Merian reductions with the LSST Science Pipelines

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Project and Community Workshop
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The Merian Survey

Designed to explore the nature of dark matter, star formation and feedback in dwarf galaxies.

Plans to map **~850 deg^2** of the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) wide survey footprint in two medium-band filters (**N708/N540**) over 60 nights with **DECam**.

Will carry out the first high-S/N measurements of **weak gravitational lensing around dwarf galaxies** (~85,000 SF dwarfs in the range $8 < \log M_*/M_\odot < 9$), detecting Hα and [OIII].

(How) Can we reduce Merian data with the LSST Science Pipelines?

Can we: **Yes!** How: **after a little bit of setup.**

Princeton Tiger cluster in the HPC Research Ctr.
Photo credit: Floe Fusin-Wischusen, PICSciE

Working alongside DM, the Merian team are reducing all of their DECam observations using the Princeton University Tiger cluster.

Tiger consists of **408 nodes** (Intel Skylake CPUs), with **192 GB** of memory and **40 cores** per node.

Merian data reduction campaigns:

- **DR1**: lsst_distrib w_2022_29 (Rubin Env 4.0.1)
- **DR2**: lsst_distrib w_2023_33 (Rubin Env 7.0.2)

A full (c. 2021) set of setup instructions is available via this note: hackmd.io/@lsk/merian.

Required raw data

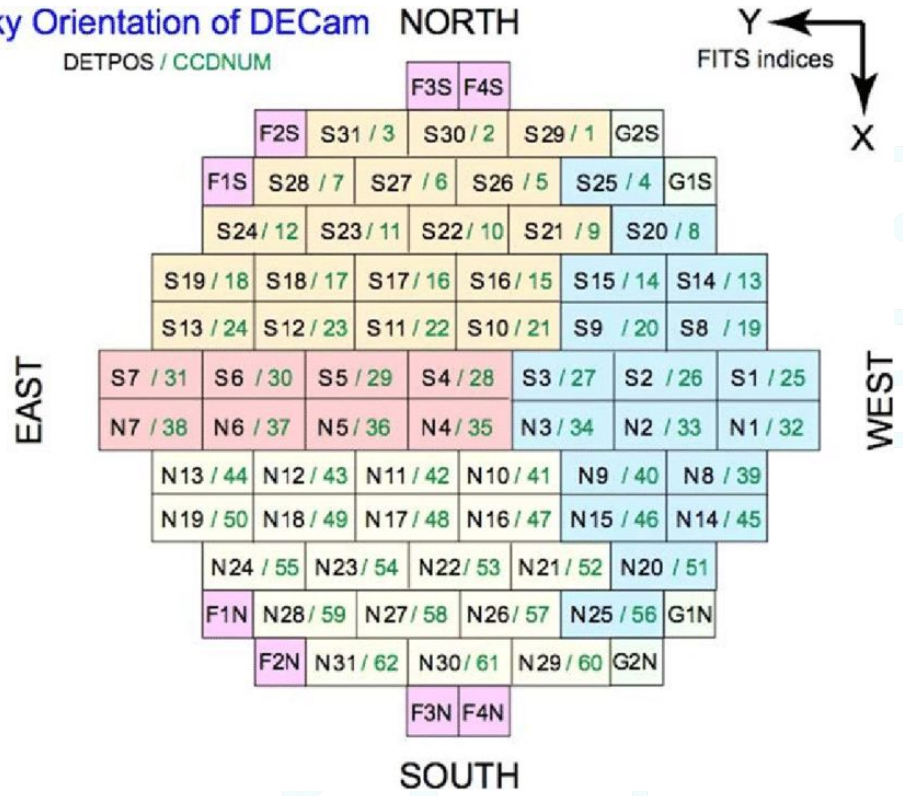
All DRP data reductions can proceed with these DECam raw data:

Primary science frames: `object`

Bias frames: `zero`

Flat frames: `domeflat`

At present, the LSST Science Pipelines does not support super calibrations (flats, biases) produced by other data reduction pipelines (e.g., the DECam Community Pipeline).



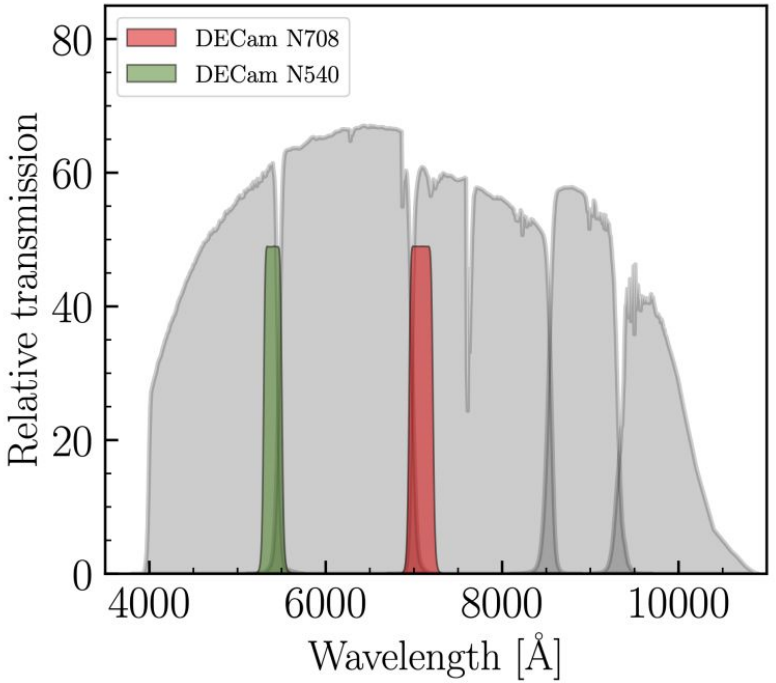
Register new filters

Before ingesting raw science frames, all necessary filters need to be defined in the obs_decam repo and the skymap repo.

A map of camera filter name to reference catalog filter name is also required in the filter map:

```
'N708': 'i'
'N540': 'g'
```

Broadband and many narrow/medium-band filters have already been defined in obs_decam, so this step may not be required.



Adapted from Figure 8, Luo et al. 2023

Create an empty Gen3 Butler repository

This can be achieved in one of two ways:

Option 1 (quickest/easiest)

Create a SQLite database

1. `butler create $REPO`

Option 2 (most efficient)

Create a PostgreSQL database

1. Create an empty PostgreSQL database
2. Construct the seed config file:
   a. Datastore root
   b. Registry database
3. Make an authentication file:
   a. Location: ~/.lsst/db-auth.yaml
   b. Contains: URL, Username, Password
4. `butler create --seed-config \ seed-config.yaml $REPO`

Final preparatory steps

Add the DECam **instrument** to the data repository:

```
butler register-instrument $REPO lsst.obs.decam.DarkEnergyCamera
```

Generate reference catalogs (**refcats**):

Reference catalogs are required for photometric/astrometric calibration.

Option 1: `butler ingest-files`

Option 2: `butler transfer-datasets`

Register the **skyMap**:

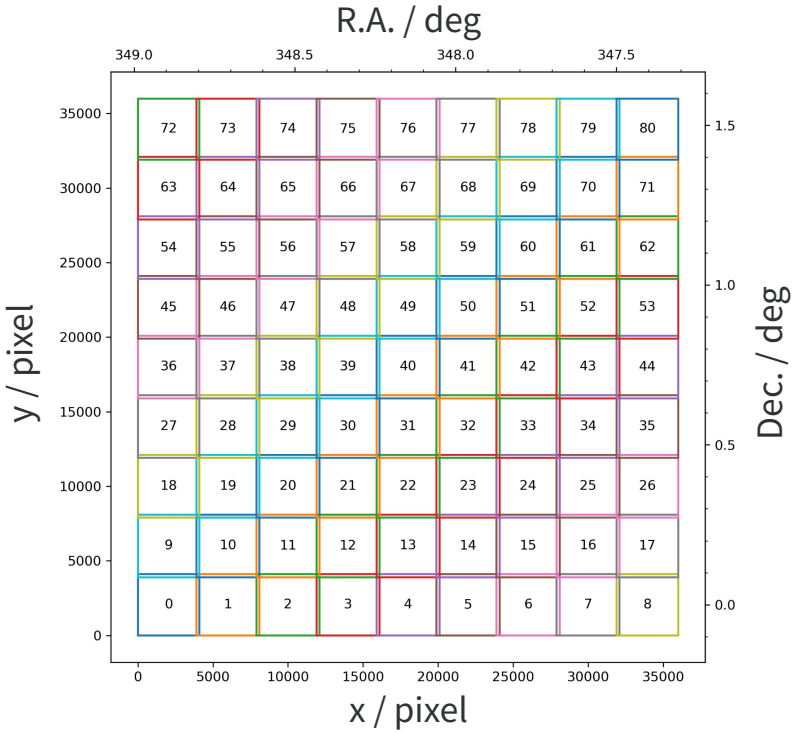
```
butler register-skymap $REPO \
-C $OBS_DECAM_DIR/config/makeSkyMap.py \
-c name='decam_rings_v1'
```

Write **curated calibrations** data, which describe various aspects of the camera and survey:

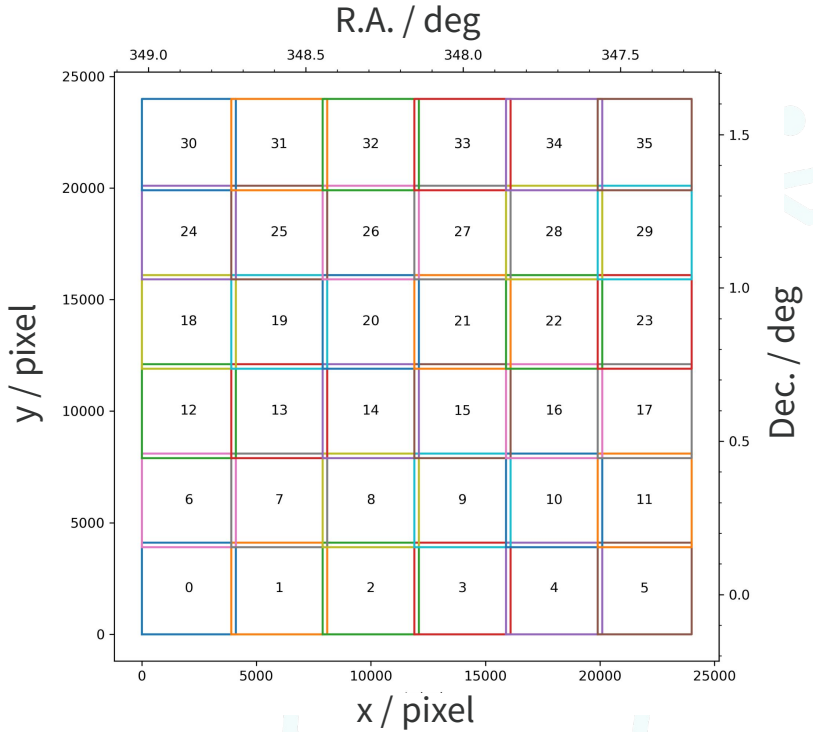
```
butler write-curated-calibrations $REPO lsst.obs.decam.DarkEnergyCamera
```

Skymaps (tract 9704)

hsc_rings_v1 (0.168"/pixel)



decam_rings_v1 (0.262"/pixel)



Ingest and characterize raw data

We can **ingest raw data** (science, biases, flats) into the data Butler simply:

```
butler ingest-raws $REPO $FILES --transfer link
```

Data can be transferred in a number of different ways, e.g.: `link`, `copy`, `move`, `direct`.

Once all raw data have been ingested, we can **define visits** from exposures in the butler registry:

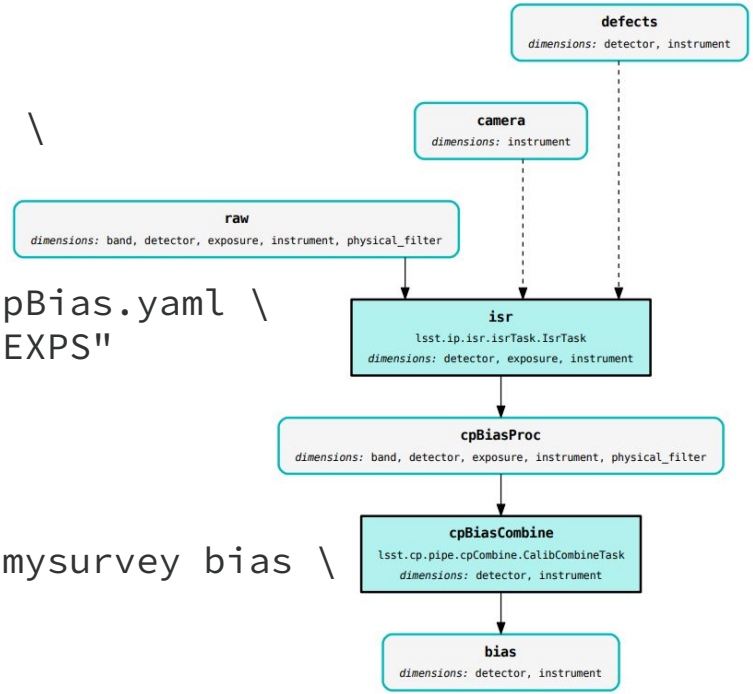
```
butler define-visits $REPO lsst.obs.decam.DarkEnergyCamera
```

Without this last step, processing steps after ISR (i.e., `characterizeImage` onwards) will fail with: `RuntimeError: QuantumGraph is empty`.

Construct and certify super biases

First, **construct** super biases using a list of bias exposures:

```
pipetask --long-log \
run --register-dataset-types -j 12 \
--instrument lsst.obs.decam.DarkEnergyCamera \
-b $REPO
-i my/input/collections \
-o DECam/calib/mysurvey/bias \
-p $CP_PIPE_DIR/pipelines/DarkEnergyCamera/cpBias.yaml \
-d "instrument='DECam' AND exposure IN $BIASEXPS"
```



Then, **certify** the biases for a given date range:

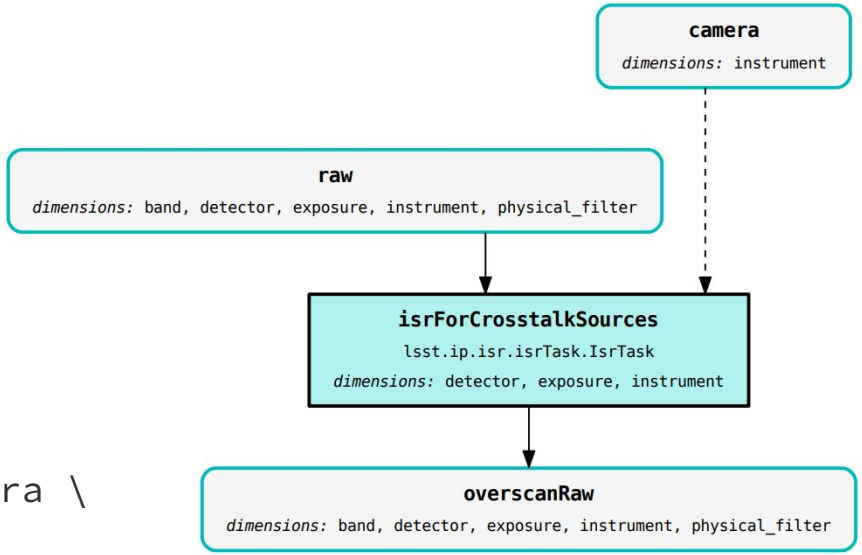
```
butler certify-calibrations \
$REPO DECam/calib/mysurvey/bias DECam/calib/mysurvey bias \
--begin-date 2021-01-01T00:00:00 \
--end-date 2022-06-30T23:59:59
```

NB: It is not recommended to run with `--register-dataset-types` beyond initial setup!

Generate crosstalk sources

Generate crosstalk sources using **step 0** of the Data Release Production (DRP) pipeline for Merian.

Crosstalk sources need to be generated for any raw we want to run actual ISR on (i.e., raw flats and raw science frames):




```
pipetask --long-log \
run --register-dataset-types -j 12 \
--instrument lsst.obs.decam.DarkEnergyCamera \
-b $REPO \
-i my/input/collections \
-o DECam/calib/mysurvey/crosstalk \
-p $DRP_PIPE_DIR/pipelines/DECam/DRP-Merian.yaml#step0 \
-d "instrument='DECam' AND exposure IN $SCIEXPS"
```

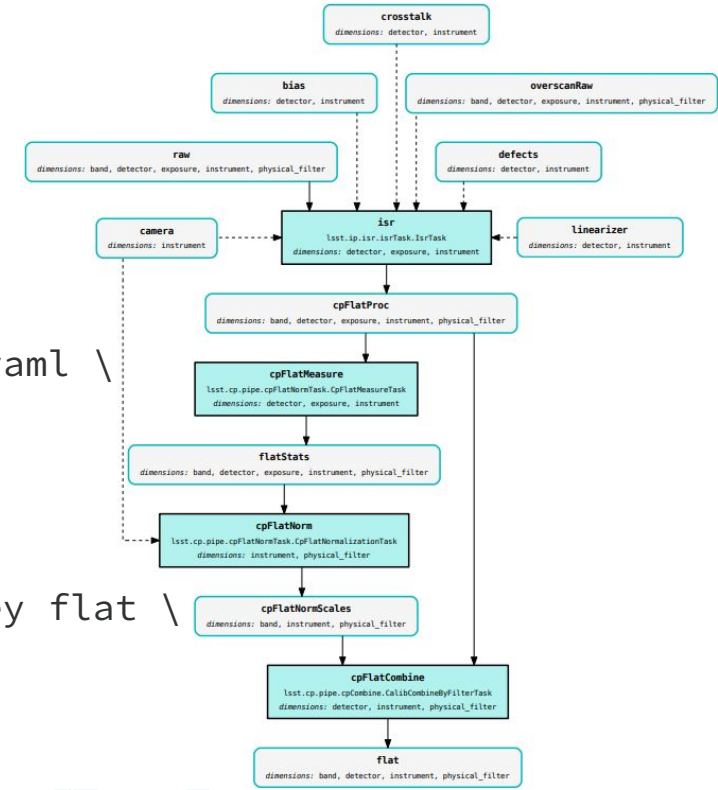
Construct and certify super flats

First, **construct** super flats using a list of flat exposures:

```
pipetask --long-log \
run --register-dataset-types -j 12 \
--instrument lsst.obs.decam.DarkEnergyCamera \
-b $REPO \
-i my/input/collections \
-o DECam/calib/mysurvey/flat \
-p $CP_PIPE_DIR/pipelines/DarkEnergyCamera/cpFlat.yaml \
-d "instrument='DECam' AND exposure IN $FLATEXPS"
```

Then, **certify** the flats for a given date range:

```
butler certify-calibrations \
$REPO DECam/calib/mysurvey/flat DECam/calib/mysurvey flat \
--begin-date 2021-01-01T00:00:00 \
--end-date 2022-06-30T23:59:59
```



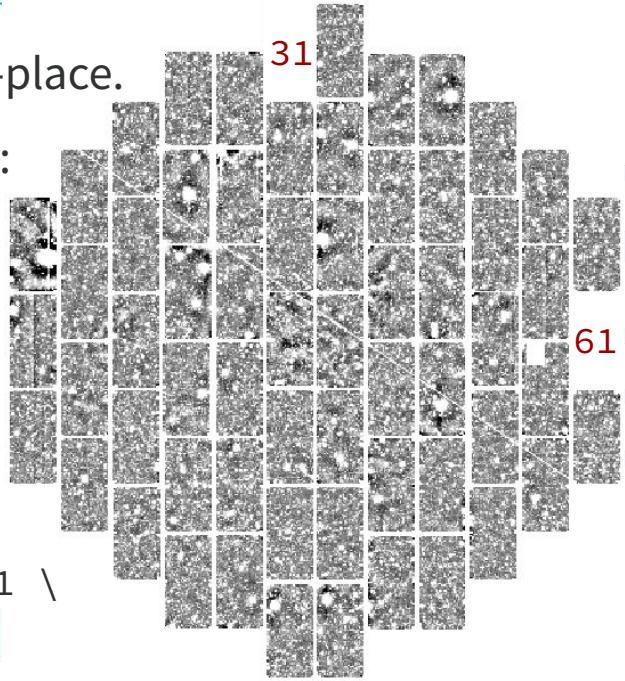
Data Release Production

All necessary raw and calibration datasets should now be in-place.

Standard Merian DRP processing consists of a series of steps:

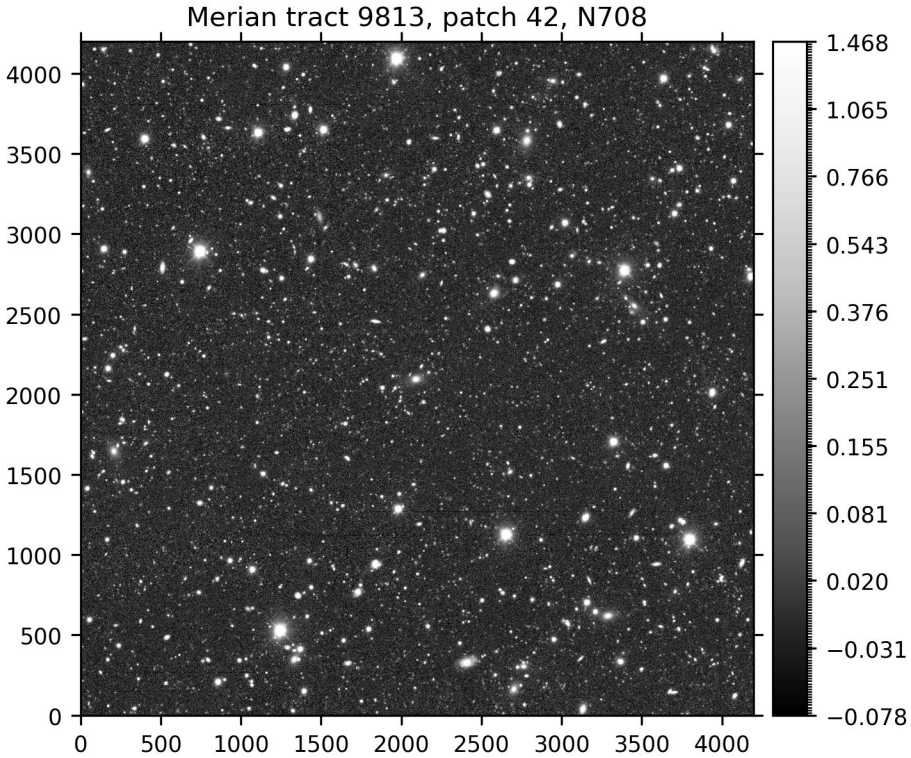
```
pipetask --long-log \
run --register-dataset-types -j 12 \
--instrument lsst.obs.decam.DarkEnergyCamera \
-b $REPO \
-i $INPUT \
-o $OUTPUT \
-p $DRP_PIPE_DIR/pipelines/DECam/DRP-Merian.yaml#step1 \
-d "instrument='DECam' AND $DATAQUERY"
```

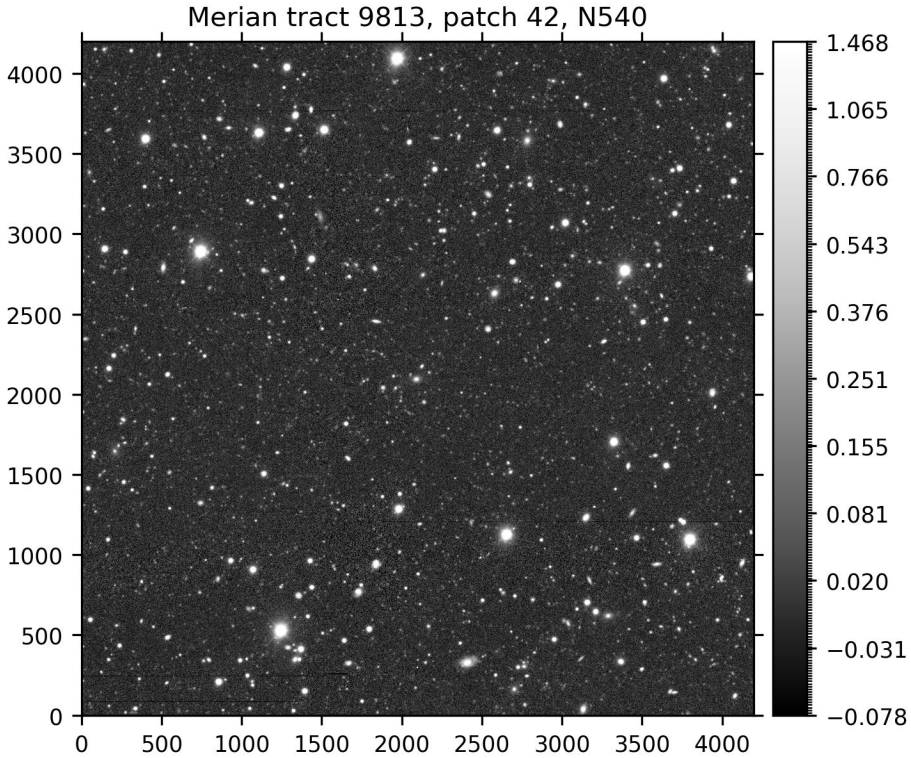
Consult the pipeline YAML description text for more information on expected data queries for each step.



Visit-level full focal plane, Merian visit 972108.
Detectors 31 & 61 are not typically processed.
Note the satellite trail streaking across!

Coadd level outputs






Merian tract 9813, patch 42

Amp-to-amp offset corrections in DECam

HSC imaging in known to exhibit a subtle ~1-2 count offset between amps.

DM-23794 implemented an empirical amp-to-amp offset correction technique within ISR processing for HSC.

Coming soon! DM-38776 will generalize our amp offset correction task for *any* camera!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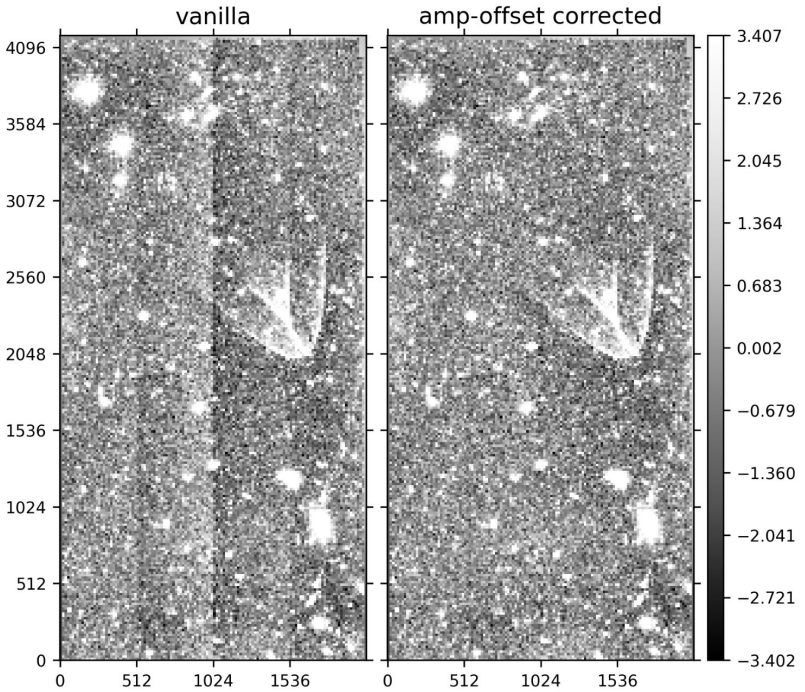
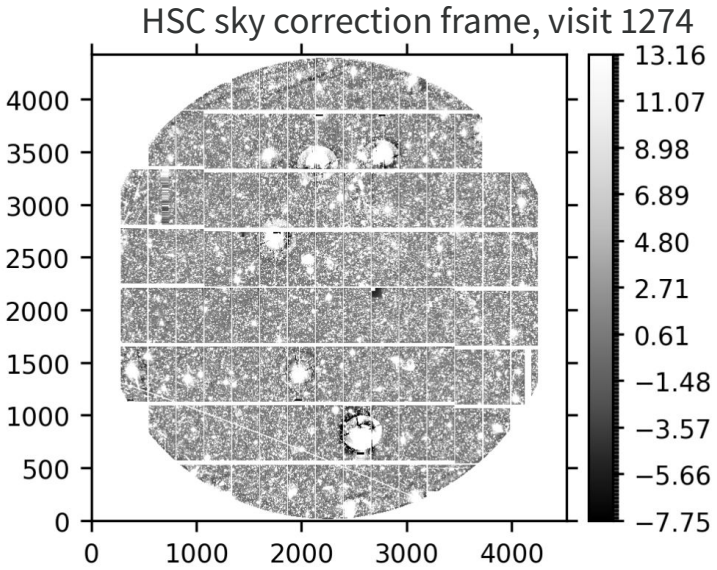


HSC visit 1252 (i-band), detector 68, 30s

More things on the horizon (potentially)…

- Implement the sparse HEALPix mapping task, **HealSparse**, in standard DECam data reductions.
  - Allows for construction of PSF and imaging depth maps.
- Consider **full-focal plane sky correction** efforts.
  - DECam coadd-level images are currently constructed based on per-detector background solutions.
- Replacement of the **jointcal** astrometric / photometric calibration task.
  - HSC processing now uses FGCM / gbdesAstrometricFit.

Community contributions into obs_decam have been immensely successful to-date, and DM would love to work with others to help address further modifications.



jointcal

`lsst.jointcal.jointcal.JointcalTask`

dimensions: instrument, physical_filter, skymap, tract

Summary

The Merian team have **successfully reduced DR1** using the LSST Science Pipelines!

Merian data processing beginning for **DR2 *soon***!

DECam data rights holders are **encouraged** to use the Science Pipelines for their own data reduction efforts:

- pipelines.lsst.io: Using obs_decam
- hackmd.io/@lsk/merian

Community input into updating and maintaining the obs_decam repository has been *tremendously* important thus far

→ aim continue going forward!