



1237 - Star Formation in the Extreme Outer Galaxy

Cycle: 1, Proposal Category: GTO

INVESTIGATORS

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OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
EOG-OBSERVATION				
	1	DC2-S-NIRCAM-N-MIRI	NIRCam Imaging	(2) DIGELC2-S
	2	DC2-N-NIRCAM	NIRCam Imaging	(1) DIGELC2-N
	3	DC2-S-MIRI	MIRI Imaging	(2) DIGELC2-S
	4	DC1-A-NIRCAM	NIRCam Imaging	(3) DIGELC1-A
	5	DC1-A-MIRI	MIRI Imaging	(3) DIGELC1-A
	6	DC1-B-MIRI	MIRI Imaging	(4) DIGELC1-B

ABSTRACT

We propose MIRI/NIRCam imaging (wavelengths from 1.15 to 21 μm) of several star-forming clusters in the distant Digel Cloud 1 and Digel Cloud 2. We will use the imaging data to build broad spectral energy distributions for all the cluster members in order to estimate their mass, luminosity, and evolutionary status. These star forming regions lie at a Galactocentric radius > 18 kpc, and so will allow us to study star formation activity within

low metallicity and gas density environments similar to those in the Magellanic Clouds and other nearby dwarf galaxies. We expect to detect sources down to 8 MJup and to distinguish whether stars down to 0.5 Msun still have circumstellar disks.

Digel 2 has two star forming clusters approximately 8' apart, very close to the separation between MIRI's and NIRCam's fields-of-view. We will take advantage of parallel MIRI/NIRCam observations to obtain MIRI images of the northern cluster while NIRCam will be gathering data on Digel 2S. Unfortunately, JWST cannot achieve a 180 degree opposite roll angle 6 months later, so we slew to 2S to get MIRI alone, then 2N to get NIRCam alone, all in the same epoch. For Digel 1, which also has two nearby clusters, we concentrate on cluster 1A, getting both MIRI and NIRCam images, while still getting MIRI imaging on cluster 1B.

For all targets (except DC1-B), we expect to get three wavelengths in each of the following combinations:

F115W - F356W - F770W

F150W - F440W - F1280W

F200W - F405N+F444W - F2100W

The parallel observations of DC2 have strict constraints on the positions angle of the observations in order that the two pairs of clusters are covered by their respective instruments at the time.

OBSERVING DESCRIPTION

The extreme outer Galaxy (EOG), which we define as the region with a Galactocentric radius (R_g) of ≥ 18 kpc, has a very different environment from the Solar neighborhood, since it has a much lower gas density, lower metallicity (~ 1 dex), and little perturbation from the spiral arms. The environment is similar to that of nearby dwarf galaxies, damped Lyman-alpha systems, and the early stage of the formation of the Galactic disk. Because of its relative proximity, compared to nearby dwarf galaxies such as the LMC and SMC (about 10 kpc vs. 50 kpc), the EOG serves as an ideal “laboratory” in which to study the details of the star formation process in such environments (Kobayashi et al., 2008).

In near-infrared (NIR) surveys of the EOG, we have found active star formation occurring in Digel Cloud 1 (DC1; Izumi et al. 2014) and Cloud 2 (DC2, Kobayashi & Tokunaga 2000), which are two of the most distant known regions with a $R_g \sim > 20$ kpc. Based on the position of the star-forming clusters with respect to local CO, MIR, H I, and radio continuum peaks and ridges, we have suggested that the DC1 clusters may have been triggered by high-velocity cloud accretion onto the Galactic disk, while the DC2 clusters may have been triggered by a supernova event. For the two

clusters in DC2, we found that the initial mass function (IMF) is consistent with that in the Solar neighborhood in terms of the high-mass slope and IMF peak (Yasui et al., 2008a,b). However, we also found that the fraction of stars with a K-band excess (which originates from the inner circumstellar dust disk at radii of $r \leq 0.1$ AU) is significantly lower than that in the Solar neighborhood, suggesting a metallicity dependence of disk lifetimes (Yasui et al., 2009).

We propose MIRI/NIRCAM imaging (1.15 - 21 μm) of DC1 and DC2 at the locations of several candidate star-forming clusters (Izumi et al., 2017). We expect to detect sources down to 8 MJup and to distinguish whether stars down to 0.5 Msun still have disks. The sensitivity and spatial resolution of JWST will enable us to study star- and planet-forming processes in the EOG at the same depth as the Solar neighborhood for the first time. Specifically, we will use the NIR and MIR data to classify the evolutionary stages of YSOs (Class 0–III; e. g., Fischer et al. 2016) and reveal their spatial distribution. The many additional YSOs we expect to detect will help to clarify the relationship of DC1 and DC2 with their surrounding environment and to suggest possible formation mechanisms. The new YSOs will allow us to also derive the IMF in this low metallicity environment down to the very low-mass end (< 0.1 Msun), which is suggested to be a sensitive function of the formation environment and initial conditions (Lada & Lada, 2003). This will be the first study of brown dwarfs and planetary mass objects in low-metallicity environments and will enable us to investigate whether they are common in such environments. And lastly, we will gain new insights into the outer ($\sim 0.1 - 5$ AU) circumstellar disk evolution. Given that we may detect up to 150 cluster members, this will allow us to quantitatively compare the disk lifetimes in low-metallicity regions with those in the Solar neighborhood that have been extensively characterized by Spitzer. This metallicity relationship has implications for the planet formation probability which may have evolved over the lifetime of our Galaxy.

References:

- Fischer, W. J., Padgett, D. L., Stapelfeldt, K. L., & Sewio, M. 2016, ApJ, 827, 96
Izumi, N., Kobayashi, N., Yasui, C., et al. 2014, ApJ, 795, 66
Izumi, N., Kobayashi, N., Yasui, C., et al. 2017, AJ, 154, 163
Kobayashi, N. & Tokunaga, A. T. 2000, ApJ, 532, 423
Kobayashi, N., Yasui, C., Tokunaga, A. T., & Saito, M. 2008, ApJ, 683, 178
Lada, C. J. & Lada, E. A. 2003, ARA&A, 41, 57
Yasui, C., Kobayashi, N., Tokunaga, A. T., et al. 2008a, ApJ, 675, 443
Yasui, C., Kobayashi, N., Tokunaga, A. T., et al. 2008b, 396, 225
Yasui, C., Kobayashi, N., Tokunaga, A. T., et al. 2009, ApJ, 705, 54

Proposal 1237 - Targets - Star Formation in the Extreme Outer Galaxy

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	DIGELC2-N	RA: 02 48 42.0326 (42.1751358d) Dec: +58 29 3.46 (58.48429d) Equinox: J2000		
<i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i>				
(2)	DIGELC2-S	RA: 02 48 28.5910 (42.1191292d) Dec: +58 23 30.28 (58.39174d) Equinox: J2000		
<i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i>				
(3)	DIGELC1-A	RA: 02 04 17.8184 (31.0742433d) Dec: +63 14 39.83 (63.24440d) Equinox: J2000		
<i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i>				
(4)	DIGELC1-B	RA: 02 05 8.6223 (31.2859263d) Dec: +63 04 54.10 (63.08169d) Equinox: J2000		
<i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i>				

Fixed Targets

Proposal 1237 - Observation 1 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	Proposal 1237, Observation 1: DC2-S-NIRCAM-N-MIRI Diagnostic Status: Warning Observing Template: NIRCam Imaging Coordinated Parallel Template(s): MIRI Imaging										
	(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(2)	DIGELC2-S	RA: 02 48 28.5910 (42.1191292d) Dec: +58 23 30.28 (58.39174d) Equinox: J2000								
<i>Comments:</i> Category=Stellar Cluster Description=[Young star clusters]											
Template	NIRCam Imaging					MIRI Imaging					
	Module: B Subarray: FULL					Subarray: FULL					
Mosaic	Rows	Columns	Row Overlap %	Column Overlap %	Row shift	Column shift	Tile Order				
	1	2	10.0	57.0	5.0	10.0	DEFAULT				
Dithers	#	Primary Dither Type	Primary Dithers	Dither Size	Subpixel Positions	Coordinated Parallel Subpixel Selector	Dither Direct Images Primes				
	1	NONE			1	4-POINT-WITH-MIRI-F2100W	NO_DITHERING				
Spectral Elements	NIRCam Imaging	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID	
	1	F115W	F356W	BRIGHT2	5	1	4	4	429.471		
	2	F150W	F444W	BRIGHT2	5	1	4	4	429.471		
	3	F200W	F405N+F444W	BRIGHT2	5	1	4	4	429.471		
Spectral Elements	MIRI Imaging	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F770W	FASTR1	35	1	1	Dither 1	4	4	388.506	
	2	F1280W	FASTR1	35	1	1	Dither 2	4	4	388.506	
	3	F2100W	FASTR1	35	1	1	Dither 3	4	4	388.506	

Proposal 1237 - Observation 1 - Star Formation in the Extreme Outer Galaxy

Special Requirements

Aperture PA Range 85.88744876 to 86.88744876 Degrees (V3 85.83161347 to 86.83161347)
Offset 16.95 arcsec, -23.31 arcsec
No Parallel Attachments
Group Observations 1, 2, 3 within 24 Hours

Proposal 1237 - Observation 2 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	<p>Proposal 1237, Observation 2: DC2-N-NIRCAM</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRCcam Imaging</p>									
Diagnostics	(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.									
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections			Miscellaneous		
	(1)	DIGELC2-N	RA: 02 48 42.0326 (42.1751358d) Dec: +58 29 3.46 (58.48429d) Equinox: J2000							
	<p><i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=/Young star clusters/</i></p>									
Template	Module				Subarray					
	B				FULL					
Dithers	#	Primary Dither Type		Primary Dithers		Subpixel Dither Type		Dither Size		Subpixel Positions
	1	NONE				STANDARD				4
Spectral Elements	#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	1	F115W	F356W	RAPID	9	1	4	4	386.524	
	2	F150W	F444W	RAPID	9	1	4	4	386.524	
	3	F200W	F405N+F444W	RAPID	9	1	4	4	386.524	
Special Requirements	<p>Aperture PA Range 85.02984889 to 86.02984889 Degrees (V3 84.9740136 to 85.9740136) Offset -21.30294527952637 arcsec, -29.195704239703613 arcsec No Parallel Attachments</p> <p>Group Observations 1, 2, 3 within 24 Hours</p>									

Proposal 1237 - Observation 3 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	<p>Proposal 1237, Observation 3: DC2-S-MIRI</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: MIRI Imaging</p>										
Diagnostics	(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(2)	DIGELC2-S	RA: 02 48 28.5910 (42.1191292d) Dec: +58 23 30.28 (58.39174d) Equinox: J2000								
	<p><i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i></p>										
Template	<p>Subarray FULL</p>										
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			DEFAULT	
Spectral Elements	#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F770W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	2	F1280W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	3	F2100W	FASTR1	37	1	1	Dither 1	4	4	410.706	
Special Requirements	<p>Aperture PA Range 89.83425324 to 90.83425324 Degrees (V3 84.99880427 to 85.99880427) Offset -13.269818307264641 arcsec, -18.91952168554755 arcsec No Parallel Attachments</p> <p>Group Observations 1, 2, 3 within 24 Hours</p>										

Proposal 1237 - Observation 4 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	<p>Proposal 1237, Observation 4: DC1-A-NIRCAM</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: NIRCAM Imaging</p>									
Diagnostics	(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.									
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections			Miscellaneous		
	(3)	DIGELC1-A	RA: 02 04 17.8184 (31.0742433d) Dec: +63 14 39.83 (63.24440d) Equinox: J2000							
	<p><i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=/Young star clusters/</i></p>									
Template	Module				Subarray					
	B				FULL					
Dithers	#	Primary Dither Type		Primary Dithers		Subpixel Dither Type		Dither Size		Subpixel Positions
	1	NONE				STANDARD				4
Spectral Elements	#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	1	F115W	F356W	RAPID	8	1	4	4	343.577	
	2	F150W	F444W	RAPID	8	1	4	4	343.577	
	3	F200W	F405N+F444W	RAPID	8	1	4	4	343.577	
Special Requirements	<p>Aperture PA Range 85.02984889 to 90.02984889 Degrees (V3 84.9740136 to 89.9740136) Offset -18.137402322573116 arcsec, -26.911981751219585 arcsec No Parallel Attachments</p> <p>Group Observations 4, 5, 6 within 24 Hours</p>									

Proposal 1237 - Observation 5 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	<p>Proposal 1237, Observation 5: DC1-A-MIRI</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: MIRI Imaging</p>										
Diagnostics	(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(3)	DIGELC1-A	RA: 02 04 17.8184 (31.0742433d) Dec: +63 14 39.83 (63.24440d) Equinox: J2000								
	<p><i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i></p>										
Template	<p>Subarray FULL</p>										
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			DEFAULT	
Spectral Elements	#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F770W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	2	F1280W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	3	F2100W	FASTR1	36	1	1	Dither 1	4	4	399.606	
Special Requirements	<p>Aperture PA Range 84.83425324 to 94.83425324 Degrees (V3 79.99880427 to 89.99880427) Offset 9.611434434836823 arcsec, -34.76246875238425 arcsec No Parallel Attachments</p> <p>Group Observations 4, 5, 6 within 24 Hours</p>										

Proposal 1237 - Observation 6 - Star Formation in the Extreme Outer Galaxy

Wed Dec 14 07:00:28 GMT 2022

Observation	<p>Proposal 1237, Observation 6: DC1-B-MIRI</p> <p>Diagnostic Status: Warning</p> <p>Observing Template: MIRI Imaging</p>										
Diagnostics	(Visit 6:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.										
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Miscellaneous			
	(4)	DIGELC1-B	RA: 02 05 8.6223 (31.2859263d) Dec: +63 04 54.10 (63.08169d) Equinox: J2000								
	<p><i>Comments:</i> <i>Category=Stellar Cluster</i> <i>Description=[Young star clusters]</i></p>										
Template	<p>Subarray FULL</p>										
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			DEFAULT	
Spectral Elements	#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	F770W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	2	F1280W	FASTR1	36	1	1	Dither 1	4	4	399.606	
	3	F2100W	FASTR1	36	1	1	Dither 1	4	4	399.606	
Special Requirements	<p>Aperture PA Range 74.83425324 to 134.83425324 Degrees (V3 69.99880427 to 129.99880427) Offset -3.808267509742092 arcsec, -3.651805807769307 arcsec No Parallel Attachments</p> <p>Group Observations 4, 5, 6 within 24 Hours</p>										