UV–Visible observations with *HST* in the *JWST* North Ecliptic Pole Time-Domain Field – III.

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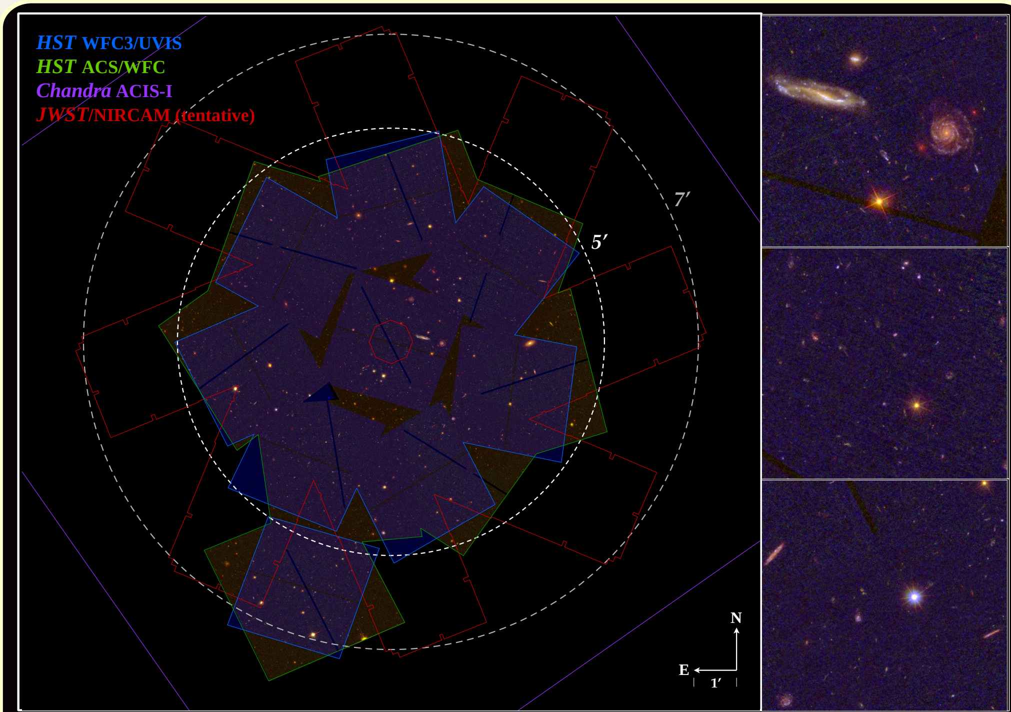
ABSTRACT

We report on a UV–Visible *HST* imaging survey of the *JWST* North Ecliptic Pole (NEP) Time-Domain Field (TDF). Using nine CVZ and pseudo-CVZ opportunities, we secured observations with WFC3/UVIS in F275W and with ACS/WFC in F435W and F606W to $m_{\rm AB} \sim 28$ mag. Our *HST* survey is designed to provide near-contiguous 3-filter coverage of the central $r \lesssim 5'$ of this new *community field* for time-domain science with *JWST* (Jansen & Windhorst 2018). The *JWST* NEP TDF at (RA,Dec)$_{\rm J2000}$ = (17:22:47.896, +65:49:21.54) is located within *JWST*'s northern Continuous Viewing Zone, will span $\sim 14'$ in diameter, is devoid of sources bright enough to saturate the sensitive NIRCam detectors, has low Galactic foreground extinction, and will be roughly circular in shape. *JWST* GTO program 1176 will initially sample the NEP TDF during Cycle 1 at four distinct orientations ("spokes") with *JWST*/NIRCam, and take NIRISS slitless grism spectroscopy in parallel such that it overlaps the coverage of an alternate NIRCam orientation. This is the *only* region in the sky where *JWST* can observe a clean extragalactic deep survey field of this size at *arbitrary cadence* or at *arbitrary orientation*. This will crucially enable a wide range of new and exciting time-domain science, including high redshift transient searches and monitoring (e.g., SNe), variability studies from Active Galactic Nuclei to brown dwarf atmospheres, as well as proper motions of extreme scattered Kuiper Belt and comets beyond the distance of Neptune, and of nearby Galactic brown dwarfs, low-mass stars, and ultracool white dwarfs. Ancillary data across the electromagnetic spectrum will exist for the NEP TDF and surrounding area when *JWST* science operations commence in 2021, ensuring a rich legacy of the UV–Visible *HST* observations. This includes deep X-ray observations; ground-based *UgrizYJHK* imaging, narrow-band spectrophotometry, and spectroscopy; (sub)mm observations; and both short- and long-wave radio observations.



[Main panel] Layout of *HST* and *Chandra* and near-future *JWST* (tentative) observations of the North Ecliptic Pole (NEP) Time-Domain Field (TDF). Mosaiced WFC3/UVIS F275W images and their overall footprint are shown in blue, while the ACS/WFC F435W images and footprint, and the F606W images appear in green and red hues, respectively. Our goal is to provide near-contiguous 3-filter UV–Visible source photometry to $m_{\rm AB} \simeq 28$ mag (the *JWST* spectroscopy limit) of the inner $r \lesssim 5'$ portion of the *JWST* NEP Time-Domain Field, which will be covered by both NIRCam and NIRISS (indicated by the dark red footprint and outer dashed circle). Additional serendipitous coverage at radii larger than 5′ exists at some position angles and in a reduced number of filters. The purple footprint indicates extant Cycle 19+20 *Chandra* ACIS-I X-ray observations. Table 1 lists the full set of ancillary observations in hand, in progress, and proposed. [right panels] Details excised from the 3-color mosaic highlighting some resolved intermediate-redshift galaxies and a star (*top*), faint background galaxies and a star in a region of overlap of two subsequent *HST* visits (*middle*), and a region containing the $z \sim 1.4$ flat-spectrum quasar that serves as the phase self-calibrator for our deep ($\sim$0.9 μJy) 3 GHz VLA radio observations (*bottom*).

The *HST* data will serve to (1) establish a baseline UV–Visible detection image at $<0.10''$ FWHM, identify ultra-high-z imposters (rest-frame UV-bright objects at $z \lesssim 6$ that would contaminate *JWST* ultra-high redshift galaxy samples), and provide a map of transients and objects moving on 37 day to $\sim$1 year time scales in the $\sim$30% areal overlap of subsequent visits; (2) identify galaxies with UV–Visible SEDs with significant non-thermal emission (weak AGN, QSOs), assess the possible escape of LyC photons at $2 < z < 3$, and place limits on that escape and IGM porosity at $3 < z < 5.6$; and (3) study mass assembly and evolution of all significantly resolved UV-bright galaxies at $z \simeq 6$ on a 'pixel-by-pixel' basis.

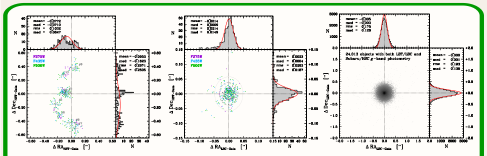


Fig. 1 — Measured astrometric offsets between the *HST* and *Gaia* DR2 astrometric reference frame as defined by 364 detected sources in common for [*a*] the initial pipeline-reduced drizzled and CTI-corrected mosaics, as reported by the WCS keyword values in the FITS headers, and [*b*] the same mosaics after correcting for systematic mean rotation and offsets resulting from the uncertainties in the absolute positions of the guide stars used in a particular visit. (*Adapted from Jansen, Grogin, et al. 2020, in prep.*). [*c*] Measured astrometric residuals with respect to the *Gaia* DR2 astrometric reference frame from a preliminary analysis of 24,013 objects observed in Sloan-*g* with both LBT/LBC and Subary/HSC within the $\sim 23' \times 25'$ area surrounding the *JWST* NEP Time-Domain Field. (*Adapted from V. Jones 2019*).

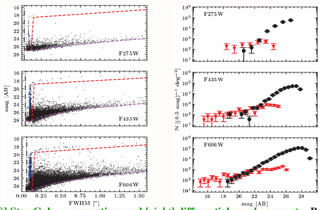


Fig. 2 — [*left*] Star-Galaxy separation, and [*right*] differential number counts. Point sources were identified and the surface brightness limit assessed in plots of source magnitude vs. fwhm for each of the three *HST* filters. Differential number counts of stars (red) and galaxies (black) are shown in units of number per 0.5 mag per deg^2 for the ACS/WFC filters, and in units of number per mag per deg^2 for the WFC3/UVIS F275W filter. The galaxy number counts follow a power law to $m_{\rm AB} \simeq 26$–28 mag, before turning over due to incompleteness, while the stellar counts follow a much shallower trend. (*Figures from C. White 2019*).

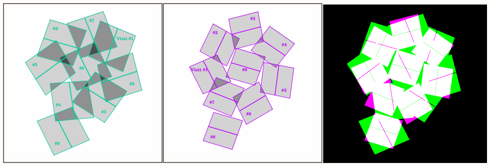


Fig. 3 — Exposure maps for [*left*] the ACS/WFC F435W and F606W images, showing the near-contiguous coverage of the central portion of the *JWST* NEP Time-Domain Field in these filters, as well as areas of 2- or 3-epoch overlap for cross-calibration and time-domain science, and [*middle*] the WFC3/UVIS F275W images, where the smaller footprint of WFC3/UVIS results in larger gaps in coverage and smaller areas of 2-epoch overlap. Each tile is labeled with its visit number. [*right*] Color composite of the combined exposure maps, with ACS/WFC F435W+F606W coverage in green and WFC3/UVIS in magenta, highlighting the area with 3-filter UV–visible coverage, which appears here as white. (*Adapted from Jansen, Grogin, et al. 2020, in prep.*)

Table 1: *JWST* NEP Time-Domain Field multiwavelength community investment

Telescope	PI	Status	Depth
NuSTAR 3–24 keV	F. Civano	approved	585 ks; >50 cts
Chandra/ACIS-I 0.2–10 keV	W.P. Maksym	in hand; 145 sources	300 ks; $\sim 4.1 \times 10^{-16}$ cgs
"	"	in progress / approved	240 ks / 360 ks
XMM-Newton 0.5–2.0 keV	M. Ward / N. Cappelluti	proposed	600 ks; 3×10^{-16} cgs
HST/WFC3+ACS *F275W,F435W,F606W*	R.A. Jansen	in hand; inner $r < 5'$ only GO 15278	36 CVZ orbits; $m \sim 27.2, 28.2, 29$ mag
"	"	proposed; annulus to $r \sim 14.2'$	52 CVZ orbits
LBT/LBC $U_{\rm sp}$*grz*	R.A. Jansen	in hand; wide-field	5 hrs; $m \sim 26.5$–25.5 mag
"	"	in hand; 2nd epoch + *i*	5 hrs; $m \sim 26.5$ mag
Subaru/HSC *giz*,nb816,nb921	G. Hasinger / E. Hu	in hand; wide-field	5 hrs; $m \sim 25.5$–25.1 mag
GTC/HiPERCAM *ugriz*	V. Dhillon	proposed; narrow-field	33 hrs; $m \sim 28$ mag
TESS (0.6–1.0μm bandpass)	G. Berriman & B. Holwerda	in progress; ultra wide-field	357 days; low-SB (tbd)
MMT/MMIRS (img) $YJHK_s$	C.N.A. Willmer	in hand	60 hrs; $m \sim 23$–24
JWST/NIRCam+NIRISS 0.8–5 μm + 1.75–2.23 μm	R.A. Windhorst / H.B. Hammel	*guaranteed time* GTO #1176, #1255	$\sim$49 hrs total; $m < 29$–28.5 mag
JCMT/SCUBA-2 850μm	I. Smail / M. Im	in progress; $\geq$93 sources	31 hrs; rms $\sim$ 1 mJy
SMA 0.87 mm	G. Fazio	approved pilot; lost to protests	37.5 hrs; rms $\sim$ 0.9 mJy
IRAM/Nika2 1.2, 2 mm	S.H. Cohen	in progress	30 hrs; rms $\sim$ 2 mJy
VLA 3(2–4) GHz	R.A. Windhorst / W. Cotton	in hand; $\sim$2500 sources	47 hrs; rms $\sim$ 0.9 μJy
VLBA 4.7 GHz	W. Brisken	in hand; $\sim$200 targets	147 hrs; rms $\sim$ 3 μJy
LOFAR 150 MHz	R. van Weeren	approved	75 hrs; rms $\sim$ 25 μJy
J-PAS (56 narrow-band spectroph.)	S. Bonoli / R. Dupke	in hand; ultra-wide field	48 hrs; $m \sim 21.5$–22.5 mag
MMT/Binospec (mos)	C.N.A. Willmer	in hand; 1378 spectra/799 redshifts	26 hrs; $m \sim 22.5$–24 mag
MMT/MMIRS (mos)	C.N.A. Willmer	approved	$m < 22$, $z > 0.4$

More Information

For more information about the *JWST* NEP Time-Domain Field, publications, and footprints of various observations, visit:

http://lambda.la.asu.edu/jwst/neptdf

Acknowledgements

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