The Large Synoptic Survey Telescope: Data Products Review

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Thursday June 1, 2017
Supernovae: The LSST Revolution
This presentation begins with a brief LSST primer and a project status update.

I will then highlight the planned data management products that are relevant to supernova science.

LSST Project Overview
- Primer Slide
- Construction Update
- Camera Update
- Commissioning Plans

LSST Data Products & Supernovae
- Data Management System Science
- Deep Drilling Fields
- DM Data Products Review
- DM & Level 3 Processing
- LSST Science Platform
LSST Primer

Hardware

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>primary mirror</td>
<td>8.4 m</td>
</tr>
<tr>
<td>field of view</td>
<td>radius = 3.5°</td>
</tr>
<tr>
<td>pixel size</td>
<td>10 µm, 0.2”</td>
</tr>
<tr>
<td>number of pixels</td>
<td>~3.2 Gpix</td>
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<tr>
<td>filters</td>
<td>ugrizy</td>
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Main Survey (Wide-Fast-Deep)

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<td>30s (2x15s)</td>
</tr>
<tr>
<td>single-visit depth</td>
<td>23.9, 25.0, 24.7, 24.0, 23.3, 22.1</td>
</tr>
<tr>
<td>survey visits/field</td>
<td>56, 80, 184, 184, 160, 160 (824)</td>
</tr>
<tr>
<td>survey full depth</td>
<td>26.1, 27.4, 27.5, 26.8, 26.1, 24.9</td>
</tr>
<tr>
<td>survey full area</td>
<td>18000°²</td>
</tr>
<tr>
<td>first light</td>
<td>2020</td>
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e.g., Ivezic et al. (2008), arXiv:0805.2366
LSST Primer

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(Update post-presentation.)

Saturation, from the Science Book:
The detectors will saturate with a star of 
u, g, r, i, z, y = 14.7, 15.7, 15.8, 15.8, 15.3 and 13.9, respectively.
Cameras Update

Commissioning Camera
- single-raft “ComCam”
- expect on summit late-2019

Science Camera
- two companies are supplying CCDs
- the first CCDs are delivered, in testing
- camera integration and testing starts 2018
- expect on summit early-2021

Last year's patch celebrates the start of camera construction.
Commissioning Plans

Early Science Verification
- starts mid-2020 with ComCam
- resumes early-2021 with the LSST Camera

Science Verification starts in mid-2021 with two operational readiness mini-surveys:

**Wide-Area Alert Production** to cover e.g., a 1600 deg$^2$ stripe with a range of source densities, produce real-time alerts.

**10-Year Depth Survey** to cover e.g., a 300 deg$^2$ field with 825 visits, reaching LSST full-depth equivalent.

Final science verification will be followed by an 8 week shut down for the Operations Readiness Review, early-2022.
Data Management

Difference Imaging Pipeline “Level 1”
- testing on DES and HSC data
- currently on track to meet specifications
  — processing time meets 2019 goals (120s)

Data Release Pipeline “Level 2”
- relevant algorithms in development
- planned releases at 0.5, 1.0, 2.0… years

Relevant Documents: (links on final slide)
Science Drivers to Reference Design (arXiv:0805.2366)
LSST Science Requirements
LSST Data Products Definitions
LSST DM Applications Design

Future: domain-specific data management papers
What is a DM Science Analyst? (i.e. What is your job?)

LSST Data Management System Science Team (SST)
The DM-SST ensures that the DM pipelines and products are designed to meet the overall LSST scientific goals (i.e., scientific validation of the DM deliverables).

- work with the science community to understand their needs and how they will be met by DM
- coordinate science investigations relevant to DM
- identify scientific opportunities and risks related to the DM subsystem and initiate change
- evaluate the scientific impact of proposed changes to DM deliverables driven by e.g., schedule, budget
- (later) science verification of the DM deliverables

Next: two relevant DM-SST studies.
Example LSST DM SST Study: LSST Photometric Redshifts in the Level 2 Catalog

General Components
- summarize the diversity of future use-cases* for catalog photo-z
- identify scientific requirements from the use-cases
- review current DM plans for calculating and storing photo-z
- evaluate how other surveys have handled this issue
- liaise with DESC-PZ to facilitate collaboration, incorporate ideas

Specific Components
- test options of template-fitting vs. machine learning
- compile metrics for photo-z algorithm assessment
- consider compression options for the P(z) array

Propose roadmap for DM to choose and integrate a photometric redshift algorithm into the DM Level 2 pipeline.

*such as SN host z estimates
Example LSST DM SST Study: Data Management and LSST Special Programs

General Components
- summarize the diversity of future special programs data
- identify requirements from the proposed science goals
- review current DM plans for processing these data
- assess whether existing pipelines meet the expected needs
- evaluate planned infrastructure for Level 3 processing

Specific Components
- investigate minimum possible exposure times
- consider reducing latency for nightly imaging data products
- assess computational and storage budgets
- suggest additions to the database schema

Example: what is the shortest possible exposure time that we could apply to a bright nearby supernova and still get decent results from DM’s difference imaging and photometry pipeline?
Deep-Drilling and Mini-Surveys

Four approved extragalactic deep fields:
ELAIS-S1, XMM-LSS, Extended CDF-S, COSMOS

DDF aspects that will be open for input:
- additional fields (broaden the RA coverage of DDFs)
- cadence (alterations to 1h/night in ugrizy)

Additional Mini-Survey Concepts:
North Ecliptic Spur (solar system)
South Celestial Pole (LMC, SMC)
Galactic Plane (stars and planets)
Mini-Moons (temporary earth-orbiting asteroids)
Meter-Sized Impactors (small earth-crossing asteroids)
Twilight Survey (short exposures for bright objects)
Gravitational Wave Counterparts (extragalactic)

2011 DDF Whitepapers: https://project.lsst.org/content/whitepapers32012
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Call for cadence proposals (white papers) for DDF out in fall 2017; due early 2018.
Call for new special programs proposals (white papers) out in late 2018; due 2019.

2011 DDF Whitepapers: https://project.lsst.org/content/whitepapers32012
The Large Synoptic Survey Telescope: Data Products Review

The next several slides will cover DM’s pipelines and products that are relevant to supernova science with LSST. I solicit your feedback on LSST regarding data products that would enable your science goals. Please talk to me during our lunch or coffee breaks, or contact me via email (mlg3k@uw.edu).

Some examples are:
(1) Level 1 catalog source measurements that will help with:
   - identifying object populations for follow-up
   - distinguishing targets of interest from interlopers
   - light curve characterizations that map directly to models
(2) Strong preferences for which variability characterization quantities should be included in the Level 1 and 2 catalogs.
(3) Science that requires specialized co-adds (Level 3 products).
Level 1: “Living” vs. “Data Release” DIA Catalogs

“Living” Level 1
- gets updated with every readout
- characterization parameters from last 12 months of sources only
- forced photometry for objects with >=1 detection in last 12 months
- precovery forced photometry from past 30 days for new sources
- association with “Data Release” object catalog

“Data Release” Level 1
- full yearly reprocessing using latest pipelines and calibrations
- characterization parameters based on full survey data set
- forced photometry for all objects in all epochs
- template will be a transient-free co-add of 6-12 months depth
Level 1: Difference Imaging Analysis (DIA)

Real-time Processing for All* Images
- single visit image (2x15s, processed) differenced with template
- source detection; those with S/N > 5 become DIASource
- DIASource characterization (PSF, flux, shape, etc.)
- DIASource association with DIAObject or creation of new DIAObject
- all “living” DIAObjects get forced photometry on difference image
- DIAObject characterization parameters updated

DIASource: detection in a single difference image
DIAObject: linked co-located source(s) in difference image(s)

- 60s: alert generated for all new DIASources
- 60s: public-facing Level 1 catalogs are updated
- 24h: 30 days of precovery forced photometry for all new DIAObjects
- 24h**: processed images become publicly available

*all WFD 2x15s, plus all appropriate SP data
**expected to be much sooner, perhaps tens of minutes
Level 1: Catalog Elements Relevant to Supernovae

**DIASource**
- characterization parameters
  - SNR, location, and time of mid-exposure at location
  - point-source, aperture, and total flux
  - shape parameters (trails, dipoles, point source, extendedness)
- association with “Living” DIAObject catalog (& SSObject)

**DIAObject**
- association with “Data Release” DIAObject
- distances to 3 nearest Level 2 Objects and their IDs
- time-averaged fluxes, periodic and non-periodic features

**Alerts (for S/N>5 sources only)**
- all elements of DIASource and associated “Living” DIAObject
- all elements of associated “Data Release” DIAObject & DIASource(s)
- an image stamp (~6”x6”; intended for ML, not host ID)
### Level 2: Catalog Elements Relevant to Supernovae

<table>
<thead>
<tr>
<th>Images</th>
<th>Single Visit</th>
<th>fully processed 2x15s exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CoAdd</td>
<td>“deep” and “best-seeing” (unless they’re equal)</td>
</tr>
<tr>
<td>Catalogs</td>
<td>Source</td>
<td>detections in Single Visit Images</td>
</tr>
<tr>
<td></td>
<td>Object</td>
<td>all Sources plus detections in CoAdd images</td>
</tr>
<tr>
<td></td>
<td>ForcedSource</td>
<td>in all Single Visit Images for all Objects</td>
</tr>
</tbody>
</table>

#### Source and Object Characterization Parameters

- more relevant for SN hosts
  - deblending results (parent/child identifiers)
  - model fits (bulge/disk, exponential, petrosian, kron)
  - surface brightness, extendedness parameters
  - color (seeing-independent)
  - photometric redshift
- less relevant for SN hosts
  - periodic and nonperiodic features
  - locations and times of all detections
  - proper motions and parallaxes
  - aperture and point source flux; PSF moments

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**LSST Data Products Definitions Document (DPDD):** [ls.st/dpdd](http://ls.st/dpdd)
Level 3: Science Pipelines

LSST will not write unique algorithms for processing Special Programs data or reprocessing Main Survey data,
— but —
LSST will make available the LSST Software Stack source code, which the community can extend to generate new Level 3 products (including special DDF processing)
— and —
LSST will commit ~10% of its computing resources toward enabling end-user analysis and Level 3 data product creation.

Example Level 3 pipeline: a supernova search in a deep drilling field
1. The DDF run is initiated by the scheduler, acquisition begins.
2. The 2x15s images are processed as Level 1, alerts released.
3. Processed images become publicly available within 24 hours*.
4. Through the Science Portal, the astronomer activates their script:
   - DM image stacking code combines each filter into a nightly CoAdd
   - DM image differencing code subtracts CoAdd from templates
   - DM source detection code creates a table of SNR>5 sources
   - DM association routine joins table to the Level 2 Object catalog

* expected to be much sooner, perhaps tens of minutes

LSST Data Products Definitions Document (DPDD): ls.st/dpdd
Science Platform Requirements:
(1) to make the data accessible for science analysis
(2) to enable science via Level 3 processing pipelines

First versions of the Archive Portal are being tested.

The intent is for it to serve as a toolkit, workspace, and a portal to the data and processing power to enable science.

Lead by Mario Juric, David Ciardi, and Gregory Dubois-Felsmann
Join us August 14-18 2017 in Tucson for the LSST Project and Community Workshop
Useful links for information and participation.

LSST Project Website  project.lsst.org
LSST Community Forums  community.lsst.org
Science Collaborations  www.lsstcorporation.org/science-collaborations
Observing Strategy White Paper  github.com/LSSTScienceCollaborations/ObservingStrategy
The 2016 LSST Project and Community Workshop  project.lsst.org/meetings/lsst2016  (slides available)
Deep Drilling Fields White Papers  https://project.lsst.org/content/whitepapers32012

LSST Science Requirements (LPM-17)  https://docushare.lsstcorp.org/docushare/dsweb/Get/LPM-17

LSST Github Repositories  github.com/lsst
LSST Software User Guide (The Stack)  confluence.lsstcorp.org/display/LSWUG/LSST+Software+User+Guide

LSST Data Science Fellowship Program for Students  ciera.northwestern.edu/Education/LSSTC_DSFPOverview.php

Maximizing Science in the Era of LSST: A Community-based Study of Needed US OIR Capabilities  noao.edu/meetings/lsst-oir-study