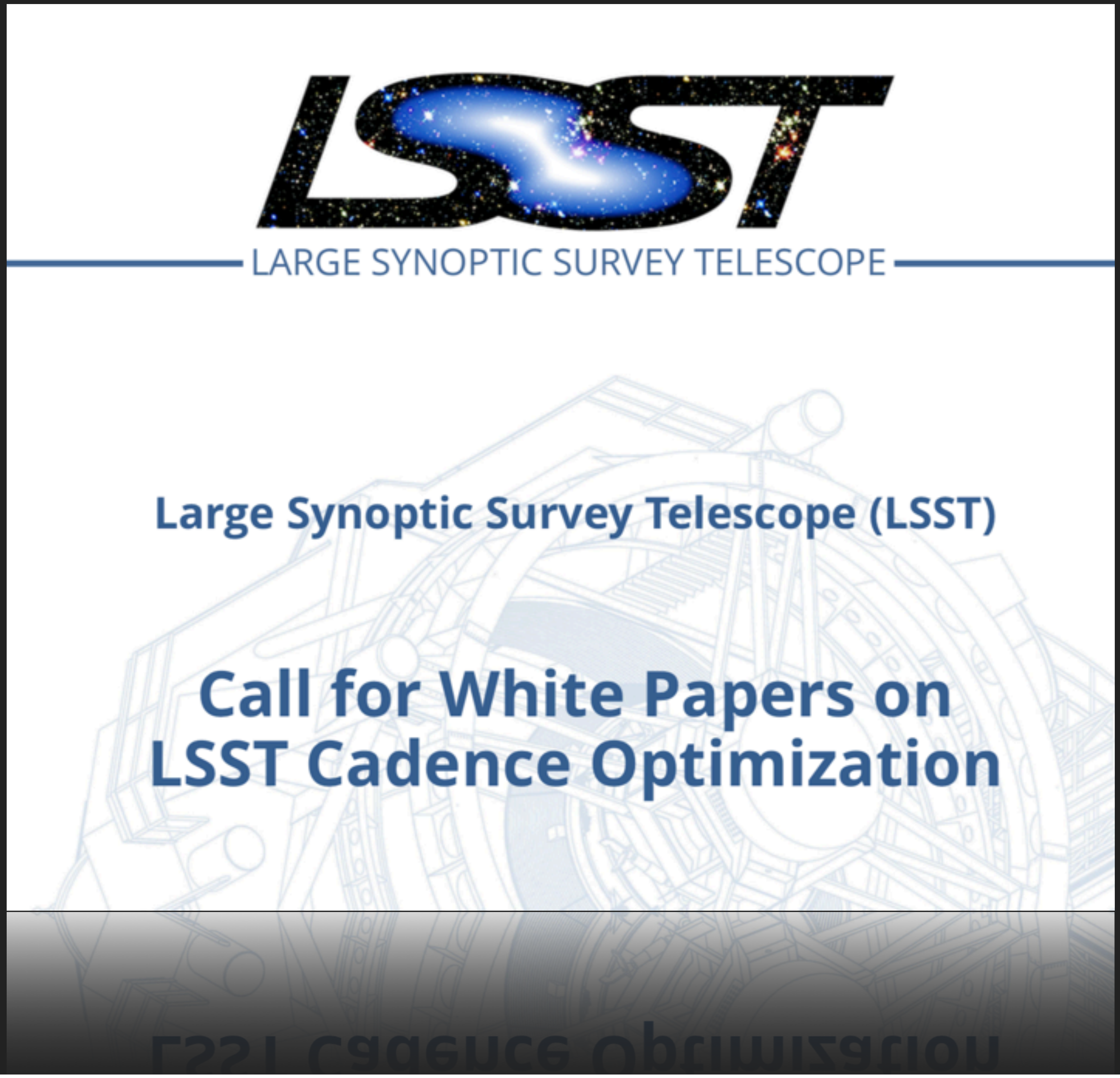
TVS SURVEY STRATEGY PROPOSAL PREPARATION WORKSHOP: THE WP PROPOSAL CALL

4-8 June 2018

Lehigh University



LARGE SYNOPTIC SURVEY TELESCOPE

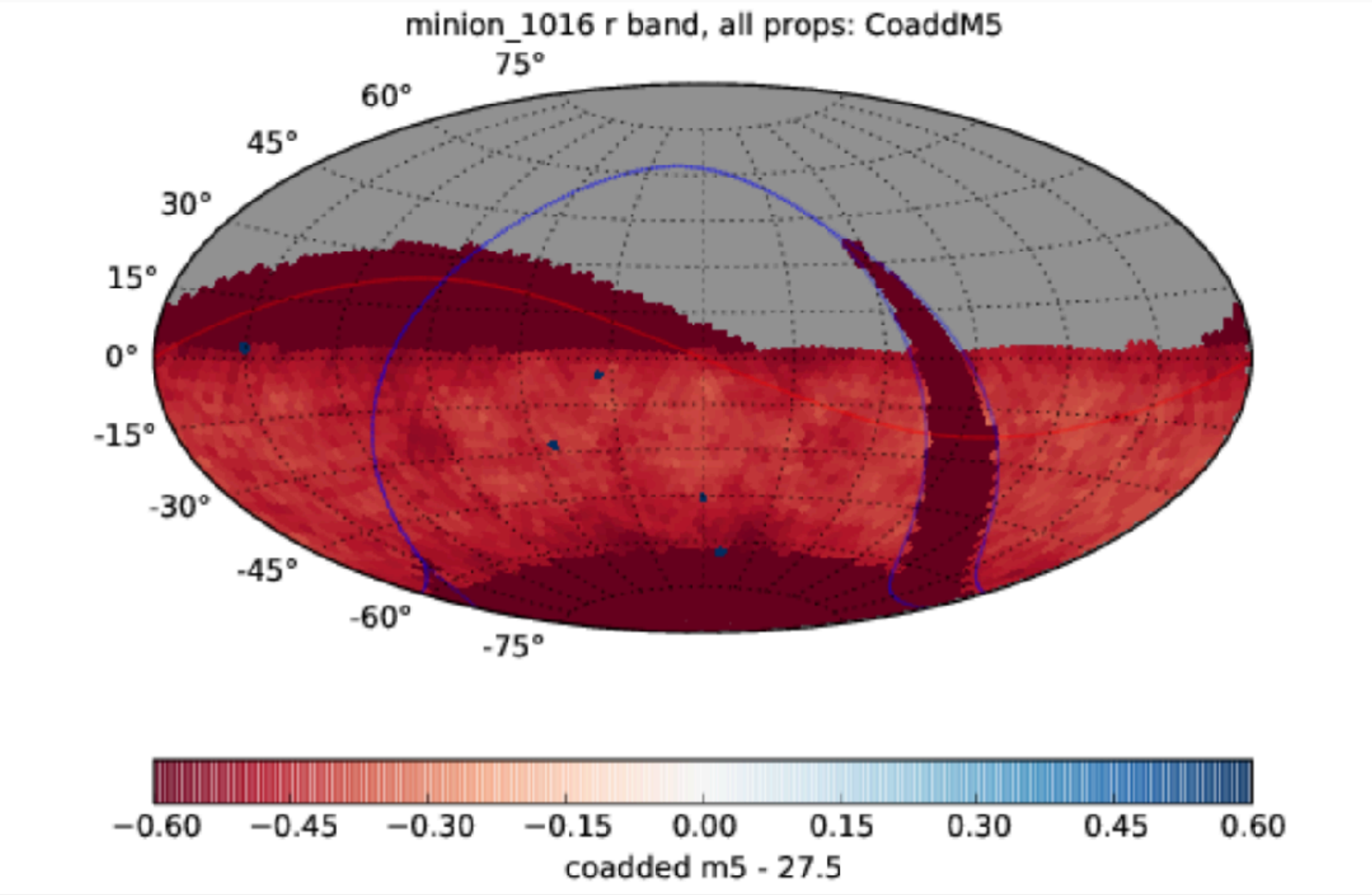
Large Synoptic Survey Telescope (LSST)

Call for White Papers on LSST Cadence Optimization

Version	Date	Description	Owner name
1	2018-05-16	First internally circulated version.	Željko Ivezić
2	2018-06-30	First released version.	Željko Ivezić

LSST: MANY SURVEYS IN ONE

Wide Fast Deep - Minisurveys - DDF - ToO

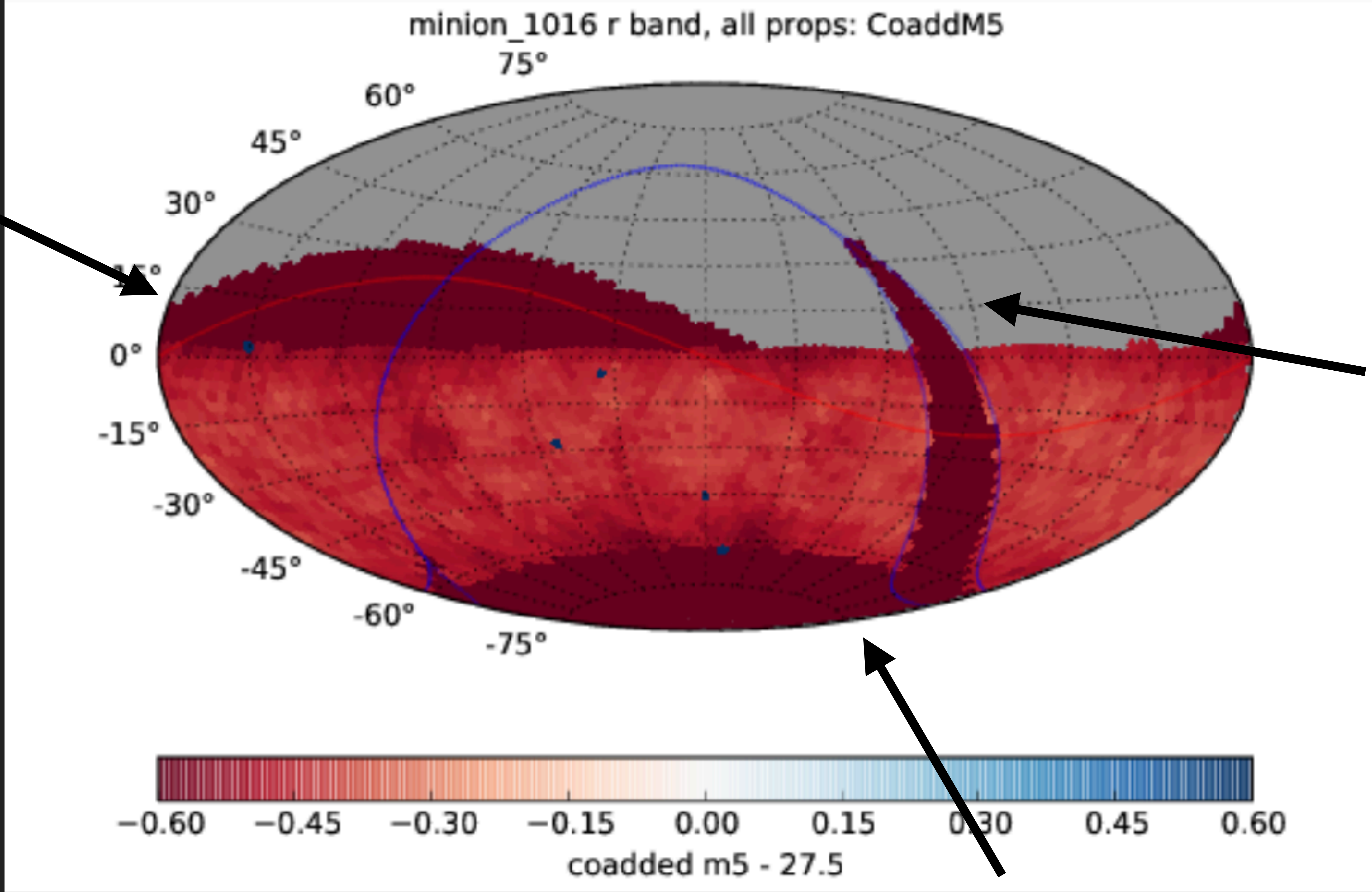


Wide-Fast-Deep
(85.1%)

LSST: MANY SURVEYS IN ONE

Wide Fast Deep - Minisurveys - DDF - ToO

North Ecliptic Survey
The NES is an extension to reach the Ecliptic at higher airmass than the WFD survey typically covers, no *u*



Galactic Plane (1.7%): covers the region where LSST is expected to be highly confused by the density of stellar sources; fewer total exposures/field and does **not collect in pairs**

Wide-Fast-Deep (85.1%)

South Celestial Pole (2.2%): higher airmass decl>–65 degrees. includes *ugrizy*, but takes fewer exposures/field than the WFD and does **not collect in pairs**.

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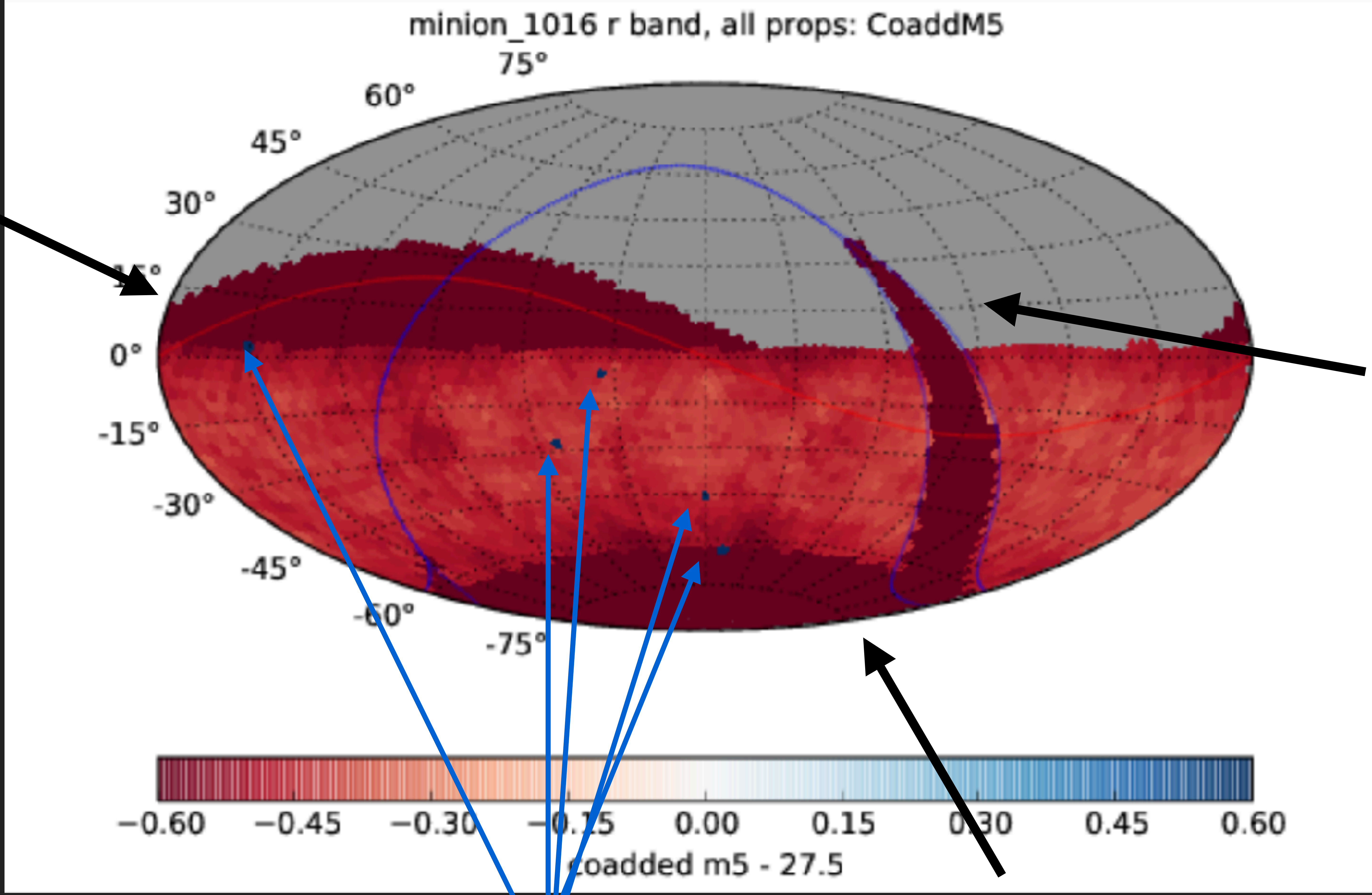

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Wide-Fast-Deep (85.1%)

Deep Drilling Fields DDF (4.5%)

South Celestial Pole (2.2%): higher airmass decl>–65 degrees. includes *ugrizy*, but takes fewer exposures/field than the WFD and does **not collect in pairs**.

LSST SCIENCE REQUIREMENTS DOCUMENT HTTP://LS.ST/SRD

If its written in the SRD document, it is basically written in stone

Science Goals

- constraining dark energy and dark matter,
- taking an inventory of the Solar System,
- **exploring the transient optical sky,** and
- mapping the Milky Way

LSST SCIENCE REQUIREMENTS DOCUMENT HTTP://LS.ST/SRD

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Technical constraints

- **A footprint for the 'main survey' of at least 18,000 deg^2** over which there must be **at least 825 30-second visits per 9.6 deg^2 field,** summed over all six filters, ugrizy (see SRD Tables 22 and 23), which places a *minimum constraint on the time required to complete the main survey, typically requires 85–90% of the available time* (10 years) even with scheduling improvements, it is unlikely that the goals of the main survey could be met with a time allocation significantly below 80%.

LSST SCIENCE REQUIREMENTS DOCUMENT [HTTP://LS.ST/SRD](http://ls.st/srd)

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Technical constraints

- **Parallax and proper motion 1σ accuracies of 3 mas and 1 mas/yr per coordinate at r = 24,** respectively, in the main survey (see SRD Table 26), which places a *weak constraint on how visits are distributed throughout the lifetime of the survey and throughout a season.*

LSST SCIENCE REQUIREMENTS DOCUMENT HTTP://LS.ST/SRD

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Technical constraints

- Rapid revisits (40 seconds to 30 minutes) must be acquired over an area of at least 2000 deg2 (see SRD table 25) for very fast transient discovery; this requirement can usually be satisfied via field overlaps when surveying contiguous areas of sky

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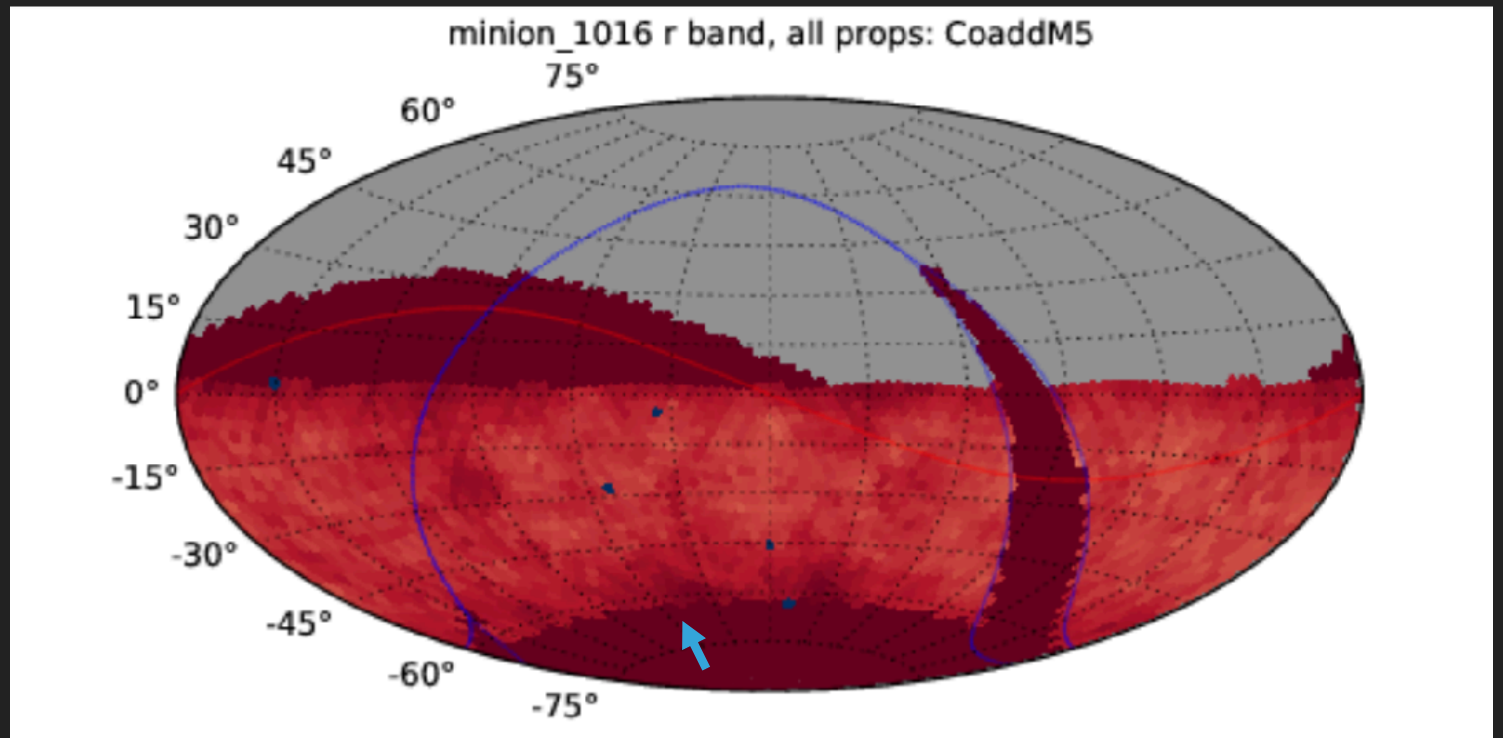

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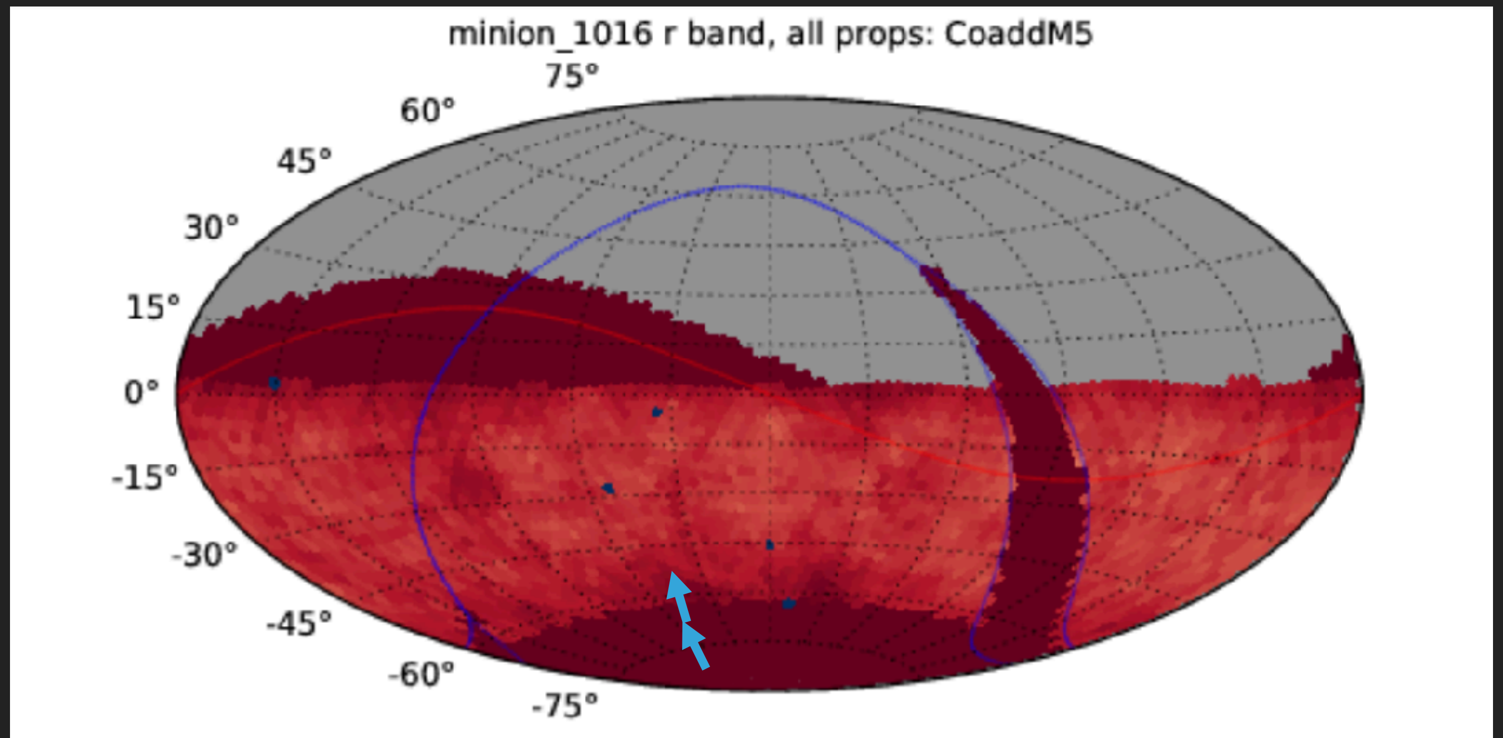

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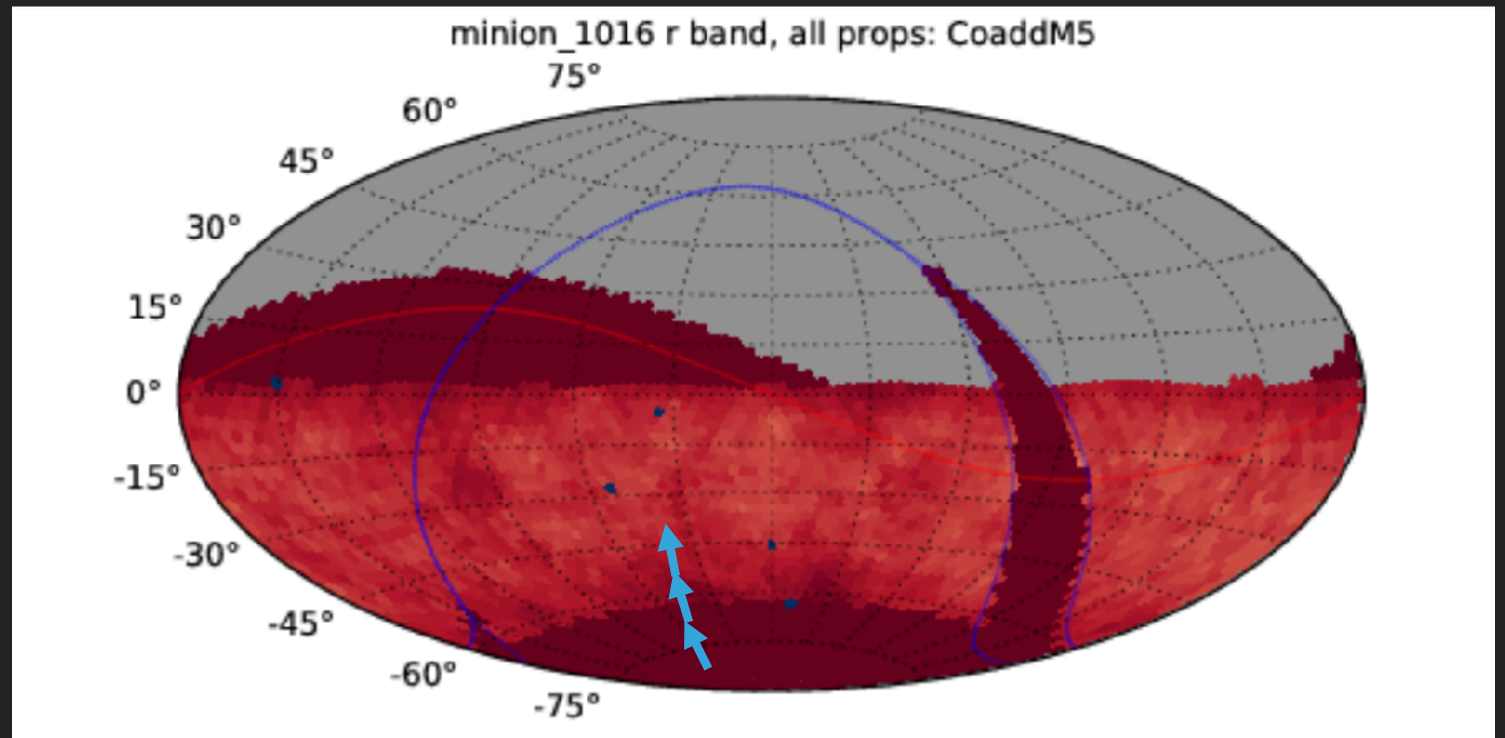

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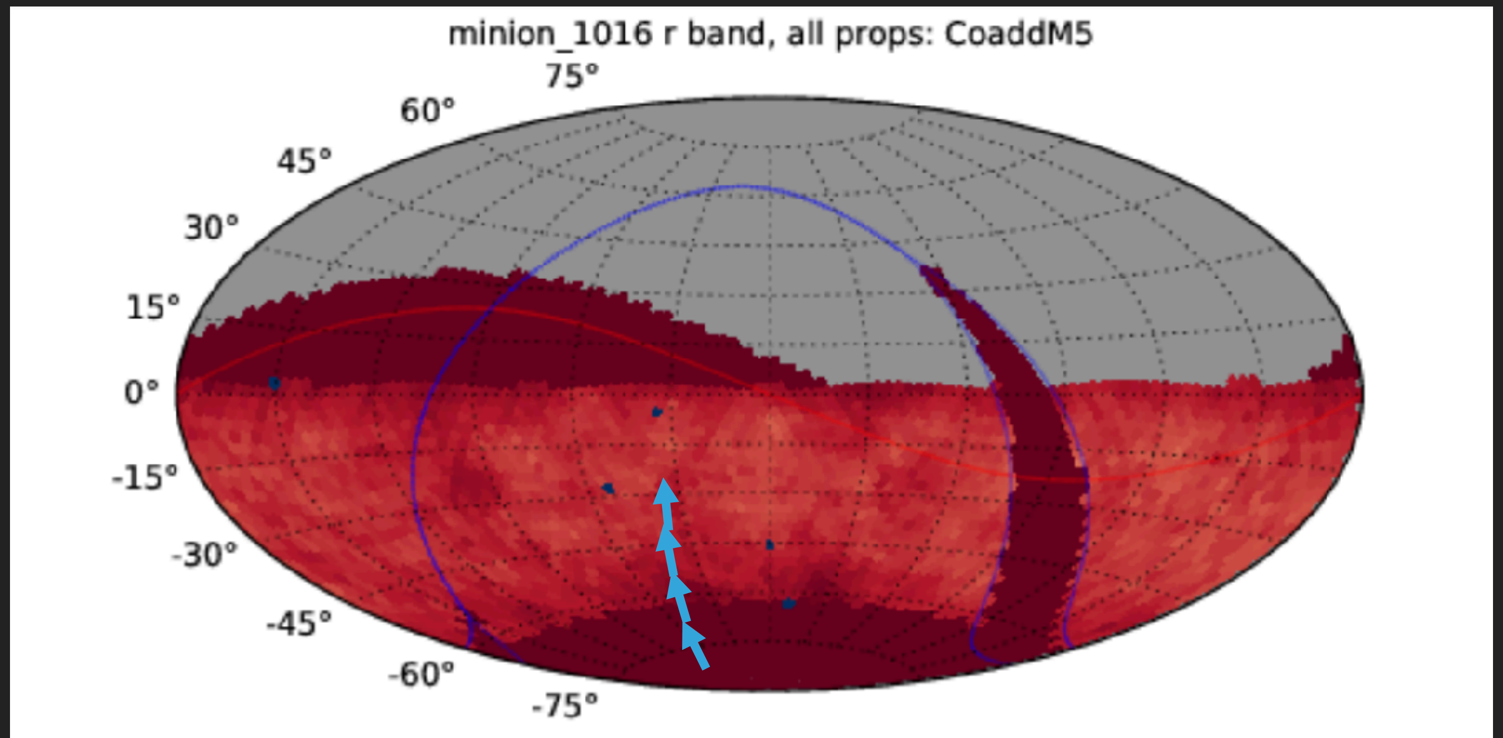

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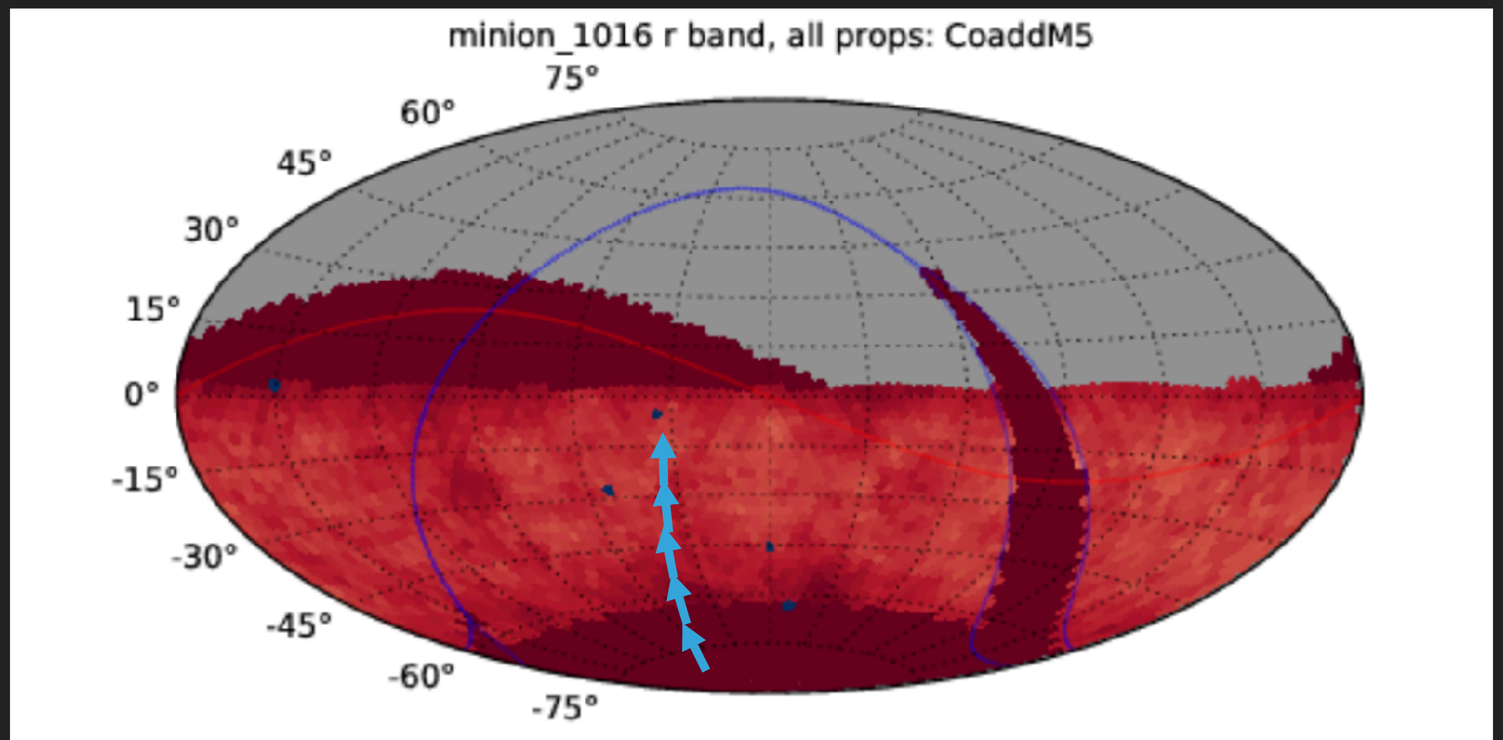

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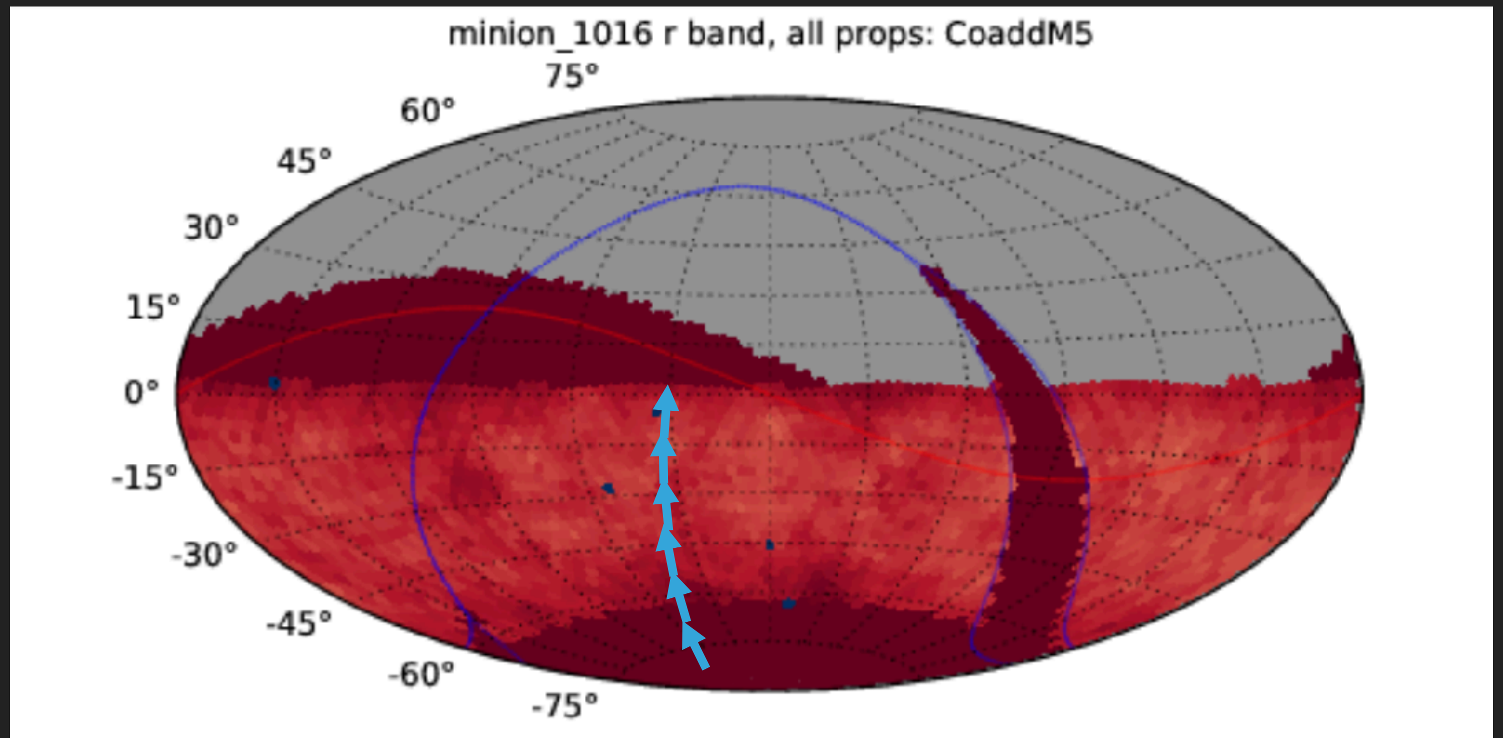

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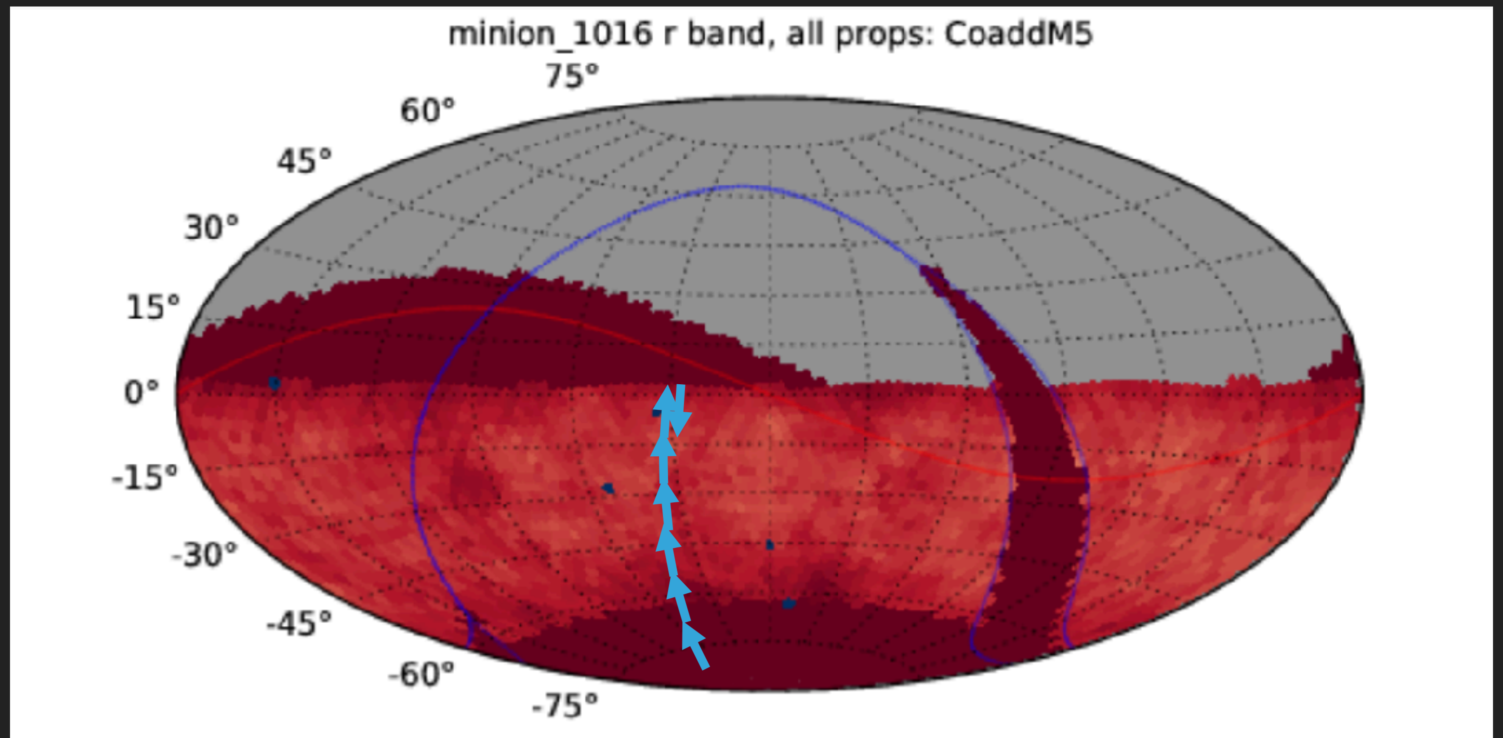

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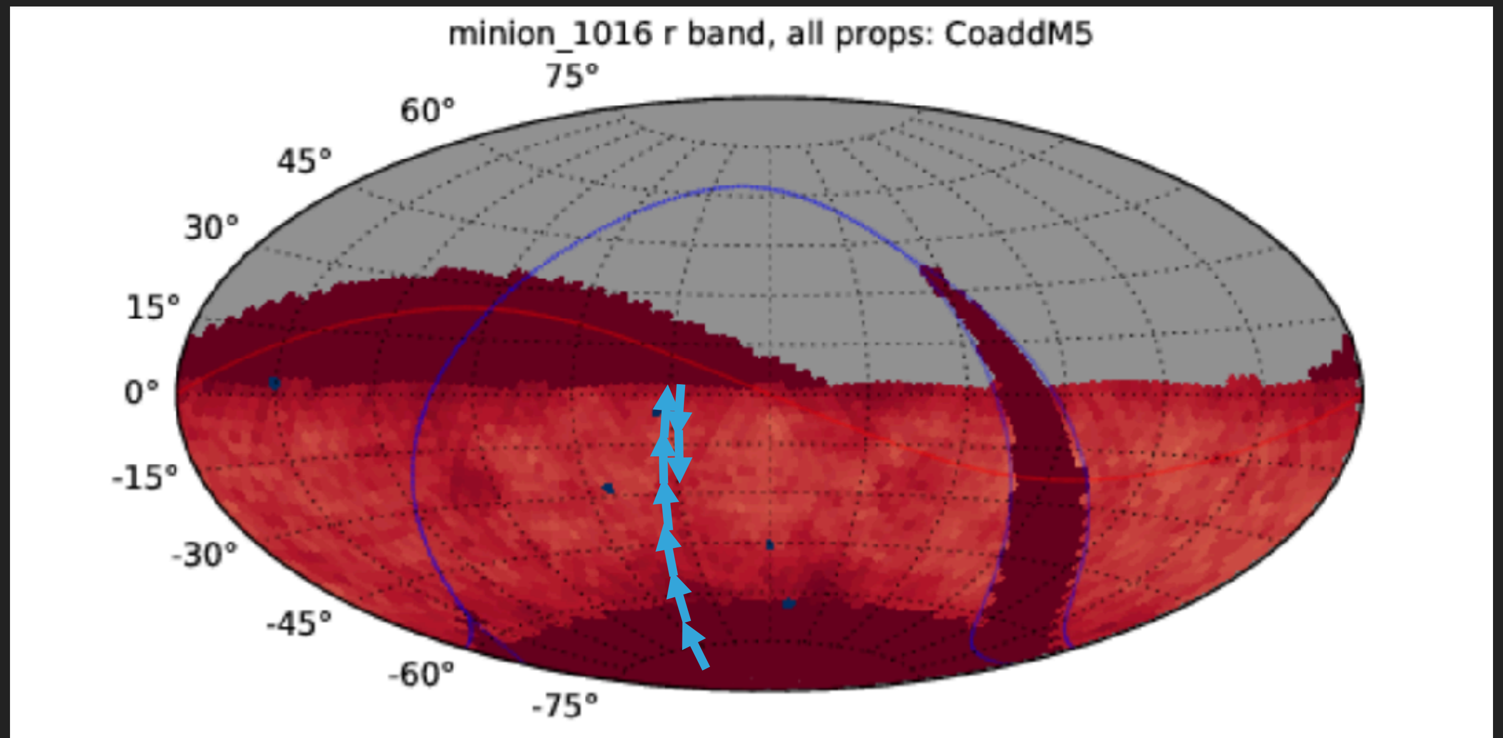

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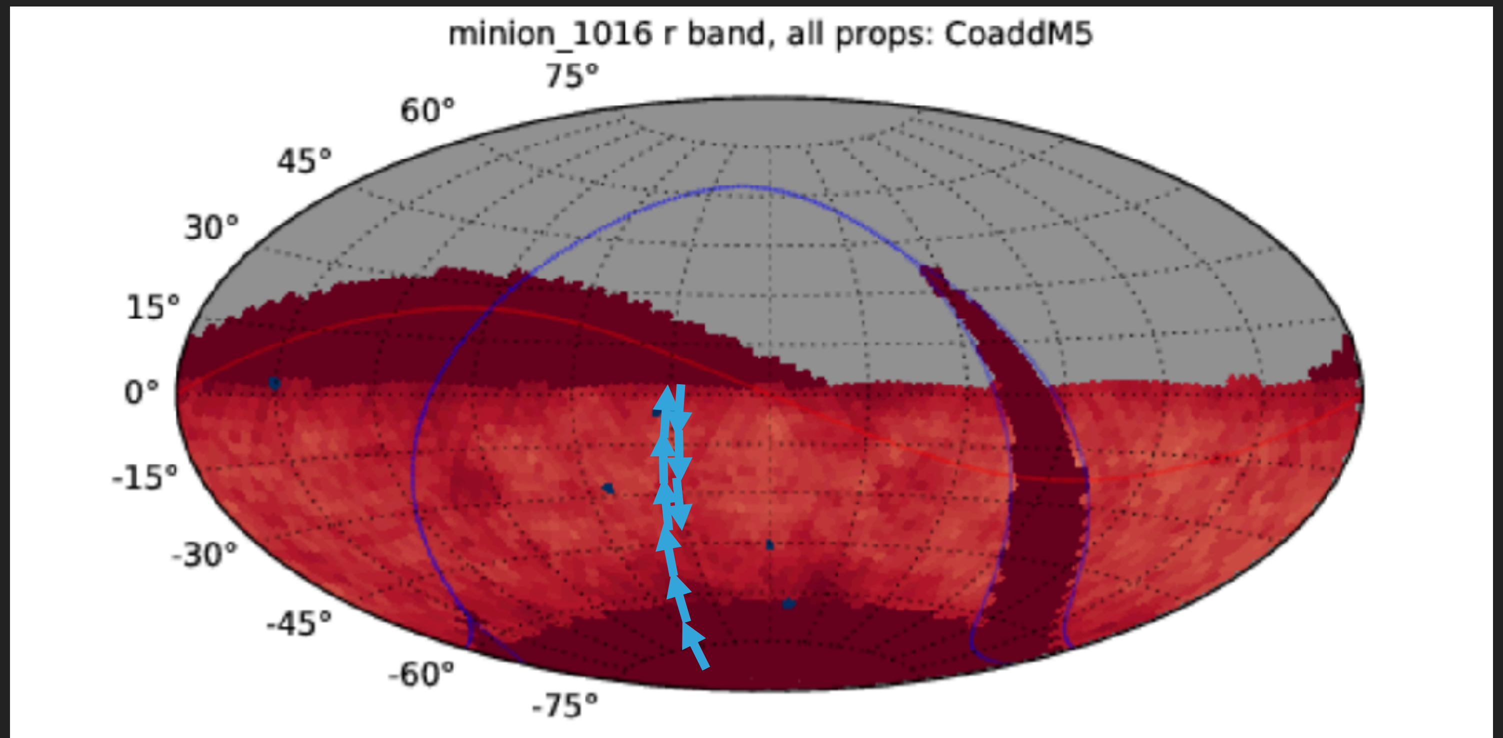

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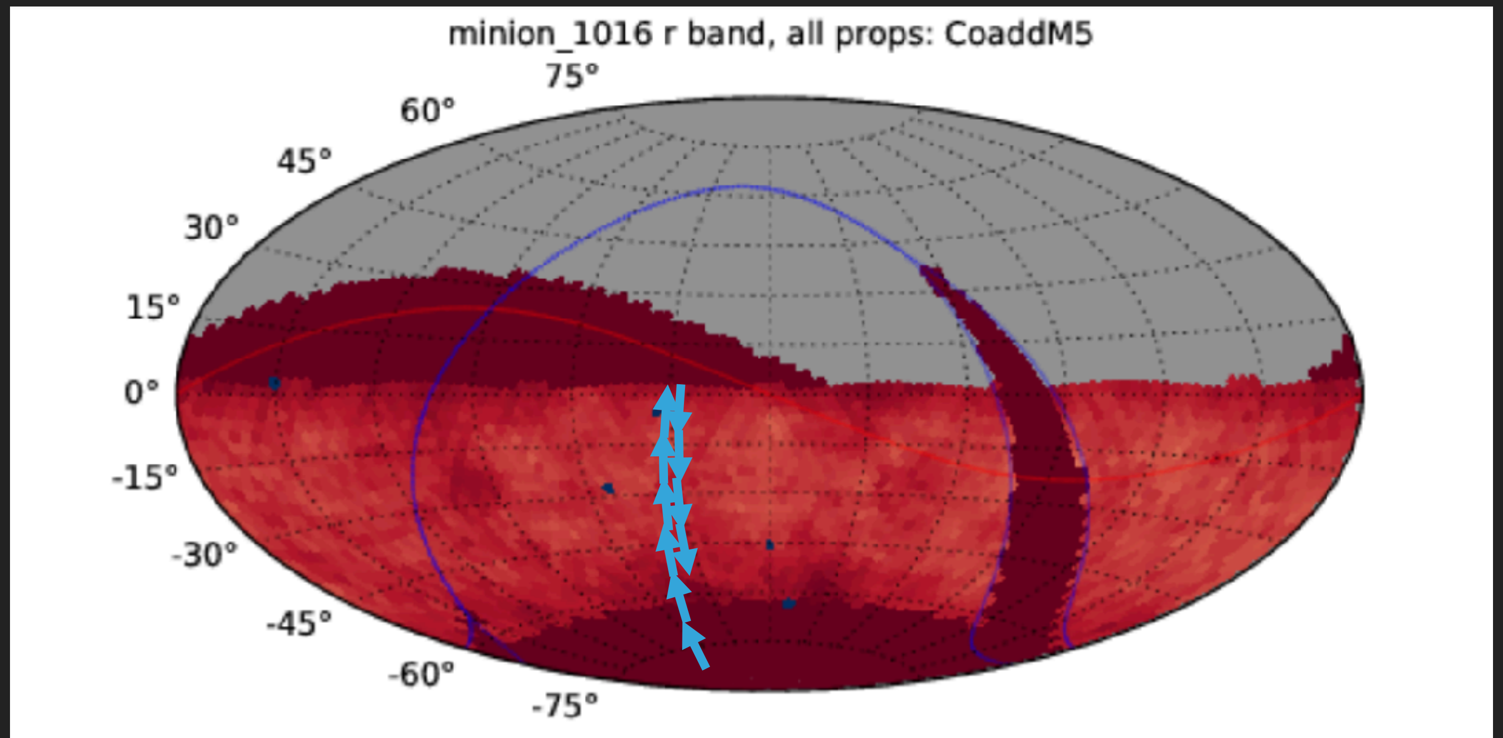

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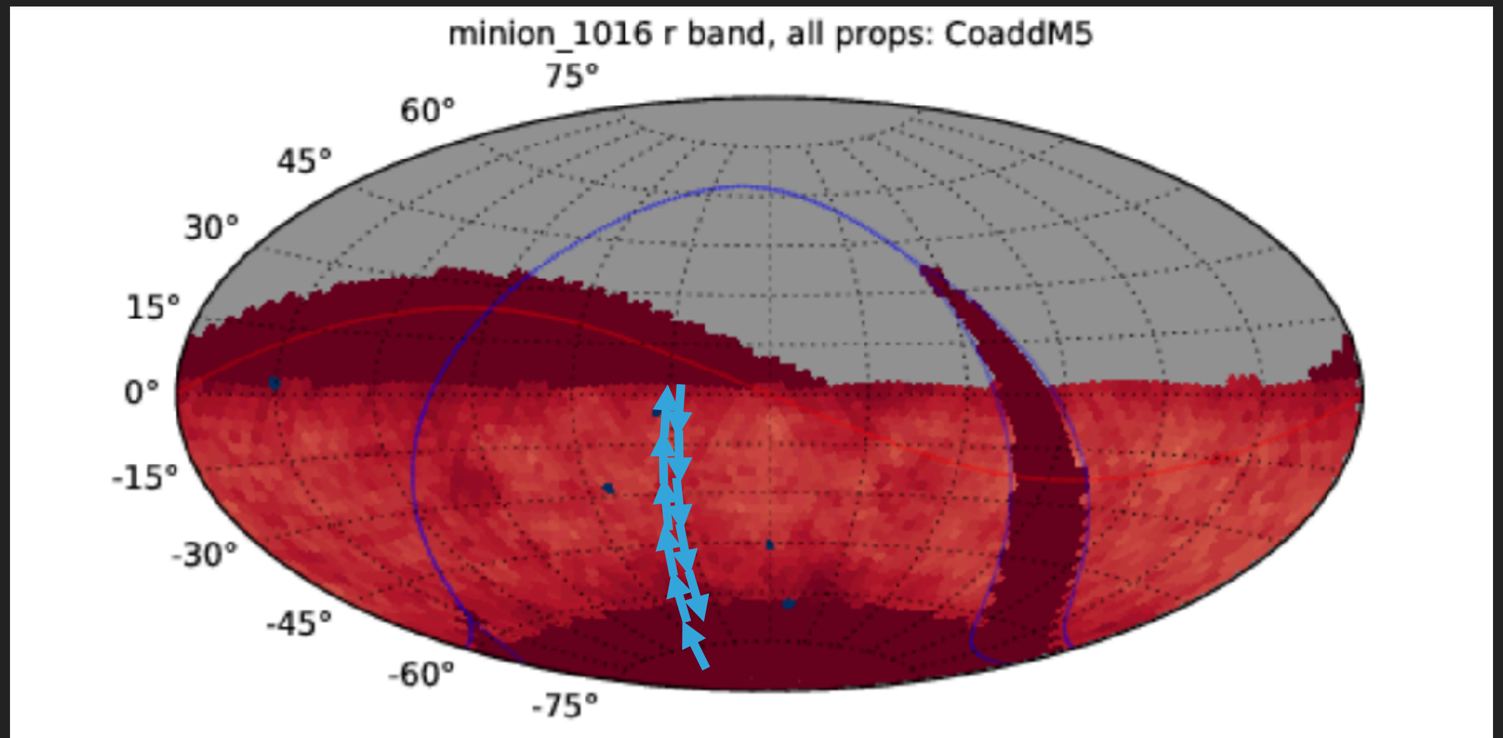

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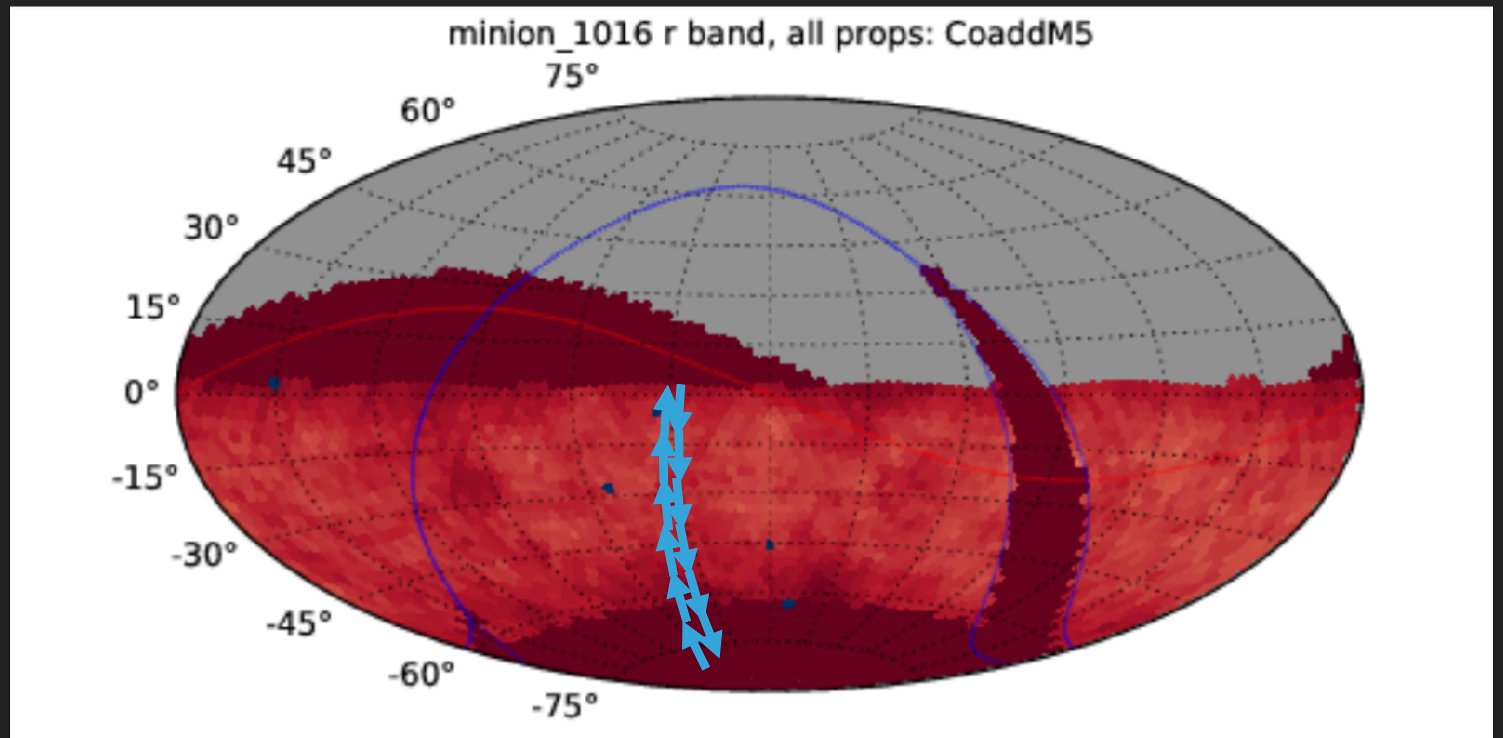

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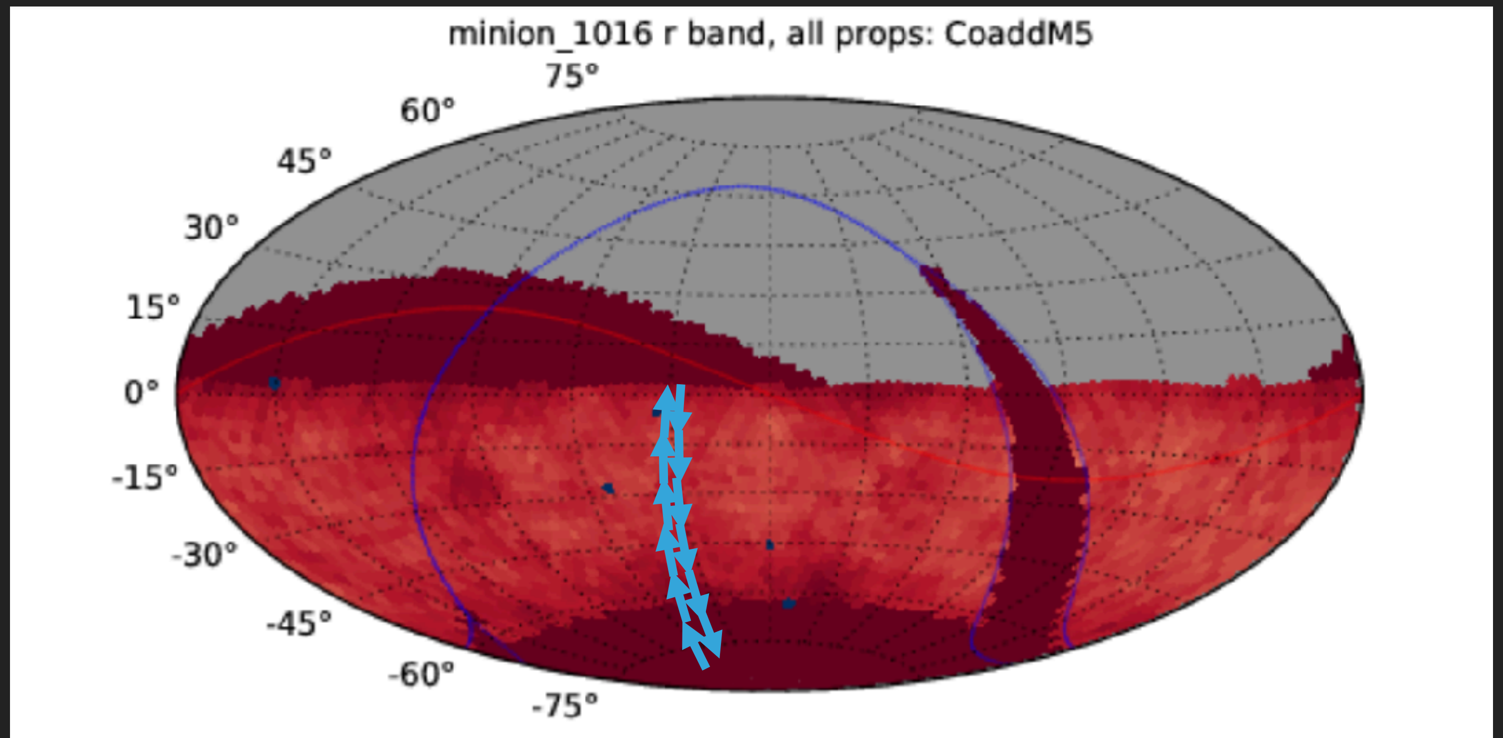

WP TIMELINE

Call for white papers	June 30, 2018
2018 Project and Community Workshop	Aug 13-17, 2018
White papers submission deadline	**November 30, 2018**
strategies selected for simulation (SAC)	April 2019
survey strategies available	End of 2019
Survey Strategy Committee (SSC) established	Early 2020
Advisory report from Project to SSC	Early 2020
SSC report on official initial LSST survey strategy	Early 2021
Baseline simulation of initial LSST survey strategy	Mid 2021
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members of the LSST Science Advisory Committee (SAC), with technical support from the Project, will undertake an initial review and decide which submitted white papers meet the criteria of scientific excellence and technical feasibility for further analysis.

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The input from the submitted white papers will be used to design multiple options in ob- serving strategies, and the Project team will generate a series of simulations based on these survey strategies.

Simulated survey outputs, generated via the LSST OpSim and LSST MAF will become available by the end of 2019

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An advisory report on the performance of the survey strategies developed as a result of this call for white papers, based on performance metrics provided in the white papers and the *Science-Driven Observing Strategy Paper*, will be prepared by the Project for this committee in early 2020.

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The SSC will undertake the work of balancing the overall scientific performance between the individual science goals, and will advise the Project on the specific survey strategy to be used at the start of full LSST operations, as well as on guidelines for the strategy throughout all ten years of the survey

WP RULES AND EXPECTATIONS

Quantitative, science-driven optimization input is requested for each of

Wide Fast Deep WFD (sky coverage, filter depth)

Deep Drilling Fields (additional pointings, detailed strategy, depth)

Minisurveys (details of strategy for existing MS:

- the candidate Galactic Plane (GP) mini surveys
- the candidate Northern Ecliptic Spur (NES) mini survey, and • the candidate South
- Celestial Pole (SCP) mini survey

and ideas for new MS)

strategy questions such as

optimal visit exposure time

co-added per-bandpass imaging depth

the sky coverage

temporal coverage

observing rules

WP RULES AND EXPECTATIONS

Proposal WPs must include

- Scientific Motivation section - explain why this survey strategy modification is important and what could be learned if the proposed observations were obtained, relative to some baseline.
- Technical Description section - detail what observations are being requested and **should provide enough detail to enable proper simulations to be created,** as well as **additional information that can help in the process of combining similar but separate survey strategy modification requests.**
- Performance Evaluation section - must contain methods to evaluate the effectiveness of the survey strategy modifications. *It is unlikely that any proposed cadence modification suggested in white papers will be carried out in its original form;* thus **metrics along with threshold values for these figures of merit to evaluate the science performance of non-ideal simulations are crucial.** Note that each white paper does not need to solve or address the global optimization problem, nor does it need to supply performance criteria across all science goals.

The **submission template and an example of the submission** https://github.com/lsst- pst/survey_strategy_wp

To submit white papers, please email the compiled PDF to lsst-survey-strategy@lsstcorp.org

For additional **help or questions,** please ask on http://community.lsst.org/c/sci/survey-strategy

WP RULES AND EXPECTATIONS

Software

- The Project will not take formal responsibility for specialized data reduction algorithms needed to process data, including that taken in "non-standard" modes; detailed discussion is available in the Data Management and LSST Special Programs document (ls.st/dmtn-065) and should be perused when proposing non-standard observing sequences. In addition, we strongly recommend that white paper authors consult Sections 5 and 6 in the LSST Data Products Definition Document.
- If a proposed dataset will require special processing, a plan to obtain necessary software and compute resources must be provided in the white paper

WP RULES AND EXPECTATIONS

Evaluation criteria:

there will be no formal acceptance or rejection . WPs will be ***ranked*** by the SAC based on the following:

- **Science Importance and legacy value** of the proposed science program, including
    - *match to the unique abilities of the LSST system*
    - consistency with the four main LSST science themes.

  This could be a single strong science goal, synergies with other astronomical facilities, or a multitude of science goals enabled by the same survey strategy.

- **Feasibility** from the hardware and software point of view, specifically including any special data processing required. The complexity of the program, in terms of additional requirements on hardware and software beyond the baseline requirements, will also be considered.

- **Time requested** (including overheads) : time required should be justified by the associated science.

WFD OPEN QUESTIONS AND OPTIMIZATION OPTIONS

- 18,000 deg^2 within $\delta = -62\circ$ and $\delta = +2\circ$, without the Galactic plane confusion zone. These boundaries were set to optimize the number of detected galaxies useful for cosmological studies, declination limits defined by an airmass limit of 1.18. These galaxy counts stay within 5-10% of the current baseline values even with a much larger survey area. This **tradeoff between the sky coverage and number of visits (co-added depth) is still open to optimization,** subject to the SRD constraints of a minimum 18,000 deg^2 footprint with at least 825 visits per field.
- **The observing time allocation per band** (number of visits per filter). Optimization of this allocation for the WFD (and different fractional allocations for MSs) are possible.
- **Rolling Cadence:** Concentrating a fraction of the observations for a given field into a shorter period of time can provide enhanced sampling rates over a part of the survey for a designated time, and reduced sampling rate the rest of the time *(while maintaining the nominal total visit counts)*. Detailed cadence parameters have not been optimized yet (e.g., how much of the survey area to "roll" at once and how long to "roll" for, or whether to "roll" in right ascension or declination). **The optimization of "rolling cadence" simulations will be driven by submitted white papers.**

WFD OPEN QUESTIONS AND OPTIMIZATION OPTIONS

- The current strategy for the main survey which obtains two visits per night could be modified to obtain a single visit, or more than two visits, per night.
- Two visits per night within 15-60 minutes in order to enable easy linking of asteroid detections, and **robust identification of rapid photometric transients**. Whether the two visits on the same night **should be obtained in the same filter or in different filters has not been decided yet** (e.g., in the context of photometric transients, same filters would provide a more accurate measurement of the brightness change, while different filters would provide a color constraint).
- The current baseline survey strategy assumes that a visit is composed of two 15-second exposures, the so-called snaps. There are compelling technical arguments – including observing efficiency – to adopt single-exposure 30 second visits. **Arguments for or against retaining the 2x15 sec visits** would be very useful in further optimization of the main survey strategy. The impact of read-out noise and other parameters on limiting depth is quantitatively discussed in the LSST Overview paper (see Section 3.2.1).

DDF OPTIMIZATION AND NEW PROPOSALS

DDF: single pointing with deeper coverage and more frequent temporal sampling than the main survey fields

- 4 fields have been identified - this selection is driven by synergy with other surveys http://ls.st/57q
- More fields are possible (up to 10 depending on WFD efficiency, MSs, ToO…
- The observing sequences (filters) and coadded depths are not yet decided.

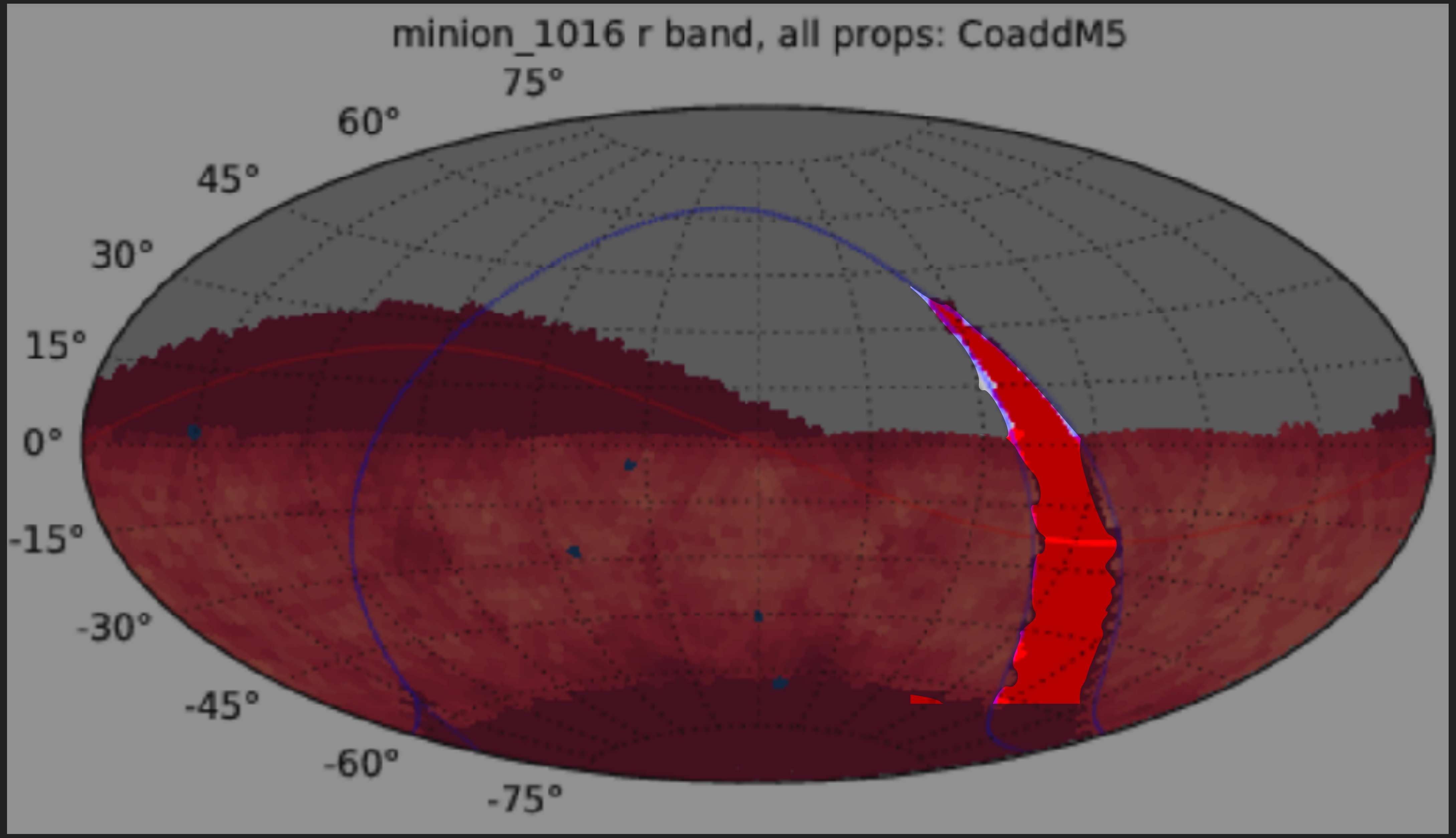
	ELAIS S1	XMM-LSS	Extended Chandra Deep Field-South	COSMOS
RA 2000	00 37 48	02 22 50	03 32 30	10 00 24
DEC 2000	-44 00 00	-04 45 00	-28 06 00	+02 10 55
Galactic l	311.30	171.20	224.07	236.83
Galactic b	-72.90	-58.77	-54.47	42.09
Ecliptic l	345.97	31.04	40.29	150.70
Ecliptic b	-43.18	-17.90	-45.47	-9.39

The current baseline cadence includes sequences of *grizy* observations during bright and gray time, and sequences of *u* band observations during dark time. The large number of filter changes in the bright time sequences are inefficient and the large gap in multi-color sampling during dark time is likely problematic for variable and transient characterization. White papers addressing improved cadences in the DD fields are desirable. Saraub Jha pointed out that focusing on *a single DDF field* per night is inefficient for SN surveys

MINISURVEYS OPTIMIZATION AND NEW PROPOSALS

Fraction of sky time spent observing one or multiple paintings according to different observing rules than WFD

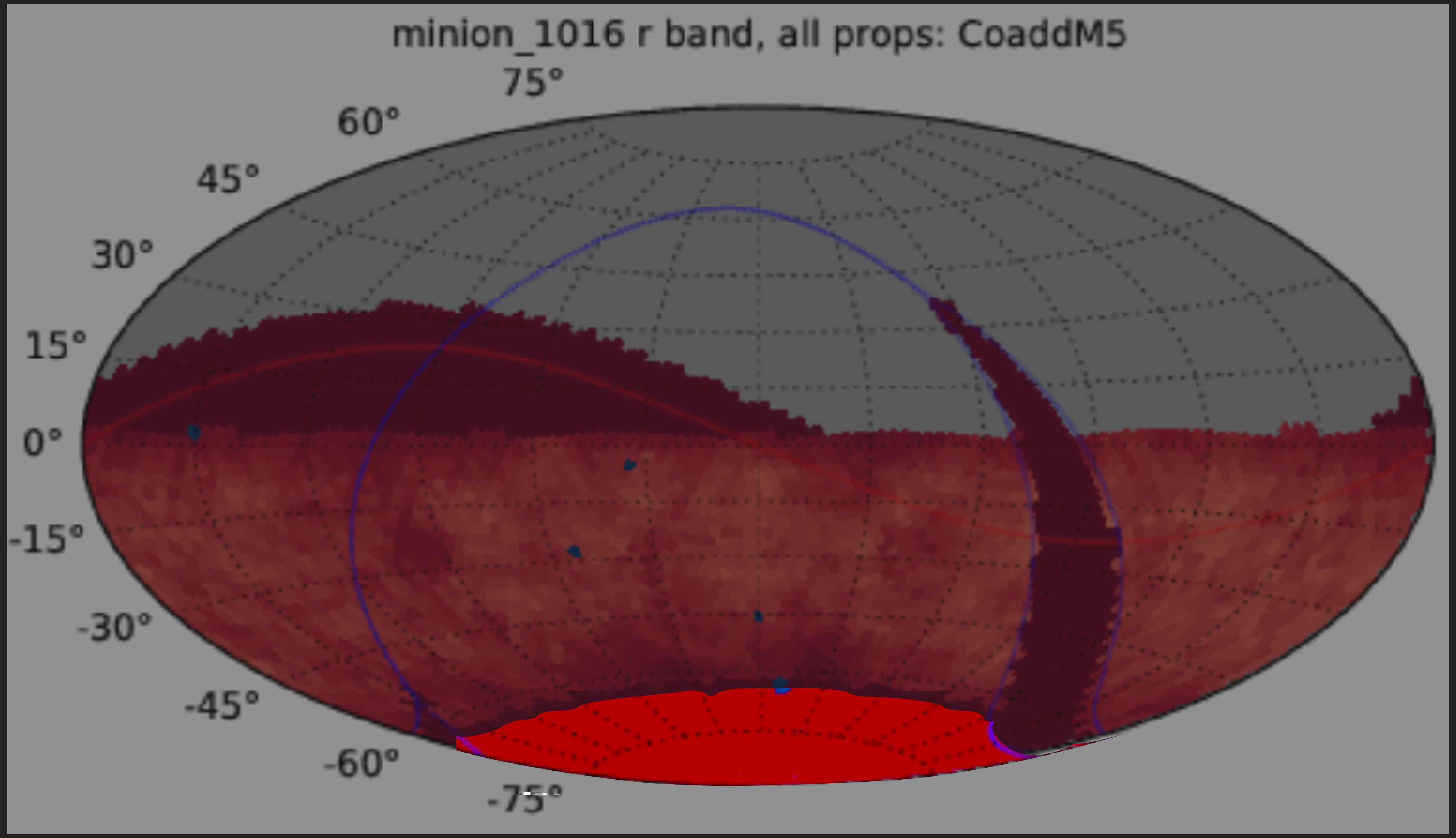
Previously proposed MiniSurveys : Galactic Plane



- WFD avoids GP due to confusion limit: *Galactic confusion zone starts* $|b|=10^{\circ}$ towards $l=0^{\circ}$ and linearly drops to $b=0^{\circ}$ at $l=90^{\circ}$ and $l=270^{\circ}$. Crowding is not expected to significantly impact the quality of data products derived from difference images Science driven input is needed for both "static science" and time domain surveys.
- GP contains ~30 per field in each of the six filters: time-domain studies using photometry from single images could still benefit from additional visits in this region
- Current GP extends to $X > 1.4$ at $\delta = +15^{\circ}$, region that can only be observed at relatively large airmass. With the advent of other surveys (e.g., Pan-STARRS and DECAPS21) Unless a strong case is made in submitted white papers, the Project is likely to limit the coverage of the Galactic plane to $\delta < +2^{\circ}$.

MINISURVEYS OPTIMIZATION AND NEW PROPOSALS

Fraction of sky time spent observing one or multiple paintings according to different observing rules than WFD

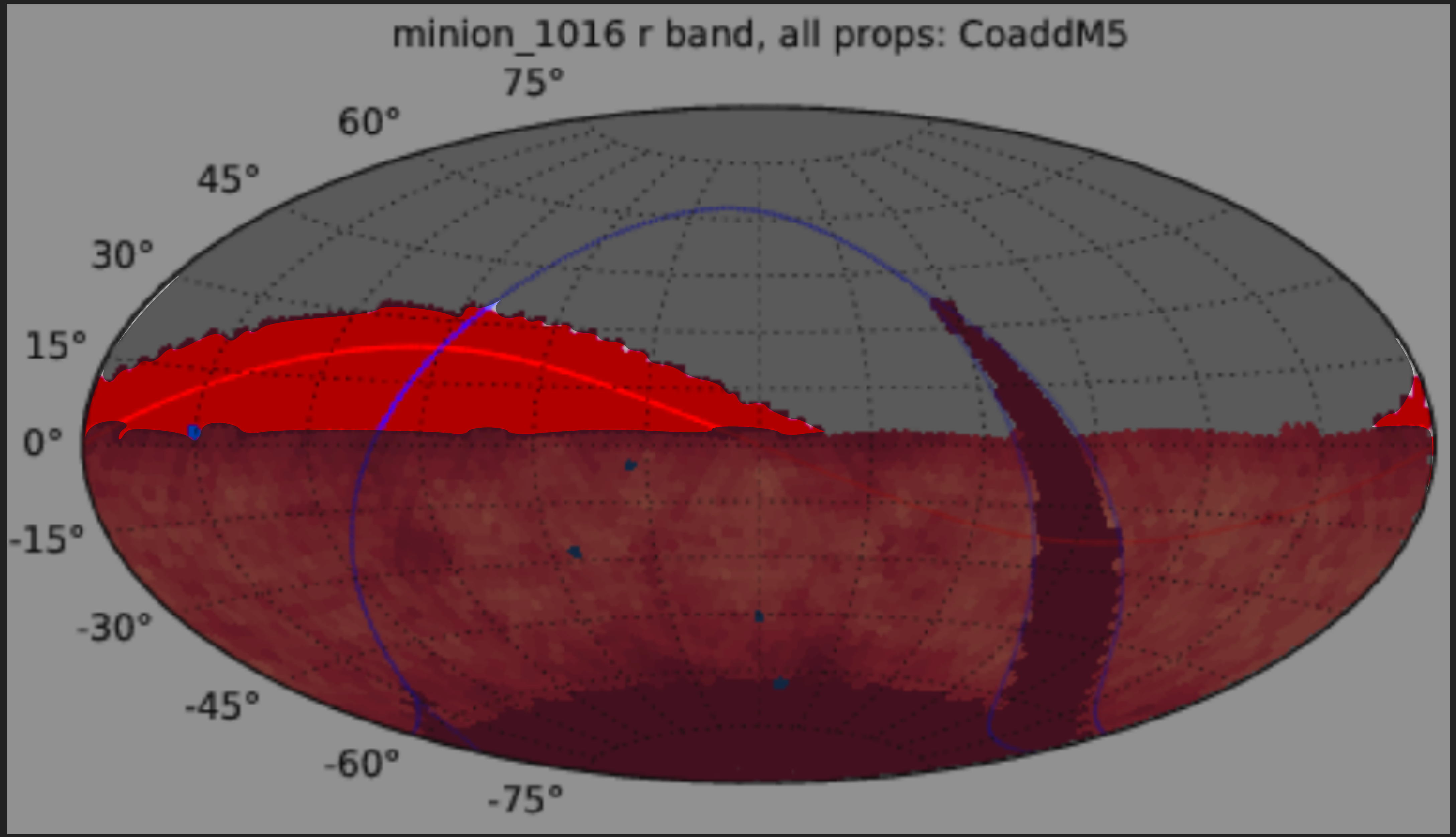


Previously proposed MiniSurveys : Southern Celestial pole

- **To allow coverage of the Large and Small Magellanic Clouds:** relaxed limits on airmass and seeing for the ~2,000 deg^2 region around the South Celestial Pole, but with fewer observations than for the main survey.
- is it necessary to extend the coverage all the way to the South Celestial pole?)
- Cadence?
- Depth?

MINISURVEYS OPTIMIZATION AND NEW PROPOSALS

Fraction of sky time spent observing one or multiple paintings according to different observing rules than WFD



Previously proposed MiniSurveys : Northern Ecliptic spur

- Coverage of a crescent reaching to +10 degrees of the Northern Ecliptic plane in the North Ecliptic Spur (NES) mini survey provides observations of small bodies, particular TNOs, throughout the full range of ecliptic longitude.

MINISURVEYS OPTIMIZATION AND NEW PROPOSALS

Fraction of sky time spent observing one or multiple paintings according to different observing rules than WFD

Previously proposed MiniSurveys : Twilight Survey

Short-exposure images during twilight time that would otherwise go unused.

Science drivers : bright star survey for Galactic science, obtaining light curves for nearby supernovae, and observations of near-Earth asteroids towards so-called "sweet spots"

- 1 sec exposure or shorter (up to 0.1sec)?
- Assuming 7-sec visits (1 sec exposure + 1 sec for shutter + 5 sec for read and slew) about 2,000 deg^2 of sky could be imaged in 25 minutes in a given filter.
- 350 exposures (1 sec + 1 sec + 2 sec) of the same field could be obtained instead.

Science drivers requested and corresponding survey details

CONSTRAINTS ON SURVEY STRATEGY IMPOSED BY THE LSST SYSTEM

Slew Time

- **minimum**: 3 second (2 sec read-out time + 1 sec telescope settling)

  t_Az min=3sec

- slew *time* depends on slew *distance* as **in the azimuth direction,**

  t_Az = 0.66 sec/deg $*$ δ Az (deg) + C_Az

  C_Az = -2 sec

  t_Alt = 0.57sec/deg $*$ δ Alt(deg) + CAlt,

  C_Alt = 3 sec for slews below 9o and

  C_Alt = 37 sec for longer slews (need to recompute optics corrections)

CONSTRAINTS ON SURVEY STRATEGY IMPOSED BY THE LSST SYSTEM

Filters

- 5 of the 6 filters (*ugrizy*) can be loaded into the filter exchange carousel and will be available on any given night.
- **Currently :** replace *z* or *y* with *u* during the day one of dark time, reversed at the end of dark time
- During a given observing night, the system could support as many changes as desired.
- Each change requires **90 seconds plus up to 30 seconds to put the camera into the required orientation.**
- Swapping a filter in the carousel will be done during daytime. ***Max 3000 loads* over its lifetime.**
- **Max 100,000 filter changes over system lifetime** (an average of about 17 changes per night of the survey, after accounting for necessary calibration activities)
- **Each individual filter is designed to support up to 30,000 changes over its lifetime.**

CONSTRAINTS ON SURVEY STRATEGY IMPOSED BY THE LSST SYSTEM

Efficiency constraints

Total visit exposure time *t_vis* **,** 2 exposures/readouts (snaps) per visit, slew and settle time of 5 sec

$$\varepsilon = \frac{t\_vis}{t\_vis + 9sec}$$

Coadded depth scaling with time:

$$m_{co-add} = m_{co-add,Final} + 1.25 \log10(t /10yrs)$$

Photometric error: 1/SNR at the faint limit of the so-called "gold" galaxy sample (4 billion galaxies with i < 25.3 which will be used for cosmological programs,

$$\sigma_{i=25} = 0.04\ (t / 10yrs)^{-1/2}\ \text{mag.}$$

Trigonometric parallax accuracy for a point source r=24

$$\sigma_\pi = 3.0(t / 10yrs)^{-1/2}\ \text{mas.}$$

Proper motion accuracy for a point source with r=24

$$\sigma_\mu = 3.0(t / 10yrs)^{-3/2}\ \text{mas/yr.}$$

Quantity	Year 1	Y3	Y5	Y8	Year 10
r_5 coadd[a]	26.0	26.5	26.8	27.1	27.2
$\sigma(i{=}25)$[b]	0.12	0.07	0.06	0.05	0.04
color vol.[c]	316	20	6	1.7	1
# of visits[d]	83	248	412	660	825
σ_π $(r{=}24)$[e]	9.5	5.5	4.2	3.3	3.0
σ_μ $(r{=}24)$[f]	32	6.1	2.8	1.4	1.0

HELP

The LSST Overview paper summary of the four primary science drivers, expected performance, high-level survey constraints and tradeoffs.

The LSST Science Book tackles an in-depth view of a broad range of LSST science goals. Writ- ten in 2009 by the LSST Science Collaborations, each chapter focuses on investigations rele- vant to a different area of astronomy. Available at https://www.lsst.org/scientists/scibook

The Community Observing Strategy Evaluation Paper (COSEP) is a community-driven paper describing a wide variety of science cases and their implications for survey strategy. Understand impact of changes to strategy and concept of metric

The LSST Science Requirements Document (SRD) describes the official requirements for LSST science deliverables.

The LSST Data Management Science Pipelines Design (LDM-151) This provides details of how and when images will be processed and catalogs will be generated

The outputs of MAF analyses for the 2018a baseline survey, as well as runs demonstrating potential options for mini surveys and Deep Drilling fields (a subset of the runs described in Chapter 2 of the COSEP) are available online at.

A short description of the current Deep Drilling fields and links to further materials (including white papers submitted in response to the 2011 call for input on the DD strategy) are available on the LSST website at http://ls.st/57q.Posts on LSST Community by searching for 'deep drilling'.

Additional information is available in the following presentations:

- Overview of the LSST Observing Strategy (Nov 16, 2015)
- The LSST Deep-Drilling Fields: White Papers and Science Council Selected Fields (Aug 15, 2016)
- Observing Strategy White Paper Status Report (Mar 5, 2017)
- LSST Plans for Cadence Optimization (May 30, 2017)
- Special Programs (Aug 15, 2017)

WHO TO CONTACT

- me and Rachel (on slack)
- The LSST Science Advisory Committee (SAC) (https://project.lsst.org/groups/sac). Strategic and political issues about the LSST survey strategy should be communicated via the SAC (chair: Michael Strauss, strauss@astro.princeton.edu).
- Our SC Liaisons: Eric Bellm and Melissa Graham (on slack) (for other SCs see http://ls.st/uj6)
- Community: http://community.lsst.org/c/sci/survey-strategy
- Mailing list lsst-survey-strategy@lsstcorp.org to contact the sur-vey strategy team in case of specific questions and/or concerns. Messages posted to the mailing list are broadcasted to the survey strategy team and archived. The same list will be used for white paper submission (see Section 2.3).
- Community meeting at the LSST 2018 Project and Community Workshop in Tucson, AZ (August 13-17, 2018).
- The Observing Strategy COSEP community on GitHub https://github.com/LSSTScienceCollaborations/ObservingStrategy
- The Project teams *cannot* support individuals or groups wishing to run the Operations Simulator themselves. The Project will provide Docker images (as well as the source code) and corresponding documentation on running OpSim; however, the Project does not have resources to provide help desk facilities on this topic.