Enabling MIRI MRS Time Series Observations

Date

05 Jun 2020

Attendees

- Nestor Espinoza
- David Law
- Sarah Kendrew

Meeting agenda:

1. Ticket JSOCINT-421 - Jira project doesn't exist or you don't have permission to view it. and request from Valenti to define requirements for minimal (& optimal) support of TSOs with MIRI MRS

Notes

NE describes 2 types of exoplanet science that can be done with integral field spectrometers:

1. "Traditional" transit spectroscopy, i.e. the companion is not spatially resolved and the observation attempts to detect the signature of the planet's atmosphere as it transits in front of the host star. This requires high precision spectrophotometry. This technique has been tried using ground-based IFS's but these attempts have had only limited success, largely due to the variable PSF. For example: Arribas et al (2006) using the William Herschel Telescope & INTEGRAL; Angerhausen & Krabbe (2011) with VLT & SINFONI; Parviainen et al (2015) using VLT & KMOS.
2. Targeting systems where the companion has a wider separation; subtracting the stellar spectrum from individual spaxels and cross-correlating the residuals with model spectra to detect signatures of molecular species in the data. This technique was first demonstrated by Konopacky et al (2013) using Keck-OSIRIS for HR8799, further demonstrations include Hoeijmakers et al (2018) using VLT-SINFONI for Pic (who call this method "molecule mapping").

Technically, TSO observations with MRS don't have a lot of complexity. The observation is typically made up of a single exposure with many integrations. The TSO special requirement disallows dithering, and removes the 10 ksec exposure limit. It ensures that the exposure is flagged as a TSO for processing. When TSOs were implemented for MRS in APT, calculation by Tea Temim led us to conclude that simultaneous imaging would severely limit the max length of TSO due to data volume limitations. We decided to disallow simultaneous imaging.

Data processing - minimal

At the basic level, data processing for these types of observation should minimize the amount of interpolation, or model-dependent fitting or other kinds of data manipulation that could introduce spurious noise. An important question is whether we need spectral cubes?

NE: previous work with IFS has used the spectral cube to perform the analysis.

DL: analysis based on the pipeline-built cubes is much easier than from the 2D focal plane as the (, ,) transformation is non-trivial. The cube building process does use interpolation and models, which is not ideal, but it is at least deterministic. A simple schema for TSOs in Calspec2() could be:

- keep assign_wcs
- no background subtraction
- no stray light correction
- fringe correction
- flux calibration
- build the cube

Calspec3() could be ignored.

There is a dedicated pipeline config file for caldetector1 for TSOs (filename calwebb_tso1.cfg), and this will likely be fine for MRS observations. The pipeline needs to be agnostic to whether TSO exposures are from LRS, imager or MRS.

SK: how important is the fringe correction and could this introduce any problematic residuals (given the difficulty of performing the fringe correction properly)?

DL: as long as nothing moves and the target remain the same position with respect to the slice (at the level of <10% of the slice width) then any errors are not likely to dominate over others.

DL: one further potential complication comes from being spatially and spectrally undersampled, which we cannot correct for without dithering. not sure where this will overall have the worst impact, but the undersampling is worst at the shortest wavelengths. The effect of this is basically that the spectrum of a single spaxel looks weird because the area covered changes as a function of wavelength.

Can we avoid having to build many many cubes? Can we perform a spectral extraction straight from the 2D focal plane?

DL: this is actually better in some ways and has been discussed but this is not currently possible with the pipeline. having to build a cube from each integration would lead to substantial file bloat and would likely take a long time. we could discuss different ways of packaging where each cube is added as a separate extension, rather than try to package everything into an individual extension - a kind of hypercube.

Follow-up notes/thoughts from SK

- the 2nd science case, as it's been done on the ground, does not actually require time series-type data processing as far as I can tell. This analysis is performed on longer-duration co-added cubes. It may be useful to observe the target at multiple epochs, or as in Hoeijmakers et al with the host star in and out of the field. I think these types of observations are possible with the regular MRS template in APT (I can see TA being required for accurate positioning, I'm not fully sure whether dithering is advisable but I think it would not be detrimental).
- transit spectroscopy with MRS, as it's done with LRS or SOSS or NIRCam grism, would require a cube to be be built at the integration level, as this is the only way we can currently extract a spectrum. possible ways of mitigating the file bloat or processing time required:
    - ability to use only 1 channel/sub-channel? (that seems like a waste of data?)
    - don't build a cube for every integration - have the ability to observe continuously but indicate how integrations should be co-added, e.g. I want 200 integrations but co-add every 10 integrations? reduces time cadence but faster processing.
    - break the time series up into multiple exposures, which would also allow full wavelength coverage. for example: 3 exposure out of transit (short, med, long), then a sequence of 3xN exposure in-transit, then 3 further exposures out of transit. Cons: might affect the stability, still requires no-dithering, no continuous coverage of the transit event so possible limit on science output. Pros: doesn't need the TSO SR as long as individual exposures are < 10 ksec in duration, doesn't require TSO data processing, data processing less onerous.