How do we deal with contaminant complexity? Analytical challenges

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Risk Assessment

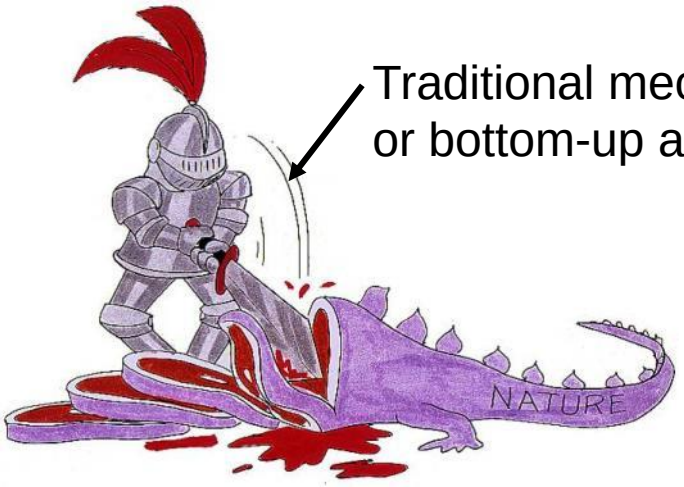
How can we improve current risk assessment procedures?

Can the most toxic chemicals in complex (environmental) samples be identified by linking chemical with toxicological fingerprints (‘the LCT concept’)?

Comprehensive investigation of single compounds

Chemical analysis and effect studies

A new paradigm for contaminant analysis



Traditional mechanistic or bottom-up approach

- Extensive sample preparation (to isolate)
- **Chemical target analysis**
- Fully quantitative analysis
- Extrapolation to complex systems

Top-down approach

- Limited sample preparation
- **Fingerprinting analysis**
- Semi-quantitative analysis (fingerprints)
- Identification of relevant compounds

Fingerprinting analysis

…conceptual understanding

Silvio Berlusconi

Barack Obama

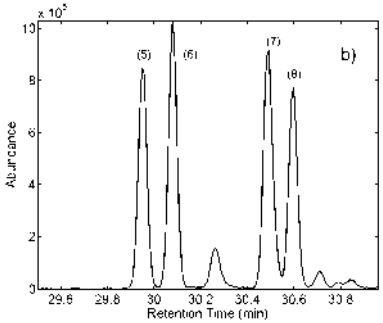
Fingerprinting analysis

…conceptual understanding

+

= ”It is Silvio and not Obama”

eyes + Brain



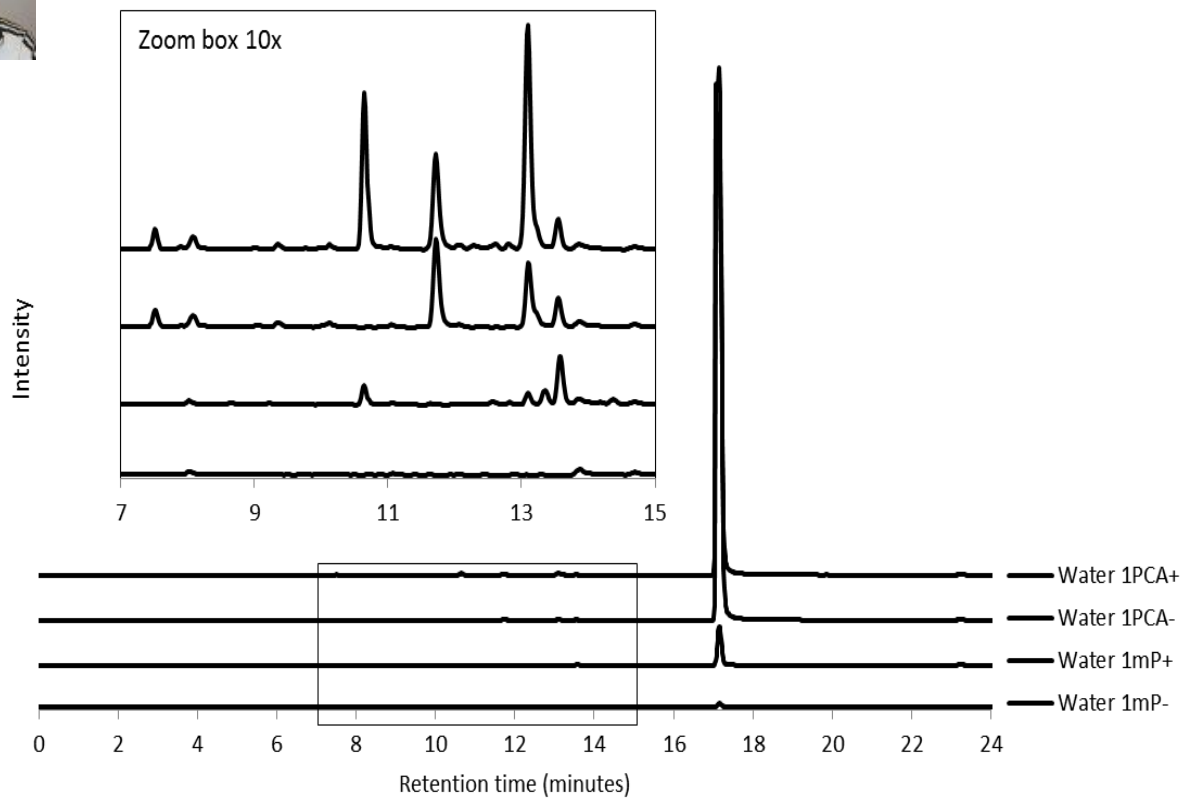
+

= ”It is a pollution marker”

Sensor + Computer with ’multivariate’ software

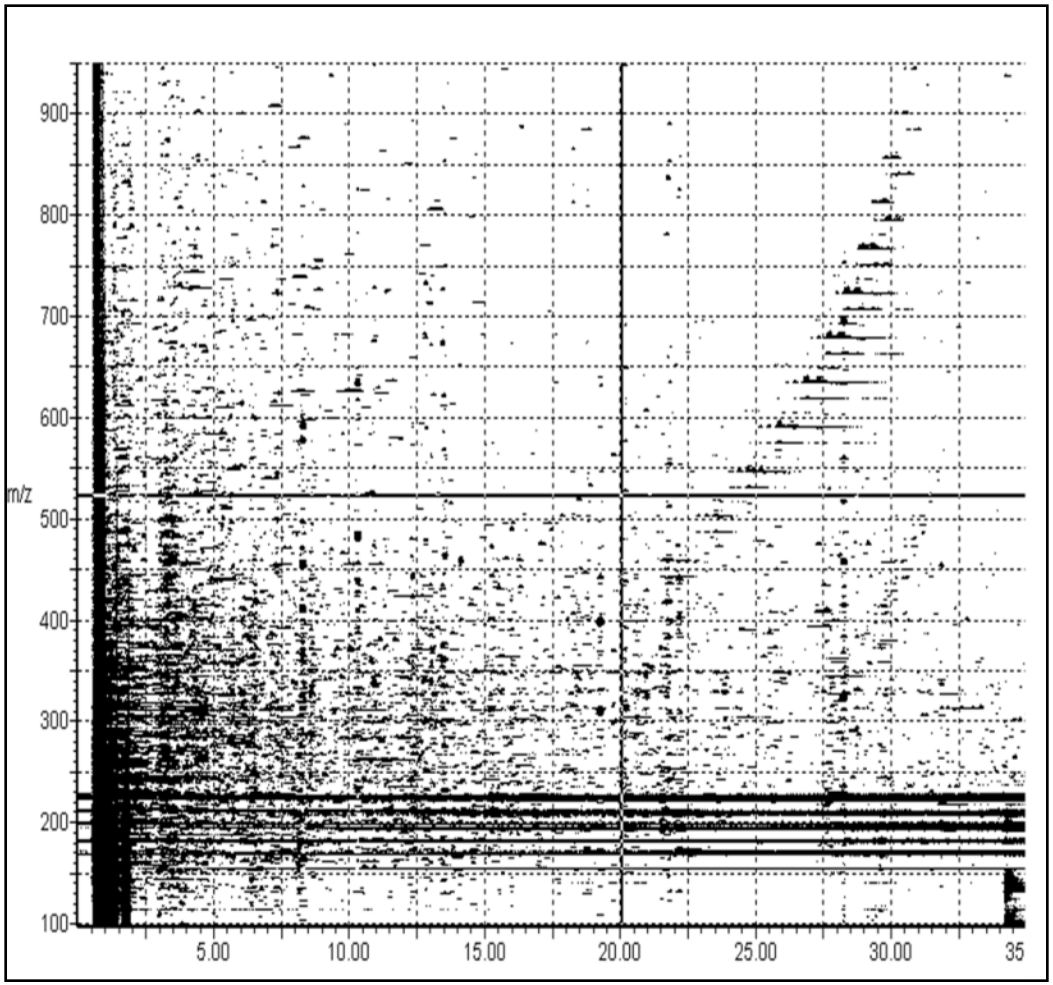
Analytical data are multivariate

Malmquist LV, Selck H, Christensen JH, Biotransformation of 1-methylpyrene and pyrene by Nereis diversicolor: Efficiency and identification of products, *Environmental Science & Techonology*, **2013,** 47 (10), 5383–5392.



…a trend that is increasing

Nielsen NJ, Tomasi G, Danielsson R, Christensen JH, ComFiDiMed: Feature detection in LC-MS fingerprints using the COMbined matched Gaussian Filter and two-fold Differentiation with MEDian measures for threshold determination, *Journal of Chromatography A, resubmitted*



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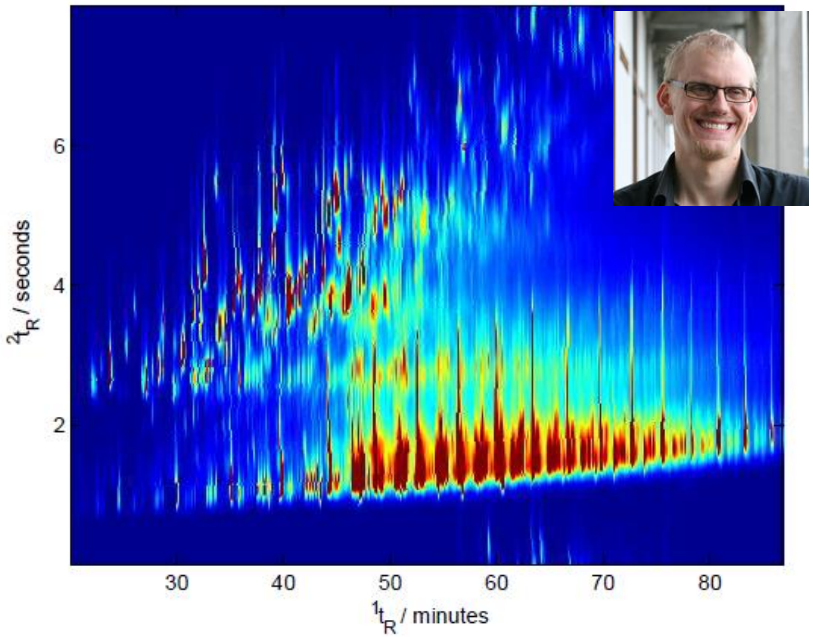
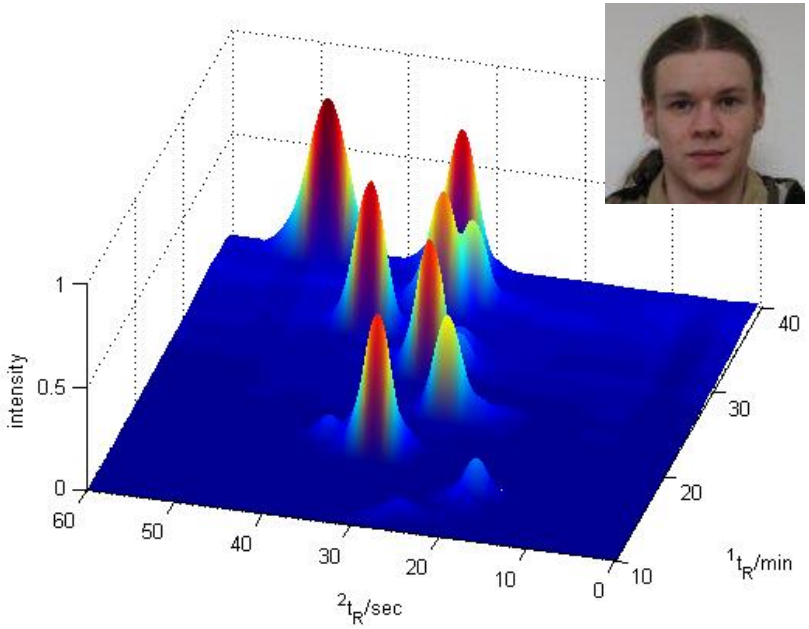
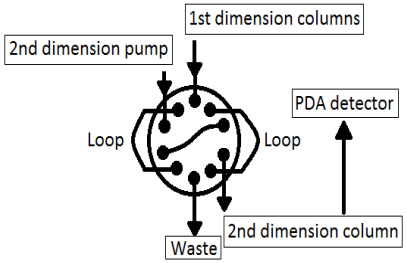


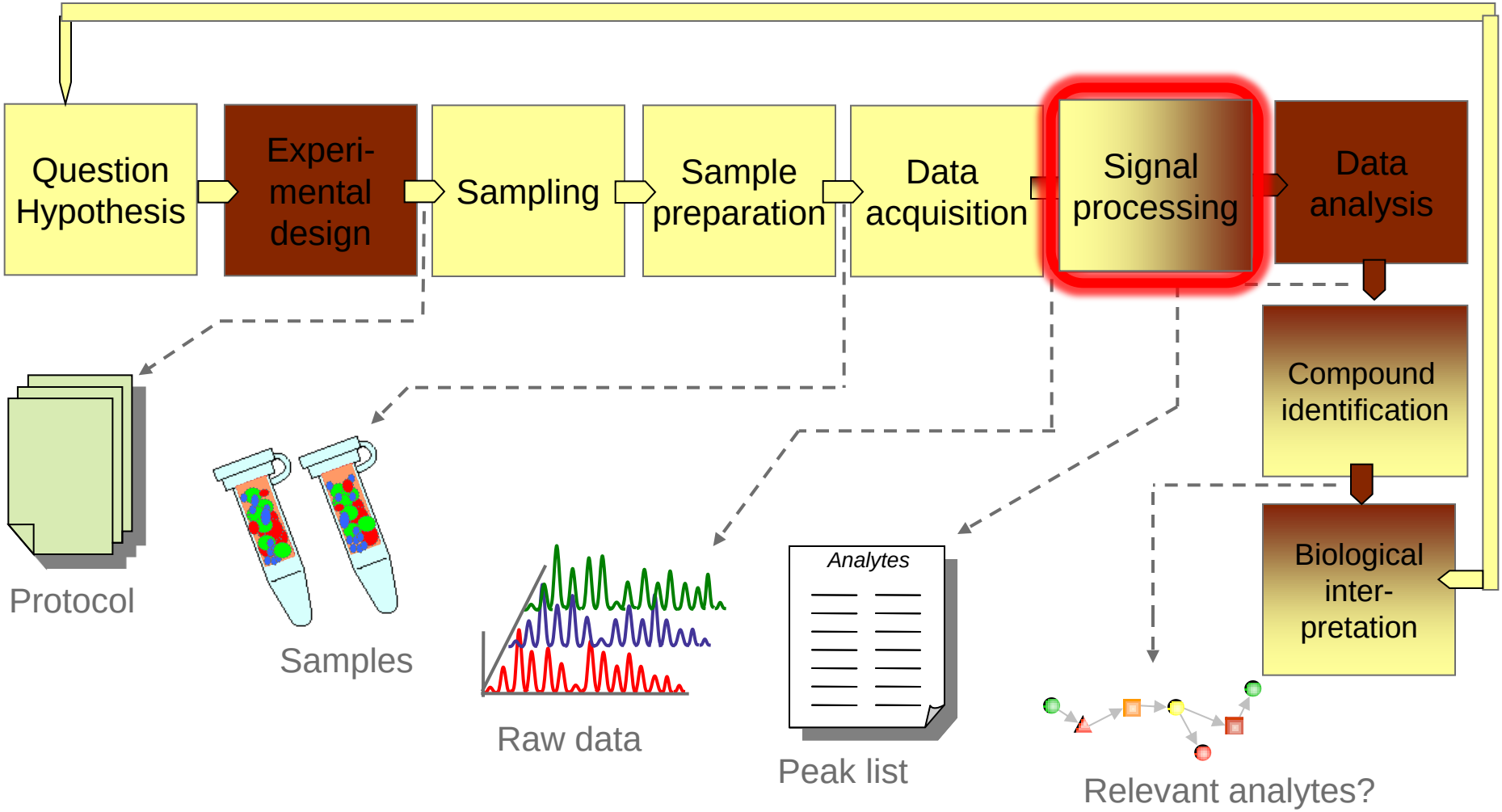
Furbo S, Hansen AB, Skov T and Christensen JH, Pixel-based analysis of comprehensive two-dimensional gas chromatograms (color plots) – A Tutorial, *Analytical Chemistry in print 2014*



Græsbøll R, Nielsen NJ, Christensen JH, Using the hydrophobic subtraction model to choose orthogonal columns for online comprehensive two-dimensional liquid chromatography, *Journal of Chromatography A* ***(Resub 2013)***

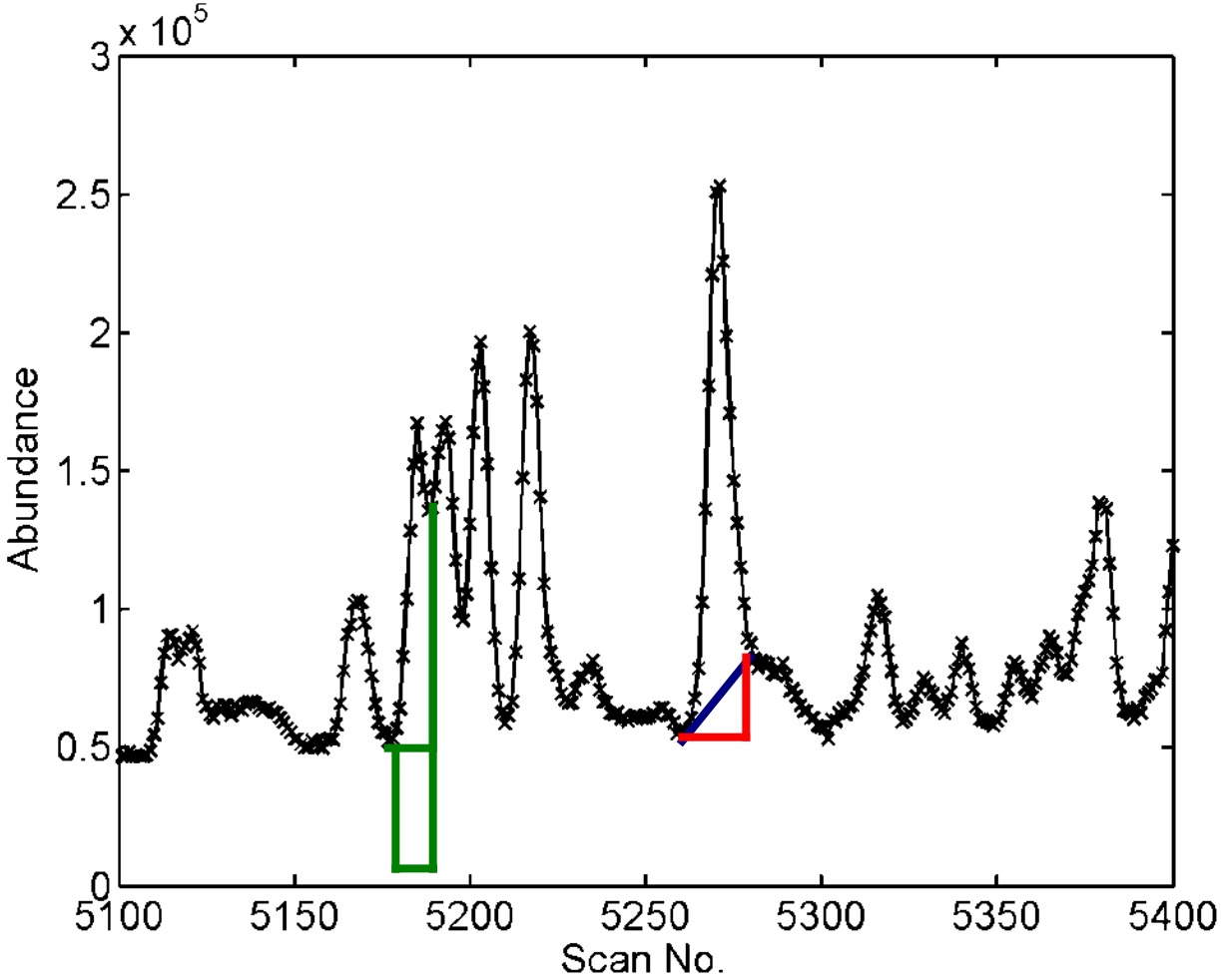


-fingerprinting workflow ('the weakest link')



Signal processing

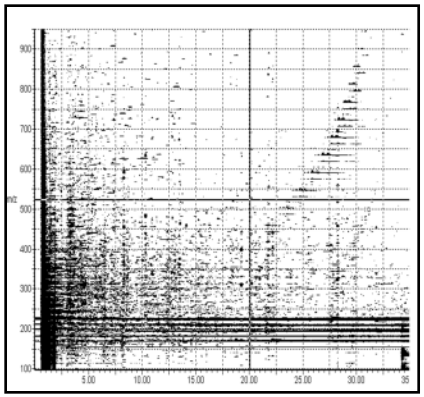
Strategy 1: Conventional integration methods



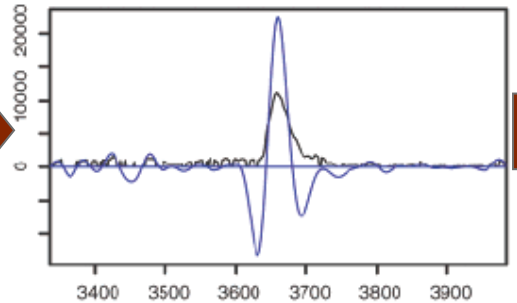
Signal processing

Strategy 2: Feature detection

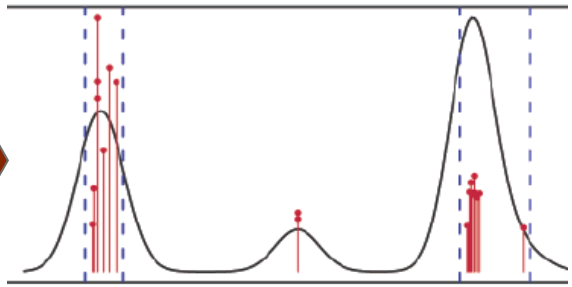
Raw data



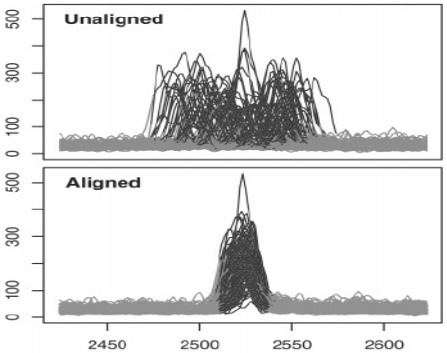
Peak detection



Peak matching



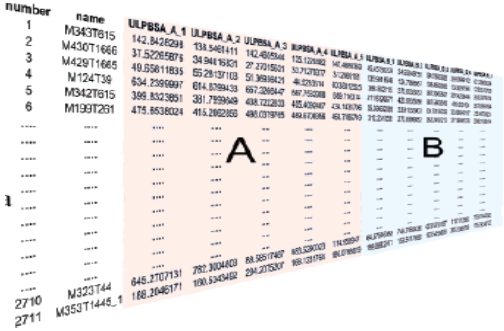
Retention time alignment



Peak integration

Peak filling

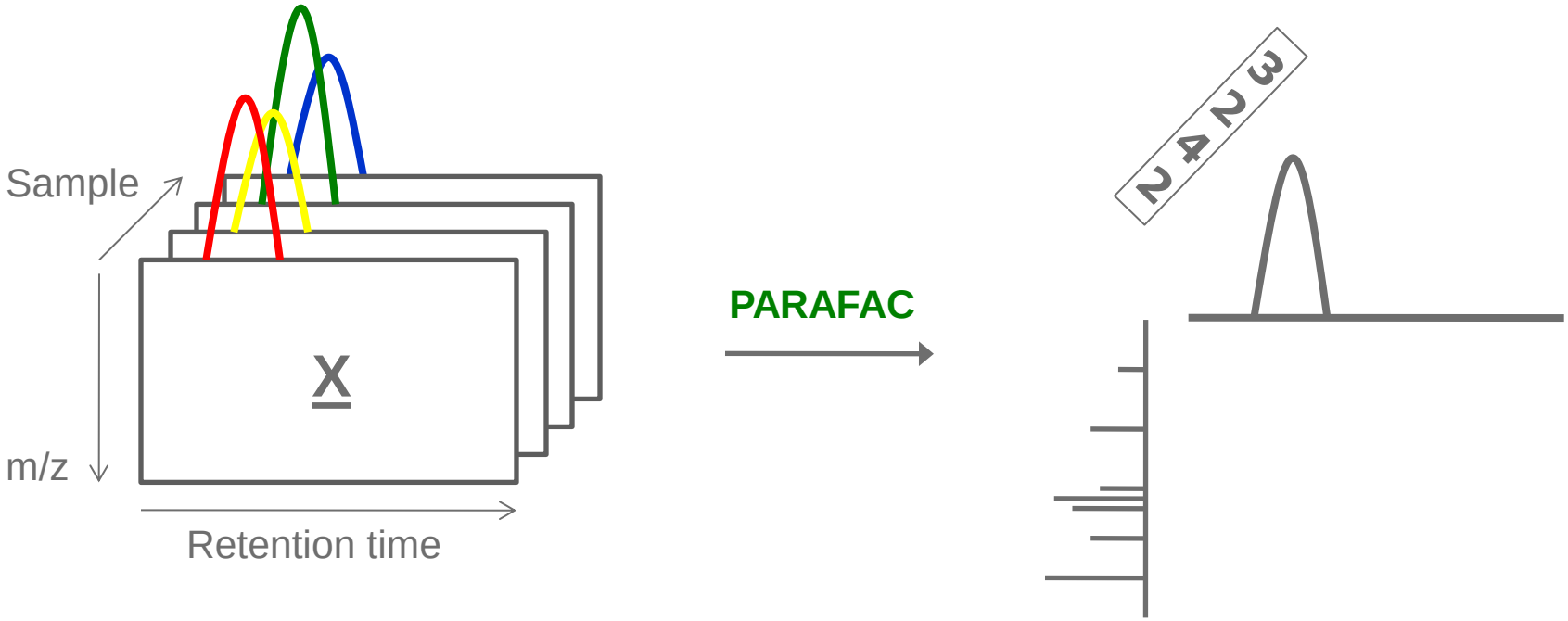
Peak table



XCMS – Smith et al. *Analytical Chemistry* 78, 779 (**2006**)

Signal processing

Strategy 3: Peak modelling

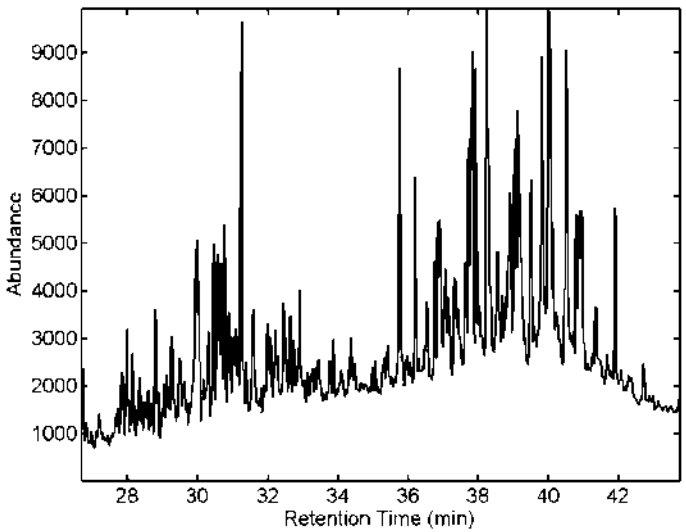


Signal processing

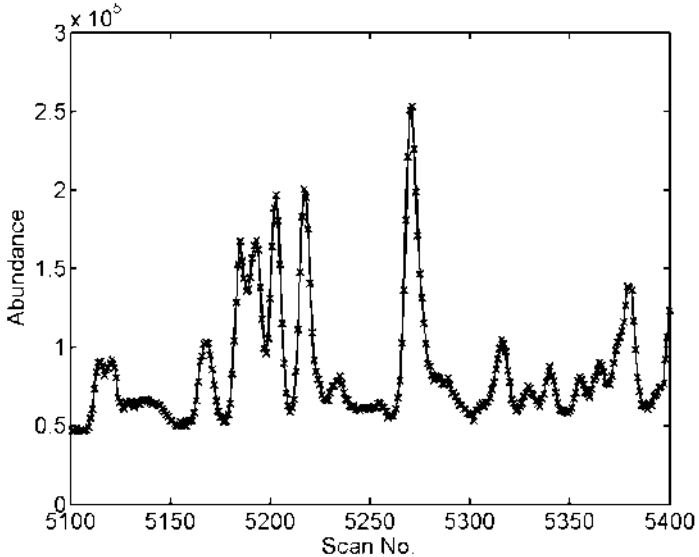
Strategy 4: The pixel-based approach

What is a pixel-based approach?

multivariate analysis on the pixel level =
…on entire chromatograms or sections of the chromatograms and not on quantified peaks

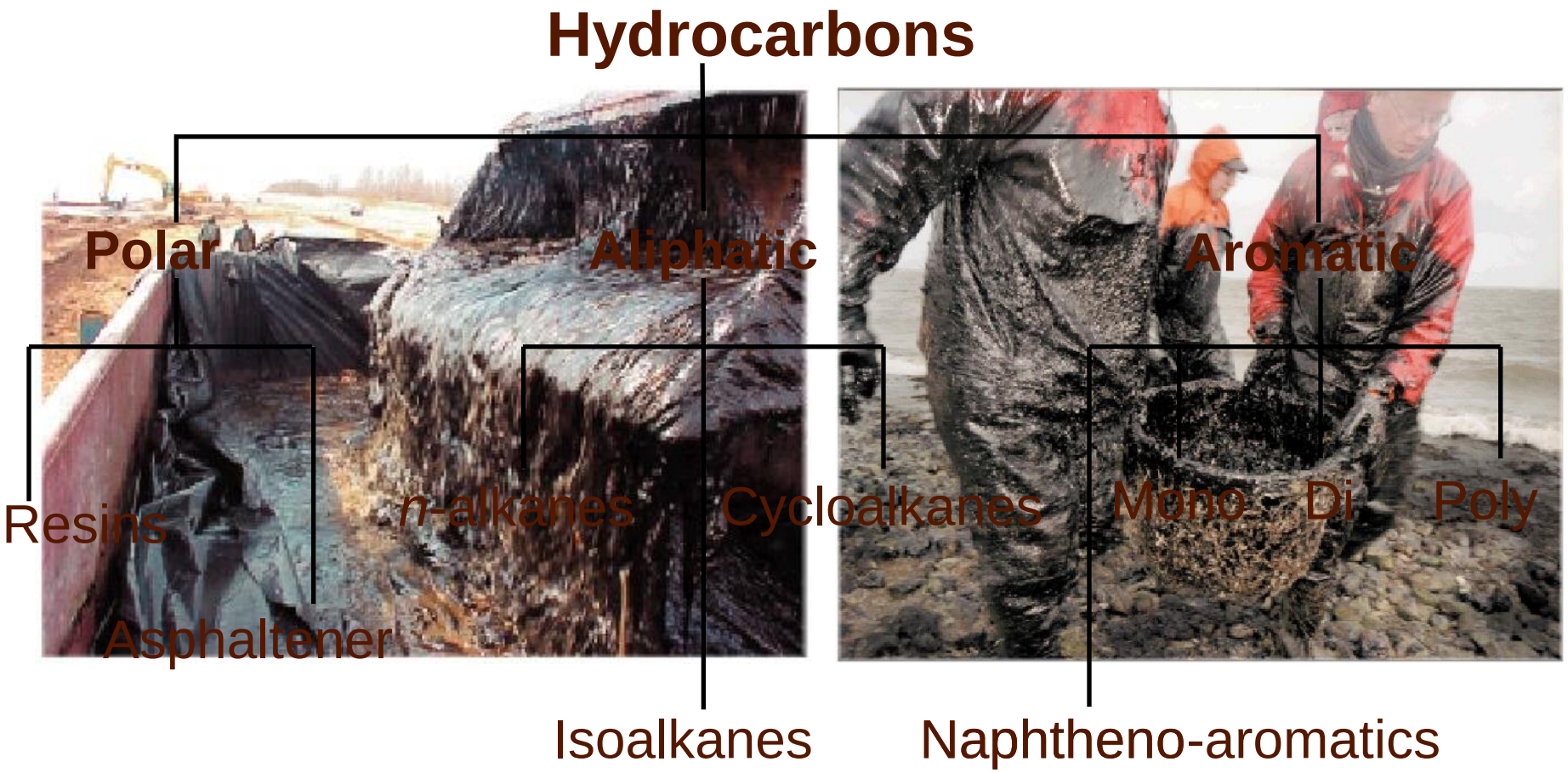


Chromatography data consists of pixels

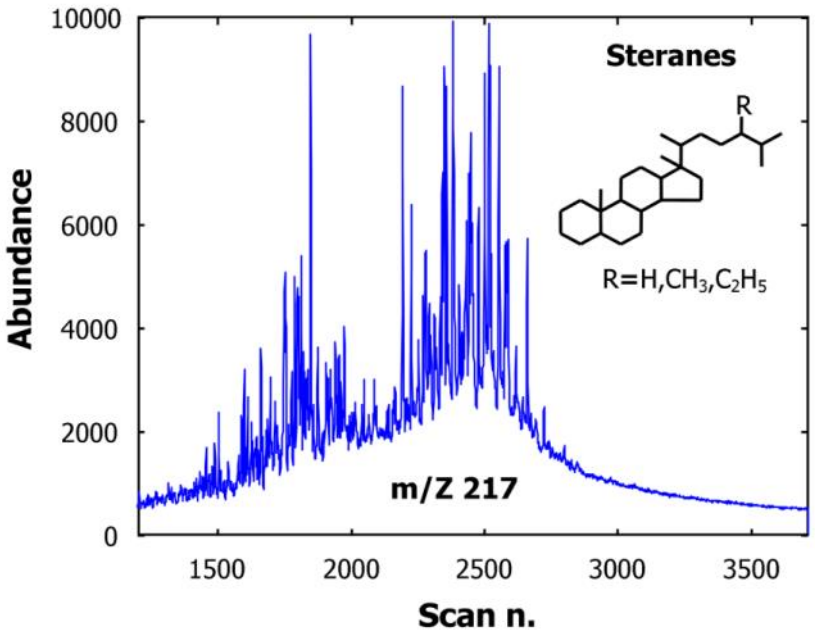


Contaminant fingerprinting in action

Oil is a super complex mixture of >100.000 chemical compounds

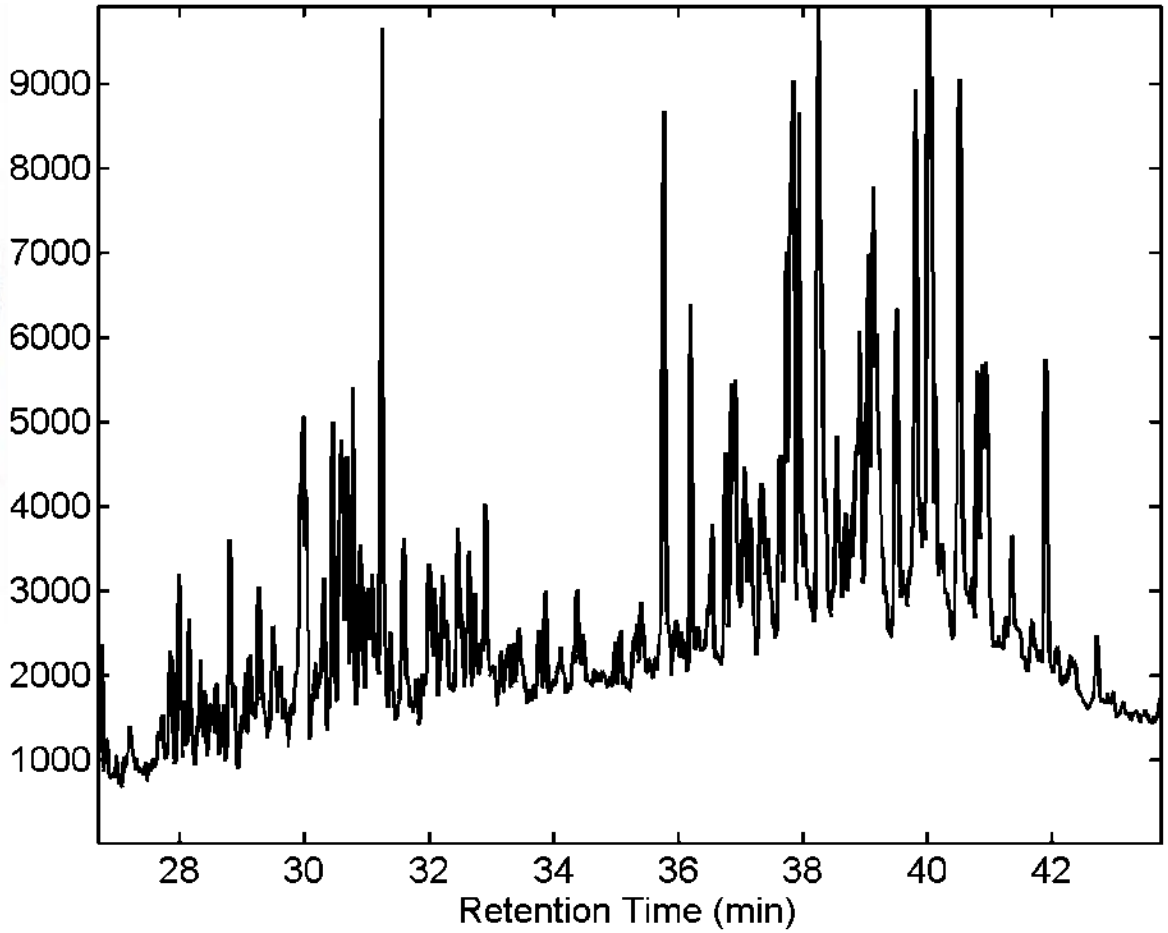


Phase I: Setting up the experiment



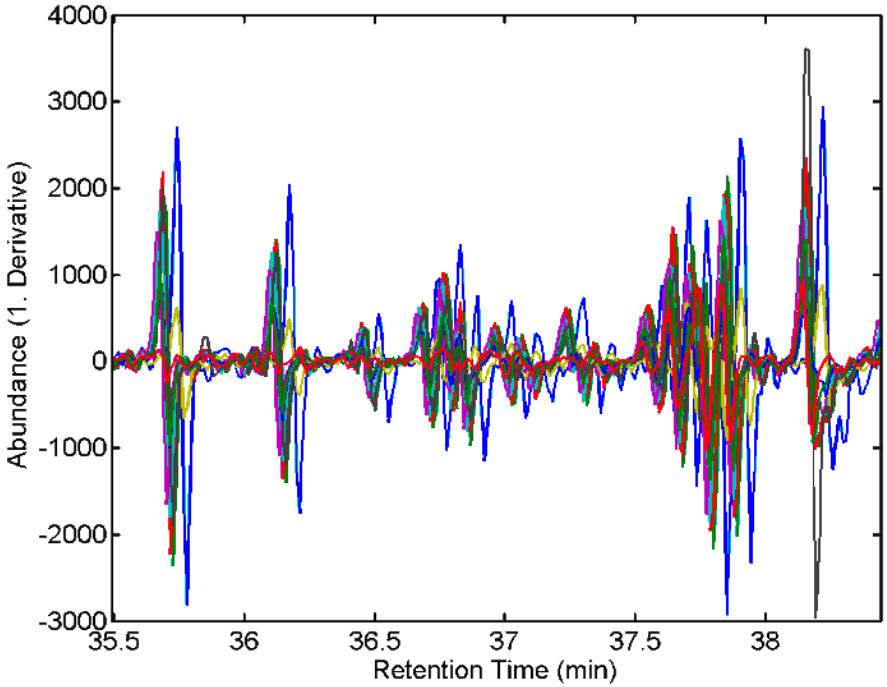
Christensen JH, Tomasi G and Hansen AB. Chemical Fingerprinting of Petroleum Biomarkers using Time Warping and PCA, *Environmental Science and Technology*, **2005**, 39 (1), 255-260.

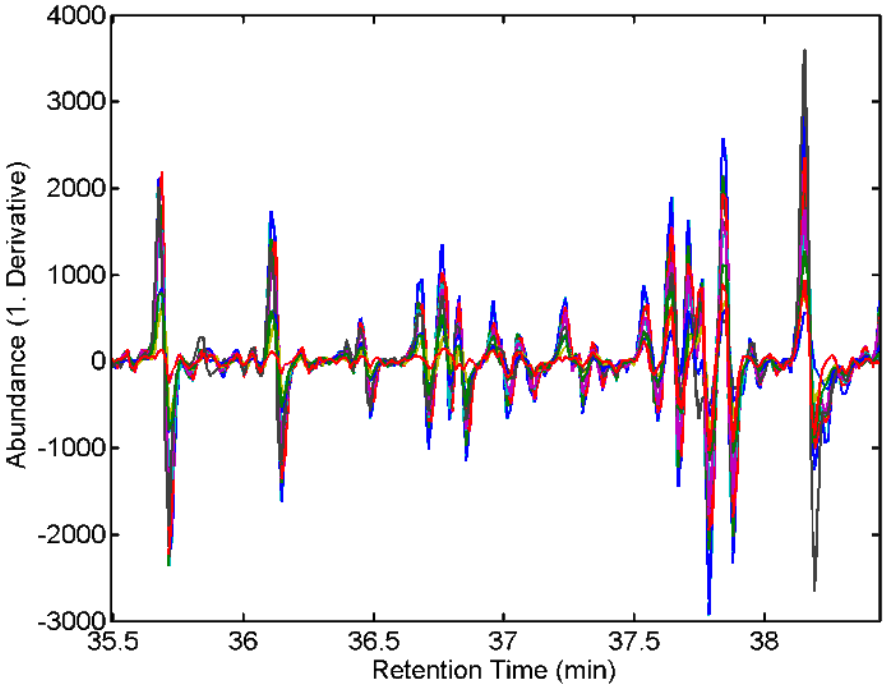
Phase II: How to deal with instrumental artifacts?



Phase II: How to deal with instrumental artifacts?

The effects of correlation optimized warping (COW) on a chromatographic section of m/z 217 in 10 oil samples

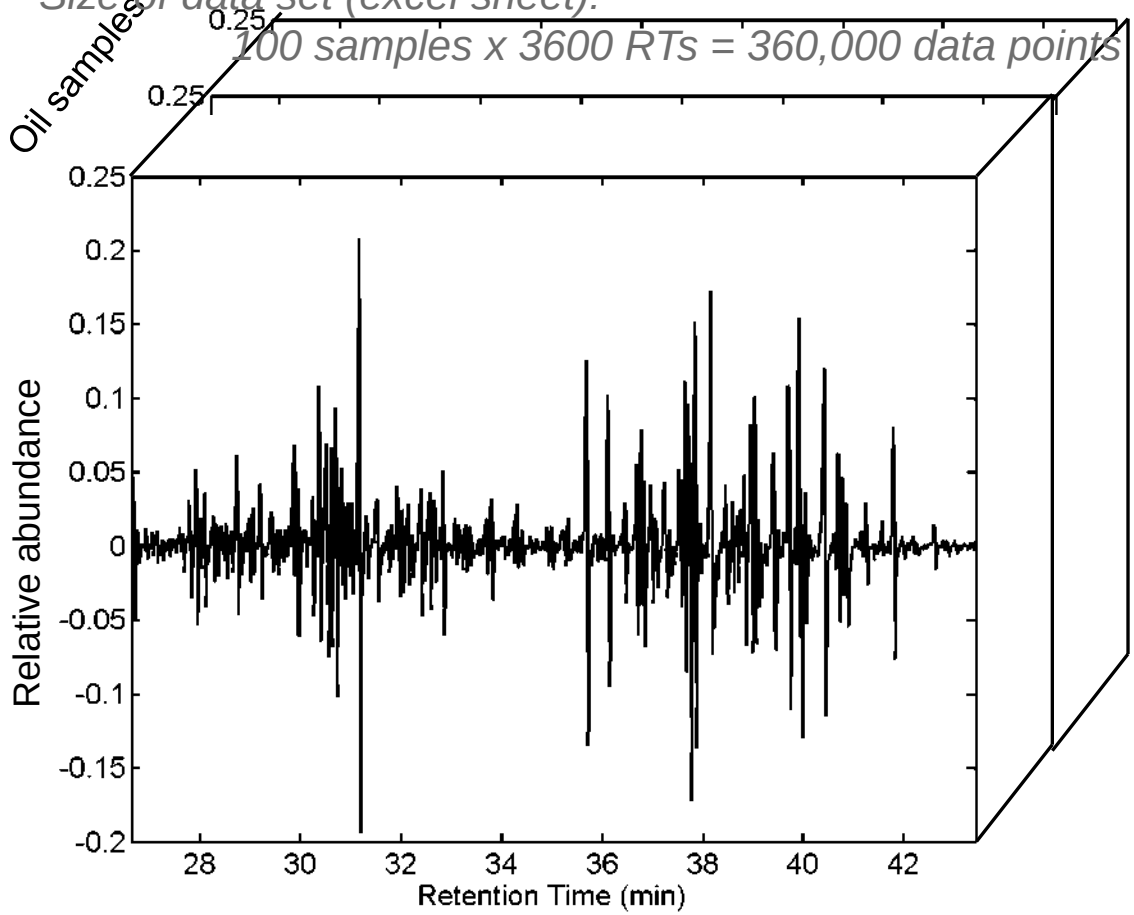




Data structure

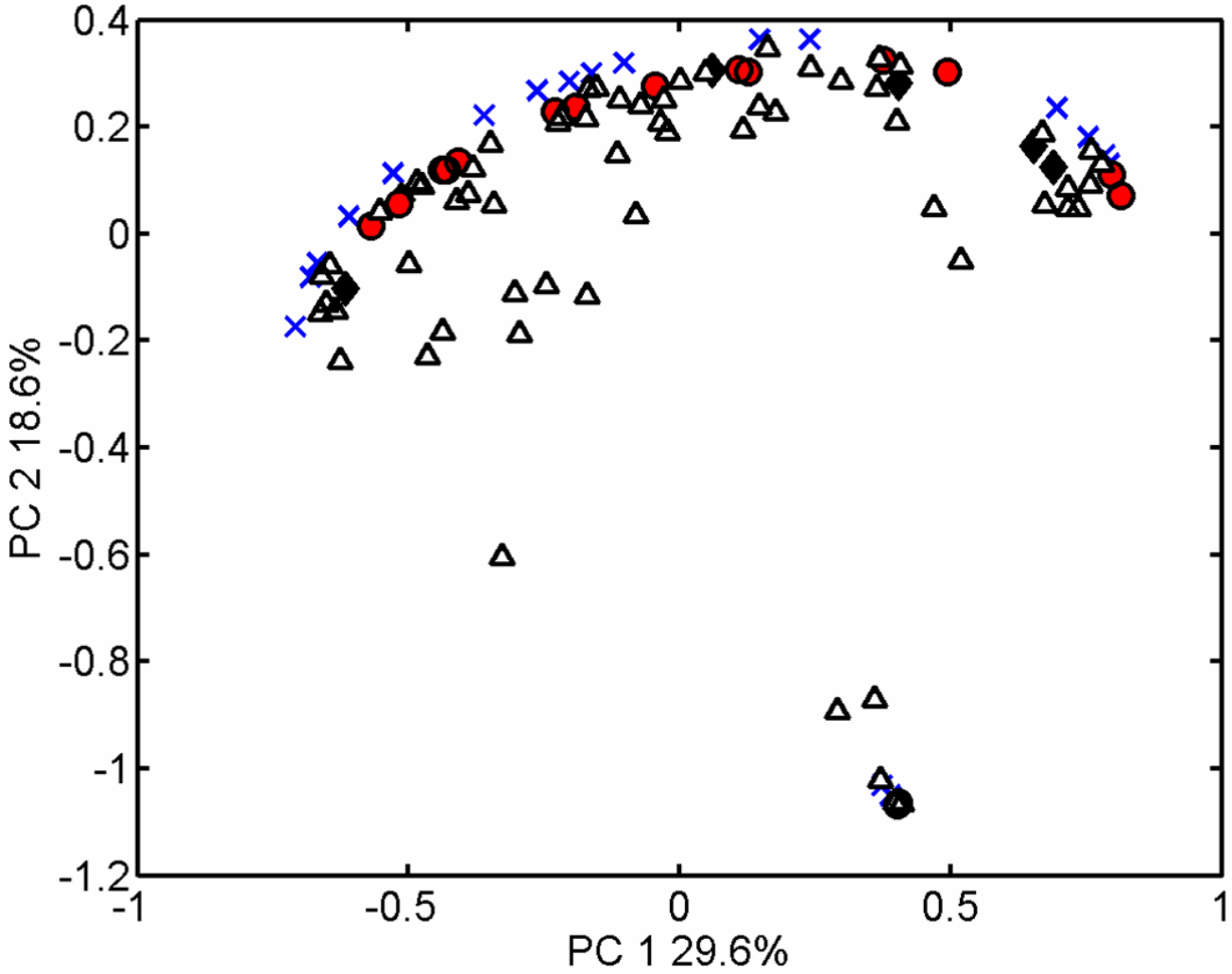
Chemical profiles of 100 crude oils or refined products

Size of data set (excel sheet):
100 samples x 3600 RTs = 360,000 data points



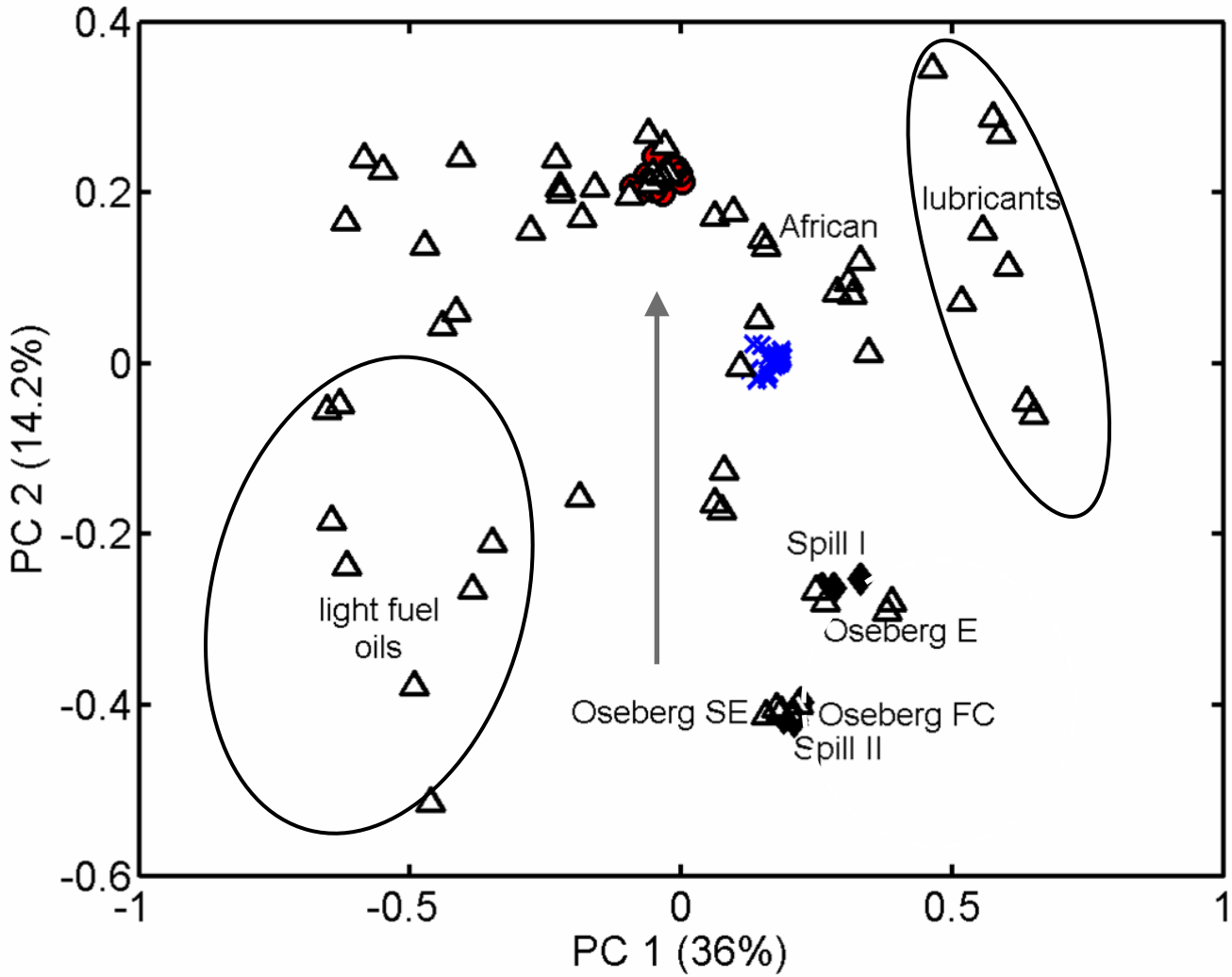
Map of samples (the score plots)

Without removing artifacts



Map of samples (the score plots)

With removal of artifacts



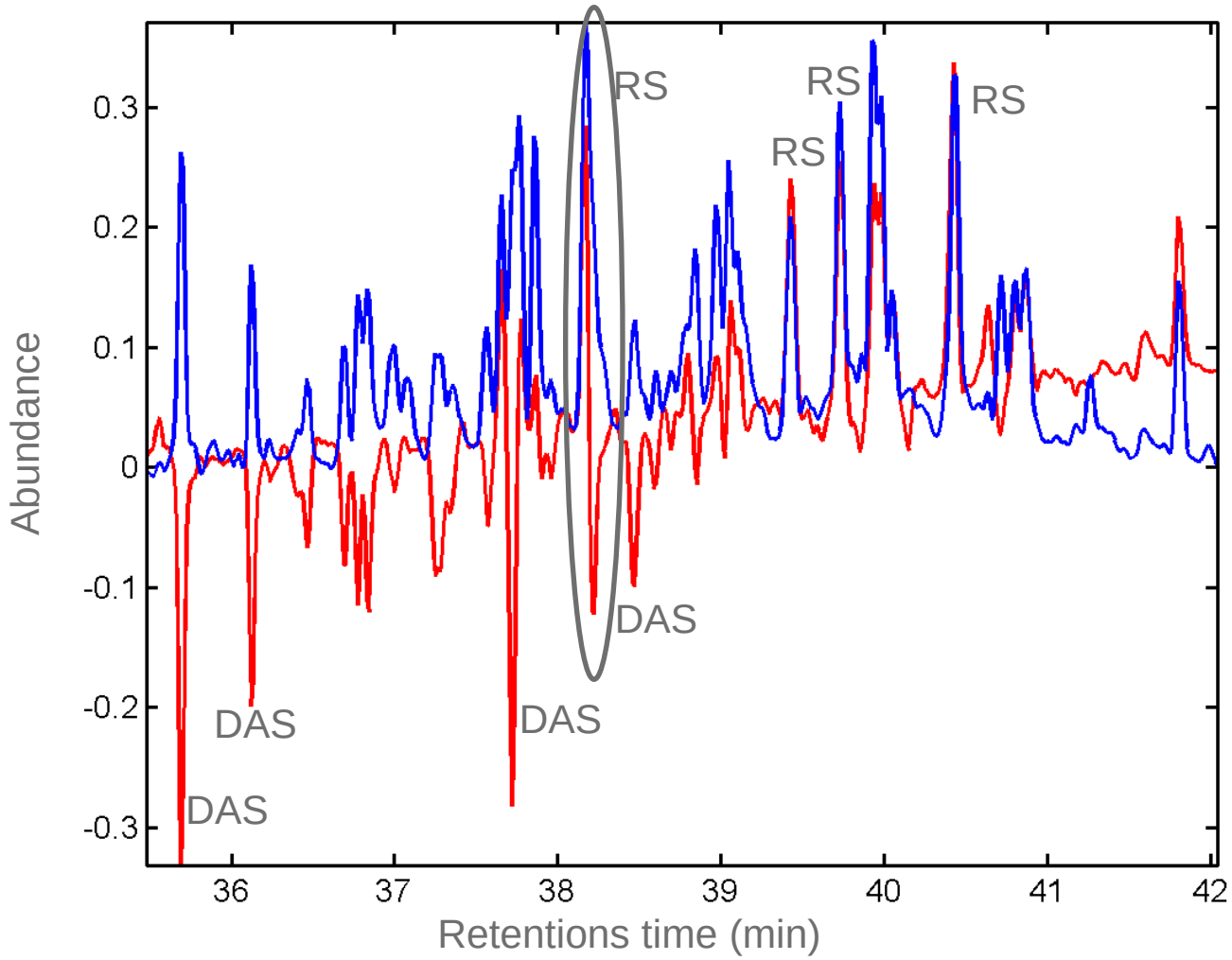
Chemical interpretation (PC2 loadings)

…Why are the oils different?

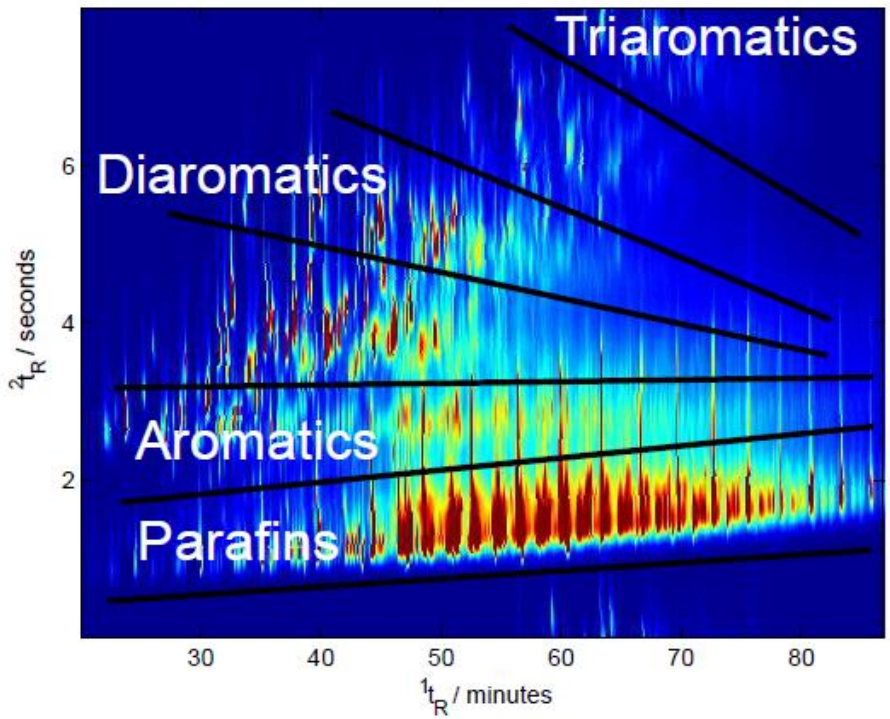
Distinguish oils originating from source rocks with different clay content

High PC2 ⇔
High DAS/RS ⇔
High clay content

Low PC2 ⇔
Low DAS/RS ⇔
Low clay content and anoxic conditions

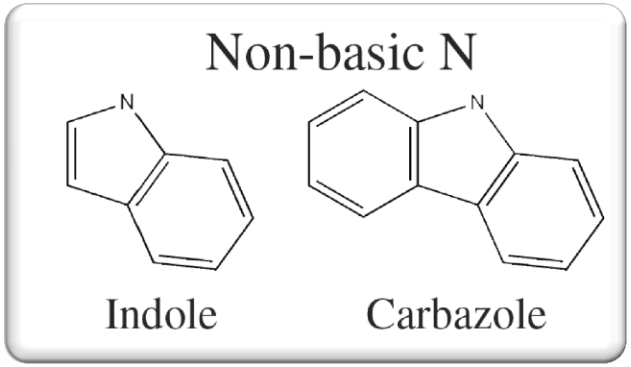


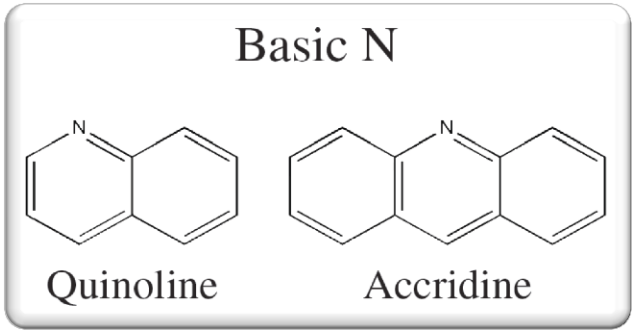
Contaminant fingerprinting: The LCT-concept



Furbo S, Hansen AB, Skov T and Christensen JH, Pixel-based analysis of comprehensive two-dimensional gas chromatograms (color plots) – A Tutorial, *Analytical Chemistry* ***in print 2014***

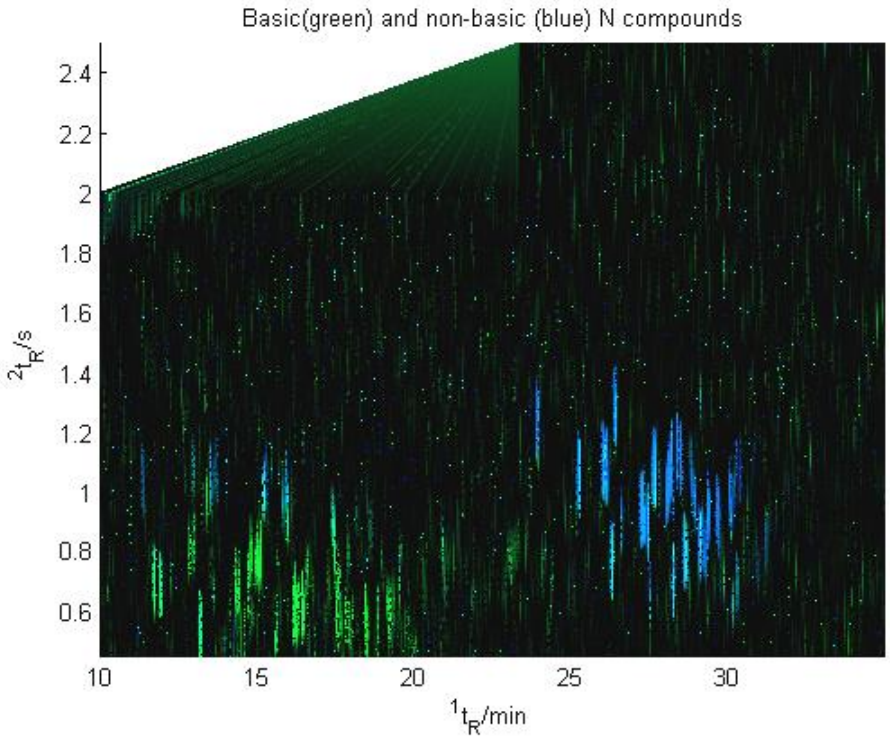
HALDOR TOPSØE

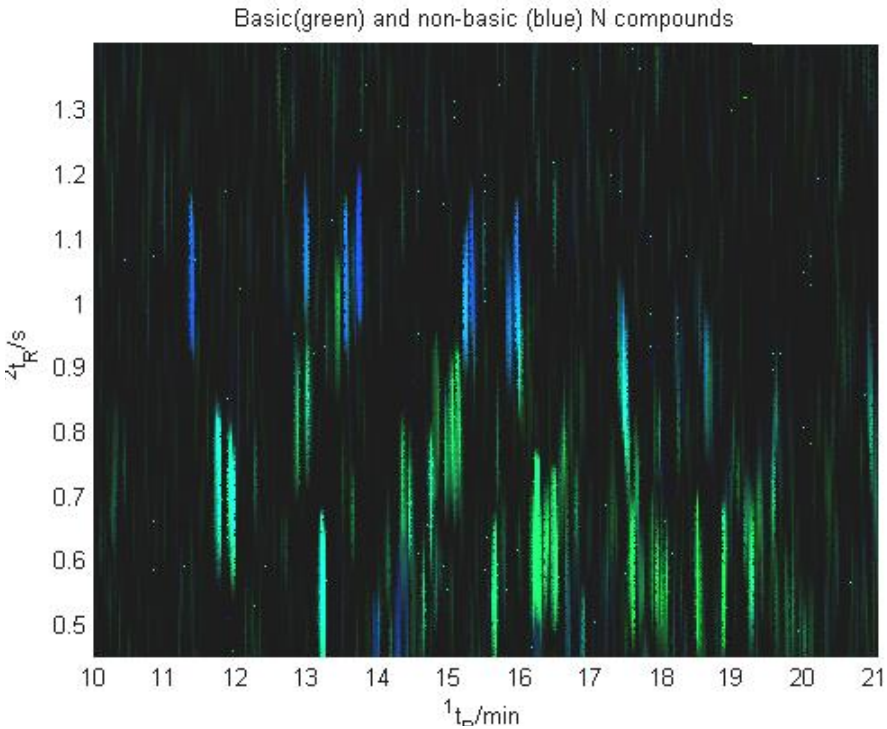




Furbo S, Hansen AB, Christensen JH: Predicting petrochemical properties by Pixel-based analysis of comprehensive two-dimensional gas chromatograms (color plots), Journal of Chromatography ***(to be submitted, 2014)***

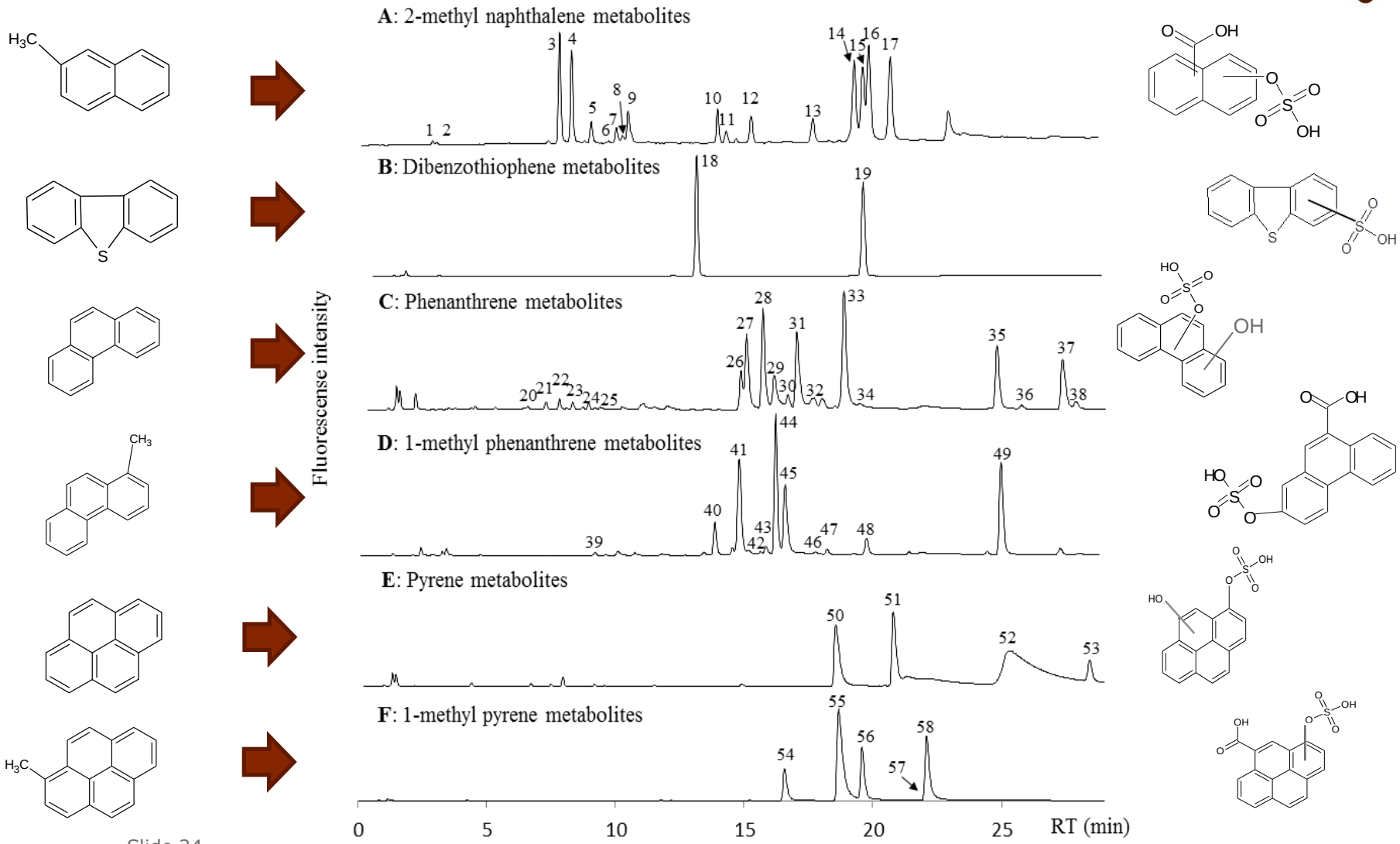
Contaminant fingerprinting: The LCT-concept



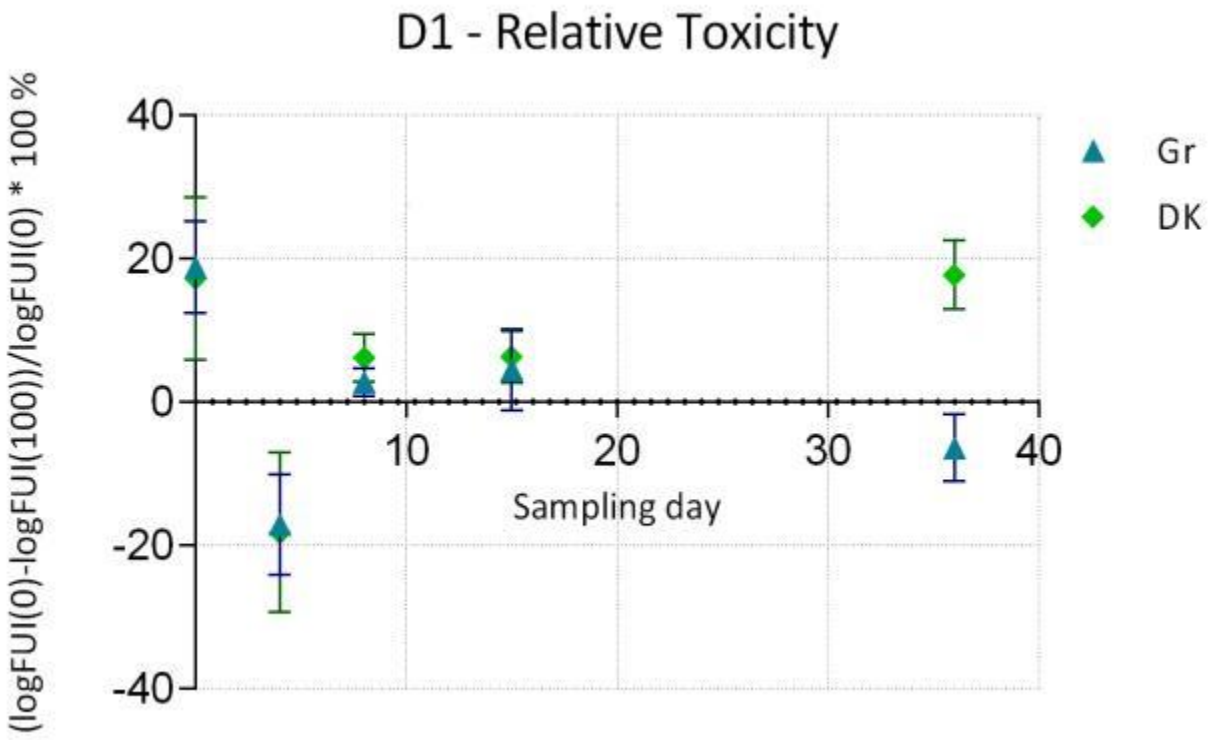


- Pixels predicting total nitrogen are blue, pixels predicting basic nitrogen are green.
- In left image, carbazoles and quinolines are visible.
- In right image, quinolines and indoles are visible.

Polar PAC metabolites: Are we measuring the most relevant compounds?



Polar PAC metabolites: Are we measuring the most relevant compounds?

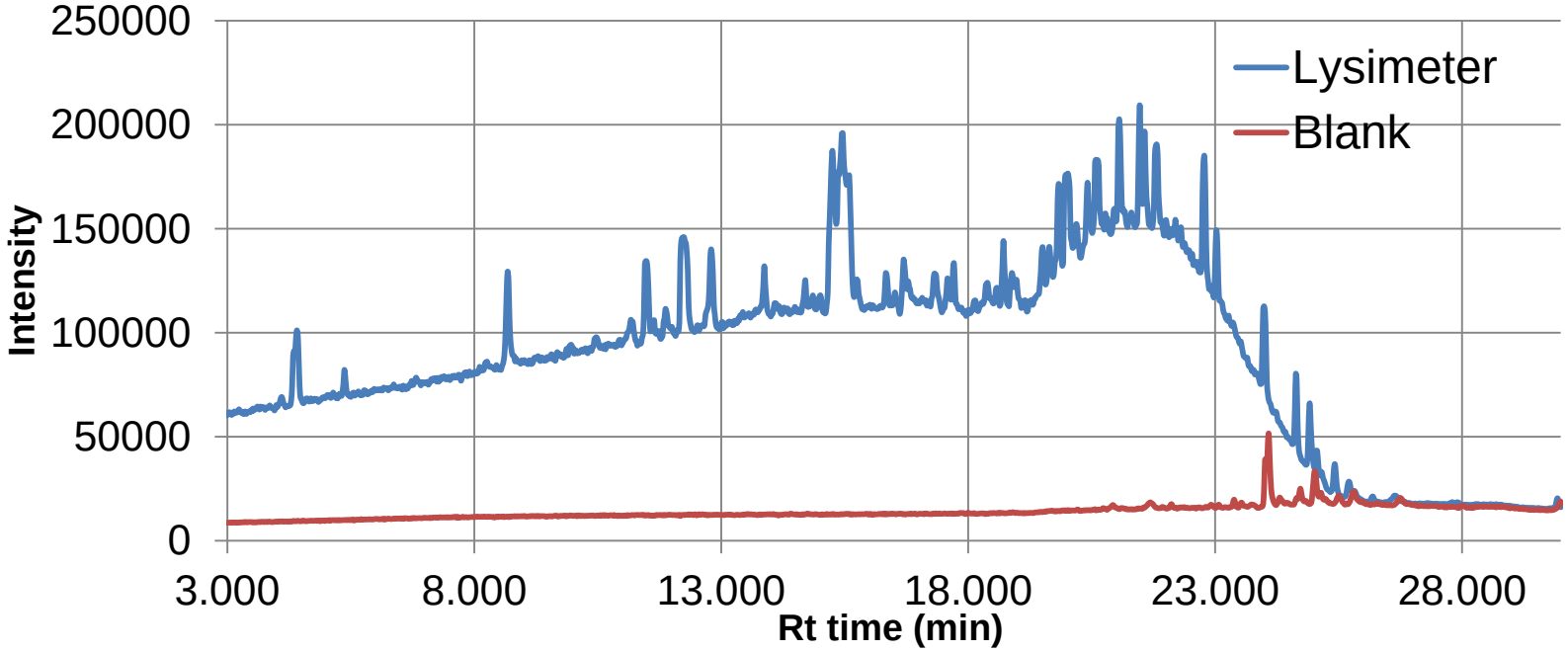


Concluding remarks and perspectives

When to use the fingerprinting approach?

(1) For chemical fingerprinting, pattern recognition, classification cases where the traditional targeted approaches fail

(2) For analysis of very complex data

(3) If your data is fit for the fingerprinting (data quality is high enough)

(4) If you know your instrument artifacts and can handle them