

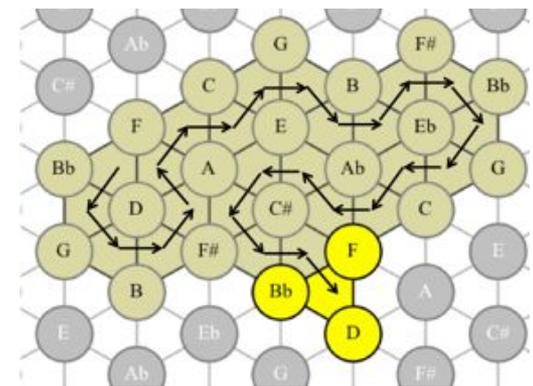
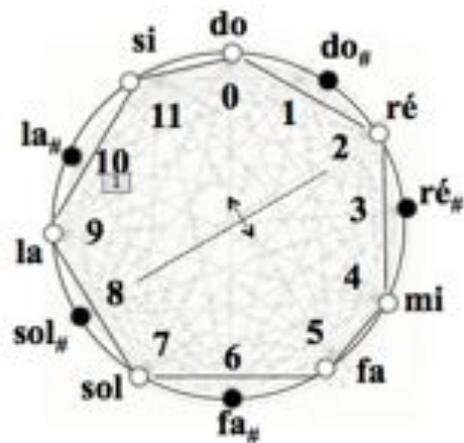
# Géométrie et algèbre en musique savante et en chanson

Petits Séminaires de vulgarisation  
LPS - Orsay  
Grand Amphi

14 avril 2016 - 13h30

Moreno Andreatta

Equipe Représentations Musicales  
IRCAM / CNRS UMR 9912 / UPMC  
Moreno.Andreatta@ircam.fr

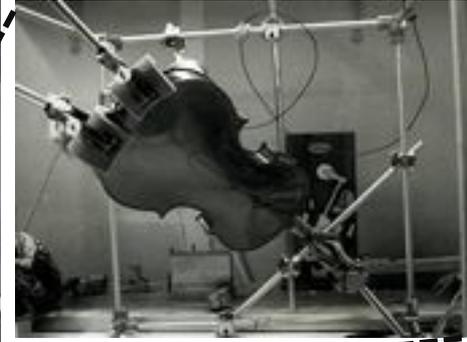
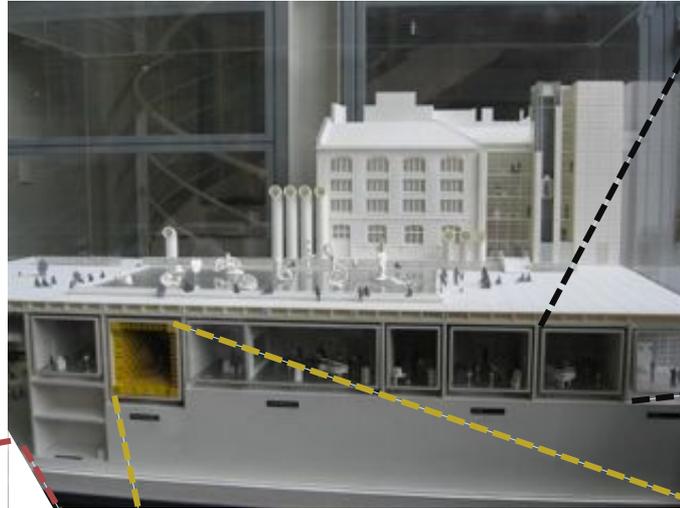


# Mon parcours entre les maths et la musique

- **1990-1996** Coursus de mathématiques (Université de Pavie) – Master 2
- **1998** 1<sup>er</sup> Prix de piano (Conservatoire de musique de Novare, Italie)
- **1998-2003** DEA et thèse en Musicologie computationnelle (EHESS) et pianiste de piano-bar (Bateaux Parisiens, jusqu'en 2009)
- **Depuis 2004** CR1 CNRS affecté à l'IRCAM (Institut de Recherche et Coordination Acoustique/Musique)
- **2005-2009** Pianiste-chanteur et directeur artistique du groupe de chanson franco-italienne *N91*
- **2010** HDR en mathématiques et ses interactions (IRMA, Strasbourg)
- **Depuis 2012** Coordinateur du Master ATIAM (Acoustique, Traitement du signal et informatique appliqués à la musique)
- **2013-2017** Comité de pilotage du GDR ESARS (Esthétique, Arts et Science) – Responsable de l'axe « Math'n Pop »



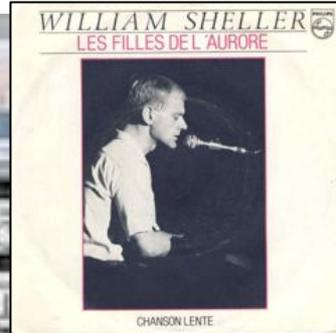
# La recherche musicale et scientifique à l'IRCAM...



# ... entre musique savante et *popular music*



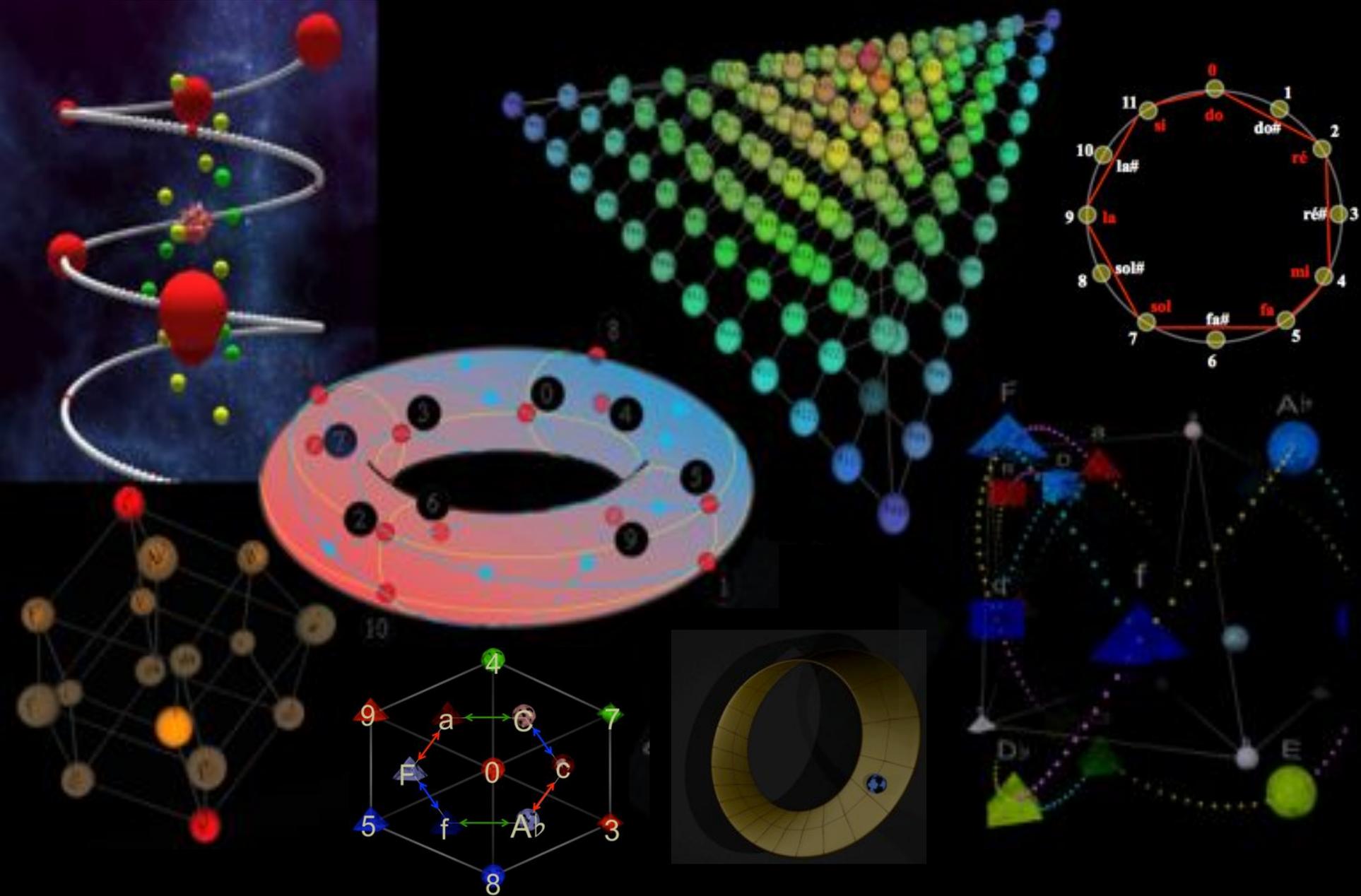
MusiqueLab 2



OMAX (logiciel d'improvisation)



# La galaxie des modèles géométriques au service de la musique



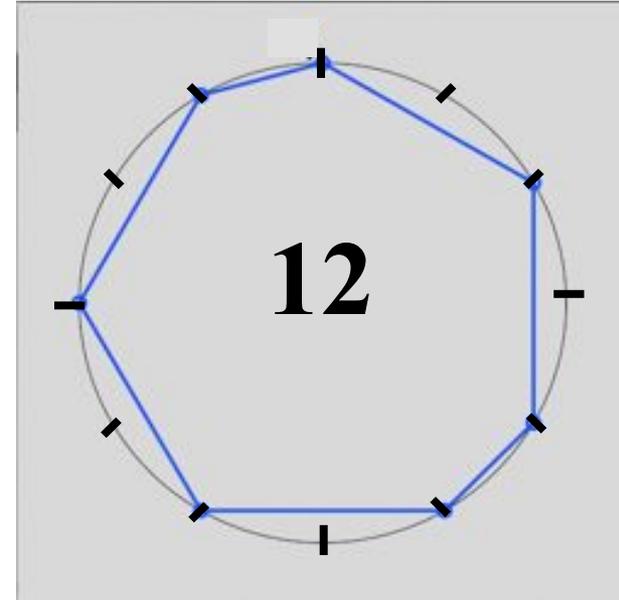
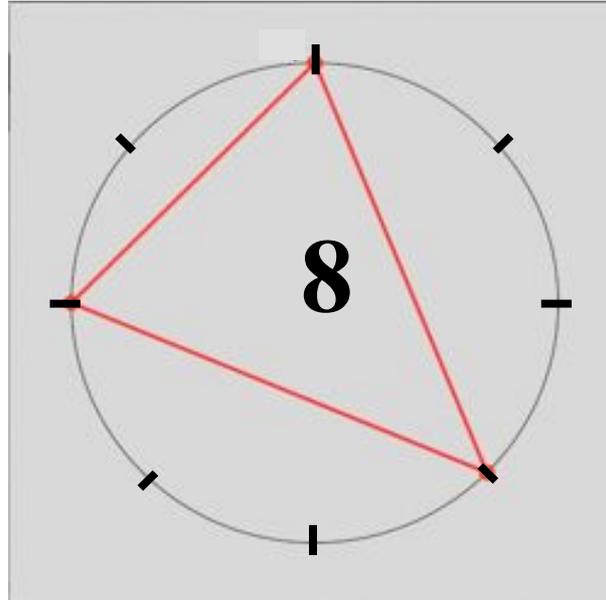
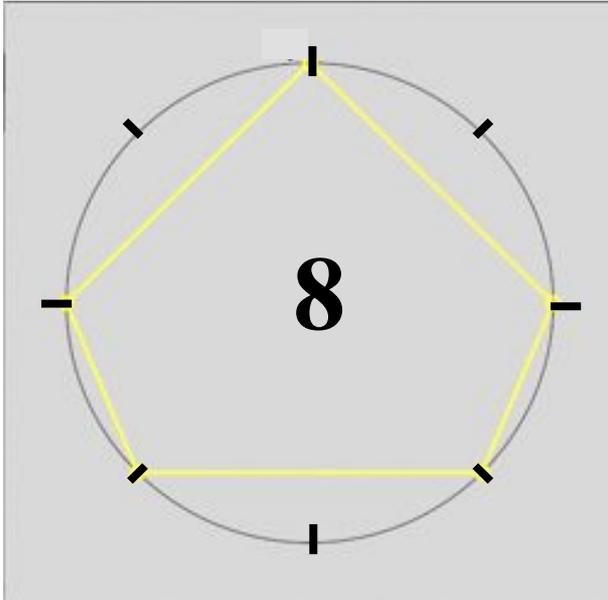
# La géométrie des rythmes afro-cubains



*Cinquillo*

*Trecillo*

*Bembé (Abadja)*



♩ = 60

♩ = 60

♩ = 60

# Le « cercle rythmique » et ses rotations

## CLAPPING MUSIC

FOR TWO PERFORMERS



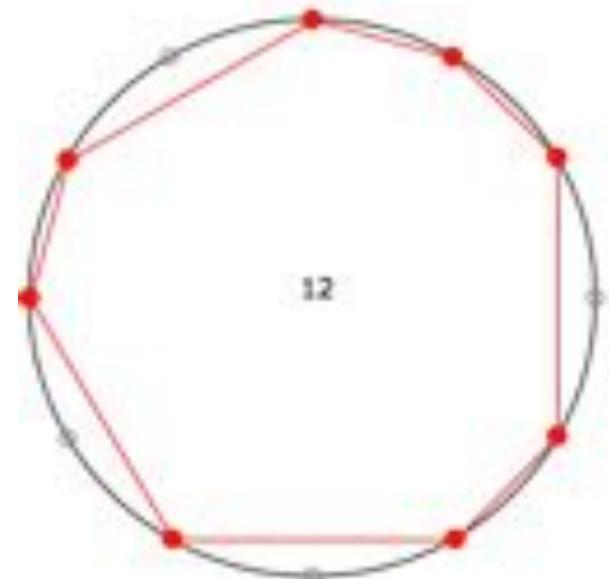
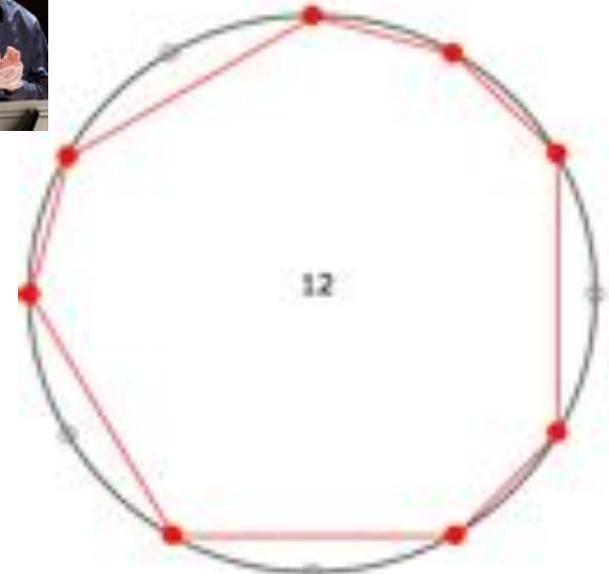
Handwritten musical notation for two clappers (CLAP 1 and CLAP 2). The notation consists of three systems of staves. The first system is highlighted with colored boxes: a red box around the first measure, a green box around the second measure, and an orange box around the third measure. The notation includes rhythmic patterns and bar numbers (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12). The text "Repeat bar 12, then end" is written at the bottom right of the notation.

The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer's part does not change, it is up to the second performer to move from one bar to the next. The second performer should try to keep his or her clapping where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his clapping always falls on a new beat of his or her underlying pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whichever sound is chosen, both performers should try to get the same one so that their two parts will blend to produce one overall exciting pattern.

Howarth 12/72  
revised 1/77

Clapping Music (1972)



# Le « cercle rythmique » et ses rotations

## CLAPPING MUSIC

FOR TWO PERFORMERS



Handwritten musical notation for two clappers (CLAP 1 and CLAP 2). The notation is organized into three systems, each with a circled measure number (1, 2, 3). The first system is highlighted with a red box, the second with a green box, and the third with an orange box. The notation consists of rhythmic patterns represented by vertical stems and horizontal lines, indicating clapping sequences.

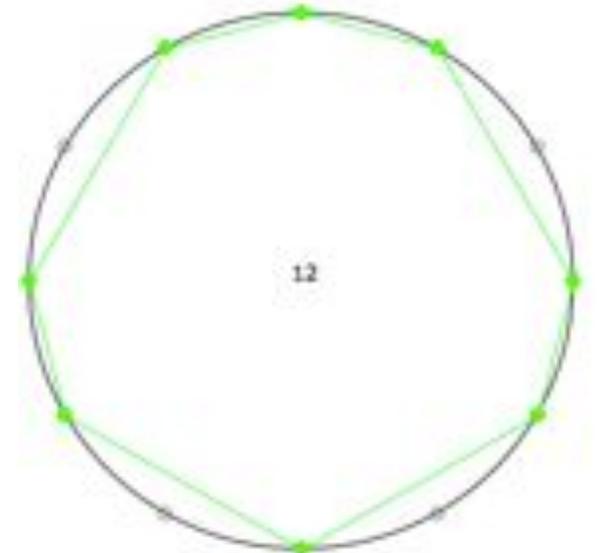
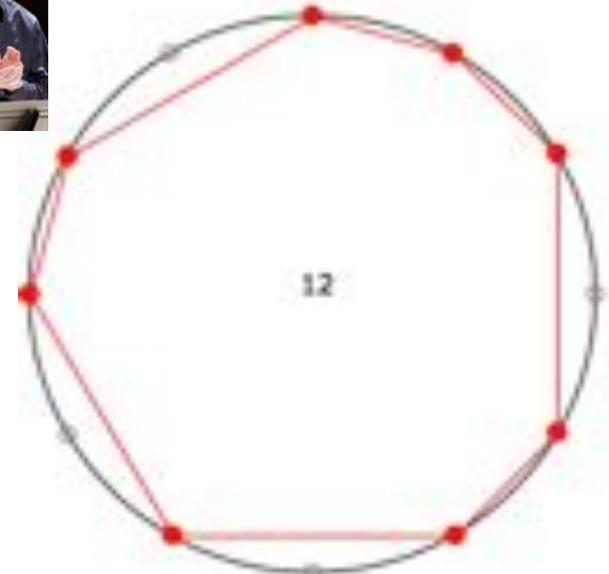
Repeat bar 12, then end

The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer's part does not change, it is up to the second performer to move from one bar to the next. The second performer should try to keep his or her clapping where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his clapping always falls on a new beat of the bar in changing pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whereas when it comes to clapping, both performers should try to get the same ones so that their two parts will blend to produce one overall exciting pattern.

Steve Reich 12/72  
revised 7/77

Clapping Music (1972)



# Le « cercle rythmique » et ses rotations

## CLAPPING MUSIC

FOR TWO PERFORMERS



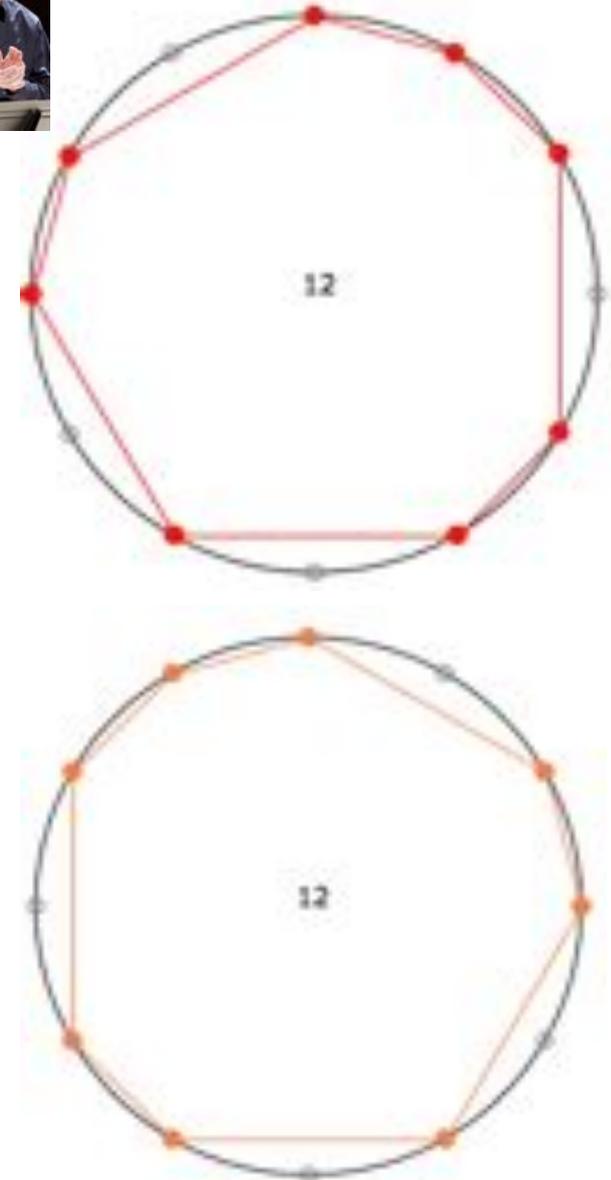
Handwritten musical notation for two clappers (CLAP 1 and CLAP 2). The notation is organized into three systems, each with a circled measure number (1, 2, 3). The first system is highlighted with a red box, the second with a green box, and the third with an orange box. The notation consists of rhythmic patterns represented by vertical stems and horizontal lines, indicating clapping and other rhythmic actions.

The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer's part does not change, it is up to the second performer to move from one bar to the next. The second performer should try to keep his or her clapping where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his clapping always falls on a new beat of his or her underlying pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whereas when it comes to clapping, both performers should try to get the same one so that their two parts will blend to produce one overall rhythmic pattern.

Steve Reich 12/72  
revised 7/77

Clapping Music (1972)



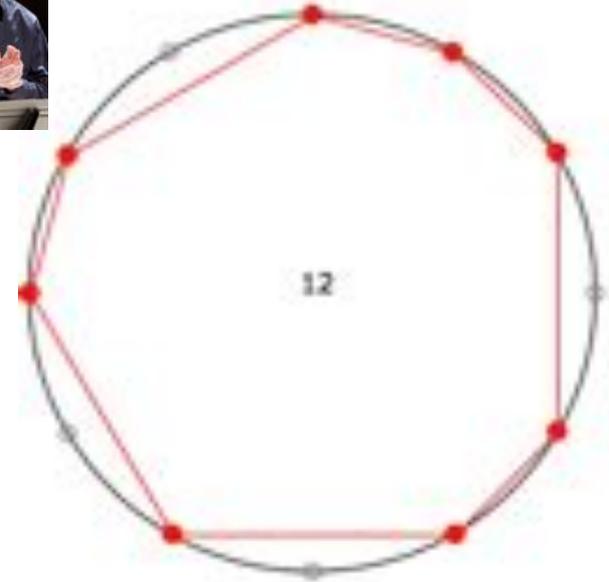
# Le « cercle rythmique » et ses rotations

## CLAPPING MUSIC

FOR TWO PERFORMERS



Handwritten musical score for two performers, labeled "CLAP 1" and "CLAP 2". The score consists of three systems of two staves each. The first system is highlighted with colored boxes: a red box around the first measure, a green box around the second measure, and an orange box around the third measure. The score includes circled measure numbers (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12) and a circled letter 'f' at the beginning of the first system. The text "Repeat bar 12, then end" is written at the bottom right of the score.



The performers begin and end with both performers in unison at bar ①. The number of repeats of each bar should be fixed at twelve repeats per bar. Since the first performer part does not change, it is up to the second performer to move from one bar to the next. The second performer should try to keep his or her downbeat where it is written, i.e. on the first beat of each measure (not on the first beat of the group of three claps), so that his downbeat always falls on a new beat of his or her underlying pattern.

The choice of a particular clapping sound, i.e. with cupped or flat hands is left up to the performers, whichever sound is chosen, both performers should try to get the same one so that their two parts will blend to produce one overall sounding pattern.

Clapping Music (1972)

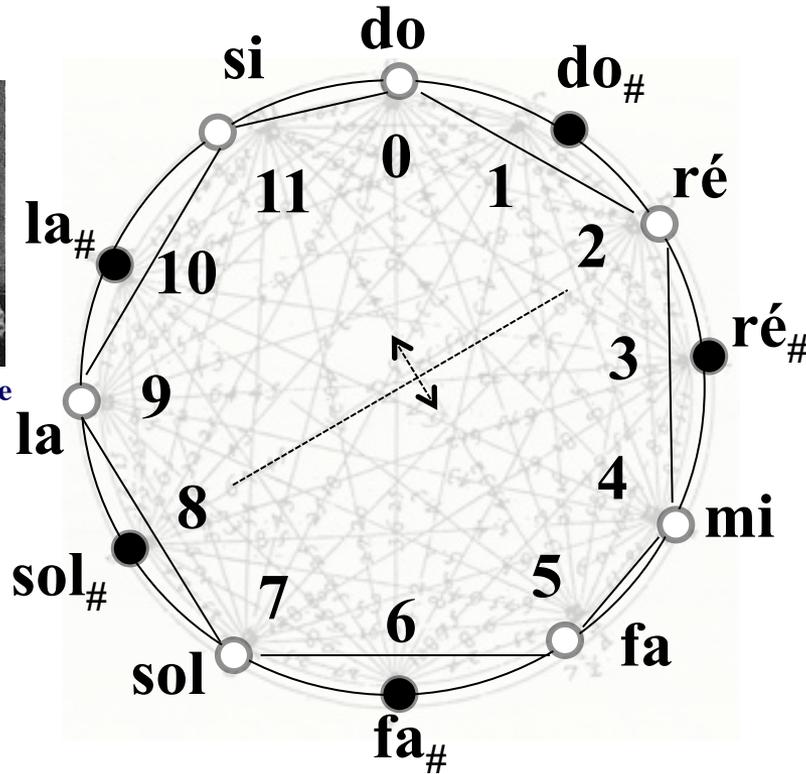
Steve Reich 12/72  
revised 7/77

Gerubach's Scrolling Score Project  
<http://www.gerubach.com>

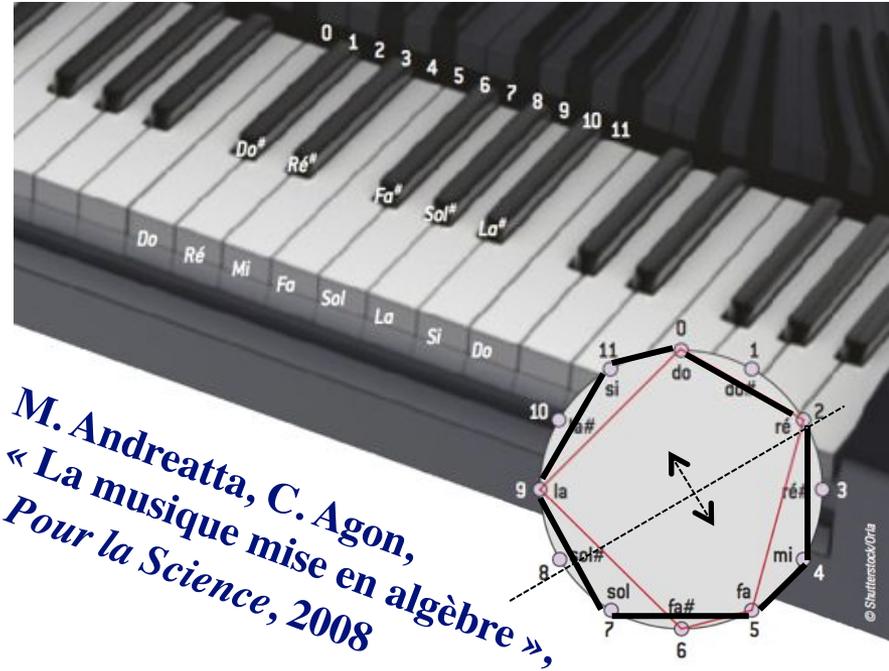
# La représentation circulaire des notes de musique



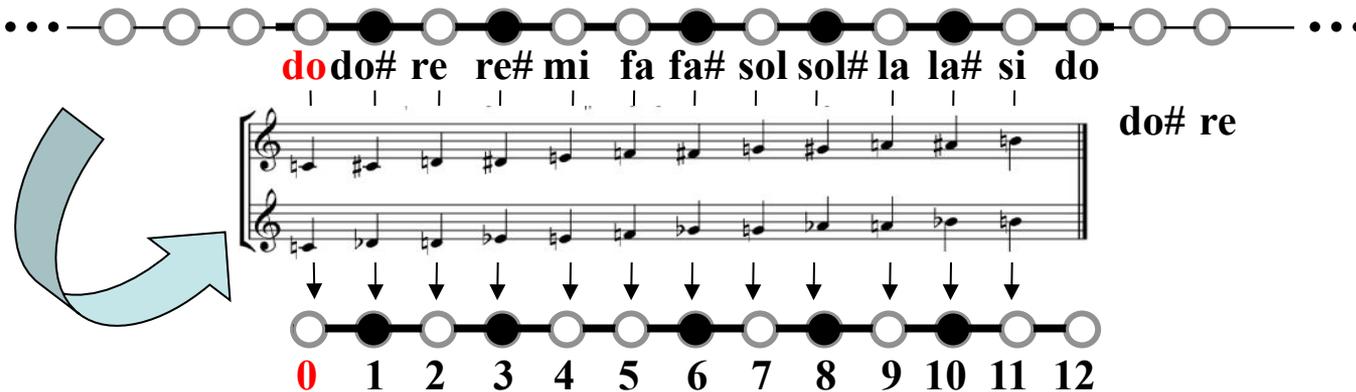
Marin Mersenne



*Harmonicorum Libri XII, 1648*



M. Andreatta, C. Agon,  
« La musique mise en algèbre »,  
Pour la Science, 2008



# Les transpositions sont des additions...



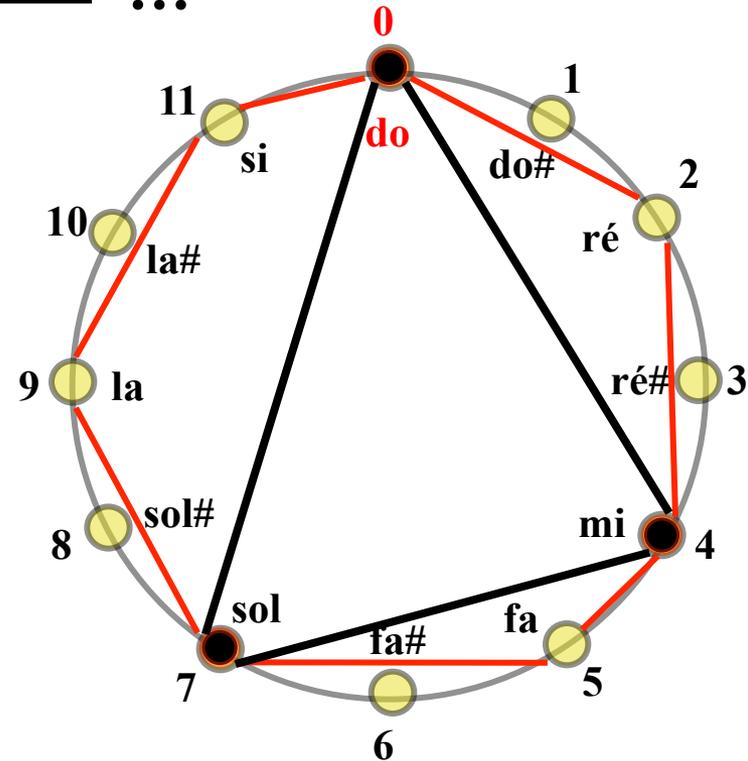
$$\text{Do maj} = \{0, 2, 4, 5, 7, 9, 11\} + 1$$



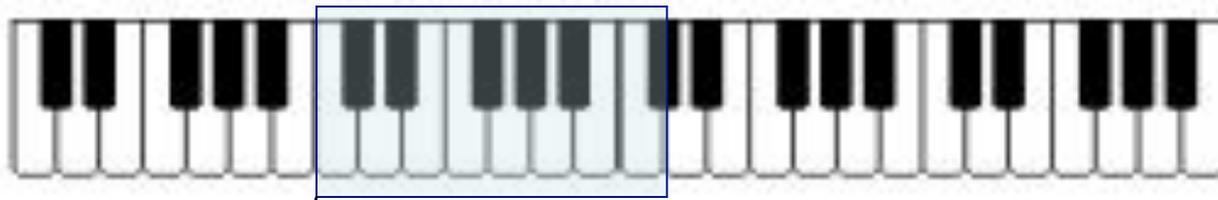
do do# ré ré# mi fa fa# sol sol# la la# si do



0 1 2 3 4 5 6 7 8 9 10 11 12



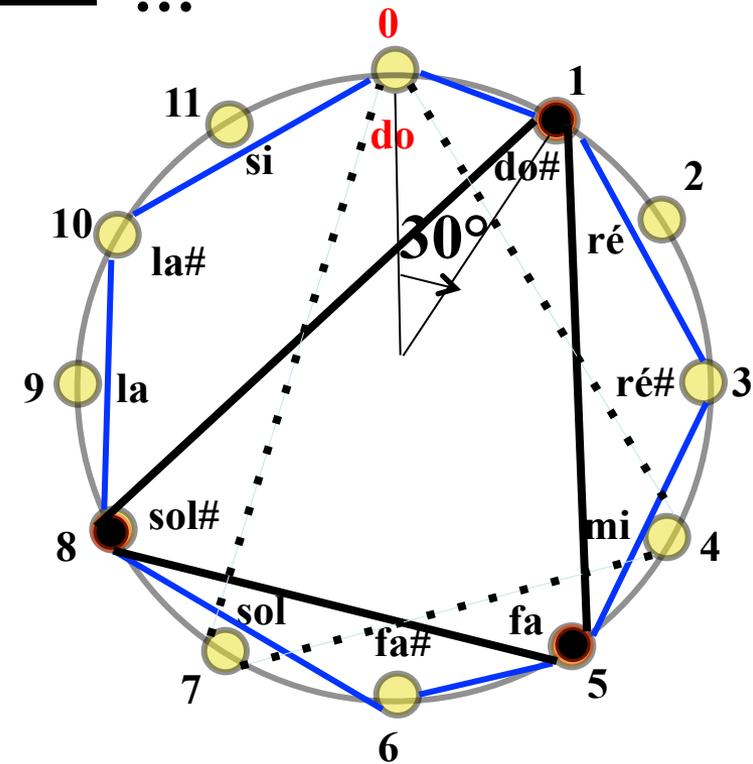
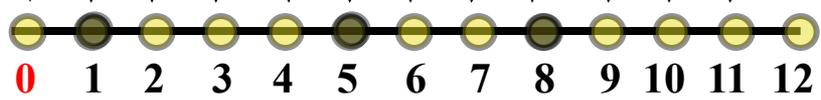
# Les transpositions sont des additions...



$$Do\# \text{ maj} = \{1, 3, 5, 6, 8, 10, 0\}$$



do do# ré ré# mi fa fa# sol sol# la la# si do



... ou des rotations !



## ACCORDS MAJEURS

## ACCORDS MINEURS

**MAGIC IN THE AIR**

**Sol** **Ré**  
 Feel the magic in the air. Allez, allez, allez

**La** **Si-**  
 Levez les mains en l'air Allez, allez, allez (x2)

(x4 avec toutes les voix)

**Ré**  
 Comme d'habitude on est calés

**La** **Si-**  
 Comme toujours ça va aller

**Sol** **Ré**  
 On sème l'ambiance à gogo

**La** **Si-**  
 Tous ensemble on fait le show

**Sol** **Ré**  
 On t'invite à la magie Y'a pas de raccourci

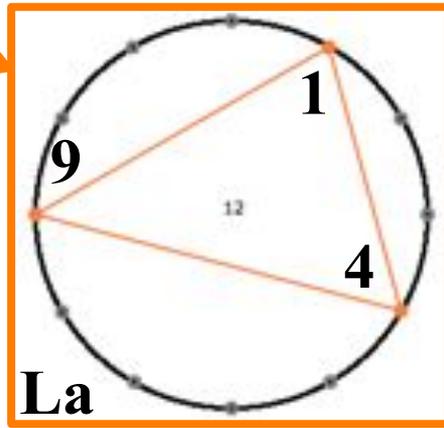
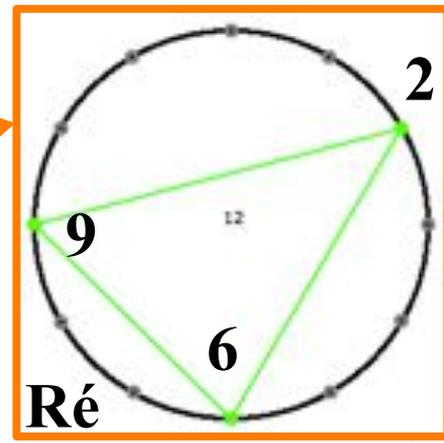
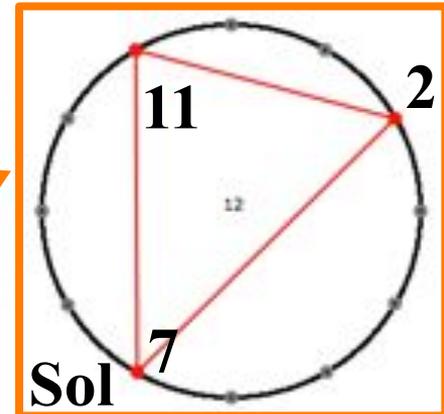
**La** **Si-**  
 Oublie tes soucis Viens faire la folie

**Sol** **Ré**  
 On t'invite à la magie Y'a pas de raccourci

**La** **Si-**  
 Oublie tes soucis Oh oh oh oh oh oh

**Sol**  
 Feel the magic in the air ...

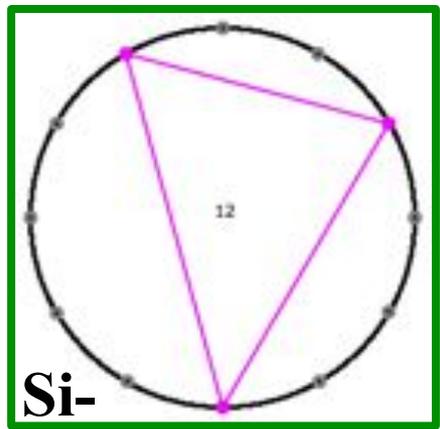
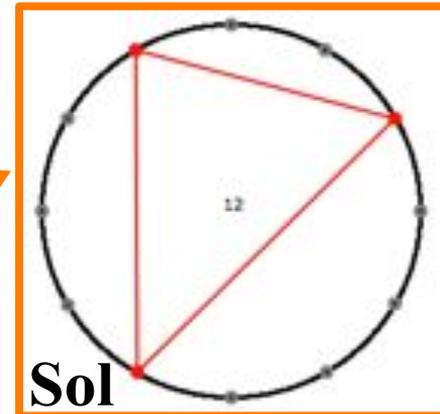
	<b>Fa</b> 		<b>Fa-</b> 
<b>Do</b> 	<b>Sol</b> 	<b>Do-</b> 	<b>Sol-</b> 
<b>Re</b> 	<b>La</b> 	<b>Re-</b> 	<b>La-</b> 
<b>Mi</b> 	<b>Si</b> 	<b>Mi-</b> 	<b>Si-</b> 





**ACCORDS MAJEURS**

**ACCORDS MINEURS**



**MAGIC IN THE AIR**

**Sol**

**Ré**

Feel the magic in the air, Allez, allez, allez

**La**

**Si-**

Levez les mains en l'air Allez, allez, allez (x2)

(x4 avec toutes les voix)

**Ré**

Comme d'habitude on est calés

**La** **Si-**

Comme toujours ça va aller

**Sol** **Ré**

On sème l'ambiance à gogo

**La** **Si-**

Tous ensemble on fait le show

**Sol**

**Ré**

On t'invite à la magie Y'a pas de raccourci

**La**

**Si-**

Oublie tes soucis Viens faire la folie

**Sol**

**Ré**

On t'invite à la magie Y'a pas de raccourci

**La**

**Si-**

Oublie tes soucis Oh oh oh oh oh oh

**Sol**

Feel the magic in the air ...

	<b>Fa</b>		<b>Fa-</b>
<b>Do</b>	<b>Sol</b>	<b>Do-</b>	<b>Sol-</b>
<b>Re</b>	<b>La</b>	<b>Re-</b>	<b>La-</b>
<b>Mi</b>	<b>Si</b>	<b>Mi-</b>	<b>Si-</b>



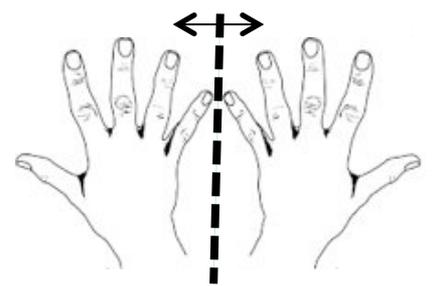
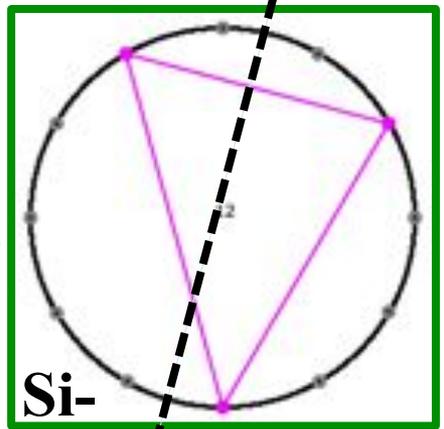
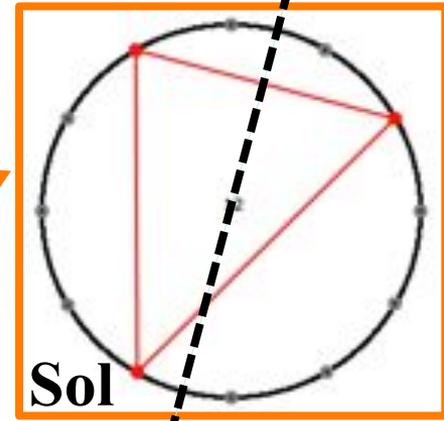
**ACCORDS MAJEURS**

**ACCORDS MINEURS**

**MAGIC IN THE AIR**

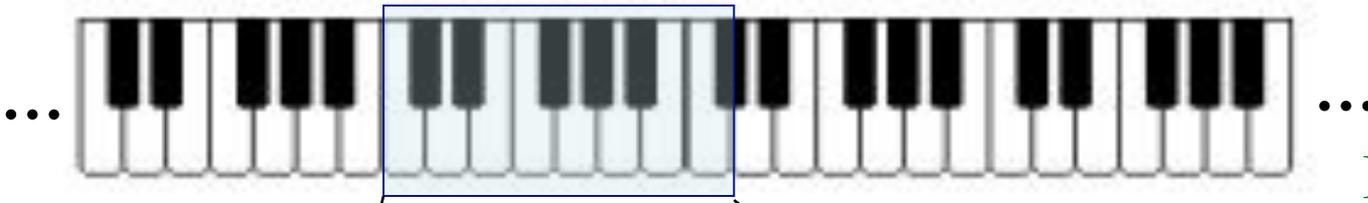
<b>Sol</b>	<b>Ré</b>
Feel the magic in the air,	Allez, allez, allez
<b>La</b>	<b>Si-</b>
Levez les mains en l'air	Allez, allez, allez
(x2)	
(x4 avec toutes les voix)	
<b>Ré</b>	
Comme d'habitude on est calés	
<b>La</b>	<b>Si-</b>
Comme toujours ça va aller	
<b>Sol</b>	<b>Ré</b>
On sème l'ambiance à gogo	
<b>La</b>	<b>Si-</b>
Tous ensemble on fait le show	
<b>Sol</b>	<b>Ré</b>
On t'invite à la magie Y'a pas de raccourci	
<b>La</b>	<b>Si-</b>
Oublie tes soucis Viens faire la folie	
<b>Sol</b>	<b>Ré</b>
On t'invite à la magie Y'a pas de raccourci	
<b>La</b>	<b>Si-</b>
Oublie tes soucis Oh oh oh oh oh oh	
<b>Sol</b>	
Feel the magic in the air ...	

	<b>Fa</b>		<b>Fa-</b>
<b>Do</b>	<b>Sol</b>	<b>Do-</b>	<b>Sol-</b>
<b>Re</b>	<b>La</b>	<b>Re-</b>	<b>La-</b>
<b>Mi</b>	<b>Si</b>	<b>Mi-</b>	<b>Si-</b>





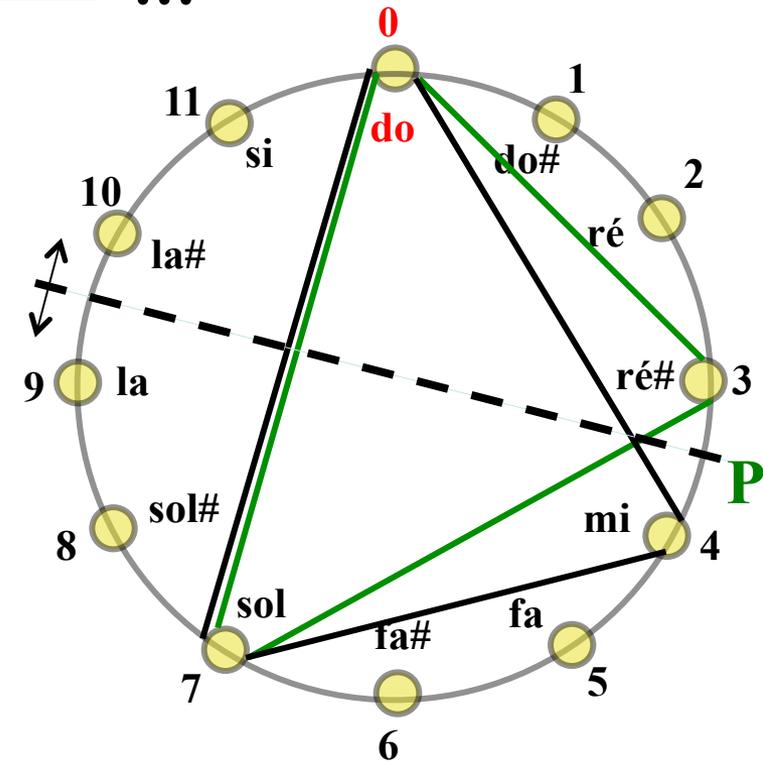
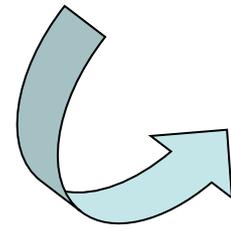
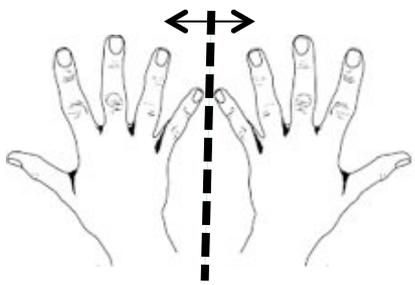
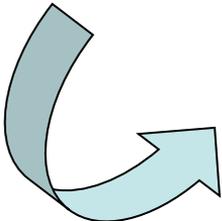
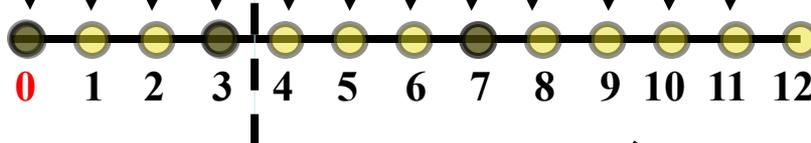
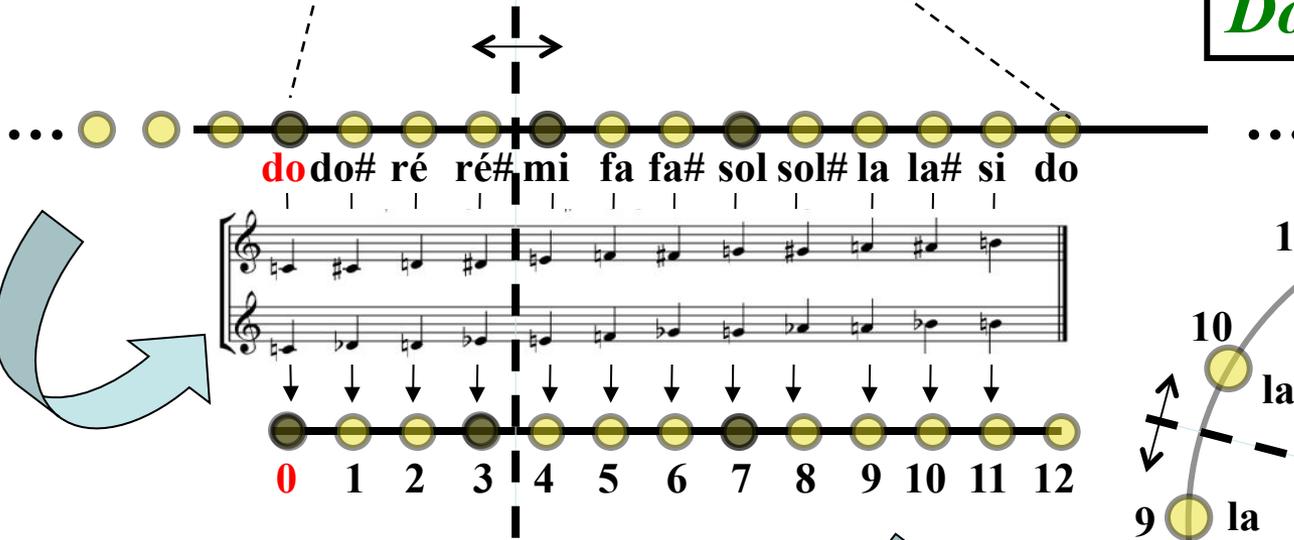
# Les inversions sont des symétries axiales



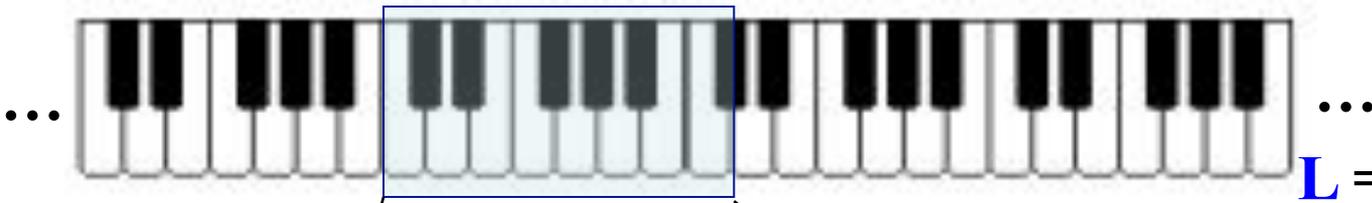
**P** comme **parallèle**

*Do* maj = {0,4,7}

*Do* min = {0,3,7}

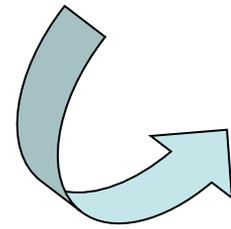
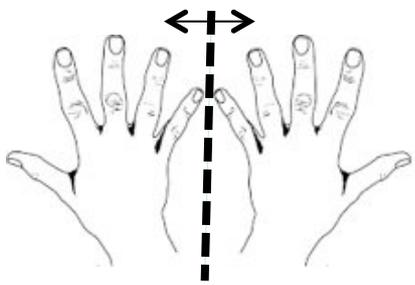
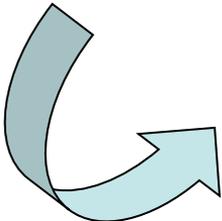
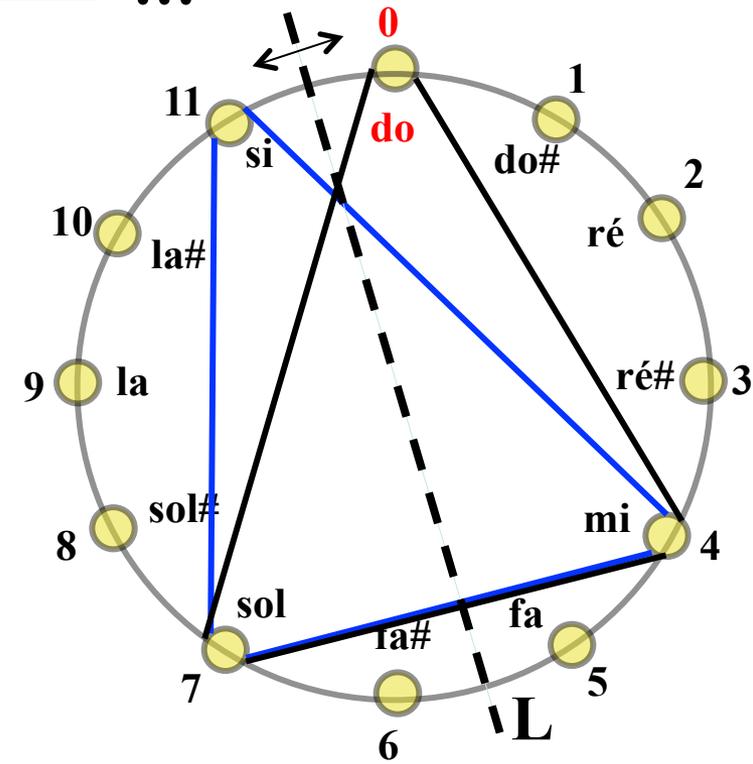
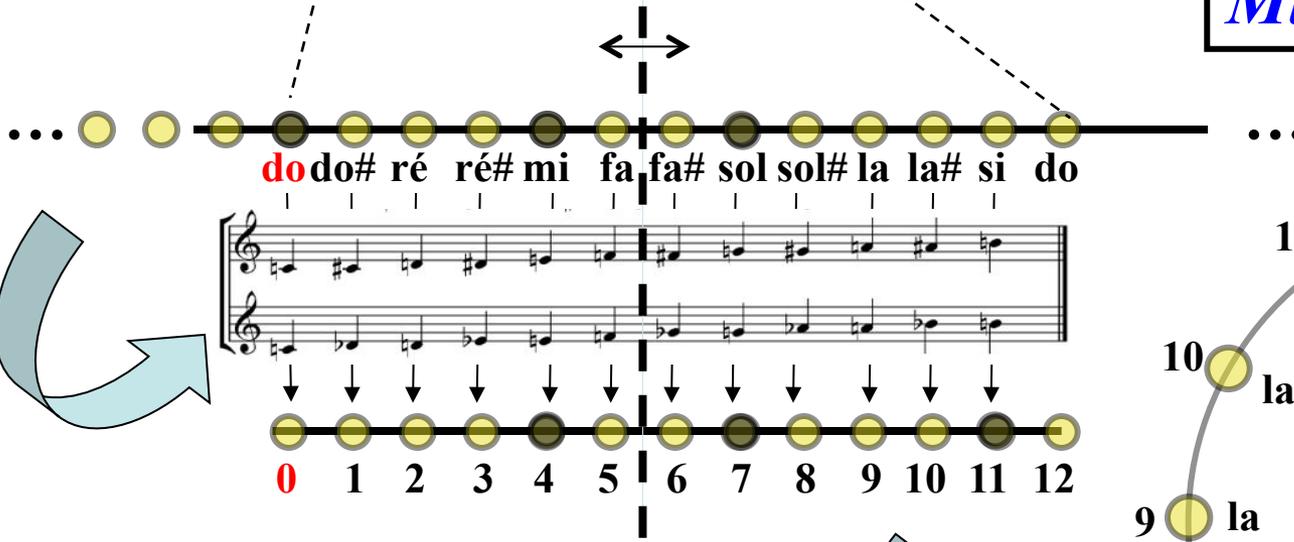


# Les inversions sont des symétries axiales



**L = Leading Tone**

*Do* maj = {0,4,7}  
*Mi* min = {4,7,11}



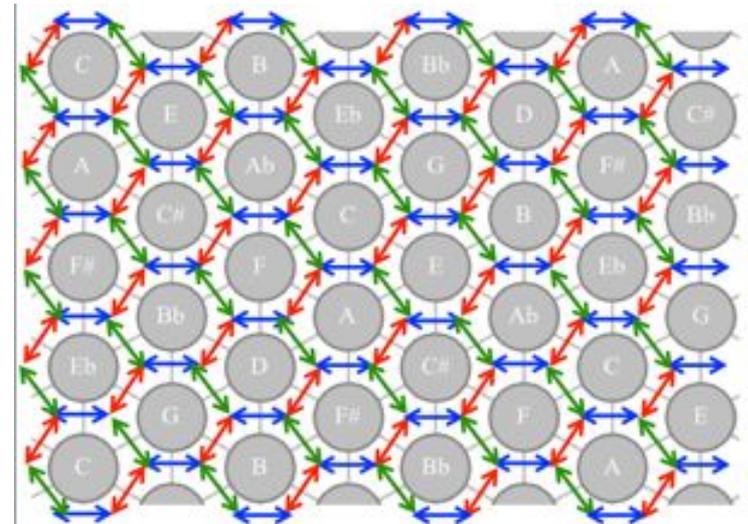
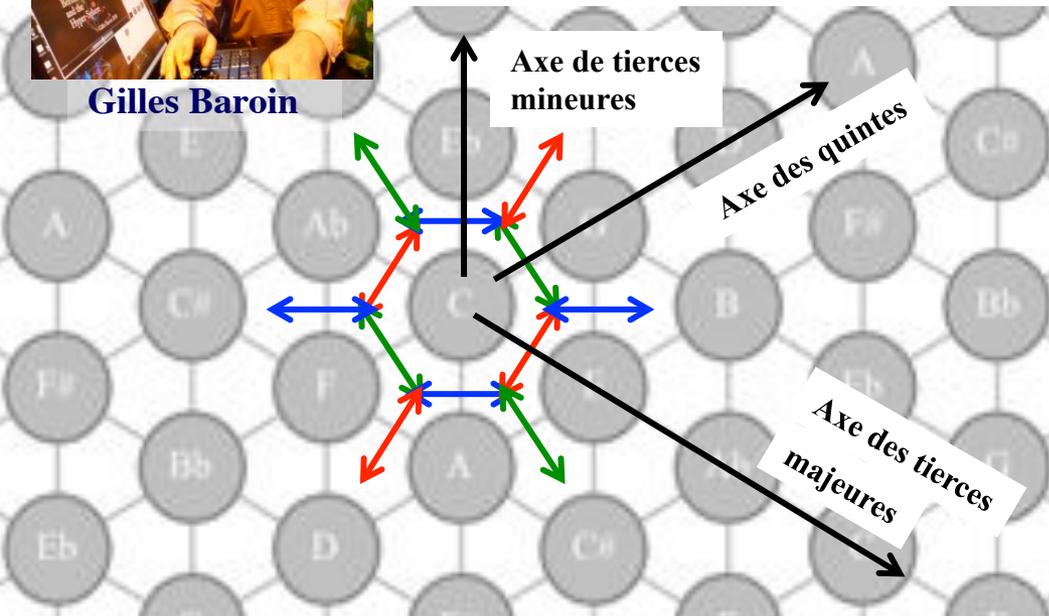
# Le Tonnetz (ou nid musical d'abeilles)



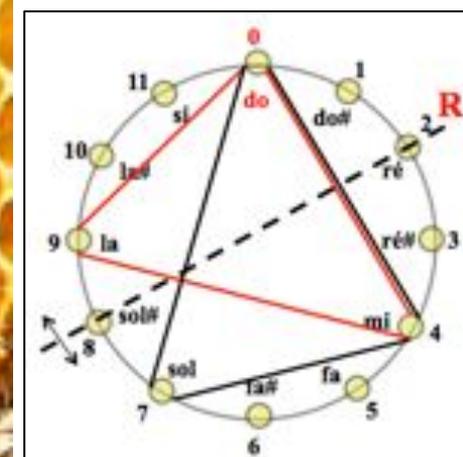
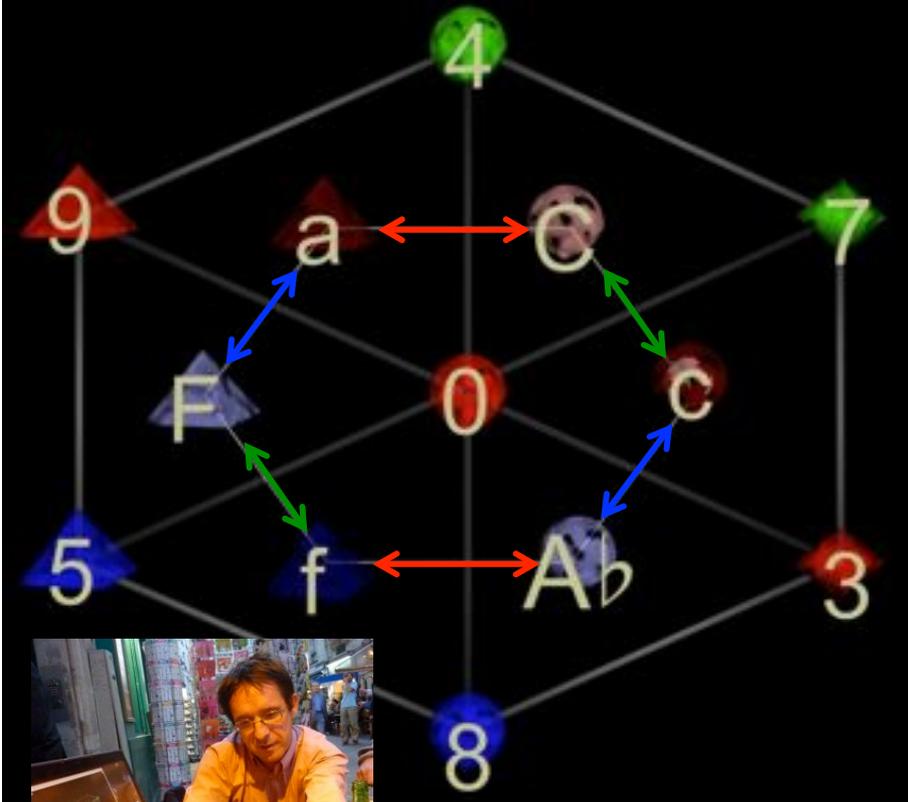
*Speculum Musicum* (Euler, 1773)



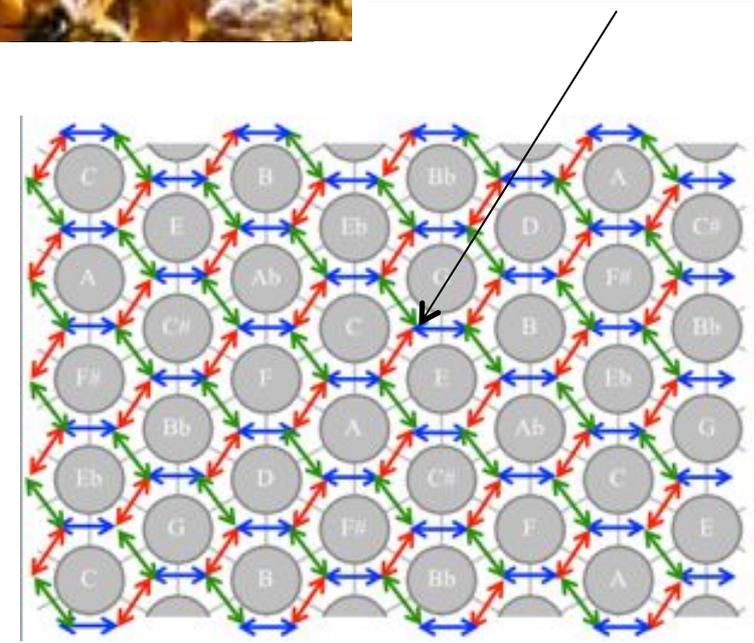
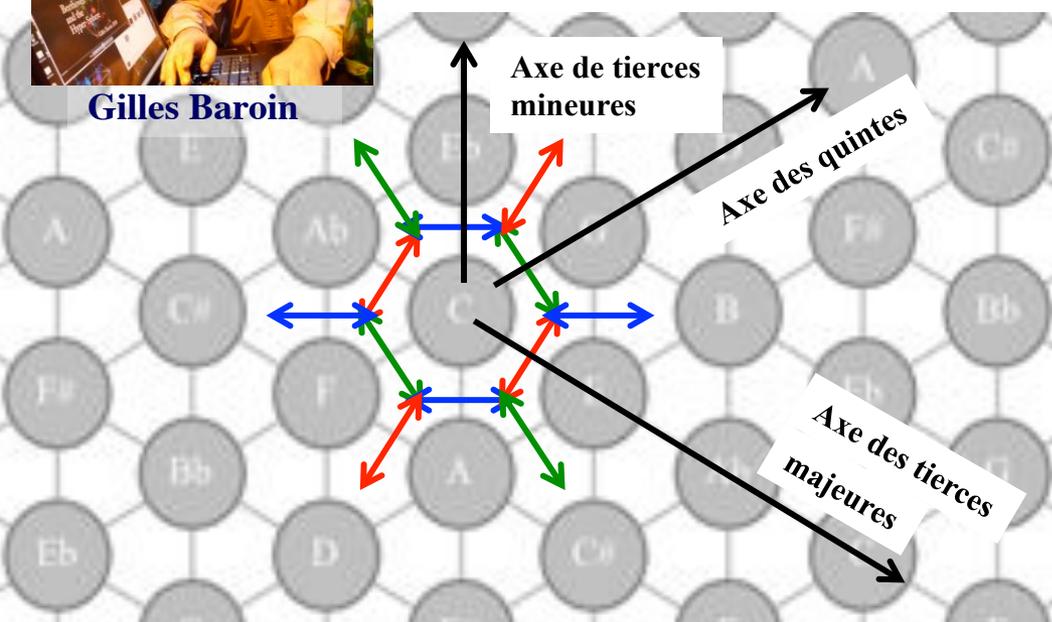
Gilles Baroin



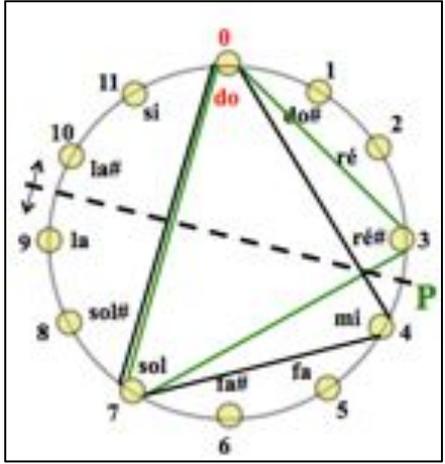
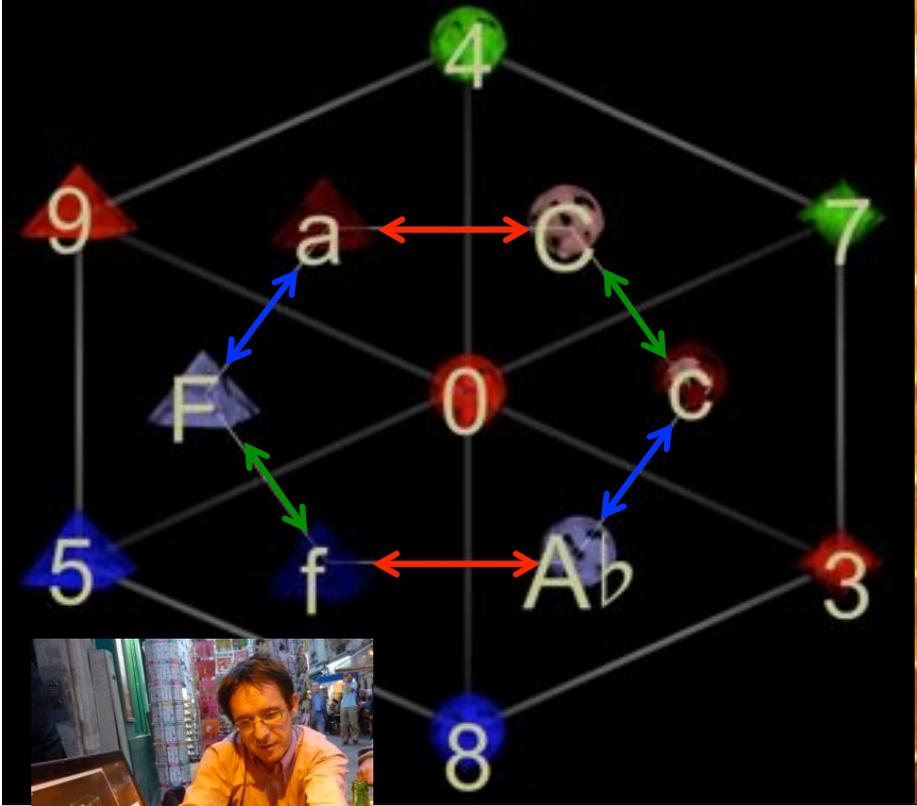
# Le Tonnetz (ou nid musical d'abeilles)



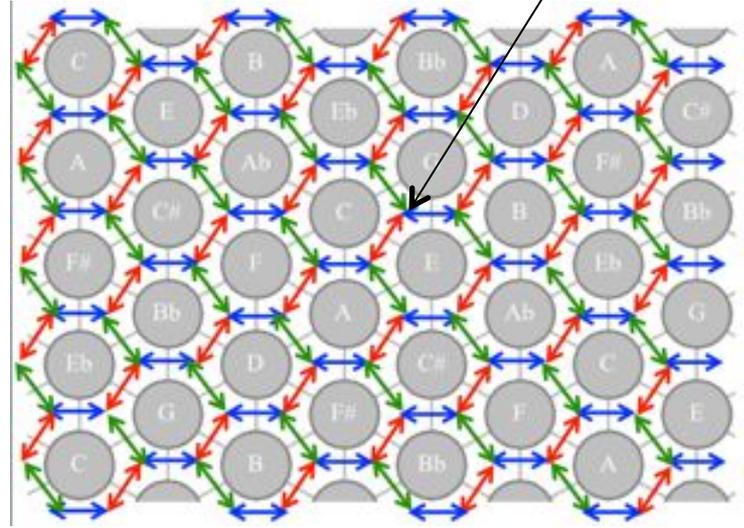
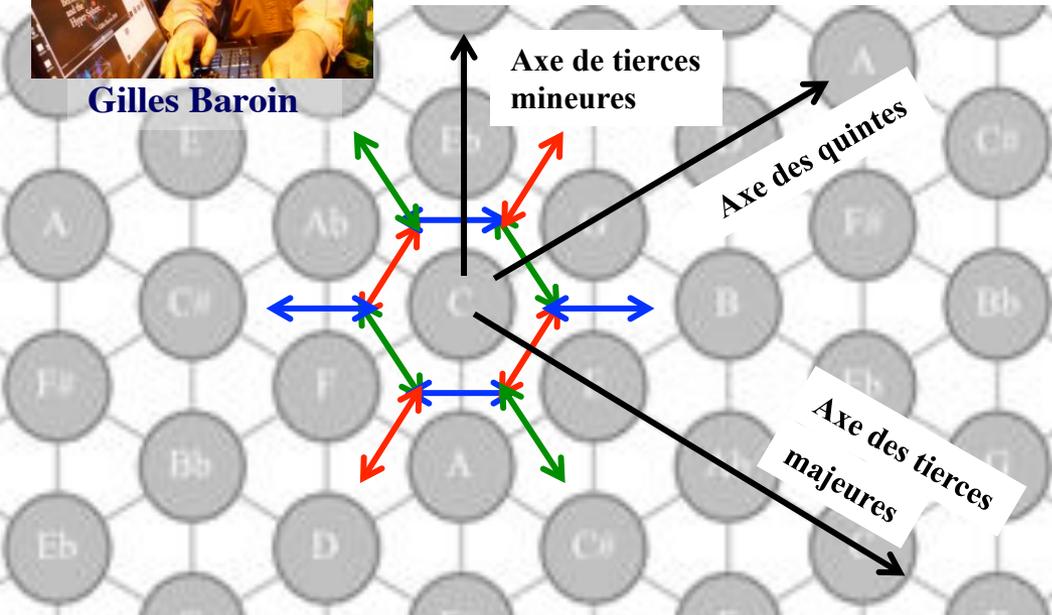
Gilles Baroin



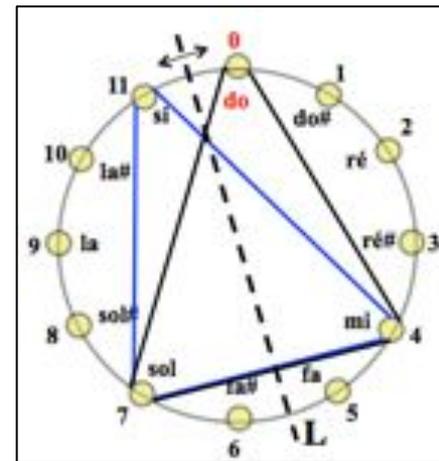
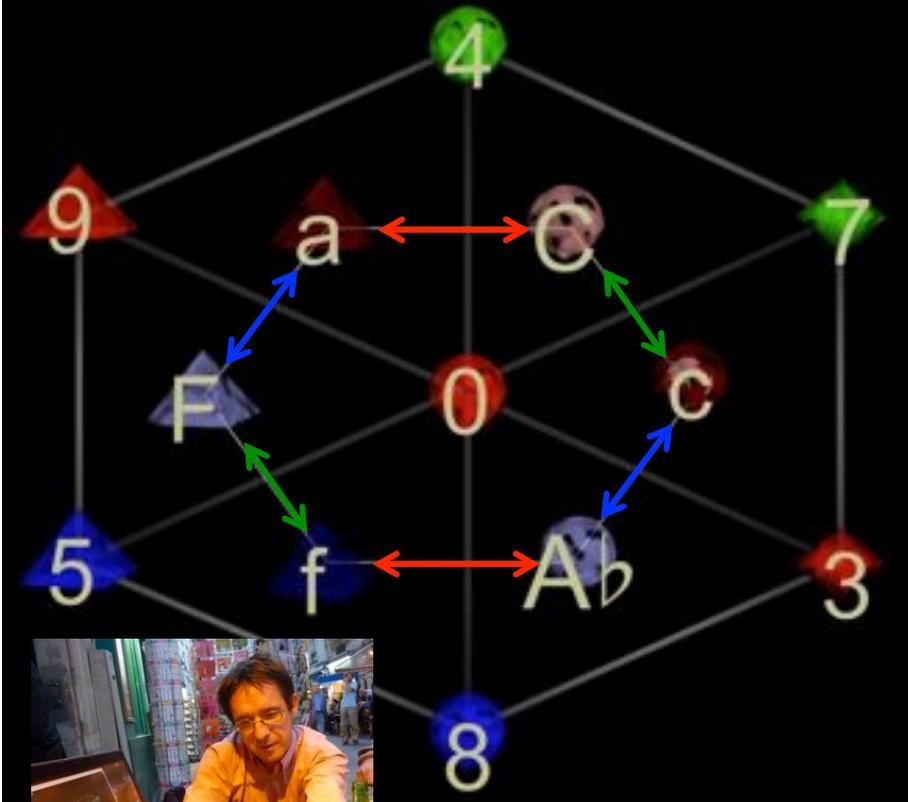
# Le Tonnetz (ou nid musical d'abeilles)



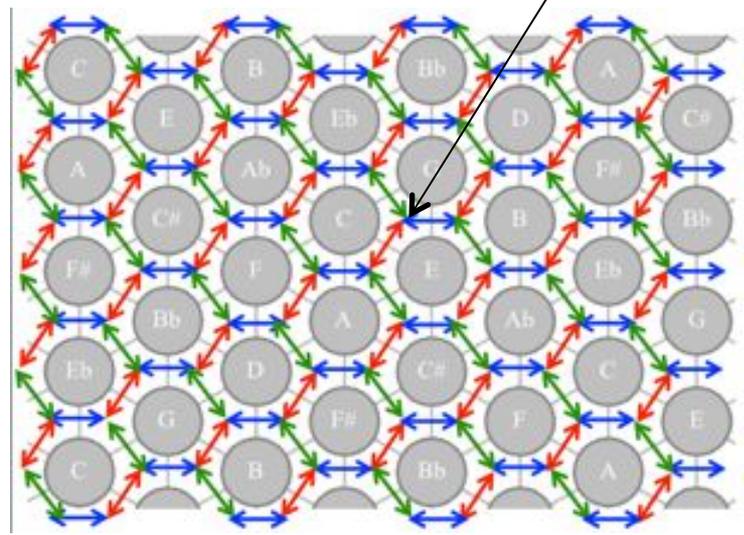
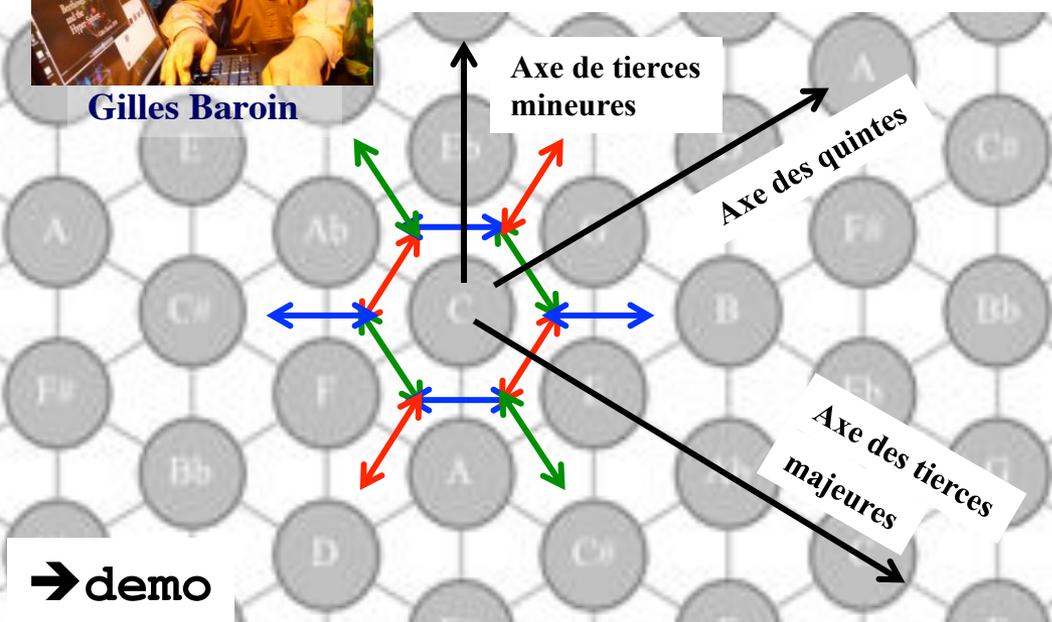
Gilles Baroin



# Le Tonnetz (ou nid musical d'abeilles)

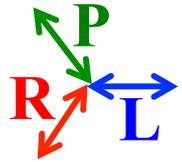


Gilles Baroin

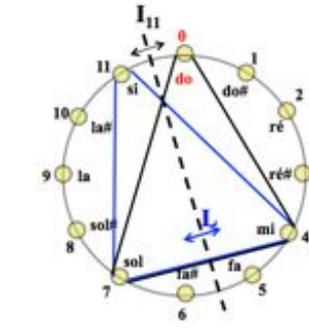
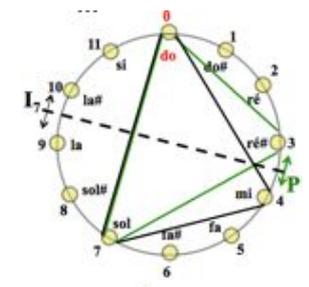
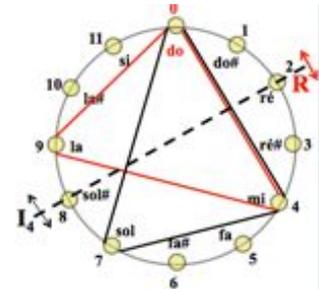
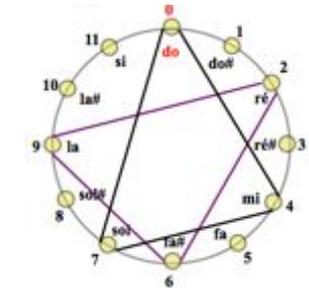
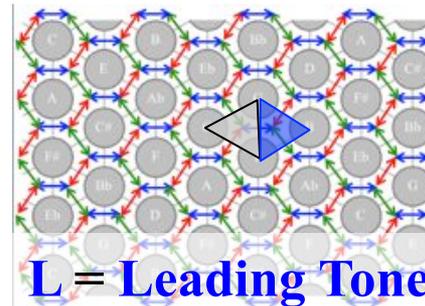
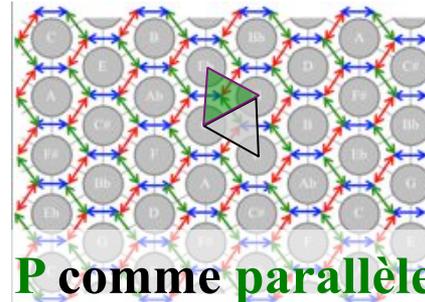
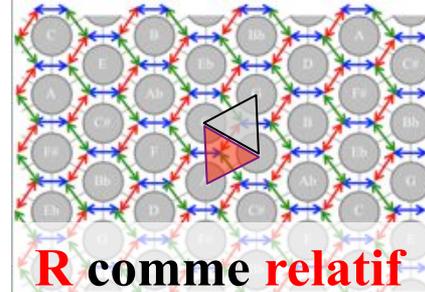
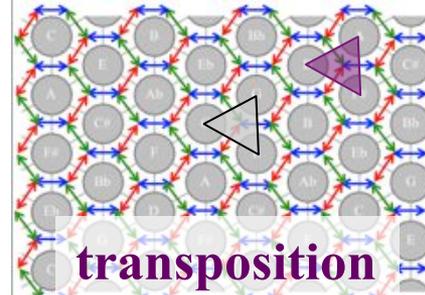
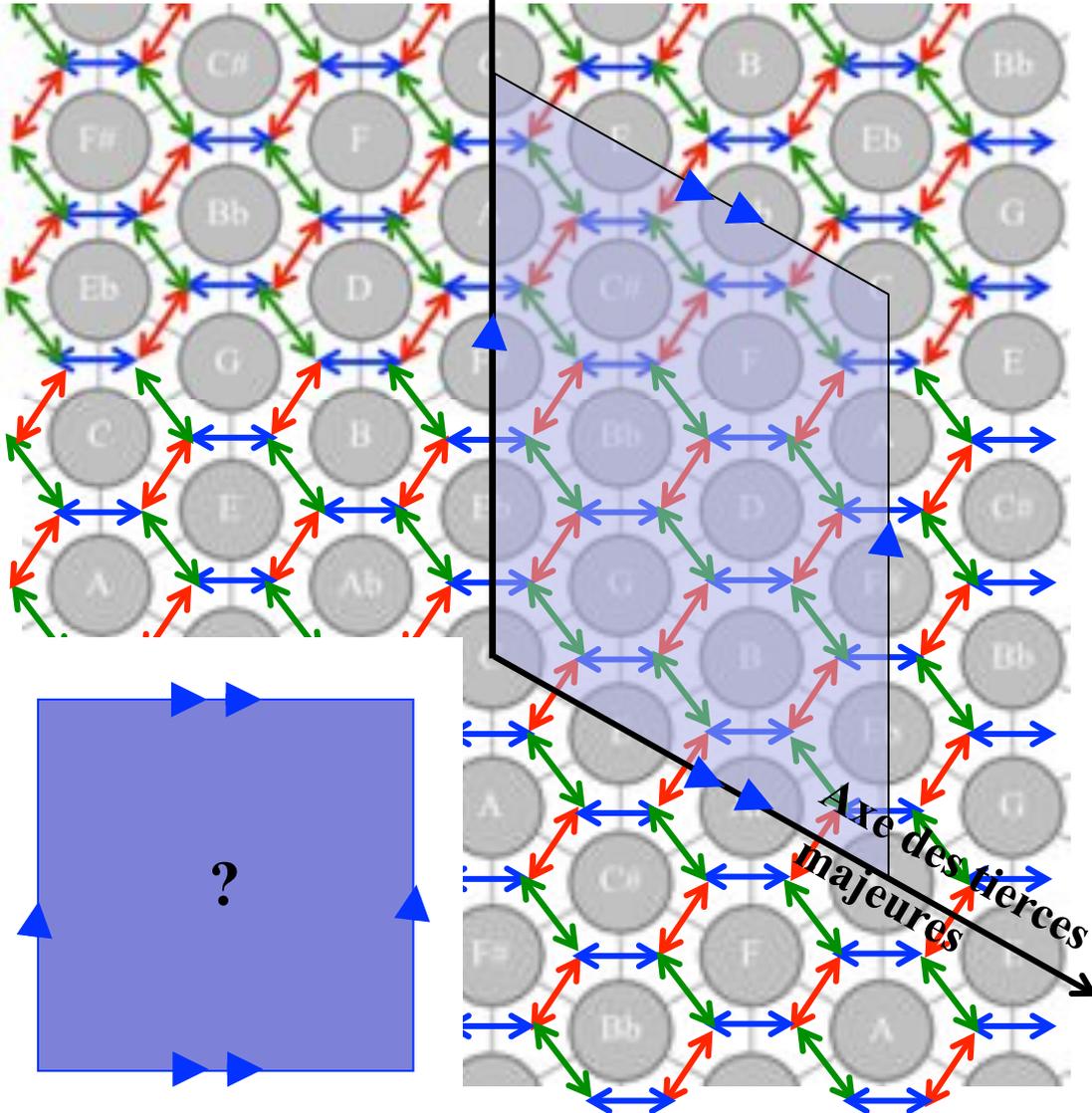


→ demo

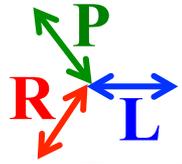
# Le Tonnetz et ses symétries



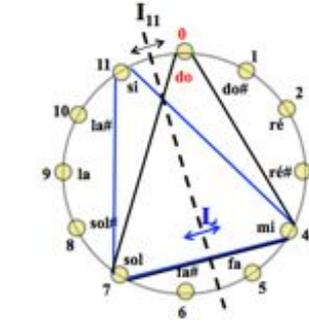
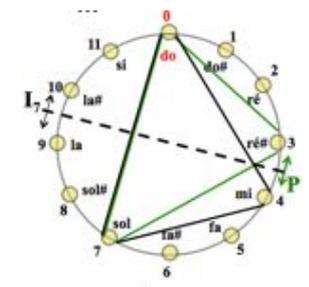
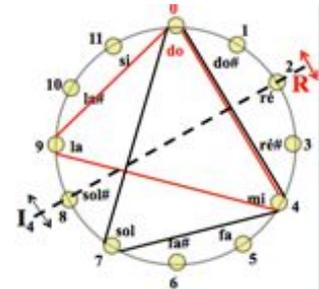
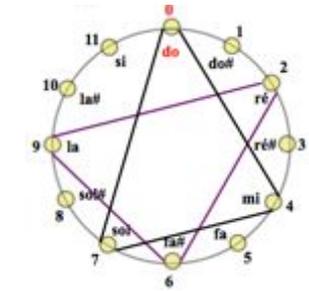
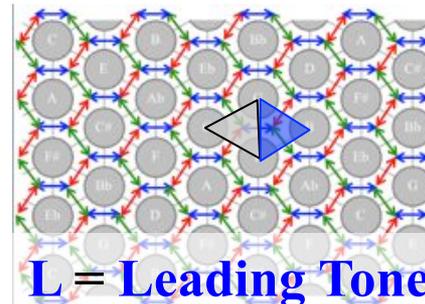
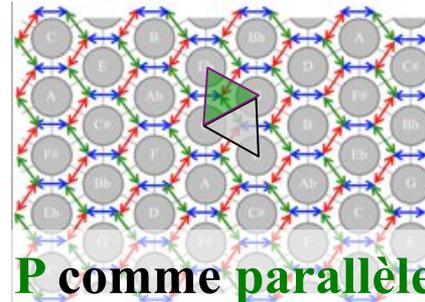
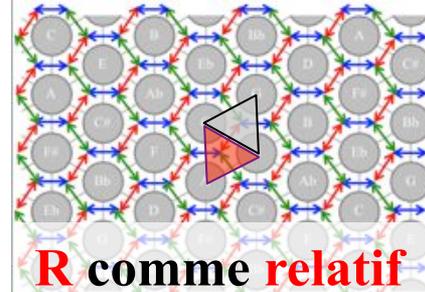
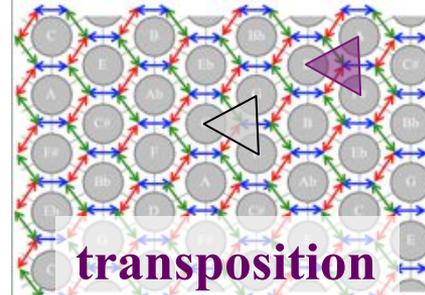
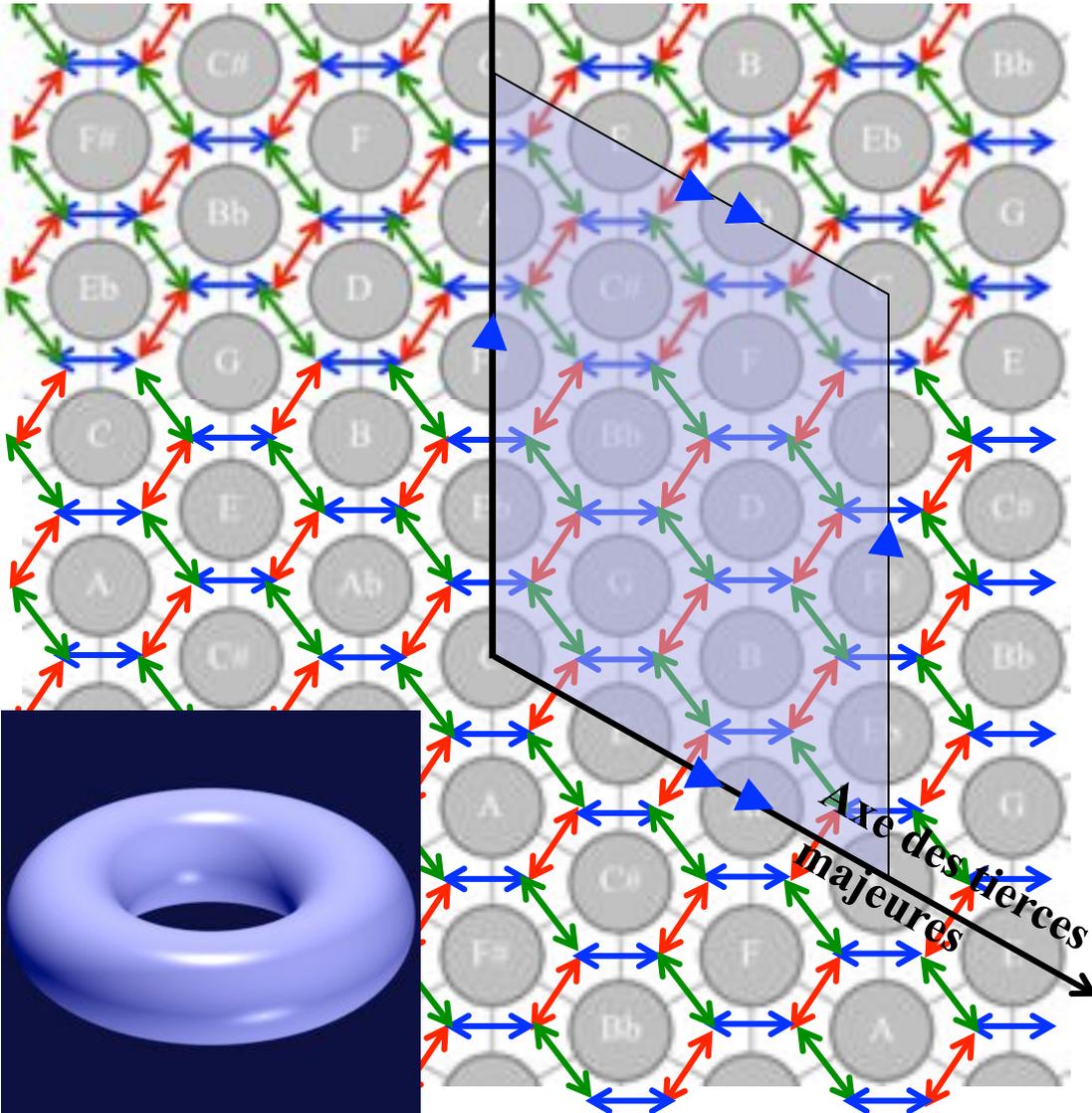
Axe de tierces mineures



# Le Tonnetz et ses symétries



Axe de tierces mineures





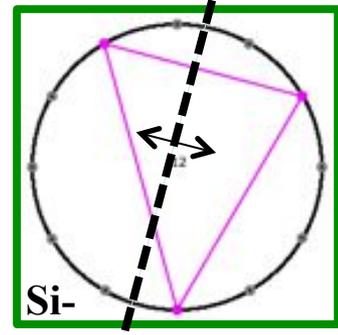
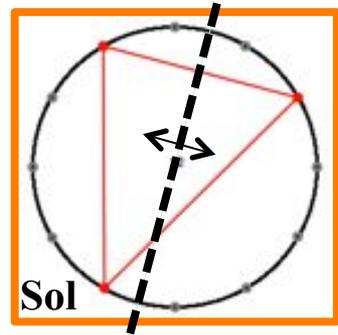
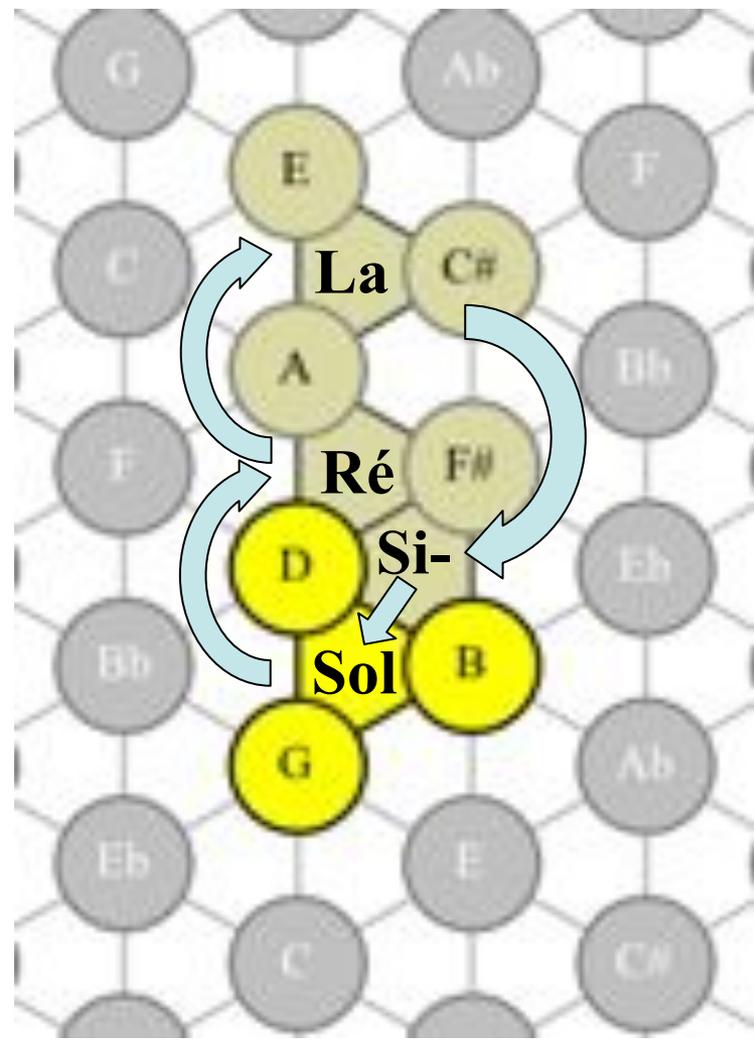
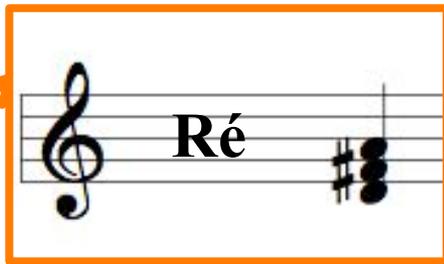
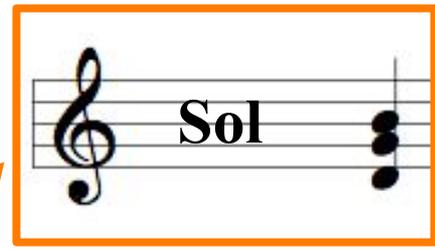
**MAGIC IN THE AIR**

**Sol**                      **Ré**  
**La**                        **Si-**

Feel the magic in the air. Allez, allez, allez  
 Levez les mains en l'air Allez, allez, allez  
 (x2)

(x4 avec toutes les voix)

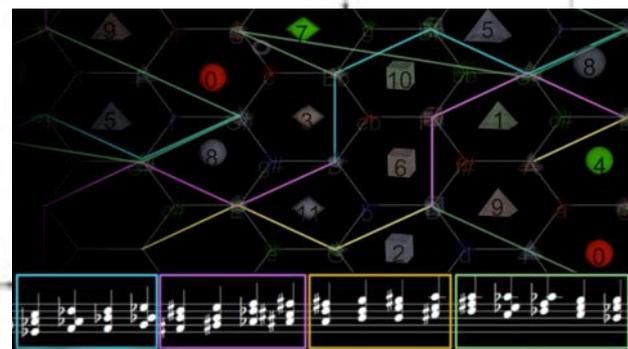
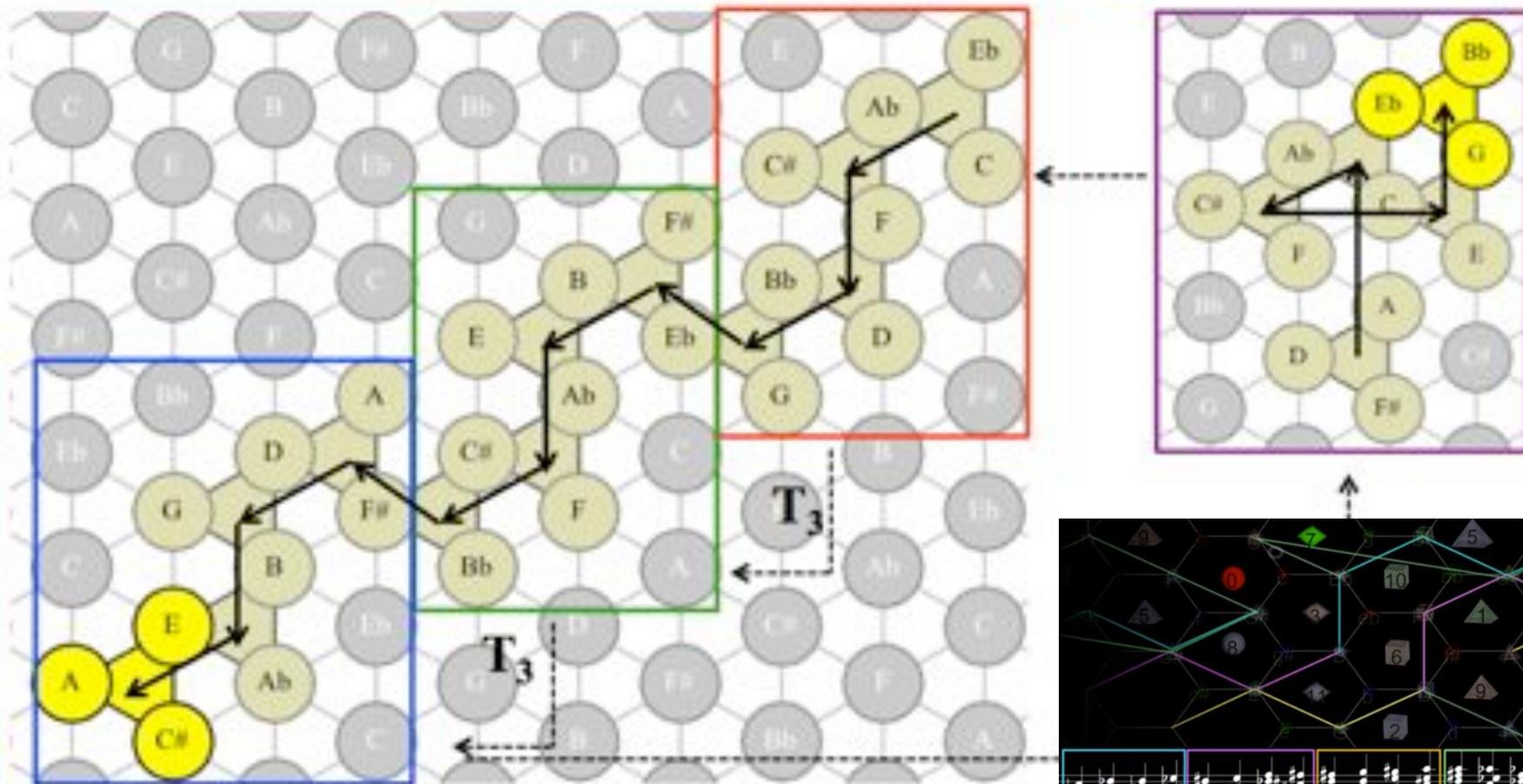
**Ré**  
 Comme d'habitude on est calés  
**La**                      **Si-**  
 Comme toujours ça va aller  
**Sol**                      **Ré**  
 On sème l'ambiance à gogo  
**La**                      **Si-**  
 Tous ensemble on fait le show  
  
**Sol**                      **Ré**  
 On t'invite à la magie Y'a pas de raccourci  
**La**                      **Si-**  
 Oublie tes soucis Viens faire la folie  
**Sol**                      **Ré**  
 On t'invite à la magie Y'a pas de raccourci  
**La**                      **Si-**  
 Oublie tes soucis Oh oh oh oh oh oh  
**Sol**  
 Feel the magic in the air ...



# Harmonies géométriques dans « Madeleine » (Paolo Conte)



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

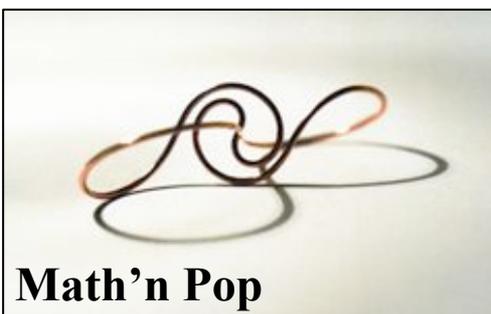
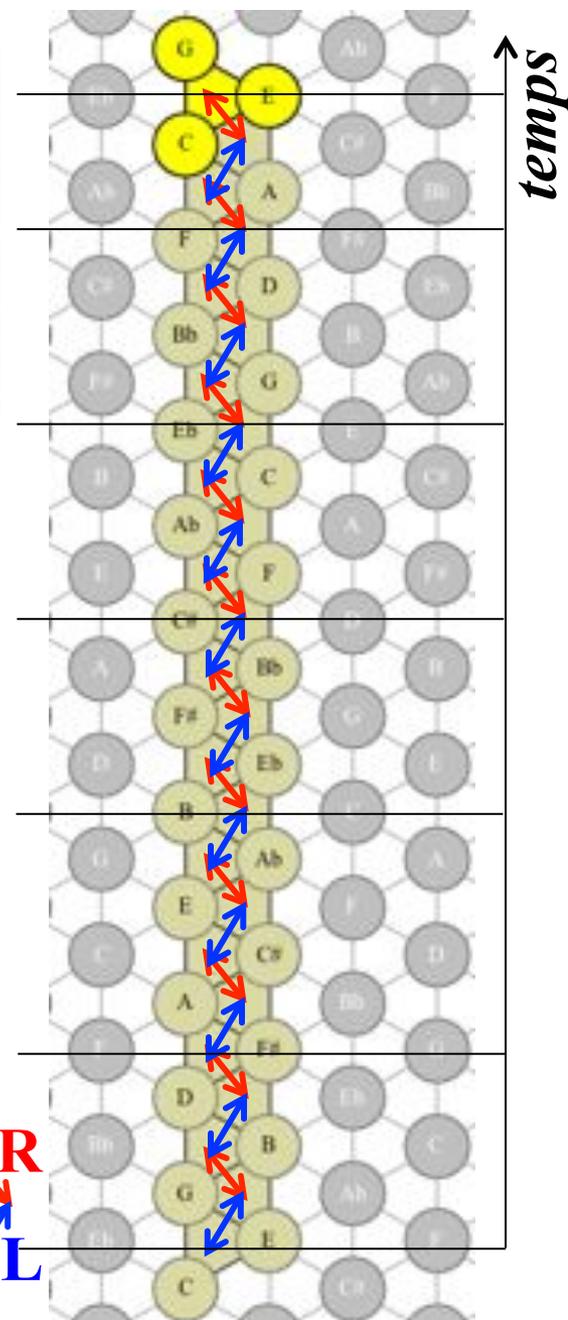
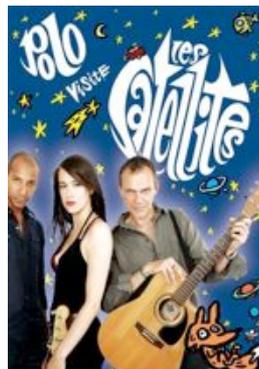




# Le Blé en Herbe

(Pola/Morena/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
	Nager comme un enfant, cheveux au vent
Algues tendres de mille plages	Sous l'océan
Frôlant le ventre des nuages	Du blé en herbe
Cheveux de pluie, dos de poissons	
Qui frissonnent à l'unisson	Marée de fruits au goût amer
	Acide et salée comme la mer
Suivre le bord des continents	
Dans l'océan du blé en herbe	Vers l'ilôt 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



# La sera non è più la tua canzone : chanson hamiltonienne ‘redondante’

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.

*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.*

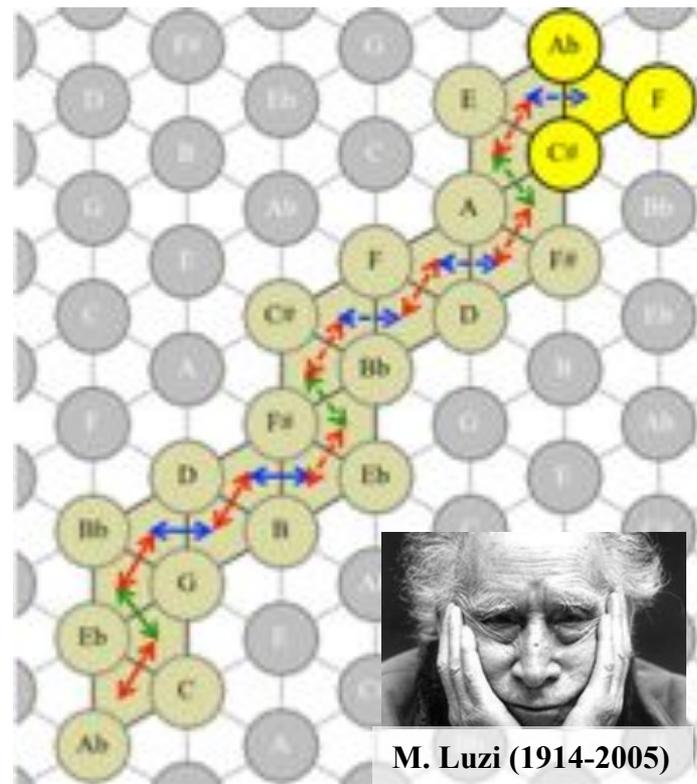
*L'air se tait et le temps derrière toi  
se lève tel une montagne aride  
où plane ton esprit et se perd,  
un vent rare glisse et stagne.*

(tr. Antonia Soulez, philosophe et poète)

**Musique :** M. Andreatta  
**Arrangements et mixage :** M. Bergomi &  
S. Geravini  
(Perfect Music Production)  
**Mastering :** A. Cutolo (Massive Arts  
Studio, Milan)



min. 1'19"



M. Luzi (1914-2005)

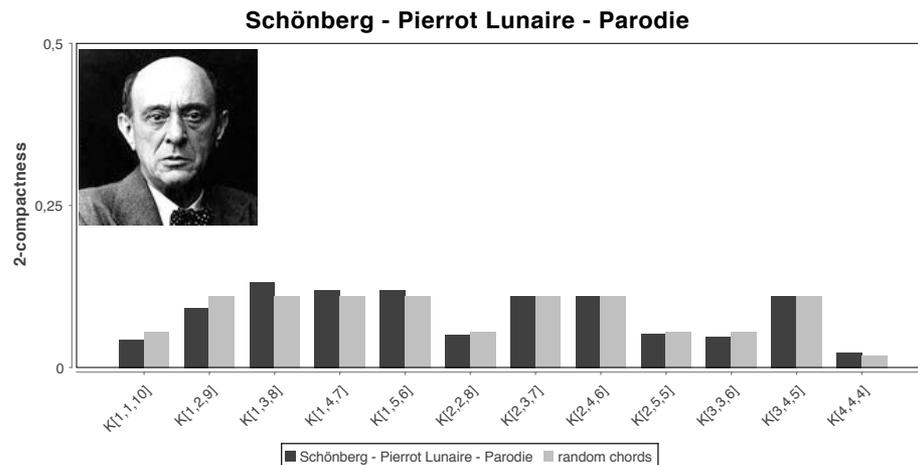
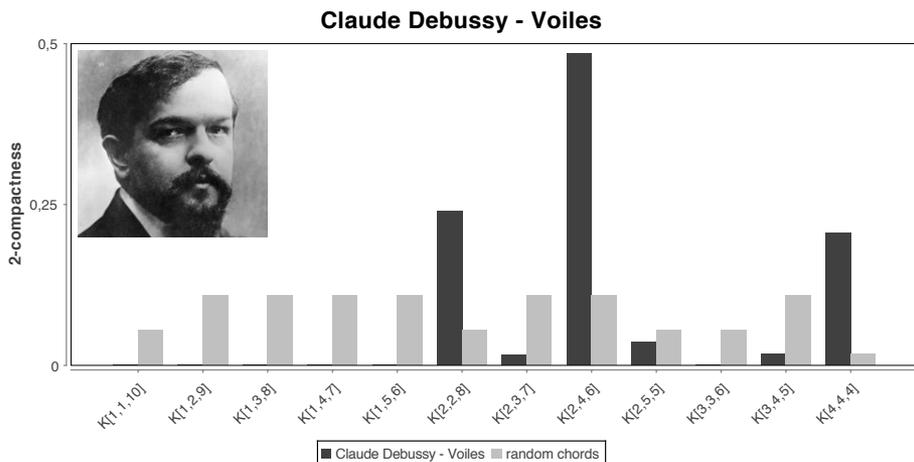
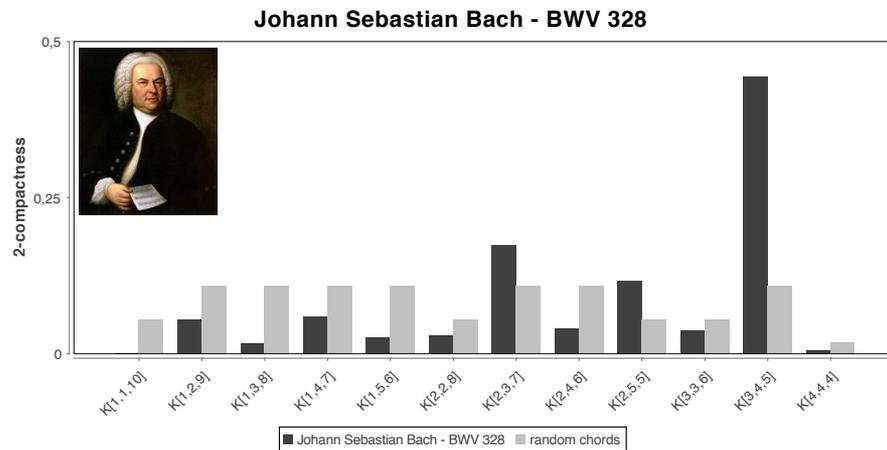
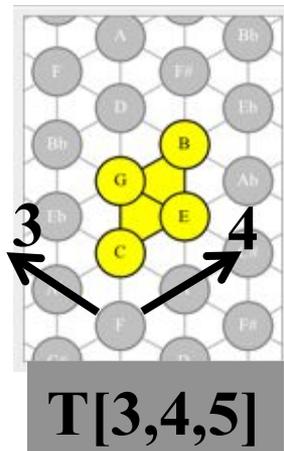
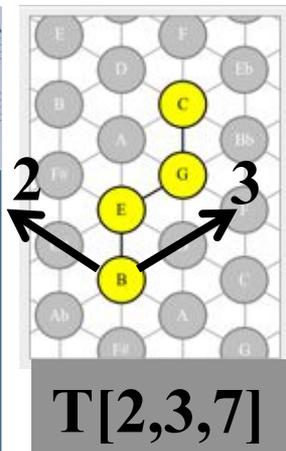
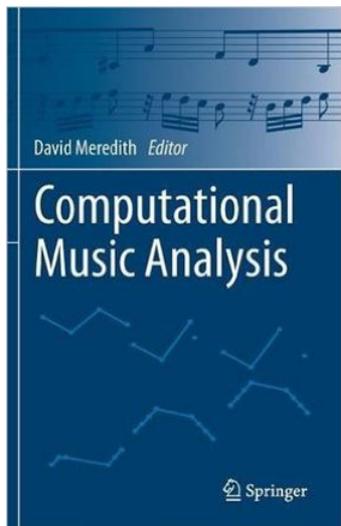






# Le caractère spatial de la « logique musicale »

Bigo L., M. Andreatta, « Musical analysis with simplicial chord spaces », in D. Meredith (ed.), *Computational Music Analysis*, Springer, 2015



# Le style...c'est l'espace !

The diagram illustrates the concept of 'style' as 'space' in music. It shows two musical styles,  $T[3,4,7]$  and  $T[2,3,7]$ , represented by grid patterns of circles and corresponding musical notation. A central diagram shows a transformation from a rectangular grid to a curved, funnel-like shape. Arrows indicate the relationship between the grid patterns and the musical notation below them.

On the left, a grid pattern labeled  $T[3,4,7]$  is shown with a vertical arrow labeled '3' pointing up and a diagonal arrow labeled '4' pointing down-right. Below it is a musical score in treble and bass clefs with a common time signature (C). A speaker icon is positioned below the score.

In the center, a diagram shows a rectangular grid with a horizontal axis labeled 0 to 6 and a vertical axis labeled a, b, c, d, e. An arrow points to a curved, funnel-like shape with a horizontal axis labeled 0 to 6 and a vertical axis labeled a, b, c, d, e.

On the right, a grid pattern labeled  $T[2,3,7]$  is shown with a vertical arrow labeled '2' pointing up and a diagonal arrow labeled '3' pointing down-right. Below it is a musical score in treble and bass clefs with a common time signature (C). A speaker icon is positioned below the score.



# Transformations stylistiques sur les Beatles

