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## SIDISO : Wideband Images Fusion for High-Resolution

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► **To cite this version:**

François Orioux, Alain Abergel. SIDISO : Wideband Images Fusion for High-Resolution. Improving JWST Data Products Workshop, Nov 2023, Baltimore, United States. . hal-04288066

**HAL Id: hal-04288066**

**<https://hal.science/hal-04288066v1>**

Submitted on 15 Nov 2023

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## Problem statement

- Observed sky is a **hyperspectral** image  $2D + \lambda$
- Images** are affected by **spatial blurring** and **spectral integration**
- The equivalent PSF is source dependent
- Common approach : **homogenize** at the longest wavelength

**Proposition :** Inverse problem approach [1] to reconstruct the  $2D + \lambda$  sky from a set of wideband images.

## Instrument model

- Sky is a  $2D + \lambda$  cube  $\mathbf{x}[i, j, l] \in \mathbb{R}^N$  at detector spatial resolution
- Optics introduce a spectral variant spatial PSF  $\mathbf{h}_o$

$$\mathbf{x}_o[i, j, l] = \mathbf{x}[i, j, l] *_{i,j} \mathbf{h}[i, j, l] \quad (1)$$

- Weighting by filter  $f$  with profile  $\mathbf{w}_f$  and detector integration

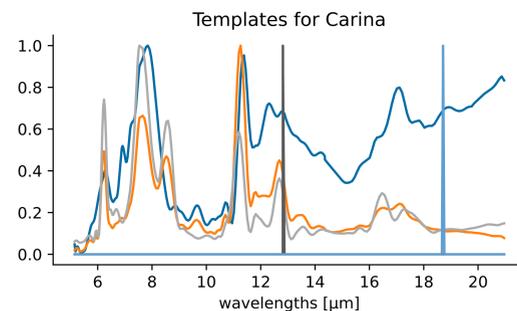
$$\mathbf{x}_i[i, j] = \sum_l \mathbf{w}_f[l] \mathbf{x}_o[i, j, l] \quad (2)$$

## Sky model

- Linear Mixing Model** [2]: sum of template spectrum  $\mathbf{s}_t$  and map  $\mathbf{a}_t$

$$\mathbf{x}[i, j, l] = \sum_{t=1}^T \mathbf{a}_t[i, j] \mathbf{s}_t[l] \quad (3)$$

- Ex: tpl. from Spitzer/IRS data of the PDR NGC 7023 [3]



- Reduce the number of unknowns, no physical meaning.
- Introduce **correlation** between wideband images.

## Data model

- Final image

$$\mathbf{x}_i[i, j] = \sum_{t=1}^T \mathbf{a}_t[i, j] *_{i,j} \mathbf{h}_{t,f}[i, j] \quad (4)$$

with the integrated equivalent spatial PSF

$$\mathbf{h}_{t,f}[i, j] = \sum_l \mathbf{w}_f[l] \mathbf{s}_t[l] \mathbf{h}[i, j, l] \quad (5)$$

- With sampling  $\mathbf{S}_f$  the forward model writes

$$\mathbf{x}_f = \mathbf{H}_f \mathbf{a} = \mathbf{S}_f \mathbf{C}_f \mathbf{a} \quad (6)$$

where  $\mathbf{C}_f$  is the sum of convolutions (4).

## Criterion and algorithm

### Criterion

- The solution is defined as the minimizer of

$$\hat{\mathbf{a}}, \hat{\mathbf{o}} = \arg \min_{\mathbf{a}, \mathbf{o}} \sum_{f=1}^F \frac{1}{\sigma_f^2} \|\mathbf{y}_f - \mathbf{H}_f \mathbf{a} - \mathbf{o}_f\|_2^2 + \sum_{t=1}^T \mu_t \sum_c \phi_t(\mathbf{d}_{t,c}^T \mathbf{a}_t) \quad (7)$$

$$\mathbf{o}_i \geq 0, \forall i,$$

$$(\mathbf{L}\mathbf{a})_i \geq 0, \forall i,$$

- Where  $\mathbf{a}$  are the abundances map,  $\mathbf{o}$  offsets,
- $\phi$  a convex penalization to stabilize the solution,
- $\{\mathbf{d}_t\}$  the vertical and horizontal differences between pixels,
- and positivity on the offsets and the hyperspectral cube  $\mathbf{L}\mathbf{a}$ .

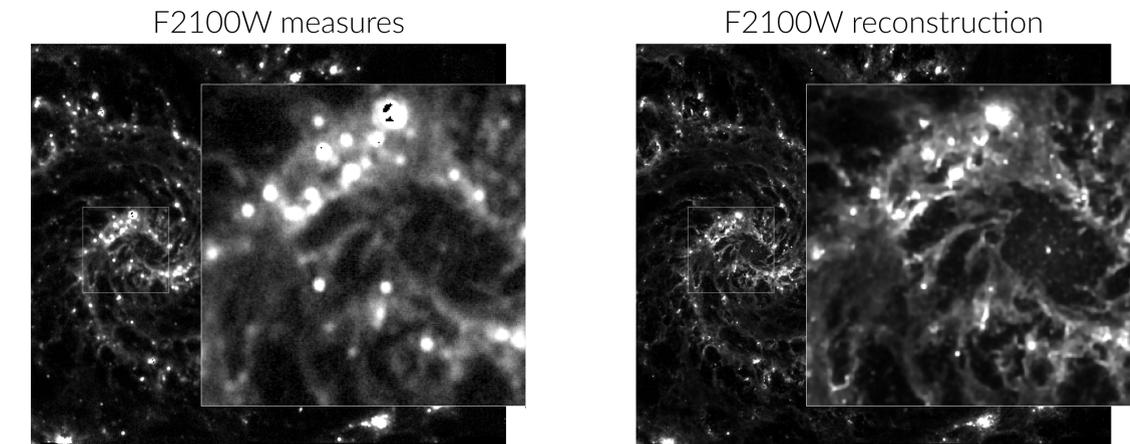
### Algorithm

- The solution is computed with alternate direction between  $\mathbf{a}$  and  $\mathbf{o}$ ,
- Half-Quadratic and Majorize-Minimize alg. for penalization,
- and Lagrange Multiplier (ADMM) for the positivity.

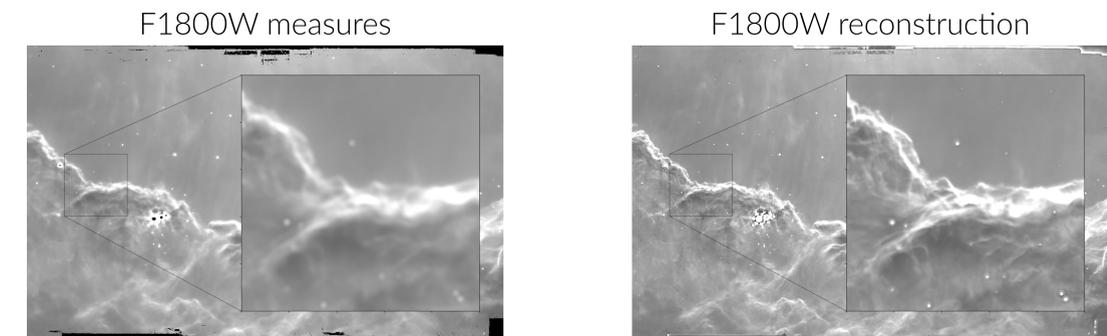
## Results for MIRI – sidiso.github.io

Most of the infrared emission of galaxies is due to photo-dominated regions (PDR).

### NGC626 – Fusion of F770W, F1000W, F1130W and F2100W



### Carina – Fusion of F770W, F1130W, F1280W and F1800W



## Conclusion – Perspectives

- An **inverse problem** for wideband images **fusion** and **deconvolution** (flux preserved)
- Publication in prep. with joint Python code **publicly available**

- G. Demoment, "Image reconstruction and restoration: Overview of common estimation structures and problems," *IEEE Trans. Acoust., Speech, Signal Processing*, vol. 37, no. 12, pp. 2024–2036, Dec. 1989.
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