



4706 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative environment.

Cycle: 3, Proposal Category: GO

INVESTIGATORS

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Dr. Harriet L. Dinerstein (CoI)	University of Texas at Austin
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OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Tc 1 MIRI				
	9	PN Tc 1 MIRI Imaging	MIRI Imaging	(8) PN-TC-1
	10	PN Tc 1 MRS On	MIRI Medium Resolution Spectroscopy	(9) PN-TC-1-MRS
	14	PN Tc 1 MRS Off	MIRI Medium Resolution Spectroscopy	(10) PN-TC1-OFF
	15	PN Tc 1 MIRI Imaging OFF	MIRI Imaging	(12) PN-TC1-MIRI-Im-OFF
Tc 1 NIRSpec IFU				
	12	PN Tc 1 On NIRSpec	NIRSpec IFU Spectroscopy	(11) PN-TC-1-NIRSpec
	13	PN Tc 1 Off	NIRSpec IFU Spectroscopy	(10) PN-TC1-OFF

ABSTRACT

We propose to observe the unique fullerene-rich planetary nebula Tc 1 with MIRI (MRS and Imaging) and NIRSpec-IFU to carry out a spatially resolved study of the spectral characteristics of C60 ("buckyballs") and their dependence on the physical conditions. Our goal is to elucidate the excitation, formation and evolution of fullerenes in radiative environments.

Tc~1 is the ideal target since it is geometrically simple, resolved (12" diameter), and its spectrum shows little contamination by other species. Our key objective is to measure the spectral characteristics of the main C60 emission bands (at 7.0, 8.5, 17.4 and 18.9 micron) across the main nebula, from the intense radiative environment near the hot central star ($T_{\text{eff}}=34,000\sim\text{K}$) to the Photo-Dissociation Region beyond the ionization front. We will use atomic emission lines to determine the local physical conditions (temperature, density, radiation field). We will thus be able to describe quantitatively how fullerenes respond to changes in their environment. We will also search for and characterize other fullerenes and compounds (e.g. C60+, C70+ and hydrogenated fullerenes).

This detailed description will provide key insights into the excitation mechanism of large aromatic species in radiative environments, and offer much needed constraints on the (photo-)chemical pathways to fullerenes in evolved stars. We will use this study to calibrate models for the excitation, ionization and processing of polycyclic aromatic hydrocarbons (PAHs) that are widespread and abundant in the Universe, and play key roles in large-

scale astrophysical processes such as star and planet formation and galaxy evolution.

OBSERVING DESCRIPTION

We will observe the C60-rich planetary nebula Tc 1 to study how C60 and other fullerenes respond to changes in their physical environment. Tc 1 has a hot central star that is surrounded by a dusty torus (3 arc seconds in diameter), and a larger ionized region (12 arc seconds in diameter). At the edge of this ionized region is a ring of enhanced fullerene emission, and some C60 emission is visible beyond that ionized region in the PDR. To spatially and spectroscopically resolve the fullerene features in these different environments, our observations include a combination of IFU spectroscopy at selected positions and imaging of larger areas.

Tc1 MIRI Imaging:

- 1 on position with BRIGHTSKY subarray.
- 9 MIRI filters with 5 groups & 1 integration each.
- 4-point dither pattern ensures good PSF sampling at all wavelengths.
- Total depth is driven by the need to avoid saturation. S/N obtained will be from a few 100 to >1000 in all filter settings.
- Special requirements: Added a small offset to center PN in mosaic.

Tc1 MIRI MRS:

- One 3x1 mosaic; one off position. The targets of these positions are linked under 'Fixed Targets' for background subtraction.
- The mosaic is designed so that the smallest apertures are contiguous, with a 5% overlap.
- All three mosaic positions use the same setup.
- There is no need for Target Acquisition.
- 210 groups, 1 integration, 1 exposure for MRSSHORT(A); 30x7x1 for MRSLONG(A); 120x1x1 for (B) and 60x1x1 for (C). Driven by S/N requirements while avoiding saturation.
- 4-point dither for good PSF sampling; 2-point dither for background off position.
- Special requirements: None added, but ideally, there should be an uninterrupted sequence for background subtraction (targets linked under Fixed Targets). We have added an Aperture PA Range to ensure that the IFU covers a bright region in the fullerene ring; depending on the chose PA, either MIRI or NIRSpec appears to point into the MAZ though. We also added small offset to ensure both the central structure of the PN and the outer ring are covered.

JWST Proposal 4706 (Created: Monday, April 7, 2025, 12:00:20PM Eastern Standard Time) - Overview

Tc1 NIRSpec IFU:

- A 3x1 mosaic (similar to the shortest wavelengths of the MIRI MRS mosaic) with corresponding background and leakcal observations.
- Standard 4-point dither for spatial sampling.
- The exposure time in the mosaic (15x1x1) is selected to achieve a S/N of roughly 10 for key [OI] and [Fe II] lines. This does not lead to saturation in the strongest lines in the nebula.
- Special requirements: Added a small offset to ensure both the center of the PN and the outer ring are covered. We have added the same Aperture PA Range as for MIRI MRS to ensure both instruments cover the same area of the object.

Proposal 4706 - Targets - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative environment.

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(8)	PN-TC-1	RA: 17 45 35.2843 (266.3970179d) Dec: -46 05 23.87 (-46.08996d) Equinox: J2000	Proper Motion RA: -2.33 mas/yr Proper Motion Dec: -9.30 mas/yr Epoch of Position: 2000	
<p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i> <i>Category=Star</i> <i>Description=[Planetary nebulae nuclei]</i> <i>Extended=YES</i></p>				
(9)	PN-TC-1-MRS	RA: 17 45 35.2843 (266.3970179d) Dec: -46 05 23.87 (-46.08996d) Equinox: J2000	Proper Motion RA: -2.33 mas/yr Proper Motion Dec: -9.30 mas/yr Epoch of Position: 2000	
<p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i> <i>Category=Star</i> <i>Description=[Planetary nebulae nuclei]</i> <i>Extended=YES</i></p>				
(10)	PN-TC1-OFF	RA: 17 45 40.3609 (266.4181704d) Dec: -46 05 40.16 (-46.09449d) Equinox: J2000		
<p><i>Comments:</i> <i>Category=ISM</i> <i>Description=[Intercloud medium]</i></p>				
(11)	PN-TC-1-NIRSpec	RA: 17 45 35.2734 (266.3969725d) Dec: -46 05 23.45 (-46.08985d) Equinox: J2000	Proper Motion RA: -2.33 mas/yr Proper Motion Dec: -9.30 mas/yr Epoch of Position: 2000	
<p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i> <i>Category=Star</i> <i>Description=[Planetary nebulae nuclei]</i> <i>Extended=YES</i></p>				
(12)	PN-TC1-MIRI-Im-OFF	RA: 17 45 30.8126 (266.3783858d) Dec: -46 04 15.46 (-46.07096d) Equinox: J2000		
<p><i>Comments:</i> <i>Category=ISM</i> <i>Description=[Intercloud medium]</i></p>				

Fixed Targets

Proposal 4706 - Observation 9 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	Proposal 4706, Observation 9: PN Tc 1 MIRI Imaging Diagnostic Status: Warning Observing Template: MIRI Imaging Background Observations:[PN Tc 1 MIRI Imaging OFF (Obs 15)]										
	(PN Tc 1 MIRI Imaging (Obs 9)) Warning (Form): Target requiring background exposure selected for template that doesn't require background exposure (Visit 9:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(8)	PN-TC-1	RA: 17 45 35.2843 (266.3970179d) Dec: -46 05 23.87 (-46.08996d) Equinox: J2000			Proper Motion RA: -2.33 mas/yr Proper Motion Dec: -9.30 mas/yr Epoch of Position: 2000					
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. Category=Star Description=[Planetary nebulae nuclei] Extended=YES											
Template	Subarray										
	BRIGHTSKY										
Dithers	#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size	
	1	CYCLING	1	4		1	1			LARGE	
Spectral Elements	#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F560W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	2	F770W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	3	F1000W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	4	F1130W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	5	F1280W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	6	F1500W	FASTR1	5	1	1	Dither 1	4	4	17.306	141044
	7	F1800W	FASTR1	5	1	1	Dither 1	4	4	17.306	63530
	8	F2100W	FASTR1	5	1	1	Dither 1	4	4	17.306	63530
	9	F2550W	FASTR1	5	1	1	Dither 1	4	4	17.306	63530
Special Requirements	Offset -3.0 arcsec, -3.0 arcsec										
	Group Observations 9, 15, Non-interruptible										

Proposal 4706 - Observation 10 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	Proposal 4706, Observation 10: PN Tc 1 MRS On Diagnostic Status: Warning Observing Template: MIRI Medium Resolution Spectroscopy Background Observations:[PN Tc 1 MRS Off (Obs 14)] Comments: <i>MIRI Mosaic for channel 1 needs to encompass the NIRSpec FOV.</i>												
Diagnostics	(Visit 10:1) Warning (Form): Data Excess over lower threshold (Visit 10:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.												
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections			Miscellaneous					
(9)	PN-TC-1-MRS	RA: 17 45 35.2843 (266.3970179d) Dec: -46 05 23.87 (-46.08996d) Equinox: J2000		Proper Motion RA: -2.33 mas/yr Proper Motion Dec: -9.30 mas/yr Epoch of Position: 2000									
Comments: <i>This object was generated by the targetselector and retrieved from the SIMBAD database.</i> Category=Star Description=[Planetary nebulae nuclei] Extended=YES													
Acquisition	#	Target											
1	NONE												
Template	AcqFilter	Primary Channel		Simultaneous Imaging		Imager Subarray		Grating Wheel Direction					
F560W	All MRS		NO		FULL		Allow Auto Reorder						
Mosaic	Rows	Columns	Row Overlap %	Column Overlap %	Row shift (deg)	Column shift (deg)	Tile Order						
3	1	10.0	10.0	0.0	0.0	DEFAULT							
Dithers	#	Dither Type		Optimized For			Direction						
1	4-Point		EXTENDED SOURCE			NEGATIVE							
Spectral Elements	#	Wavelength Range	Detector	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	LONG(C)	MRSLONG		FASTR1	60	1	1	Dither 1	4	4	666.01	167834	
1	LONG(C)	MRSSHORT		FASTR1	60	1	1	Dither 1	4	4	666.01	167834	
2	MEDIUM(B)	MRSLONG		FASTR1	120	1	1	Dither 1	4	4	1332.019	167834	
2	MEDIUM(B)	MRSSHORT		FASTR1	120	1	1	Dither 1	4	4	1332.019	167834	
3	SHORT(A)	MRSLONG		FASTR1	30	7	1	Dither 1	4	28	2397.635	167834	
3	SHORT(A)	MRSSHORT		FASTR1	210	1	1	Dither 1	4	4	2331.034	167834	

Proposal 4706 - Observation 10 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative envir...

Special Requirements

Offset -0.8 arcsec, 3.5 arcsec

Group Observations 10, 14, Non-interruptible

Proposal 4706 - Observation 14 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	Proposal 4706, Observation 14: PN Tc 1 MRS Off Diagnostic Status: Warning Observing Template: MIRI Medium Resolution Spectroscopy Background Observation For: [PN Tc 1 MRS On (Obs 10)]												
	(Visit 14:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.												
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous				
	(10)	PN-TC1-OFF	RA: 17 45 40.3609 (266.4181704d) Dec: -46 05 40.16 (-46.09449d) Equinox: J2000 <i>Comments:</i> <i>Category=ISM</i> <i>Description=[Intercloud medium]</i>										
Acquisition	#	Target											
	1	NONE											
Template	AcqFilter	Primary Channel			Simultaneous Imaging		Imager Subarray		Grating Wheel Direction				
	F560W	All MRS			NO		FULL		Allow Auto Reorder				
Dithers	#	Dither Type			Optimized For			Direction					
	1	2-Point			EXTENDED SOURCE			NEGATIVE					
Spectral Elements	#	Wavelength Range	Detector	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	LONG(C)	MRSLONG		FASTR1	60	1	1	Dither 1	2	2	333.005	
	1	LONG(C)	MRSSHORT		FASTR1	60	1	1	Dither 1	2	2	333.005	
	2	MEDIUM(B)	MRSLONG		FASTR1	120	1	1	Dither 1	2	2	666.01	
	2	MEDIUM(B)	MRSSHORT		FASTR1	120	1	1	Dither 1	2	2	666.01	
	3	SHORT(A)	MRSLONG		FASTR1	30	7	1	Dither 1	2	14	1198.817	
	3	SHORT(A)	MRSSHORT		FASTR1	210	1	1	Dither 1	2	2	1165.517	

Proposal 4706 - Observation 14 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative envir...

Special Requirements

Aperture PA Range 66 to 82 Degrees (V3 66.0 to 82.0)

Offset -0.8 arcsec, 3.5 arcsec

Group Observations 10, 14, Non-interruptible

Proposal 4706 - Observation 15 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	Proposal 4706, Observation 15: PN Tc 1 MIRI Imaging OFF Diagnostic Status: Warning Observing Template: MIRI Imaging Background Observation For: [PN Tc 1 MIRI Imaging (Obs 9)]										
	(Visit 15:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(12)	PN-TC1-MIRI-Im-OFF	RA: 17 45 30.8126 (266.3783858d) Dec: -46 04 15.46 (-46.07096d) Equinox: J2000								
Template	<i>Comments:</i>										
	Category=ISM Description=[Intercloud medium]										
Dithers	Subarray										
	BRIGHTSKY										
Spectral Elements	#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size	
	1	CYCLING	1	4						LARGE	
Spectral Elements	#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F560W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	2	F770W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	3	F1000W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	4	F1130W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	5	F1280W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	6	F1500W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	7	F1800W	FASTR1	5	1	1	Dither 1	4	4	17.306	
	8	F2100W	FASTR1	5	1	1	Dither 1	4	4	17.306	
9	F2550W	FASTR1	5	1	1	Dither 1	4	4	17.306		
Special Requirements	Group Observations 9, 15, Non-interruptible										

Proposal 4706 - Observation 12 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	<p>Proposal 4706, Observation 12: PN Tc 1 On NIRSpec</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRSpec IFU Spectroscopy</p> <p>Background Observations:[PN Tc 1 Off (Obs 13)]</p> <p><i>Comments: MIRI Mosaic for channel 1 needs to encompass the NIRSpec FOV.</i></p>																																																																																															
Diagnostics	<p>(Visit 12:1) Warning (Form): Data Excess over lower threshold</p> <p>(Visit 12:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p> <p>(Visit 12:1) Informational (Form): Visit schedulable, but most scheduling windows are when JWST is pointed in direction of greatest micrometeoroid impact risk. This is likely due to scheduling special requirements.</p>																																																																																															
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Spectral Elements	<table border="1"> <thead> <tr> <th>#</th> <th>Grating/Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Leakcal</th> <th>Dither</th> <th>Autocal</th> <th>Total Dithers</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>G395H/F290LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> <tr> <td>2</td> <td>G395H/F290LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>true</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> <tr> <td>3</td> <td>G235H/F170LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> <tr> <td>4</td> <td>G235H/F170LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>true</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> <tr> <td>5</td> <td>G140H/F100LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> <tr> <td>6</td> <td>G140H/F100LP</td> <td>NRSIRS2RAPID</td> <td>15</td> <td>1</td> <td>true</td> <td>true</td> <td>NONE</td> <td>4</td> <td>4</td> <td>933.689</td> <td>167834</td> </tr> </tbody> </table>												#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	1	G395H/F290LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	167834	2	G395H/F290LP	NRSIRS2RAPID	15	1	true	true	NONE	4	4	933.689	167834	3	G235H/F170LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	167834	4	G235H/F170LP	NRSIRS2RAPID	15	1	true	true	NONE	4	4	933.689	167834	5	G140H/F100LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	167834	6	G140H/F100LP	NRSIRS2RAPID	15	1	true	true	NONE	4	4	933.689	167834
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Proposal 4706 - Observation 12 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative envir...

Special Requirements

Aperture PA Range 74.97164917 to 76.97164917 Degrees (V3 296.0 to 298.0)
Offset 0.0 arcsec, 3.0 arcsec

Group Observations 12, 13, Non-interruptible

Proposal 4706 - Observation 13 - Fullerenes in Tc 1: a quantitative study of the interaction of large molecules with their radiative enviro...

Mon Apr 07 17:00:21 GMT 2025

Observation	<p>Proposal 4706, Observation 13: PN Tc 1 Off</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRSpec IFU Spectroscopy</p> <p>Background Observation For: [PN Tc 1 On NIRSpec (Obs 12)]</p>											
Diagnostics	(Visit 13:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.											
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous			
	(10)	PN-TC1-OFF	RA: 17 45 40.3609 (266.4181704d) Dec: -46 05 40.16 (-46.09449d) Equinox: J2000									
	<p><i>Comments:</i> <i>Category=ISM</i> <i>Description=[Intercloud medium]</i></p>											
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	ETC Wkbk.Calc ID
	1	G395H/F290LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	
	2	G235H/F170LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	
	3	G140H/F100LP	NRSIRS2RAPID	15	1	false	true	NONE	4	4	933.689	
Special Requirements	Group Observations 12, 13, Non-interruptible											