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Science Validation of LSST Alert Processing

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ABSTRACT

A description of the Prompt Processing Performance with respect to ComCam and LSSTCam observations including sustained observing periods and science validation surveys. This should include the completeness of alert generation, the fraction of false positives, the performance of machine learning for false positive classification, the photometric accuracy of the time series data, how the performace degrades as a function of system parameters and observing conditions (focal plane position, airmass, seeing, transparency, source color). Examples of alerts detected in the commissioning period.

1. INTRODUCTION

The focus of the paper will be early commissioning observations and demonstrating that prompt processing and the Rubin Observatory system as a whole meet the requirements describes in LPM-17 and LSE-30. The timeline for publication of the paper (e.g. readiness review, data previews) will determine the data set that is presented in this work and the level of detail in the analysis.

1. Description of the Rubin Observatory including telescope, camera, and site characteristics

2. Description of the science drivers for prompt processing (including an overview of the science cases)

3. Description of the science requirements (OSS and SRD) in the context of observables (photometry, astrometry, number of false positives, classification of variability, variability statistics) and expectations for this stage of processing

2. THE RUBIN OBSERVATORY PROMPT PROCESSING PIPELINE

1. Overview of the prompt processing pipeline (referencing PSTN-021) and the processing of the nightly data

2. Paragraph describing the steps in the ISR processing of data: bias subtraction, interpolation of bad pixels, generation of flats and application to data, astrometric solutions, photometric calibration (all ISR steps are just at the level of those used in prompt processing)

3. Paragraph describing the template generation that is used for this analysis (image-to-image, coaddition, DCR) depending on the type of templates working at the time of the ORR (or when this paper is published)

4. Paragraph on characterization of the sources (variability measurements and algorithms for the removal of false positives)

5. Paragraph on streaming of events (if that is running at the ORR)

3. COMMISSIONING FIELDS AND SCIENCE VALIDATION SURVEYS

1. Description of field used in prompt processing testing: ComCam fields (if we decide to publish ComCam data), deep drilling fields (positions, filters, depth). Include description of existing data in these fields specific to variability or moving sources

2. Description of template generation (observations that go into the templates, airmass range, constraints due to the limited baseline for the generation of the templates - limits on tests of proper motion and moving sources)

3. Characteristics of the images: noise level (sky and bias), source density, stellar and galaxy density

4. Table of the observations used in the analysis in this paper (time, filters, depth, image quality, airmass, cadence)

5. Reference to PSTN-039 and other papers that describe filter throughputs

6. Figures showing example data, images with sources identified on them, templates, resulting difference images

4. CHARACTERISTICS OF PHOTOMETRIC AND ASTROMETRIC PERFORMANCE

Details for how we measured the astrometric and photometric performance would be in PSTN-039. Here we would just describe the accuracy of system with respect to image differencing.

1. Description of the astrometric residuals relative to Gaia from a single visit and averaged over a series of images. Focus will be on the focal plane variation in astrometry and how that relates to dipoles and artifacts within the image differencing

2. Figure of the astrometric vector field for residuals and the histogram of the astrometric residuals
3. Description of photometric precision of individual images compared to an existing space based photometric catalogs
4. Figure of the photometric residuals (mag difference vs limiting magnitude) for a single CCD and a histogram of residuals for the full focal plane (depending on any calibration issues that might be uncovered)
5. Discussion of the effect of vignetting on photometry and any systematics present within the data

5. IMAGE SUBTRACTION AND THE DETECTION OF MOVING AND VARIABLE SOURCES

1. Description of the templates that are used in 3 (depends if DCR, or traditional templates are adopted)
2. Description of the source density of subtracted images and the numbers of true and false positives. Description of how artifacts were identified and classified (probably identified by eye or cross correlated with known variable catalogs). For known main sequence variable stars plot the colors of these sources (assumes small temporal difference in observations) to demonstrate the photometric performance. For known variable stars identified by Gaia show residuals in a comparison of the astrometry (to show there is no degradation in photometry and astrometry with respect to the undifferenced images modulo signal-to-noise)
3. Figure comparing astrometry and colors of single visit and image subtraction sources
4. Description of artifacts within the data: characteristics (dipoles, scattered light, ghosts, etc). Comparison to ZTF, DECam data in terms of numbers of artifacts and types of artifacts present in the data
5. Figure showing mosaic of artifacts
6. Comparison of numbers of sources and false positives with different templates (assuming we have different types)

6. EVENT CLASSIFICATION AND FILTERING

1. Description of the event classification algorithm (neural network architecture) and the training sample including how these sources were visually classified (number of sources in the training, types of labels of sources, uncertainty or dispersion in the classified labels from human classifiers) templates that are used in 3 (depends if DCR, or traditional templates are adopted)

2. Description of performance of the classifier (confusion matrix) in terms of the number of false and true positives including as a function of image quality, airmass, focal plane, stellar density.
3. Figure of confusion matrix for all labels user in the classifier
4. Figure of ROC curve for the true/artifact classification (with a definition of the threshold that meets the OSS and SRD on required number of false positives)
5. Description of how the classification depends on observing conditions: airmass, position on focal plane, image quality, signal-to-noise
6. Description of the sources density of variable stars and comparisons to Gaia or other variable star catalogs
7. Comment on the use of quality flags and spuriousness metric for removing artifacts in the data

7. SOURCE COMPLETENESS AND CONTAMINATION

1. Description of the source injection process for estimating completeness (including streaks and moving sources)
2. Figure of the number of sources as a function of magnitude that are recovered
3. Comparison of variable sources that are detected on multiple images (with different spatial and rotational dithers) as a measure of single visit contamination (assume that sources detected at a range of rotation angles are true variable sources and those detected on single images are contamination)
4. Comparison of completeness of detected moving sources give MPC catalog (focus on detection and not orbit linkage - orbit characterization should be the subject of a different paper)
5. Figure of the number of sources false positives as a function of magnitude
6. Comment on the issues of deblending if in a high density field
7.

8. CHARACTERIZING VVRIABILITY IN THE RUBIN DATA

1. Description of the variability metrics in the prompt processing pipeline (reference back to PSTN-021) including period estimation
2. Crossmatch against existing variable catalogs (e.g. RR Lyrae from Gaia) with accurate periods. Describe the completeness of the source crossmatches.
3. Description of how well the Rubin variability measures compared to published values including periods (note the time scale of the observations will likely limit this to variable stars with variability less than a few days)

4. Figures comparing the Rubin metrics to those derived from Gaia or deeper data sets (period, variability characteristics)
5. Figure showing example light curves compared to Gaia light curves for a subset of know variables
6. Comment on the ability to recover periods or other variability measures with number of epochs of observations and the benefit of the forced photometry for light curves

9. ALERT DISTRIBUTION IN THE COMMISSIONING DATA

This section will depend on whether alerts are generated within commissioning (even if they are not made public) and whether a Science Validation data set is used or a Deep Drilling Field

1. Description of the schema for the alert packets and the Kafka stream: cite PSTN-021 and the DPDD. Description of the number of alert packages generated in a single nightly
2. Description of the timing of the prompt processing and alert distribution (time to produce alerts, number of alerts emitted) together with any dependence on focal plane, stellar density, image quality in terms of the numbers alerts and the timing of the alerts.
3. Figure for the all sky distribution of alerts from a single night

10. CLASSES OF ASTRONOMICAL SOURCES IN THE COMMISSIONING DATA

1. Description of examples of astronomically interesting light curves. This would include the identification of SN, asteroids, variable stars etc Expectation that any discoveries would be part of separate papers and here we would just describe a set of example sources from the SRD science cases to show that we can recover these sources in the early Rubin data.
2. Figures of example SN, variables, asteroid light curves. Selection would be as a function of depth and cadence and show the recovered statistics (e.g. periods) compared to published values. Types of examples would depend on baseline of observations

11. READINESS OF THE RUBIN PROMPT PROCESSING

1. Summary of the metrics that were used define prompt processing readiness and how the current data performs
2. Description of any issues that are known about in the quality of the data that will be addressed in future releases (so readers know what they should report on)

APPENDIX

A. REFERENCES

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B. ACRONYMS

Acronym	**Description**
CCD	Charge-Coupled Device
ComCam	The commissioning camera is a single-raft, 9-CCD camera that will be installed in LSST during commissioning, before the final camera is ready.
DCR	Differential Chromatic Refraction
DPDD	Data Product Definition Document
ISR	Instrument Signal Removal
LPM	LSST Project Management (Document Handle)
LSE	LSST Systems Engineering (Document Handle)
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
ORR	Operations Readiness Review
OSS	Observatory System Specifications; LSE-30
PSTN	Project Science Technical Note
SN	SuperNovae
SRD	LSST Science Requirements; LPM-17
ZTF	Zwicky Transient Facility