Jupiter: MIRI/MRS Great Red Spot Mosaic

L.N. Fletcher, University of Leicester (leigh.fletcher@le.ac.uk)

Part of GTO1246[1] Programme (PI: Fletcher, using IDS time from H.B. Hammel)

Rationale:

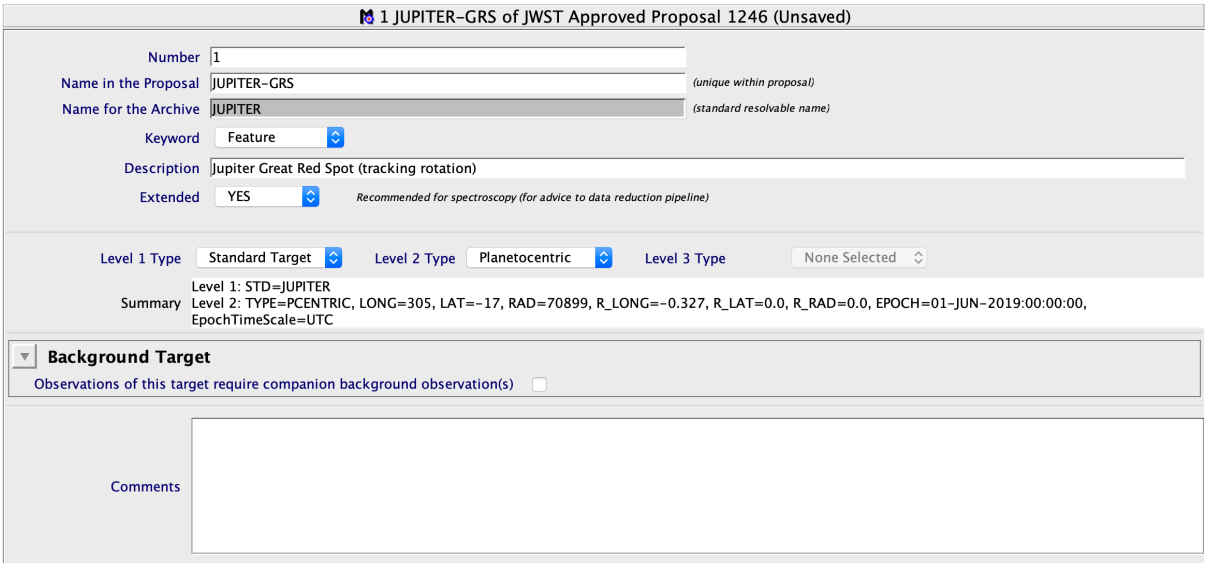
Jupiter's extended disk and brightness present an extreme test of JWST capabilities. We will use MIRI/MRS spatio-spectral imaging to create a 3-point mosaic of the Great Red Spot (GRS) and its environs in the 6-11 µm range to determine the 3-dimensional temperature, composition, and aerosol distribution. We will explore moist convective activity surrounding the GRS via ammonia, phosphine, and condensed ices detectable in this spectral range. We will also search spectra for chemical products that may be unique to the GRS region as a by-product of the production of the poorly understood red chromophores. We will use methane emission to study stratospheric effects of the underlying GRS and moist-convective plumes.

Technique:

We test the ability of JWST to create a mosaic of an extended, bright, moving, and rotating object by defining three positions (the GRS, and points immediately east and west of that feature). It is hoped that the mosaic (along with the 2-point dither pattern) will capture the GRS in its entirety, and include observations of the wider SEB and Equatorial Zone (EZ) for comparison.

APT Target:

Defined three targets for the GRS mosaic, centred on 17S (centric), and with a central longitude (defined based on recent JUPOS positioning and a longitudinal drift rate) and two offset points, one 10 degrees east and one 10 degrees west.



MIRI Mosaic:

[1] http://www.stsci.edu/jwst/observing-programs/program-information?id=1246

Observations use a 4-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]: 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).

The three mosaic points and the background observation are deemed as non-interruptible.

[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

Great Red Spot (Obs 2) of JWST Approved Proposal 1246

Number 2 Status: IMPLEMENTATION

Label Great Red Spot

Instrument MIRI

Template MIRI Medium Resolution Spectroscopy

Target 1 JUPITER-GRS

	Splitting Distance	Number of Visits
Visit Splitting:	38.0 Arcsec	1
	Science	Total Charged
Duration (secs)	1068	4900
Data Volume	2336 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
1	4-Point	EXTENDED SOURCE	NEGATIVE

Add | Duplicate | Insert Above | Remove

Simultaneous Imaging NO

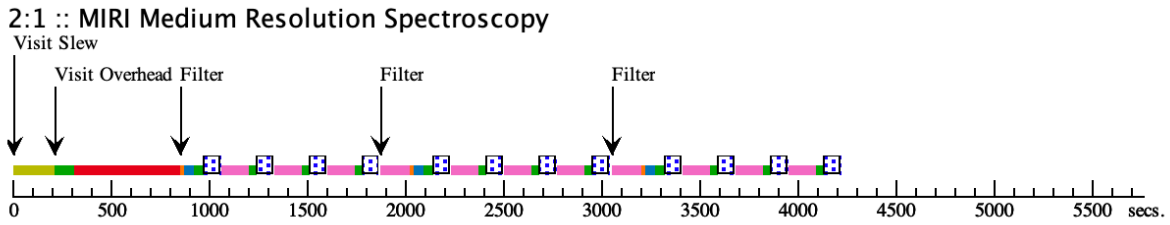
Exposure Parameters

#	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	Dither 1	4	32	355.205		
1	MRSSHORT	SHORT(A)		FAST	4	8	1	Dither 1	4	32	355.205		
2	MRSLONG	MEDIUM(B)		FAST	4	8	1	Dither 1	4	32	355.205		
2	MRSSHORT	MEDIUM(B)		FAST	4	8	1	Dither 1	4	32	355.205		
3	MRSLONG	LONG(C)		FAST	4	8	1	Dither 1	4	32	355.205		
3	MRSSHORT	LONG(C)		FAST	4	8	1	Dither 1	4	32	355.205		

Add | Duplicate | Insert Above | Remove

Visit 2:1 Status: IMPLEMENTATION

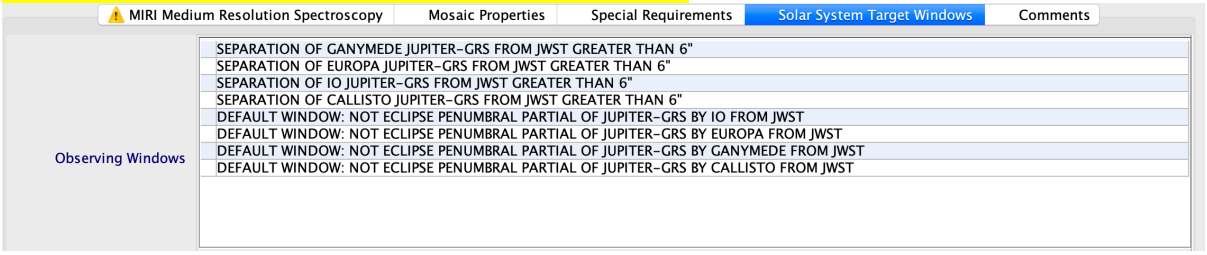
	Science	Instrument Overheads	Slew	Observatory Overheads	Direct Scheduling Overheads	Total Charged
Visit Duration (secs)	1068	2945	211	676	0	4900
Data Volume	2336 MB					



Note that the observatory overheads increased from APT v27.1.1 (June 2019) to APT 2020.1.2 (February 2020), increasing the GRS observation from 13580s (3.8hrs) to 16544s (4.6hrs) (this includes a major 1800s slew), and the background frame from 1399s (0.4hrs) to 1720s (0.5hrs).

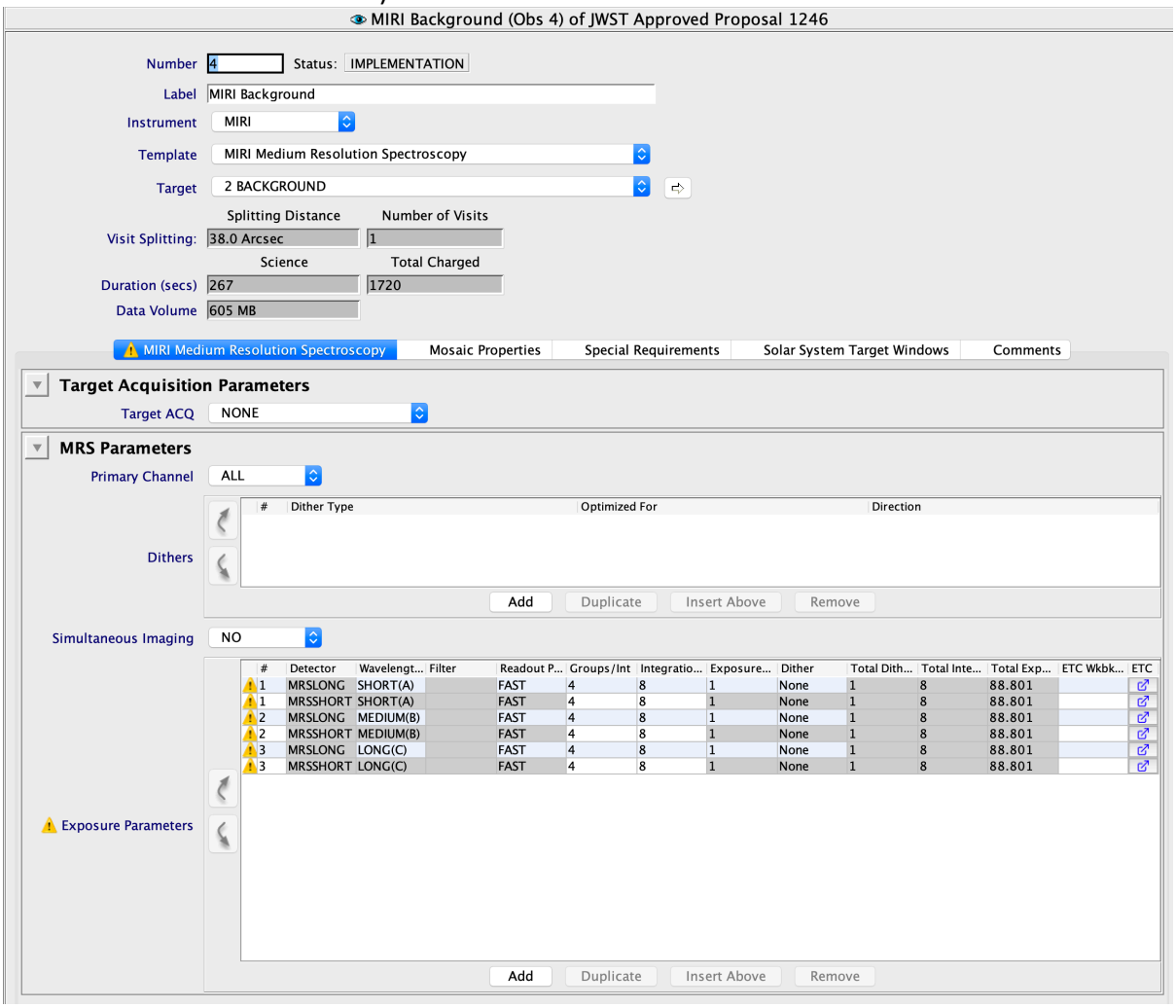
Observing windows:
In an attempt to ensure that the GRS (or any target) is near to the centre of the disc, we apply a target window in terms of “separation”, using a negative distance in arcseconds to ensure that the target is more than 5” from the centre of the disc:
SEPARATION OF JUPITER-GRS JUPITER FROM JWST LESS THAN -5"

NB. This wasn't included in our 2019 APT submission.



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.

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).
- 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.

Total time:

The charged time in APTv2020.1.2 is 5.07hrs (of 7.4 allocated). Running the visit planner (still without the central-meridian constraint) doesn't change this.