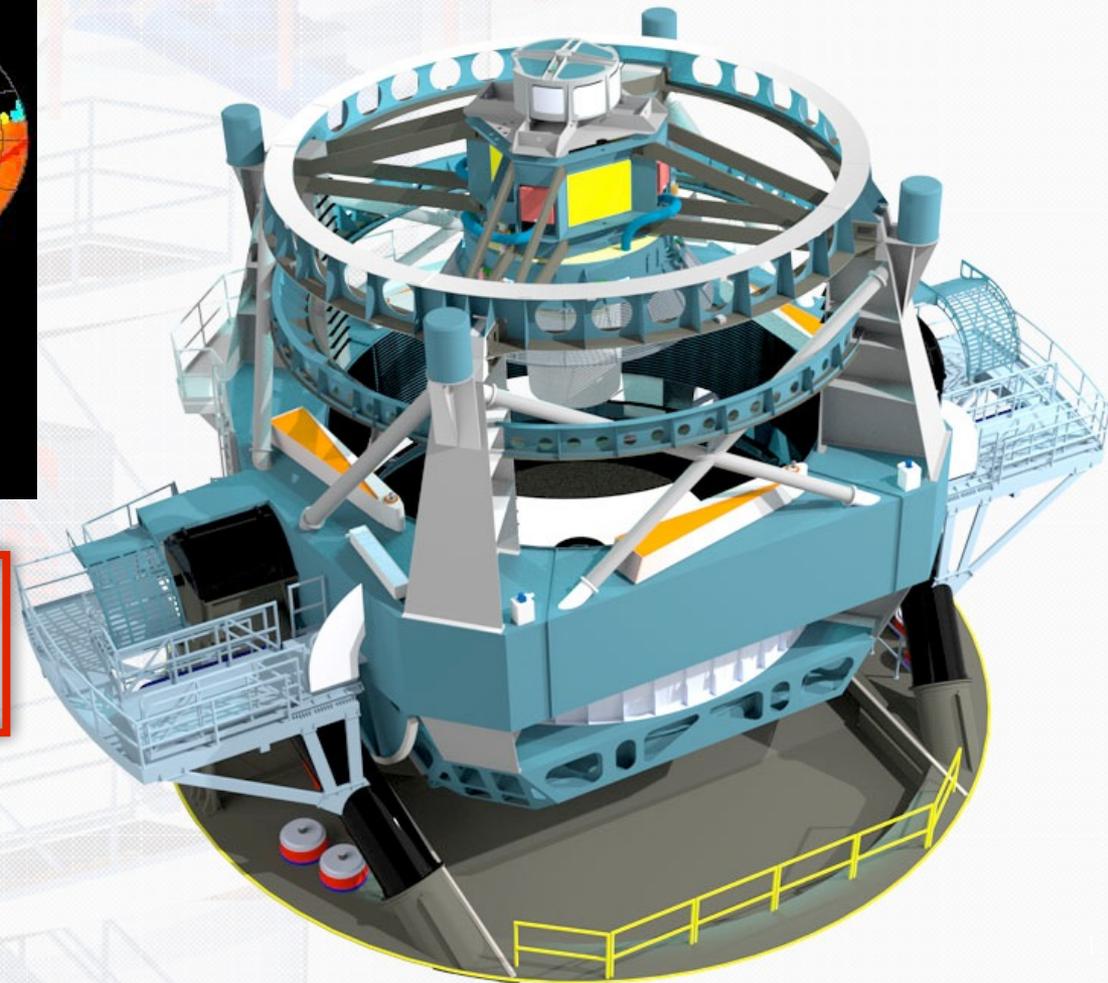
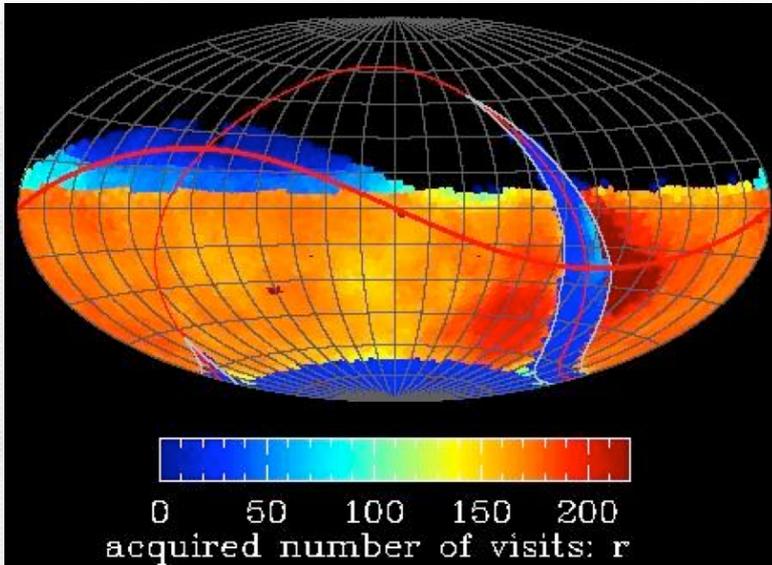


# Observing Strategy White Paper Status Report

Željko Ivezić, White Paper authors, and the LSST Simulations Team

LSST SAC Meeting

Glendale, Mar 5, 2017



This talk is available as

<http://ls.st/zj2>





# Last talk to SAC about the LSST observing strategy (Nov 2015):

- 1) Brief overview of tools for simulating LSST surveys: OpSim & MAF
- 2) Why is survey optimization a hard problem: hierarchy of survey complexity
- 3) What can and cannot be done? Cadence “conservation laws”
- 4) Examples of cadence optimization and future optimization directions.
- 5) The community and SAC role in advising the Project on cadence-related decisions

Available as:

<http://ls.st/4yh>

A detailed talk on cadence optimization

<http://ls.st/kaq>

- 1) **Brief overview of cadence work done in 2016**
  - adopted new baseline cadence
  - NEO cadence improvements
  - towards OpSim v4 and rolling cadence
  
- 2) **Motivation and goals for a white paper on “Science–Driven Optimization of the LSST Observing Strategy”**
  
- 3) **Lessons learned from “The ten cadence questions”**
  - implement, analyze and improve the rolling cadence idea(s)
  - execute a systematic effort to further improve the ultimate LSST cadence strategy

# Adopted new Baseline (minion\_1016)

## Basic characteristics (see <http://ops2.lsst.org:8888>):

- the total number of visits is 2.45 million, with 85.1% spent on the Universal proposal (the main deep–wide–fast survey), 6.5% on the North Ecliptic proposal, 1.7% on the Galactic plane proposal, 2.2% on the South Celestial pole proposal, and 4.5% on the Deep Drilling proposal (5 fields)

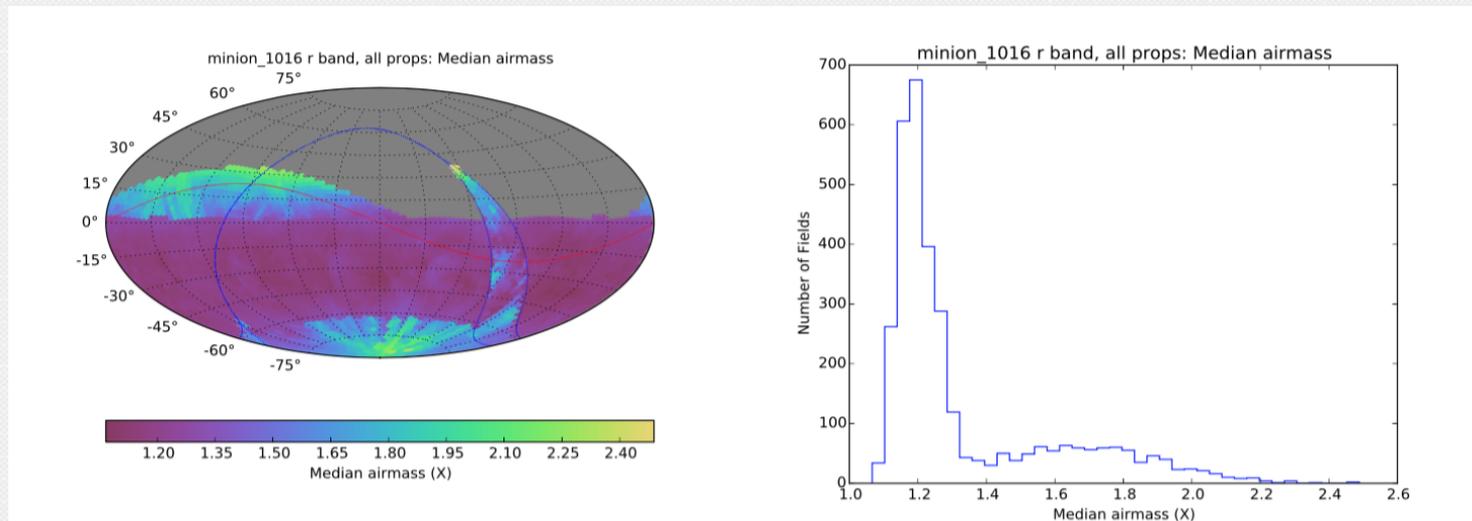


Figure 2.1: The median airmass in the  $r$  band across the sky for simulated cadence `minion_1016` is shown in Aitoff projection of equatorial coordinates in the left panel. The red line shows the Ecliptic and the blue line shows the Galactic equator. The blue curve splits to enclose the so-called “Galactic confusion zone”. The corresponding airmass histogram is shown in the right panel. For the main survey area, the maximum allowed airmass was set to 1.5.

## Main accomplishments:

- a series of NEO-optimized cadences produced and analyzed
- a paper on “The LSST as a Near-Earth Object Discovery Machine” by Jones et al. submitted to Icarus
- a joint report with a NASA-funded JPL group (Chesley & Ivezić) submitted to NASA NEO Office in January 2017

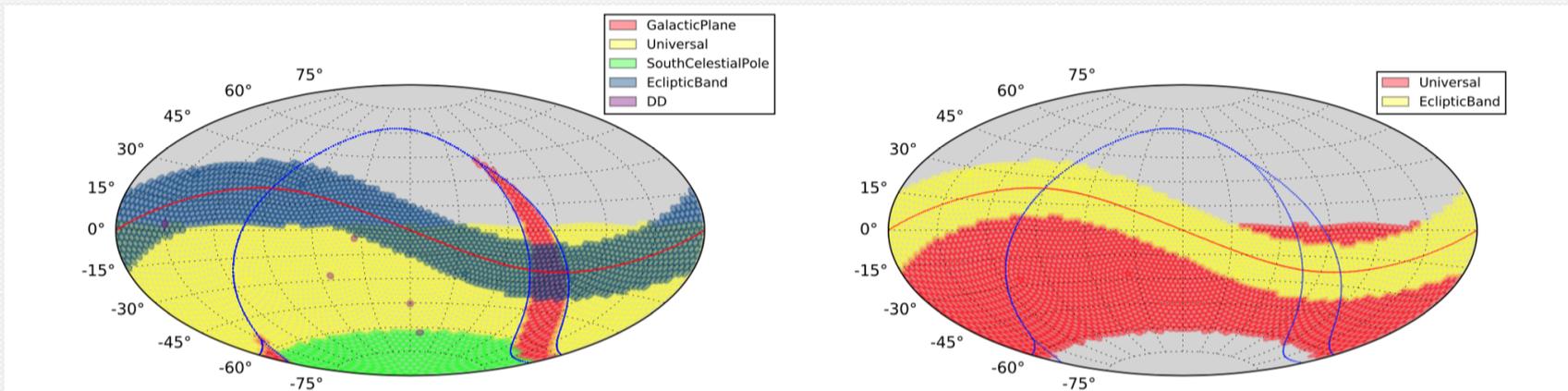


Fig. 7.— The footprints of the proposals, including the Ecliptic Band proposal, used in the NEO-optimized simulated surveys `astro_lsst_01_1015` (the “longer ecliptic visits” survey, left) and `astro_lsst_01_1017` (the “NEO-focused” survey, right). The `astro_lsst_01_1017` survey only includes two proposals.

# Towards OpSim v4 and rolling cadence

## Main drivers for non-uniform, more frequent, visits:

- supernovae: need about three times higher sampling rate
- asteroids: tracklet linkage would be easier
- short-period variability (e.g. cataclysmic variables)

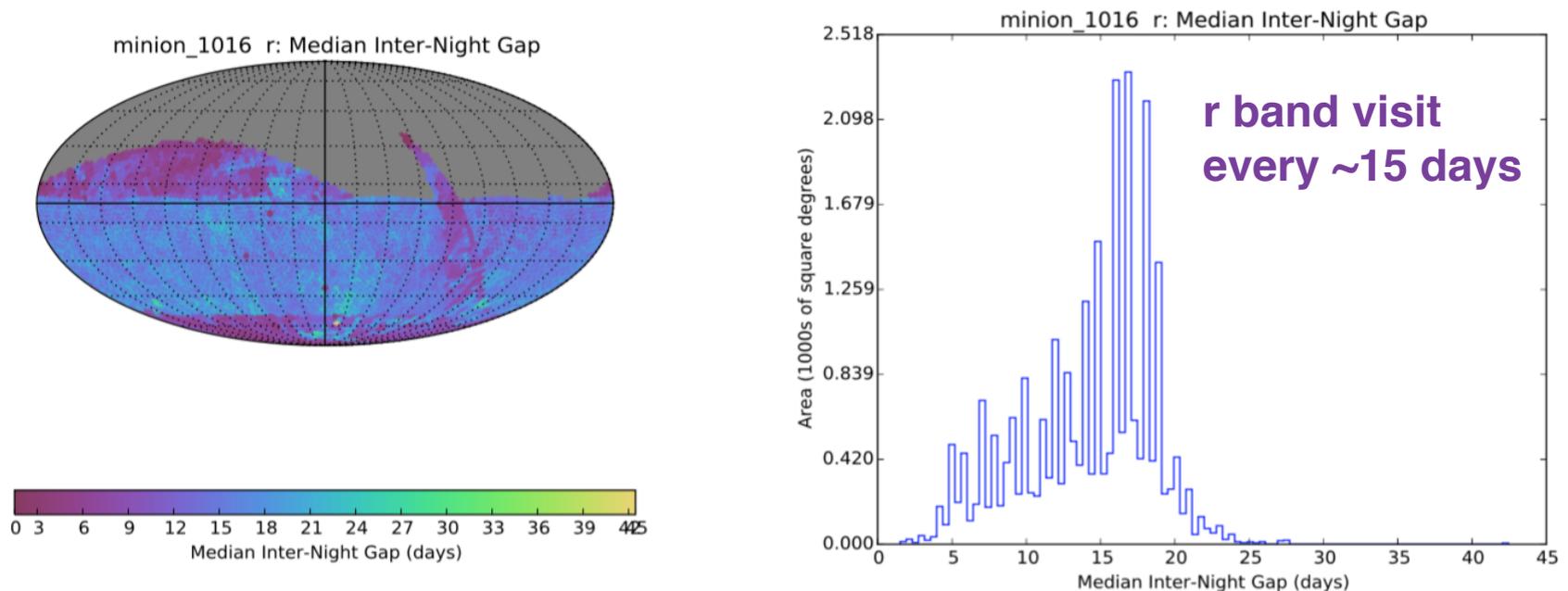
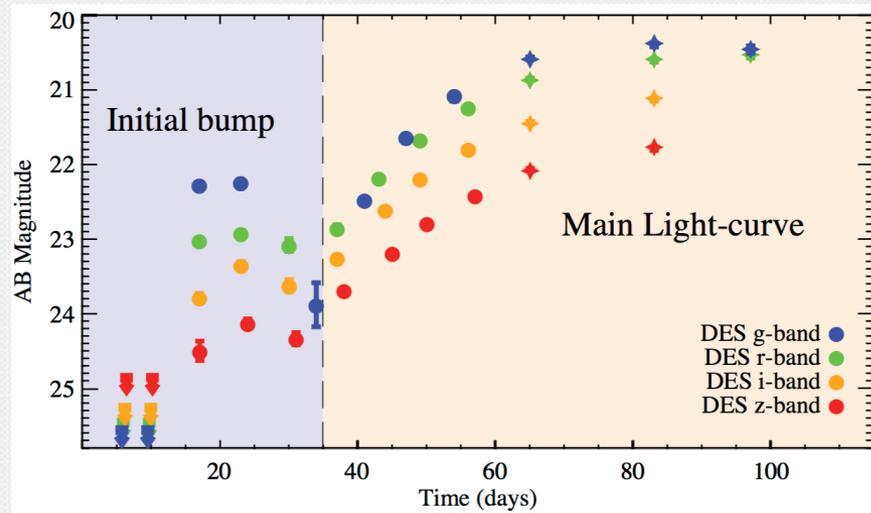


Figure 2.9: The median inter-night gap for r band visits is shown in Aitoff projection for all proposals and all filters for candidate Baseline Cadence [minion\\_1016](#). On average, fields in the main survey get revisited in the r band about every two weeks.

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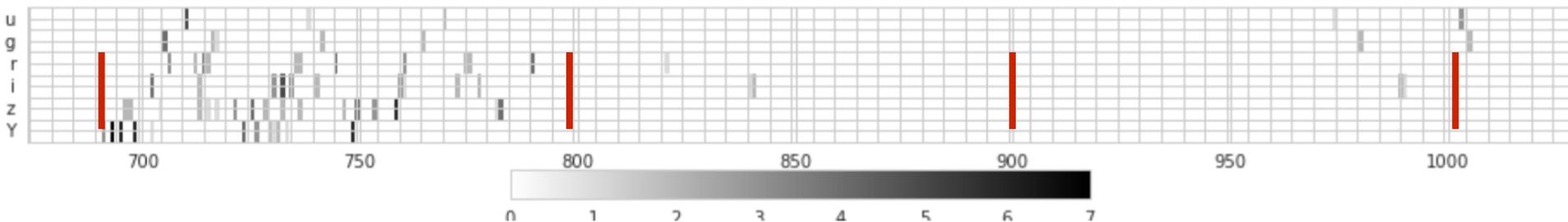


**Left:** light curve for supernova DES14X3taz (Smith et al. 2016)

To resolve pre-peak bump, need revisit rate of  $\sim 5$  days.

**Bottom:** an illustration of an LSST rolling cadence implementation (Connolly and Biswas)

fieldID: 1447 (ra: +94.040938 dec: -26.923688), visits: 175, nights: 354, nights in bands: 67



# Cadence improvements



## Drivers for baseline cadence modifications:

- improved knowledge of the system (now due to simulations, eventually due to performance measurements)
- changing science landscape on timescales of a few years
- unscheduled technical delays or substandard performance (e.g. broken filter, dead CCD, extra noise)
- even 10% improvement in surveying efficiency would be significant accomplishment (c.f. entire DD observing time)
- improved time-domain programs
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**We must construct a sufficiently flexible system that will be able to respond to unexpected and re-optimize the survey!**



## Potential for improvements:

- minimizing the impact of read-out noise (mostly in u band)
- optimizing sky coverage (Galactic plane, south celestial pole, LMC/SMC, Ecliptic)
- **temporal sampling** (SNe, variable stars, asteroids)
- interplay between sky coverage and temporal sampling (the so-called “rolling cadence” idea)
- deep drilling fields
- dynamic cadence (in response to expected SNR)
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**Given finite resources, what should we prioritize?**

# Motivation and goals for a white paper on “Science-Driven Optimization of the LSST Observing Strategy”

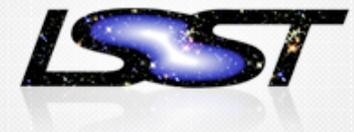
<https://github.com/LSSTScienceCollaborations/ObservingStrategy>

The baseline cadence may not be the best way to deploy the LSST system.

The baseline strategy is not set in stone, and can be improved. Even small changes could result in **significant improvements** to the overall science yield.

How can we design an observing strategy that maximizes the scientific output of the LSST system?

The LSST Observing Strategy community formed in July 2015 to tackle this problem.



# Lessons learned from “The ten cadence questions”

LSST Observing Strategy White Paper considers **a large number of LSST science cases** that cover all major science themes to provide guidelines for improving baseline LSST cadence (~300 pages by ~80 authors).

In order to standardize various constraints derived from diverse science cases, **ten questions about cadence were formulated** and provided to all authors.

Detailed answers were provided for 20 major science cases; 76 answers provided actionable input.

Conclusions derived from those answers are listed in a document provided to SAC by Beth last week, and are only briefly summarized here.



# Lessons learned from “The ten cadence questions”

1) The Project should implement, analyze and optimize the rolling cadence idea (driven by supernovae, asteroids, short timescale variability).

2) The Project should execute a systematic effort to further improve the ultimate LSST cadence strategy (e.g. sky coverage optimization, u band depth, special surveys, DDFs).

Some related work has already been done, more details in Andy’s presentation.



# Rolling cadence comments

Supernovae provide the strongest driver for the implementation of rolling cadence. A sampling rate about three times higher than the uniform sampling implemented in baseline cadence (revisit time scale of about one day), and lasting 3-4 months, is suggested by SNe (also asteroid orbits and short timescale variables).

Extreme cases of rolling cadence, with about a week-long campaigns, for special sky regions would be beneficial for studies of Young Stellar Objects.

The production and analysis of several families of rolling cadence simulations by the Project should be the highest priority because **this baseline cadence modification might provide more significant science benefits than any other proposed modification.**



# Why systematic cadence work?

E.g.

The Milky Way Disk science case: “We have FoMs, but we need many OpSim runs with a variety of temporal distributions of exposures within the ten-year survey lifetime to make these FoMs useful.”

The Project should enable finer optimization by providing several more simulations with the sky coverage in between the baseline cadence sky area of 18,000 deg<sup>2</sup> and the so-called “Pan-STARRS cadence” with ~30,000 deg<sup>2</sup>.

An improvement of u band single-visit depth of 0.6 mag can be achieved with only a minor loss of depth and the number of visits in other bands.



# Main Conclusions

The LSST Observing Strategy community and the white paper effort are providing exceedingly useful guidance about cadence to the Project (many thanks to Phil Marshall for his leadership!)

While **baseline cadence** meets the basic science requirements for the LSST survey, we know that it **can be meaningfully improved!**

The Project should continue cadence improvement efforts and further explore different survey strategy ideas: even 1% gain means 30 nights on a unique 8m-class telescope! (~"a few \$M").



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The Project should continue cadence improvement efforts and further explore different survey strategy ideas: even 1% gain means 30 nights on a unique 8m-class telescope! (~"a few \$M").

Perhaps more importantly, **we must construct a sufficiently flexible system that will be able to respond to unexpected and gracefully re-optimize the survey!**