



7729 - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z>6$ Galaxies from Deep JWST Spectroscopy

Cycle: 4, Proposal Category: GO

INVESTIGATORS

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OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	gdn-dr5-final	NIRSpec MultiObject Spectroscopy	(3) gdn-final-dr5-precise
	2	gds-dr5-final	NIRSpec MultiObject Spectroscopy	(4) gds_dr5_omega_targets

ABSTRACT

What are the metal contents of galaxies, how quickly did they form, are strong-line diagnostics sufficiently robust to measure them? JWST has extended the frontier of galaxy metallicity studies, enabling measurements of strong diagnostics lines out to $z\sim 12$. However, tracing the build up of metals across the first billion years remains extremely challenging and current constraints are sorely lacking. At $z>6$, simulations yield contrasting

predictions due to different feedback physics, while observationally only 17 objects observed with JWST have benefited from gold-standard, electron temperature-based metallicities. The vast majority of objects have instead relied on inferences using uncertain Oxygen and Balmer strong-line calibrations anchored to small numbers of $2 < z < 9$ Te-based measurements. Comparisons between those calibrations indicate large discrepancies (up to 0.5-1 dex), casting serious doubt on the robustness of metallicities inferred thus far and indicating a need for stronger constraints.

This proposal aims to address these issues by determining direct metallicities for a statistical sample of confirmed $z > 6$ galaxies in the GOODS fields, through deep NIRSpec G395M/F290LP spectroscopy of [O III]4963 and [O II]3728,3730. With a $\sim 4\times$ increase in detections compared to current samples, we will: (i) Establish the most robust R23 and O32 calibrations to date, and explore [Ne III]-based indices for applications at $z > 10$. (ii) Utilize those calibrations to obtain robust metallicities in > 500 sources at $z = 6-13$ for mass-metallicity characterizations. (iii) Examine evolutionary trends and characterize the intrinsic scatter of galaxy metallicities over the first billion years.

OBSERVING DESCRIPTION

Pinpointing the onset and evolution of chemical enrichment over the first billion years represents a major goal of extragalactic astronomy and a key tracer of ISM evolution in primordial sources. Strong-line indices (e.g., $R23 = [\text{O III}]4960,5008 + [\text{O II}]3727,3729 / \text{H}\beta$, $O32 = [\text{O III}]5008 / [\text{O II}]3727,3729$) represent the most practical and realistic path towards obtaining a census of galaxy metallicities at $z > 6$, given the strength and detection rates of the relevant lines in JWST spectra. However, even the latest JWST calibrations benefit from only a handful of gold standard, temperature-based ("direct") metallicities, owing to the dearth of auroral emission line measurements at $z > 6$ (17 sources with [OIII]4364 to date). As such, current high- z calibrations suffer from significant scatter given small sample sizes (typically 15-20 sources) that extend over large redshift ranges ($2 < z < 9$) and trace varying ISM conditions.

In this proposal we target a large sample (> 75) of confirmed $z > 6$ galaxies in the GOODS-N and GOODS-S fields, where [O III]4364 (and [O II]3727,3729) detections are enabled for accurate Oxygen abundances using direct-method measurements. Each of the sources already benefit from strong-line measurements allowing us to make predictions on expected [O III]4364 line flux using realistic metallicity assumptions. We will obtain ~ 12.6 hrs of deep NIRSpec G395M/F290LP MSA spectroscopy for four independent pointings, two in each GOODS field amount to a total of 50.3 hrs science time, or 67.2 hrs including overhead. The chosen setup of an NRS readout pattern, 39 grps/int, 1 int/exp, and 27 exposures with a 3-shutter dither pattern allows us to achieve a peak S/N ratio $> 3\sigma$ for integrated fluxes down to $1\text{E-}19$ erg/s/cm². The observations proposed here represents a unique, optimized, and sorely needed data set to achieve a census of galaxy metallicities within the first billion years.

Proposal 7729 - Targets - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z>6$ Galaxies from Deep JWST Spectroscopy

Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
	(3)	gdn-final-dr5-precise	RA: 12 36 46.7958 (189.1949825d) Dec: +62 14 54.23 (62.24840d) Equinox: J2000		
	Comments: Description=[]				
Fixed Targets	(4)	gds_dr5_omega_targets	RA: 03 32 26.3885 (53.1099521d) Dec: -27 49 46.20 (-27.82950d) Equinox: J2000		
	Comments: Description=[]				

Proposal 7729 - Observation 1 - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z > 6$ Galaxies from Deep JWST Spectroscopy

Observation	Proposal 7729, Observation 1: gdn-dr5-final										Mon Jun 29 23:00:32 GMT 2026
	Diagnostic Status: Warning										
	Observing Template: NIRSpec MultiObject Spectroscopy										
Diagnostics	(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
	(Visit 1:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous		
	(3)	gdn-final-dr5-precise	RA: 12 36 46.7958 (189.1949825d) Dec: +62 14 54.23 (62.24840d) Equinox: J2000								
	Comments: Description=[]										
Acquisition	#	Reference Star Bin	Target	Filter	MSA Configuration	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	Optional ETC ID
	1	Filter: CLEAR; Readout: NRSRAPIDD6; 8 sources in 4 quads; [Optimal TA Accuracy]	SAME	CLEAR	Auto Acq MSA Config	NRSRAPIDD6	3	1	4	687.153	
	2	Filter: CLEAR; Readout: NRSRAPIDD6; 8 sources in 3 quads; [Optimal TA Accuracy]	SAME	CLEAR	Auto Acq MSA Config	NRSRAPIDD6	3	1	4	687.153	
Template	TA Method	HFF Readout Mode	Obtain Confirmation Images	Science Aperture	Primary Candidate List	Filler Candidate List	Spectral Overlap Map	Spectral Overlap Threshold			
	MSATA	false	No	MSA Center	Primary (144 sources)	Filler (801 sources)	jwst-nirspec-mr	1.5			
Reference Stars	Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude	
	1	10084	189.161869	62.247674	24.703	1	1008299	189.229448	62.249930	25.529	
	1	10117	189.235216	62.245169	24.541	1	1019607	189.159218	62.289641	24.260	
	1	10158	189.227536	62.260074	24.765	1	1029243	189.159935	62.260999	23.576	
	1	10171	189.219751	62.265081	24.909	1	1091033	189.269777	62.295885	25.105	
	Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude	
	2	10075	189.175448	62.219473	23.411	2	10100	189.146255	62.209070	23.111	
	2	10076	189.170408	62.209382	23.971	2	10106	189.107424	62.226893	23.803	
	2	10081	189.183564	62.249866	23.193	2	10162	189.188535	62.244937	24.906	
	2	10084	189.161869	62.247674	24.703	2	1005856	189.188893	62.242951	25.165	

Proposal 7729 - Observation 1 - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z>6$ Galaxies from Deep JWST Spectroscopy

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	3 Shutter Slitlet	189.20595641666 668 Degrees 62.271743888888 885 Degrees	275.17588352195 29			3	21	27879.369
	2	2 (G395M/F290LP)	c1	3 Shutter Slitlet	189.20595641666 668 Degrees 62.271743888888 885 Degrees	275.17588352195 29			3	15	19913.835
	3	1 (G395M/F290LP)	c2	3 Shutter Slitlet	189.13275174999 998 Degrees 62.230395 Degrees	275.11120889083 33			3	21	27879.369
	4	2 (G395M/F290LP)	c2	3 Shutter Slitlet	189.13275174999 998 Degrees 62.230395 Degrees	275.11120889083 33			3	15	19913.835
Special Requirements	Group Visits within 53.0 Days Visits Same PA MSA Scheduled Aperture PA 275.1662 to 275.1662 Degrees (V3 136.59164 to 136.59164)										

Proposal 7729 - Observation 2 - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z > 6$ Galaxies from Deep JWST Spectroscopy

Observation	Proposal 7729, Observation 2: gds-dr5-final										Mon Jun 29 23:00:32 GMT 2026
	Diagnostic Status: Warning										
	Observing Template: NIRSpec MultiObject Spectroscopy										
Diagnostics	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
	(Visit 2:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous		
	(4)	gds_dr5_omega_targets	RA: 03 32 26.3885 (53.1099521d) Dec: -27 49 46.20 (-27.82950d) Equinox: J2000								
	Comments: Description=[]										
Acquisition	#	Reference Star Bin	Target	Filter	MSA Configuration	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	Optional ETC ID
	1	Filter: CLEAR; Readout: NRSRAPIDD6; 8 sources in 4 quads; [Optimal TA Accuracy]	SAME	CLEAR	Auto Acq MSA Config	NRSRAPIDD6	3	1	4	687.153	
	2	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	HFF Readout Mode	Obtain Confirmation Images	Science Aperture	Primary Candidate List	Filler Candidate List	Spectral Overlap Map	Spectral Overlap Threshold			
	MSATA	false	No	MSA Center	Primary (118 sources)	Filler (324 sources)	jwst-nirspec-mr	1.5			
Reference Stars	Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude	
	1	7296	53.142171	-27.832751	23.838	1	7940	53.157685	-27.825048	24.972	
	1	7408	53.113395	-27.799240	25.018	1	7993	53.163835	-27.804183	24.674	
	1	7409	53.122051	-27.799070	24.989	1	8057	53.132910	-27.772471	24.413	
	1	7517	53.139255	-27.774923	24.481	1	8064	53.144265	-27.769136	24.455	
	Visit	ID	RA	Dec	Magnitude	Visit	ID	RA	Dec	Magnitude	
	2	7209	53.106399	-27.849546	24.537	2	7882	53.093686	-27.846584	23.489	
	2	7759	53.076040	-27.878214	23.159	2	7890	53.103404	-27.841695	23.974	
	2	7827	53.066361	-27.861905	24.875	2	7893	53.095185	-27.840100	24.745	
	2	7857	53.131575	-27.855499	23.459	2	8389	53.123359	-27.874687	22.487	

Proposal 7729 - Observation 2 - Unveiling Early Cosmic Enrichment: Direct Metallicities in $z>6$ Galaxies from Deep JWST Spectroscopy

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	3 Shutter Slitlet	53.147230249999 99 Degrees - 27.796178055555 572 Degrees	48.756086061430 65			3	21	27879.369
	2	2 (G395M/F290LP)	c1	3 Shutter Slitlet	53.147230249999 99 Degrees - 27.796178055555 572 Degrees	48.756086061430 65			3	15	19913.835
	3	1 (G395M/F290LP)	c2	3 Shutter Slitlet	53.103483791666 67 Degrees - 27.867088888888 873 Degrees	48.776361244190 64			3	21	27879.369
	4	2 (G395M/F290LP)	c2	3 Shutter Slitlet	53.103483791666 67 Degrees - 27.867088888888 873 Degrees	48.776361244190 64			3	15	19913.835
Special Requirements	Group Visits within 53.0 Days Visits Same PA MSA Scheduled Aperture PA 48.7734 to 48.7734 Degrees (V3 270.19885 to 270.19885)										