Rubin Observatory Cadence Strategy: Science Drivers and Observing Trade-offs (2025–2035)

(see document PSTN-056)

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(To make recommendations to Rubin)
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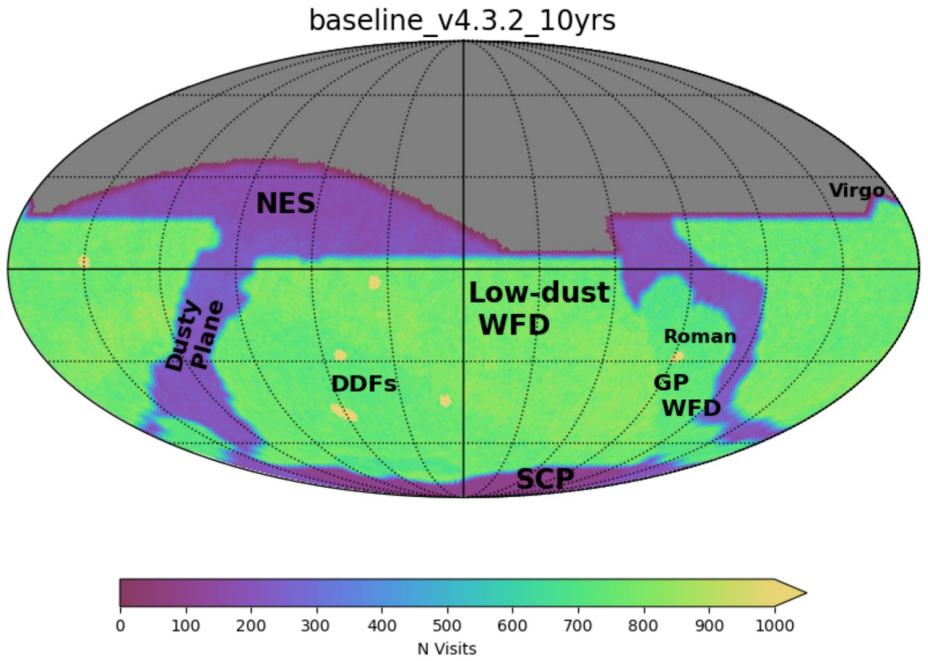
1: Introduction

- **Rubin Observatory & LSST**: Mapping the Southern Sky for 10 years
- **Main science pillars**: Cosmology, Transients, Galaxy, Solar System
- **Cadence = strategy for how and when the sky is observed**
  - How to distribute 2 millions of visits over 18000 deg^2 southern sky over time for next 10 years
  - Choice of preferred bands according the science cases
  - Trade-off among the different science-cases
- **How this is achieved:**
  - Simulations of different observation plans and evaluation with different science metrics (MAF)
  - Science collaborations/SCOC check the metrics results and make propositions
- **Annual SCOC workshop 6 & 7 may 2025**
  - **2 French highlighted presentations:**
    - SN1a : Phillipe Gris
    - Micro/Nano-Survey on molecular H_2 detection by scintillation (% level signal source variations) to detect Dark Matter in our galaxy : Marc Moniez

2: Overview of LSST Survey Components

- Cadence version v4 (in 2025)
- 2 10^6 visits / 10 years
- **Wide-Fast-Deep (WFD): ~83% of total time :** weak lensing, galaxy evolution, AGN demographics, Milky Way structure
  - Low dust regions : 17800°² (static cosmology)
  - Galaxy : MW + LMC + SMC + SCP: 2000°² (MW science, micro-lensing & Dwarf Galaxies discovery)
  - North Ecliptic Spur (Solar System Science)
- **Deep Drilling Fields (DDFs): ~7% of time : calibration & extragalactic transients**
- **Mini-surveys (3%), Nano survey (0.3%) and special programs**
  - Near sun NEO twilight (Y1)
  - Northern strip survey (Y1)
  - Galactic plane pencil beam (nano-survey)
  - other (after Y1)
- **Target of Opportunity (ToO) 3%**
  - GW follow-up (85% of ToO) (Ligo-Virgo-Kagra O5 run in 2028)
  - Neutrinos counterpart (from SN in MW) (5% of ToO)
  - Asteroids (10% of ToO)



low- dust mostly for DESC – Static cosmology

Band	u	g	r	i	z	y	**Total**
Visits	54	66	174	176	158	155	≈ 783

g,r,I,z in carousel and u,y swapping according moon phase

3: The Deep Drilling Fields

Smaller fields observed much more deeply and more frequently

Static Science (co-added): faint sources, photo-z calibration, etc.

- reach at least 10x WFD depth

(u:520, g:630, r:1670, i:1670, z:1500, y:1480 visits)

- AGN, Galaxies, DESC desire extra u-band depth

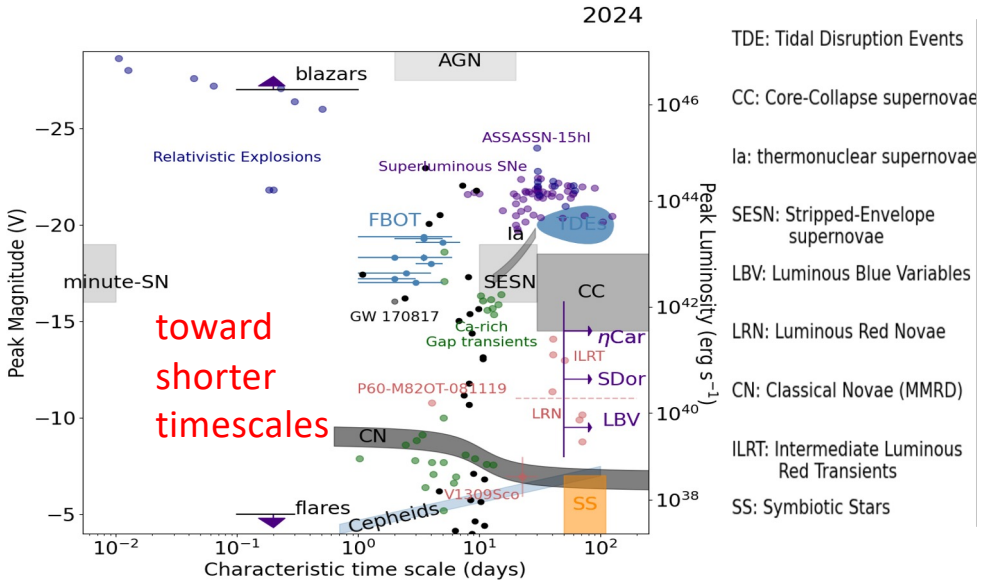
(e.g., z ~ 3 dropout galaxies)

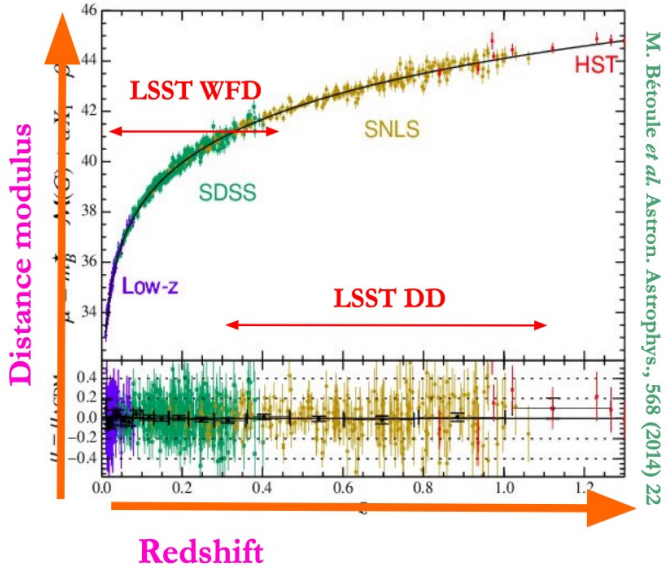
- AGN want to hit specific coadded depths:

(u:28.3, gri:28.5, z:27.9, y:26.5 AB mag)

Time-Domain Science: SN Ia cosmology, AGN reverb/ monitoring, extragalactic transients

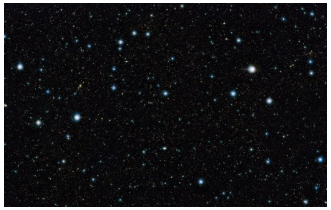
- AGN want every night or every-other-night sampling in griz (and u/y as possible)
- DESC want high nightly depth (many visits) seasons for high-redshift SN Ia (z >~ 0.7)

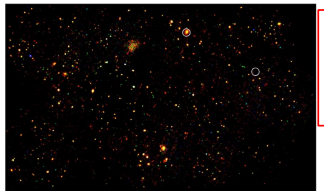




4: The DDFs (next)

	ELAISS1	XMM_LSS	ECDFS	COSMOS	EDFS_a	EDFS_b
RA	9.45	35.71	53.12	150.10	58.90	63.60
Dec	-44.00	-4.75	-28.10	2.18	-49.32	-47.60



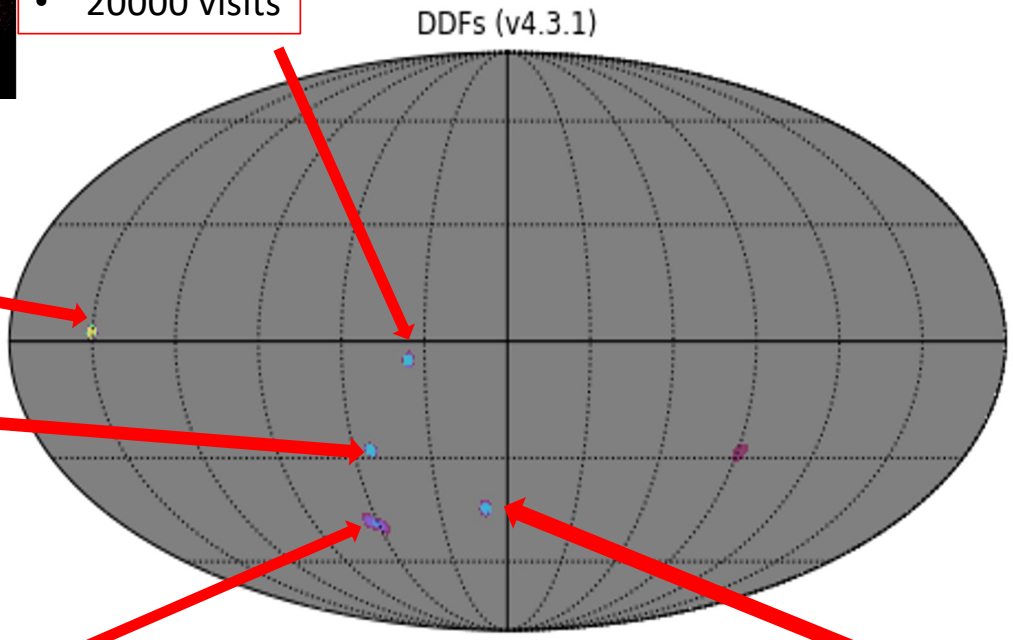


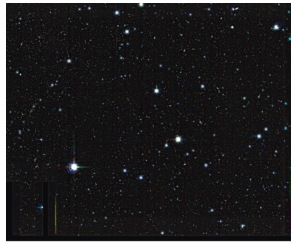
XMM-LSS
- 20000 visits

COSMOS
- 40000 visits

Extended Chandra Deep Field South
- 20000 visits

Euclid Deep South
2 pointed separated regions
- total 20000 visits

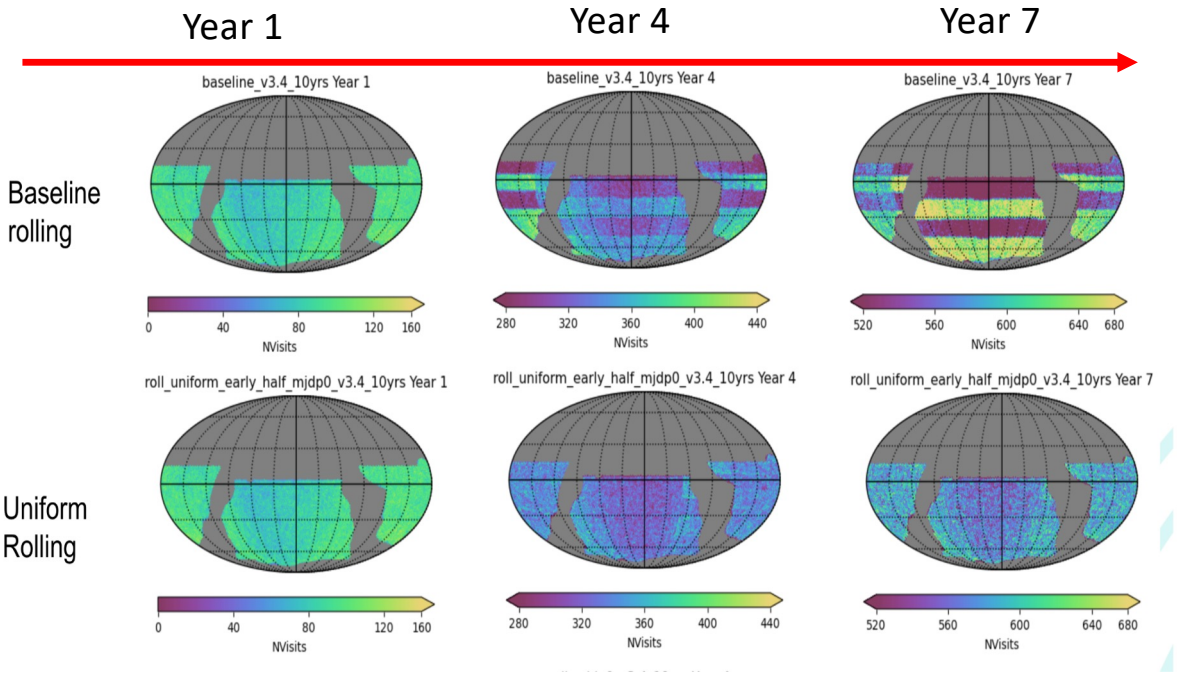




ELAIS-S1
- 20000 visits

5: Rolling vs. Uniform Cadence

- **Uniform**: consistent visits rate across the sky
- **Rolling**: focus on part of the sky for 1–2 years, then shift
- Pros/cons:
  - Rolling boosts transient sampling (SNe Ia,AGN)
  - Uniform needed for galaxy/cosmic shear uniformity



- Proposition to have a New Uniform Rolling cadence (instead of a 4 strips cadence)
- Better for the Uniformity for DESC static science
- Requirement : Release of uniform data products for static cosmology
  - Y2, Y5 and Y8

- ➢ No rolling at early phases
- ➢ No rolling for galactic &Ecliptic regions
- ➢ Visits distribution:

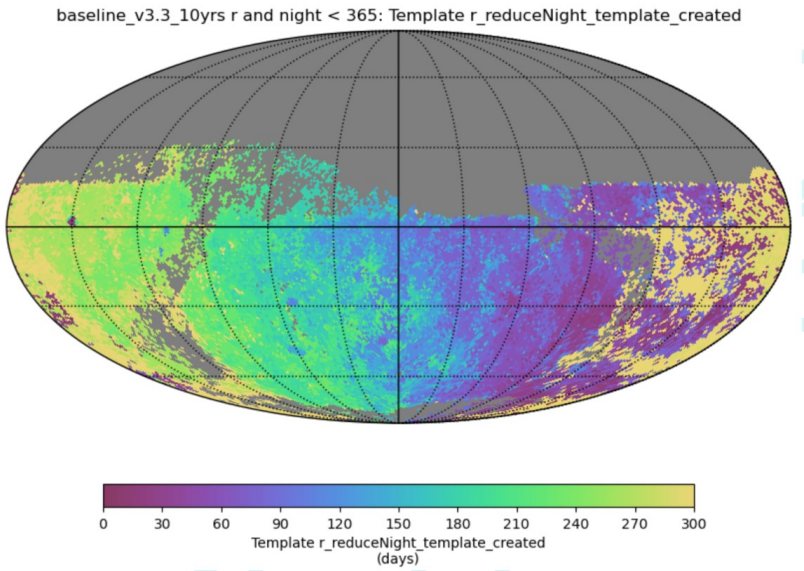
  Some regions receive up to **125 visits per season** during "high" seasons and as few as **25** in "low" seasons.

  Over the 10-year survey, each region cycles through **3 high/low seasons**, with "uniform" seasons in between

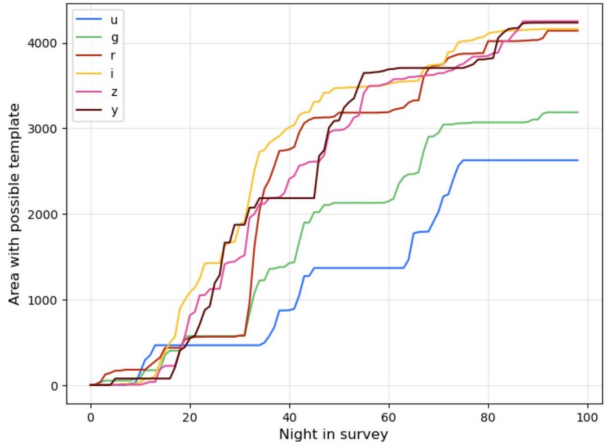
6: Image Templates & DIA

- Transients detection requires **difference imaging**
- Need **template images** built from stacked observations
- Templates limit early alert capabilities

Coadded templates generated every night in DDF:
- very first alerts from DDFs
- updated Templates at month, years level

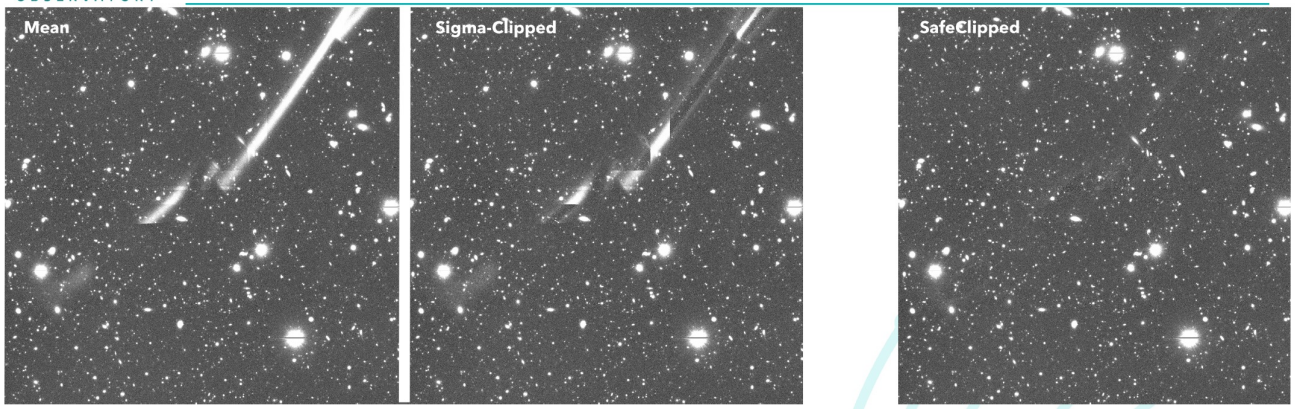


Build Template within less than 1 year

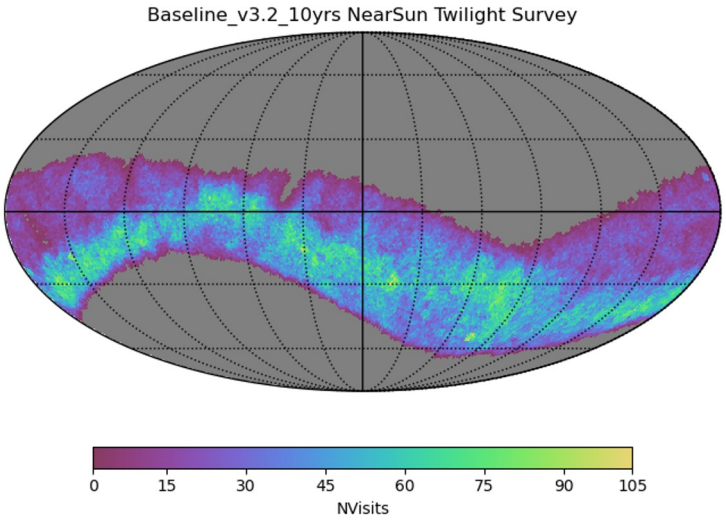


VERA C. RUBIN OBSERVATORY

Image differencing performance will be best with 3+ high SNR, good seeing images.



7. Micro-Surveys



a) <u>Rubin-LSST Mini-Survey: Near-Earth Objects (NEOs)</u>

➢ **Status : will be done**

Goal: Detect & track NEOs >140 m for planetary defence

Area: Focused on the ecliptic and low solar elongation regions

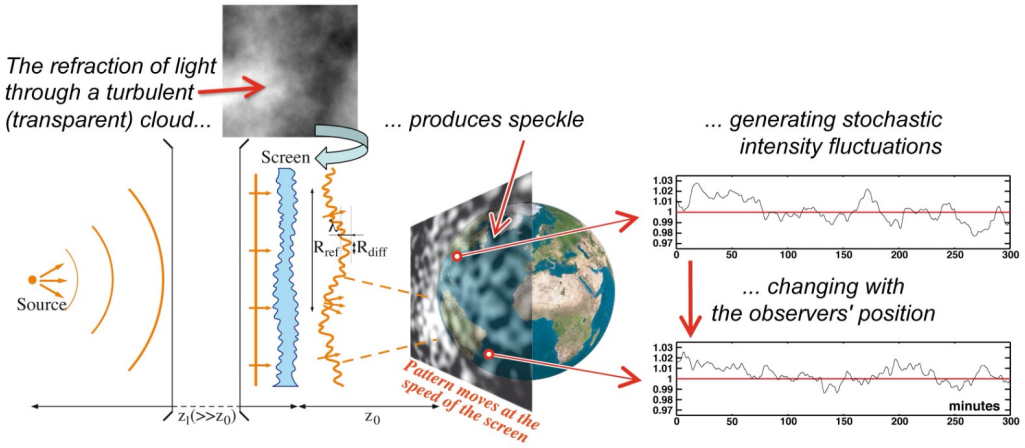
Cadence: 2–4 visits/night, repeated over 3–4 nights

Filters: Mainly *r*-band; short exposures to reduce trailing

Output:

Orbits, sizes, rotation, composition

Supports NEO cataloging & hazard assessment



b) <u>Galactic Scintillation from H_2 Molecular Clouds</u>

➢ **Status : proposed**

Definition: Intensity fluctuations in the light of distant sources by small-scale refractive structures in molecular clouds

Cause: Density inhomogeneities in cold H_2 clouds act like lenses

Effect:

Temporal variability (10 minutes), variations few %

Typical Conditions:

Requires compact sources

Most prominent at optical/infrared wavelengths

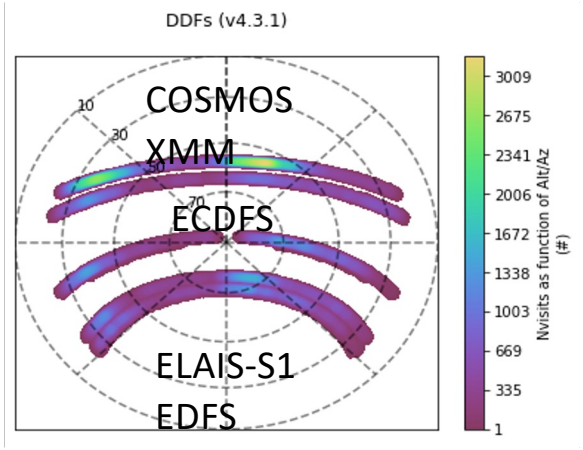
Scientific Use:

Constrain the presence of cold, dense baryonic matter (e.g. in dark matter studies)

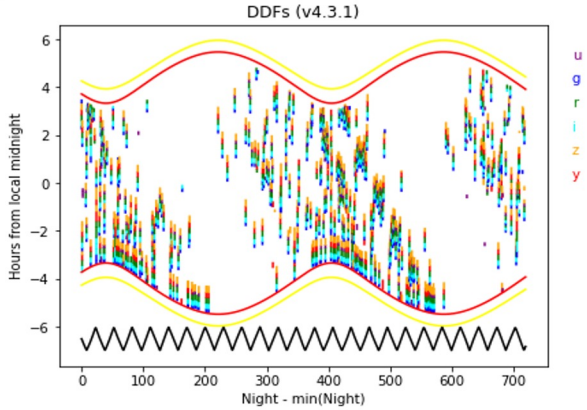
8: Ocean Strategy to be submitted soon (2025–2035)

- **Shallow high-cadence every year** for all DDFs
- **1 deep season per field** (3 for COSMOS)
- Designed to balance AGN and SN Ia science
- Compatible with Euclid/Roman synergies

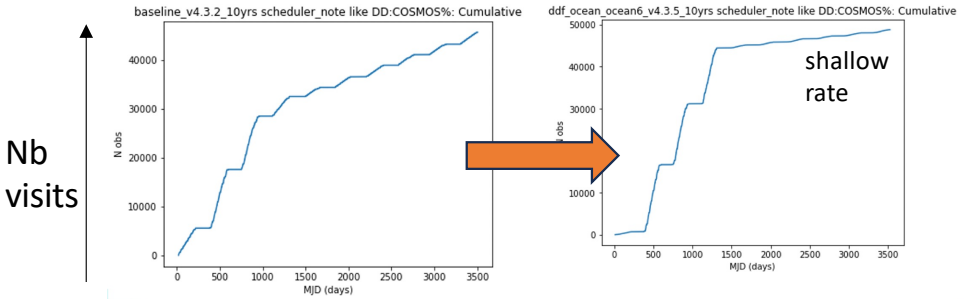
sky trajectories



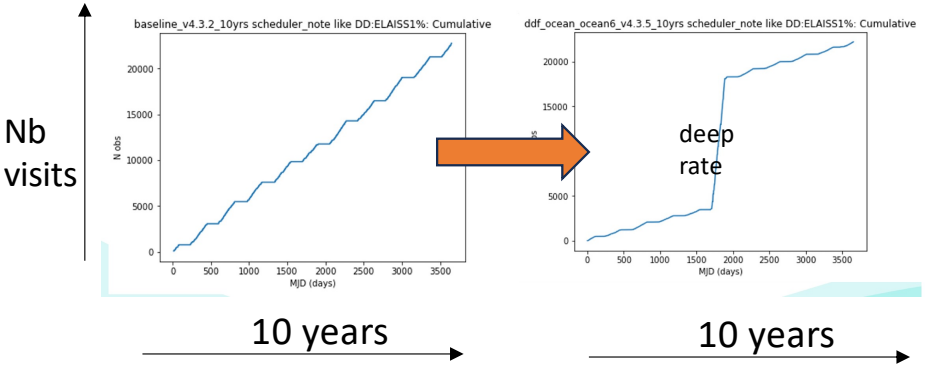
High seasons / Low seasons



COSMOS still 3 deep seasons early



Going from 10 uniform seasons, to 1 deep 9 shallow



9. Synergies between Rubin, Euclid, and Roman Observatories

1. Spatial Synergy – Sky Overlap

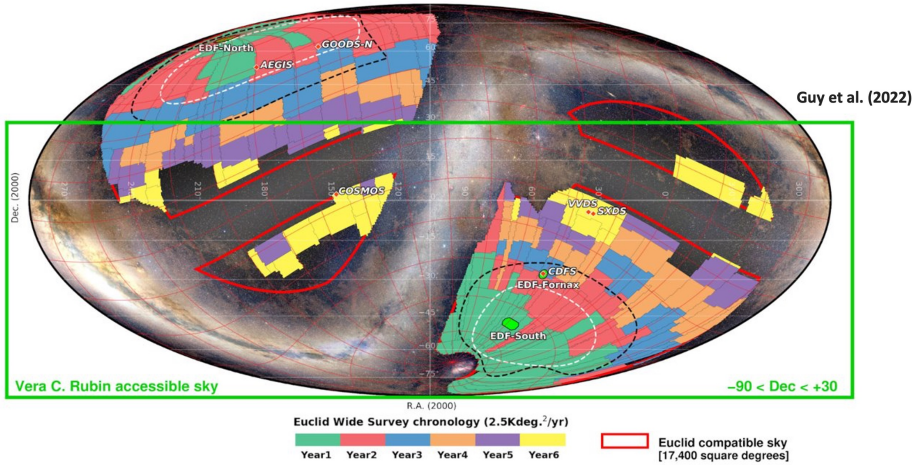
- **Maximize overlapping sky coverage**: ~15,000 deg² for Euclid, ~18,000 deg² for Rubin.
- Focus on shared regions like **COSMOS**, **XMM-LSS**, and **ELAIS-S1**.
- Rubin's Wide-Fast-Deep (WFD) survey and Deep Drilling Fields (DDF) align with Euclid/Roman deep fields.

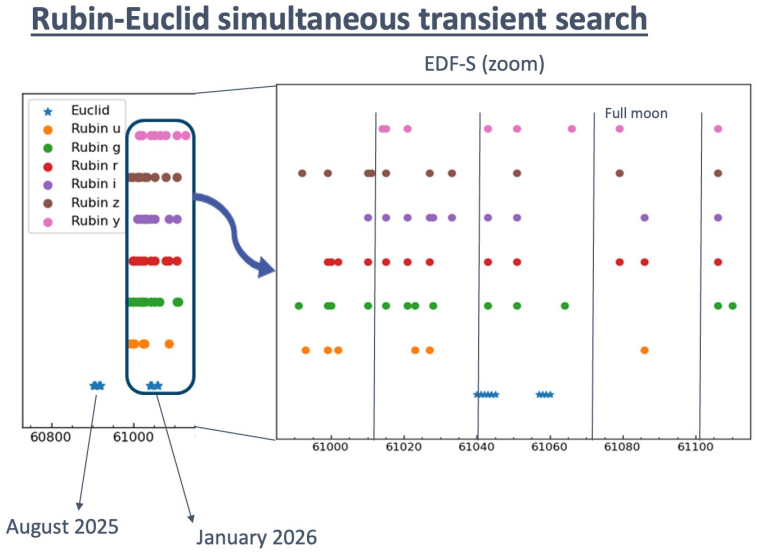
2. Temporal Synergy – Coordinated Cadence

- **Rubin can adjust observation cadence** to match Euclid/Roman timelines.
- Increase visit frequency during **Roman SN surveys** or **Euclid time windows**.
- Enables **dense light curves** and rapid follow-up of transients.

3. Rubin Cadence Strategy Implications

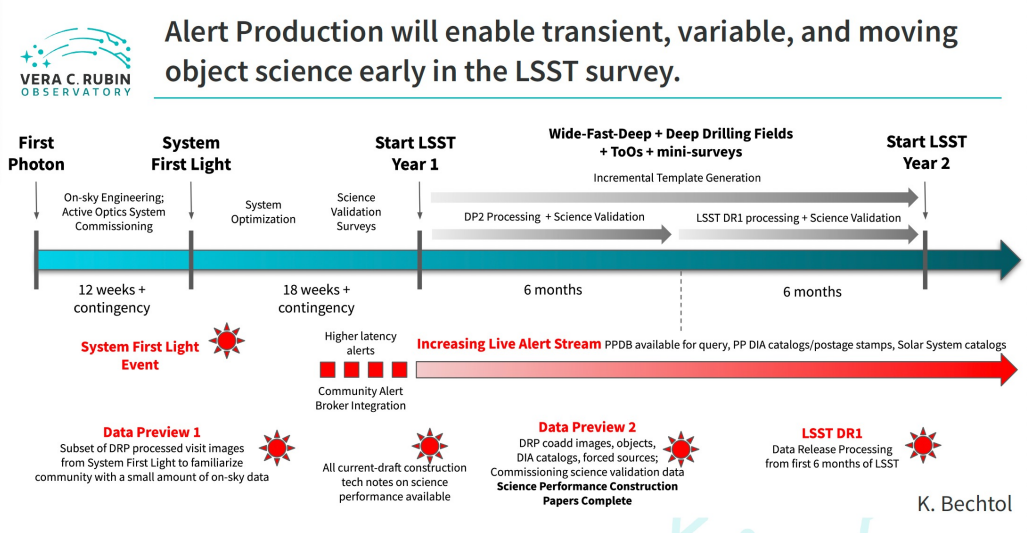
- Prioritize overlapping fields.
- Enhance cadence in DDFs aligned with Roman SN programs.
- Enable rolling cadence modes in sync with Euclid/Roman.





10. Rubin Observatory: Early Survey Strategy (2025–2026)

- **Commissioning Phase (until mid-2025)**
  - On-sky tests with LSSTCam
  - Gradual shift from engineering to regular observations
  - Optimization of system and scheduler (Feature Based Scheduler)
- **Pilot Survey (~mid-June 2025)**
  - Short nightly observations interleaved with engineering
  - Goal: test SV survey configurations and system readiness
- **Science Validation Surveys (SV, July–Sept 2025)**
  - Full rehearsal of survey operations over ≥30 nights
  - Two components:
    - **Deep**: ~60 deg² to 10-year WFD depth
    - **Wide**: ~1000 deg² to 1-year WFD depth
  - Enables: coadd tests, alert stream, template generation
- **Early Science Phase (from late 2025)**
  - Data reprocessed into **Data Preview 2 (DP2)**
  - Start of **public alerts** (tentative)
  - Early science with high-quality data & broad sky coverage
  - Smooth transition into full LSST operations

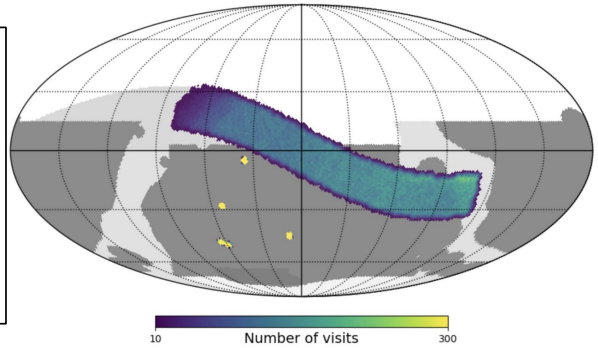


Science Validation Survey

Deep: LSST DDFs (total ~60 deg^2) in *ugrizy*

South Galactic cap DDFs visible in July-September (ELAIS_S1, XMM_LSS, ECDFS, and EDFSa + EDFSb)

Wide: LSST Year 1 WFD in *ugrizy* constrained to a region around the ecliptic, e.g., ±10 deg



11. Take away: Rubin-LSST Cadence Strategy

- **Cadence = balancing act** between multiple science goals
- **Rolling cadence (** time-domain)/**Uniform cadence(**static cosmology)
- **Recent DDF "Ocean Strategy"** ➔ better compromise (SN,AGN)
- **Coming soon : Early alert system and image template generation : Pilot survey + Science Validation + Full Survey start**
- **Combined observations with Euclid** scheduled
- **Technically : Feature Based Scheduler** implemented (score calculation in each field according features like seeing, airmass, Nvisit, visit-time-gap, moon, DDF/WFD strategy,…)
- **Improved efficiency :** Mirrors silver coated + 1 snap of ~30 s (instead of 2 x 15 s)
- **SCOC will continue during the whole Survey**
  - evaluation of performances & comparison with expectations
  - corrections / new propositions

The End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