

# Harmonie dans l'univers

*Entre Sciences et musique*

Jean-Philippe UZAN



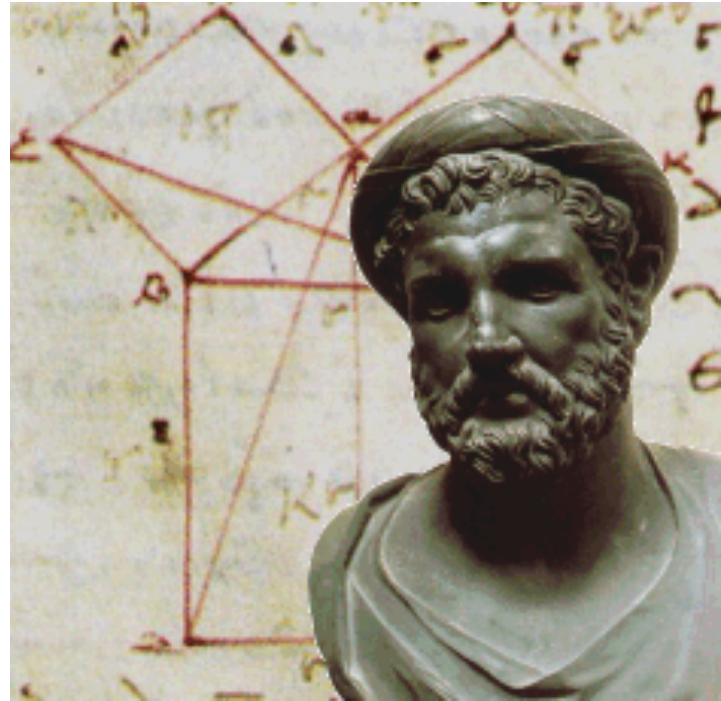
Il semble que, comme les yeux ont été formés pour l'astronomie, les oreilles l'ont été de même pour le mouvement harmonique et que ces sciences sont sœurs (αδελφαι), comme le disent les Pythagoriciens, et comme nous l'admettons avec eux.

Platon, *La République*, VII, 530



Πυθαγόρας

*Musei Capitolini, Roma, Italy: Roman copy of the greek original*





*Pythagore a transformé le bruit en information.*

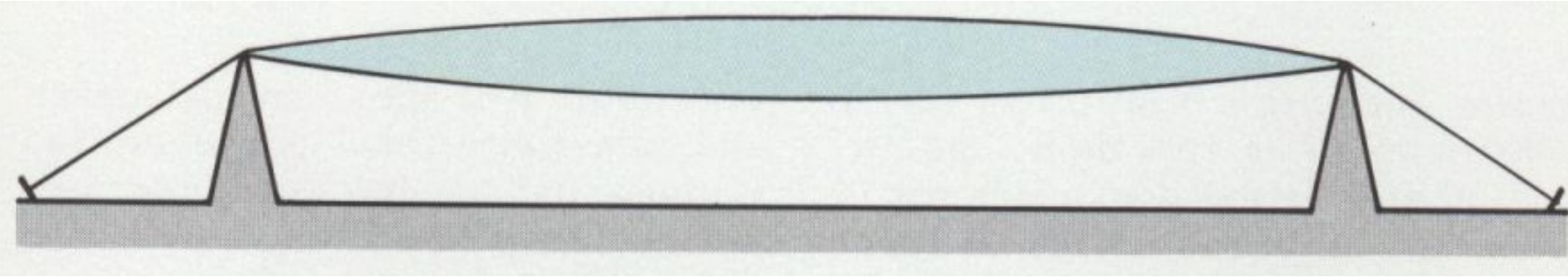
Arthur Kostler



*De Theorica musicae* de Franchino Gaffurio, 1492 (1480?)



# Une très belle expérience



**Fréquence:** nombre de fois qu'une corde vibre en une seconde.

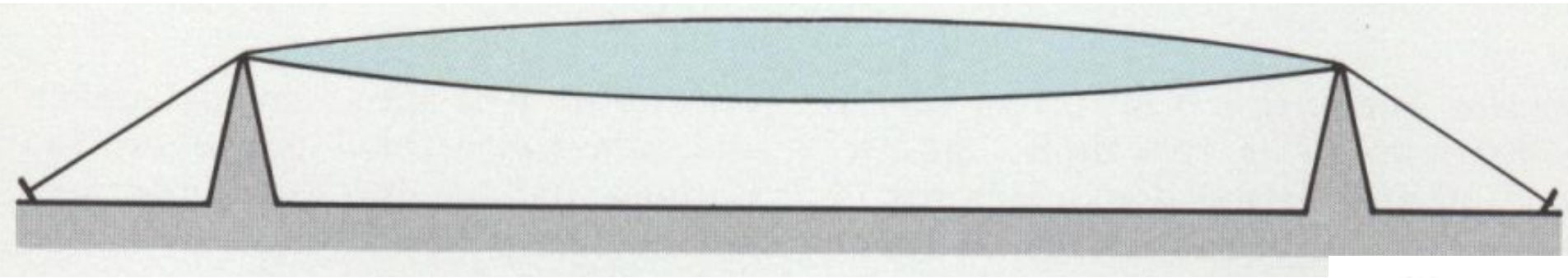
On la mesure dans une unité appelée Hertz (Hz)

Par exemple, une corde qui vibre 440 fois par seconde a une fréquence de 440 Hz.

C'est la fameuse note La



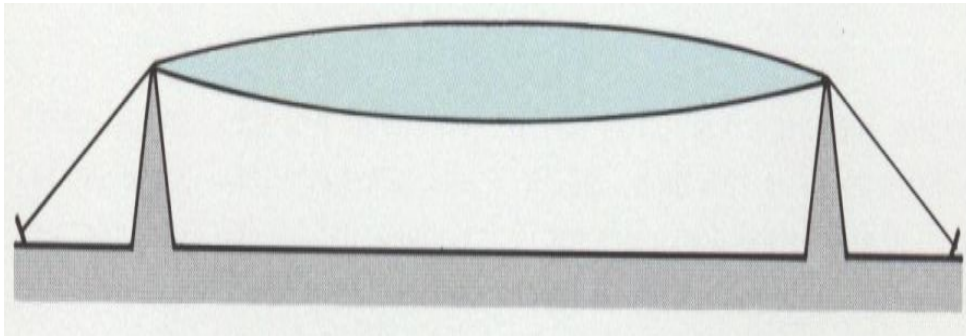
# Une très belle expérience



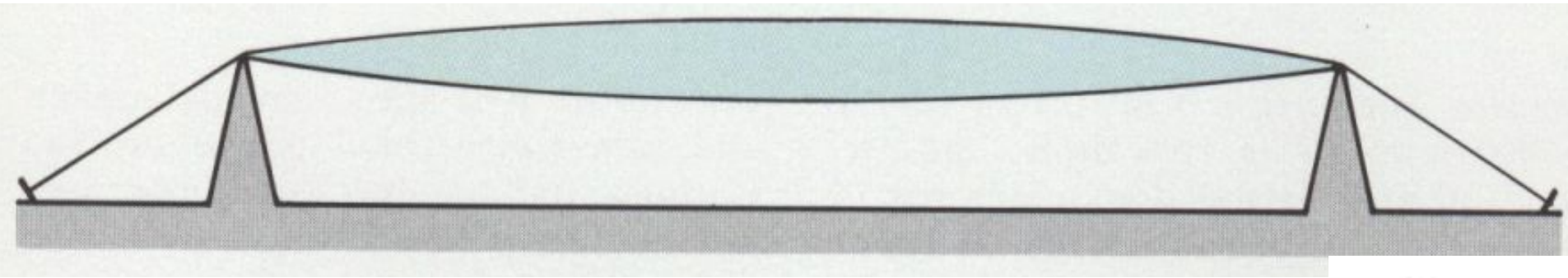
440 Hz – La<sup>4</sup>



Pinçons la corde au milieu



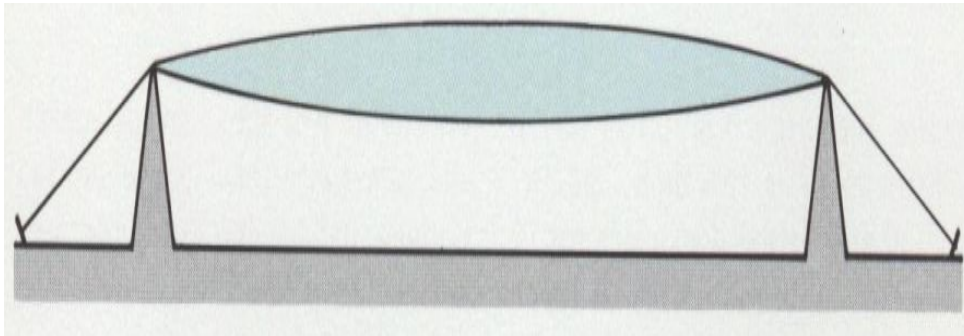
# Une très belle expérience



440 Hz – La<sup>4</sup>



Pinçons la corde au milieu

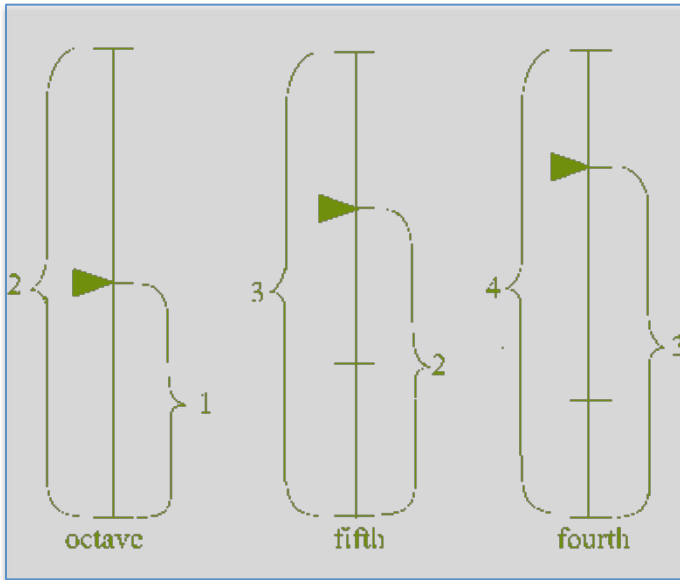


880 Hz – La<sup>5</sup>



Octave = longueur/2 = 2 x fréquence

# La gamma pythagoricienne



1/2: octave

2/3: quinte

3/4: quarte

Il existe une relation étonnante entre les accords « harmonieux » et les nombres entiers.

L'arithmétique des sons:

$$\frac{3}{4} \times \frac{2}{3} = \frac{1}{2}$$

quarte + quinte = octave



↗ quinte ascendante      ↓ changement d'octave

do sol ré la mi si fa# do#

do# sol# ré# la# fa mi# si# do# octave de référence

Quinte suivante:  $\times (2/3)$   
 Changement d'octave:  $\times (2)$

note	do	ré	mi	fa	sol	la	si	do
Rapport de fréquences	1	8/9	64/81	3/4	2/3	16/27	128/243	1/2

$$\left(\frac{3}{2}\right)^{12} = 2^7$$

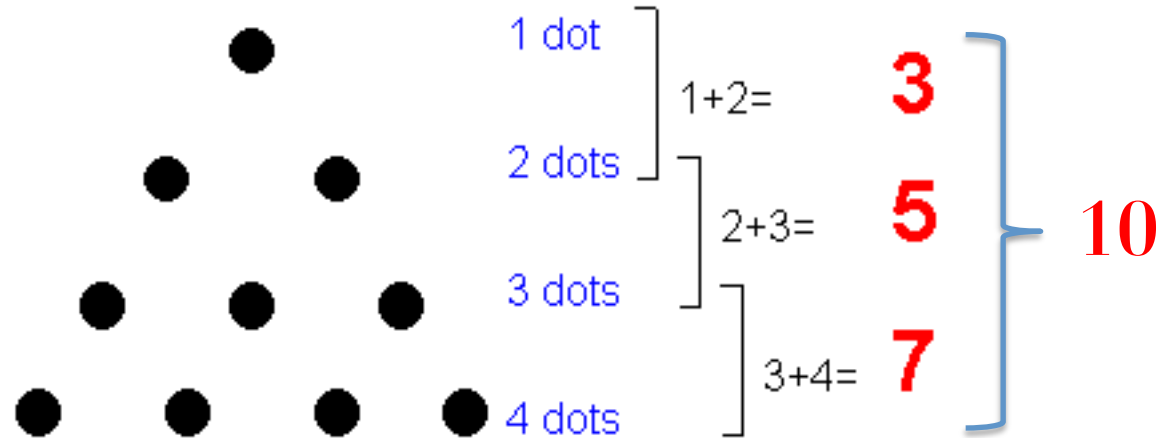
« *La musique est un exercice arithmétique secret et toute personne qui s'y adonne ne réalise pas qu'il manipule des nombres.* »

Leibnitz (1712)

# Tetractys

$$1 + 2 + 3 + 4 = 10$$

1/2: octave  
2/3: quinte  
3/4: quarte



*"Bless us, divine number, thou who generated gods and men! O holy, holy Tetractys, thou that containest the root and source of the eternally flowing creation! For the divine number begins with the profound, pure unity until it comes to the holy four; then it begets the mother of all, the all-comprising, all-bounding, the first-born, the never-swerving, the never-tiring holy ten, the keyholder of all »*

# Harmonia tou kosmou

## Relation entre:

- un phénomène physique (sons), une formulation mathématique (nombres)
- révélée par l'expérience (cordes...)

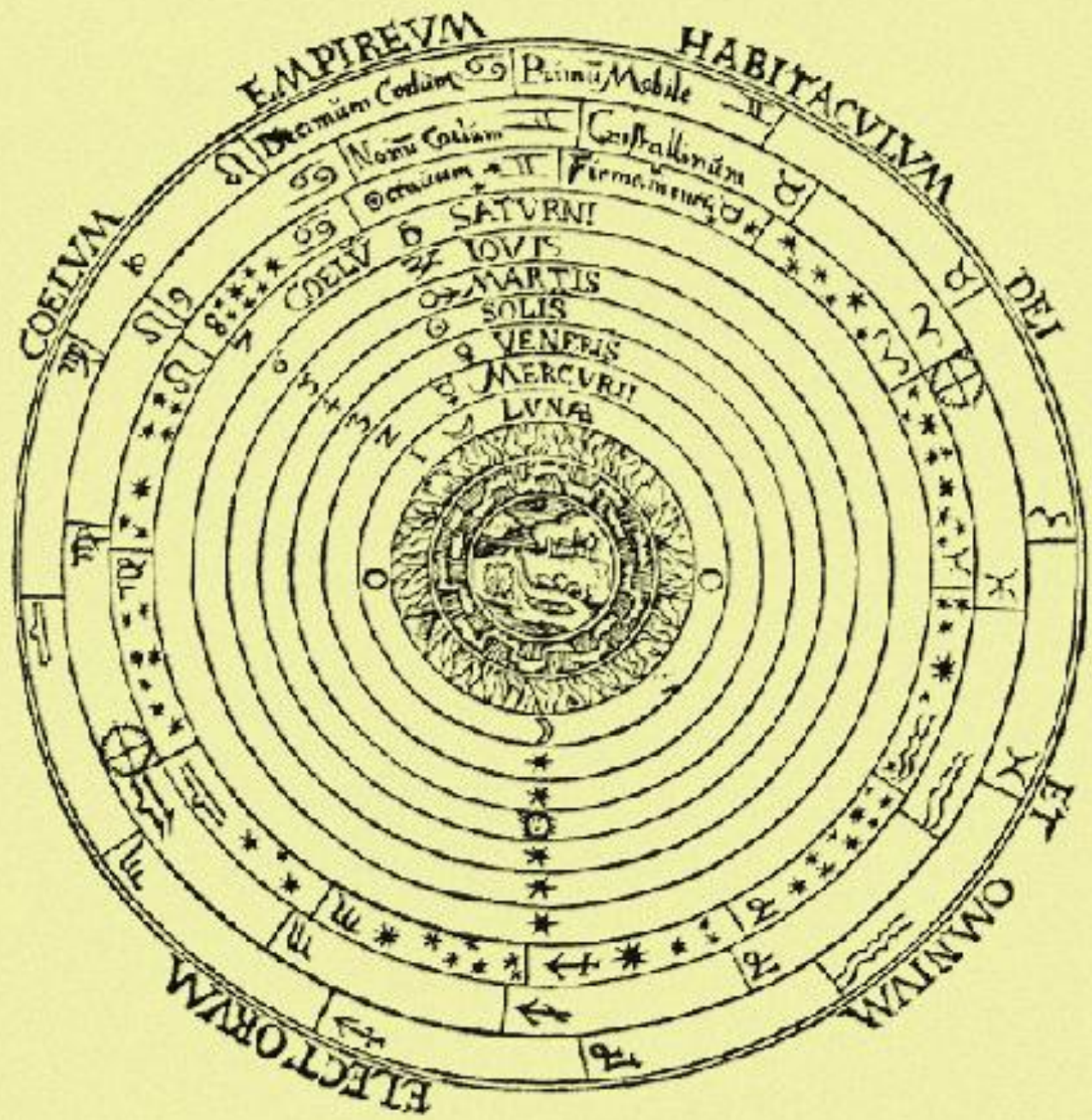
## Mysticisme fondé sur l'harmonie

*Toute chose est nombre. (Aristotle)*

**Kósmos**: mot caractérisant le monde organisé (opposé au chaos)

- univers → *cosmologie/cosmonautes/...*
- beauté → *cosmétique*

Schema huius præmissæ diuisionis Sphærarum.



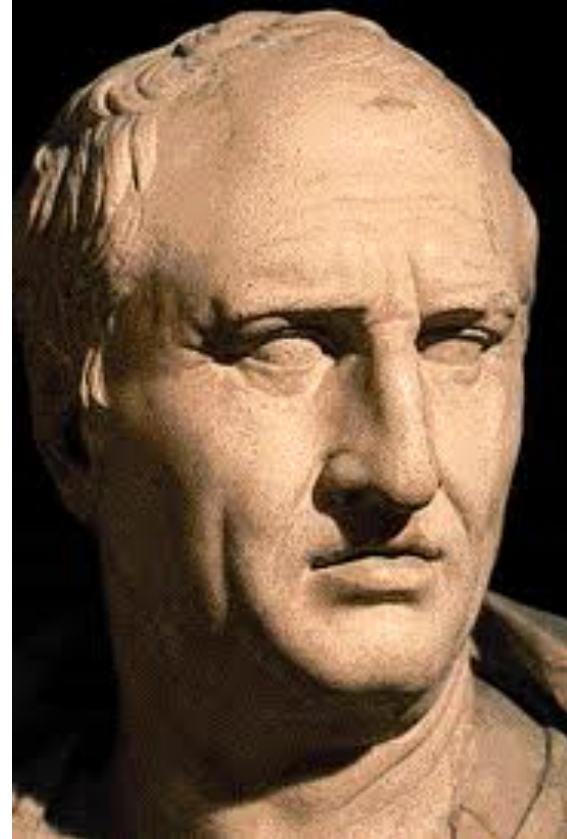


# Harmonie des sphères

**Harmonie:** musique – nombres – orbites planétaires



Platon: *Timée* (360 BC)  
Aristote: *Du ciel* (de caelo)

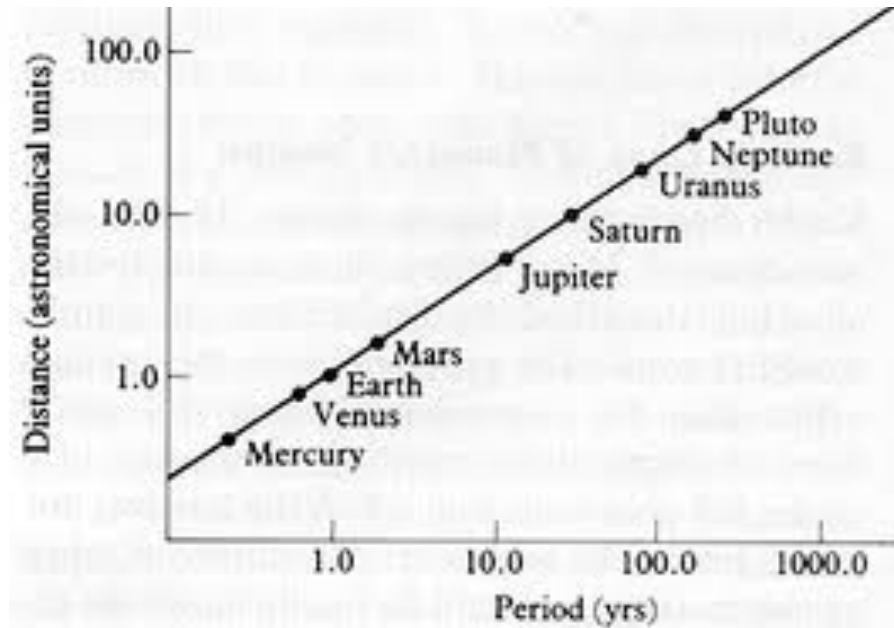
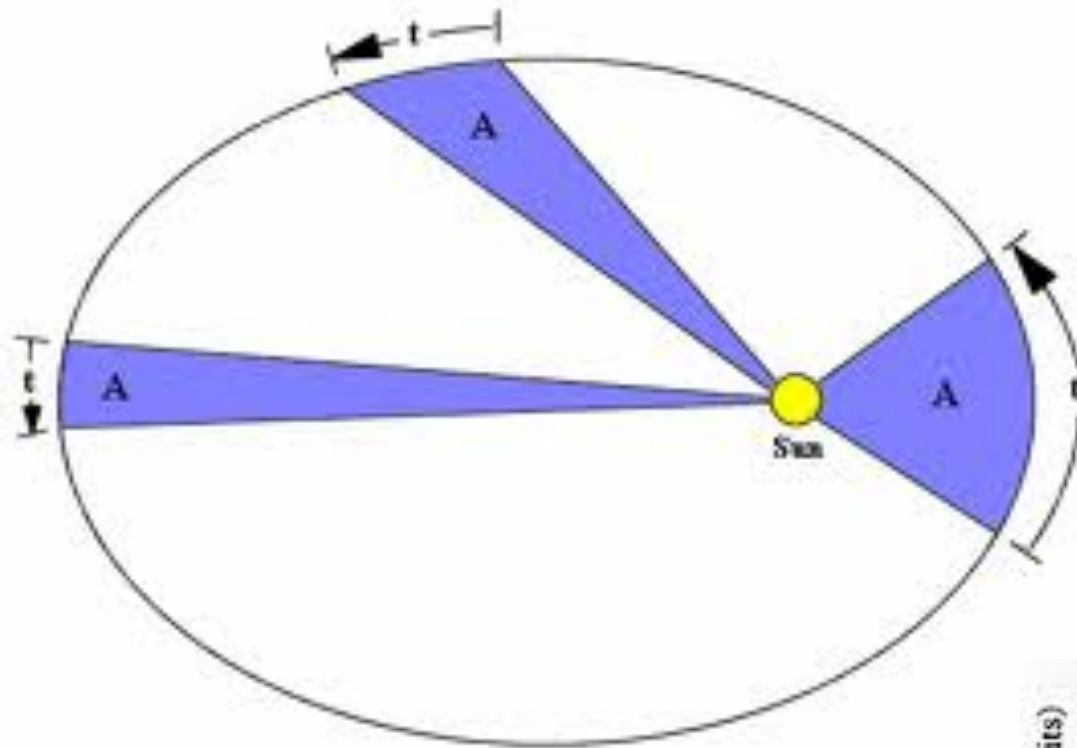


Cicéron: *Le songe de Scipion* (146 BC)

# Kepler Harmonices Mundi (1619)



(1571-1630)

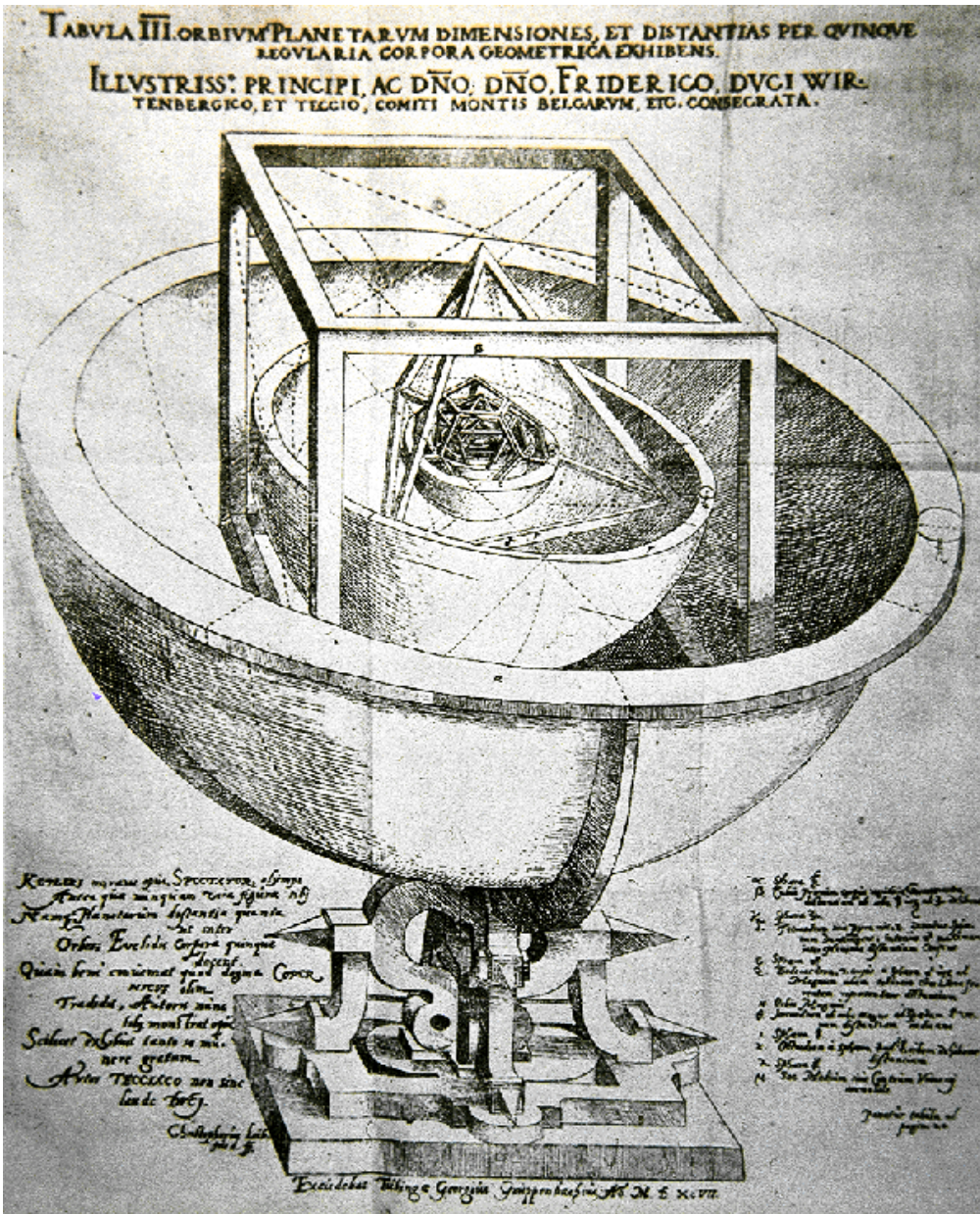




# Kepler Harmonices Mundi (1619)



- 1<sup>st</sup>: polyèdres réguliers
- 3<sup>rd</sup>: proportions harmoniques en musique
- 4<sup>th</sup>: configurations harmoniques en astrologie
- 5<sup>th</sup>: harmonie des orbites planétaires



# L'harmonie des sphères *en* Musique

Anonymous (XII):

*Naturalis concordia vocum cum planetis*

Jean-Baptiste Lully (1676):

*Ballet des planètes*

Joseph Haydn (1777)

*Il mondo della luna (opera)*

Gustav Holst (1917)

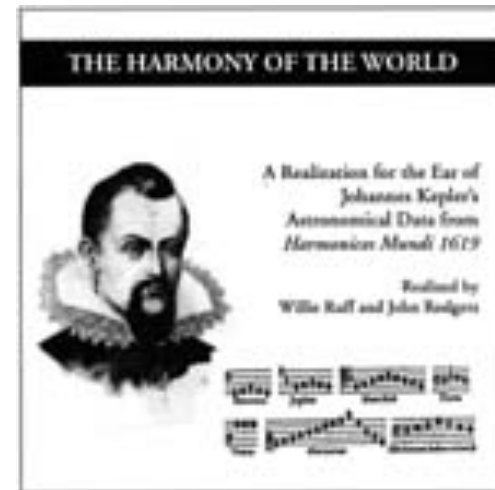
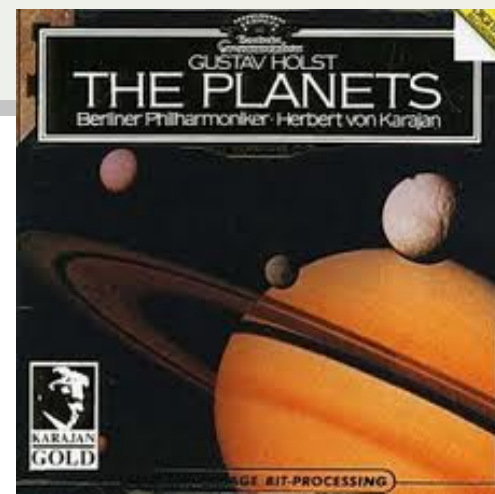
*Les planètes*

Willie Ruff & John Rodgers (2008)

*The harmony of the world*

Eddie Ladoire & J.-P. Uzan (2010)

*Vostok*





# Intermède musical (1)

The image displays six musical staves, each representing a planet. The staves are arranged in two rows. The top row contains Saturnus, Jupiter, Mars ferè, and Terra. The bottom row contains Venus and Mercurius. Each staff features a unique set of notes and clefs, representing the musical 'signature' of each planet as defined by Johannes Kepler in his work *Harmonice Mundi*. The notes are represented by diamond-shaped symbols on the staves.



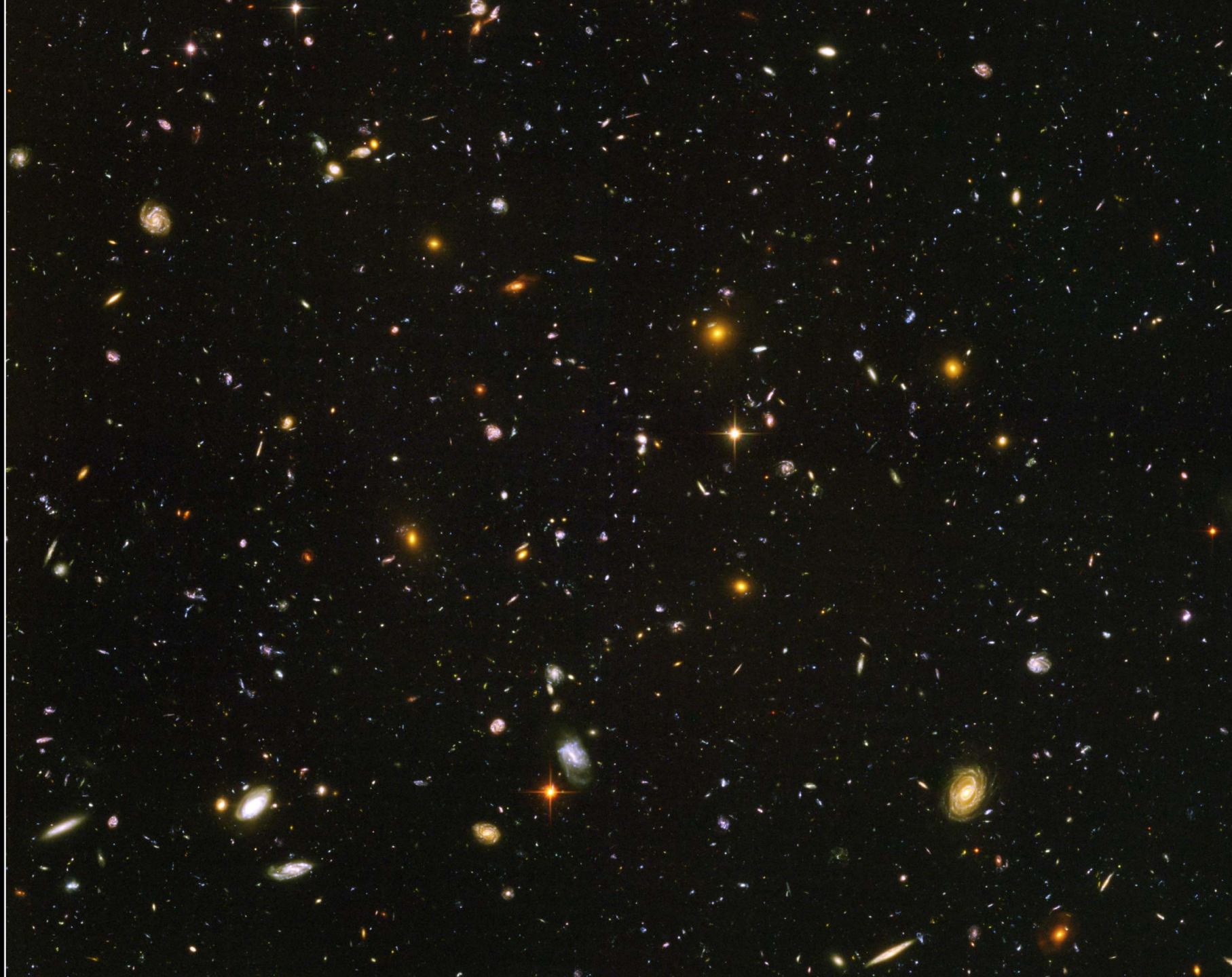
**THE HARMONY OF THE WORLD**

A Realization for the Ear of  
Johannes Kepler's  
Astronomical Data from  
*Harmonice Mundi* 1619

Edited by  
Wille Ruff and John Rodgers

Small musical notation at the bottom of the slide, including a treble clef and several notes.

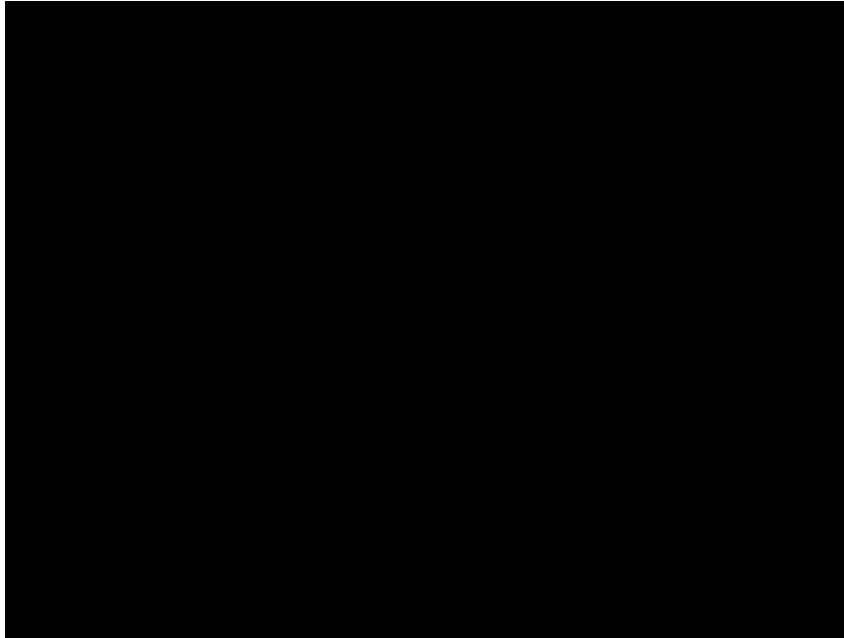




# Son et lumière

Les sons et la lumière sont 2 types d'ondes

**Son:** ondes de pression, mouvement d'un fluide/gaz.  
ne peuvent pas se propager dans le vide.



<http://164.81.14.35/spipmusee/spip.php?rubrique33>



Robert Boyle (1627-1691)

**Lumière:** ondes électromagnétiques  
peuvent se propager dans le vide.





Les deux nécessitent quelque chose qui vibre et un milieu pour se propager. Elles se propagent à des vitesses différentes.



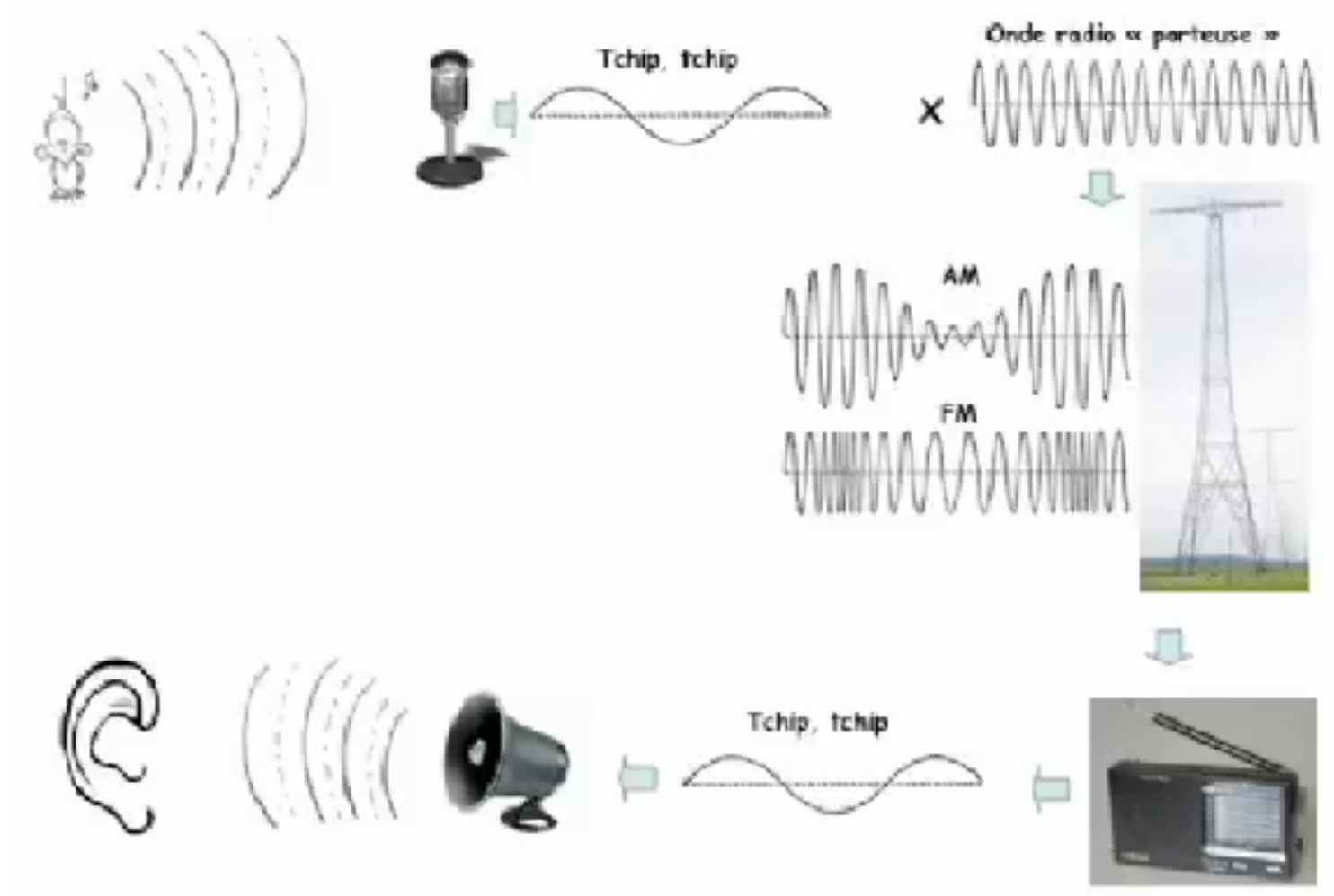
# Instruments de musique de la nature



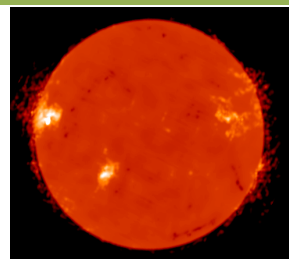
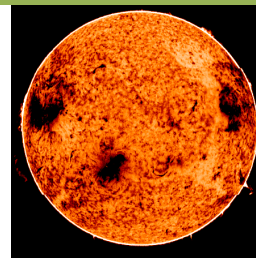
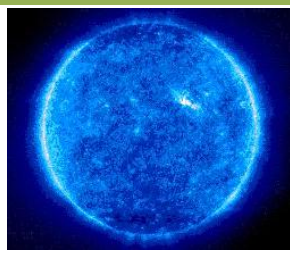
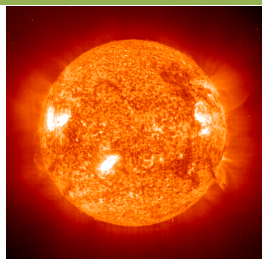
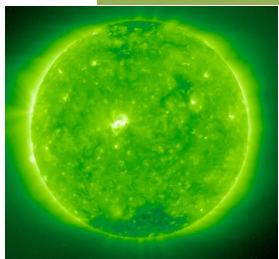
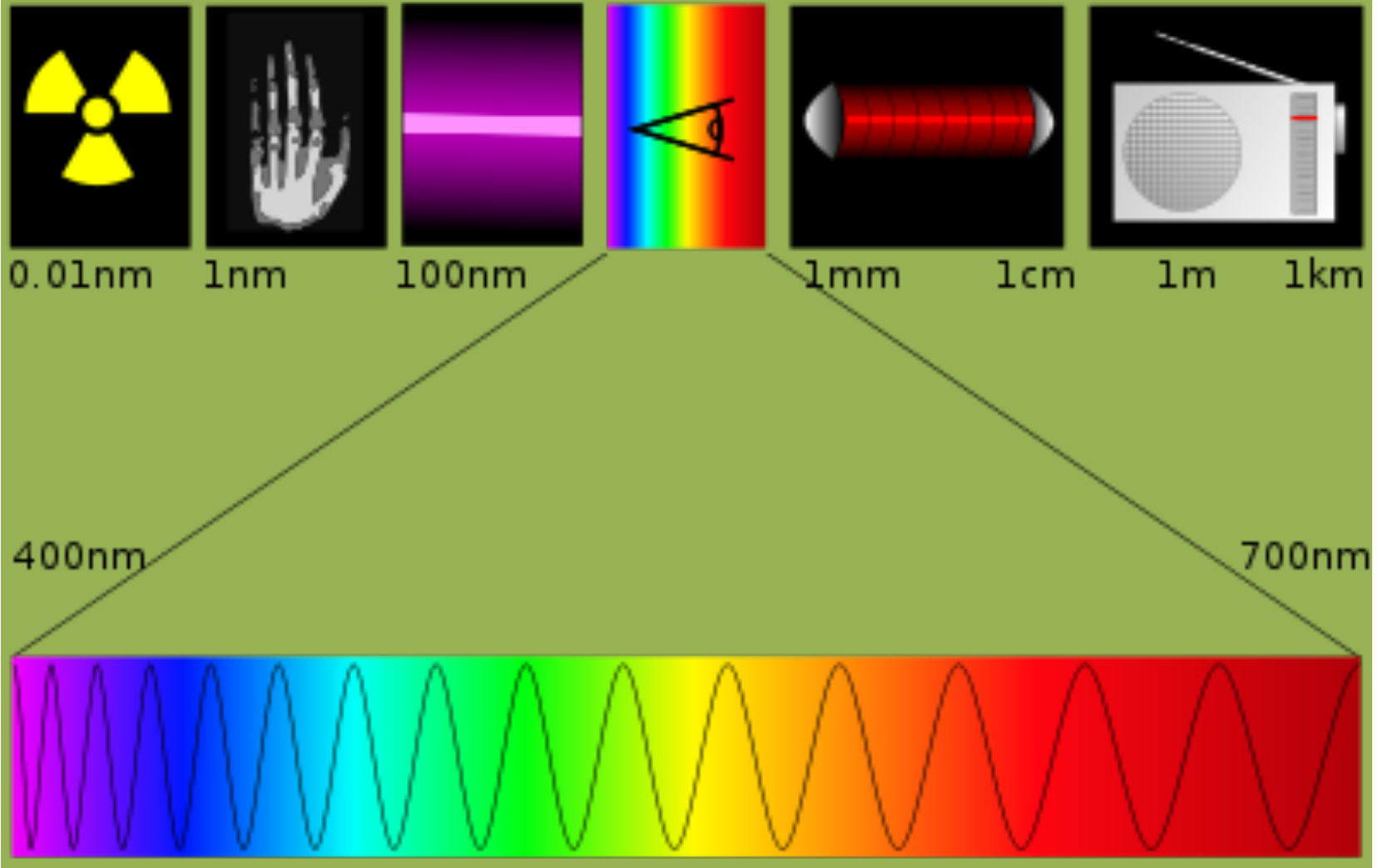
# Instruments de musique de la nature



# De la lumière au son (et du son à la lumière)



# L'œil et au-delà





Peut-on voir les sons? Peut-on entendre les couleurs?

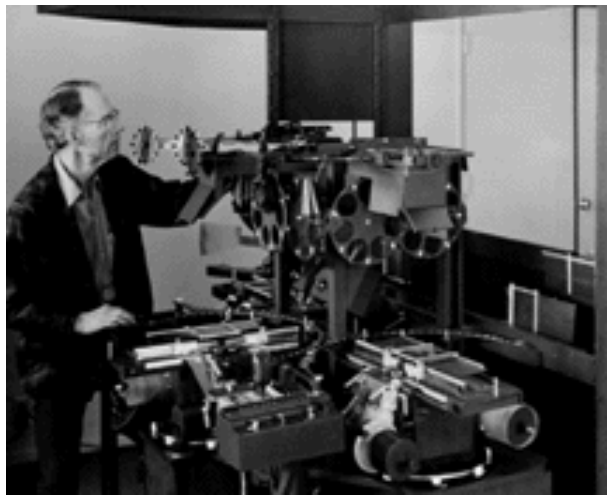


JOHN WILLIAM WATERHOUSE

# Les sons ont une couleur



ÉDITIONS D'ART  
CHROMOPHONIQUE  
P. A. R. I. S  
EN GROS AUX  
ÉDITIONS HACHETTE  
11, rue Monnaie, PARIS-2<sup>e</sup>



*Charles Blanc-Gatti  
L'orchestre*

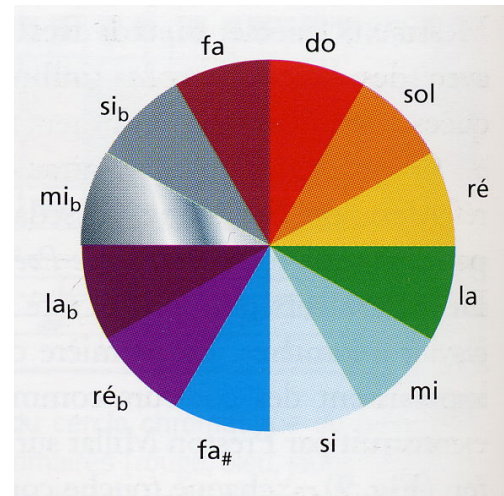
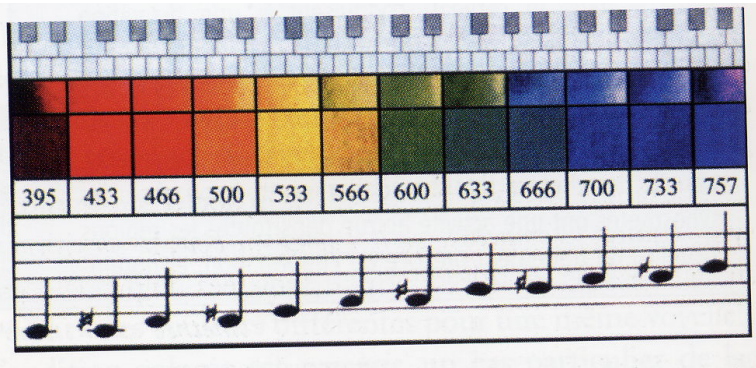




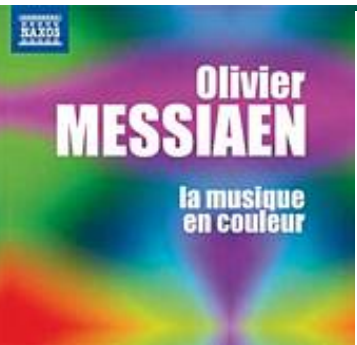


*Fuge in Rot, Paul Klee (1921)*

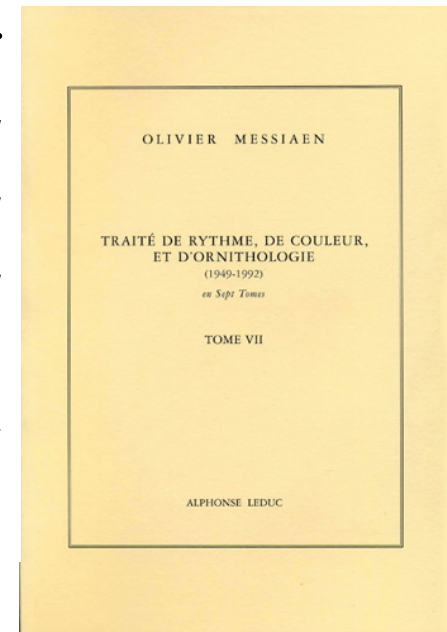
# Gamme chromatique



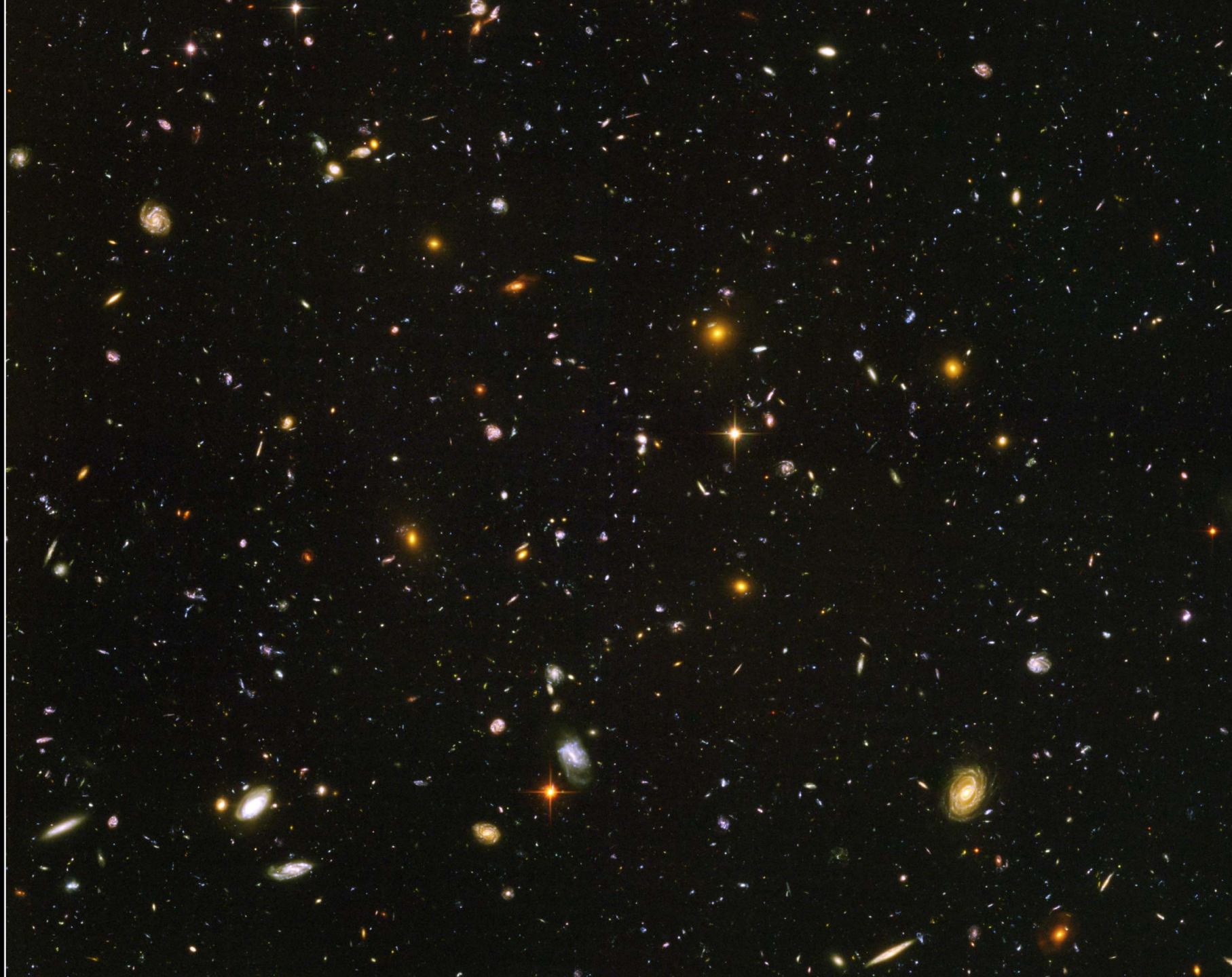
Alexander Scriabin



*« Certaines sonorités sont liées pour moi à certains complexes de couleurs et je les utilise comme des couleurs, en les juxtaposant et en les mettant en valeur les une par rapport aux autres, comme un peintre souligne une couleur par sa complémentarité »*









# MONTY PYTHON'S GALAXY SONG



The Galaxy Song  
by Eric Idle

Just remember that you're standing on a planet that's evolving  
And revolving at nine hundred miles an hour,  
That's orbiting at nineteen miles a second, so it's reckoned,  
A sun that is the source of all our power.  
The sun and you and me and all the stars that we can see  
Are moving at a million miles a day  
In an outer spiral arm, at forty thousand miles an hour,  
Of the galaxy we call the 'Milky Way'.  
Our galaxy itself contains a hundred billion stars.  
It's a hundred thousand light years side to side.  
It bulges in the middle, sixteen thousand light years thick,  
But out by us, it's just three thousand light years wide.  
We're thirty thousand light years from galactic central point.  
We go 'round every two hundred million years,  
And our galaxy is only one of millions of billions  
In this amazing and expanding universe.

The universe itself keeps on expanding and expanding  
In all of the directions it can whizz  
As fast as it can go, at the speed of light, you know,  
Twelve million miles a minute, and that's the fastest speed there is  
So remember, when you're feeling very small and insecure,  
How amazingly unlikely is your birth,  
And pray that there's intelligent life somewhere up in space,  
'Cause there's bugger all down here on Earth.

A 3495

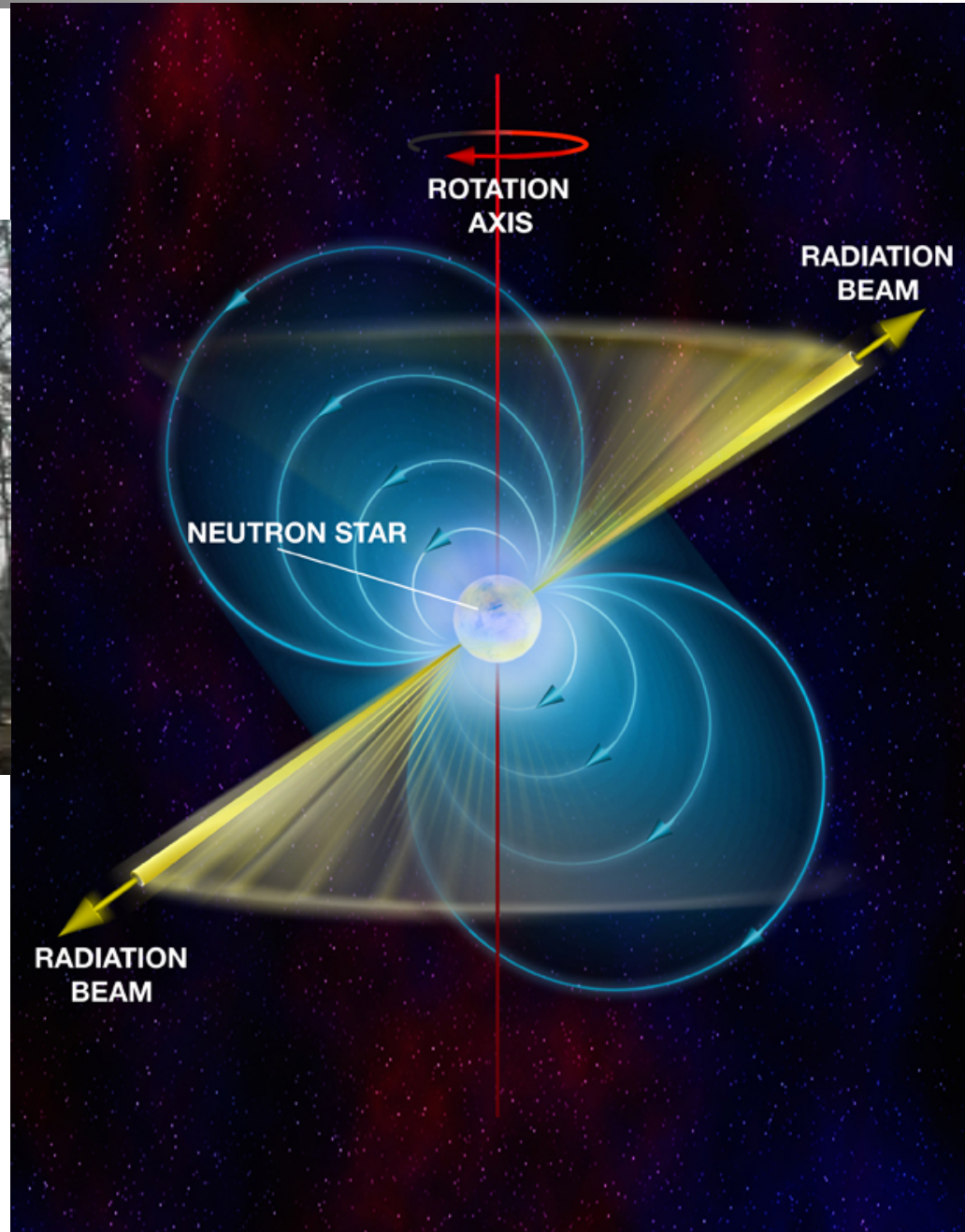


# Du rythme dans l'univers



## Vela pulsar:

- Hémisphère sud
- formé il y a 12000 ans
- 11 /s





# Le noir de l'étoile

GÉRARD GRISEY LES PERCUSSIONS DE STRASBOURG



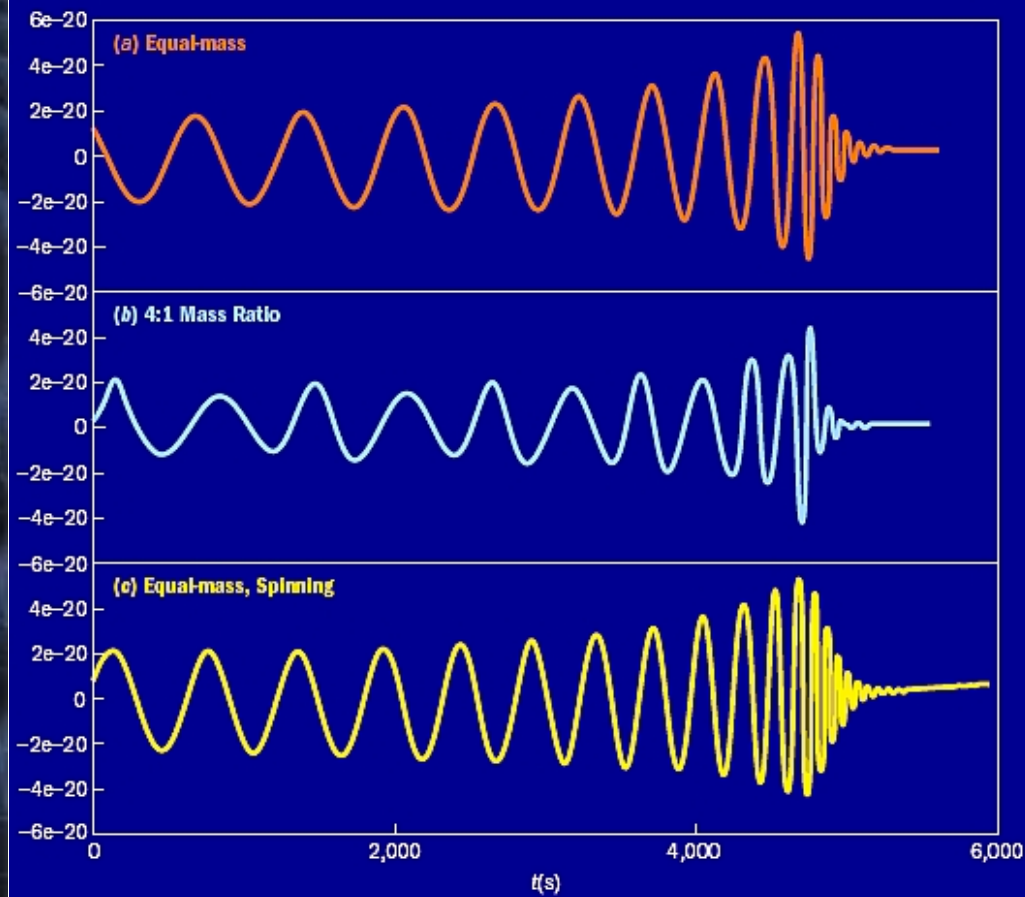
Gérard Grisey (1946-1998)



<http://www.youtube.com/watch?v=tOpoqkMNPTU>



# Un nouveau type d'ondes



Capture d'un trou noir de 10 masse solaire par un trou noir de 1 million mass solaire



Début de la phase inspiralante



Fin de la phase inspiralante

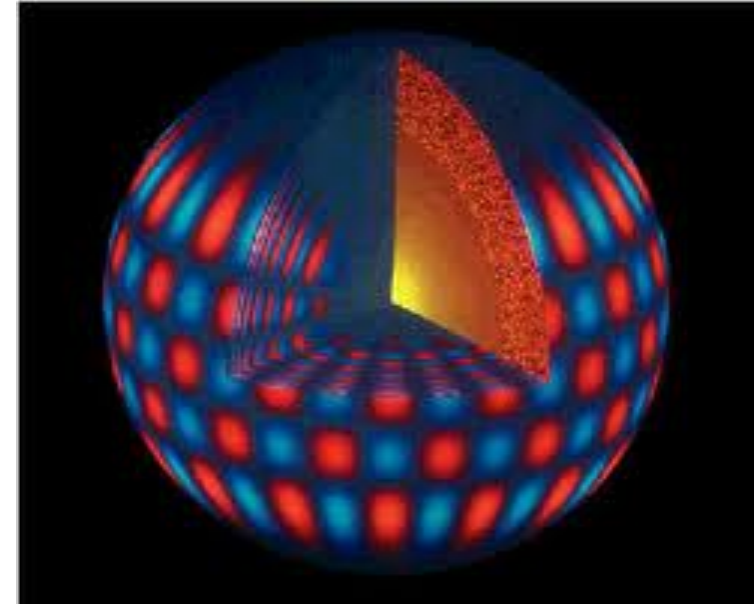


# De « vrais » sons dans l'univers

Les étoiles pulsent. Elles sont comme des tambours.

Ces vibrations dépendent de la masse, température, composition chimique.

Asterosismologie (comme pour les tremblements de Terre)



Xi-hydrae

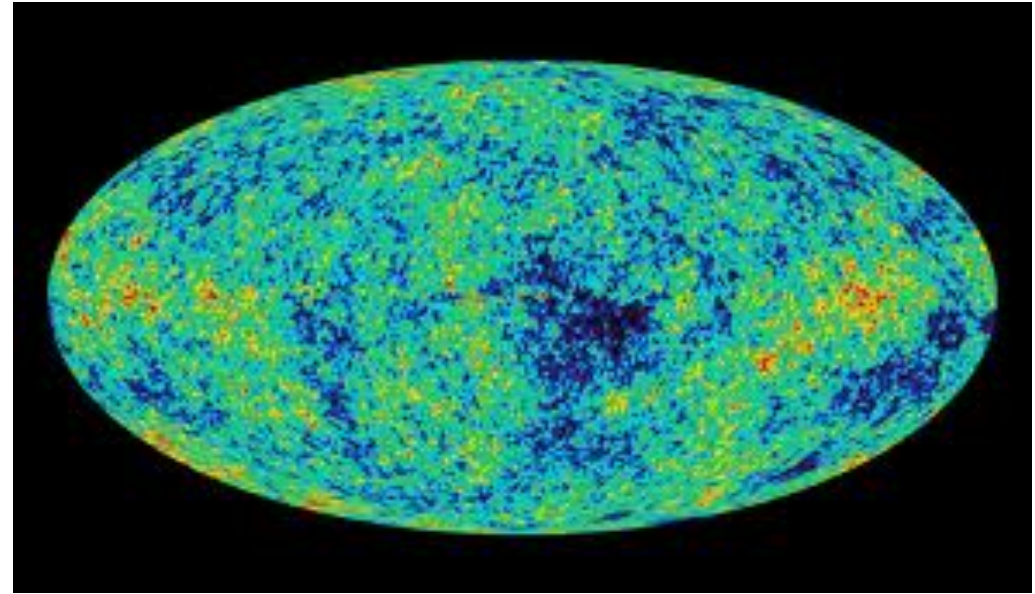
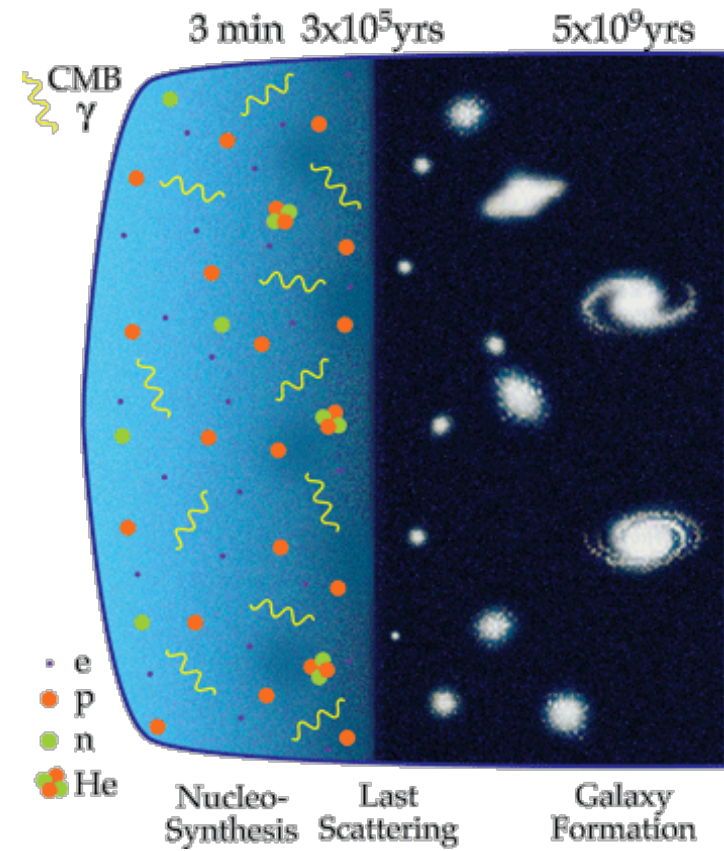
HR3831



*Stellar Music No. 1* de Jenő Keuler et Zoltán Kolláth

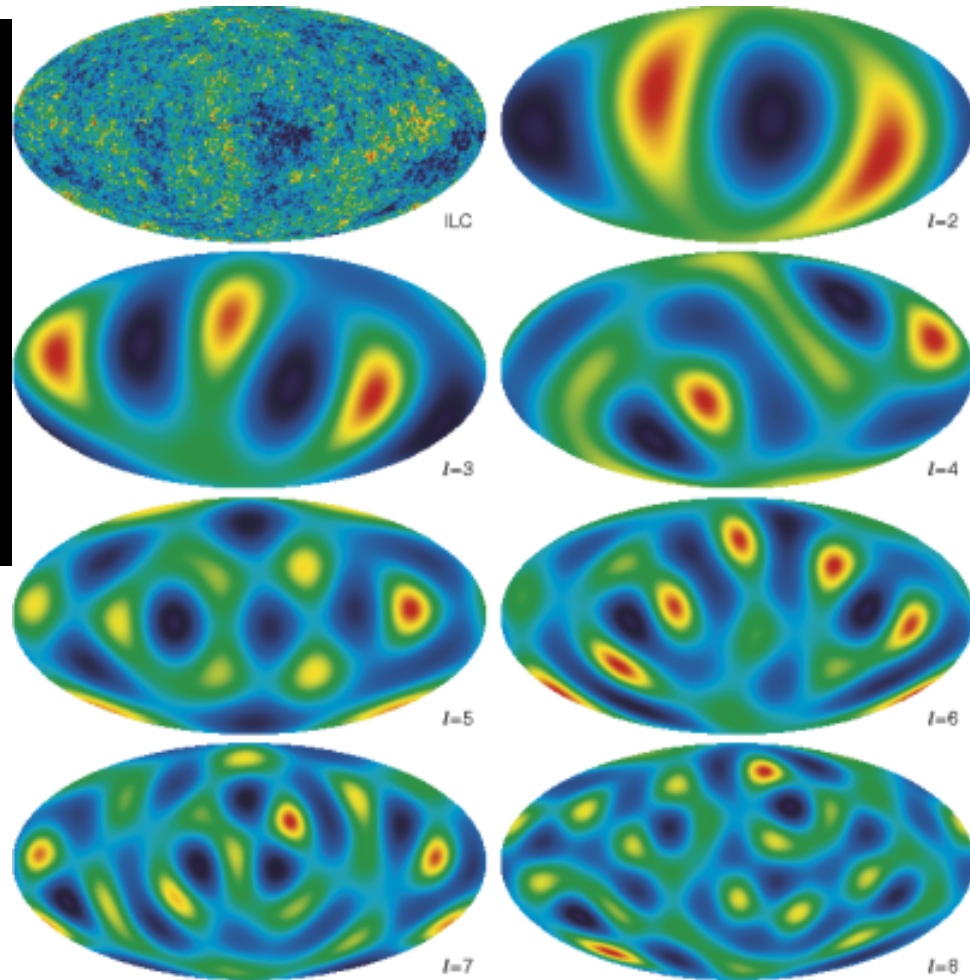
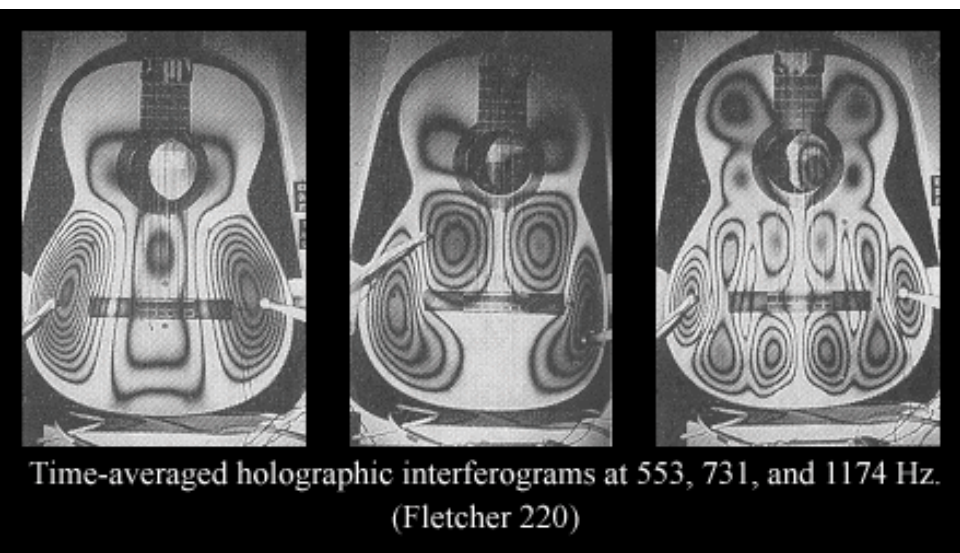
[see [http://www.world-science.net/othernews/060809\\_spheres.htm](http://www.world-science.net/othernews/060809_spheres.htm)]

# De « vrais » sons dans l'univers





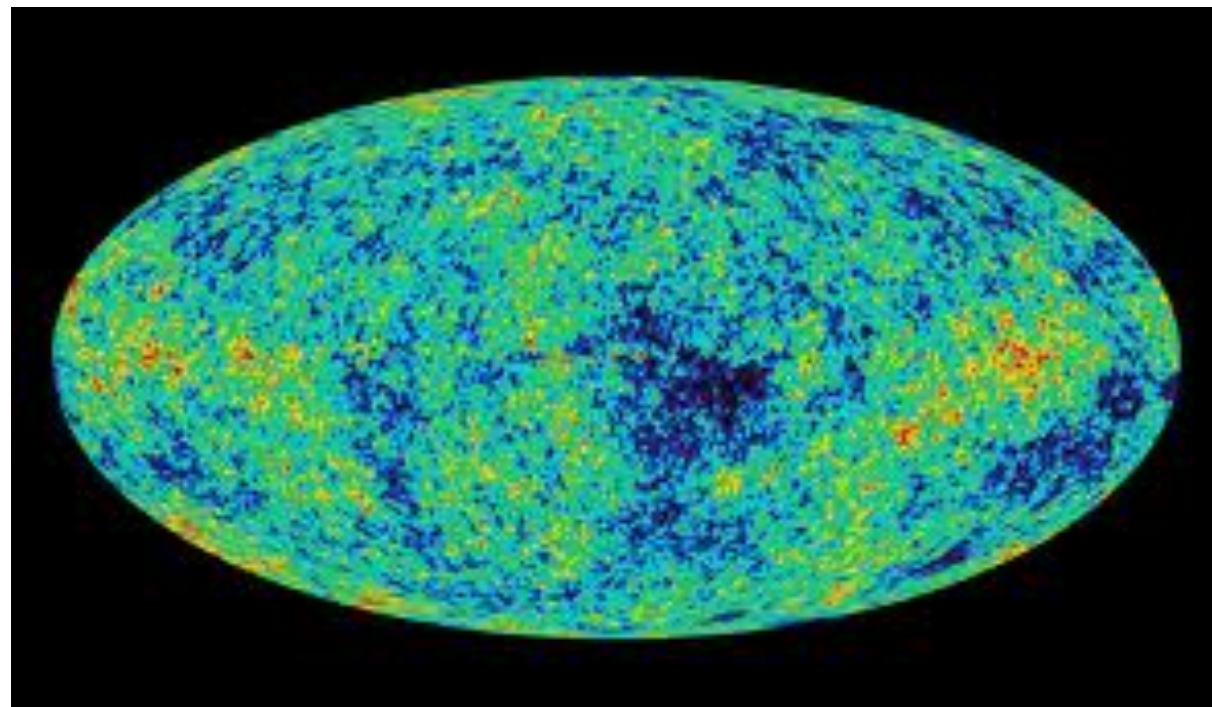
# De « vrais » sons dans l'univers



Peut-on entendre la forme de l'univers ?



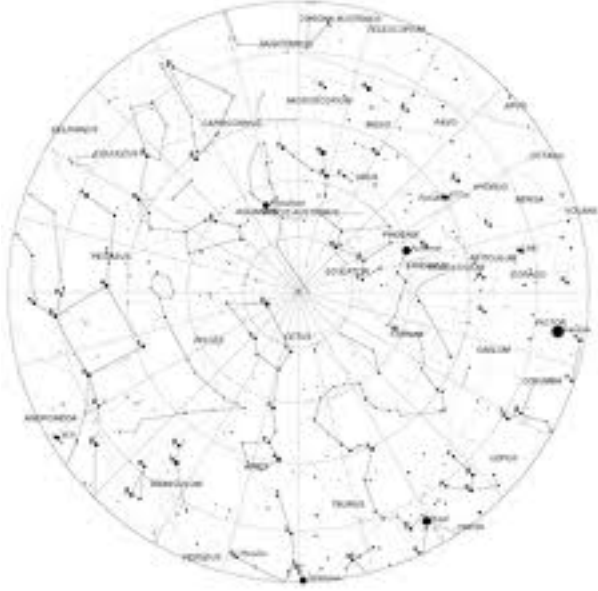
# De « vrais » sons dans l'univers



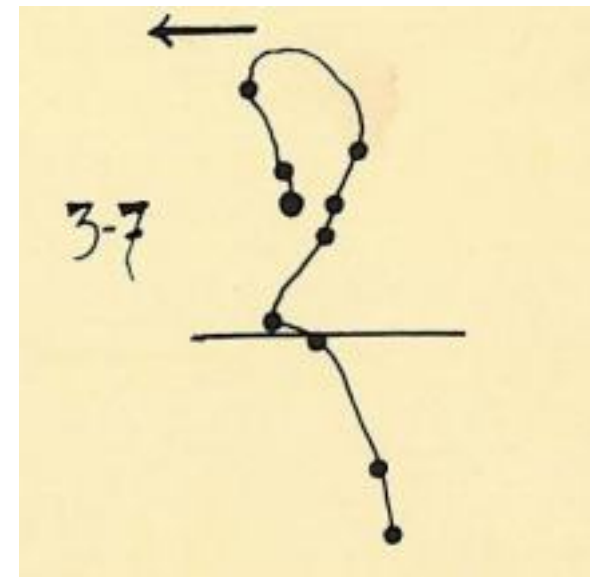
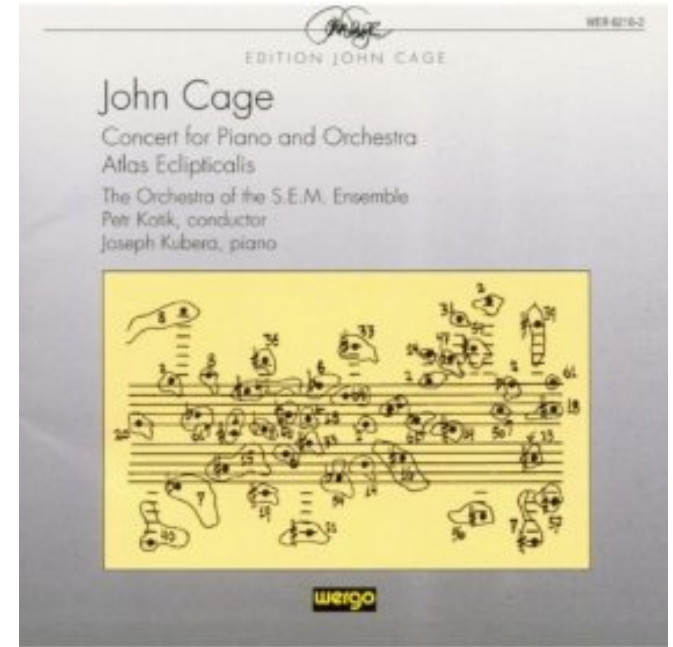
Signal – bruit = données intéressantes



# Ecouter la distribution des galaxies



# Ecouter la distribution des galaxies



# Ecouter la distribution des galaxies

John Cage, *Atlas Eclipticalis* (1961)

David Bedford, *Great Equatorial* (1993)

Philipp Glass, *Orion* (2004)

Olivier Messiaen, *Eclairs sur l'au-delà...* (1987-91)

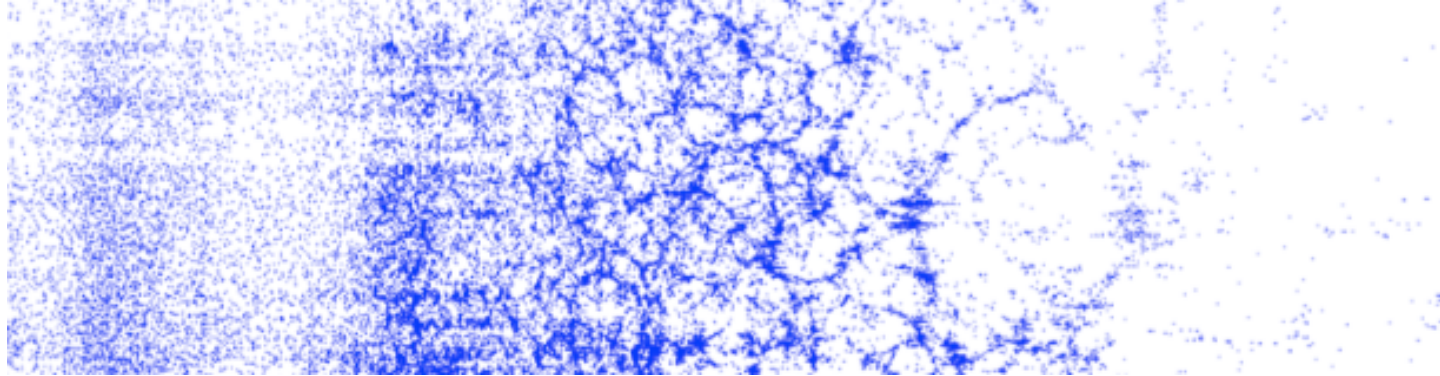
CELLO 2

The image displays a page of musical notation for a cello part, labeled 'CELLO 2'. It consists of five systems of music, each with a single staff. The notation is highly complex and includes various symbols, numbers, and arrows. The numbers 26, 14, 44, 72, 8-2, 25, 4-4, 91, 61, 61, 32, 41, 26, 32, 25, 72, 1-2, 64, 5-5, 1-5, and 1-2 are scattered throughout the score. The notation includes notes, rests, and other musical symbols, with some notes having arrows pointing to them. The overall appearance is that of a highly technical and abstract musical score.





# Ecouter la distribution des galaxies



E. Ladoire & J.-P. Uzan, *Vostok* (2010)

# Ecouter des théories?

$\mathcal{L}_{Gauge} = -\frac{1}{4} G_{\mu\nu}^\alpha G_{\mu\nu}^\alpha - \frac{1}{4} F_{\mu\nu} F_{\mu\nu} - \frac{1}{4} (\partial_\mu B_\nu - \partial_\nu B_\mu)^2$

Don't Forget Higgs

$\mathcal{L}_H = D_\mu \phi^\dagger D_\mu \phi - \lambda \left( \phi^\dagger \phi - \frac{v^2}{2} \right)^2$

where

$D_\mu \phi = \left( \partial_\mu - i g \frac{\tau}{2} - i \frac{1}{2} g' B_\mu \right) \phi$

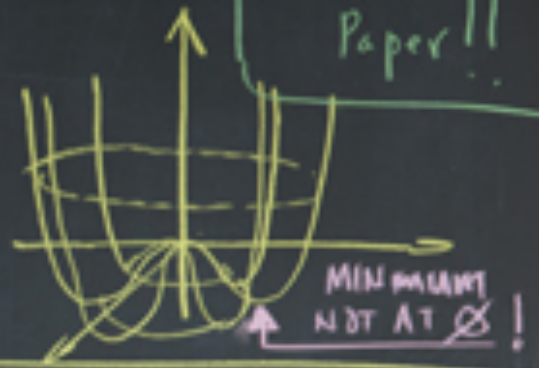
and

$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$

Two Component      Options

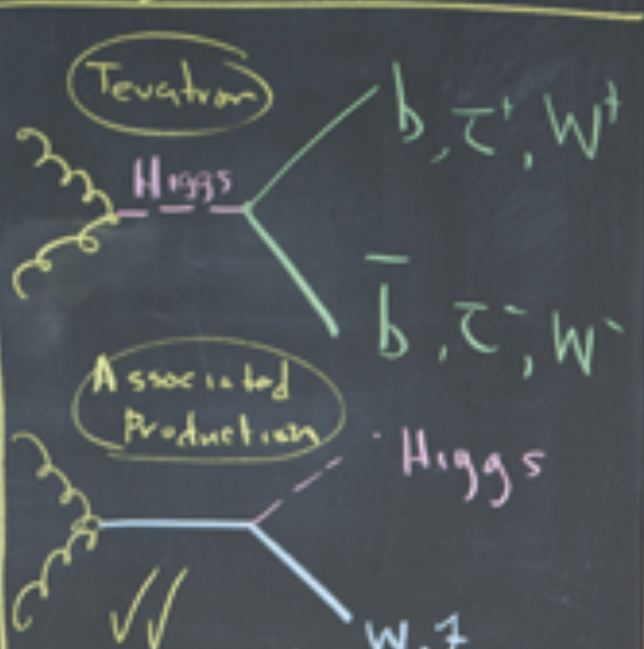
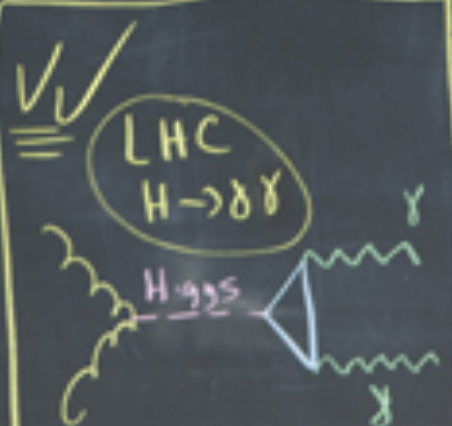
Conference  
 3/17 - 3/23

Don't forget  
 to Submit  
 Paper!!



Integrated Luminosity  
 Tevatron  $\sim 10 \text{ fb}^{-1}$   
 LHC  $\sim 150 \text{ fb}^{-1} (+)$

19.6 TeV vs 7 TeV (14 TeV)



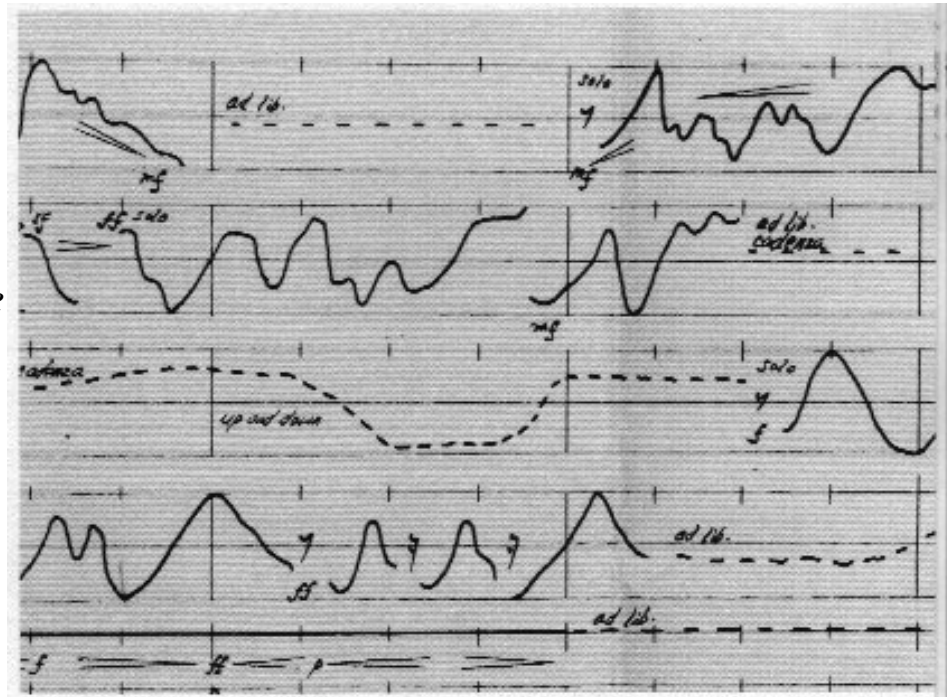
# Ecouter des théories?

En physique fondamentale, tout se réduit à des vibrations

Mécanique quantique: les particules sont aussi des ondes.

## Edgar Varèse, *Ionisation* (1929-1931)

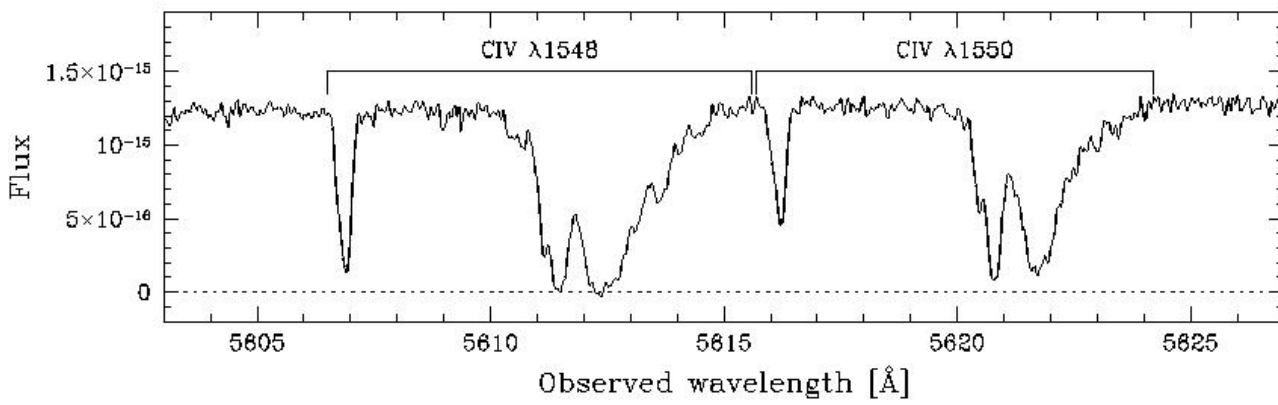
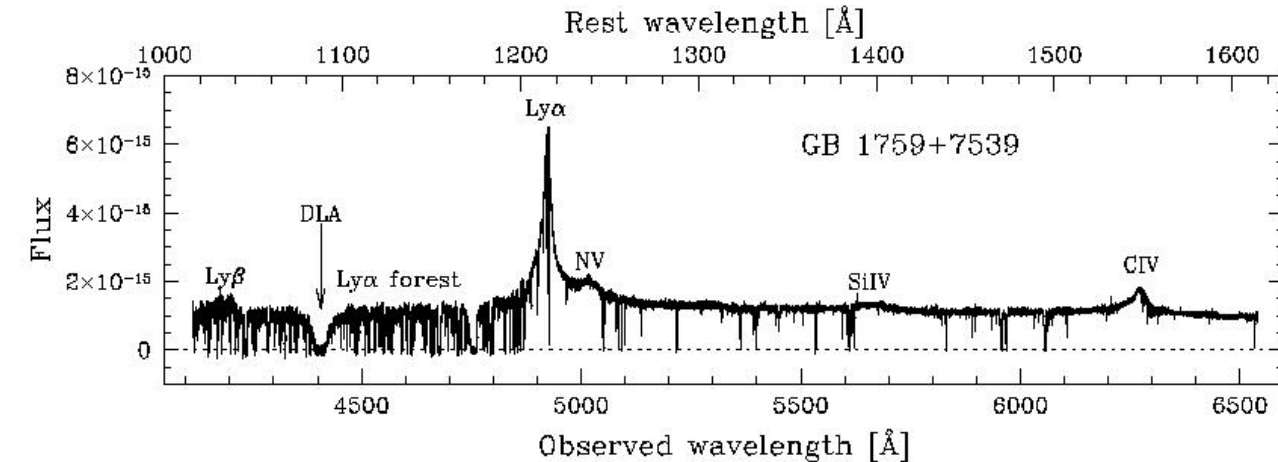
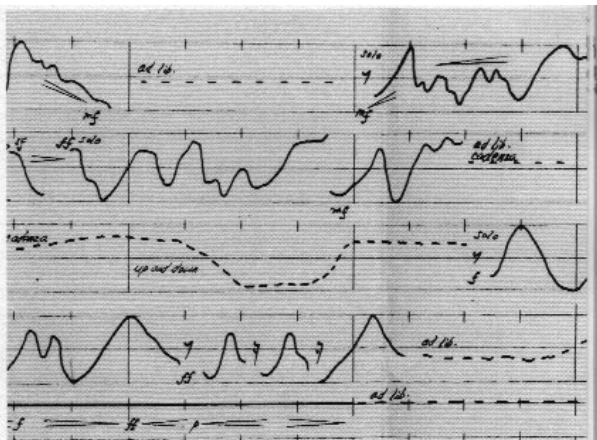
*I often borrow from higher mathematics or astronomy only because these sciences stimulate my imagination and give me the impression of movement, of rhythm. For me there is more musical fertility in the contemplation of the stars...and the high poetry of certain mathematical expositions than in the most sublime gossip of human passions.*



*...I decided to call my music "organized sound" and myself, not a musician, but a "worker in rhythms, frequencies and intensities."*



# Ecouter des théories?

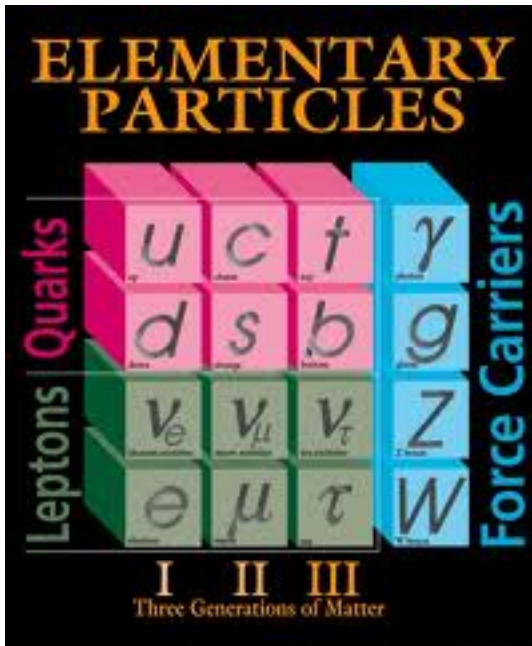


# Ecouter des théories?

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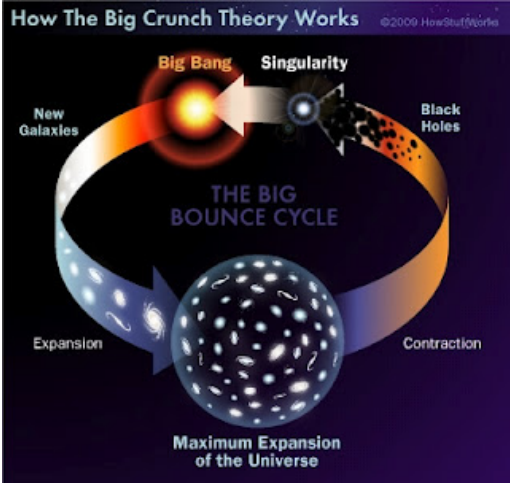
Peut-être que tout n'est fait que de cordes....



# Ecouter des théories?

Big bang: le modèle cosmologique porte le « nom » d'un son!

Cosmologies cycliques





# Les artistes ont été inspiré par le cosmos

David Bedford, *Star's end* - fin de l'univers

Peter Eotvos, *Cosmos* - big bang

Bernard Parmegiani, *La création du Monde* - big bang

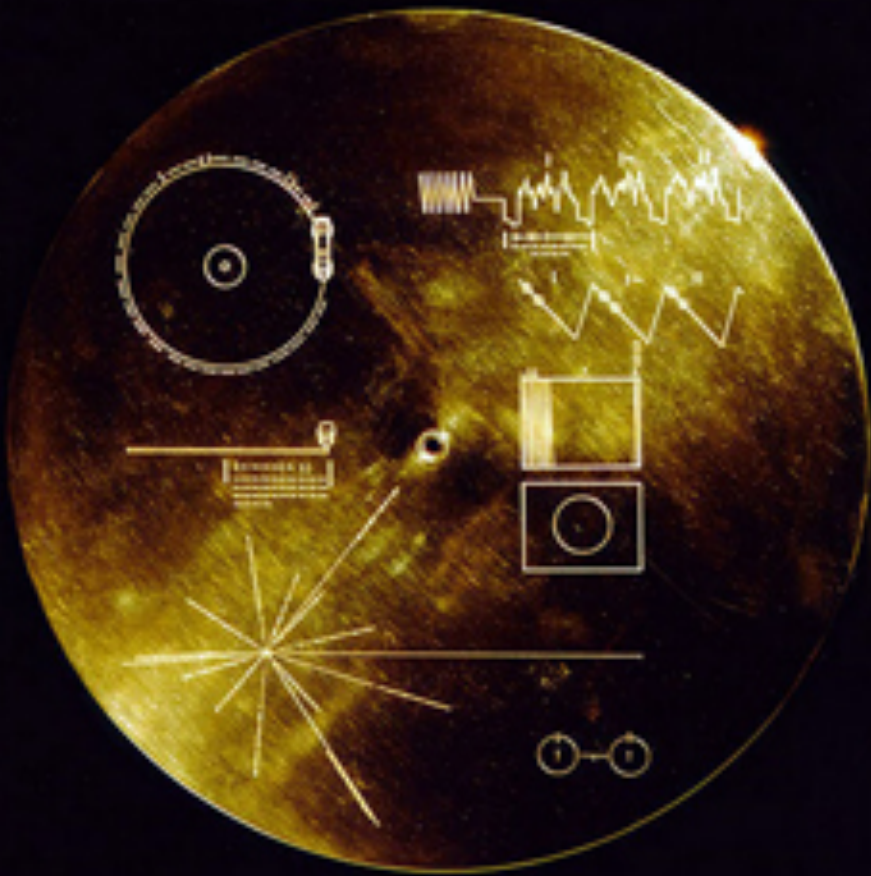
Krzysztof Penderecki, *Kosmogonia*

Charls Wuorinen, *Genesis* - Cantate sur la création & big bang

... et beaucoup d'autres qu'il me reste à découvrir!







*Credit: NASA*



- » Bach, Brandenburg Concerto No. 2 in F. First Movement
- » Java, court gamelan, Kinds of Flowers
- » Senegal, percussion
- » Zaire, Pygmy girls' initiation song
- » Australia, Aborigine songs, "Morning Star" and "Devil Bird,"
- » Mexico, El Cascabel,
- » "Johnny B. Goode, » Chuck Berry
- » New Guinea, men's house song,
- » Japan, shakuhachi, "Tsuru No Sugomori" ("Crane's Nest, »)
- » Bach, "Gavotte en rondeaux" from the Partita No. 3 in E major for Violin,
- » Mozart, The Magic Flute, Queen of the Night aria, no. 14.
- » Georgian S.S.R., chorus, "Tchakrulo, »
- » Peru, panpipes and drum,
- » "Melancholy Blues, » Louis Armstrong
- » Azerbaijan S.S.R., bagpipes,
- » Stravinsky, Rite of Spring, Sacrificial Dance,
- » Bach, The Well-Tempered Clavier, Book 2, Prelude and Fugue in C, No.1.
- » Beethoven, Fifth Symphony, First Movement,
- » Bulgaria, "Izlel je Delyo Hagdutin,
- » Navajo Indians, Night Chant
- » Holborne, Paueans, Galliards, Almains and Other Short Aeirs, "The Fairie Round,
- » Solomon Islands, panpipes,
- » Peru, wedding song,
- » China, ch'in, "Flowing Streams,
- » India, raga, "Jaat Kahan Ho, »
- » "Dark Was the Night, » Blind Willie
- » Beethoven, String Quartet No. 13 in B flat, Opus 130