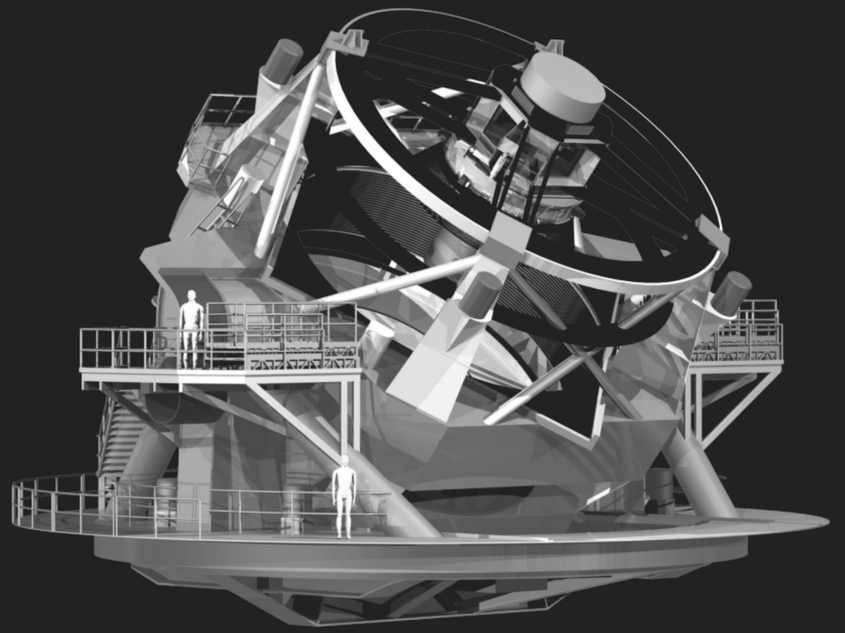


UPDATE ON THE

RUBIN OBSERVATORY

R. Street, Las Cumbres Observatory

TVS Microlensing Group: S. Khakpash, N. Abrams, M.P.G. Hundertmark, Y. Tsapras, M. Makler, A. Varela, E. Bachelet, M. Moniez, R. Di Stefano, with thanks to L. Jones, F. Bianco, P. Joachim

Supported by the NSF under Grant No. 2209852.

RUBIN OBSERVATORY

- Wide-field optical (ugrizy) survey telescope in Chile
- Now in commissioning phase

Aperture: 8.4m (effective: 6.423m)
Field of view: 9.6 sq.deg.
Pixel scale: 0.2 “/pixel

Limiting magnitudes in 30s:
u : 23.9 g : 25.0
r : 24.7 i : 24.0
z : 23.3 y : 22.1

[Ivezić, Z., et al., 2019, ApJ, 873, id.111]

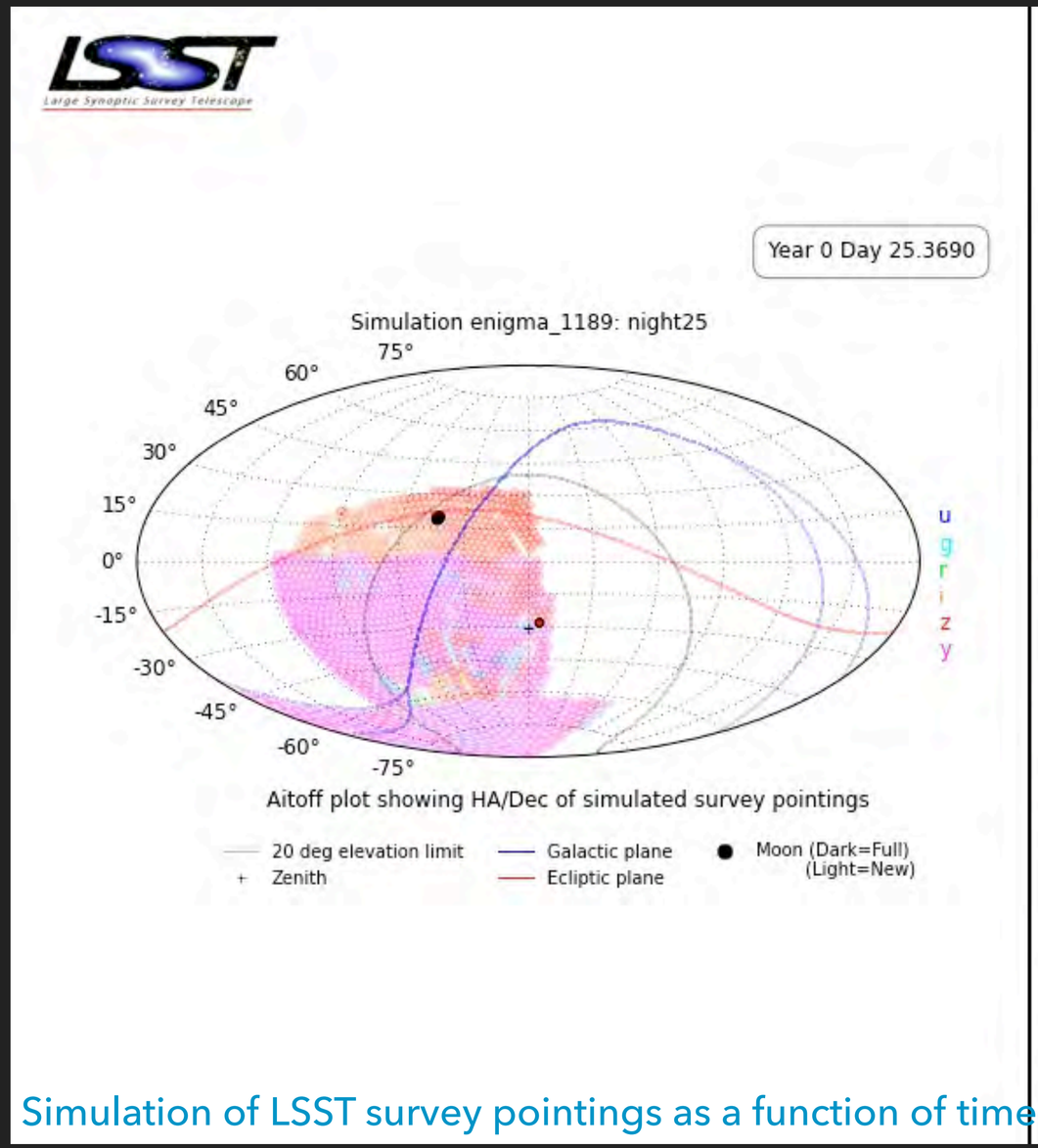
Image credit: Dawn/Y.AlSayyad/RubinObs/NSF/AURA

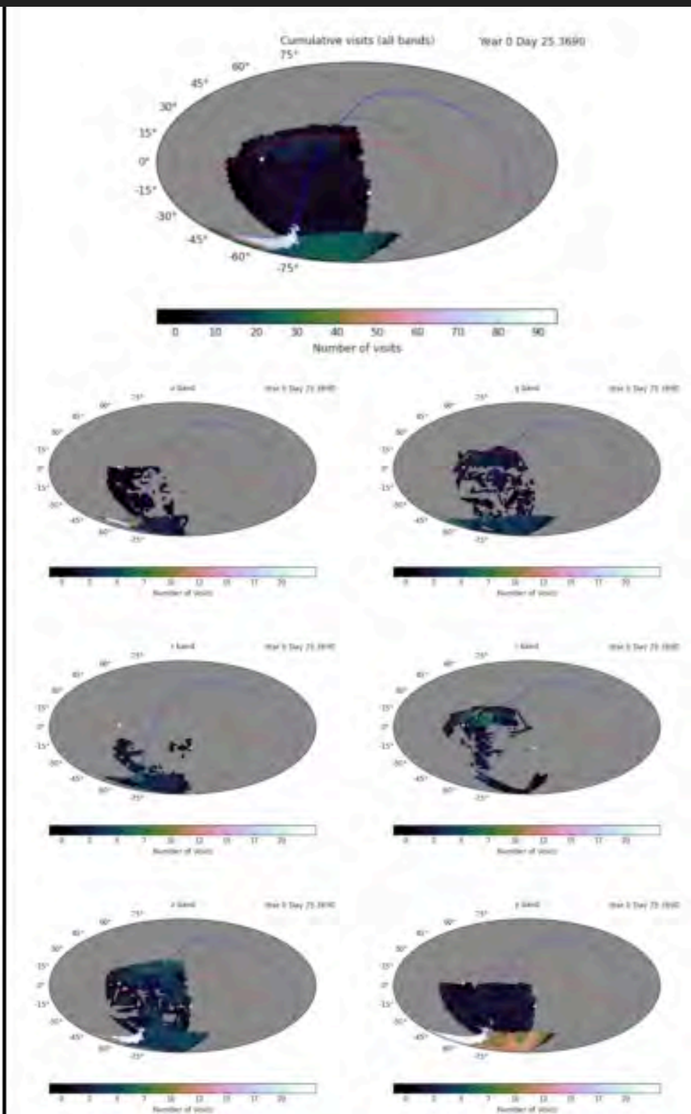
https://lsst.org

LEGACY SURVEY OF SPACE AND TIME (LSST)

- 10yr, 6-color, time-domain survey of Southern Sky
- Due to start early 2025
- Rapid discovery alerts

- No dedicated science team; community-based Rubin Science Collaborations
- Transients and Variable Stars Science Collaboration has active Microlensing Group (coord: Somayeh Khakpash)





Simulation of LSST survey pointings as a function of time. L. Jones, P. Yoachim, Rubin Obs.

CONSTRUCTION STATUS

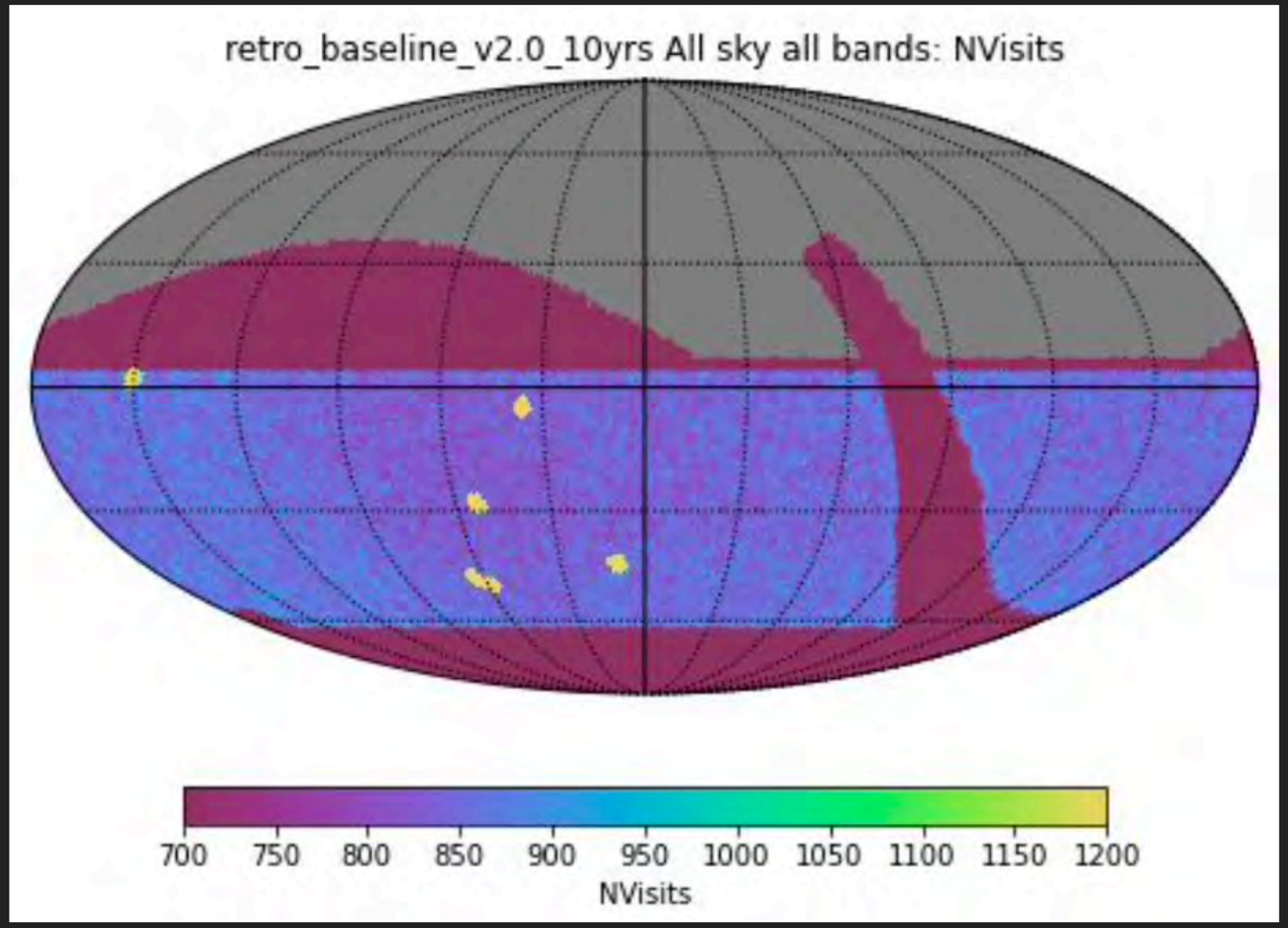
For updated schedule see: https://ls.st/dates

- Telescope Mount Assembly in testing
- Mirrors being coated with 3 layers of Ag, ready for installation
- Camera complete and undergoing testing
- Operations and data pipeline software testing with AuxTel + ComCam
- LSSTCam on sky by Dec 2024
- 2025 May Operational Readiness Review complete

SURVEY STRATEGY OPTIMIZATION

Primary science drivers:

- ✦ Probing dark energy and dark matter
- ✦ Taking an inventory of the Solar System
- ✦ Exploring the transient optical sky
- ✦ Mapping the Milky Way



N visits as a function of position, v1.0 (c2018)

- Unique, iterative process designed to incorporate very wide range of science goals
- Community driven: hundreds of contributors around the world

SURVEY SIMULATIONS AND ANALYSIS

L. Jones and P. Joachim, LSST, developed sophisticated software to simulate the survey in operation, given alternative strategies
Large set of Python metrics contributed by science community

OpSims	Sophisticated simulations of the 10-yr survey in operation, exploring alternative strategies
MAF	Metric Analysis Framework Software to calculate a set of scientific and operational metrics for each OpSim [Jones+ 2014]

MAF Github link: https://github.com/lsst/rubin_sim

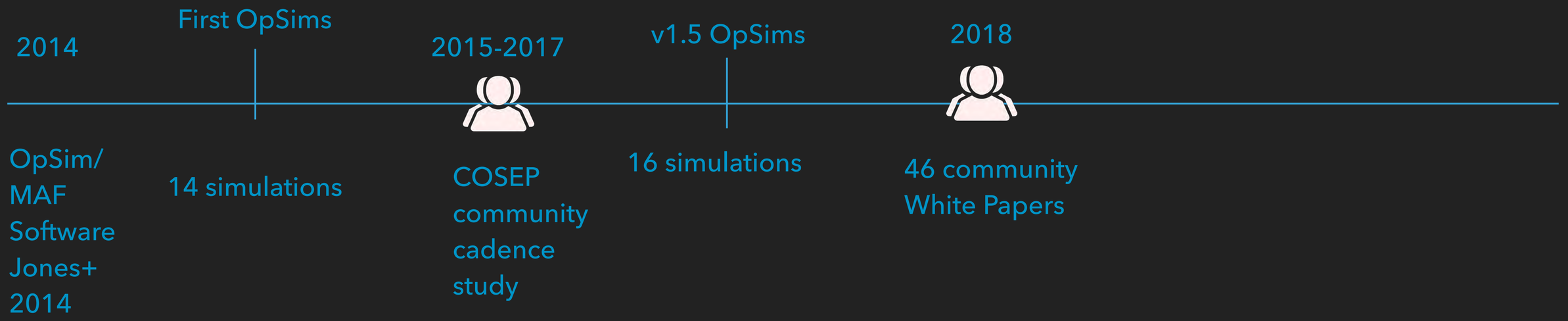
SURVEY STRATEGY OPTIMIZATION

See Bianco et al (2022) ApJS, 258, 1

Multiple iterations of survey simulations and community feedback

2018 White Papers by Poleski, Street argued for strategies favoring microlensing in Bulge, Plane and Magellanic Clouds

9 White Papers argued for Galactic Plane coverage - wide range of science!



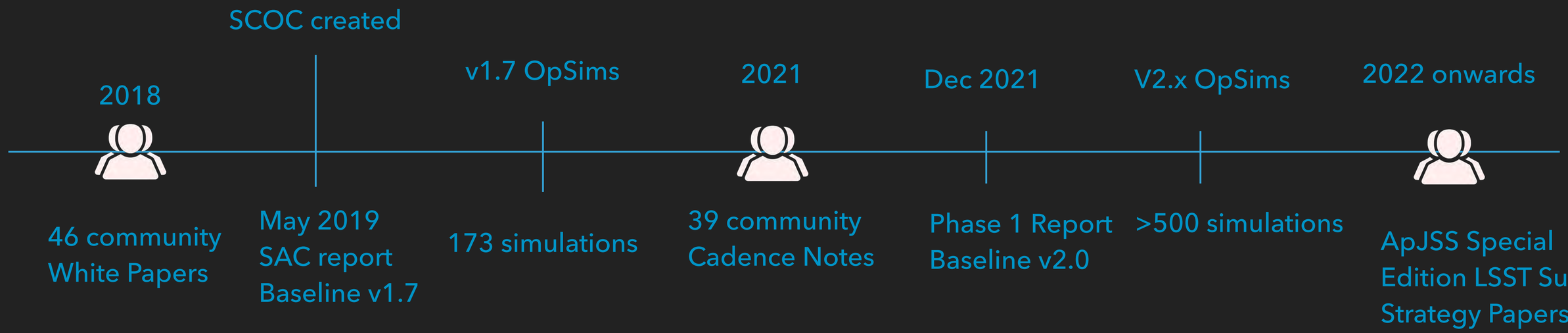
Jones, L., Yoachim, P, et al. 2014, SPIE, 9149, 91490B
COSEP: Marshal & Science Collaborations, 2017, https://ui.adsabs .harvard.edu/abs /2017arXiv17080 4058L/abstract
2018 Community White Papers: https://www.lsst.org/submitted-whitepaper-2018

Graphic adapted from Federica Bianco

SURVEY STRATEGY OPTIMIZATION

See talks by Natasha Abrams and Aníbal Varela

- SCOC: Survey Cadence Optimization Committee
- Microlensing-related analysis papers and cadence notes submitted by N. Abrams, E. Bachelet, T. Blaineau, M. Hundertmark, R. Street, & TVS Microlensing Group



Cadence Notes: https://www.lsst.org/content/survey-cadence-notes-2021
ApJSS Special Edition: https://iopscience.iop.org/journal/0067-0049/page/rubin_cadence

Graphic adapted from Federica Bianco

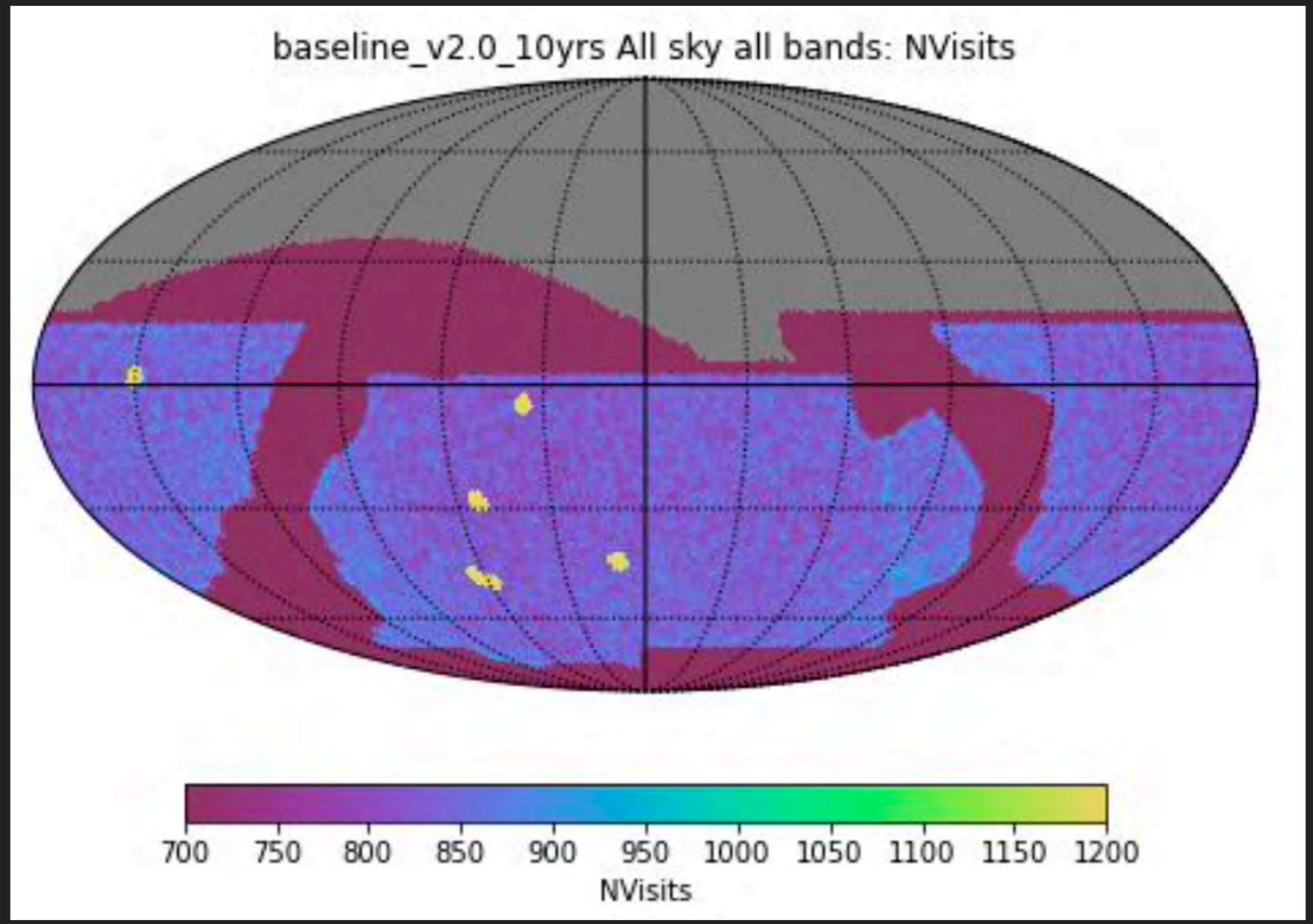
SURVEY STRATEGY OPTIMIZATION

Phase 1 report: pstn-053.lsst.io

Major changes to survey footprint: Galactic Plane survey added + Magellanic Clouds included
But refinements continued…

Dec 2021

Phase 1 Report
Baseline v2.0



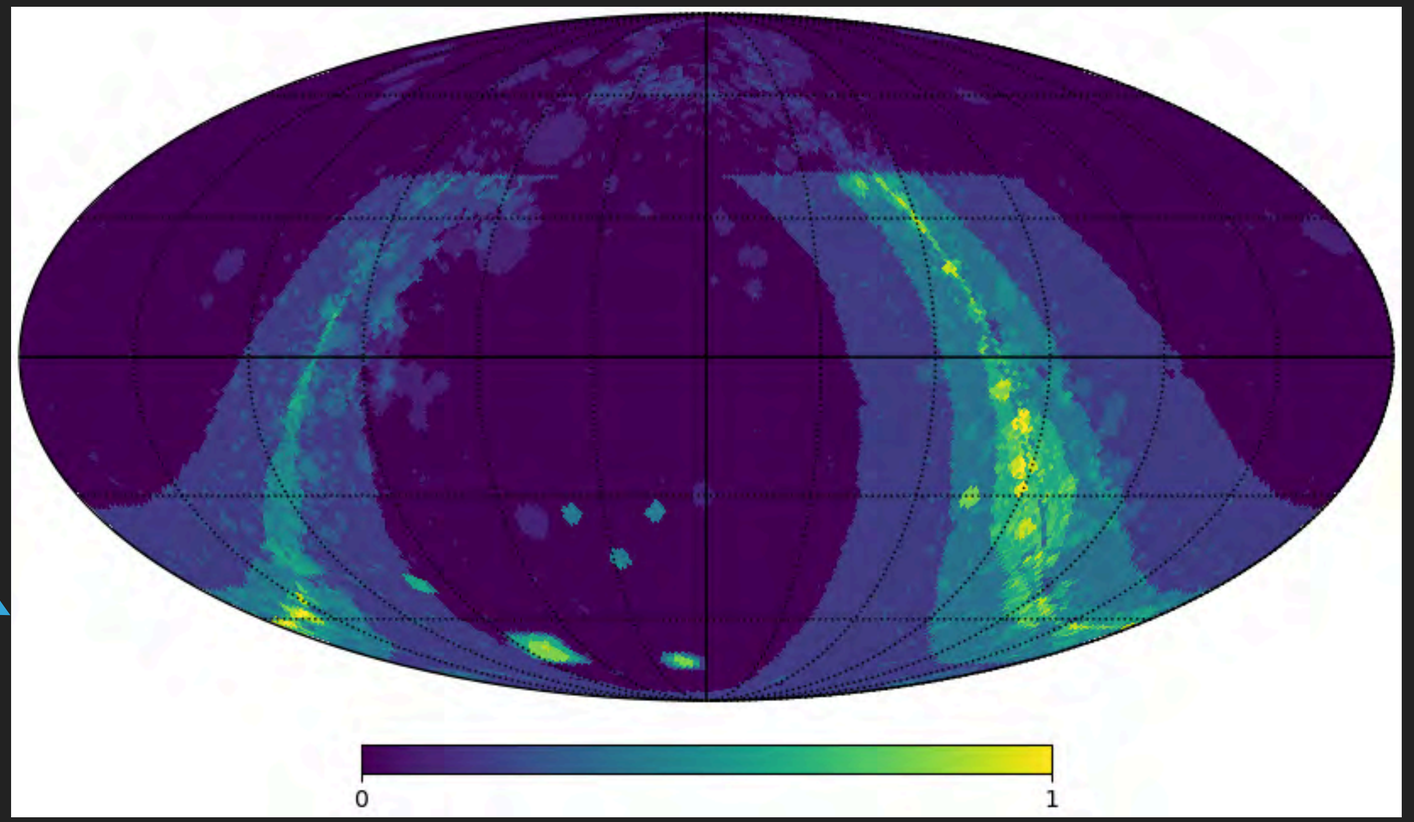
REFINING THE GALACTIC PLANE SURVEY STRATEGY

White Paper	Region	Gal long (l°)	Gal lat (b°)	Filters
Bono+ (deep survey)	Gal. Plane center	20 – +20	-3 – +3	izy
Bono+ (shallow survey)	Gal. Plane	20 – +20	-15 – +10	ugriyz
Gonzalez+	Gal. Plane center	-15 – +15	-10 – +10	grizy
Street+	Gal. Plane	-85.0 – +85.0	-10.0 – +10.0	griz
Prisinzano+,Bonito+	Gal. Plane/SFRs	-90.0 – +90.0	-5.0 – +5.0	gri
Poleski+, Street+ Clementini+	LMC	277.8 – 283.2	-35.2 – -30.6	griz
Street+, Lund+	Gal. Plane	-85.0 – +85.0	-10.0 – +10.0	griz
Poleski+, Street+ Clementini+	SMC	301.5 – 304.1	-45.1 – -43.6	griz
Street+(a)	Gal. Bulge	2.216	-3.14	griz
Clementini+	M54	5.60703	-14.08715	gri
Clementini+	Sculptor	287.5334	-83.1568	gri
Clementini+	Carina	260.1124	-22.2235	gri
Clementini+	Fornax	237.1038	-65.6515	gri
Clementini+	Phoenix	272.1591	-68.9494	gri
Clementini+	Antlia2	264.8955	11.2479	gri
Kharchenko+	Open Clusters	catalog	catalog	
Baumgardt & Hilker	Globular Clusters	catalog	catalog	

Revised survey regions, cadence and filter selections proposed based on combined requirements

Needed to find a strategy that served multiple science goals proposed for Galactic Plane:

- Microlensing (inc RGES Field)
- RR Lyrae
- X-ray binaries
- Young Stellar Objects
- Resolved stellar populations
- And more

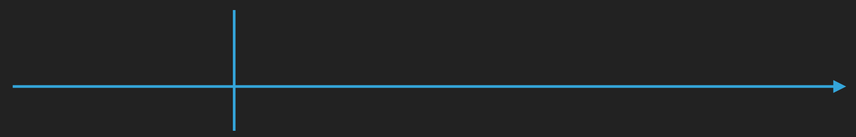


From Street et al. 2023, ApJSS, 267, 15

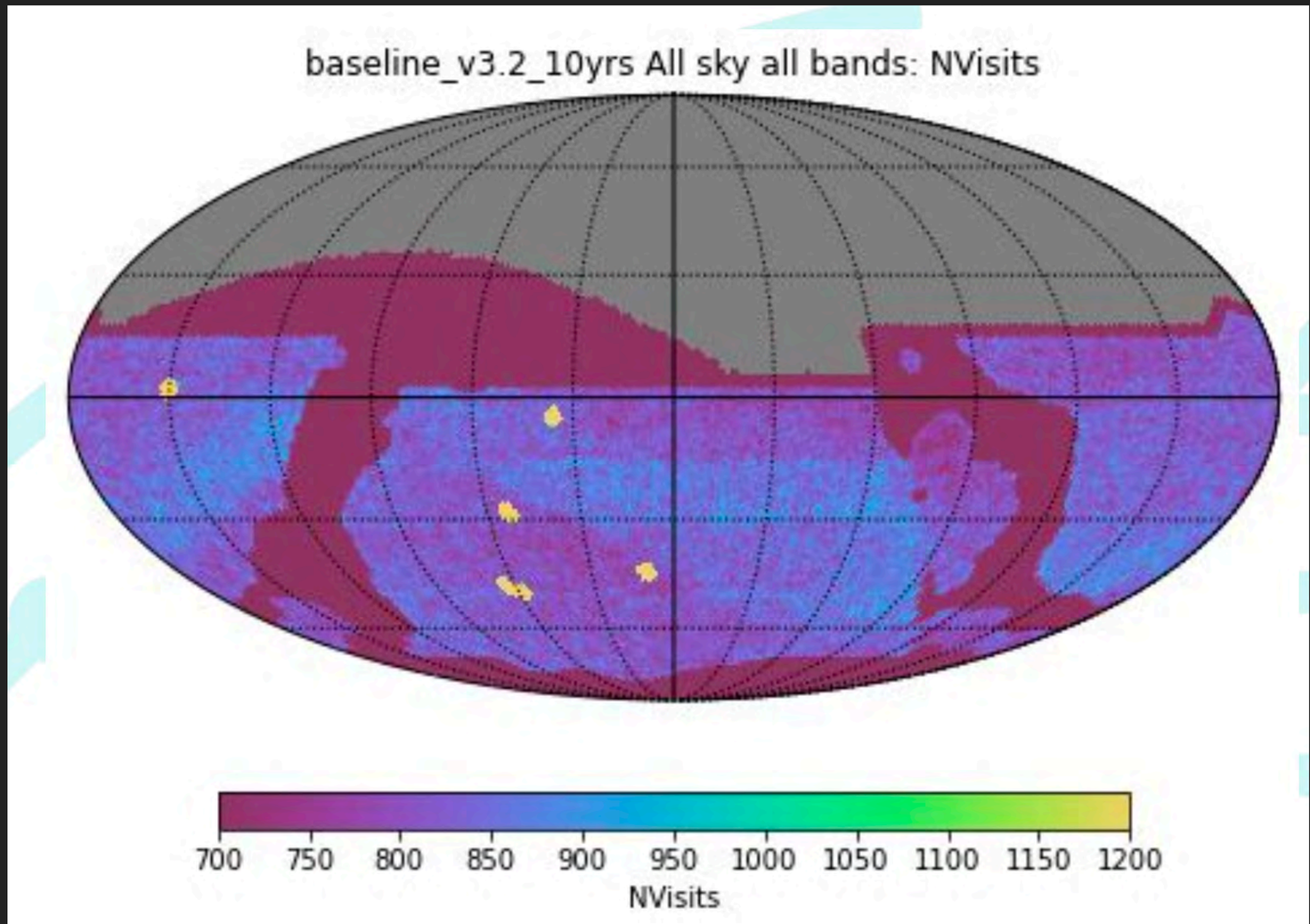
SURVEY STRATEGY OPTIMIZATION

Phase 2 report: pstn-055.lsst.io
Revised Galactic Plane footprint adopted
Rolling cadence implemented for Wide-Fast-Deep (higher cadence for alternate years)

v3.3 opsims



Analysis continues



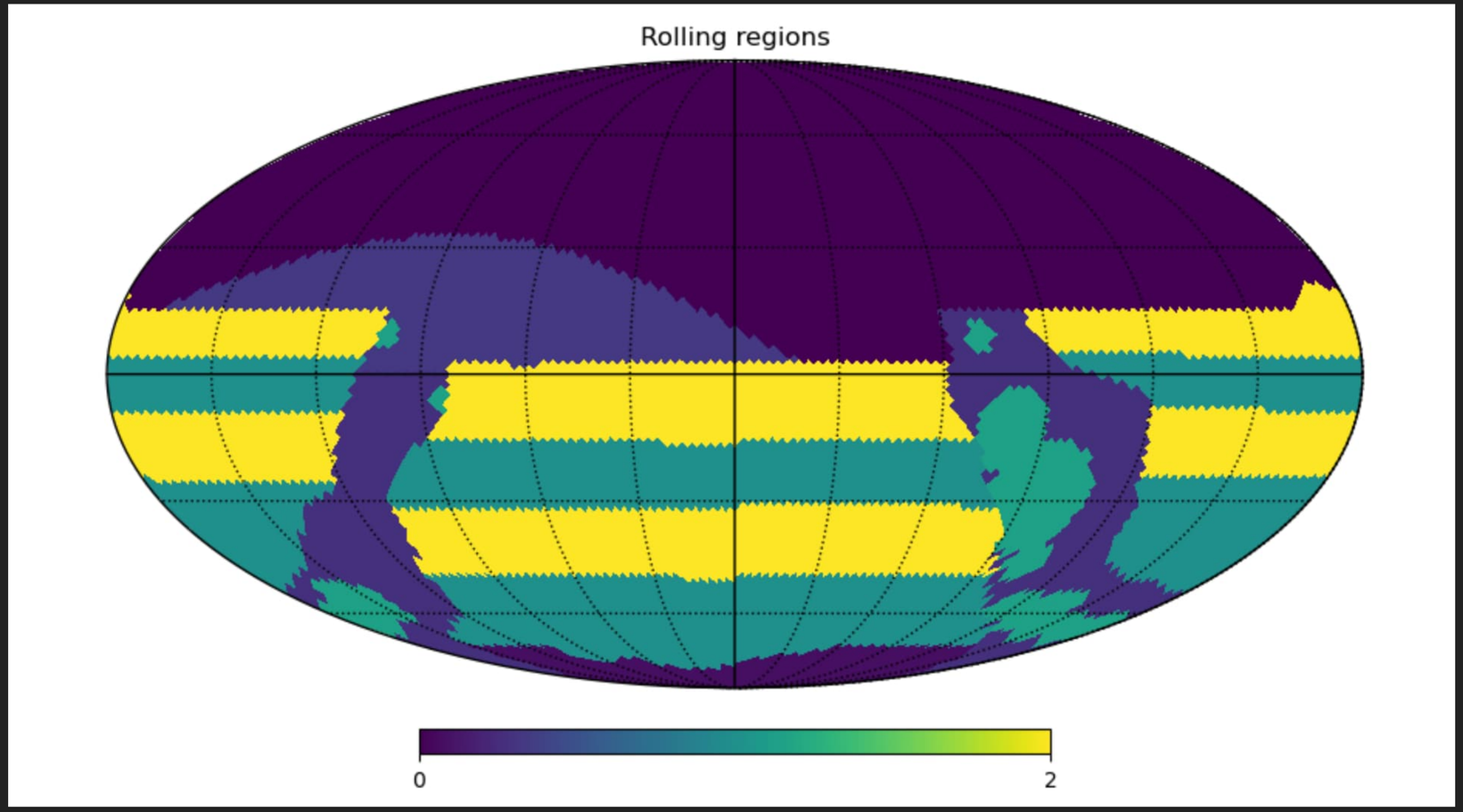
v3.2 survey footprint

ROLLING CADENCE

- Alternate bands of the sky receive higher cadence in alternate years
- Many variations explored; 2-band strategy adopted

Rolling explored for whole Galactic Plane but overall detrimental for longer events

Currently analyzing simulations of rolling cadence just for Roman Galactic Exoplanet Survey region while maintaining regular cadence over the rest of the Plane



PLANS FOR EARLY SCIENCE PROGRAM

Guy et al. 2023: https://rtn-011.lsst.io

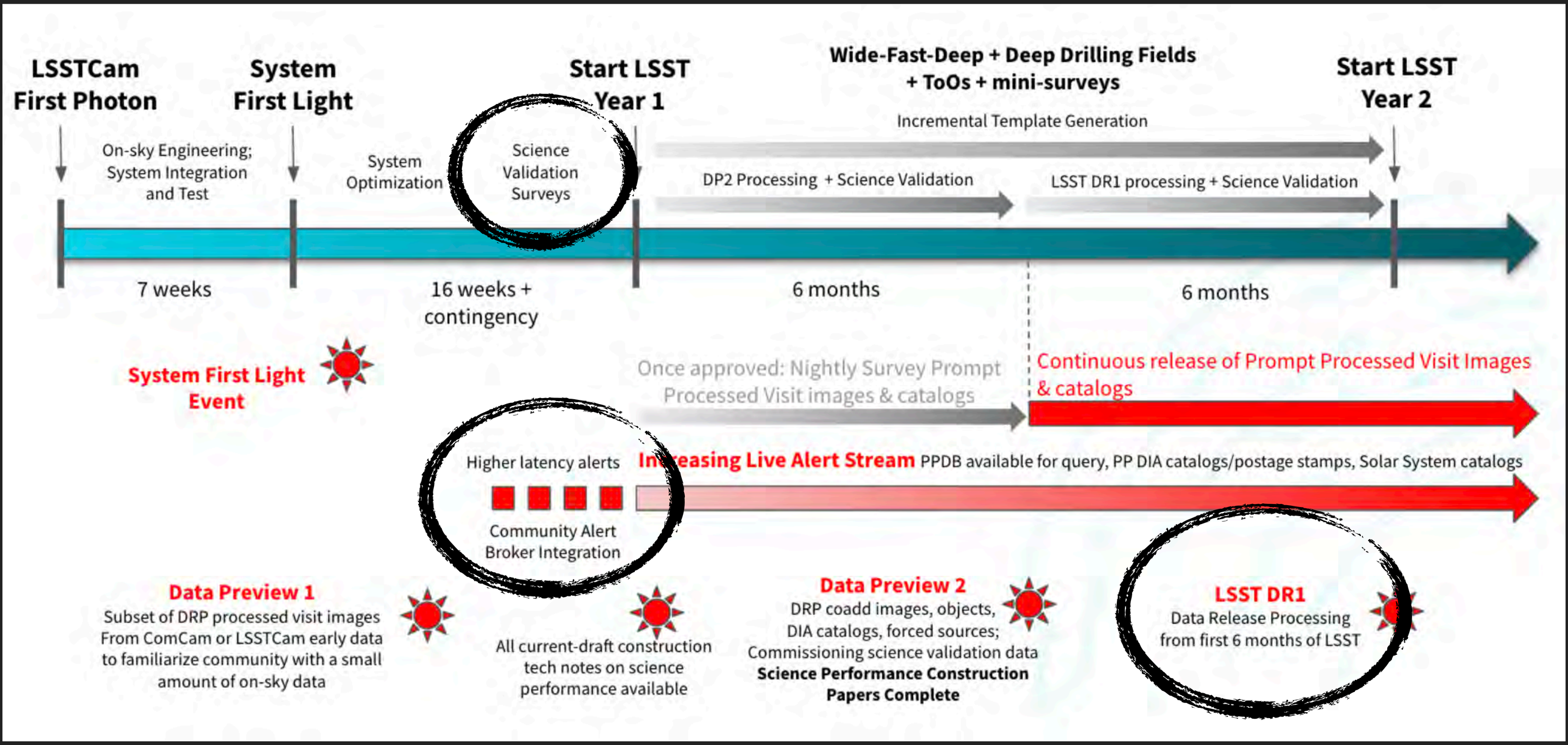
- Imaging data will be reduced with a DIA-based pipeline
- Key phase is all-sky template image acquisition in 6 filters

- Rubin Science Collaborations gave input on template acquisition strategy
  - Hambleton et al., 2020, Street et al. 2020, Schwamb et al. 2021

Commissioning data templates	Build templates, where possible, from all commissioning data before the start of Year 1, and use them to generate alerts during Year 1.
Year 1 templates	Build templates progressively from data obtained during Year 1, use to generate alerts
	At least 3 images in Year 1; at least 5 for the rest of the survey
	Templates will only be replaced by subsequent annual data releases

LSST EARLY SCIENCE PROGRAM

Guy et al. 2023: https://rtn-011.lsst.io



DATA PREVIEWS

Guy et al. 2023: https://rtn-011.lsst.io

- Staged releases of simulated and real data products to enable preparations and software dev

Rubin Early Science Data Release Scenario

Data Product	Jun 2021 – DP0.1 – DC2 Simulated Sky Survey	Jun 2022 – DP0.2 – Reprocessed DC2 Survey	Jun 2023 – DP0.3 – Solar System PPDB Simulation	Oct 2024 – Jul 2025 – DP1 – ComCam or early LSSTCam Data	Nov 2025 – May 2026 – DP2 – LSSTCam Science Validation Data	May 2026 – Jan 2027 – DR1 – LSST First 6 Months Data	May 2027 – Jan 2028 – DR2 – LSST Year 1 Data	May 2028 – Nov 2028 – DR3 – LSST Year 2 Data
Raw Images	●	●	–	●	●	●	●	●
DRP Processed Visit Images and Visit Catalogs	●	●	–	●	●	●	●	●
DRP Coadded Images	●	●	–	–	●	●	●	●
Object and ForcedSource Catalogs	●	●	–	–	●	●	●	●
DRP Difference Images and DIASources	–	●	–	–	●	●	●	●
DRP ForcedSource Catalogs including DIA output	–	●	–	–	●	●	●	●
PP Processed Visit Images	–	–	–	–	–	●	●	●
PP Difference Images	–	–	–	–	–	●	●	●
PP Catalogs	–	–	–	–	●	●	●	●
PP SSP Catalogs	–	–	●	–	●	●	●	●
DRP SSP Catalogs	–	–	–	–	–	●	●	●

OPPORTUNITIES

- Rubin Science Collaborations are the best way to get involved
  - Stay up to date
  - Learn about Rubin, LSST, software tools, student/post-doc opportunities, computing resources and more!
  - Provide input into science goals

- Transients and Variable Stars Science Collaboration has a very active Microlensing Group (Coordinator: Somayeh Khakpash)

- See TVS website: https://lsst-tvssc.github.io/

- Data Previews: Simulated and early Rubin data products and tutorials designed to help community learn how to science with them