ÖAW AUSTRIAN ACADEMY OF SCIENCES

Acoustics Research Institute

ARI

Piotr Majdak

The Acoustics Research Institute (ARI)

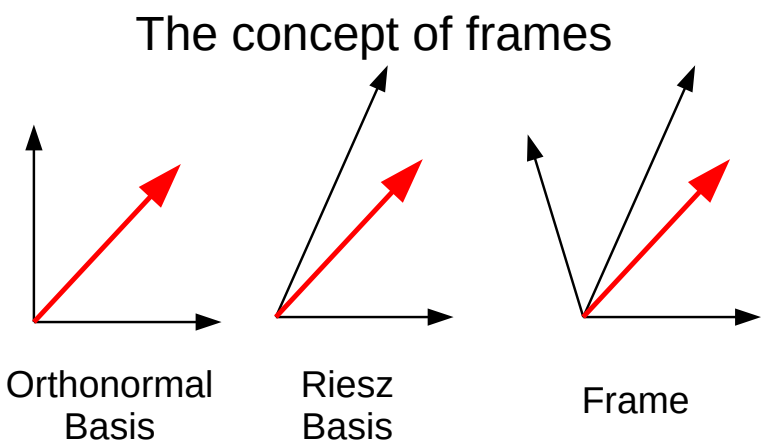
2-9.4.2020, 3GPP TSG SA WG4#108-e meeting

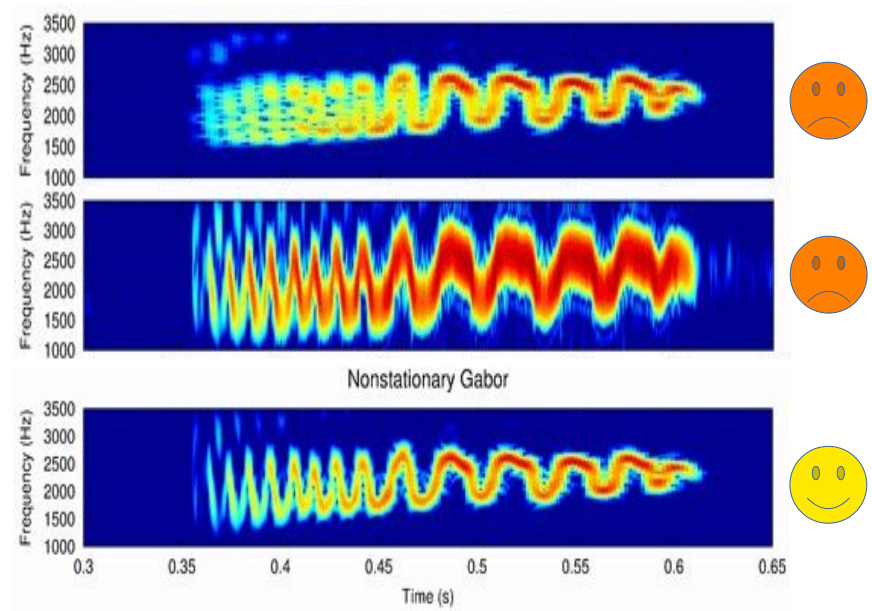
Acoustics Research Institute (ARI)

- Part of the **Austrian Academy of Sciences** (ÖAW):
  - Non-university science institution
  - Founded in 1847 as a learned society
  - 1.700 employees
  - Dedicated to:
    - Innovative **basic research**
    - Interdisciplinary exchange of knowledge
    - The dissemination of new insights
  - 28 research institutes
    - Natural sciences
    - Humanities
    - Social sciences

Acoustics Research Institute (ARI)

- Application-oriented fundamental research in the field of **acoustics and hearing**
- 45 employees, including 35 scientists or Phd's
- Five working groups:
  - Mathematics and Signal Processing in Acoustics





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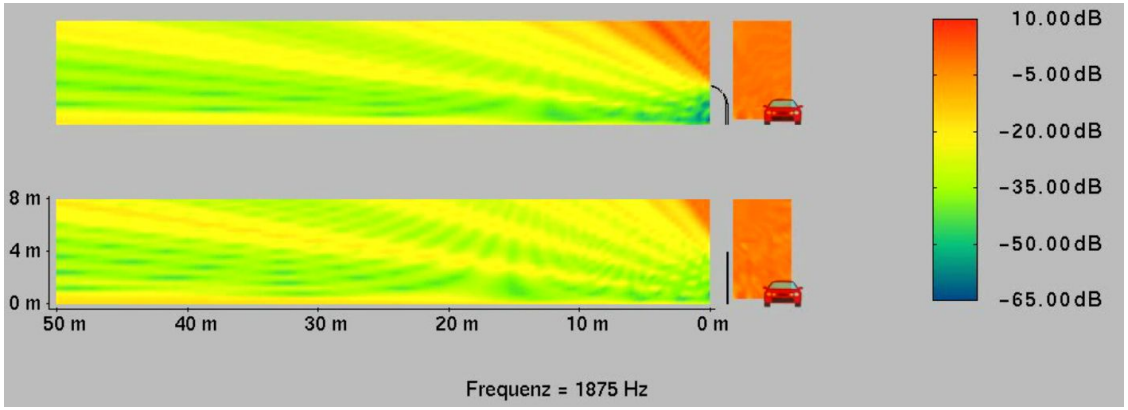

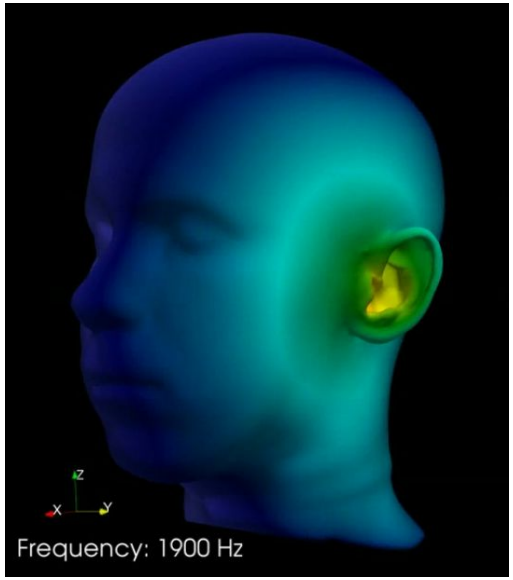

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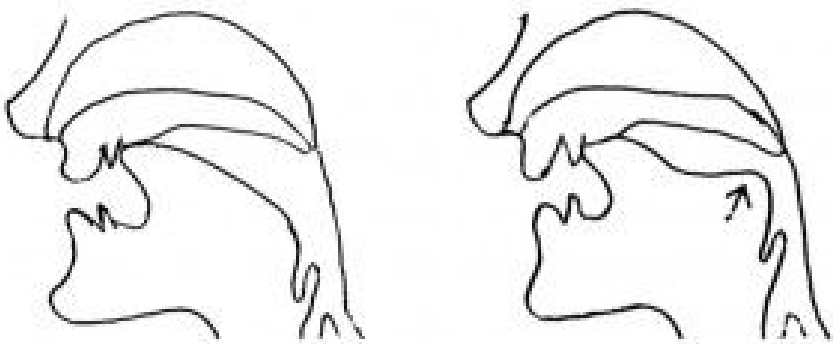

Speech production and dialects: clear / *l* / dark / *l* /

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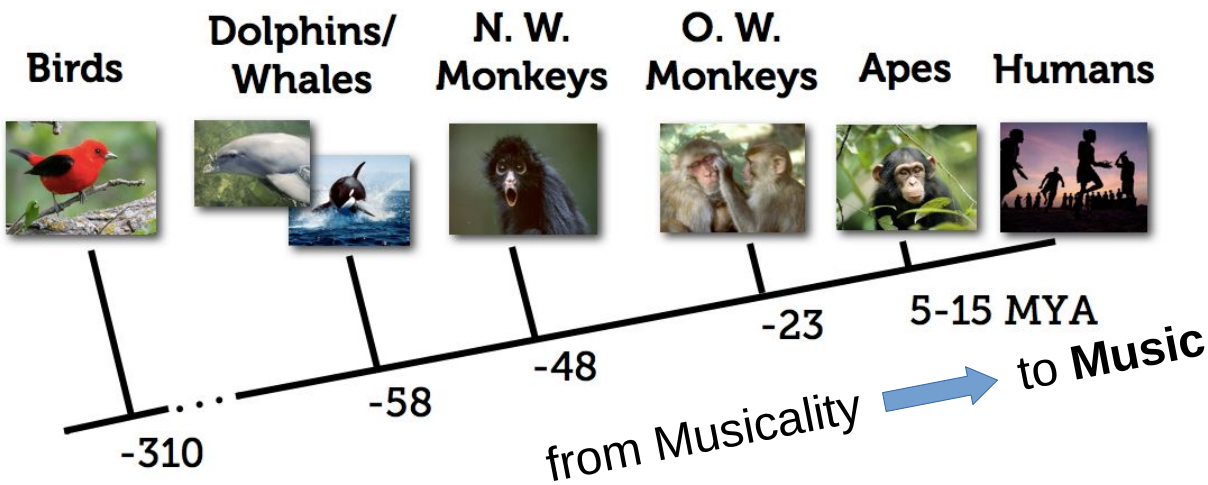
  - Musicality and Bioacoustics



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  - **Psychoacoustics and Experimental Audiology**

Psychoacoustics & Experimental Audiology

- Fundamental and applied research in **psychoacoustics**
- Goals:
  - Study **auditory perception** in human listeners
  - Advance **auditory models**
  - Develop methods to **compensate for hearing deficits**
  - Pave road for perception in **audio applications**
- Run laboratory facilities for the research

Output of ARI

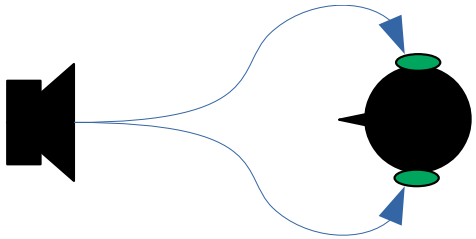
- Journal publications (> 300 journal papers since 2010)
- Conference contributions (presentations, sessions)
- Standards, e.g.:
  - Room acoustics for classrooms/kindergardens
  - Noise requirement for heat pumps
  - Data representation for spatial audio
- Software toolboxes, e.g.:
  - Large Time-Frequency Analysis Toolbox (LTFAT)
    - Resources: **https://ltfat.github.io/**
  - Auditory Modeling Toolbox (AMT)
    - 29 auditory models and over 30 data sets
    - Resources: **http://amtoolbox.sourceforge.net/**

Reach out

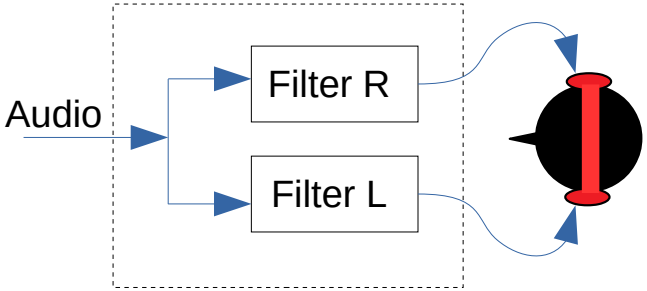
- Linked with local universities:
  - Vienna: University, Technical University, University of Music, various Universities for Applied Sciences
  - Graz: University of Music, Technical University
  - Munich: Technical University
- Integrated in the audio/acoustical landscape:
  - Members of international associations, e.g., ASA, IEEE, AES, ARO
  - Active members of local societies:
    - Austrian Acoustics Association (ÖGA)
    - German Acoustical Society (DEGA)
    - Chair of the Austrian Section of the AES (AES-Austria)
  - Scientific advice to local industry
    - **Note**: No commercial work

ARI and 3GPP (SA4)

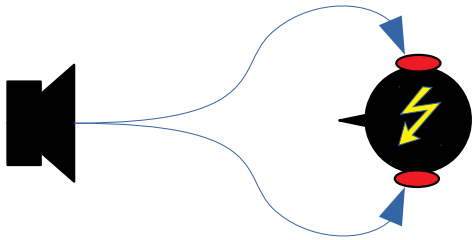
- Fundamental research on spatial auditory perception
  - **Various hypotheses on realistic sound reproduction**
- Behavioral experiments in human listeners:
  - Free field:



  - Via headphones:



  - Via hearing assistive devices:

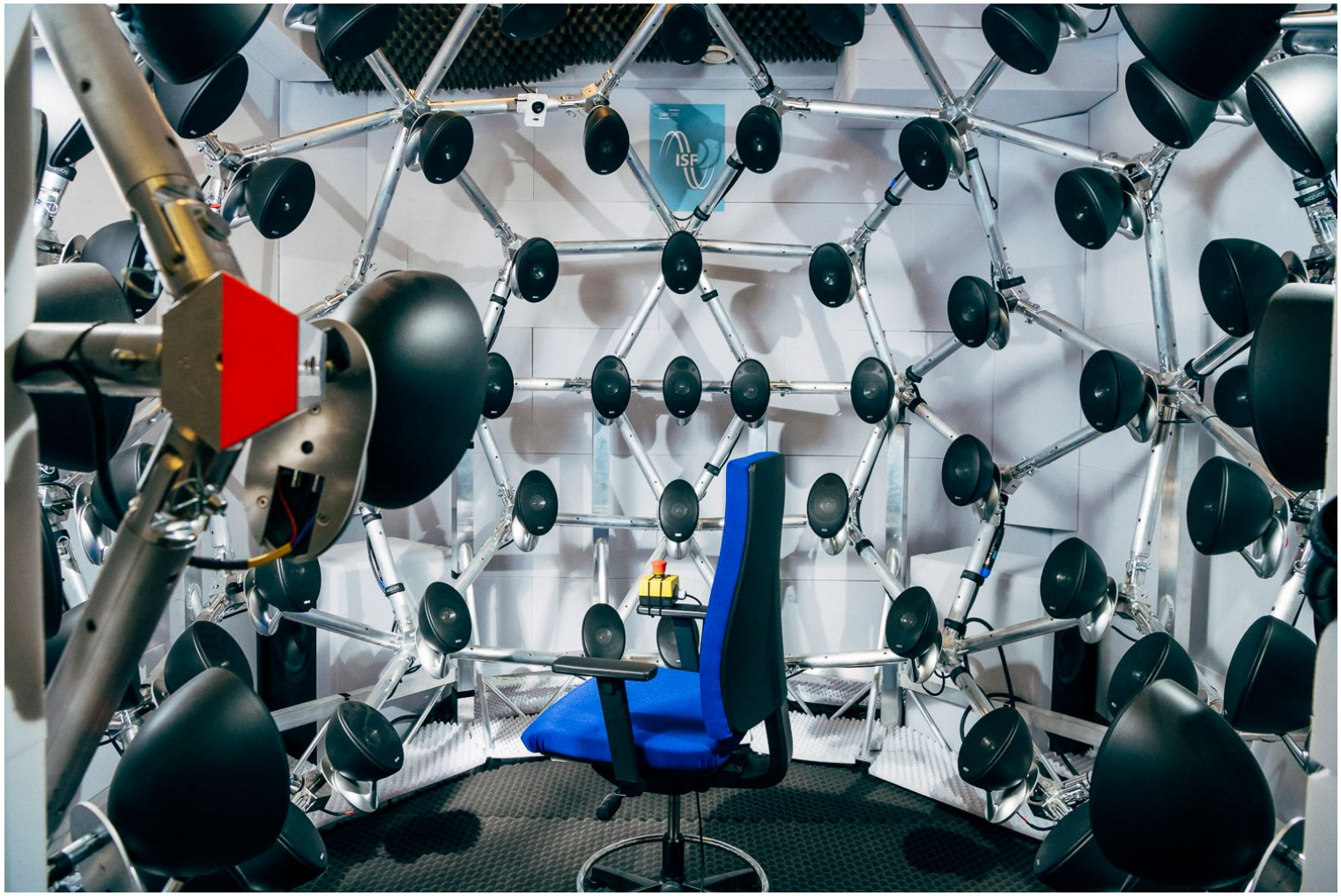


Psychoacoustic experiments

- Traditional, via headphones, in a sound booth:

Psychoacoustic experiments

- Via loudspeakers, virtual acoustics:

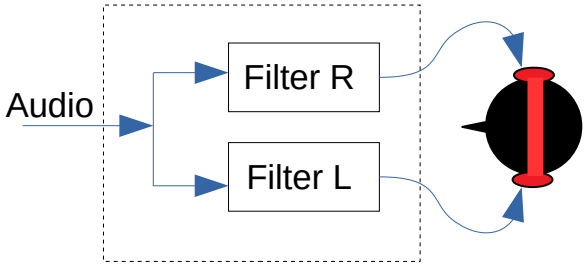


Psychoacoustic experiments

- VR: Virtual acoustics and headset:

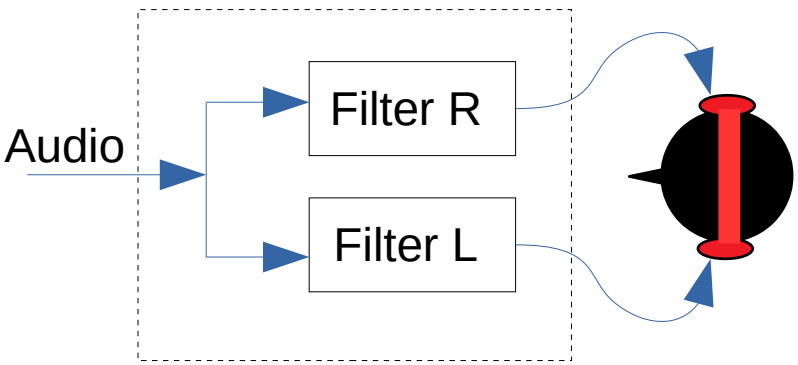
Psychoacoustic experiments

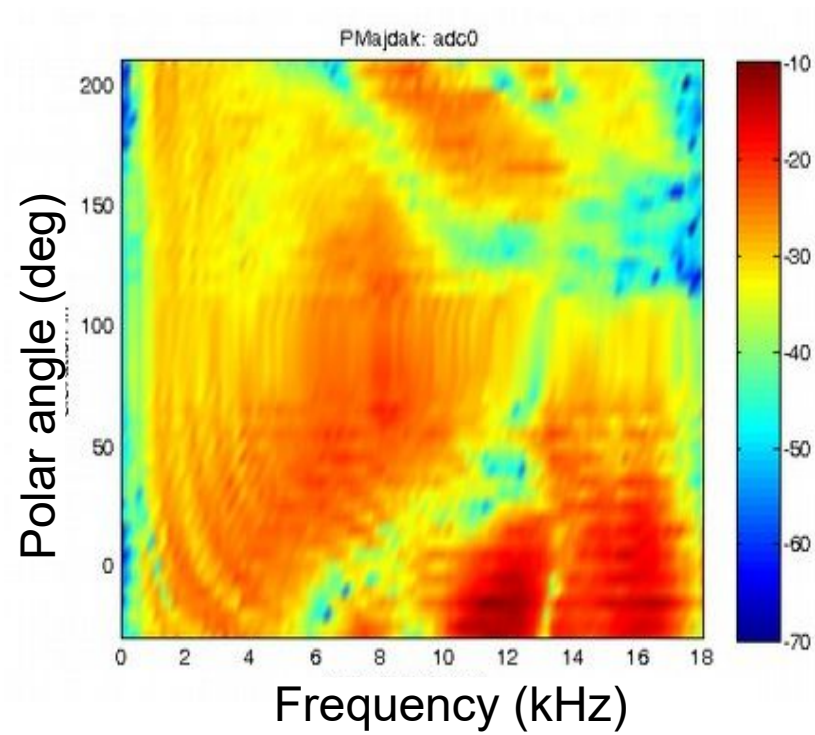
- Binaural virtual acoustics: (Majdak et al., 2010, 2011)



Binaural virtual acoustics

– Required: Head-related transfer functions (HRTFs)



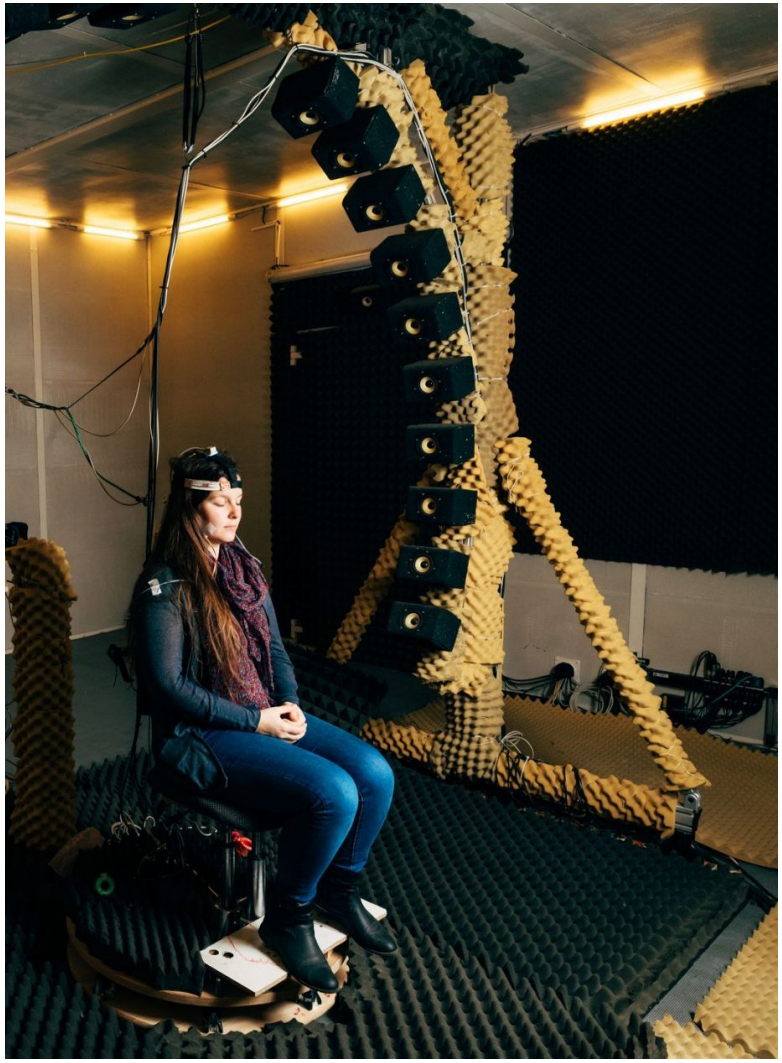


– Binaural set of HRTFs:
  - Broadband interaural time and level differences (ITDs, ILDs)
  - Spectral cues (monaural, interaural)

Acquisition of listener-specific HRTFs

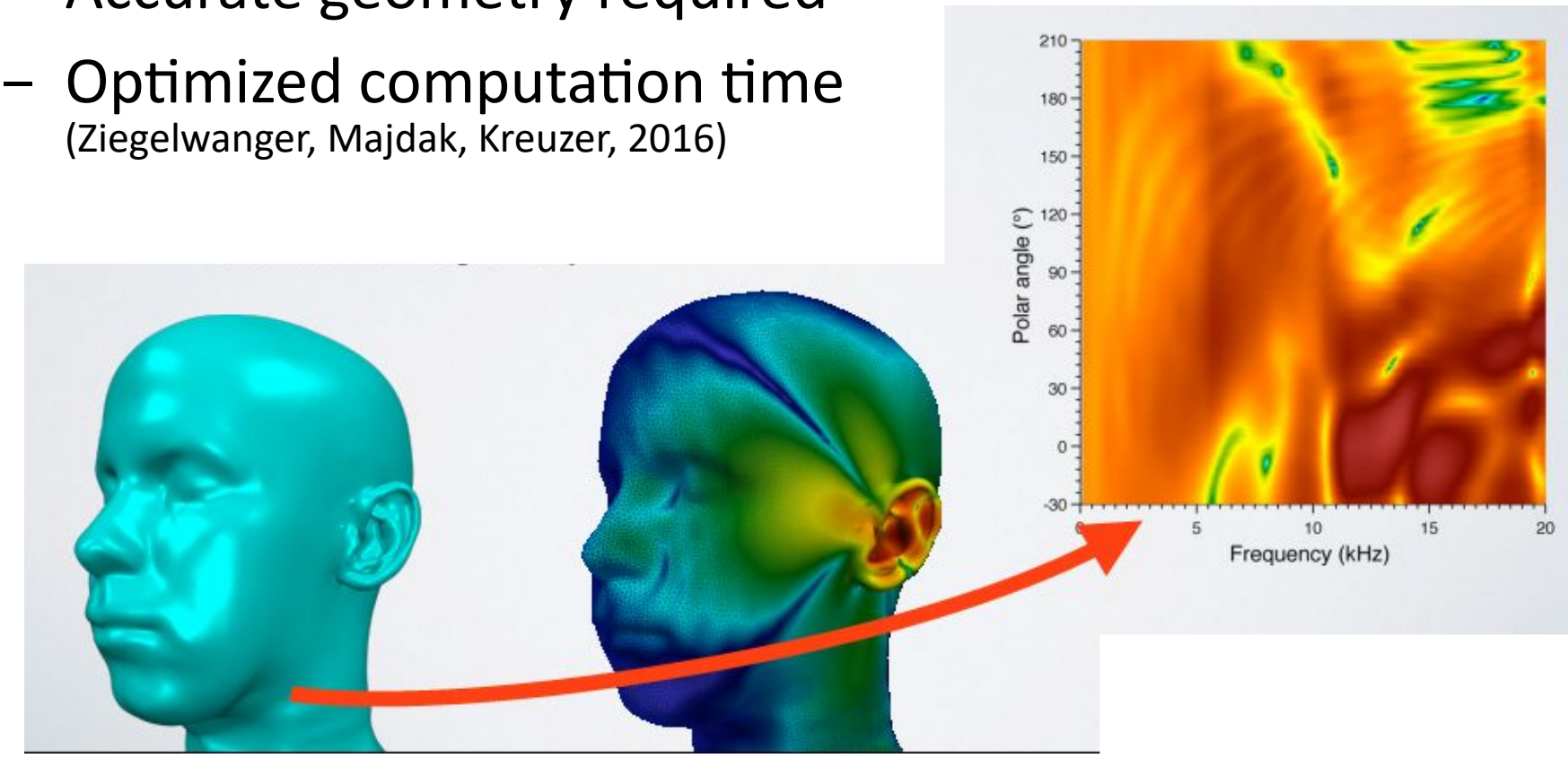
- Classical way: Acoustic system identification

- Our setup:
  - Multiple Exponential Sweep Method (Majdak et al., 2007)
  - Measurement of 1550 positions in 16 minutes
  - Since 2005 over 300 listeners measured



Acquisition of HRTFs: Numeric calculation

- Boundary-element method (BEM) coupled with fast multipole (Kreuzer, Majdak, Chen, 2009)
- Software package: Mesh2HRTF (Ziegelwanger, Majdak, Kreuzer, 2015)
  - Accurate geometry required
  - Optimized computation time (Ziegelwanger, Majdak, Kreuzer, 2016)



ARI testing capabilities

- Behavioral experiments in human listeners:
  - Traditional (**headphones**): Two sound booths
  - Virtual acoustics (**loudspeaker array,** including all **surround setups**)
  - Binaural virtual acoustics (headphones & **listener-specific HRTFs**)
  - **Virtual-reality** environments, real-time tracked
  - 64-channel EEG recordings
- Acoustic measurements:
  - 95-channel loudspeaker array
  - Semi-anechoic sound chamber
  - Access to local anechoic chambers and recording studios
- Access to a large pool of test subjects
- Own software framework for testing (http://sf.net/projects/**ExpSuite**)
- Decades of experience in handling testing issues (logistics, ethics, etc)

ARI and 3GPP (SA)

- **Spatially oriented** file **format** for description of **acoustic** systems (SOFA):
  - ARI as development leader (Majdak et al., 2013)
  - File format for any spatial acoustic system:
    - Free-field HRTFs, binaural room impulse responses (BRIRs)
    - Directional room impulse responses (DRIRs via microphone arrays)
    - Headphone data, loudspeaker-array data
  - Machine independent, Huge-file support, Partial data access, Data compression (GZIP)
- Standard of the Audio Engineering Society (AES69)
- **Noted by 3GPP in 5G**; 3GPP Virtual reality profiles for streaming applications (3GPP TS 26.118 version 15.0.0 Release 15)
- Picked up by companies (e.g., Unity, part of Ubuntu distribution)
- Under revision this years:
  - Ambisonics for spatially-continuous representation of directivities
  - Multiperspective for walk-through VR
  - MIME type for .SOFA extension
- Resources: **http://www.sofaconventions.org/**

Acoustics Research Institute (ARI)

- Governmental-funded institution
  - Multidisciplinary application-oriented fundamental research
- Collaborative daily work
- Experience in working on standards
- Longstanding expertise in conducting behavioral experiments in human listeners:
  - Traditional (headphones)
  - Virtual acoustics (loudspeaker arrays)
  - Binaural virtual acoustics (headphones & HRTFs)
  - Virtual-reality environments, real-time tracked