Saturn: MIRI/MRS Summer Hemisphere Scan (&Rings)

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Part of GTO1247[1] Programme (PIs: Fletcher, using IDS time from H.B. Hammel)

Rationale:

Cassini's long-term exploration of Saturn's seasonal atmosphere concludes in 2017 at northern summer solstice, shortly before JWST's launch. We propose observations that establish a baseline for continuing time-domain observations of the planet, rings and satellites: spectra of faint targets in the Saturn system using JWST's unprecedented sensitivity; cross-calibration of JWST instruments with the instruments on board the Cassini spacecraft; and a test of procedures for JWST observations of faint targets near bright objects. Observations include a reconnaissance of the Saturn system with NIRCam, NIRSpec, and MIRI. A mosaic of Saturn's north polar region using MIRI spectro-spatial imaging (5-16 µm) will explore the continued evolution of the polar temperatures, aerosols and composition, including (i) the expected growth of a wide, hot summer vortex in the stratosphere; (ii) variability within the polar cyclones associated with ammonia, phosphine and aerosols; and (iii) identification of any unique polar chemicals/haze species inaccessible to Cassini in the 5.5-7.5 µm region. Deep spectra of selected small moons of Saturn (Epimetheus, Pandora, Pallene, and Telesto) with NIRSpec will test the capacity of JWST to take deep spectra of faint targets near a bright planet. Spectra of Saturn's main rings with MIRI will test the capacity of JWST to take spatially resolved thermal spectra of icy ring systems and will fill a wavelength gap between Cassini VIMS and CIRS.

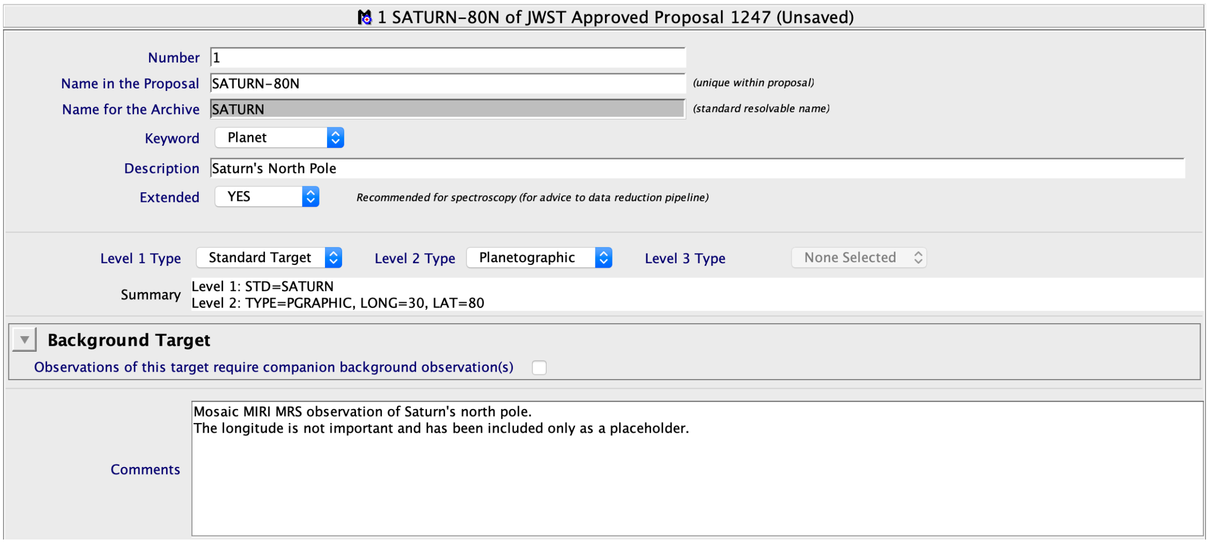
Technique:

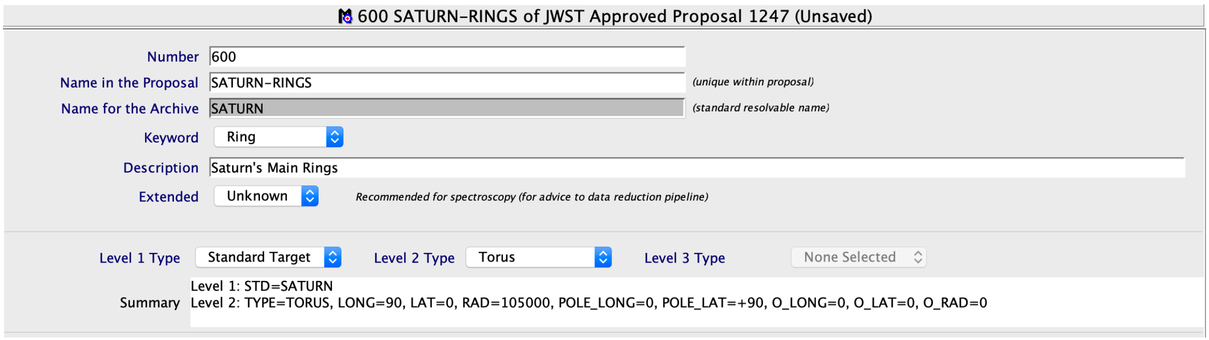
We test the ability of JWST to create a mosaic of an extended, bright, moving, and rotating object by defining three positions on Saturn (Saturn's north pole, and stepping down the central meridian towards the equator), and a fourth point on Saturn's rings. This is different to a specific MIRI mosaic. It is hoped that the scan (along with the 2-point dither pattern) will capture Saturn's summer hemisphere in its entirety. Three overlapping footprints (based on the smallest MRS FOV) target the northern summer hemisphere. Top priority is a direct view of the northern summer pole and hexagon; secondary priority is to step along the prime meridian towards the equator, third priority is the Saturn ring observation.

APT Target:

Three dummy longitudes have been specified in APT assuming 1 hour (36 degrees of Saturn rotation) between footprints; L0; L0+36; L0+72; where the value of L0 can take on any value. Instead of a mosaic, we have targeted three different latitudes (80N, 45N and 15N), and hope that these observations can be executed consecutively. A fourth point in the MIRI observation sequence then offsets to capture Saturn's main rings, using the torus definition of the observation.

[1] http://www.stsci.edu/jwst/observing-programs/program-information?id=1247





MIRI Mosaic:

Observations use a 4-point dither pattern for an extended source, and capture Saturn using all four channels[2] (i.e., the four IFUs) and the three diffraction grating settings within each channel (A-short, B-medium, C-long) to span the 4.9-28.3 µm spectrum. The four channels are observed simultaneously, but only one grating can be used at a time (thus three separated observations are needed for the three grating settings).

Choice of groups: ETC calculations show that the 5-16 µm range is accessible without saturation using only two groups to sample up the ramp. However, later interactions with the MIRI team highlighted concerns about the ability to calibrate with such a small number, and there was a strong recommendation to increase to a minimum of 4 groups, even though some of the later groups would be saturated. A commissioning activity is planned to verify the optimum number of groups per integration to use for bright targets, and could hopefully be used to optimise the proposed GTO observations. For the time being, we retain the ability to read out more groups (and use only those up to saturation for analysis. There will be an efficiency hit from throwing away a lot of saturated data, but the low quality of ramps derived from only 2 frames almost certainly eliminates and outweighs this benefit.

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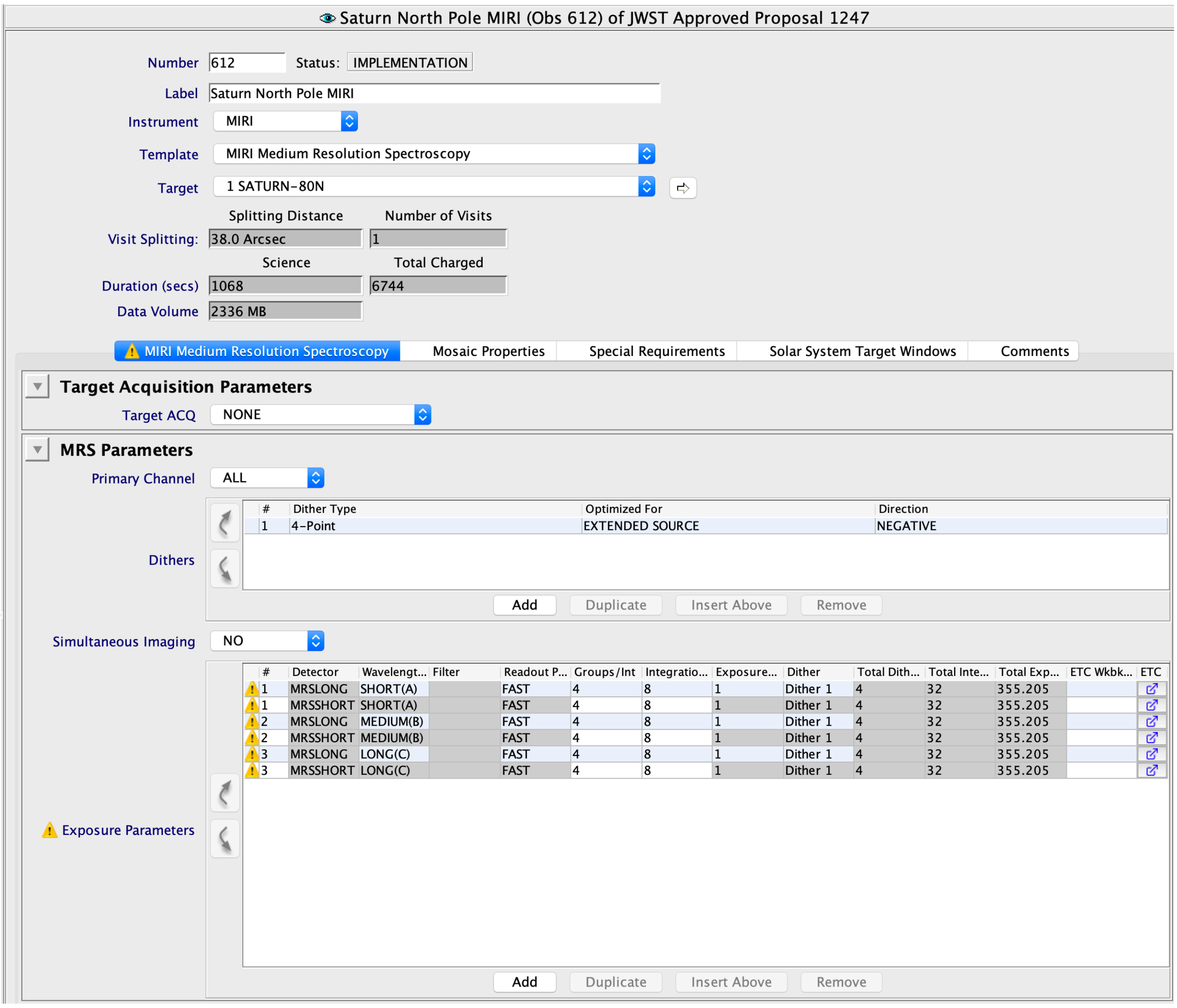
[2] https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-observing-modes/miri-medium-resolution-spectroscopy

Choice of dither[3]: A 4-point dither has been assumed to optimise imaging quality across Channels 1-2, but as we hope to optimise over the full field of view, only small dither steps are required (large 1" dither steps would not work, as this would render only a small area of the FOV optimised). If the 2-point dither pattern turns out to be more suitable, we request to be able to make this change as it would increase the exposure time on target (reducing overheads).



Note that the observatory overheads increased from APT v27.1.1 (June 2019) to APT 2020.1.2 (February 2020), increasing the Saturn atmosphere and rings observation from 19334s (5.4hrs) to 23288s (6.5hrs, this includes two major 1800s slews, one to the north pole, and one to the rings), and the background frame from 1399s (0.4hrs) to 1720s (0.5hrs).

Note: central meridian timing windows had been removed from APT do that the visit planner would actually work.

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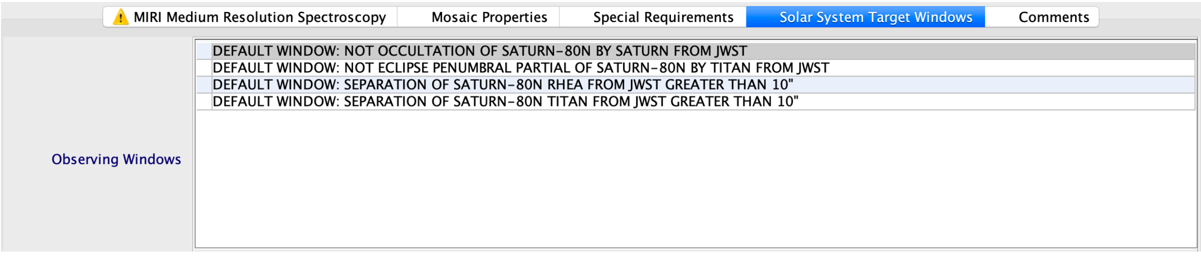
[3] https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-operations/miri-dithering/miri-mrs-dithering

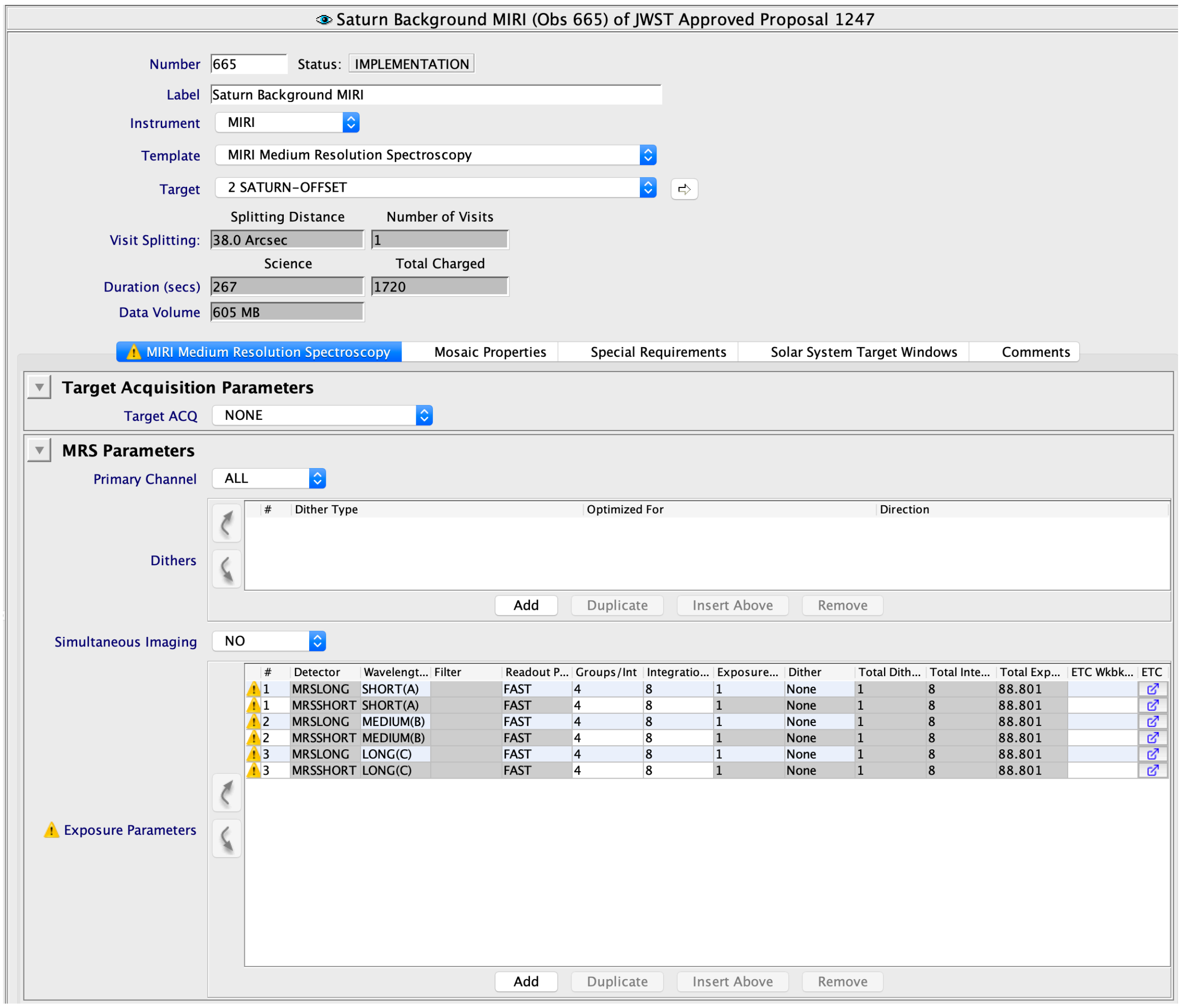

MIRI Medium Resolution Spectroscopy | Mosaic Properties | Special Requirements | Solar System Target Windows | Comments

Observing Windows

DEFAULT WINDOW: NOT OCCULTATION OF SATURN-80N BY SATURN FROM JWST
DEFAULT WINDOW: NOT ECLIPSE PENUMBRAL PARTIAL OF SATURN-80N BY TITAN FROM JWST
DEFAULT WINDOW: SEPARATION OF SATURN-80N RHEA FROM JWST GREATER THAN 10"
DEFAULT WINDOW: SEPARATION OF SATURN-80N TITAN FROM JWST GREATER THAN 10"

Background Observation:

A calibration frame, targeting blank sky, is desired to subtract spurious contributions to the observations from foreground emission (i.e., thermal emission from the instrument itself and scattered light from the telescope), and also any systematic additive features in the slope images. These may well be bigger in magnitude than the background signal itself, but they will also be different between two different readout cadences. For the small MRS FOV the expectation is that the background will be quite homogeneous, but may change with the epoch of observations. Hence these are designed to have the same groups/integrations as the target observation, but no dither is required, and only a single exposure. The background frame should be taken as close as possible to the target observations (they are linked to occur within 5 hours).


Saturn Background MIRI (Obs 665) of JWST Approved Proposal 1247

Number 665 Status: IMPLEMENTATION
Label Saturn Background MIRI
Instrument MIRI
Template MIRI Medium Resolution Spectroscopy
Target 2 SATURN-OFFSET

	Splitting Distance	Number of Visits
Visit Splitting:	38.0 Arcsec	1

	Science	Total Charged
Duration (secs)	267	1720
Data Volume	605 MB	

MIRI Medium Resolution Spectroscopy | Mosaic Properties | Special Requirements | Solar System Target Windows | Comments

Target Acquisition Parameters

Target ACQ NONE

MRS Parameters

Primary Channel ALL

Dithers

#	Dither Type	Optimized For	Direction

Add Duplicate Insert Above Remove

Simultaneous Imaging NO

Exposure Parameters

#	Detector	Wavelengt...	Filter	Readout P...	Groups/Int	Integratio...	Exposure...	Dither	Total Dith...	Total Inte...	Total Exp...	ETC Wkbk...	ETC
1	MRSLONG	SHORT(A)		FAST	4	8	1	None	1	8	88.801		
1	MRSSHORT	SHORT(A)		FAST	4	8	1	None	1	8	88.801		
2	MRSLONG	MEDIUM(B)		FAST	4	8	1	None	1	8	88.801		
2	MRSSHORT	MEDIUM(B)		FAST	4	8	1	None	1	8	88.801		
3	MRSLONG	LONG(C)		FAST	4	8	1	None	1	8	88.801		
3	MRSSHORT	LONG(C)		FAST	4	8	1	None	1	8	88.801		

Add Duplicate Insert Above Remove

A offset of 90” and zero position angle has been used to define the sky background.

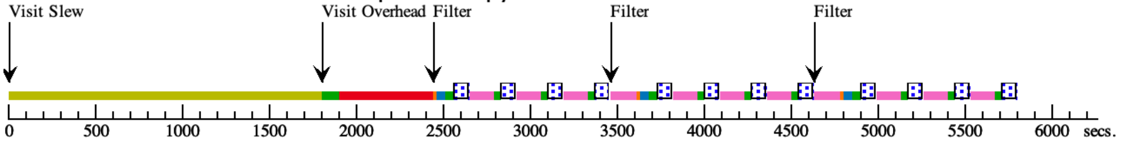
ETC Calculations (v1.1)

The SHORT detectors (Channel 1 and 2) only saturate with ngroups>4, so we have specified 4 groups. For the LONG detectors (Channels 3 and 4), saturation can only be avoided with 2 groups.

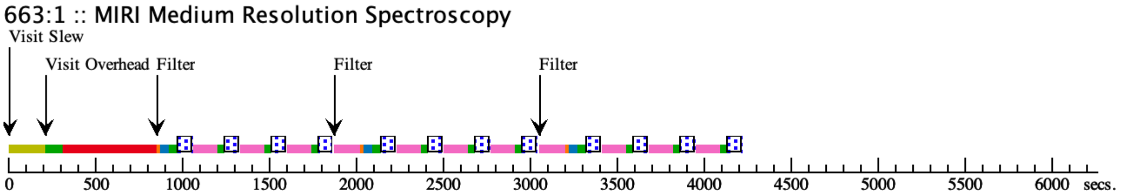
Total Time:

The Saturn atmosphere and rings MIRI observations (plus the background) account for 7 hours of the GTO programme (which also includes NIRCAM and NIRSPEC observations of the satellites). The total allocated time was 21.4 hours, and APTv2020.1.2 reports 14.3 hours before the visit planner is run, and 18.9 hours after.

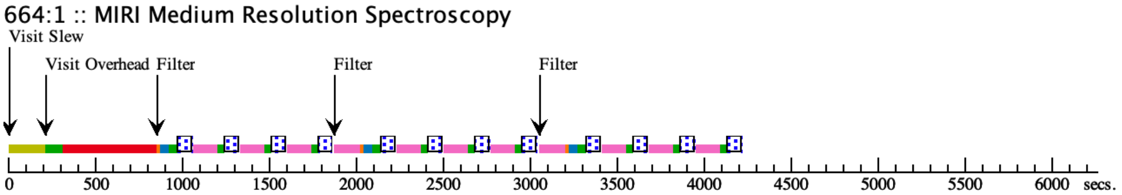
612:1 :: MIRI Medium Resolution Spectroscopy



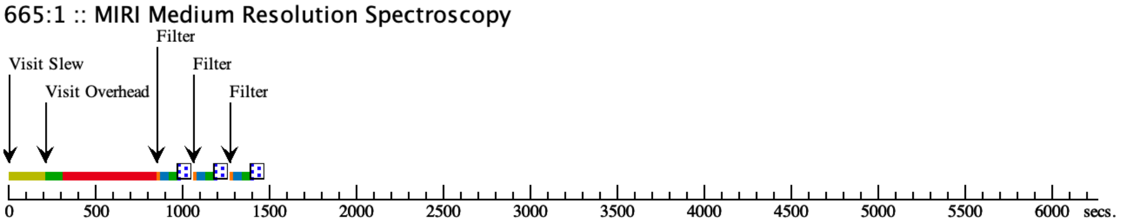
663:1 :: MIRI Medium Resolution Spectroscopy



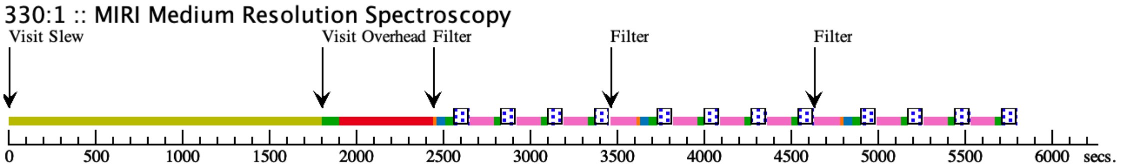
664:1 :: MIRI Medium Resolution Spectroscopy

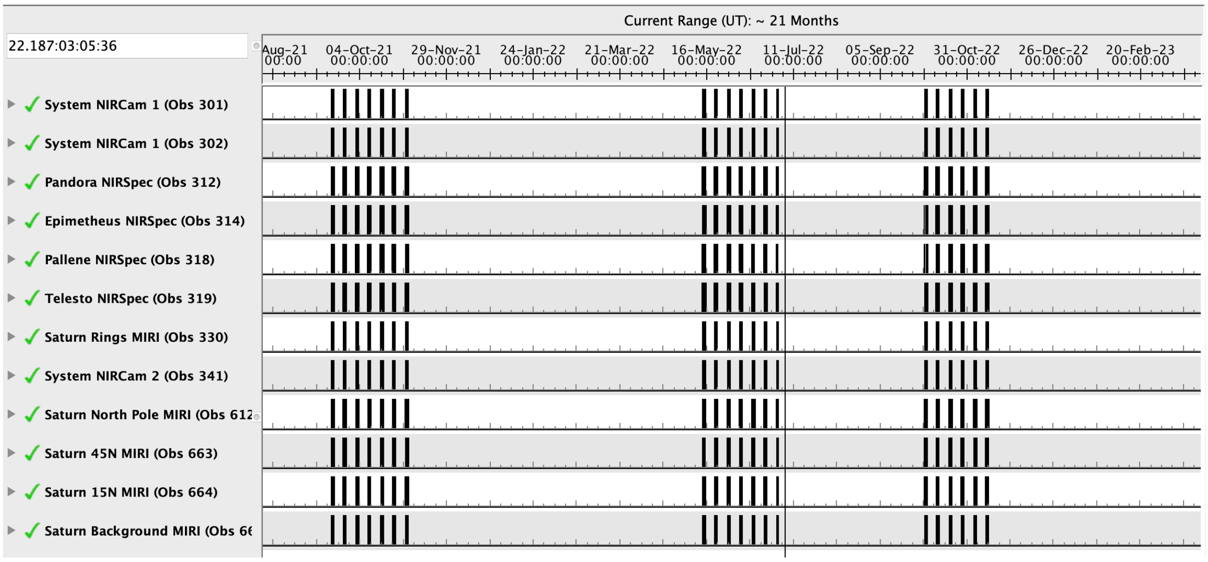


665:1 :: MIRI Medium Resolution Spectroscopy



330:1 :: MIRI Medium Resolution Spectroscopy




Current Range (UT): ~ 21 Months
22.187:03:05:36
Aug-21 00:00
04-Oct-21 00:00:00
29-Nov-21 00:00:00
24-Jan-22 00:00:00
21-Mar-22 00:00:00
16-May-22 00:00:00
11-Jul-22 00:00:00
05-Sep-22 00:00:00
31-Oct-22 00:00:00
26-Dec-22 00:00:00
20-Feb-23 00:00:00
System NIRCam 1 (Obs 301)
System NIRCam 1 (Obs 302)
Pandora NIRSpec (Obs 312)
Epimetheus NIRSpec (Obs 314)
Pallene NIRSpec (Obs 318)
Telesto NIRSpec (Obs 319)
Saturn Rings MIRI (Obs 330)
System NIRCam 2 (Obs 341)
Saturn North Pole MIRI (Obs 612
Saturn 45N MIRI (Obs 663)
Saturn 15N MIRI (Obs 664)
Saturn Background MIRI (Obs 6