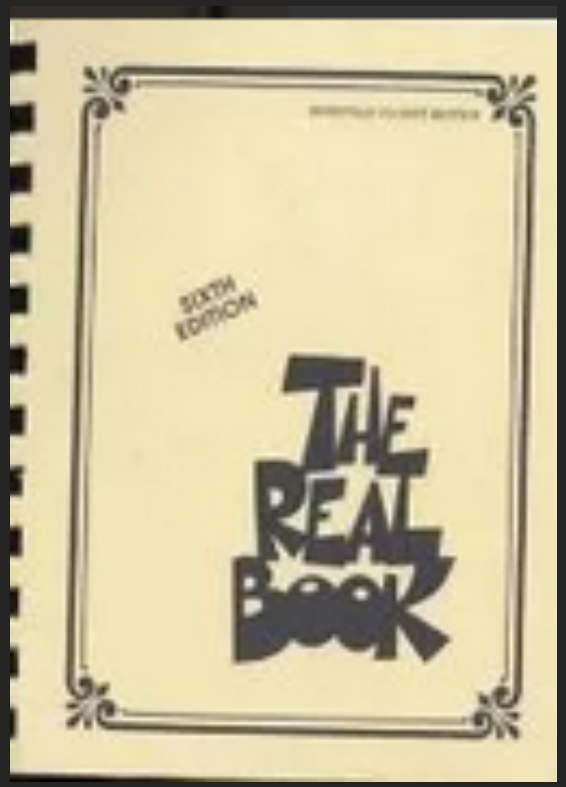
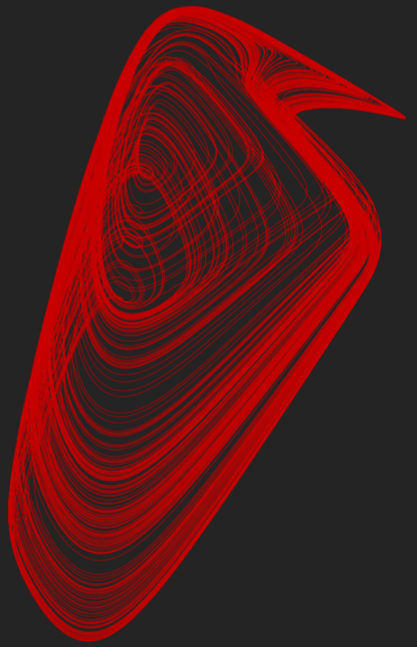
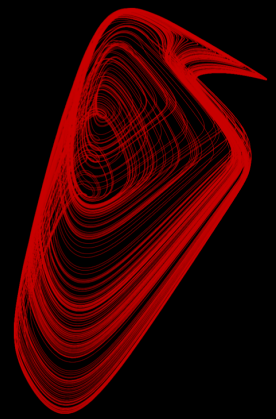


El origen de la notación musical

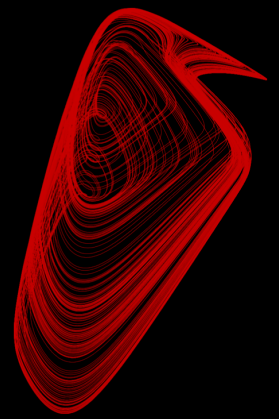
Y la notación sonora



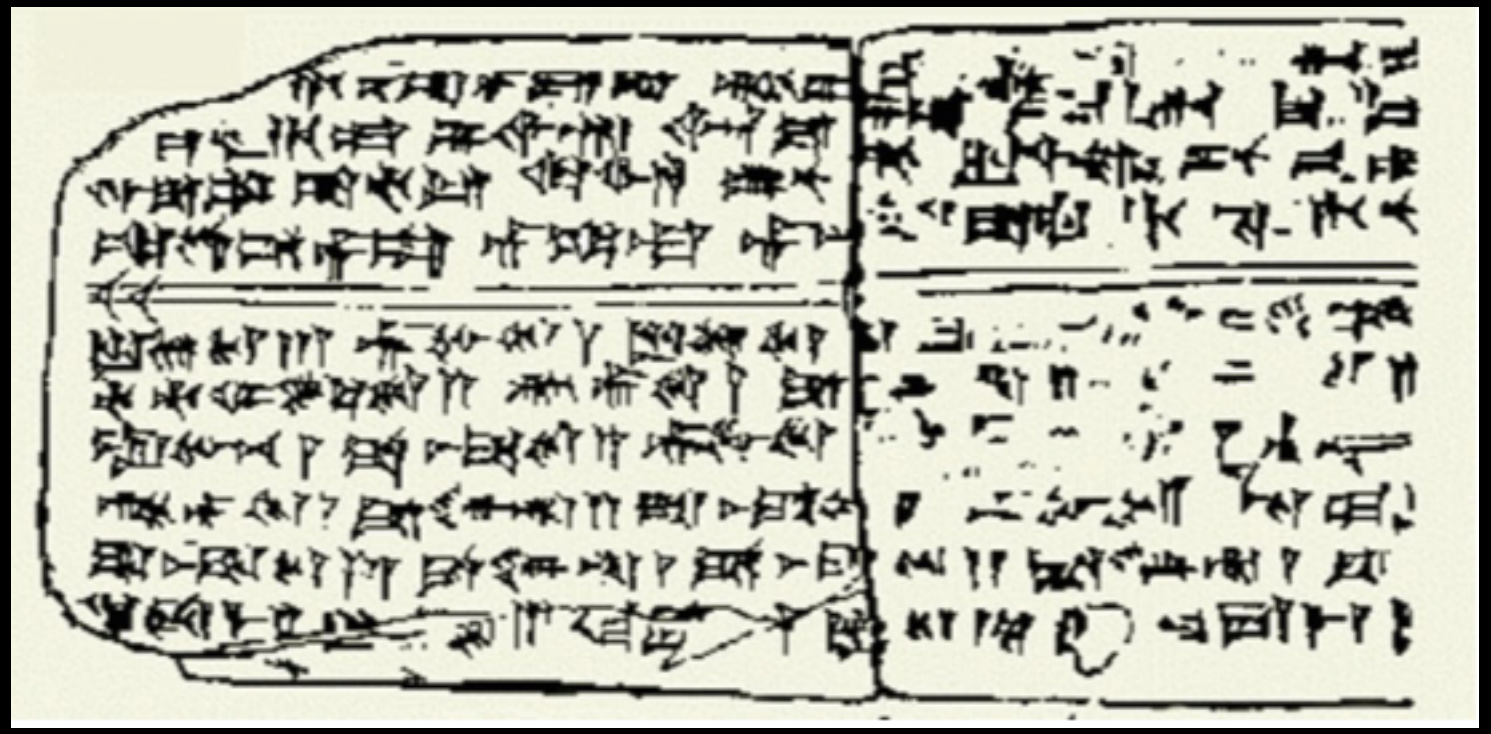


Dar cuenta de lo sonoro, fue un desafio
historico para la humanidad.

“In my childhood, this bird warbled to me through the lines of a poem I read, and now, many years later, I hear the song for the first time. It is beautiful, but how unlike what I had imagined”. W.H. Hudson (1842-10922)

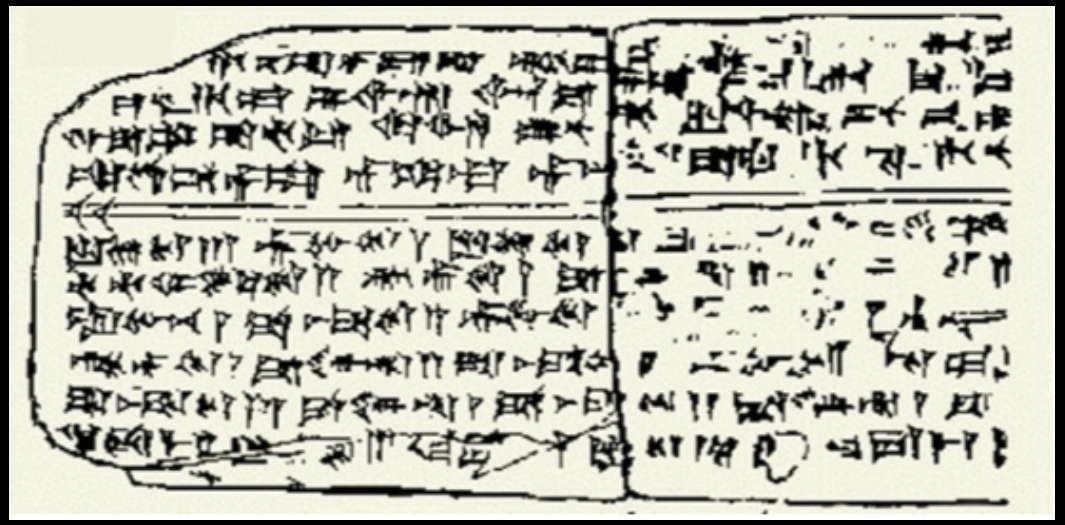


La discretizacion del espectro sonoro para constituir notas,
un conjunto finito, fue clave para que en lo musical, fuera mas facil
transmitir informacion.



Himno del siglo 14 BC, de la ciudad de Ugarit (actualmente territorio Sirio).

El origen de la notacion musical



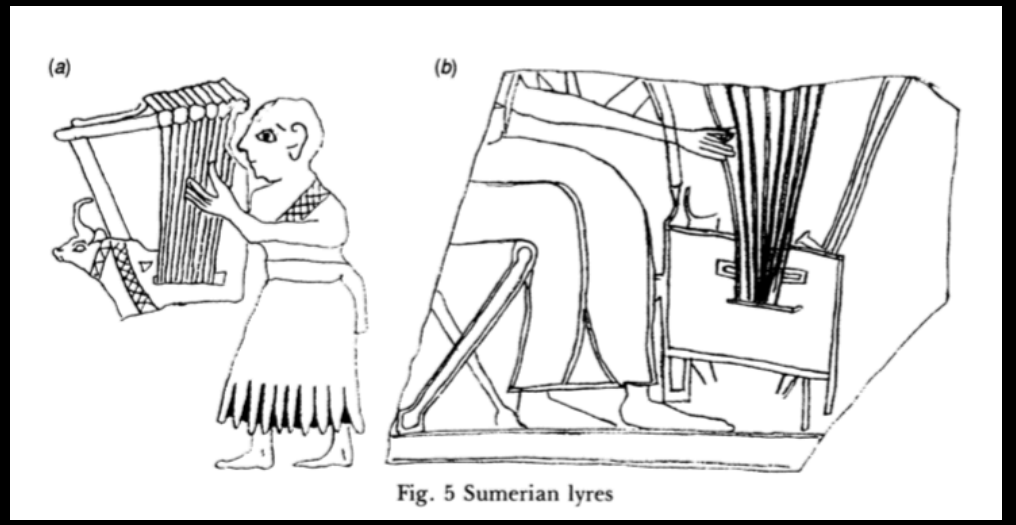


Fig. 5 Sumerian lyres

Los simbolos hacen referencia a las cuerdas
de un instrumento dado (una Lira de 9 cuerdas)
Y a un sistema de afinacion para las cuerdas.

2 versiones

Krar Etiope (y Somali) asi como el pluriarco de Africa occidental, son herederos directos de la familia de Liras pentatonicas gracias a las cuales recuperamos melodias antiguas.


ΕΙΚΩΝΗΛΙΟΘΟΣ
ΕΙΜΙ·ΤΙΘΗΣΙΜΕ
ΣΕΙΚΙΛΟΣΕΝΘΑ
ΜΝΗΜΗΣΑΦΑΝΑΤΟΥ
ΣΗΜΑΠΟΛΥΧΡΟΝΙΟΝ
ΟΣΟΝΖΗΣΦΑΙΝΟΥ
ΜΗΔΕΝΟΛΩΣΥ
ΛΥΠΟΥΤΡΟΣΟΛΙ
ΓΟΝΕΣΤΙΤΟΖΗΝ
ΤΟΤΕΛΟΣΟΧΡΟ
ΝΟΣΑΠΑΙΤΕΙ
ΣΕΙΚΙΛΟΣΤΕΥΤΕΡ

- Primera notacion musical totalmente decifrada

- 300 BC, approx
- Letras, referidas a cuerdas (de la Khitara)
- Signos arriba de las letras refieren a duraciones

Tomb of Marquis Yi of Zeng
(aprox. 400 BC), cada campana con un nombre
(no se encontraron partituras)

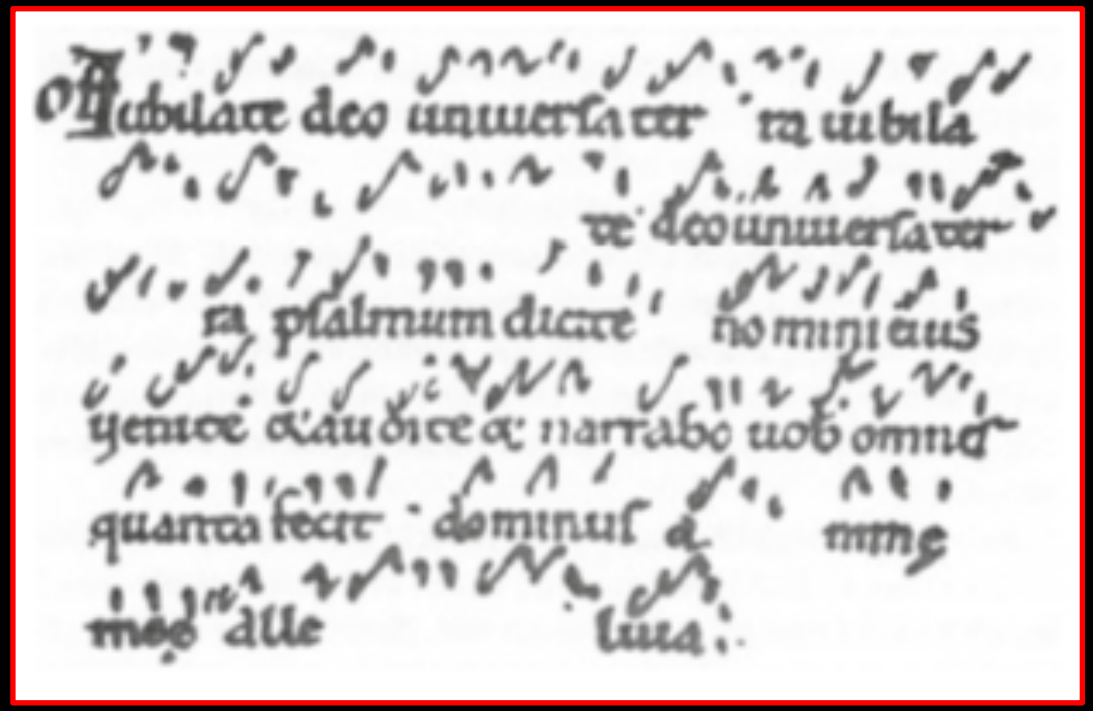
Canto tibetano

El canto Tibetano esta muy incorporado a las celebraciones religiosas Buddistas (introducidas en el siglo VII). Las modulaciones representan modulaciones suaves (subidas y bajadas) en la altura del sonido

Canto tibetano

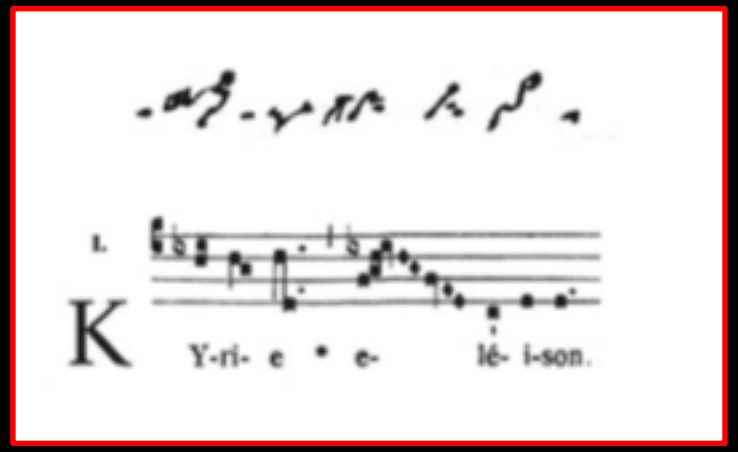
Entrada
de un instrumento,
ej. cimbales

El canto Tibetano esta muy incorporado a las celebraciones religiosas Buddistas (introducidas en el siglo VII). Las modulaciones representan modulaciones suaves (subidas y bajadas) en la altura del sonido



Siglo IX, AD, comienzan a usarse en los monasterios europeos los “neumes”.

Los signos curvilineos hacen referencia a las modulaciones de la altura de los sonidos (la frecuencia fundamental)



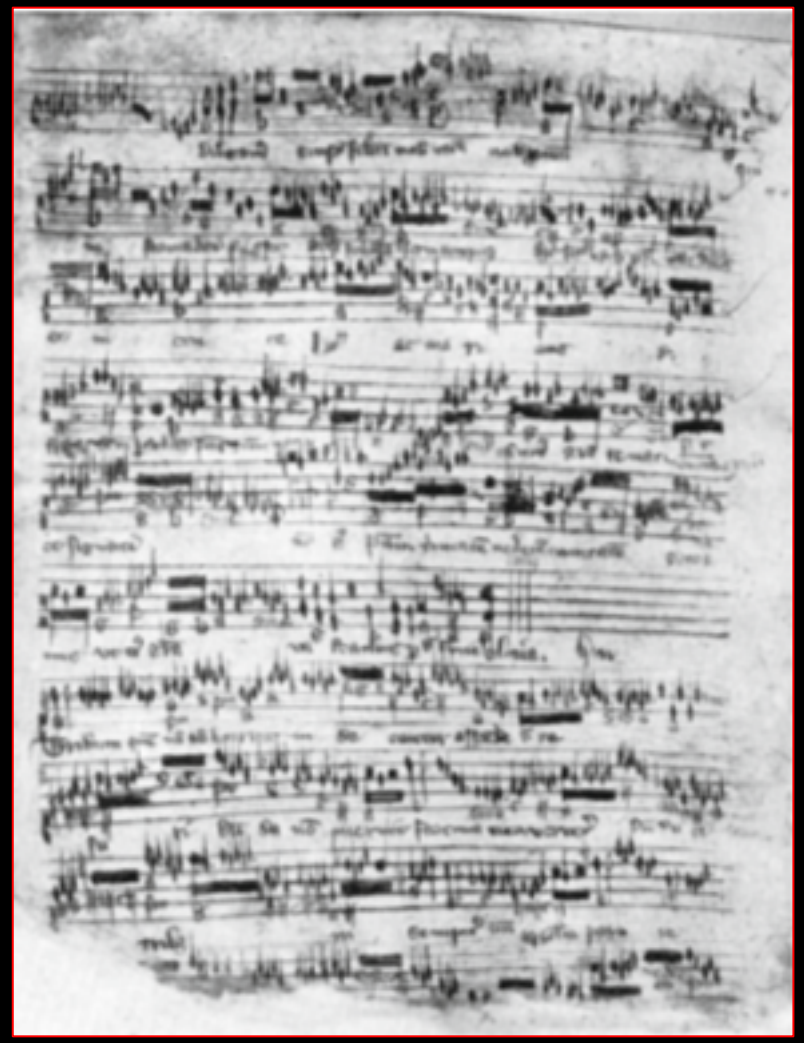
Siglo XI, AD, Guido da Arezzo

Enseñanza masiva a monjes

Comienza a anotar líneas para F y C, a las que luego se le suman dos mas, Para enmarcar las modulaciones de altura en referencias precisas.

Juan XIX lo lleva a Roma a demostrar la clave del éxito (enseñanza masiva)

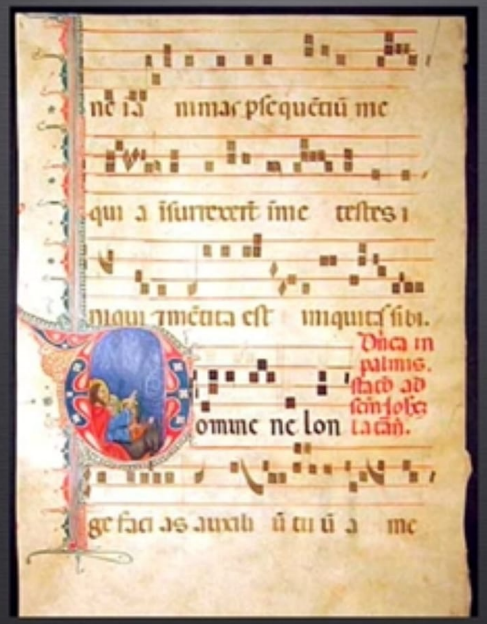
En Francia en el siglo XVI comienzan a usarse 5 líneas como referencias, y símbolos distintos para denotar duración.



Tablatura (siglo XIV)
donde un numero de lineas representa las cuerdas, y los puntos, los lugares en los que apoyar los dedos…

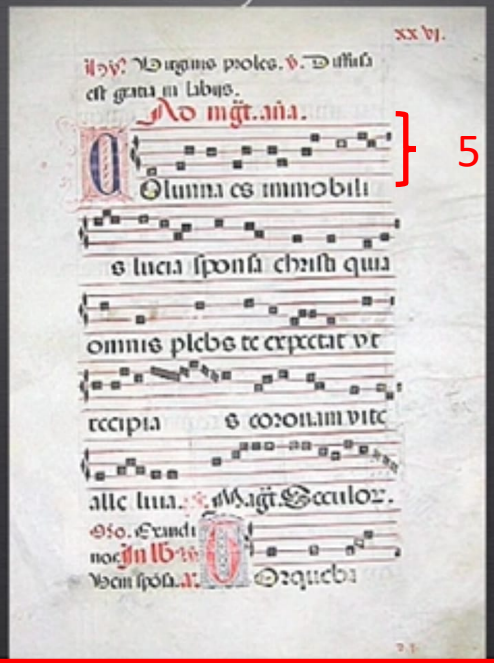
Si! Las tablas de guitarra actuales

Italy, 1370



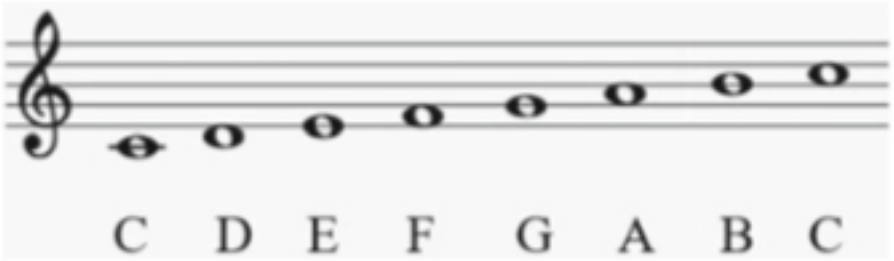
(Illuminated Manuscript)

Spain, 1500

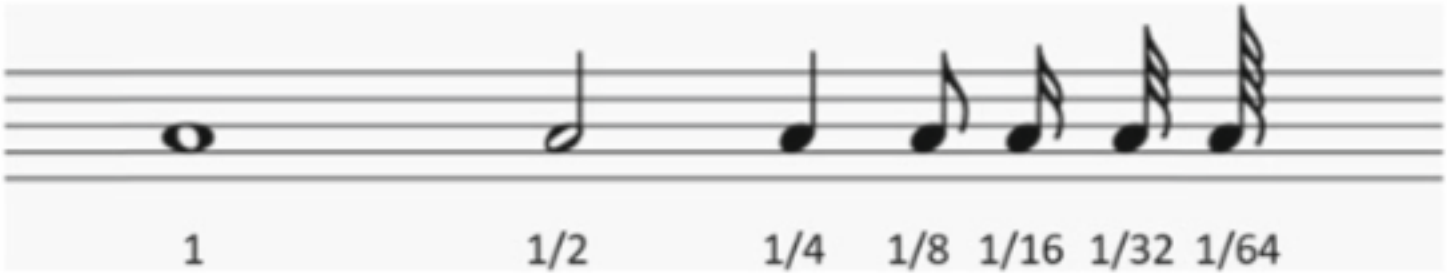


5 lineas

Convenciones en altura

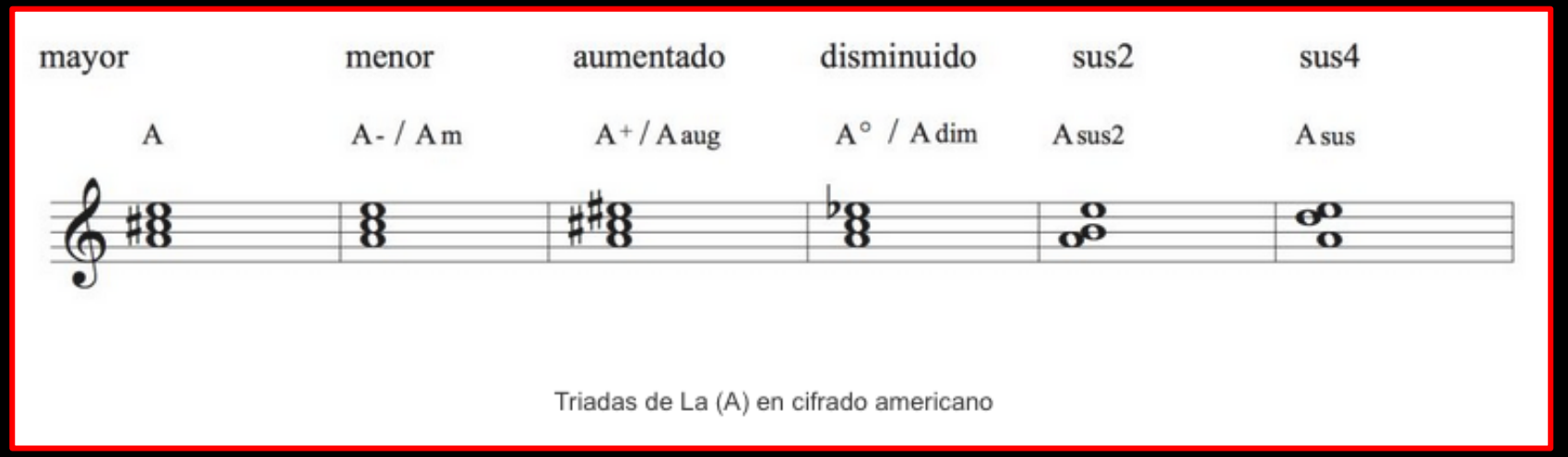


Convenciones temporales

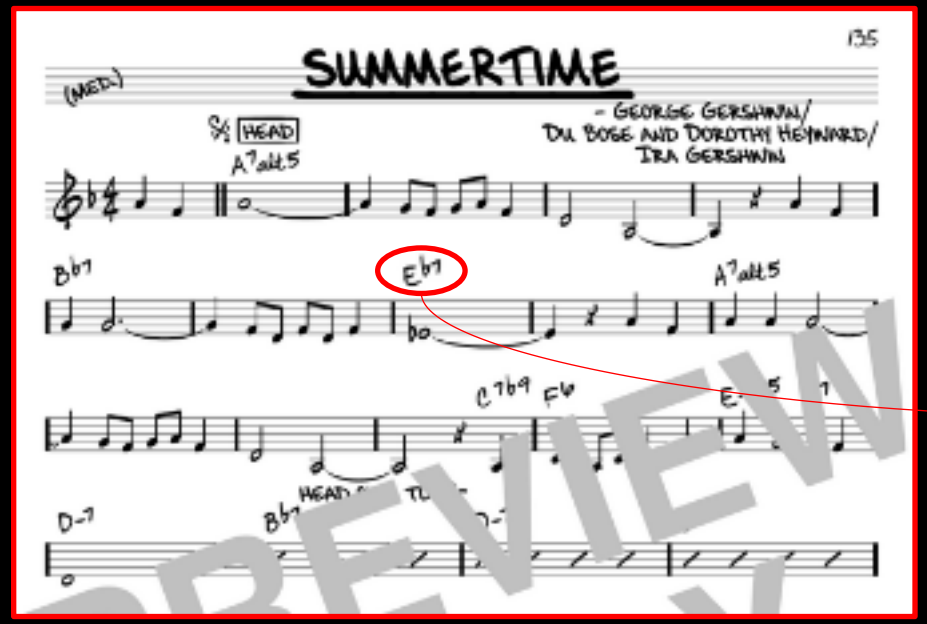


Cifrado americano
(notacion de acordes)

A (La) B(Si) C(Do) D(Re) E(Mi) F(Fa) G(Sol)



Triadas de La (A) en cifrado americano

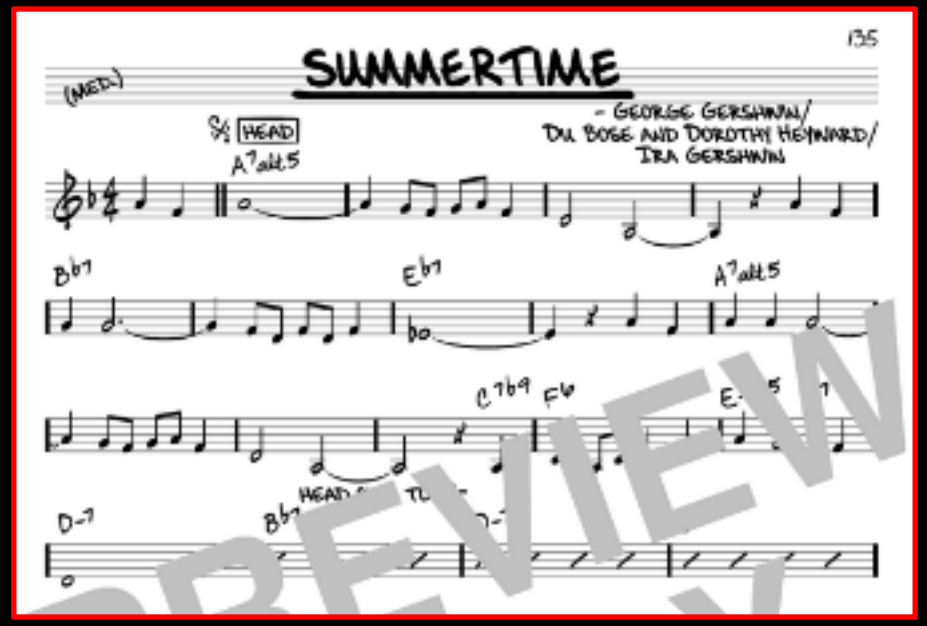


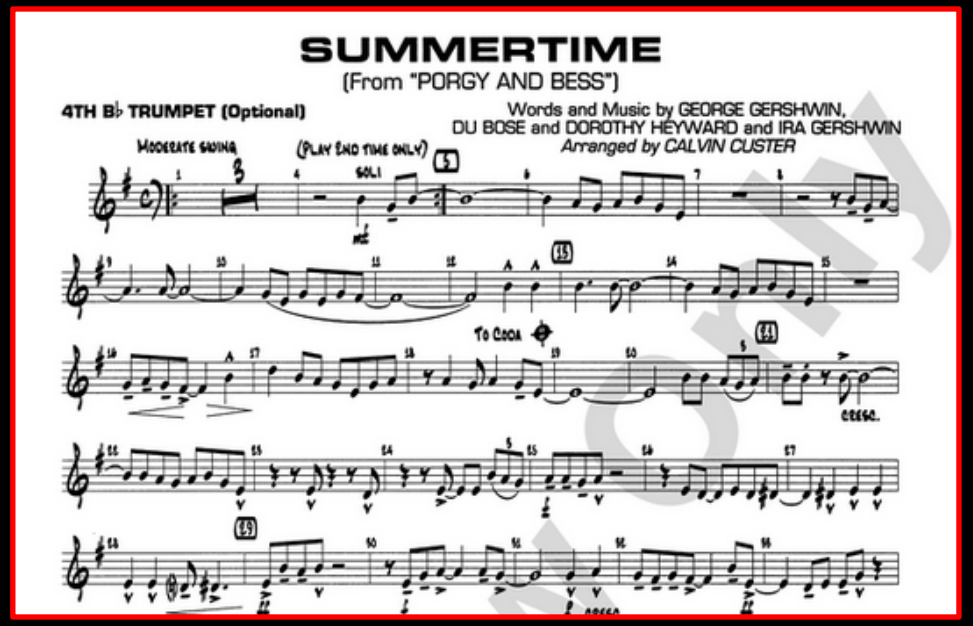
Cifrado americano

Luces y sombras

armonia

Instrumentos transpositores





Mas larga, mas grave (Bb)

Mas corta, mas aguda (C)

(5a Mahler)

En la misma familia de instrumentos,
mismos simbolos
asociados a
mismas digitaciones

De este modo, un interprete puede tocar instrumentos que cubren un rango diferente

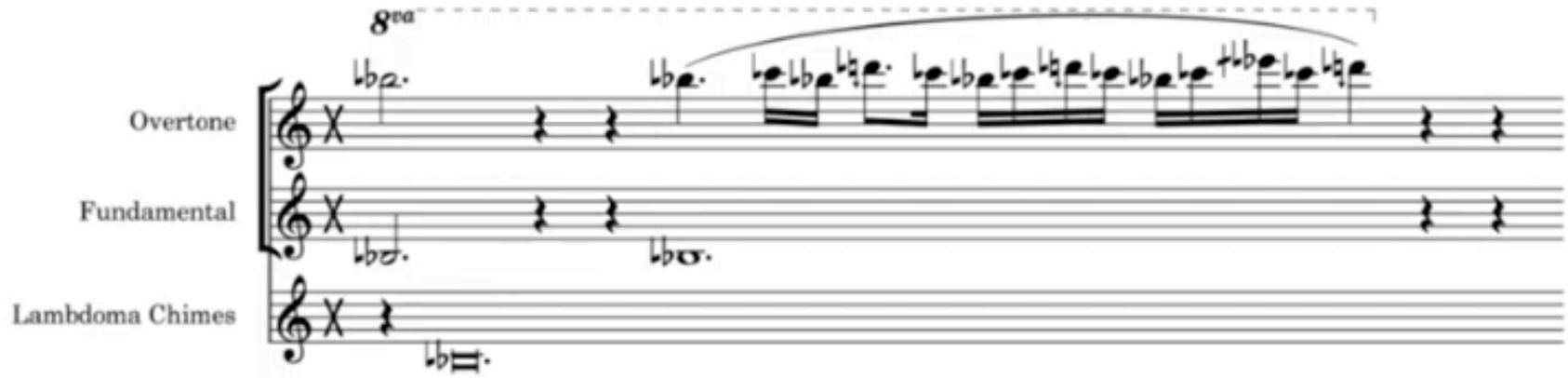
Por supuesto, hay que escribir las partes para cada instrumento, con las notas transpuestas adecuadamente

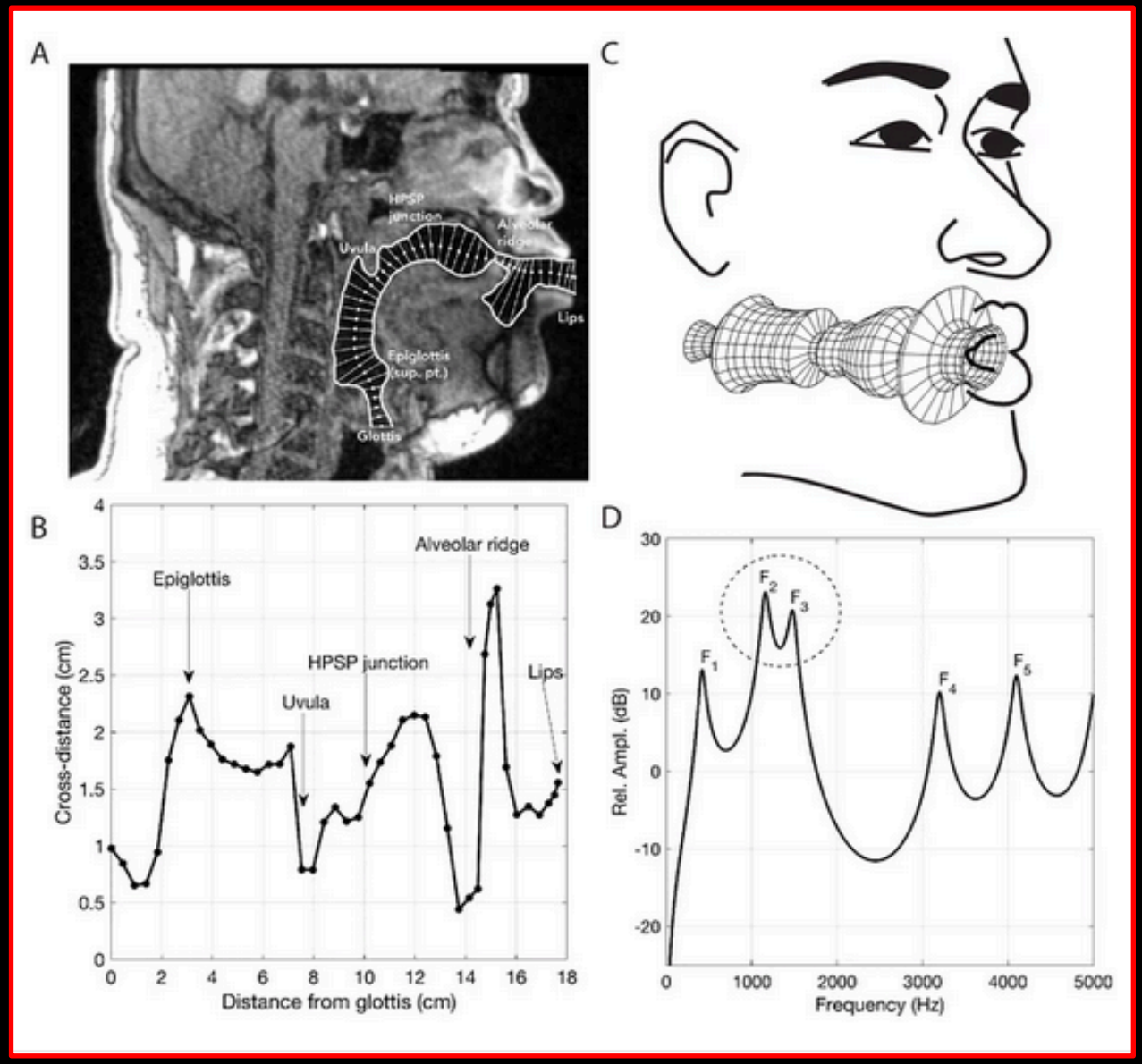
OVERTONE SINGING & LAMBDOMA

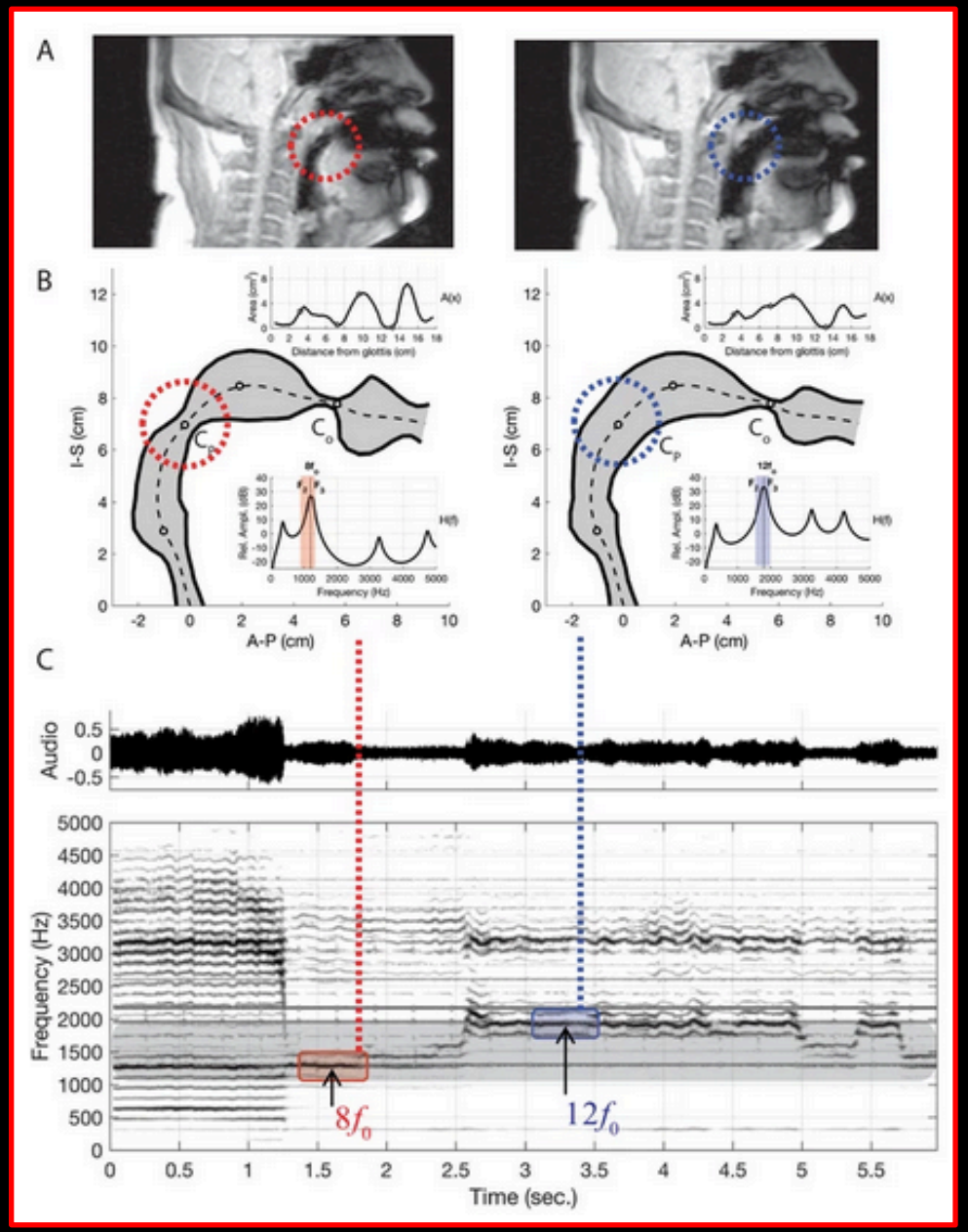
Transcription: Stephen Weigel

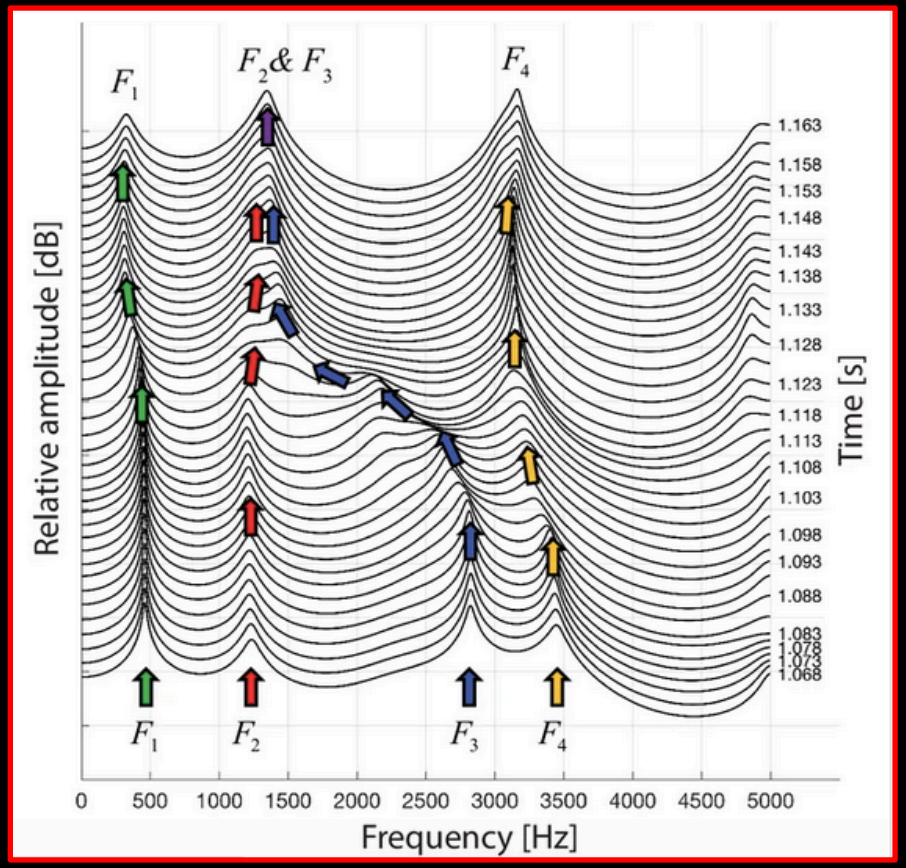
Anna-Maria Hefele & Josef Baier

EXCERPT 1



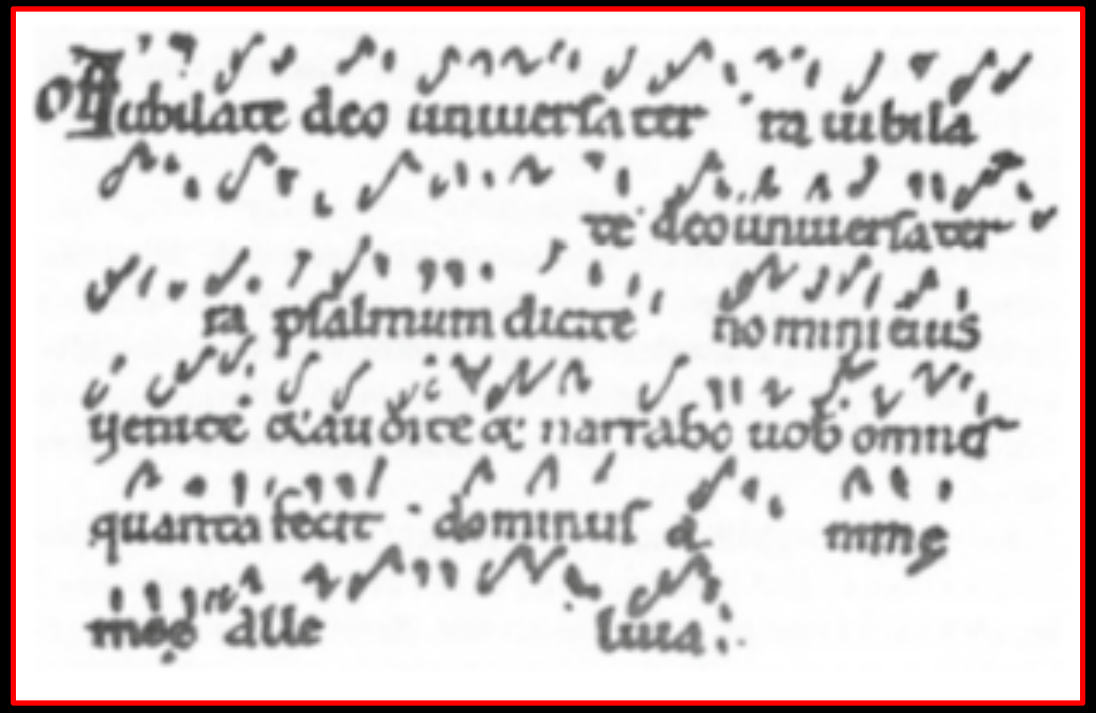

A
HPSP junction
Uvula
Alveolar ridge
Lips
Epiglottis (sup. pt.)
Glottis
C
B
Epiglottis
Alveolar ridge
HPSP junction
Uvula
Lips
Cross-distance (cm)
Distance from glottis (cm)
D
F1
F2
F3
F4
F5
Rel. Ampl. (dB)
Frequency (Hz)


A
B
C
I-S (cm)
A-P (cm)
Distance from glottis (cm)
Area (cm²)
A(x)
H(f)
Rel. Ampl. (dB)
Frequency (Hz)
Audio
Frequency (Hz)
Time (sec.)
$8f_0$
$12f_0$

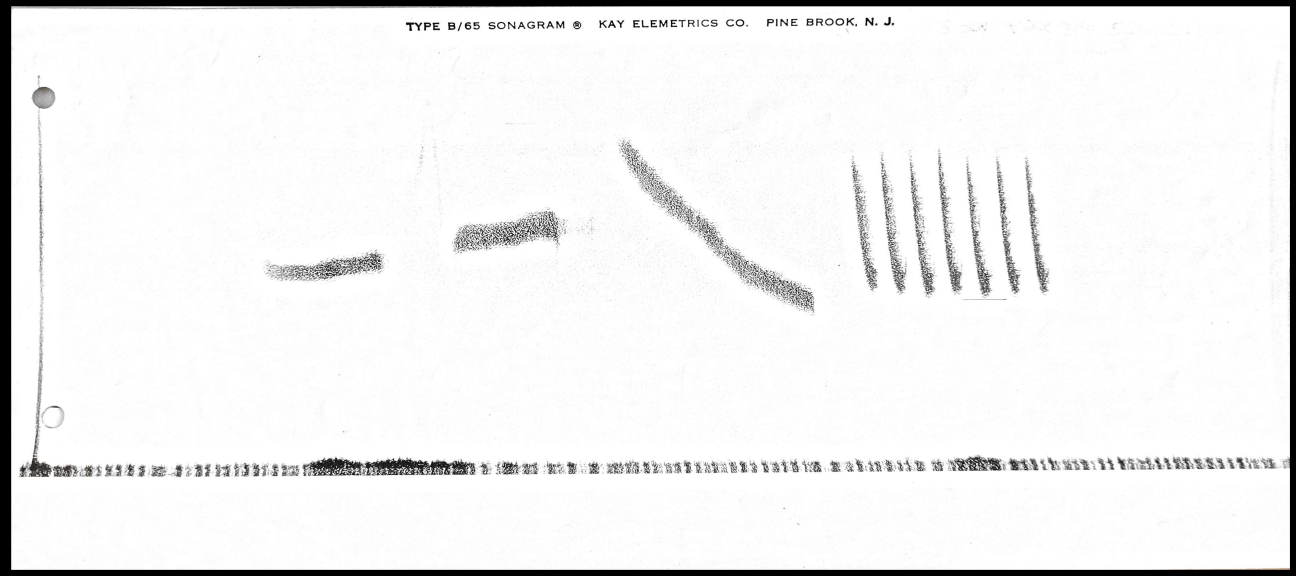

F_1
F_2 & F_3
F_4
Relative amplitude [dB]
Time [s]
Frequency [Hz]

Dar cuenta de lo sonoro,
(particularmente, si no hay parcelizacion espectral)
fue un desafio historico para la humanidad.

"In my childhood, this bird warbled to me through the lines of a poem I read, and now, many years later, I hear the song for the first time. It is beautiful, but how unlike what I had imagined". W.H. Hudson (1842-10922)



Espectrografo, desarrollo reservado para uso militar en los 40, accesible a la investigacion cientifica abierta en los 50.

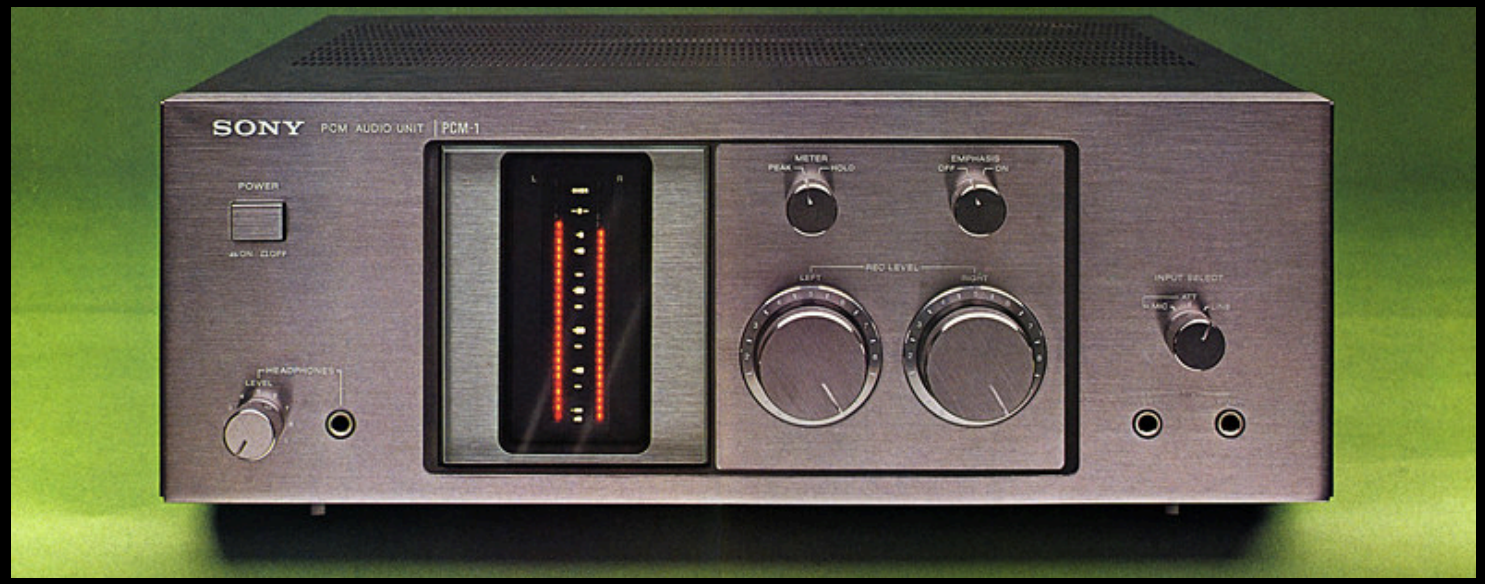


Espectrograma del canto de un chingolo

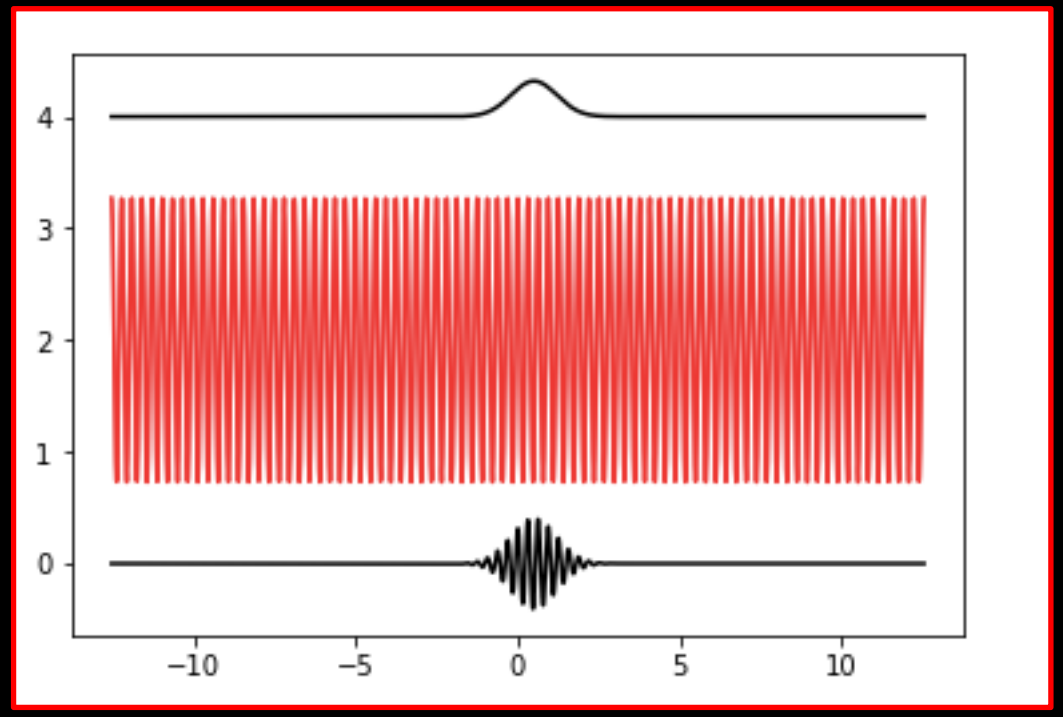

Sound Spectrograph
Takayuki Arai
(Sophia University)
0:00
Sound Spectrograph
Takayuki Arai
(Sophia University)

Digitalizacion: 1937 (PCM, for “pulse code modulation”), Alec Reeves

Primer grabador digital comercial: 1977, PCM-1 Sony



Con datos digitalizados, podemos computar espectrogramas de modo computacional



$$f_i(t) = e^{-\frac{(t-t_i)^2}{\tau}}$$

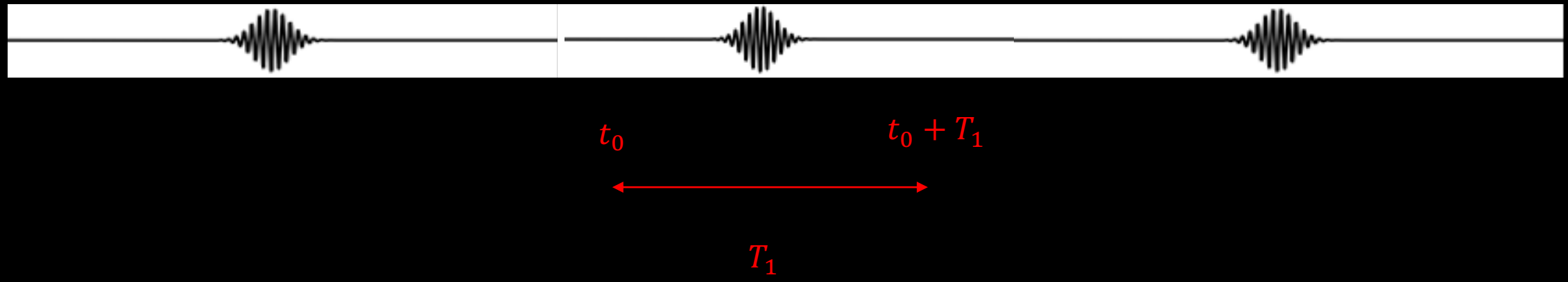
$$s(t)$$

$$\psi(t) \equiv s(t) f_i(t)$$

Y como describimos a esta funcion $\psi(t)$?

Construimos una F(t) copiando segmentos

F(t)



Y analizamos esa nueva funcion periodica, usando Fourier

$$F(t) = B_0 + \sum_{n=1}^{\infty} A_n \sin(n\omega_1 t) + B_n \cos(n\omega_1 t)$$

$$\omega_1 = \frac{2\pi}{T_1}$$

$$B_0 = \frac{1}{T_1}\int_{t_0}^{t_0+T_1} F(t)dt$$

$$A_n = \frac{2}{T_1}\int_{t_0}^{t_0+T_1} F(t)\sin(n\omega_1 t)\,dt$$

$$B_n = \frac{2}{T_1}\int_{t_0}^{t_0+T_1} F(t)\cos(n\omega_1 t)\,dt$$

Y analizamos esa nueva funcion periodica, usando Fourier

$$F(t) = B_0 + \sum_{n=1}^{\infty} A_n \sin(n\omega_1 t) + B_n \cos(n\omega_1 t)$$

$$\omega_1 = \frac{2\pi}{T_1}$$

$$B_0 = \frac{1}{T_1}\int_{t_0}^{t_0+T_1} F(t)dt \sim 0$$

Si la media es nula

$$A_n = \frac{2}{T_1}\int_{t_0}^{t_0+T_1} F(t)\sin(n\omega_1 t)\,dt \sim 0$$

$$B_n = \frac{2}{T_1}\int_{t_0}^{t_0+T_1} F(t)\cos(n\omega_1 t)\,dt \sim 0$$

Si n es chico

Y analizamos esa nueva funcion periodica, usando Fourier

$$F(t) = \cdots A_n \sin(n\omega_1 t) + A_{n+1} \sin(n\omega_1 t + \omega_1 t) + \cdots$$

Entonces pensamos $n\omega_1 = \omega$

$$F(t) = \int_0^{\infty} A(\omega) \sin(\omega t)\, d\omega + B(\omega) \cos(\omega t)\, d\omega$$

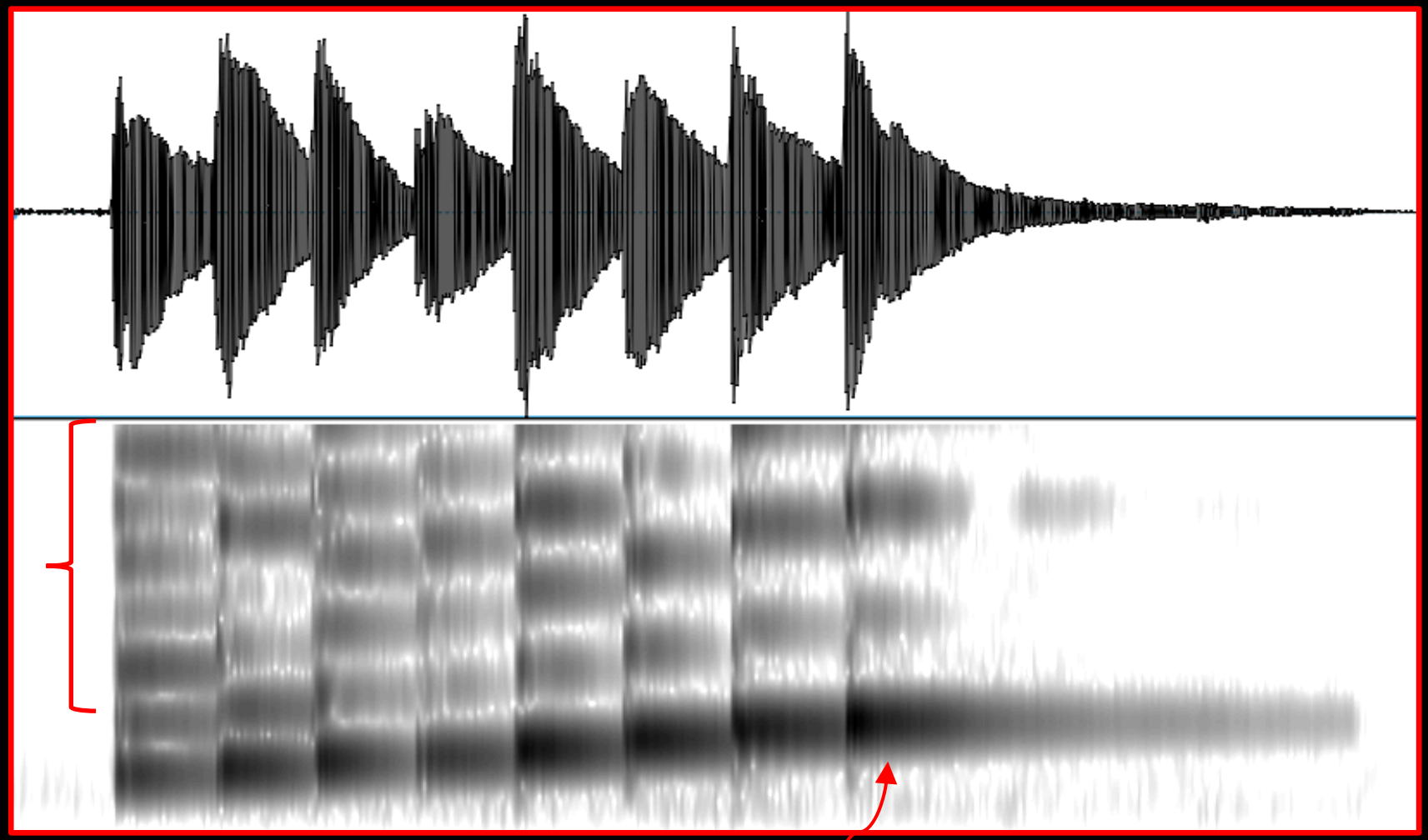
$$A(\omega) = \frac{2}{\omega_1 T_1} \int_{t_0}^{t_0+T_1} F(t) \sin(\omega t)\, dt = \frac{1}{\pi} \int_{t_0}^{t_0+T_1} \psi(t) \sin(\omega t)\, dt$$

$$B(\omega) = \frac{2}{\omega_1 T_1} \int_{t_0}^{t_0+T_1} F(t) \cos(\omega t)\, dt = \frac{1}{\pi} \int_{t_0}^{t_0+T_1} \psi(t) \cos(\omega t)\, dt$$

“Nueva” notacion: el espectrograma
¿Que ganamos?

P

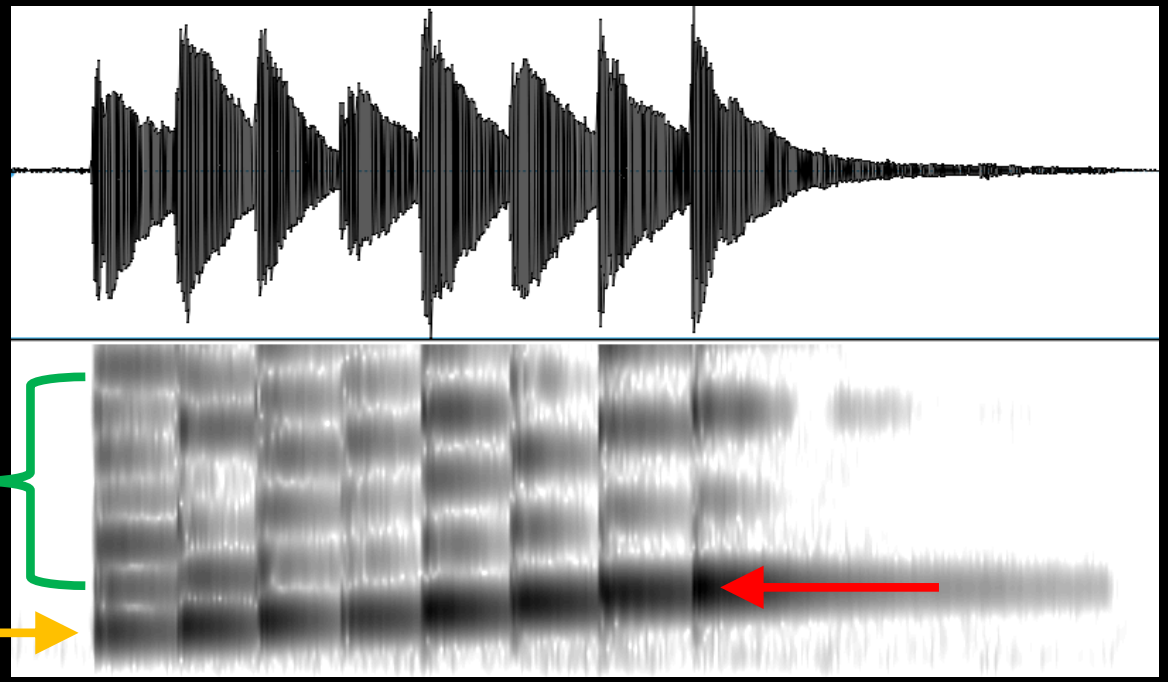
armonicos

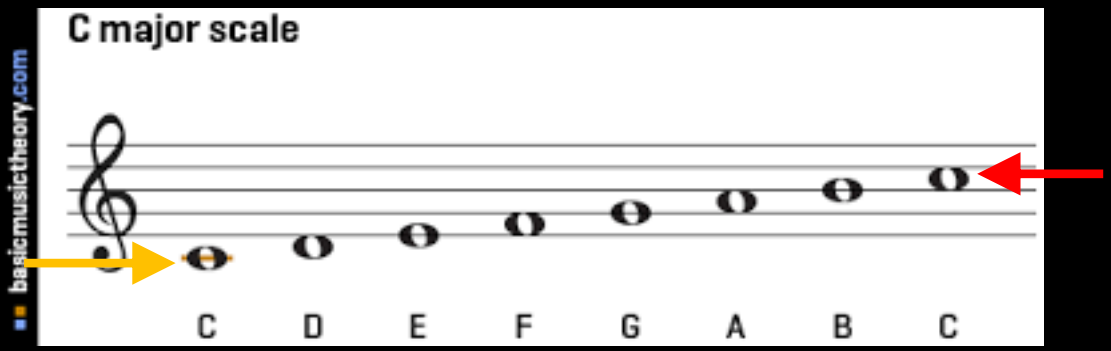


Fundamentales

t

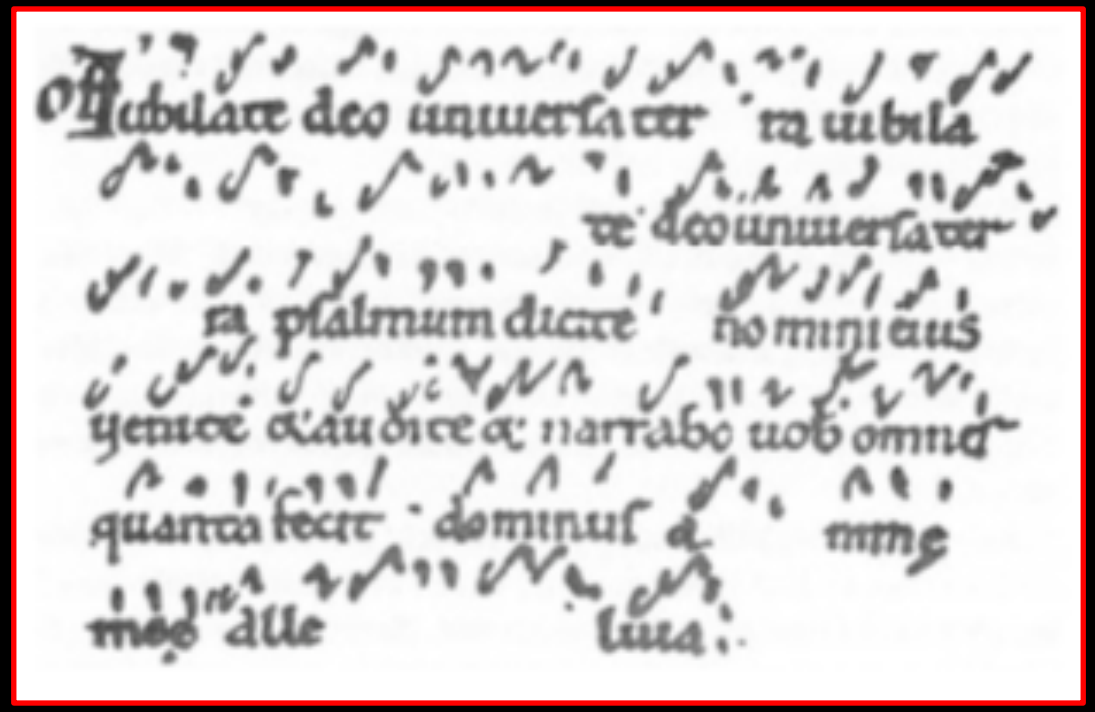
Armonicos,
que definen el timbre



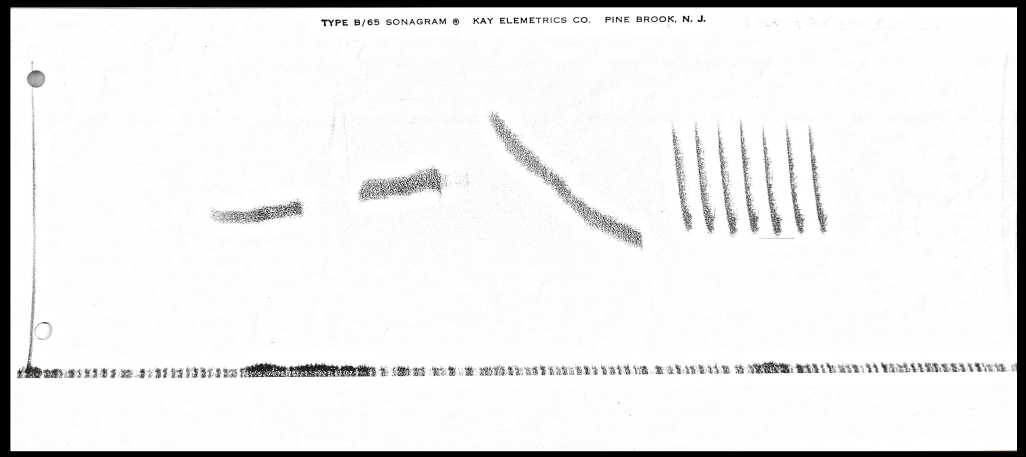


Un ejemplo inusual de interdisciplina: de la musica a la ciencia

Monjes aprendiendo a cantar



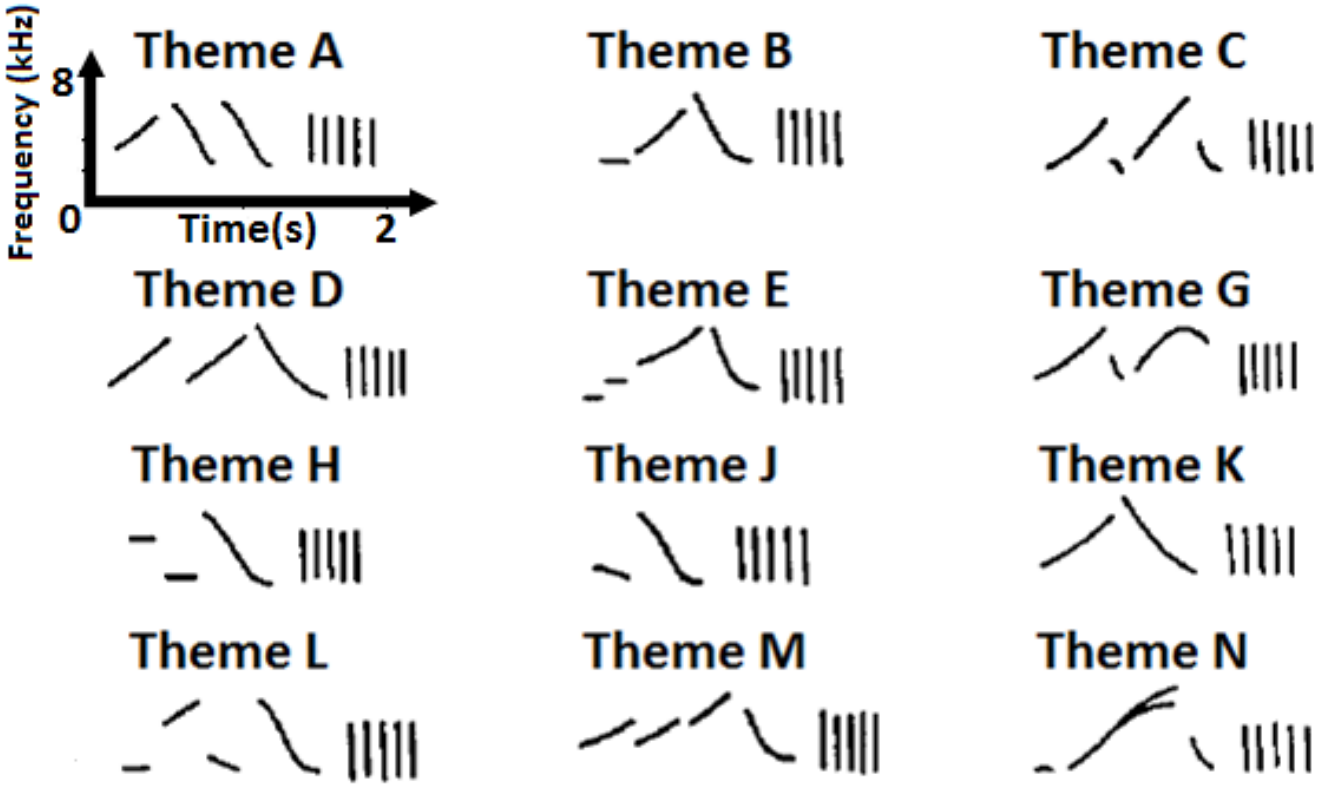
Chingolos aprendiendo a cantar



Gran formacion musical

Sketches by Nottebohm, taken in **1966**

Gran formacion musical



Are the same we are measuring now?

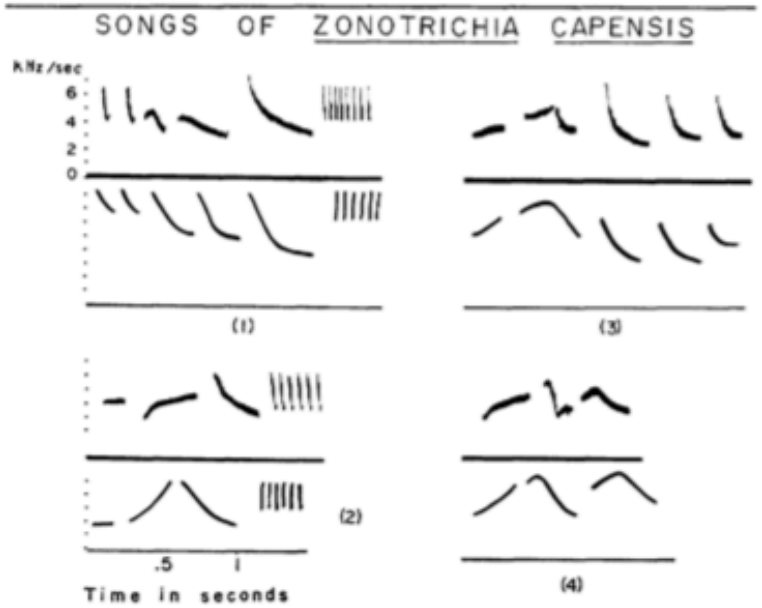
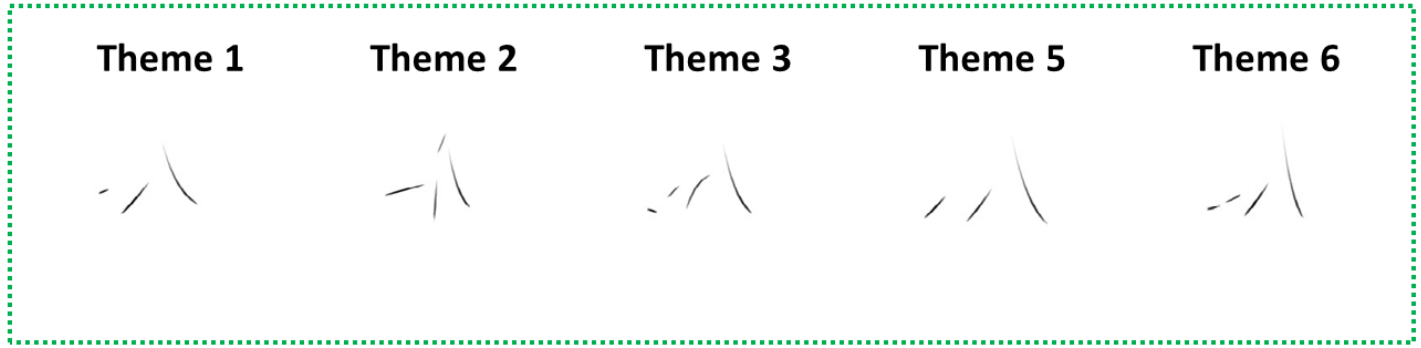


FIGURE 2. Four *Zonotrichia capensis* songs from the following sources: (1) Colombia, bird captured by A. H. Miller and recorded by Peter Marler at Berkeley, California, 2 June 1960; (2) and (4) two different birds recorded by Josué Nuñez, at Boulogne, near Capital Federal, Argentina, October 1967; song (4) is incomplete, lacking a trill; (3) Brazilian Chingolo song, from "Surco" record OL 7012, "Cantos de Aves de América del Sur," by Johan Dalgas Frisch. Each song is represented by a sound-spectrograph (upper) and its corresponding version in field notation system (lower).

We will train a neural network to quantify the difference between the songs in 1966 and the songs in 2022

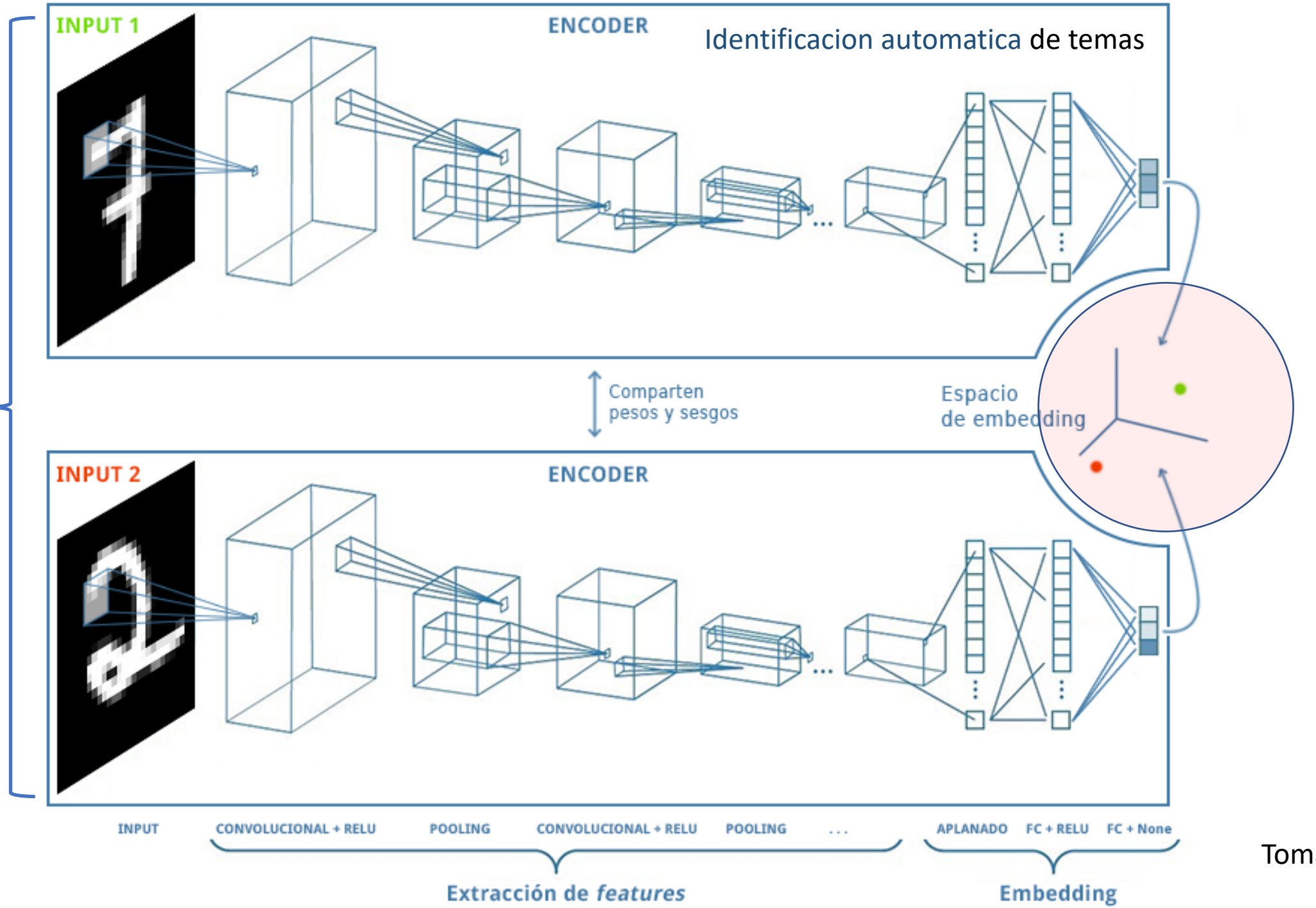
Synthetic songs emulating the frequency modulations of the songs recorded in 2020

Synthetic songs emulating the frequency modulation sketched from the songs in 1966



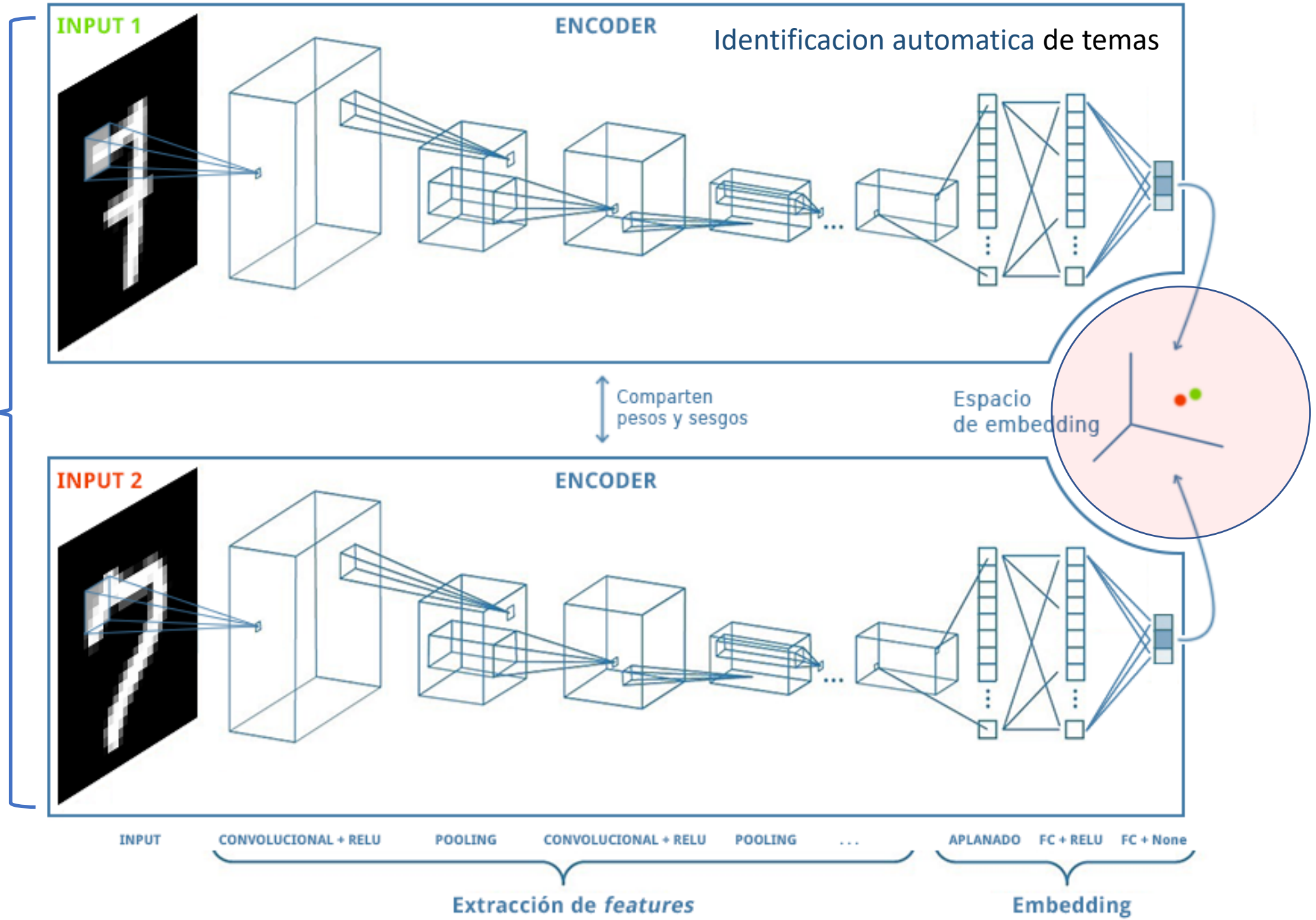
And with the 2022, we will train a siamese network
In order to define a **metric**

Redes Siamesas (definen una metrica)

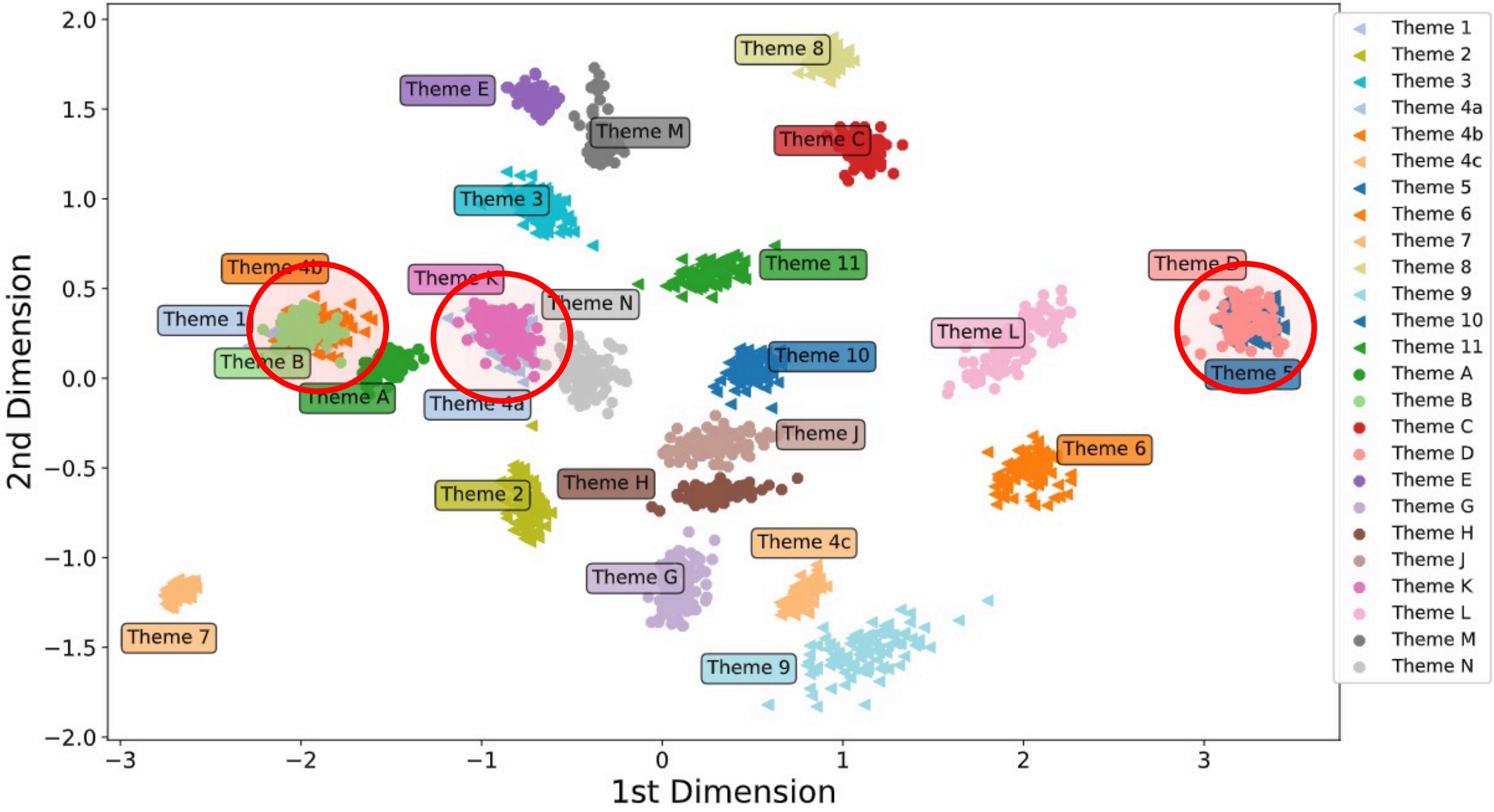


Tomas Bossi

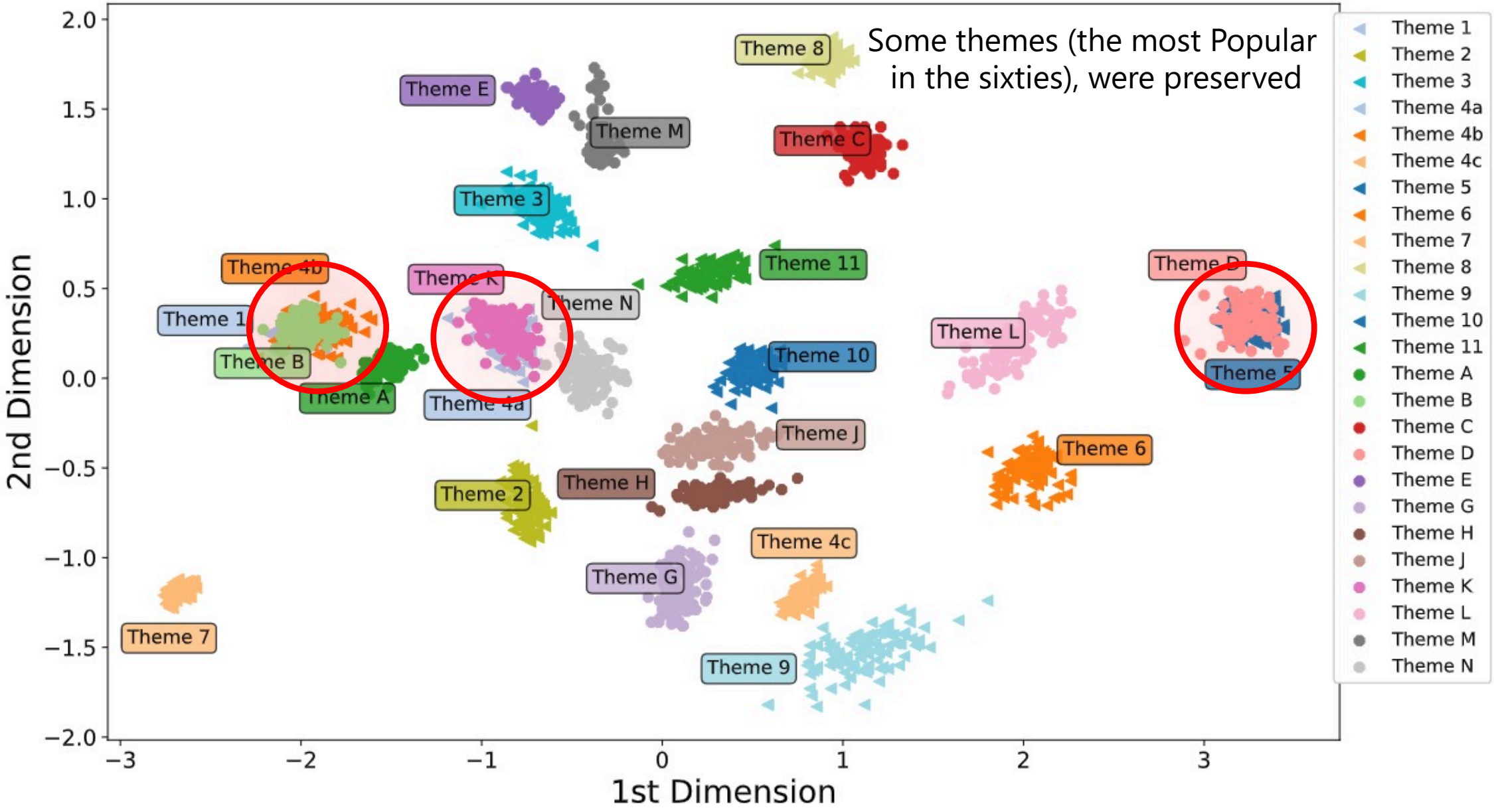
Redes Siamesas (definen una metrica)



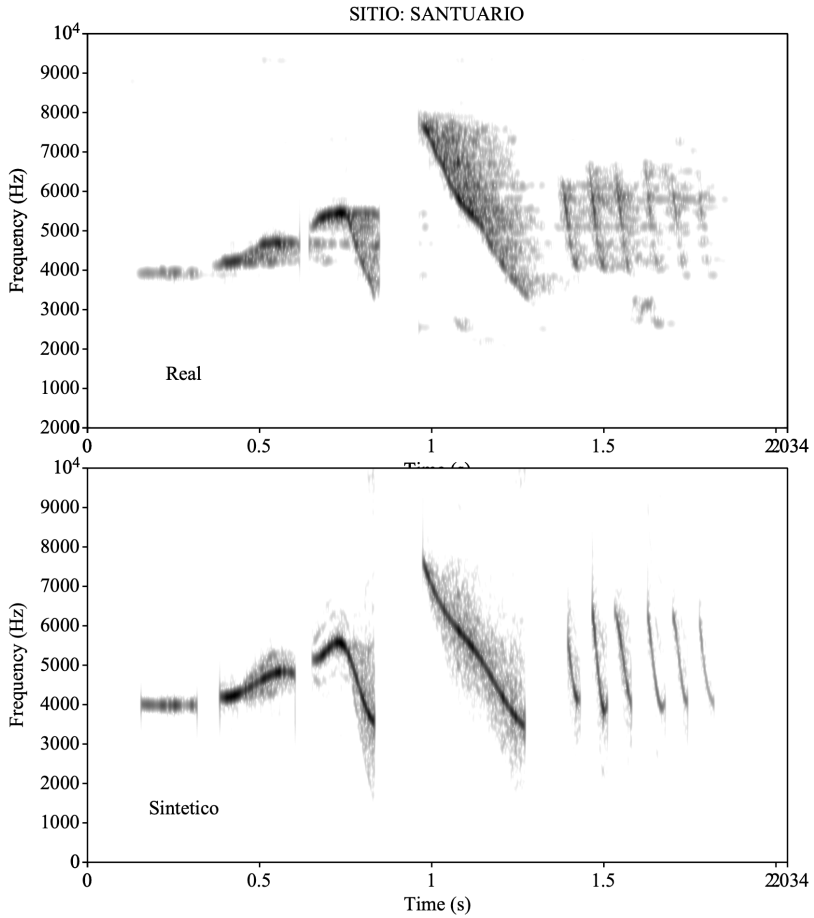
And we process with the networks, the resynthesized songs of 1966...



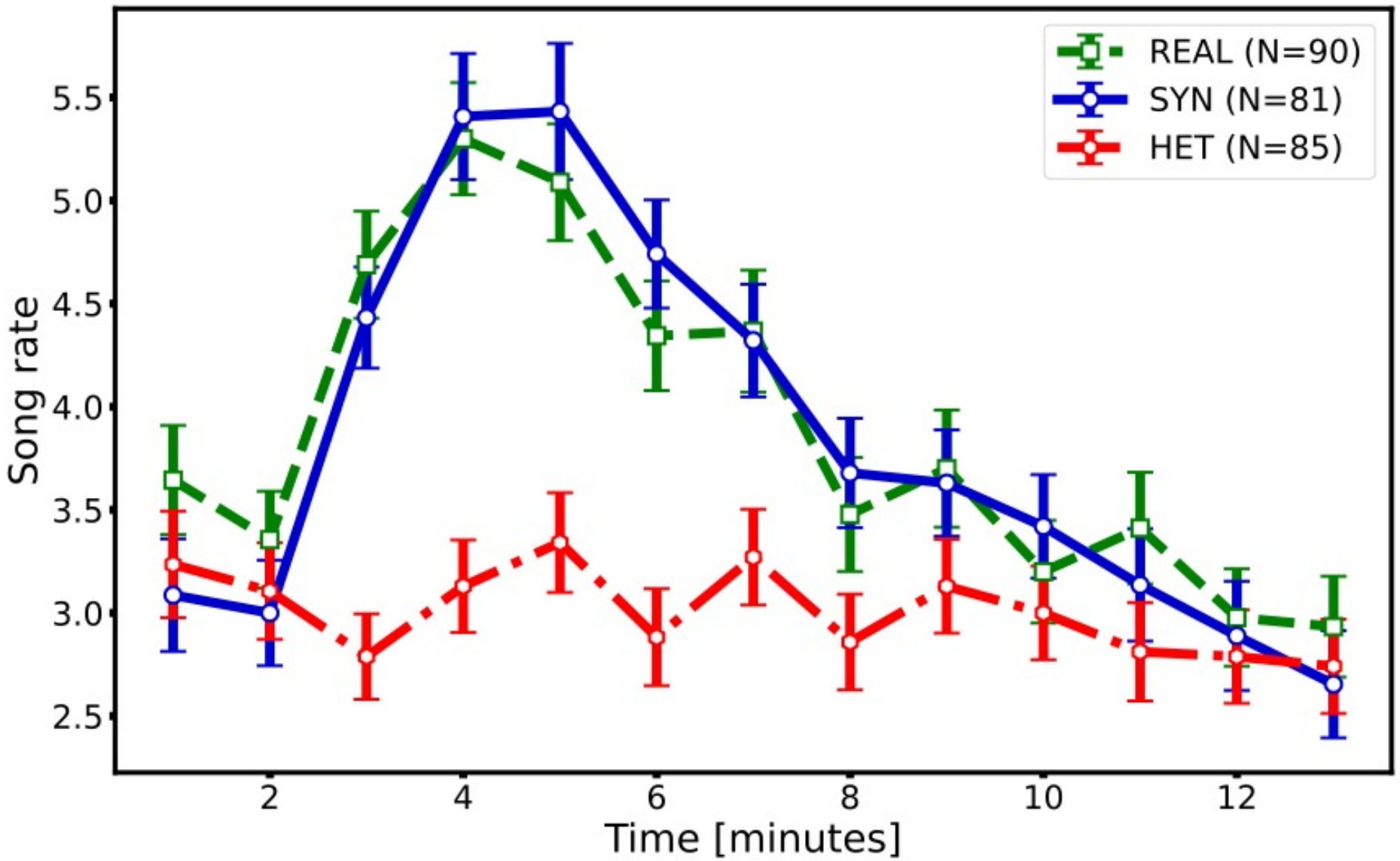
And we process with it the resynthesized songs of 1966...



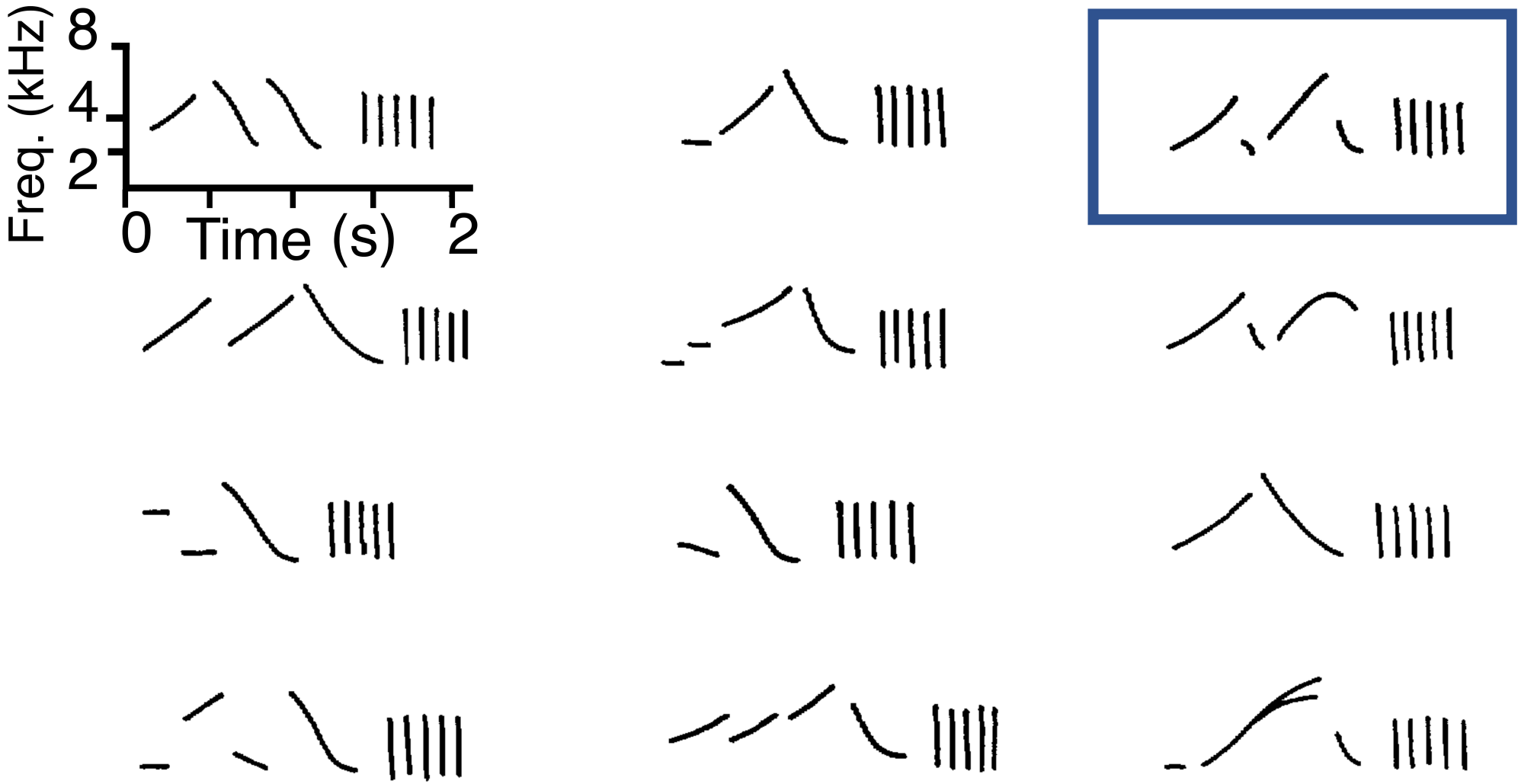
1. A song, and a synthetic copy, as played by our robots



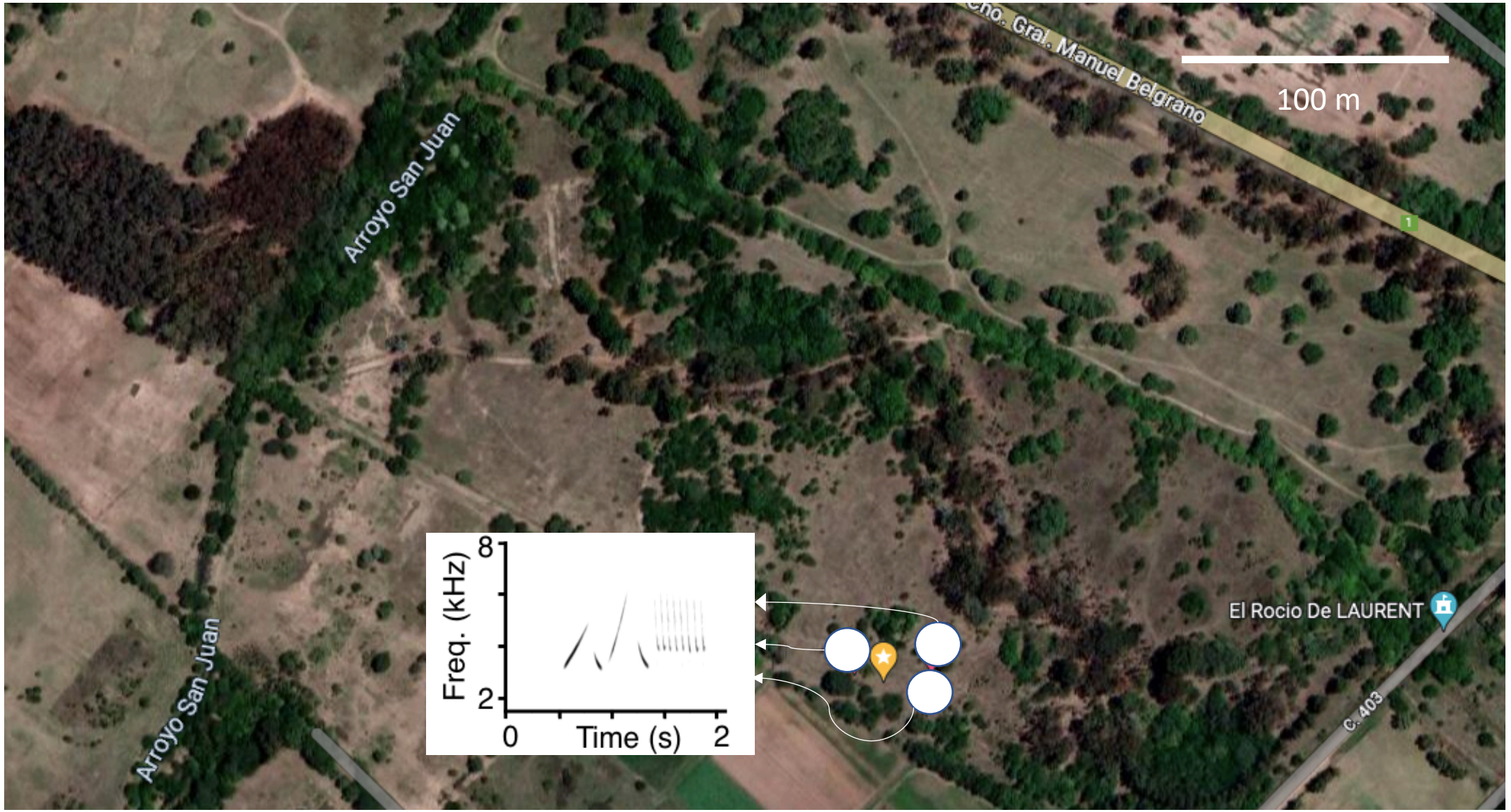
2. Birds do respond similarly to synthetic and real song



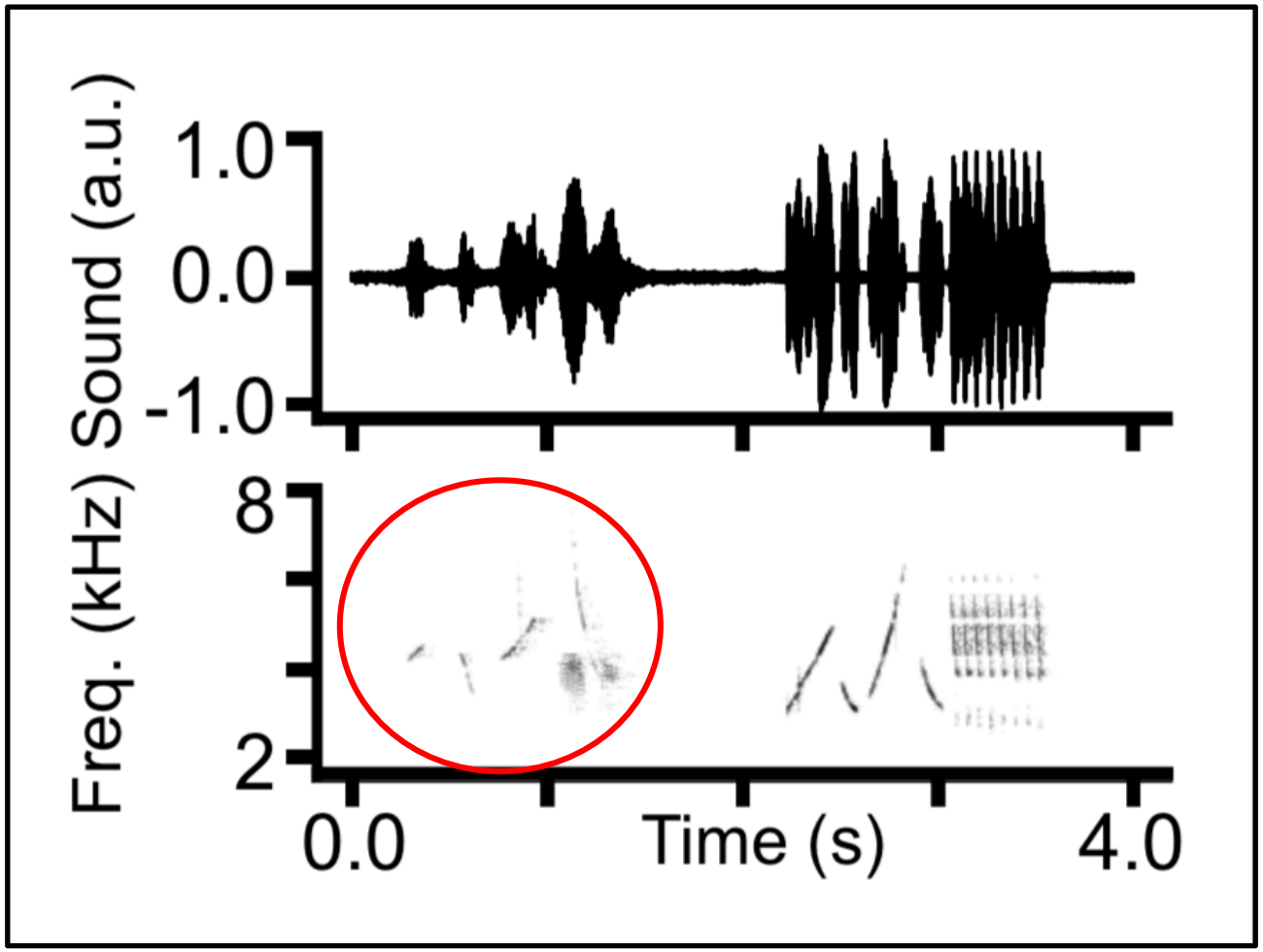
3. We select a song from the sixties which is not sung now



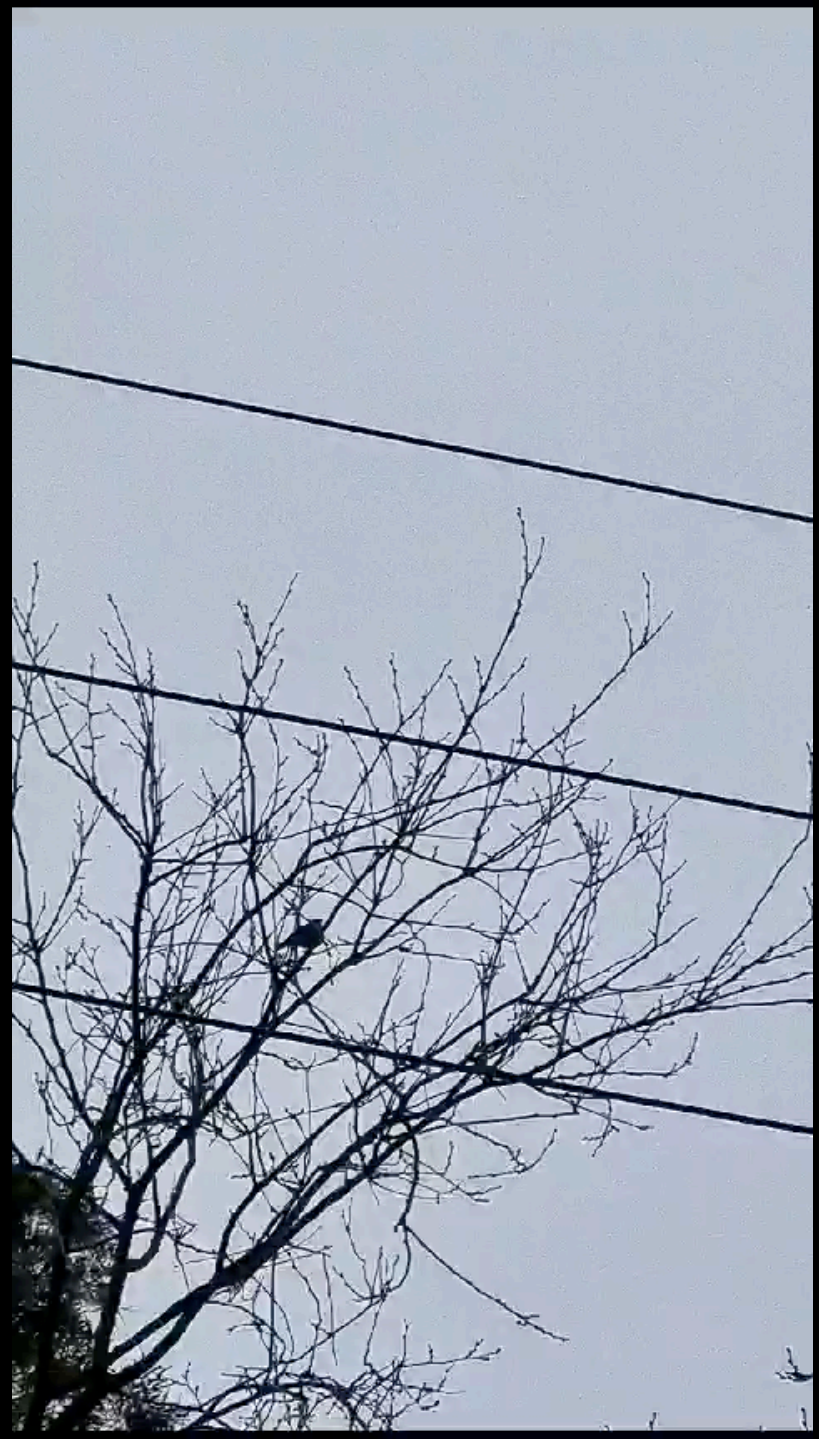
4. Three robots playing the synthetic version of the “extint” song

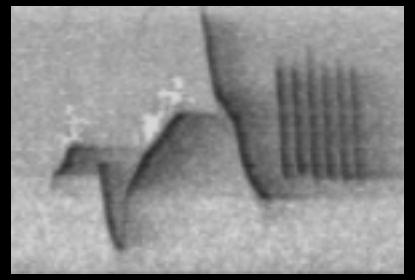


5. On January the 24th, we recorded the first juvenile singing to its robot tutor



2nd September 2023

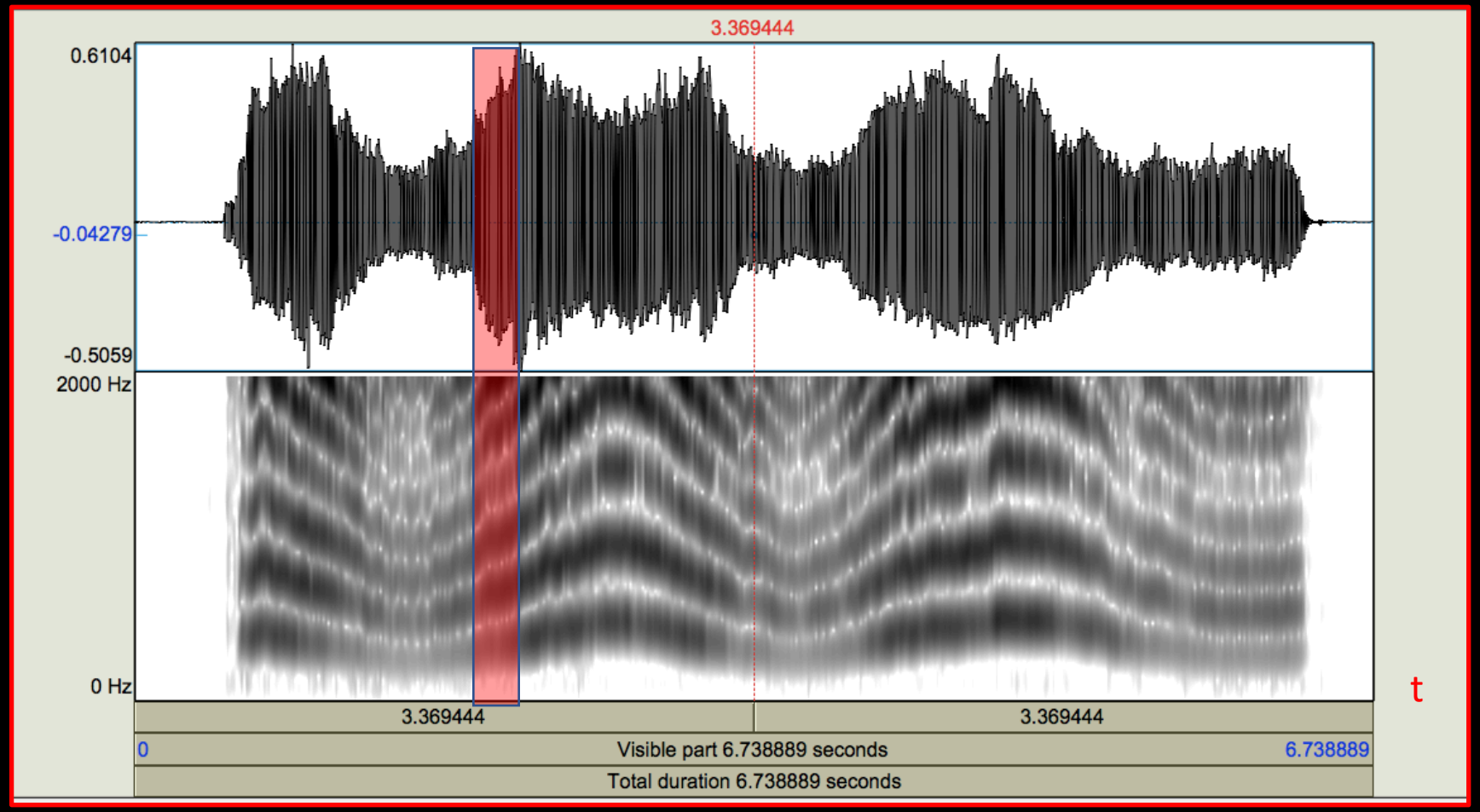




¿Que mas podemos aprender a leer de un sonograma, que de una partitura es dificil?

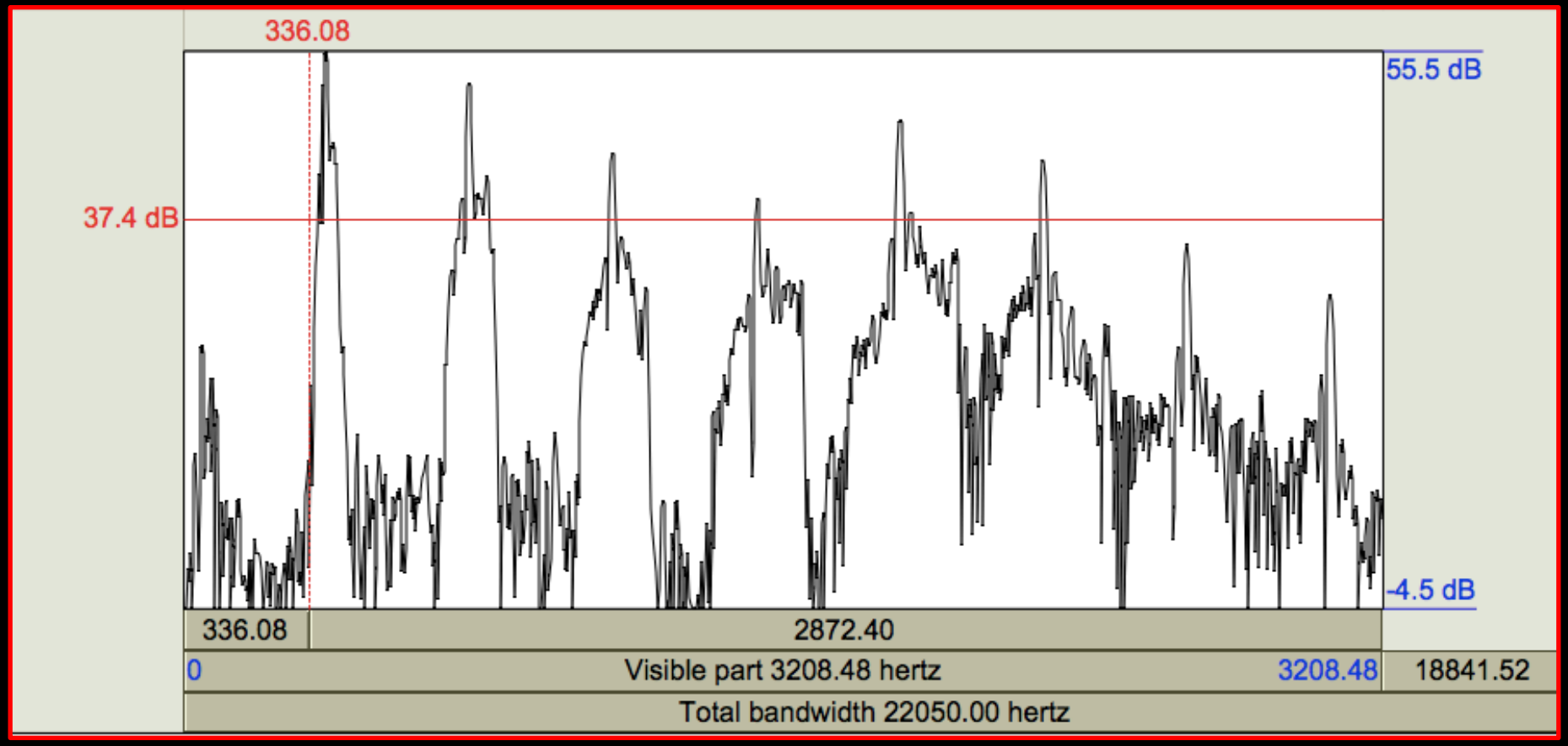
P

W



t

F(w)

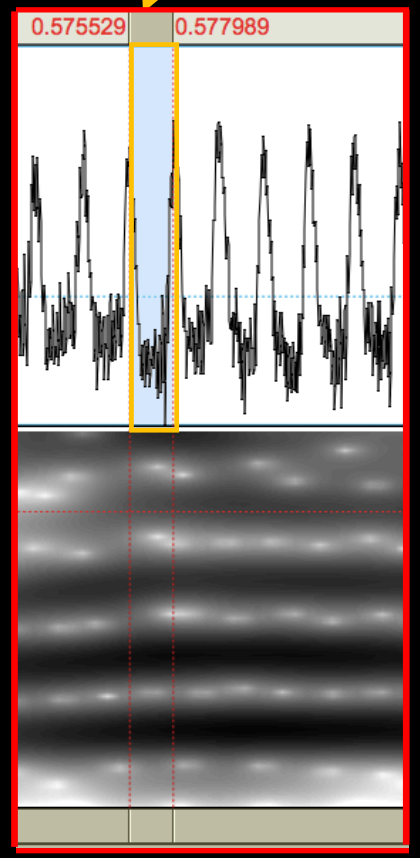


w

Bastante parejos los picos del espectro, de un corte.
Indica cierto comportamiento “explosivo” en la dinamica de la fuente.

¿Como dar cuenta de la aparicion de una oscilacion que gran parte del tiempo este cerca de un valor?

(i.e. oscilacion impulsiva)



Señal temporal

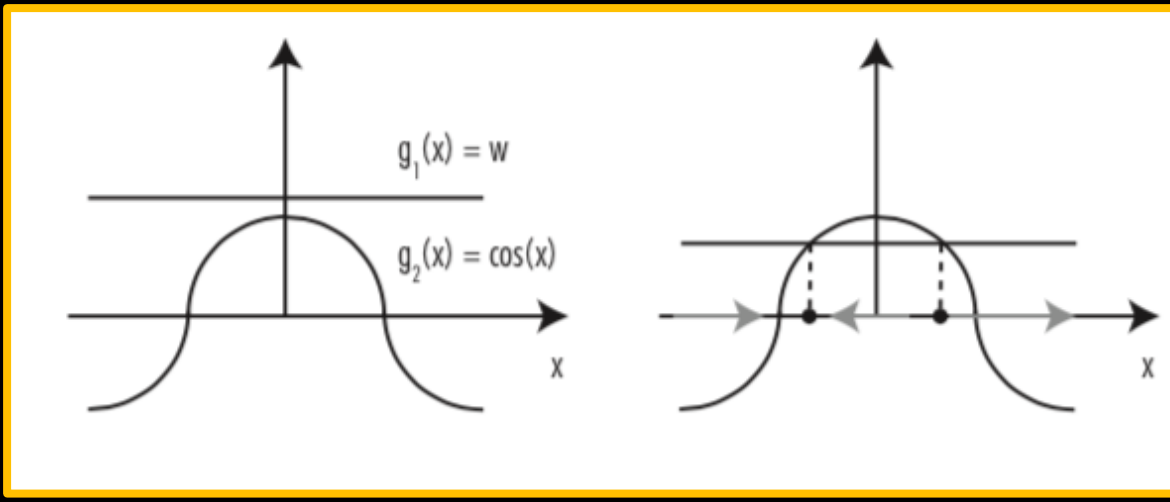
Evolucion temporal del espectro

Como se describe dinámicamente un Comportamiento periódico impulsivo?

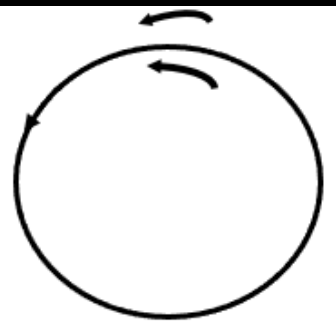
$$\frac{dr}{dt} = r(1-r)$$

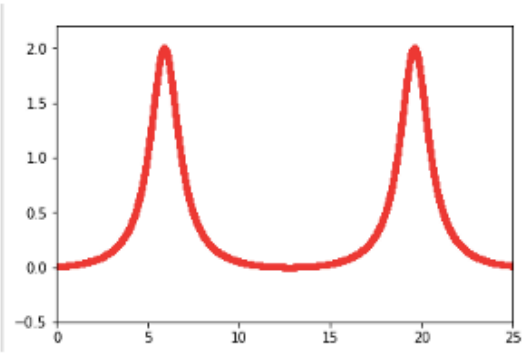
$$\frac{d\theta}{dt} = \omega - cos\theta$$

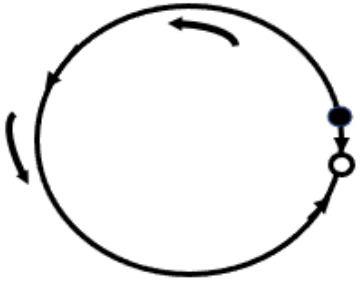
Notemos que para la parte angular,

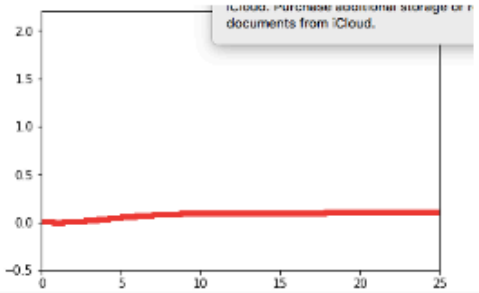


O sea, cuando $\omega > 1$, el sistema oscila. Las oscilaciones nacen con periodo infinito.









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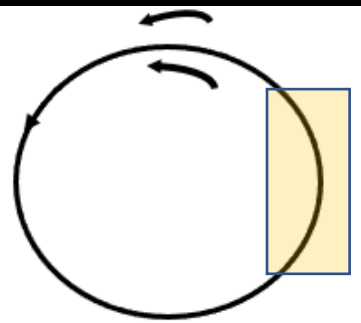
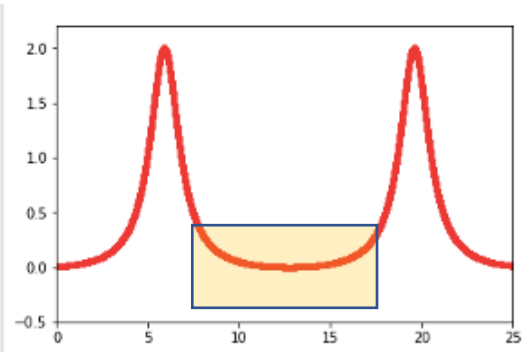
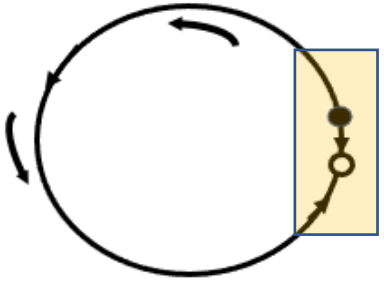
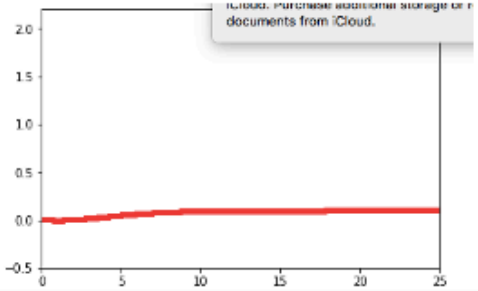
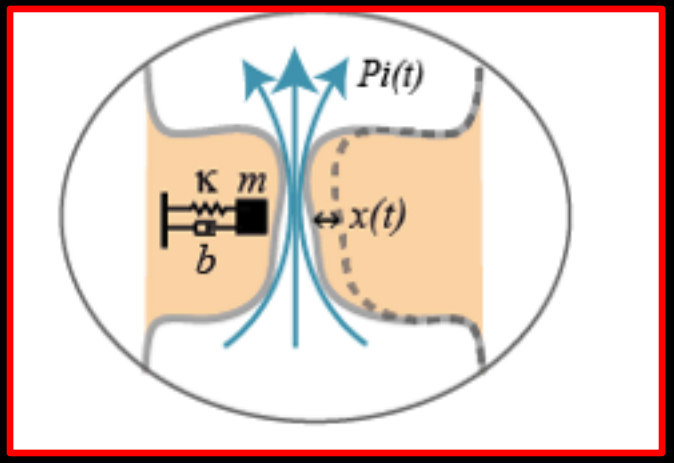




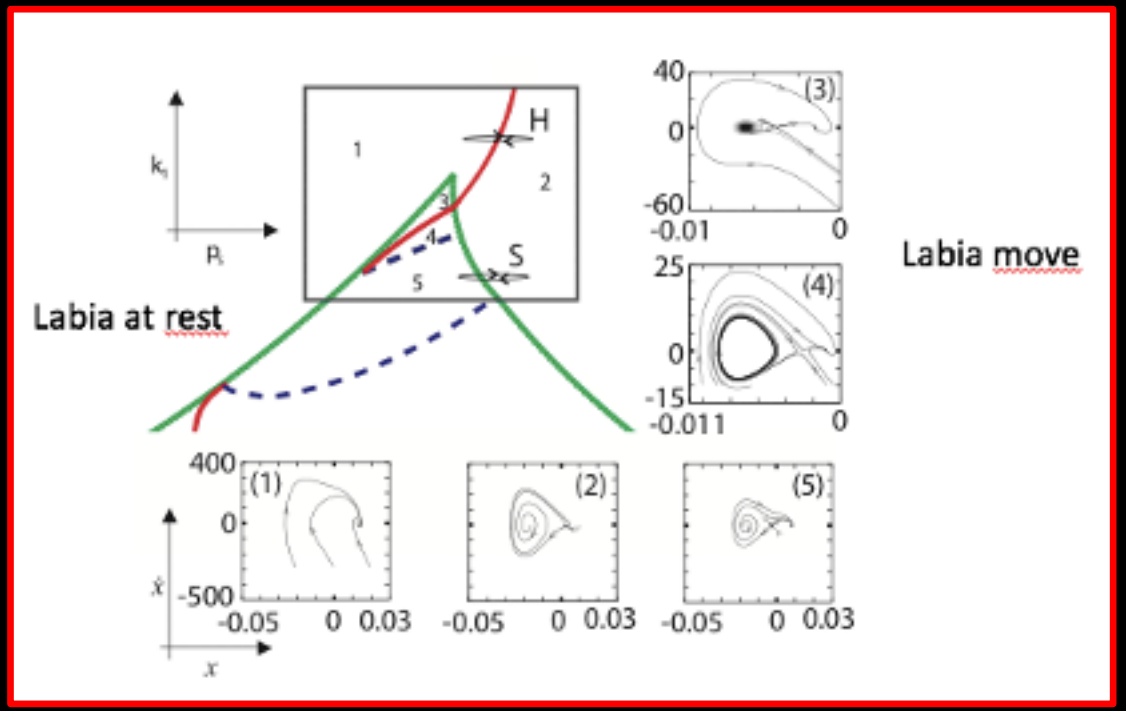
El critical slowing down
huella de la bifurcacion nodo silla.







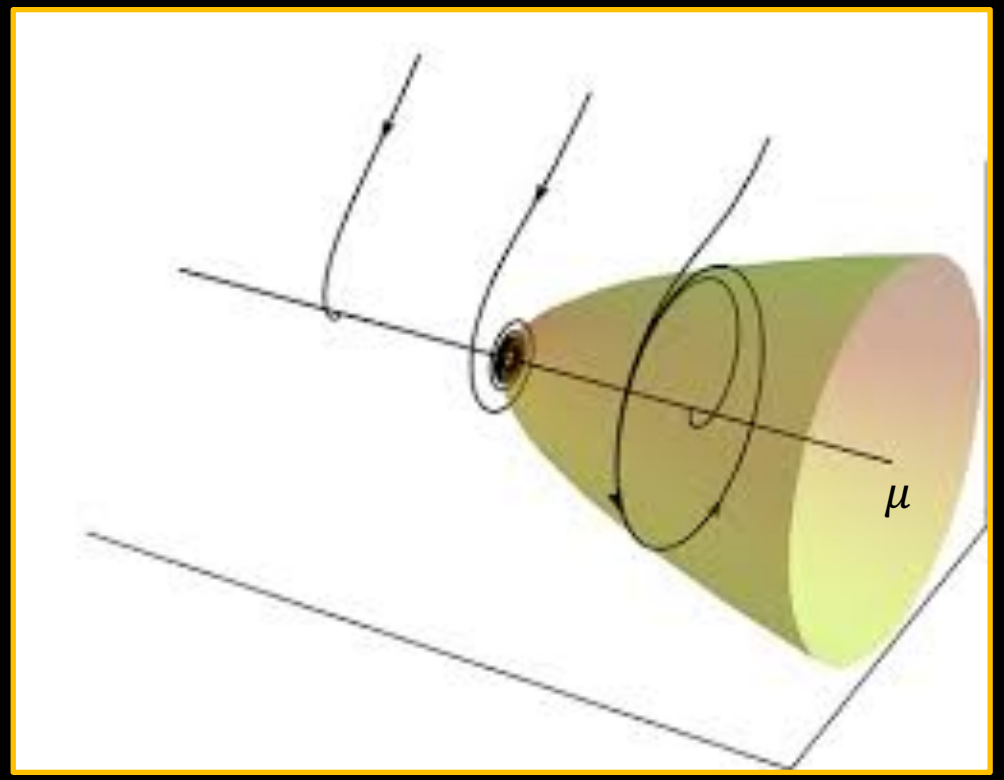
$$\begin{cases} \dfrac{dx}{dt} = y, \\ \dfrac{dy}{dt} = (1/m)\left[-k(x)x - b(y)y - cx^2y + a_{lab}p_s\left(\dfrac{\Delta a + 2\tau\tau}{a_{01} + x + \tau y}\right)\right]. \end{cases}$$



¿Como se describe dinámicamente
el nacimiento suave de una oscilación?

$$\frac{dr}{dt} = \mu\, r - r^3$$

$$\frac{d\theta}{dt} = \omega + br^2$$


μ

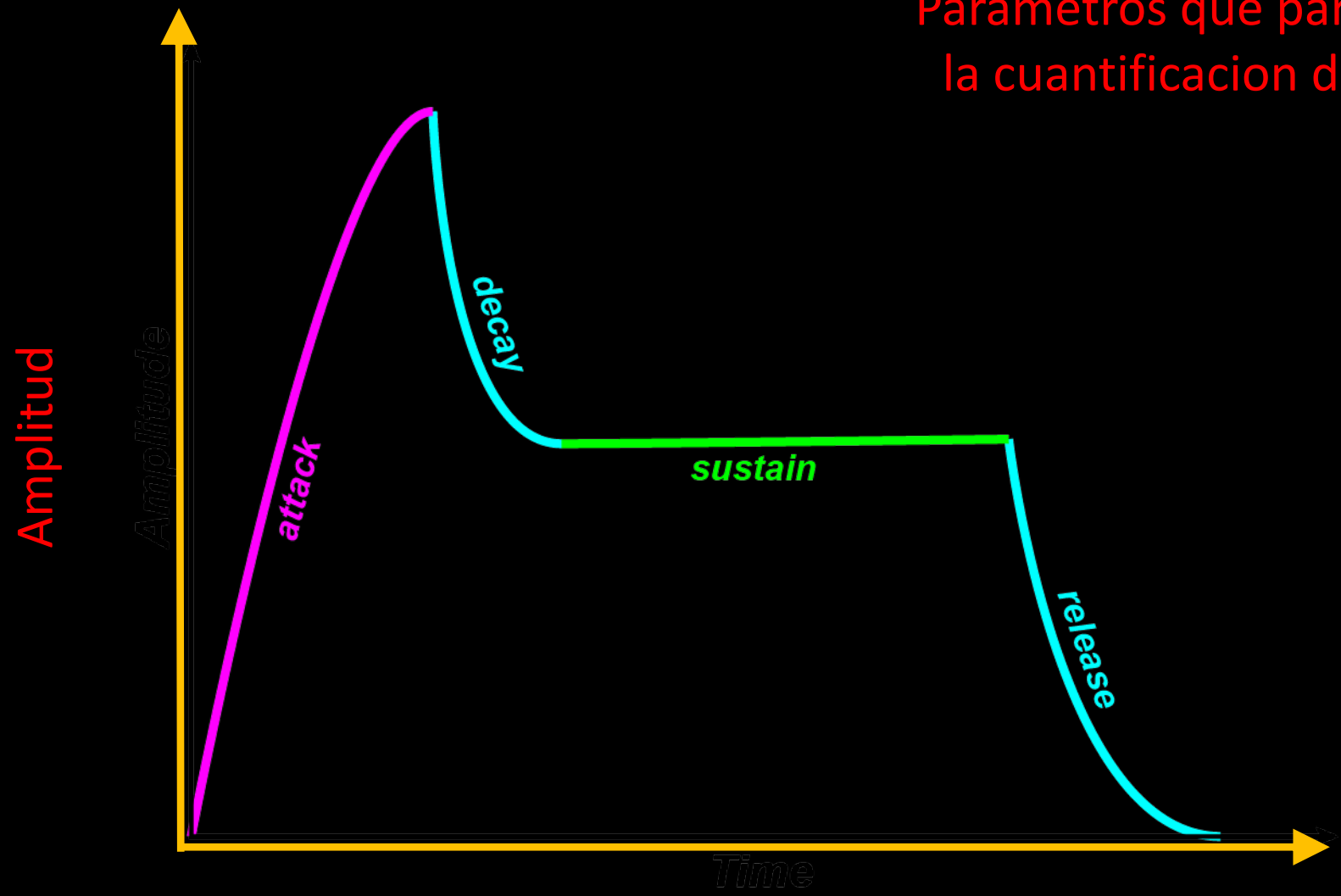
Hopf bifurcation

1. Oscilaciones nacen con amplitud cero
2. Oscilaciones nacen con frecuencia no nula
3. Mecanismo para generar sonidos tonales

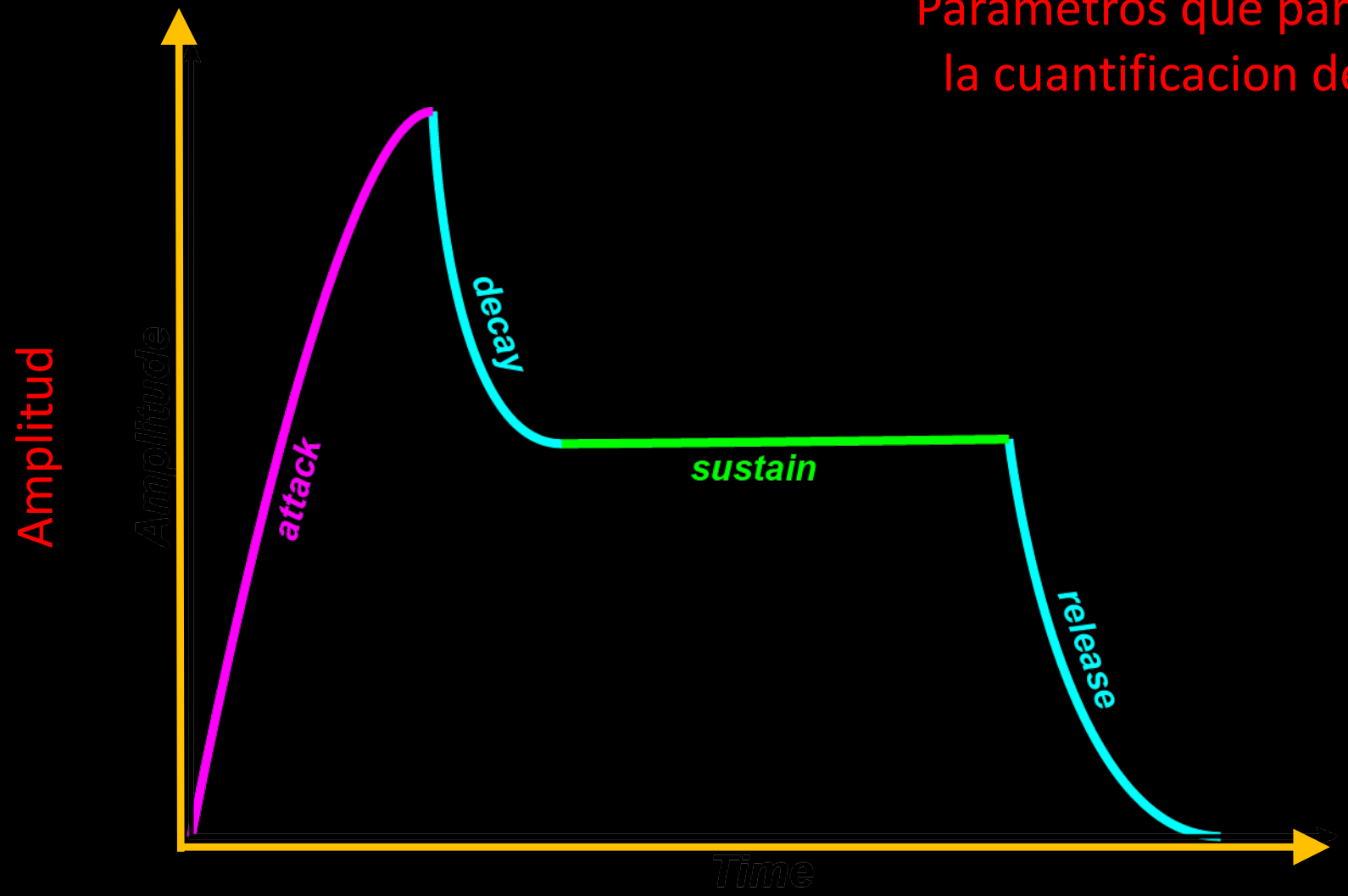
SNILC

1. Oscilaciones nacen con amplitud finita
2. Oscilaciones nacen con frecuencia cero
3. Mecanismo para generar sonidos mas asperos, de alto contenido espectral

Parametros que participan de la cuantificacion del timbre



Parametros que participan de la cuantificacion del timbre



Una oscilacion que nace en una Hopf, tendra attack largo, decay chico…