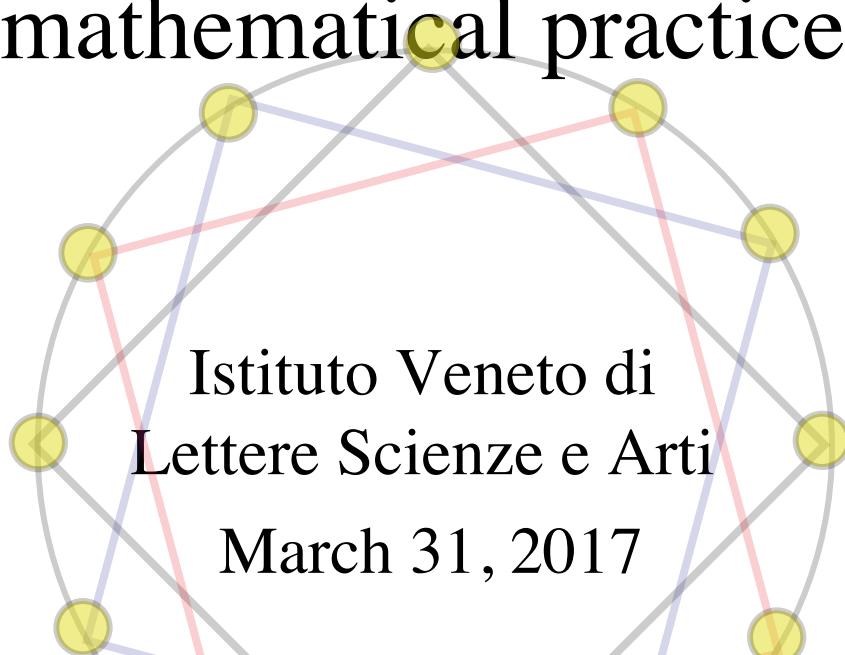
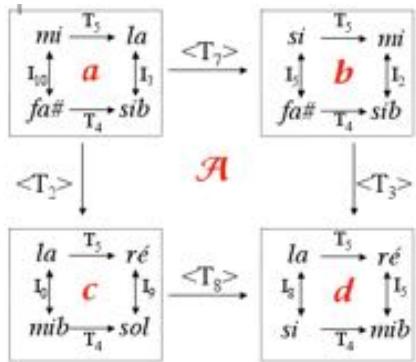


Exploring the “mathemusical” dynamics: some aspects of a musically driven mathematical practice

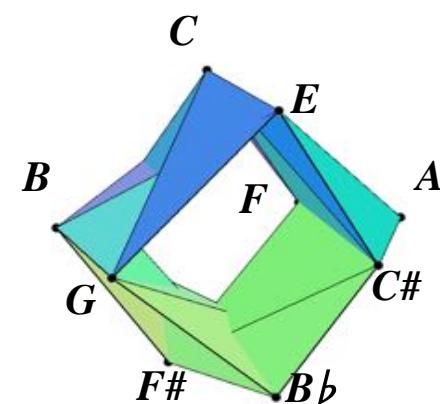


Istituto Veneto di
Lettere Scienze e Arti

March 31, 2017

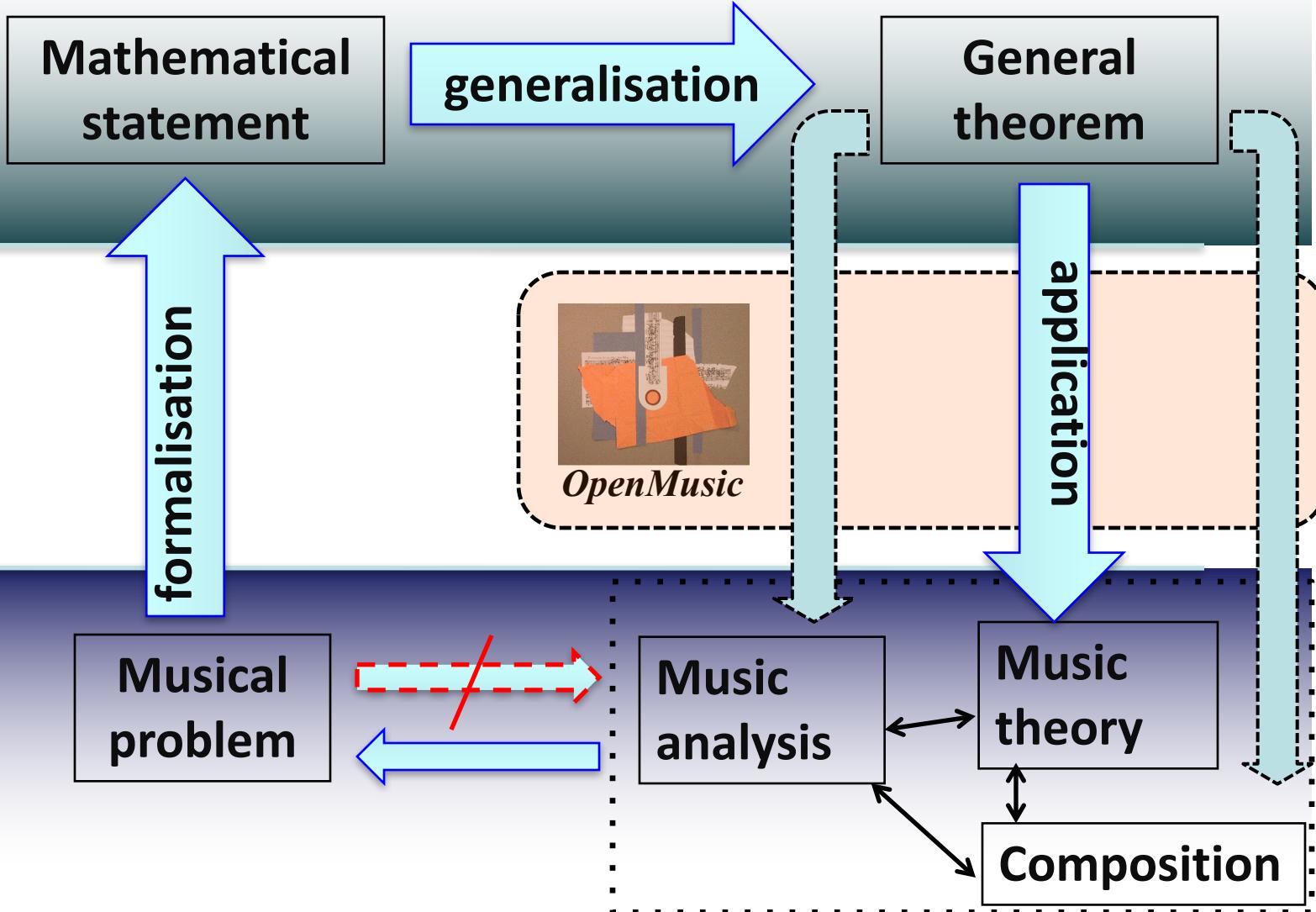
Moreno Andreatta
Music Representations Team

IRCAM/CNRS/UPMC & IRMA/USIAS Strasbourg
<http://www.ircam.fr/repmus.html>



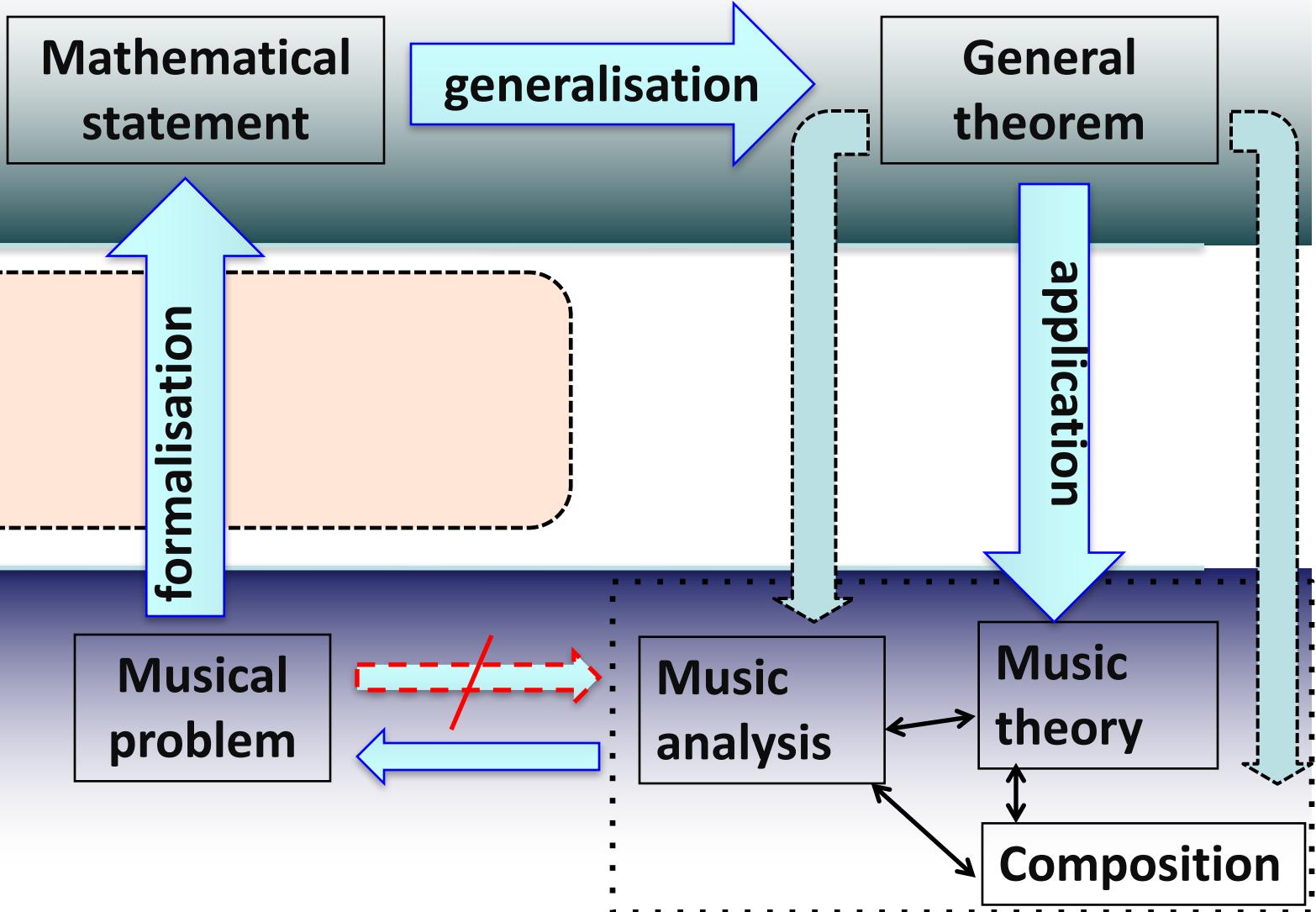
The double movement of a ‘mathemusical’ activity

MATHEMATICS



The double movement of a ‘mathemusical’ activity

MATHEMATICS



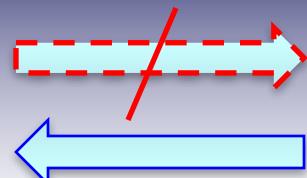
The double movement of a ‘mathemusical’ activity

MATHEMATICS



MUSIC

Musical problem



Music analysis

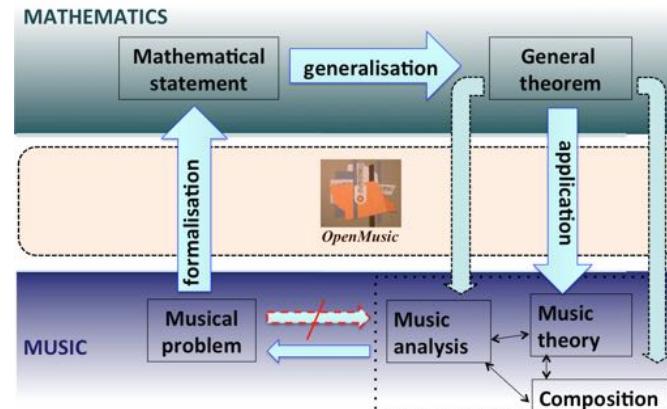
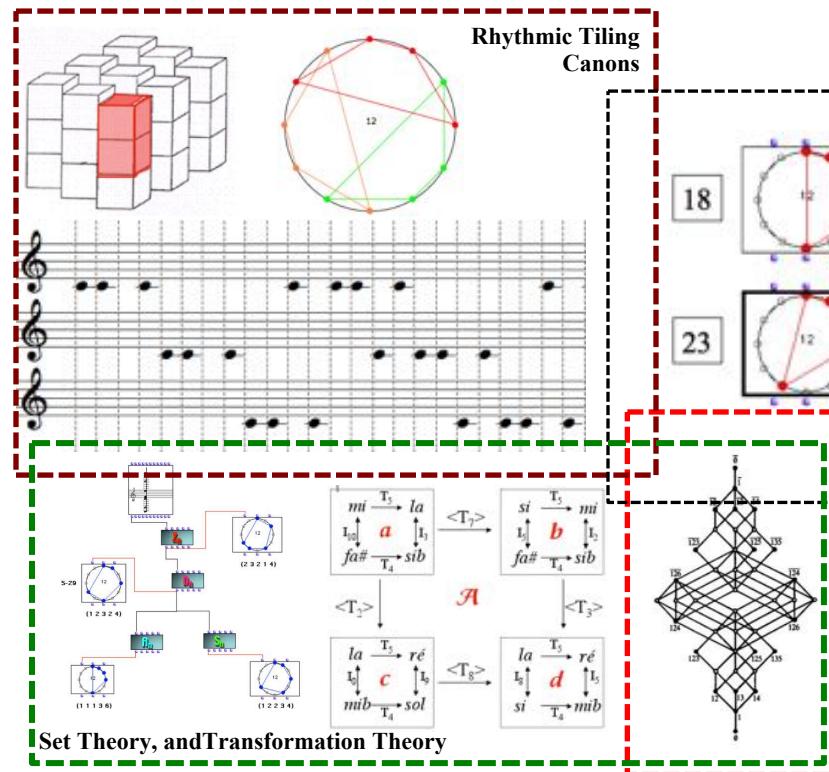
Music theory

Composition

Some examples of ‘mathemusical’ problems

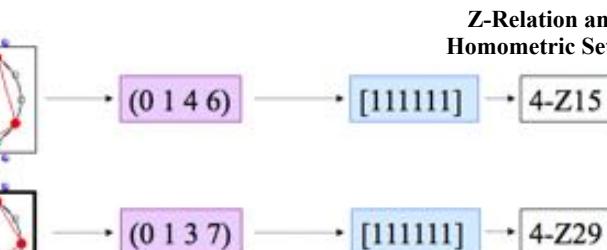
M. Andreatta : *Mathematica est exercitium musicae*, Habilitation Thesis, IRMA University of Strasbourg, 2010

- The construction of Tiling Rhythmic Canons
- The Z relation and the theory of homometric sets
- Set Theory and Transformational Theory
- Neo-Riemannian Theory, Spatial Computing and FCA
- Diatonic Theory and Maximally-Even Sets
- Periodic sequences and finite difference calculus
- Block-designs and algorithmic composition



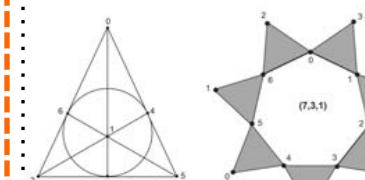
$$Df(x) = f(x) - f(x-1).$$

7 11 10 11 7 2 7 11 10 11 7 2 7 11...
 4 11 1 8 7 5 4 11 18 7 5 4 11...
 7 2 7 11 10 11 7 2 7 11 10 11...
 7 5 4 11 1 8 7 5 4 11 18...



Neo-Riemannian Theory and Spatial Computing

Finite Difference Calculus



The interplay between algebra and geometry in music

MATH / MUSIC MEETINGS

Creativity in Music and Mathematics

Pierre Boulez & Alain Connes

Encounter with two major figures of musical creation and contemporary mathematical research: Pierre Boulez and Alain Connes.

What is the role of intuition in mathematical reasoning and in artistic activities? Is there an aesthetic dimension to mathematical activity? Does the notion of elegance of a mathematical demonstration or of a theoretical construction in music play a role in creativity?



Gérard Assayag, director of the CNRS/IRCAM Laboratory for The Science and Technology of Music and Sound, will lead this dialogue on invention in the two disciplines.

Photo: Pierre Boulez © Jean Radel

Wednesday, June 15, 2011, 6:30pm / IRCAM, Espace de projection

→ <http://agora2011.ircam.fr>



“Concerning music, it takes place in **time**, like **algebra**. In **mathematics**, there is this fundamental duality between, on the one hand, **geometry** – which corresponds to the visual arts, an immediate intuition – and on the other hand **algebra**. This is not visual, it has a temporality. This fits in time, it is a computation, something that is very close to the language, and which has its diabolical precision. [...] **And one only perceives the development of algebra through music**” (A. Connes).

→ <http://videotheque.cnrs.fr/>



Centre National de la Recherche Scientifique

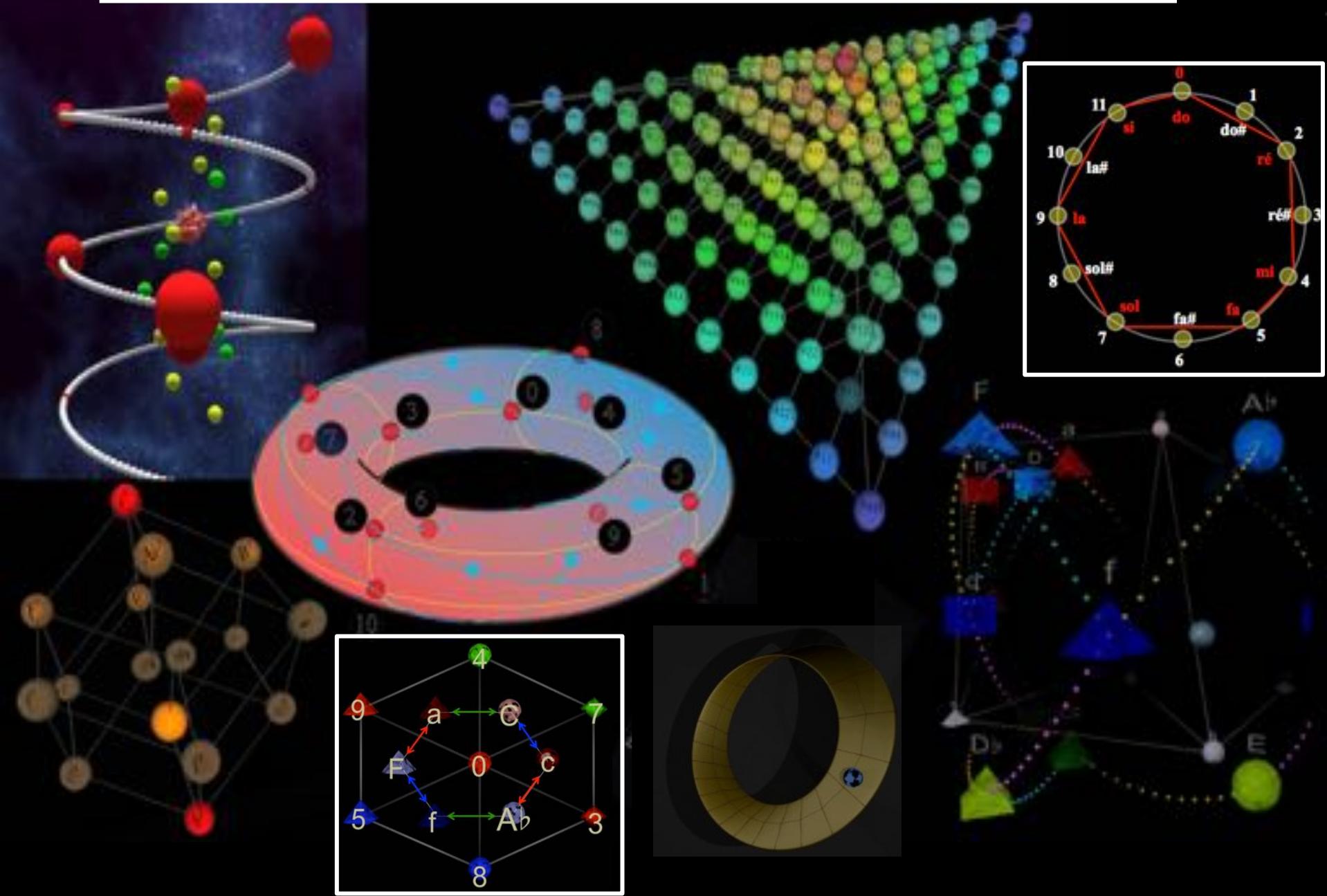
Mathematics and Computation in Music

FIRST INTERNATIONAL CONFERENCE, NICE 2011

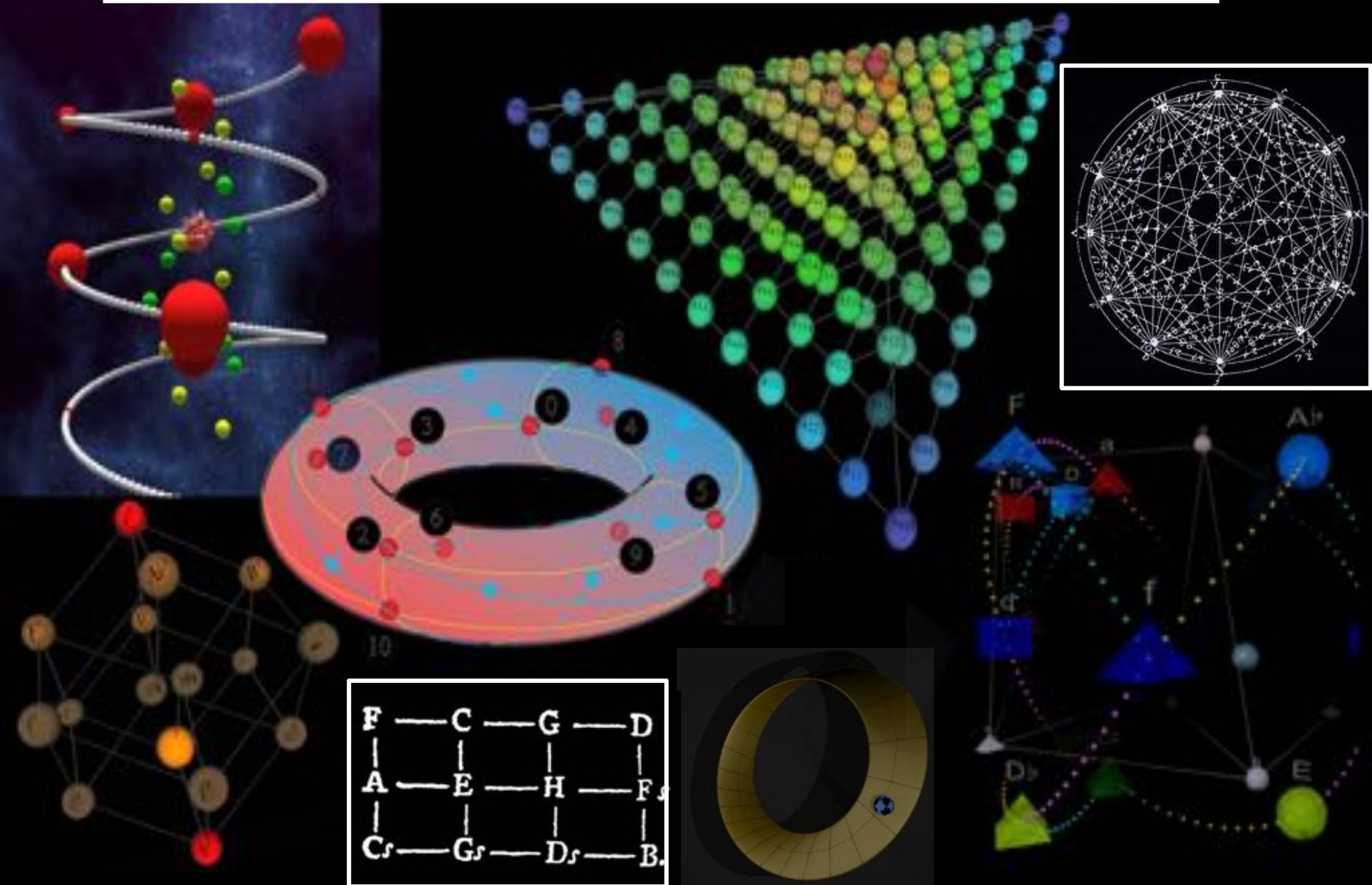
July 11-14, 2011, University of Nice Sophia Antipolis, France

Springer

The galaxy of geometrical models at the service of music



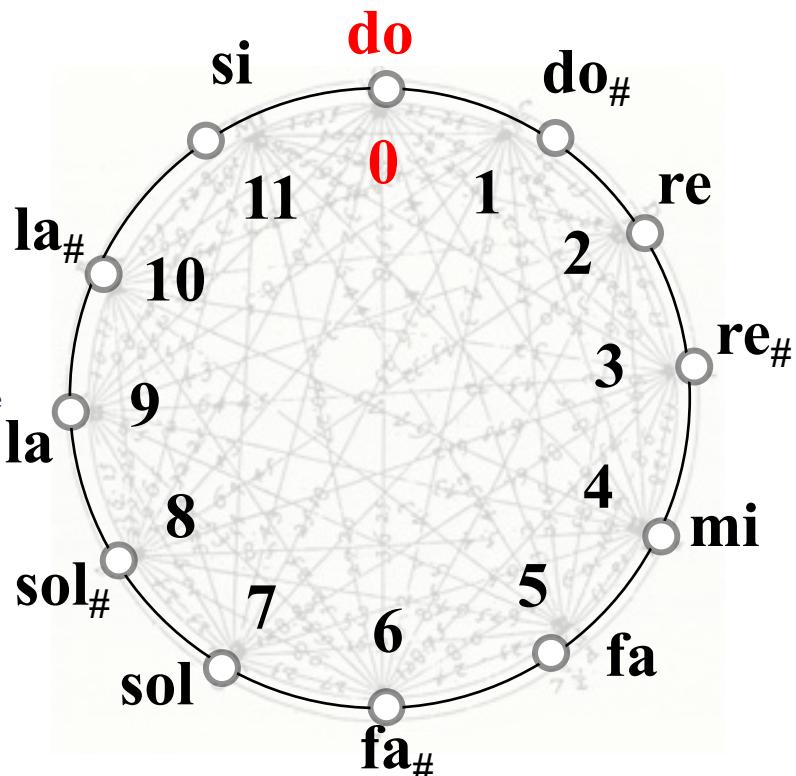
The galaxy of geometrical models at the service of music



The circular representation of the pitch space



Marin Mersenne



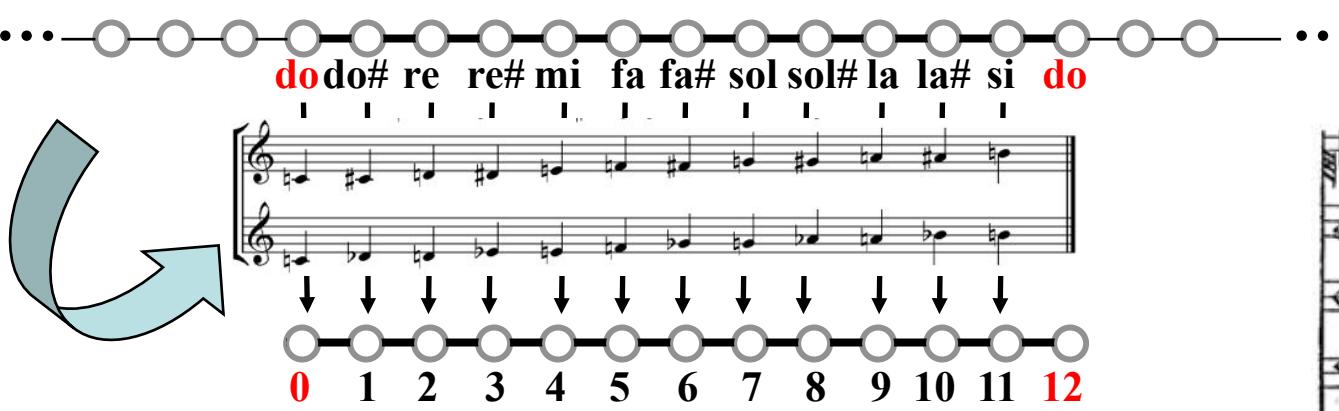
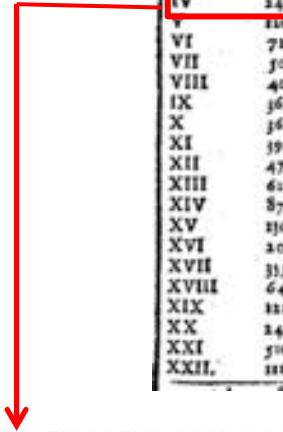
Harmonicorum Libri XII, 1648



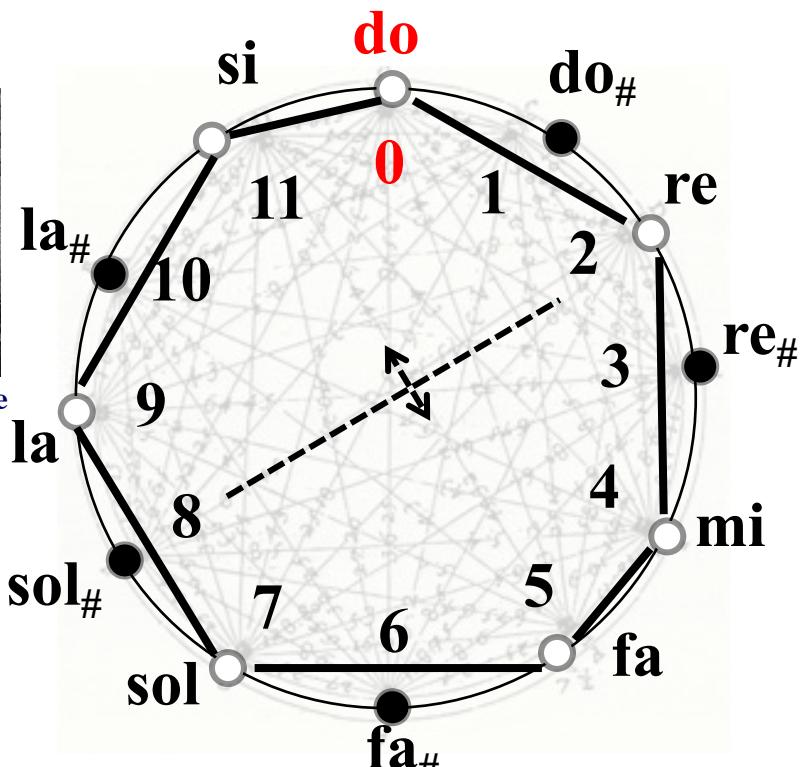
LIBER SEPTIMVS
DE CANTIBVS, SEV CANTILENIS,
EARVMQ; NVMERO, PARTIBVS, ET SPECIEBV.

Tafela Combinationes ab 1 ad 23.

I	1
II	2
III	6
IV	24
V	110
VI	710
VII	1040
VIII	40320
IX	361880
X	3618800
XI	39916800
XII	479004600
XIII	617101800
XIV	377859100
XV	1107674568000
XVI	20912759588000
XVII	311687418096000
XVIII	640417370578000
XIX	1116410040183000
XX	141350100176640000
XXI	51090941171709440000
XXII	1114000737777607180000



The circular representation of the pitch space



Harmonicorum Libri XII, 1648

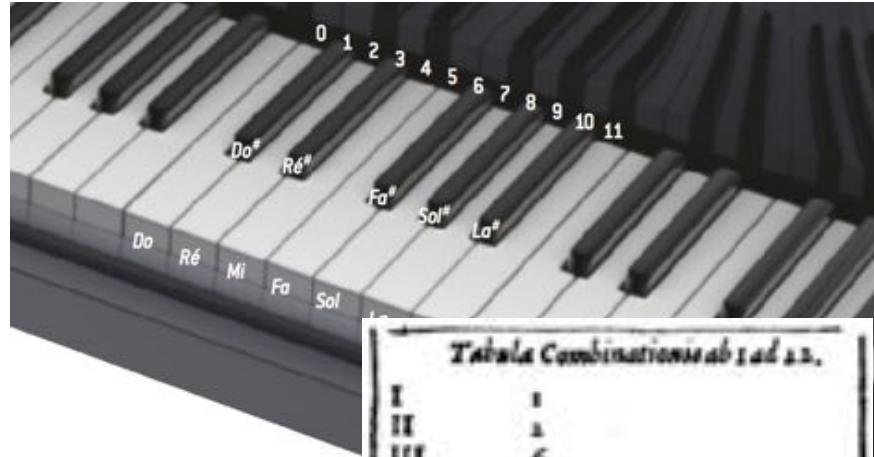
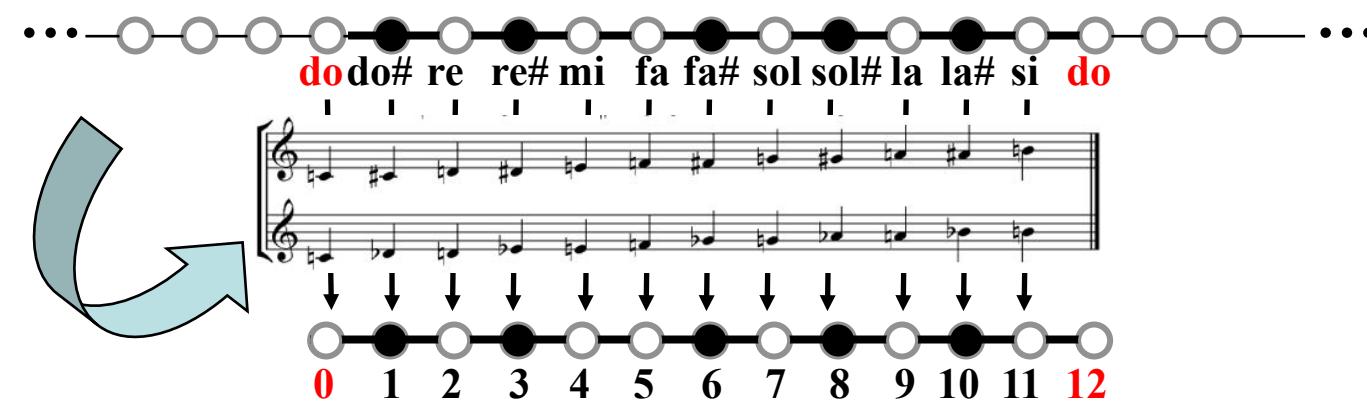
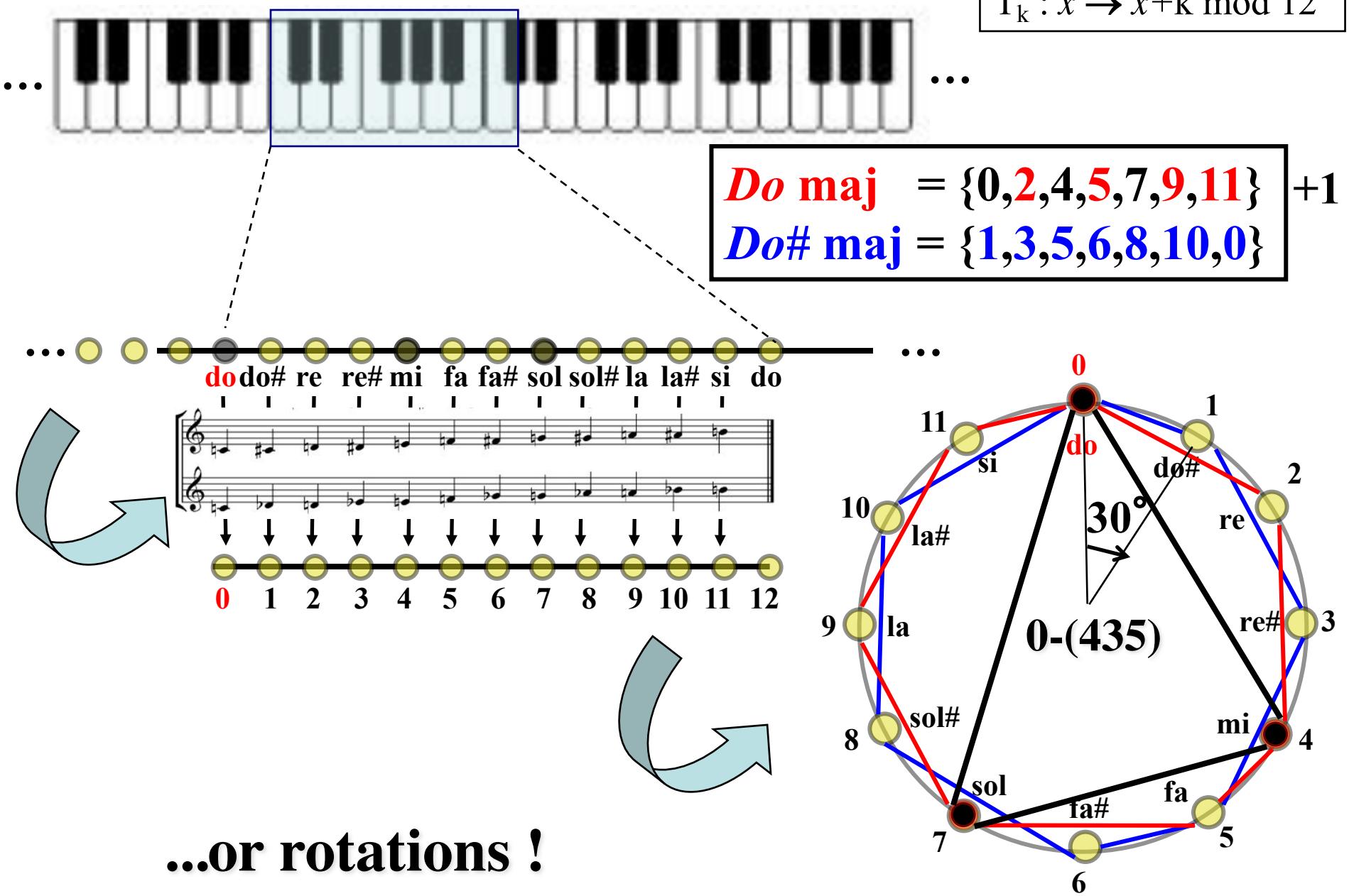


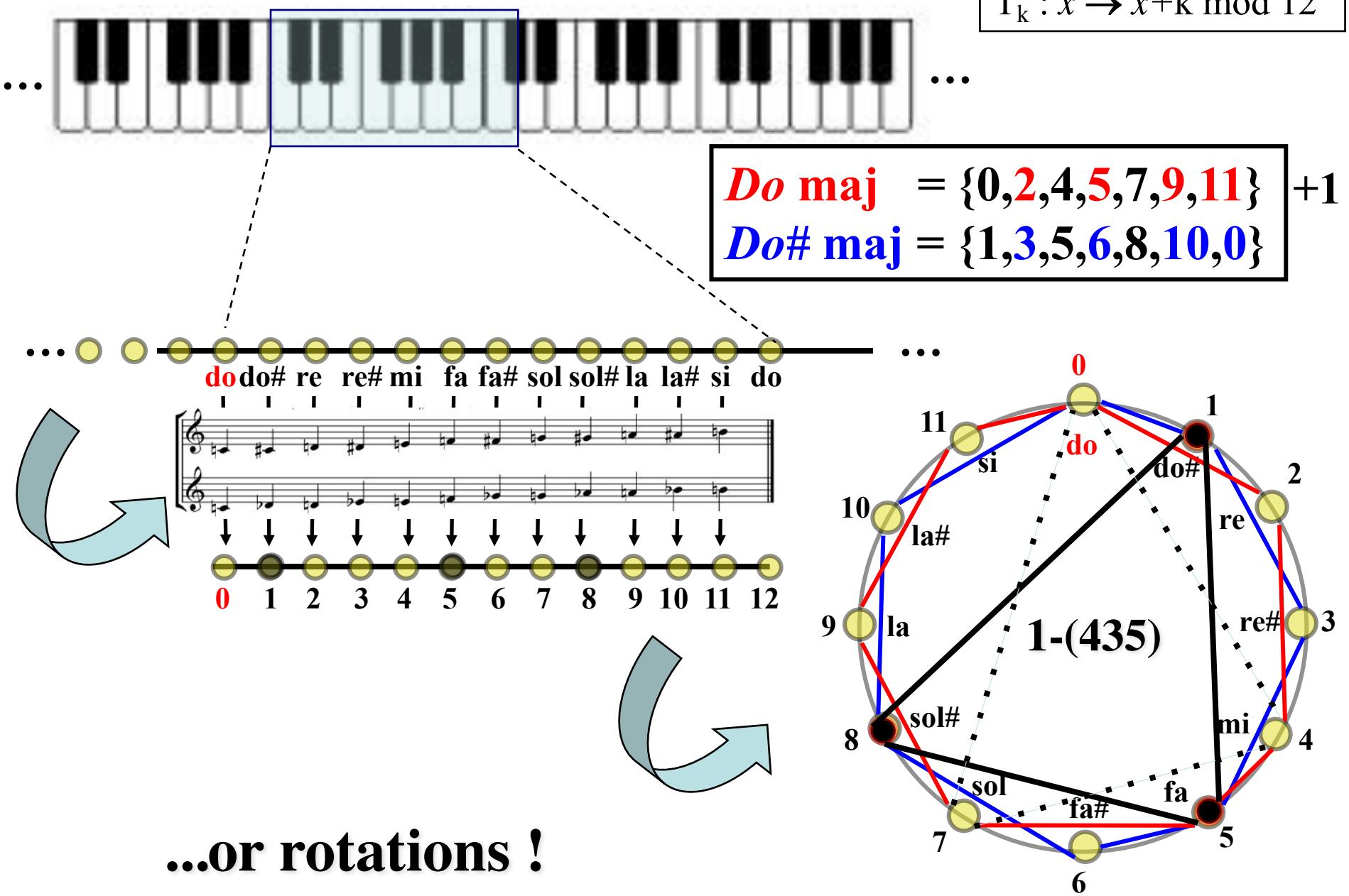
Tabelle Combinationis ab I ad XXII.	
I	I
II	II
III	III
IV	IV
V	V
VI	VI
VII	VII
VIII	VIII
IX	IX
X	X
XI	XI
XII	XII
XIII	XIII
XIV	XIV
XV	XV
XVI	XVI
XVII	XVII
XVIII	XVIII
XIX	XIX
XX	XX
XXI	XXI
XXII.	XXII.



Musical transpositions are additions...



Musical transpositions are additions...



Musical inversions are differences...

... or axial symmetries!

The diagram illustrates musical inversions and axial symmetries in a 12-note system, mapping notes from a piano keyboard to a circle of 12 notes labeled 0 through 11.

Piano Keyboard: Shows a segment of a piano keyboard with black and white keys. A blue box highlights a segment of three black keys (C# to E) and four white keys (F to G). Dashed arrows point from this segment to the 12-note circle and the musical staff.

12-Note Circle: A circle divided into 12 equal segments, each labeled with a note name: do (0), do# (1), re (2), re# (3), mi (4), fa (5), fa# (6), sol (7), sol# (8), la (9), la# (10), si (11), and do (0) again. Arrows point from the piano keyboard segment to the notes 4, 5, 6, 7, 8, 9, 10, and 11 on the circle. A large blue arrow points from the piano keyboard to the circle.

Musical Staff: A musical staff with two staves. The top staff uses a treble clef and the bottom staff uses a bass clef. Notes are placed on the staff corresponding to the 12-note circle. Arrows point from the piano keyboard segment to the notes 4, 5, 6, 7, 8, 9, 10, and 11 on the staff. A large blue arrow points from the piano keyboard to the staff.

Equation: $I : x \rightarrow -x \bmod 12$

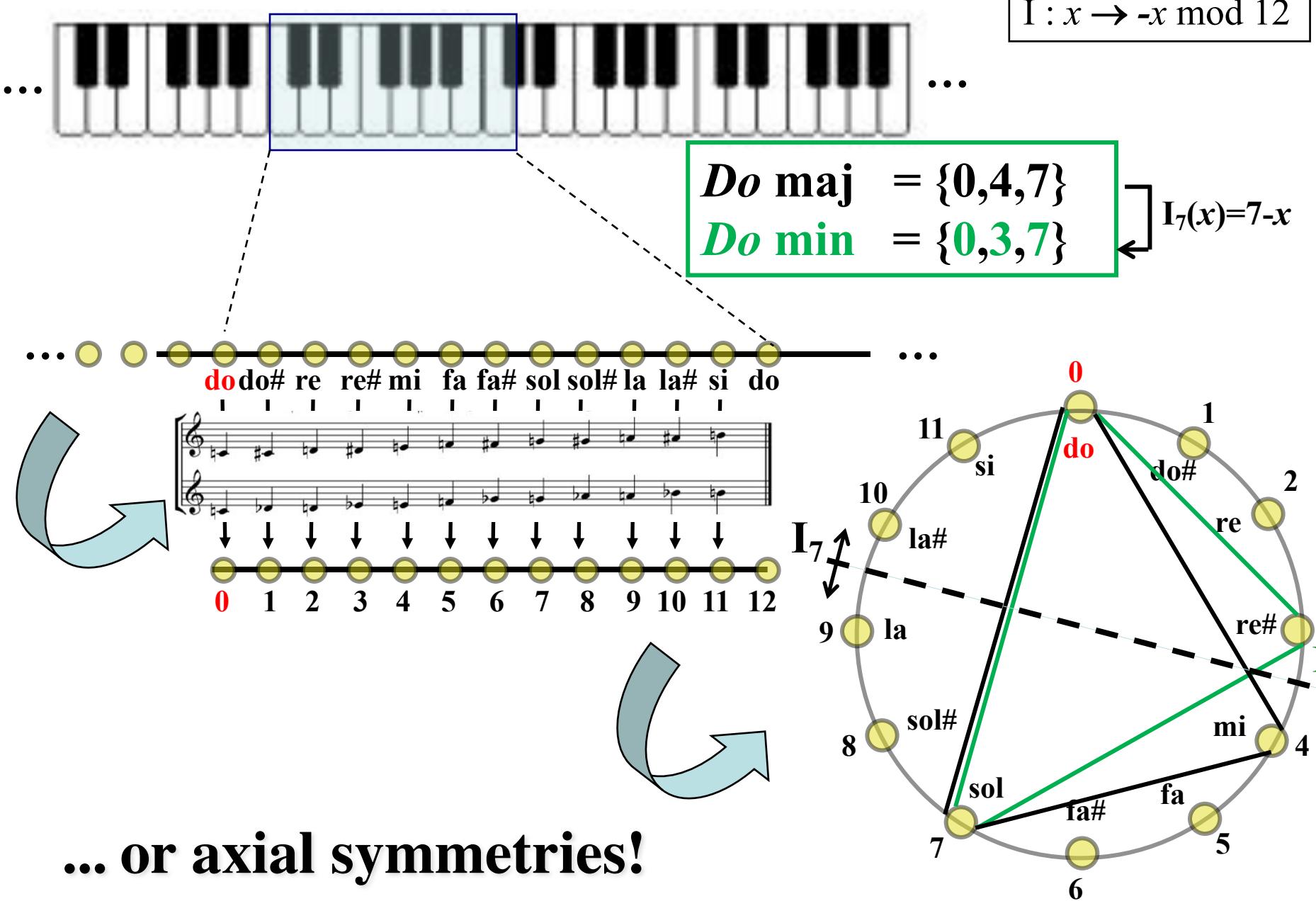
Set Equations:

- Do maj** = {0, 4, 7}
- La min** = {0, 4, 9}

Mapping: $I_4(x) = 4 - x$

Circle Diagram: A circle with 12 points labeled 0 through 11. Points 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 are connected by gray arcs. Red lines connect 0 to 4, 4 to 8, 8 to 10, 10 to 9, 9 to 5, 5 to 7, 7 to 6, 6 to 11, 11 to 1, 1 to 2, 2 to 3, and 3 to 0. A red line also connects 0 to 11. A dashed line connects 0 to 6. A red arrow labeled **R** points from 0 to 4. A blue arrow labeled I_4 points from 0 to 4.

Musical inversions are differences...



Musical inversions are differences...

... or axial symmetries!

The diagram illustrates musical inversions and axial symmetries using a piano keyboard, a circle of fifths, and a musical staff.

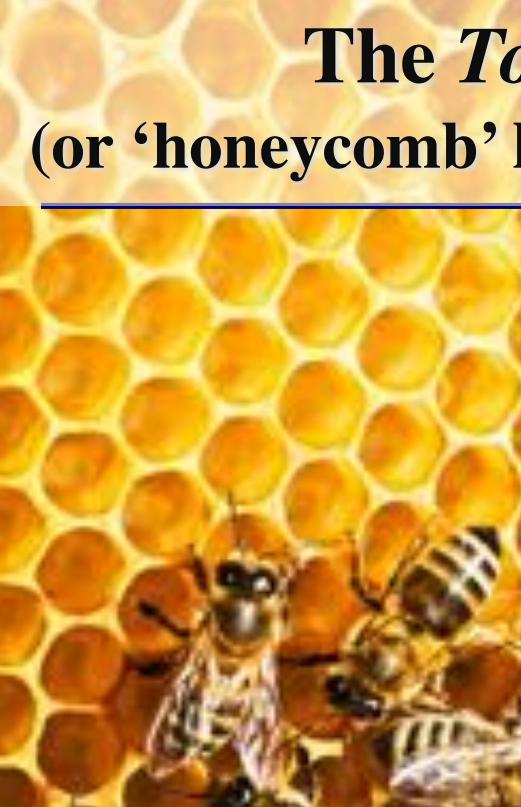
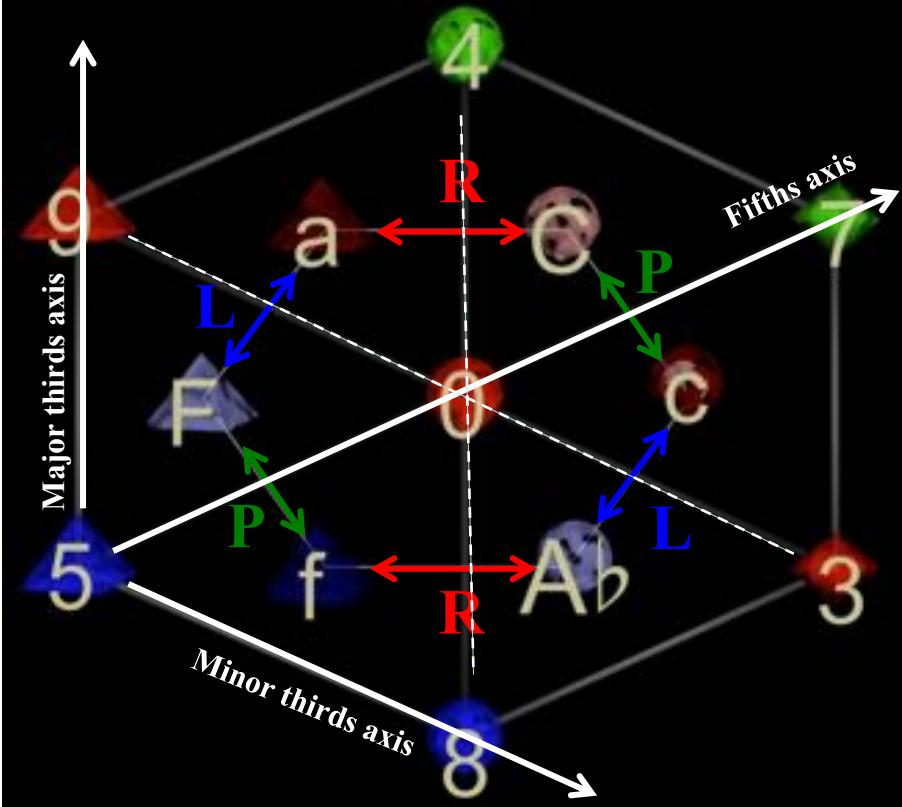
Piano Keyboard: A horizontal piano keyboard is shown with a blue box highlighting a segment of keys. Dashed arrows point from this segment to a circle of fifths and a musical staff.

Circle of Fifths: A circular diagram showing the 12 notes of the chromatic scale. The notes are labeled: do, do#, re, re#, mi, fa, fa#, sol, sol#, la, la#, si, do. The circle is divided into 12 equal segments, each representing a perfect fifth interval. A vertical axis through the center is labeled I_{11} . A blue arrow labeled L indicates a 180-degree rotation (antipodal symmetry).

Musical Staff: A musical staff with two staves is shown. The top staff has a treble clef and the bottom staff has a bass clef. Notes are placed on the staff, corresponding to the notes on the circle of fifths. Arrows point from the staff to the circle of fifths and the piano keyboard.

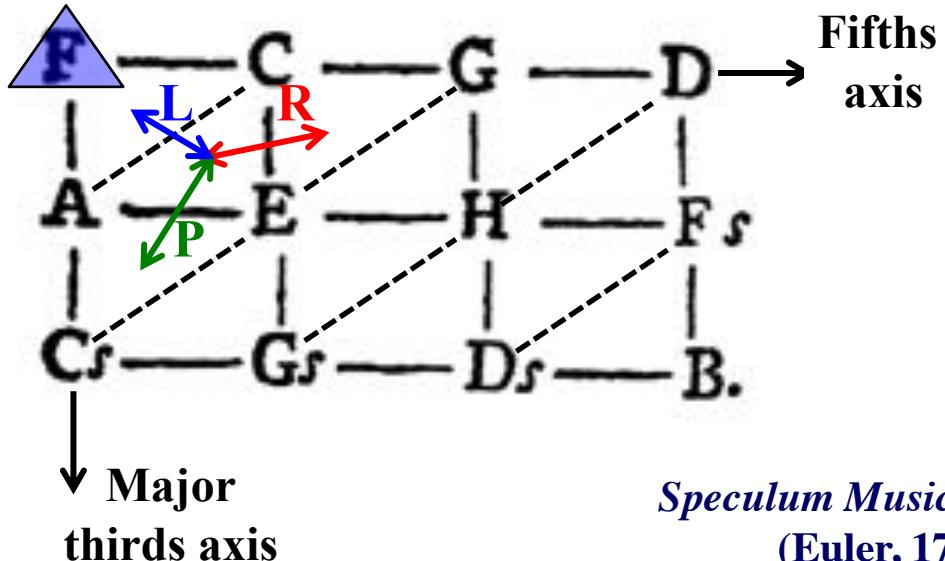
Mathematical Formulas:

$$I : x \rightarrow -x \bmod 12$$
$$Do \ maj = \{0, 4, 7\}$$
$$Mi \ min = \{4, 7, 11\}$$
$$I_{11}(x) = 11 - x$$



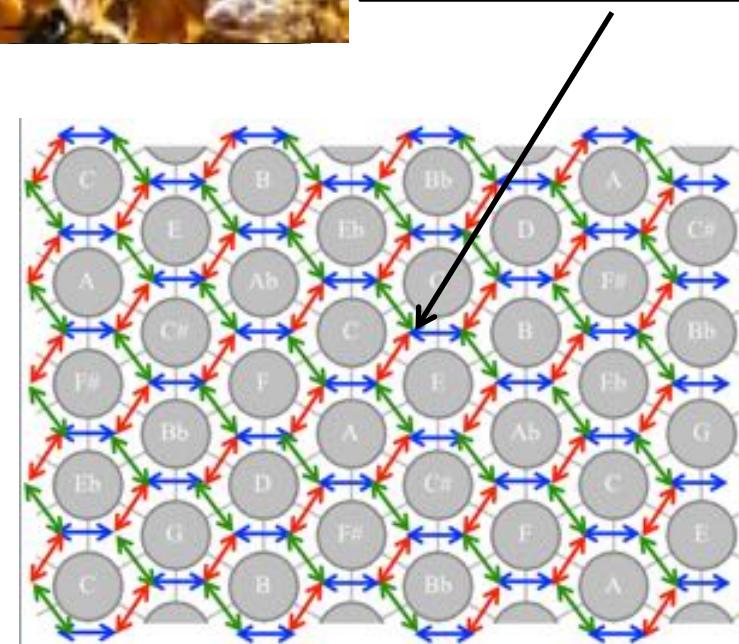
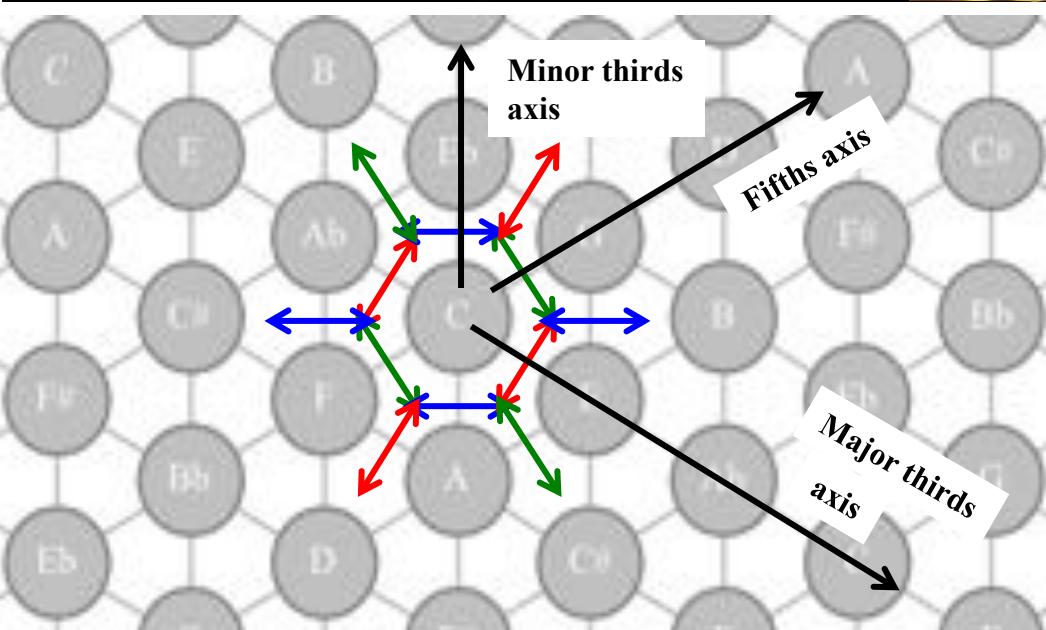
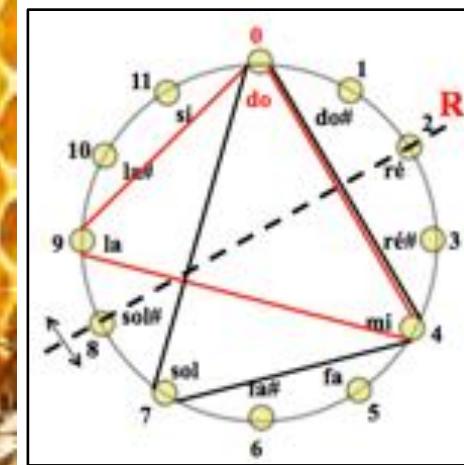
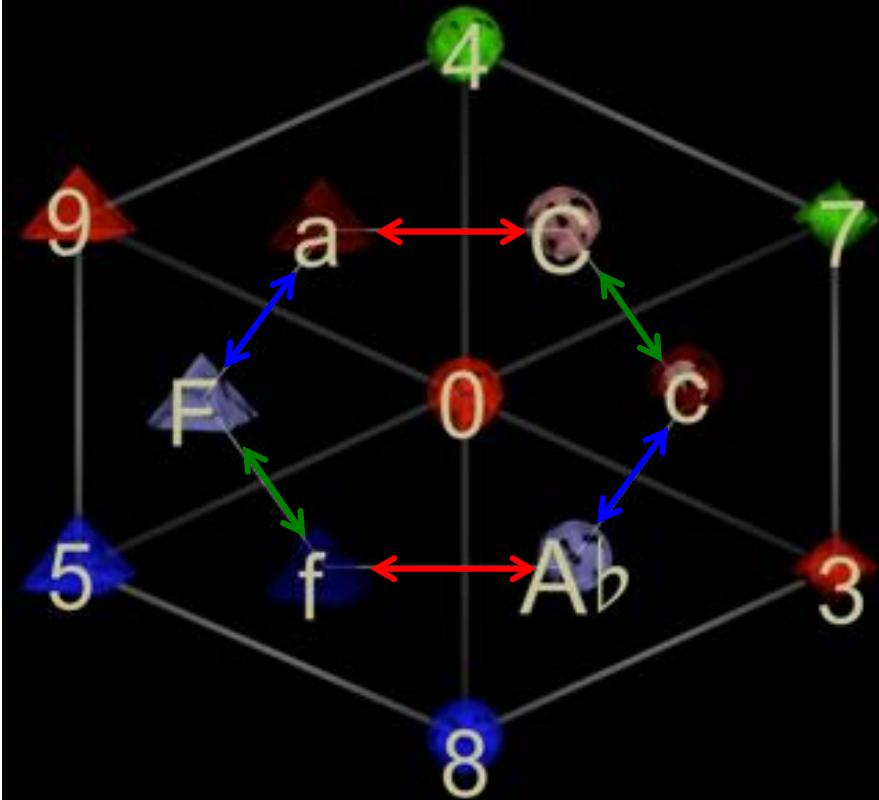
The Tonnetz

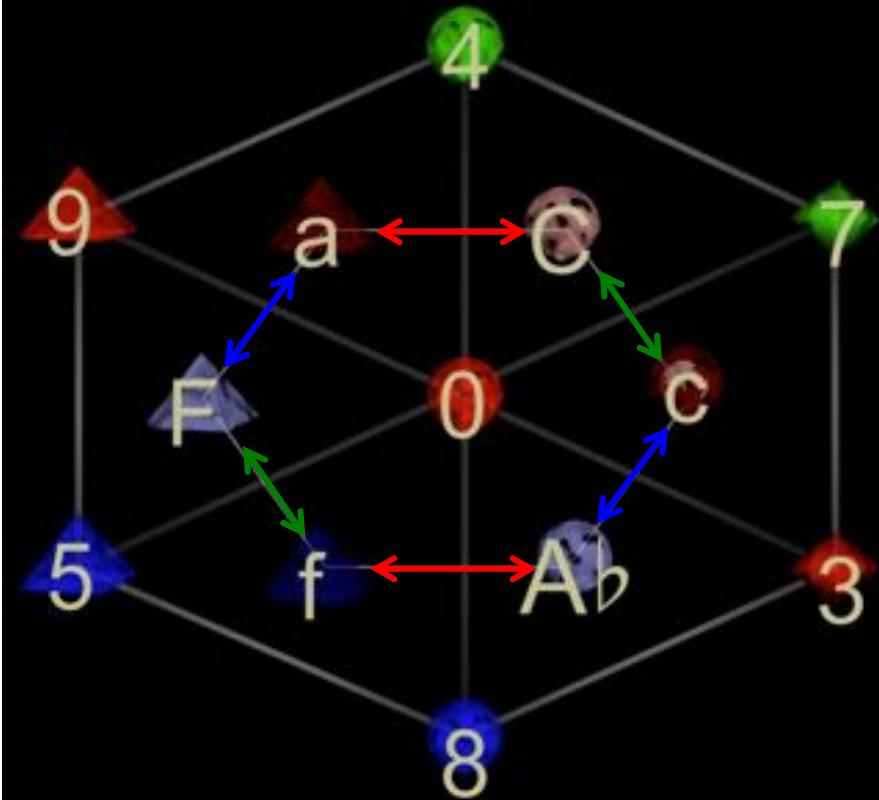
(or ‘honeycomb’ hexagonal tiling)



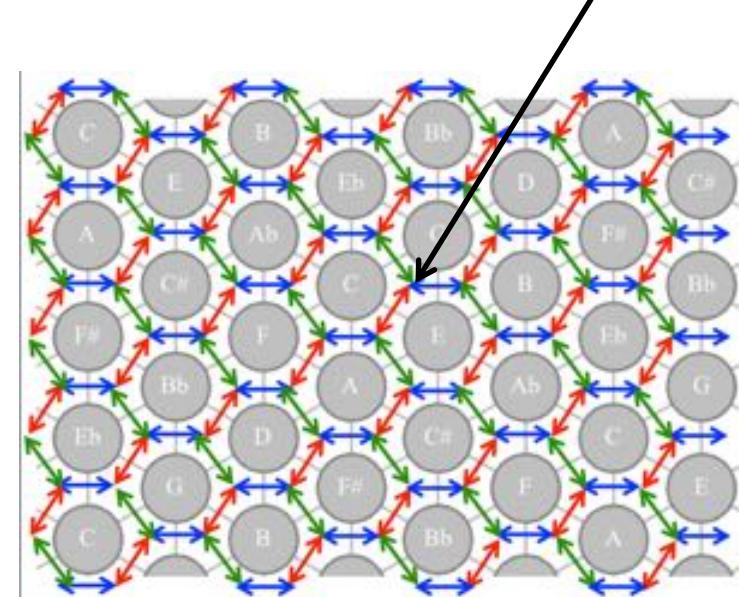
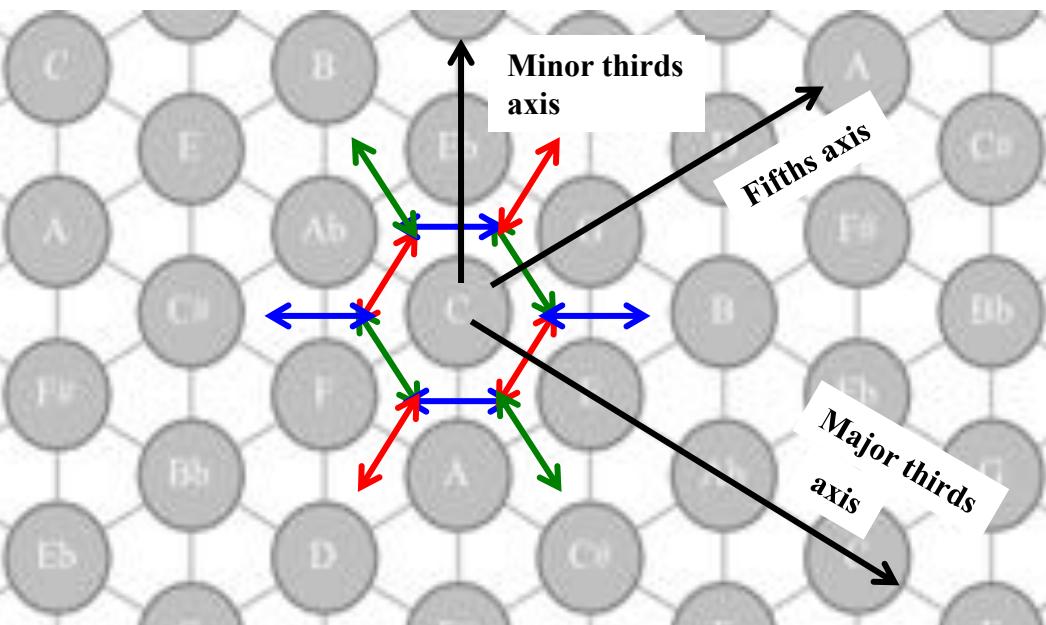
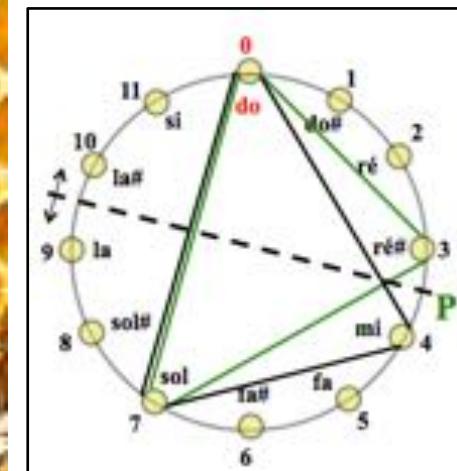
Speculum Musicum
(Euler, 1773)

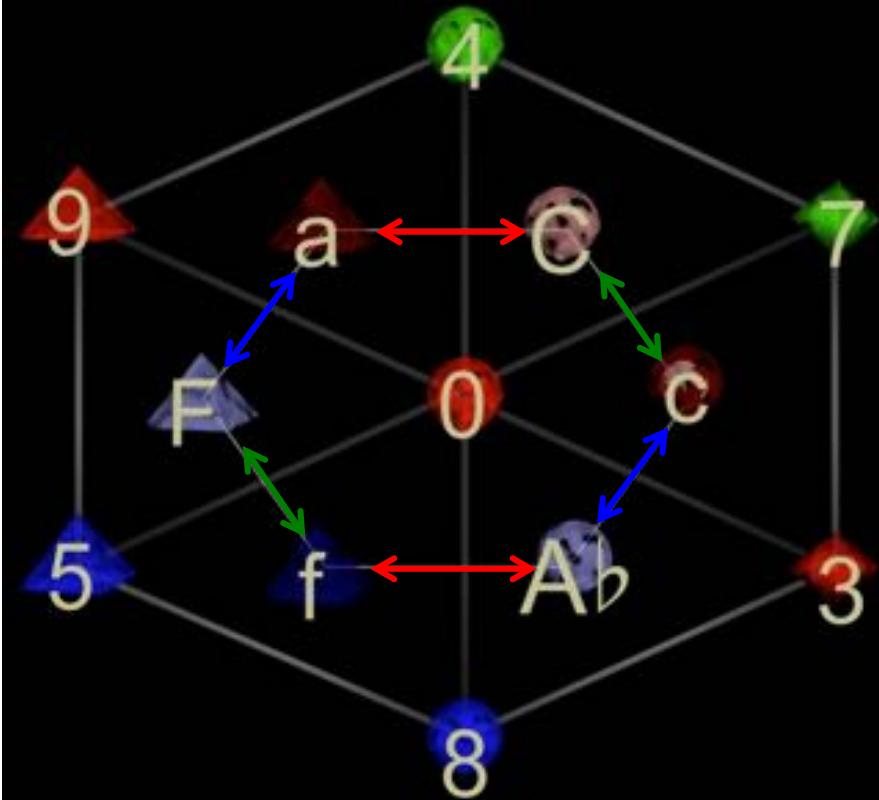
The *Tonnetz* (or ‘honeycomb’ hexagonal tiling)



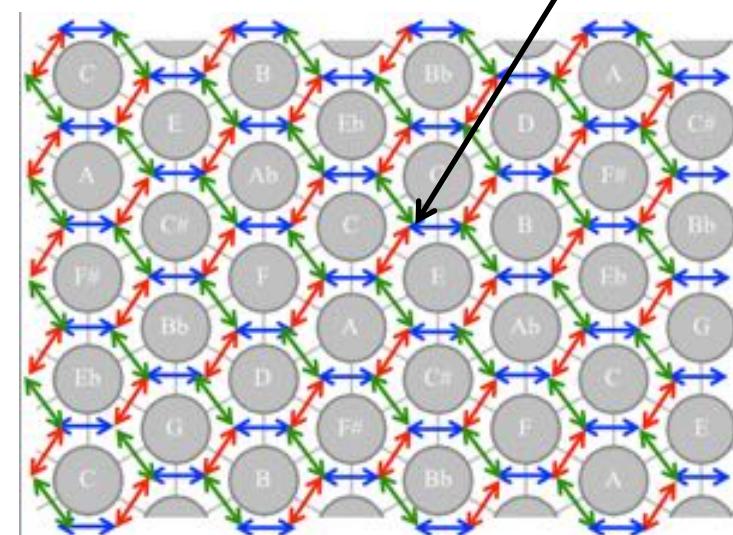
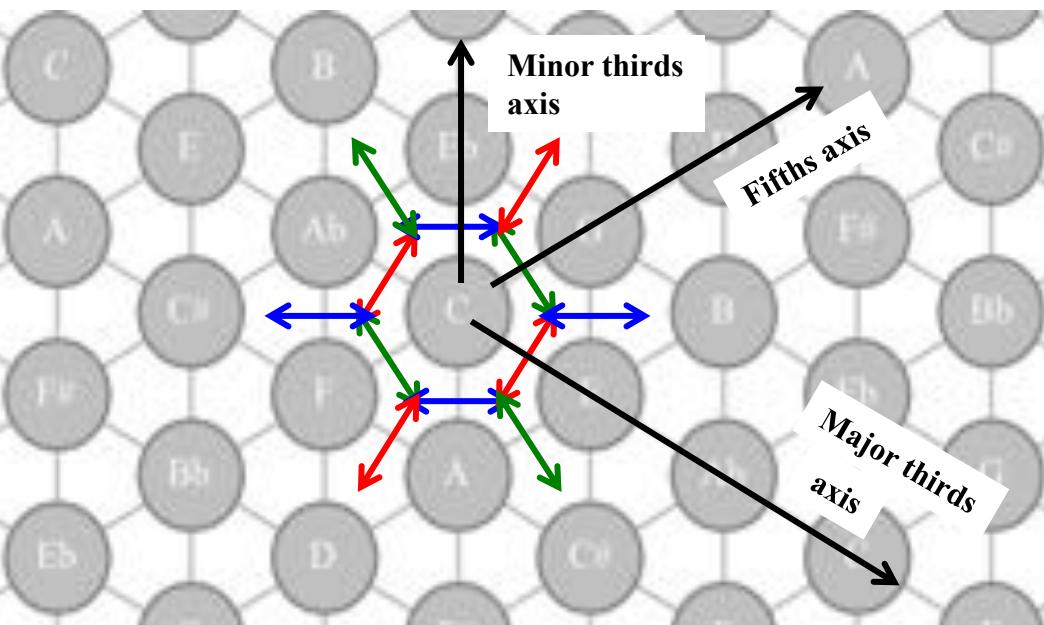
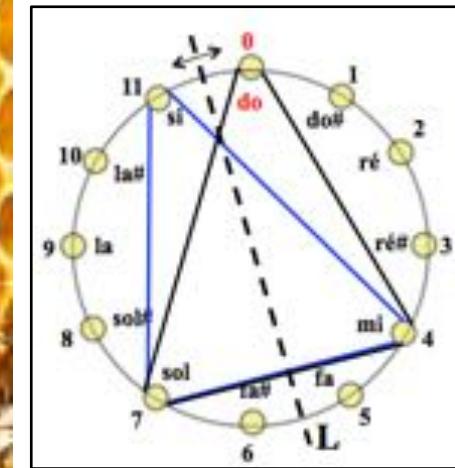


The *Tonnetz* (or ‘honeycomb’ hexagonal tiling)





The *Tonnetz* (or ‘honeycomb’ hexagonal tiling)

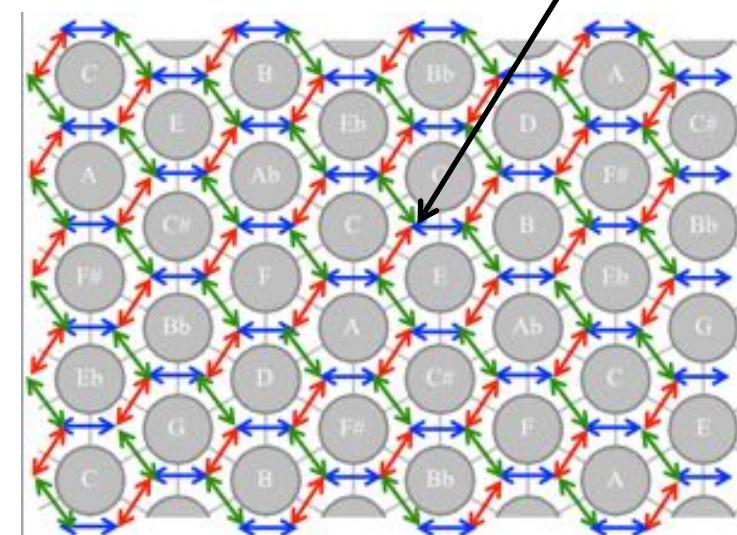
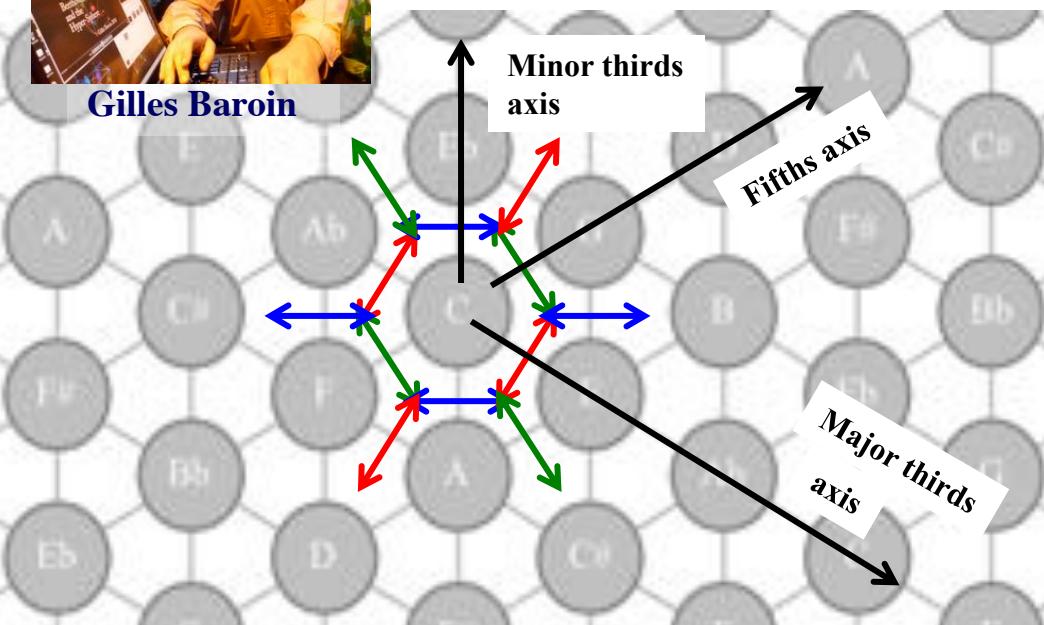
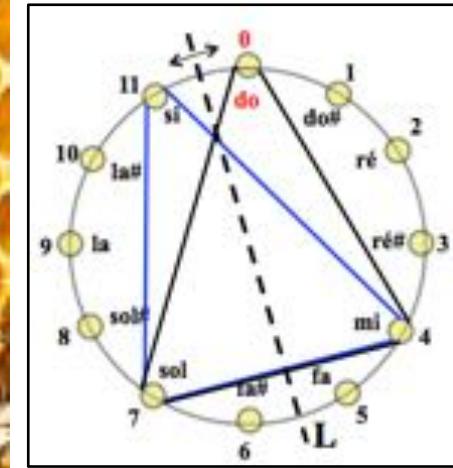
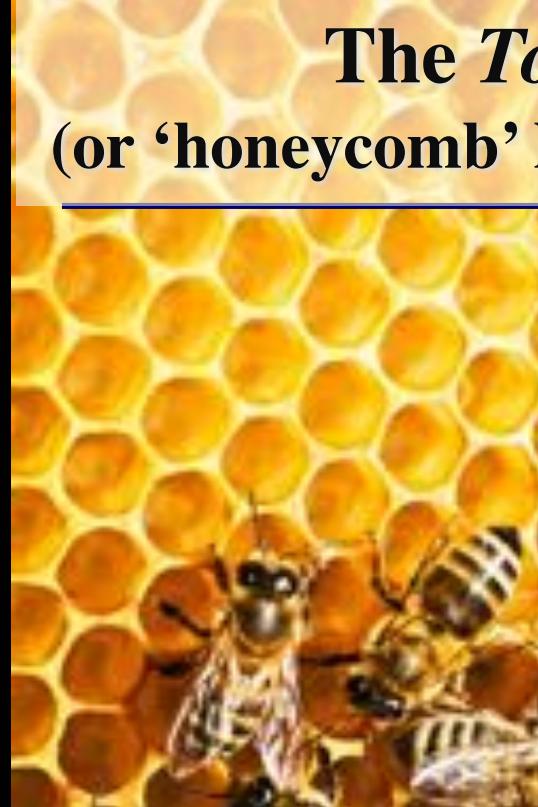


The Tonnetz

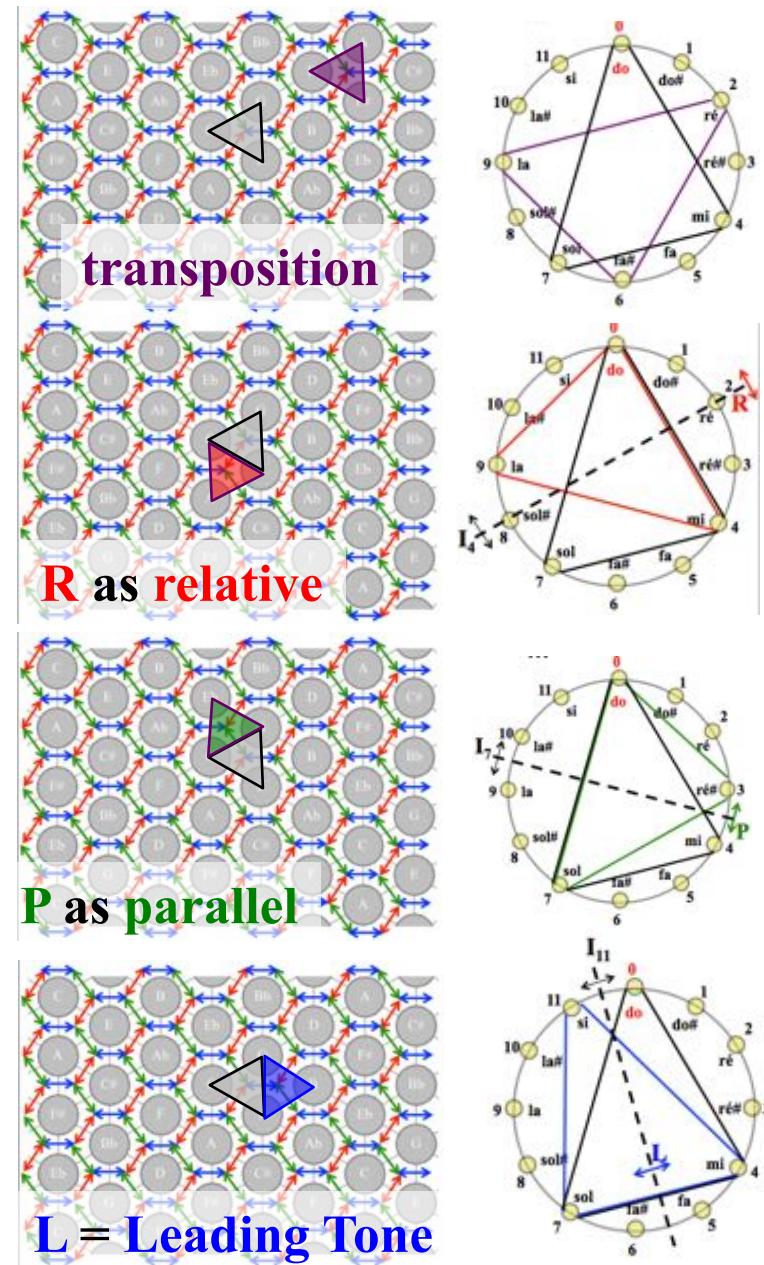
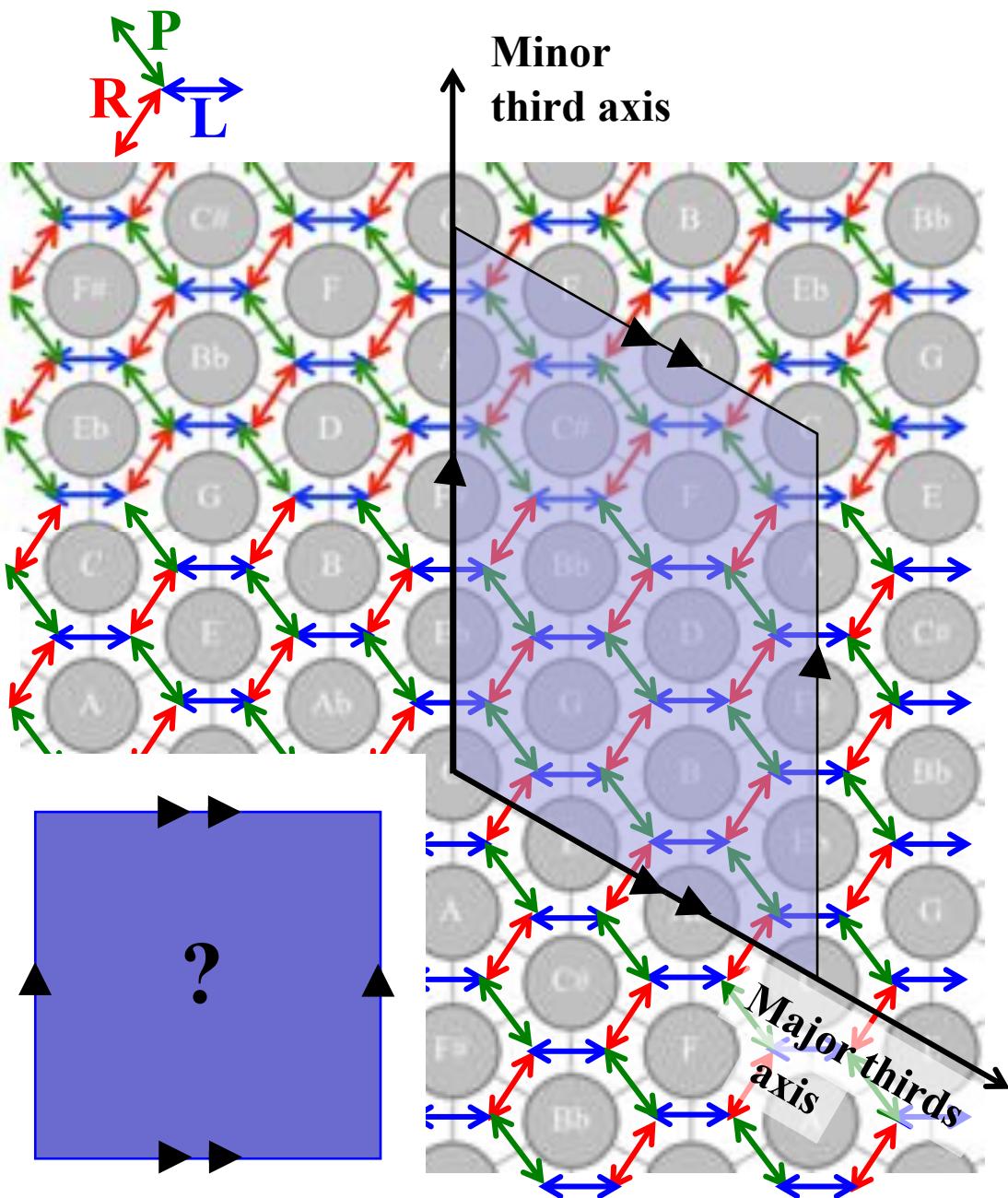
(or ‘honeycomb’ hexagonal tiling)



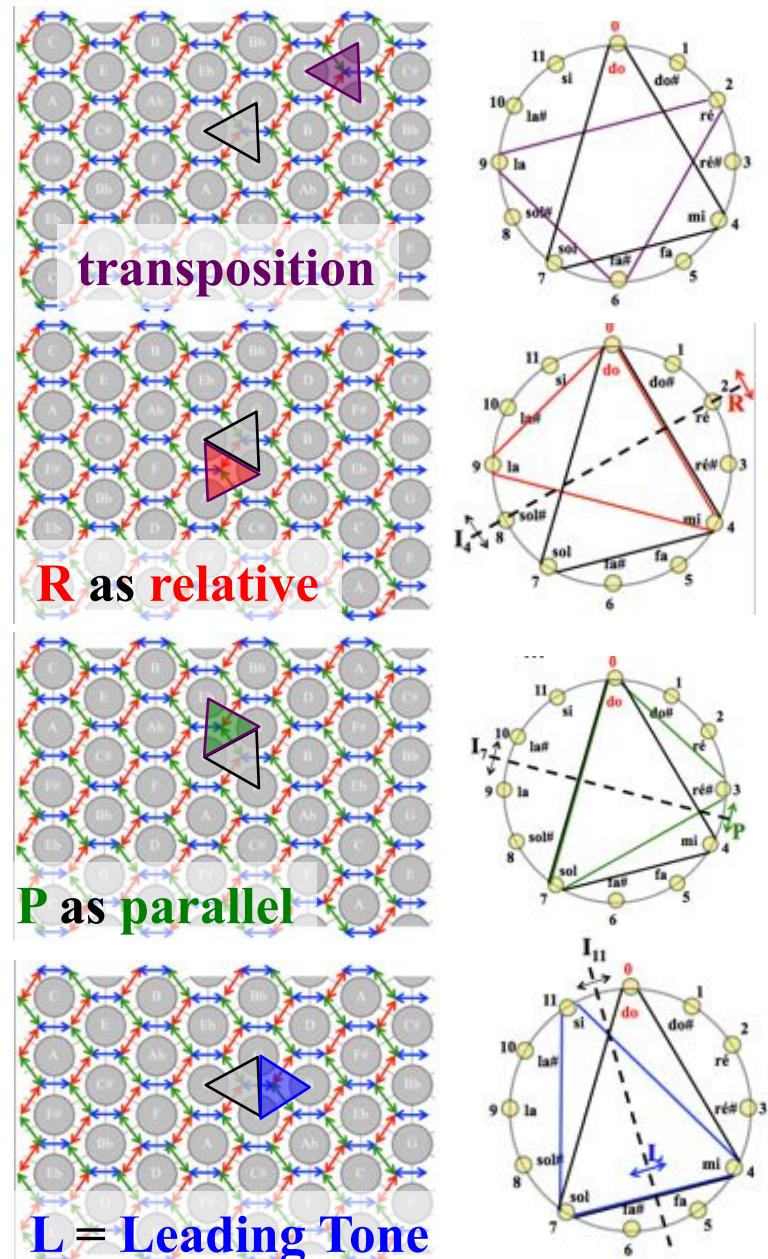
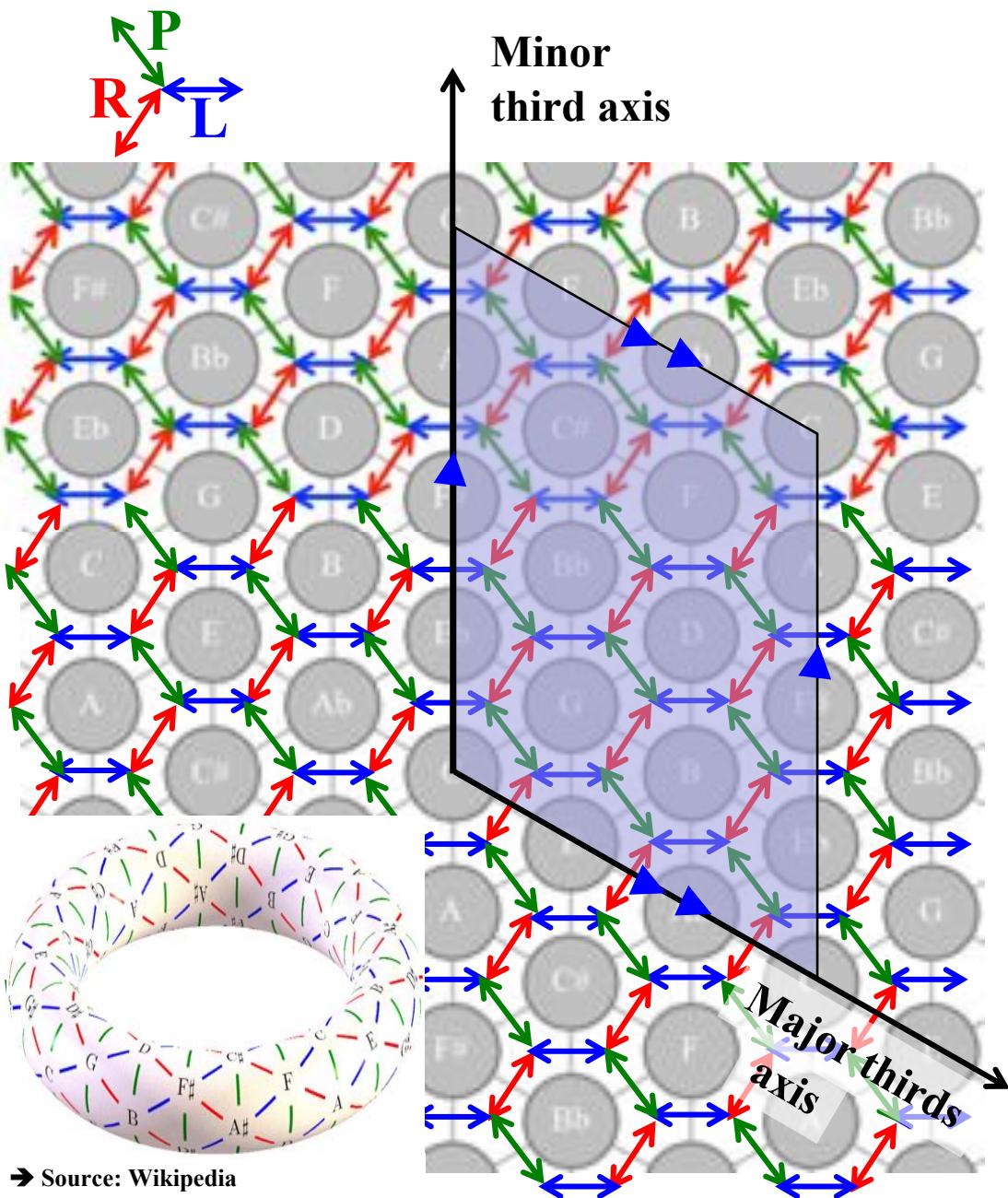
Gilles Baroin



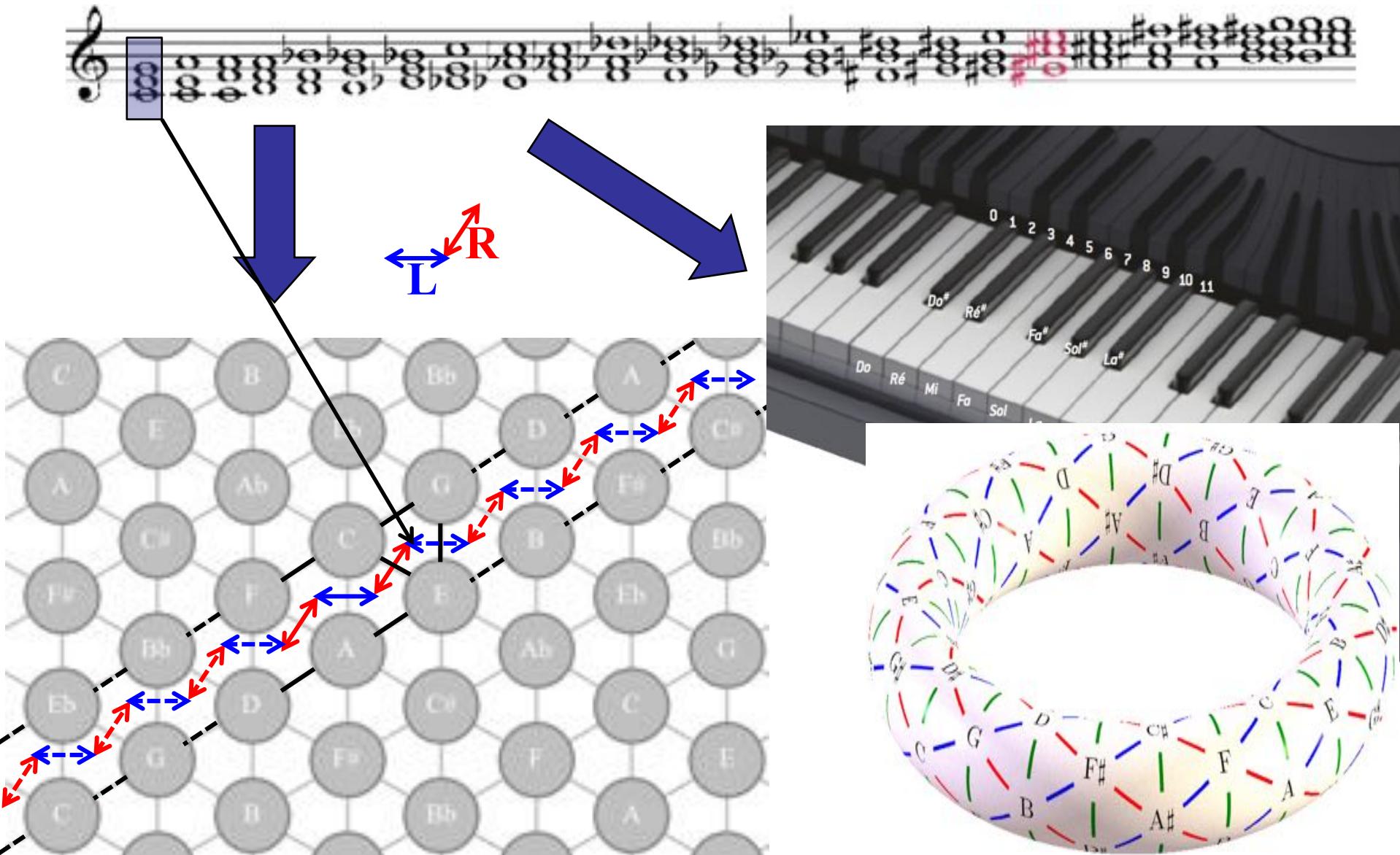
The Tonnetz, its symmetries and its topological structure



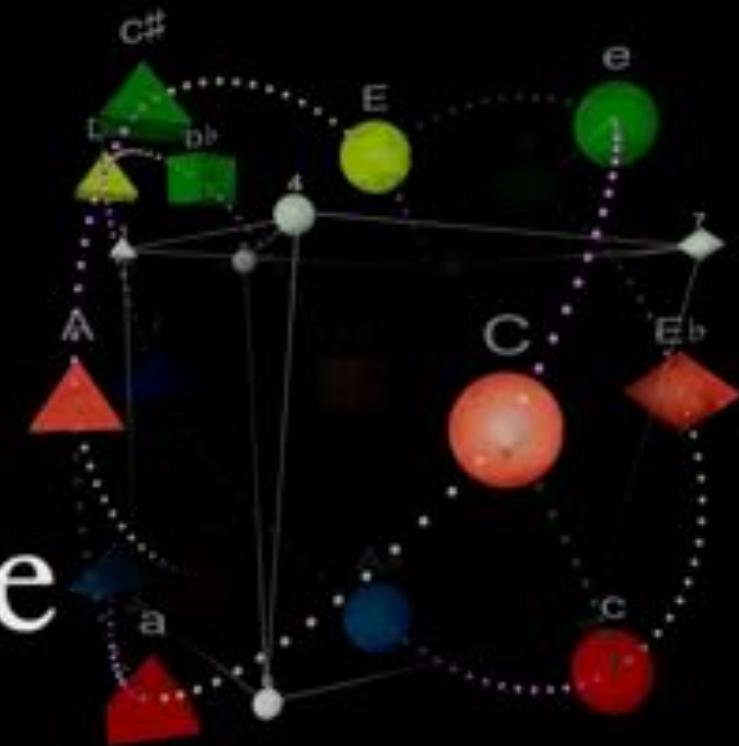
The Tonnetz, its symmetries and its topological structure



Harmonic progressions as spatial trajectories

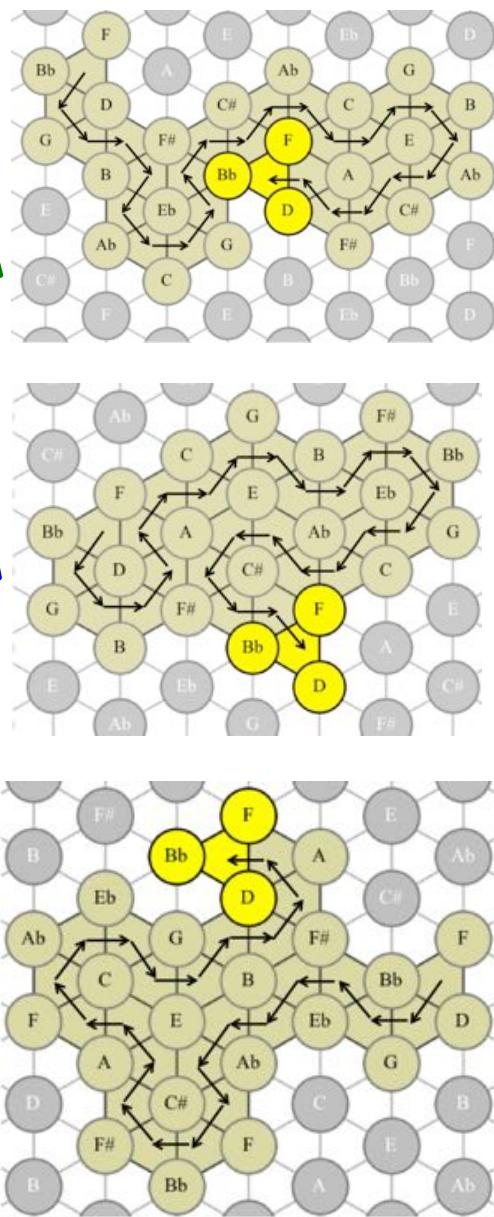
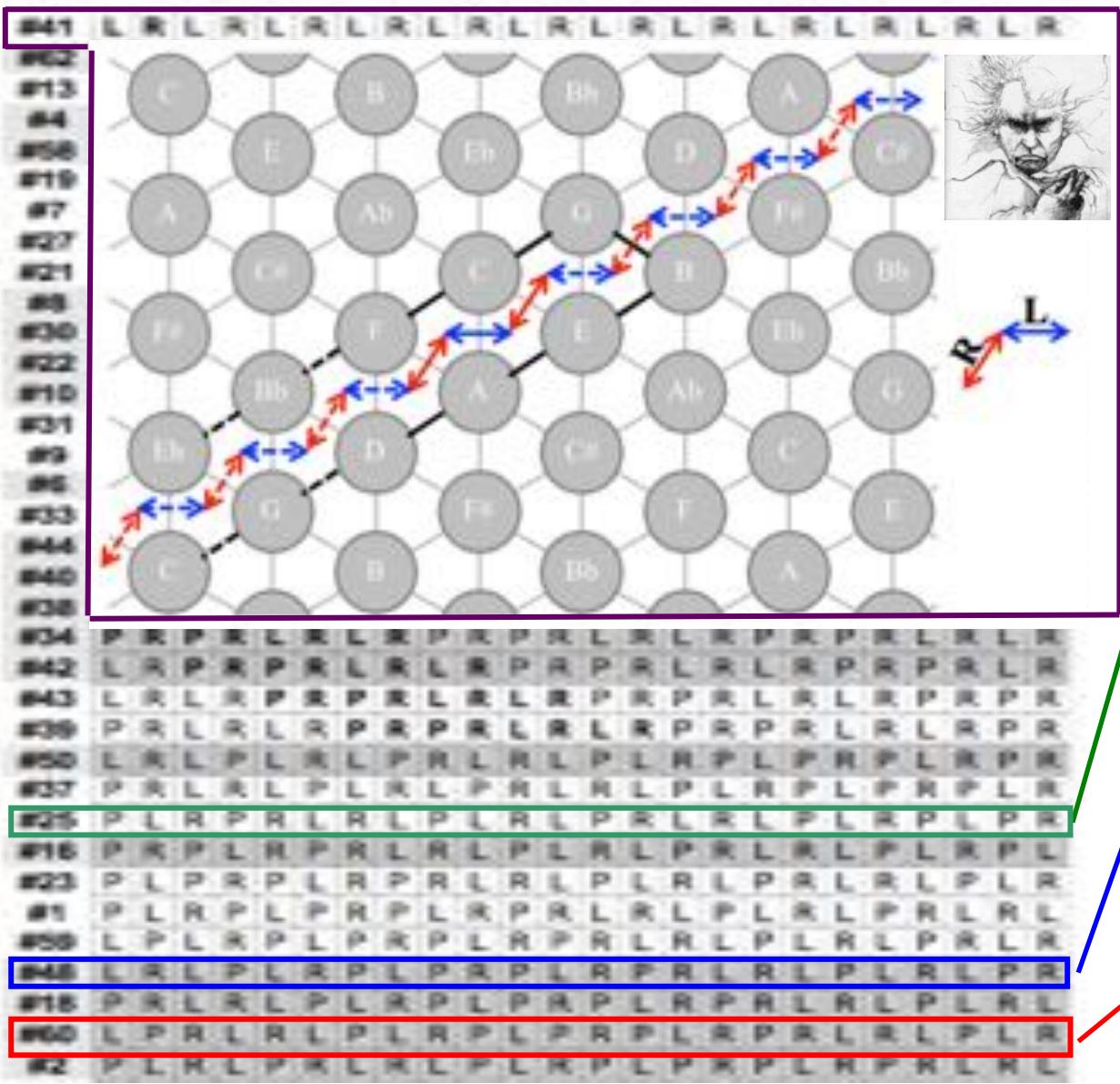


Beethoven and the Hypersphere *(and the Tonnetz)*



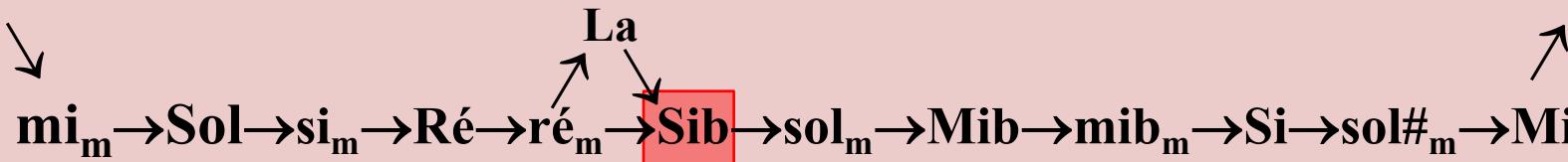
Gilles Baroin 2016
www.MatheMusic.net

Hamiltonian cycles and song writing



Aprile, a Hamiltonian « decadent » song

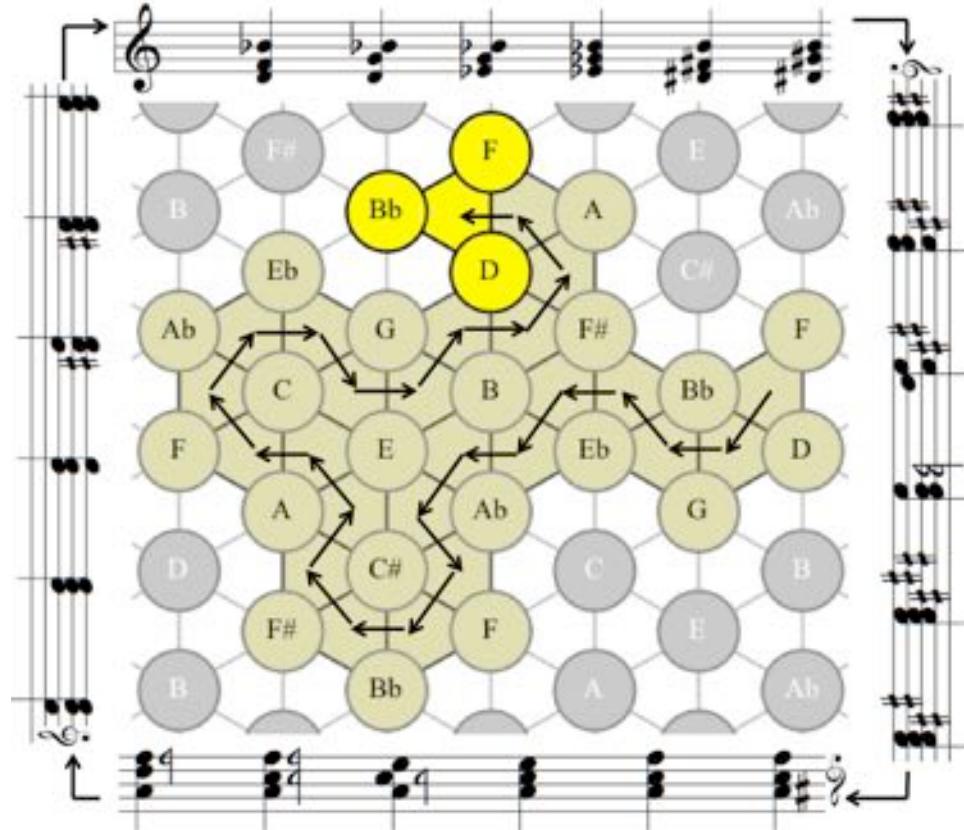
Do←**do_m**←**Sol#**←**fa_m**←**Fa**←**la_m**←**La**←**fa#_m**←**Fa#**←**sib_m**←**Do#**←**do#_m**



*Socchiusa è la finestra, sul giardino.
Un'ora passa lenta, sonnolenta.
Ed ella, ch'era attenta, s'addormenta
A quella voce che già si lamenta,
Che si lamenta in fondo a quel giardino.*

*Non è che voce d'acque su la pietra:
E quante volte, quante volte udita!
Quell'amore e quell'ora in quella vita
S'affondan come ne l'onda infinita
Stretti insieme il cadavere e la pietra.*

*Ella stende l'angoscia sua nel sonno.
L'angoscia è forte, e il sonno è così lieve!
(Par i' luce d'aprile quasi una neve
che sia tiepida.)
Ed ella certo deve soffrire,
Vagamente, anche nel sonno.*



ACTIONS

Math'n'pop

G. D'Annunzio (1863-1938)

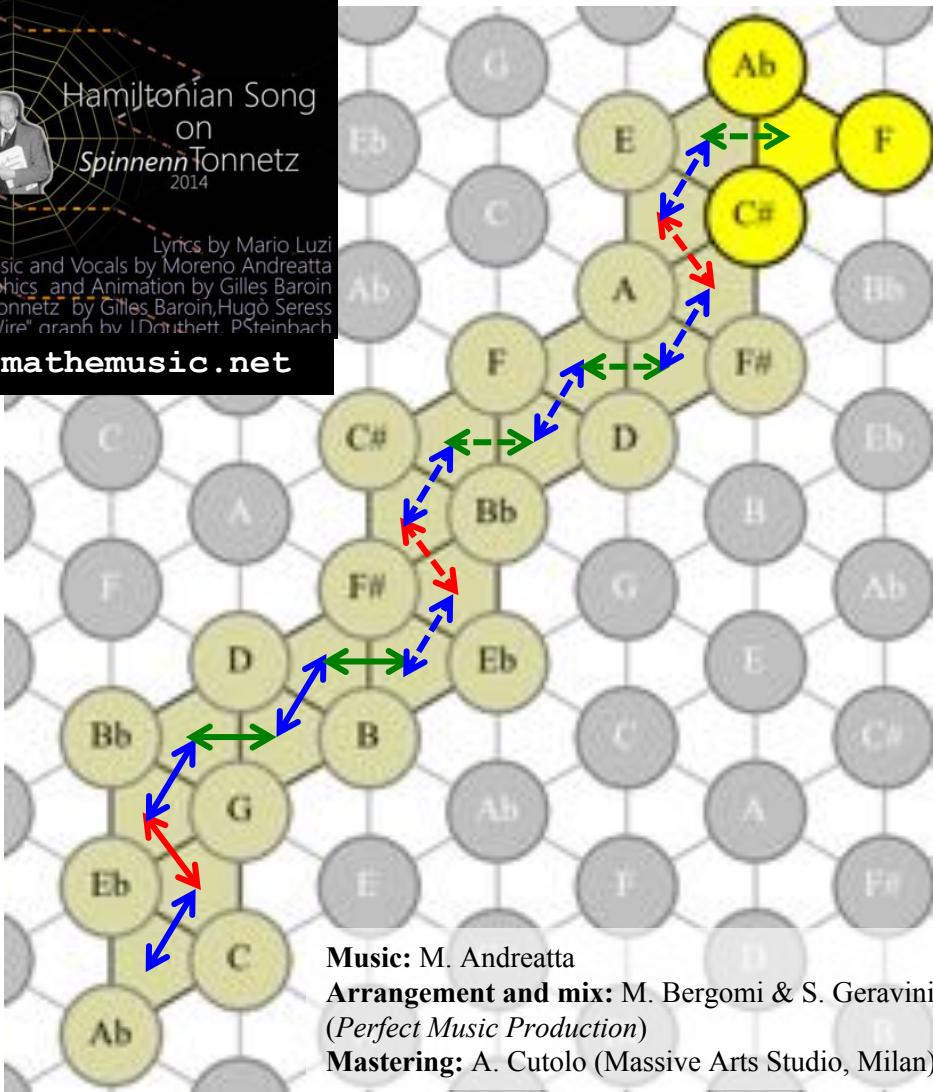
Hamiltonian Cycles with inner periodicities

8. C-Cm-Eb-Gm-Bb-Dm-F-Fm-Ab-Abm-B-Ebm-F#-Bbm-C#-C#m-E-Em-G-Bm-D-F#m-A-Am--PRLRLRPR
9. C-Em-E-Abm-Ab-Cm-Eb-Gm-G-Bm-B-Ebm-F#-Bbm-Bb-Dm-D-F#m-A-C#m-C#-Fm-F-Am--LPLPLR
10. C-Em-E-Abm-B-Ebm-Eb-Gm-G-Bm-D-F#m-F-Bbm-Bb-Dm-F-Am-A-C#m-C#-Fm-Ab-Cm--LPLRLP
11. C-Em-G-Gm-Bb-Bbm-C#-C#m-E-Abm-B-Bm-D-Dm-F-Fm-Ab-Cm-Eb-Ebm-F#-F#m-A-Am--LRPRPRPR
12. C-Em-G-Gm-Bb-Bbm-C#-Fm-Ab-Cm-Eb-Ebm-F#-F#m-A-C#m-E-Abm-B-Bm-D-Dm-F-Am--LRPRPRLR



L P L P L R ...
 P L P L R L ...
 L P L R L P ...
 PL R L P L ...
L R L P L P ...
 R L P L P L ...

Luzi



La sera non è più la tua canzone
 (Mario Luzi, 1945, in *Poesie sparse*)

La sera non è più la tua canzone,
 è questa roccia d'ombra traforata
 dai lumi e dalle voci senza fine,
 la quiete d'una cosa già pensata.

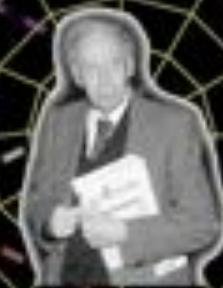
Ah questa luce viva e chiara viene
 solo da te, sei tu così vicina
 al vero d'una cosa conosciuta,
 per nome hai una parola ch'è passata
 nell'intimo del cuore e s'è perduta.

Caduto è più che un segno della vita,
 riposi, dal viaggio sei tornata
 dentro di te, sei scesa in questa pura
 sostanza così tua, così romita
 nel silenzio dell'essere, (compiuta).

L'aria tace ed il tempo dietro a te
 si leva come un'arida montagna
 dove vaga il tuo spirito e si perde,
 un vento raro scivola e ristagna.



Luzi



Hamiltonian Song
on
SpinnenTonnetz
2014

Lyrics by Mario Luzi

Music and Vocals by Moreno Andreatta

Graphics and Animation by Gilles Baroin

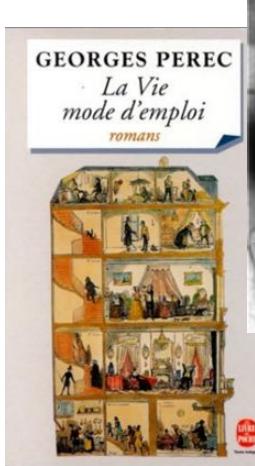
SpinnenTonnetz by Gilles Baroin, Hugò Seress

Original "Chicken Wire" graph by J.Douthett, P.Steinbach

The use of constraints in arts



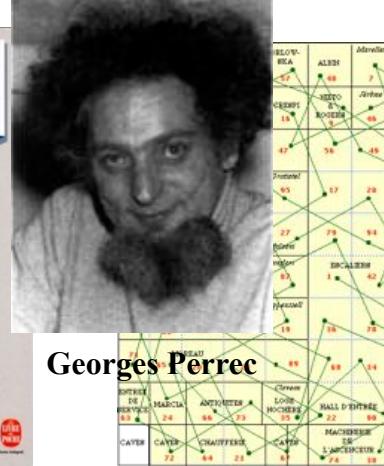
Cent mille milliards de poèmes, 1961



La vie mode d'emploi,



Georges Perec



*Georges
Perec*

Roman

La disparition

Les Lettres Nouvelles

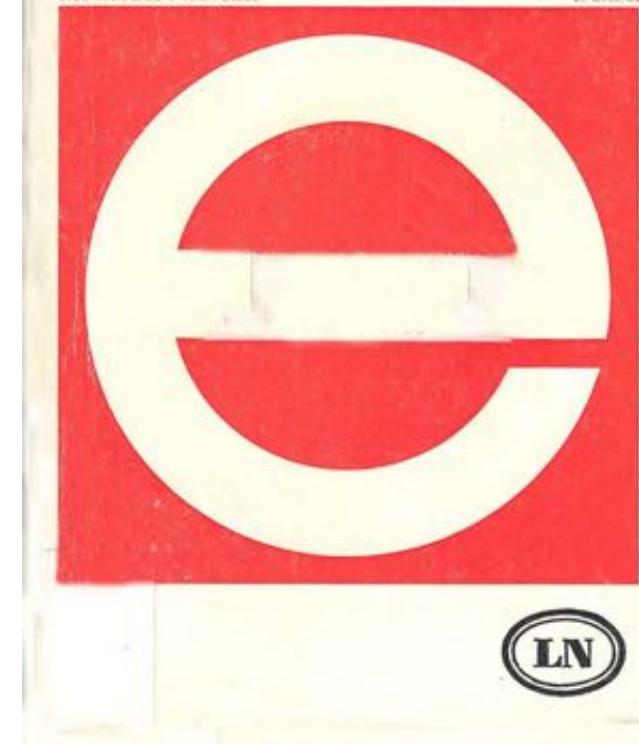
Denoël



Raymond Queneau

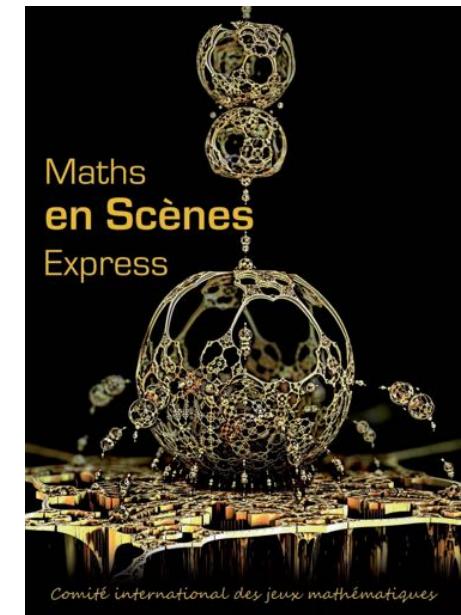


Italo Calvino
Il castello dei destini incrociati, 1969



LN

From the OuLiPo to the OuMuPo (ouvroir de musique potentielle)



<http://oumupo.org/>

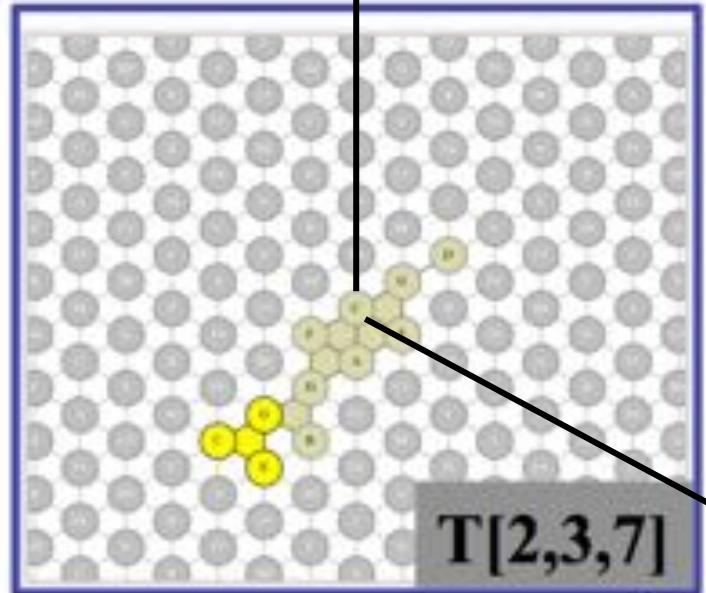
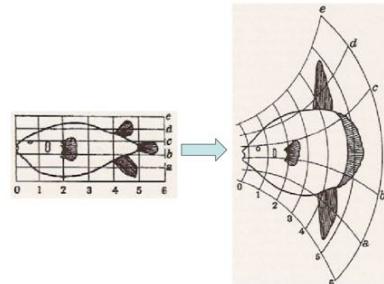
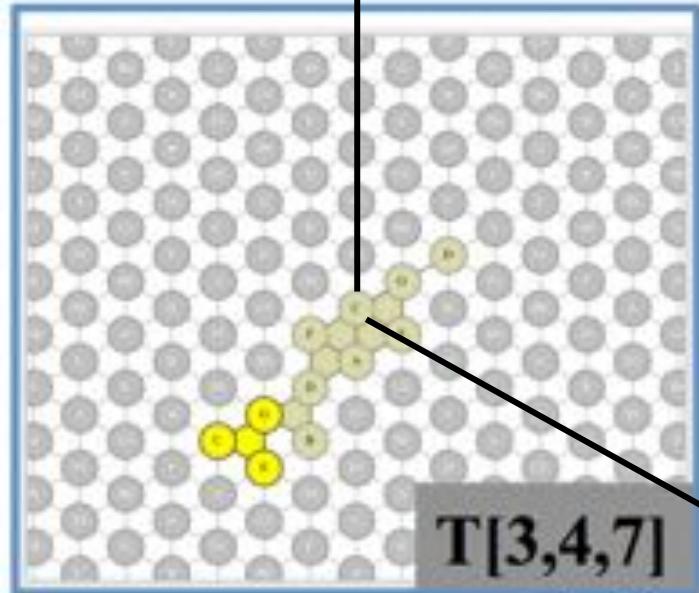
A grid of seven images showing people involved in the OuMuPo project:

- Valentin Villenave (left, sitting at a computer).
- Mike Solomon (center-left, portrait).
- Jean-François Piette (center, playing drums).
- Martin Granger (center-right, portrait).
- Joseph Boisseau (blue icon with a question mark).
- Moreno Andreatta (right, playing piano).
- Tom Johnson (far right, portrait).

Below each image is the name of the person:

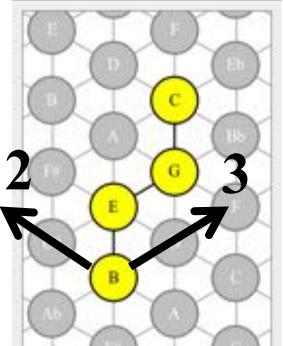
- Valentin Villenave
- Mike Solomon
- Jean-François Piette
- Martin Granger
- Joseph Boisseau
- Moreno Andreatta
- Tom Johnson

The musical style...is the space!

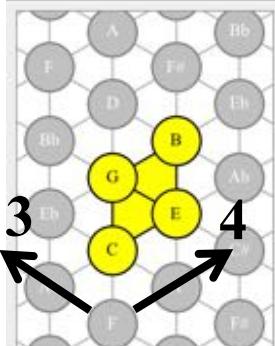


The geometric character of musical logic

1

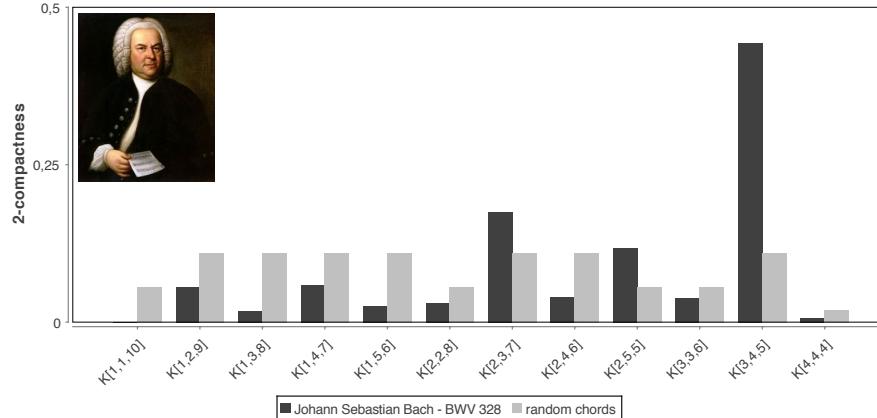


T[2,3,7]



T[3,4,5]

Johann Sebastian Bach - BWV 328

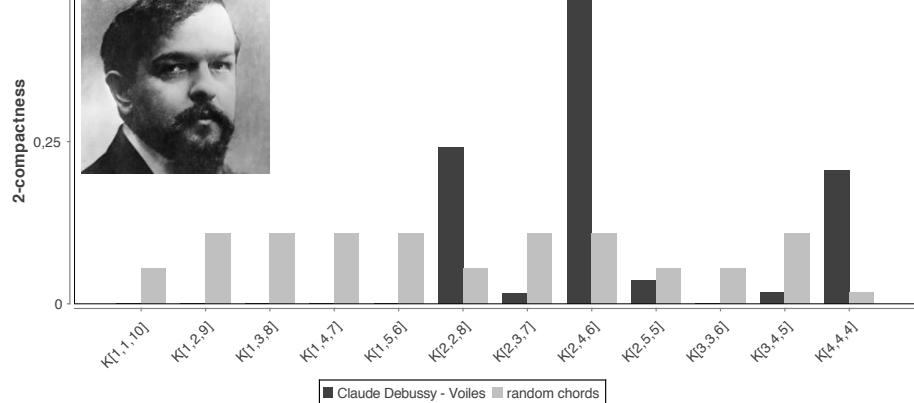


David Meredith Editor

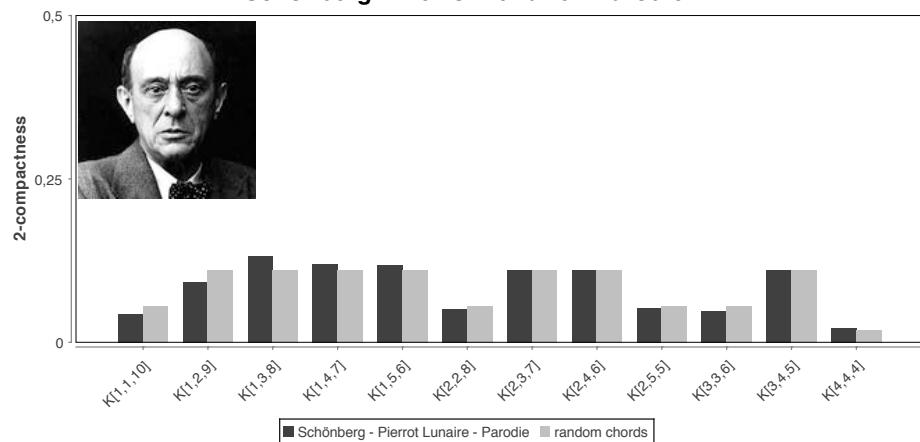
Computational
Music Analysis

Springer

Claude Debussy - Voiles



Schönberg - Pierrot Lunaire - Parodie

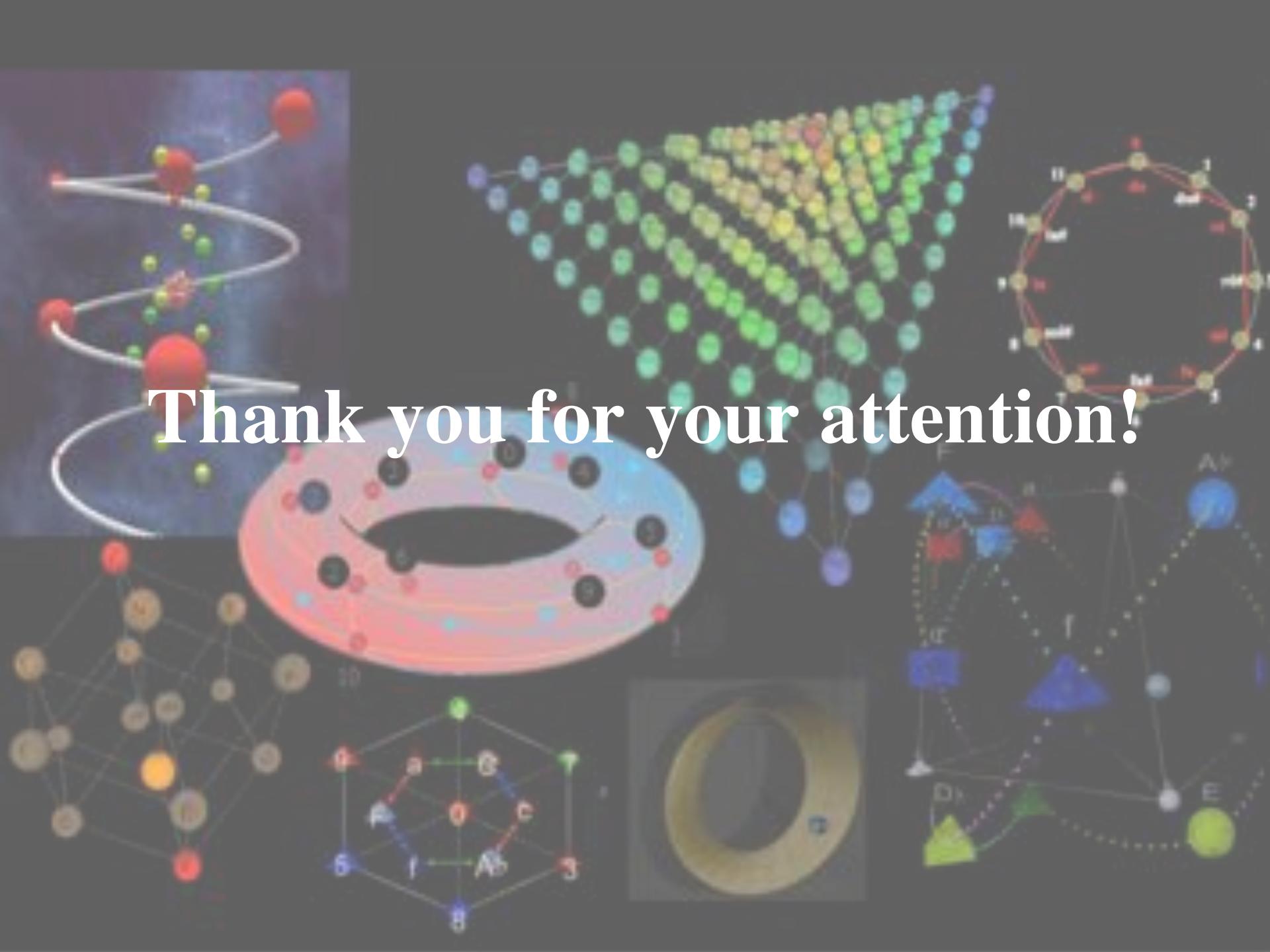


Spatial music analysis via *Hexachord*

The image shows a screenshot of the Hexachord software interface, which includes several windows and panels:

- Phx Viewer:** A 3D visualization of a geometric polyhedron.
- Tessellate (A3,A3):** A hexagonal grid visualization showing musical complexes labeled with letters A through T.
- InfoBox:** A control panel for a MIDI file named "bwv0281.mid". It includes:
 - Tempo slider (set to 10).
 - Play and Stop buttons.
 - Select midi file input field.
 - Chromatic complexes and Heptatonic complexes dropdown menus.
 - Trace off and Harmonization ON buttons.
 - Display graph button.
 - Vertical compactness section with compactness dimension (2), 2-compactness, compute compactness, and absolute compactness buttons.
 - Path Transformation section with Origin complex (K[3,4,5]) and Destination complex (K[3,4,5]), Rotation (0), North translation (0), and North-east translation (0) buttons, and a Path Transformation button.
 - Chart section titled "2-compactness : bwv0281" showing a bar chart of 2-compactness values over time.
- Computer Music Journal:** A sidebar showing a thumbnail of the journal cover and a small chart.
- 2-compactness Chart:** A bar chart titled "2-compactness : bwv0281" with the y-axis ranging from 0 to 0.050 and the x-axis showing time intervals. The legend indicates red bars for "bwv0281" and blue bars for "random choice".

→ <http://www.lacl.fr/~lbigo/hexachord>



Thank you for your attention!