Draft version January 16, 2024
Typeset using LaTeX default style in AASTeX631

Ultraviolet and blue optical imaging of UVCANDELS

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ABSTRACT

The UltraViolet Imaging of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey Fields (UVCANDELS) survey provided ultraviolet (UV) F275W imaging with coordinated parallel optical F435W imaging in four of the five CANDELS fields: GOODS-N, GOODS-S, EGS, and COSMOS, covering a total area of $\sim$ 426 arcmin^2. UVCANDELS takes primary WFC3/UVIS F275W exposures at a uniform 3-orbit depth and ACS F435W exposures (in parallel) at slightly varying depth due to the roll angle constraints and the overlap from the increased field of view (FoV) of the ACS camera, reaching a limiting magnitude of $\sim$27 and $\sim$28 ABmag (5σ in 0.″2 apertures) for F275W and F435W, respectively. We present the results of the UVCANDELS observations, custom calibrations, and the creation of F275W and F435W imaging mosaics, which have been made publicly available on the Barbara A. Mikulski Archive for Space Telescopes (MAST).

Keywords: Galaxy evolution (594) — Galaxy photometry (611) — High-redshift galaxies (734) — Astronomical techniques (1684)

1. INTRODUCTION

The UVCANDELS program (HST-GO-15647, PI: Teplitz) obtained 164 orbits of primary F275W imaging and coordinated parallel F435W imaging in four of the five fields targeted by the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS, Grogin et al. 2011; Koekemoer et al. 2011), providing new UV (F275W) and wide-area blue optical (F435W) coverage in the COSMOS and EGS fields, and doubling the UV area in the GOODS fields. In total, the UV coverage secured by UVCANDELS amounts to $\sim$426 arcmin^2.

In this research note, we describe the observations of the UVCANDELS program, present data reduction methodologies, and describe the creation of image mosaics for the F275W and F435W imaging.

2. OBSERVATIONS

To reach a 5-σ limiting magnitude of mag$_{\rm F275W}$=27 for compact galaxies (with 0.″2 radius), 3 orbits of two $\sim$ 1350 seconds exposures each for a total exposure time of 8100 seconds per pointing were secured in F275W. Here a minimum of 6 exposures were required for good rejection of cosmic rays. In GOODS-N, Continuous Viewing Zone increased the efficiency of the observations. To reduce the effect of UVIS charge transfer efficiency (CTE) degradation (Mackenty & Smith 2012), exposures included post-flash at a level that brings the on-chip background up to 12 e$^-$ per pixel on average, based on the STScI's best practices. The depth of the F435W parallels varies due to the overlap from the greater FOV of the ACS camera. For most area of COSMOS and EGS, 3 orbit depth was obtained with 5σ sensitivity of mag$_{\rm F435W}$=28, while the overlap regions reached 28.4mag with 6 orbits. Since the GOODS fields already have B-band coverage of sufficient depth (mag$_{\rm F435W}$ $\sim$28), we placed the new F435W data in the central CANDELS-Deep region, where deep archival UV and near-infrared data are available. The raw data is available at MAST[1]. We note that visits EGS-V07 (visits 25 and 96) and COSMOS-V48 (visits 9C and 48) had telescope issues and are not included in the DOI.

In Figure 1, we show the UVCANDELS F275W mosaics with the CANDELS F160W imaging footprints overlaid. The number of pointings in each UVCANDELS fields are 16 in GOODS-N, 8 in GOODS-S, 20 in EGS, and 16 in COSMOS. A standard dithering pattern of WFC3-UVIS-DITHER-LINE was employed in the survey to enable recovery of spatial resolution when creating mosaics with the AstroDrizzle package (Gonzaga 2012).

[1] UVCANDELS raw data is at DOI 10.17909/782k-1713.

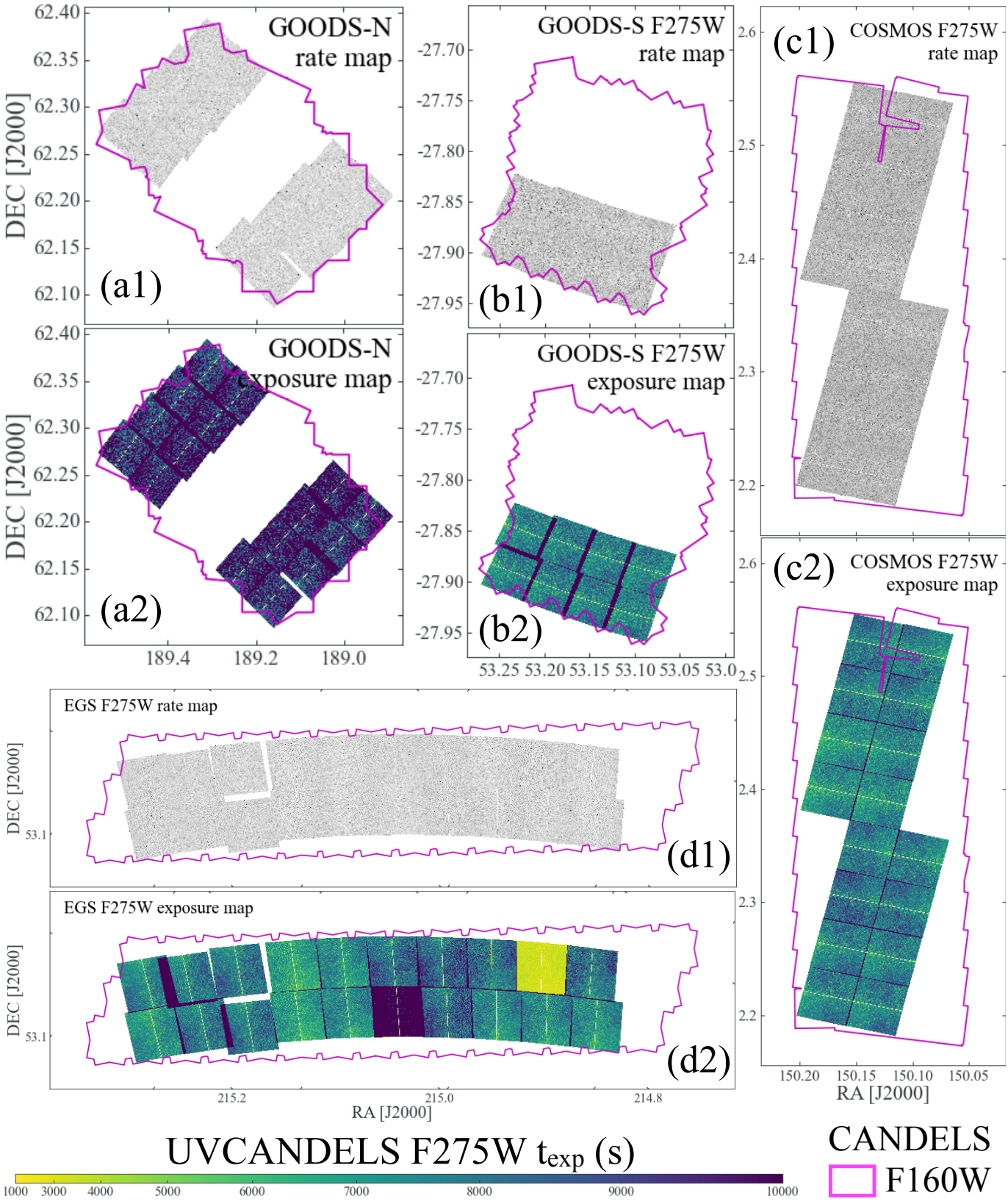

Figure 1. The UVCANDELS F275W coadded count-rate and exposure maps for the four premier CANDELS fields: GOODS-N, GOODS-S, COSMOS, and EGS, shown in panels (a), (b), (c), and (d) respectively. For all four fields, the exposure maps are on the same color scale represented by the color bar on the bottom. In all maps, we also overlay the footprints of the CANDELS F160W mosaics in magenta lines.

3. ANALYSIS

The WFC3/UVIS and ACS/WFC images were calibrated using custom routines developed in Rafelski et al. (2015); Prichard et al. (2022) and modified specifically for the UVCANDELS data. The F275W data were corrected with the updated CTE correction algorithm (Anderson et al. 2021) to account for radiation damage of the WFC3/UVIS detector over time. The official improved calibrations after 2021 and updated flux calibration to match the latest CALSPEC models were also included, which is especially important in the UV (Calamida et al. 2022). Custom hot pixel masks were generated using co-temporal darks and a variable threshold as a function of the distance to the readout to ensure a uniform number of hot pixels across the CCDs[2]. In the F275W data we also flag readout cosmic rays (ROCRs) that fall on the detector after the readout of the amplifiers has begun, which appears as negative divots in the images due to over-correction by the CTE code. We identified the ROCRs as 3 sigma negative outliers within 5 pixels of the readout direction of cosmic ray hits reported in AstroDrizzle. These negative pixels were flagged as bad pixels. We then equalize the background levels on the four amplifiers to derive clean images with constant background levels[3]. For the WFC/ACS F435W images, we also correct for scattered light likely caused by earth limb light reflected off the telescope structure (Biretta et al. 2003; Dulude et al. 2010). We checked each exposure for the existence of a 2D background gradient across the entire CCD chips and applied a difference threshold of $5e^-$ to a 3-σ clipped median. We masked sources above the threshold in the image and modeled the gradient with the Photutils Background2D module. The background level of the two chips is then equalized to the mean level determined from a 3-σ clipped mean after source masking[4].

The images were registered and stacked using pipeline adapted from Alavi et al. (2014). Briefly, we use AstroDrizzle to combine the calibrated, flat fielded WFC3/UVIS and ACS/WFC images. First, the individual calibrated images within each visit were aligned to ensure relative astrometric alignment. To correct for the small offset in pointing and rotation from different visits, we then run AstroDrizzle on each visit and align the drizzled output image to the CANDELS astrometric reference grid. The alignment is performed on the 30 mas/pix images at a precision of 0.15 pixel, using unsaturated stars and compact sources. Finally, all of these aligned calibrated images are drizzled to the same pixel scale of 60 (30) milliarcsec matched to the CANDELS reference images for the various fields[5]. Figure 1. shows the overall image footprints.

Besides the science images, AstroDrizzle also generates an inverse variance map that will be used later to make weight images and to calculate photometry uncertainties. Following Casertano et al. (2000), we apply the additional correction to the weight images to account for the correlated noise. We make publicly available these image mosaics on MAST[6].

4. SUMMARY

The results of UVCANDELS UVIS/F275W and ACS/F435W imaging were presented. The WFC3/UVIS and ACS/WFC images were calibrated using custom software including additional hot pixel rejection, readout cosmic ray rejection, image gradient flattening and amplifier normalization, and stacked with the drizzle pipeline. The calibrated, flat fielded images were combined with AstroDrizzle, and the imaging mosaics of F275W and F435W were finally created for each UVCANDELS fields, available at MAST at https://archive.stsci.edu/hlsp/uvcandels.

This work is based on the NASA/ESA HST observations obtained at the STScI. Support for Program number HST-GO-15647 was provided through a grant from the STScI under NASA contract NAS5-26555. XW is supported by the Fundamental Research Funds for the Central Universities, and the CAS Project for Young Scientists in Basic Research, Grant No. YSBR-062.

Facilities: HST (WFC3)

[2] https://github.com/lprichard/HST_FLC_corrections

[3] https://github.com/bsunnquist/uvis-skydarks, also available at DOI 10.5281/zenodo.10519230

[4] https://github.com/bsunnquist/uvis-skydarks/blob/master/remove_gradients.ipynb

[5] https://archive.stsci.edu/hlsp/candels

[6] https://archive.stsci.edu/hlsp/uvcandels

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