



# 4106 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Cycle: 2, Proposal Category: GO

## INVESTIGATORS

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<b>Prof. Erica Nelson (PI)</b>	<b>University of Colorado at Boulder</b>
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Dr. Katherine Suess (CoI)	University of Colorado at Boulder
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Dr. Joel Leja (CoI)	The Pennsylvania State University
Prof. Ivo Labbe (CoI) (CoPI)	Swinburne University of Technology
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Chloe Benton (CoI)	University of Colorado at Boulder
Dr. Bingjie Wang (CoI)	Princeton University
Dr. Renske Smit (CoI) (ESA Member)	Liverpool John Moores University

## OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	5	38094u2	NIRSpec MultiObject Spectroscopy	(9) msa-cat-v2
	6	35300u1	NIRSpec MultiObject Spectroscopy	(9) msa-cat-v2

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
	8	RC2	NIRSpec MultiObject Spectroscopy	(10) msa-cat-14mar25
	7	2859u2	NIRSpec MultiObject Spectroscopy	(9) msa-cat-v2

## ABSTRACT

One of the most remarkable findings from JWST's first month of public data was the discovery of six galaxies at  $7 < z < 10$  with extremely red colors implying stellar masses so large they challenge early galaxy assembly models in a standard LCDM cosmology (Labbe+22, Boylan-Kolchin+22). Namely, there are no halos massive enough to contain these galaxies at these redshifts, even if ALL baryons in them were converted to stars. The seemingly more likely possibility is that the stellar mass estimates are too high because the broad-band photometry is dominated by bright emission lines. Interestingly, this solution requires formation times of  $< 10$  Myr. The first spectroscopic follow-up of one of these candidate massive galaxies has revealed third equally exciting and unanticipated solution: the object is revealed to be a low-luminosity quasar hosting a Milky-way sized black hole at  $z=5.6$ . Any result here is exciting: it is a win-win scenario. Here, we propose JWST/NIRSpec spectroscopy that will yield precise redshifts and constrain the emission line contributions that could be boosting the broadband NIRCам fluxes and biasing  $M_{\star}$  estimates. The proposed combination of low- and medium-resolution spectra offers the only efficient and comprehensive test of the masses and redshifts of these objects. Whether this program confirms extreme stellar masses, finds more exotic Milky-way black holes, or reveals that galaxies can form in  $< 10$  Myr, it will pave the way for detailed studies of uncharted discovery space in future JWST cycles.

## OBSERVING DESCRIPTION

This program will obtain Nirspec spectroscopy of 5 galaxies with  $\log(M) > 10$  at  $z=7-10$  from Labbe et al. 2022. This will be done in three MSA pointings in the CEERS field. For each source, we will take two NIRSpec spectra: one in Prism R100, one in G395M. PRISM exposure times are set by the requirement of SNR resolution element  $> 3$  which allowing the measurment of aa redshifted continuum break. G395M exposure times are set by the requirement of detecting any line with equivalent width greater than 100Angstroms at a signal to noise of 5. These integration times range from 1-4 hours and result in a total on source integration time of 8 hours. 20-30 additional targets will be used to fill the remainder of available MSA real estate prioritized as:  $\log(M) < 10$  galaxies from Labbe et al. 2022, HST-dark galaxies, galaxies with  $z > 2$  in order of decreasing F150W-F444W color.

Proposal 4106 - Targets - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
	(9)	msa-cat-v2	RA: 14 19 38.5331 (214.9105546d) Dec: +52 52 37.53 (52.87709d) Equinox: J2000  <i>Comments:</i> Description=[]		
(10)	msa-cat-14mar25	RA: 14 19 32.7289 (214.8863704d) Dec: +52 51 35.05 (52.85974d) Equinox: J2000  <i>Comments:</i> Description=[]			

Proposal 4106 - Observation 5 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Tue Mar 18 22:00:41 GMT 2025

<b>Observation</b>	<b>Proposal 4106, Observation 5: 38094u2</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSpect MultiObject Spectroscopy										
	(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>			<b>Targ. Coord. Corrections</b>			<b>Miscellaneous</b>		
	(9)	msa-cat-v2	RA: 14 19 38.5331 (214.9105546d) Dec: +52 52 37.53 (52.87709d) Equinox: J2000								
<i>Comments: Description=[]</i>											
<b>Acquisition</b>	<b>#</b>	<b>Reference Star Bin</b>	<b>Target</b>	<b>Filter</b>	<b>MSA Configuration</b>	<b>Readout Pattern</b>	<b>Groups/Int</b>	<b>Integrations/Exp</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>	<b>ETC Wkbk.Calc ID</b>
	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	
<b>Template</b>	<b>TA Method</b>	<b>HFF Readout Mode</b>	<b>Obtain Confirmation Images</b>	<b>Science Aperture</b>	<b>Primary Candidate List</b>	<b>Filler Candidate List</b>	<b>Spectral Overlap Map</b>	<b>Spectral Overlap Threshold</b>			
	MSATA	false	After Target ACQ and New MSA Config	MSA Center	New Candidate Set (5 sources)	msa-cat-v2 (11339 sources)	jwst-nirspec-hr	1.5			
<b>Reference Stars</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	
	1	56020	214.959700	52.923336	24.00128922731221	1	78189	214.910164	52.930539	22.856680189180317	
	1	56679	214.948798	52.916920	23.78837797262687	1	79390	214.911055	52.933124	22.431242658955036	
	1	67657	214.937906	52.929503	24.67838851943401	1	84031	214.903282	52.937869	24.099291911842755	
	1	71701	214.950396	52.946655	22.62499316854253	1	84822	214.901389	52.938101	23.937936283004753	
<b>Confirmation</b>	<b>#</b>	<b>Confirmation Type</b>	<b>Conf. Readout Pattern</b>	<b>Conf. Groups/Int</b>	<b>Conf. Integrations/Exp</b>	<b>Conf. Total Integrations</b>	<b>Conf. Total Exposure Time</b>				
	1	c1_mb	NRSIRS2RAPID	6	1	1	102.122				

Proposal 4106 - Observation 5 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

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_mb	3 Shutter Slitlet	214.92768791666 666 Degrees 52.94555 Degrees	23.897368509654 33			3	3
	2	2 (PRISM/CLEAR)	c1_mb	3 Shutter Slitlet	214.92768791666 666 Degrees 52.94555 Degrees	23.897368509654 33			3	3	2669.767
Special Requirements	MSA Scheduled Aperture PA 23.8836 to 23.8836 Degrees (V3 245.30904 to 245.30904)										

Proposal 4106 - Observation 6 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Tue Mar 18 22:00:41 GMT 2025

<b>Observation</b>	<b>Proposal 4106, Observation 6: 35300u1</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSpect MultiObject Spectroscopy										
	(35300u1 (Obs 6)) Warning (Form): Config c1_mb (#1) has 2 filler slits affected by failed closed shutters. (35300u1 (Obs 6)) Warning (Form): Config c1_mb (#2) has 2 filler slits affected by failed closed shutters. (Visit 6:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>			<b>Targ. Coord. Corrections</b>			<b>Miscellaneous</b>		
	(9)	msa-cat-v2	RA: 14 19 38.5331 (214.9105546d) Dec: +52 52 37.53 (52.87709d) Equinox: J2000								
<i>Comments: Description=[]</i>											
<b>Acquisition</b>	<b>#</b>	<b>Reference Star Bin</b>	<b>Target</b>	<b>Filter</b>	<b>MSA Configuration</b>	<b>Readout Pattern</b>	<b>Groups/Int</b>	<b>Integrations/Exp</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>	<b>ETC Wkbk.Calc ID</b>
	1	Filter: F140X; Readout: NRSRAPIDD6; 8 sources in 4 quads; [ Optimal TA Accuracy ]	SAME	F140X	Auto Acq MSA Config	NRSRAPIDD6	3	1	4	687.153	
<b>Template</b>	<b>TA Method</b>	<b>HFF Readout Mode</b>	<b>Obtain Confirmation Images</b>	<b>Science Aperture</b>	<b>Primary Candidate List</b>	<b>Filler Candidate List</b>	<b>Spectral Overlap Map</b>	<b>Spectral Overlap Threshold</b>			
	MSATA	false	After Target ACQ and New MSA Config	MSA Center	New Candidate Set (5 sources)	msa-cat-v2 (11339 sources)	jwst-nirspec-hr	1.5			
<b>Reference Stars</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	
	1	58432	214.887522	52.876959	23.59603821088049	1	82932	214.866895	52.909539	23.90564236985999	
	1	59884	214.881595	52.875542	23.94601926048945	1	83673	214.874738	52.916611	23.19289157857705	
	1	61935	214.899369	52.891989	23.82703096585686	1	84463	214.856300	52.904970	24.05890506375774	
	1	62925	214.898420	52.892871	24.42732888010860	1	87141	214.817984	52.882991	22.91274212923147	
<b>Confirmation</b>	<b>#</b>	<b>Confirmation Type</b>	<b>Conf. Readout Pattern</b>	<b>Conf. Groups/Int</b>	<b>Conf. Integrations/Exp</b>	<b>Conf. Total Integrations</b>	<b>Conf. Total Exposure Time</b>				
	1	c1_mb	NRSIRS2RAPID	6	1	1	102.122				

Proposal 4106 - Observation 6 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

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_mb	3 Shutter Slitlet	214.86714083333 334 Degrees 52.890933333333 33 Degrees	23.744133969331 5			3	6
	2	2 (PRISM/CLEAR)	c1_mb	3 Shutter Slitlet	214.86714083333 334 Degrees 52.890933333333 33 Degrees	23.744133969331 5			3	15	13348.834
Special Requirements	MSA Scheduled Aperture PA 23.7787 to 23.7787 Degrees (V3 245.20416 to 245.20416)										

Proposal 4106 - Observation 8 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Tue Mar 18 22:00:41 GMT 2025

<b>Observation</b>	<b>Proposal 4106, Observation 8: RC2</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSpec MultiObject Spectroscopy										
	(Visit 8:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>			<b>Targ. Coord. Corrections</b>			<b>Miscellaneous</b>		
	(10)	msa-cat-14mar25	RA: 14 19 32.7289 (214.8863704d) Dec: +52 51 35.05 (52.85974d) Equinox: J2000								
<i>Comments: Description=[]</i>											
<b>Acquisition</b>	<b>#</b>	<b>Reference Star Bin</b>	<b>Target</b>	<b>Filter</b>	<b>MSA Configuration</b>	<b>Readout Pattern</b>	<b>Groups/Int</b>	<b>Integrations/Exp</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>	<b>ETC Wkbk.Calc ID</b>
	1	Filter: CLEAR; Readout: NRSRAPID; 8 sources in 4 quads; [ Optimal TA Accuracy ]	SAME	CLEAR	Auto Acq MSA Config	NRSRAPID	3	1	4	171.788	
<b>Template</b>	<b>TA Method</b>	<b>HFF Readout Mode</b>	<b>Obtain Confirmation Images</b>	<b>Science Aperture</b>	<b>Primary Candidate List</b>	<b>Filler Candidate List</b>	<b>Spectral Overlap Map</b>	<b>Spectral Overlap Threshold</b>			
	MSATA	false	No	MSA Center	Primary (156 sources)	Secondary (5448 sources)	jwst-nirspec-hr	1.5			
<b>Reference Stars</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	<b>Visit</b>	<b>ID</b>	<b>RA</b>	<b>Dec</b>	<b>Magnitude</b>	
	1	62043	214.868588	52.869203	21.56278317703866	1	83160	214.829958	52.883296	22.34801031772942	
	1	64561	214.830810	52.846661	22.93960951933325	1	85268	214.807315	52.871139	22.31267486669325	
	1	67731	214.870531	52.880743	22.93999410389813	1	88453	214.835142	52.897868	22.92792180974156	
	1	80305	214.836603	52.881921	22.02585377749108	1	89333	214.796507	52.873591	22.62198687892193	
<b>Spectral Elements</b>	<b>#</b>	<b>Exposure Specification</b>	<b>MSA Configuration</b>	<b>Nod Pattern</b>	<b>Pointing</b>	<b>Aperture PA</b>	<b>Dispersion Offset (Shutters)</b>	<b>Cross-Dispersion Offset (Shutters)</b>	<b>Total Dithers</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>
	1	2 (PRISM/CLEAR)	c1	3 Shutter Slitlet	214.8355 Degrees 52.871494444444 444 Degrees	318.39550560712 03			3	9	10635.301
	2	1 (G395M/F290LP)	c2-2	3 Shutter Slitlet	214.8355 Degrees 52.871494444444 444 Degrees	318.39550560712 03			3	9	13917.801
	3	1 (G395M/F290LP)	c2-2	3 Shutter Slitlet	214.8355 Degrees 52.871494444444 444 Degrees	318.39550560712 03			3	9	13917.801

Proposal 4106 - Observation 8 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Special Requirements

Background Limited. Background no more than 20th percentile above minimum  
MSA Scheduled Aperture PA 318.4360 to 318.4360 Degrees (V3 179.86147 to 179.86147)

Proposal 4106 - Observation 7 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

Tue Mar 18 22:00:41 GMT 2025

<b>Observation</b>	<b>Proposal 4106, Observation 7: 2859u2</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSspec MultiObject Spectroscopy																																																											
	(2859u2 (Obs 7)) Warning (Form): Config c1_mb (#1) has 2 filler slits affected by failed closed shutters. (2859u2 (Obs 7)) Warning (Form): Config c1_mb (#2) has 2 filler slits affected by failed closed shutters. (Visit 7:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.																																																											
<b>Diagnosics</b>																																																												
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(9)	msa-cat-v2	RA: 14 19 38.5331 (214.9105546d) Dec: +52 52 37.53 (52.87709d) Equinox: J2000																																																										
Comments: Description=[]																																																												
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<b>Reference Stars</b>	<table border="1"> <thead> <tr> <th>Visit</th> <th>ID</th> <th>RA</th> <th>Dec</th> <th>Magnitude</th> <th>Visit</th> <th>ID</th> <th>RA</th> <th>Dec</th> <th>Magnitude</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>40102</td> <td>214.850721</td> <td>52.808509</td> <td>23.12430753224446 5</td> <td>1</td> <td>71245</td> <td>214.790992</td> <td>52.831060</td> <td>23.54415200689558 3</td> </tr> <tr> <td>1</td> <td>50652</td> <td>214.866691</td> <td>52.843275</td> <td>23.39297654300636 3</td> <td>1</td> <td>72816</td> <td>214.823373</td> <td>52.857423</td> <td>23.38509865596627 4</td> </tr> <tr> <td>1</td> <td>55412</td> <td>214.869655</td> <td>52.857127</td> <td>23.01998224127235 6</td> <td>1</td> <td>75015</td> <td>214.787732</td> <td>52.836063</td> <td>22.78701235816806 7</td> </tr> <tr> <td>1</td> <td>70689</td> <td>214.842762</td> <td>52.867144</td> <td>23.52288543405407 5</td> <td>1</td> <td>75790</td> <td>214.785715</td> <td>52.836071</td> <td>22.51722571743432</td> </tr> </tbody> </table>										Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude	1	40102	214.850721	52.808509	23.12430753224446 5	1	71245	214.790992	52.831060	23.54415200689558 3	1	50652	214.866691	52.843275	23.39297654300636 3	1	72816	214.823373	52.857423	23.38509865596627 4	1	55412	214.869655	52.857127	23.01998224127235 6	1	75015	214.787732	52.836063	22.78701235816806 7	1	70689	214.842762	52.867144	23.52288543405407 5	1	75790	214.785715	52.836071	22.51722571743432
	Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude																																																		
	1	40102	214.850721	52.808509	23.12430753224446 5	1	71245	214.790992	52.831060	23.54415200689558 3																																																		
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1	70689	214.842762	52.867144	23.52288543405407 5	1	75790	214.785715	52.836071	22.51722571743432																																																			
<b>Confirmation</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Confirmation Type</th> <th>Conf. Readout Pattern</th> <th>Conf. Groups/Int</th> <th>Conf. Integrations/Exp</th> <th>Conf. Total Integrations</th> <th>Conf. Total Exposure Time</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>c1_mb</td> <td>NRSIRS2RAPID</td> <td>6</td> <td>1</td> <td>1</td> <td>102.122</td> </tr> </tbody> </table>										#	Confirmation Type	Conf. Readout Pattern	Conf. Groups/Int	Conf. Integrations/Exp	Conf. Total Integrations	Conf. Total Exposure Time	1	c1_mb	NRSIRS2RAPID	6	1	1	102.122																																				
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Proposal 4106 - Observation 7 - Extremely massive galaxies in the early universe: a challenge to Lambda-CDM?

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_mb	3 Shutter Slitlet	214.8367675 Degrees 52.842655555555 56 Degrees	23.767647744538 905			3	3
	2	2 (PRISM/CLEAR)	c1_mb	3 Shutter Slitlet	214.8367675 Degrees 52.842655555555 56 Degrees	23.767647744538 905			3	9	6696.301
Special Requirements	MSA Scheduled Aperture PA 23.8265 to 23.8265 Degrees (V3 245.25197 to 245.25197)										