Coupling multimodal and multiresolution hyperspectral images by an extended version of Multiple Co-Inertia Analysis

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GRD ISIS
Décomposition tensorielle et Applications
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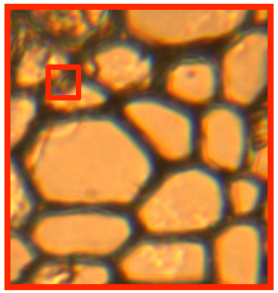
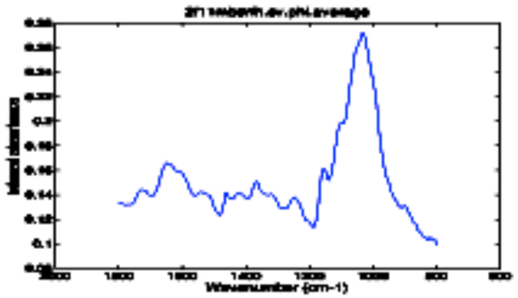
Hyperspectral imaging

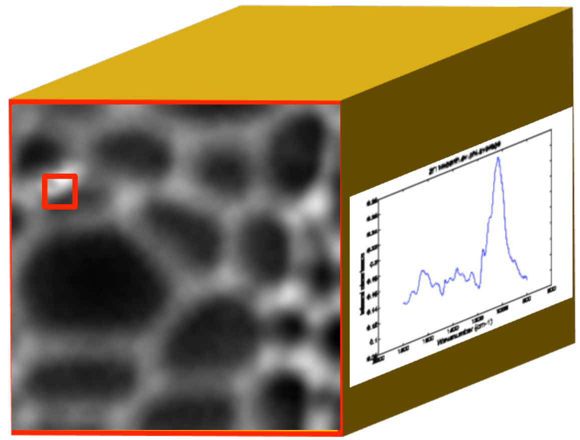


Field of view



A complete spectrum is acquired for each pixel

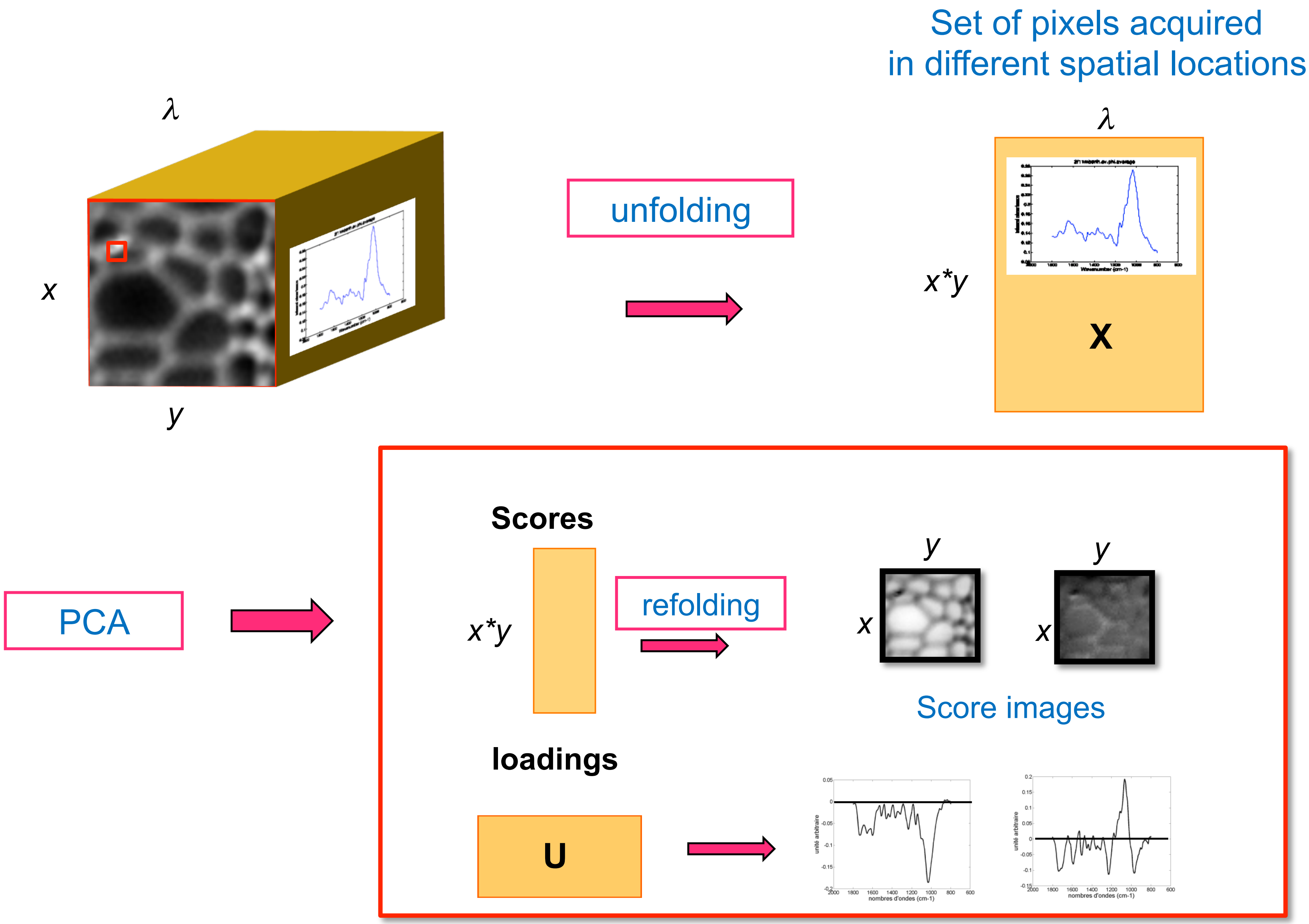
pixels



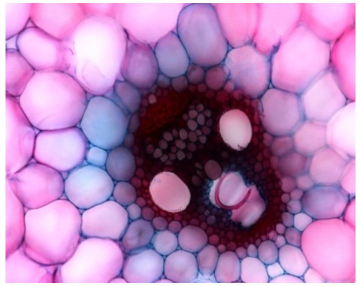
pixels

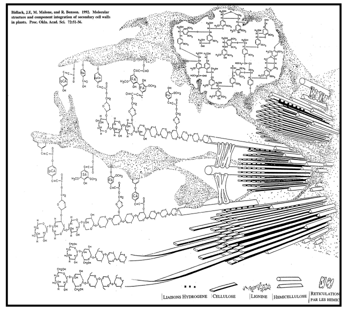
Hyperspectral image

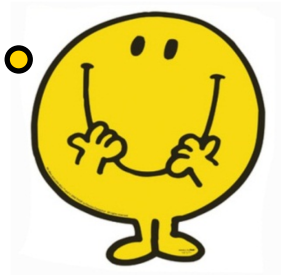
Principal Component Analysis of hyperspectral images



Coupling hyperspectral images



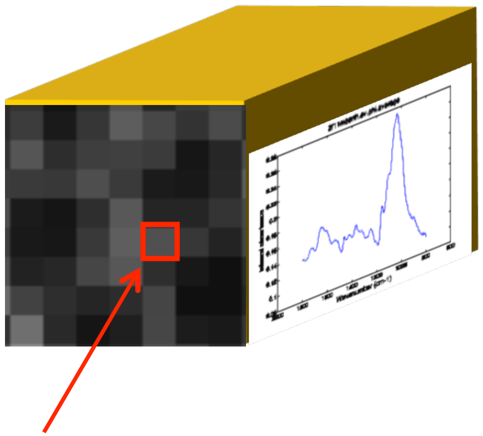




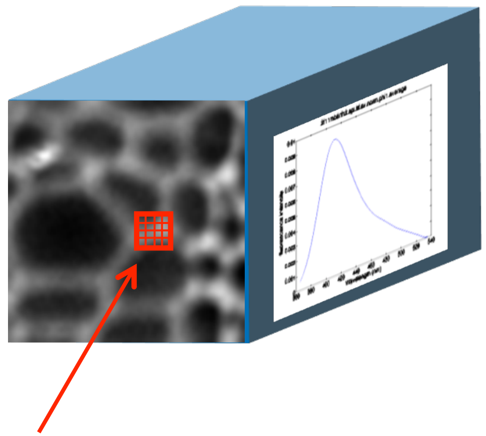
infrarouge ∪ fluorescence ∪ Raman = Complete characterization of complex samples

infrarouge ∩ fluorescence ∩ Raman = Common information + complementarities

Multiresolution pixels



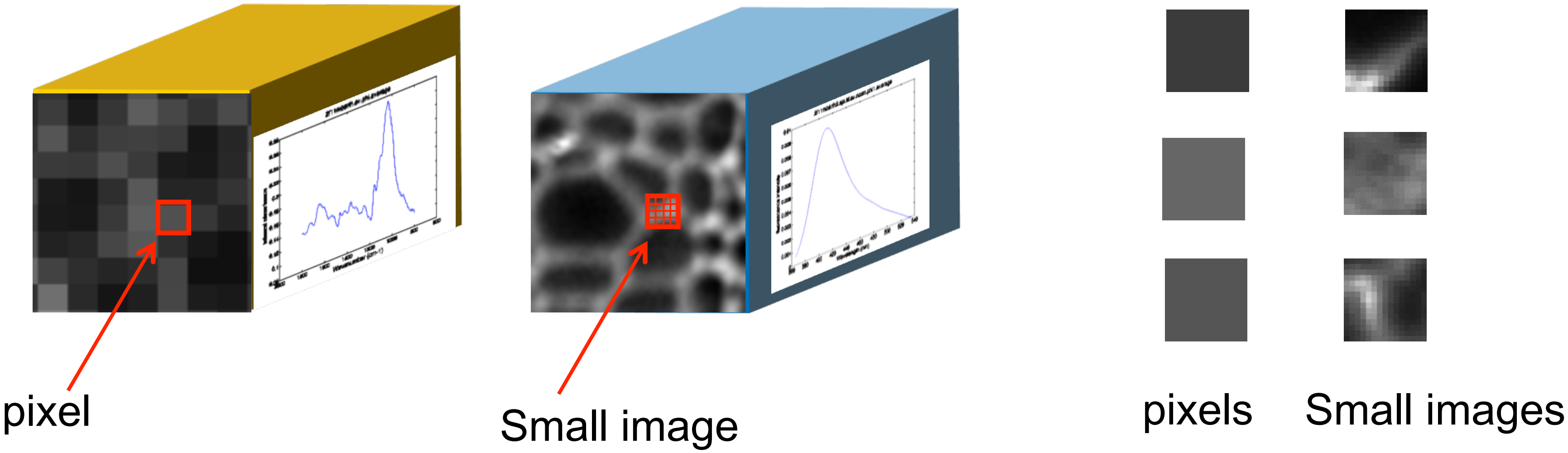
pixel



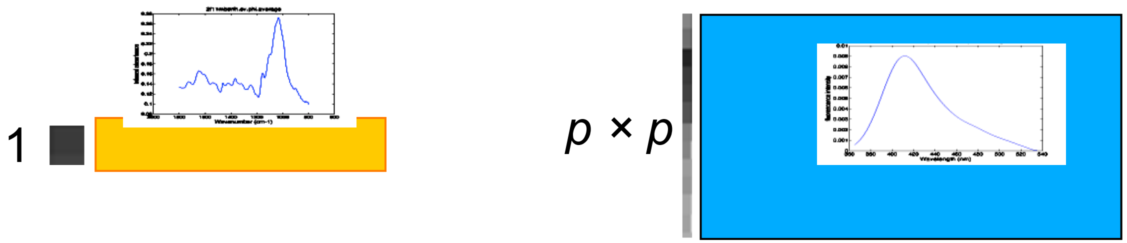
pixels

Pixel size depends on the spectral technique : Mid Infrared : 5-10 µm
Raman : < 1 µm
Fluorescence : < 1µm

Pairing multiresolution pixels

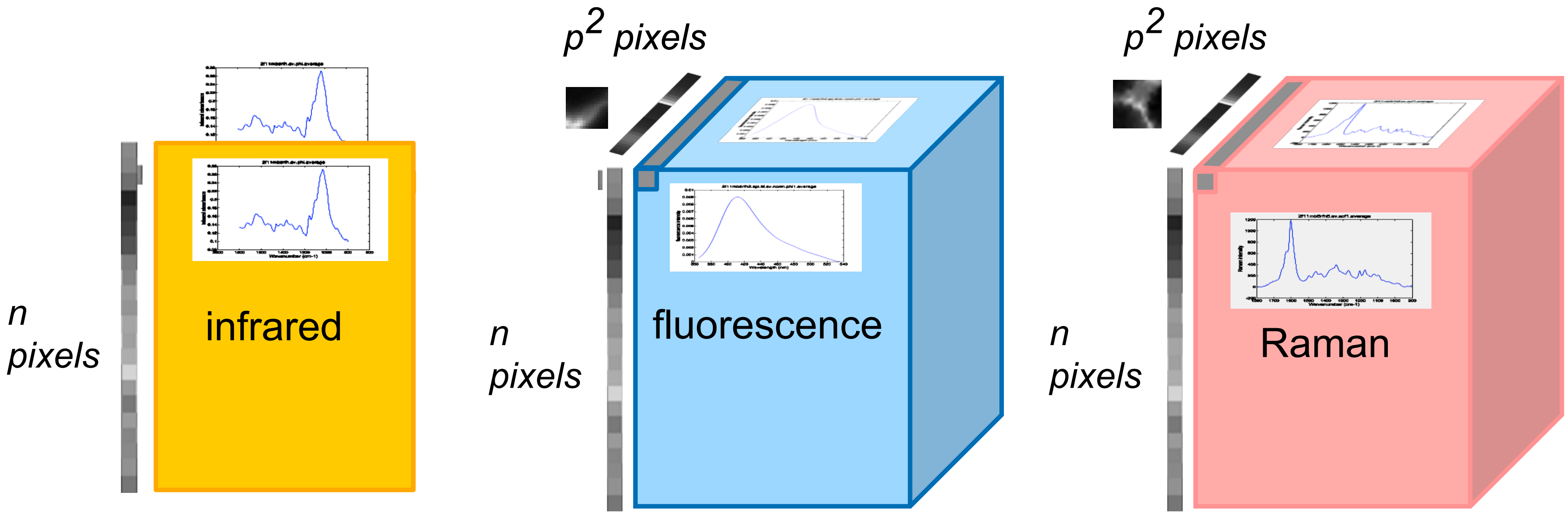


Low resolution pixels correspond to small images of size p × p high resolution pixels.



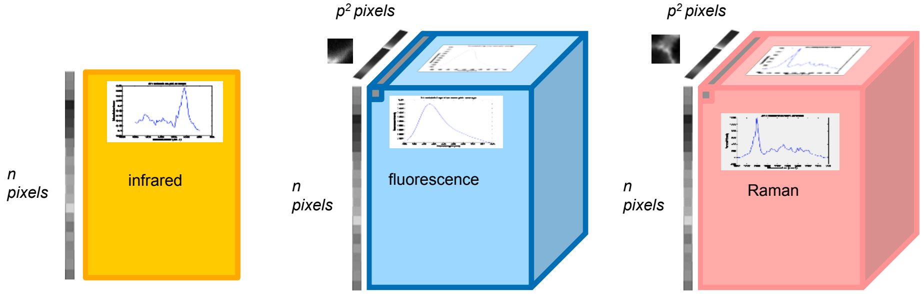
Unfolding small images

Pairing multiresolution pixels: data structure



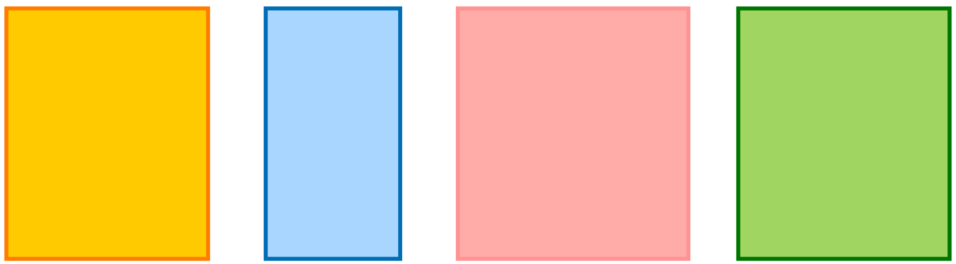
Coupling two and three-way data tables…

Coupling two and three-way data tables



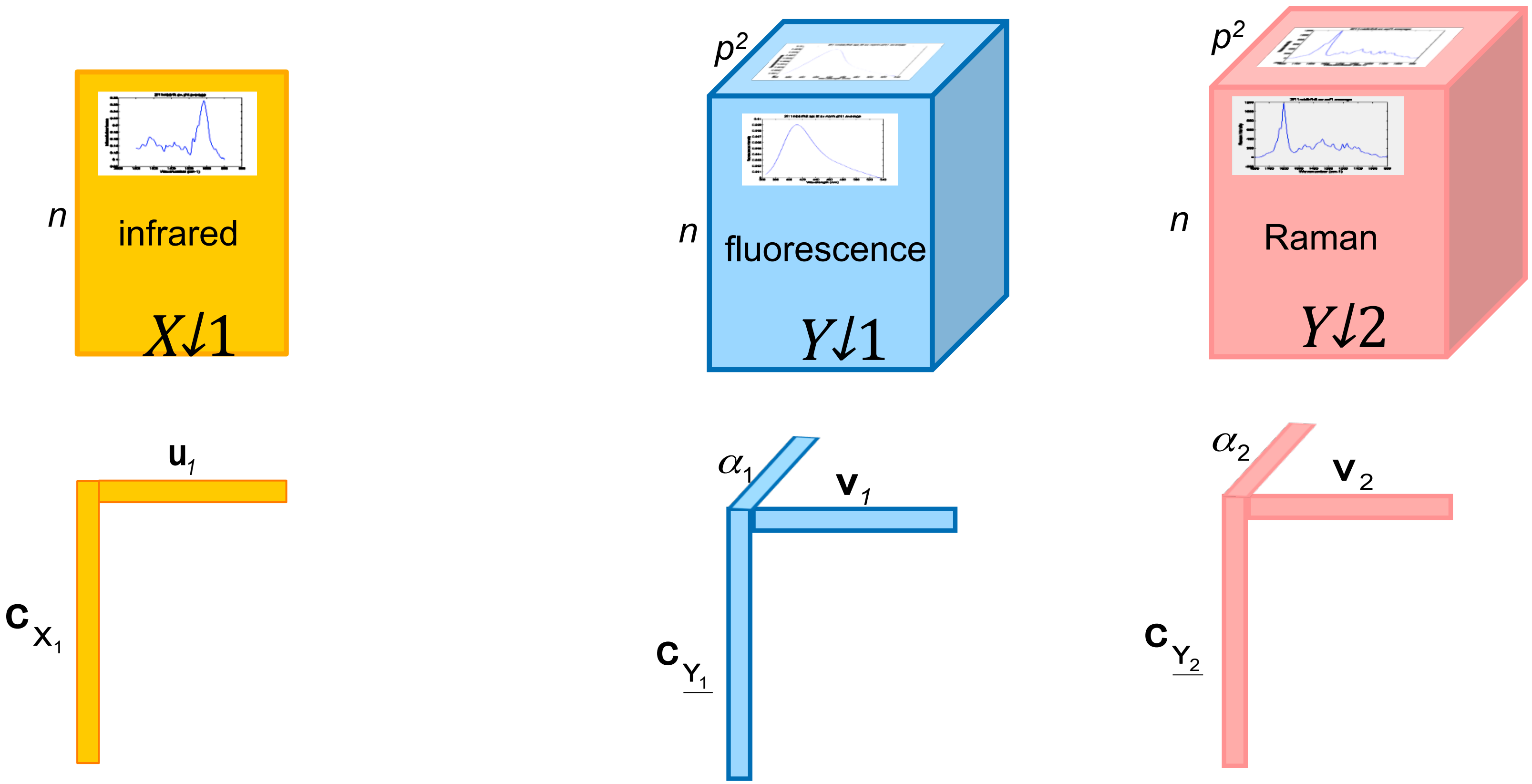
How can we envision multiblock data analysis while preserving the full resolution of data tables

?



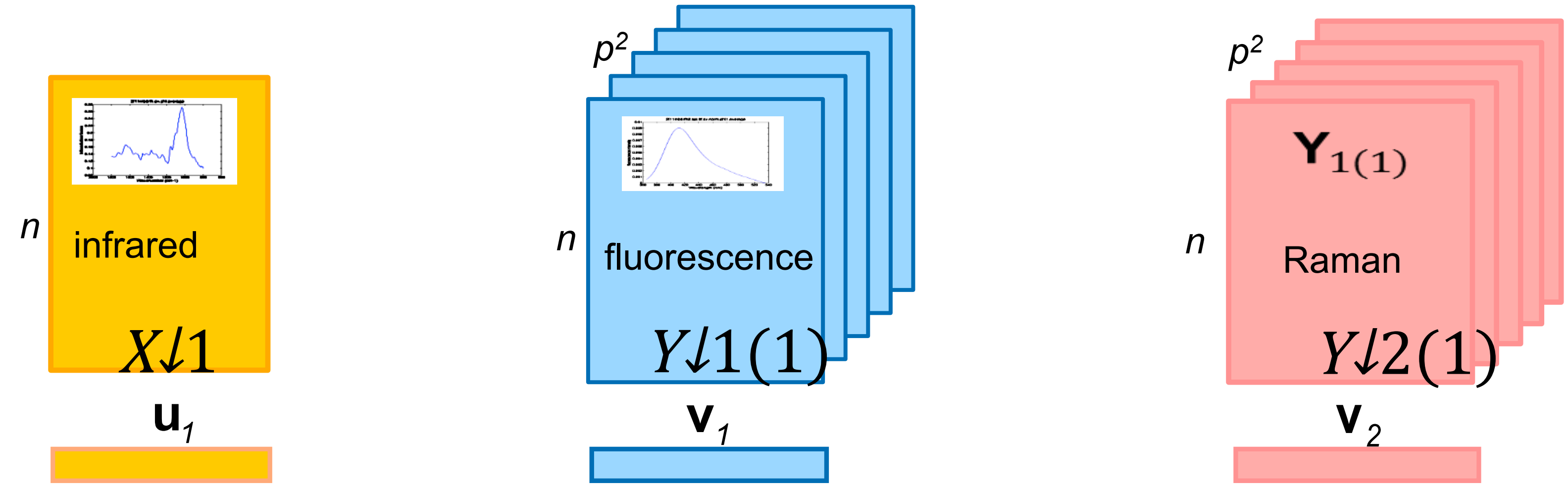
Extension of Multiple Co-inertia Analysis….

Extension of Multiple Co-inertia Analysis
Developing Trilinear Multiple Co-inertia Analysis



$$\mathbf{Max}\ \mathrm{cov}^2(\mathbf{c}_{X_k}, \mathbf{c}_g) + \sum \mathrm{cov}^2(\mathbf{c}_{\underline{Y}_i}, \mathbf{c}_g)$$

Developing Trilinear Multiple Co-inertia Analysis



Assessing Block Loadings and Components

Two-way data tables

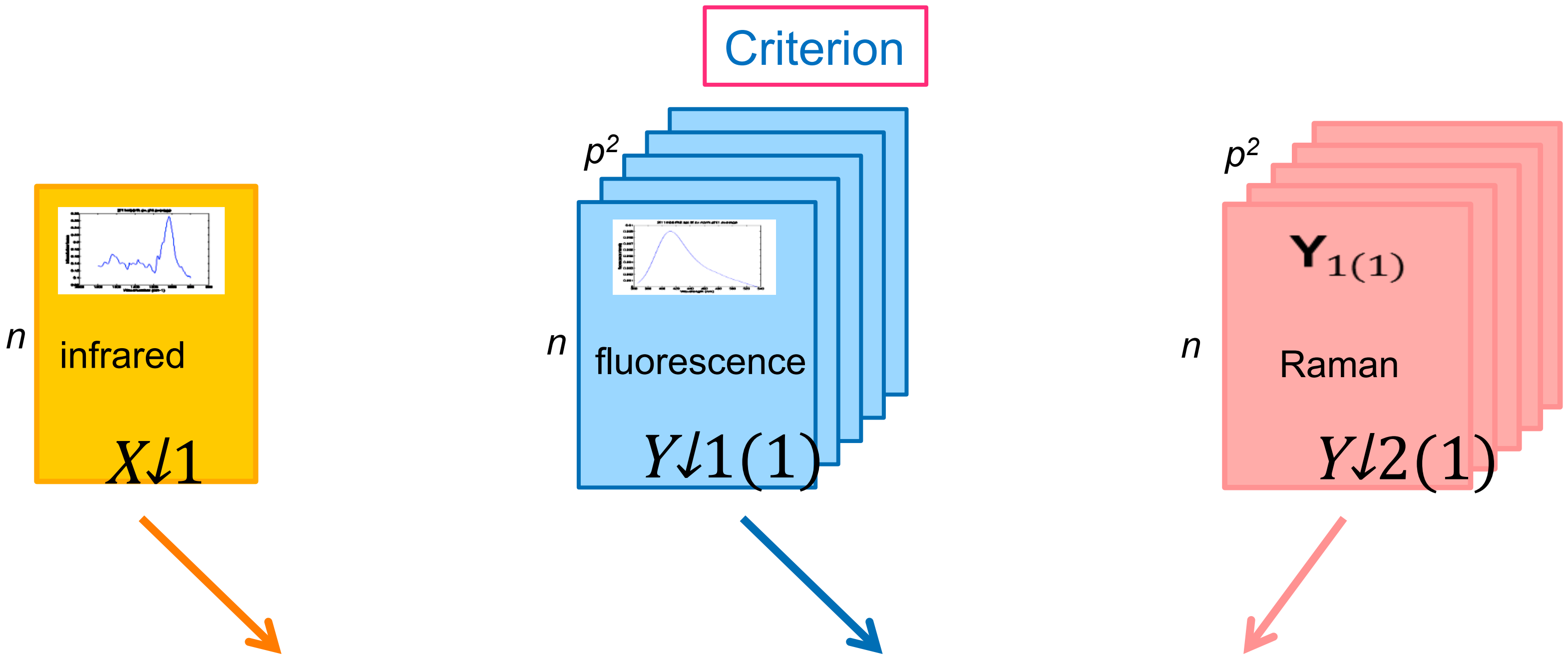
$$\mathbf{c}_{\mathbf{X}_k} = \mathbf{X}_k u_k$$

Three way data tables:

For each stack $\mathbf{Y}_{j(z)}$ of the three-way block

$$\mathbf{c}_{\mathbf{Y}_{j(z)}} = \mathbf{Y}_{j(z)} \mathbf{v}_j$$

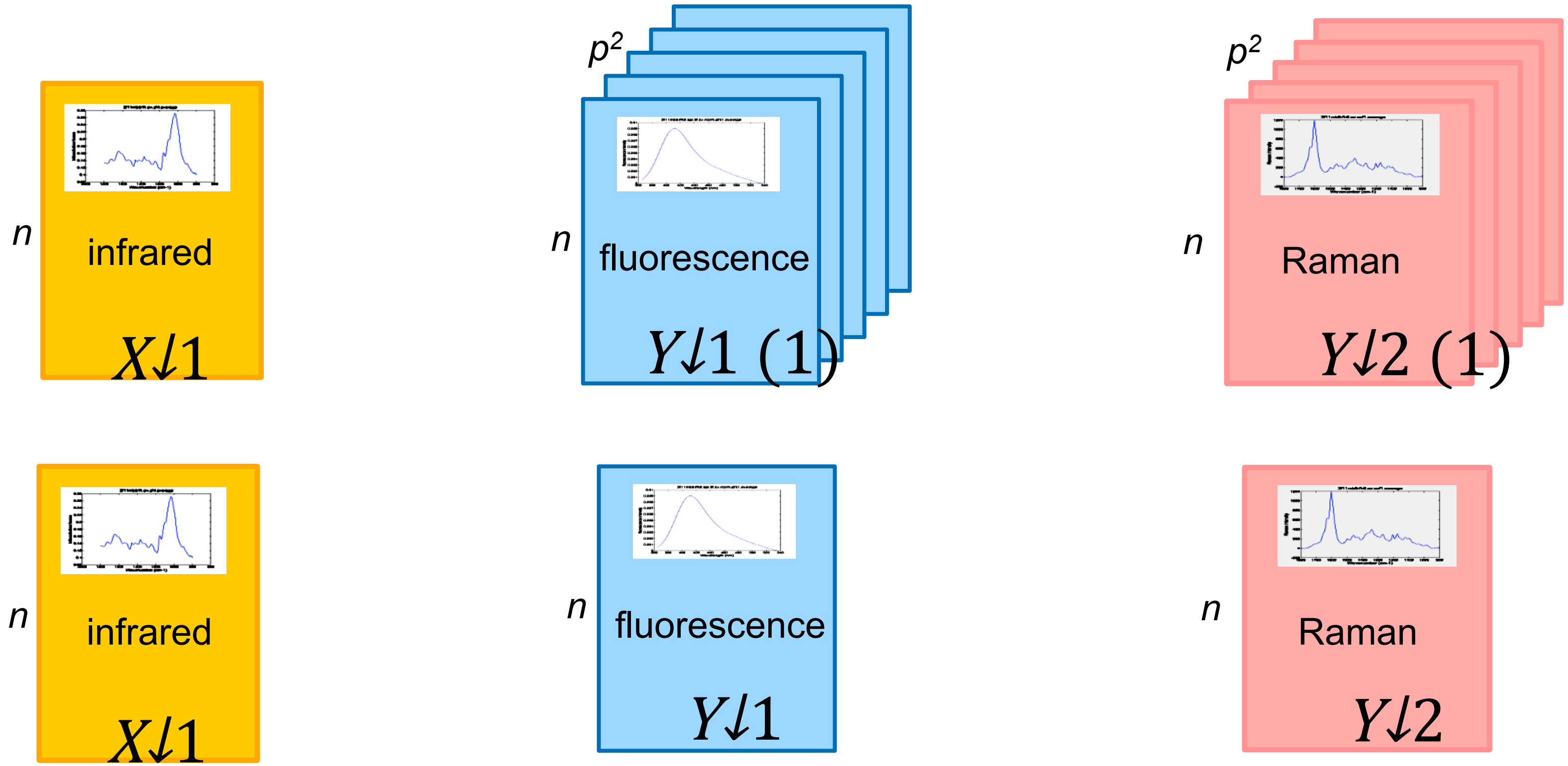
Developing Trilinear Multiple Co-inertia Analysis



$$\mathbf{c}_{\mathbf{X}_k} = \mathbf{X}_k \mathbf{u}_k \qquad \mathbf{c}_{\mathbf{Y}_{j(z)}} = \mathbf{Y}_{j(z)} \mathbf{v}_j$$

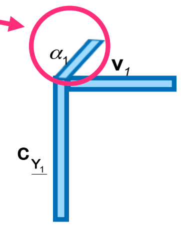
$$\mathbf{Max} \sum \mathrm{cov}^2(\mathbf{c}_{\mathbf{X}_k}, \mathbf{c}_g) + \sum\sum \mathrm{cov}^2(\mathbf{c}_{\mathbf{Y}_{j(z)}}, \mathbf{c}_g)$$

Developing Trilinear Multiple Co-inertia Analysis

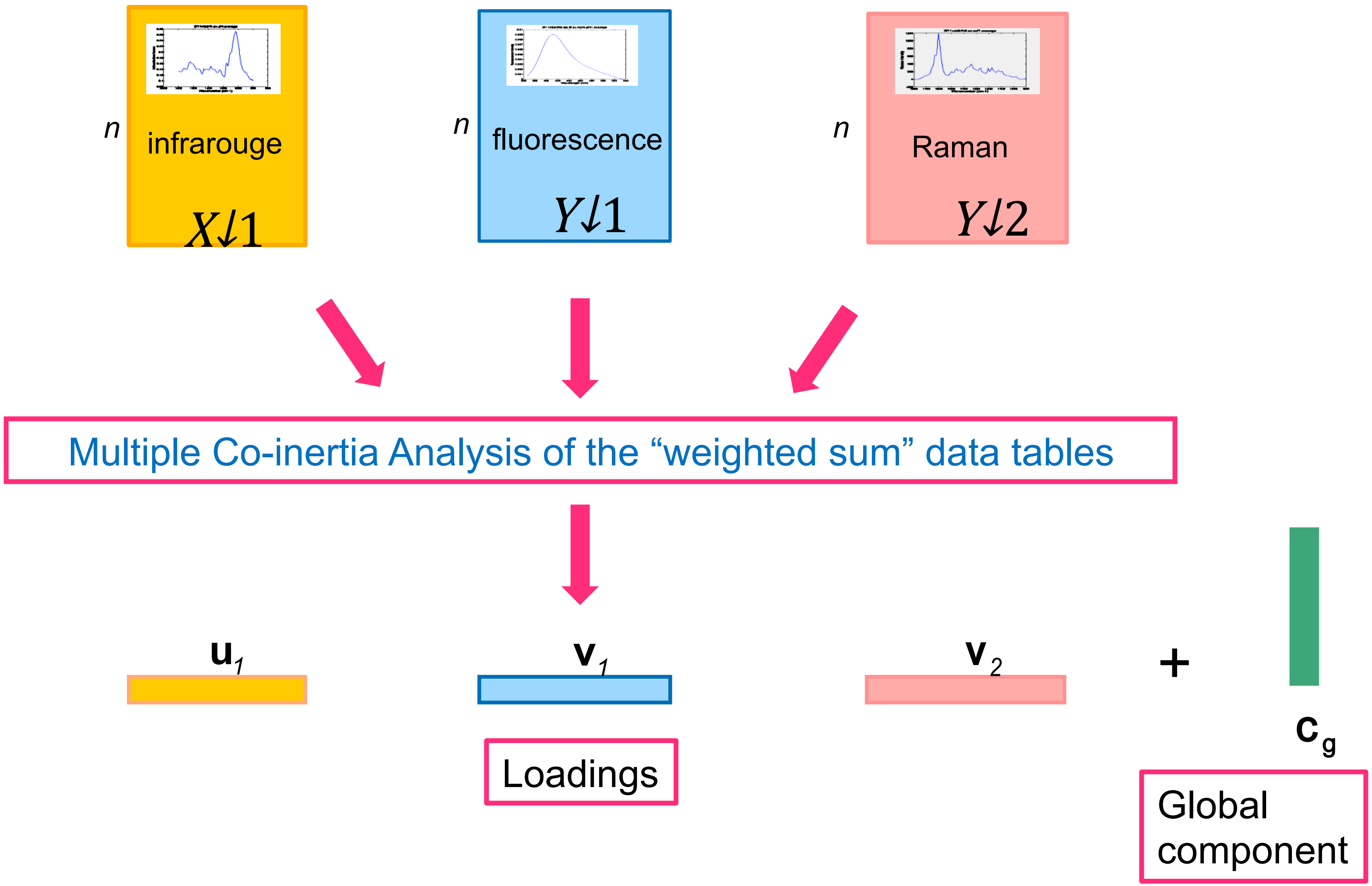


Assessing a weighted sum of block stacks

$$\bar{\mathbf{Y}}_j = \sum \alpha_{j(z)} \times \mathbf{Y}_{j(z)}$$



Developing Trilinear Multiple Co-inertia Analysis



Trilinear Multiple Co-inertia Analysis: algorithm

Initialisation :

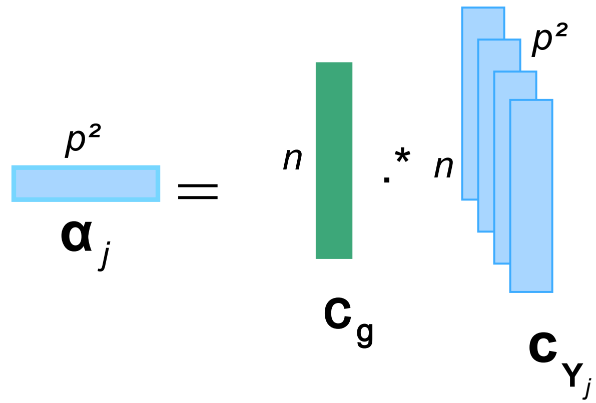
- Start with random α weight vector with $\|\alpha\|=1$

Iteration :

- Apply Multiple Co-inertia Analysis to weighted sum data tables

- Set α weight vector:
  similarity between global and block component

- Normalise weight vector: $\|\alpha\|=1$



Convergence :

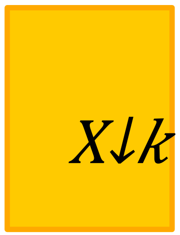
- Stop when **loadings and scores** do not change between two iterations.

Trilinear Multiple Co-inertia Analysis: deflation

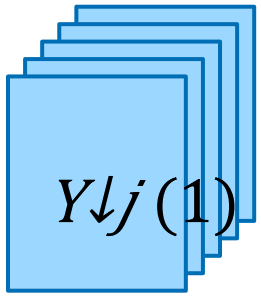
Next components, loadings and weight vectors are assessed after deflation

Deflation is performed to provide orthogonal loadings per block

$$\mathbf{X}_k^{(h+1)} = \mathbf{X}_k^{(h)} - \mathbf{c}_{X_k}^{(h)}\mathbf{u}_k^{(h)'}$$

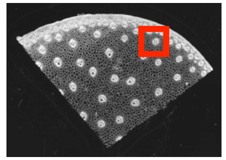


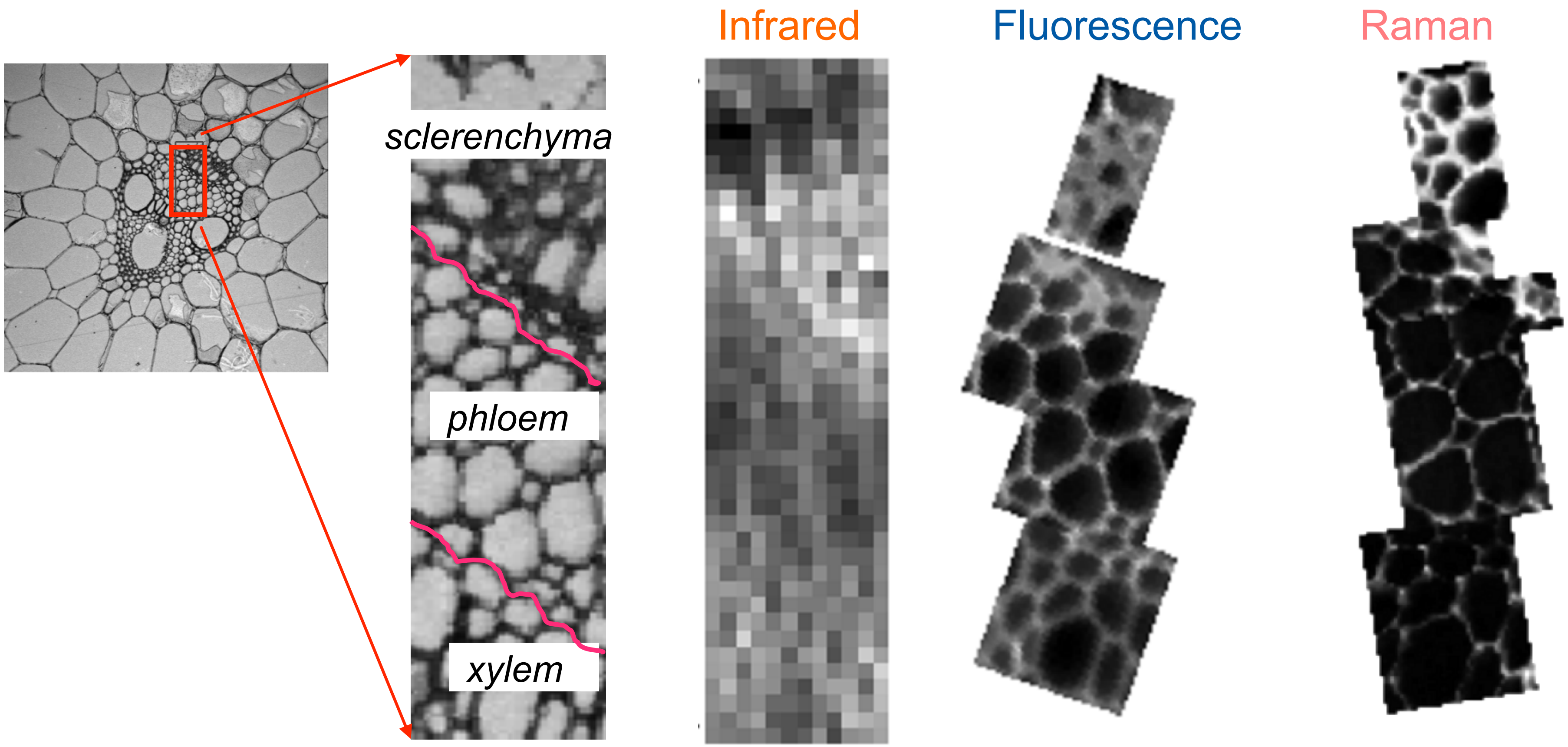
Deflation is performed on each stack of the three-way block



$$\mathbf{Y}_{j(z)}^{(h+1)} = \mathbf{Y}_{j(z)}^{(h)} - \mathbf{c}_{Y_{j(z)}}^{(h)}\mathbf{v}_j^{(h)'}$$

Comparing cell types in maize stem



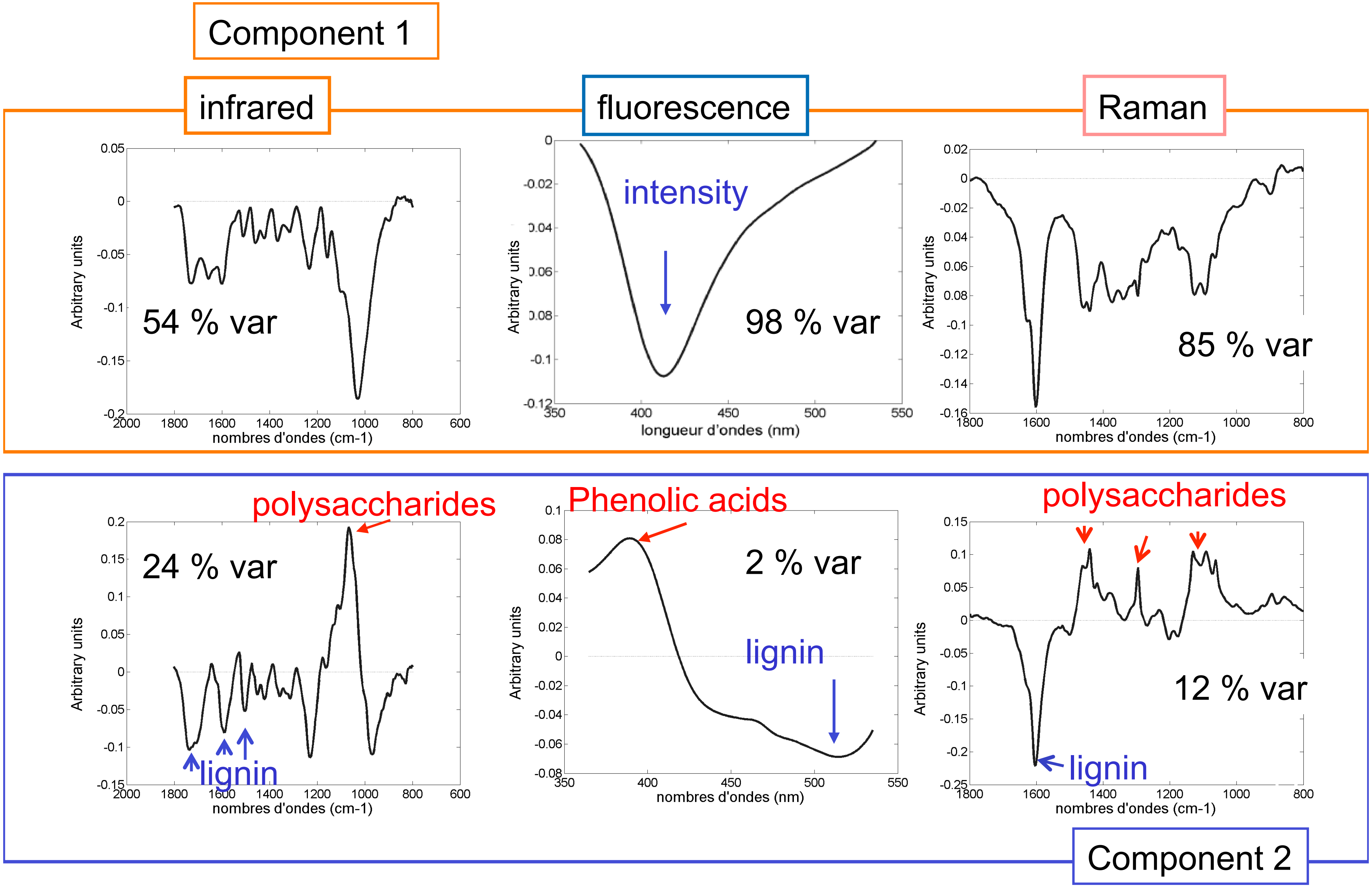


Registrated images

Images of the spectral area between:

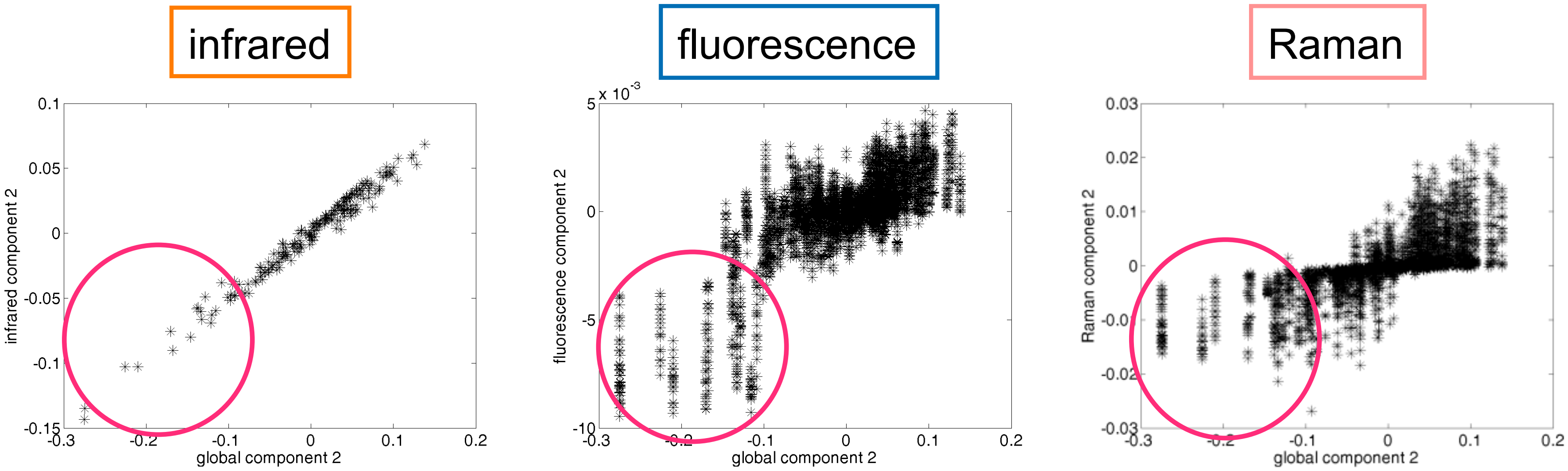
	Infrared	Fluorescence	Raman
	1200-950 cm^{-1}	*360-540 nm*	*1800-800 cm^{-1}*
Spatial resolution	5 µm	1 µm	1 µm

Trilinear Multiple Co-inertia Analysis: maize stem loadings



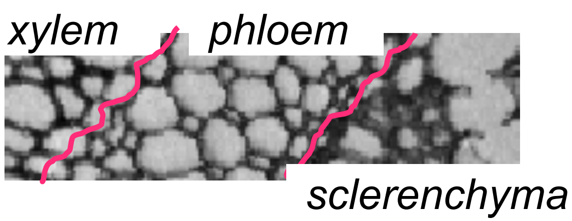
Trilinear Multiple Co-inertia Analysis: maize stem
Global and Block components

Component 2 : lignin / polysaccharides + phenolic acid



Segmented image: $\mathbf{c_g} < -0.1$ → lignin

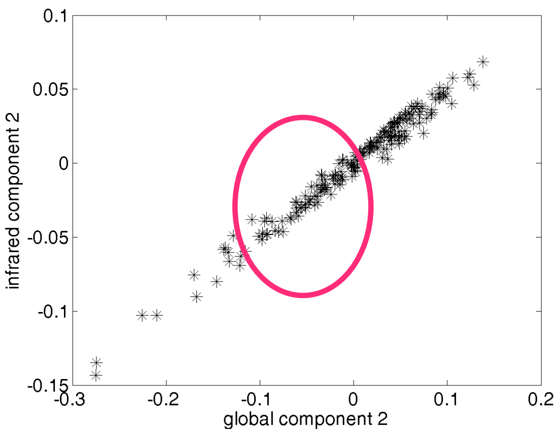
sclerenchyma



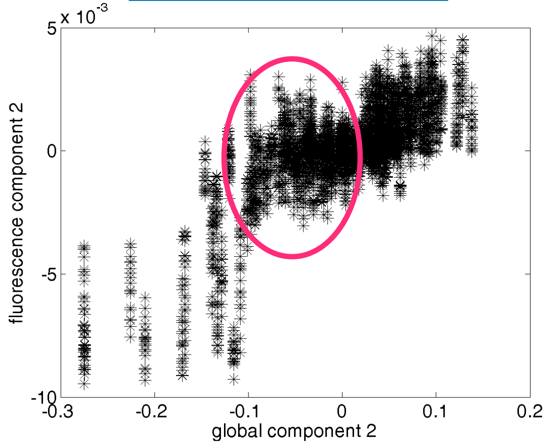
Trilinear Multiple Co-inertia Analysis: maize stem
Global and Block components

Component 2 : lignin / polysaccharides + phenolic acid

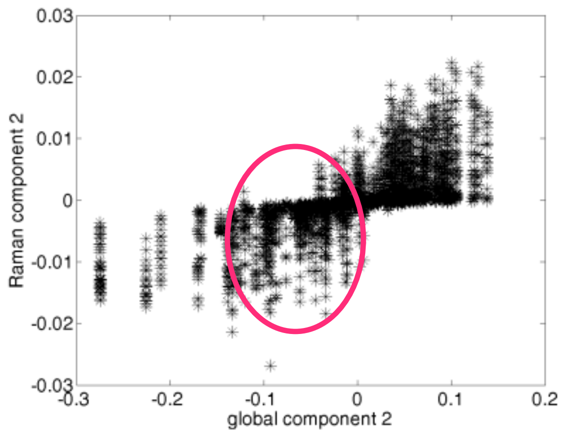
infrared



fluorescence

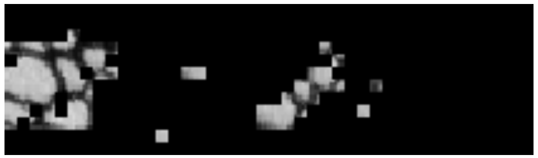


Raman

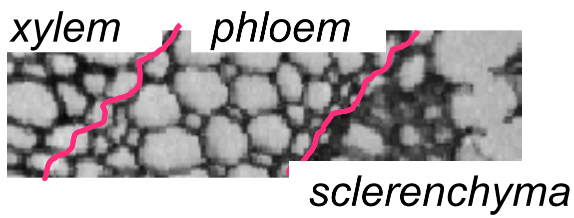


Segmented image: $-0.1 < \mathbf{c_g} < 0$ → lignin + phenolic acids

sclerenchyma



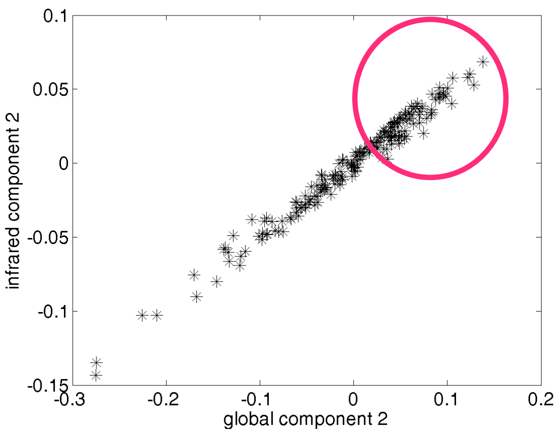
xylem



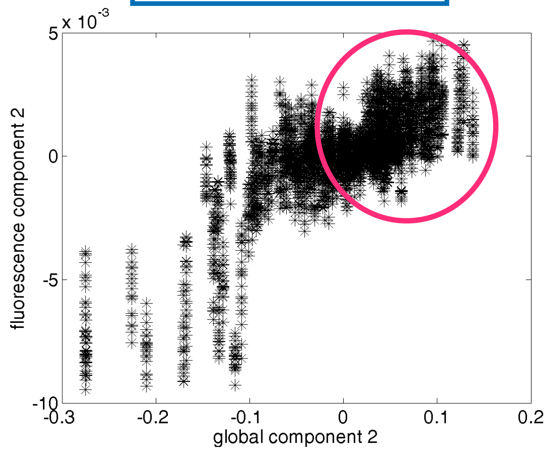
Trilinear Multiple Co-inertia Analysis: maize stem
Global and Block components

Component 2 : lignin / polysaccharides + phenolic acid

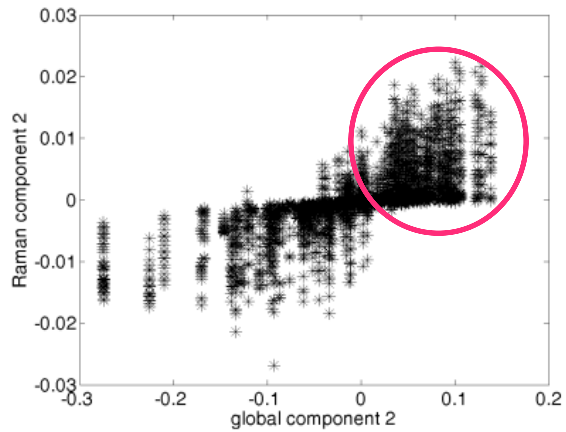
infrared



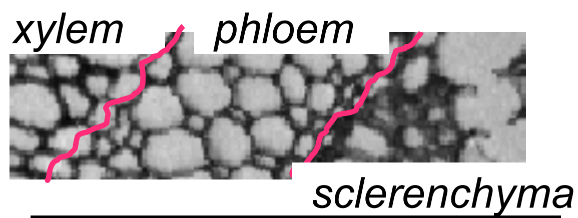
fluorescence



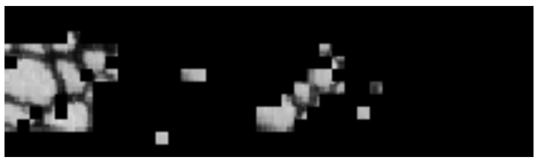
Raman



Segmented image: $c_g > 0$ → phenolic acids + polysaccharides



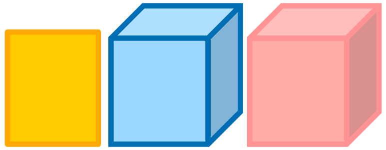
sclerenchyma



xylem

phloem

Conclusion



Designing data blocks that preserve spatial resolution

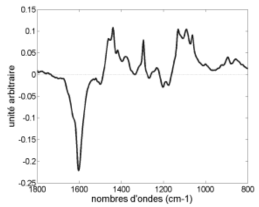
Extension of Multiple Co-inertia Analysis to data tables with an heterogeneous number of way.

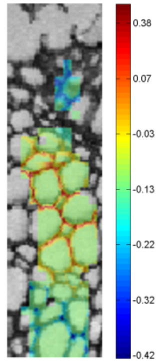
Application to hyperspectral images

Loadings for spectral interpretation

Component images for spatial analysis:

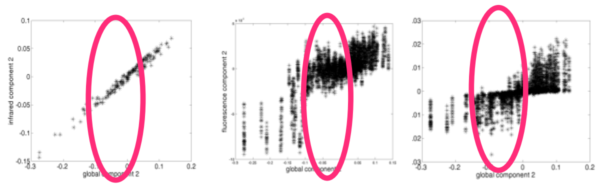
Maize stem: comparing cell types.



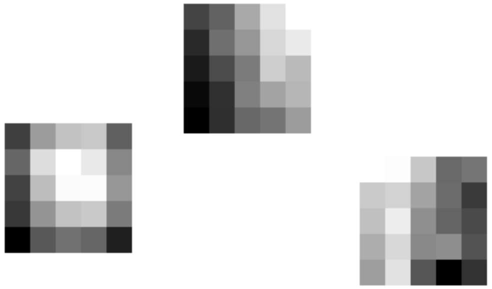


Complementarity and common information

Global and Block component



Perspectives



- Hyperspectral images: what about the third way?

  Spatial interpretation of the α weight vectors

- Testing other multiblock techniques:

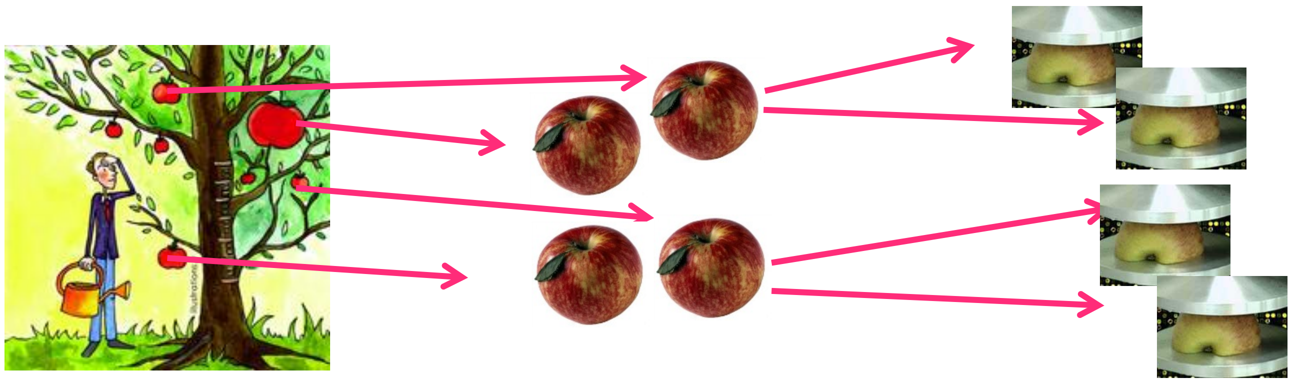
  deflation, spectral decomposition: MCR, ICA ????

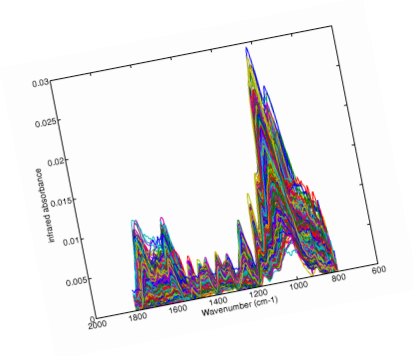
- Including other spectral images:

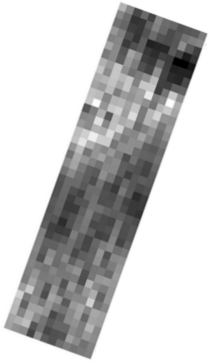
  Confocale microscopy, RX, MALDI…

- Generic approach: can be applied in any multiscale context.

  anytime a vector can be paired to a set of vector

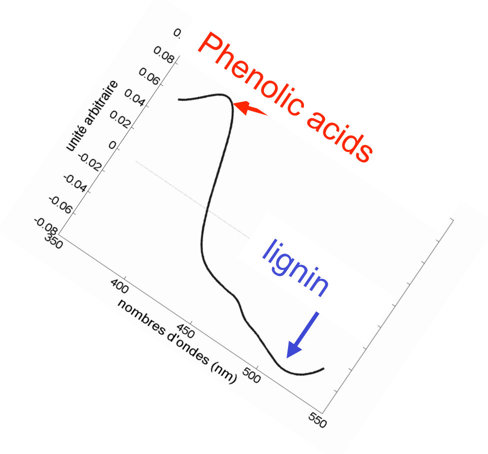






$$c_{X_k} = X_k u_k \qquad c_{Y_{j(z)}} = Y_{j(z)} v_j$$

$$Max \sum cov^2(c_{X_k}, c_g) + \sum\sum cov^2(c_{Y_{j(z)}}, c_g)$$



Thank you for your attention !