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The Vera C. Rubin Observatory Data Preview 2

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ABSTRACT

We present an early version of Rubin Data Preview 2 (DP2), the second data preview from the National Science Foundation–Department of Energy Vera C. Rubin Observatory. Early Data Preview 2 (EDP2) comprises coadds, detection catalogs, and ancillary data products; eventually, the full DP2 will also include single-epoch images and difference images. DP2 is derived from observations acquired by the LSST Science Camera (LSSTCam) on the Simonyi Survey Telescope at the Summit Facility on Cerro Pachón, Chile, primarily during the on-sky commissioning campaign between 2025-04-16 and 2025-09-21, supplemented by observations taken between 2025-10-25 and 2026-01-06 that overlap the commissioning footprint. The DP2 footprint comprises the Science Validation wide-area survey, five Deep Drilling Fields, and a number of targeted small-field regions, including Trifid and Lagoon, Prawn, M49, and New Horizons, all observed as part of the Rubin First Look campaign. Each field was imaged in up to six broad photometric bands, *ugrizy*, and coadded to produce deep imaging covering an estimated 3,000 deg^2. The addition of single-visit-only areas expands the total DP2 footprint to an estimated 15,000 deg^2, with coverage in at least one filter. The median per-visit PSF FWHM across the wide-area survey ranges from 1.17 arcsec in the z band to 1.26 arcsec in g and r bands, with the sharpest fields reaching $\sim 0.''0$. COSMOS, the deepest field, reaches estimated coadded 5σ

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depths of u=26 mag, g=26.8 mag, r=26.3 mag, i=26.1 mag, z=25.3 mag, y=23.9 mag. DP2 contains X distinct astrophysical objects, of which X are extended in at least one band in coadds, and X solar system objects, of which X are new discoveries. DP2 is approximately 59.15 TB in size and is available to Vera C. Rubin Observatory data rights holders via the Rubin Science Platform, a cloud-based environment for the analysis of petascale astronomical data. Based on a roughly five-month primary observing baseline and covering only part of the eventual LSST footprint, DP2's area, depth, and multiband coverage nonetheless support a broad range of early science investigations ahead of LSST Data Release 1.

Keywords: Rubin Observatory - LSST

1. INTRODUCTION

The National Science Foundation (NSF)–Department of Energy (DOE) Vera C. Rubin Observatory is a ground-based, wide-field optical-near-infrared facility on Cerro Pachón in northern Chile, built to carry out the Legacy Survey of Space and Time (LSST) (Ivezić et al. 2019). The observatory is named in honor of Vera C. Rubin, whose observations in the latter half of the 20th century established the first compelling empirical case for dark matter (Rubin & Ford 1970; Rubin et al. 1980). Its 10-yr survey will image the entire visible southern sky every 3–4 nights, reaching a coadded depth of $\sim$ 27 mag in the r-band across an 18,000 deg^2 footprint (Bianco et al. 2022).

At the heart of the facility is the 3.2 gigapixels-gigapixel LSST Science Camera (LSSTCam), mounted on the 8.4 m (6.5 m effective aperture) Simonyi Survey Telescope (Stalder et al. 2024). Together they deliver an instantaneous field of view of 9.6 deg^2 in six broadband filters, *ugrizy* (320–1050 nm), with seeing-limited image quality. The system's étendue of 319 $\mathrm{deg}^2\,\mathrm{m}^2$ exceeds that of any previous optical facility by over an order of magnitude, enabling the rapid, deep, all-sky cadence that underpins Rubin's four core science themes: the nature of dark energy and dark matter; a census of the solar system; the transient and variable optical sky; and the structure of the Milky Way (Ivezić et al. 2019). An automated Data Management System processes tens of terabytes of images per night to produce science-ready data products within minutes of each observation for a global community of scientists.

This paper presents Rubin's third Data Preview, Data Preview 2 (DP2) (NSF-DOE Vera C. Rubin Observatory 2025), and the first to be based entirely on LSSTCam data. It marks the conclusion of the Rubin commissioning program and the transition to full survey operations. DP2 is a reprocessing of all science-grade exposures acquired with LSSTCam during on-sky commissioning and the initial phase of early operations, prior to the formal start of the LSST on 2026-06-29. As such, it represents a natural boundary and provides a comprehensive dataset that captures the on-sky performance of the as-built system at the end of the Rubin construction project.

Two earlier Data Previews preceded DP2 as part of the Rubin Early Science Program (Guy et al. 2026), established to provide the community with early access to data products and services needed to produce high-impact science during the period spanning commissioning through the first Data Release. Data Preview 0 (DP0) was based on simulated LSST-like data (LSST Dark Energy Science Collaboration (LSST DESC) et al. 2021) and served primarily to stand up early versions of the Rubin Science Platform (RSP) and prepare the community for data access at scale. Data Preview 1 (DP1) (NSF-DOE Vera C. Rubin Observatory 2025) delivered the first data products derived from on-sky observations using science-grade exposures acquired with Rubin Commissioning Camera (LSSTComCam) (Stalder et al. 2022, 2020; Howard et al. 2018; SLAC National Accelerator Laboratory & NSF-DOE Vera C. Rubin Observatory 2024); a 144-megapixel, single-raft instrument used during early commissioning prior to the installation of LSSTCam on the Simonyi Survey Telescope. DP2 supersedes both in scope, fidelity, and scientific depth.

DP2 contains X science-grade exposures acquired over 158 nights between 2025-04-16 and 2025-09-21, covering a total sky area of $\sim$15 deg^2 across X fields. The data products include raw and calibrated single-epoch images, coadded images, difference images, source detection catalogs, and a range of derived data products. The release totals approximately 59.15 TB and contains around X distinct astronomical objects. Full release documentation is available at https://dp2.lsst.io.

Because DP2 is drawn from a commissioning and early-operations data rather than from the more uniform and systematic LSST, its images and derived products reflect a system that was still being commissioned and tuned. LSSTCam's greater scale and complexity relative to LSSTComCam introduced systematics with no direct counterpart in DP1. For much of the campaign the Active Optics System (AOS) closed loop converged on a slightly mis-calibrated focus target, imprinting a spatially varying defocus across the focal plane that was only corrected on sky in December 2025 and that remains visible in the point-spread function (PSF) of a large fraction of DP2 exposures. Delivered image quality and PSF ellipticity did not consistently meet LSST design requirements in wide-area survey-mode observations by the close of commissioning; and stray- and scattered-light artifacts, sky-background systematics in crowded fields, and a chromatic PSF dependence[20] were identified and only partially mitigated in DP2 processing. These effects, their diagnosis, and the mitigations applied are described in §2 and §5.

Unlike the systematic, rolling revisit pattern that will characterize the LSST, DP2's observing cadence is opportunistic: fields and filters were prioritized to serve AOS and Science Pipelines commissioning rather than to build a representative time series. The Science Validation survey footprint was repeatedly re-scoped over the course of the science validation campaign due to the competing demands of engineering tests and filter availability, which was constrained by hardware issues for part of the campaign. Visit counts and time sampling therefore vary substantially and idiosyncratically from field to field, and DP2 should not be read as a preview of LSST's eventual survey cadence, revisit statistics, or depth-accumulation pattern.

DP2 is being delivered in two phases across the Jul–Dec 2026 window. The first phase, Early DP2 (EDP2), comprises the deep coadd images and all associated catalogs, including new cell-based coadds and the first releases of the Object Shear (§??) shape-measurement catalog and the Isolated Star Stellar Motions catalog (§??). EDP2 is targeted for 2026-07-27. The second phase, DP2, adds the visit-level single-epoch and difference images, completing the full release, and is expected in the Oct–Dec 2026 range. Data products delivered as EDP2 will be incorporated into DP2 unchanged, without additional reprocessing (Guy et al. 2026). This phased delivery follows directly from Rubin's hybrid cloud architecture (O'Mullane et al. 2024), in which science data products are stored at the United States Data Facility (USDF) and served to users via the US Data Access Center (DAC) in Google Cloud. Deep coadd images and catalogs are hosted directly in Google Cloud and are therefore unaffected by hybrid-cloud readiness, allowing them to ship as EDP2. Visit-level images, however, must be streamed from the USDF, and the necessary capacity is not yet fully in place, introducing timing uncertainty for the second phase. Delivery of the Prompt Data Products follows the same logic. The Prompt Products DataBase (PPDB), Rubin's real-time catalog of transient, variable, and moving-object detections, does not depend on USDF–Google Cloud bandwidth and is therefore prioritized as the second Early-Operations delivery milestone, following EDP2 and preceding the full DP2 release, expected in the Sep–Oct 2026 range. Prompt images (raw images, Processed Visit Images, and difference images), which do require that bandwidth, have been deprioritized relative to EDP2 and the PPDB and are expected to become available only in the Oct–Dec 2026 range, following both.

DP2, like all Rubin Data Previews and Data Releases, is subject to a 2 yr proprietary period; during this time access is restricted to LSST data rights holders (Blum & the Rubin Operations Team 2020) via the RSP (Jurić et al. 2019), Rubin's cloud-based data science platform (Jurić et al. 2019). After the proprietary period, DP2 will be made public, though access through Rubin DACs in the US and Chile will remain limited to data rights holders (Blum & the Rubin Operations Team 2020). Alternative public access mechanisms have not yet been finalized.

The structure of this paper is as follows. Section 2 describes the observatory system and its status at the close of commissioning, the fields included in DP2, and the observing strategy employed. Section 3 summarizes the data products in the release. The processing pipelines are described in Section 4, followed by data validation and performance characterization in Section 5. Section 6 describes the RSP. Section 7 outlines Rubin's community support model. A summary and outlook toward the start of formal LSST Data Releases is given in Section 8.

All magnitudes are quoted in the AB system (Oke & Gunn 1983) unless otherwise specified.

2. COMMISSIONING WITH LSSTCAM

3. OVERVIEW OF THE CONTENTS OF RUBIN DP2

4. DATA RELEASE PROCESSING

5. PERFORMANCE CHARACTERIZATION AND KNOWN ISSUES

Look at the science requirements document. ls.st/srd, ls.st/lsr, ls.st/oss, ls.st/dmsr.

This DP2 paper should give a good indication of what we expect for LSST proper.

The following subsection headers are placeholders.

In the following, groups of three numbers in brackets correspond to (design, minimum, stretch).

[20] LSSTCam has no atmospheric dispersion corrector

5.1. *Visit-level*

5.1.1. *Filter compliment*

See SRD.

5.1.2. *PVI Depth*

Median point source r-band 5sigma depth of D1 mag, where D1=(24.7,24.3, 24.8).

No more than DF1 per cent of images will have point source r-band 5sigma depths greater than Z1, where DF=(10,20,5) and z=(24.4,24,24.6).

D1 for all bands are:

- u: (23.9,23.4,24.0)
- g: (25.0,24.6,24.3)
- r: (24.7,24.3,24.8)
- i: (24.0,23.6,24.1)
- z: (23.3,22.9,23.4)
- y: (22.1,21.7,22.2)

Put the above compatison in a table (table 1?).

Variation in depth across the FOV:

For a median-depth visit, no more than DF2 per cent of detector-images will have a 5sigma point source depth brighter than Z2, where DF2=(15,20,10) and Z2=(0.2,0.4,0.2). This should be in a section, not (necessarily) in a table.

May also want to include an estimate of the saturation limit (in magnitudes) in this subsection.

5.1.3. *Image quality*

Note that image quality improved over commissioning (DP2). Take a late-stage subset, or perhaps a curated late-stage subset that we can argue would be representative of what we expect going forward.

5.1.4. *Astrometric accuracy*

5.1.5. *Photometric accuracy*

5.2. *Coadd-level*

5.3. *Prediction for 10-year survey*

Details of calculation should go in a separate paper. This section should probably be just two or three paragraphs, depending on what parameters we want to predict.

5.3.1. *Star–Galaxy Separation*

DP2 provides several different star–galaxy classifiers within the Object catalog. We use objects located within a 1 deg radius of the Milky Way satellite Virgo III located at (R.A., decl.) $= (186.^\circ3, 4.^\circ4)$ in the Rubin 'Cosmic Treasure Chest' (M49) First Look field to observe the performance of the various star–galaxy classifiers around Milky Way halo systems. Although the depth of the M49 field is not representative of the other DP2 fields, we see a similar trend in the performances of the various star–galaxy classifiers around other Milky Way halo objects such as the Aquarius II dwarf galaxy (SV1000 field) and AM1 globular cluster (EDFS field). Figure 1 shows the performance of various star–galaxy separation cuts. In the top panel, for each star–galaxy cut we plot the cumulative g-band median signal to noise ratio (SNR) of all the selected "stars" as a function of magnitude limit. The bottom panel shows the fraction of objects that pass the cut as a function of magnitude limit. Note that `refExtendedness` and `{band}_size_extendedness` are binary classifiers, while `griz_model_extendedness` is a floating point classifier. The behavior of the classifiers stars to diverge around $g \sim 23$. The median SNR of the most conservative `griz_model_extendedness` < 0.25 cut remains the highest at faint magnitudes as expected, while the `refExtendedness` classifier selects the most number of objects at faint magnitudes. We expect therefore expect the most complete star sample using `refExtendedness`, at the cost of heavy galaxy contamination at faint magnitudes. We therefore recommend the use of `refExtendedness` in studies where the completeness of the stellar sample is of higher priority than galaxy contamination. Conversely, if the purity of the stellar sample is of paramount importance, we recommend the use of the floating point `griz_model_extendedness` with suitable tuning of the floating point cut to minimize galaxy contamination.

6. RUBIN SCIENCE PLATFORM

7. SUPPORT FOR COMMUNITY SCIENCE

8. SUMMARY AND FUTURE RELEASES

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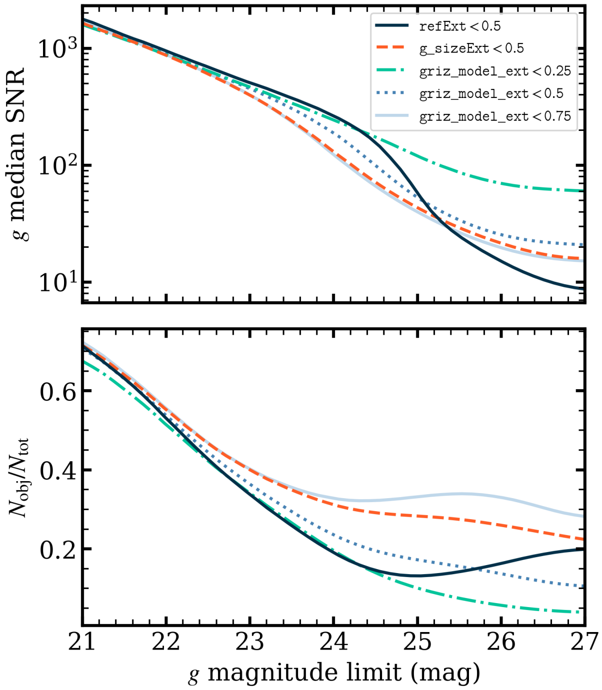

Figure 1. The performance of various star–galaxy classifiers around the Milky Way satellite Virgo III as a function of g-band magnitude limit. The top panel shows the cumulative g-band median SNR of all objects that pass the star–galaxy cut. The bottom panel shows the fraction of objects that pass the respective cut. The SNR remains the highest for the most conservative `griz_model_extendedness` < 0.25 cut due to the low fraction of objects selected at faint magnitudes. Conversely, the fraction of objects selected by the `refExtendedness` cut increases for magnitudes fainter than ~ 24.5. This increase is mostly due to the misclassification of galaxies as stars at these faint magnitudes, leading to a drop in the cumulative SNR.

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Facilities: Rubin:Simonyi (LSSTComCam), Rubin:USDAC

Software: Rubin Data Butler (Jenness et al. 2022), LSST Science Pipelines (Rubin Observatory Science Pipelines Developers 2025), LSST Feature Based Scheduler v3.0 (Jones 2026) Astropy (Astropy Collaboration et al. 2013, 2018, 2022) PIFF (Jarvis et al. 2021), GBDES (Bernstein 2022), Qserv (Wang et al. 2011; Mueller et al. 2025), Slurm, HTCondor, CVMFS, FTS3, ESNet

APPENDIX

Glossary

AOS: Active Optics System.

AURA: Association of Universities for Research in Astronomy.

DAC: Data Access Center.

Data Management System: The computing infrastructure, middleware, and applications that process, store, and enable information extraction from the LSST dataset; the DMS will process petascale data volume, convert raw images into a faithful representation of the universe, and archive the results in a useful form. The infrastructure layer consists of the computing, storage, networking hardware, and system software. The middleware layer handles distributed processing, data access, user interface, and system operations services. The applications layer includes the data pipelines and the science data archives' products and services.

DOE: Department of Energy.

DP0: Data Preview 0.

DP1: Data Preview 1.

DP2: Data Preview 2.

EDP2: Early Data Preview 2.

LSST: Legacy Survey of Space and Time.

LSSTCam: LSST Science Camera.

LSSTComCam: Rubin Commissioning Camera.

NSF: National Science Foundation.

PPDB: Prompt Products DataBase.

RSP: Rubin Science Platform.

USDF: United States Data Facility.

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