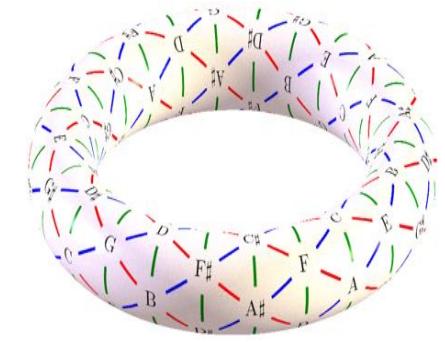
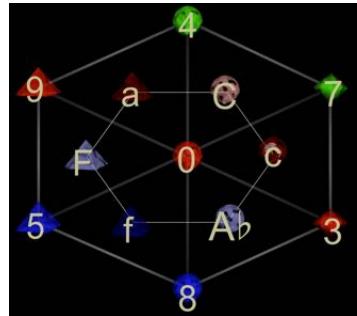
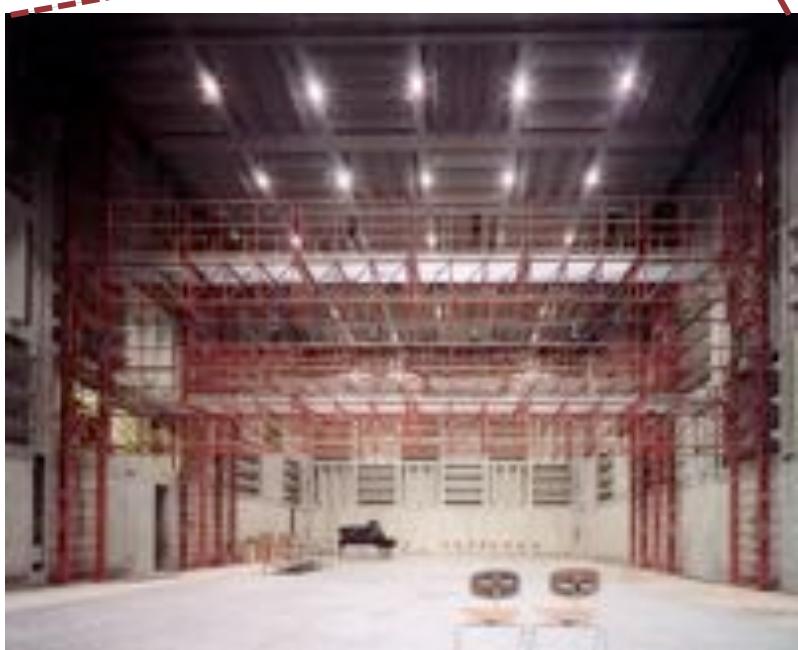
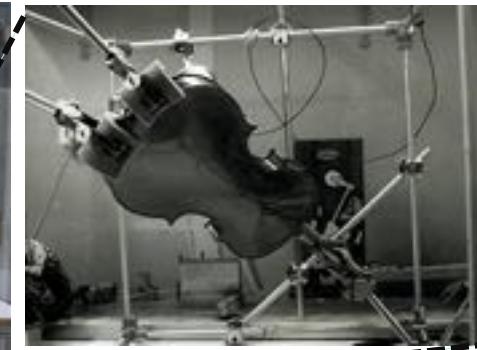
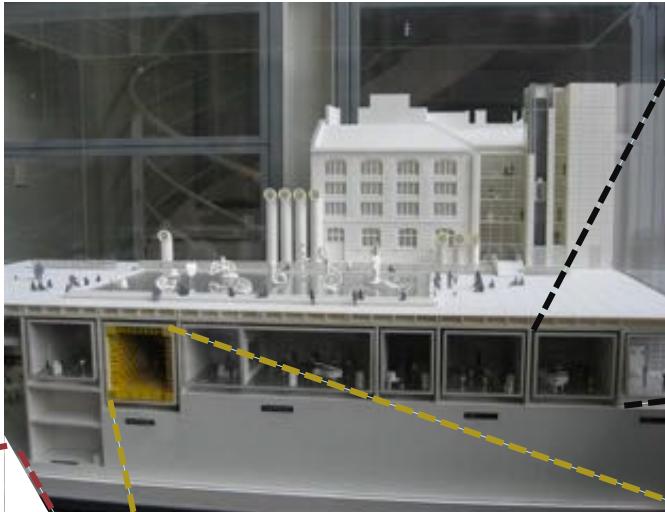


# Computer-Aided Music Analysis and Composition between scientific research and artistic practice

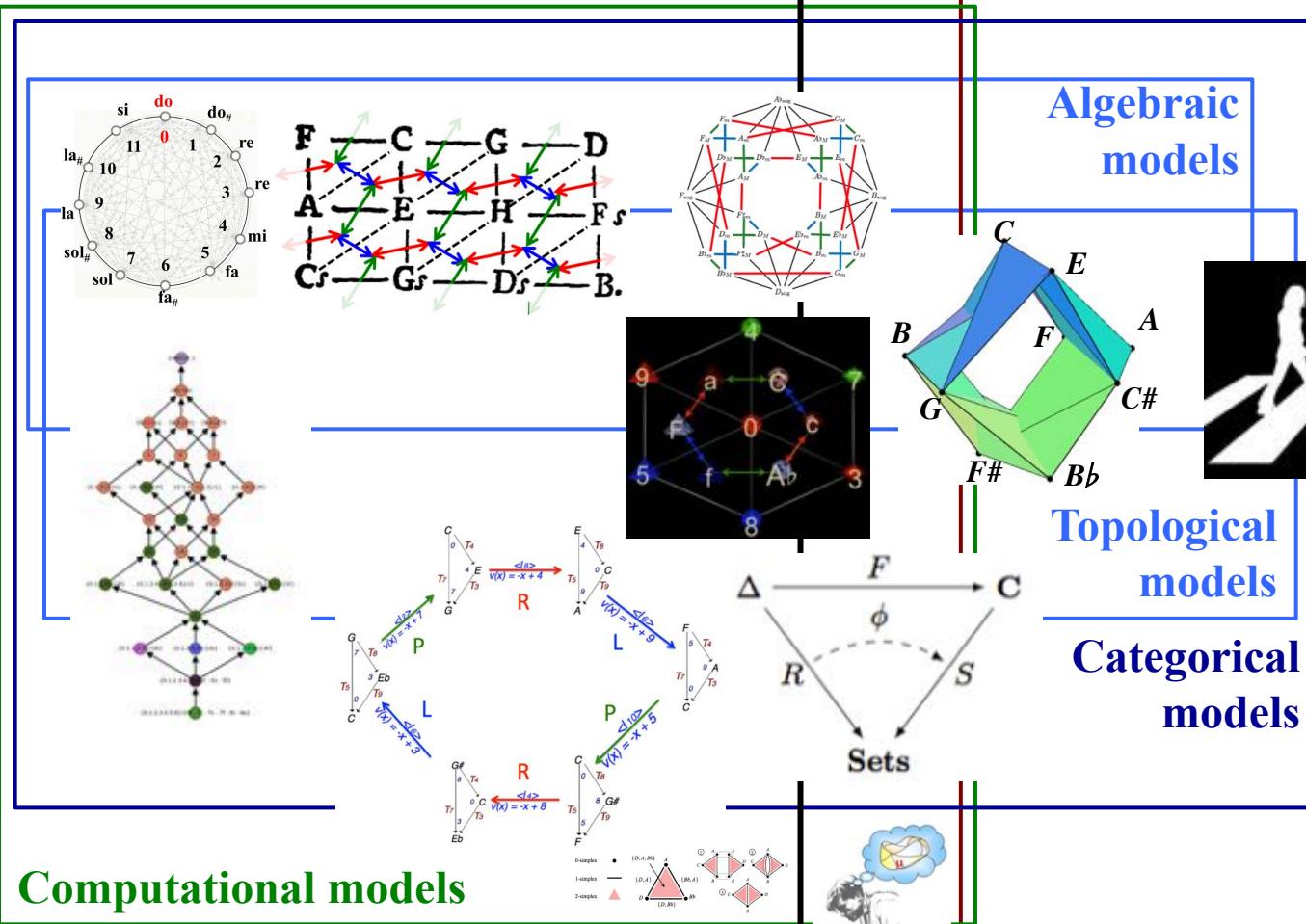


IRMA/USIAS Strasbourg & IRCAM/CNRS/Sorbonne University  
<http://www.ircam.fr/repmus.html>

# The musical and scientific research at IRCAM



# The SMIR Project: advanced maths for the working musicologist



Signal-based  
Music  
Information  
Retrieval



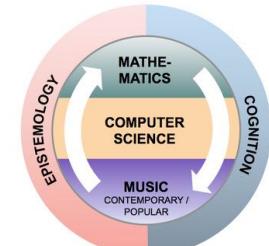
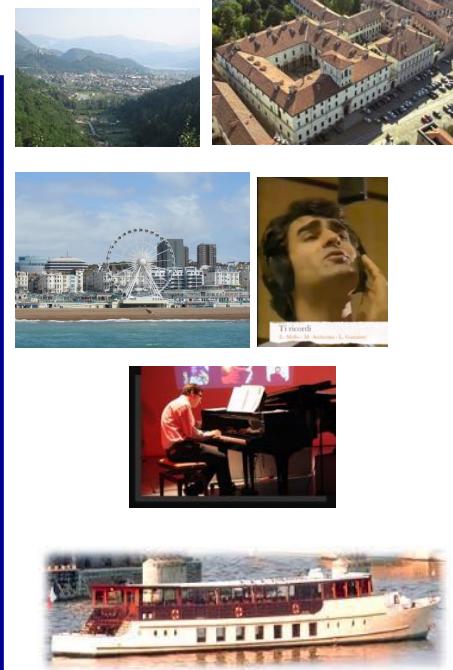
Symbolic Music  
Information Research



MajorvsMinor

# My personal path through maths and art/popular music

- **1993-1996** Music analysis, composition and conducting (Trento) + electronic music (University of Milan) + mathematics (University of Pavia)
- **1996-1997** Visiting Student (Brighton, UK)
- **1997-1998** Professional training « composer and arrangeur of applied music » and contemporary music composition courses (Milan)
- **1998** Piano diploma (Conservatory of Novara, Italy)
- **1998-2003** Master 2 (DEA) and PhD in Musicology at the EHESS / IRCAM and piano-bar pianist (Bateaux Parisiens, until 2009)
- **2004** Recruitment from CNRS
- **2005-2009** Pianist-singer and artistic director of the *N91* music group
- **2010** HDR in mathematics and its interactions (IRMA, Strasbourg)
- **2012-2016** Coordinator of the ATIAM Master Program (Acoustique, Traitement du signal et informatique appliqués à la musique)
- **2016** Research Director at the CNRS at IRCAM
- **2017-2019** USIAS fellow (SMIR Project – Structural Music Information Research)
- **Since 2019** Research Director at the CNRS at IRMA / Univ. of Strasbourg



# Some examples of PhD on maths & music

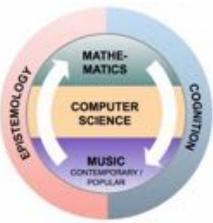
- **Greta Lanzarotto**, *Fuglede Spectral Conjecture, Musical Tilings and Homometry*, PhD in **maths** in cotutelle agreement, **University of Pavia** (L. Pernazza) / **Université de Strasbourg** (M. Andreatta), ongoing.
- **Alessandro Ratoci**, *Vers l'hybridation stylistique assistée par ordinateur*, PhD in music **composition & research**, Sorbonne University / IRCAM (cosupervised with Laurent Cugny), ongoing
- **Sonia Cannas**, *Représentations géométriques et formalisations algébriques en musicologie computationnelle*, PhD in **maths** in cotutelle agreement, **University of Pavia** (L. Pernazza) / **Université de Strasbourg** (A. Papadopoulos & M. Andreatta), 2019.
- **Grégoire Genuys**, *Théorie de l'homométrie et musique*, PhD in **maths**, **Sorbonne University** / IRCAM (cosupervised with Jean-Paul Allouche), 2017.
- **Hélianthe Caure**, *Pavages en musique et conjectures ouvertes en mathématiques*, PhD in **computer science**, **Sorbonne University** (cosupervised with Jean-Paul Allouche), 2016.
- **Mattia Bergomi**, *Dynamical and topological tools for (modern) music analysis*, PhD in **maths** in a cotutelle agreement Sorbonne University / University of Milan (cosupervised with Goffredo Haus, 2015).
- **Charles De Paiva**, *Systèmes complexes et informatique musicale*, thèse de doctorat, Programme Doctoral International « Modélisation des Systèmes Complexes », PhD in **musicology** in a cotutelle agreement, **Sorbonne University** / **UNICAMP**, Brésil, 2016.
- **John Mandereau**, *Des systèmes d'Intervalles Généralisés aux Systèmes Evolutifs à Mémoire : aspects théoriques et computationnels*, thèse de doctorat en mathématiques, PhD in cotutelle agreement **University of Pisa** / **Sorbonne University** (cosupervised with F. Acquistapace). PhD in **maths** (aborted).
- **Louis Bigo**, *Représentation symboliques musicales et calcul spatial*, PhD in **computer science**, **University of Paris Est Créteil** / **IRCAM**, 2013 (cosupervised with Olivier Michel and Antoine Spicher)
- **Emmanuel Amiot**, *Modèles algébriques et algorithmiques pour la formalisation mathématique de structures musicales*, PhD in, **Sorbonne University** / **IRCAM**, 2010 (cosupervised with Carlos Agon) **computer science**
- **Yun-Kang Ahn**, *L'analyse musicale computationnelle*, PhD in **computer science**, **Sorbonne University** / **IRCAM**, 2009 (cosupervised with Carlos Agon)



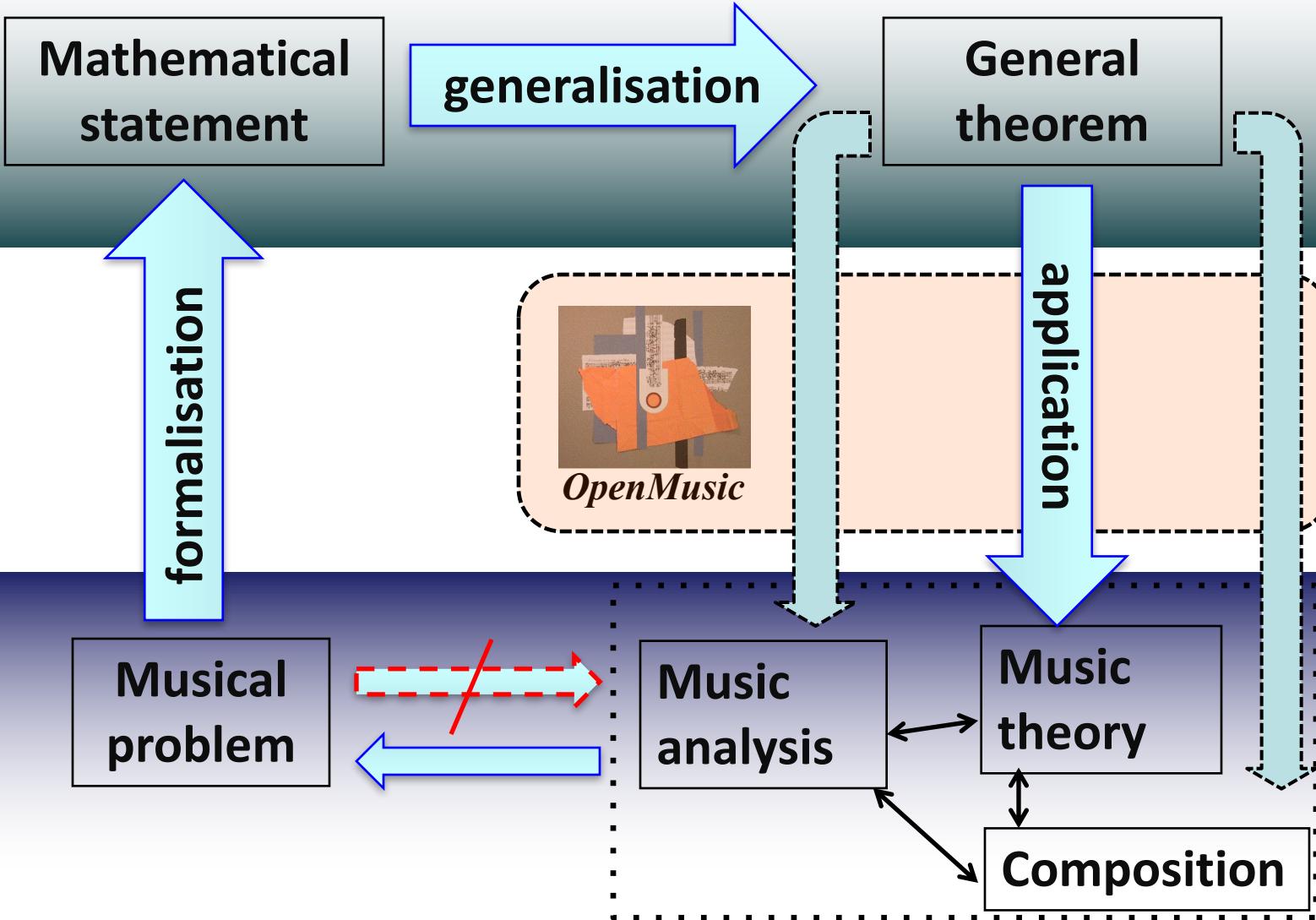
UNIVERSITÀ DI PISA



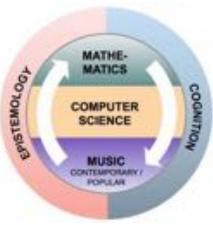
# The double movement of a ‘mathemusical’ activity



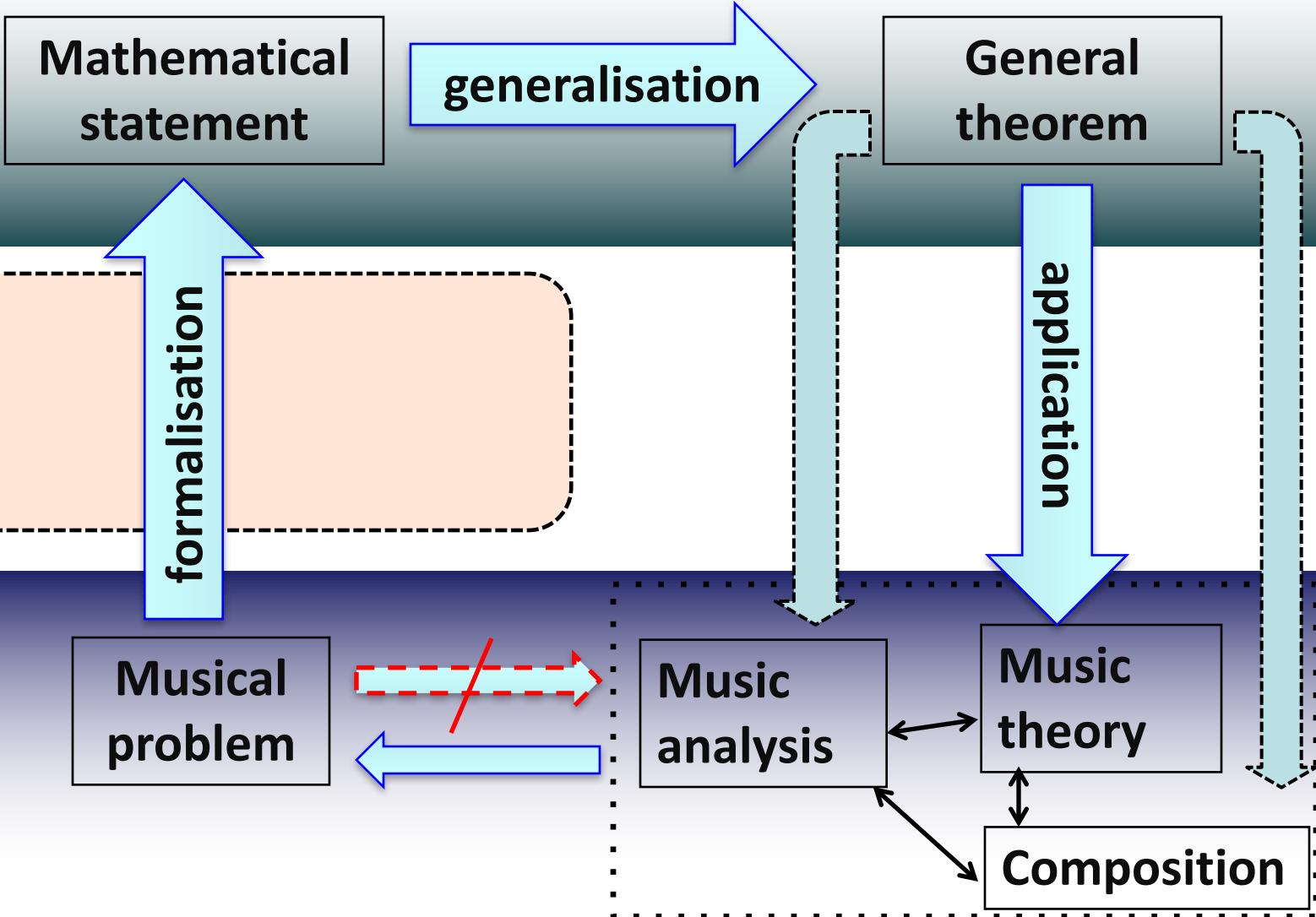
## MATHEMATICS



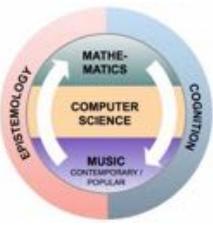
# The double movement of a ‘mathemusical’ activity



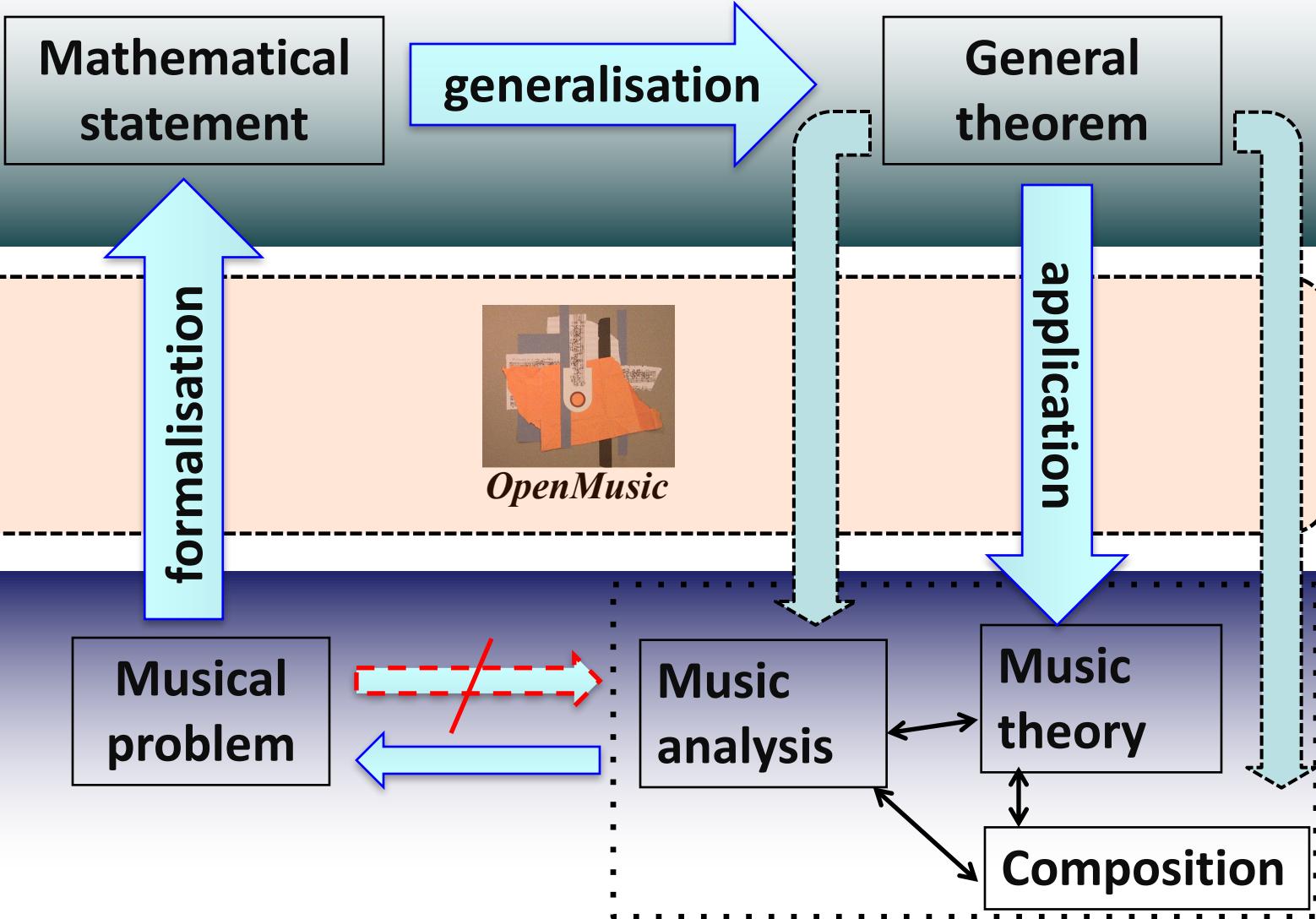
## MATHEMATICS



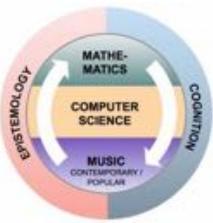
# The double movement of a ‘mathemusical’ activity



## MATHEMATICS



# The double movement of a ‘mathemusical’ activity

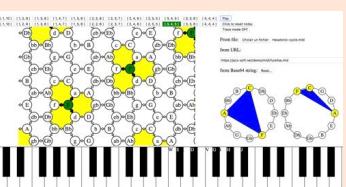


## MATHEMATICS

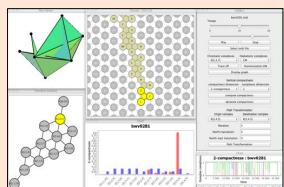
Mathematical statement

generalisation

General theorem



Tonnetz



Hexachord

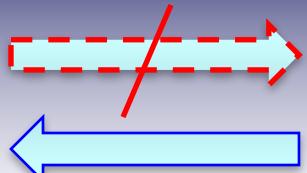


OpenMusic

formalisation

## MUSIC

Musical problem



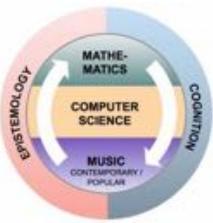
Music analysis

Music theory

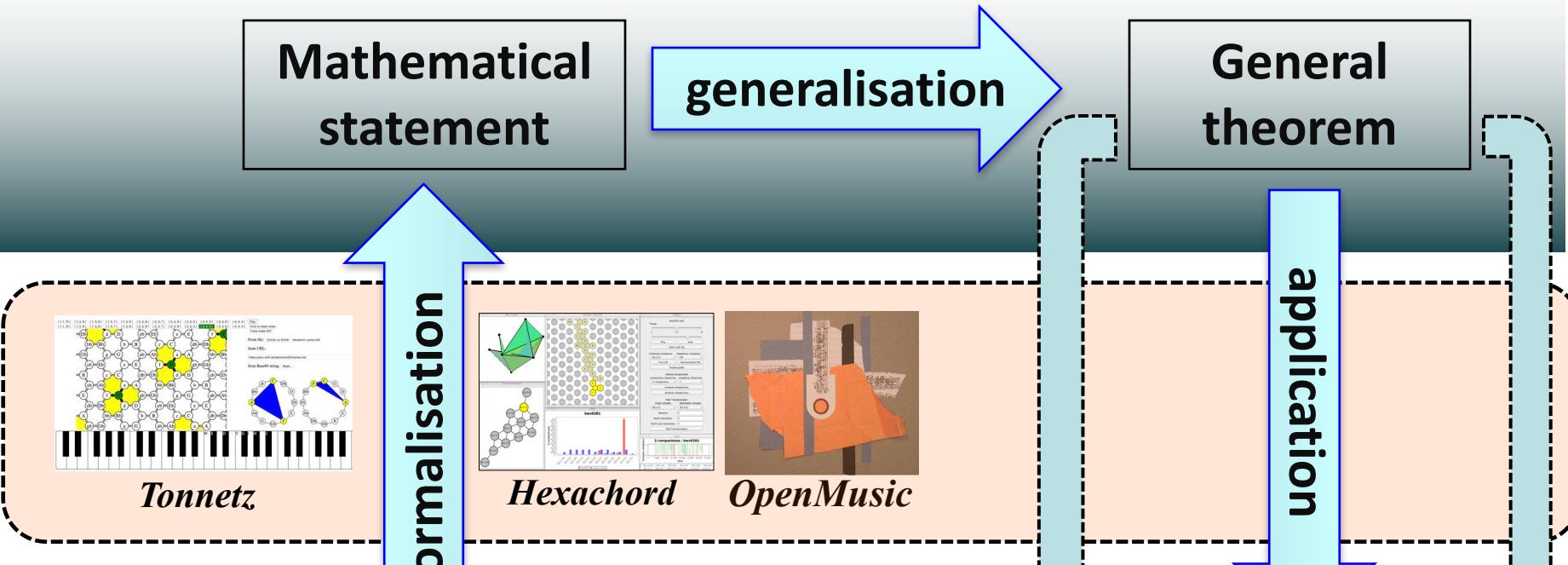
Composition

application

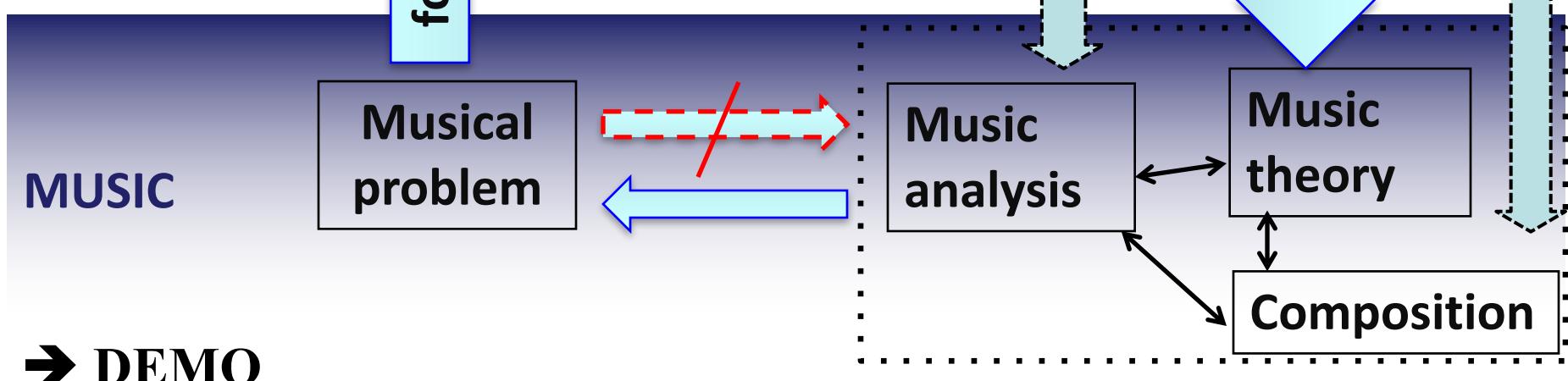
# The double movement of a ‘mathemusical’ activity



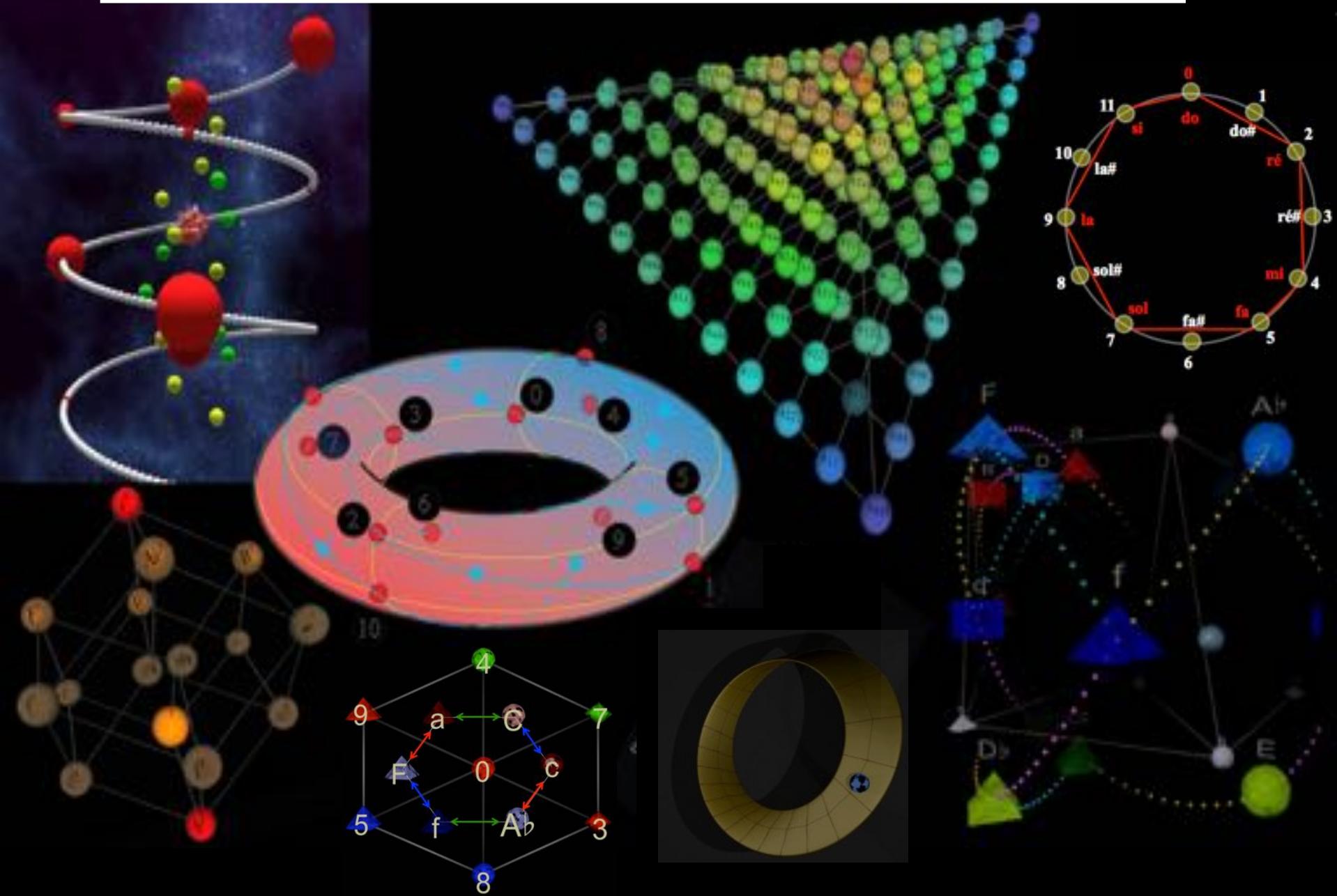
## MATHEMATICS



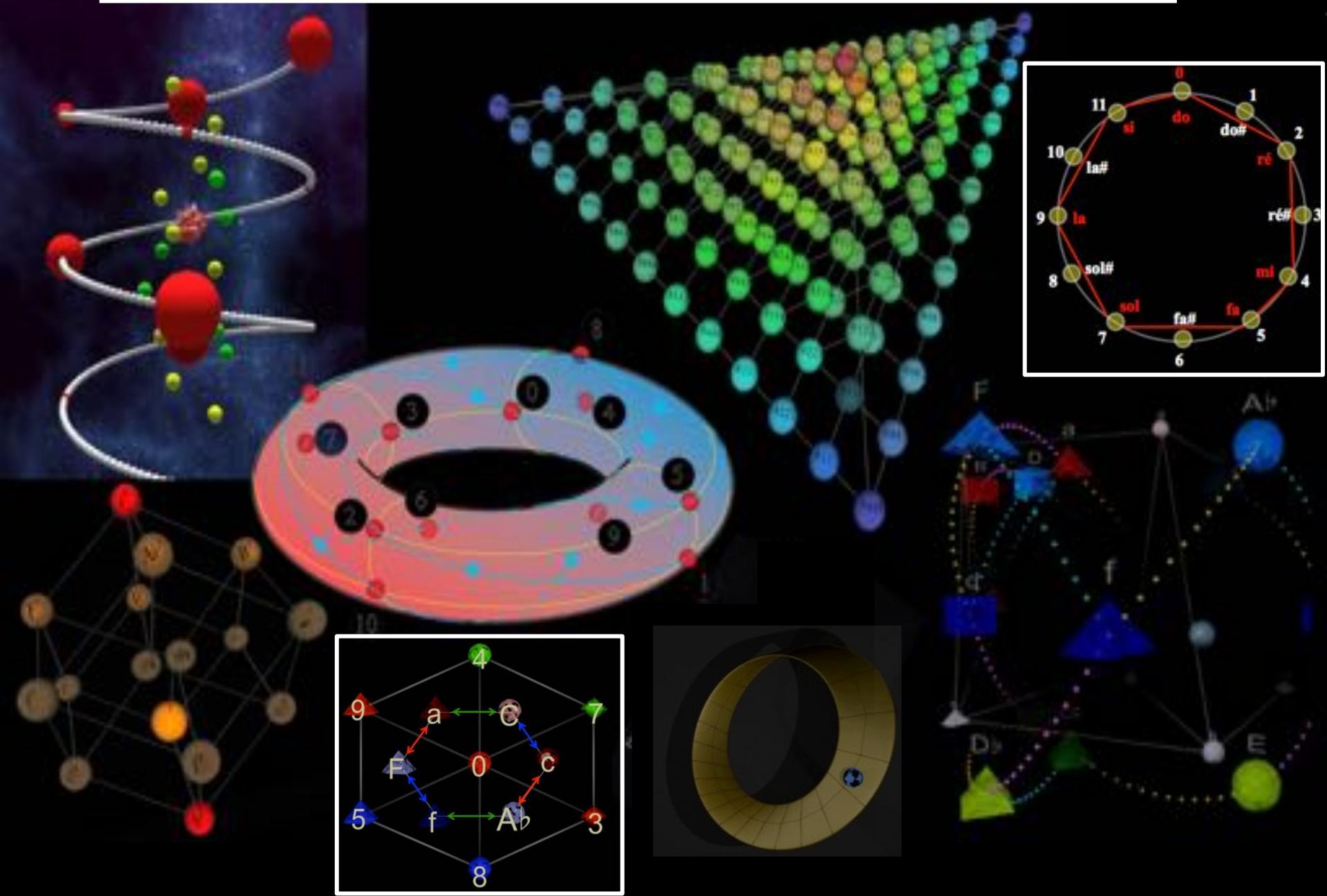
## MUSIC



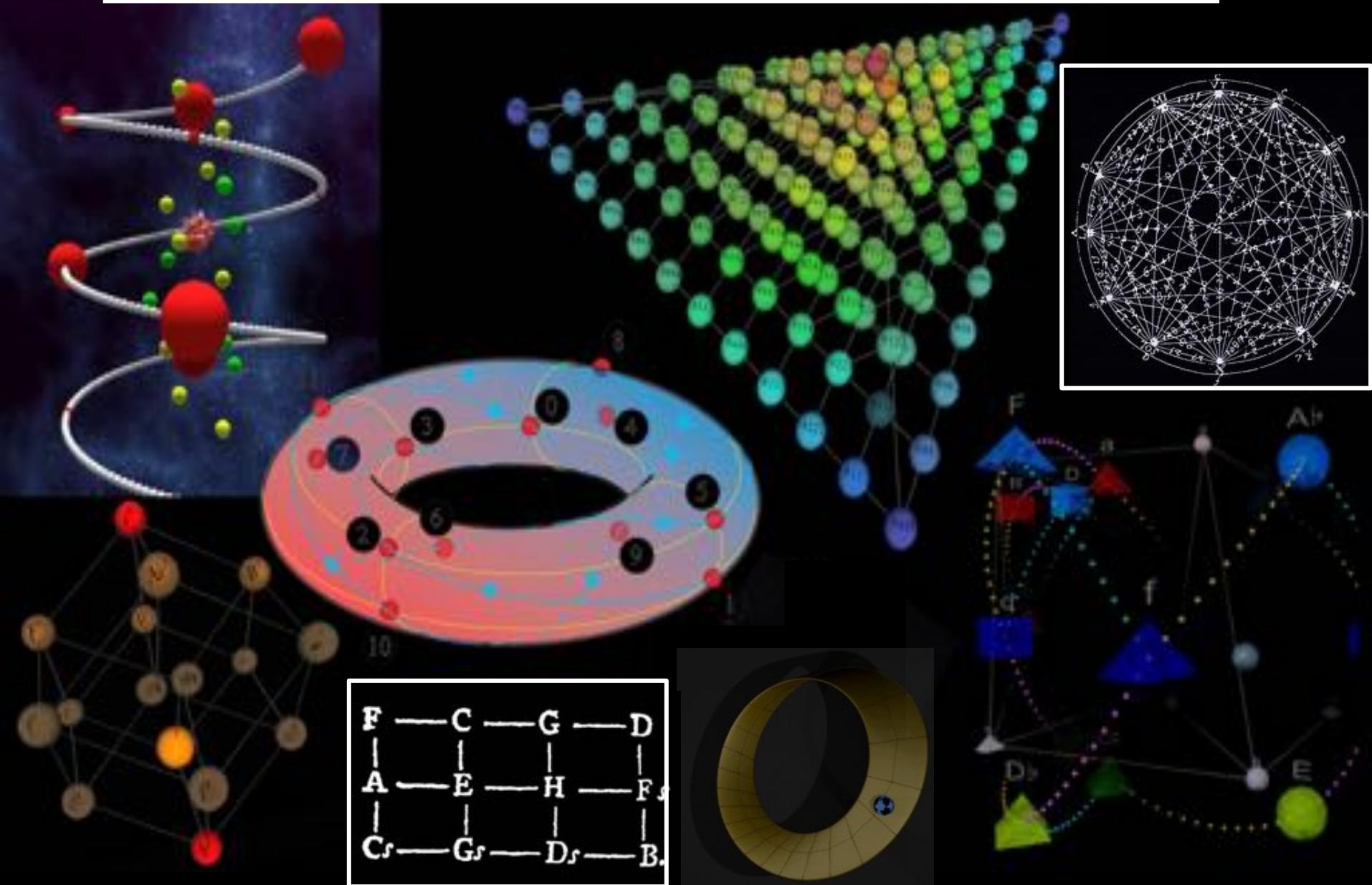
# The galaxy of geometrical models at the service of music



# The galaxy of geometrical models at the service of music



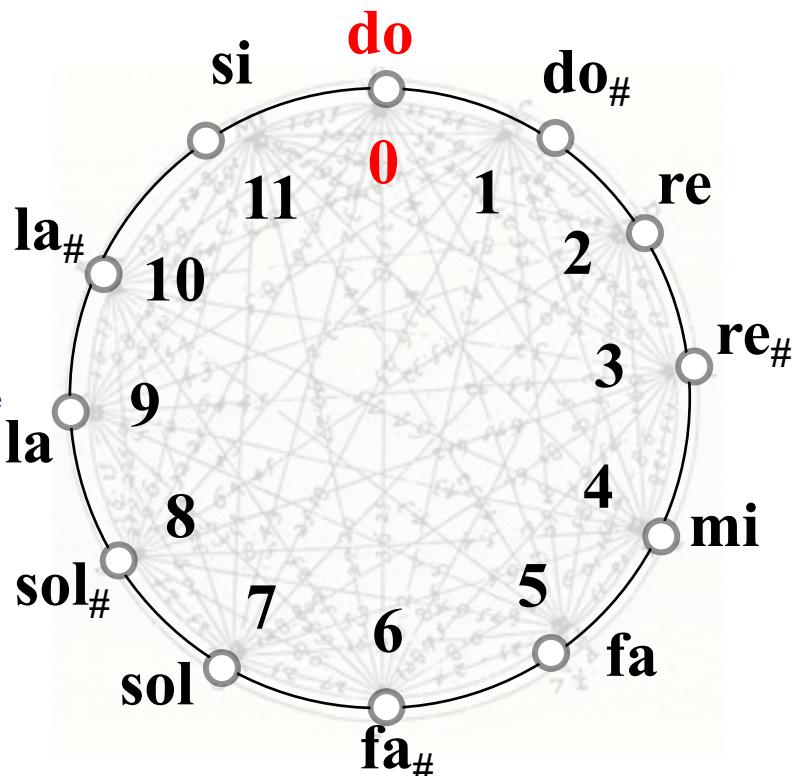
# The galaxy of geometrical models at the service of music



# The circular representation of the pitch space



Marin Mersenne



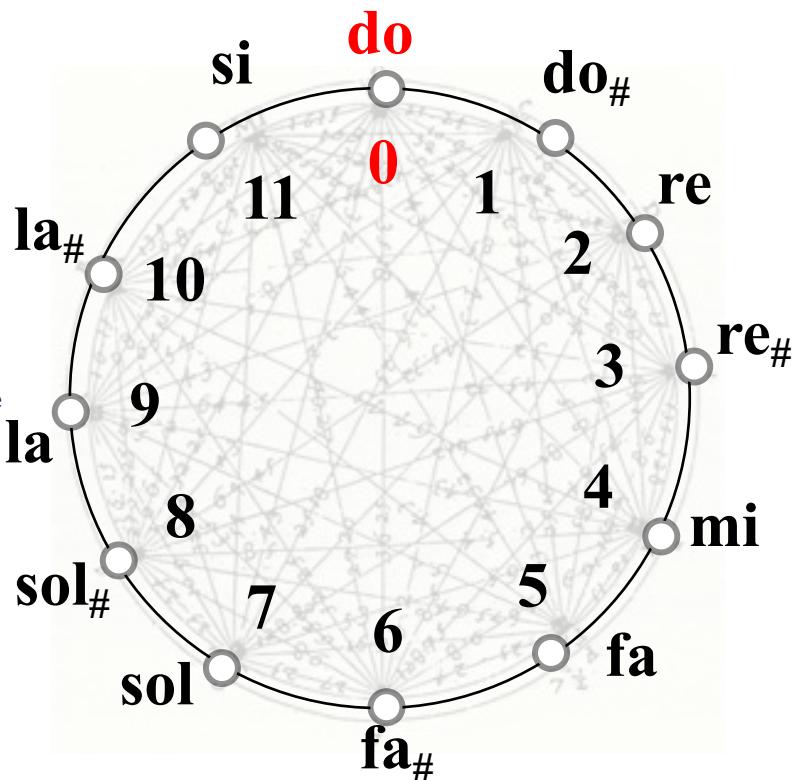
*Harmonicorum Libri XII, 1648*



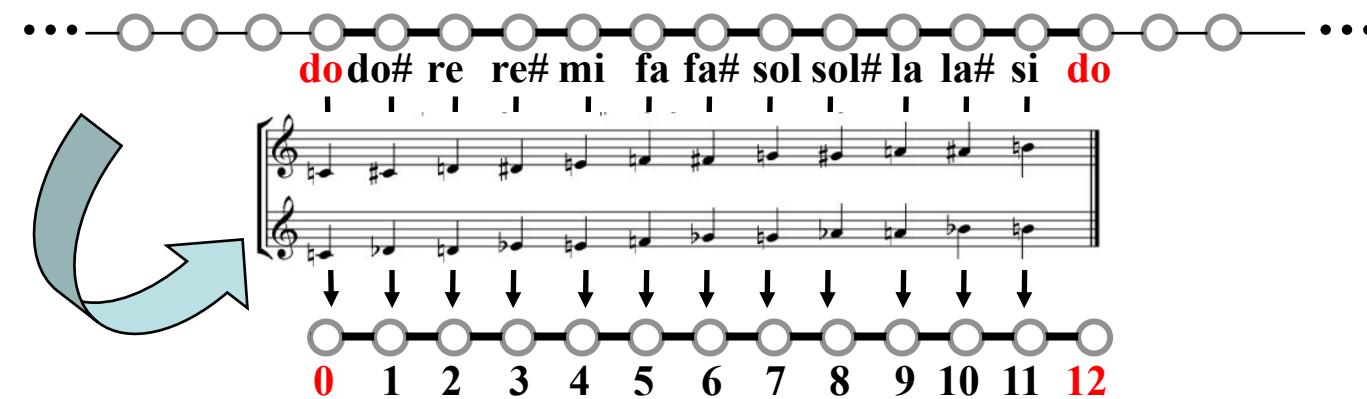
*Varietas, seu Combinatio quatuor notarum.*



# The circular representation of the pitch space



*Harmonicorum Libri XII, 1648*



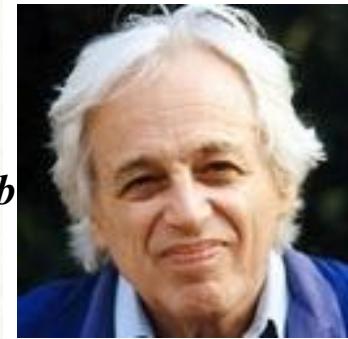
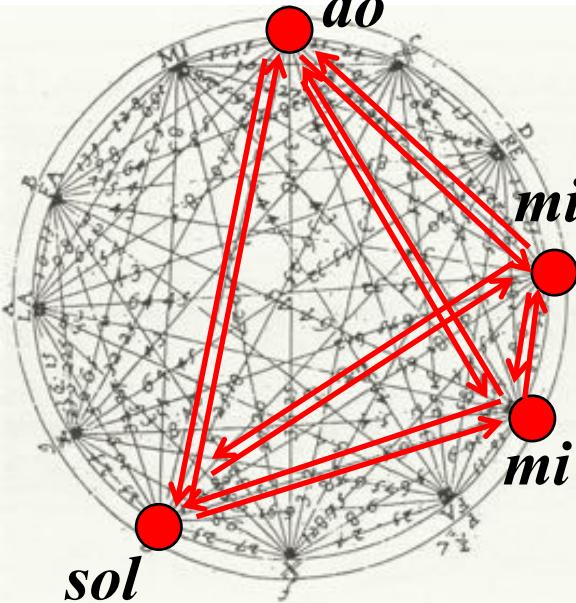
# Permutational melodies in contemporary (art) music

II.4 Marin Mersenne, *Harmonicorum Libri XII*, 1648

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

*Tabela Combinationis ab I ad XXII.*

I	I
II	II
III	6
IV	24
V	120
VI	720
VII	5040
VIII	40320
IX	361800
X	3618000
XI	39916800
XII	479001600
XIII	6117010800
XIV	87178191200
XV	1107674568000
XVI	10922789888000
XVII	311687418296000
XVIII	6401173705718000
XIX	11164100040813000
XX	1433904008176640000
XXI	51090941171709440000
XXII.	1884000737777607680000



*Six Bagatelles*  
(G. Ligeti, 1953)



A musical score titled "Varietas, seu Combinatio quatuor notarum." The score consists of 24 staves of music, numbered 1 through 24. Each staff is a single-line staff with square note heads. The music is composed of four notes per staff, which correspond to the notes do, mi, and sol, as indicated by the circular diagram above. The notes are placed at various intervals along each staff, creating a complex and repetitive pattern of permutations.



# Permutational melodies in song writing

*Se telefonando*, 1966 (Maurizio Costanzo/Ennio Morricone) / Mina

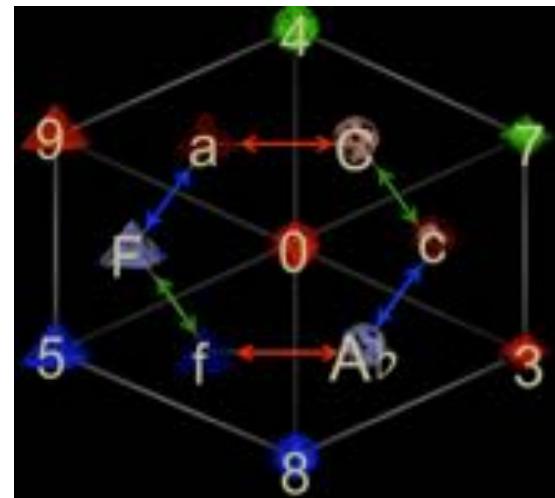


(min. 0'53")



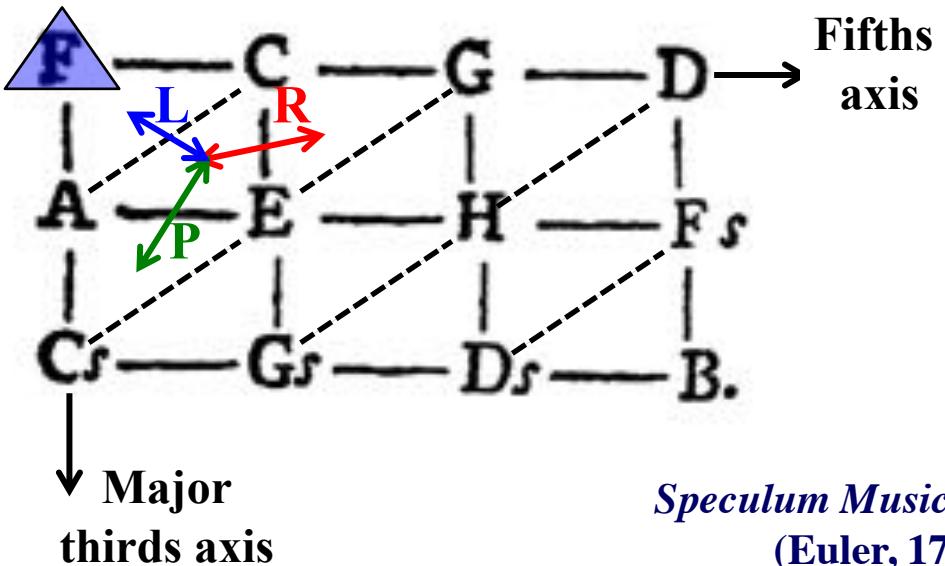
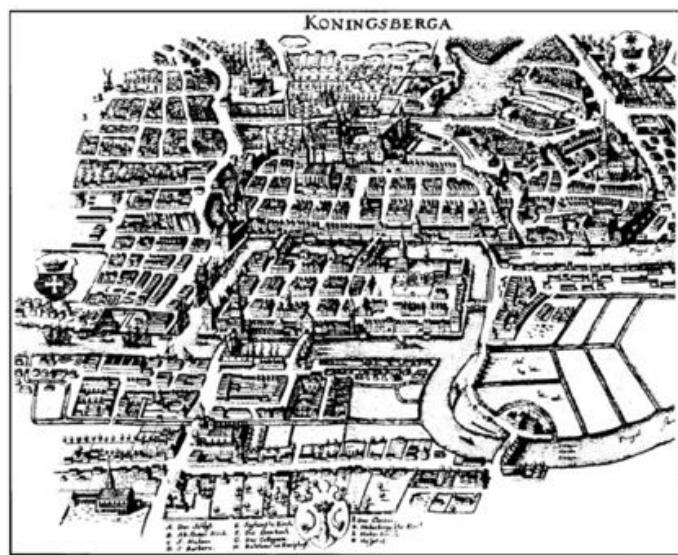
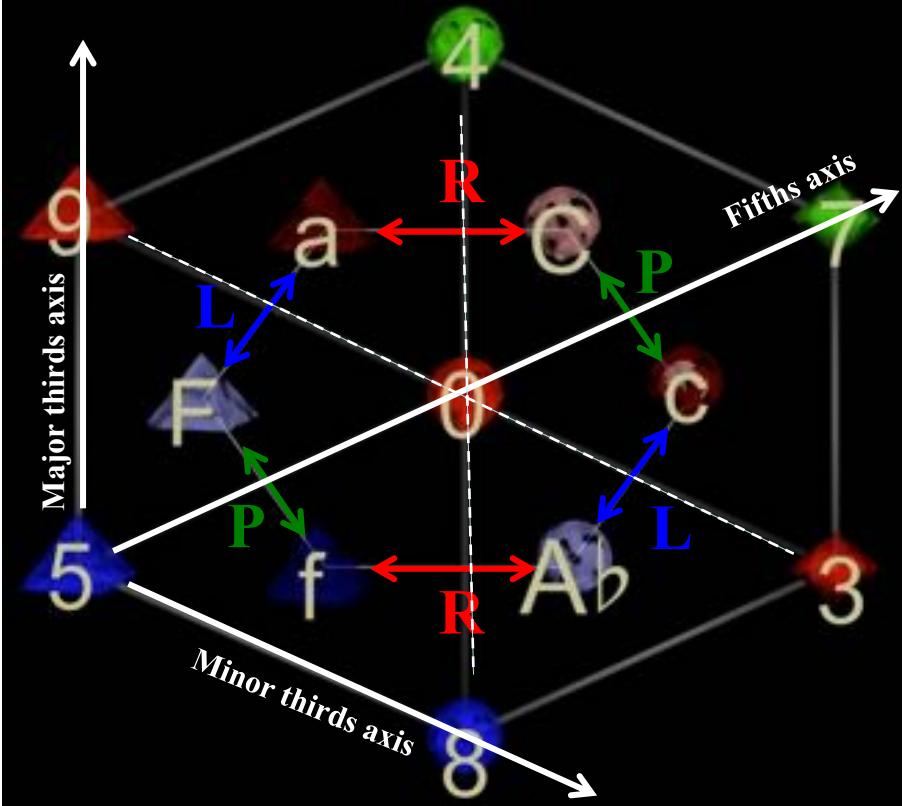
Ennio Morricone

The harmonic space

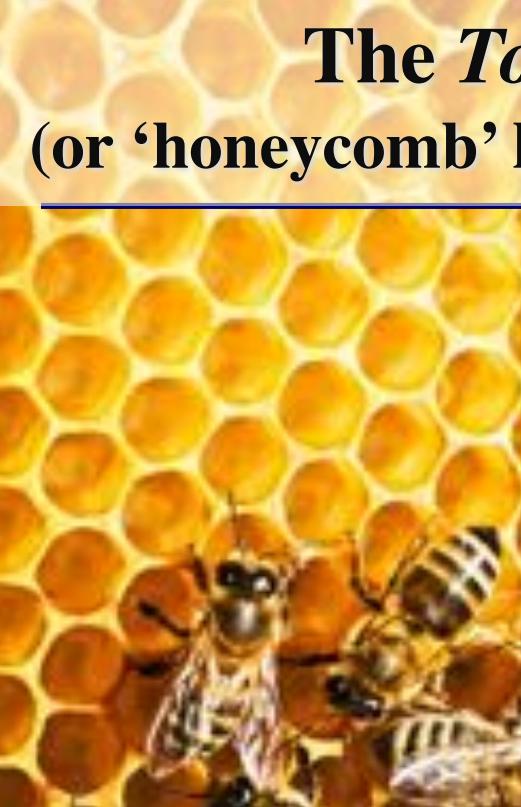
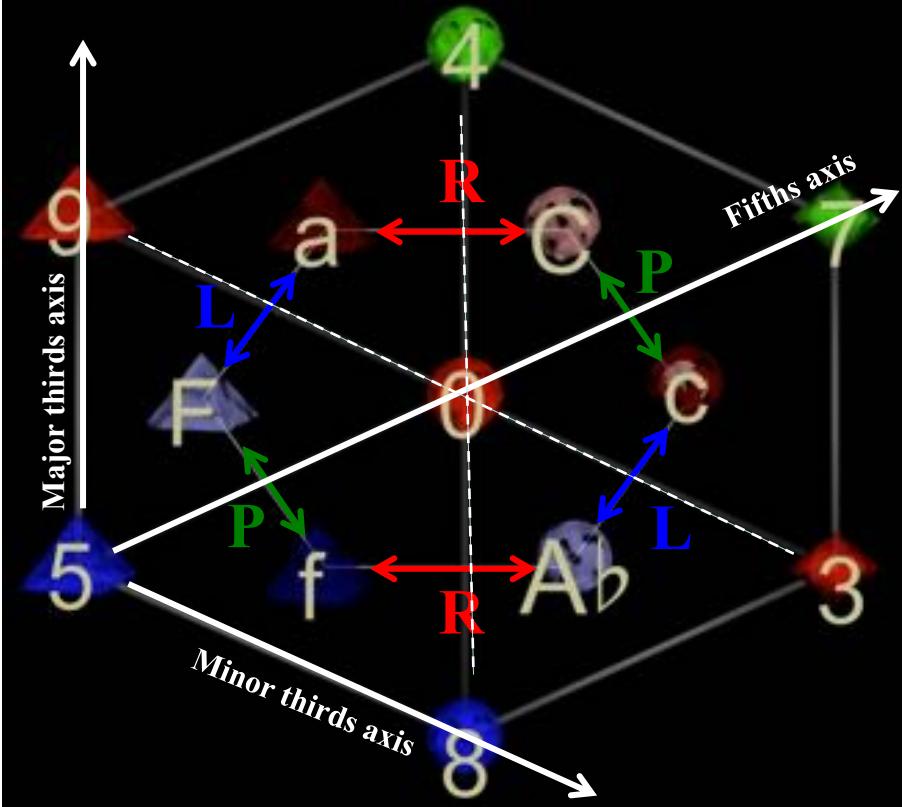


C	c	<b>C<sub>#</sub></b>	c <sub>#</sub>	D	<b>d</b>
E <sub>b</sub>	e <sub>b</sub>	E	e	F	f
F <sub>#</sub>	f <sub>#</sub>	G	<b>g</b>	G <sub>#</sub>	g <sub>#</sub>
A	a	<b>B<sub>b</sub></b>	<b>b<sub>b</sub></b>	<b>B</b>	<b>b</b>

**Chord enumeration**

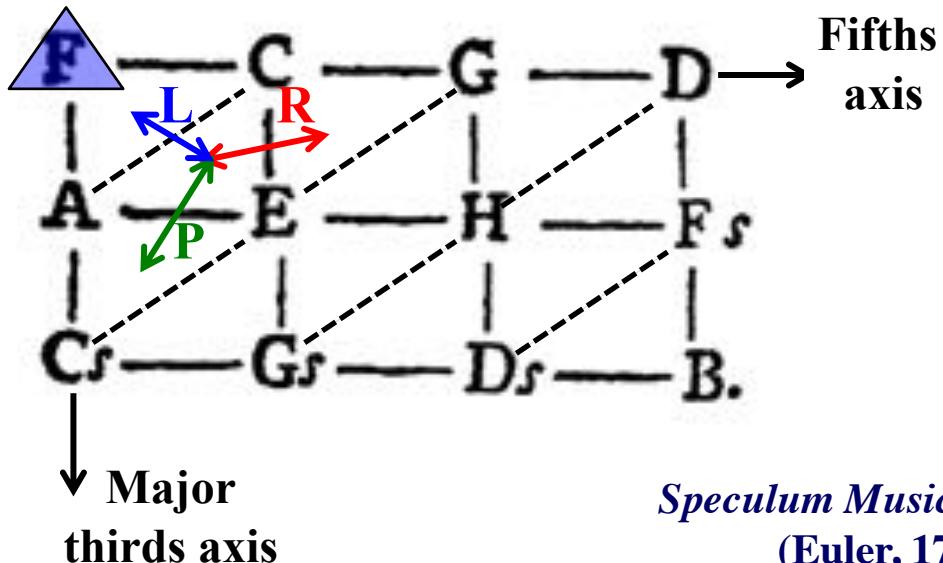
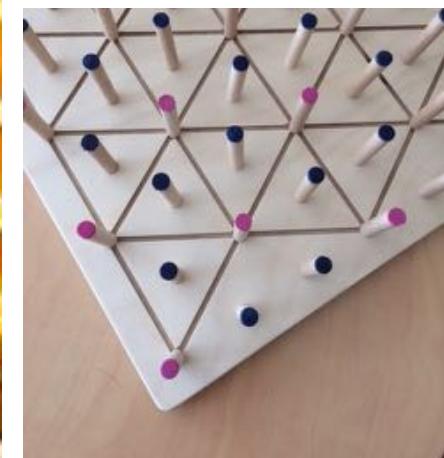


*Speculum Musicum*  
(Euler, 1773)



# The Tonnetz

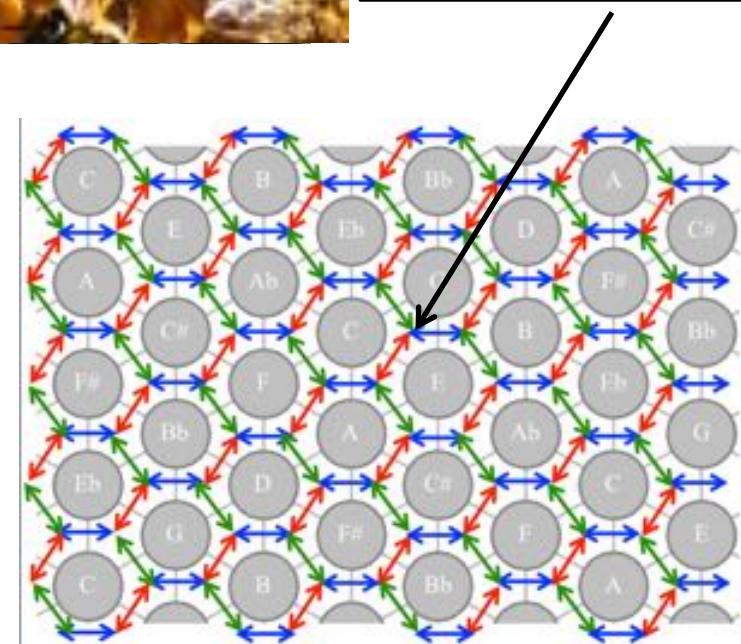
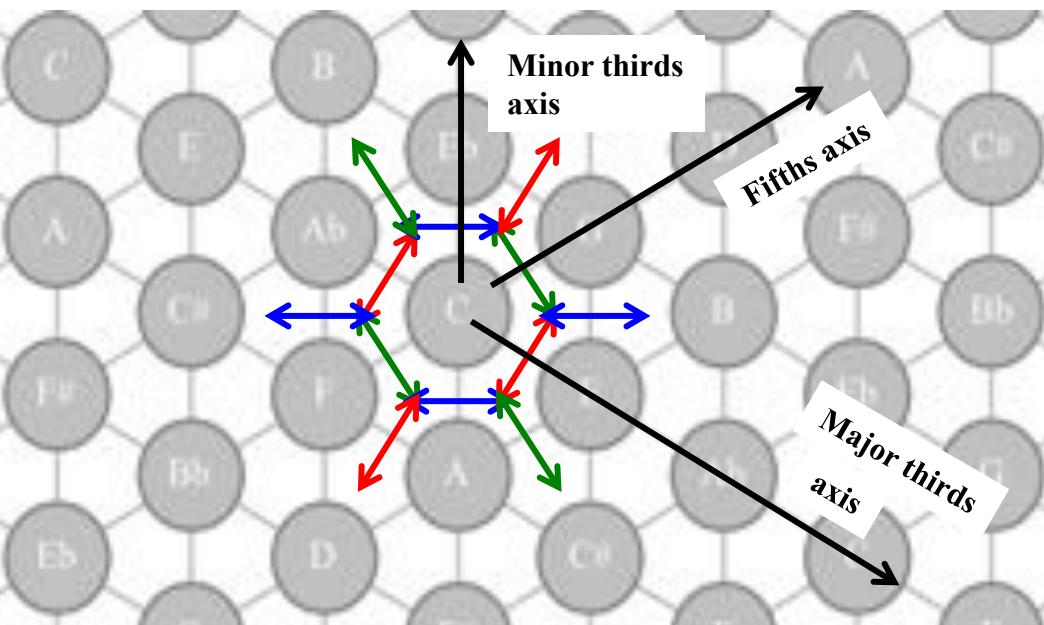
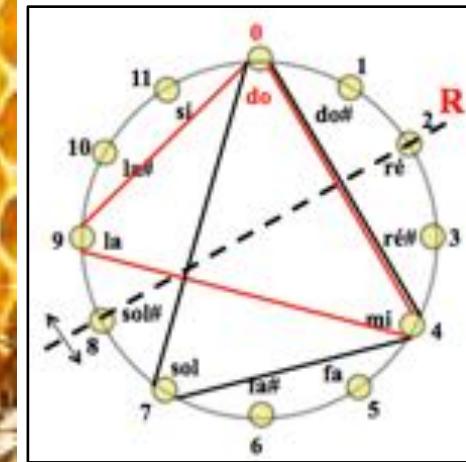
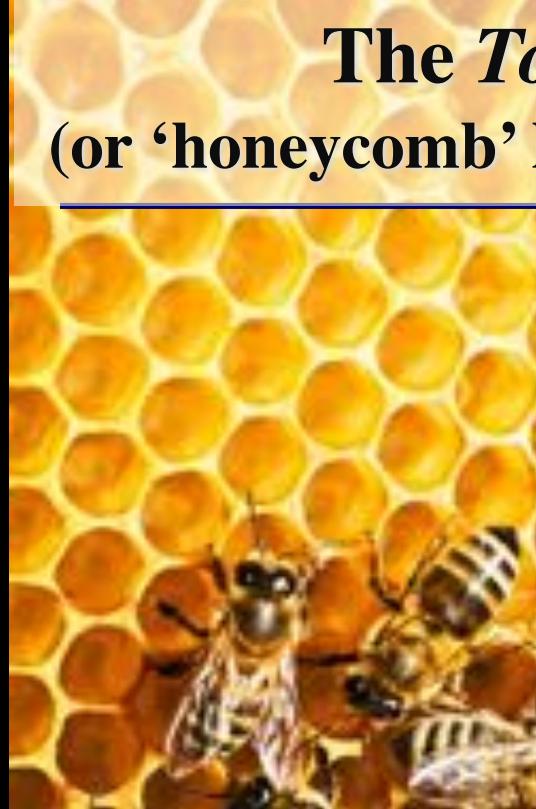
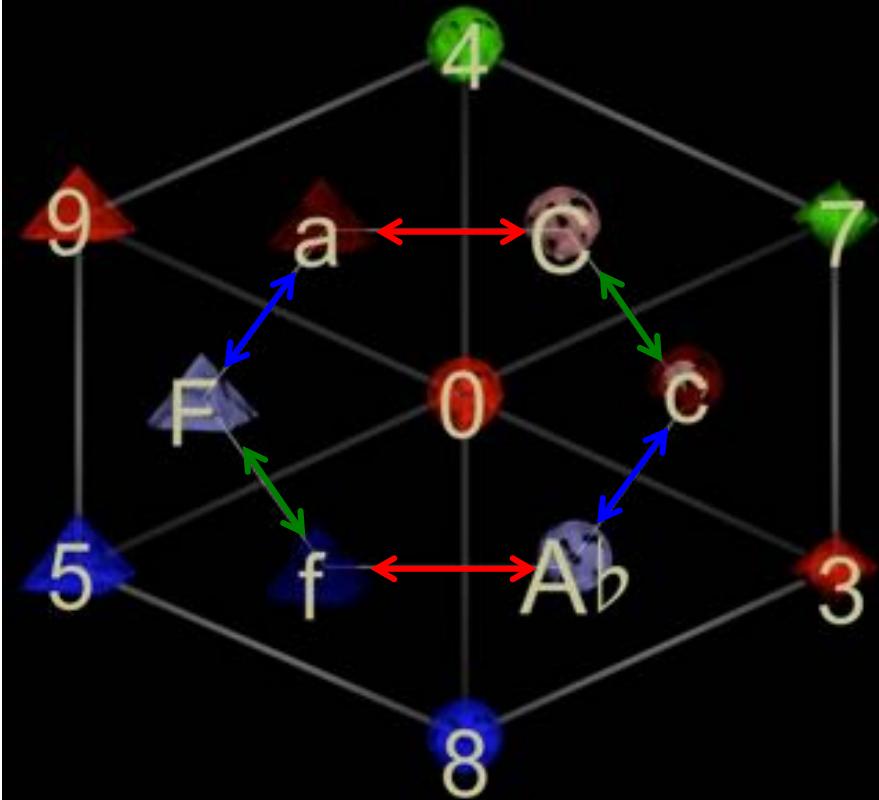
(or ‘honeycomb’ hexagonal tiling)

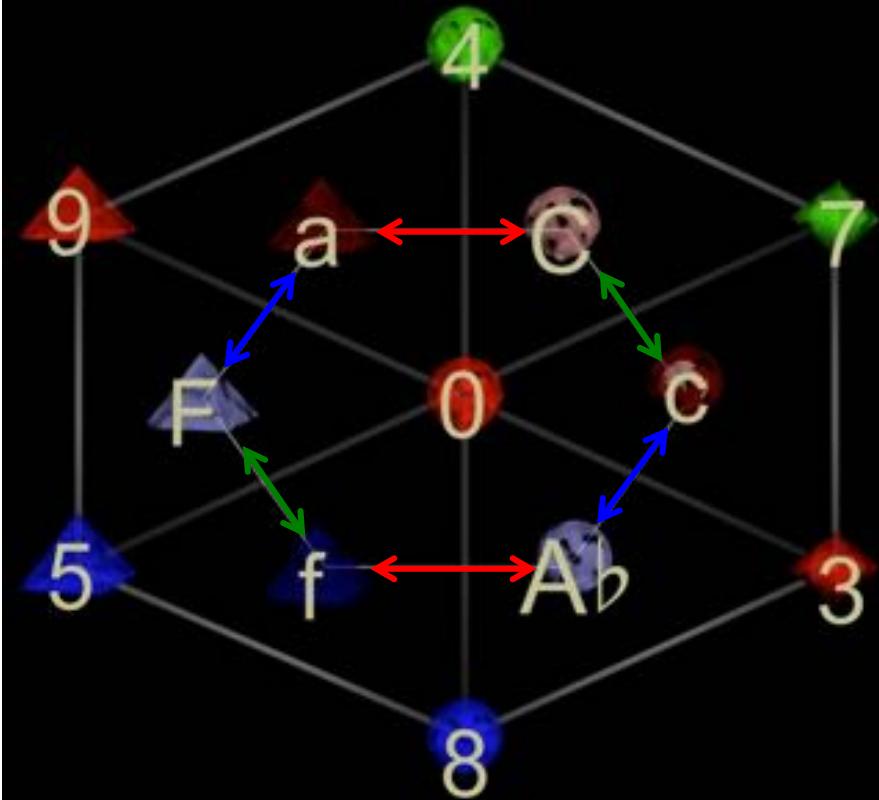


*Speculum Musicum*  
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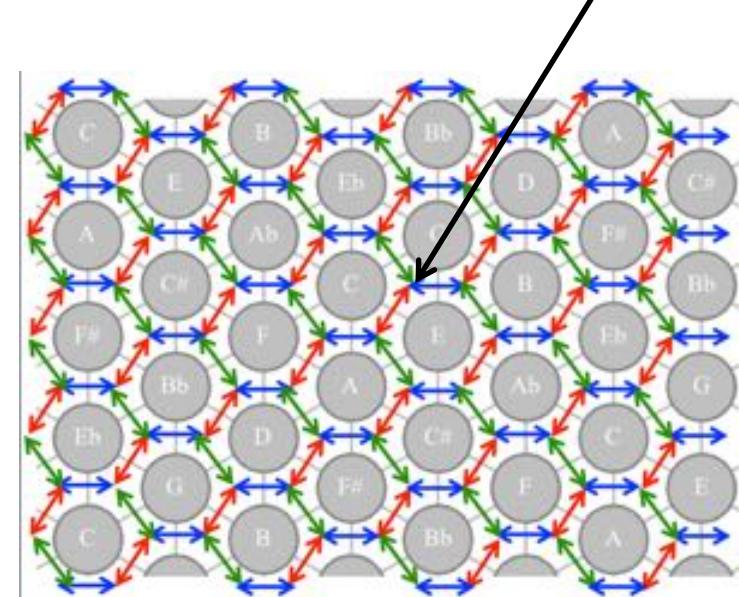
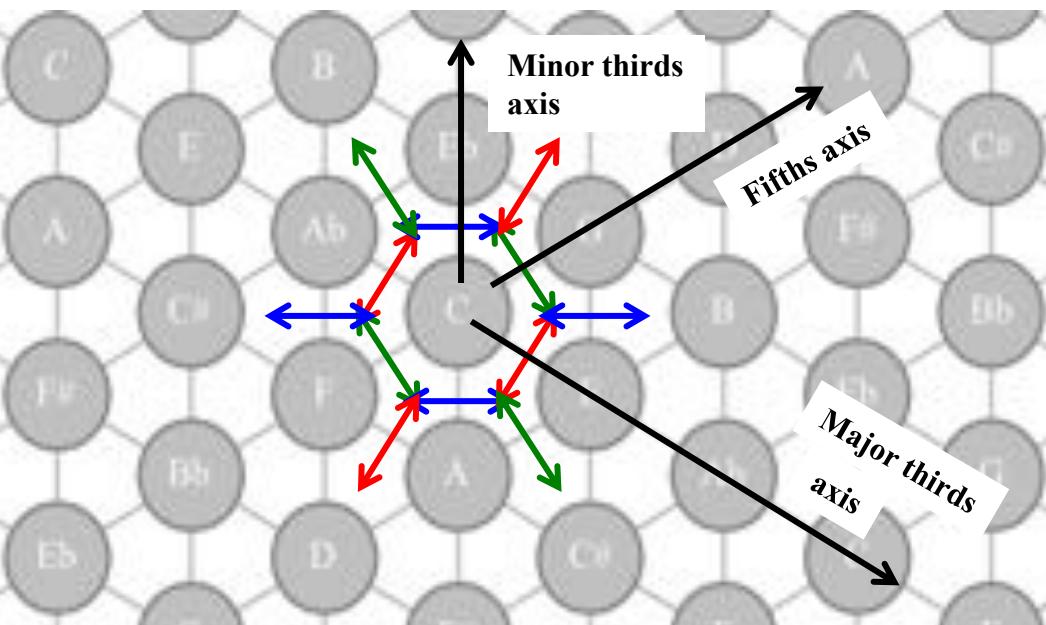
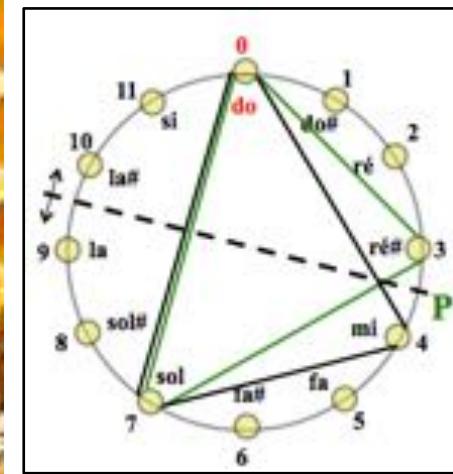
# The Tonnetz

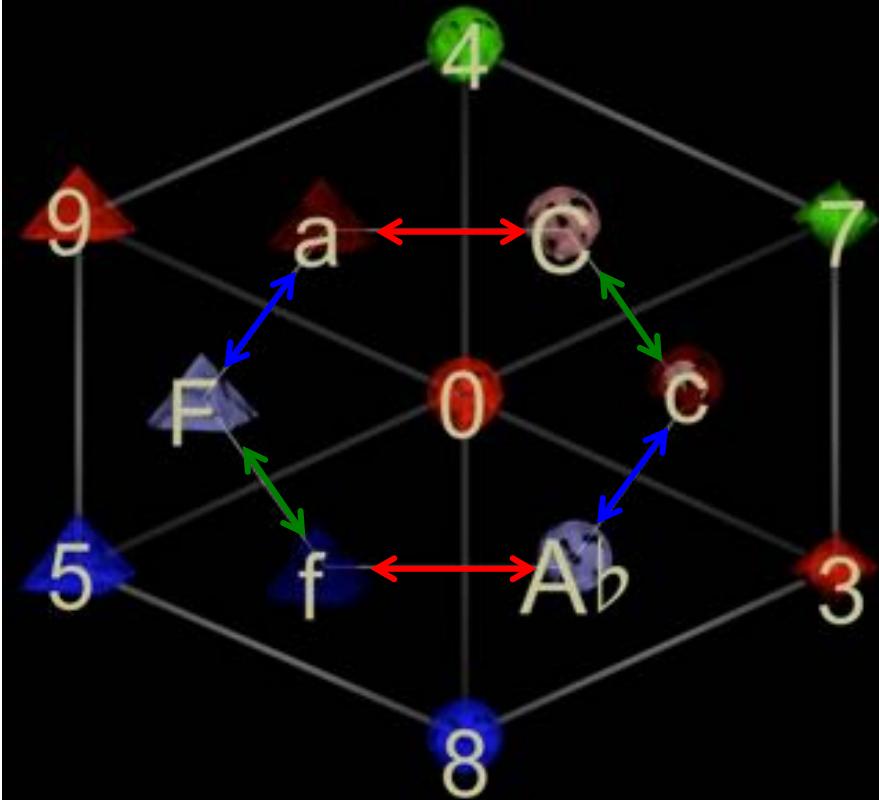
(or ‘honeycomb’ hexagonal tiling)



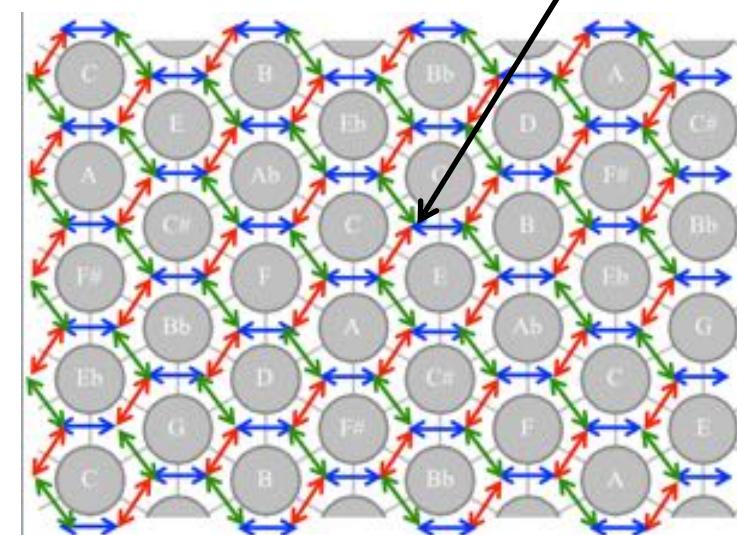
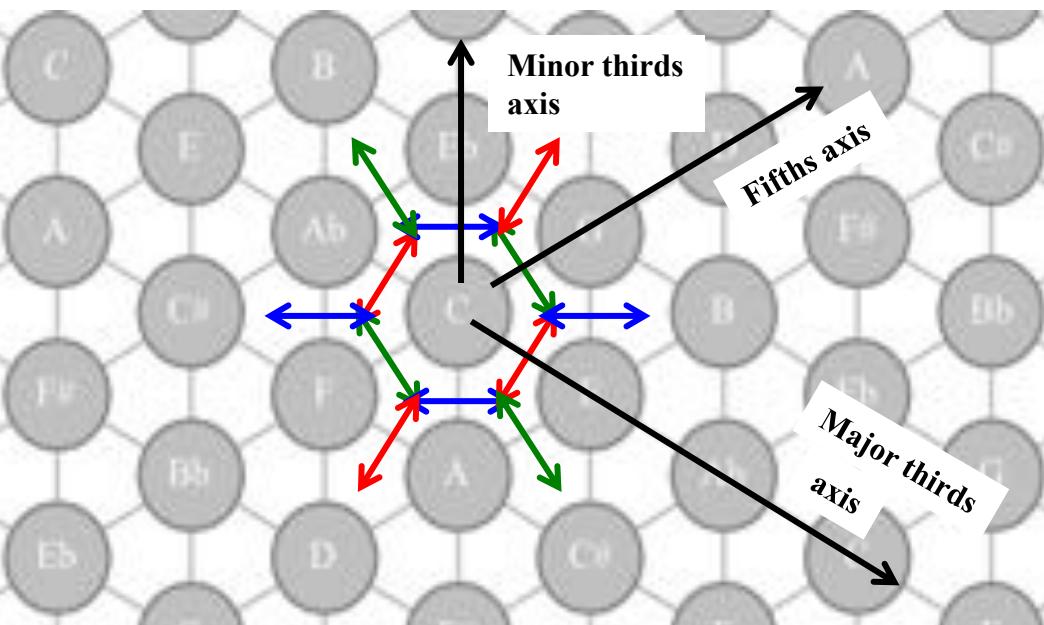
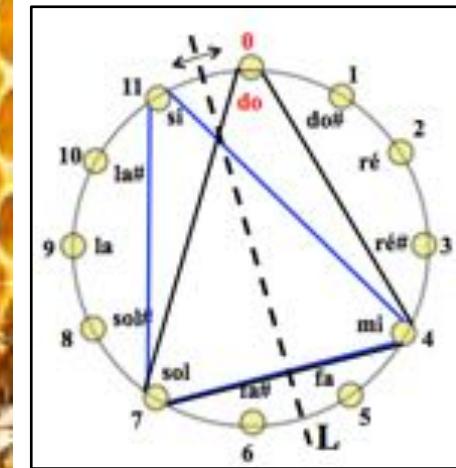


# The *Tonnetz* (or ‘honeycomb’ hexagonal tiling)

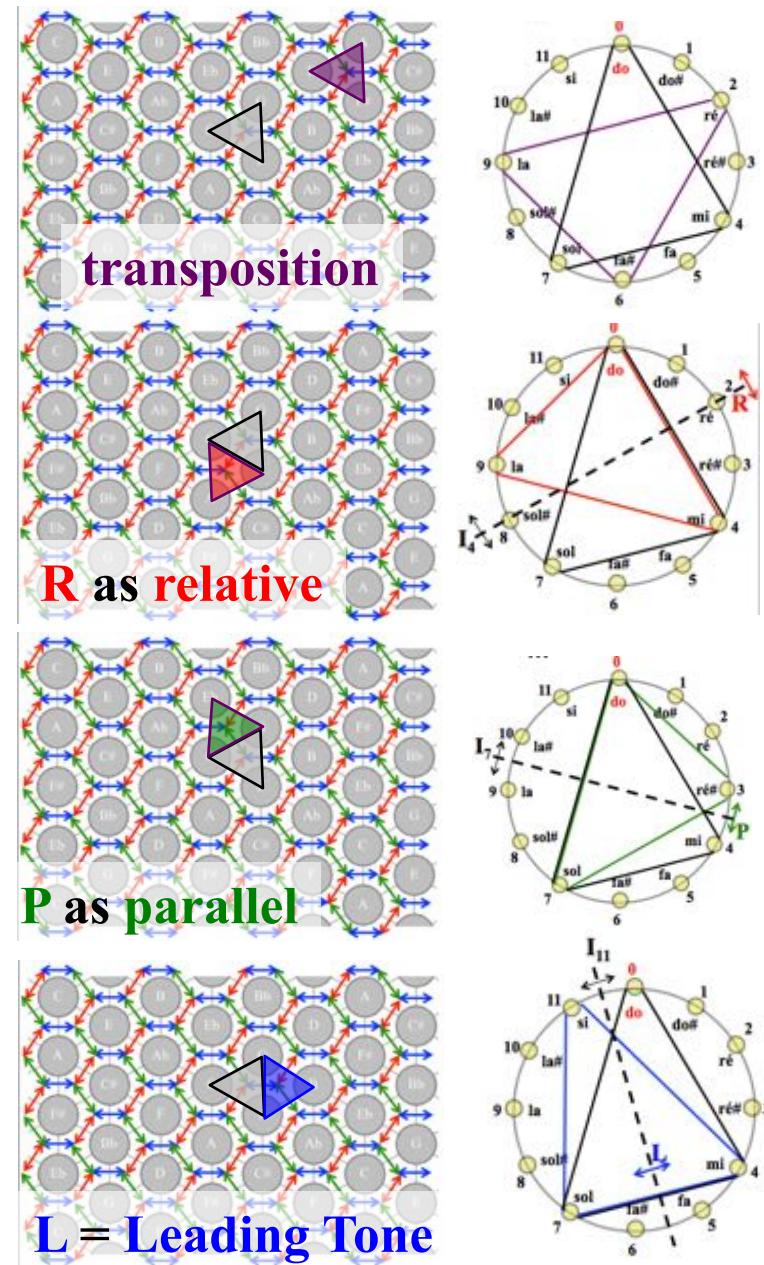
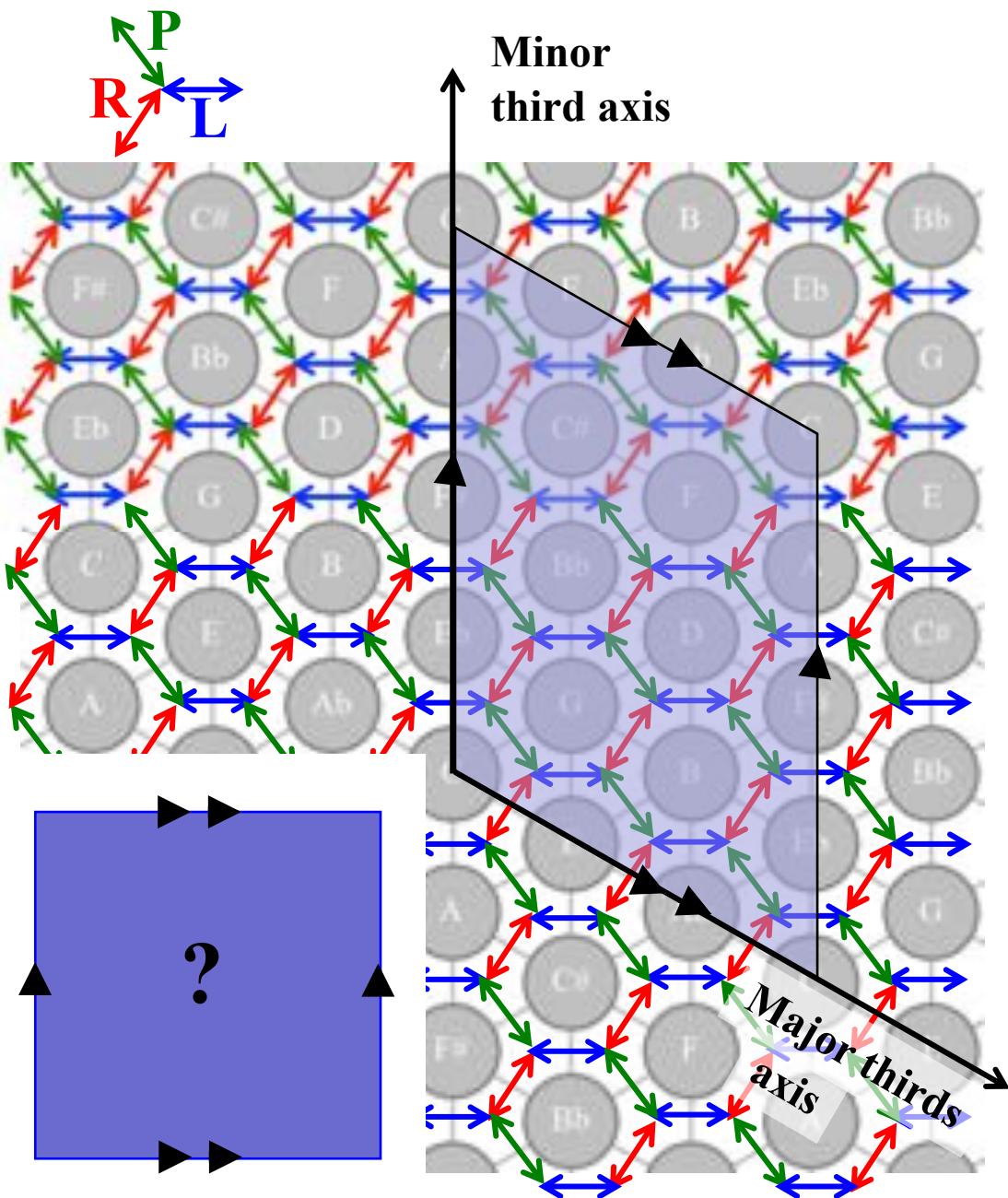




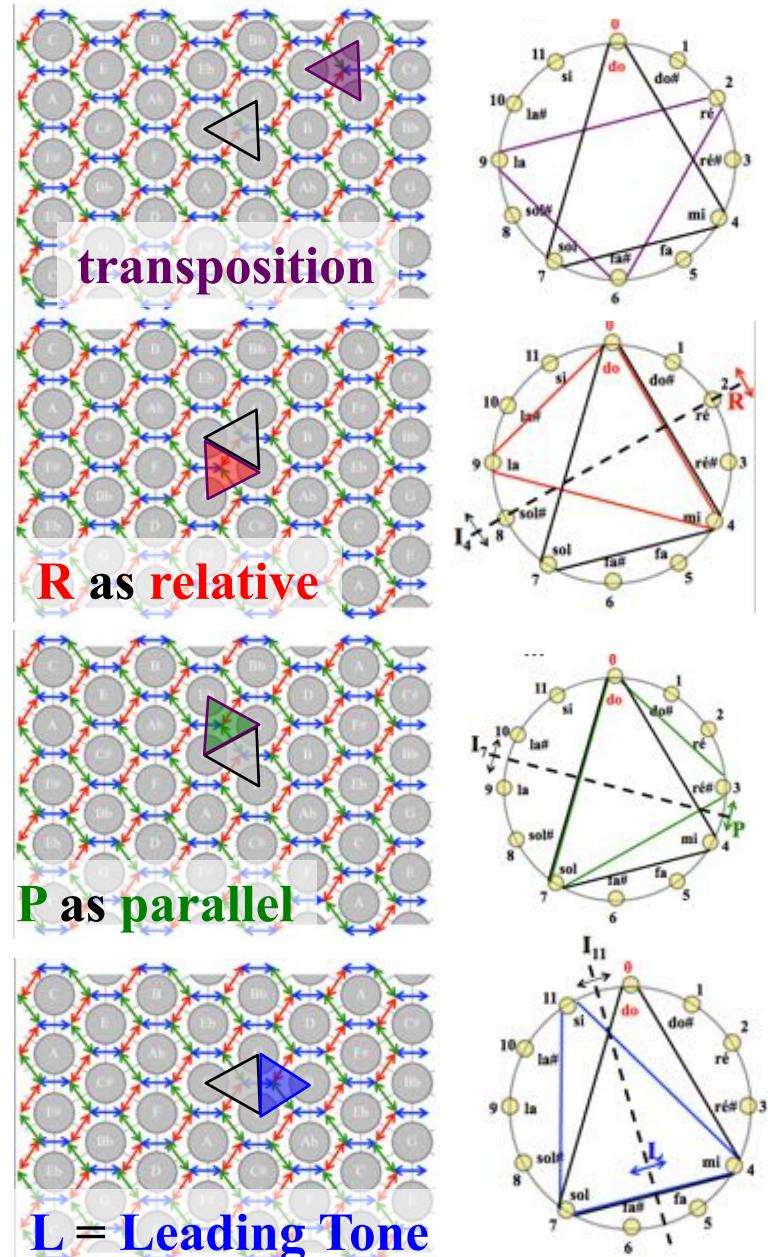
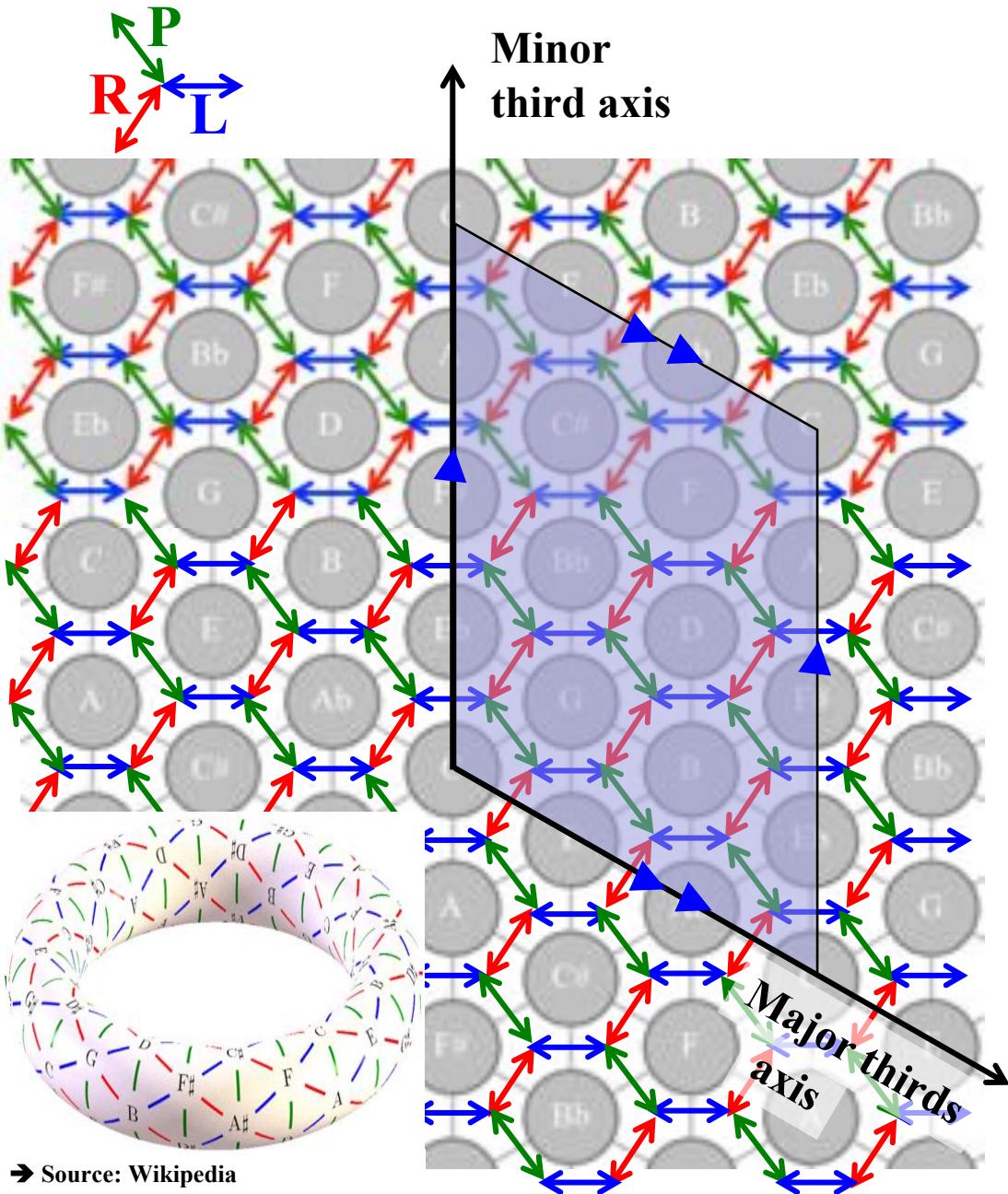
# The *Tonnetz* (or ‘honeycomb’ hexagonal tiling)



# The Tonnetz, its symmetries and its topological structure



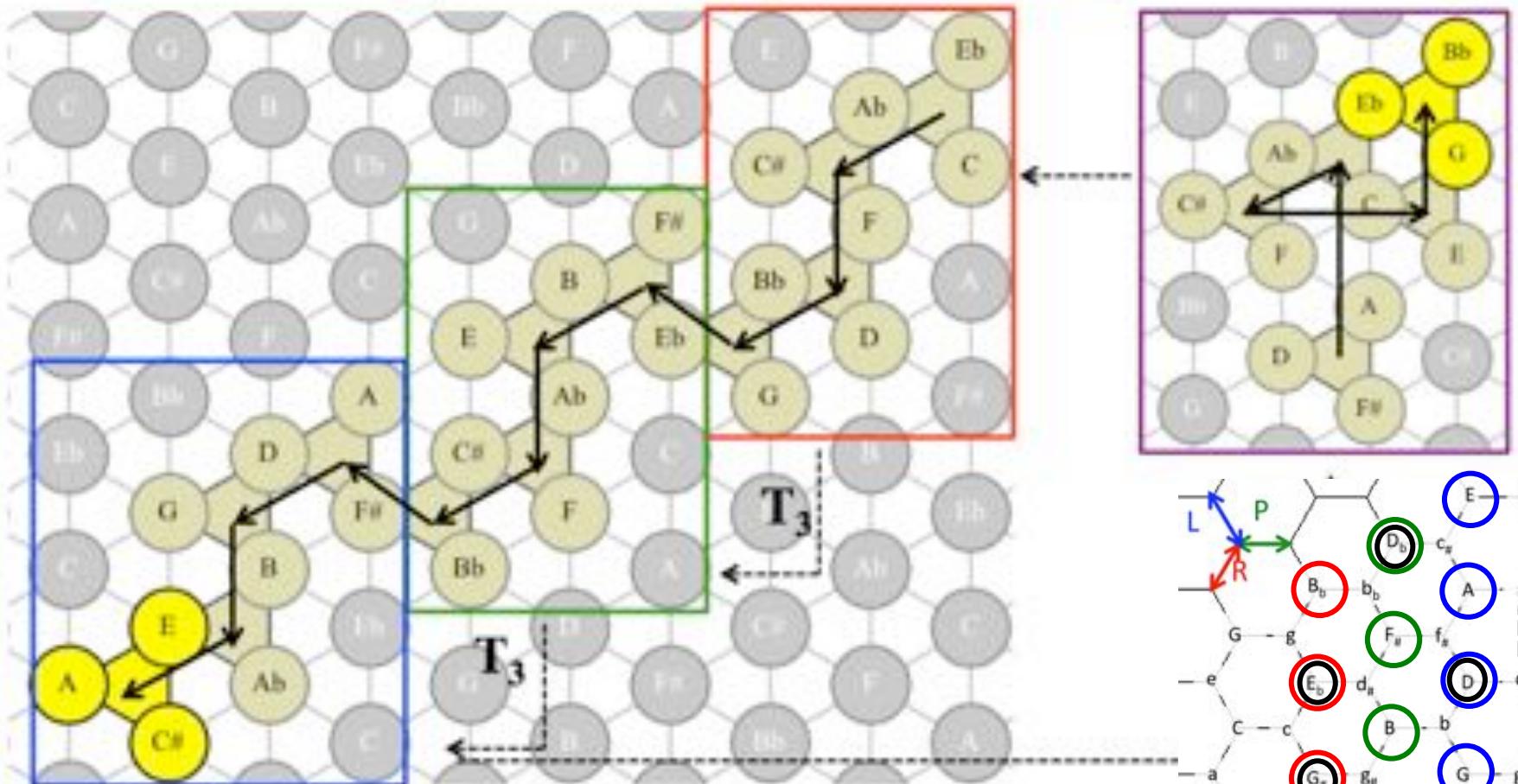
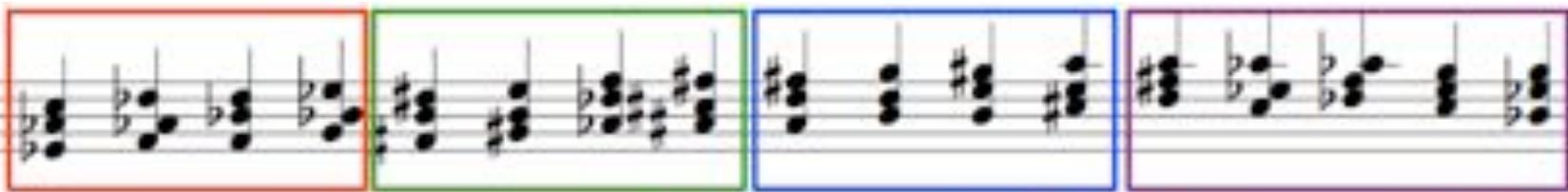
# The Tonnetz, its symmetries and its topological structure



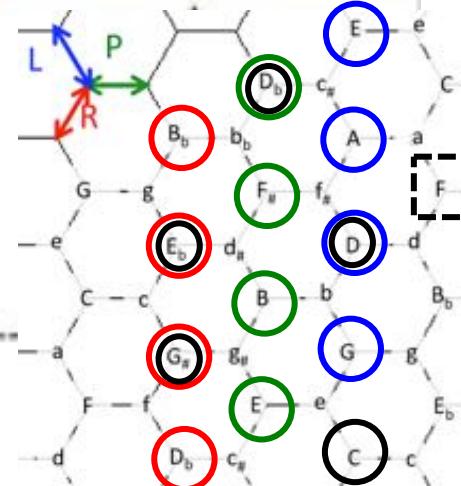


# Symmetries in Paolo Conte's *Madeleine*

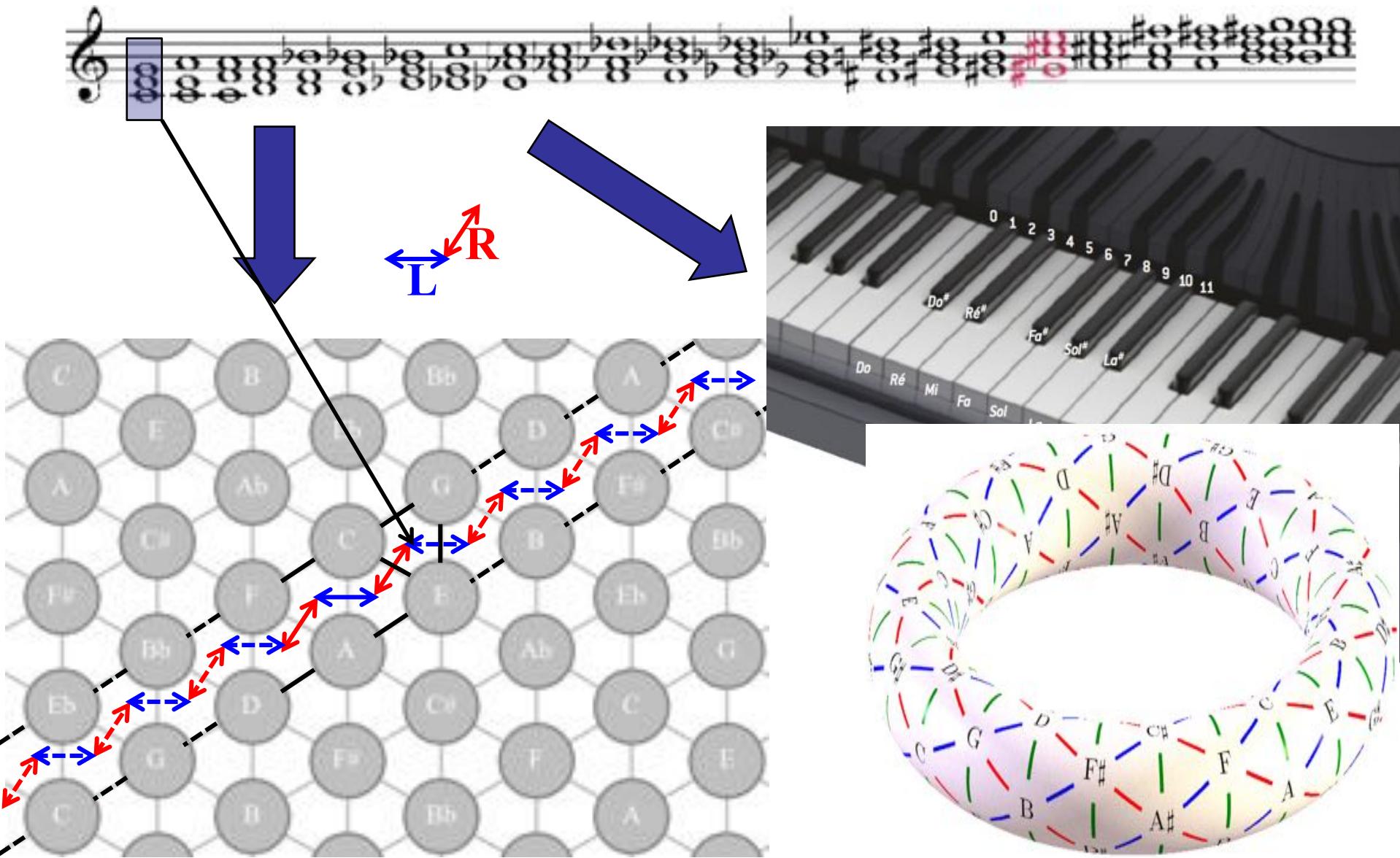
La<sub>b</sub> Re<sub>b</sub> Si<sub>b</sub> Mi<sub>b</sub> Si Mi Re<sub>b</sub> Fa<sub>#</sub> Re Sol Mi La Re La<sub>b</sub> Re<sub>b</sub> Do Mi<sub>b</sub>



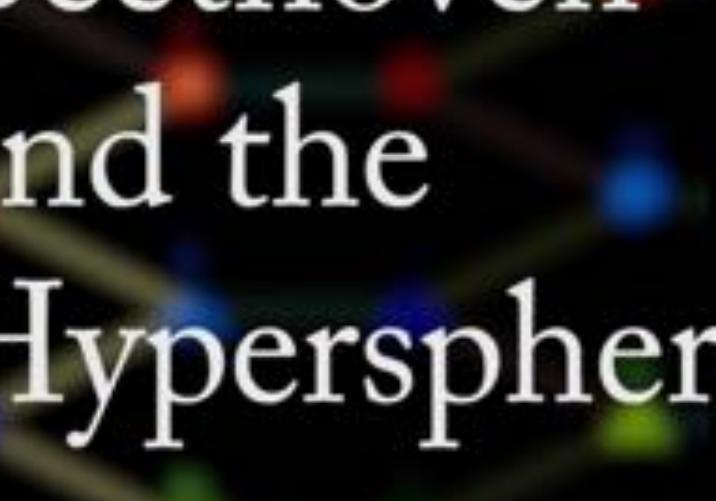
Almost total covering of the major-chords space

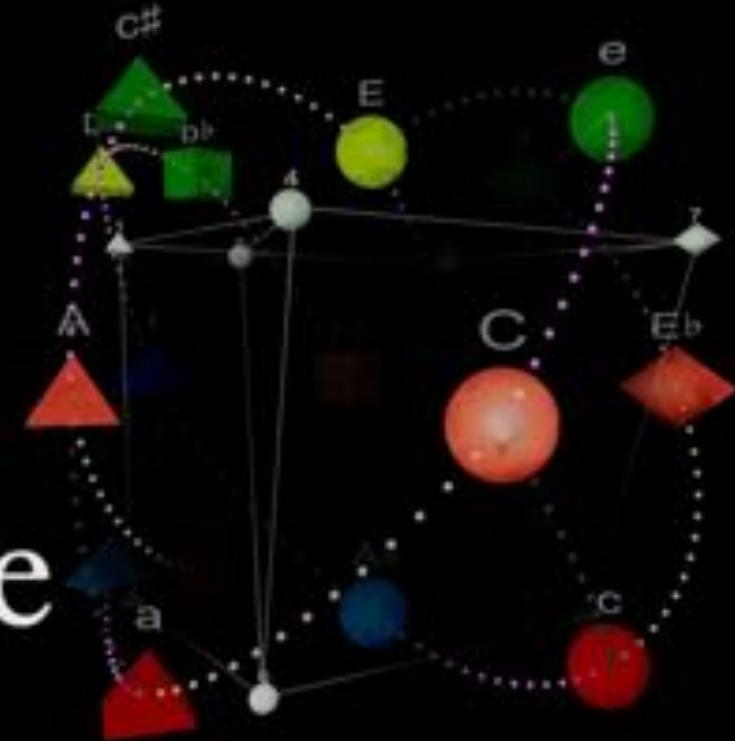


# Harmonic progressions as spatial trajectories



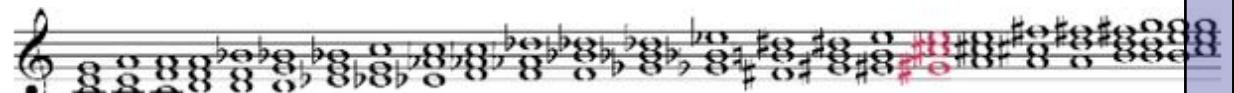
# Beethoven and the Hypersphere *(and the Tonnetz)*





Gilles Baroin 2016  
www.MatheMusic.net

# Reading Beethoven backwards

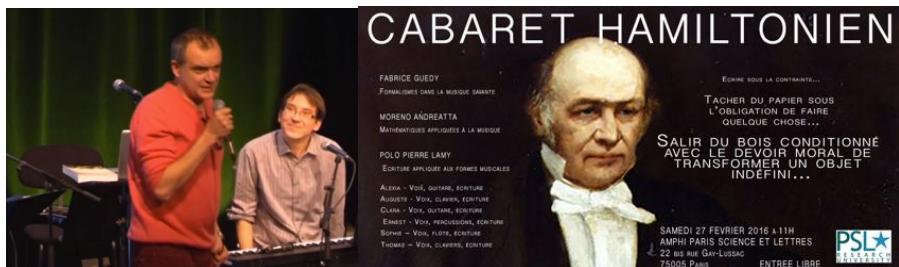
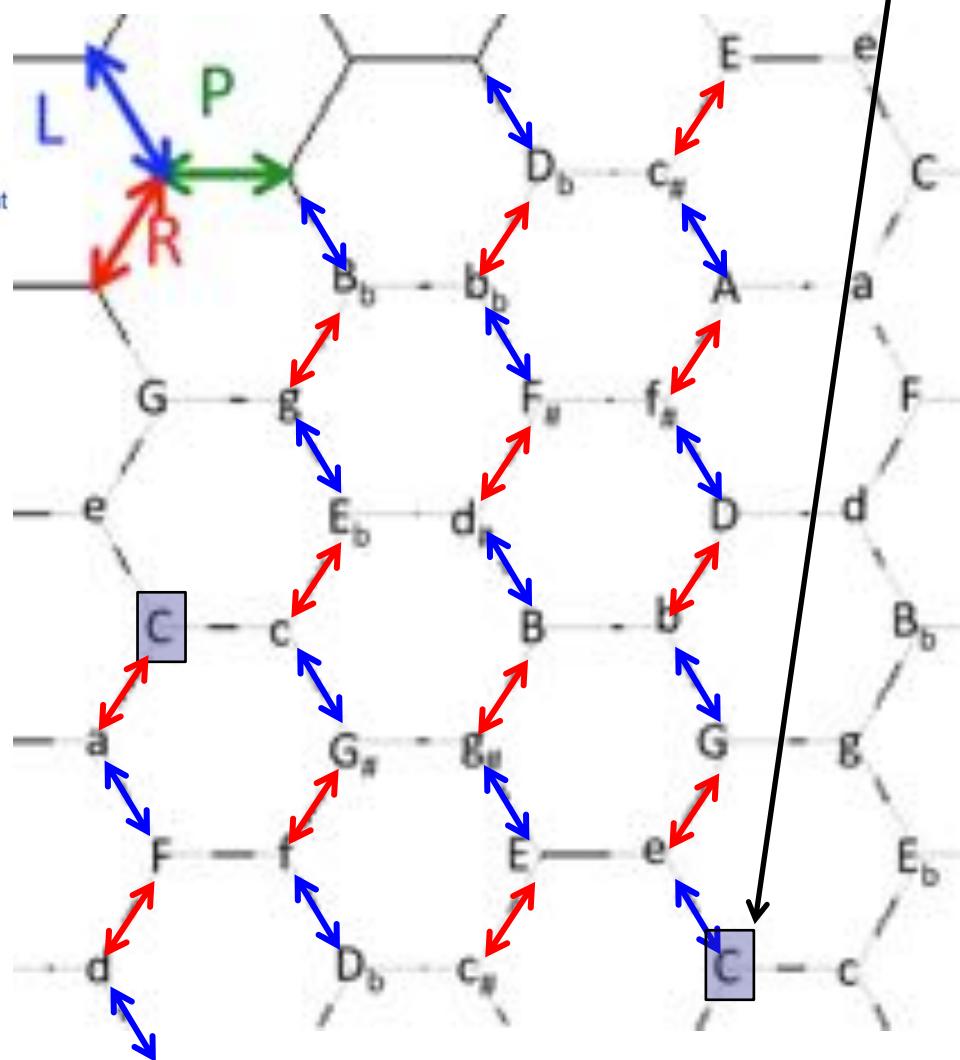


← time

## Le Blé en Herbe

(Polo/Moreno/Dieu)

- |  |  |
|--|--|
| Plonger comme un enfant, cheveux au vent | Croiser matin dans l'herbe folle       |
| Sous l'océan du blé en herbe             | Deux tourterelles qui s'envolent       |
| Marée d'épis couleur d'amande            | Suivre les jeux des hirondelles        |
| Qui tendent à caresser le ciel           | Sur le paysage éternel                 |
| Algues tendres de mille plages           | Nager comme un enfant, cheveux au vent |
| Frôlant le ventre des nuages             | Sous l'océan                           |
| Cheveux de pluie, dos de poissons        | Du blé en herbe                        |
| Qui frissonnent à l'unisson              | Marée de fruits au goût amer           |
| Suivre le bord des continents            | Acide et salée comme la mer            |
| Dans l'océan du blé en herbe             | Vers l'îlot d'un petit village         |
| Pêcher le corail du pavot                | Vers un château d'eau sur la plage     |
| Dans le sang des coquelicots             | Quand tout s'éteint avant l'orage      |
|  | Quand se lève le vent du large         |
|  | Sur le blé vert                        |





# From poetry to song writing:

## hamiltonian compositional strategies

A part (Andrée Chedid, poème tiré du recueil *Rhymes Collection Poésie/Gallimard* (n. 527), Gallimard, 2018)

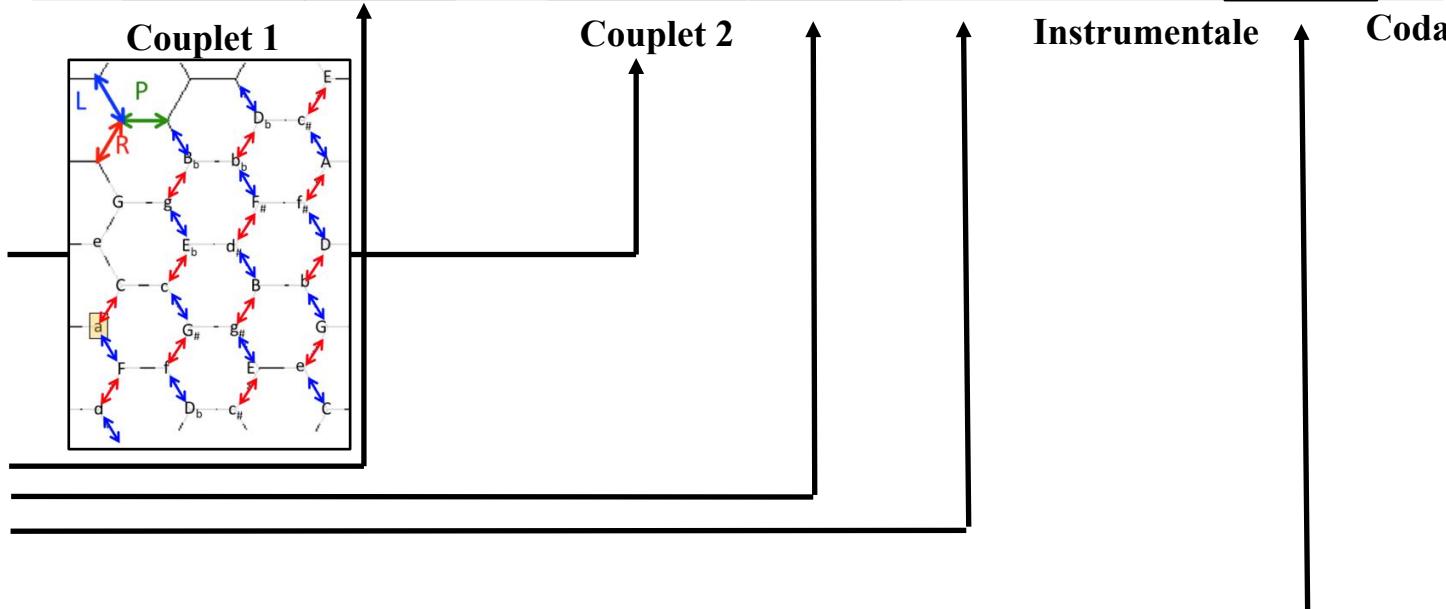
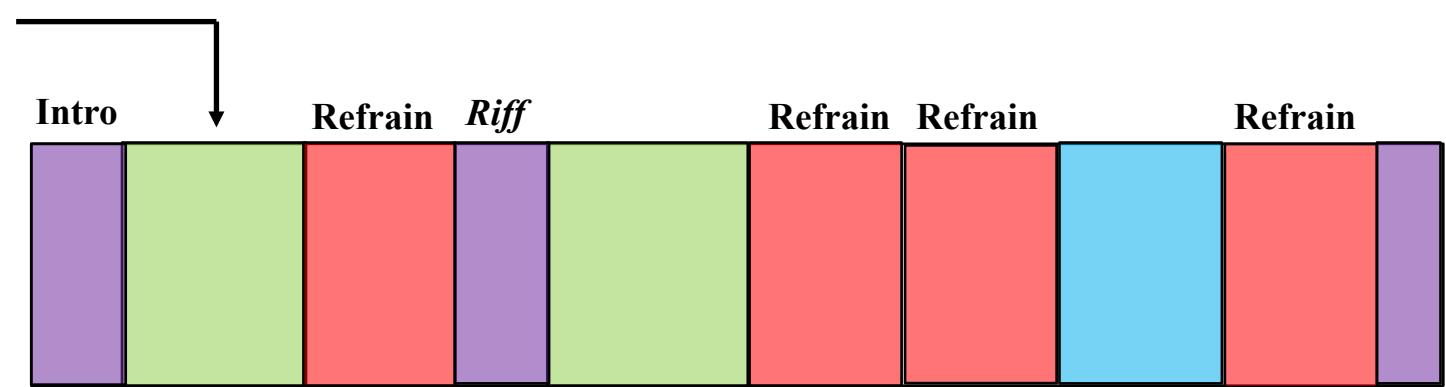


À part le temps  
Et ses rouages  
À part la terre  
En éruptions  
À part le ciel  
Pétrisseur de nuages  
À part l'ennemi  
Qui génère l'ennemi

À part le désamour  
Qui ronge l'illusion  
À part la durée  
Qui moisit nos visages

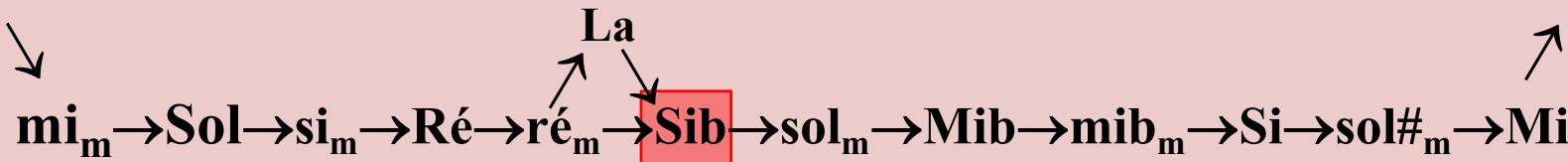
À part les fléaux  
À part la tyrannie  
À part l'ombre et le crime  
Nos batailles nos outrages

Je te célèbre ô Vie  
Entre cavités et songes  
Intervalle convoité  
Entre le vide et le rien



# *Aprile*, a Hamiltonian « decadent » song

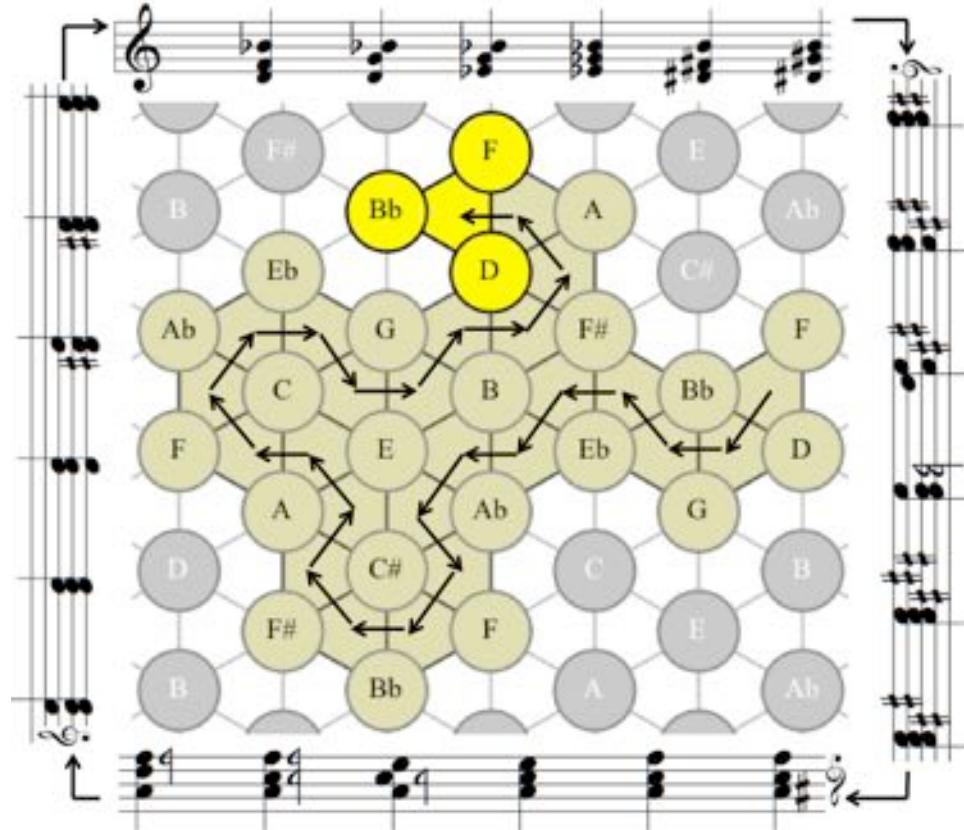
**Do**←**do<sub>m</sub>**←**Sol#**←**fa<sub>m</sub>**←**Fa**←**la<sub>m</sub>**←**La**←**fa#<sub>m</sub>**←**Fa#**←**sib<sub>m</sub>**←**Do#**←**do#<sub>m</sub>**



*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.*

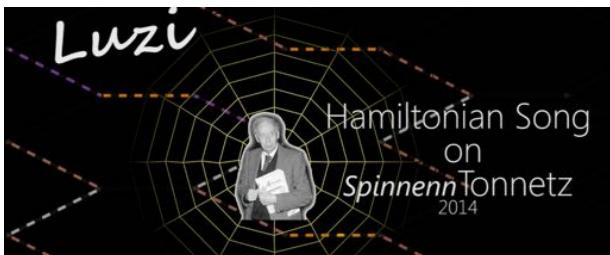


# ACTIONS

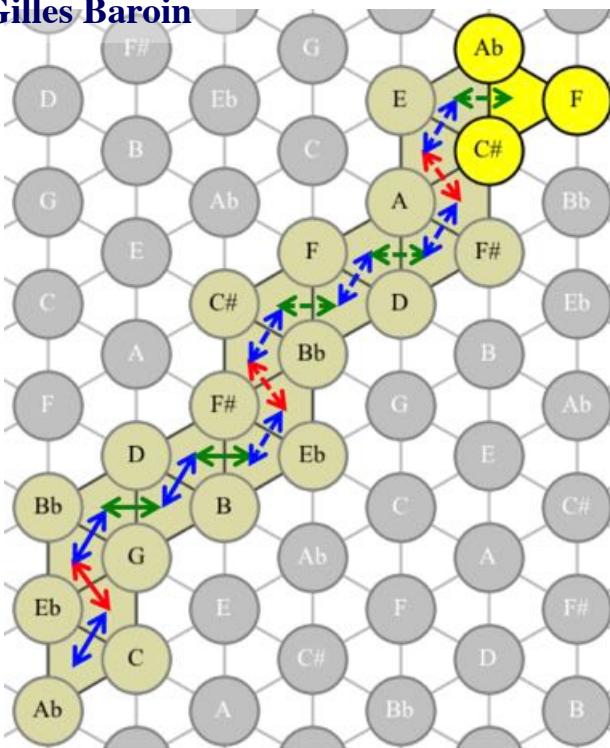
Math'n'pop

## **Aprile (d'après Gabriele D'Annunzio)**

# *La sera non è più la tua canzone (after Mario Luzi)*



Gilles Baroin

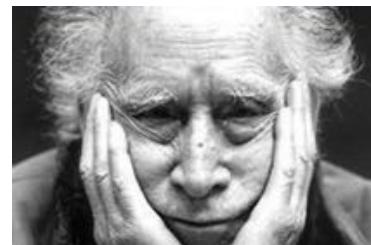


**La sera non è più la tua canzone,  
è questa roccia d'ombra traforata  
dai lumi e dalle voci senza fine,  
la quiete d'una cosa già pensata.**

**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.**



M. Luzi (1914-2005)

*Le soir n'est plus ta chanson,  
c'est ce rochet d'ombre transpercé  
par les lumières et les voix sans fin,  
la paix d'une chose déjà pensée.*

*Ah, cette lumière vive et claire vient  
uniquement de toi, tu es si proche  
du vrai d'une chose connue,  
tu as pour nom une parole qui est passée  
dans l'intimité du cœur où elle s'est  
perdue .*

*Tombé est plus qu'un signe de la vie,  
tu te reposes, du voyage tu es revenue  
à l'intérieur de toi même, tu es  
descendue dans cette  
pure substance qui est si tienne,  
si éloignée  
dans le silence de l'être, achevée.*

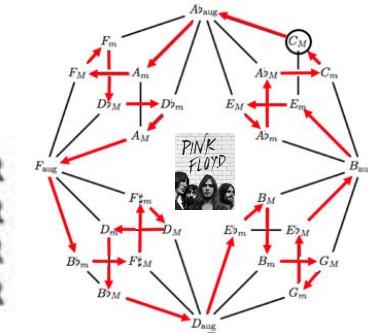
*L'air se tait et le temps derrière toi  
se lève tel une montagne aride  
où plane ton esprit et se perd,  
un vent rare glisse et stagne.*

(tr. Antonia Soulez, philosophe et poète)

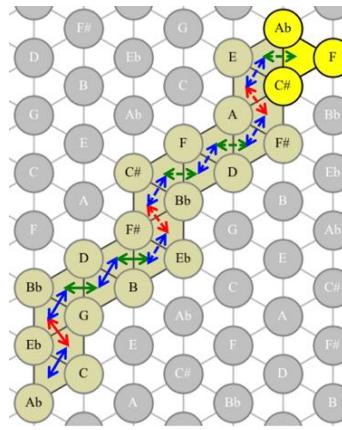
**Music:** M. Andreatta  
**Arrangement and mix:** M. Bergomi & S. Geravini  
*(Perfect Music Production)*  
**Mastering:** A. Cutolo (Massive Arts Studio, Milan)

# Exploring Hamiltonian trajectories in song writing

1. C-Cm-Ab-Abm-E-C#m-A-Am-F-Fm-C#-Bbm-F#-F#m-D-Dm-Bb-Gm-Eb-Ebm-B-Bm-G-Em--PLPLRL
2. C-Cm-Ab-Fm-C#-C#m-A-Am-F-Dm-Bb-Bbm-F#-F#m-D-Bm-G-Gm-Eb-Ebm-B-Abm-E-Em--PLRLPL
3. C-Cm-Eb-Ebm-F#-F#m-A-C#m-E-Em-G-Gm-Bb-Bbm-C#-Fm-Ab-Abm-B-Bm-D-Dm-F-Am--PRPRPRLR
4. C-Cm-Eb-Ebm-F#-Bbm-C#-C#m-E-Em-G-Gm-Bb-Dm-F-Fm-Ab-Abm-B-Bm-D-F#m-A-Am--PRPRLRPR
5. C-Cm-Eb-Ebm-F#-Bbm-C#-Fm-Ab-Abm-B-Bm-D-F#m-A-C#m-E-Em-G-Gm-Bb-Dm-F-Am--PRPRLRLR
6. C-Cm-Eb-Gm-Bb-Bbm-C#-C#m-E-Em-G-Bm-D-Dm-F-Fm-Ab-Abm-B-Ebm-F#-F#m-A-Am--PRLRPRPR
7. C-Cm-Eb-Gm-Bb-Bbm-C#-Fm-Ab-Abm-B-Ebm-F#-F#m-A-C#m-E-Em-G-Bm-D-Dm-F-Am--PRLRPLR
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-Ed-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
13. C-Em-G-Gm-Bb-Dm-F-Fm-Ab-Cm-Eb-Ebm-F#-Bbm-C#-C#m-E-Abm-B-Bm-D-F#m-A-Am--LRPR
14. C-Em-G-Bm-B-Ebm-Eb-Gm-Bb-Dm-D-F#m-F#-Bbm-C#-Fm-F-Am-A-C#m-E-Abm-Ab-Cm--LRLPLP
15. C-Em-G-Bm-D-Dm-F-Fm-Ab-Cm-Eb-Gm-Bb-Bbm-C#-C#m-E-Abm-B-Ebm-F#-F#m-A-Am--LRLRPRPR
16. C-Em-G-Bm-D-F#m-A-C#m-E-Abm-B-Ebm-F#-Bbm-C#-Fm-Ab-Cm-Eb-Gm-Bb-Dm-F-Am--LR
17. C-Am-A-F#m-F#-Ebm-Eb-Cm-Ab-Fm-F-Dm-D-Bm-B-Abm-E-C#m-C#-Bbm-Bb-Gm-G-Em--RPRPRPRL
18. C-Am-A-F#m-F#-Ebm-B-Abm-Ab-Fm-F-Dm-D-Bm-G-Em-E-C#m-C#-Bbm-Bb-Gm-Eb-Cm--RPRPRLRP
19. C-Am-A-F#m-F#-Ebm-B-Abm-E-C#m-C#-Bbm-Bb-Gm-Eb-Cm-Ab-Fm-F-Dm-D-Bm-G-Em--RPRPRLRL
20. C-Am-A-F#m-D-Bm-B-Abm-Ab-Fm-F-Dm-Bb-Gm-G-Em-E-C#m-C#-Bbm-F#-Ebm-Eb-Cm--RPRLRPRP
21. C-Am-A-F#m-D-Bm-B-Abm-E-C#m-C#-Bbm-F#-Ebm-Eb-Cm-Ab-Fm-F-Dm-Bb-Gm-G-Em--RPRPL
22. C-Am-A-F#m-D-Bm-G-Em-E-C#m-C#-Bbm-F#-Ebm-B-Abm-Ab-Fm-F-Dm-Bb-Gm-Eb-Cm--RPRRLRLP
23. C-Am-F-Fm-C#-C#m-A-F#m-D-Dm-Bb-Bbm-F#-Ebm-B-Bm-G-Gm-Eb-Cm-Ab-Abm-E-Em--RLPLPL
24. C-Am-F-Dm-D-Bm-B-Abm-Ab-Fm-C#-Bbm-Bb-Gm-G-Em-E-C#m-A-F#m-F#-Ebm-Eb-Cm--RLRPRPRP
25. C-Am-F-Dm-D-Bm-B-Abm-E-C#m-A-F#m-F#-Ebm-Eb-Cm-Ab-Fm-C#-Bbm-Bb-Gm-G-Em--RLRPRPRL
26. C-Am-F-Dm-D-Bm-G-Em-E-C#m-A-F#m-F#-Ebm-B-Abm-Ab-Fm-C#-Bbm-Bb-Gm-Eb-Cm--RLRP
27. C-Am-F-Dm-Bb-Gm-G-Em-E-C#m-A-F#m-D-Bm-B-Abm-Ab-Fm-C#-Bbm-F#-Ebm-Eb-Cm--RLRLRPRP
28. C-Am-F-Dm-Bb-Gm-Eb-Cm-Ab-Fm-C#-Bbm-F#-Ebm-B-Abm-E-C#m-A-F#m-D-Bm-G-Em--RL



LPLPLR...  
PLPLRL...  
LPLRLP...  
PLRLPL...  
RLRLPLP...



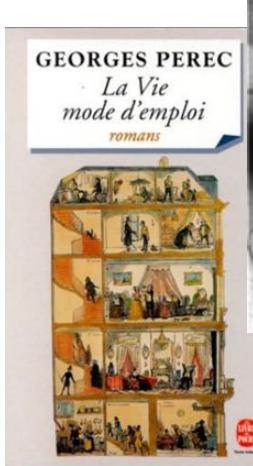
*Luzi*  
Hamiltonian Song  
on  
Spinnetonnetz  
2014

Music and Vocals by Moreno Andreatta  
Graphics and Animation by Gilles Baroin  
Spinnetonnetz by Gilles Baroin, Hugo Seress  
Original 'Chicken Wire' graph by J.Douillet, P.Sternbach

# The use of constraints in arts



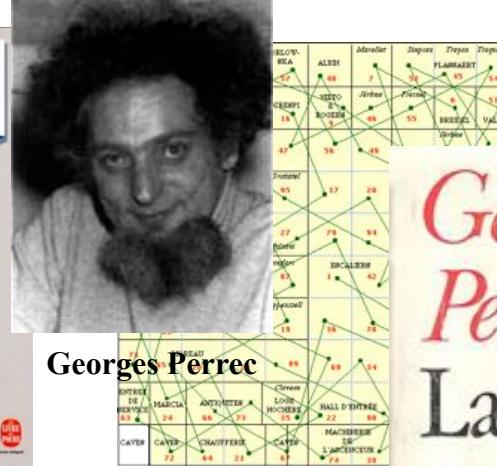
*Cent mille milliards de poèmes*, 1961



*La vie mode d'emploi*,



Georges Perec



*Georges  
Perec*

Roman

*La disparition*

Les Lettres Nouvelles

Denoël



Raymond Queneau

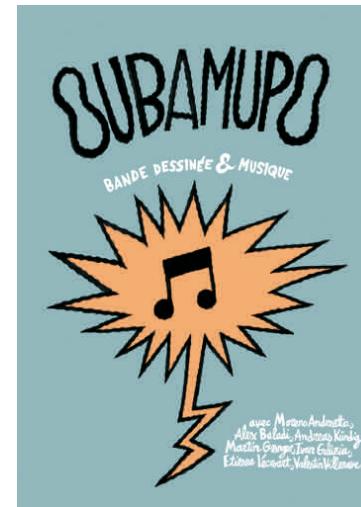


Italo Calvino

*Il castello dei destini  
incrociati*, 1969



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



Valentin Villenave

Mike Solomon

Jean-François  
Piete

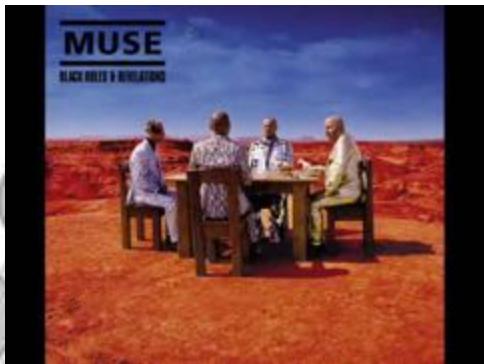
Martin  
Granger

Joseph Boisseau

Moreno Andreatta

Tom Johnson

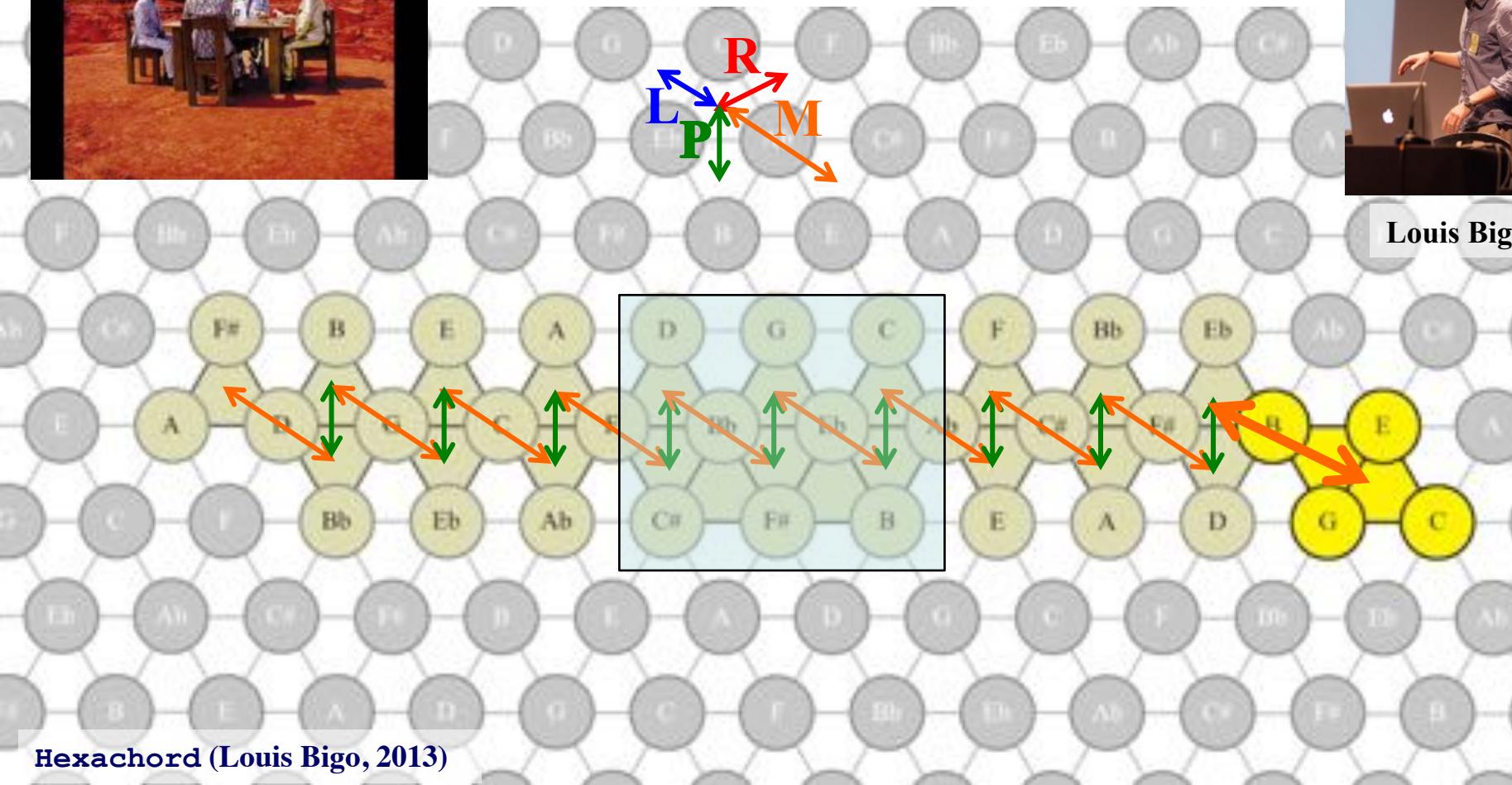
# Symmetries and algorithmic processes in *Muse*



“Take a bow” (*Black Holes and Revelations*, 2006)



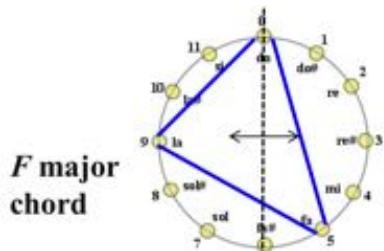
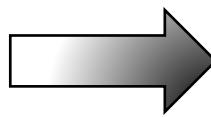
Louis Bigo



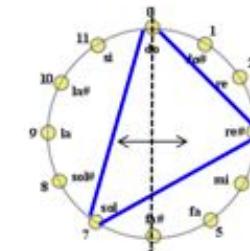
Hexachord (Louis Bigo, 2013)

Temporal axis

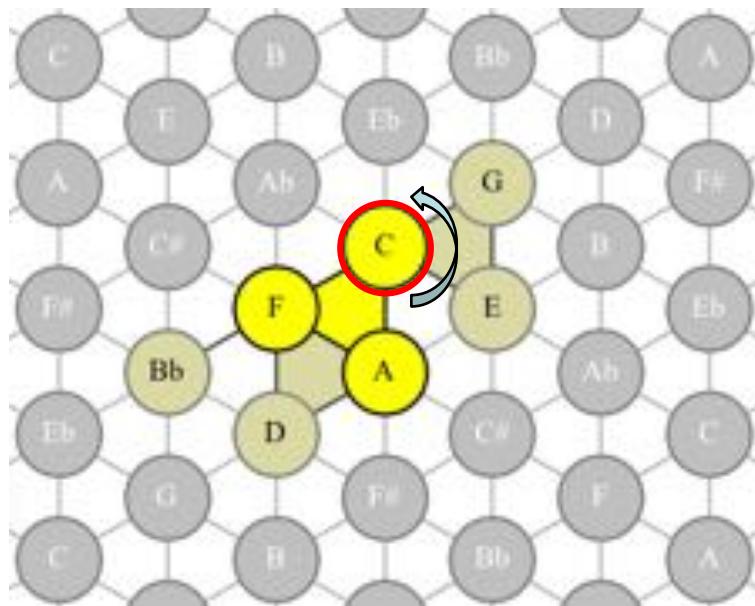
# Keeping the space...but changing the trajectory!



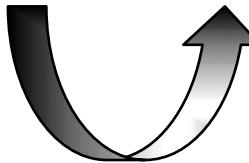
## **inversion**



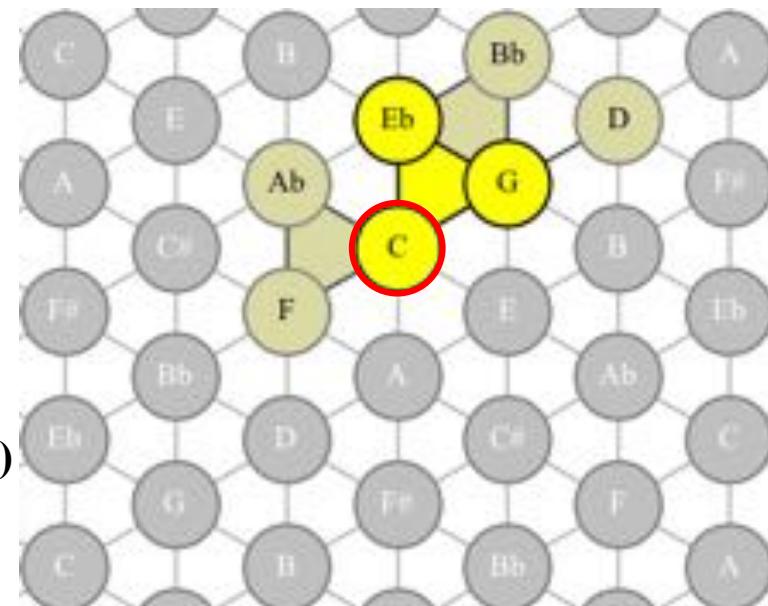
**C**  
mino  
chord



## **Beatles, Hey Jude (orig. version)**



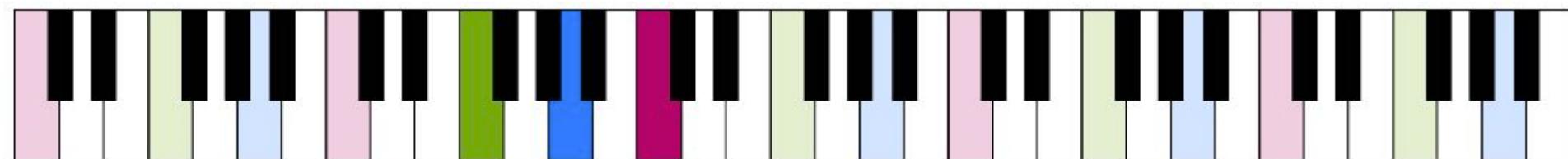
# Rotation (autour du *do*)



## Beatles, Hey Jude (transformed version)



<https://imaginary.org/>



## The Tonnetz web environment

(conceived and developed by C. Guichaoua & M. Andreatta / SMIR Project, USIAS/Univ. Of Strasbourg)

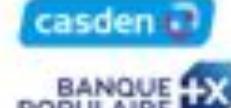
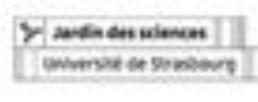
→ <https://guichaoua.gitlab.io/web-hexachord/>

# Math'n Pop within the Year of Mathematics

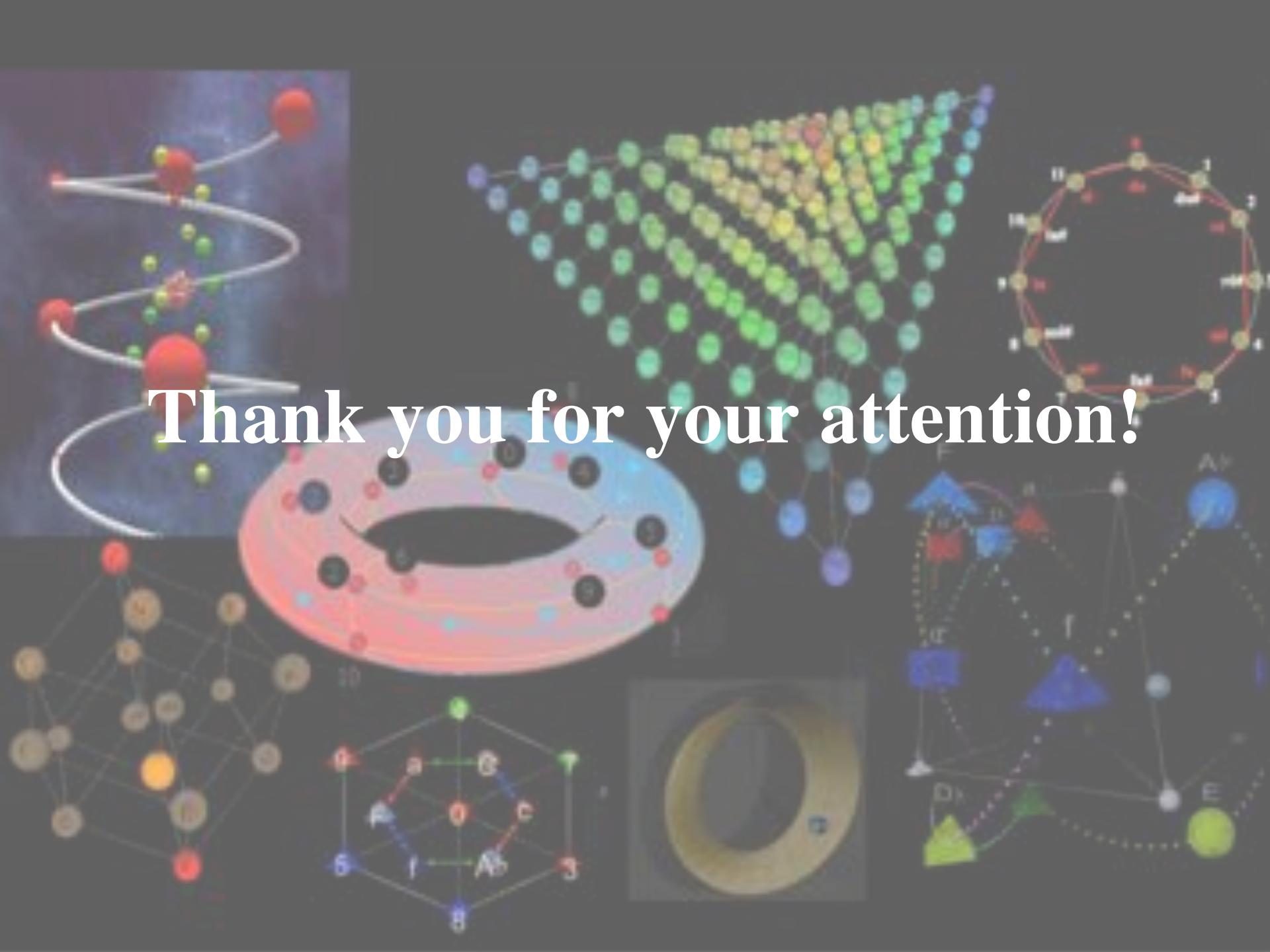


Conférence  
concert

3 octobre 2019  
19h45



→ <https://www.mathnpop.com/>



Thank you for your attention!