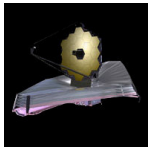

2417 - Physical Characterization of a Massive Galaxy Protocluster ~1 Billion Years after the Big Bang

Cycle: 1, Proposal Category: GO

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
az3				
	1	nircam_imag	NIRCam Imaging	(1) AZTEC-3
	3	miri_imag	MIRI Imaging	(1) AZTEC-3
	2	nirspec_ifu	NIRSpec IFU Spectroscopy	(1) AZTEC-3

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
az3_msa				
	4	phase2.0M	NIRSpec MultiObject Spectroscopy	(5) CAT5

ABSTRACT

Hyper-luminous dusty massive starburst galaxies in the first billion years of cosmic history trace some of the highest density peaks in the early universe, making them ideal benchmarks for the growth of large-scale structure. We here propose a comprehensive JWST study of the richest galaxy protocluster known at these epochs (with at least 30 members within 5 comoving Mpc, including 2 with extended Lyman-alpha halos), which is associated with one of the only three known unlensed massive starbursts at z>5. Six-band rest-frame optical to near-infrared photometry and resolved spectroscopy of H-alpha, H-beta, [NII], [SII], and [OIII] will reveal the morphology and ages of the unobscured starlight from young and old populations, the star formation histories and energetic processes in and metal enrichment of the interstellar medium and its kinematic structure, and potential feedback processes due to intense star formation or buried active galactic nuclei down to sub-kpc scales in "typical" galaxies and dusty starbursts alike - with a secure handle on dust extinction for the entire sample. This will provide a reference sample for studies of "blank field" selected samples at similar epochs from the GTO programs (which entirely miss exceptionally rare regions like the one studied here), allowing us to study the environmental dependence of galaxy evolution and the resulting galaxy properties as a function of local galaxy density. Requiring only 4.7hr on source, this program thus will make a key addition to the portfolio of JWST in its quest to solve the final mysteries of galaxy evolution towards the earliest epochs.

OBSERVING DESCRIPTION

This program has one primary target, the dusty starburst AzTEC-3 at z=5.298, 12 secondary targets (Lyman-break galaxies at z=5.3), and ~15 tertiary targets (Lyman-alpha emitter candidates at z=5.3). The observing plan includes single-pointing NIRCam and MIRI imaging in 6 bands for the field containing all sources, NIRSpec IFU spectroscopy for AzTEC-3, and NIRSpec MSA multi-object spectroscopy for the 12 secondary targets (covering 3 tertiary targets as fillers). This yields a total of 4 visits.

All sensitivities were calculated using the ETC, with fluxes predicted based on the current best spectral energy distribution fits (see examples in Fig. 3). Line fluxes for the dusty starburst were estimated based on an average spectrum of the same type of galaxies at z~2, scaled to the redshift and star formation rate of AzTEC-3. This choice was made because line fluxes cannot be predicted reliably from spectral energy distribution modeling due to patchiness of the dust extinction in dusty starbursts. Signal-to-noise ratios were obtained by choosing optimized apertures (typically 0.16"-0.21", but as large as 0.33" in some cases) for extraction based on the source sizes (e.g., 0.4"x0.2" diameter for AzTEC-3 and 1.0"x0.3" diameter for LBG-1, the examples shown in the proposal) and applying background subtraction, and then cross-checked against point source extractions and noiseless sky

background extractions for consistency.

For the spectroscopy, the main lines of interest are H-alpha at rest-frame 656.3 nm, [OIII] at 500.8 nm, H-beta at 486.1 nm, and [NII] at 658.5 nm, redshifted to 3.06-4.15 um. These lines were entered at the expected fluxes and line widths at their observed-frame wavelengths into the ETC, on top of the expected continuum fluxes.

We request 20 min on source per filter for all imaging observations and 60 min on source for all spectroscopic observations, which will be sufficient to achieve the signal-to-noise ratios necessary to complete our science goals. This yields ~4.7 hr on source total to complete all science goals.

1. NIRCAM imaging:
We request NIRCAM imaging, using the F200W, F356W, and F444W filters, to cover the spectral energy distributions longward of HST/WFC3-IR observations. F200W is used for both required setups to double the total exposure time, given the expected lower signal-to-noise ratio compared to the longer wavelength filters. We select the FULL subarray to probe the larger environment of our targets, together with the DEEP8 imaging mode, as our target sources are faint and thus require longer exposures. We use the INTRAMODULEBOX small-grid dither patterns so as to have uniform sensitivity across as much of the field as possible while optimizing the PSF sampling.

2. MIRI imaging:
We request MIRI imaging, using the F1000W, F1500W, and F2100W filters, to cover the spectral energy distributions longward of the NIRCam observations. We use a 4-point dither to achieve optimal spatial sampling in the entire field of view. We use the default FAST readout mode. The number of groups was kept modest to avoid saturation issues at the longer wavelengths.

3. NIRSpec IFU spectroscopy:
We request the NIRSpec IFU with the G395M/F290LP filter with R=1000 (given that the most important line, H-alpha, would fall onto the detector gap for the R=2700 mode), so as to simultaneously observe the H-alpha, H-beta, [NII], and [OIII] lines. This will be sufficient to resolve the 420 km/s FHWM, ~1000 km/s FWZI lines expected (based on the published [CII] 158um line profile). We request the NRS IRS2 readout pattern for improved noise performance and better sky background subtraction, and since our target sources are suffiently faint not to saturate the detector. We use a 4-point dither, so as to improve sampling of the PSF. MSATA target acquisition is selected to maximize scheduling flexibility, but we note that a m_AB(F160W)=20.4 star is available nearby (J2000 10:00:21.19, +02:35:22.36) and should be suitable for this purpose. Accurate astrometry is available based on existing HST ACS+WFC3 imaging tied to the radio and GAIA reference frames, which should be sufficient to position the IFU

detector. We choose a SPARSE-CYCLING/LARGE position 1-4 dither pattern with offsets (x:-0.575",0.575",0.425",-0.425"; y:-0.525",0.525",-0.575",0.575") to efficiently cover the entire region of interest containing the dusty starburst (at full depth; primary science goal), its Ly-alpha halo (at full to half depth), and the neighboring companions LBG-2 and LBG-3 (at half to quarter depth; secondary science goals).

4. NIRSpec MOS spectroscopy:

We request the same filter setup, acquisition, and readout mode as for the IFU spectroscopy of AzTEC-3 (given that the same lines and redshift are targeted), which will be sufficient to not dilute the lines and measure accurate line fluxes, while retaining some kinematic information for the typically 200 km/s FWHM, ~400 km/s FWZI lines expected (based on the [CII] 158um line profile of one of the sources, LBG-1). We tested the available range of position angles and found the best MSA planning solutions for a position angle of 71 deg, where all 12 targets can be covered with two MSA setups (also covering three filler targets). All primary targets can be covered with three open MSA shutters, such that the standard opening pattern is suitable. While the existing HST imaging may be sufficient to place the MSA, we conservatively request to use the NIRCam imaging for pre-imaging. We thus request to schedule these observations at least 45 days (preferrably 60 days) after the NIRCam imaging.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	AZTEC-3	RA: 10 00 20.7008 (150.0862533d) Dec: +02 35 20.31 (2.58898d) Equinox: J2000		
Comments: *Category=Galaxy* *Description=[High-redshift galaxies, Starburst galaxies, Ultraluminous infrared galaxies]* *Extended=YES*				
(4)	CAT4	RA: 10 00 20.9860 (150.0874417d) Dec: +02 35 23.67 (2.58991d) Equinox: J2000		
Comments: *Description=[]*				
(5)	CAT5	RA: 10 00 21.1040 (150.0879333d) Dec: +02 35 31.62 (2.59212d) Equinox: J2000		
Comments: *Description=[]*				

Observation

Proposal 2417, Observation 1: nircam_imag

Tue May 07 18:00:26 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Comments: We request NIRCAM imaging, using the filters F200W, F356W, and F444W filters. We select the FULL subarray, together with the DEEP8 imaging mode, as our target sources are faint and thus require longer exposures. We use the INTRAMODULEBOX dither patterns so as to have uniform sensitivity across as much of our main target field as possible.

Diagnostics

(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	AZTEC-3	RA: 10 00 20.7008 (150.0862533d) Dec: +02 35 20.31 (2.58898d) Equinox: J2000		

Comments:
Category=Galaxy
Description=[High-redshift galaxies, Starburst galaxies, Ultraluminous infrared galaxies]
Extended=YES

Template

Module	Subarray	Target Placement
B	FULL	Module Gap

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEX	2	SMALL-GRID-DITHER		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F200W	F356W	SHALLOW4	6	1	4	4	1245.465	
2	F200W	F444W	SHALLOW4	6	1	4	4	1245.465	

Observation

Proposal 2417, Observation 3: miri_imag Tue May 07 18:00:26 GMT 2024

Diagnostic Status: Warning

Observing Template: MIRI Imaging

Comments: We request MIRI imaging, using the filters F1000W, F1500W, and F2100W filters to obtain coverage over a broad range of the spectral energy distribution. We select the FULL subarray to cover the target field. A 4-point dither is employed to improve PSF sampling.

Diagnostics

(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	AZTEC-3	RA: 10 00 20.7008 (150.0862533d) Dec: +02 35 20.31 (2.58898d) Equinox: J2000		

Comments:
Category=Galaxy
Description=[High-redshift galaxies, Starburst galaxies, Ultraluminous infrared galaxies]
Extended=YES

Template

Subarray
FULL

Dithers

#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size
1	CYCLING	1	4		5	1			LARGE

Spectral Elements

#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	F1000W	FASTR1	27	4	1	Dither 1	4	16	1232.118	
2	F1500W	FASTR1	27	4	1	Dither 1	4	16	1232.118	
3	F2100W	FASTR1	27	4	1	Dither 1	4	16	1232.118	

Observation

Proposal 2417, Observation 2: nirspec_ifu

Tue May 07 18:00:26 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec IFU Spectroscopy

Comments: We request the NIRSpec IFU with the G395M/F290LP filter, so as to simultaneously observe the H-alpha and [OIII] lines. We request the NRS IRS2 readout pattern for improved noise performance and better sky background subtraction, and since our target sources are suffiently faint as not to saturate the detector. We use a 4-point dither with a large patten, so as to improve sampling of the PSF while also covering the entire region of interest associated with the main target.

Diagnostics

(nirspec_ifu (Obs 2)) Warning (Form): Record ETC Wkbk.Calc ID used to verify target acquisition.

(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	AZTEC-3	RA: 10 00 20.7008 (150.0862533d) Dec: +02 35 20.31 (2.58898d) Equinox: J2000		

Comments:
Category=Galaxy
Description=[High-redshift galaxies, Starburst galaxies, Ultraluminous infrared galaxies]
Extended=YES

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	1 AZTEC-3	WATA	FULL	F140X	NRSRAPIDD6	3	1	1	171.788	

Dithers

#	Dither Type	Size	Starting Point	Number of Points	Points
1	SPARSE-CYCLING	LARGE			1, 2, 3, 4

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	G395M/F290LP	NRSIRS2	12	1	false	true	NONE	4	4	3559.689	

Special Requirements

MSA Scheduled Aperture PA 71.9360 to 71.9360 Degrees (V3 292.9644 to 292.9644)

Observation

Proposal 2417, Observation 4: phase2.0M Tue May 07 18:00:26 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec MultiObject Spectroscopy

Comments: Two MSA setups are used to cover the full sample of 11 Lyman-break/color-selected galaxies, also including 12 filler sources.

Diagnostics

(Visit 4:1) Warning (Form): Data Excess over lower threshold

(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(5)	CAT5	RA: 10 00 21.1040 (150.0879333d) Dec: +02 35 31.62 (2.59212d) Equinox: J2000		

Comments:
Description=[]

Acquisition

#	Reference Star Bin	Target	Filter	MSA Configuration	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	Filter: F140X; Readout: NRSRAPIDD6; 8 sources in 3 quads; [Optimal TA Accuracy]	SAME	F140X	Auto Acq MSA Config	NRSRAPIDD6	3	1	4	687.153	

Template

TA Method	Obtain Confirmation Images	Science Aperture	Primary Candidate List	Filler Candidate List	Spectral Overlap Map	Spectral Overlap Threshold
MSATA	No	MSA Center	primary2 (12 sources)	filler2 (30 sources)	jwst-nirspec-g395m	1.5

Reference Stars

Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude
1	2001	150.091297	2.590933	24.00	1	2486	150.087099	2.597852	24.68
1	2004	150.087565	2.604813	24.31	1	2644	150.093489	2.603605	23.52
1	2015	150.066012	2.584428	24.73	1	2947	150.097673	2.572375	23.96
1	2205	150.076738	2.601789	24.76	1	204807	150.106290	2.562305	24.7584

Spectral Elements

#	Exposure Specification	MSA Configuration	Nod Pattern	Pointing	Aperture PA	Dispersion Offset (Shutters)	Cross-Dispersion Offset (Shutters)	Total Dithers	Total Integrations	Total Exposure Time
1	1 (G395M/F290LP)	c1	2 Shutter Slitlet	150.07892091666668 Degrees 2.5719991666666666 Degrees	249.77263948936215			2	6	6127.334
2	1 (G395M/F290LP)	c2	2 Shutter Slitlet	150.07941495833333 Degrees 2.5786938888888886 Degrees	249.77264771034024			2	6	6127.334

Special Requirements	MSA Scheduled Aperture PA 249.7730 to 249.7730 Degrees (V3 111.19847 to 111.19847)