



8976 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Cycle: 4, Proposal Category: GO

INVESTIGATORS

<i>Name</i>	<i>Institution</i>
Matthew Belyakov (PI)	California Institute of Technology
Dr. Michael E Brown (CoI) (Contact)	California Institute of Technology
Konstantin Batygin (CoI)	California Institute of Technology

OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	2024LY9	NIRSpec IFU Spectroscopy	(1) 2024-LY9
	2	2014AT28	NIRSpec IFU Spectroscopy	(2) 2014-AT28
	7	2014AT28-redo	NIRSpec IFU Spectroscopy	(2) 2014-AT28
	3	2020HM98	NIRSpec IFU Spectroscopy	(3) 2020-HM98
	4	2015KZ120	NIRSpec IFU Spectroscopy	(4) 2015-KZ120
	5	2023SO7	NIRSpec IFU Spectroscopy	(5) 2023-SO7
	6	2017UX51	NIRSpec IFU Spectroscopy	(6) 2017-UX51

ABSTRACT

Results on Kuiper belt, Centaur, and Jupiter Trojan spectroscopy with JWST have shown evidence for a compositional link between the KBOs and Trojans via the thermal evolution of Centaur surfaces. However, the pathway through which these surfaces evolve remains unclear. We propose a test of outer Solar System surface evolution with the high-inclination and retrograde Centaurs. These objects with inclinations above 60 degrees are a dynamically anomalous population injected from a yet undetermined source population past 30 au, and with significantly longer average dynamical lifetimes in the planetary region as compared to their lower inclination counterparts. Thus far, JWST has not observed a single Centaur or KBO with $i > 60$ and $5 < a < 100$, a large missing chunk of Kuiper belt dynamical space. By observing six of these targets and determining whether their

significantly longer lifespans result in diminished O-H and CO₂ features, we will obtain a critically important sample for testing pathways of surface evolution on Centaur surfaces.

OBSERVING DESCRIPTION

We will observe six high-inclination Centaurs and KBOs total using NIRSpec IFU mode, seeking to both generally characterize this subpopulation, and obtain vital measurements of the band depths of water ice and CO₂ spectral features as a point of comparison to lower inclination Centaurs. We use the low-resolution PRISM grating as our targets are faint and our science does not require higher wavelength resolution mode data. We use the NRSIRS2RAPID readout pattern where possible and NRSIRS2 where the data volume is prohibitively long, with a minimum of 4 dithers, increased to more depending on the necessary exposure time. NIRSpec is the sole instrument that can obtain high-quality 1-5 micron spectra necessary to observe the 4.25 micron CO₂ feature. Our targeted signal-to-noise ratio (SNR) is set to match the lower end of past JWST KBO observations (SNR ~10-20 at 4.0 microns), which we match for our targets to enhance the growing library of outer solar system small body data. Total science time for this program is 11.4 hours, total charged time is 21.2 hours.

Proposal 8976 - Targets - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

#	Name	Level 1	Level 2	Level 3
(1)	2024-LY9	TYPE=ASTEROID,A=59.10266353881379,E=0.8362 808259224178,I=146.0722653139367 .O=116.8044463918539,W=208.6646605146186,M=3 55.9356926903181,EQUINOX=J2000,EPOCH=11- APR-2023:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				
(2)	2014-AT28	TYPE=ASTEROID,A=10.95157716427263,E=0.4054 240386643543,I=165.5581936701164 .O=262.5162199017071,W=279.5727056929045,M=3 48.9542624817633,EQUINOX=J2000,EPOCH=25- JUN-2016:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				
(3)	2020-HM98	TYPE=ASTEROID,A=81.56833532311327,E=0.8374 134014679037,I=137.8223837614223 .O=31.0606505645853,W=181.5442252019002,M=35 8.7632856451058,EQUINOX=J2000,EPOCH=25- NOV-2017:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				
(4)	2015-KZ120	TYPE=ASTEROID,A=46.38360585677209,E=0.8195 592517002165,I=85.54327222346441 .O=249.9765163533705,W=66.376737698049,M=0.08 247167429659423,EQUINOX=J2000,EPOCH=02- APR-2019:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				
(5)	2023-SO7	TYPE=ASTEROID,A=69.54183171813825,E=0.7187 59981308848,I=96.72895586764584 .O=171.3501421864779,W=185.5991939528752,M=3 56.2380729465805,EQUINOX=J2000,EPOCH=06- MAY-2023:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				
(6)	2017-UX51	TYPE=ASTEROID,A=30.14537209762544,E=0.7474 81354550094,I=90.52378497227592 .O=217.7952032116296,W=255.0339188996624,M=3 51.780380840508,EQUINOX=J2000,EPOCH=17- NOV-2018:00:00:00,EpochTimeScale=TDB		
<i>Comments: Extended=NO</i>				

Solar System Targets

Proposal 8976 - Observation 1 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 1: 2024LY9 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2024LY9 (Obs 1)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Diagnosics												
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(1)	2024-LY9	TYPE=ASTEROID,A=59.10266353881379,E=0.8362 808259224178,I=146.0722653139367 ,O=116.8044463918539,W=208.6646605146186,M=3 55.9356926903181,EQUINOX=J2000,EPOCH=11- APR-2023:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>									
Template	TA Method						HFF Readout Mode					
	NONE						false					
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	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2RAPID	60	1	false	true	NONE	4	4	3559.689	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2024-LY9 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 2 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 2: 2014AT28 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2014AT28 (Obs 2)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(2)	2014-AT28	TYPE=ASTEROID,A=10.95157716427263,E=0.4054 240386643543,I=165.5581936701164 ,O=262.5162199017071,W=279.5727056929045,M=3 48.9542624817633,EQUINOX=J2000,EPOCH=25- JUN-2016:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>									
Template	TA Method						HFF Readout Mode					
	NONE						false					
Dithers	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	CYCLING		SMALL		1		10				
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Ex p	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2	21	1	false	true	NONE	10	10	15464.223	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2014-AT28 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 7 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 7: 2014AT28-redo Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 7:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2014AT28-redo (Obs 7)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Diagnosics												
Solar System Targets	#	Name	Level 1			Level 2			Level 3			
	(2)	2014-AT28	TYPE=ASTEROID,A=10.95157716427263,E=0.4054 240386643543,I=165.5581936701164 ,O=262.5162199017071,W=279.5727056929045,M=3 48.9542624817633,EQUINOX=J2000,EPOCH=25- JUN-2016:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>									
Template	TA Method						HFF Readout Mode					
	NONE						false					
Dithers	#	Dither Type		Size	Starting Point		Number of Points		Points			
	1	CYCLING		SMALL	5		6					
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Ex p	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2	21	1	false	true	NONE	6	6	9278.534	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2014-AT28 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 3 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 3: 2020HM98 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2020HM98 (Obs 3)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(3)	2020-HM98	TYPE=ASTEROID,A=81.56833532311327,E=0.8374 134014679037,I=137.8223837614223 ,O=31.0606505645853,W=181.5442252019002,M=35 8.7632856451058,EQUINOX=J2000,EPOCH=25- NOV-2017:00:00:00,EpochTimeScale=TDB Comments: Extended=NO									
Template	TA Method						HFF Readout Mode					
	NONE						false					
Dithers	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	CYCLING		SMALL		1		8				
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2	20	1	false	true	NONE	8	8	11787.823	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2020-HM98 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 4 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 4: 2015KZ120 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2015KZ120 (Obs 4)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Diagnostics												
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(4)	2015-KZ120	TYPE=ASTEROID,A=46.38360585677209,E=0.8195 592517002165,I=85.54327222346441 ,O=249.9765163533705,W=66.376737698049,M=0.08 247167429659423,EQUINOX=J2000,EPOCH=02- APR-2019:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>									
Template	TA Method						HFF Readout Mode					
	NONE						false					
Dithers	#	Dither Type		Size	Starting Point		Number of Points		Points			
	1	CYCLING		SMALL	1		5					
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Ex p	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2RAPID	85	1	false	true	NONE	5	5	6273.223	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2015-KZ120 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 5 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 5: 2023SO7 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
Diagnostics	(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2023SO7 (Obs 5)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Solar System Targets	#	Name	Level 1				Level 2			Level 3		
	(5)	2023-SO7	TYPE=ASTEROID,A=69.54183171813825,E=0.7187 59981308848,I=96.72895586764584 ,O=171.3501421864779,W=185.5991939528752,M=3 56.2380729465805,EQUINOX=J2000,EPOCH=06- MAY-2023:00:00:00,EpochTimeScale=TDB									
	Comments: Extended=NO											
Template	TA Method						HFF Readout Mode					
	NONE						false					
Dithers	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
Spectral Elements	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Ex p	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2RAPID	30	1	false	true	NONE	4	4	1809.022	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2023-SO7 FROM JWST LESS THAN 0.075											

Proposal 8976 - Observation 6 - Testing Outer Solar System Surface Evolution with Retrograde Centaurs

Fri Feb 06 18:00:51 GMT 2026

Observation	Proposal 8976, Observation 6: 2017UX51 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 6:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2017UX51 (Obs 6)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
Solar System Targets	#	Name	Level 1				Level 2				Level 3	
	(6)	2017-UX51	TYPE=ASTEROID,A=30.14537209762544,E=0.7474 81354550094,I=90.52378497227592 ,O=217.7952032116296,W=255.0339188996624,M=3 51.780380840508,EQUINOX=J2000,EPOCH=17- NOV-2018:00:00:00,EpochTimeScale=TDB <i>Comments: Extended=NO</i>									
Template	TA Method						HFF Readout Mode					
	NONE						false					
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	Optional ETC ID
	1	PRISM/CLEAR	NRSIRS2RAPID	40	1	false	true	NONE	4	4	2392.578	
Special Requirements	DEFAULT WINDOW: ANGULAR RATE 2017-UX51 FROM JWST LESS THAN 0.075											