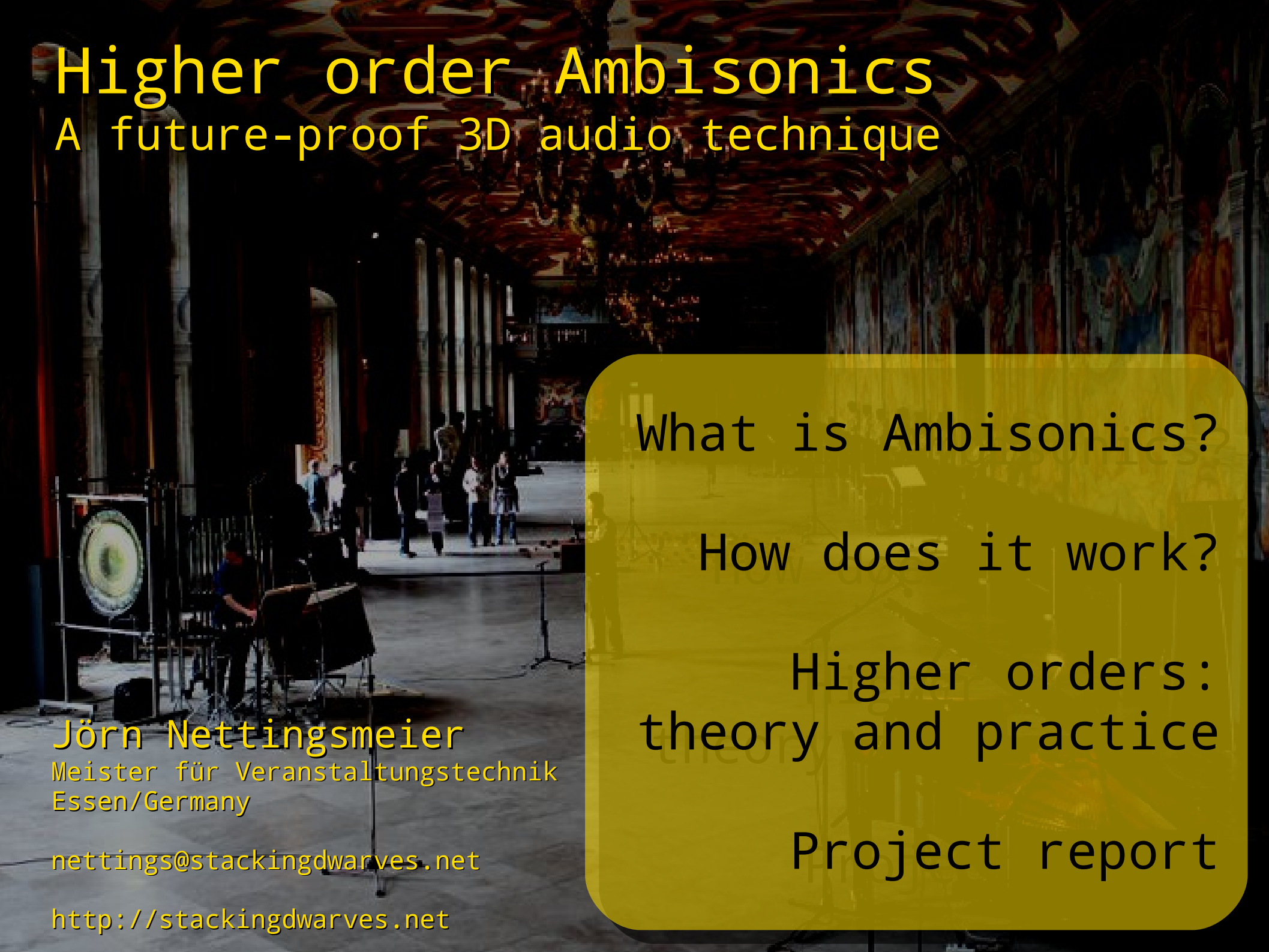
Higher order Ambisonics

A future-proof 3D audio technique



What is Ambisonics?

How does it work?

Higher orders: theory and practice

Project report

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http://stackingdwarves.net

Ambisonics is...

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...just a signal representation. It is not equivalent or limited to the sound field microphone.

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...based on the concept of spatial sampling. Just as in temporal sampling, you can scale the sampling density to the desired resolution.

...independent of the consumer's speaker layout.

...systematic and mathematically sound, making optimal use of hardware and transmission bandwidth (three channels for basic horizontal home surround!).

Also, Ambisonics...

...degrades gracefully when playback capabilities are limited.

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...allows for very reasonable automatic fold-downs to stereo or 5.0.

...provides perfectly smooth panning, without timbral or focal changes.

...is fully isotropic, i.e. it works equally well in all directions.

...naturally includes height, without requiring special case panning.

The Kirchhoff-Helmholtz Integral

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The Kirchhoff-Helmholtz Integral

“If you know the sound pressure and velocity in any point on the surface of a source-free volume, you have complete knowledge of the sound field inside.”

The Kirchhoff-Helmholtz Integral

= If you can record the boundary,

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The Kirchhoff-Helmholtz Integral

= If you can record the boundary,

“If you know the sound pressure and velocity in any point on the surface of a source-free volume, you have complete knowledge of the sound field inside.”

you can reproduce the entire inside!

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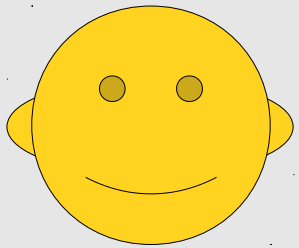
The Kirchhoff-Helmholtz Integral

Consider a spherical volume that encloses the listener:



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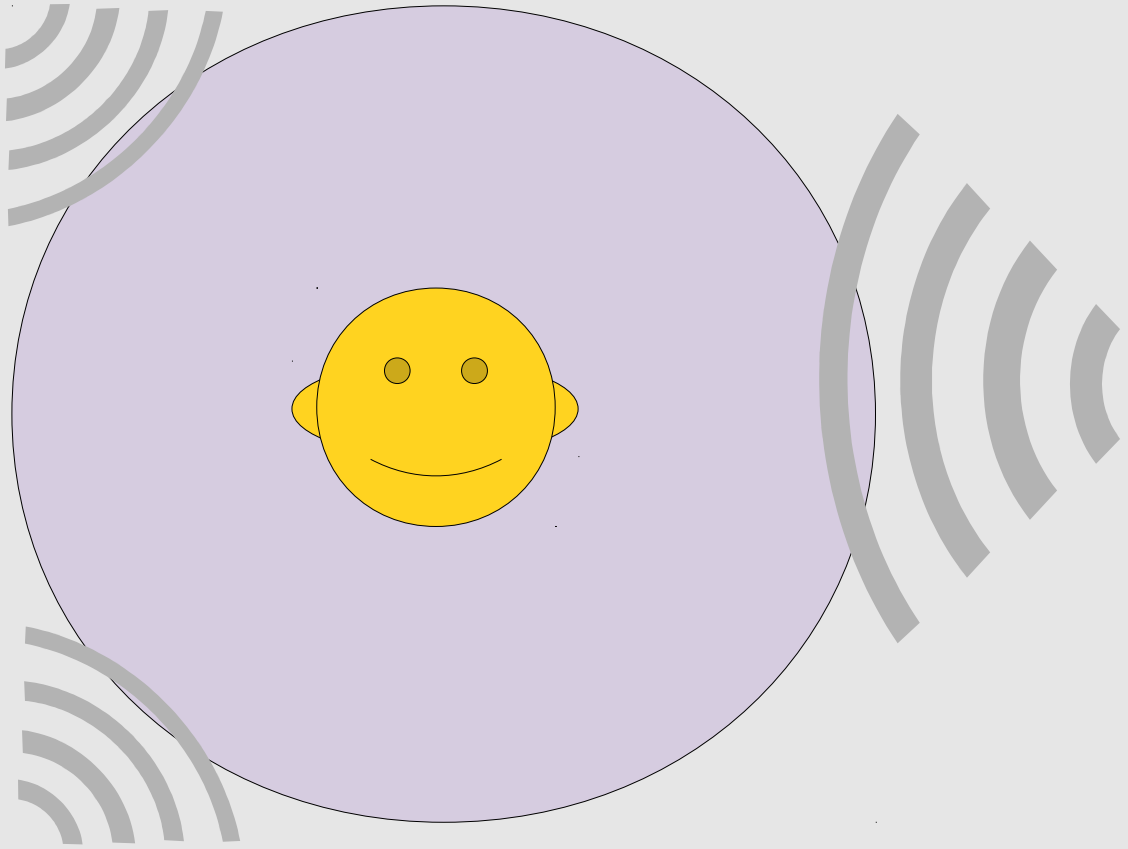
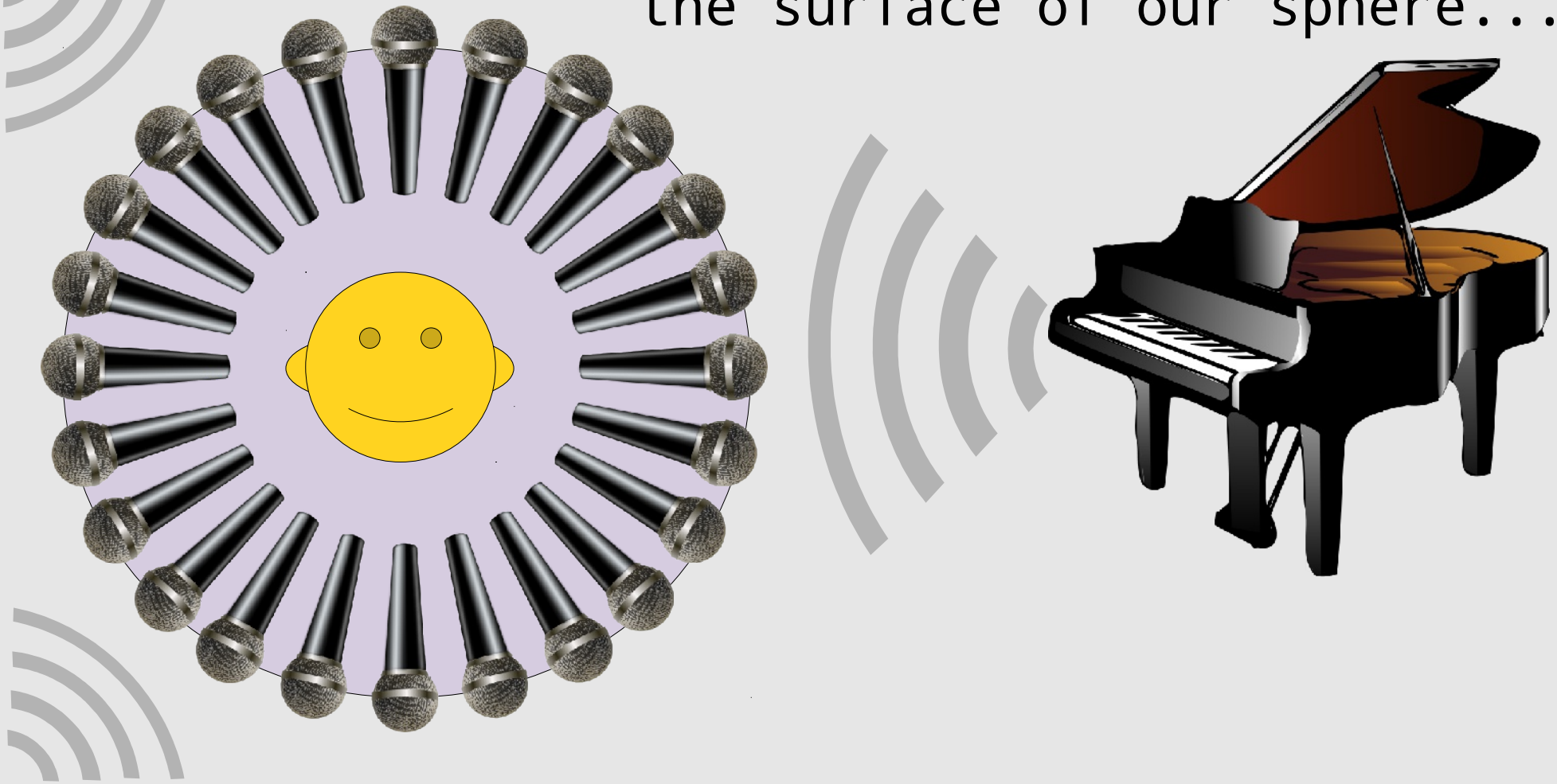
The Kirchhoff-Helmholtz Integral



The Kirchhoff-Helmholtz Integral

If we put an infinite number of mics all over the surface of our sphere...



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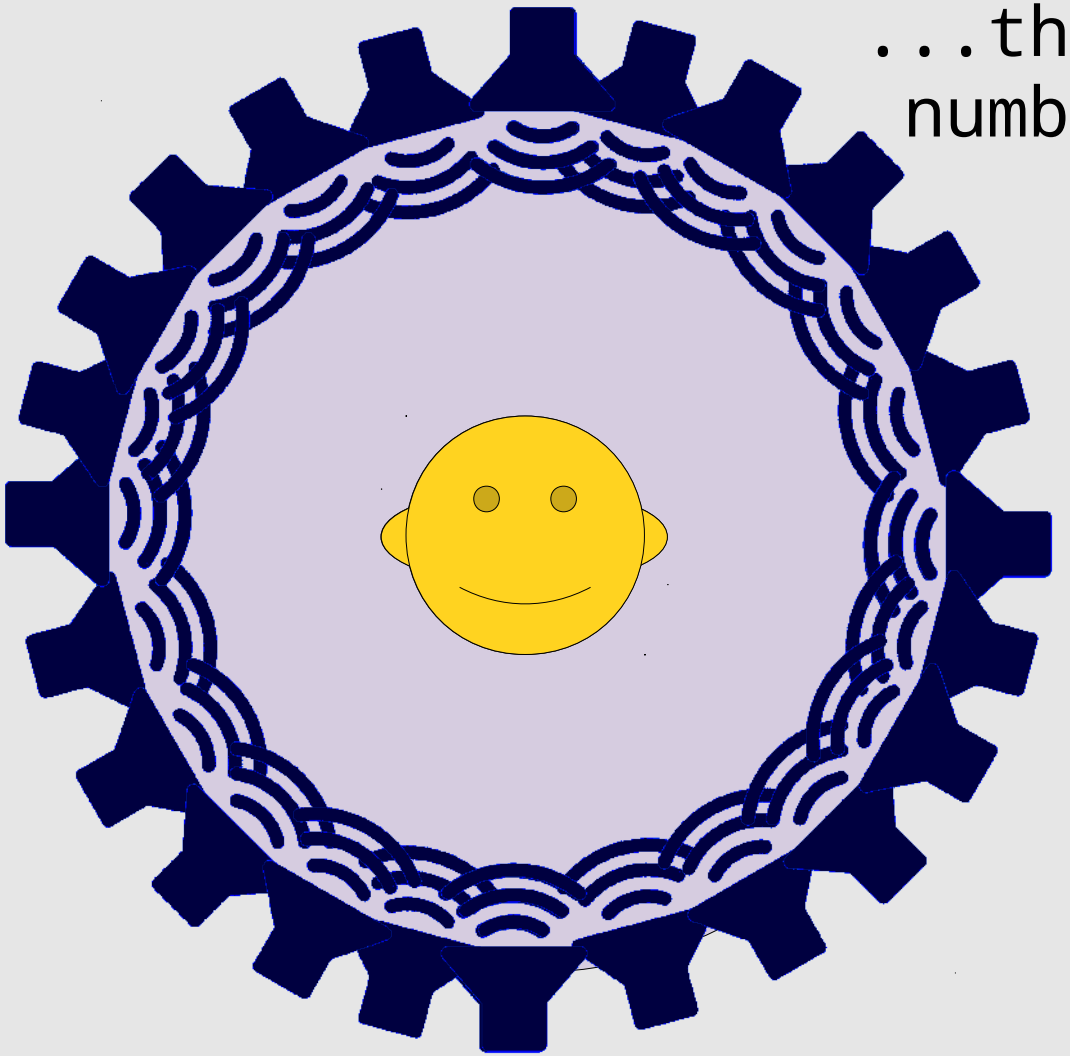
The Kirchhoff-Helmholtz Integral



...then use an infinite number of loudspeakers to play back the recorded signal...

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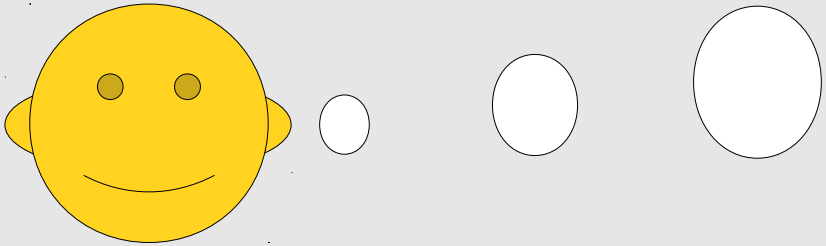
The Kirchhoff-Helmholtz Integral

...the result will be *identical* to the original performance.



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Sampling the sphere

Microphones can be thought of as spatial sampling instruments.

By using their directional characteristics, maybe we can use a *finite* number of mics and still get good results.

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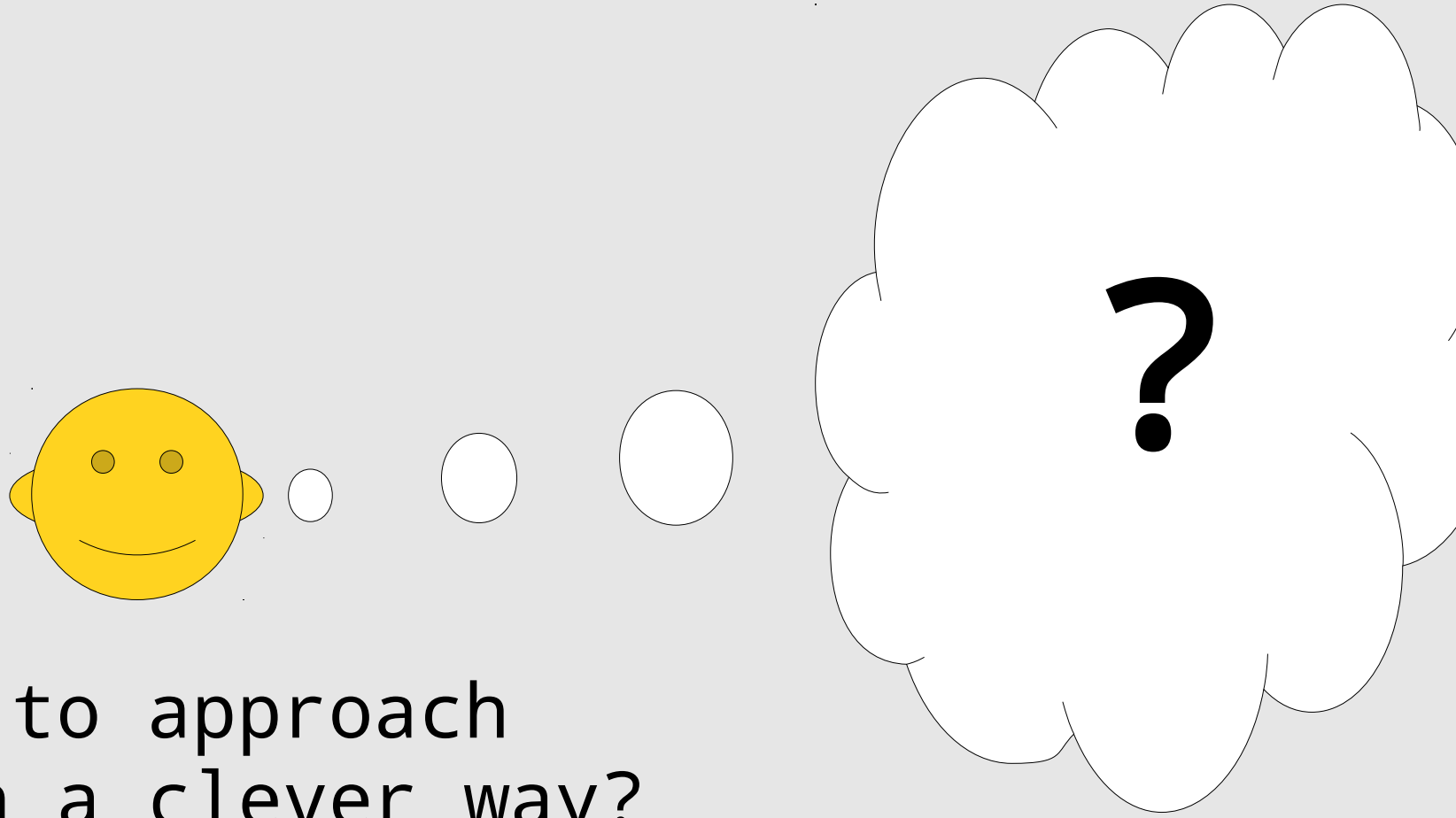
Sampling the sphere



So how to approach
this in a clever way?

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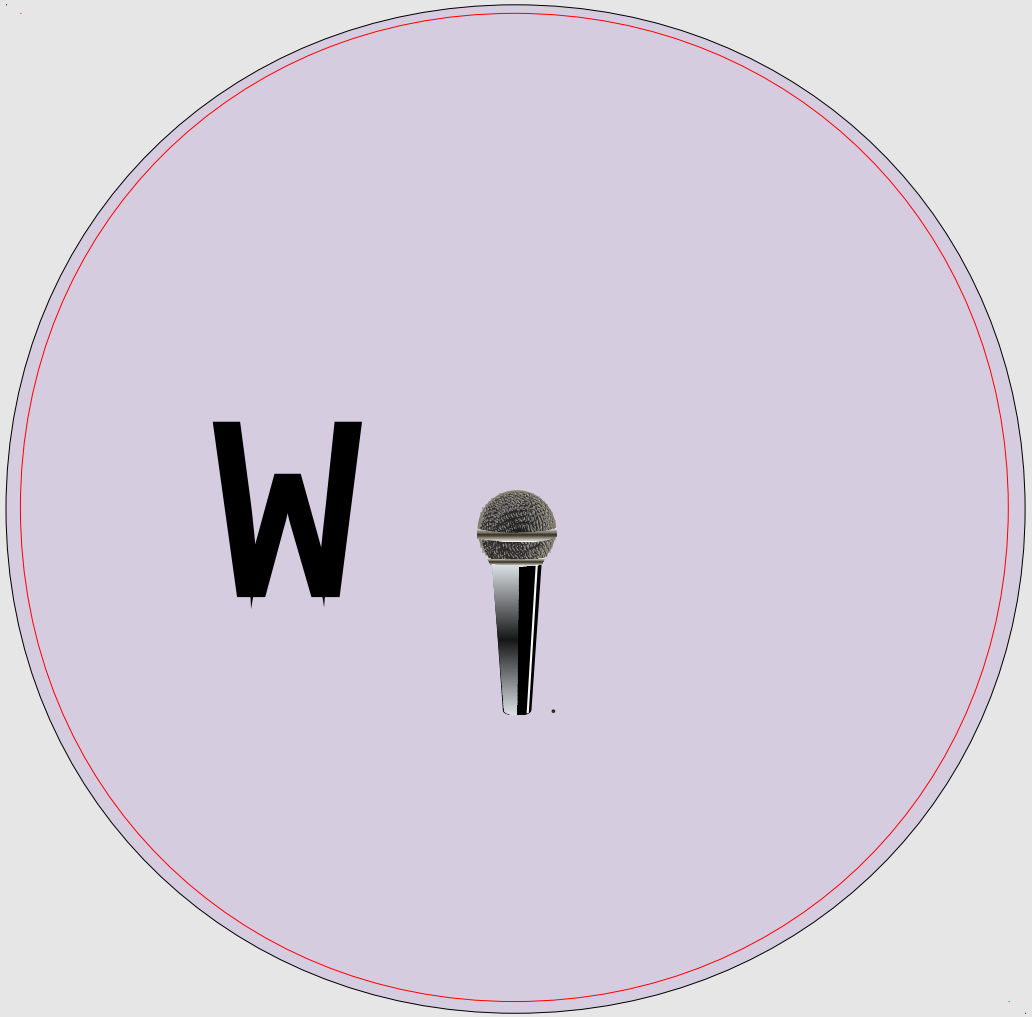
Sampling the sphere

The systematic approach:

Find a set of polar patterns that cover the sphere uniformly.

Avoid redundant information.

Sampling the sphere



An omni pattern will sample the sphere completely.

No directional information, unfortunately.

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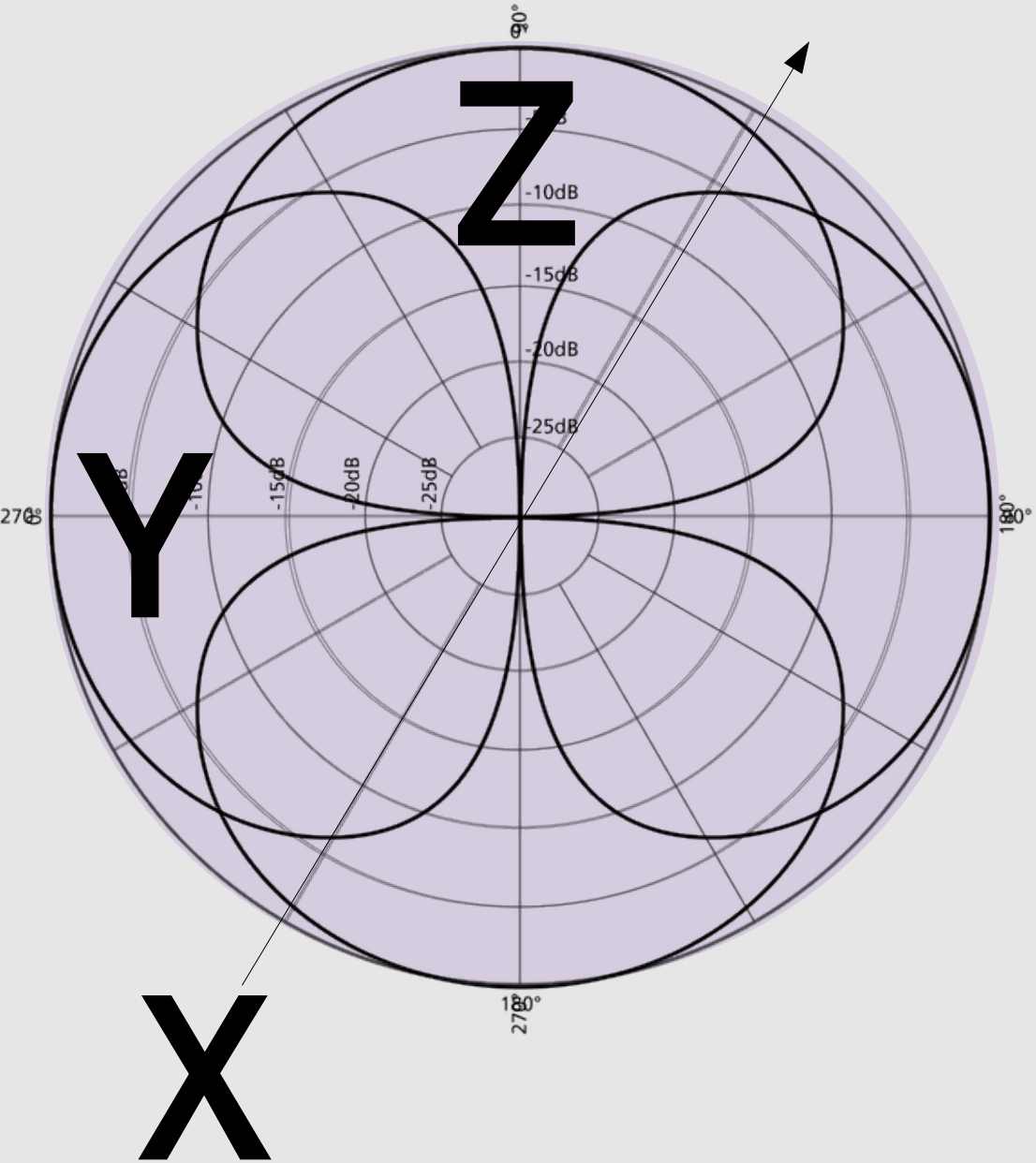
Sampling the sphere

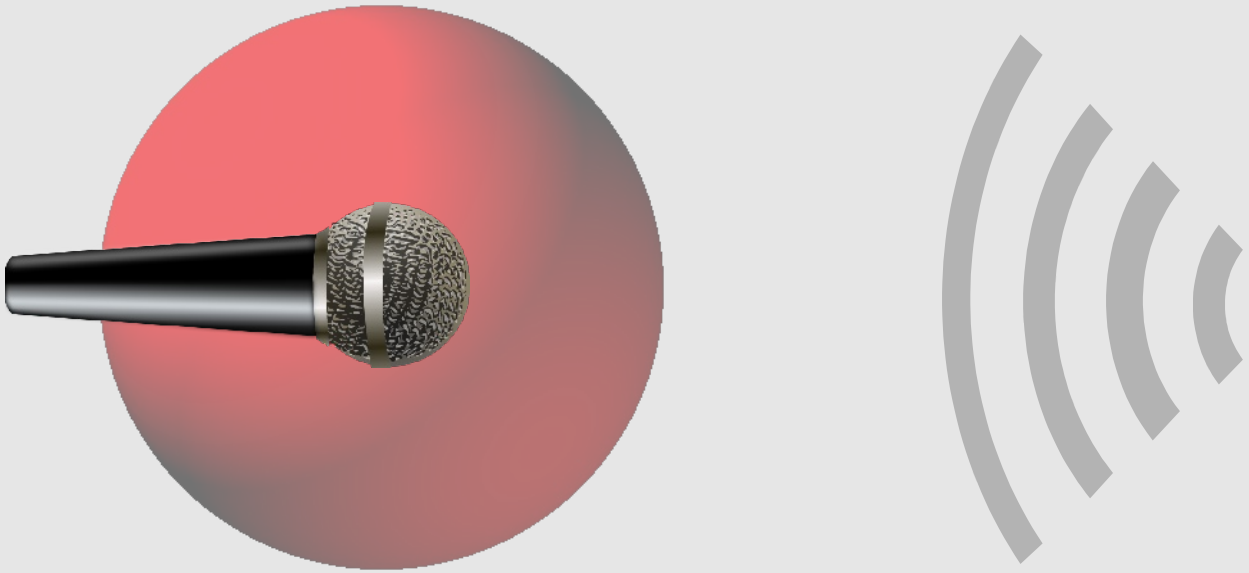


Three figures-of-eight will also cover the sphere uniformly.

Together with **W**, they provide directional information.

“Native” B-format microphone:

an omni in the middle



“Native” B-format microphone:

an omni in the middle

a fig8 for left-right

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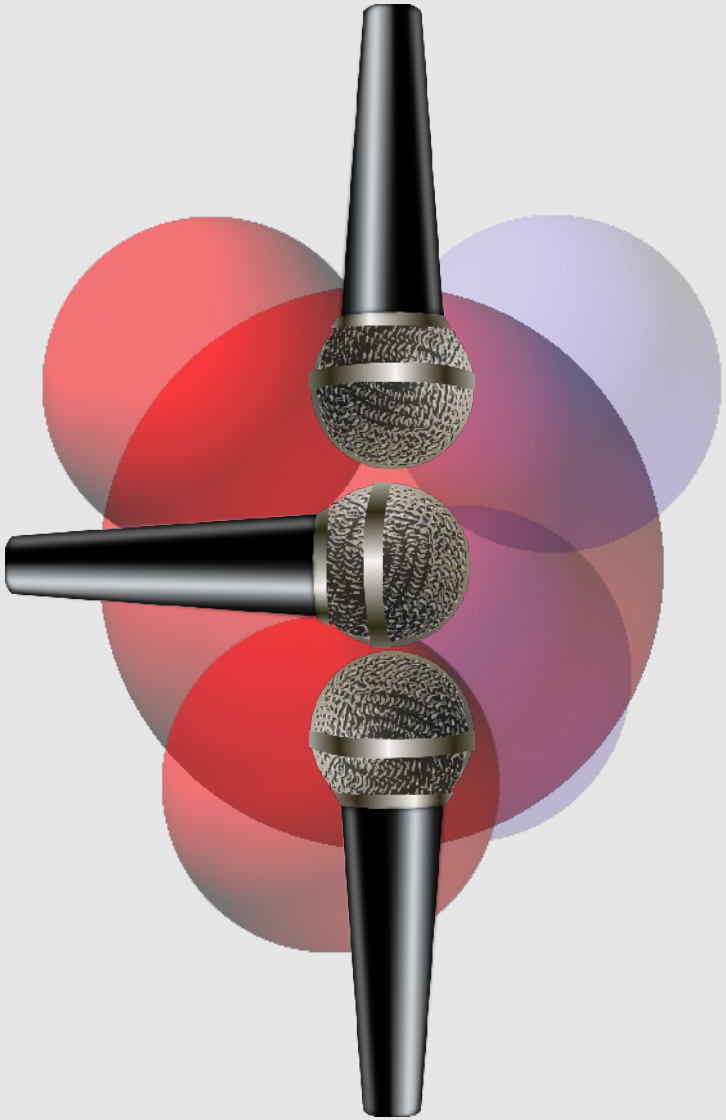
“Native” B-format microphone:

a fig8 for front-back

an omni in the middle

a fig8 for left-right



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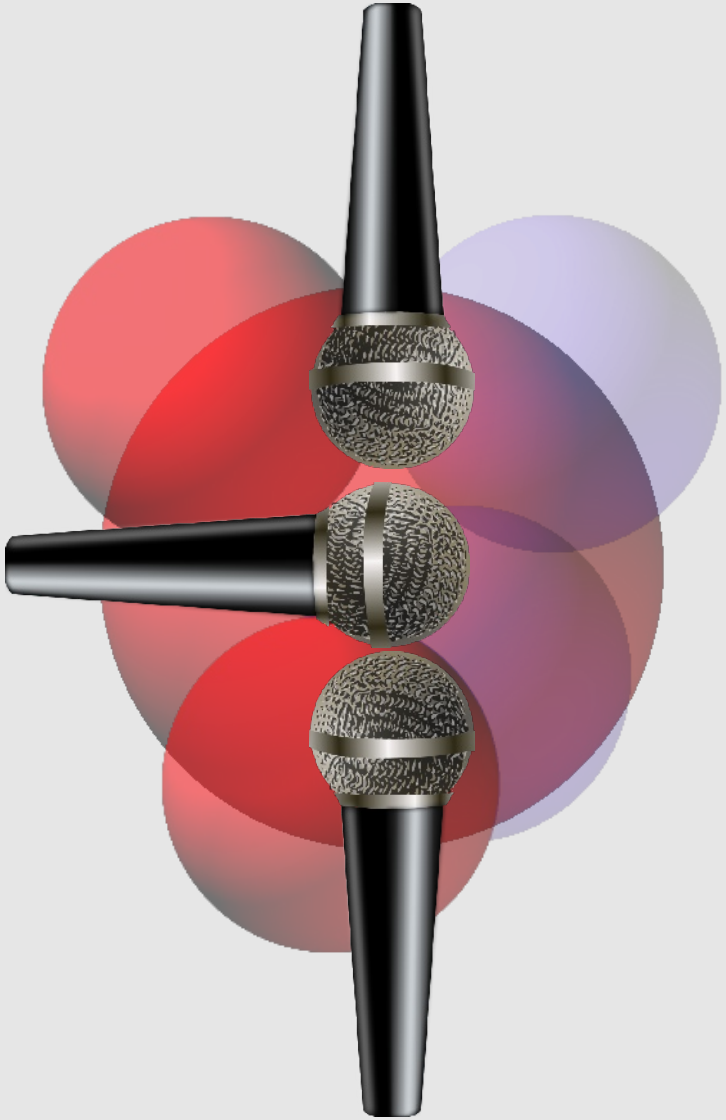
“Native” B-format microphone:

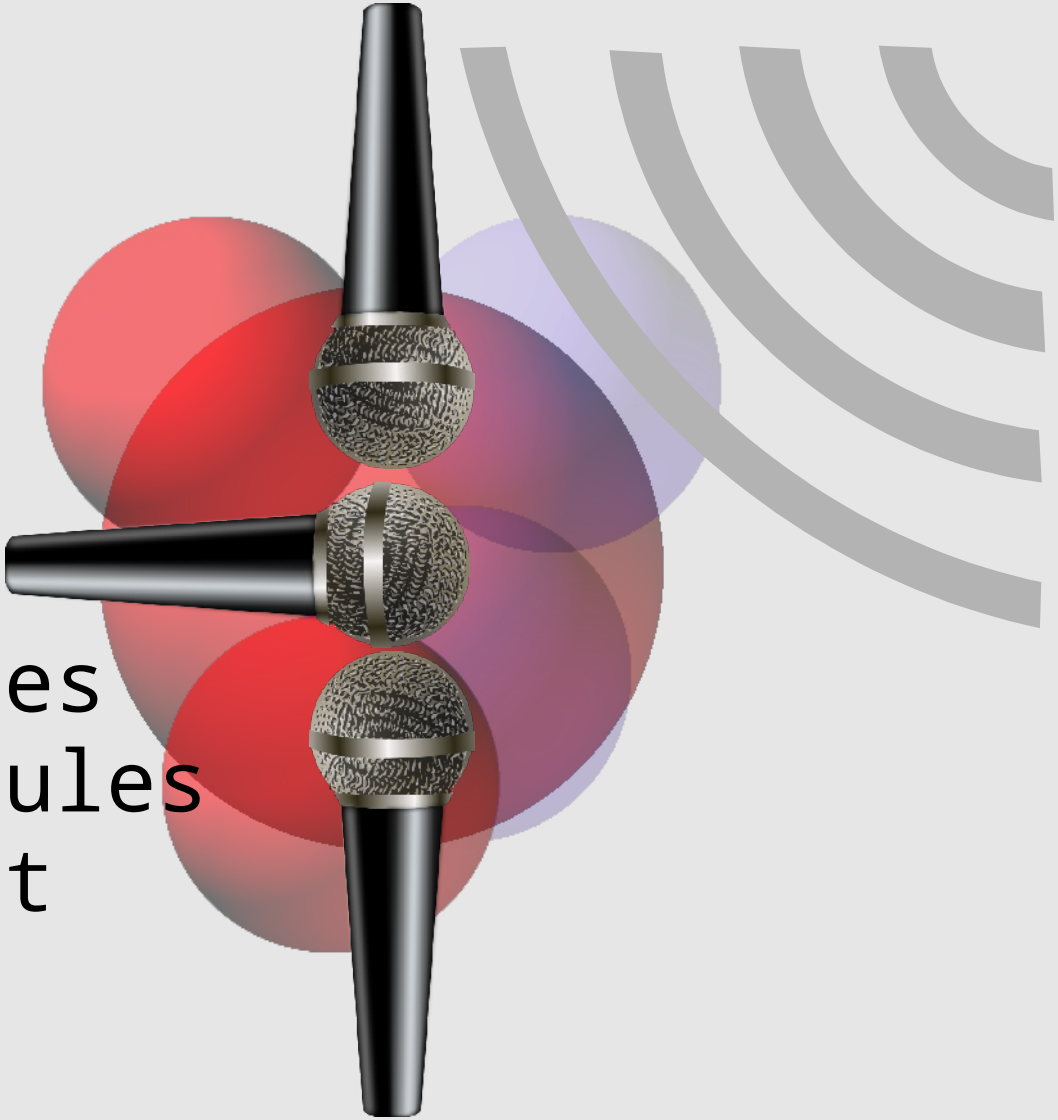
works well for horizontal sound



“Native” B-format microphone:

Problem:

Sound from outside the horizontal plane arrives at the capsules at different times.



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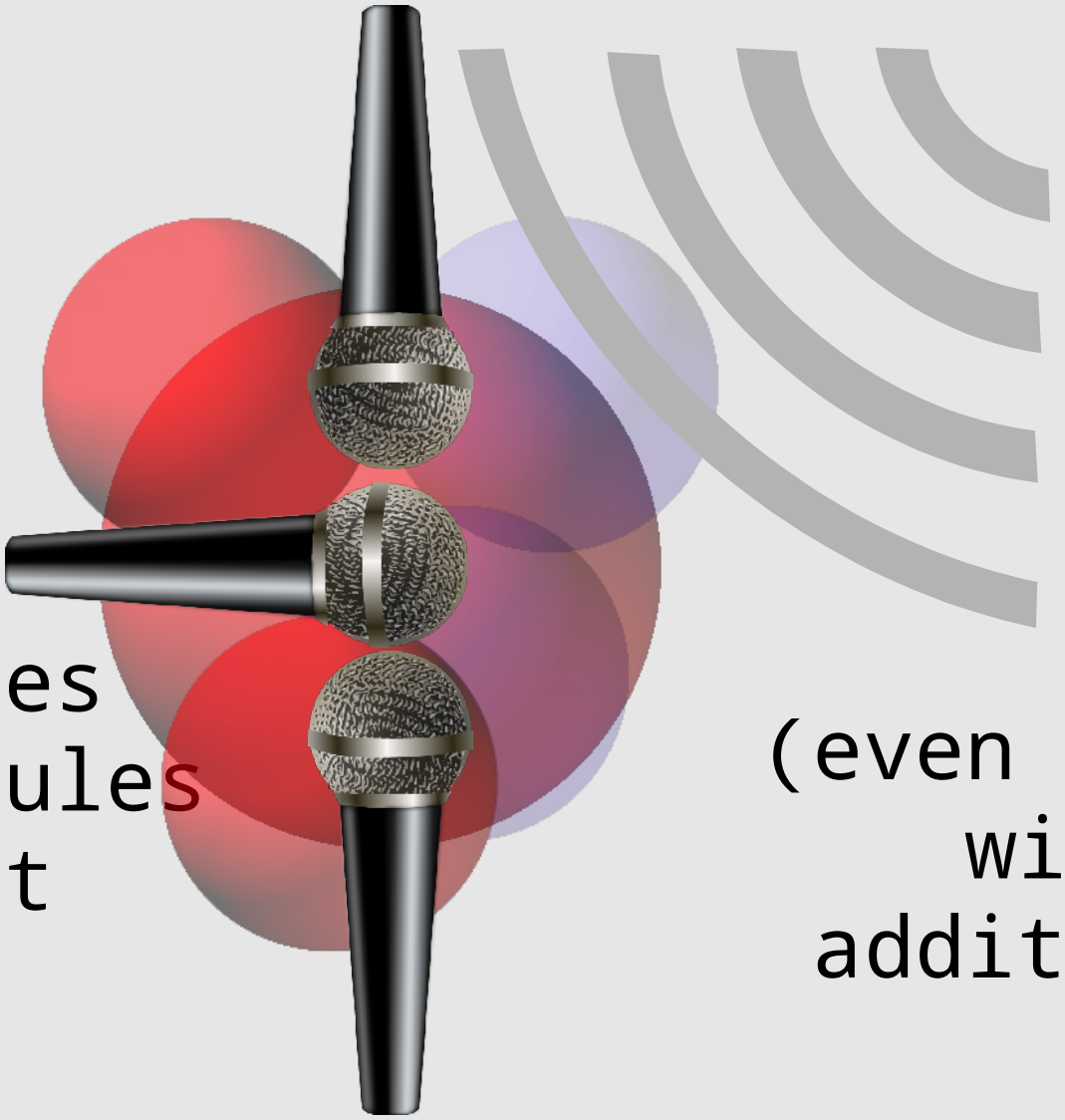

(even worse with an additional Z mic)

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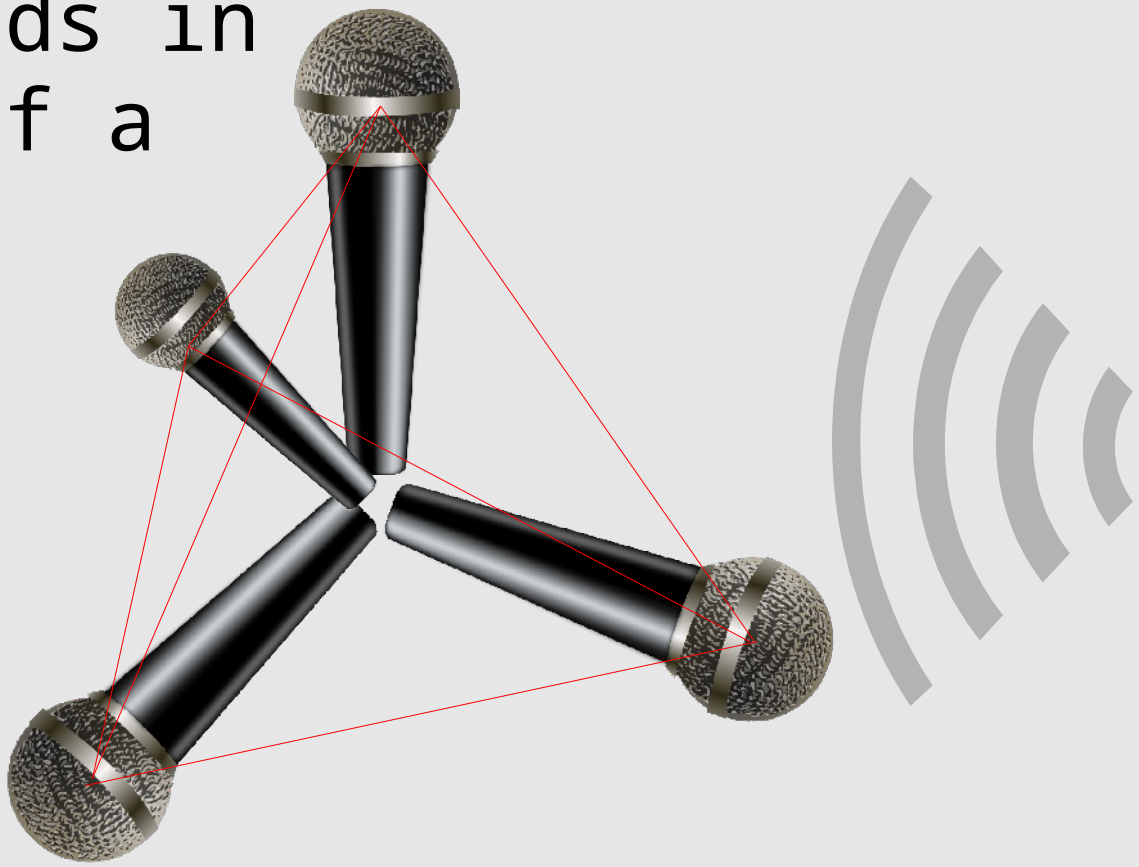
Sound field microphone:

three cardioids in the corners of a tetrahedron



Jörn Nettingsmeier, http://stackingdwarves.net

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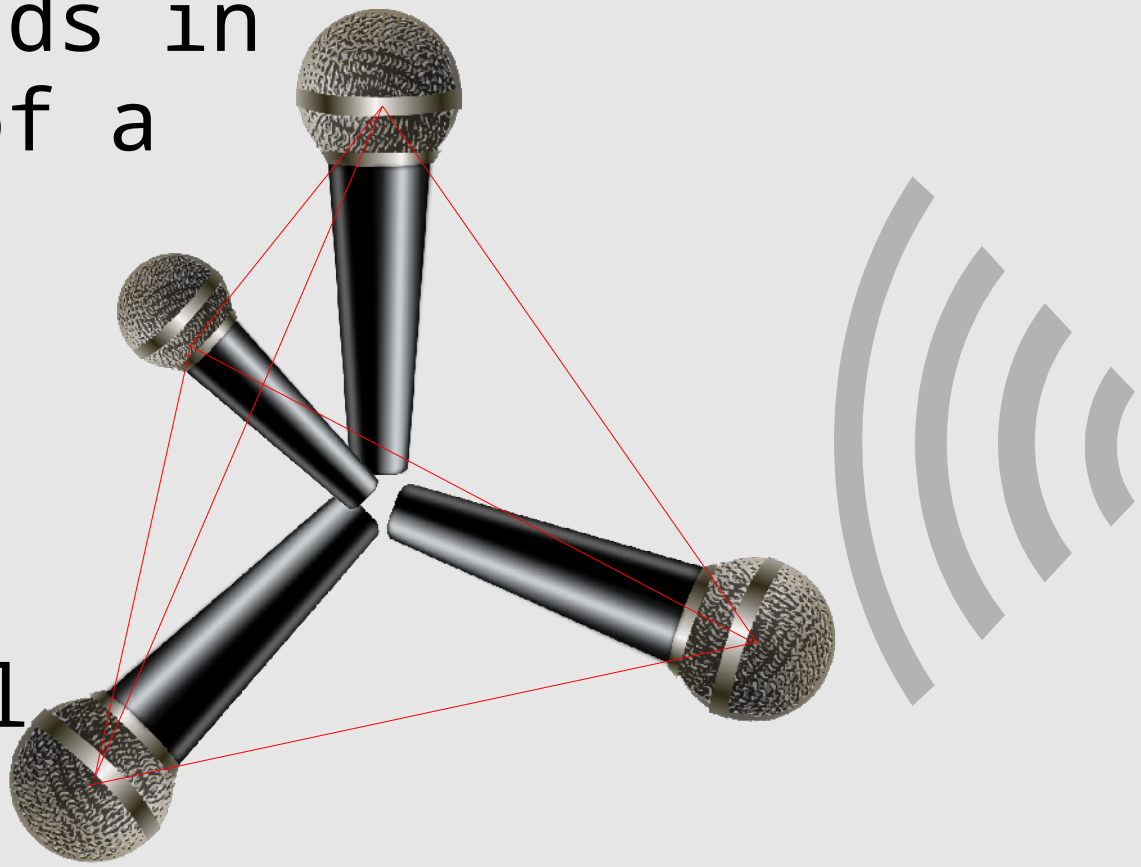

uniform time errors in all directions

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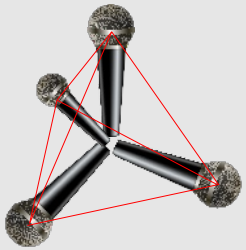
Sound field microphone:

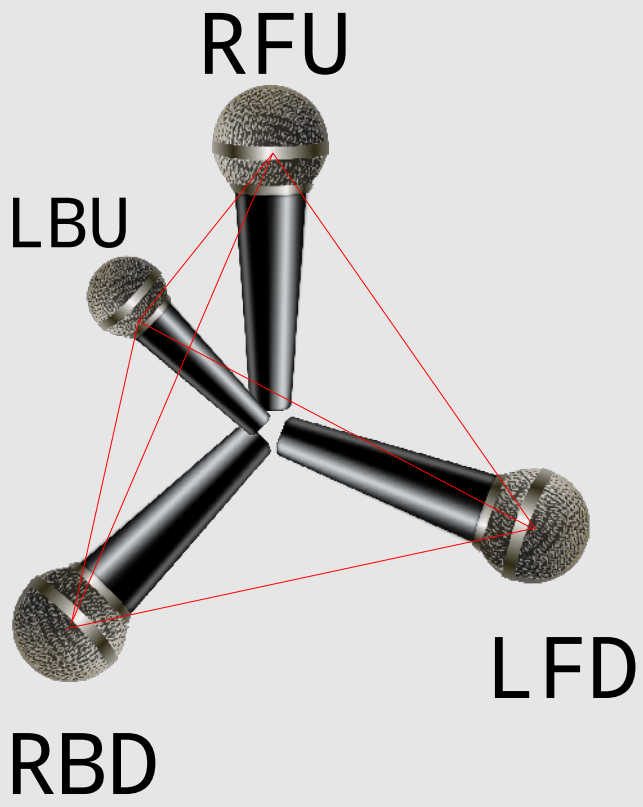
works well when
you make the
array small



Sound field microphone:

equivalent to
B-format:

$$
\begin{aligned}
W &= \ LFD + RFU + LBU + RBD \\
X &= \ LFD + RFU - LBU - RBD \\
Y &= \ LFD - RFU + LBU - RBD \\
Z &= -\ LFD + RFU + LBU - RBD
\end{aligned}
$$



works because our approach is systematic!

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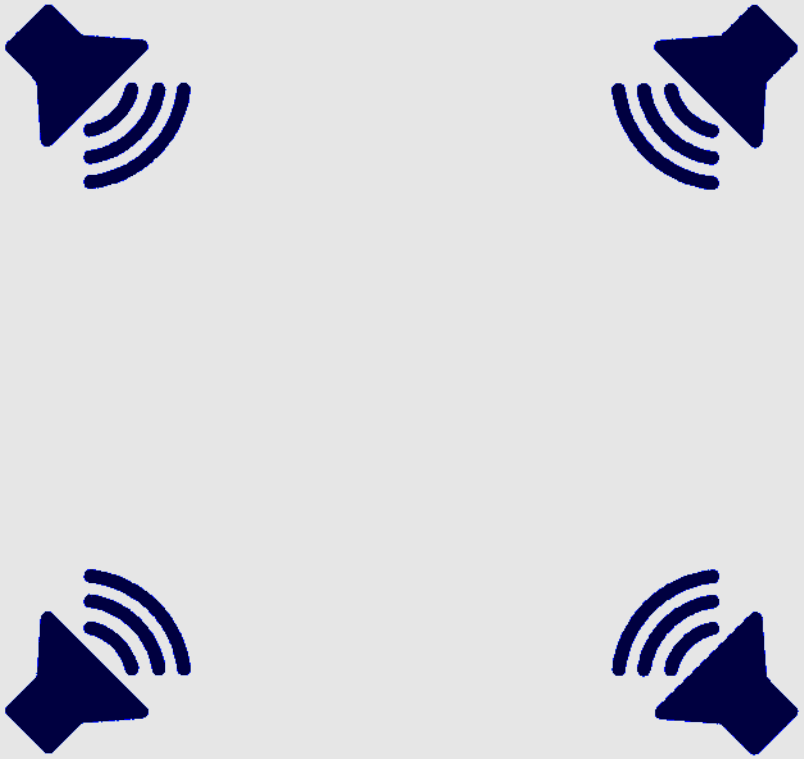
Decoding B-format

B-format to square layout:



```
LF = W + X + Y
RF = W + X - Y
LB = W - X + Y
RB = W - X - Y
```


Jörn Nettingsmeier, http://stackingdwarves.net

Decoding B-format

B-format to
diamond layout:

$$F = W + X$$
$$L = W + Y$$
$$R = W - Y$$
$$B = W - X$$

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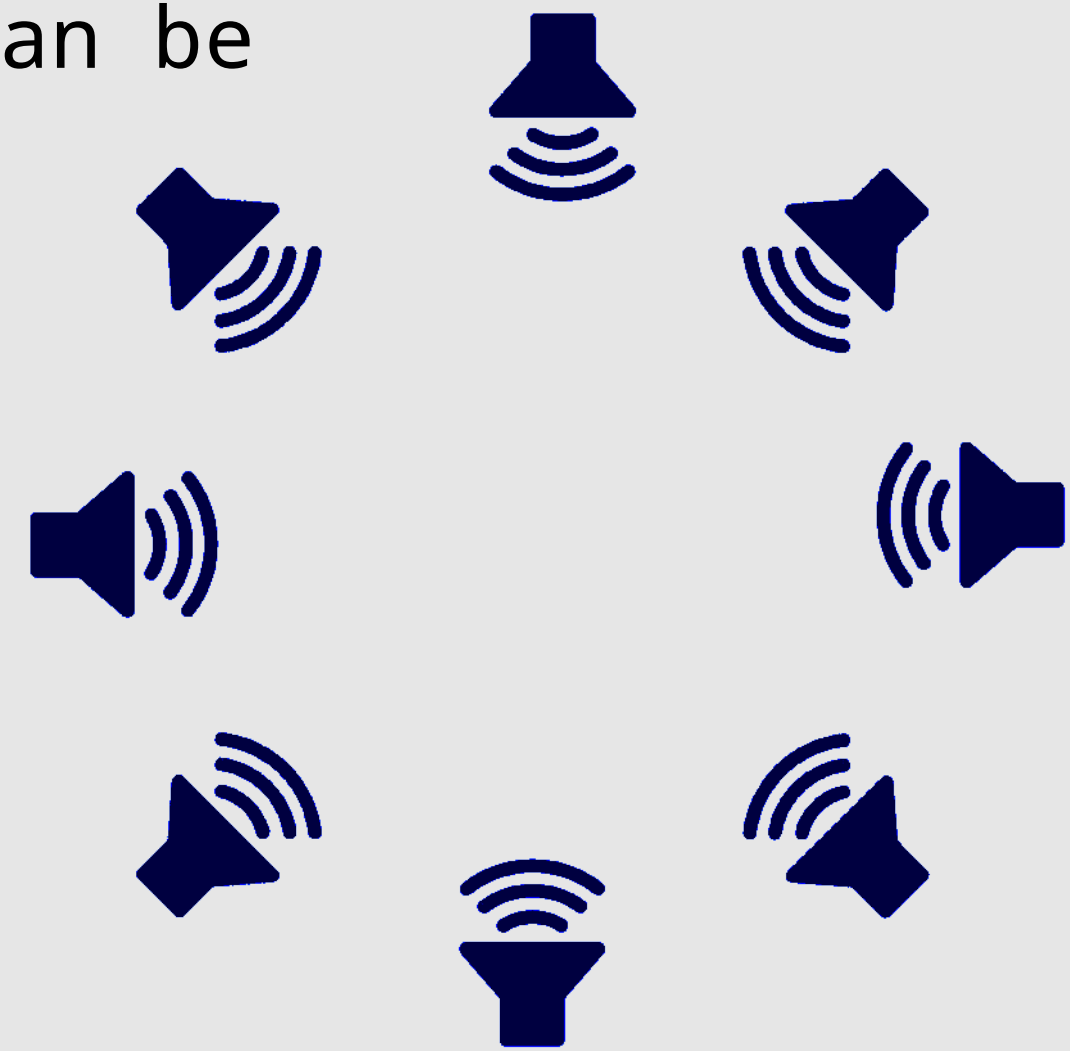
Decoding B-format

Other layouts can be derived using trigonometric functions and gain coefficients.



Decoding B-format

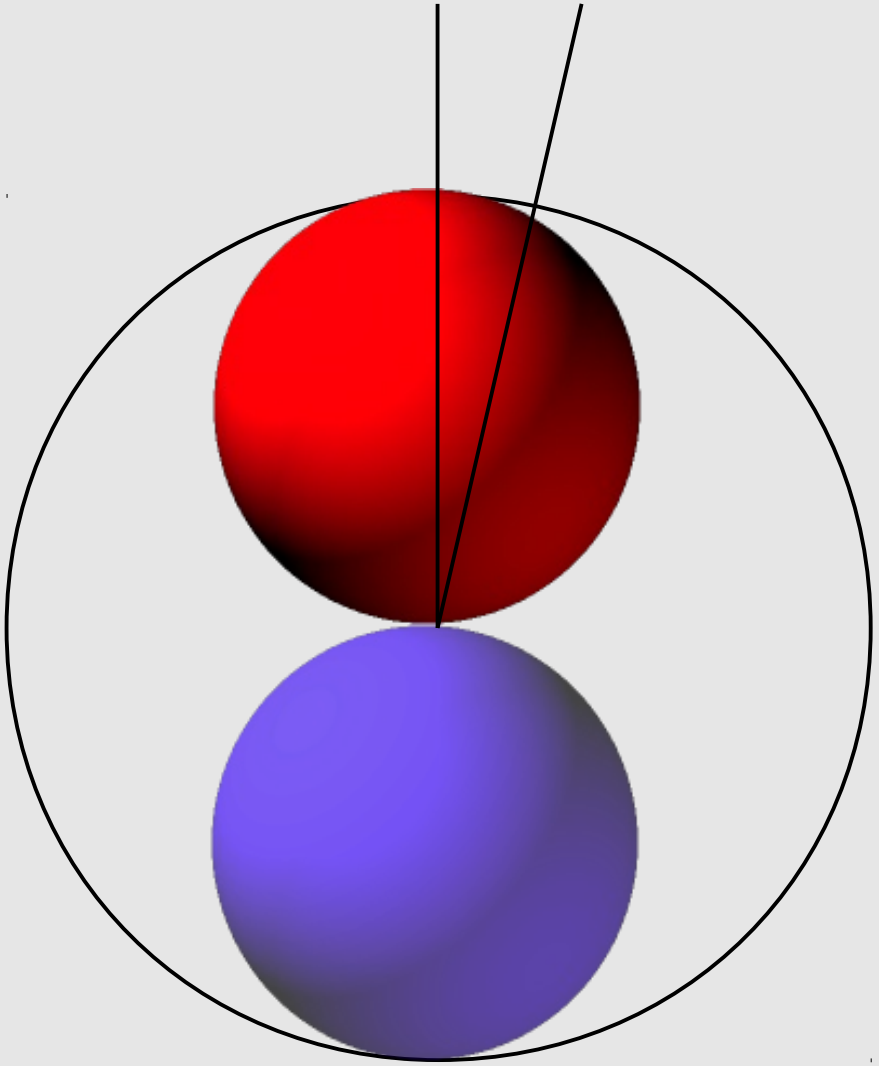
5.0 or stereo
fold-downs work
similarly.

Irregular layouts
lose some spatial
resolution and
will introduce
slight localisation errors.

What's wrong with first-order Ambisonics?

Jörn Nettingsmeier, http://stackingdwarves.net

What's wrong with first-order Ambisonics?



Low angular resolution: shallow off-axis roll-off.

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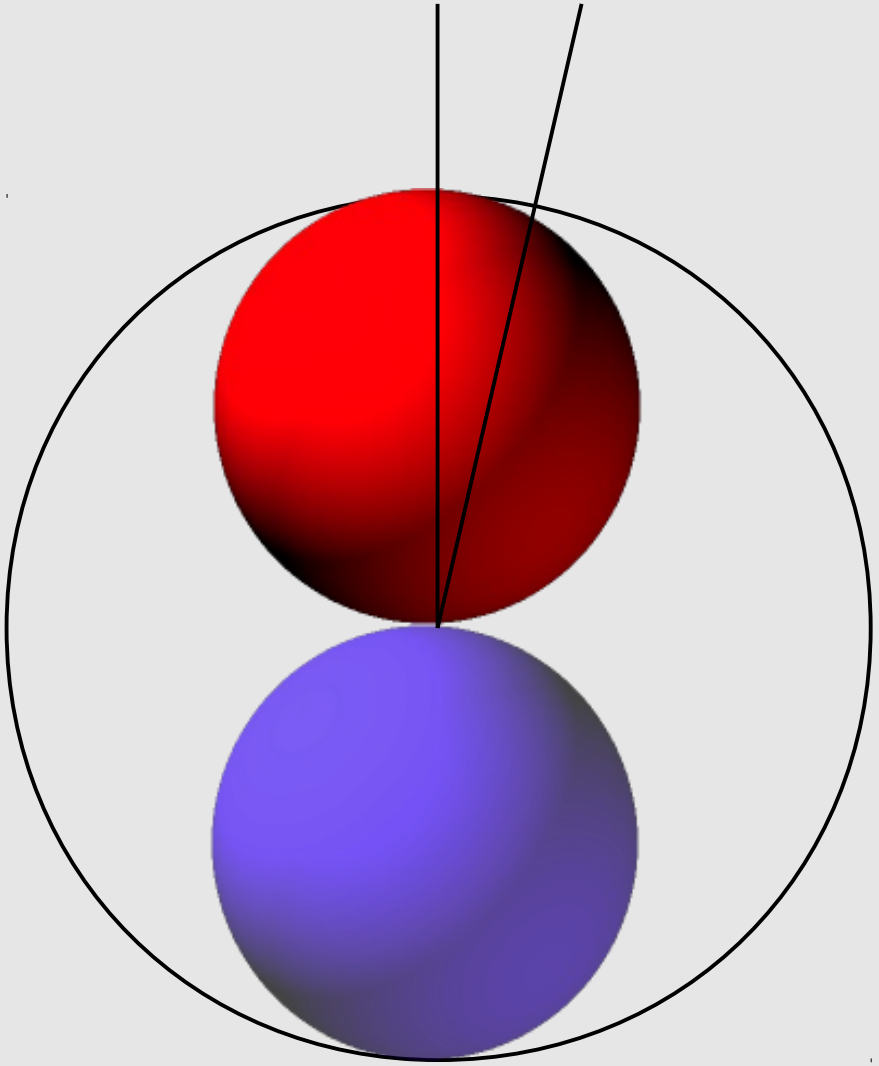
What's wrong with first-order Ambisonics?



In practice, this means instability and a small sweet spot (= listening area)

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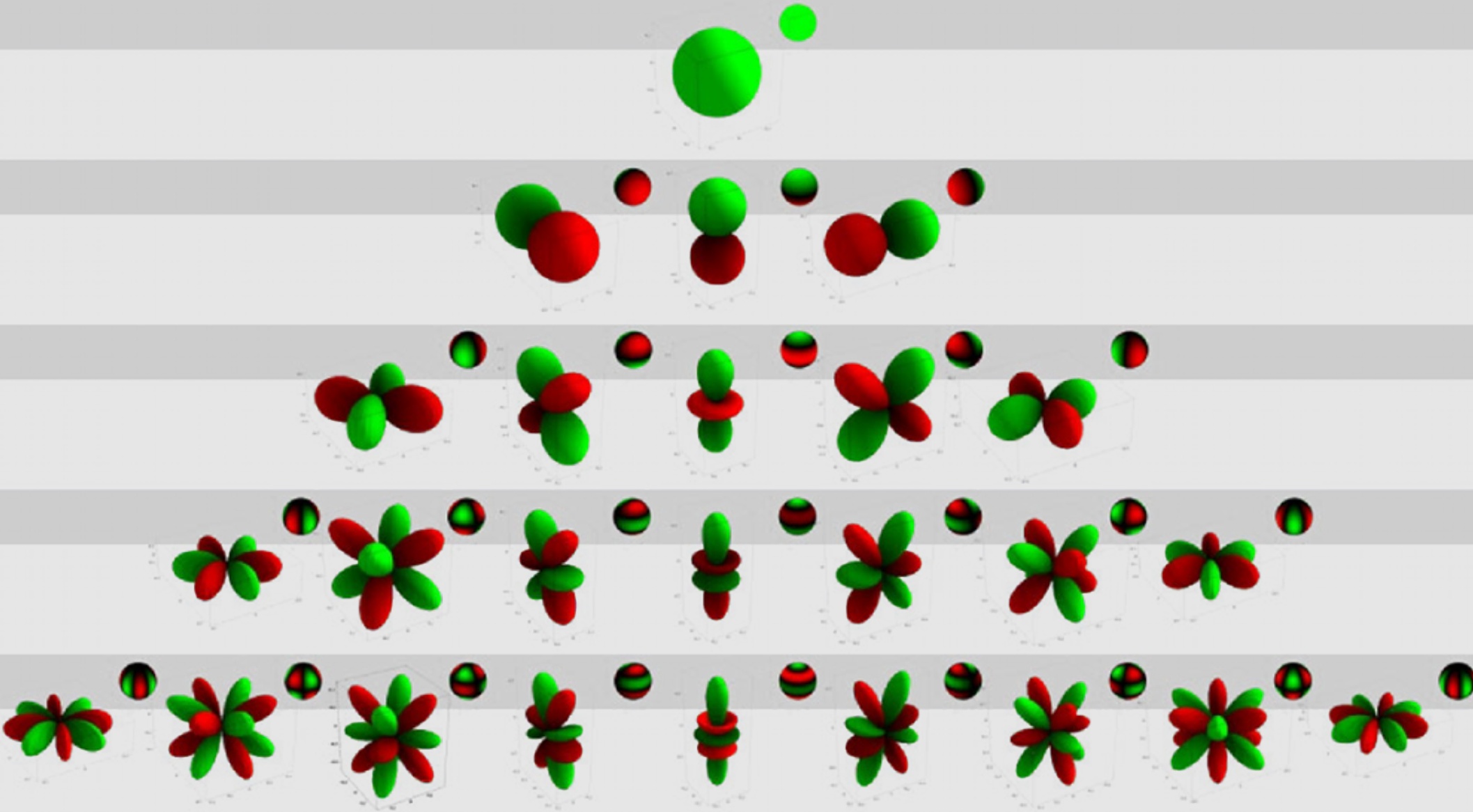
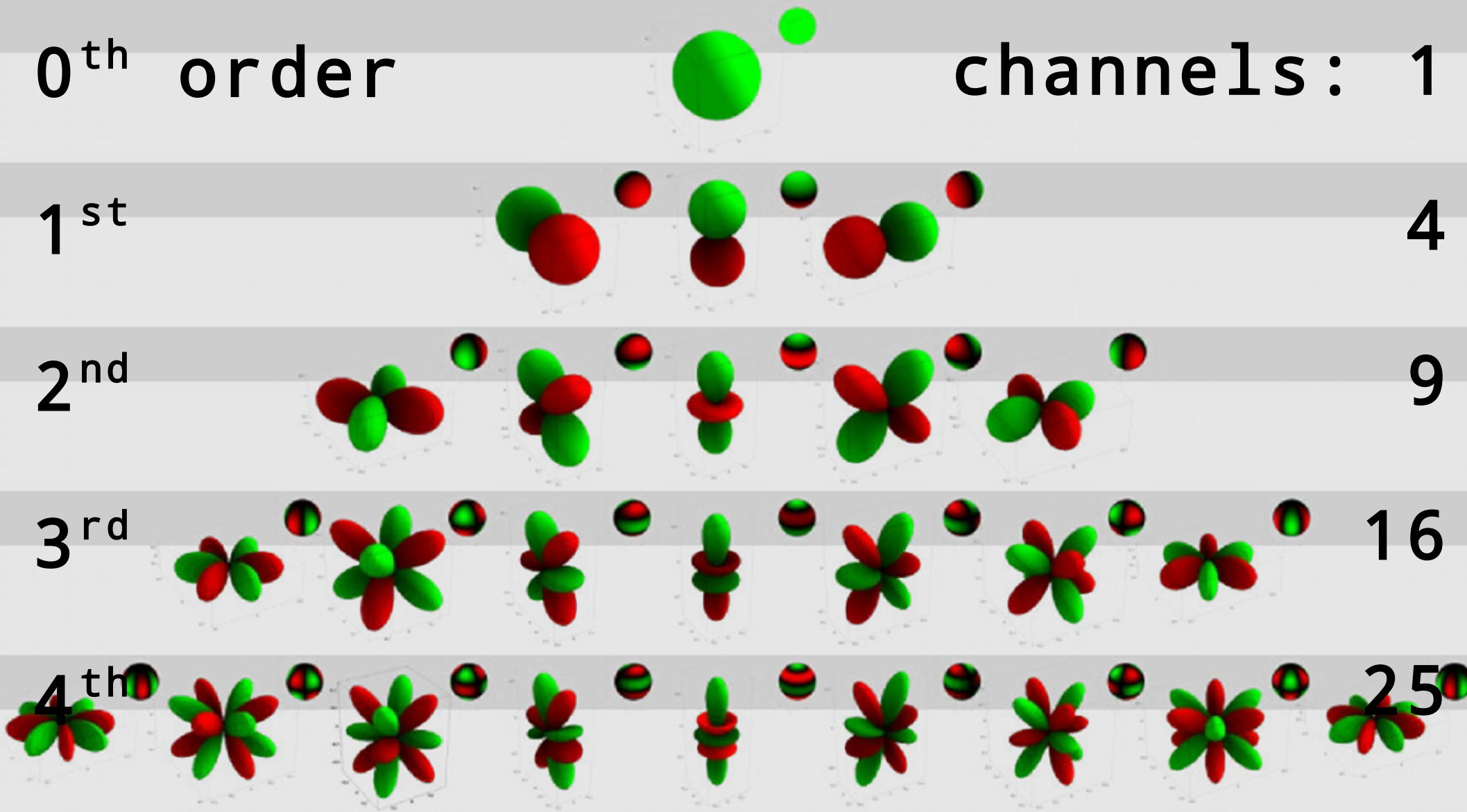
So we need
narrower polar patterns
which again sample the sphere
uniformly and are
linearly independent

...

...and here they are:



Higher-order Ambisonics



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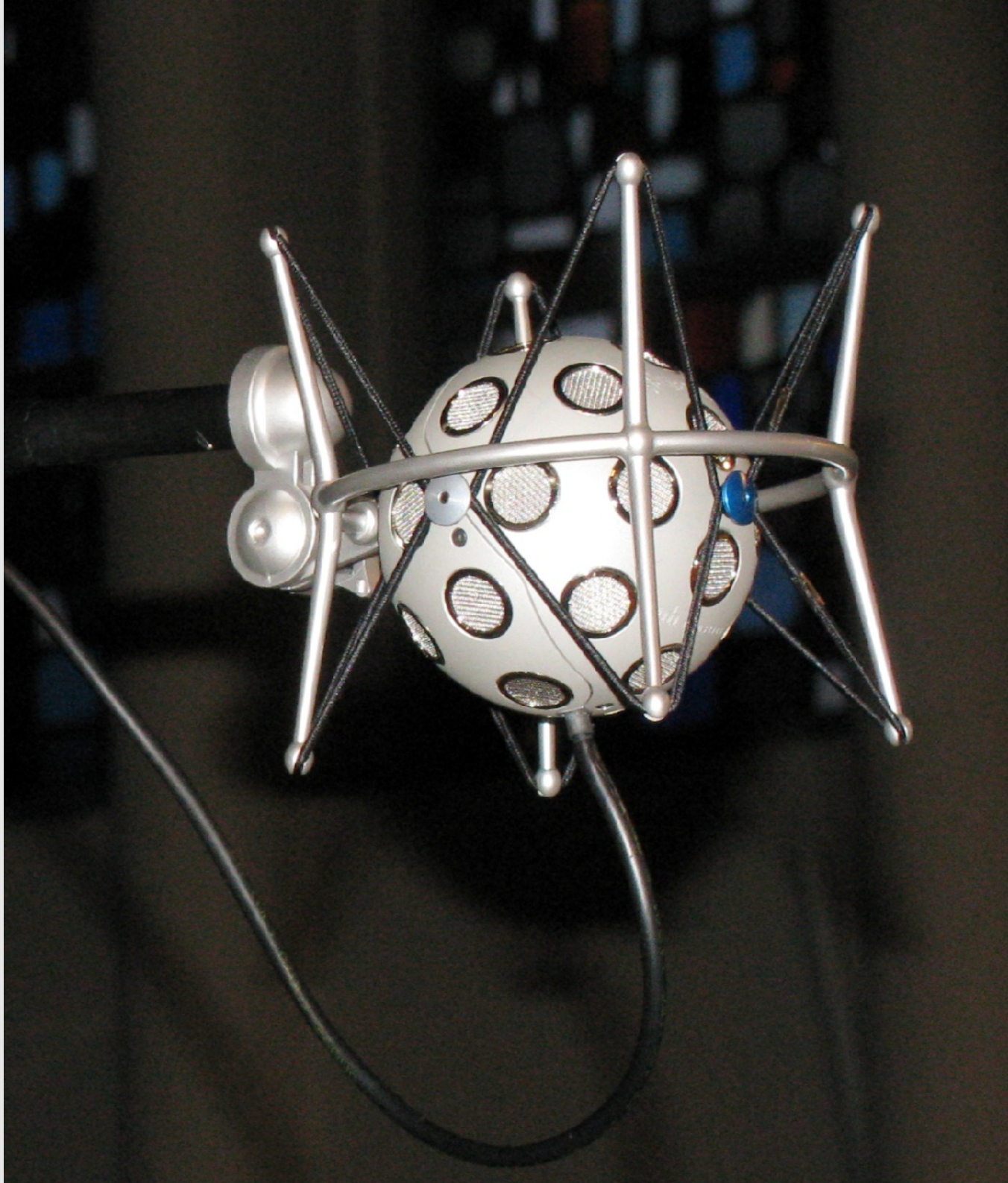
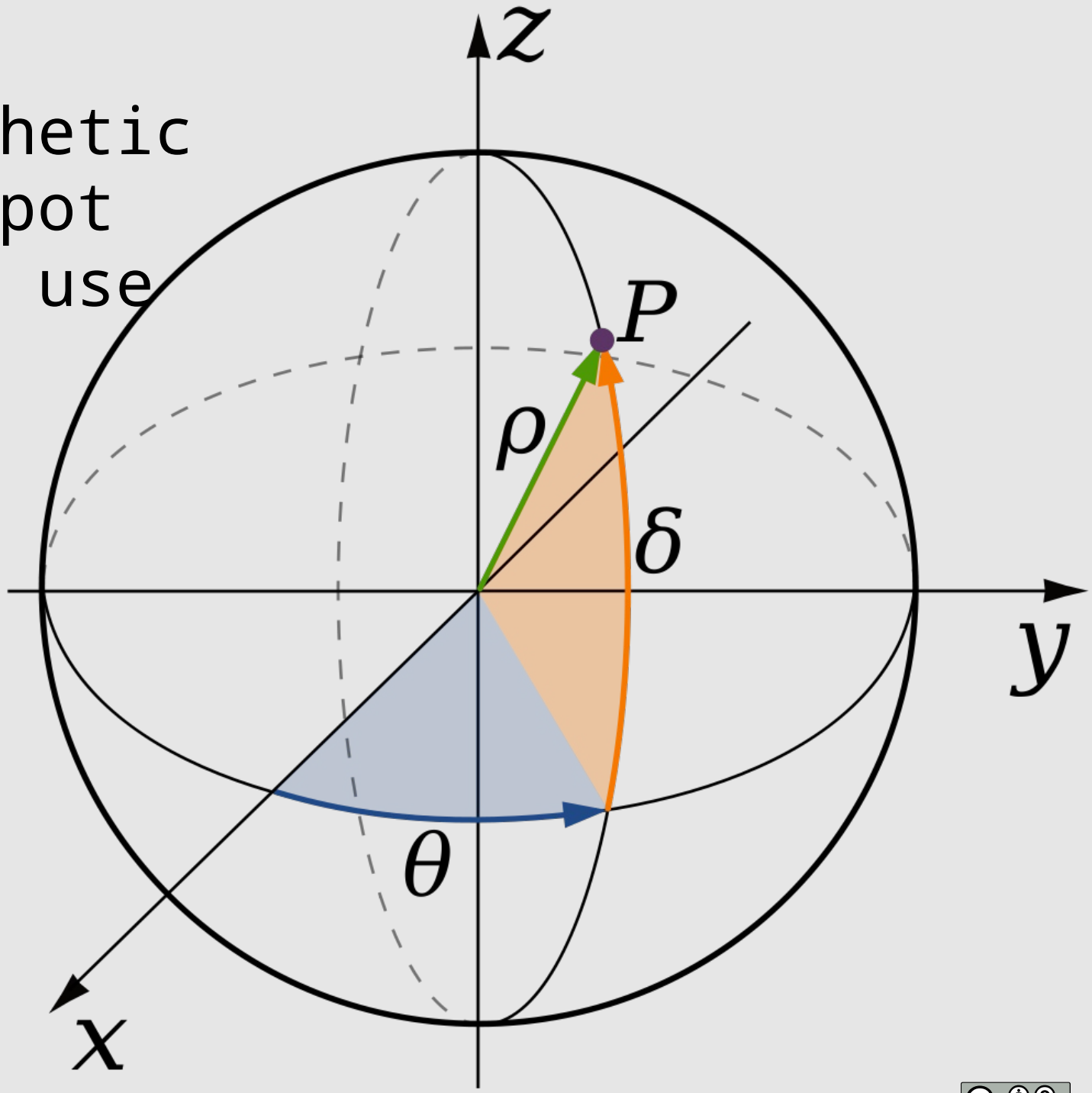
“Native” higher order microphones do not exist.

But we can use the same trick as the tetrahedral mic:



And for synthetic sources or spot mics, we can use panning functions that compute higher-order components.



Producing in HOA

Problem: Existing higher-order microphones are not satisfactory for high-quality recording.

Producing in HOA

Problem: Existing higher-order microphones are not satisfactory for high-quality recording.

But: There is no satisfying single 7.1, 22.2 or Auro-3D mic either – no problem: we can combine and pan mono sources easily.

Producing in HOA

- Pop: √
- Cinema: √
- Electro-acoustic music: √

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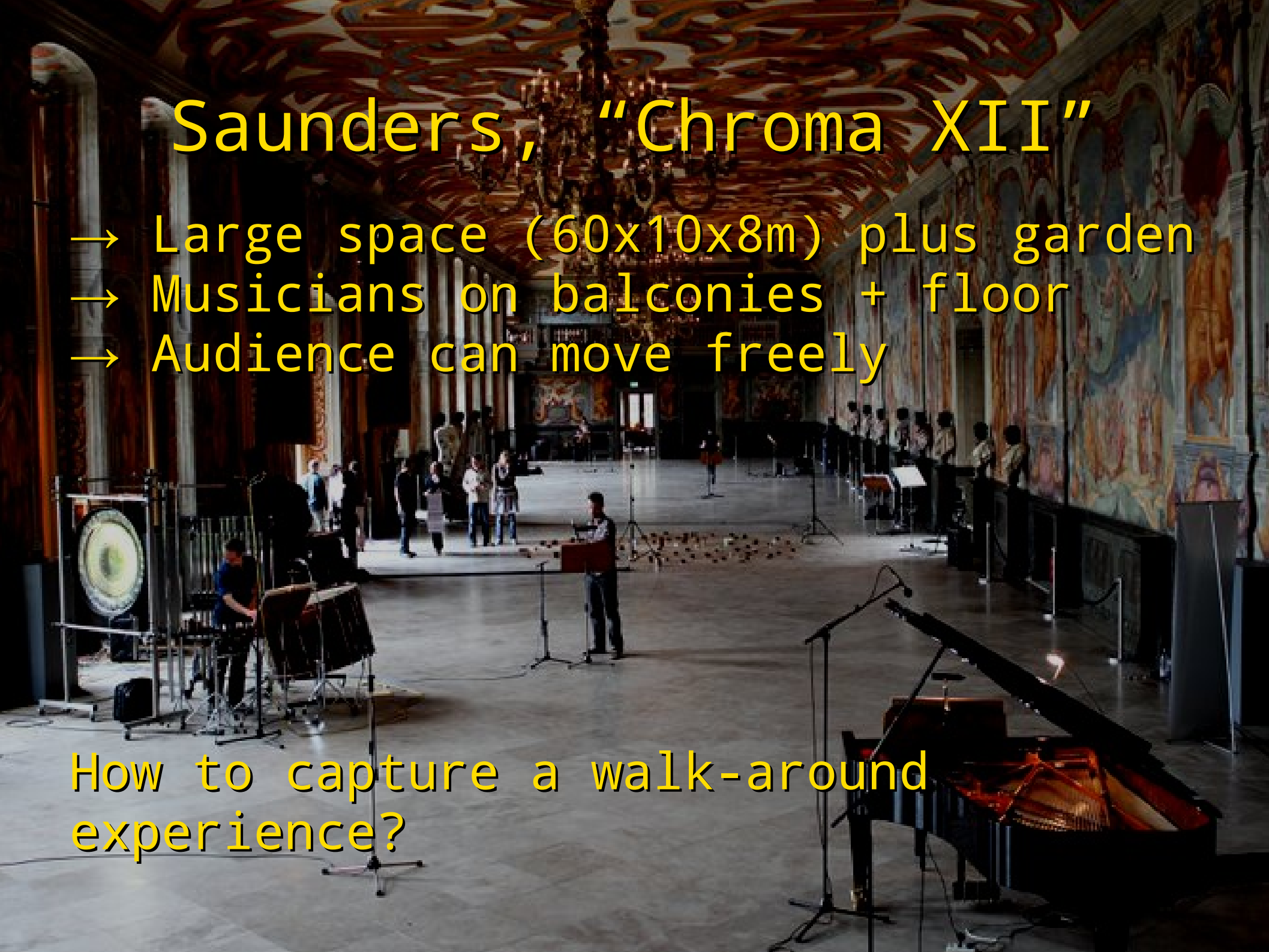
Producing in HOA

- Pop: √
- Cinema: √
- Electro-acoustic music: √

But how to record classical events?



Saunders, “Chroma XII”

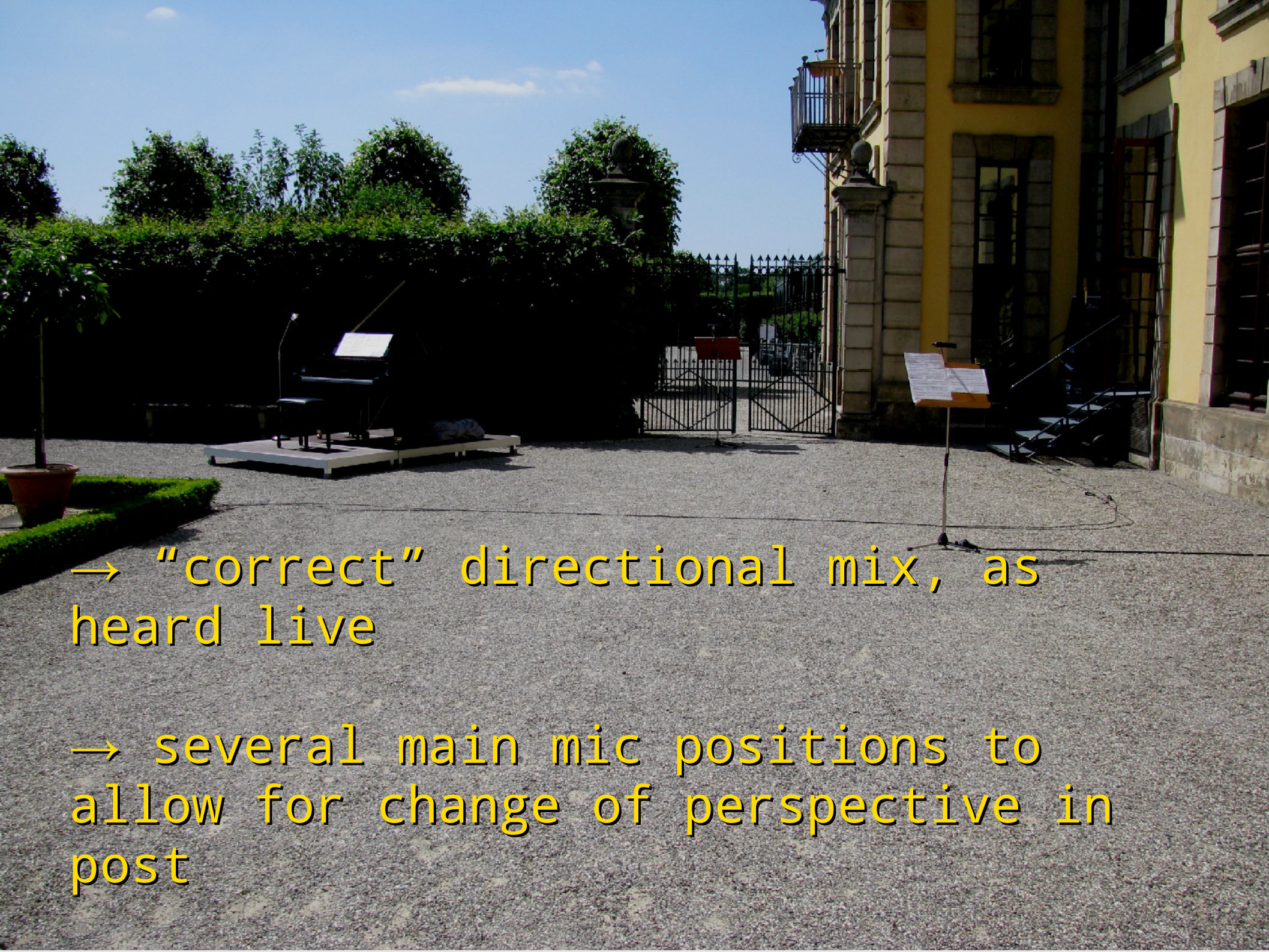
→ Large space (60x10x8m) plus garden
→ Musicians on balconies + floor
→ Audience can move freely

How to capture a walk-around experience?

Hybrid miking approach

→ SoundField as main mic: very good ambience, but unstable and blurry.

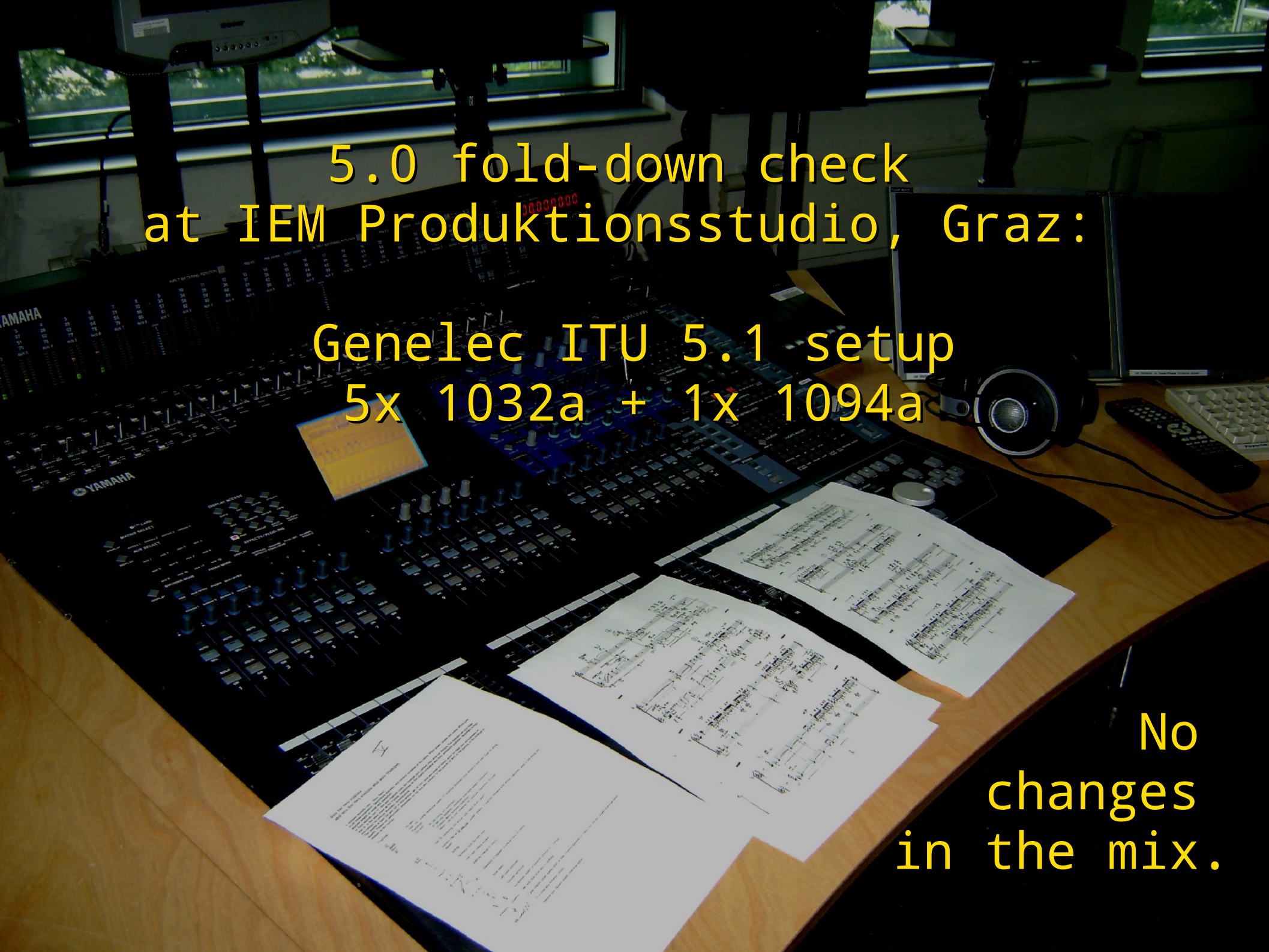
→ Spot mics panned in 3rd order, one for each(!) instrument: add focus, allow for balance correction and score interpretation.



→ “correct” directional mix, as heard live

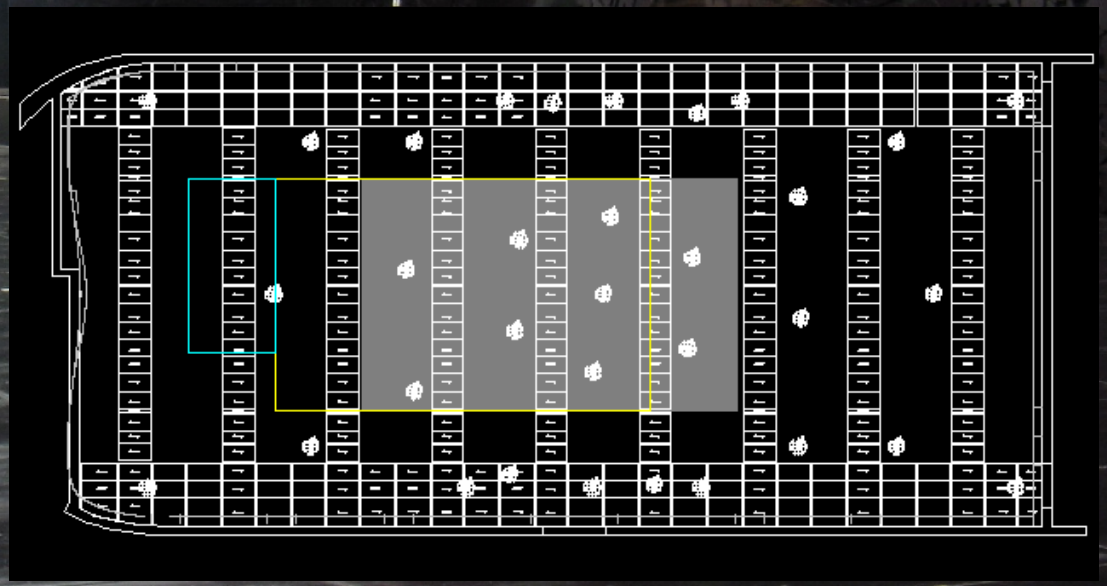
→ several main mic positions to allow for change of perspective in post


Post-production at IEM Cube, Graz:
24 Tannoy 1200
in a 12-8-4 hemisphere

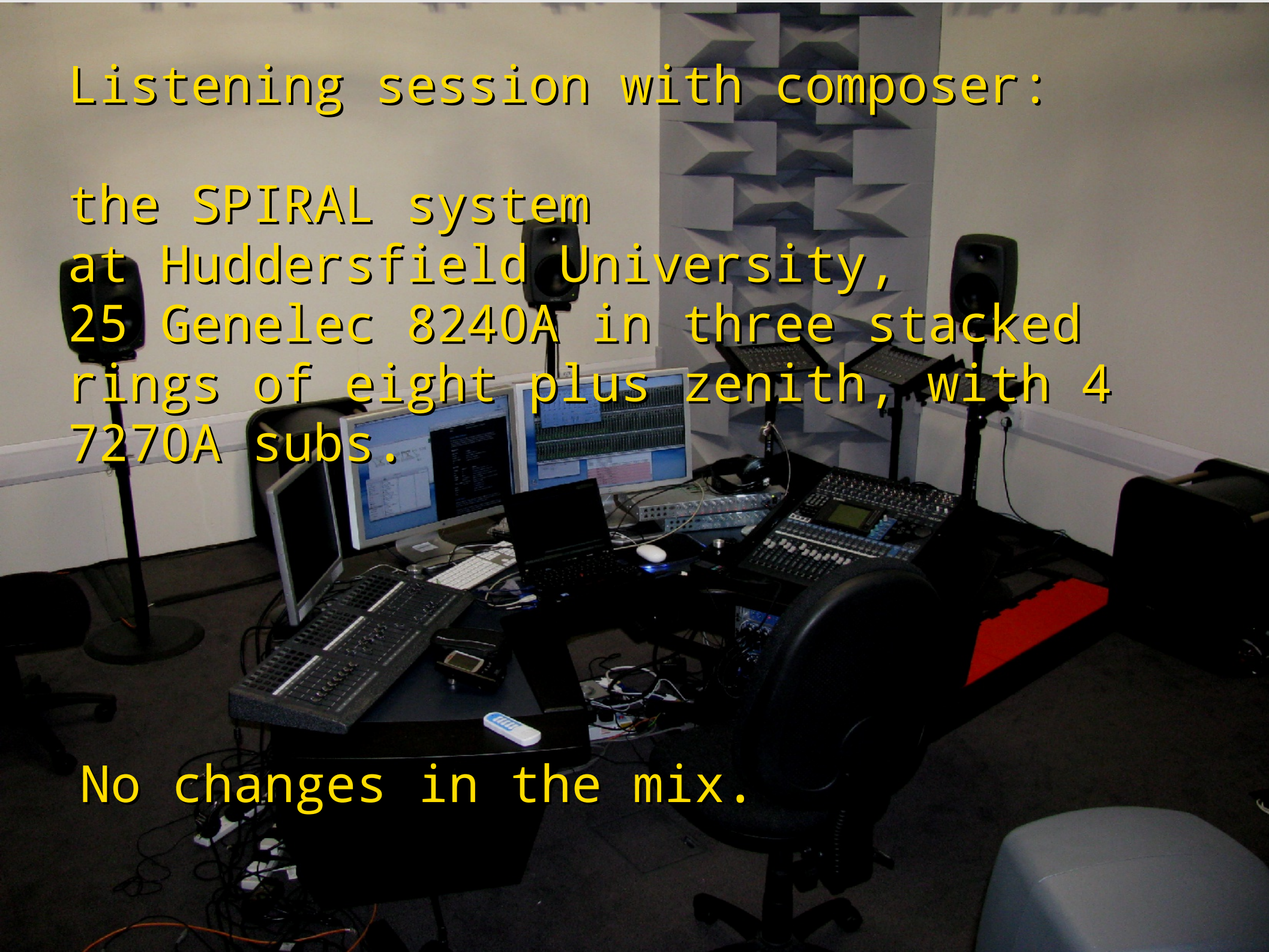

5.0 fold-down check
at IEM Produktionsstudio, Graz:
Genelec ITU 5.1 setup
5x 1032a + 1x 1094a
No
changes
in the mix.

Concert performance at MUMUTH, Graz:

29 Kling & Freitag CA 1001
on motorized
telescopes plus
two sub stacks,
arranged in a
squashed
12-10-6-1
hemisphere



No changes in the mix.


Listening session with composer:
the SPIRAL system
at Huddersfield University,
25 Genelec 8240A in three stacked rings of eight plus zenith, with 4 7270A subs.
No changes in the mix.


Thanks for your attention!
I'm looking forward to your questions.

Acknowledgements:

Polar pattern graphs:
Wikimedia Commons
Microphone and grand piano clipart:
openclipart.org
Spherical harmonics chart:
Robin Green, Spherical Harmonic Lighting:The Gritty Details, 2003