6991 - Testing planet-disk interaction theory by imaging a unique spiral-arm-driving and gap-opening protoplanet

Cycle: 4, Proposal Category: GO

INVESTIGATORS

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
V1247ORI-ADI-RDI				
	1	V1247ORI-ROLL1	NIRCam Coronagraphic Imaging	(1) V-V1247-Ori
	2	V1247ORI-ROLL2	NIRCam Coronagraphic Imaging	(1) V-V1247-Ori
	3	V1247ORI-PSF-REF	NIRCam Coronagraphic Imaging	(2) HD-37443

ABSTRACT

At the early stages of planet formation, giant planets interact with and shape their surrounding protoplanetary disks. While we have identified nearly two dozen spiral arm systems in protoplanetary disks, none of the planets that shape these spiral structures are confirmed. To locate these hidden planets, ground-based high-contrast imagers are observing these spiral systems at two distinct epochs over 5 or more years. With these observations, we constrain spiral motion, identify spiral formation mechanism, and pinpoint the orbits for these spiral-arm-driving giant planets. With the recent

validation of the theory using the co-motion between a spiral and a stellar companion, we can now start hunting these spiral arm drivers in the planetary regime.

A two-epoch observational study of the V1247 Ori spiral motion prescribed a hidden giant planet at 118 au or 0.29". The orbit aligns with an ALMA dust continuum gap, and there is a near-infrared high-contrast imaging candidate from Keck/NIRC2 almost exactly matching hydrodynamical simulation location. These four pieces of evidence complementarily support the theory that a giant planet is driving the scattered-light spirals and creating a millimeter gap. Situated at 0.29" ± 0.05", this hidden giant planet is the best target for NIRCam high-contrast imaging, thanks to unprecedented NIRCam sensitivity and contrast that are otherwise unachievable from the ground. Once confirmed, this joint-evidence approach will establish a new way of planet imaging, and deepen our understanding of planet formation. If not, this poses serious challenges to planet-disk interaction theories and protoplanet evolutionary models for further refinement.

OBSERVING DESCRIPTION

For V1247 Ori, we request DEEP8, ngroup=20, nint=5 for 2067s of exposure at F410M/F210M and nint=6 for 2481s of exposure at F460M/F210M. We repeat this at two roll angles spaced by 10 degrees. To removed the stellar signals and speckles from the V1247 Ori observations, we have selected HD 37443 as the reference stardue to its close proximity (< 10 deg from the star), magnitude, and color. For the reference star, we repeat the same exposure pattern, but using the 5-point small grid dither to ensure pointing repeatability, which is essential to increase constrast from post-processing.

To image the hidden companion located at ~0.3 arcsec, as well as ring-sheperding planet exteior to ~0.5 arcsec, the filters are F410M/F460M and F210M for the long and short wavelength channels. In this way, we can obtain both short wavelength channel and long wavelength channels simultaneously within one exposure, and use the F210M images to remove disk contamination (which is already significantly small in the F410M/F460M wavelengths). Upon simulations with the NIRCam ETC, we do not further increase the exposure time, since the constrast does not improve between 0.3 arcsec and 0.8 arcsec with this optimal observational setup.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	V-V1247-Ori	RA: 05 38 5.2519 (84.5218829d) Dec: -01 15 21.70 (-1.25603d) Equinox: J2000	Proper Motion RA: -0.391 mas/yr Proper Motion Dec: -0.5300000566421659 mas/yr Parallax: 0.0024918999999999996" Epoch of Position: 2000	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. SIMBAD listed proper motion for this target. When retrieving targets with PM from SIMBAD, APT requests the coordinates be calculated with an epoch of the year 2000. Do not modify this epoch. Always review coordinates using the Target Confirmation tool, which graphically displays the PM. Category=Star Description=[Protoplanetary disks]				
(2)	HD-37443	RA: 05 38 32.6439 (84.6360162d) Dec: -01 03 30.57 (-1.05849d) Equinox: J2000	Proper Motion RA: -30.666 mas/yr Proper Motion Dec: 5.753 mas/yr Parallax: 0.0067338" Epoch of Position: 2000	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. SIMBAD listed proper motion for this target. When retrieving targets with PM from SIMBAD, APT requests the coordinates be calculated with an epoch of the year 2000. Do not modify this epoch. Always review coordinates using the Target Confirmation tool, which graphically displays the PM. Category=Star Description=[F stars]				

Observation

Proposal 6991, Observation 1: V1247ORI-ROLL1

Wed Sep 24 20:00:09 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRCam Coronagraphic Imaging

Diagnostics

(V1247ORI-ROLL1 (Obs 1)) Warning (Form): The selected fiducial point is not a standard option for the instrument.

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

(V1247ORI-ROLL1 (Obs 1)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

(Visit 1:1) 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.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	V-V1247-Ori	RA: 05 38 5.2519 (84.5218829d) Dec: -01 15 21.70 (-1.25603d) Equinox: J2000	Proper Motion RA: -0.391 mas/yr Proper Motion Dec: -0.5300000566421659 mas/yr Parallax: 0.0024918999999999996" Epoch of Position: 2000	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

SIMBAD listed proper motion for this target. When retrieving targets with PM from SIMBAD, APT requests the coordinates be calculated with an epoch of the year 2000. Do not modify this epoch. Always review coordinates using the Target Confirmation tool, which graphically displays the PM.
Category=Star
Description=[Protoplanetary disks]

Acquisition

#	Target	Filter	Target Brightness	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	Optional ETC ID
1	1 V-V1247-Ori	F335M	BRIGHT (ND Square)	MEDIUM2	65	1	1	32.255	223525

Template

Module	Occulting Mask	Obtain Astrometric Confirmation Images?	Subarray	Dither Pattern
A	MASKLWB	true	SUB400X256ALWB	NONE

Confirmation

#	Conf. Readout Pattern	Conf. Groups/Int	Conf. Integrations/Exp	Conf. Total Integrations	Conf. Total Exposure Time	Conf. Total Dithers
1	RAPID	4	1	1	42.947	1

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F210M	F410M	DEEP8	20	5	1	5	2067.56	
2	F210M	F460M	DEEP8	20	6	1	6	2481.072	

PSF References	V1247ORI-PSF-REF (Obs 3) (PSF Reference; Filters [F210M/F410M, F210M/F460M]) V1247ORI-ROLL2 (Obs 2) (Filters [F210M/F410M, F210M/F460M]) Additional Justification: false
Special Requirements	Aperture PA Range 278 to 301.25 Degrees (V3 277.583417 to 300.833417) No Parallel Attachments Fiducial Point Override NRCA5_MASKLWB_NARROW Group Observations 1, 2, 3, Non-interruptible Aperture PA Offset 2 from 1 by 7 to 14 Degrees (Same offsets in V3)

Observation

Proposal 6991, Observation 2: V1247ORI-ROLL2

Wed Sep 24 20:00:09 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRCam Coronagraphic Imaging

Diagnostics

(V1247ORI-ROLL2 (Obs 2)) Warning (Form): The selected fiducial point is not a standard option for the instrument.

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

(V1247ORI-ROLL2 (Obs 2)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

(Visit 2:1) 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.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	V-V1247-Ori	RA: 05 38 5.2519 (84.5218829d) Dec: -01 15 21.70 (-1.25603d) Equinox: J2000	Proper Motion RA: -0.391 mas/yr Proper Motion Dec: -0.5300000566421659 mas/yr Parallax: 0.0024918999999999996" Epoch of Position: 2000	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

SIMBAD listed proper motion for this target. When retrieving targets with PM from SIMBAD, APT requests the coordinates be calculated with an epoch of the year 2000. Do not modify this epoch. Always review coordinates using the Target Confirmation tool, which graphically displays the PM.
Category=Star
Description=[Protoplanetary disks]

Acquisition

#	Target	Filter	Target Brightness	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	Optional ETC ID
1	SAME	F335M	BRIGHT (ND Square)	MEDIUM2	65	1	1	32.255	223525

Template

Module	Occulting Mask	Obtain Astrometric Confirmation Images?	Subarray	Dither Pattern
A	MASKLWB	true	SUB400X256ALWB	NONE

Confirmation

#	Conf. Readout Pattern	Conf. Groups/Int	Conf. Integrations/Exp	Conf. Total Integrations	Conf. Total Exposure Time	Conf. Total Dithers
1	RAPID	4	1	1	42.947	1

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F210M	F410M	DEEP8	20	5	1	5	2067.56	
2	F210M	F460M	DEEP8	20	6	1	6	2481.072	

PSF References	V1247ORI-PSF-REF (Obs 3) (PSF Reference; Filters [F210M/F410M, F210M/F460M]) V1247ORI-ROLL1 (Obs 1) (Filters [F210M/F410M, F210M/F460M]) Additional Justification: false
Special Requirements	Aperture PA Range 278 to 301.25 Degrees (V3 277.583417 to 300.833417) No Parallel Attachments Fiducial Point Override NRCA5_MASKLWB_NARROW Group Observations 1, 2, 3, Non-interruptible Aperture PA Offset 2 from 1 by 7 to 14 Degrees (Same offsets in V3)

Observation

Proposal 6991, Observation 3: V1247ORI-PSF-REF

Wed Sep 24 20:00:09 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRCam Coronagraphic Imaging

Diagnostics

(V1247ORI-PSF-REF (Obs 3)) Warning (Form): The selected fiducial point is not a standard option for the instrument.

(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)	HD-37443	RA: 05 38 32.6439 (84.6360162d) Dec: -01 03 30.57 (-1.05849d) Equinox: J2000	Proper Motion RA: -30.666 mas/yr Proper Motion Dec: 5.753 mas/yr Parallax: 0.0067338" Epoch of Position: 2000	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

SIMBAD listed proper motion for this target. When retrieving targets with PM from SIMBAD, APT requests the coordinates be calculated with an epoch of the year 2000. Do not modify this epoch. Always review coordinates using the Target Confirmation tool, which graphically displays the PM.
Category=Star
Description=[F stars]

Acquisition

#	Target	Filter	Target Brightness	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	Optional ETC ID
1	SAME	F335M	BRIGHT (ND Square)	SHALLOW4	65	1	1	16.305	223525

Template

Module	Occulting Mask	Obtain Astrometric Confirmation Images?	Subarray	Dither Pattern
A	MASKLWB	false	SUB400X256ALWB	5-POINT-BAR

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Dithers	Total Integrations	Total Exposure Time	Optional ETC ID
1	F210M	F410M	DEEP8	13	3	5	15	3970.463	
2	F210M	F460M	DEEP8	15	3	5	15	4608.239	

PSF References

PSF Reference: true

Special Requirements	
	Fiducial Point Override NRCA5_MASKLWB_NARROW Group Observations 1, 2, 3, Non-interruptible