A High-Latitude Time Domain Reference Survey

arXiv:2111.03081

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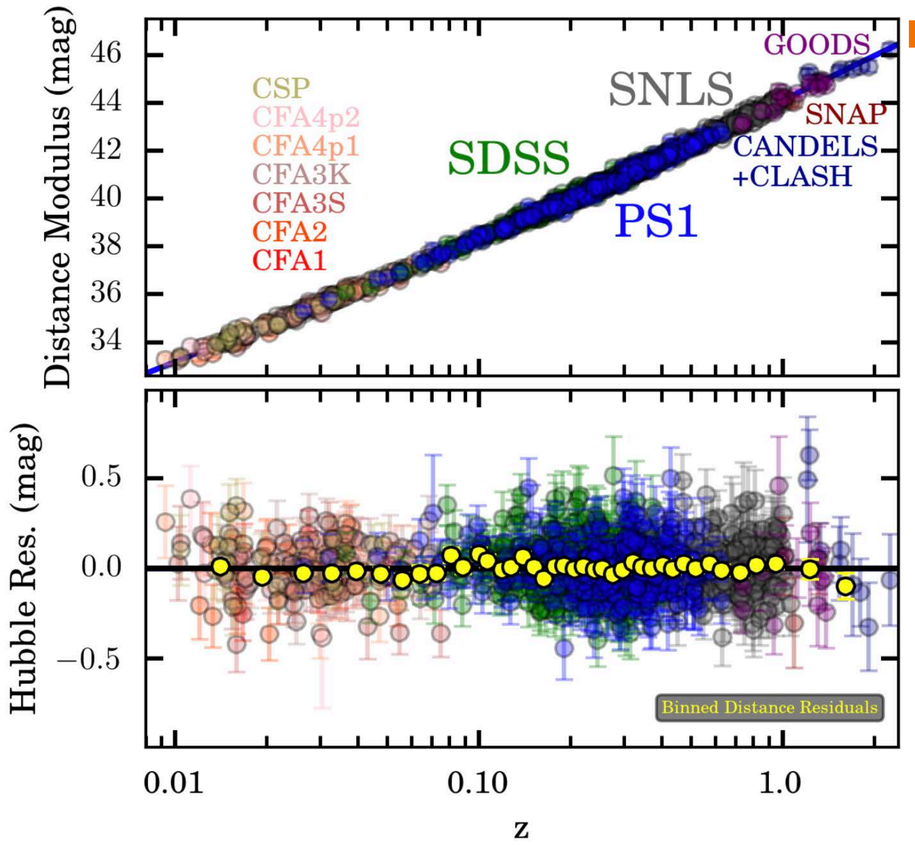
with the Foley and Perlmutter Supernova SITs
November 18, 2021

Why Roman?

It is the ideal SN survey that leverages high statistics and pristine control of systematics.

- Improved calibration (see later talks)
- Larger field of view & faster slew and settle times
  - 100x the survey rate of Hubble
- Near-IR observations to observe at higher redshift events
- Prism for spectroscopy of transients

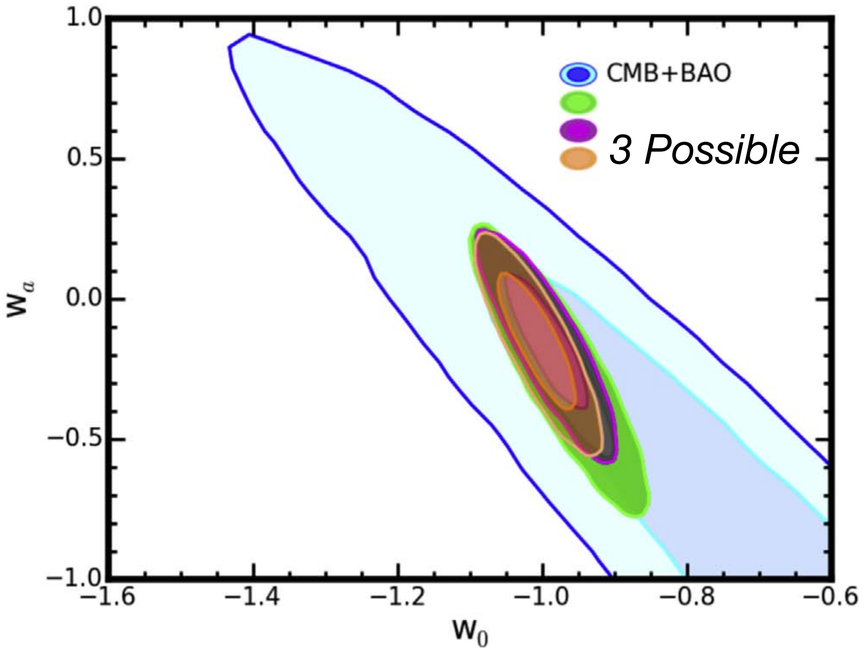
Roman to z ~ 2



Scolnic et al. 2016

Roman Cosmology with Type Ia Supernovae

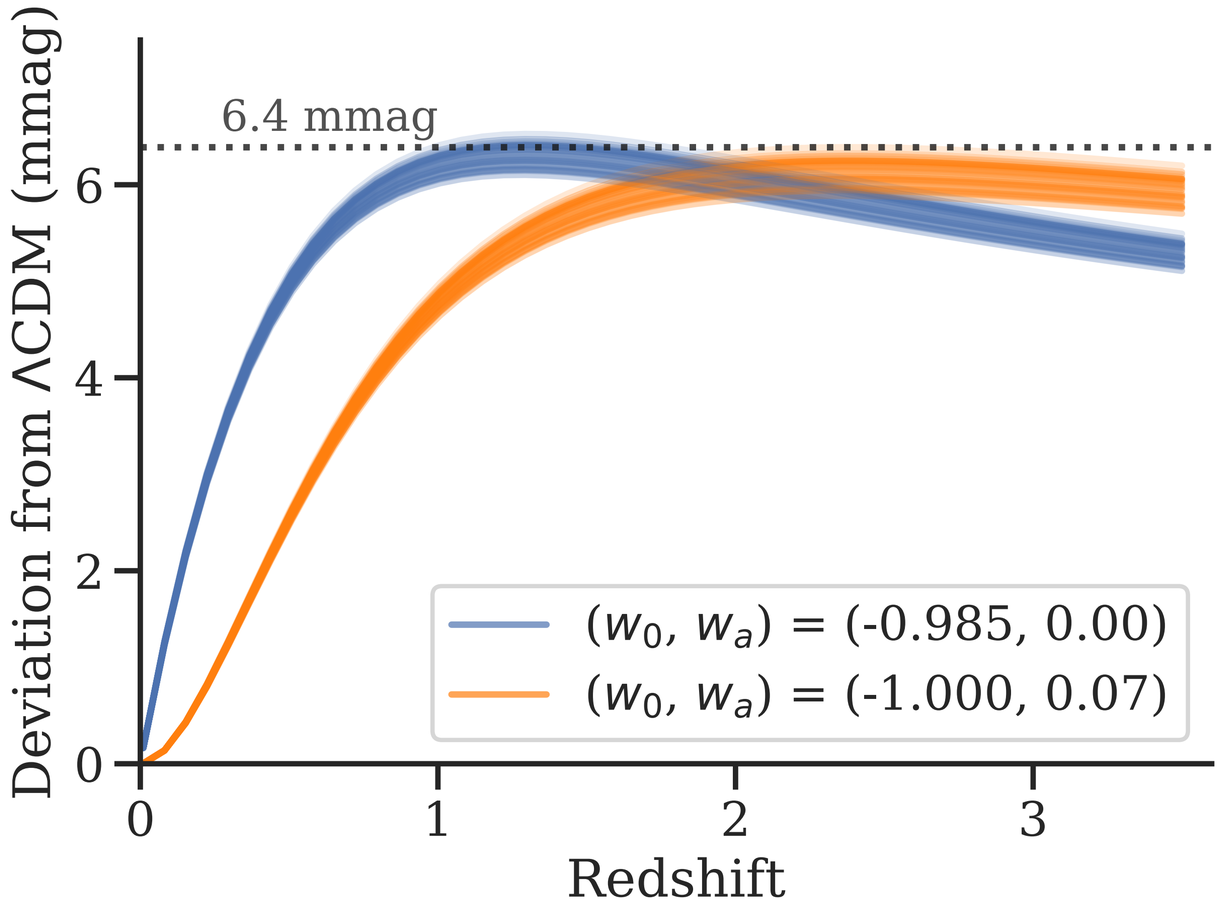
Hounsell et al. 2018



SN Requirement 2.0.1

FoM > 325

The Figure of Merit requirement includes data from the CMB (the Planck Collaboration 2016) and BAO (Anderson et al 2014) .



Shaded region shows effect of Ω_M uncertainty

Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 4 Nov 2021]

A Reference Survey for Supernova Cosmology with the Nancy Grace Roman Space Telescope

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This note presents an initial survey design for the Nancy Grace Roman High-latitude Time Domain Survey. This is not meant to be a final or exhaustive list of all the survey strategy choices, but instead presents a viable path towards achieving the desired precision and accuracy of dark energy measurements using Type Ia supernovae (SNe Ia). We describe a survey strategy that use six filters (RZYJH and F) and the prism on the Roman Wide Field Instrument. This survey has two tiers, one "wide" which targets SNe Ia at redshifts up to 1 and one "deep" targeting redshifts up to 1.7; for each, four filters are used (with Y and J used in both tiers). We propose one field each in the north and south continuous viewing zones, and expect to obtain high-quality distances of ∼12,000 SNe Ia with ∼5,000 at $z > 1$. We propose a wide-tier area of ∼19 deg^2 and a deep tier of ∼5 deg^2. Exposure times range from 100 s to 900 s for imaging and 900 s to 3600 s for the prism. These exposure times would reach ∼25.5 mag and ∼26.5 mag for the wide and deep tiers respectively, with deep co-add stacks reaching ∼28 mag and ∼29 mag. The total survey spans two years, with a total allocation time of six months, and a cadence of ∼5 days.

Comments: A report to NASA from the Roman Supernova Science Investigation Teams

Subjects: **Cosmology and Nongalactic Astrophysics (astro-ph.CO)**; Astrophysics of Galaxies (astro-ph.GA)

Cite as: arXiv:2111.03081 **[astro-ph.CO]**

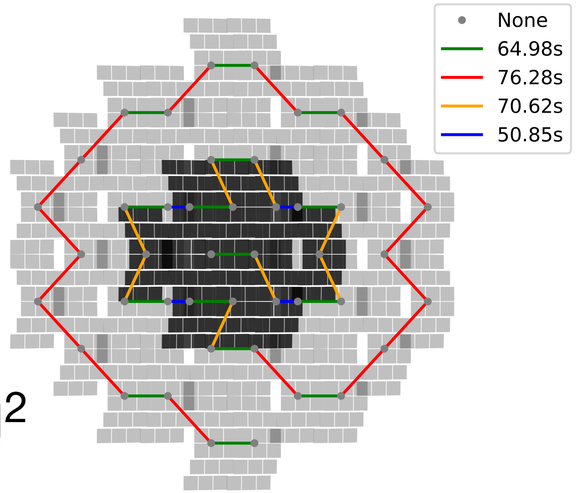
(or arXiv:2111.03081v1 **[astro-ph.CO]** for this version)

This is the only number you need to write down.

arXiv:2111.03081

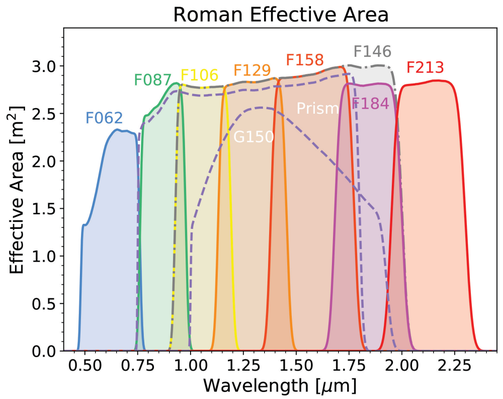
The Reference Survey, Abstract

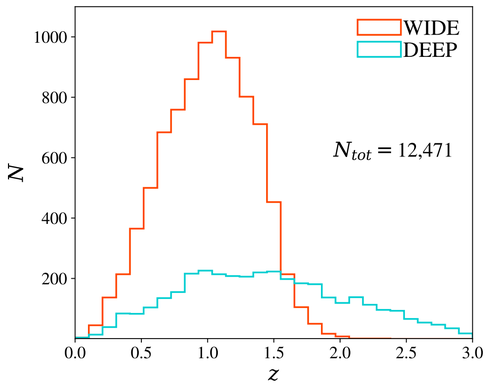
arXiv:2111.03081

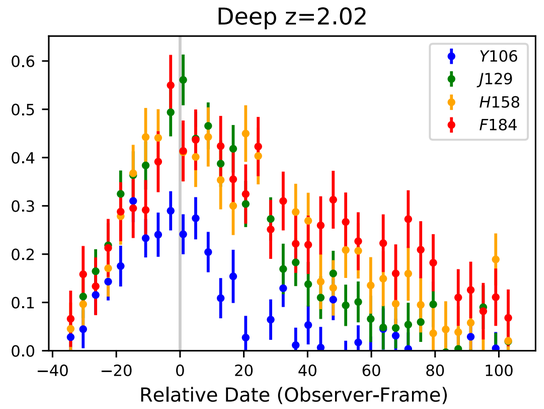


- 2 fields - likely GOODS-N and Euclid Deep South
- 2 tiers
- 4 filters+prism per tier
- 12,000 SNe Ia, 5,000 at z >1

- Wide tier of ~19 deg^2
- Deep tier of ~4 deg^2
- Single Exposures to ~25.5th mag and ~26.5th mag
- Template coadds to ~28th mag and ~29th mag







Defining a Reference Time Domain Survey

- **Choice of fields** - minimize effects of cosmic variance and coordinate with other surveys and followup instruments.
- **Number and area of tiers** - Effects number of objects as a function of redshift
- **Number of filters** - Need broad wavelength coverage for measuring colors and building templates
- **Cadence** - used in discovery and characterization of light curves shape
- **Imaging exposure times** - need a sufficient signal-to-noise to reach the 6 mmag precision
- **Prism exposure times** - need enough signal-to-noise for redshifts, classification, standardization, systematics and evolution control

Survey Length & Cadence

- 6 months of observing over 2 years

  SN Requirement 2.0.1

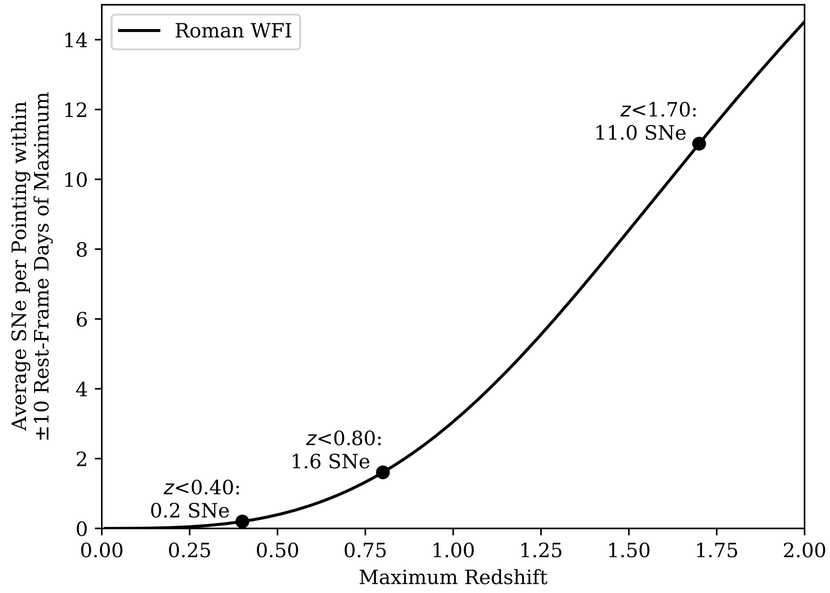
- Target SN Ia over the redshift

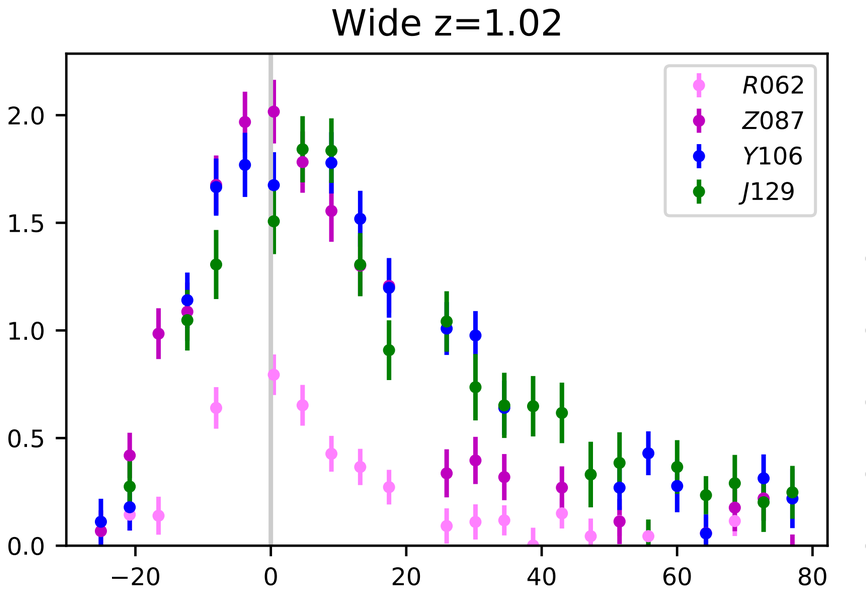
  range of 0.2≤ z ≤ 1.7

  SN Requirement 2.0.2

- So, ~30 hours per every 5 day visit

Rubin 2021 arXiv:2010.15112

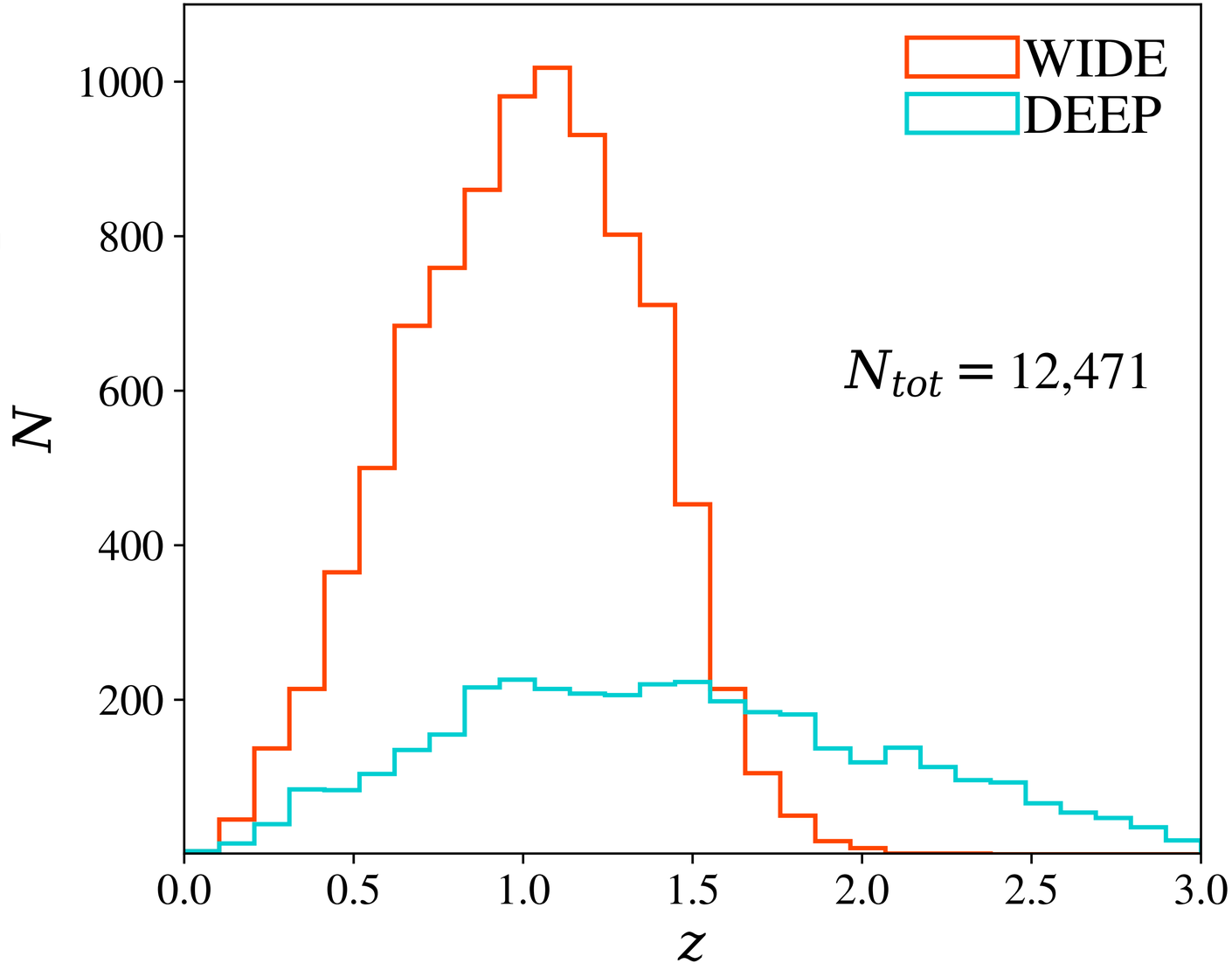




Number of Tiers

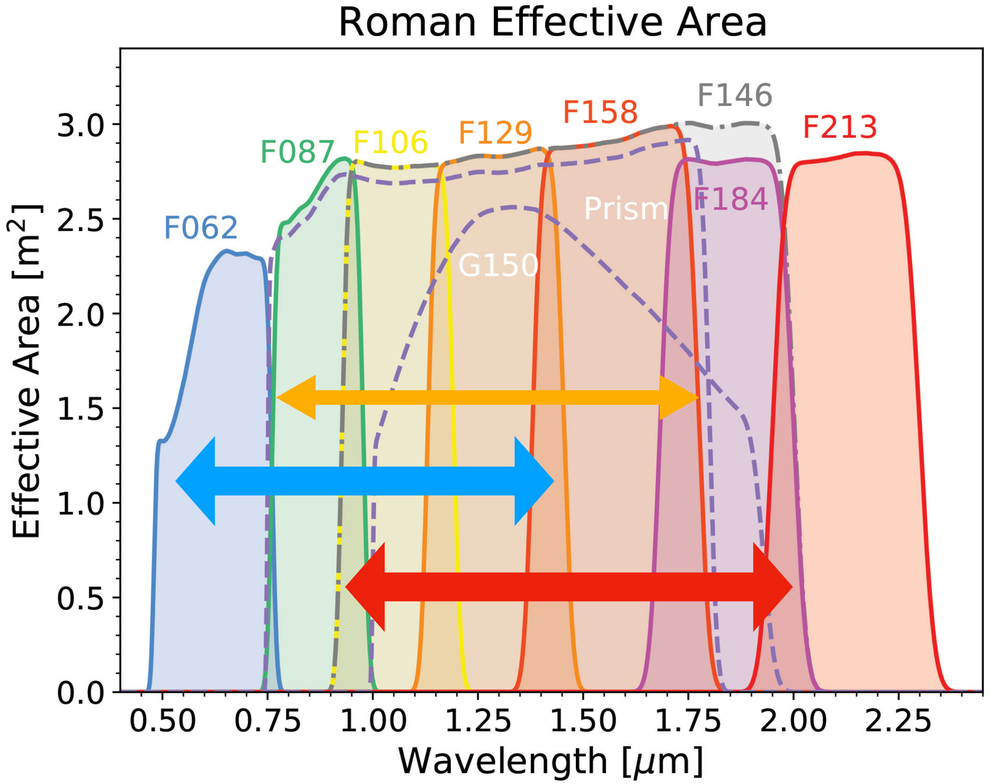
Wide & Deep

- Wide tier of ~19 deg²
- Deep tier of ~4 deg²
- These areas may be split over two locations



WFI Hardware

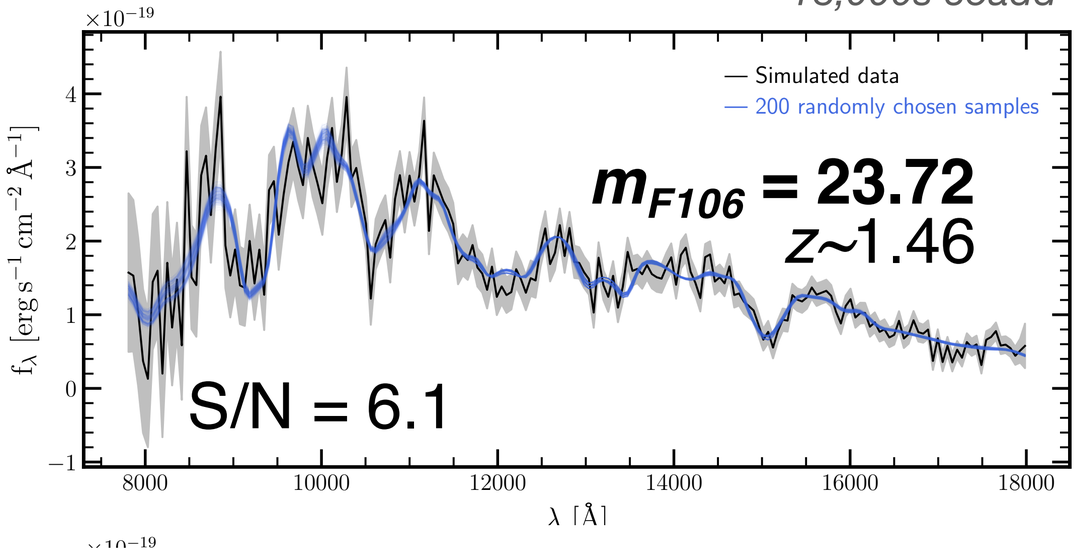
- RZYJ (wide)
- YJHF (deep)
- slitless, multiobject prism



Why?

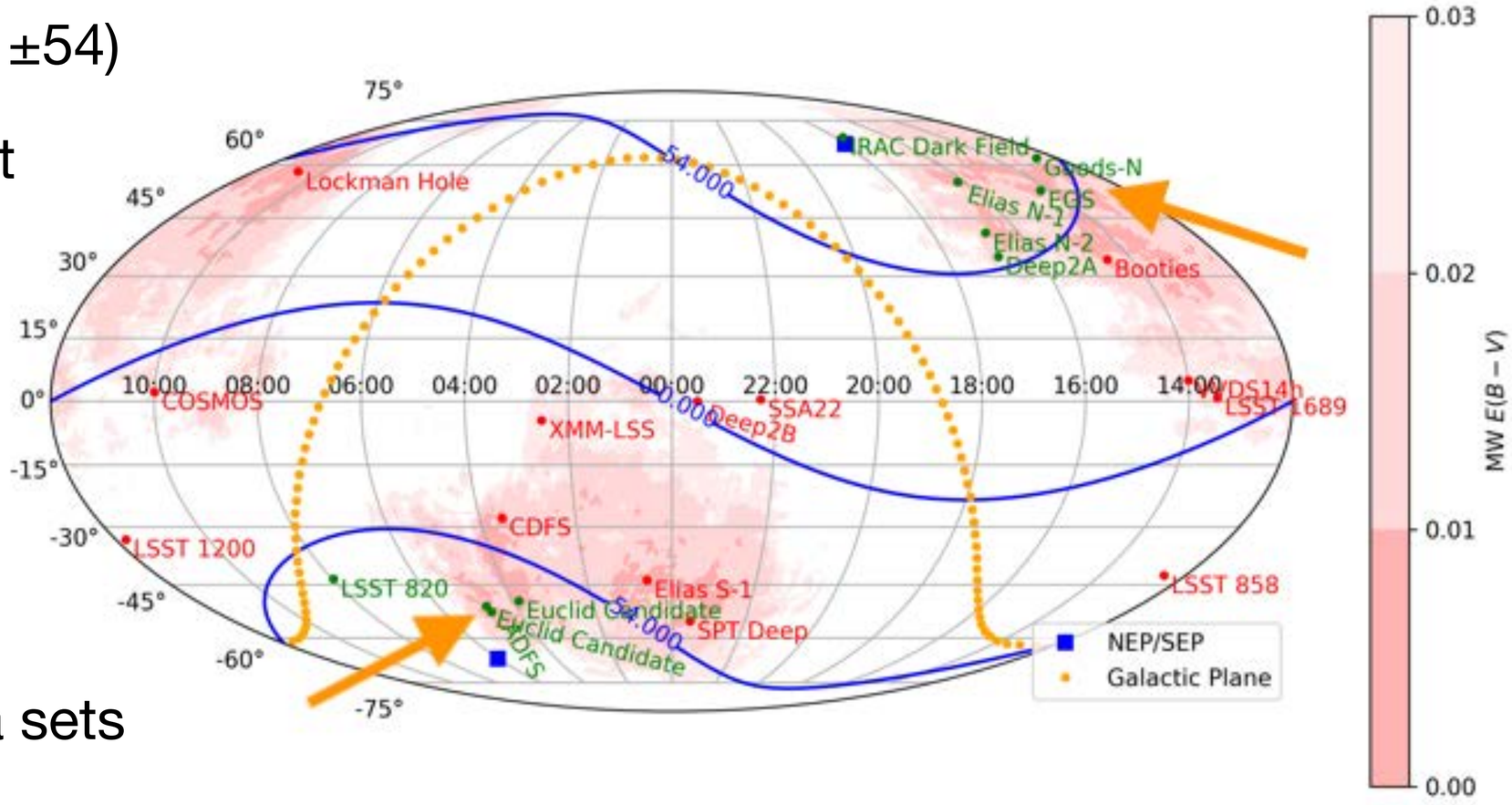
- Targets rest frame optical
- Prism is ~2 mag more sensitive than G150

18,000s coadd



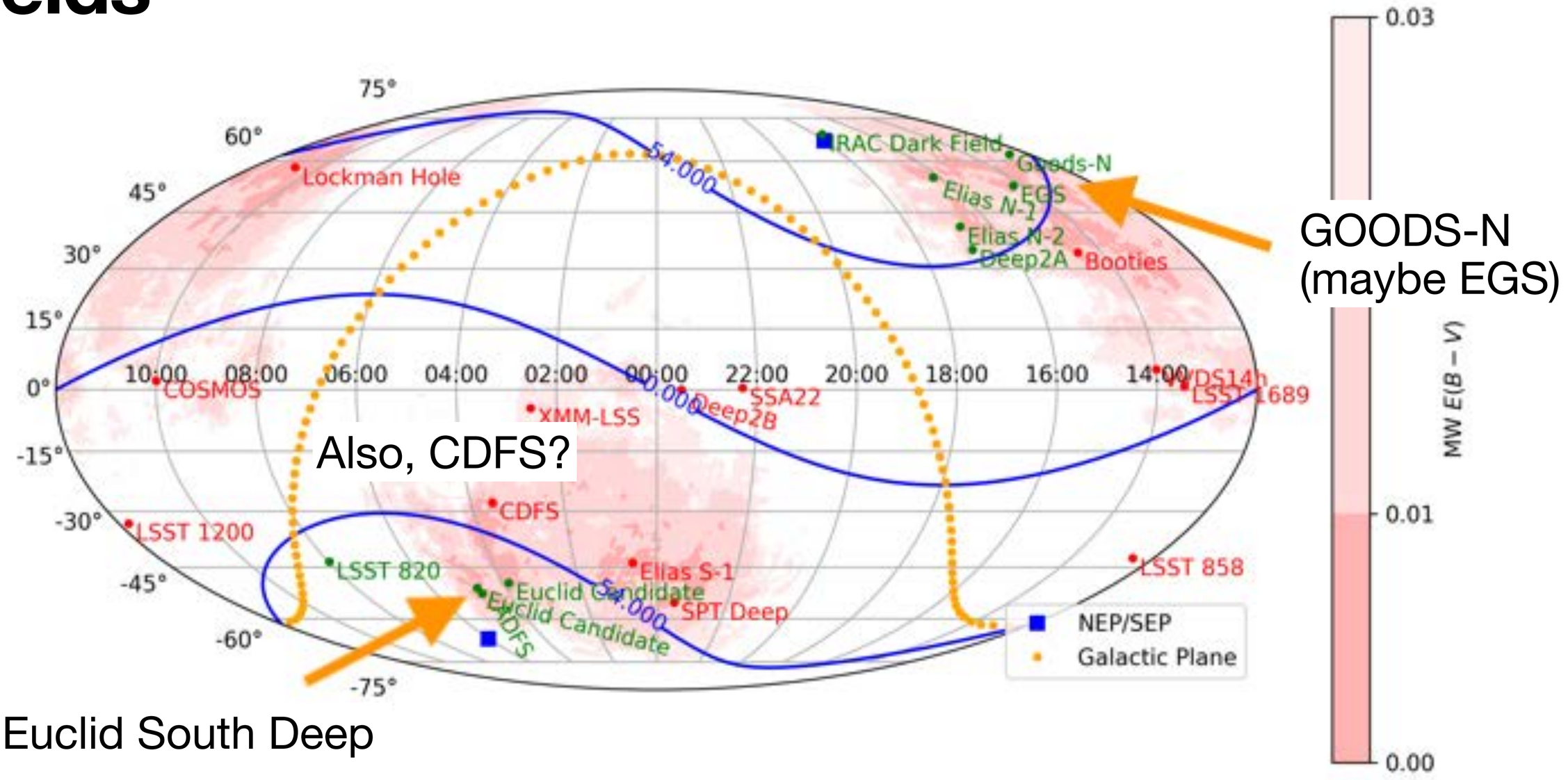
Fields

1. High ecliptic latitude (> ±54)
   - minimize zodiacal light
   - in Roman CVZ
     (SN 2.3.4)



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

Fields



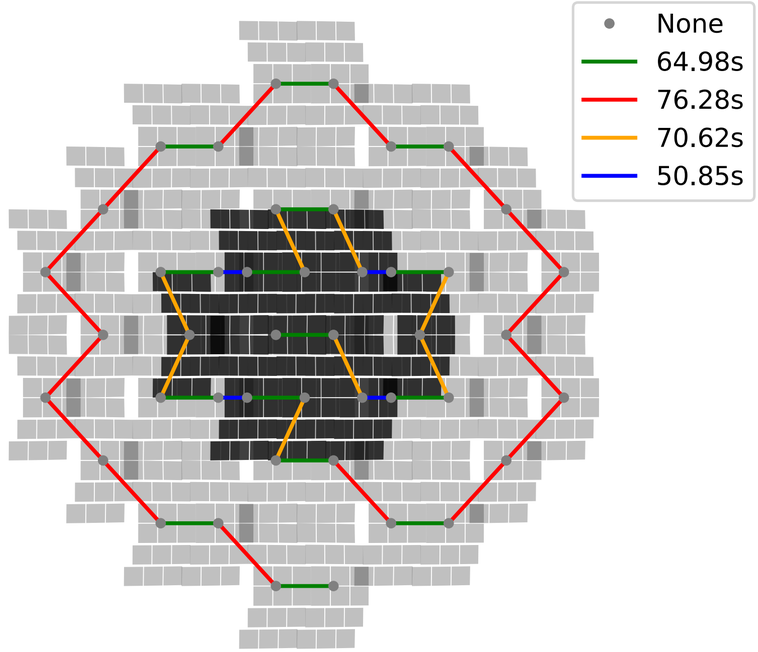
GOODS-N
(maybe EGS)

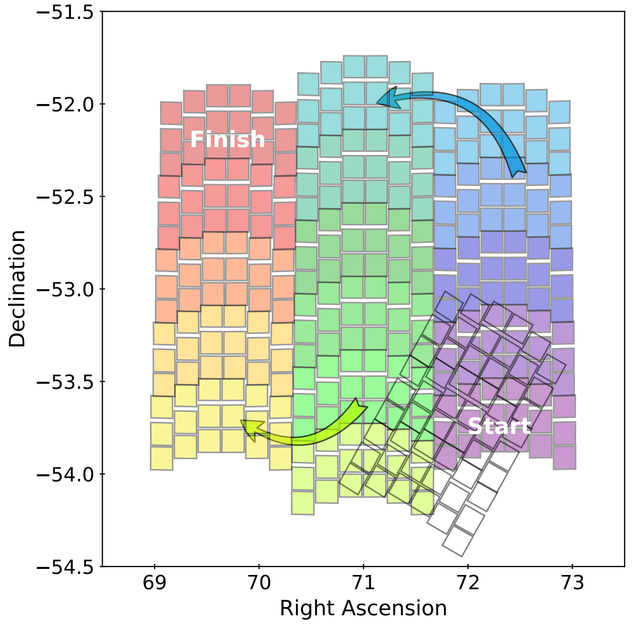
Also, CDFS?

Euclid South Deep

Slewing and Roll angles

- Circular fields - can be tiled the same as the observatory rotation angle changes.
- Concentric wide and deep fields - Minimize edge effects
- The roll angle:
    1. The natural roll of the observatory (~1 deg/day) or
    2. 30 deg jumps to maintain a specific angle for as long as possible.
- Prism will be used like the any other filter, a rolling survey





Exposure times

Two main considerations

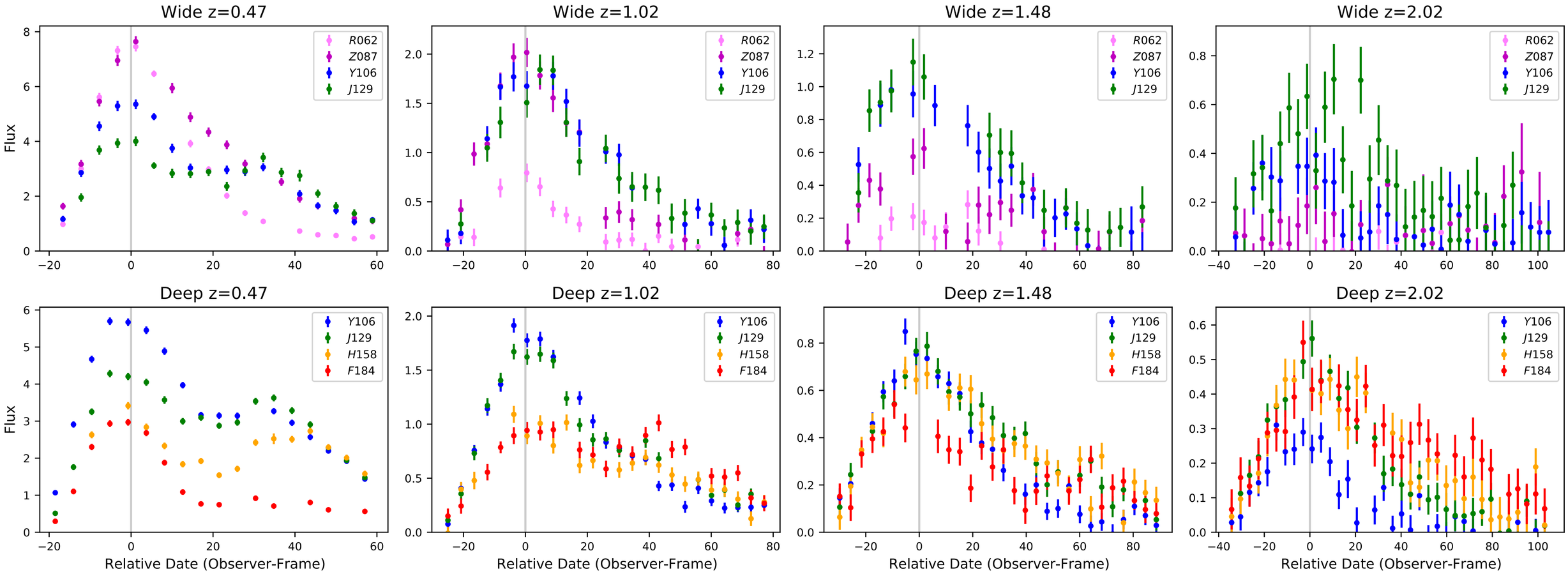
1. Target redshift where mean SN Ia at max get a S/N=10 per exposure.

2. 100s minimum

Mode	Tier	$z_{\rm targ}$*	Filters	Exp.Time+Overhead (s)	No. of Pointings	Area (deg^2)	Time/Visit (hours)	Total SN Ia
25% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	68	19.04	14.0	8804
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	15	4.20	8.5	3520
Subtotal							**22.5**	**12324**
Spec	Wide	1.0	prism	900 + 70	12	3.36	3.2	831
Spec	Deep	1.5	prism	3600 + 70	4	1.12	4.1	652
Subtotal							**7.3**	**1483**

*$z_{\rm targ}$ denotes the redshift where the average SN Ia at peak is observed with S/N=10 per exposure for imaging, and S/N=25 for spectroscopy.

Exposure times



Limiting Magnitude

	F062/R	F087/Z	F106/Y	F129/J	F158/H	F184/F
Wide Tier						
Exposure time (sec)	160	100	100	100	—	—
Single-exposure limiting magnitude	26.4	25.6	25.5	25.4		
125-exposure co-add limiting magnitude	29.0	28.2	28.1	28.0		
Deep Tier						
Exposure time (sec)	—	—	300	300	300	900
Single-exposure limiting magnitude			26.7	26.6	26.5	26.7
125-exposure co-add limiting magnitude			29.3	29.2	29.1	29.3

- ~87% fill fraction
- ~125 observations per static object
- ~19 deg^2 at ~28^{th} mag
- ~4 deg^2 at ~29^{th} mag

All magnitudes are AB mags

Limiting Magnitude

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Exposure time (sec)	160	100	100	100	—	—
Single-exposure limiting magnitude	26.4	25.6	25.5	25.4		
125-exposure co-add limiting magnitude	29.0	28.2	28.1	28.0		
Deep Tier						
Exposure time (sec)	—	—	300	300	300	900
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125-exposure co-add limiting magnitude			29.3	29.2	29.1	29.3

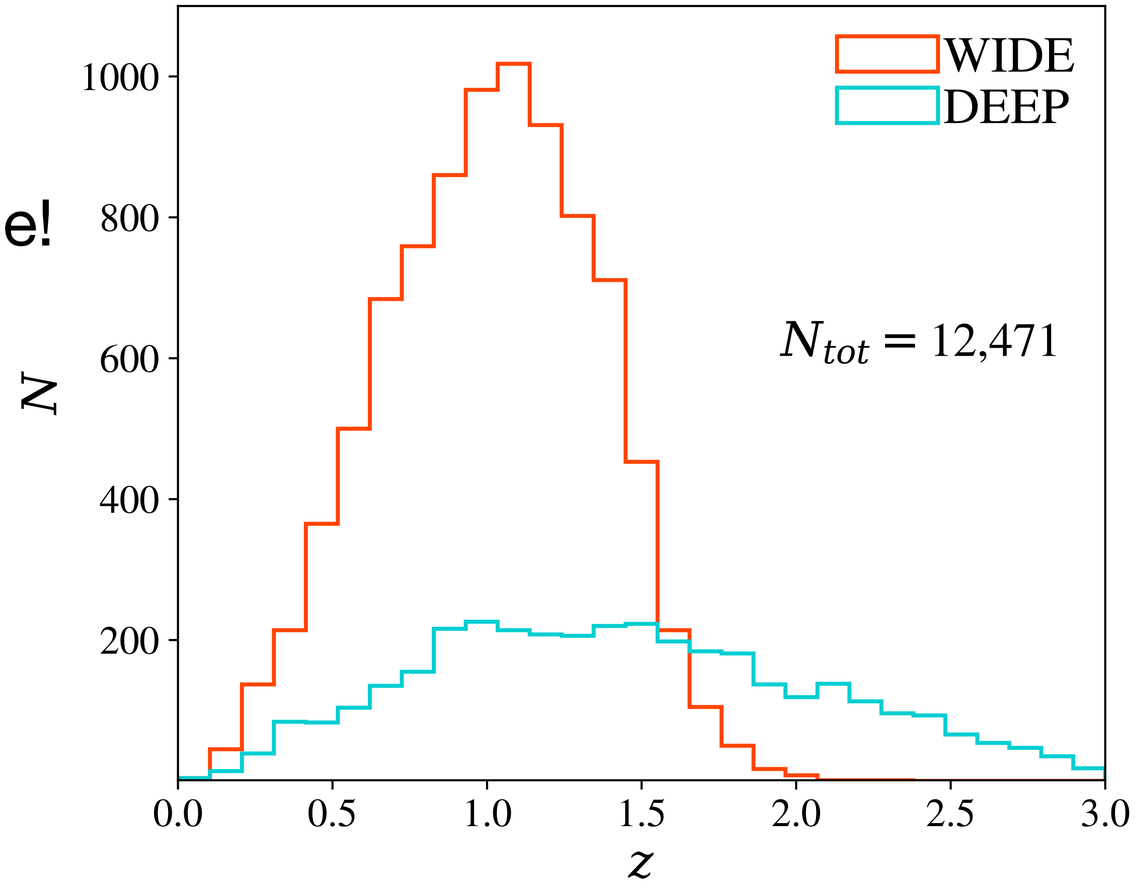
- ~87% fill fraction
- ~125 observations per static objec
- ~19 deg^2 at ~28th mag
- ~4 deg^2 at ~29th mag

HUDF is ~30th mag but only 11.5 arcminutes^2

All magnitudes are AB mags

Number of SN Ia

- 12,000 SNe Ia
  - And about the same number of CC SNe!
- 5,000 z >1
- Should see 100s of z>2 SN Ia!
- This gets us the statistics we need for FoM. Now we need to ensure the systematics are constrained enough.



Variations

Variations

Fraction of prism time

- With 10% spectral time
  - Photometry area goes from 19 and 4 deg² to 23 and 5 deg².
- With 75% time to spectroscopy
  - 100% of objects get time series spectra!
  - Areas go to 5 and 1.5 deg²

Mode	Tier	$z_{\rm targ}$	Filters	Exp.Time+Overhead (s)	No. of Pointings	Area (deg^2)	Time/Visit (hours)	Total SN Ia
10% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	82	22.96	16.8	10617
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	18	5.04	10.2	4224
Subtotal							**27.0**	**14841**
Spec	Wide	1.0	prism	900 + 70	4	1.12	1.0	277
Spec	Deep	1.5	prism	3600 + 70	2	0.56	2.0	326
Subtotal							**3.0**	**603**
50% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	45	12.60	9.3	5826
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	10	2.80	5.8	2347
Subtotal							**15.1**	**8173**
Spec	Wide	1.0	prism	900 + 70	25	7.00	6.7	1731
Spec	Deep	1.5	prism	3600 + 70	8	2.24	8.2	1302
Subtotal							**14.9**	**3032**
75% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	19	5.32	3.9	2460
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	6	1.68	3.5	1408
Subtotal							**7.4**	**3868**
Spec	Wide	1.0	prism	900 + 70	19	5.32	5.1	2460
Spec	Deep	1.7	prism	10400 + 70	6	1.68	17.5	1408
Subtotal							**22.6**	**3868**

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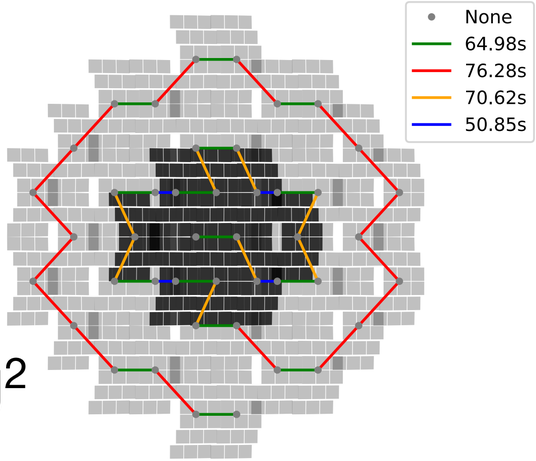
- 2 tiers
- 4 filters+prism per tier
- 12,000 SNe Ia, 5,000 at z >1



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