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SIDISO : Wideband Images Fusion for High-Resolution

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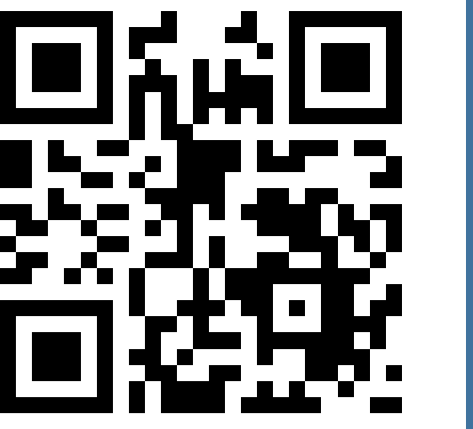
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Problem statement

- 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

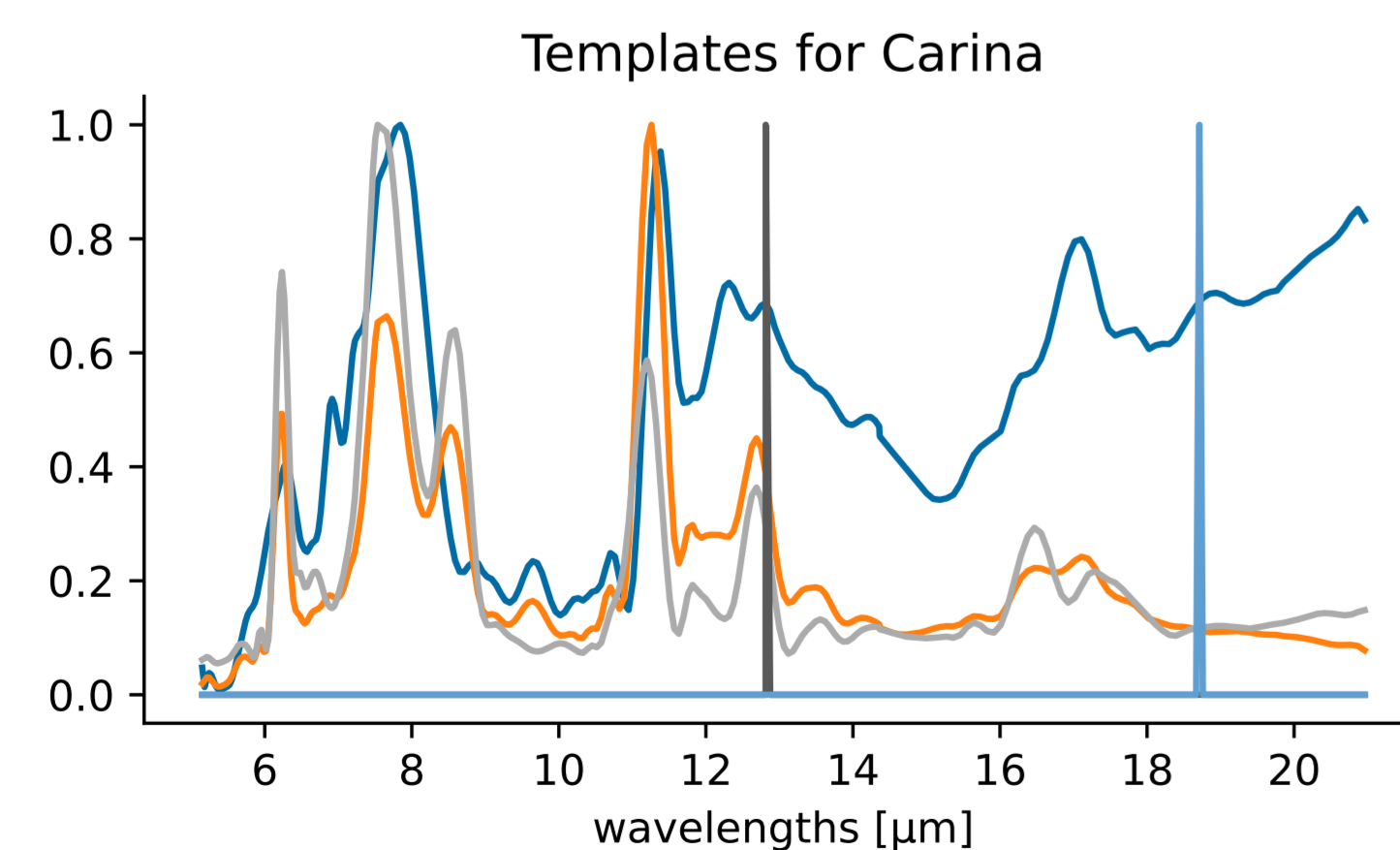
$$\mathbf{x}_i[i, j] = \sum_l \mathbf{w}_f[l] \mathbf{x}_o[i, j, l] \quad (2)$$

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,
- ϕ 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 $\mathbf{L}\mathbf{a}$.

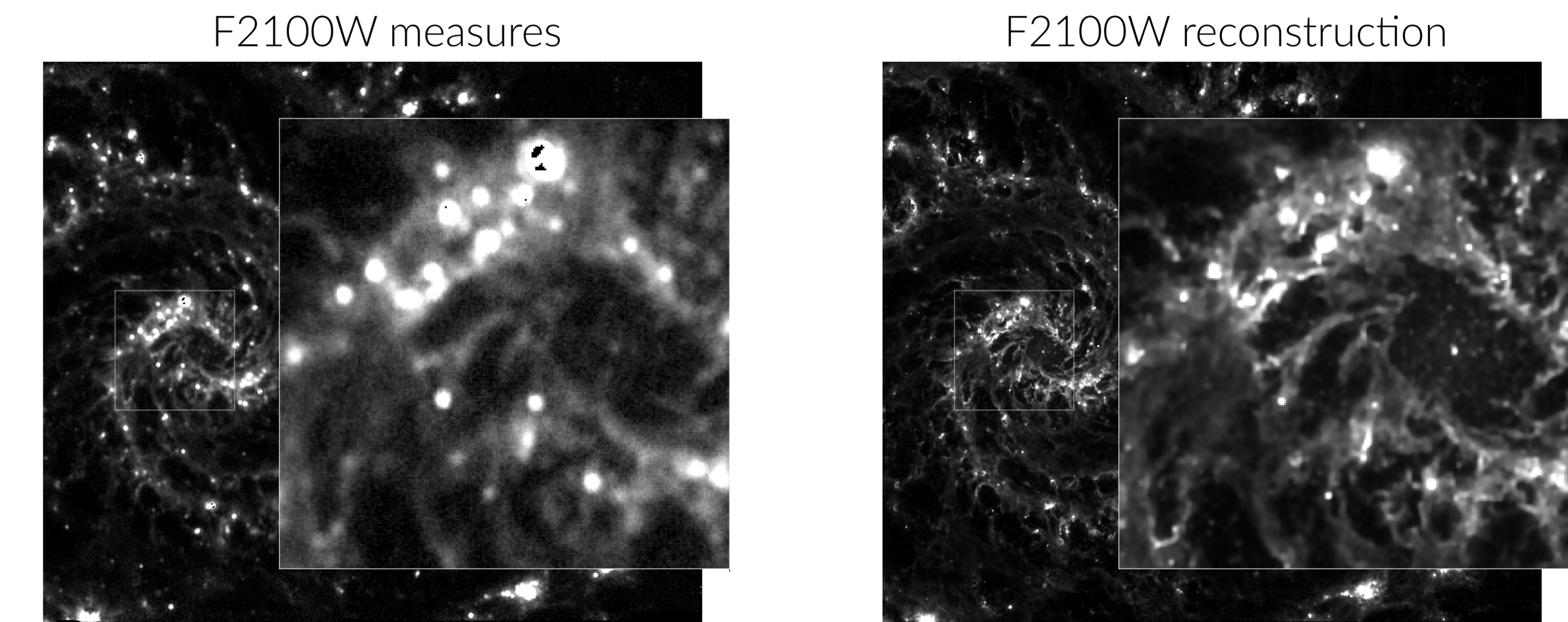
Algorithm

- 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.

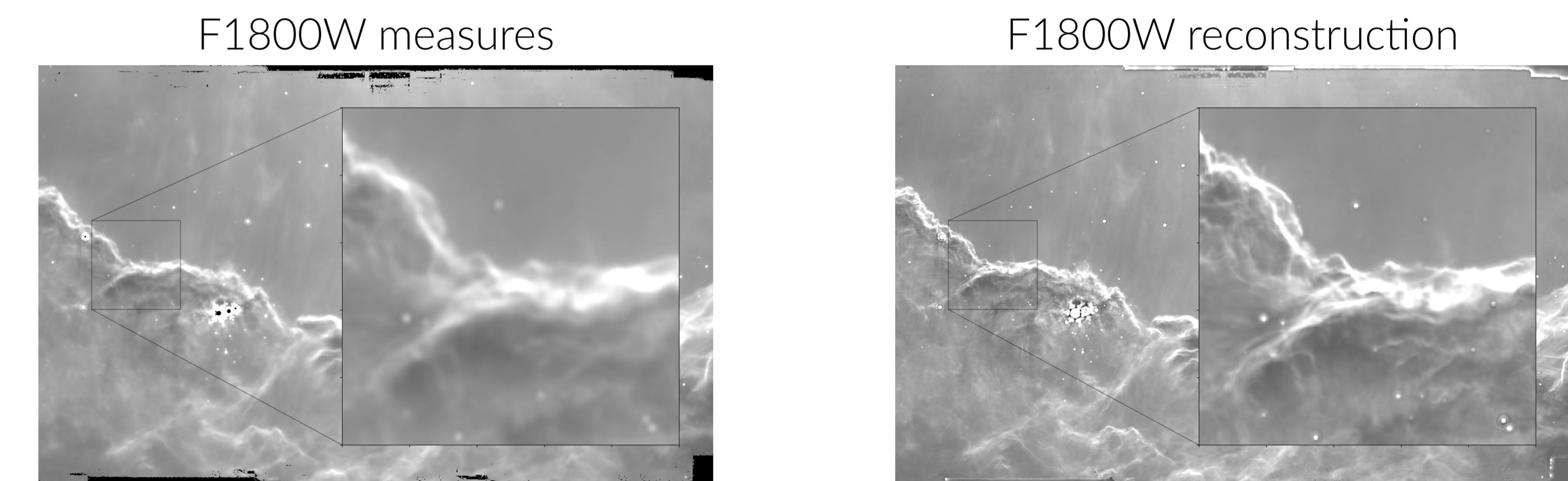
Results for MIRI – sidiso.github.io

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**

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