LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

Call for White Papers for LSST Cadence Optimization

Željko Ivezić, Lynne Jones, Tiago Ribeiro,
the LSST Project Science Team,
and the LSST Science Advisory Committee

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Abstract

The LSST community is invited to play a key role in the refinement of LSST's Observing Strategy by submitting white papers that will describe proposed modifications of the current baseline cadence, including both the main survey and the so-called "deep drilling fields" and mini surveys.

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Call for White Papers for LSST Cadence Optimization

1 Introduction

The Large Synoptic Survey Telescope (LSST) will provide an unprecedented optical imaging dataset that will support investigations of our Solar System, Galaxy and Universe, across half the sky and over ten years of repeated observation. LSST observations will be scheduled automatically, with the scheduling algorithm designed to address all science goals and maximize observing efficiency for given observing constraints. LSST is constructing a flexible scheduling system that can respond to the unexpected and be re-optimized. It has already been shown that a basic implementation of LSST's 10-year survey (simulations of the observing strategy or "cadence") can deliver on a wide range of science.

Nevertheless, exactly how the LSST observations will be taken is not yet finalized and there are a number of open optimization questions. Indeed, it is anticipated that the observing strategy will continue to be refined and optimized throughout operations. The main purpose of this call for white papers to communities interested in LSST science is to solicit detailed proposals for specific modifications of the current baseline cadence, including both the main survey and the so-called "deep drilling fields" and mini surveys.

1.1 LSST Community and LSST Observing Strategy

The LSST Community is already playing a key role in the refinement of LSST's Observing Strategy by developing and analyzing metrics for quantifying the success of simulated observing strategies. An open github community[1] is where this work is being assembled. How the detailed performance of the anticipated science investigations is expected to depend on small changes to the LSST observing strategy is explored in a living dynamically-evolving community white paper (the first version was published as arXiv:1708.04058 in August 2017). The main lessons learned from the first version of this paper are:

1. The LSST Project should implement, analyze and optimize the rolling cadence idea (a non-uniform sampling in time designed to "compress" observations for better coverage

[1] https://github.com/LSSTScienceCollaborations/ObservingStrategy

of variable phenomena on time scales of a few months, driven by supernovae, asteroids, and short-timescale stellar variability), and

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

Through the end of construction and commissioning, this community Observing Strategy White Paper will remain a living document and the main vehicle for the community to broadly communicate to the LSST Project regarding observing strategies. The LSST Project Scientist will periodically synthesize and act on the results presented in this paper, with support from the Project Science Team, the Science Advisory Committee and the future Survey Strategy Committee.

1.2 Motivation for this white paper call

Guided by the community input summarized in the Observing Strategy white paper, and further advice from the Science Advisory Committee (SAC), the LSST Construction Project has decided to solicit detailed technical proposals for specific modifications of the current baseline cadence.

As discussed in more detail in Appendix A, cadence analysis to date indicates that the baseline cadence, while meeting the basic science requirements for the LSST survey, can be meaningfully improved (baseline cadence is described in detail in Sections 1.1 and 2.3 in the Observing Strategy white paper, arXiv:1708.04058). The LSST Science Requirements Document[2] is intentionally vague on cadence details because it recognized that science evolves and that the initial, by now more than a decade old, survey strategy will have to be re-optimized closer to first light. With LSST first light expected in 2020, now is the time to undertake the final pre-commissioning optimization of the LSST baseline observing strategy. We seek science-driven input for cadence properties such as per-bandpass imaging depth, the sky coverage, temporal coverage, observing rules, etc., as summarized in Appendix A. Investigations of a limited number of such cadence modifications are reported in Chapter 2 from the Observing Strategy white paper (and discussed in various supplementary materials listed in Appendix C).

[2] See ls.st/srd

1.3 General guidelines

We solicit detailed proposals for specific modifications of the current baseline cadence, including both the main survey and the so-called "deep drilling fields" and mini surveys. There are no specific limitations on what kind of science programs will be considered, but please note that the overall four LSST science themes remain the cornerstones of the LSST survey and cannot be easily abandoned (the LSST Science Requirements Document states that "the adopted observing strategy will not jeopardize the goals of any of the four main science themes").

Detailed proposals are also solicited for novel ideas, such as twilight observing and (hypothetical) narrow-bandpass surveys, as well as synergies with other major surveys (e.g., Euclid). At this time we do not solicit proposals for optimizing observations during commissioning period. Once the start of commissioning surveys is known with adequate accuracy (1-2 months), the Project will solicit detailed suggestions in due time.

Technical constraints imposed by the system and observing conditions are summarized in Appendix B. In cases that require more detail, or in case of specific questions not addressed in this document, please start discussion at community.lsst.org[3]

The LSST Science Requirements Document states that "the adopted baseline design assumes a nominal 10-year duration with about 90% of the observing time allocated for the main LSST survey.", and further clarifies that "The remaining 10% of observing time will be used to obtain improved coverage of parameter space. . . ". While detailed allocation will depend on currently unknown system performance, it is unlikely that the goals of the main survey could be met with a time allocation significantly below 80%. In other words, it is plausible that the time allocated to programs other than the main survey could significantly exceed 10% (perhaps by as much as a factor of two), but no firm commitments beyond this statement of plausibility can be made at this time.

The data from any given specialized survey will be treated exactly the same way as all LSST data: the proposers will have no proprietary access to it. Indeed, the final set of the so-called deep-drilling fields and other mini-surveys may be based on an amalgam of ideas from different white papers; there will be no sense in which a given proposal must be accepted or rejected as-is.

[3]Add the link here.

1.4 Review process and timeline

The deadline for submitting white papers is November 29, 2018. For submission instructions, please see the next section. The input from submitted white papers will be used for quantitative cadence optimization and design of multiple observing strategies. These multiple strategies will address varying science drivers and will form a "menu" of possible options (e.g., a main survey with 18,000 deg^2 of sky coverage vs. the sky coverage of 23,000 deg^2 to somewhat shallower depth). Analysis of simulated observing strategies on this "menu" will be presented to the LSST Science Advisory Committee in 2020, who will advise the Project on specific observing strategy to be used at the start of LSST survey (anticipated in 2022). In developing their recommendations to the Director, the SAC will be guided by selection criteria set by the Project Science Team (e.g., in consideration of the limiting technical criteria, such as those discussed in Appendix B). The Director can further consult with the Project Science Team about the SAC cadence recommendations.

Soon after the November 2018 submission deadline, members of the Science Advisory Committee, with technical support from the Project[4], will triage white papers and decide which of them meet the criteria of scientific excellence and technical feasibility for further quantitative analysis (including suggestions for combining proposals into single programs, and giving suggestions for maturation of the current notional extragalactic observing strategy).

We anticipate that the resulting list of observing strategies that will be simulated and analyzed (the "menu" above) will be available by April 2019. Simulated surveys and Metric Analysis Framework (MAF) analysis will become available by the end of 2019. The preparation of the final cadence report for the LSST Science Advisory Committee, in a close collaboration between the Project and the Observing Strategy github community and Science Collaborations, will take place during early 2020.

An overall aim of the Project and all stakeholders is to make this process transparent and to base all decisions on quantitative input and pre-defined criteria to the maximum extent possible. The Project will organize a dedicated session about this call for white papers, to further clarify details, exchange ideas, discuss baseline, and coordinate teams that plan to submit white papers, at the LSST 2018 All-hands meeting (Tucson, Aug 13-17).

[4]The Project will establish a Survey Strategy Committee to evaluate competing survey strategy proposals and to propose a survey strategy for commissioning and operation. The committee will be comprised of both project and non-project personnel, with SAC making recommendations for committee membership.

2 How to submit a white paper?

2.1 Who can submit a white paper?

All members of scientific community interested in LSST science are eligible to submit a white paper. We reiterate that the data from any given specialized survey will be treated exactly the same way as all LSST data: the proposers will have no proprietary access to it. There will be no formal "acceptance" of proposals; with the overall ranking priority advice provided to the Project by the SAC, the Project Science Team will implement several strategies that will be used as quantitative input ("a menu of options") by the SAC when recommending the strategy to be used during the early phase of LSST survey.

2.2 Requested input

Response will require science objectives, positions, depth, filters, cadence of observations, and metrics to demonstrate requirements

DDFs, mini-surveys (Northern Ecliptic Spur, Galactic Plane, South Celestial Pole)

descriptions in the overview paper

We may want to allow proposers to flag their proposal as belonging to one of:

- a specific pointing(s) that is (relatively) agnostic of the detailed observing strategy (e.g., a science case enabled by deep precise multi-color photometry)
- a specific observing strategy to enable specific time domain science, that is relatively agnostic of the pointing (e.g., search for extragalactic transient populations)
- an integrated program with science that hinges on the pointing/detailed observing strategy combination (e.g., search for variable stars in the LMC/SMC)

refer to an example of DDF in tex template below

Questions of mini-surveys and deep drilling fields are coupled at some level to wide-fast-deep: more time for the former means less for the latter, and some of the design decisions for the latter affect the science case for the former. For example, how rolling cadence is done may allow some variable and transient science to happen that would otherwise be the focus of a deep drilling field, and changes in the main survey footprint will affect the definition of a Galactic Plane survey.

2.3 TeX template for submission

We need to provide a tex template...

ZI: it seems that submitting via pull requests to a github repo should be the easiest. If undergrads can do it for their homeworks, our colleagues should be able to do it, too. But whatever we do, we need to think about how to make it easy for us to handle them once submitted.

mention any restrictions on the length of the paper.

give an example as part of template, perhaps from the overview paper

can we abstract the existing DDF strategies into this template form, too?

Explain how to submit by a pull request to Observing Strategy White Paper repo (a new dir? talk to Phil M.)

3 Proposal ranking criteria

There will be no formal "acceptance" of proposals; with the overall ranking priority advice provided to the Project by the SAC, the Project Science Team will implement several integrated observing strategies (simulated cadences) that will be used as quantitative input ("a menu of options") by the SAC when recommending the strategy to be used during the early phase of LSST survey.

Satisfy minimum technical requirements [evaluated by PST or designates], including coming in under a "rule of thumb" amount of total observing time (<1%, e.g. 250-300 hours of time, including overhead)

Ranking criteria for DDF selection [For the SAC to evaluate]:

(i) Select an ensemble that will maximally enable LSST's diverse science objectives. Functionally, this means that Solar System and Milky Way science will be prioritized for pointing selection, with Time Domain science likely driving the detailed observing strategies;

(ii) Provide a legacy dataset that will inform the development of and/or add scientific value to data from other astronomical facilities;

(iii) Observable by other flagship facilities on ground and in space.

Importance and robustness of proposed science programs

Versatility of data set

Observing efficiency (including the system safety considerations)

Consistency with the main four LSST science themes

Acknowledgments: this document has greatly benefited from discussions between the LSST Project Science Team, the LSST Science Advisory Committee and Kem Cook, Phil Marshall, Steve Ridgway, Daniel Rothchild, Peter Yoachim and numerous other members of the LSST Science Collaborations.

A Examples of current open cadence questions

Summarize issues addressed in the living Observing Strategy White Paper, including "The top 10 questions"...

A.1 The main Wide-Fast-Deep survey

SAC: We recommend that the formal definitions of the boundaries of the Wide-Fast-Deep survey be re-examined with the tools available with the OpSim.

different bands in pairs of visits?

dithering?

rolling cadence properties (RA vs. Dec rolling)

area vs. coverage tradeoff ("Pan-STARRS cadence")

minimizing the impact of read-out noise in u band

abandon snaps?

twilight observing?

A.2 "Deep Drilling" fields

White papers available from https://project.lsst.org/content/whitepapers32012

4 locations already fixed (Elais-S1, CDF-S, XMM-LSS, Cosmos)

The detailed cadence for the four existing deep drilling fields, and the existence and parameters for the current suggested mini-surveys (North Ecliptic Spur, the Galactic Plane, and the South Celestial Cap) need justificatio and finalization, and therefore are also suitable topics for white papers.

A.3 Galactic plane survey

Confusion issue (refer to software constraints in Appendix B).

The static science (such as the Rich bulge survey with DECam and Schlafly's DECAPS survey) vs. time domain survey (e.g. Saha's RR Lyrae survey with DECam)

The footprint in the current baseline cadence extends to far north along the Galactic plane, to the region that can only be observed at relatively large airmass from Cerro Pachon ($X > 1.4$ at Dec=$+15°$). Originally, this extension was designed to extend longitudinal coverage of the Galactic plane with Galactic structure studies in mind. With the advent of other surveys (e.g. Pan-STARRS and DECAPS), the reasons for obtaining these less efficient observations (due to unavoidable high airmass) are less compelling. Unless a strong case is made in submitted white papers, the Project is likely to limit the coverage of the Galactic plane to Dec=$< 7°$).

A.4 Southern Celestial pole mini survey

LMC and SMC as the main drivers, but also calibration and legacy

A.5 Northern Ecliptic spur mini survey

NEOs vs. main belt vs. TNOs

A.6 Twilight survey

Copy relevant info from Stubbs document.

B Cadence constraints imposed by the LSST system

B.1 Observing and exposure time constraints

The LSST Science Requirements Document "...assumes a nominal 10-year duration with about 90% of the observing time allocated for the main LSST survey.", and thus 10% of observing time is left for all other programs. However, if the system will perform better than expected, or if science priorities will change over time, it is conceivable that 90% could be modified and become as low as perhaps 80%, with the observing time for other programs thus doubled. At this time, details are TBD but the Project is developing flexible scheduling procedures to enable such modifications.

Minimum Exposure time: Science Requirements Document stretch goal is 1s; design spec is 5s. Short exposures might have problems with irregular PSFs and will have a lower efficiency due to finite read-out time (2 sec). Exposures much longer than standard 30 sec will cause fast asteroids to be trailed. In dark time, the u band exposures are not background limited with the standard exposure time (see Table 2 and related discussions in the LSST overview paper).

Read-out time

Slew time

Standard exposure sequence: 2x15 sec

B.2 Limiting depth estimates and "cadence scaling laws"

Summarize here m5 expressions from the overview paper and the dependence of various measurement errors on time.

B.3 Hardware constraints

Telescope altitude limit, the zenith exclusion zone

Per LSST Document SPT-494, the constraints on the filter exchange strategy are:

For planning observations and in-dome calibration exposures, there is interest in the relevant engineering constraints on filter exchanges, beyond what is captured in requirements. As the system is not yet completely built and characterized, the following represents our current understanding, based on the design and on engineering judgement. As such, some of the details should be considered preliminary and subject to change. Expanded ranges could be possible if there are strong scientific motivations along with sufficient resources during operations.

The filter change mechanism is designed to undergo a total of 100,000 changes over its lifetime. Each filter is designed to support up to 30,000 changes over its lifetime.

A maintenance cycle is anticipated, and this would nominally occur after 10,000 changes or one year, whichever is reached first. The actual need will be informed by experience during Integration & Test and commissioning.

During a given observing night, the system could support as many changes involving the 5 filters loaded in the carousel as desired, without any practical limitation beyond the two-minute change interval (which consists of 90 seconds for the exchange plus up to 30 seconds to put the camera into the required orientation).

Filter loader operations (swapping a filter in the carousel) will be done during daytime. The system is designed for 3000 loads over its lifetime.

B.4 Software constraints

Double check DMTN-065

The Project will not take formal responsibility for specialized data reduction algorithms needed to process data, including that taken in "non-standard" modes;

Refer to Melissa's doc on Special Programs

Mention crowded fields (and perhaps deblending?), document from Mario.

C Supplementary materials

C.1 Useful publications and documents

The LSST Overview paper provides a short summary of the four primary science drivers, as well as the expected performance of LSST in terms of throughputs, and calibration. Also relevant for the purposes of survey strategy, there are discussions on survey constraints and tradeoffs in this paper. http://ls.st/pif

The Observing Strategy White Paper (OSWP) is a community-driven paper describing a wide variety of science cases and their implications for survey strategy. This paper is primarily aimed at helping define the main (90%) WideFastDeep survey. http://ls.st/3y1

The LSST Science Requirements Document (SRD) describes the official requirements for LSST science deliverables. Section 3.4 is the most relevant for survey strategy, although other sections are relevant for telescope and camera performance such as throughputs and readout time. http://ls.st/srd

The LSST Data Products Definition Document (DPDD) describes the data products that LSST will provide, with some high-level background on how they will be produced. If you want to know what will be contained in various catalogs, this is a good place to look. http://ls.st/dpdd

The LSST Data Management Science Pipelines Design (LDM-151) document describes the LSST data management processing pipelines. This provides details of how and when images will be processed and catalogs will be generated, including information on the algorithms used in each processing stage. If you want to know more about the details of a value in an output catalog and how it will be calculated, this is the place to look. http://ls.st/ldm-151

The baseline simulated survey document describes the new features enabled in Opsim v4, as well as characteristics of the updated baseline simulated survey.

C.2 Useful websites and slide collections

Note that these websites are still in development

Documentation about MAF, including a high-level overview and descriptions of current standard metric analyses, is available at `http://sims-maf.lsst.io`. The outputs of MAF analyses for the new baseline survey, as well as runs demonstrating potential options for minisurveys and deep drilling (a subset of the runs described in Chapter 2 of the OSWP) are available online at `http://astro-lsst-01.astro.washington.edu:8080`.

Documentation about OpSim (SOCS and Scheduler), including a high-level overview and description of scheduling options, is available at `http://sims-opsim.lsst.io`.

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. Additional posts on LSST Community can be found by searching for 'deep drilling'.

An open, searchable resource for asking questions not addressed in this document is available on LSST Community, in the Science category, SurveyStrategy subcategory. Team members will monitor and respond in a timely manner to questions posted there. `http://community.lsst.org`

Additional information is available in the following presentations:

- "Overview of the LSST Observing Strategy" (Nov 16, 2015): `http://ls.st/4yh`
- "The LSST Deep-Drilling Fields: White Papers and Science Council Selected Fields" (Aug 15, 2016): `http://ls.st/wzy`
- "Observing Strategy White Paper Status Report" (Mar 5, 2017): `http://ls.st/zj2`
- "LSST Plans for Cadence Optimization" (May 30, 2017): `http://ls.st/ot2`
- "Special Programs" (Aug 15, 2017): `http://ls.st/10o`

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C.3 Communication about the LSST survey strategy

The Project Scientist (Željko Ivezić, e-mail: ivezic at astro.washington.edu) is formally responsible for survey strategy optimization efforts and is the formal liaison between the community and the LSST Scheduler and Operations Simulation teams.

The LSST Science Advisory Committee (SAC) is charged with collecting and delivering various community input to the Project. Strategic and political issues about the LSST survey strategy should be communicated via the SAC (chair: Michael Strauss, strauss at astro.princeton.edu).

In addition to this call for white papers, the Observing Strategy white paper[5]) provides a coordinated mechanism for providing scientific input about survey strategy. LSST science collaborations are also official channels for communication with the LSST project — a Data Management liaison is assigned to each Science Collaboration to answer specific questions about data products generated by the project.

There will be public (open and archived) discussions with the survey strategy team, as well as LSST Data Management and LSST Education and Public Outreach teams, on LSST Community (`http://community.lsst.org`).

Throughput the survey strategy design process there will be open meetings. The first of these will be at the LSST All Hands Meeting 2018 in Tucson, AZ (August 13-17, 2018).

[5] A living document available at https://github.com/LSSTScienceCollaborations/ObservingStrategy