





# LSST Science Pipelines















### Who am I?





### Who am I?



### Who am I?

- DE



![](_page_3_Picture_2.jpeg)

## **LSST Science Pipelines overview**

#### Raw Data: 20TB/night

![](_page_4_Picture_2.jpeg)

Sequential 30s images covering the entire visible sky every few days

![](_page_4_Picture_4.jpeg)

Access to proprietary data and the Science Platform require Rubin data rights

#### Prompt Data Products

Alerts: up to 10 million per night

Raw & Processed Visit Images, Difference Images, Templates

Transient and variable sources from Difference Image Analysis

Solar System Objects: ~ 6 million

#### Data Release Data Products

Final 10yr Data Release:

- Images: 5.5 million x 3.2 Gpixels
- Catalog: 15PB, 37 billion objects

#### Rubin Science Platform

Provides access to LSST Data Products and services for all science users and project staff.

Credit: Leanne Guy

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![](_page_4_Picture_19.jpeg)

![](_page_4_Figure_20.jpeg)

#### Credit: Leanne Guy

![](_page_4_Picture_22.jpeg)

## **Rubin Data Product Categories**

![](_page_5_Picture_1.jpeg)

### Prompt Data Products

Real Time Difference Image Analysis (DIA)

- Stream of ~10 million time-domain events per night (Alerts), transmitted to event distribution networks within 60s of camera readout.
- Images, Object and Source catalogs derived from DIA, and an orbit catalog for ~6 million Solar System bodies within 24h.
- Enables discovery and rapid follow-up of time domain events.

![](_page_5_Picture_7.jpeg)

#### User Generated Data Products

User-produced derived, added-value data products

- Deep KBO/NEO, variable star classifications, shear maps, etc ...
- Enabled by services & computing resources at Rubin DACs and via the Rubin Science Platform (RSP).

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![](_page_5_Picture_14.jpeg)

![](_page_5_Picture_15.jpeg)

#### Data Release Data Products

Reduced single-epoch & deep co-added images, catalogs, reprocessed DIA products

- Catalogs of ~37 billion objects (20 billion galaxies, 17 billion stars), ~7 trillion sources and ~30 trillion forced source measurements.
- 11 Data Releases, produced ~annually over 10 years of operation.
- Accessible via the Rubin Science Platform (RSP) & Rubin Data Access Centers (DACs).

10% of computing resources at the US Data Facility (USDF) will be allocated for User Generated data product storage & processing.

Credit: Leanne Guy

![](_page_5_Picture_25.jpeg)

![](_page_5_Picture_26.jpeg)

### **LSST Science Pipeline Data Products**

![](_page_6_Picture_1.jpeg)

Data

You will get data products fast and slow

#### **Annual Data Release Products (DRP)**

11 Data releases in 10 years. Final catalog: 15PB Final pixels: 100PB

#### **Prompt Data Products via nightly alert streams** (Alert Production = AP)

~10 million alerts per night issued within 60 s of shutter close

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![](_page_6_Picture_8.jpeg)

![](_page_6_Picture_9.jpeg)

LSSTScience Platform!

	Portal !	Notebooks!	Jupyter	Web AP is !	
Releases!	AlertStreams!	User Databases!	User Files!	User Computing !	Softwa

![](_page_6_Picture_13.jpeg)

![](_page_6_Picture_14.jpeg)

### **LSST Science Pipeline Data Products**

You will get data products fast and slow

**Annual Data Release Products (DRP)** 

11 Data releases in 10 years. Final catalog: 15PB

Final pixels: 100PB

#### **Prompt Data Products via nightly alert streams** (Alert Production = AP)

~10 million alerts per night issued within 60 s of shutter close

![](_page_7_Picture_8.jpeg)

![](_page_7_Figure_9.jpeg)

![](_page_7_Picture_11.jpeg)

![](_page_8_Figure_0.jpeg)

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Legacy Survey of Space and Time

## **LSST Science Pipelines overview**

- What is a "pipeline", anyway?
  - "a set of data processing elements connected in series, where the output of one element is the input of the next one." (Wikipedia)
- For us, those data processing elements are the scientific algorithms, and the connections are data products.
- For a complex pipeline, we build a Directed Acyclic Graph of the connections
  - Predetermine every data product that will be produced, and the inputs and outputs of every algorithm
  - · Each algorithm is executed as soon as all of the expected data products are available

![](_page_9_Picture_8.jpeg)

![](_page_9_Picture_9.jpeg)

![](_page_10_Figure_1.jpeg)

![](_page_10_Picture_3.jpeg)

## How do we write code in a collaboration?

![](_page_11_Figure_1.jpeg)

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![](_page_11_Picture_3.jpeg)

![](_page_11_Picture_4.jpeg)

#### Lines of LSST Science Pipelines code and comments

![](_page_11_Picture_6.jpeg)

## **Science Pipelines documentation**

#### **LSST Science Pipelines**

#### LSST Science Pipelines »

ISST

#### Search

#### On this page

- The LSST Science Pipelines
- Getting started
- Installation
- Frameworks
- Python modules
- Packages
- **Release details**
- Indices
- More info

### **The LSST Science Pipelines**

The LSST Science Pipelines are designed to enable optical and near-infrared astronomy in the "big data" era. While they are being developed to process the data for the Rubin Observatory Legacy Survey of Space and Time (Rubin's LSST), our command line and programming interfaces can be extended to address any optical or near-infrared dataset.

This documentation covers version v24\_0\_0. Learn what's new. You can also find documentation for other versions.

#### **Getting started**

If you're new to the LSST Science Pipelines, these step-by-step data processing tutorials will get you up and running.

Data processing tutorial series (these were developed using the w\_2021\_33 version of the science pipelines):

- Part 1 Data repositories
- Part 2 Single frame processing
- Part 3 Image and catalog display
- Part 4 Global calibration
- Part 5 Image coaddition
- Part 6 Source measurement
- Part 7 Multi-band catalog analysis.

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![](_page_12_Picture_29.jpeg)

### https://pipelines.lsst.io/

![](_page_12_Picture_31.jpeg)

# LSST developer guide

/ LSST DM Developer Guide

This guide includes a mix of normative requirements and helpful, descriptive, pages. When it's particularly important that you closely follow a standard, we include an annotation box at the top of the page.

Any member of DM can contribute to this guide. It's published from the https://github.com/lsstdm/dm\_dev\_guide GitHub repo. Check out the README to get started.

Jump to: Team · Communications · Project documentation · Work management

**Development guides:** Overview · C++ · Python · Pybind11 · JavaScript · ReStructuredText · DM **Stack** · Git · Editors · Legal · User documentation style

Services: Overview · Jenkins

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#### TEAM

**Onboarding Checklist** 

Team Culture and Conduct Standards

Focus Friday

**Meeting Free Weeks** 

**Empowerment of DM team members** 

Data Release Production

#### COMMUNICATIONS

Slack Culture

Configuring your GitHub username in your Slack profile

**VERA C. RUBIN** SERVATORY

Edition: main

Change edition

Search docs

![](_page_13_Picture_22.jpeg)

#### C Edit on GitHub

#### **LSST DM Developer Guide**

This is an internal guide for LSST DM staff during project construction, and for Rubin Observatory Data Production staff in operations. It's also openly available so that others can understand how we're building the LSST's data management subsystem. In some cases, other Rubin groups (for example Telescope & Site Software) have chosen to follow various sections as it applies to them.

### https://developer.lsst.io/

![](_page_13_Picture_27.jpeg)

## Unit tests

- Tests of a single feature, or of required behavior
- Every line of code should be covered by a test
- Tests ensure that future code changes or new features maintain existing functionality
- Tests of python code can be run by pytest, which will provide a test coverage report and show missed statements or code branches

![](_page_14_Picture_6.jpeg)

```
class AlardLuptonSubtractTest(lsst.utils.tests.TestCase):
    def test_allowed_config_modes(self):
        """Verify the allowable modes for convolution.
        config = subtractImages.AlardLuptonSubtractTask.ConfigClass()
        config.mode =
                     'auto'
        config.mode = 'convolveScience'
                      'convolveTemplate'
        config.mode =
       with self.assertRaises(FieldValidationError):
            config.mode = 'aotu'
    def test mismatched template(self):
        """Test that an error is raised if the template
       does not fully contain the science image.
        .....
        xSize = 200
        ySize = 200
       science, sources = makeTestImage(psfSize=2.4, xSize=xSize + 20, ySize=ySize + 20)
       template, _ = makeTestImage(psfSize=2.4, xSize=xSize, ySize=ySize, doApplyCalibration=True)
        config = subtractImages.AlardLuptonSubtractTask.ConfigClass()
        task = subtractImages.AlardLuptonSubtractTask(config=config)
            self.assertRaises(AssertionError):
            task.run(template, science, sources)
```

![](_page_14_Picture_8.jpeg)

![](_page_14_Picture_9.jpeg)

### **Code review**

### DM-36265: Fix subtractImages failures when compatibility mode is off #236

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![](_page_15_Picture_4.jpeg)

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![](_page_16_Picture_3.jpeg)

#### Ľ. <u></u> >\_ Show in Finder Terminal Settings ĉ 0 Jump to: Date Author Commit Today at 4:43 PM test that raises InvalidParameterError 63f1ca5 Ian Sullivan <sullii... Today at 2:38 PM Today at 1:30 PM da1381e Arun Kannawadi <... f55bb8d Arun Kannawadi <... Today at 1:30 PM M-35207 ef7b216 Jim Bosch <jbosc... Today at 10:36 AM nd aperture corrections. 2051303 Jim Bosch <jbosc... Today at 4:06 AM etection and measurement tests 60ce4e1 Ian Sullivan <sullii... Jan 9, 2023 at 6:... 4606bd0 Ian Sullivan <sullii... Jan 9, 2023 at 6:... Jan 9, 2023 at 6:... de097bb Ian Sullivan <sullii... d2e4e7d Ian Sullivan <sullii... Jan 9, 2023 at 6:... f8e1efc lan Sullivan <sullii... Jan 9, 2023 at 6:... 84ffd45 Bruno Sanchez <b... Jan 9, 2023 at 6:... 5ae0c9e lan Sullivan <sullii... Jan 9, 2023 at 6:... 833bfa4 Ian Sullivan <sullii... Jan 9, 2023 at 6:... 30f43c4 Ian Sullivan <sullii... Jan 9, 2023 at 6:... asure unit tests cc9ece0 Ian Sullivan <sullii... Jan 9, 2023 at 4:... f3dff6f lan Sullivan <sullii... Jan 9, 2023 at 4:... 4decc16 John Parejko <par... Jan 9, 2023 at 1:... 463a89c John Parejko <par... Dec 28, 2022 at... John Parejko <par... Dec 25, 2022 at... bc9de45 PSFs and aperture corrections. 181862c Jim Bosch <jbosc... Jan 5, 2023 at 12... request #240 from lsst/tickets/DM-25132 cmsaunders <cms... Dec 14, 2022 at 7... a7308b0 8b84c9f Clare Saunders <c... Dec 14, 2022 at 7... 520cfd9 Ian Sullivan <sullii... Dec 13, 2022 at 7... ity mode from subtractImages 3d04794 lan Sullivan <sullii... Dec 8, 2022 at 11... 626469f Clare Saunders <c... Dec 9, 2022 at 10... Il request #237 from lsst/tickets/DM-36928 0d53e28 Josh Meyers <jme... Nov 22, 2022 at 1... 213057f Josh Meyers <jme... Nov 18, 2022 at 3...

![](_page_16_Picture_5.jpeg)

### **Continuous integration**

![](_page_17_Figure_1.jpeg)

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![](_page_17_Picture_3.jpeg)

![](_page_18_Figure_0.jpeg)

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![](_page_18_Picture_2.jpeg)

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# **Data Release Processing Overview**

![](_page_19_Figure_1.jpeg)

Produced once a year after the first Data Release

![](_page_19_Picture_4.jpeg)

![](_page_19_Picture_7.jpeg)

## **Prompt Processing Overview**

![](_page_20_Figure_1.jpeg)

Produced nightly, in close to real time

![](_page_20_Picture_4.jpeg)

![](_page_20_Picture_5.jpeg)

![](_page_20_Picture_8.jpeg)

# 1: Single Visit Processing

### **AP and DRP**

- Principal algorithmic components:
  - Image characterization
    - Background fitting
    - PSF modeling
    - Cosmic ray removal
    - Calibration
      - Astrometric
      - Photometric
- Data products: •
  - Source catalogs (src)
  - Calibrated images (calexp)

![](_page_21_Figure_14.jpeg)

![](_page_21_Picture_15.jpeg)

# 2: Image Coaddition

### DRP

- Principal algorithmic components
  - Warping calibrated images to a skymap
  - PSF-matching
  - Identifying and masking artifacts •
  - Modeling Differential Chromatic Refraction (DCR)
  - Stacking warped images
- Data products •
  - Coadded images (e.g. deepCoadd, goodSeeingCoadd, dcrCoadd, ...)

![](_page_22_Figure_11.jpeg)

![](_page_22_Picture_12.jpeg)

# 3: Coadded Image Analysis

### DRP

- Principal algorithmic components
  - Detection of static sources
  - Deblending sources
  - Merging sources into objects
  - Measurements on objects
- Data products
  - Object catalogs (\*Coadd)

![](_page_23_Figure_10.jpeg)

![](_page_23_Picture_11.jpeg)

![](_page_23_Picture_12.jpeg)

# 4: Object Characterization

### DRP

- Principal algorithmic components
  - Source measurements
  - Stellar motion fitting
  - Variability measurements
  - Photometric redshifts
- Data products
  - Object catalogs (\*Coadd\_)
  - Forced source catalogs **\*Coadd\_forcedSrc**)

![](_page_24_Figure_11.jpeg)

![](_page_24_Picture_12.jpeg)

![](_page_24_Picture_13.jpeg)

# 5: Image Differencing

### **AP and DRP**

- Principal algorithmic components
  - Warping (template)
  - PSF matching
- Data products
  - Difference images (\*Diff\_differenceExp)

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![](_page_25_Figure_8.jpeg)

![](_page_25_Picture_9.jpeg)

![](_page_25_Picture_10.jpeg)

Coadded Images templates

# 6: Difference Image Analysis

### **AP and DRP**

- Principal algorithmic components
  - **Detection of DIA sources**
  - Measurement
  - Forced measurement on objects from last 30 days
  - Object association
- Data products
  - Difference Image Analysis (DIA) sources **\*Diff\_diaSrc**)
  - DIA objects (apdb database)

![](_page_26_Figure_11.jpeg)

![](_page_26_Picture_12.jpeg)

## 7: Alert Distribution

### AP

- Principal algorithmic components
  - Alert packaging
  - Cutout extraction
  - Alert filtering
- Data products
  - Packaged alerts

![](_page_27_Figure_9.jpeg)

![](_page_27_Picture_10.jpeg)

# 8: Solar System Processing

### **AP and DRP**

- Principal algorithmic components
  - Known SSO association
  - Moving object association (linking)
  - Orbit fitting
- Data products
  - Solar System object catalog
  - Updated **MPCORB** database

![](_page_28_Figure_10.jpeg)

![](_page_28_Picture_11.jpeg)

![](_page_28_Picture_12.jpeg)

![](_page_29_Figure_1.jpeg)

![](_page_29_Picture_8.jpeg)

![](_page_29_Picture_9.jpeg)

![](_page_29_Picture_10.jpeg)

![](_page_30_Picture_0.jpeg)

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![](_page_30_Picture_4.jpeg)

![](_page_30_Picture_5.jpeg)

## How to get involved

- This class is a great start!
- Many people in the department working on LSST:
- Science pipelines developers
  - Ari Heinze
  - Brianna Smart
  - Erin Howard
  - Ian Sullivan
  - John Parejko
  - Krzystof Findeisen
  - Meredith Rawls
  - Nima Sedaghat

- Data Management Scientists Colin Slater Melissa Graham Peter Yoachim

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![](_page_31_Picture_17.jpeg)

 Commissioning Scientists Bryce Kalmbach Chris Suberlak Neven Caplar

- Professors
- Andrew Connolly
- Eric Bellm
- Mario Juric
- Zeljko Ivezic

![](_page_31_Picture_25.jpeg)

![](_page_31_Picture_26.jpeg)