Jupiter: MIRI/MRS Polar Observations

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Part of ERS1373[1] Programme (PIs: Imke de Pater & Thierry Fouchet)

Rationale:

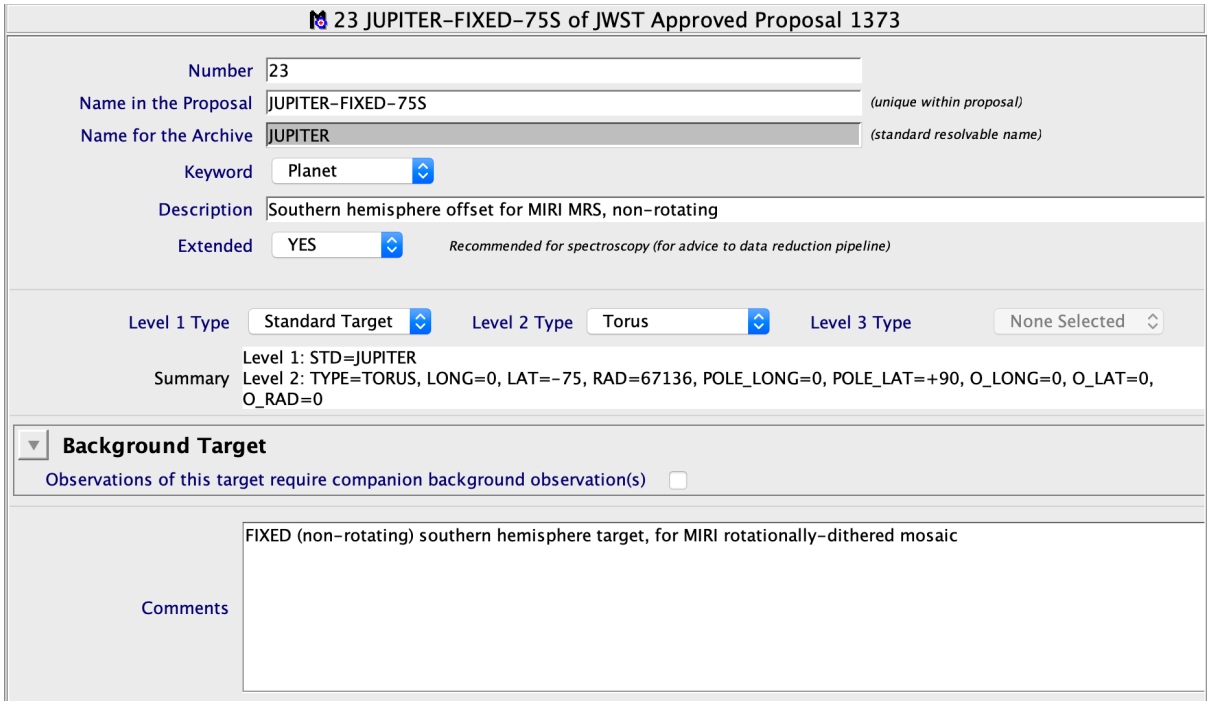
- MIRI 5-29 µm spectroscopic mapping of Jupiter's polar auroral region to constrain (i) the properties of the cold polar vortex in the troposphere and stratosphere, poleward of ~65° latitude; and (ii) the thermal emission from within the auroral oval. We expect the 6-11 µm region to be accessible without saturation, with the possibility that limb-darkened regions from 5-6 µm and 11-16 µm might also be available. This spectral range gives access to:
    - (i) Stratospheric temperatures (via CH4 nu2 and nu4 band) and hydrocarbons (C2H6 at 1379 and 1468 cm-1, possibly other more exotic species: C2H4 at 950 cm-1, C3H8 at 1050-1200, 1340-1380, 1470-1480 cm-1).
    - (ii) Tropospheric disequilibrium species (PH3) and volatiles (NH3), along with their associated aerosols within the polar hazes.
    - (iii) D/H ratios in CH4 and C2H6 for planetary origins and chemical fractionation.
- The south-polar auroral oval has been targeted as a counterpoint to the oft-studied north-polar oval, as the former is more narrowly confined to Jupiter's polar latitudes. The northern aurora is also being more closely studied by Juno during its mission (2016-2021).
- The southern oval is most visible from Earth between approximately 50-90W (System III longitude).
- MIRI observations are being planned in tandem with NIRSPEC observations of the same region, primarily to connect the thermal-IR auroral emission to the morphology of the oval in H3+ emission.

Technique: Given the challenges and overheads associated with MIRI mosaicking, we developed a sit-and-stare technique, targeting the central meridian and staring for tens of minutes (Jupiter's rotation sweeps through 10 degrees of longitude in ~16.5 minutes). A background/foreground calibration frame, using the same number of MIRI groups/integrations, will be executed as soon as possible after the MIRI scan.

APT Target:

Fixed at 75S and non-rotating, using a torus level-2 definition at lon=0, lat=-75. This currently has a starting longitude of 0W, which needs updating to ~50W to ensure that we capture the south polar emission.

[1] http://www.stsci.edu/jwst/observing-programs/approved-ers-programs/program-1373



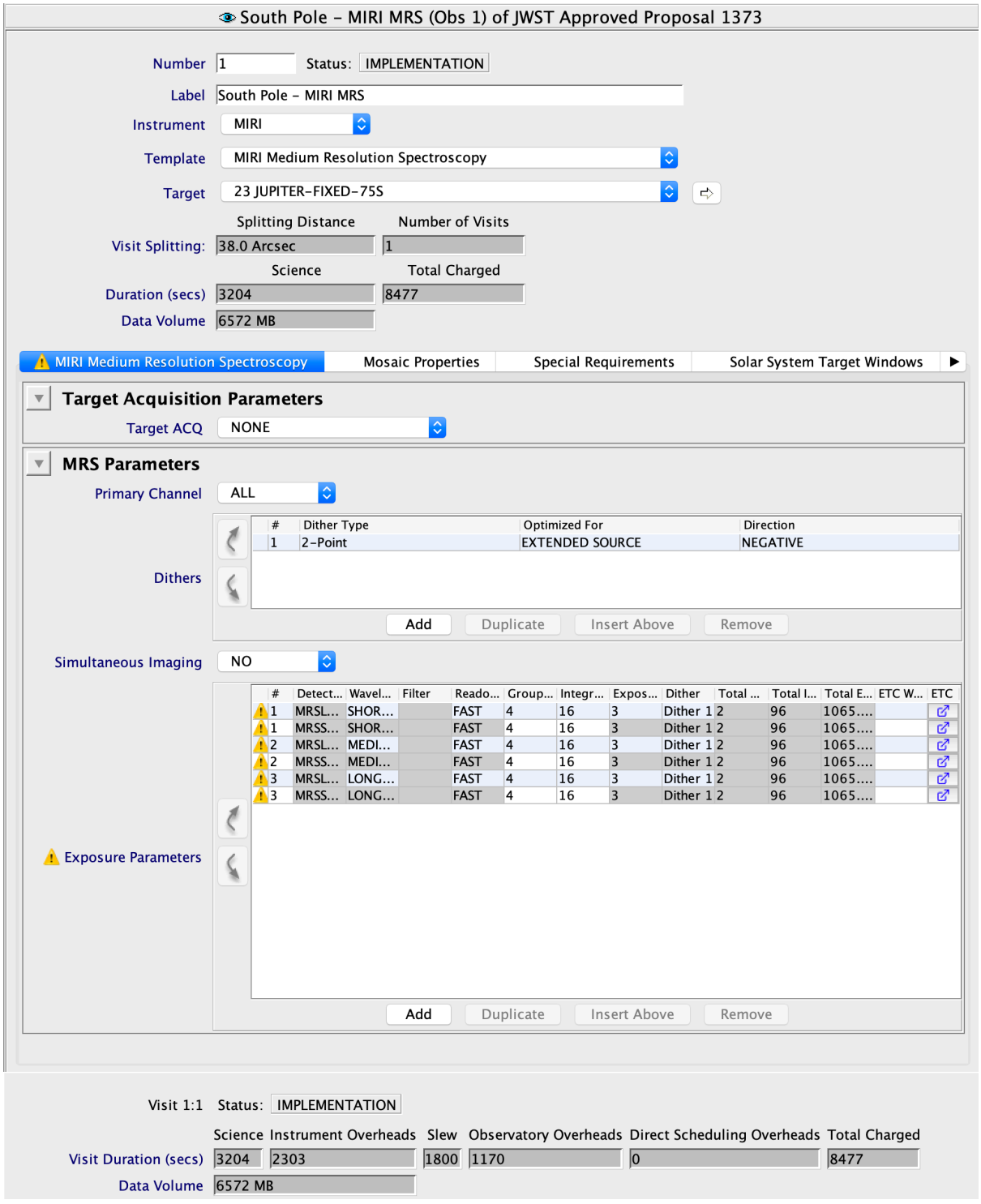
MIRI Jupiter Polar Stare:
Observations use a 2-point dither pattern for an extended source, and capture Jupiter using all four channels[2] (i.e., the four IFUs) and the three diffraction grating settings within each channel (A-short, B-medium, C-long) to span the 4.9-28.3 µm spectrum. The four channels 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 6-11 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 ERS 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.

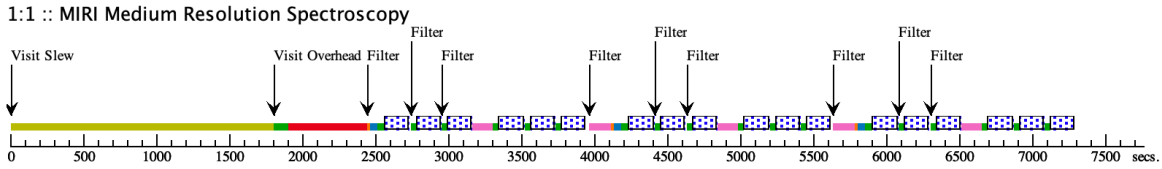
Choice of dither[3]*:* The 2-point dither pattern is chosen to eliminate any bad-pixel clusters, and so should not be needed on the background measurement. A simple *2-Point* dither pattern will nominally allow the MRS to achieve half-integer sampling in all four channels. The selected extended-source dither gives a ~1" offset between frames. A 2-point extended ALL dither pattern should be acceptable - this gives good sampling in channels 3 and 4 and fair sampling in channels 1 and 2. Image quality in channels 1 and 2 will therefore not be optimal, but shouldn't be too bad. Unless you want to do some really complex super-

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

resolved reconstruction of the IFU scene (where you might need sub-pixel sampling at the shortest wavelengths), we were advised to just go with a 2-point dither.



Note that the observatory overheads increased from APT v27.1.1 (June 2019) to APT 2020.1.2 (February 2020), increasing the south polar observation from 7850s to 8477s (this includes a major 1800s slew), and the background frame from 1709s to 2029s.

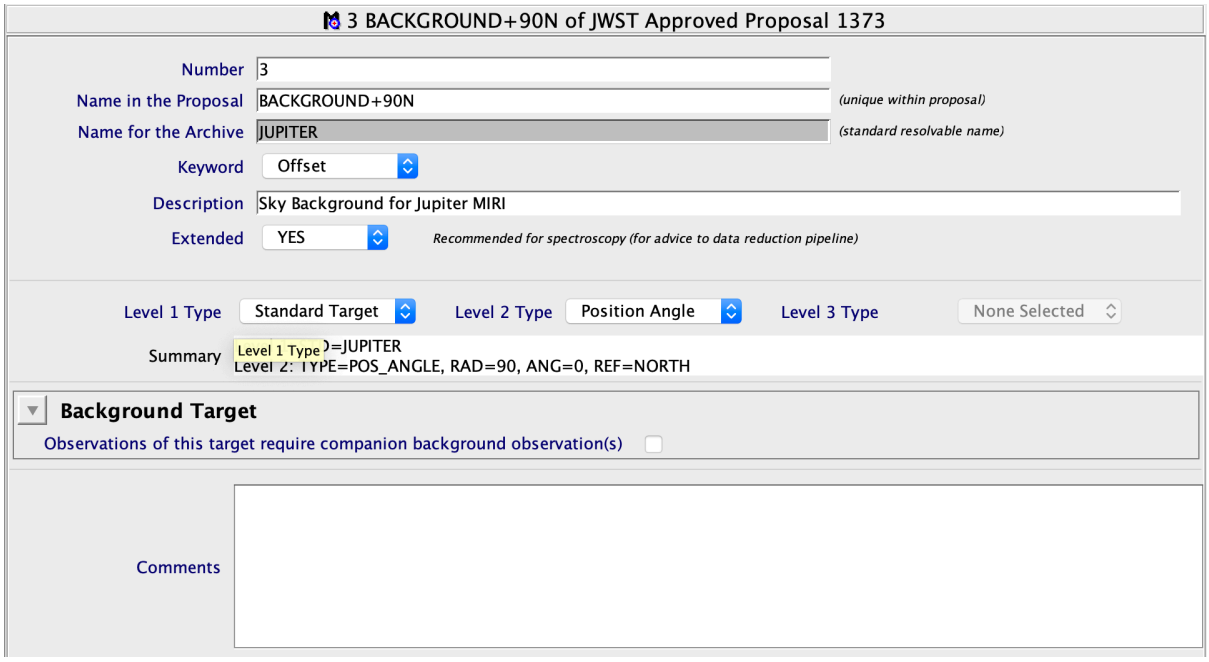


The observation timeline (above) shows when the science observations will take place (two dithers of the three grating settings; three consecutive exposures), spanning approximately 4800s (or 48.3 degrees of longitude). We aim for the science exposure to start when 50W is on the central meridian.

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).

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



MIRI Background – Jupiter 4x16 (Obs 20) of JWST Approved Proposal 1373

Number 20 Status: IMPLEMENTATION

Label MIRI Background – Jupiter 4x16

Instrument MIRI

Template MIRI Medium Resolution Spectroscopy

Target 3 BACKGROUND+90N

	Splitting Distance	Number of Visits
Visit Splitting:	38.0 Arcsec	1

	Science	Total Charged
Duration (secs)	534	2029
Data Volume	1139 MB	

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

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

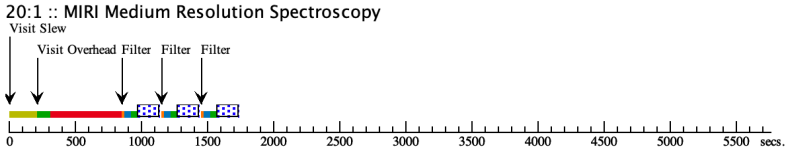
Exposure Parameters

#	Detect...	Wavel...	Filter	Readо...	Group...	Integr...	Expos...	Dither	Total ...	Total I...	Total E...	ETC W...	ETC
1	MRSL...	SHOR...		FAST	4	16	1	None	1	16	177.6...		
1	MRSS...	SHOR...		FAST	4	16	1	None	1	16	177.6...		
2	MRSL...	MEDI...		FAST	4	16	1	None	1	16	177.6...		
2	MRSS...	MEDI...		FAST	4	16	1	None	1	16	177.6...		
3	MRSL...	LONG...		FAST	4	16	1	None	1	16	177.6...		
3	MRSS...	LONG...		FAST	4	16	1	None	1	16	177.6...		

Add | Duplicate | Insert Above | Remove

Visit 20:1 Status: IMPLEMENTATION

	Science	Instrument Overheads	Slew	Observatory Overheads	Direct Scheduling Overheads	Total Charged
Visit Duration (secs)	534	1004	211	280	0	2029
Data Volume	1139 MB					



ETC Calculations (v1.1)

- Jupiter MIRI ETC calculator v1.1, uploaded a file containing irradiance in mJy and specifying a circular source of 43.5” diameter so that the surface brightness is used

correctly. This uses a spectral calculation for nadir viewing (zero emission angle), so that limb darkening is not accounted for.

- Use the wavelength-dependent MIRI MRS PSF, and calculate an 'equivalent radius' (0.15" at <8 µm, 0.54" at 29 µm) to use as the aperture radius in the strategy tab.
- For the nadir simulation, the brightest point in 2SHORT is 8.57 µm - with 2 groups we don't saturate, with 3+ groups we have 'partial saturation at the end of the ramp'. Stepping through the different settings with 2 groups, we have full saturation in 1SHORT, but we shouldn't saturate in 1MED, 1LONG, 2SHORT, 2MED, 2LONG, but we do saturate (full saturation in the first group) in anything in channel 3 and 4.