JWST-MIRI Data Reduction Pipeline: Fringe Correction in Spectroscopic Data

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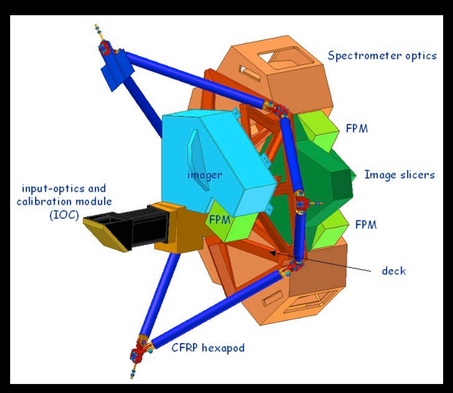
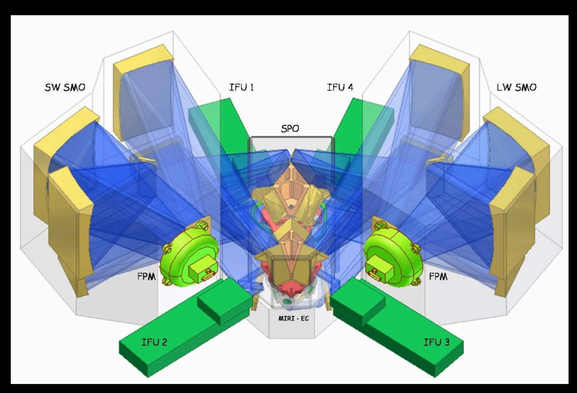
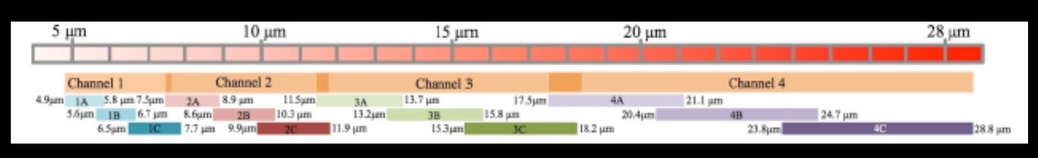
JWST-MIRI

The James Webb Space Telescope (JWST) is slated for launch in 2021. With its 6.5m aperture, it will be the most sensitive IR facility available to the astronomical community. Its Mid-Infrared Instrument (MIRI) offers, among other modes, the Medium-Resolution Spectrometer (MRS), an integral field spectrometer with a field of view of ~2"x2" or bigger and a spectral resolution of R~1,600 or better. The wavelength range of ~5—28 μm is split over four channels (1—4) and three bands (A—C or SHORT/MEDIUM/LONG) on two chips.

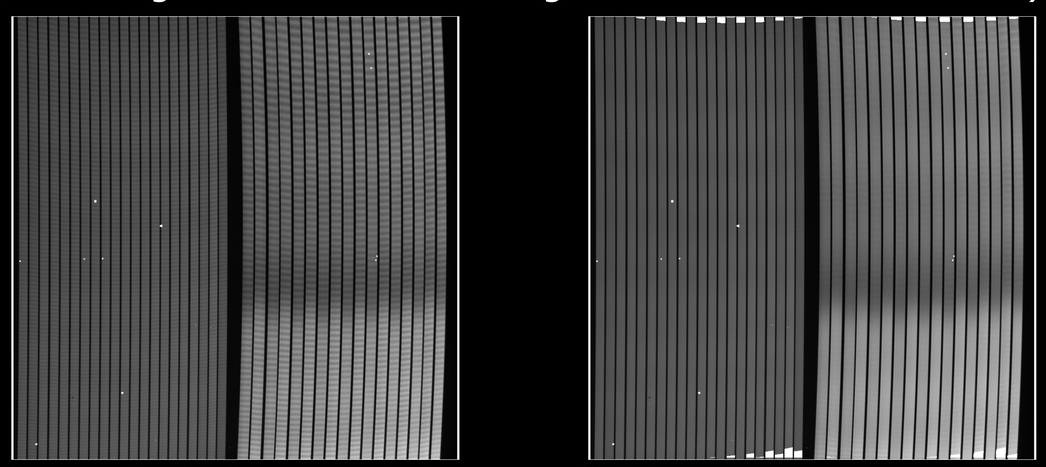






MRS Fringes

Like most spectrometers, MRS is subject to fringes, periodic gain variations due to standing waves in the optical path (MRS fringes are due to standing waves within the detector):



(Channels 1+2, extended source @ lab;
Left: raw data, right: after division by fringe flat)

Raw fringes have amplitudes up to ~30—40 %.
Requirement: correct them to < 2%.

For each pixel, the fringe transmission is described by the Airy function (Fabry-Pérot étalon):

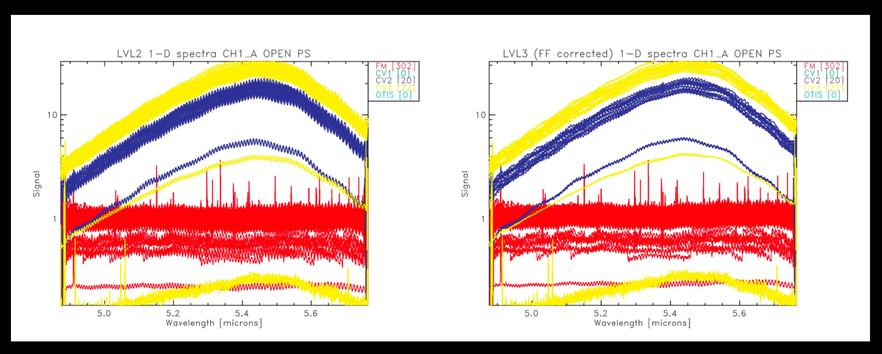
$$I(w,x,y) = \frac{T^2}{(1-R)^2} \times \frac{I_o}{1 + (\frac{4R}{(1-R)^2}) \sin^2(\cos(\theta) w D \pi)}$$

with wavenumber w, optical thickness D, incidence angle Θ.

Fringe Modeling

Use *BayesicFitting* (github.com/dokester/BayesicFitting) to fit (background times) Airy function to extended-source data. Works well for bands 1A—2B (~5—10 μm). Longer wavelengths: need two fringe frequencies, beating with one another (Airy1*Airy2). Work in progress.

Fitting data from different test campaigns, we found the fringe flat stable *within* campaigns, but different *between* campaigns. Released campaign-specific fringe flats.

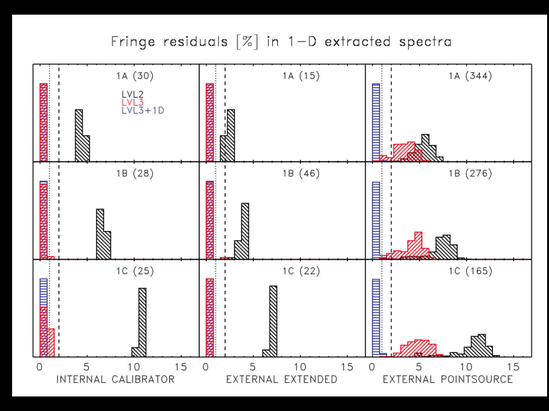


(Flux extracted along one column before and after application of fringe flat, band 1A)

After application of fringe flat:

- Apply 1D "residual-fringe" correction (sinusoidal fit; 1st order approximation to Airy function; ISO-Spitzer-Herschel heritage)

After both correction steps (flat and residual fringes; see blue parts of histogram below), all lab data are corrected to < 1—2 % in channels 1A—2B:



Challenges remaining

- Two-etalon fits (λ > 10 μm, 2C—4C)
- Point sources display fringe-phase offsets from extended sources!
  - Reasons are under study
  - … as are correction algorithms.
  - Test data: practically always spatially extended. In orbit: mostly point sources. Very different! Won't get more point-source data before in-orbit commissioning.