PHY 103
Auditory Illusions

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Reading

- Reading for this week:
  - *Music, Cognition, and Computerized Sound: An Introduction to Psychoacoustics* by Perry Cook

Auditory Illusions

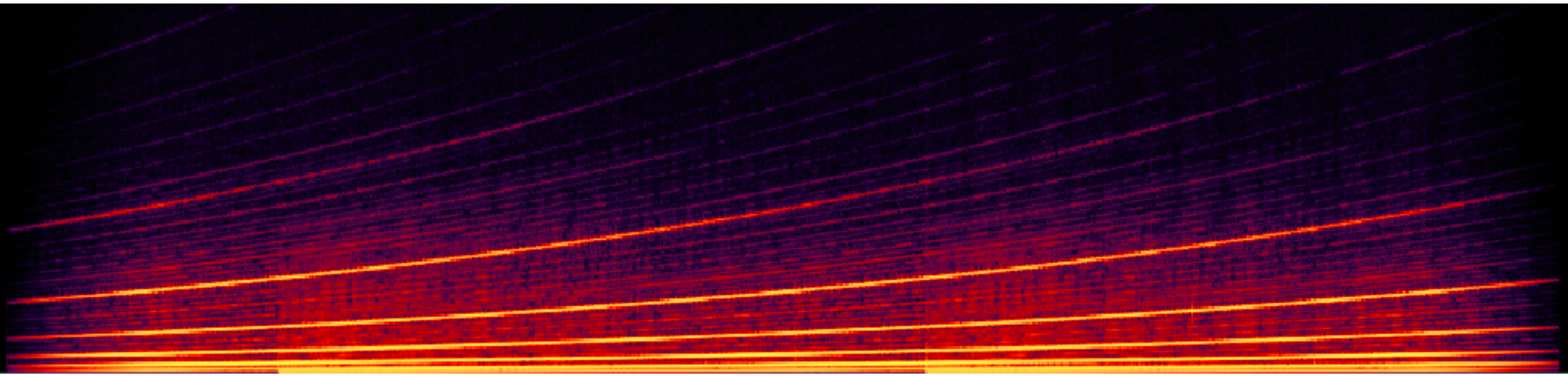
- Pitch
- Scale
- Beat
- Timbre

Rising Pitch

- Listen to this tone. What happens to the pitch from start to finish?
- Now, listen to the **same exact clip** once again. I promise you it's the same audio file, played in the same way
- What do you hear? How is this possible?
- Let's try a similar clip, this time with continuous notes

Shepard Tone

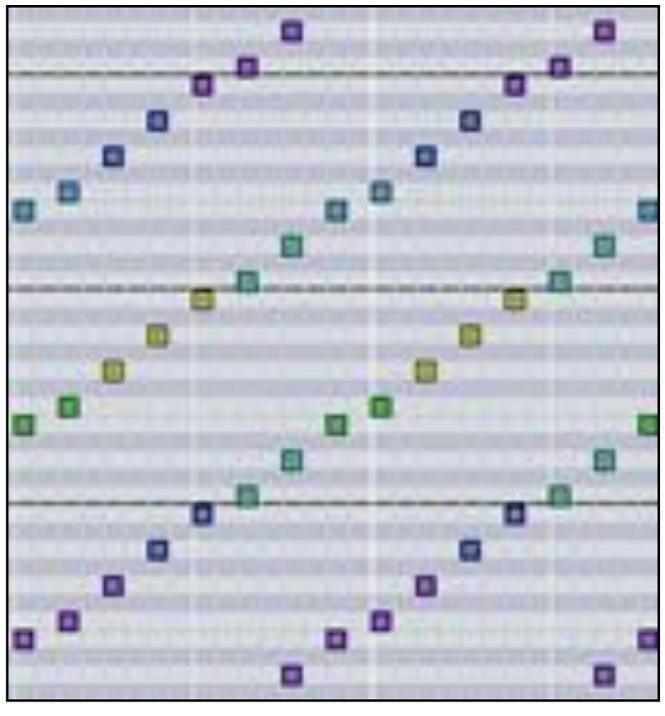
- The clips you heard are examples of Shepard tones (after Roger Shepard, cognitive scientist)

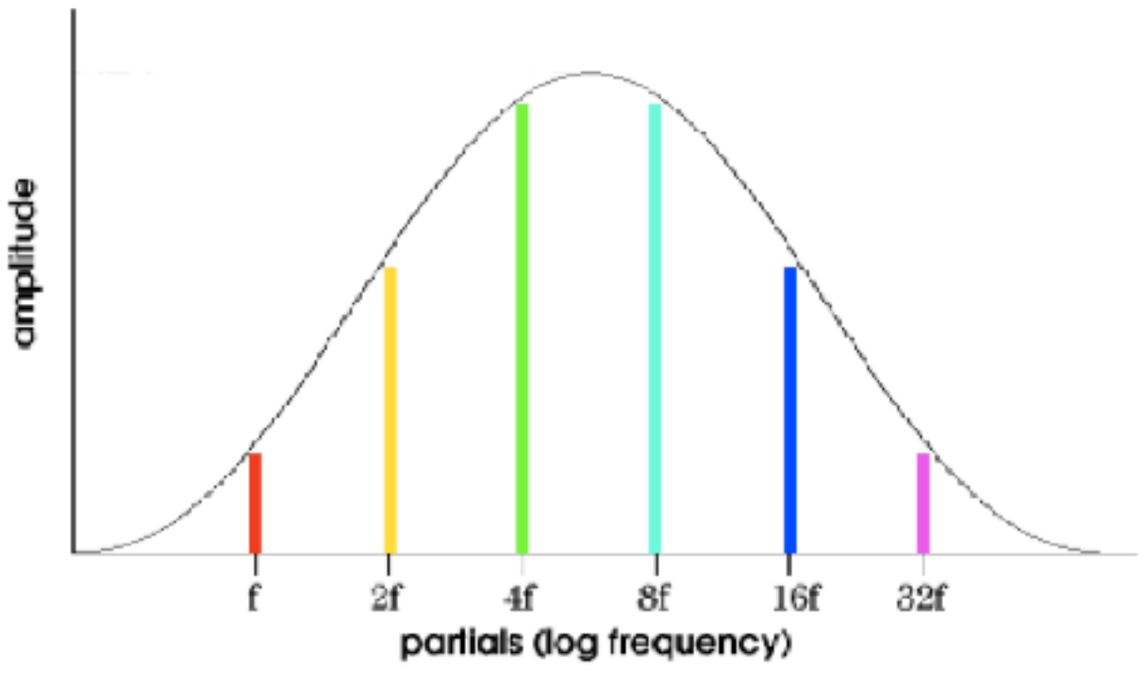


- The tone is actually a set of sinusoidal partials one octave apart, with an envelope that goes to zero at low and high frequencies
- Increase frequencies by a semitones, giving impression of rising pitch. After 12 semitones, we arrive back where we started

The Shepard Scale

- The tones in the Shepard scale are shown at left, and the intensity envelope is shown on the right

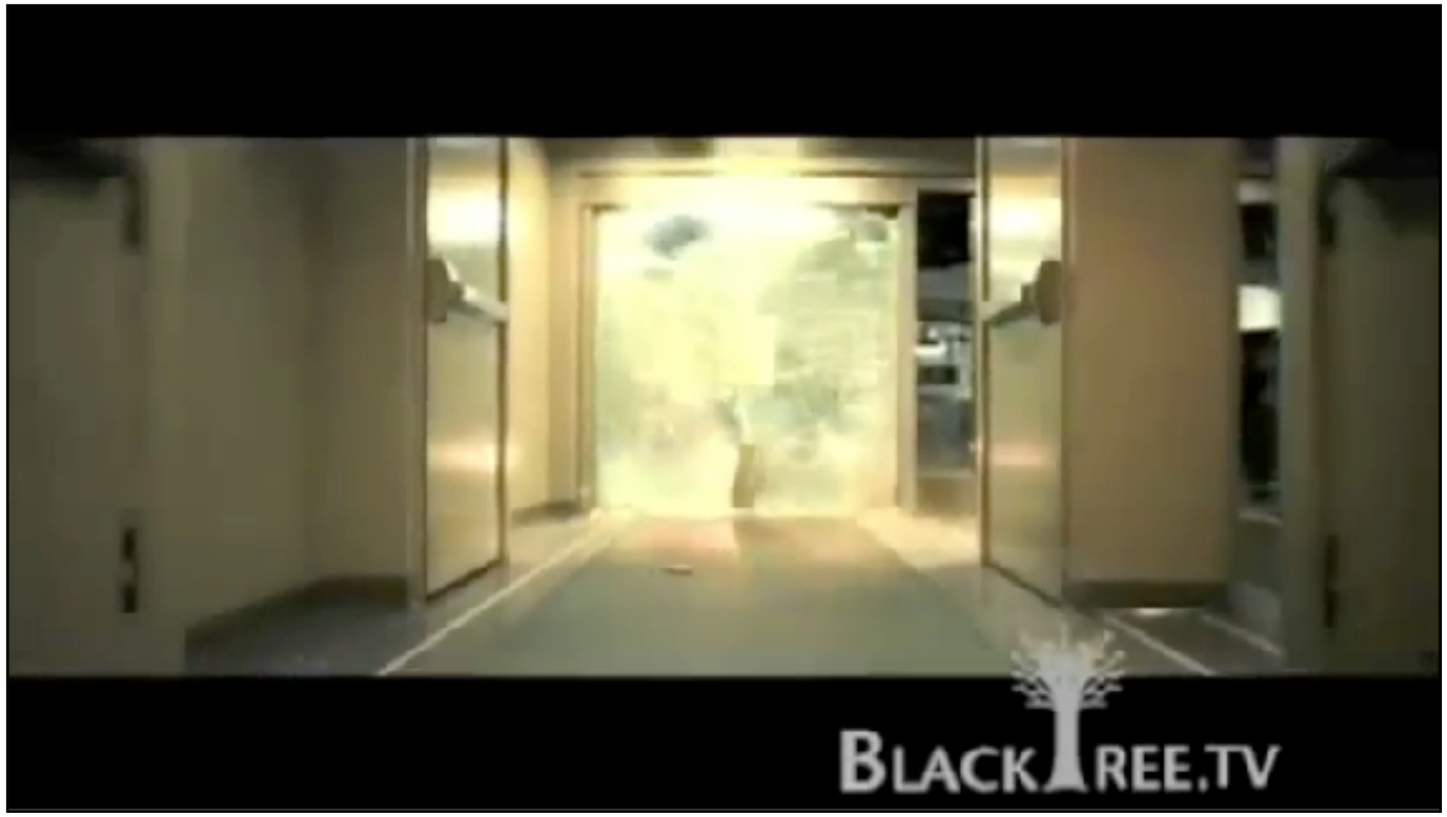




- Overlapping tones are one octave apart
- We can't hear the tones at the ends, so it's hard to perceive the repetition point in the pitch

Shepard Tone in Pop Culture

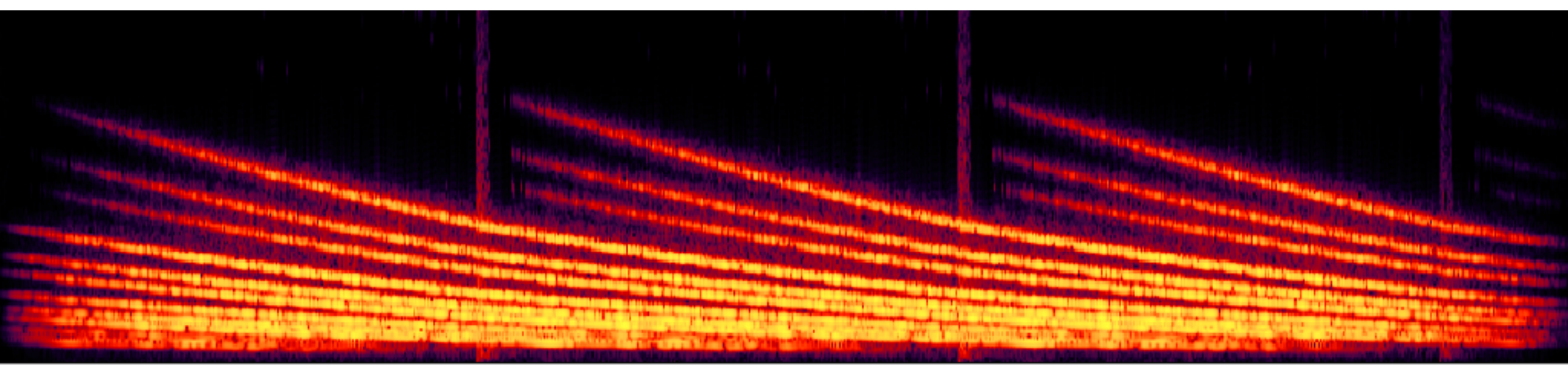
The Dark Knight, Warner Bros. (2008)



- Richard King, Sound Designer (*The Dark Knight*), *LA Times*, February 2009: "I used the concept of the Shepard tone to make the sound appear to continually rise in pitch. The basic idea is to slightly overlap a sound with a distinct pitch (a large A/C electric motor, in this case) in different octaves. When played on a keyboard, it gives the illusion of greater and greater speed; the pod appears unstoppable."

Descending Shepard Tone

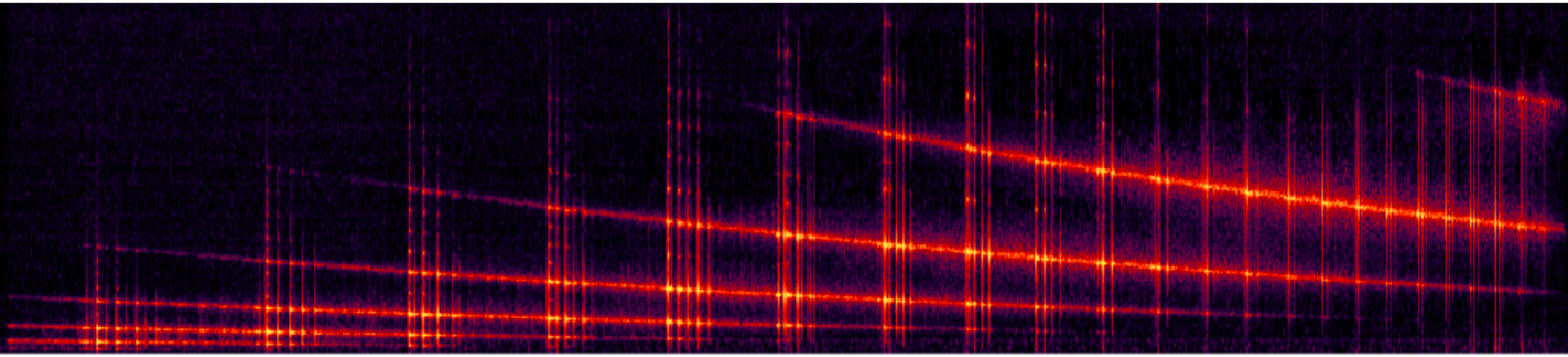
- No reason that the sequences has to step up by semitones
- We can also create an infinitely descending sonic staircase



- A little depressing?

Falling Bells Illusion

- Bells sound as if they are falling through space, and the pitch drops continuously
- Actually, the pitch ends higher than where it started

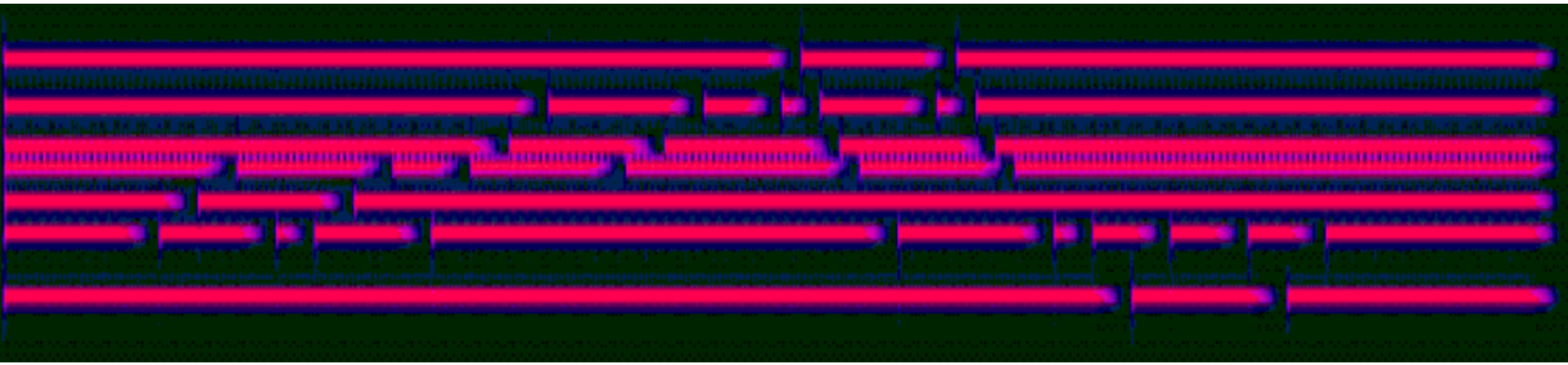


- Same trick as the Shepard scale, plus playing a bit with stereo

Filling in Melodies

- Start with a set of tones and then insert silences
- We don't perceive the silences, but we do perceive the tones when they restart

Yoshitaka Nakajima et al., *Demonstrations of Auditory Illusions*

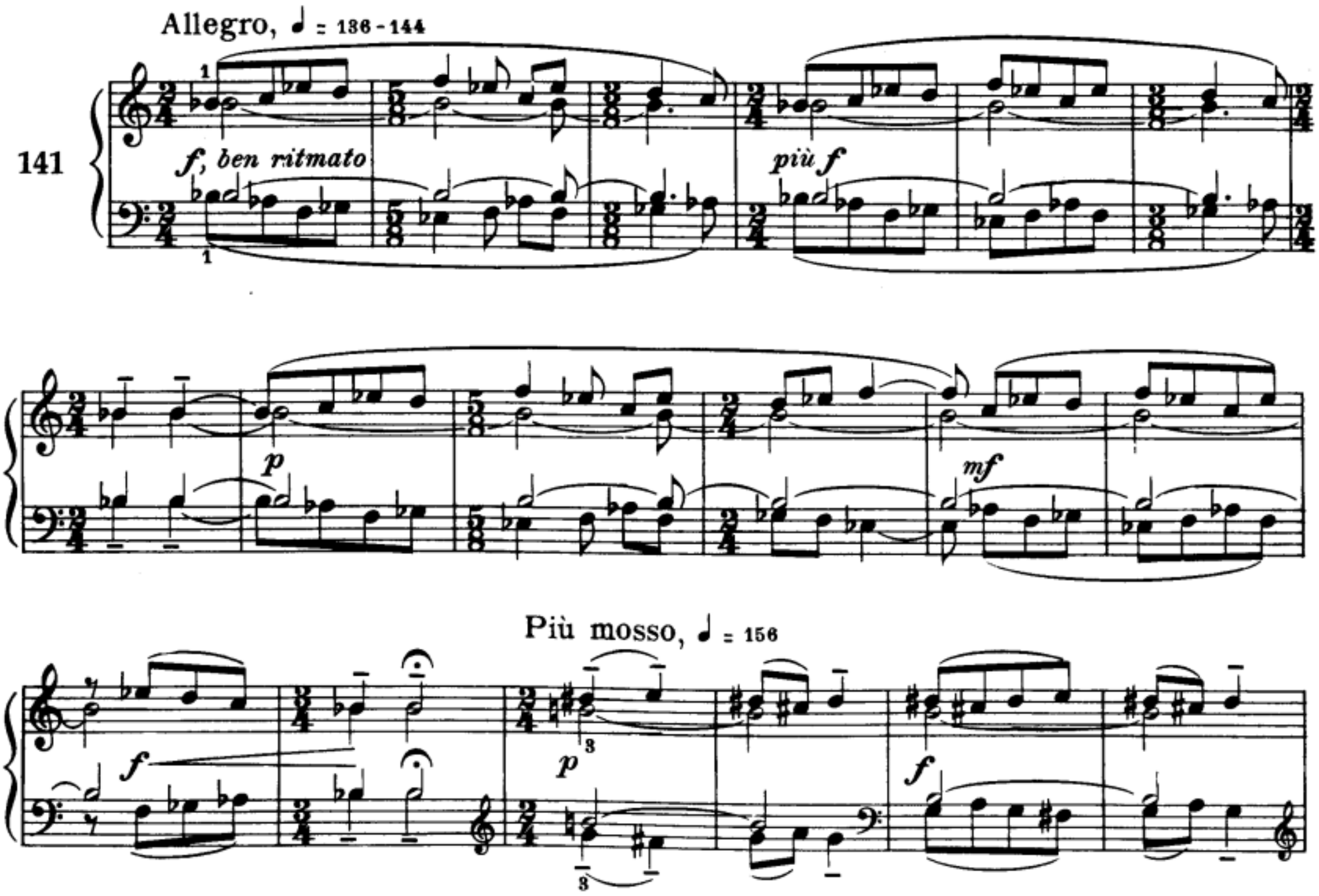


- We interpret the result as a clear melody. Do you hear it?

Reflection in Composition

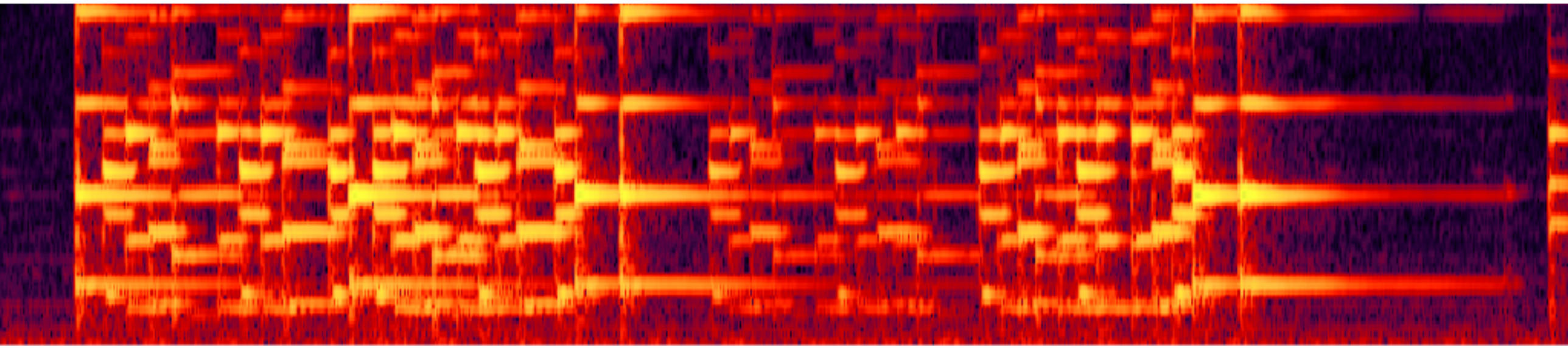
- Bartók, Mikrokosmos Vol. 6, No. 141, "Subject and Reflection"
- Two melodies are played: one goes up while the other goes down, and vice versa
- Can you pick out the reflective tonal symmetry without seeing the music?

Reflection in Composition



Reflection in Composition

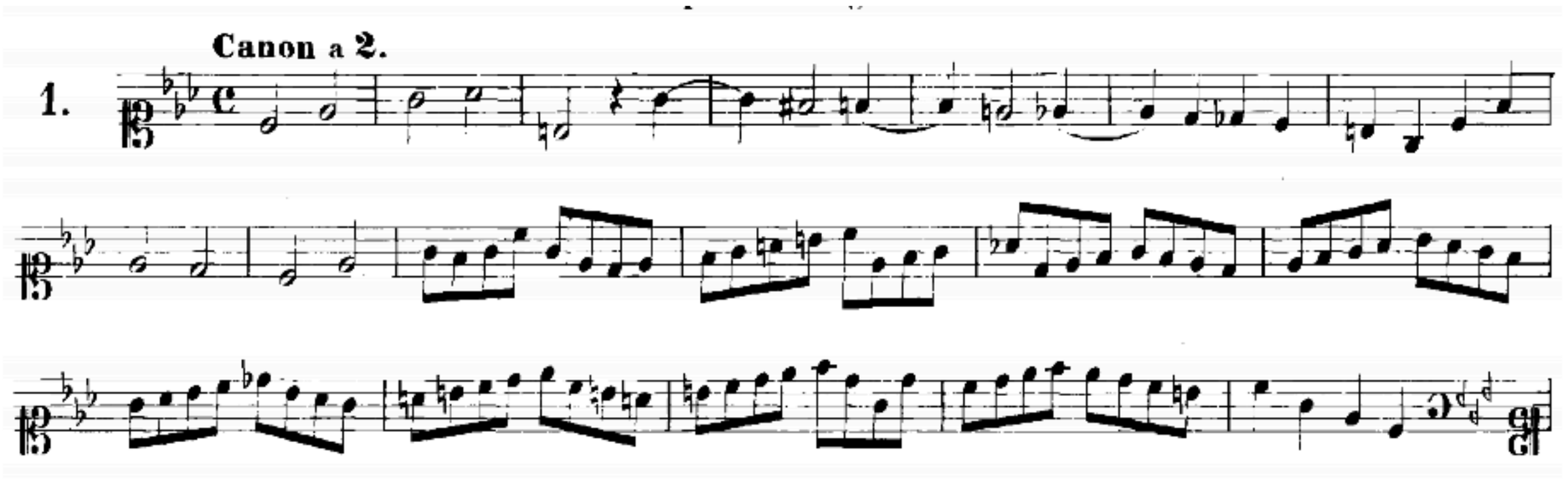
- Is the reflective tonal symmetry easy for you to see in the spectrogram?



- Is it easier for you to *see* the reflective tonal symmetry rather than *hear* it?

Time Reversal

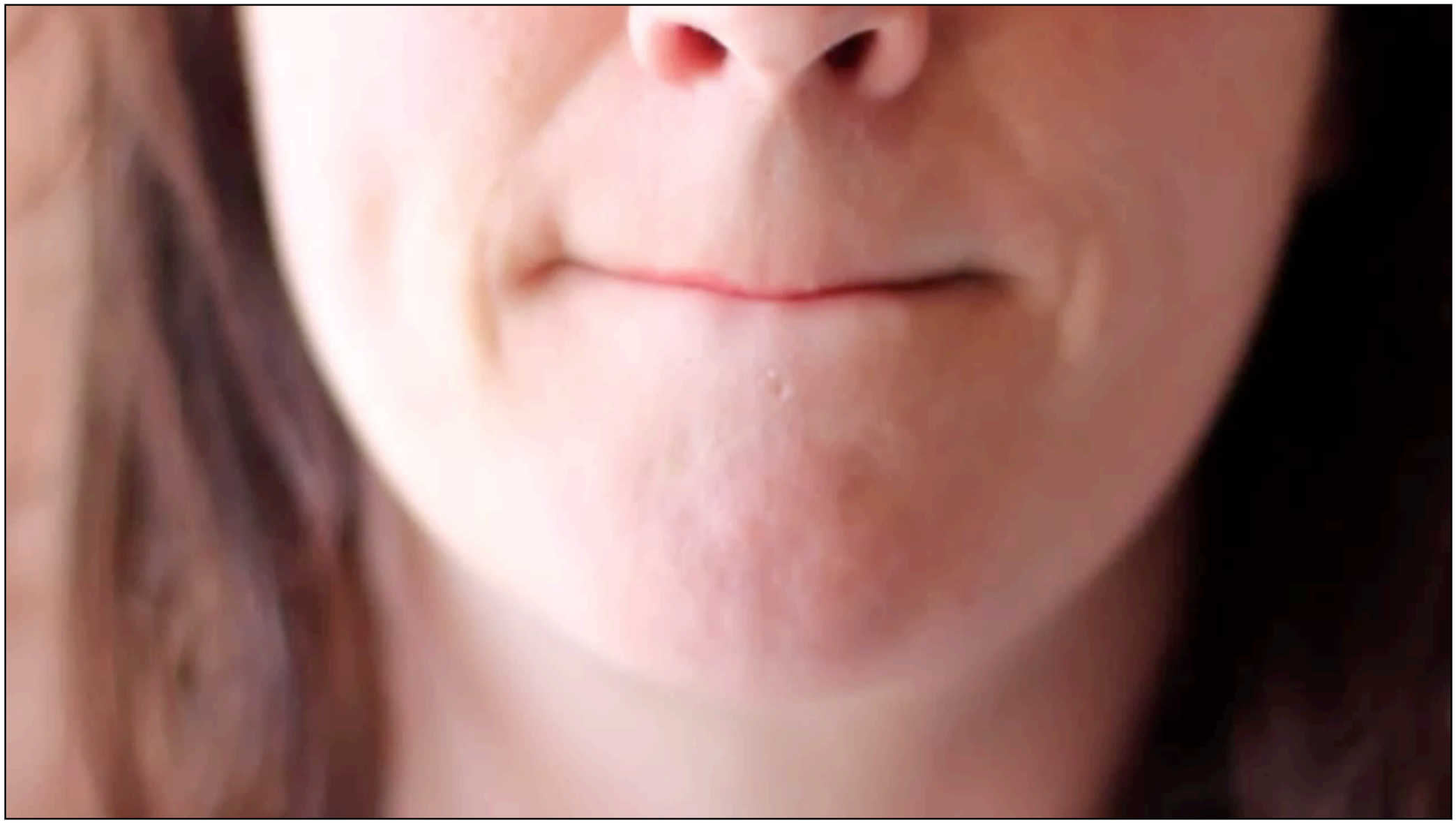
- There is also a long tradition of arranging music in so-called crab canons (or retrograde canons)
- Two lines are arranged complementary and backwards, like a palindrome



- Example: *A Musical Offering* by Bach

Sensory Integration Illusion

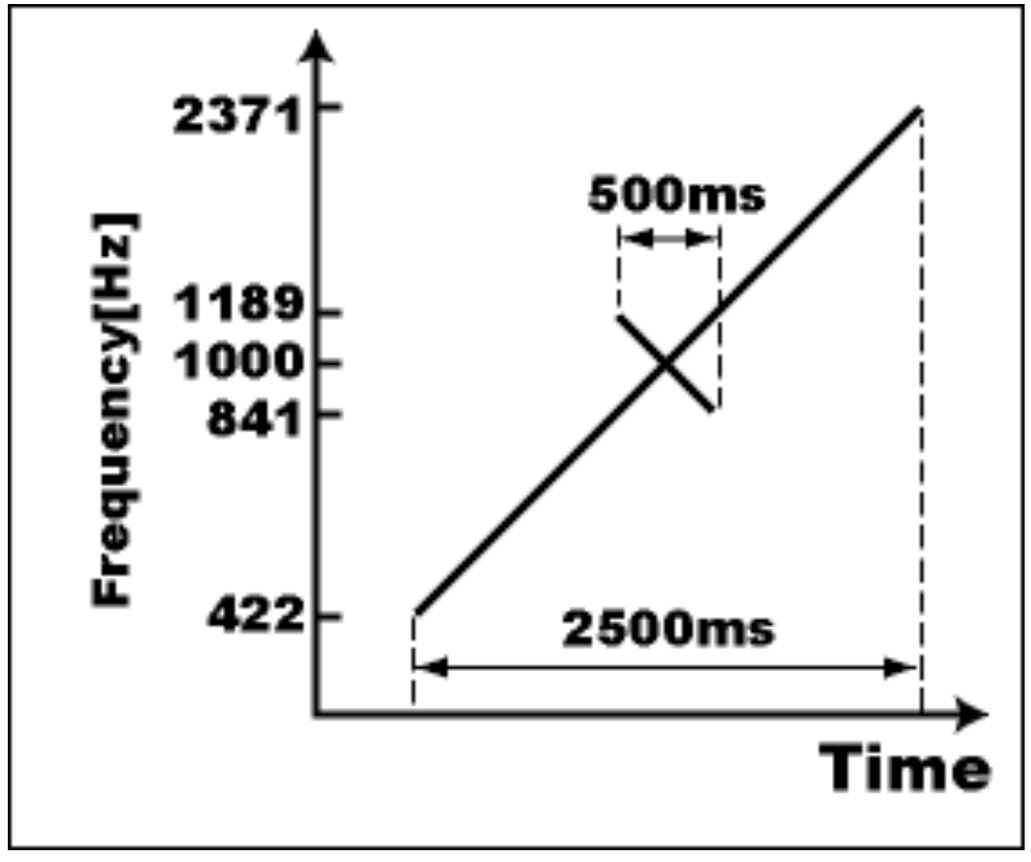
- McGurk Effect: "hearing" with the visual system first!



Gap Transfer Illusion

- Long ascending glide and short descending glide tones cross

Yoshitaka Nakajima et al., *Demonstrations of Auditory Illusions*

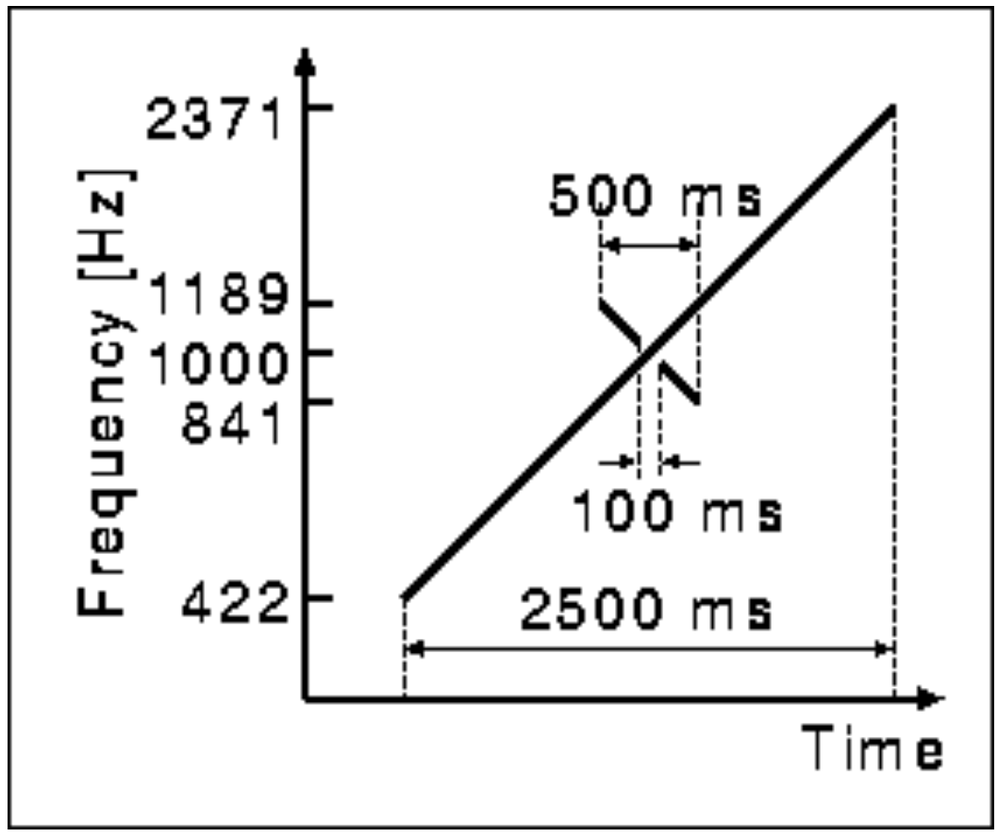


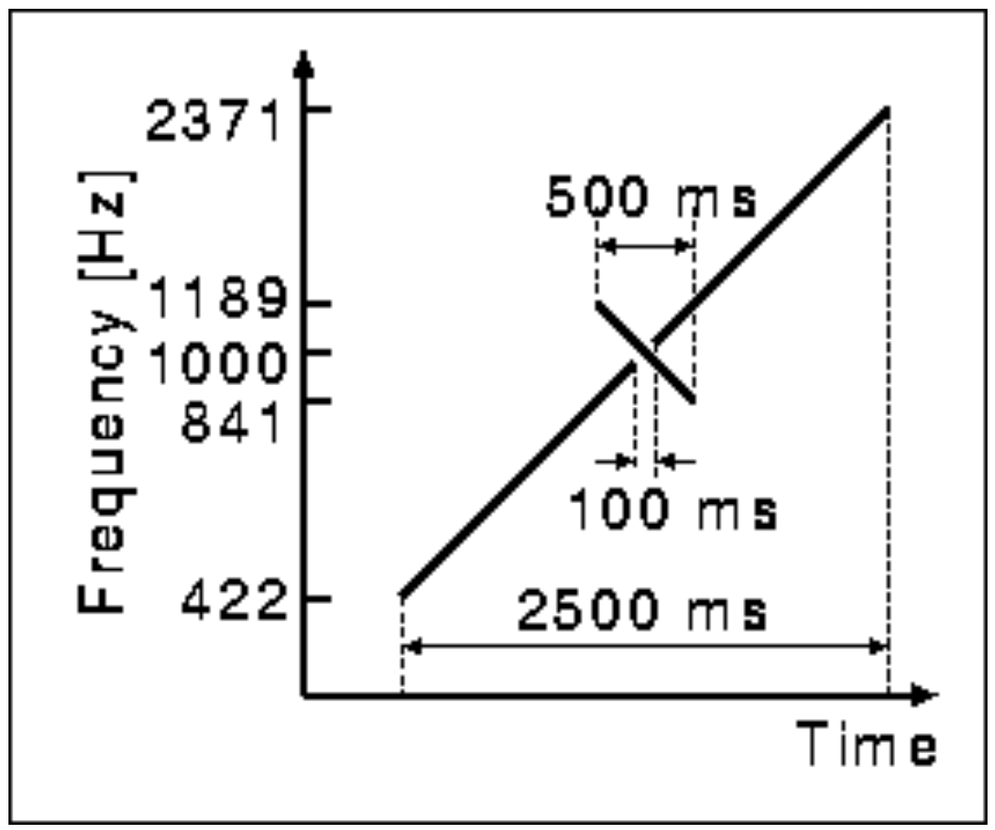
- A "bounce" is often perceived in the gliding tones

Gap Transfer Illusion (2)

- Pattern is disrupted by a 0.1 second gap, first in the descending glide, then in the ascending

Yoshitaka Nakajima et al., *Demonstrations of Auditory Illusions*



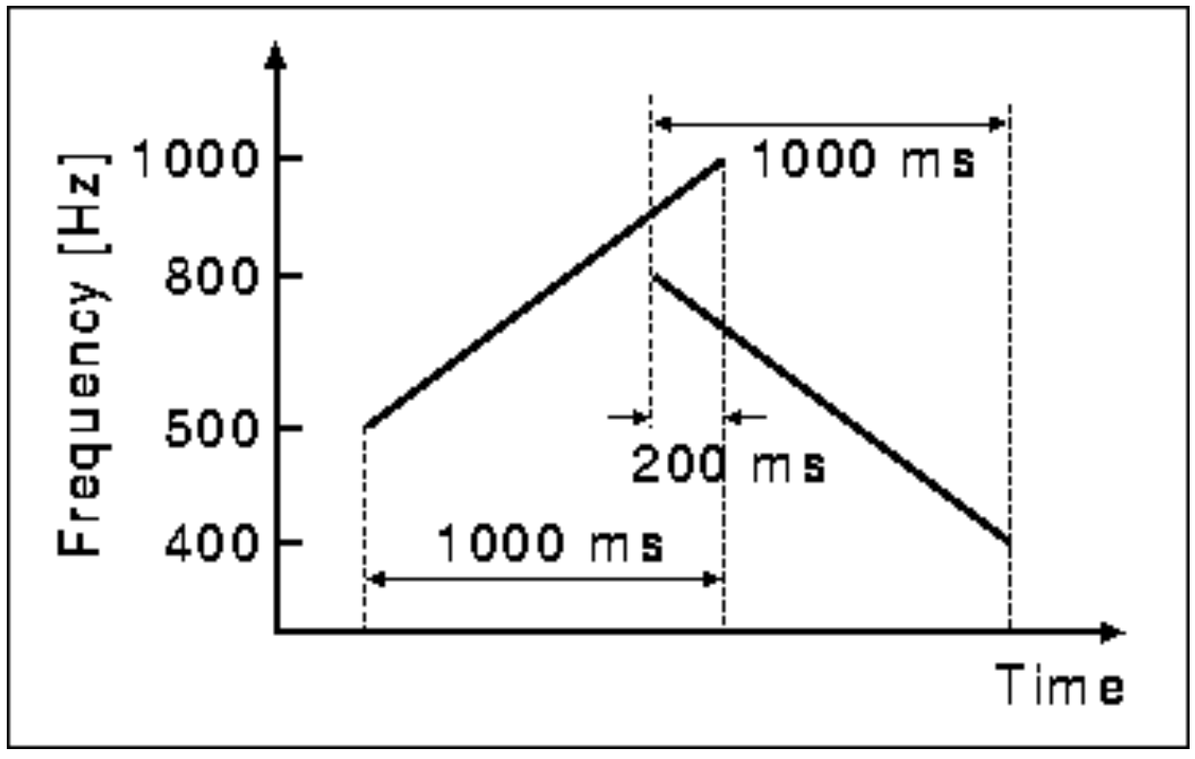


- People tend to perceive these as identical

Split-Off Illusion

- An ascending and descending glide tone overlap for 0.2 s

Yoshitaka Nakajima et al., *Demonstrations of Auditory Illusions*

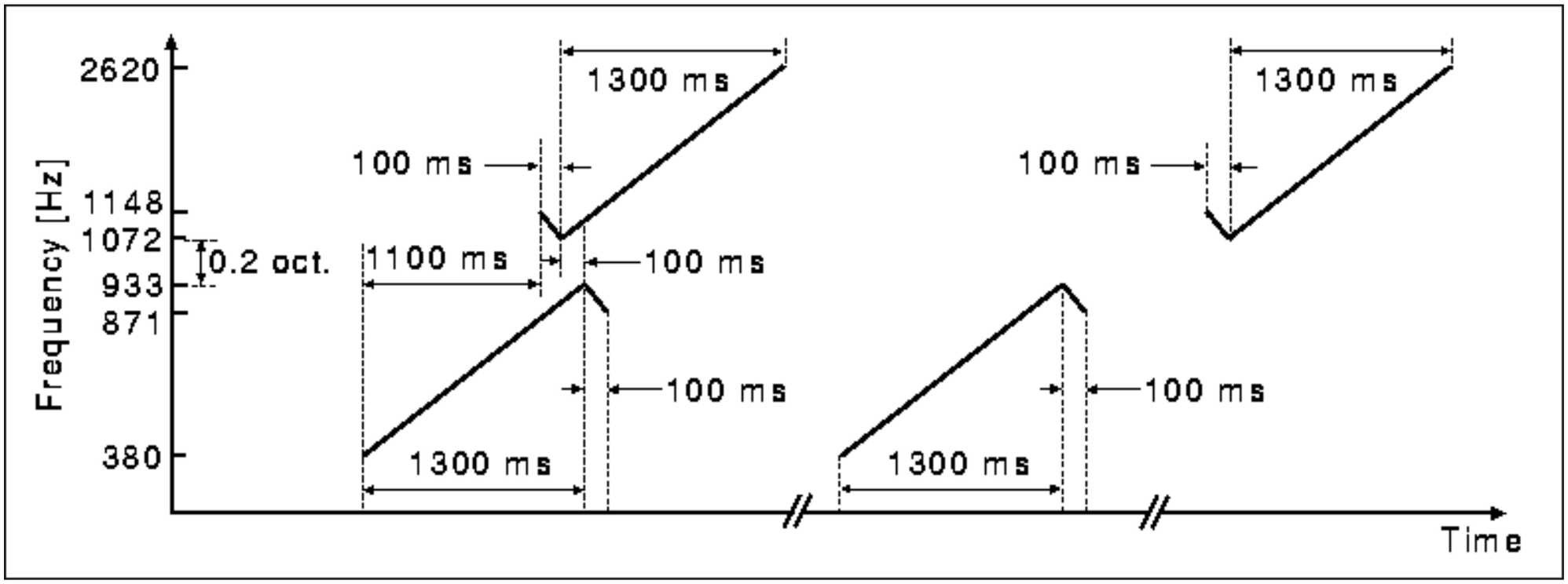


- Listeners tend to perceive one long tone which rises and falls, with a short tone in the center due to the termination of the ascending glide tone

Split-Off Illusion (2)

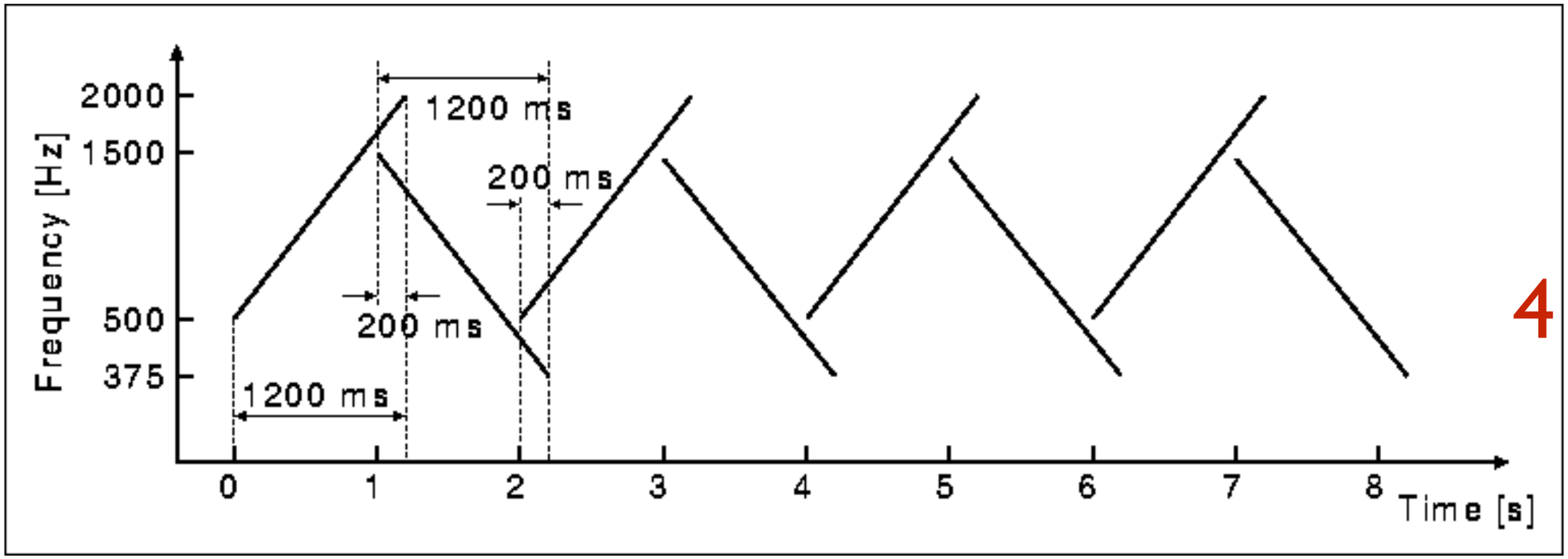
- Two glide tones bounce off each other

Yoshitaka Nakajima et al., *Demonstrations of Auditory Illusions*

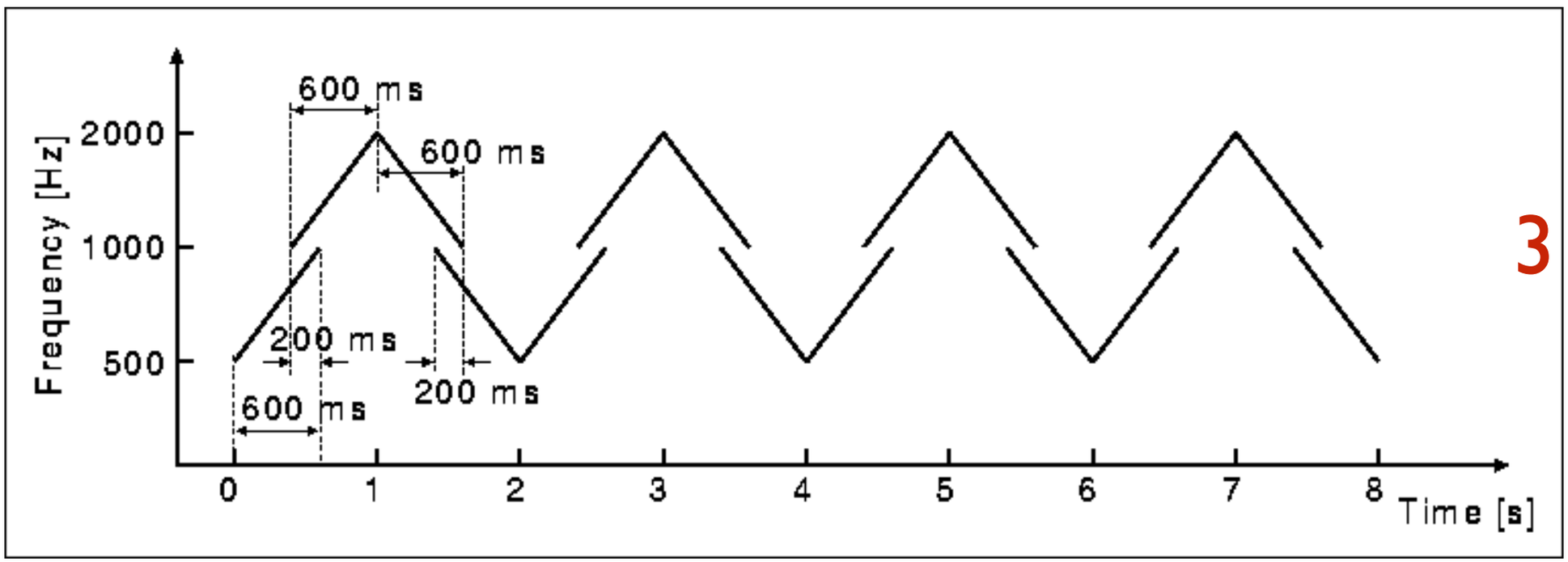


- Perceptually, it sounds more like the glide tones are crossing instead of bouncing

Split-Off Illusion (3)



4 tones



3 tones

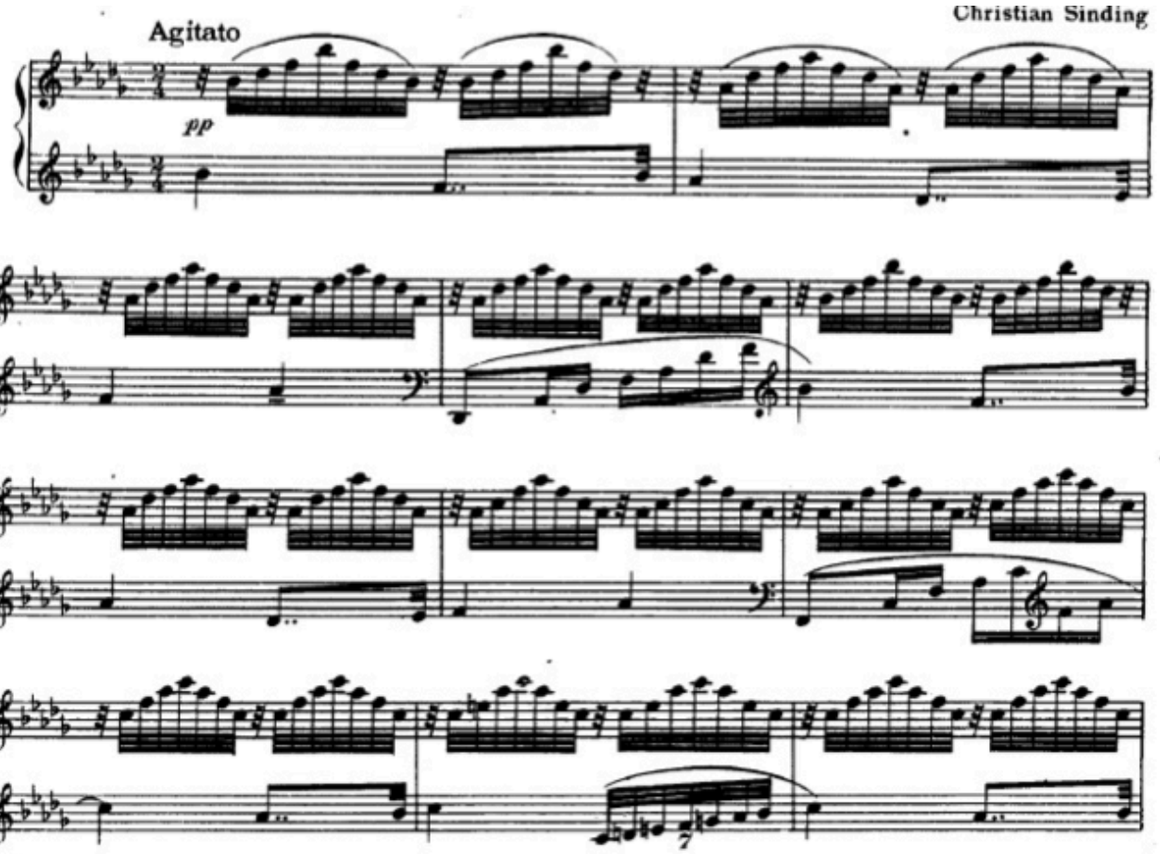
"Apparent Motion"

- If tones are far apart and alternated slowly you can track a melodic pattern
- But as the speed increases their order becomes indeterminate. Eventually you just hear beeps and boops. Example: yodeling

Yodeling Demo:
Perry R. Cook
Sample 33

Phantom Melodies

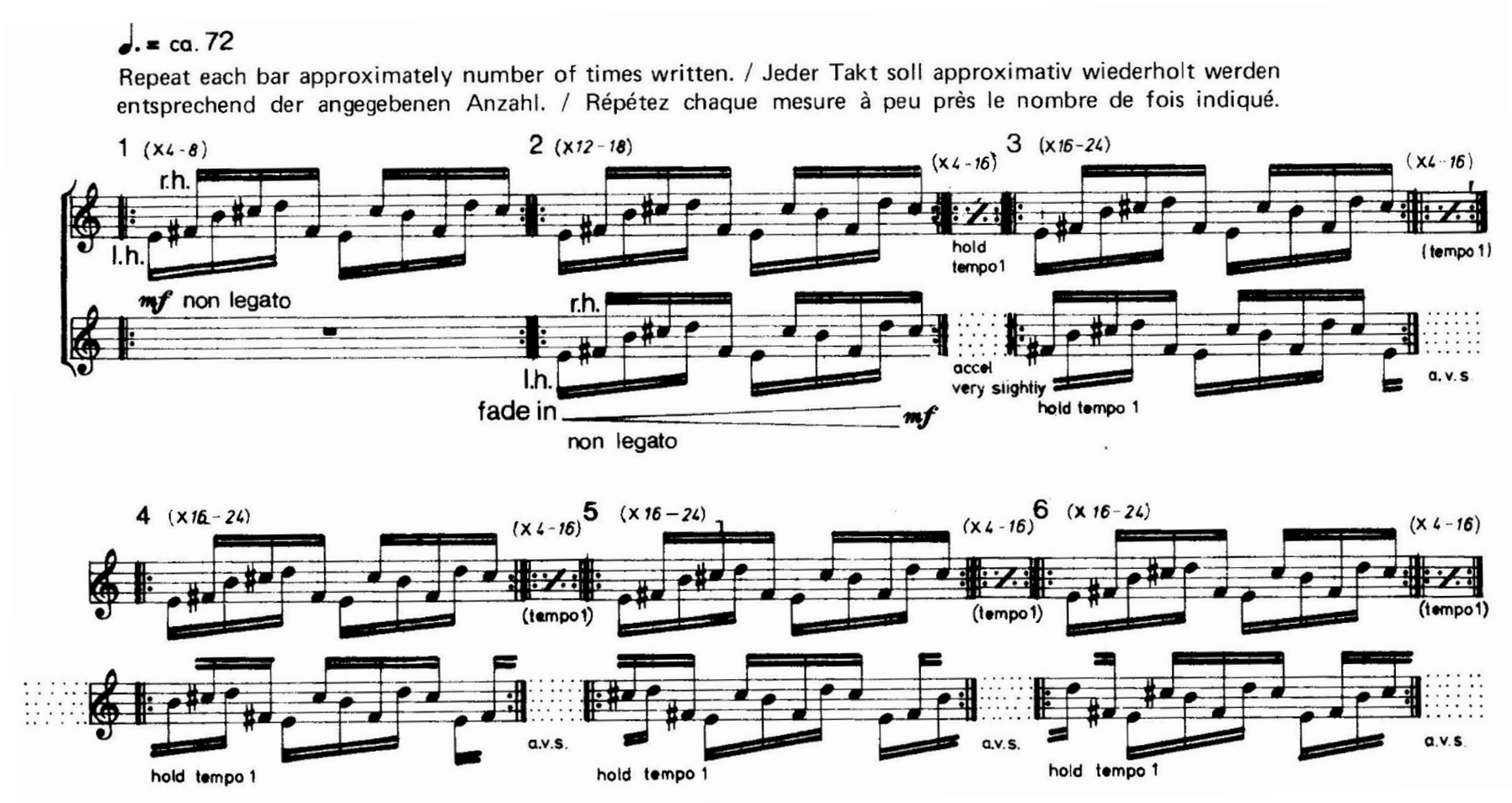
- Frühlingsrauschen ("Rustle of Spring") played fast and at 1/4 speed (exit slideshow)



- Fast: arpeggios blend together into a phantom melody.
  Slow: we hear the notes separately without the melody

Perceptual Groupings

- Fast rhythm in presence of timbre variations leads to sounds joining into perceptual groupings
- Ex: *Piano Phase*, Steve Reich



Scale Illusion

- Our brains like to group similar notes together, and will do so when separate melodies are played

- Effect discovered by Diana Deutsch (Psychologist, UCSD) in the 1970s

Timbre and Auditory Streams

- Two melodies played simultaneously can produce a single emergent melody
- Example: auditory streaming in African xylophones

- However, if there is a large difference in timbre between the xylophones, the combined melody does not emerge. Similarly if there is an octave difference in pitch
- Instead, you just hear the two instruments separately

Deutsch's Tritone Paradox

- Listen to the following tones.
- Are they ascending or descending in pitch?
- Why do you think so?

Tritone Paradox

- A tritone is two pitches 1/2 an octave apart (e.g., C to F#)
- Musicians often disagree on whether or not the pitch is ascending or descending

- Issue: our brains have a preference for listening to the higher or lower tone. It differs from person to person