Swift–LSST Synergies

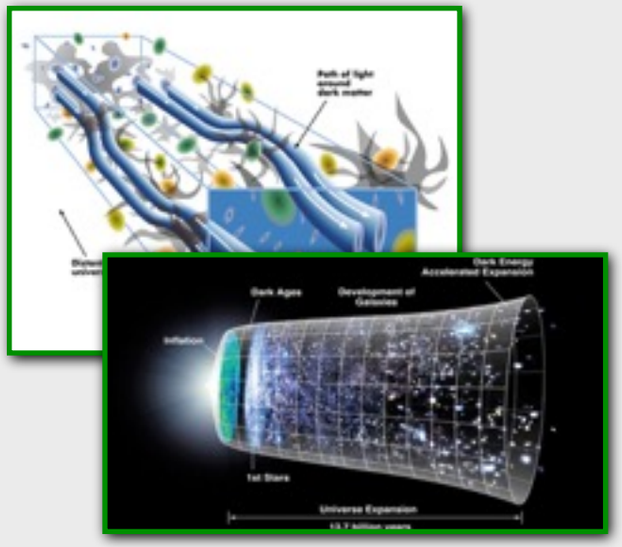
Time-Domain Astrophysics with Swift III - Oct 3 2018

Melissa Graham - LSST Data Management Science Analyst - U. of Washington

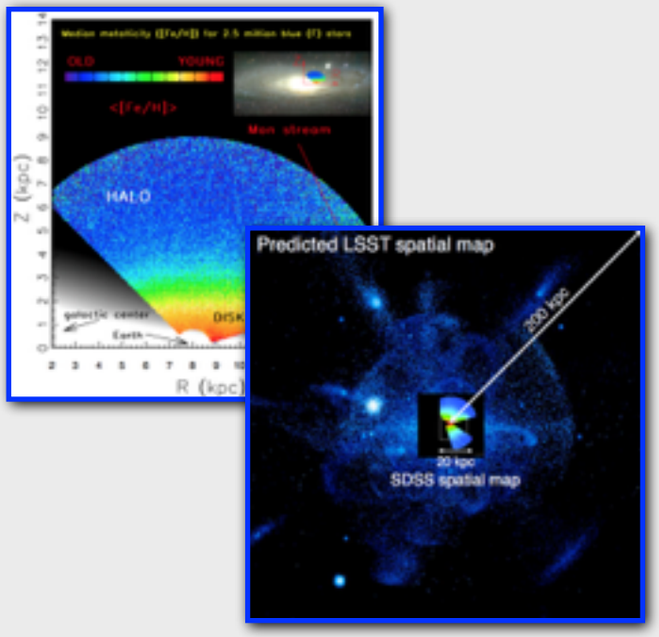
LSST

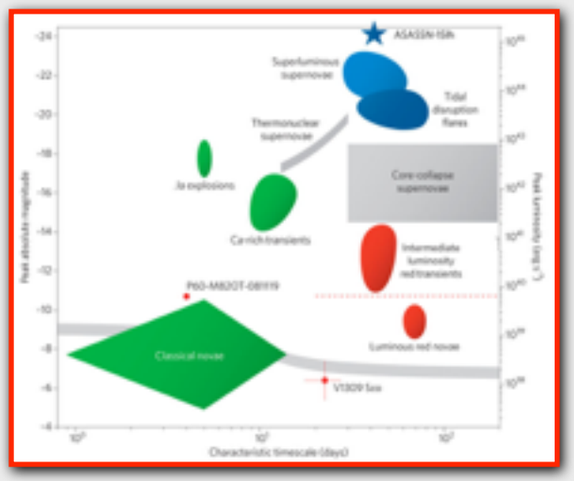
Large Synoptic Survey Telescope

LSST: Four Primary Science Themes

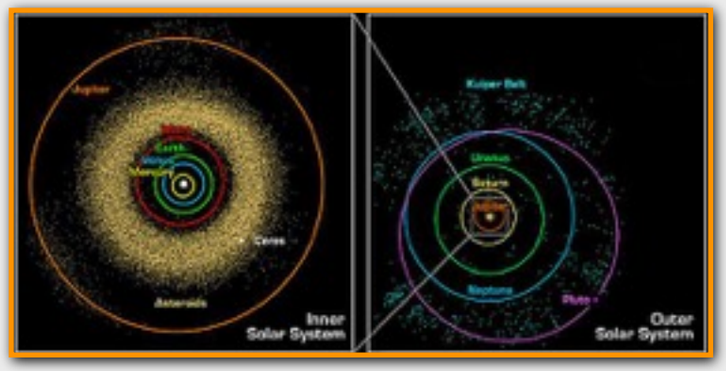


- Cosmology:
  - weak lensing
  - baryon acoustic oscillations
  - type Ia SN dark energy





- Transient & Variable Phenomena
  - fill in variability phase-space
  - physical mechanisms



- Solar System Small Objects
  - object inventory, dynamics
  - potentially hazardous asteroids
  - (U.S. Congressional mandate for NASA to find 90% of near earth objects with diameter >140m)

"From Science Drivers to Reference Design", Ivezić et al. (2008), arXiv:0805.2366

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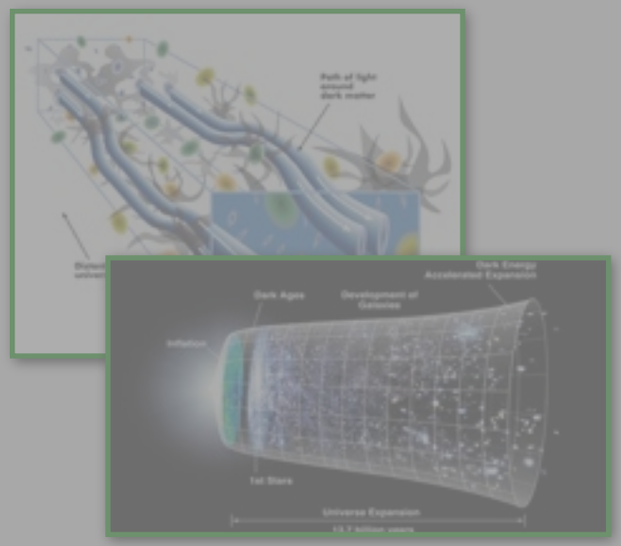

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  - weak lensing
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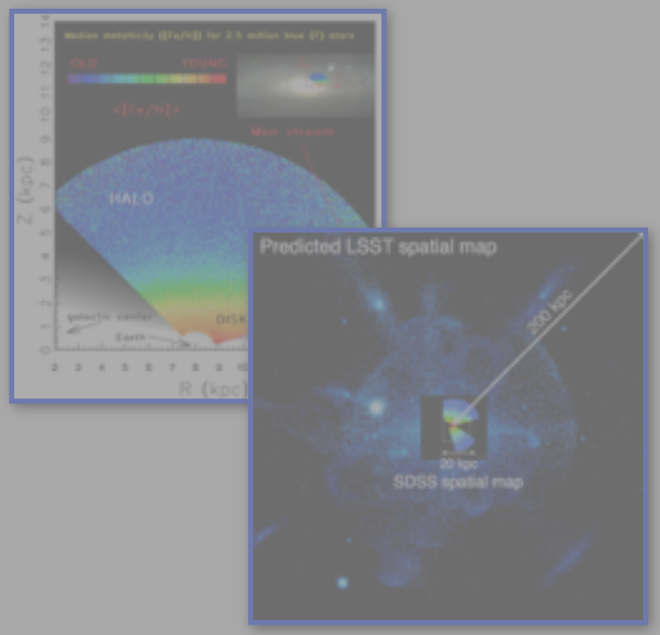
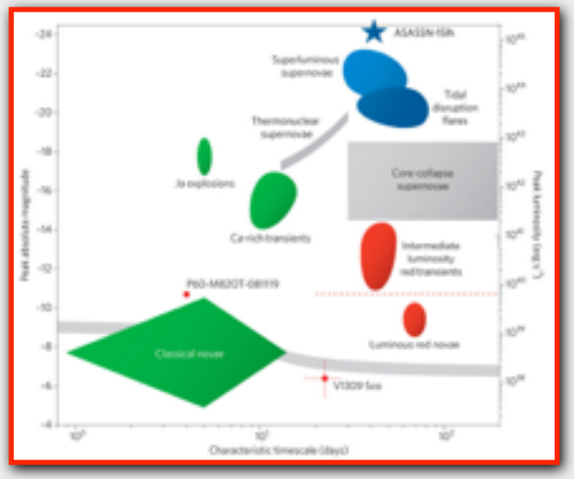
  - type Ia SN dark energy

- Milky Way:
  - spatial maps of stellar characteristics
  - reach well into the halo





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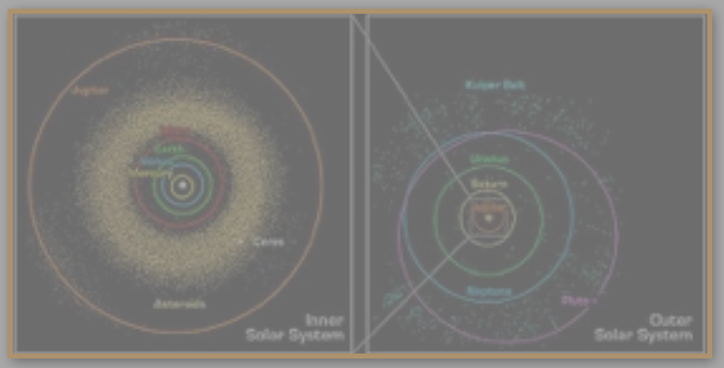

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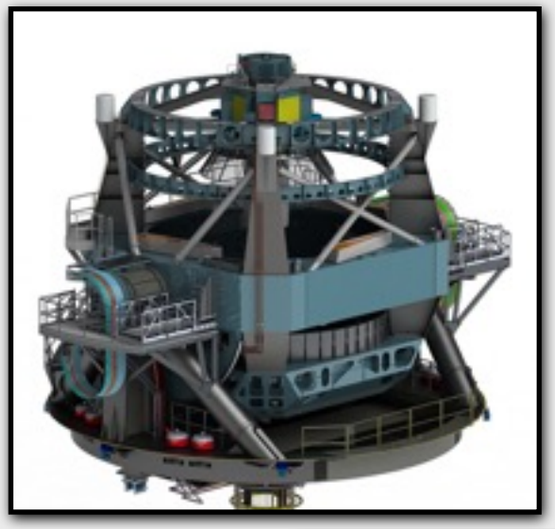
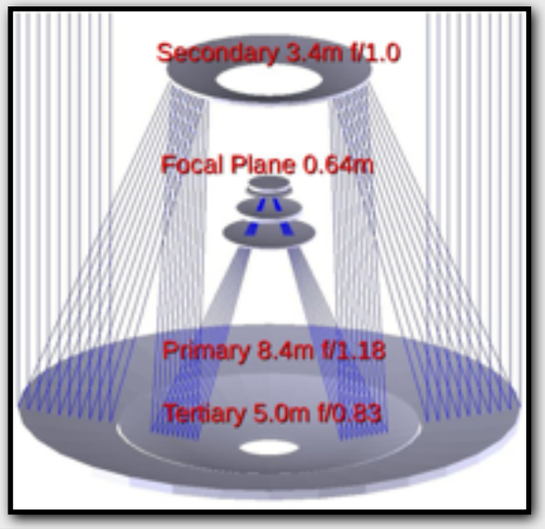
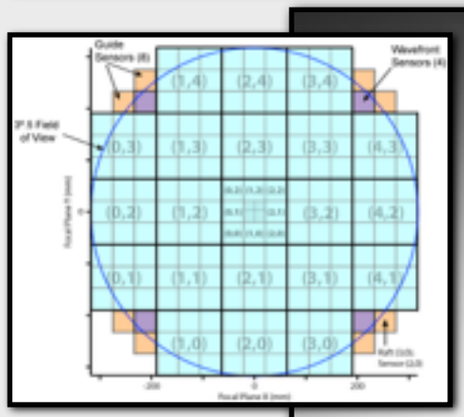
LSST: Design







Hardware

primary mirror	8.4 m
field of view	9.6 deg^2
pixel size	10 μm, 0.2″
number of pixels	~3.2 Gpix
filters	*u g r i z y*

Main Survey (Wide-Fast-Deep)

single-visit exposure	30s (2x15s)
single-visit depth	~ 24, 25, 24.7, 24, 23, 22
single-visit saturation	~ 15, 16, 16, 16, 15, 14
survey visits/field	56,80,184,184,160,160 (824)
survey full depth	~ 26, 27, 27.5, 27, 26, 25
survey full area	18000°^{2}
first light	2020
survey start	2022

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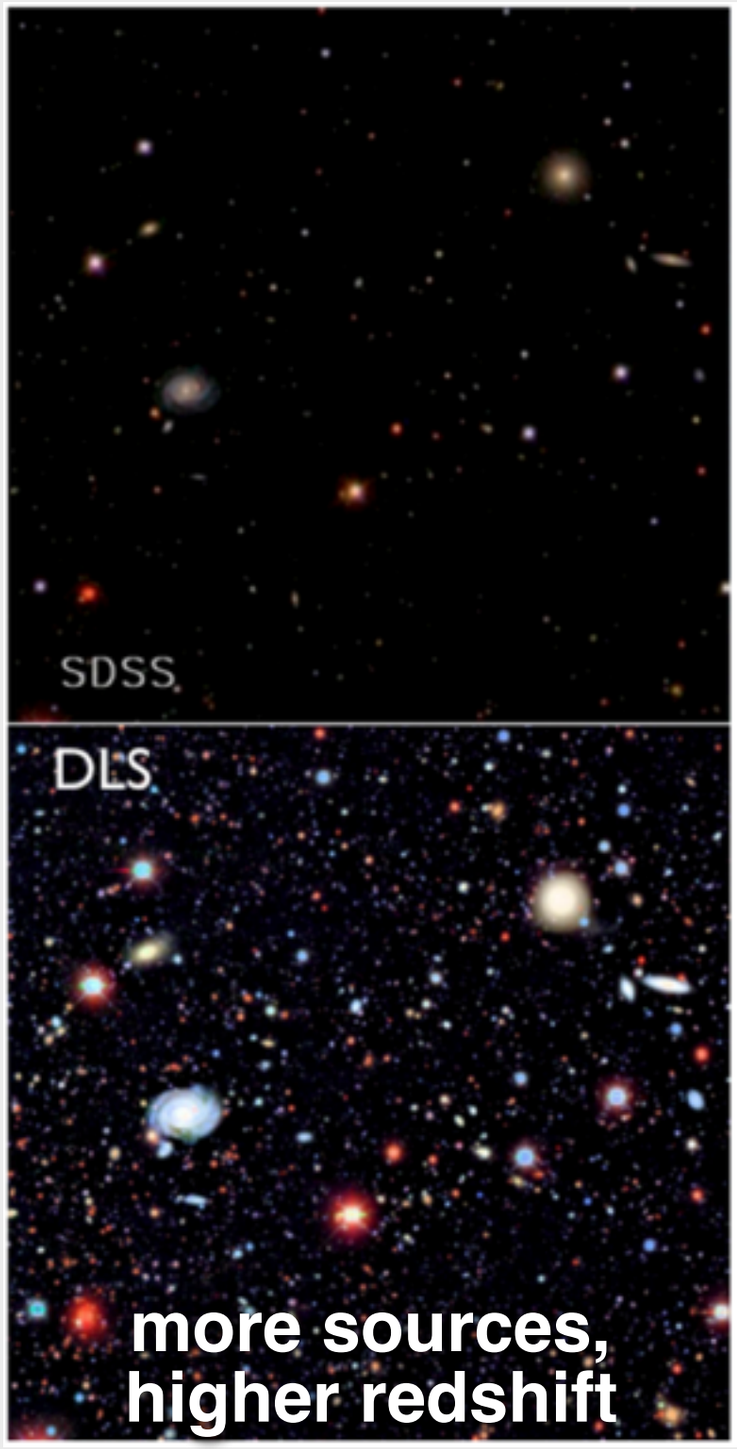
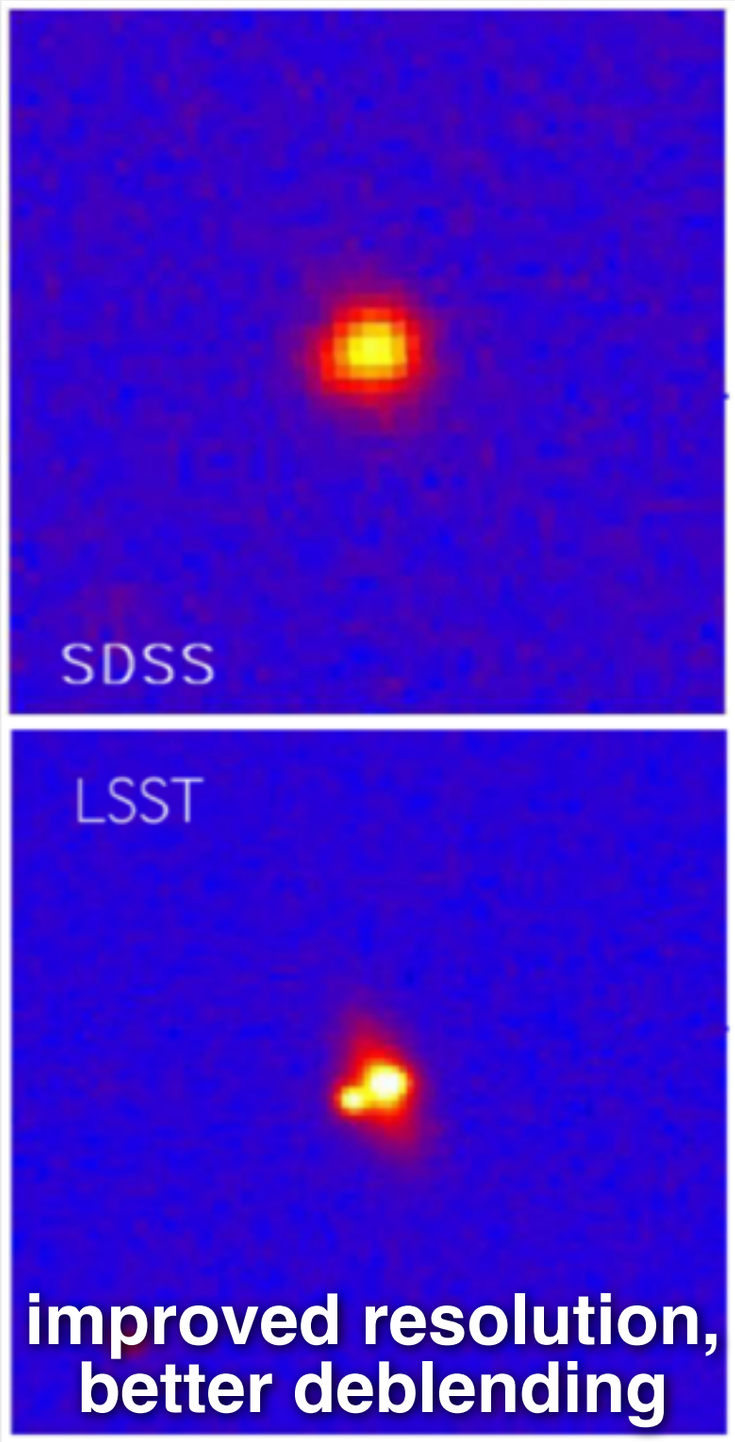
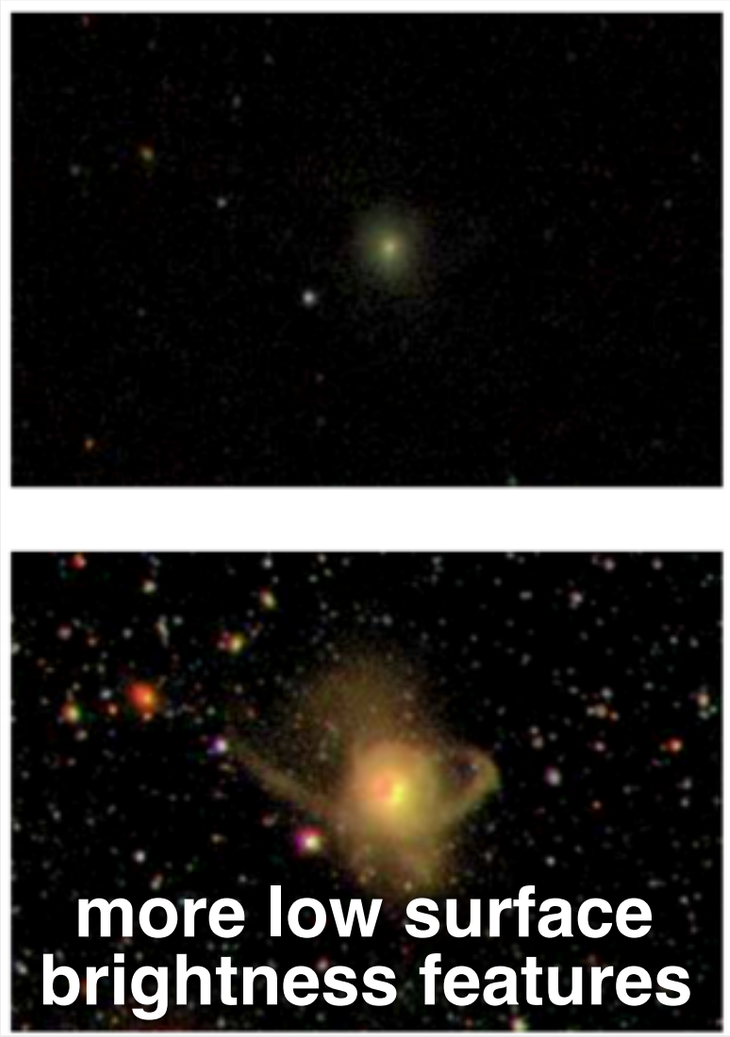
LSST: Projected Data





Nightly alerts on ~10 million time-domain events, and final catalogs of ~32 trillion observations of ~40 billion objects over 10 years.



LSST: Status

August 2018

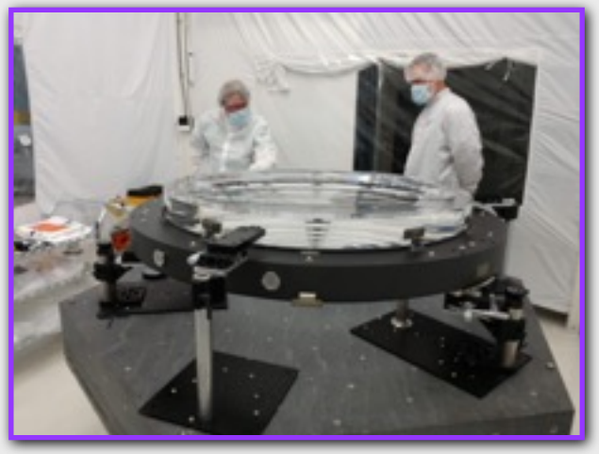
LSST: Status

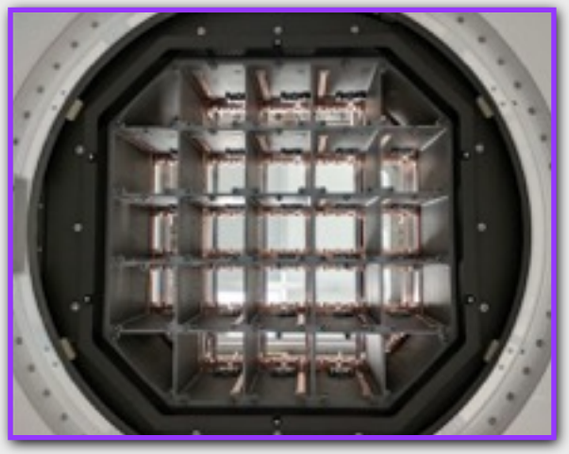
Hardware and Software Highlights in 2018

- La Serena base facility expected completion in 2019
- optical fiber runs to summit; path completed
- Cerro Pachon **summit facility** receiving shipments
- auxiliary telescope is being installed
- mirror coating chamber has been delivered to Chile
- **telescope mount assembly** slews; testing in Spain
- almost all camera sensors have been delivered
- **camera** raft assembly: 1.6 out of 3.2 GP installed (50%)
- camera integration and testing in progress
- **Data Management** (DM) has early version of Science Platform
- DM testing pipelines by applying to HSC images, ZTF Alerts
- Systems Engineering and DM coordinating on **Commissioning plans**
- EPO continues to prototype and test projects & interfaces

All systems are on track for

- **first light 2019**
- **Commissioning start 2020**
- **full Operations 2022**

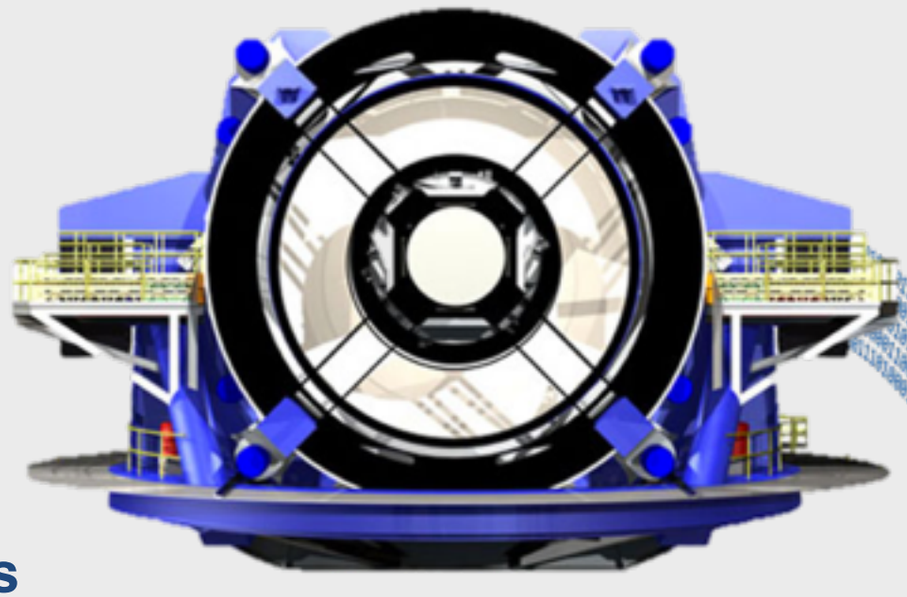




LSST: Data Management

Data Release Data Products
via Annual Data Releases

11 data releases in 10 years
Final database catalog: 15 PB



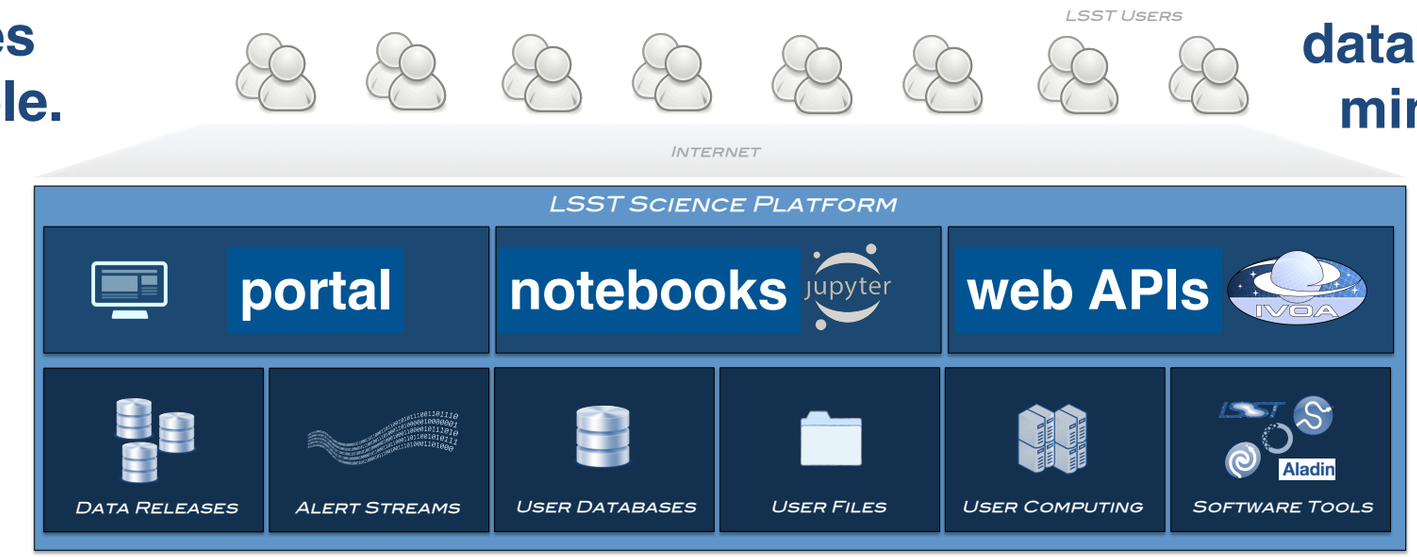
Prompt Data Products
via Alert Streams

Average ~10^6 per night
Real-time latency: 60 sec

Last 2 data releases available.

LSST Science Platform

Alerts database and mini-broker.



Data access and next-to-the-data processing.

LSST: Data Products

Prompt

Previously "Level 1" data products

Real-time difference image analysis (DIA).

A stream of ~10^6 time-domain events per night (Alerts), detected, characterized, and distributed within 60 seconds.

A catalog of orbits for ~6 million bodies in the Solar System.

Data Release

Previously "Level 2" data products

Processed single-epoch and deep co-added images, and reprocessed DIA products.

A database of ~7×10^{12} detections (~30×10^{12} measurements) for ~37×10^9 objects (20×10^9 galaxies and 17×10^9 stars), produced annually and accessible online.

User Generated

Previously "Level 3" data products

User-produced added-value data products, e.g., deep KBO/NEO catalogs, variable star classifications, shear maps, etc.

Enabled by services and computing resources at the Data Access Centers and via the LSST Science Platform.

LSST: Data Products

World Public

World Public data can be shared with anyone, with or without data rights.

Alerts: The full stream will be delivered to a limited set of community brokers who can share the Alerts with anyone.

Data Releases after 2 years: Could be accessed through collaboration with data rights holders, or by paying the "cost of shipping and handling".

Education and Public Outreach: Limited data subsets for citizen science.

Proprietary

Proprietary data cannot be shared, and requires data rights.

Prompt Images and Catalogs: Difference images and source catalogs that are created and made available in real time (60s to 24h latency).

Annual Data Releases: Image stacks and source catalogs.

LSST Science Platform: Data portal, analysis toolkit, help-desk service, computational resources for user processing, an Alerts filtering service ("mini-broker"), access to the Alerts Database.

Now that we know about LSST, we can discuss Swift–LSST Scientific & Technical Synergies

LSST–Swift Synergies

At this point in the meeting, we barely need this slide!

LSST will provide optical emission for transients and variable stars such as:

- gamma-ray bursts
- tidal disruption events
- active galactic nuclei
- compact object mergers; kilonovae
- ‘fast transients’ (e.g., Drout+14)
- supernova shock break-out
- SN-CSM interaction; shocked material
- SNIa “blue bump” of shocked companion
- SNIa NUV groups (Brown+13)
- recurrent novae & non-terminal explosions

And all the other objects and emission processes we’ve heard about this week.

Remark: most energetic events are fast-evolving and/or short-lived. What will LSST deliver in terms of time-sampling for time domain objects?

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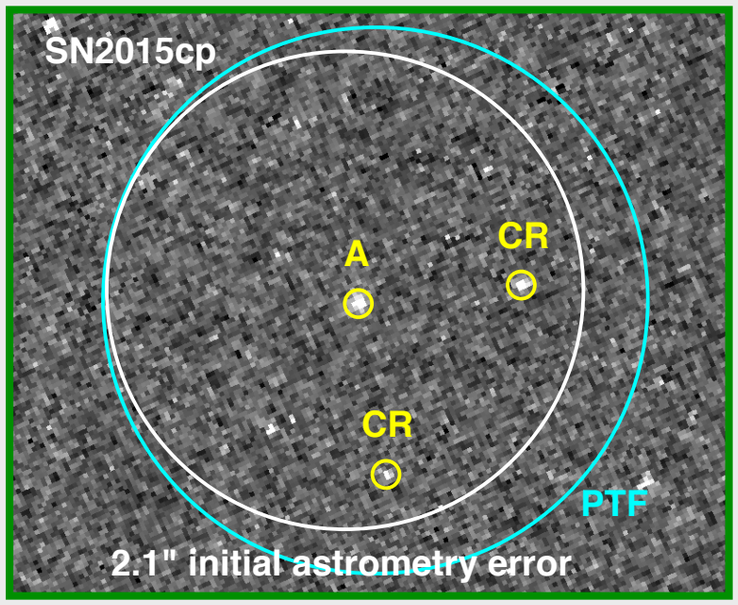
Delayed Circumstellar Interaction for Type Ia SN2015cp Revealed by an HST Ultraviolet Imaging Survey
Graham et al. (2018; submitted)

Our snapshot survey of ~70 nearby SNeIa at 1-3 years after explosion to search for ejecta interacting with CSM at R>10^{16}cm, like SNIa PTF11kx, finds one: SN2015cp.



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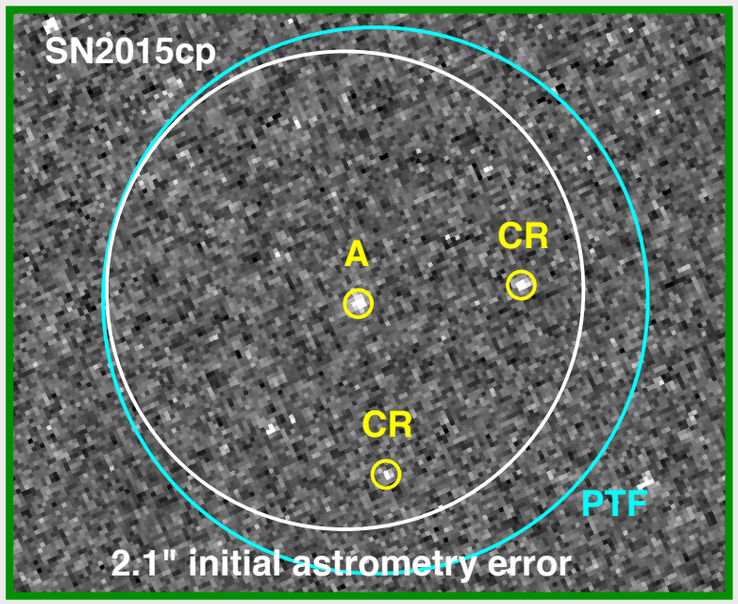

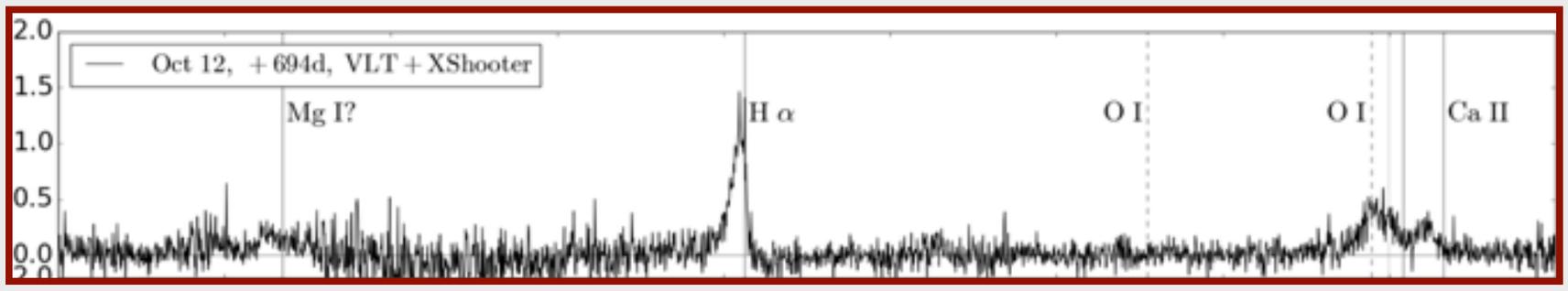

Ground-based optical spectra reveal hydrogen & calcium emission, typical of CSM interaction, are declining rapidly.

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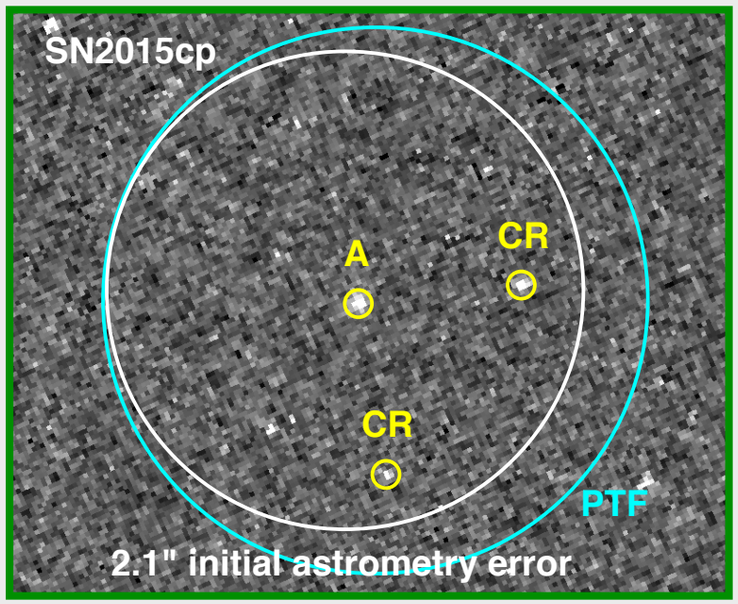

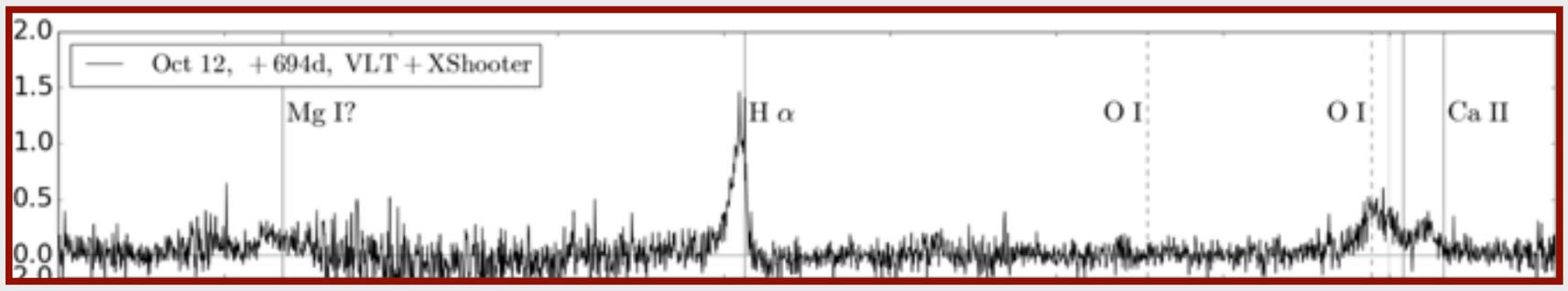

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Future prospects: LSST will find the r~24 optical emission from late-onset CSM interaction in SNeIa as part of the wide-fast-deep "main survey", and NUV observations with HST and Swift will be an integral part of the follow-up.

See also radio and *Swift* follow-up results in Harris et al. (2018; submitted).

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Consider the following two basic scenarios for these time-domain facilities.

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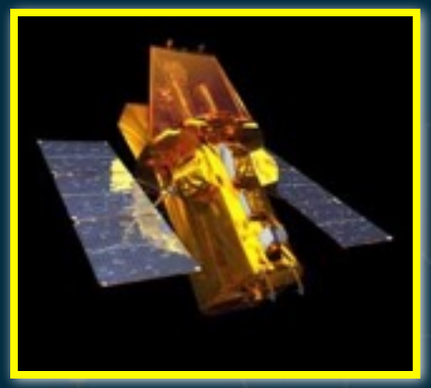

Swift finds a source.
Has it been detected in the optical before?
Context: is it a star, or in a galaxy?
Check what **LSST** knows about it.

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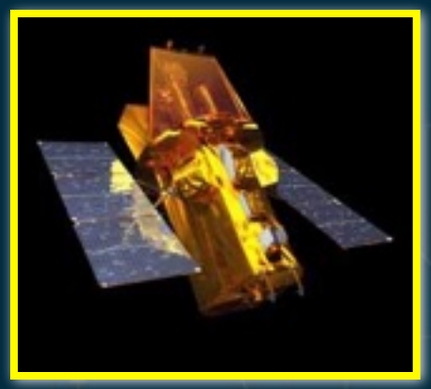

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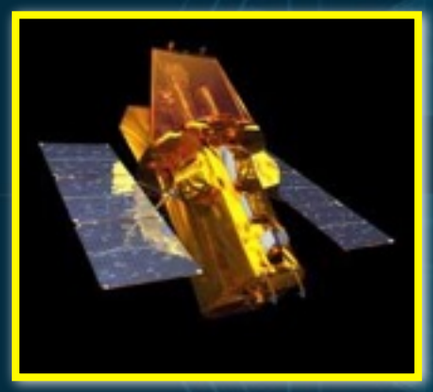

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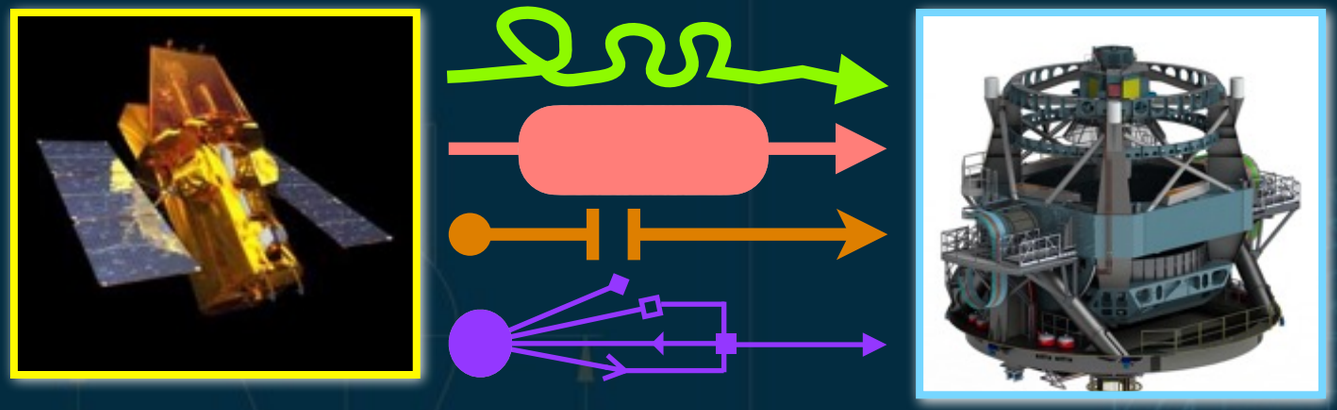

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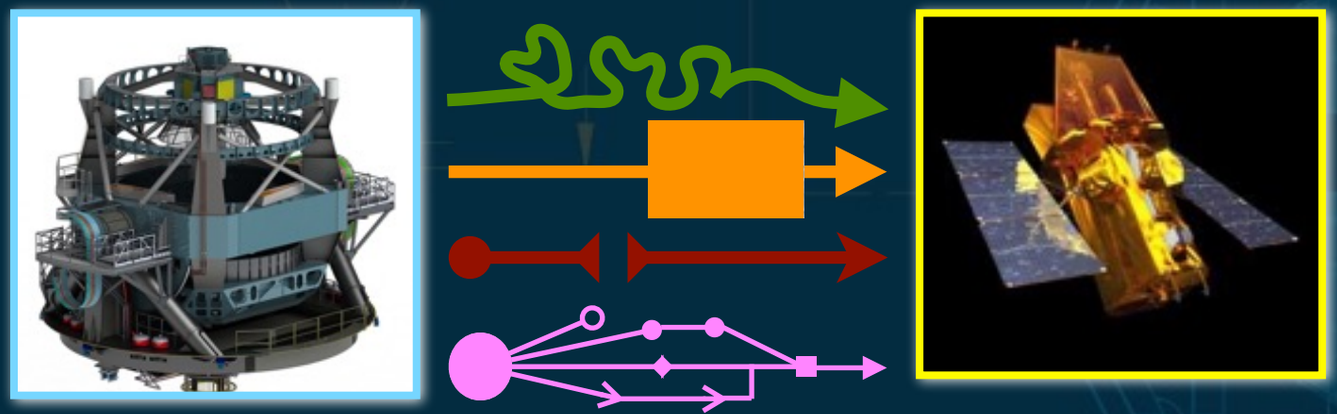

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- Human Review and Action
- Alert Brokers (e.g., Machine Learning)
- Third-party Follow-Up Data

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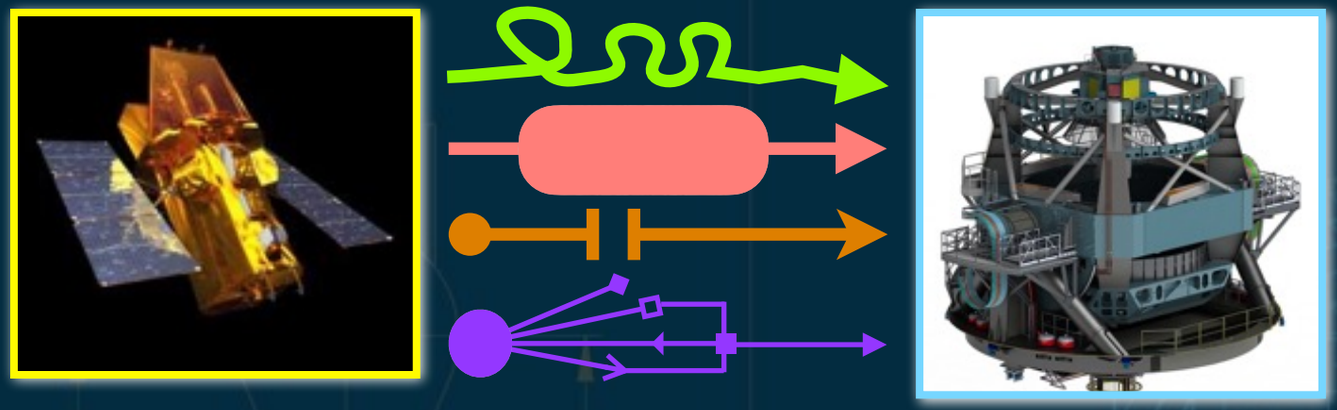

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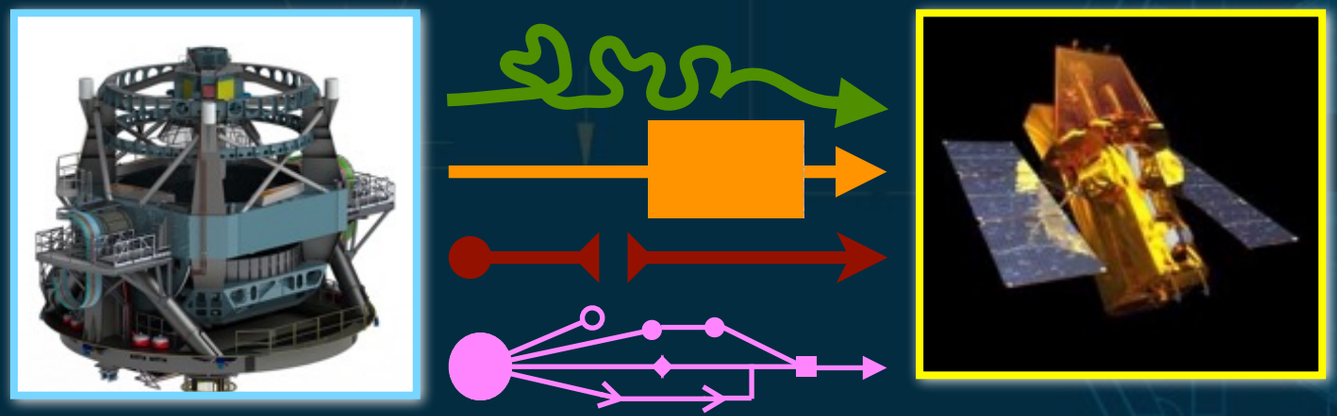

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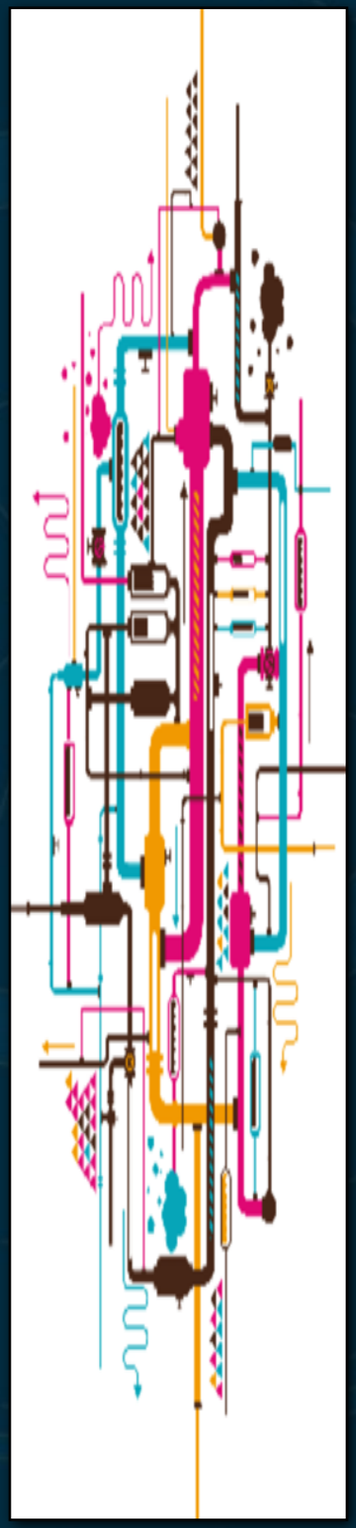
First we must understand the relevant **LSST** data products: the Alert Stream, processed images, and source catalogs.

LSST: Data Management Pipelines & Data Products



What is an LSST Alert Packet?

- formatted text file containing schema and data
- full record of the triggering DIASource* (|S/N|>5)
- entire associated DIAObject or SSObject records
- last 12 months of DIASource records
- matching Object IDs from latest Data Release catalog
- image stamps
  - ↳ at least 6"x6"; difference and template; flux, variance, and mask; includes meta-data such as WCS, zero-point, PSF
- 1 per DIASource; VOEvent packet format (or similar)
- released to Alert Stream within 60s of shutter close

*DIA = Difference Image Analysis

LSST Data Products Definitions Document (DPDD): ls.st/dpdd

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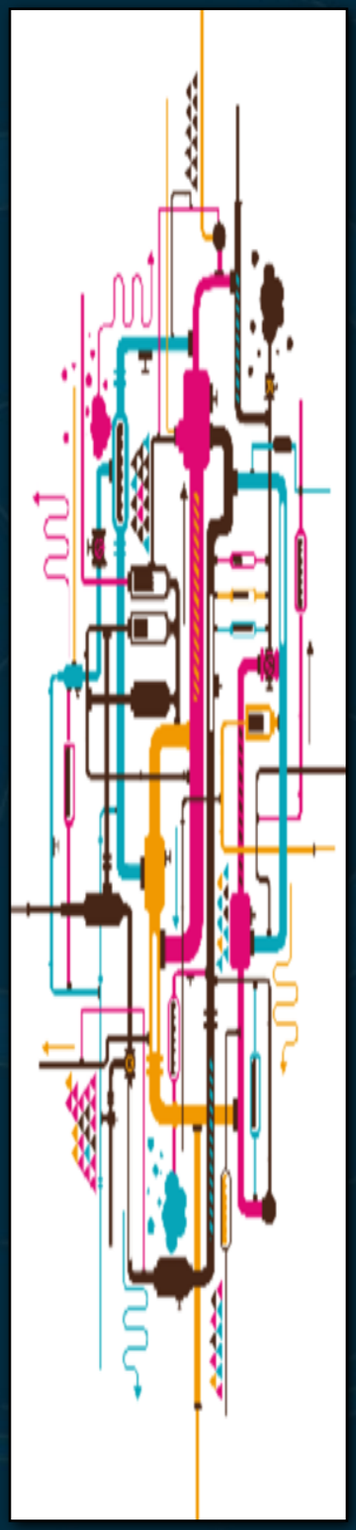

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What is a Community Alert Broker?

Software developed independently of LSST to receive, filter, classify, and redistribute alerts; several brokers will be selected by LSST. LSST will provide a basic, limited capacity alert filtering service for astronomers via the Science Platform: "the LSST Mini-Broker".

Examples of Community Alert Brokers Currently Processing ZTF Alerts

ALeRCE
Automatic Learning for the Rapid Classification of Events

Lasair
THE UNIVERSITY OF EDINBURGH · QUEEN'S UNIVERSITY BELFAST · LSST · ZTF

ANTARES

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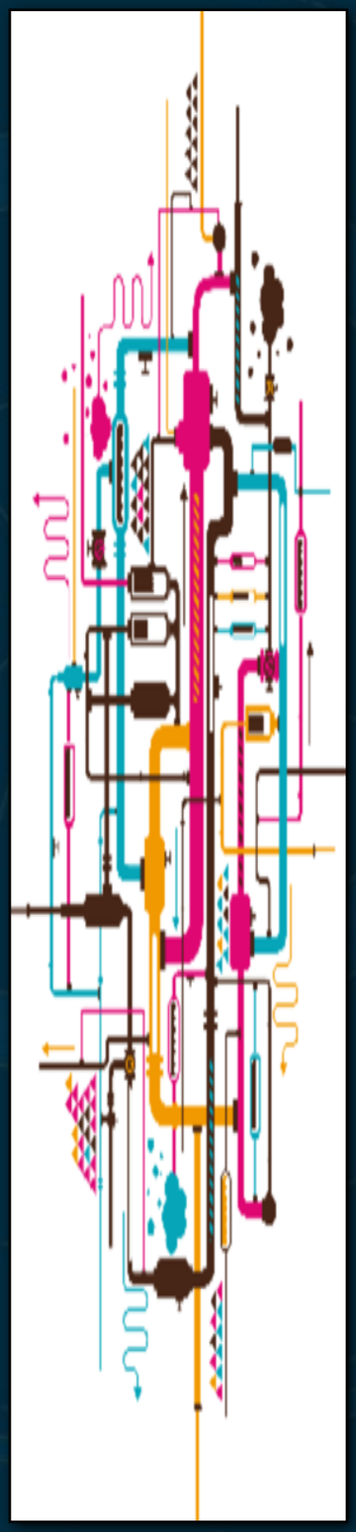

What are the Prompt Pipeline's Images and Catalogs?

- DIASource and DIAObject catalogs updated in 60s, which includes:
  - characterization parameters (e.g., shape, variability, nearby Objects)
  - forced photometry for DIAObjects detected in past 12 months
- processed visit images, and difference images, available in 24h
- forced precovery photometry from past 30 days available within 24h

What are the annual Data Release's Images and Catalogs?

- reprocessed visit images and difference images
- deep stacks in each filter (short period, e.g., yearly, and full survey)
- Object, Source, and ForcedSource catalogs (forced photometry)

How will LSST Data Products be accessed?

- through the Science Platform at the Data Access Center
- portal and workspace for e.g., queries, Jupyter notebooks
- Web Application Programming Interface (Web API) options
- "mini-broker" for real-time Alert filtering

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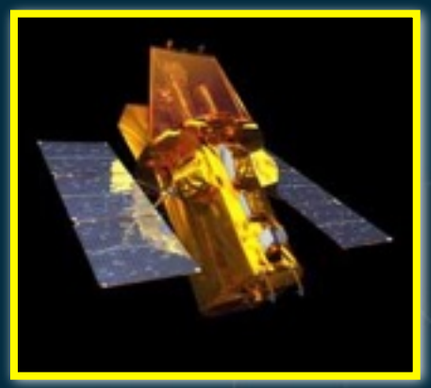
LSST–Swift Synergies

Recall these two scenarios:



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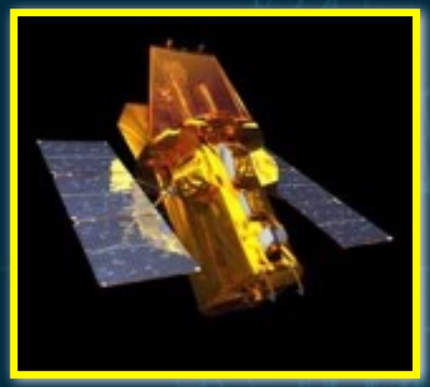
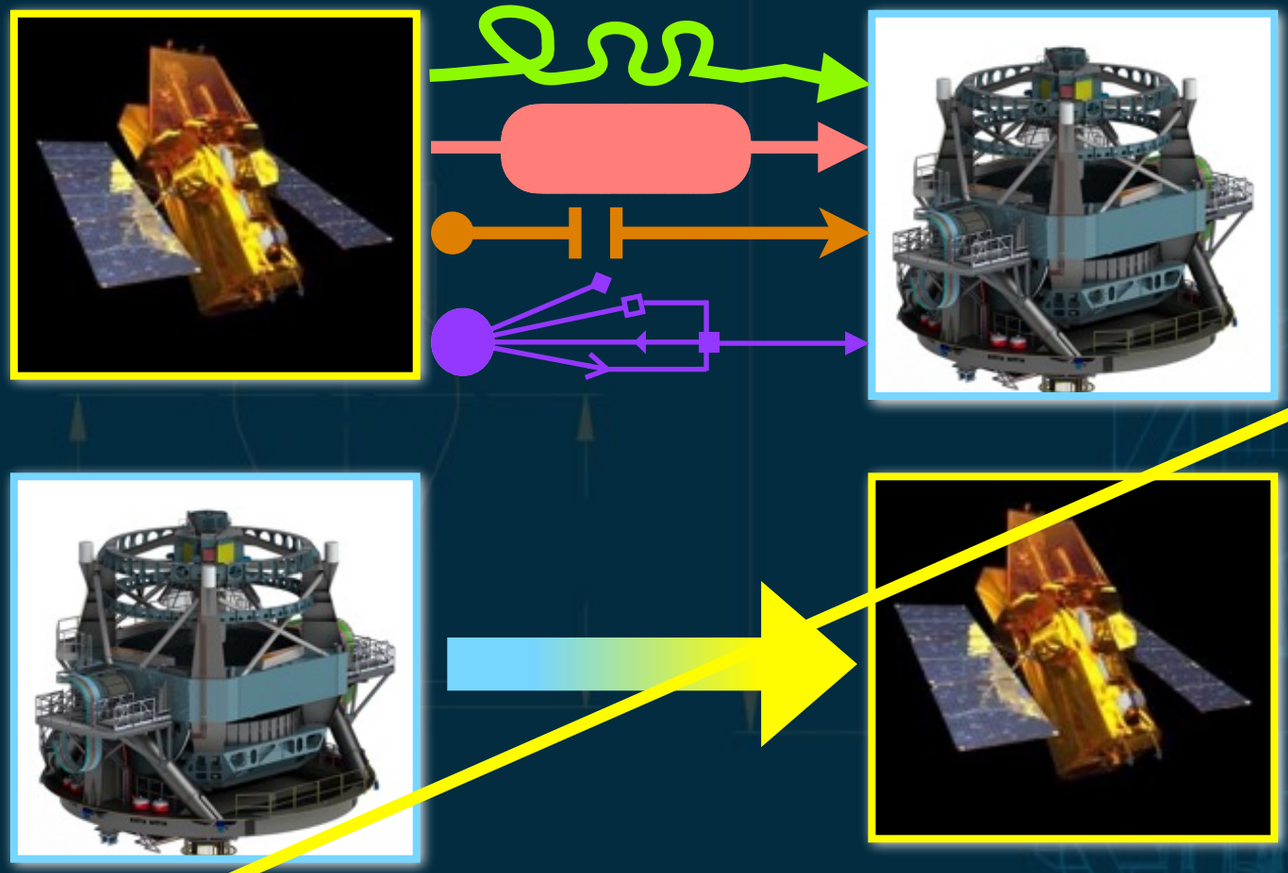


LSST finds a source.
This source is very interesting! (E.g., new, blue, and and rapidly brightening).
Swift should get UVOT/XRT data for source.

LSST-Swift Synergies

Recall these two scenarios:



Swift finds a source.
Has it been detected in the optical before?
Context: is it a star, or in a galaxy?
Check what **LSST** knows about it.

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- use a Broker or the Science Platform to cross-match to Alerts, DIAObjects, Objects
- review characterization parameters of nearby sources, potential host galaxies
- in the Science Platform, reconfigure LSST software tasks to do forced photometry at the location and search for S/N<5 detections

LSST-Swift Synergies

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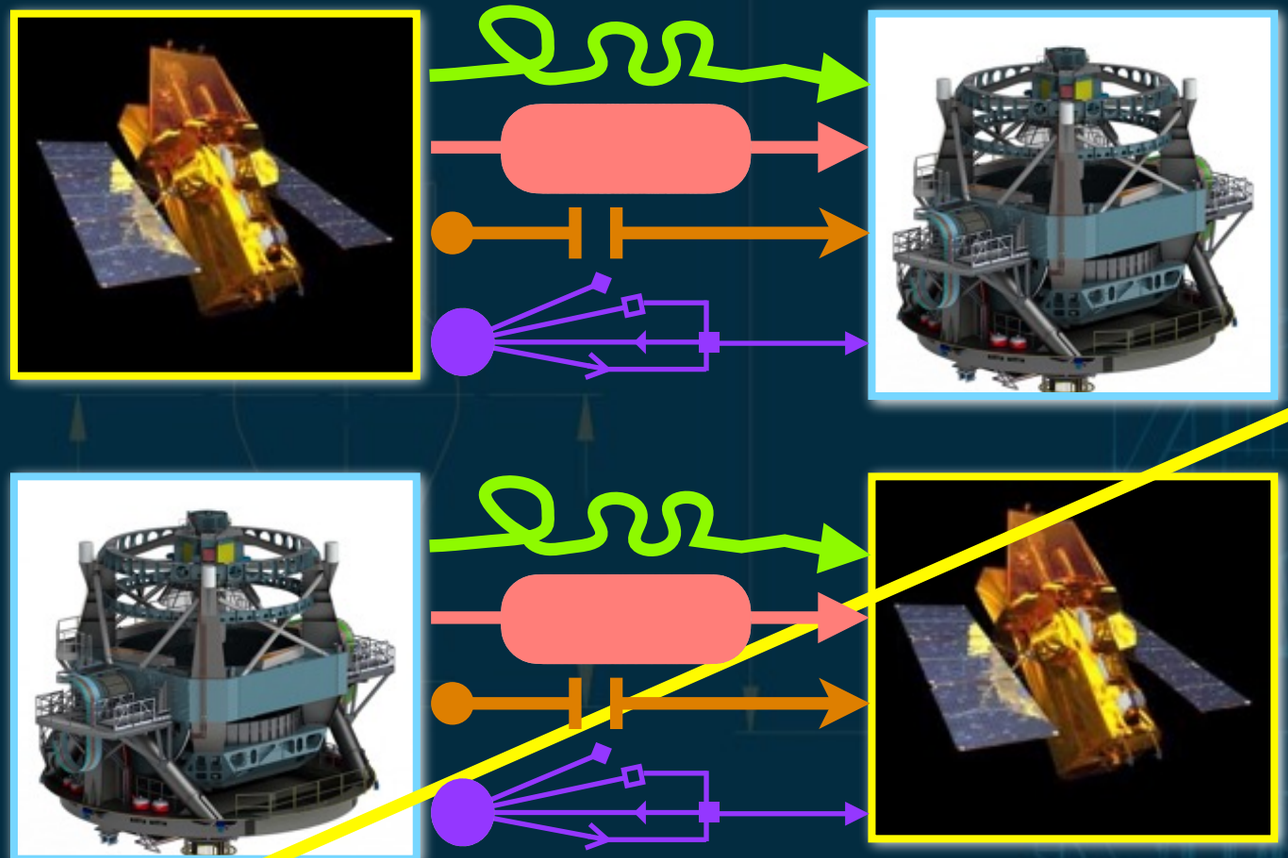

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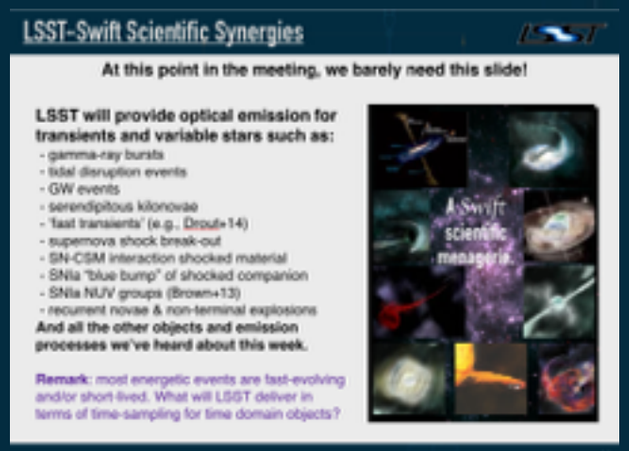
LSST finds a source.
This source is very interesting! (E.g., new, blue, and and rapidly brightening).
Swift should get UVOT/XRT data for source.

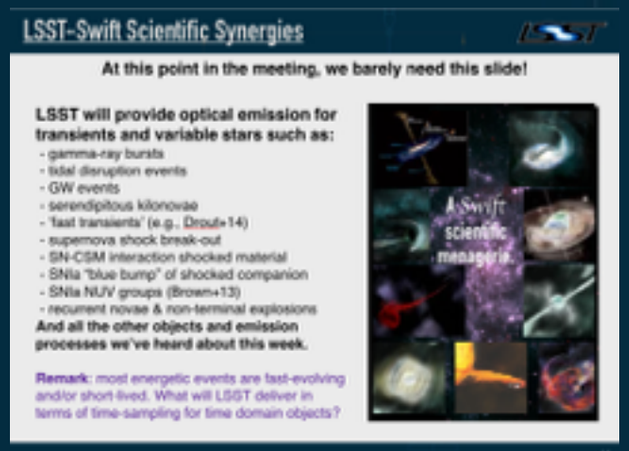
- "interestingness" is not an LSST data product
- LSST source detections are released via the Alert Stream (and in the Science Platform)
- *humans decide if it is interesting* (e.g., by setting broker configurations)
- how many "very interesting" objects - from a Swift science perspective - will LSST find?

LSST–Swift Synergies



Recall earlier remark that most energetic events, i.e., Swift targets, evolve quickly and/or are short-lived: fast transients and fast features.

LSST–Swift Synergies



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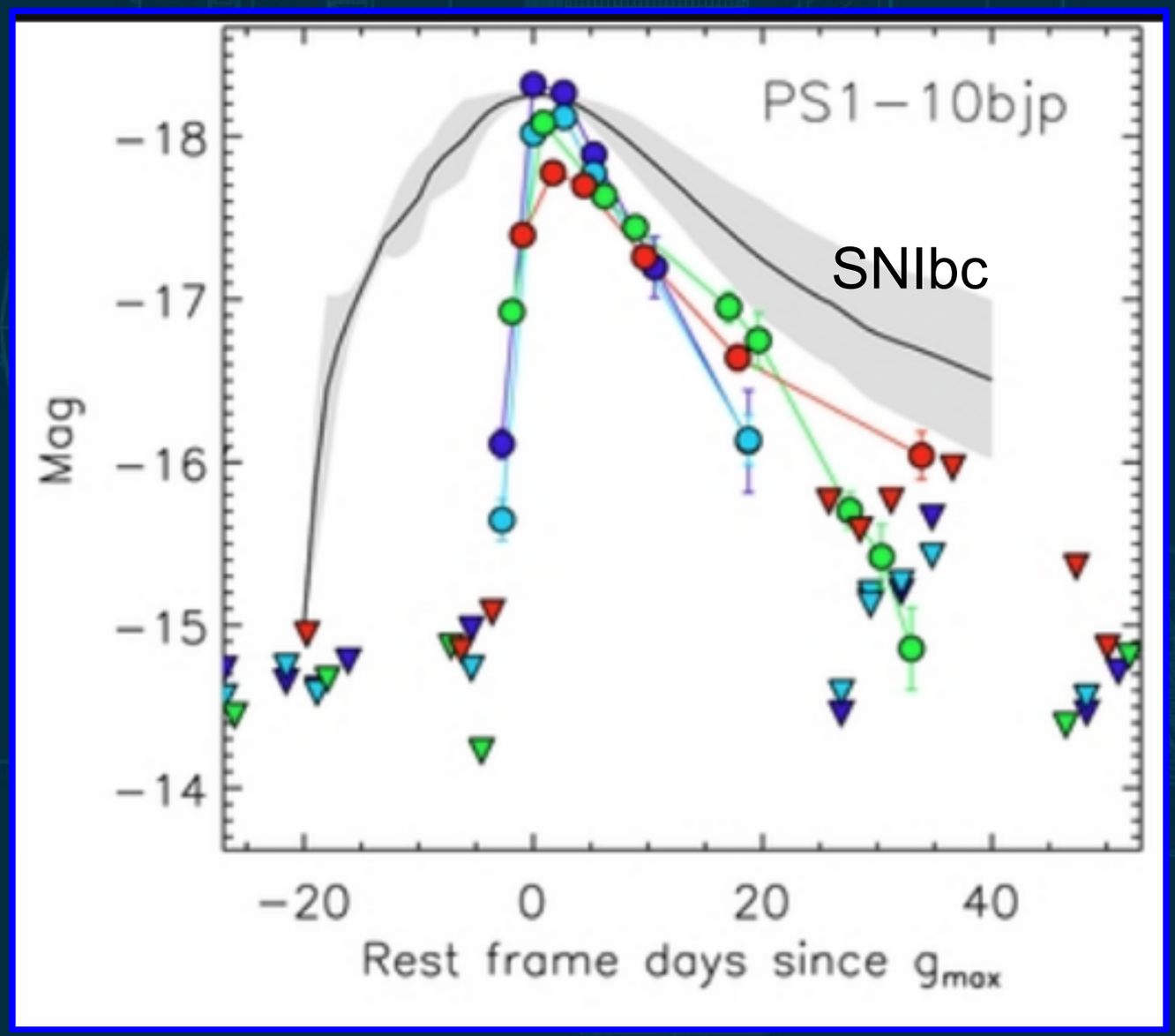
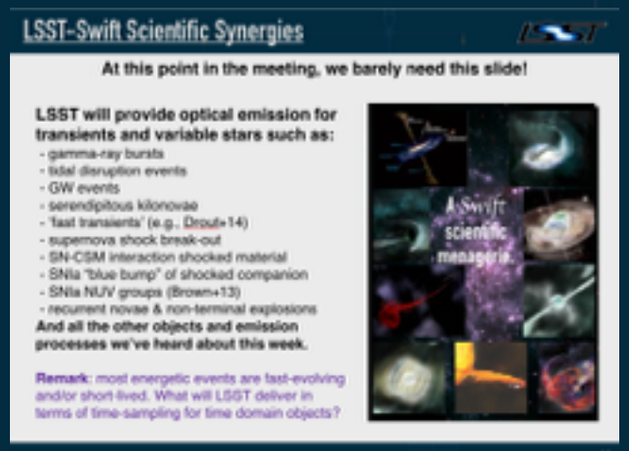


Fast transient from PanSTARRS (Drout+14). Peak lasts <12 days.

See also Perley et al. (2018) which shows fast-declining UV for AT2018cow.

LSST–Swift Synergies



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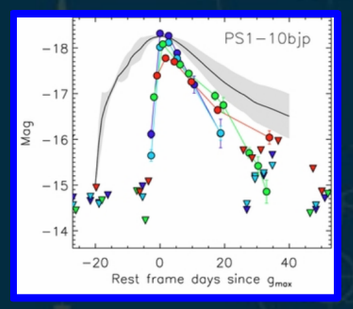
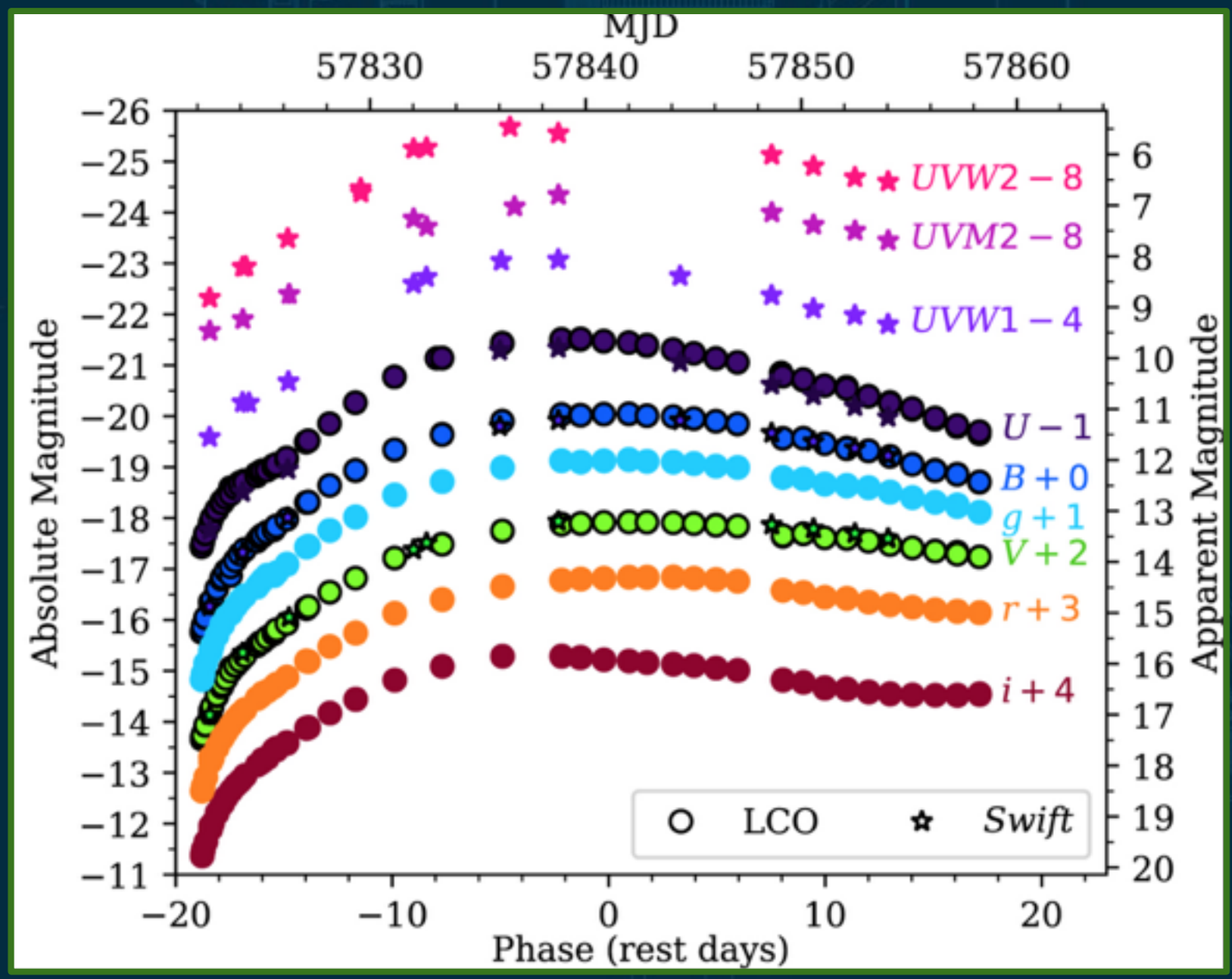
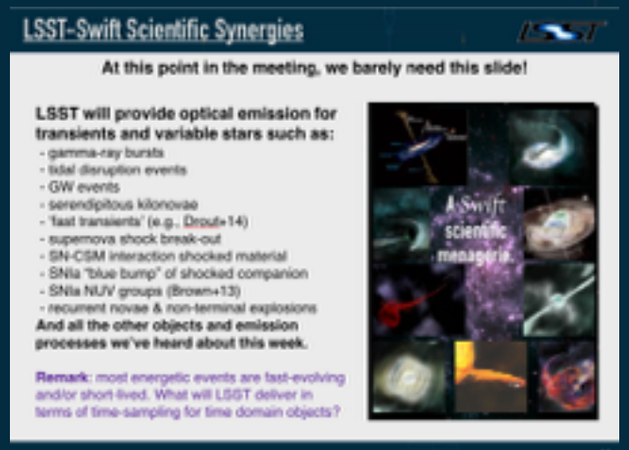


SNIa with an early blue bump in the first 5 days (Hosseinzadeh et al. 2017).



LSST–Swift Synergies



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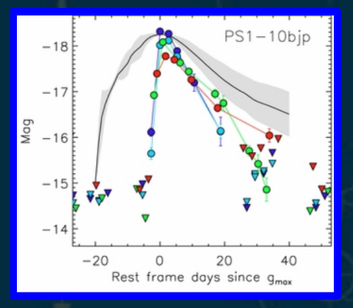
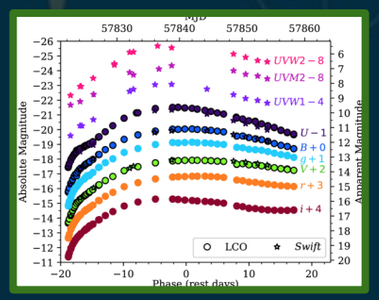
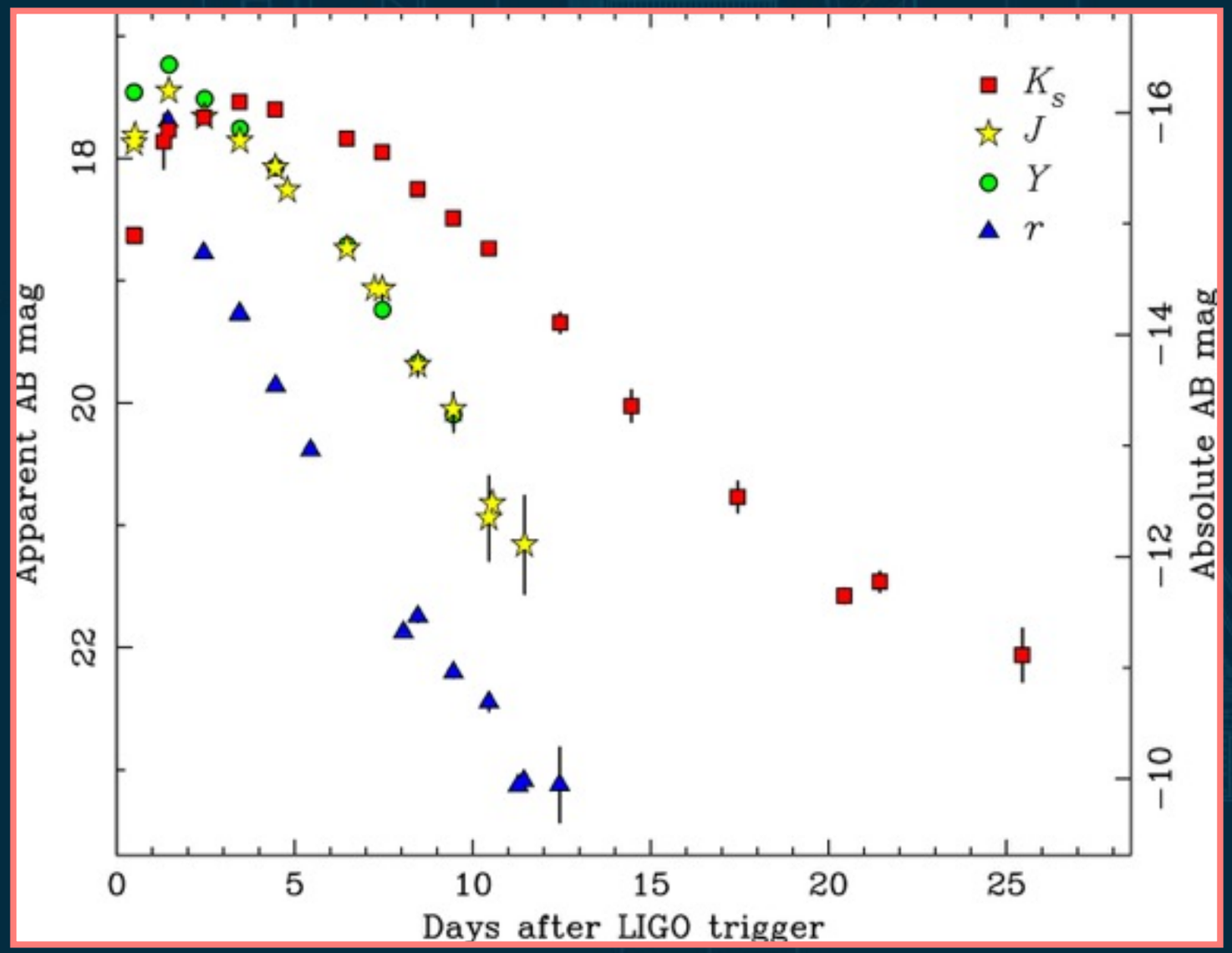
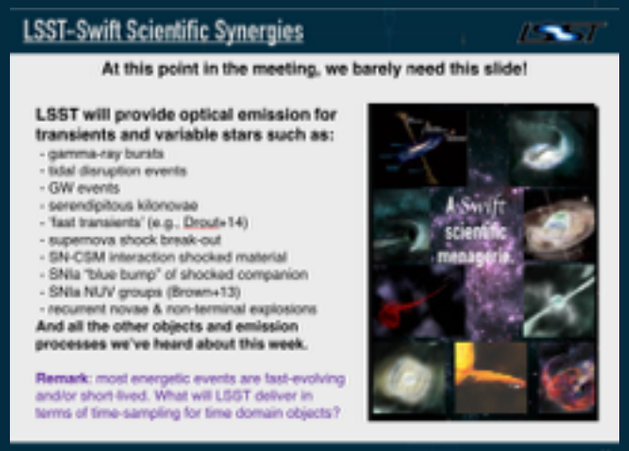






NSNS merger's kilonova rapidly declines in 10 days (Tanvir et al. 2017).

LSST–Swift Synergies



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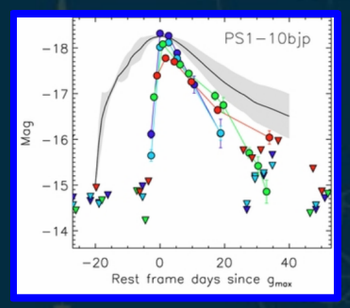
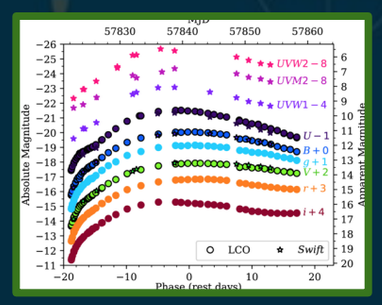
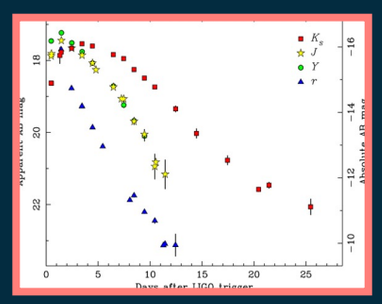






But what will LSST actually deliver in terms of densely sampled time series for fast transients and fast features?

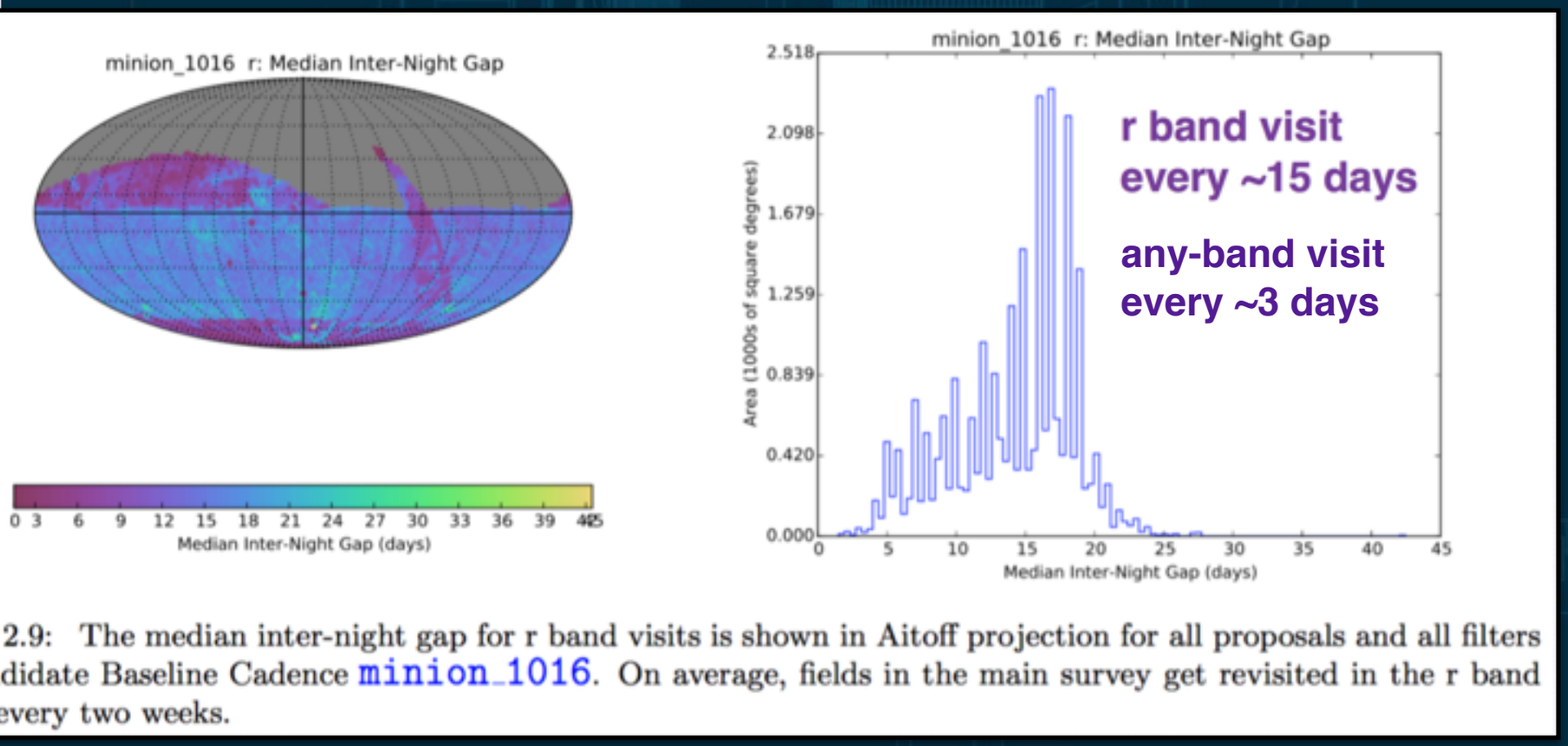
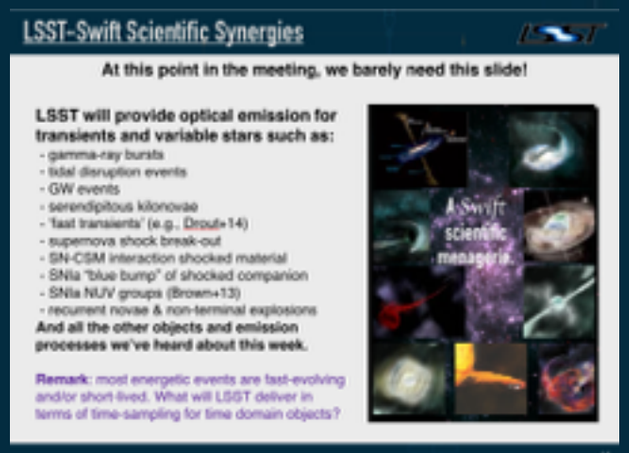


Figure 2.9: The median inter-night gap for r band visits is shown in Aitoff projection for all proposals and all filters for candidate Baseline Cadence `minion_1016`. On average, fields in the main survey get revisited in the r band about every two weeks.

See slides for "LSST Observing Strategy - Zeljko Ivezic" posted to https://www.lsst.org/scientists

LSST–Swift Synergies



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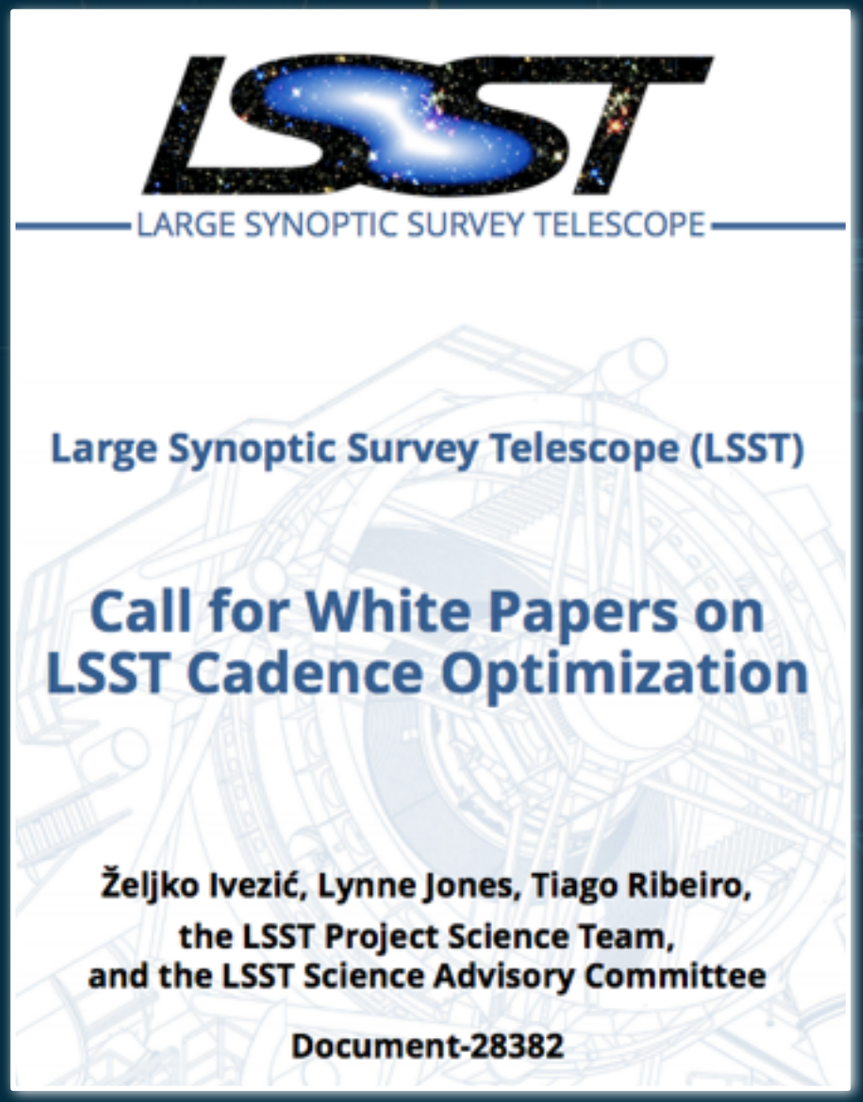


Now is the time to propose cadences that optimize the scientific return on your targets of interest.

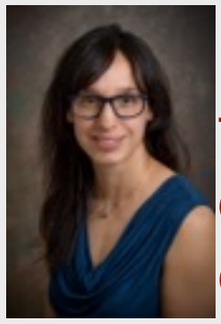
Areas:
- mini-surveys
- WFD extensions
- deep drilling fields

Observing Strategies:
- rolling cadences
- target of opportunity
- airmass tolerances
- field revisits
- exposure times

LSST-Swift Synergies

FLATIRON INSTITUTE

LSST Cadence Hackathon



Federica Bianco has an **idea** for a cadence to optimize detection and characterization of fast transients and features.

Contact Fed or I to participate in this white paper's development.

LSST-Swift Synergies

FLATIRON INSTITUTE

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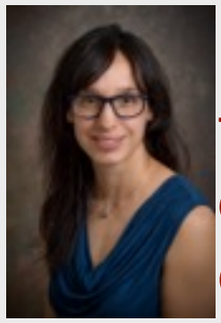

Federica Bianco has an **idea** for a cadence to optimize detection and characterization of fast transients and features.

For fast transients/features we *PROPOSE*:

Color - revisit pair of 2 images in 2 filters within $\Delta t1$ (e.g., 30 minutes)

Brightness evolution - repeat either filter after time $\Delta t2$ (e.g., 1.5 hours)

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LSST–Swift Synergies

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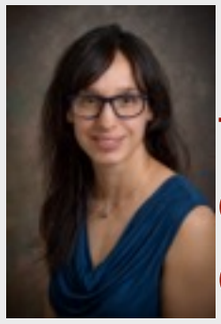
LSST Cadence Hackathon



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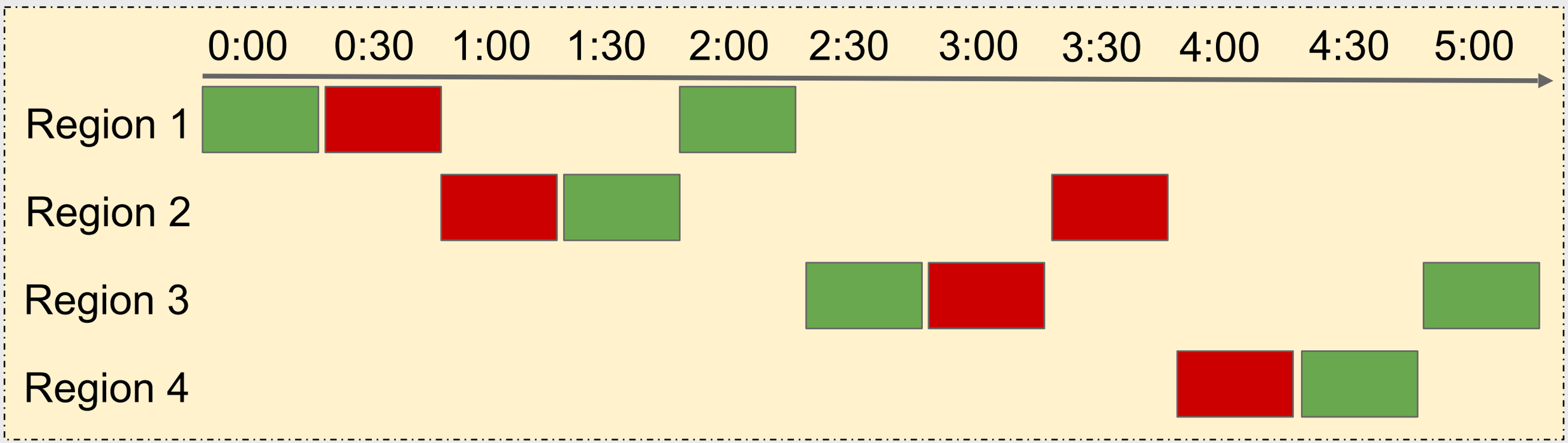

Preliminary results from a test OpSim run:

- triplets in WFD and NES areas; filters g+i and r+z

- 1% efficiency loss due to the extra filter changes

Under Study:

- optimal filters

- optimal Δt

Contact Fed or I to participate in this white paper's development.

Thank you very much!

Questions Welcome

You're also welcome to contact me at mlg3k@uw.edu

Resources:

Join an LSST Science Collaboration: https://www.lsstcorporation.org/node/37

"From Science Drivers to Reference Design", Ivezić et al. (2008), arXiv:0805.2366

"The LSST Science Book" https://www.lsst.org/scientists/scibook

"Science-Driven Optimization of the LSST Observing Strategy", arXiv:1708.04058

LSST Science Platform Vision Document, ls.st/lse-319

LSST Data Products Definition Document, ls.st/dpdd

LSST Community Forum, https://community.lsst.org/

Four Pre-Selected Deep Drilling Fields, https://www.lsst.org/scientists/survey-design/ddf

LSST Call for White Papers on Cadence Optimization, https://www.lsst.org/call-whitepaper-2018

Additional Slides

LSST: Data Management

Data Management — System Science Team

Mandate: scientific validation* of the planned DM deliverables to ensure that the DM pipelines and products are designed to meet the LSST science goals.

1. Work with the science community to understand their needs.

2. Identify scientific opportunities and risks and initiate change.

3. Evaluate the scientific impact of proposed changes to DM deliverables.

*__Validation -__ *do the specifications capture the customer's needs.*
__Verification -__ *does the product meet the specifications.*

LSST: Data Management

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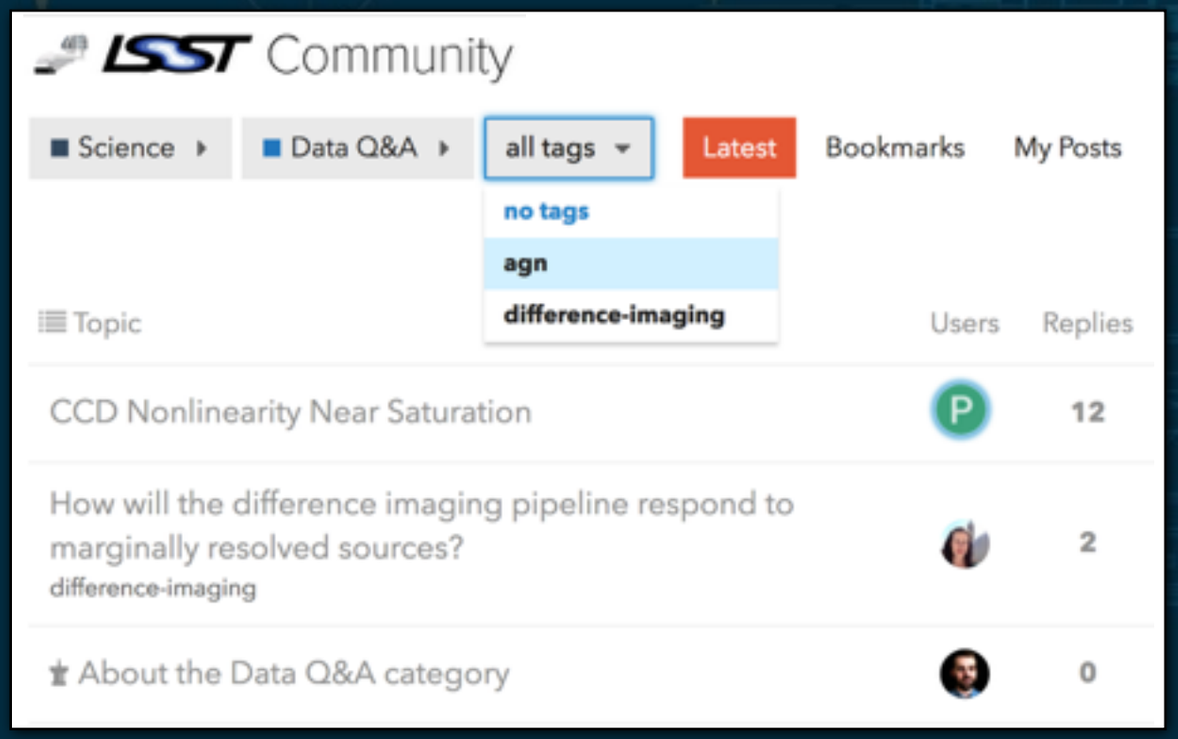


https://community.lsst.org/

The DM SST interacts with scientists by attending meetings, delivering webinars, providing tutorials, serving as Science Collaboration liaisons, and curating a Q&A thread on Community.

Please feel free to contact me or post to Community *if you have any LSST DM related questions.*

*__Validation -__ *do the specifications capture the customer's needs.*
__Verification -__ *does the product meet the specifications.*

Two anticipated LSST-Swift synergy questions.

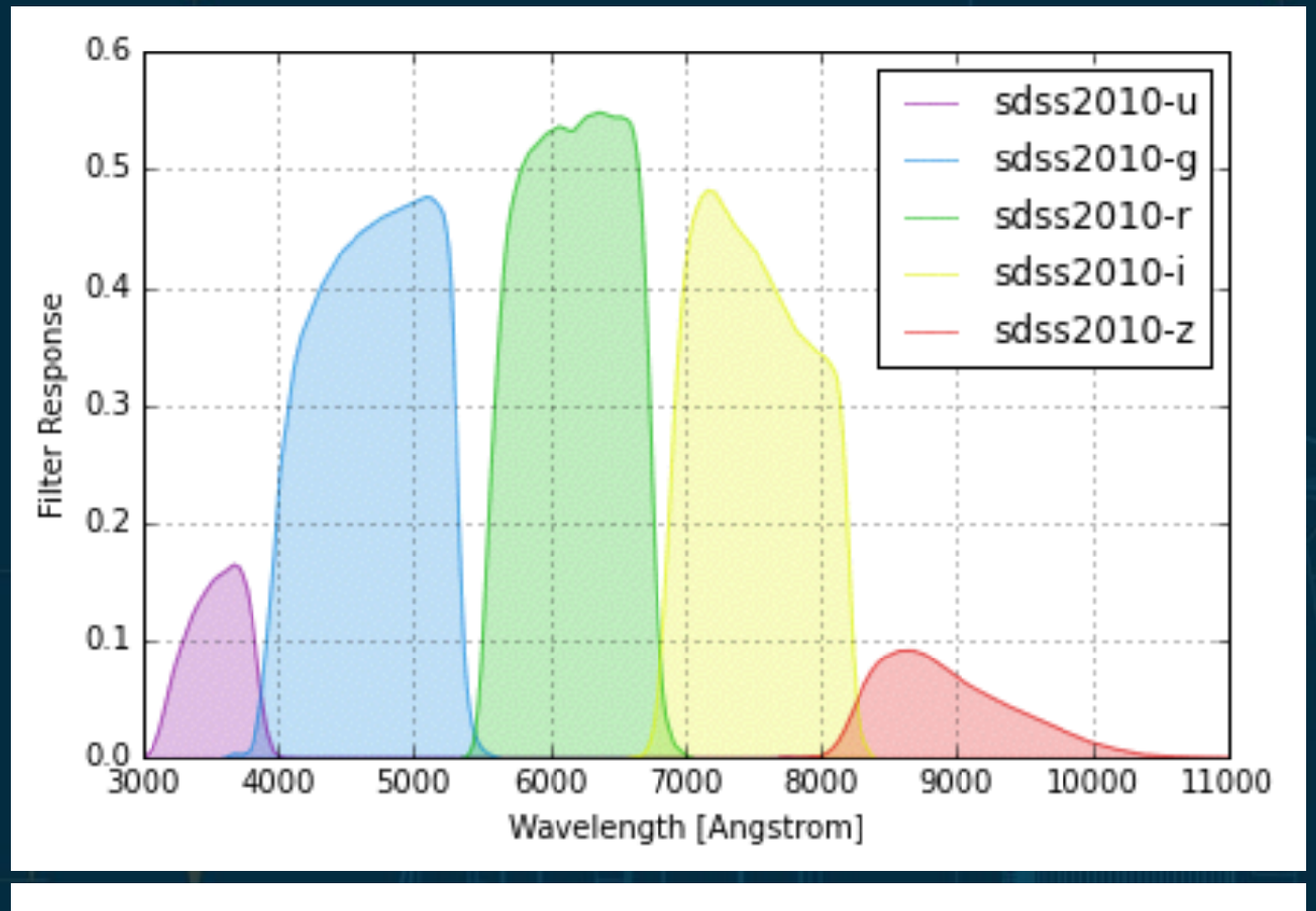
1) What happens if a GW triggers an LSST ToO imaging survey?
If LSST surveys an area with standard visits, that data can (and will) be processed by the Prompt Pipeline and new DIASource detections will be released as Alert Packets. Such GW ToO programs are being proposed by community members as part of the call for white papers on cadence optimization.

2) How could automated 'shadow' surveys that image LSST fields on the same night, with some Δt, be designed to work?
*It is a requirement that "the scheduling of the observing sequence lasting at least 2 hours shall be published in advance of each observing visit", and part of the design that "…the next visit location and the telescope scheduler's predictions of its future observations … [are published] as an unauthenticated, globally-accessible web service comprising both a web page for human inspection and a web API for usage by automated tools." **

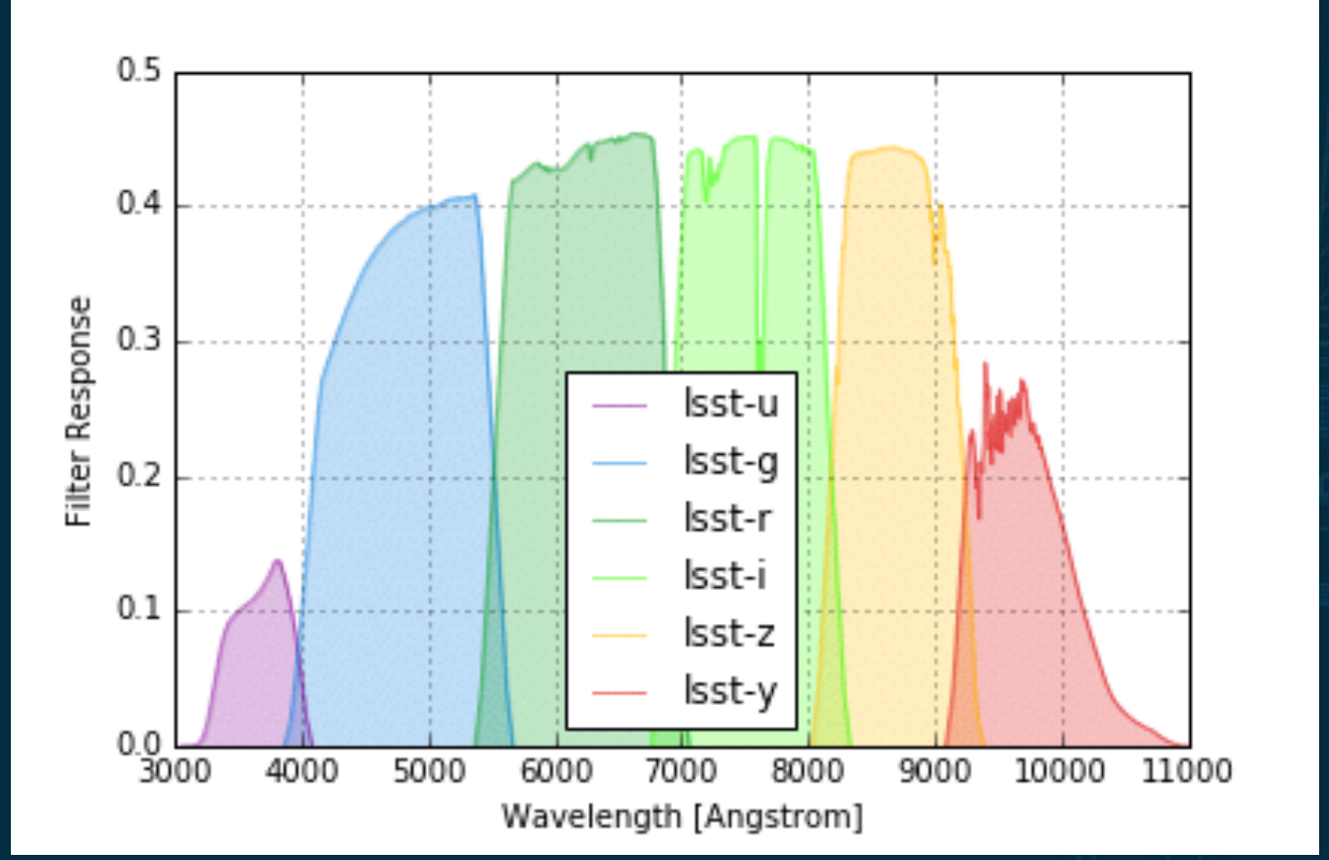
* https://community.lsst.org/t/will-there-be-a-live-feed-of-the-telescope-schedule-during-operations/3218

Additional Slides

SDSS Filters



LSST Filters



Commissioning Plans

Early Verification
with ComCam
~3 months

Early Verification
with LSST Camera
~2 months+

Wide-Area Alert Survey
template generation
~3 weeks

10 Year Depth Survey
In fields overlapping external imaging and spectroscopy.
~6 weeks

Wide-Area Alert Survey
alert production
~3 weeks

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.

LSST Special Programs

WFD
Wide-Fast-Deep

DDF
Deep Drilling Field

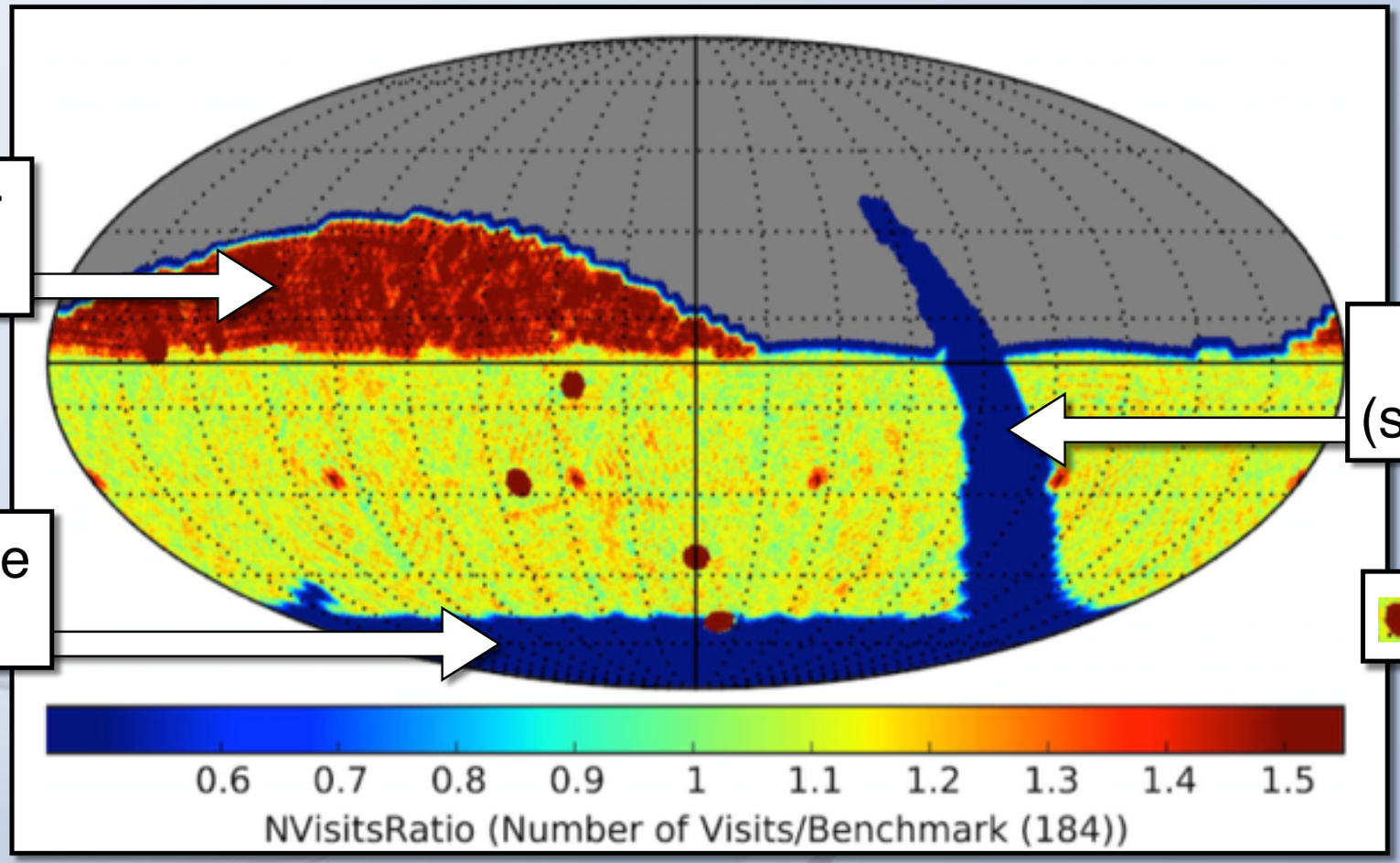
MS
Mini-Survey

What is a Special Program?

Anything not in the “wide-fast-deep” main survey: different areas, survey strategies, non-standard visit images, etc.

Why do Special Programs exist?

Special Programs provide additional or improved science results with the ~10% of observable time not taken up by the WFD main survey.

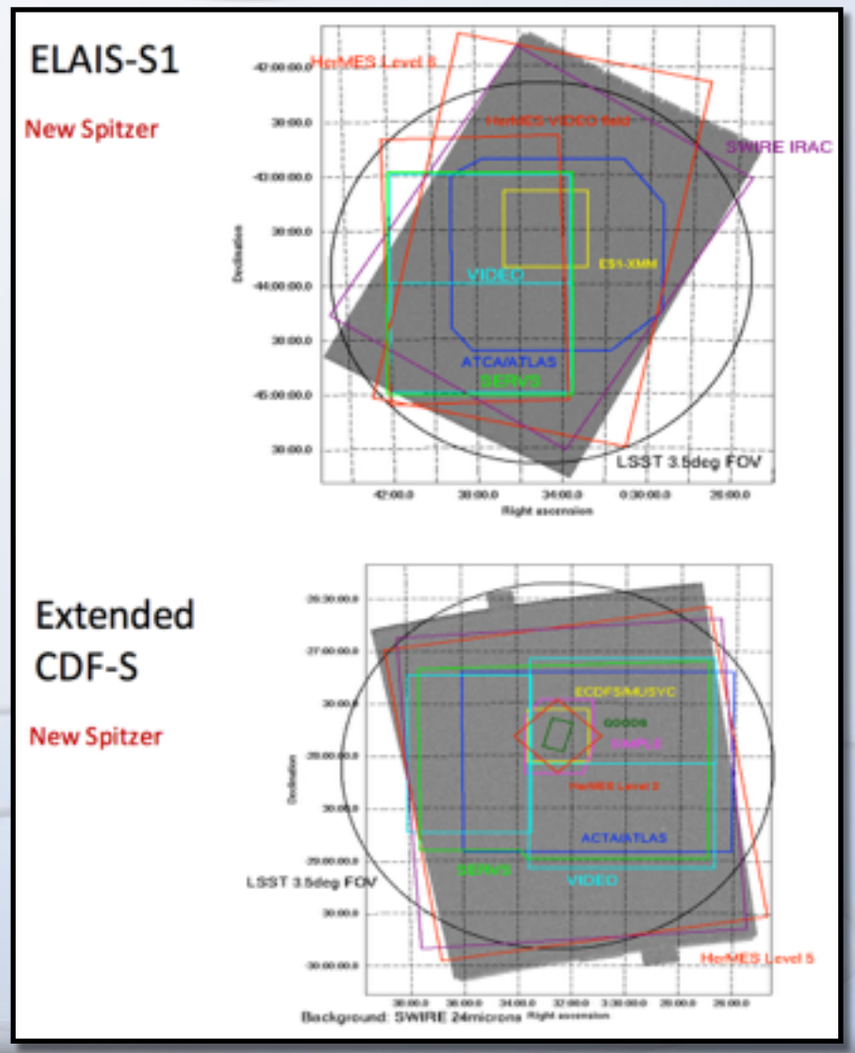


Ivezić et al. (2008), Figure 18.

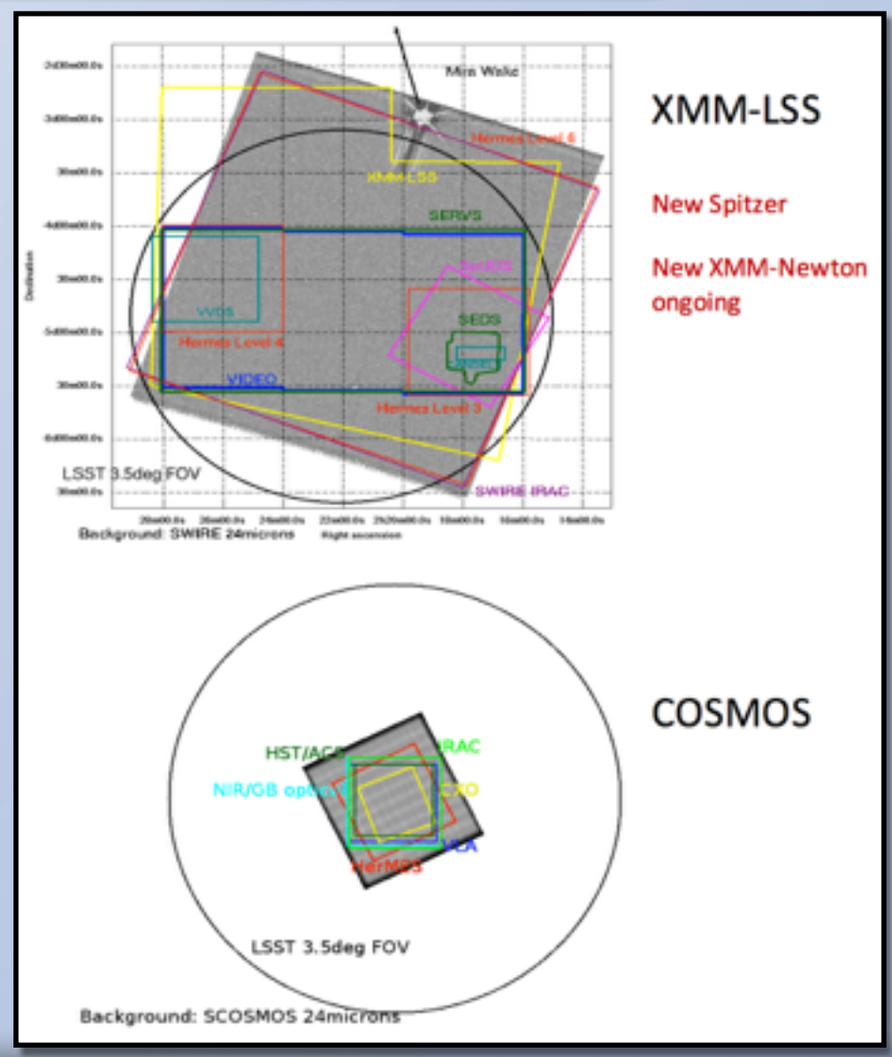
LSST Special Programs

Nominal DDF Observing Strategy:
Ivezić et al. (2008) describes a nominal DDF data set as, e.g.: ~50 x 15s exposures in *griz*, every two nights for four months.

single image limit	r<24.5	*Assuming a conservative 60% completion rate (weather) yields ~7.5 hours of DDF data, stacked with the ~1.5 hours of WFD data.*
nightly stack limit	r<26.5	
full stack limit	r<28.0	



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



https://www.lsst.org/scientists/survey-design/ddf

LSST Special Programs

Slide of additional information about Special Programs

Additional Mini-Survey Concepts:
Mini-Moons (temporary earth-orbiting asteroids)
Meter-Sized Impactors (small earth-crossing asteroids)
Twilight Survey (short exposures for bright objects)
Gravitational Wave Counterparts (extragalactic)

See also Chapter 10 of the Observing Strategy White Paper:
https://github.com/LSSTScienceCollaborations/ObservingStrategy/tree/pdf/whitepaper

"Simulations, Metrics, and Merit Functions for DDF/MS", Steve Ridgway, LSST AHM, Aug 2016:
https://project.lsst.org/meetings/lsst2016/sites/lsst.org.meetings.lsst2016/files/Ridgway-SimulationsMetrics_1.pdf

Neil Brandt's LSST AHM 2016 talk:
https://project.lsst.org/meetings/lsst2016/sites/lsst.org.meetings.lsst2016/files/Brandt-DDF-MiniSurveys-01.pdf

https://www.lsst.org/scientists/survey-design/ddf

2011 DDF Whitepapers: https://project.lsst.org/content/whitepapers32012

LSST Special Programs

First four extragalactic deep fields chosen.

First round of white paper proposals for LSST Special Programs.

planning continues through Science Collaborations, Observing Strategy White Paper

June 2018
Call for white paper proposals

DMTN-065

Nov 30 2018
Deadline for white paper proposals

Project Science Team defines criteria; Science Advisory Council reviews proposals and makes recommendations.

Latest set of Special Programs incorporated into the Operations Simulator.

planning continues

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

DMTN-065: “Data Management and Special Programs”, assesses DM’s plans for processing the diversity of raw data that may be generated by the community’s Special Programs proposals.

LSST Special Programs

https://www.lsst.org/call-whitepaper-2018

What is set and what is open to community* proposals?

Set

- the positions of the four pre-existing deep drilling fields

Open

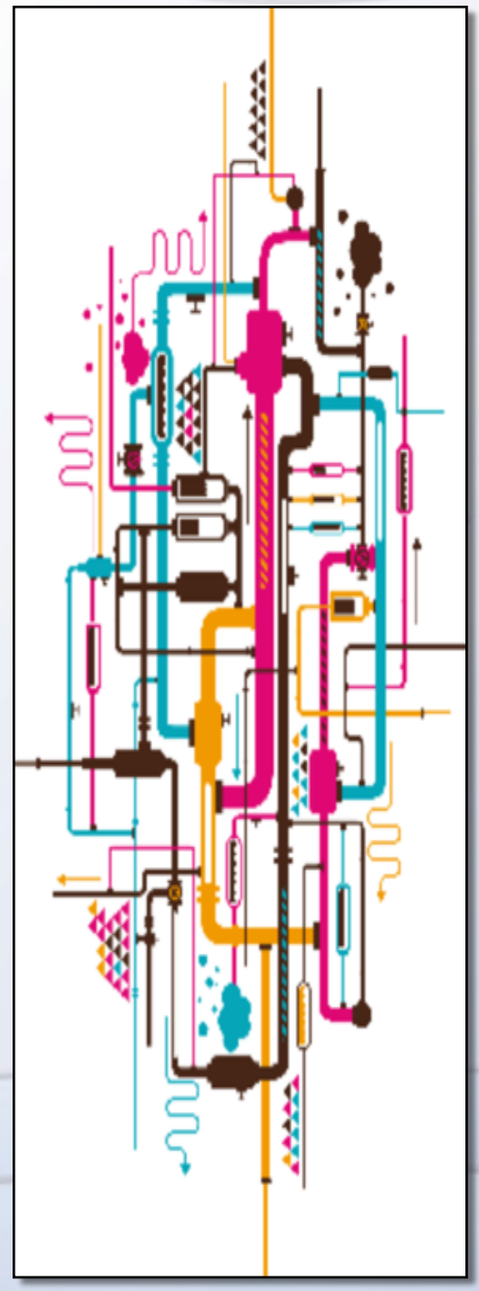
- additional deep drilling fields
- refined observing strategies** for existing deep drilling fields
- optimized survey areas for the NES, South Pole, and Galactic Plane
- refined observing strategies** for the NES, South Pole, and GP
- additional mini-surveys areas and observing strategies
- refined observing strategies for the wide-fast-deep main survey

Timeline:
call in June 2018
due in Nov 30 2018

*Not limited to science collaboration members.
**OpSim runs for proposed DDF/MS expected by late 2019.

LSST Special Programs

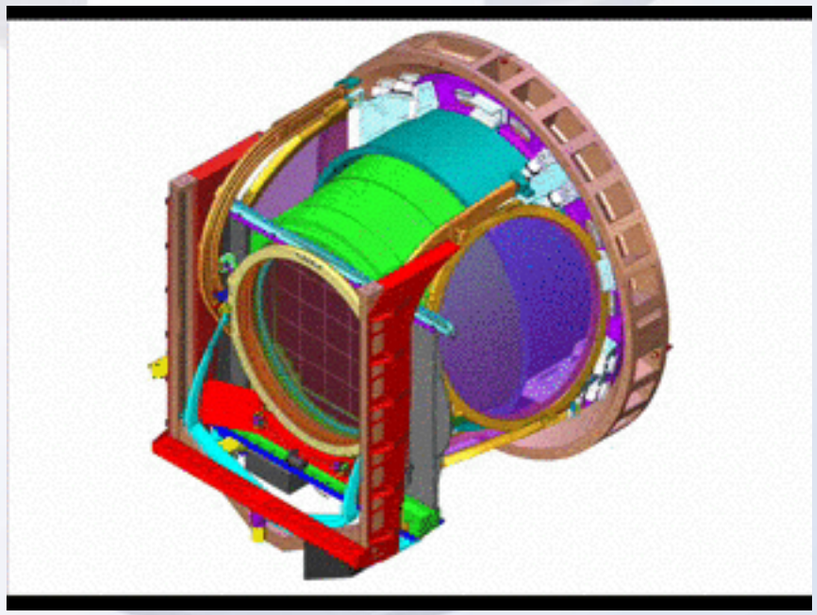
Data Management and Special Programs



LSST-DM will:

- **not** write unique algorithms for processing SP data
- allocate 10% of its computational resources for processing SP data
- incorporate SP data into the prompt and data release products when scientifically beneficial
- reconfigure pipelines to generate separate imaging and catalog products for SP data, whenever possible
- make the Software Stack source code available to the community
- allocate an additional ~10% of the LSST computing resources for user-driven analysis and data product creation in the US DAC

LSST Special Programs



Filter Changes

The maximum time for filter change is 120 seconds (30 seconds for the telescope to reorient the camera to its nominal zero angle position on the rotator, and 90 seconds to the camera subsystem for executing the change; OSS-REQ-0293, ls.st/lse-30).

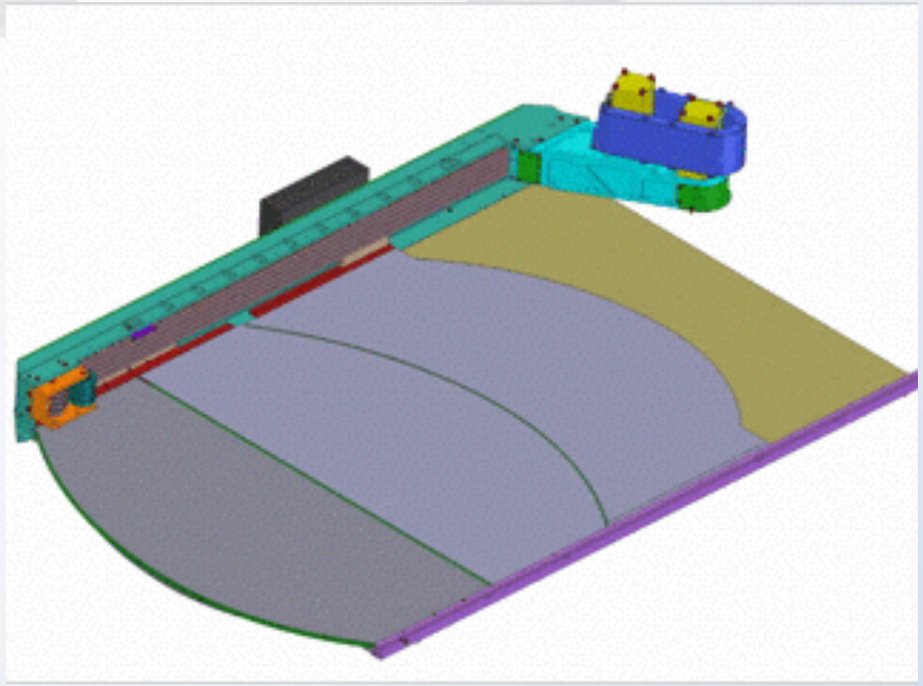
The minimum time between filter changes has no restrictions from e.g., thermal tolerances. However, based on overheads and efficiency, it is recommended to keep the filter change rate lower than once every 10 minutes.

The maximum total number of filter changes is 100,000 over 15 years, an average of 18 changes per night.

The maximum number of filter swaps in/out of the carousel is 3000 in 15 years, or once every two nights.

Last three points are from Steve Ritz and Zeljko Ivezic, to be incorporated into public-facing documents soon.

LSST Special Programs



Exposure Times

The minimum exposure time is 1 second, with a stretch goal of 0.1 seconds.
(OSS-REQ-0291, ls.st/lse-30)

1) The minimum exposure time needed to create an image with a PSF that is well-formed enough for difference imaging is a separate question.
2) Assuming a 1 second exposure can be reduced and calibrated, its detected point sources will span 13 < r < 21 magnitudes, whereas a 15 second exposure saturates at r~15.8 mag.

The maximum exposure time is not restricted.

However, a 2x150 second image would saturate at r~18.3, perhaps leaving too few stars overlapping with e.g., templates or WFD images, for astrometric and photometric calibrations; additionally, the impact on CR rejection routines is untested for long exposures.