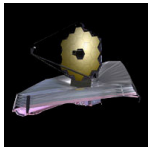

7978 - Our grasp of star formation, feedback, and galaxy evolution is incomplete without a JWST+HST look at the HI-dominated, outer disk of a spiral galaxy

Cycle: 4, Proposal Category: GO

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
Observation Folder				
	1	NGC628-OUTER1	MIRI Imaging	(2) NGC-628-OUTER1
	2	NGC628-OUTER1and 2-NIRCam	NIRCam Imaging	(2) NGC-628-OUTER1
	3	NGC628-OUTER2	MIRI Imaging	(4) NGC-628-OUTER2

ABSTRACT

Outer disks of galaxies, so easily overlooked in the glare of their spectacular central regions, offer unique information regarding: the physics of the interstellar medium (ISM) and of the star formation (SF) process; the intimate relation between stellar populations and the conditions of the surrounding ISM; and the evolution of galaxies. Analysis of outer disks is required for fully understanding the physics of SF, as the low-density environment provides a stress test. We propose JWST's first detailed look at the outer disk ecosystem of a spiral galaxy, NGC 628 (M 74), paired with commensurate joint HST UV-visible imaging, to document dusty ISM and stellar components of the matter cycle. This project crucially informs studies of the Milky Way for which we lack an external perspective. As a nearby, face-on galaxy with an extended HI/UV-disk hosting low-level SF, and with existing inner disk JWST imaging, the benefit of leveraging the Cycle 1 dataset is clear. Our goals are two-fold: (1) tracing diffuse and structured ISM properties (via morphology metrics, spectral energy distribution) as a function of estimated SF feedback strength from the galaxy center to the atomic-dominated, low SFR surface density, outer disk regime; (2) looking for elusive ingredients of SF -- a novel PAH-based search for the yet undetected cold neutral medium (CNM) clouds supporting outer disk SF. Pursuing these topics will test current model predictions, advancing theory and simulations with rare constraint in a regime not yet sampled.

OBSERVING DESCRIPTION

This is a joint JWST + HST imaging project to examine the physical conditions of the outer disk ISM in NGC 628, specifically including a detailed connection to the stellar populations that have managed to form in this extreme environment.

We build on the PHANGS-JWST coverage of NGC 628's inner disk, adding a seven MIRI tile radial extension to the NW for the entire radial extent of the detected HI disk ($\Sigma_{\rm HI}\sim1$~M$_{\odot}\,$pc^{-2}), oriented to align with Herschel/PACS spectroscopic mapping. This strip (reaching to $1.8~r_{25}$, 25.8 kpc) broadens the range of physical conditions probed by JWST in several ways, reaching $f_{\rm mol}\sim0$, $Z\sim0.2~Z_\odot$, log~$\Sigma_{\rm SFR}\sim-4$ [M$_{\odot}$~yr^{-1}~kpc^{-2}]. The decline in SF activity corresponds to a order-of-magnitude reduction in the interstellar radiation field (ISRF). Each MIRI tile is paired with NIRCam and HST imaging.

Filter Choice: Following the PHANGS-JWST survey, we choose a NIRCam and MIRI filter set that enables us to SED-fit robust ages, masses and extinctions of young stellar clusters, detect the emission from hot dust tracing obscured SF, and capture the abundance and physical state of PAHs. As illustrated in Fig.~2 of Lee+2023, F200W, F300M, and F360M provide low obscuration views of photospheric emission, with some contribution from hot dust to F300M and F360M. F335M, F770W, F1130W capture PAH emission, tracing a combination of size and charge, with the F300M and F360M playing a key role in continuum subtraction for F335M, isolating the $3.3~\micron$ PAH. F1000W and F2100W capture the dust continuum, with some contribution to the F1000W band by silicate absorption. We also opt for the well-established LEGUS and PHANGS-HST filter set for our WFC3/UVIS observations, obtaining F275W, F336W, F438W, F555W, F658N, and F814W.

Dithering: With MIRI, we use a 4-point pattern optimized for extended sources to achieve optimal PSF sampling. For NIRCam we use the B~module and 4~primary dithers with the INTRAMODULEBOX pattern. This is sufficient to sample the PSF at all observed wavelengths (≥2~\micron). In parallel, the MIRI background observation will also obtain 4~dithers, which will enable high quality bad pixel flagging to improve the sky background removal.

Exposure times: Achieved surface brightness sensitivity of MIRI is used for exposure estimation. Sandstrom+23 shows that PAH emission provides an approximately linear, high resolution, high sensitivity tracer of total diffuse gas surface density. We aim to recover down to $\Sigma_{gas}\simeq1.0$~M$_{\odot}$~pc^{-2} at 3σ per resolution element, implying σ=0.04 and 0.08 MJy~sr^{-1}, respectively for F770W and F1130W. This requires exposure times of (F770W: 744~s, F1130W: 1276~s). For F2100W, dominated by thermal emission, we use the SED-fit based scaling of Aniano+20 to estimate a representative dust mass surface density ($\Sigma_{\rm Mdust}$) to 21~$\micron$ surface brightness ratio (0.3 M$_{\odot}$~pc^{-2} / MJy~sr^{-1}) for the outer disk. To reach a 3σ target of $\Sigma_{\rm Mdust}$~\sim~0.1 M$_{\odot}$~pc^{-2} we require 1276~s in F2100W. Thus, we use the FASTR1 readout with 4~dithers and plan 16, 11, 28 and 28 groups and 4, 4, 4, 4~integrations for F770W, F1000W, F1130W, and F2100W. We split all band in 4~integrations/dither to minimize potential saturation on bright point sources while still obtaining good S/N on the diffuse emission.

We adopt the a similar set-up to the PHANGS-JWST NIRCam exposure times (F200W: 1200~s, F300M: 386~s, F335M: 386~s, F360M: 429~s) which were designed to ensure detection of young clusters, even embedded ones, such as expected in some portions of the strip and in the three new central regions. For NGC\,628, this depth achieves $\textrm{S/N} \gtrsim 10$ in the stellar photospheric and dust continuum bands (F200W, F300M, F360M, [F1000W, F2100W]) down to $\sim\!7\!\times\!10^2~\mathrm{M}_\odot$ and $A_V\lesssim10$ at 9.8~Mpc. For MIRI F1000W and F2100W, more stringent requirements described above set the exposure. We use NIRCam BRIGHT1 readout with module~B only, to enable the MIRI parallel. NIRCam exposures are divided into~4, to match the number of MIRI background exposures, with one exposures with 5~groups and 2~integration over 4~dithers (815~s) and three exposures with 5~groups and 1~integration over 4~dithers (386.5~s).

We operate MIRI in parallel during primary NIRCam imaging, with a constraint on the position angle so that MIRI points to blank sky for NIRCAM tiles at the end of the radial strip (for inner tiles the MIRI parallel lands within the disk).

For HST WFC3/UVIS imaging, we fit the observations into a 4 orbit sequence per field (16 orbits total), with exposure times of $\sim$2190~s (F275W), $\sim$1110~s (F336W), $\sim$1050~s (F438W), $\sim$670~s (F555W), $\sim$800~s (F814W), deep enough to identify and physically characterize the cluster/association population. In each orbit, we take a single exposure in every filter at the same position to maximize the exposure time obtained. A different dither position is used in each orbit via POS-TARGs offsets, resulting in three-point sub-pixel dither pattern to cover the WFC3 chip gap, remove CRs, and improve sampling of the PSF.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	NGC-628-OUTER1	RA: 01 36 34.4868 (24.1436950d) Dec: +15 51 42.24 (15.86173d) Equinox: J2000	Epoch of Position: 2015.5	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. *Category=Galaxy* *Description=[Barred spiral galaxies]*				
(4)	NGC-628-OUTER2	RA: 01 36 31.1116 (24.1296317d) Dec: +15 54 36.57 (15.91016d) Equinox: J2000	Epoch of Position: 2015.5	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. *Category=Galaxy* *Description=[Barred spiral galaxies]*				

Observation

Proposal 7978, Observation 1: NGC628-OUTER1 Fri Oct 24 00:00:12 GMT 2025

Diagnostic Status: Warning

Observing Template: MIRI Imaging

Diagnostics

(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 1:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 1:3) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 1:4) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(NGC628-OUTER1 (Obs 1)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	NGC-628-OUTER1	RA: 01 36 34.4868 (24.1436950d) Dec: +15 51 42.24 (15.86173d) Equinox: J2000	Epoch of Position: 2015.5	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Galaxy
Description=[Barred spiral galaxies]

Template

Subarray
FULL

Mosaic

Rows	Columns	Row Overlap %	Column Overlap %	Row shift (deg)	Column shift (deg)	Tile Order
1	6	10.0	5.0	0.0	0.0	ROW_ORDER

Dithers

#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size
1	CYCLING	1	4		5	1			DEFAULT

Spectral Elements

#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F770W	FASTR1	16	4	1	Dither 1	4	16	743.711	
2	F1000W	FASTR1	11	4	1	Dither 1	4	16	521.708	
3	F1130W	FASTR1	28	4	1	Dither 1	4	16	1276.518	
4	F2100W	FASTR1	28	4	1	Dither 1	4	16	1276.518	

Special Requirements

Sequence Visits within 53 Days
Aperture PA Range 70.83544897 to 72.83544897 Degrees (V3 66.0 to 68.0)
Visits Same PA
Offset -26.0 arcsec, -8.0 arcsec

Sequence Observations 2, 3, 1 (reordered), Non-interruptible
Aperture PA Offset 2 from 1 by -1 to 1 Degrees (V3 3.78282206 to 5.78282206)
Aperture PA Offset 3 from 1 by 0 to 2.2 Degrees (Same offsets in V3)

Observation

Proposal 7978, Observation 2: NGC628-OUTER1and2-NIRCam Fri Oct 24 00:00:12 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Coordinated Parallel Template(s): MIRI Imaging

Diagnostics

(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 2:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 2:3) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 2:4) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(NGC628-OUTER1and2-NIRCam (Obs 2)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	NGC-628-OUTER1	RA: 01 36 34.4868 (24.1436950d) Dec: +15 51 42.24 (15.86173d) Equinox: J2000	Epoch of Position: 2015.5	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Galaxy
Description=[Barred spiral galaxies]

Template

NIRCam Imaging	MIRI Imaging
Module: B	Subarray: FULL
Subarray: FULL	

Mosaic

Rows	Columns	Row Overlap %	Column Overlap %	Row shift (deg)	Column shift (deg)	Tile Order
1	5	10.0	10.0	0.0	0.0	ROW_ORDER

Dithers

#	Primary Dither Type	Primary Dithers	Dither Size	Subpixel Positions	Coordinated Parallel Subpixel Selector	Dither Direct Images Primes
1	INTRAMODULEBOX	4		1	NIRCam Only	NO_DITHERING

Spectral Elements

NIRCam Imaging	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	Optional ETC ID
1	F200W	F360M	BRIGHT1	5	1	4	4	386.524	
2	F200W	F360M	BRIGHT1	5	1	4	4	386.524	
3	F200W	F335M	BRIGHT1	5	1	4	4	386.524	
4	F200W	F300M	BRIGHT1	5	2	8	4	815.995	

Spectral Elements

MIRI Imaging	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F770W	FASTR1	16	2	1	Dither 1	4	8	366.305	
2	F1000W	FASTR1	11	2	1	Dither 1	4	8	255.304	
3	F1130W	FASTR1	28	1	1	Dither 1	4	4	310.804	
4	F2100W	FASTR1	28	2	1	Dither 1	4	8	632.709	

Special Requirements	
	Sequence Visits within 53 Days Visits Same PA No Parallel Attachments Sequence Observations 2, 3, 1 (reordered), Non-interruptible Aperture PA Offset 2 from 1 by -1 to 1 Degrees (V3 3.78282206 to 5.78282206)

Observation

Proposal 7978, Observation 3: NGC628-OUTER2

Fri Oct 24 00:00:12 GMT 2025

Diagnostic Status: Warning

Observing Template: MIRI Imaging

Diagnostics

(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 3:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 3:3) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(NGC628-OUTER2 (Obs 3)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(4)	NGC-628-OUTER2	RA: 01 36 31.1116 (24.1296317d) Dec: +15 54 36.57 (15.91016d) Equinox: J2000	Epoch of Position: 2015.5	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=Galaxy
Description=[Barred spiral galaxies]

Template

Subarray
FULL

Mosaic

Rows	Columns	Row Overlap %	Column Overlap %	Row shift (deg)	Column shift (deg)	Tile Order
1	3	10.0	5.0	0.0	0.0	ROW_ORDER

Dithers

#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size
1	CYCLING	1	4		5	1			LARGE

Spectral Elements

#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F770W	FASTR1	16	4	1	Dither 1	4	16	743.711	
2	F1000W	FASTR1	11	4	1	Dither 1	4	16	521.708	
3	F1130W	FASTR1	28	4	1	Dither 1	4	16	1276.518	
4	F2100W	FASTR1	28	4	1	Dither 1	4	16	1276.518	

Special Requirements

Sequence Visits within 53 Days
Visits Same PA
Offset -22.0 arcsec, -1.0 arcsec

Sequence Observations 2, 3, 1 (reordered), Non-interruptible
Aperture PA Offset 3 from 1 by 0 to 2.2 Degrees (Same offsets in V3)