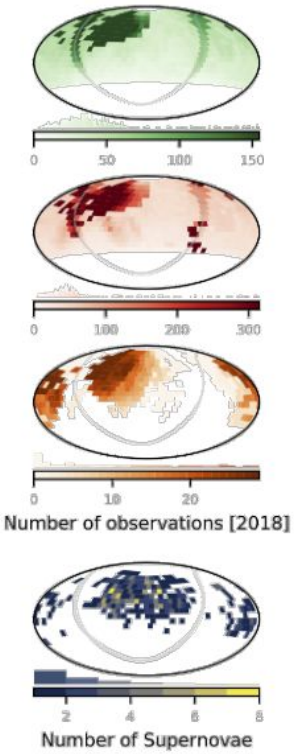


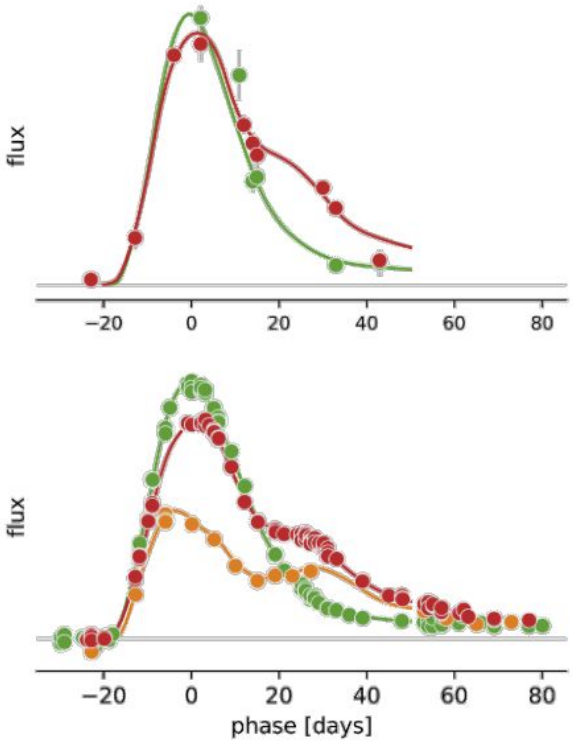


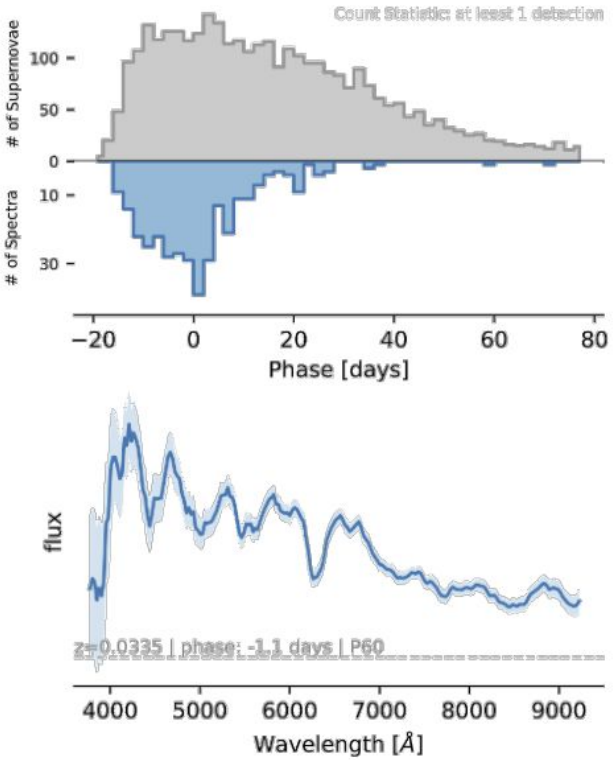


- 3 bands
  - g,r & I
- "MSIP" survey
  - LSST-like survey of northern sky in g & r (2-3 day cadence)
- Partnership survey
  - High cadence observations of 10% of the sky (5-6 visits/night)
  - I-band observations of 50% of the sky (~5 day cadence)
- + other partnership programmes (solar system, ToO monitoring of GW events …)

ZTF DR1 (2019)


0
50
100
150
0
100
200
300
0
10
20
Number of observations [2018]
2
4
6
8
Number of Supernovae

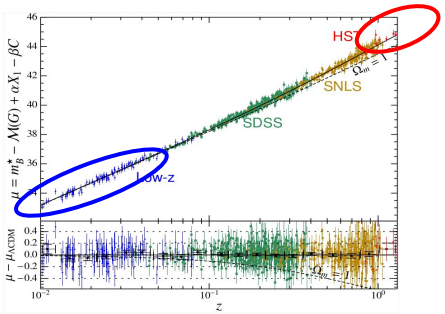

flux
−20
0
20
40
60
80
flux
−20
0
20
40
60
80
phase [days]


Count Statistic: at least 1 detection
# of Supernovae
100
50
0
# of Spectra
10
30
−20
0
20
40
60
80
Phase [days]
flux
z=0.0335 | phase: -1.1 days | P60
4000
5000
6000
7000
8000
9000
Wavelength [Å]

ZTF SN science goals

Measure (w,wa)

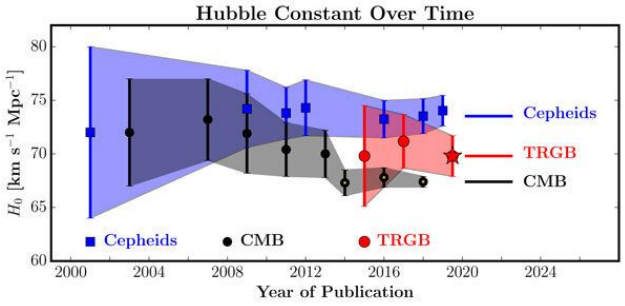
- low -z anchor to HD
- (if well calibrated)
- Not superseded by LSST sample



Relative flux calibration +++
Passbands ++
Uniformity +

Measure H0

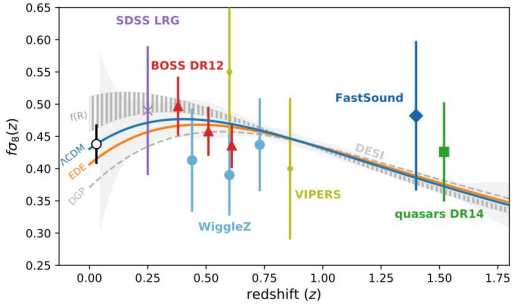
- *Homogeneous* sample of
  - ~ 40 very low-z SNe
  - O(5000) SNe in the Hubble flow



Relative flux calibration +
Passbands ++
Uniformity +++

Test gravity at low-z

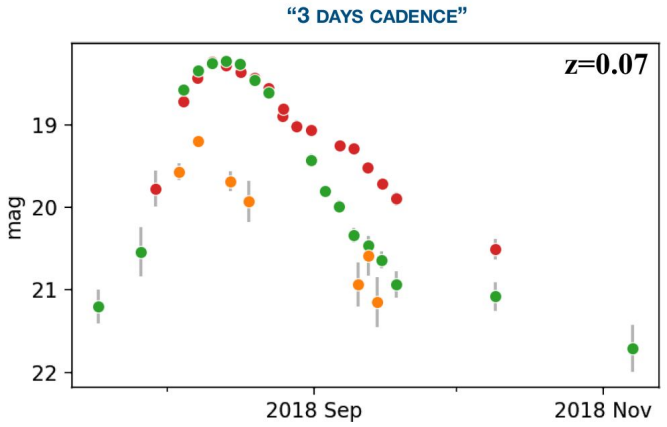
- Correlations of peculiar velocities of nearby SNe Ia
- Constraints on growth rate of structures ($f\sigma_8$)



Relative flux calibration +
Passbands +
Uniformity ++

Pipelines

Scene modeling light curves for all SNe



Scene modeling pipeline

ZTF data

Survey & instrument uniformity pipeline

Flux reference

(a.k.a. starDICE)

Passband metrology

(a.k.a. CBP)

Instrument model

- Natural magnitudes (no SED dependent corrections)

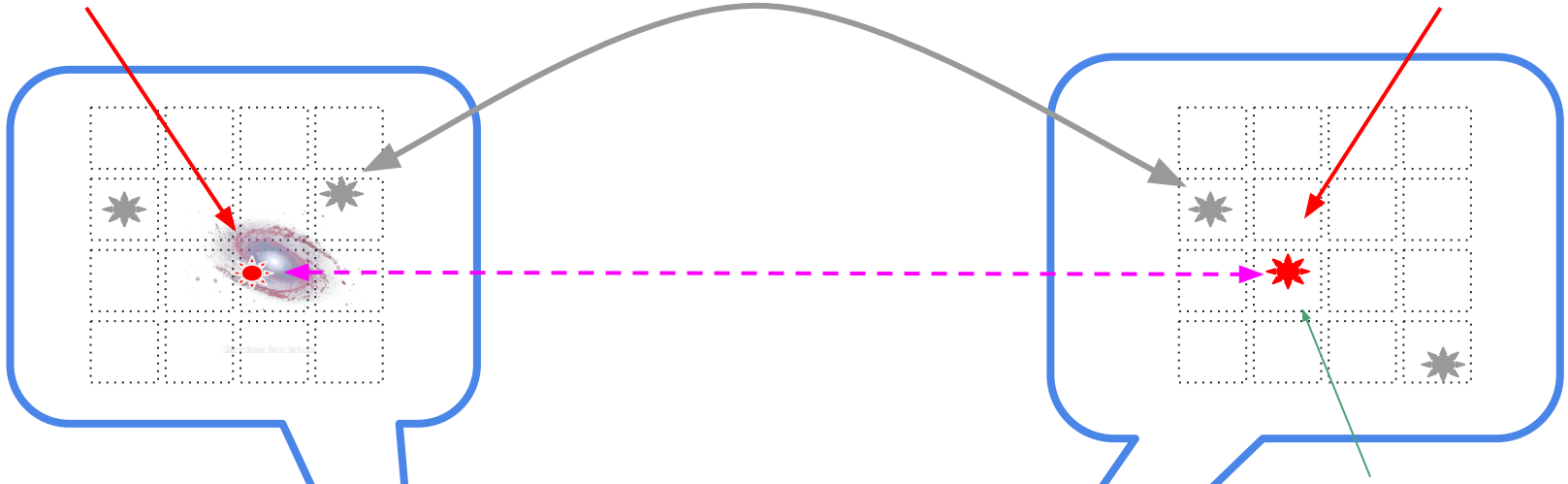
$$m = -2.5 \log_{10} \int \lambda \, S(\lambda) \, T(\lambda) \, d\lambda + ZP$$

- Anchored on reference flux standard
- Passband models

Supernova

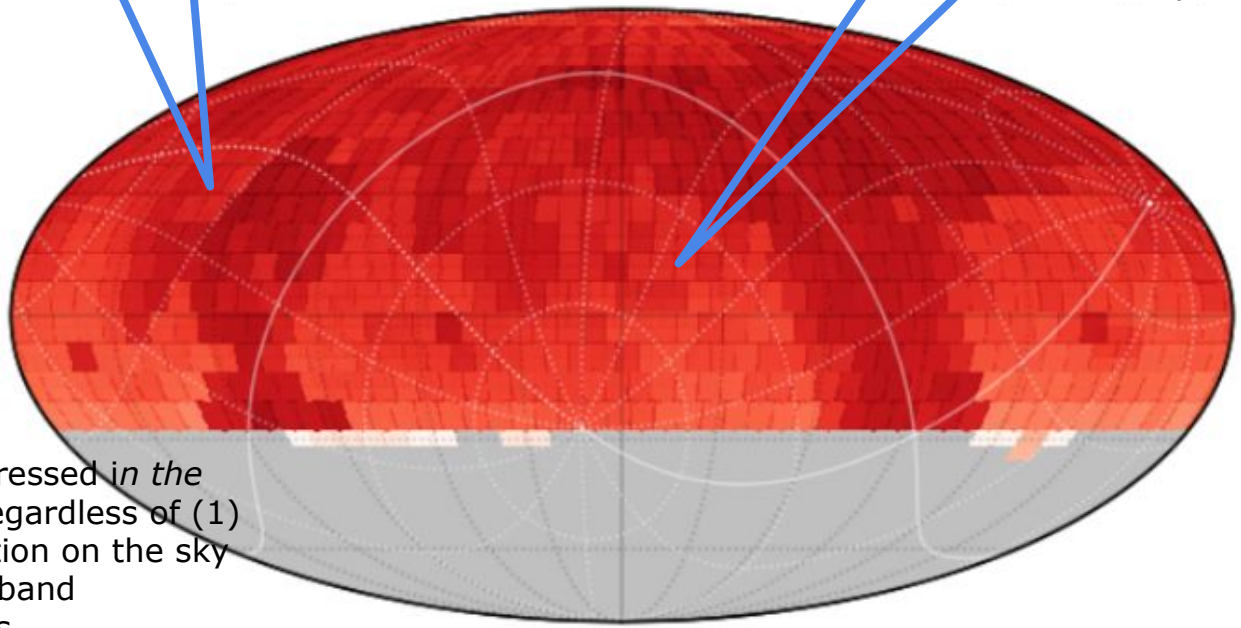
Ubercal

Primary standard



$$f_{SN} = \alpha' \int S_{SALT}(\lambda)\lambda T(\lambda, x', t')d\lambda$$

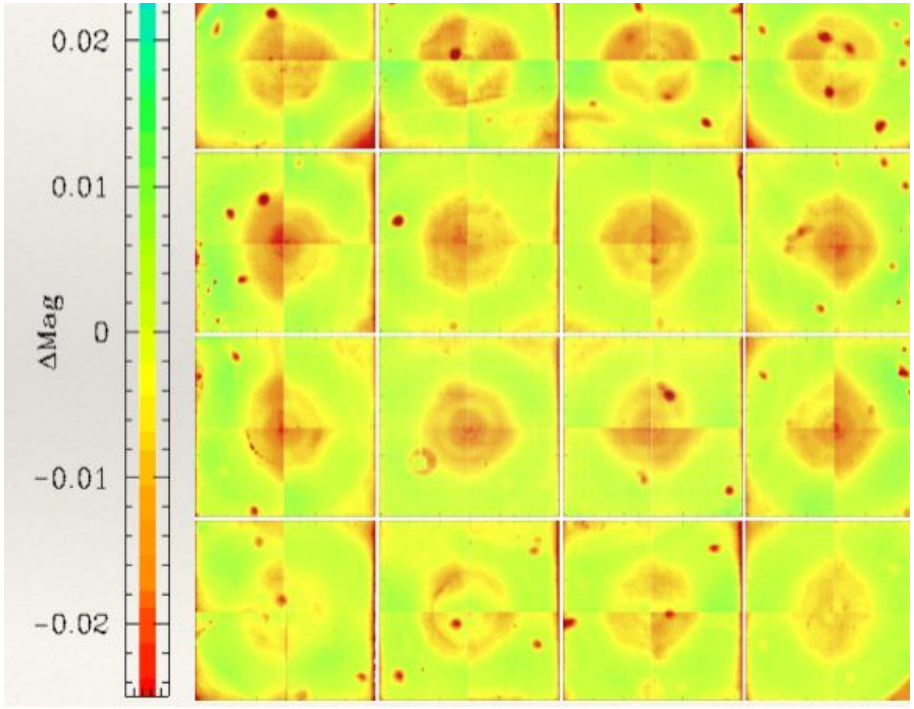
$$f_\star = \alpha \int S_{ref}(\lambda)\lambda T(\lambda, x, t)d\lambda$$



- SN fluxes expressed *in the same units*, regardless of (1) band (2) position on the sky
- Accurate passband measurements

Instrument & survey uniformity

- Very difficult to base flux metrology chain on PSF photometry
- Workaround:
  - Robust flux estimator for uniformity pipeline
    - aperture photometry
    - Aperture correction maps
    - Residual corrections in associated star flat
- Survey uniformity:
  - Open problem
  - GAIA DR3 is probably key



Map from A. Drake

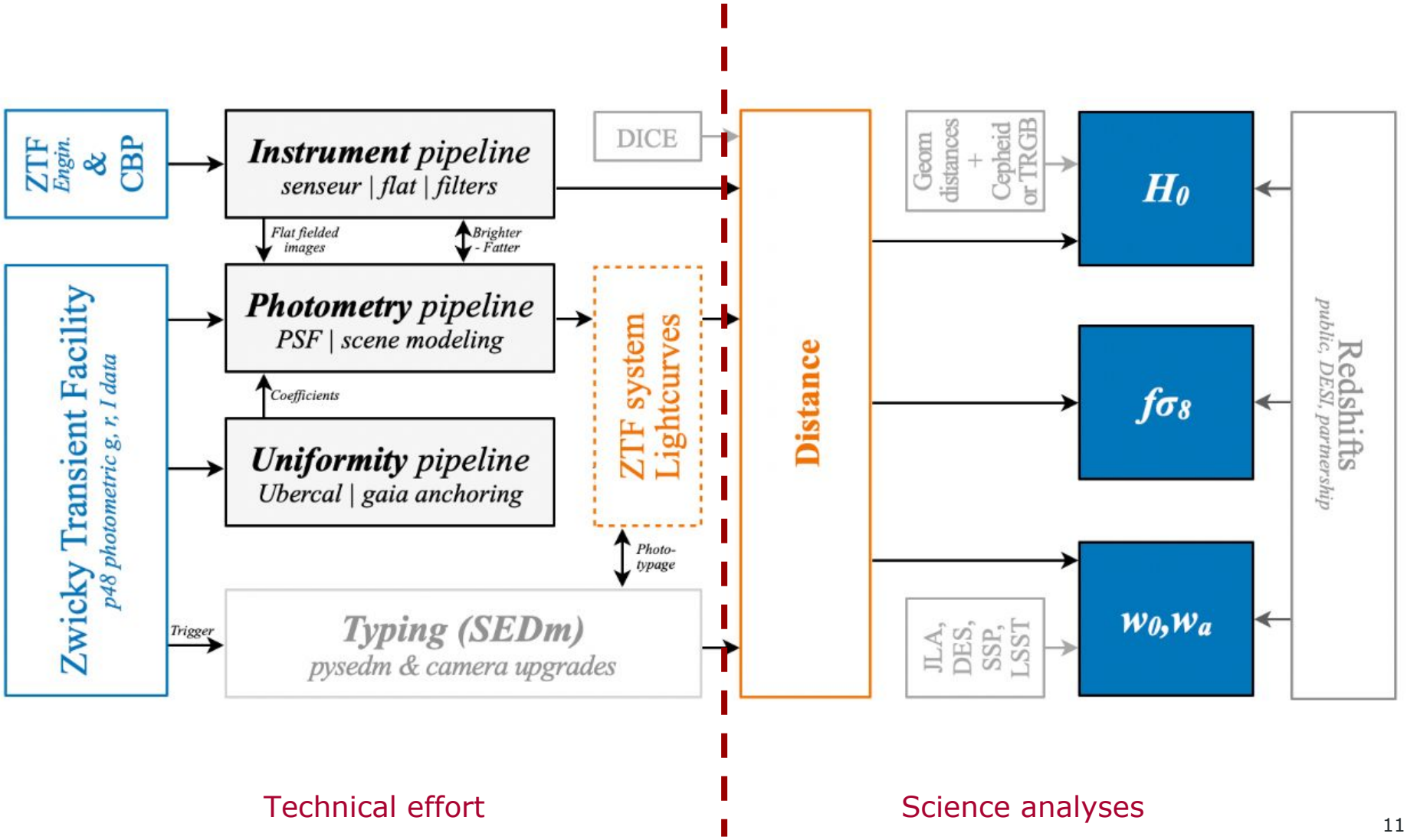
Current exercise

- Select O(1000 deg^2) footprint around interesting CALSPEC stars
  - and a dataset covering this area (~ 1 month)
- Revisit detrending process
  - Per CCD instead of per-quadrant
  - Bias & flat field frame variability
- Fast aperture photometry algorithm (just for stars)
  - Captures constant fraction of flux
- Map focal plane response
  - Star flats
- Uniformize stellar fluxes on survey footprint
  - ubercal

Conclusion

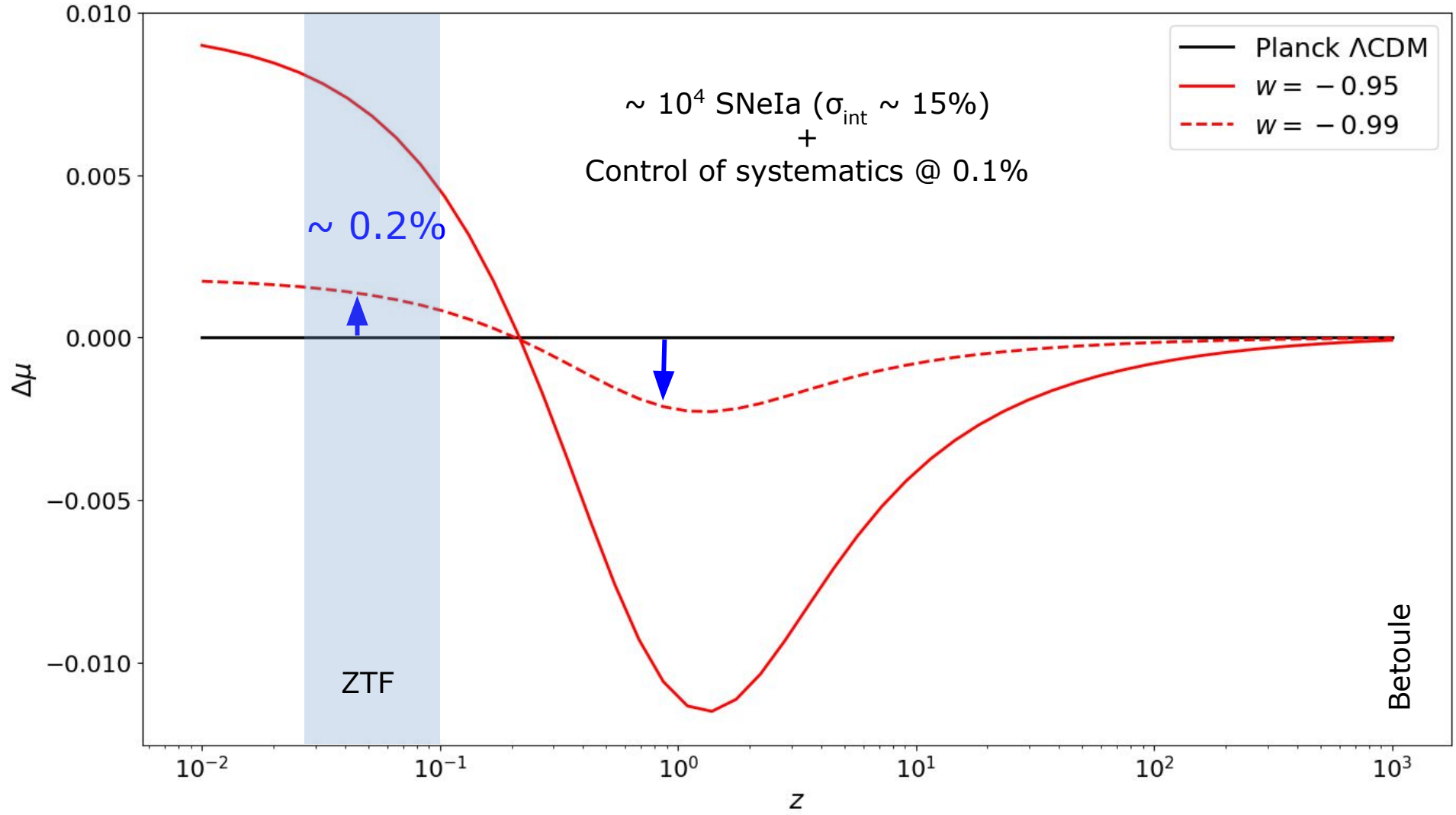
- IN2P3 calibration effort driven by SN science (cosmology)
- However, will benefit the entire collaboration
- Main products
  - Unique SN dataset (not superseded by LSST)
  - Scene modeling pipeline, with corrections for instrumental effects studied within ZTF calibration group
  - Photometry linked to a well known set of standards
  - Usable on request by ZTF collaboration
- Secondary products
  - Improved instrument model
  - Passband metrology

Pipelines & deliveries

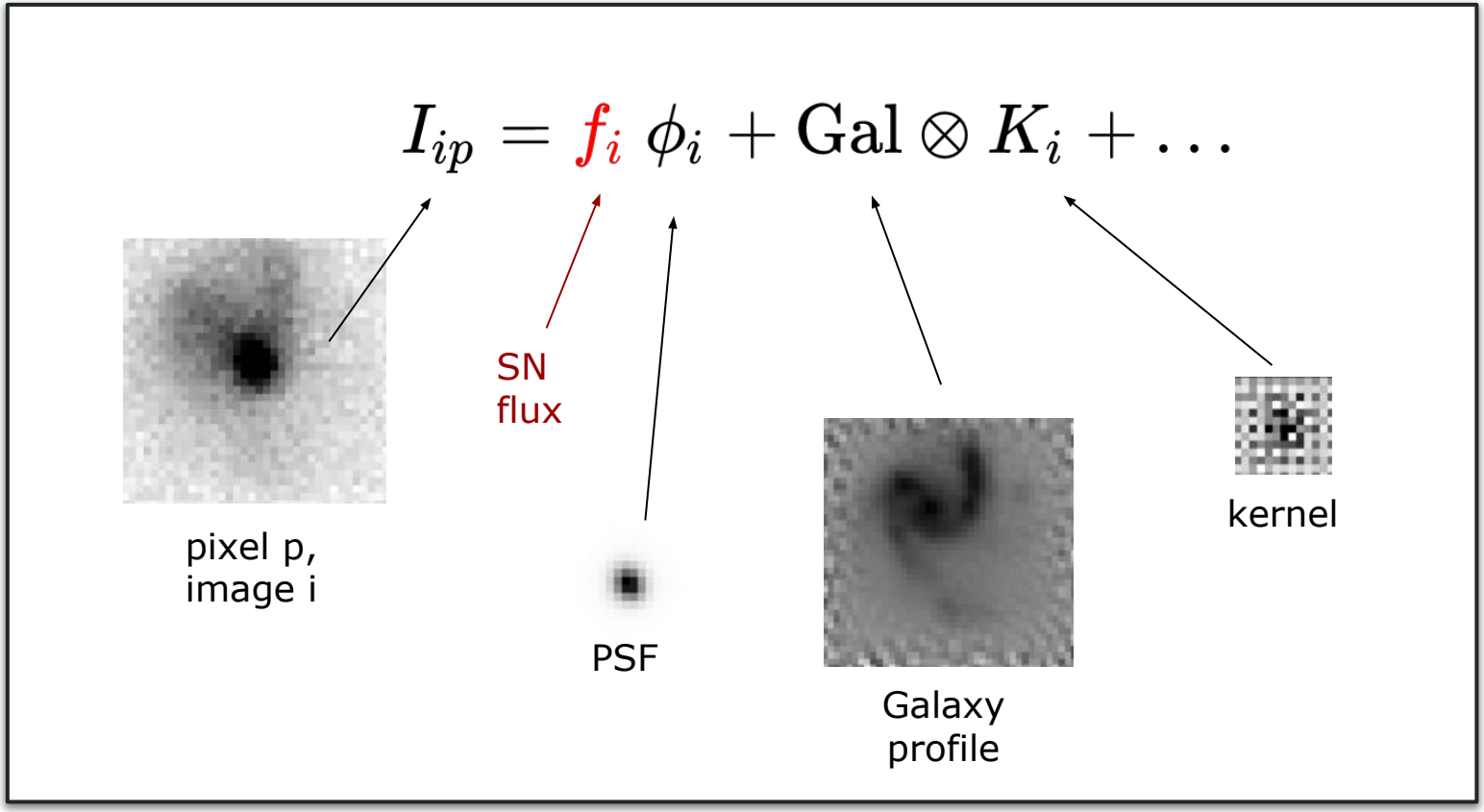


backup

Why are z<0.1 SNe so important ?



Scene modeling photometry



- Maximum likelihood flux estimator
- Model: simultaneous description of the "scene" around the supernova
  - SN flux + empirical host galaxy flux profile
  - Fitted on a set of vignettes containing the SN
- Statistically optimal photometry, incorporating all the effects unveiled by A. Drake et al

Passband metrology

- Collimated beam projector (CBP)
  - Collimated monochromatic beam
  - -> spot (direct light) + ghosts
  - Adopted for characterization / monitoring of LSST passbands
- Experience with CBP
  - CBP sent to LPNHE and used to monitor starDICE telescope
  - Wavelength reproducibility ~ 0.1-nm
  - Close to target accuracy of 0.1-nm in filter determination