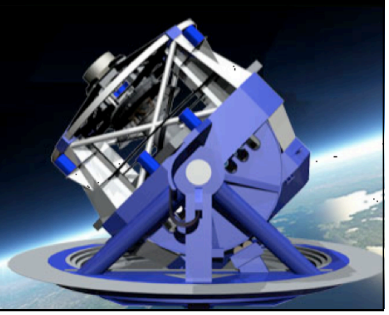
Transient Observations with LSST

Lucianne Walkowicz
UC Berkeley



on behalf of
the Transients and Variable Stars Science Collaboration

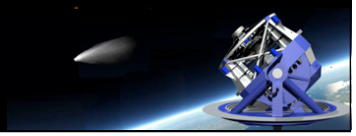
Decadal Survey Astro2010

Large Synoptic Survey Telescope ranked #1

"a treasure trove of discovery"

"The Large Synoptic Survey Telescope (LSST) would employ the most ambitious optical sky survey approach yet and would revolutionize investigations of transient phenomena. [...] The top rank of LSST is a result of its capacity to address so many of the identified science goals and its advanced state of technical readiness. "

http://sites.nationalacademies.org/bpa/BPA_049810



34 Institutional Members

Adler Planetarium
Brookhven National Laboratory
California Institute of Technology
Carnegie Mellon University
Chile
Cornell University
Drexel University
George Mason University
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Harvard-Smithsonian Center for Astrophysics
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Lawrence Livermore National Laboratory
Los Alamos National Laboratory
National Optical Astronomical Observatories
Princeton University
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Research Corporation for Scientific Advancement
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SLAC National Accelerator Laboratory
Space Telescope Science Institute
Texas A & M University
The Pennsylvania State University
University of Arizona
UC Davis
UC Irvine
University of Illinois at Urbana-Champaign
University of Michigan
University of Pennsylvania
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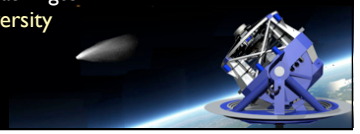
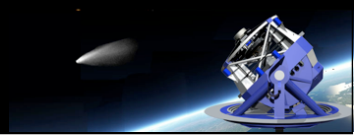


LSST Scientific Possibilities

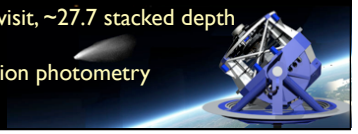
LSST Science Book:
http://www.lsst.org/lsst/science/scibook

598 pages
245 authors

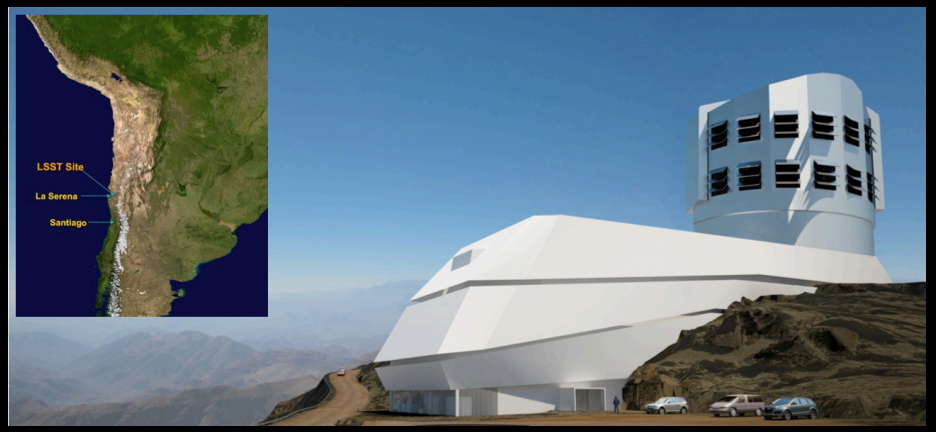


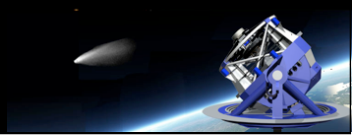
LSST Basics

8.4m mirror
9.6 sq deg FOV
20,000 deg of sky
1000 visits per field
filters: ugrizY
320 - 1035 nm
r ~24.7 in single visit, ~27.7 stacked depth
3.2 Gpix camera
~0.01 mag precision photometry

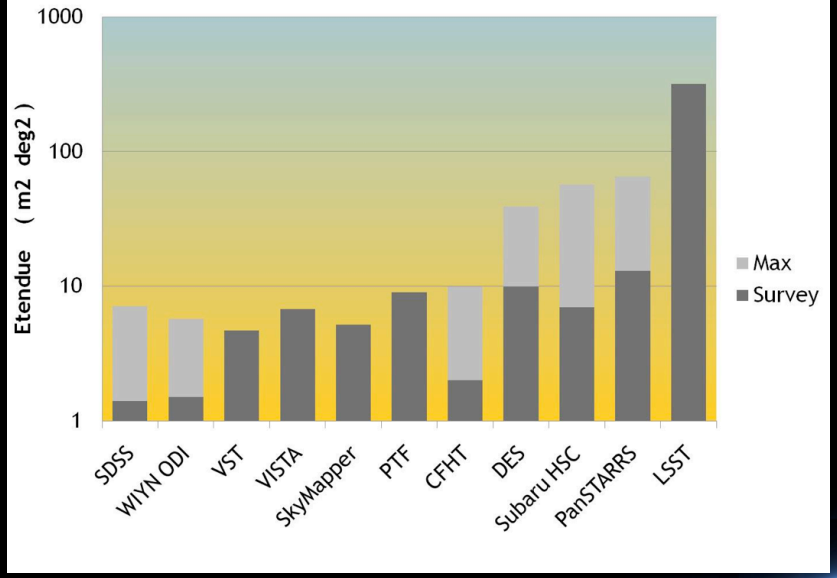


Site and base design



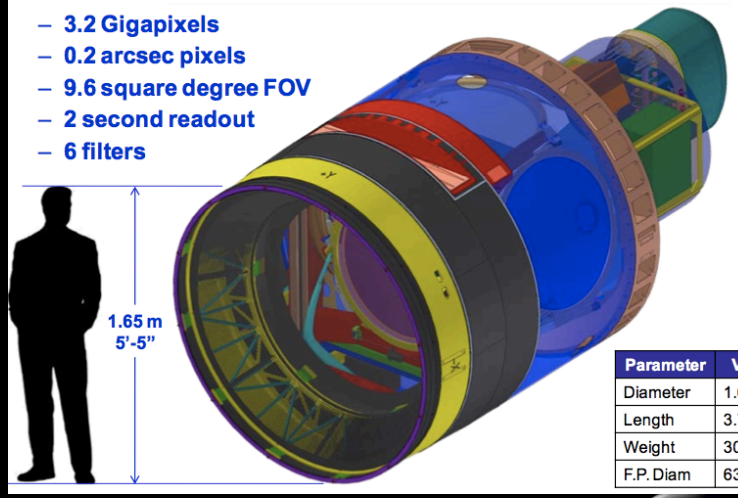


Comparison with other surveys

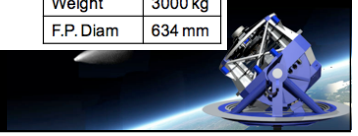


LSST Camera

- 3.2 Gigapixels
- 0.2 arcsec pixels
- 9.6 square degree FOV
- 2 second readout
- 6 filters



Parameter	Value
Diameter	1.65 m
Length	3.7 m
Weight	3000 kg
F.P. Diam	634 mm



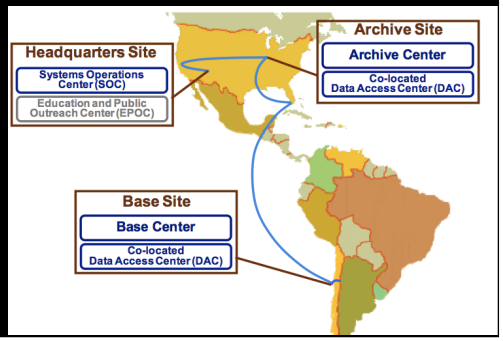
LSST Operations

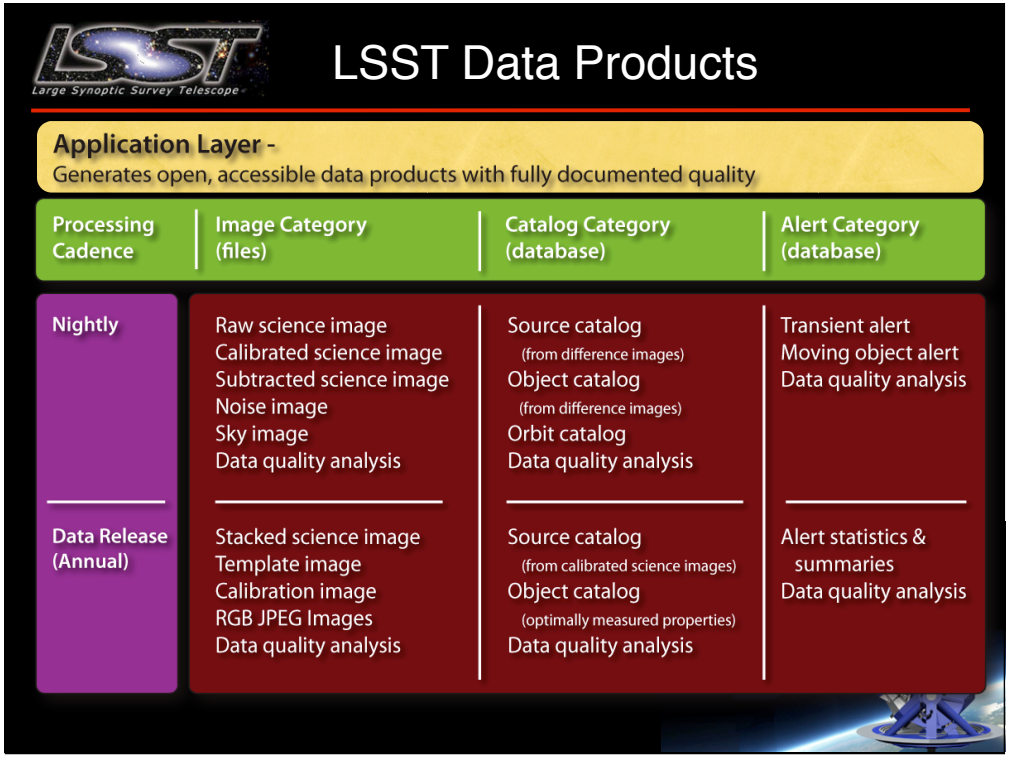
Universal Cadence: pairs of 15 sec exposures
90% of the time

Specialized Programs to improve parameter space
10% of the time

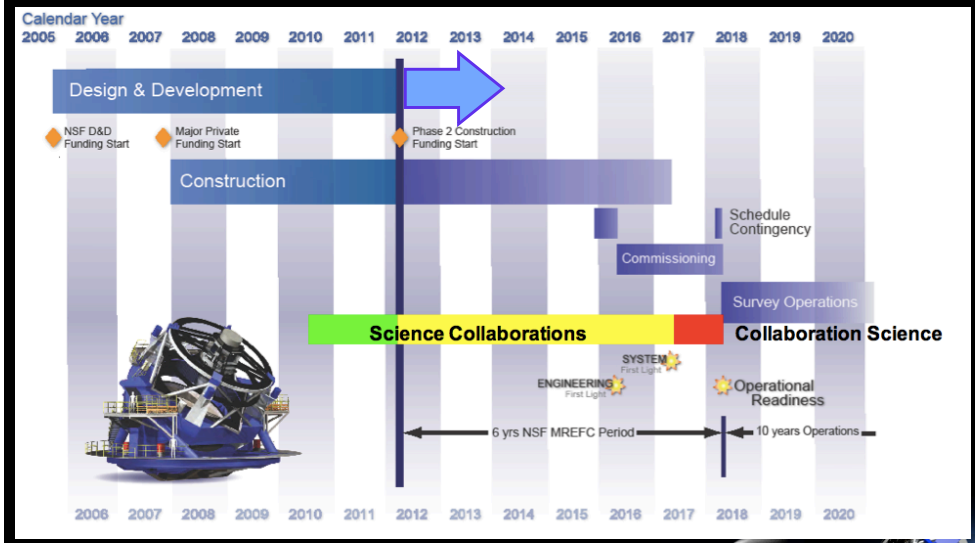
30 Tb of data per night
30 petabyte database, ~100 Pb images over 10 years

60 sec alerts for transient or moving objects



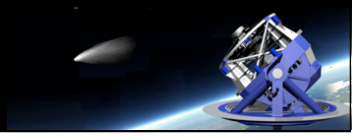

LSST
Large Synoptic Survey Telescope
LSST Data Products
Application Layer -
Generates open, accessible data products with fully documented quality
Processing Cadence
Image Category (files)
Catalog Category (database)
Alert Category (database)
Nightly
Raw science image
Calibrated science image
Subtracted science image
Noise image
Sky image
Data quality analysis
Source catalog
(from difference images)
Object catalog
(from difference images)
Orbit catalog
Data quality analysis
Transient alert
Moving object alert
Data quality analysis
Data Release (Annual)
Stacked science image
Template image
Calibration image
RGB JPEG Images
Data quality analysis
Source catalog
(from calibrated science images)
Object catalog
(optimally measured properties)
Data quality analysis
Alert statistics & summaries
Data quality analysis

Schedule of Operations



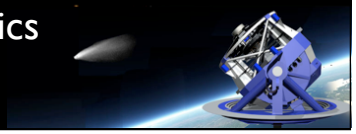
Data access

Data immediately available to the US and Chile
Derived data products available worldwide
Working with foreign partners to expand access



Science Collaborations

Solar System
Milky Way and Local Volume Structure
Transients & Variable Stars
Galaxies
Active Galactic Nuclei
Supernovae
Stellar Populations
Strong Lensing
Weak Lensing
Large Scale Structure & Baryon Oscillations
Informatics & Statistics



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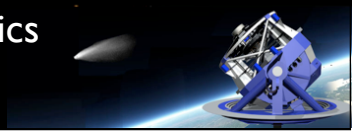
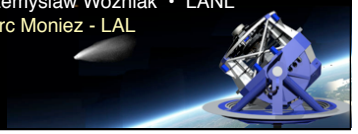


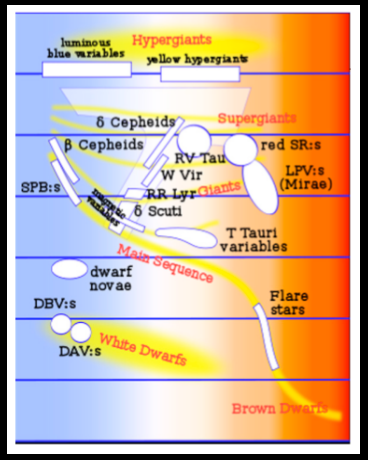
Transients and Variable Stars Collaboration

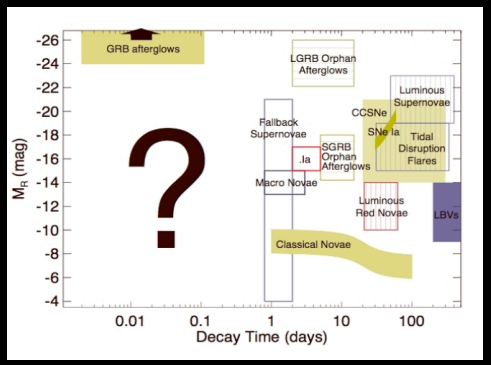
Chairs: Lucianne Walkowicz & Josh Bloom

Ghaleb Abdulla • LLNL
Eric Agol • UW
Marcel Agueros • Columbia
Scott Anderson • UW
David Arnett • U of A
Charles Bailyn • Yale
Andrew Becker • UW
Edo Berger • CFA
Josh Bloom • UC Berkeley
Howard Bond • STScI
Tim Brown • LCOGT
Mark Claire • UW
Kem Cook • LLNL
Nick Cowan • UW
Victor Debattista •
Rosanne DiStephano • CfA
Jeremy Drake • CFA
Derek Fox • Penn State
Chris Fryer • U of A
Suvi Gezari • Johns Hopkins
Josh Grindlay • Harvard
Zoltan Haiman • Columbia
Suzanne Hawley • UW
Arne Henden • AAVSO
Eric Hilton • UW
Steve Howell • NOAO
Mark Huber • LLNL
Zeljko Ivezic • UW
Lynne Jones • UW
Steven Kahn • SLAC
Mansi Kasliwal • Caltech
Adam Kowalski • UW
Shri Kulkarni • Caltech
Knox S. Long • STScI
Julie Lutz • UW
Lucas Macri • Texas A&M
Ashish Mahabal • Caltech
Eran O. Ofek • Caltech
Hakeem Oluseyi • FIT
Eliot Quataert • UC Berkeley
Arne Rau • Max Planck Institute
James E. Rhoads • ASU
Mercedes Richards • Penn State
Stephen Ridgway • NOAO
Roger Romani • Stanford
Wayne Rosing • LCOGT
Abi Saha • NOAO
Masao Sako • UPen
Dimitar Sasselov • CfA
Allen W. Shafter • SDSU
Chris Smith • NOAO/CTIO
Nathan Smith • U of A
Paula Szkody • UW
James P. Theiler • LANL
Virginia Trimble • UC Irvine
Tom Vestrand • LANL
Alistair Walker • NOAO
Lucianne Walkowicz • UC Berkeley
Przemyslaw Wozniak • LANL
Marc Moniez - LAL



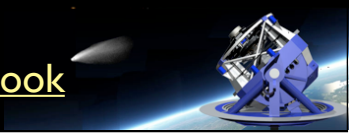
Incredible Diversity



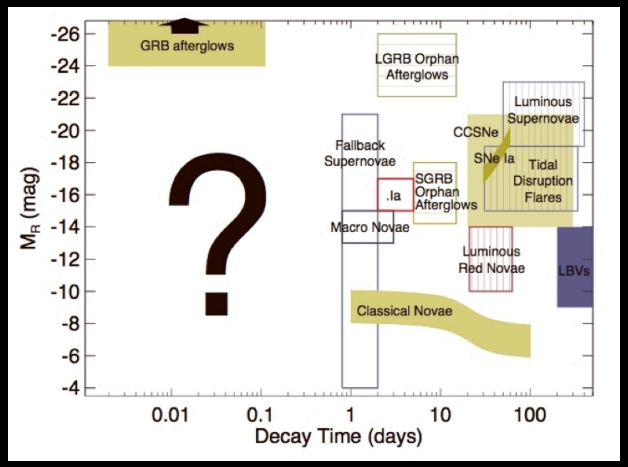


Also: microlensing, transiting planets...

LSST Science Book:
http://www.lsst.org/lsst/science/scibook



Discovery Space of Transients



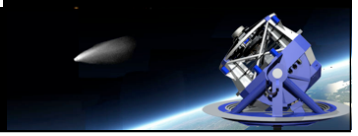
adapted from Rau et al 2008

Filled: Well observed

Vertical Stripe: Rare

Horizontal Stripe: Not yet detected

Unfilled: Theoretical



Example science: GRBs

Detection of off-axis afterglows by synoptic imaging can help determine beaming fraction (and true rate)

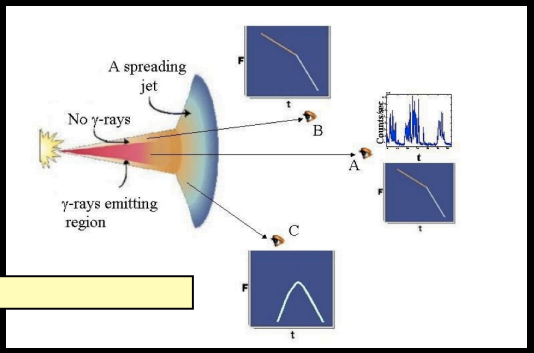
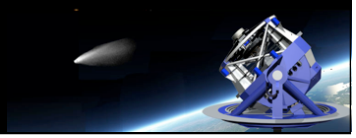


Figure from Nakar & Piran 2003



Example Science: Very Fast Transients

Potential Sources

Contemporaneous GRB optical counterparts

Giant pulses from pulsars

Flare from anomalous X ray pulsars

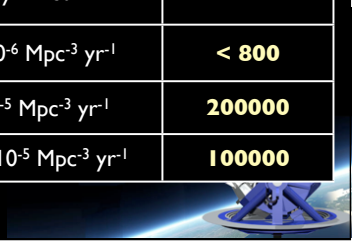
...the unknown!

Accessible via deep drilling fields and
also by differencing 15 sec exposure pairs

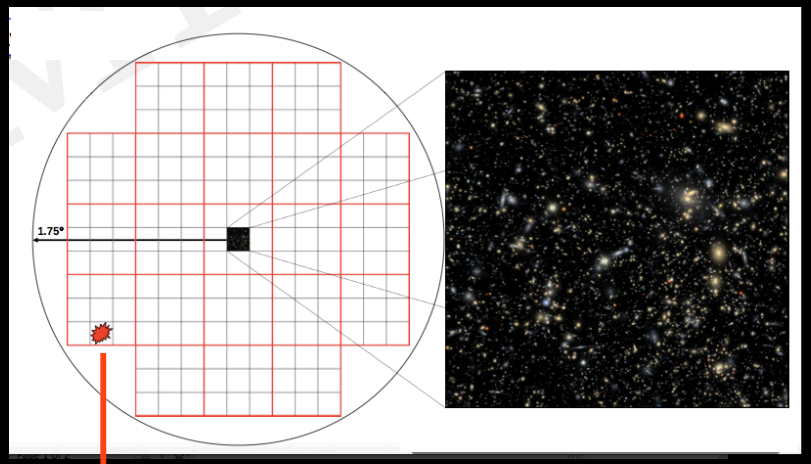
Expected Rate of Transients

Class	Mag	t (days)	Universal Rate	LSST Rate
Luminous SNe	-19...-23	50 - 400	10^{-7} Mpc^{-3} yr^{-1}	**20000**
Orphan Afterglows SHB	-14...-18	5 -15	3 x$10^{-7...-9}$ Mpc^{-3} yr^{-1}	**~10 - 100**
Orphan Afterglows LSB	-22...-26	2 - 15	3 x $10^{-10...-11}$ Mpc^{-3} yr^{-1}	**1000**
On-axis GRB afterglows	...-37	1 - 15	10^{-11} Mpc^{-3} yr^{-1}	**~50**
Tidal Disruption Flares	-15...-19	30 - 350	10^{-6} Mpc^{-3} yr^{-1}	**6000**
Luminous Red Novae	-9...-13	20 - 60	10^{-13} yr^{-1} Lsun^{-1}	**80 - 3400**
Fallback SNe	-4...-21	0.5 - 2	<5 x 10^{-6} Mpc^{-3} yr^{-1}	**< 800**
SNe Ia	-17...-19.5	30 - 70	3 x 10^{-5} Mpc^{-3} yr^{-1}	**200000**
SNe II	-15...-20	20 - 300	(3..8) x 10^{-5} Mpc^{-3} yr^{-1}	**100000**

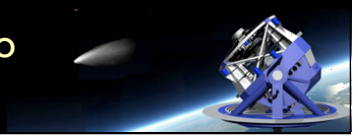
Table adapted from Rau et al. 2009



a-LIGO / LSST



LSST field-of-view well-matched to localize LIGO events



Targets of Opportunity

- Why provide Target of Opportunity Triggering and Cadencing?
  - Scientific: LSST is uniquely suited to finding EM counterparts to GW events
  - Political: Supports NSF-funded a-LIGO and responds directly to DOE science

How would such a capability translate to operation requirements?

White paper in development on scientifically-motivated performance desires (Bloom, Becker, Cook, Walkowicz)

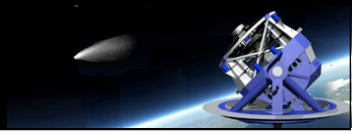
Upcoming Challenges

Science Collaborations are currently working on:

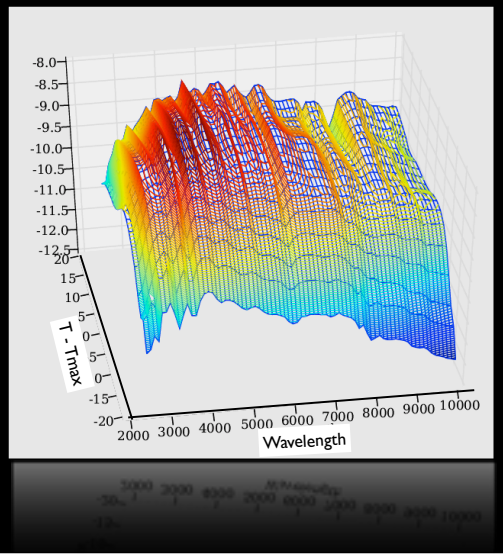
Simulating LSST data stream to evaluate requirements

Classification algorithms

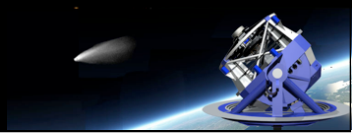
Science verification plans



Spectrotemporal Surface

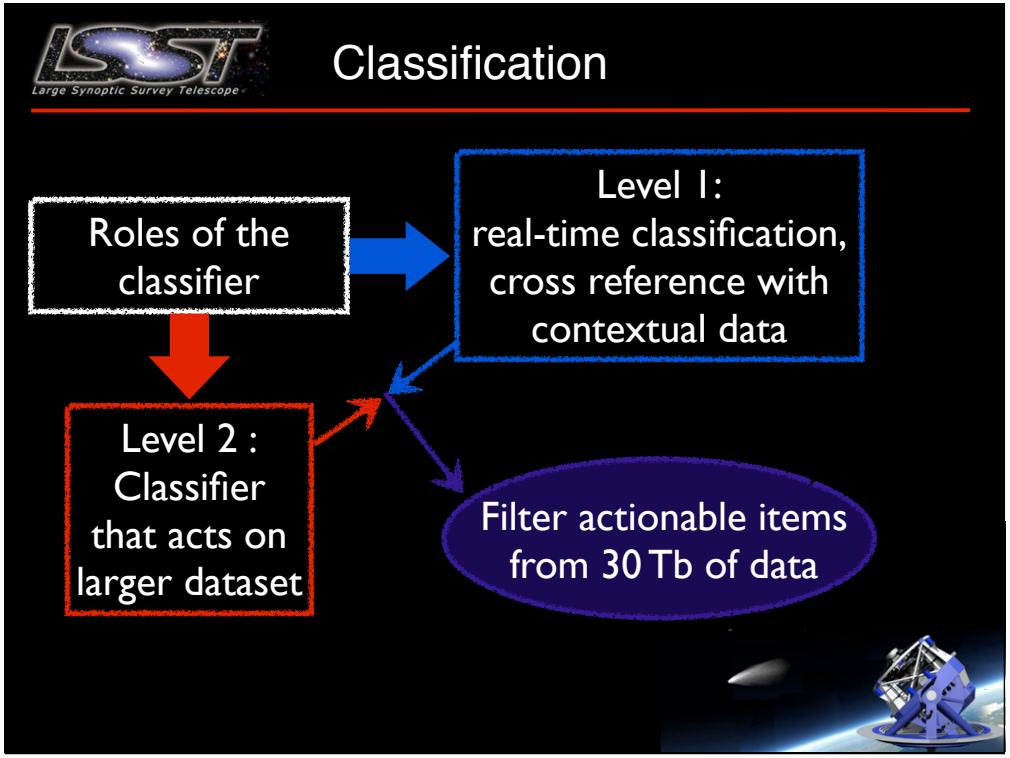


Hsaio
Supernova
Template

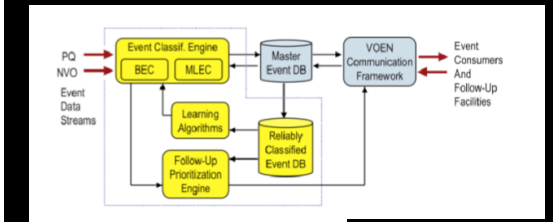


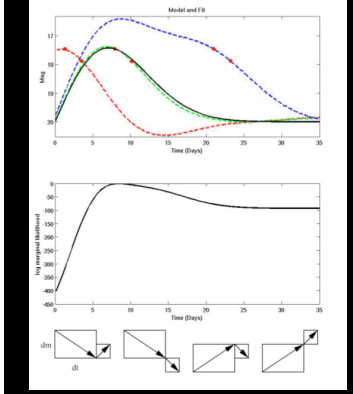
Large Synoptic Survey Telescope

Example simulation: 1.7ppm of the survey


LSST
Large Synoptic Survey Telescope
Classification
Roles of the classifier
Level 1: real-time classification, cross reference with contextual data
Level 2 : Classifier that acts on larger dataset
Filter actionable items from 30 Tb of data

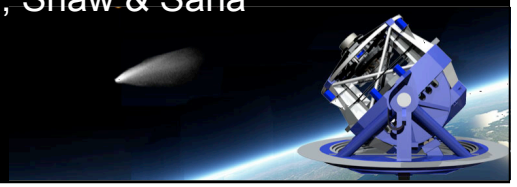
Alerts, Categorization, Classification





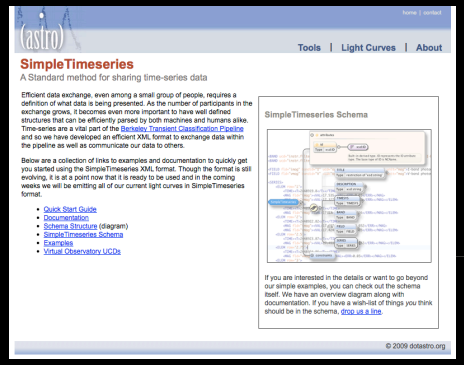
Collation of templates for ImSim feeds directly to development of plug-in classification / categorization

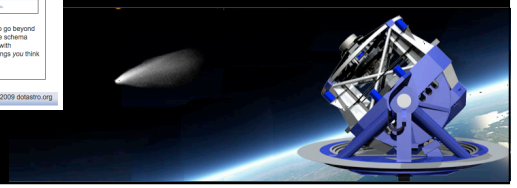
Topic of ongoing work:
Mahabal
Bloom
Borne, Shaw & Saha



VOEvent 2.0

- http://dotastro.org/simpletimeseries
- http://en.wikipedia.org/wiki/VOEvent





Early Science Verification

- About 10-15% of LSST point sources will be variable (at the few tenths of a mag level or above)
- Of these, only 10-15% will be periodic
- True Transient Events?
  - *–Most things that vary do not vary periodically*

Light curve library would enhance LSST science and provide an opportunity for Science Verification


Thank you!