



# 11995 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Cycle: 5, Proposal Category: GO

## INVESTIGATORS

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Dr. Silvia Protopapa (CoI)	Southwest Research Institute

## OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	2016LN8	NIRSpec IFU Spectroscopy	(1) 2016LN8
	2	2000EC98	NIRSpec IFU Spectroscopy	(2) 2000EC98
	3	2001BL41	NIRSpec IFU Spectroscopy	(3) 2001BL41
	4	2023JF4	NIRSpec IFU Spectroscopy	(4) 2023JF4
	5	2023QB47	NIRSpec IFU Spectroscopy	(5) 2023QB47
	6	2020RR5	NIRSpec IFU Spectroscopy	(6) 2020RR5
	7	2021DB17	NIRSpec IFU Spectroscopy	(7) 2021DB17

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
	8	2014UJ225	NIRSpec IFU Spectroscopy	(8) 2014UJ225

## ABSTRACT

Current theories of solar system evolution posit that the Kuiper belt objects (KBOs) and Jupiter Trojans share a common outer solar system origin. However, recent JWST observations have presented a conundrum: while KBO spectra show a rich array of spectroscopic features, Trojan spectra are mostly featureless. In order to reconcile this discrepancy within our current understanding of solar system history, some process must have altered the Trojans' surfaces during their inward migration. Centaurs - inward-scattered KBOs on orbits that cross the giant planet region - are the ideal proxy population for addressing this question. JWST spectra of Centaurs hint at a progression in spectral shape that bridges the gap between the surface properties of KBOs and Trojans. Specifically, a handful of low-perihelion Centaurs show starkly attenuated features when compared to the more distant Centaurs and KBOs, suggesting that thermophysical processing of the surface may be the key to explaining the Trojans' muted spectral features. However, the current sample of close-in Centaurs is limited by small number statistics and size-dependent selection biases. To properly investigate this emergent trend, we propose to obtain NIRSpec PRISM mode spectra of 8 additional Centaurs. By confirming the signal of thermal evolution in the spectral features of close-in Centaurs, we will obtain a definitive explanation for the discrepant KBO and Trojan spectra, which would serve as a powerful empirical validation of current dynamical instability models of solar system evolution.

## OBSERVING DESCRIPTION

We will observe 8 inactive Centaurs with the NIRSpec IFU. The targets include 5 objects with  $q < 9$  au and 3 small high-perihelion Centaurs with  $q > 12$  au and  $H > 10$ . The goal of these observations will be to search for distinctive attenuated spectral features at 3 and 4.25 microns among the low-perihelion Centaurs.

The spectra will be obtained using the low-resolution PRISM grating, which will provide continuous coverage from 0.6 to 5.3 microns. We require  $SNR = 15$  at 4.25 microns to detect carbon dioxide features on the low-perihelion Centaurs with depths as low as 10%. For the fainter high-perihelion targets, the observations are designed to provide  $SNR = 15$  at 3.0 microns, which is sufficient to reliably measure 3-micron band depths as low as 10%. Our observing strategy follows standard procedures for faint moving target observations. We will collect a set dithered single-integration exposures, utilizing the NRSIRS2RAPID readout and a 4-point dither pattern to minimize readout noise and detector effects.

Proposal 11995 - Targets - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

#	Name	Level 1	Level 2	Level 3
(1)	2016LN8	TYPE=ASTEROID,A=5.703468183745511,E=0.0558 5013697773352,I=43.34277188506416 .O=87.537189688485,W=20.78907678122914,M=219. 5592393532241,EQUINOX=J2000,EPOCH=13-JUN- 2021:00:00:00,EpochTimeScale=TDB		
<i>Comments: Low-q Centaur Extended=NO</i>				
(2)	2000EC98	TYPE=ASTEROID,A=10.68157908449444,E=0.4556 502001690135,I=4.34448151763652 .O=173.3335947107531,W=162.8058173882833,M=2 3.85115053104231,EQUINOX=J2000,EPOCH=13- AUG-2017:00:00:00,EpochTimeScale=TDB		
<i>Comments: Low-q Centaur Extended=NO</i>				
(3)	2001BL41	TYPE=ASTEROID,A=9.878153857193981,E=0.2959 726108531721,I=12.47705967535625 .O=280.8044880782476,W=129.3705408084037,M=2 88.4167585678019,EQUINOX=J2000,EPOCH=26- JAN-2022:00:00:00,EpochTimeScale=TDB		
<i>Comments: Low-q Centaur Extended=NO</i>				
(4)	2023JF4	TYPE=ASTEROID,A=12.80161589063305,E=0.4106 670637193994,I=15.63947955325999 .O=142.3095481737561,W=202.8301941419238,M=3 05.268962184222,EQUINOX=J2000,EPOCH=22- JUL-2023:00:00:00,EpochTimeScale=TDB		
<i>Comments: Low-q Centaur Extended=NO</i>				
(5)	2023QB47	TYPE=ASTEROID,A=18.99330034106888,E=0.6660 482160621791,I=21.20339014899395 .O=331.2065879788498,W=78.31418537672766,M=3 51.0921834924132,EQUINOX=J2000,EPOCH=25- DEC-2023:00:00:00,EpochTimeScale=TDB		
<i>Comments: Low-q Centaur Extended=NO</i>				
(6)	2020RR5	TYPE=ASTEROID,A=22.56620527309062,E=0.4585 369562642291,I=13.23856190632177 .O=133.3812274619198,W=261.0415850908157,M=3 48.582724706013,EQUINOX=J2000,EPOCH=16- MAR-2020:00:00:00,EpochTimeScale=TDB		
<i>Comments: Small Centaur with q&gt;12 AU Extended=NO</i>				
(7)	2021DB17	TYPE=ASTEROID,A=19.23342514151166,E=0.3606 922807643508,I=7.504005076883376 .O=28.15723485781824,W=177.5213733804687,M=3 40.9417987619114,EQUINOX=J2000,EPOCH=17- JUN-2019:00:00:00,EpochTimeScale=TDB		
<i>Comments: Small Centaur with q&gt;12 AU Extended=NO</i>				
(8)	2014UJ225	TYPE=ASTEROID,A=23.11429564824502,E=0.3766 476606604401,I=21.35040114847518 .O=18.95911490810907,W=82.49007186988477,M=3 33.2304737078431,EQUINOX=J2000,EPOCH=04- MAY-2017:00:00:00,EpochTimeScale=TDB		
<i>Comments: Small Centaur with q&gt;12 AU Extended=NO</i>				

Solar System Targets

Proposal 11995 - Observation 1 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	<p><b>Proposal 11995, Observation 1: 2016LN8</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: NIRSpec IFU Spectroscopy</p>											
<b>Diagnostics</b>	<p>(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p> <p>(2016LN8 (Obs 1)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.</p>											
<b>Solar System Targets</b>	<b>#</b>	<b>Name</b>	<b>Level 1</b>				<b>Level 2</b>				<b>Level 3</b>	
	(1)	2016LN8	TYPE=ASTEROID,A=5.703468183745511,E=0.0558 5013697773352,I=43.34277188506416 ,O=87.537189688485,W=20.78907678122914,M=219. 5592393532241,EQUINOX=J2000,EPOCH=13-JUN- 2021:00:00:00,EpochTimeScale=TDB									
	<p><i>Comments: Low-q Centaur Extended=NO</i></p>											
<b>Template</b>	<b>TA Method</b>						<b>HFF Readout Mode</b>					
	NONE						false					
<b>Dithers</b>	<b>#</b>	<b>Dither Type</b>		<b>Size</b>	<b>Starting Point</b>			<b>Number of Points</b>	<b>Points</b>			
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	<b>#</b>	<b>Grating/Filter</b>	<b>Readout Pattern</b>	<b>Groups/Int</b>	<b>Integrations/Exp</b>	<b>Leakcal</b>	<b>Dither</b>	<b>Autocal</b>	<b>Total Dithers</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>	<b>Optional ETC ID</b>
	1	PRISM/CLEAR	NRSIRS2RAPID	28	1	false	true	NONE	4	4	1692.311	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2016LN8 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 2 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 2: 2000EC98 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2000EC98 (Obs 2)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Diagnosics</b>												
<b>Solar System Targets</b>	#	Name	Level 1				Level 2				Level 3	
	(2)	2000EC98	TYPE=ASTEROID,A=10.68157908449444,E=0.4556 502001690135,I=4.34448151763652 ,O=173.3335947107531,W=162.8058173882833,M=2 3.85115053104231,EQUINOX=J2000,EPOCH=13- AUG-2017:00:00:00,EpochTimeScale=TDB  Comments: Low-q Centaur Extended=NO									
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	37	1	false	true	NONE	4	4	2217.511	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2000EC98 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 3 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 3: 2001BL41 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
<b>Diagnostics</b>	(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2001BL41 (Obs 3)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Solar System Targets</b>	#	Name	Level 1				Level 2				Level 3	
	(3)	2001BL41	TYPE=ASTEROID,A=9.878153857193981,E=0.2959 726108531721,I=12.47705967535625 ,O=280.8044880782476,W=129.3705408084037,M=2 88.4167585678019,EQUINOX=J2000,EPOCH=26- JAN-2022:00:00:00,EpochTimeScale=TDB									
	Comments: Low-q Centaur Extended=NO											
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	24	1	false	true	NONE	4	4	1458.889	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2001BL41 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 4 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 4: 2023JF4 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2023JF4 (Obs 4)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Diagnosics</b>												
<b>Solar System Targets</b>	#	Name	Level 1				Level 2				Level 3	
	(4)	2023JF4	TYPE=ASTEROID,A=12.80161589063305,E=0.4106 670637193994,I=15.63947955325999 ,O=142.3095481737561,W=202.8301941419238,M=3 05.268962184222,EQUINOX=J2000,EPOCH=22- JUL-2023:00:00:00,EpochTimeScale=TDB  Comments: Low-q Centaur Extended=NO									
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	41	1	false	true	NONE	4	4	2450.934	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2023JF4 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 5 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 5: 2023QB47 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
<b>Diagnostics</b>	(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2023QB47 (Obs 5)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Solar System Targets</b>	#	Name	Level 1				Level 2			Level 3		
	(5)	2023QB47	TYPE=ASTEROID,A=18.99330034106888,E=0.6660 482160621791,I=21.20339014899395 ,O=331.2065879788498,W=78.31418537672766,M=3 51.0921834924132,EQUINOX=J2000,EPOCH=25- DEC-2023:00:00:00,EpochTimeScale=TDB									
	Comments: Low-q Centaur Extended=NO											
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	81	1	false	true	NONE	4	4	4785.156	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2023QB47 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 6 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	<b>Proposal 11995, Observation 6: 2020RR5</b> <b>Diagnostic Status: Warning</b> Observing Template: NIRSpec IFU Spectroscopy											
	(Visit 6:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2020RR5 (Obs 6)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Diagnostics</b>												
<b>Solar System Targets</b>	<b>#</b>	<b>Name</b>	<b>Level 1</b>				<b>Level 2</b>				<b>Level 3</b>	
	(6)	2020RR5	TYPE=ASTEROID,A=22.56620527309062,E=0.4585 369562642291,I=13.23856190632177 ,O=133.3812274619198,W=261.0415850908157,M=3 48.582724706013,EQUINOX=J2000,EPOCH=16- MAR-2020:00:00:00,EpochTimeScale=TDB  <i>Comments: Small Centaur with q&gt;12 AU                      Extended=NO</i>									
<b>Template</b>	<b>TA Method</b>						<b>HFF Readout Mode</b>					
	NONE						false					
<b>Dithers</b>	<b>#</b>	<b>Dither Type</b>		<b>Size</b>		<b>Starting Point</b>		<b>Number of Points</b>		<b>Points</b>		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	<b>#</b>	<b>Grating/Filter</b>	<b>Readout Pattern</b>	<b>Groups/Int</b>	<b>Integrations/Exp</b>	<b>Leakcal</b>	<b>Dither</b>	<b>Autocal</b>	<b>Total Dithers</b>	<b>Total Integrations</b>	<b>Total Exposure Time</b>	<b>Optional ETC ID</b>
	1	PRISM/CLEAR	NRSIRS2RAPID	38	1	false	true	NONE	4	4	2275.867	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2020RR5 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 7 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 7: 2021DB17 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
<b>Diagnostics</b>	(Visit 7:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2021DB17 (Obs 7)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Solar System Targets</b>	#	Name	Level 1				Level 2				Level 3	
	(7)	2021DB17	TYPE=ASTEROID,A=19.23342514151166,E=0.3606 922807643508,I=7.504005076883376 ,O=28.15723485781824,W=177.5213733804687,M=3 40.9417987619114,EQUINOX=J2000,EPOCH=17- JUN-2019:00:00:00,EpochTimeScale=TDB  Comments: Small Centaur with q>12 AU Extended=NO									
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	58	1	false	true	NONE	4	4	3442.978	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2021DB17 FROM JWST LESS THAN 0.075											

Proposal 11995 - Observation 8 - Exploring the surface evolution of Centaurs: An empirical test of solar system dynamical history

Mon Apr 13 15:00:18 GMT 2026

<b>Observation</b>	Proposal 11995, Observation 8: 2014UJ225 Diagnostic Status: Warning Observing Template: NIRSpec IFU Spectroscopy											
<b>Diagnostics</b>	(Visit 8:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. (2014UJ225 (Obs 8)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.											
<b>Solar System Targets</b>	#	Name	Level 1				Level 2				Level 3	
	(8)	2014UJ225	TYPE=ASTEROID,A=23.11429564824502,E=0.3766 476606604401,I=21.35040114847518 ,O=18.95911490810907,W=82.49007186988477,M=3 33.2304737078431,EQUINOX=J2000,EPOCH=04- MAY-2017:00:00:00,EpochTimeScale=TDB  Comments: Small Centaur with q>12 AU Extended=NO									
<b>Template</b>	TA Method						HFF Readout Mode					
	NONE						false					
<b>Dithers</b>	#	Dither Type		Size		Starting Point		Number of Points		Points		
	1	4-POINT-DITHER										
<b>Spectral Elements</b>	#	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	65	1	false	true	NONE	4	4	3851.467	
<b>Special Requirements</b>	DEFAULT WINDOW: ANGULAR RATE 2014UJ225 FROM JWST LESS THAN 0.075											