Hubble

Better than the Sum of its Parts:

Synergistic Observations for Roman Extragalactic Transient Science

Benjamin Rose, Duke U.

Exploring the Transient Universe with the Nancy Grace Roman Space Telescope

February 8, 2022

Content from arXiv:2104.01199

Synergies between Vera C. Rubin Observatory, Nancy Grace Roman Space Telescope, and Euclid Mission: Constraining Dark Energy with Type Ia Supernovae

B. M. Rose, G. Aldering, M. Dai, S. Deustua, R. J. Foley, E. Gangler, Ph. Gris, I. M. Hook, R. Kessler, G. Narayan, P. Nugent, S. Perlmutte K. A. Ponder, B. Racine, D. Rubin, B. O. Sánchez, D. M. Scolnic, W. M Wood-Vasey, D. Brout, A. Cikota, D. Fouchez, P. M. Garnavich, R. Hounsell, M. Sako, C. Tao, S. W. Jha, D. O. Jones, L. Strolger, H. Qu

We review the needs of the supernova community for improvements in survey coordination and data sharing that would significantly boost the constraints on dark energy using samples of Type Ia supernovae from the Vera C. Rubin Observatories, the \textit{Nancy Grace Roman Space Telescope}, and the \textit{Euclid} Mission. We discuss improvements to both statistical and systematic precision that the combination of observations from these experiments will enable. For example, coordination will result in improved photometric calibration, redshift measurements, as well as supernova distances. We also discuss what teams and plans should be put in place now to start preparing for these combined data sets. Specifically, we request coordinated efforts in field selection and survey operations, photometric calibration, spectroscopic follow-up, pixel-level processing, and computing. These efforts will benefit not only experiments with Type Ia supernovae, but all time-domain studies, and cosmology with multi-messenger astrophysics.

Comments: Response to the recent DOE/NASA Request for Information. Endorsed by the Roman Supernova Science Investigation Teams and the LSST DESC Supernova Working Group

Roadmap to being better than the sum of our parts

- **Why** is coordination important?
- **Who** will be working together?
- **What** are synergistic observations?
- **When** do we need to work on this?
- ~~**Where**?~~
- **How** can we make this happen?

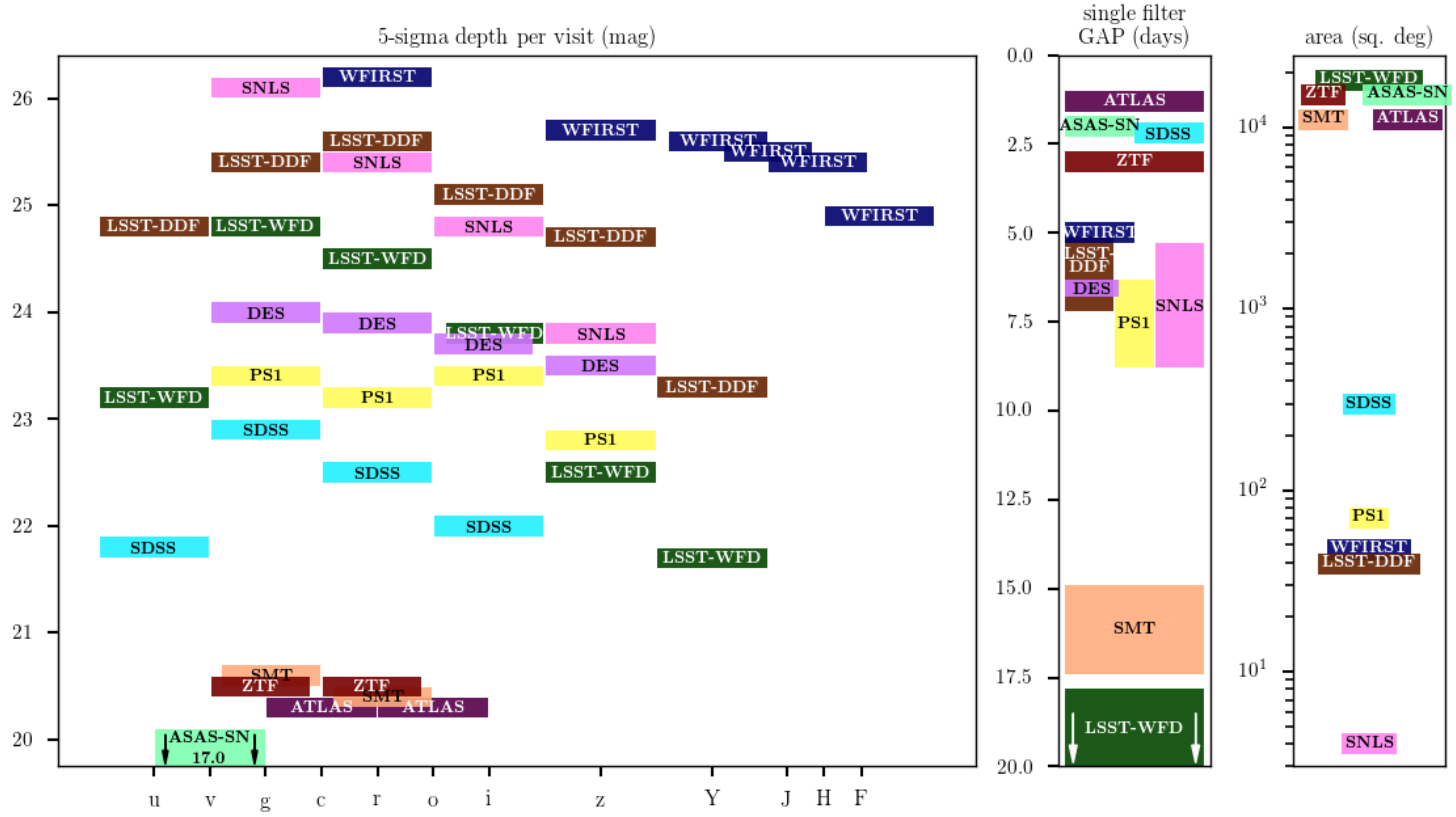
Why is coordination important?

Why is coordination important?

1. Unique information
2. Photometric calibration
3. Host-galaxy redshifts
4. Spectroscopy of transients
5. NIR light curves
6. Selection functions
7. Forced-position photometry
8. Artificial source injection

Each survey has unique information

1. Depth
2. Filter coverage
3. Temporal sampling
4. Sky location/area

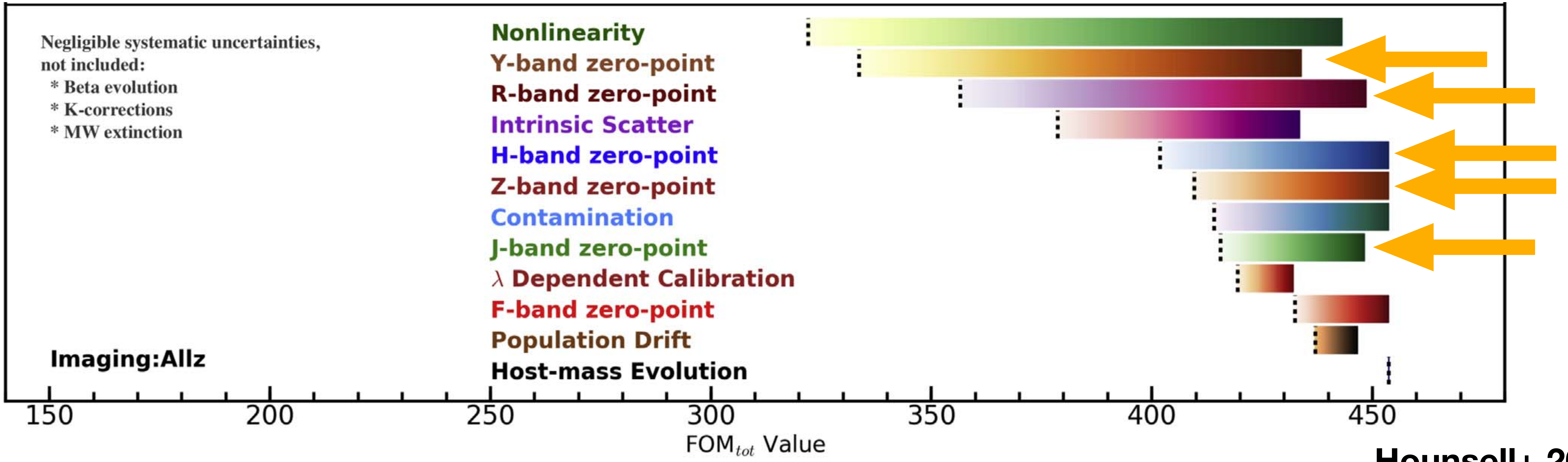


Scolnic, Kessler, Brout, et al. 2017

Photometric calibration

- The uncertainty in the flux standards, and hence, the photometric zero points are a large systematic uncertainty when measuring Dark Energy with Type Ia supernovae.
- Coordinated stellar calibration networks allow for improvements via cross survey calibrations

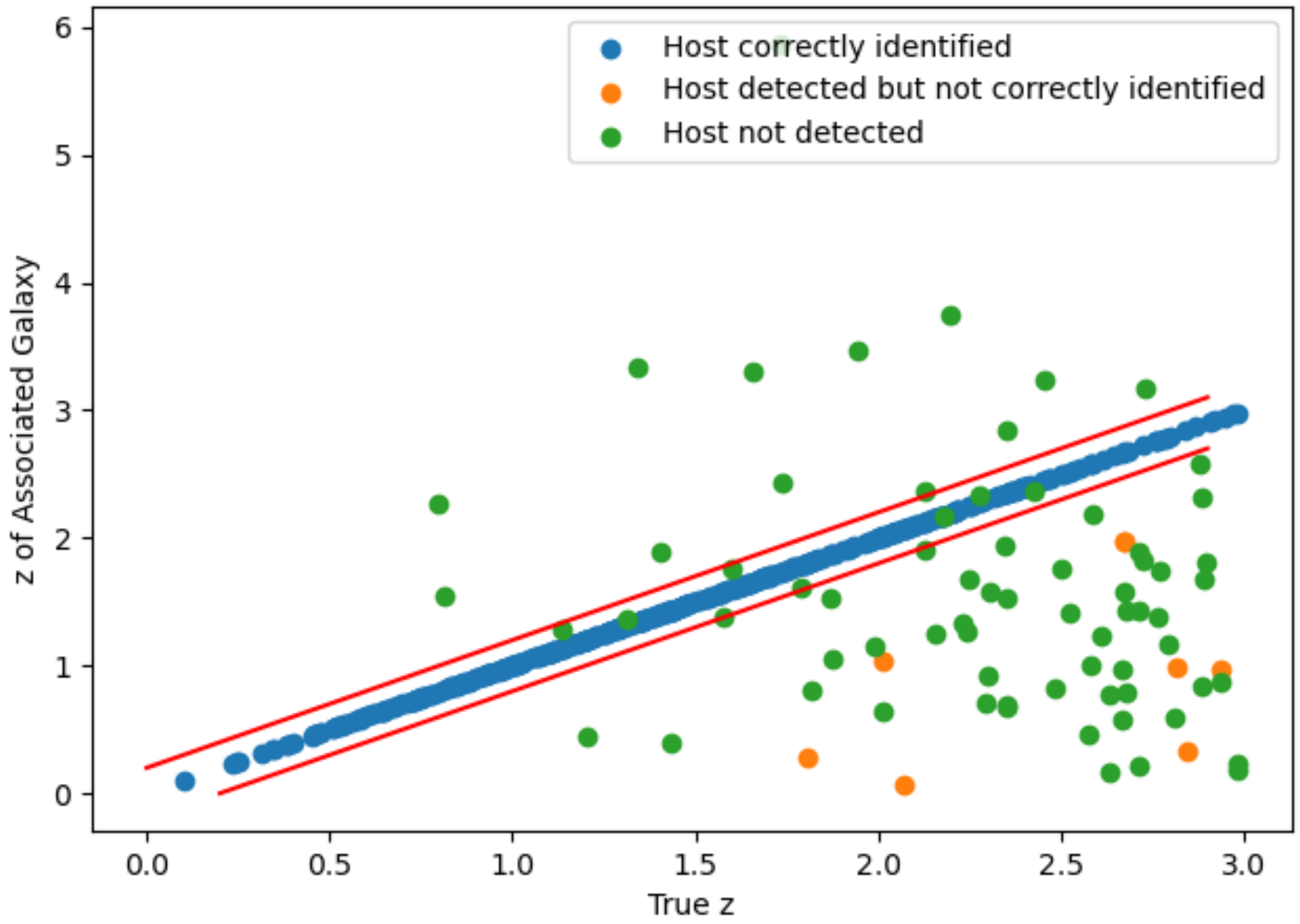
Roman Systematic Uncertainties



Hounsell+ 2018

Host-galaxy redshifts

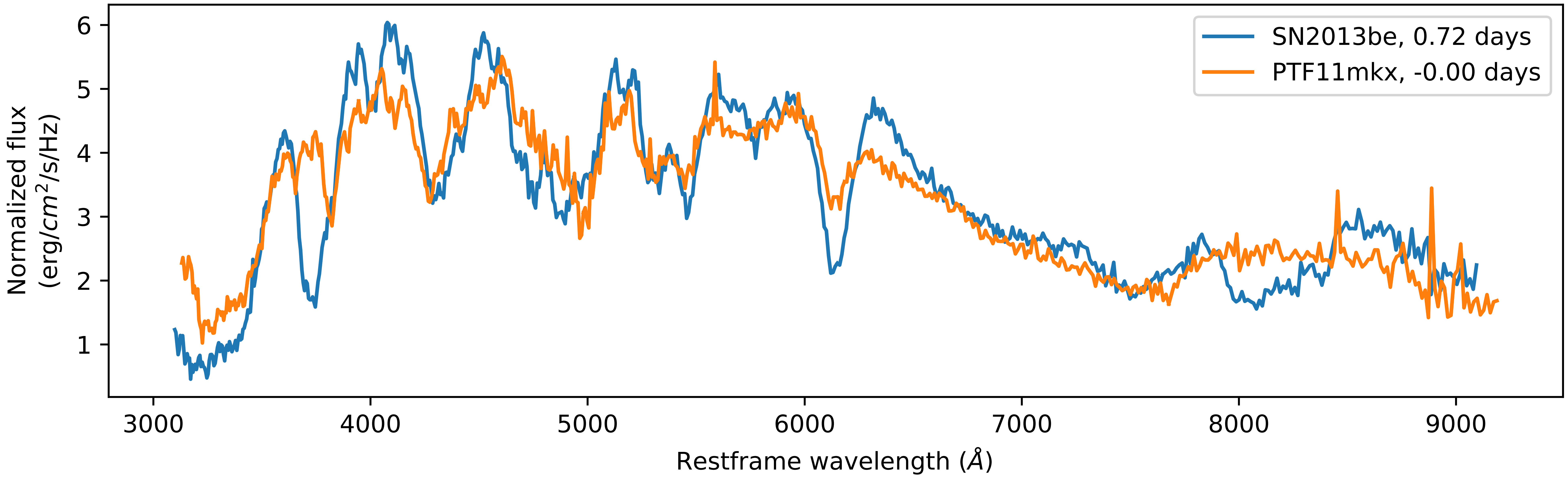
- Redshifts are necessary for many science cases: classification, rates, etc.
- For SNIa cosmology, redshifts are one of the two fundamental quantities we need.
- Determining correct host-galaxy isn’t always easy, programs with different depths are important, and need coordinated follow-up programs.



Wang+ in prep

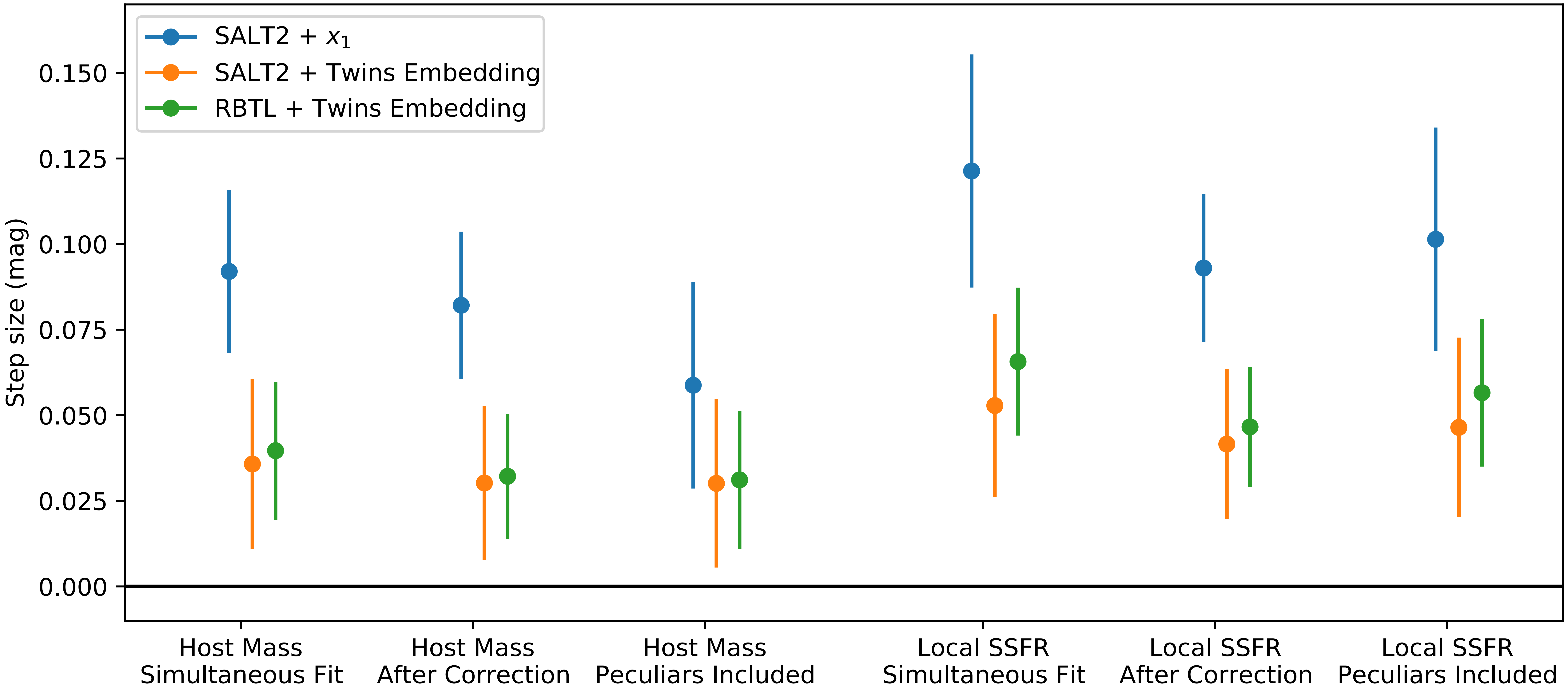
Spectroscopy of transients

- Transient classification
- Astrophysics - seeing lanthanides in kilonovae
- Time series can be used in SN Ia standardization (Boone+ 2021a)



Boone+ 2021b

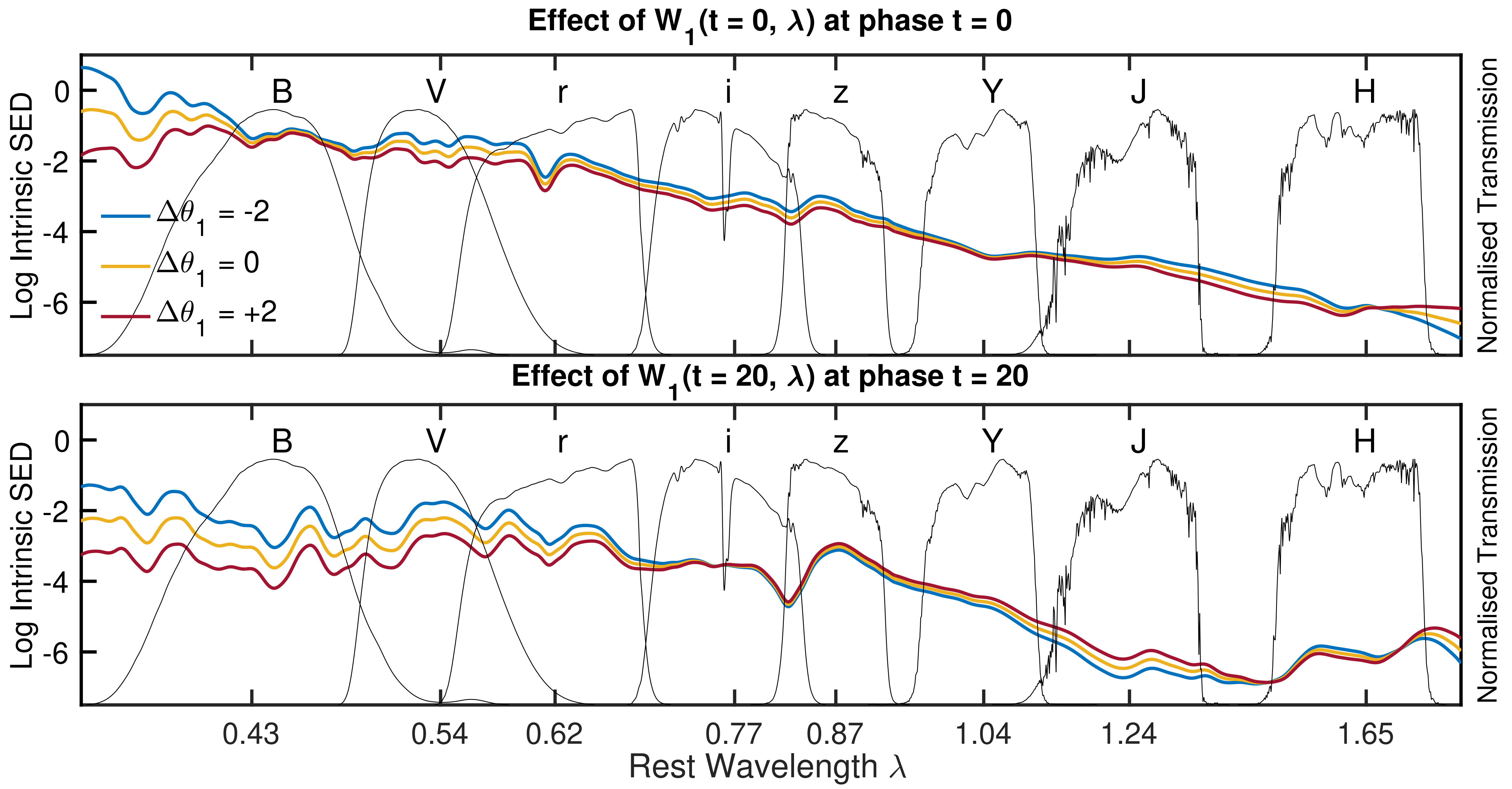
Spectroscopy of transients

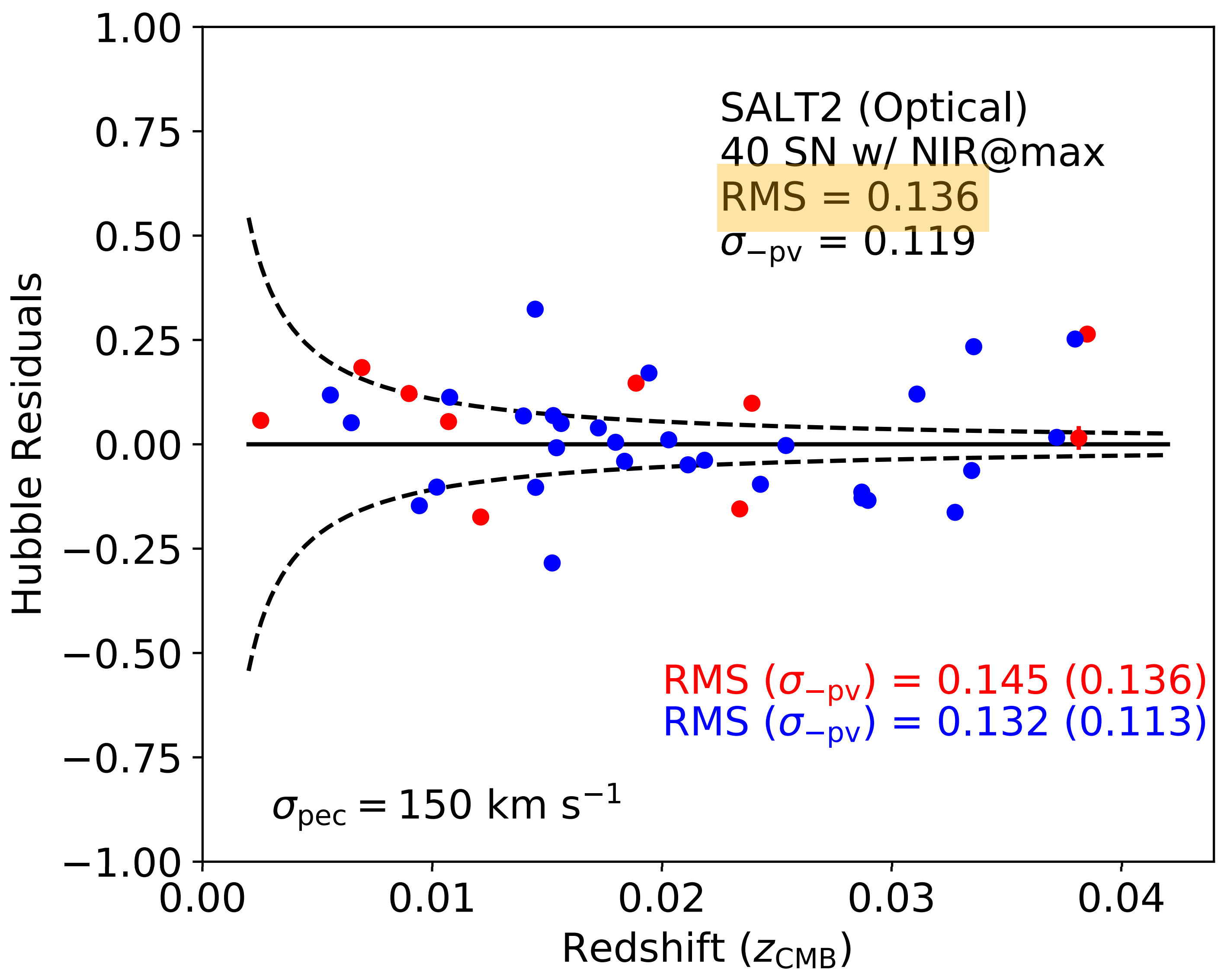


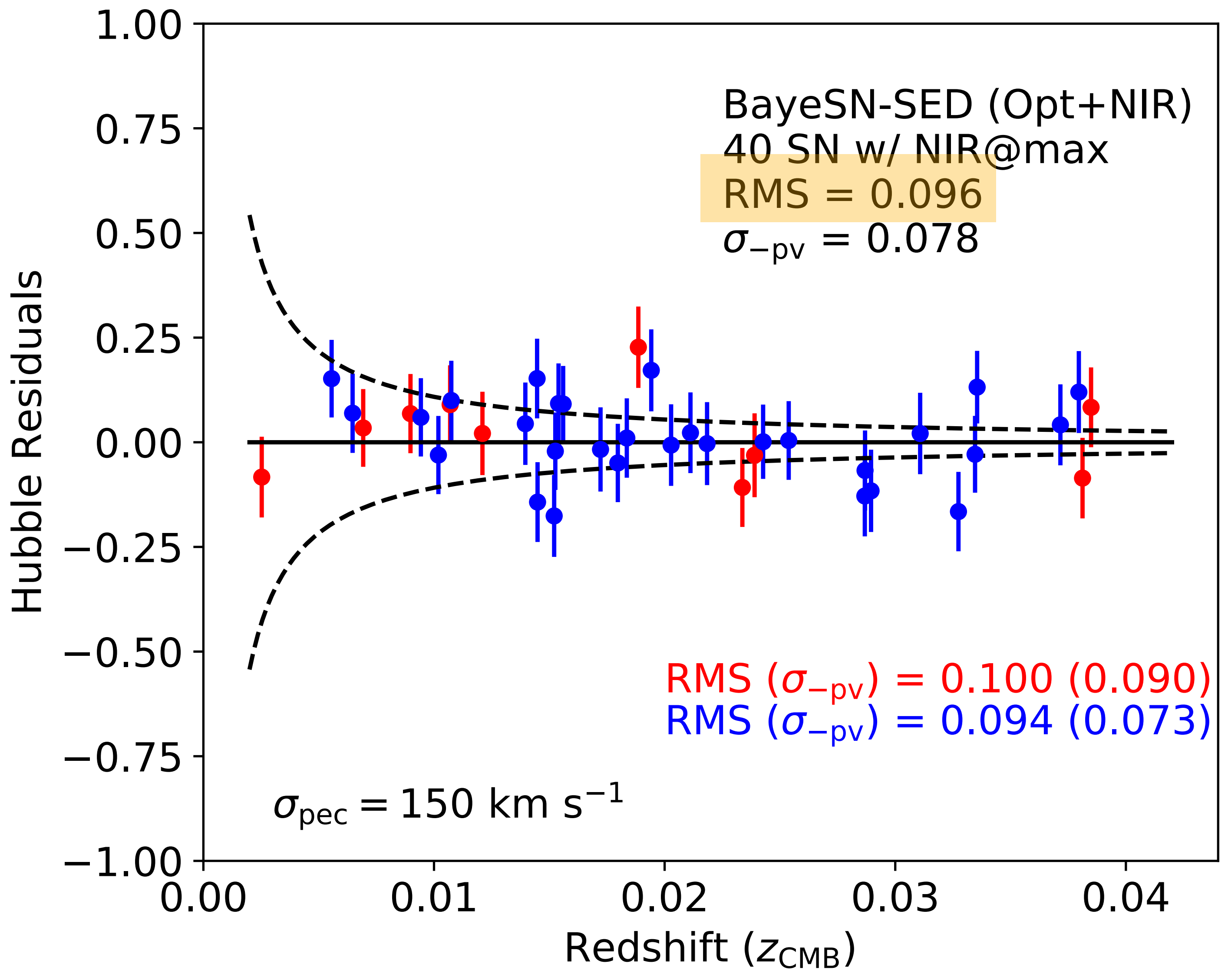
Boone+ 2021b

NIR Light curves

- Template building of transients
- Increasing wavelength range can improve constraining power
- NIR can improve SN standardization





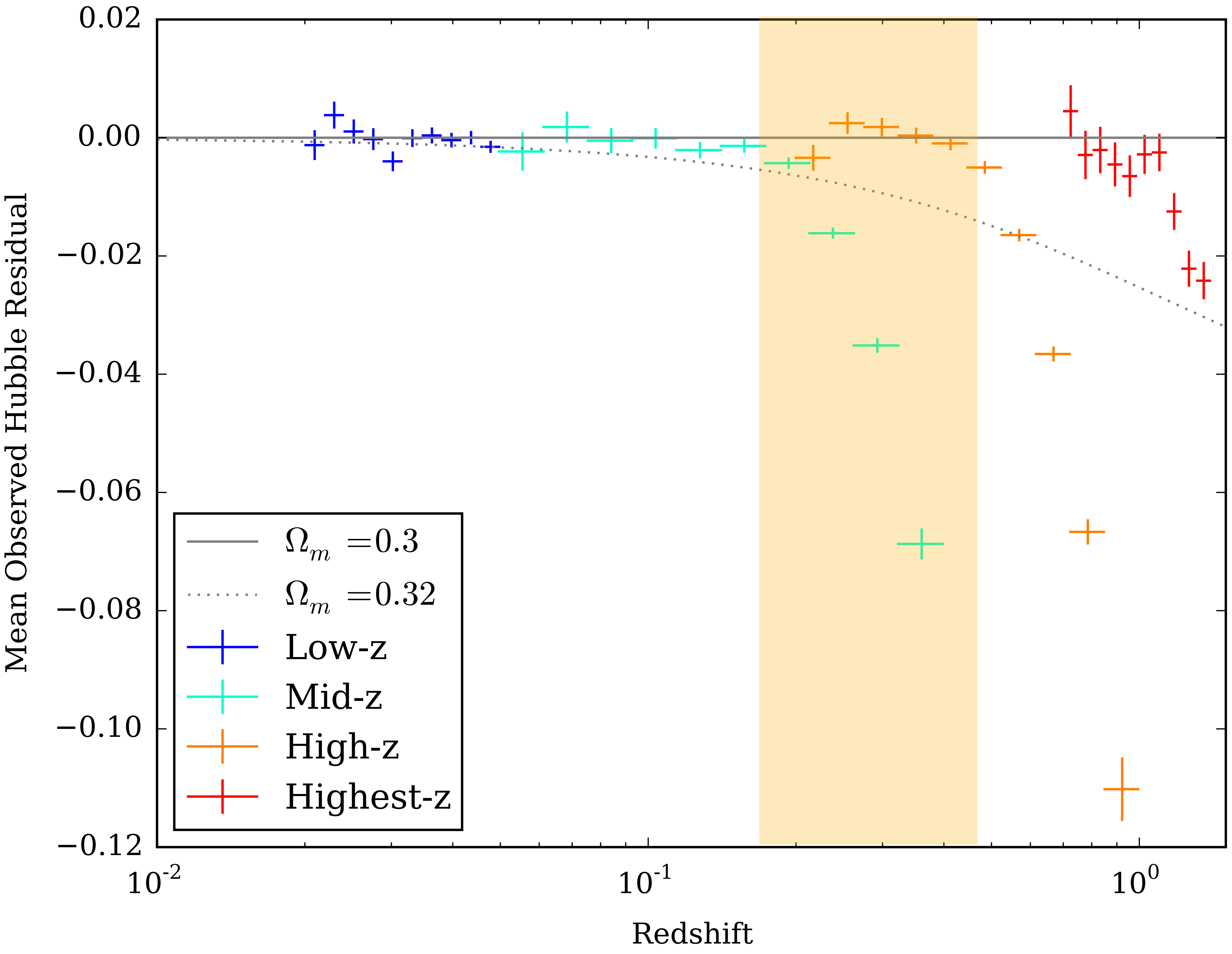


Mandel+ 2020

Selection functions

- Because of magnitude limited surveys, the average observed values changes as a function of redshift

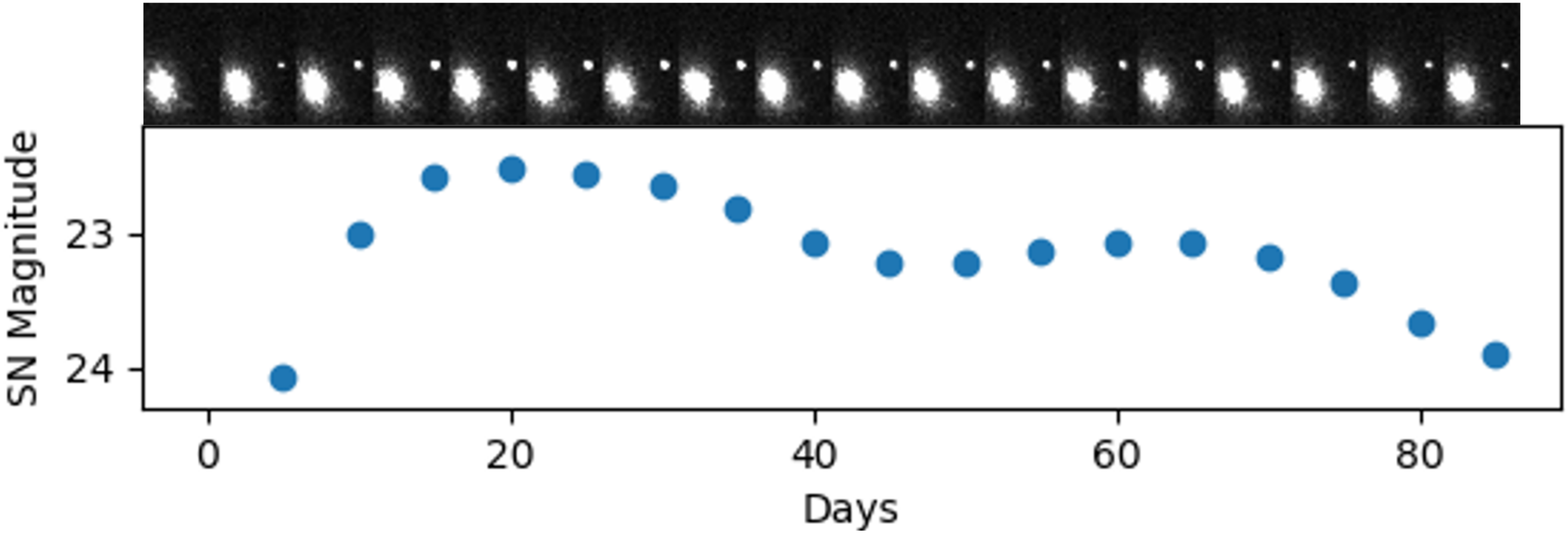
- Deeper surveys help define the selection function for shallower surveys, see how the high-z survey shows that the mid-z survey is being biased.



Rubin+ 2015

Forced-position photometry

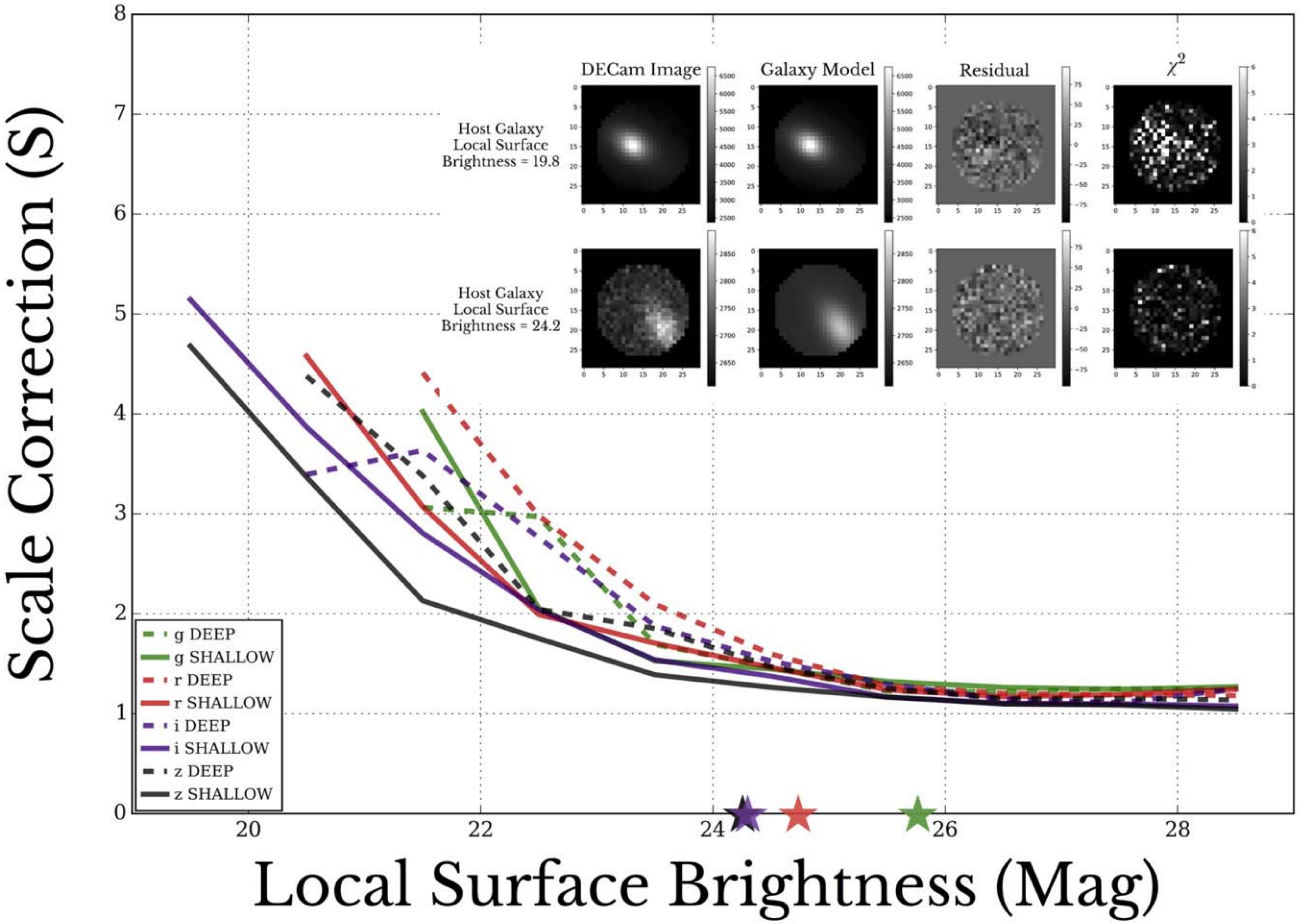
- When you know the location of a transient, sub-threshold photometry becomes possible.
- Detections in one survey but not another can lead to photometry at a wide set of wavelengths.



Wang+ in prep

Artificial source injection

- Characterizing anomalous noise in bright galaxies
- Bright galaxy subtraction has more photometric noise
- S = RMS(Δflux/σ_{stat})
- Joint tests of artificial source injection lead to better characterized selection effects and photometry biases

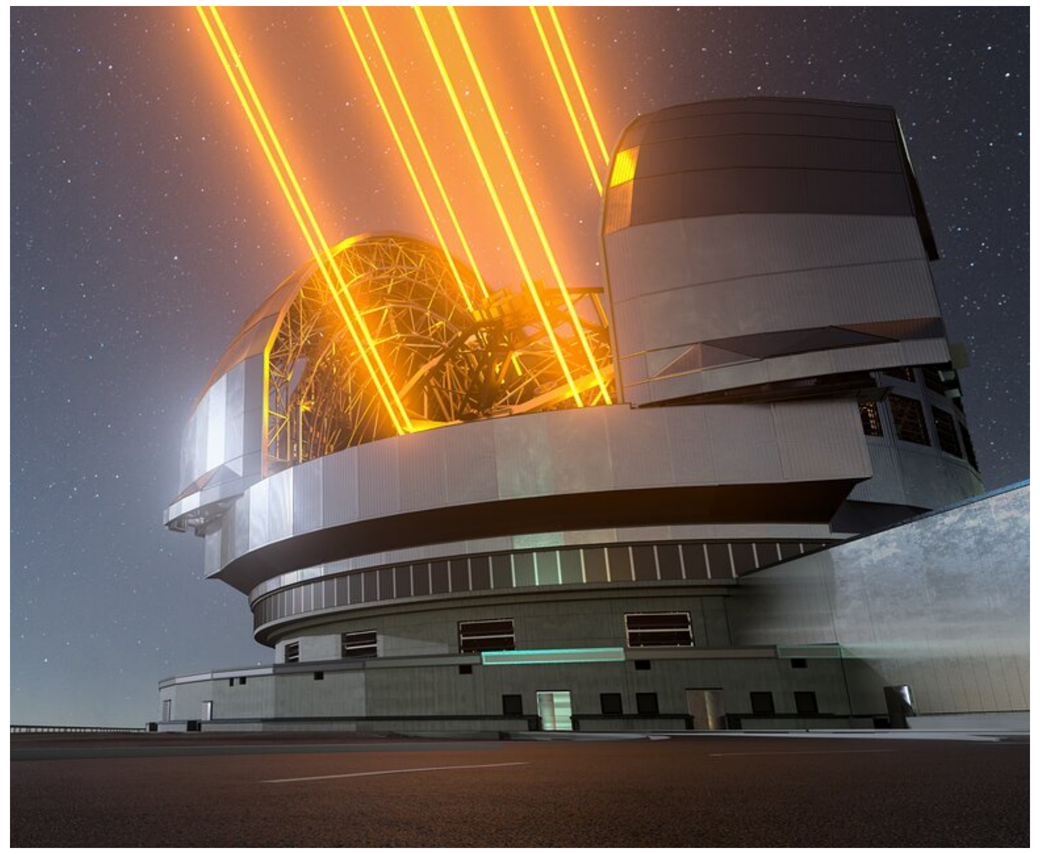


Brout+ 2019a

Who?

Who?

And others



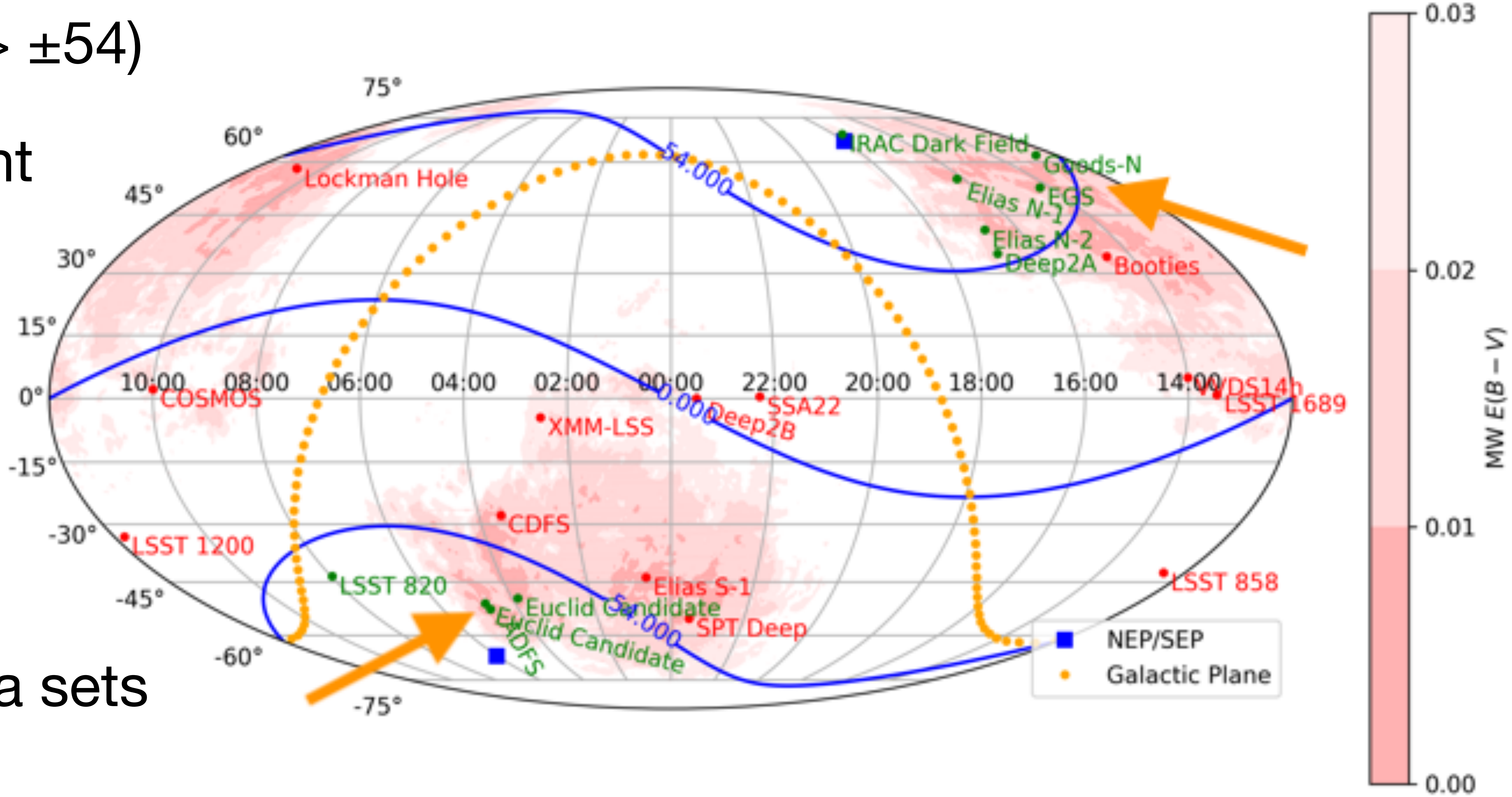
What synergistic observations?

What synergistic observations?

- Overlapping fields
- A calibration network
- Coordinated spectroscopic followup

Overlapping fields

1. High ecliptic latitude (> ±54)
   - minimize zodiacal light
   - in Roman CVZ



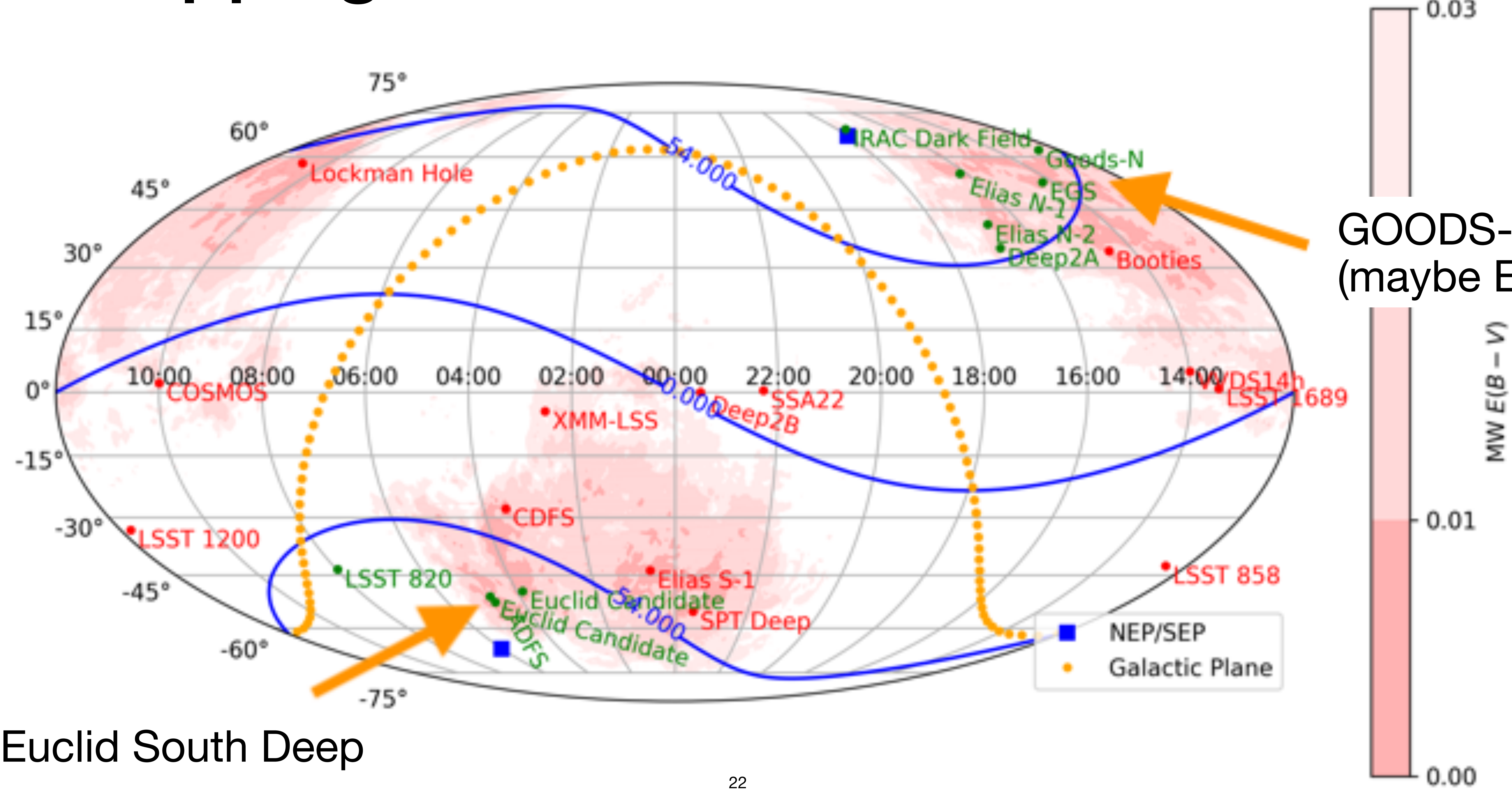
2. High Galactic Latitude (low dust)
3. Overlap with other data sets
4. Avoid bright stars

Overlapping fields

NANCY GRACE ROMAN SPACE TELESCOPE

VERA C. RUBIN OBSERVATORY

euclid

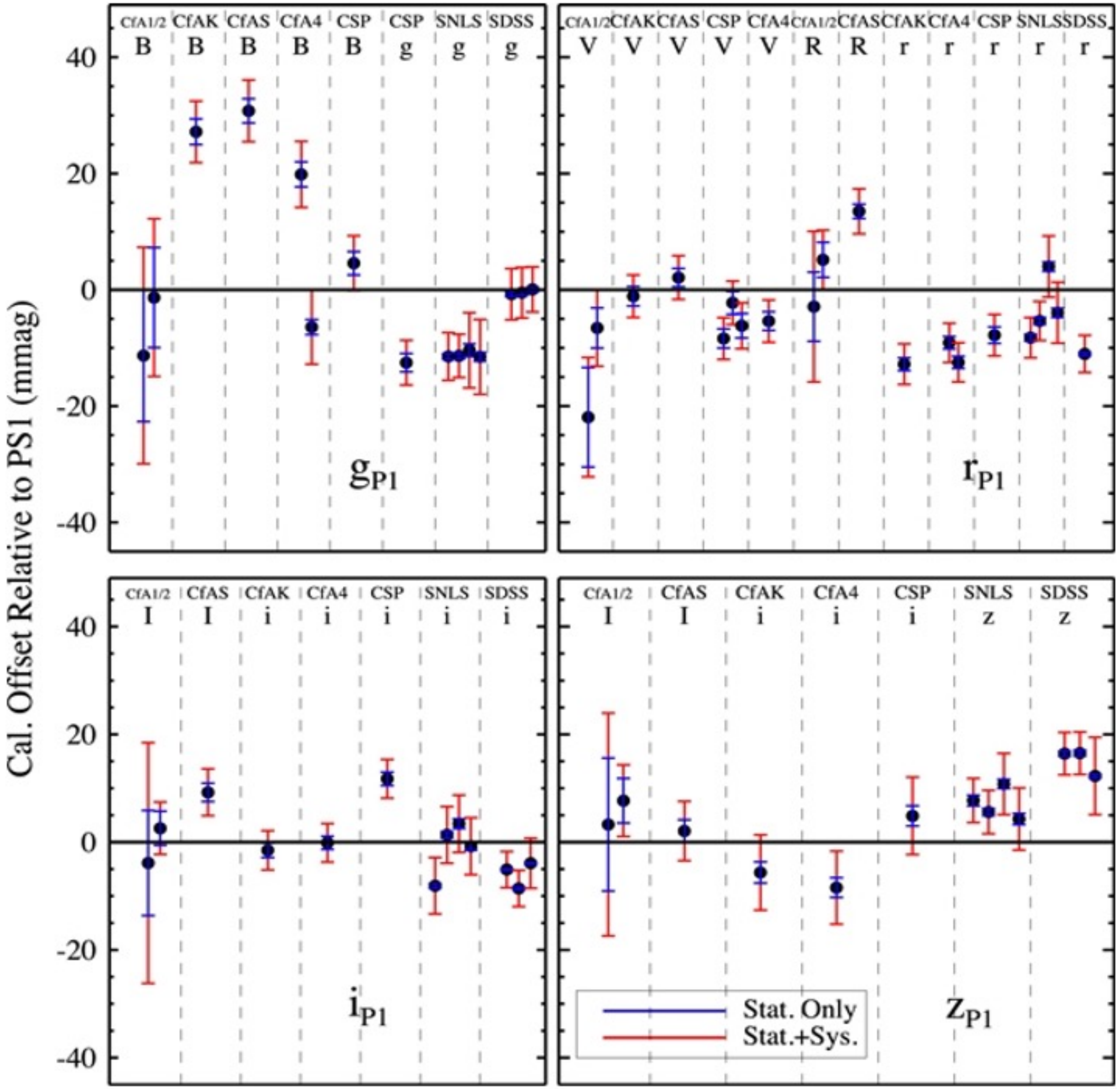


GOODS-N (maybe EGS)

Euclid South Deep

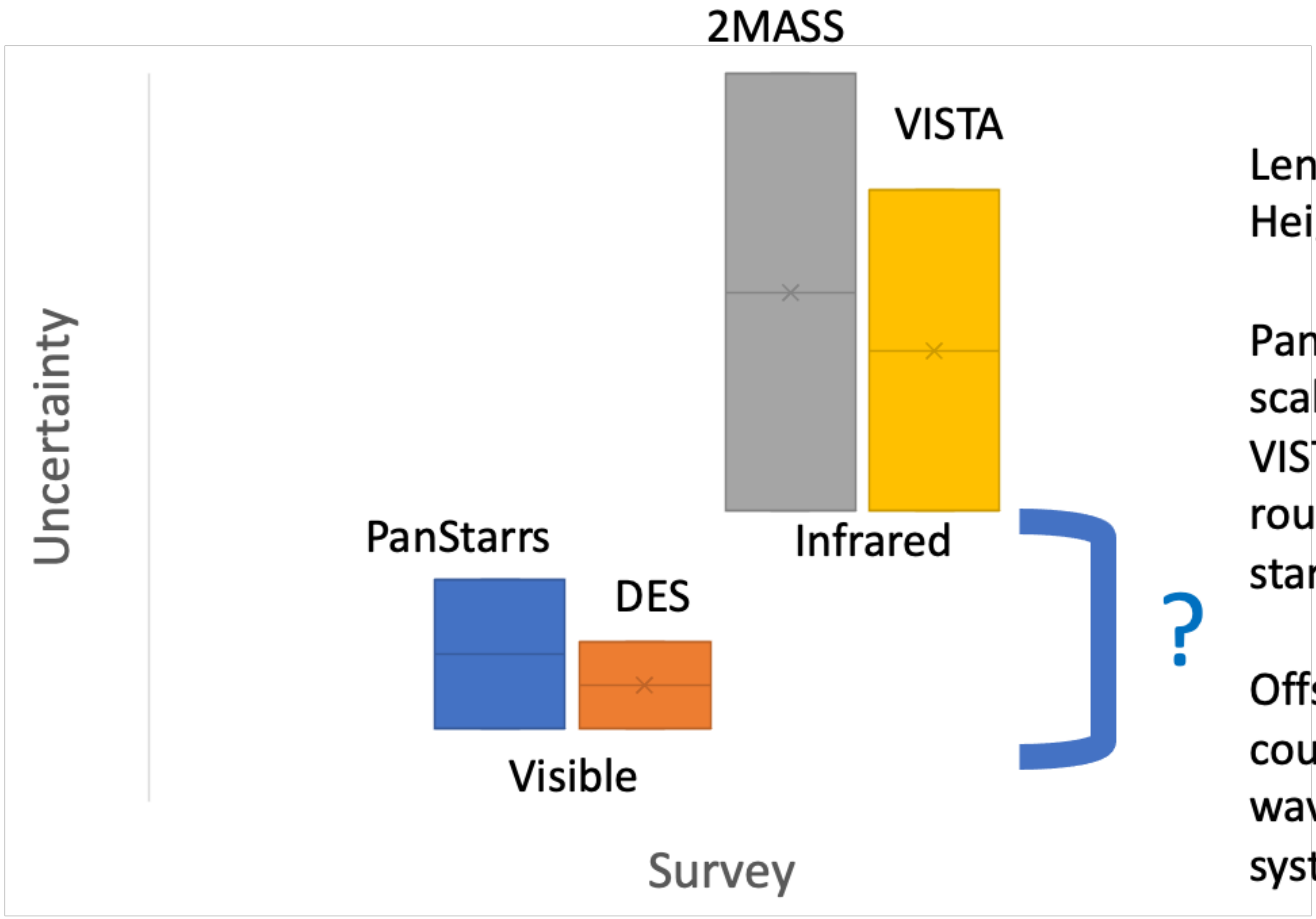
Cross Calibration

- There exists several attempts at re-calibration wide area surveys to the same photometric system, < 10 mmags.
- Latests by as a part of Paetheon+ by Brout+ 2021.



Scolnic+ 2015

Visible to NIR calibration



Length of box: reported precision
Height of box bottom: reported systematic

PanStarrs and DES are on roughly the same flux scale => common stars/fields
VISTA's calibration is based on 2MASS, so they're roughly on the same scale => common stars/fields

Offset in scale between visible and infrared could be small. Cross calibration of different wavelength regions can be tricky because systematics are complicated

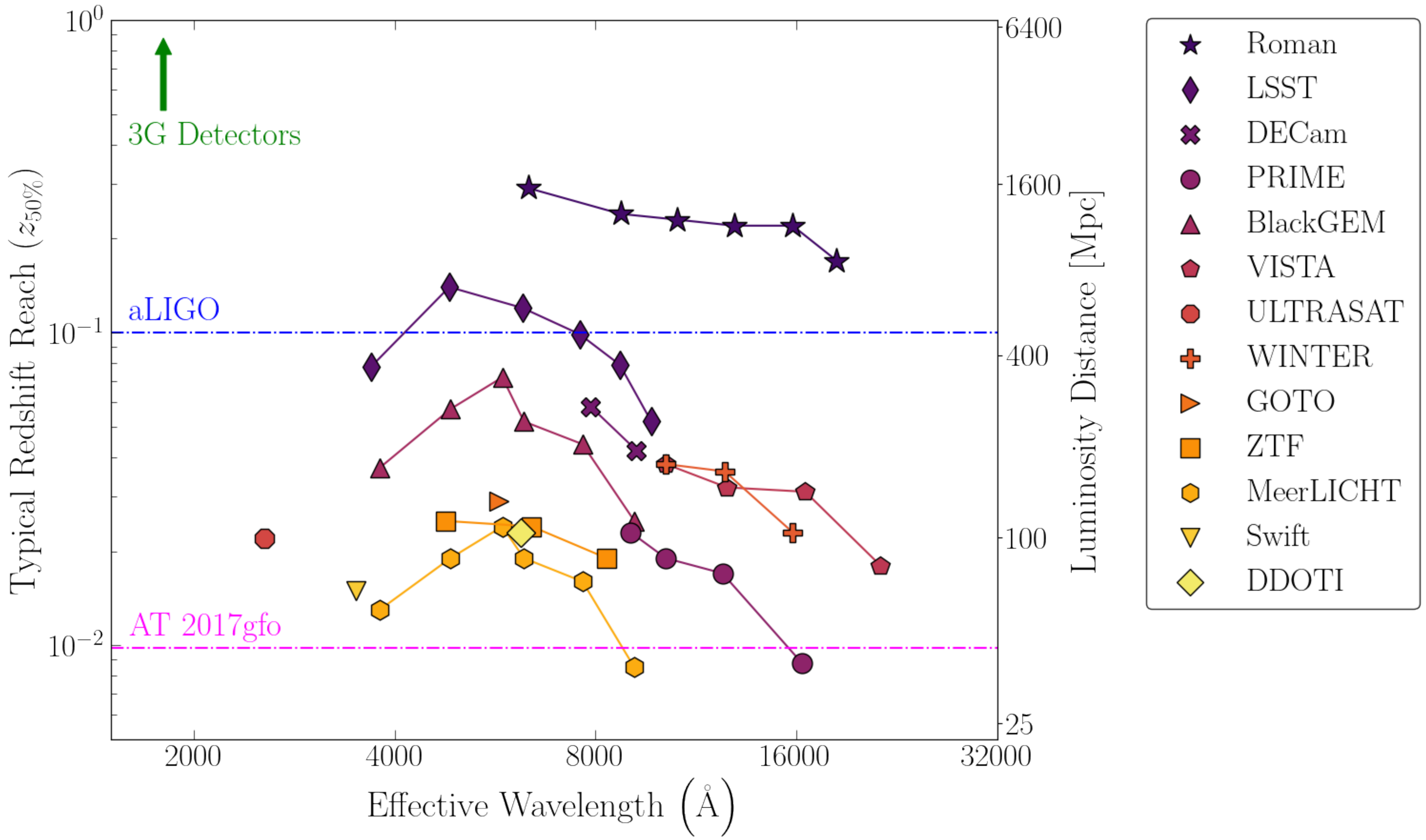
Slide from Susana Deustua

What synergistic observations?

- Overlapping fields
- A calibration network
- Coordinated spectroscopic followup **(this time, not just of transients)**
  - Redshifts for photometric redshift training, cosmology, and more.

Kilonova Follow up

With aLIGO sensitivity, only Roman will is expected to to see >50% of these high redshift kilonovae.

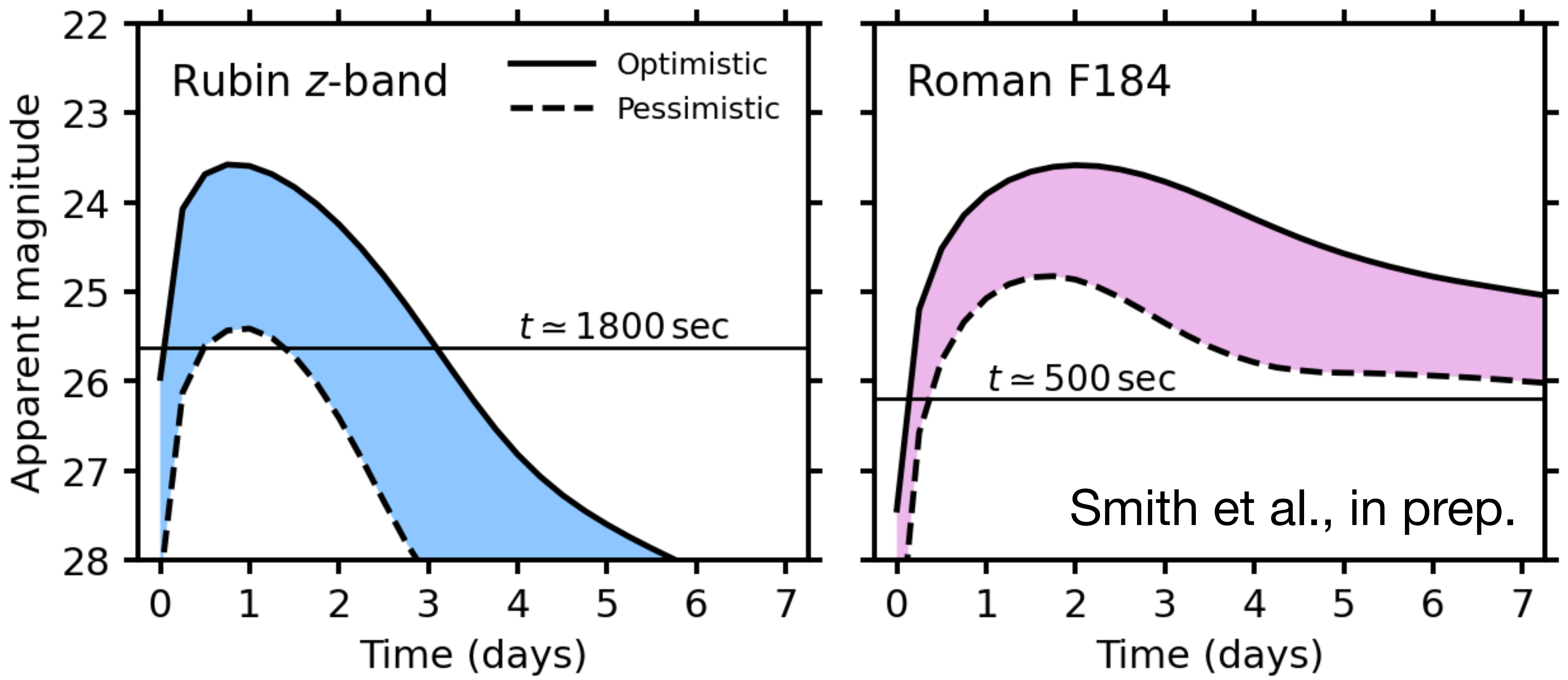


LIGO VIRGO

Chase+ 2021

Rubin and Roman in the late 2020s: discovering lensed kilonovae via ToO follow-up of lensed NS-NS mergers

Example predicted lensed KN lightcurves for lensed NS-NS mergers detectable by LIGO from mid-2020s onwards (i.e. A+ sensitivity):



ToO observations with Roman and Rubin are a powerful combination!

For details see upcoming preprint or contact Graham Smith, gps@star.sr.bham.ac.uk
University of Birmingham, U.K., and co-Chair Rubin Strong Lensing Science Collaboration

Co-authors: Matteo Bianconi[1], Mathilde Jauzac[2], Guillaume Mahler[2], Richard Massey[2], Matt Nicholl[1], Johan Richard[3], Andrew Robertson[4], Dan Ryczanowski[1], Keren Sharon[5]

[1] University of Birmingham, [2] Durham University, [3] CRAL Lyon, [4] Caltech JPL, [5] University of Michigan

When?

Now

- Calibration
- Observational Strategies

C.2.1. Rolling DDF 1: 5 fields, same depth

Field	COSMOS	XMM-LSS	CDFS	ELAIS	Euclid/Roman
cadence	1				
season length [days]	180				
Nseasons	2				
Years	1,3	3,4,5	8,9	6,7,8	2,3,5,6
Nvisits	89 2/2/28/39/18 in $g/r/i/z/y$				

Lochner+ 2021 LSST Cadence Note

The Impact of Observing Strategy on Cosmological Constraints with LSST

Michelle Lochner, Dan Scolnic, Husni Almoubayyed, Timo Anguita, Humna Awan, Eric Gawiser, Satya Gontcho A Gontcho, Philippe Gris, Simon Huber, Saurabh W. Jha, R. Lynne Jones, Alex G. Kim, Rachel Mandelbaum, Phil Marshall, Tanja Petrushevska, Nicolas Regnault, Christian N. Setzer, Sherry H. Suyu, Peter Yoachim, Rahul Biswas, Tristan Blaineau, Isobel Hook, Marc Moniez, Eric Neilsen, Hiranya Peiris, Daniel Rothchild, Christopher Stubbs (for the LSST Dark Energy Science Collaboration)

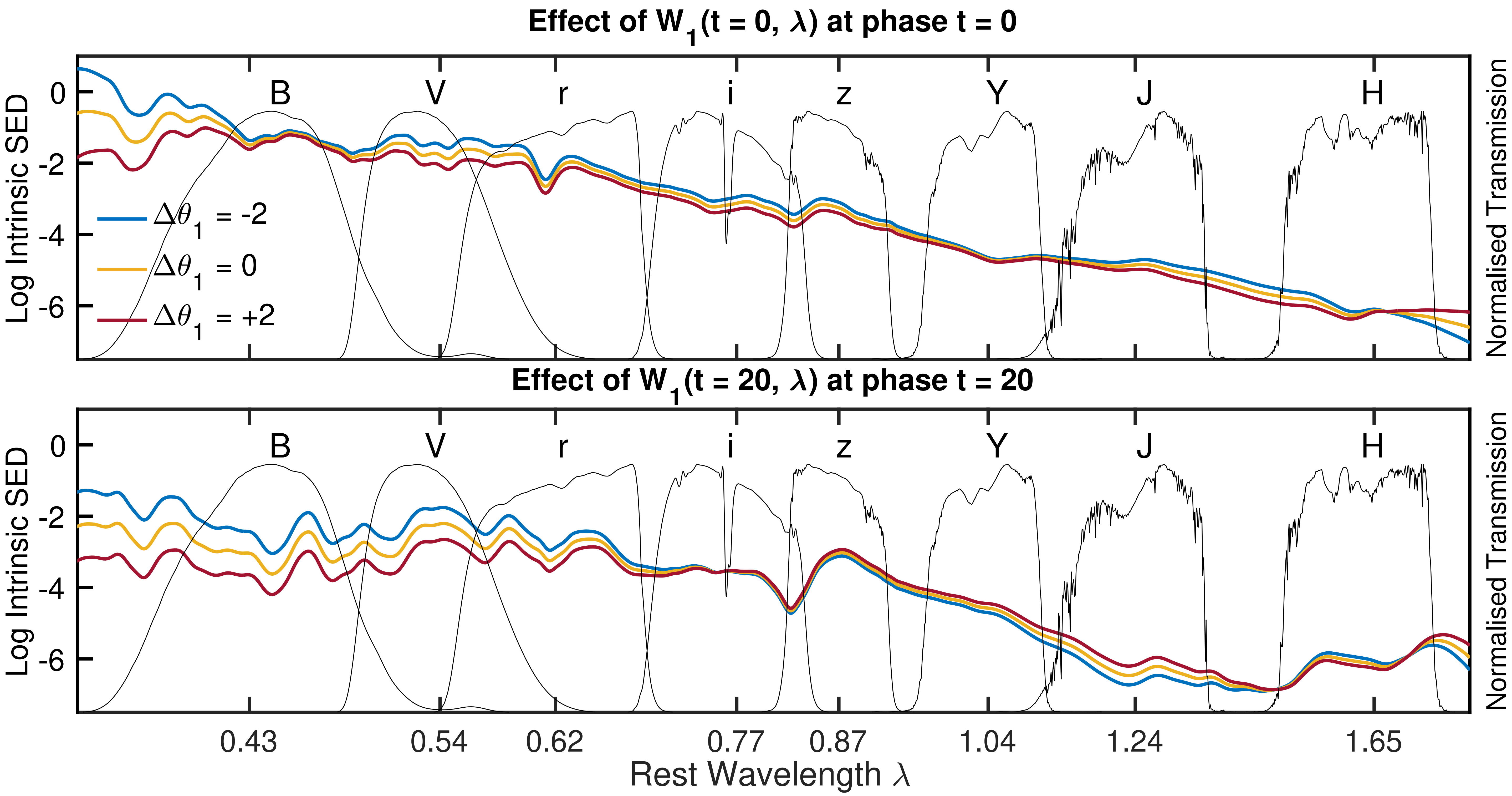
The generation-defining Vera C. Rubin Observatory will make state-of-the-art measurements of both the static and transient universe through its Legacy Survey for Space and Time (LSST). With such capabilities, it is immensely challenging to optimize the LSST

arXiv:2104.05676

VERA C. RUBIN OBSERVATORY

During

- Spectroscopy of transients
    - Transient classification, ...
- Combined catalogues
    - NIR light-curves, template building, ...



Mandel+ 2020

Follow up

- Transient host galaxy observations (redshifts)
- Broad wavelength based photo-z's

How?

How can we make this happen?

- The creation of a joint survey calibration task force.
- Spectroscopic follow-up task force
  - to ensure that access to sufficient follow-up spectroscopy resources is obtained, through different TACs, MoUs, etc.
- Joint computational task force
  - to manage shared computing of these multi-mission datasets, including common simulations, and tools for data access and processing.

Rubin-Euclid Derived Data Products Initial Recommendations

REC-3-CC: Instigate a simulations group

Fund and support the development of a joint simulations group to better quantify the scientific gain of many of the recommended DDPs (REC-10-CC, REC-20-LV, REC-22-LU, REC-33-SC, REC-34-SL, REC-35-PU). Additional Euclid participation in an ongoing Rubin/Roman joint simulation effort would satisfy this recommendation; appropriate augmentations to that effort on all sides should be explored. This effort should build on previous efforts in this area, such as those of Chary et al. (2020).

arXiv:2201.03862

Obstacles

- The key obstacles are communication and timeliness.
- There are also some potential challenges with the proprietary nature of some data (Roman+LSST as in the USA vs Europe).

Summary

- *Why is coordination important?*
  - Unique data from each instrument
- *Who will be working together?*
  - Everyone
- *What synergies?*
  - Contemporaneous observations, using the same calibration network, ...
- *When do we need to work on this?*
  - We need to start now
- *How can we make this happen?*
  - Improving official communication channels between organizations running each survey

Next Steps & Open Questions

- What calibration efforts can we support, as an individual, as TAC members, or in other ways?
- Where does your science needs influence observational strategies?
- How can we move from a scientific desire to official partnerships at the operations level?
- Where are you going to get involved?