A Five-Minute Introduction to Blind Source Separation

Matthieu PUIGT Gilles DELMAIRE Gilles ROUSSEL

LISIC – Fusion Team – ULCO
FirstName.LASTNAME@lisic.univ-littoral.fr

DYMAPHY Meeting
March 22, 2013

Let's talk about linear systems

All of you know how to solve this kind of systems :

$$\left\{ \begin{array}{rcl} 2 \cdot s_1 + 3 \cdot s_2 & = & 5 \\ 3 \cdot s_1 - 2 \cdot s_2 & = & 1 \end{array} \right. \tag{1}$$

If we resp. define A, $\underline{s}$, and $\underline{x}$ the matrix and the vectors :

$$A = \left[\begin{array}{cc} 2 & 3 \\ 3 & -2 \end{array} \right], \underline{s} = [s_1, s_2]^T, \text{ and } \underline{x} = [5, 1]^T$$

Eq. (1) begins

$$\underline{x} = A \cdot \underline{s}$$

and the solution reads :

$$\underline{s} = A^{-1} \cdot \underline{x} = [1, 1]^T$$

Let's talk about linear systems

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$$\left\{ \begin{array}{rcl} ? \cdot s_1 + ? \cdot s_2 & = & 5 \\ ? \cdot s_1 + ? \cdot s_2 & = & 1 \end{array} \right. \quad (1)$$

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All of you know how to solve this kind of systems :

$$\left\{ \begin{array}{rcl} a_{11} \cdot s_1 + a_{12} \cdot s_2 & = & 5 \\ a_{21} \cdot s_1 + a_{22} \cdot s_2 & = & 1 \end{array} \right. \quad (1)$$

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How can we solve this kind of problem ? ? ?

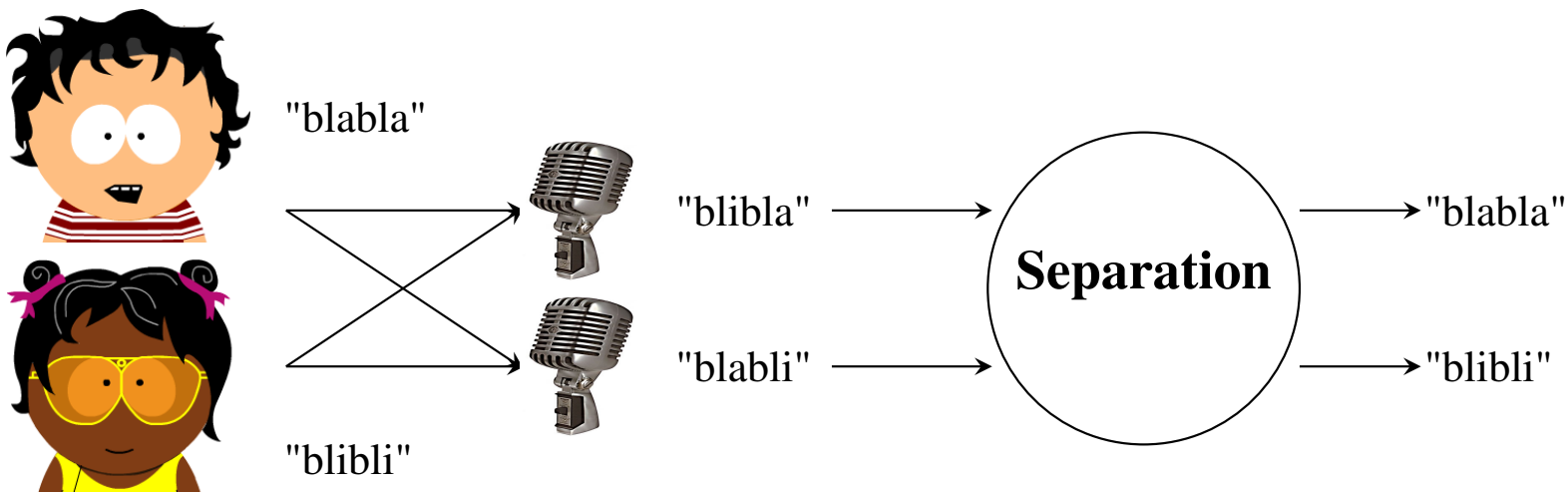
This problem is called **Blind Source Separation**.

Blind Source Separation problem

- N unknown sources s_j.
- One unknown operator $\mathcal{A}$.
- P observed signals x_i with the global relation

$$\underline{x} = \mathcal{A}(\underline{s}).$$

Goal : Estimating the vector $\underline{s}$, up to some indeterminacies.



Sources $s_j(t)$ Observations $x_i(t)$ Outputs $y_k(t)$

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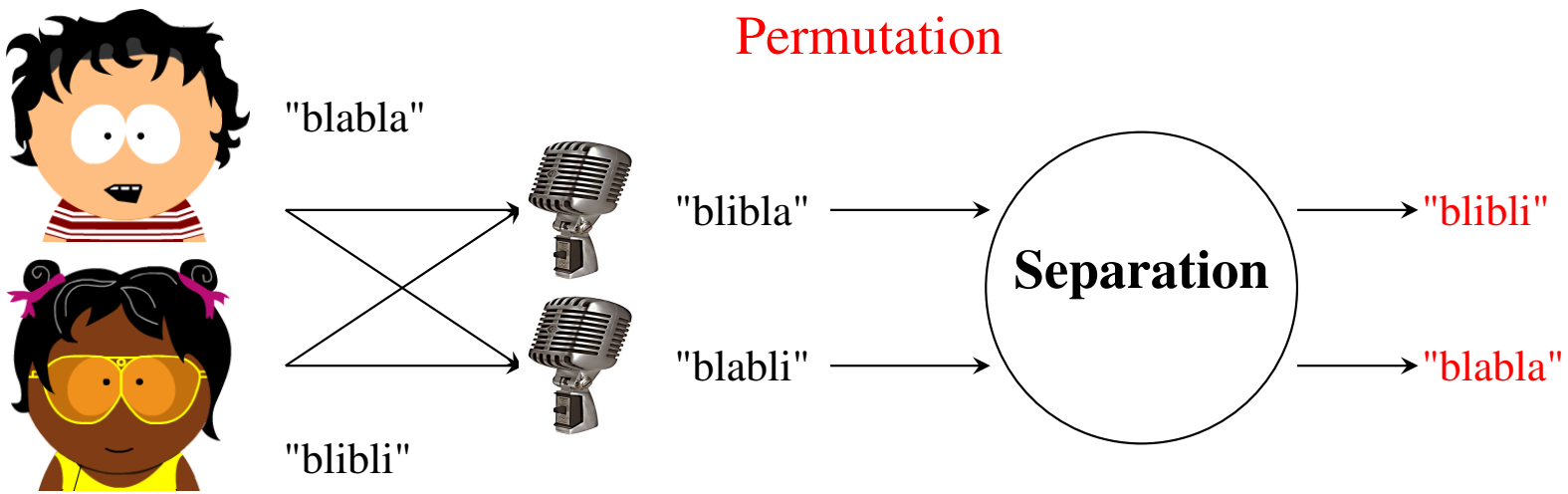

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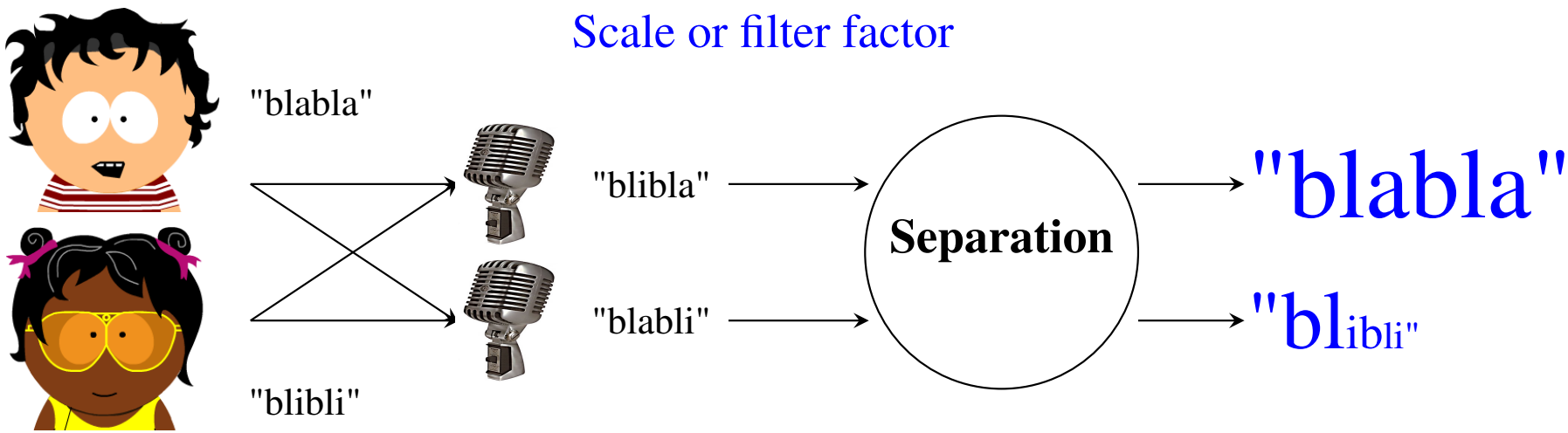

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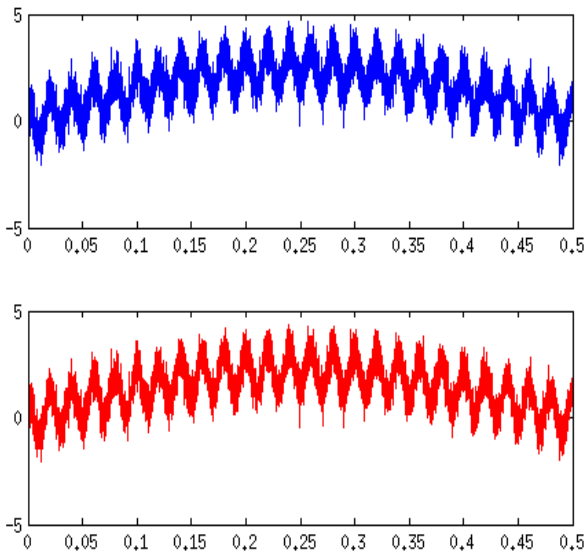
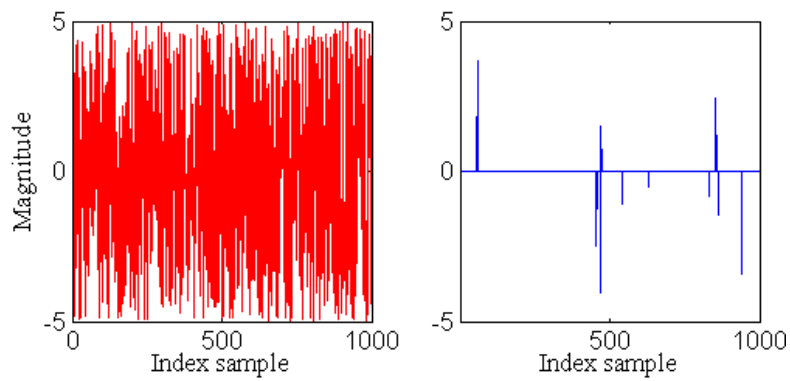
How to solve Blind Source Separation ?

Three main families of methods :

1. **Independent Component Analysis (ICA) :** Sources are statistically independent.
2. **Sparse Component Analysis (SCA) :** Sparse sources (i.e., most of the samples are null (or close to zero)).
3. **Non-negative Matrix Factorization (NMF) :** Both sources et mixtures are positive, with possibly sparsity constraints.

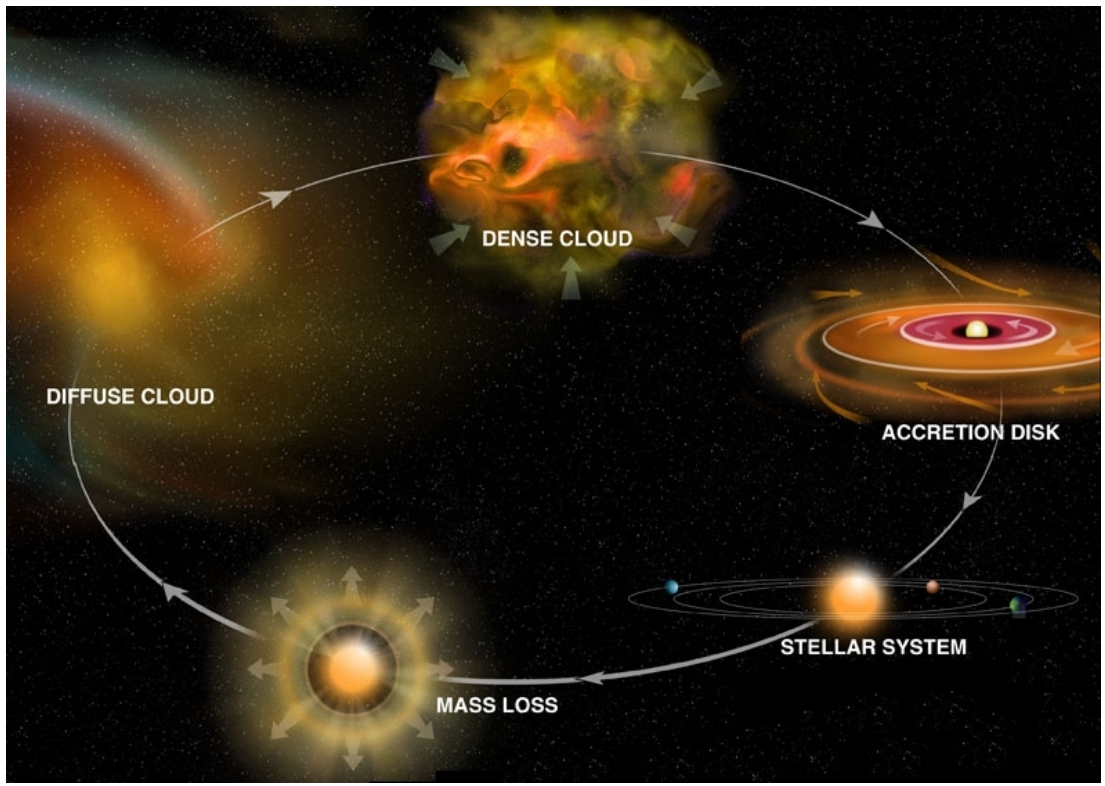




Application (1)

Separation and mapping of chemical species (Puigt *et al.*, 2009)

- Interstellar medium : lies between stars in our galaxy
- Concentrated in dust clouds which play a major role in the evolution of galaxies



Adapted from `http://www.nrao.edu/pr/2006/gbtmolecules/`, Bill Saxton, NRAO/AUI/NSF

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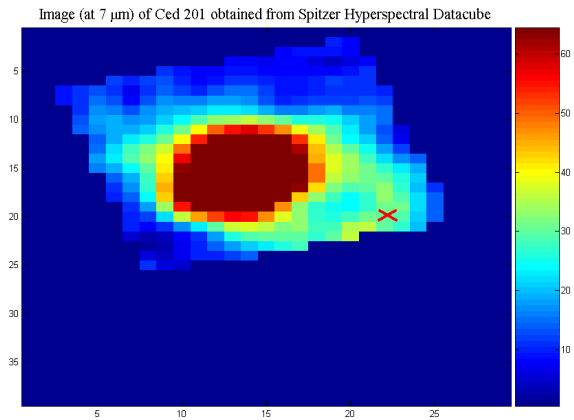
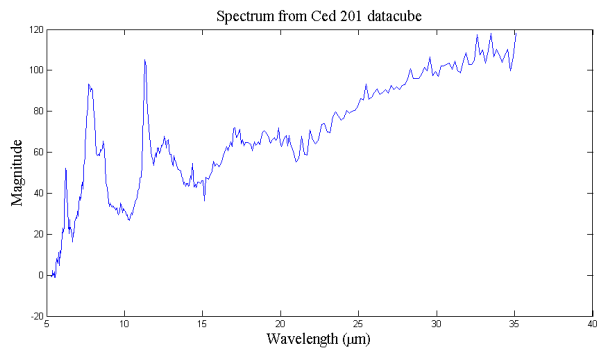
- Spitzer IR spectrograph provides datacubes
- Observed spectra are mixes of the grain spectra (to estimate)

⇨ **Blind Source Separation Problem**





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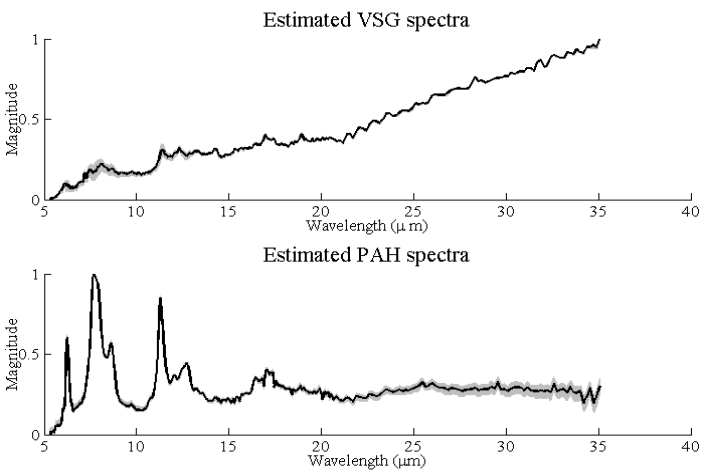
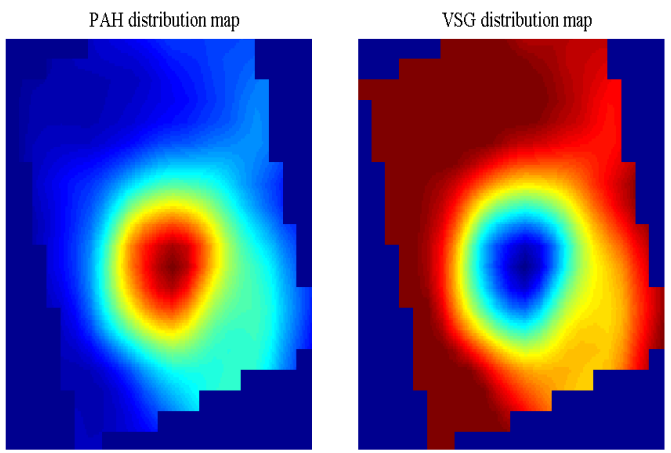
⇨ Grain localization in the dust clouds





Application (2)

Source apportionment of particulate matter (Delmaire *et al.*, 2010-2013)

- Industrial areas : precise pollution profiles to be known and localized
- Project with an important integrated steelworks, near Dunkerque
- Measures of particulate matter in the city area
- Observations are mixtures of background sources (sea salts, inorganic aerosols, crustal particles) and industrial pollution sources (blast furnaces, steel slag, ores sintering plant and sintering chimney, ferromanganese plant)

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➪ **Blind Source Separation Problem**

More information on Gilles' presentation

Thank you for your attention

- M. Puigt : matthieu.puigt@lisic.univ-littoral.fr
- G. Delmaire : gilles.delmaire@lisic.univ-littoral.fr
- G. Roussel : gilles.roussel@lisic.univ-littoral.fr