Haute Couture

Spectral stitching of JWST MIRI-IFU cubes with matrix completion

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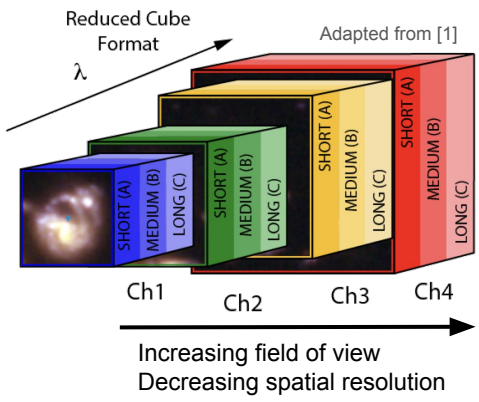
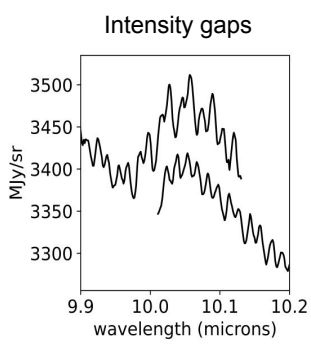
MIRI is the imager and spectrograph covering wavelengths from 4.9 to 27.9 *μm* embedded on the James Webb Space Telescope (JWST). The Medium-Resolution Spectroscopy (MRS) mode consists of Integral Field Units, divided into four channels partitioning the wavelength range. These four channels are subdivided into three sub-channels. This results in twelve cubes with different fields of view and spatial resolutions. Each cube shares a common portion of the spectrum with adjacent cubes. Besides the different fields of view and spatial resolutions, the cubes also exhibit global intensity mismatches that need to be accounted for (due for example to heterogeneous calibrations). *Stitching* consists in obtaining a single uniform cube supported by the entire wavelength range, by combining the twelve available sub-channels. We propose a novel method, named *Haute Couture*, to solve this problem. Our approach is based on *matrix completion*, by means of *non-negative matrix factorization* (NMF). Indeed, the data available from the sub-channels can be organized as twelve sub-matrices of a larger incomplete matrix, which motivates our approach. Prior to matrix completion, we also introduce a novel pre-processing to homogenize the global intensities of the twelve cubes. Our pre-processing consists in jointly optimizing a set of global scale parameters that maximize the fit between the cubes where spectral overlap occurs. We apply our novel stitching method to JWST data obtained as part of the PDRs4All observing program of the Orion Bar, and produce a uniform cube reconstructed with the best spatial resolution over the full range of wavelengths.

MIRI-MRS



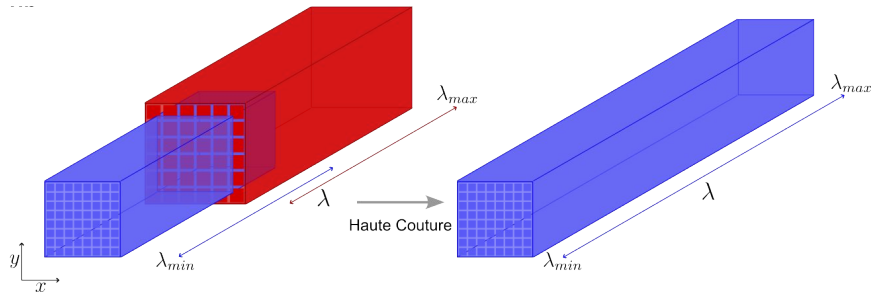


Problem Twelve cubes with different properties

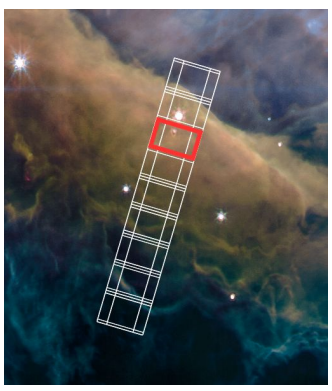
Objective One unique cube with same properties

Concept

Illustration of the stitching problem for two cubes.

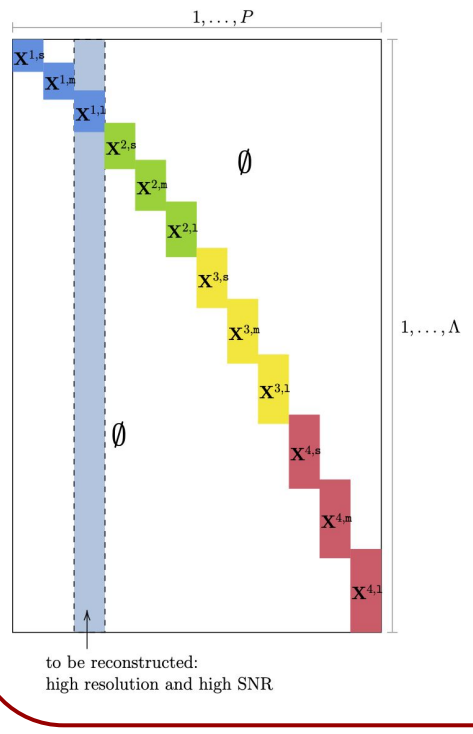


Data



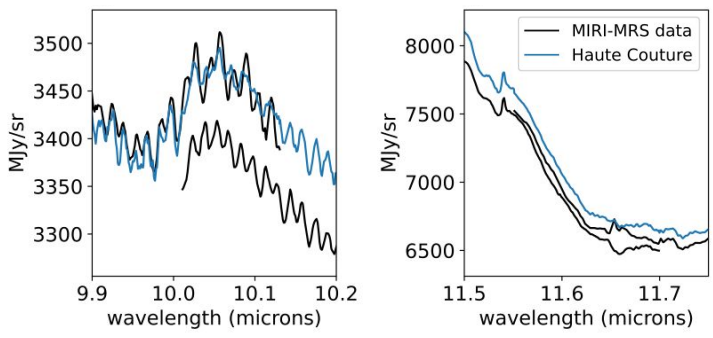
- Data from the ERS program PDRs4All [2].
- Observation of the Orion Bar with MIRI-MRS in a 1×9 pointing mosaic in the four channel (white).
- In our experiments, we used the pointing of MIRI-MRS (red) containing the protoplanetary disk d203-506.

Method

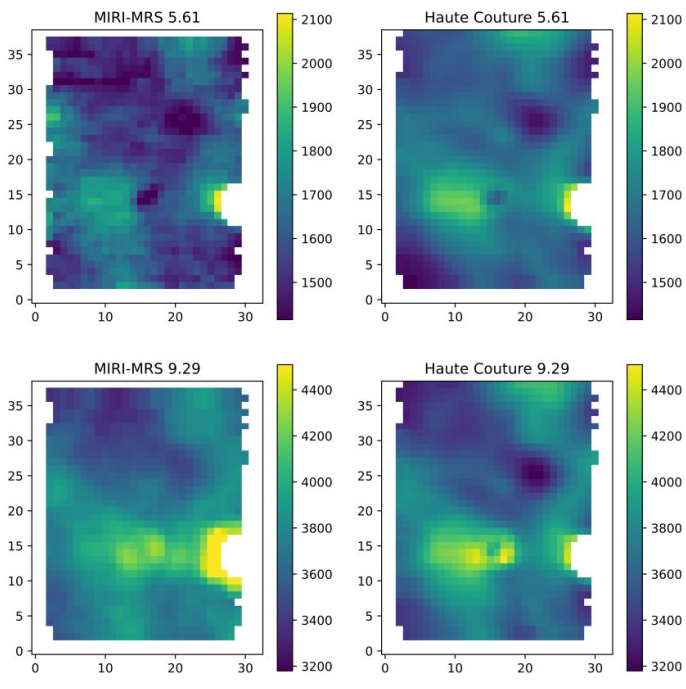


- **Assemble matrix X** using the twelve sub-matrices of MIRI-MRS.
- Apply custom pre-processing to **eliminate the intensity gaps** (optimise a set of global scale parameters that maximize the fit between the cubes where spectral overlap occurs)
- Recover the values located in the blue shaded area using **matrix completion**. Produces a data cube at the spatial resolution of the channel 1-long over the full spectral extent offered by MIRI-MRS.
- Matrix completion is performed with **nonnegative matrix factorization (NMF) [3,4].**

Results



⇨ Continuous spectrum without gap



Channel 1
⇨ Denoising

Channel 2
⇨ Improved angular resolution

References

[1] Law et al. 2023, AJ, 166, 45L
[2] Berné et al. 2022, PASP 134, 1035
[3] Smaragdis et al. 2014, IEEE Signal Processing Magazine 31 (3)
[4] Gillis 2020, Nonnegative Matrix Factorization (SIAM)