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Citation

Williams, C. C., Oesch, P. A., Weibel, A., Brammer, G., Cloonan, A. P., Whitaker, K. E., ... Xiao, M. (2025). The PANORAMIC Survey: pure parallel wide area legacy imaging with JWST/NIRCam. *The Astrophysical Journal*, 979(2). doi:10.3847/1538-4357/ad97bc

Version: Publisher's Version

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Note: To cite this publication please use the final published version (if applicable).



The PANORAMIC Survey: Pure Parallel Wide Area Legacy Imaging with JWST/NIRCam

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Received 2024 August 27; revised 2024 November 19; accepted 2024 November 25; published 2025 January 22

Abstract

We present the PANORAMIC survey, a pure parallel extragalactic imaging program with JWST/NIRCam observed during Cycle 1. The survey obtained ~ 530 square arcmin of NIRCam imaging from $1\text{--}5\ \mu\text{m}$, totaling ~ 192 hr of science integration time. This represents the largest on-sky time investment of any Cycle 1 GO extragalactic NIRCam imaging program by nearly a factor of 2. The survey includes ~ 432 square arcmin of novel sky area not yet observed with JWST using at least six NIRCam broadband filters, increasing the existing area covered by similar Cycle 1 data by $\sim 60\%$. Additionally, 70 square arcmin was also covered by a seventh filter (F410M). A fraction of PANORAMIC data (~ 200 square arcmin) was obtained in or around extragalactic deep fields, enhancing their legacy value. Pure parallel observing naturally creates a “wedding cake” survey with both wide and ultra-deep tiers, with 5σ point-source depths at F444W ranging from 27.8–29.4 (ABmag), and with minimized cosmic variance. The $\gtrsim 6$ -filter strategy yields remarkably good photometric redshift performance, achieving similar median scatter and outlier fraction as CANDELS ($\sigma_{\text{NMAD}} \sim 0.07$; $\eta \sim 0.2$), enabling a wealth of science across redshift without need for follow-up or ancillary data. We overview the proposed survey, the data obtained as part of this program, and document the science-ready data products in the data release. PANORAMIC has delivered wide-area and deep imaging with excellent photometric performance, demonstrating that pure parallel observations with JWST are a highly efficient observing mode that is key to acquiring a complete picture of galaxy evolution from rare bright galaxies to fainter, more abundant sources across redshifts.

Unified Astronomy Thesaurus concepts: Galaxies (573); High-redshift galaxies (734); Redshift surveys (1378); Extragalactic astronomy (506); Lyman-break galaxies (979); AGN host galaxies (2017); Starburst galaxies (1570); Quenched galaxies (2016)

1. Introduction

In past decades, deep observations with the Hubble Space Telescope (HST) and Spitzer Space Telescope traced the evolution and the assembly of galaxies up to $z \sim 8$, and detected a handful of sources up to $z \sim 11$, (e.g., M. Song et al. 2016; I. Davidzon et al. 2017; P. A. Oesch et al. 2018). A hard boundary prevented pushing further into the early Universe due to HST’s limited area and wavelength coverage, and Spitzer’s

limited sensitivity to detect the red light of previously unexplored galaxy populations. Thus, many critical open questions remained prior to JWST launch, including: When and how do the first galaxies form out of the primordial gas at $z > 9$? When and how do the first galaxies shut off their star formation and turn quiescent after $z \sim 6$? What fraction of the cosmic star formation rate density is obscured and still missing at $z > 3\text{--}7$? All of these questions lie at the core of JWST’s mission, necessitating deep imaging at $2\text{--}5\ \mu\text{m}$. While JWST/NIRCam’s unprecedented sensitivity and resolution probe more than $100\times$ fainter than Spitzer/IRAC at $3\text{--}5\ \mu\text{m}$ (M. J. Rieke et al. 2023), the above questions can only be answered with statistical samples of early massive galaxies. As massive galaxies become increasingly rare with redshift (T. Harvey et al. 2025; A. Weibel et al. 2024b), the required areas to probe of the sky are significantly larger than the blank-

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field surveys that were planned by the GTO and ERS teams prior to Cycle 1 (~ 430 square arcmin in total; M. B. Bagley et al. 2023; D. J. Eisenstein et al. 2023b; S. L. Finkelstein et al. 2023; R. A. Windhorst et al. 2023). This motivated the pursuit of wider area imaging among Cycle 1 GO programs.

The advent of the first JWST Cycle 1 data sets immediately revolutionized our view of galaxies in the early Universe even from small-area fields probed by the first data sets, and led to several surprising discoveries. The first NIRCcam images revealed hitherto unknown galaxy populations, which are posing complex challenges to our understanding of galaxy formation. These include: (1) overly luminous galaxies at $z > 10$ that appear more abundant than expected even from the most optimistic models (e.g., R. P. Naidu et al. 2022; H. Atek et al. 2023; C. T. Donnan et al. 2023; Y. Harikane et al. 2023); (2) extremely massive galaxy candidates whose early formation time could challenge our cosmological models (e.g., M. Boylan-Kolchin 2023; I. Labbé et al. 2023; M. Xiao et al. 2024); (3) quiescent galaxies at $z \sim 3.5\text{--}5$, which only further increases the tension between observations and theory (A. C. Carnall et al. 2023a; K. Glazebrook et al. 2024; A. de Graaff et al. 2024; A. Weibel et al. 2024a), requiring a stronger and earlier influence of feedback from an active galactic nucleus (AGN; S. Kurinchi-Vendhan et al. 2023; M. Park et al. 2023); (4) a significant population of dust-obscured, red galaxies at $z > 3\text{--}9$, proving that our census of star formation with HST+Spitzer was incomplete (L. Barrufet et al. 2023; M. Xiao et al. 2024; C. C. Williams et al. 2024); and (5) a puzzling high abundance of putative obscured AGNs at $z \sim 5\text{--}7$ (so-called little red dots, LRDs). A hundred times more common than quasars (and a few percent of all galaxies), their black-hole-to-stellar-mass ratios put pressure on black hole seeding and growth models (D. D. Kocevski et al. 2023; V. Kokorev et al. 2023; I. Labbé et al. 2023; L. J. Furtak et al. 2024; J. E. Greene et al. 2024; J. Matthee et al. 2024).

While these early JWST results could present daunting challenges to our models of galaxy formation, they are only based on small numbers of sources collected over a limited survey volume of current imaging data sets. Even 2 yr into the JWST mission, the total area in extragalactic deep/blank-field imaging at NIR wavelengths (using six or more NIRCcam filters), including GO programs, remains only $\lesssim 730$ square arcmin¹⁷ (J. S. Dunlop et al. 2021; M. B. Bagley et al. 2023; D. J. Eisenstein et al. 2023b; S. L. Finkelstein et al. 2023; R. A. Windhorst et al. 2023). To truly establish the number densities of these rare objects, significantly larger areas of the sky need to be surveyed (e.g., M. Trenti & M. Stiavelli 2008; B. P. Moster et al. 2011; A. K. Bhowmick et al. 2020; G. Ucci et al. 2021). Further, the discovery of intrinsically bright sources that we need for spectroscopy must be selected from wider areas.

Unfortunately, JWST is not optimized for targeted wide-area surveys. While revolutionary for its sensitivity and spatial resolution, NIRCcam’s field of view, at ~ 10 square arcmin in area, is of similar size to that of its predecessors on HST and Spitzer. The observing times required to cover wide areas (0.1–1 square degree scales) are dominated by overhead cost, and these observing strategies can also significantly reduce JWST’s lifetime due to a build-up of momentum, which results

in high fuel consumption. While the Nancy Grace Roman Space Telescope (D. Spergel et al. 2015) and Euclid (R. Laureijs et al. 2024) will ultimately provide wide-area mapping capabilities in space at wavelengths $< 2\ \mu\text{m}$, JWST remains the only facility with $> 2\text{--}5\ \mu\text{m}$ coverage for the foreseeable future. The $> 2\text{--}5\ \mu\text{m}$ wavelength capability is the necessary tool enabling the discovery space of these poorly explored galaxy populations at $z > 3$, whose red colors necessitate measurements at longer wavelengths. To fully capitalize on JWST’s unparalleled imaging and spectroscopic capabilities (J. P. Gardner et al. 2023), it is critical that we map large areas in order to pinpoint rare, yet critical evolutionary phases in the lives of early galaxies. Further, we must discover the most precious, intrinsically luminous candidate galaxies, since they are our best opportunities to study the detailed astrophysics of the first stars and galaxies with spectroscopy.

Fortunately, JWST is capable of pure parallel observations, building on decades of pure parallel work with HST that have established the wide-area tiers for extragalactic surveys. The successful HST pure parallel imaging programs (e.g., BORG and HIPPIES; M. Trenti et al. 2011, 2012; H. Yan et al. 2011; V. Calvi et al. 2016; T. Morishita et al. 2018) led the search for intrinsically bright galaxies during the reionization era, building our knowledge of the bright end of the UV luminosity function (L. D. Bradley et al. 2012; K. B. Schmidt et al. 2014; S. Rojas-Ruiz et al. 2020; G. Roberts-Borsani et al. 2022; M. B. Bagley et al. 2024). JWST is now demonstrating the success of these programs by confirming the high-redshift nature of these intrinsically bright discoveries at $z \sim 7\text{--}9$ (G. Roberts-Borsani et al. 2024; S. Rojas-Ruiz et al. 2024). However, the multiplex capabilities of JWST instruments provide exciting advances beyond what was possible with HST. While HST pure parallel observations typically only obtained a three-filter baseline design for Lyman-break color selection, science with this data often required substantial HST and Spitzer imaging follow-up to obtain more extensive multiwavelength data. Since NIRCcam simultaneously images in the short- and long-wavelength channel made possible by its dichroic (M. J. Rieke et al. 2023), it is particularly efficient at building up multiwavelength photometry in a single visit. JWST’s ability to accumulate deep imaging in parallel is also unprecedented: the equivalent area of a compilation of parallel imaging with HST over 10+ Cycles is achievable by JWST in one Cycle (e.g., 0.4 square degrees; SuperBORG; T. Morishita 2021, see Section 2.2).

While pure parallel observations allow for efficient mapping of wide areas on the sky with negligible cost to observatory resources, observing noncontiguous pointings is even more beneficial for rare galaxy science. Mapping uncorrelated areas of the sky enables the detection of overdensities at the highest redshifts most efficiently, minimizing cosmic variance (e.g., simulations for JWST pure parallels; A. C. Trapp et al. 2022). Especially when searching for the rare, luminous galaxies that are expected only in overdense regions, cosmic variance can be a dominant contribution to the uncertainty budget (M. Trenti & M. Stiavelli 2008; A. C. Trapp & S. R. Furlanetto 2020; C. Kragh Jespersen et al. 2024). While most lines of sight will not contain any galaxy, the densest regions may contain many sources (C. L. Steinhardt et al. 2021), motivating the collection of as many independent sight lines as possible. Thus, by design, pure parallel JWST surveys represent the most efficient way to pinpoint the most overdense regions of the Universe

¹⁷ Based on similar observing strategies to PANORAMIC. COSMOS-Web mapped 0.5 square degrees but only used four NIRCcam filters (C. M. Casey et al. 2023).

where galaxy formation started first, and provide the most efficient data for follow-up studies.

This paper introduces the PANORAMIC Survey (Parallel wide-Area Nircam Observations to Reveal And Measure the Invisible Cosmos), the first extragalactic pure parallel imaging program executed using JWST in Cycle 1 (JWST-GO-02514; PIs: C. Williams and P. Oesch). Thanks to a flexible and tiered, ≥ 6 -filter survey strategy, this program was capable of efficiently using many heterogeneous parallel opportunities to map wide areas. Thanks to the dichroic enabling simultaneous imaging in two filters, the NIRCcam parallel images obtained as part of PANORAMIC are fully self-contained, providing reliable samples and accurate photometric redshifts (see Section 3.6) resulting in an enormous legacy data set for the community. Pure parallels are a powerful (and needed) wide-tier data set that complement targeted deep-field programs: the data obtained as part of this program naturally follow the “wedding cake” survey strategy, including both wide-area and ultra-deep tiers, that have become a gold standard strategy for extragalactic surveys (e.g., CANDELS; N. A. Grogin et al. 2011). In Section 2 we overview the proposed observations and survey design, and the actual Cycle 1 observations. In Section 3, we present our data processing methods including image reduction, photometric measurements, redshift estimations that make up the initial data release. In Section 4 we overview the science goals that motivated the PANORAMIC survey and highlight the exciting science potential of pure parallel imaging with JWST. We assume a cold dark matter (Λ CDM) cosmology with $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$, and magnitudes are specified in the AB system (J. B. Oke & J. E. Gunn 1983).

2. Survey Design and Cycle 1 Observations

The pure parallel observing mode by nature is dependent on “prime-instrument” observational designs (i.e., the telescope configuration while collecting data on primary targets of other programs approved in the same Cycle). The areas and integration times that are achievable in parallel cannot be known a priori. Thus, pure parallel observations are considered shared risk (not guaranteed), and the realized Cycle 1 data set naturally differs from that proposed. In the Sections below, we first introduce the as-proposed survey design (Section 2.1, which we used as a baseline for optimizing the designs of the real observations). Then, in Section 2.2 we describe the realized data set.

2.1. Proposed Survey Design

The PANORAMIC survey design (i.e., the NIRCcam filters, depths, and number of NIRCcam pointings) is driven by the requirement to probe a statistical sample of relatively bright ($F200W \lesssim 27 \text{ ABmag}$) galaxies out to the highest redshift, and to create the wide-area tier of JWST extragalactic imaging for the widest array of science. The baseline strategy mandates at least 1 hr on-source time, split over the three short-wavelength filters F115W, F150W, and F200W, and the three long-wavelength filters F277W, F356W, and F444W. For 20 minute exposures, the expectation from the exposure time calculator was 5σ depths of 27.6–28.3 ABmag in apertures of $0''.16$ radius, under medium background conditions. Our proposed area was 150 pointings, approximately 0.4 square degrees (~ 1500 square arcmin; see the next Section for the actual achieved survey area).

This remarkably wide area is comparable to the widest Cycle 1 program COSMOS-Web (C. M. Casey et al. 2023), but would have effectively tripled the deep extragalactic survey area from ERS+GTO surveys while allowing ≥ 6 NIRCcam filters, at essentially zero overhead cost.

Given that the pure-parallel slots are assigned to a primary program, the achieved data includes many longer visits than the minimal request of 1 hr. As was the case for HST parallels (e.g., H. Atek et al. 2011; M. Trenti et al. 2011; H. Yan et al. 2011; V. Calvi et al. 2016), we find that the real JWST observations in any given Cycle follow a power-law distribution of exposure time. Therefore, any pure-parallel survey has a “built-in” multi-tiered design with a large area covered by relatively shallow pointings and a small number of very deep pointings. While the prime-instrument always drives the division of exposure time between filters, where possible, we planned to split the exposure times up to obtain the deepest data set in F115W, which significantly reduces the outlier fractions in photometric redshifts. In this case, the least-efficient filter, F444W, shares this deeper slot. When more than three mechanism moves (i.e., filter wheel changes) are allowed by the primary program, we additionally obtain a fourth filter-set including the medium-band filter F410M (paired with additional imaging in F115W to increase depth), motivated to improve the photometric redshifts and physical constraints for fainter red galaxies at $3 < z < 7$ (e.g., O. B. Kauffmann et al. 2020; G. Roberts-Borsani et al. 2021).

2.2. Cycle 1 Observations

The data described here were obtained as part of Cycle 1 program ID 2514 (PIs C. Williams & P. Oesch). Due to unanticipated pressure on the deep space network (DSN) during JWST commissioning from 2022 January to June (J. Rigby et al. 2023), the start of science pure parallels in Cycle 1 was postponed by 3 months in order to first gain experience during science operations with the DSN connectivity before implementing science pure parallels (which increase the overall data volume obtained by the spacecraft). Due to this delay, in addition to various software technical difficulties that were unforeseen, JWST has only been executing science pure parallel observations since 2022 December.¹⁸ Thus, science pure parallel data was collected for only approximately half of Cycle 1.

The proposed survey design required at least six filters, with integration times that total $> 1 \text{ hr}$ across all filters, which correspond to $\gtrsim 28 \text{ ABmag}$ (5σ detection limit) in F444W. Due to the late start of science pure parallel observations, we relaxed the minimum requirement of 1 hr integration per pointing to 42 minutes to increase the area that could obtain data for the remainder of Cycle 1.

The observational design of PANORAMIC can be achieved through a range of possible prime-instrument observational setups. Thus, we selected from available pure parallel slots for this survey according to the following criteria: First, we required that parallel slots allow two or more mechanism moves. This allows NIRCcam to change filters twice, resulting in imaging for three filter-sets, i.e., six filters total when accounting for the fact that NIRCcam can image in the short- and long-wavelength channel at the same time. Furthermore, we required that the prime instrument’s integration time for

¹⁸ <https://parallels.stsci.edu/jwst/1/status-report.html>

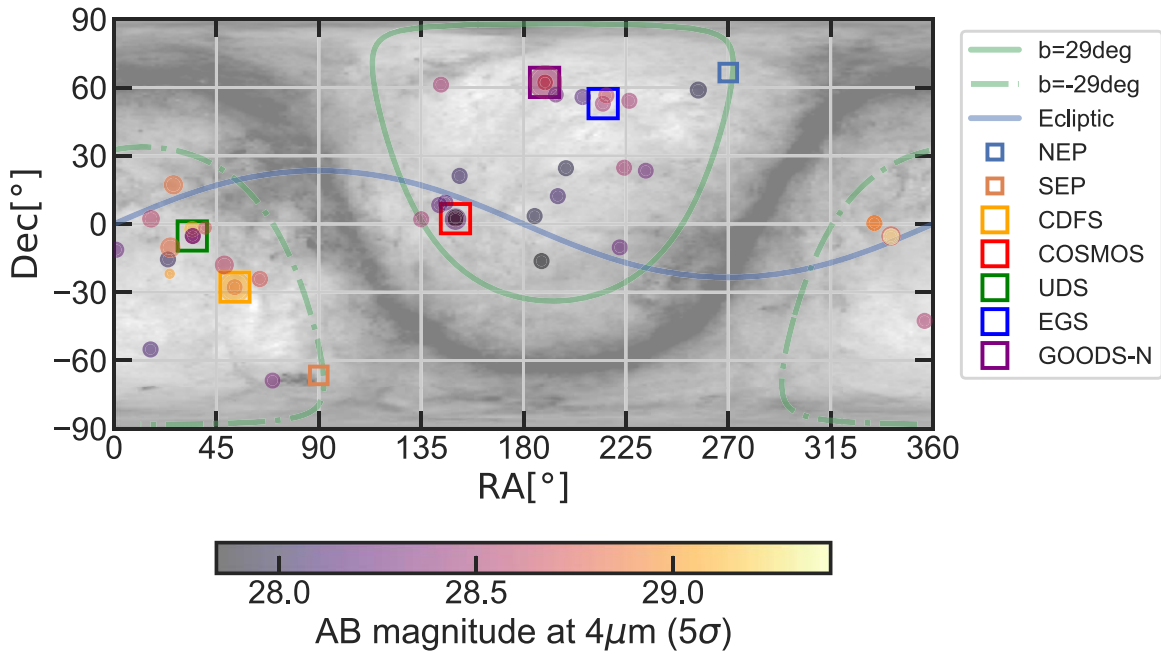


Figure 1. Full-sky map of our observed pointings. Circles indicate the location of data obtained by PANORAMIC, color coded according to the 5σ detection limits at $4\mu\text{m}$, with circle size scaled by on-sky area (not to scale). Existing extragalactic fields are marked with squares, and CANDELS fields (where we obtained data) are also additionally exaggerated in size for visibility. Background grayscale indicates the $4\mu\text{m}$ background, with regions of low background (galactic latitude $|b| > 29$) used to select parallel visits indicated by green solid and dotted–dashed lines.

individual exposures allow for NIRCcam readout patterns with at least four groups for ramp fitting, to ensure robust cosmic-ray rejection. This means that we only selected parallel opportunities where the minimum individual exposure time was 182 s (four groups with SHALLOW2 readout). All of our pointings were designed with at least two exposures per filter (corresponding to two dither locations; the dither size is set by the prime-instrument’s observing strategy for any given pointing). We additionally required that observations be taken at low background conditions at $4\mu\text{m}$ (10th percentile) and that pointings lie well outside the plane of the Milky Way at galactic latitude $\pm 29^\circ$ or higher/lower. For asymmetric division of integration time per filter, we paired the longest integrations with the least sensitive filters. Finally, we visually inspected the prime-instrument on-sky footprint for each dither-set (i.e., the exposures that would be taken with the same parallel filter) within a visit, and between visits, of the same prime program. This step was necessary to determine whether each of the three filter-sets mapped in parallel by NIRCcam would result in a majority overlapping area between the six filters. In some cases, this allowed us to group exposures from different visits together that map similar areas of the sky, in order to increase the integration time and number of filters. The on-sky locations of our obtained data are presented in Figure 1.

As shown in Figure 2, the real distribution of integration times among pure-parallel-eligible observations for NIRCcam in Cycle 1 that met the above criteria include a range of total exposure times, from 42 minutes to a small number of very deep pointings with ~ 30 hr. However, in practice, we found that it is not possible to safely design NIRCcam parallel observations that take advantage of the full integration among those very long parallel slots, without risk of exceeding the data rate limitations of the solid-state recorder on board JWST. The actual data volume depends on the data rate of other programs scheduled between DSN connections and thus cannot be

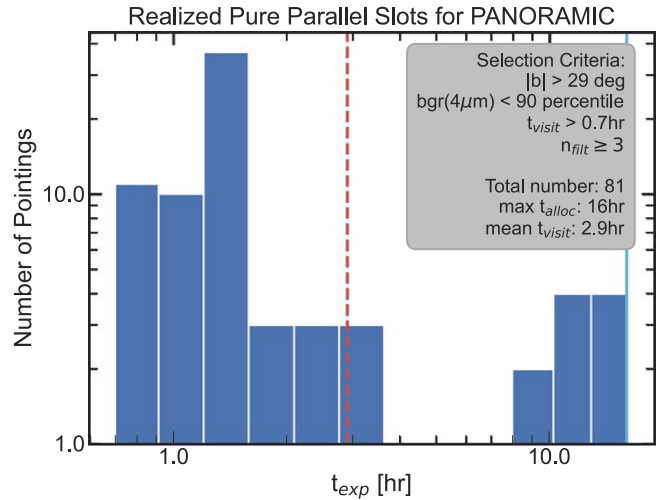


Figure 2. Distribution of the total exposure times per individual pointing for NIRCcam parallels that were designed in as part of this program, to illustrate the capability for NIRCcam parallels during Cycle 1 (not all designs were observed; see the Appendix). The PANORAMIC parallel visits were selected to have long total integration times (> 42 minutes), high galactic latitude $|b| > 29$, low $4\mu\text{m}$ background, and have at least two mechanism moves (three filter-sets). While we requested visits with at least 1 hr total integration for our minimum survey design, the real distribution of integration times per visit are typically longer (on average 2.9 hr; red dashed line; median 1.5 hr). To avoid data loss due to data rate limitations, we found that the parallel-eligible visits with long total exposure times had to be truncated to ~ 16 hr if NIRCcam was the parallel instrument (cyan line).

known in advance at the time of the APT designs. Thus, we opted for a conservative approach of not exceeding the minimum data volume recommendations¹⁹ and found that this typically limited the pure-parallel NIRCcam data collection to

¹⁹ <https://jwst-docs.stsci.edu/jwst-general-support/jwst-data-volume-and-data-excess>

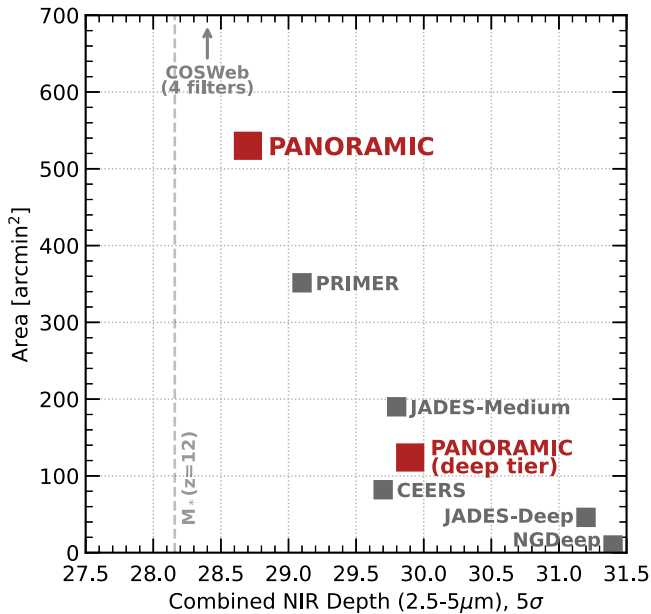


Figure 3. Area and depth of the PANORAMIC survey relative to other Cycle 1 programs. The near-infrared depth was estimated by a weighted combination of all filters in the long-wavelength channel of NIRCcam, i.e., covering $\sim 2.5\text{--}5\ \mu\text{m}$. The top 20% deepest pointings of PANORAMIC combined (deep tier) are of comparable depth and area as the ERS CEERS survey. The full area is shown at the depth of the 20% shallowest pointings (28.7 mag). For reference, the characteristic magnitude of the UV luminosity function at $z \sim 12$ is shown as a dashed vertical line.

~ 16 hr per pointing (corresponding to < 4 hr per filter, because the prime instruments typically allowed four mechanism moves during longer visits).

Scheduling of parallel data for PANORAMIC began in 2023 January, and the first data arrived in 2023 February. In 2023 March, a series of problems with updates to the scheduling software resulted in a series of pointings obtained between 2023 March and April only having four filters (see the Appendix, where we overview these various issues). By the end of Cycle 1, the program obtained 55 pointings (~ 530 square arcmin) with at least two filters of imaging. Our program successfully obtained 45 pointings (corresponding to ~ 432 square arcmin, or 0.12 square degrees) using our ≥ 6 filter setup as initially proposed. This effectively increases the available extragalactic imaging with ≥ 6 filters from Cycle 1 by 60% (compared to ~ 730 square arcmin from ERS, GO, and GTO combined; see Figure 3). Approximately 200 square arcmin of PANORAMIC data falls near or around extragalactic legacy fields, and 40 associations (45 pointings) probe a novel area with JWST (in our NIRCcam filters) for the first time. An overview of the imaging that PANORAMIC obtained is listed in Table 1, and a summary of the pointings that contribute to existing imaging in extragalactic legacy fields is presented in Table 2.

We finish this Section by noting that while the actual scheduling efficiency for pure-parallel NIRCcam observations was essentially unknown prior to approval of Cycle 1 GO programs, our experience offers a first opportunity to explore the typical parallel designs that are feasible within one cycle. Although science pure-parallels started 6 months late in Cycle 1 (about half-way through, excluding scheduling rollover) our program was successful at designing about half of the requested parallel pointings (81 out of 150), all of which met the

proposed criteria (≥ 42 minutes total integration with ≥ 6 filters; see public APT file). While not all of these observations were observed for various reasons (see the Appendix), the fact that we could design half of the pointings to fit within half of a cycle nonetheless confirms that for a typical cycle, it is feasible for NIRCcam parallels to collect ~ 0.4 square degrees while using two mechanism moves (three filter-sets). Since the various technical problems that prevented data collection described in the Appendix are now resolved, it is reasonable to expect that future cycles can obtain similar areas to the originally proposed ~ 0.4 square degrees of imaging in parallel using three filter-sets. We find that only $\sim 10\%$ of these parallels (seven pointings) can accommodate a third mechanism move (four filter-sets), which represents a relatively limited area. This highlights the importance of maintaining flexibility with a tiered parallel design to enable successful collection of observations over wide areas.

3. Data Processing

3.1. Image Reduction

The basic data reduction (as well as the astrometric alignment, coadding, and mosaicking) is performed using the grism redshift and line analysis software for space-based spectroscopy (*grizli*) pipeline (G. Brammer 2025, in preparation, version 1.9.13.dev26).

Using the stage 1 reduced NIRCcam images from the Space Telescope Science Institute (STScI) stage 1 pipeline, *grizli* performs the masking for various artifacts, such as “snowballs” (cosmic-ray hits that impact hundreds of pixels), $1/f$ noise, and scattered light (e.g., claws, wisps; J. Rigby et al. 2023). We use the updated *snowblind* code²⁰ for masking NIRCcam snowballs and an updated NIRCcam bad pixel mask that is included in the *grizli* code repository.

Astrometric alignment is performed in two steps. In fields with no prior JWST or HST data, the F444W images are first aligned to the Gaia reference frame, either using the Gaia DR3 sources themselves (Gaia Collaboration et al. 2021), or bootstrapped from the deeper wide-field, ground-based Dark Energy Spectroscopic Instrument (DESI) Legacy Imaging Surveys²¹ (A. Dey et al. 2019, and references therein) catalog that itself is aligned to Gaia but has a significantly higher source density. All of the remaining filters in a particular PANORAMIC field are then aligned to a source catalog extracted from the F444W image of that field.

All *grizli* pipeline settings correspond to the version 7.2 mosaic release hosted and described in additional detail on the DAWN JWST Archive (DJA;²² unless otherwise noted). In addition, we add the following esthetic corrections to all data. We model and subtract out large diffraction spikes from bright stars at $\pm 30^\circ$ and $\pm 90^\circ$ relative to the detector pixel axes. In the case of two pointings (j153500p2325 and j125652p5652), the use of only four groups resulted in visibly worse cosmic-ray removal in the individual exposure ramp fits. For these two pointings, we use more aggressive AstroDrizzle parameters `driz_cr_snr` 1.0 0.5 and `driz_cr_scale` 1.0 0.6 to better identify cosmic rays from the ensemble of exposures.

²⁰ <https://github.com/mpi-astronomy/snowblind>

²¹ <https://www.legacysurvey.org/>

²² <https://dawn-cph.github.io/dja/imaging/v7/>

Table 1
Associations Obtained by PANORAMIC for Which We Release Image Mosaics

Association	Field ^a	N_{exp}	N_{filters}	R.A.	Decl.	Obs Date ^b	$E(B - V)$
j000352m1120	...	120	6	0.960430	-11.326817	2023-07-14	0.029
j010408m5508	...	120	6	16.039404	-55.141650	2023-08-05	0.016
j010500p0217	...	200	7	16.245068	2.282488	2023-08-18	0.023
j013444m1532	...	120	6	23.687083	-15.531187	2023-08-13	0.019
j013748m2152	MRG0138	160	7	24.453443	-21.864537	2023-12-27	0.013
j013900m1019	...	180	6	24.743085	-10.320011	2023-08-23	0.019
j014428p1715	...	180	6	26.108409	17.240552	2023-08-29	0.050
j021716m0520	UDS	70	6	34.323502	-5.331135	2023-08-20	0.023
j021728m0214	XMM/UDS	240	6	34.362961	-2.228235	2023-08-06	0.020
j021800m0521	UDS	70	6	34.496029	-5.354210	2023-08-19	0.019
j021824m0517	UDS	70	6	34.598771	-5.278195	2023-07-23	0.018
j024000m0142	Abell370	90	6	40.007217	-1.691671	2023-09-05	0.026
j031404m1759	...	180	6	48.511560	-17.973015	2023-09-17	0.027
j033212m2745	GDS	70	6	53.009876	-27.765500	2024-01-27	0.008
j033224m2756	GDS	460	7	53.070160	-27.946099	2023-10-14	0.006
j041616m2409	MACS0416	210	6	64.090215	-24.179155	2023-08-27	0.035
j043844m6849	LMC	60	6	69.682710	-68.821463	2023-07-25	0.079
j090000p0207	...	80	4	135.003870	2.114068	2023-04-03	0.037
j093144p0819	...	120	6	142.941080	8.325030	2023-04-20	0.039
j093452p6116	...	80	4	143.708385	61.272367	2023-04-06	0.029
j094232p0923	...	120	6	145.629850	9.378996	2023-04-19	0.024
j100024p0208	COSMOS-WEB	140	6	150.104485	2.131158	2024-01-06	0.016
j100040p0242	COSMOS	120	6	150.164400	2.693489	2023-12-03	0.016
j100736p2109	...	60	6	151.906160	21.155276	2023-05-07	0.025
j121932p0330	...	120	6	184.880170	3.497880	2023-06-12	0.016
j123140m1618	...	120	6	187.911310	-16.305448	2023-07-02	0.037
j123732p6216	GDN	180	6	189.380245	62.259910	2024-05-19	0.010
j123744p6211	GDN	70	6	189.438515	62.180307	2024-01-30	0.010
j123816p6214	GDN	90	6	189.560465	62.232738	2023-03-24	0.010
j125652p5652	...	240	6	194.211875	56.865695	2023-04-01	0.009
j130016p1215	...	60	6	195.064890	12.249040	2023-06-25	0.024
j131432p2432	...	120	6	198.635240	24.529744	2023-06-11	0.012
j134348p5549	...	120	6	205.941740	55.819387	2023-06-10	0.008
j142536p5630	...	120	6	216.404605	56.507497	2023-06-24	0.014
j144904m1017	...	120	6	222.271220	-10.283259	2023-07-02	0.099
j145652p2444	...	40	4	224.223640	24.740027	2023-03-24	0.036
j150604p5409	...	160	4	226.514625	54.154775	2023-04-03	0.014
j153500p2325	...	240	6	233.742220	23.420023	2023-03-06	0.045
j170720p5853	...	120	6	256.841610	58.879343	2023-02-18	0.025
j221648p0025	SSA22	120	7	334.169740	0.416990	2023-11-29	0.053
j221700p0025	SSA22	120	7	334.246045	0.415294	2023-11-21	0.049
j224604m0518	...	180	6	341.515745	-5.304581	2023-07-17	0.030
j224616m0531	...	430	7	341.565315	-5.519552	2023-07-16	0.028
j234512m4235	...	80	7	356.304565	-42.590595	2023-07-28	0.012

Notes. This excludes pointings where footprints entirely overlap deeper data in EGS, COSMOS-PRIMER, and UDS-PRIMER. These are recorded in Table 2 and in Figure 5.

^a We identify the name of the region if the association is within or adjacent to known field targets.

^b Observation date indicated is for the last image obtained.

3.2. Image Associations

While the typical PANORAMIC pointing consists of just a single NIRCcam footprint with some dithers, there are a few fields in which our program obtained several pointings from different pure parallel slots. We thus group different exposures into “associations” on the sky by searching around each within a buffer of 25′. This leads to several associations that include more than one pointing. In a second step, we manually regroup a few of these collections of pointings into different associations in order to, e.g., split out pointings with only four filter exposures, or to separate out exposures that fully overlap

with existing legacy field data that are publicly released through the DJA archive.

The associations are then named by their coordinates using ID j[ra]p[m[dec] where [ra] and [dec] are the mean coordinate of all exposures within the association in hours, minutes, seconds for R.A. and degrees, minutes for decl., respectively. For each association, we then define an output WCS frame to which all of the exposures are combined and drizzled using *astrodrizzle* (S. Gonzaga et al. 2012), with pixel scales of 20 mas for the SW detectors and 40 mas for the LW detectors. Information on the different associations and their images is listed in Tables 1 and 2, where we also list the names

Table 2
All Pointings Inside or Proximate to Extragalactic Legacy Fields

Field Name	$N_{\text{pointings}}$	N_{filters}	Association ID	Area (sq arcmin)
GOODS-S	7	6–7	j033212m2745 j033224m2756 j033216m2755 ^a	~60
GOODS-N	11	2–6	j123744p6211 j123816p6214 j123732p6216 j123800p6217 ^a j123816p6217 ^a j123720p6215 ^a	~80
COSMOS	1	6	j100040p0242	~9
COSMOS-Web	2	6	j100024p0208	~18
COSMOS-PRIMER	2	6	j100028p0215 ^a	~18
EGS	1	6	j141932p5254 ^a	~9
UDS-PRIMER	2	6	j021748m0516 ^a	~18
UDS	3	6	j021716m0520 j021800m0521 j021824m0517	~28
XMM/UDS	1	6	j021728m0214	~9

Note.

^a Associations are excluded from this data release (either because it sits entirely inside deeper data from other surveys, was corrupted by artifacts or NIRSpec shorts, or lacks full six-filter coverage). Usable data will be folded into DAWN JWST Archive (DJA) mosaic releases coadded with other data.

of the known fields that are either adjacent to or overlapping with PANORAMIC. Images of fields with newly covered area are shown in Figure 4.

3.3. Ancillary Data

While PANORAMIC was developed specifically to be useful as a stand-alone survey not relying on ancillary data, we still include all available HST and JWST imaging that overlaps with our association footprints in our analyses. This is done through the `aws` module of the `grizli` tool, which allows us to include all available reduced and aligned exposures in the archive. This is especially important in pointings that lie around legacy fields, which often have multiwavelength coverage that extends beyond the legacy footprint due to parallel observations. The PANORAMIC pointings that lie near or overlapping with legacy fields are shown in Figure 5.

3.4. A Special Pointing

The above description of the PANORAMIC survey data applies to all pointings except for one: association j123732p6216 in the GOODS-N field. This pointing was not initially available as a pure parallel-eligible slot because it had a coordinated parallel, but became parallel-eligible after the prime-instrument observation required a repeat and the coordinated parallel data was successfully obtained. The orientation angle was fixed and known at the time of our parallel design in APT, and our footprint was to fall within extremely deep JADES imaging that already obtained all of our broad- and medium-band filters (D. J. Eisenstein et al. 2023b). In this case, we adapted our filter-set to obtain six medium-band filters (F162M, F182M, F210M, F300M, F430M, and F460M) rather than incrementally adding to existing filters. The filter choice followed the motivation for existing medium-band

surveys such as the JWST Extragalactic Medium-band Survey (JEMS) and JADES Origins Field (JOF) survey (D. J. Eisenstein et al. 2023a; C. C. Williams et al. 2023).

3.5. Photometric Catalogs

From the drizzled mosaics (Section 3.1), we generate photometric catalogs, largely following the methods outlined in A. Weibel et al. (2024b). In brief, we run `SourceExtractor` (E. Bertin & S. Arnouts 1996) in dual mode, using an inverse-variance weighted stack of all of the LW wide filters, F277+F356W+F444W as the detection image. We then measure fluxes in all the available individual filters through circular apertures of various radii, adopting a radius of 0.16 for our fiducial measurements. The images are point-spread function (PSF)-matched to F444W prior to those measurements. As opposed to A. Weibel et al. (2024b), we do not construct empirical PSFs from the stars in the images. Due to the small area of each pointing, the number of suitable stars is small in some pointings, making the PSF extraction difficult. Therefore, we derive PSFs with `webbpsf` (M. D. Perrin et al. 2014) setting the `jitter_sigma` parameter to 0.02 and rotating them to match the position angle of each pointing, respectively.

We have used legacy field data to confirm that empirical PSFs extracted from the latest reductions of the images are in excellent agreement with those generated through `webbpsf` (see also T. Morishita et al. 2024; A. Weibel et al. 2024b). As an additional test, we compare the curve of growth (CoG) for `webbpsf` to those derived from moderately bright (<20.5 ABmag) individual stars selected across all fields. The top panel of Figure 6 shows results for F444W; we find that the `webbpsf` CoG is more concentrated than that for real stars, deviating by 10%–20% within a diameter of 0.32 (see also, J. R. Weaver et al. 2024). However, deviations beyond this radius are <1%, indicating that the photometry is reliable given the apertures adopted herein. The field-to-field variation in the recovered CoG for individual stars is <1%. The bottom panel of Figure 6 shows a similar test, but now considering the CoG for stars within the F150W PSF homogenized images. Here, we see no significant offsets at any radius and a slightly higher field-to-field variation of the order of 1%. While these tests emphasize that our decision to use `webbpsf` does not impact the resulting photometry, we caution the reader for other applications. Namely, `webbpsf` would not be adequate for a morphological analysis using this same data set, as the underestimated PSF CoG in the cores would systematically bias the sizes larger. If it is not possible to generate an empirical PSF from real stars for these purposes, it is preferable to use an empirical PSF from other similar data sets (e.g., J. R. Weaver et al. 2024).

Finally, for ancillary HST filters, we use empirical PSFs extracted from nearby legacy data using `EPSFBuilder` from the `photutils` python package (J. Anderson & I. R. King 2000; J. Anderson 2016). Using the PSFs, we derive matching kernels using `pypher` (A. Boucaud et al. 2016) and convolve each image with the corresponding kernel.

The PSF-matched aperture fluxes are scaled to total fluxes in two steps: First, we scale them to the flux measured through a Kron-like aperture determined by `SourceExtractor` on the detection image and evaluated on a PSF-matched version of it, and second, we divide them by the encircled energy of the

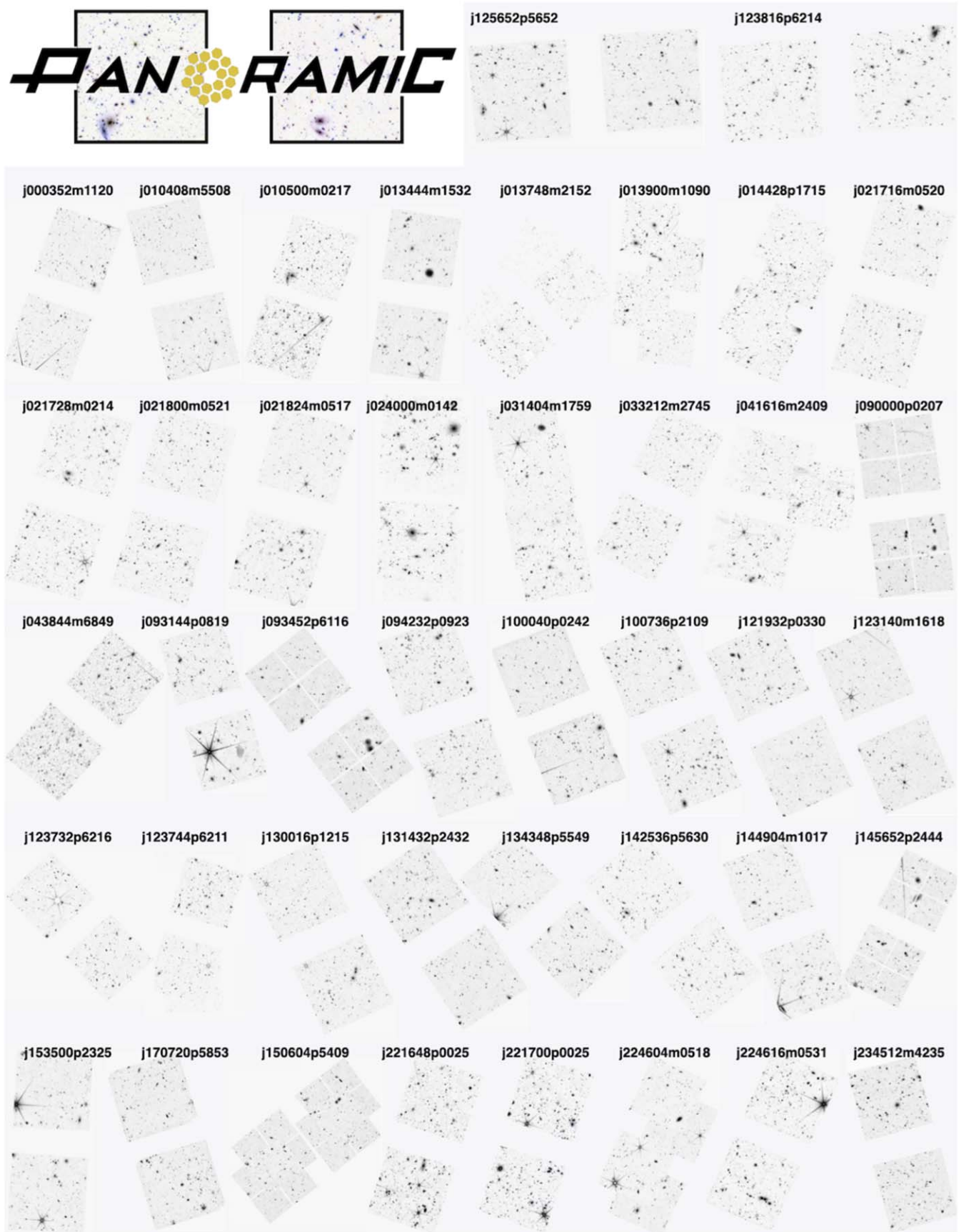


Figure 4. The subset of parallel imaging footprints from Table 1 that cover novel sky area with JWST (not all on the same scale). Large mosaics including substantial ancillary data are excluded for clarity (j033212m2745 in GOODS-S and j100024p0208 in COSMOS-Web; see Figure 5).

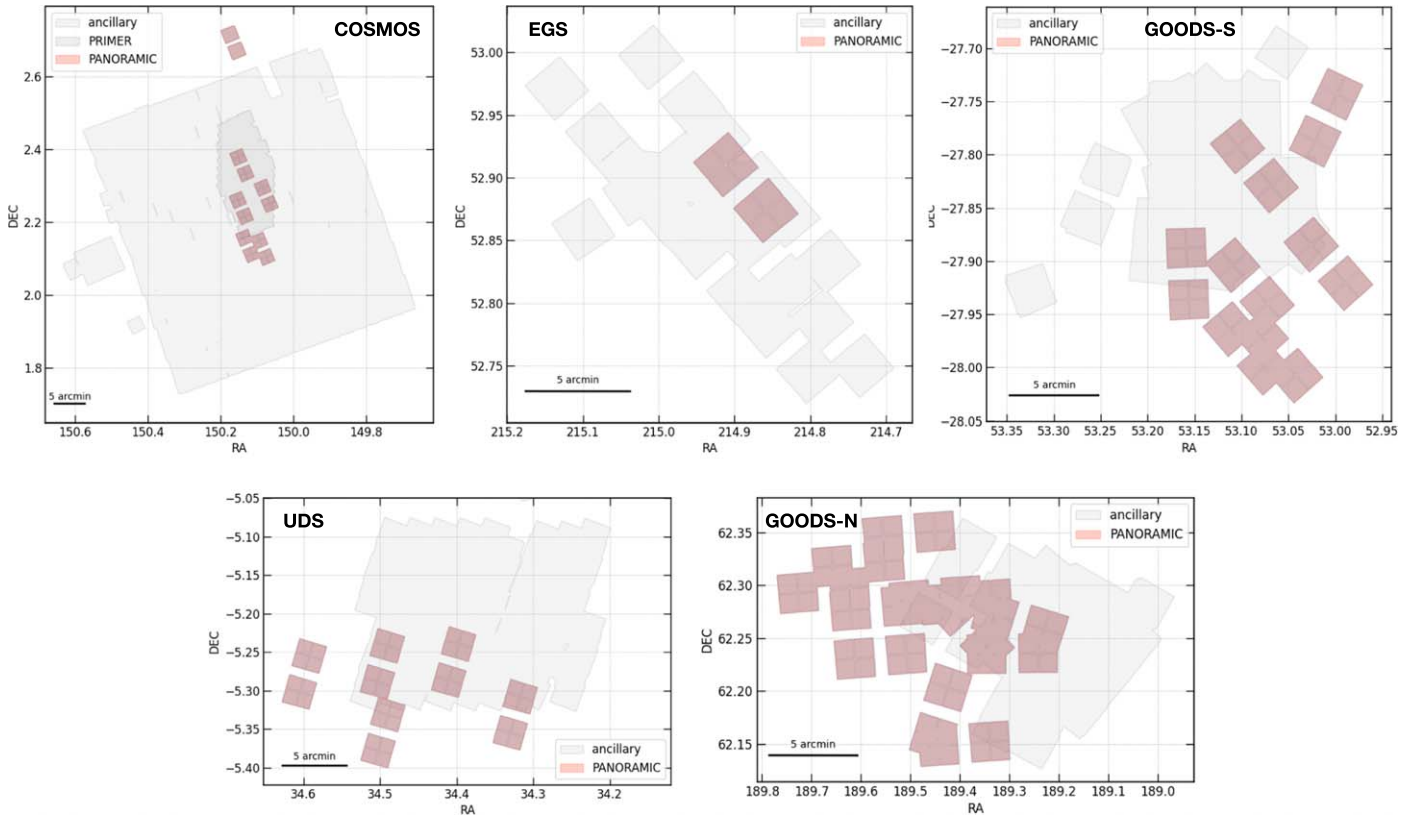


Figure 5. Parallel imaging footprints in and around extragalactic deep fields. Gray regions show JWST footprints from prime-instrument programs that were publicly available as of 2024 July 1 (including COSMOS-Web, PRIMER, JADES, and CEERS; J. S. Dunlop et al. 2021; M. B. Bagley et al. 2023; C. M. Casey et al. 2023; D. J. Eisenstein et al. 2023b). Dark red indicates imaging obtained with PANORAMIC (PID 2514). PANORAMIC footprints show imaging with F444W (red) and F150W (blue outline), while gray ancillary footprints indicate coverage with any NIRCcam filter.

Kron ellipse on the F444W PSF (e.g., R. E. Skelton et al. 2014; K. E. Whitaker et al. 2019).

To assess the depth of each pointing, we measure fluxes through $0''.16$ radius circular apertures in 5000 random positions without any nearby sources. The inferred 5σ depths in each available filter are listed in Table 3. In this Table, we also provide the area of each association’s footprint, which we assess based on the overlapping area between LW filters. By this metric, our survey obtained ~ 432 square arcmin of area with six or more filters of data for which we provide the photometric catalogs.

We note that the LW overlapping footprint area can sometimes be smaller than the actual area of on-sky data that is obtained, due to the prime-instrument’s observing strategy and our program’s optimization of pure parallel opportunities discussed in Section 2.2.

Various flags are added to the catalogs. First, we flag all objects whose isophotal footprint is determined by *SourceExtractor* to overlap with one or more flagged pixels in the respective flag map. The latter are derived from the weight maps provided by *grizli*, flagging pixels with no weight. In addition, we grow the flag images through binary dilation in order to more generously flag objects near the edge of the mosaics or near regions with data quality issues.

We then flag stars using two different criteria. The first one identifies bright point sources ($\text{mag}(\text{F444W}) < 24.5$) by requiring $1.2 < F(0''.35)/F(0''.16) < 1.4$ where $F(0''.35)$ and $F(0''.16)$ are the fluxes measured through circular apertures with radii of $0''.16$ and $0''.35$, respectively. To also flag fainter stars as well as diffraction spikes or contaminated sources

around stars, we match our catalogs to sources with nonzero proper motion in the GAIA DR3 catalog (Gaia Collaboration et al. 2016, 2023) using a search radius of $2''.5$. Based on the *SourceExtractor* output, we flag sources with unreasonably large sizes ($R_{50}(\text{F444W}) > 50$ pix) or Kron ellipses (circularized Kron radius > 150 pix). This identifies spurious detections around bright stars as well as objects near stars or extended foreground sources contaminating their Kron ellipses. Further spurious detections and hot pixels are flagged using $0 < R_{50}(\text{F444W}) < 1.2$ corresponding to unphysically small sizes. Finally, we flag objects that do not have a signal-to-noise ratio (S/N) > 3 detection in any of the available NIRCcam wide filters, and objects with no valid photometric redshift fit (see Section 3.6). All flags are combined into a `use_phot` column, so that `use_phot` = 0, if any of the flags described above is set. In order for a source to have `use_phot` = 1, it is further required to not have any flagged pixels in any of the LW wide filters (F277W, F356W, and F444W) that contribute to the stacked detection image. We use this latter criterion to estimate the survey area of each field, by counting the pixels that are not flagged in any of those three filters. The inferred survey areas are specified for each field in Table 3.

3.6. Photometric Redshifts

We run the template-based SED-fitting code *eazy* (G. B. Brammer et al. 2008) to estimate photometric redshifts for all of the galaxies in our catalogs. To allow for some flexibility in the fitting and account for possible systematic uncertainties, we adopt an error floor of 5% on all of the fluxes.

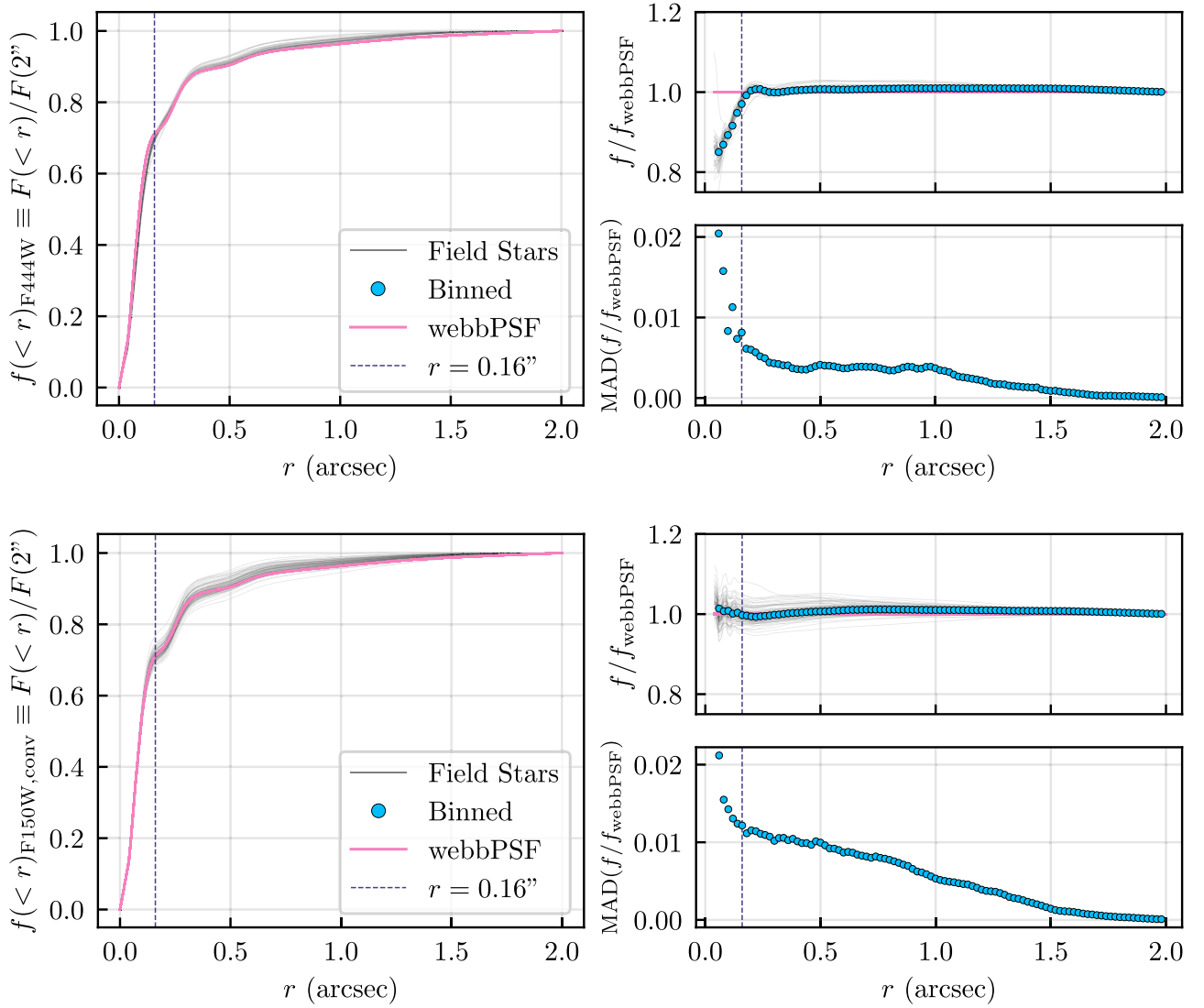


Figure 6. An analysis of the point-spread function (PSF) curve of growth (CoG) with radius r for F444W (top) and PSF-matched F150W reveals that the aperture photometry is robust when comparing `webbpsf` (pink) to individual bright (<20.5 ABmag) stars (grayscale). In all cases, the CoGs agree at $<1\%$ for the adopted aperture diameter of $0.32''$ (dashed vertical line). There exists an offset of $\sim 10\%$ for the F444W CoG within a $0.32''$ diameter; the reader is cautioned to not use `webbpsf` for structural analyses with this data set. The median absolute deviation in the CoGs at a given radius for individuals stars is of the order of 0.5% for F444W (top panel, bottom right) and 1% for PSF-matched F150W (bottom panel, bottom right).

We use the `blue_sfhz` template set,²³ which consists of 14 templates, 13 of which are generated through the Flexible Stellar Population Synthesis code (C. Conroy et al. 2009; C. Conroy & J. E. Gunn 2010). In addition, one template is derived from a recently obtained NIRSpc spectrum of an extreme emission line galaxy at $z = 8.5$ (A. C. Carnall et al. 2023b). We allow the best-fitting redshift to vary in the range $z \in (0.01, 20)$, and we run three iterations of the internal zero-point optimization, which corrects for possible calibration offsets based on the template fitting residuals. This yields small correction factors ranging from $\sim 1\%$ to $\sim 8\%$ in all filters and pointings, except for F115W in j043844m6849 ($\sim 12\%$) and F150W and F200W in j010500p0217 ($\sim 11\%$ and $\sim 16\%$).

3.6.1. Photometric Redshift Performance

In this Section, we simulate the photometric redshift performance of typical pointings in our survey. We characterize

this using the Jades extraGalactic Ultradeep Artificial Realizations (JAGUAR; C. C. Williams et al. 2018). The individual realizations of JAGUAR mock catalogs are limited in area (~ 120 square arcmin), significantly smaller than the PANORAMIC combined survey footprint. Due to the rapid decline with redshift of the assumed pre-JWST luminosity function in JAGUAR (P. A. Oesch et al. 2018), our target populations become increasingly rare in single JAGUAR realizations. Thus, we join 10 realizations in order to enable a better characterization of the performance at higher redshifts.

Because of the heterogeneity of our full data set, we base our performance on two typical subsets of our survey. The two categories include: pointings that have six broadband filters, and pointings where we obtained a seventh filter (F410M). For each survey subset, we take the average of the limiting flux detection limits in each filter across all pointings in the category. For the six-filter survey, these depths correspond to 5σ detection limits in the shortwave bands of 27.5, 27.8, and 27.9 ABmag (F115W, F150W, and F200W) and long wave

²³ <https://github.com/gbrammer/eazy-photoz/tree/master/templates/sfhz>

Table 3

5 σ Depths (AB Magnitudes) Measured in Circular Apertures of 0".16 Radius in Each Filter and the Survey Area in arcmin² of Each Pointing, for 6+ Filter Footprints Covering Novel Sky Area Only

Field Name	F115W	F150W	F200W	F277W	F356W	F410M	F444W	Area ^b (arcmin ²)
j000352m1120	27.50	27.72	27.94	28.37	28.50	...	28.24	9.37
j010408m5508	27.03	27.31	27.52	28.17	28.30	...	28.11	9.36
j010500p0217	28.66	28.51	28.74	29.16	29.06	28.58	...	11.67
j013444m1532	27.01	27.27	27.48	28.17	28.20	...	28.03	9.38
j013748m2152	28.98	29.04	29.30	29.34	29.36	28.88	29.01	3.04
j013900m1019	28.36	28.54	28.75	29.08	29.18	...	28.83	16.13
j014428p1715	28.39	28.56	28.76	29.11	29.21	...	28.86	14.50
j021716m0520	27.93	28.15	28.25	28.64	28.78	...	28.41	9.23
j021728m0214	28.78	28.95	28.20	28.70	29.53	...	29.12	9.23
j021800m0521	27.91	28.12	28.21	28.61	28.69	...	28.41	9.23
j021824m0517	27.97	28.13	28.19	28.54	28.65	...	28.39	9.23
j024000m0142	28.06	28.31	28.48	28.91	29.02	...	28.71	6.15
j031404m1759	27.88	28.11	28.31	28.85	28.92	...	28.60	13.63
j033212m2745	28.16	28.40	28.36	28.75	28.85	...	28.62	9.24
j033224m2756	28.75	28.84	28.62	29.27	29.47	29.34	29.08	43.22
j041616m2409	28.39	28.59	28.83	29.08	29.11	...	28.72	9.80
j043844m6849	27.69	27.93	28.15	28.63	28.65	...	28.33	9.25
j093144p0819	27.47	27.76	27.89	28.36	28.43	...	28.20	9.36
j094232p0923	27.47	27.70	27.91	28.35	28.49	...	28.21	9.36
j100024p0208	27.47	27.66	28.22	28.37	28.78	...	28.25	18.37
j100040p0242	26.85	27.16	27.29	27.98	28.02	...	27.84	10.71
j100736p2109	27.44	27.67	27.88	28.33	28.33	...	28.05	9.33
j121932p0330	27.25	27.56	27.72	28.17	28.21	...	27.97	9.23
j123140m1618	27.01	27.28	27.43	28.06	28.08	...	27.84	9.37
j123732p6216 ^a	28.37	28.61	28.43	28.71	...	28.06	27.83	9.30
j123744p6211	28.21	28.47	28.34	28.82	28.96	...	28.83	9.23
j123816p6214	28.26	28.69	28.44	28.86	28.99	...	28.80	9.22
j125652p5652	27.39	27.61	27.92	28.33	28.51	...	28.28	8.84
j130016p1215	27.65	27.86	28.05	28.39	28.43	...	28.08	9.23
j131432p2432	27.05	27.32	27.47	28.12	28.21	...	27.97	9.25
j134348p5549	27.33	27.58	27.81	28.32	28.38	...	28.15	9.27
j142536p5630	27.91	28.19	28.39	28.89	28.95	...	28.64	9.40
j144904m1017	27.47	27.71	27.92	28.38	28.43	...	28.24	9.37
j153500p2325	27.36	27.63	27.86	28.44	28.57	...	28.29	9.09
j170720p5853	26.91	27.16	27.40	28.13	28.18	...	27.98	10.68
j221648p0025	29.15	28.99	29.15	29.34	29.15	28.59	28.82	9.23
j221700p0025	29.13	29.05	29.23	29.51	29.48	28.83	28.96	9.23
j224604m0518	28.23	28.10	27.85	28.36	28.83	...	28.76	14.83
j224616m0531	28.98	28.96	29.18	29.62	29.62	28.72	29.40	9.18
j234512m4235	28.39	28.26	28.10	28.50	28.89	28.18	28.53	9.19

Notes.

^a Filter depths listed correspond instead to F162M, F182M, F210M, F300M, F430M, and F460M; see the end of Section 3.1.

^b Area is assessed based on the overlapping area of all LW filters, i.e., matches the area probed by our photometric catalogs. The actual area by total coverage of all filters is larger. We do not measure photometry from pointings where we obtained fewer than six filters; see the Appendix. Four-filter pointings do not appear in this table.

bands 28.4, 28.6, and 28.3 (F277W, F356W, and F444W). For the seven-filter survey, the depths are 28.9, 28.8, and 28.8 (F115W, F150W, and F200W) and 29.3, 29.0, and 28.7 (F277W, F356W, F410M, and F444W). We select JAGUAR sources with brightnesses that correspond to S/N > 10 in the F444W filter (given our sensitivity limits), and include photometric scatter and uncertainty in the mock photometry according to the average rms. We then measure photometric redshifts using EAZY with the same setup as described in Section 3.6.

In Figure 7 we show the photometric redshift recovery for JAGUAR mock galaxies assuming our six-filter baseline survey (top panels) and seven-filter (bottom panels). We

characterize the photometric redshift performance using σ_{NMAD} defined as $\sigma_{\text{NMAD}} = 1.48 \times \text{median}\left(\frac{|\Delta z - \text{median}(\Delta z)|}{1 + z_{\text{spec}}}\right)$ and outlier fraction defined as $f_{\text{outlier}} = \Delta z / (1 + z_{\text{spec}}) \geq 0.15$ (G. B. Brammer et al. 2008) where z_{spec} is the redshift of the mock galaxy, and δz is the difference between the photo- z and z_{spec} . We find that our six(seven)-filter survey has typical $\sigma_{\text{NMAD}} = 0.074(0.042)$ and typical $f_{\text{outlier}} = 0.24(0.12)$ (see Figure 7). We find that at F150W magnitudes <26 that were probed by the CANDELS survey (N. A. Grogin et al. 2011), our survey achieves similar σ_{NMAD} to that obtained by CANDELS (T. Dahlen et al. 2013; R. Bezanson et al. 2016; M. Salvato et al. 2019), even without the use of ancillary data.

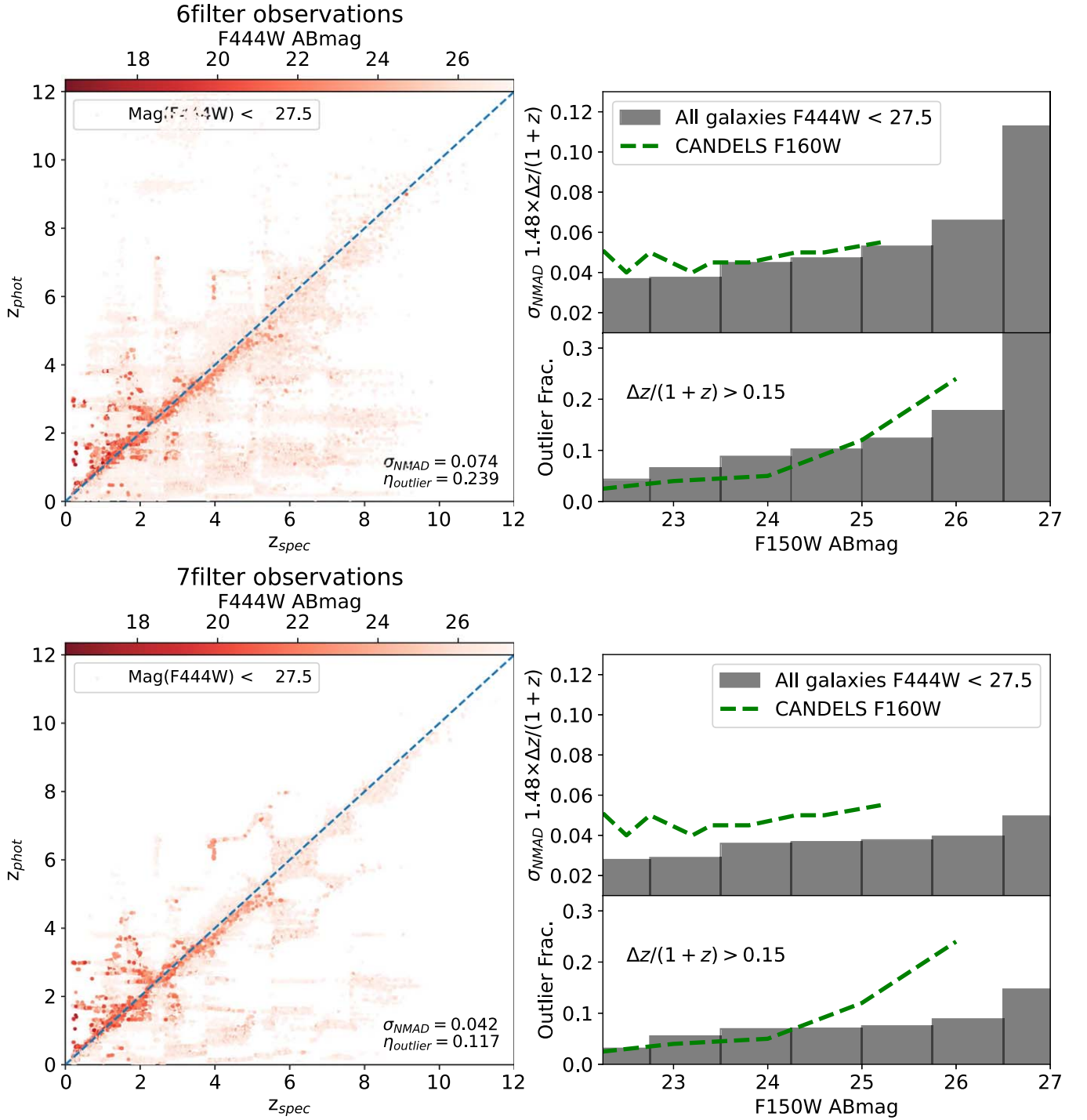


Figure 7. EAZY photo- z performance using JAGUAR simulation of our six-filter (top row) and seven-filter strategy (bottom row). Left panels: points represent galaxies at various apparent magnitudes in F444W and are rank sorted by magnitude (brightest lie on top). Right panels: photo- z scatter (σ_{NMAD}) and outlier fraction (fraction of galaxies with $\sigma_{\text{NMAD}} > 0.15$ as a function of F150W ABmag). Green curves show the typical scatter and outlier fraction as a function of HST H -band magnitude from CANDELS (T. Dahlen et al. 2013; M. Salvato et al. 2019), demonstrating that PANORAMIC achieves similar photometric redshift performance to HST legacy surveys without the need of ancillary data.

This clearly demonstrates the power of pure-parallel imaging in producing a wide-field infrared survey that achieves CANDELS-like data quality but at longer wavelengths, opening a whole new realm of discovery space.

We note a few redshift ranges where the catastrophic outliers are more obvious. These include $z < 1.8$, where there are no major spectral continuum breaks sampled by the six broad bands (the Balmer break is blueward of F115W) and the photo-

z solution relies primarily on weak emission lines and continuum shape for redshifts. $z \sim 8$ is also challenging, because strong rest-optical emission lines redshifted out of F444W and F410M, and the Lyman break is still blueward of F115W.

Since the empirical galaxy evolution model that underlies the JAGUAR mock catalog is based on pre-JWST data sets, it inherently lacks populations of red galaxies across redshifts

where pre-JWST data sets were less complete. This is particularly true for massive galaxies at $z > 3$, which are primary science targets of this program (see Section 4), although these are likely too rare to significantly impact the photometric redshift statistics. However, it is also the case that the lowest-mass galaxies detectable by PANORAMIC at intermediate redshifts in JAGUAR have properties based on extrapolations of the stellar mass function from pre-JWST data, observations that were likely more incomplete at redder colors. Thus, we note the possibility that the low-mass galaxies that dominate numbers across redshifts (and thus our photometric redshift statistics) are bluer with a higher fraction of detectable emission lines in JAGUAR than in the real Universe, making photometric redshifts appear easier to determine.

4. Science Goals

The primary motivations for PANORAMIC are twofold: to reveal statistical samples of (1) luminous galaxies at $z > 9$, and (2) the most massive, red sources at $3 < z < 9$. Since the abundances of these populations are critical constraints on galaxy formation models, the pure parallel strategy has a strong advantage in lowering the uncertainties due to cosmic variance. As we will show in this Section, this is true even though the data obtained as part of PANORAMIC is smaller in area than proposed. The area of PANORAMIC still increases the Cycle 1 area with ≥ 6 filters and $F444W < 28$ ABmag by 60%, with the key advantage that it does so using 40 independent sight lines. As such, this data set will enable a wealth of community science. Further, random sight lines enable new source discovery, which is a key goal of PANORAMIC, since this is a first step before detailed follow-up can be launched for statistical samples of bright populations. Here, we list only a few of the most important scientific questions that were motivating factors in the design of PANORAMIC.

4.1. Unveiling the Brightest Galaxies at $9 < z < 12$

While the first JWST observations have immediately pushed the cosmic frontier beyond HST's limit of $z \sim 11$ (e.g., P. A. Oesch et al. 2018), our knowledge of galaxies at these redshifts remains extremely uncertain. The number density evolution of galaxies at $z > 10$ remains debated and is only based on a handful of spectroscopically confirmed galaxies to date (e.g., S. L. Finkelstein et al. 2022; P. Arrabal Haro et al. 2023a; E. Curtis-Lake et al. 2023; S. Carniani et al. 2024; M. Castellano et al. 2024; B. Wang et al. 2024; for a review, see A. Adamo et al. 2024). The star formation rate density (SFRD) at $z > 10$ is found to be extremely high based on early JWST-identified candidates at $z > 10$ (e.g., R. P. Naidu et al. 2022; H. Atek et al. 2023; C. T. Donnan et al. 2023; Y. Harikane et al. 2023). These candidates lie more than an order of magnitude above the predicted luminosity functions from simulations (e.g., S. L. Finkelstein et al. 2024; Y. Harikane et al. 2024). Interestingly, galaxy formation models largely diverge at $z > 8$, resulting in predicted SFRDs that differ by factors of up to $50\times$ by $z \sim 12$ (R. Feldmann et al. 2025). These divergences could reflect our uncertainty in the efficiency of galaxy growth in dark matter halos, or, could highlight a critical change in our understanding of early galaxy formation, including a lack of dust attenuation (e.g., A. Ferrara et al. 2023; V. Mauerhofer & P. Dayal 2023), an evolving initial mass function (e.g., A. Trinca et al. 2024; L. Y. A. Yung et al. 2024; although see E. R. Cueto et al. 2024), bursty star formation (e.g., C. A. Mason et al. 2023;

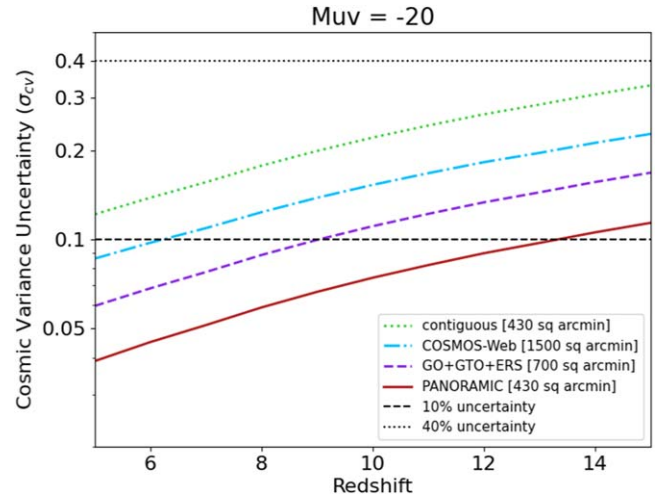


Figure 8. Cosmic variance uncertainty for galaxies with $M_{UV} = -20$ with redshift (A. C. Trapp & S. R. Furlanetto 2020), estimated for the 40 independent sight lines with PANORAMIC (red) compared to an equivalent contiguous survey of the same area, and to existing extragalactic surveys.

J. Mirocha & S. R. Furlanetto 2023), black hole contribution (F. Pacucci et al. 2022), and/or low-redshift interlopers (P. Arrabal Haro et al. 2023b). The extremely small sample sizes still prevent firm conclusions. Thus, measuring the UV luminosity function at $z > 10$ with $\sim 2 \mu\text{m}$ imaging is a powerful test of these models—in particular, when probing the most luminous sources (P. Behroozi & J. Silk 2018).

PANORAMIC was designed to build a wide-area extragalactic tier capable of identifying statistical samples of bright, $z > 9$ galaxies that make meaningful improvements to abundances and population-level census uncertainties, while providing spectroscopic targets that are bright enough to contribute significant astrophysical constraints on galaxy formation. In our original survey design, we expected to identify $\gtrsim 12$ galaxies of similar brightness to GNz-11, and up to 80 new $z \gtrsim 9$ galaxies at $\gtrsim L^*$, as tracers of early reionization. Due to their highly biased nature, the most luminous sources are subject to the largest cosmic variance uncertainties, which limits the ability of smaller fields to constrain models. However, we find that our survey will still set meaningful constraints even at $\sim 1/3$ of the proposed size. To estimate the cosmic variance uncertainty (σ_{cv}) of PANORAMIC, we use the `galcv` code from A. C. Trapp & S. R. Furlanetto (2020) using our real association areas from Table 3. We combine the individual cosmic variances of each of our pointings following B. P. Moster et al. (2011) for separate, and uncorrelated fields, which, with $N = 40$ pointings, roughly improve the uncertainty compared to each individual pointing as $\sqrt{N}$. Figure 8 shows that the excess uncertainty due to cosmic variance in our survey is a factor of 3 improvement at $z \sim 12$ over comparable surveys of contiguous area. We additionally include estimates for the existing GO+GTO+ERS and COSMOS surveys. This plot demonstrates that PANORAMIC will make meaningful improvements to abundance, census, and luminosity function estimates.

In Section 2, we demonstrated that parallel NIRCcam imaging of the scale originally proposed for PANORAMIC (~ 0.4 square degrees using three filter-sets) is feasible within one JWST cycle. This indicates that the science originally proposed will soon be possible using accumulated parallel imaging on single-cycle timescales in the future.

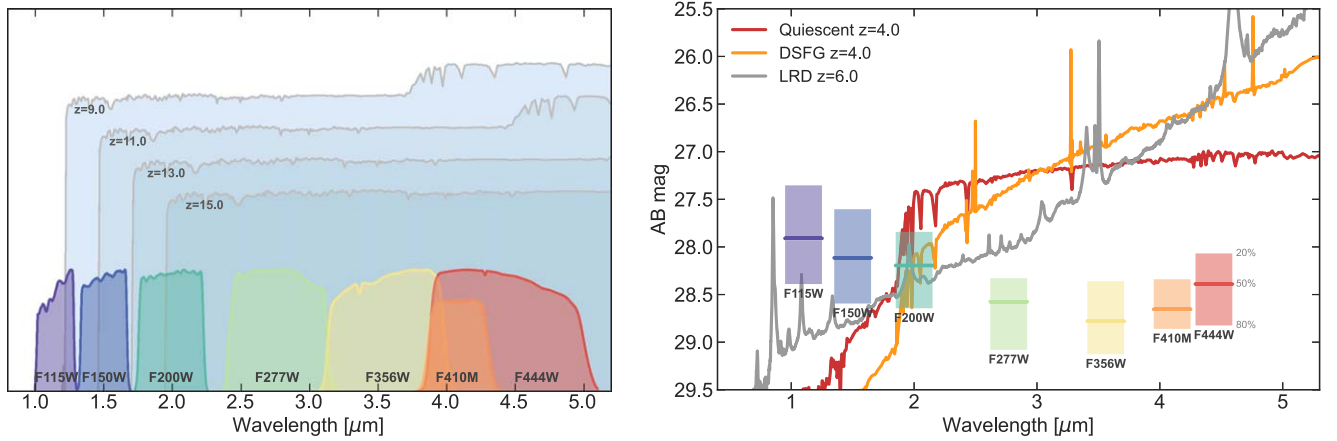


Figure 9. Target galaxy SEDs and PANORAMIC survey design. Left: high-redshift Lyman-break galaxies together with the filter-set of PANORAMIC. The strong spectral break at the redshifted Ly α line allows us to identify $z \gtrsim 9$ galaxies as dropouts in successively redder filters. Right: the sensitivity limits of PANORAMIC are shown together with typical galaxy types of interest at $z \gtrsim 3$: quiescent galaxies (red), dusty star-forming galaxies (orange), and LRD AGN candidates (gray). The vertical bars extend from the 20% deepest to the 20% brightest fields of the final PANORAMIC survey, with the center line denoting the median 5σ depth (as measured in fixed circular apertures of $0''.16$ radius in empty sky regions).

4.2. The Census of Red Massive Galaxies at $z > 3$

Because HST was only sensitive to the rest-frame UV light of $z > 3$ galaxies, the pre-JWST census of galaxies in the first 2 Gyr of cosmic history remained highly biased to relatively unobscured, star-forming galaxies. Additionally, the discovery of significant numbers of (more-massive) IRAC- or ALMA-selected galaxies over large areas that remained undetected with HST demonstrates a striking, and still little explored, discovery space (K. I. Caputi et al. 2012, 2015; T. Wang et al. 2019; C. C. Williams et al. 2019; S. M. Manning et al. 2022). Pre-JWST surveys were largely incomplete at the extremely red rest-optical colors of these $z > 3$ massive galaxies (e.g., F150W–F444W $\gtrsim 2$).

The first small-area JWST images immediately revealed very red galaxies missed by HST, including dust-obscured and quiescent candidates at $z \sim 3$ –9. The number densities, typical masses, and redshift distributions of these red sources are still highly uncertain (e.g., J. McKinney et al. 2024), but support pre-JWST conclusions that HST surveys might have missed up to 90% of massive galaxies ($\log_{10} M_*/M_\odot > 10.5$ at $z > 3$; T. Wang et al. 2019) because the massive end is almost entirely optically faint (R. Gottumukkala et al. 2023; T. Harvey et al. 2025; A. Weibel et al. 2024b). Surprisingly, JWST-selected red sources span lower-than-expected stellar masses ($9 < \log_{10} M_*/M_\odot < 10.5$; L. Barrufet et al. 2023, 2024; P. G. Pérez-González et al. 2023; G. Rodighiero et al. 2023; C. C. Williams et al. 2024) based on dust scaling relations from lower redshift (K. E. Whitaker et al. 2017). These discoveries indicate that the incompleteness in HST selection clearly does not only impact the high-mass end, but also highlights the importance of wedding cake survey strategies (e.g., PANORAMIC along with other surveys; see Figure 3).

Despite the short cosmic time available for dust production at high redshift, early galaxies host surprisingly abundant dust (Y. Fudamoto et al. 2021; S. Schouws et al. 2022; H. B. Akims et al. 2023; J. McKinney et al. 2023; M. Xiao et al. 2024). This explains why even the deepest HST+Spitzer campaigns missed these “dark” galaxies, but brings new questions to the forefront. Some fraction of newly discovered red galaxies at $3 < z < 9$ show higher-than-expected efficiency of baryon conversion into stars (I. Labbé et al. 2023; M. Xiao et al. 2024), while exhibiting dramatic field-to-field variation (G. Desprez et al.

2024). Others exhibit surprisingly dominant AGN signatures whose black holes are more massive than expected, appearing as LRDs (I. Labbé et al. 2023; L. J. Furtak et al. 2024; J. E. Greene et al. 2024; J. Matthee et al. 2024). However, a gap exists between the lower-mass tail of the distribution probed by JWST deep fields and the $\gtrsim$ degree-scale areas tracing the most extreme quasars (K. Inayoshi & K. Ichikawa 2024; V. Kokorev et al. 2024). In particular, at $z \sim 7$, we totally lack constraints on the abundances at $L_{\text{bol}} \lesssim 10^{46}$ – 10^{47} erg s $^{-1}$ scales (between LRDs and massive QSOs). Thus, PANORAMIC provides the opportunity to discover such candidates, the first step to quantifying the strain on both black hole seeding and early growth models (K. Inayoshi et al. 2020) while mitigating cosmic variance to enable robust conclusions.

Collectively, these surprises require larger sample sizes to adequately interpret the implication for our theories about black hole formation and galaxy growth. PANORAMIC stands to address these important issues: ≥ 6 broadband filters have proved remarkably efficient at identifying LRDs, massive dusty galaxies, and quiescent galaxies at $z > 3$ without the need for ancillary data (e.g., J. E. Greene et al. 2024; A. S. Long et al. 2024; C. C. Williams et al. 2024). For all classes of red galaxies at this poorly sampled epoch, probing larger volumes to collect larger and brighter samples, while using increased numbers of sight lines to decrease abundance uncertainties, is the best way to improve the empirical picture.

A key feature of the design of PANORAMIC is the capability to distinguish various red galaxy populations at $3 < z < 9$. In Figure 9 (right panel), we show a range of example SEDs with our average imaging depths (see Section 3.6.1) demonstrating that the data have the capability to distinguish the SED shapes, where existing wide-area ground-based broadband NIR and Spitzer imaging were largely unable to do so without spectroscopy (e.g., K. Glazebrook et al. 2017; B. Forrest et al. 2020; Z. C. Marsan et al. 2022; T. Nanayakkara et al. 2024). Conveniently, the optimal selection for high-redshift sources (science targets discussed in Section 4.1) coincides with the optimal design for red galaxies at $3 < z < 9$ discussed here, given the need for deep NIR coverage where the galaxies are faint, and well-sampled SEDs between 1 and 5 μm distinguish blue from red continuum in the longer-wavelength bands.

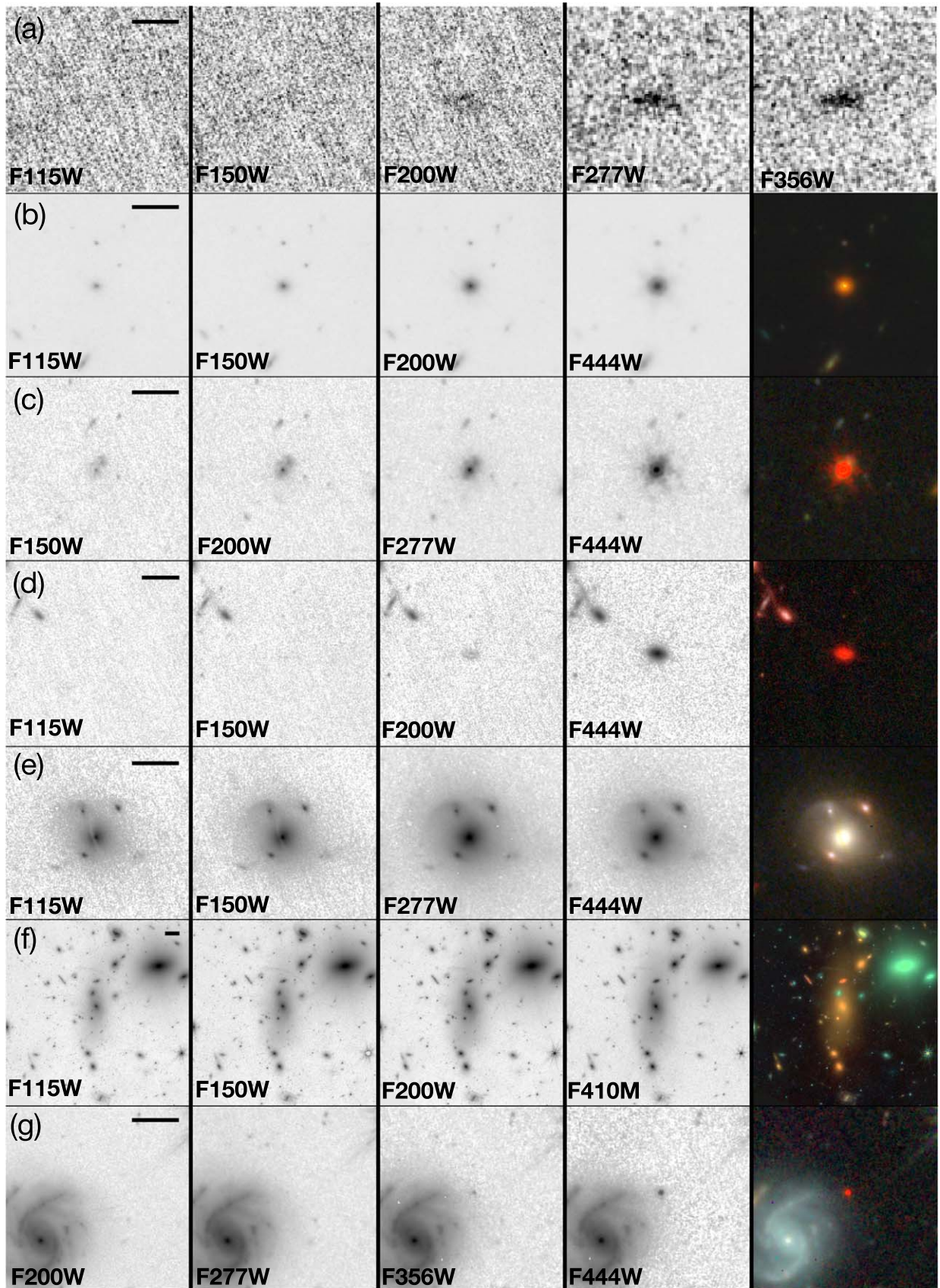


Figure 10. Exceptional sources discovered from parallel imaging highlighting importance of wide areas. Top to bottom: (a) candidate F150W-dropout; (b) candidate quiescent galaxy at $z > 3$; (c) intrinsically bright ($F444W \sim 20$ ABmag) LRD; (d) the reddest (lower limit to color $F150W - F444W > 6.4$ ABmag) galaxy at $z \sim 3.4$ in our survey; its color exceeds that of any other source in the JADES, PRIMER, and CEERS areas combined (~ 730 square arcmin); (e) $z = 3.9$ twice-imaged galaxy-galaxy lens; (f) a $z \sim 1$ galaxy cluster candidate with newly revealed lensing arcs; and (g) an $F444W \sim 24$ ABmag Y-dwarf candidate. The horizontal scale bar in each row indicates 1".

4.3. Discovery Space

Pursuing novel sky area with pure parallel imaging presents an exciting opportunity to discover unknown unknowns, and open up poorly explored parameter space of known populations of objects. Here we list a few categories of such objects we have identified using PANORAMIC beyond those discussed in the previous subsections, to illustrate the immense potential of, and motivate the collection of, additional areas with pure parallels.

4.3.1. Intrinsically Bright Sources at $z > 14$

The first JWST imaging data sets revealed possible ultraluminous galaxy candidates at $z > 14$ (e.g., R. P. Naidu et al. 2022; C. T. Donnan et al. 2023) that are seemingly inconsistent with Λ CDM. Although one candidate was ultimately an improbable $z \sim 5$ contaminant (P. Arrabal Haro et al. 2023b), more successful candidates continue to be identified at magnitudes accessible by PANORAMIC (e.g., $z_{\text{spec}} = 14.3$ and $F444W < 27.3$ ABmag; S. Carniani et al. 2024). Continuing the search over a wide area will, critically, improve the existing limits on abundances even at $z \sim 14$ (e.g., B. Robertson et al. 2024). Our filter combination will allow for robust three-filter selection of dropout sources to $z = 30$ (in principle), enabling a fast characterization of abundances at these early epochs. Even upper limits from nondetections over wider areas, with improved uncertainties from cosmic variance, provide valuable baselines for interpreting the results from deeper narrow surveys.

4.3.2. Discovery of Strong Lensing Structures

Probing wider areas increases the chances for identifying other rare phenomena, typically limited to ground-based all-sky (or square degree-scale) surveys. PANORAMIC has identified four strong galaxy–galaxy lens candidates with sources likely at $z > 3$ (e.g., Figure 10, panel (e)). Additionally, one pointing by chance overlaps a candidate $z \sim 1$ galaxy cluster in existing DECam Legacy Survey DR9 imaging (A. Dey et al. 2019; R. Zhou et al. 2021, 2023), but the new near-IR imaging from PANORAMIC now reveals multiple lensing arcs indicating a likely galaxy cluster (Figure 10, panel (f)).

4.3.3. Unknown Unknowns

Wide parallel imaging opens the opportunity to explore the fringes of the distribution of physical properties of known types of sources. For example, among our data, we identified the reddest galaxy in the known Universe (panel (d); Figure 10), which, thanks to our deep upper limits in F150W, puts a lower limit to the F150W–F444W color of > 6.35 , despite its very bright F444W magnitude (22 ABmag). While such red colors are a bit more common at fainter magnitudes ($F444W > 25$; e.g., C. C. Williams et al. 2024), no similar source (to our knowledge) exists in similar extragalactic data.

Targeting new, unexplored areas of the sky (compared to revisiting regions that already have 3–5 μm imaging from Spitzer) opens up the potential for new unexpected discoveries. Numerous PANORAMIC pointings contain unexpected surprises. As examples, PANORAMIC has identified several 3 μm dropouts ($F356W - F444W > 1.6$ and $F444W < 24 - 26.5$; Figure 10 panel (g)). While these are more plausibly cool stars that have similarly red $F356W - F444W > 1.6$ colors (e.g., Y-dwarfs; S. A. Beiler et al. 2023, 2024; K. N. Hainline et al.

2024) than $z \sim 30$ Lyman-break dropouts, given their extremely bright magnitudes, to our knowledge such objects are uncommon among the deep-field data sets. This may be because deep fields typically point outside of the plane of the Milky Way, only probing halo stellar populations. In any case, any of the plausible interpretations of F356W-dropouts (bright halo brown dwarf, very red-continuum strong emission line galaxies, $z \sim 30$ candidates) are likely to be rare occurrences among deep-field data sets, making these identifications and their follow-up interesting for a variety of astronomical subfields.

This potential should motivate further ambitious programs to collect wide-area imaging for random sight lines.

5. Summary and Data Release

We have presented and characterized the PANORAMIC Survey, the first JWST NIRCам extragalactic pure parallel imaging program in Cycle 1. This program obtained > 430 square arcmin of imaging in novel sky area, increasing the total extragalactic area observed in Cycle 1 by 60% (compared to the total area of all Cycle 1 programs including GO, GTO, and ERS with 6+ filters). The data are deep, with excellent photometric redshift performance, demonstrating the power of the pure parallel observing mode for collecting wide and deep, scientifically informative, imaging data. This is all possible at negligible cost to observatory resources, while representing the largest science-time investment of any extragalactic GO imaging program (including those with fewer filters) by more than a factor of 2 (~ 190 hr of science time on sky).

We also characterize the properties of this survey using our first data release (DR1), which includes the following science-ready data products. For data that probes novel sky area using JWST/NIRCам, we release mosaics in each filter. For images that entirely overlap other JWST/NIRCам surveys, our data will appear in legacy mosaics released in the DJA (with exception of COSMOS-Web footprints, where our data represents the longest integration time on sky, we present coadded mosaics). We also generate fitsmap viewers for each footprint (R. Hausen & B. Robertson 2022).

The mosaics and fitsmaps are currently available at <https://panoramic-jwst.github.io/>. Upon acceptance of this manuscript our refereed data products, including photometric catalogs, will be hosted on MAST as high-level science products at doi:10.17909/fpzz-as35.

The PANORAMIC survey demonstrates the unique power of pure parallel imaging programs, which can be an extremely efficient and important tool to obtain a wide-area legacy imaging data set with JWST for a wealth of science and follow-up studies by the community, from the local Universe (e.g., the environment around the LMC) up to the most distant galaxies.

Acknowledgments

The PANORAMIC team gratefully acknowledges Shelly Meyett at STScI who's efforts enabled the science pure parallels mode on JWST, only operational for the first time in Cycle 1 to be successful. Blair Porterfield is thanked for program support.

We thank the anonymous referee for providing thoughtful feedback that significantly improved this paper.

This data release and science-ready data products make use of archival JWST imaging from the following programs: 1180, 1181, 3215 (PI Eisenstein); 1210 (PI Luetzgendorf); 1283 (PI Oestlin); 1727 (PI Kartaltepe); 1810 (PI Belli); 1837 (PI Dunlop); 1895 (P. Oesch); 1963 (PI Williams); 2198 (PI Barrufet); 3383 (PI Glazebrook); and 6541 (PI Egami). The authors acknowledge the following teams and PIs for developing their observing program with a zero-exclusive-access period: COSMOS-Web (PIs Jeyhan Kartaltepe & Caitlin Casey), PRIMER (PI James Dunlop), JEMS (PIs Christina Williams, Michael Maseda, Sandro Tacchella), FRESCO (PI Pascal Oesch), CEERS (PI Steve Finkelstein), JOF (PIs Daniel Eisenstein & Roberto Maiolino), and PID 6541 (PI Eiichi Egami). This work is based in part on observations made with the NASA/ESA/CSA James Webb Space Telescope.

This research is based on observations made with the NASA/ESA Hubble Space Telescope obtained from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. This data release and science-ready data products makes use of archival HST imaging from programs with PID 10092, 10189, 10258, 10339, 10340, 10530, 11108, 11144, 11359, 11600, 12007, 12060, 12061, 12062, 12064, 12099, 12177, 12190, 12328, 12385, 12440, 12442, 12443, 12444, 12445, 12459, 12461, 12578, 12866, 12990, 13002, 13063, 13294, 13386, 13420, 13459, 13496, 13641, 13657, 13779, 13790, 13792, 13793, 13868, 13871, 13872, 14038, 14043, 14114, 14209, 14216, 14496, 14721, 14747, 14895, 15115, 15117, 15229, 15363, 15647, 15663, 15862, 15936, 16259, 16278, 16872, 9352, 9425, 9480, 9500, 9583, 9584, 9727, 9728, 9803, and 9822.

This research was supported by the International Space Science Institute (ISSI) in Bern, through ISSI International Team project 562 (First Light at Cosmic Dawn: Exploiting the James Webb Space Telescope Revolution). Ideas for this project were conceived in part at meetings made possible by the Sixten Center for Astrophysics and the Aspen Center for Physics.

This work is based in part on observations made with the NASA/ESA/CSA James Webb Space Telescope. The data were obtained from the Mikulski Archive for Space Telescopes at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-03127 for JWST. These observations are associated with program 2514. Support for program JWST-GO-2514 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-03127. C.C.W., A.C., Z.J. and K.E.W. acknowledge funding from program JWST-GO-2514 that was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-03127. S.M.M. acknowledges funding from program JWST-AR-05213.005-A that was provided through a grant from the STScI under NASA contract NAS5-03127.

The work of C.C.W. is supported by NOIRLab, which is managed by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. This work has received funding from the Swiss State Secretariat for Education, Research and

Innovation (SERI) under contract No. MB22.00072, as well as from the Swiss National Science Foundation (SNSF) through project grant 200020_207349. The Cosmic Dawn Center (DAWN) is funded by the Danish National Research Foundation under grant DNRFF140. P.D. acknowledges support from the NWO grant 016.VIDI.189.162 (“ODIN”) and warmly thanks the European Commission’s and University of Groningen’s CO-FUND Rosalind Franklin program. A.H. acknowledges support by the VILLUM FONDEN under grant 37459. DAWN is funded by the Danish National Research Foundation under grant DNRFF140. M.V.M. acknowledges support from the National Science Foundation via AAG grant 2205519 and the Wisconsin Alumni Research Foundation via grant MSN251397.

This paper uses data that were obtained by The Legacy Surveys: the Dark Energy Camera Legacy Survey (DECaLS; NOAO Proposal ID No. 2014B-0404; PIs: David Schlegel and Arjun Dey), the Beijing-Arizona Sky Survey (BASS; NOAO Proposal ID No. 2015A-0801; PIs: Zhou Xu and Xiaohui Fan), and the Mayall *z*-band Legacy Survey (MzLS; NOAO Proposal ID No. 2016A-0453; PI: Arjun Dey). DECaLS, BASS, and MzLS together include data obtained, respectively, at the Blanco telescope, Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory (NOAO); the Bok telescope, Steward Observatory, University of Arizona; and the Mayall telescope, Kitt Peak National Observatory, NOAO. NOAO is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. Please see <http://legacysurvey.org> for details regarding the Legacy Surveys. BASS is a key project of the Telescope Access Program (TAP), which has been funded by the National Astronomical Observatories of China, the Chinese Academy of Sciences (the Strategic Priority Research Program “The Emergence of Cosmological Structures” grant No. XDB09000000), and the Special Fund for Astronomy from the Ministry of Finance. The BASS is also supported by the External Cooperation Program of Chinese Academy of Sciences (grant No. 114A11KYSB20160057) and Chinese National Natural Science Foundation (grant No. 11433005). The Legacy Surveys imaging of the DESI footprint is supported by the Director, Office of Science, Office of High Energy Physics of the U.S. Department of Energy under contract No. DE-AC02-05CH1123, and by the National Energy Research Scientific Computing Center, a DOE Office of Science User Facility under the same contract; and by the U.S. National Science Foundation, Division of Astronomical Sciences under contract No. AST-0950945 to the National Optical Astronomy Observatory.

Appendix Known Issues

Beyond the pressure on the DSN, the implementation of science pure parallels presented a few additional early challenges to parallel data collection. While these challenges ultimately were resolved quickly, here we briefly track the impacted parallel observations. Observations that were skipped or rescheduled are marked as withdrawn in APT and the visit status page.²⁴

A.1. Skipped Observations

A number of single exposures were skipped for various reasons, but for which we still obtained data in at least one

²⁴ <https://www.stsci.edu/cgi-bin/get-visit-status?id=2514&markupFormat=html&observatory=JWST>

exposure per filter. These include the eastern-most pointing in association j033212m2745, which lost exposures in F200W and F444W when the prime visit (PID 1211, visit 1, observation 16) lost lock on the guide star. In total, we have four visits with only one exposure, corresponding to our program's observation Nos. 264, 265, 112, and 076.

A.2. NIRSpec Shorts

A high fraction of our data was taken in parallel with NIRSpec multi-shutter array (MSA) observations. MSA electrical shorts are known to corrupt NIRCам imaging obtained in parallel, and several of our NIRCам exposures were impacted by this effect. This impacted two pointings in GOODS-N (that in any case only received imaging in four filters instead of six due to other software issues; see Section A.5). We excluded imaging that was corrupted from our data release.

A.3. Guide Star Failures

For a few pointings, a guide star failure for the prime program forced rescheduling of the observations. For prime-program observations based on MSA (e.g., the NIRSpec GTO Wide program; M. V. Maseda et al. 2024), these observations were repeated at the same orientation angle. However, in at least one case (j013748m2152), this resulted in the repeated observations being taken at a different observatory position angle, causing 2 of the filter footprints to be significantly rotated relative to the other filters, decreasing the area covered by all filters simultaneously.

A.4. Artifacts

Several pointings exhibit scattered light features (e.g., wisps, claws, dragons breath; J. Rigby et al. 2023) that were not adequately or effectively removed using existing scattered light templates. In the case of j041616m2409 (a field also targeted by the CANUCS survey), the module and pointing most impacted sits on top of a CANUCS pointing that was uncorrupted. For simplicity, we have removed this module's data for building our catalogs in the DR1 data release since uncorrupted data over the entire module exists elsewhere.

We also note that pointing j130016p1215 is affected by a persistence image of Saturn from an earlier observation. We did not attempt to remove persistence artifacts in this data release.

A.5. Unforeseen Complications

A series of updates to the scheduling software and the onboard operating system in March 2023 resulted in skipped parallel observations (corresponding to two filters of parallel imaging) per prime-instrument visit until a solution was identified a few weeks later. This impacted ~ 20 of our parallel pointings, which, as a result, were observed only in four filters instead of six. This primarily impacted our pointings near GOODS-N since this time period spanned the scheduled observations for the NIRSpec GTO-Wide program in this field (M. V. Maseda et al. 2024). Four pointings in novel sky area were also impacted and thus only have four filters: j145652p2444, j090000p0207, j094232p0923, and j150604p5409.

During this timeframe, an update to the operating system on board the spacecraft also resulted in five of the parallel pointings from prime program PID 1213 (PANORAMIC

program observation numbers 23–25 and 35–46) getting skipped entirely in 2023 March.

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