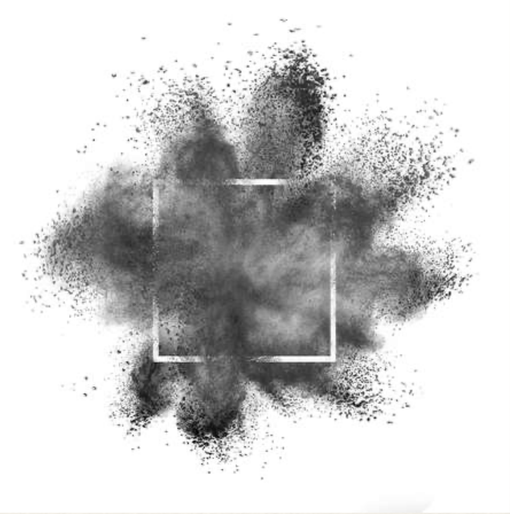


The Zwicky Transient Facility

SNIa Cosmology in 2022

Mathew Smith (IP2I, Lyon) on behalf of N. Regnault and the ZTF SNIa WG

ZWICKY TRANSIENT FACILITY

erc USNAC

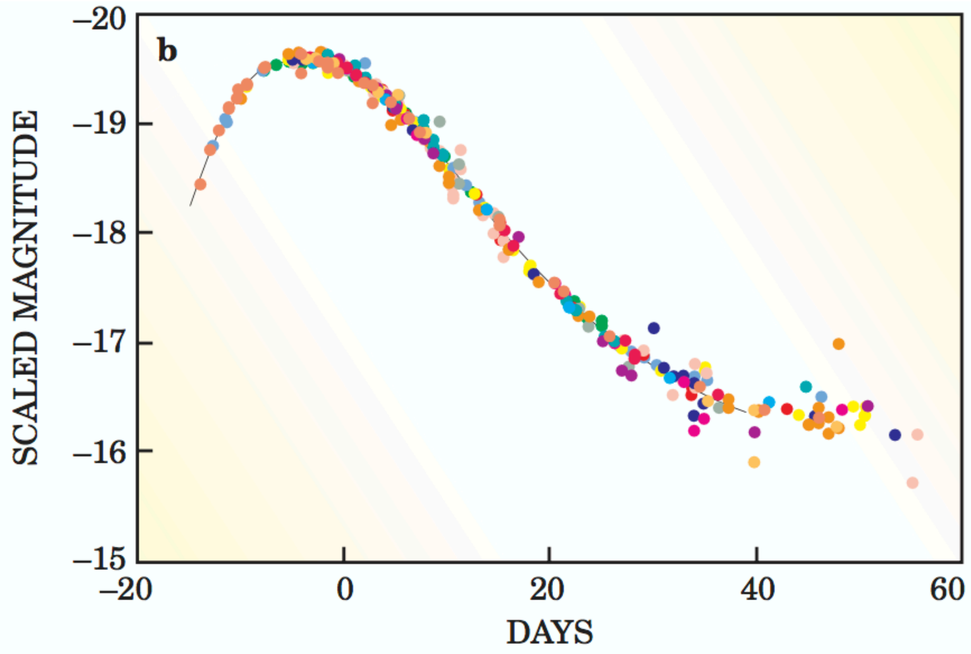
SNIa Cosmology

SNeIa

Luminous explosions of evolved stars

Homogeneous: **Standard Candles**

Uncertain origin

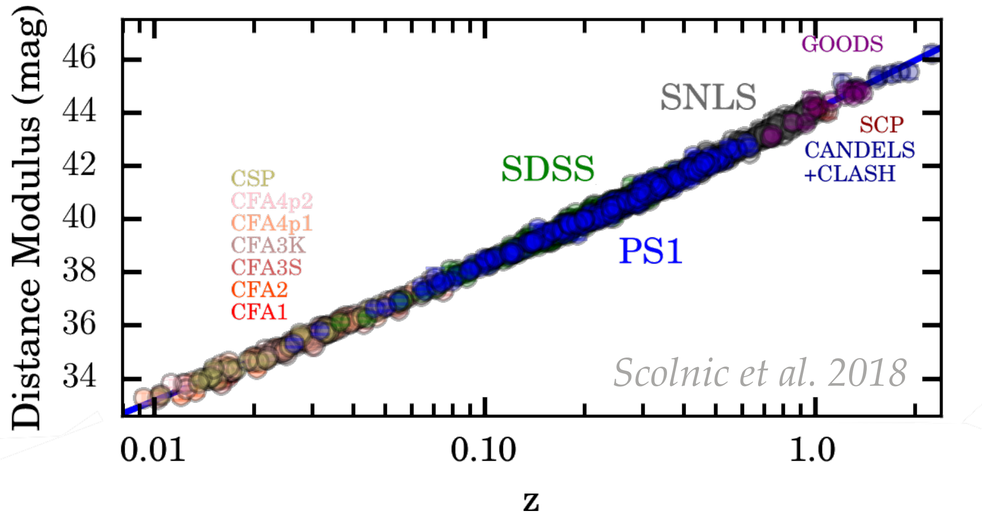


(SN) Cosmology

Relative distances

Probe of expansion history

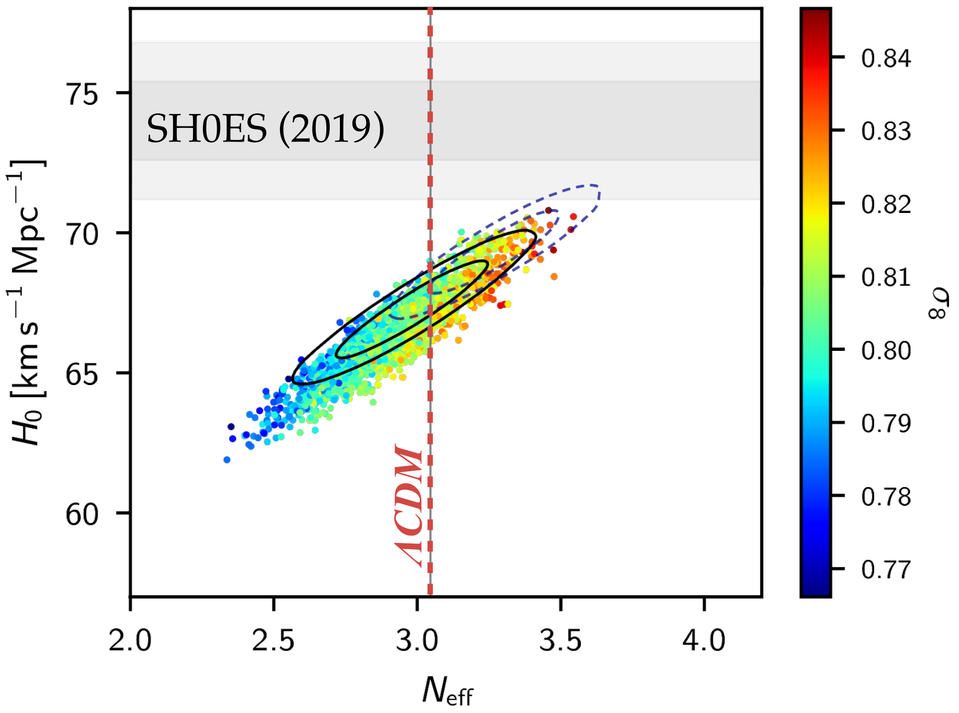
Combination of experiments



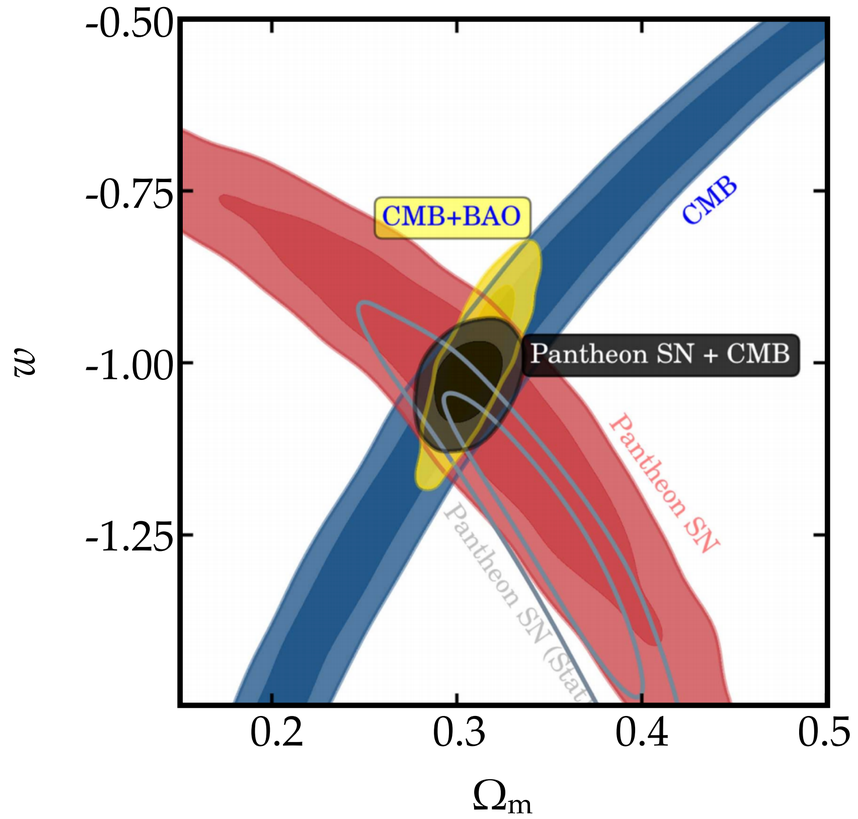
Cosmological Tensions

H_0 Tension | 5 σ

Universe's expansion is too fast

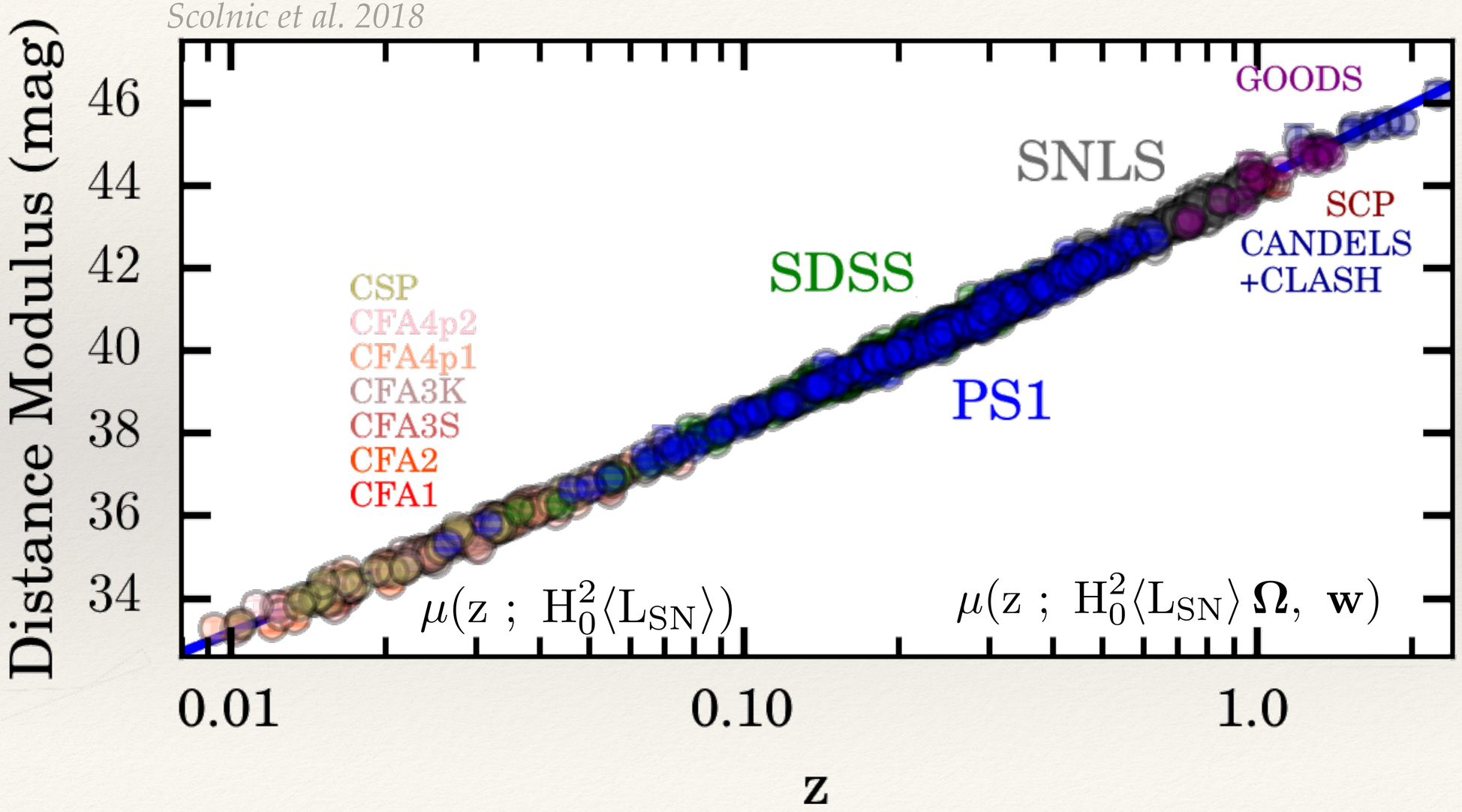


Λ 'Tension': Acceleration is unexplained

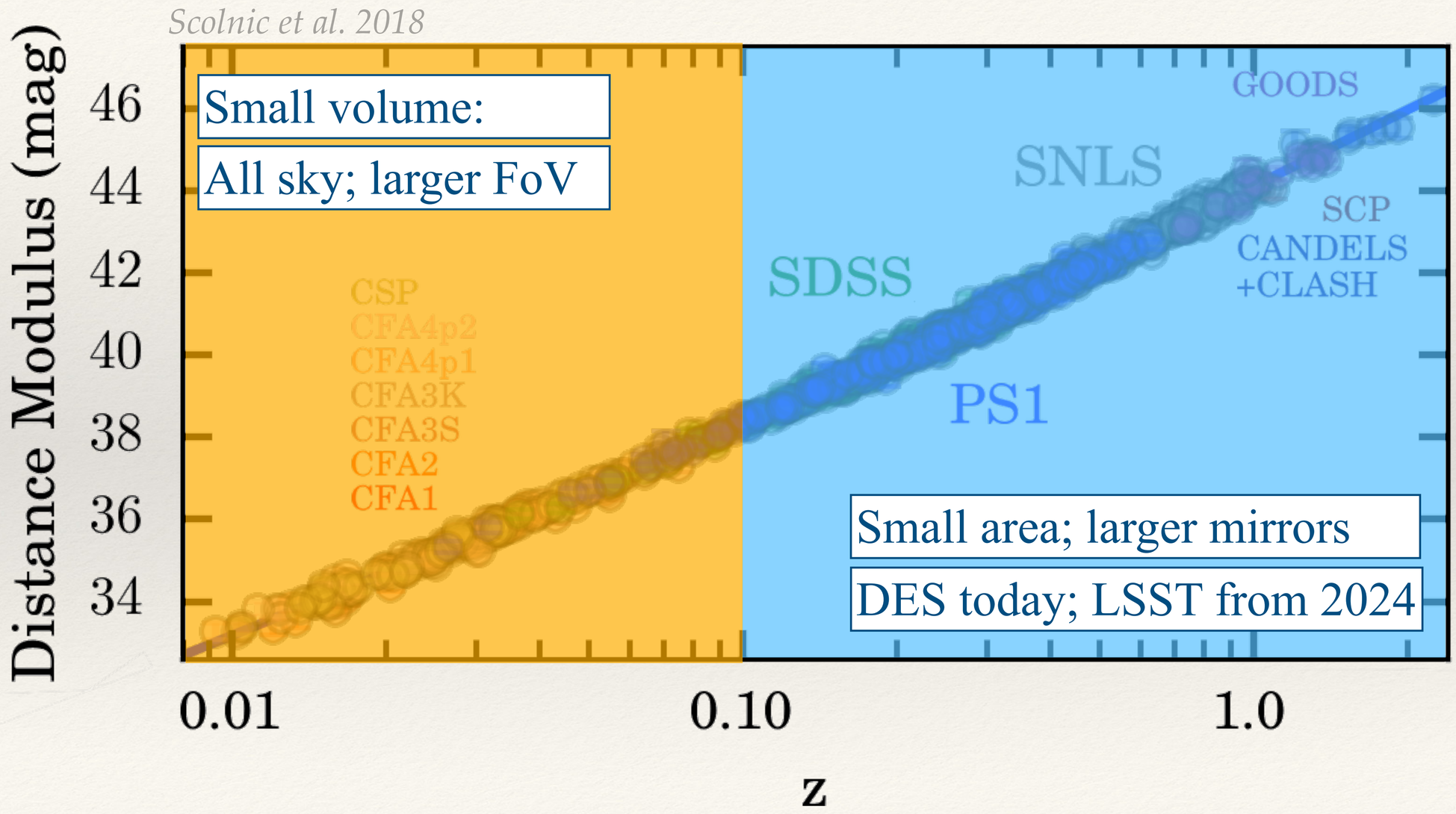


SNIa Cosmology: Today

Scolnic et al. 2018

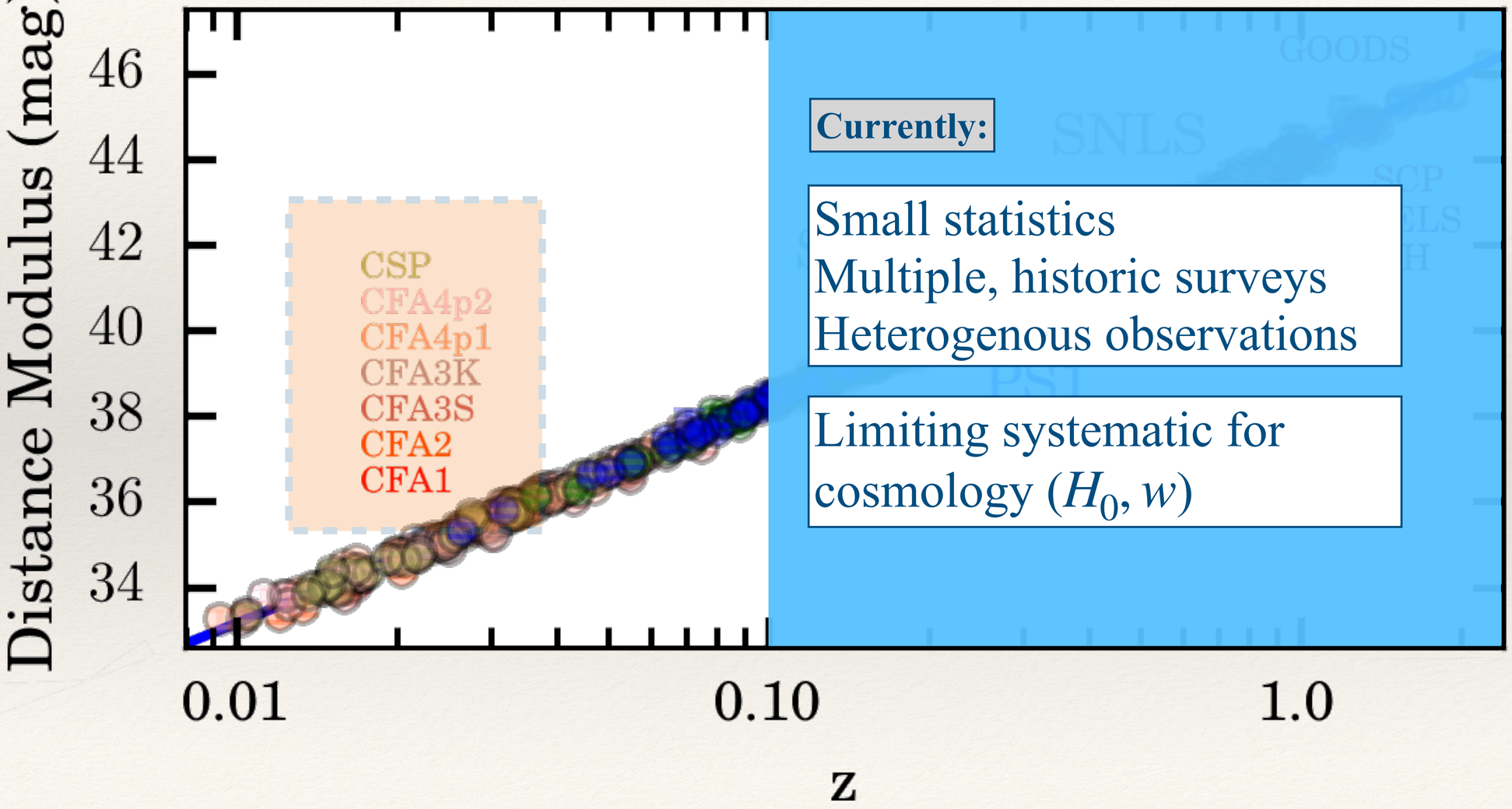


SNIa Cosmology: Simplified



SNIa Cosmology: Today

Scolnic et al. 2018

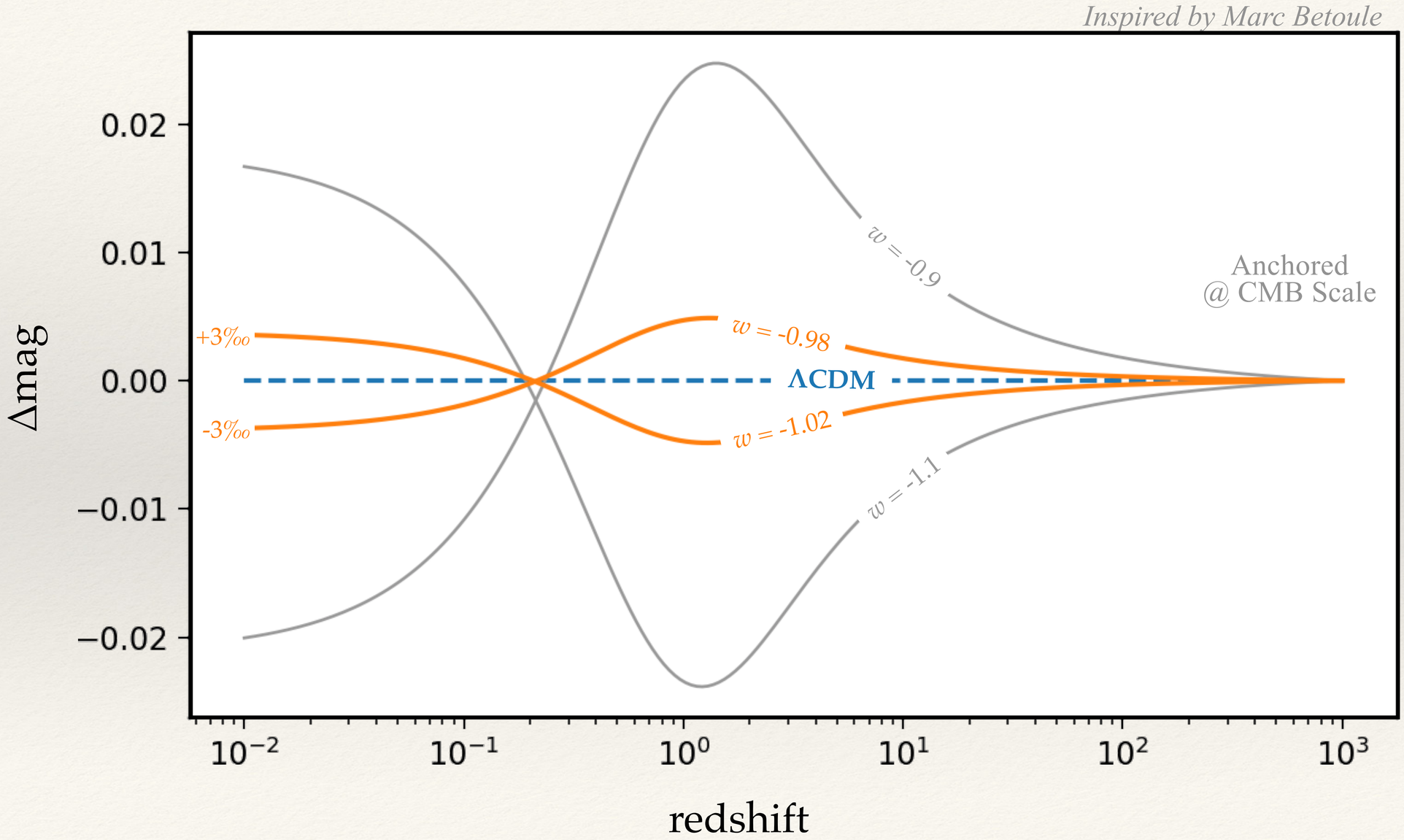


Currently:

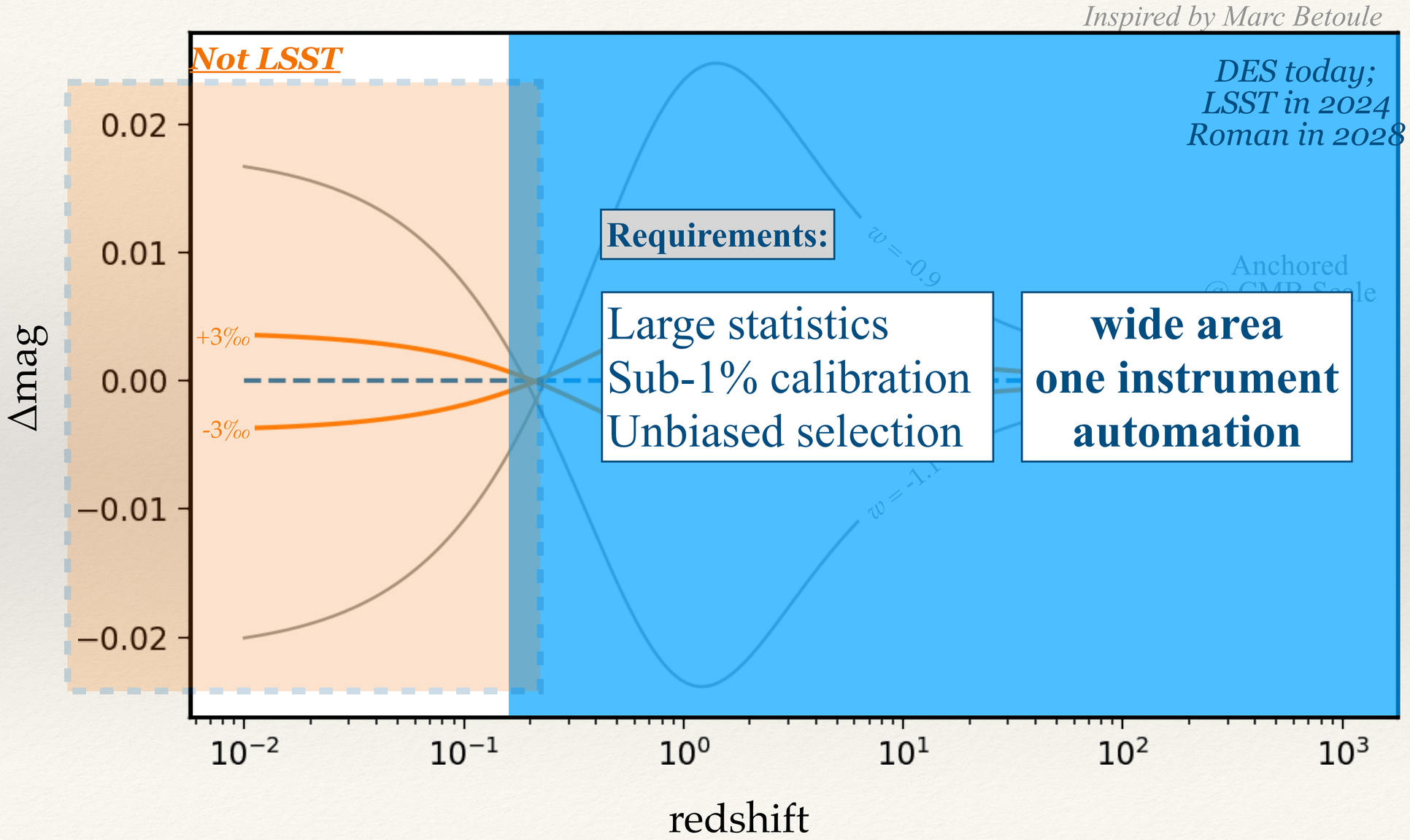
Small statistics
Multiple, historic surveys
Heterogenous observations

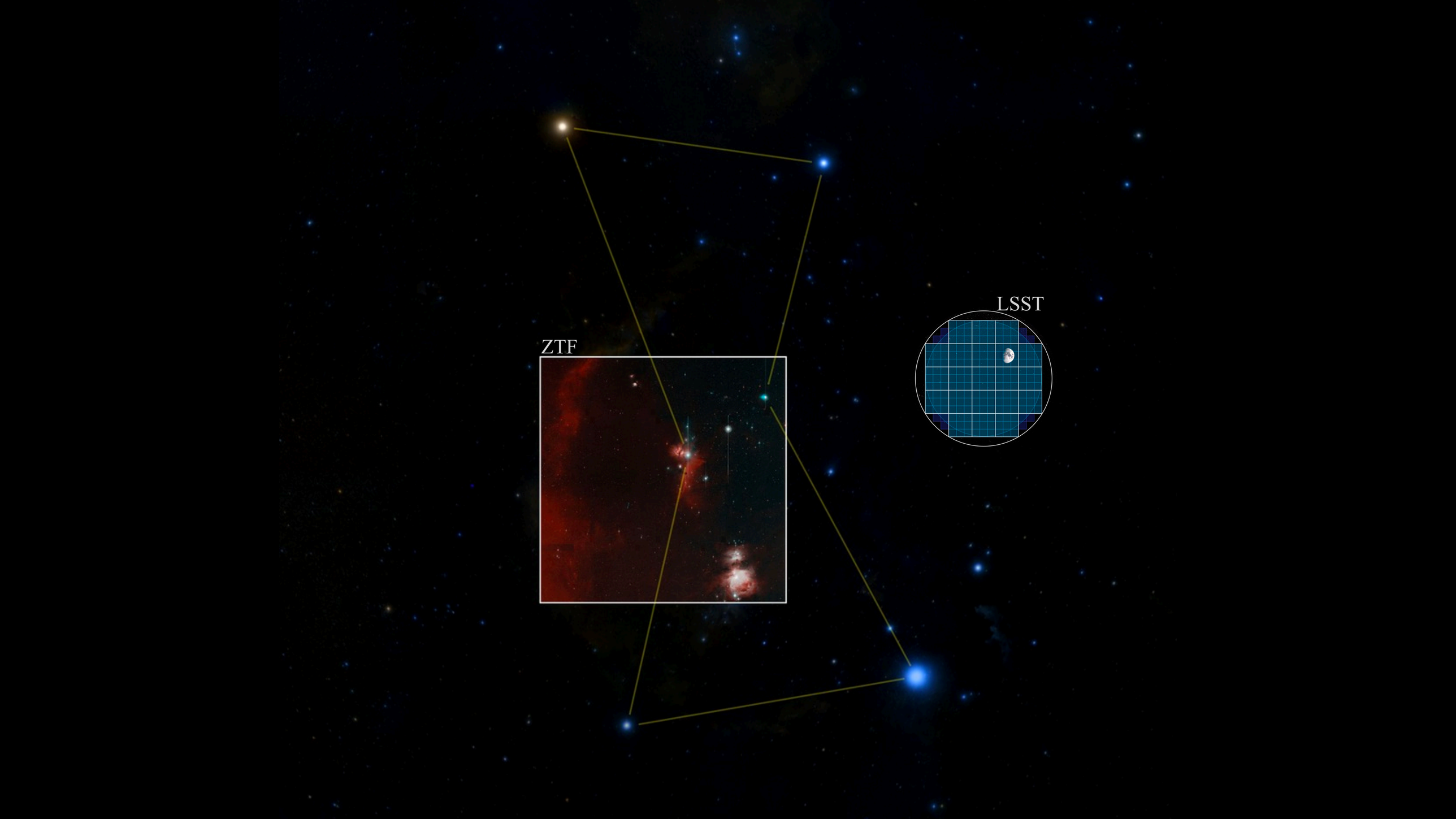
Limiting systematic for cosmology (H_0, w)

SNIa Cosmology: Today



SNIa Cosmology: Today




ZTF
LSST

Zwicky Transient Facility (ZTF)

3 filters (g, r, i)

FoV: **47** deg^2

5σ depth: **20.5 mag**

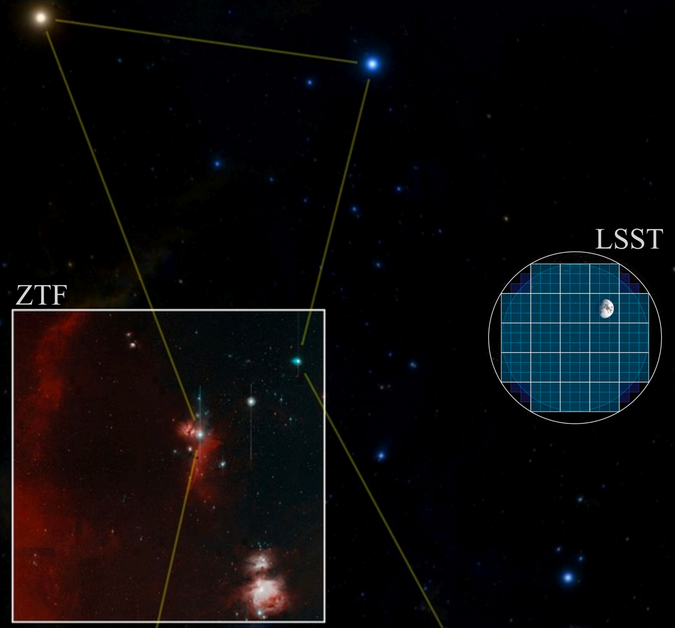
CCD: **1pixel = 1arcsec**

footprint: 15,000 deg

dedicated spectroscopy

—

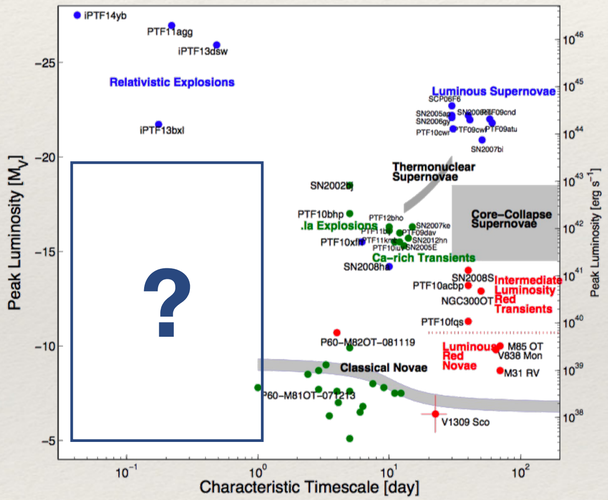
ZTF 1: 2018->2020 3 day (g+r) + some i
ZTF 2: 2021->2023 2 day (g+r) + 5 day i



Some ZTF Science Cases

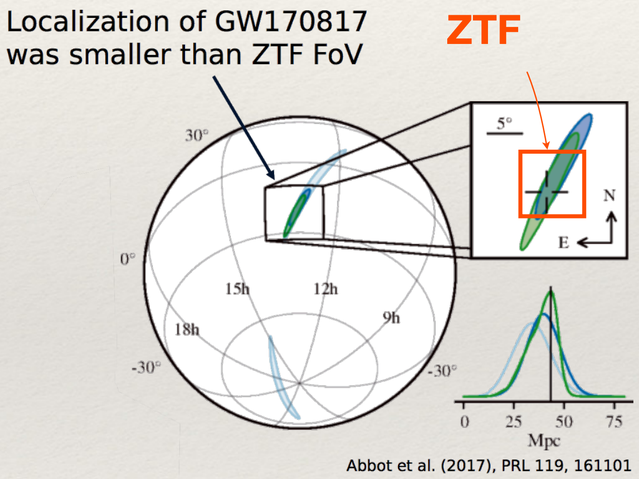
Transient Astro.

Flash Spectroscopy



Multi-Messenger

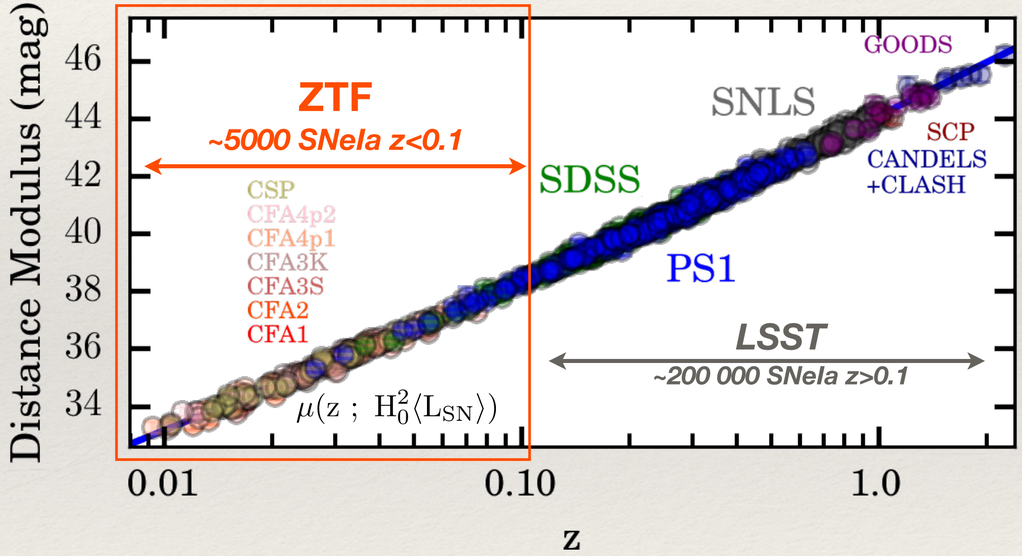
GW & Neutrinos



Abbot et al. (2017), PRL 119, 161101

Supernova Cosmology

Incl. w, H_0, σ_8

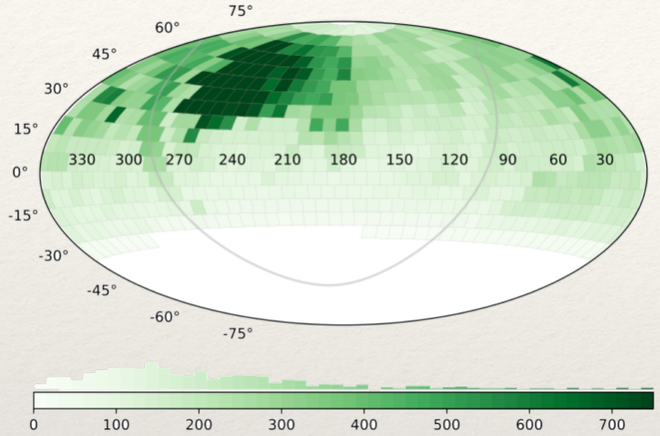


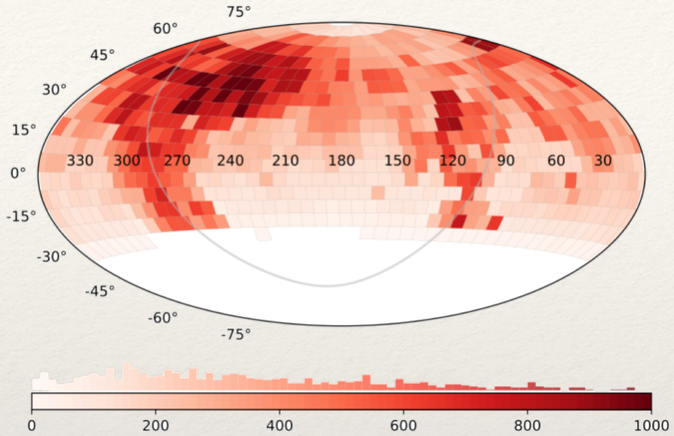
Tidal Disruption Events | Stellar Astrophysics | Solar System Bodies | …

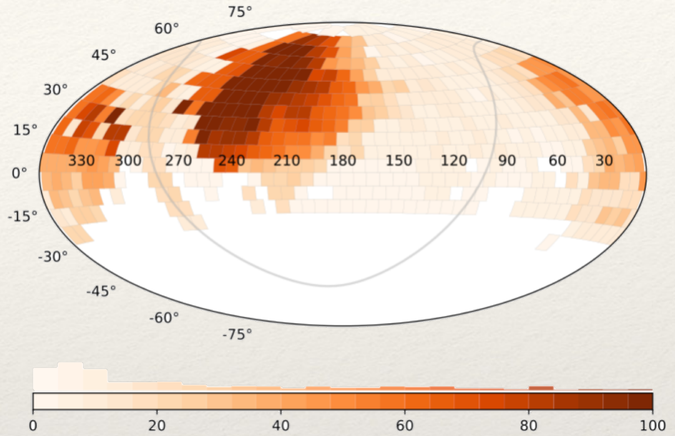
ZTF: *In reality*

Observing the Transient (Northern) Sky

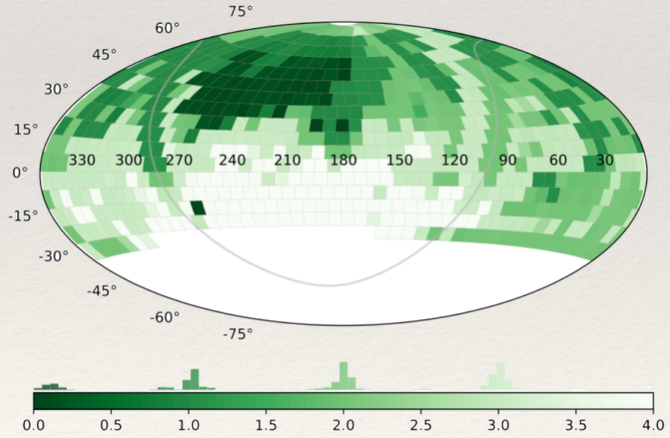
Total Number of Exposures

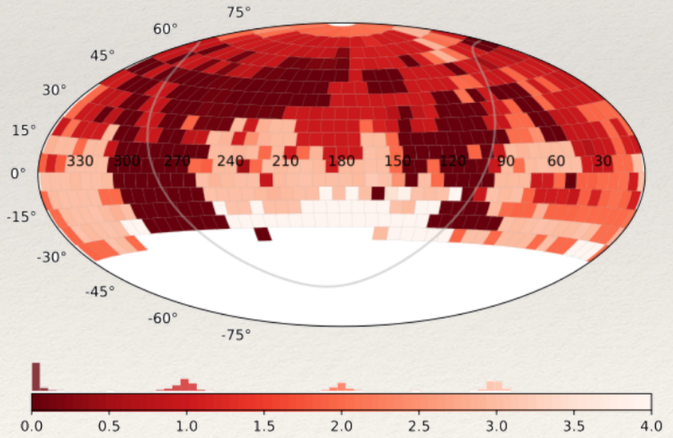


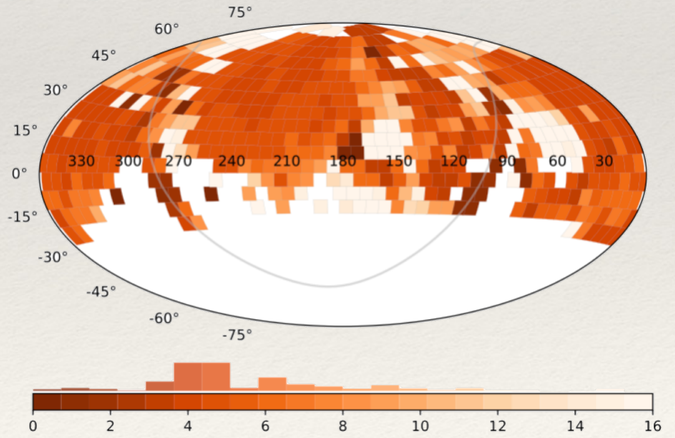




Cadence [in days]



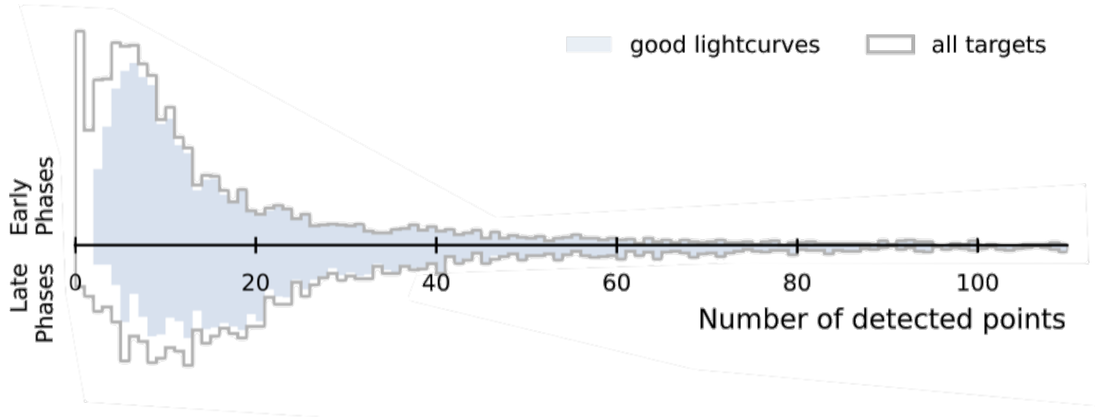




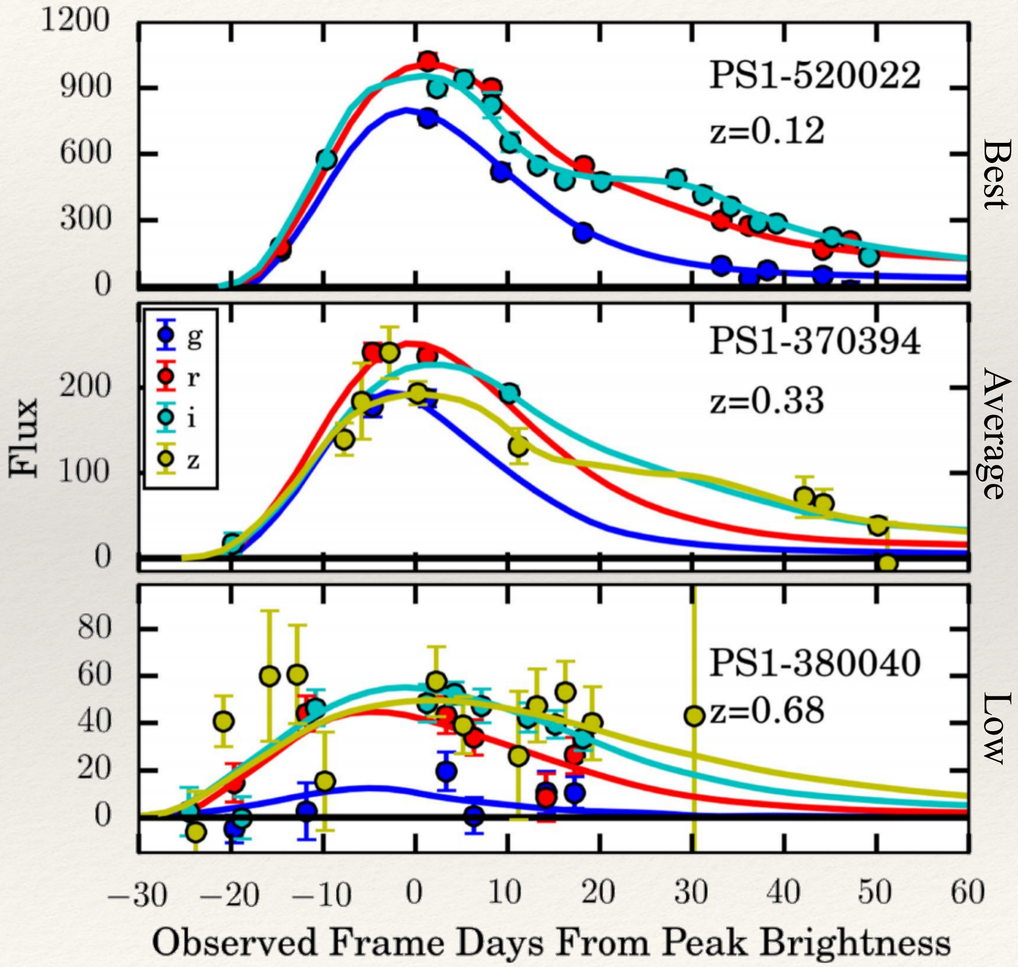
ztf:g **ztf:r** **ztf:i**

Cosmology light-curves: Today

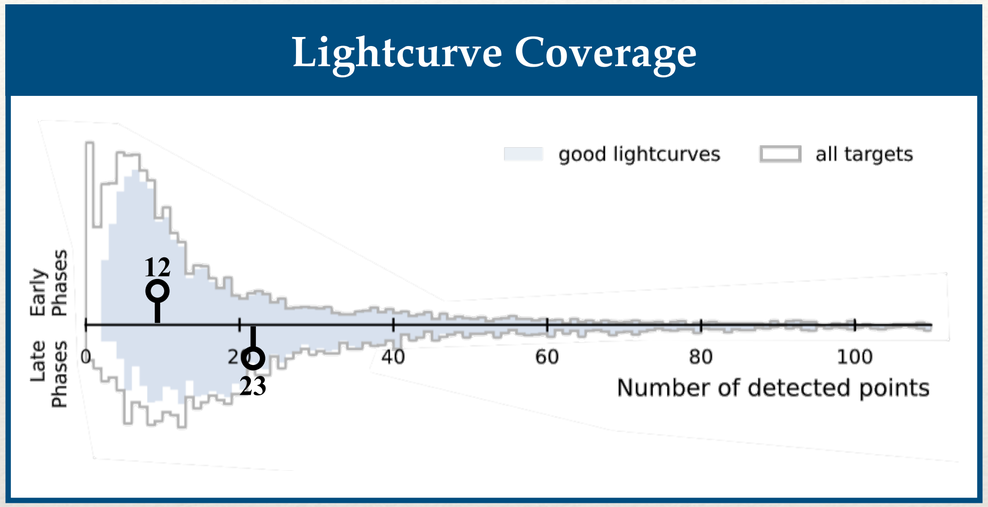
ZTF Lightcurve Coverage

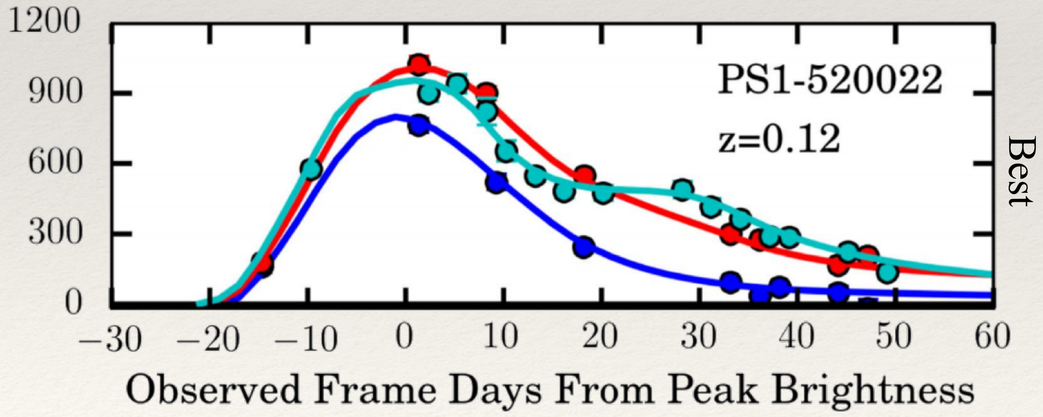


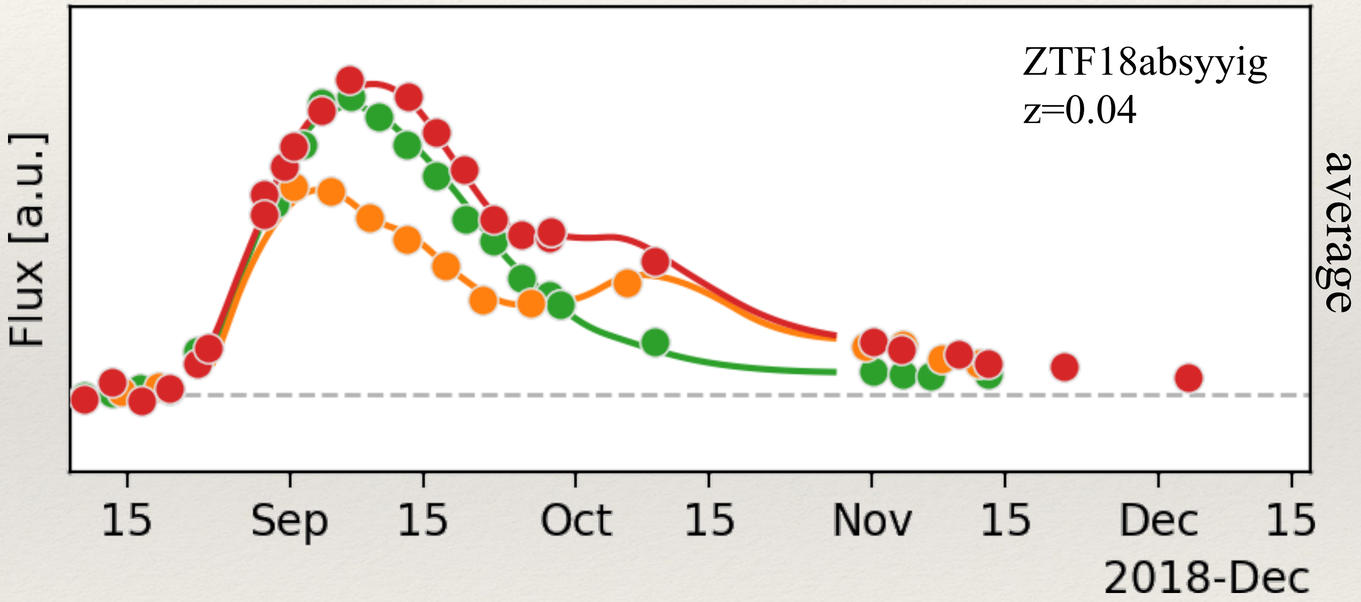
Pre-ZTF State of the art
(Pan STARRS, Scolnic 2018)



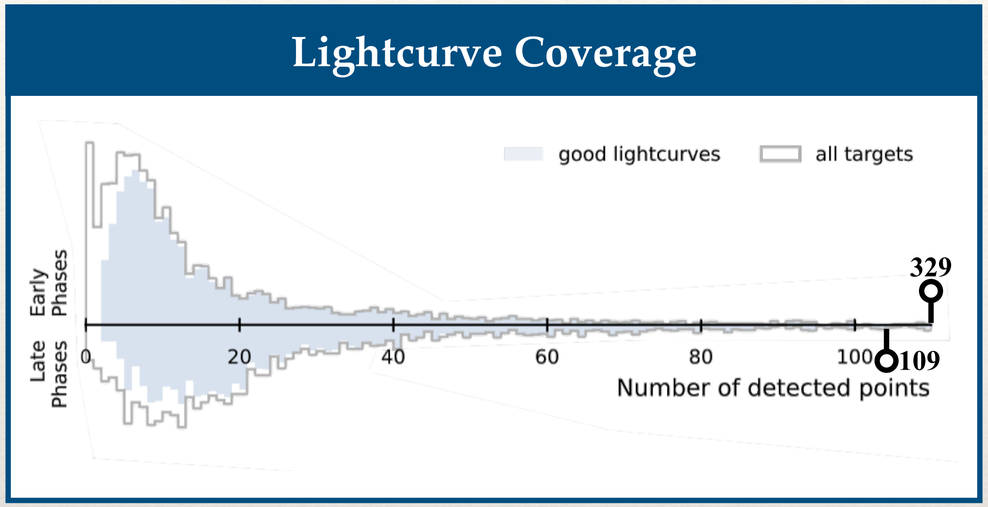
Light-curves: ZTF

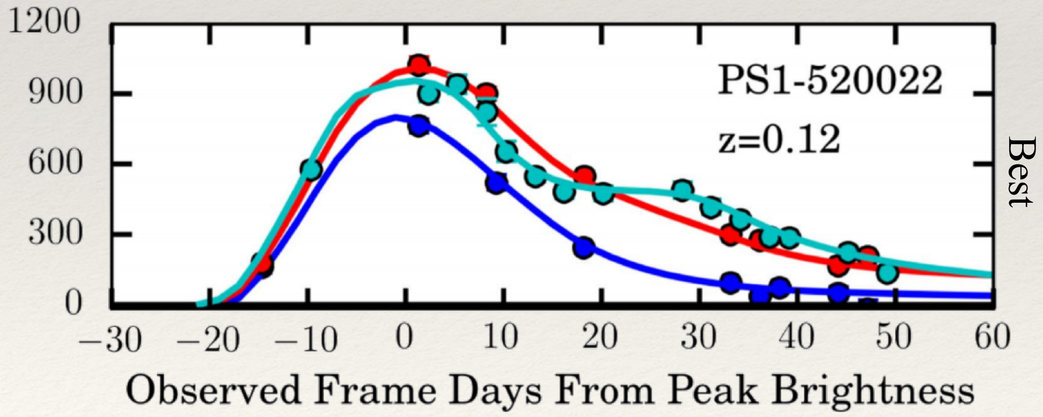


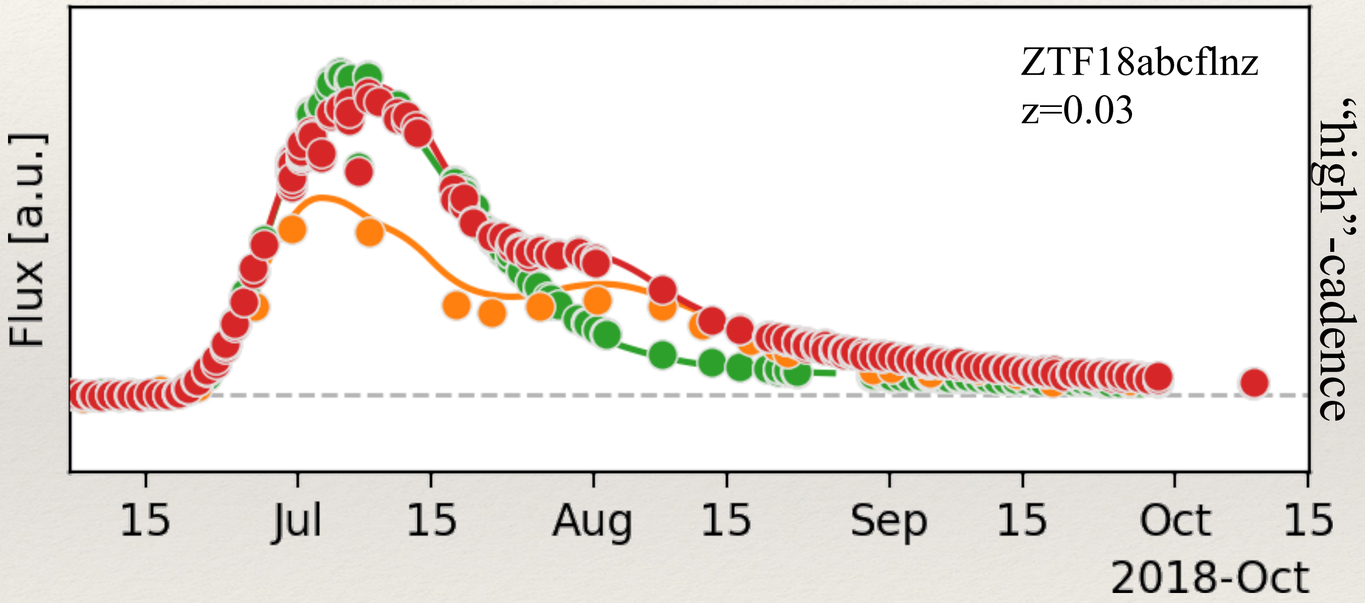




Light-curves: ZTF





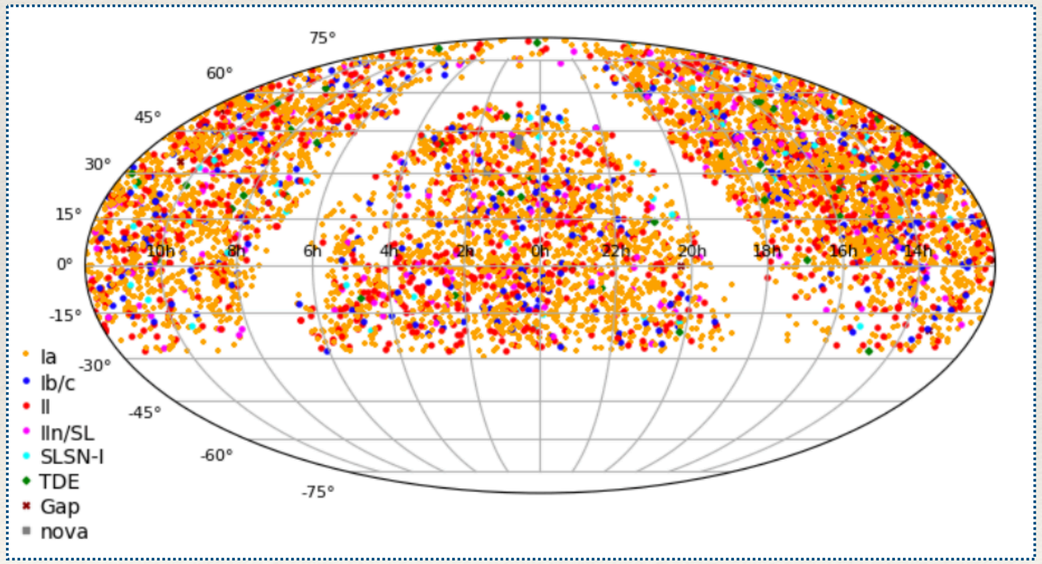


An all in one survey

Automated spectroscopy

Bringing it all together

ZTF *Today*



Raw numbers

>1 million images

>2 million alerts

likely 200,000 SNe

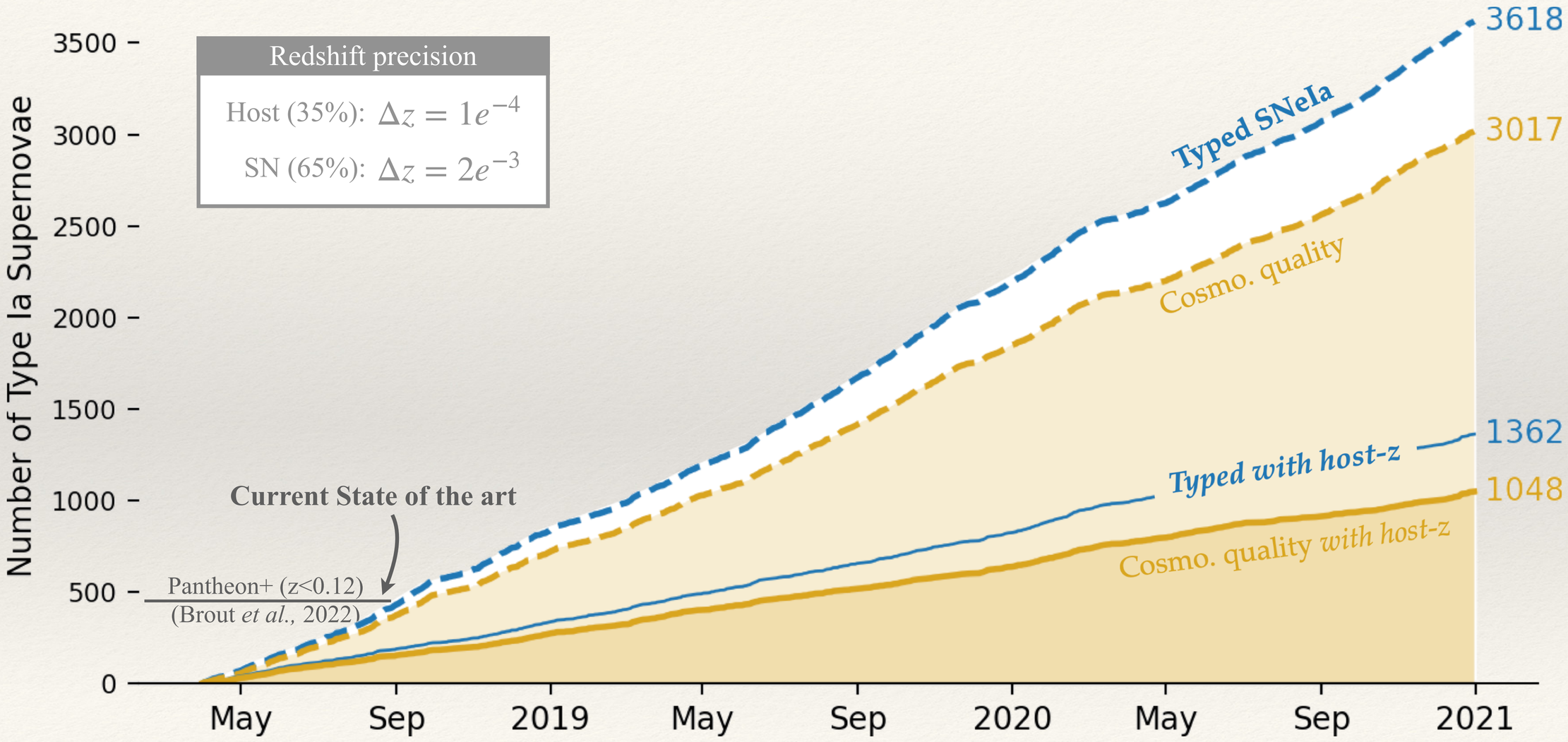
Supernovae

12,000 discoveries
($r < 19$)

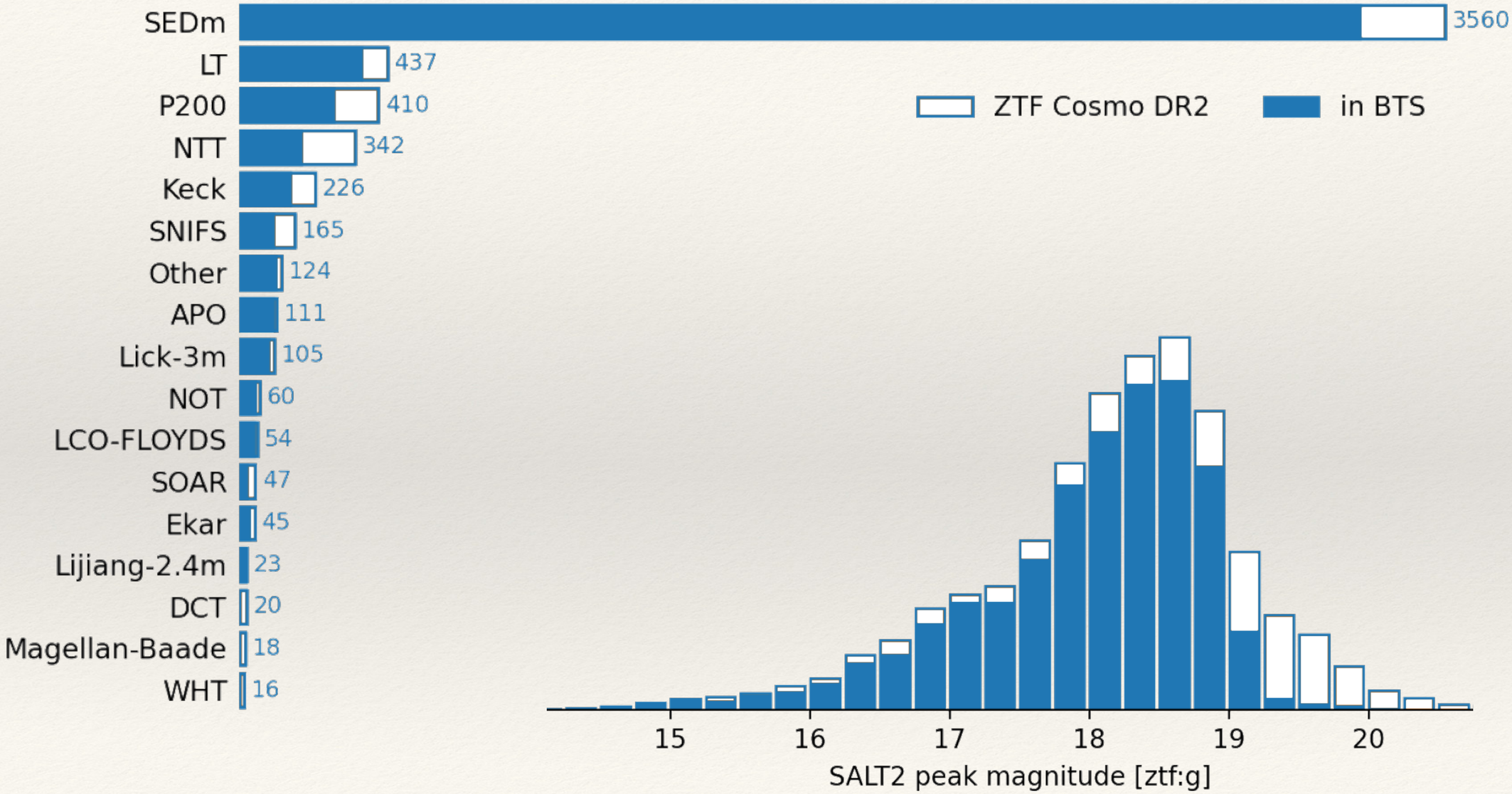
8,000 classifications

5,000 SNeIa

ZTF | *Changing the scale of SN Cosmology*



Spectroscopic Follow-up

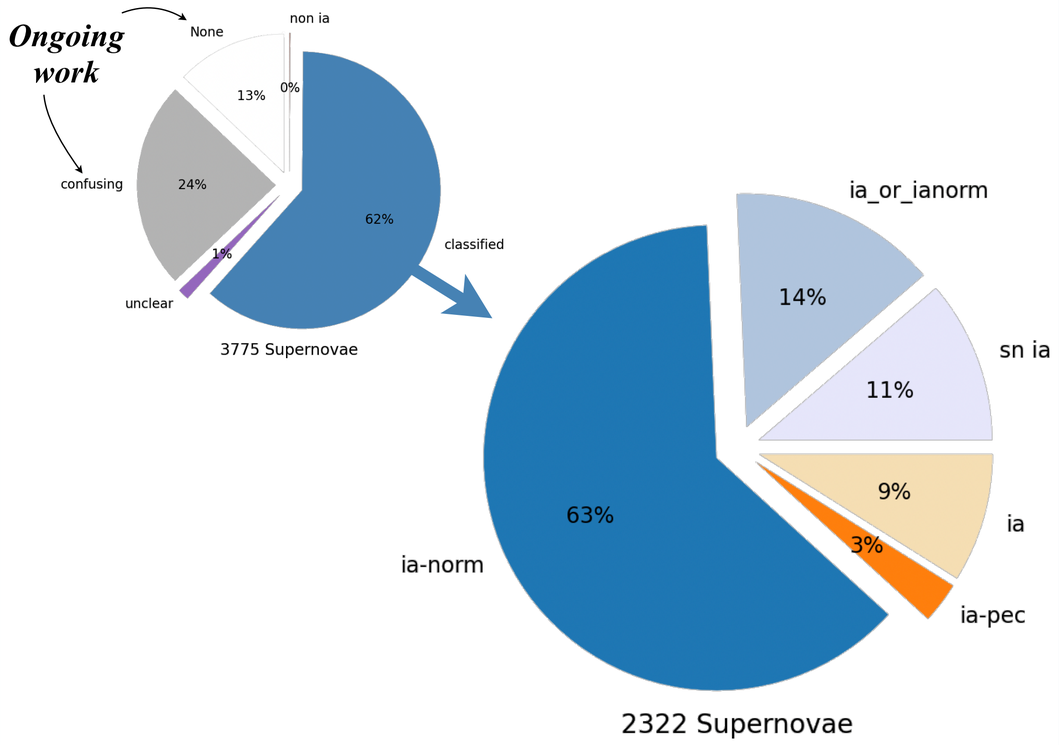


Towards Cosmology: Introducing ZTF-DR2

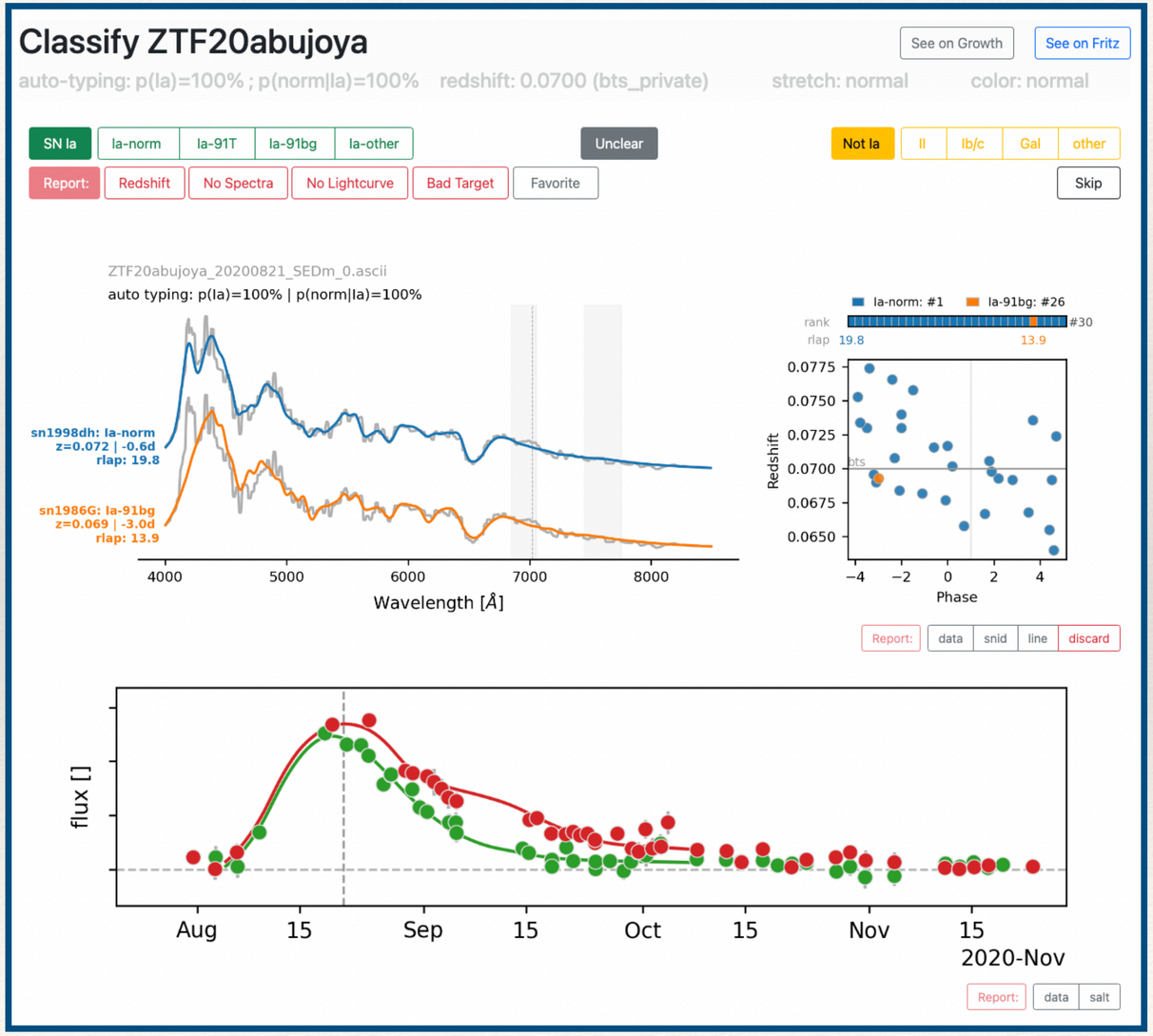
Spectroscopic Typing

A large collaborative effort

Unique effort that shall define "SN Ia"

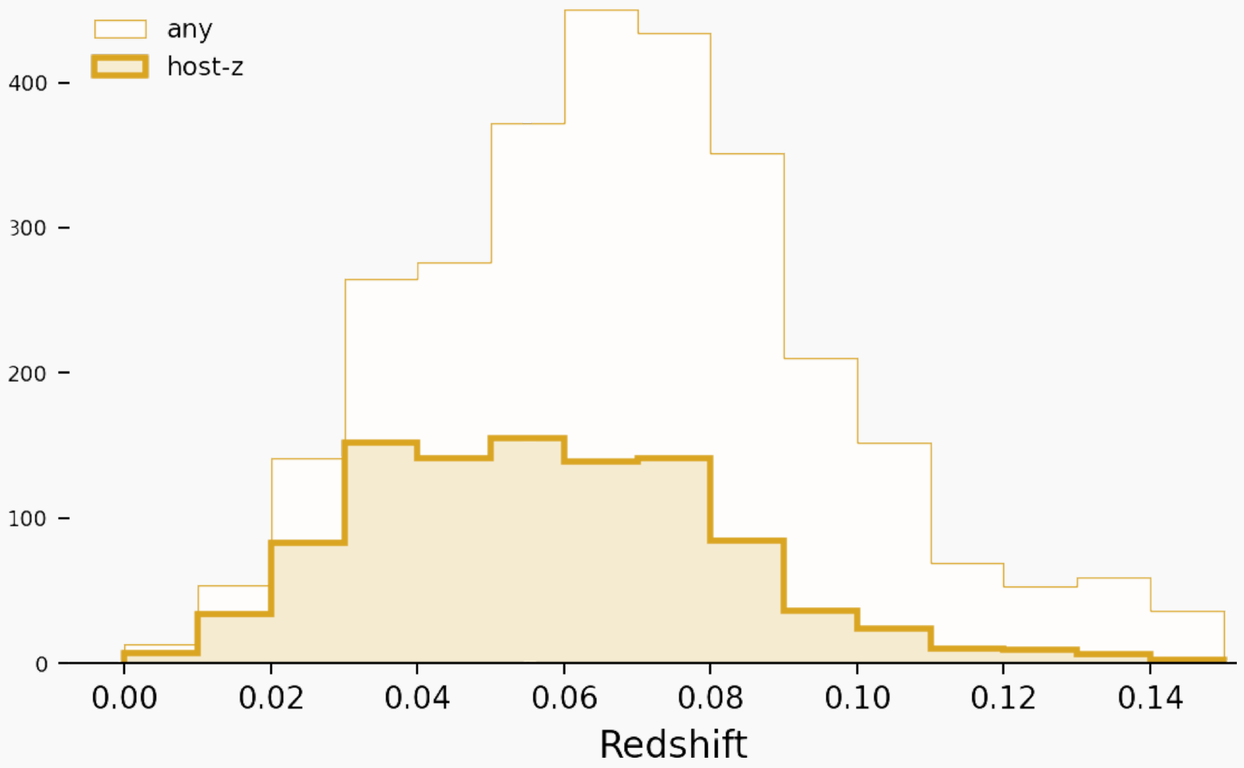


3 775 Targets • 13 505 classifications • 5 496 reports • 42 users

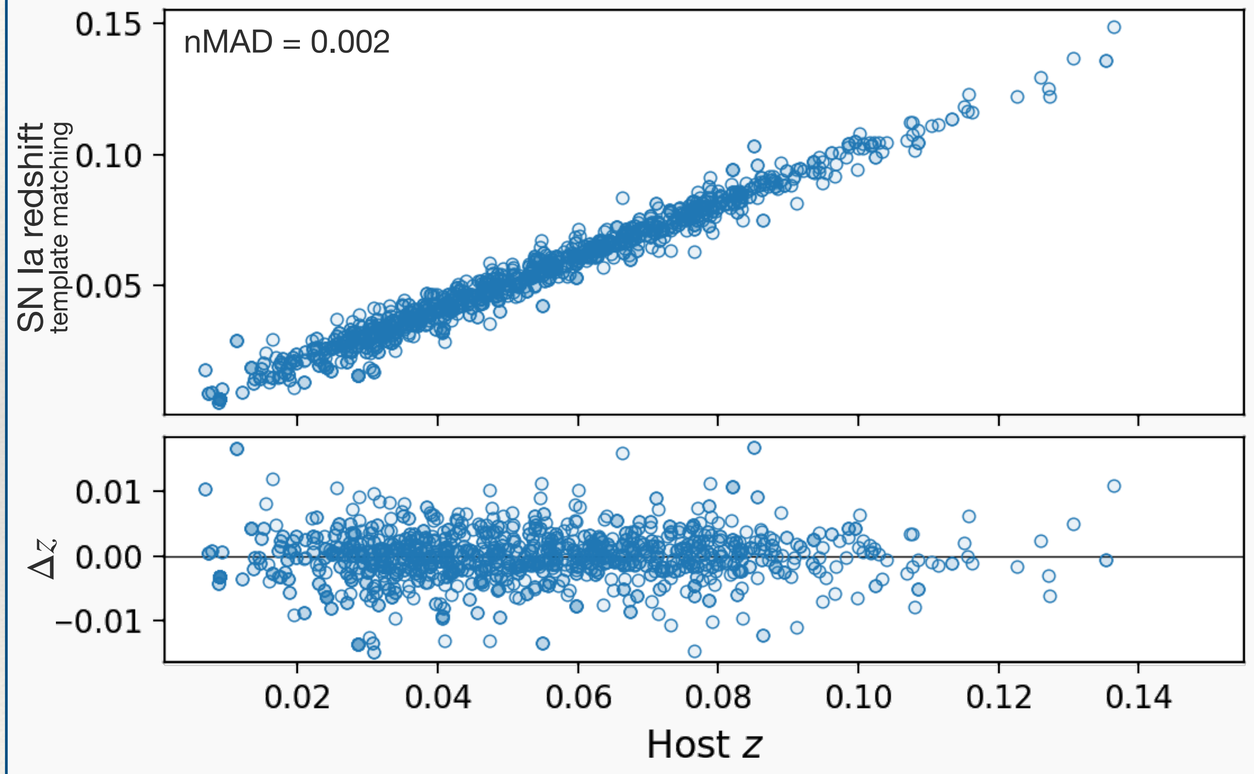


Redshifts

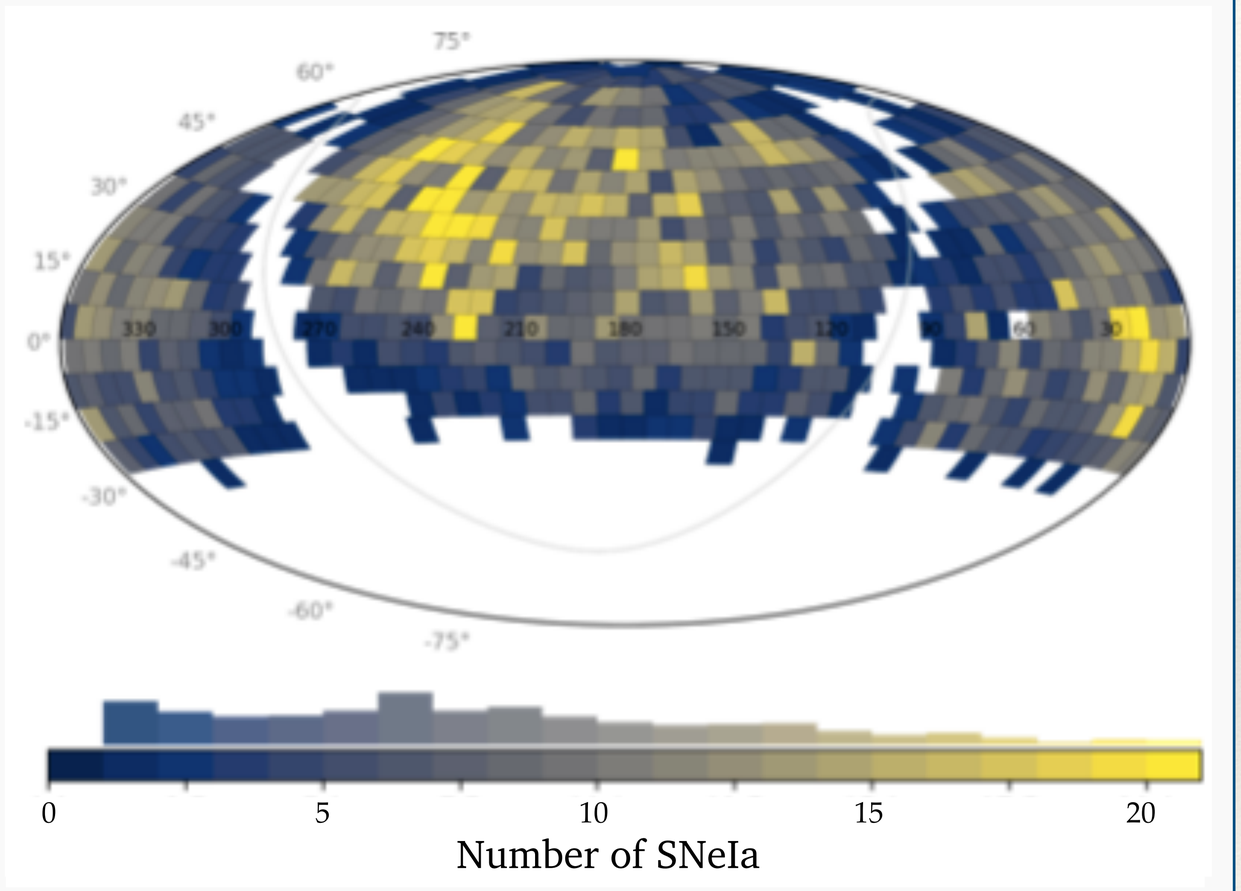
spec-z for 50% of events; DESI and WEAVE to come?

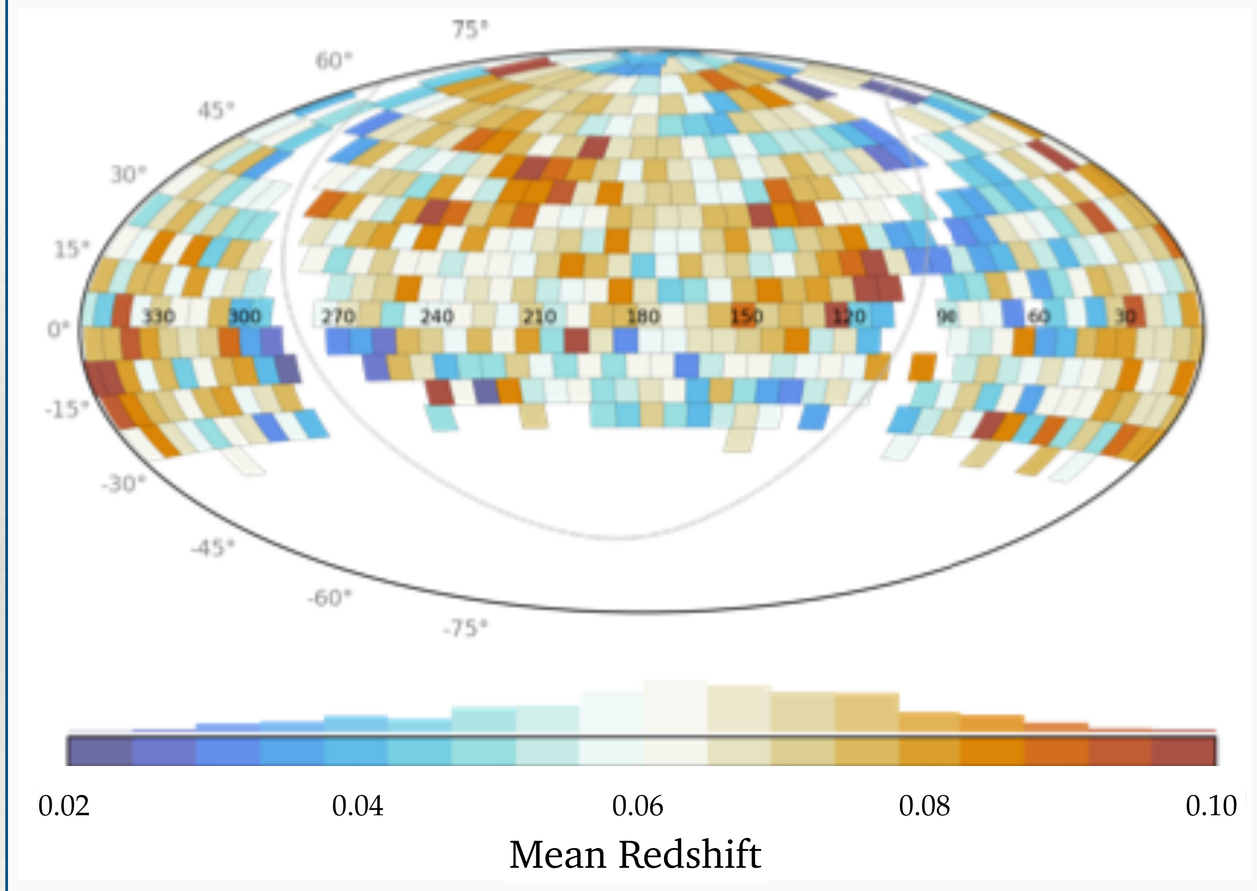


Redshifts are unbiased

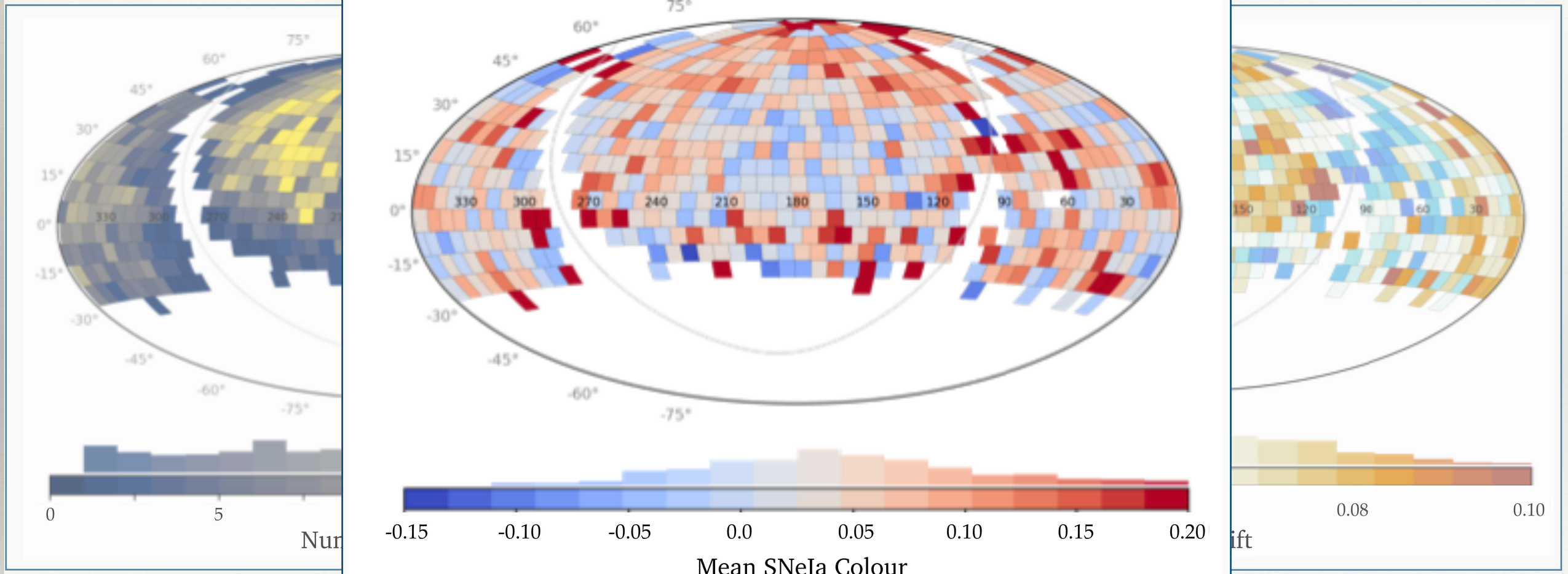


Spatial Uniformity



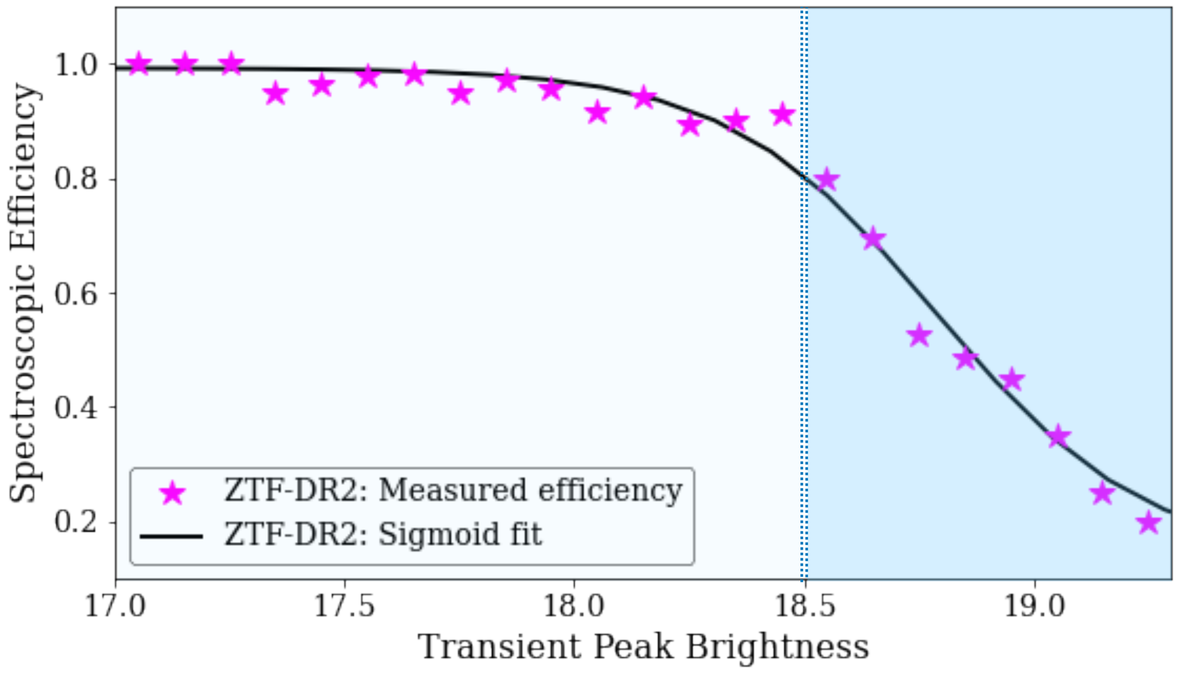


Spatial Uniformity

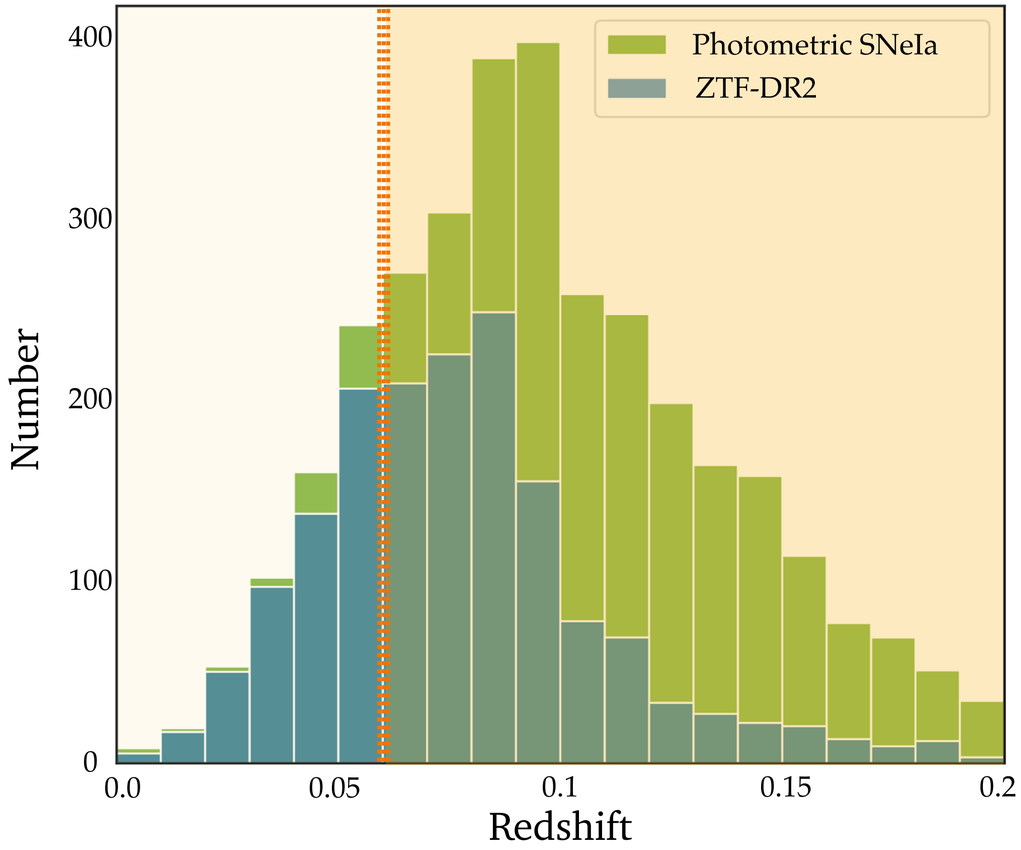


Completeness

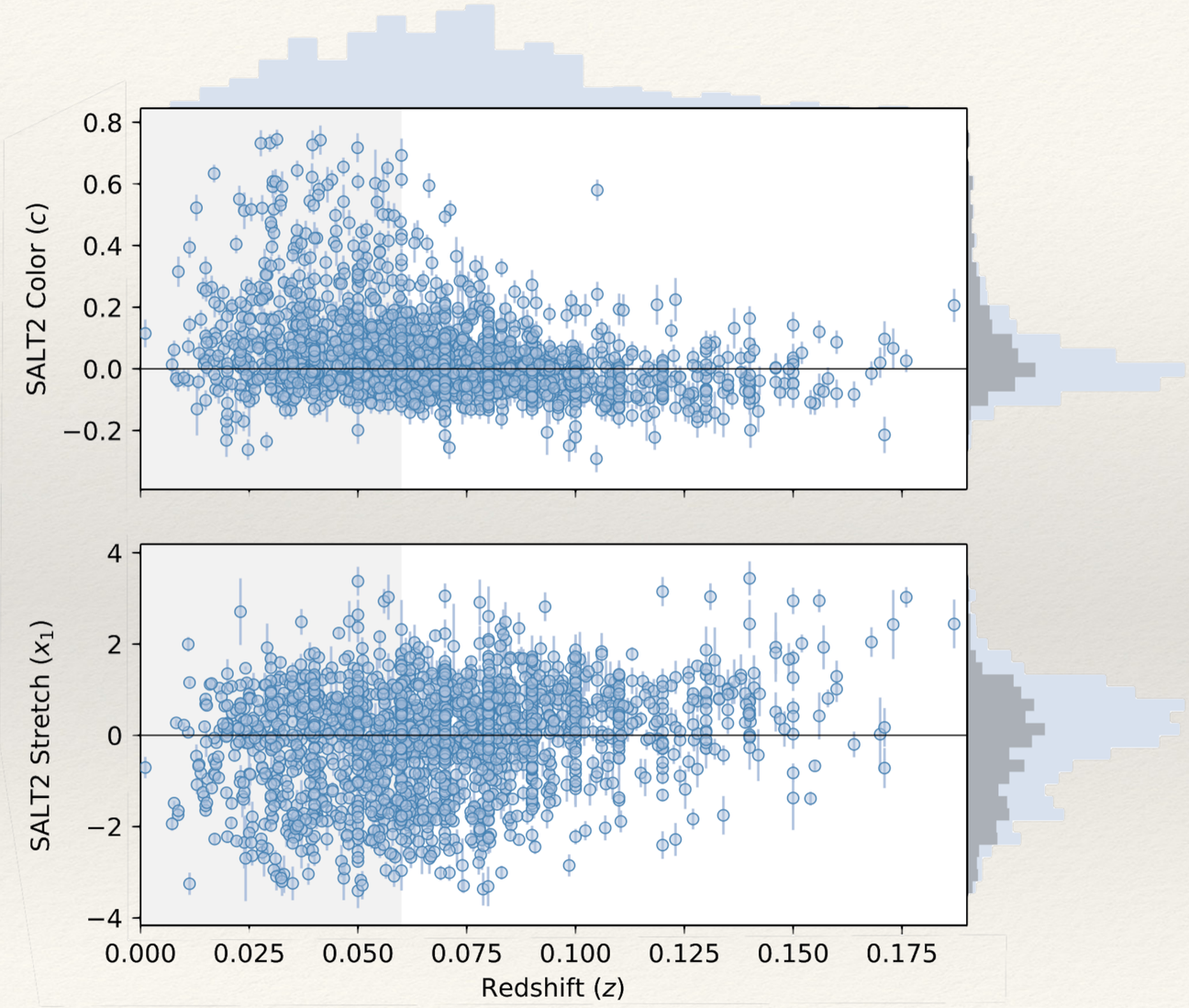
Complete and unbiased to m=18.5



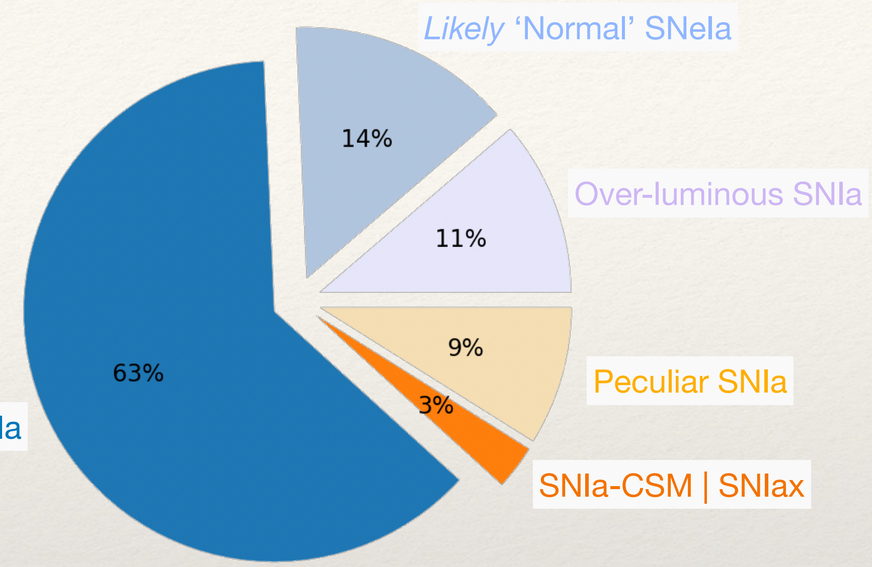
Unbiased to z=0.06

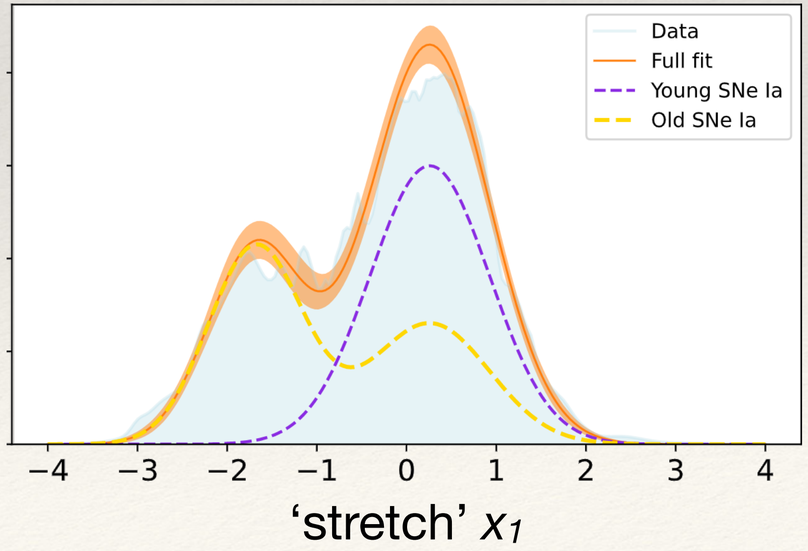


ZTF DR2 | *Defining SNeIa*



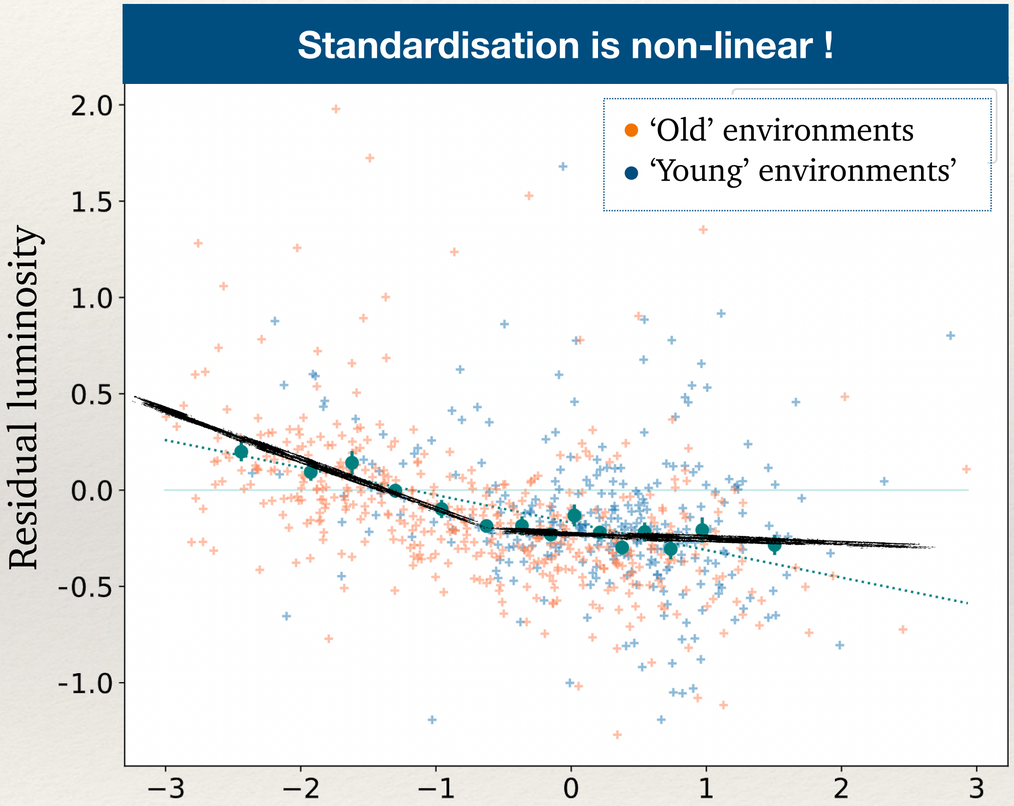
Normal SNeIa

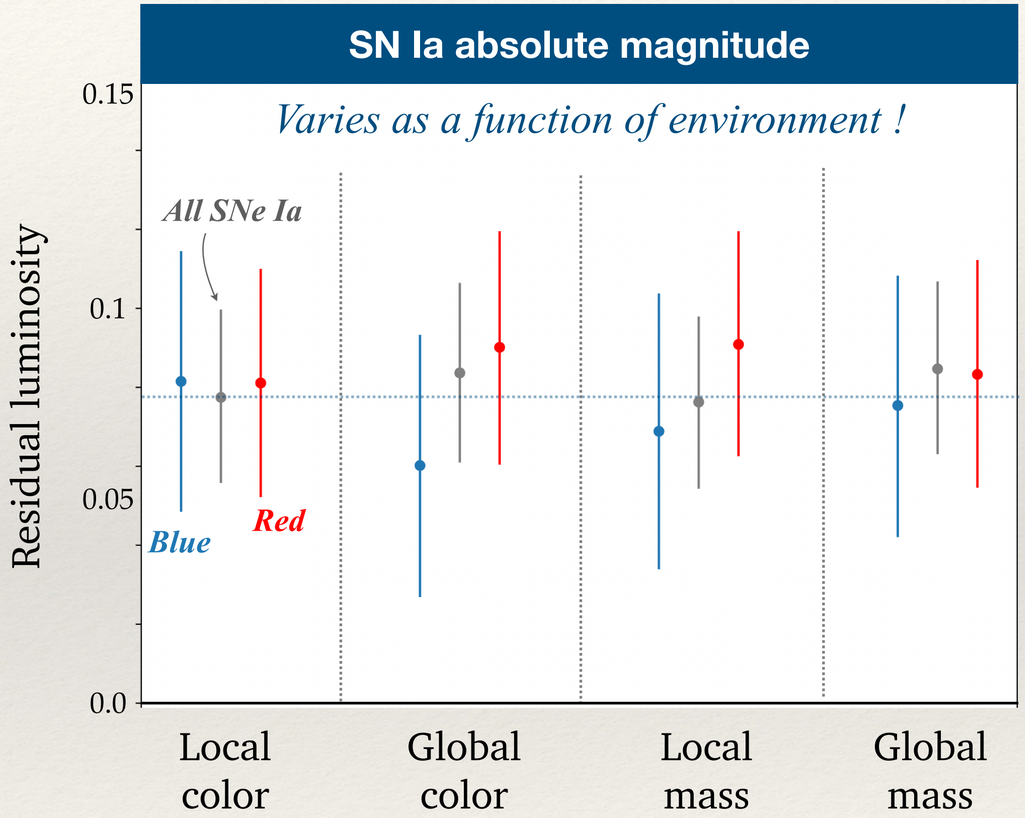




Astrophysical biases

Ginolin et al. in prep



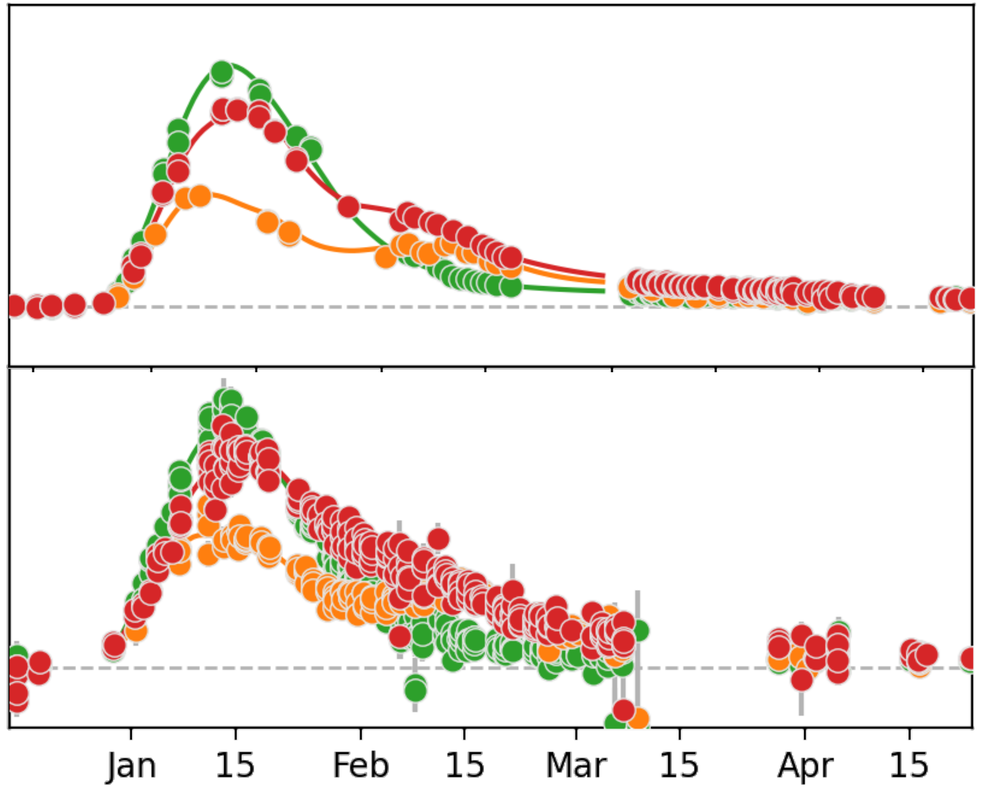


SNeIa properties and standardisation depend on environment

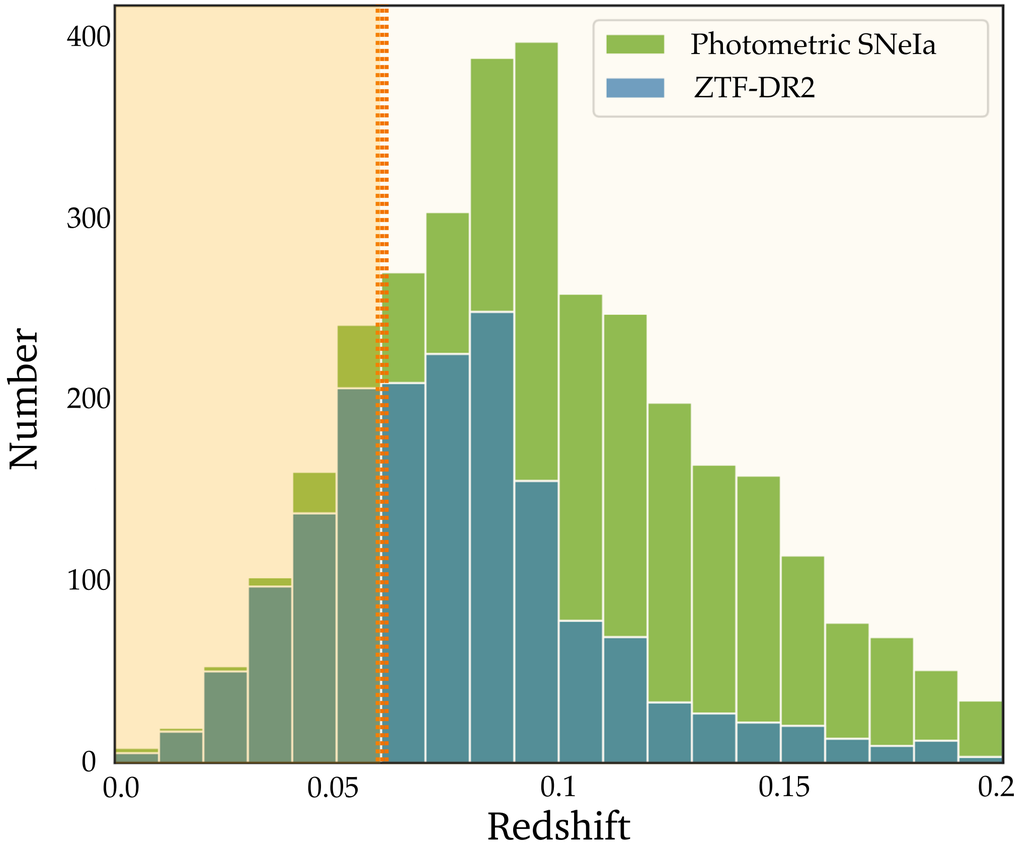
Towards Cosmology

Two outstanding issues

Field-to-field calibration uncertainties



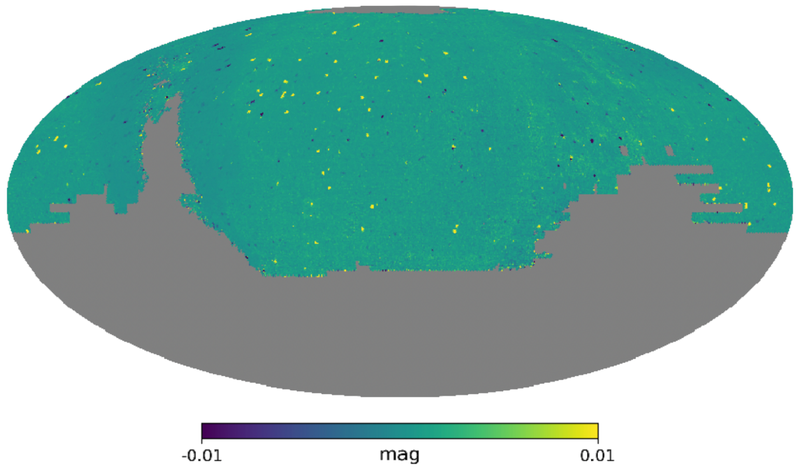
Quantifying biases



Photometry: ZTF-IN2P3 pipeline

Survey uniformity (space & time)

Ubercal : anchored using multi-fields stars

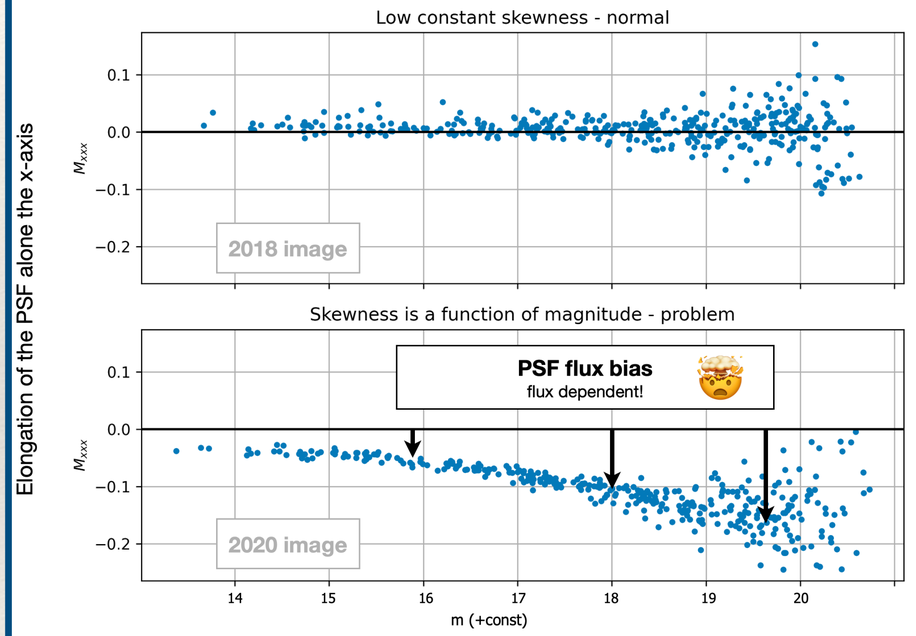


self-consistent ZTF photometric system | *no more PS1*

Racine et al. in prep

Flux uniformity

Scene modeling : Same flux estimator for stars & transient



Working on sub-percent detector biases

Lacroix et al. in prep

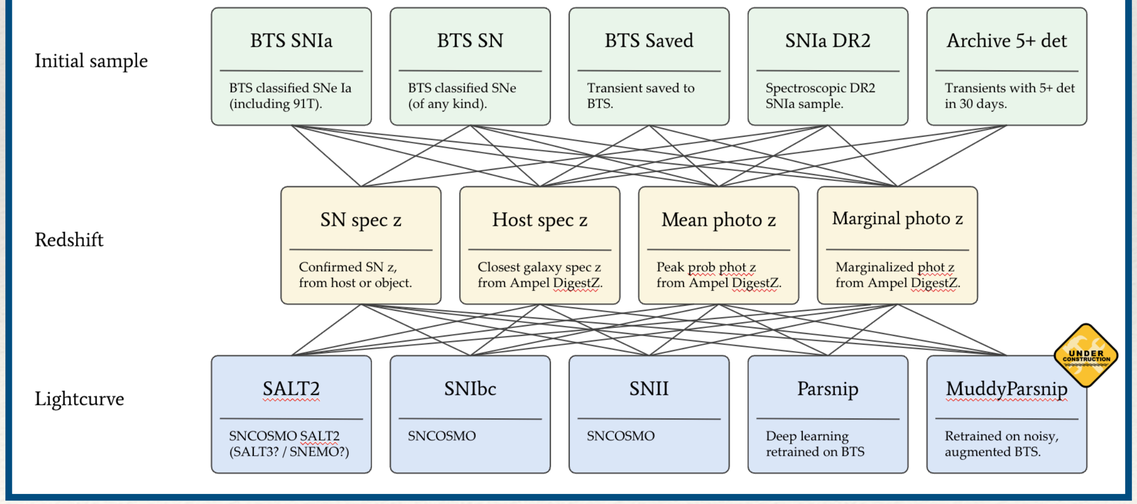
Quantifying Biases

Simulation | Forward modelling to quantify selection

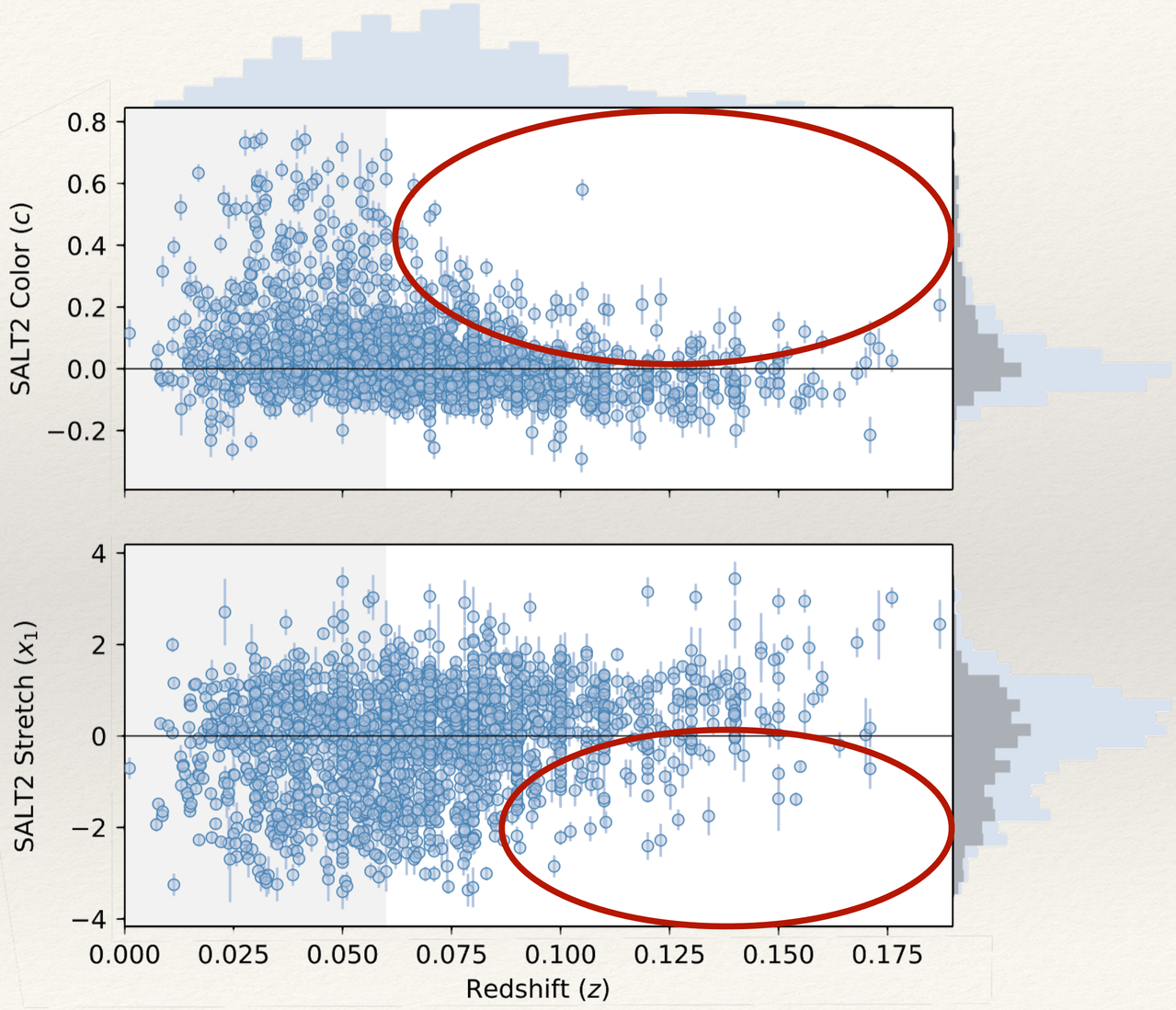
simsurvey | *Amenouche et al. in prep*

Selection function & cosmology | *Carreres et al. in prep*

Large ongoing effort starting in Berlin | *AMPEL-based*



AMPEL | *Townsend & Nordin et al. in prep*

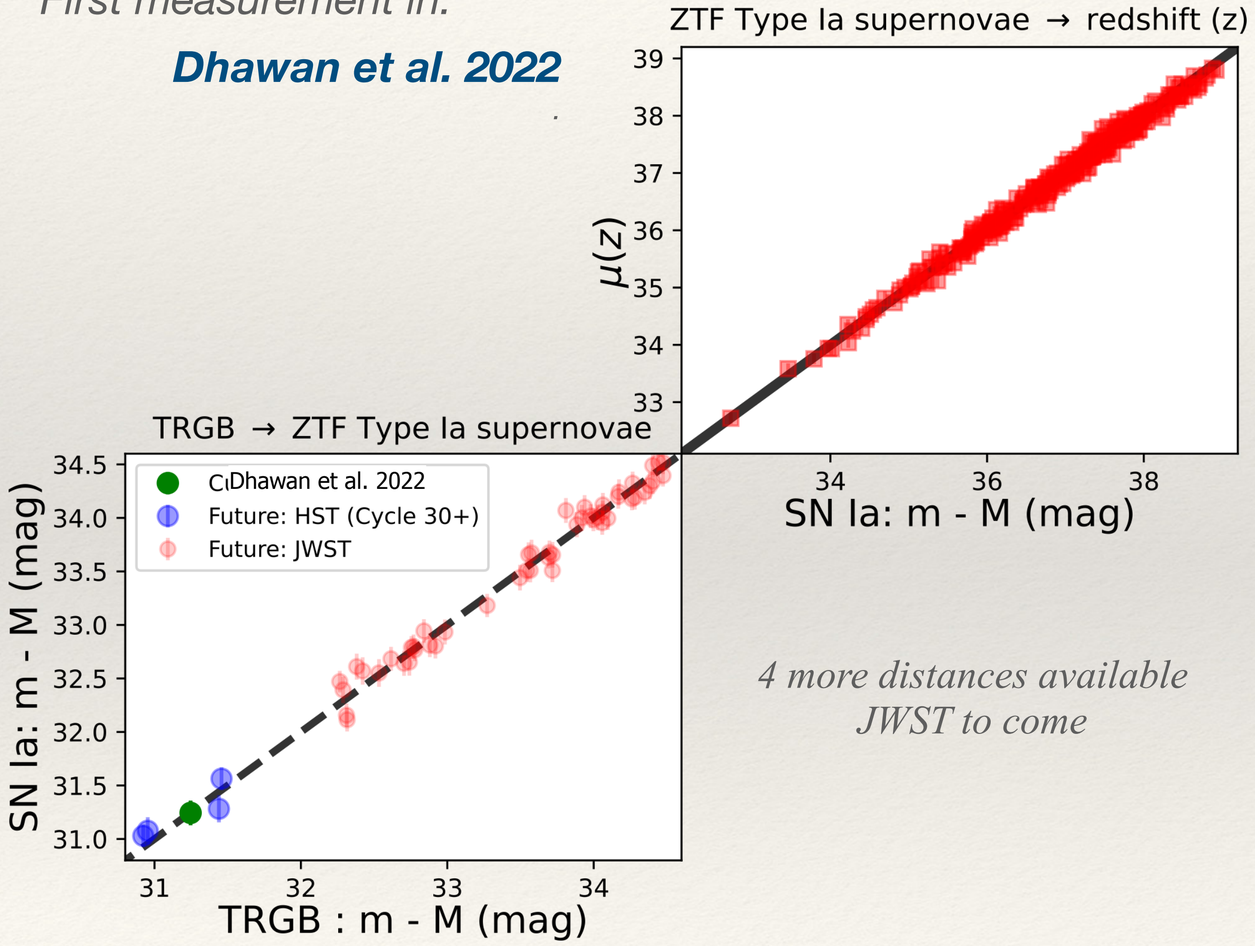


Teasing Cosmology

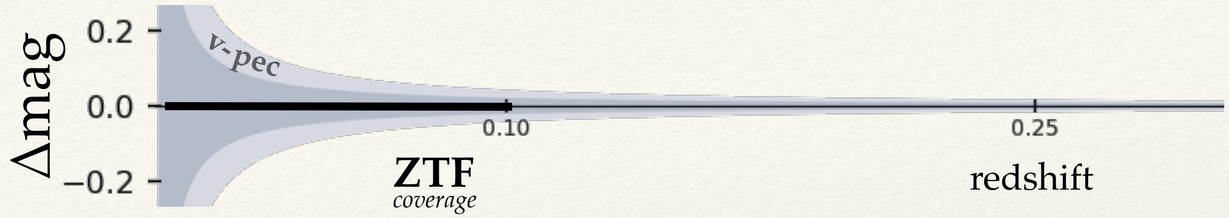
Hubble Constant (H_0) | Growth rate (σ_8)

First measurement in:

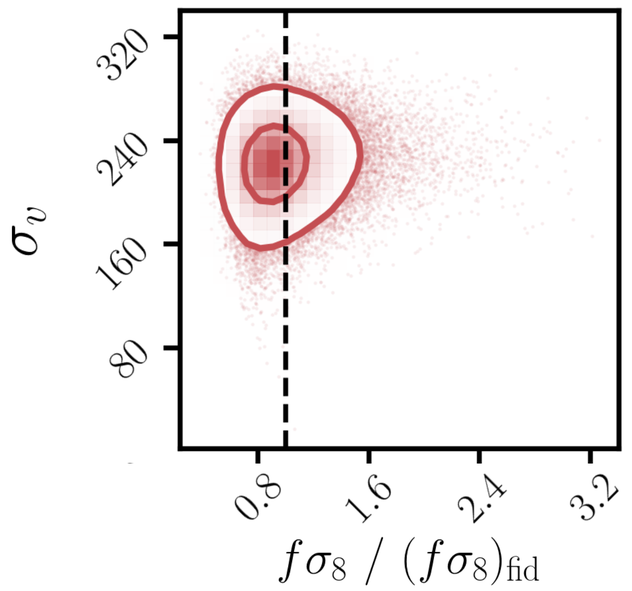
Dhawan et al. 2022



4 more distances available
JWST to come



First robust measurement with SNeIa



Unique probe:

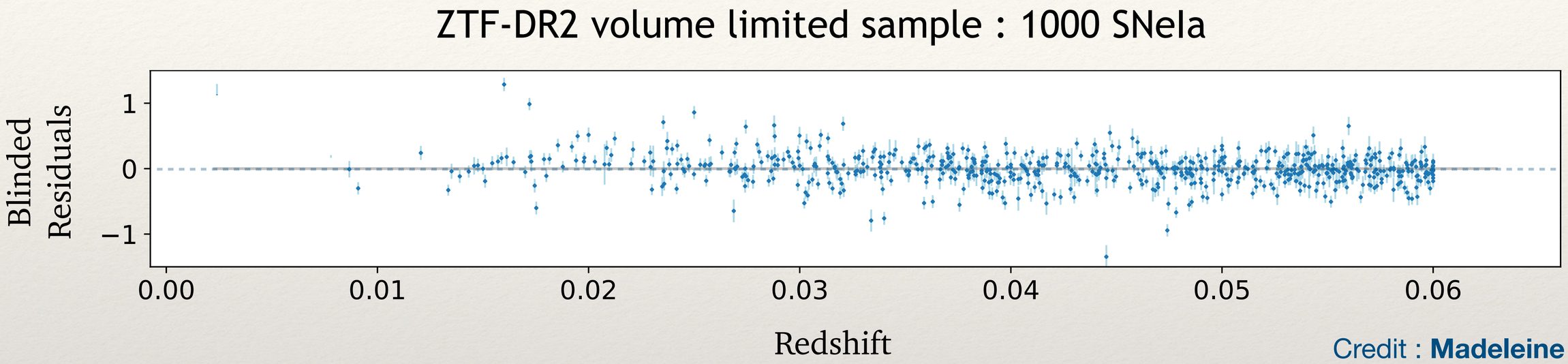
$f\sigma_8$ @ 20%

(2000 SNe Ia)

Carreres et al. in prep

Stay tuned for Bastien!

Dark Energy



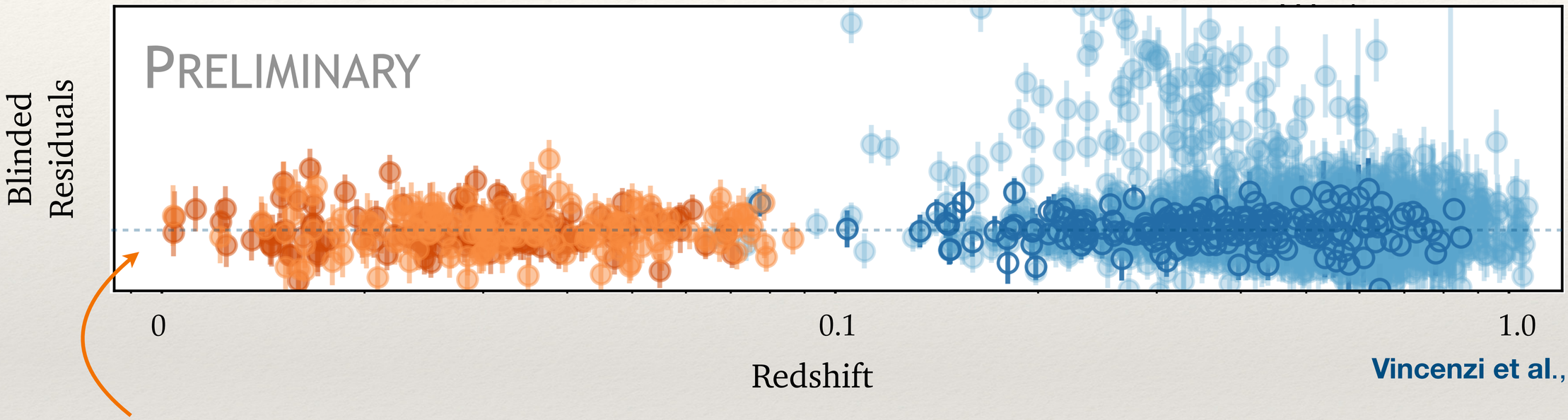
Credit : **Madeleine Ginolin**

$\sigma_{\text{scatter}} = 0.14$

Force-photometry light-curves

Dark Energy : Elsewhere

DES5YR Sample : 1600 SNeIa



Vincenzi et al., *in prep*

Compilation of 300 Low-Z SNeIa

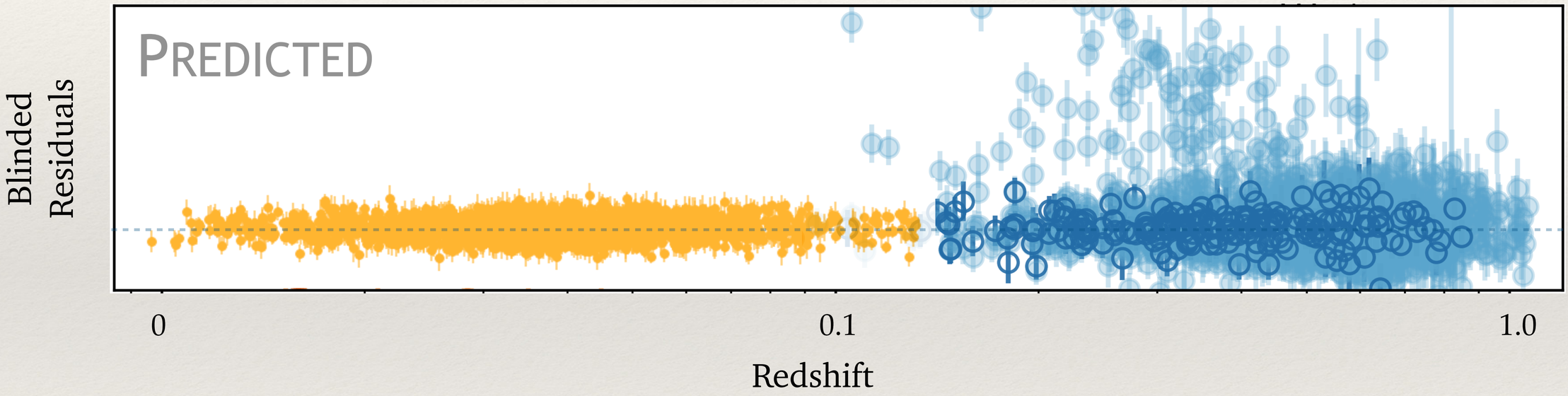
$\sigma_{\text{scatter}} = 0.12$

Release date: 2023

Dark Energy : Forthcoming

ZTF x DES Cosmology Taskforce formed in July 2022

PI: M. Smith | Data and Expertise Sharing



3500 SNeIa : $0 < z < 1$

Unrivalled prior to LSST

Late 2023 | First estimates of w

ZTF Cosmo Data Release 2 | *20 ongoing papers*

SN In Clusters

$f\sigma_8$ from SNe Ia measurements

I-band second bump analysis

Impact of survey selection function on fs8

SNe Ia Subclasses statistical study

Progenitor physics in SN lightcurves

Minimal metallicity SNe Ia

Data Release

Hypergal

Host-less SNe Ia and Exotic Dark Matter

ZTF DR2 sample simulation

w-letter

Early and Late Lightcurve modelling

Search for Strongly lensed SNe Ia

Toward the 1 per mil calibration

SN Astrophysical bias

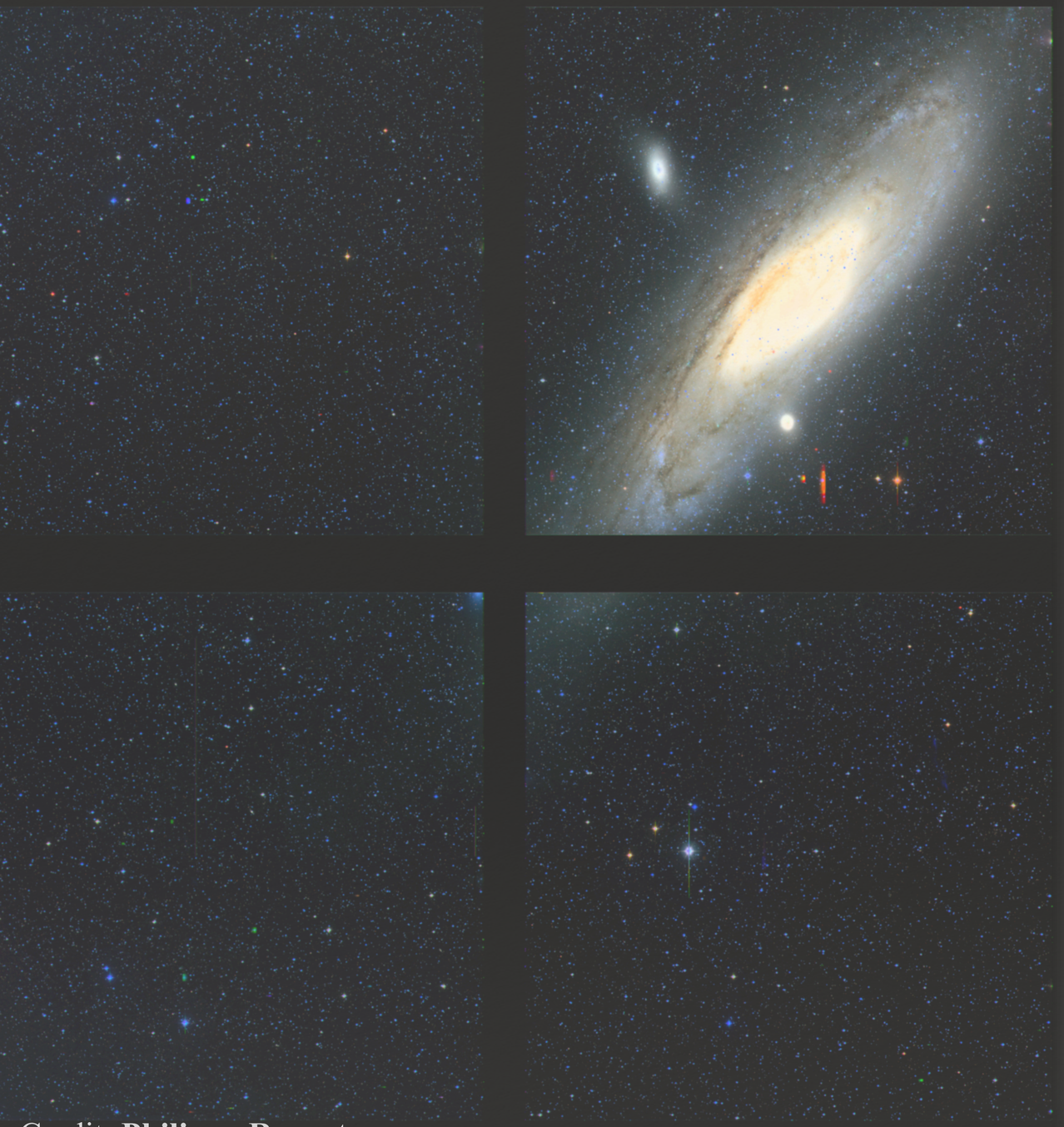
SNe Ia Spectral properties

Very reddened objects

two colour model and the mass step

SNe Ia Siblings

Release in early-2023



Credit: **Philippe Rosnet**

Merci

&

Thank you