Multibloc analysis of multimodal and multiresolution hyperspectral images
Application to plant cell wall analysis

bia
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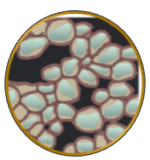
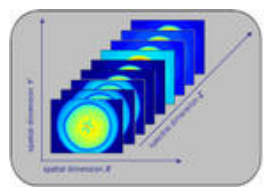
F Jamme





DISCO

Parois Végétales & Polysaccharides Pariétaux

Sensométrie & Chimiométrie

Dichroisme, Imagerie, Spectrométrie de masse pour la Chimie et la Biologie

PhD Fatma Allouche: 2009-2012

Plant cell wall

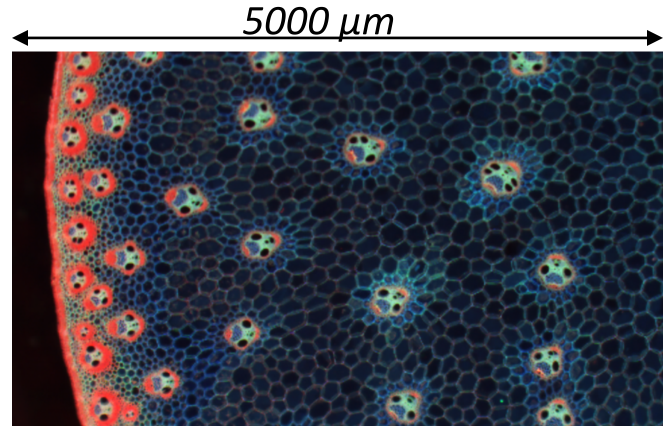
Chemical composition

Major constituents are complex polymers

- Carbohydrates
- Lignins
- Proteins
- Lipids

Constituents are organised….

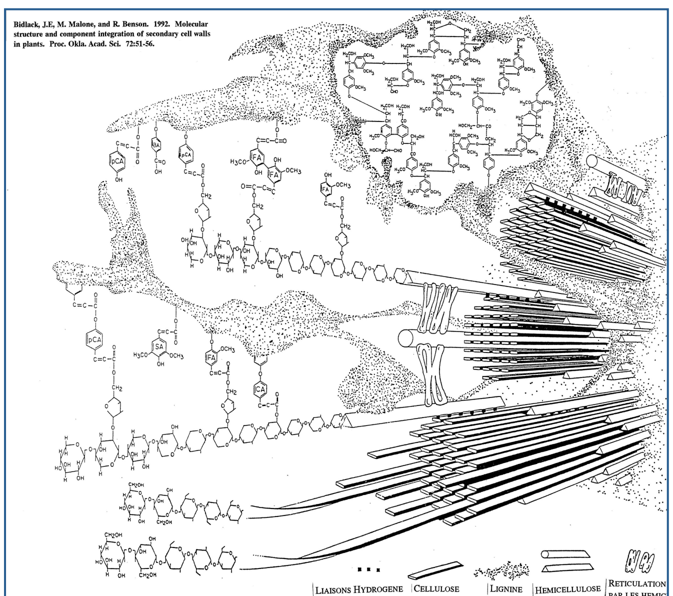
In the plant



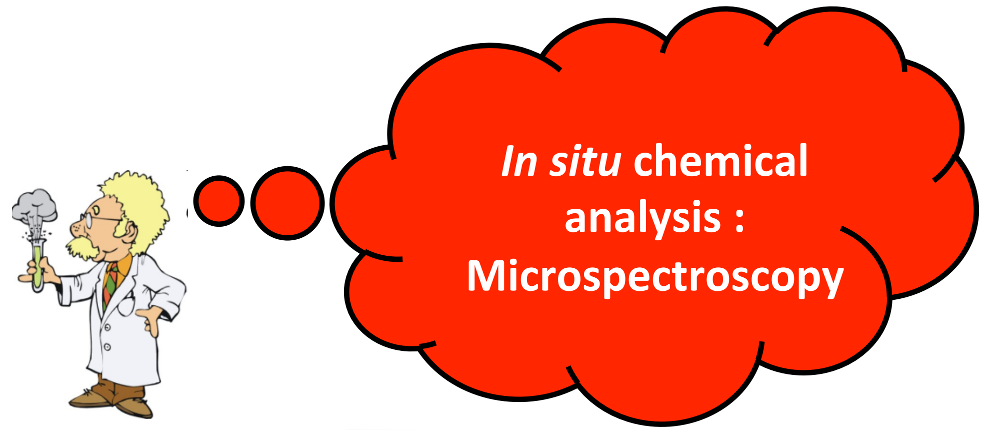
Maize stem

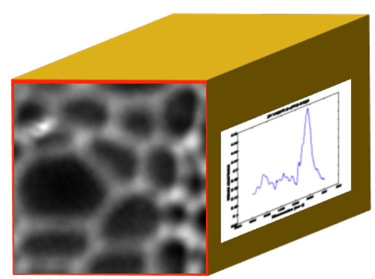
Autofluorescence:
false color, Blue and UV fluorescence

In the wall



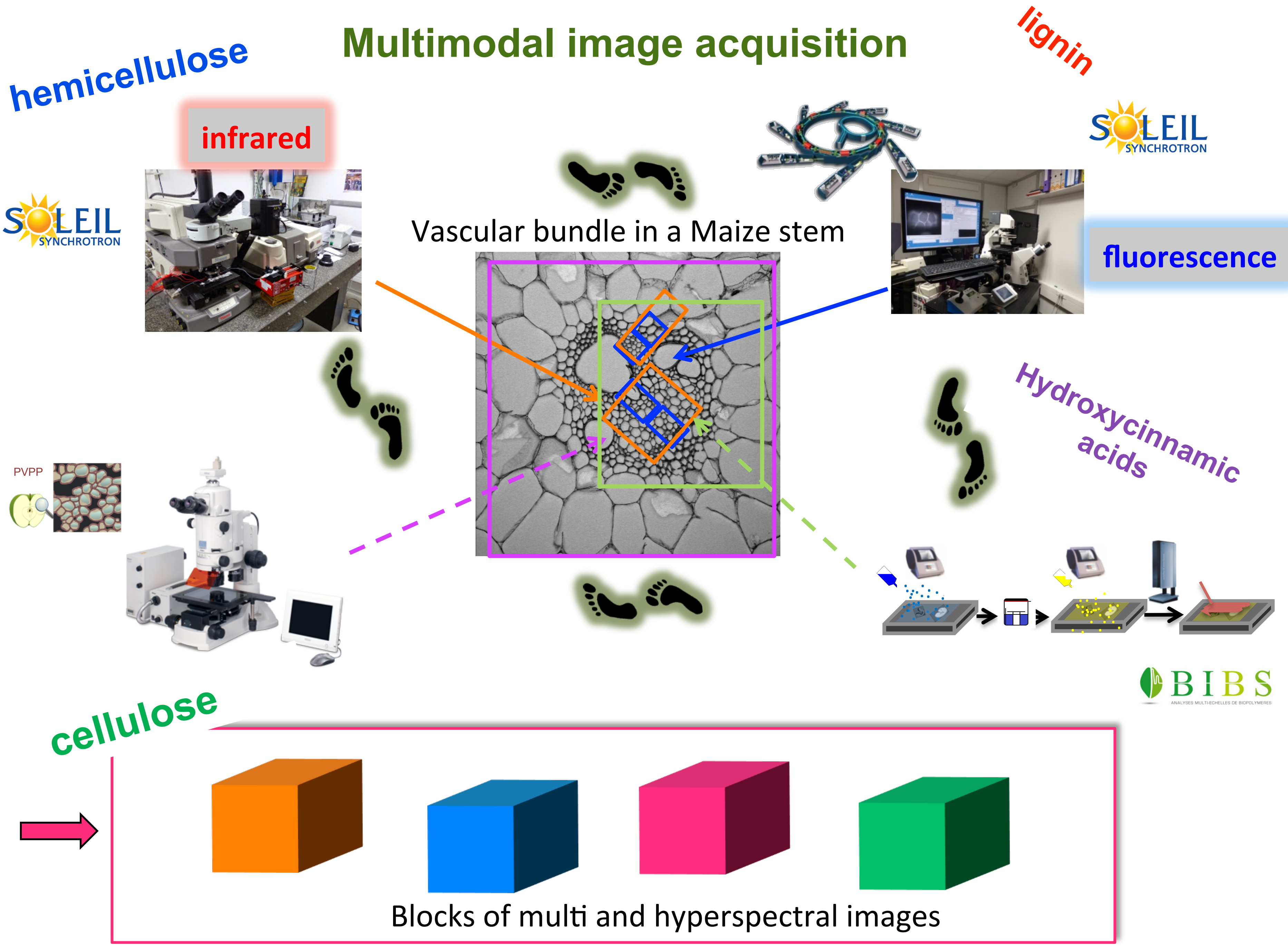
Bidlack et al., 1992



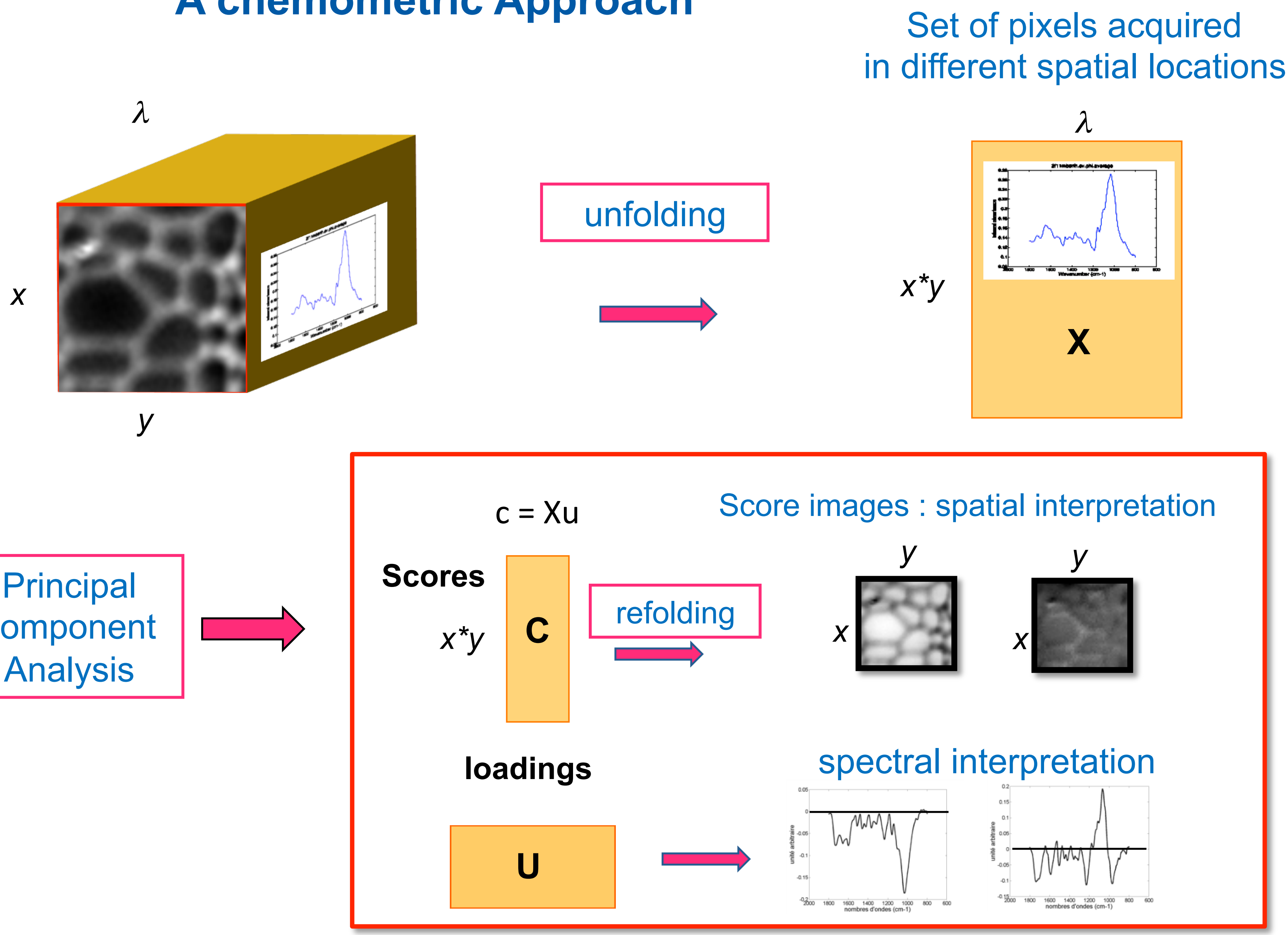


hyperspectral images

Multimodal image acquisition

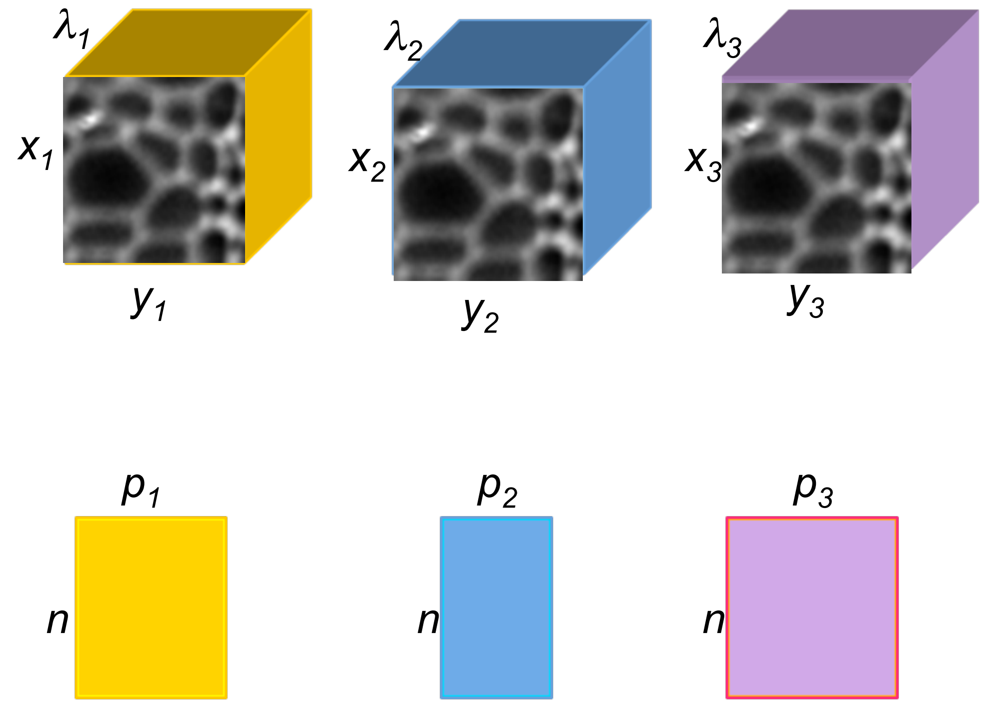


Multi and Hyperspectral Image Analysis
A chemometric Approach



Multimodal spectral images : Multiblock Data Analysis

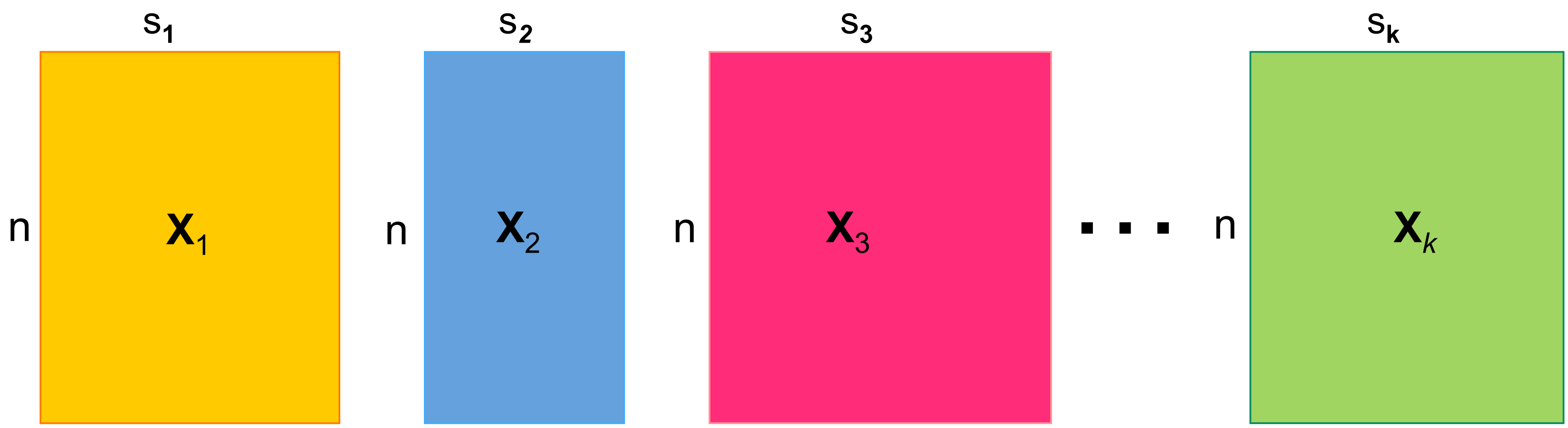
Coupling different hyperspectral images



Joint analysis
of different blocks of data

Parafac, Tucker, Multiple Co-inertia Analysis
N-way Partial Least Square, Multiset Multivariate Curve resolution,

Multiblock analysis: multiple co-inertia analysis

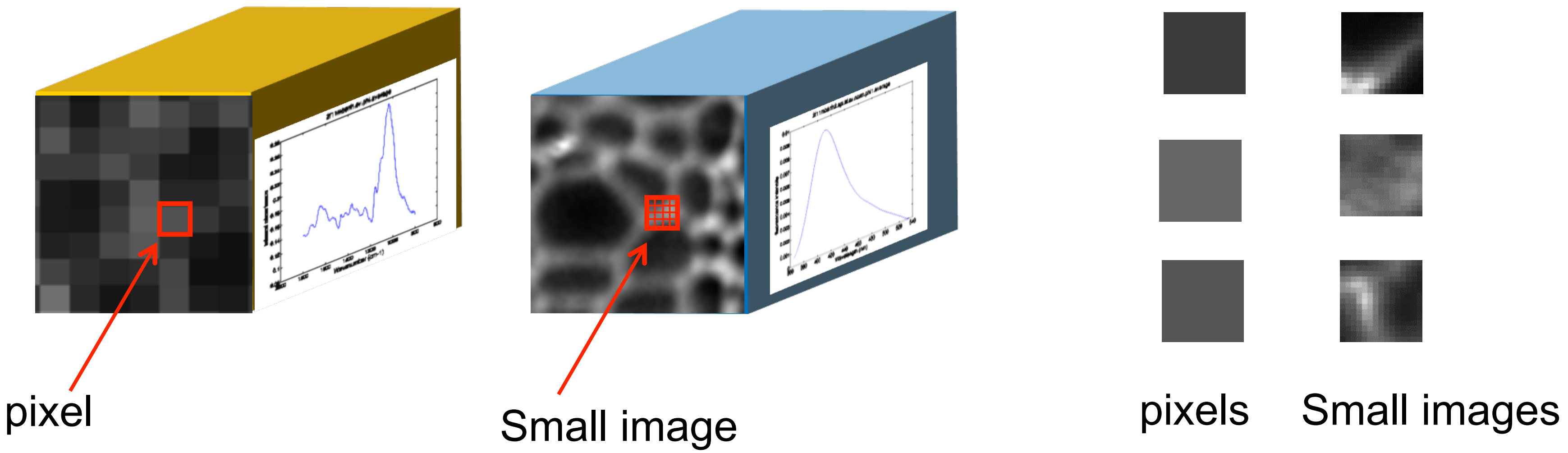


block component → $c_{X_k} = X_k u_k$ ← loadings

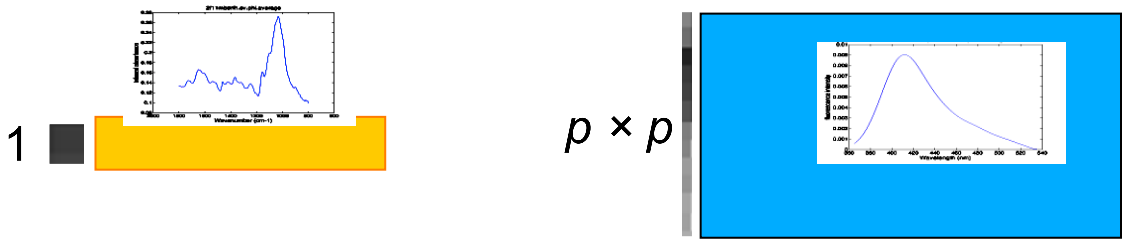
Maximise $\sum_{k=1}^{K} \mathrm{cov}^2(\mathbf{c}_{X_k}, \mathrm{c}_g)$ ← global component

Chessel, Hanafi, 1993

Blocks of hyperspectral images with different spatial resolution



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

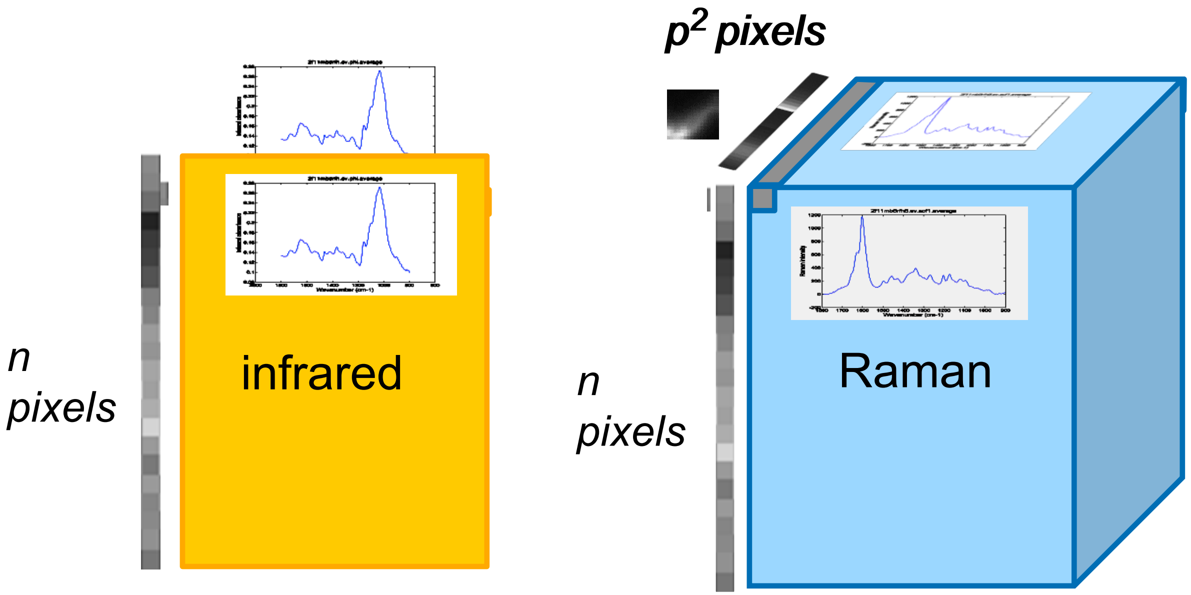


Unfolding small images

Pairing multiresolution pixels

Blocks of hyperspectral images with different spatial resolution

paired data structure

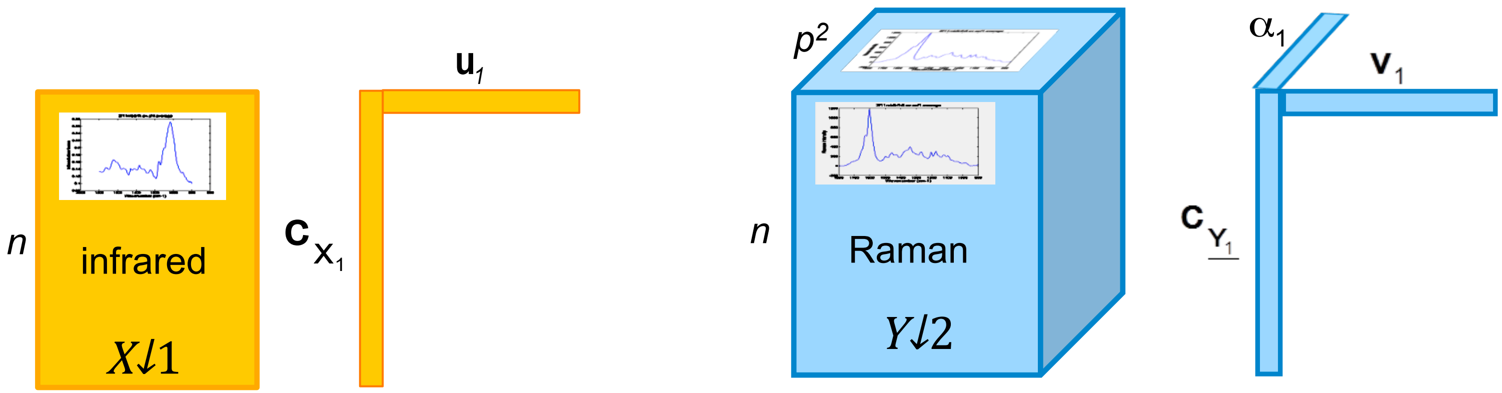


How can we envision multiblock data analysis while preserving the full resolution of data tables

?

Extension of Multiple Co-inertia Analysis….

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



bilinear decomposition of 2-way data tables

trilinear decomposition of 3-way data tables

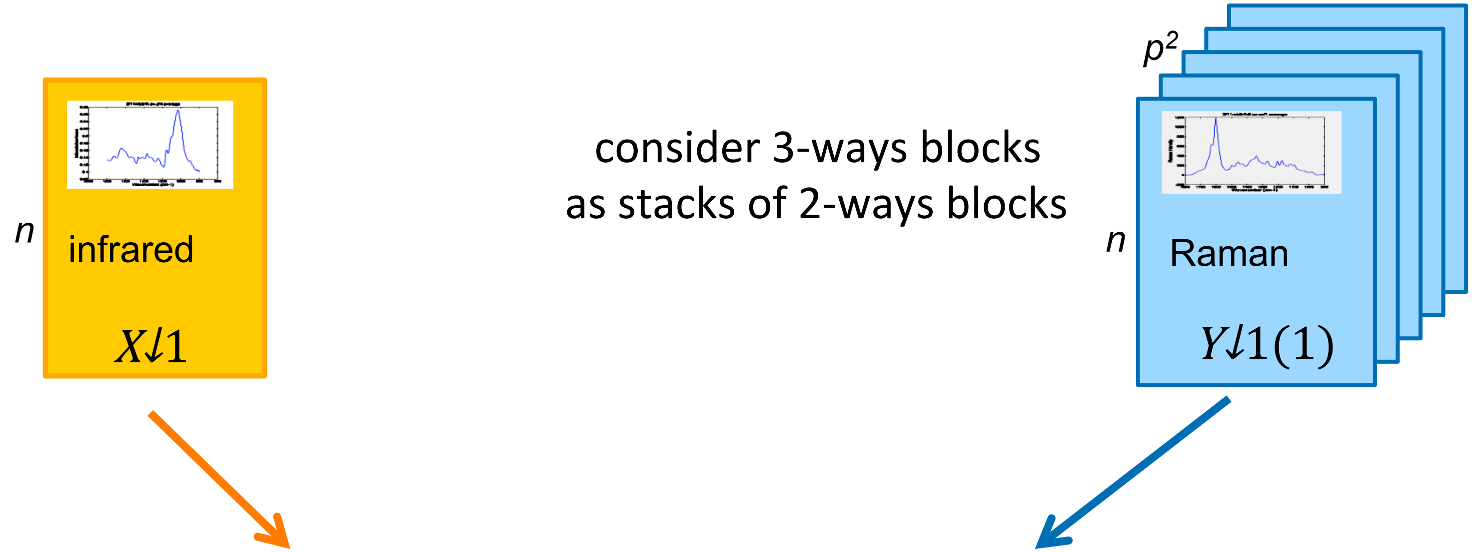
Assessing global and block components

global component

$$\text{Max} \quad \text{cov}^2(\mathbf{c}_{X_k}, c_g) + \text{cov}^2(\mathbf{c}_{\underline{Y}_i}, c_g)$$

Trilinear Multiple Co-inertia Analysis

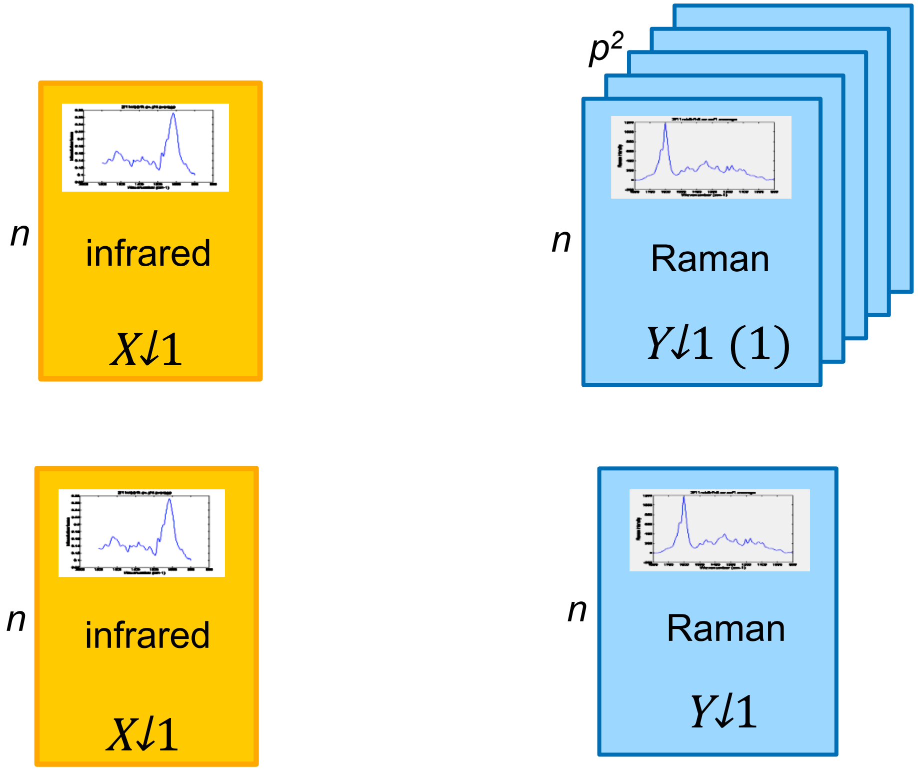
Assessing global and block components



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

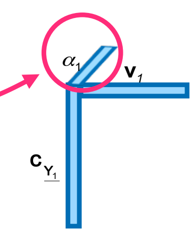
$$\mathrm{cov}^2(\mathbf{c}_{\mathrm{X}_k}, \mathbf{c}_{\mathrm{g}}) + \sum \mathrm{cov}^2(\mathbf{c}_{\mathrm{Y}_{j(z)}}, \mathbf{c}_{\mathrm{g}})$$

Trilinear Multiple Co-inertia Analysis

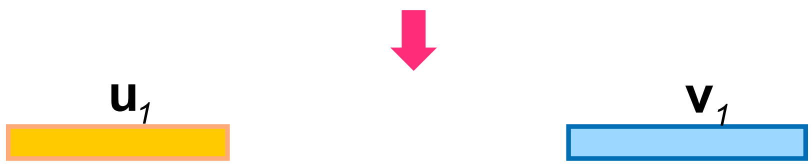


Assessing a weighted sum of block stacks

$$\overline{\mathbf{Y}}_j = \sum_z \alpha_{j(z)} \times \mathbf{Y}_{j(z)}$$

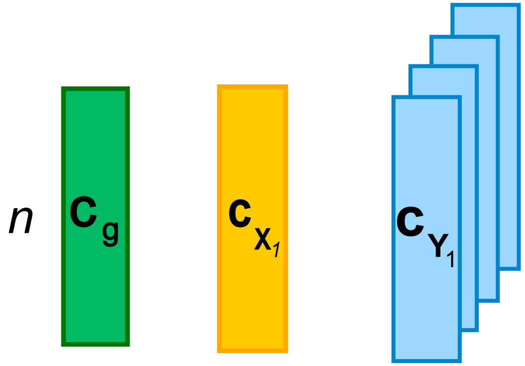


Multiple Co-inertia Analysis of the “weighted sum” data tables

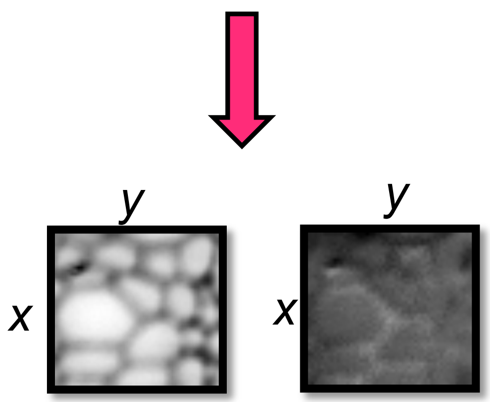


Loadings

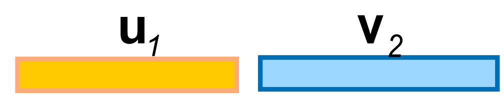
Trilinear Multiple Co-inertia Analysis: results



Global and block component

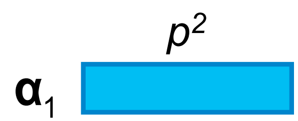


Spatial interpretation



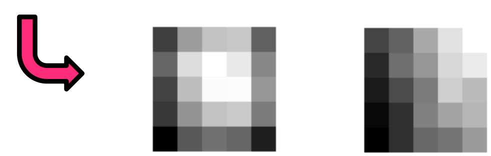
Loadings

Spectral interpretation



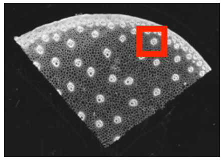
Weight vector

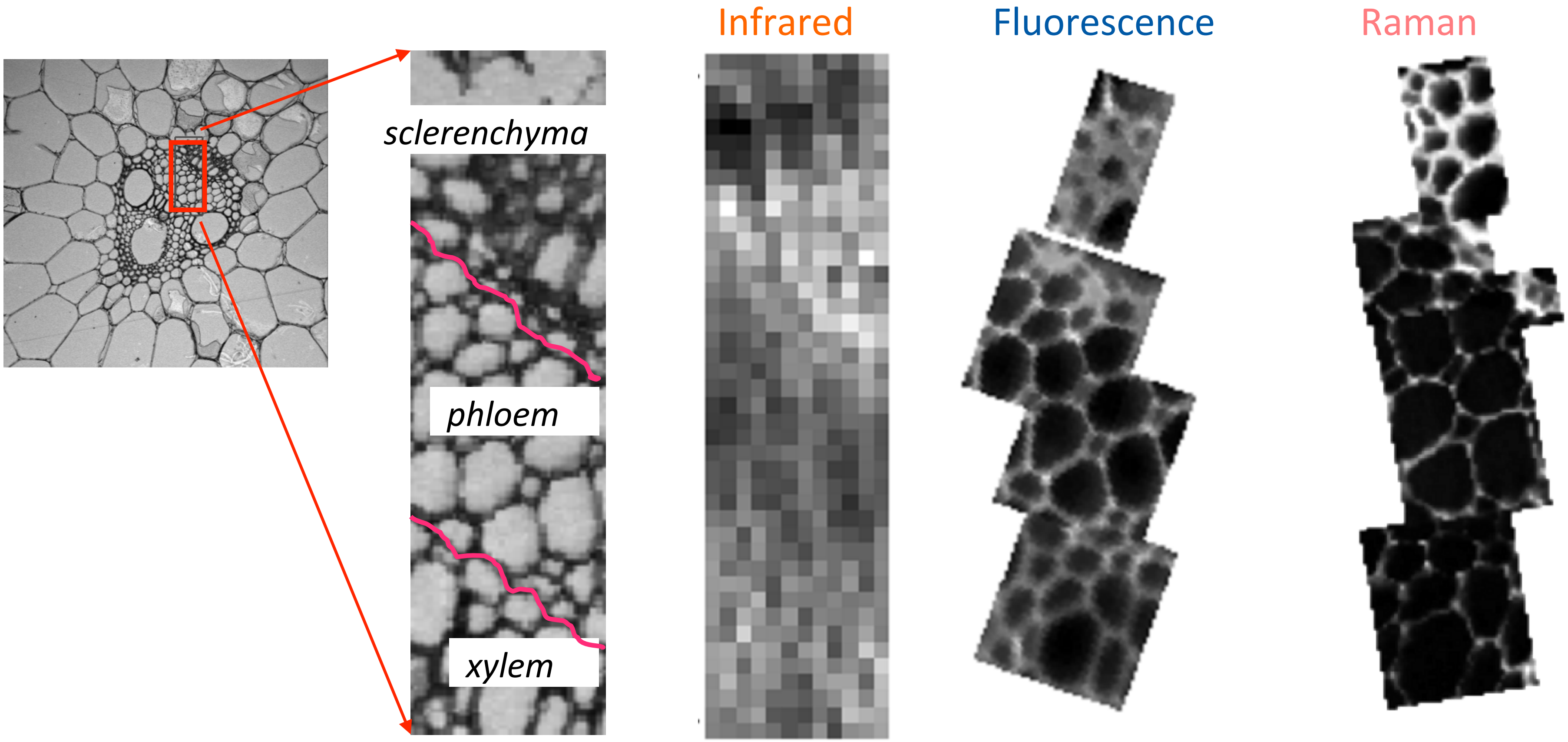
Refolding



Spatial interpretation

Comparing cell types in maize stem





Registrated images

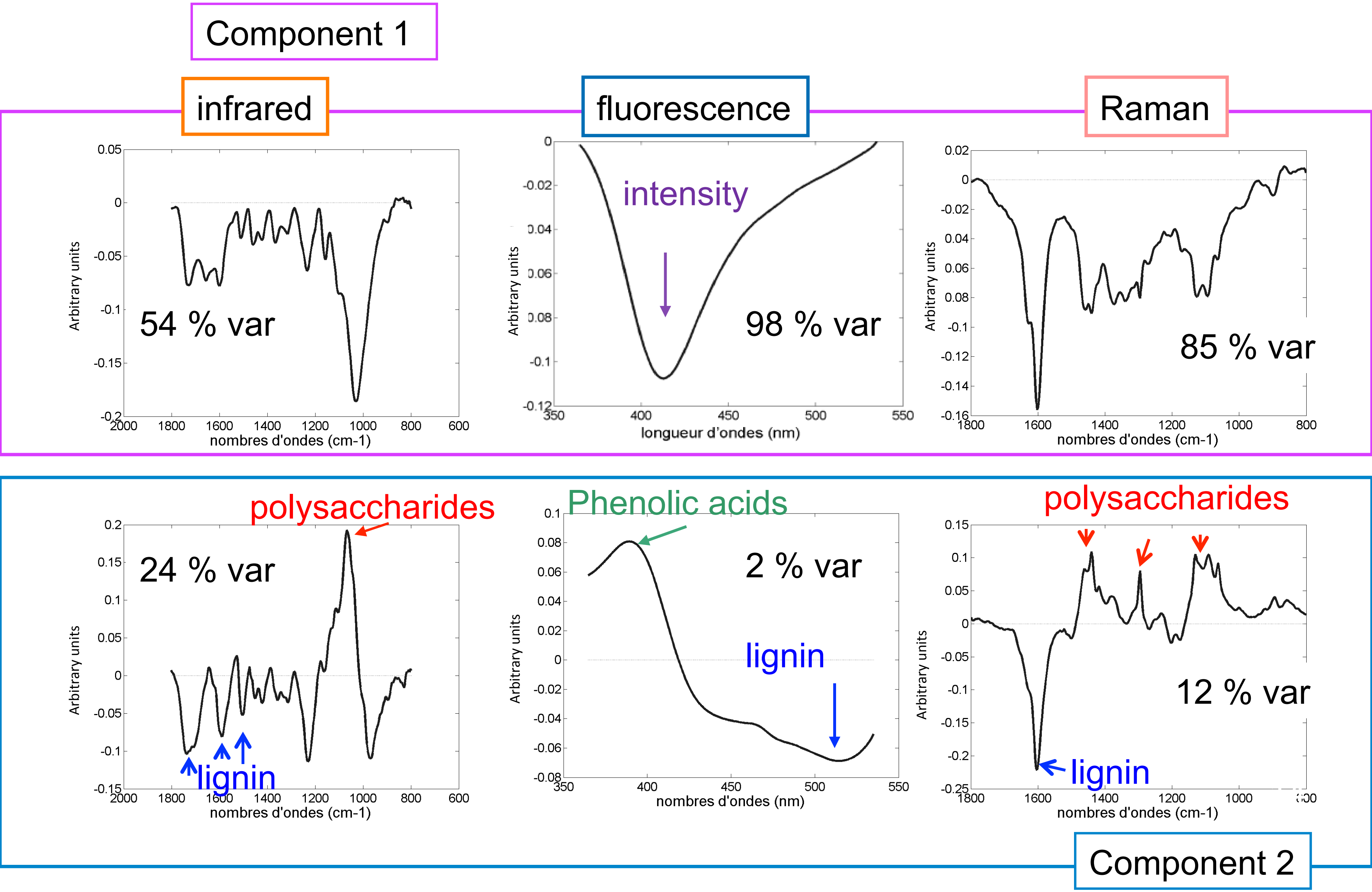
Images of the spectral area between:

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

Spatial resolution

	Infrared	Fluorescence	Raman
Spatial resolution	5 µm	1 µm	1 µm

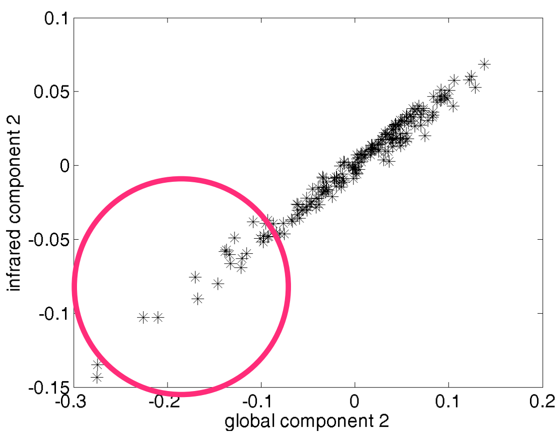
Trilinear Multiple Co-inertia Analysis: maize stem loadings



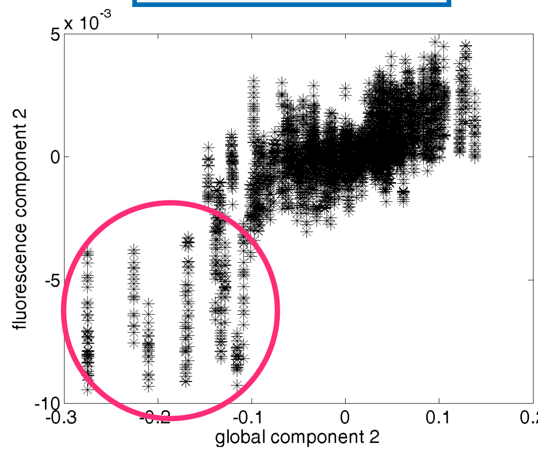
Trilinear Multiple Co-inertia Analysis: maize stem
Global and Block components

Component 2 : lignin / polysaccharides + phenolic acid

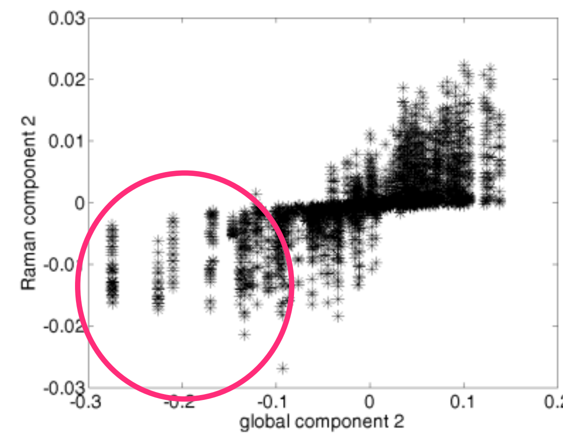
infrared



fluorescence

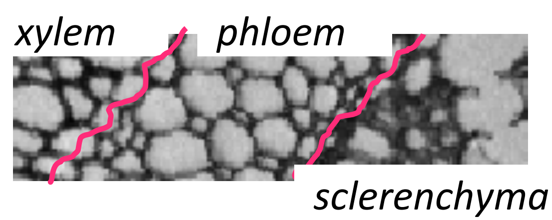


Raman



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

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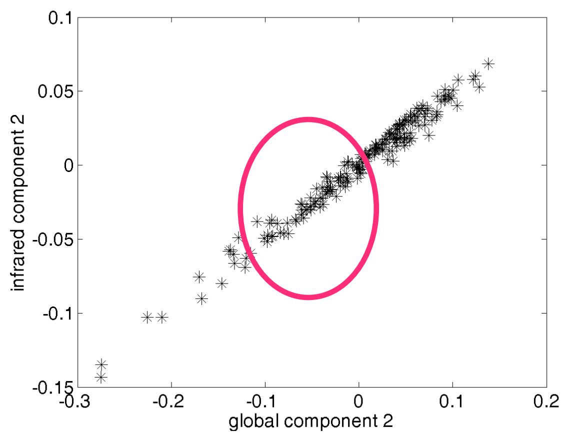
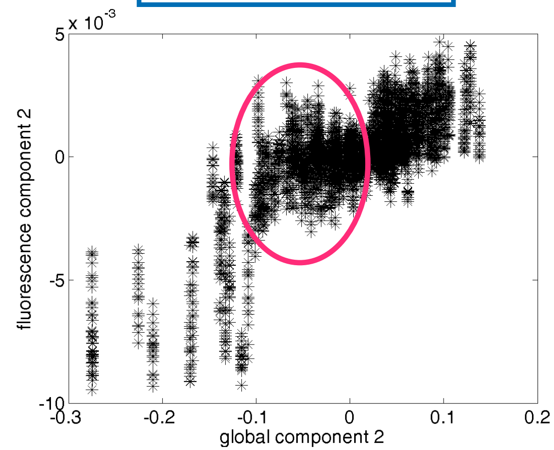
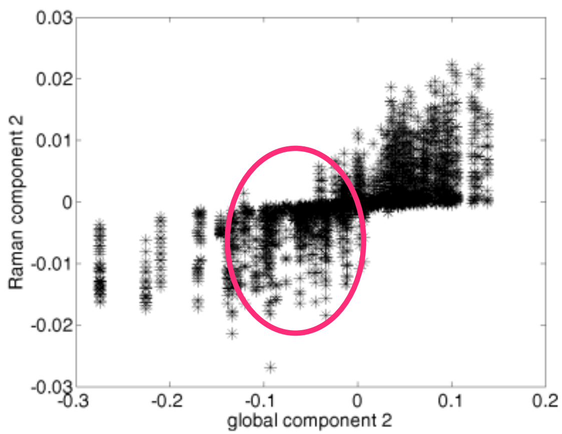


fluorescence

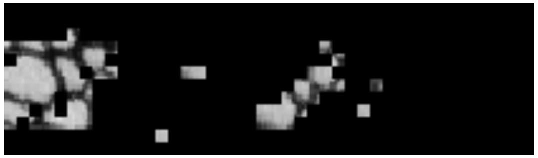


Raman

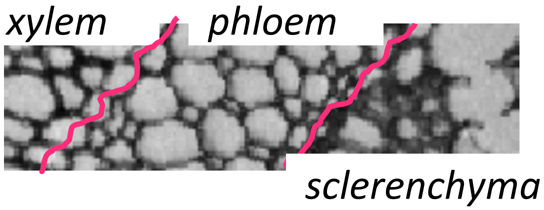


Segmented image: $-0.1 < \mathbf{c_g} < 0$ → lignin + phenolic acids

sclerenchyma



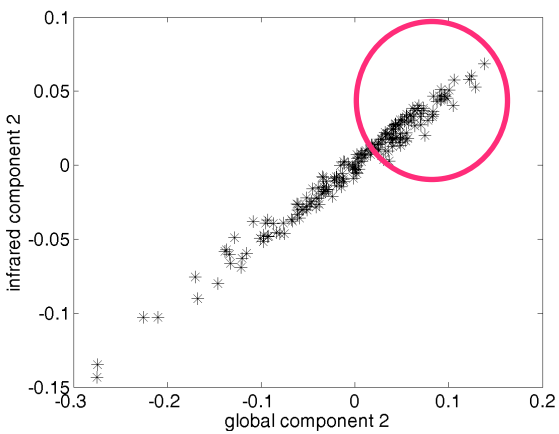
xylem



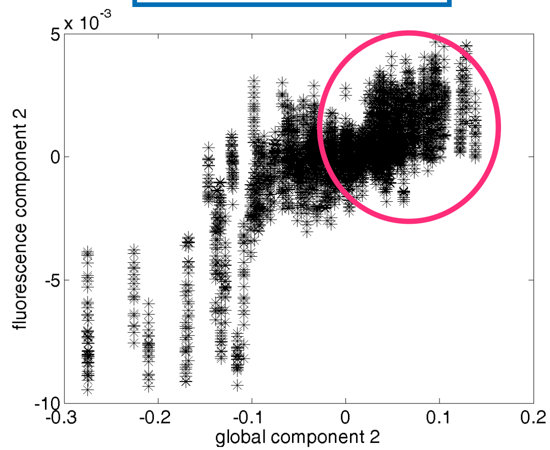
Trilinear Multiple Co-inertia Analysis: maize stem
Global and Block components

Component 2 : lignin / polysaccharides + phenolic acid

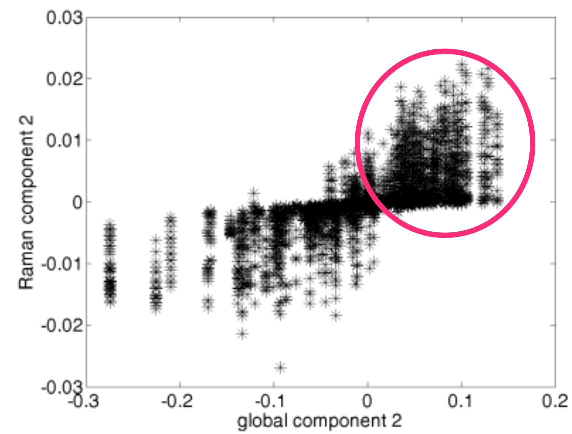
infrared



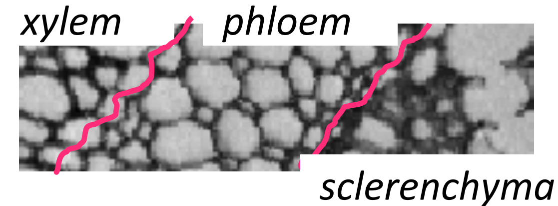
fluorescence



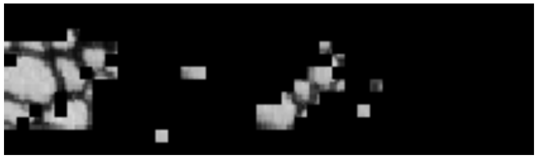
Raman



Segmented image: $\mathbf{c_g} > 0$ → phenolic acids + polysaccharides



sclerenchyma



xylem

phloem

Conclusion

Designing data blocks that preserve spatial resolution

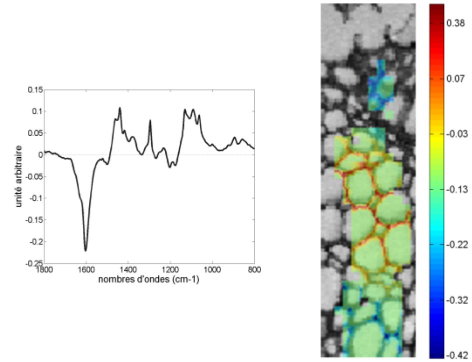
Extension of Multiple Co-inertia Analysis to data tables with an heterogeneous number of way.

Application to hyperspectral images

Loadings for spectral interpretation

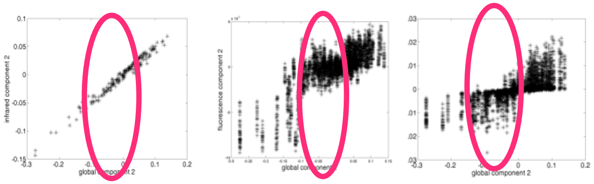
Component images for spatial analysis:

Maize stem: comparing cell types.



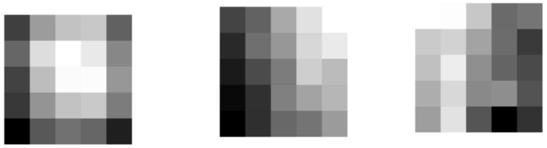
Complementarity and common information

Global and Block component

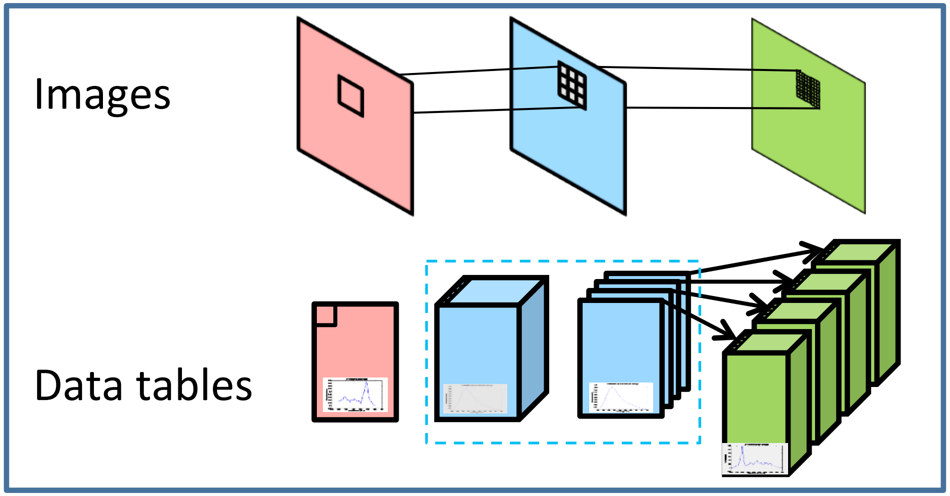


Perspectives

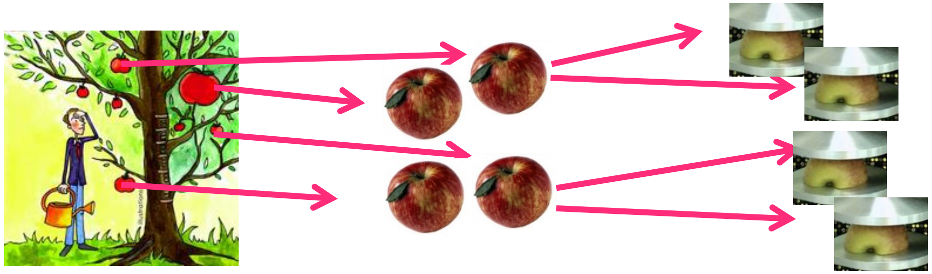
- Hyperspectral images: what about the third way?
  Spatial interpretation of the α weight vectors

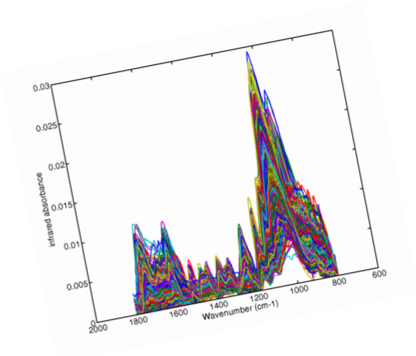


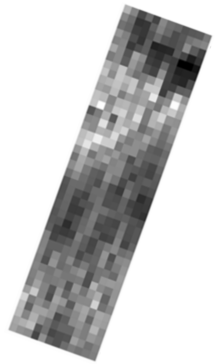
- With more than 2 spatial resolution



- Generic approach:
  multiscale context.
  anytime a vector can be
  paired to a set of vector

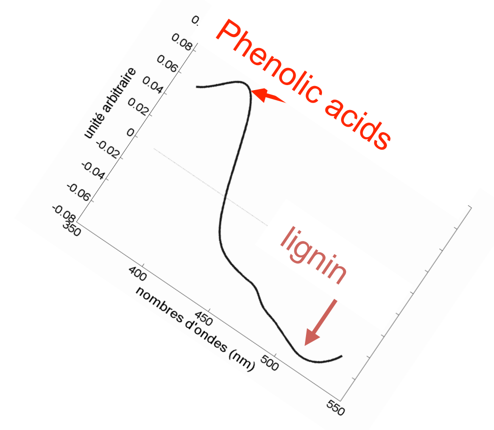




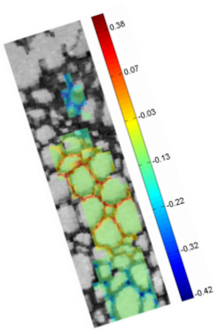


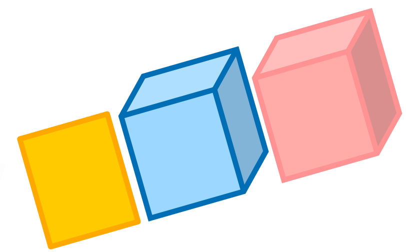
$$c_{X_k} = X_k u_k \qquad c_{Y_{j(z)}} = Y_{j(z)} v_j$$

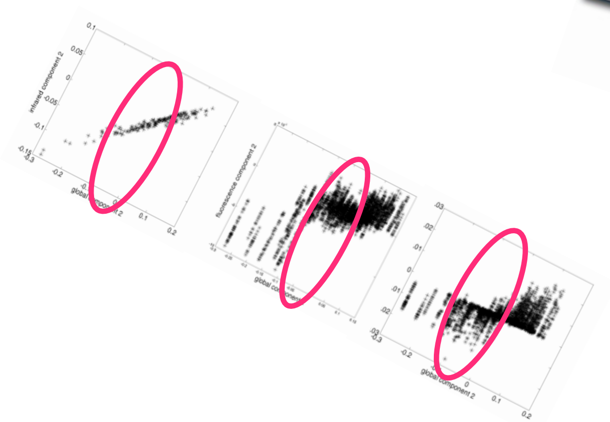
$$Max \sum cov^2(c_{X_k}, c_g) + \sum\sum cov^2(c_{Y_{j(z)}}, c_g)$$

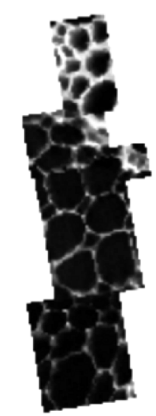


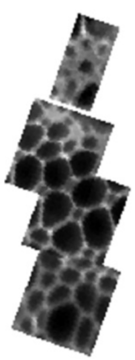
Thank you for your attention !

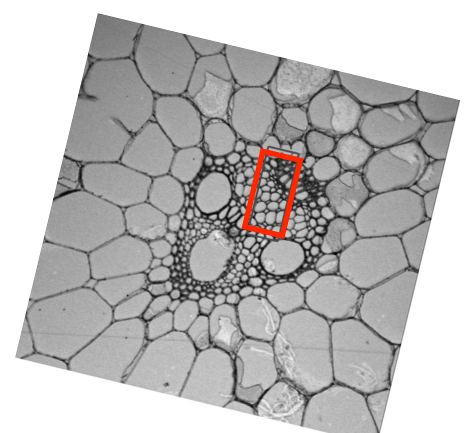




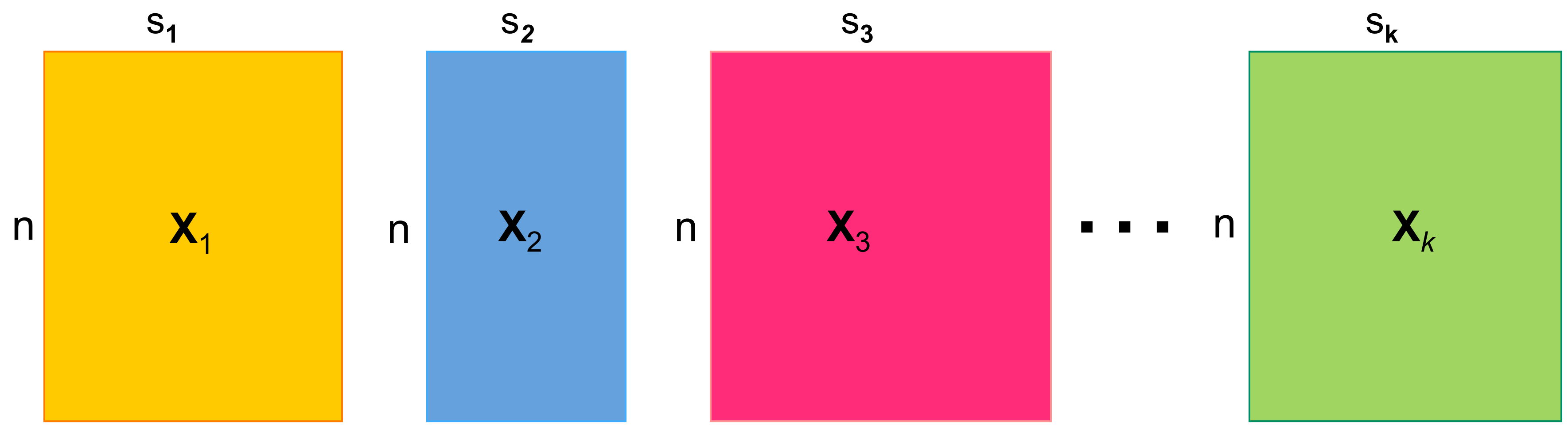








Multiblock analysis: multiple co-inertia analysis



block component → $c_{X_k} = X_k u_k$ ← loadings

Maximise $\sum_{k=1}^{K} \text{cov}^2(\mathbf{c}_{X_k}, c_g)$ ← global component

Deflation : $X_k^{(h)} = X_k^{(h-1)} - c_{X_k}^{(h-1)} u_k^{(h-1)\prime}$

⇩ subtract the information described in the block component

Chessel, Hanafi, 1993

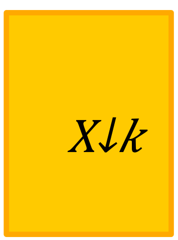
Trilinear Multiple Co-inertia Analysis: deflation

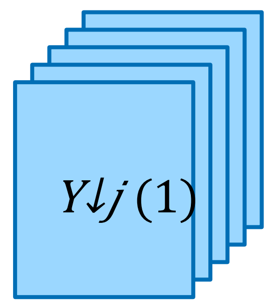
Next components, loadings and weight vectors are assessed after deflation

Deflation is performed to provide orthogonal loadings per block

$$X_k^{(h+1)} = X_k^{(h)} - c_{X_k}^{(h)} u_k^{(h)'}$$

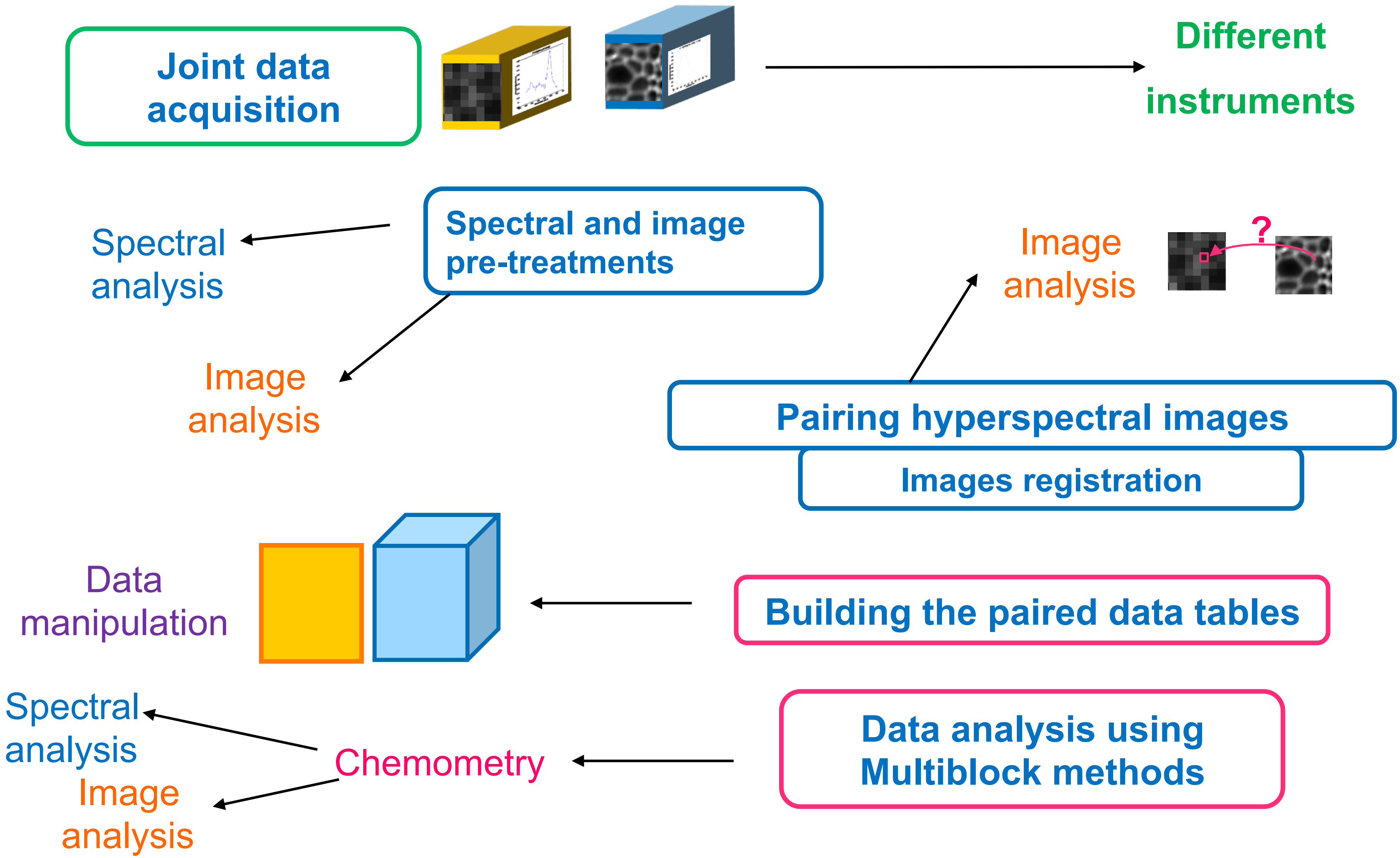
Deflation is performed on each stack of the three-way block





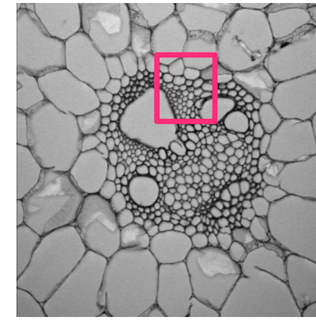
$$Y_{j(z)}^{(h+1)} = Y_{j(z)}^{(h)} - c_{Y_{j(z)}}^{(h)} v_j^{(h)'}$$

Coupling multimodal hyperspectral images
Multidisciplinary steps…



Demonstration of the whole chain of analysis: PhD thesis F Allouche 2009-2012

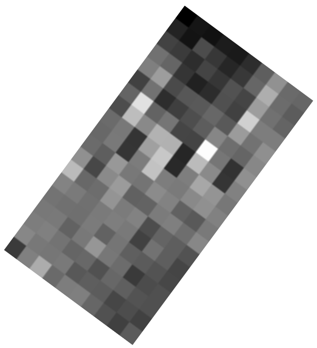
Définir une image de référence
Recaler, Fusionner ?



Reference image
(confocal-brightfield)

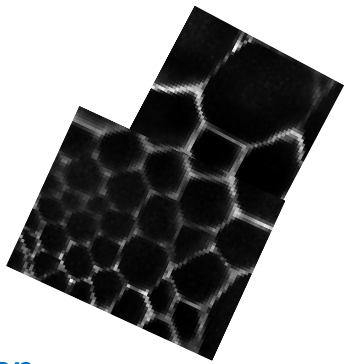
Définir une image de référence…

Sum of intensities



Infrared

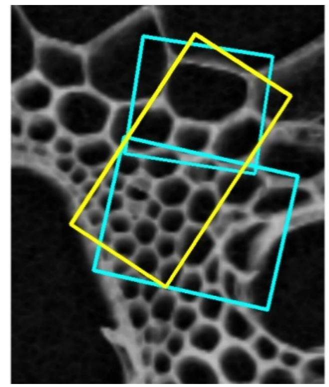
Pixel size
5 µm



Raman

Pixel size
1 µm

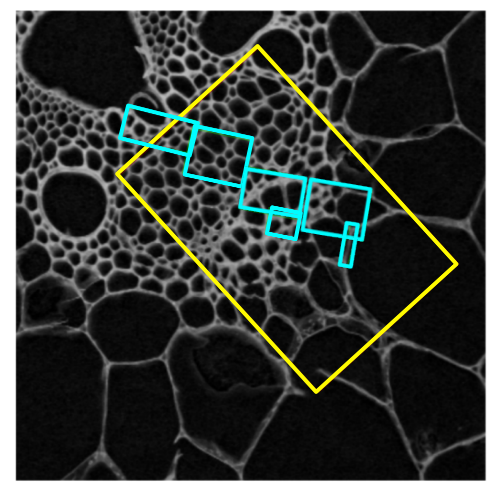
Reference image inverted



Registered image

Dataset 1

Dataset 2



Trilinear Multiple Co-inertia Analysis: algorithm

Initialisation :

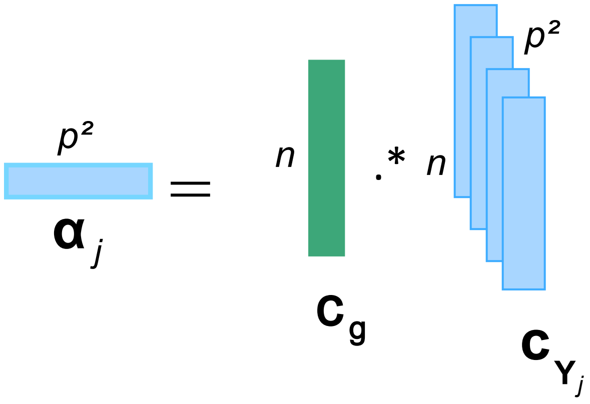
- Start with random α weight vector with $||\alpha||=1$

Iteration :

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

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

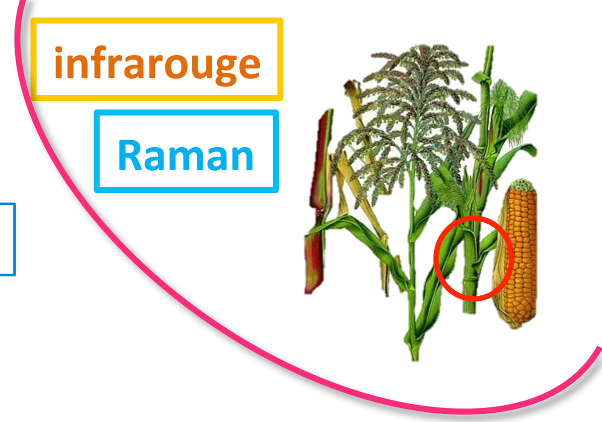
- Normalise weight vector: $||\alpha||=1$

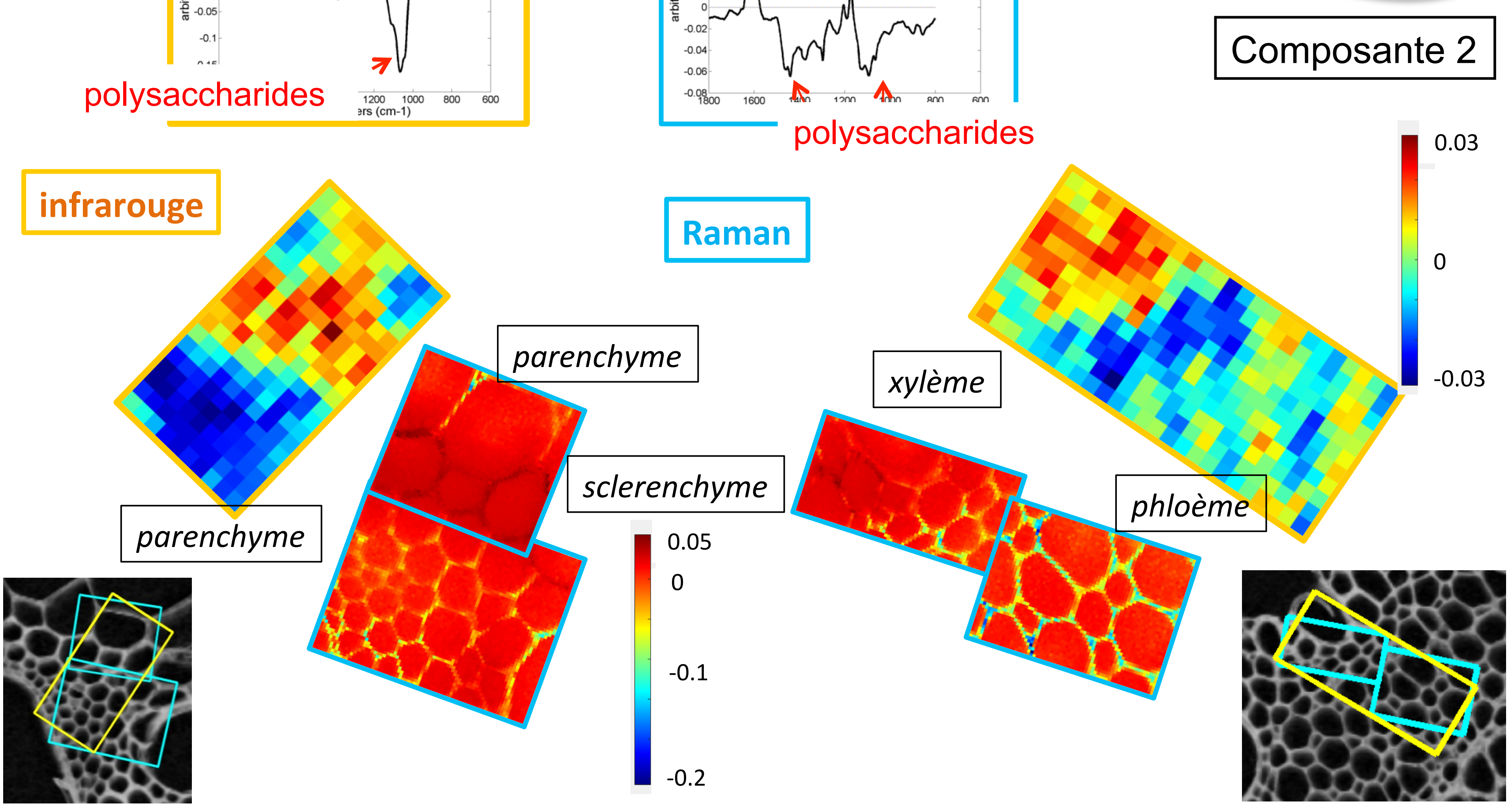


Convergence :

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

Analyse Trilinéaire en Co-inertie Multiple
section de tige de maïs



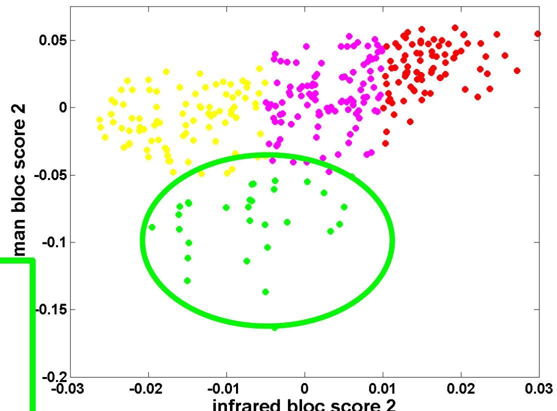


Analyse Trilinéaire en Co-inertie Multiple

composante 2: lignin / polysaccharides

IR 5 µm / Raman 1µm

Dataset 1



Raman région non correlée

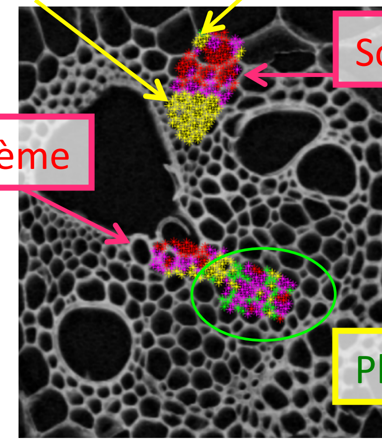
parenchyme du Xylème

parenchyme

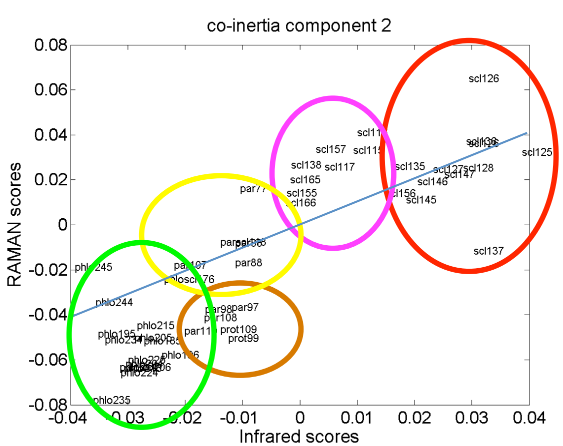
Sclerenchyme

Fibre de Xylème

Phloeme



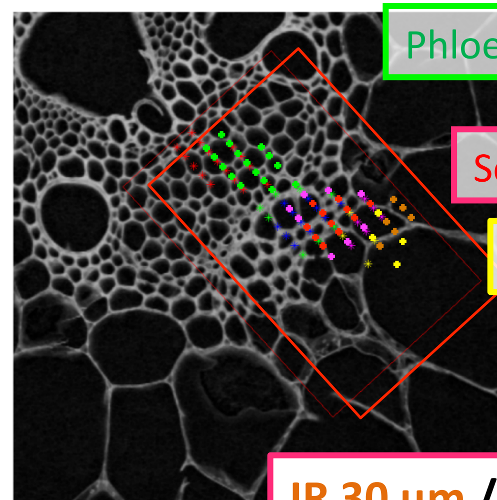
Dataset 2



Phloeme

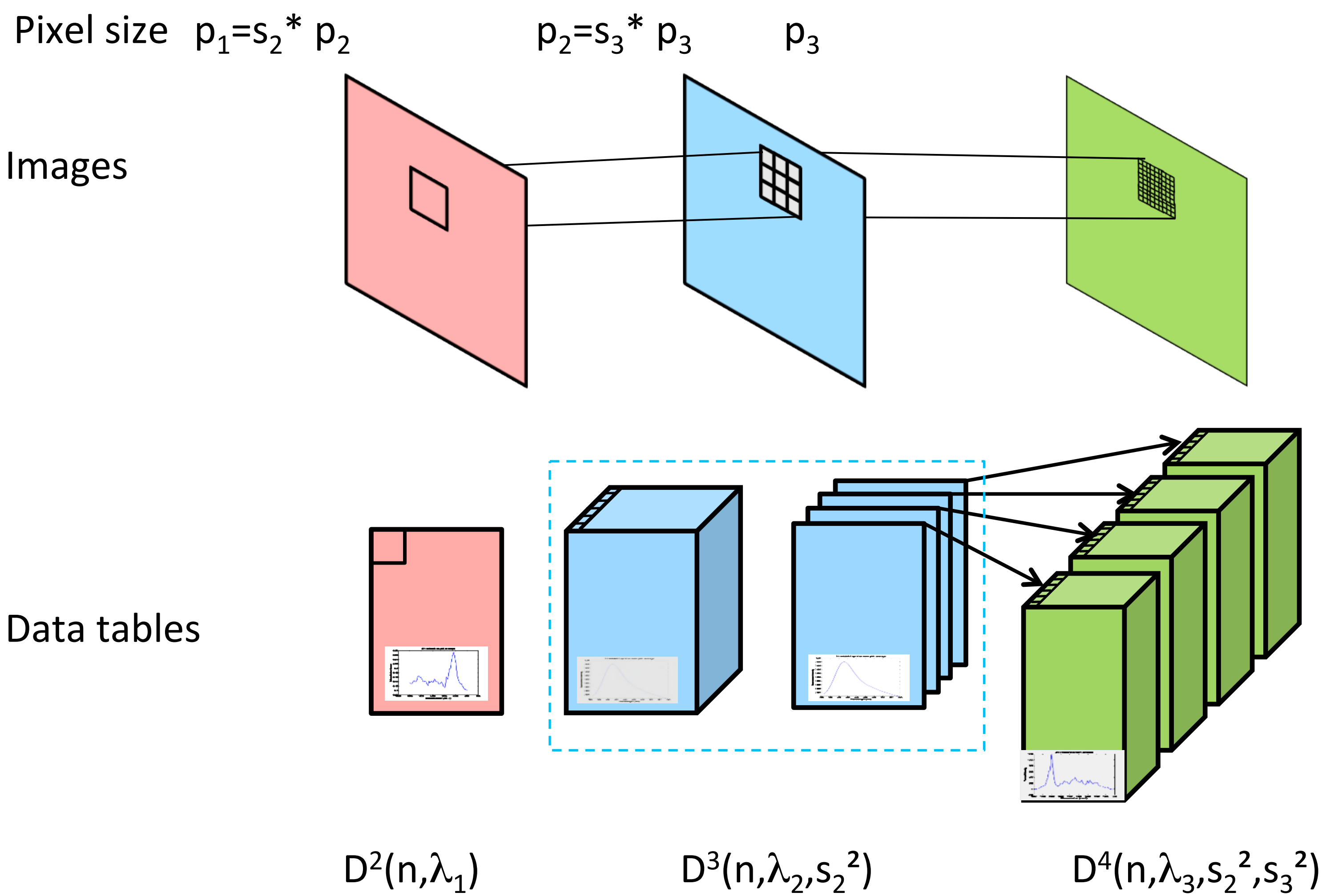
Sclerenchyme

parenchyme



IR 30 µm /Raman 1 µm

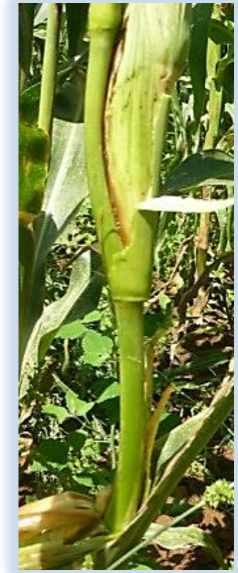
Data structure
Multiresolution hyperspectral images / Multiresolution data tables



Unfolding small images leads to multiresolution data tables

=> multiway data tables with heterogeneous numbers of way

Plant cell wall

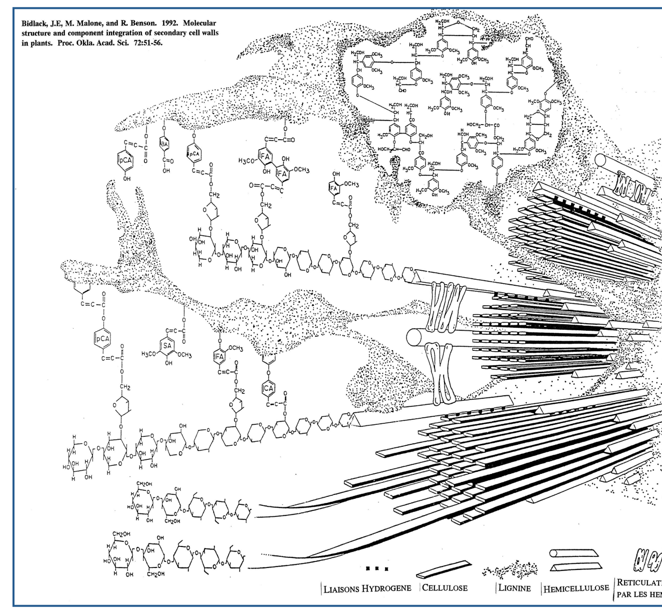


Chemical composition

Major constituents are complex polymers

- Carbohydrates
- Lignins
- Proteins
- Lipids

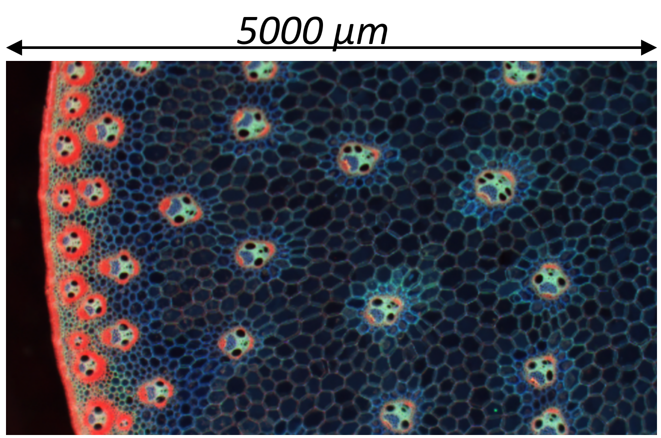
Constituents are organised….
Ex: In cell walls



Bidlack et al., 1992

Maize stem

In the plant

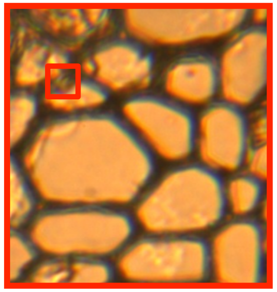


Autofluorescence: false color, Blue and UV fluorescence

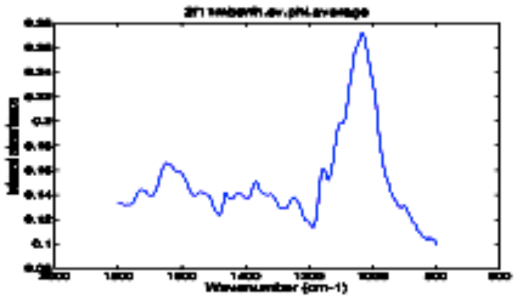
Microspectroscopy and hyperspectral imaging

in situ chemical analysis

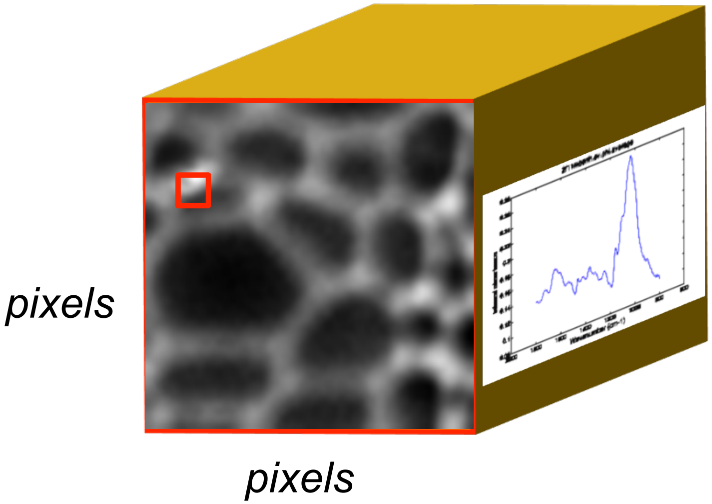
Spectrophotometer + Microscope



Sample region



One complete
spectrum is acquired
for each pixel



Scanning a region lead
to one
hyperspectral image