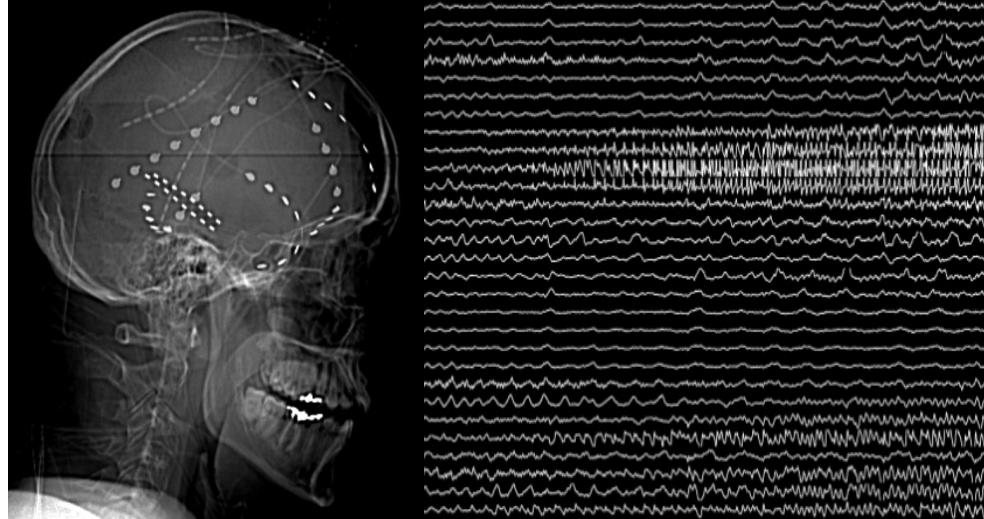


BENESCO Lecture Series
„Signal Analysis and
Brain Oscillations in Health and Disease“

Bern, March 31st 2017



Correlation analysis of multivariate time series and Principle Component Analysis – another lecture without (too many) formulae



UNIVERSITÄTSSPITAL BERN
HOPITAL UNIVERSITAIRE DE BERNE
BERN UNIVERSITY HOSPITAL

Christian Rummel

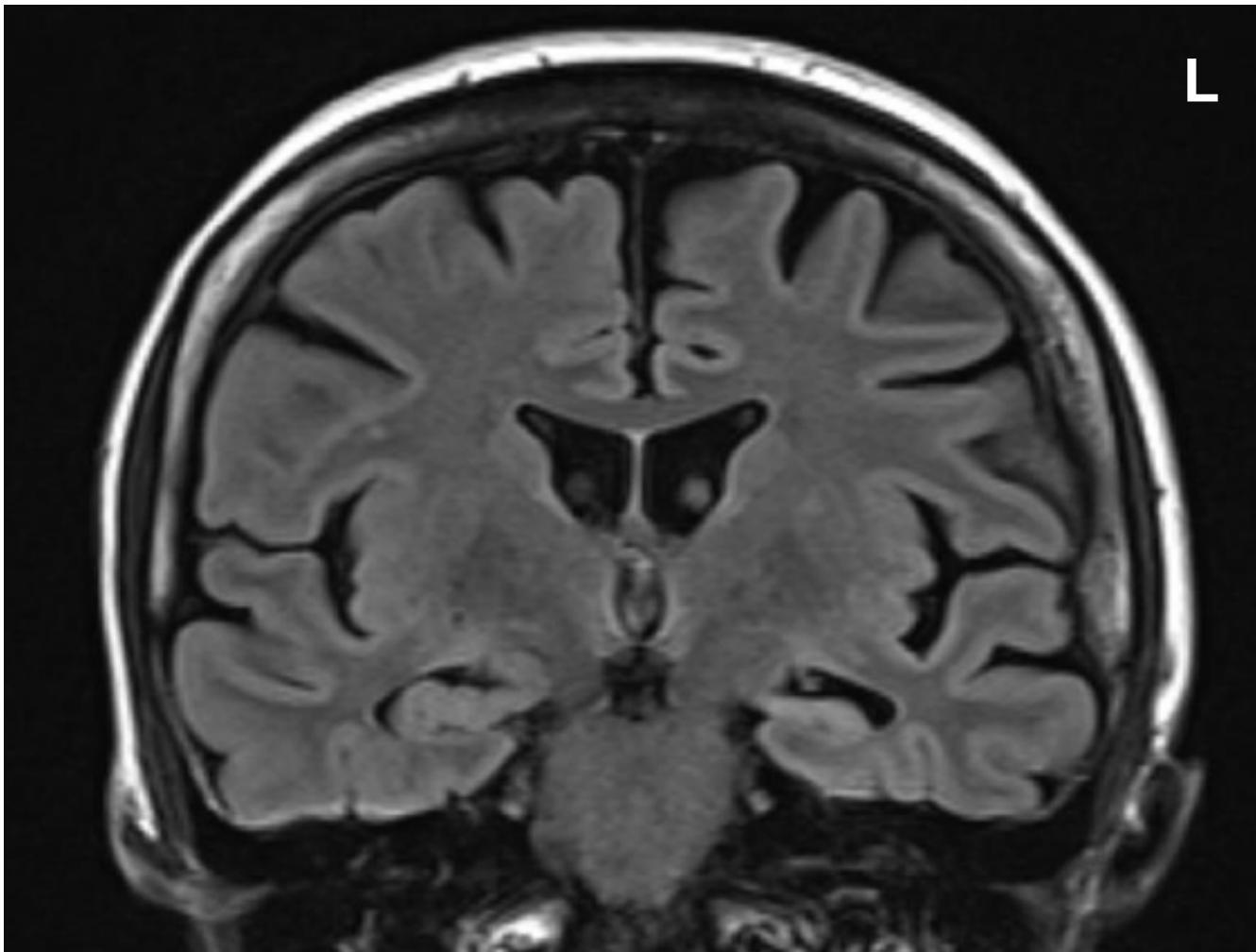
SCAN, University Institute of Diagnostic and Interventional Neuroradiology
University of Bern, Inselspital
christian.rummel@insel.ch

Example EEG

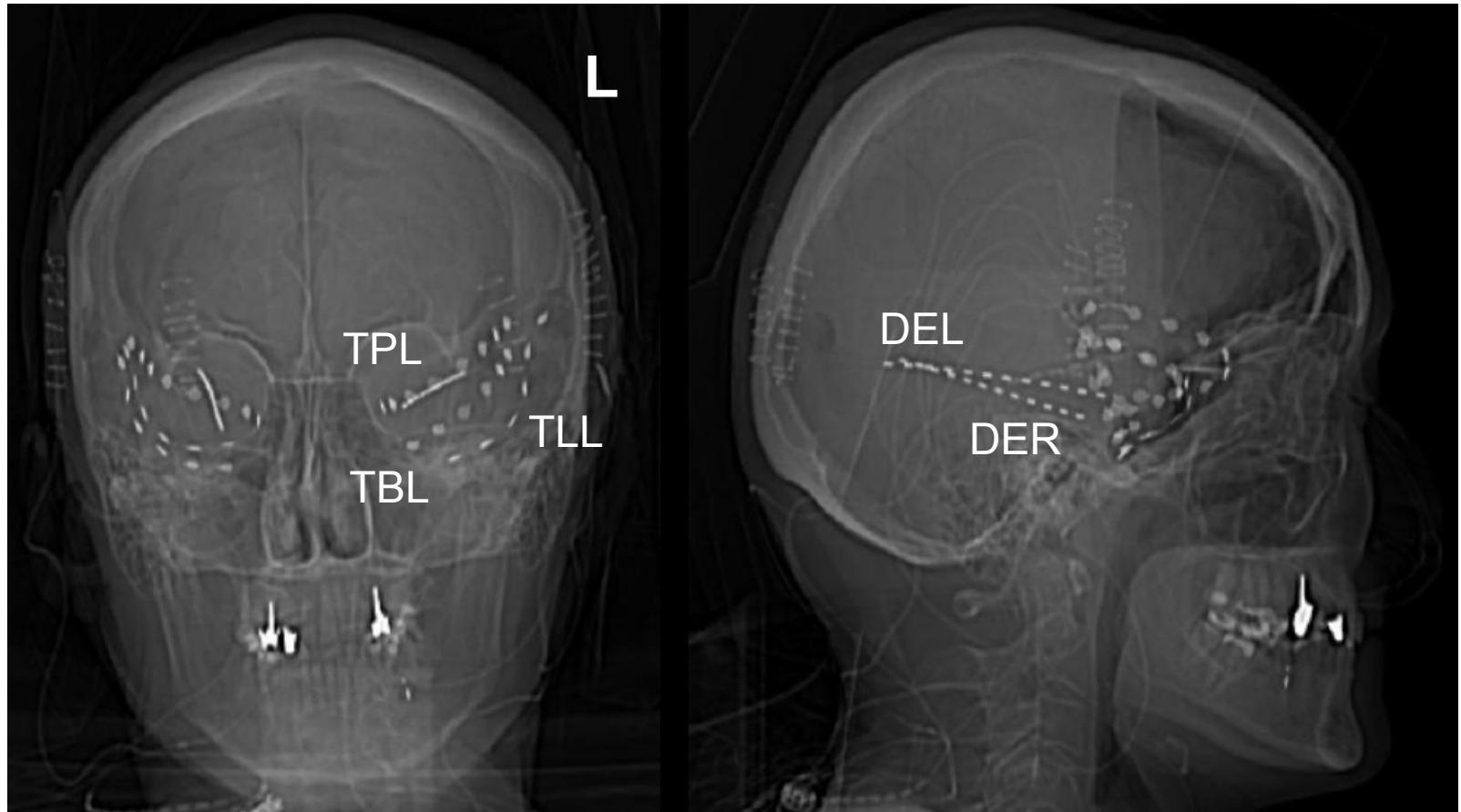
phase II monitoring

- 48 year old, female
 - mesial temporal lobe epilepsy
 - hippocampal sclerosis on the left
-
- 2 depth electrodes
 - 6 strip electrodes
 - 64 contacts

Example EEG

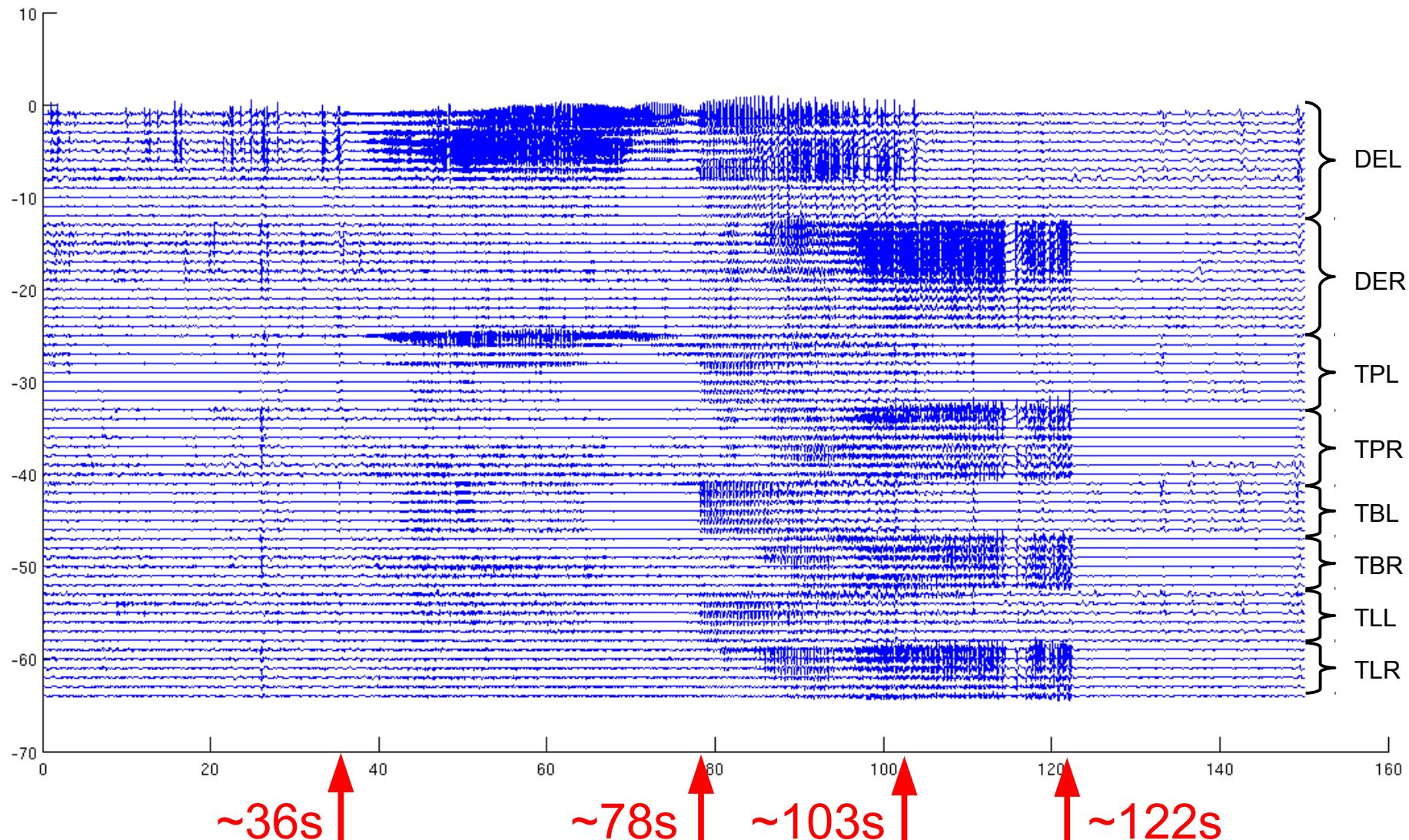


Example EEG

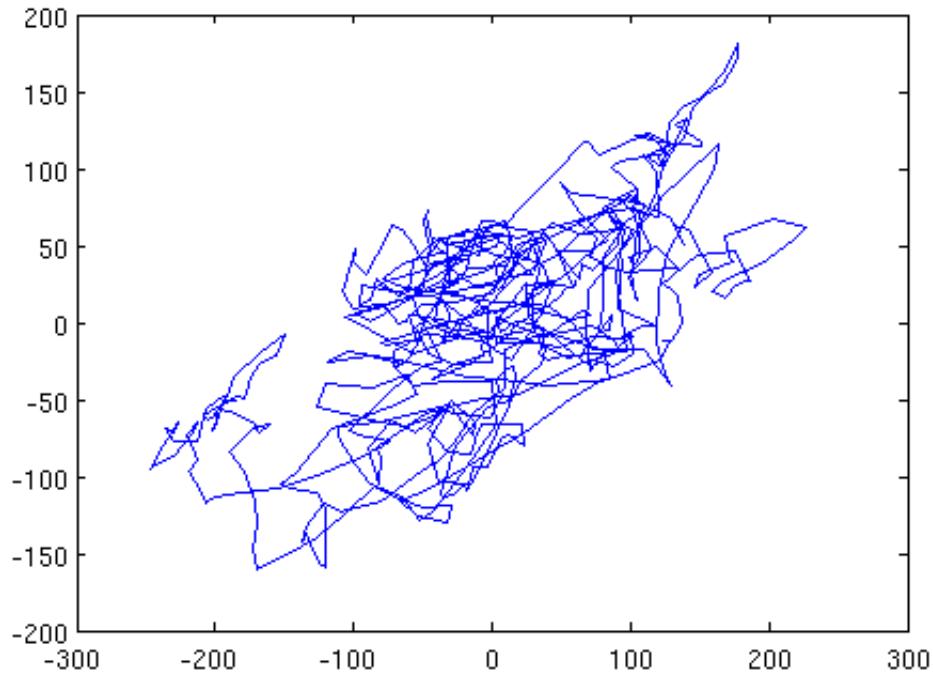


```
[tme,EEG] =  
display_EEG ('./data/','EEG_lecture.mat',128);
```

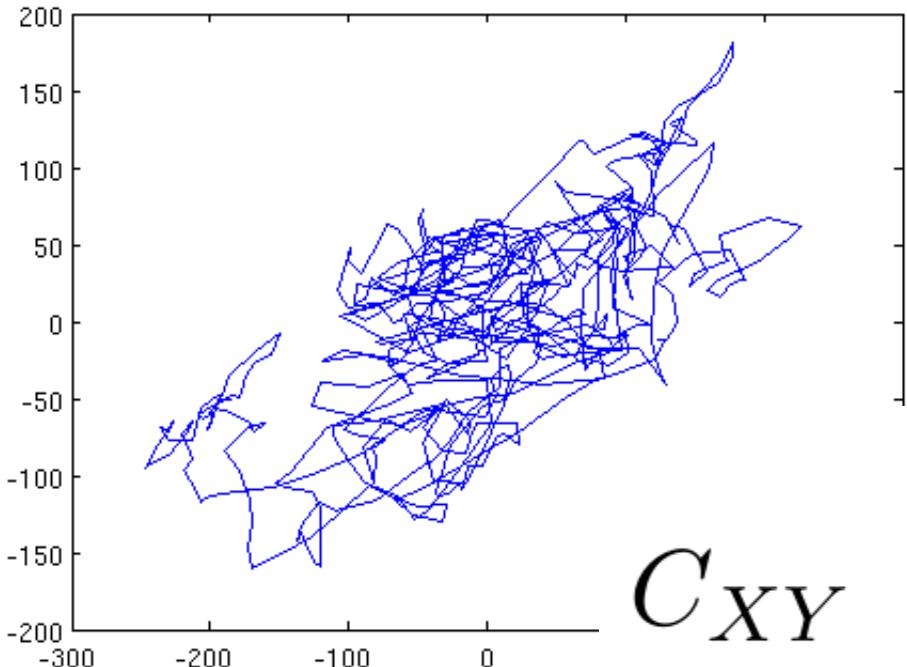
Example EEG



Covariance and Correlation



Covariance and Correlation

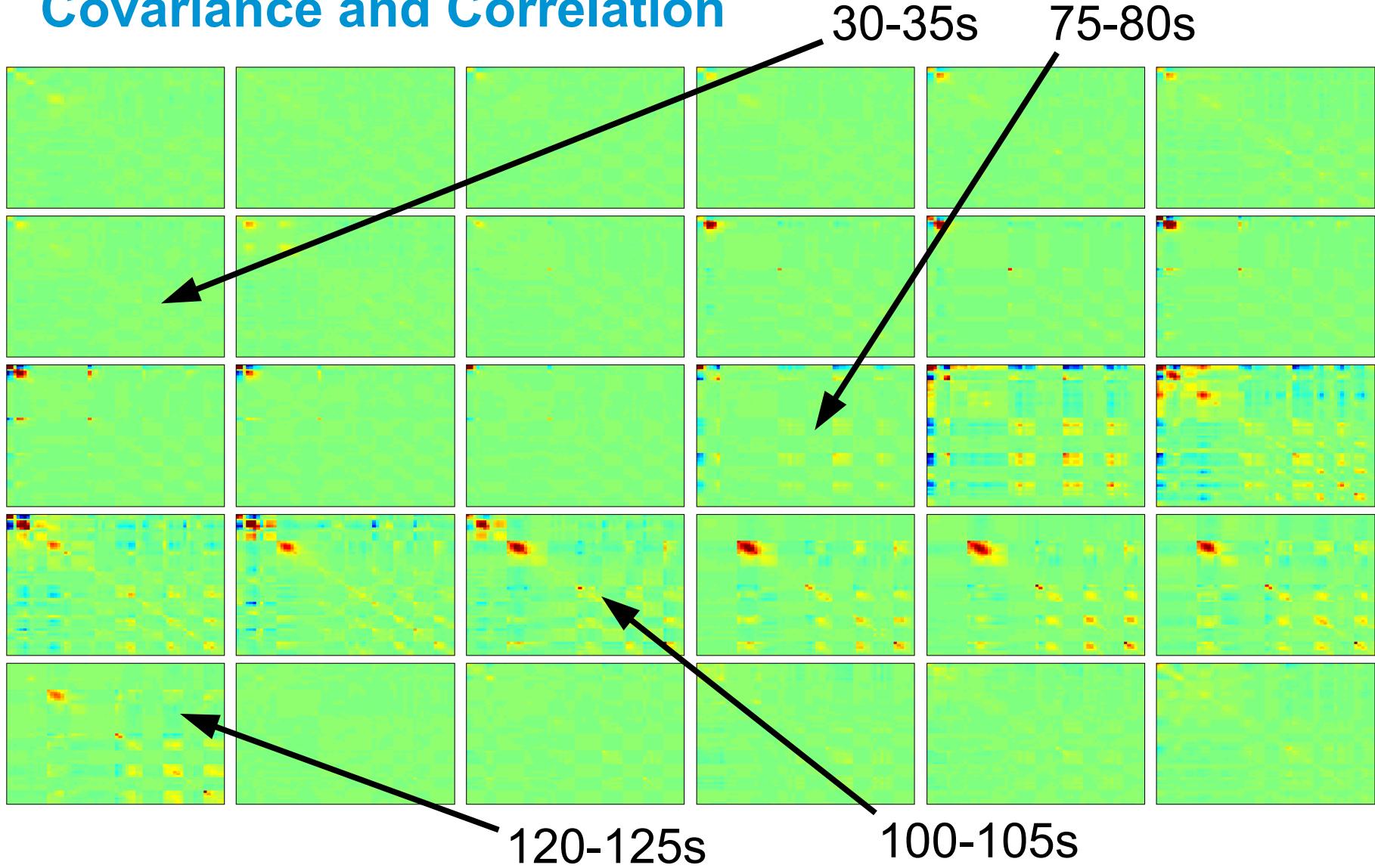


$$C_{XY} = \frac{1}{T} \sum_{t=1}^T \tilde{X}_t \tilde{Y}_t$$

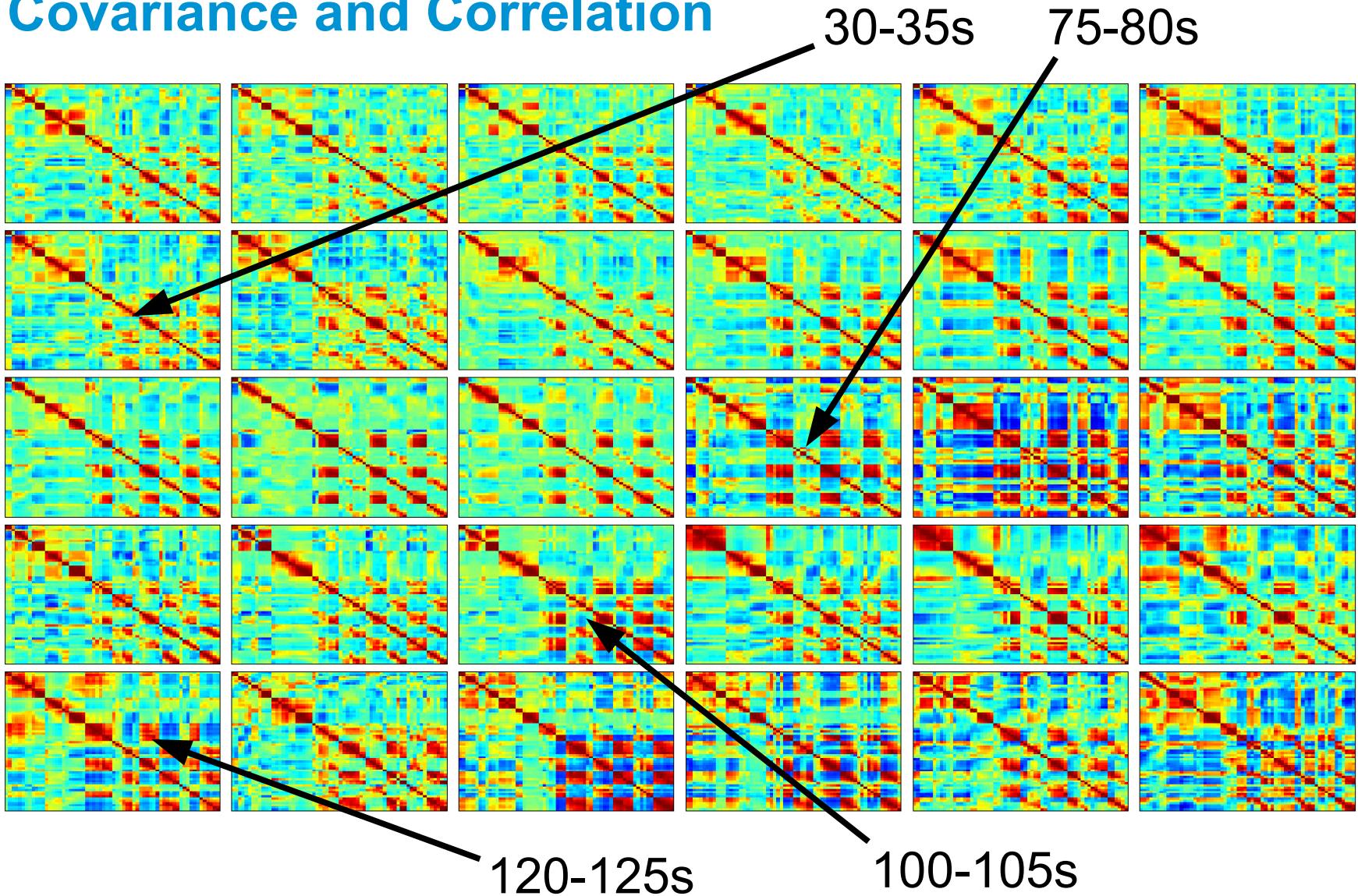
```
CovVsCorr (tme,EEG, 640,640, 1);
```

```
CovVsCorr (tme,EEG, 640,640, 0);
```

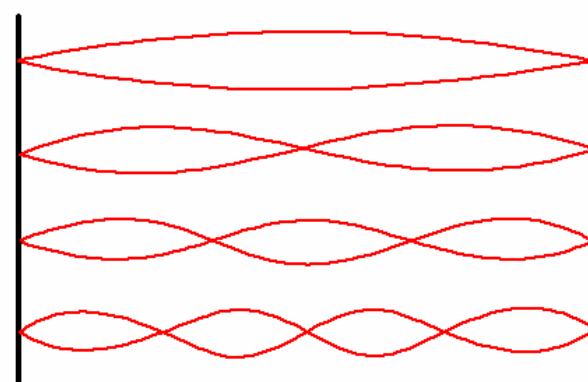
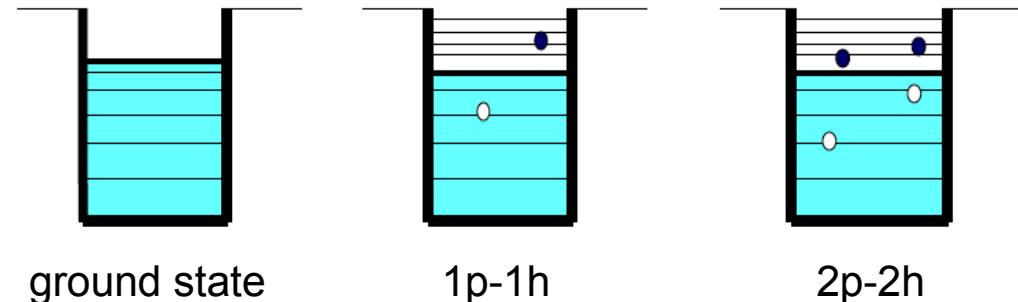
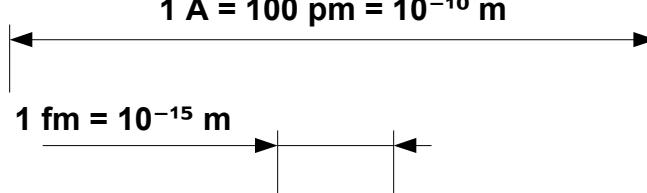
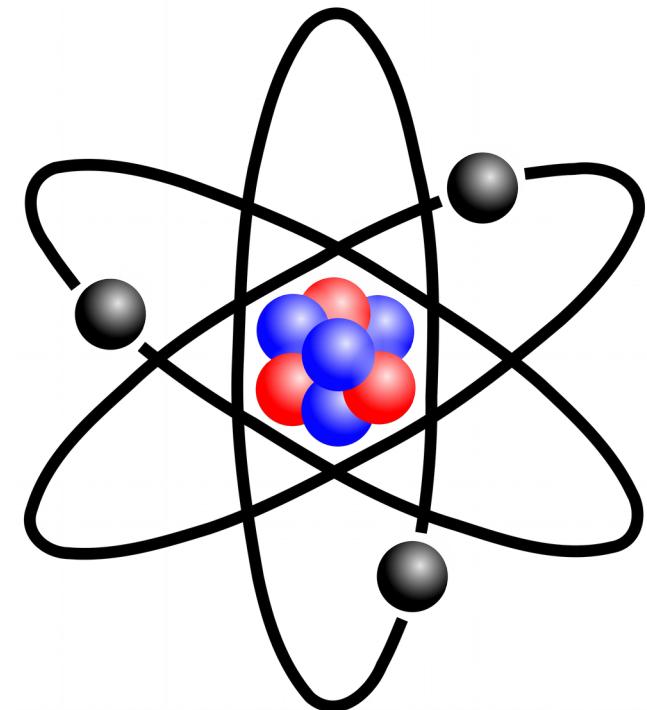
Covariance and Correlation



Covariance and Correlation

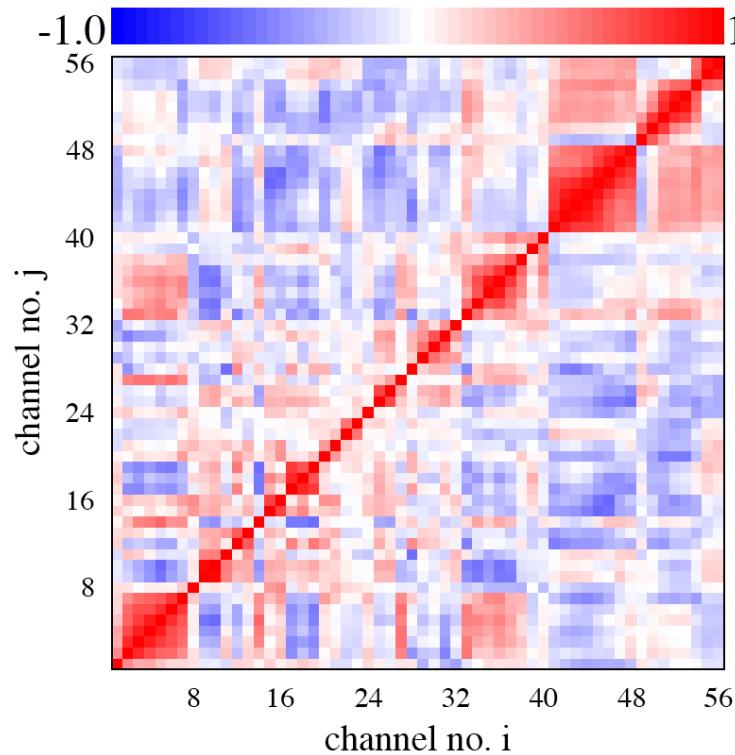


Eigenvalues and Eigenvectors: Nuclear Physics

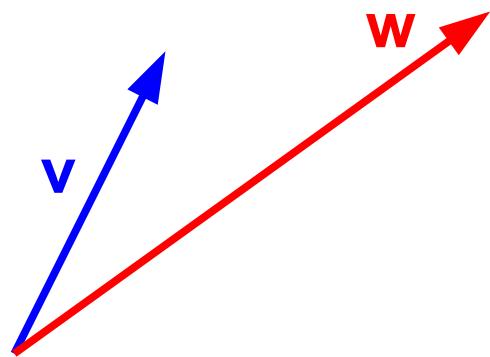


Schrödinger's equation:
$$H \psi = E \psi$$

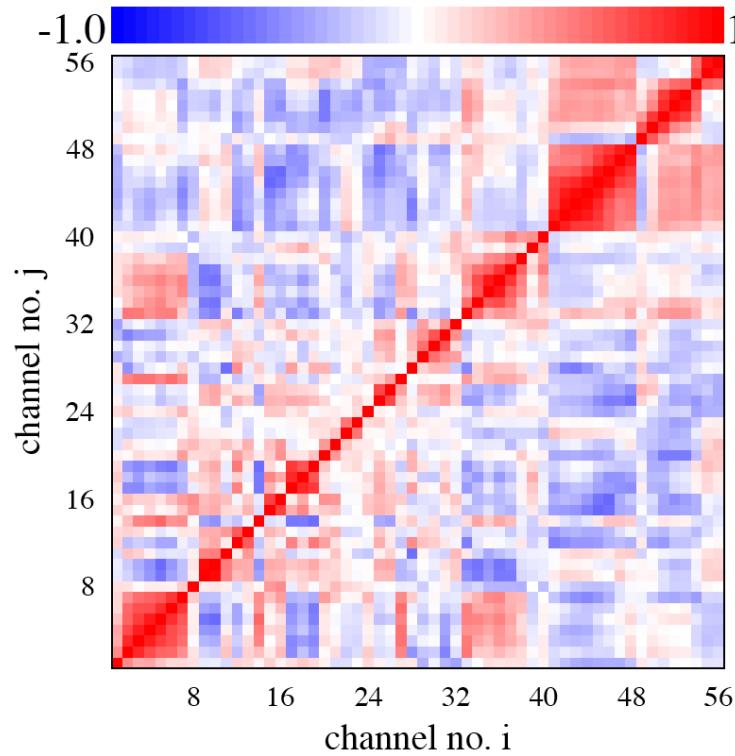
Eigenvalues and Eigenvectors



$$C v = w$$

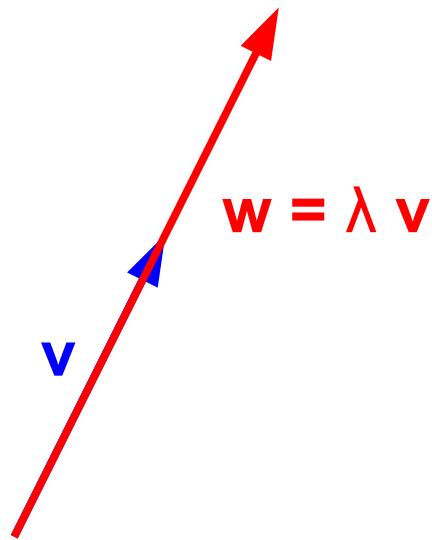


Eigenvalues and Eigenvectors

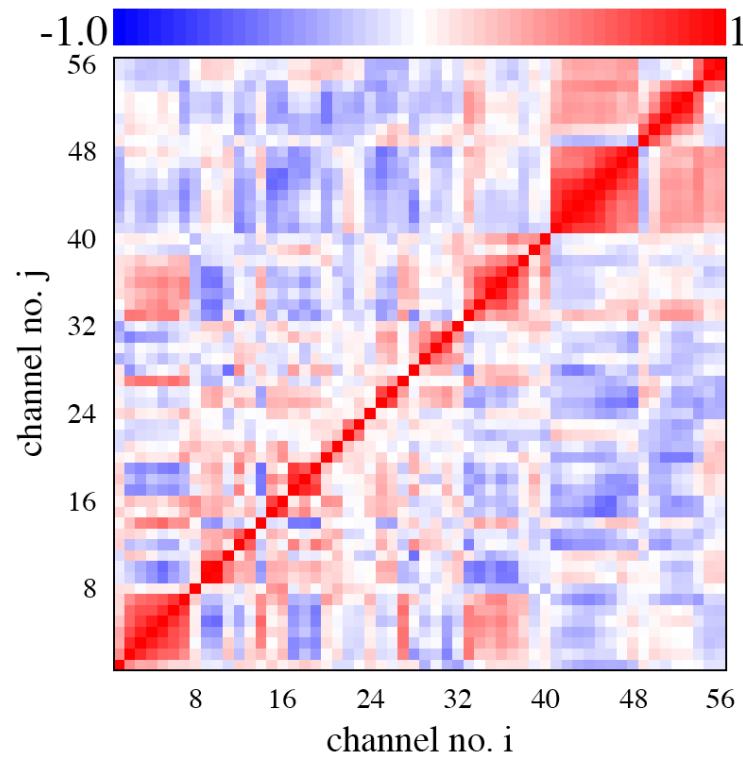


$$\mathbf{C} \mathbf{v} = \mathbf{w}$$

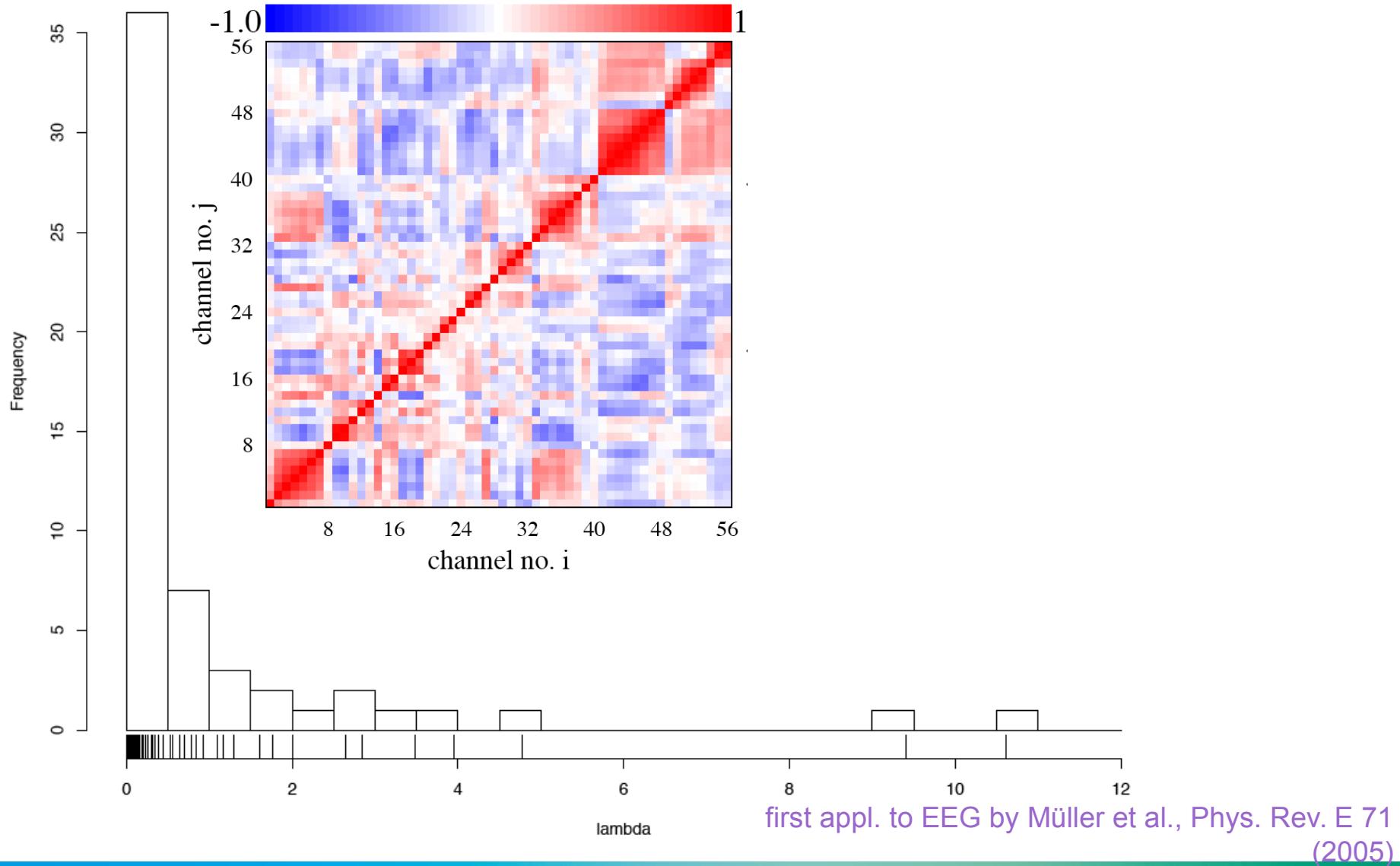
$$\mathbf{C} \mathbf{v} = \lambda \mathbf{v}$$



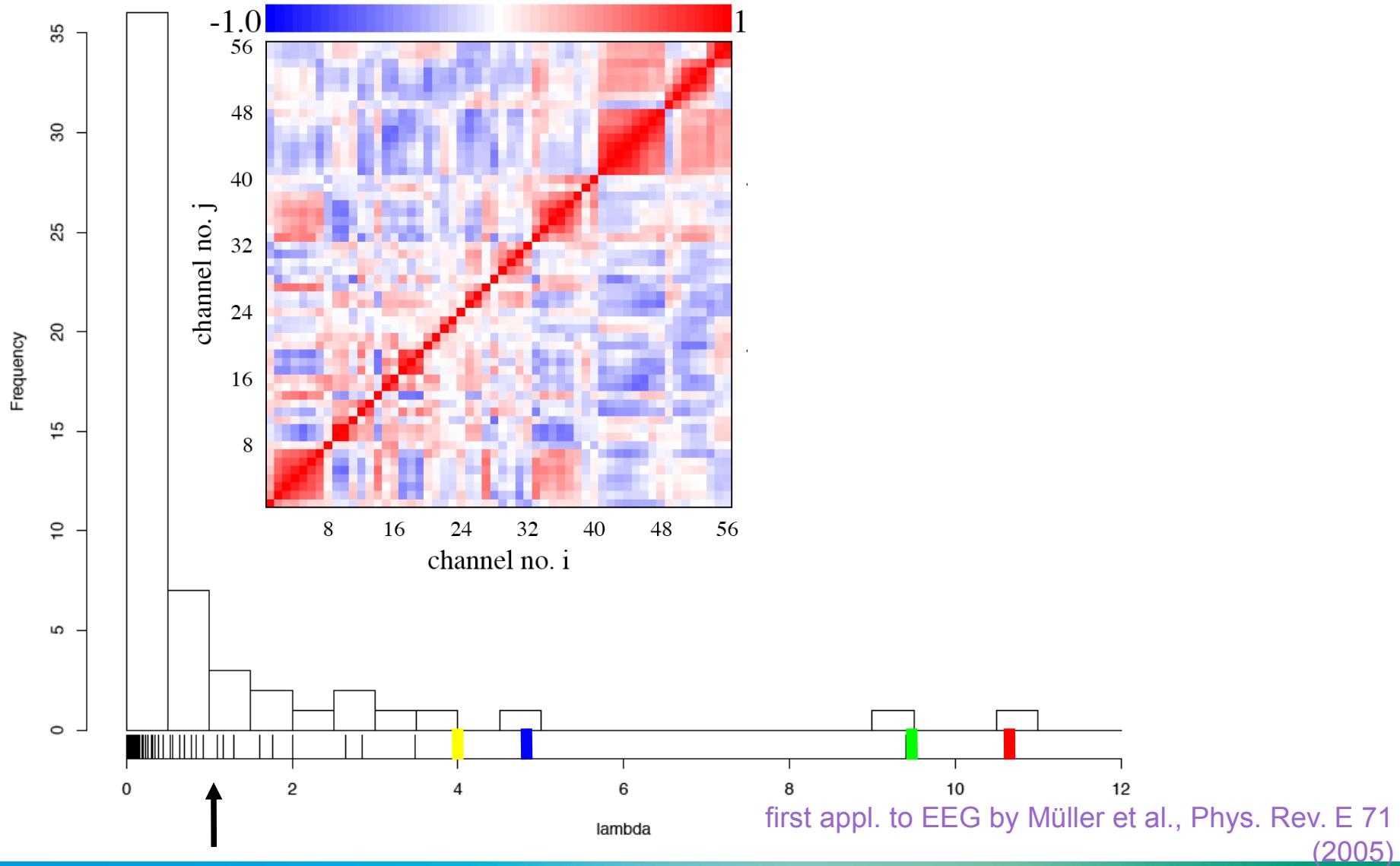
Eigenvalues and Eigenvectors



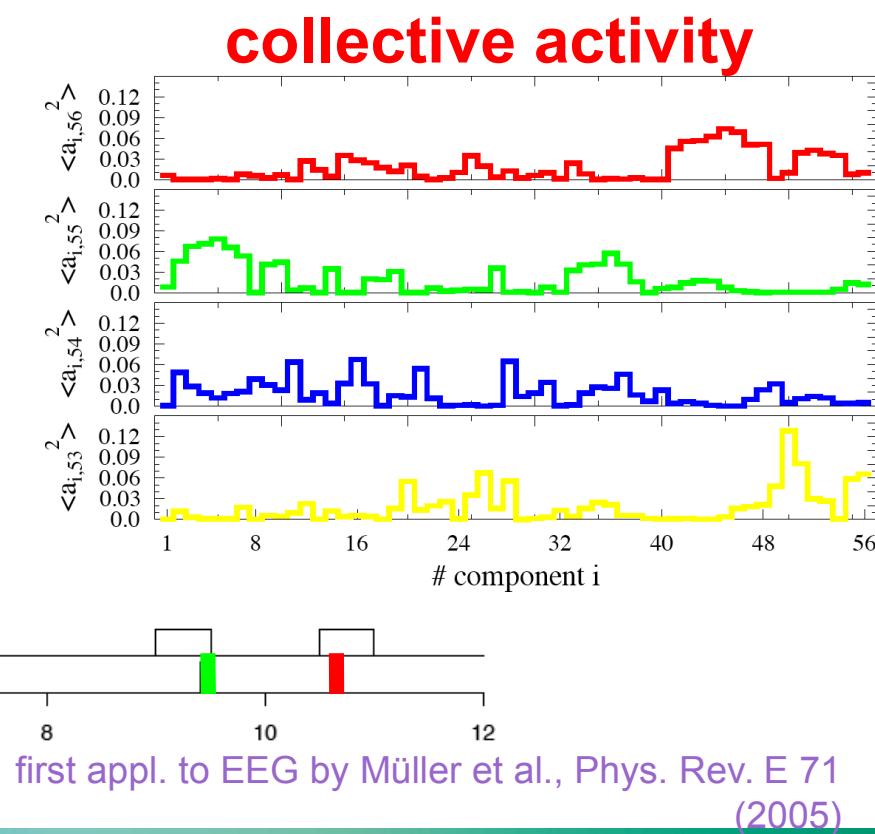
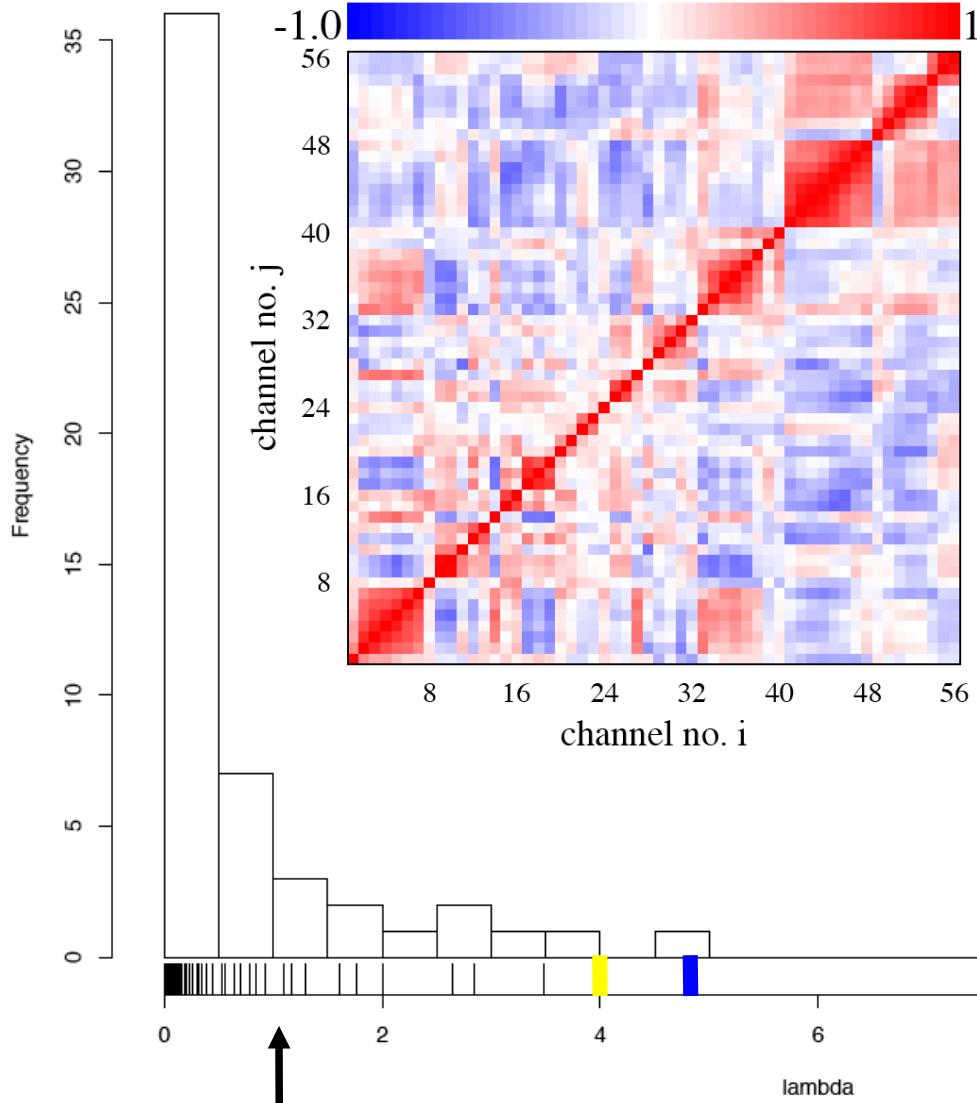
Eigenvalues and Eigenvectors



Eigenvalues and Eigenvectors



Eigenvalues and Eigenvectors



Eigenvalues and Eigenvectors

properties of eigenvalues:

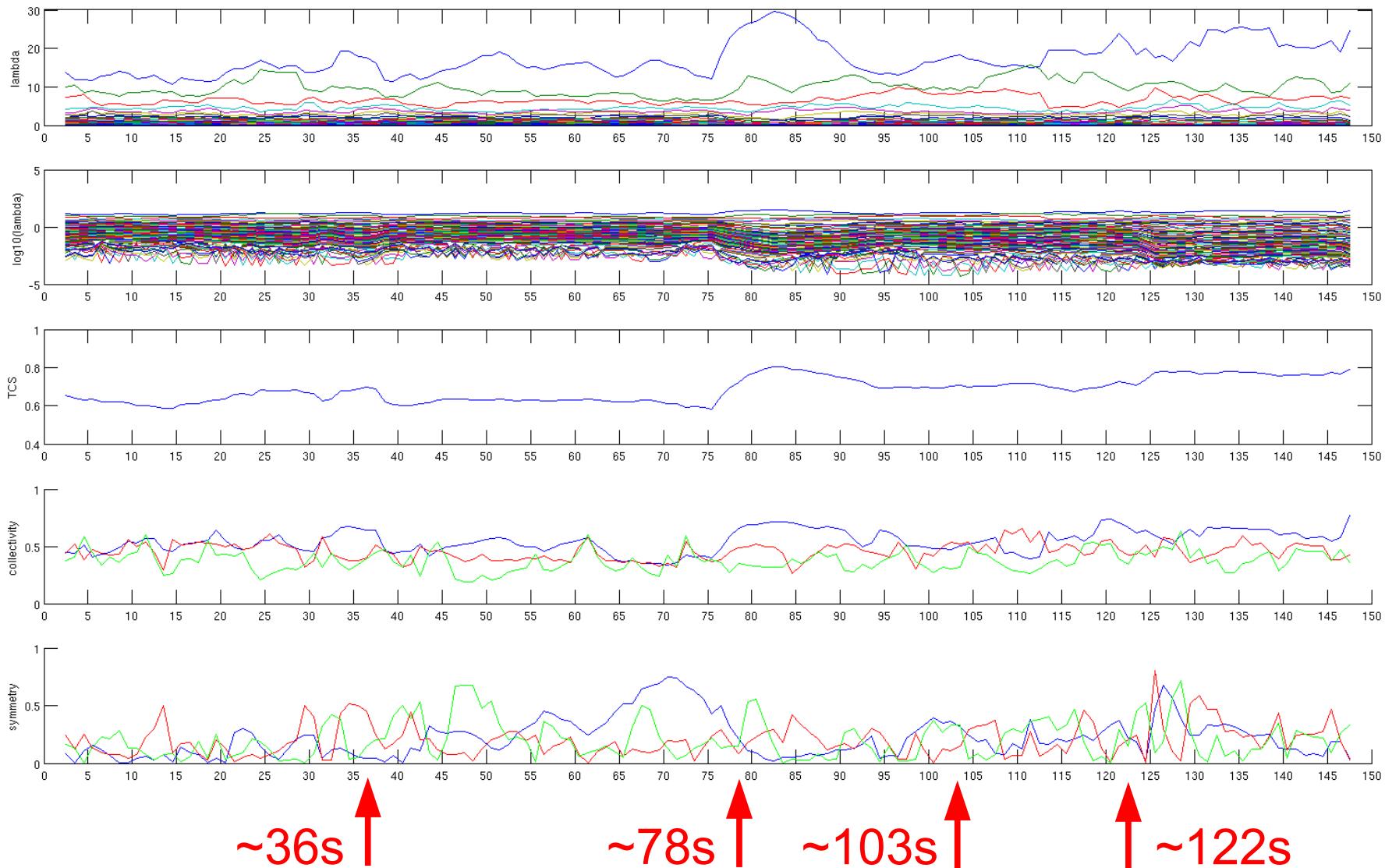
- can be sorted
- measure for total correlation strength (TCS)

properties of eigenvectors:

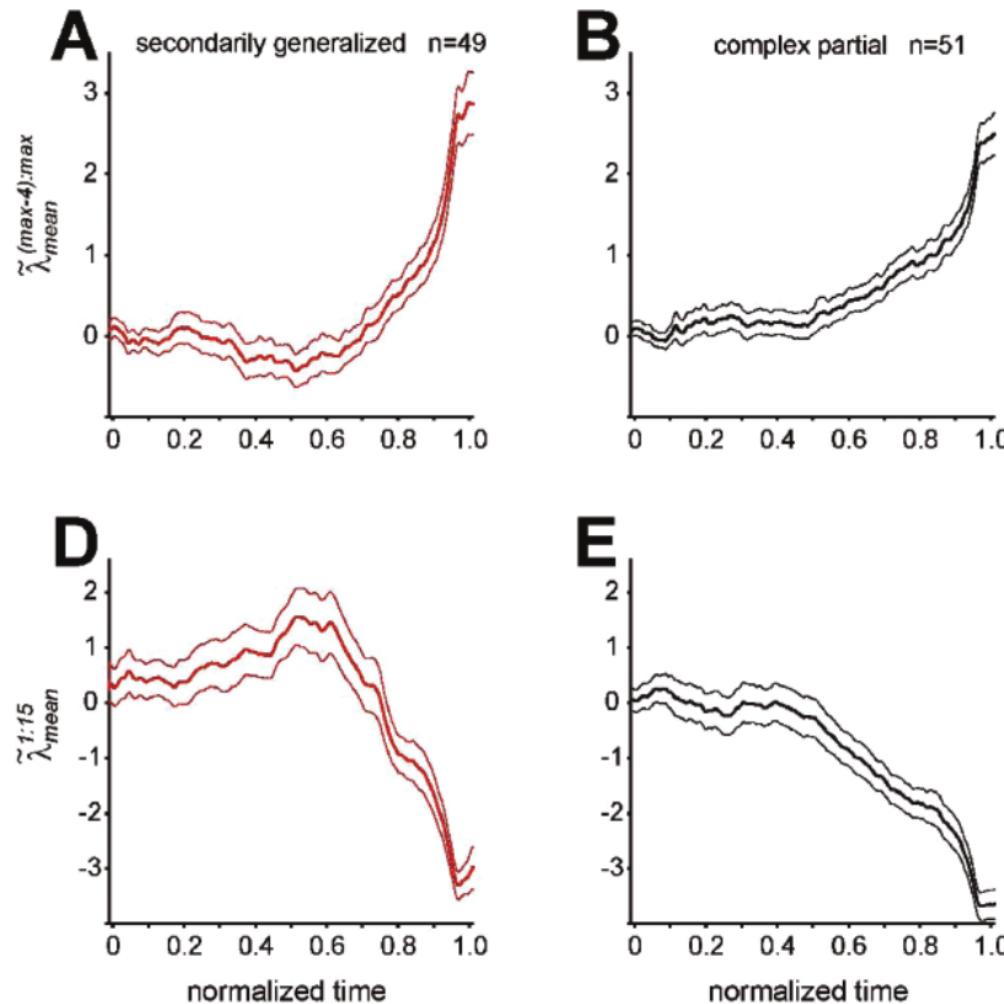
- collectivity
- symmetry

```
eig_val_vec (tme,EEG, 640,128, 1);  
eig_val_vec (tme,EEG, 640,128, 0);
```

Eigenvalues and Eigenvectors



Eigenvalues: correlation dynamics of seizures



Schindler et al., Brain 130 (2007)

Artificially correlated EEG

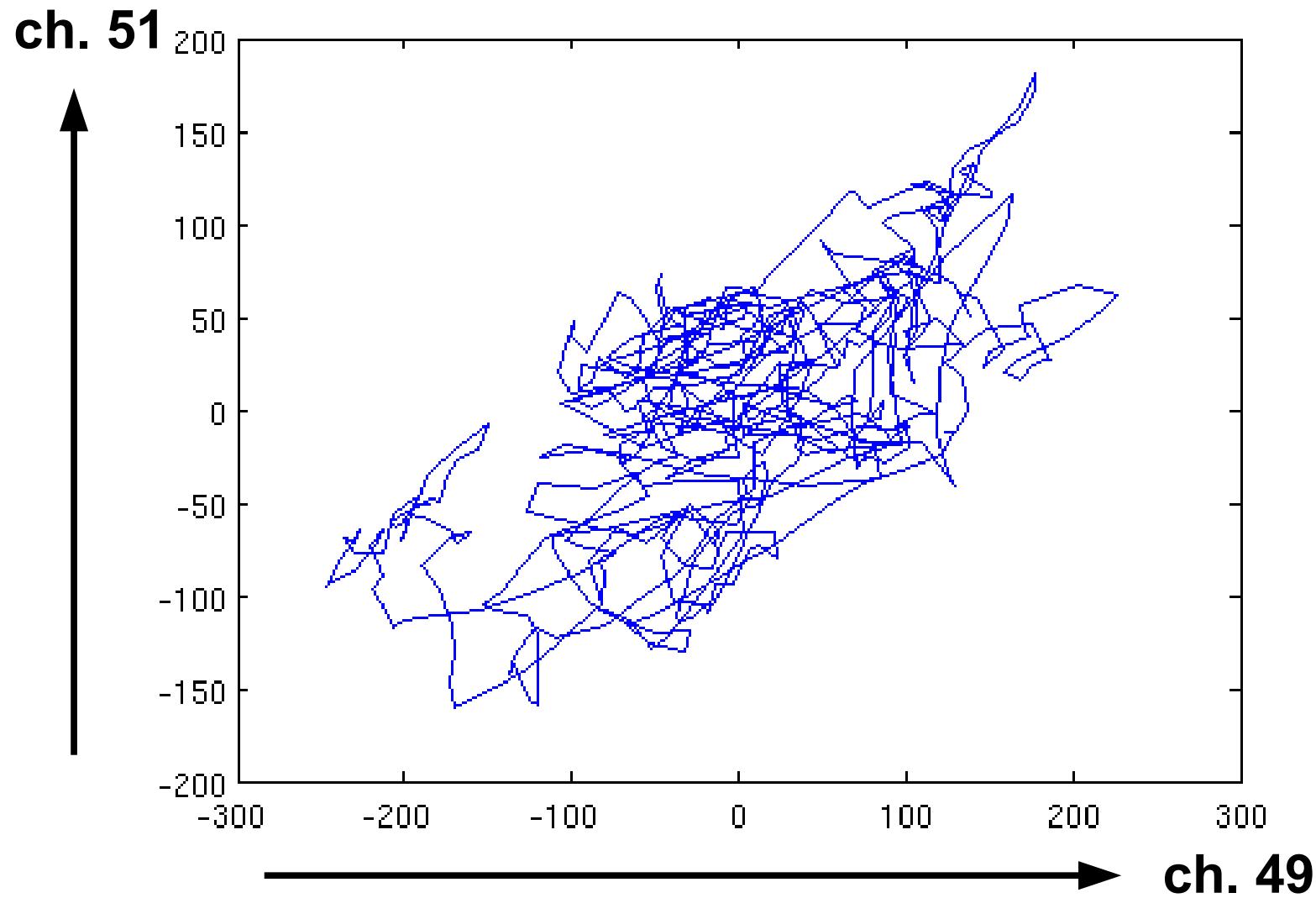
“black box” script

homework:

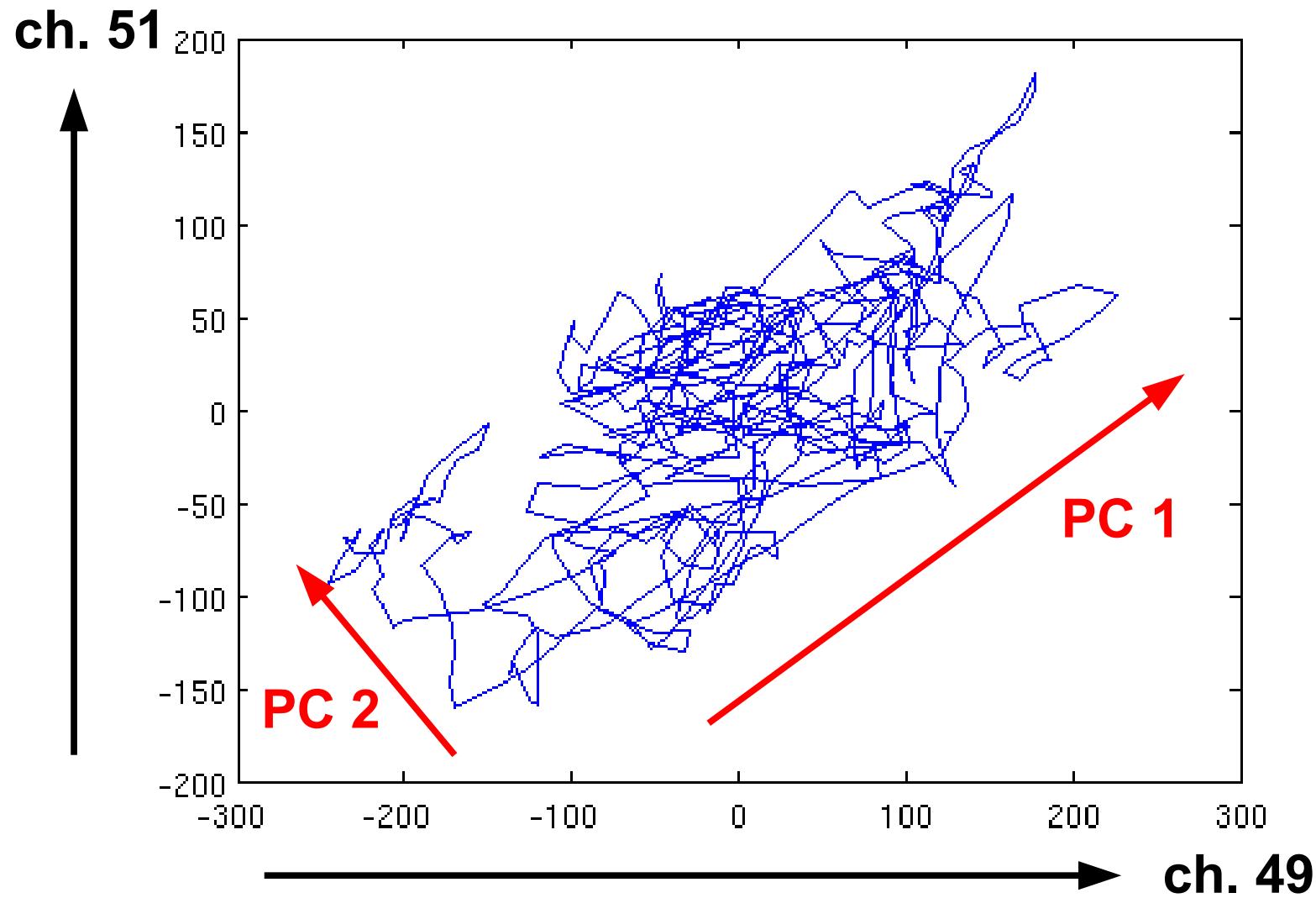
- analyze the script
- understand why it produces “EEG like” signals with desired arbitrary correlation pattern

```
EEG_blockcorr = blockcorr_EEG (EEG, corratt, 4);  
CovVsCorr (tme, EEG_blockcorr, 640, 640, 1);
```

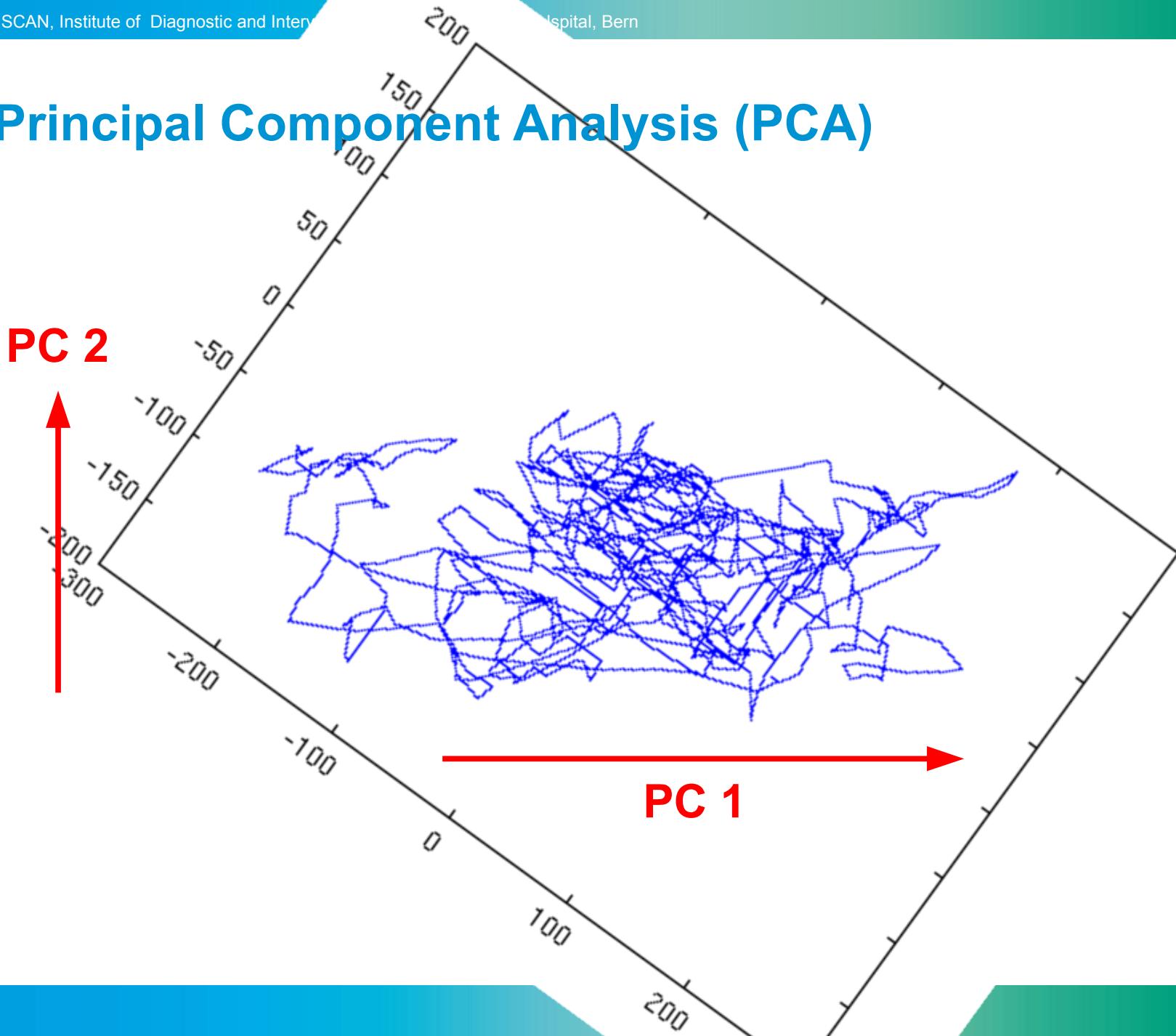
Principal Component Analysis (PCA)



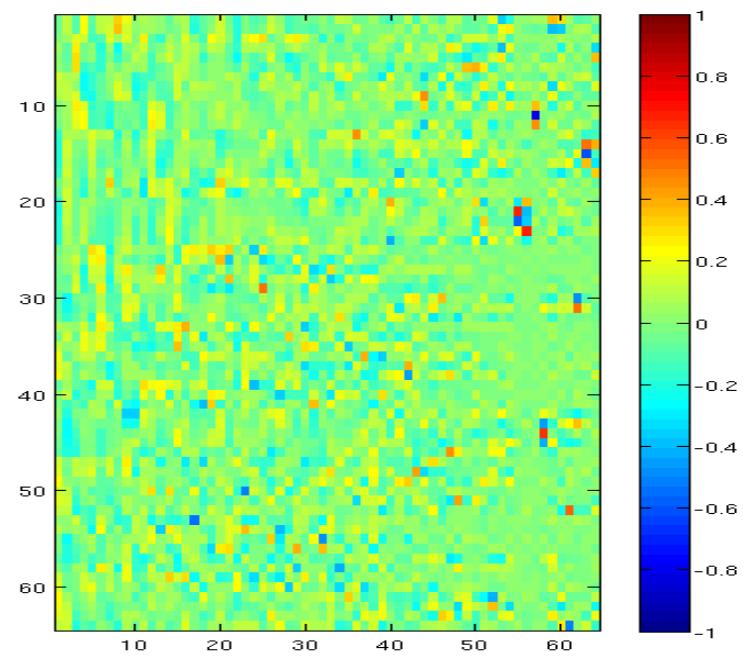
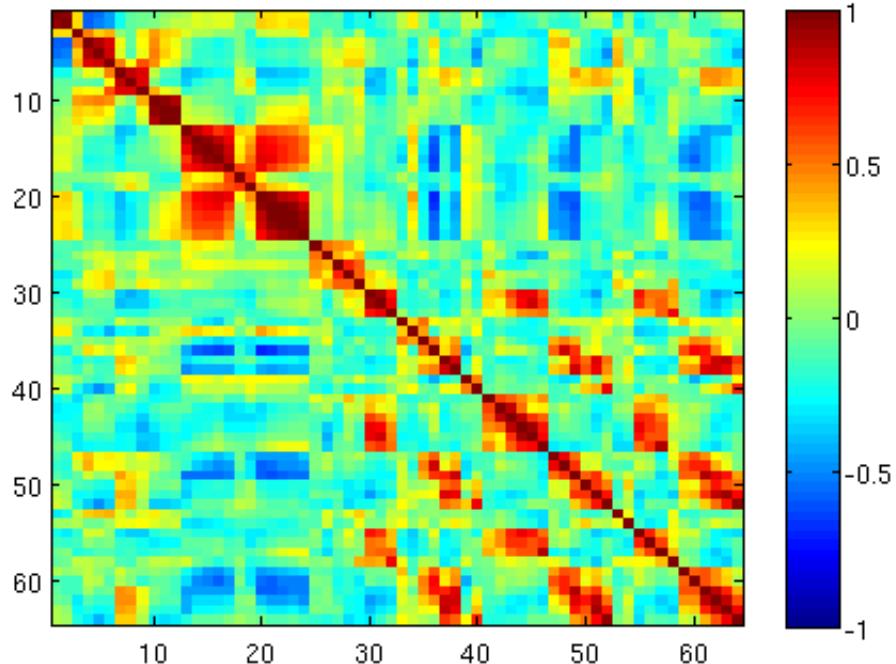
Principal Component Analysis (PCA)



Principal Component Analysis (PCA)



Principal Component Analysis (PCA)



```
PrinCompAna (tme,EEG, 1:50);  
PrinCompAna (tme,EEG, 61:64);  
PrinCompAna (tme,EEG_blockcorr, [8]);
```

Literature suggestions

- Müller et al. (2005), Phys. Rev. E71, 046116.
- Müller et al. (2008), Europhys. Lett. 84, 10009.
- Rummel et al. (2013), Neuroinformatics 11, 159-173.
- Shlens (2014). A Tutorial on Principal Component Analysis.
- Schindler et al. (2007), Brain 131, 65-77.
- Schindler et al. (2007), Clin. Neurophysiol. 118, 1955-1968.

Literature suggestions

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- Schindler et al. (2007), Clin. Neurophysiol. 118, 1955-1968.

Homework suggestions I

Analyze the uncommented Matlab function `blockcorr_EEG.m`:

- 1) Which **mechanism** makes it possible to combine features of real EEG with a desired, arbitrary correlation pattern?
- 2) **Construct** an artificial EEG with 19 channels and three uncorrelated blocks of size 7, 5 and 3.
- 3) **Analyze** your artificial EEG with `CovVsCorr.m`.

Homework suggestions II

Use **different SNR** in `blockcorr_EEG.m`.

- 1) **Analyze** your artificial EEG with `CovVsCorr.m`.
- 2) There is a small and varying **between-block correlation** even when SNR is very large, e.g SNR = 100. Explain it!

Homework suggestions III

Use the Matlab functions `CovVsCorr.m` and `eig_val_vec.m` to analyze the data set `EEG_homework.mat`:

- 1) When and where do you think the **seizure starts**?
- 2) When do you think the **seizure terminates**?
- 3) Repeat analysis for the first temporal **derivative**
`diff(EEG,1)`.
- 4) **Which seizure** of the Supplementary Material of Rummel et al. (2013) is it?

Master and PhD theses



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