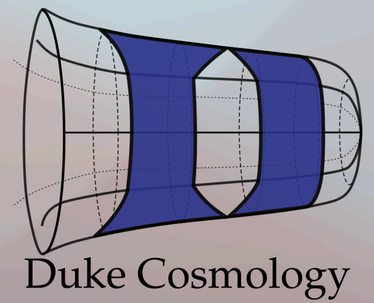
Roman Transient Light Curves

Benjamin Rose, Duke University
with special thanks to Maria Vincenzi & Rebekah Hounsell
NASA Time Domain and Multi-Messenger Workshop
August 22, 2022

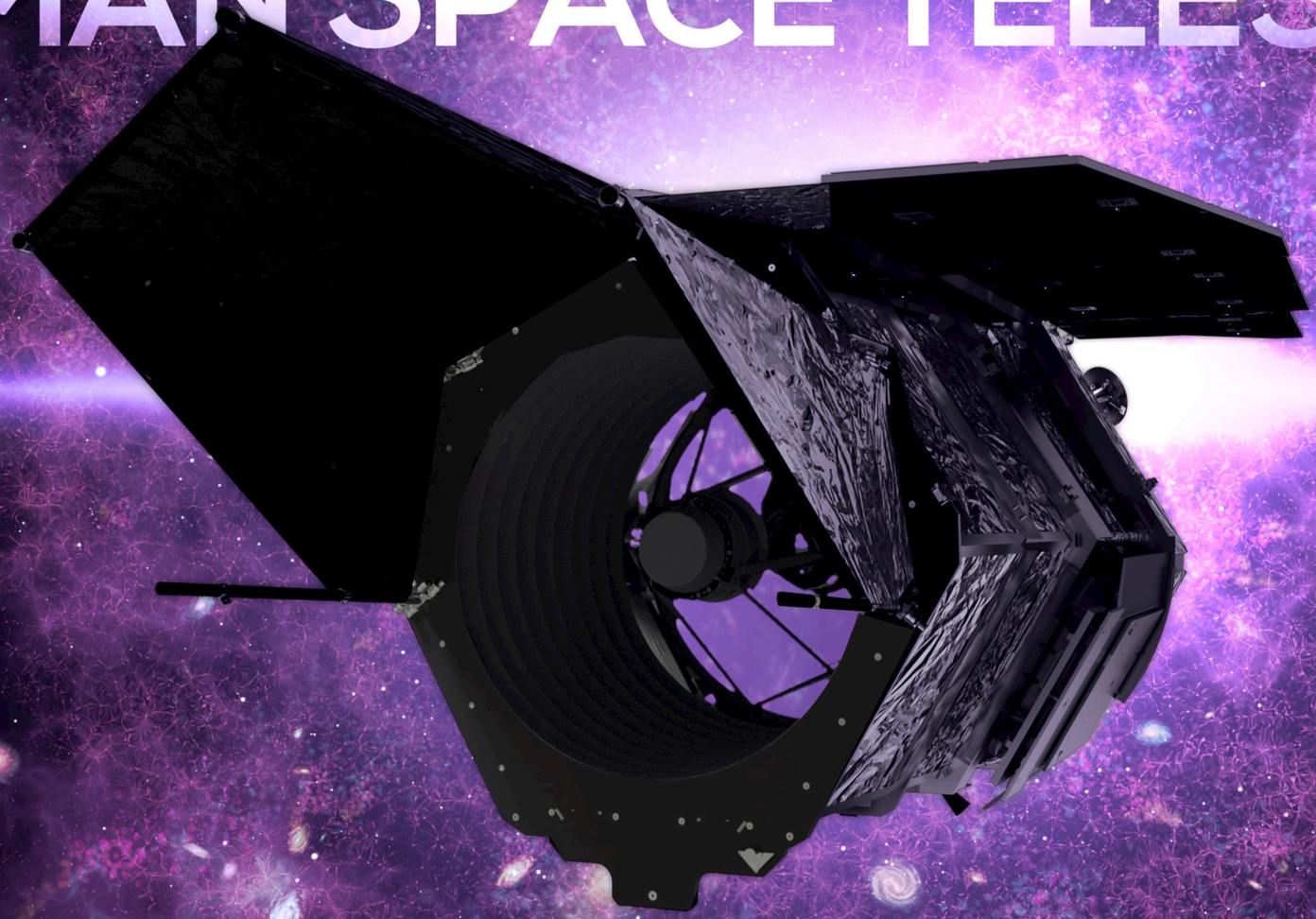
NANCY GRACE ROMAN SPACE TELESCOPE



What time domain observations are needed in the next 10 years?

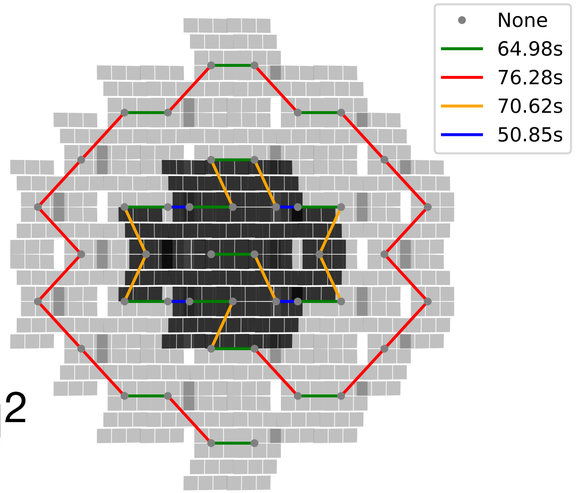
What time domain observations *will we have* in the next 10 years?

THE NANCY GRACE ROMAN SPACE TELESCOPE



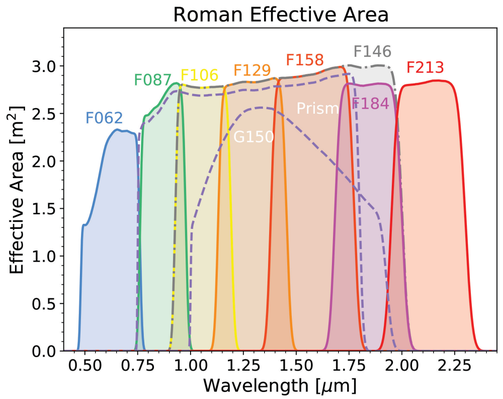
The Reference Survey

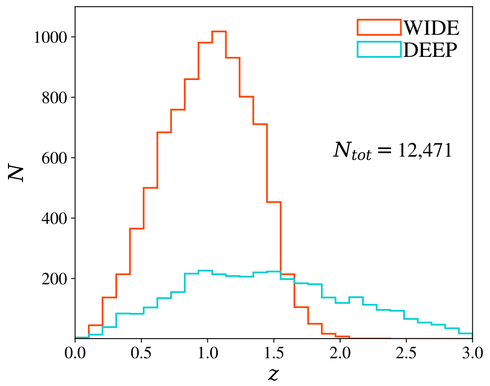
arXiv:2111.03081

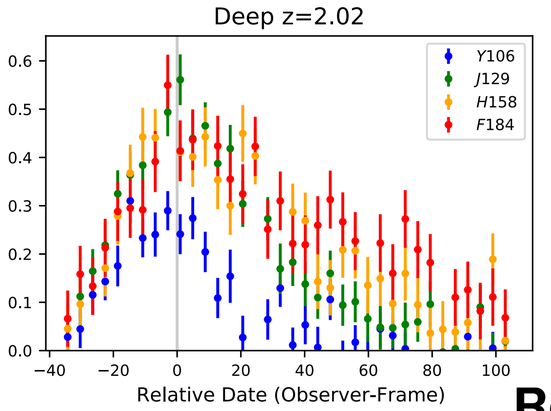


- 2 fields - likely GOODS-N and Euclid Deep South
- 2 tiers
- 4 filters+prism per tier
- 12,000 SNe Ia, 7,000 at z >1

- 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



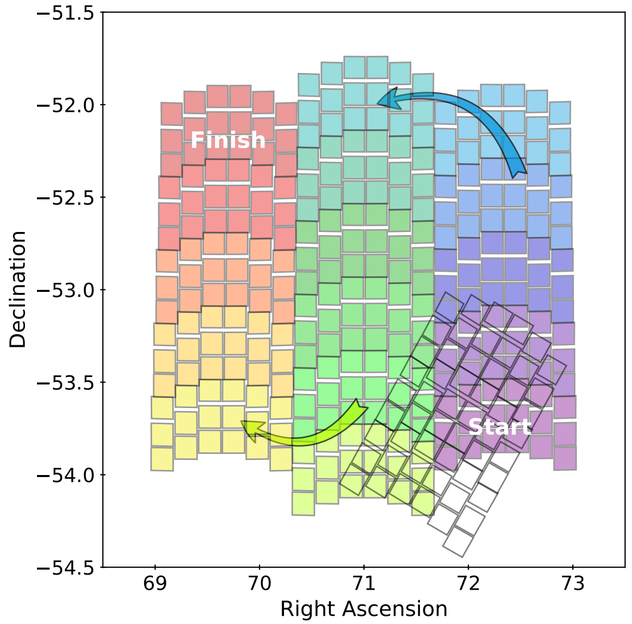




Rose+, 2021

Cadence, Tiers, & Field

- A 5 day cadence
- Likely in Euclid South Deep and/or GOODS-N
- Roughly circular filed, rolling ~5 deg/visit
- Photometry: Wide 19 deg^2, Deep 4 deg^2
- Spectroscopy: Wide 3 deg^2, Deep 1 deg^2



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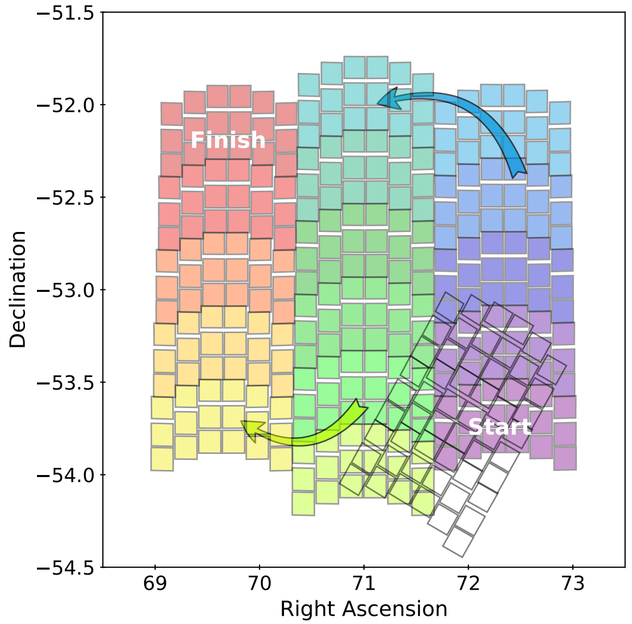

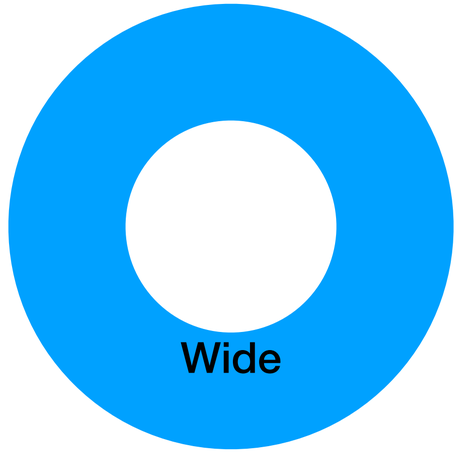

Concentric Tiers

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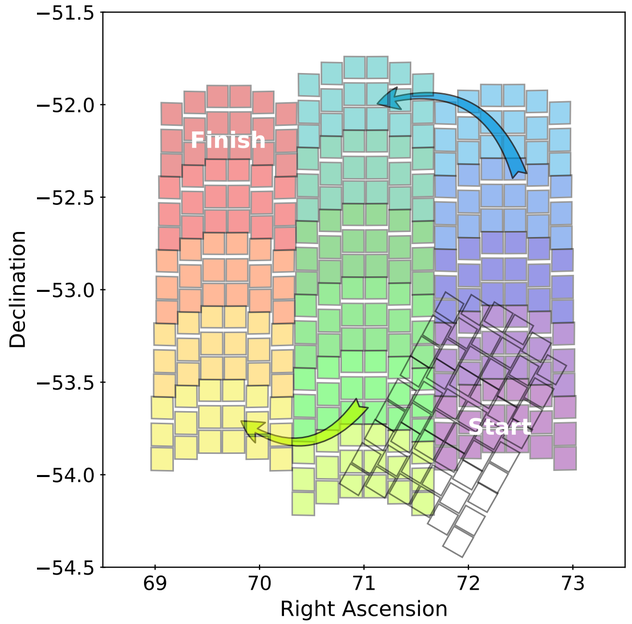

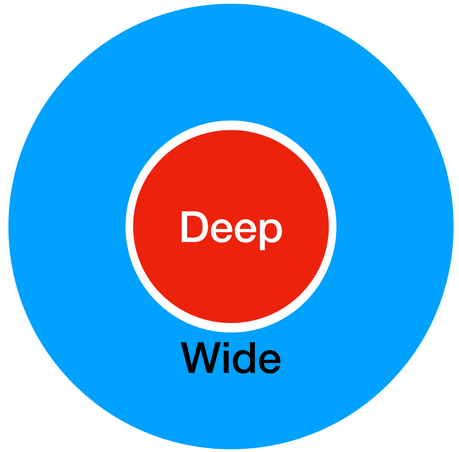

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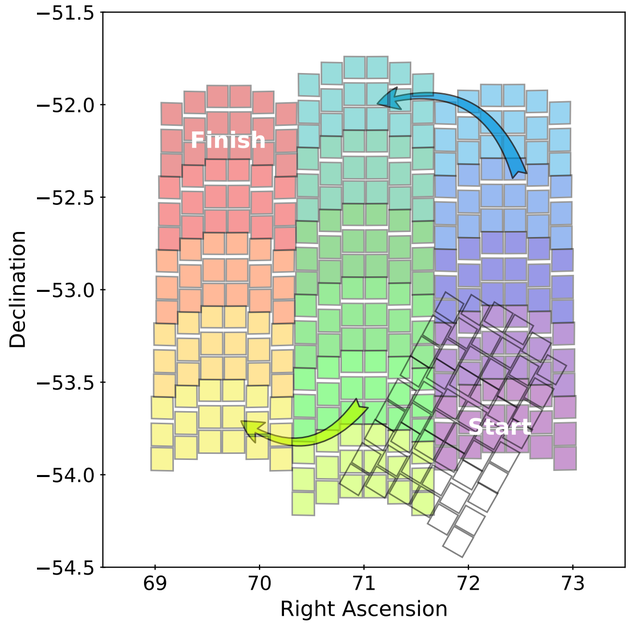

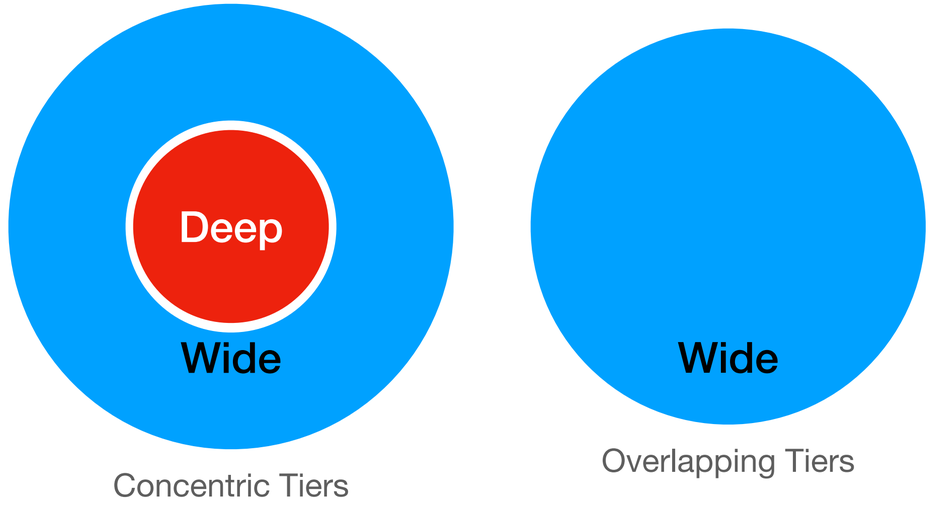

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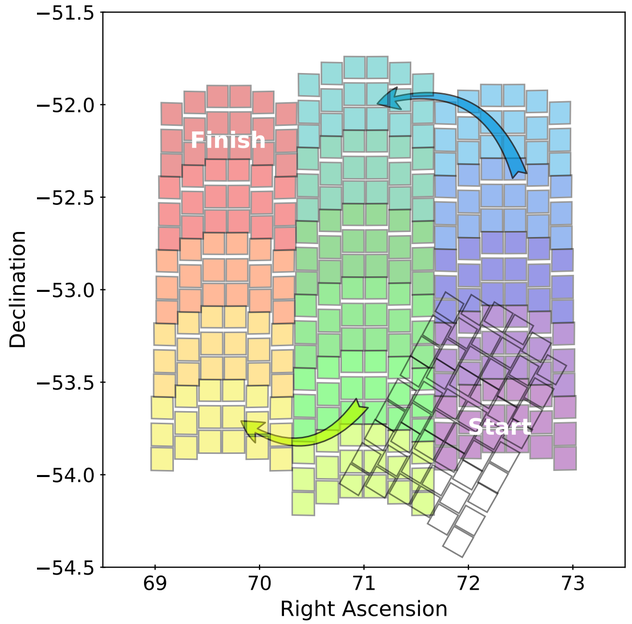
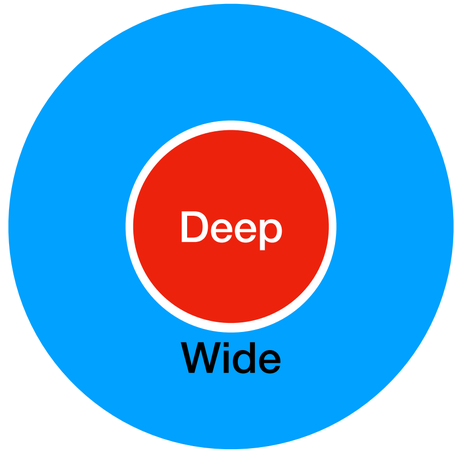
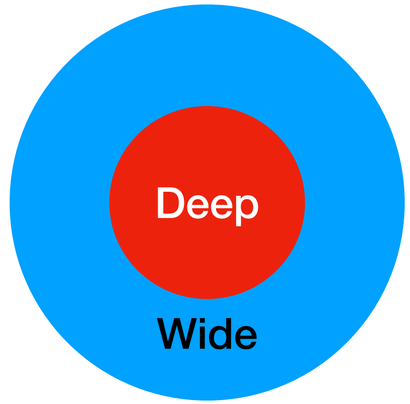




Concentric Tiers



Overlapping Tiers

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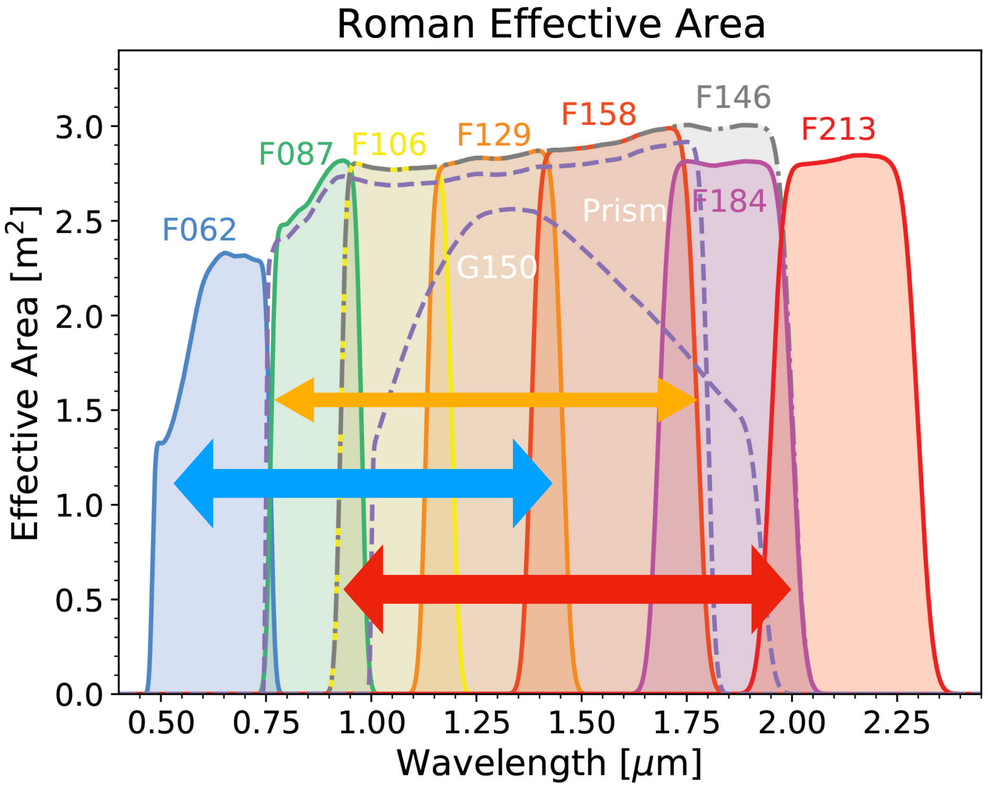
Filters & Depths



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

	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

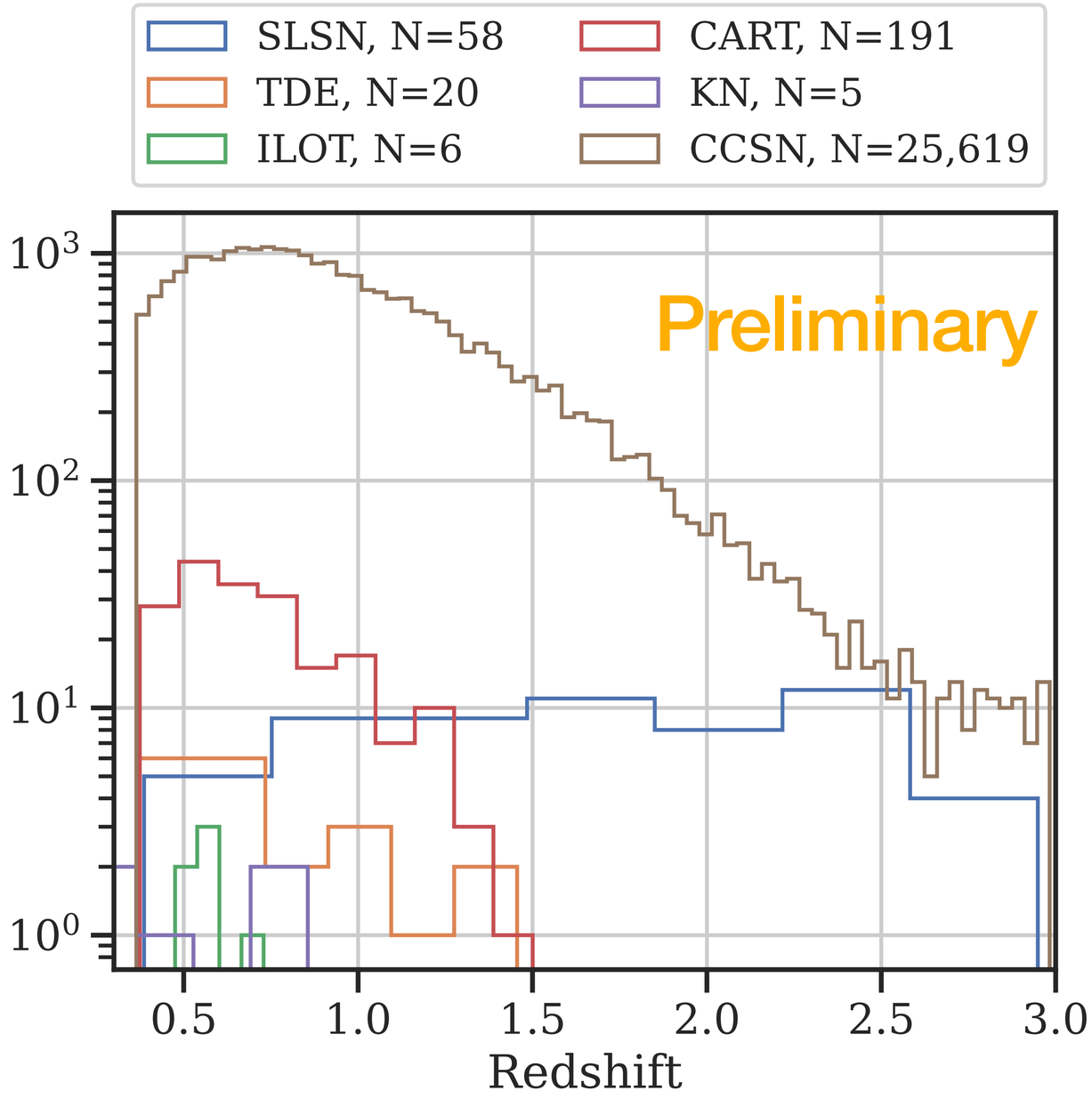
- Target redshift where mean SN Ia at max get a S/N=10 per exposure.
- 100s minimum

Rose+, 2021

A Forecast of Light Curves!

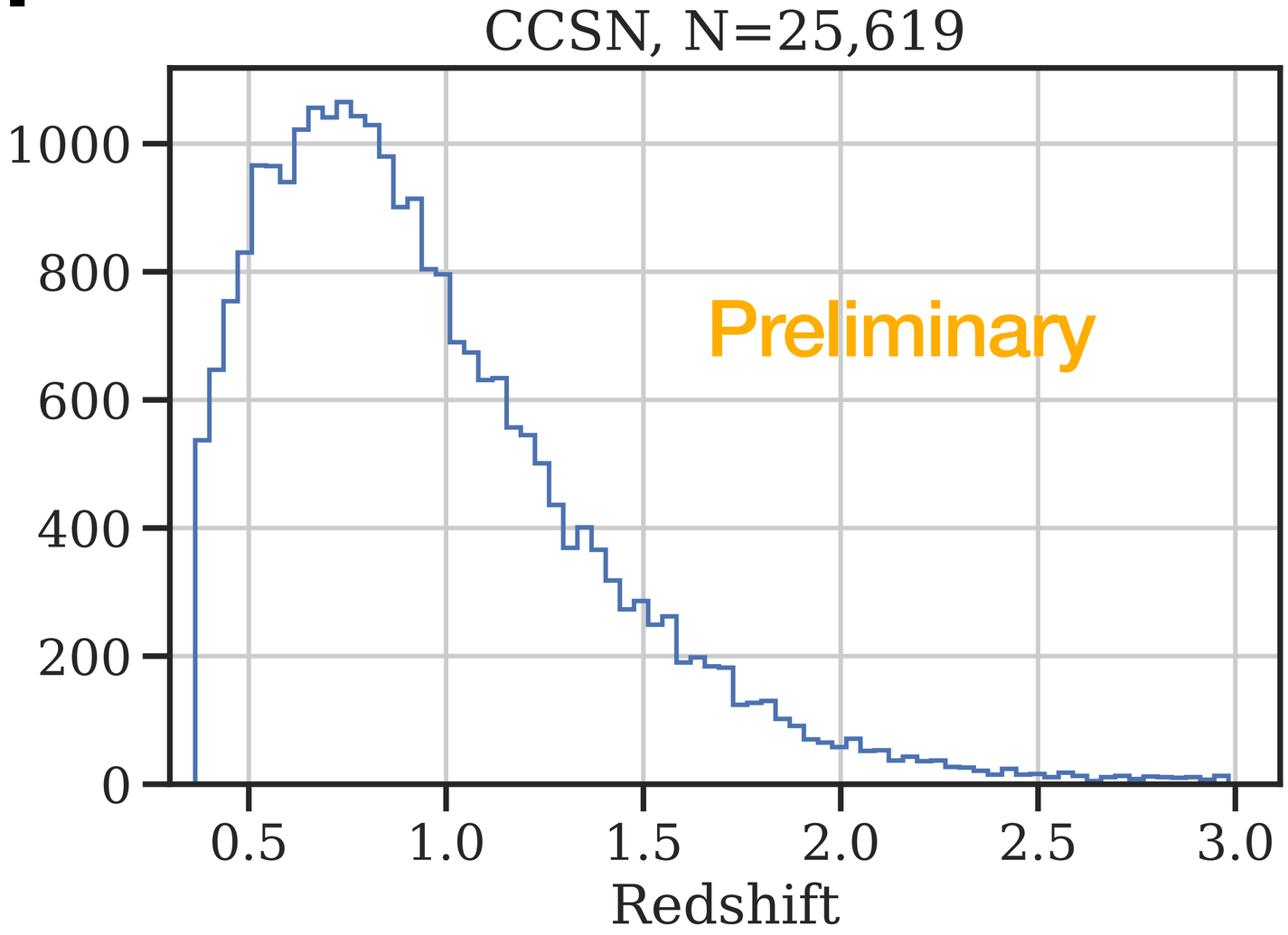
Simulations Basics

- SNANA for simulations
- PLAsTiCC SEDs (Kessler+ 2019)
  - Most using MOSFiT
- Sims from 0.3 < z < 3.0 (limitation of SNANA and red edge of SEDs)
- Detected is S/N at max > 7

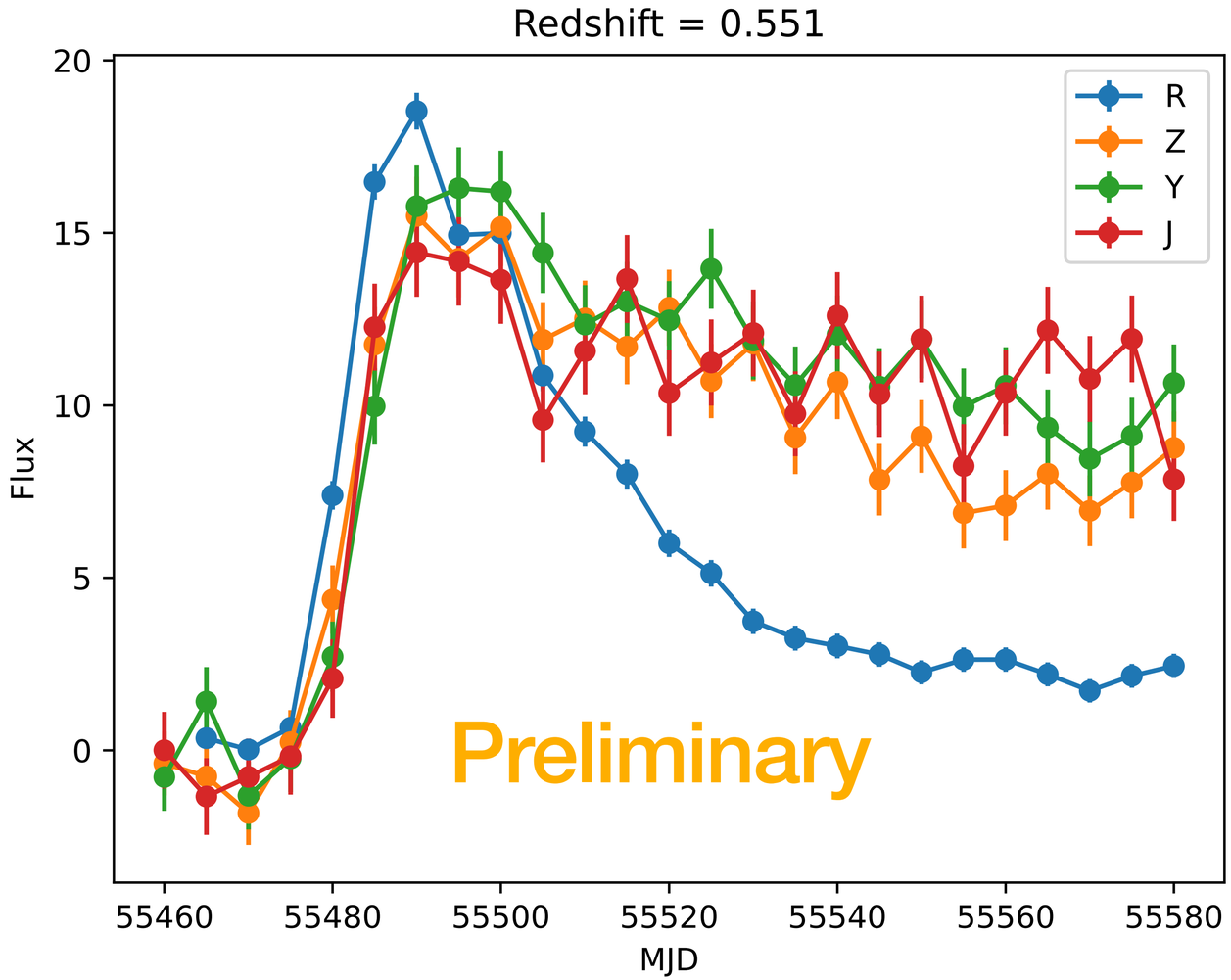


Core-Collapse Supernovae

- Used the Vincenzi+ 2021 Templates
- >25,000 CCSN
- ~30 per z=0.1 bin at z>2.5.

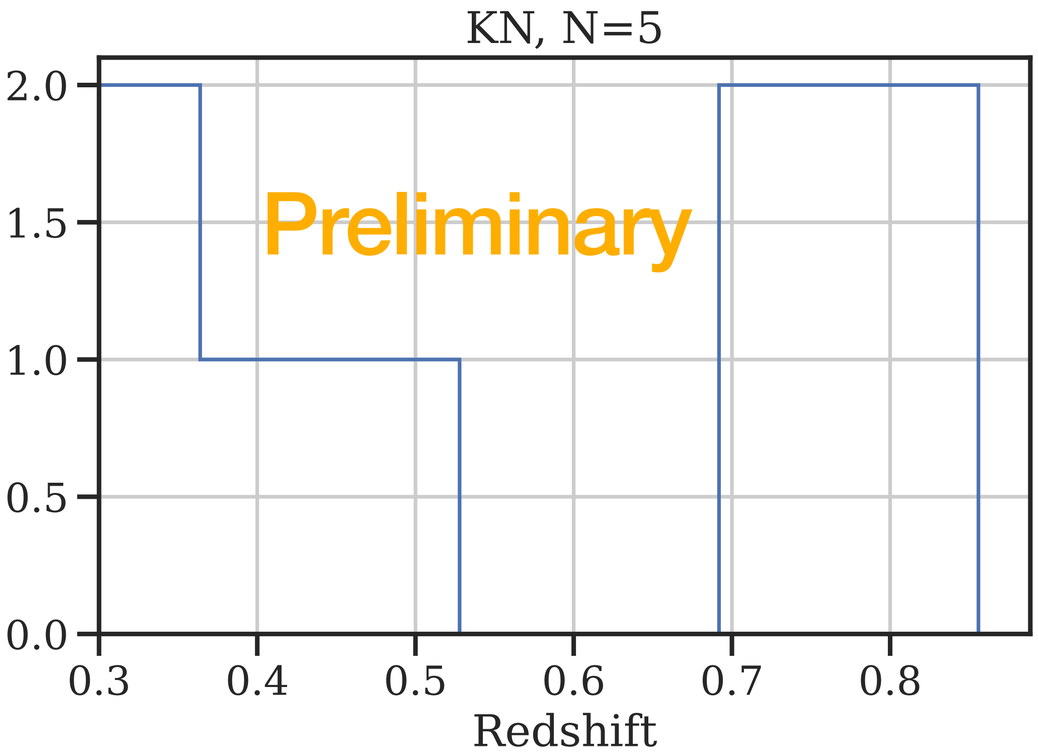


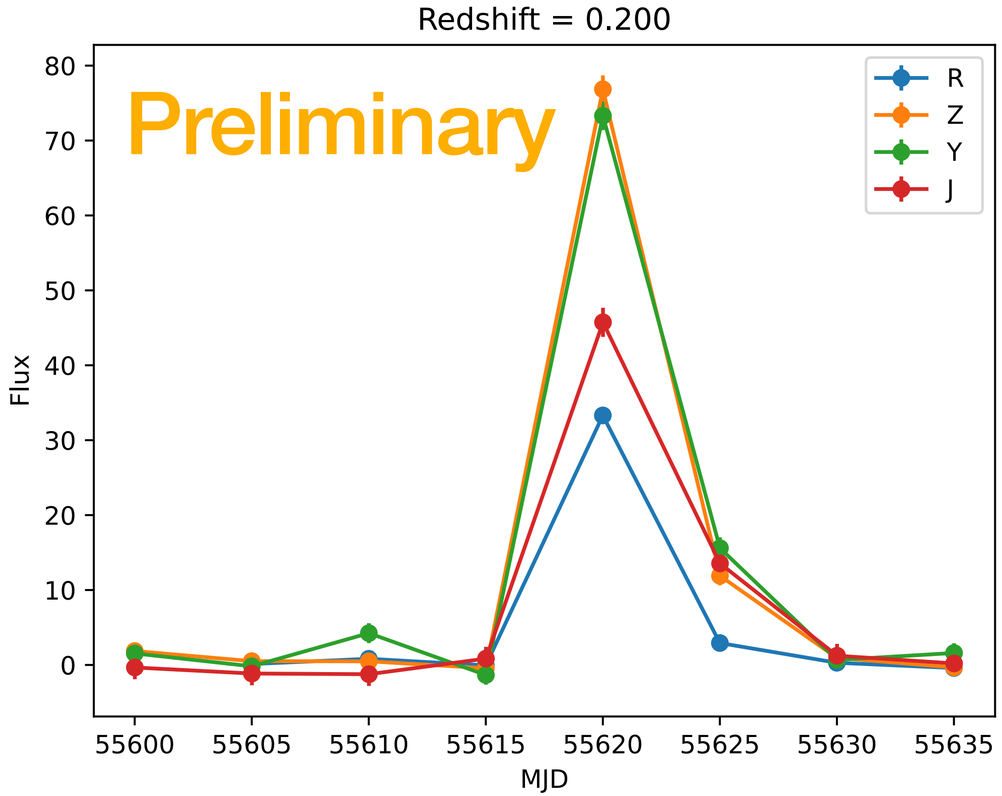
Core-Collapse Supernovae



Kilonovae

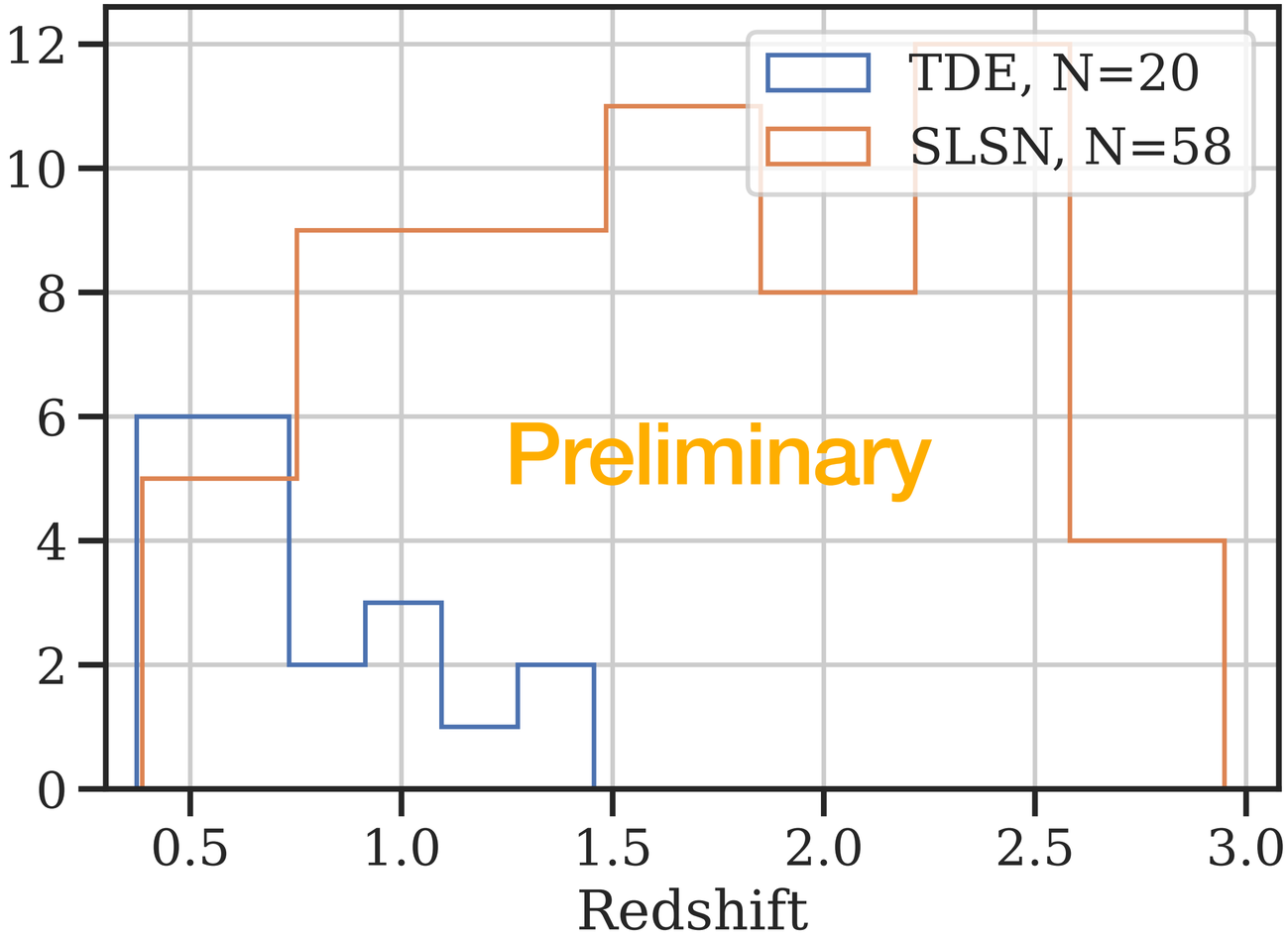
- Not many & a bad cadence





Tidal Disruption Events & Super Luminous Supernovae

- Few dozen TDE's to z=1.5
- >50 SLSN to z=3.0
- Lower limit of SLSN because of current z < 3.0 simulation constraint.



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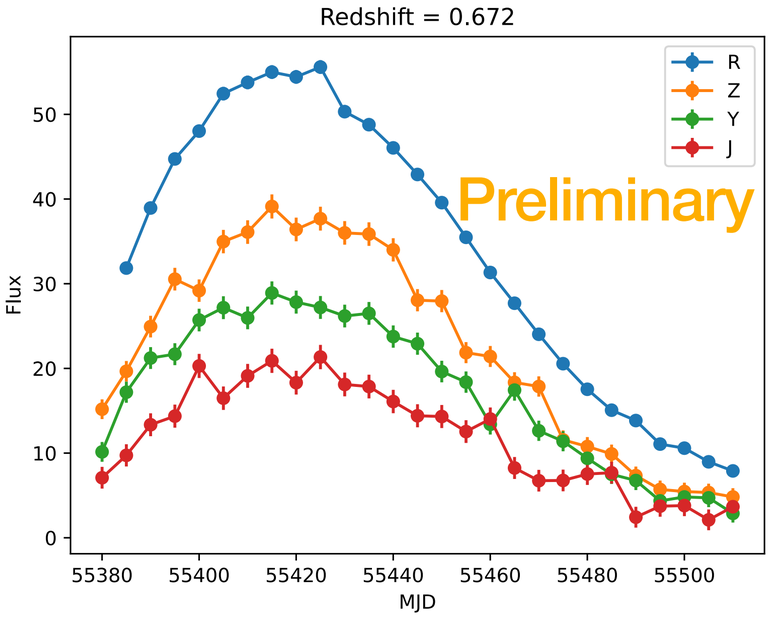
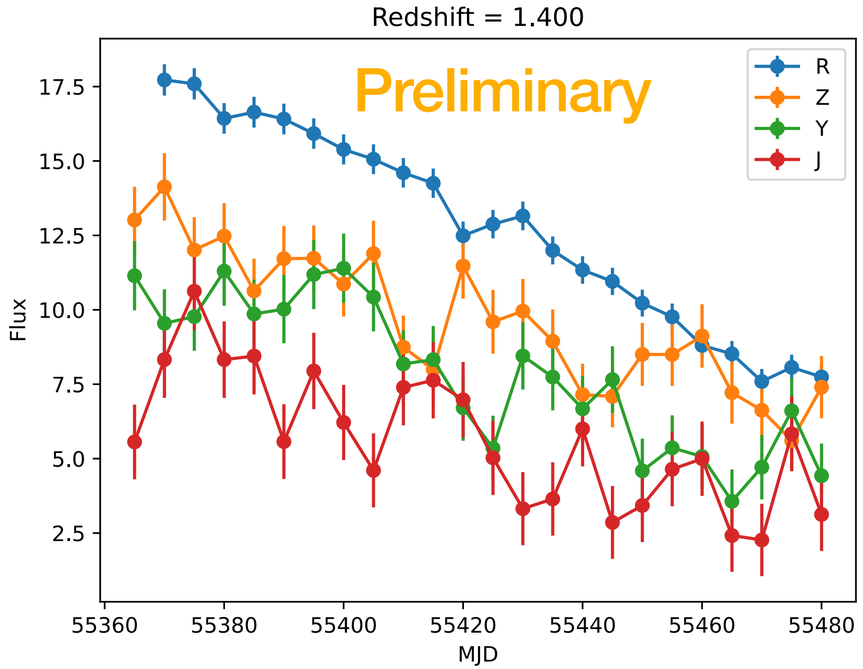
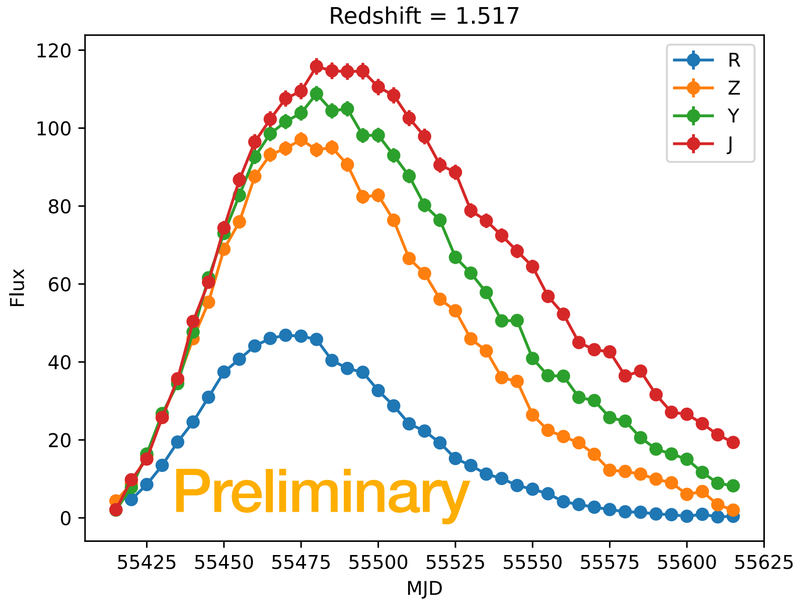


TDE - median S/N



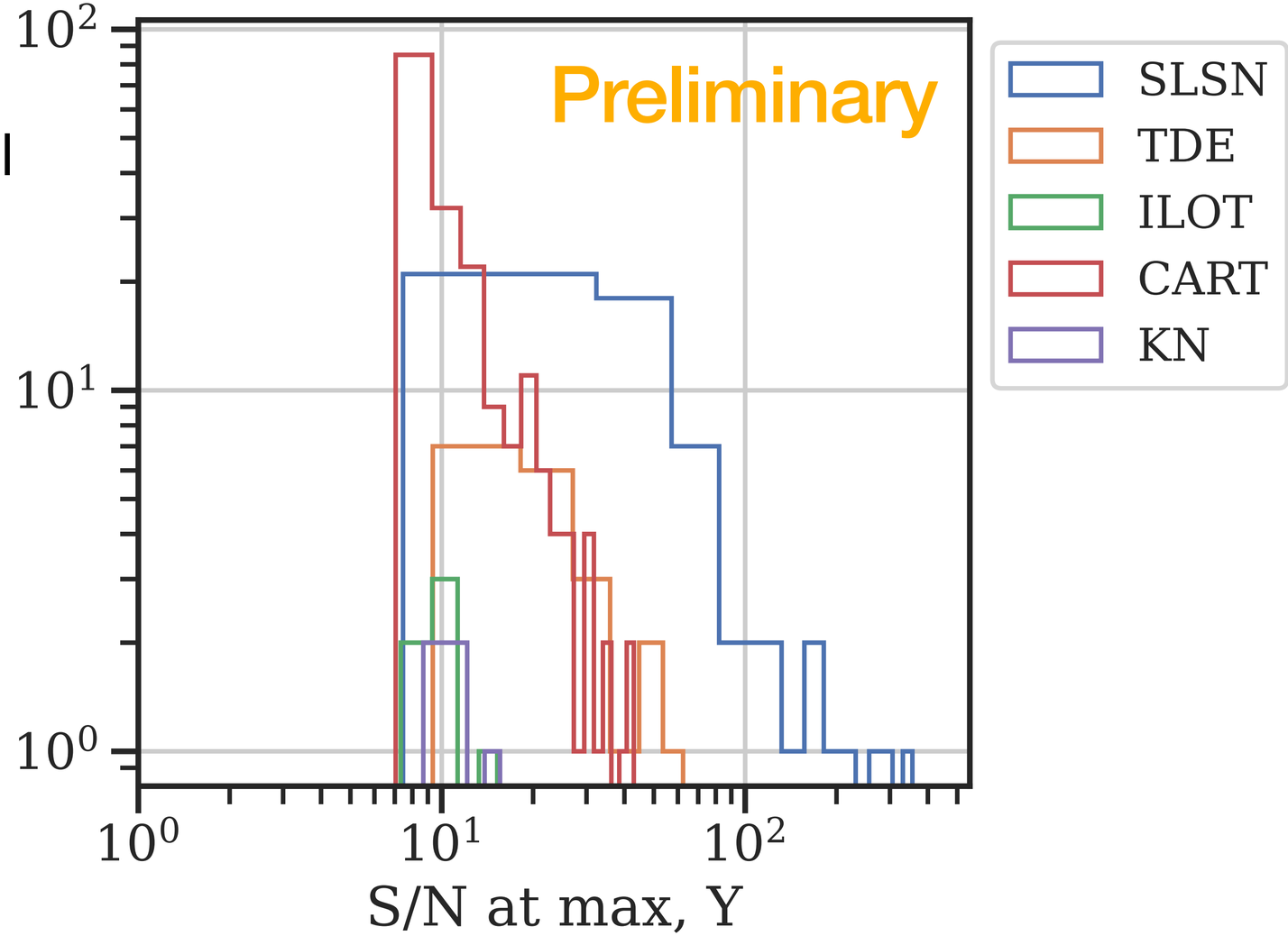
TDE - worse S/N



SLSN - median S/N

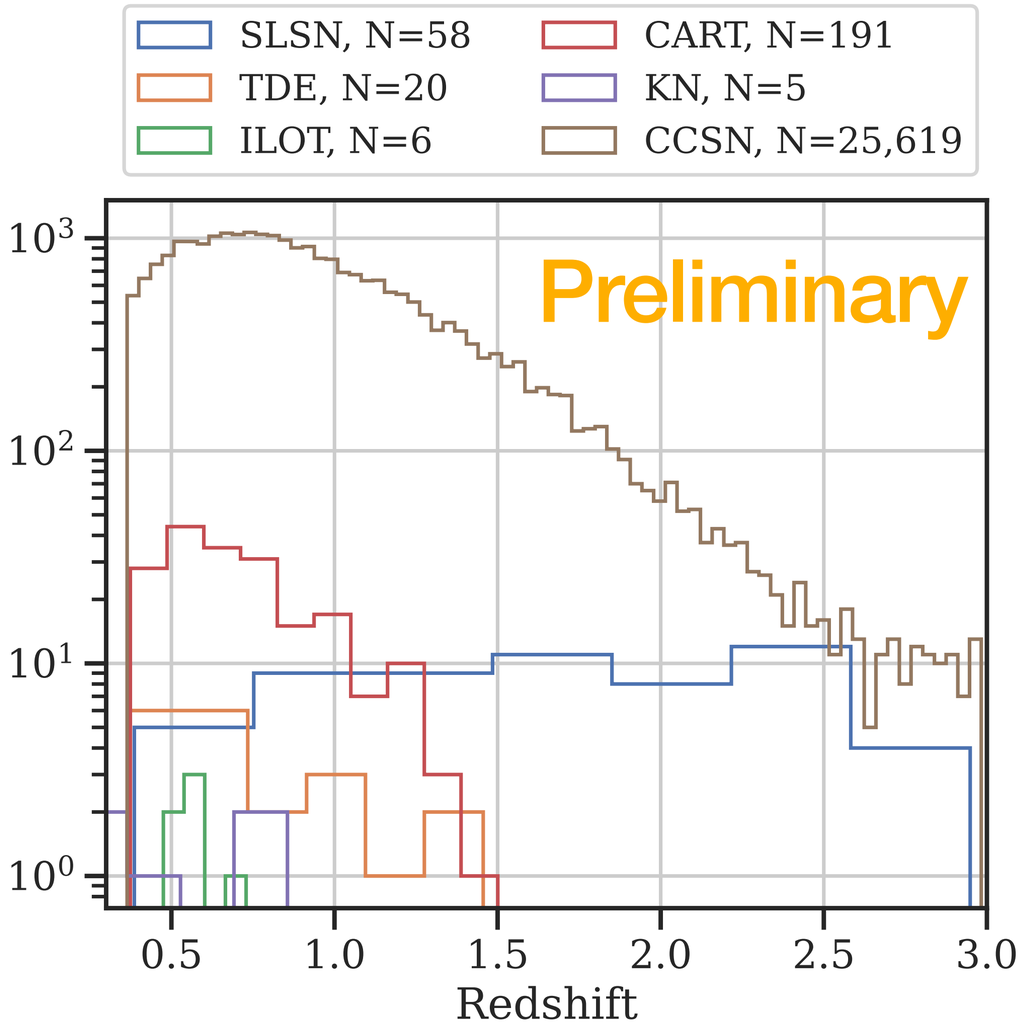
Still working on . . .

- ✓ Intermediate Luminosity Optical Transients
- ✓ Ca-Rich Transients
- Pair Instability SNe
- AGNs
- Stellar Variables



What time domain observations will Roman provide?

- Over 20,000 CCSN with ~30 per z=0.1 bin at z>2.5.
- A few KN, to z ~ 0.8
- A few dozen TDE to z~1.5
- >50 SLSN to z<3.0



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Backup slides

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

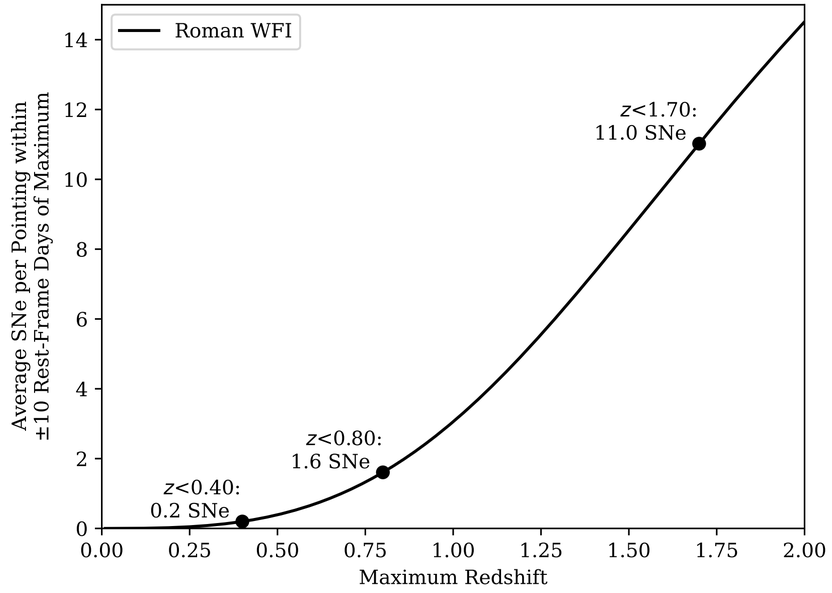
- Target SN Ia over the redshift

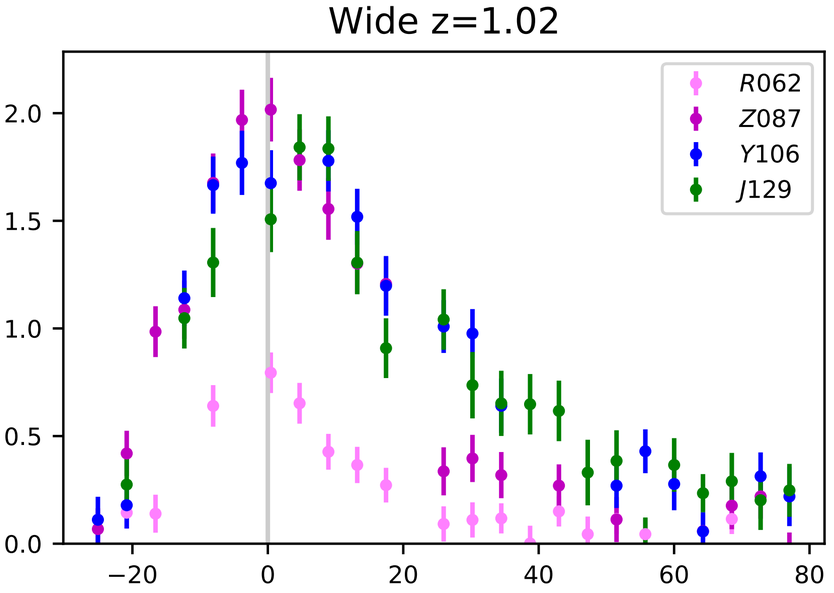
  range of 0.2≤ z ≤ 1.7

  SN Requirement 2.0.2

- So, ~30 hours per every 5 day visit

Rubin 2021 arXiv:2010.15112

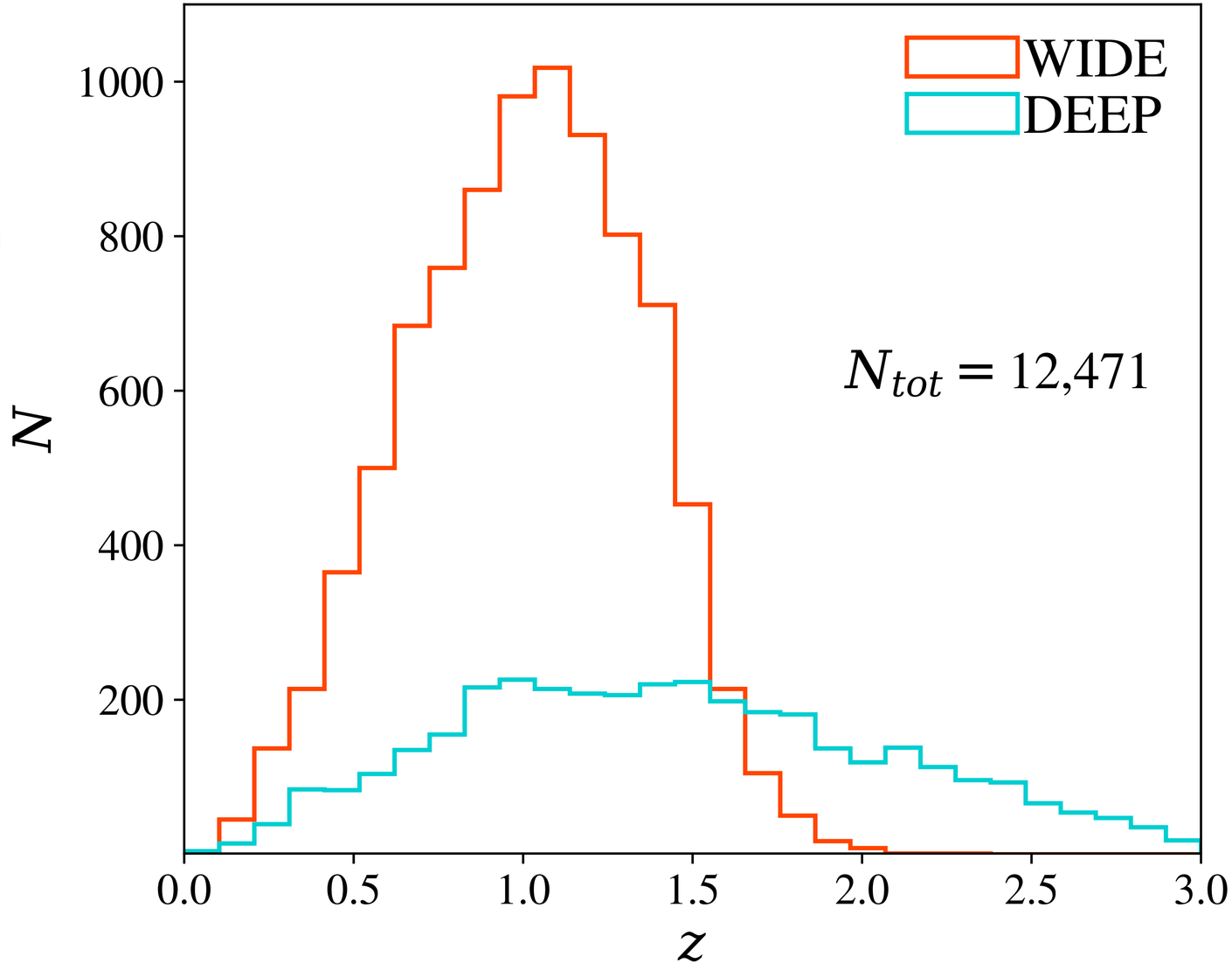




Number of Tiers

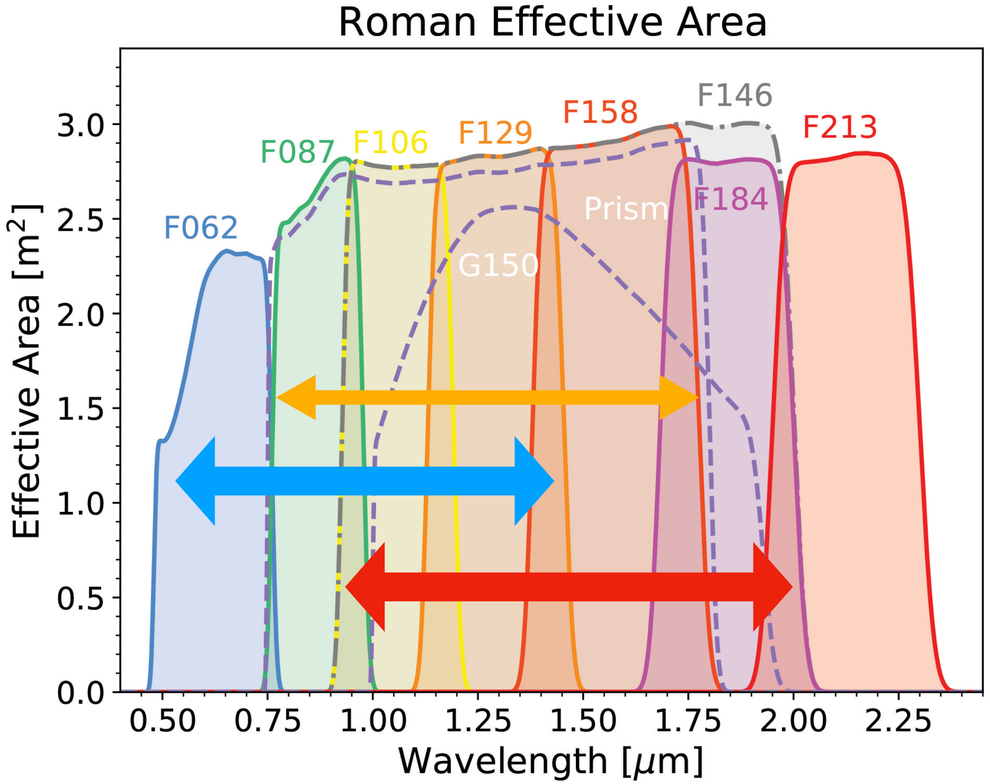
Wide & Deep

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



WFI Hardware

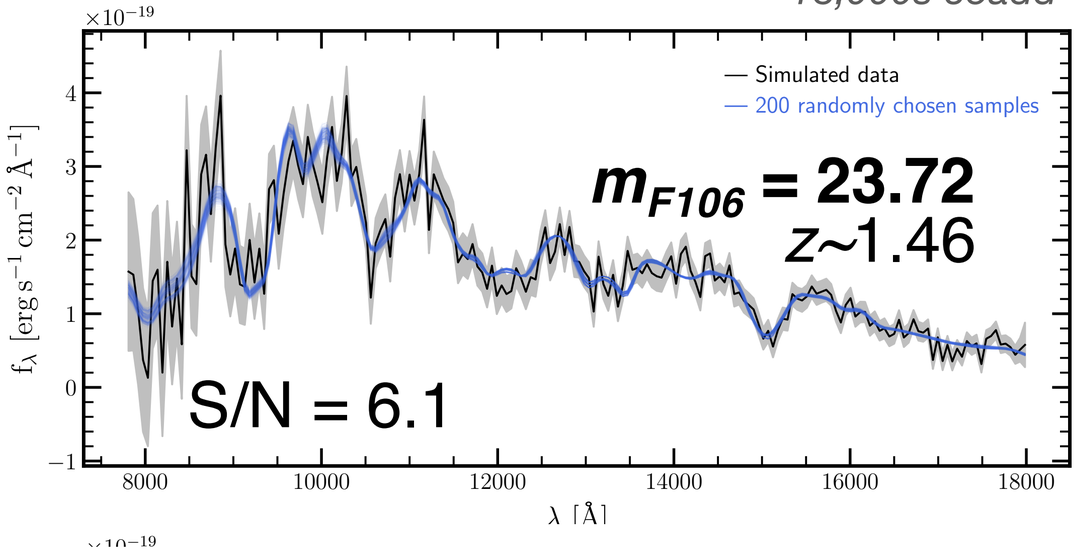
- RZYJ (wide)
- YJHF (deep)
- slitless, multiobject prism



Why?

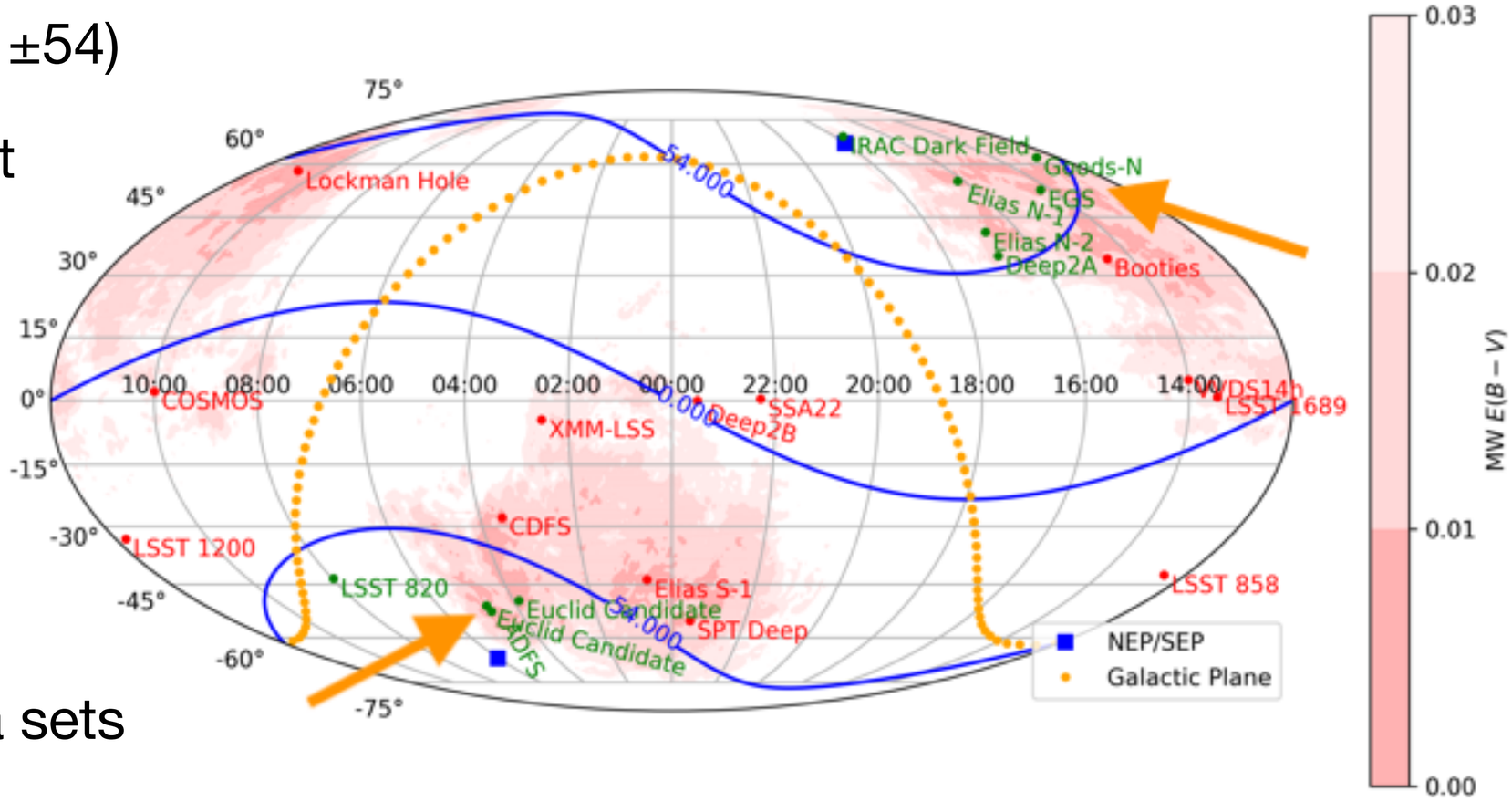
- Targets rest frame optical
- Prism is ~2 mag more sensitive than G150

18,000s coadd



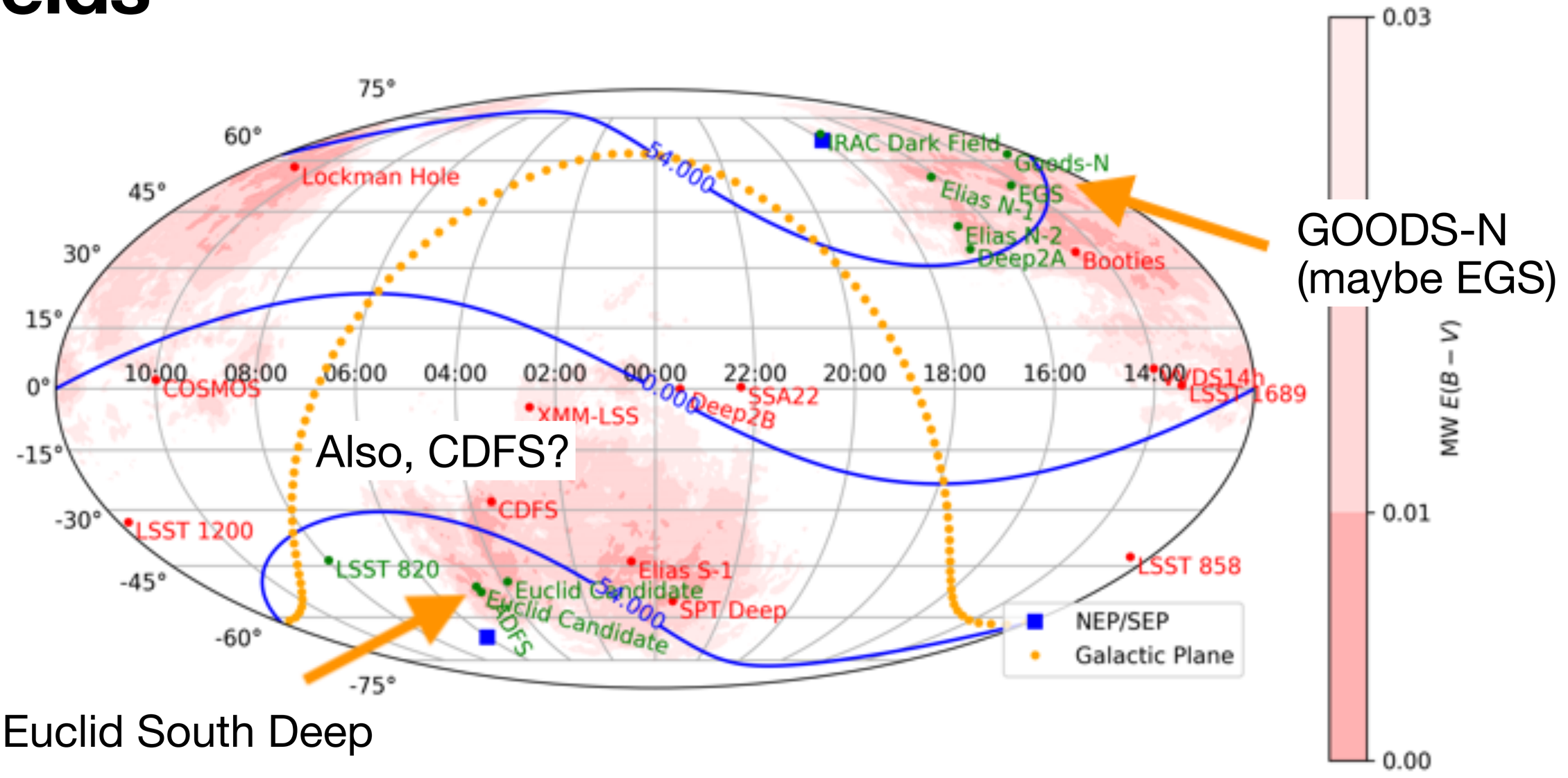
Fields

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



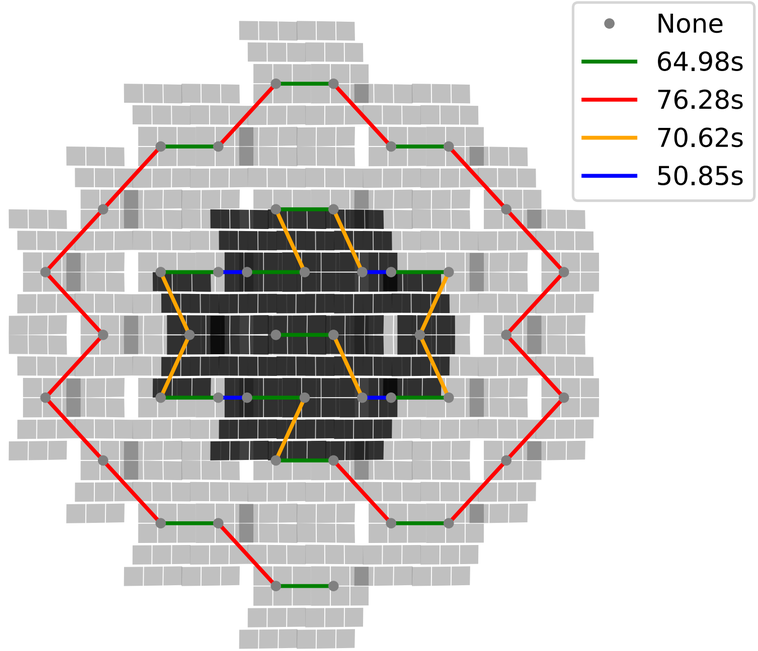
Also, CDFS?

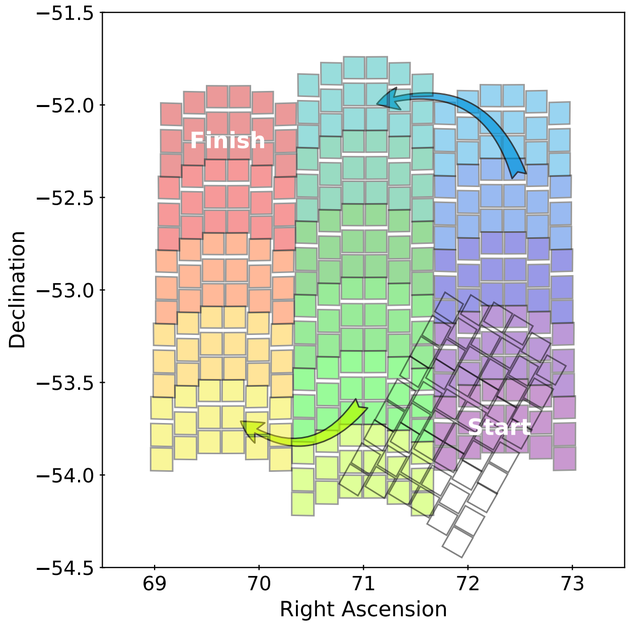
GOODS-N
(maybe EGS)

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

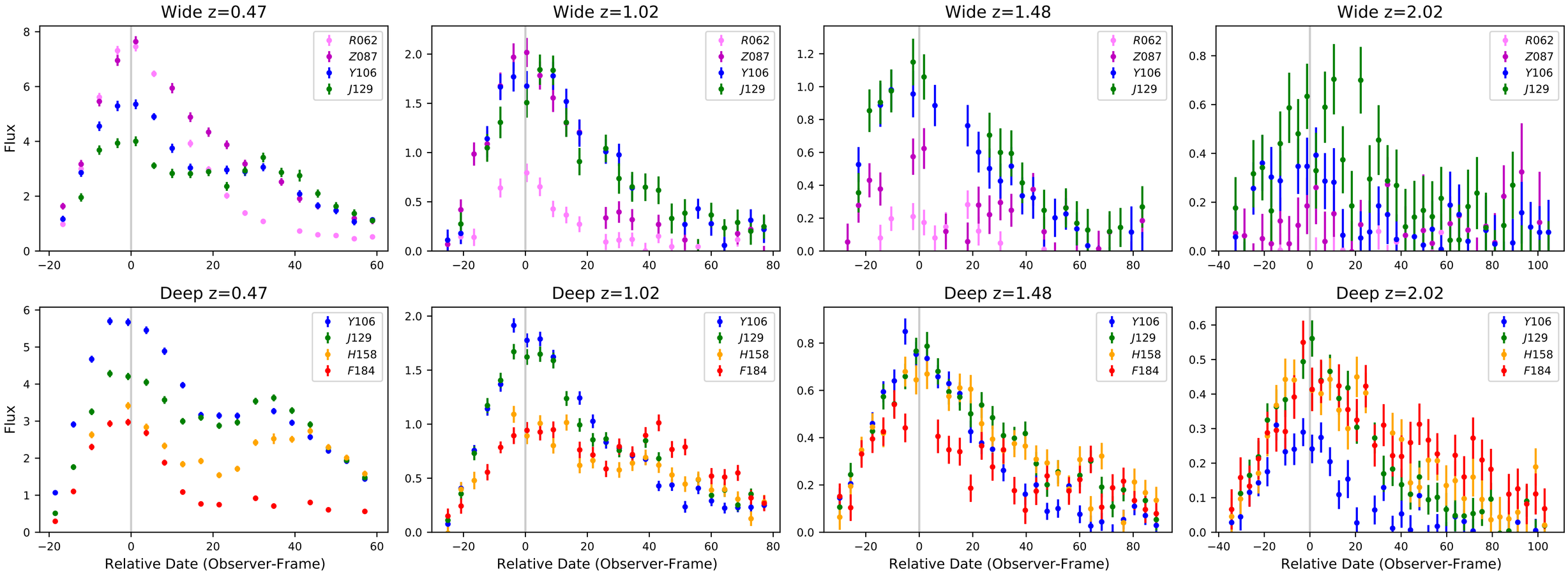
1. Target redshift where mean SN Ia at max get a S/N=10 per exposure.

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

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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						
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Single-exposure limiting magnitude			26.7	26.6	26.5	26.7
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- ~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

Number of SN Ia

- 12,000 SNe Ia
  - And about the same number of CC SNe!
- 7,000 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.