Blind Source Separation (BSS) methods for hyperspectral imaging applications in Astrophysics and Earth Observation

Andréa Guerrero

PhD student 1st year
Paul Sabatier University, IRAP-CNRS
PhD Supervisors : Yannick Deville and Shahram Hosseini

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Why this thesis ?

- many application fields for BSS methods, **Astrophysics and Earth Observation** for instance
- Need to develop BSS methods for complex cases
- **hyperspectral imaging** booming

Outline

Outline

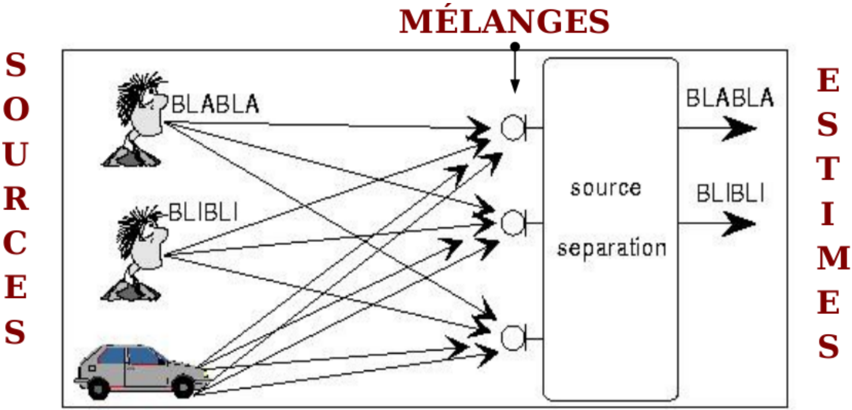
BSS principle 1/2

$$\underset{known\ observation}{X = \begin{pmatrix} x_1(t) \\ x_2(t) \\ \dots \\ x_M(t) \end{pmatrix}} \qquad \underset{unknown\ sources}{S = \begin{pmatrix} s_1(t) \\ s_2(t) \\ \dots \\ s_N(t) \end{pmatrix}} \tag{1}$$

Purpose : **Source estimation** based on the observations and the mixture nature (linear or non-linear, variant, ..).

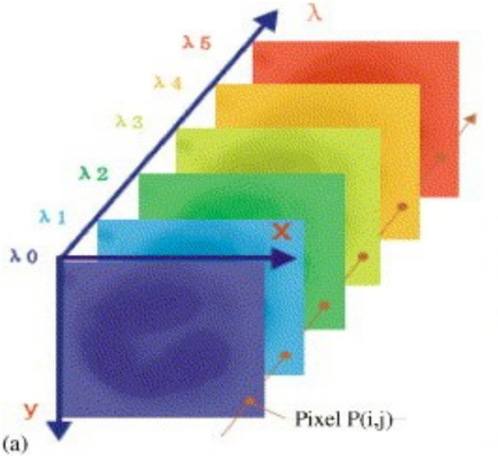
$\Rightarrow$ mixture parameters unknown = estimation needed

BSS principle 2/2



hyperspectral data

- More than 100 spectral band
- Data type more and more common in fields like Astrophysics and Earth Observation
- Difficulty increases with the large amount of data



2 topics

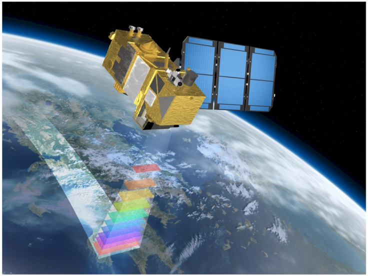
Context

Data used: hyperspectral images from observation satellite.

1. **Astrophysics**: Faraway = small objects, Objects spreading and mixture due to the Point Spread Function (PSF) of the imaging system
2. **Earth Observation**: multiple ray reflections, 1 pixel tantamount to several km = multiple materials in 1 pixel

Outline

Case of classic satellite observation



Linear Invariant model (LI) :

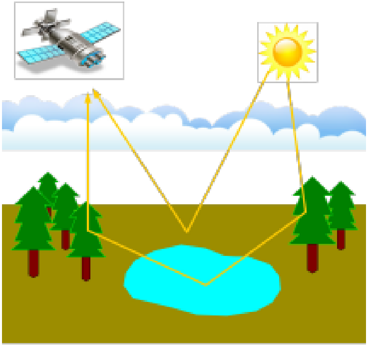
$$X = A \times S$$

$$\begin{pmatrix} x_1 \\ : \\ x_M \end{pmatrix} = \begin{pmatrix} a_{1,1} & .. & a_{1,N} \\ : & .. & : \\ a_{M,1} & .. & a_{M,N} \end{pmatrix} \times \begin{pmatrix} s_1 \\ : \\ s_N \end{pmatrix} \quad (2)$$

Observations Mixing matrix Sources

→ Want to estimate the sources S and contribution of each in the mixture.

Case of multiple reflections

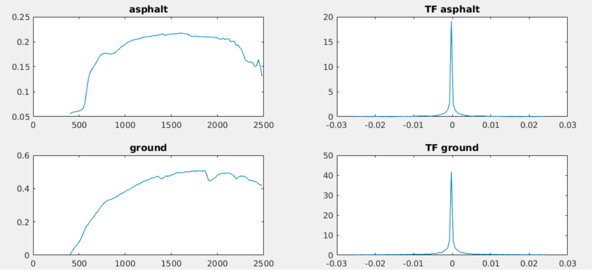


Linear Quadratic model (LQ)

$$x_i = \sum_{j=1}^{N} a_{i,j} s_j + \sum_{1 \leq j < k < N} b_{i,j,k} s_j s_k \quad \forall i \in \{1, .., M\} \tag{3}$$

→ A ray meets one element then an other and then, finally reachs the satellite.

Why develop another BSS method ?



spectres tirés de la librairie MEMOIRES de l'ONERA

- **No** spectral or other **sparseness** → we can't use BSS methods based on sparseness
- **Dependence** in case of LQ model → we can't use ICA
- Non-negative Matrix Factorization : sources are positive but **initialization is a big issue**, so NMF isn't really efficient

Outline

Euclid mission

EUCLID :

- an *ESA* mission, launch expected in 2020
- find the dark energy nature and understand it
- how it may affect the Universe expansion and its acceleration
- *NISP* instrument (Near-Infrared Spectro-Photometer) measures redshift of galaxies in several directions

What's done :

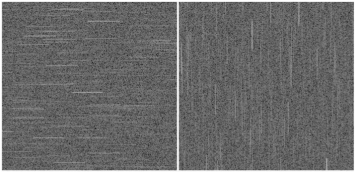
→ PSF model = sum of 2 Gaussians
→ Focus on spectra of 1st order

→ Grism 0 and 90 used
→ Blind and semi-blind algorithms

Model

NISP : near-infrared 3-filter and a **slitless spectrograph** (λ =0.935 to 1.85 μm)

GRISM effect = Spectra mixed so we need BSS to measure redshift of a precise object



Variant model :

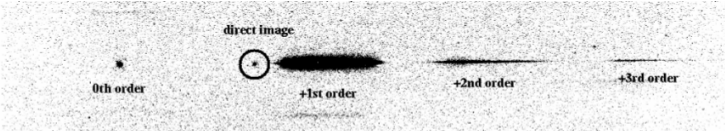
$$o(p) = \sum_{i=1}^{N} \sum_{l=1}^{L} m_i(p, \lambda_l) s_i(\lambda_l) \quad (4)$$

Observations Mixtures Sources

What I am going to do for EUCLID

Objectives :

1. Include spectra of **order 0 and 2**



2. Include **noise** in the model
3. Include the **other directions** : 90 and 180
4. Change the PSF model to a more appropriate solution

Outline

Conclusion & Perpectives

- 2 different topics but **a common purpose**
- Earth observation : **complex case**, hard to build an efficient method
- Euclid : **European mission**, so important work to do to improve blind method

Thanks for your attention !

How many galaxy redshifts will be measured thanks to EUCLID mission ?

1. few million
2. some ten million
3. few billion
4. some ten billion