

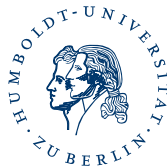
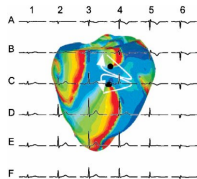


# Cardiorespiratory Coordination in Cheyne-Stokes Respiration

## a case study

P. Granitza, H. Krause, J.F. Kraemer and N. Wessel

Cardiovascular Physics, Department of Physics, Humboldt-Universität zu Berlin





- 1 **Cardiorespiratory Coordination**
  - Towards Cardiorespiratory Coordination
  - Interpreting the Cardiorespiratory Coordigram
  
- 2 **Cheyne-Stokes Respiration**
  
- 3 **Case Study**
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  - Fourier-Method
  
- 4 **Future Research**



## Cardiorespiratory Coordination

- ESGCO 2016: Niels Wessel, Humboldt University, Germany:  
*Cardiorespiratory Coordination During Sleep (Session 2)*

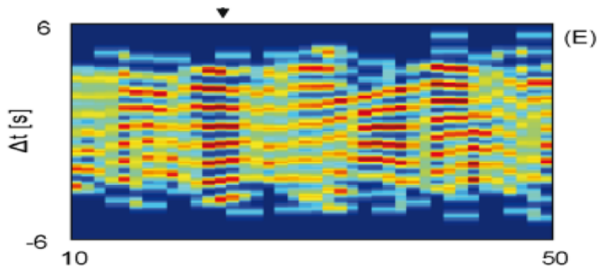


Figure: An exemplary Coordigram.



## Common Basis of Coordigram and Synchrogram: Onsets

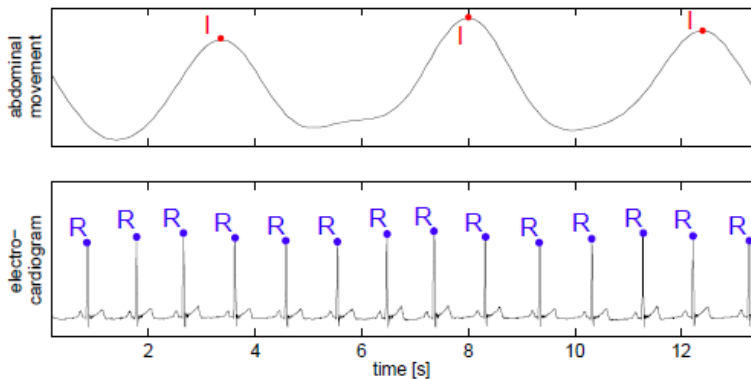


Figure: Respiratory Onsets (I) and Heartbeats (R).

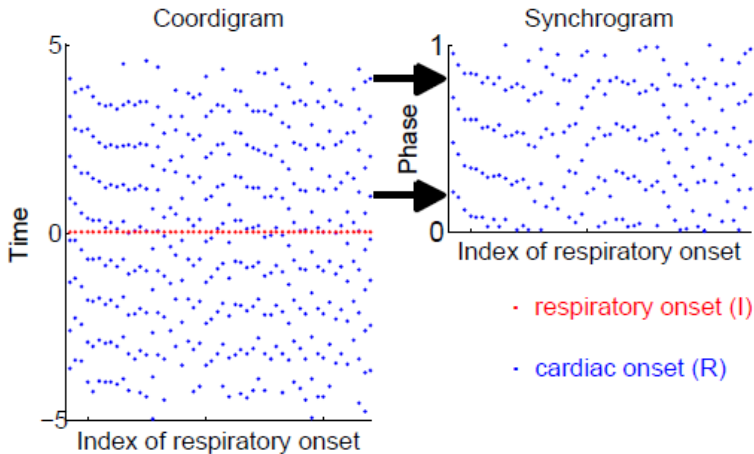
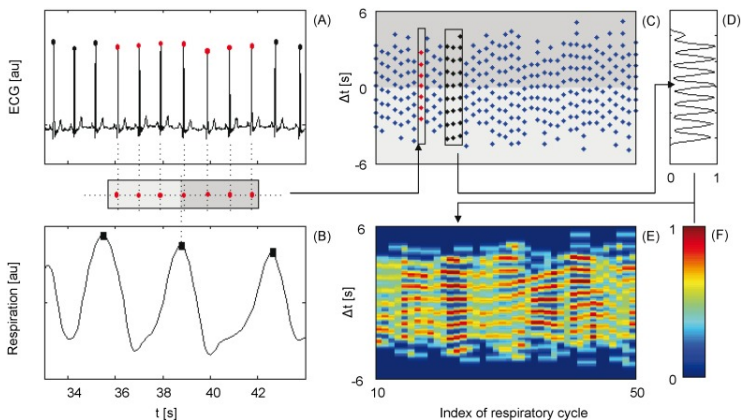


Figure: The coordigram is based in time-, the synchrogram in phase-space.



# Overview: The Cardiorespiratory Coordigram<sup>1</sup>



<sup>1</sup>M. Riedl, et al. *Cardio-Respiratory Coordination Increases during Sleep Apnea*. In: *PLoS ONE* 2014 **9(4)** e93866

## Interpreting the Cardiorespiratory Coordigram I

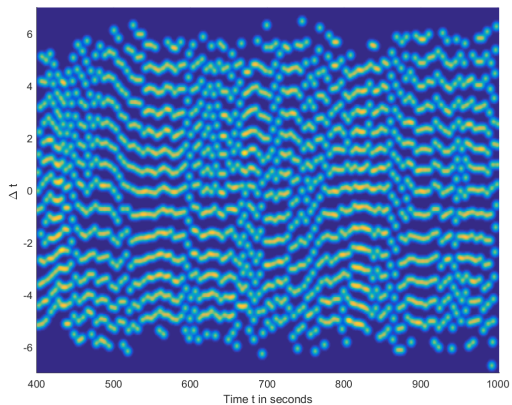
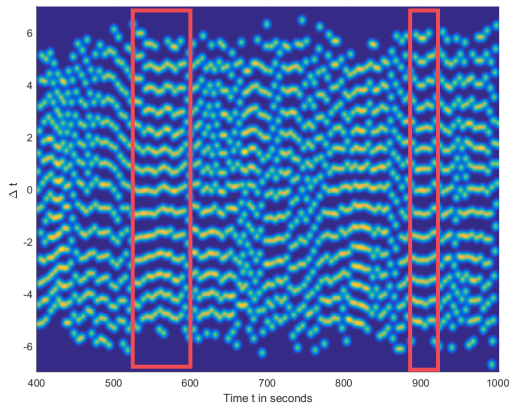


Figure: An exemplary Coordigram.

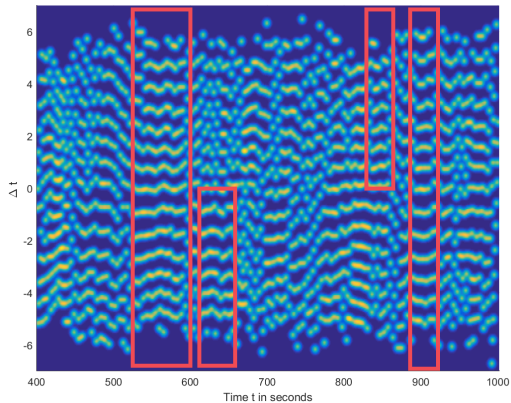
## Interpreting the Cardiorespiratory Coordigram II



**Figure:** An exemplary coordigram. Horizontal parallel lines imply coordination.



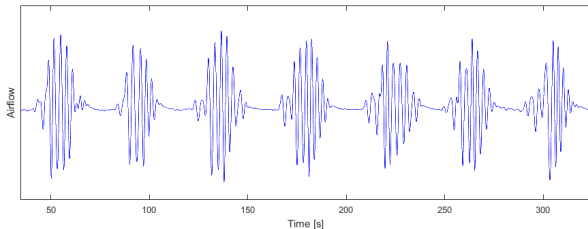
## Interpreting the Cardiorespiratory Coordigram III



**Figure:** An exemplary coordigram. Horizontal parallel lines imply coordination. For  $\Delta t < 0$  the heart triggers the respiration. For  $\Delta t > 0$  the respiration triggers the heart.



## Cheyne-Stokes Respiration (CSR) I



**Figure:** Periodic Respiration of a patient with Cheyne-Stokes Respiration. Central apneas are followed by increasingly deeper breaths which then transition to central apneas again.

## Cheyne-Stokes Respiration (CSR) II

- Periodic Respiration
- Central apneas, dysfunction of the respiratory center
- often associated with severe forms of heart failure<sup>1,2</sup>
- adverse prognostic implications<sup>2,3</sup>
- Possible Therapeutic approach: Adaptive Servo-Ventilation<sup>4</sup>
  - Successful therapy of CSR
  - increased mortality

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<sup>1</sup>T. D. Bradley, et al. *Sleep Apnea and Heart Failure - Part I: Obstructive Sleep Apnea*. In: *Circulation* 2003 **107** 1671-1678

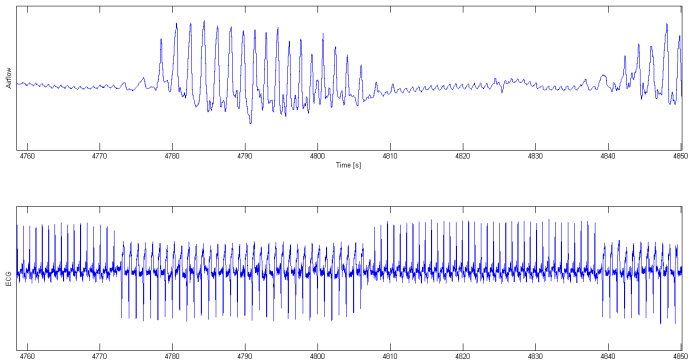
<sup>2</sup>*Part II: Central Sleep Apnea*. In: *Circulation* 2003 **107** 1822-1826

<sup>3</sup>T. Bitter, et al. *Cheyne-Stokes respiration and obstructive sleep apnoea are independent risk factors for malignant ventricular arrhythmias requiring appropriate cardioverter-defibrillator therapies in patients with congestive heart failure*. In: *European Heart Journal* 2011 **32** 61-74

<sup>4</sup>M. R. Cowie, et al. *Adaptive Servo-Ventilation for Central Sleep Apnea in Systolic Heart Failure*. In: *New England Journal of Medicine* 2015 **373** 1095-1105



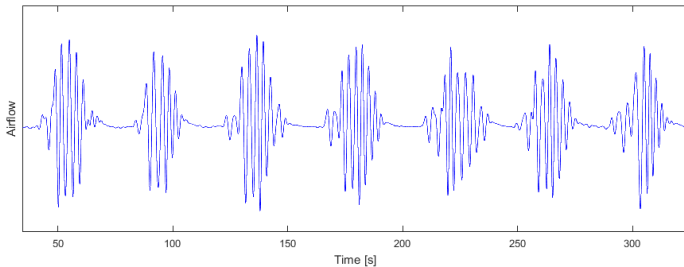
## Those Darn Pacemakers



**Figure:** Data of a CSR-Patient with CRT-ICD (Cardiac Resynchronization Therapy and Implantable Cardioverter-Defibrillator).



## Case Study: Patient X



- Male Patient
- Age: 61 years
- BMI:  $24.5 \frac{\text{kg}}{\text{m}^2}$
- no pacemaker



## Synchrogram vs Coordigram I

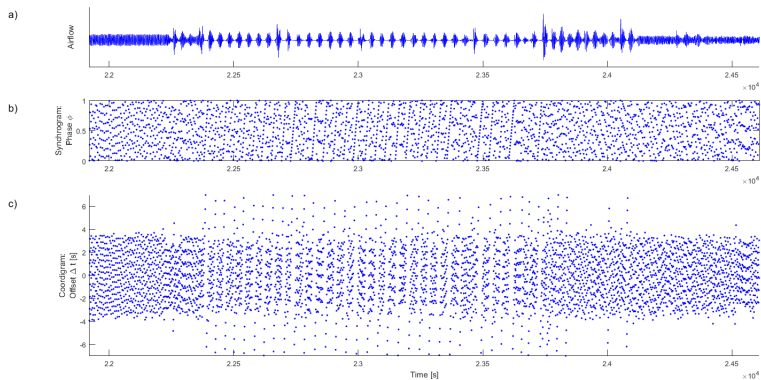
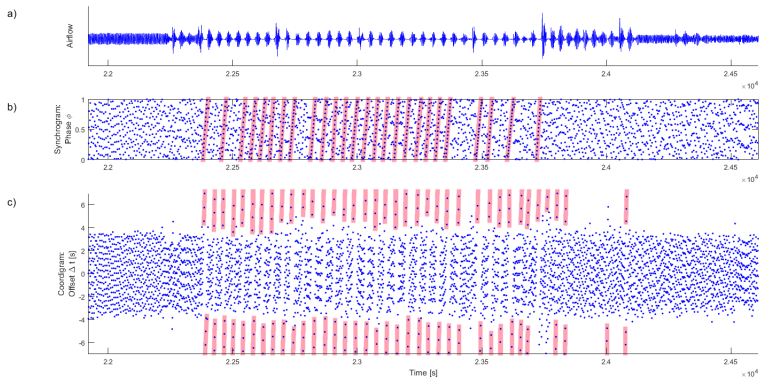


Figure: Synchrogram (b) and Coordigram (c) during an episode of CSR.



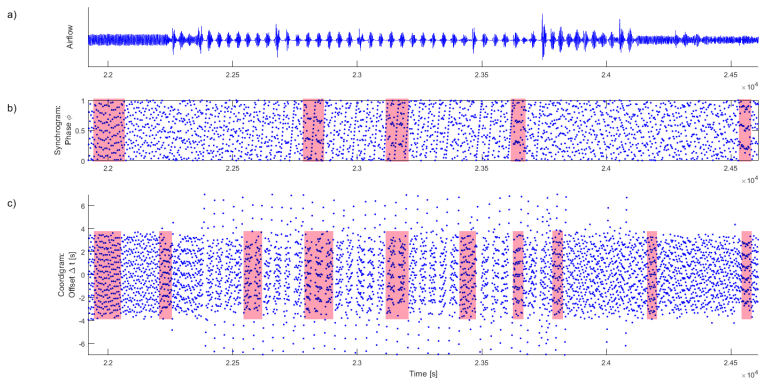
## Synchrogram vs Coordigram II



**Figure:** Synchrogram (b) and Coordigram (c) during an episode of CSR. Apneas are marked in red.



## Synchrogram vs Coordigram III



**Figure:** Synchrogram (b) and Coordigram (c) during an episode of CSR. Areas of horizontal lines are marked in red. They imply synchronization (b) or coordination (c).



## Fourier-Method

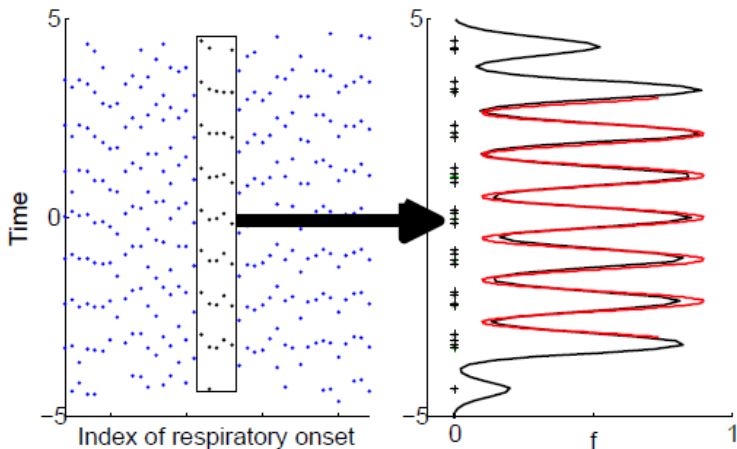


Figure: Estimate the point distribution over a certain timewindow.



## Fourier-Method

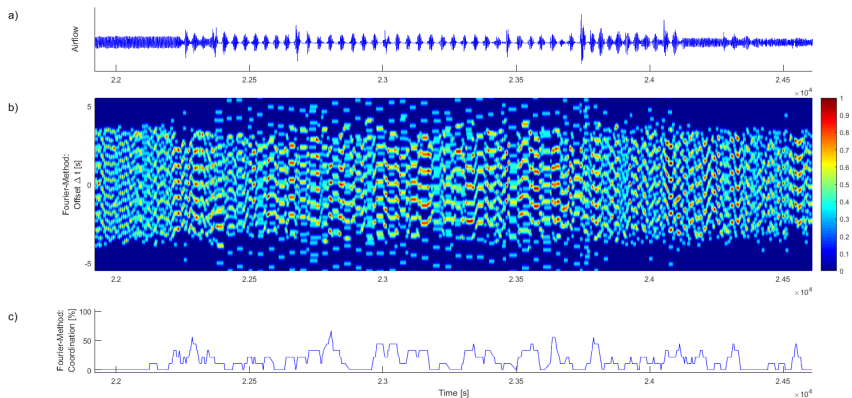


Figure: Analysis of the coordigram using the Fourier-Method<sup>1</sup>.

<sup>1</sup>M. Riedl, et al. *Cardio-Respiratory Coordination Increases during Sleep Apnea*. In: *PLoS ONE* 2014 **9**(4) e93866

## Future Research

- Verification using surrogate data
  - other methods of quantifying the coordigram
  - influence of
    - sleepstages
    - Circadian Rhythm
    - age
    - BMI
    - ...
- on cardiorespiratory coordination
- **Goal:** Extension to more CSR-patients (without pacemaker!)

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**Thank you for your attention!**