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Litholog generation with the StratigrapheR package & Signal decomposition for cyclostratigraphic purposes

Wouters S., Da Silva A.-C., Crucifix M., Sinnesael M., Zivanovic M., Boulvain F. & Devleeschouwer X.

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EGU General Assembly 2019

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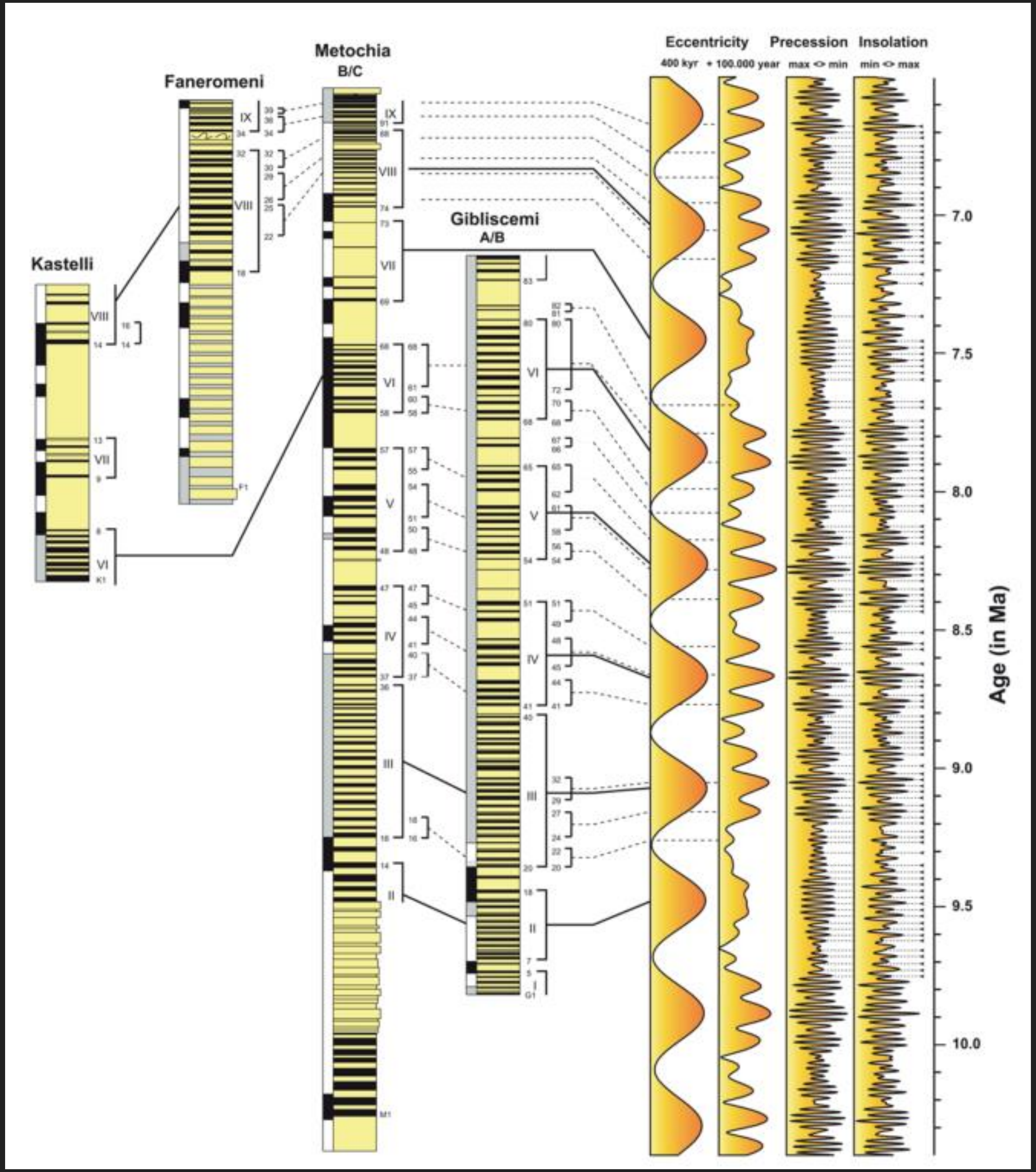
Keywords: Wouters StratigrapheR

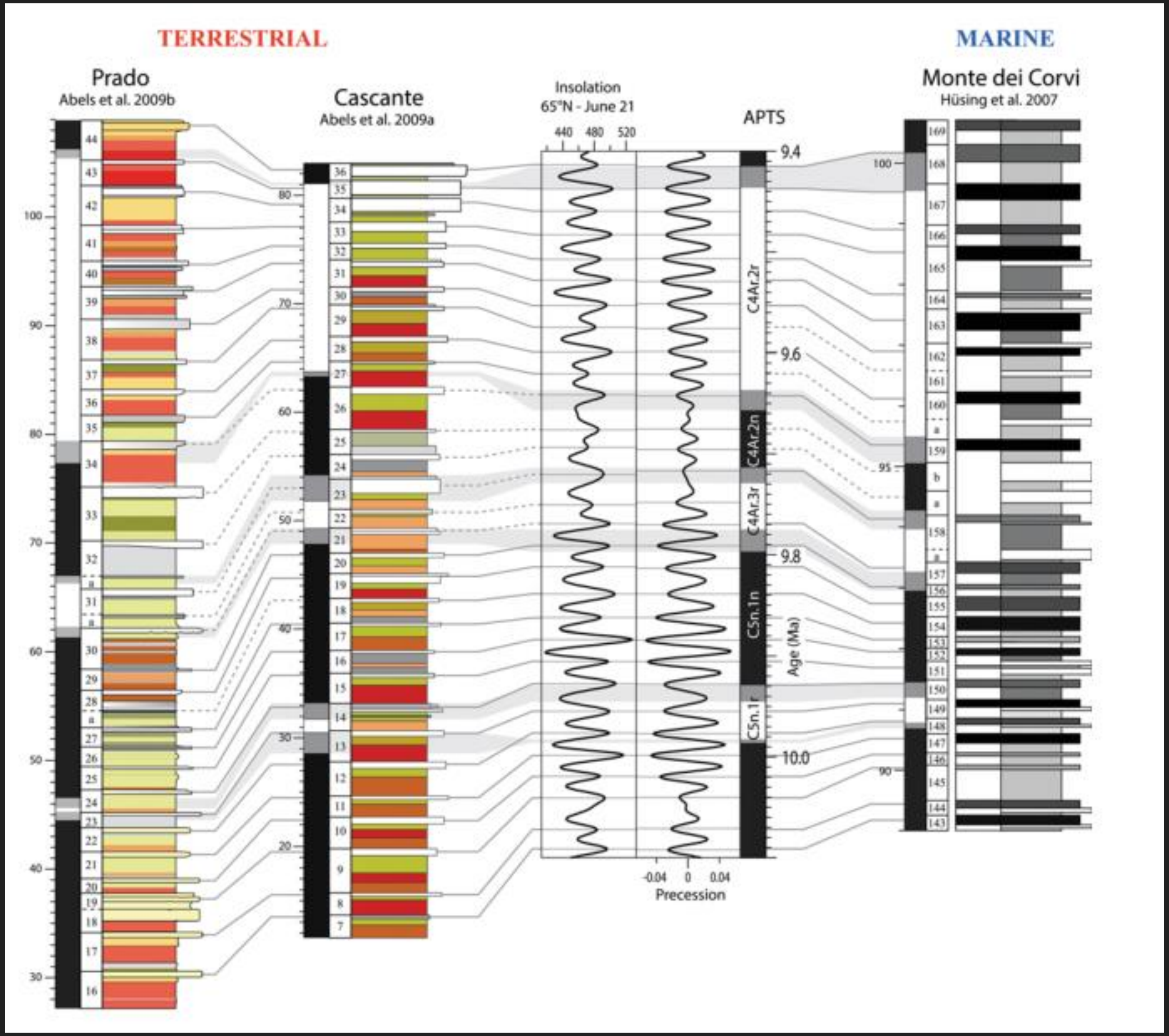
Introduction

Two main approaches for astrochronology:

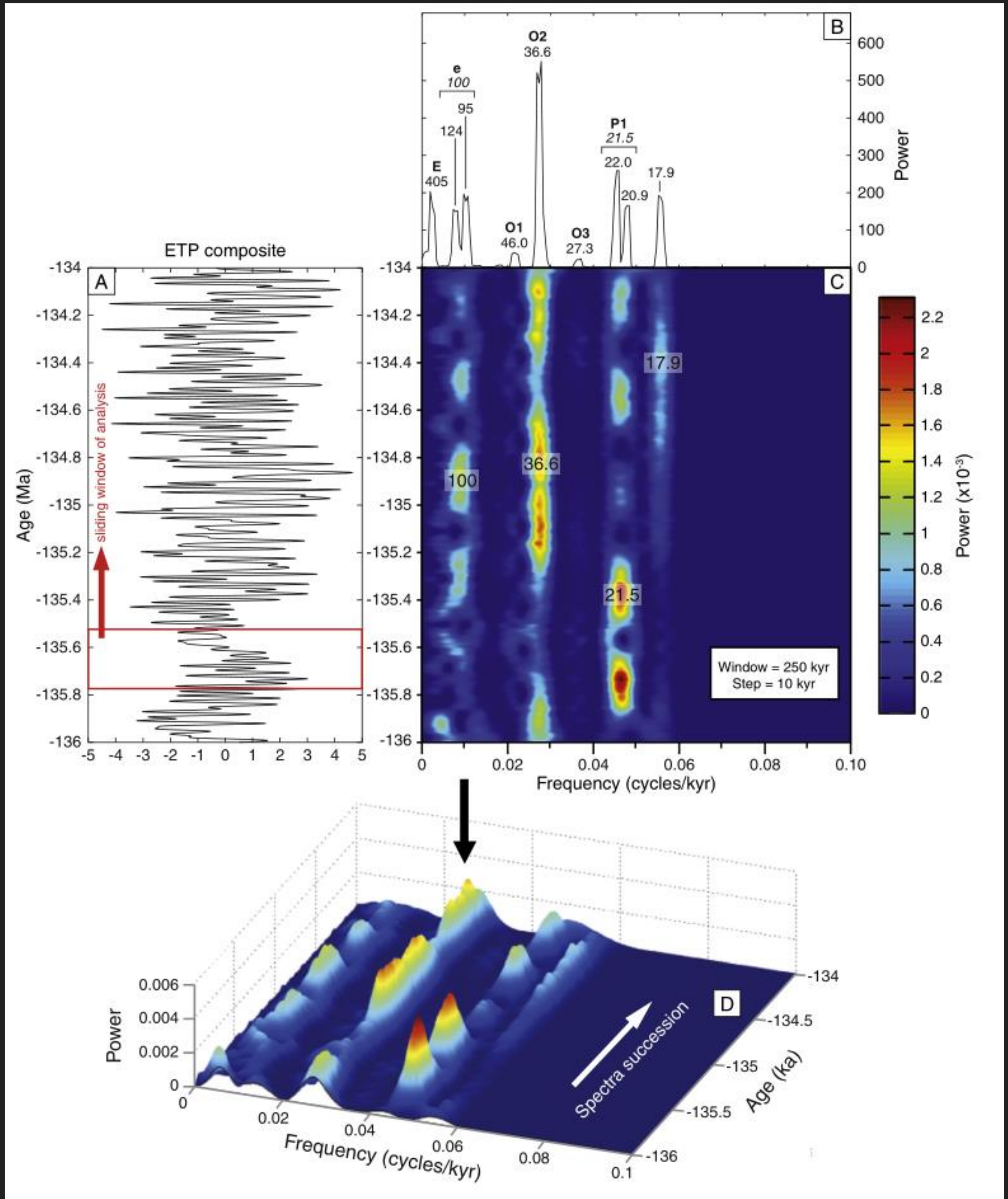
- Visual analysis
- Time-series analysis



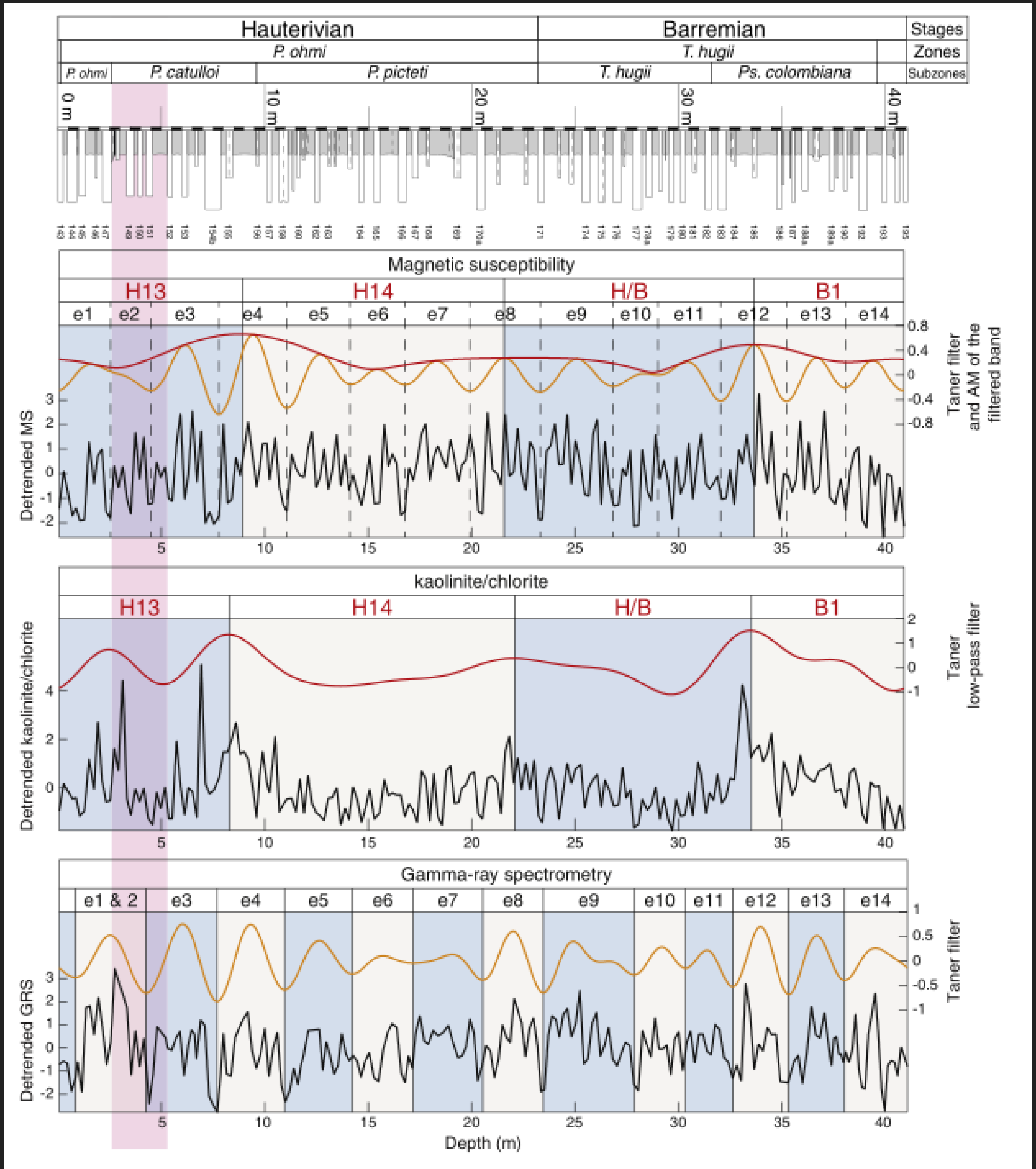
Astronomical tuning
(Hilgen et al., 2014)



High resolution precession correlations and tuning
(Hilgen et al., 2014)



Time–Frequency Weighted Fast Fourier Transform (Martinez et al., 2015)



Taner band-pass filtering (Martinez et al., 2015)

Introduction

Two main approaches for astrochronology:

- Visual analysis:

  - Mainly on **lithological information**, but can be performed on proxy data

- Time-series analysis

  - Mainly on **proxies**, but can be performed on lithological information

Introduction

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Two main approaches for astrochronology:

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  - Mainly on **proxies**, but can be performed on lithological information

Data processing challenges:

- Visual analysis:

  - **High resolution visualisation on large datasets**

- Time-series analysis

  - Having **intuitive understanding** of the mathematic transformations & **avoiding misinterpretation**

StratigrapheR

Sébastien Wouters [author, maintainer]
Adam Smith [contributor]
Anne-Christine Da Silva [tester]

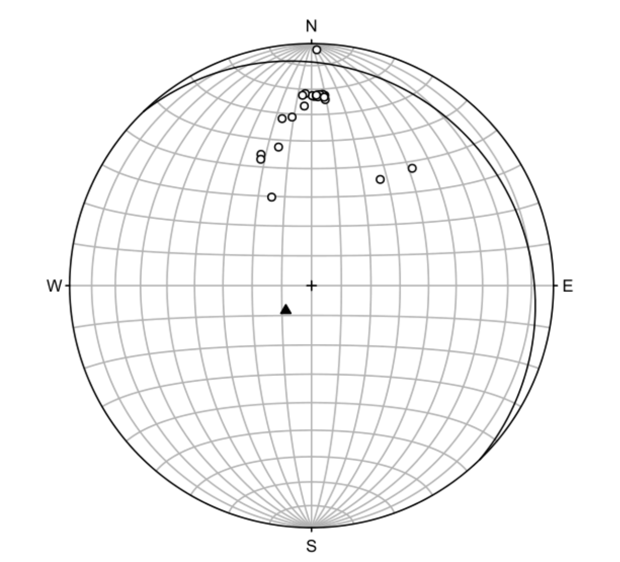
StratigrapheR

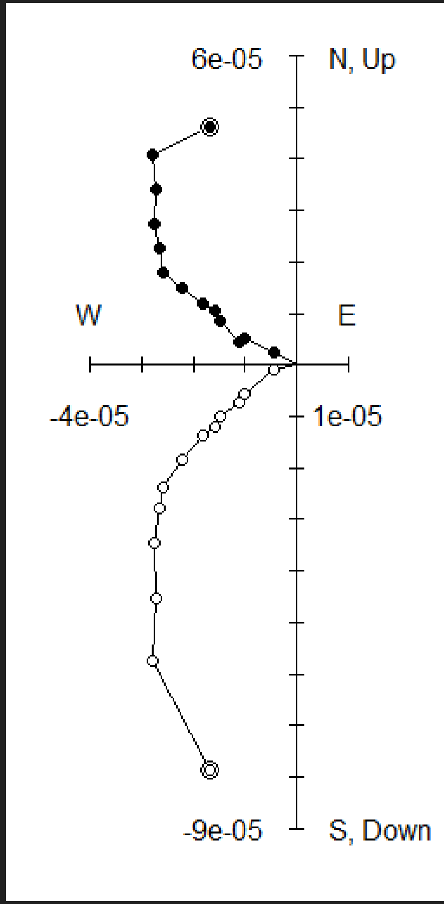
StratigrapheR: Integrated Stratigraphy

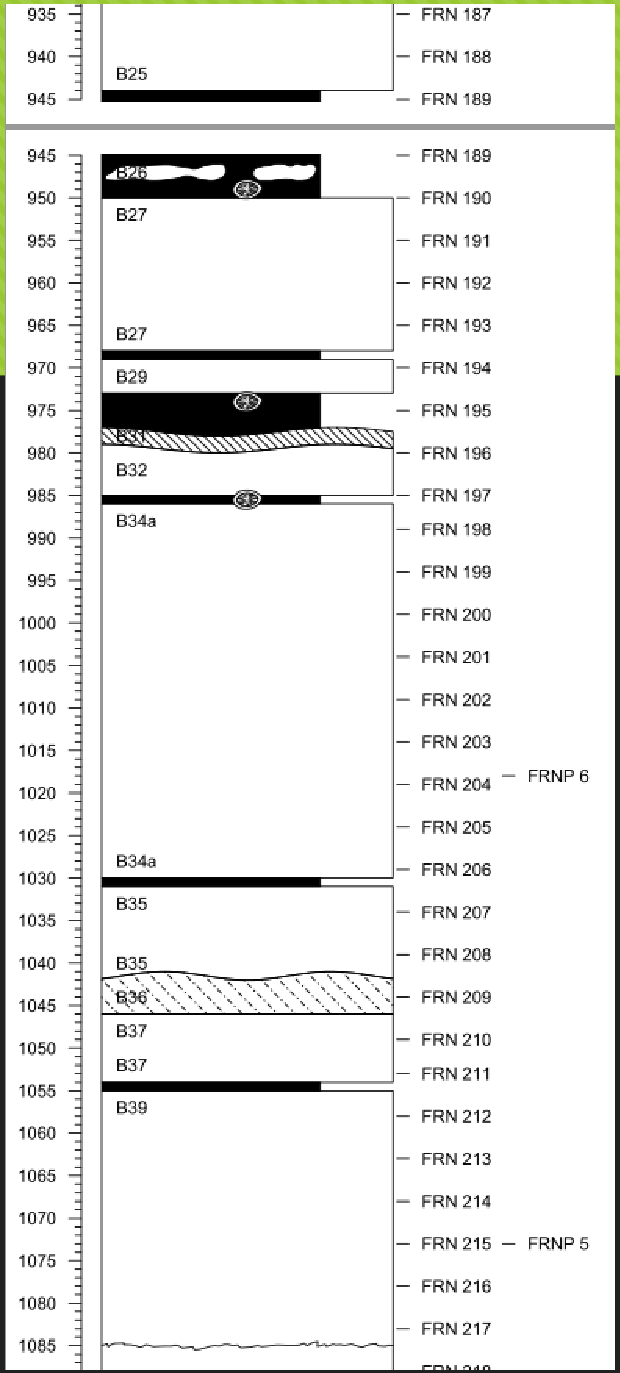
Version:	0.0.2
Depends:	R (≥ 3.5.0)

https://CRAN.R-project.org/package=StratigrapheR

- R package available on the Comprehensive R Archive Network (**CRAN**)
- Entirely **open source**
- Implements R functions for integrated stratigraphy, to be used in **combination of base R functions**







StratigrapheR

- Comes with help, information and examples for each function in the common R format calling **?name_of_function**
- A general example of litholog generation is provided in the main help calling **?StratigrapheR**

`StratigrapheR` *StratigrapheR: integrated stratigraphy for R*

Description

This package includes bases for litholog generation: graphical functions based on R base graphics (e.g. multigons()), interval gestion functions (with the as.lim() function, and other related .lim functions) and simple svg importation functions (e.g. pointsvg()) among others. It also includes stereographic projection functions (e.g. the earnet(), earpoints() and earplanes() functions; ear standing for equal area), and other functions made to deal with large datasets while keeping options to get into the details of the data. **IF YOU WANT TO START LEARNING HOW TO CREATE LITHOLOGS WITH STRATIGRAPHER GO SEE THE EXAMPLE BELOW.**

A StratigrapheR() function is provided: it generates organisational charts for common use of the functions in the package

Usage

```
StratigrapheR(i = 1:3)
```

Arguments

`i`	the index(es) of the organisational charts of the functions in the StratigrapheR package

Details

Package: StratigrapheR

Type: R package

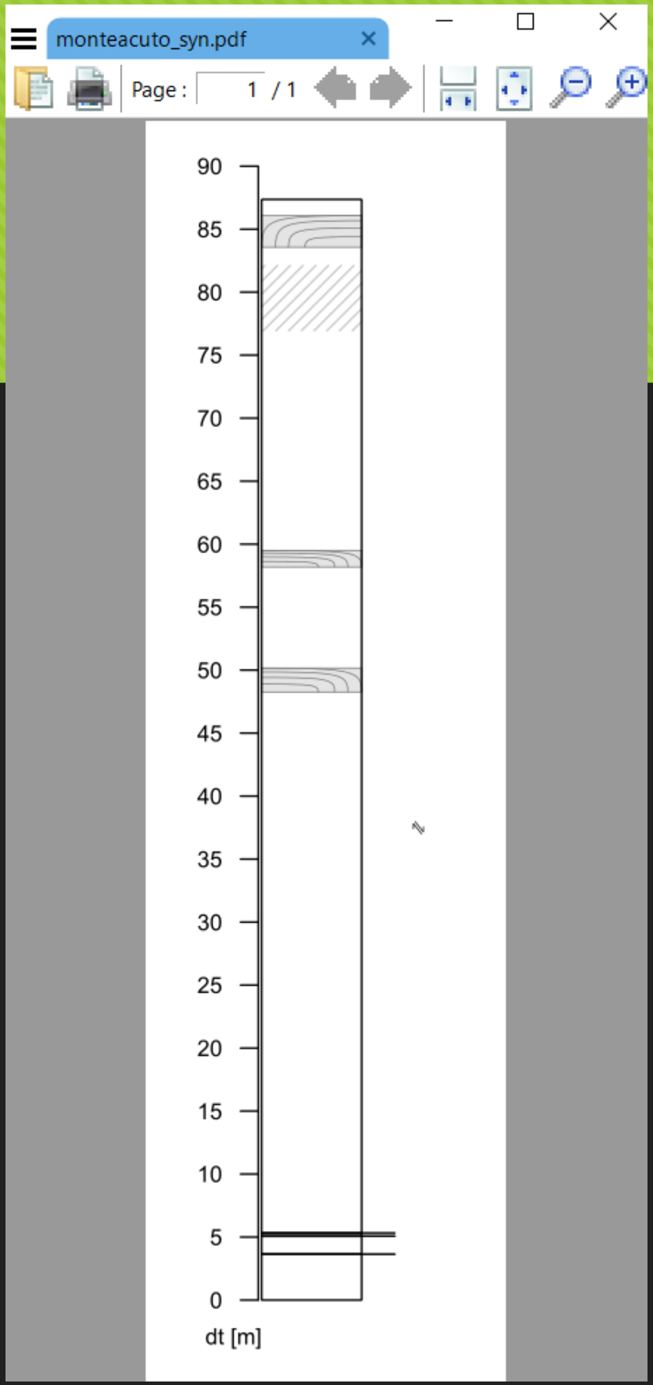
Version: 0.0.2 (January 2019)

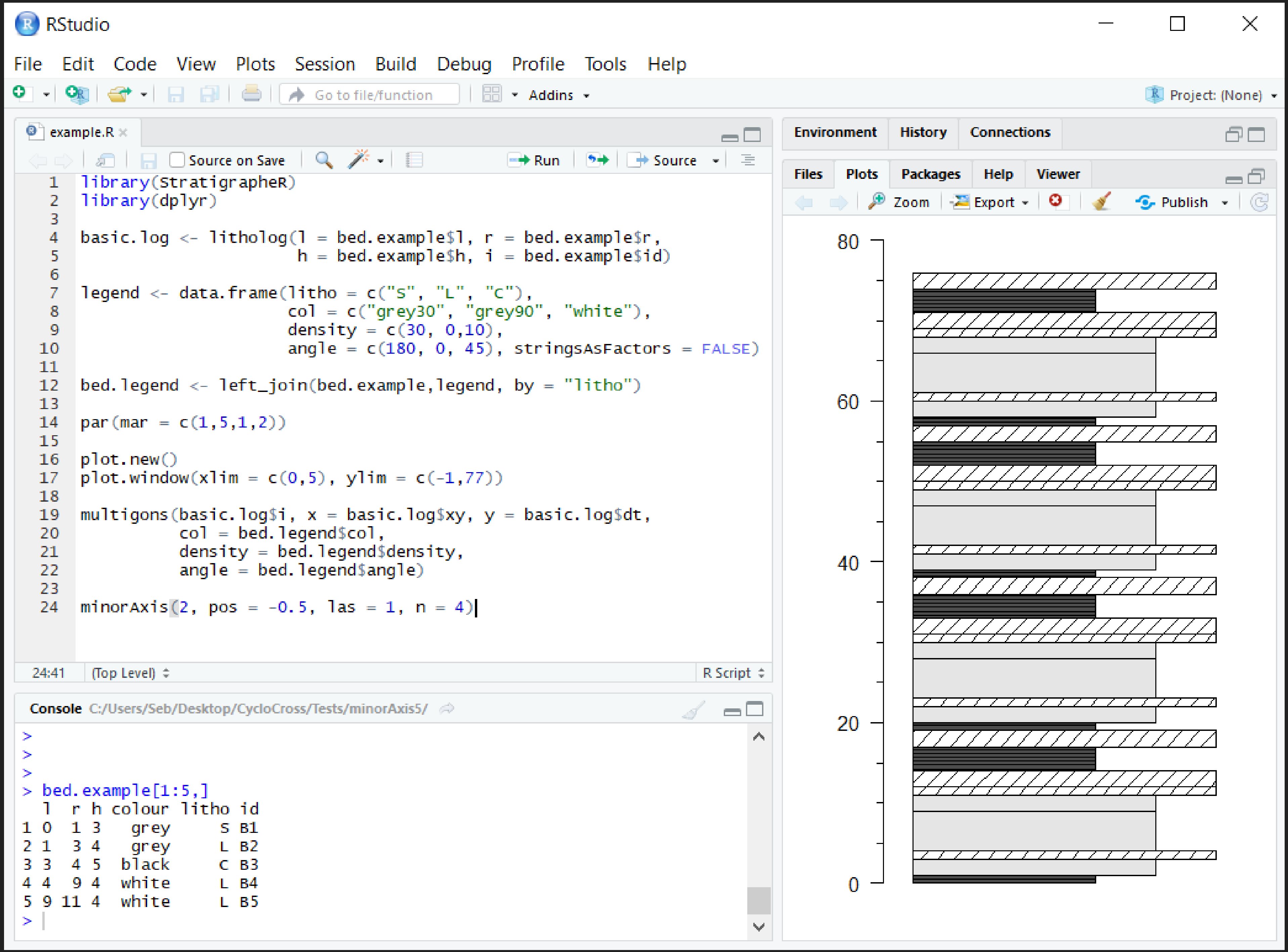
License: GPL-3

StratigrapheR

pdfDisplay()

- Uses the default **PDF** reader as a graphical window
- Each plot can be generated as a **PDF** or SVG (the name changes incrementally)




RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
Project: (None)
example.R
Source on Save
Run
Source
library(StratigrapheR)
library(dplyr)
basic.log <- litholog(l = bed.example$l, r = bed.example$r,
h = bed.example$h, i = bed.example$id)
legend <- data.frame(litho = c("S", "L", "C"),
col = c("grey30", "grey90", "white"),
density = c(30, 0,10),
angle = c(180, 0, 45), stringsAsFactors = FALSE)
bed.legend <- left_join(bed.example,legend, by = "litho")
par(mar = c(1,5,1,2))
plot.new()
plot.window(xlim = c(0,5), ylim = c(-1,77))
multigons(basic.log$i, x = basic.log$xy, y = basic.log$dt,
col = bed.legend$col,
density = bed.legend$density,
angle = bed.legend$angle)
minorAxis(2, pos = -0.5, las = 1, n = 4)
24:41
(Top Level)
R Script
Console C:/Users/Seb/Desktop/CycloCross/Tests/minorAxis5/
> bed.example[1:5,]
l r h colour litho id
1 0 1 3 grey S B1
2 1 3 4 grey L B2
3 3 4 5 black C B3
4 4 9 4 white L B4
5 9 11 4 white L B5
Environment History Connections
Files Plots Packages Help Viewer
Zoom
Export
Publish
80
60
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20
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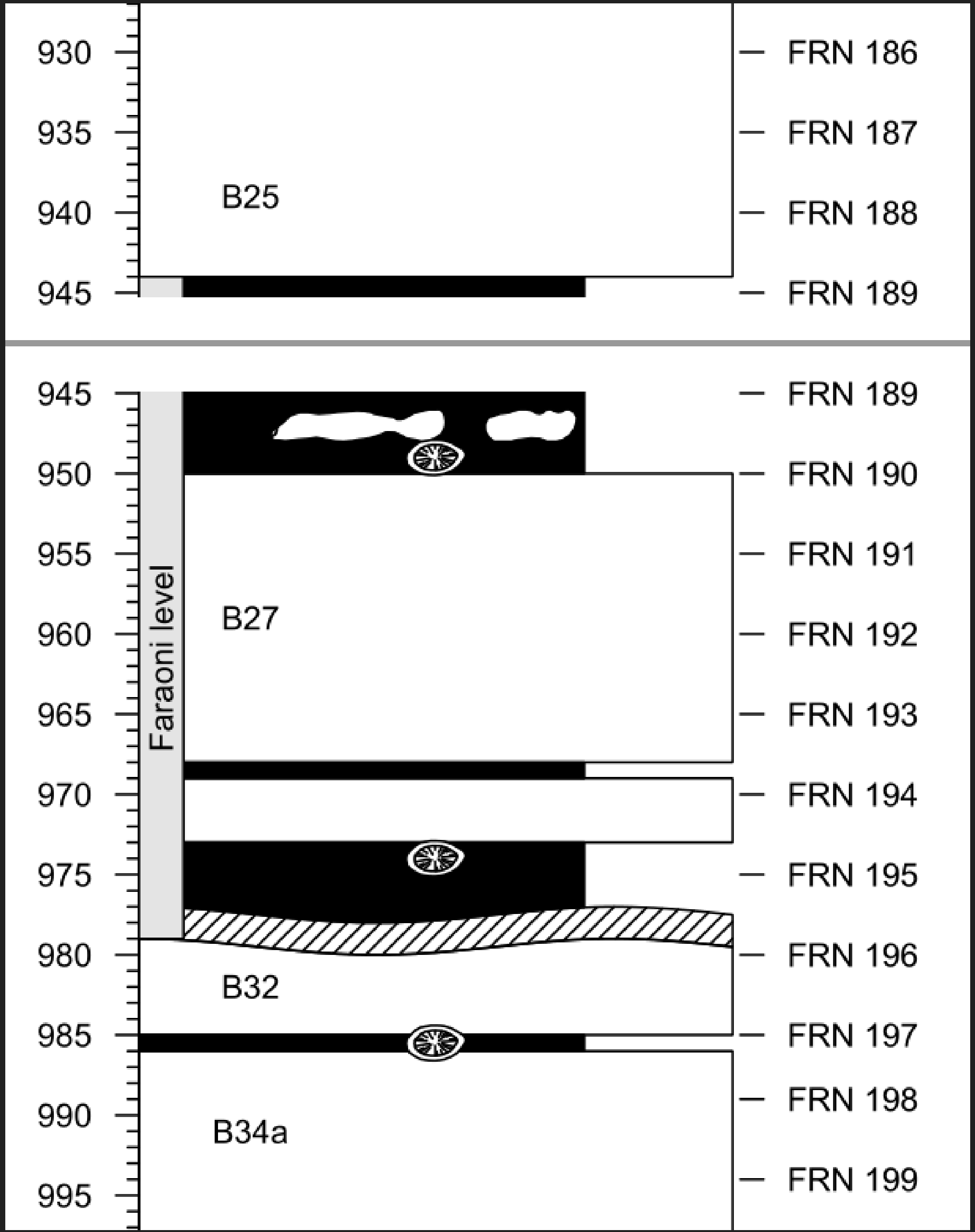
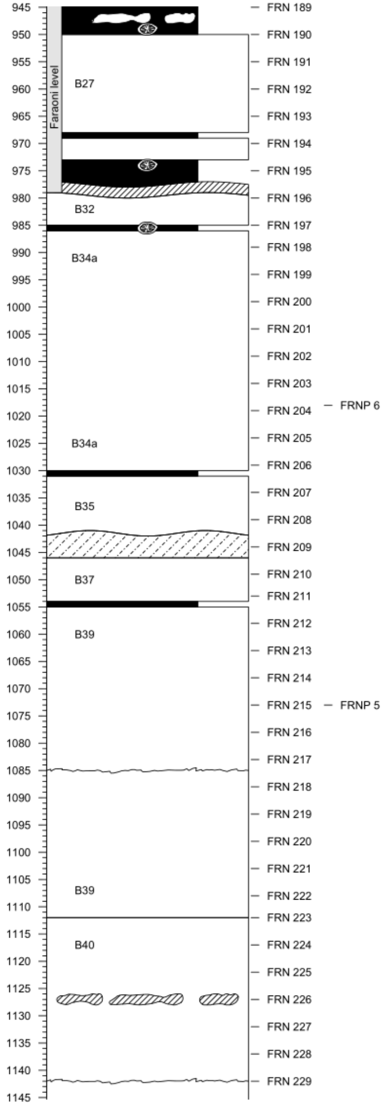
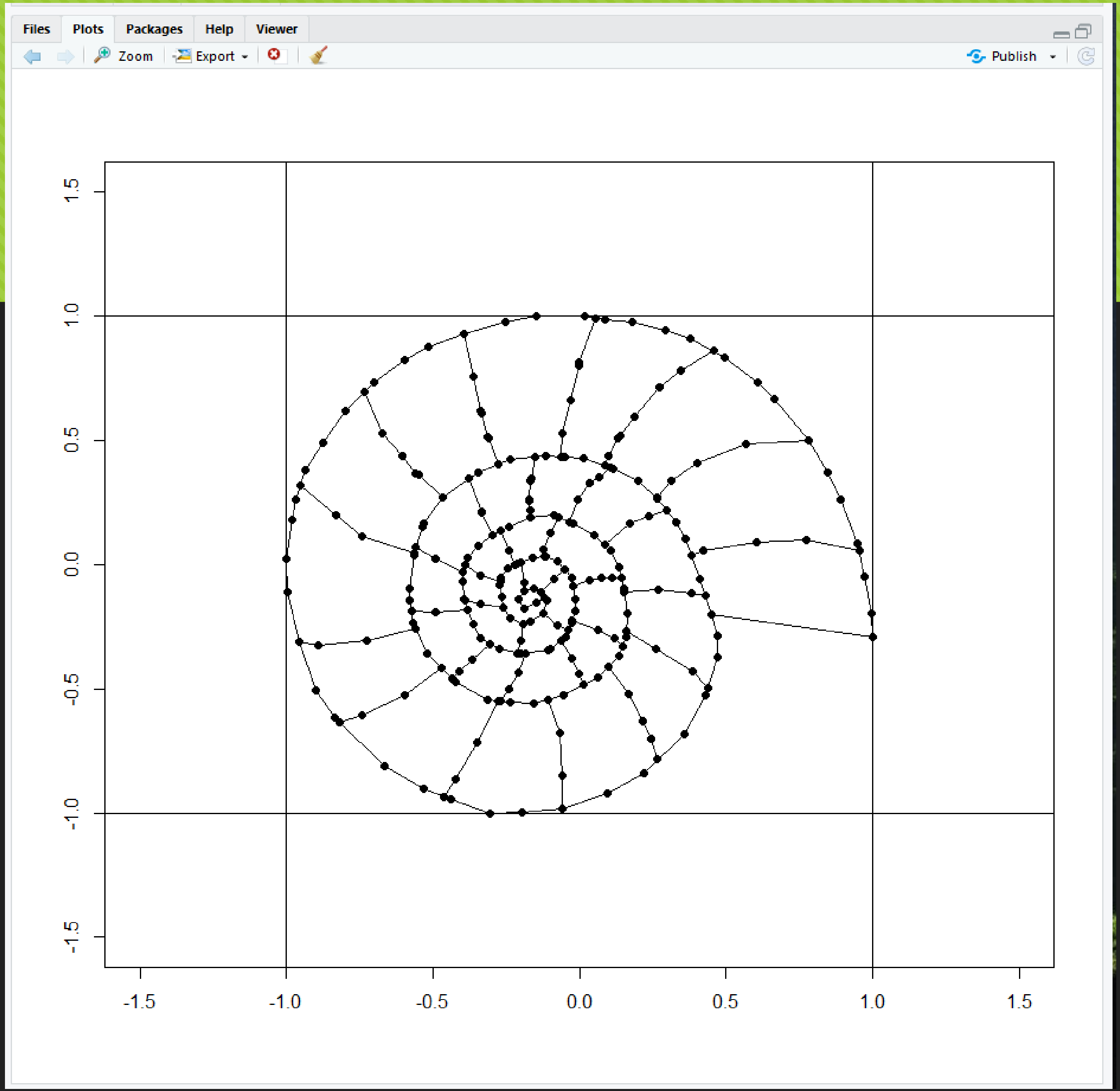


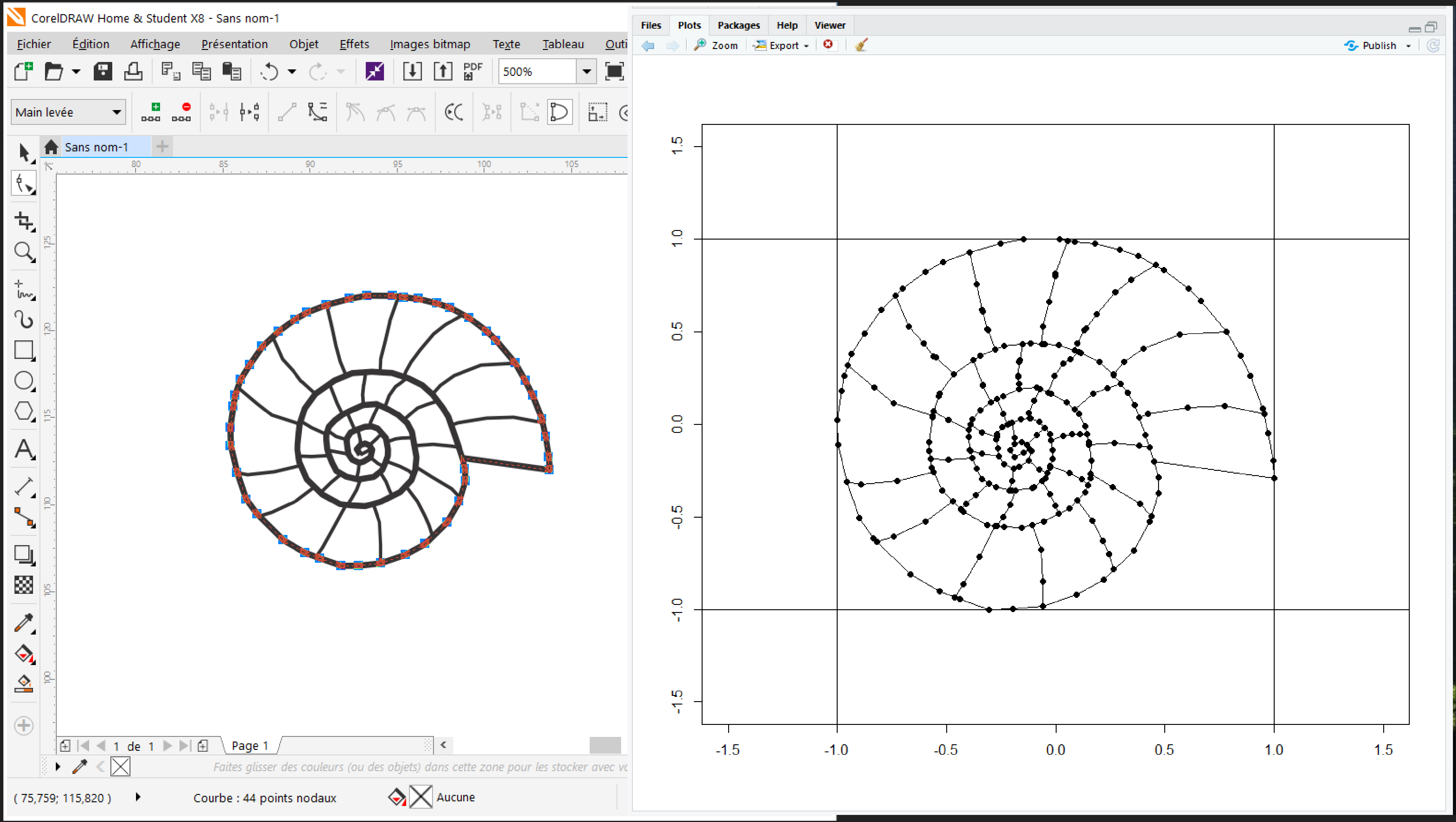


Depth is provided in cm.

StratigrapheR

- The package is based on the **incremental addition of elements to a drawing**
- It allows importation of **simple SVG objects**: polygons and polylines (nodes connected by straight lines)




CorelDRAW Home & Student X8 - Sans nom-1
Fichier Édition Affichage Présentation Objet Effets Images bitmap Texte Tableau Outi
500%
Main levée
Sans nom-1
80 85 90 95 100 105
1 de 1 Page 1
Faites glisser des couleurs (ou des objets) dans cette zone pour les stocker avec vo
(75,759; 115,820)
Courbe : 44 points nodaux
Aucune
Files Plots Packages Help Viewer
Zoom Export Publish
1.5
1.0
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-1.0
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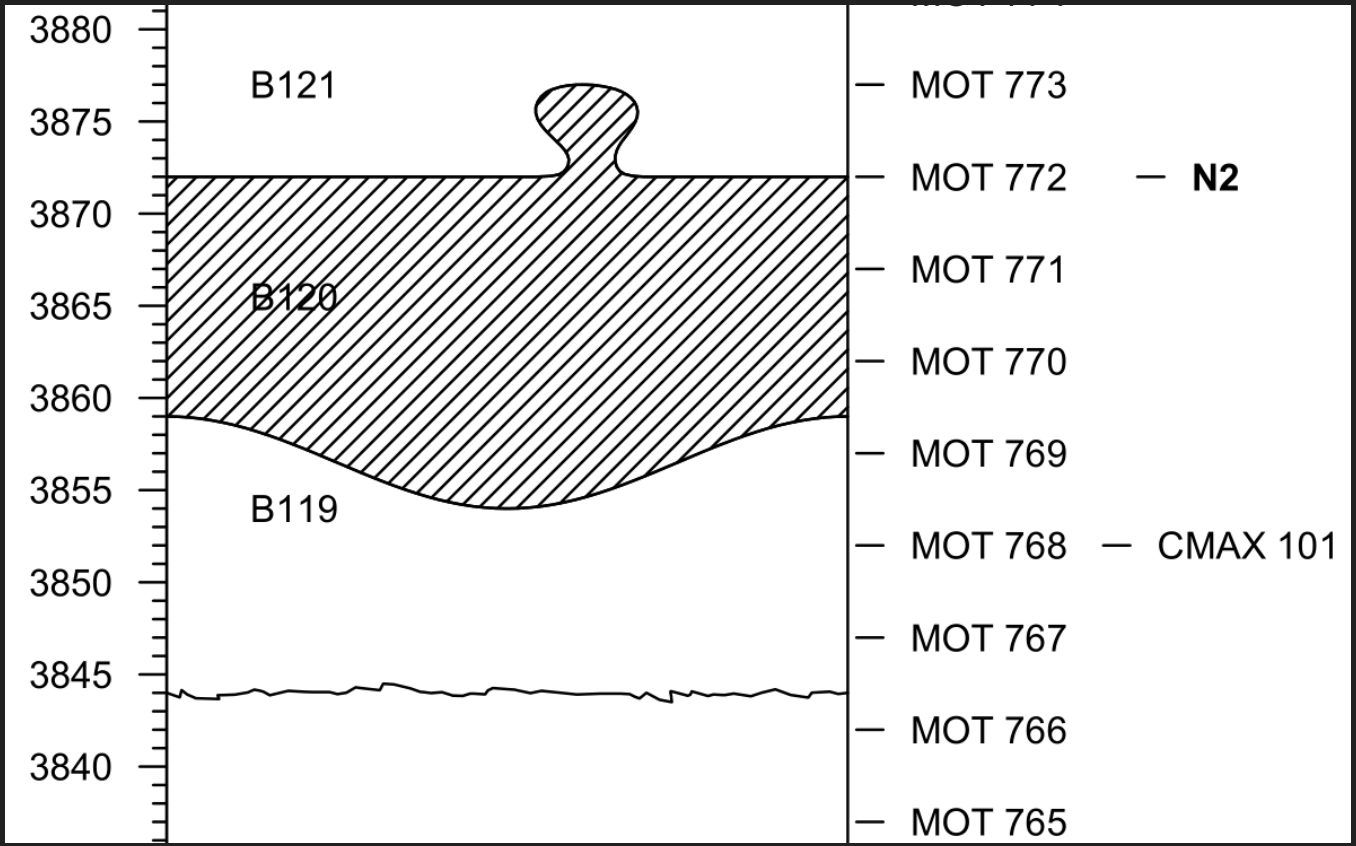
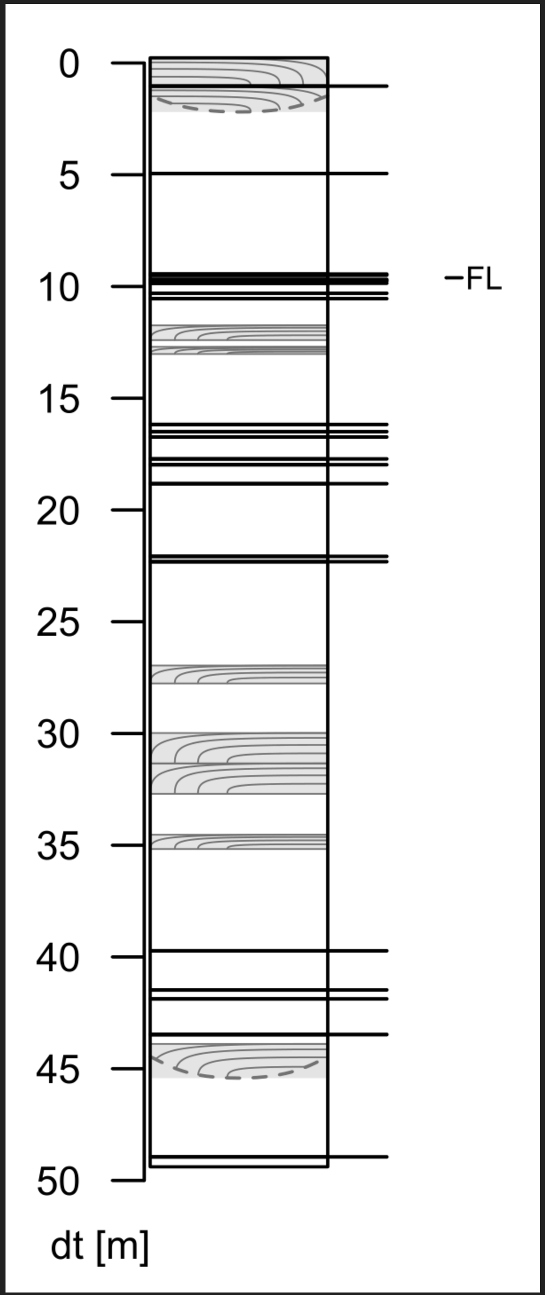
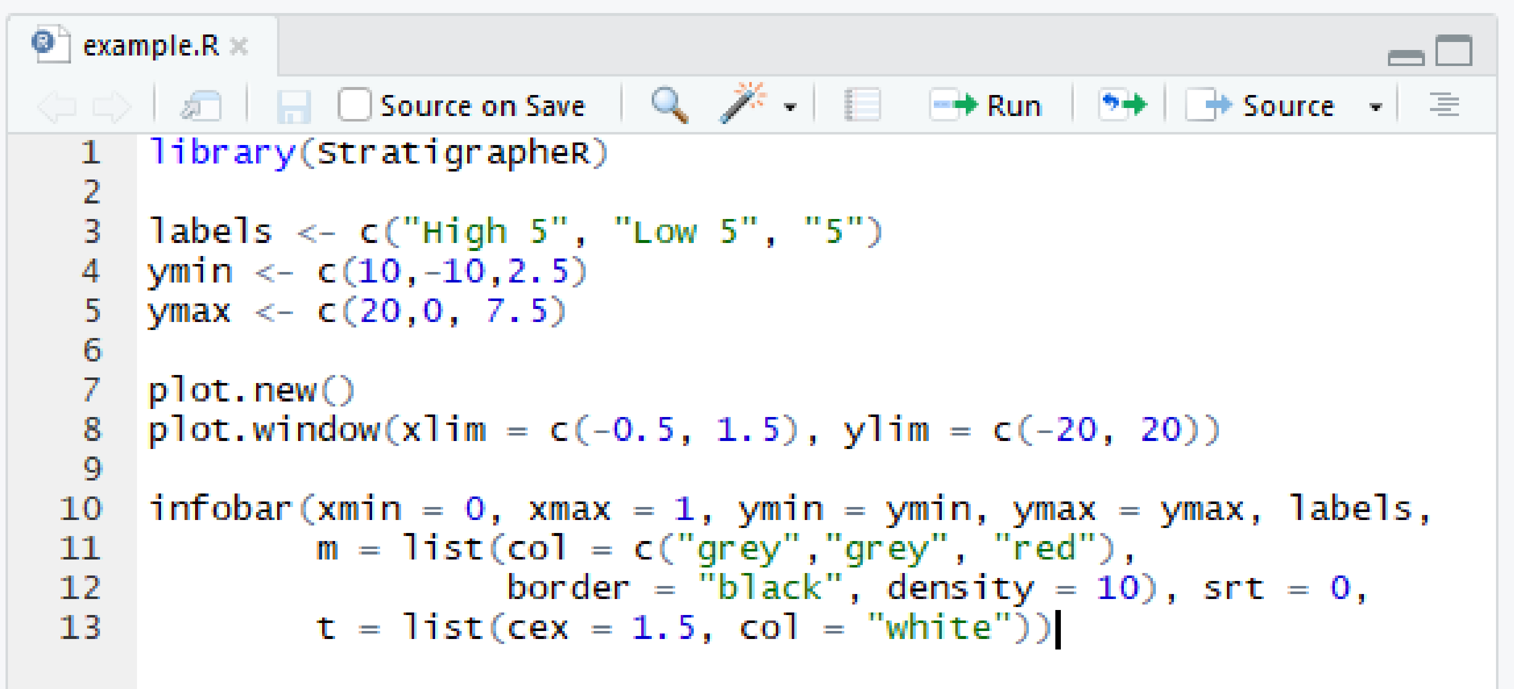
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

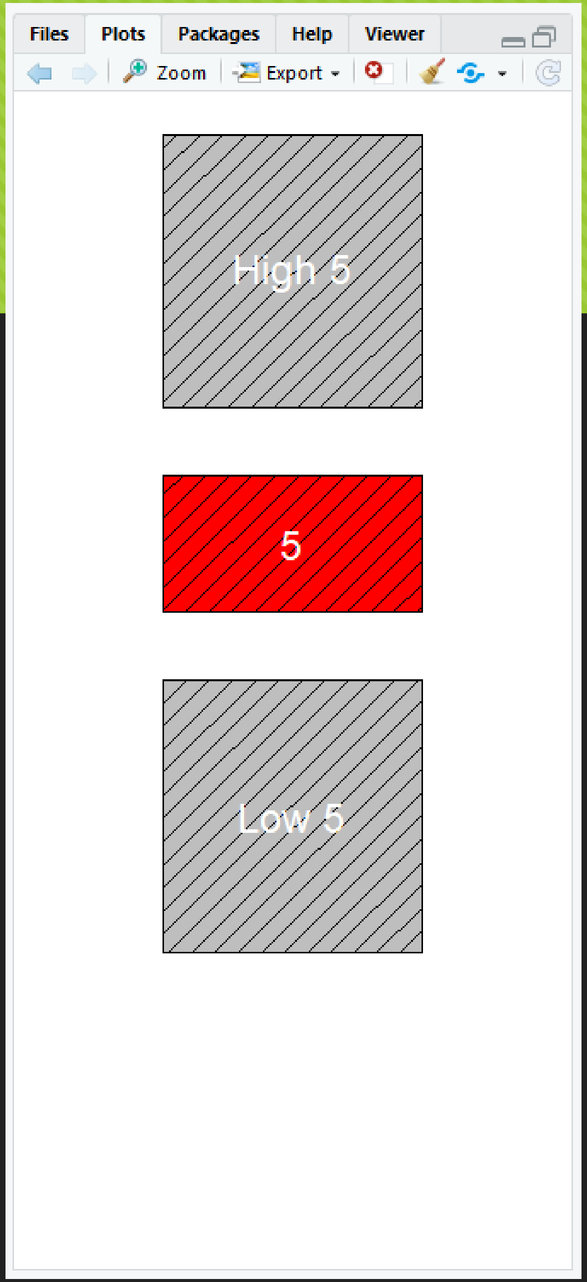

3880
3875
3870
3865
3860
3855
3850
3845
3840
B121
B120
B119
MOT 773
MOT 772
MOT 771
MOT 770
MOT 769
MOT 768
MOT 767
MOT 766
MOT 765
N2
CMAX 101

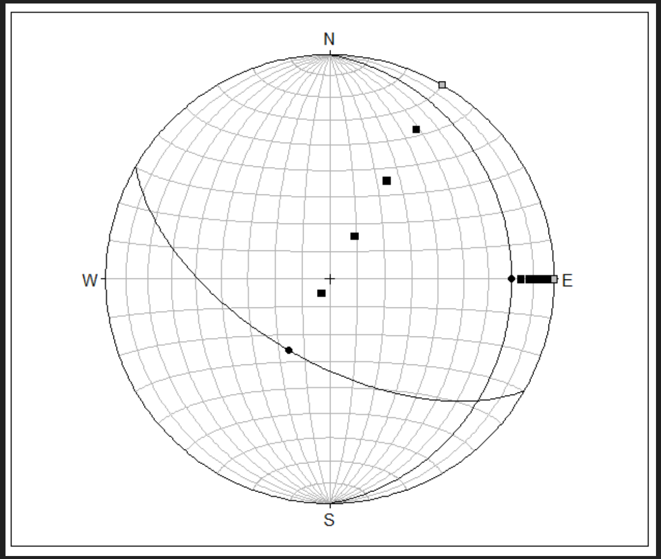

0
5
10
15
20
25
30
35
40
45
50
dt [m]
FL

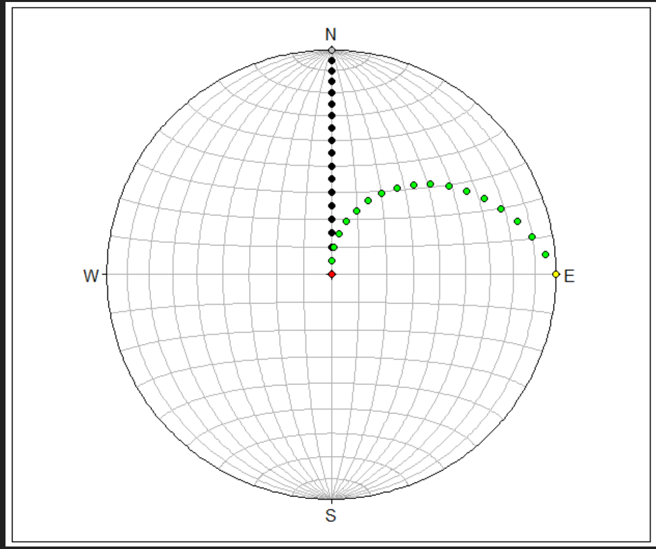
StratigrapheR

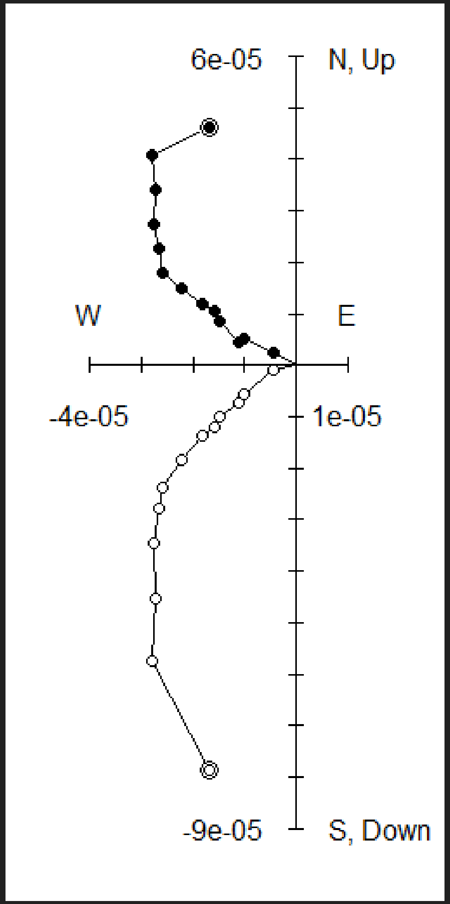
- Commitment to **generality**, **versatility**, **modularity**, and **open source**

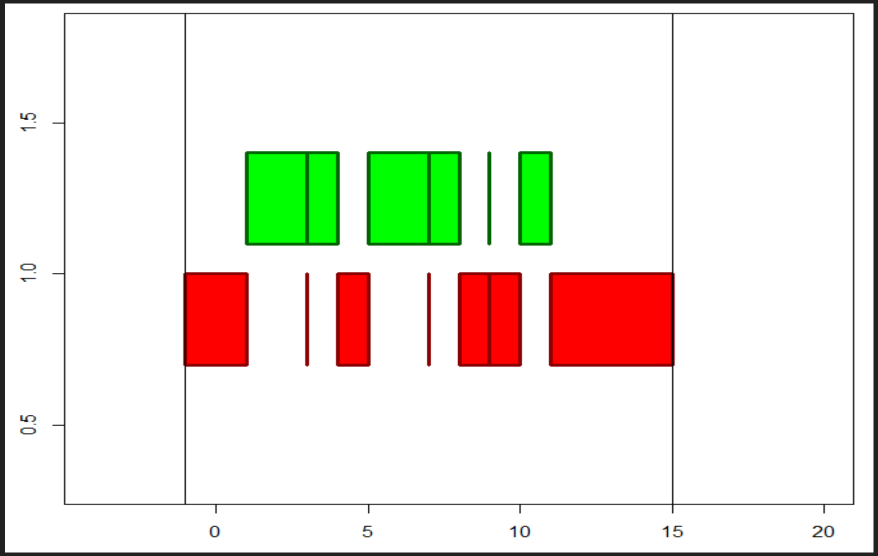


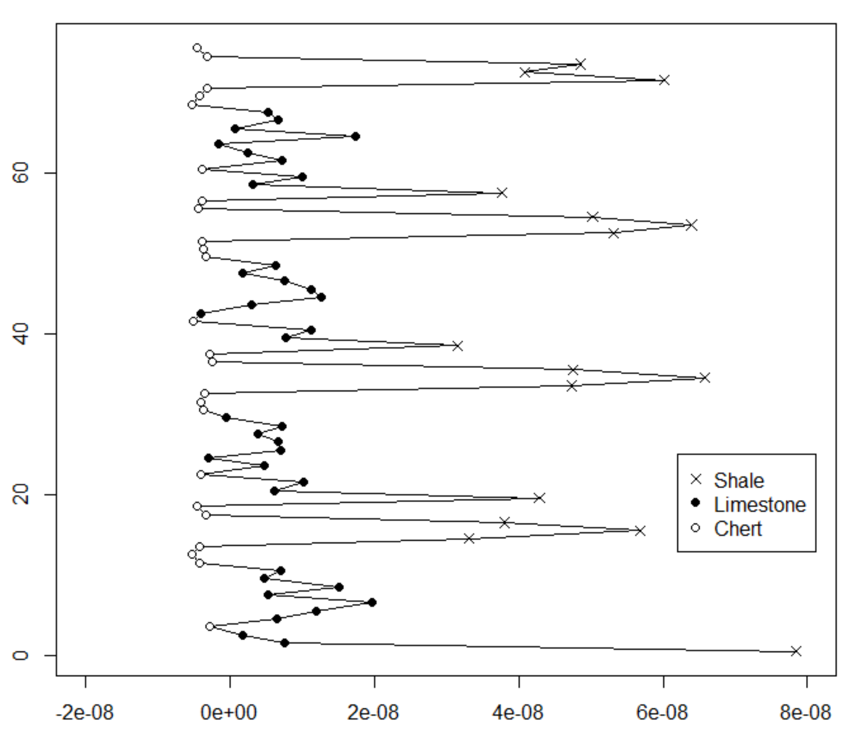












- Complete set of functions to deal with stratigraphic interval data
- **[-1,1[form for instance**

- Basic oriented data functions (visualisation, rotation, data conversion)

Signal decomposition

Theoretical advances

Signal decomposition

- **IMF** :

Intrinsic

Mode

Functions

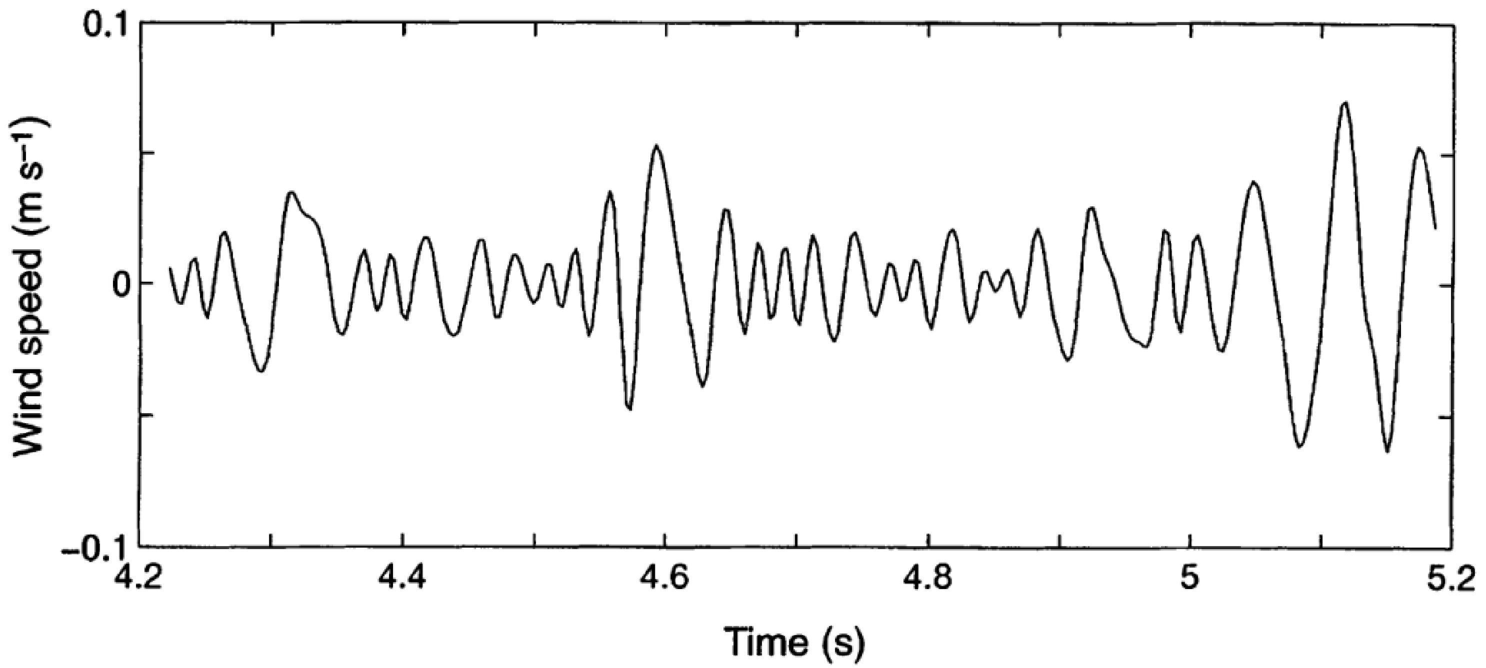


Figure 2. A typical intrinsic mode function with the same numbers of zero crossings and extrema, and symmetry of the upper and lower envelopes with respect to zero.

(Huang et al., 1998)

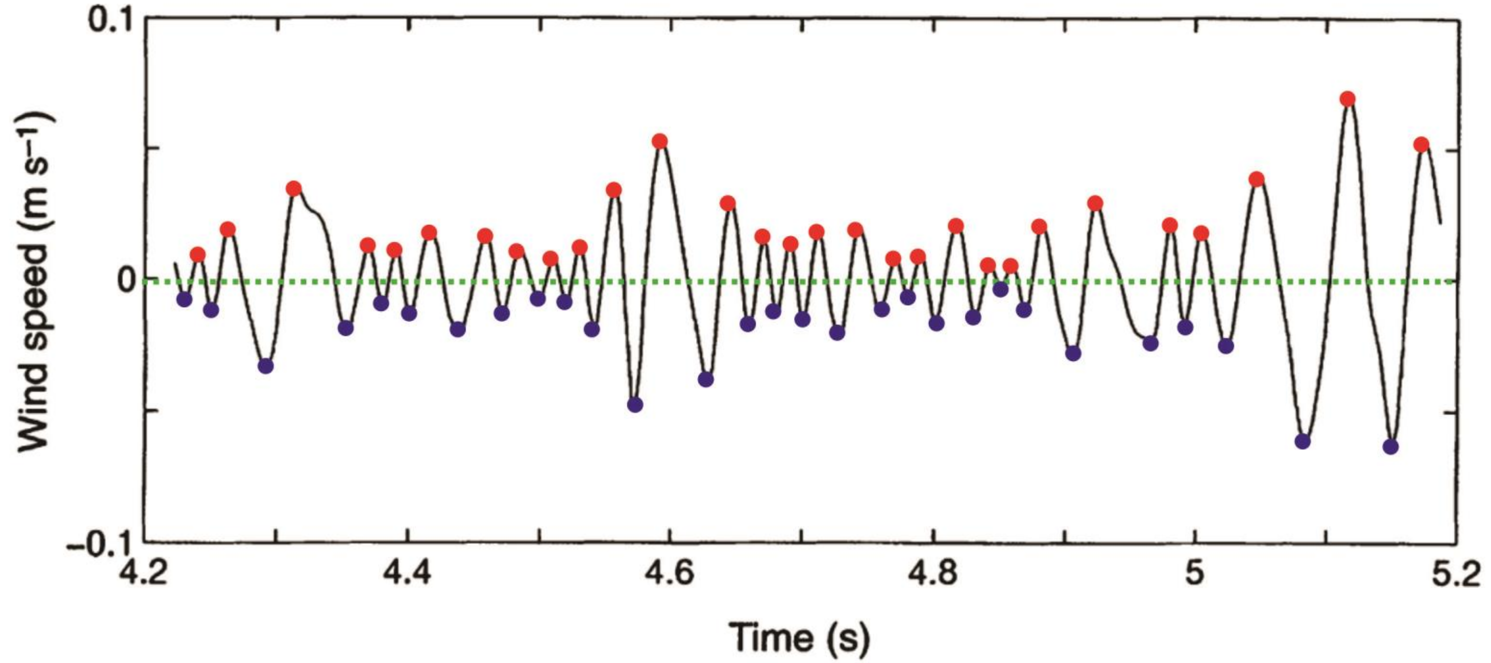
Signal decomposition

- **IMF** :

Intrinsic

Mode

Functions



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Signal decomposition

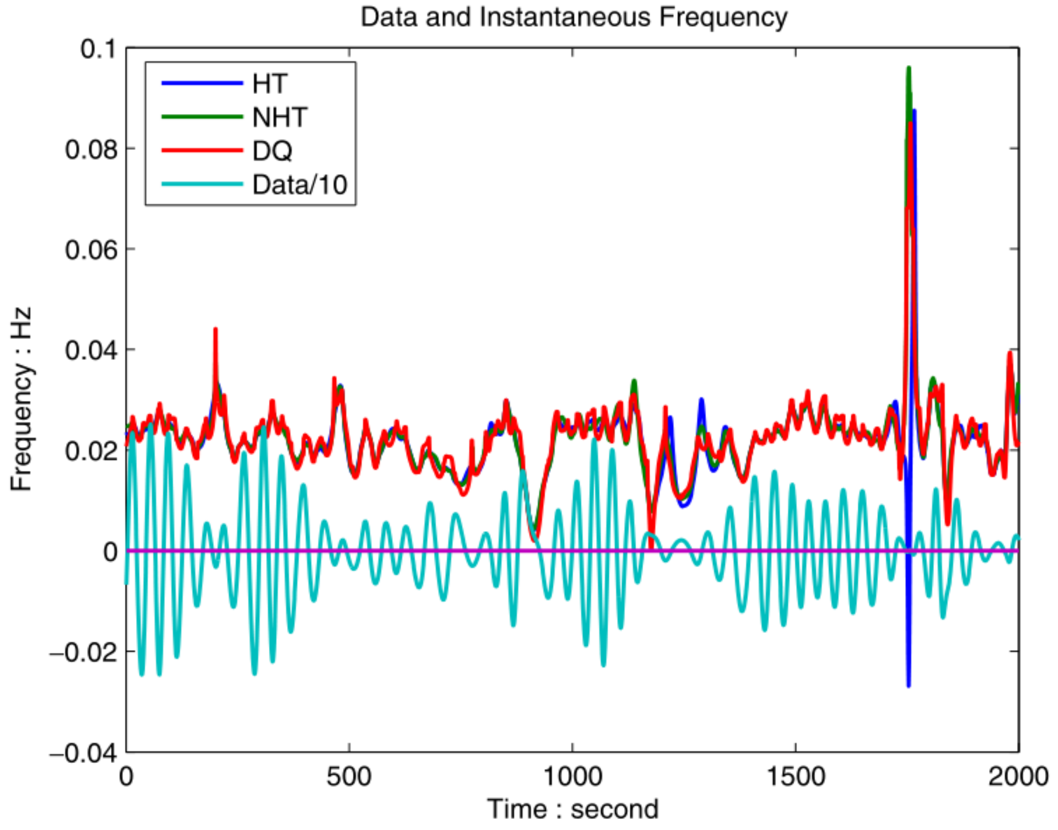


Fig. 9. The IF of the sample data based on various methods: direct quadrature (DQ), HT, and NHT, with the data plotted at one-tenth scale.

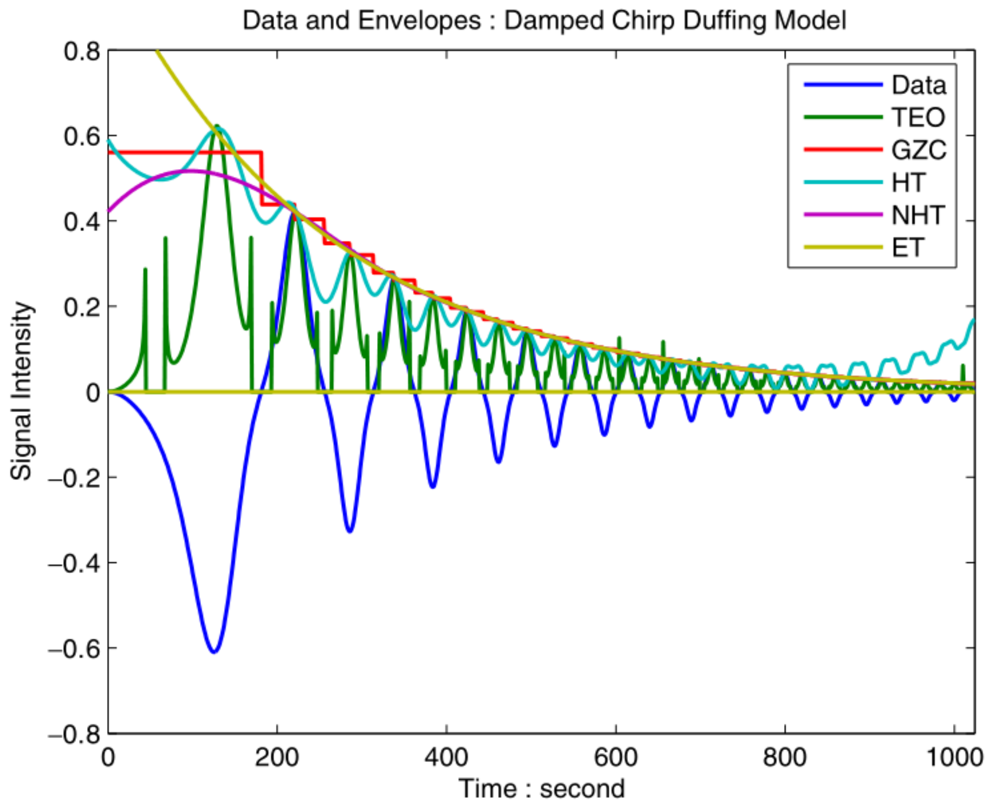


Fig. 14. The amplitude determined from various methods: TEO, GZC, and HT, spline fitting used in DQ and NHT. The spline line is identical to the theoretic value; therefore, it is defined as the envelope in the direct quadrature method.

(Huang et al., 2009)

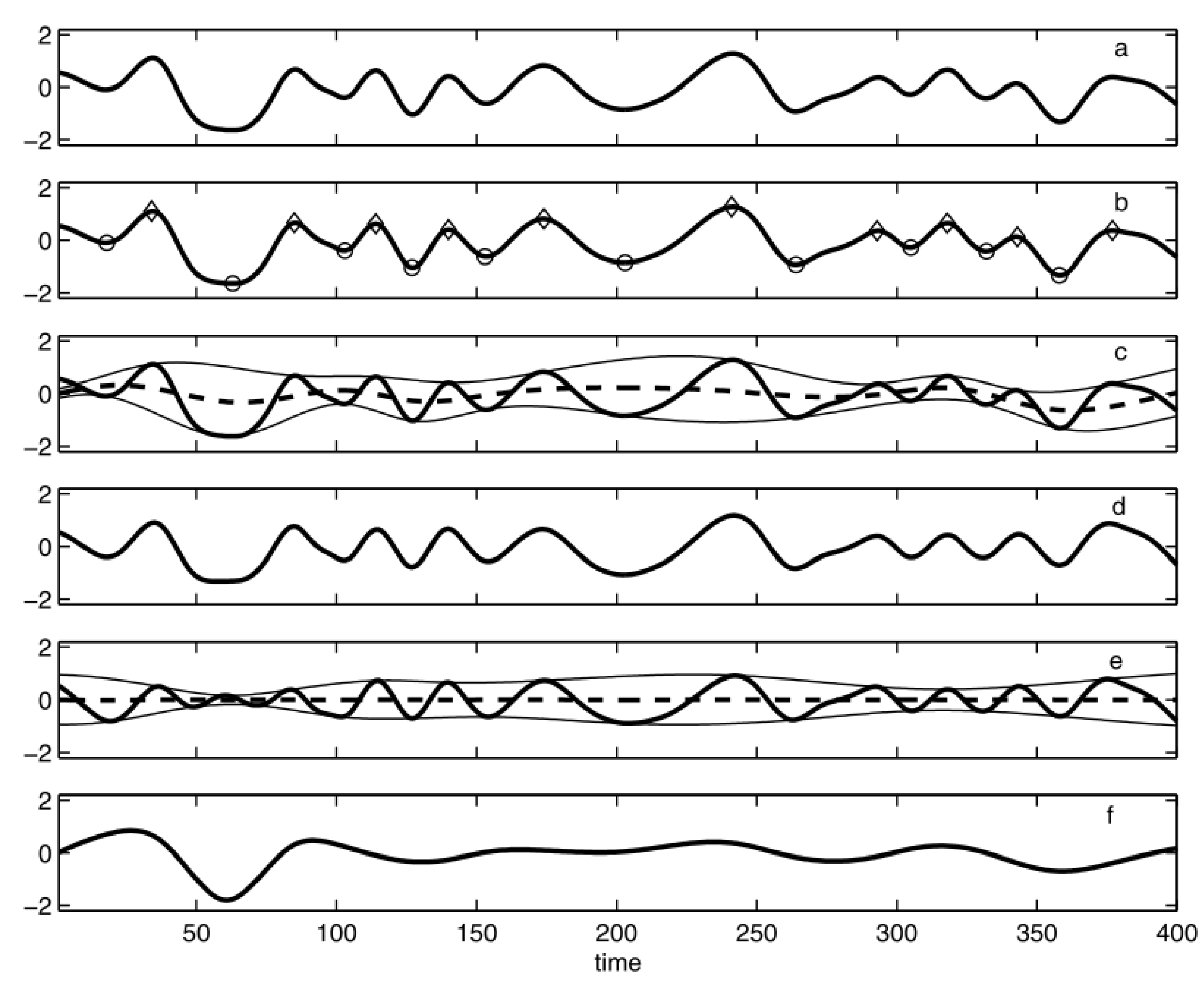
Signal decomposition: the **EMD**

- **EMD** :

Empirical

Mode

Decomposition



(Huang & Wu, 2008)

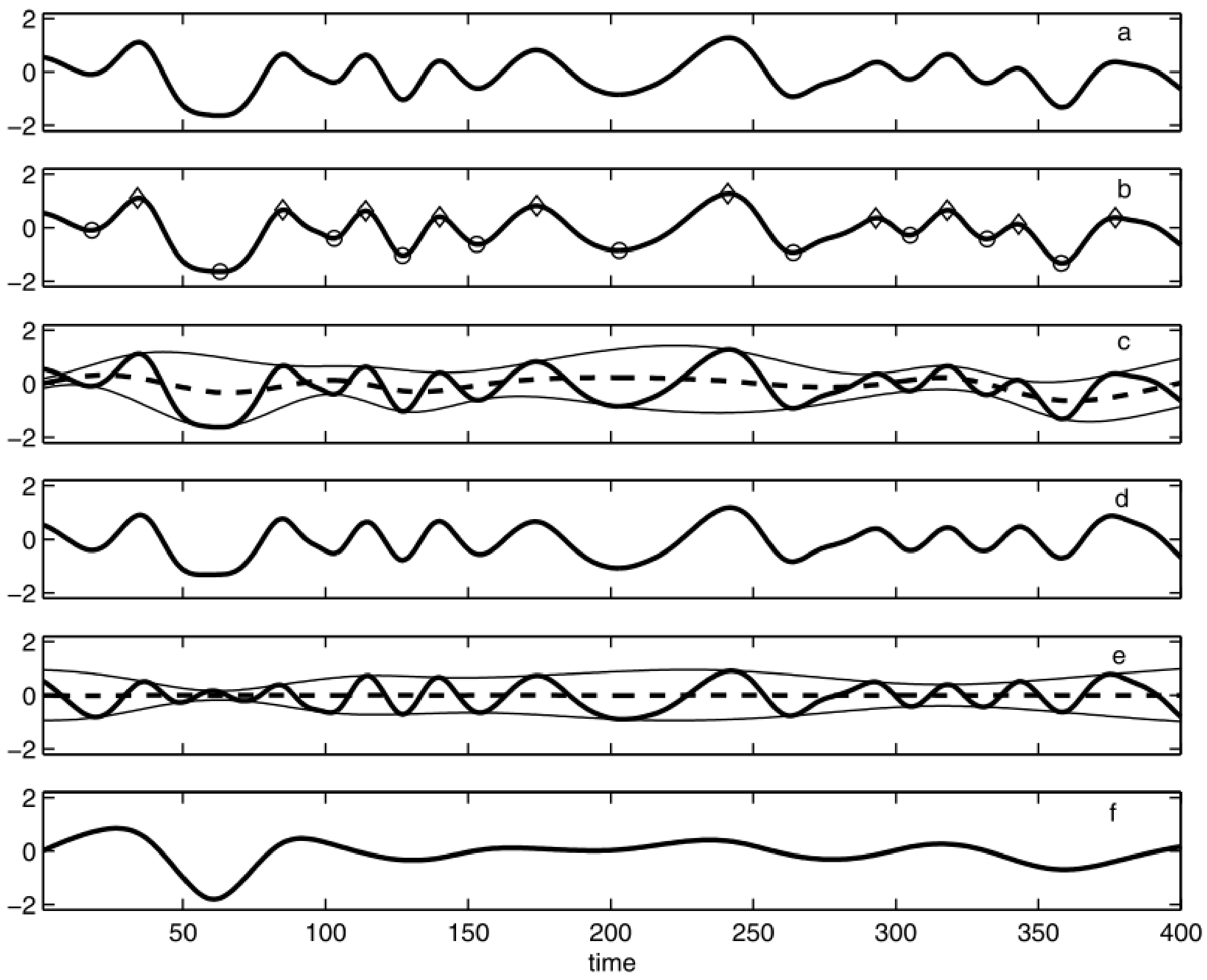
Signal decomposition: the **EMD**

- **EMD** :

Empirical

Mode

Decomposition



Signal

(Huang & Wu, 2008)

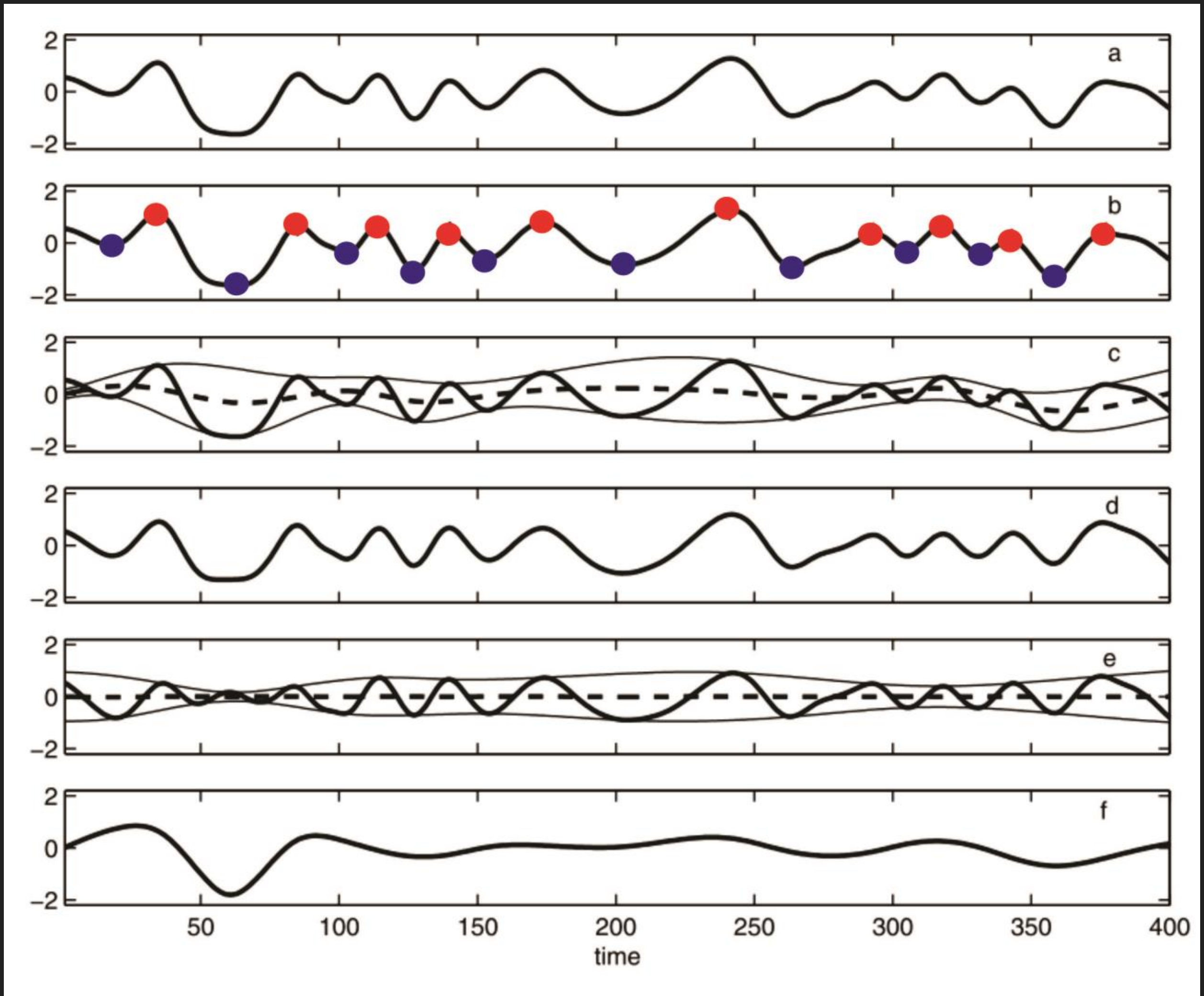
Signal decomposition: the **EMD**

- **EMD** :

Empirical

Mode

Decomposition



Signal

Local extrema

(modified from Huang & Wu, 2008)

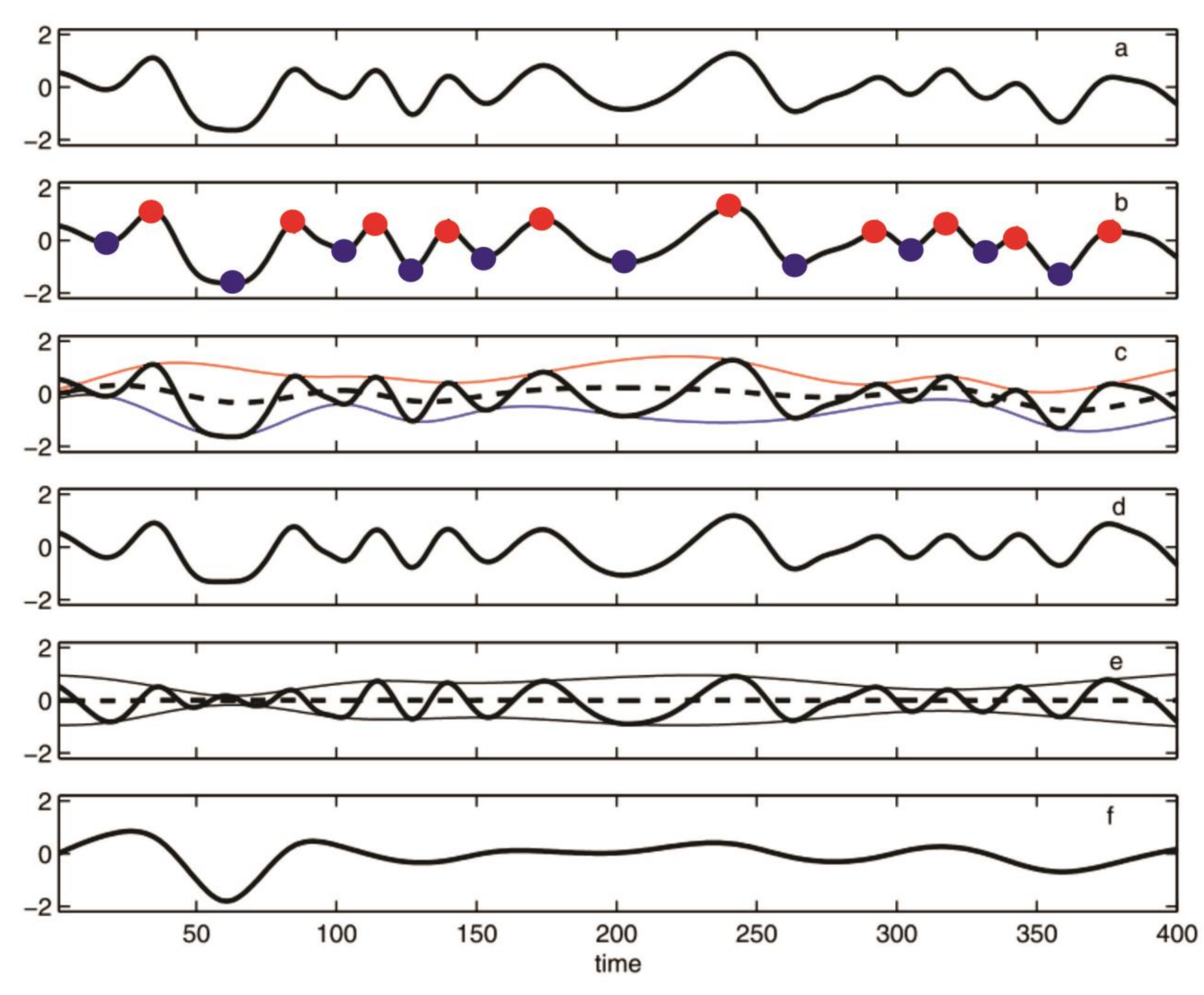
Signal decomposition: the **EMD**

- **EMD** :

Empirical

Mode

Decomposition



Signal

Local extrema

Envelopes (spline)

(modified from Huang & Wu, 2008)

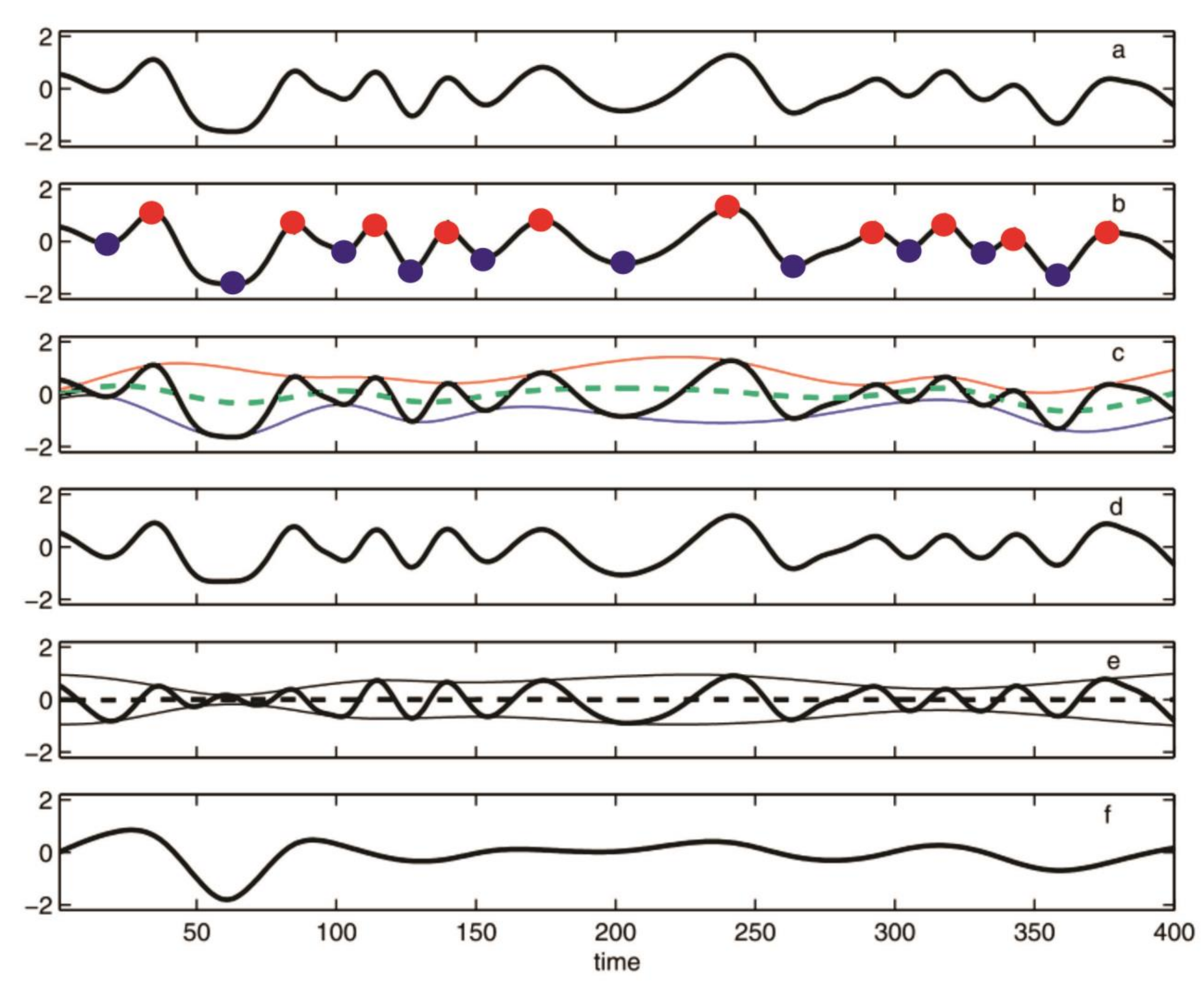
Signal decomposition: the **EMD**

- **EMD** :

Empirical

Mode

Decomposition



Signal

Local extrema

Envelopes (spline)

Mean of envelopes

(modified from Huang & Wu, 2008)

Signal decomposition: the **EMD**

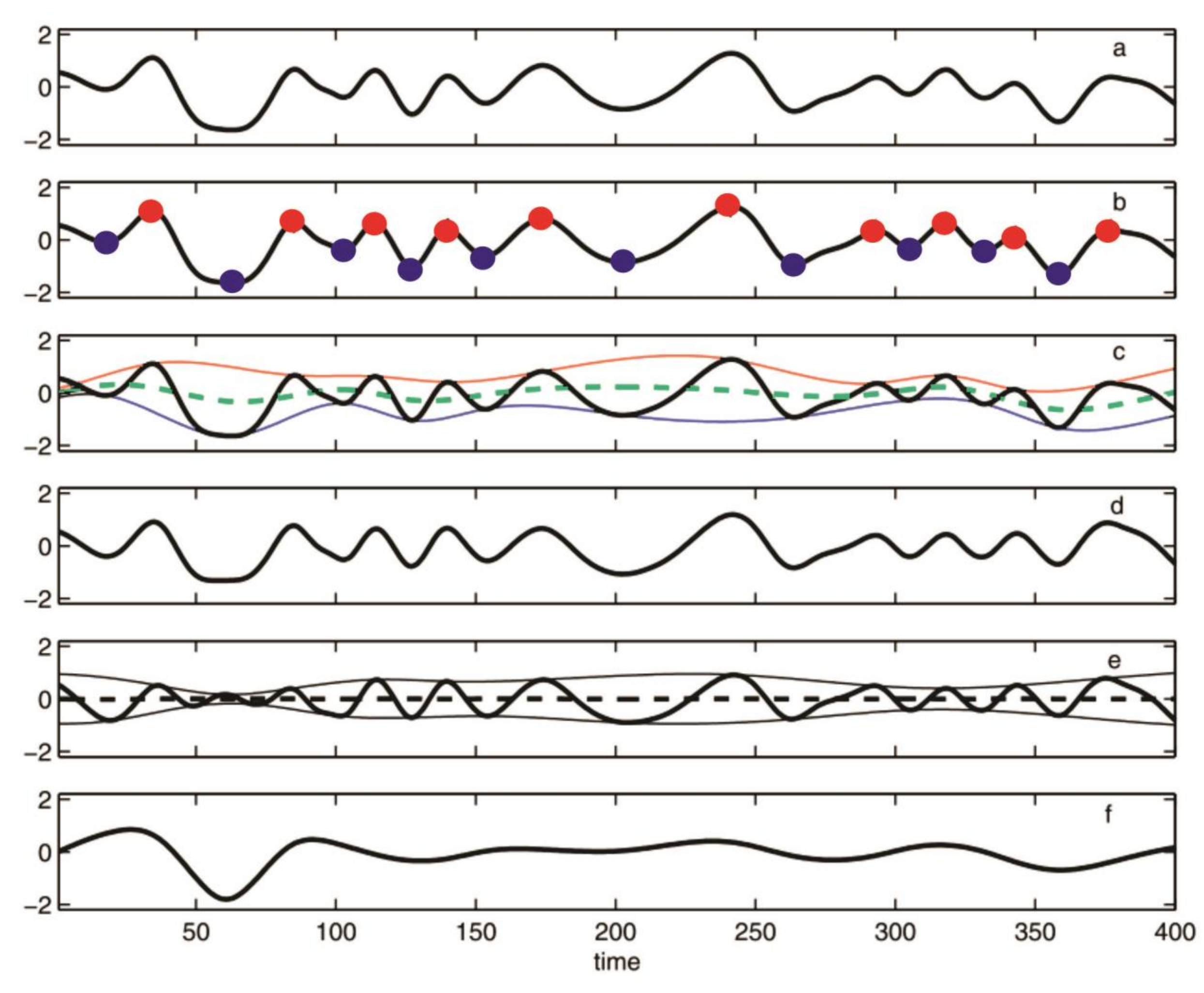
- **EMD** :

Empirical

Mode

Decomposition

(modified from Huang & Wu, 2008)



Signal

Local extrema

Envelopes (spline)

Mean of envelopes

Prototype of IMF
(Signal – Mean)

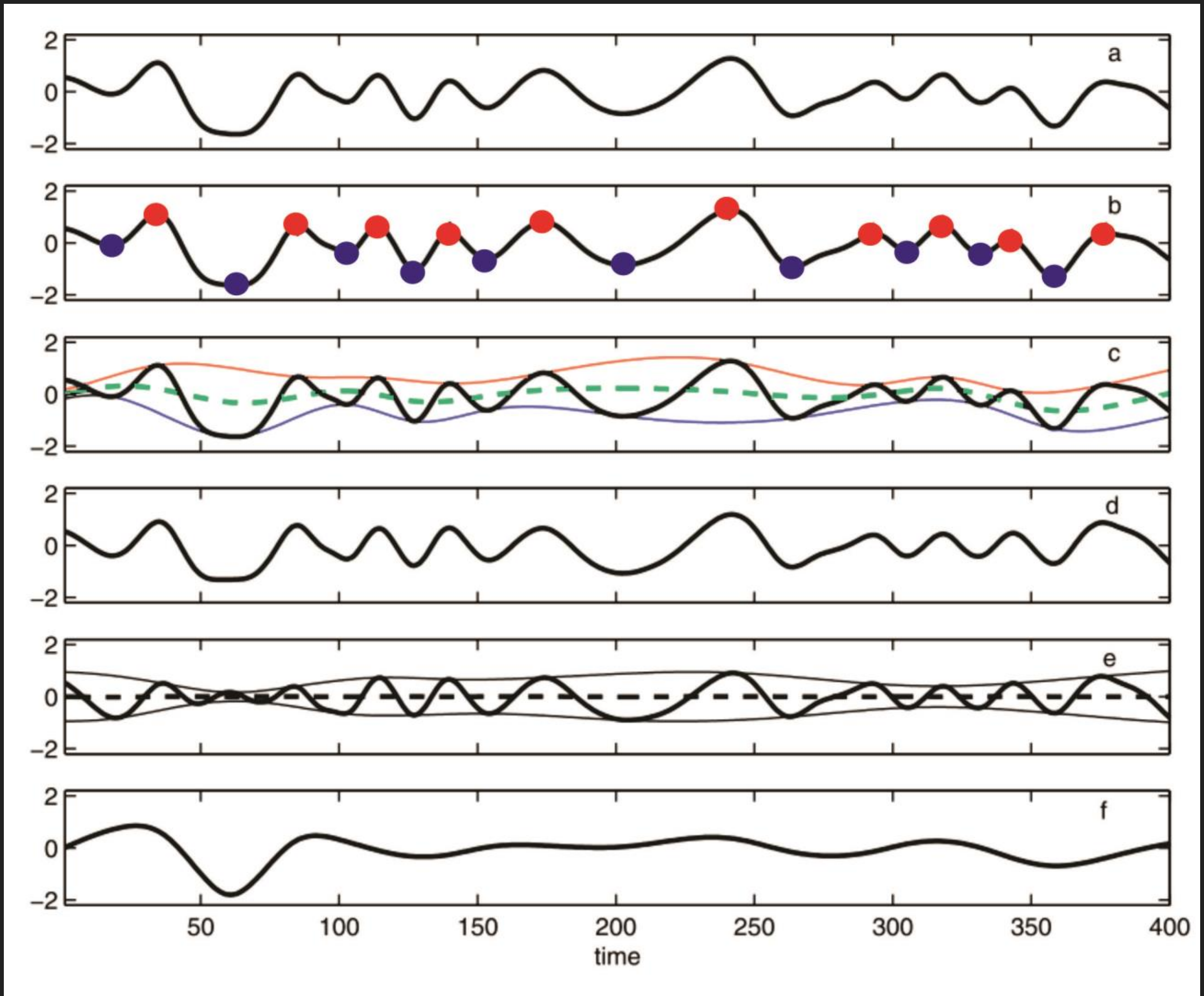
Signal decomposition: the EMD

- EMD :

Empirical

Mode

Decomposition



Signal

Local extrema

Envelopes (spline)

Mean of envelopes

Prototype of IMF
(Signal – Mean)

Repetition of process
to refine IMF (sifting)

(modified from Huang & Wu, 2008)

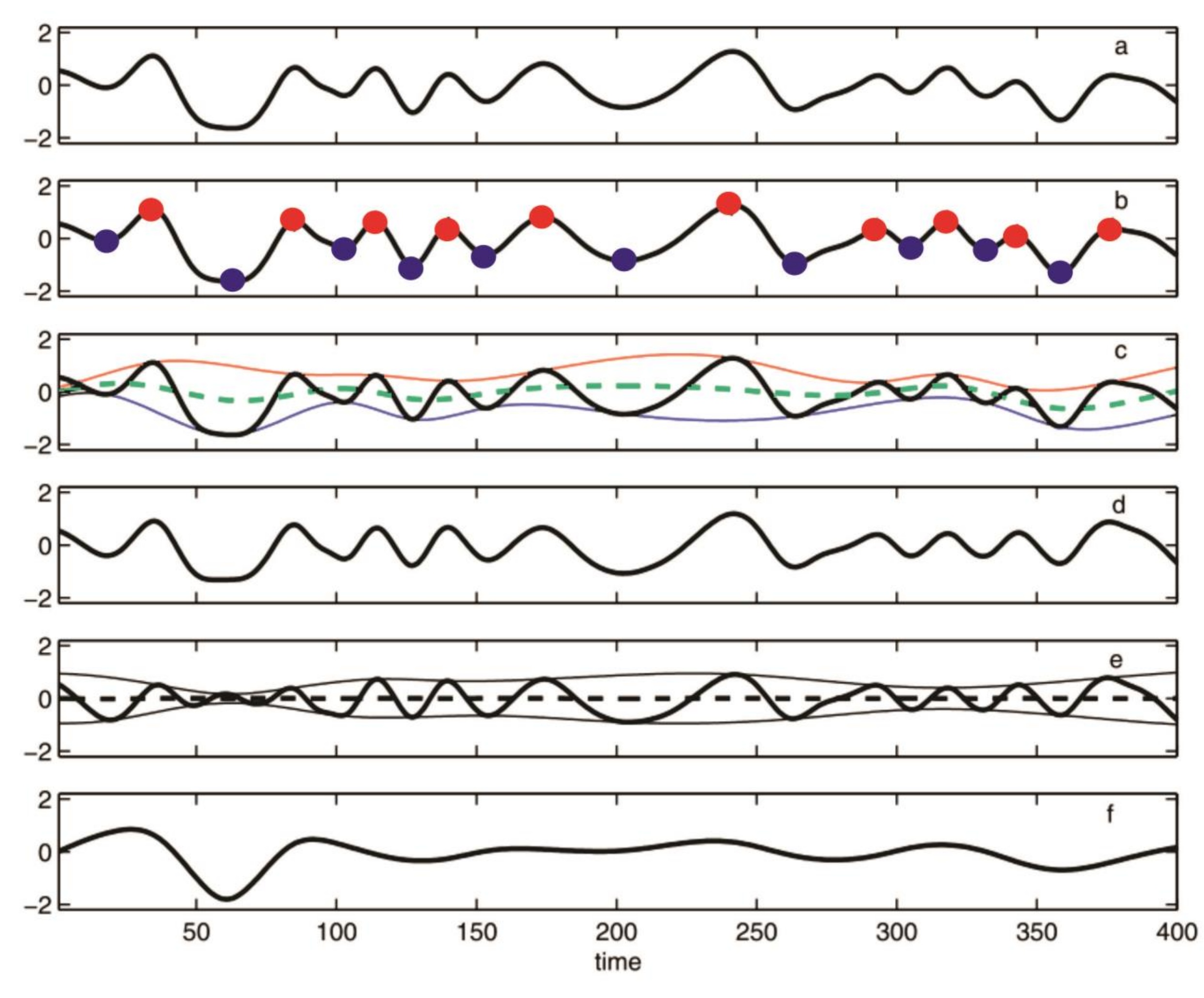
Signal decomposition: the EMD

- EMD :

Empirical

Mode

Decomposition



Signal

Local extrema

Envelopes (spline)

Mean of envelopes

Prototype of IMF
(Signal – Mean)

Repetition of process
to refine IMF (sifting)

Remainder
(Signal – refined IMF)

(modified from Huang & Wu, 2008)

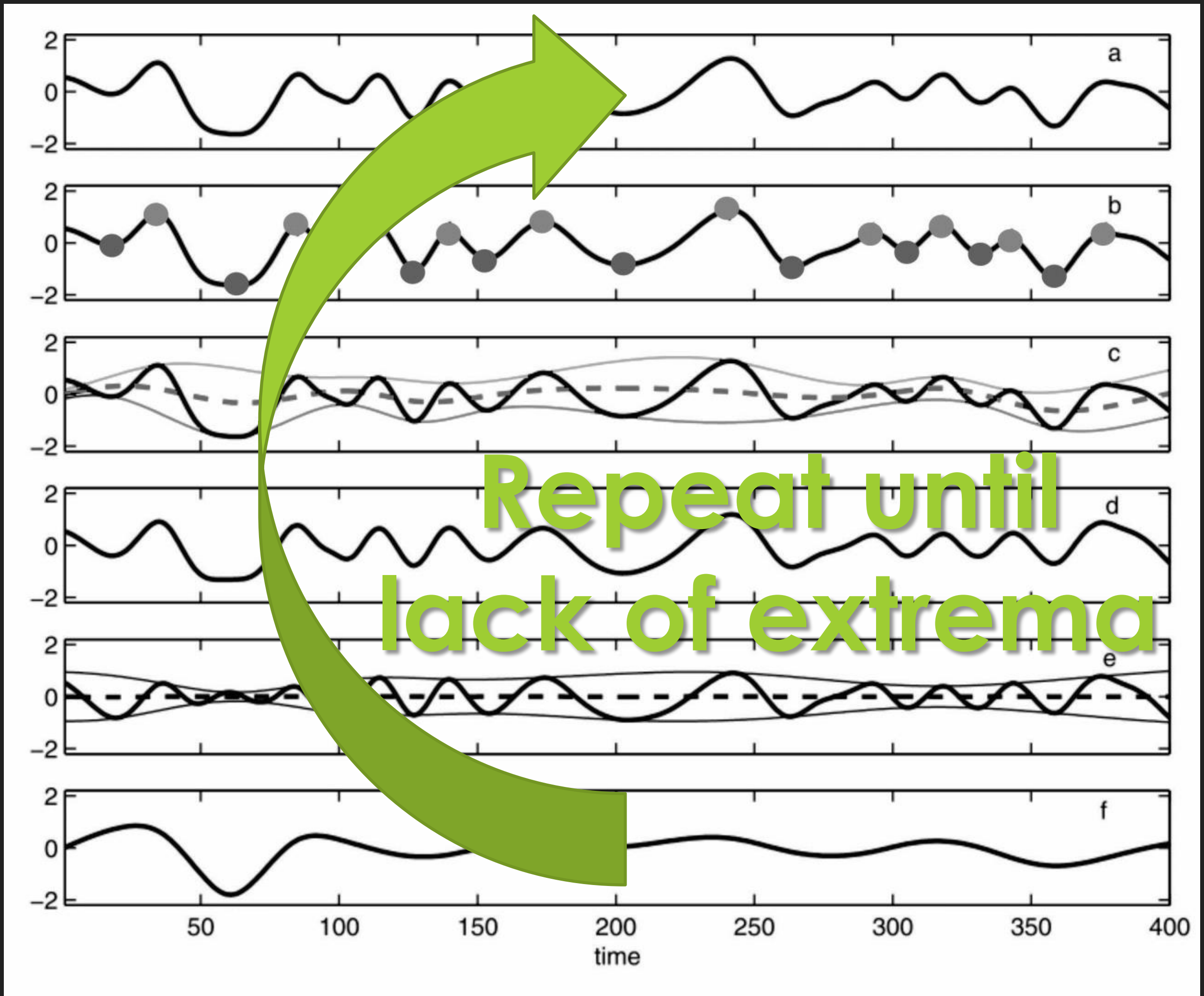
Signal decomposition: the EMD

- EMD :

Empirical

Mode

Decomposition



Signal

Local extrema

Envelopes (spline)

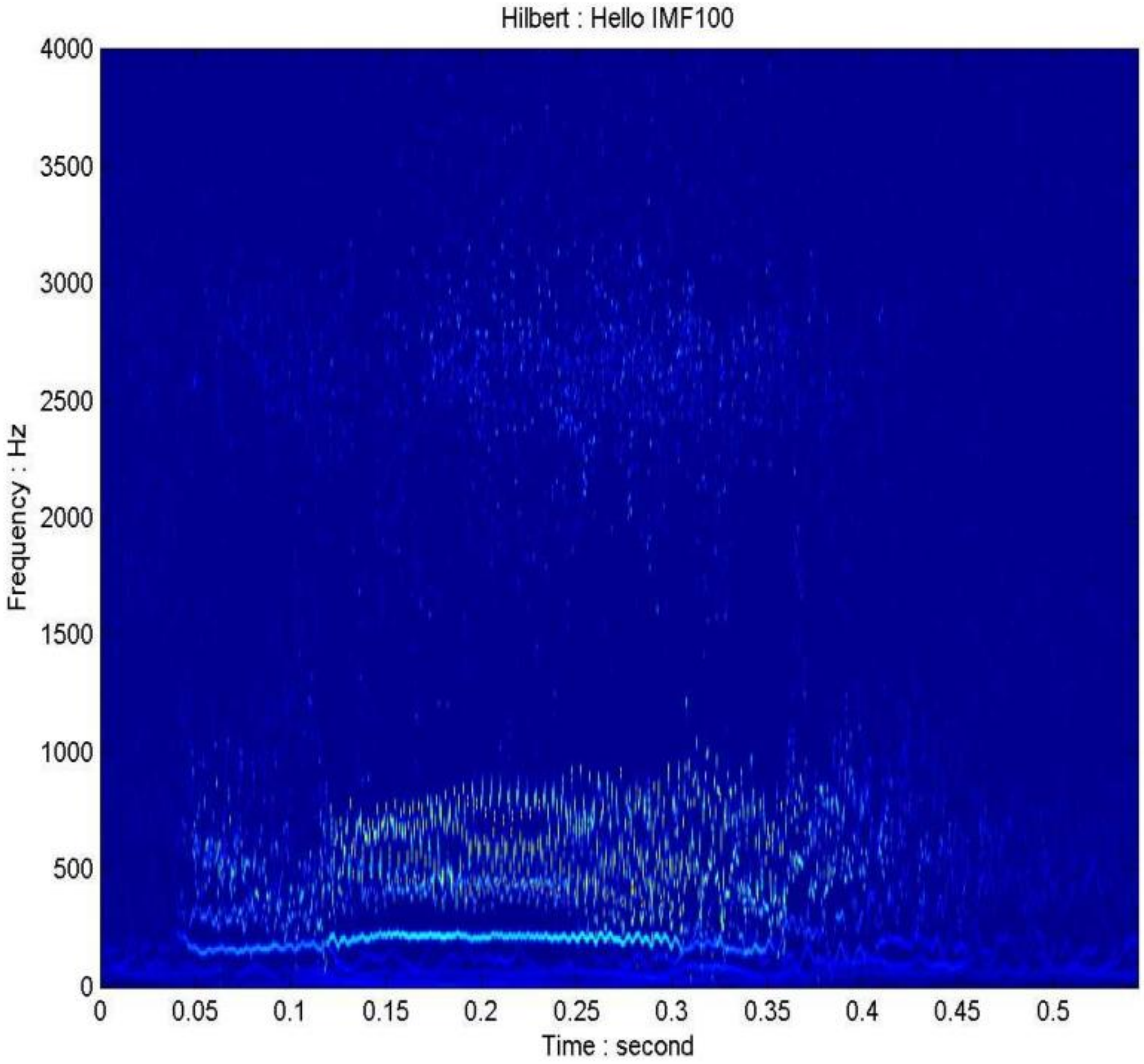
Mean of envelopes

Prototype of IMF (Signal – Mean)

Repetition of process to refine IMF (sifting)

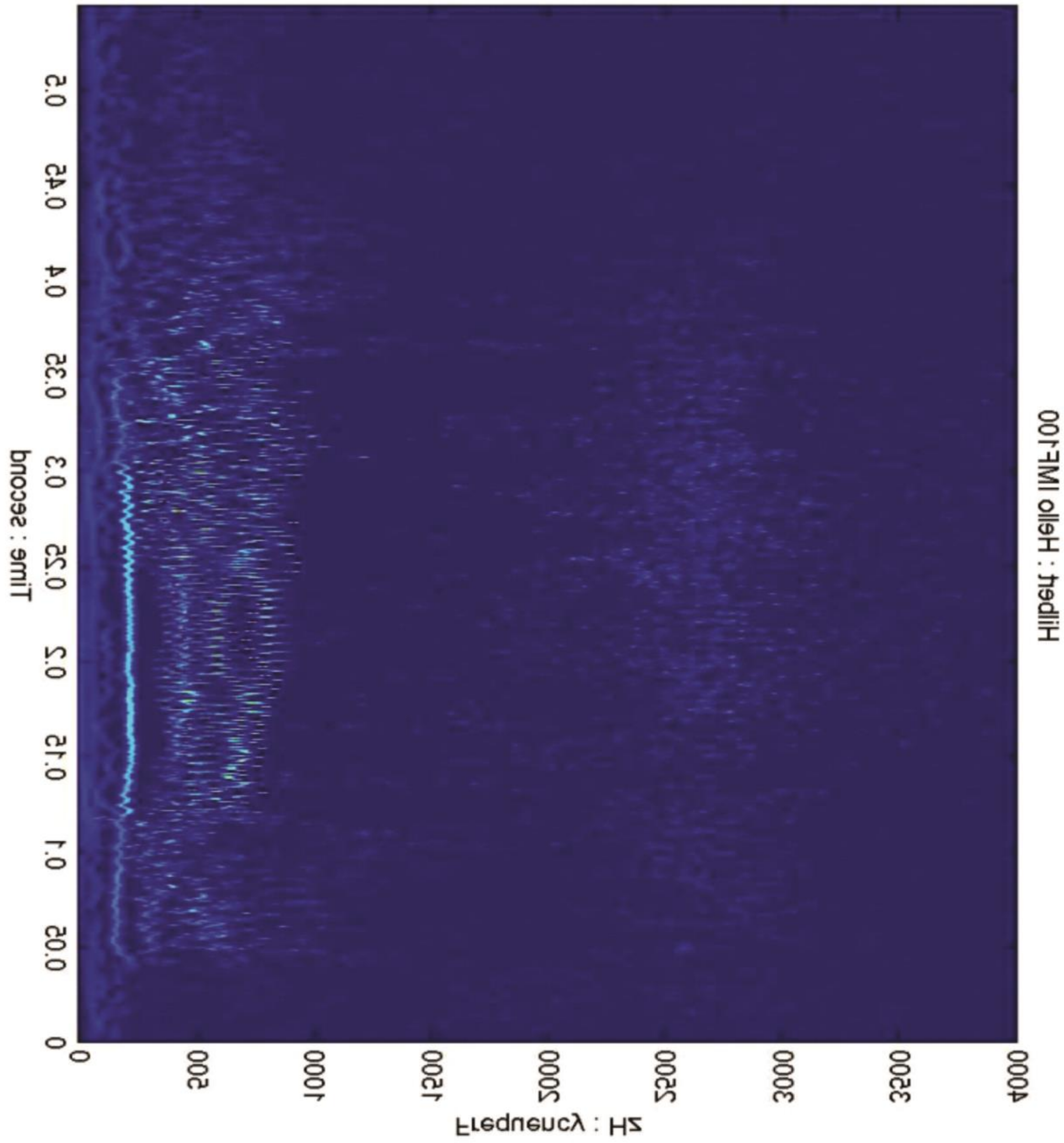
Remainder (Signal – refined IMF)

(modified from Huang & Wu, 2008)



Hilbert spectrum of a digitalised sound “Hello”

(Wu & Huang, 2009)



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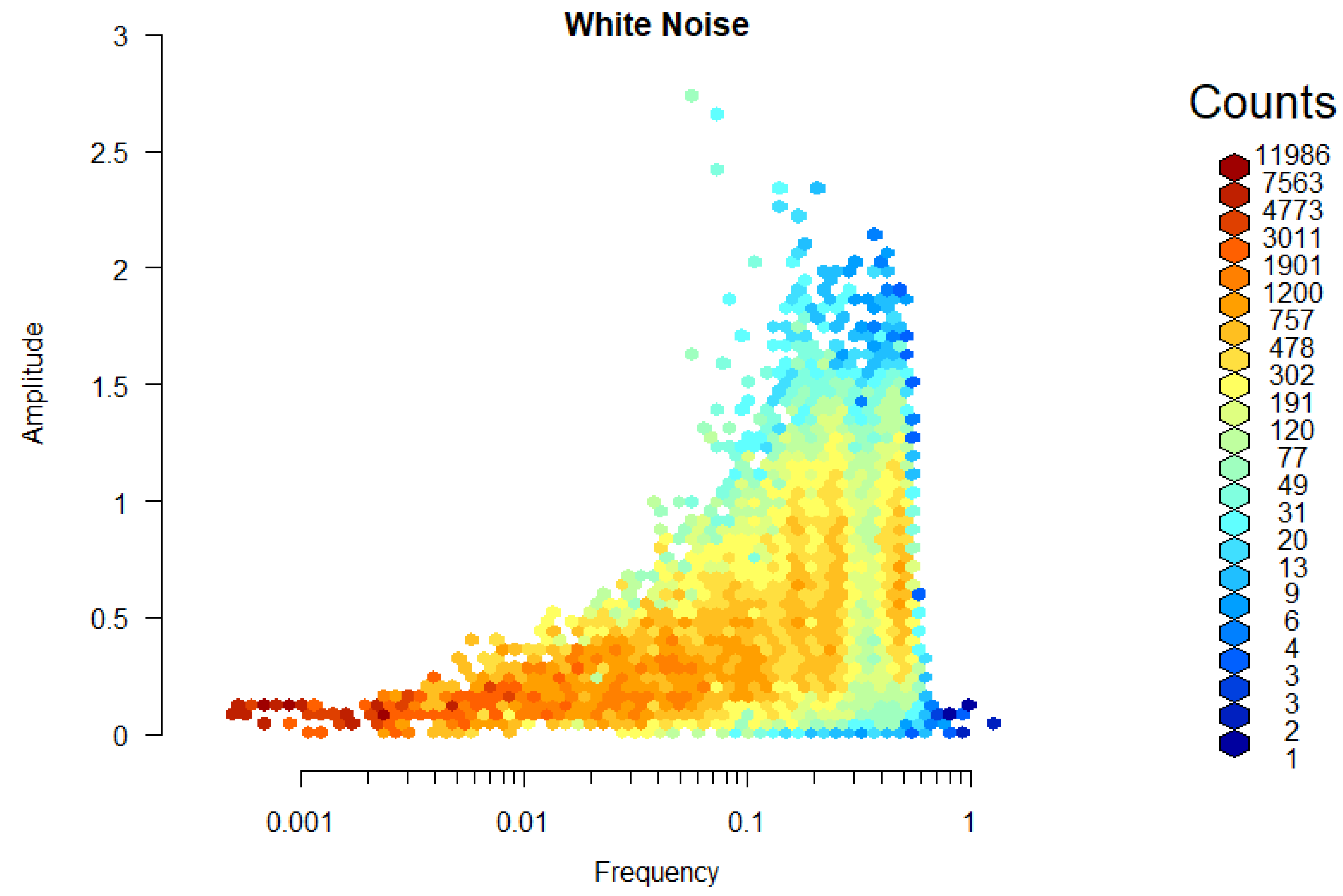
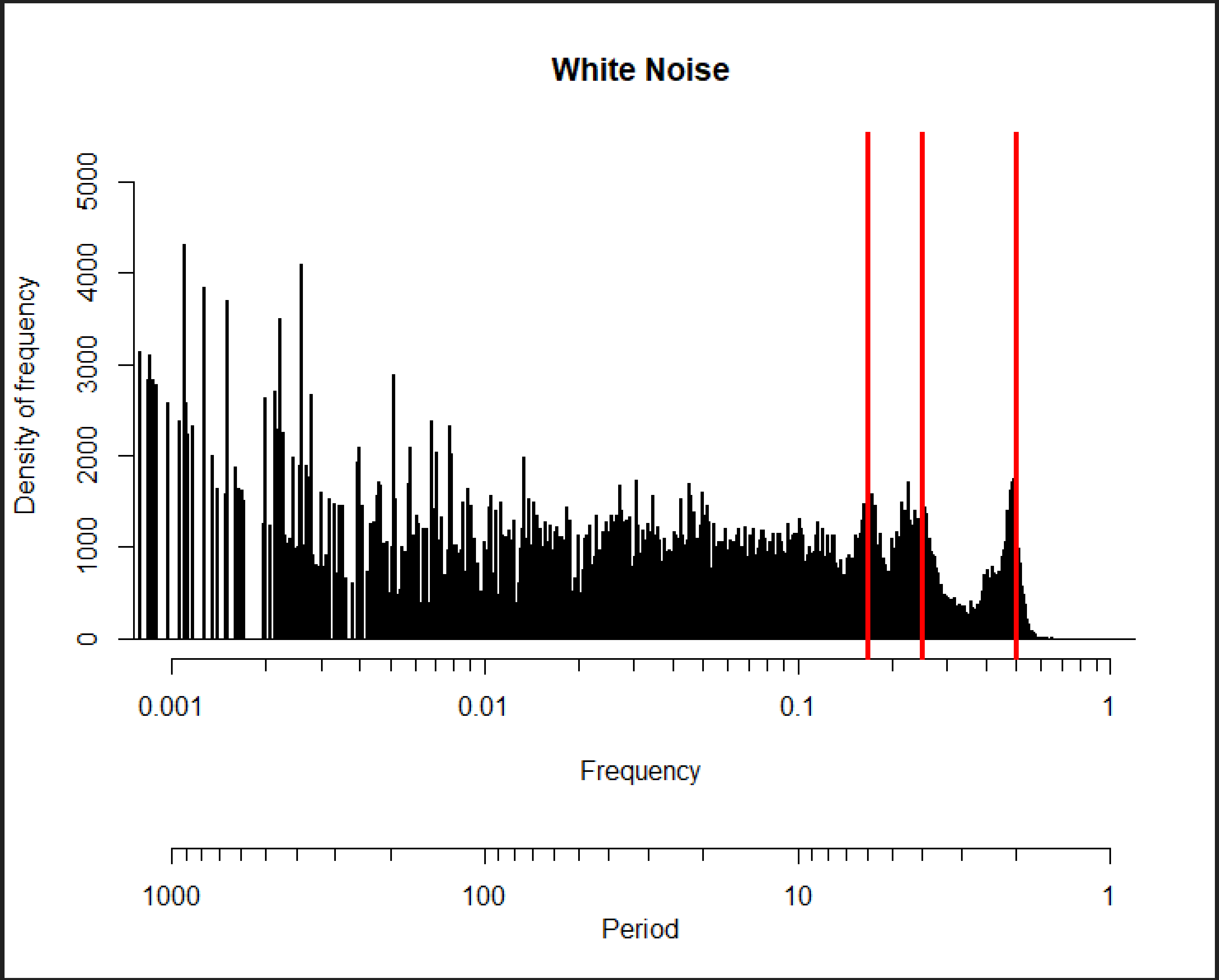
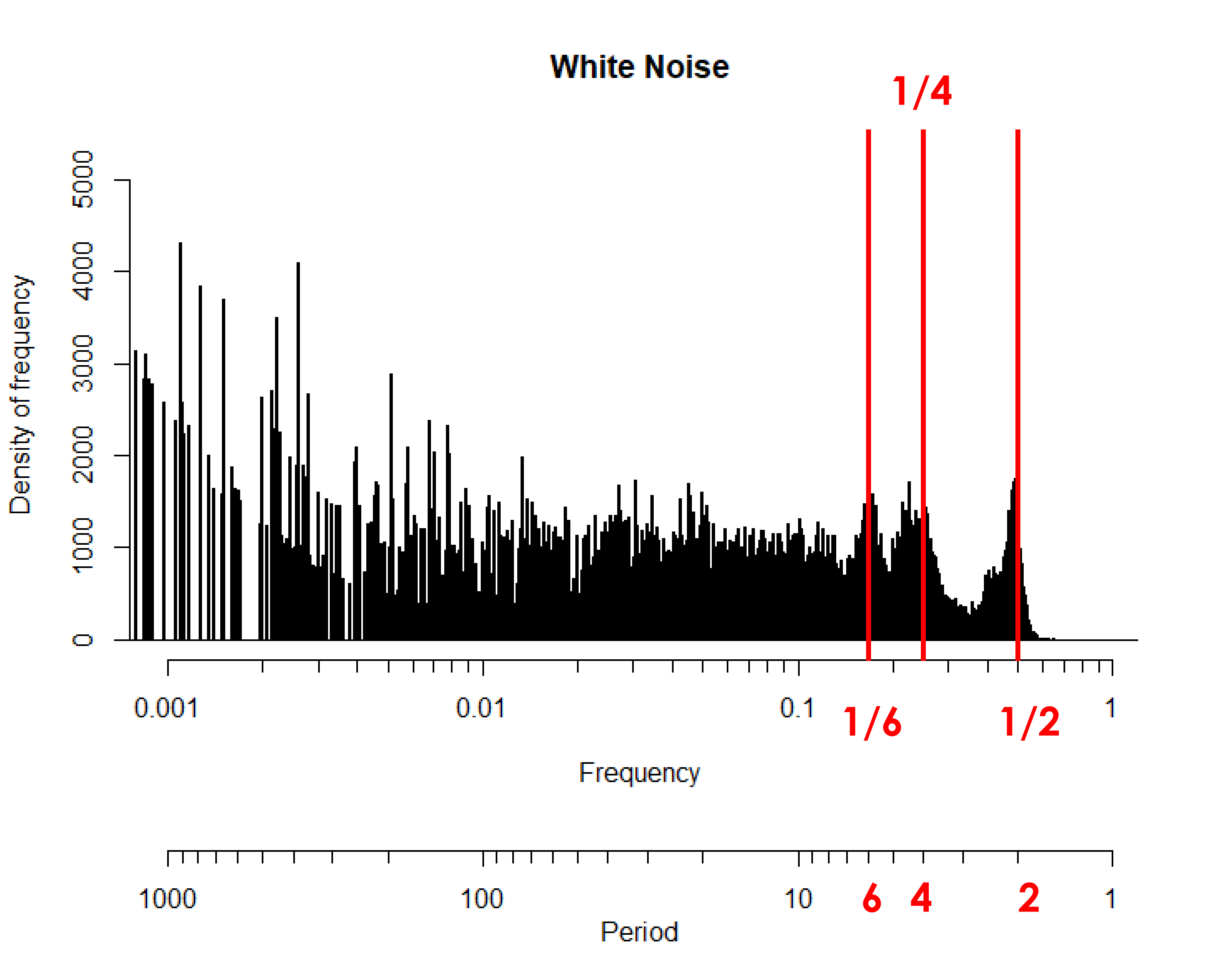
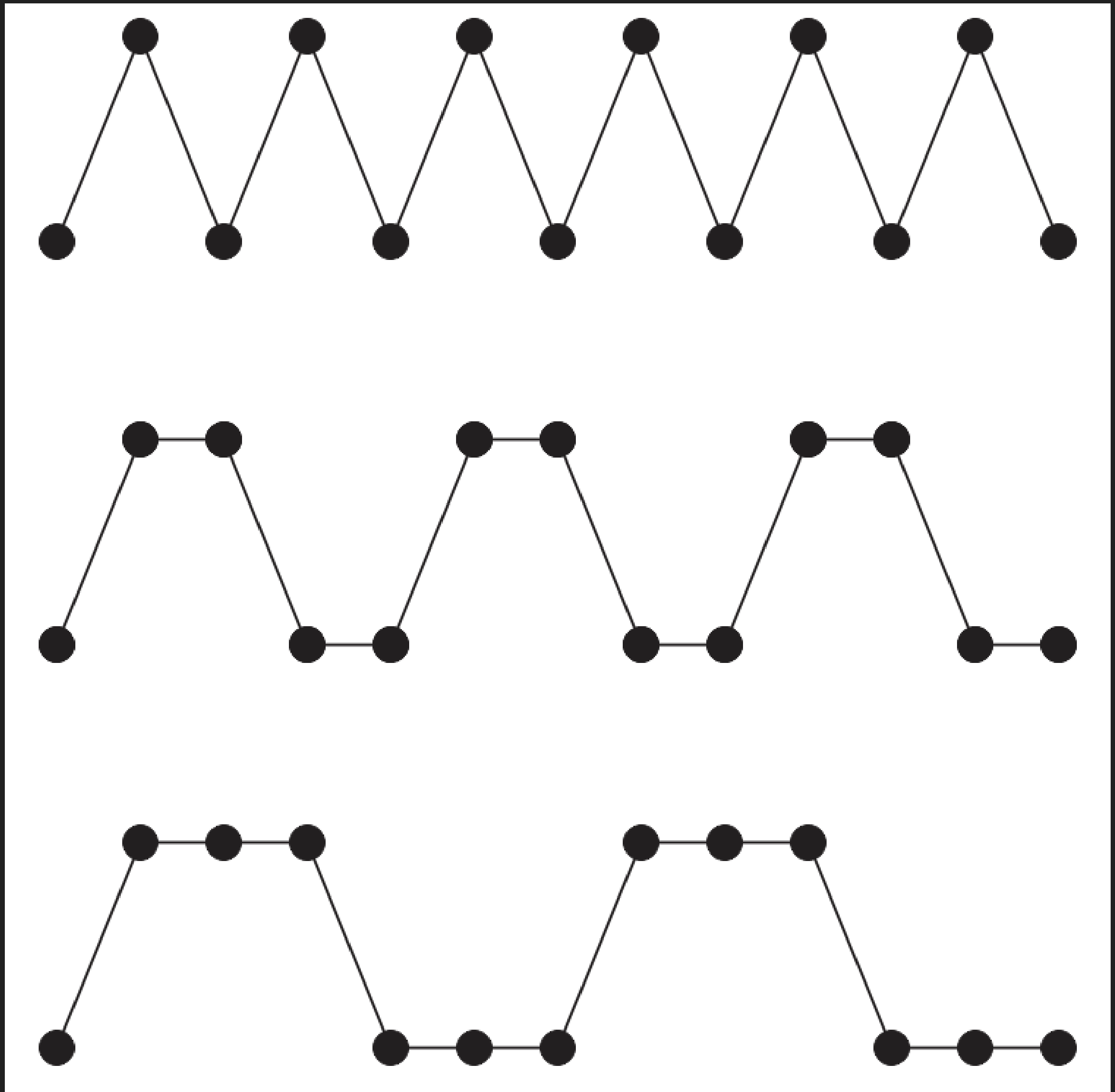
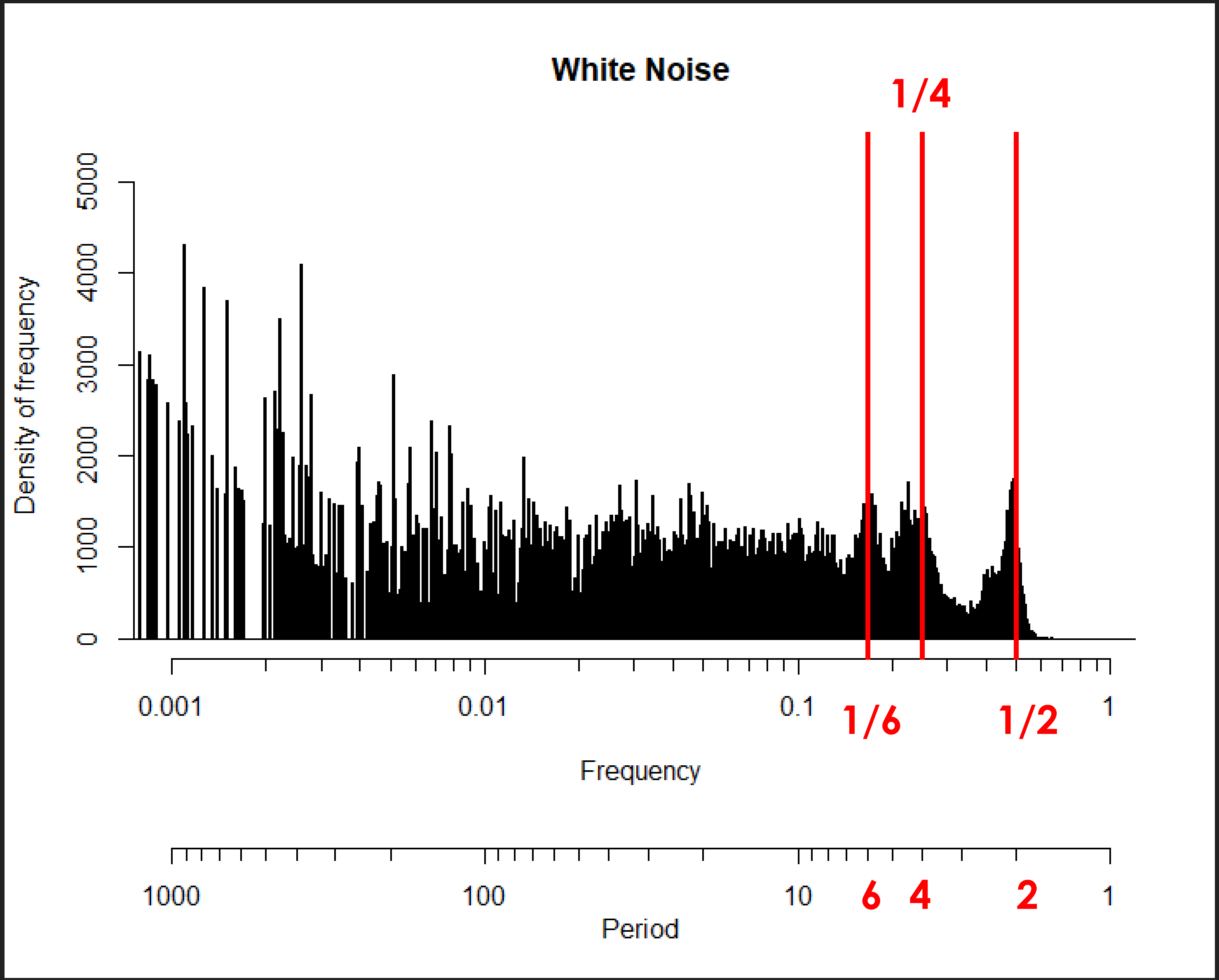

White Noise
Amplitude
Frequency
0
0.5
1
1.5
2
2.5
3
0.001
0.01
0.1
1
Counts
11986
7563
4773
3011
1901
1200
757
478
302
191
120
77
49
31
20
13
9
6
4
3
3
2
1


White Noise
Density of frequency
0
1000
2000
3000
4000
5000
0.001
0.01
0.1
1
Frequency
1000
100
10
1
Period



White Noise
1/4
Density of frequency
0
1000
2000
3000
4000
5000
0.001
0.01
0.1
1/6
1/2
1
Frequency
1000
100
10
6
4
2
1
Period





White Noise
1/4
Density of frequency
0
1000
2000
3000
4000
5000
0.001
0.01
0.1
1/6
1/2
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Frequency
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6
4
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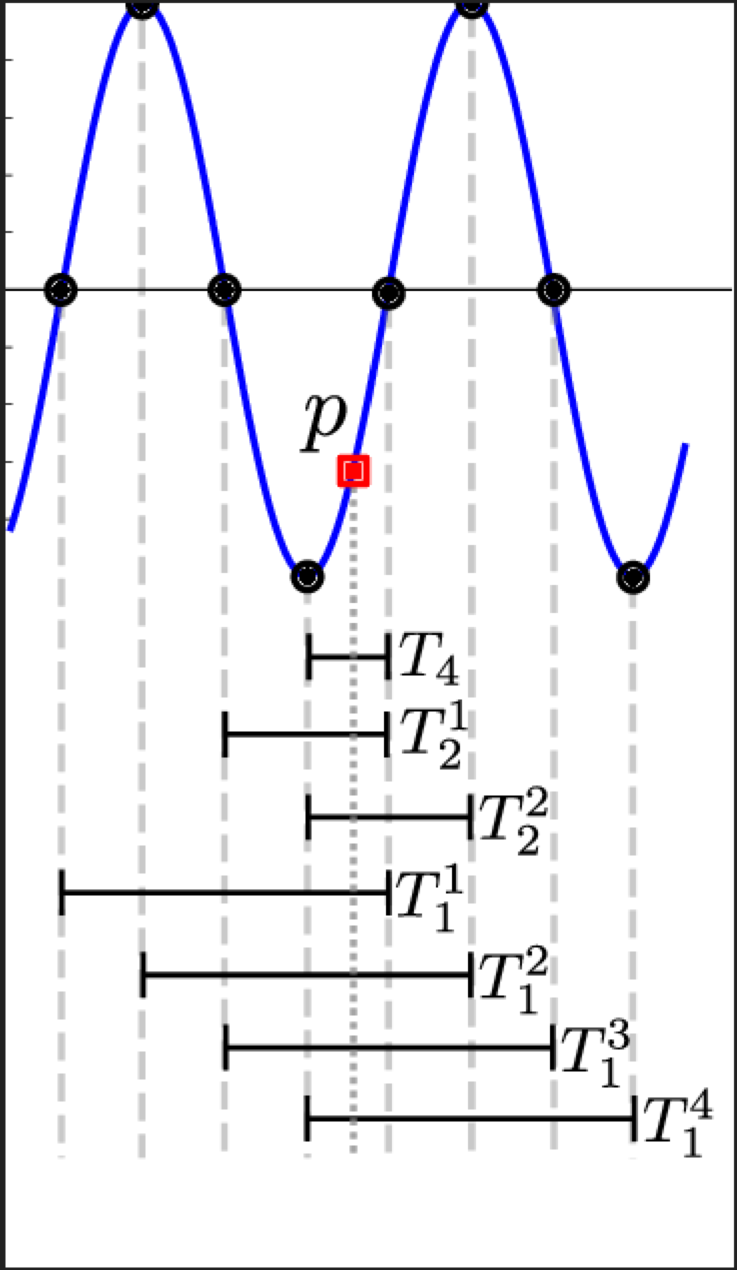
Period



(Fontugne et al., 2013)

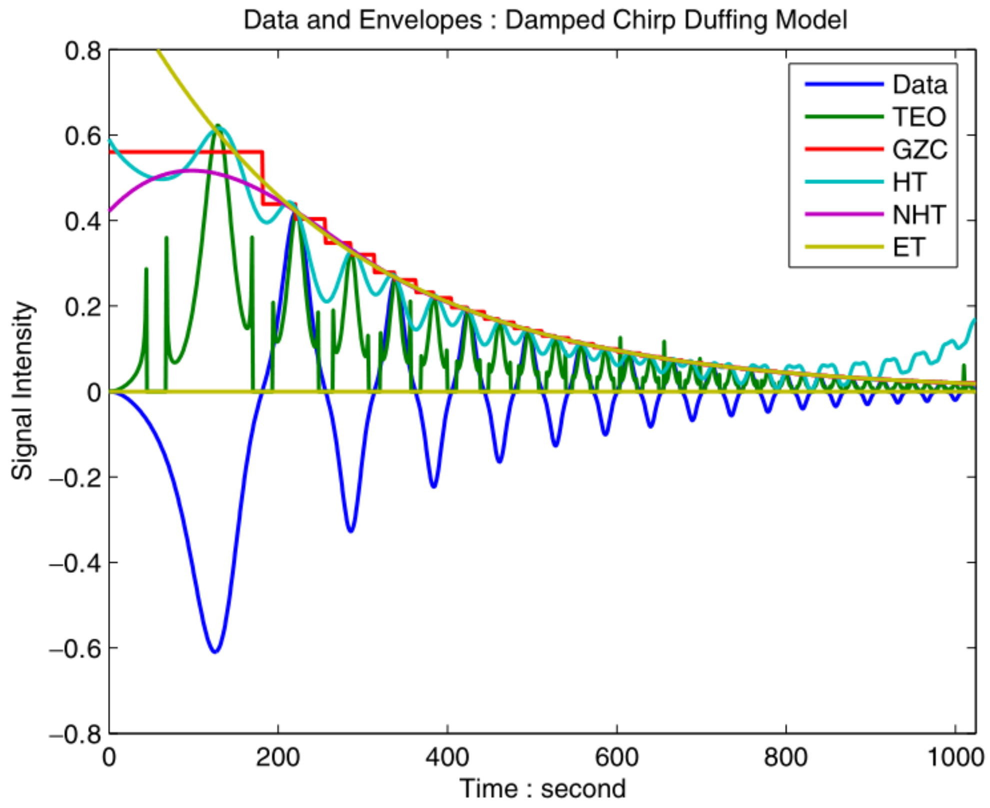


Fig. 14. The amplitude determined from various methods: TEO, GZC, and HT, spline fitting used in DQ and NHT. The spline line is identical to the theoretic value; therefore, it is defined as the envelope in the direct quadrature method.

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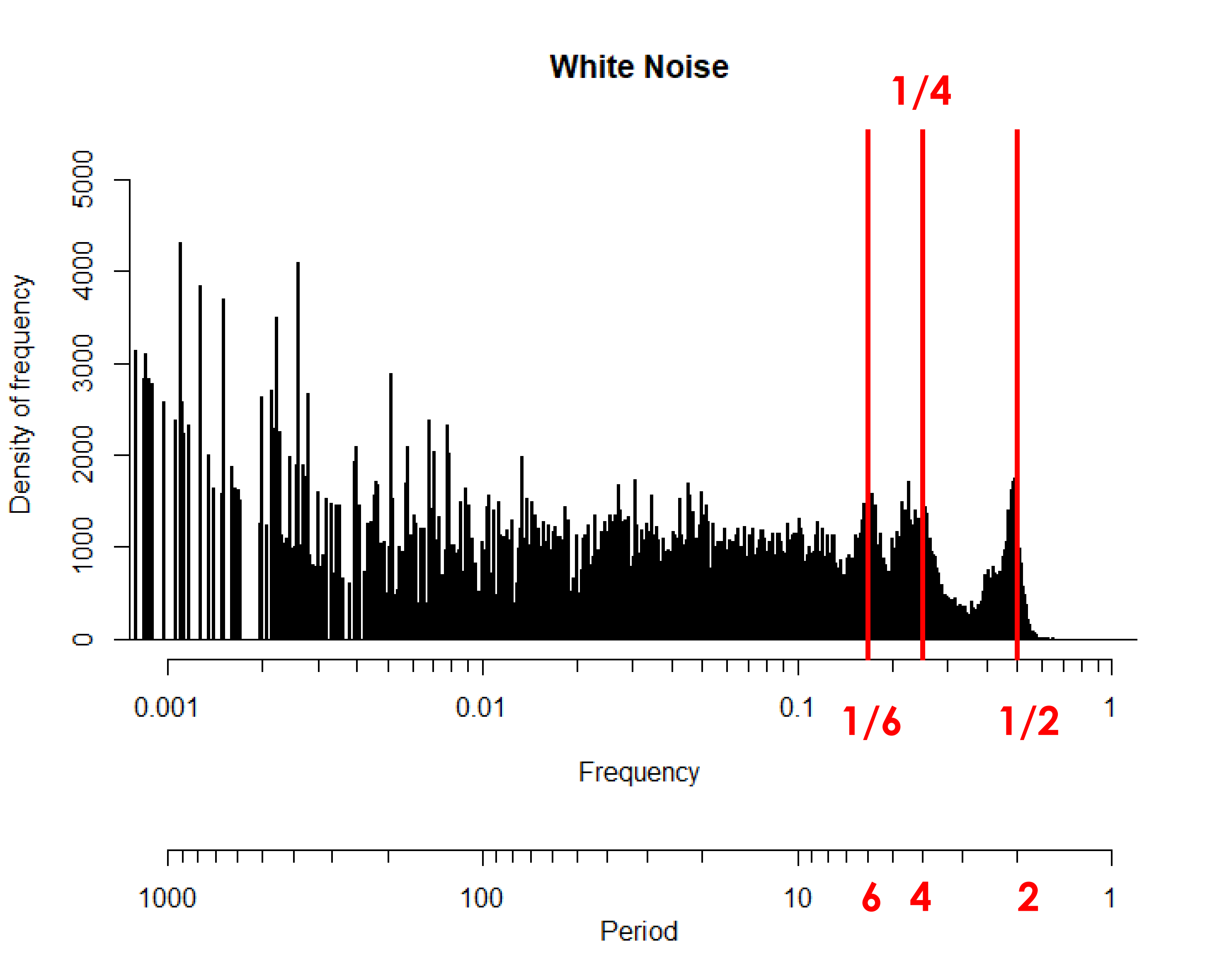
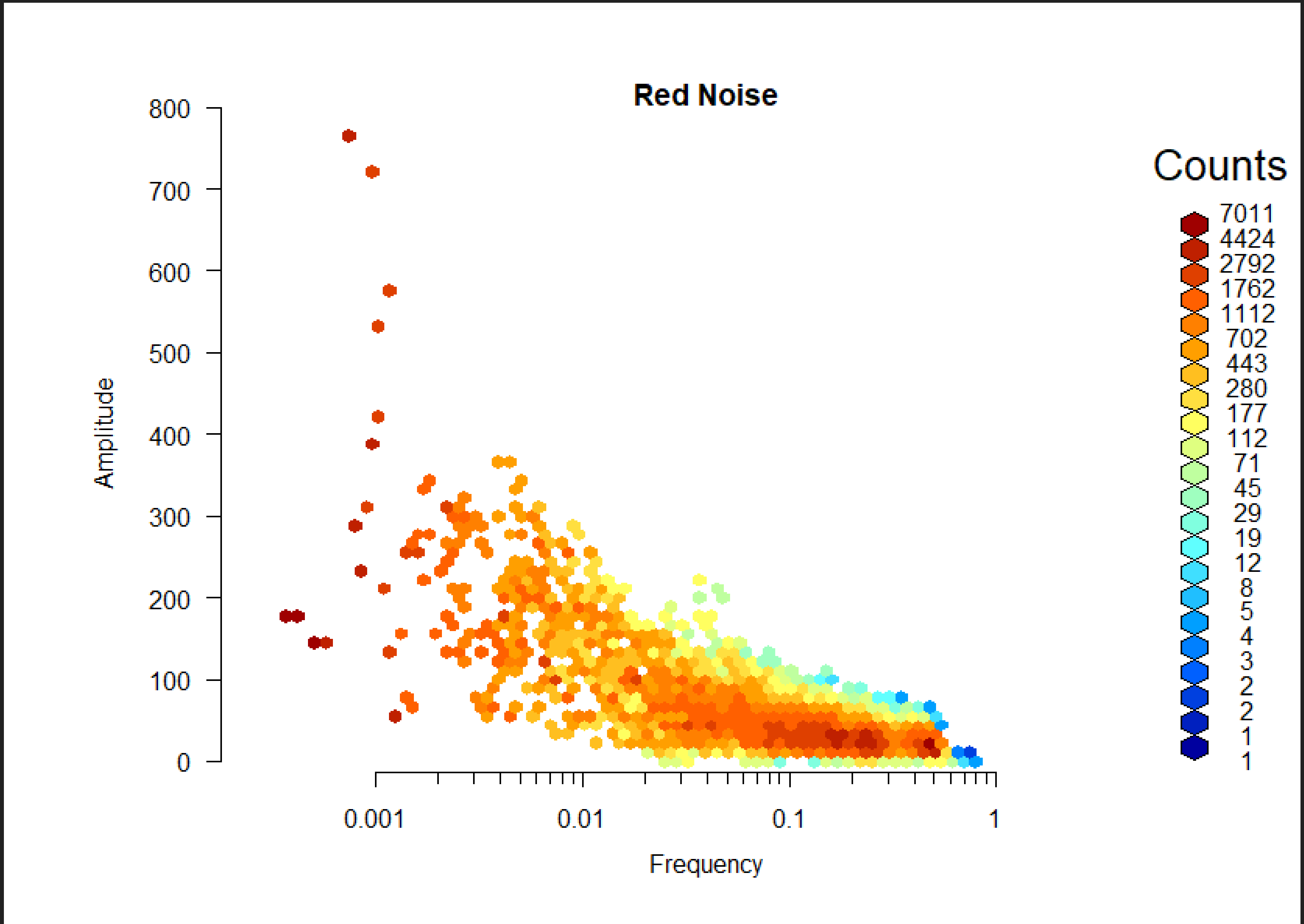
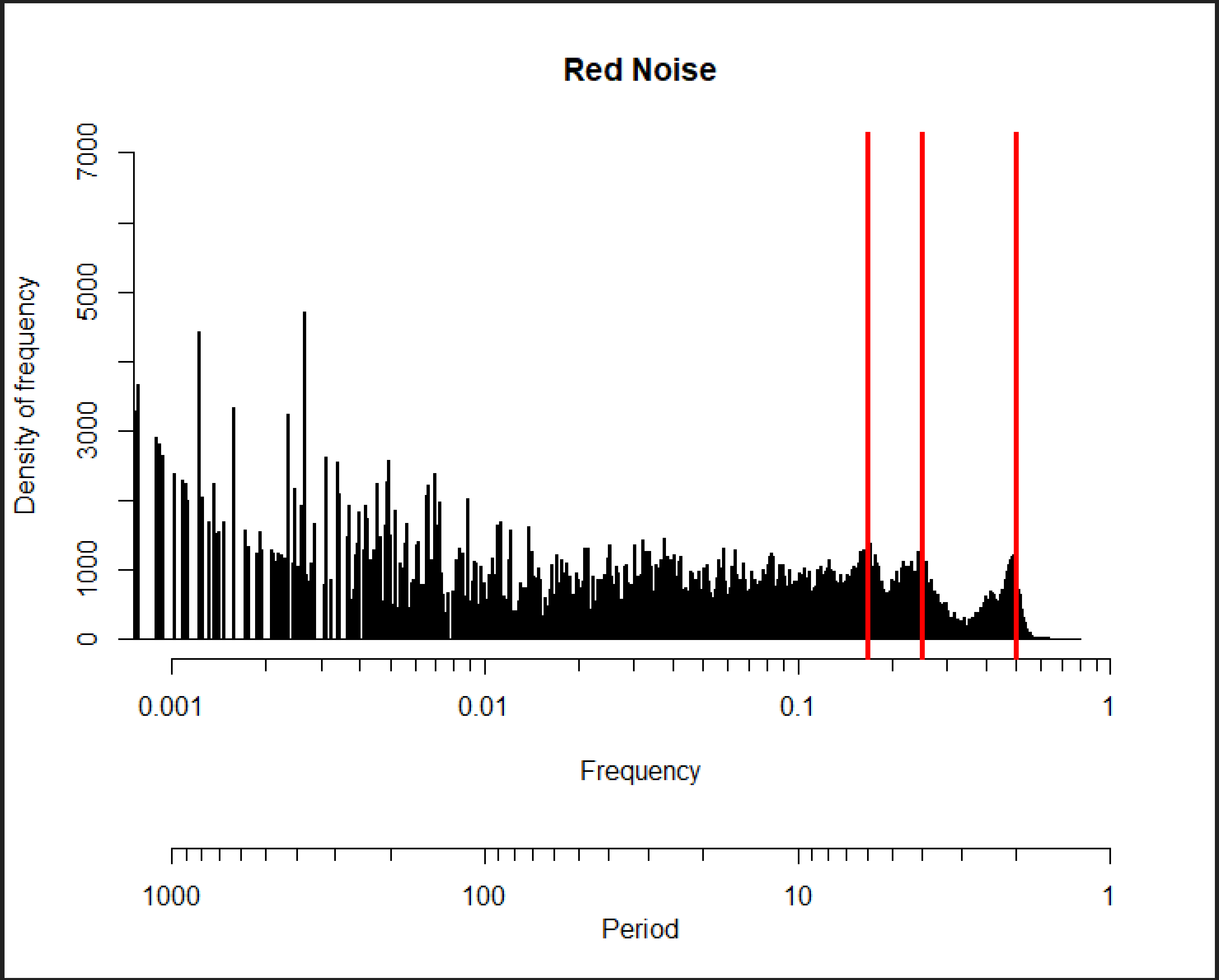
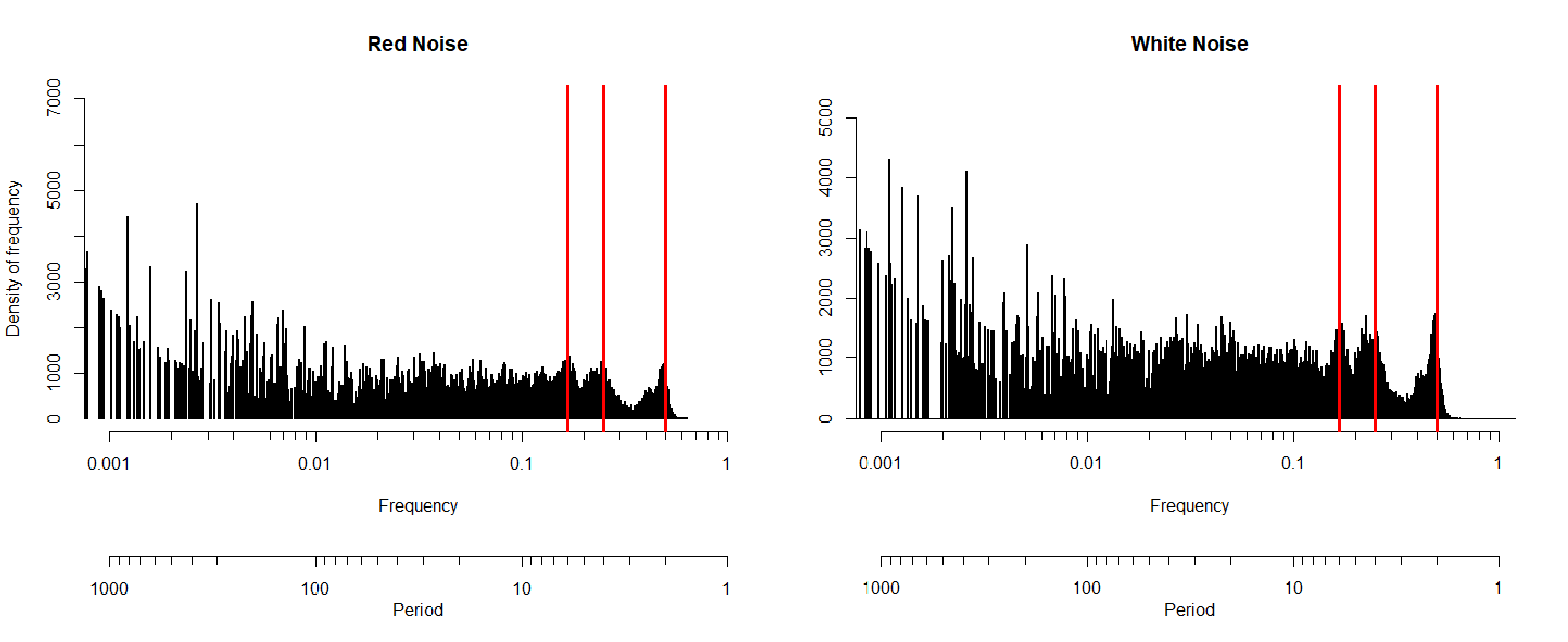
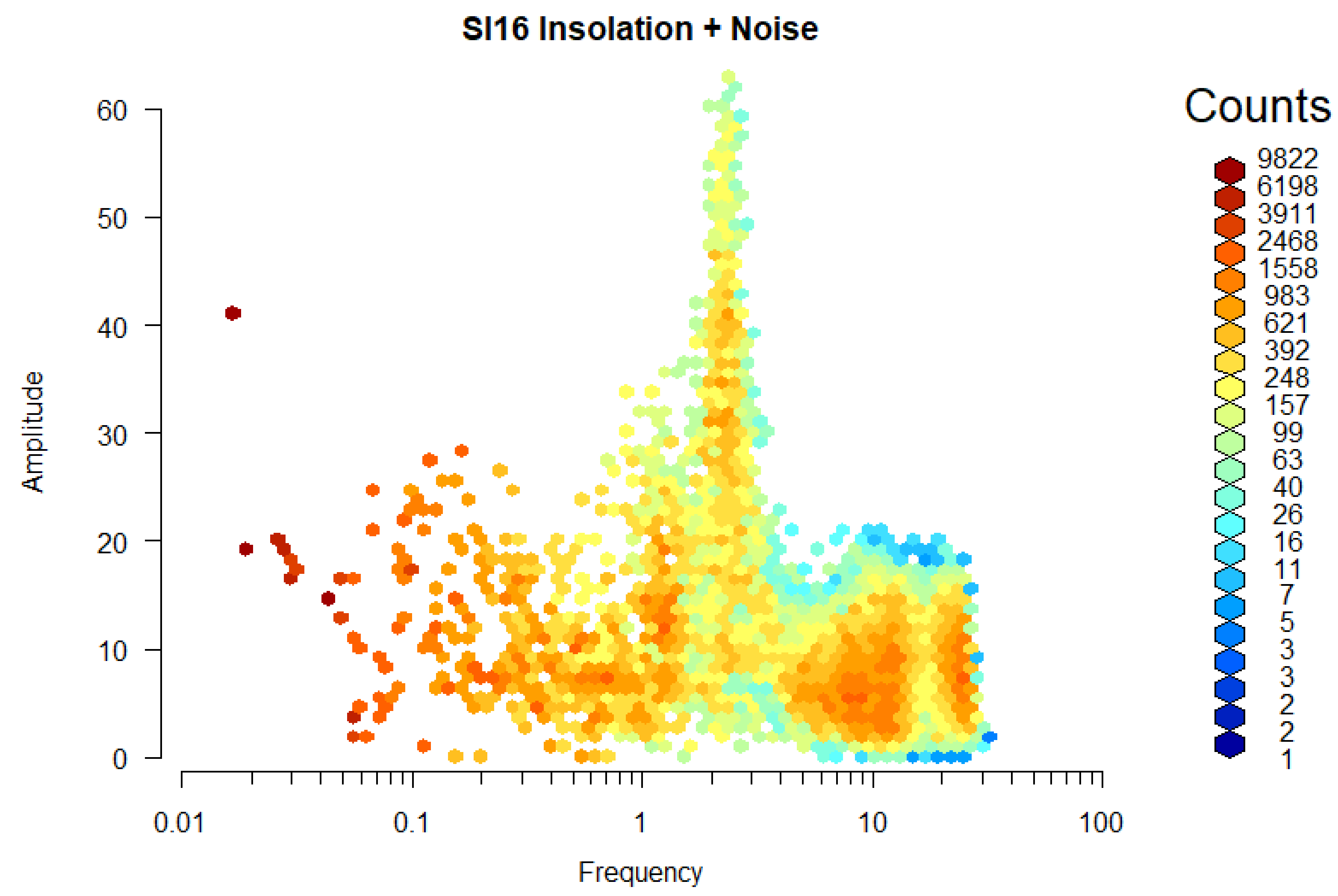

White Noise
1/4
Density of frequency
0
1000
2000
3000
4000
5000
0.001
0.01
0.1
1/6
1/2
1
Frequency
1000
100
10
6
4
2
1
Period


Red Noise
Amplitude
800
700
600
500
400
300
200
100
0
0.001
0.01
0.1
1
Frequency
Counts
7011
4424
2792
1762
1112
702
443
280
177
112
71
45
29
19
12
8
5
4
3
2
2
1
1

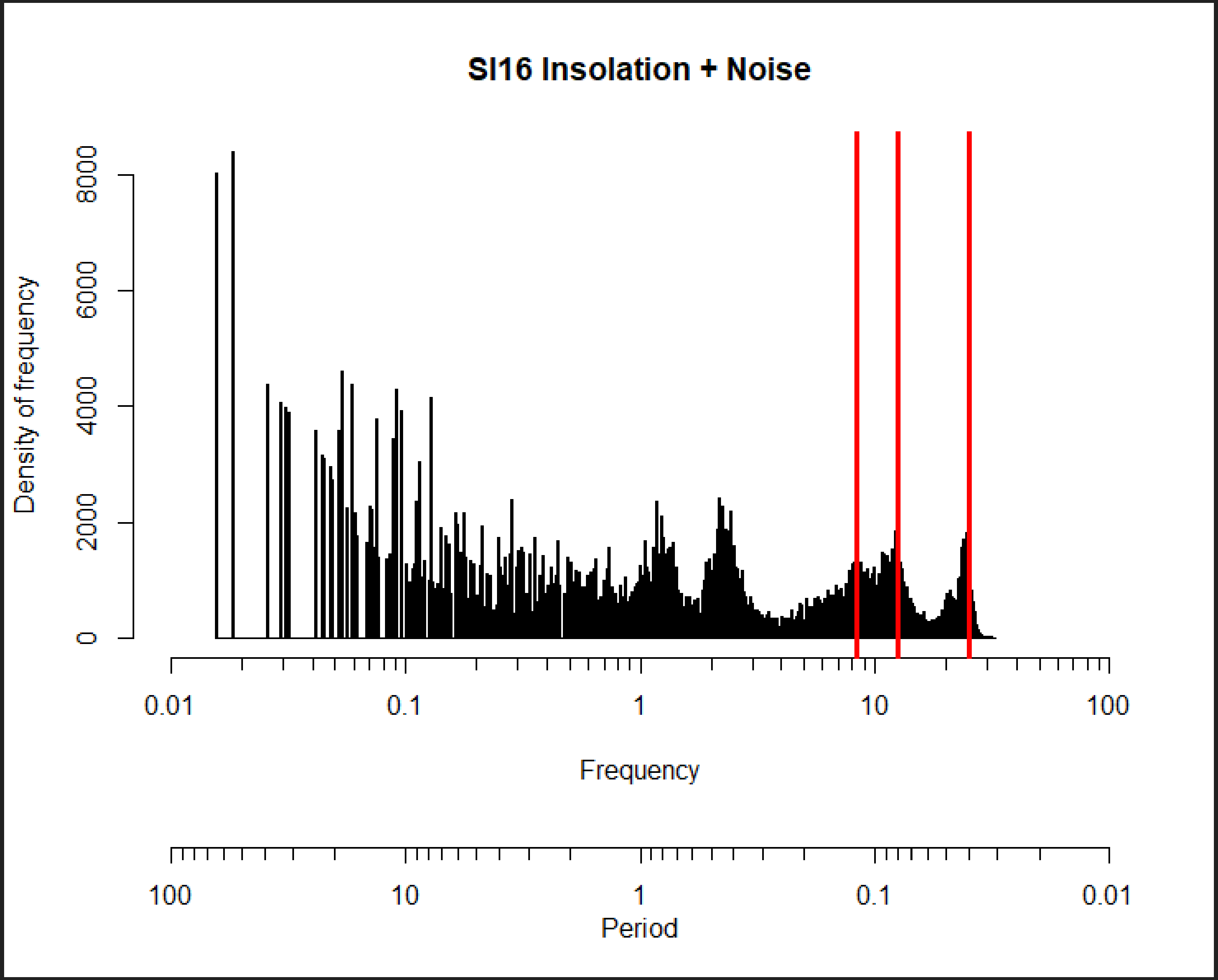


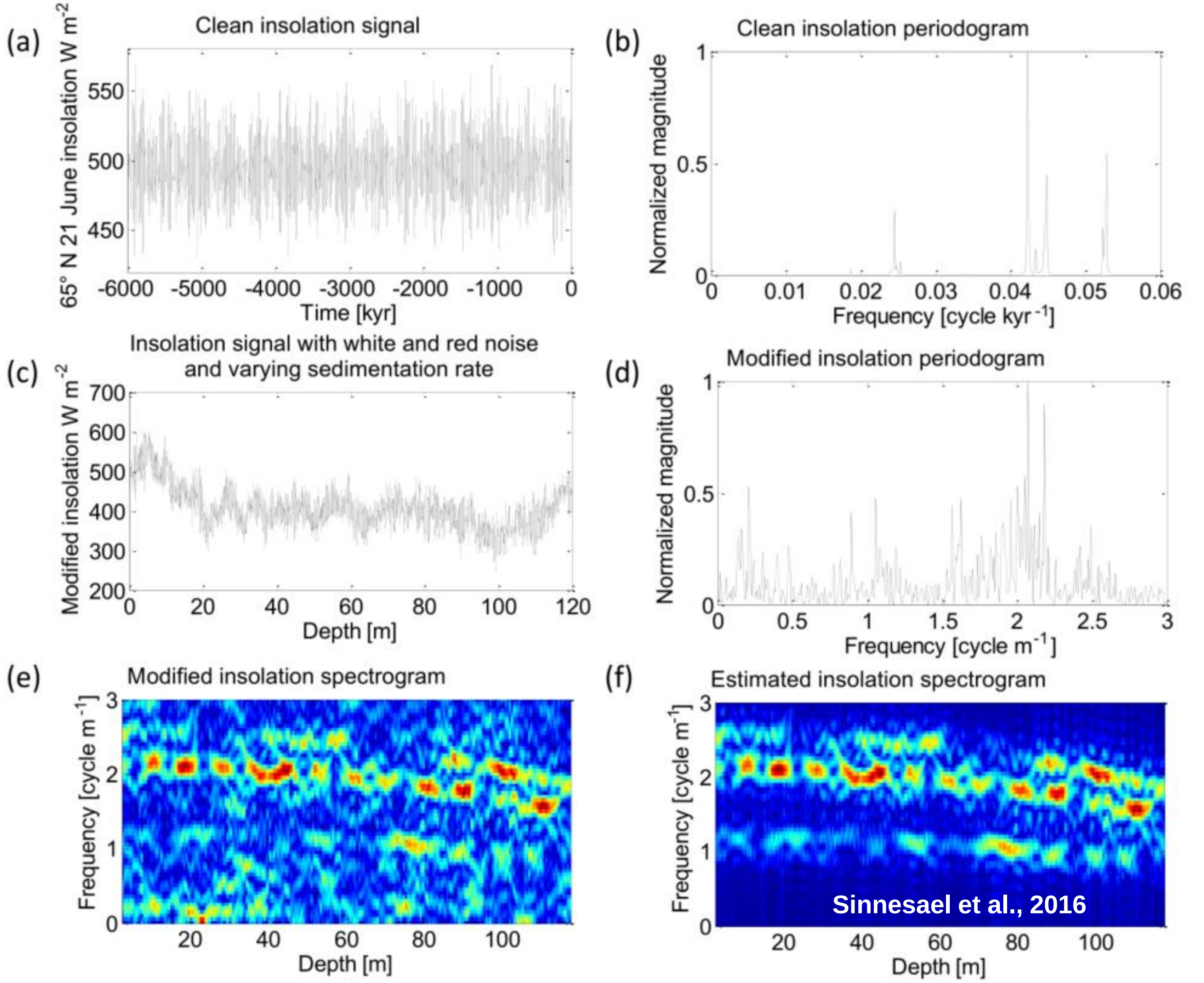
Red Noise
Density of frequency
7000
5000
3000
1000
0
0.001
0.01
0.1
1
Frequency
1000
100
10
1
Period

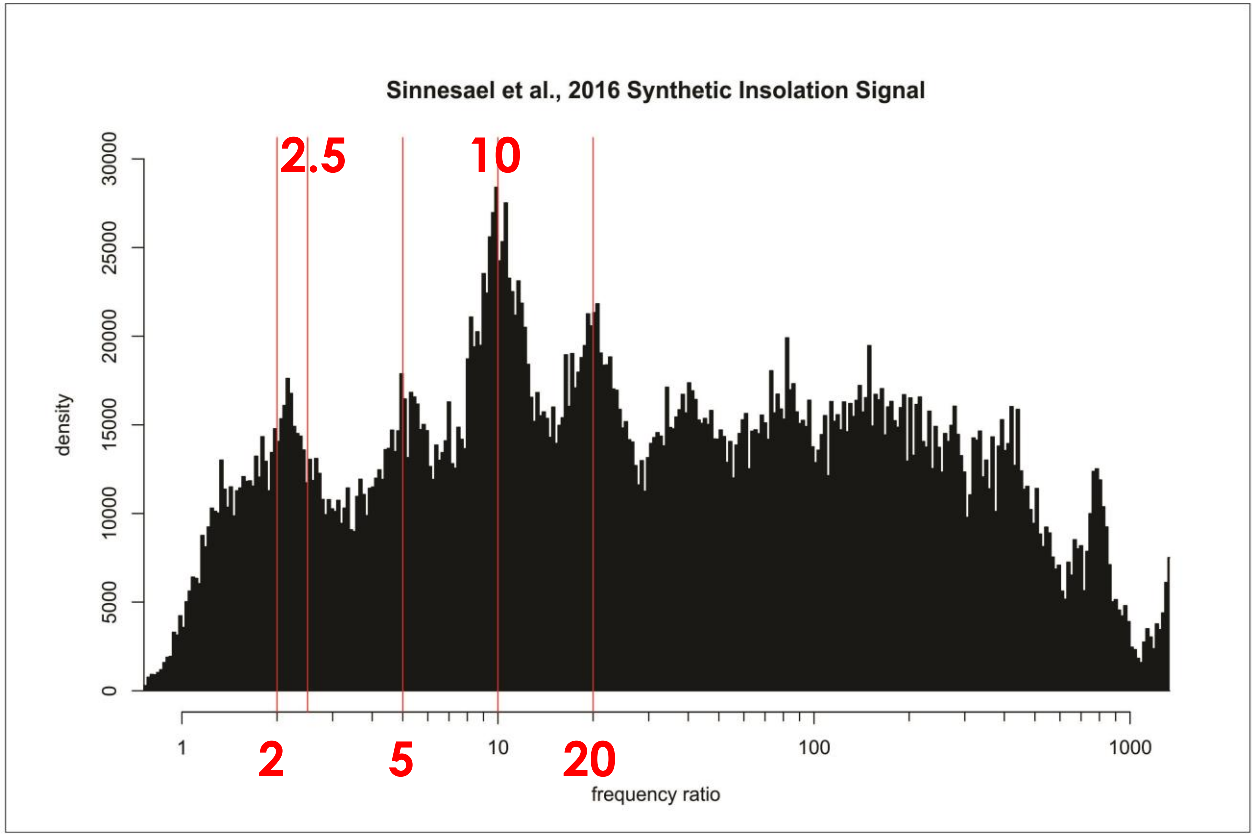

Red Noise
White Noise
Density of frequency
7000
5000
3000
1000
0
4000
2000
0.001
0.01
0.1
1
Frequency
1000
100
10
1
Period

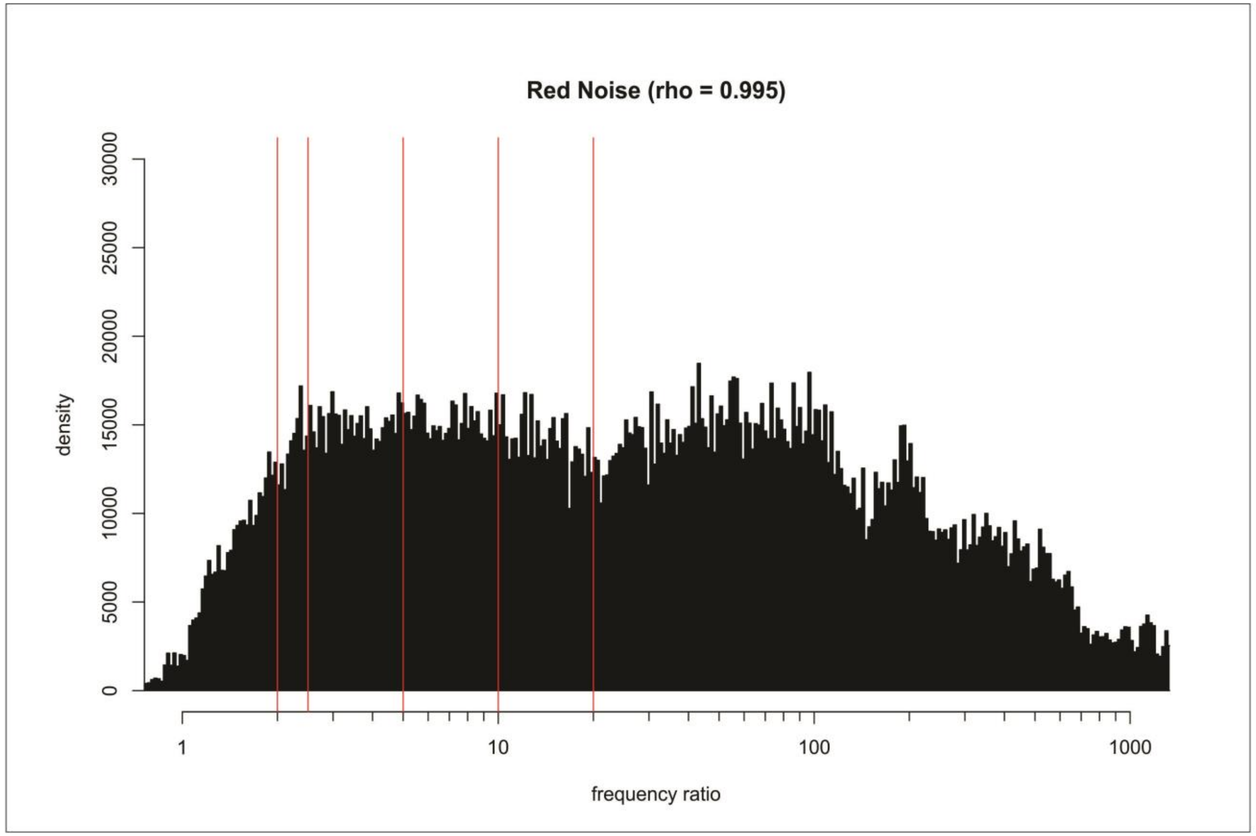


SI16 Insolation + Noise
Amplitude
Frequency
0
10
20
30
40
50
60
0.01
0.1
1
10
100
Counts
9822
6198
3911
2468
1558
983
621
392
248
157
99
63
40
26
16
11
7
5
3
3
2
2
1


SI16 Insolation + Noise
Density of frequency
0
2000
4000
6000
8000
0.01
0.1
1
10
100
Frequency
100
10
1
0.1
0.01
Period


(a)
Clean insolation signal
65° N 21 June insolation W m-2
550
500
450
-6000 -5000 -4000 -3000 -2000 -1000 0
Time [kyr]
(b)
Clean insolation periodogram
Normalized magnitude
1
0.5
0
0 0.01 0.02 0.03 0.04 0.05 0.06
Frequency [cycle kyr-1]
(c)
Insolation signal with white and red noise and varying sedimentation rate
Modified insolation W m-2
700
600
500
400
300
200
0 20 40 60 80 100 120
Depth [m]
(d)
Modified insolation periodogram
Normalized magnitude
1
0.5
0
0 0.5 1 1.5 2 2.5 3
Frequency [cycle m-1]
(e)
Modified insolation spectrogram
Frequency [cycle m-1]
3
2
1
0
20 40 60 80 100
Depth [m]
(f)
Estimated insolation spectrogram
Frequency [cycle m-1]
3
2
1
0
20 40 60 80 100
Depth [m]
Sinnesael et al., 2016





20 kyr (precession), **40 kyr** (obliquity), **100 kyr** & **400 kyr** (eccentricity)

Westphal et al., 2015

Signal decomposition: the **EMD**

- **EMD**: allows decomposition in **IMF**,
- In turn it allows the determination of **instantaneous frequency, amplitude and ratio**
- **Entirely reversible**: from the instantaneous parameters you can go back to the position in the components (modes) and in the original signal

- No matter the decomposition algorithm, you can verify its result visually

Conclusion

- Two tools to link visual and time-series analysis approaches for cyclostratigraphy:

- **StratigrapheR**: Deal with **lithological information** in **R**
- **EMD**: provides a new (rough?) time-series analysis scheme,
  allowing **reversibility** and **visual checking**


Thank you for your attention ☺

References

- Fiet, N., and G. Gorin. 2000. 'Lithological Expression of Milankovitch Cyclicity in Carbonate-Dominated, Pelagic, Barremian Deposits in Central Italy'. *Cretaceous Research* 21 (4): 457–67. https://doi.org/10.1006/cres.2000.0220.
- Fontugne, R., J. Ortiz, N. Tremblay, P. Borgnat, P. Flandrin, K. Fukuda, D. Culler, and H. Esaki. 2013. 'Strip, Bind, and Search: A Method for Identifying Abnormal Energy Consumption in Buildings'. In *2013 ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN)*, 129–40. https://doi.org/10.1145/2461381.2461399.
- Hilgen, Frederik J., Linda A. Hinnov, Hayfaa Abdul Aziz, Hemmo A. Abels, Sietske Batenburg, Joyce H. C. Bosmans, Bas de Boer, et al. 2014. 'Stratigraphic Continuity and Fragmentary Sedimentation: The Success of Cyclostratigraphy as Part of Integrated Stratigraphy'. *Geological Society, London, Special Publications* 404 (October): SP404.12. https://doi.org/10.1144/SP404.12.
- Huang, Norden E., Zheng Shen, Steven R. Long, Manli C. Wu, Hsing H. Shih, Quanan Zheng, Nai-Chyuan Yen, Chi Chao Tung, and Henry H. Liu. 1998. 'The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Non-Stationary Time Series Analysis'. *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 454 (1971): 903–95. https://doi.org/10.1098/rspa.1998.0193.
- Huang, Norden E., and Zhaohua Wu. 2008. 'A Review on Hilbert-Huang Transform: Method and Its Applications to Geophysical Studies'. *Reviews of Geophysics* 46 (2). https://doi.org/10.1029/2007RG000228.
- Huang, Norden E., Zhaohua Wu, Steven R. Long, Kenneth C. Arnold, Xianyao Chen, and Karin Blank. 2009. 'On Instantaneous Frequency'. *Advances in Adaptive Data Analysis* 01 (02): 177–229. https://doi.org/10.1142/S1793536909000096.
- Martinez, Mathieu, Jean-François Deconinck, Pierre Pellenard, Laurent Riquier, Miguel Company, Stéphane Reboulet, and Mathieu Moiroud. 2015. 'Astrochronology of the Valanginian–Hauterivian Stages (Early Cretaceous): Chronological Relationships between the Paraná–Etendeka Large Igneous Province and the Weissert and the Faraoni Events'. *Global and Planetary Change* 131 (August): 158–73. https://doi.org/10.1016/j.gloplacha.2015.06.001.
- Sinnesael, M., M. Zivanovic, D. De Vleeschouwer, P. Claeys, and J. Schoukens. 2016. 'Astronomical Component Estimation (ACE v.1) by Time-Variant Sinusoidal Modeling'. *Geosci. Model Dev.* 9 (10): 3517–31. https://doi.org/10.5194/gmd-9-3517-2016.
- Westphal, Hildegard, Jonathan Lavi, and Axel Munnecke. 2015. Diagenesis Makes the Impossible Come True: Intersecting Beds in Calcareous Turbidites. Facies 61 (2): 3.
- Wu, Zhaohua, and Norden E. Huang. 2009. 'Ensemble Empirical Mode Decomposition: A Noise-Assisted Data Analysis Method'. *Advances in Adaptive Data Analysis* 01 (01): 1–41. https://doi.org/10.1142/S1793536909000047.