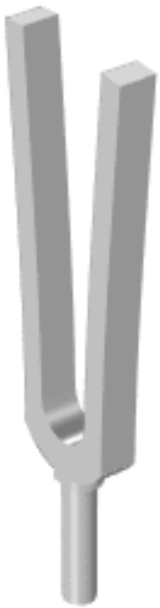


movie made by me

Percussion

Physics of Music
PHY103

Dr. Dan Russell, Penn State

Animation courtesy of Dr. Dan Russell,
Grad. Prog. Acoustics, Penn State

Percussion

Divided into

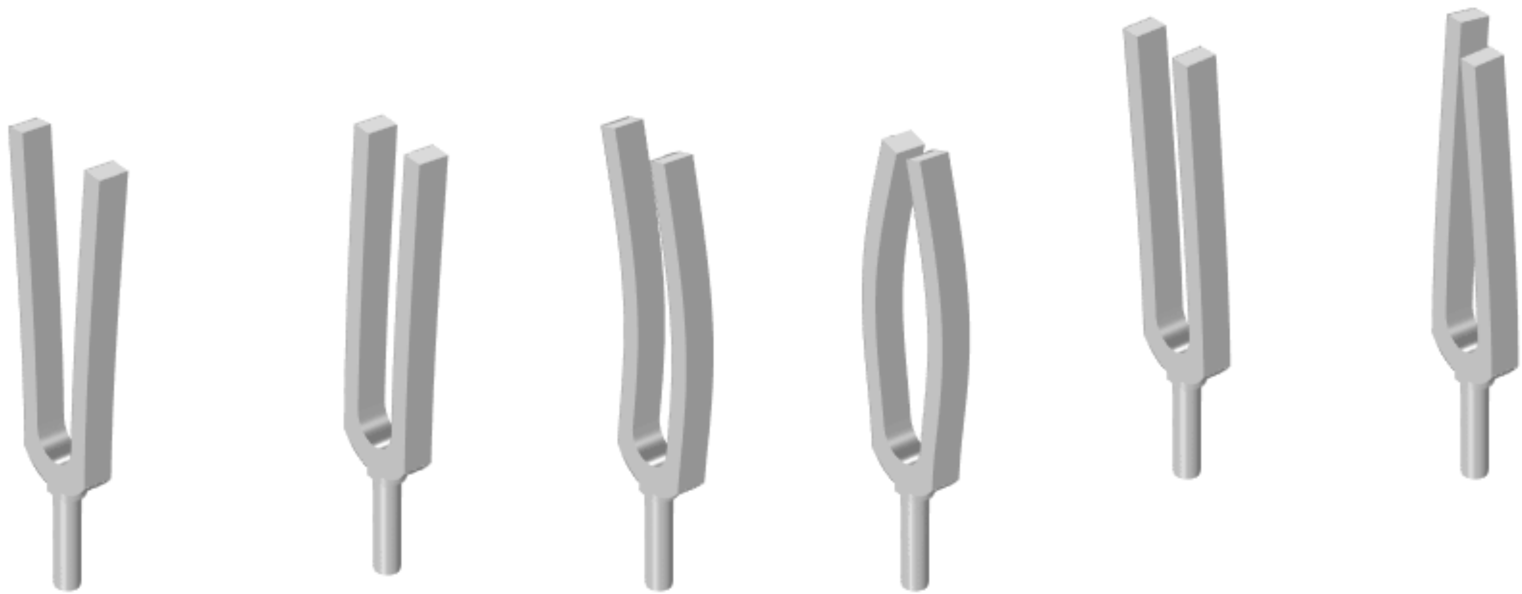
- Membranophones: drums

and

- Ideophones: chimes, xylophones, marimbas, jawharps, boos, tongue drums, bells, gongs

Could also be divided into those with pitch and those without

Modes of a tuning fork



fundamental mode

In plane asymmetric bending

In plane symmetric bending “clang”

Out of plane symmetric and anti symmetric

Animations courtesy of Dr. Dan Russell, Grad. Prog. Acoustics, Penn State

Circular Membranes modes of vibration

- The first three modes C_1,C_2, C_3 are axisymmetric (circular rings).
- The last 2 modes have azimuthal structure (bilateral) L_1, L_2
- C vs L mode spectrum depends on where you hit the drum. You get higher frequency vibrations when you hit the edge of the drum

C_1	f_1	
C_2	$2.3f_1$	sharp major 9^{th}
C_3	$3.6f_1$	octave + minor 7^{th}
L_1	$1.59f_1$	minor 6^{th}
L_2	$2.92\ f_1$	octave + 5^{th}

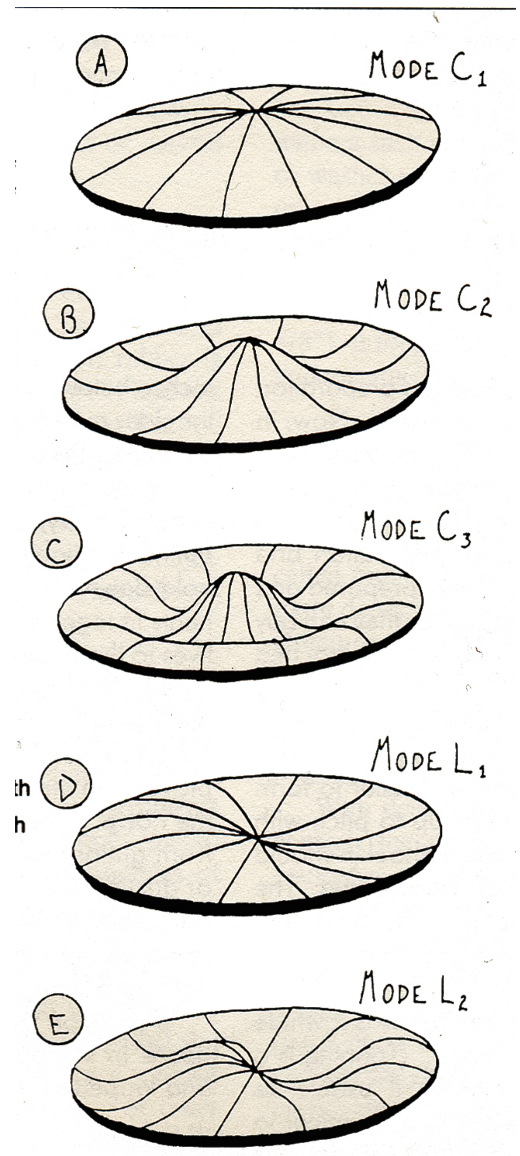


Figure from Musical Instrument Design by Bart Hopkin

Resonances of the membrane

- By changing the tension on the membrane you can change the pitch of the drum (experiment with flatdrum!)
- By making the membrane heavier you should be able to lower the pitch

Nodal diameters and circles

(a,b)

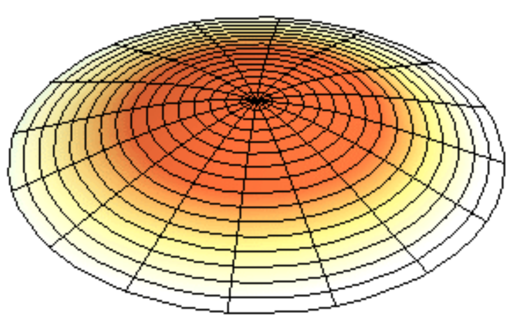
a= The number of circular nodes (circles that don't move)

b= number of diameters nodes (lines that don't move)

C1: (0,1)

no diameter nodes

1 circular node, the outer edge



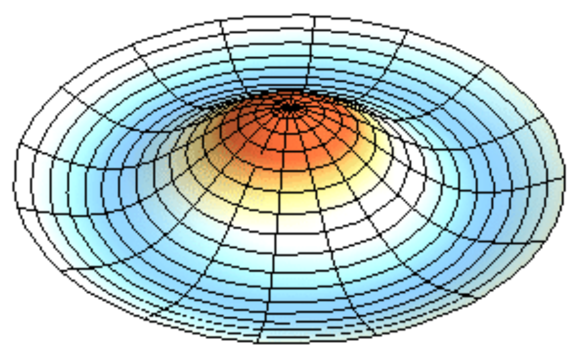
Radiates sound very quickly

The only mode that is not on average zero

C2: (0,2)

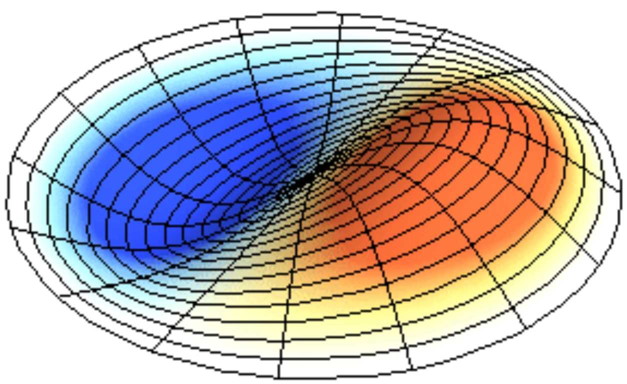
two circular nodes

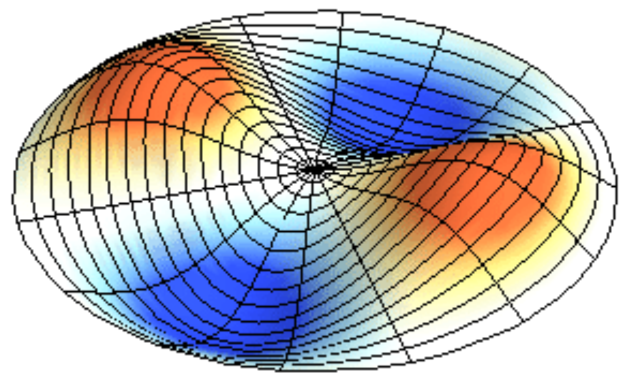
outer edge and at radius=0.43



Animations courtesy of Dr. Dan Russell, Grad. Prog. Acoustics, Penn State

L modes



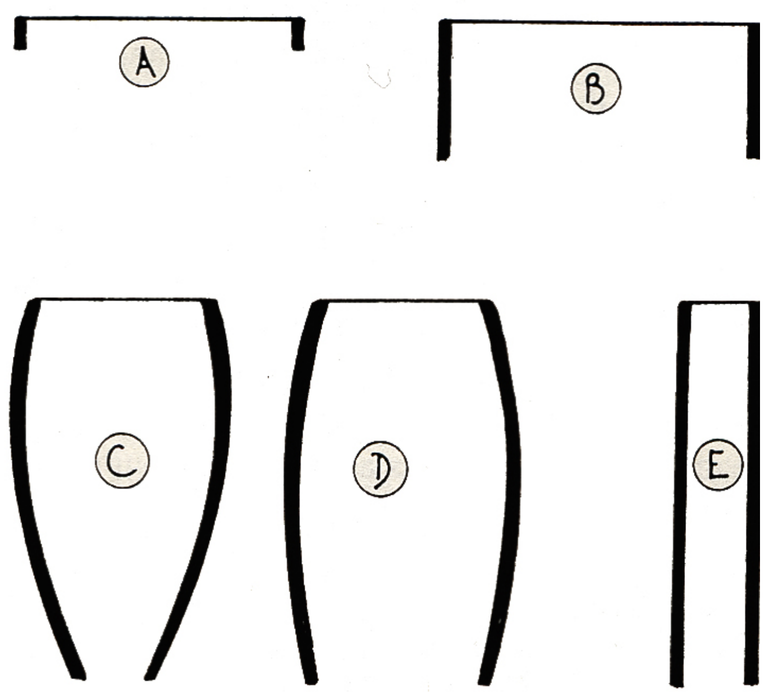


L1 (1,1)
one diameter node
one circular node, the edge

L2 (2,1)
two diameter nodes
perpendicular to
each other

Animations courtesy of Dr. Dan Russell,
Grad. Prog. Acoustics, Penn State

Resonances of the drum vs that of the body



- A: frame drum
- B: Tenor drum
- C: Barrel drum with narrow opening
- D: Barrel drum with large opening
- E: tube drum

Figure from Musical Instrument Design by Bart Hopkin

Resonances of the drum vs that of the body

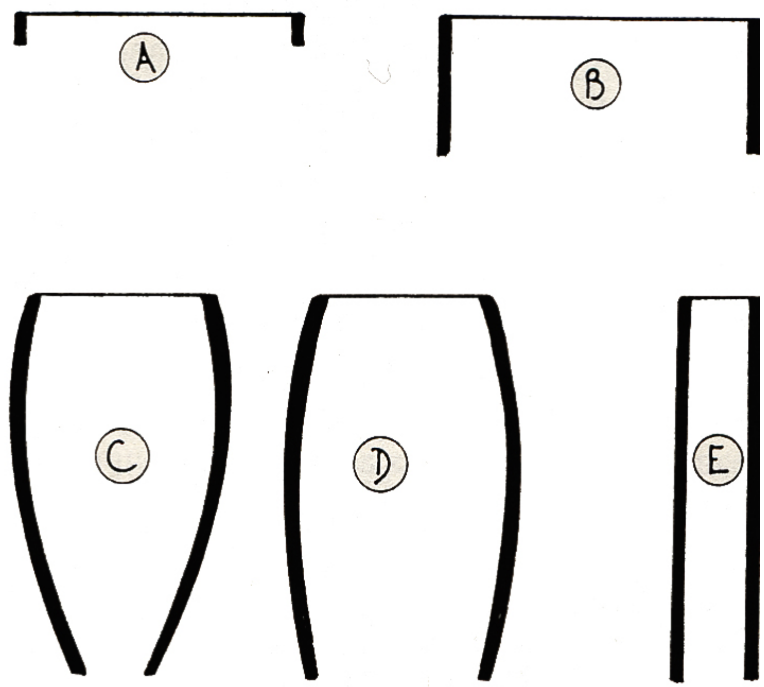


Figure from Musical Instrument Design by Bart Hopkin

- A: No added resonance -- out of phase waves from front and back cancel
- C: Membrane and barrel could have different resonances- barrel usually has a deeper tone than the drum head – narrow resonance peak for barrel
- D: Barrel might have a wider resonance peak

Drum tuning

- Adjusting the tension of the drum head changes the resonant frequencies of the drum head
- It also changes the resonant frequencies within the drum chamber --- this is because the rigidity of the walls affects these resonances
- Process of adjustment required to have the resonances of the membrane reinforce the resonances of the drum body --- leading to a fuller sound

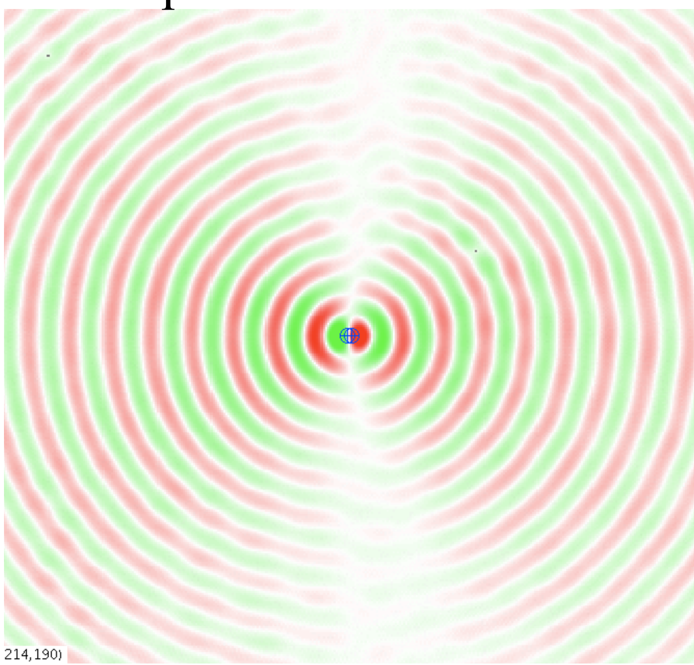
Drum sound

- Coupling of membrane motions to Helmholtz modes (air moving in and out)
  - If air and membrane move together, we expect a lower frequency combined mode, if they move in opposite directions we expect a higher frequency combined mode
- Interference between sound launched from the front and sound driven from the back of the drum
  - back wave cancels out the front wave unless they are shifted in phase

Two emitting sources that are closer than a wavelength

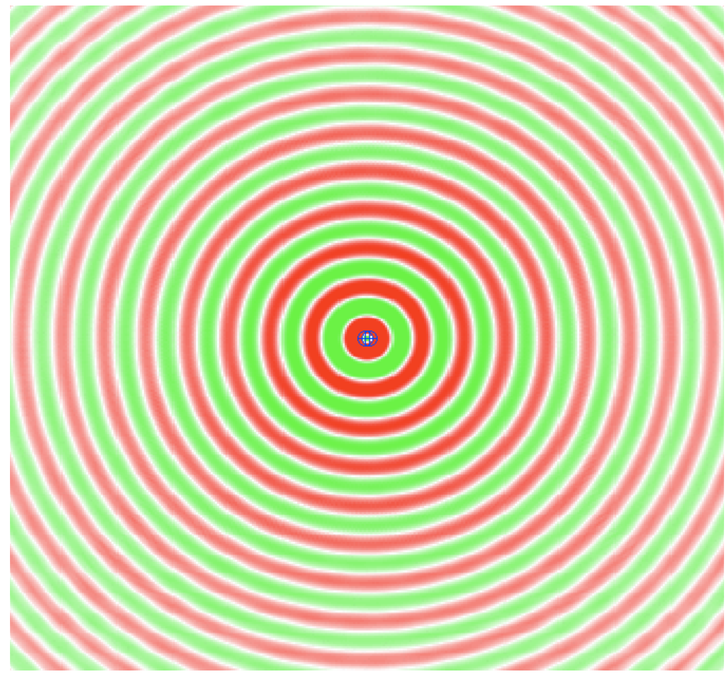
Using [www.falstad.com/**ripple**/](www.falstad.com/ripple/) *(Paul Falstad's applet)*

dipole: two nearby sources
180^o out of phase

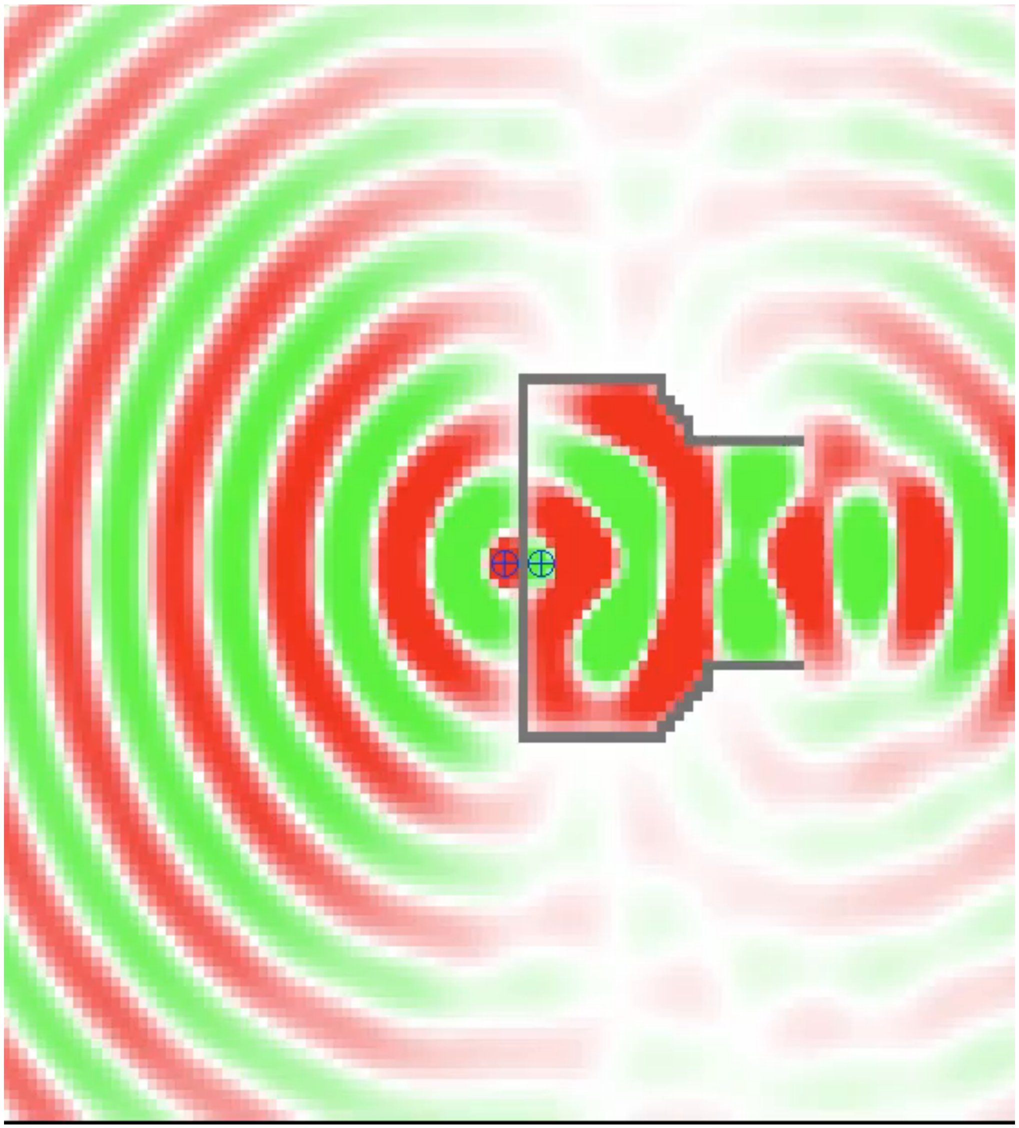


In the far field, the two sources cancel each other
$1/r^3$ law

monopole:
Two nearby sources, in phase



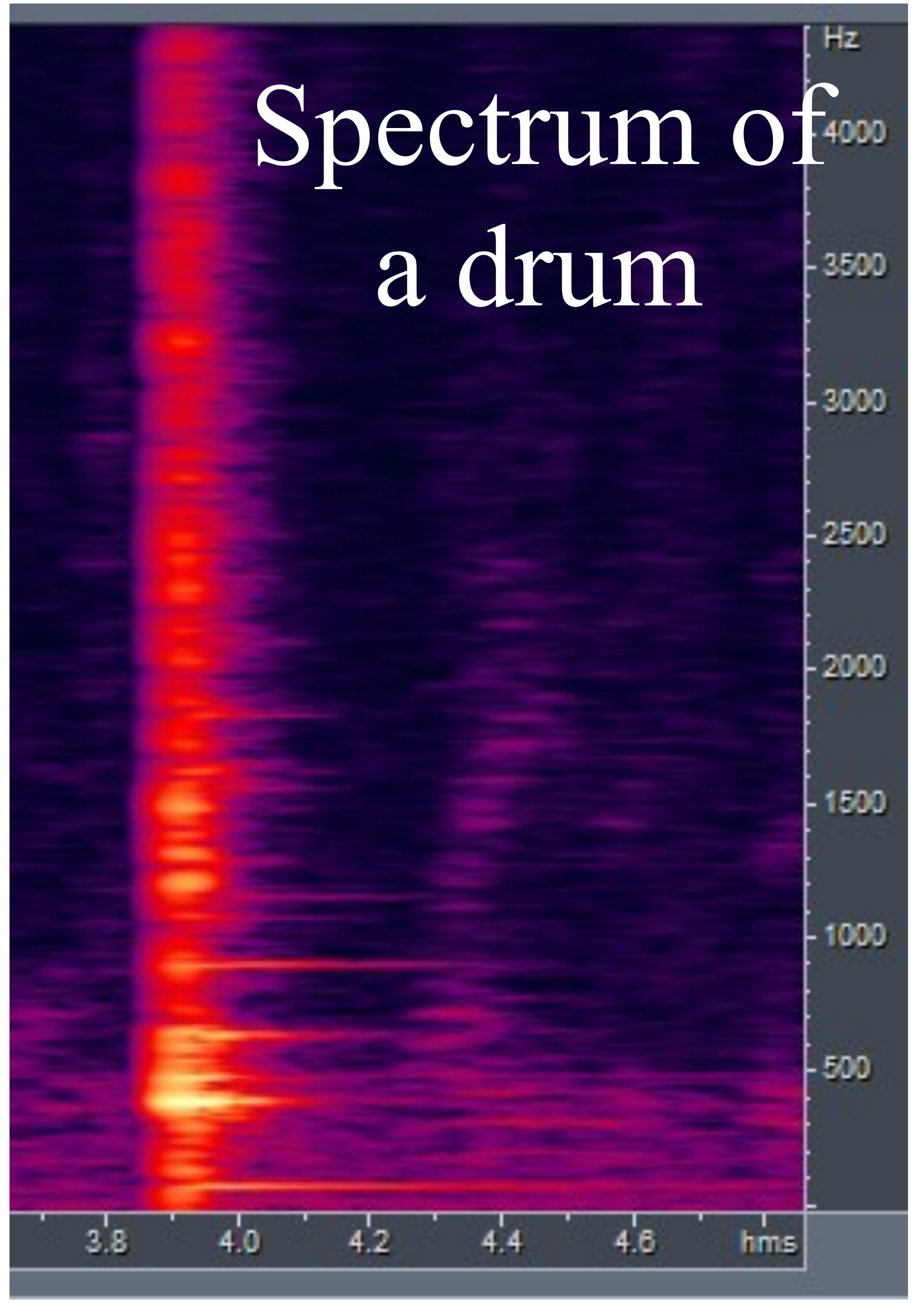
Far field radiation pattern is similar to a single source
$1/r^2$ law



Baffling

using Falstad's applet and quicktime capture


Toca drum


Spectrum of a drum
Hz
4000
3500
3000
2500
2000
1500
1000
500
3.8
4.0
4.2
4.4
4.6
hms

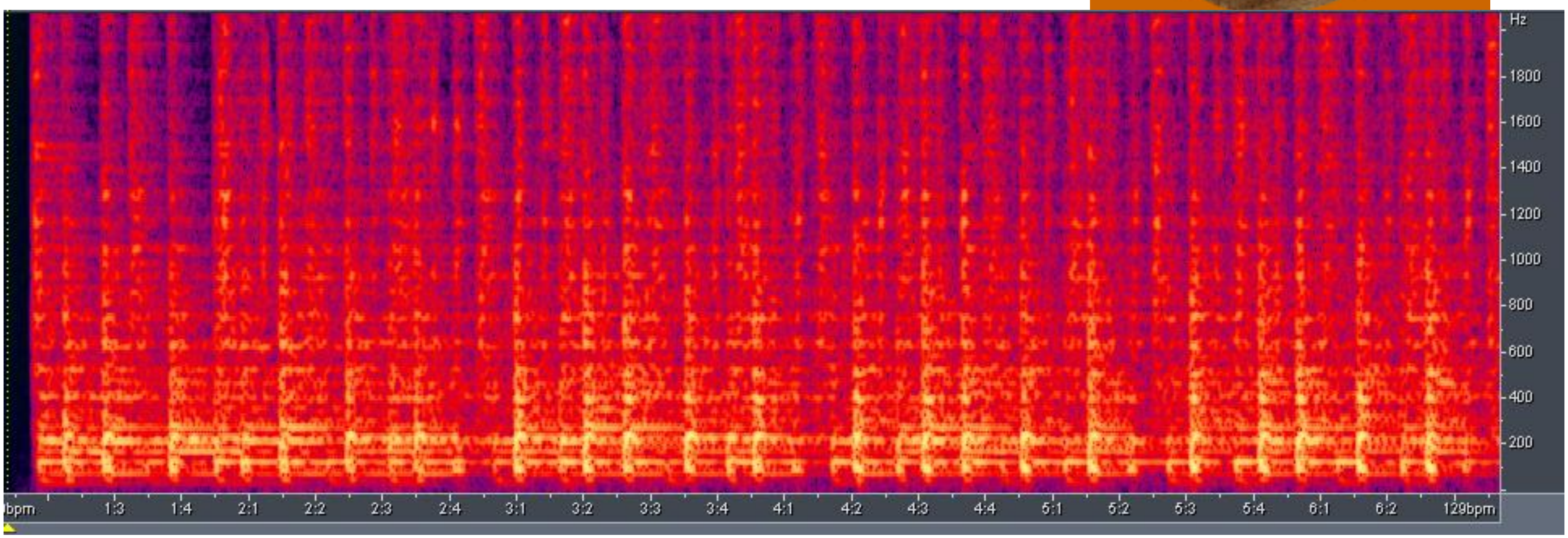
Drum ensemble from Benin

Sound box of wood with a laced skin membrane. The sound changes when stuck at different positions on the drum head.

Music taken from CD
Musical instruments of the World 1990 CNRS

Frame Drum

- Example from Rajasthan
- One meter large, can be hit by more than one player



Goblet Drum - Darbuka

- Egypt
- Goblet with a glued membrane of lambskin
- Tone quality is adjusted solely from changes of power and angle of attack

Spectrum of Darbuka

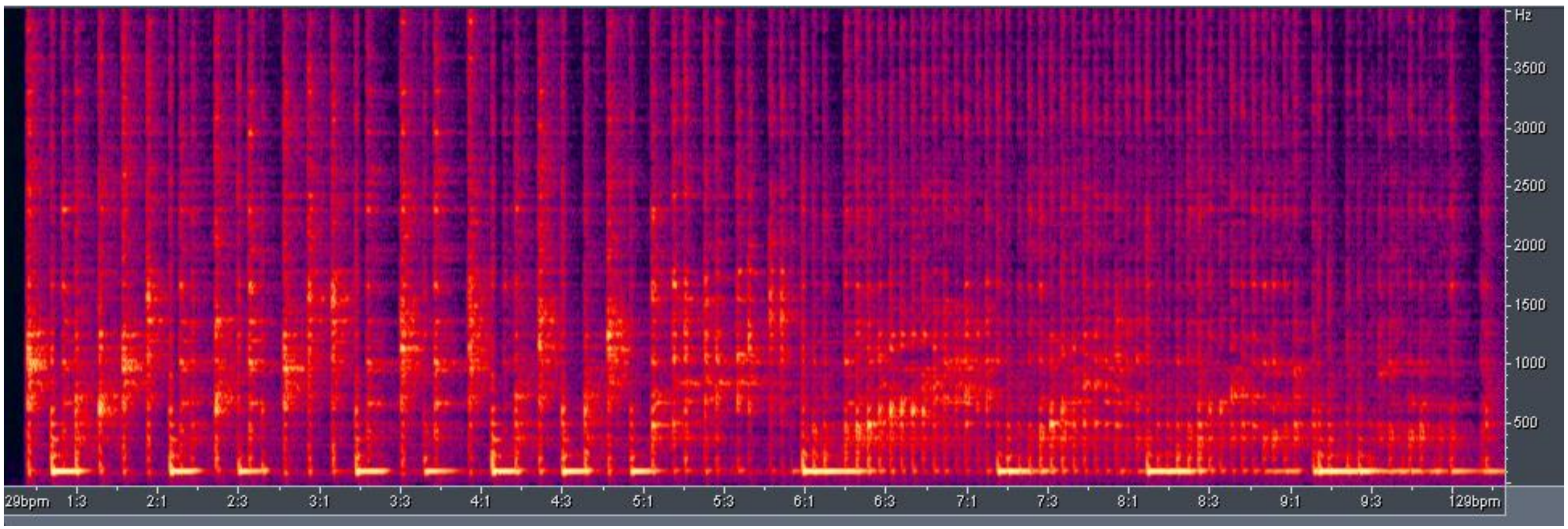
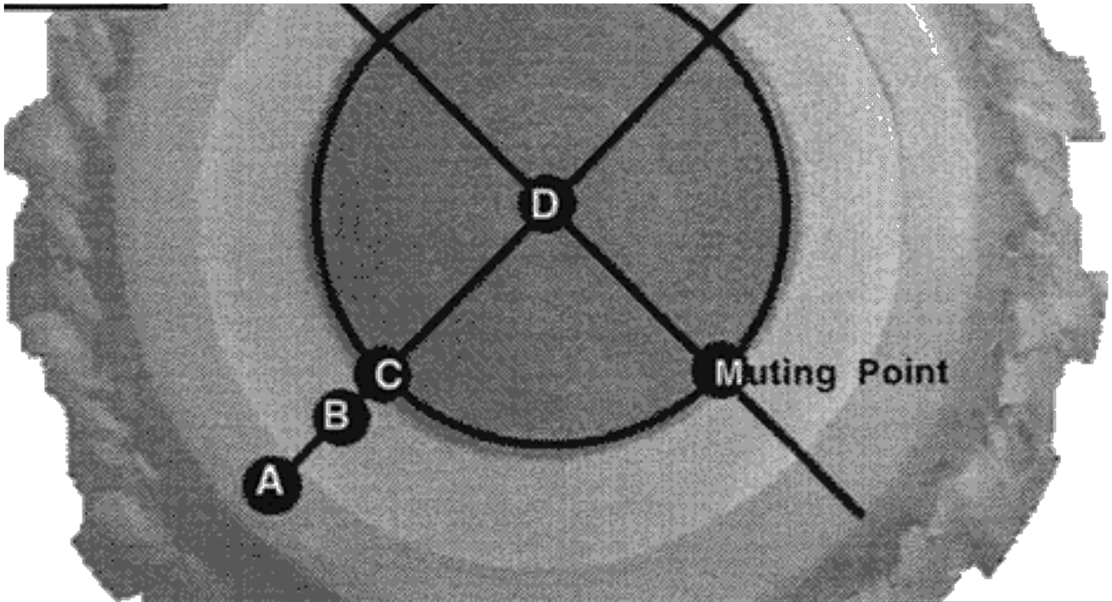


Tabla India

- Note vocalization following
- membrane thickness varies so sound is very sensitive to position hit

Tabla Talas

Image from http://www.chandrakantha.com/tablasite/quick.htm



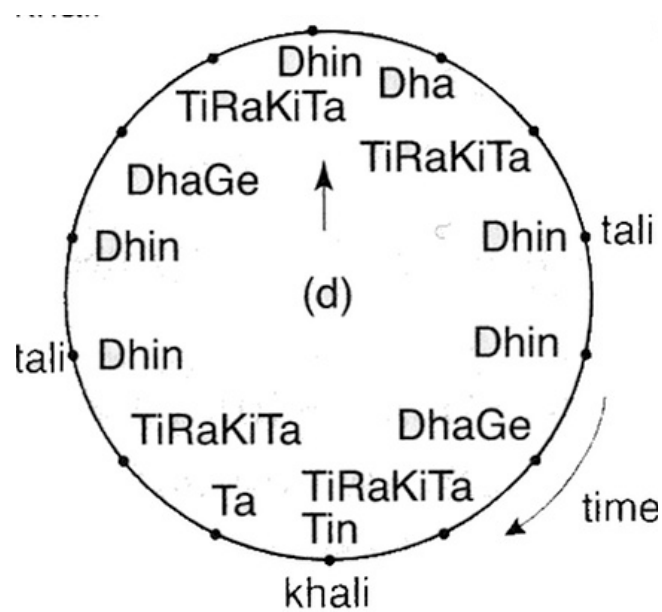
Bol	English	MUTING (Rt Hnd)	STROKE (Rt Hnd)	LEFT HAND	COMMENTS	Page #
ना	Na	Yes	A	-	sharp sound	38
तिं	Tin	Yes	C	-	soft sound	39-40
ग	Ga	-	-	Resonant	strike in maidan	38-39
धा	Dha	Yes	A	Resonant	strong right sound	39
धिं	Dhin	Yes	C	Resonant	soft right sound	40
ती	Ti	Yes	D	-	middle finger nonresonant	41-42
तू	Tu	No	D	-	soft and resonant	42
ता	Ta (Dilli)	Yes	A	-	Forceful	39
ता	Ta (Purbi)	Yes	B	-	Forceful	58
क	Ka	-	-	Nonresonant		37-38

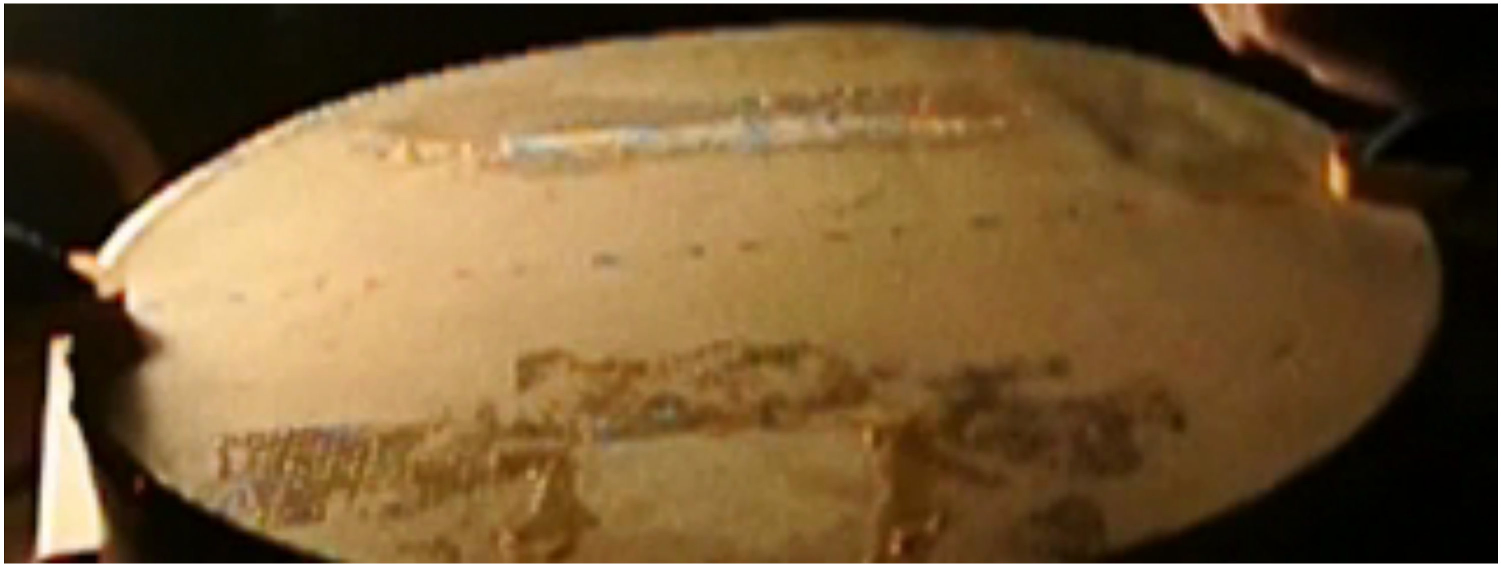
Science of Tabla

Jhumra

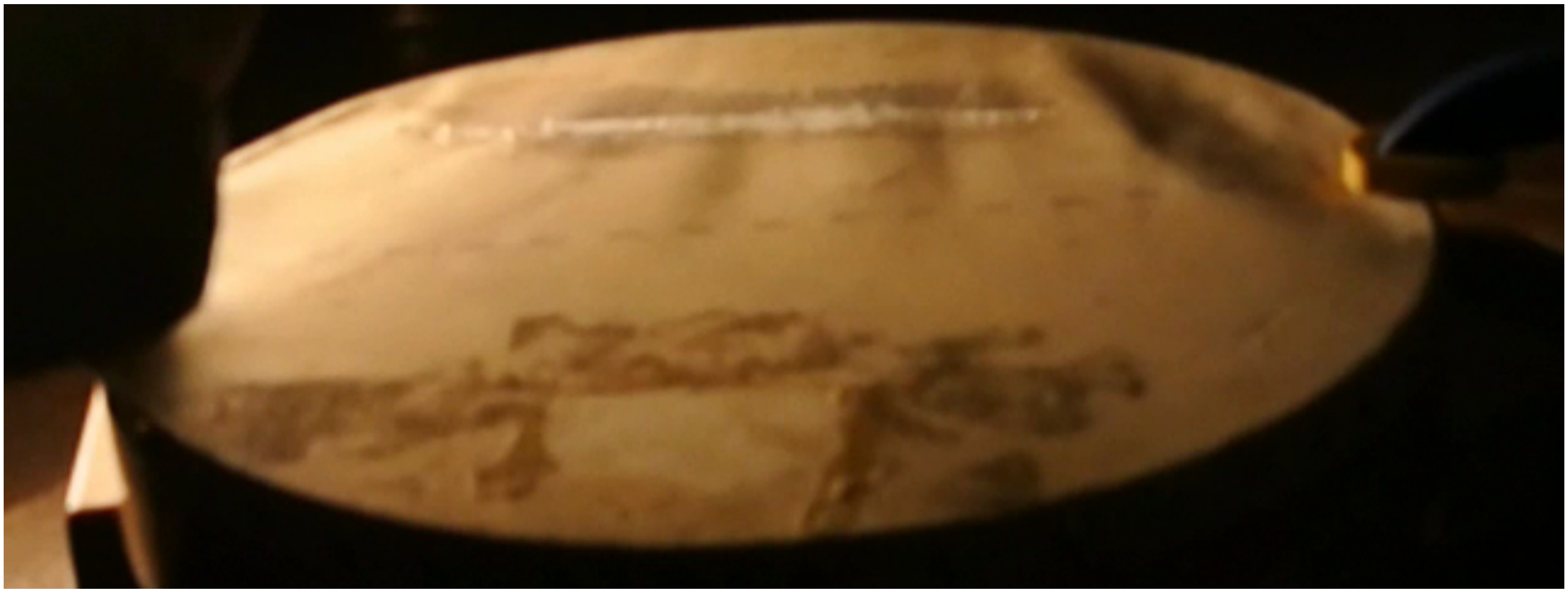
Image and clip from http://www.chandrakantha.com/tala_taal/jhoomra/jhumra.html

Necklace notation Figure From Rhythm and Transforms by W. Sethares





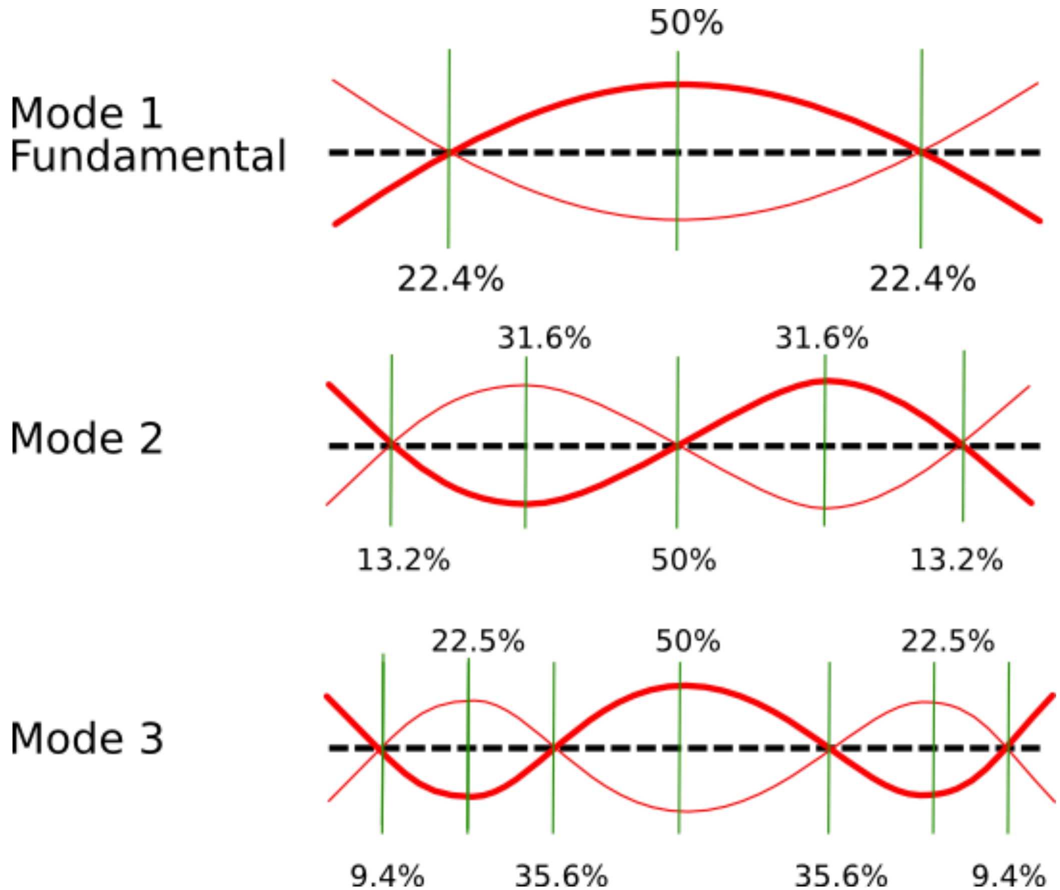
filmed in lab, plan is to make more movies
This one is hit in the center, 1200 fps but seems to primarily show a long lived fundamental mode



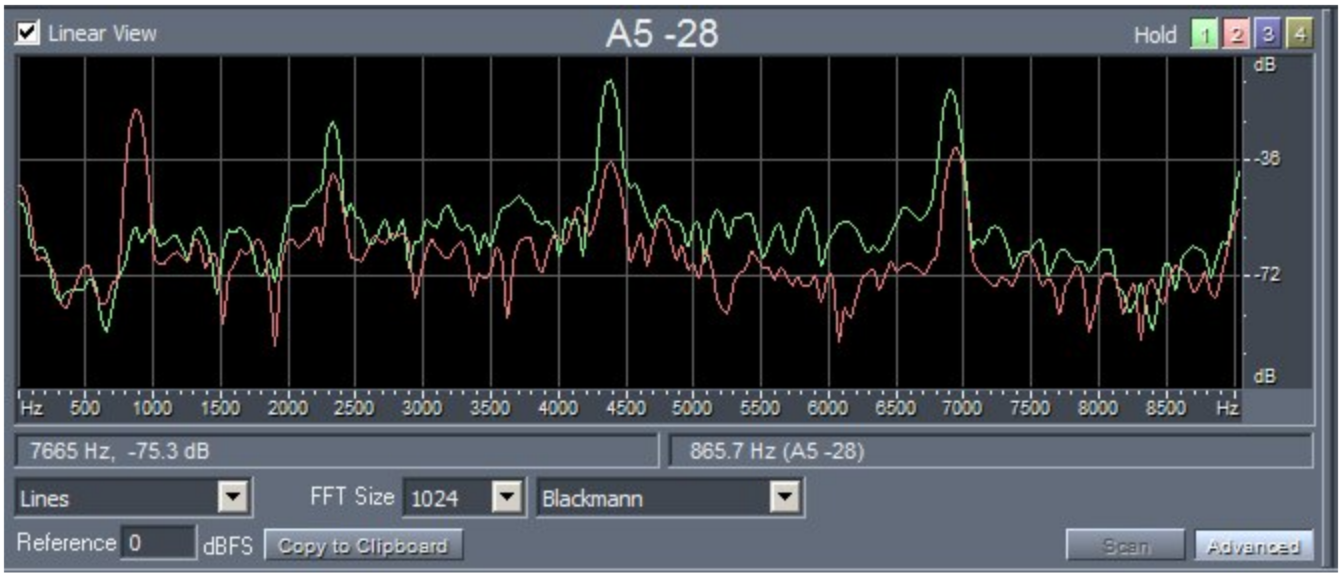
hit offcenter

Steel pipe

Modes exited depend on where you hold it

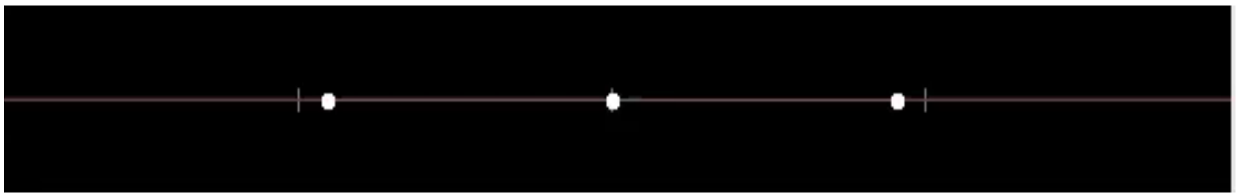


Steel pipe held at different locations

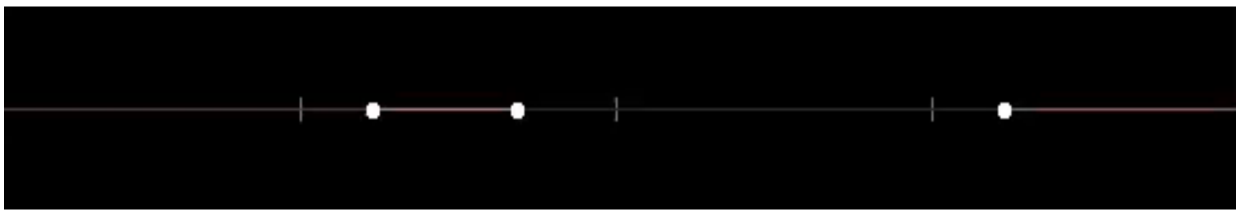


- Note first overtone absent in green spectrum
- Where did I hold the pipe for the green spectrum?

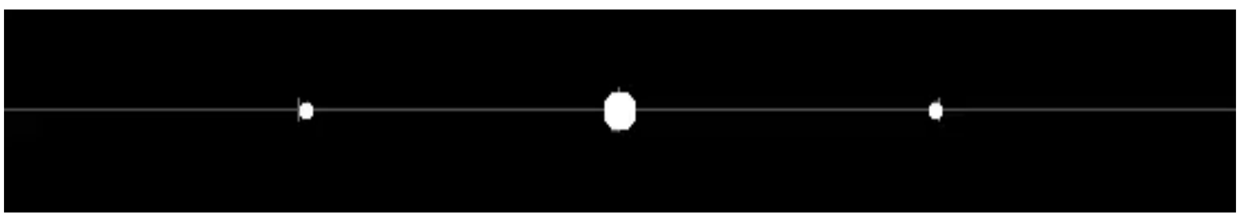
Adjusting the pitch of one mode compared to another



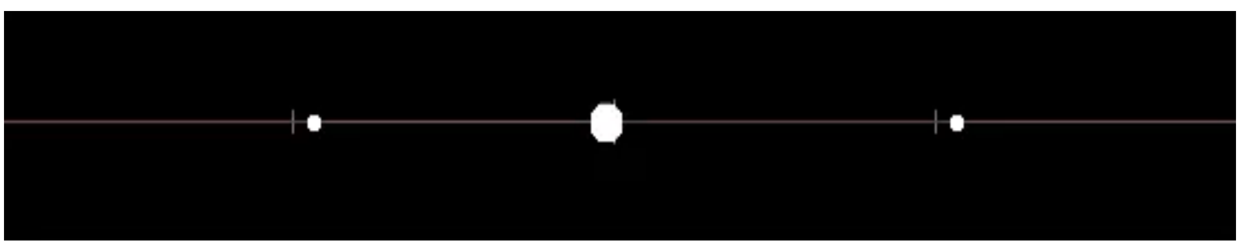
symmetric mode



asymmetric mode



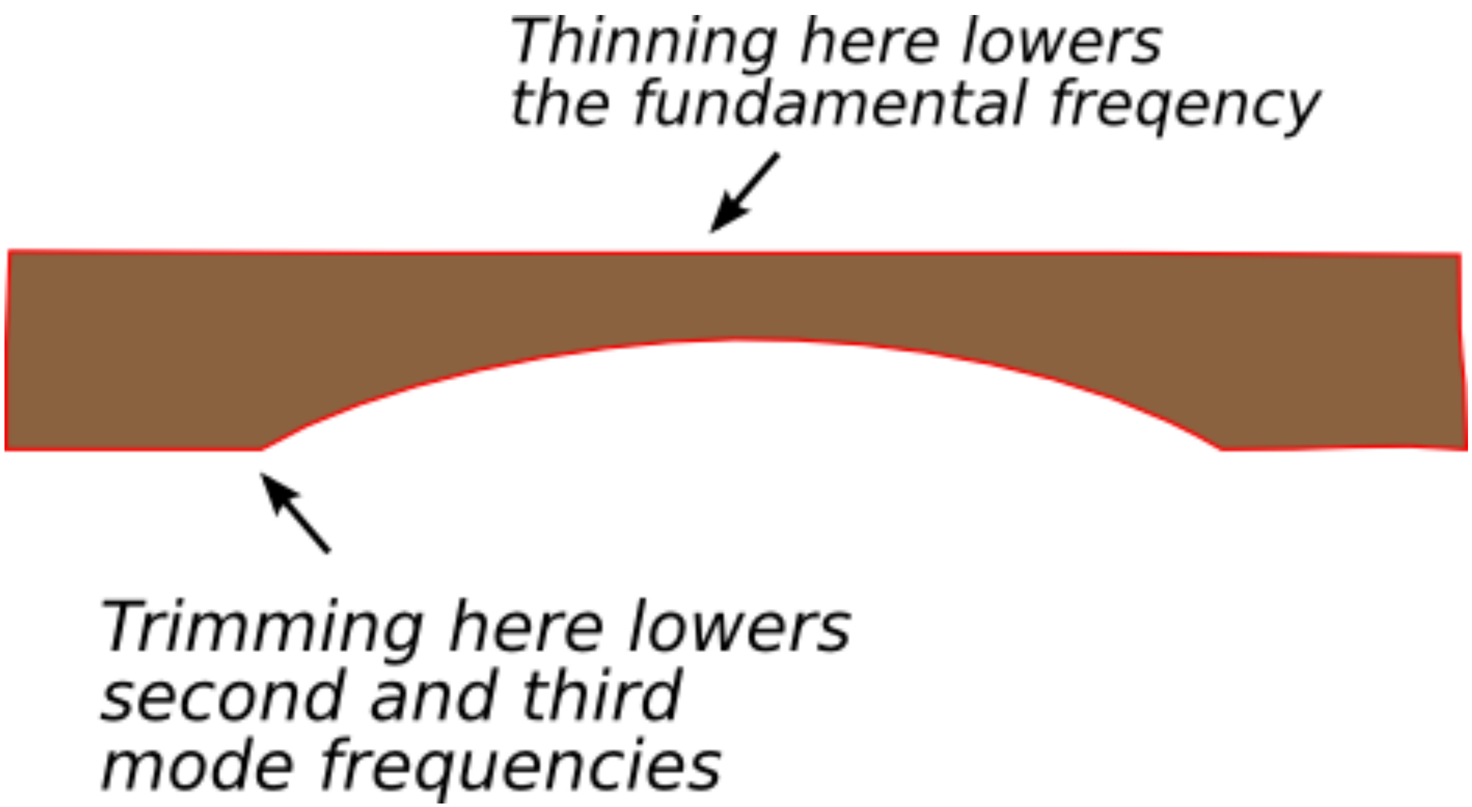
center higher mass but this mode frequency is unchanged



frequency of asymmetric mode is slower

movies made with paul falstad's applet

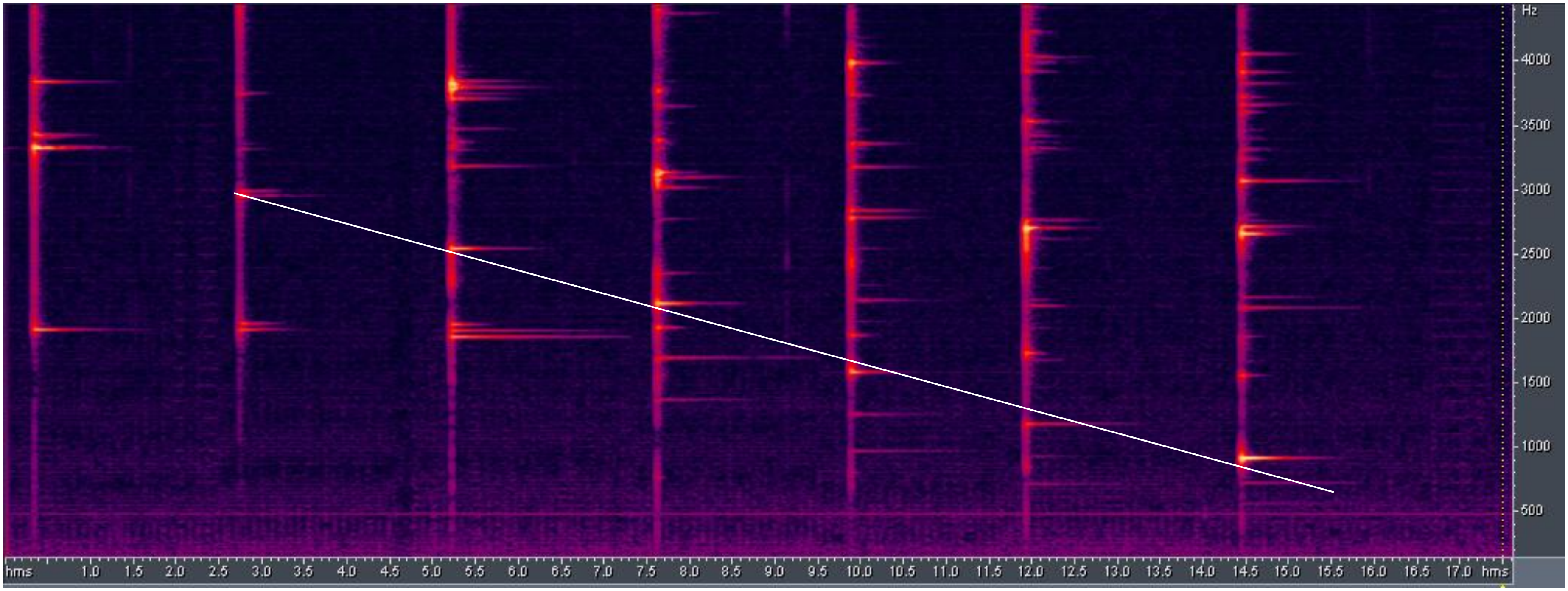
Marimba tuning



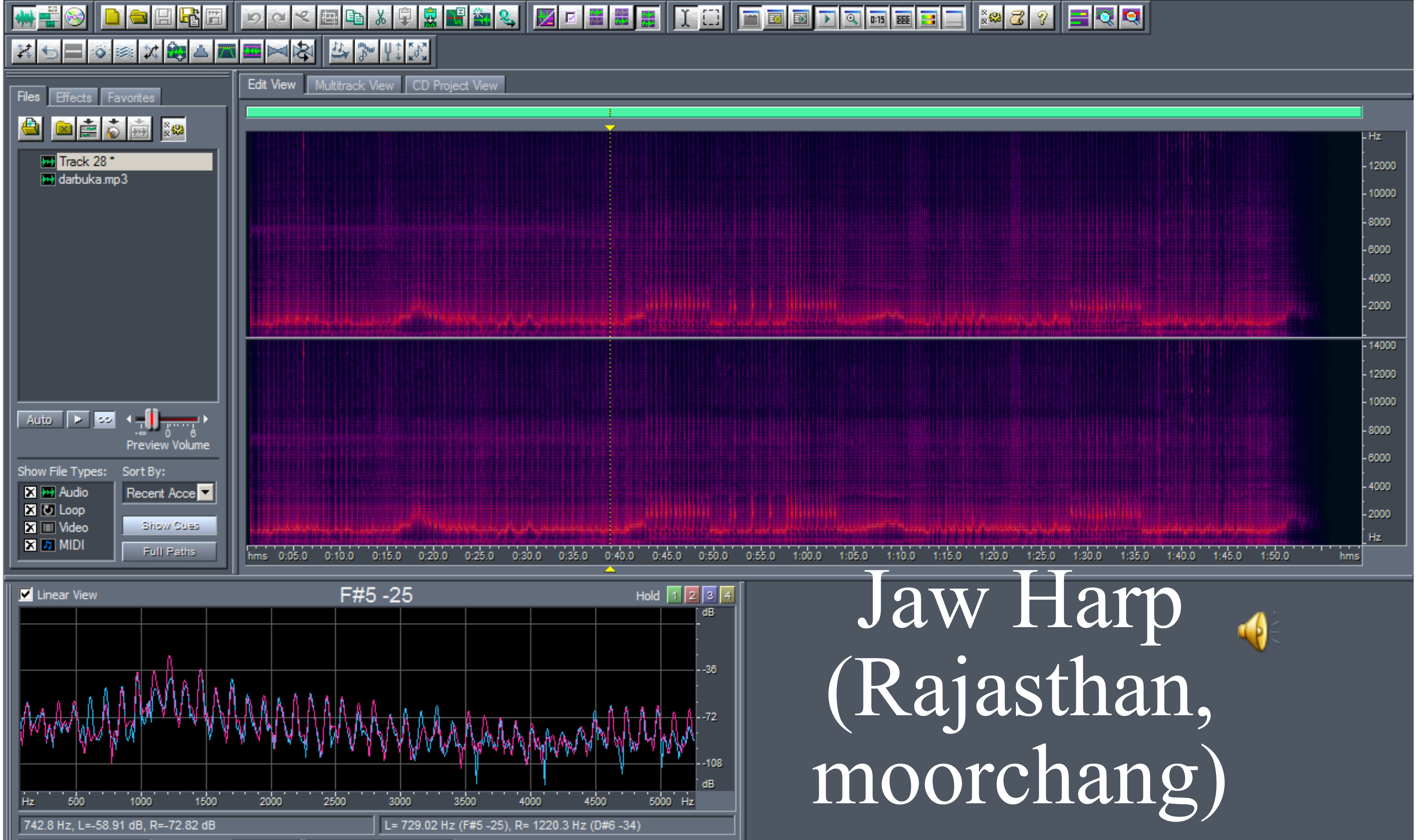
Instruments made in this class 2005 and before

- copper pipe xylophone
- glass xylophone — Bobbi Stewart
- solid aluminum chimes — Alex Frissel

Copper pipe with slit cut to different lengths



Jaw Harp (Rajasthan, moorchang)



Lamellaphone – Sanza -west africa

Slit Drum -central Africa

- hollowed out wood with uneven thickness to the edges

Guinea Bala Xylophone

hydrid percussion/wind or percussion/resonator

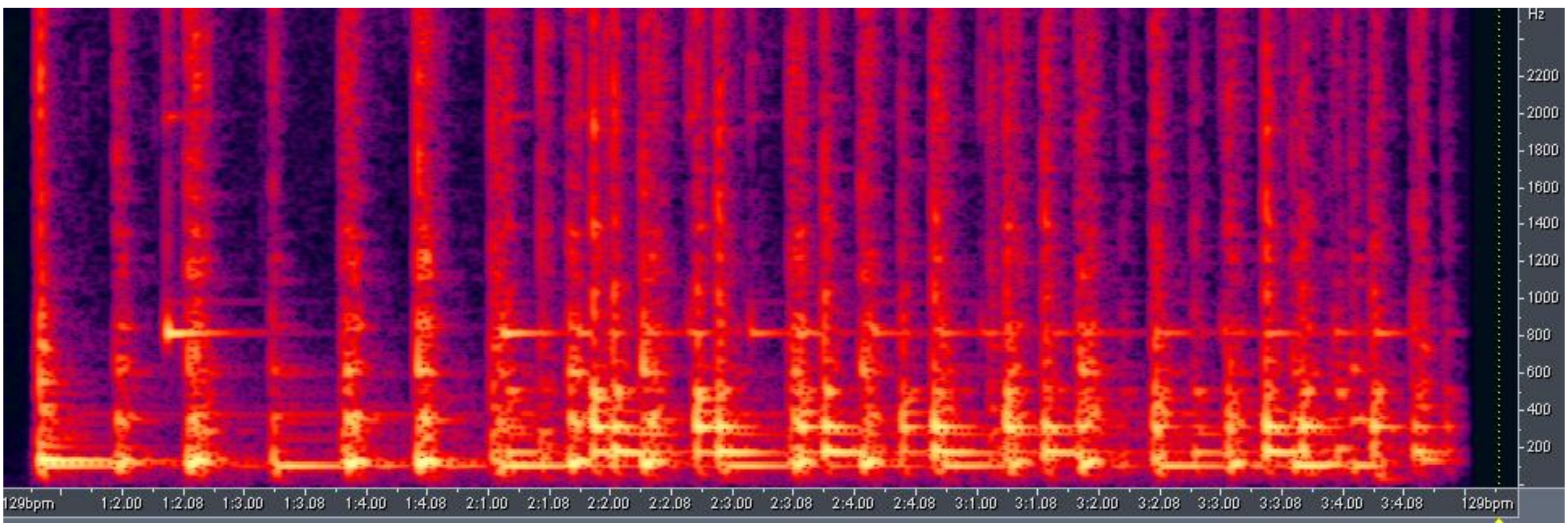
Clay percussion

Claycussion

- Ward Hartenstein and the Eastman percussion ensemble
- from Gravikords, Whirlies and Pyrophones

Double pit xylophone
Benin doso

pit dug into the ground serves as a resonator



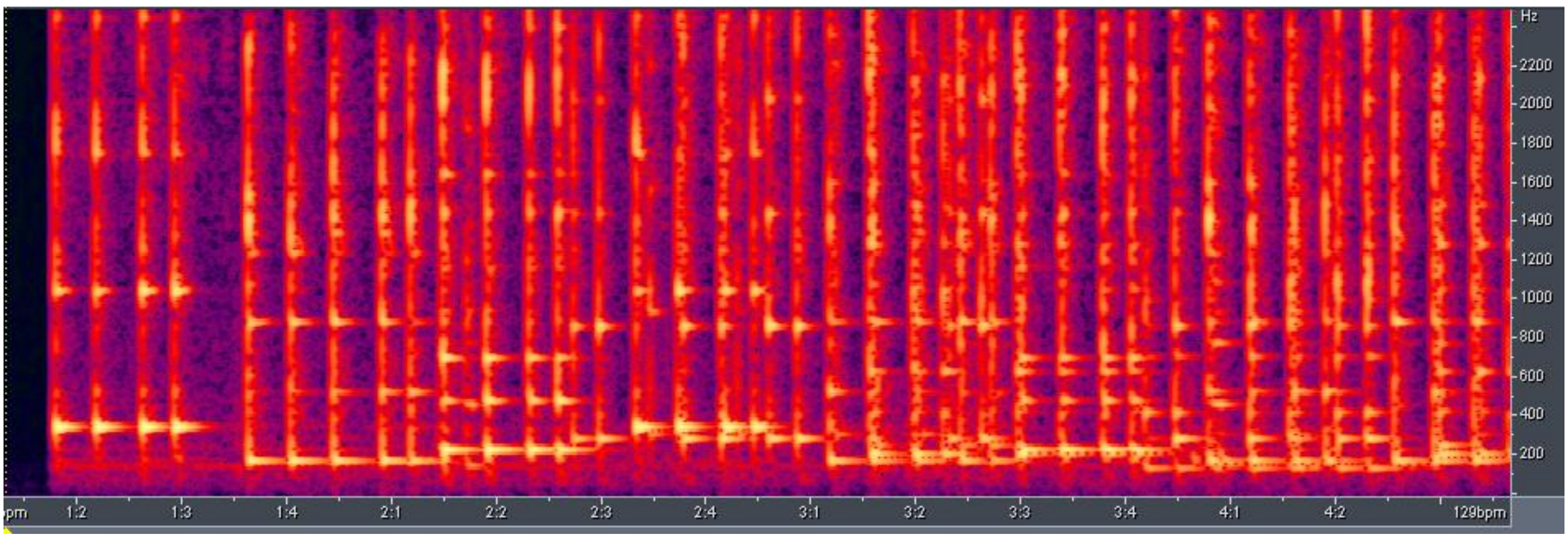
Stamping tubes- Solomon islands

Bamboo pipes striking a rock or the ground

The bamboo tube is held in one hand, the closed end at the bottom, and struck against the ground or a hard surface. The palm of the other hand partly opens or closes the open end, changing the timbre.

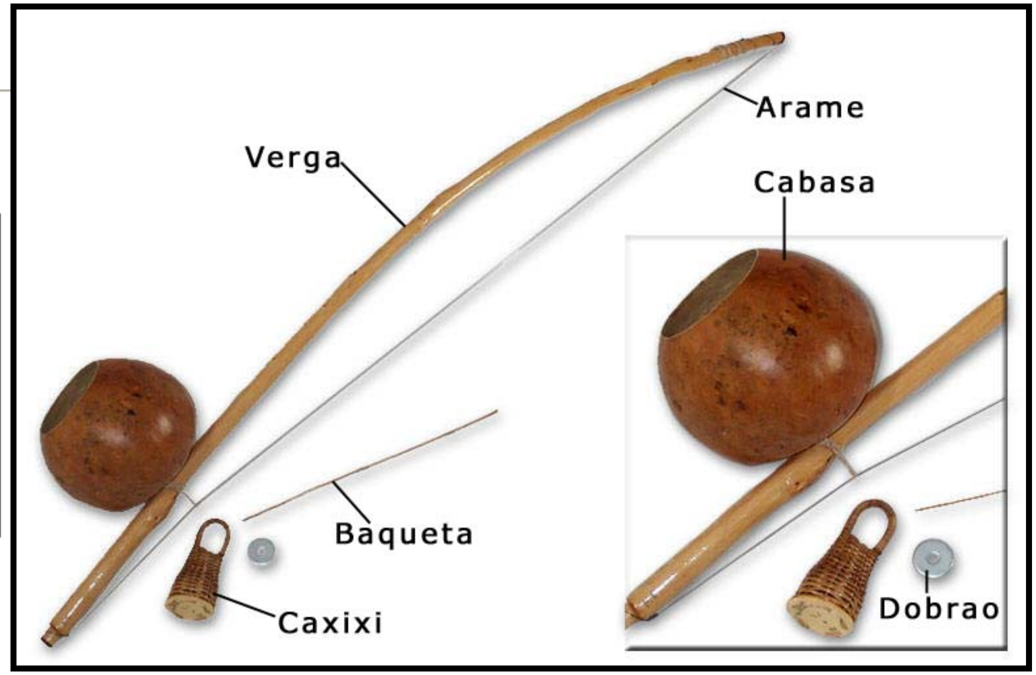
Image from http://www.folkenberg.net/Travel%20highlights/97%20SPD/97-2-Solomon_islands-2.htm

Stomping tube spectrogram
flat + open/closed end pipe spectrum



Toques de Berimbau

top line : note played	bottom line : cabaça position
✧ open (low note)	v cabaça near
◆ closed (high note)	^ cabaça far
× buzz	
open to closed	
△ caxixi	



basic toques

Toque: Angola

Toque: São Bento Grande de Angola

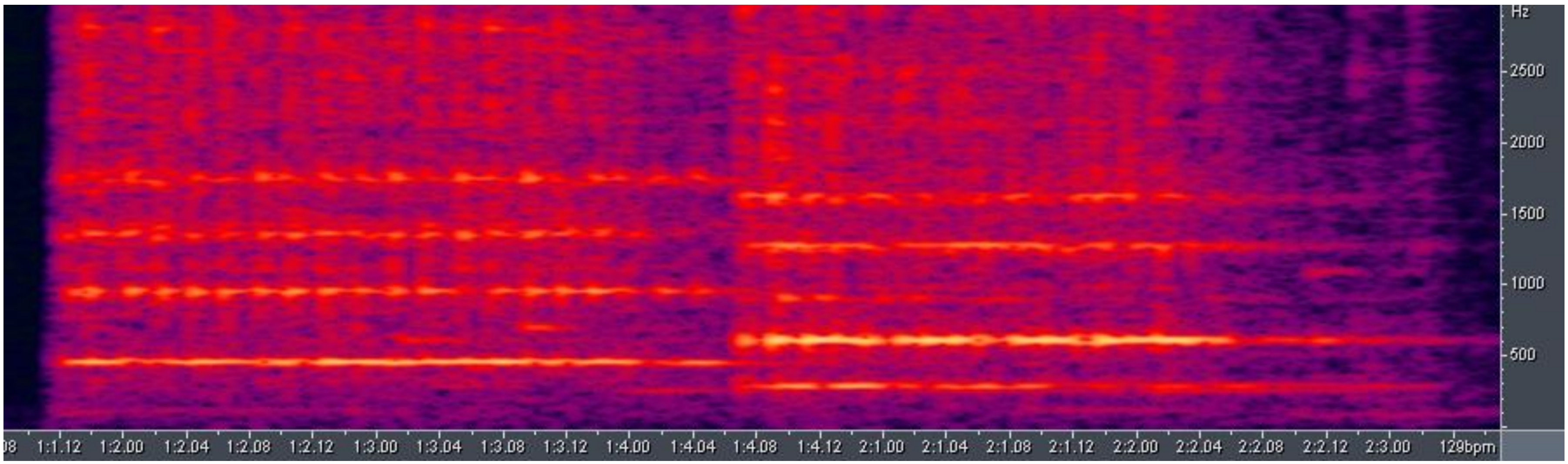
Toque: São Bento Grande de Bimba (Regional)

http://www.nccapoeira.com/music/toques.html

Angklung-sliding rattle Java

tongue vibration is tuned to be the same as the column of air below it

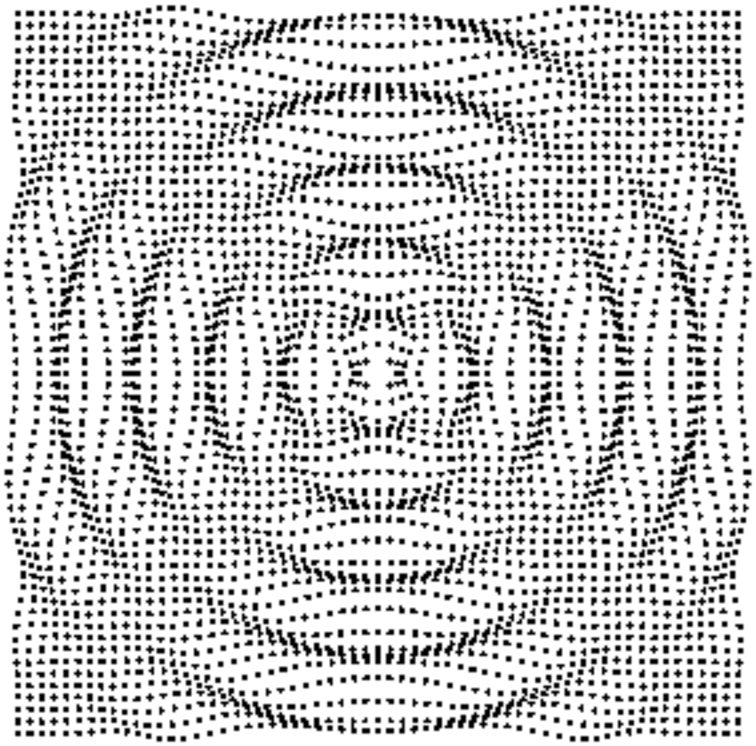
Angklung spectrogram



Gamelan – Bali – Metallophone Ensemble

Bell mode

lateral
quadrupolar
radiation field

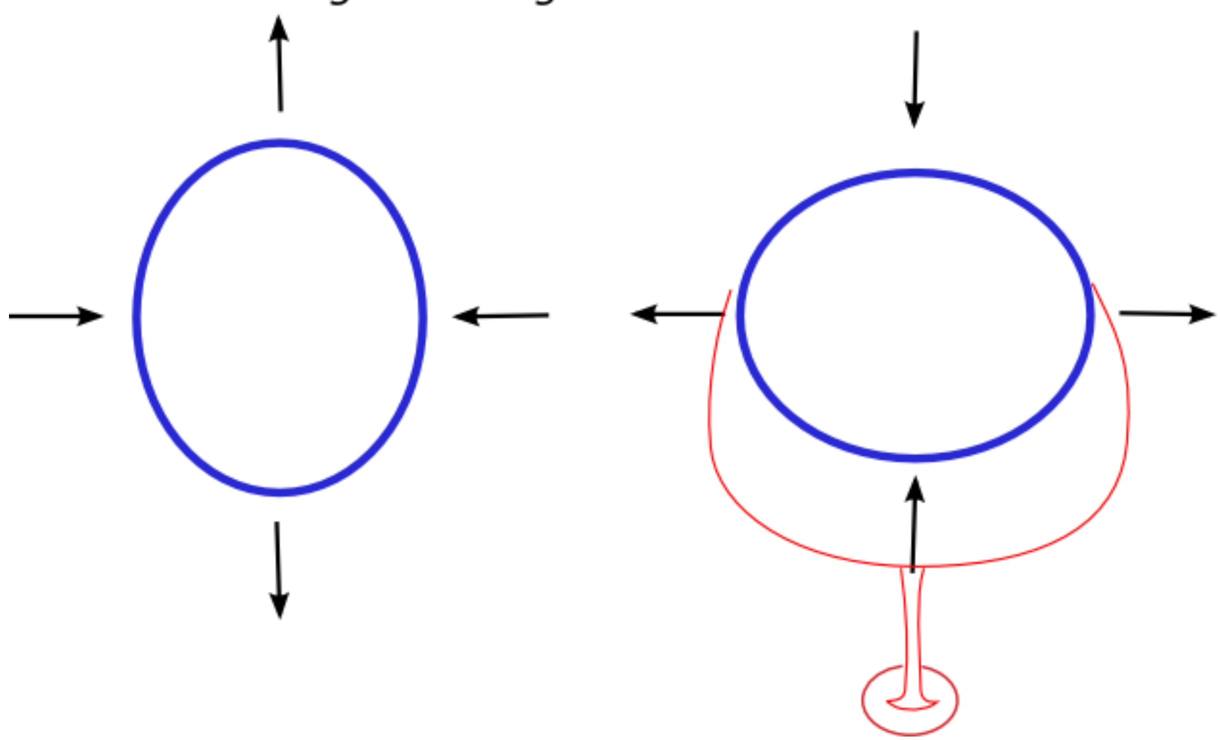


Animation courtesy of Dr. Dan Russell,
Grad. Prog. Acoustics, Penn State

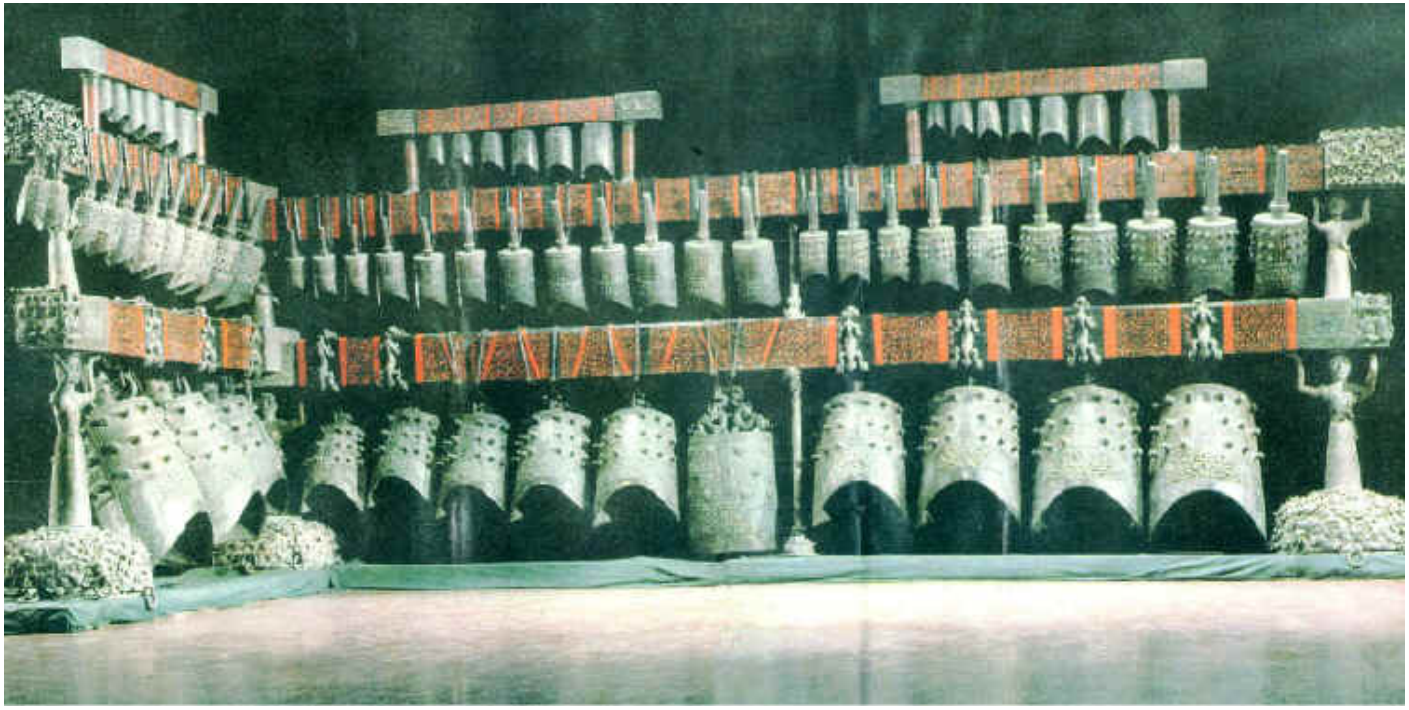
Movie by me

Fundamental mode of a wine glass

Fundamental mode of a wine glass. The blue line is the edge of the glass as seen from above



Archeology of Chinese Bells



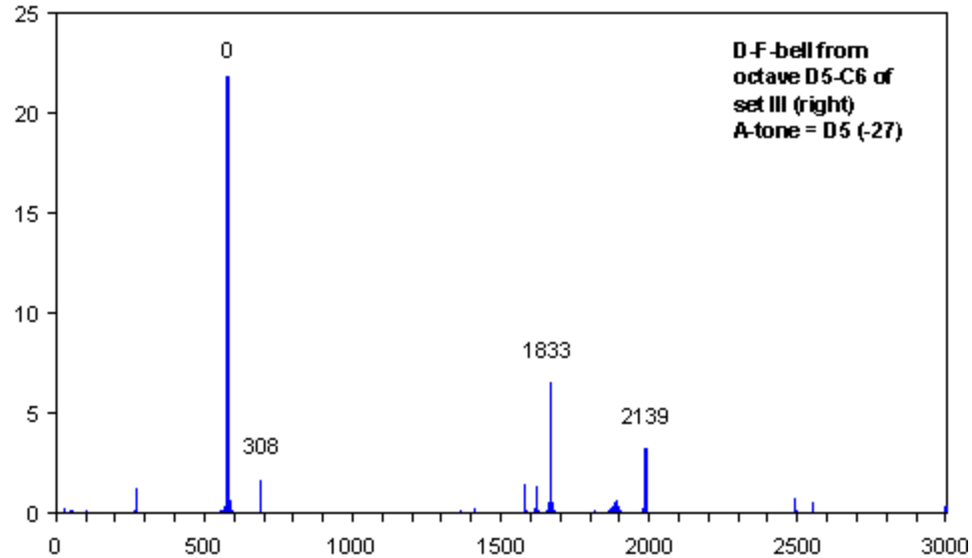
An ensemble of 65 bells, with 130 discrete strike tones, was excavated in a fully preserved state 1978 in the Chinese province of Hubei from the tomb of the Marquis Yi of Zeng from 433 B.C. The ensemble's tuning system could now be investigated! http://web.telia.com/~u57011259/Zengbells.htm (Martin Braun)

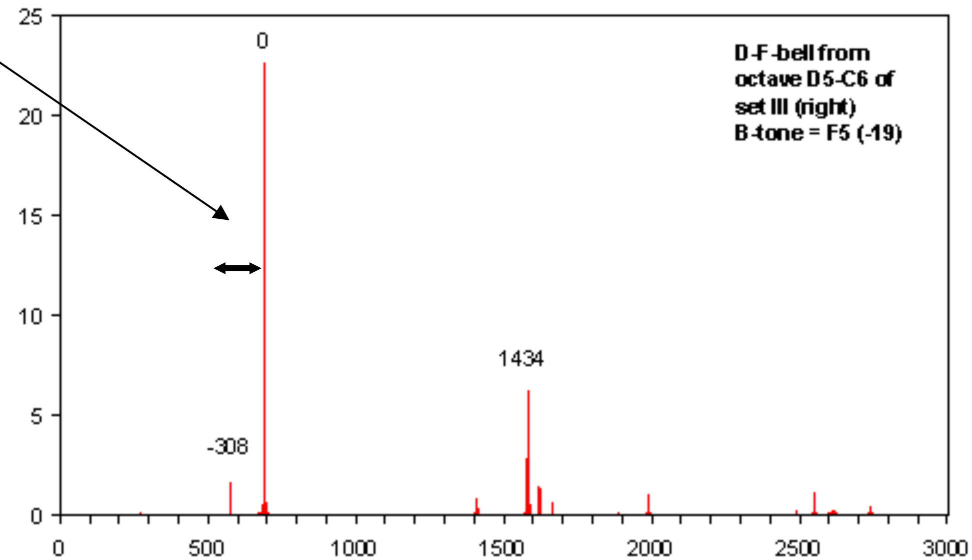
“Two Tone” bells

- Due to favorable conditions of tomb preparation, soil, and soon natural water filling, the bronze of the bells survived fully intact. The bells sound as they did 2,436 years ago.
- The bells have an eye-shaped cross-section and vibrate in one of two modes, depending on where they are struck. A strike in the middle of the front makes frontside and backside vibrate as whole units and produces the lower tone ***sui***. A strike between the middle of the front and a side edge makes frontside and backside vibrate as two units each and produces the higher tone ***gu*.** If struck correctly, both tones are fully independent, each with its own fundamental and harmonics.

Two tones (continued)

- The two tones a third apart, purposely





Evidence for tuning

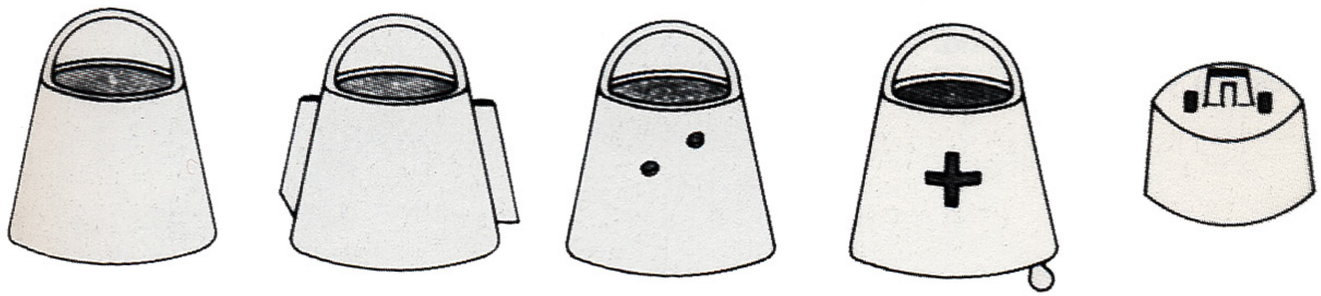


Figure 3-6

Drawing: Ways of tuning small bells: (1) adding tuning flanges; (2) drilling holes into bell body; (3) cutting cross into bell body; (4) drilling holes into bell roof.

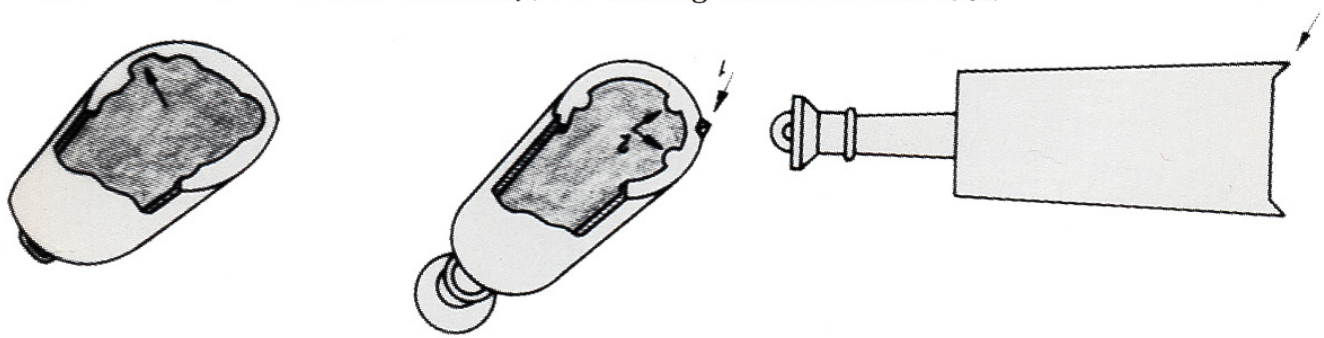
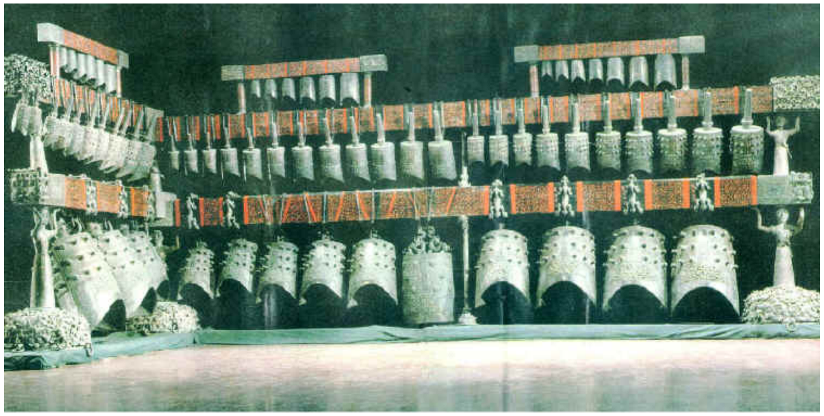


Figure 3-8

Drawing: Tuning by manipulating the lower rim of bell: adding metal to outer rim; cutting away from lower rim; cutting away from doubled lower rim.

Images from The Archeology of Music in Ancient China, Kutner, Fritz



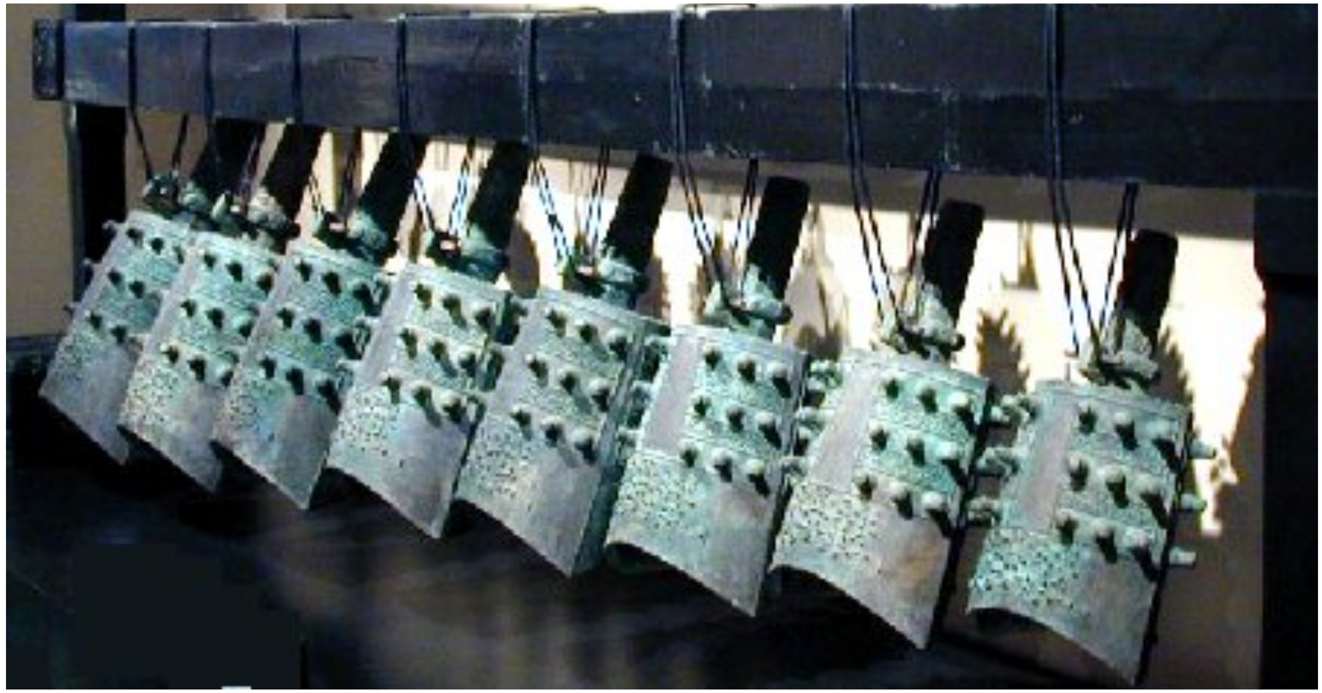
The scale

- Scale D-E-F-G-A-C occurs eight times in melody bells

Set I - left												
Octave D6-C7, 3 bells	D	E*	F		G		A*			C*		
Octave D5-C6, 3 bells	D	E	F		G		A			C		
Octave D4-D#5, 5 bells	D	E	F		G	G#	A		B	C	C#	D#
Set II - middle												
Octave D6-C7, 3 bells	D	E	F		G		A			C		
Octave D5-C6, 3 bells	D	E	F		G		A			C		
Octave D4-D#5, 6 bells	D	E	F	F#	G	G#	A	A#*	B	C	C#	D#
Set III - right												
Octave D5-C6, 4 bells	D	E	F	F#	G		A	A#		C		
Octave D4-C5, 3 bells	D	E	F		G		A			C		
Octave G3-D#4, 3 bells					G		A		B	C	C#	D#

* 4 of 66 tones possibly mistuned; see footnote in data tables

The bumps?



- Western bells rarely have bumps --- Church bells have lasting rings.
- Players of handbells damp the sound if they require a short note
- Bumps do change the modes of oscillation as they give extra mass
- They also help radiate sound and so damp the sound purposely
- The bell can be louder?

Topics

- Resonances/modes of a membrane
- Modes of a vibrating pipe or bar
- Modes of a resonating cavity coupled to a membrane
- Membranophones/ideophones and lamellaphones
- Suggested reading: Chapters 4,5,7 of Hopkins