# High-Latitude Time Domain Survey Definition Committee Update

Brad Cenko (NASA/GSFC) &
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• NASA GODDARD SPACE FLIGHT CENTER • JET PROPULSION LABORATORY •
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• CENTRE NATIONAL d'ÉTUDES SPATIALES • MAX PLANCK INSTITUTE FOR ASTRONOMY •

Roman Virtual Town Hall
8/28/2024

# HLTDS Definition Committee Members

Brad Cenko
(NASA/GSFC, Co-chair)

Masao Sako
(Penn, Co-chair)

Alessandra Corsi
(Texas Tech)

Michael Fasnaugh
(Texas Tech)

Sebastian Gomez
(STScI)

Rebekah Hounsell
(NASA/GSFC, SN PIT)

Takashi Moriya
(NAOJ)

Gordon Richards
(Drexel)

Russell Ryan
(STScI)

Schuyler van Dyk
(IPAC, RAPID PIT)

V. Ashley Villar
(Harvard)

Solar system liaisons: Susan Benecchi (PSI) & Rosemary Pike (CfA)

# Roman Observational Program

Large Core Community Surveys (CCS) *majority of observing time*

**Dark Energy**

**High-latitude wide area survey**
Enables Weak Lensing, Baryon Acoustic Oscillation cosmology investigations

**High-latitude time-domain survey**
Enables Supernovae Ia cosmology investigations

**Exoplanets**

**Galactic Bulge time-domain survey**
Enables exoplanet microlensing investigations

**Astrophysics with Wide Field IR Surveys**

General Astrophysics Surveys (GAS) *at least 25% of observing time*

- Include **Galactic Plane Survey** (Early Definition Community Call)
- Primarily selected via a peer-review process
- First call for proposals Oct 2025

Archival Investigations

- All data will be public immediately
- Anticipated to be main component of community involvement

Also Coronagraph Technology Demonstration Observations

# Our “Dual Mandate”

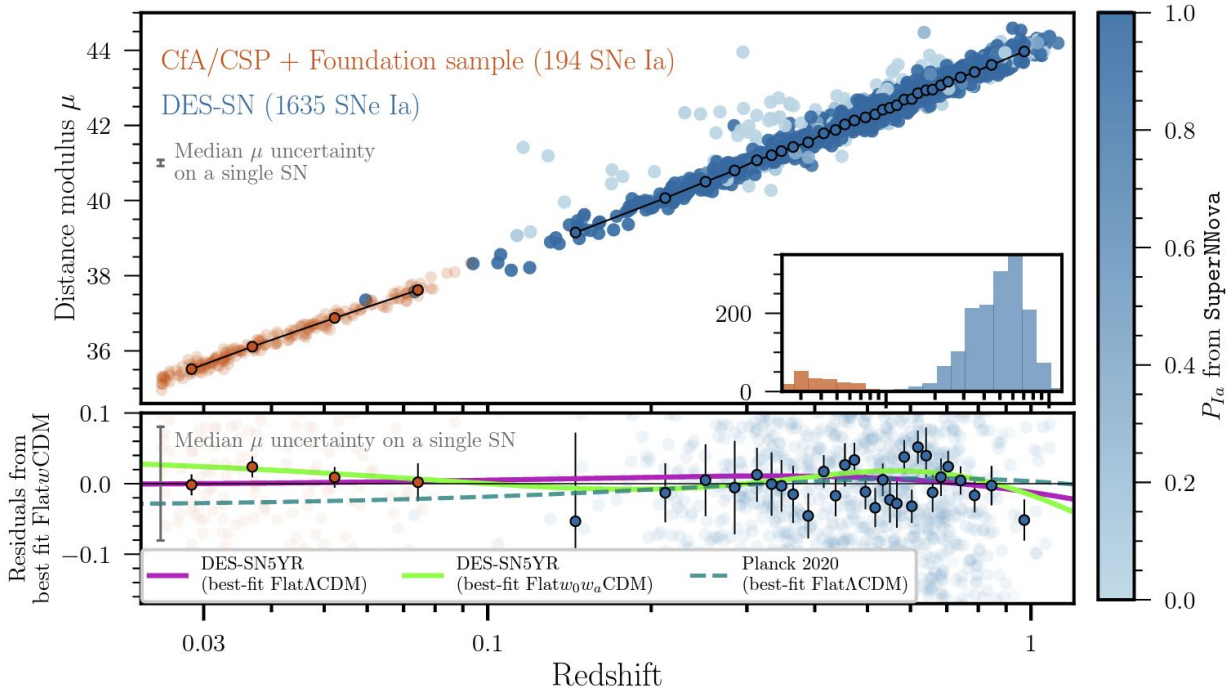
The charge of the HLTDS Core Community Survey Committee is to recommend an implementation for the HLTDS that:

- Meets the scientific requirements related to type Ia supernova cosmology
- **AND** maximizes the broader scientific return for the entire Roman community

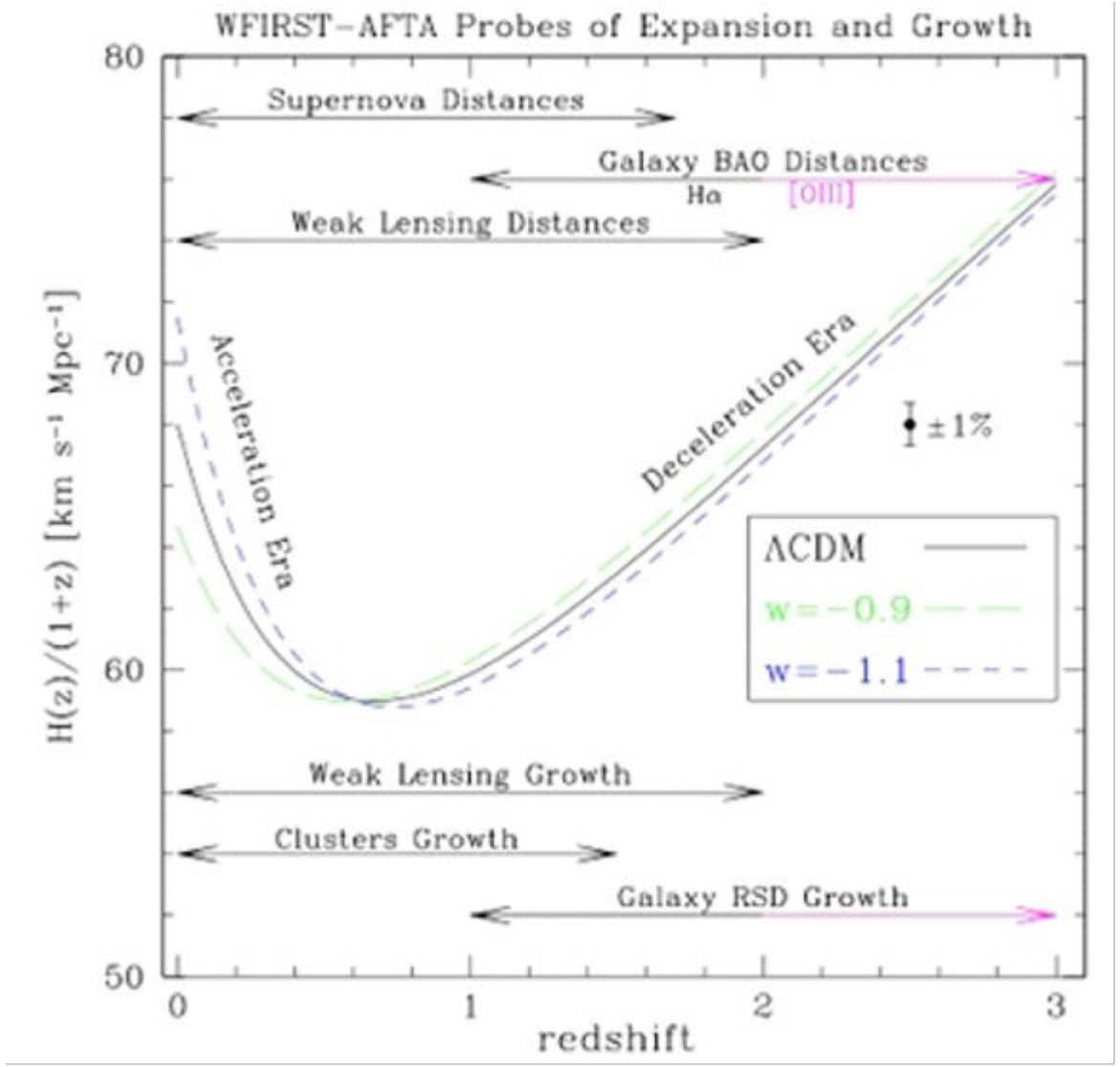
We are your voice to the Roman project!


Engineering a “soft landing” for the HLTDS

# HLTDS Science Goal: SN Ia Cosmology




DES 2024



# HLTDS Science Requirements

**SN 2.0.1:** RST shall be capable of executing a supernova Type Ia survey that can, if allocated 0.5 years of total observing time, achieve constraints that yield

$$\mathrm{FoM_{SN}} \geq \mathrm{FoM_{SN,Ref}} / 2 = 325,$$

$$\mathrm{FoM} = \det [\mathrm{C}(w0, wa)]^{-1/2}$$

where C is the covariance matrix for w0 and wa. This definition is equivalent in the limit of Gaussian uncertainties, is more readily computed, and has since been widely adopted. Larger FoMs indicate greater accuracy. For the planning purposes, the FoM is a reasonable choice.

$\mathrm{FoM_{SN,Ref}}$ is computed for a reference survey neglecting systematic uncertainties.

# HLTDS Science Requirements

**SN 2.0.2:** RST shall enable a supernova survey that can measure the distance modulus $\mu(z)$ over the redshift range $0.2 \leq z \leq 1.7$, with observational noise contributions to the uncertainty $\sigma\mu \leq 0.02$ per $\Delta z = 0.1$ bin.

**SN 2.0.3:** RST shall enable a SN survey to observe more than 100 SNe-Ia per $\Delta z = 0.1$ bin.

**SN 2.0.4:** RST shall enable a SN survey with the systematic bias in redshift, $\sigma_z / (1 + z)$, less than the values in the following table:

| Z | 0.3 | 0.6 | 0.9 | 1.2 | 1.5 |
|---|---|---|---|---|---|
| $\sigma_z / (1+z)$ | 0.001 | 0.0016 | 0.0019 | 0.0022 | 0.0024 |

# HLTDS Mission Requirements

**SN 2.3.2:** RST shall be able to observe supernovae in fields with low Galactic extinction, such that E(B-V) $\leq$ 0.02 over 90% of the area, and low zodiacal light background. Here, Galactic extinction is that defined by Schlafly & Finkbeiner 2011 (ApJ 737, 103).

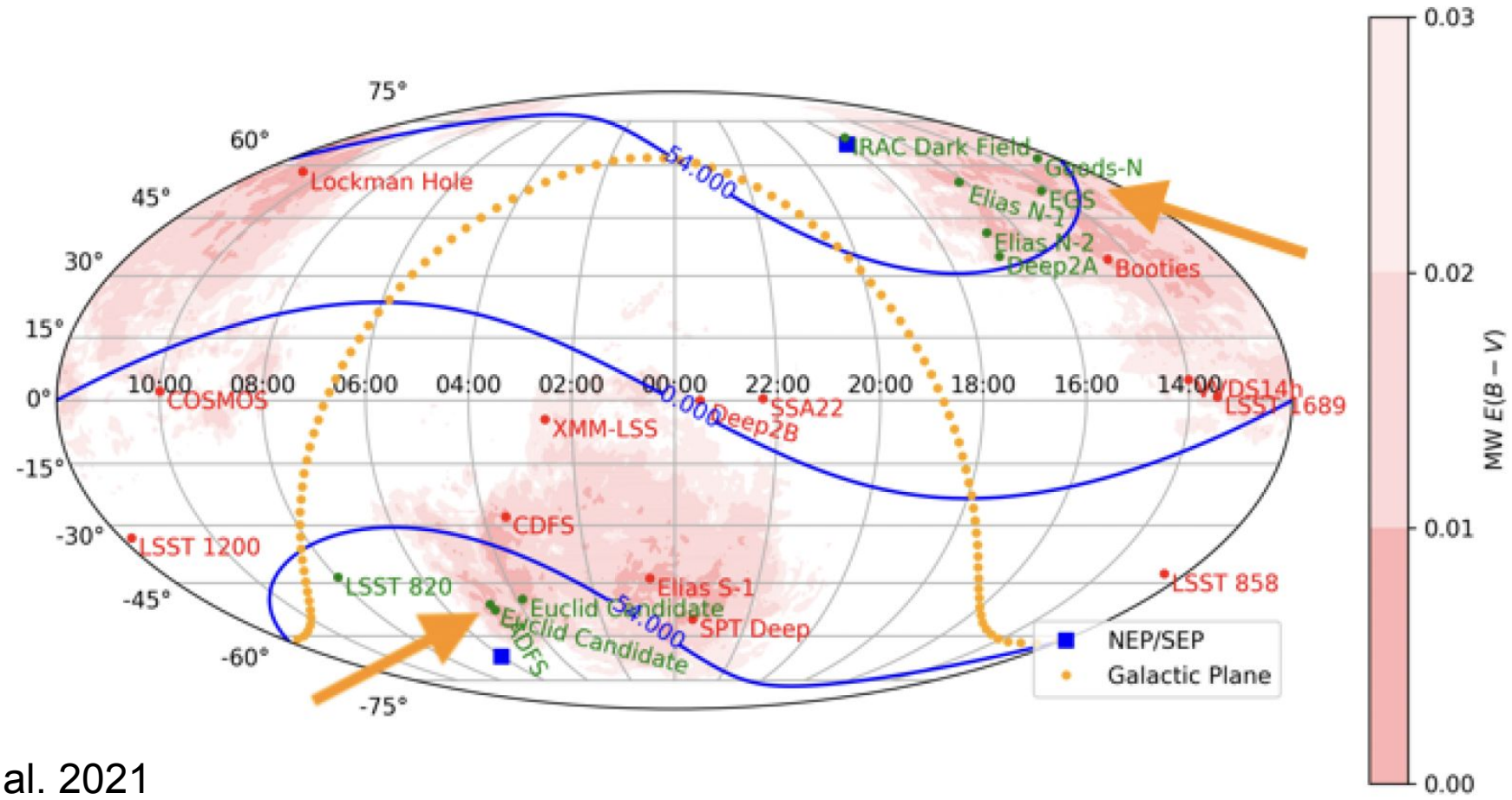
**SN 2.3.3:** The RST field of regard shall be large enough to provide a continuous viewing zone (CVZ) that encompasses regions of the sky suitable for observing supernovae.

**SN 2.3.4:** RST shall enable a SN survey that monitors the SN fields with an uninterrupted sampling cadence $\leq$ 5 days.

**SN 2.3.5:** RST shall have the capability of providing raw images of SN fields in up to six filters that span roughly 0.5 – 2.0 μm.

# Reference HLTDS Design

6 months of observations conducted over a 2 year period (nominally mid-mission)




Rose et al. 2021

# Reference HLTDS Design

Reference observing strategy: 30 hour visits every 5 days

| 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** |

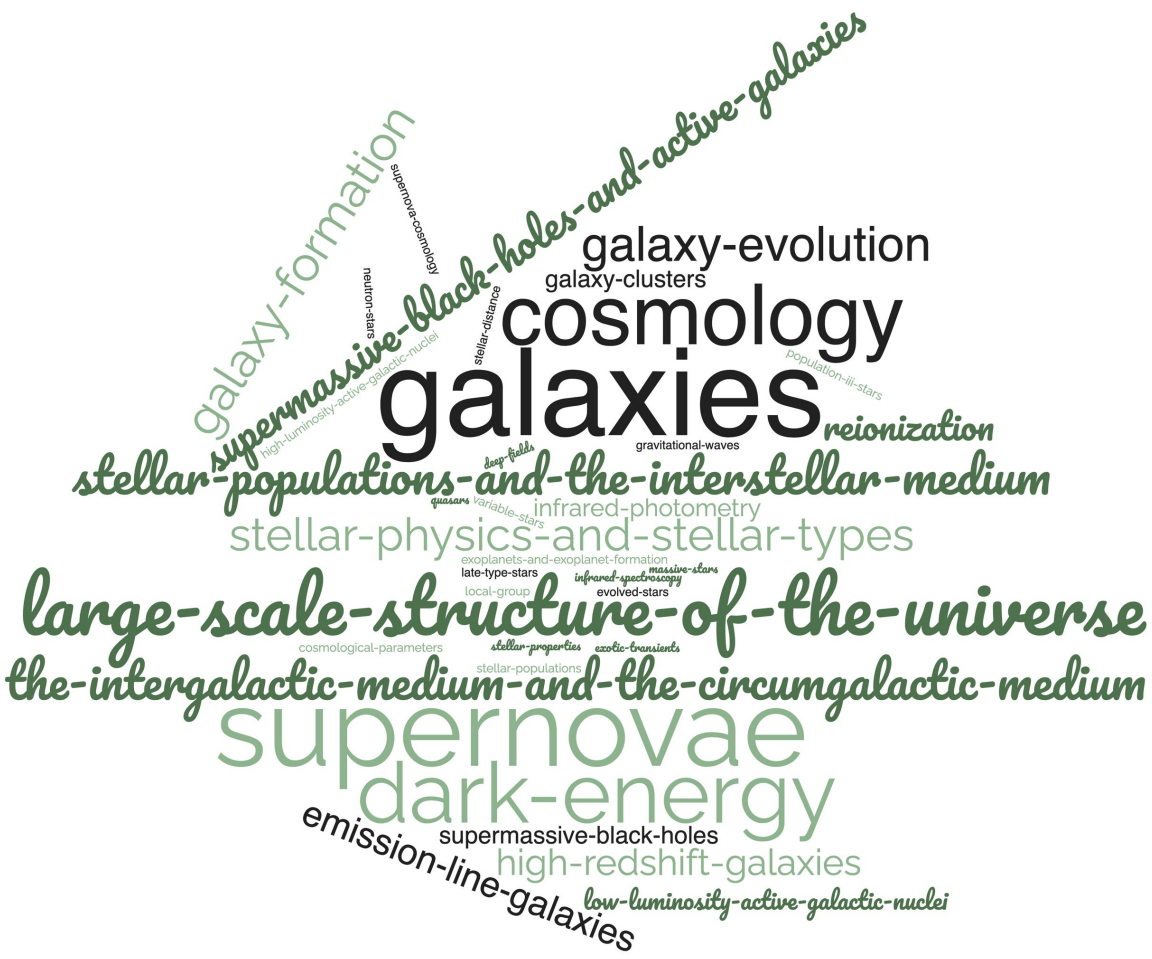
*$z_{\rm targ}$ denotes the redshift where the average SN Ia at peak is observed with S/N=10 per exposure for imaging, and S/N=25 for spectroscopy.

**Table 1.** A High-latitude Time Domain reference survey.

Rose et al. 2021

# Community Input on Science Enhancements

- Roman-organized (2023)
  - White Paper Pitches
  - White Papers
  - White Paper Updates
- IPAC Roman Meeting (July 2024)
  - Public Presentation
  - Working Group Meetings
- STRIDE Working Group (August 2024)
- Community Forum Update (August/September 2024)

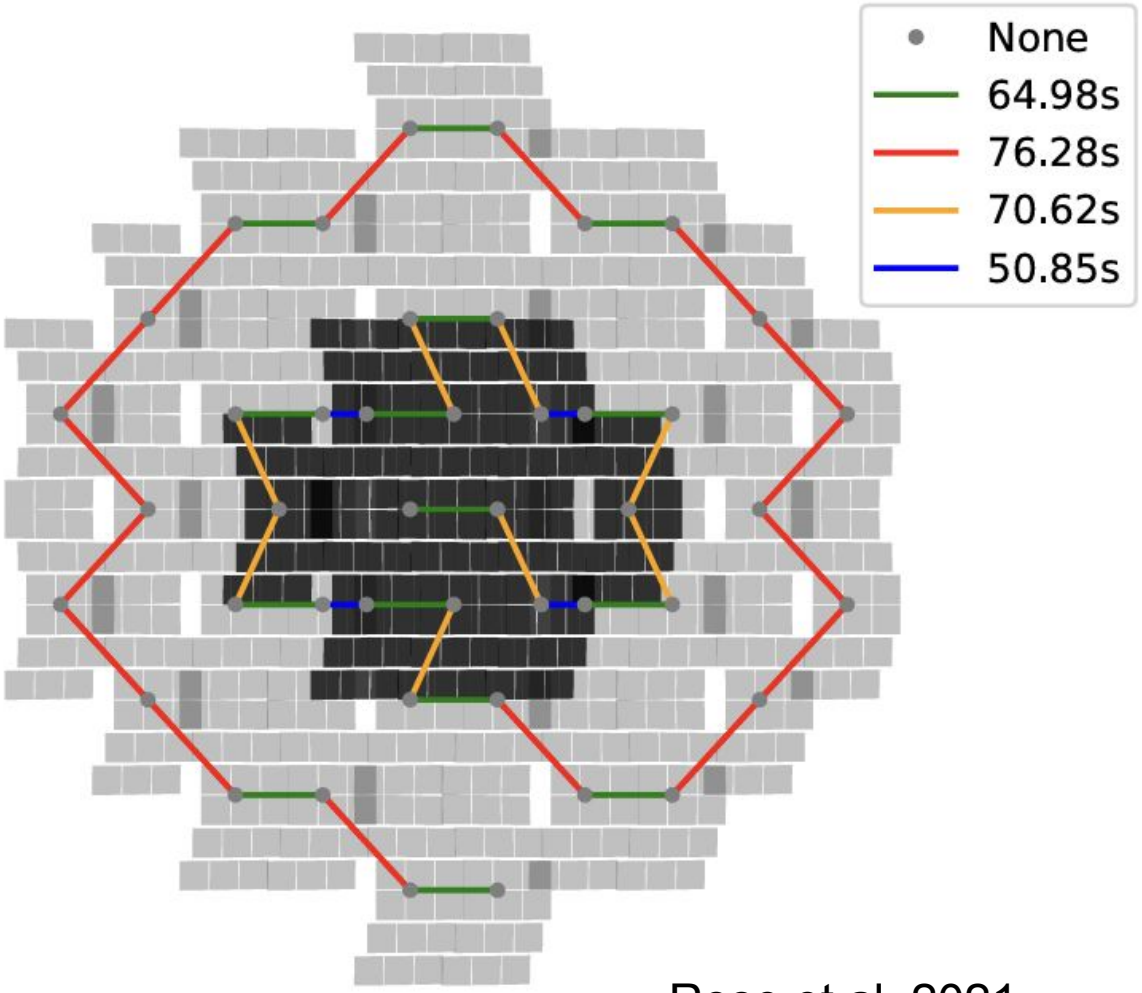


# Working Groups

- Cadence / Filters / Depth / Area
  - Investigate trade space to meet dual mandates (SNe Ia and community science)
- Spectroscopy Fraction
  - Fraction of survey devoted to prism spectroscopy
- Field Selection
  - Visibility, Extant/planned complementary data sets
- Survey Extensions
  - Reference images, pre/post extension
- Leveraging Complementary Data Sets
  - Roman-supported Subaru time, Rubin overlap, etc.

# Cadence / Filters / Depth / Area

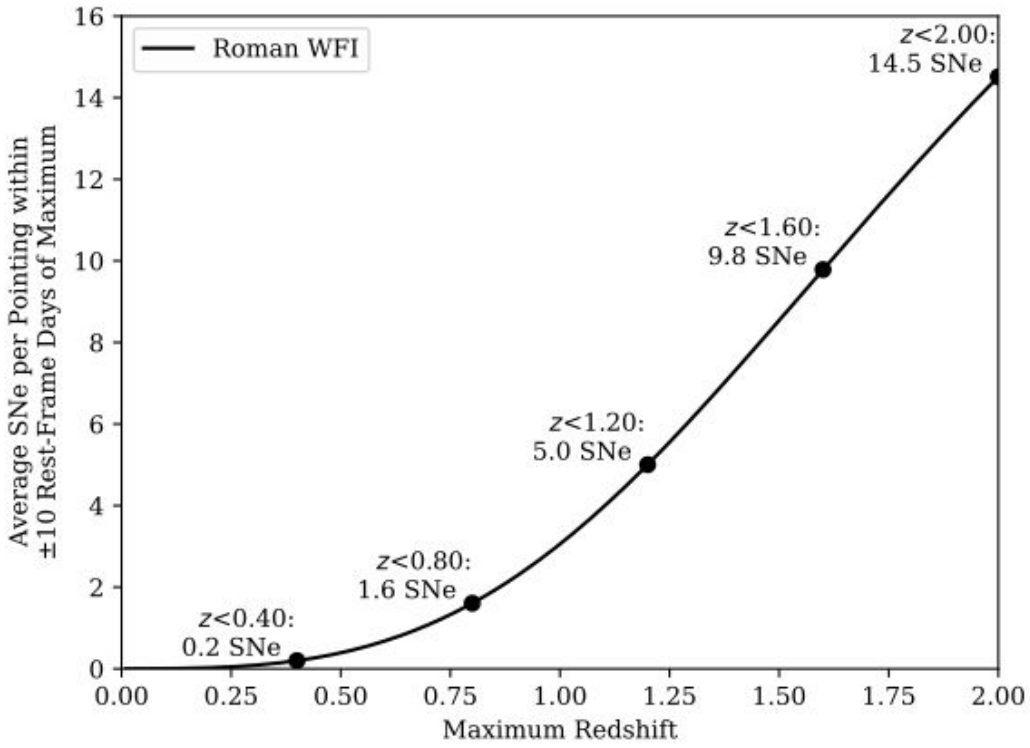
- Overarching approach:
  - Identify range of survey designs that meet SN Ia cosmology requirements
  - Prioritize amongst those that enable broadest range of community science
- Start with acceptable cadences, then work towards filters / depth / area optimization
  - Cadence recommendations most strongly constrain the range of science possible




Rose et al. 2021

# Complication #1: Complementary Data

- Figure of merit calculation depends on assumptions of complementary (lower redshift) SNe Ia
  - Nearby ($z < 0.1$) sample assumed to anchor Hubble diagram
  - Rubin sample (intermediate $z$) not currently available to entire Roman community
- Survey Design Implications
  - Drives towards much larger area and *r*-band to discover sufficient events at $z \sim 0.3$
- Our Approach
  - Unanimous desire for Roman to focus on unique (NIR and high-$z$) science
  - Work with Roman project to attempt to negotiate public release of relevant Rubin data sets
  - Recommend distinct surveys depending on Rubin data availability



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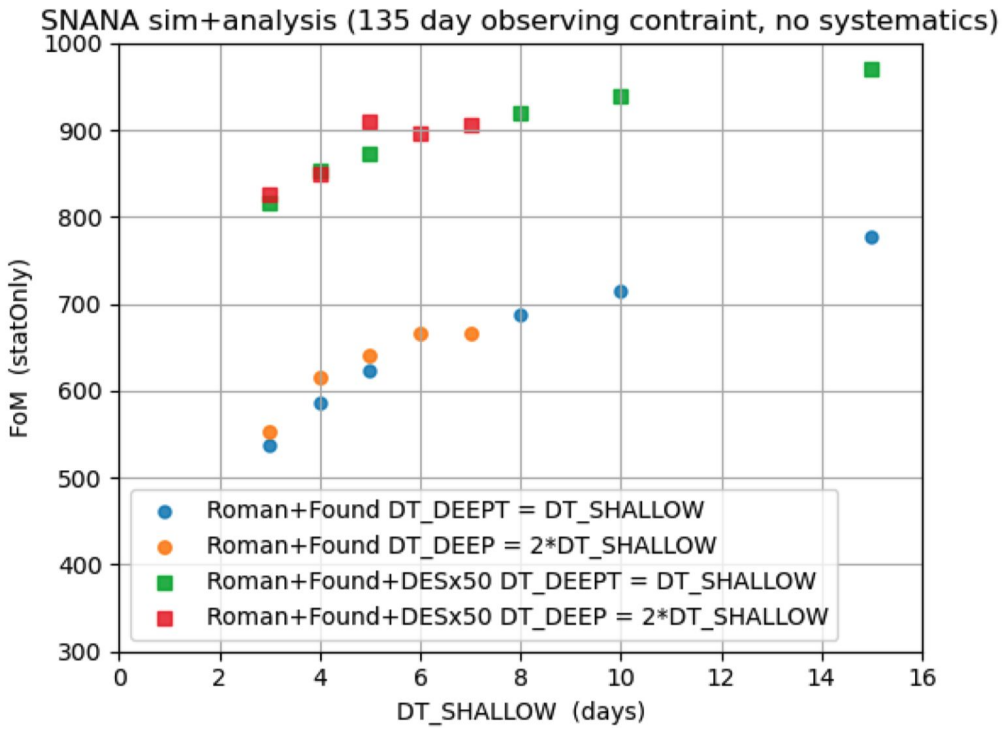
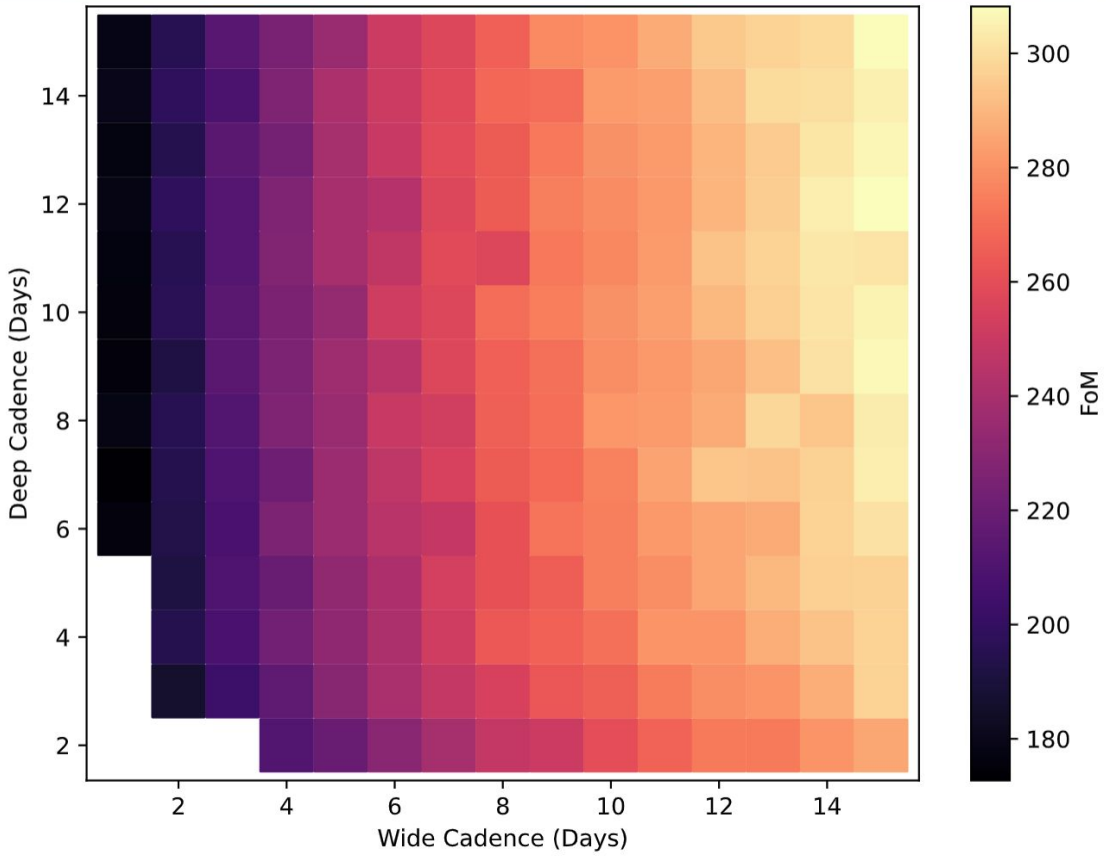


# Cadence Results

- SNe Ia cosmology requires cadences ranging from ~ 5-15 days
  - Shorter cadences have no benefit for cosmology analysis (and result in correspondingly reduced survey area/depth)
  - Longer cadences lose ability to match SN Ia templates
- Cannot accommodate high cadence (e.g., kilonova / “fast” transients)
  - Opportunity to augment with Guest Investigator program
- Considering variations to the cadence to avoid aliasing for periodic sources and fill out AGN structure functions.

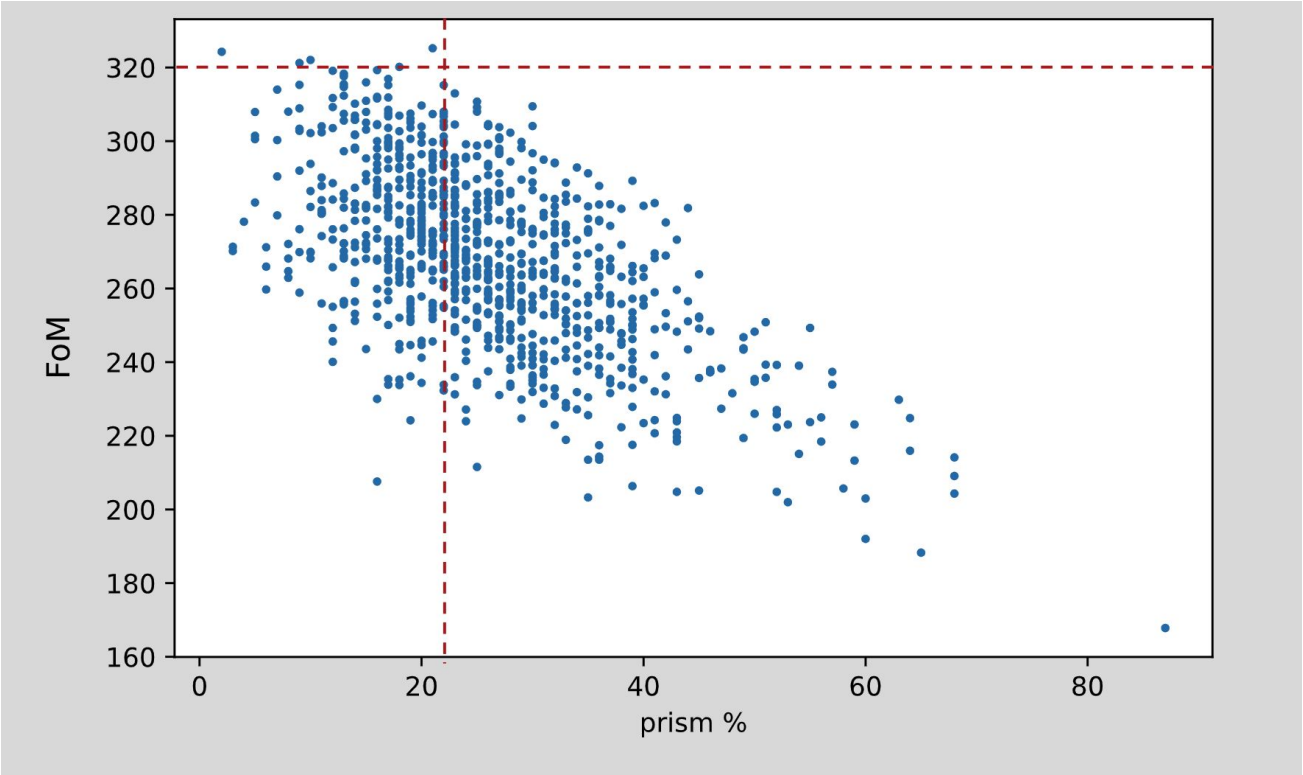


# Filters / Depth / Area

- Currently exploring trade space in filter / depth / area
- Preliminary results:
  - “Wide” and “Deep” tiers favored (no strong advantage to adding “Medium” tier)
  - At least 4 bands in each tier for photometric redshifts and template matching
  - Interlacing filters (e.g., rJ in epoch 1, zH in epoch 2) generally provides sufficient temporal coverage and increases survey area

# Spectroscopy

- For SN Ia cosmology (e.g., twinning), prism spectra have limited benefit
  - Likely prism fraction of survey time will be <~ 20%
- For community science, some spectra beneficial for classification, training, etc., and highly unique to Roman
  - Currently exploring spectroscopy fractions ~ 10-30% of survey time.

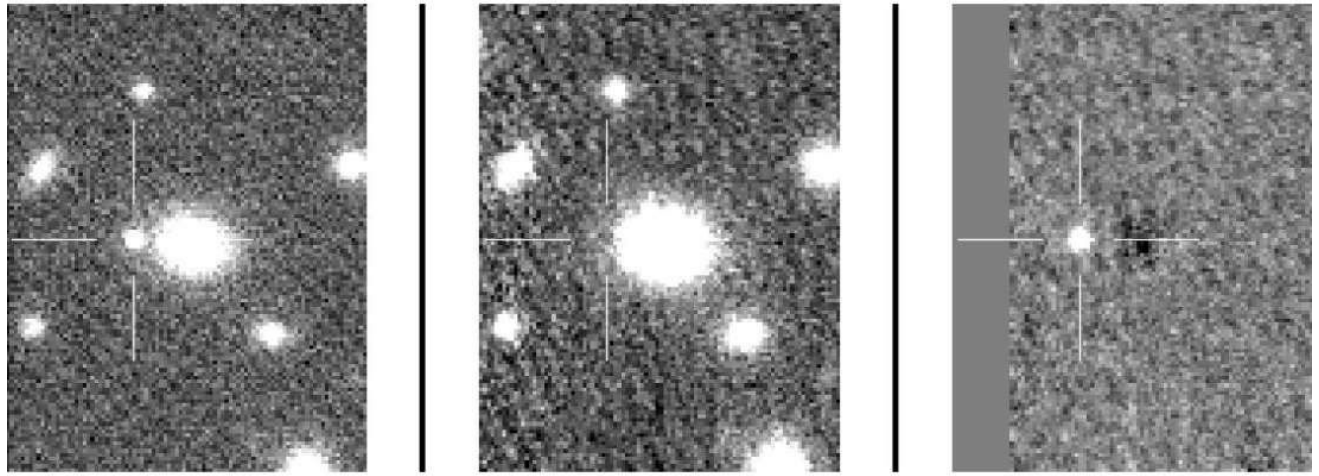


# Field Selection

- Strong motivations for splitting survey fields into two areas, one in Northern and one in Southern hemisphere
  - Cross-validation / jackknife testing of cosmology results
  - Continuous ground-based visibility for follow-up
  - Complementary data sets (Rubin in South, Subaru in North)
- Currently preferred field areas
  - South: Euclid Deep Field (also Rubin Deep Drilling Field)
  - North: ELIAS-N1 (though others still under consideration)
- Still exploring exact apportionment in each hemisphere
  - E.g., preferentially split wide and deep tiers into different hemispheres
  - Recommendations dependent on allocation of Subaru data

# Survey Extensions

- Reference Imaging
  - Deep reference imaging obtained **prior** to survey commencement necessary to enable real-time science
  - Should be collected in a way to allow testing of pipelines, follow-up, etc.
- Expanded Baseline
  - Roman uniquely capable of discovering high-redshift transients
  - Many (TDEs, pair instability SNe, AGN) will have extremely long time scales that would benefit from extending survey baseline
- K-band observations
- Currently under consideration:
  - Under- vs. In- vs. Over-guide
  - Compatibility with other core community surveys



# Leveraging Complementary Data Sets

- 100 nights of Subaru time have been reserved for joint Roman science
- For the HLTDS, these could be critical for:
  - Host galaxy spectroscopy
  - Spectral transient classification / characterization
  - Concurrent imaging of HLTDS fields
- Currently attempting to understand constraints (e.g., PFS availability, overall demand for Subaru time) to inform HLTDS field selection recommendations

Subaru Telescope (Mauna Kea, HI)

# HLTDS Definition Committee: Where we stand

- **Feb 2024:** Kick-off meeting
- **Mar 2024:** Design & organize review process for white papers & science pitches
- **Apr-Jun 2024:** Reviews, rankings & discussion of science ideas
- **Jul-Aug 2024:** Report to community for feedback and iteration.
  - Jul 9-12: Roman Science Conference, Pasadena, CA
  - **Aug 28: Virtual Town Hall (we are here!)**
- **Sep 2024:** Refine trade studies, simulations and develop implementation plans
- **Oct 2024:** Preview results of survey definitions to community for feedback
- **Nov 2024:** Report due to Roman project

# Roman HLTDS: Let us know your thoughts!

Questionnaire:

https://forms.gle/4UogRf4KS2RkADHY7

Via email to the committee co-chairs:
brad.cenko@nasa.gov,
masao@sas.upenn.edu