The *Nancy Grace Roman Space Telescope* High Latitude Time Domain Survey

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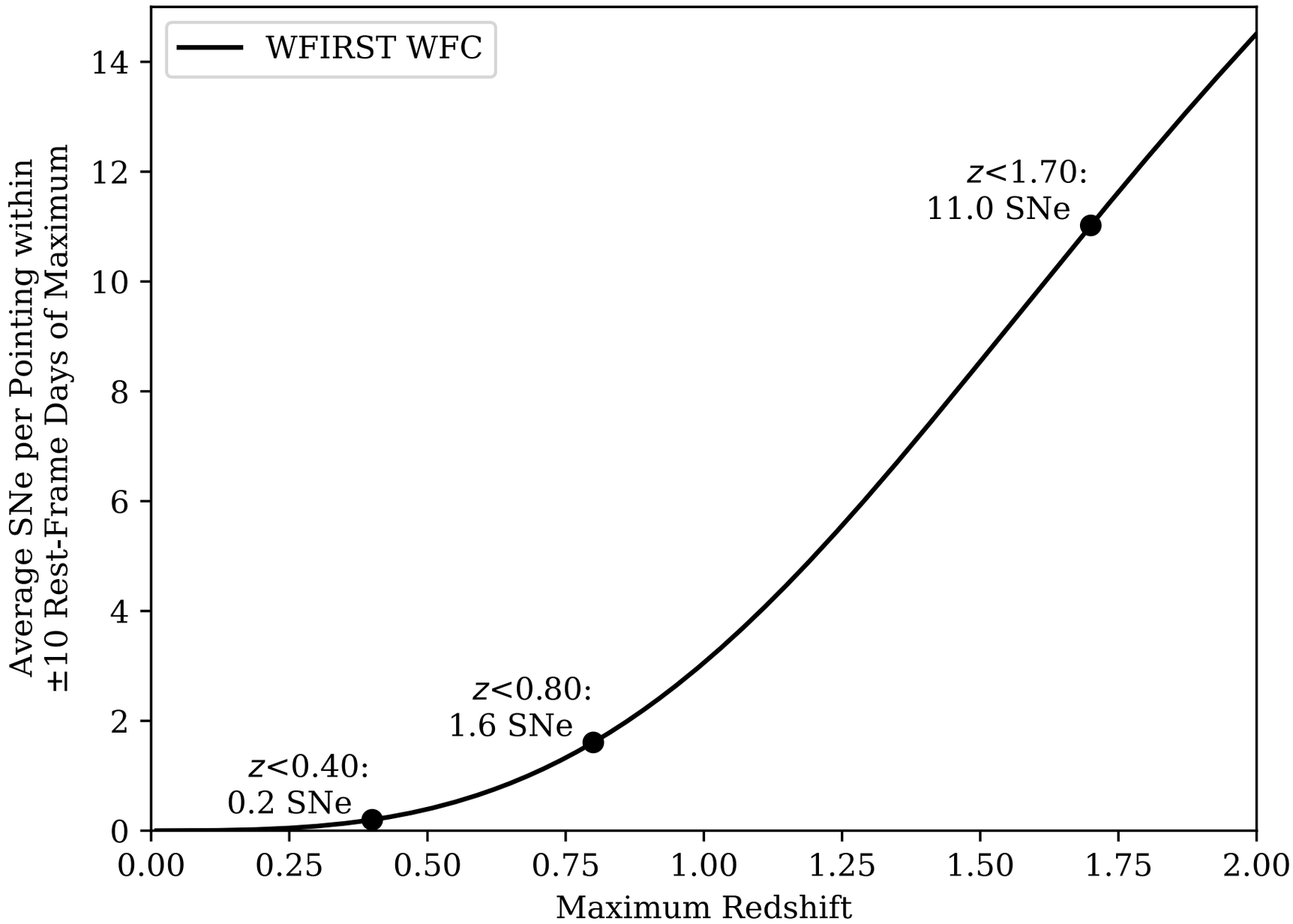
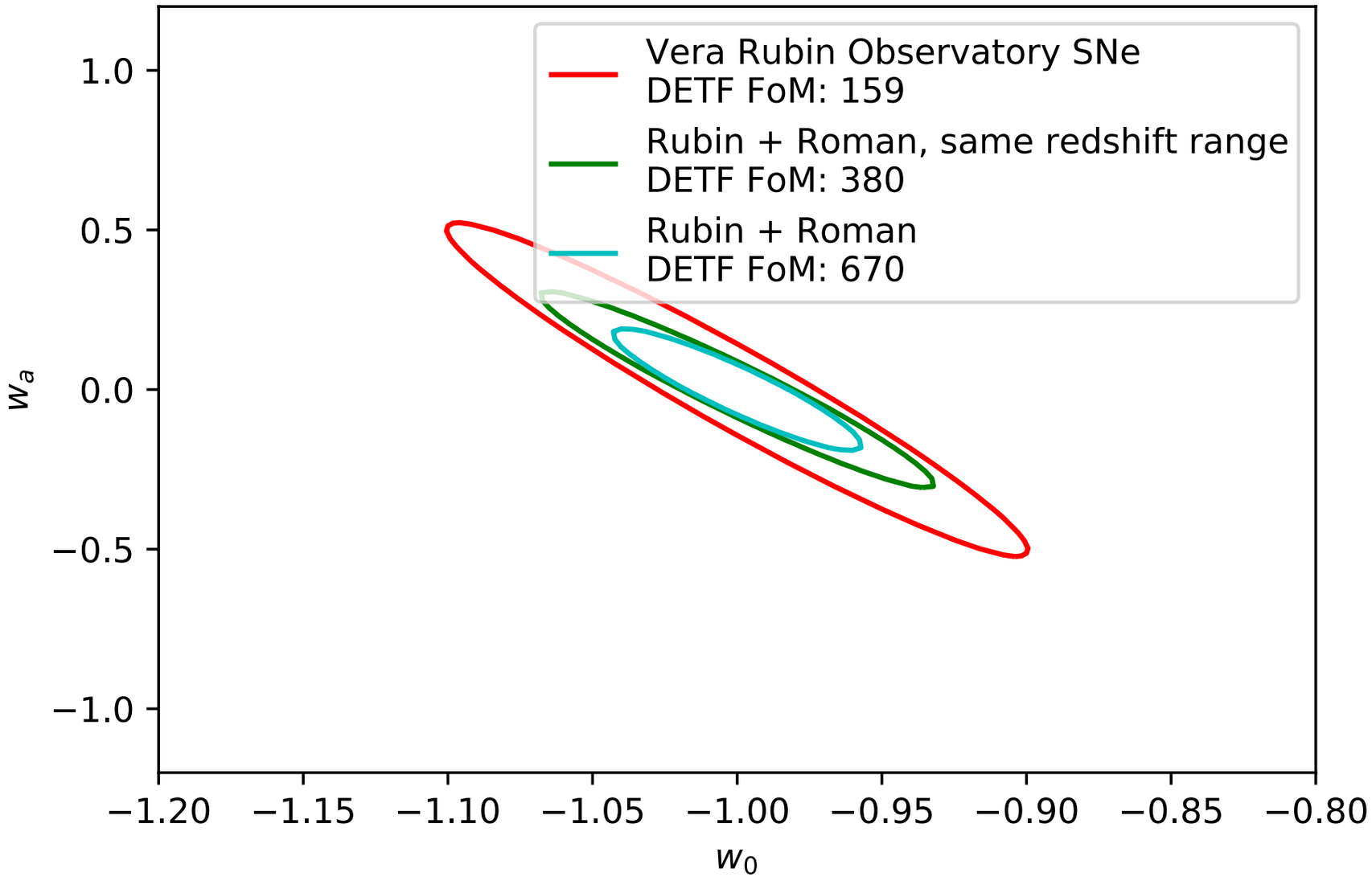
Opportunities

Why is Roman great for a time-domain survey?



- Field of view, IR sensitivity, calibration, and spectroscopic capabilities!

Cosmology Forecast

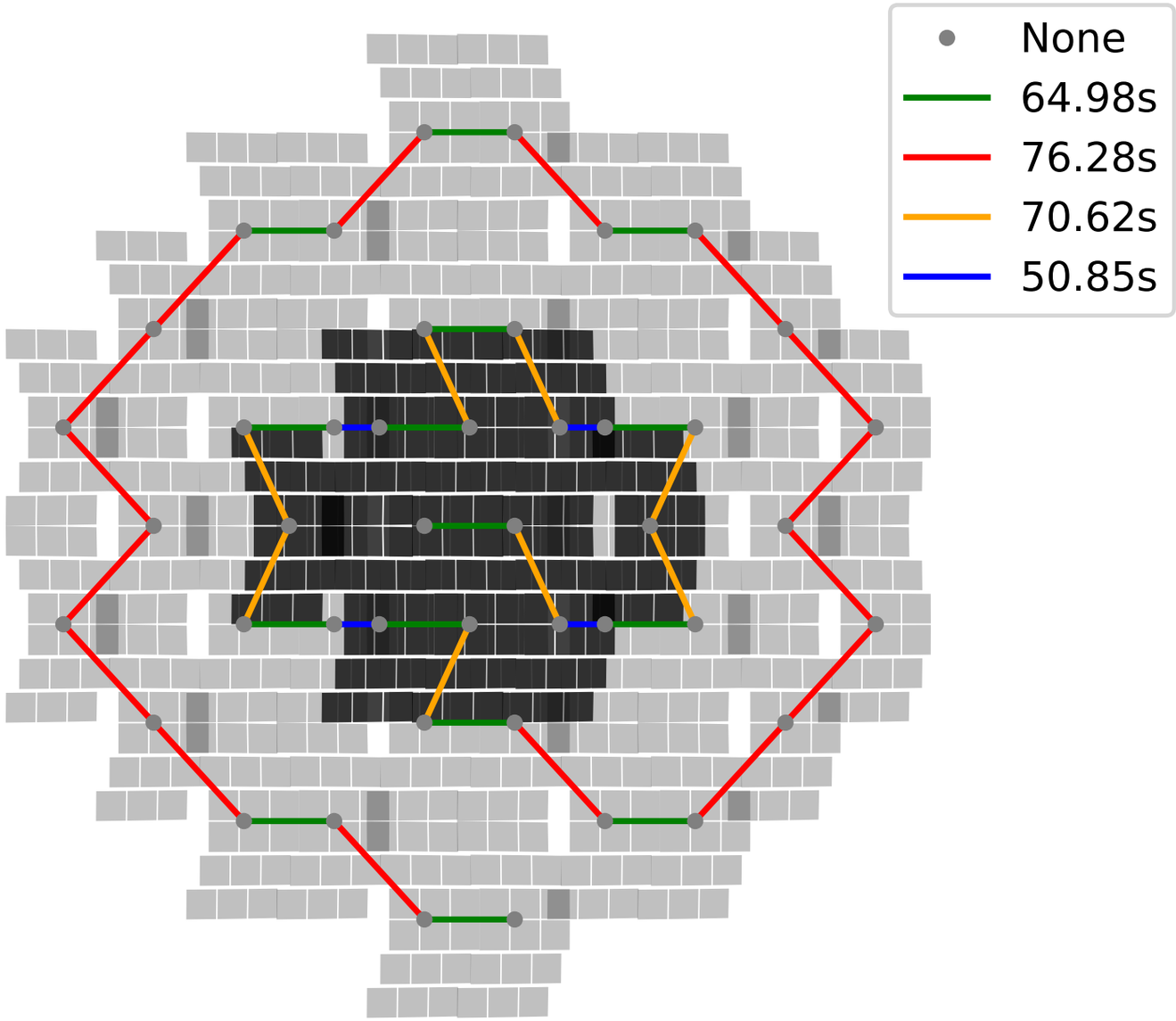


DETF Figure of Merit evaluated with a Fisher-matrix code similar to Astier+ 2011 (see also Hounsell+ 2018)

(flat universe, CMB S4, and 1000 nearby SNe assumed)

Proposed Time-Domain Survey

- Both Science Investigation Teams (SITs) are jointly writing up our findings, including survey proposals
- 5 day cadence over two years (144 epochs)
- Two concentric imaging tiers: Medium + Deep, two (smaller) prism tiers for SN spectroscopy
- The survey will probably split into northern and southern fields



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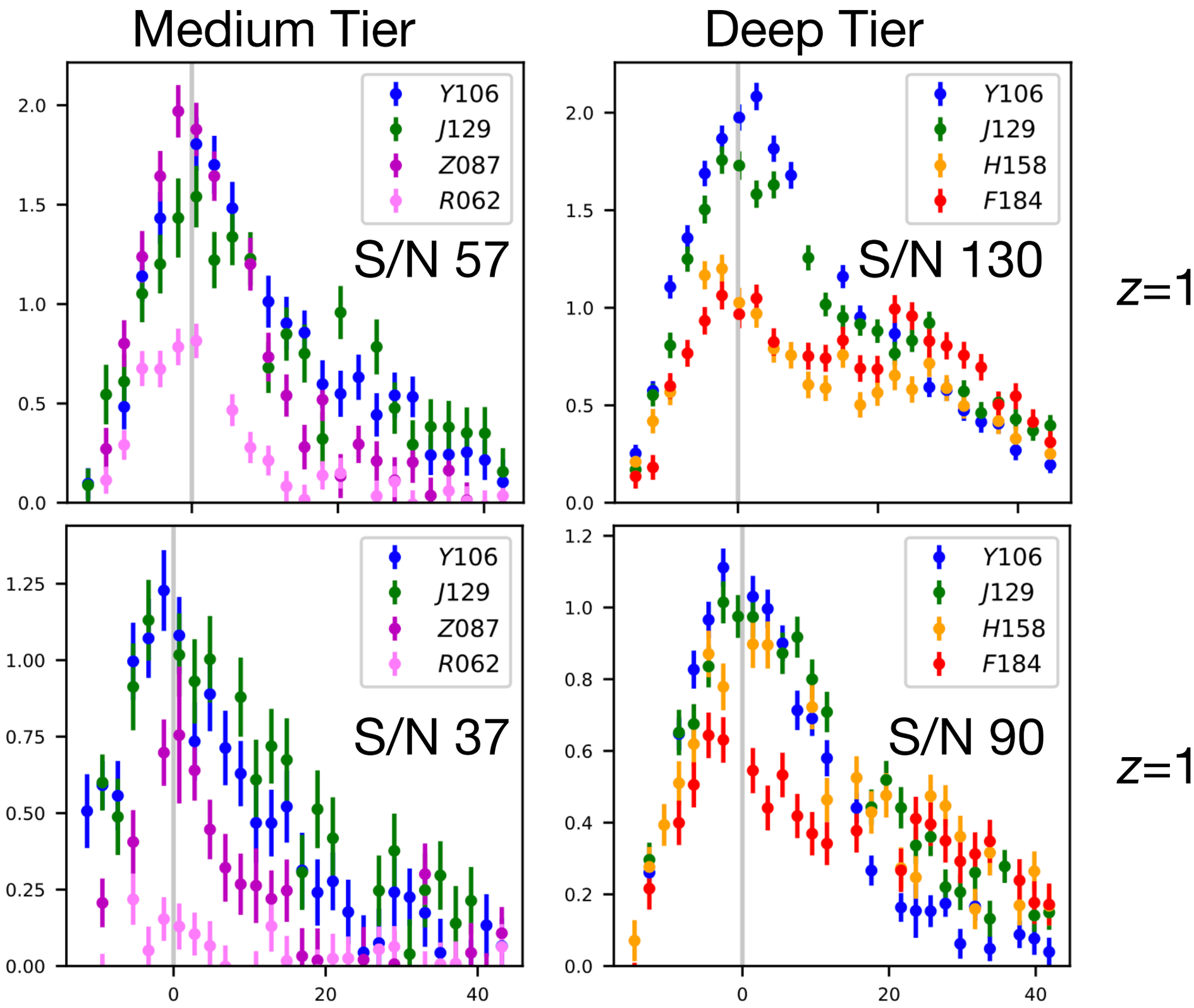
	F062	F087	F106	F129	F158	F184	Prism
Medium Tier 15.96 deg^2	160s 26.4 AB 29.1 AB	100s 25.6 AB 28.3 AB	100s 25.5 AB 28.2 AB	100s 25.4 AB 28.1 AB			900s 3.36 deg^2
Deep Tier 5.32 deg^2			300s 26.7 AB 29.4 AB	300s 26.6 AB 29.3 AB	300s 26.5 AB 29.2 AB	900s 26.7 AB 29.4 AB	3600s 1.12 deg^2

Sample SN Ia Light Curves



~10,000 high-quality SN Ia distances extending beyond redshift 2

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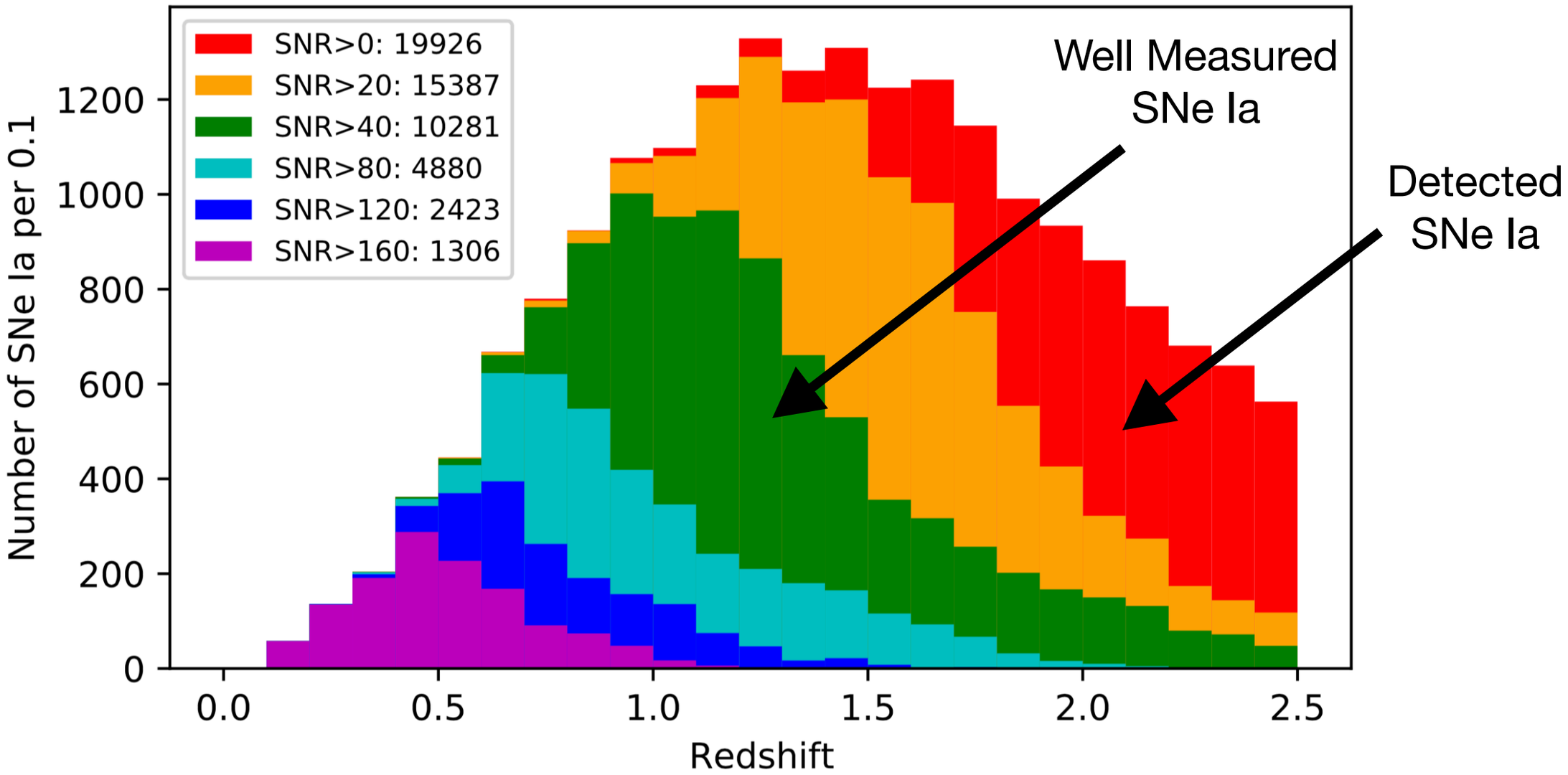
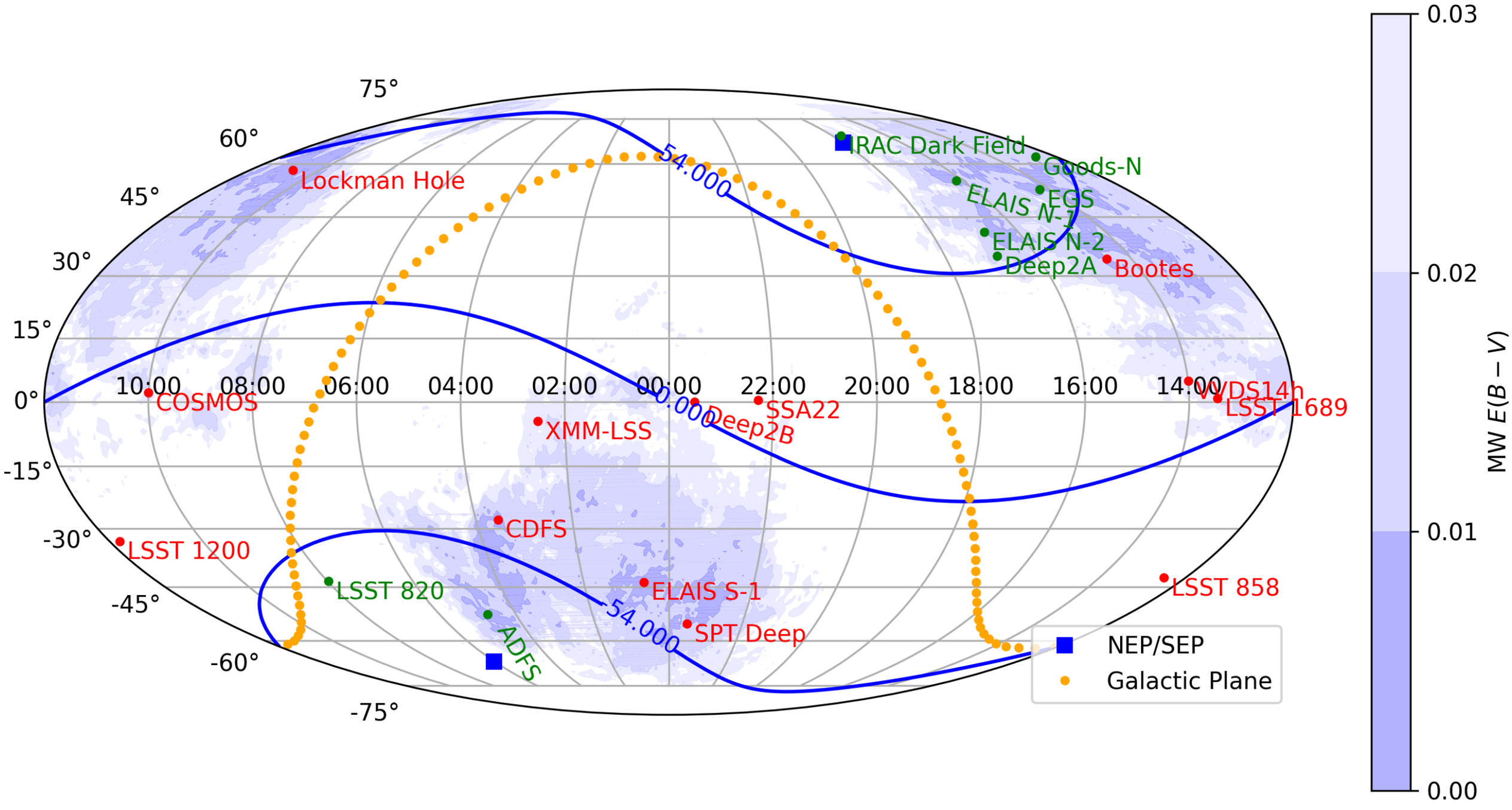


~10,000 high-quality SN Ia distances extending beyond redshift 2

Which Fields?

- See Koekemoer, Foley, Spergel+ 2019 for a detailed discussion of field choice.
- Roman continuous-viewing zone is within 36 degrees of ecliptic poles.
- Tri-Agency working group proposed southern field (Capak+ 2019) is an excellent choice (Euclid Deep + Vera Rubin Observatory + Spitzer).
- CDF-S would be acceptable if the Roman continuous-viewing zone could be extended in the anti-sun direction, otherwise a few good northern-hemisphere fields (e.g., EGS)

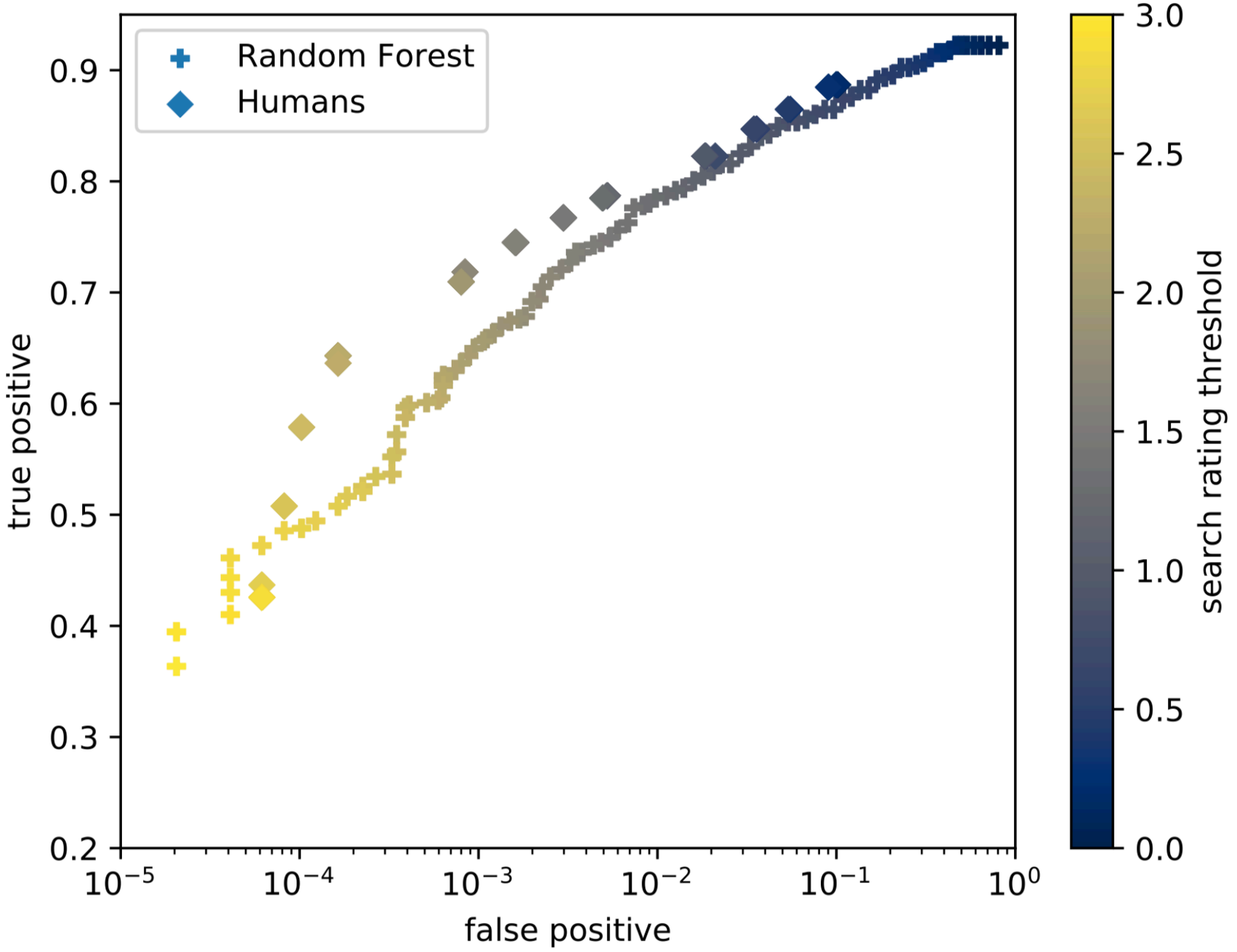
Which Fields to Pick?



Challenges

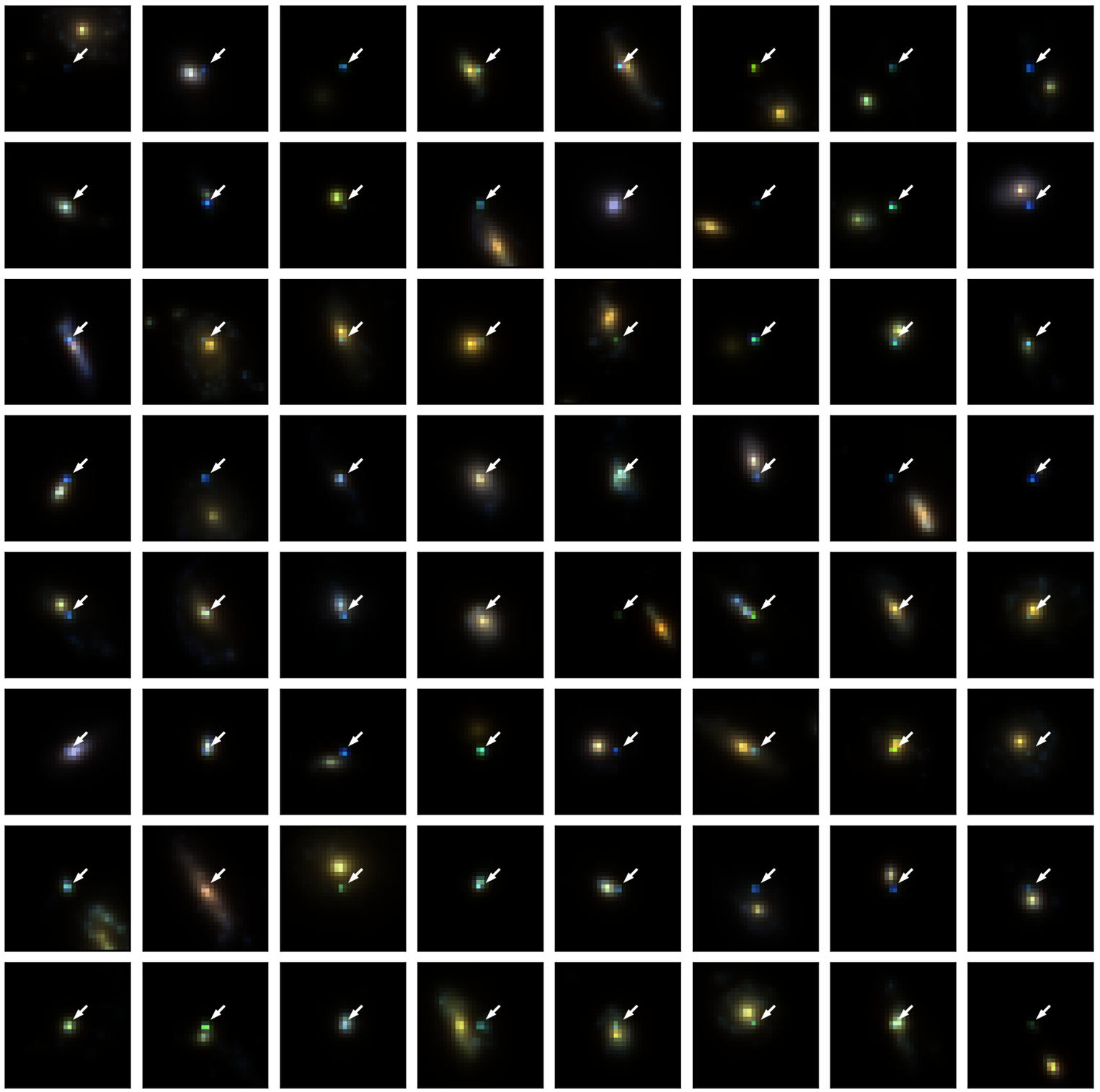
Challenges: Find the SNe

- The search is equivalent to 3,000 *HST* WFC3 IR pointings per day.
- Hayden, Rubin, Boone+ 2021 demonstrate automated transient searching in undersampled WFC3 IR images.
- The overall performance was comparable to humans.

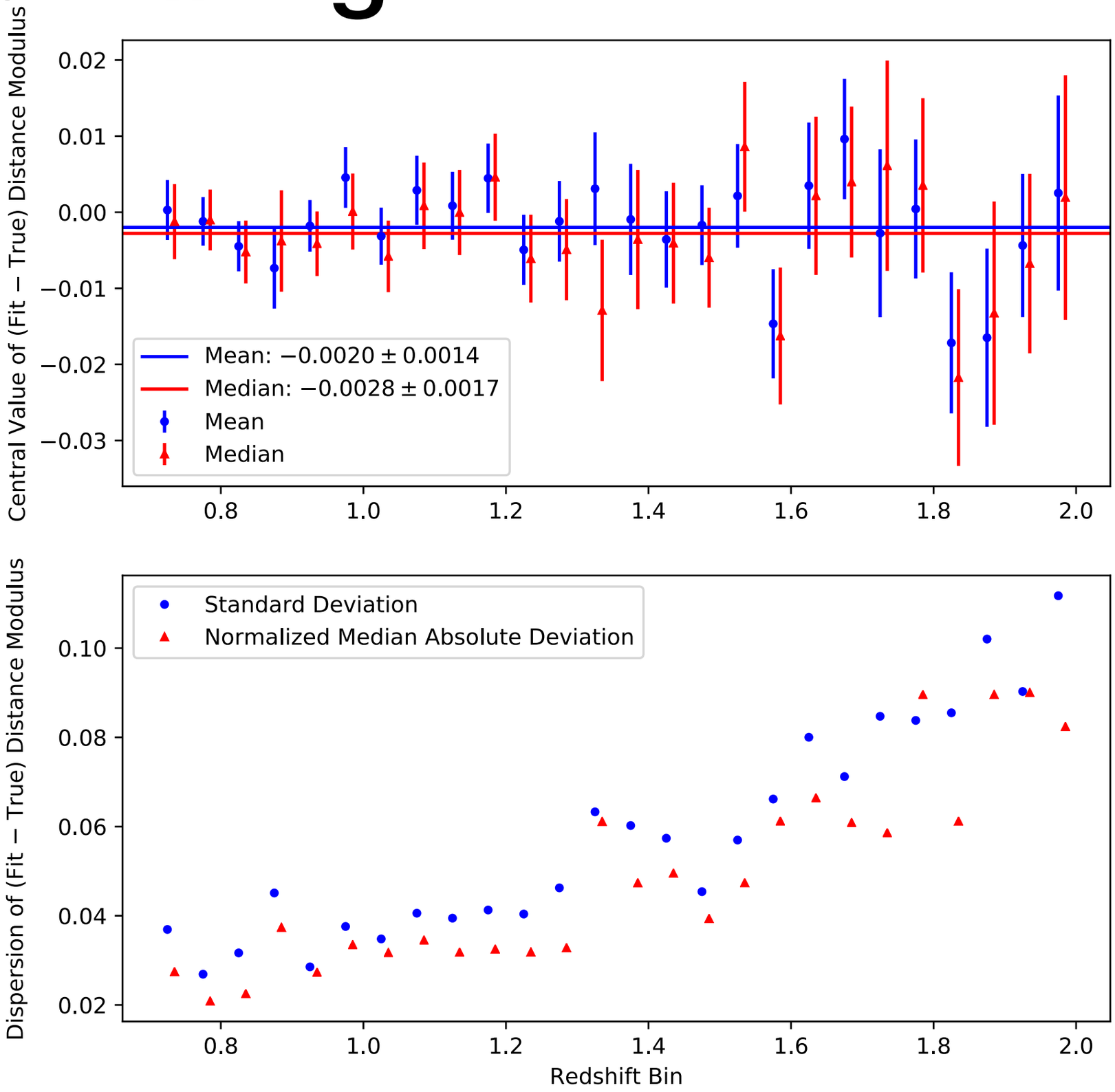


Challenges: Measure the SNe

- Undersampled imaging presents a challenge for removing the host-galaxy light underlying each SN.
- Foward-modeling ("scene modeling") used for ground-based SN photometry (Holtzman+ 2008, Astier+ 2013)
- Rubin and Cikota+ 2021 simulated ~ 10% of a full-scale survey and demonstrate a forward-model for Roman photometry



Challenges: Measure the SNe



- Rubin and Cikota+ find generally mild biases, well within the *Roman* requirements

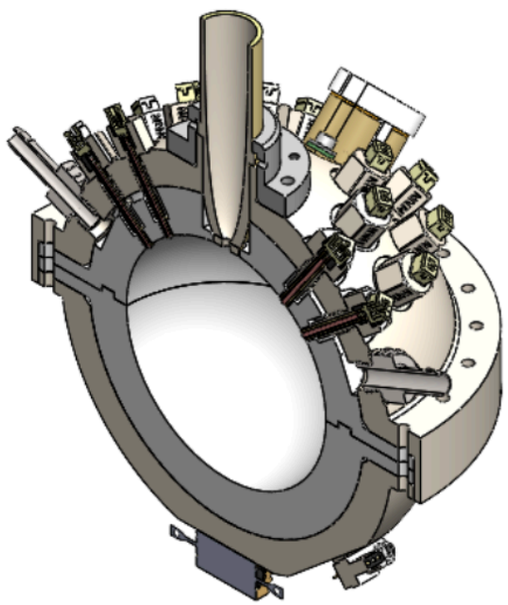
Challenges: Photometric Calibration

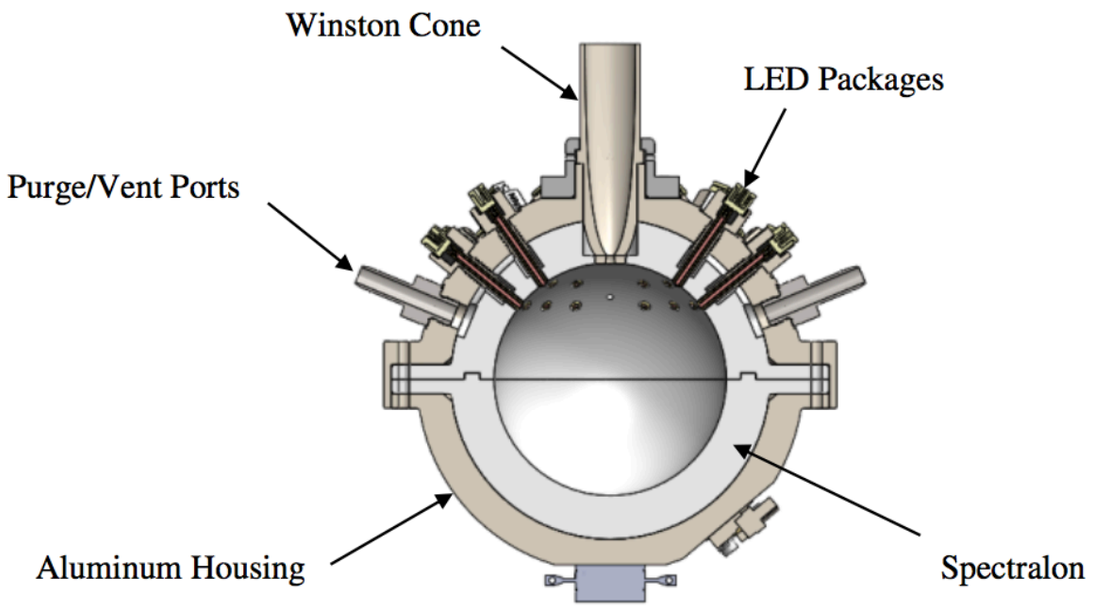
- Photometric calibration is an important systematic uncertainty in SN cosmology.
  - Cross-wavelength (“absolute color calibration” or “fundamental calibration,” for calibrating the same rest-frame wavelength range as a function of redshift)
  - Cross-magnitude (*Roman* requirement is 0.3% between AB magnitude 15 and 26), including count-rate nonlinearity calibration
  - (Cross-sky)
  - (Cross-time)
  - (Cross-survey) combining *Roman* with lower-redshift SNe to anchor the Hubble diagram and measure lower redshifts than *Roman* is optimal for.

See the Roman calibration plan for more details

Challenges: Photometric Calibration

- Roman addresses cross-magnitude and pixel-to-pixel calibration with the Relative Calibration System, and LED system that
  - direct-illumination test: LED light reflects off the dark onto the focal plane; combinations of LEDs give an overdetermined system of equations
  - lamp-on/lamp-off test: light reflects off filter masks while observing on-sky
- Should enable much more precise calibration than *Hubble* WFC3 IR, which only barely meets the Roman requirement (and only then by combining all methods of calibration, all wavelengths, and all count-rates)



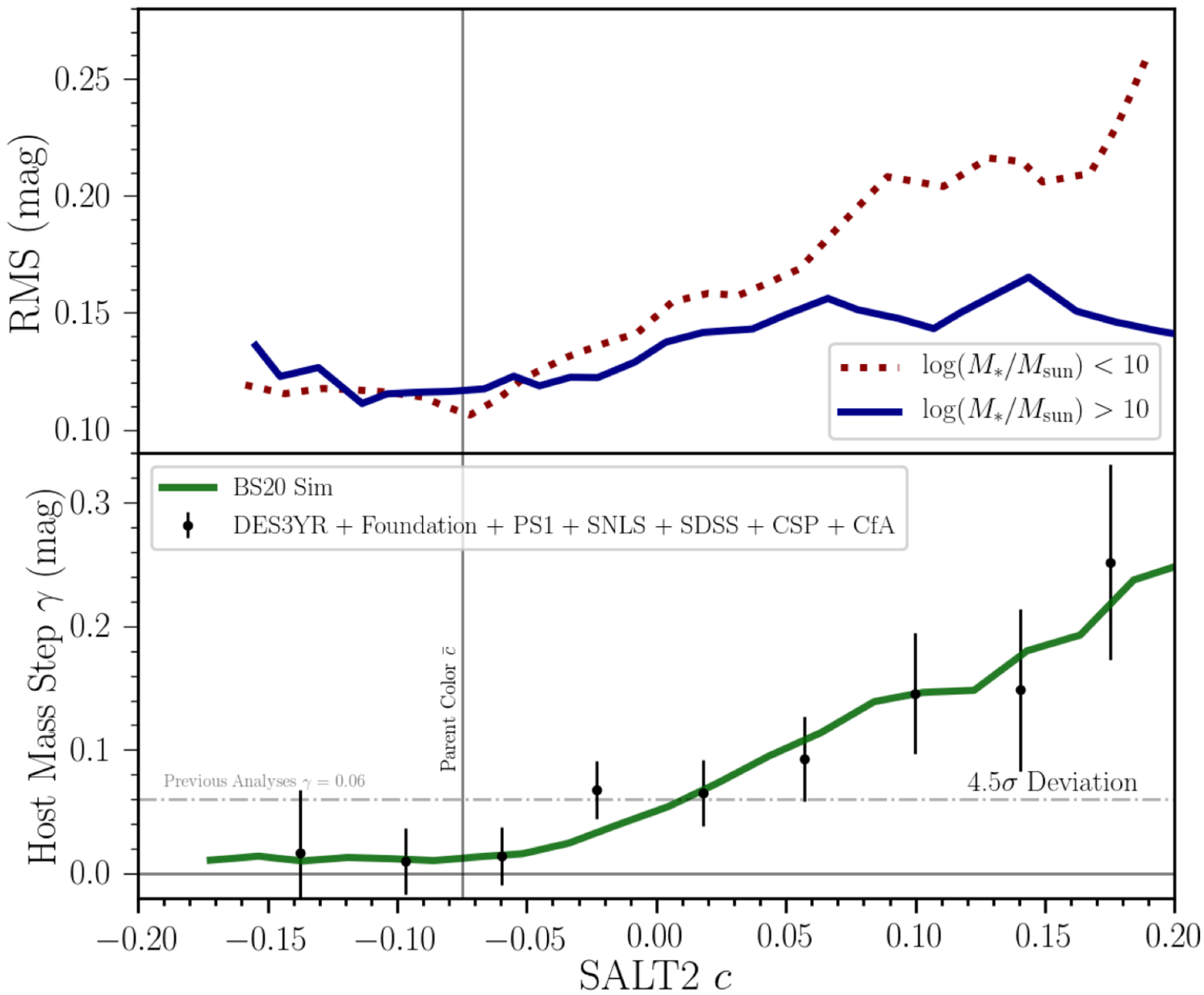


Challenges: Redshifts

- With ~ 1,000 supernova host galaxies per square degree, multiplexed spectroscopy (e.g., Yuan+ 2015) is a huge help!
- Euclid grism, Subaru Prime Focus Spectrograph, 4MOST, and the *Roman* grism and prism are all important redshift sources and together can deliver redshifts for most host galaxies and a significant fraction of the SNe (ongoing SN SIT work).

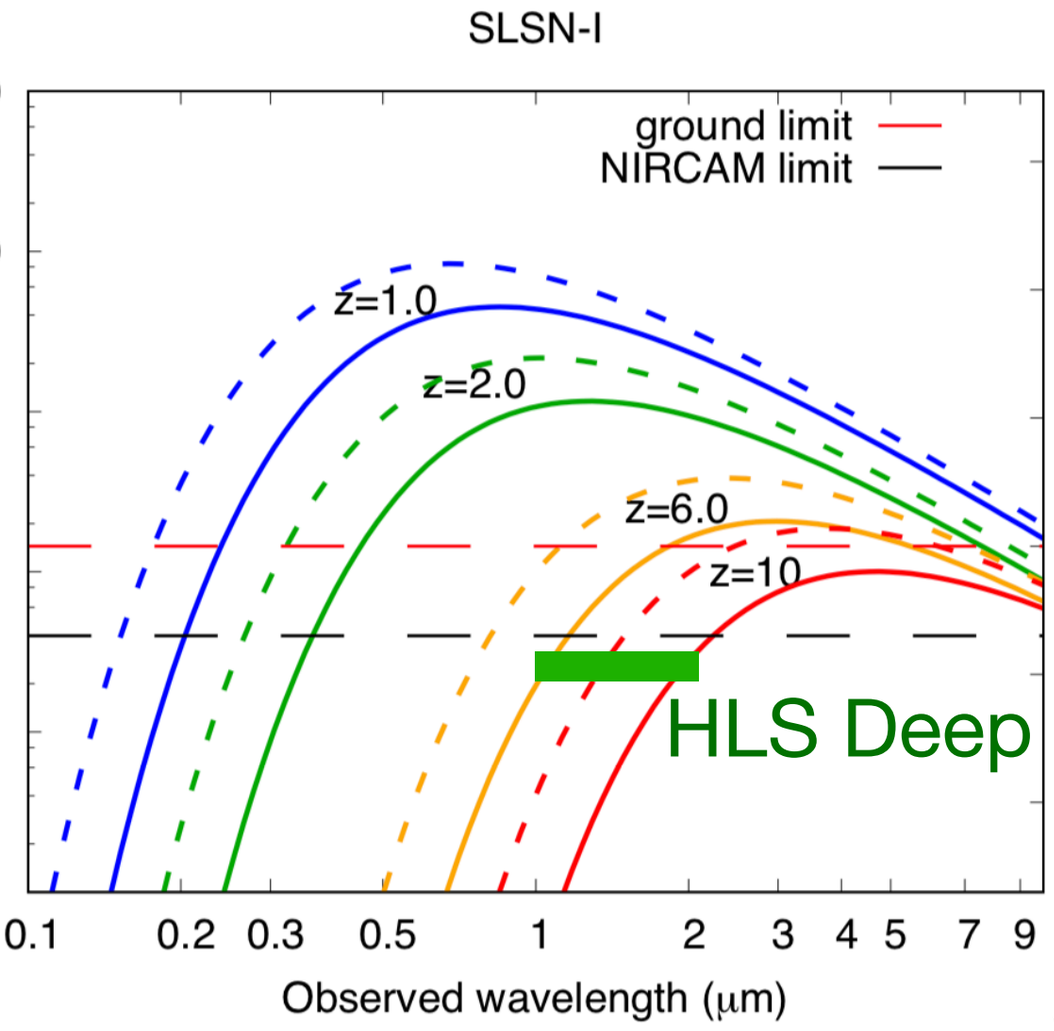
Challenges: Astrophysics

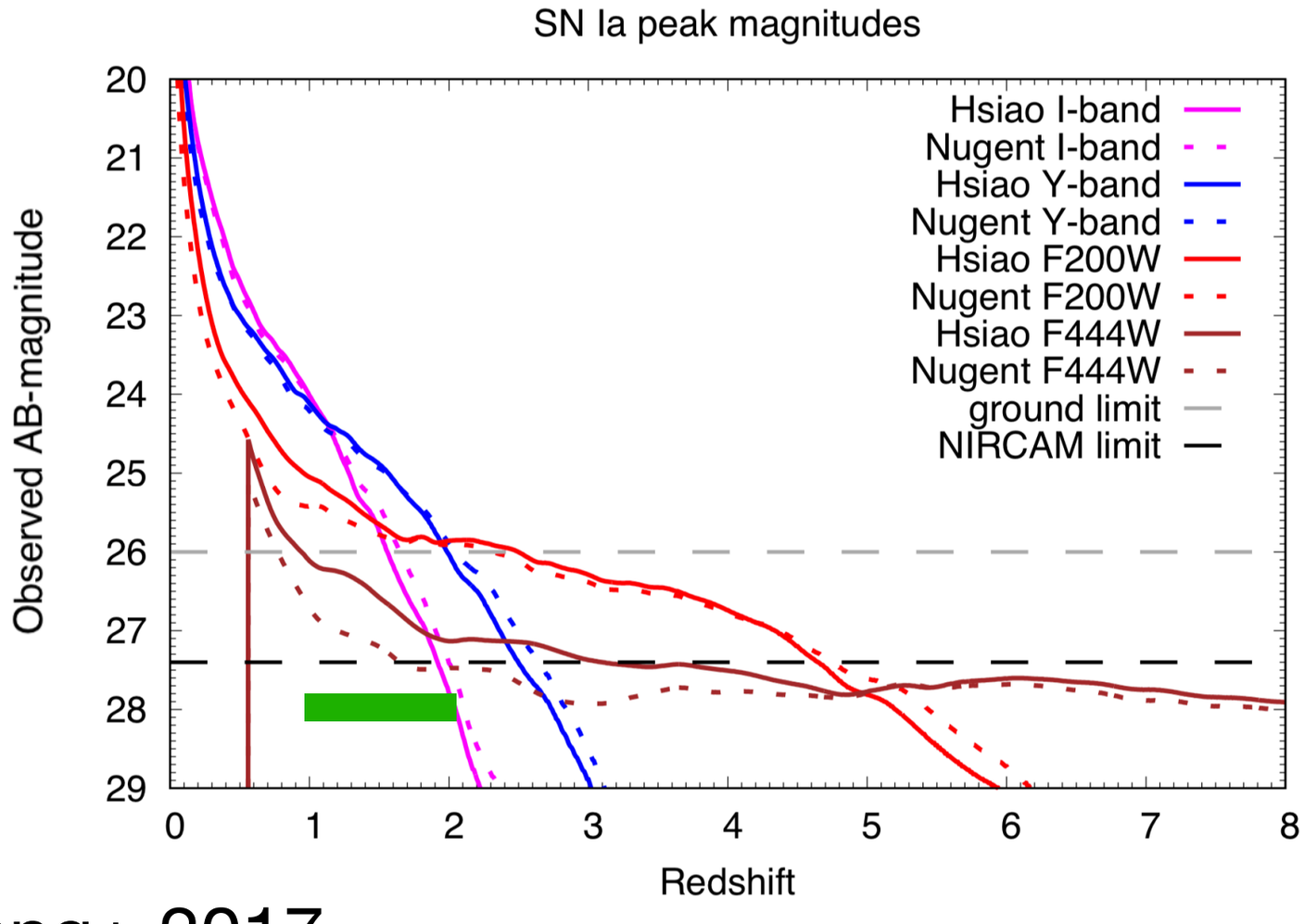
- Use both large numbers of SNe and extensive data per SN to constrain astrophysical systematic uncertainties.
- For example, correlation between SN host-galaxy properties and standardized luminosity is weaker for bluer SNe (e.g., Brout and Scolnic 2021).
- SN Ia subclassification also dramatically reduces correlation (Boone+ 2021)



Other TDS Transient Science

- Just as one example, stacking 90 observer-frame days of data for the deep tier reaches ~ 28.2 AB at 5 sigma. This is deeper than many of the proposed JWST transient surveys, and over many times the area on the sky!





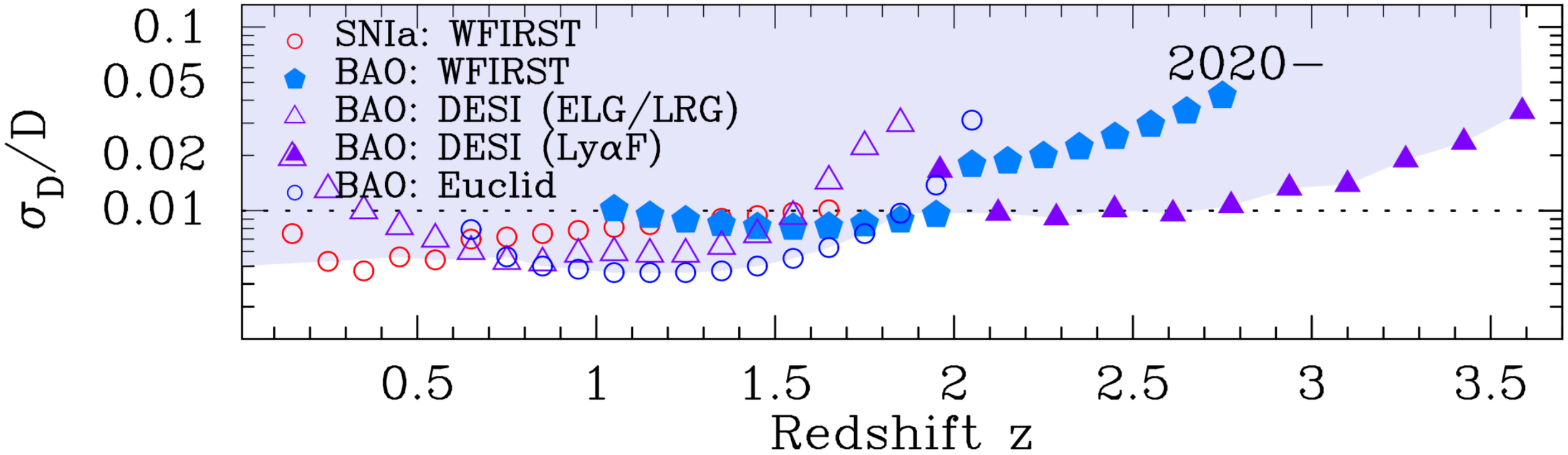
Wang+ 2017

Conclusions

- The time-domain survey will benefit from the field of view, IR sensitivity, calibration, and spectroscopic capabilities of Roman.
- These will combine to produce the definitive SN Ia cosmological measurement!
- There are challenges to the analysis, but no showstoppers that we have seen.
- Other exciting transient science will come out of this survey.

Backup Slides

Redshift ~ 1 Cosmology in the 2020's



Kim and Padmanabhan+ 2015