The LSST Operations Simulator

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OpSim lead

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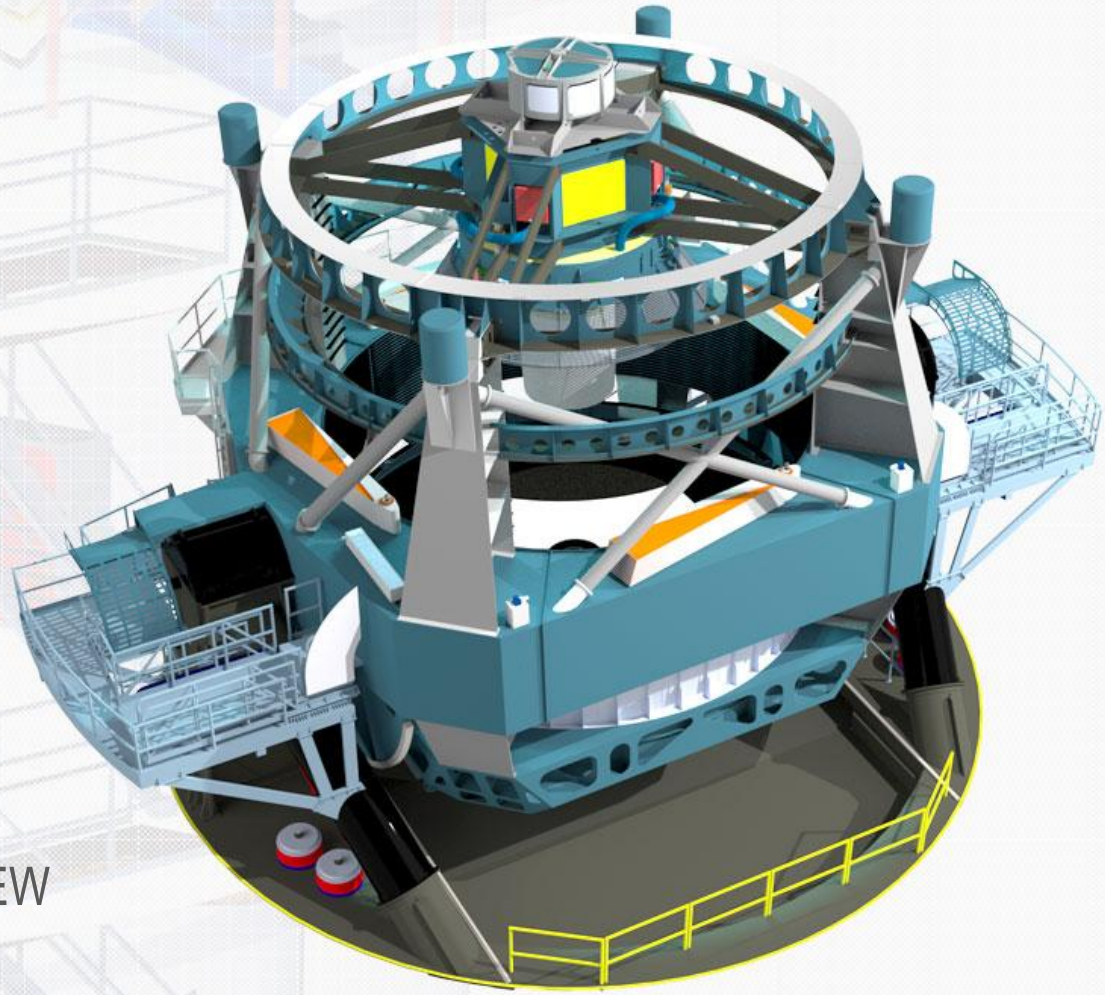


The Need for Scheduling Tools

- To schedule observations with LSST in real time according to:
  - Science Requirements and survey priorities
  - Target position and availability
  - The capabilities and constraints of the telescope
  - Environmental parameters: sky conditions, sky brightness, etc.
  - Scheduled and Unscheduled downtime
  - Adapt to changes in goals and strategy over survey duration

- A pair of tools:
  - A “scheduler” that queues observations to the working telescope
    - Uses real time environment data
  - A simulator that is logically identical to the scheduler, except that:
    - Uses simulations of environmental stimuli
    - Can simulate alternate scenarios

A Tool for Advanced Planning

- Can the science goals in the SRD be met?
  - An early achievement was to ascertain the minimal needed FOV area
  - Determined constraints for readout and slew times
- How can the survey be designed for the most compelling mix of science? What kinds of use cases are prohibitive?
- How can performance margin be increased?
- Learn how to construct scheduling tools for run-time operation
- Communicate with science community re: survey cadence and coverage priorities

Simulator Overview

Parametrized Telescope/Instrument Model

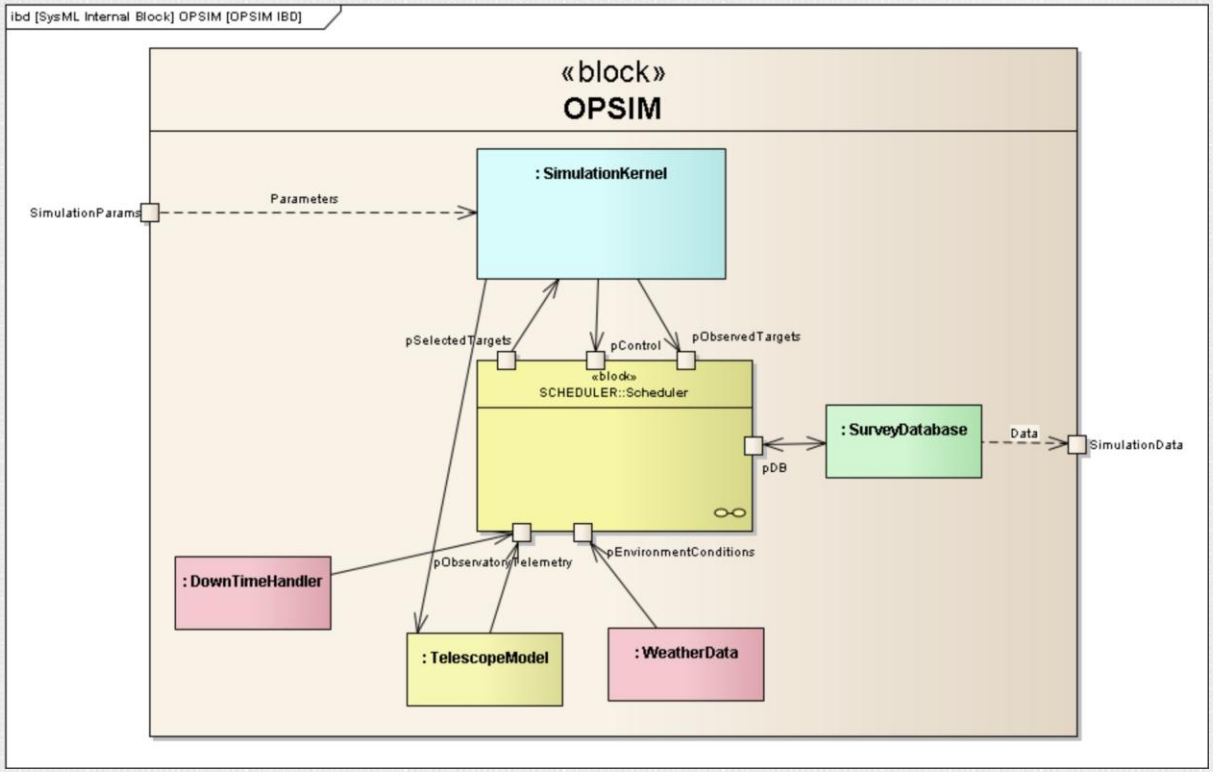
Site specific Observation Environment modeling: site, weather, sky-brightness

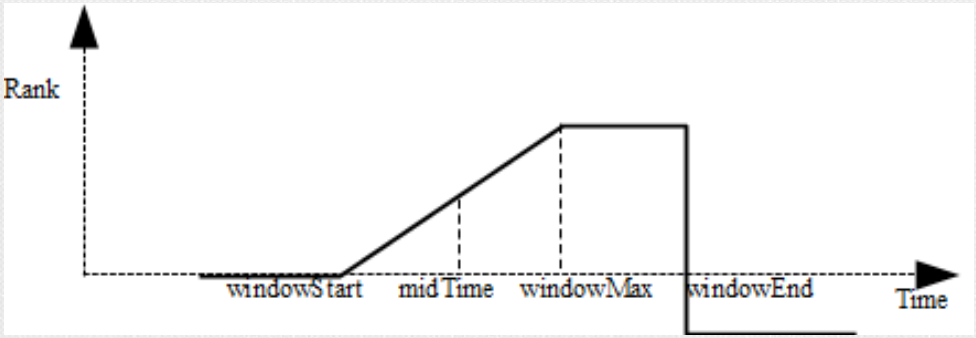
Observational desiderata coded as “proposals” – generate time dependent “demand”

Optimization: Maximize science programs simultaneously

Output Observation History to Survey Database

Supplementary analysis and reporting tools and metrics





Salient Features

- Sophisticated Telescope Model
  - All movements tracked: mount, dome, optics, rotator, cable wraps, filter change
  - 50 parameters configure speeds, accelerations, delays and limits
  - Configurable table to determine sequence of movements for any given slew
  - Simulation output can guide telescope engineering
- Proposals Implement science programs
  - Proposals run simultaneously
  - Each proposal calculates demand dynamically
  - Demand from all proposals aggregated - tuneable priorities
  - Configurable parameters for defining target lists, filter and timing requirements, and other specifications

Science Cases and Proposal Variety

Can run any or all of the following types:

- Deep Cosmology coverage
  - total visits per field/filter combination
- Transient proposals
  - Simple to complex cadence with simple filter requirements
    - NEA proposal
    - Transients without color requirements
- Transient SubSequence proposals
  - Complex, independent, cadences for multiple filters
  - Multi-color SN survey, multi-color KBO survey

Universal Cadence – special case:

Deep cosmology visits collected in 30 min pairs

Designed to deliver several science goals simultaneously

Simulation Runs

- Well over 1000 simulations have been run over the years
  - Simulator capabilities have grown over time
  - Runs with different combinations of proposal types and parameter sets
  - Informed engineering decisions:
    - Early: Telescope FOV, read-out time. Recent: Cable-wrap orientation
- Primary survey: Universal Cadence for Wide Fast Deep survey for Cosmology and Milky Way studies, with ~30 min. pairs for Solar System objects. 18,000+ square degrees
- Smaller area surveys devoted to:
  - Deep supernovae and KBO – time sequences for SNe
  - North ecliptic plane for NEOs
  - Milky Way plane
  - South celestial cap, including Magellanic Clouds

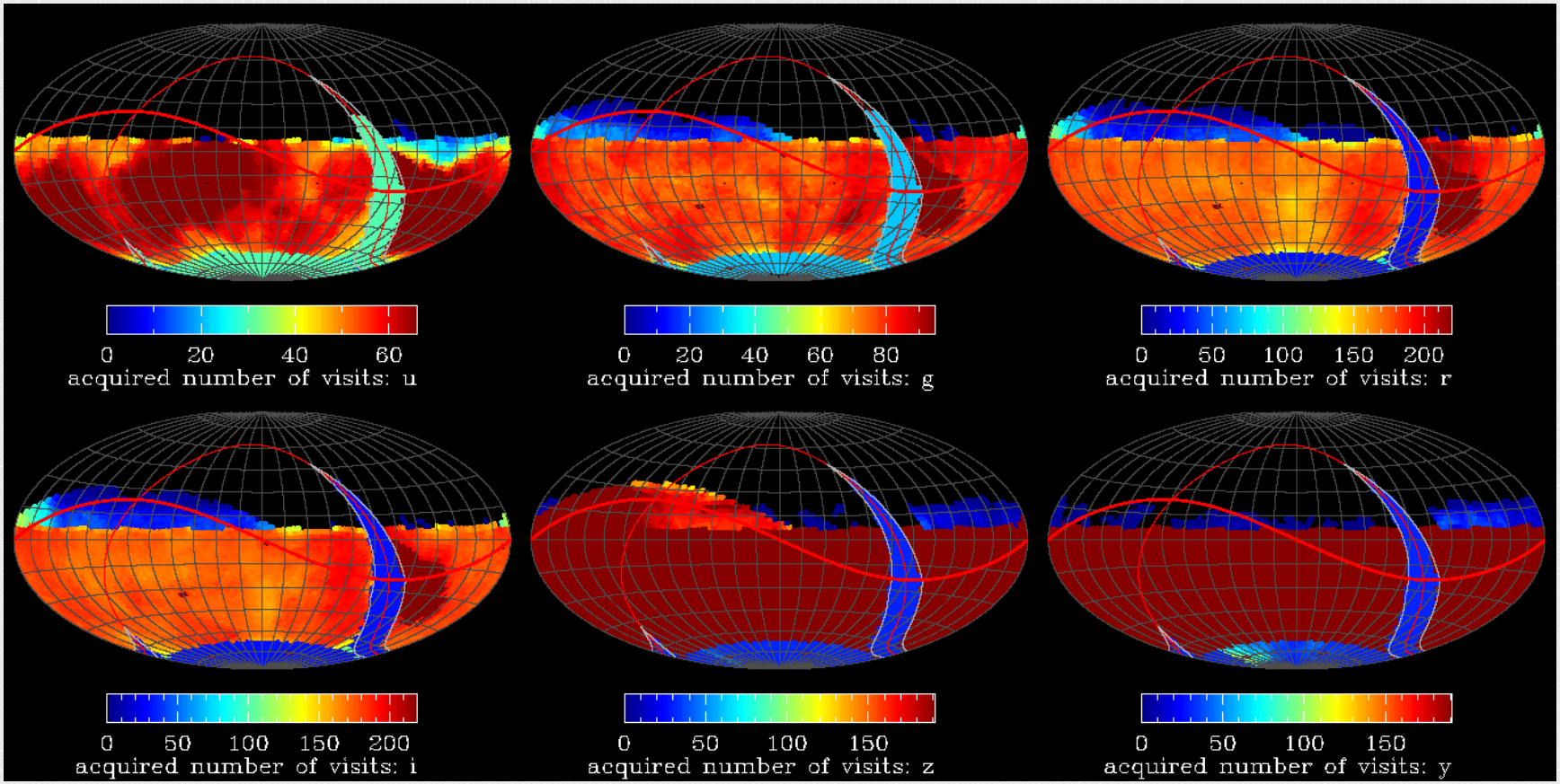
A Fiducial Run (OpSim 3.61)

- 10 year simulation: “existence proof” for an LSST survey

- Observing start/stop at 12 degree twilight
- CTIO 4m weather log as weather model
- Scheduled downtime for maintenance
- u filter in camera ~ 6 days per lunation
- Five science proposals:
  - WideFastDeep – Universal Cadence
  - Galactic plane: collect 30 visits in each passband
  - North ecliptic – Universal Cadence
  - South Pole: collect 30 visits in each filter
  - 6 fields of “deep drilling” for supernovae
    - 100 day sequence – visit every 5 days in *grizy*

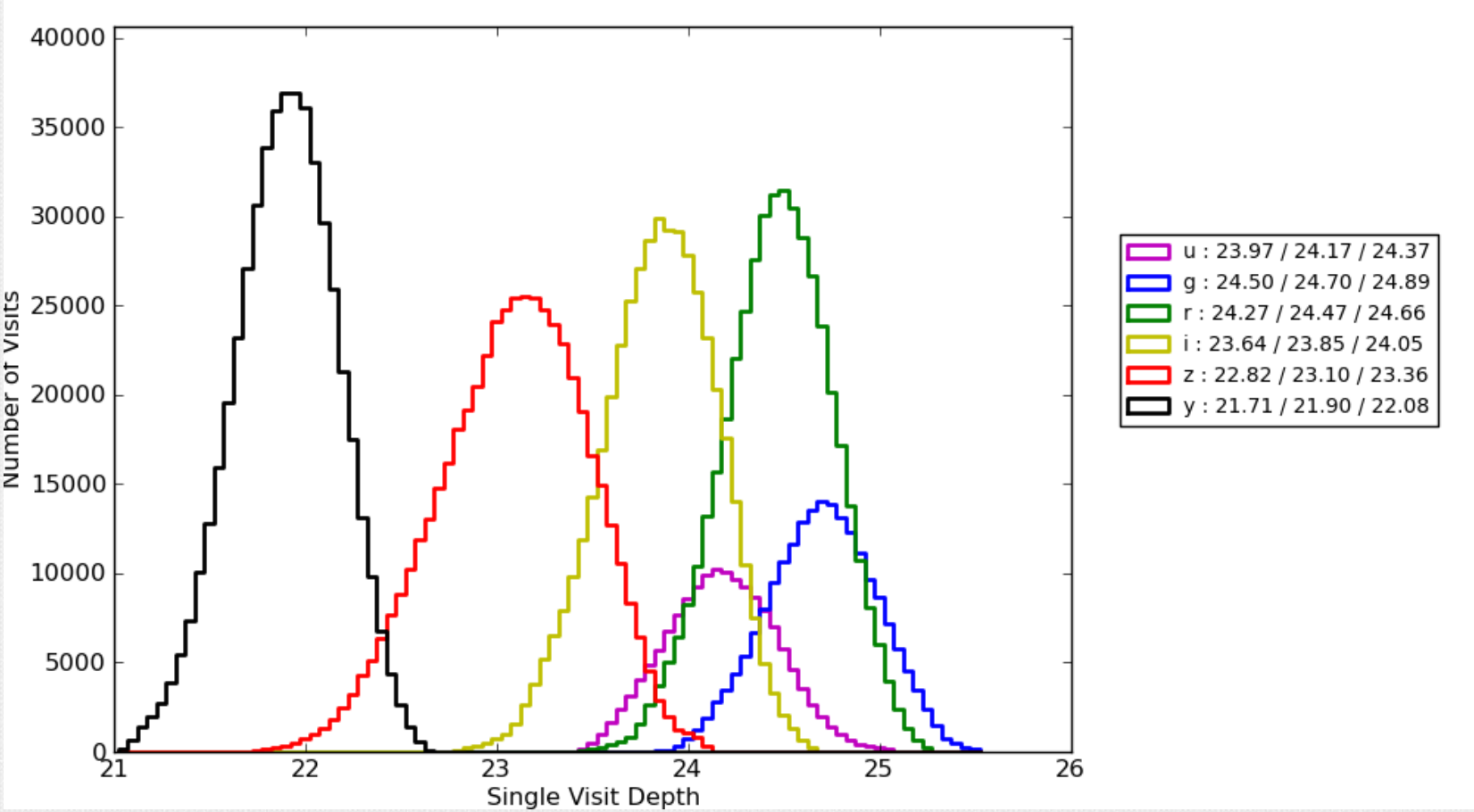
OpSim 3.61 visit distribution on sky (SSTAR)

The number of visits acquired for each field is plotted in Aitoff projection for each filter. All visits acquired by all observing modes are included in this plot.



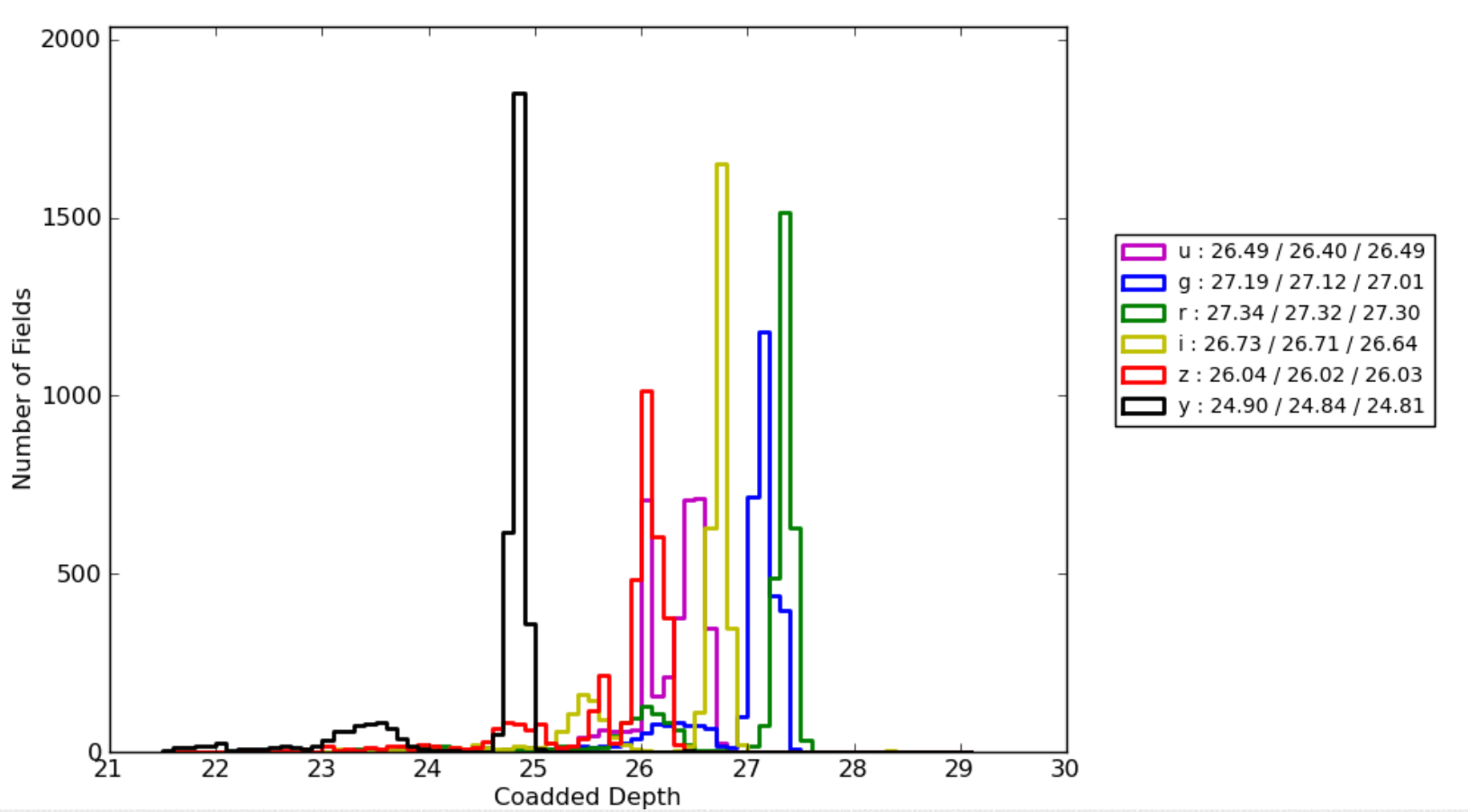
Single Visit limiting magnitudes (5-sigma)

- The side box contains the values of the 25th, 50th (median), and 75th percentiles for each curve. The Simulator has limits for sky brightness and seeing conditions for each filter in each observing cadence. These limits result in the relatively tight distributions of limiting magnitudes for each filter



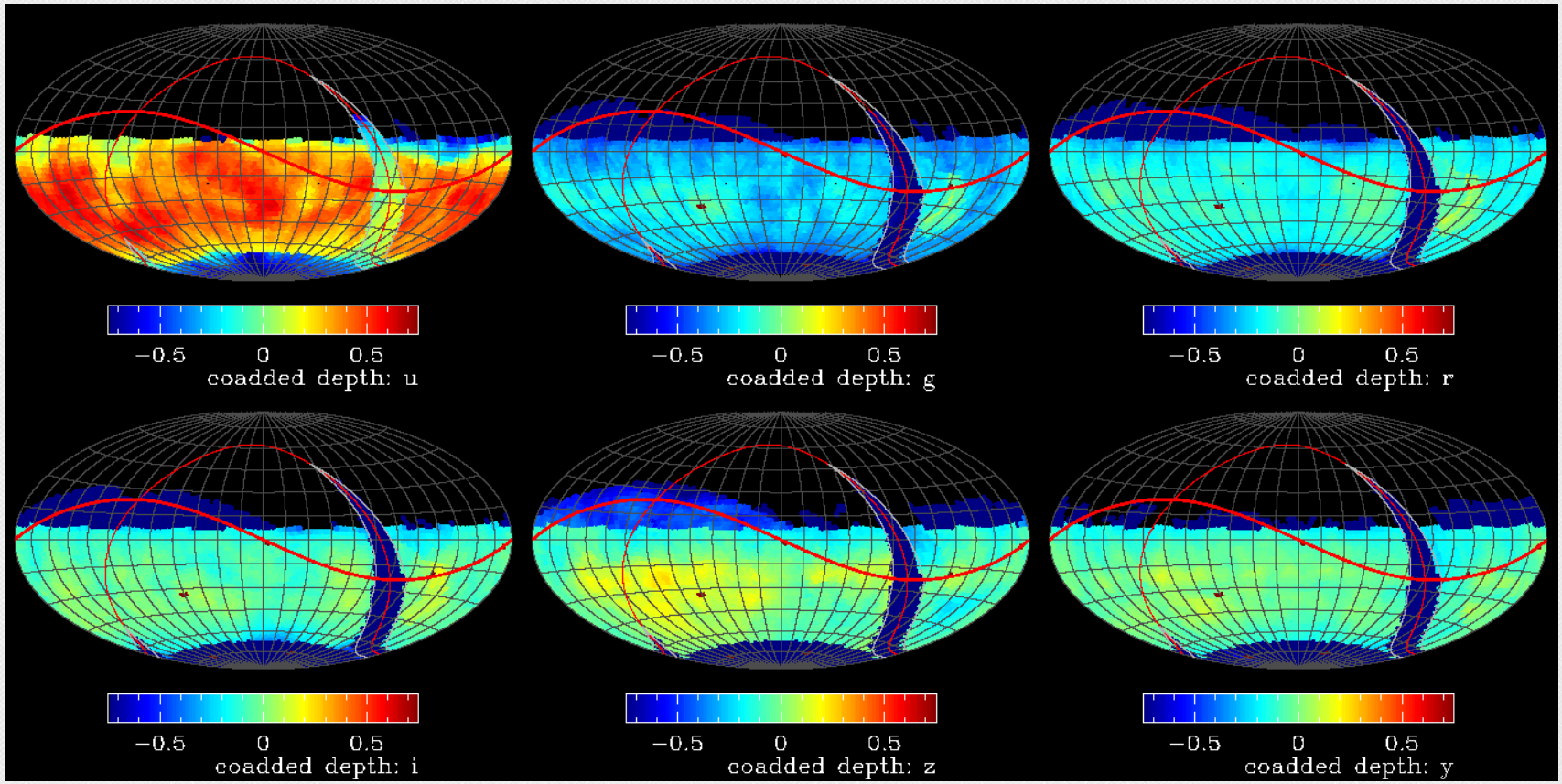
Coadded depth for the WideFastDeep fields

The distribution of fields with co-added depth in each filter. Only visits acquired by observing modes designed to meet the WFD number of visits are included. The inset box contains the values of the 25th , 50th (median), and 75th percentiles for each curve.



Full survey co-added depth

The WFD design spec is used as a fiducial and the difference between it and the co-added depth for each field is plotted in Aitoff projection for each filter. Fields with positive values have a co-added depth deeper than the WFD zenith value. Visits acquired by all observing modes are included in this plot and are not limited only to observing designed to meet the WFD number of visits.



Parameters of Opsim-3.61

- 3.61 has 20000 square degrees for the Wide-Fast-Deep Survey (WFD)
- 3.61 has 1030 visits per WFD field over ten years
- SRD design goals:
  - 18000 square degrees for WFD
  - 824 visits per WFD field
- Simulator has investigated design vs stretch
- OpSim 3.61 and a small number of variant project approved simulations are available to the whole LSST collaboration through a web-page:

  http://www.lsstcorp.org/opsim/home

Current and Future Development

- Four themes:
  - Towards the scheduler-simulator pair
    - Modularize to make environment stimuli interchangeable
    - Address interface with OCS
  - Explore algorithms to optimize scheduling
    - Implement “look-ahead” architecture
    - Make optimization code modular (ideally interchangeable)
  - Improve functionality
    - Change “proposals” or telescope constraints during a simulation
    - Improved sky-brightness model, implement dithering, etc.
  - Explore cadence space
    - Run simulations with different cadence scenarios
    - Communicate with community
- OpSim Version-3 (major rewrite) addresses above issues
  - Platform for future development

Evaluation Tools: Beyond SSTAR

- A large set of metrics have been developed to score the efficacy of simulations for a variety of science cases. Purpose: study of multiple simulations in a way that renders the complexity of the schedules comprehensible in a comparative way
- Additional metrics have been sought from project and science collaborations
- We have developed a general concept for a post-processing Framework, which would accept a list of merit functions, a list of simulations, evaluate those merits for those runs and produce a report for simulation comparison, or as material for further processing.

Work schedule

- Complete all development work by 2016
- Continue running simulations for engineering needs, as well as survey design
- Complete design of scheduler-simulator pair by 2016
- Build final scheduler-simulator and deliver in 2019.