



1567 - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongly Lensed Sub-L* Galaxy at $z=6.072$

Cycle: 1, Proposal Category: GO

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OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	4	NIRCam Imaging	NIRCam Imaging	(8) NIRCAM-CENTER
	2	NIRSpec IFU (z6.3)	NIRSpec IFU Spectroscopy	(5) Group Z6.3-BG
	3	NIRSpec IFU(z6.1/6.2)	NIRSpec IFU Spectroscopy	(6) Group Z6.1-6.2-BG
	5	NIRSpec IFU(z6.1/6.2) [resobservation]	NIRSpec IFU Spectroscopy	(6) Group Z6.1-6.2-BG

ABSTRACT

We propose NIRCam imaging and NIRSpec IFU spectroscopy for two multiple images of a strongly lensed Lyman break galaxy at $z_{\text{[CII]}}=6.072$ discovered by a 100-hr ALMA Lensing Cluster Survey. Among normal star-forming galaxies at $z>5$, both of the multiple images are the brightest lensed sources known, with the H-band continuum of $H\sim 23.7$ mag and the [CII]158 μm line flux of ~ 20 mJy due to the high magnification factors. One of the lensed images is stretched over a 6''-scale arc crossing the critical line, making a $z=6$ sub-L* galaxy ($M_{\text{star}}\sim 10^9 M_{\text{sun}}$) with extremely faint dust emission ($L_{\text{FIR}}\sim 10^9 L_{\text{sun}}$) highly visible. Exploiting these unique ALMA lensed sources with well characterised cold inter-stellar medium (ISM) properties, this JWST program unveils the remaining key elements of their hot ISM and stellar properties by 1) mapping out star-forming regions and stellar mass distributions down to ~ 20 -80 pc scales and ~ 32 -35 mag after the lens correction, 2) obtaining rest-frame optical lines of H α , H β , [OIII]5007, [NII]6583, [SII]6716,6731 to determine ionizing sources on the BPT diagram and to estimate electron density, metal gradients, and dust attenuation, and 3) probing kinematics of star-forming clumps and the rotation curve of the host galaxy disk up to

~2.5x effective radius to test the existence of inflow/outflowing gas clumps and a potential declination of the rotation curve as reported in baryon-dominated massive galaxies at $z \sim 1-2$. This joint ALMA and JWST study is an essential step in providing a representative view of the early galaxy assembly at $z=6$ with building blocks of both dark matter and baryon down to globular cluster scales.

OBSERVING DESCRIPTION

The proposed observations perform NIRCam F150W/F356W/F444W imaging and NIRSpec G395H/290LP IFU spectroscopy towards uniquely bright, strongly lensed and multiply imaged Lyman-break galaxy at $z=6.072$, aiming at 1) mapping out star-forming regions and stellar mass distributions down to $\sim 20-80$ pc scales and $\sim 32-35$ mag after the lens correction, 2) obtaining rest-frame optical lines of H α , H β , [OIII]5007, [NII]6583, [SII]6716,6731 to evaluate ionizing sources on the BPT diagram and to estimate electron density, metal gradients, and dust attenuation, and 3) probing kinematics of star-forming clumps and a rotation curve of the host galaxy disk up to ~ 2.5 x effective radius to test the existence of inflow/outflowing gas clumps and a potential declination as reported in baryon-dominated massive galaxies at $z \sim 1-2$.

Proposal 1567 - Targets - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongly Lens...

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	Z6.3	RA: 06 00 9.5593 (90.0398304d) Dec: -20 08 11.02 (-20.13639d) Equinox: J2000		
<i>Comments:</i> Category=Galaxy Description=[High-redshift galaxies] Extended=YES				
(2)	Z6.1-6.2	RA: 06 00 9.2184 (90.0384100d) Dec: -20 08 26.25 (-20.14062d) Equinox: J2000		
<i>Comments:</i> Category=Galaxy Description=[High-redshift galaxies] Extended=YES				
(3)	BG-Z6.3	RA: 06 00 9.4674 (90.0394475d) Dec: -20 08 7.66 (-20.13546d) Equinox: J2000		
<i>Comments: This is a background target for the off scene nod in the NIRSpect IFU observations for z6.3.</i> Category=Galaxy Description=[High-redshift galaxies] Extended=NO				
(4)	BG-Z6.1-6.2	RA: 06 00 9.4216 (90.0392567d) Dec: -20 08 28.21 (-20.14117d) Equinox: J2000		
<i>Comments: This is a background target for the off scene nod in the NIRSpect IFU observations for z6.1/6.2.</i> Category=Galaxy Description=[High-redshift galaxies] Extended=NO				
(5)	Group Z6.3-BG			
<i>Comments: NIRSpect IFU observations in off scene nod</i> Target Selection=[1 Z6.3, 3 BG-Z6.3]				
(6)	Group Z6.1-6.2-BG			
<i>Comments: NIRSpect IFU observations in off scene nod</i> Target Selection=[2 Z6.1-6.2, 4 BG-Z6.1-6.2]				
(8)	NIRCAM-CENTER	RA: 06 00 5.6632 (90.0235967d) Dec: -20 08 20.86 (-20.13913d) Equinox: J2000		
<i>Comments: This is the pointing center of B module in NIRCcam observations.</i> Category=Calibration Description=[Aperture location] Extended=NO				
(9)	TA	RA: 06 00 9.9557 (90.0414821d) Dec: -20 08 9.36 (-20.13593d) Equinox: J2000		
<i>Comments: This is a star nearby z6.3 which we use for the target acquisition in NIRSpect observations.</i> Category=Calibration Description=[Target acquisition test] Extended=NO				

Fixed Targets

Proposal 1567 - Targets - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongly Lens...

(10)	Z6ALMA	RA: 06 00 4.9907 (90.0207946d) Dec: -20 09 24.36 (-20.15677d) Equinox: J2000
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Comments:
Category=Galaxy
Description=[High-redshift galaxies]
Extended=YES

Proposal 1567 - Observation 4 - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongl...

Fri Oct 21 20:00:58 GMT 2022

Observation	<p>Proposal 1567, Observation 4: NIRCam Imaging</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRCam Imaging</p> <p><i>Comments: Since our targets z6.1/6.2 and z6.3 are separated just by ~20", our targets are fitted in the 2'x2' Field-of-View (FoV) of NIRCam. However, there is a bright star located east of source z6.3, and we have to ensure that its diffraction spikes do not overlap z6.3. Based on results from the JWST PSF simulation and general target visibility tools, we find that any position angle in the ranges of 17-67, 295-309, AND 317-33 deg will successfully avoid placing these spikes on the source and be schedulable.</i></p> <p><i>We confirm that there is a preferable position for the FoV center of the module B where z6.1/6.2 and z6.3 (and even the other remaining multiple images z6.4, and z6.5 by chance) will be observed in any of the above position angles without falling in the ~5" detector gaps in the shorter wavelength image. We adopt this position for the FoV center in the NIRCam observation.</i></p>									
	<p>(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p>									
Diagnostics										
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections			Miscellaneous		
	(8)	NIRCAM-CENTER	RA: 06 00 5.6632 (90.0235967d) Dec: -20 08 20.86 (-20.13913d) Equinox: J2000							
<p><i>Comments: This is the pointing center of B module in NIRCam observations.</i></p> <p><i>Category=Calibration</i></p> <p><i>Description=[Aperture location]</i></p> <p><i>Extended=NO</i></p>										
Template	Module					Subarray				
	ALL					FULL				
Dithers	#	Primary Dither Type		Primary Dithers	Subpixel Dither Type		Dither Size	Subpixel Positions		
	1	INTRAMODULEBOX		4	STANDARD			1		
Spectral Elements	#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	1	F150W	F356W	MEDIUM8	6	1	4	4	2490.931	54045
	2	F150W	F444W	MEDIUM8	6	1	4	4	2490.931	54045
	3	F115W	F277W	SHALLOW4	9	1	4	4	1889.672	
Special Requirements	Aperture PA Range 28.88744876 to 59.88744876 Degrees (V3 28.95880186 to 59.95880186)									
	Offset 87.0 arcsec, 1.0 arcsec									

Proposal 1567 - Observation 2 - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongl...

Fri Oct 21 20:00:58 GMT 2022

Observation	Proposal 1567, Observation 2: NIRSpec IFU (z6.3) Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy Background Observations:[]																																												
	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.																																												
Diagnostics																																													
Fixed Targets	<table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th colspan="4">Targ. Coord. Corrections</th> <th colspan="4">Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(5)</td> <td>Group Z6.3-BG</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="11"> <i>Comments: NIRSpec IFU observations in off scene nod</i> <i>Target Selection=[1 Z6.3, 3 BG-Z6.3]</i> </td> </tr> </tbody> </table>											#	Name	Target Coordinates	Targ. Coord. Corrections				Miscellaneous				(5)	Group Z6.3-BG											<i>Comments: NIRSpec IFU observations in off scene nod</i> <i>Target Selection=[1 Z6.3, 3 BG-Z6.3]</i>										
	#	Name	Target Coordinates	Targ. Coord. Corrections				Miscellaneous																																					
(5)	Group Z6.3-BG																																												
<i>Comments: NIRSpec IFU observations in off scene nod</i> <i>Target Selection=[1 Z6.3, 3 BG-Z6.3]</i>																																													
Acquisition	<table border="1"> <thead> <tr> <th>#</th> <th>Target</th> <th>TA Method</th> <th>Subarray</th> <th>Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>9 TA</td> <td>WATA</td> <td>SUB32</td> <td>F140X</td> <td>NRSRAPID</td> <td>3</td> <td>1</td> <td>1</td> <td>0.08</td> <td>54045</td> </tr> </tbody> </table>											#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	1	9 TA	WATA	SUB32	F140X	NRSRAPID	3	1	1	0.08	54045												
	#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID																																		
1	9 TA	WATA	SUB32	F140X	NRSRAPID	3	1	1	0.08	54045																																			
Dithers	<table border="1"> <thead> <tr> <th>#</th> <th>Dither Type</th> <th>Size</th> <th>Starting Point</th> <th>Number of Points</th> <th>Points</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>4-POINT-DITHER</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>											#	Dither Type	Size	Starting Point	Number of Points	Points	1	4-POINT-DITHER																										
	#	Dither Type	Size	Starting Point	Number of Points	Points																																							
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Spectral Elements	<table border="1"> <thead> <tr> <th>#</th> <th>Grating/Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Leakcal</th> <th>Dither</th> <th>Autocal</th> <th>Total Dithers</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>G395H/F290LP</td> <td>NRSIRS2</td> <td>20</td> <td>1</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>5893.912</td> <td>54045</td> </tr> </tbody> </table>											#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	1	G395H/F290LP	NRSIRS2	20	1	false	true	NONE	4	4	5893.912	54045										
	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID																																	
1	G395H/F290LP	NRSIRS2	20	1	false	true	NONE	4	4	5893.912	54045																																		

Proposal 1567 - Observation 3 - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongl...

Fri Oct 21 20:00:58 GMT 2022

Observation	Proposal 1567, Observation 3: NIRSpec IFU(z6.1/6.2) Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy Background Observations:[]											
	(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.											
Diagnosics												
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous			
	(6)	Group Z6.1-6.2-BG										
Comments: NIRSpec IFU observations in off scene nod Target Selection=[2 Z6.1-6.2, 4 BG-Z6.1-6.2]												
Acquisition	#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	
	1	9 TA	WATA	SUB32	F140X	NRSRAPID	3	1	1	0.08	54045	
Dithers	#	Dither Type		Size	Starting Point			Number of Points		Points		
	1	4-POINT-DITHER										
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	G395H/F290LP	NRSIRS2	20	1	false	true	NONE	4	4	5893.912	54045

Proposal 1567 - Observation 5 - Early Galaxy Assembly Uncovered with ALMA and JWST: A Remarkably UV and [CII] Bright, Strongl...

Fri Oct 21 20:00:58 GMT 2022

Observation	Proposal 1567, Observation 5: NIRSpec IFU(z6.1/6.2) [resobservation] Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy Background Observations:[]											
	(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.											
Diagnostics												
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous			
	(6)	Group Z6.1-6.2-BG										
Comments: NIRSpec IFU observations in off scene nod Target Selection=[2 Z6.1-6.2, 4 BG-Z6.1-6.2]												
Acquisition	#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	
	1	9 TA	WATA	SUB32	F140X	NRSRAPID	3	1	1	0.08	54045	
Dithers	#	Dither Type		Size	Starting Point			Number of Points		Points		
	1	4-POINT-DITHER										
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	G395H/F290LP	NRSIRS2	20	1	false	true	NONE	4	4	5893.912	54045