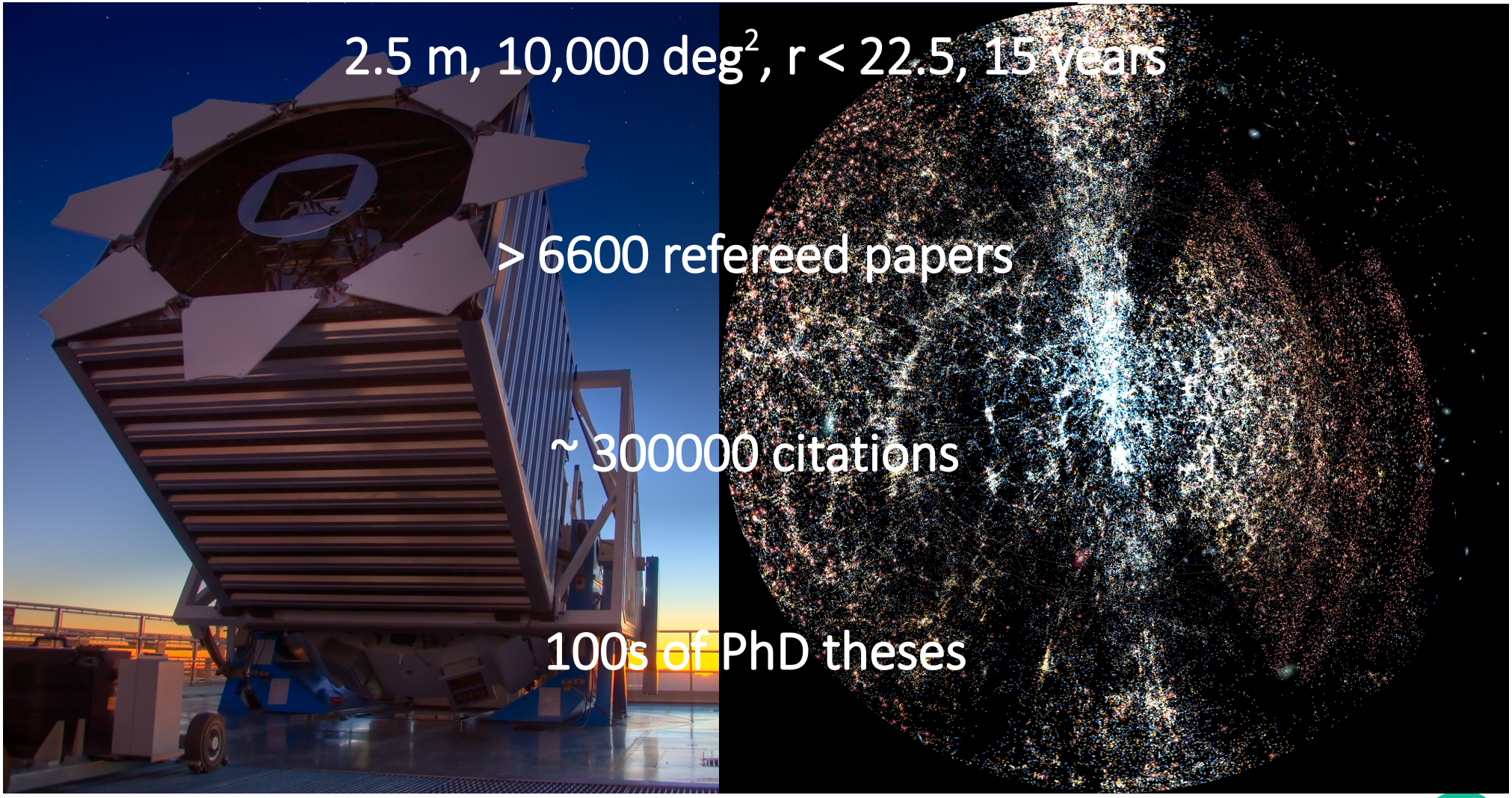
Surveying the Dynamic Sky with the LSST

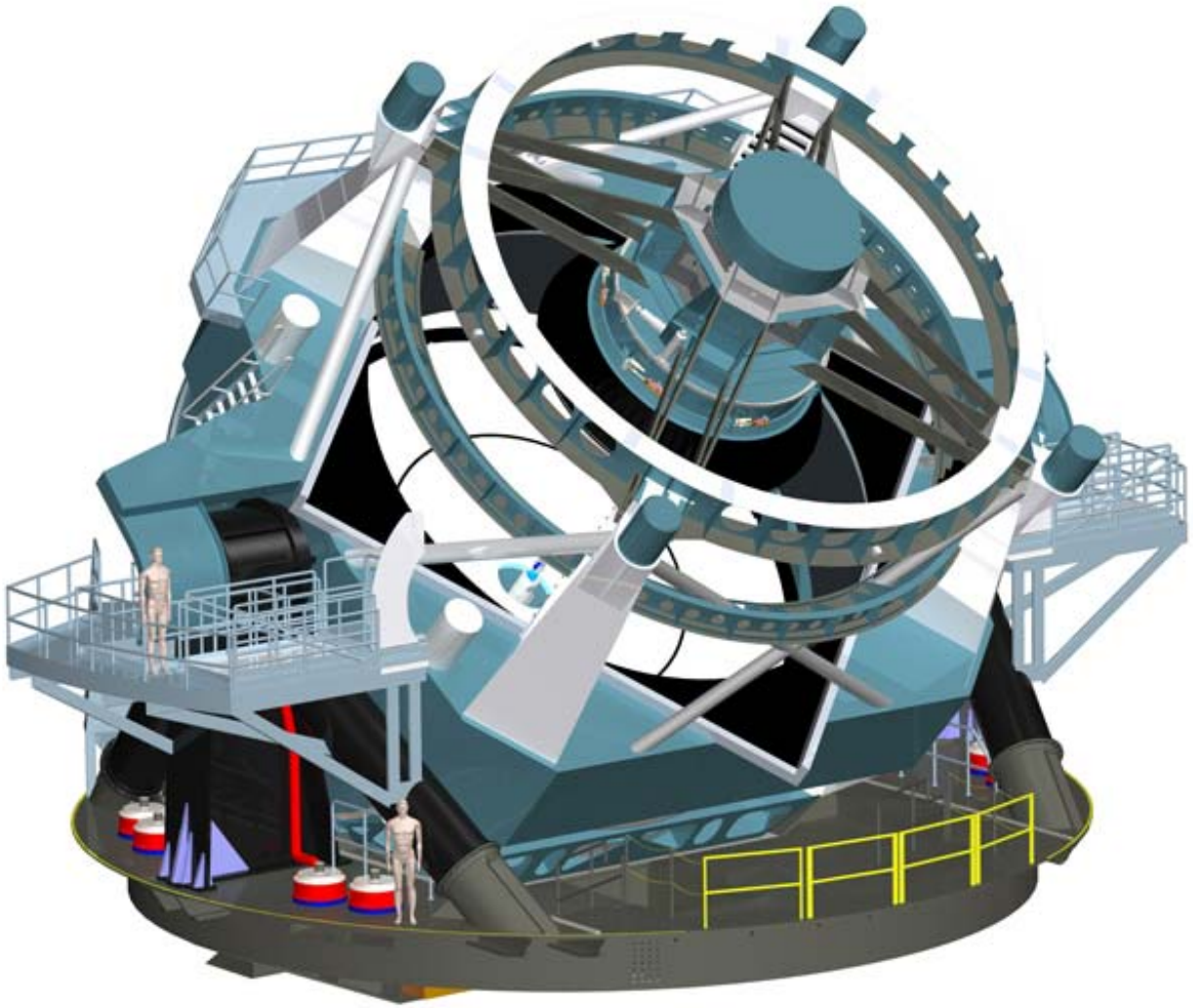
Vishal Kasliwal

2016 KARL LSST Workshop

Sloan Digital Sky Survey

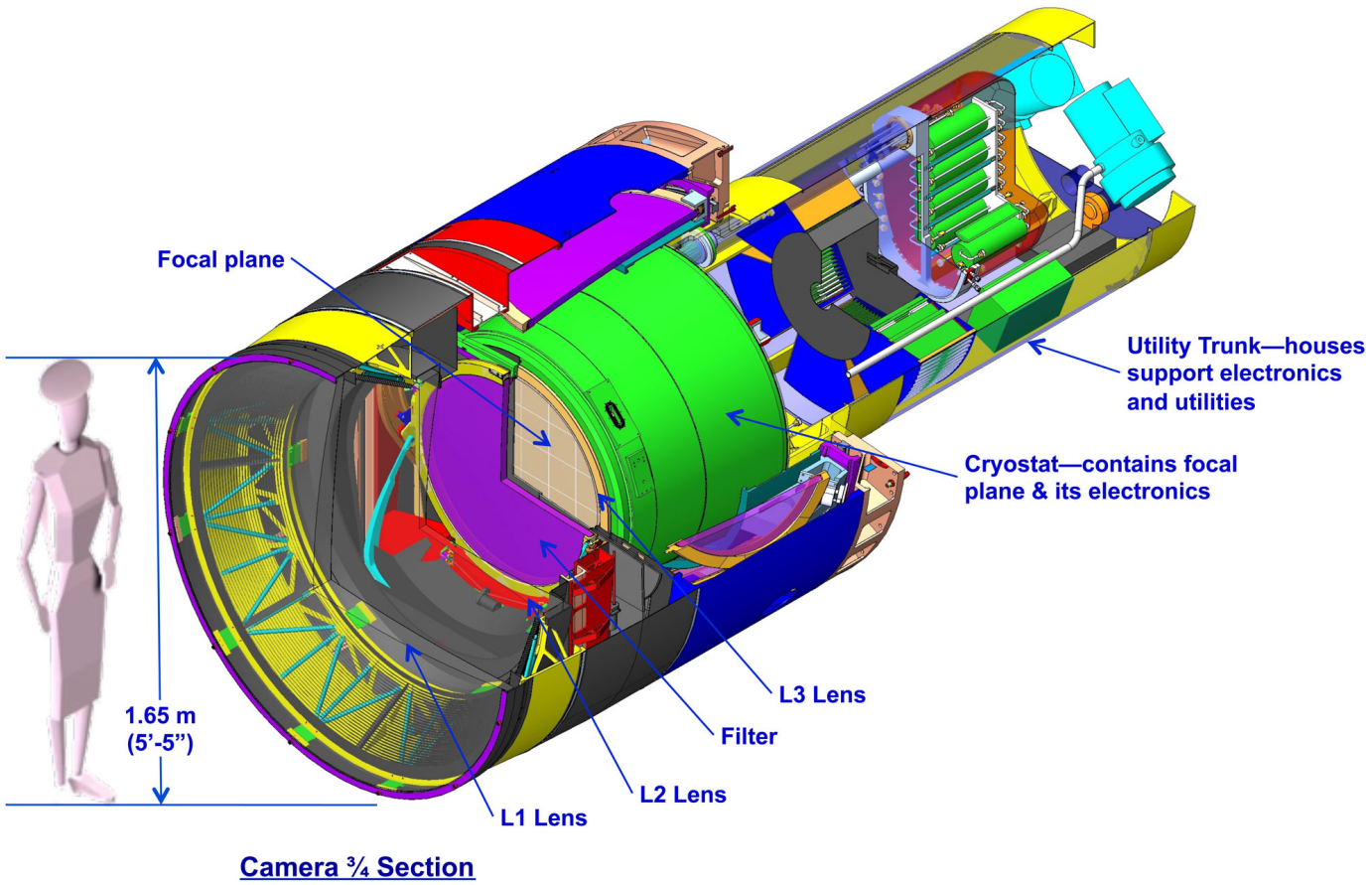


Large Synoptic Survey Telescope



- Modified Paul-Baker three-mirror system
- 8.4 m f/1.234 (6.8 m clear aperture)
- 3.5° FOV
- 50.9 micron/arcsec plate scale.

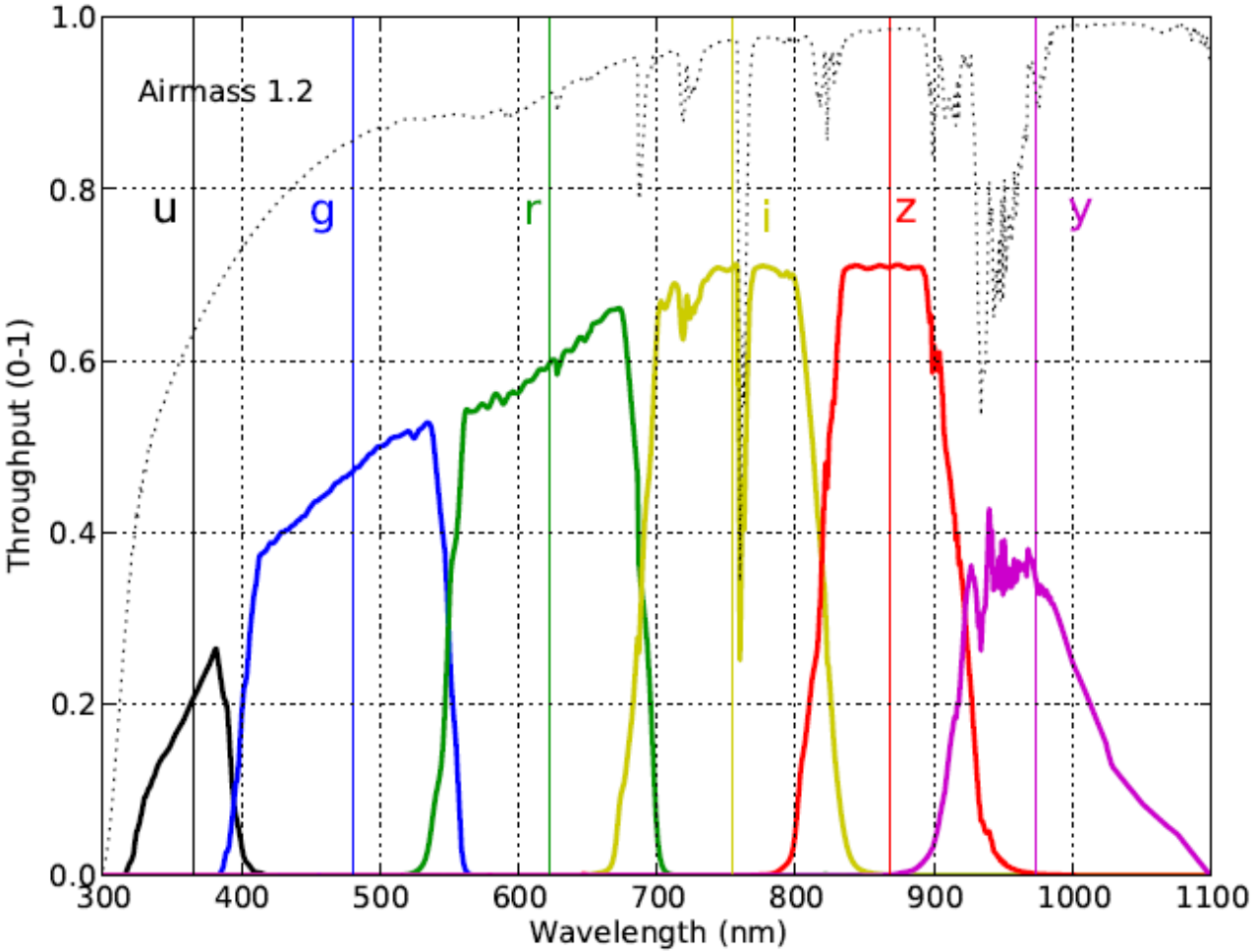
LSST Camera



Camera ¾ Section

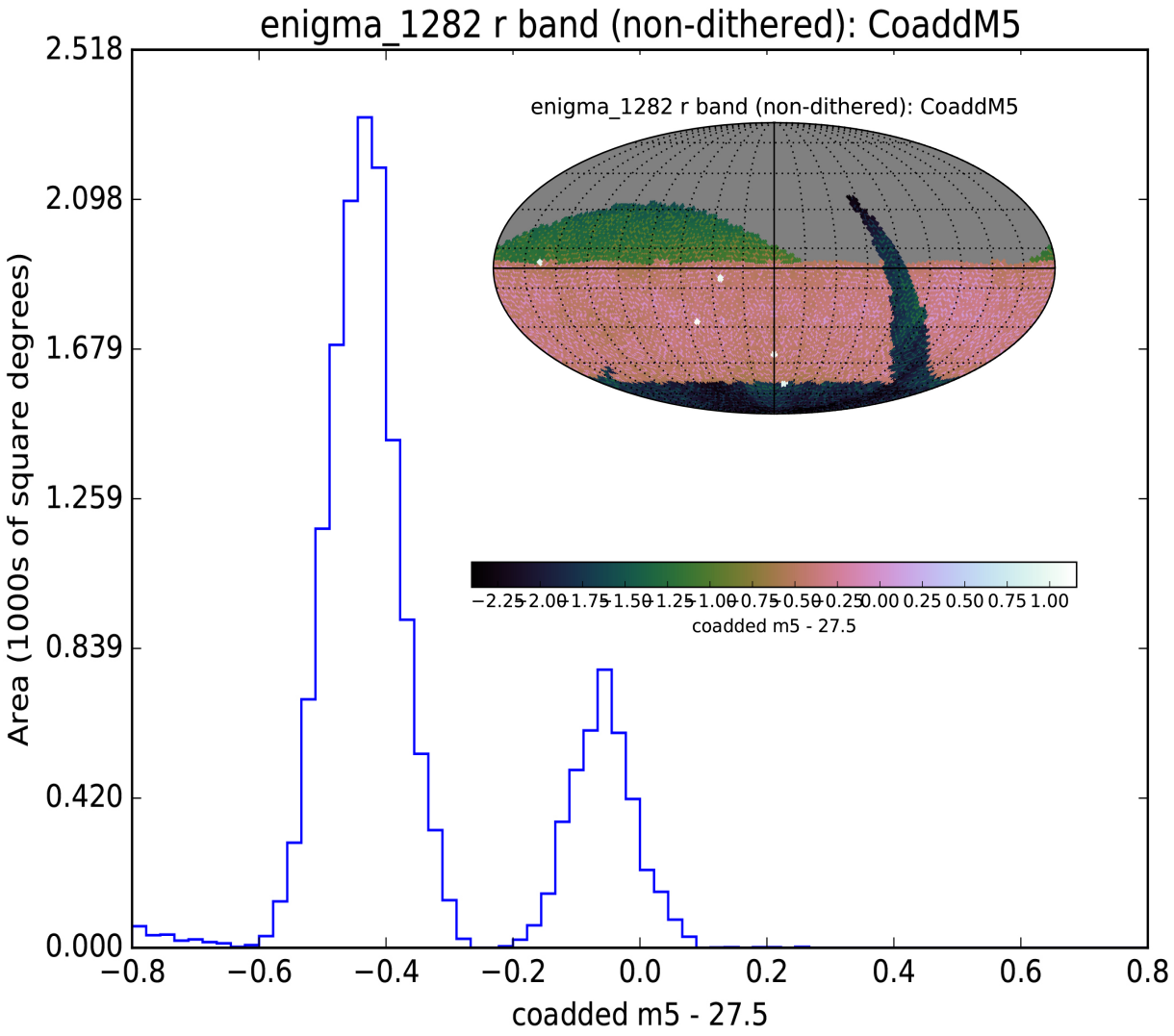
- 3.2 Gigapixel
- 10 micron pixels (0.2 arcsec)
- 189 4K x 4K CCDs
- 0.64 m diameter focal plane

Filter System



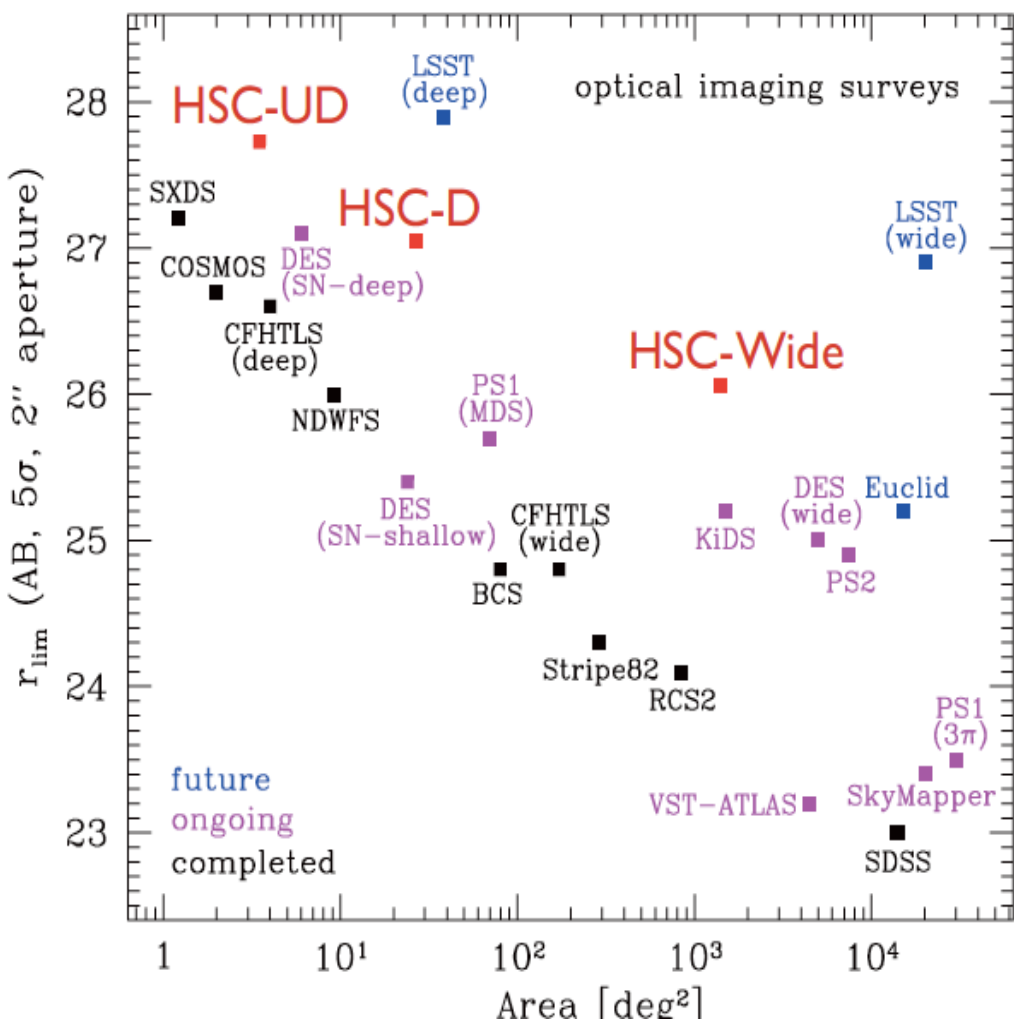
- ugrizy
- 320-1050 nm

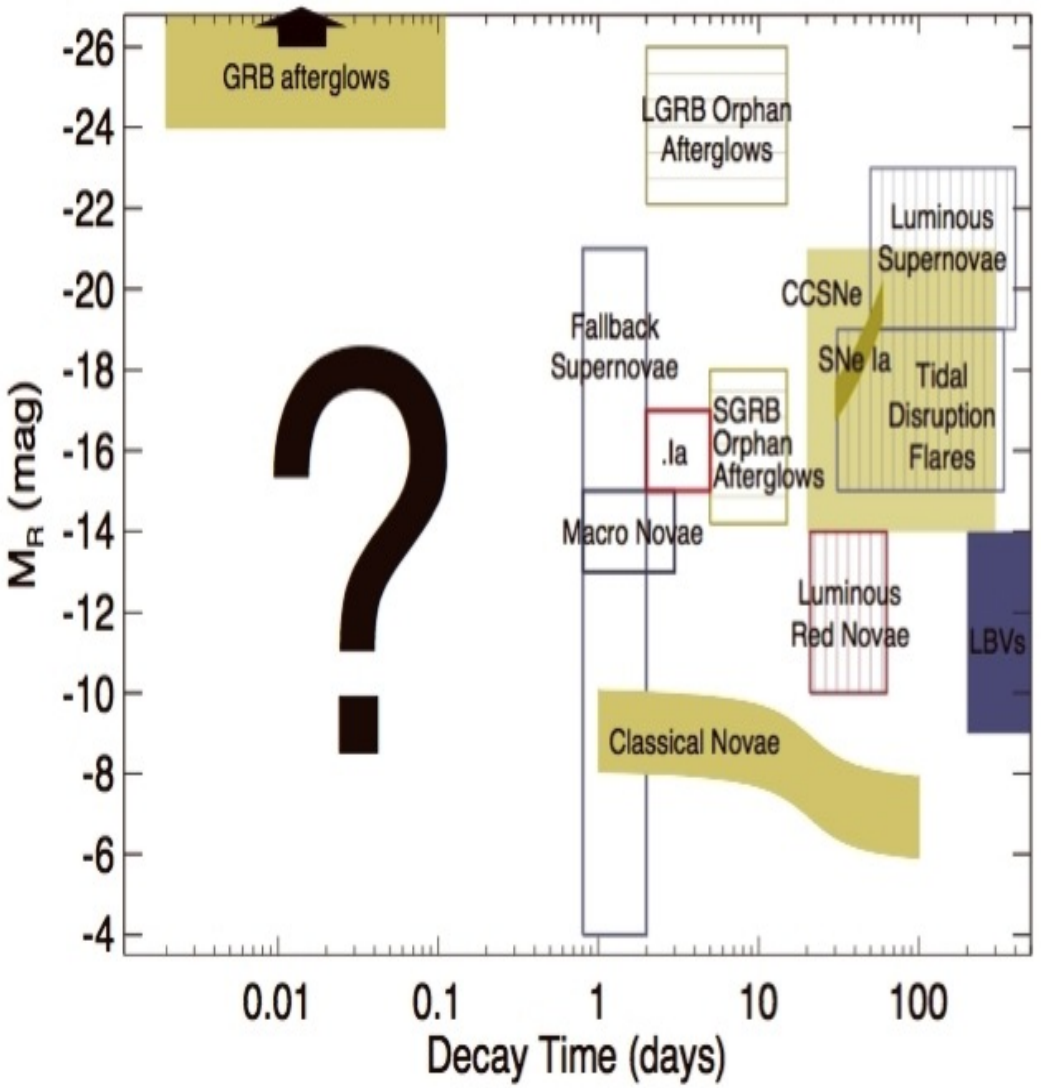
Survey Strategy



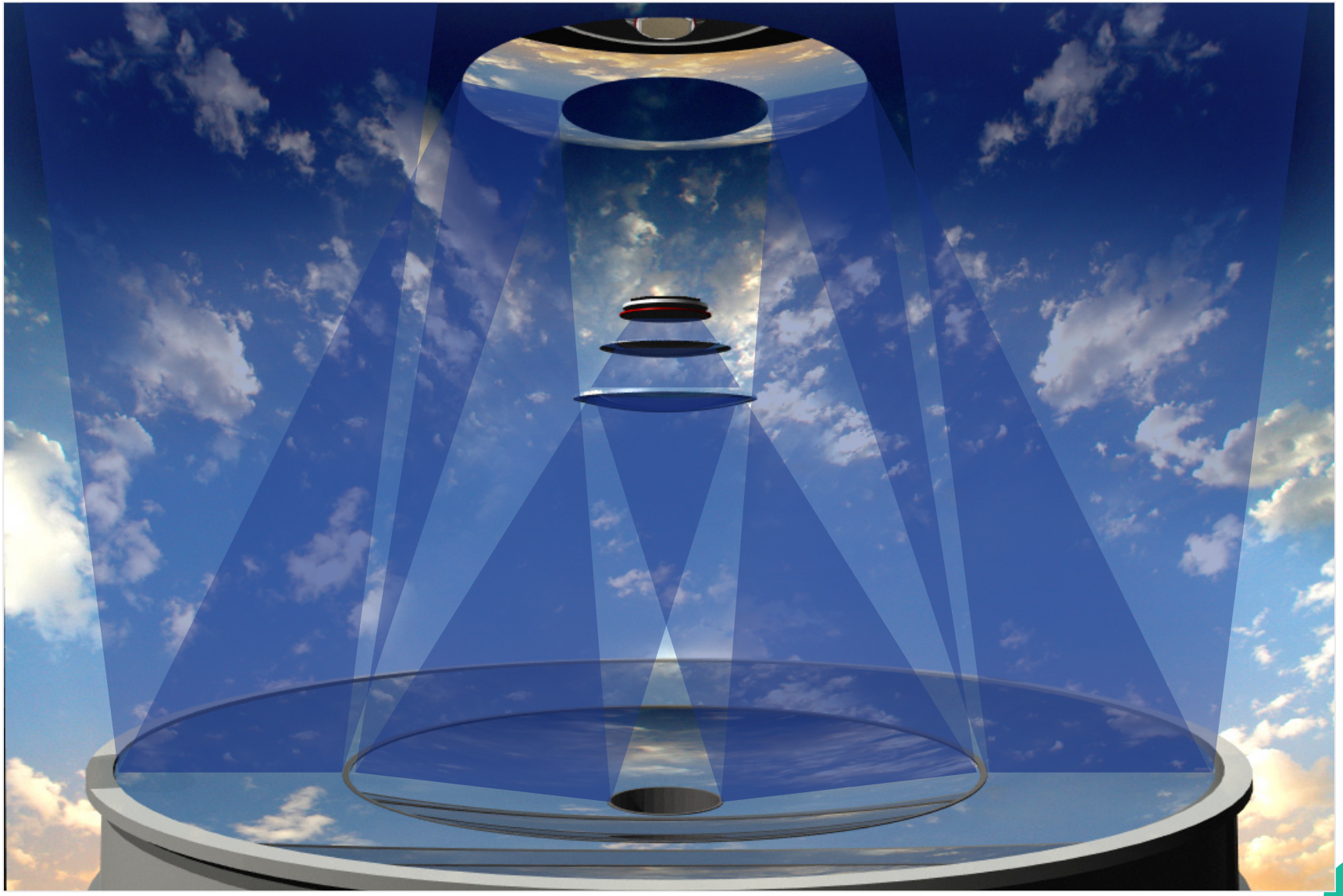
- 2 x 15 sec. Exposures
- 1000 visits/night
- 20,000 deg^2 deep-wide-fast

LSST Discovery Space





LSST Optical Train



SDSS vs HSC – LSST will provide similar IQ

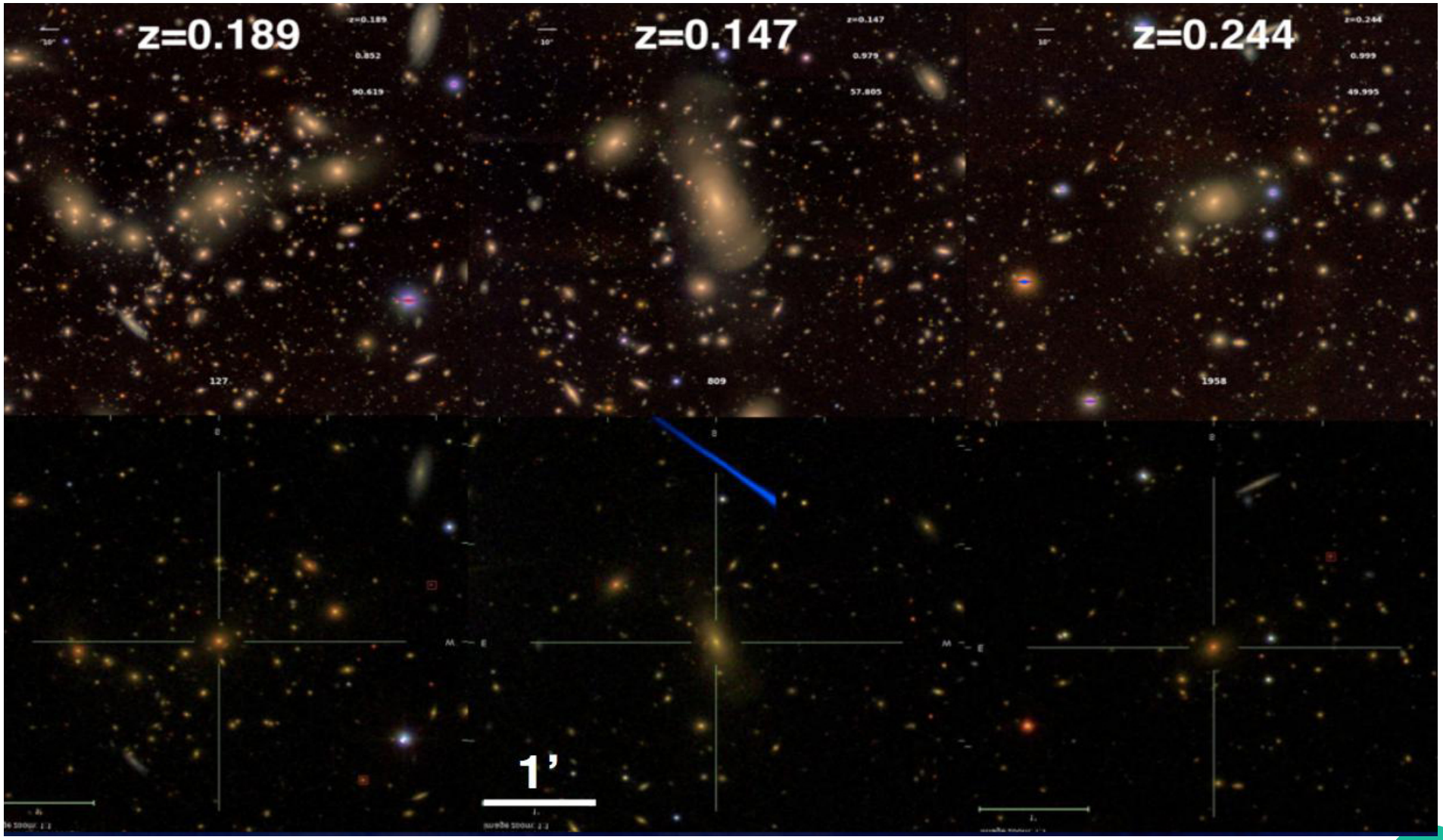


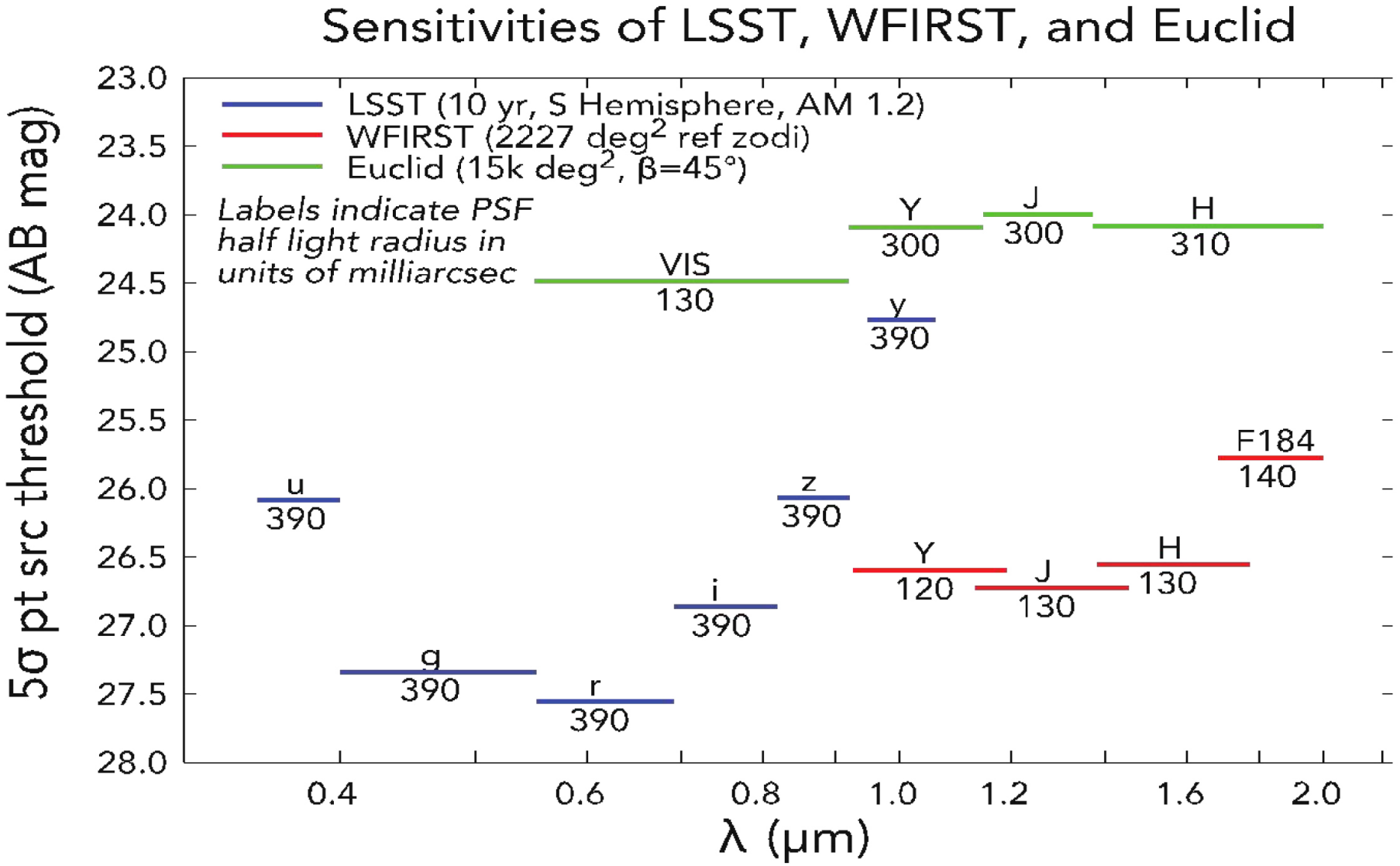
image credit Song Huang

Another HSC image...

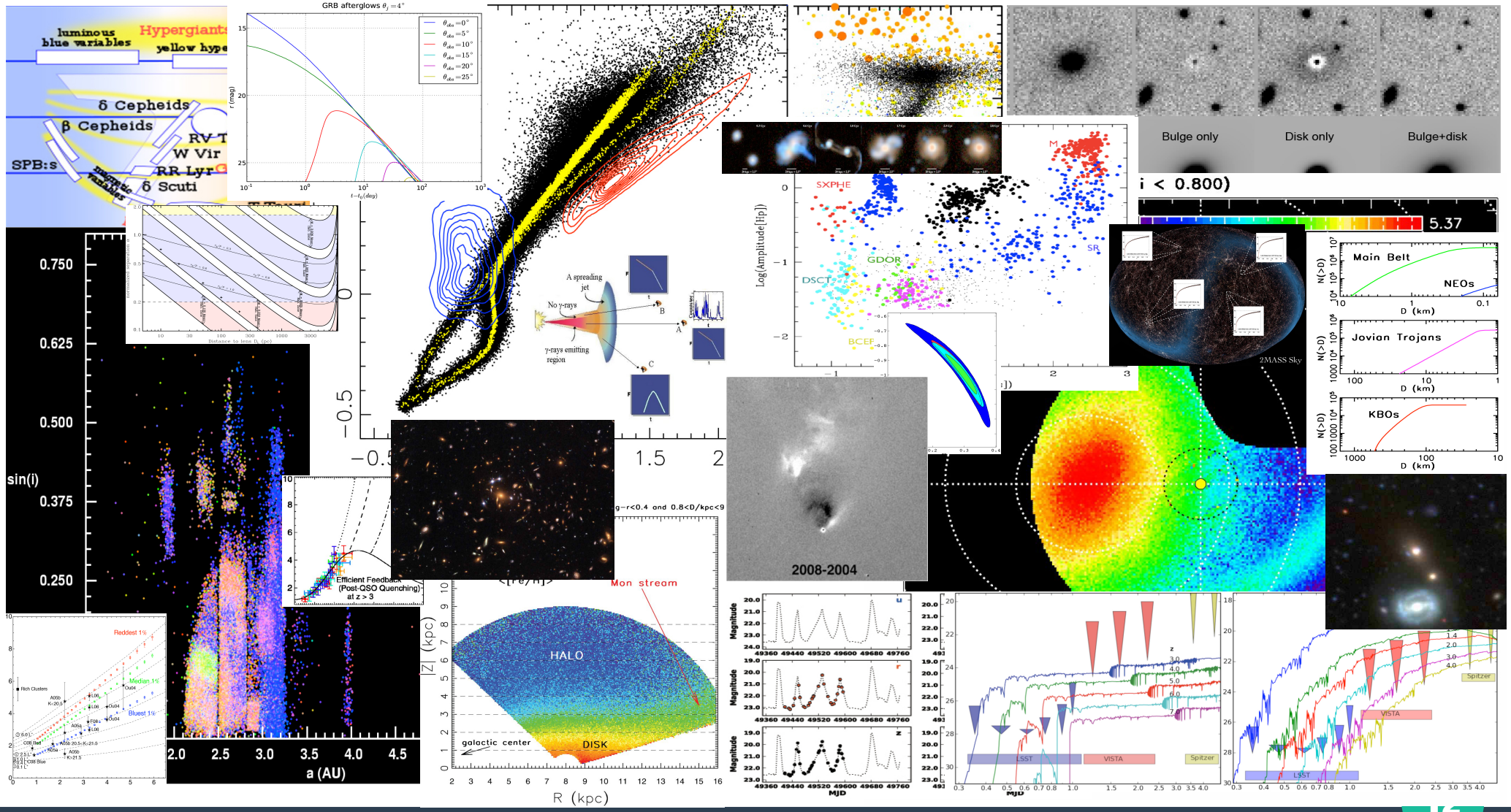
image credit Lauren MacArthur

- 1.5 hrs in each filter (grizy)
- little less than LSST full depth
- 0.6 – 0.7 arcsec seeing
- lots of blending!

Synergy with IR Surveys



LSST Science



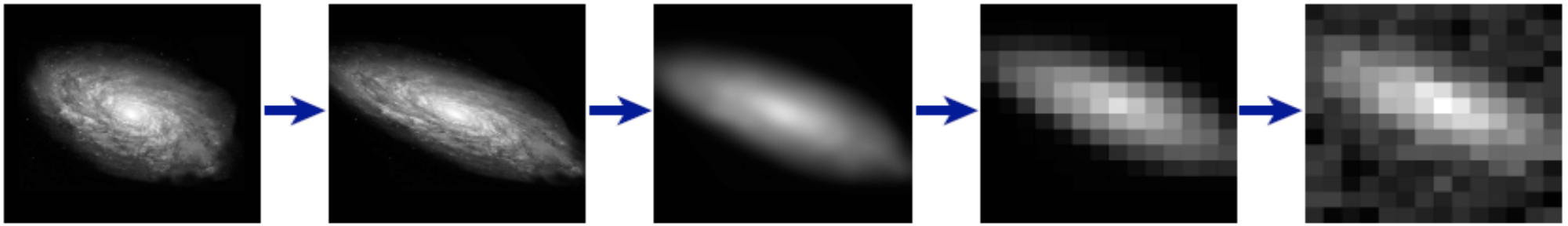
The ultimate deliverable of LSST is not just the telescope, nor the camera, but the fully reduced science-ready data.

- Zeljko Ivezic

A Game of Cosmic Telephone

The Forward Process.

Galaxies: Intrinsic galaxy shapes to measured image:



Stars: Point sources to star images:

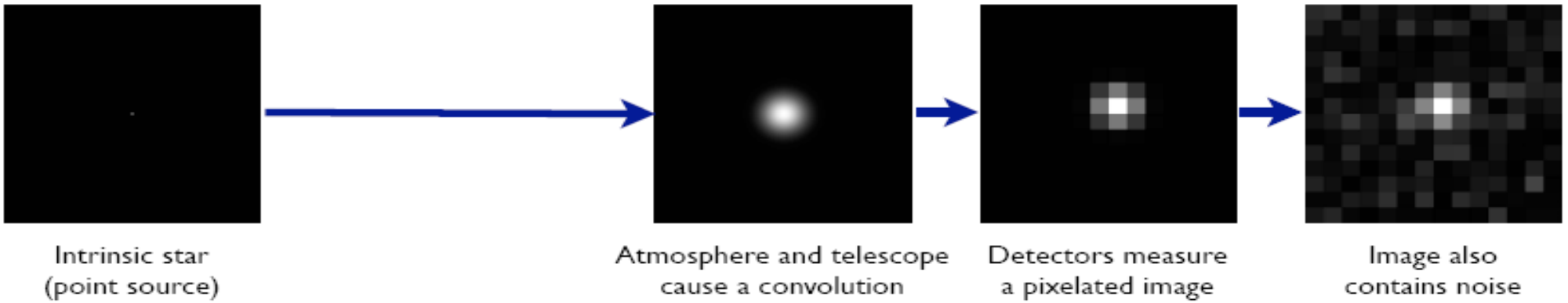


Figure from S. Bridle

LSST Data Management (LSST DM)

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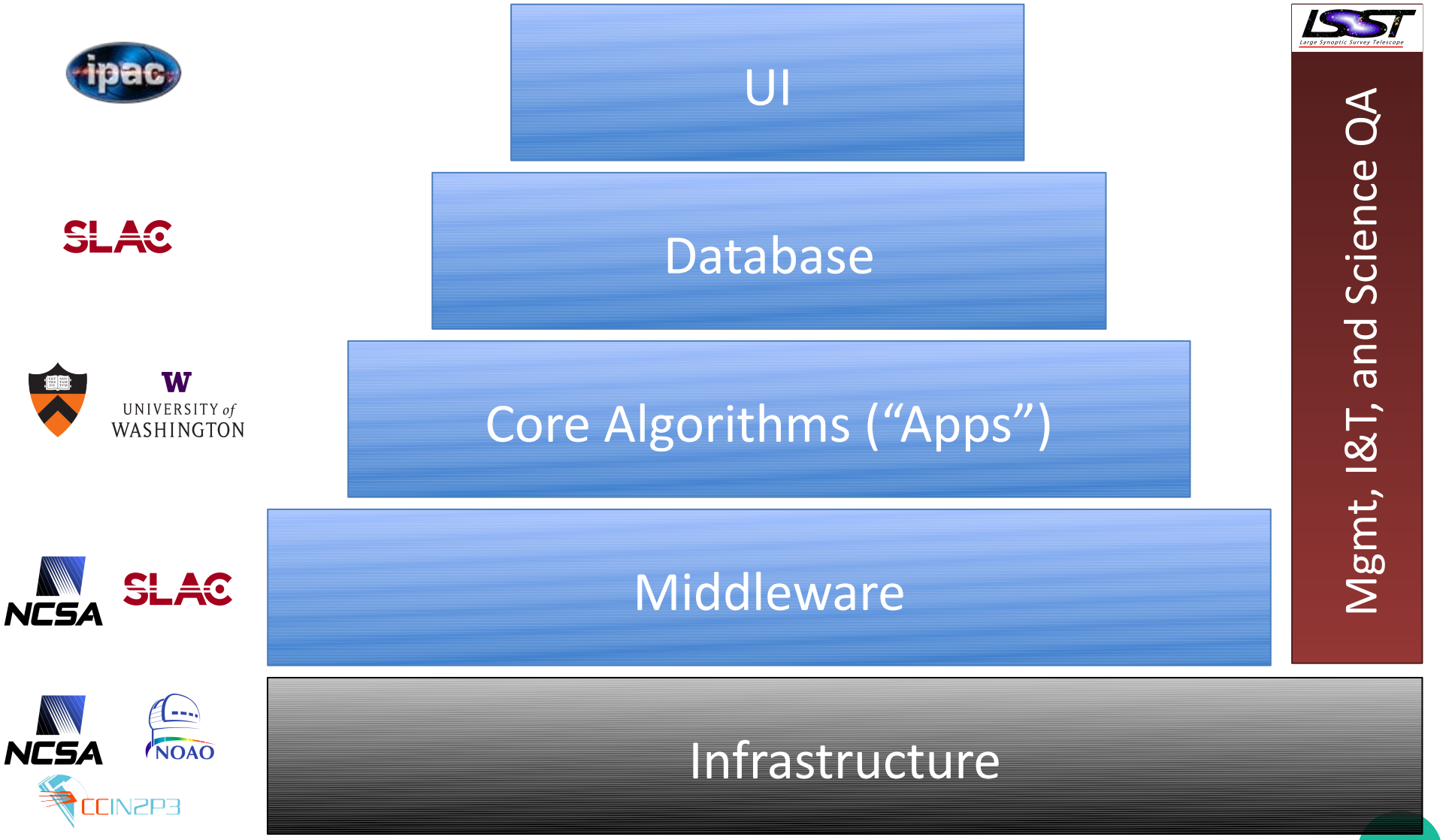
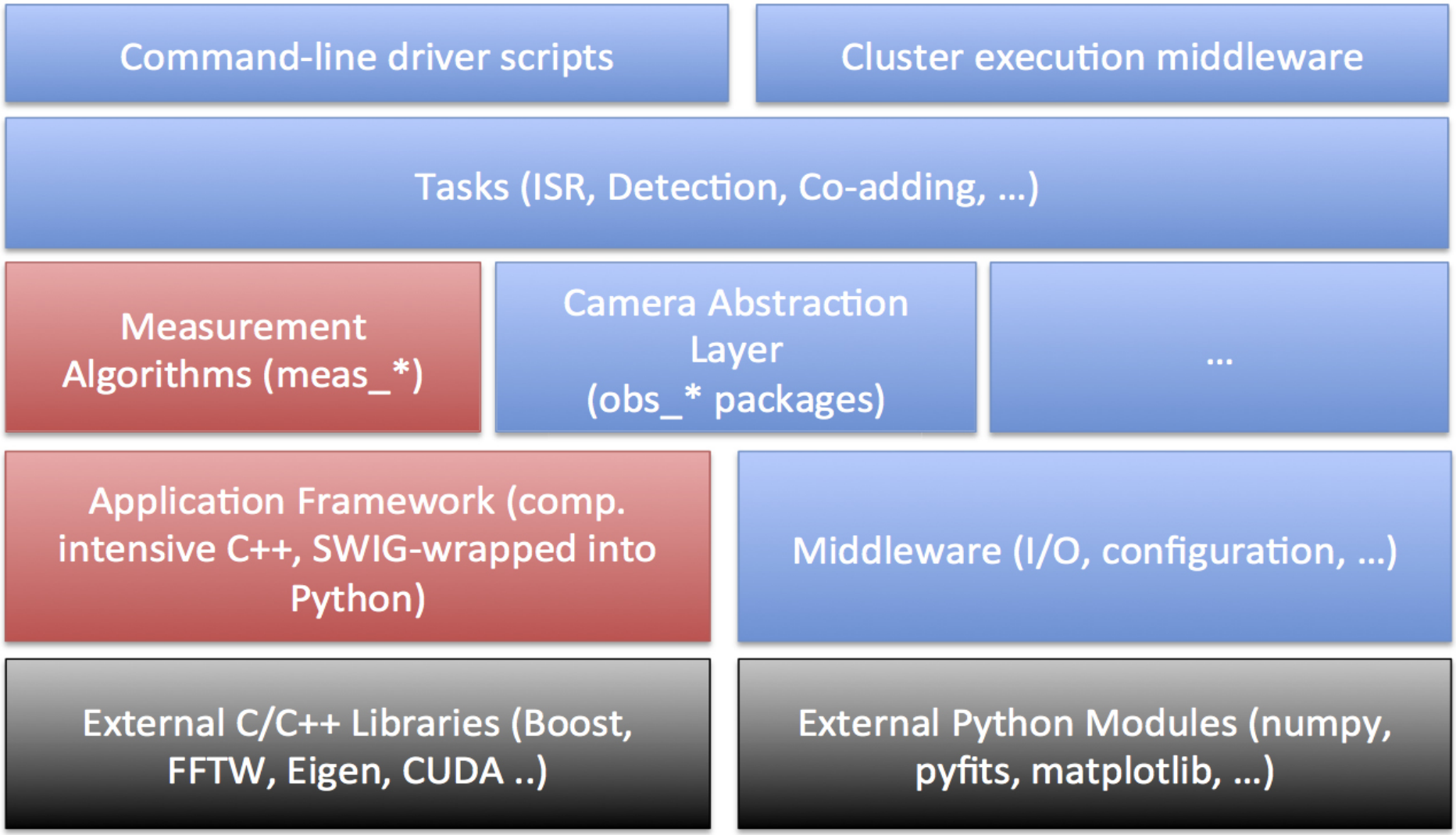


LSST Software Stack

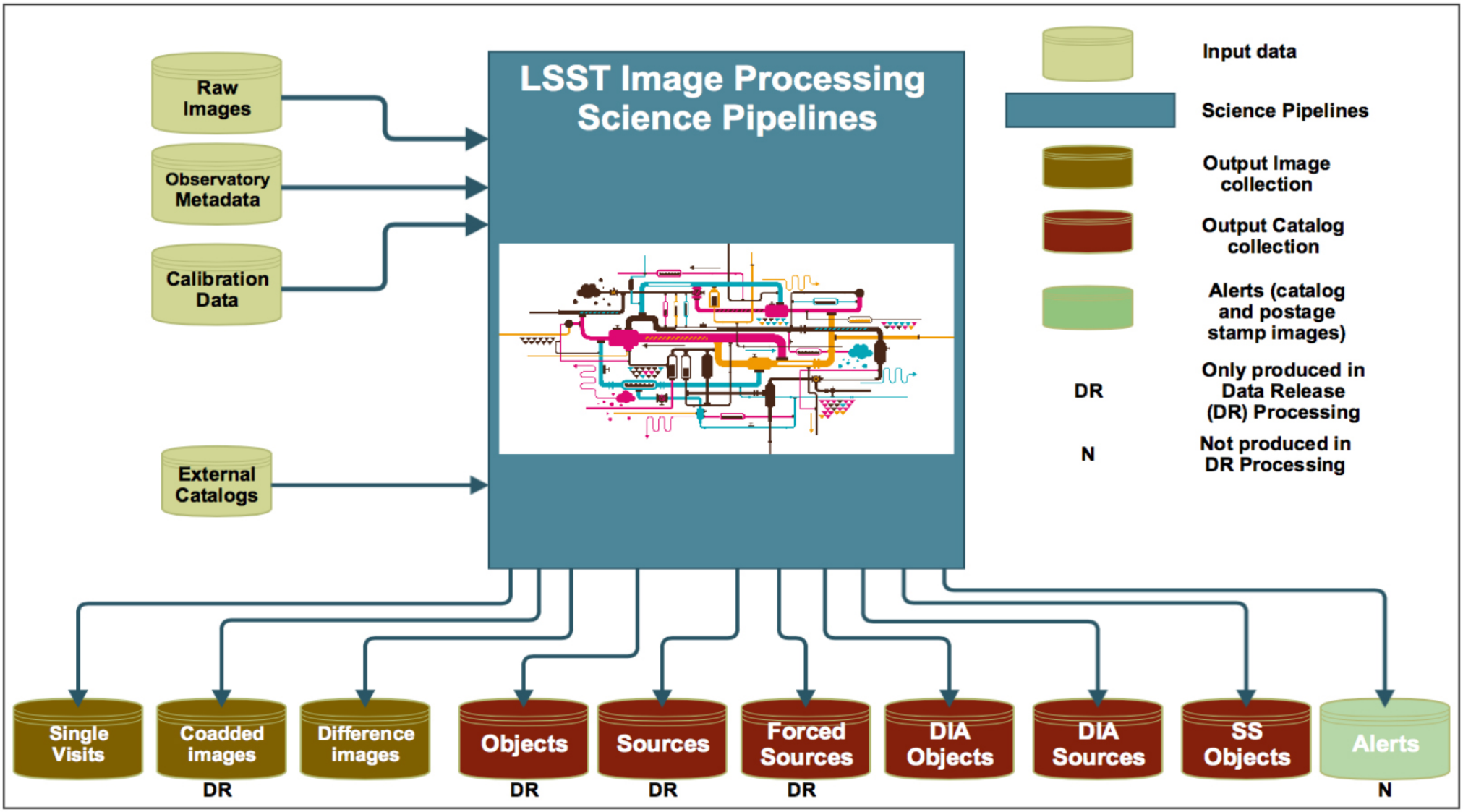


Red: Mostly C++ (but Python wrapped); Blue: Mostly Python; Black: External Libraries

Data Products Overview

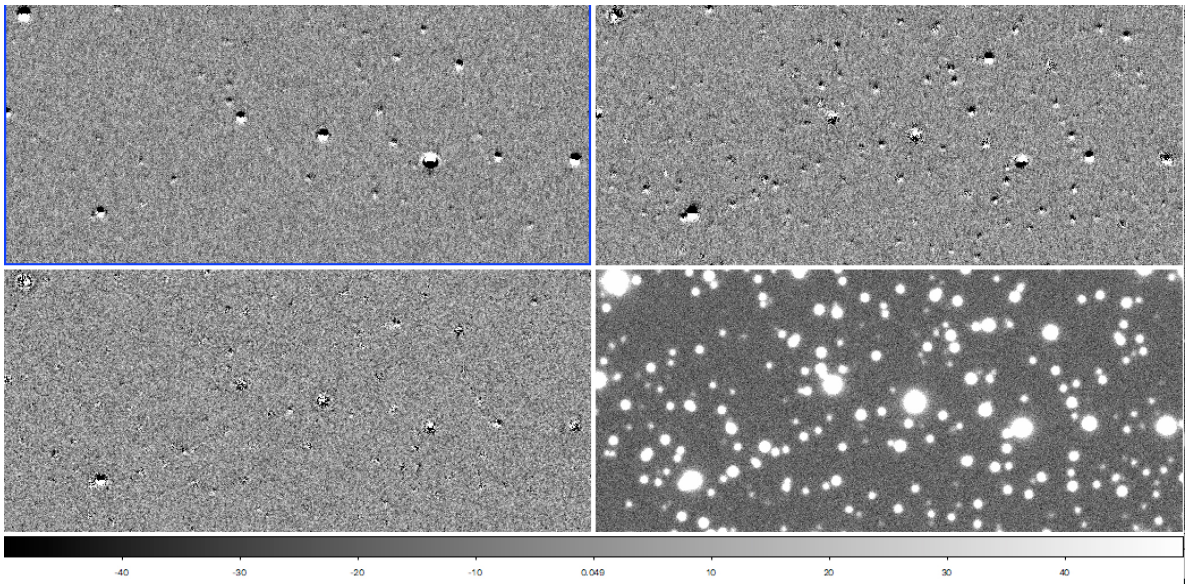
	IMAGES CATEGORY (FILES)	CATALOG CATEGORY (DATABASE)	ALERT CATEGORY (DATABASE)
NIGHTLY Level 1	Raw science images Calibrated science images Subtracted science images Data quality analysis	Catalog of sources (detections) found on difference images Catalog of objects found on difference images Orbit catalog Data quality analysis	Transient alert Data quality analysis (within 60 seconds)
DATA RELEASE (Annual) Level 2	Stacked science images Calibration images RGB JPEG images Data quality analysis	Source (detection) catalog from calibrated science images Object catalog from optimally measured properties Data quality analysis	Alert statistics and summaries based on annual reprocessing Data quality analysis

Data Products Overview



Level 1 (Nightly) Data Products

- Detection & follow up of transients
- Near real-time processing
- Continuously generated
- Updated nightly
- Maximal automation

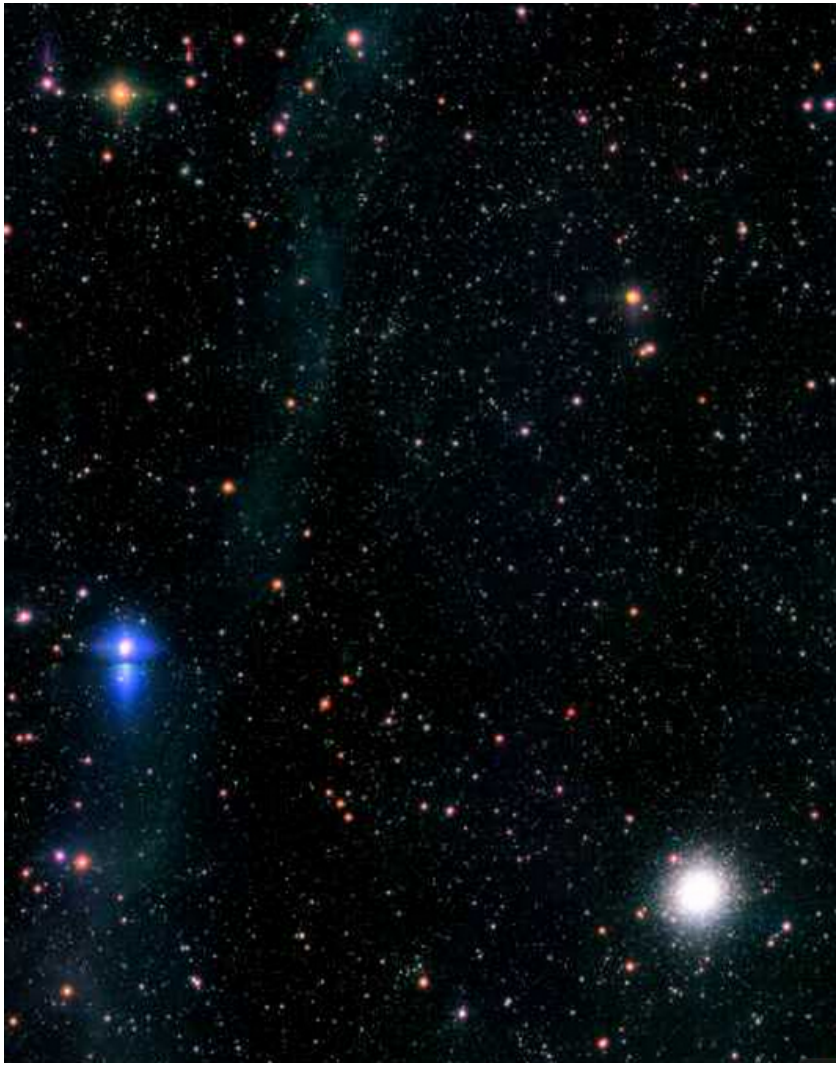


Difference images: Bottom right is g-band template. Bottom left is g-band difference image. Upper panels are u & r band. Dipoles in upper difference images are due to Differential Chromatic Refraction (DCR).

From DMTN-019 (Ian Sulivan)

Level 2 (Yearly) Data Products

- Extensive computation required
- May combine multiple exposures
- Significant human interaction (may be) needed at key-points
- Includes re-processed Level 1 products



SDSS Stripe 82 Re-processing in vicinity of M2

Level 1 Pipeline

- **Single Frame Processing (SFM)**
  - Reduce visit (single CCD PSF estimation) + Detect + Characterize
- **Image Differencing Pipeline**
  - Create image differences + Detect + Characterize
- **Association Pipeline**
  - Associate detected sources with known objects
- **Alert Generation Pipeline**
  - Generate + Transmit alerts
- **Moving Object Pipeline**
  - Identify + Link + Compute orbits of SS bodies

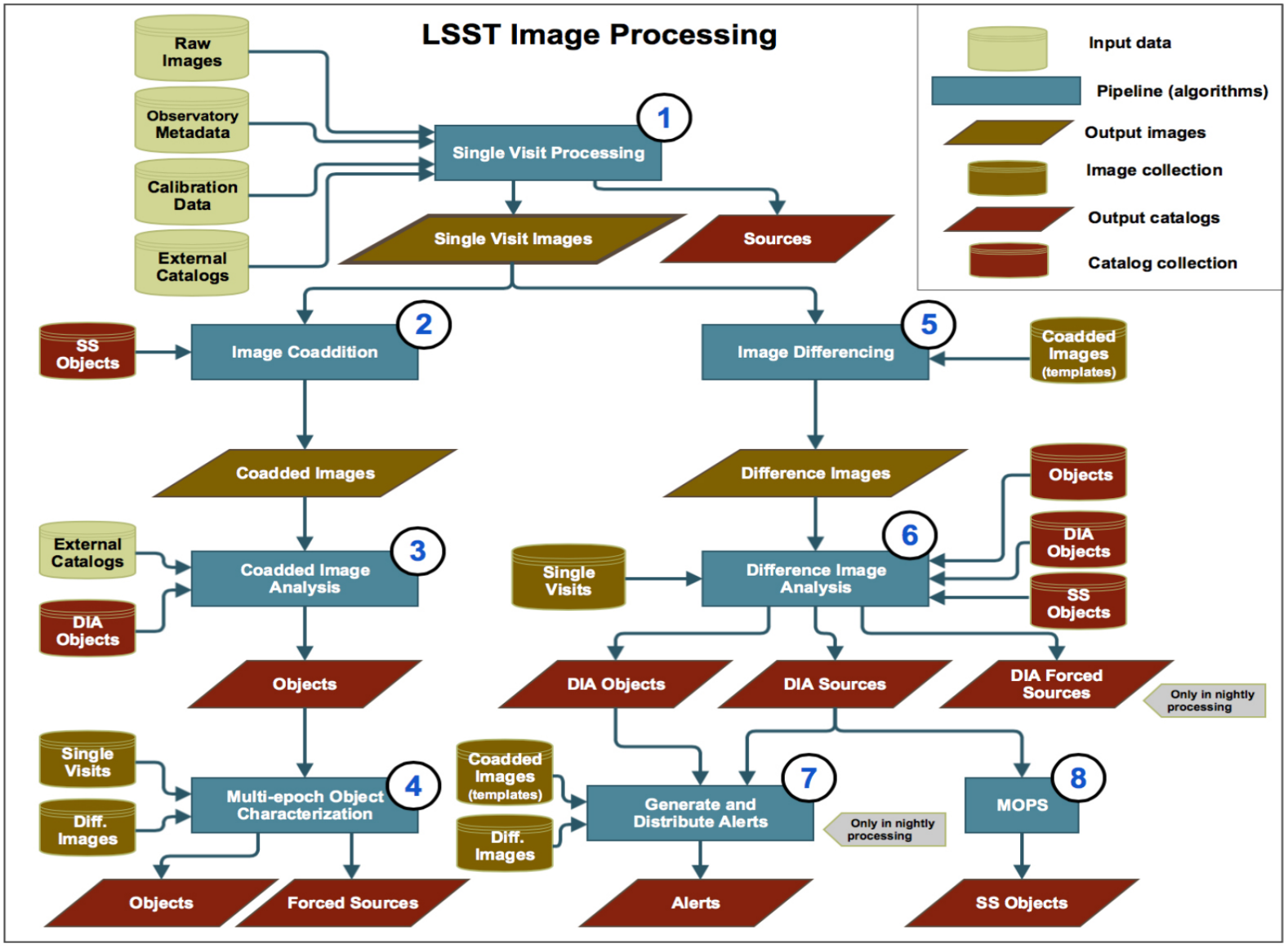
Level 2 Pipeline

- **PSF Estimation Pipeline**
  - Full visit PSF estimation
- **Image Coaddition Pipeline**
  - Generate + Characterize coadds & Create difference imaging templates
- **Object Detection & Deblending**
  - Detect + Deblend
- **Object Characterization Pipeline**
  - Characterize objects in both visits & coadds

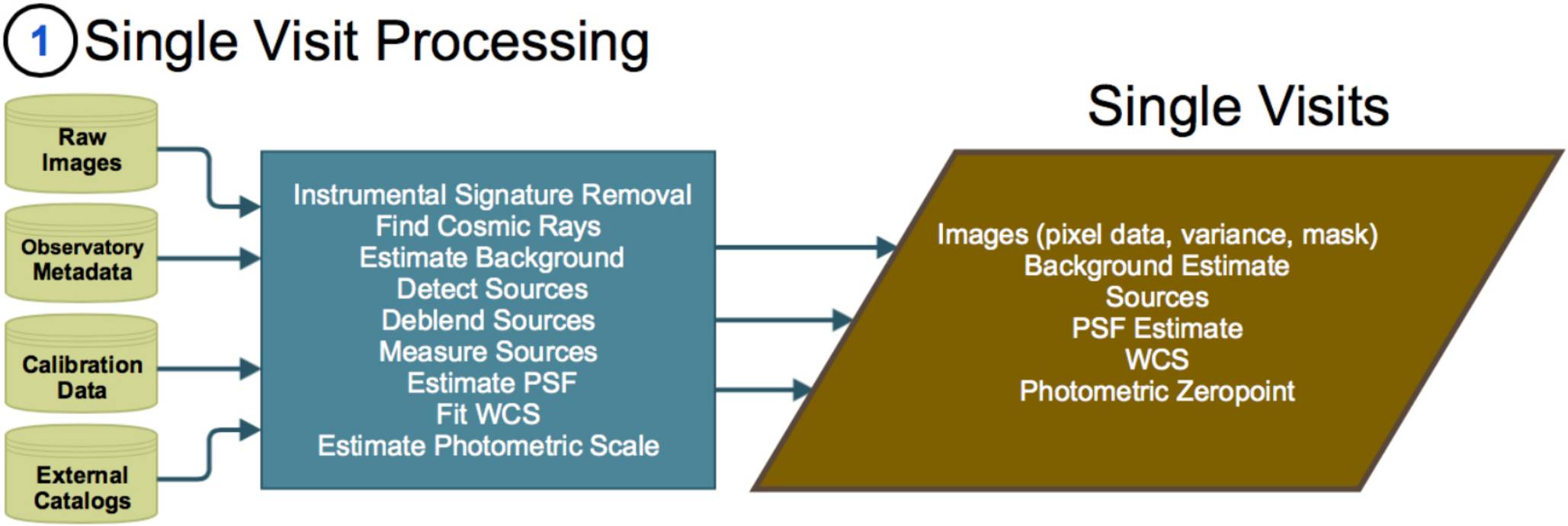
Auxiliary Pipelines

- **Calibration Pipelines**
  - Calibration Products Pipeline: flats + biases + atmospheric models
  - Photometric Calibration Pipeline
  - Astrometric Calibration Pipeline
- **Science Data Quality Assessment Pipelines & Toolkits**
- **Common Image & Catalog Processing Framework**
  - Application Framework (afw)
- **Science Pipeline Toolkit**
  - Enables Level 3 Data Products

Pipeline Data Flow



Single Visit Processing



Pipeline Data Flow

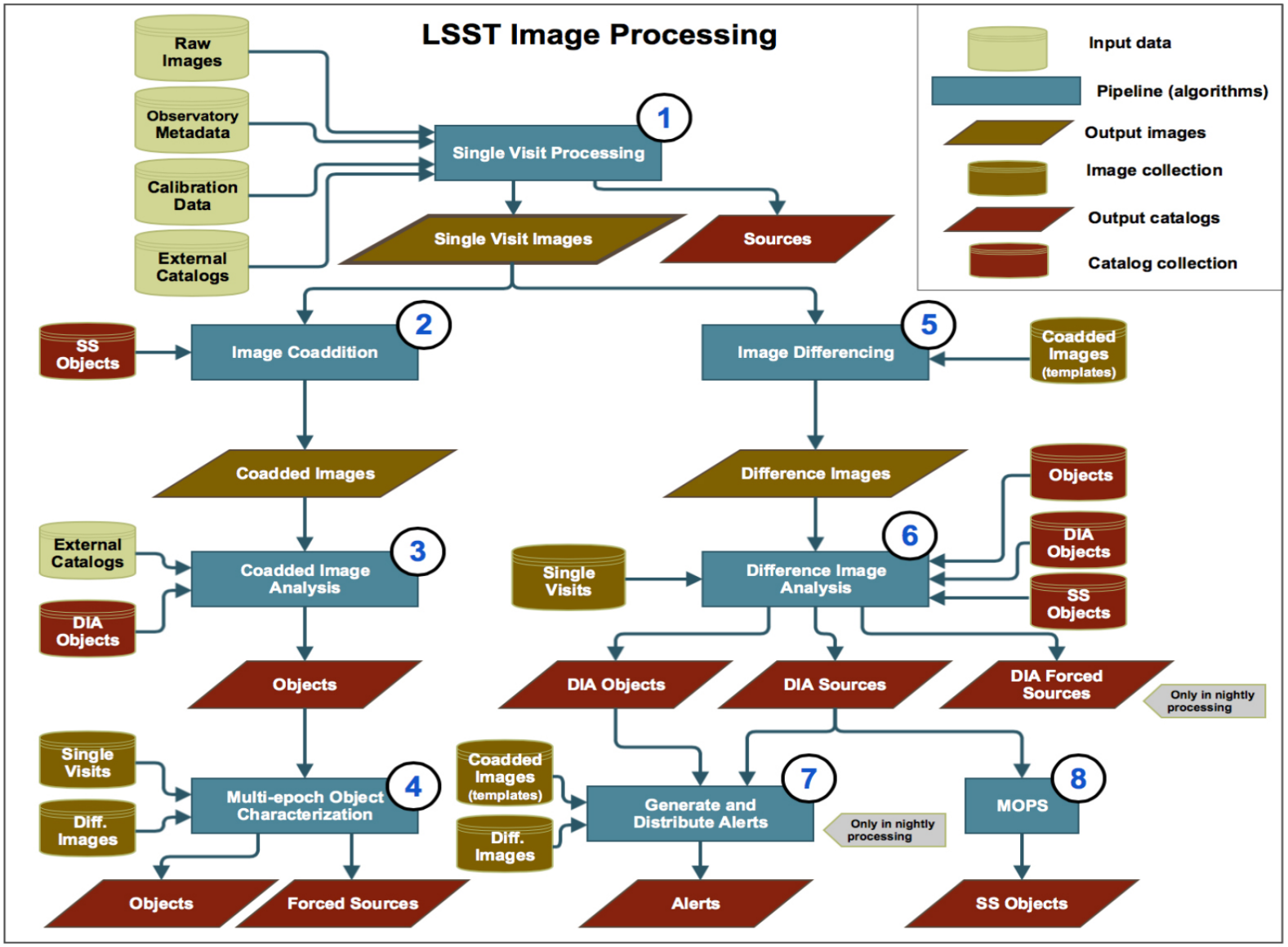
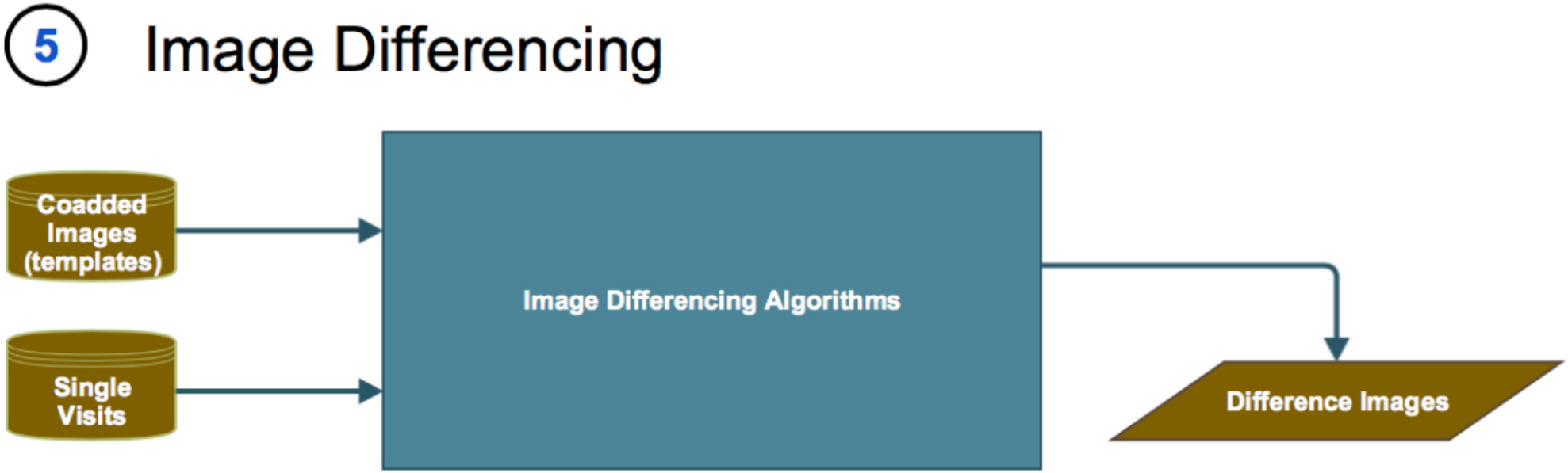
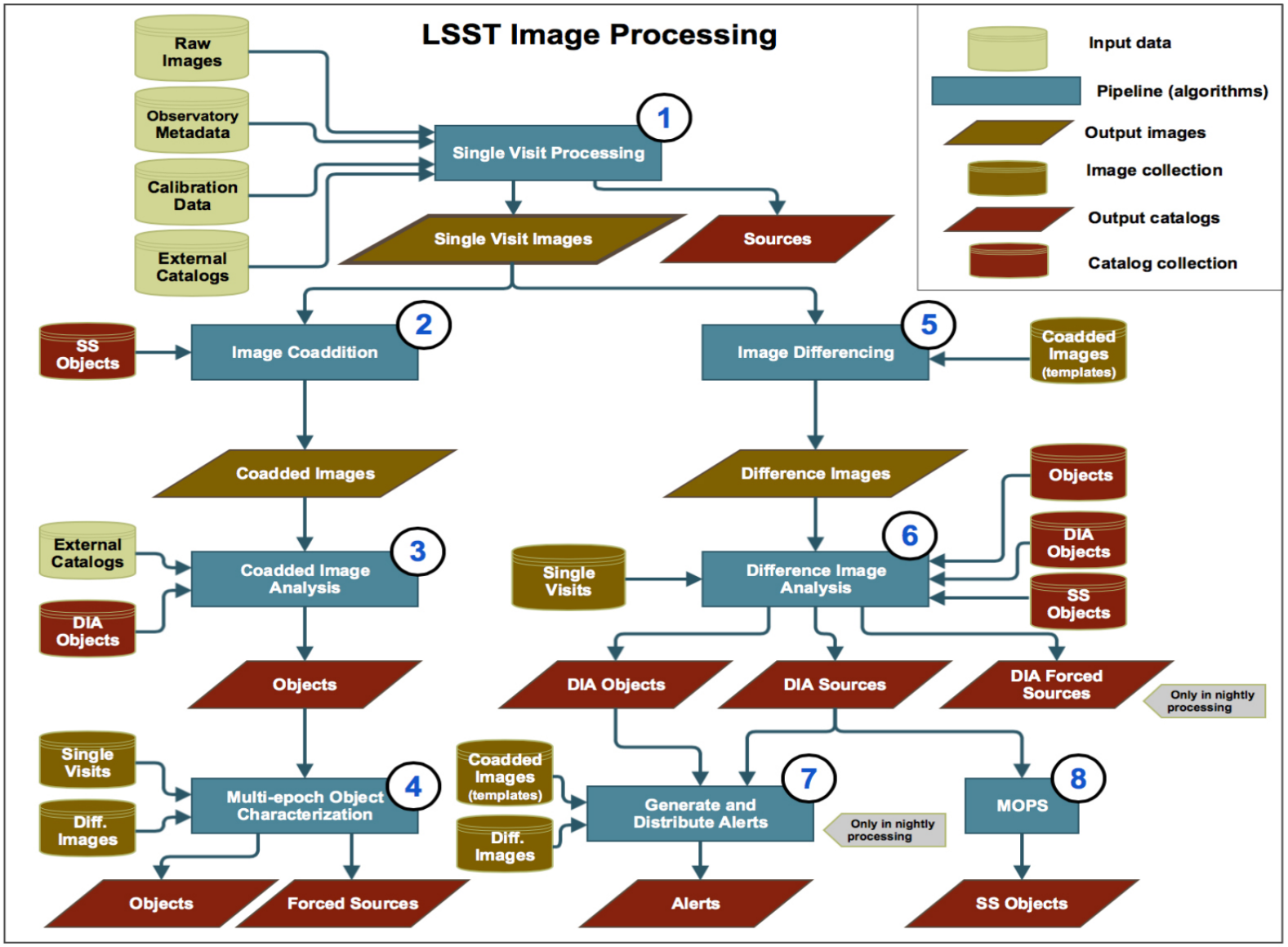


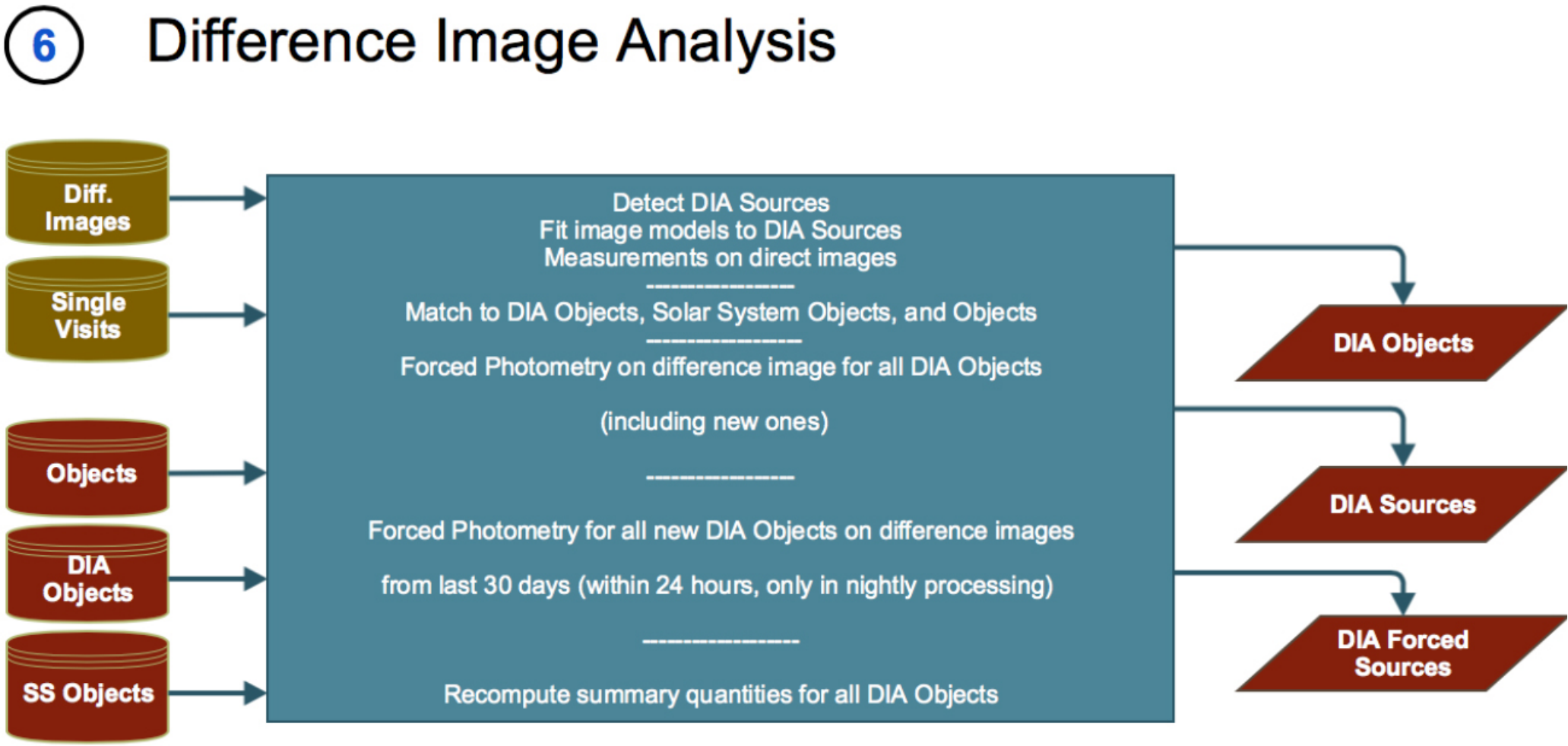
Image Differencing



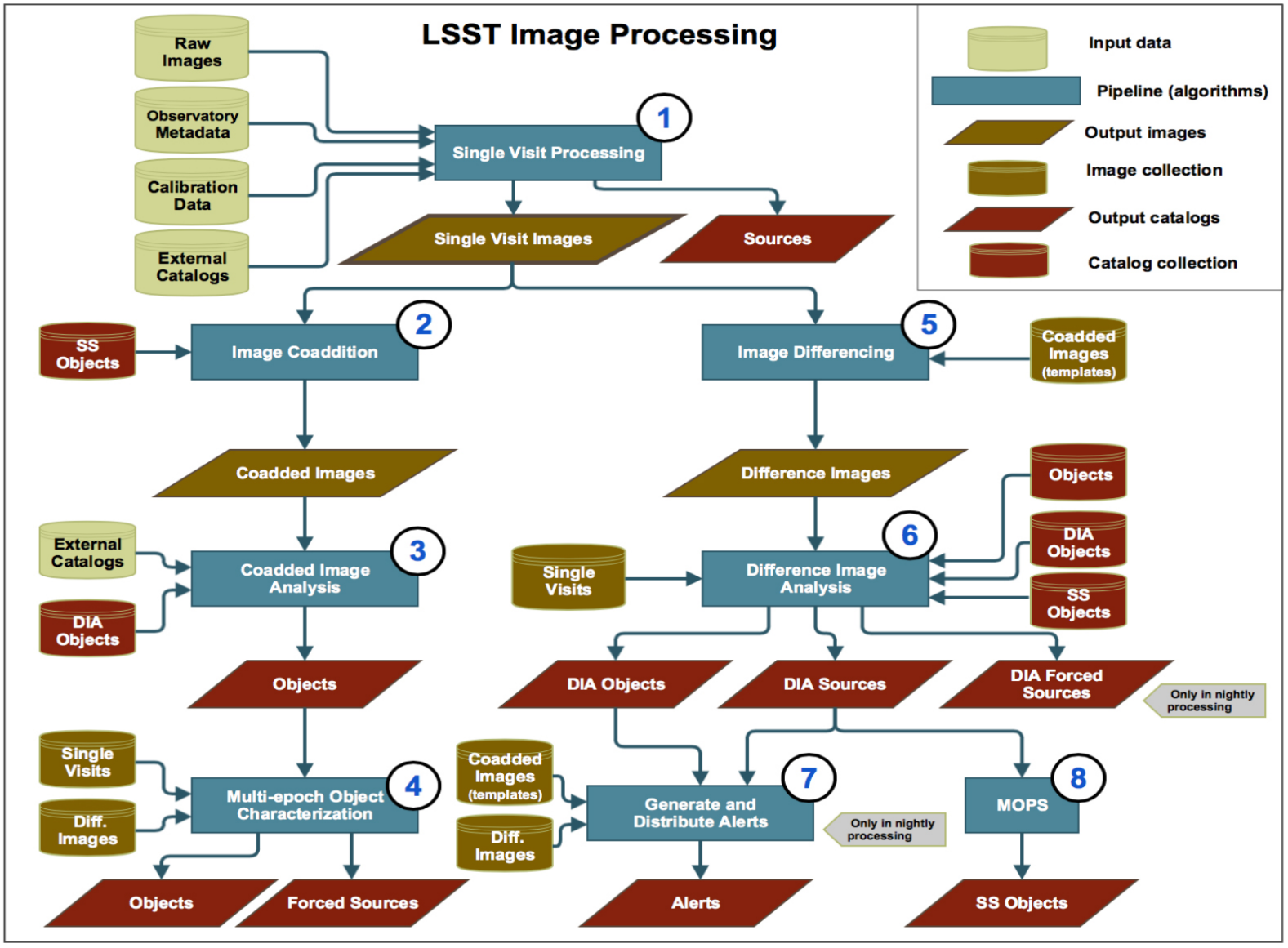
Pipeline Data Flow



Difference Image Analysis

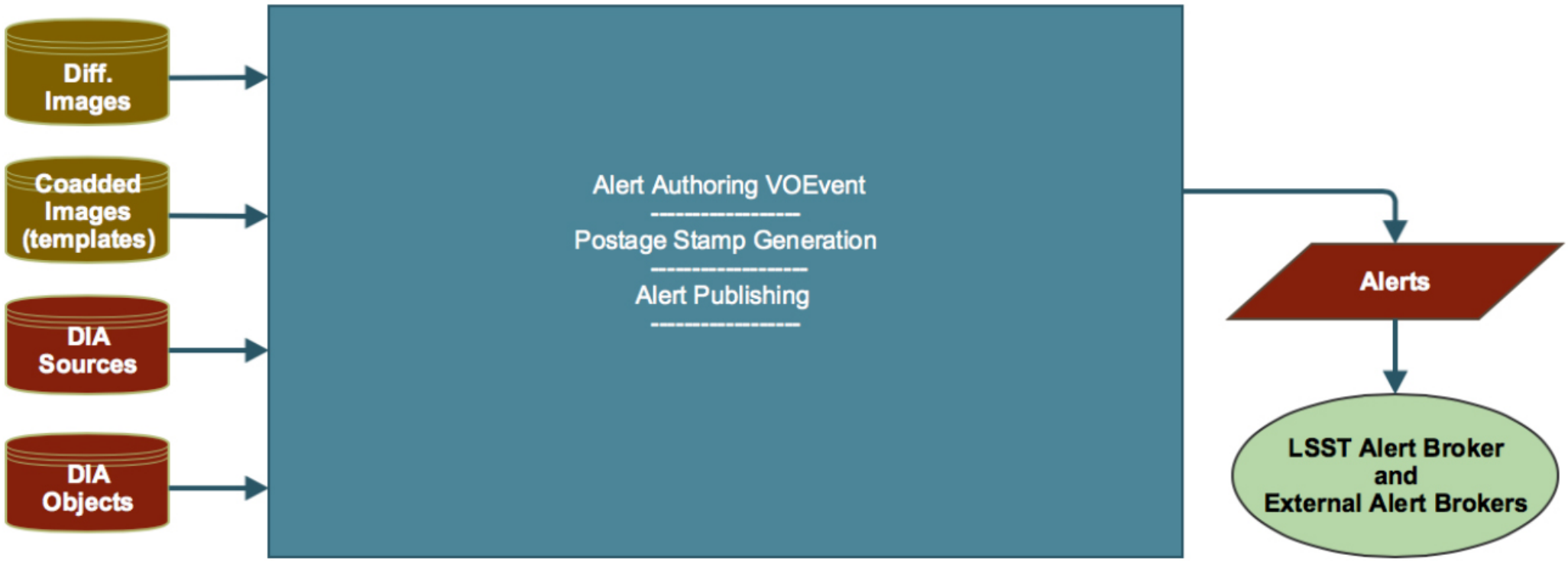


Pipeline Data Flow

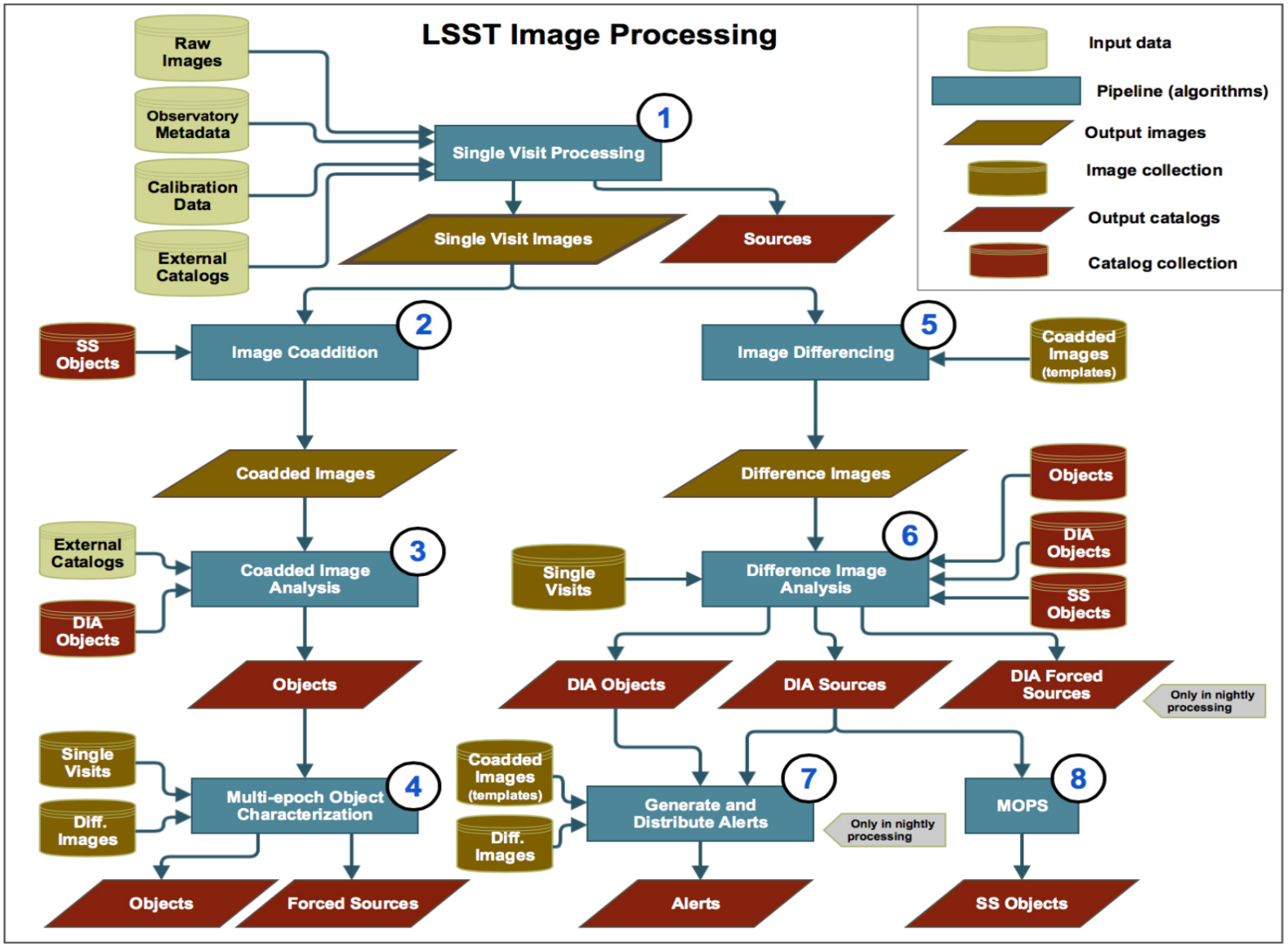


Alert Generation & Distribution

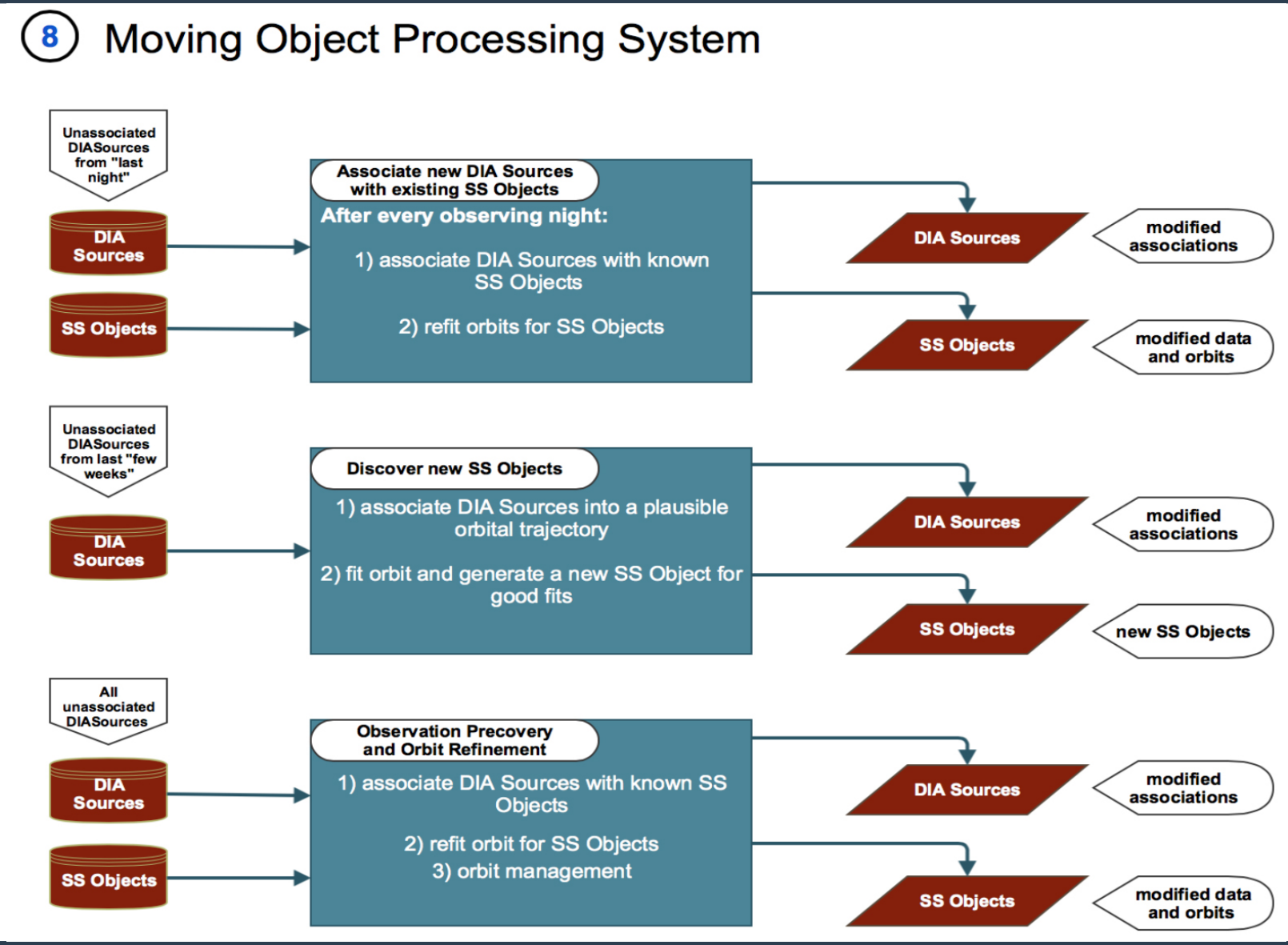
7 Alert Generation and Distribution



Pipeline Data Flow



Moving Object Processing System



Pipeline Data Flow

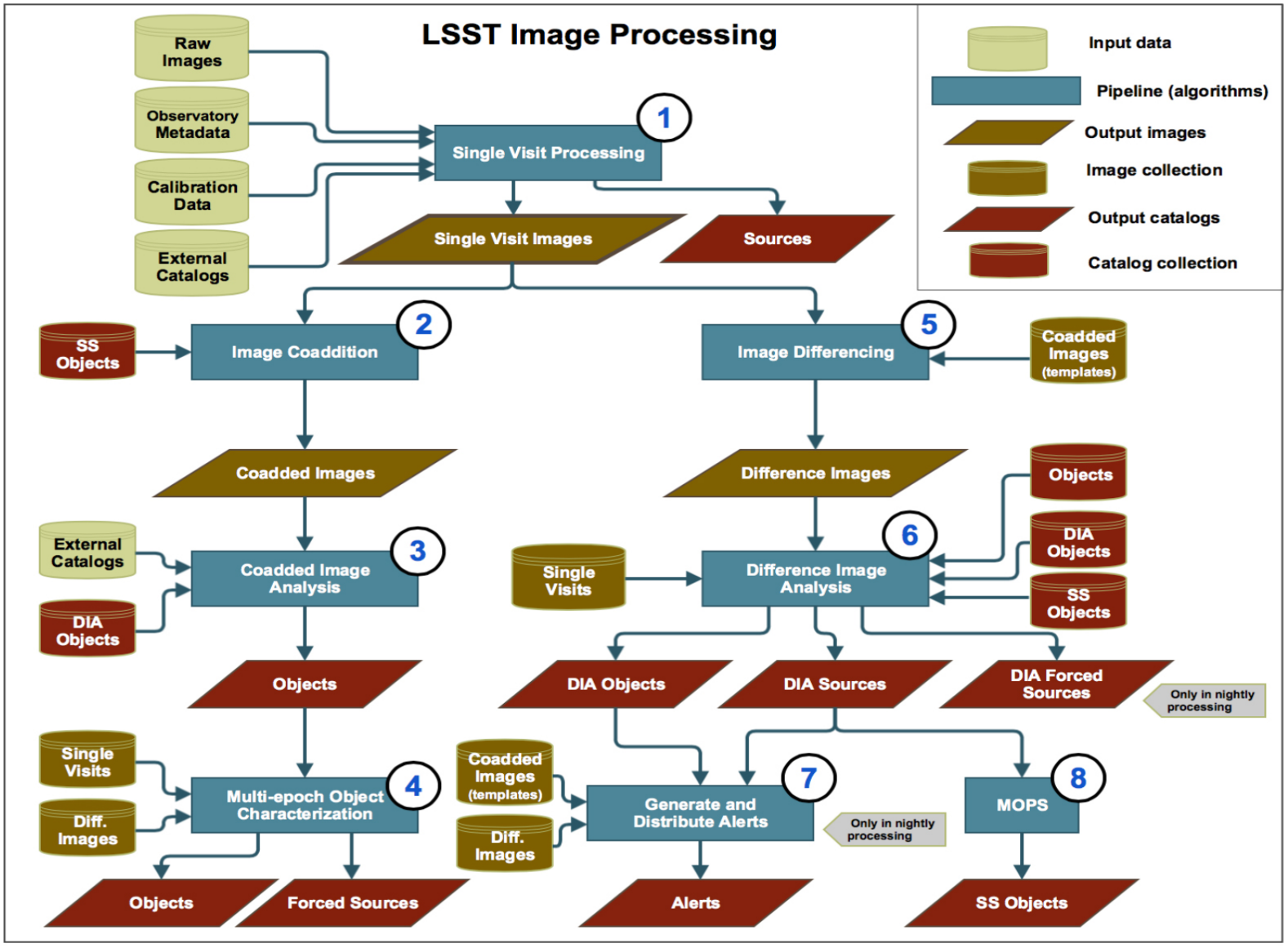
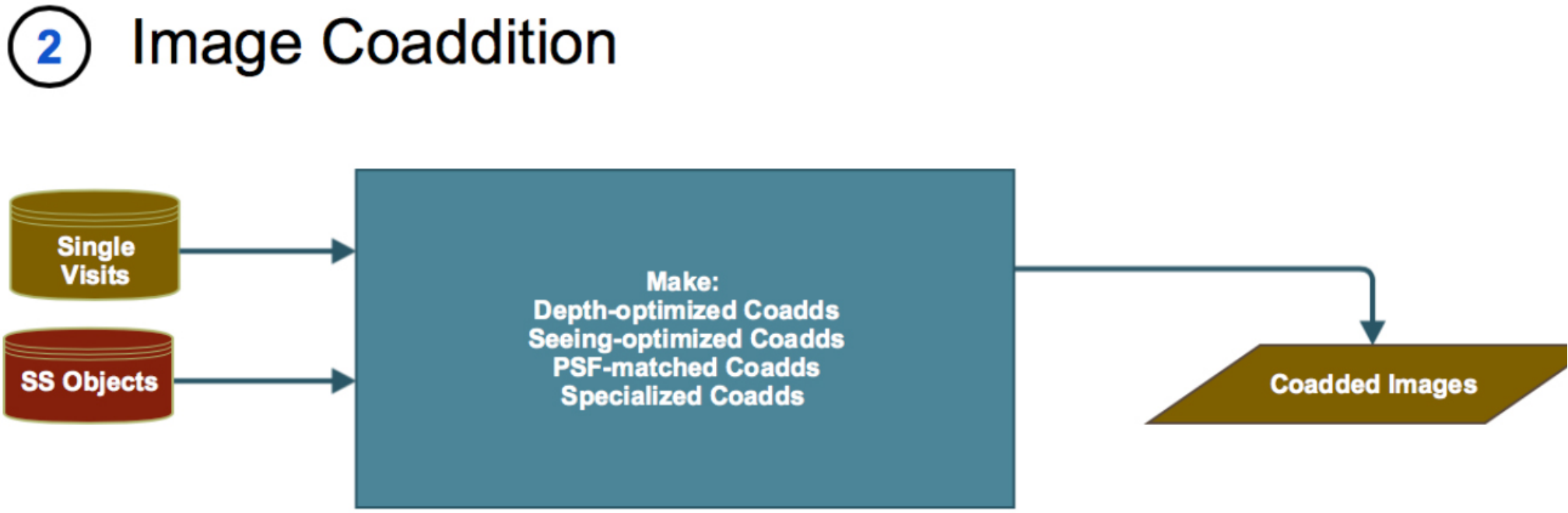
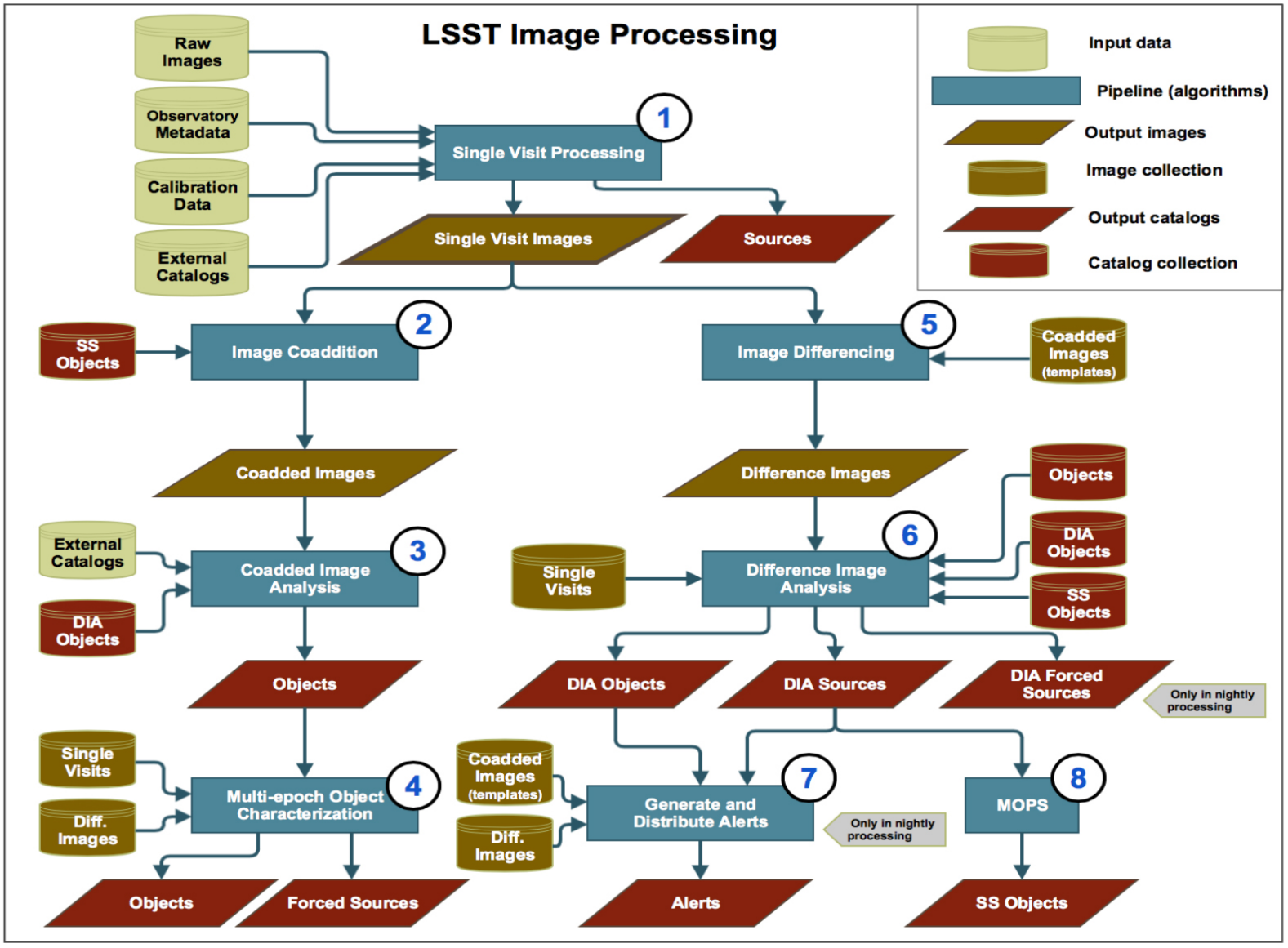


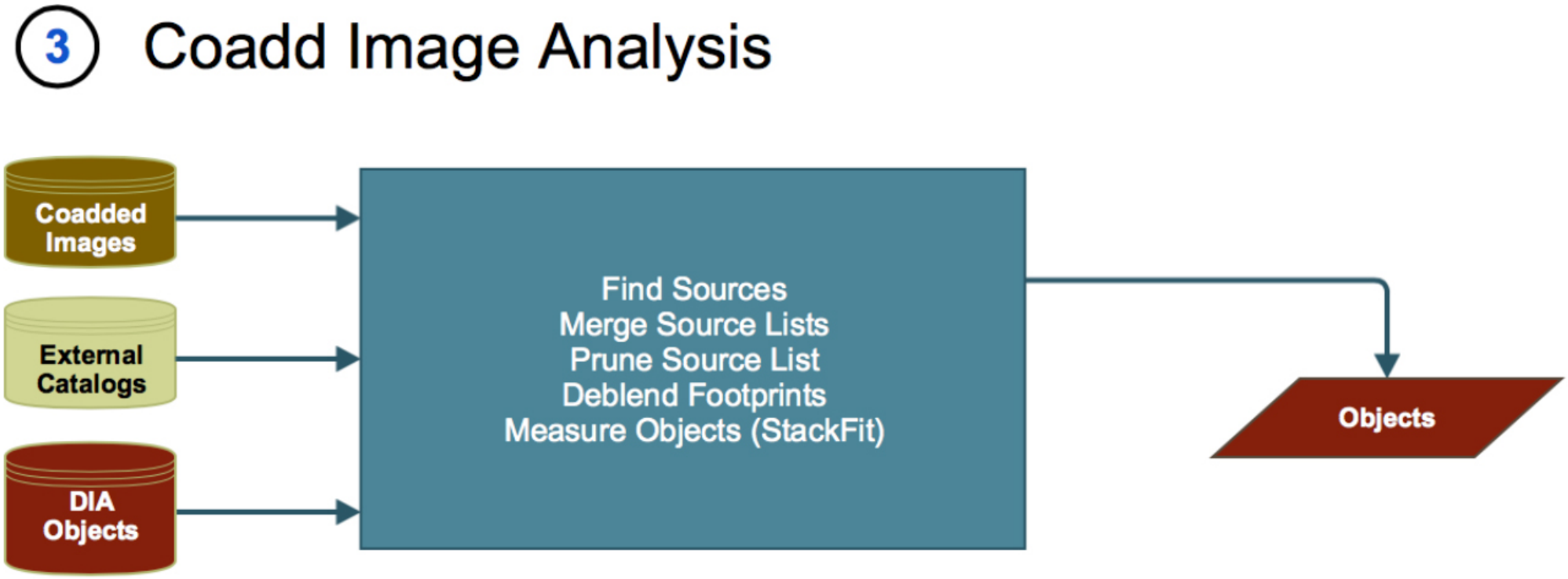
Image Coaddition



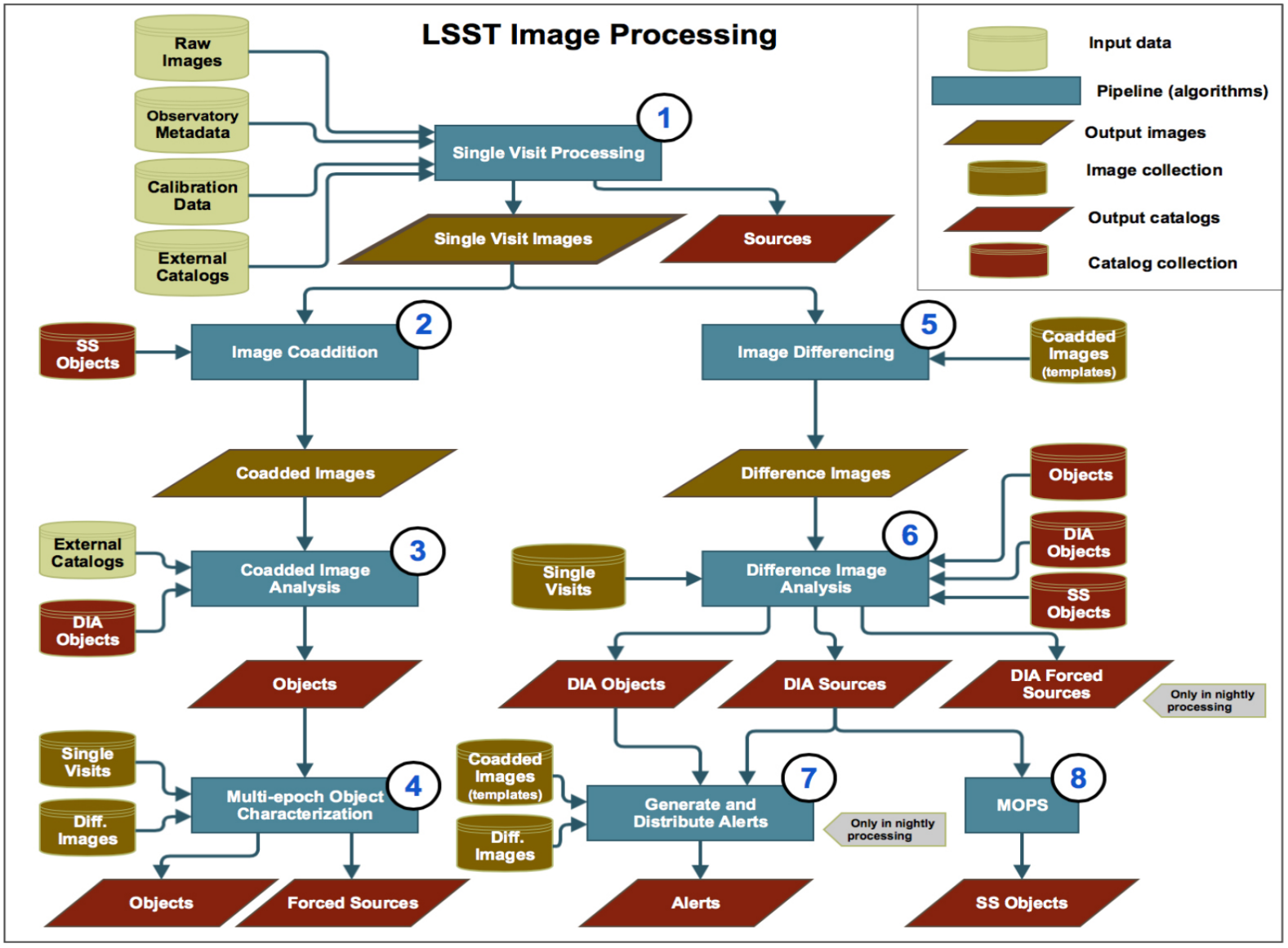
Pipeline Data Flow



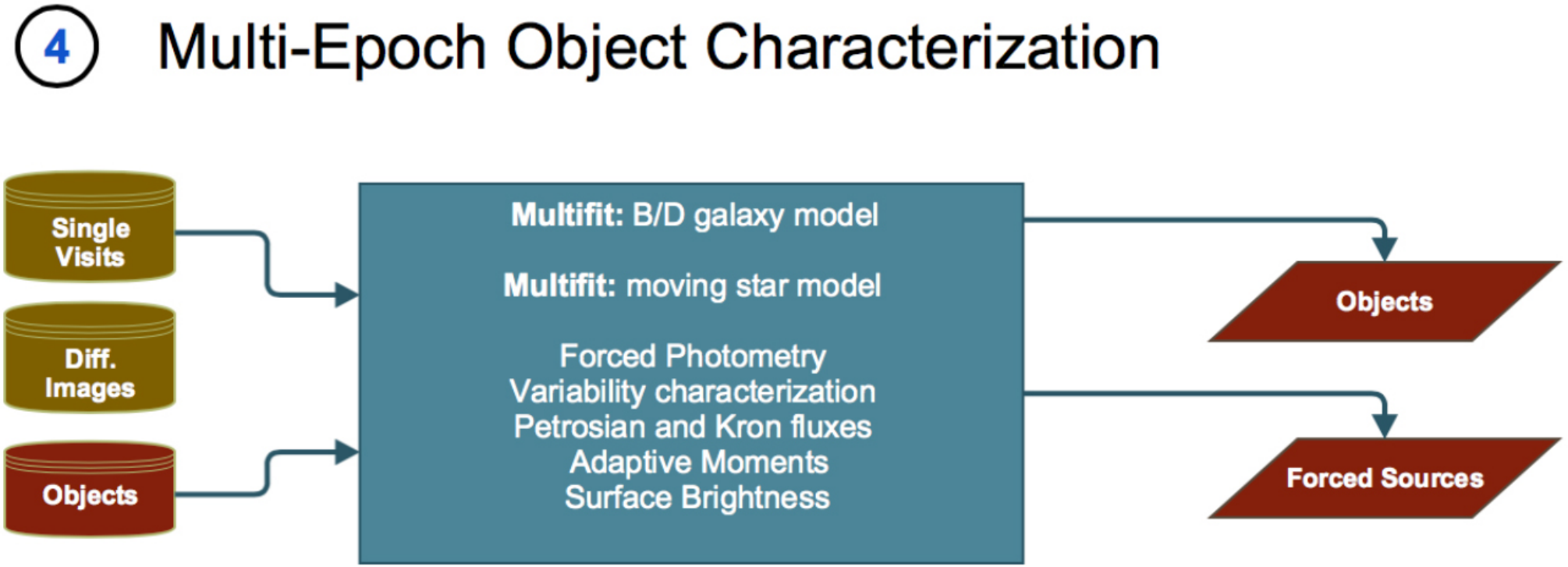
Coadd Image Analysis



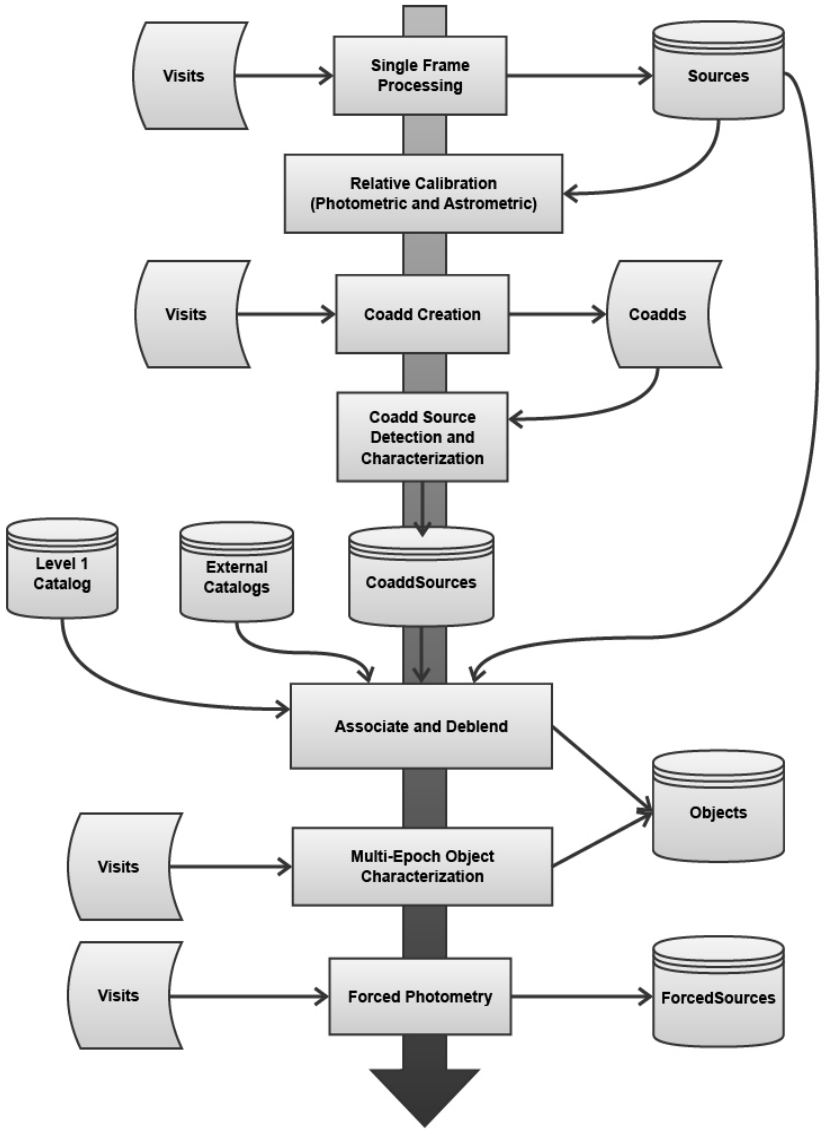
Pipeline Data Flow



Multi-Epoch Object Characterization



Level 2 Pipeline Data Flow



- Single Frame Processing
- Relative Calibration
- Coadd Creation
- Coadd Source Detection
- Coadd Source Deblending & Characterization
- Multi-Epoch Object Characterization
- Forced Photometry

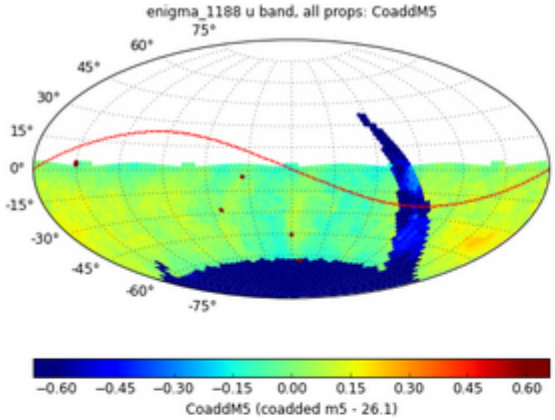
Object Characterization Pipeline Products

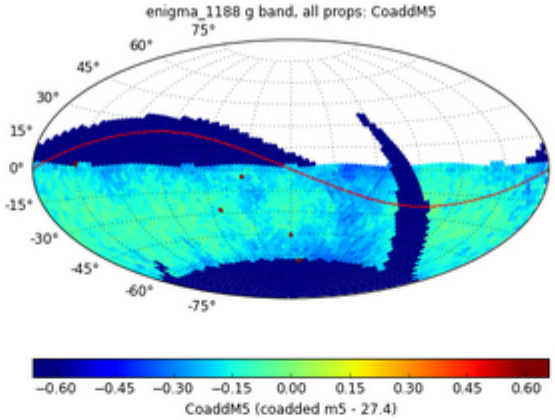
- Single Epoch + Multifit
- Normal + Forced + Crowded Field Photometry
- Deblending (TBD...)

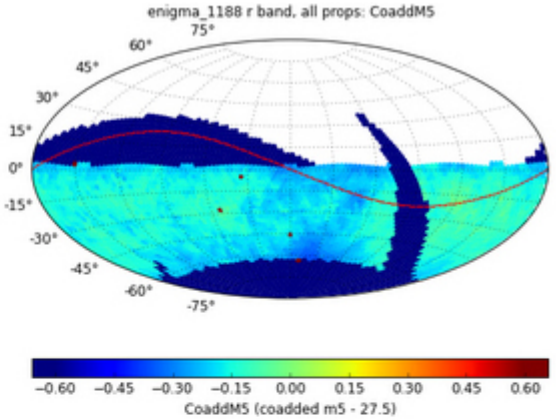
- Point Source Fits
- Bulge+Disk Fits
- Trailed Fits
- Dipole Fits
- Standard Colors (seeing insensitive)

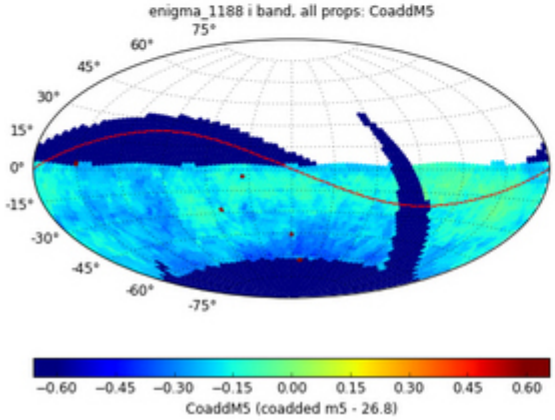
- Centroids
- Adaptive Moments
- Aperture Surface Brightness
- Petrosian Flux
- Kron Flux
- Variability Characterization

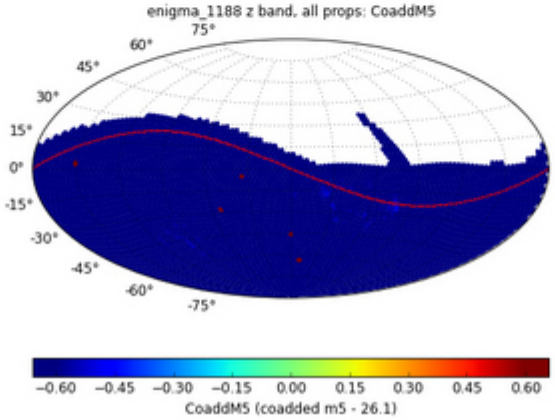
The Cadence Wars

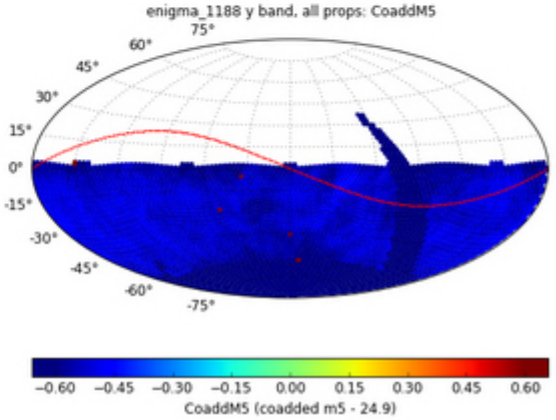












- OpSim + MAF (Metric Analysis Framework)
- LSST Cadence Whitepaper

Take Home Message

- Giant Community Survey
- Targets Most Areas-of-Interest
- Raw Data Available
- Alerts Broadcast in Near Real-Time
- Fully Calibrated Data Available
- LSST Science Book, LDM-151 & LSE-163
- User Products Supported
- Optimal Scan Strategy?

Acknowledgements

- LSST DM Team
- LSST Science Community