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

Rolf A. Jansen,[†,1] Rogier Windhorst,[1] Norman Grogin,[2] Patricia Royle,[2] Anton Koekemoer,[2] Nimish Hathi,[2] Victoria Jones,[1] Seth Cohen,[1] Teresa Ashcraft,[1] Christopher Willmer,[3] Christopher Conselice,[4] Cameron White,[1] & Brenda Frye[3]

[†]*Rolf.Jansen@asu.edu; School of Earth & Space Exploration, Arizona State University, Tempe, U.S.A.*

(1) ASU, Tempe AZ; (2) STScI, Baltimore MD; (3) UofA, Tucson AZ; (4) U.Nottingham, Nottingham (U.K.)

[#354.14]

ABSTRACT

We report the first results from a UV–Visible *HST* imaging survey of the *JWST* North Ecliptic Pole (NEP) Time-Domain Field (TDF). Using CVZ and near-CVZ opportunities we observed the first two out of nine tiles with WFC3/UVIS in F275W and with ACS/WFC in both F435W and F606W. Over the course of the next 13 months, this survey is designed to provide near-contiguous 3-filter coverage of the central $r \leq 5'$ of this new *community field* for time-domain science with *JWST*. The *JWST* NEP TDF is located within *JWST*'s northern Continuous Viewing Zone, will span $\sim$14′ in diameter ($\sim$10′ with NIRISS coverage), is devoid of sources bright enough to saturate the NIRCam detectors, has low Galactic foreground extinction, and will be roughly circular in shape (initially sampled during Cycle 1 at four distinct orientations with *JWST*/NIRCam — the JWST "windmill"). NIRISS slitless grism spectroscopy will be taken in parallel, overlapping an alternate NIRCam orientation. This is the *only* region in the sky where *JWST* can observe a clean extragalactic deep survey field of this size at *arbitrary cadence* or at *arbitrary orientation*. This will crucially enable a wide range of new and exciting time-domain science, including high redshift transient searches and monitoring (e.g., SNe), variability studies from Active Galactic Nuclei to brown dwarf atmospheres, as well as proper motions of extreme scattered Kuiper Belt and Oort Cloud Objects, and of nearby Galactic brown dwarfs, low-mass stars, and ultracool white dwarfs. Ancillary data across the electromagnetic spectrum will exist for this field when *JWST* science operations commence in the second half of 2019. This includes deep ($m_{\rm AB} \gtrsim 26$ mag) wide-field ($\sim$23′$\times$25′) *Ugriz* photometry of this field and its surroundings from LBT/LBC and Subaru/HSC, *JHK* from MMT/MMIRS, VLA 3 GHz and VLBA 4.5 GHz radio observations, IRAM 30m mm observations, and *Chandra*/ACIS X-ray images. Proposals to secure spectroscopy to $m_{\rm AB} \sim 24$ mag are pending.

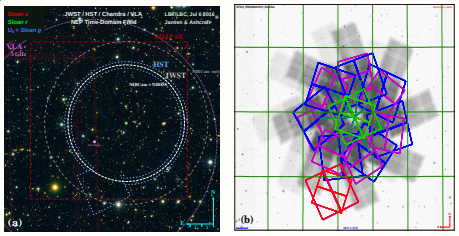
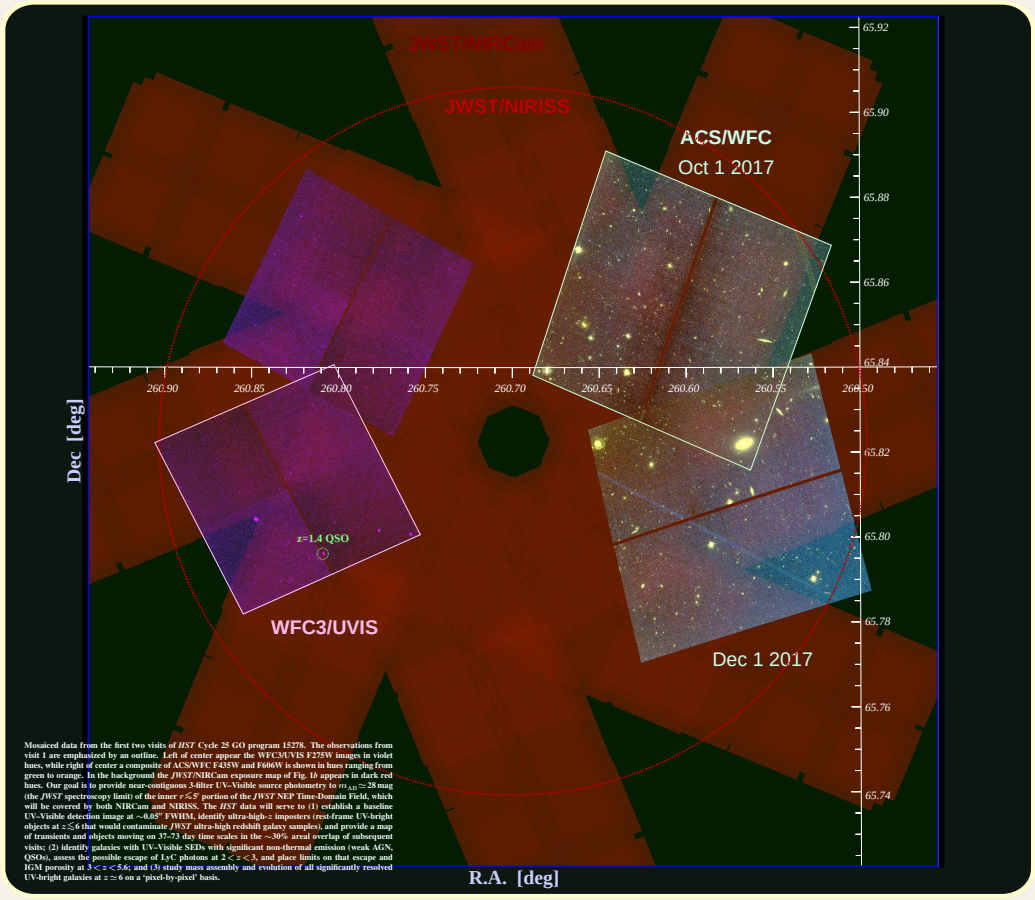


Fig. 1 (*a*) — 18.4′×19.2′ LBT/LBC *Ugrz* color mosaic centered on the *JWST* NEP TDF, with the tentative *JWST*, *HST*, MMT, and VLA survey areas indicated. *Chandra* ACIS-I observations scheduled for Apr–Jun 2018 will cover the entire field shown. The white and grey dashed circles indicate the core *JWST* NEP TDF survey area with both NIRCam 0.8–5 μm imaging *and* 1.7–2.3 μm NIRISS slitless grism spectroscopy (5′ radius), and the larger area with only NIRCam coverage (7′ radius). Very few bright stars are seen inside the $r = 5'$ radius in this ground-based image, which reaches $m_{\rm AB} \sim 26.5$ mag.
(*b*) — Layout of our *HST* ACS/WFC F435W + F606W and WFC3/UVIS F275W exposures, overlayed on a DSS image and a tentative *JWST*/NIRCam exposure map. Suitable pointing offsets and roll-angles, and the fixed angular separation of WFC3 and ACS combine to allow CVZ observations that will yield near-contiguous 3-filter UV–Visible photometry of the $r \lesssim 5'$ core region of the *JWST* NEP TDF. The *JWST* exposure map shown includes the core 4-spoke GTO survey, as well as an anticipated community-driven GO extension at a notional ΔPA of 45°. Overlap between the ACS/WFC and WFC3/UVIS footprints of subsequent visits provides a first 2-epoch baseline for time-domain science.



Mosaiced data from the first two visits of *HST* Cycle 25 GO program 15278. The observations from visit 1 are emphasized by an outline. Left of center appear the WFC3/UVIS F275W images in violet hues, while right of center a composite of ACS/WFC F435W and F606W is shown in hues ranging from green to orange. In the background the *JWST*/NIRCam exposure map of Fig. 1*b* appears in dark red hues. 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. The *HST* data will serve to (1) establish a baseline UV–Visible detection image at $\sim$0.05″ 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 37–73 day 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 $3 \lesssim z \lesssim 5.6$; and (3) study mass assembly and evolution of all significantly resolved UV-bright galaxies at $z \simeq 6$ on a 'pixel-by-pixel' basis.

Release Policy for JWST GTO data in the NEP Time-Domain Field

Raw *JWST* data on the *first* epoch of observations in the NEP TDF will be made available to the community as soon as the Windhorst IDS GTO team has access to it. Our GTO team intends to produce "Level 2 or 3" calibrated data of subsets of the NEP field as they become available, and make these public in conjunction with NEP papers and press releases as they come out. We intend to produce and make public all "Level 3" mosaiced and calibrated data of our entire *JWST* NEP TDF dataset, including ancillary data obtained by our team, 1 year after completion of our GTO program.

Moreover, we will make the NEP data of *any* subsequent epochs available immediately to any scientist or team of scientists that contribute non-trivial data sets at any wavelength, according to the "builders" model of large scientific collaborations. That way, *JWST* ERS or GO proposers should never be at a disadvantage to successfully propose for sequel epochs to our initial *JWST* NEP Time-Domain Field — thus realising the full potential of this unique field for time-domain studies.

Acknowledgements

We gratefully acknowledge support for program number HST-GO-15278 (PI: R.A. Jansen) from NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, incorporated, under NASA contract NAS5-26555.

We used the `Montage` (v5.0) toolkit (Jacob et al. 2009), funded by NASA's ESTO/CTP under Cooperative Agreement NCC5-626 between NASA and Caltech. That code was developed at the Infrared Processing and Analysis Center (IPAC) and the Jet Propulsion Laboratory (JPL) by Bruce Berriman, John Good, Joseph Jacob, Daniel Katz, and Anastacia Laity, and is maintained by the NASA/IPAC InfraRed Science Archive.

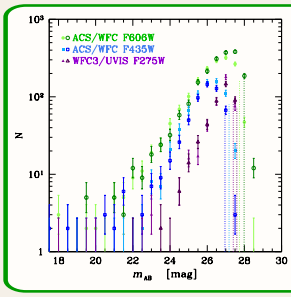


Fig. 2 — *HST* source counts per 0.5 mag bin as a function of AB magnitude for each of the 3 filters and for each of the two visits executed to date. The observed turn-over in the source counts for F275W, F435W, and F606W occurs near $m_{\rm AB} \simeq$ 27.0, 26.3, and 27.3 mag, with counts dropping to 50% of the peak at $m_{\rm AB} \simeq$ 27.5, 27.1, and 27.9 mag, respectively.

HST-GO-15278 observations to date

Visit	Date (UTC)	$N_{\rm orbit}$	Instrument	Filter	$N_{\rm exp}$	$t_{\rm exp}$ (s)
1	Oct 1, 2017	4	WFC3/UVIS	F275W	8	20,378
			ACS/WFC	F435W	8	9,273
				F606W	8	9,273
2	Dec 1, 2017	4	WFC3/UVIS	F275W	8	20,408
			ACS/WFC	F435W	8	9,273
				F606W	8	9,273
3*	Jan 20/21, 2018	4	WFC3/UVIS	F275W	8	...
			ACS/WFC	F435W	8	...
				F606W	8	...

* Scheduled visit, subject to change.