

MULTIVARIATE ‘MIXED-MODE’ ANALYSES

for characterising archaeological ceramics using the cerUB package in R

Andreas Angourakis, Verónica Martínez Ferreras, Josep M. Gurt

Day 2, Session 2: Session in Honour of Michael Baxter

available at <https://andros-spica.github.io/EMAC-Angourakis-et-al-2019/>

<https://andros-spica.github.io/EMAC-Angourakis-et-al-2019/index.html?print-pdf> (printable version)



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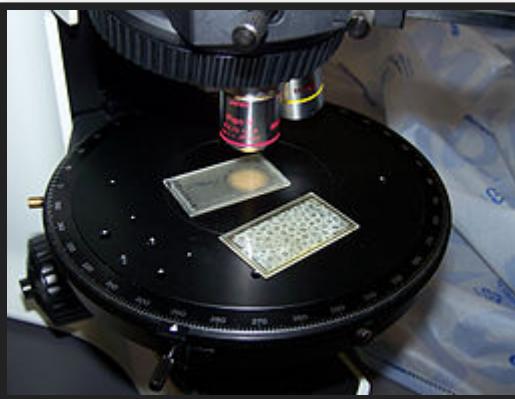
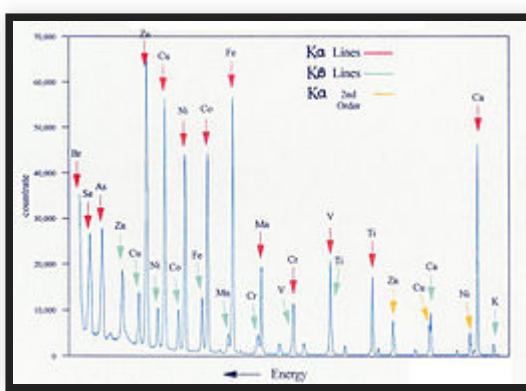


EMAC
2019 Barcelona

TO BE OR NOT TO BE ---

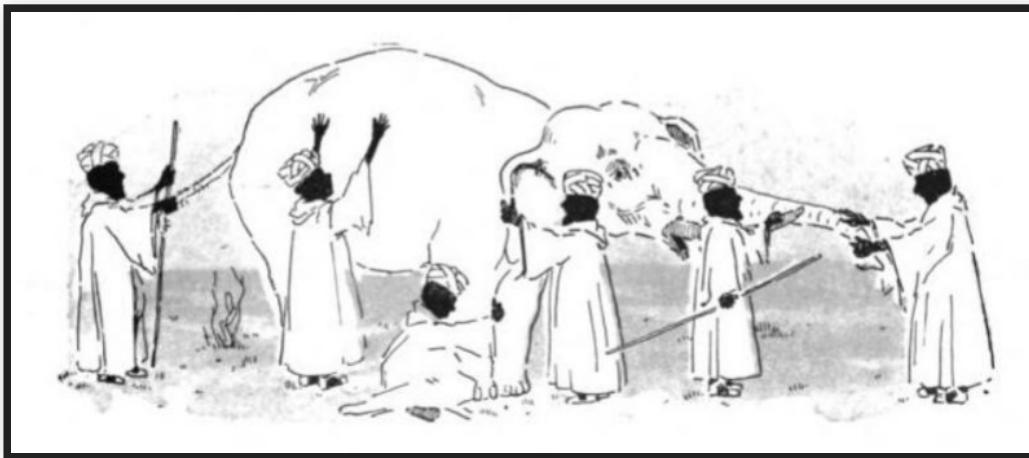
TO BE OR NOT TO BE ---
'MIXED-MODE'

Several techniques can be applied to characterise archaeological materials



ceramics → X-ray fluorescence, thin section petrography, etc.

Techniques offer different information...



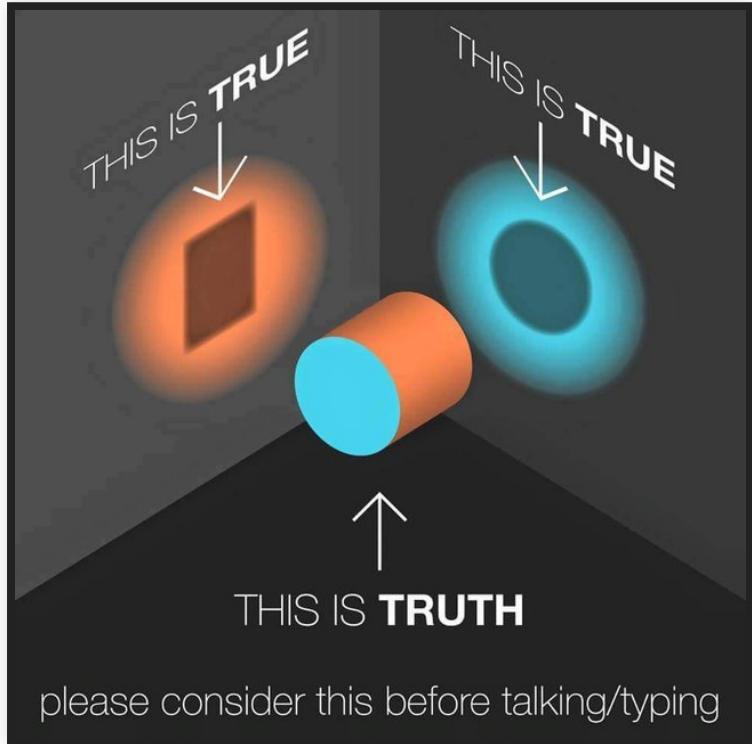
... but also are redundant to a certain extent

Many archaeometry studies combine the results of more than one technique, mainly by means of argumentation

Few integrate such results using statistical methods

BENEFITS

- *Statistics using ALL information available*
- *Synthetic visualisation*



CHALLENGES



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- *Multivariate statistics: hard and demanding*



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- *Multivariate statistics: hard and demanding*
- *Computational tools still underdeveloped in terms of user-friendliness and documentation*
- *Most archaeologists are not convinced by the benefits of scripting (reproducibility!)*



Inaugural example of 'mixed-mode' analysis apply to ceramics:

Baxter M J, Beardah C C, Papageorgiou I, Cau Ontiveros M-Á, Day P M and Kilikoglou V (2008). *On statistical approaches to the study of ceramic artefacts using geochemical and petrographic data*. Archaeometry, 50:142–57.

<http://doi.wiley.com/10.1111/j.1475-4754.2007.00359.x>

Presenting an approach that combines geochemical and mineralogical data

A 'MIXED-MODE' APPROACH TO CERAMICS

How to combine different types of data?

THE 'APPLES'

Geochemical compositions

Fe2O3	Al2O3	MnO	P2O5	TiO2	MgO	CaO	Na2O	K2O	SiO2	Ba
6,12	16,51	0,07	0,10	0,74	1,62	3,22	0,57	2,94	64,75	0,0578
4,94	14,16	0,06	0,18	0,65	3,73	6,96	0,59	4,01	58,67	0,0843
5,98	16,57	0,08	0,12	0,66	1,87	9,26	0,53	2,79	54,18	0,0735
5,13	15,07	0,07	0,23	0,69	1,54	11,65	1,03	2,60	58,47	0,0554
4,97	13,62	0,06	0,14	0,71	1,25	9,76	0,55	2,75	60,16	0,0465

*numeric and continuous
tractable with widely-known quantitative methods*

THE 'ORANGES'

Macroscopic and thin-section petrography, other qualitative assessments

 mineralogical variables

*ordinal or nominal variables with no direct numeric representation**
demands specialised methods

*Assuming not using point-counting or similar techniques

How to count oranges as apples?



Transform ordinal variables into:

- '*binary dummy variables*' (Baxter et al. 2008)
- *numeric continuous variables*
- *ranks* (Podani 1999)

Case	VAR 4. Texture Category recorded	Category 3 (medium)	Category 4 (coarse)	Category 5 (very coarse)
CS-1	4	0	1	0
CS-2	4	0	1	0
CS-3	5	0	0	1
CS-4	4	0	1	0
CS-5	4	0	1	0
CS-6	3	1	0	0
CS-7	5	0	0	1
CS-25	4	0	1	0

 *ordinal to continuous*

OTUs:	1	2	3	4	5	6	7	8
1. Fully ranked variable	0	4	7	5	3	10	12	13
2. Fully ranked variable converted to ranks	1	3	5	4	2	6	7	8
3. Partially ranked variable	1	2	1	4	1	2	2	1
4. Partially ranked variable converted to ranks	2.5	6	2.5	8	2.5	6	6	2.5
5. T value	4	3	4	1	4	3	3	4

Podani (1999). Extending Gower General Coefficient of Similarity to Ordinal Characters. *Taxon*, 48(2): 331-340.
<http://www.jstor.org/stable/1224438>

FOUR PROTOCOLS

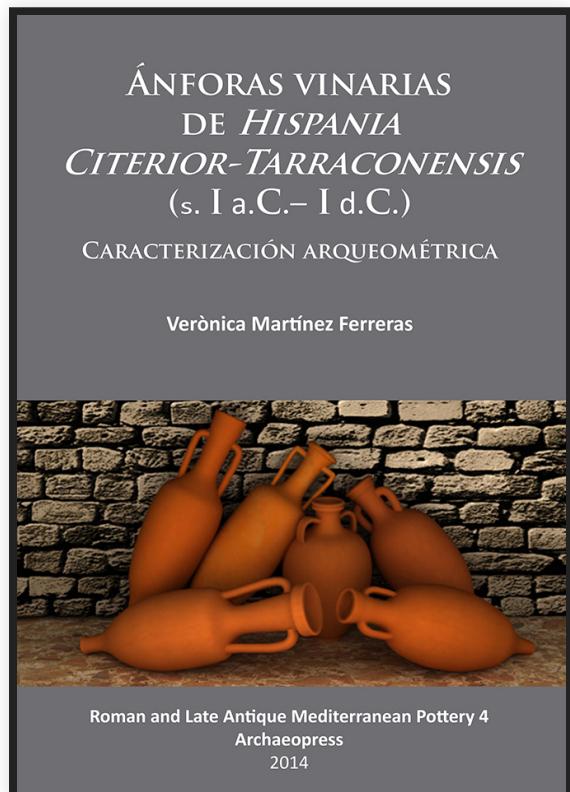
1. For geochemical data (CHEM)

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- 2. For mineralogical/petrographic data (PETRO)*

1. *For geochemical data (CHEM)*
2. *For mineralogical/petrographic data (PETRO)*
3. *all geochemical and mineralogical/petrographic data (CHEM + PETRO)*

1. For geochemical data (*CHEM*)
2. For mineralogical/petrographic data (*PETRO*)
3. all geochemical and mineralogical/petrographic data (*CHEM + PETRO*)
4. For geochemical and a subset of mineralogical/petrographic data best representing *provenance* (*CHEM + PETRO_{PROV}*)

CASE STUDY: ROMAN WINE AMPHORAE



- *Wine Roman amphorae from Hispania Citerior-Tarragonensis (Catalonia)*
- *175 individuals from 15 workshops (Martínez Ferreras 2014)*
- *61 individuals from 3 shipwrecks in the region (Martínez Ferreras et al. 2013, 2015)*
- *Dated from c. 75 BC to c. 50 AD*

DATA SOURCES

- *Geochemical composition*: X-ray fluorescence readings (XRF-WD) using a Philips PW 2400 spectrometer
- *Range of firing temperature*: estimated with mineralogical phase by X-ray diffraction readings (XRD) using Siemens D-500 and Panalytical X'Pert PRO alpha 1 diffractometers
- *Petrographic observations*: thin-section analysis using polarising optical microscope Olympus BX41, digital camera Olympus DP70, and Analysis Five software (following Whitbread 1995)

PROTOCOL 1

CHEM dataset

+

*isometric log-ratio transformation
(ILR)*

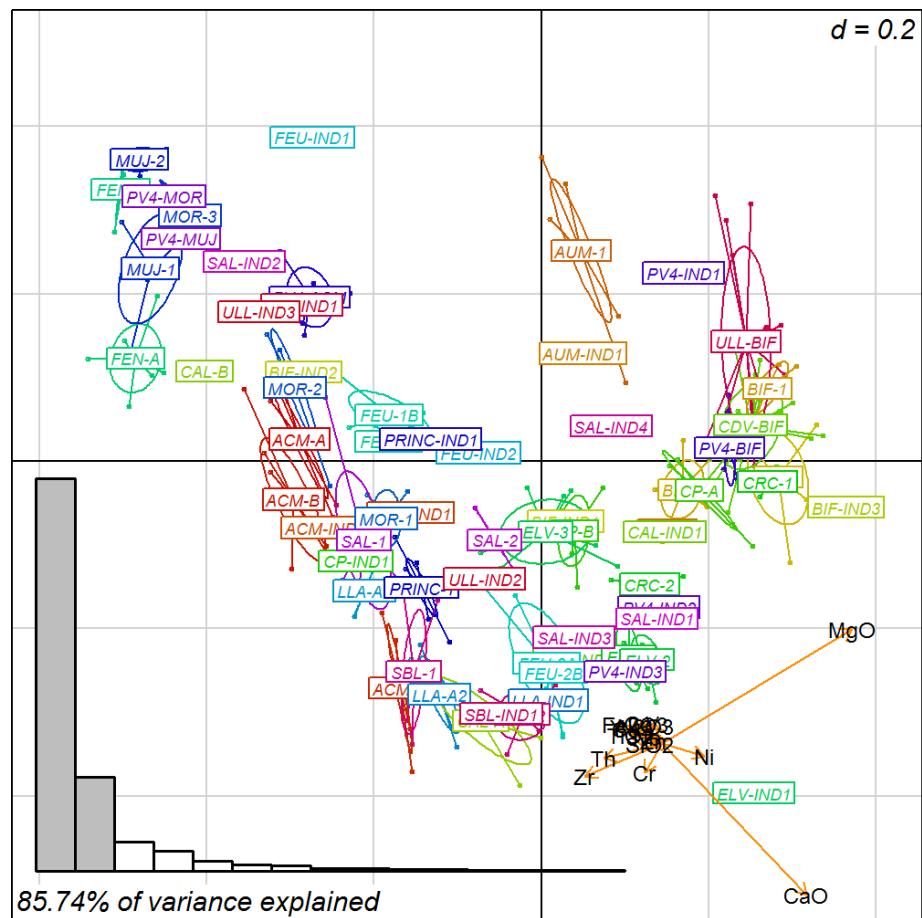
+

*robust Principal Components
Analysis (robPCA)*

following the procedure explained in:

Filzmoser, Hron and Reimann (2009). Principal component analysis for compositional data with outliers. Environmetrics, 20:621-632. DOI: 10.1002/env.966

PROTOCOL 1



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PROTOCOL 2

PETRO dataset

+

transformation to ranks

+

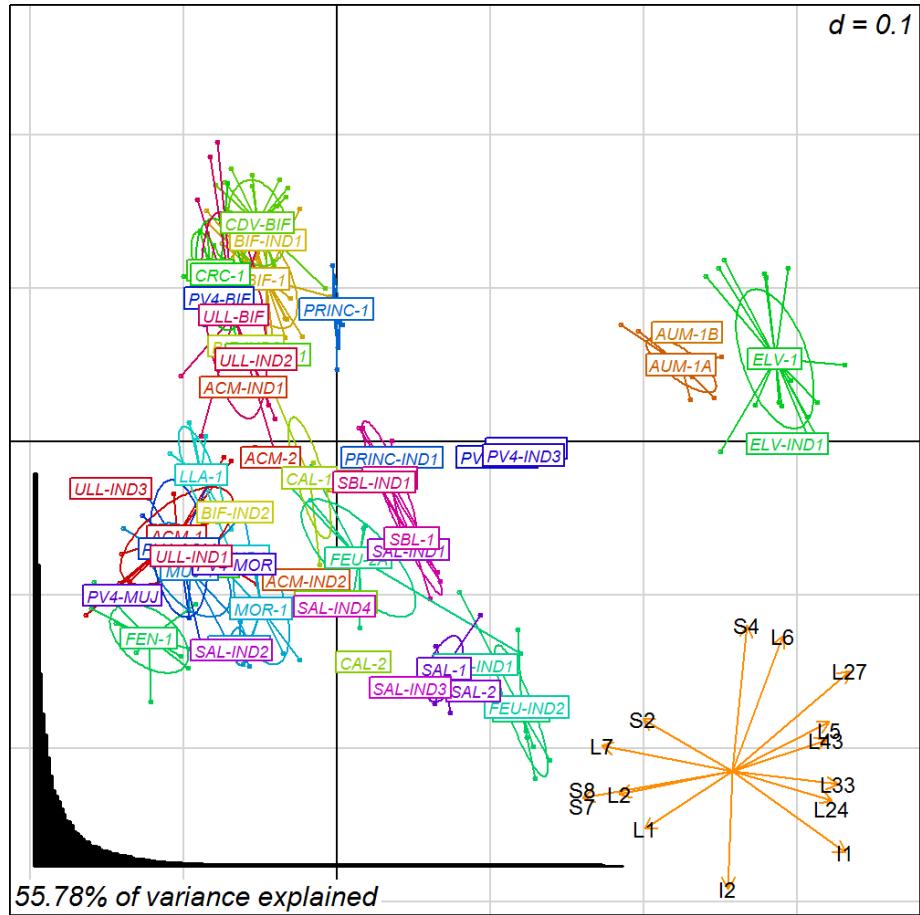
Relative ranking difference (RRD)

+

*Principal Coordinates Analysis
(PCoA)*

See: [Podani \(1999\). Extending Gower General Coefficient of Similarity to Ordinal Characters. Taxon, 48\(2\): 331-340.](#)
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PROTOCOL 2



PETRO dataset
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PROTOCOL 3

CHEM + PETRO dataset

+

CHEM: centred log-ratio transformation (CLR)

*PETRO: transformation to ranks + Relative ranking difference
(RRD)*

+

Extended Gower distance

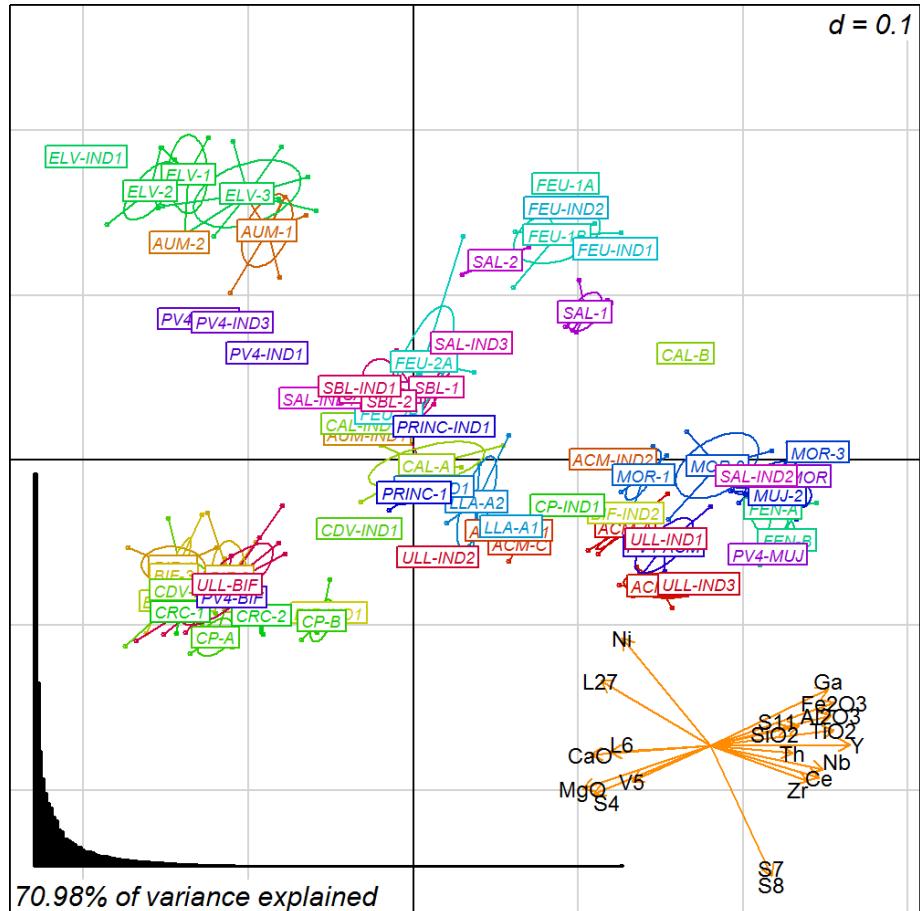
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Principal Coordinates Analysis

(PCoA)

See: [Pavoine, S., Vallet, J., Dufour, A.-B., Gachet, S. and Daniel, H. \(2009\), On the challenge of treating various types of variables: application for improving the measurement of functional diversity. Oikos, 118: 391–402. doi: 10.1111/j.1600-0706.2008.16668.x](#)

PROTOCOL 3



CHEM + PETRO dataset

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CHEM: centred log-ratio transformation (CLR)

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Extended Gower distance

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Principal Coordinates Analysis (PCoA)

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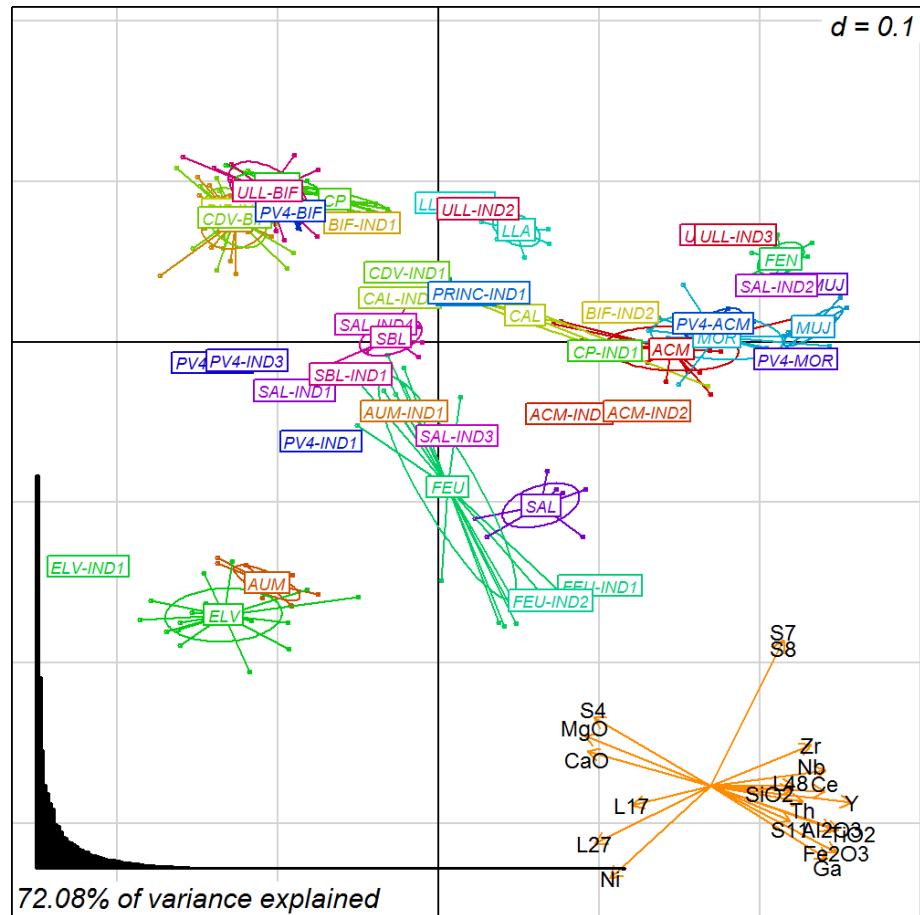
PROTOCOL 4

CHEM + PETRO_{PROV} dataset

+

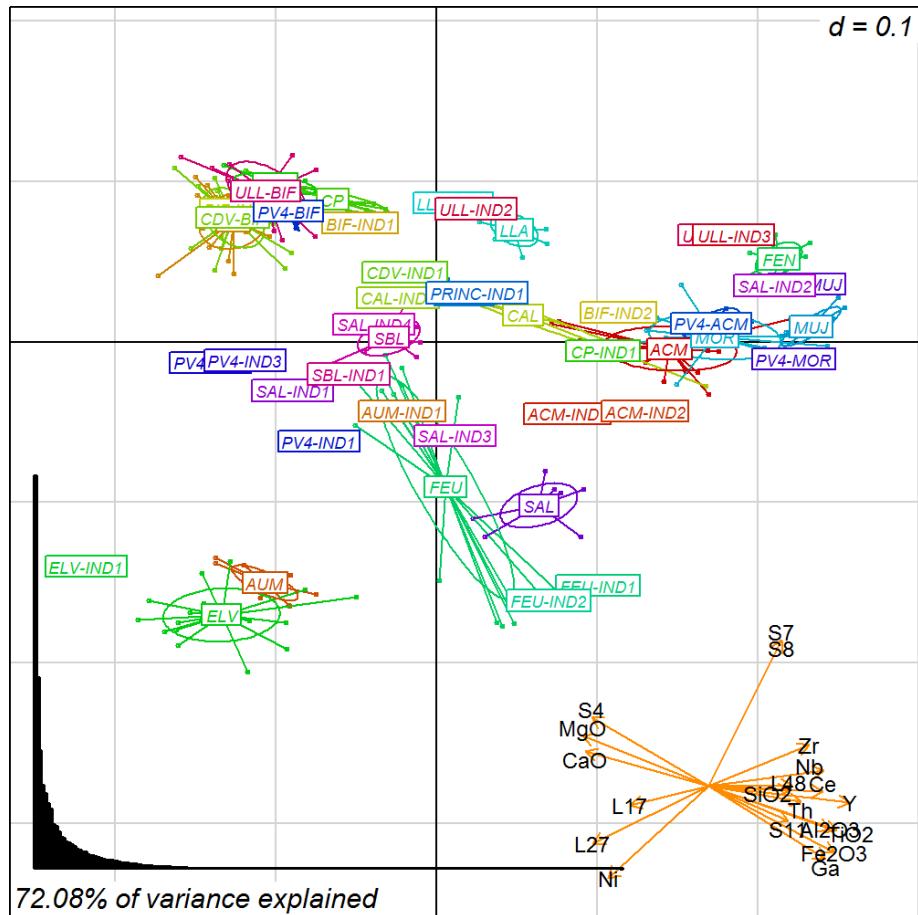
apply procedures in Protocol 3

PROTOCOL 4



CHEM + PETRO_{PROV} dataset
+
apply procedures in Protocol 3

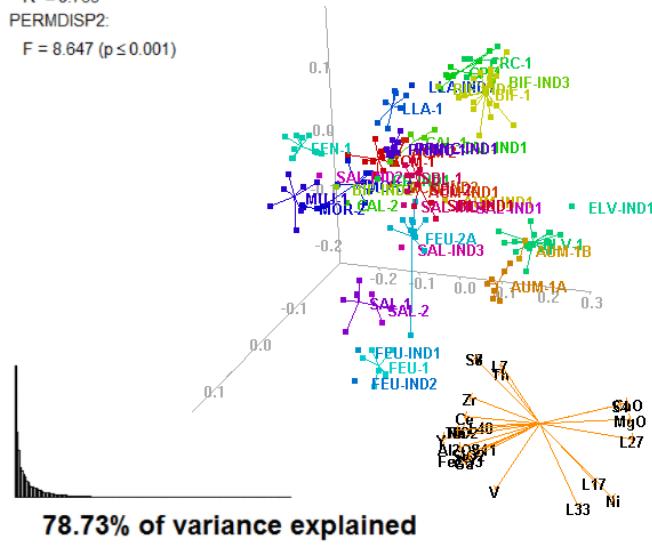
PROTOCOL 4



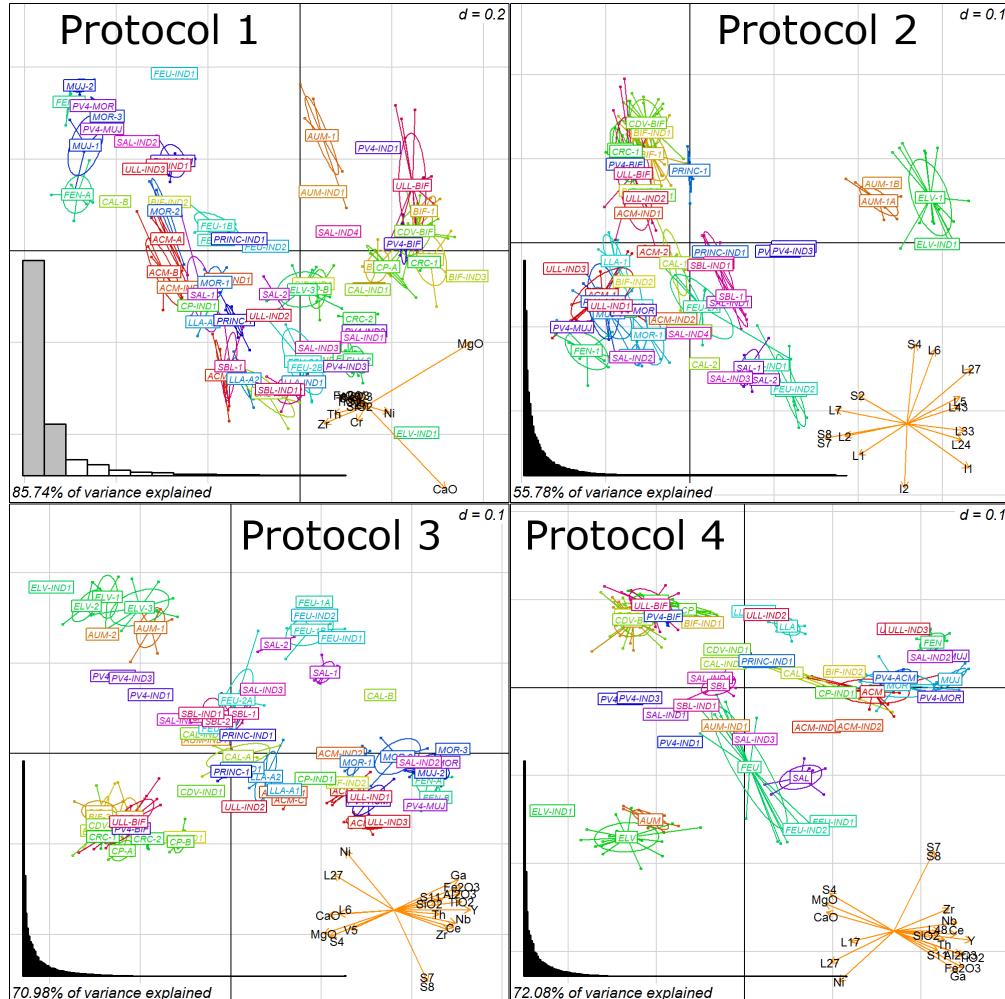
CHEM + PETRO_{PROV} dataset
+

apply procedures in Protocol 3

PERMANOVA:
 $F = 12.302$ ($p \leq 0.001$)
 $R^2 = 0.735$
PERMDISP2:
 $F = 8.647$ ($p \leq 0.001$)



GENERAL COMPARISON

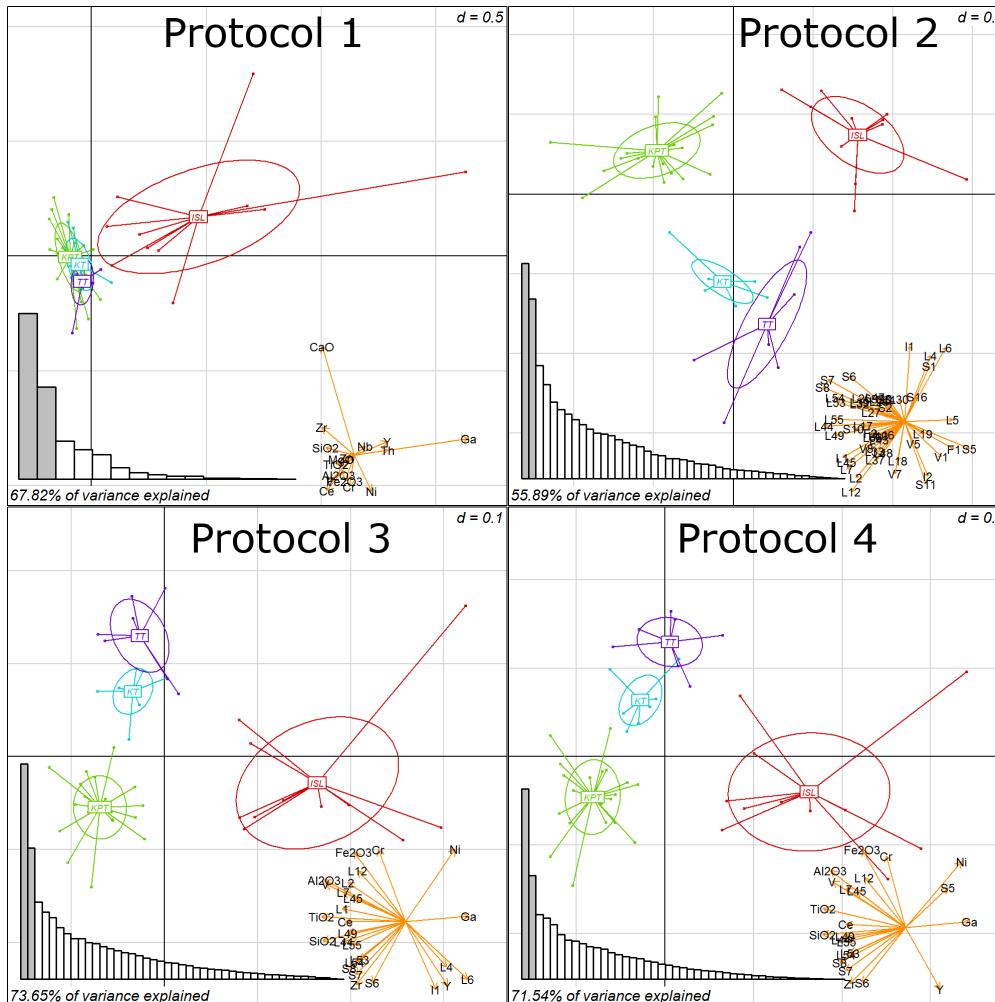


CASE STUDY: TABLEWARE FROM BACTRIA

- *Tableware from NW ancient Bactria (Surkhan Darya region, Uzbekistan)*
- *45 individuals from 4 sites: Kampyr Tepe (KPT) (Martínez Ferreras 2015) and three locations associated to ancient Termez (KT, TT, ISL) (Tsantini et al. 2016)*
- *KPT dates from the Hellenistic Period (c. 327-140 BC), TT the Yuezhi Period (c. 148 BC to 78 AD), KT the Kushan-Sassanian Period (c. 280-400 AD), and ISL the Late Pre-Mongol Islamic Period (c. 1000-1200)*



GENERAL COMPARISON



The protocols can be applied using the cerUB package in R

*Custom biplots can be done with **biplot2d3d***

Angourakis, A., Martínez Ferreras, V., Torrano, A. and Gurt Esparraguera, J.M. (2018). Presenting multivariate statistical protocols in R using Romanwine amphorae productions in Catalonia, Spain. Journal of Archaeological Science, 93: 150-165.

<https://doi.org/10.1016/j.jas.2018.03.007>

Visit the cerUB package tutorial:

https://andros-spica.github.io/cerUB_tutorial

FUNDING

Characterization and modeling of technological processes in the manufacture of ceramics from ancient societies in Central Asia. From Hellenism to Islam (CAMOTECER), HAR2012-32653, funded by Ministerio de Economía y Empresa, Secretaría de Estado de Investigación, Desarrollo e Innovación (Ayudas para la realización de proyectos de investigación, Subprograma de proyectos de investigación fundamental no orientada).

Las sociedades antiguas complejas de Asia Central a través de la cerámica. Entre la tradición nómada y las influencias mediterráneas (CERAC), HAR2016-75133-C3-1-P, (subprojetcs: Caracterización arqueométrica de cerámicas de Asia Central: Patrones tecnológicos, interacción y evolución cultural [CATECCER], HAR2016-75133-C3-3-1-P, and Centros de producción cerámica y centros de consumo en Asia Central: Contextualización arqueológica [CONCERAC], HAR2016-75133-C3-3-P), funded by the Ministerio de Ciencia, Innovación y Universidades (Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016).

Termez en Bactriana, Fundación Palarq. Paleoantropología y Arqueología. Convocatoria del año 2017.



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THANK YOU!

address any questions to A. Angourakis: andros.spica@gmail.com

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