Neue Wege für die Musikforschung

Meinard Müller

International Audio Laboratories Erlangen
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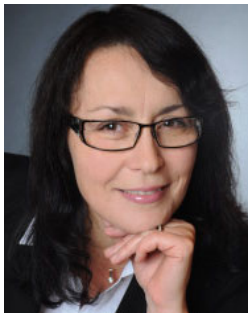
Festkolloquium
70 Jahre Musikforschung an der UdS
11. November 2022

Friedrich-Alexander-Universität Erlangen-Nürnberg

Fraunhofer IIS

Meinard Müller: Research Group

- Michael Krause
- Yigitcan Özer
- Simon Schwär
- Johannes Zeitler
- Vlora Arifi-Müller
- Peter Meier (external)



Meinard Müller

- Mathematics (Diplom/Master, 1997)
  Computer Science (PhD, 2001)
  Information Retrieval (Habilitation, 2007)
  Universität Bonn

- Senior Researcher (2007-2012)
  MPI für Informatik, Saarland

- Professor Semantic Audio Processing (since 2012)
  Universität Erlangen-Nürnberg

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- Mathematics (Diplom/Master, 1997)
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universitätbonn

- Senior Researcher (2007-2012)
  MPI für Informatik, Saarland

Cluster of Excellence on
Multimodal Computing and Interaction

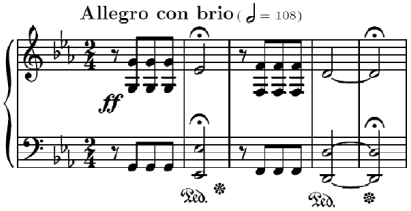
- Professor Semantic Audio Processing (since 2012)
  Universität Erlangen-Nürnberg

FAU

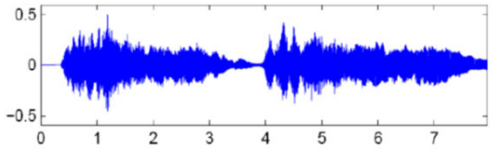
Multimodal Music Processing

Multimodal Music Processing

Sheet Music (Image)



CD / MP3 (Audio)



MusicXML (Text)

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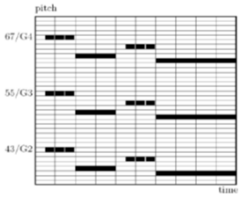
    <step>E</step>
    <alter>-1</alter>
    <octave>4</octave>
  </pitch>
  <duration>2</duration>
  <type>half</type>
</note>
```

Dance / Motion (Mocap)

Music

MIDI



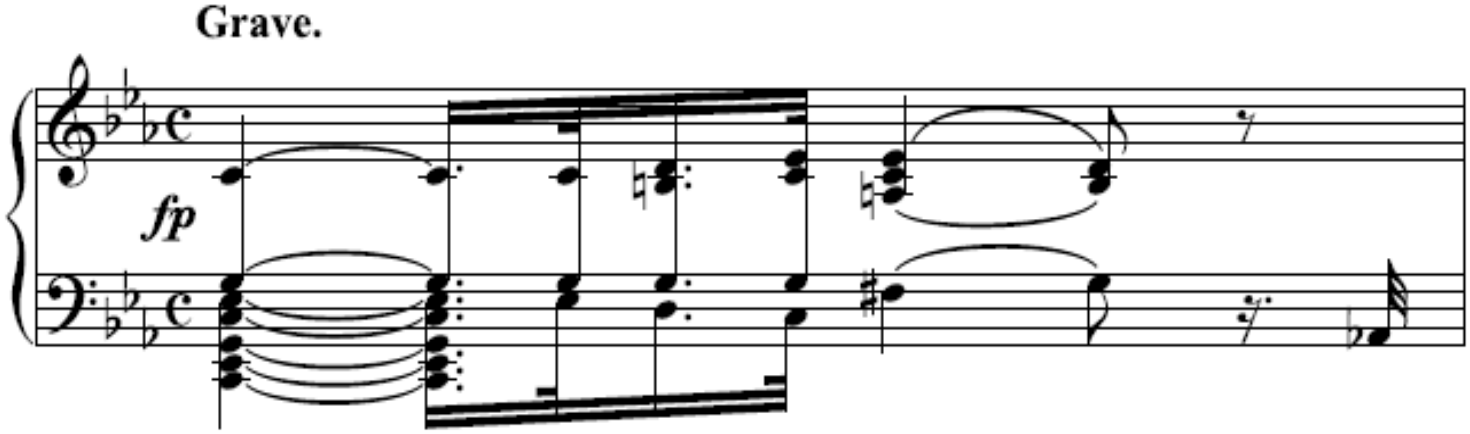
Singing / Voice (Audio)

Music Film (Video)

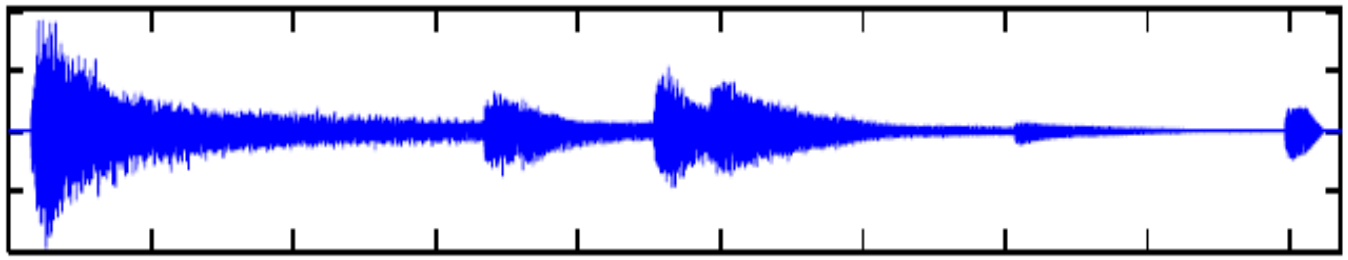
Music Literature (Text)

Multimodal Music Processing

Image



Audio

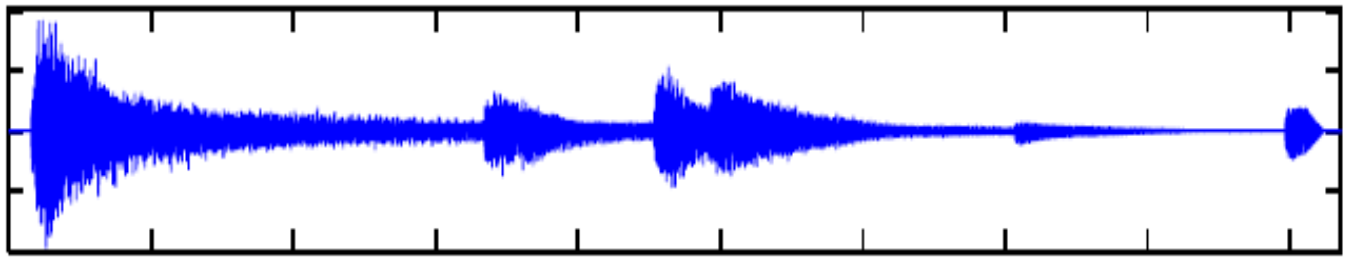


Multimodal Music Processing

Image Processing: Optical Music Recognition

Image

Audio



Multimodal Music Processing

Image Processing: Optical Music Recognition

Image

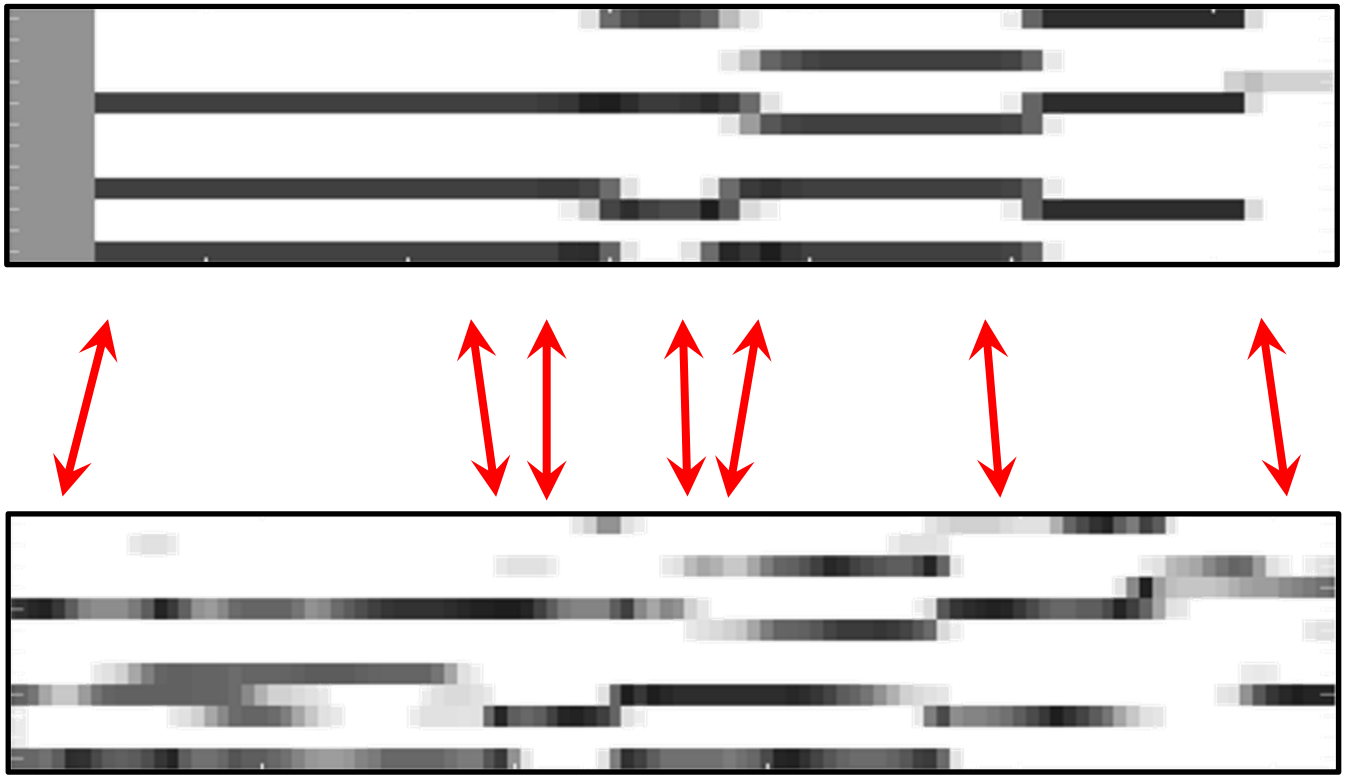
Audio

Audio Processing: Fourier Analysis

Multimodal Music Processing

Image Processing: Optical Music Recognition

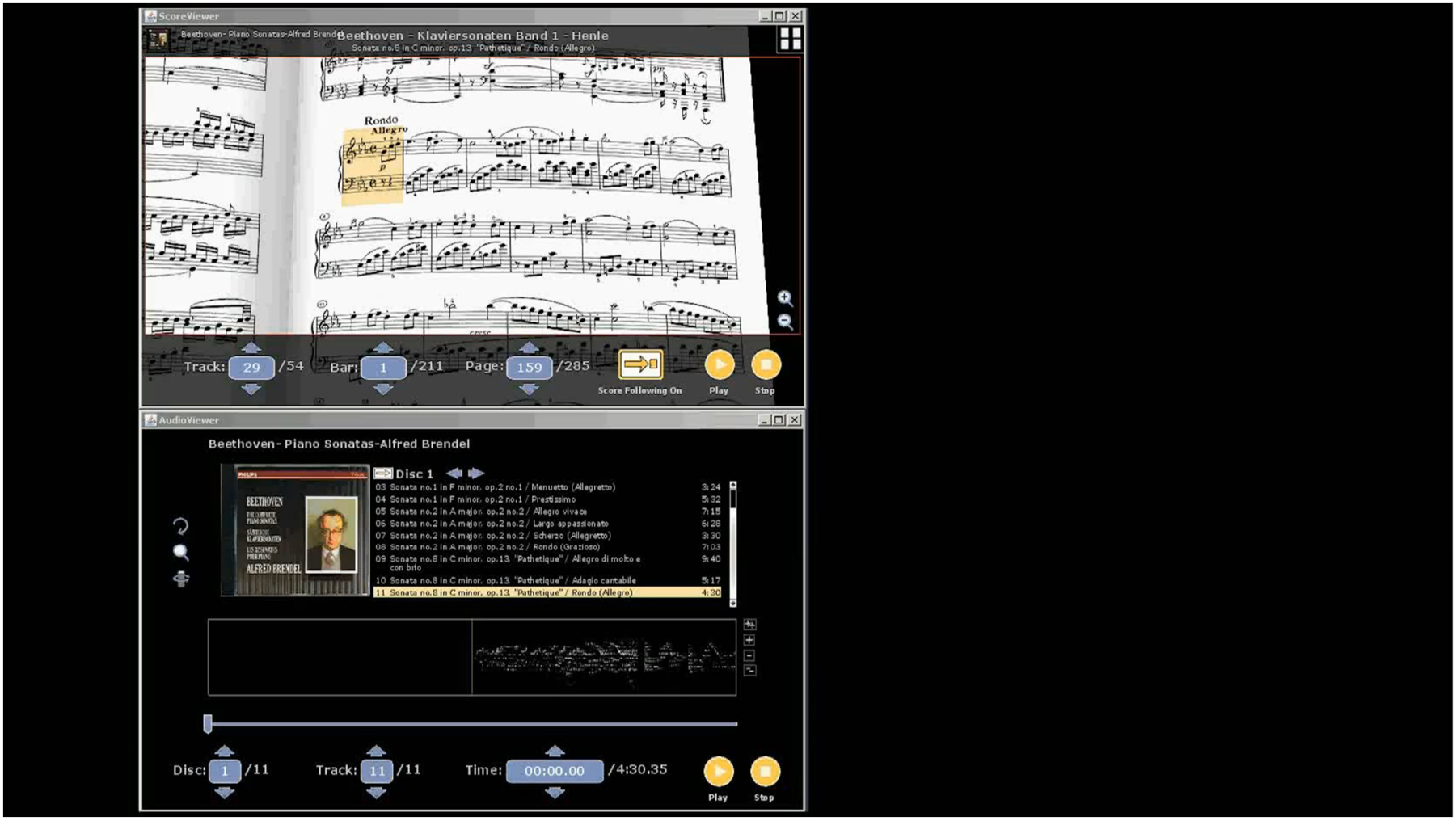
Image



Audio

Audio Processing: Fourier Analysis

Multimodal Music Processing



Multimodal Music Processing

- Cooperation Agreement (2009)
  - Wolfgang Bogler
  - Thomas Duis
  - Hans-Peter Seidel

- Experiments with Player Piano
- User Interfaces
- Saarland Music Data (SMD)

max planck institut informatik

HfM SAAR Hochschule für Musik

Multimodal Music Processing

- Cooperation Agreement (2009)
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max planck institut informatik

HfM SAAR Hochschule für Musik

Computational Musicology

- Cooperation: Rainer Kleinertz
- Harmony-based structural analysis
- Visualization techniques
- Exploration of interdisciplinary research

Verena Konz, Meinard Müller, Rainer Kleinertz:
A Cross-Version Chord Labelling Approach for Exploring Harmonic Structures –
A Case Study on Beethoven's Appassionata
Journal of New Music Research, 42(1): 61–77, 2013

Computational Musicology

- Cooperation: Rainer Kleinertz
- Harmony-based structural analysis
- Visualization techniques
- Exploration of interdisciplinary research

UNIVERSITÄT DES SAARLANDES

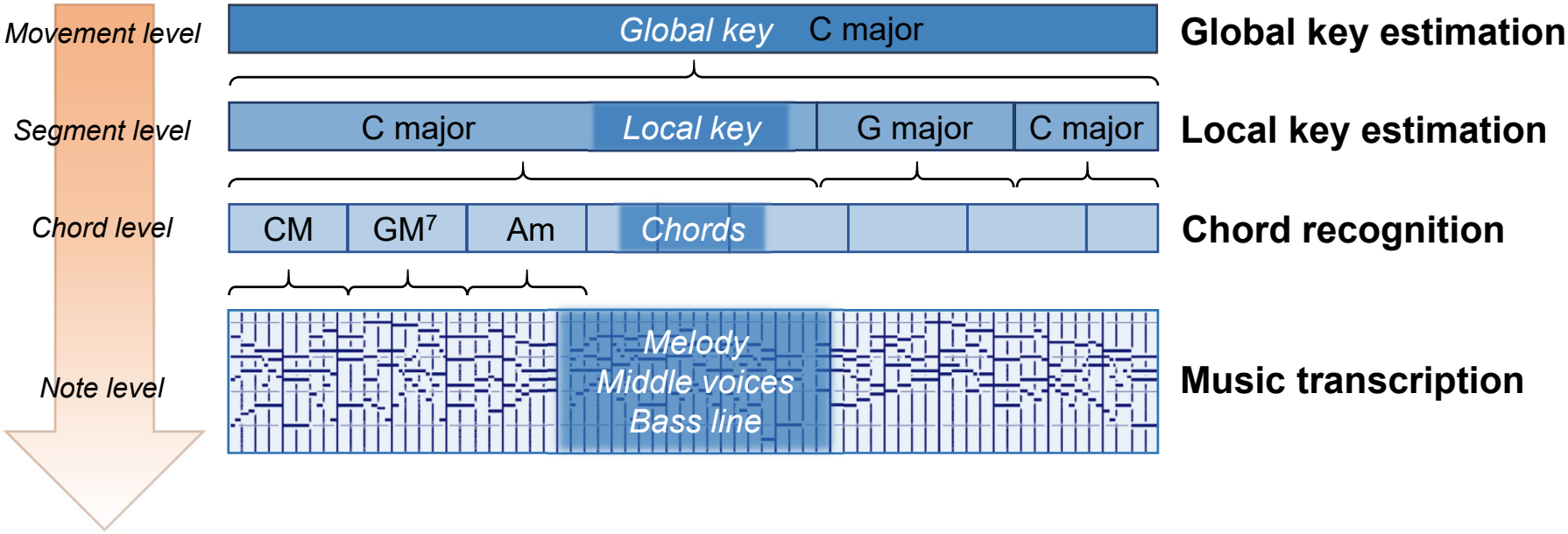
FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

- Since 2014: DFG-funded project

DFG

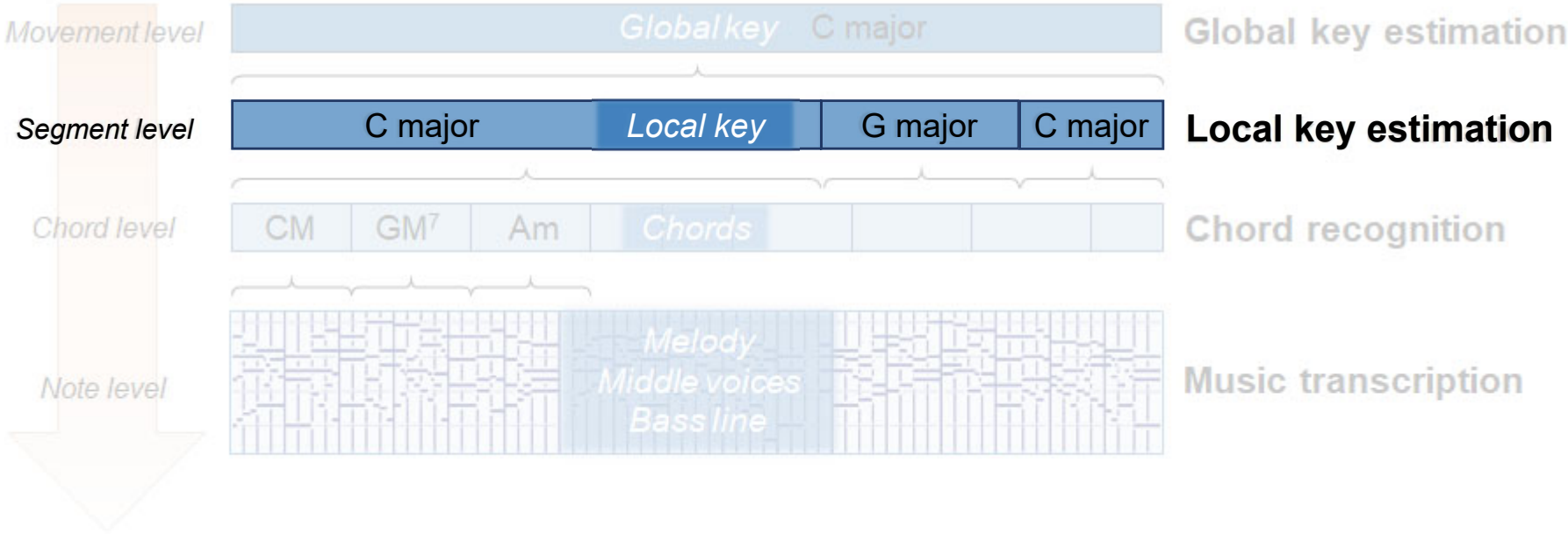
Harmony Analysis

- Different concepts
- Different temporal levels



Harmony Analysis

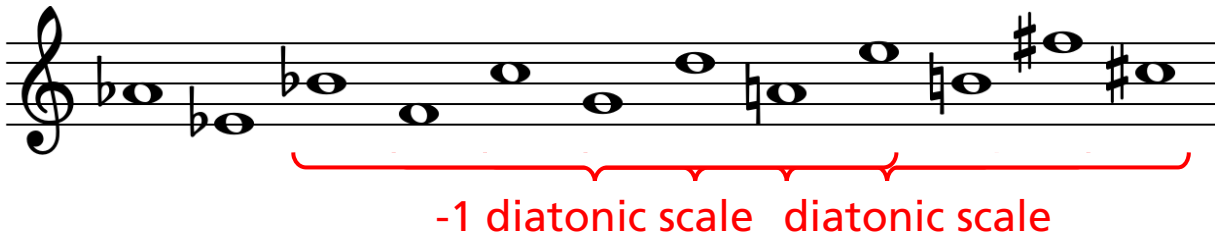
- Different concepts
- Different temporal levels



Local Key Estimation

Assumption: Music based on **diatonic scales**

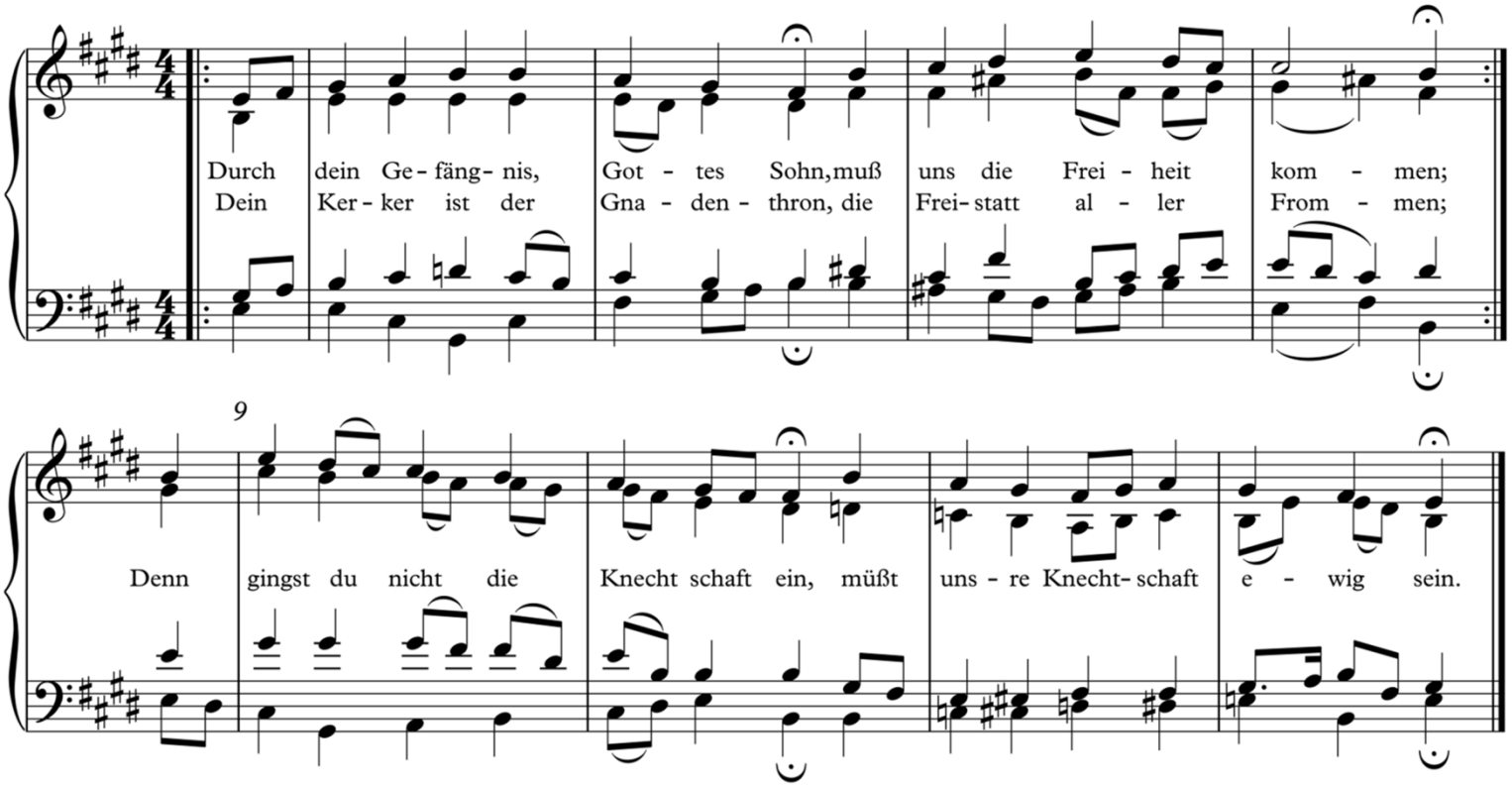
- Heptatonic scales
- Ordering of scales according to the circle of fifths
- Each scale consists of chain of six perfect fifth
- Fifth-neighboring scales share 6 of 7 notes



Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)

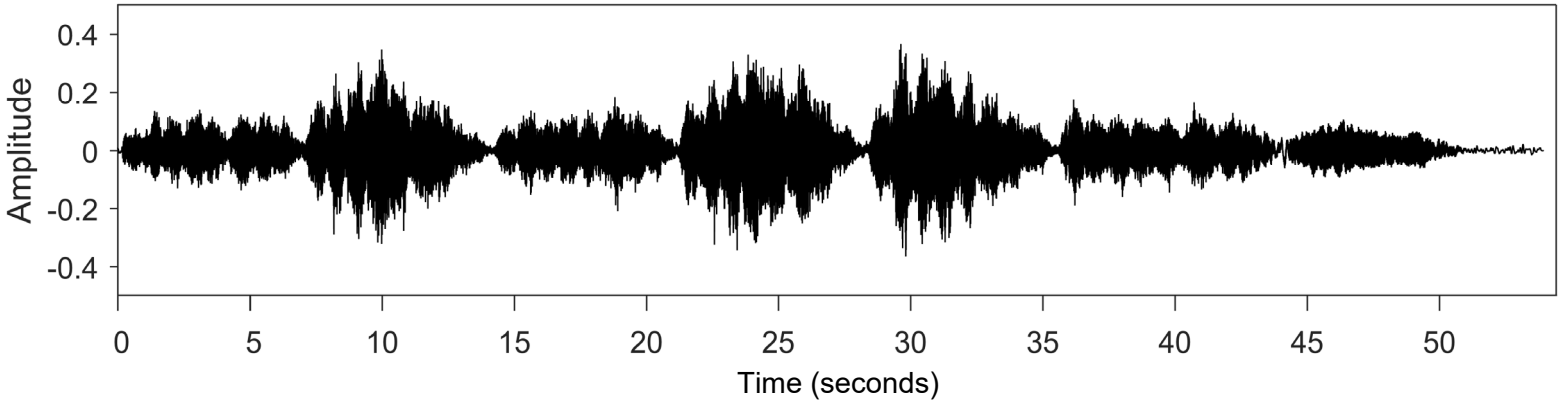
Score representation (piano reduction)



Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)

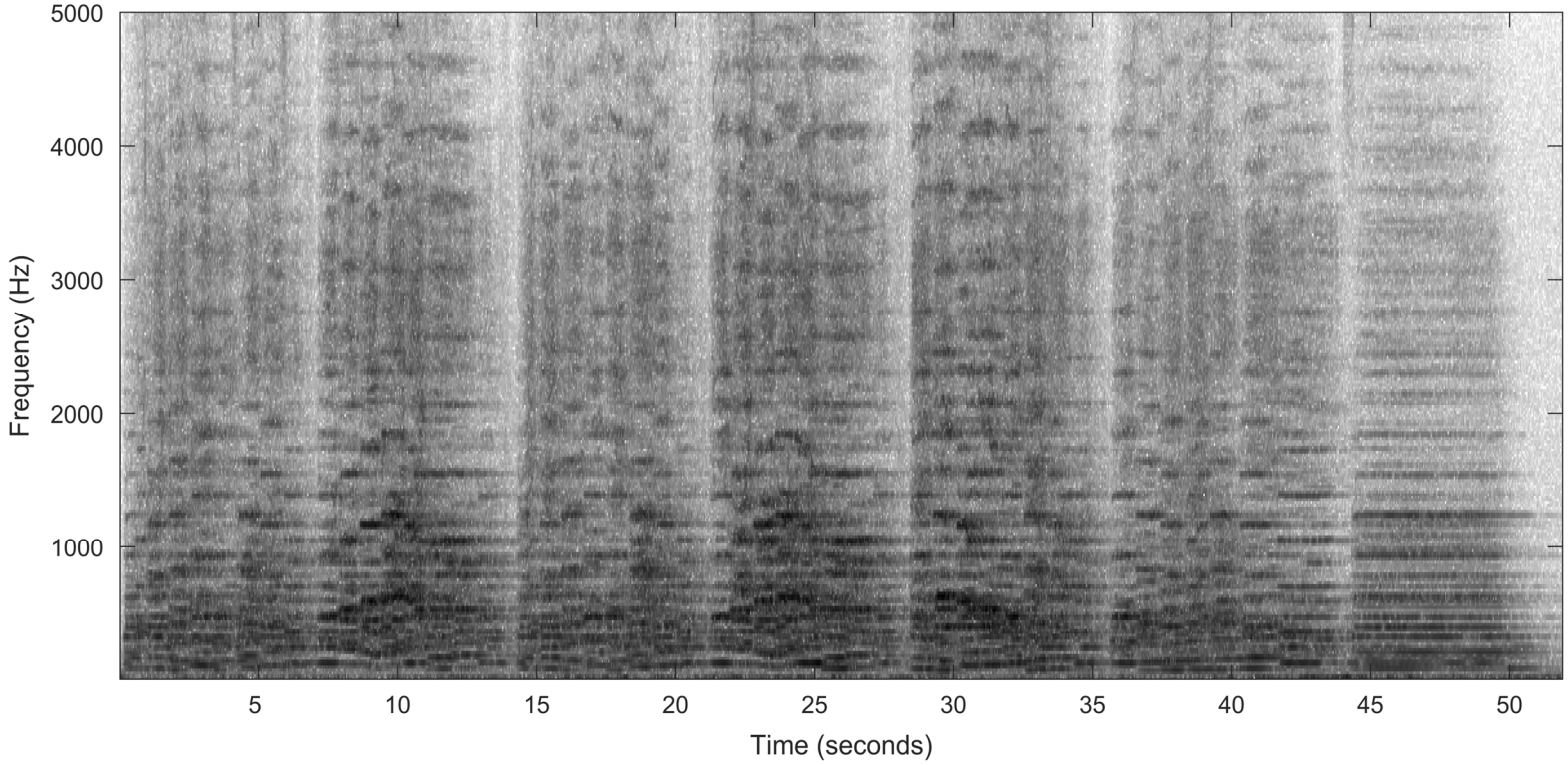
Recording (Scholars Baroque Ensemble, Naxos 1994) **Waveform**



Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)

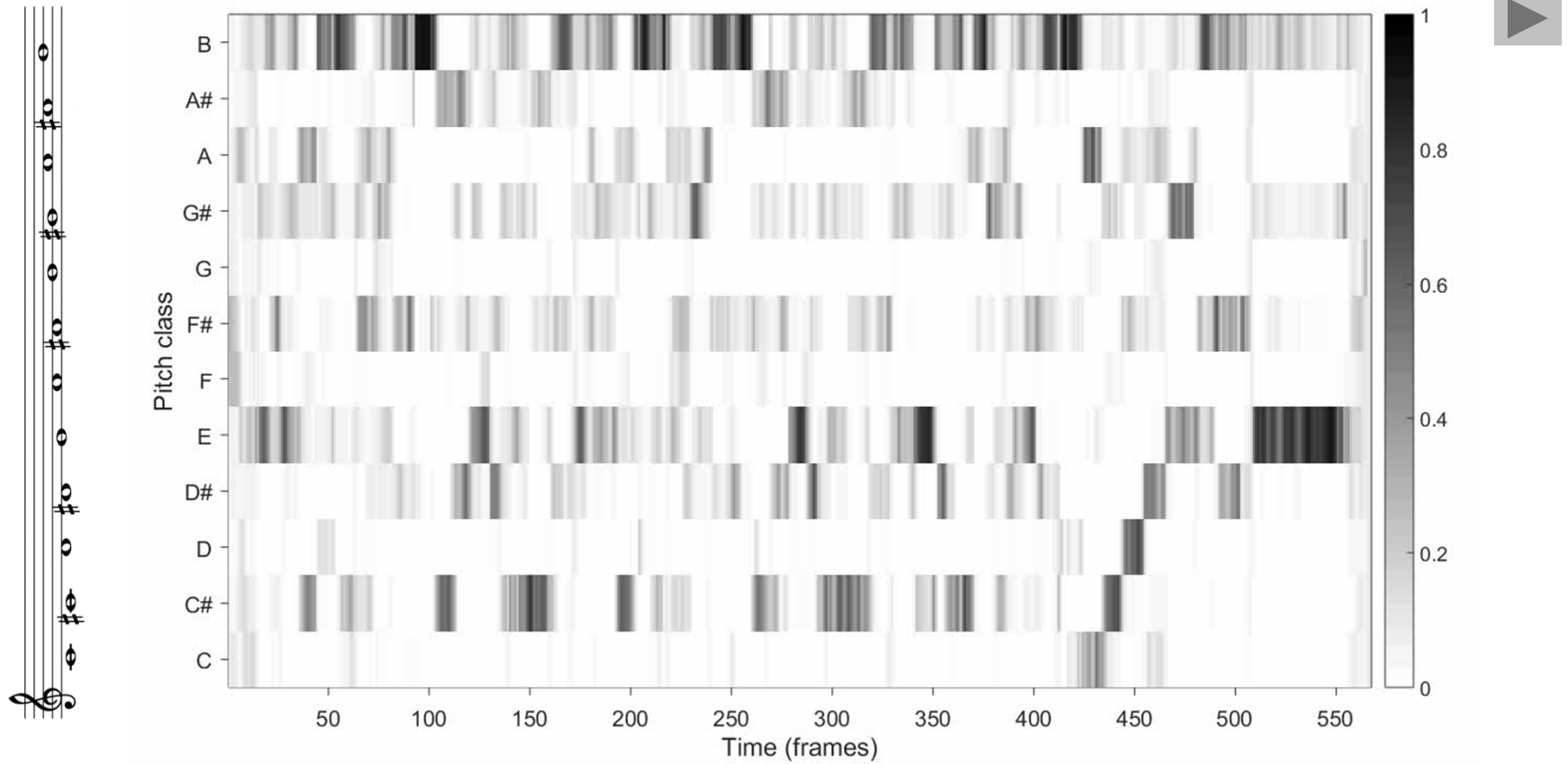
Recording (Scholars Baroque Ensemble, Naxos 1994) **Spectrogram**



Local Key Estimation

Example: J.S. Bach, Choral "Durch Dein Gefängnis" (*Johannespassion*)

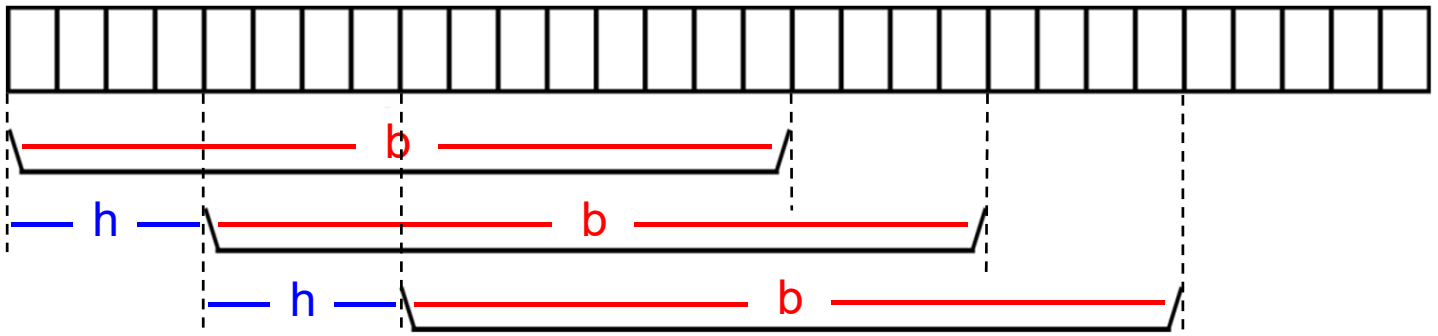
Recording (Scholars Baroque Ensemble, Naxos 1994) **Chromagram**



Local Key Estimation

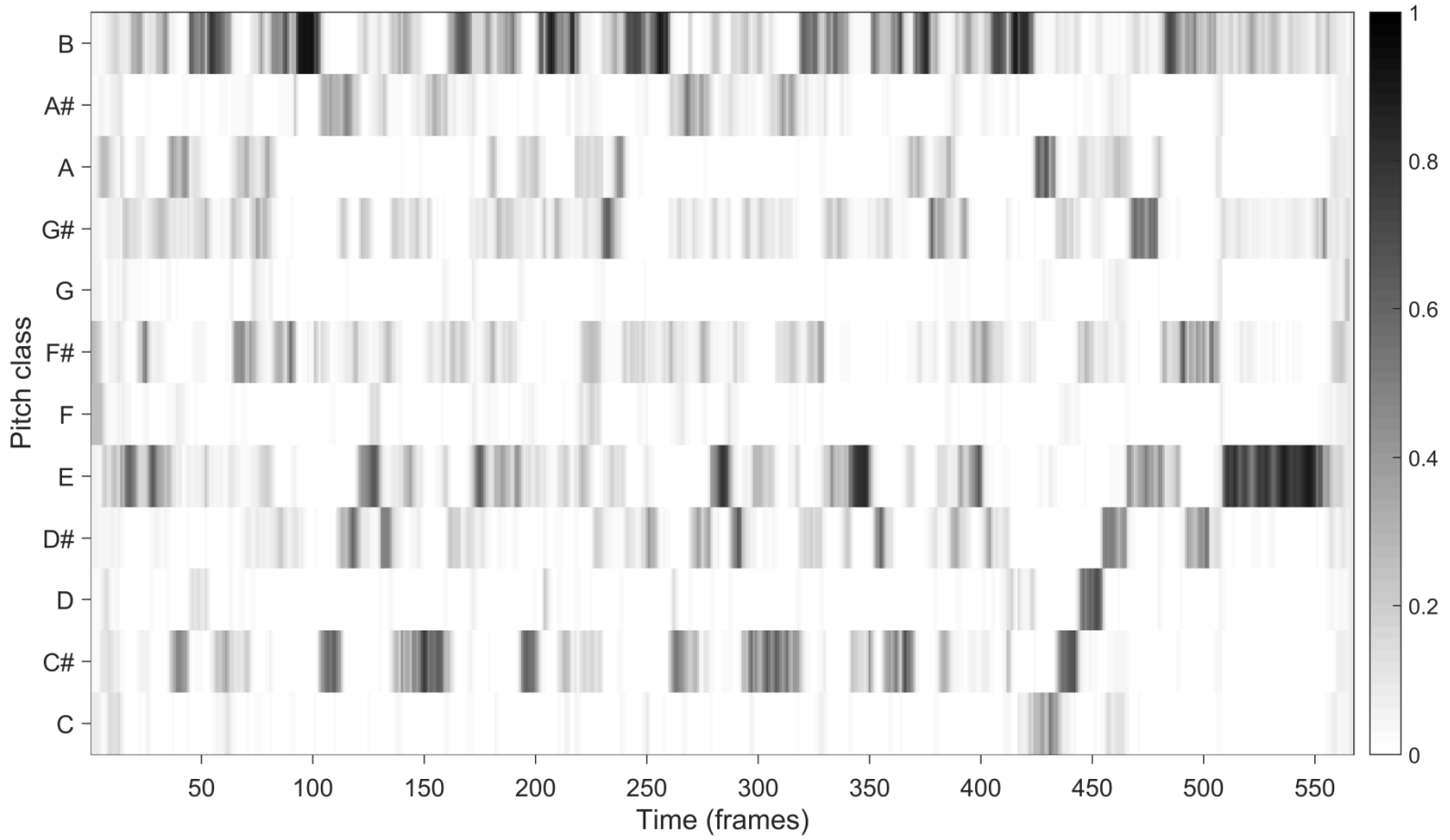
Summarize pitch class (chroma) content over a certain time period

- Feature smoothing
- Parameters: blocksize b and hopsize h



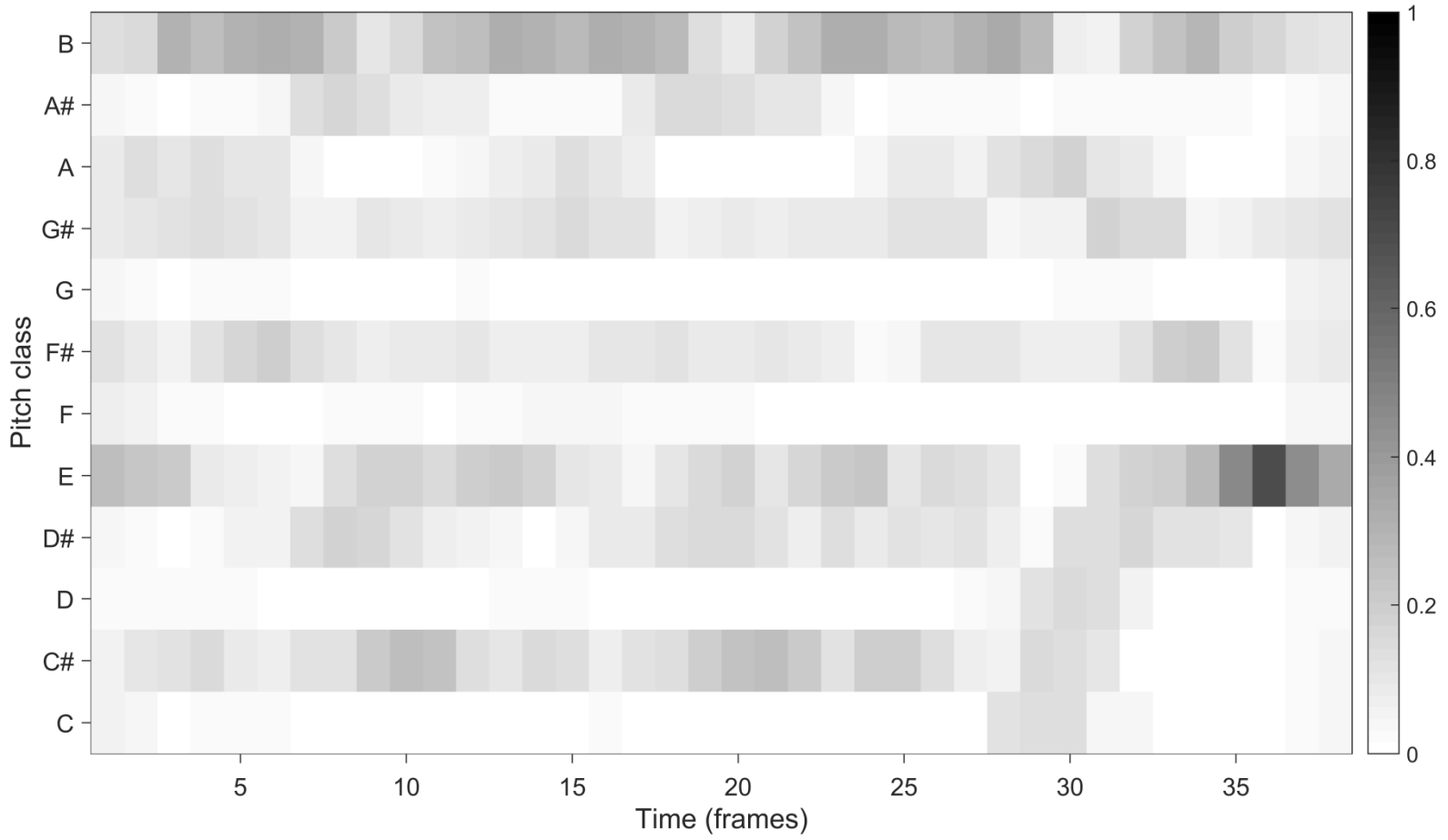
Local Key Estimation

Chromagram



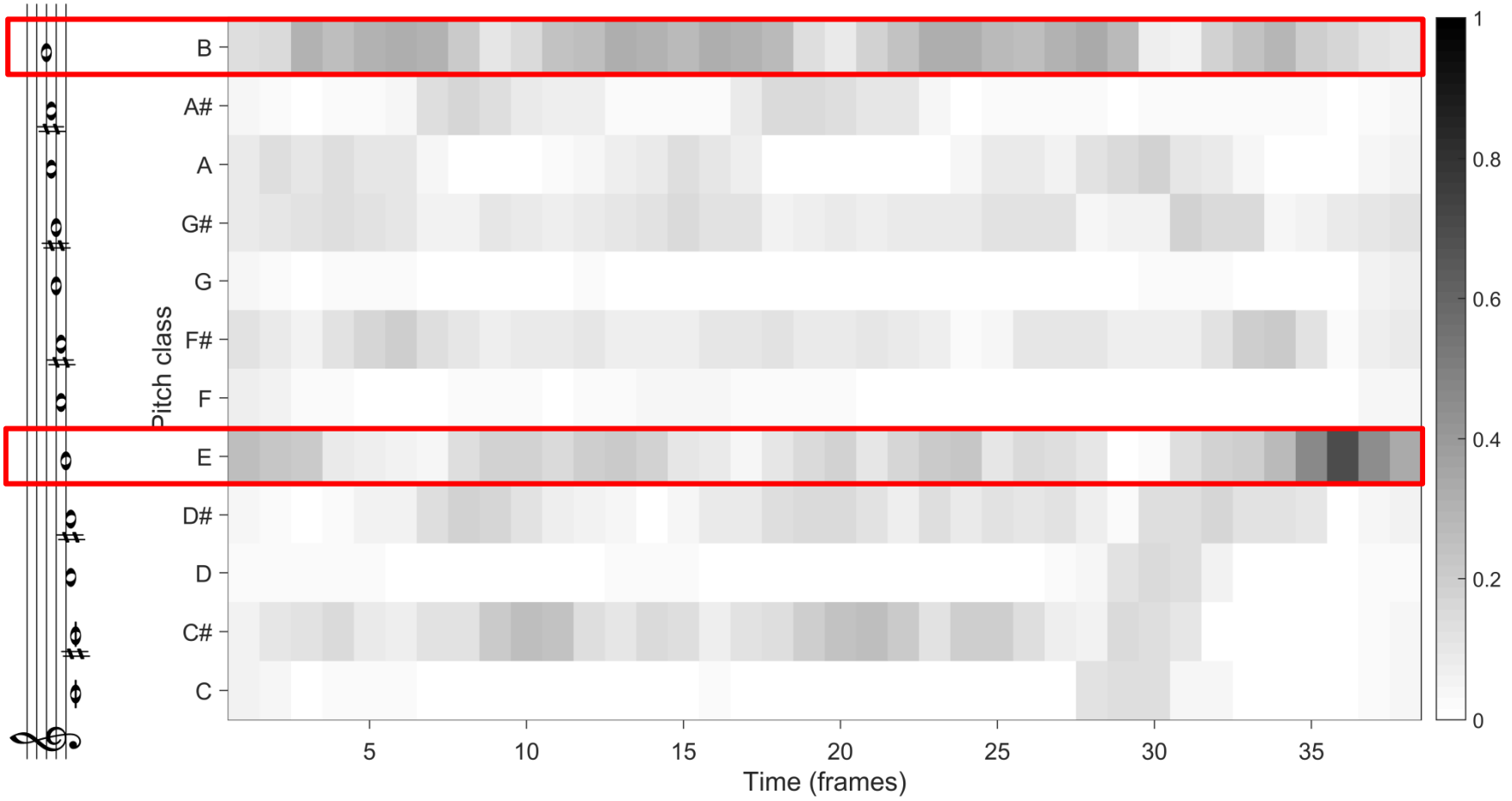
Local Key Estimation

Chromagram after smoothing (b = 42, h = 15)



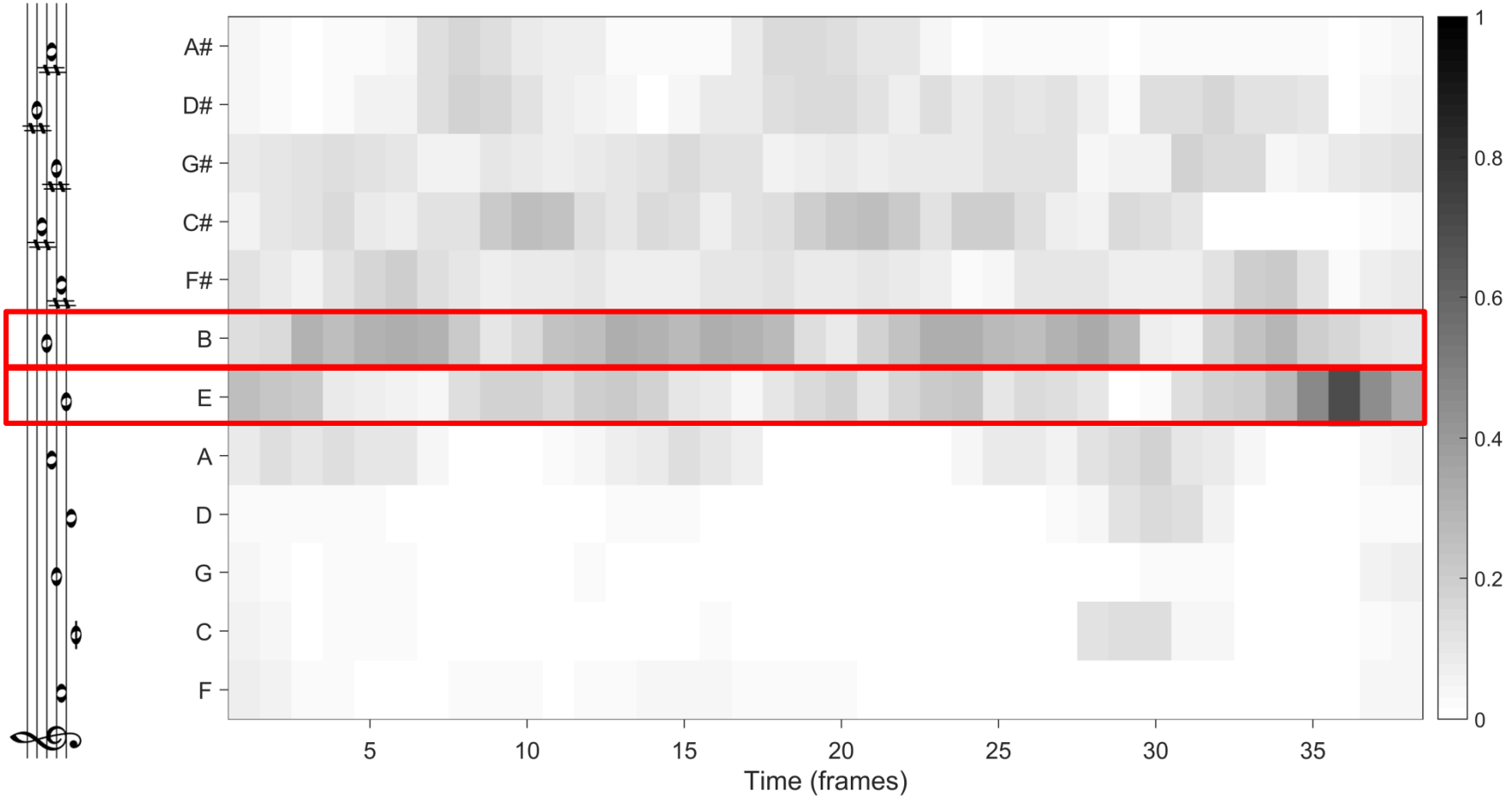
Local Key Estimation

Arrange pitch classes according to **perfect fifth** series



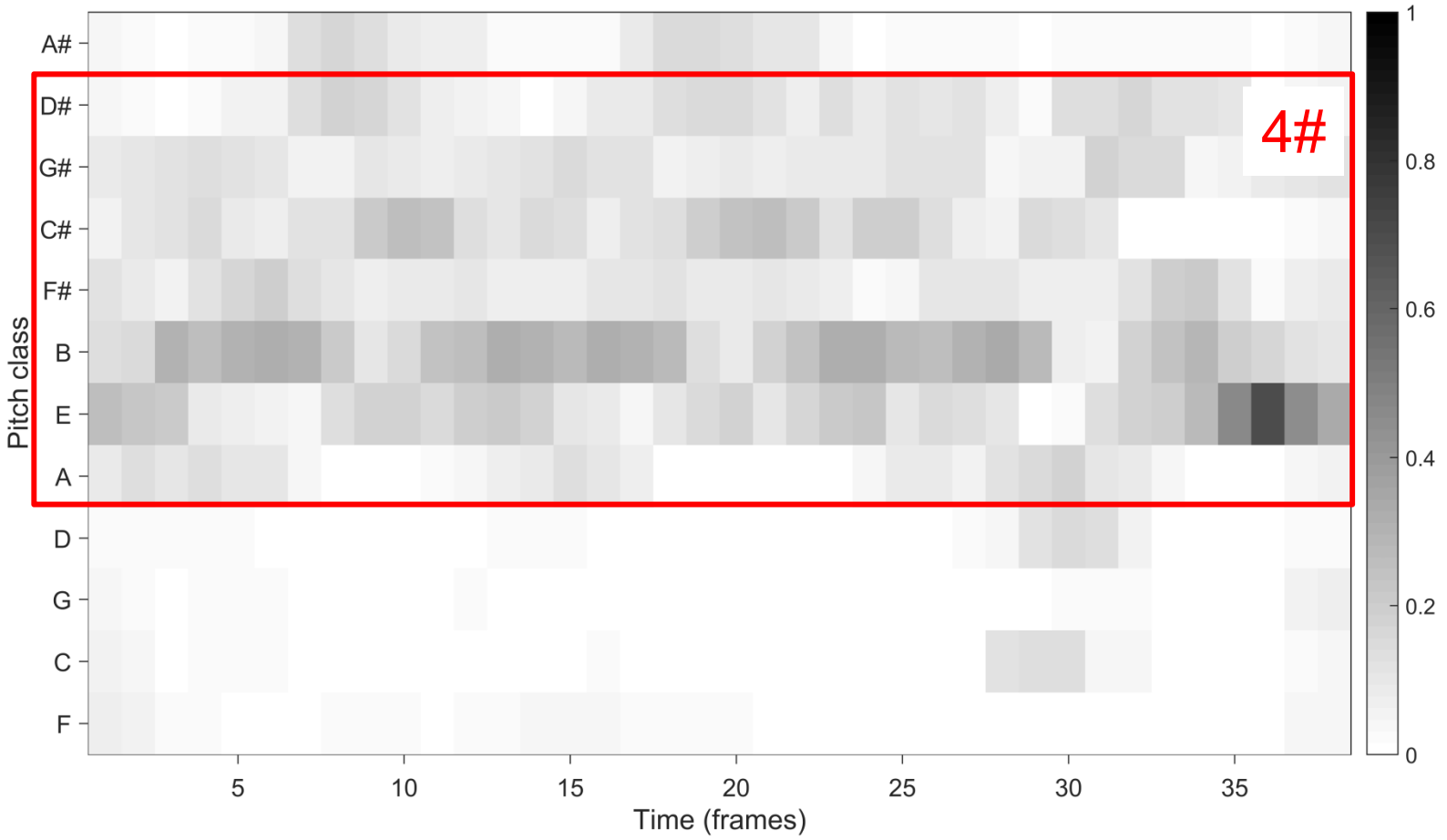
Local Key Estimation

Arrange pitch classes according to **perfect fifth** series



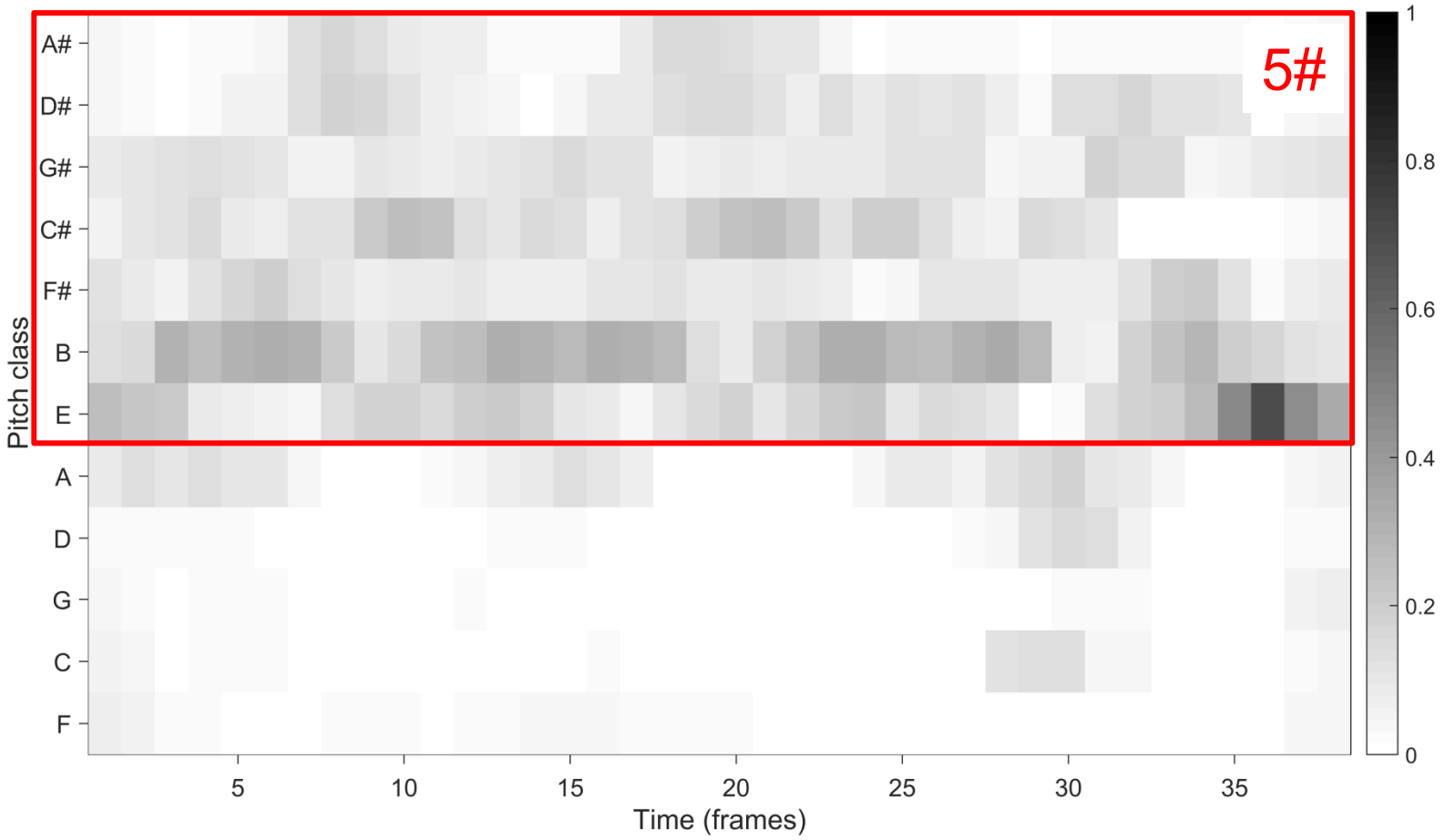
Local Key Estimation

Summarize pitch class content according to **diatonic scales**



Local Key Estimation

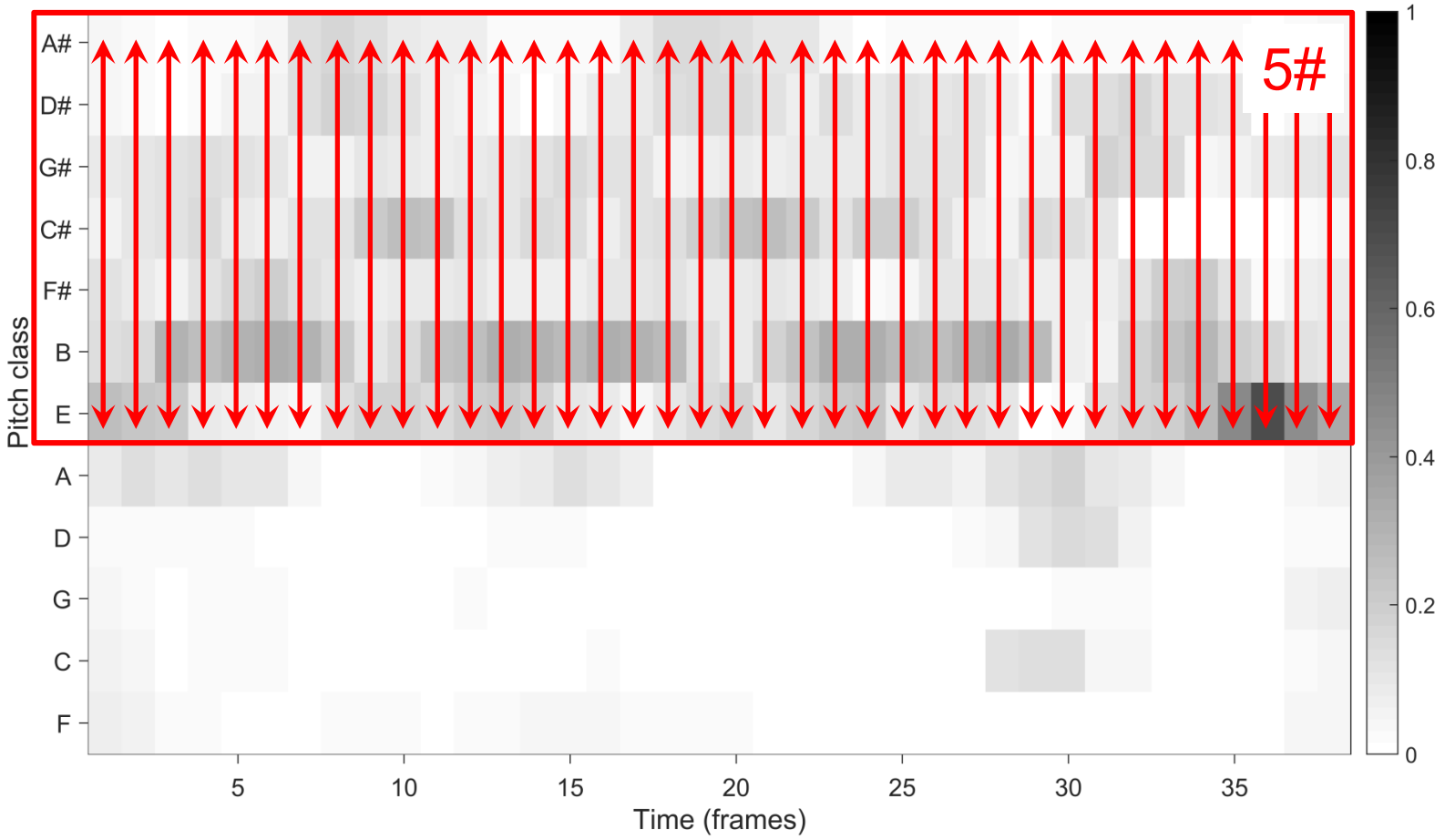
Summarize pitch class content according to **diatonic scales**



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

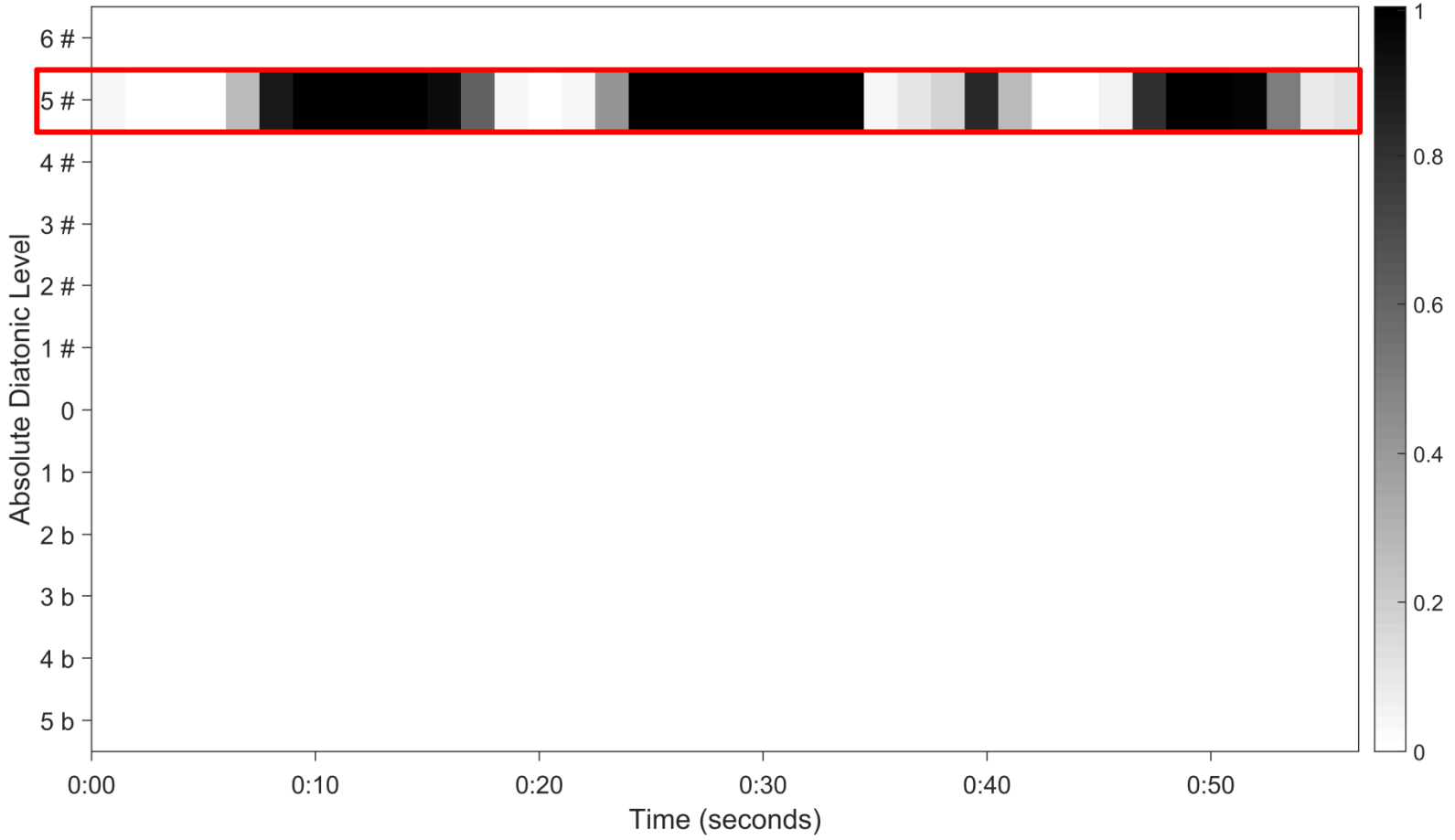
Multiply chroma values (in each column)



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

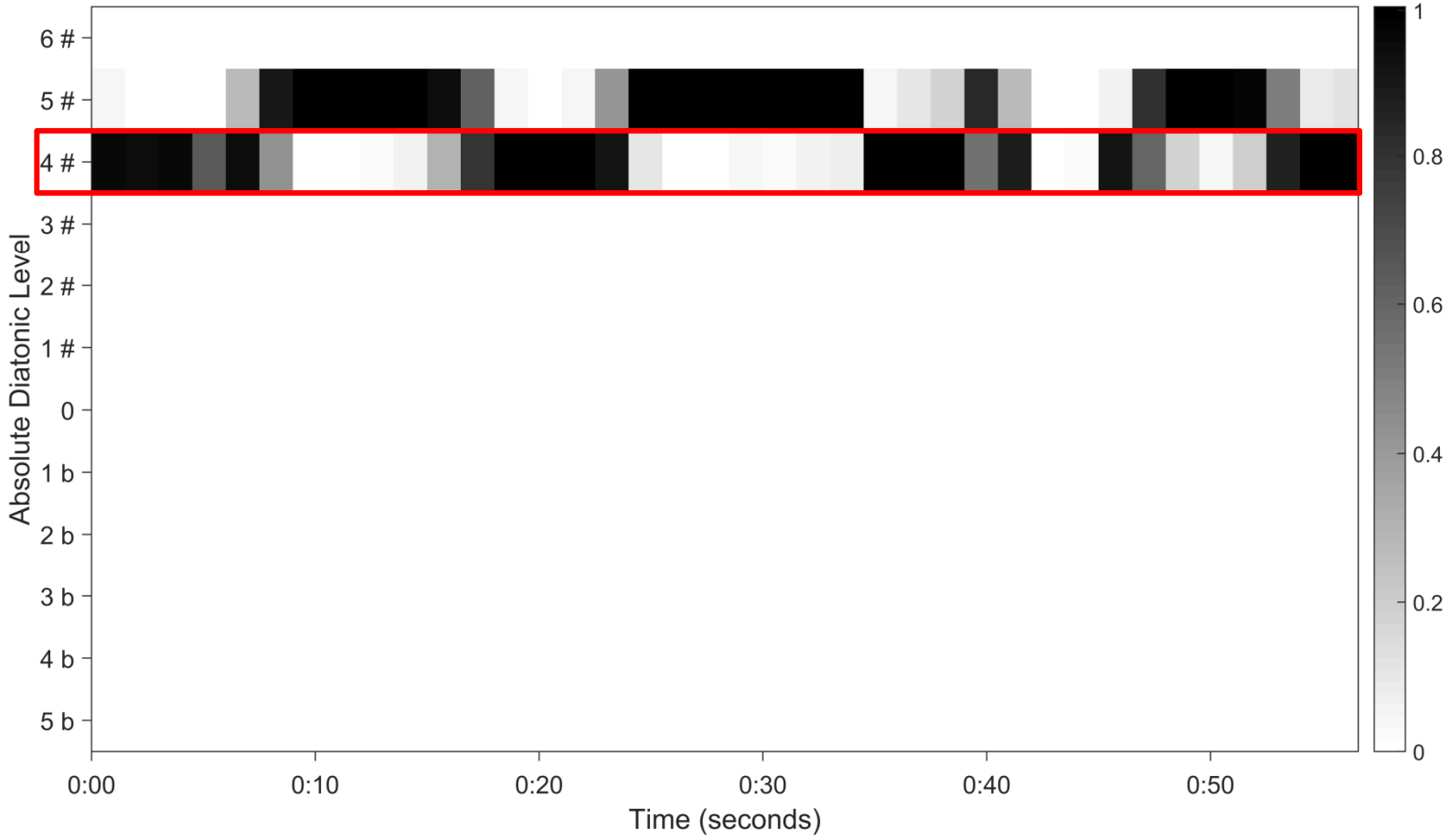
Multiply chroma values



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

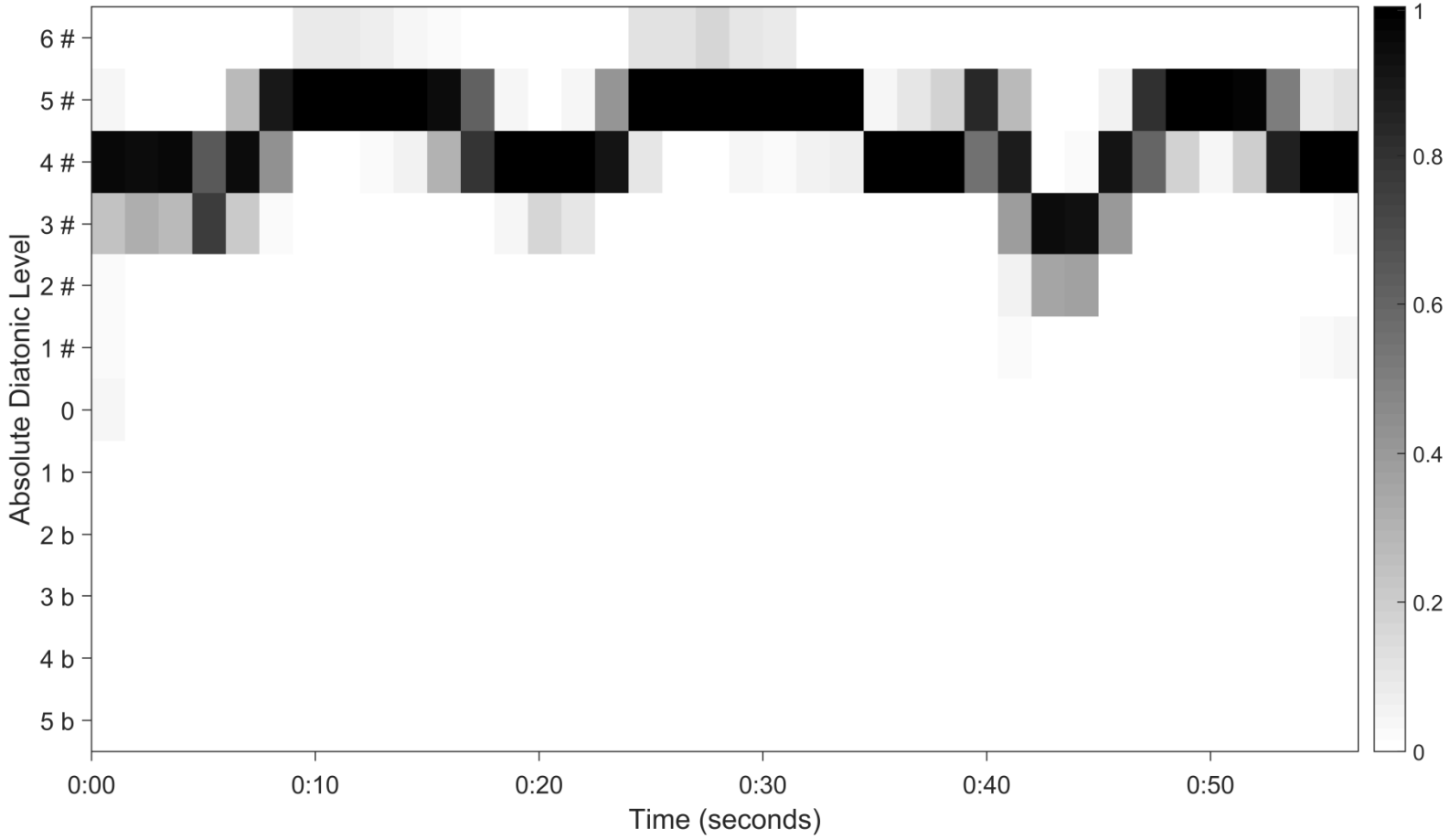
Multiply chroma values



Local Key Estimation

Summarize pitch class content according to **diatonic scales**

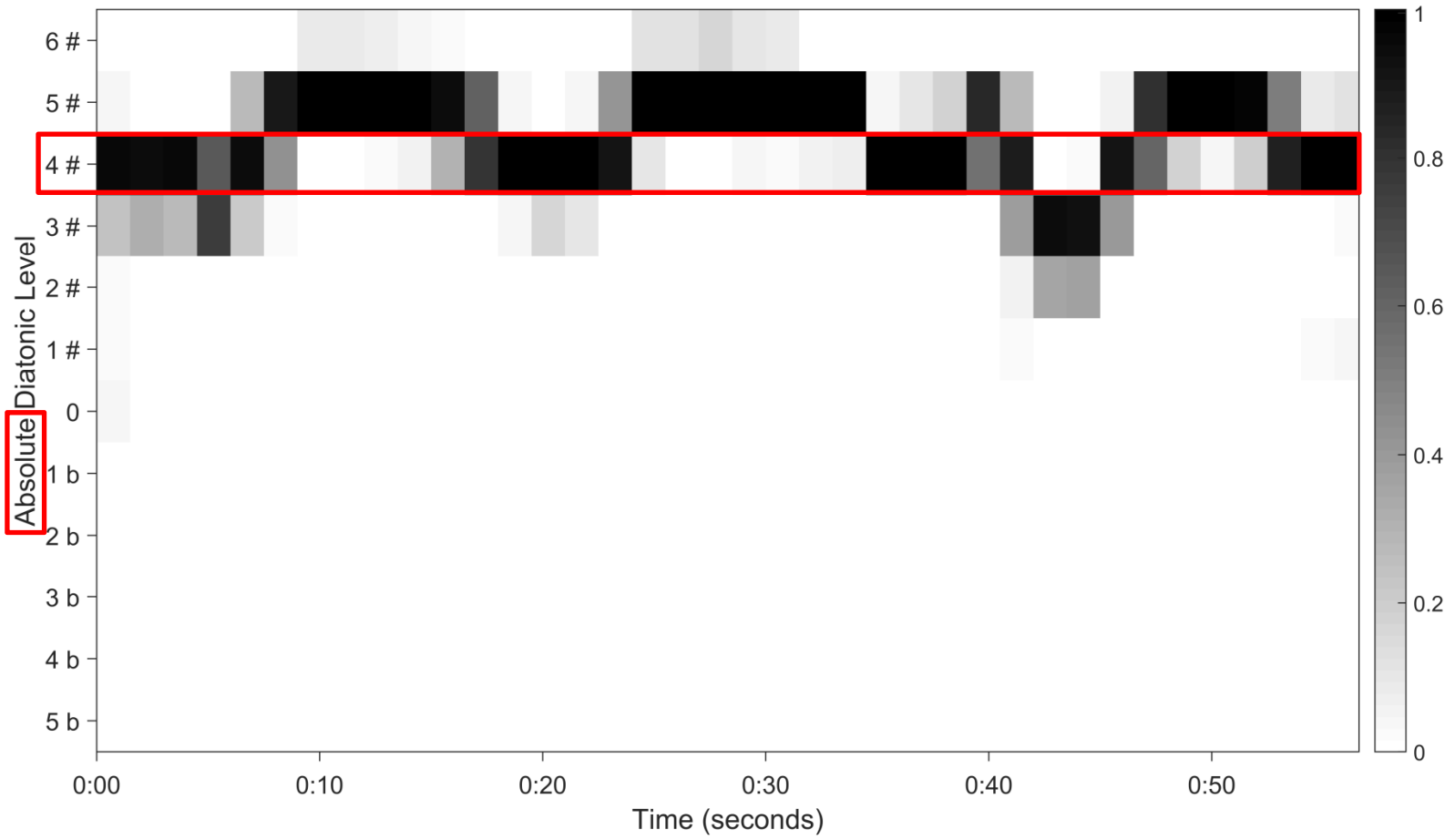
Multiply chroma values



Local Key Estimation

Normalize representation relative to global key

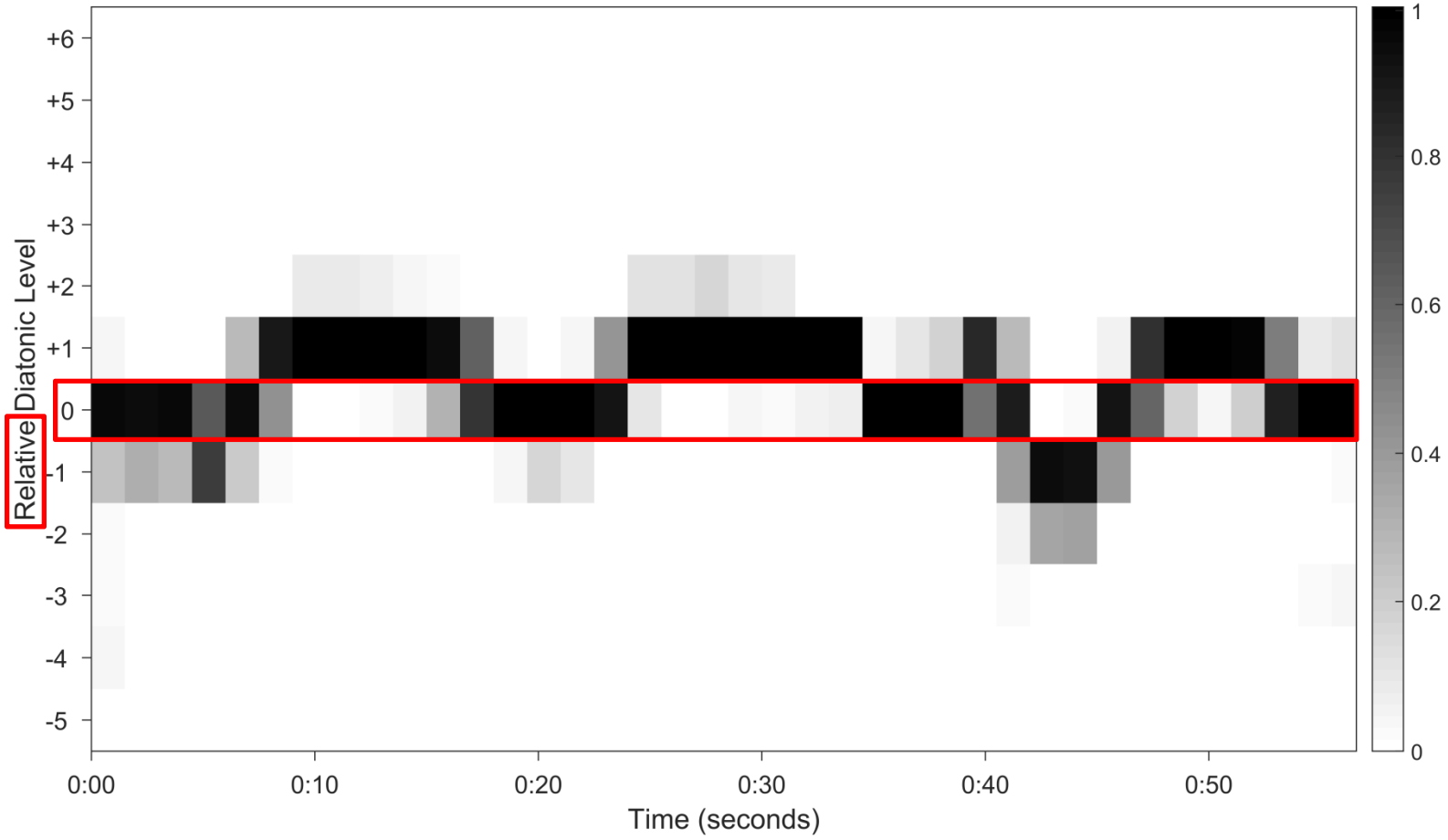
4 #
(E major)



Local Key Estimation

Normalize representation relative to global key

4 #
(E major)

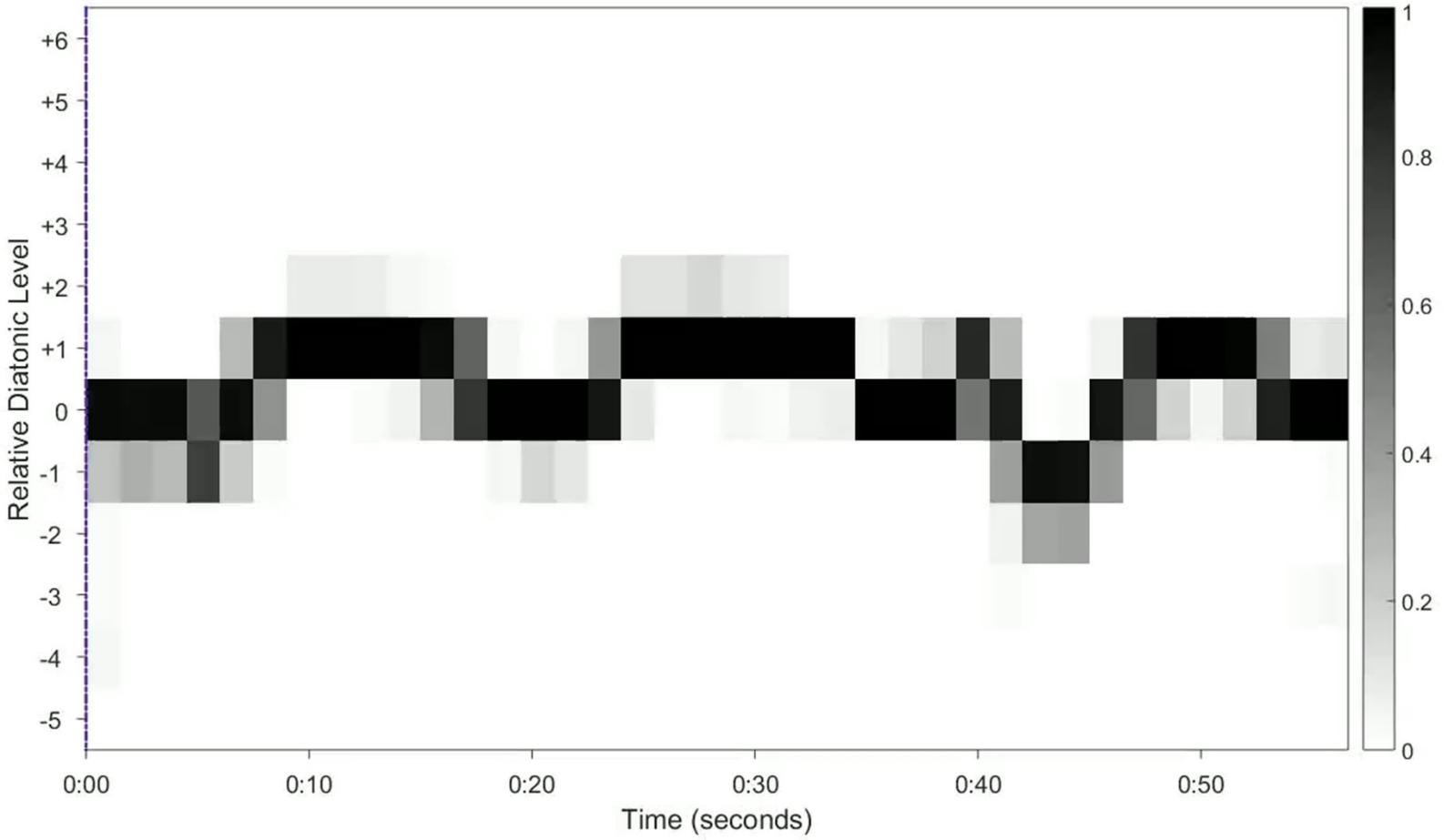


Local Key Estimation

J.S. Bach: Choral "Durch Dein Gefängnis" (*Johannespassion*)

Recording: Scholars Baroque Ensemble, Naxos 1994

4 #
(E major)

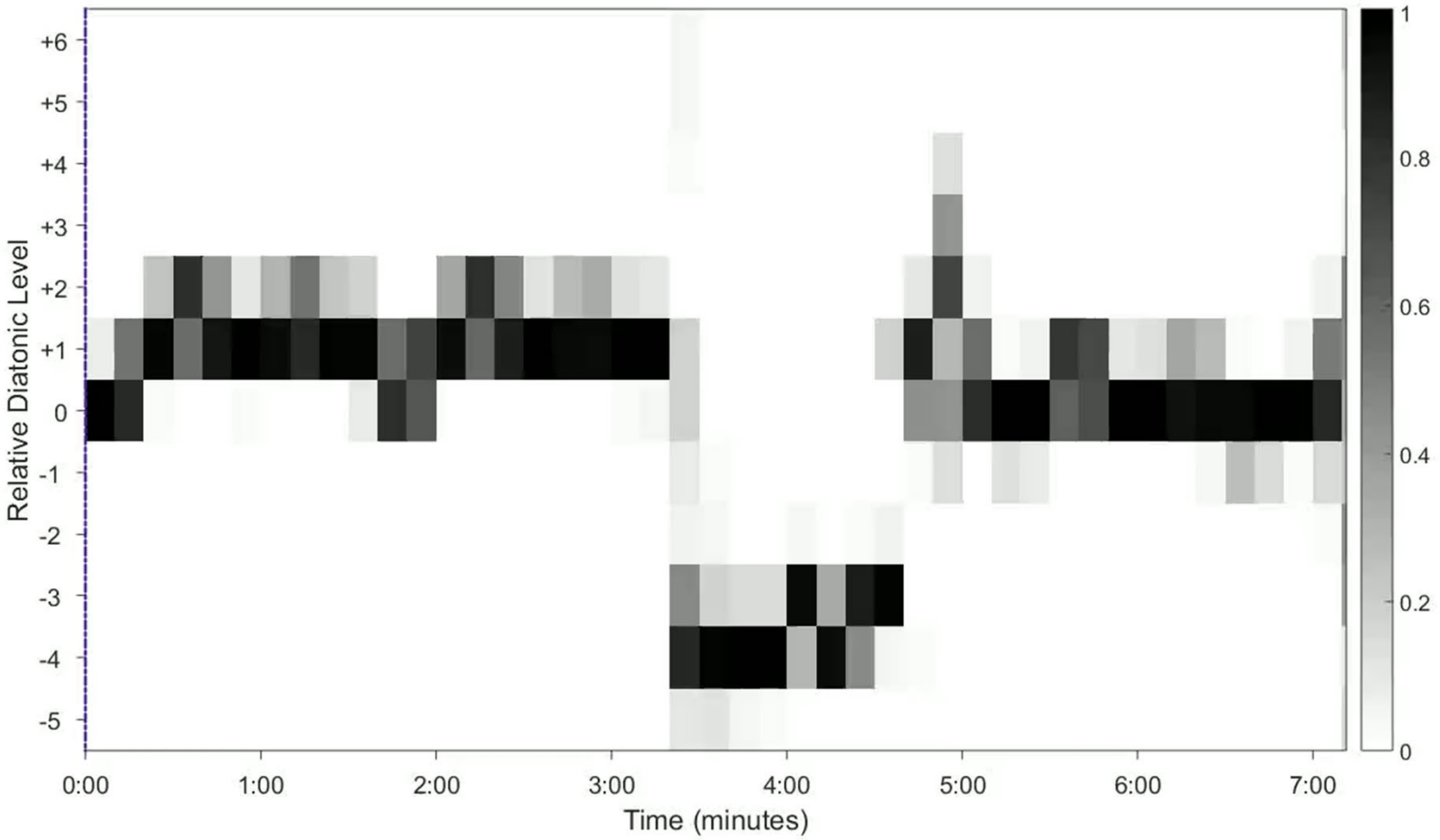


Local Key Estimation

L. v. Beethoven: Piano Sonata No. 10 (Op. 14 Nr. 2), 1. Allegro

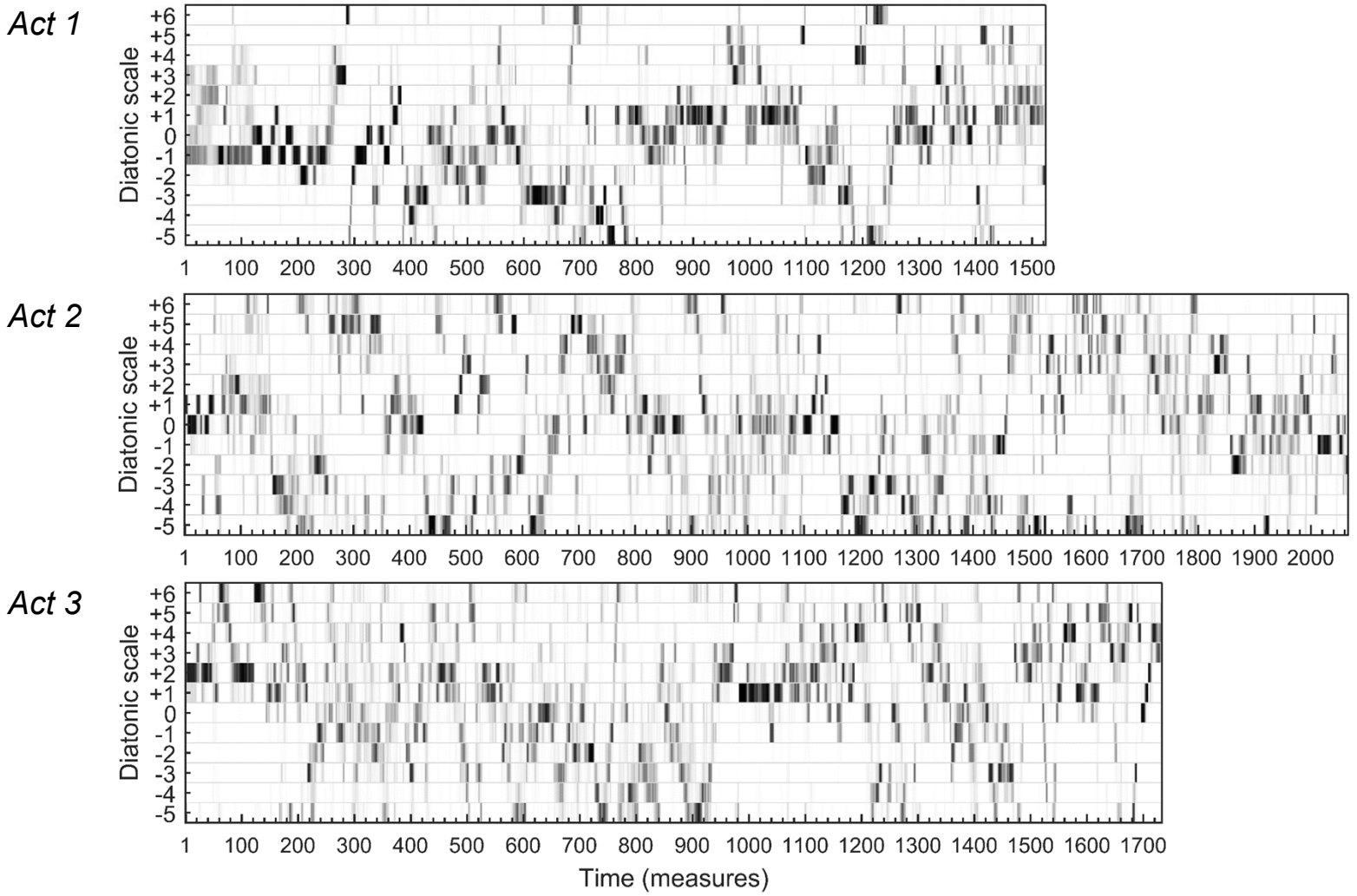
Recording: Barenboim, EMI 1998

1 #
(G major)



Local Key Estimation

R. Wagner: WWV 86 B (*Die Walküre*)



Local Key Estimation

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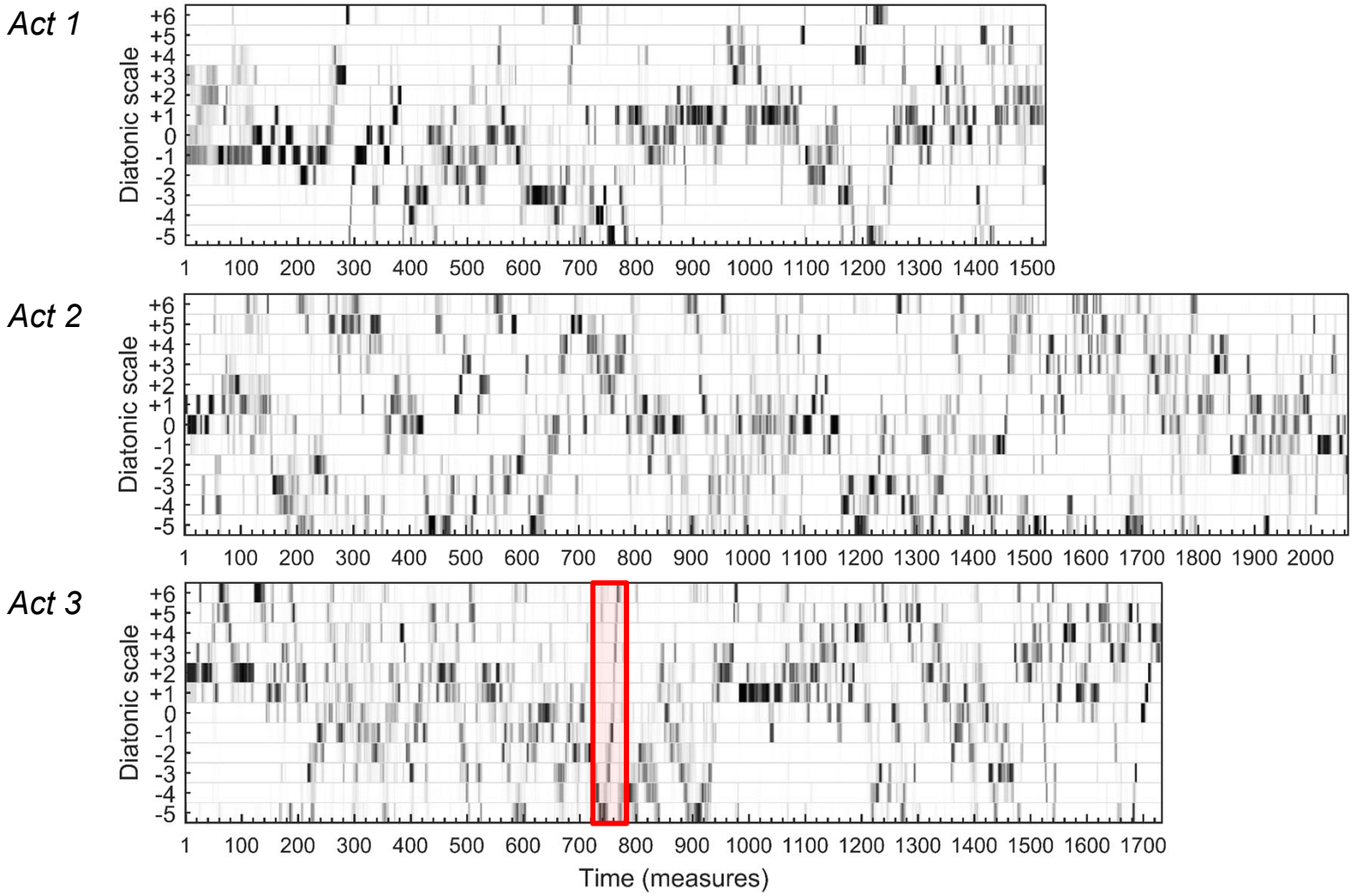
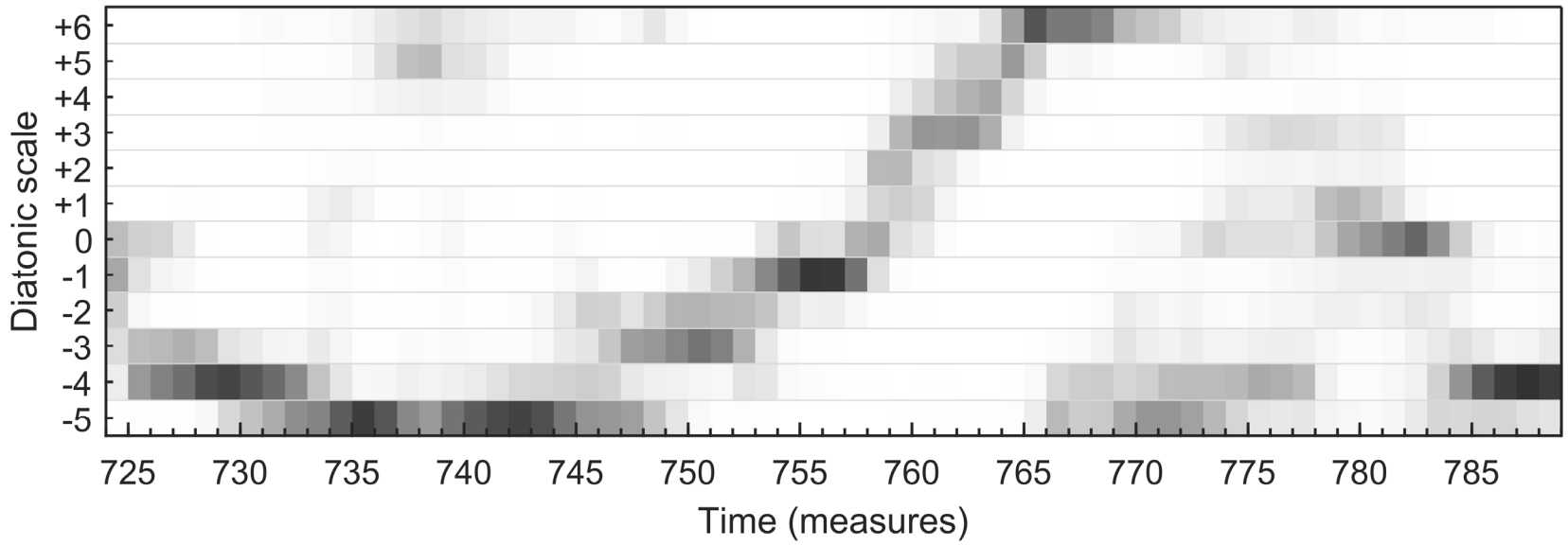


Local Key Estimation

R. Wagner: WWV 86 B (*Die Walküre*)
Act 3, measure 724–789 (*Wotan's punishment*)



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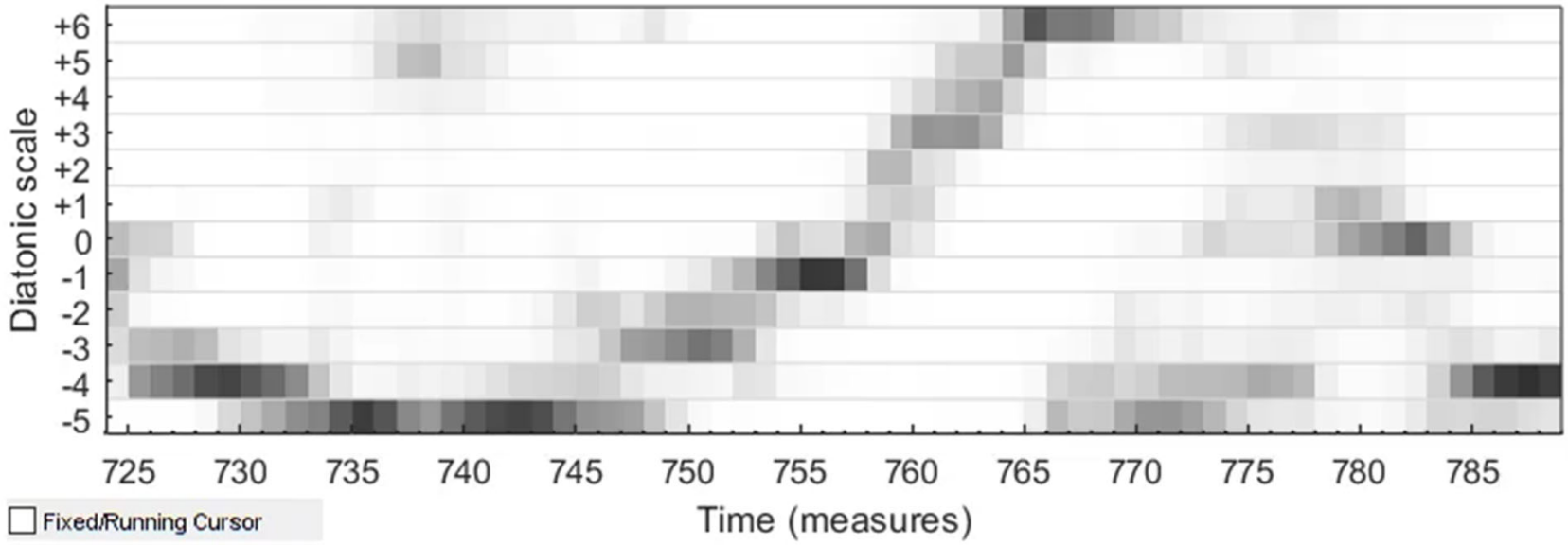
R. Wagner: WWV 86 B (*Die Walküre*)
Act 3, measure 724–789 (*Wotan's punishment*)



Interdisciplinary Dialogue

- Dagstuhl Seminar (2016):

  Computational Music Structure Analysis

Interdisciplinary Dialogue

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  Computational Music Structure Analysis

- GI Jahrestagung (2017):

  Workshop: Musik trifft Informatik

Interdisciplinary Dialogue

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  Computational Music Structure Analysis

- GI Jahrestagung (2017):

  Workshop: Musik trifft Informatik

- Tagung (2022):

  Understanding Beethoven

  Musicology and Computer Science in Dialogue

Qualification

- Mark Gotham

  2021: Universität des Saarlandes → TU Dortmund

  Professor of Music Theory

Qualification

- Mark Gotham

  2021: Universität des Saarlandes → TU Dortmund

  Professor of Music Theory

- Stephanie Klauk

  2022: Habilitation, Universität des Saarlandes

Qualification

- Mark Gotham

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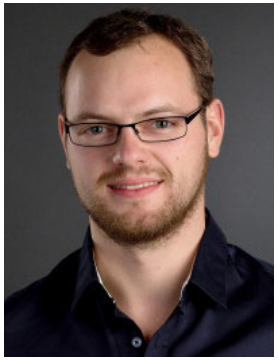
  2022: Habilitation, Universität des Saarlandes

- Christof Weiß

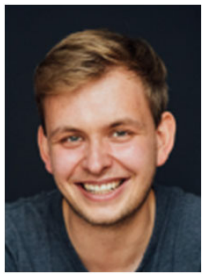
  2022: FAU → Universität Würzburg

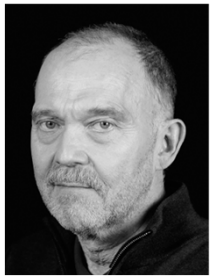
  Professor of Computational Humanities



Computational Analysis of Traditional Georgian Vocal Music

- Interdisciplinary research project
  - Prof. Dr. Frank Scherbaum (Potsdam)
  - Dr. Nana Mzhavanadze (Tbilisi)
  - Sebastian Rosenzweig (FAU)

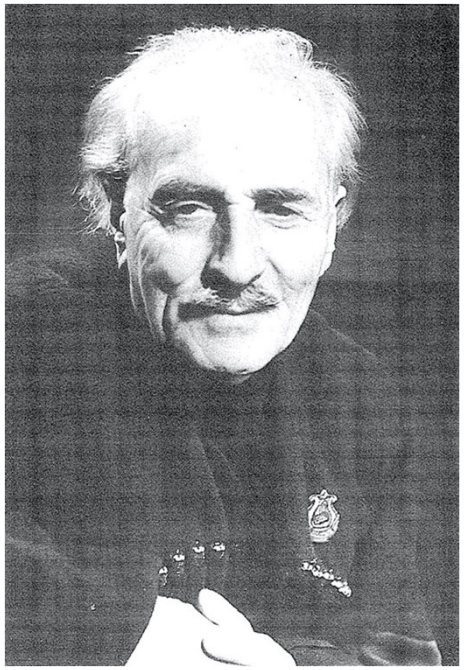




- Objective: Tonal analysis

- 2018 – 2022: DFG-funded project

Traditional Georgian Vocal Music



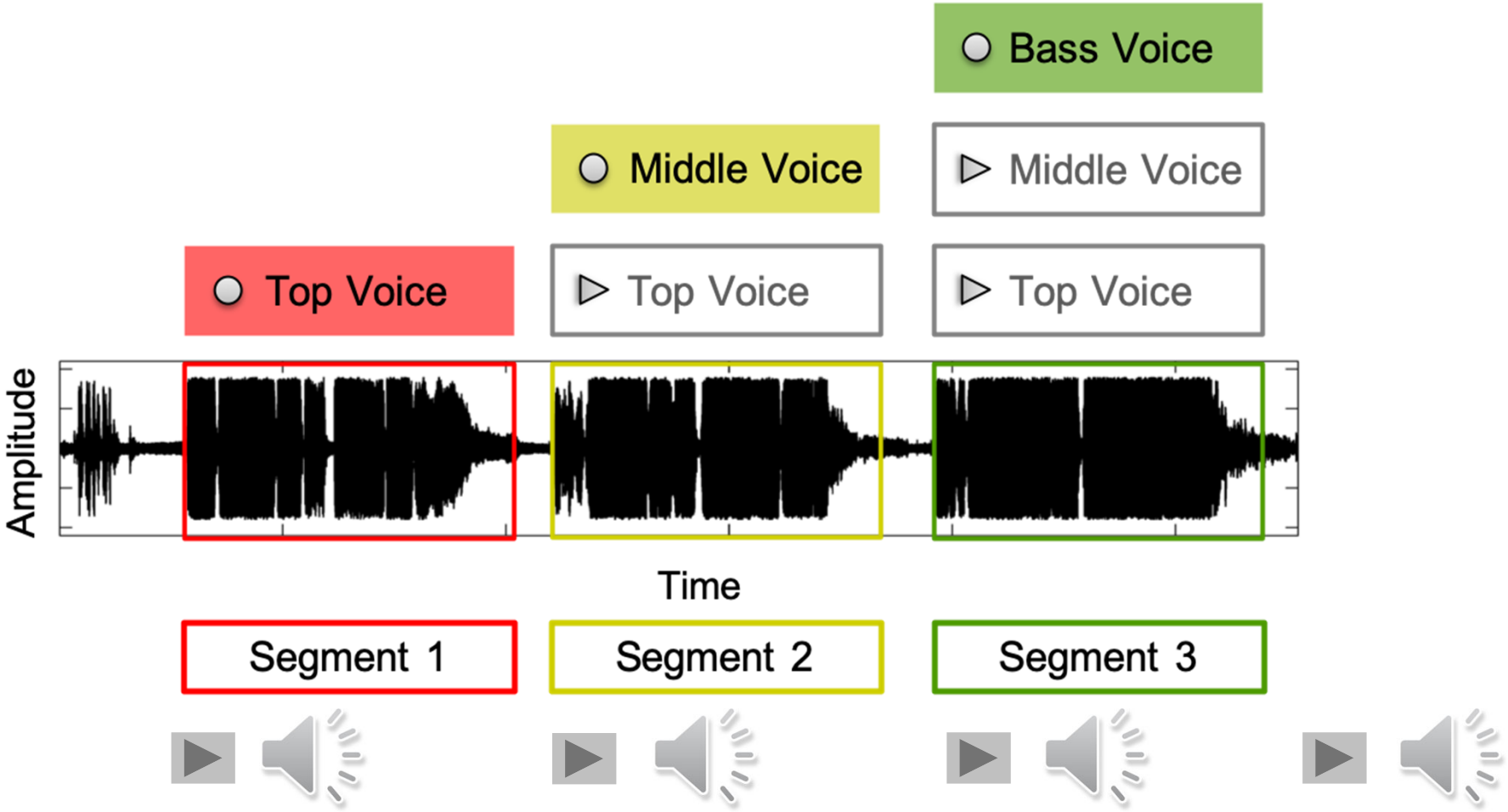
Example: Erkomaishvili corpus

- Collection of traditional three-voice Georgian songs
- Performed by the former Georgian master chanter Artem Erkomaishvili (1887-1967)
- Recordings of 100 songs using tape recorders (1966)

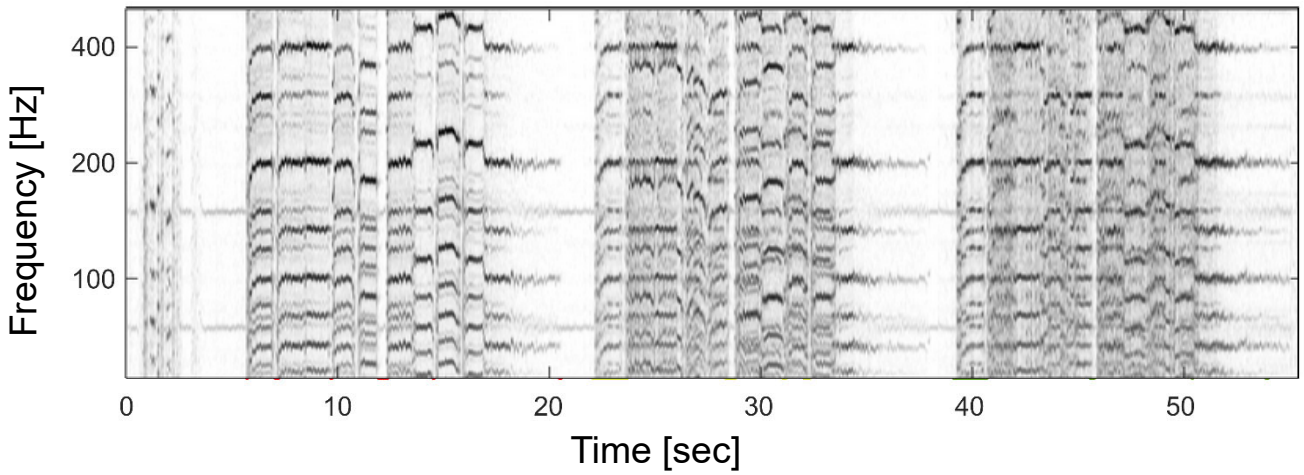
> "*Original masterpieces of Georgian musical thinking.*" (Shugliashvili, 2014)

Traditional Georgian Vocal Music

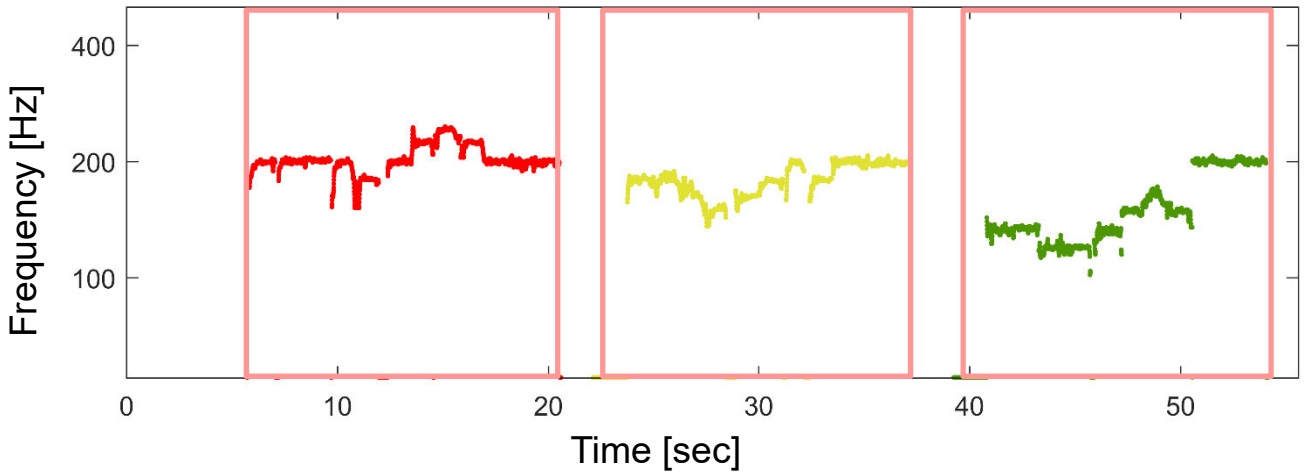
Example: Erkomaishvili corpus



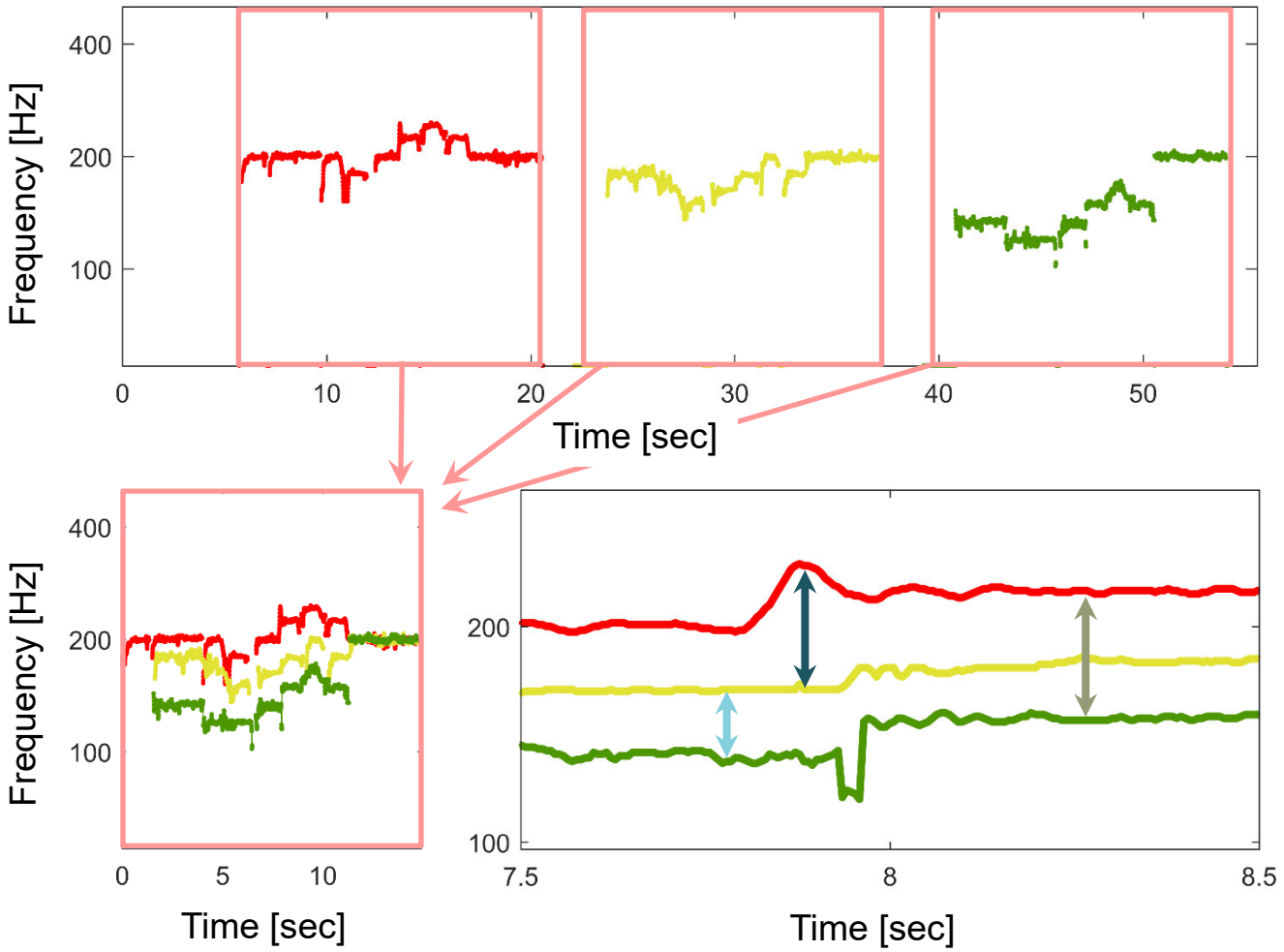
Traditional Georgian Vocal Music



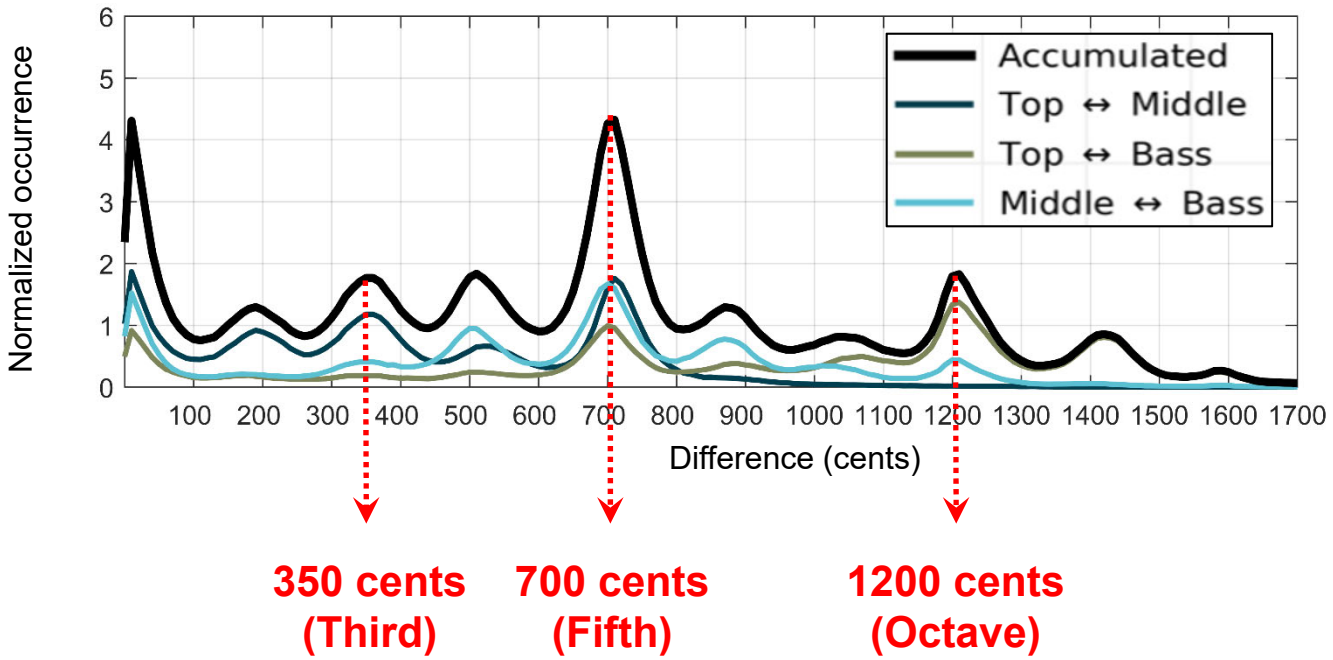
Traditional Georgian Vocal Music



Traditional Georgian Vocal Music



Traditional Georgian Vocal Music



- Peak at 350 cents (between minor and major third)
- **Non-western temperament**

Traditional Georgian Vocal Music

- Recordings from field expedition in 2016
- 216 performances
- Multitrack audio + video
  - Room, HSM, LRX
- Total duration: 6 h

Room Microphone

Traditional Georgian Vocal Music

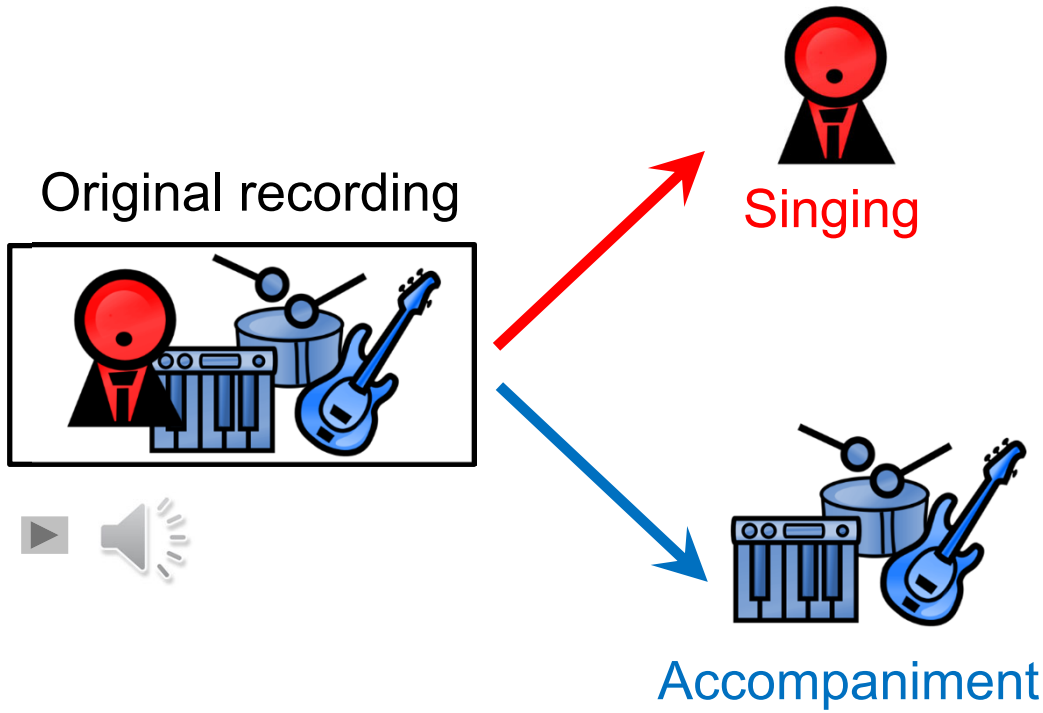
- Musical scales
- Harmonic / melodic intervals
- Singer interaction
- Curation of music corpora
- New sensors
  (larynx microphones)

Honorary doctorate (2022)
State Conservatory of Georgia

Frank Scherbaum

Computational Audio Analysis

Source separation



Reference
SP
AI

Reference
SP
AI

- Reference: Best possible result
- SP: Using traditional signal processing
- AI: Using data-driven approach

Computational Audio Analysis

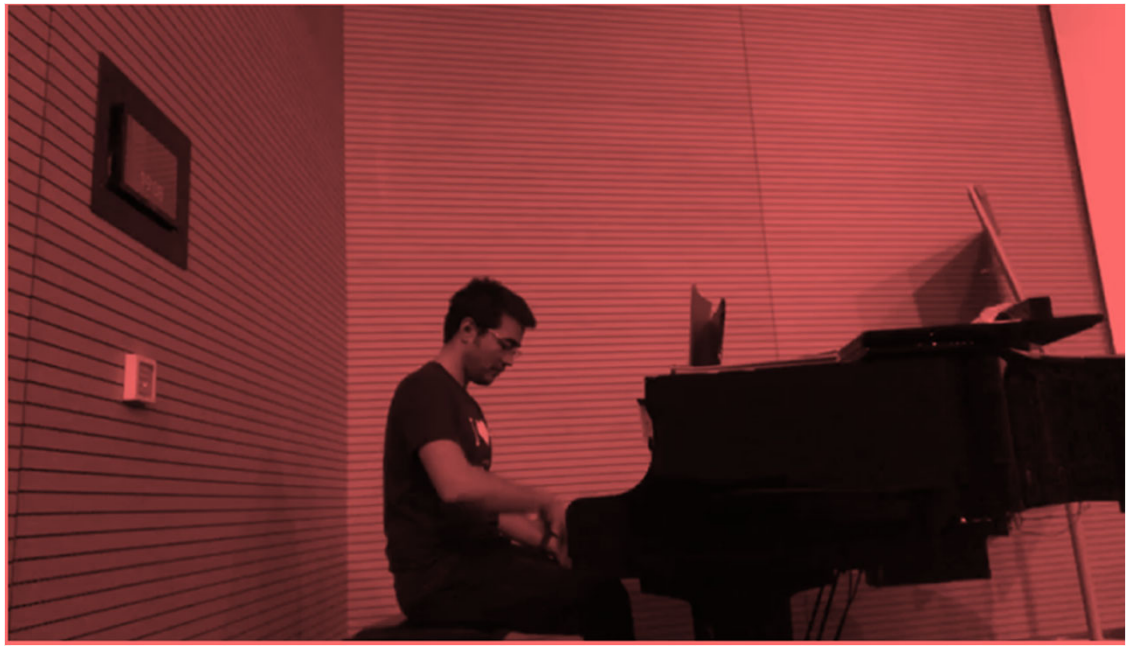
Source separation

- Yigitcan Özer
- PhD student in engineering
- Pianist

Computational Audio Analysis

Source separation

- Yigitcan Özer
- PhD student in engineering
- Pianist

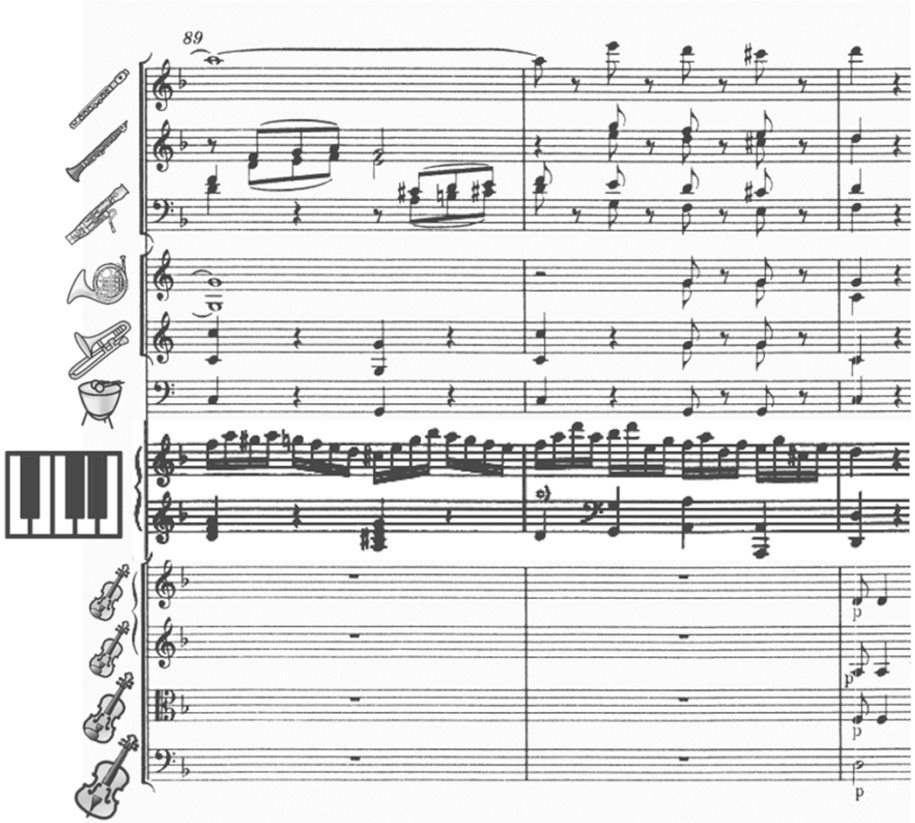


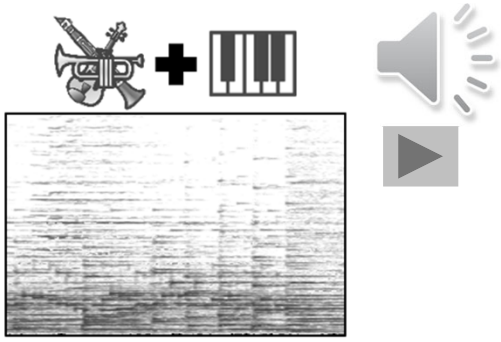
Only Piano!

Where is the orchestra?

Computational Audio Analysis

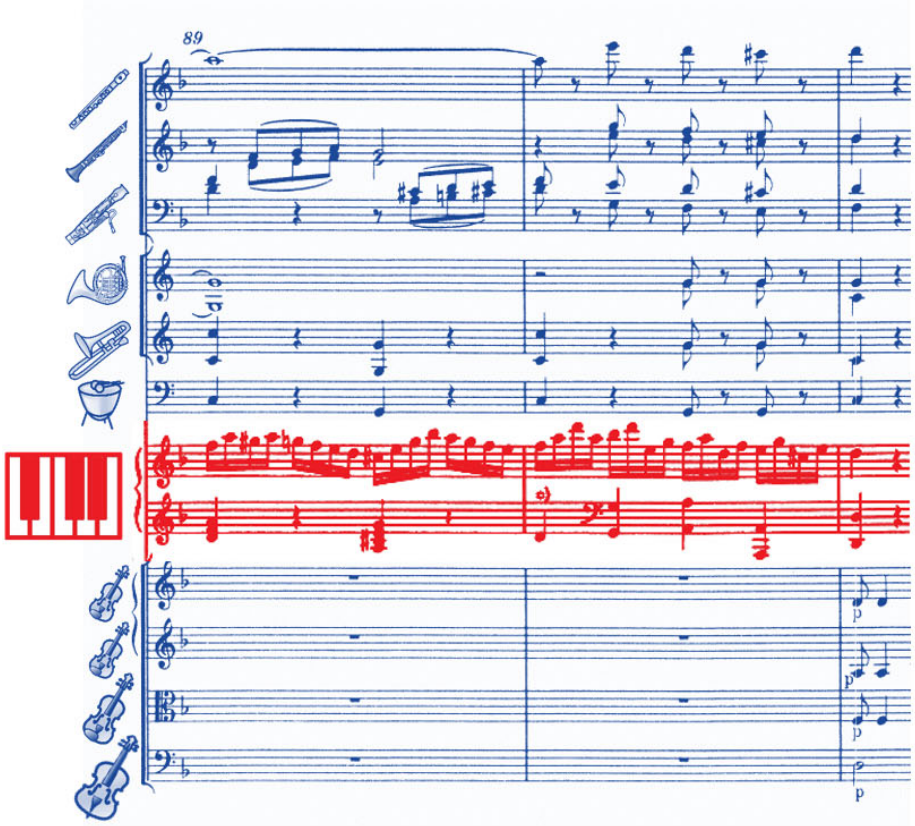
Source separation

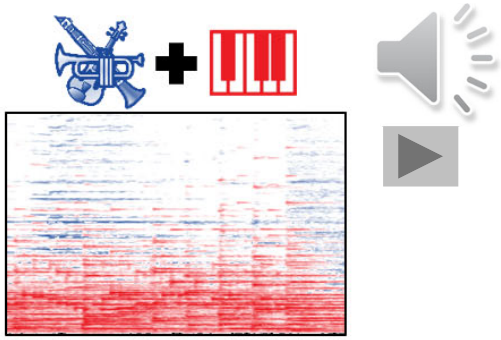




Computational Audio Analysis

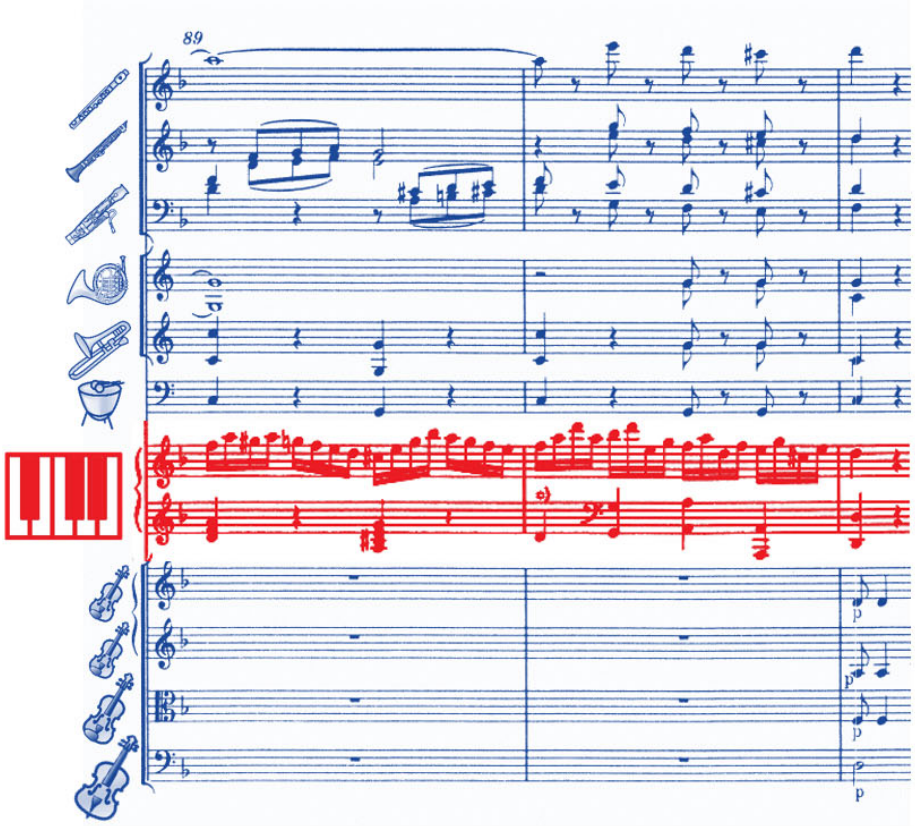
Source separation

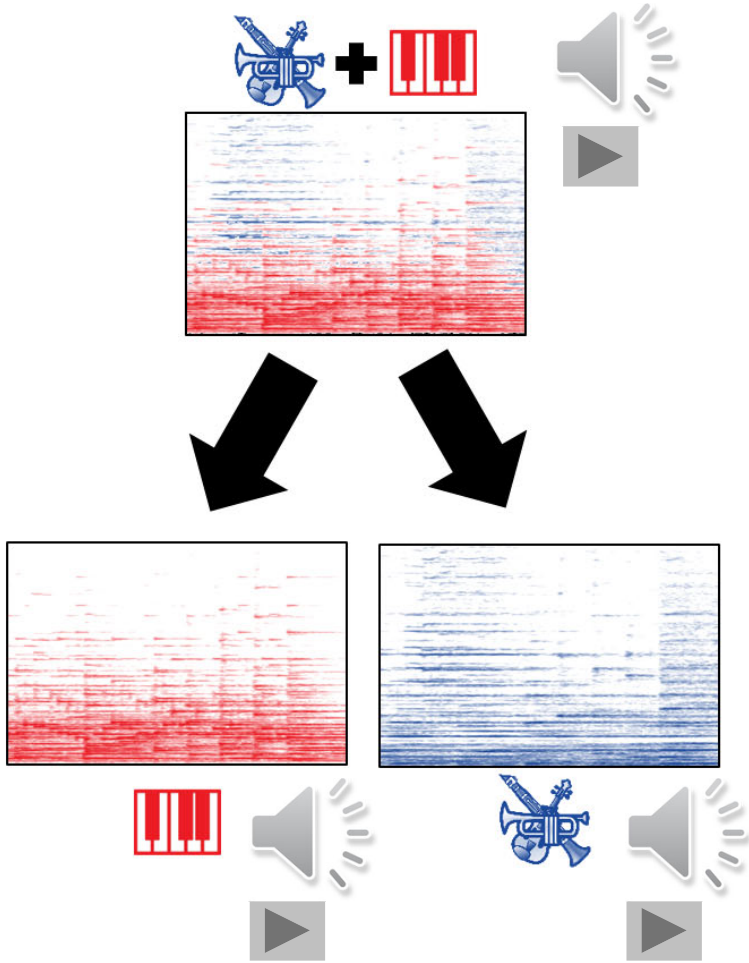




Computational Audio Analysis

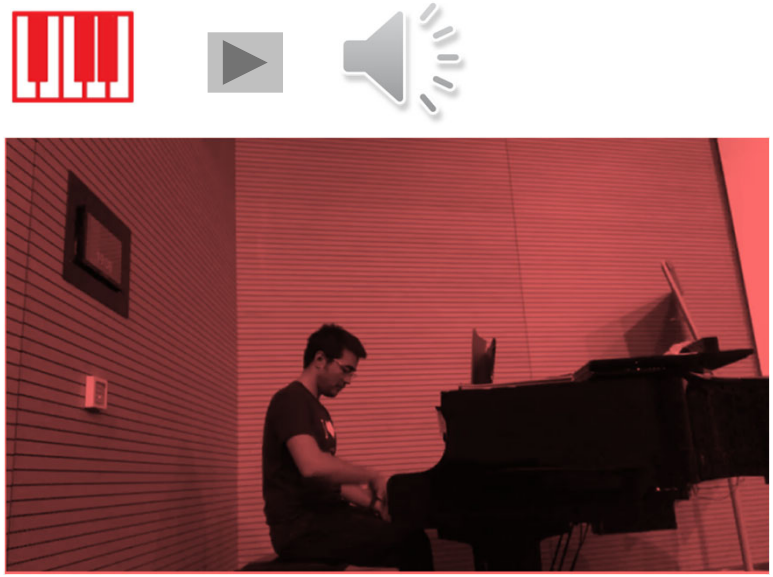
Source separation

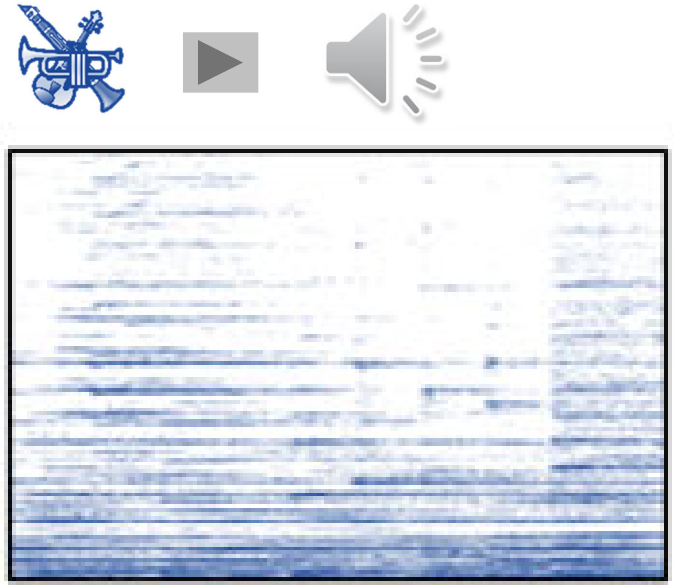




Computational Audio Analysis

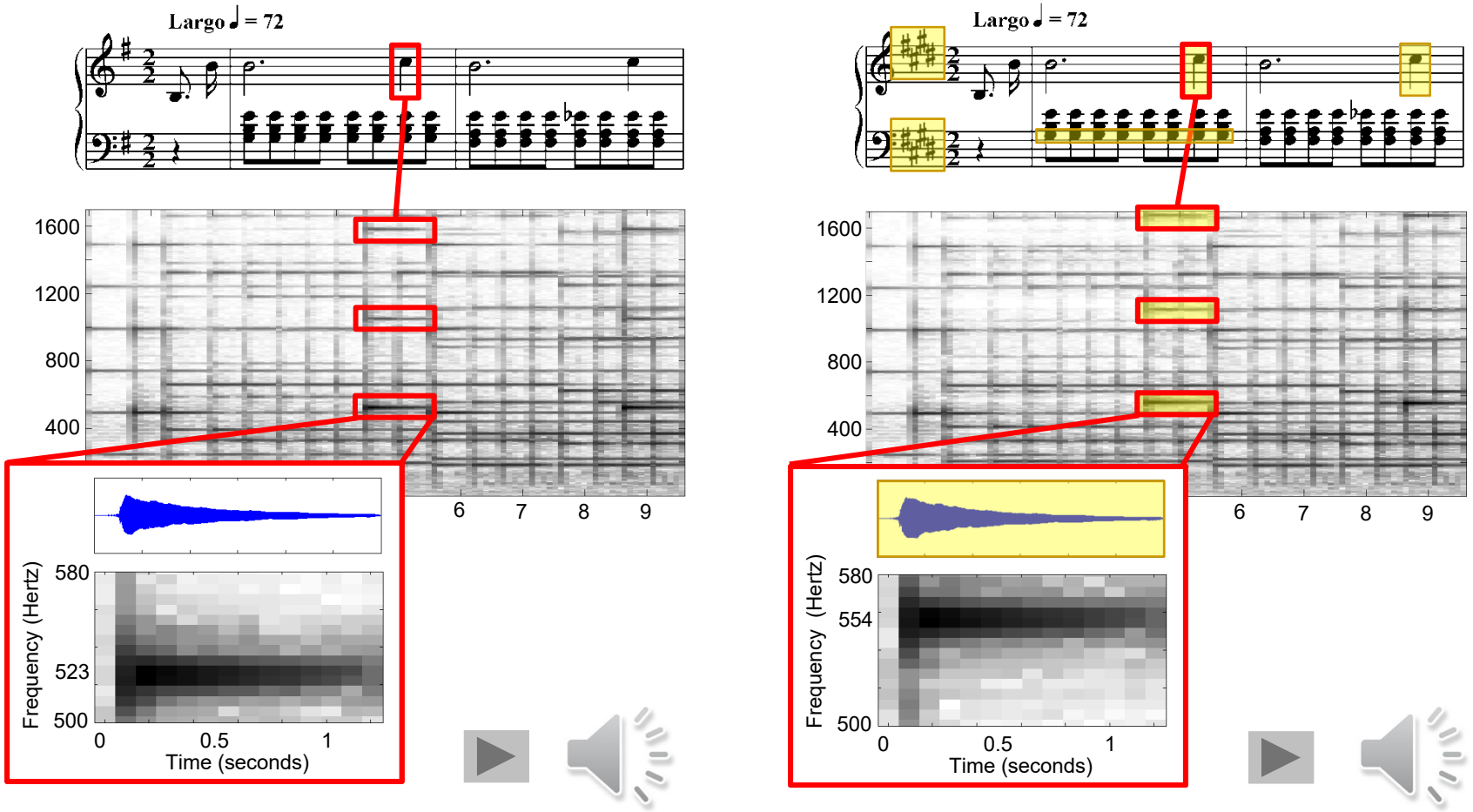
Source separation





Computational Audio Analysis

Score-informed audio decomposition

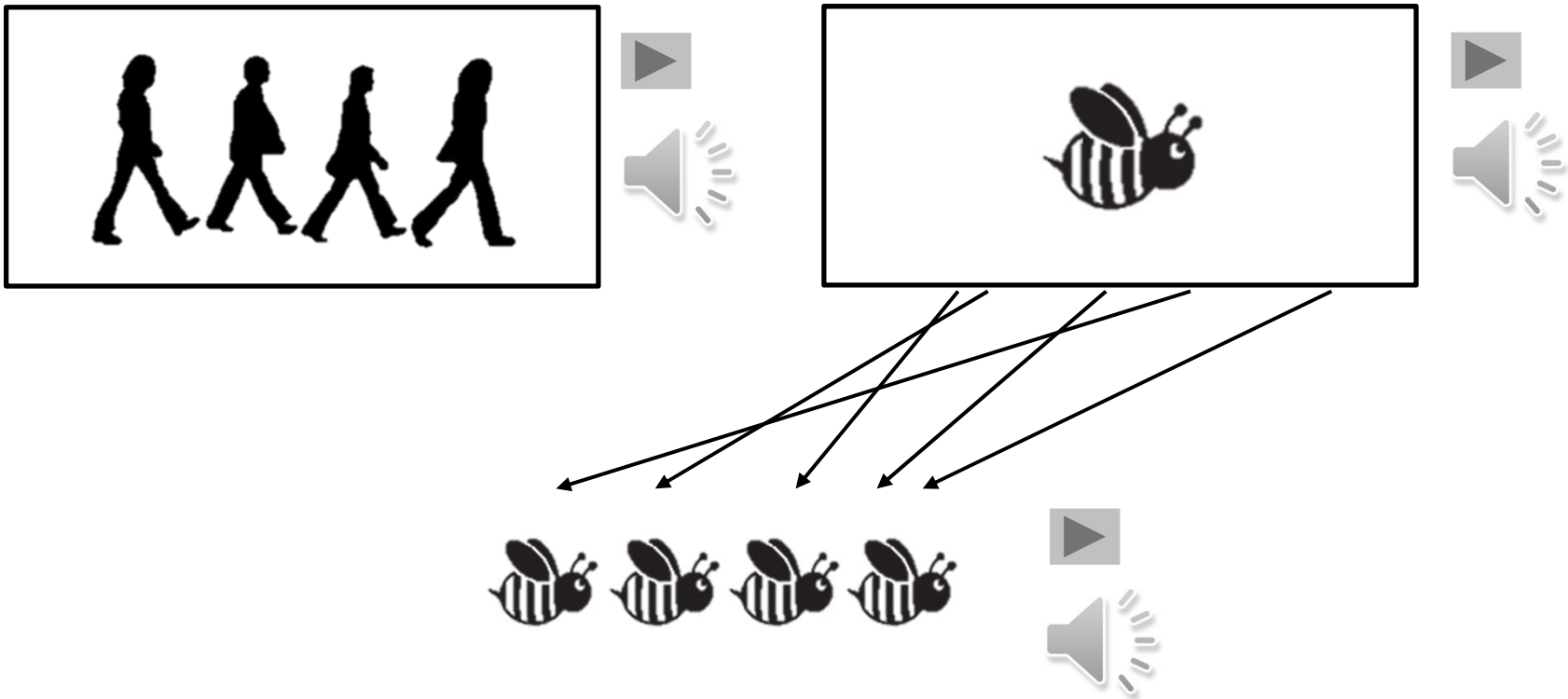


Computational Audio Analysis

Audio mosaicing (style transfer)

Target signal: Beatles–Let it be

Source signal: Bees



Mosaic signal: Let it Bee

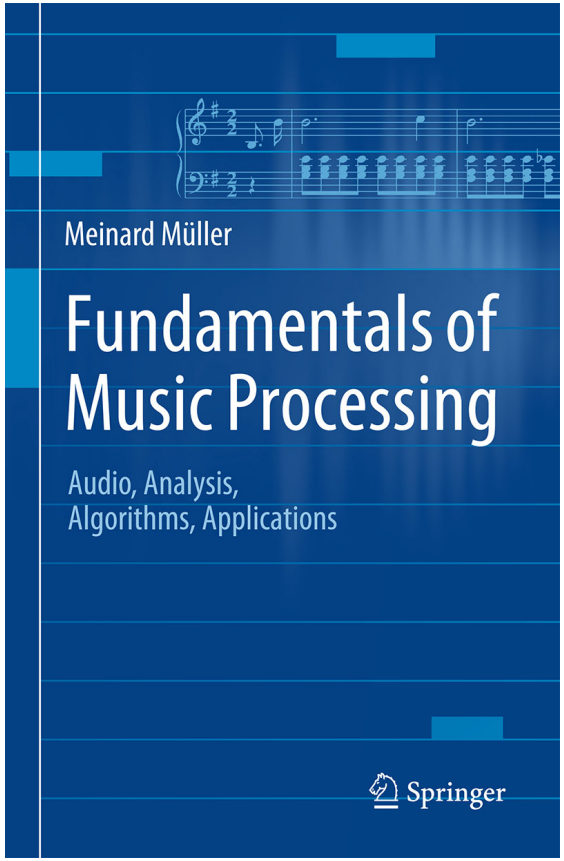
Computational Audio Analysis

- Understanding modern machine learning techniques
- Critical questioning of artificial intelligence (AI) concepts
- Developing explainable AI models
- Educating next generation of scientists
- …

Neue Wege für die Musikforschung

Ziel soll dabei nicht die Ablösung der Historischen Musikwissenschaft durch eine wie auch immer zu definierende Musikinformatik sein, sondern vielmehr ein Dialog zwischen Historischer Musikwissenschaft und Informatik auf der Basis ihrer unterschiedlichen Voraussetzungen und Methoden.

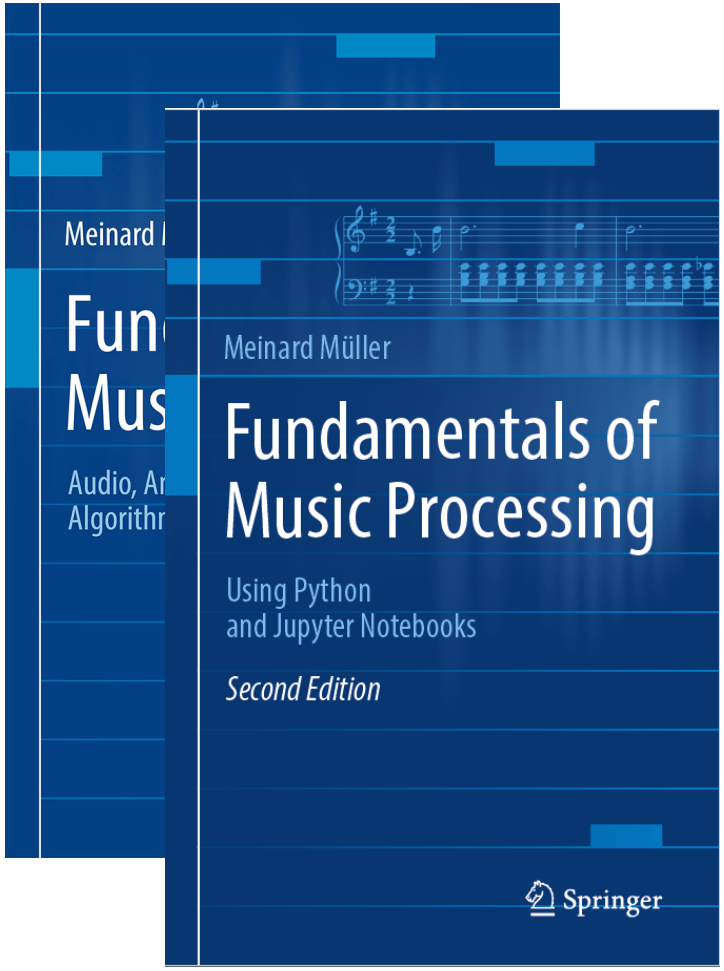
Fundamentals of Music Processing (FMP)



Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
Springer, 2015

Accompanying website:
www.music-processing.de

Fundamentals of Music Processing (FMP)

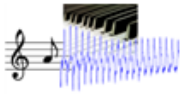
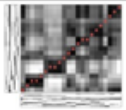
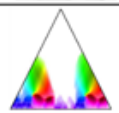
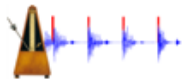
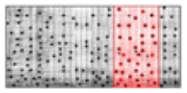
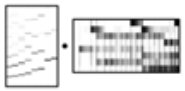


Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
Springer, 2015

Accompanying website:
www.music-processing.de

2nd edition
Meinard Müller
Fundamentals of Music Processing
Using Python and Jupyter Notebooks
Springer, 2021

Fundamentals of Music Processing (FMP)

Chapter		Music Processing Scenario
1		Music Represenations
2		Fourier Analysis of Signals
3		Music Synchronization
4		Music Structure Analysis
5		Chord Recognition
6		Tempo and Beat Tracking
7		Content-Based Audio Retrieval
8		Musically Informed Audio Decomposition

Meinard Müller
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Springer, 2015

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2nd edition
Meinard Müller
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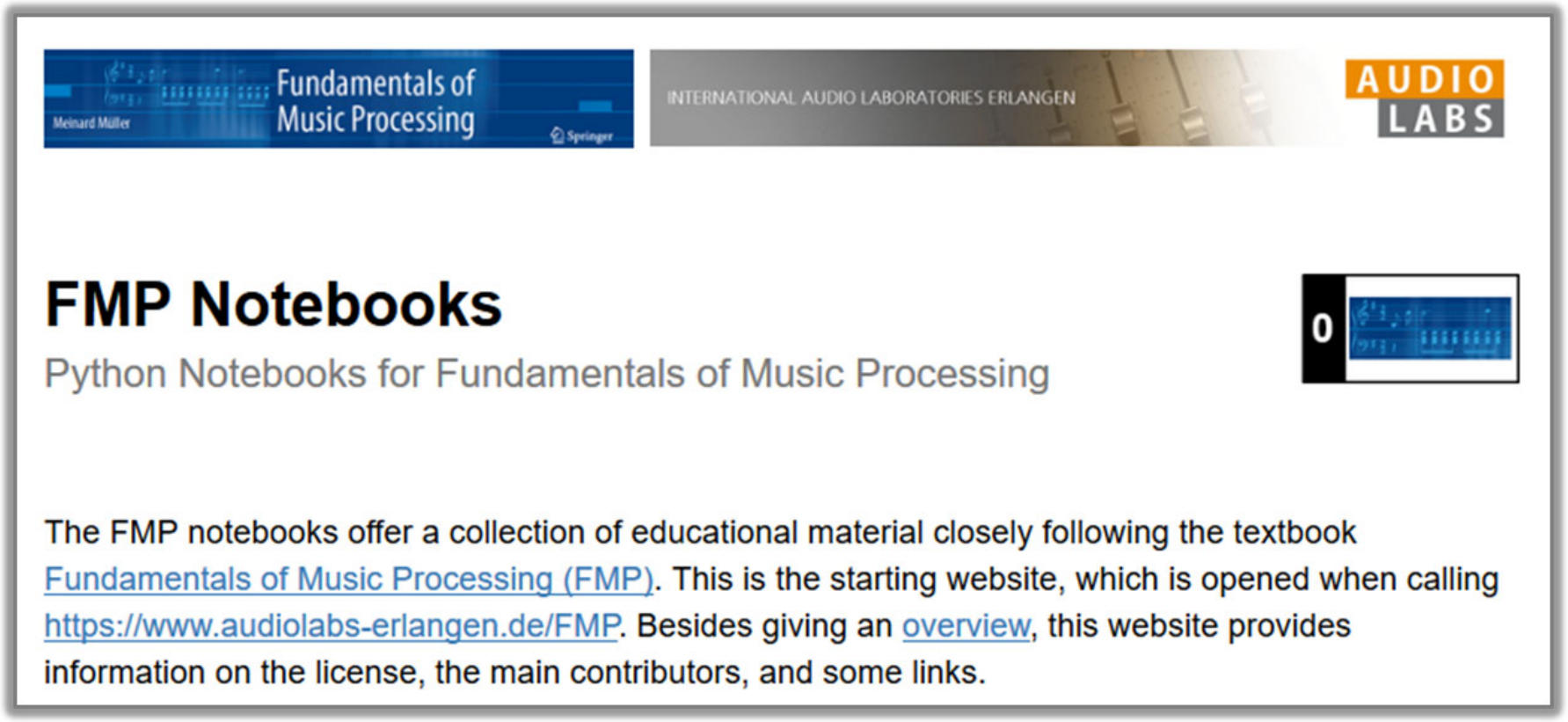
Springer, 2021

FMP Notebooks: Education & Research



https://www.audiolabs-erlangen.de/FMP

References

- Meinard Müller: Fundamentals of Music Processing – Using Python and Jupyter Notebooks. 2nd Edition, Springer, 2021.
  https://www.springer.com/gp/book/9783030698072

- Meinard Müller and Frank Zalkow: libfmp: A Python Package for Fundamentals of Music Processing. Journal of Open Source Software (JOSS), 6(63): 1–5, 2021.
  https://joss.theoj.org/papers/10.21105/joss.03326

- Meinard Müller: An Educational Guide Through the FMP Notebooks for Teaching and Learning Fundamentals of Music Processing. Signals, 2(2): 245–285, 2021.
  https://www.mdpi.com/2624-6120/2/2/18

- Meinard Müller and Frank Zalkow: FMP Notebooks: Educational Material for Teaching and Learning Fundamentals of Music Processing. Proc. International Society for Music Information Retrieval Conference (ISMIR): 573–580, 2019.
  https://zenodo.org/record/3527872#.YOhEQOgzaUk

- Meinard Müller, Brian McFee, and Katherine Kinnaird: Interactive Learning of Signal Processing Through Music: Making Fourier Analysis Concrete for Students. IEEE Signal Processing Magazine, 38(3): 73–84, 2021.
  https://ieeexplore.ieee.org/document/9418542

Resources (Group Meinard Müller)

- FMP Notebooks:
  https://www.audiolabs-erlangen.de/FMP
- libfmp:
  https://github.com/meinardmueller/libfmp
- synctoolbox:
  https://github.com/meinardmueller/synctoolbox
- libtsm:
  https://github.com/meinardmueller/libtsm
- Preparation Course Python (PCP) Notebooks:
  https://www.audiolabs-erlangen.de/resources/MIR/PCP/PCP.html
  https://github.com/meinardmueller/PCP