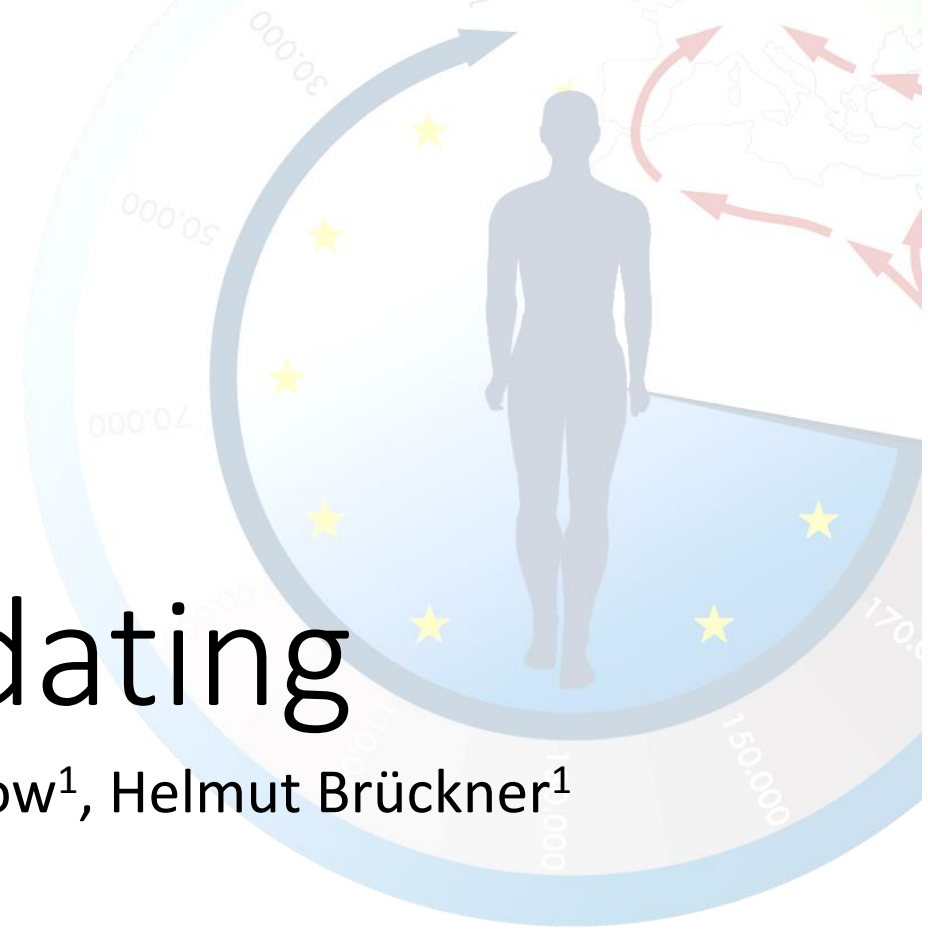


Using R for TL dating

David Strebler¹, Dominik Brill¹, Christoph Burow¹, Helmut Brückner¹

¹*Institute of Geography – University of Cologne, Cologne, North Rhine-Westphalia, Germany*



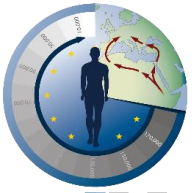
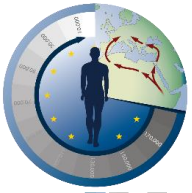


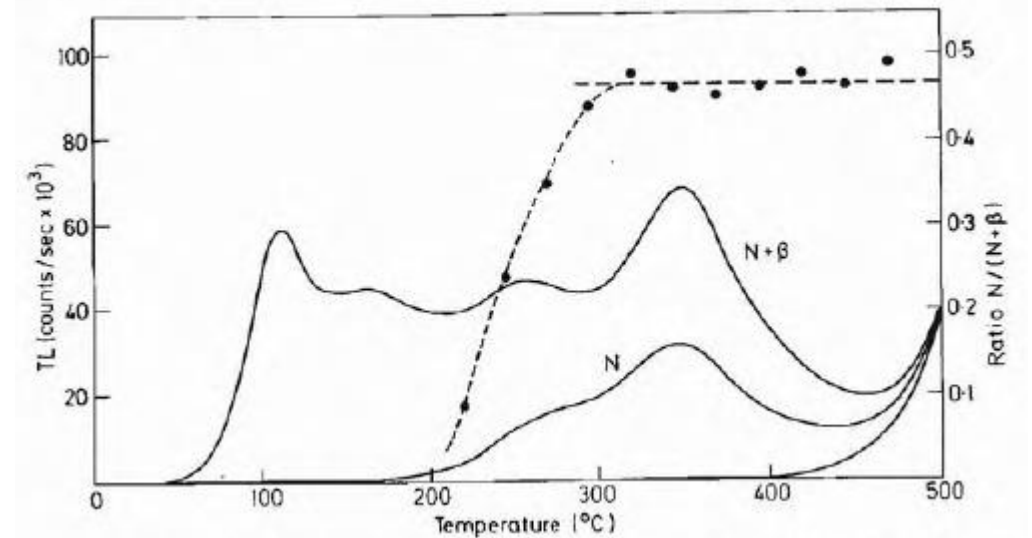
Table of Contents

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 - Philosophy & main focuses
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- Bibliography

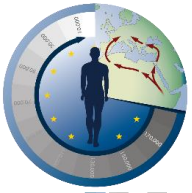


Introduction

- $Age = \frac{D_e}{\dot{D}}$
- TL dating
 - Luminescence vs. temperature
- Available software
 - Analyst (Duller 2015)
 - Excel
 - MATLAB
 - “Homemade” (C, Java, Pascal,...)
 - **R**
 - *Luminescence* package (Kreutzer et al. 2012)
 - ...



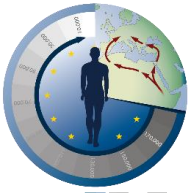
Aitken, M.J., *Thermoluminescence Dating*, Academic Press, London (1985)



The new R package TLdating

Philosophy & main focuses

- TL orientated
- **Easy to use**
 - BIN-file
- **Compatibility**
 - *Luminescence package*
- Using metadata
 - Data type
- **Uncertainty tracking**
 - Generated when the object is created
 - Updated when the data are manipulated
 - Only random uncertainty
 - Addition: $\Delta x = \sqrt{\sum_i \Delta x_i^2}$
 - Division: $\frac{\Delta x}{x} = \sqrt{\sum_i \left(\frac{\Delta x_i}{x_i}\right)^2}$



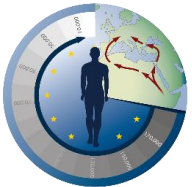
Our new R package: *TLdating*

Pretreatment

- Update metadata
 - Two new data types
 - Preheat
 - Testdose
- Select or remove specific discs
 - TL, Preheat, Aliquots,...
- Manipulate data
 - Subtract background
 - Align peaks
- Independent of applied dating protocol

D_e estimation

- Two dating protocols
 - MAAD vs. SAR
 - Output as similar as possible.
- Plateau test
- Fitting
 - Temperature & Dose intervals
 - Different curves
 - Lin., Exp., ...
- Two approaches
 - D_e plateau (DP) vs. Growth curve (GC)



Application: Burnt flints dating

```

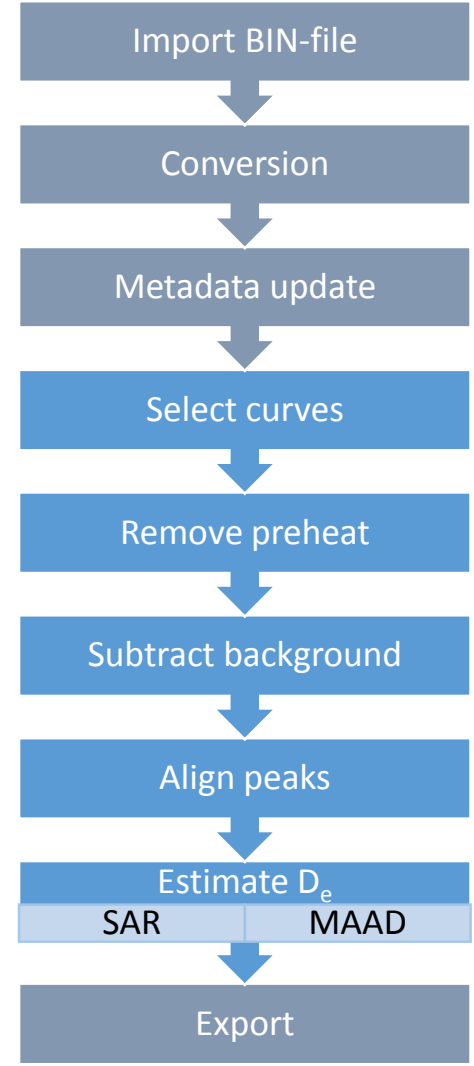
~/R/TLdating - master - RStudio
File Edit Code View Plots Session Build Debug Tools Help
Go to file/function

Example MAAD.R * Example SAR.R * Example Fading.R *
Source on Save Run Source
1 fm(list = ls())
2 setwd("~/R/test/glasgow")
3 require("TLdating")
4 require("Luminescence")
5
6 # Parameters #
7 file.name <- "TAI_19A_QG_TL_SAR"
8
9 eval.Tmin <- 340
10 eval.Tmax <- 380
11
12 relative.error <- 0.05
13
14 aligning.parameters <- list(peak.Tmin=250,
15                             peak.Tmax=400)
16
17 fitting.parameters <- list(fit.method="LIN",
18                             fit.weighted=TRUE,
19                             fit.rDoses.min=150,
20                             fit.rDoses.max=800)
21
22 plotting.parameters <- list(plot.Tmin=250,
23                             plot.Tmax=420)
24
25 rejection.criteria <- list(recycling.ratio = 10,
26                             recuperation.rate = 10,
27                             testdose.error = 10,
28                             paleodose.error = 10)
29
30 # De estimation #
31 result <- script_TL_SAR(file.name=file.name,
32                         relative.error = relative.error,
33                         eval.Tmin=eval.Tmin,
34                         eval.Tmax=eval.Tmax,
35                         aligning.parameters = aligning.parameters,
36                         fitting.parameters=fitting.parameters,
37                         plotting.parameters=plotting.parameters)
38
39 # De distribution (Luminescence package) #
40 de.values.DP <- result$de.values.DP
41 de.values.GC <- result$de.values.GC
42
43 plot_AbanicoPlot(de.values.DP,
44                  polygon.col=adjustcolor(col="blue2",alpha.f=0.33),
45                  bar.col=adjustcolor(col="grey80",alpha.f=0.53),
46                  stats=c("min","max"),
47                  summary=c("n","mean","median","sdrel"))
48
49 plot_AbanicoPlot(de.values.GC,
50                  polygon.col=adjustcolor(col="blue2",alpha.f=0.33),
51                  bar.col=adjustcolor(col="grey80",alpha.f=0.53),
52                  stats=c("min","max"),
53                  summary=c("n","mean","median","sdrel"))
54

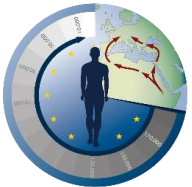
```

Parameters

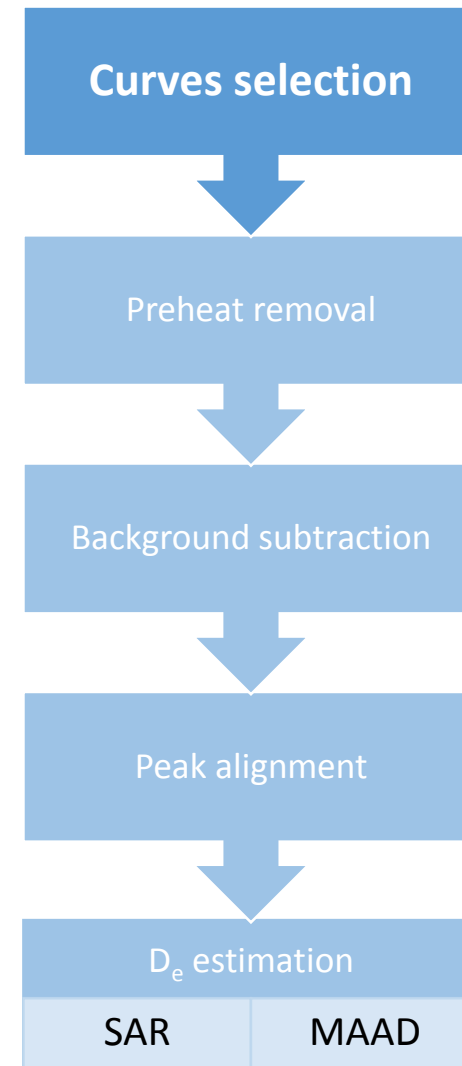
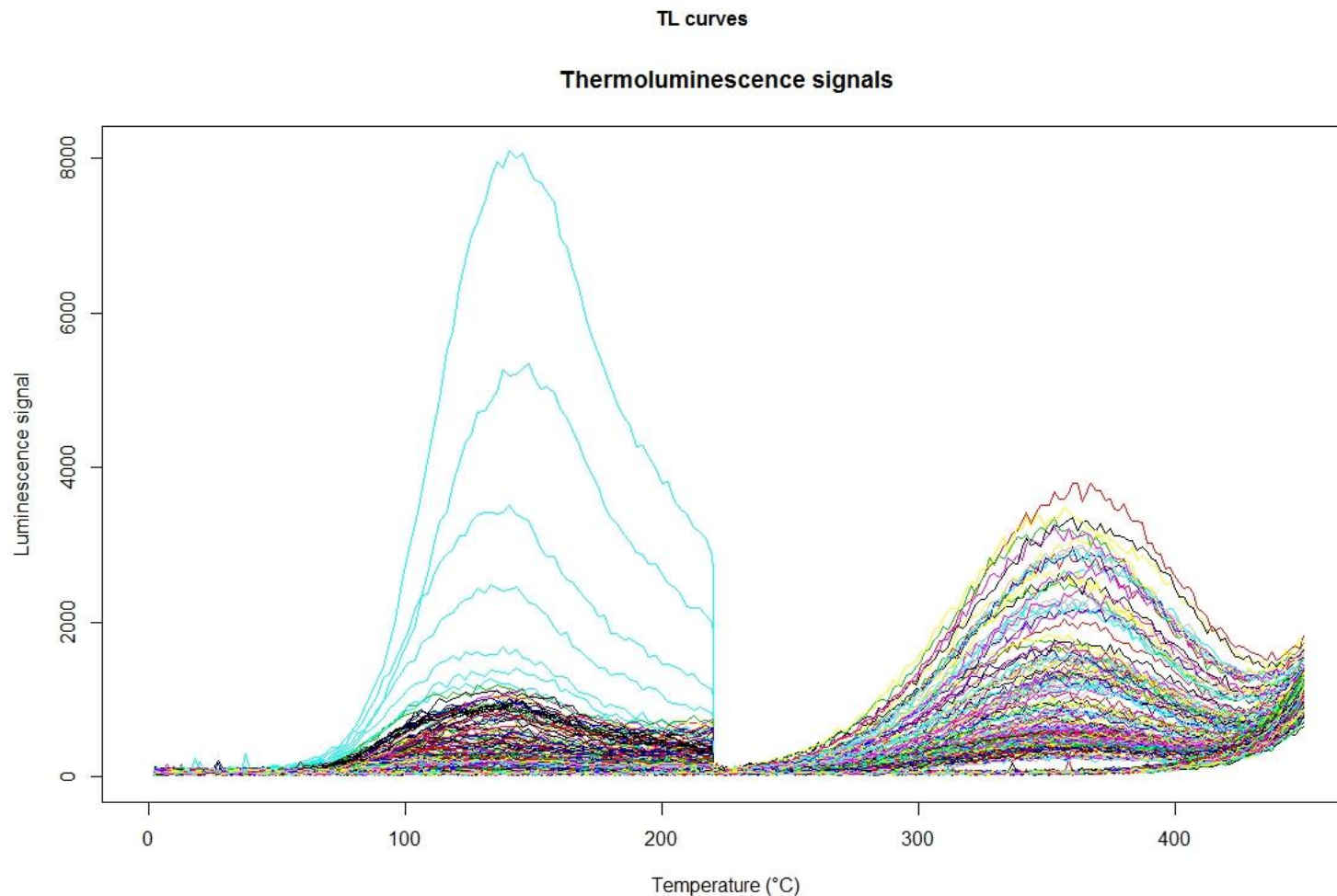
For SAR only

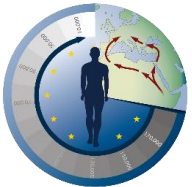


Data pretreatment

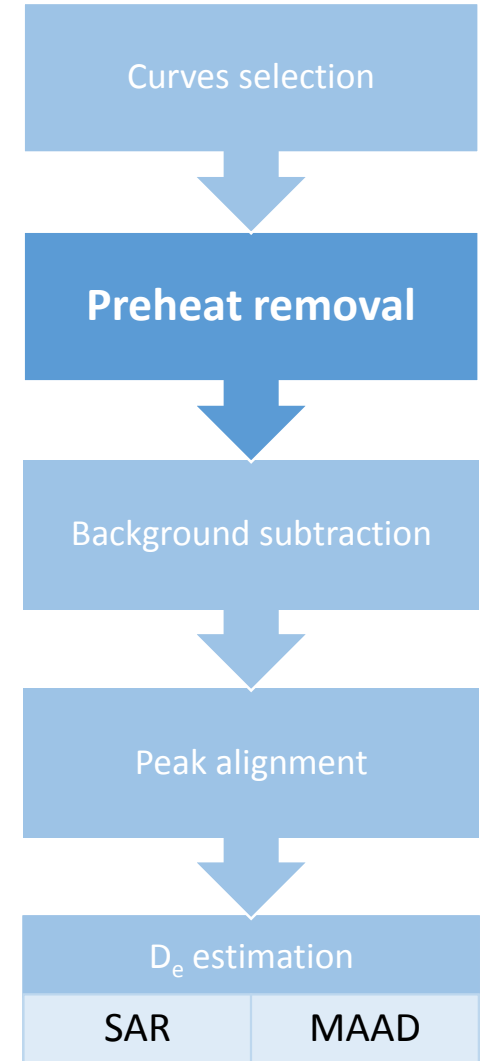
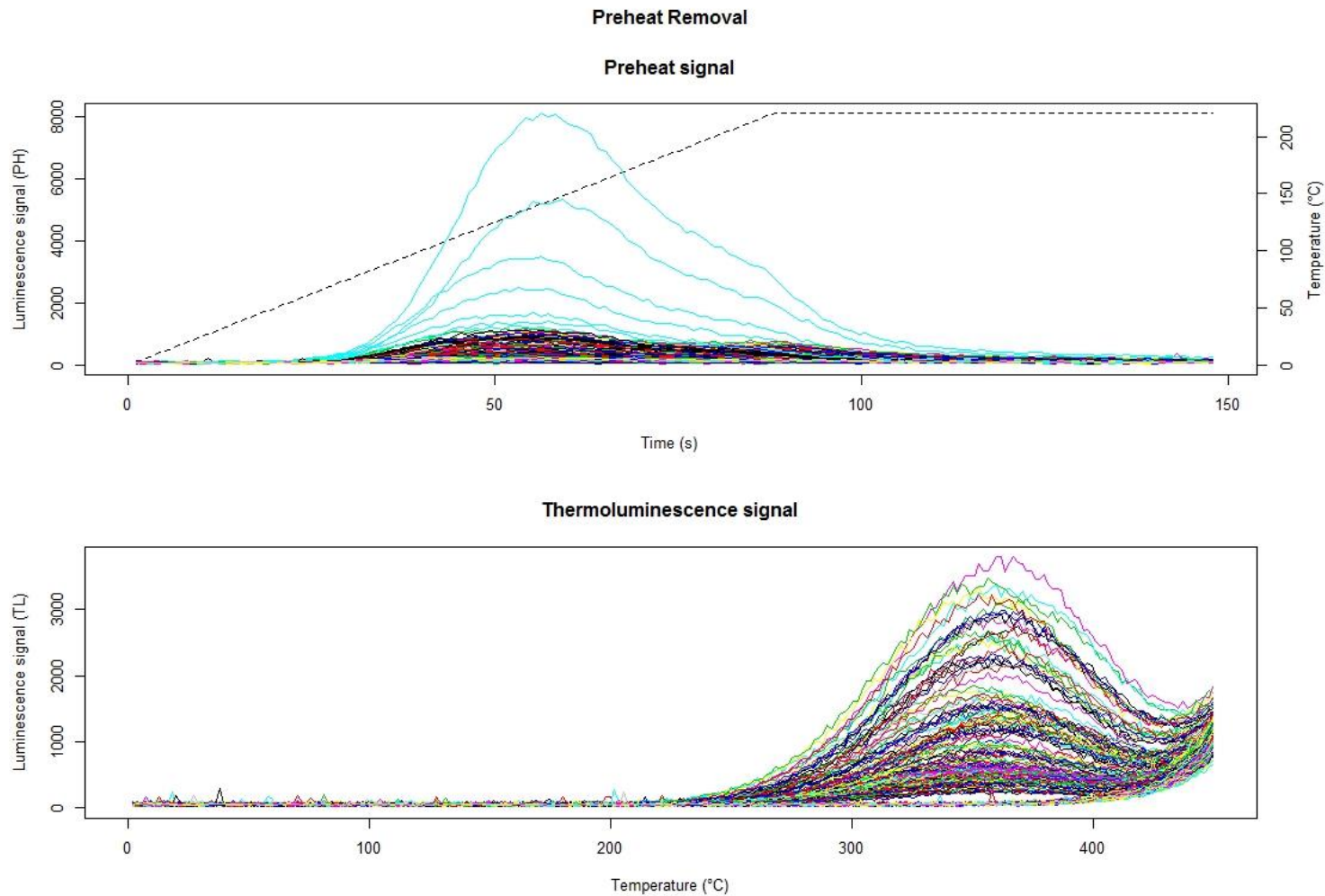


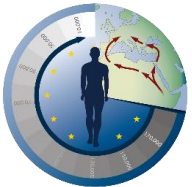
Burnt flints dating: Curve selection



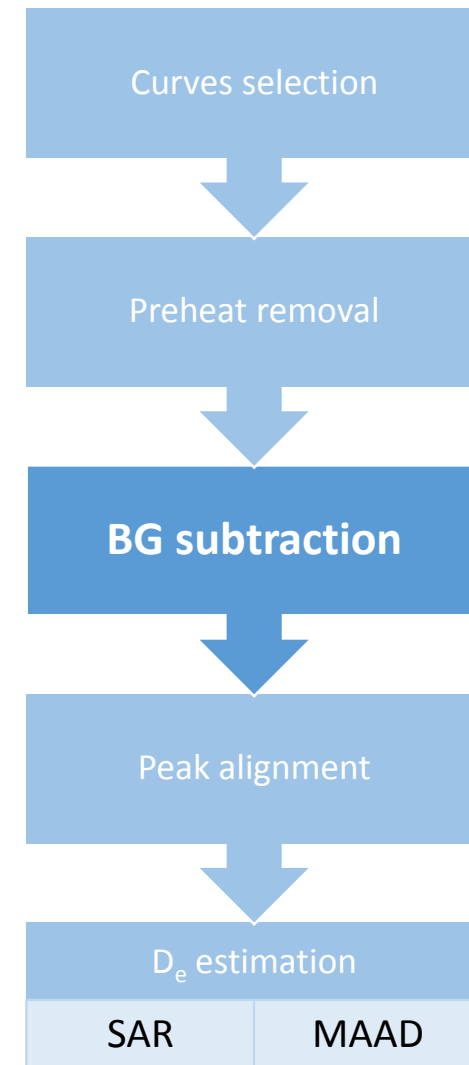
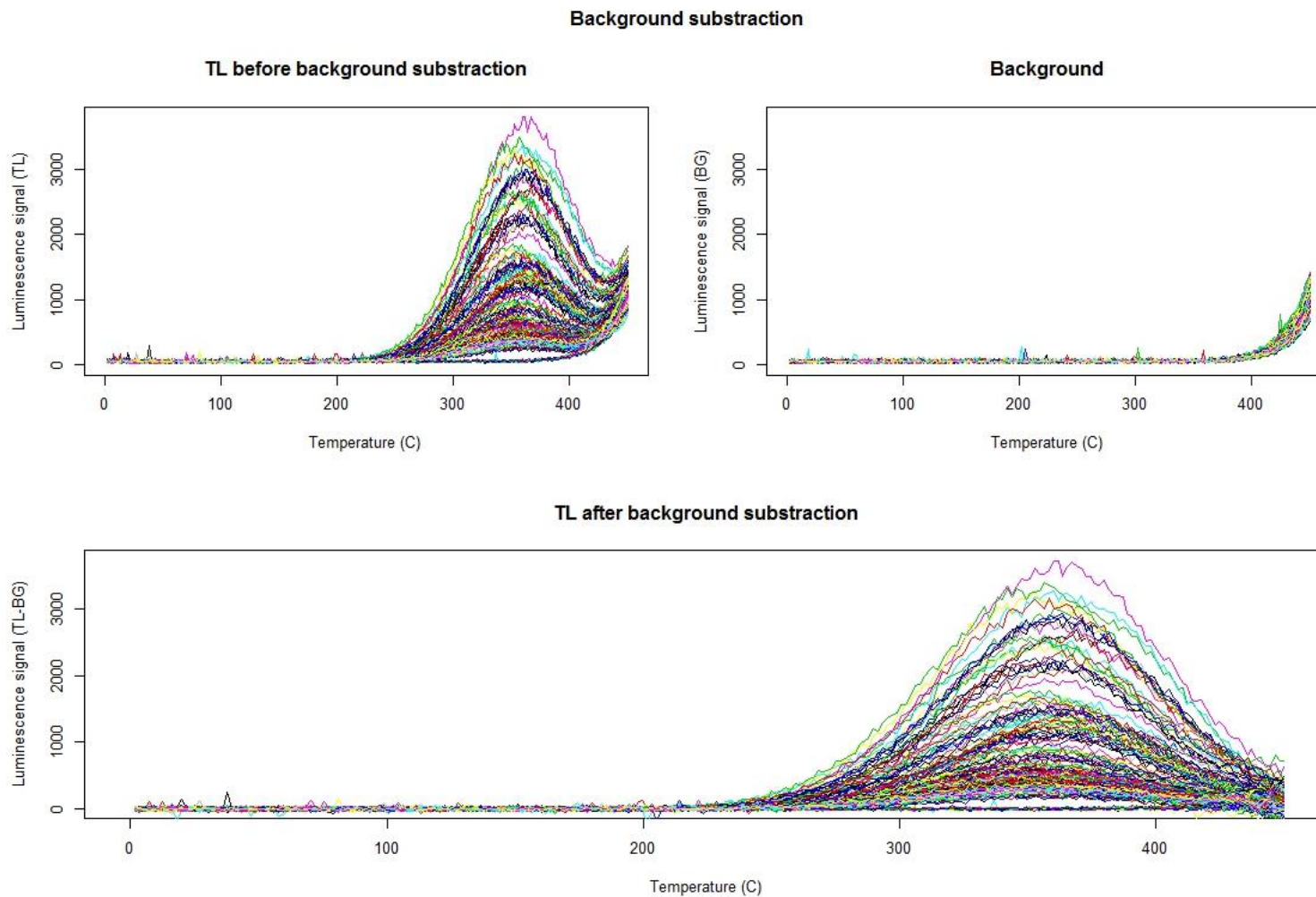


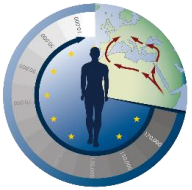
Burnt flints dating: Preheat removal



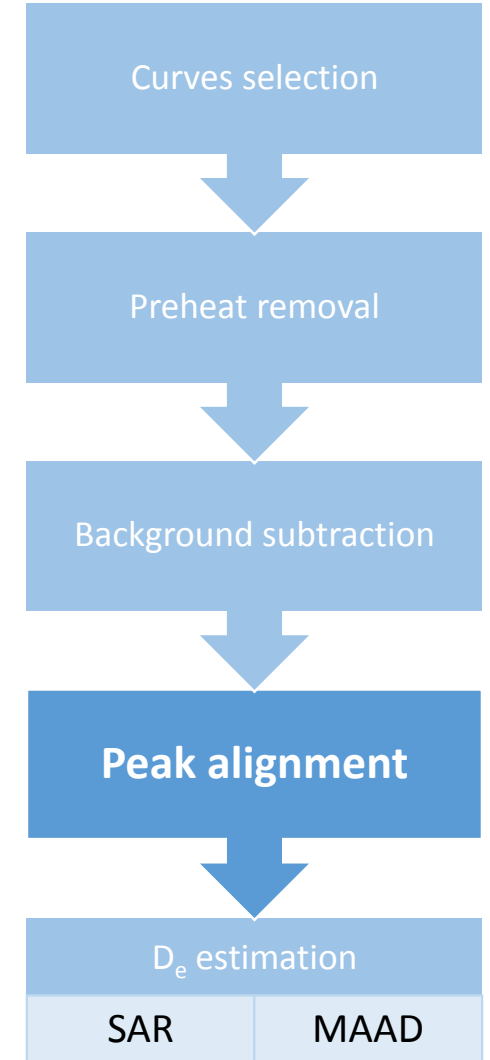
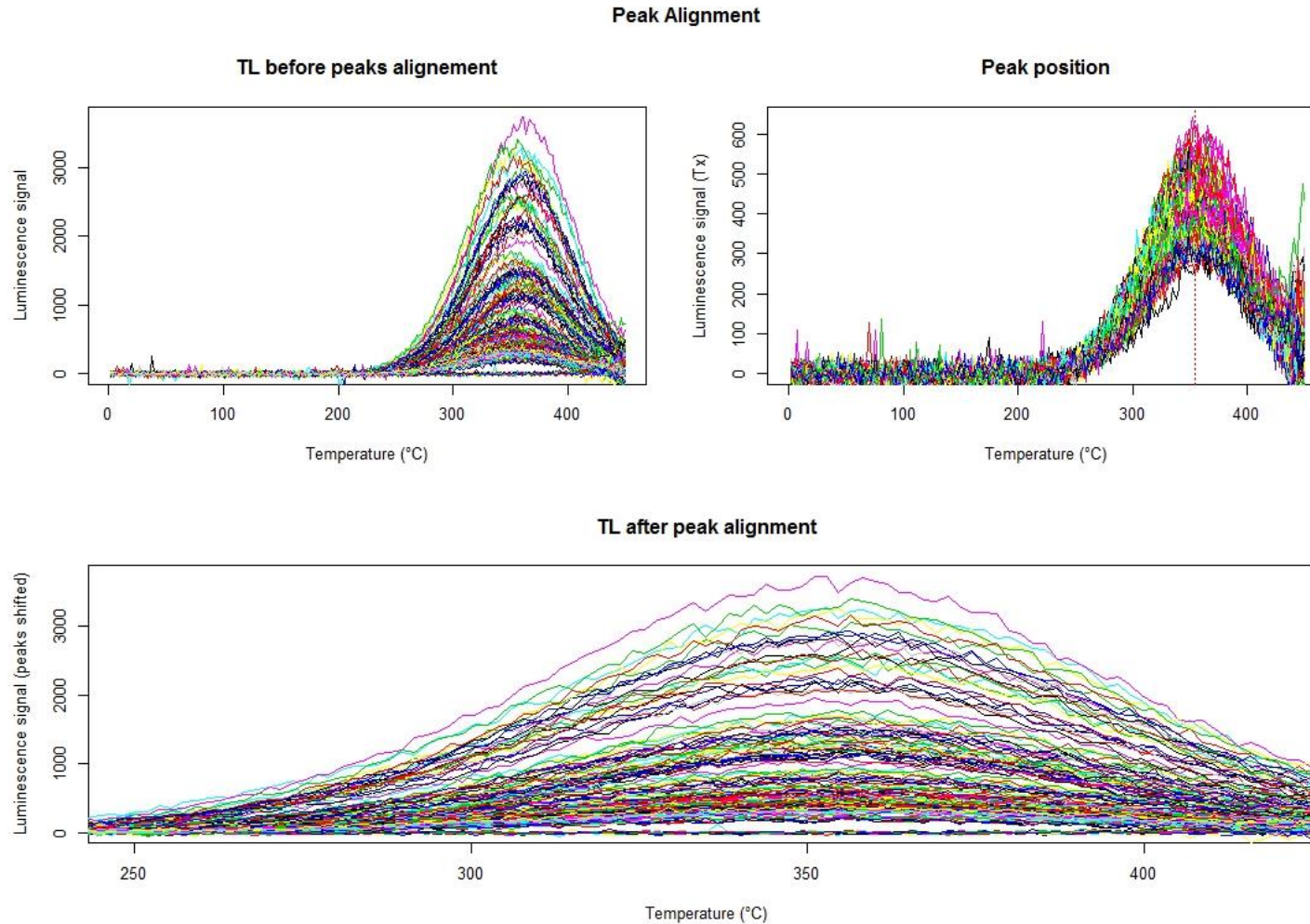


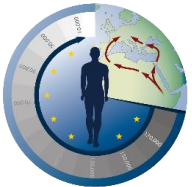
Burnt flints dating: Background subtraction





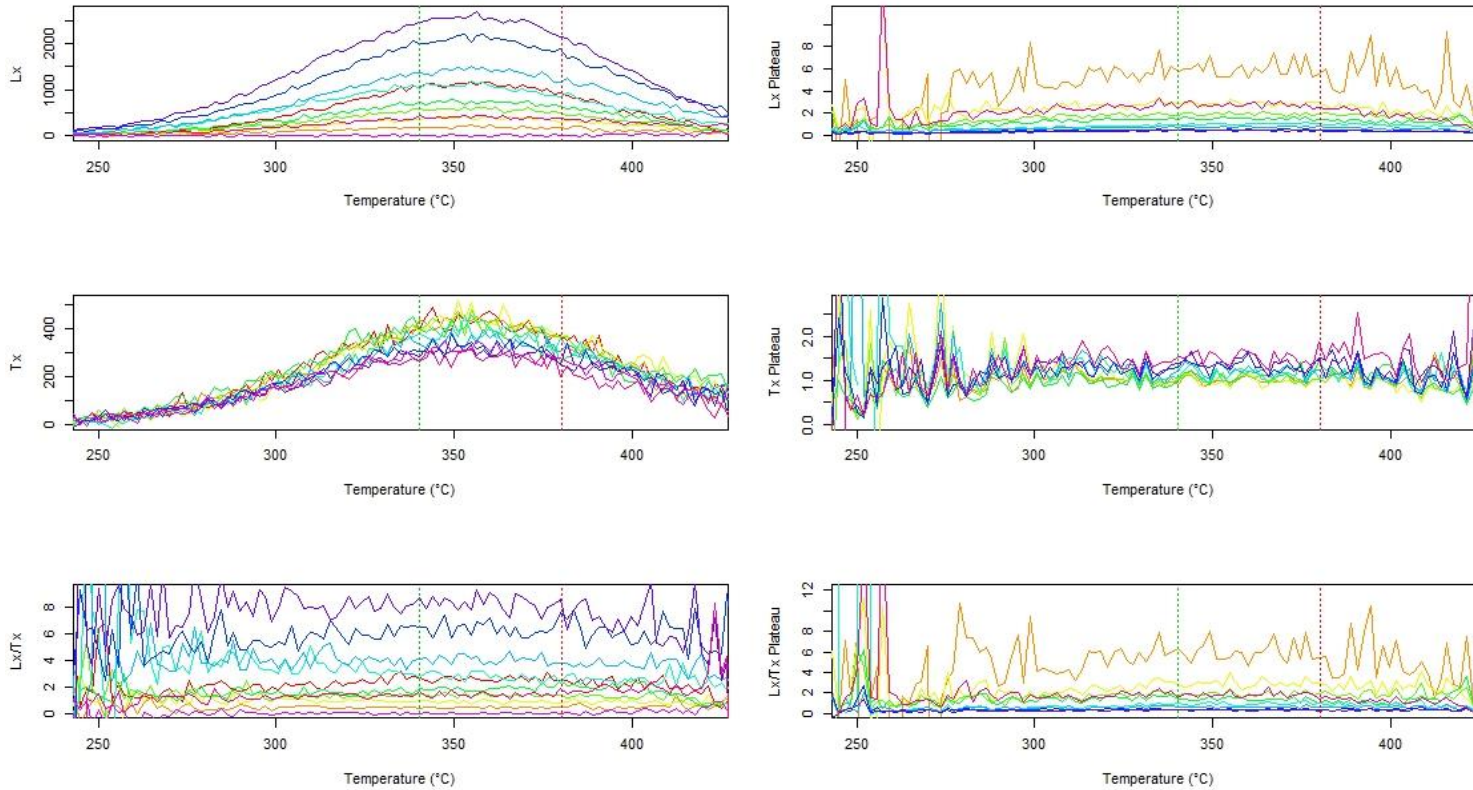
Burnt flints dating: Peak alignment





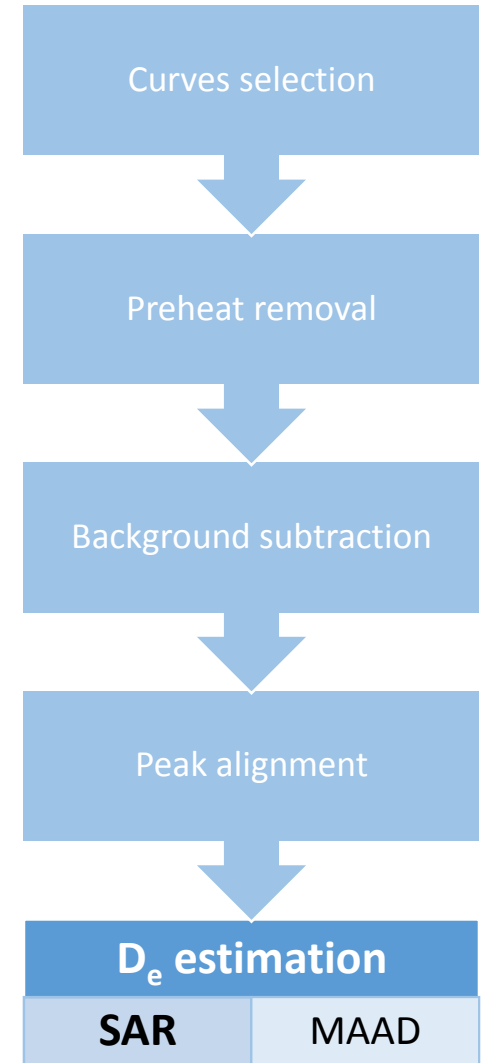
Burnt flints dating: SAR 1

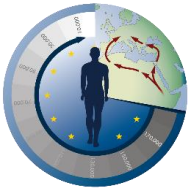
SAR: TAI 19A, Disk 1 - page 1: Regenerative doses



Legend

Names	N	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Doses (s)	0	40	80	120	160	240	320	480	640	0	120

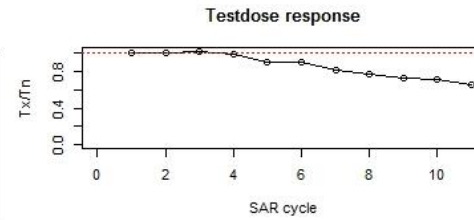
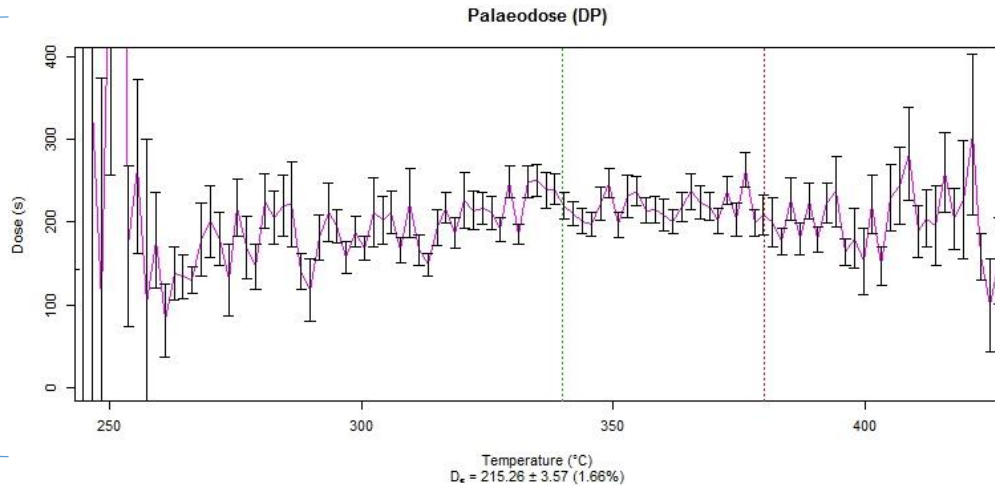




Burnt flints dating: SAR 2

SAR: TAI 19A, disk 1 - page 2: Paleodose estimation | fit:LIN (weighted)

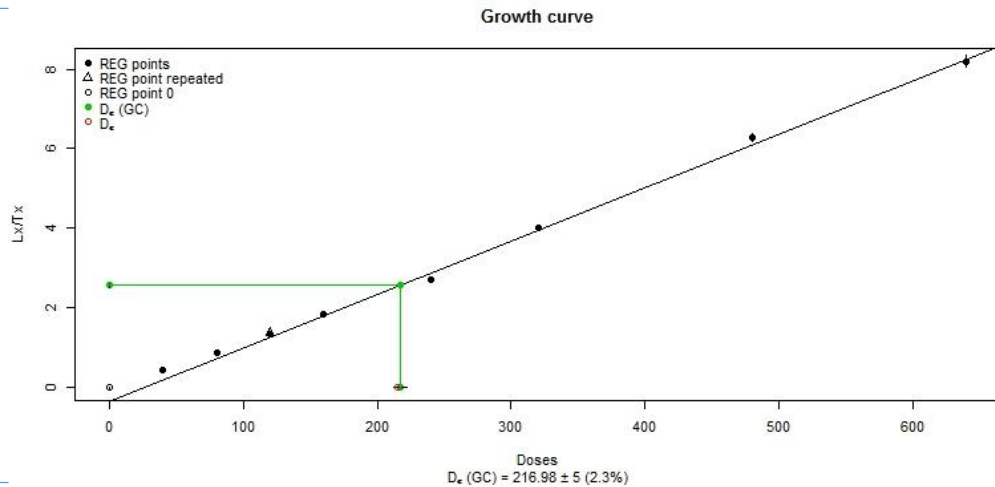
D_e plateau



Rejection criteria

Recycling ratio: 1 (R10/R3)
 Recuperation rate: -0.14% (R9/N)
 Lx error (max): 7%
 Tx error (max): 6.5%

Growth curve

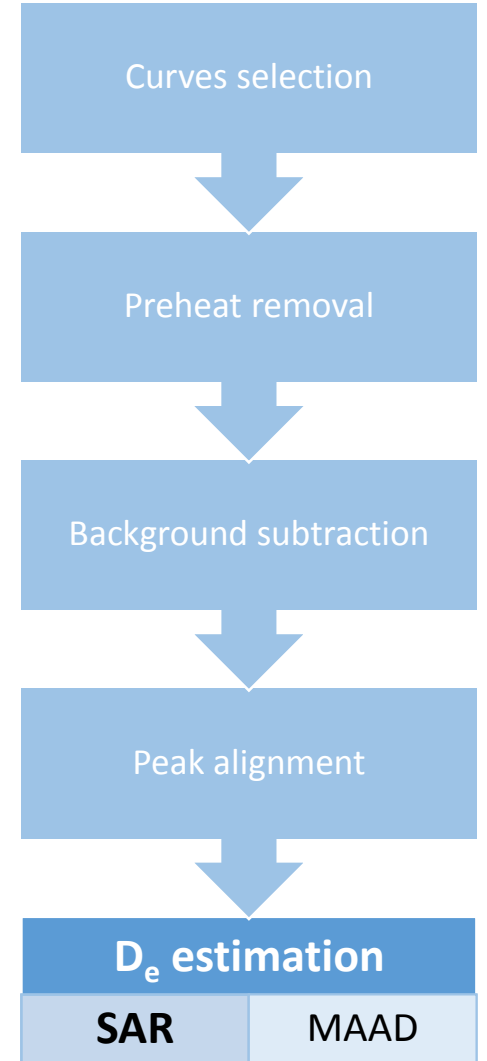


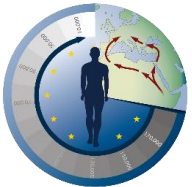
Curve fitting (GC): Linear (weighted) $y = a + bx$

a = -3.42e-01 ± 5.16e-02
 b = 1.34e-02 ± 8.03e-06

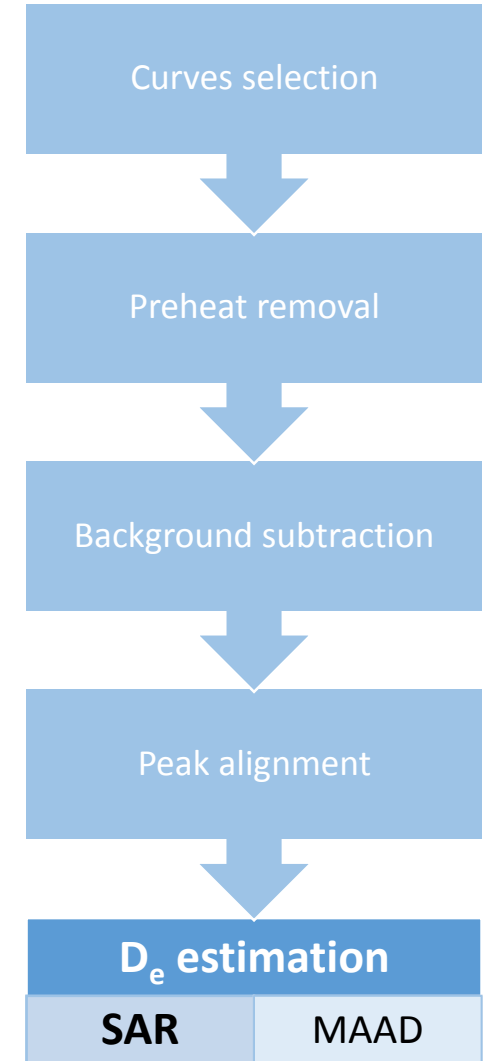
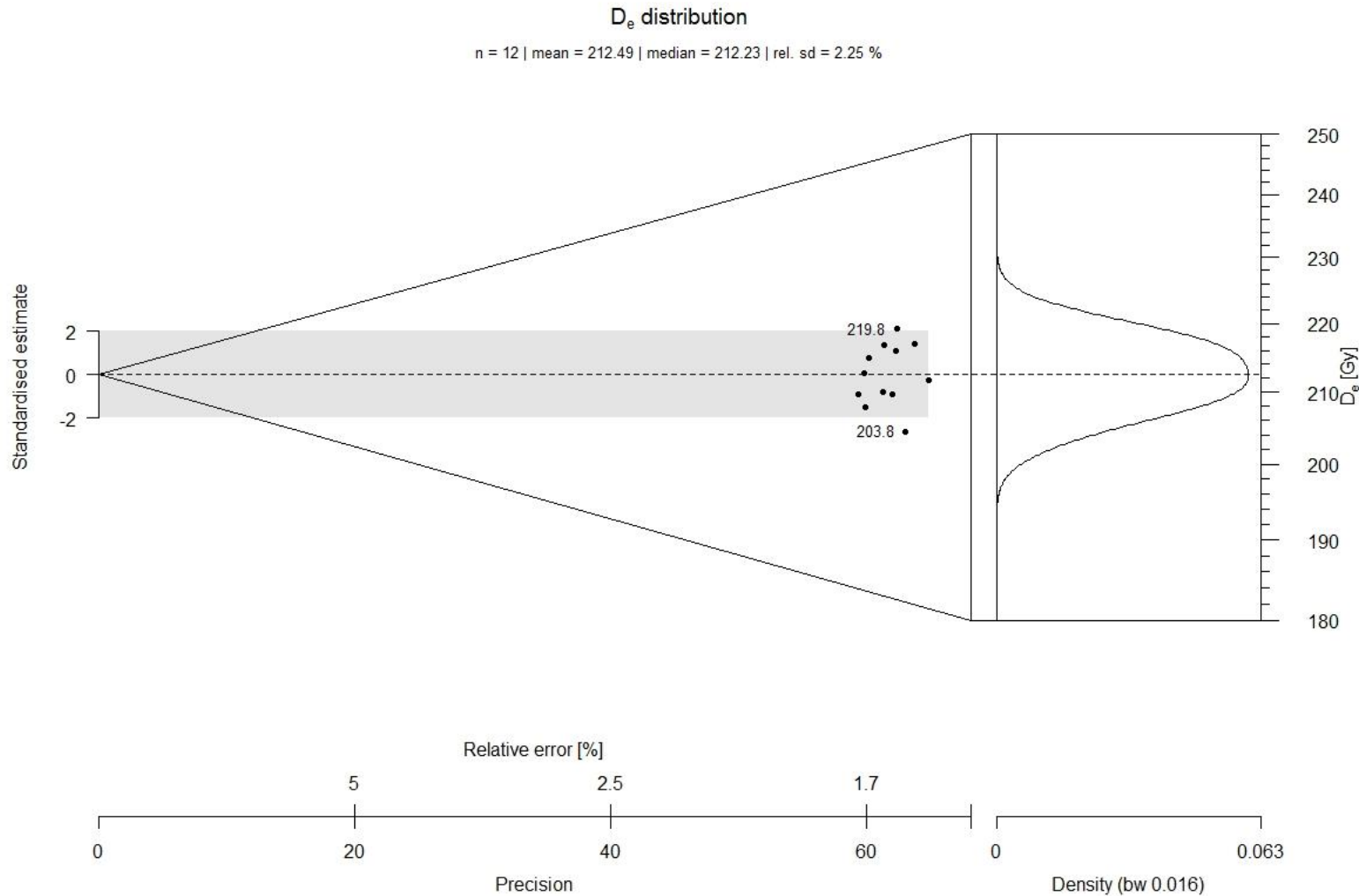
Results

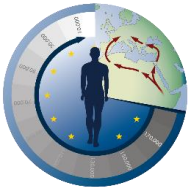
D_e (DP): 215.26 ± 3.57
 (±1.66%)
 D_e (GC): 216.98 ± 5
 (±2.3%)



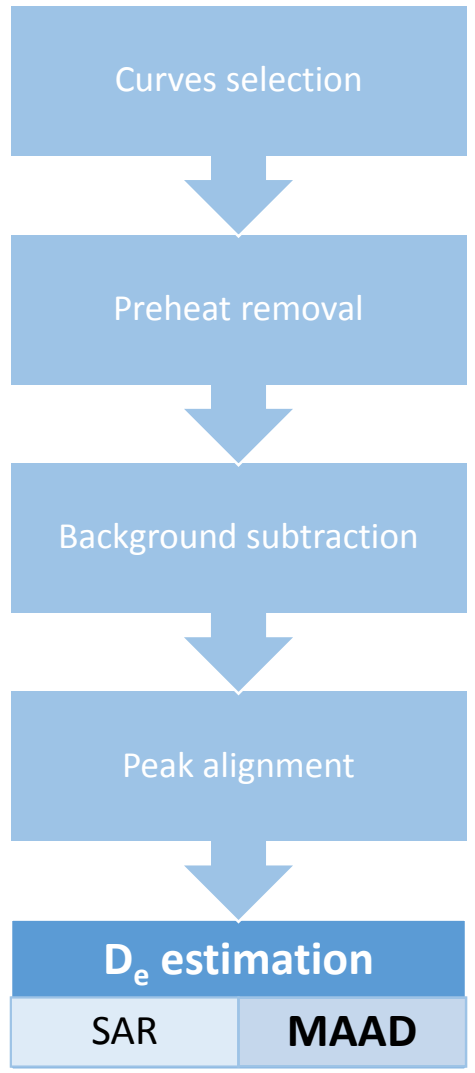
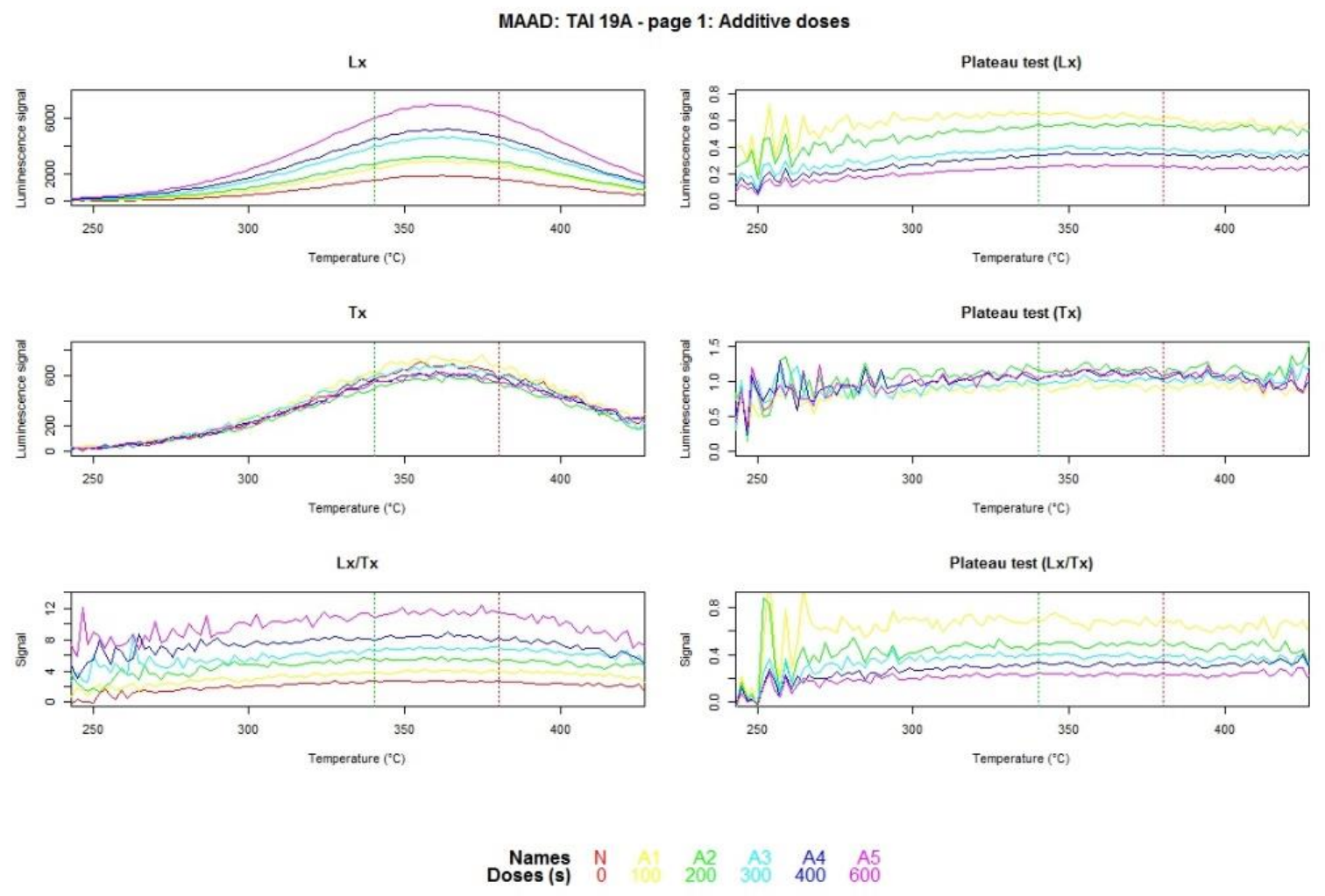


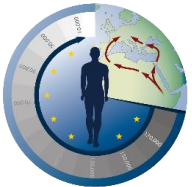
Burnt flints dating: D_e distribution





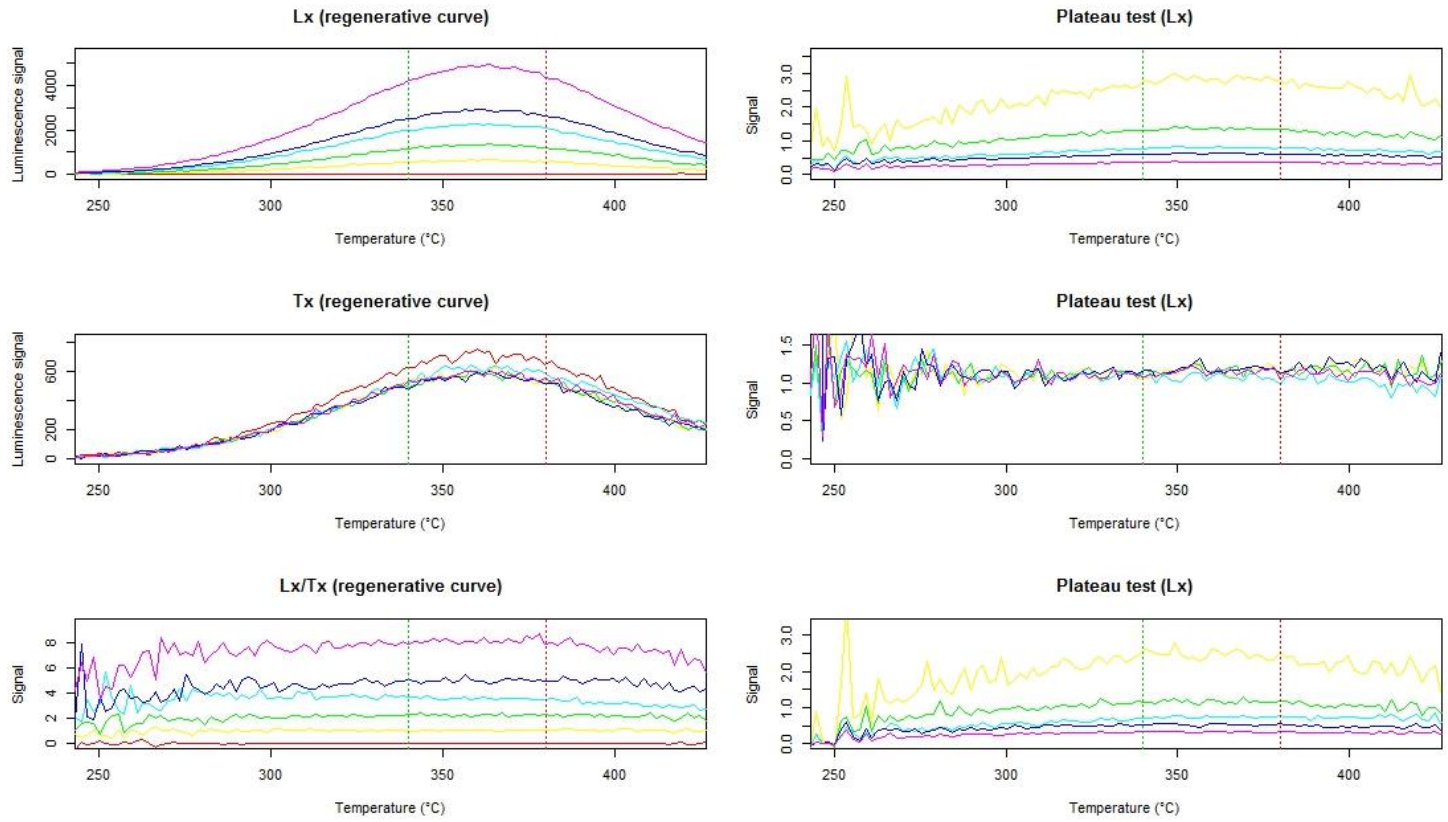
Burnt flints dating: MAAD 1



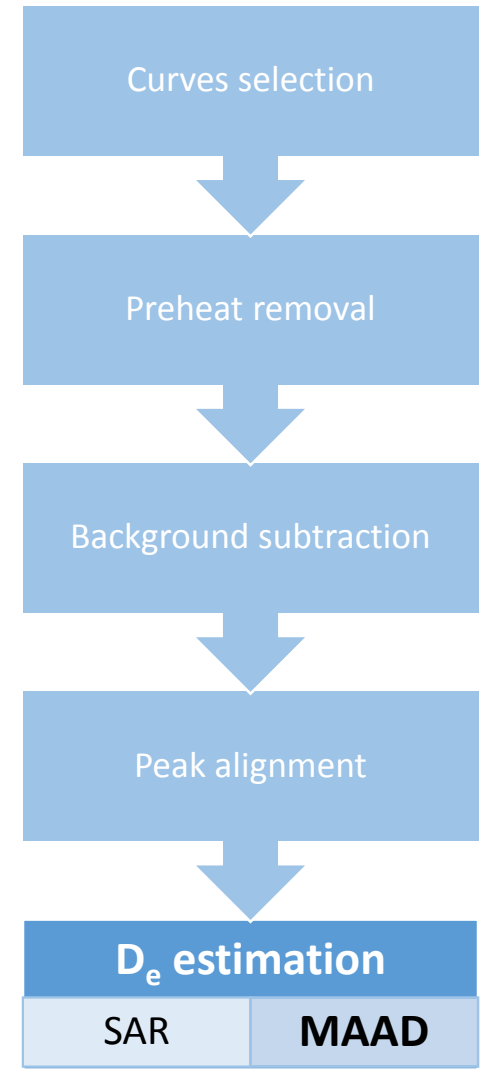


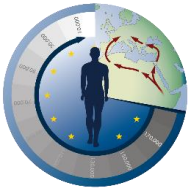
Burnt flints dating: MAAD 2

MAAD: TAI 19A - page 2: Regenerative doses



Names	R0	R1	R2	R3	R4	R5
Doses (s)	0	100	200	300	400	600





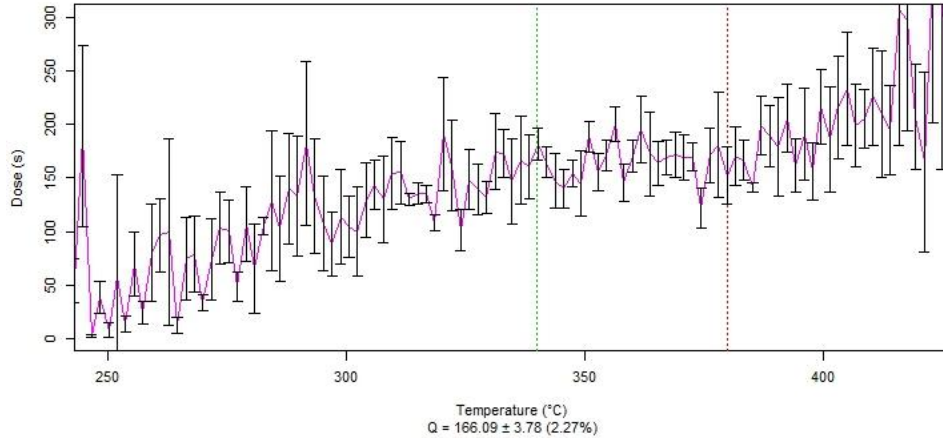
Burnt flints dating: MAAD 3

D_e plateau

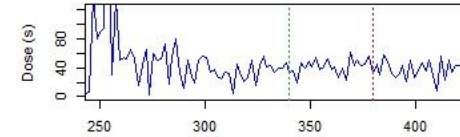
Growth curve

MAAD: TAI 19A - page 3: Palaeodose estimation | fit: LIN (weighted)

D_e plateau - Palaeodose (Q)



D_e plateau - Sublinearity corr. (I)



Rejection criteria

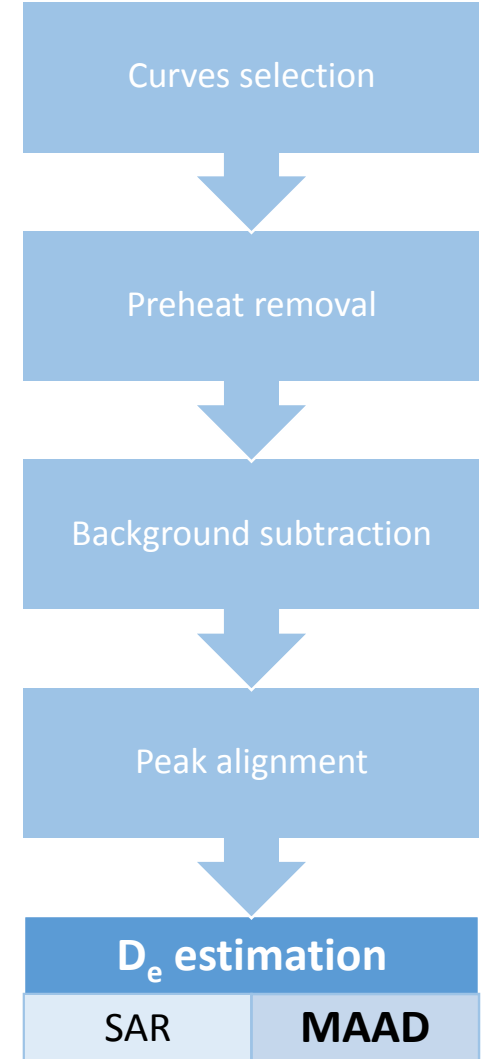
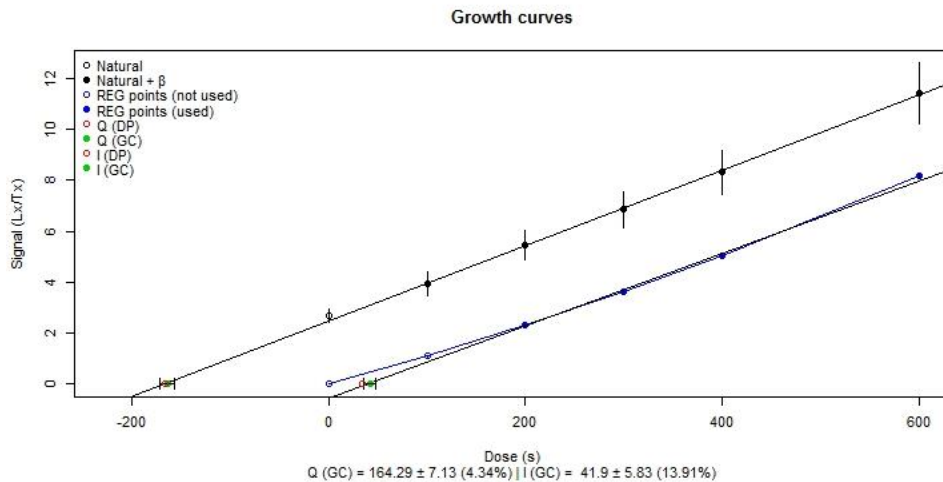
Q:
Lx error (max): 5.16%
Tx error (max): 6.03%
I:
Lx error (max): 5.3%
Tx error (max): 5.69%

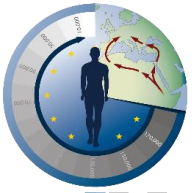
Curve fitting (GC): Linear (weighted)
 $y = a + bx$

a (Q) = 2.44e+00 ± 1.06e-01
b (Q) = 1.49e-02 ± 2.44e-06

Results

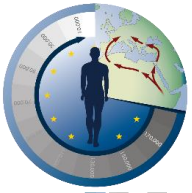
D_e (DP): 200.64 ± 3.78 (1.88%)
 D_e (GC): 206.19 ± 9.21 (4.47%)





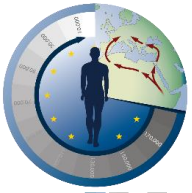
Burnt flints dating: first results

- Difference between SAR-TL and MAAD-TL generally $< \pm 5\%$
- For SAR-TL: variation $< \pm 2\%$
 - Between DP and GC approaches.
 - Between weighted and unweighted linear fitting.
- For MAAD-TL: variation from $\pm 1\%$ to $\pm 20\%$
 - Probable sources of variation
 - Sublinearity correction estimation
 - Low maximum additive dose
- Both SAR-TL and MAAD-TL provide reliable results
- SAR-TL
 - Pro: less material
 - Contra: more machine time
- MAAD-TL
 - sublinearity correction
- DP helps to select the temperature interval
- GC help to select the dose interval.



Conclusion & Outlook

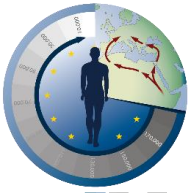
- *TLdating* package still in active development
 - Known bugs
 - Usage of Q slope for I estimation (MAAD).
 - Need improvements
 - Increase *user-friendliness*
 - Add additional fitting models
 - Improve documentation
 - **But:** it is already fully functional and open for use!
- **Looking for beta-tester!**
 - What functionality would you like to see implemented?



Acknowledgment

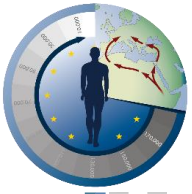
- We would like to thank Christoph Schmidt, who collected the flint samples, and Anja Zander, who provides extra TL curves to test the package.
- This project was realized in the context of the CRC 806 “Our way to Europe” funded by the German Research Foundation (DFG).



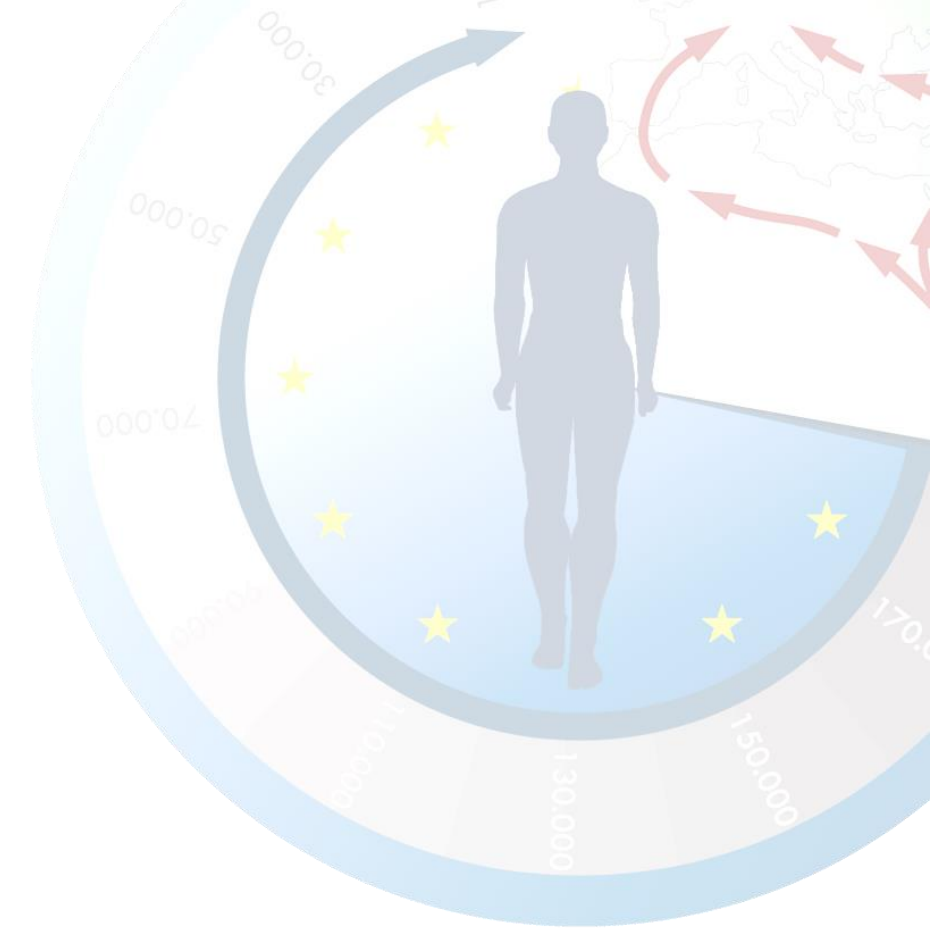


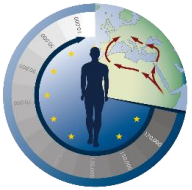
Bibliography

- *Aitken, M.J. 1985. Thermoluminescence Dating, Academic Press, London.*
- Duller, G.A.T. 2015. The Analyst software package for luminescence data: overview and recent improvements. *Ancient TL* 33 (1), 35-42.
- Kreutzer, S., Schmidt, C., Fuchs, M.C., Dietze, M., Fischer, M., Fuchs, M., 2012. Introducing an R package for luminescence dating analysis. *Ancient TL* 30 (1), 1–8.



Extra





Application: Looking for Fading

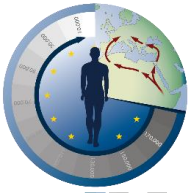
```
~/R/TLdating - master - RStudio
File Edit Code View Plots Session Build Debug Tools Help
Example.MAAD.R x Example.SAR.R x Example.Fading.R x
Source on Save
[-.data.frame] Next Prev Replace Replace All
In selection Match case Whole word Regex [x] Wrap
1 rm(list = ls())
2 setwd("~/R/test/glasgow")
3 require("TLdating")
4 require("Luminescence")
5
6 file.name <- "D-BGB TL Fading 1,2,3,4,5-PM irradiated signal"
7 file.extension <- ".binx"
8
9 folder.in <- "/"
10 folder.out <- "/"
11
12 aligning.parameters <- list(peak.Tmin=250,
13                             peak.Tmax=400,
14                             no.testdose=TRUE)
15
16 plotting.parameters <- list(plot.Tmin=250,
17                              plot.Tmax=450,
18                              no.plot=FALSE)
19
20 relative.error <- 0.05
21
22
23
24 path.in <- paste(folder.in, file.name, file.extension, sep="")
25 path.out <- paste(folder.out, "new_", file.name, file.extension, sep="")
26
27 # Read file
28 data.in <- readBIN2R(path.in)
29
30 data <- Risoec.BINfileData2TLum.FileData(object = data.in,
31                                         relative.error = relative.error)
32
33 # Identify test-dose
34 data <- mod_identify.dtype(object = data,
35                             use.comment = FALSE,
36                             sequence = c("Dose", "Background"))
37
38 # Select Aliquot
39 data <- mod_extract.aliquot(data, list = 13:18)
40
41 # Background subtraction
42 data <- mod_substract.background(data)
43
44 # Peaks alignment
45 mod_align.peaks(object=data,
46                 aligning.parameters=aligning.parameters,
47                 plotting.parameters=plotting.parameters)
48
49 # Saving of preliminary results
50 data.out <- TLum.fileData2Risoec.BINfileData(data)
51 writer2BIN(data.out, path.out)
52
```

Parameters

Import

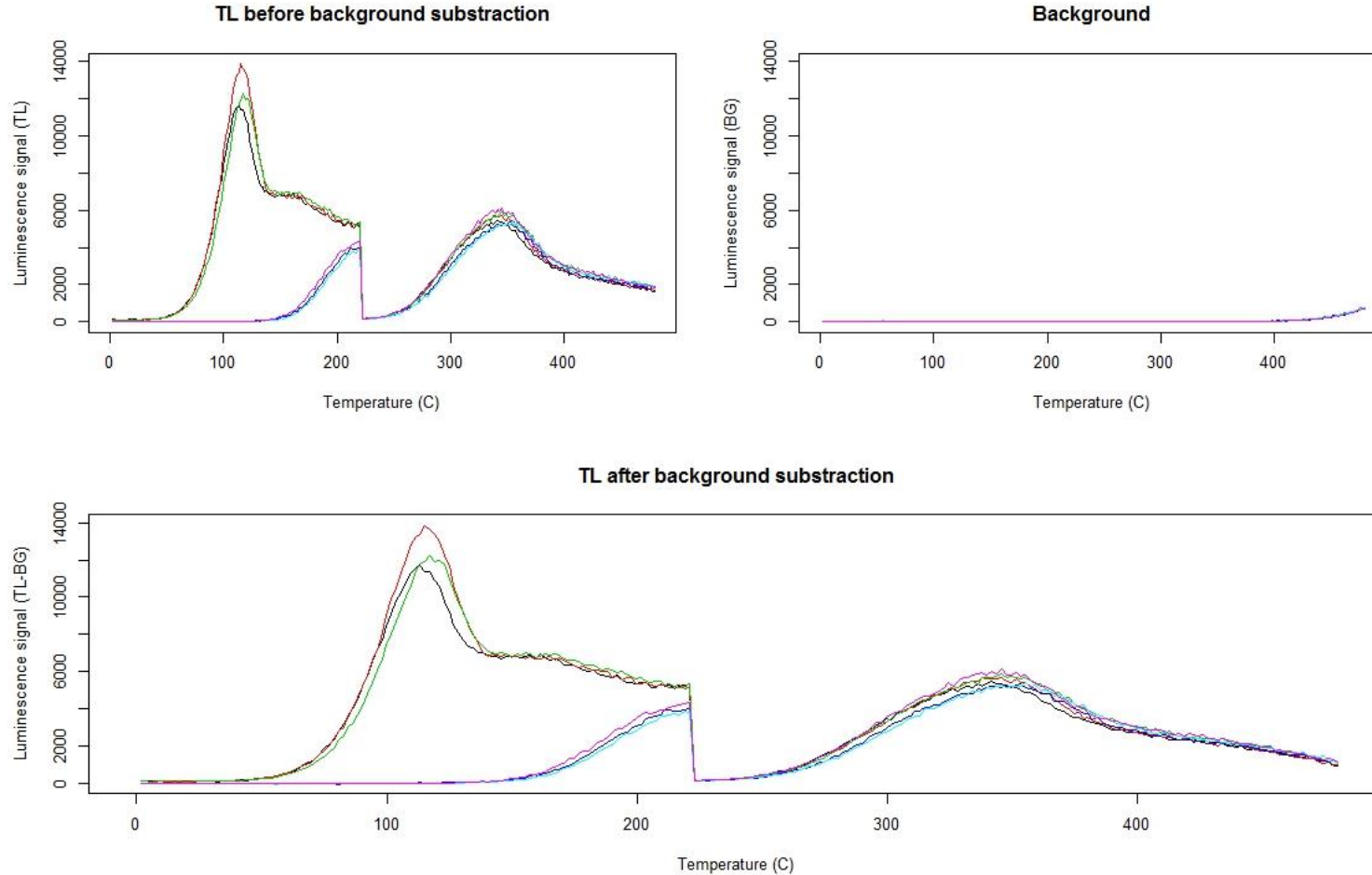
Pretreatment

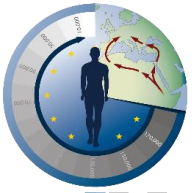
Export



Extra: Looking or Fading

Background subtraction





Extra: Looking or Fading

Peaks Alignment

