



## 5734 - Placing a $z=7.27$ AGN in context with cosmic structure formation

Cycle: 3, Proposal Category: GO

### INVESTIGATORS

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Prof. Anna-Christina Eilers (CoI)	Massachusetts Institute of Technology
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Dr. Feige Wang (CoI)	University of Michigan

### OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
NIRSpec Follow-up				
	2	APA246p7_A2_add, A PA246p7_A1_add	NIRSpec MultiObject Spectroscopy	(4) J1007_msa_catalog_add
MIRI LRS follow-up				
	4	MIRI LRS slit spectros copy	MIRI Low Resolution Spectroscopy	(1) J1007_4562

### ABSTRACT

Deep spectroscopic JWST observations have unveiled an emerging population of faint  $z>5$  active galactic nuclei (AGN). First estimates of their number densities exceed the expectations from extrapolating the quasar luminosity function by factors of 1000, possibly constituting as much as 10% of the total galaxy population. With supermassive black hole (SMBH) estimates of  $10^6$ - $10^8$   $M_{\text{sun}}$ , their high number densities challenge theories

## JWST Proposal 5734 (Created: Monday, March 10, 2025, 12:00:34PM Eastern Standard Time) - Overview

of SMBH formation and it is unclear how they fit into the context of cosmic structure formation as a whole. The serendipitous discovery of a faint  $z=7.27$  AGN within an overdensity of 8 associated galaxies provides the first opportunity to place this population in the cosmological context via AGN-galaxy clustering analysis. However, the low resolution NIRSpec/PRISM discovery spectrum is inadequate to determine the SMBH mass, bolometric luminosity and Eddington ratio for two reasons: i) estimates imply high levels of dust attenuation, which remain largely unconstrained ( $A_v=1$  to 5), but are critical to correct for and ii) the low resolution does not resolve narrow line components, strongly biasing the SMBH mass estimate based on the decomposed broad H $\beta$  line.

We propose for a small 12h program to obtain R=1000 NIRSpec G395/F290LP fixed-slit spectroscopy (8.4h), resolving the narrow line emission and MIRI/LRS spectroscopy (3.5h) to determine the H $\alpha$  flux for an accurate measurement of the dust attenuation with the H $\alpha$ /H $\beta$  Balmer decrement. During the NIRSpec/fixed-slit observations, MSA shutters will be opened on galaxy candidates to additionally identify more associated sources for an improved clustering measurement.

### **OBSERVING DESCRIPTION**

This program targets a faint, high-redshift AGN at  $z=7.27$  discovered in data from the JWST Cycle 1 Program GO #2073. In this proposal we aim to determine its rest-frame optical properties to i) robustly determine its extinction via the H $\alpha$ /H $\beta$  Balmer decrement and ii) estimate its SMBH mass from the extinction corrected broad H $\beta$  line component and continuum luminosity. The rest-frame optical spectrum will be obtained using NIRSpec/fixed-slit observations with the F395M/F290LP disperser-filter combination and MIRI/LRS slit spectroscopy to cover the H $\alpha$  line redshifted to  $\sim 5.4$  micron. This is the only faint, high-redshift AGN residing in a detected overdensity, allowing for a galaxy-AGN cross-correlation measurement to determine its host dark matter halo mass. To improve the cross-correlation measurement we place further galaxy candidates in NIRSpec/MSA shutters in parallel to the NIRSpec fixed-slit observations.

Below we summarize the observing plans for each mode:

#### 1) NIRSpec/fixed-slit + MSA spectroscopy:

We will observe two NIRSpec/MSA configurations (Obs 2 and Obs 5) with equal exposure time in each. The MSA centering is determined by the position of the AGN in the fixed slit. For one exposure we use the S200A1 slit, for the other the S200A2 slit to maximize the number of unique galaxy candidates that can be observed with the same APA. Each configuration will consist of 2 exposures with the standard 3 shutter slitlet nod pattern. The exposures use the NRSIRS2 readout mode with 20 groups per integration and 1 integration per exposure. The NRSIRS2 readout mode

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was chosen to stay below the lower data volume limit for these considerable integration times. The total science time for each exposure is 4420s, resulting in a total science time of 8754s per configuration and 16474s including overheads. The observations are acquired using the standard MSATA method with 8 sources in quads for optimal targeting accuracy.

### 2) MIRI/LRS slit spectroscopy:

Our MIRI/LRS observations use the standard LLRS parameters (FULL subarray, FASTR1 readout mode, ALONG SLID NOD). In order to reach our desired signal-to-noise ratio (SNR), we require 15 integrations per exposure with 100 groups per integration resulting in 2 nodded exposures with a total exposure time of 8402s, starting below the recommended 10000s limit (cosmic rays). As the target is too faint to acquire directly (F444W~25), we have selected a bright, compact offset source (F444~23) within at a separation of 59 arcseconds. This is the only bright enough source with a separation of <60 arcsec to our target. Choosing the F560W filter (closest to F444W) we have selected the FASTGRPAVG16 readout mode with 10 acq-groups per integration to reach the required SNR>20 (22.7 in our case). We decided to also acquire an LRS verification image in the F560W, covering the wavelength range with the Ha line, to be able to correct for slit losses in the data reduction. Using the FASTR1 readout mode (FULL subarray) we set 30 groups per integration and 3 integrations per exposure to reach a SNR of ~5 for the verification image.

Proposal 5734 - Targets - Placing a z=7.27 AGN in context with cosmic structure formation

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	J1007_4562	RA: 10 07 54.7742 (151.9782258d) Dec: +21 17 2.38 (21.28399d) Equinox: J2000	Proper Motion RA: 0 Proper Motion Dec: 0 Epoch of Position: 2000	
<i>Comments:</i> Category=Galaxy Description=[Active galactic nuclei] Extended=NO				
(3)	Offset-Acq-Star-MIRI	RA: 10 07 50.6215 (151.9609229d) Dec: +21 16 48.33 (21.28009d) Equinox: J2000		
<i>Comments:</i> Category=Unidentified Description=[Infrared sources] Extended=NO				
(4)	J1007_msa_catalog_add	RA: 10 07 58.2090 (151.9925375d) Dec: +21 15 40.62 (21.26128d) Equinox: J2000		
<i>Comments:</i> Description=[]				
(5)	Offset-Acq-Star-MIRI-NEW	RA: 10 07 50.6108 (151.9608783d) Dec: +21 16 10.82 (21.26967d) Equinox: J2000	Proper Motion RA: -8.550587270333661 mas/yr Proper Motion Dec: 0.2812699872138162 mas/yr Parallax: 0.00025540999087409594" Epoch of Position: 2016	
<i>Comments:</i> Category=Unidentified Description=[Visible sources] Extended=NO				

Fixed Targets

Proposal 5734 - Observation 2 - Placing a z=7.27 AGN in context with cosmic structure formation

Mon Mar 10 17:00:34 GMT 2025

<b>Observation</b>	<b>Proposal 5734, Observation 2: APA246p7_A2_add, APA246p7_A1_add</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSpec MultiObject Spectroscopy <i>Comments: Given the fixed center position due to our NIRSpec/fixed-slit observations of J1007_AGN, the number of galaxy candidates observable with the NIRSpec/MSA is strongly dependent on the Aperture PA (APA) of the observations. For this proposal we determined one (of multiple) possible configurations that maximizes the number of galaxy candidates. The submitted configuration has an APA of 246.5 degrees and can accommodate a total of 12 unique sources. We have implemented a special requirement for this APA for now. In general small changes to the APA are possible and other APA's with a similar number of galaxy candidates exist. Therefore, there is flexibility in the APA and we will closely communicate with STScI to optimize the configuration for scheduling.</i>																																																											
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Proposal 5734 - Observation 2 - Placing a  $z=7.27$  AGN in context with cosmic structure formation

Special Requirements

Aperture PA Range 246.3 to 246.7 Degrees (V3 107.7254303 to 108.1254303)  
MSA Scheduled Aperture PA 246.7000 to 246.7000 Degrees (V3 108.12543 to 108.12543)

Proposal 5734 - Observation 4 - Placing a z=7.27 AGN in context with cosmic structure formation

Mon Mar 10 17:00:34 GMT 2025

<b>Observation</b>	<b>Proposal 5734, Observation 4: MIRI LRS slit spectroscopy</b> <b>Diagnostic Status: Warning</b> Observing Template: MIRI Low Resolution Spectroscopy									
	(Visit 4:1) 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>			
	(1)	J1007_4562	RA: 10 07 54.7742 (151.9782258d) Dec: +21 17 2.38 (21.28399d) Equinox: J2000		Proper Motion RA: 0 Proper Motion Dec: 0 Epoch of Position: 2000					
Comments: Category=Galaxy Description=[Active galactic nuclei] Extended=NO										
<b>Acquisition</b>	<b>#</b>	<b>Target</b>	<b>Filter</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	5 Offset-Acq-Star-MIRI-NEW	F560W	FAST	6	1	1	16.65	242216.6	
<b>Template</b>	<b>Subarray</b>				<b>Obtain Verification Image?</b>					
	FULL				true					
<b>Dithers</b>	<b>#</b>	<b>Dither Type</b>	<b>No. Spectral Steps</b>	<b>Spectral Step Offset</b>	<b>No. Spatial Steps</b>	<b>Spatial Step Offset</b>				
	1	ALONG SLIT NOD								
<b>Pointing Verification</b>	<b>#</b>	<b>PV Readout Pattern</b>	<b>PV Groups/Int</b>	<b>PV Integrations/Exp</b>	<b>PV Total Integrations</b>	<b>PV Exposures/Dith</b>	<b>PV Total Dithers</b>	<b>PV Total Exposure Time</b>	<b>PV ETC Wkbk.Calc ID</b>	<b>Filter</b>
	1	FASTR1	30	3	3	1	1	255.304		F560W

Proposal 5734 - Observation 4 - Placing a  $z=7.27$  AGN in context with cosmic structure formation

Spectral Elements	#	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Exposures/Dith	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	1	FASTR1	100	15	30	1	2	8402.821	173141.3