https://doi.org/10.5281/zenodo.2209001

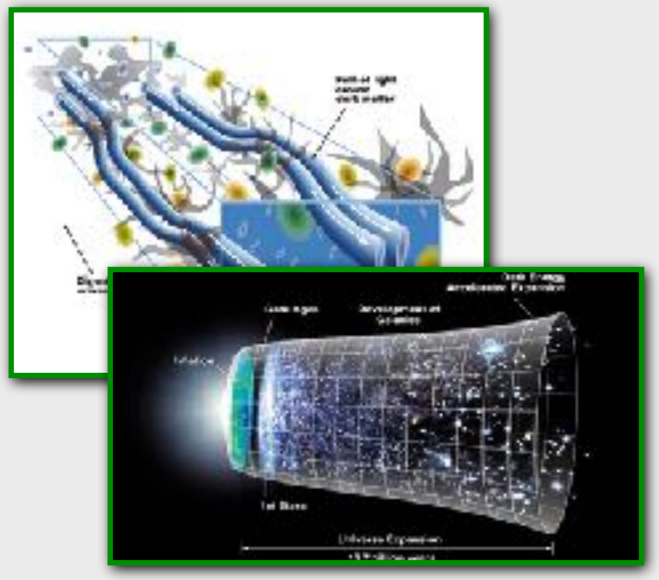
TMT & LSST
Data Infrastructures for Time-Domain Science

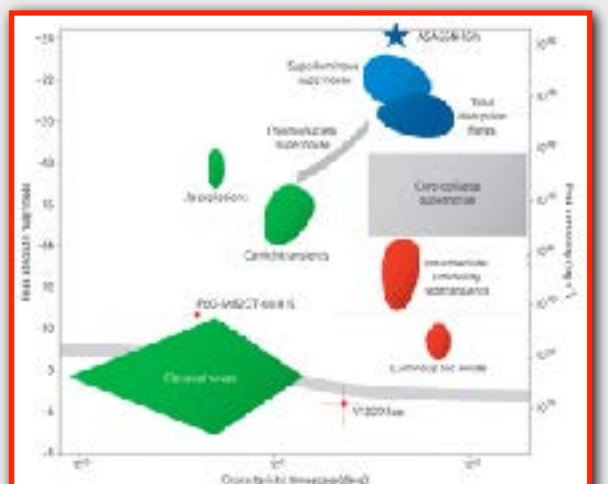
TMT Science Forum, December 2018

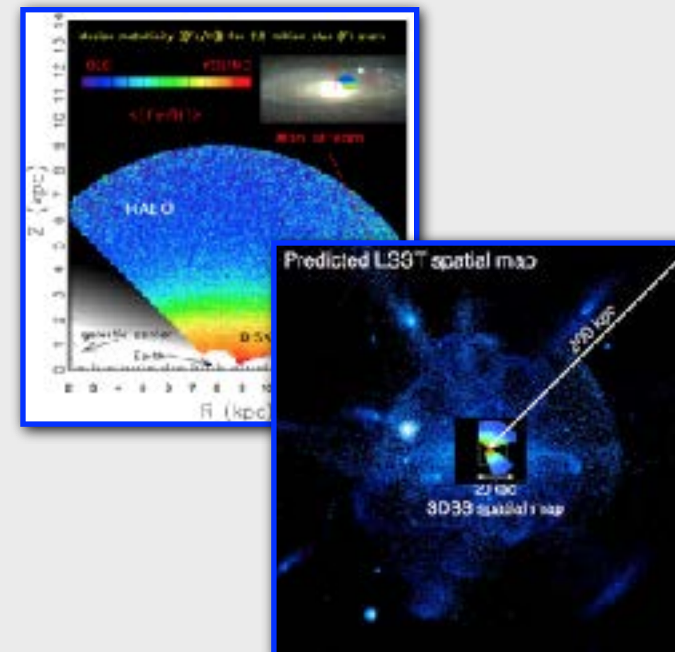
Melissa Graham - LSST Data Management Science Analyst - U. of Washington

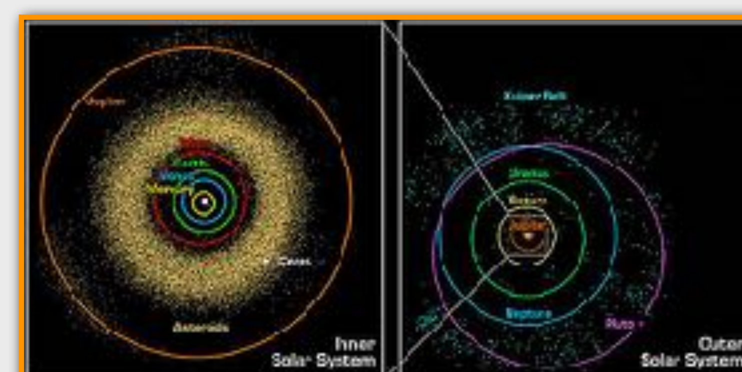
Large Synoptic Survey Telescope

LSST: Four Primary Science Themes









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

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

- 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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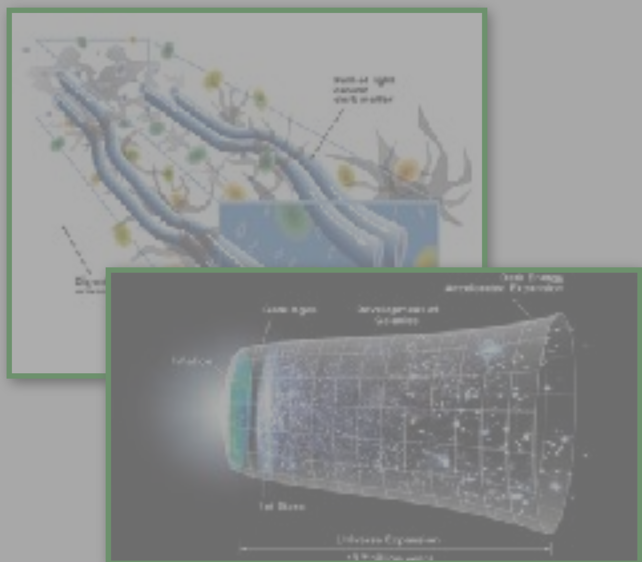

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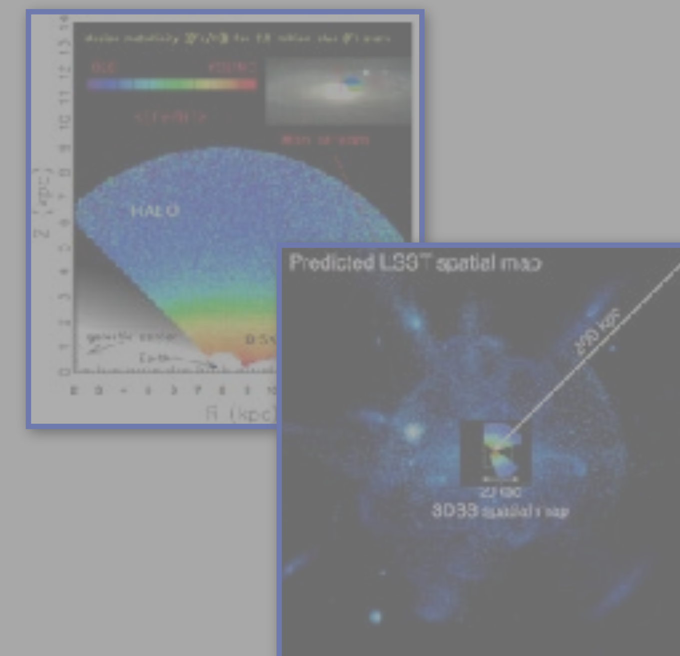

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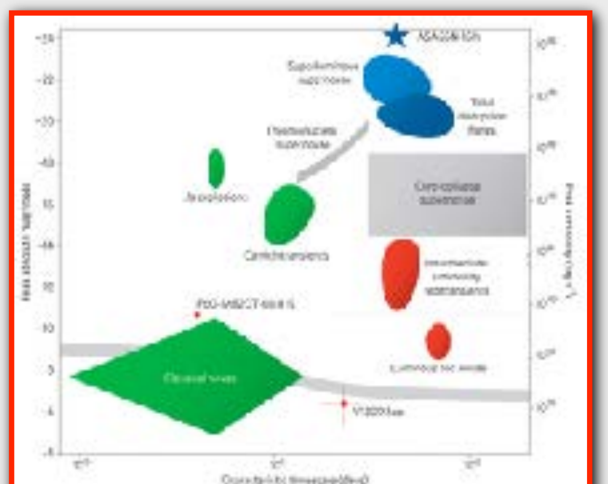

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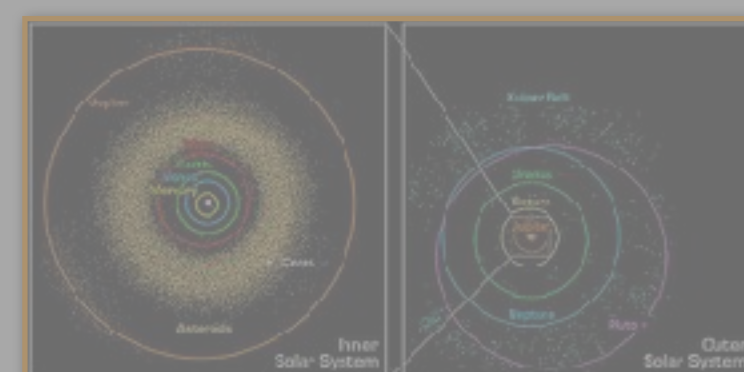

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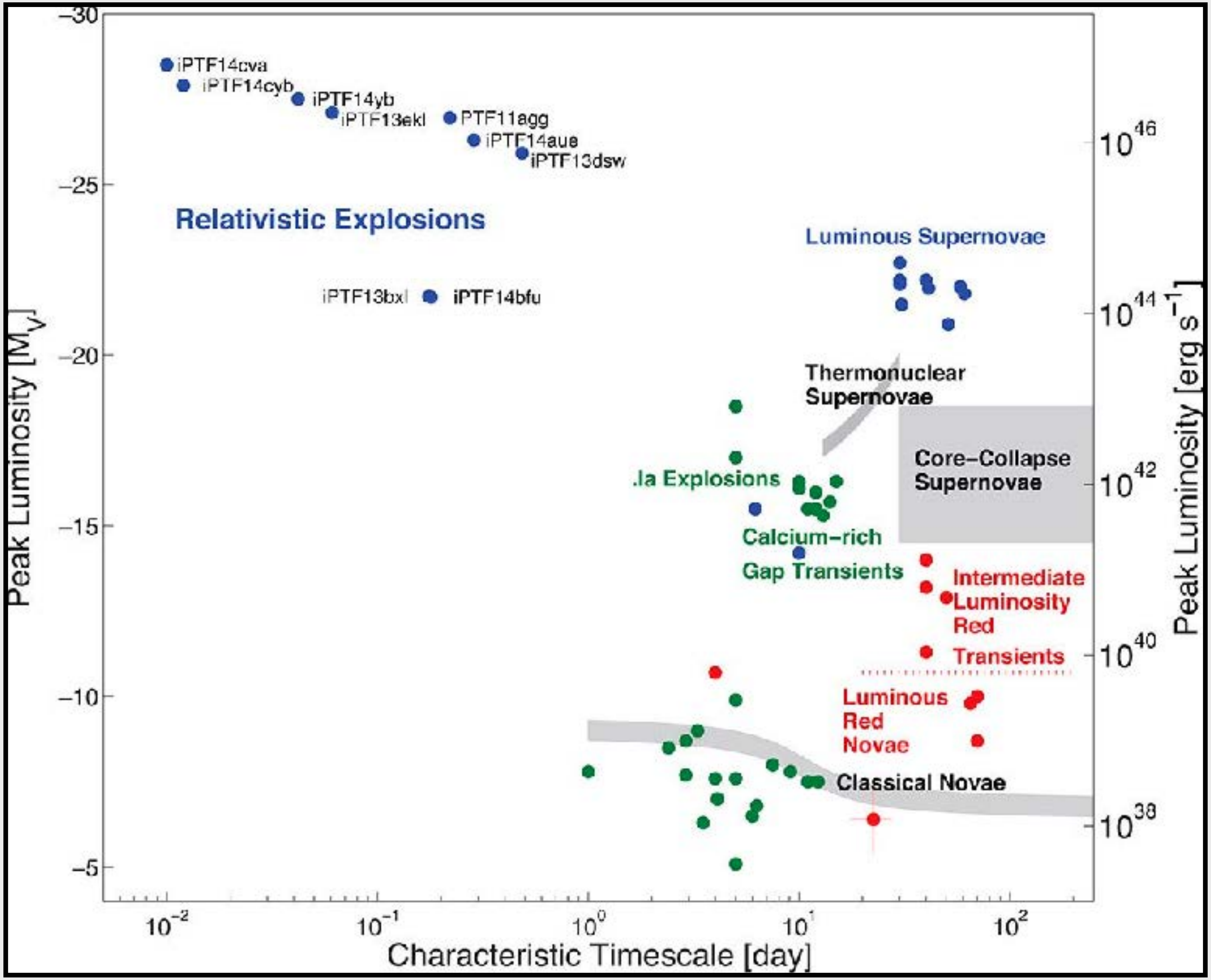
See also: https://www.lsst.org/scientists/scibook

TMT-LSST: Where Is Breakthrough Territory?



Nugent 2015, SPIE Newsroom. DOI: 10.1117/2.1201502.005738; L/τ phase-space diagram first presented by Kulkarni et al. 2007

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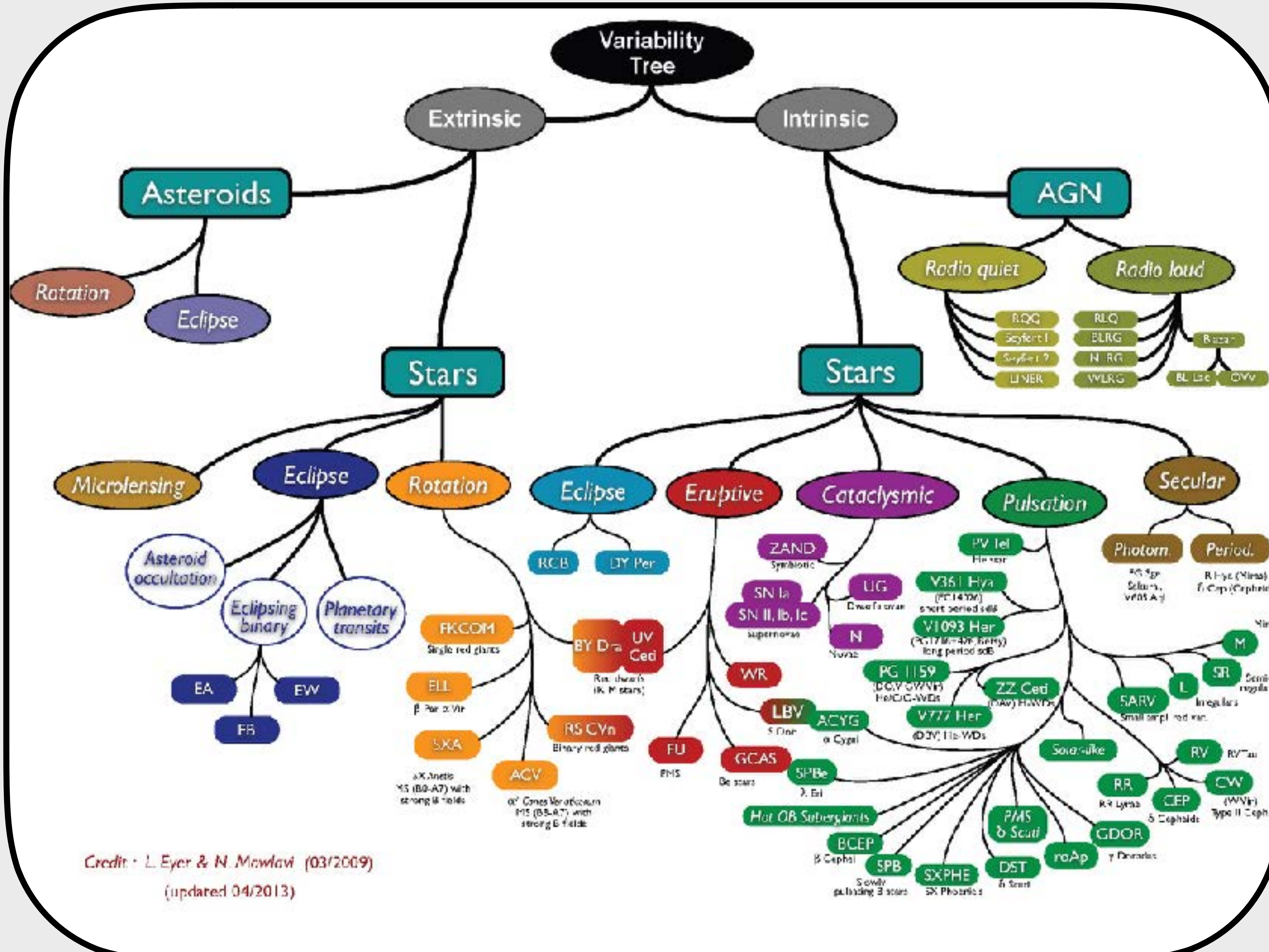

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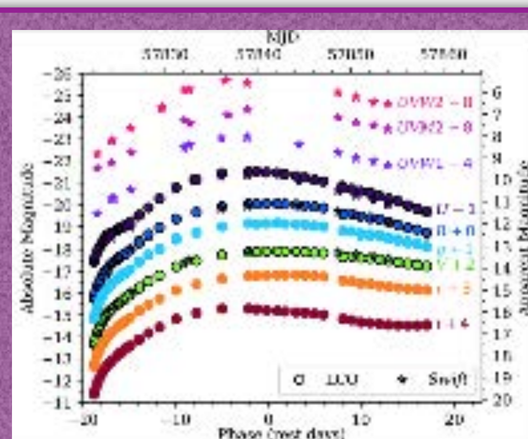

SNe Ia at faint phases: young (left) and old (right).

SNIa 2017cbv
Hosseinzadeh+17

SNIa 2011fe
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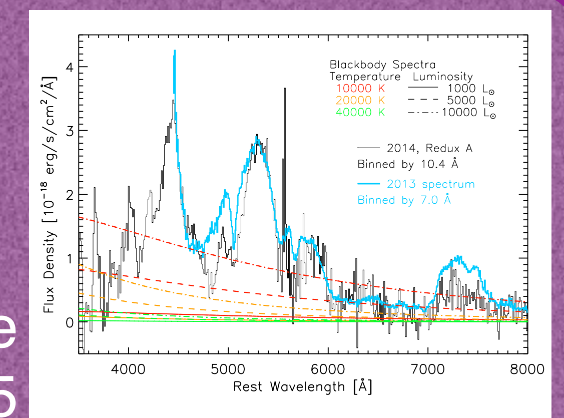

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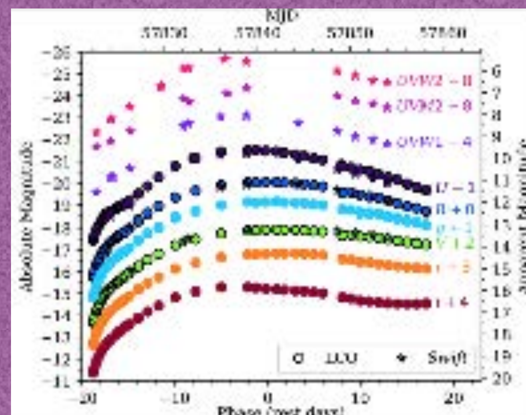

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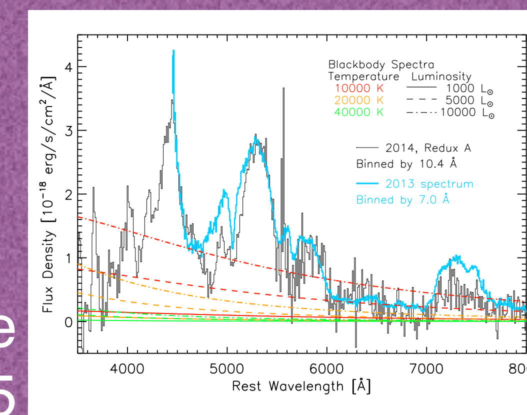
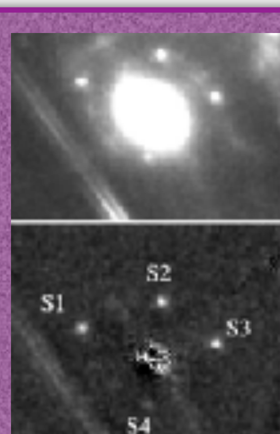


Higher Spatial Resolution



Multiply lensed SNe, circumstellar material (CSM), and SN light echoes.

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Kelly+14

E.g., 1987A
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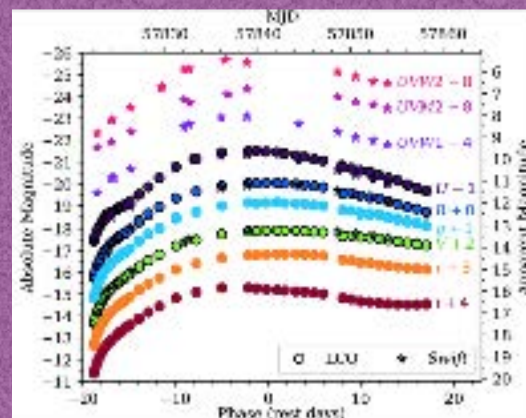

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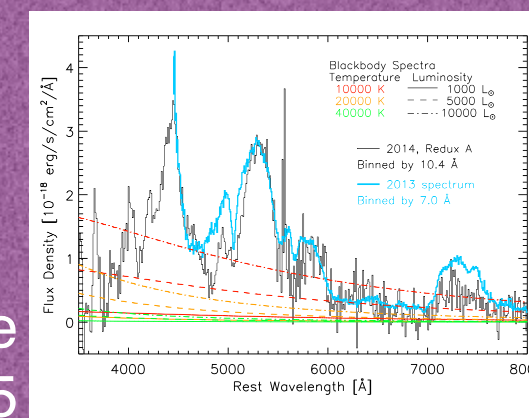

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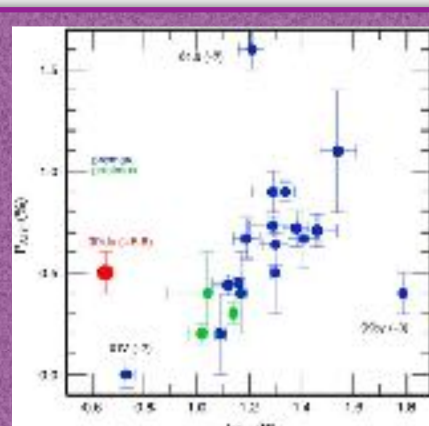

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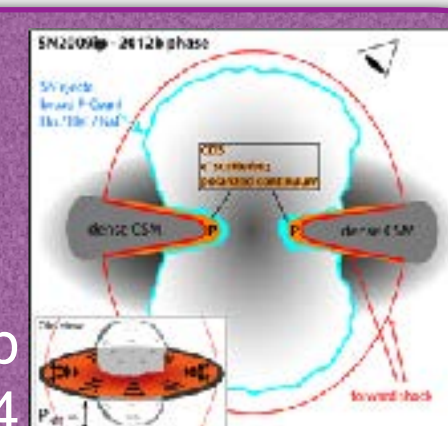

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For such rare objects and events, the volume of LSST is needed to build larger samples.

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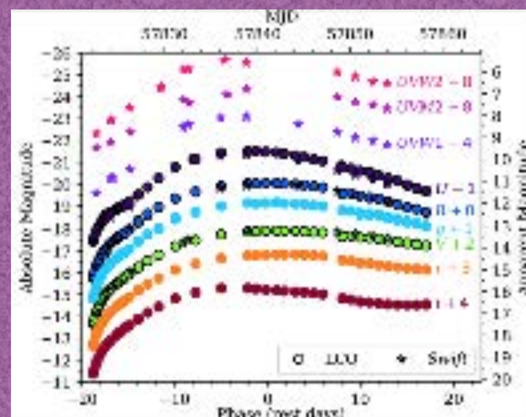

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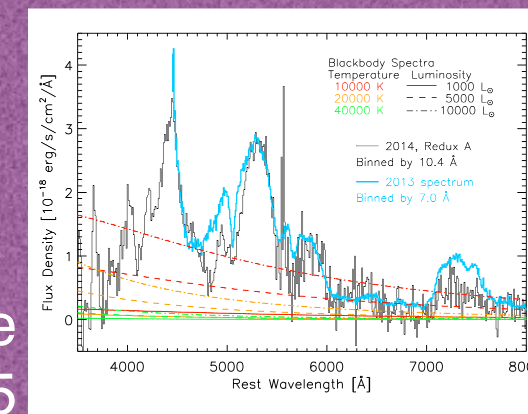

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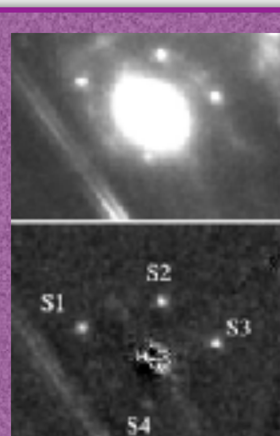

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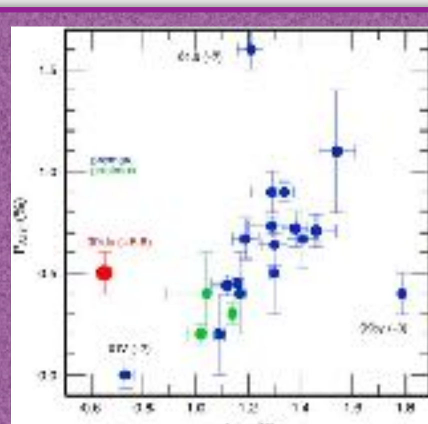

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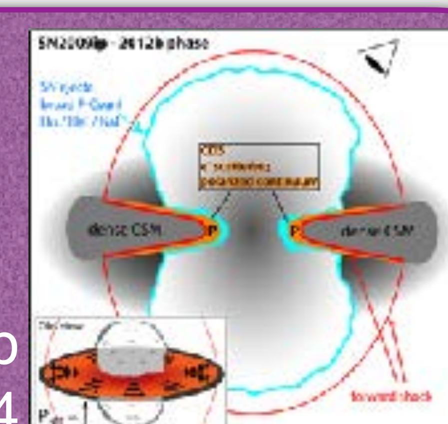

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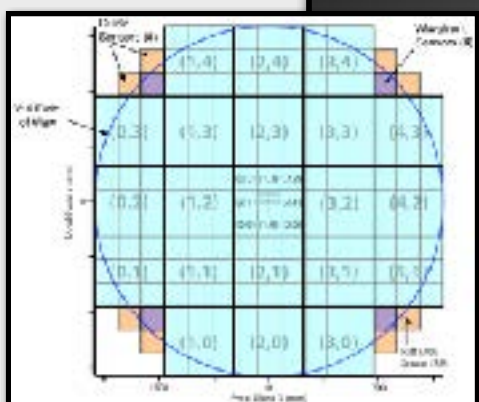

Hardware

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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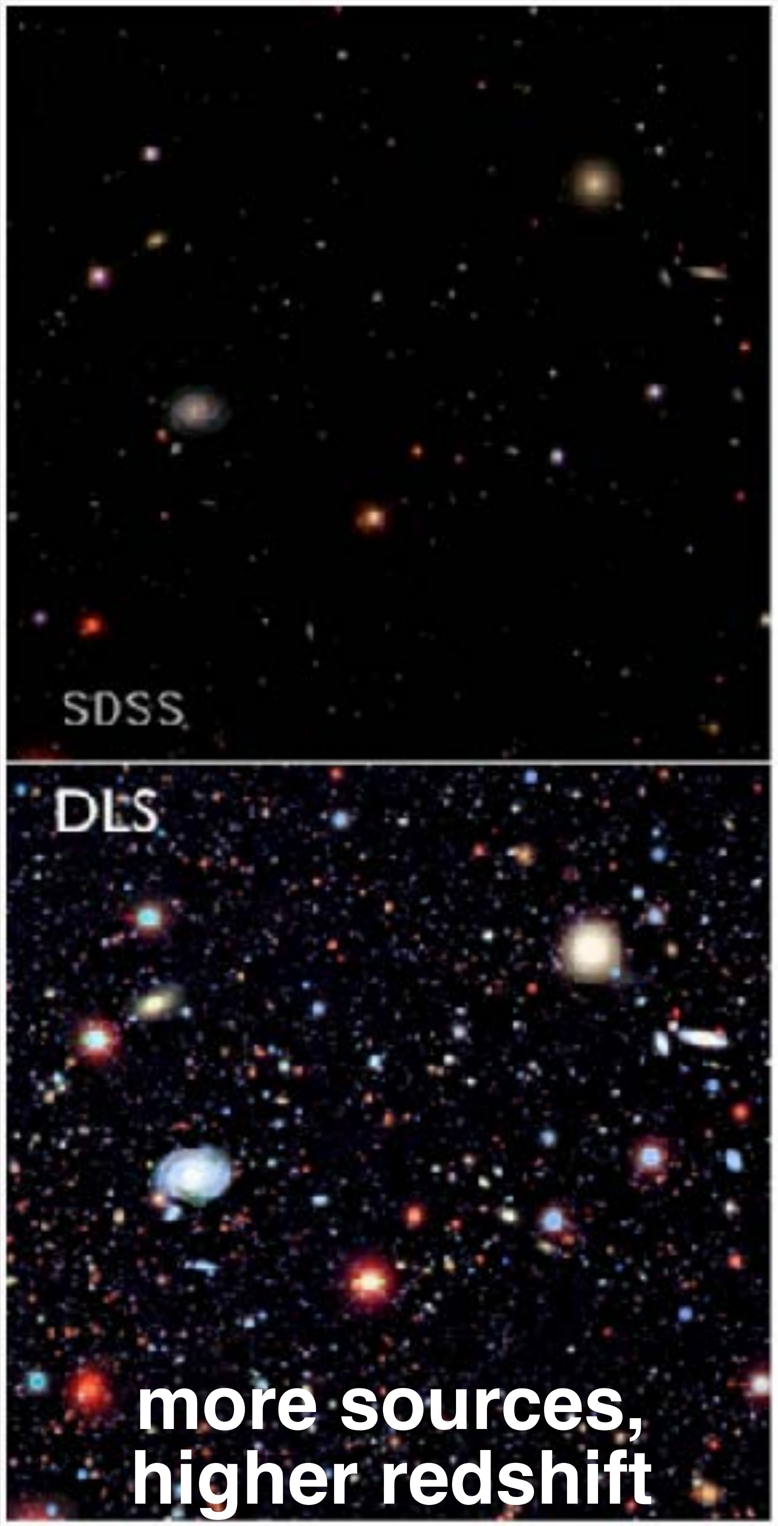
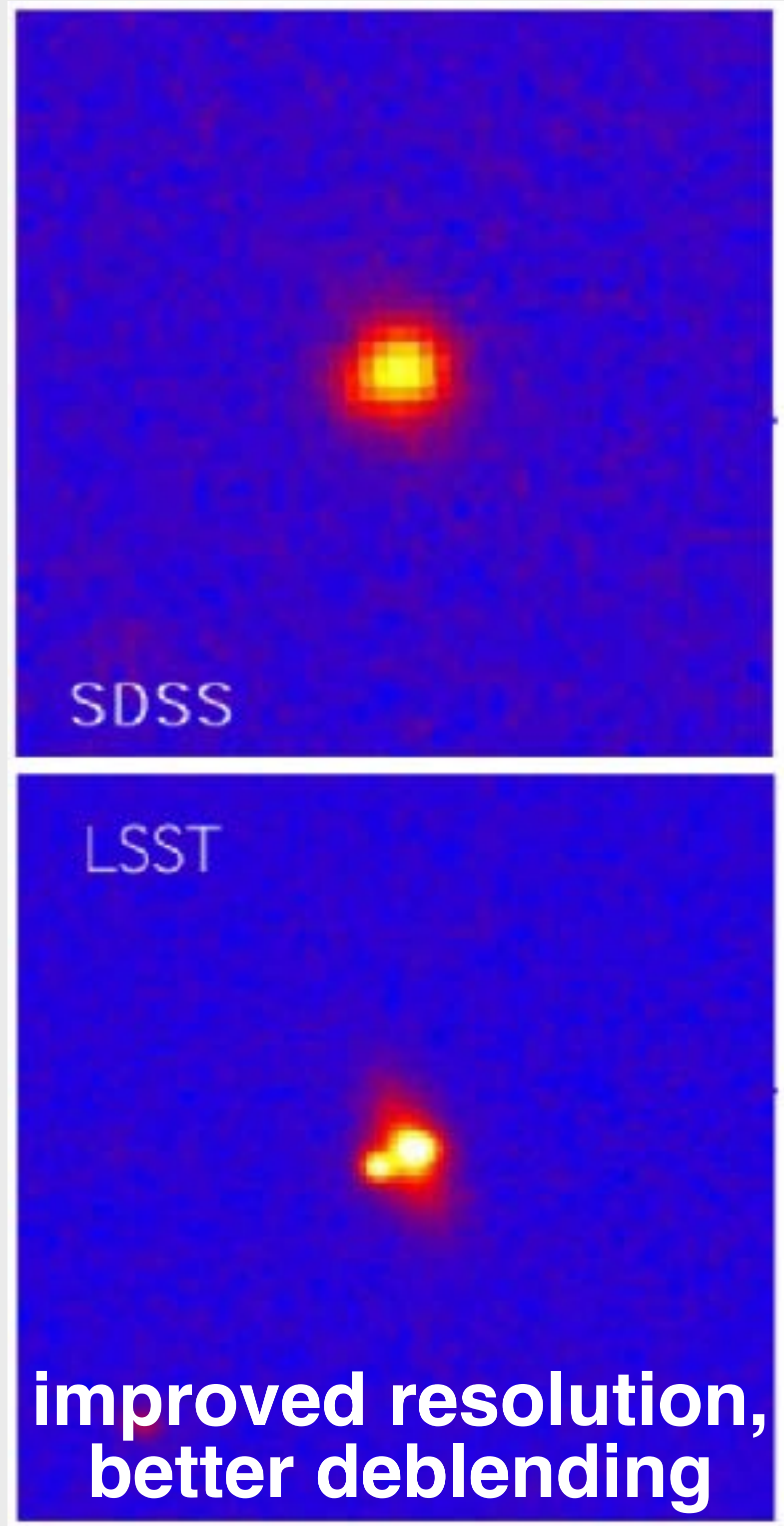
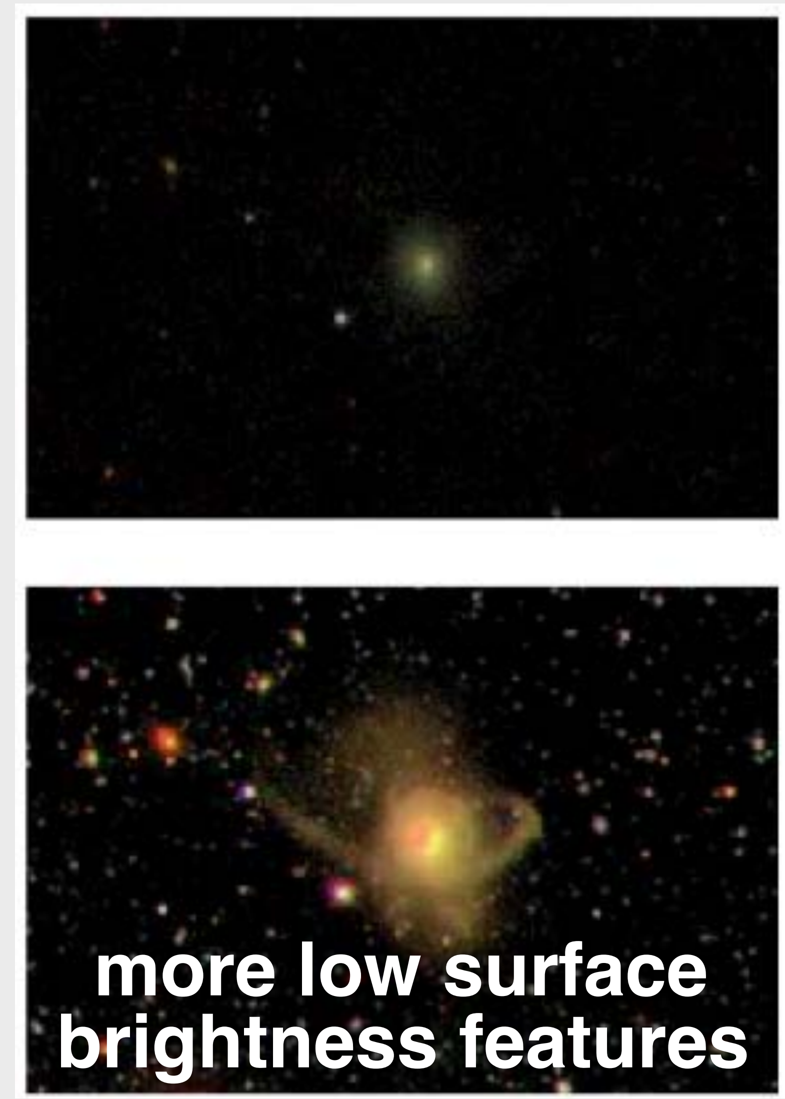
LSST: Projected Data





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



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LSST: Status

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Nov 2018:
arch girders!
LSST Project/NSF/AURA
Gianluca Lombardi

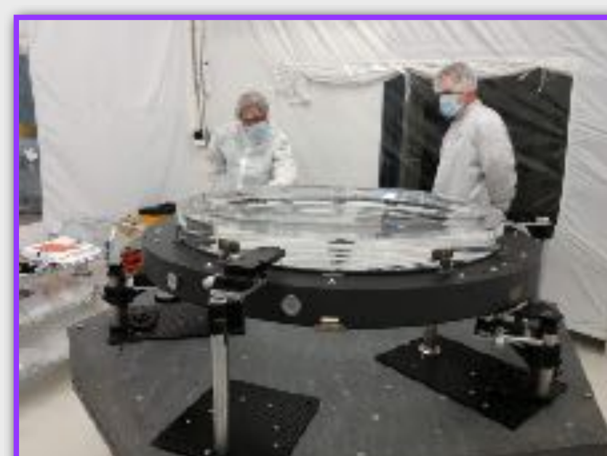
LSST: Status

Hardware and Software Highlights in 2018

- La Serena base facility construction began
- optical fiber runs to summit; path completed
- Cerro Pachon **summit facility** receiving shipments
- mirror coating chamber delivered to the summit
- auxiliary telescope is being installed at the summit
- **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:

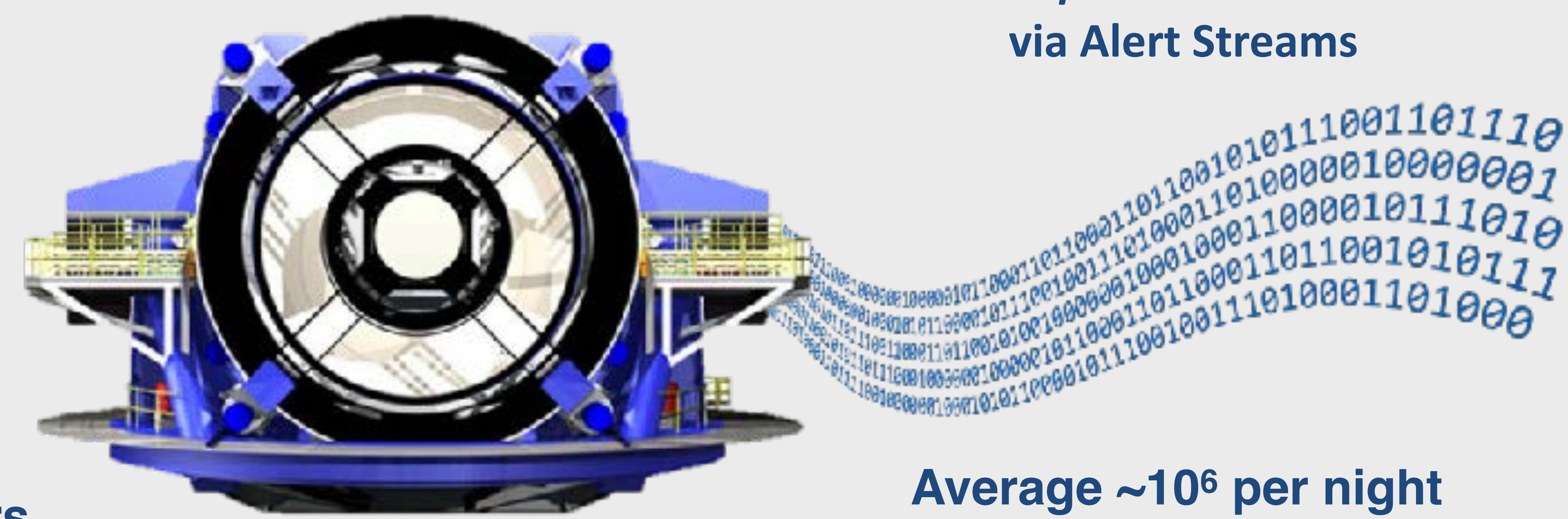
- **ComCam observations, Oct 2020**
- **LSSTCam observations, July 2021**
- **commissioning surveys, July 2021**
- **full operations, late 2022**



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

LSST Science Platform

Last 2 data releases available.

Alerts database and filter service.

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

LSST: Data Products

Prompt

Previously "Level 1".

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".

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".

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 within 24h.

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, and access to the alerts database.

LSST Data Rights document in preparation.

LSST: Data Management Pipelines & Data Products

Alert Packets

- formatted text file containing schema and data (e.g., VOEvent)
- 1 Alert per source detected in difference image with |S/N|>5
- released to Alert Stream within 60s of image readout
- the source's detection and characterization parameters
- any/all associated LSST static or moving objects
- a ~12 month history of LSST detections
- image stamps

  ↳at least 6"x6"; difference and template; flux, variance, and mask; includes meta-data such as WCS, zero-point, PSF

*DIA = Difference Image Analysis

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

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Community Alert Brokers

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.

Examples of Community Alert Brokers Currently Processing ZTF Alerts

ALeRCE Automatic Learning for the Rapid Classification of Events

Lasair

ANTARES

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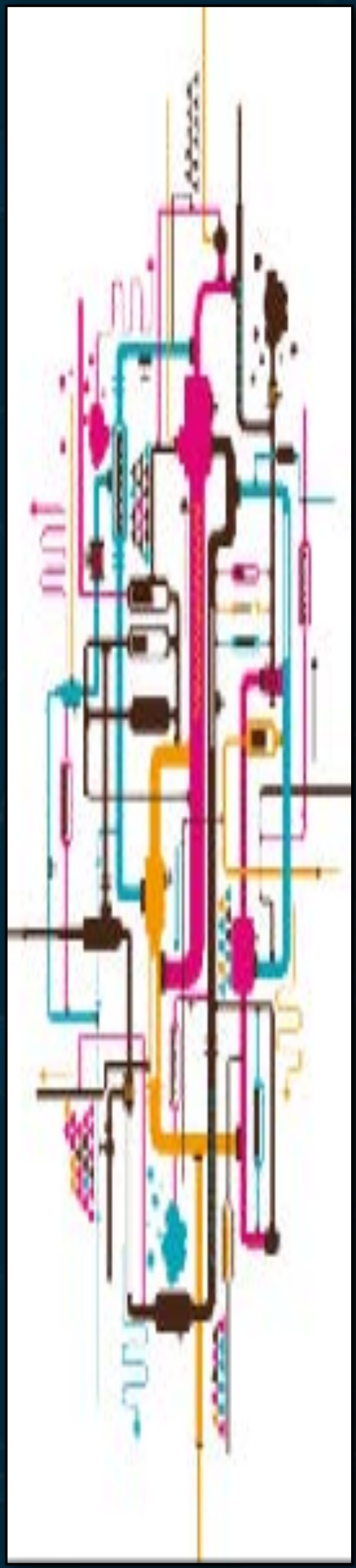

Prompt (<24 h) Data Products: Difference Images and Catalogs

Difference-image source catalogs are updated with new data, including:

- characterization parameters (e.g., shape, variability, association with known objects)
- forced photometry for objects detected in past 12 months
- forced precovery photometry from past 30 days for new sources

Moving-object tracklets identified and reported to the Minor Planets Center.

Processed visit images and difference images are available in the Science Platform.

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Annual Data Products: Stacked Images and Catalogs

- reprocessed single-visit images and difference images
- deep stacks in each filter (full survey and short period, e.g., yearly)
- catalogs of sources, objects (sources associated by coordinate), and forced photometry

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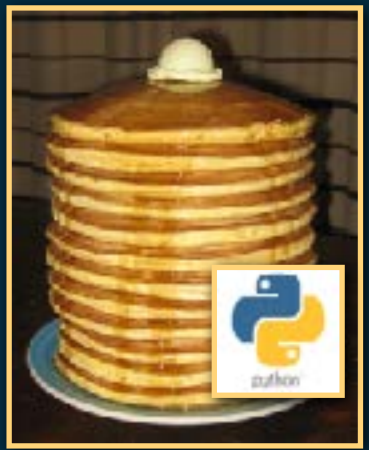
Access to LSST Pipelines and Data Products

- 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
- a real-time alert filtering service



"The Stack", a common term for the LSST science pipelines, will be available in the Science Platform.

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Consider the following two basic scenarios for time-domain science.

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What are its optical parameters?
Does it have a history of variability?
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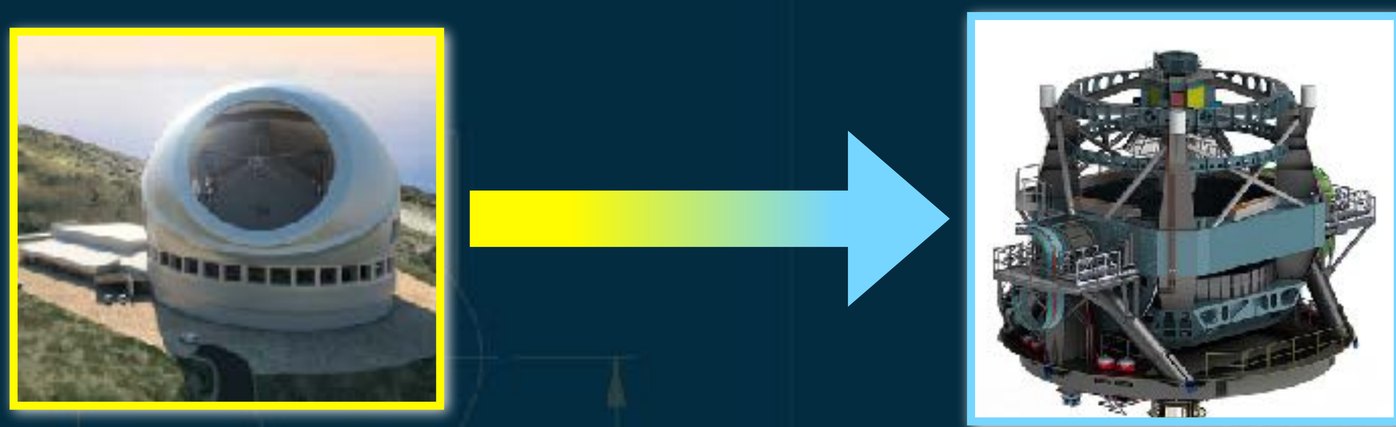

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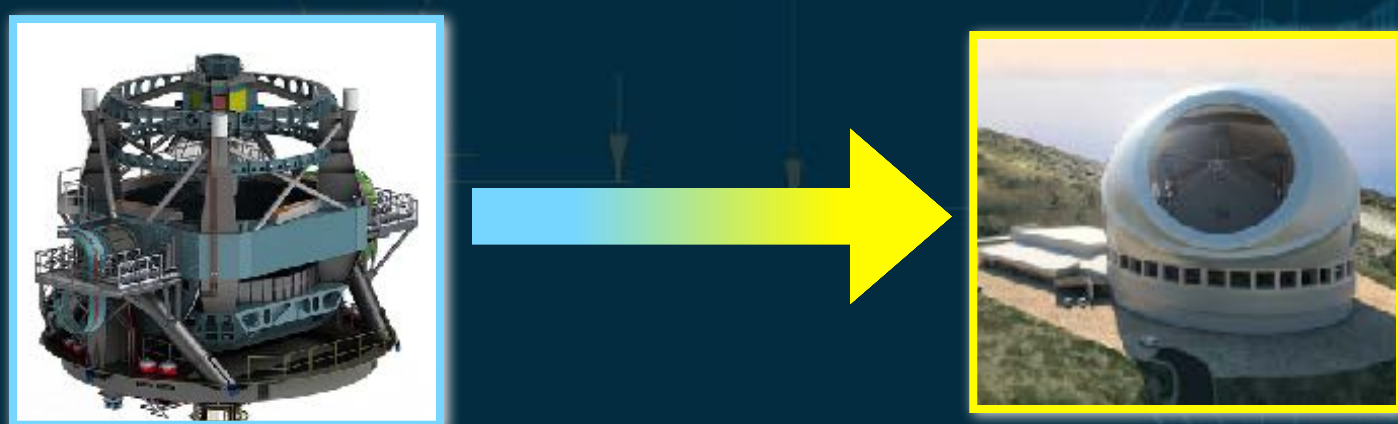

LSST finds a source.
This source is very interesting! E.g., new, blue, $\sim$16 Mpc, a rapid rise – but still faint.
TMT should get a WFOS spectrum.

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The TMT astronomer might use the LSST Science Platform to:

- cross-match the coordinates to the latest Data Release object catalog
- review the variability characterization parameters of the matched object(s)
- perform further analysis, e.g., upload TMT imaging and co-register to LSST image for more accurate deblending and source measurements

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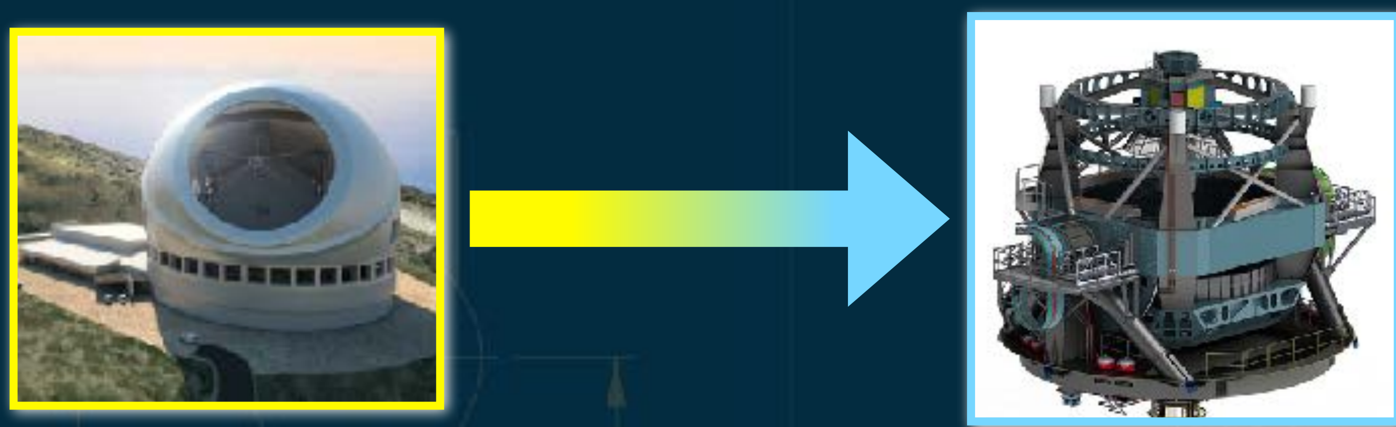

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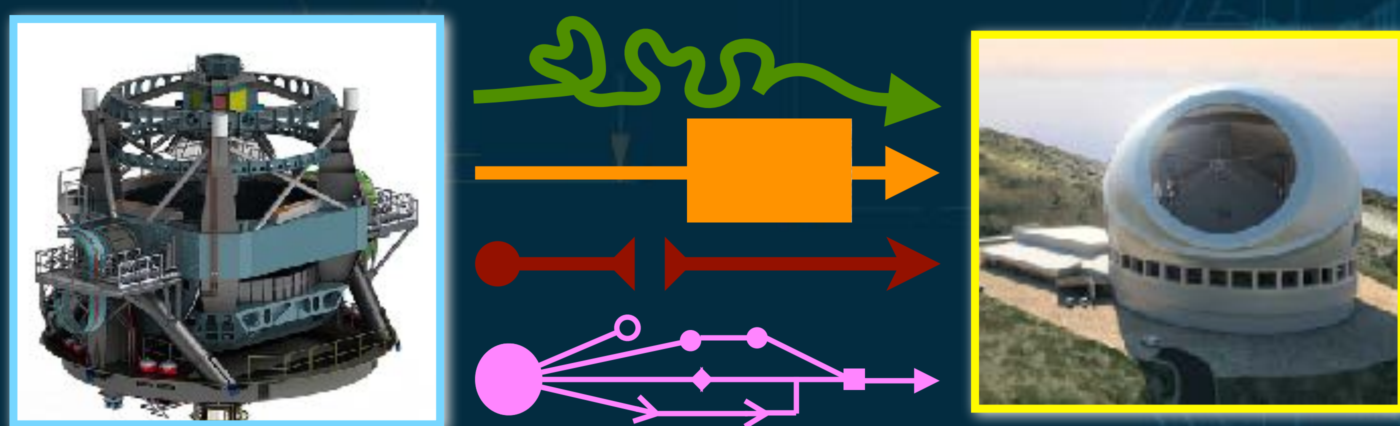

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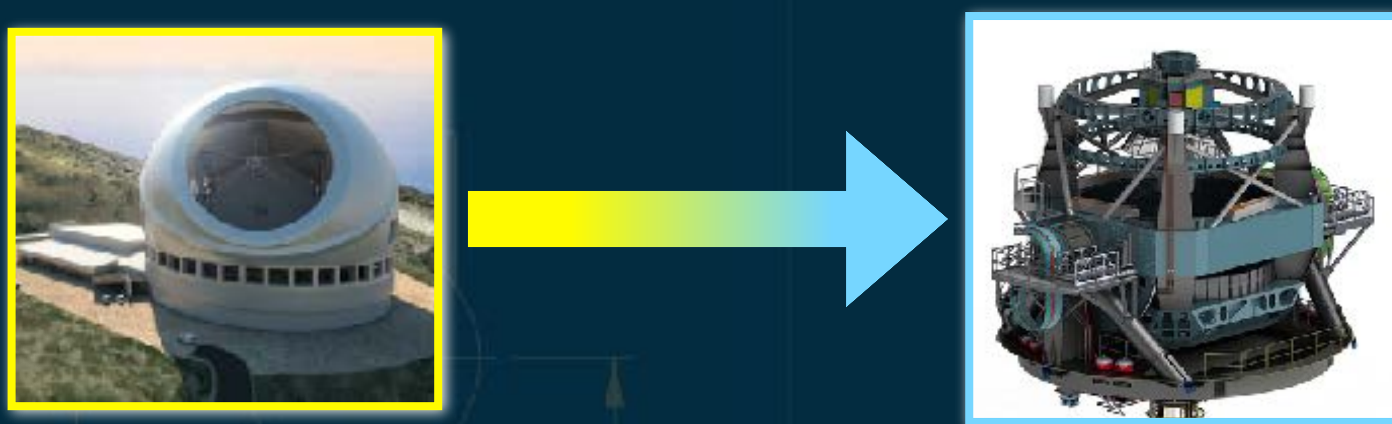
This process cannot be represented with a smooth and straightforward arrow, as it's comprised of:

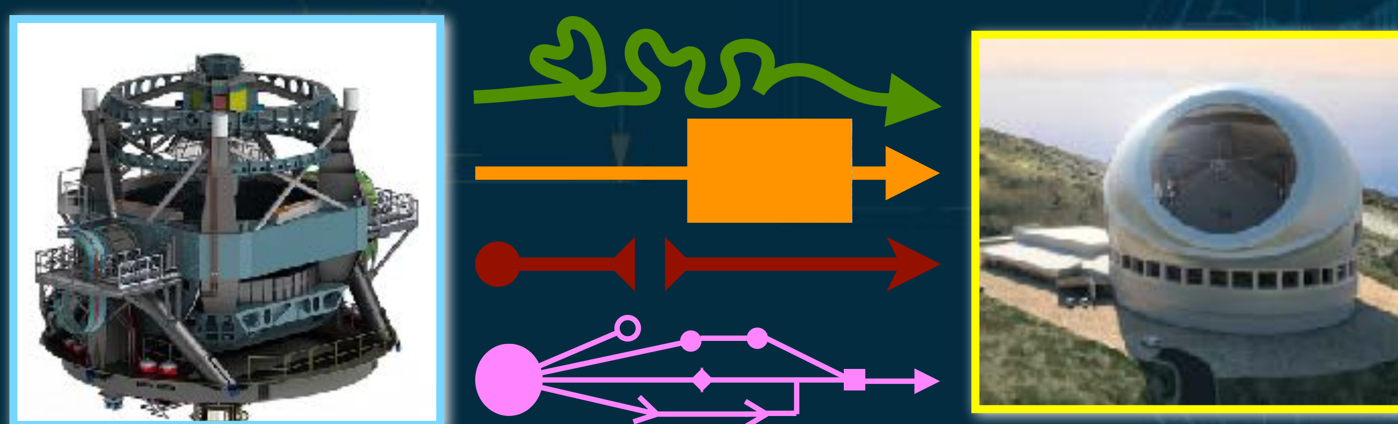
- Alert Brokers (e.g., Machine Learning)
- Human Review and Action
- Third-party Follow-Up Data

TMT-LSST Synergy: Practical Scenarios

Consider the following two basic scenarios for time-domain science.



TMT user finds an interesting NIR source.
What are its optical parameters?
Does it have a history of variability?
Check what LSST knows about it.



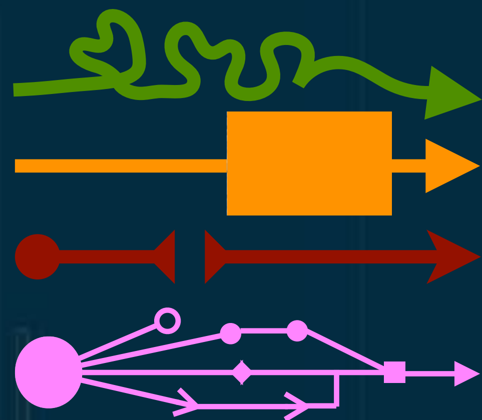
LSST finds a source.
This source is very interesting! E.g., new, blue, ~16 Mpc, a rapid rise – but still faint.
TMT should get a WFOS spectrum.

This process cannot be represented with a smooth and straightforward arrow, as it's comprised of:

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

Preparations for facilitating this process are underway.

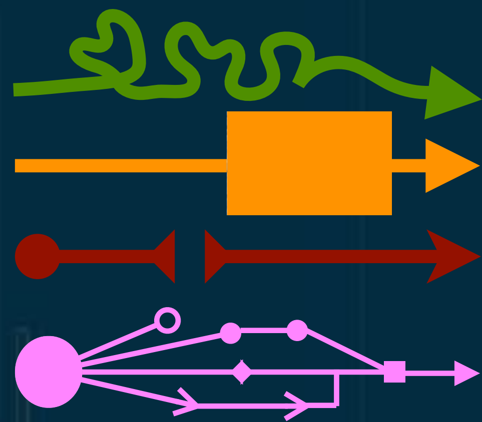
TMT-LSST Synergy: Building Infrastructure



"Interestingness" is not an LSST product.

How is the community working towards maximizing science from TMT + LSST, especially rapid target-of-opportunity?

TMT-LSST Synergy: Building Infrastructure

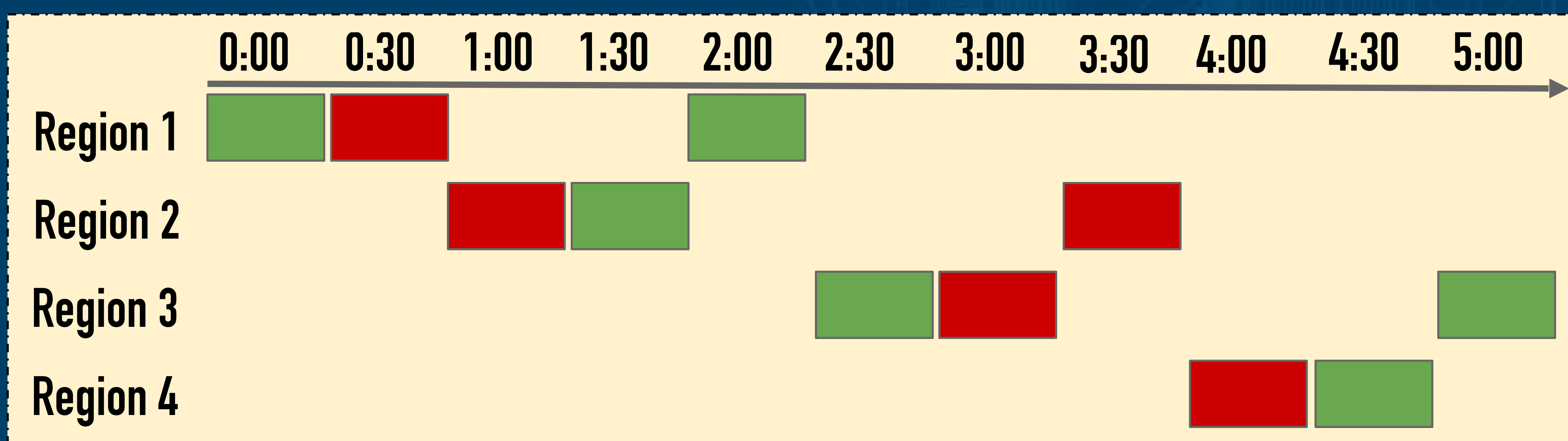


(1) LSST Cadence Optimization

Ensure that LSST's observing strategy will find many "interesting" events.

Metric Analysis Framework (MAF) software for evaluating Operations Simulations (OpSim) of different observing strategies.

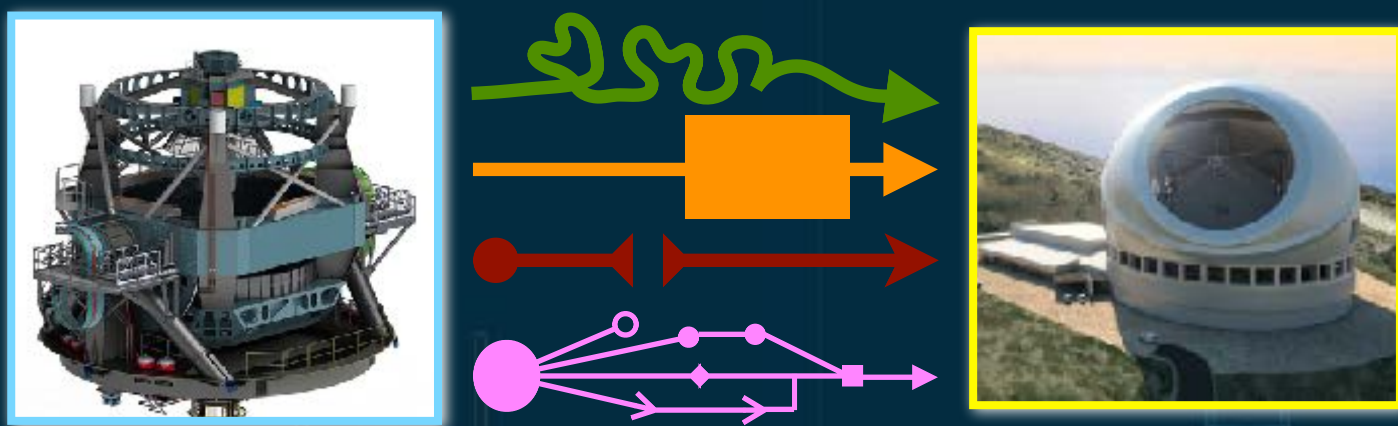
For fast transients we proposed the "*Presto-Color*" cadence to obtain color (2 filters in <Δt1) and lightcurve slope (repeat filter <Δt2).



Initiative by the LSST Transients and Variable Stars Science Collaboration

Bianco +18

TMT-LSST Synergy: Building Infrastructure



(1) LSST Cadence Optimization
(2) Alert Broker Development

Build broker software* to use the alert stream.

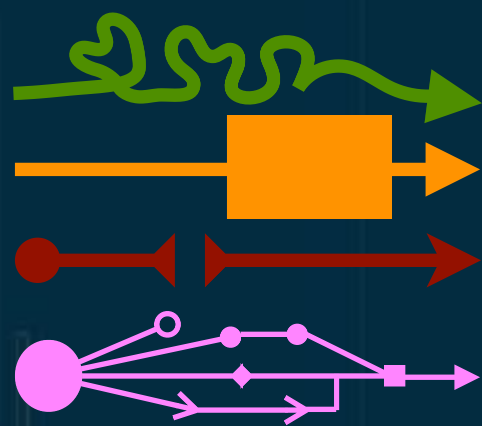
Proposed Criteria for Selected Brokers
- facilitate full scientific exploitation of alerts
- redistribute, filter, cross-match, classify
- provide user interfaces to world community
- trigger/coordinate/integrate follow-up
- demonstrated technical/personnel resources

Proposed Timeline
2019: Letters of Intent
2020: Broker Proposals
2021: Commissioning
2022: Operations
(>2022, periodic review)

Several Brokers in development are currently running/testing on the ZTF Alert Stream.

*brokers, 'downstream' brokers, or software subsystems in partnership with brokers

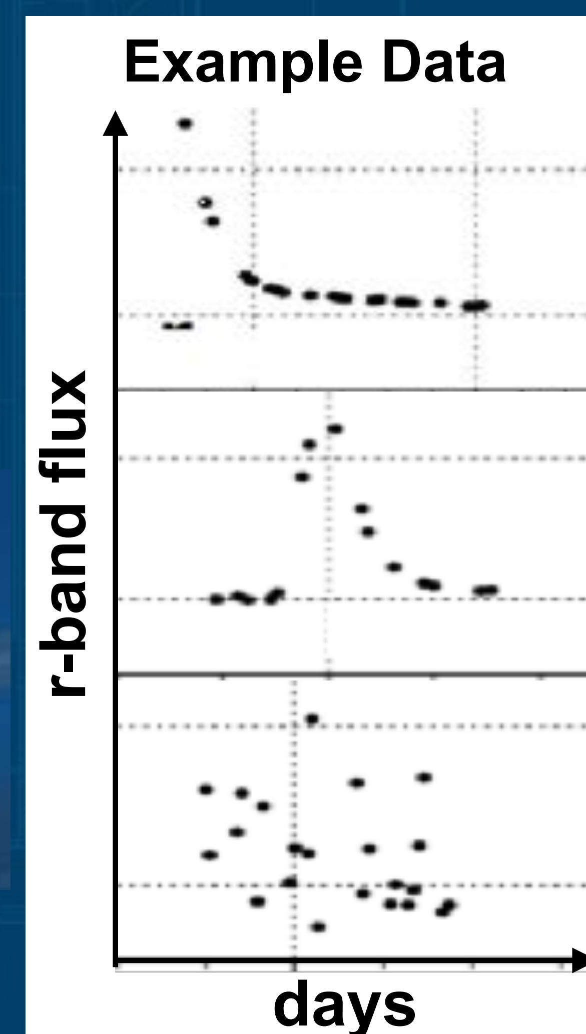
TMT-LSST Synergy: Building Infrastructure



(1) LSST Cadence Optimization
(2) Alert Broker Development
(3) Photometric Classifications

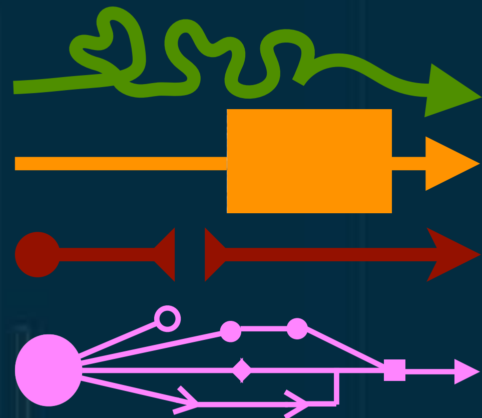
Ensure that brokers can identify many "interesting" events, and quickly.

Light curve classification software via template fits and/or machine learning, which can run in a broker.



The PLAsTiCC Team 2018, arXiv:1810.00001

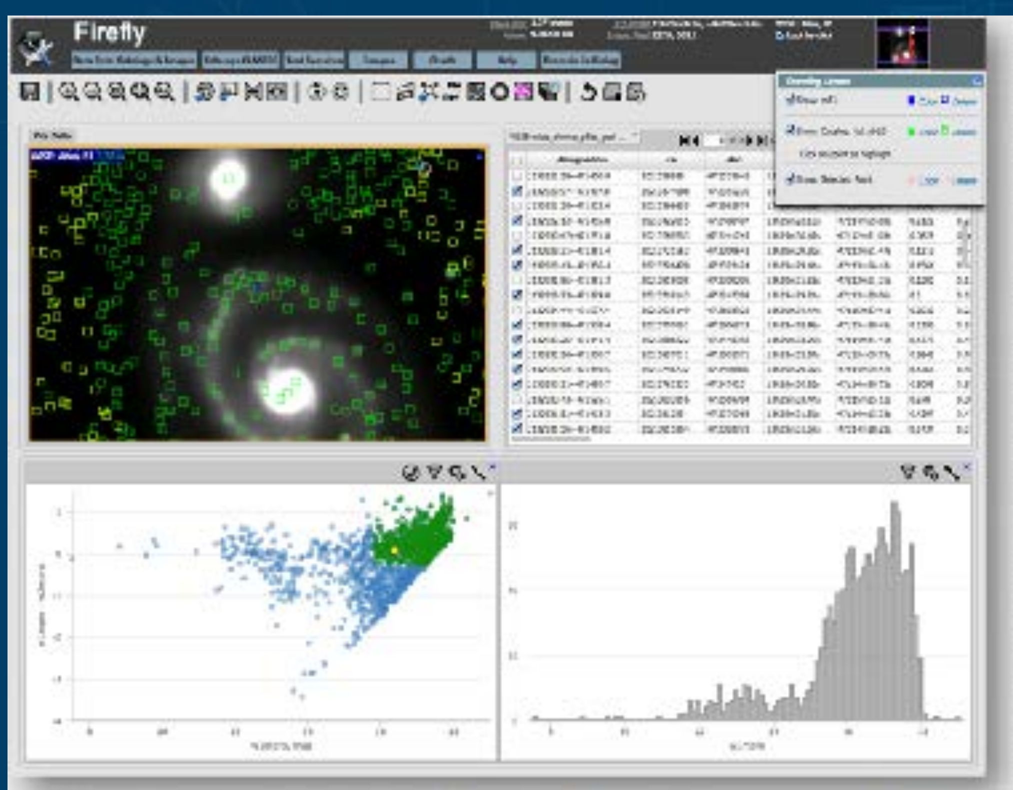
TMT-LSST Synergy: Building Infrastructure



(1) LSST Cadence Optimization
(2) Alert Broker Development
(3) Photometric Classifications
(4) LSST Science Platform Tutorials

Prepare to use the LSST Science Pipelines in a Jupyter Lab Environment.

Science Collaborations "Stack Club": user-generated tutorials



The Firefly Web Science User Interface (Wu et al, 2016; ADASS)

Learn to, e.g., query catalogs, process images to identify samples for TMT follow-up:
- faint, slow-evolving transients
- rich samples of static-sky objects

"The Stack", a common term for the LSST science pipelines, will be available in the Science Platform.

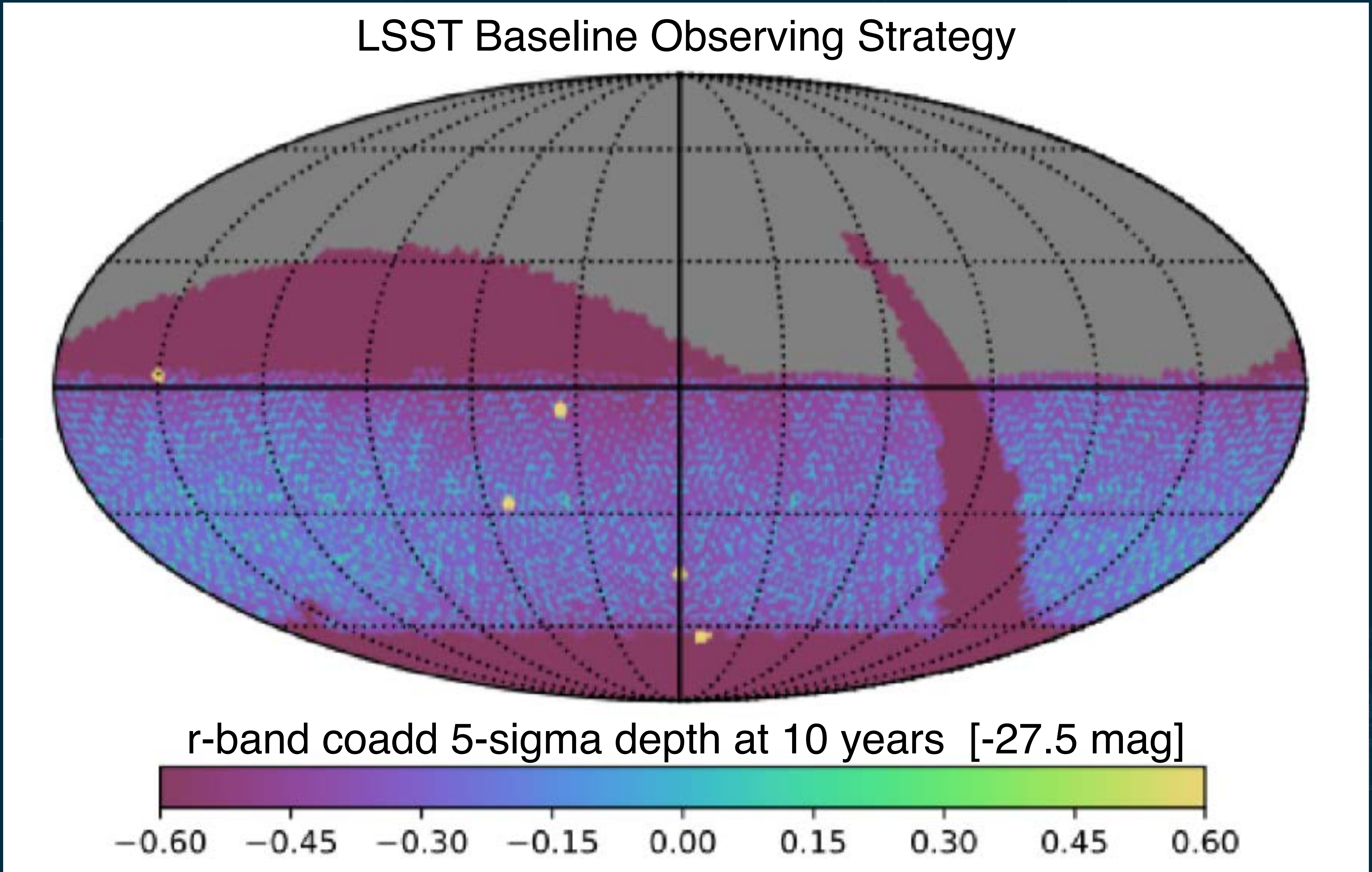
TMT-LSST Synergies: Compare the “Big Three”

TMT vs. GMT vs. E-ELT — Rapid ToO Follow-up of LSST Detections

http://astro-lsst-01.astro.washington.edu:8080/

TMT-LSST Synergies: Compare the "Big Three"

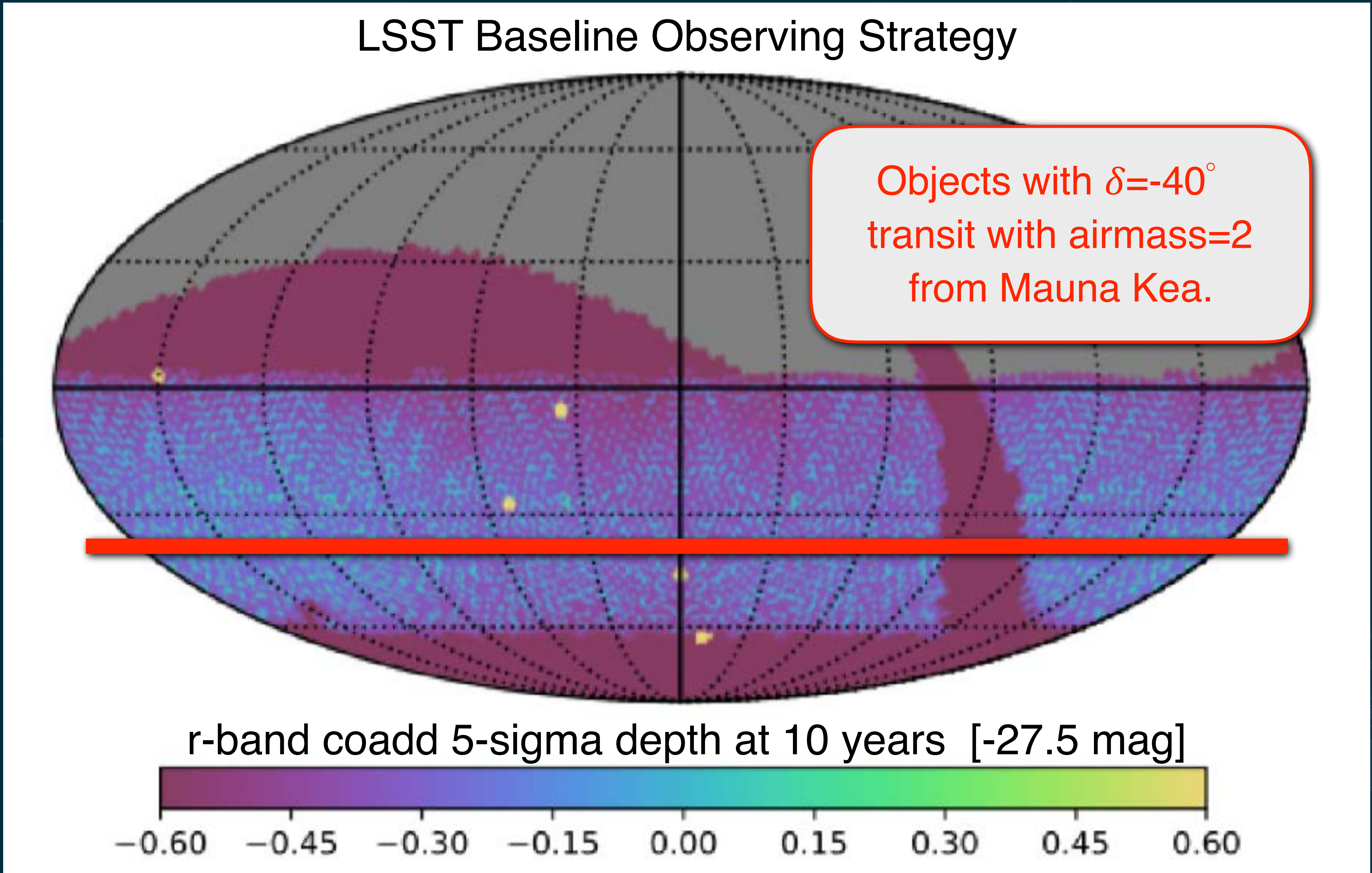
TMT vs. GMT vs. E-ELT — Rapid ToO Follow-up of LSST Detections



http://astro-lsst-01.astro.washington.edu:8080/

TMT-LSST Synergies: Compare the "Big Three"

TMT vs. GMT vs. E-ELT — Rapid ToO Follow-up of LSST Detections



http://astro-lsst-01.astro.washington.edu:8080/

TMT-LSST Synergies: Compare the "Big Three"

TMT vs. GMT vs. E-ELT — Rapid ToO Follow-up of LSST Detections

	TMT	GMT	E-ELT
ToO Proposals Accepted	yes	yes	yes
Automatic Triggering	expected	likely (when in queue mode)	
Instruments Deployed	all hot	some hot (those w/ <3' field, +1 w/ 3")	all hot
Rapid ToO Acquisition Time	<10 minutes (slew, instrument change, & AO)	<10 minutes (slew & instrument change)	<20 minutes (<10 min if same platform)
Optical Spectroscopy?	yes (WFOS)	yes (GMACS) (& G-CLEF high-res echelle)	yes (bluest: IFU >470 nm)
Non-sidereal guiding?	yes (up to ±10% of the sidereal rate)	yes (up to 6"/min)	yes (up to 2"/min)
Immediate auto-reduction?	quick-look	quick-look	real-time assessment

References in Extra Slides; thank you Suzanne Ramsay and Rebecca Bernstein for E-ELT/GMT information

TMT-LSST Synergies: Compare the "Big Three"

TMT vs. GMT vs. E-ELT — Rapid ToO Follow-up of LSST Detections

now 2020 2022 2024 2026 2028 2030 2032 2034

LSST Construction

LSST Operations
10 Year Main Survey

LSST
?

TMT M1 1st Light

TMT
Science Operations

GMT
First Light Target 2024

E-ELT
First Light Target Nov 2024 at earliest

Thank you very much!

Questions Welcome

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

https://doi.org/10.5281/zenodo.2209001

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

Extra Slides

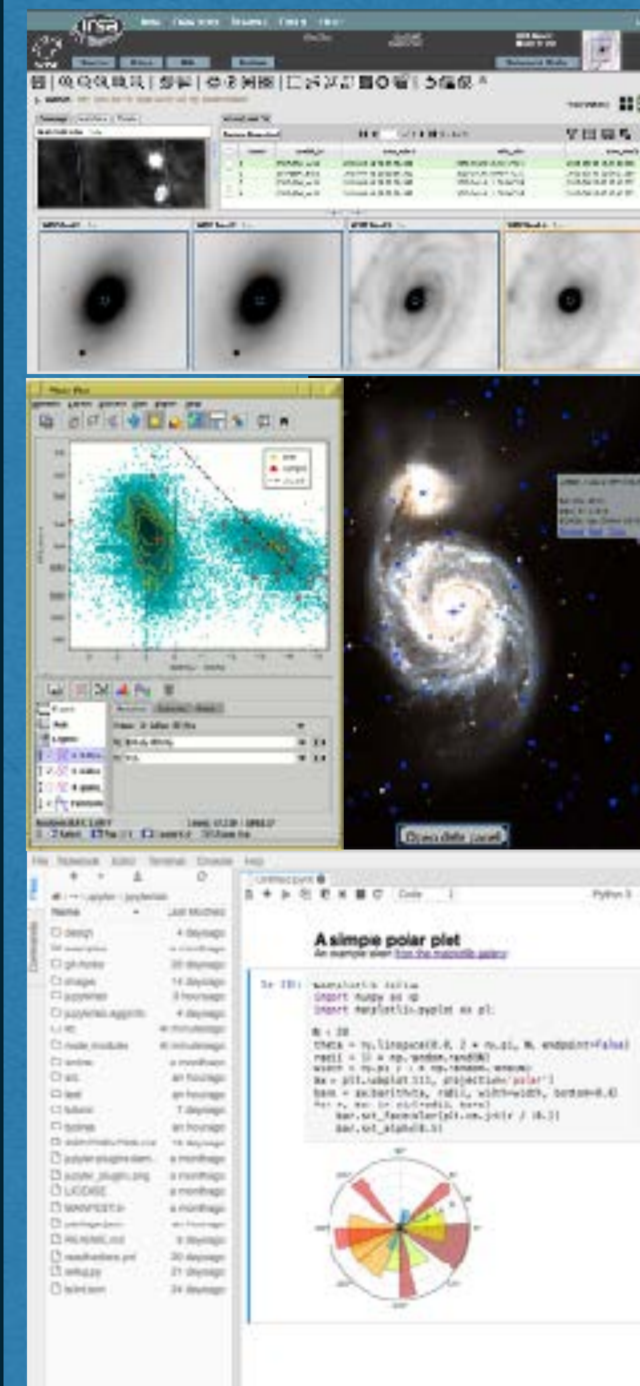
LSST: Data Management Pipelines & Data Products

How will LSST Data Products be accessed by individuals who have LSST data rights?

- 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
- computational resources for user processing*
- storage space for User Generated data products
- “mini-broker” for real-time Alert filtering

*Ballpark forecast: by DR11 up to ~8k cores / ~150 TFLOPS reserved for user processing.

User-facing tools will look familiar.



Science Platform Design: ls.st/ldm-542

Science Platform Vision Document: ls.st/lse-319

LSST: No Mo' FoMO*

What can individuals without data rights/access do?

(1) Build infrastructure* to use the Alerts (and/or the moving objects via MPC).

*brokers, 'downstream' brokers, or software subsystems in partnership with brokers

Proposed Criteria for Selected Brokers

- facilitate full scientific exploitation of Alerts
- redistribute, filter, cross-match, classify
- provide user interfaces to world community
- trigger/coordinate/integrate follow-up
- demonstrated technical/personnel resources

Proposed Timeline

2019: Letters of Intent
2020: Broker Proposals
2021: Commissioning
2022: Operations
(>2022, periodic review)

(2) Pay "shipping" for delivery of post-proprietary data, and serve it.

Final image collection, processed data and calibrations (DR11): 500 Petabytes
A single deep stack of the WFD area: ~100 TB** (x6 filters = 600 TB)
Final full catalogs are ~2 Petabytes (DR1) to ~15 Petabytes (DR11)
Catalog Lite*** could be ~75 Terabytes

**a conservatively large (25000 sq. deg.) 2600 fields x3.2 Gpix/field x12 bytes/pixel = 100 TB
***does not include, for example, the full posteriors for the bulge+disk likelihood parameters

*Fear of Missing Out

https://www.lsst.org/scientists/keynumbers

References for TMT Time-Domain Features (Slide 33)

TMT Observatory Architecture Document

https://www.tmt.org/download/Document/29/original

ToO Acquisition with Instrument Change – The TMT requirement for telescope preset is 10 minutes maximum. This includes telescope slewing, target acquisition and AO and instrument configurations, up to the beginning of science observations. https://www.tmt.org/page/observing-modes#observing-modes-archivesandpipelines

Slew time calculations – all of these times are "including smooth ramping profiles and settling time".
Pg. 80, 4.2.3.6.1 Telescope Azimuth Axis Slewing: maximum 2.5 deg/s, accel/decel 0.13 deg/s2
–>accel/decel to/from 2.5deg/s takes: (2.5/0.13=) 19.2s or (0.5*0.13*19.2**2=) 23.96 deg
–>the remaining 42.1deg will take (42.1/2.5=) 16.8s, so the total azimuthal slew for 90 deg is 55.2s
Pg. 80, 4.2.3.6.2 Telescope Elevation Axis Slewing: maximum 2.0 deg/s, accecl/decel 0.1 deg/s2
–>accel/decel to/from 2.5deg/s takes: (2.0/0.1=) 20.0s or (0.5*0.1*20**2=) 20 deg
–>the remaining 50deg will take (50/2=) 25s, so the total elevation slew for 90 deg is 65s
Pg. 4.5.1.3 Enclosure Base Axis Slewing: maximum 1.25 deg/s, accel/decel 0.25deg/s2
–>accel/decel to/from 1.25deg/s takes: (1.25/0.25=) 5s or (0.5*0.25*5**2=) 3 deg
–>the remaining 84deg will take (84/1.25=) 67.2s, so the total base axis slew for 90 deg is 77.2s
Pg. 4.5.1.3.2 Enclosure Cap Axis Slewing: maximum 1.75 deg/s, accel/decel 0.15deg/s2
–>accel/decel to/from 1.75deg/s takes: (1.75/0.15=) 11.7s or (0.5*0.15*11.7**2=) 10.3 deg
–>the remaining 69.4deg will take (69.4/1.75=) 39.7s, so the total base axis slew for 90 deg is 63.1s

Fraction of ToO Acquisition from:
Scheduler Interrupt –
Instrument Change –

Non-sideral guiding – [REQ-1-OAD-8050] The telescope control system (TCS) shall control NGS WFS probe positioning in coordination with the mount to perform non-sidereal tracking, dithering, and differential refraction compensation.
"The observatory has a top level requirement to support observations of targets moving at up to ±10% of the sidereal rate." https://www.tmt.org/page/observing-modes#observing-modes-archivesandpipelines

Immediate Auto-reduction – "quick-look data will be provided by the observatory to help with real-time decision and data quality assessment"
https://www.tmt.org/page/observing-modes#observing-modes-archivesandpipelines

WFOS imaging/spectroscopy spatial resolution 0.2"
[REQ-1-OAD-3326] WFOS, in Imaging Mode, shall have an image quality ≤ 0.2 arcsec FWHM
[REQ-1-OAD-3328] WFOS, in Spectroscopy Mode, shall have an image quality ≤ 0.2 arcsec FWHM at every wavelength

TMT Timeline: https://www.tmt.org/page/timeline

References for GMT Time-Domain Features (Slide 33)

GMT Observatory Requirements Document

https://www.gmto.org/wp-content/uploads/web-GMT-REQ-03214_Rev.-B_GMT-Observatory-Requirements-Document-ORD.pdf

REQ-L2-ORD-25111 : Time to Start an Exposure — The GMT Observatory shall be able to start a science exposure on a new target with any deployed instrument in less than 600 seconds from the initiation of slew.
Rationale: From REQ-L1-SCI-23092, -23226, and -23288.
Note: The start of the 600 second time is the initiation of a slew to the target, and the end is the start of a science observation. This requirement is more stringent than required by REQ-L1-SCI-23226 and REQL1-SCI-23288. This includes the time to slew, image the field, identify the science target, and center the science target appropriately within the instrument field of view. It also includes setting up the instrument for the required observation. It only applies to deployed instruments; those that do not need to be moved into position to receive the optical beam from the telescope and are in an operational state

REQ-L2-ORD-25094 : Non-Sidereal Guiding
The GMT Observatory shall guide on targets moving at any non-sidereal rates up to 6 arcsec/min while meeting all image quality requirements, with no more than an additional 0.1 * PSF image elongation.

References for E-ELT Time-Domain Features (Slide 33)

E-ELT Top-Level Requirements
https://www.eso.org/sci/facilities/eelt/docs/ESO-193696_2_Observatory_Top_Level_Requirements.pdf

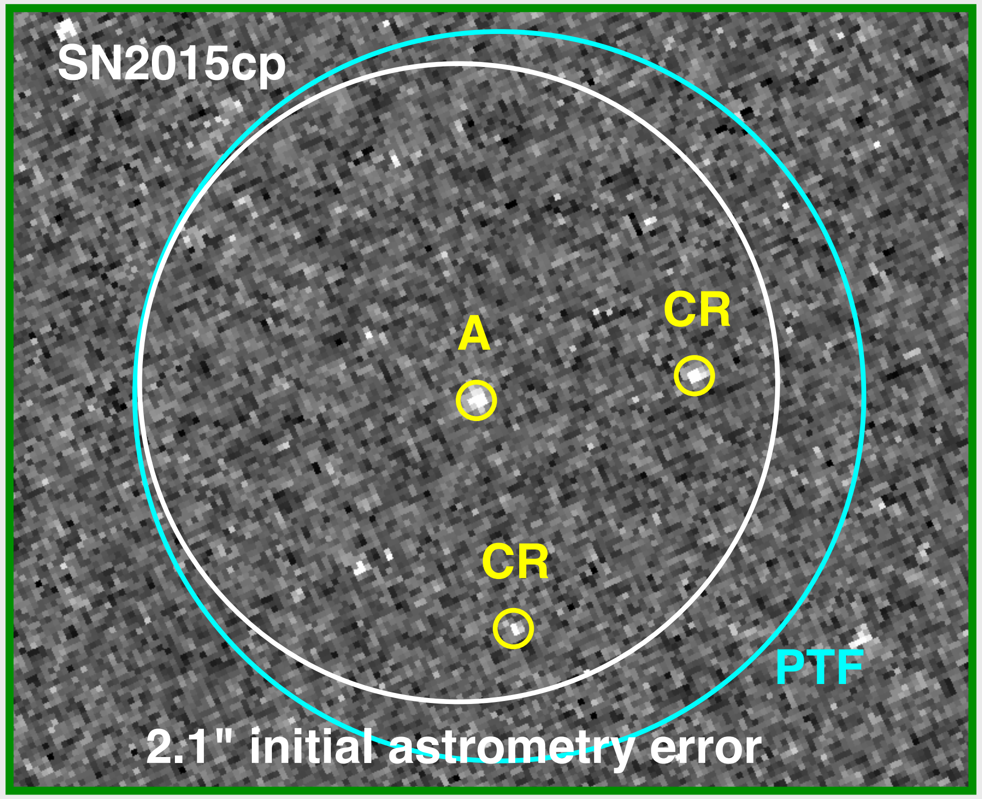
ToO? Yes b/c ESO generally accepts: https://www.eso.org/sci/observing/policies/too_policy.html

Optical Spectroscopy? Both ELT-CAM and ELT-IFU are NIR, lowest wavelength 5000 A
https://www.eso.org/sci/facilities/eelt/docs/ESO-193104_2_Top_Level_Requirements_for_ELT-CAM.pdf
https://www.eso.org/sci/facilities/eelt/docs/ESO-191883_2_Top_Level_Requirements_for_ELT-IFU.pdf

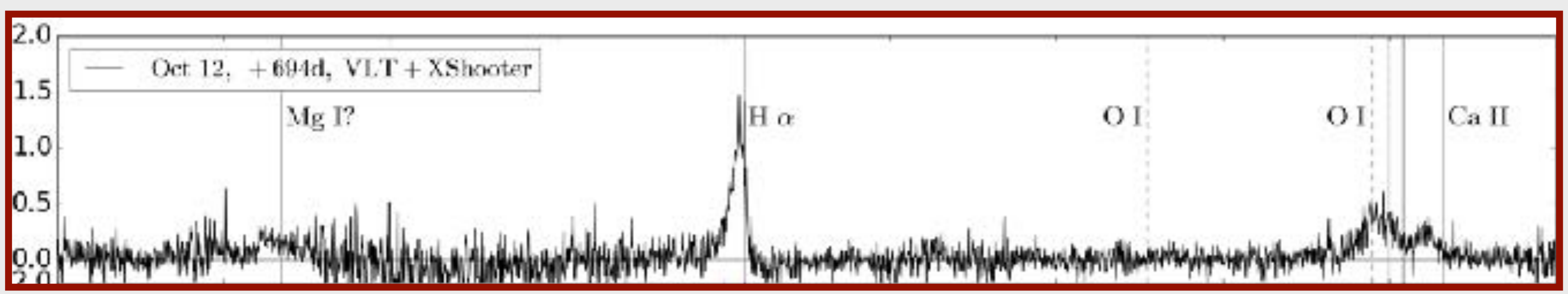
Non-sidereal guiding: yes and <33"/minute from Section 6.9 of the Observatory Top-Level Requirements
https://www.eso.org/sci/facilities/eelt/docs/ESO-193696_2_Observatory_Top_Level_Requirements.pdf

LSST-TMT Synergies

Delayed Circumstellar Interaction for Type Ia SN2015cp Revealed by an HST Ultraviolet Imaging Survey



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



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

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

Graham et al. (2018; accepted)

LSST: Data Management

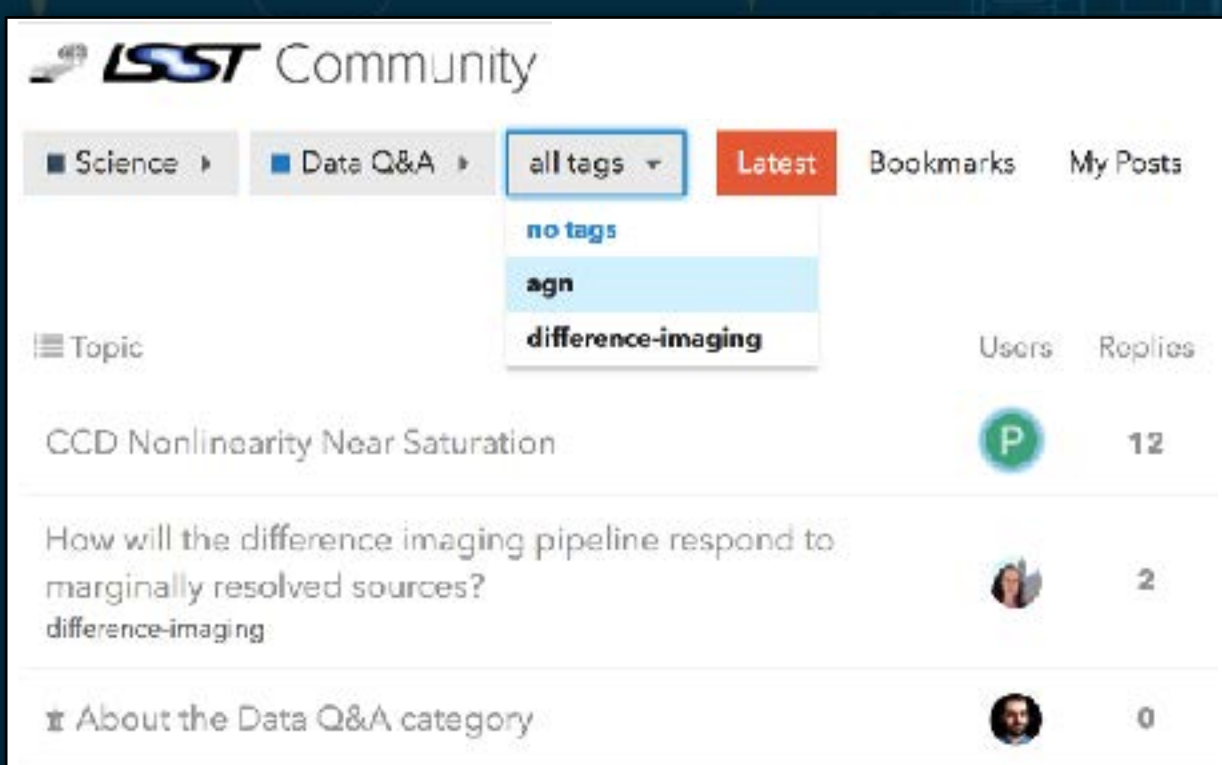
Data Management — System Science Team

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.



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.*

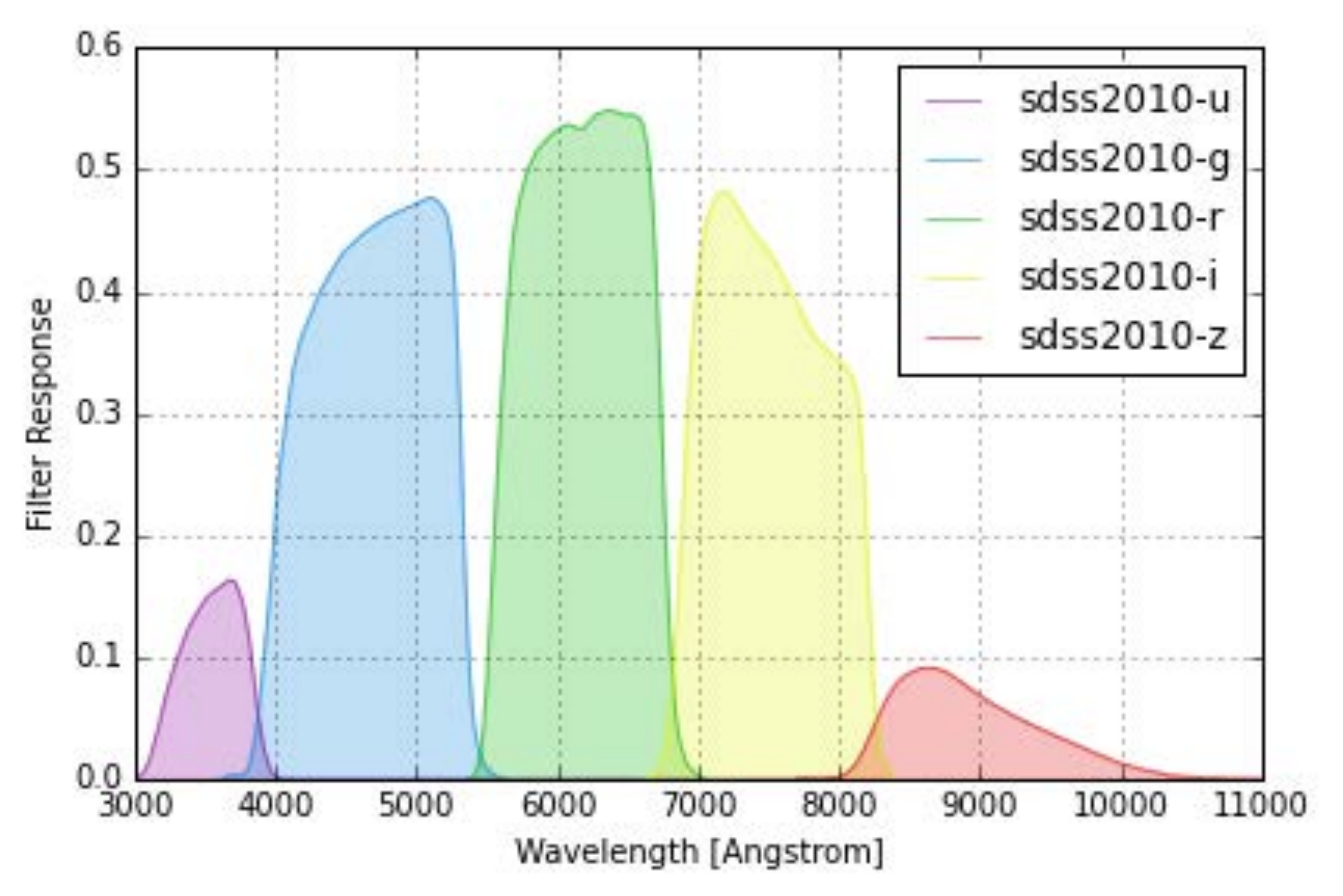
Two anticipated synergy questions.

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.

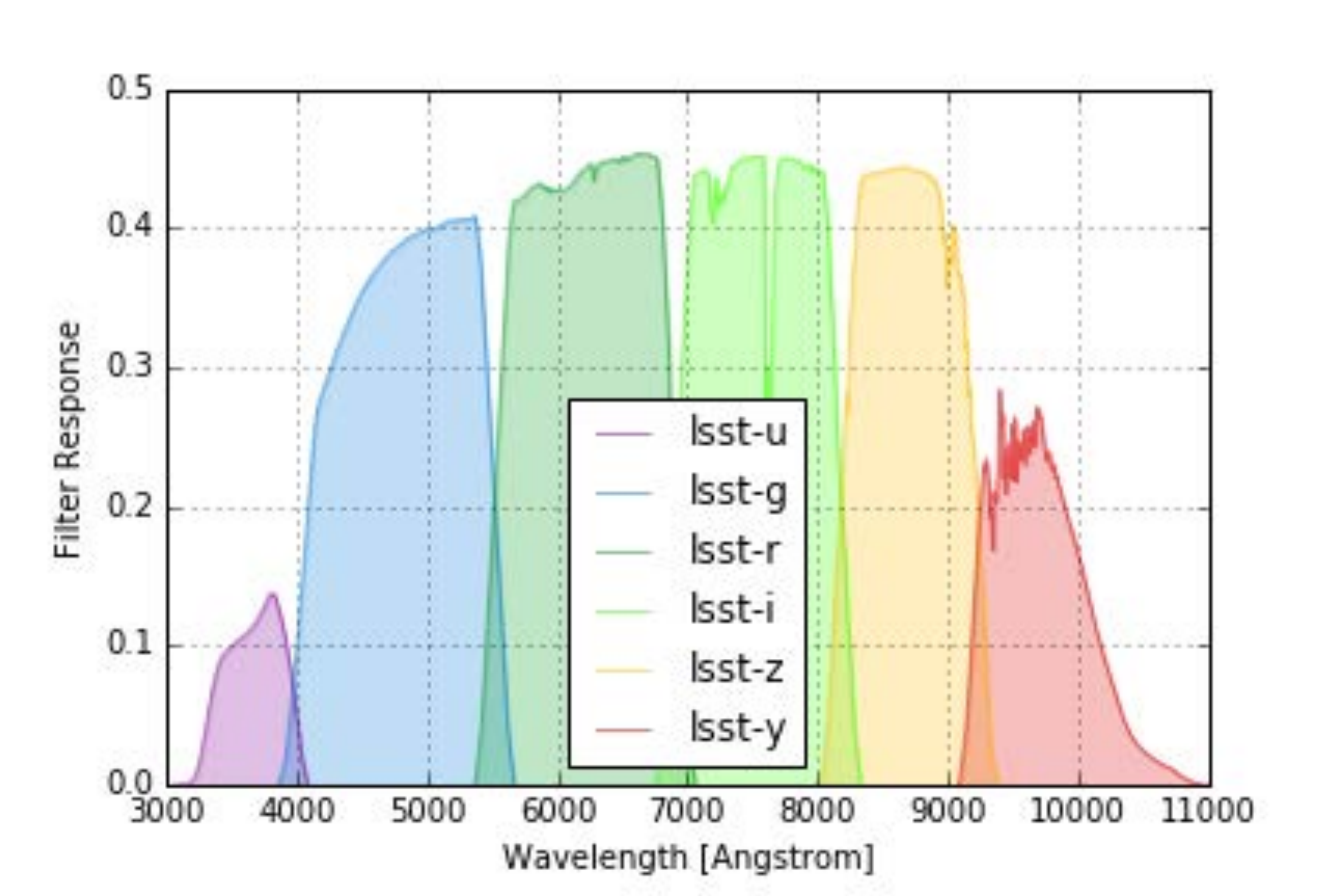
2) How could automated 'shadow' surveys that image LSST fields on the same night, with some Δt, be designed to work?
*It is a requirement that "the scheduling of the observing sequence lasting at least 2 hours shall be published in advance of each observing visit", and part of the design that "…the next 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

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

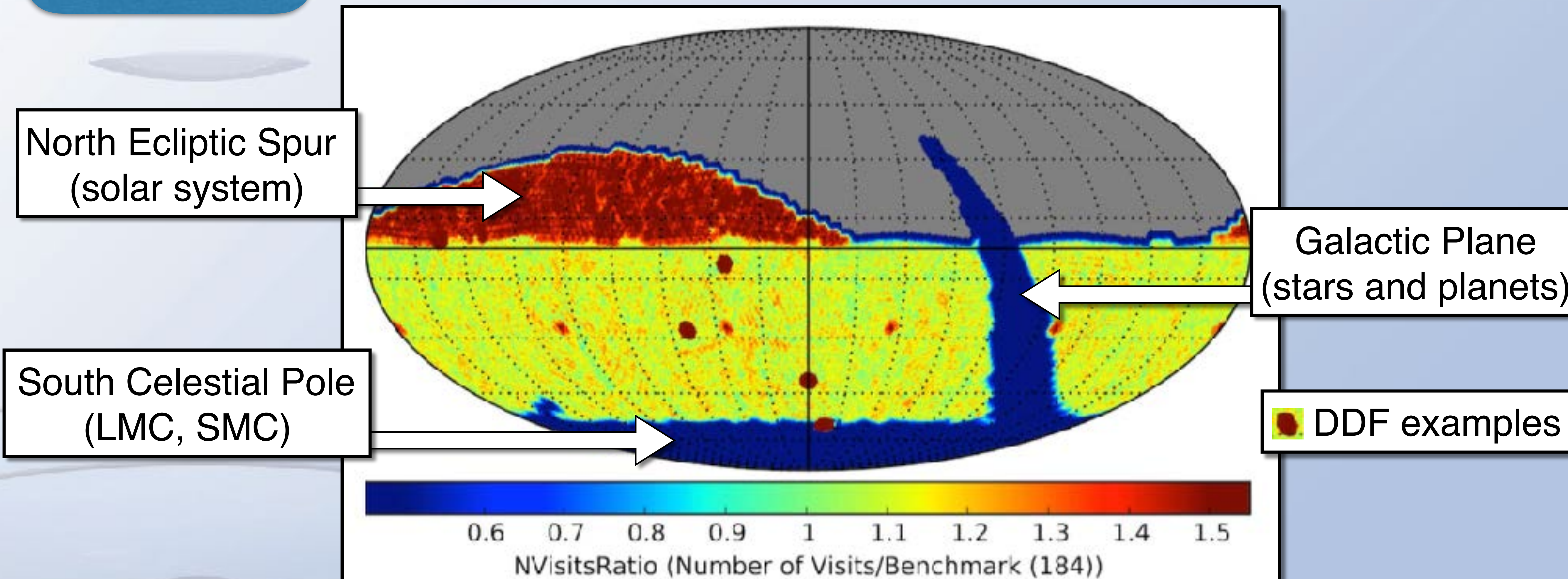
MS
Mini-Survey

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.



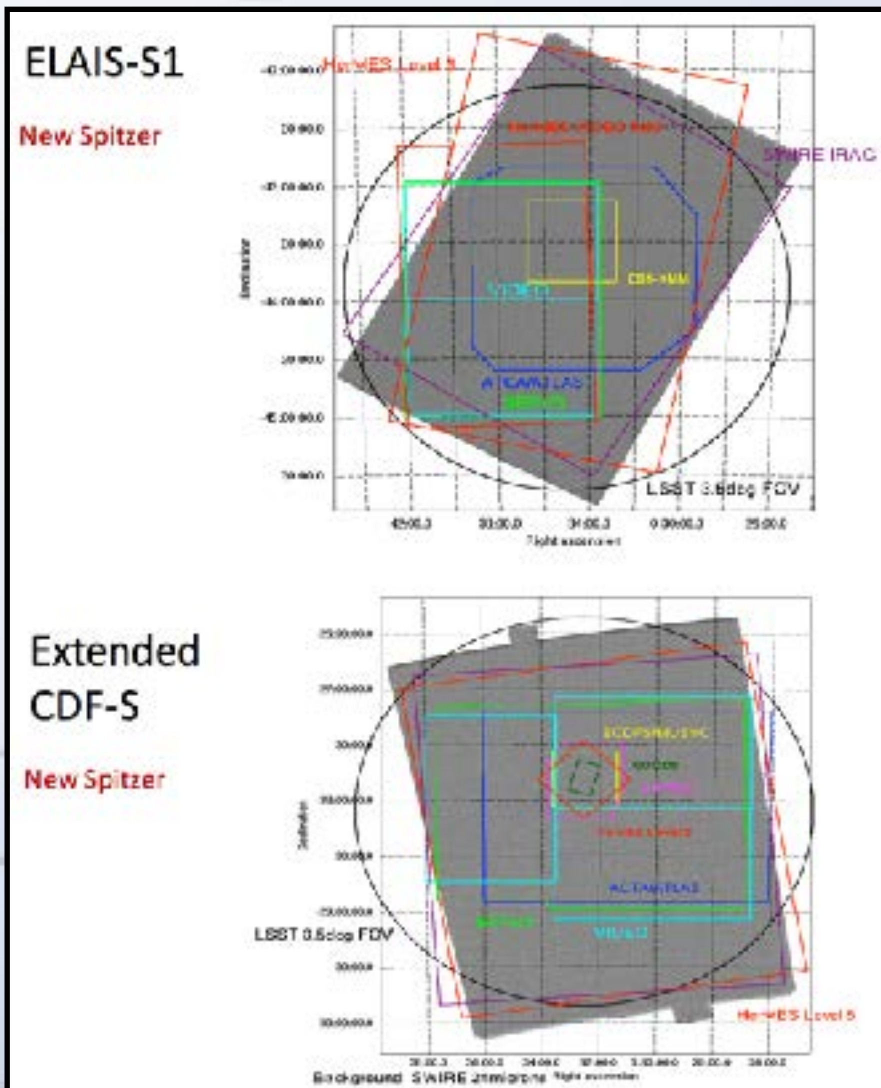
Ivezić et al. (2008), Figure 18.

LSST Special Programs

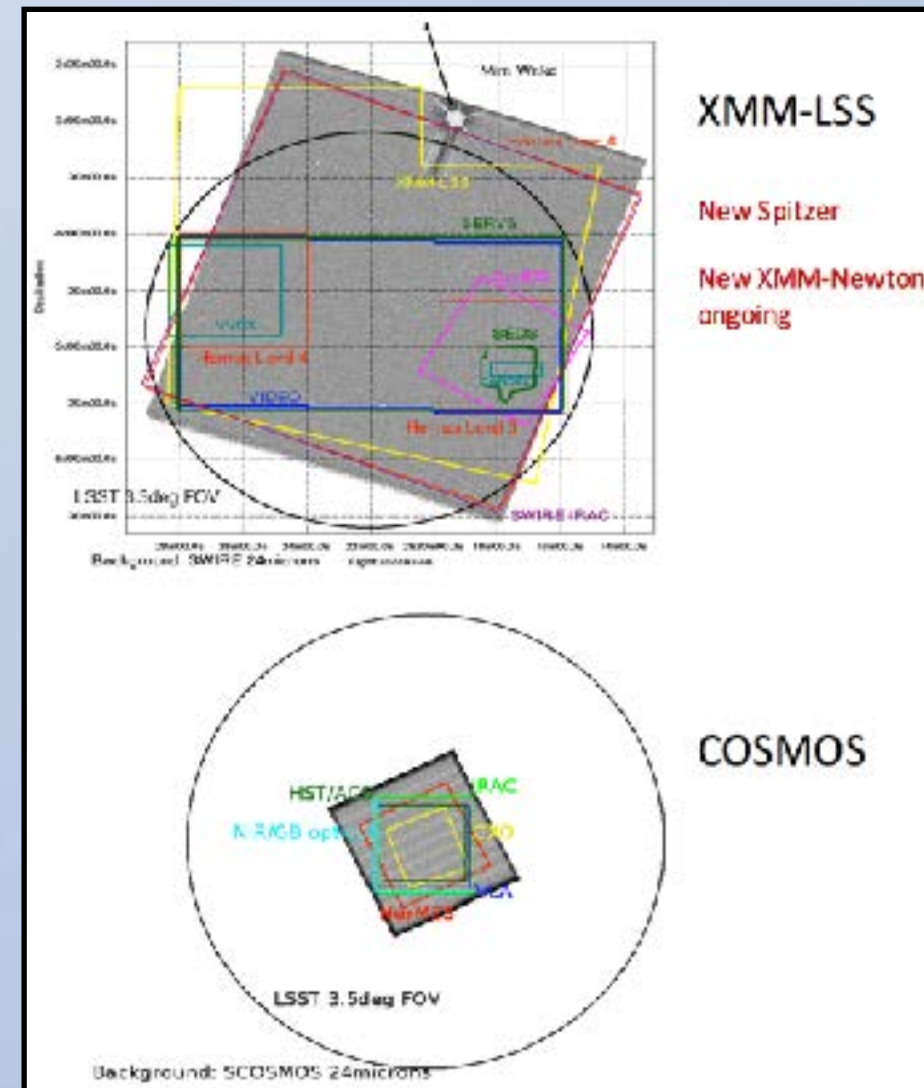
Nominal DDF Observing Strategy:
Ivezić et al. (2008) describes a nominal DDF data set as, e.g.: ~50 x 15s exposures in *griz*, every two nights for four months.

single image limit r<24.5
nightly stack limit r<26.5
full stack limit r<28.0

Assuming a conservative 60% completion rate (weather) yields ~7.5 hours of DDF data, stacked with the ~1.5 hours of WFD data.



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



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

DMTN-065

June 2018
Call for white paper proposals

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

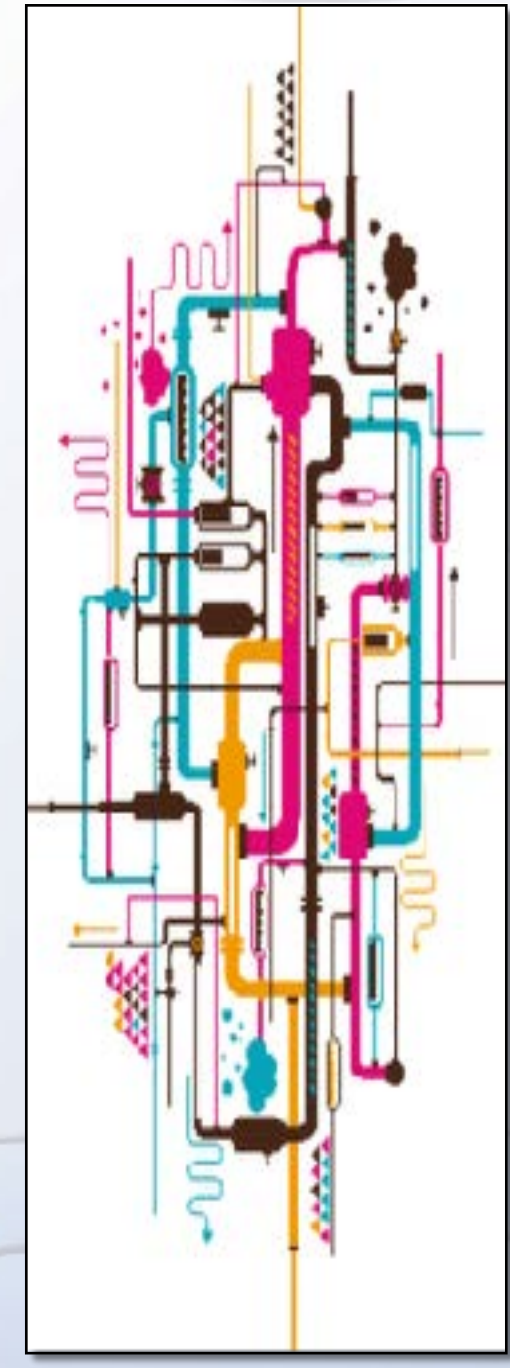
Open
- additional deep drilling fields
- refined observing strategies** for existing deep drilling fields
- optimized survey areas for the NES, South Pole, and Galactic Plane
- refined observing strategies** for the NES, South Pole, and GP
- additional mini-surveys areas and observing strategies
- refined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

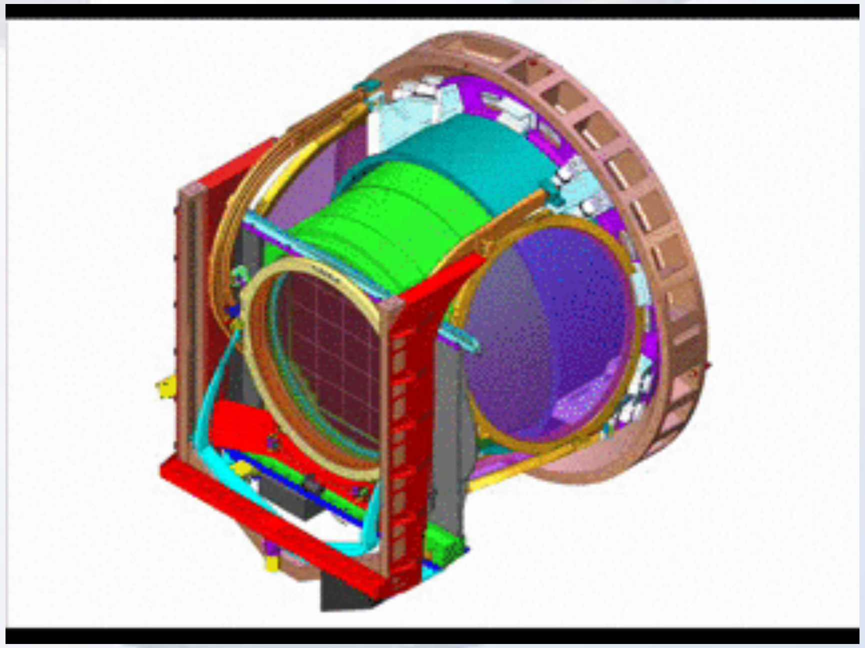
LSST Special Programs

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



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).

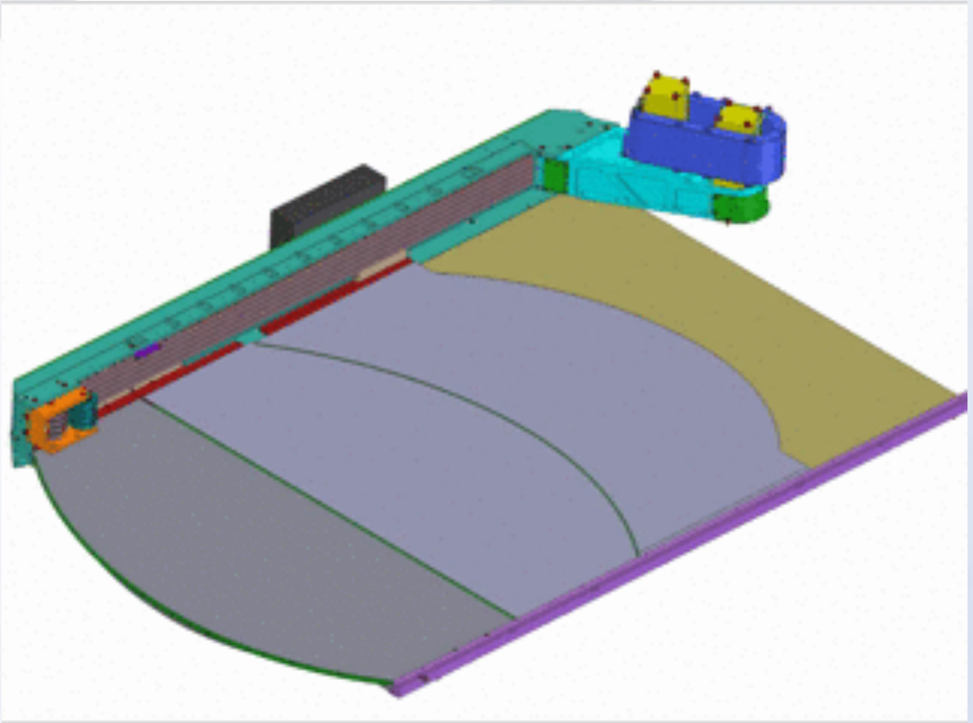
The minimum time between filter changes has no restrictions from e.g., thermal tolerances. However, based on overheads and efficiency, it is recommended to keep the filter change rate lower than once every 10 minutes.

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.