VERA C. RUBIN
OBSERVATORY

**Vera C. Rubin Observatory
Data Management**

Characterization Metric Report: Science Pipelines Version 24.1.0

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DMTR-391

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Abstract

This brief report describes measurements of data quality metrics that were carried out for release v24.1.0 of the LSST Science Pipelines. The report for the previous version can be found in [DMTR-351].

Change Record

Version	Date	Description	Owner name
1	2023-01-04	First draft.	Jeff Carlin
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Document source location: `https://github.com/lsst-dm/DMTR-391`

Contents

Characterization Metric Report: Science Pipelines Version 24.1.0

In this report, we characterize the performance of the Rubin Observatory Science Pipelines Version 24.1.0. We illustrate the performance via metrics that are measured on the HSC-RC2 dataset. RC2 consists of 3 tracts of data taken from the HSC-SSP survey, and selected to provide a means of testing various "pathological" cases (e.g., difficult astrometric solutions, extremely good seeing that does not provide a well-sampled PSF, difficult fields for deblending, and large galaxies, among others). These three tracts each contain between 112–149 visits split between the HSC-G, HSC-R, HSC-I, HSC-Z, and HSC-Y (*grizy*) filters.

Following the switch to Generation 3 ("Gen 3") Middleware that took place in Version 23.0.0 of the Science Pipelines, Version 24.1.0 contains a number of updates to the Gen 3 Middleware. Other important changes in the v24 release include the adoption of the Scarlet Lite deblender for all measurements on coadds, changing the default PSF modeling algorithm to Piff, producing a repeatable selection of stars for PSF modeling, and matching the background levels of adjacent amplifiers during ISR tasks. For more details on the major new features, see the release notes for v24.

All metrics reported here were calculated using the faro (DMTN-211) metric calculation package, which is part of the standard pipeline builds. All of the underlying algorithms to calculate metrics within `faro` are the same as they were in v23.0.0 of the Science Pipelines, so any differences between metrics from the v23 and v24 releases are due to changes in the underlying pipelines.

The metric calculation pipelines from `faro` were run on the RC2 tracts to derive the photometric, astrometric, and shape metrics that are reported here. We exclude the two astrometry metrics (AM3 and AF3) that concern residuals on 200-arcminute scales, since the individual tracts of RC2 do not span large enough spatial scales to enable these measurements.

For comparison, we provide the SRD required "design" value of each Key Performance Metric (KPM) as defined in the Science Requirements Document [LPM-17]. For the ellipticity correlation metrics, there are specifications only for *r* and *i* bands. The *ugzy*-band measurements are of interest primarily for historical tracking.

Some KPMs (e.g., PF1, AF1, AF2) involve thresholds that are different for "design", "minimum",
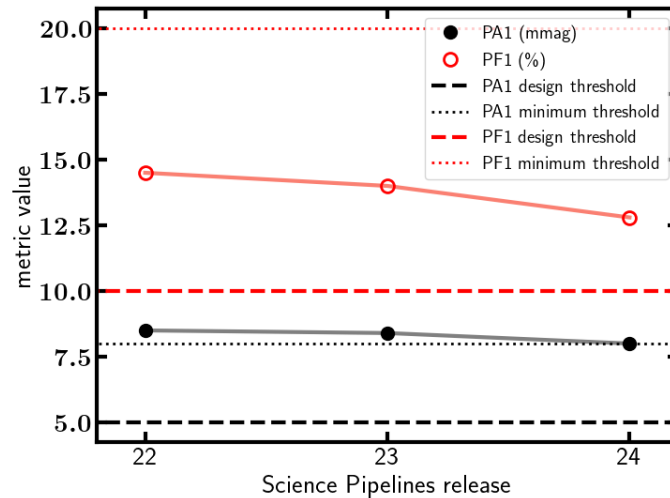
FIGURE 1: Photometry metrics PA1 (photometric repeatability) and PF1 (percentage of measurements exceeding the outlier threshold) measured in the r-band. The figure shows the values of these metrics as measured in versions 22-24 of the LSST Science Pipelines, compared against the SRD requirements (for both the "design" and "minimum" thresholds). The measured values of both metrics have improved slightly between the previous release (v23) and the current one (v24), likely due to the implementation of consistent, repeatable selection of PSF stars in v24 (and perhaps due to the adoption of a new PSF fitting algorithm).

and "stretch" specifications. Metrics in this report are all compared to the "design" thresholds. The assessment of these KPMs would be different if evaluated against different thresholds.

1 Summary of performance metrics

The major changes between versions 23 and 24 outlined in the previous section include many updates that may affect photometric measurements. While minor, the improvements in both photometry metrics (Section 2) shown in Figure 1 are likely due to the newly-implemented selection of a repeatable set of PSF stars. The effect of changing the PSF modeling routine from PSFEx to Piff, as well as the improved modeling of amplifier offsets in ISR tasks, may also have contributed to the slight improvement in photometry metrics. The measured values of the astrometry metrics (Section 3) are virtually unchanged over the past three major pipelines release versions. The ellipticity correlation metrics (Section 4) continue a trend of improvement over the past three versions of the pipelines. This is likely due to improvements in photometric calibration, and perhaps upgrades to the deblending algorithm (Scarlet) and the PSF modeling tool (Piff).

2 Photometric Performance

These photometric performance metrics are defined in LSS-REQ-0093 (LSE-29) and Table 14 of LPM-17. Values in this table represent the mean of the results reported by `faro` for the three tracts in RC2.

Any entries left blank are those for which we do not have data in the given filter for that dataset.

Metric	Unit	SRD Requirement – Design	Release 23 Value (RC2)	Release 24 Value (RC2)	Comments
PA1: u	mmag	≤ 7.5	—	—	No data
PA1: g	mmag	≤ 5.0	7.1	6.8	
PA1: r	mmag	≤ 5.0	8.4	8.0	
PA1: i	mmag	≤ 5.0	8.7	8.6	
PA1: z	mmag	≤ 7.5	6.7	6.4	
PA1: y	mmag	≤ 7.5	7.9	7.0	
PF1: u	%	≤ 20	—	—	No data
PF1: g	%	≤ 20	10.7	9.4	
PF1: r	%	≤ 10	14.0	12.8	
PF1: i	%	≤ 10	14.5	13.5	
PF1: z	%	≤ 20	8.1	6.6	
PF1: y	%	≤ 10	11.5	8.2	

3 Astrometric Performance

The following metrics are defined following LSR-REQ-0094 [LSE-29] and Table 18 of LPM-17. Values in this table represent the mean of the results reported by `faro` for the three tracts in RC2.

Any entries left blank are those for which we do not have data in the given filter for that dataset.
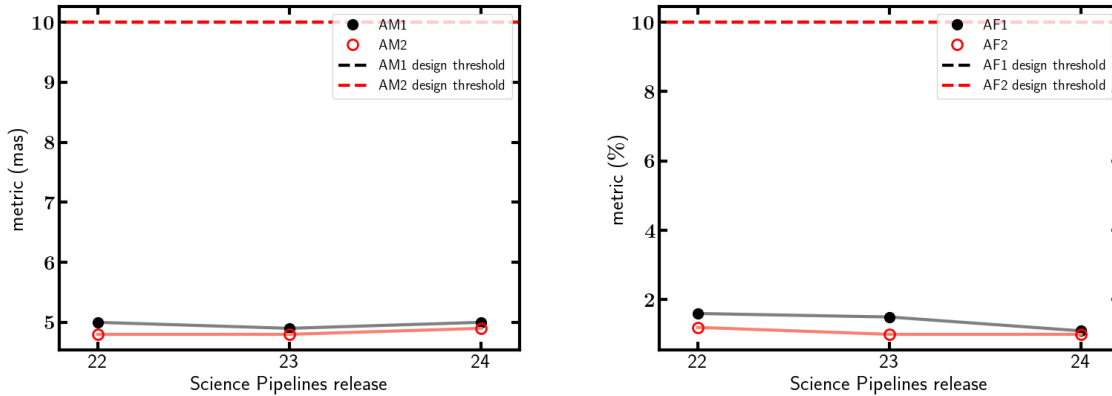
FIGURE 2: Astrometry metrics measured on *r*-band images compared over the past few major pipelines releases. *Left:* Median astrometric measurement error on 5-arcminute scales (AM1) and 20-arcminute scales (AM2), compared against the SRD requirements (for the "design" thresholds; note that the thresholds for AM1 and AM2 are the same, and thus indistinguishable on the figure). *Right:* Fraction of astrometric measurements exceeding the outlier threshold on 5-arcminute (AF1) and 20-arcminute (AF2) scales, compared against the SRD requirements (for the "design" thresholds; note that the thresholds for AF1 and AF2 are the same, and thus indistinguishable on the figure). The measured values of these metrics were virtually unchanged between pipelines version 23 and v24, as expected since no major changes have been made to astrometric measurement algorithms between v23 and v24.

Metric	Unit	SRD Requirement – Design	Release 23 Value (RC2)	Release 24 Value (RC2)	Comments
AM1: *u*	mas	≤ 10	—	—	No data
AM1: *g*	mas	≤ 10	5.3	5.4	
AM1: *r*	mas	≤ 10	4.9	5.0	
AM1: *i*	mas	≤ 10	4.4	4.9	
AM1: *z*	mas	≤ 10	5.1	5.8	
AM1: *y*	mas	≤ 10	6.7	8.5	
AF1: *u*	%	≤ 10	—	—	No data
AF1: *g*	%	≤ 10	0.8	0.9	
AF1: *r*	%	≤ 10	1.5	1.1	
AF1: *i*	%	≤ 10	0.5	0.8	
AF1: *z*	%	≤ 10	0.8	0.8	
AF1: *y*	%	≤ 10	2.5	3.6	
AD1: *u*	mas	≤ 20	—	—	No data
AD1: *g*	mas	≤ 20	7.5	7.7	

| Metric	Unit	SRD Requirement – Design	Release 23 Value (RC2)	Release 24 Value (RC2)	Comments
AD1: r	mas	≤ 20	7.6	7.4	
AD1: i	mas	≤ 20	6.4	6.6	
AD1: z	mas	≤ 20	7.8	7.7	
AD1: y	mas	≤ 20	10.0	11.4	
AM2: u	mas	≤ 10	—	—	No data
AM2: g	mas	≤ 10	5.2	5.3	
AM2: r	mas	≤ 10	4.8	4.9	
AM2: i	mas	≤ 10	4.4	4.7	
AM2: z	mas	≤ 10	5.2	5.7	
AM2: y	mas	≤ 10	6.5	8.3	
AF2: u	%	≤ 10	—	—	No data
AF2: g	%	≤ 10	0.8	0.9	
AF2: r	%	≤ 10	1.0	1.0	
AF2: i	%	≤ 10	0.6	0.7	
AF2: z	%	≤ 10	0.8	0.8	
AF2: y	%	≤ 10	3.2	3.7	
AD2: u	mas	≤ 20	—	—	No data
AD2: g	mas	≤ 20	7.7	7.7	
AD2: r	mas	≤ 20	7.4	7.5	
AD2: i	mas	≤ 20	6.5	6.5	
AD2: z	mas	≤ 20	7.8	7.7	
AD2: y	mas	≤ 20	10.8	11.5	
AB1: u	mas	≤ 10	—	—	No data
AB1: g	mas	≤ 10	8.5	4.8	
AB1: r	mas	≤ 10	4.6	4.8	
AB1: i	mas	≤ 10	5.1	5.7	
AB1: z	mas	≤ 10	4.4	4.9	
AB1: y	mas	≤ 10	6.1	7.0	
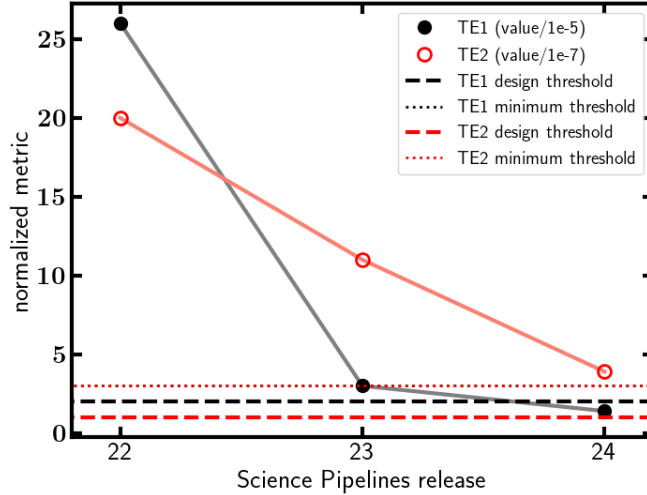
FIGURE 3: Median ellipticity residual correlations at 1-arcminute (TE1; normalized by a factor of 1×10^{-5}) and 5-arcminute (TE2; normalized by 1×10^{-7}) scales, as measured on r-band images, compared over the past few major pipelines releases. Measurements are compared against the SRD requirements (for both the "design" and "minimum" thresholds; note that the normalized minimum thresholds for TE1 and TE2 are the same, and thus indistinguishable on the figure). The measured values of these metrics show minor improvements between v23 and v24, likely due to improvements in photometric calibration (and thus weighting of images going into coadds), and perhaps due to the adoption of a new PSF modeling algorithm.

4 Ellipticity Correlations

The following metrics are defined following LSR-REQ-0097 [LSE-29] and Table 27 of LPM-17. Values in this table represent the mean of the results reported by `faro` for the three tracts in RC2.

Any entries left blank are those for which we do not have data in the given filter for that dataset.

Metric	Unit	SRD Requirement – Design	Release 23 Value (RC2)	Release 24 Value (RC2)	Comments
TE1: u	—	$\leq 2 \times 10^{-5}$	—	—	No data
TE1: g	—	$\leq 2 \times 10^{-5}$	1.8×10^{-5}	1.4×10^{-5}	
TE1: r	—	$\leq 2 \times 10^{-5}$	3.0×10^{-5}	1.4×10^{-5}	

Metric	Unit	SRD Requirement – Design	Release 23 Value (RC2)	Release 24 Value (RC2)	Comments
TE1: i	—	$\leq 2 \times 10^{-5}$	1.0×10^{-5}	1.5×10^{-5}	
TE1: z	—	$\leq 2 \times 10^{-5}$	7.9×10^{-6}	9.1×10^{-6}	
TE1: y	—	$\leq 2 \times 10^{-5}$	1.3×10^{-5}	2.4×10^{-5}	
TE2: u	—	$\leq 1 \times 10^{-7}$	—	—	No data
TE2: g	—	$\leq 1 \times 10^{-7}$	9.7×10^{-7}	7.6×10^{-7}	
TE2: r	—	$\leq 1 \times 10^{-7}$	1.1×10^{-6}	3.9×10^{-7}	
TE2: i	—	$\leq 1 \times 10^{-7}$	1.5×10^{-6}	4.2×10^{-7}	
TE2: z	—	$\leq 1 \times 10^{-7}$	8.2×10^{-7}	4.0×10^{-7}	
TE2: y	—	$\leq 1 \times 10^{-7}$	1.4×10^{-6}	7.5×10^{-7}	

5 Computational Performance

Computational performance metrics were not measured for this release.

A References

[1] **[DMTR-351]**, Carlin, J., 2022, *Characterization Metric Report: Science Pipelines Version 23.0.0*, DMTR-351, URL `https://dmtr-351.lsst.io/`, Vera C. Rubin Observatory Data Management Test Report

[2] **[LSE-29]**, Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2017, *LSST System Requirements (LSR)*, LSE-29, URL `https://ls.st/LSE-29`

[3] **[DMTN-211]**, Guy, L.P., 2022, *Faro: A framework for measuring the scientific performance of petascale Rubin Observatory data products*, DMTN-211, URL `https://dmtn-211.lsst.io/`, Vera C. Rubin Observatory Data Management Technical Note

[4] **[LPM-17]**, Ivezić, Ž., The LSST Science Collaboration, 2018, *LSST Science Requirements Document*, LPM-17, URL `https://ls.st/LPM-17`

B Acronyms

Acronym	Description
DM	Data Management
DMTN	DM Technical Note
DMTR	DM Test Report
HSC	Hyper Suprime-Cam
ISR	Instrument Signal Removal
KPM	Key Performance Metric
LPM	LSST Project Management (Document Handle)
LSE	LSST Systems Engineering (Document Handle)
LSR	LSST System Requirements; LSE-29
LSS	Large Scale Structure
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
PSF	Point Spread Function
SRD	LSST Science Requirements; LPM-17
SSP	Solar System Processing