# Sound Asleep

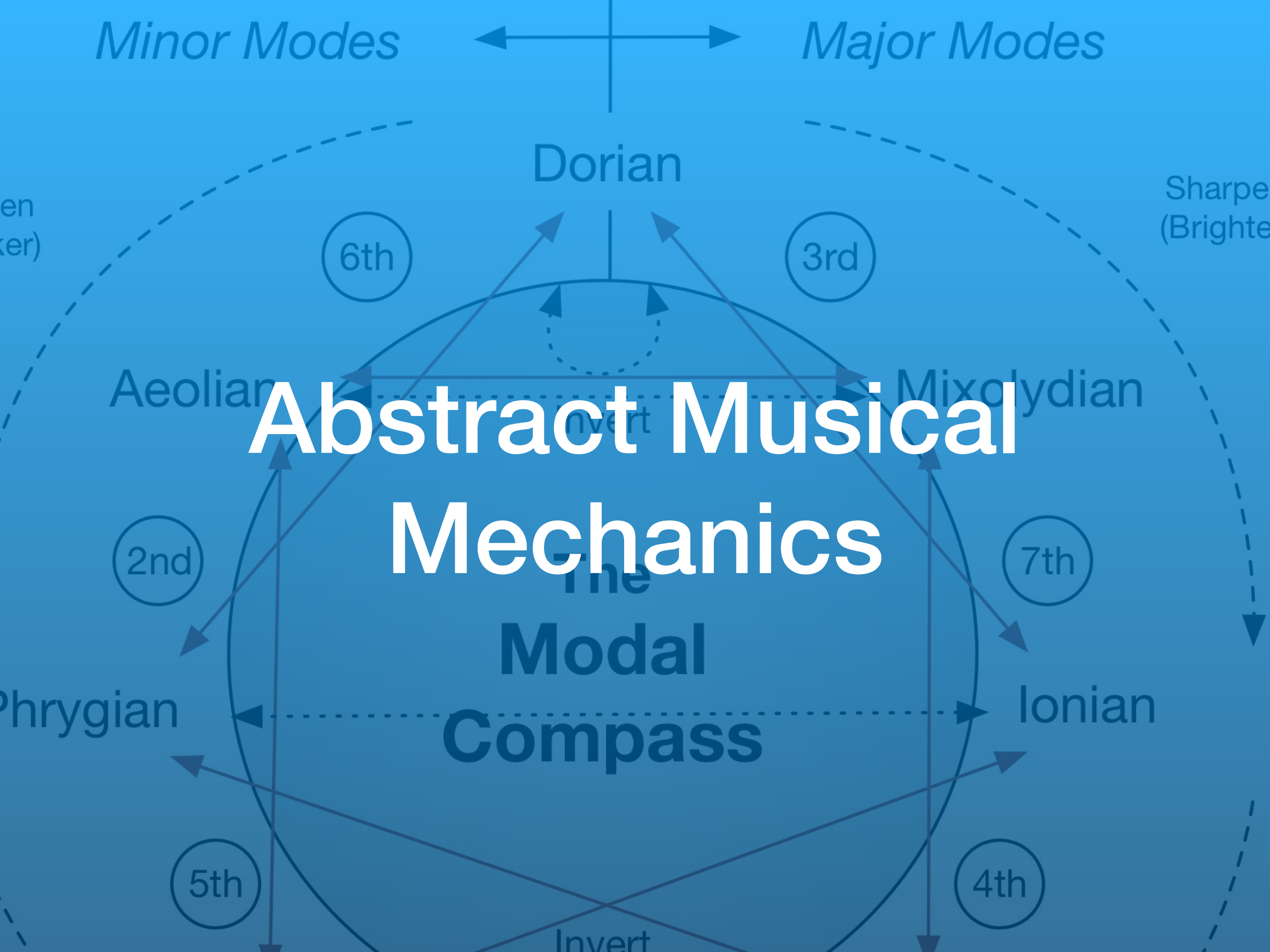
## Harmonic Cadences in the Human Sleep Cycle

**Prof Morten Kringelbach** University of Oxford

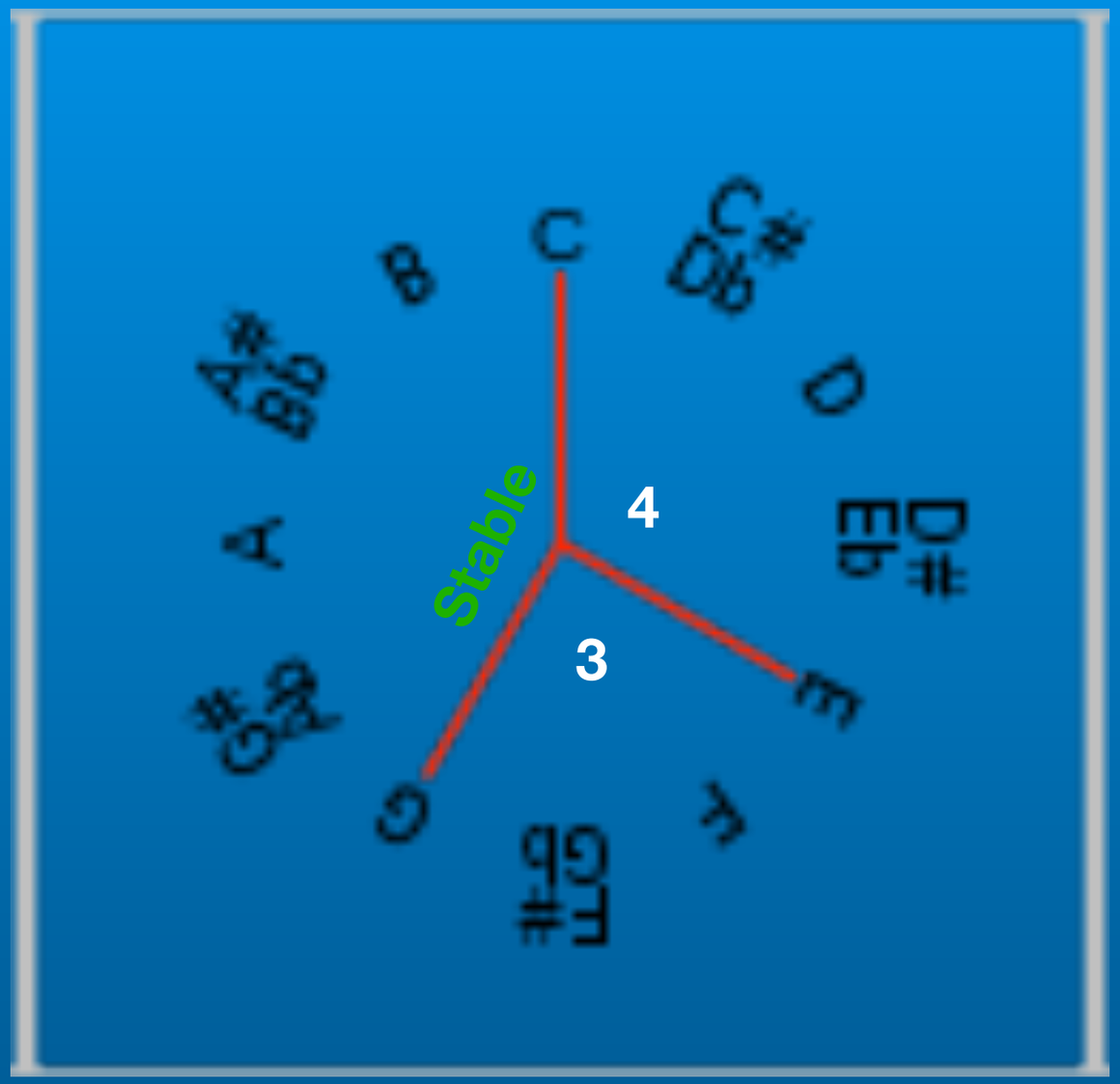
**Dr Milton Mermikides** University of Surrey

# Blue Jay Way

# Abstract Musical Mechanics

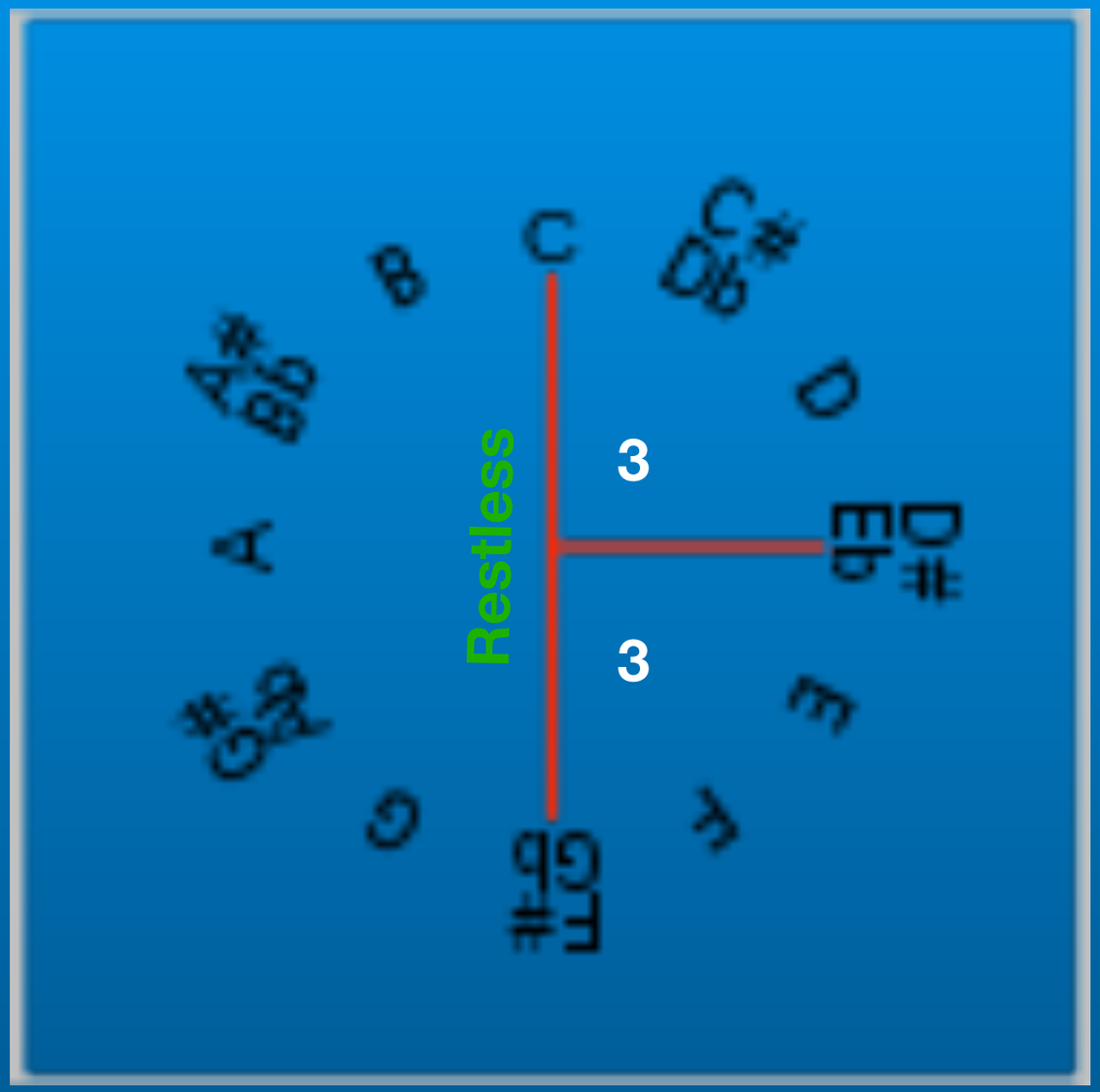


Major



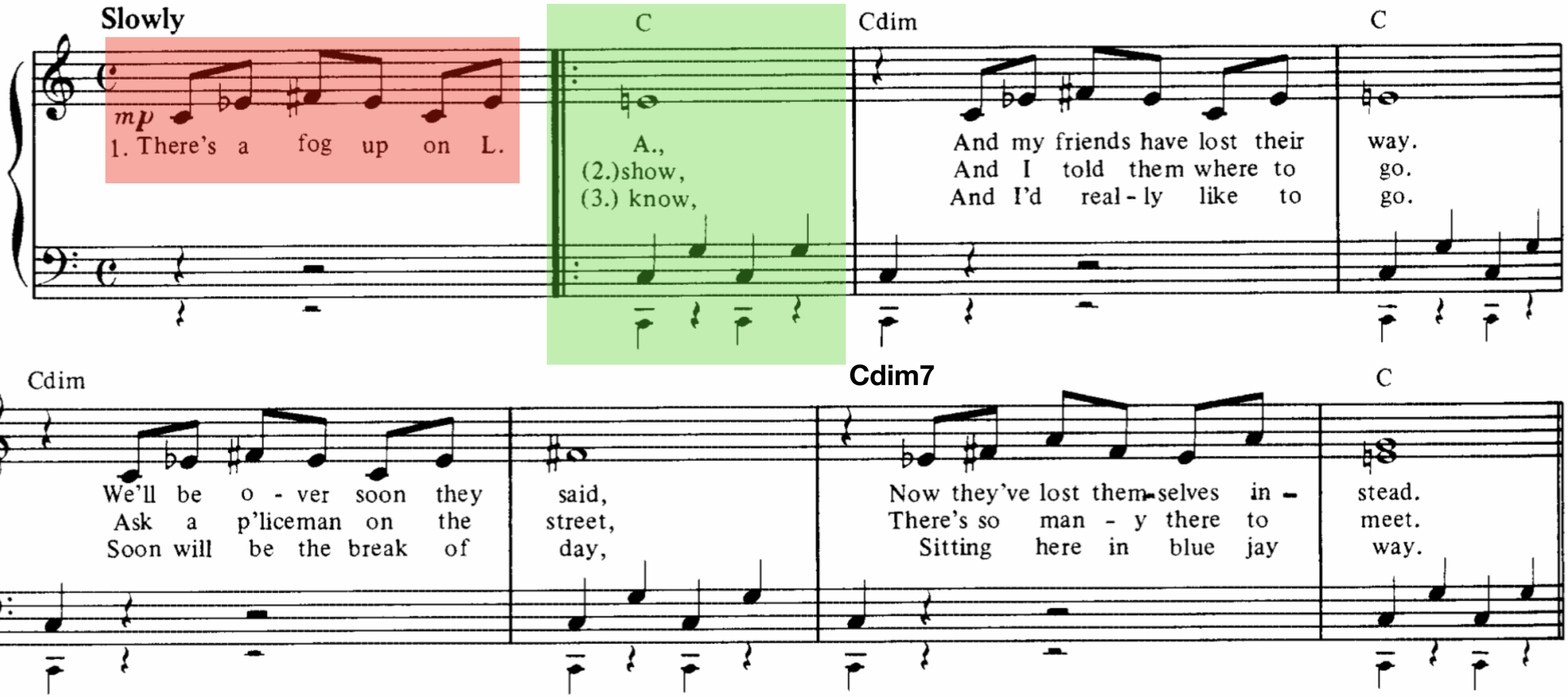

Simple Harmonic Ratios
Consonant

Diminished

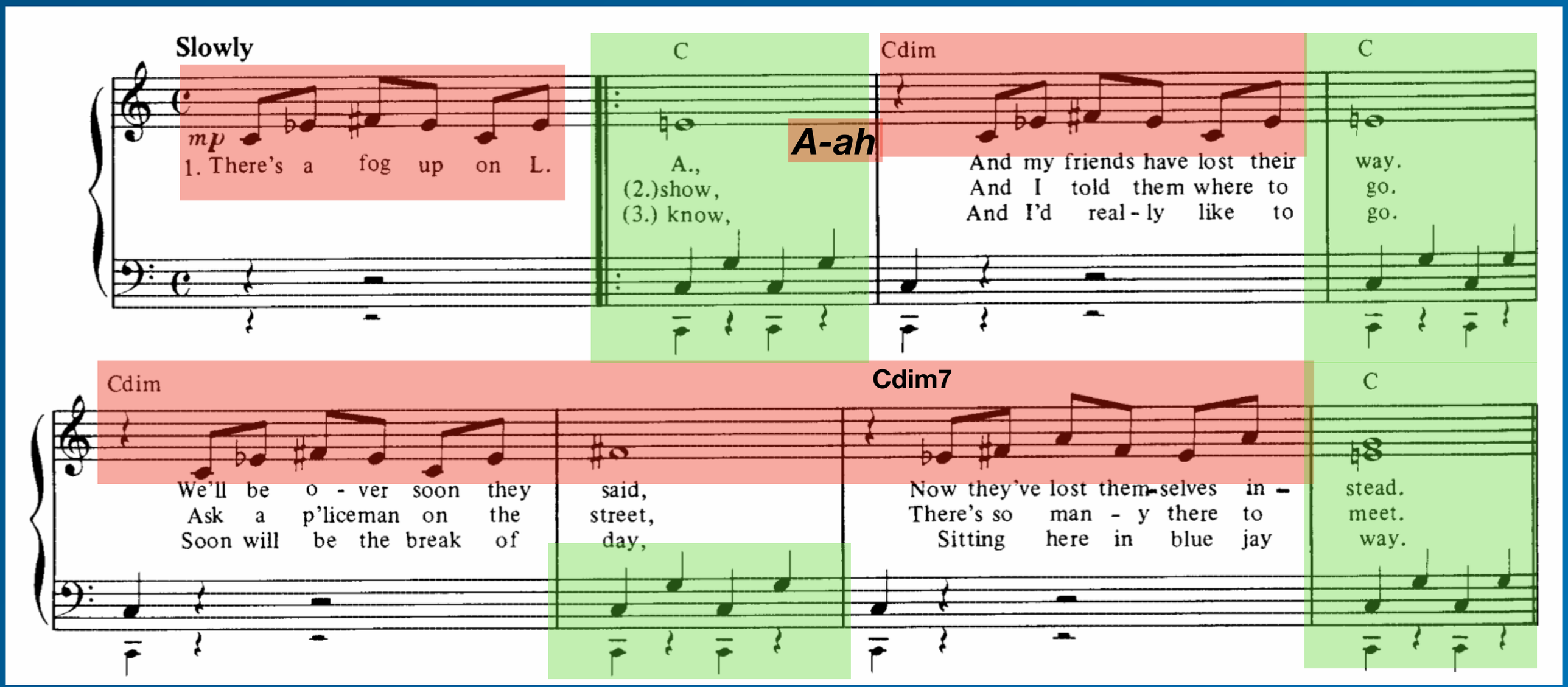



More complex Harmonic Ratios
Dissonant

# *Blue Jay Way* analysis



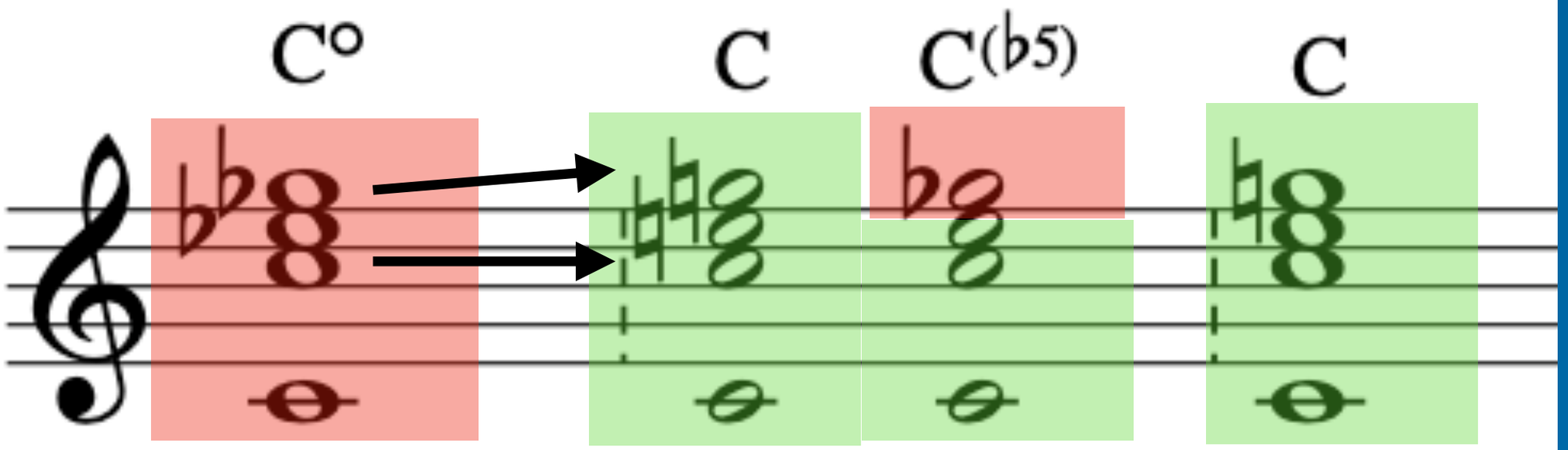
# *Blue Jay Way's strange cadence*




Dissonance

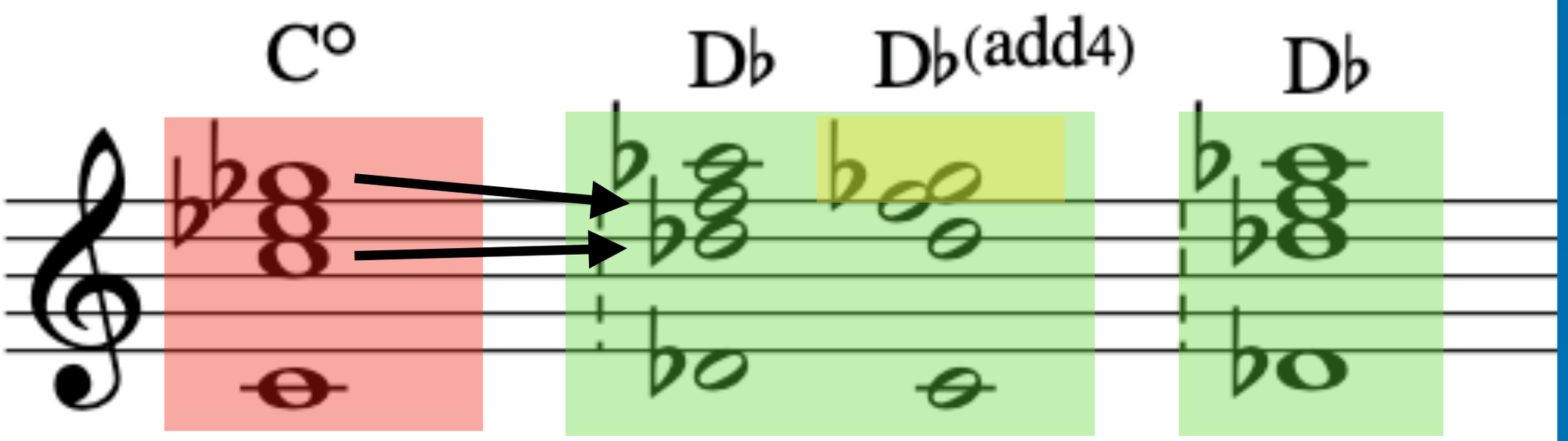
Consonance

## *Blue Jay Way* Harmonic Reduction - Dissonance resolved in place

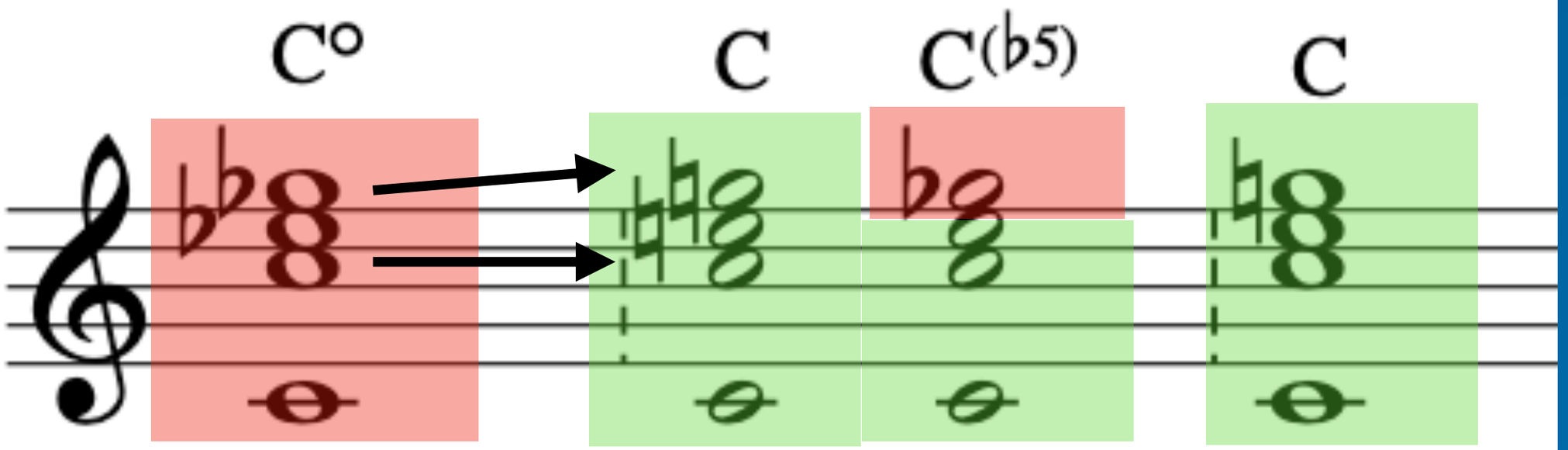



***There's a fog up on.... LA***
***And my friends have lost their... way***

## *Blue Jay Way* Sanitised Version - Dissonance resolved 'away'

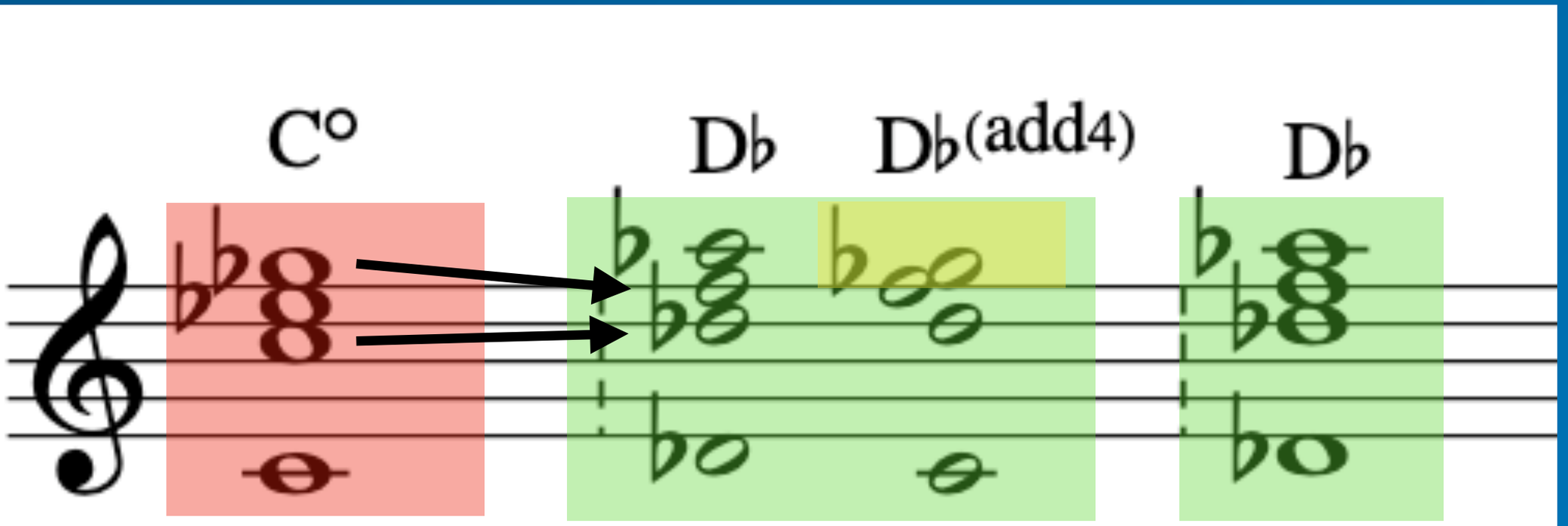


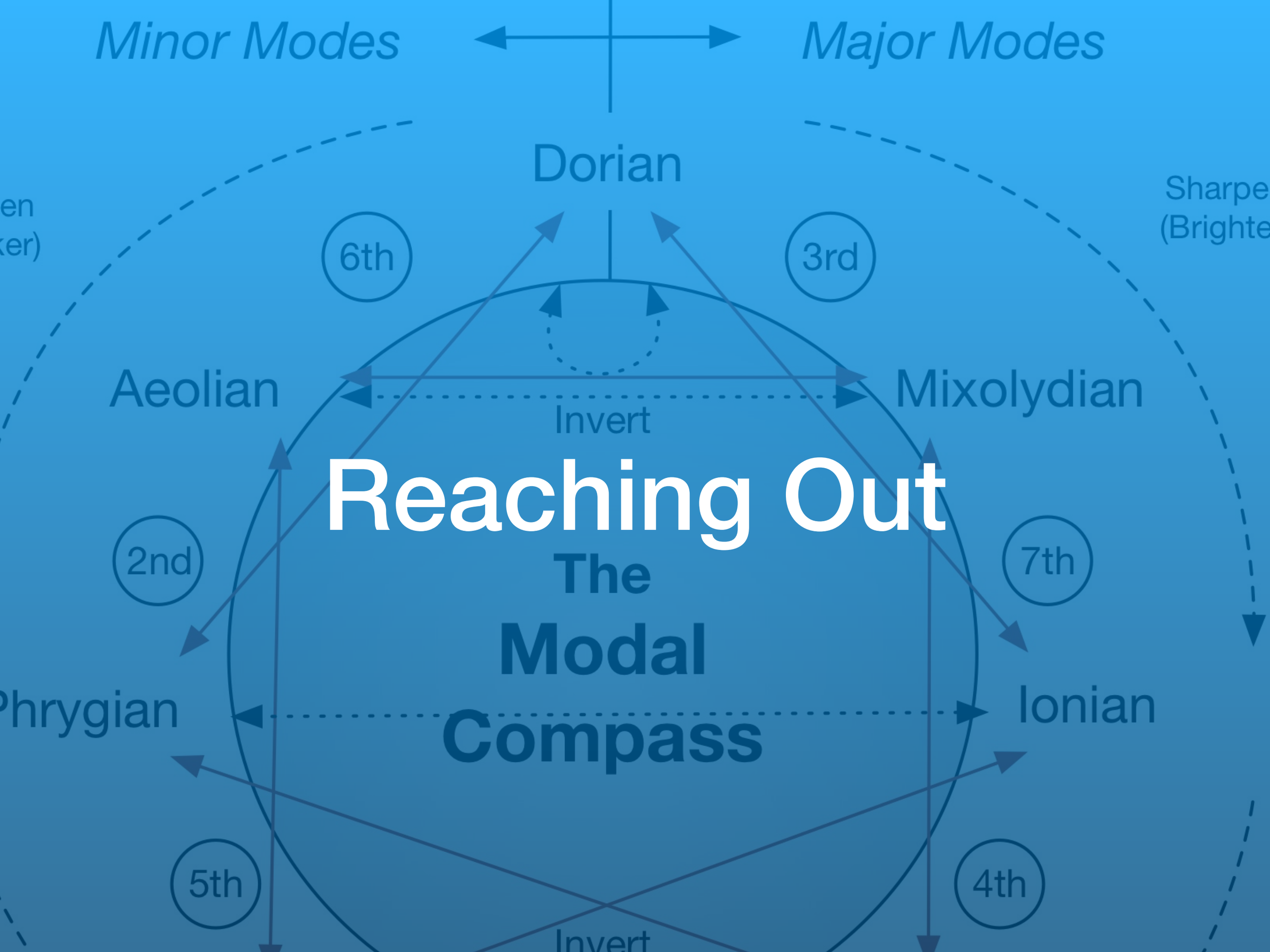
## *Blue Jay Way* Harmonic Reduction - Dissonance resolved ‘in place’



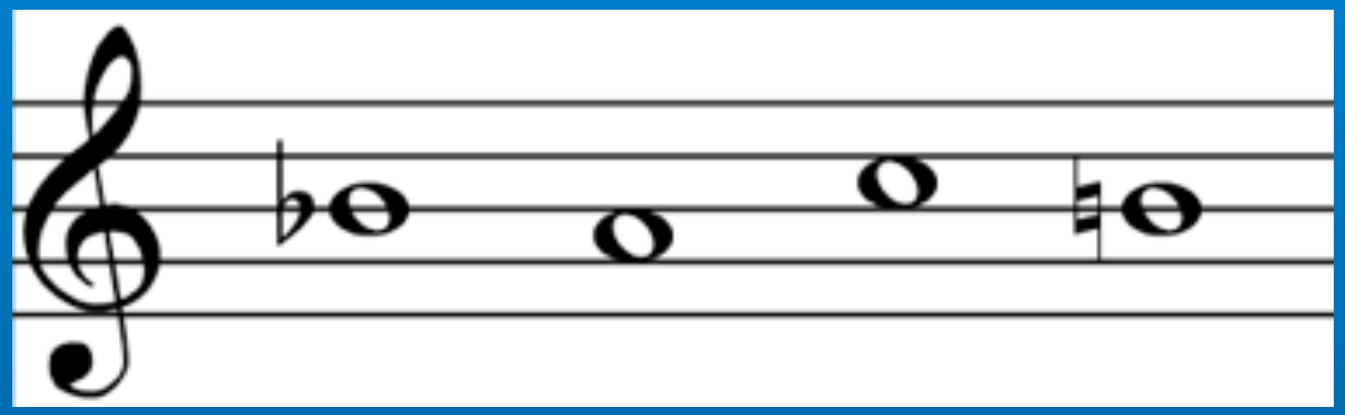

***There’s a fog up on…. LA***
***And my friends have lost their… way***

## *Blue Jay Way* Sanitised Version - Dissonance resolved ‘away’

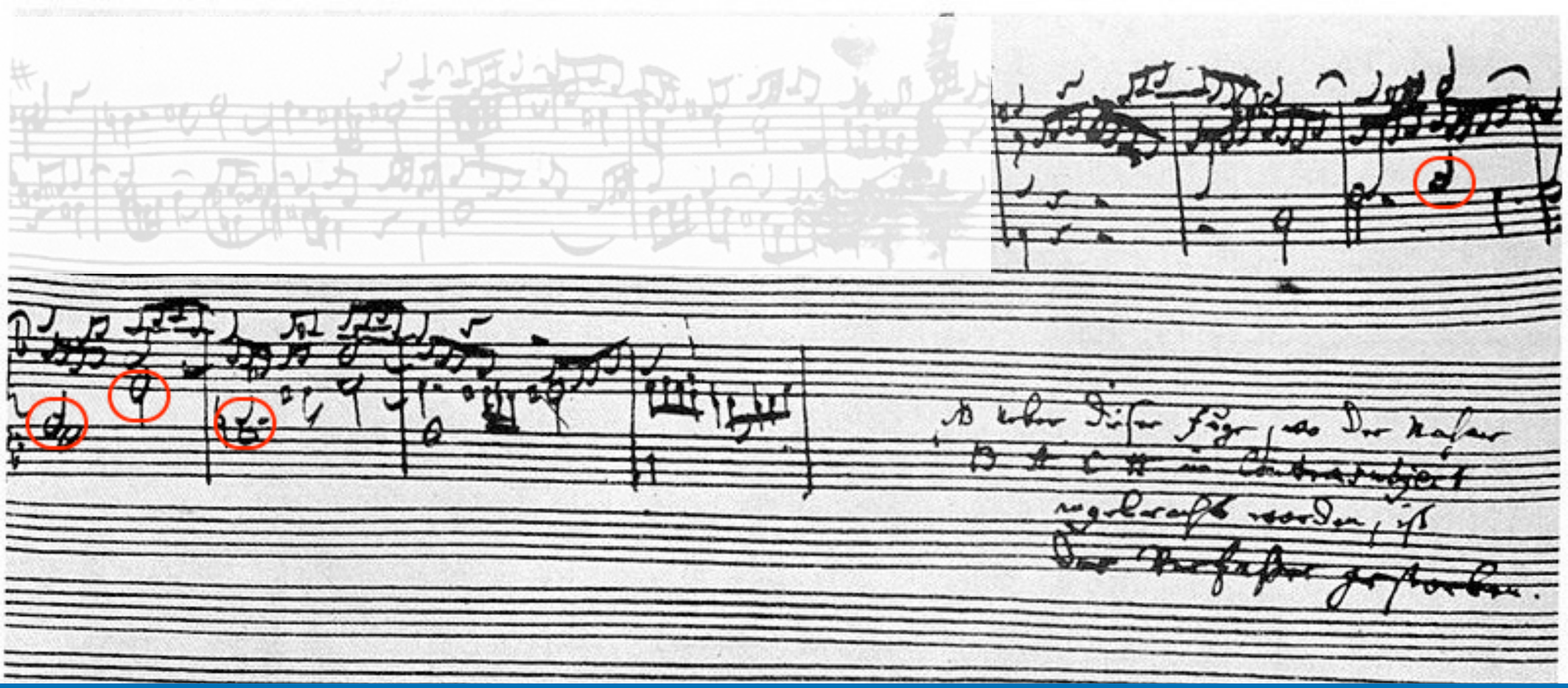





# Reaching Out



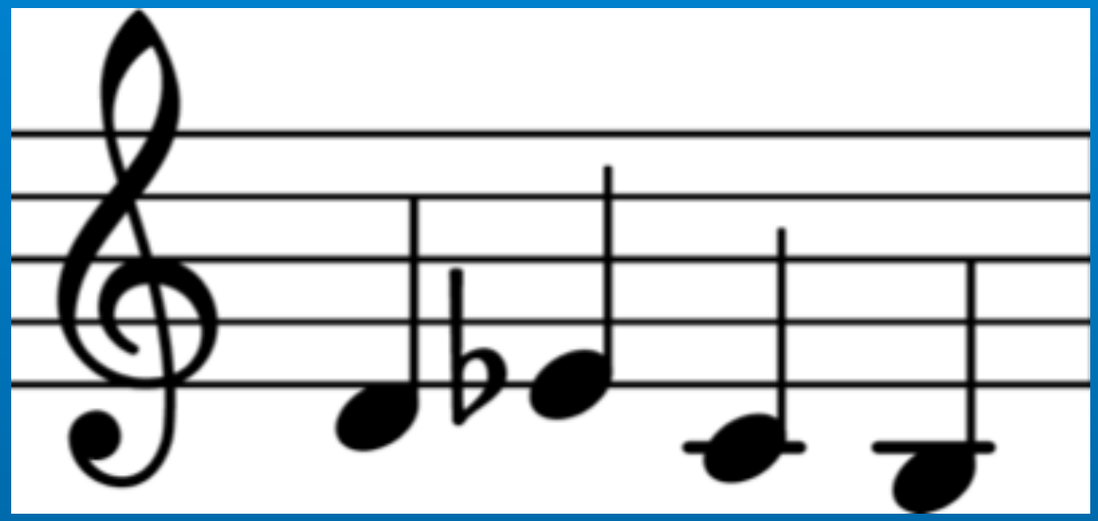
B A C H



The unfinished *Contrapunctus XIV* C.P.E. Bach's note reads "*At the point where the composer introduces the name BACH in the countersubject to this fugue, the composer died.*"

**Another of 100s of examples through the ages…**

# Dimitri Schostakovich

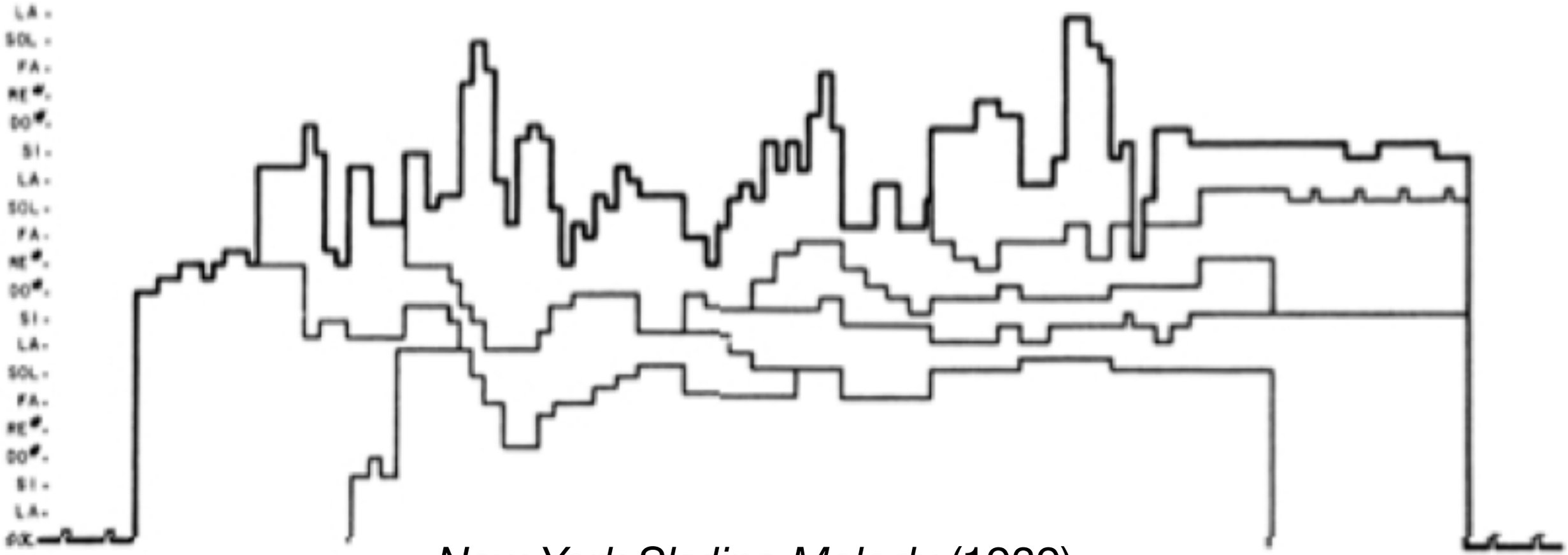


D Eb(S) C H

# Extending the concept

Villa-Lobos
(1887-1959)

VILLA-LOBOS: **NEW YORK SKY LINE MELODY** - GRÁFICO DERIVADO DA VERSÃO DE 1957. (C. KATER, 1982)




*New York Skyline Melody* (1939)

The coronal suture of the skull [has] a certain similarity to the closely wound line […]of a phonograph […] Suppose, one played a trick on this needle and caused it to retrace a path not made by the graphic translation of a sound, but self-sufficing and existing in nature […] what would happen? …

Ur-Geräusch  (Rilke 1919)

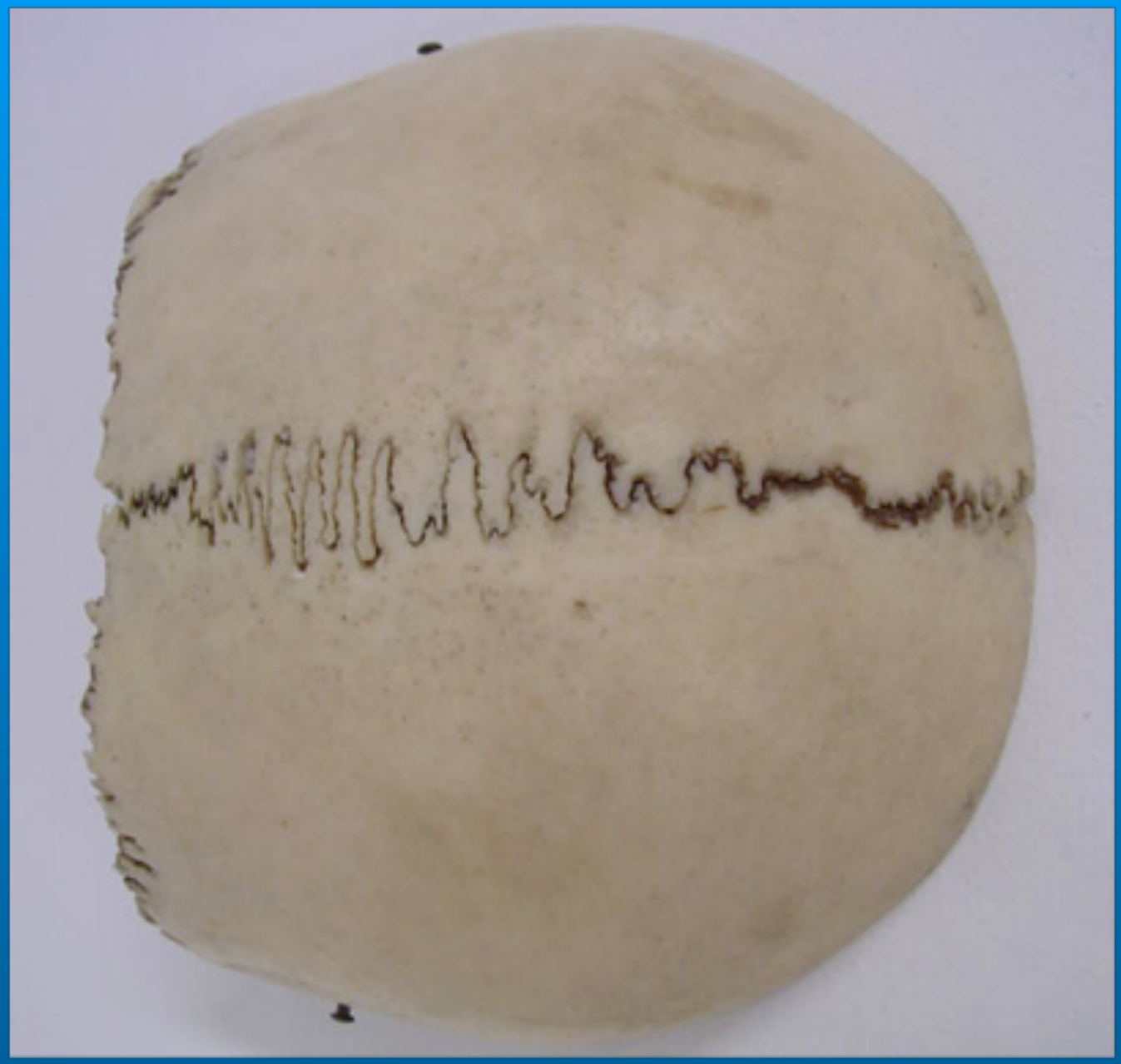


Image ©2004 Palmer

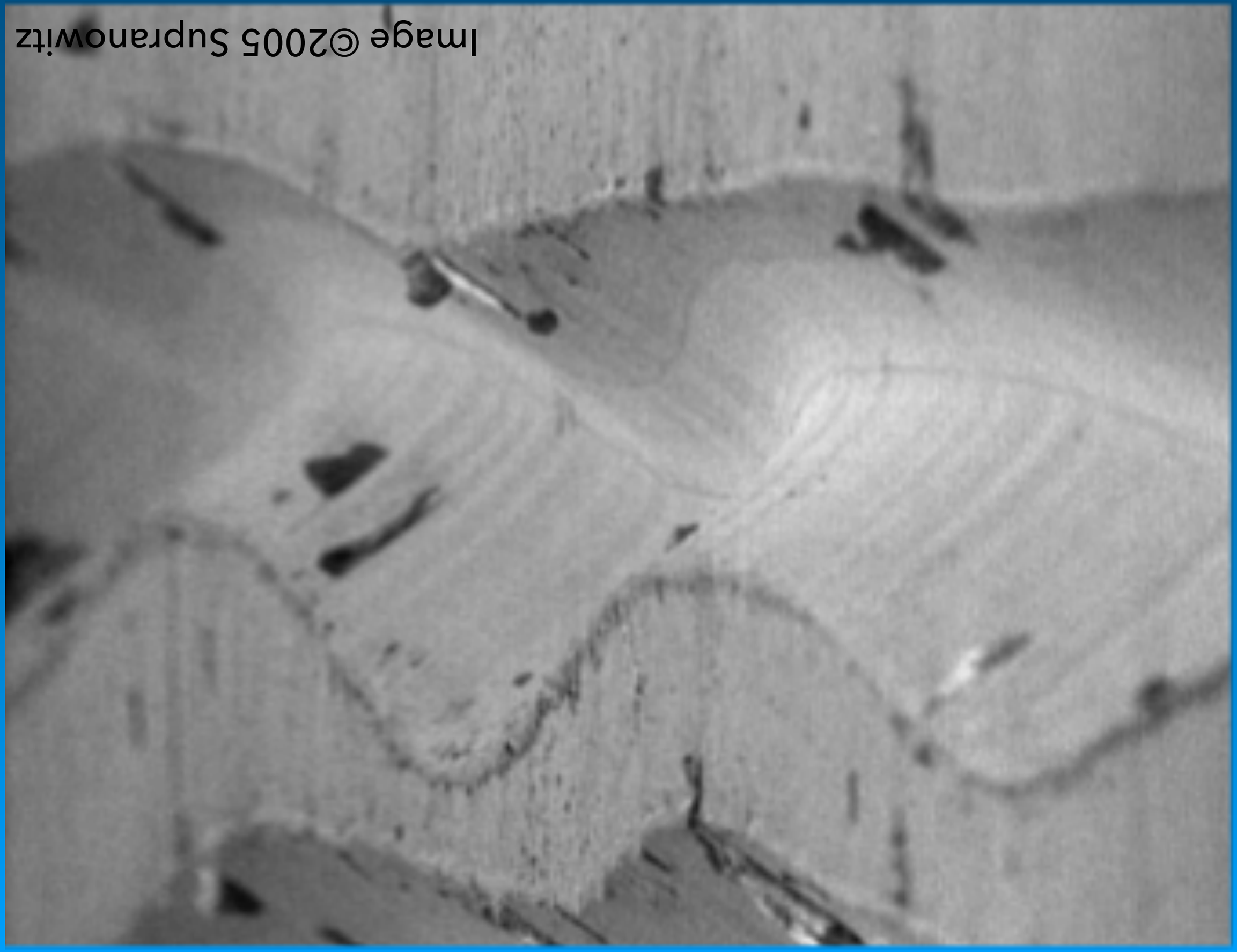
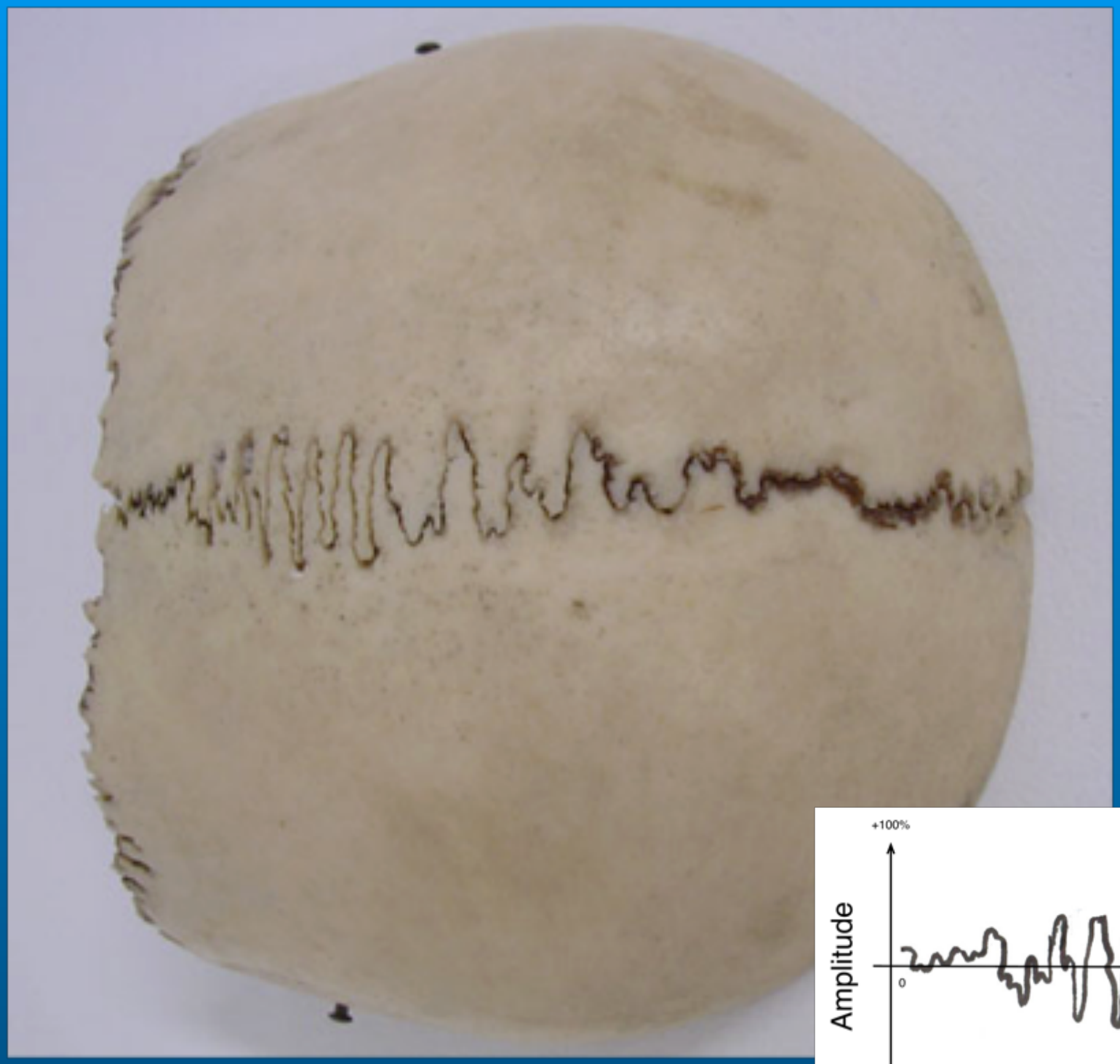
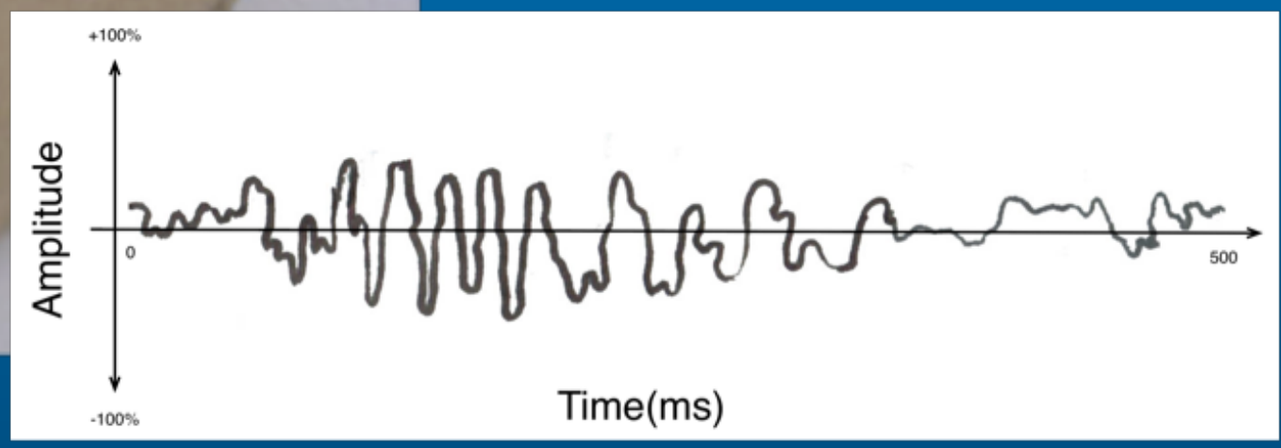


Image ©2005 Supranowitz

# *Primal Sound* (2004)





# MUSIC IN THE BLOOD

# *BloodLines* (2004, 2013)

| DATE | WBC | RBC | HB | HCT | MCV | MCH | MCHC | RDW | Platelets | Neutrophl | Lymphocy | Monocy | Eosinop | Basophi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22/11/04 | 340.0 | 5.74 | 10.0 | 0.343 | 59.7 | 17.4 | 29.1 | 17.0 | 31 | | | | | |
| 23/11/04 | 332.0 | 5.29 | 10.5 | 0.317 | 59.9 | 19.6 | 33.1 | 16.8 | 39 | | | | | |
| 24/11/04 | | 4.74 | 8.3 | 0.280 | 59.2 | 17.5 | 29.5 | 16.5 | 35 | 14.4 | 311.0 | 19.5 | 0.4 | 0.2 |
| 24/11/04 | 345.0 | 4.66 | 8.5 | 0.280 | 59.9 | 18.3 | 30.8 | 16.8 | 73 | | | | | |
| 24/11/04 | 370.0 | 4.90 | 7.3 | 0.300 | 61.1 | 19.1 | 29.3 | 16.2 | 72 | | | | | |
| 25/11/04 | 242.0 | 4.42 | 8.2 | 0.266 | 60.1 | 18.6 | 31.0 | 16.0 | 72 | 12.4 | 212.0 | 17.5 | 0.3 | 0.2 |
| 25/11/04 | 81.4 | 4.63 | 9.1 | 0.276 | 59.5 | 19.7 | 33.1 | 15.8 | 50 | 8.6 | 68.6 | 4.0 | 0.2 | 0.0 |
| 26/11/04 | 17.9 | 4.10 | 8.5 | 0.252 | 60.2 | 20.3 | 33.8 | 15.0 | 32 | 4.4 | 12.7 | 0.7 | 0.0 | 0.0 |
| 26/11/04 | 16.3 | 4.18 | 8.3 | 0.249 | 59.5 | 19.9 | 33.5 | 15.4 | 32 | 4.4 | 11.3 | 0.5 | 0.0 | 0.0 |
| 27/11/04 | 6.6 | 3.72 | 7.7 | 0.225 | 60.5 | 20.7 | 34.3 | 15.3 | 18 | 2.5 | 3.9 | 0.2 | 0.0 | 0.0 |
| 28/11/04 | 5.6 | 3.79 | 7.7 | 0.226 | 59.6 | 20.3 | 34.0 | 15.1 | 17 | 1.8 | 3.7 | 0.1 | 0.0 | 0.0 |
| 28/11/04 | 5.7 | 3.84 | 7.8 | 0.228 | 59.4 | 20.4 | 34.3 | 15.1 | 16 | 1.7 | 3.8 | 0.1 | 0.0 | 0.0 |
| 29/11/04 | 4.0 | 3.23 | 6.6 | 0.197 | 61.1 | 20.6 | 33.7 | 15.4 | 13 | 1.1 | 2.9 | 0.1 | 0.0 | 0.0 |
| 30/11/04 | 5.3 | 4.14 | 9.3 | 0.263 | 63.5 | 22.5 | 35.4 | 20.2 | 36 | 1.9 | 3.3 | 0.1 | 0.0 | 0.0 |
| 01/12/04 | 5.4 | 3.90 | 8.7 | 0.250 | 64.2 | 22.3 | 34.7 | 20.1 | 30 | 1.6 | 3.6 | 0.1 | 0.0 | 0.0 |
| 02/12/04 | 5.2 | 4.40 | 9.8 | 0.280 | 63.6 | 22.4 | 35.2 | 20.7 | 43 | 2.1 | 2.8 | 0.3 | 0.0 | 0.0 |
| 02/12/04 | 5.5 | 4.21 | 9.3 | 0.270 | 64.1 | 22.2 | 34.6 | 20.7 | 37 | 2.9 | 2.3 | 0.3 | 0.0 | 0.0 |
| 03/12/04 | 2.5 | 3.73 | 8.3 | 0.239 | 64.2 | 22.3 | 34.8 | 20.8 | 51 | 2.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| 04/12/04 | 3.2 | 3.25 | 7.1 | 0.211 | 65.0 | 21.9 | 33.6 | 20.8 | 66 | 1.5 | 1.6 | 0.1 | 0.0 | 0.0 |
| 05/12/04 | 2.8 | 3.39 | 8.7 | 0.246 | 68.5 | 24.1 | 35.2 | 22.6 | 113 | 1.4 | 1.4 | 0.0 | 0.0 | 0.0 |
| 06/12/04 | 4.0 | 3.04 | 9.4 | 0.271 | 70.5 | 24.9 | 34.8 | 22.0 | 220 | 2.7 | 2.1 | 0.0 | 0.0 | 0.0 |
| 07/12/04 | 3.0 | 3.44 | 8.3 | 0.247 | 71.7 | 24.8 | 33.5 | 23.0 | 240 | 1.1 | 1.9 | 0.0 | 0.0 | 0.0 |
| 08/12/04 | 2.1 | 3.31 | 8.2 | 0.235 | 71.1 | 24.9 | 35.0 | 23.0 | 281 | 0.6 | 1.4 | 0.1 | 0.0 | 0.0 |
| 09/12/04 | 2.0 | 3.40 | 8.8 | 0.249 | 71.4 | 25.1 | 35.2 | 23.3 | 270 | 0.8 | 0.9 | 0.2 | 0.0 | 0.0 |
| 10/12/04 | 3.2 | 4.38 | 10.7 | 0.324 | 74.1 | 24.6 | 33.2 | 23.1 | 289 | 2.1 | 0.9 | 0.2 | 0.0 | 0.0 |
| 11/12/04 | 2.8 | 4.09 | 10.0 | 0.305 | 74.7 | 24.5 | 32.8 | 23.1 | 292 | 1.7 | 0.9 | 0.1 | 0.0 | 0.0 |
| 12/12/04 | 1.6 | 4.16 | 10.2 | 0.315 | 75.6 | 24.4 | 32.9 | 23.0 | 280 | 0.6 | 1.0 | 0.0 | 0.0 | 0.0 |
| 13/12/04 | 2.1 | 4.46 | 10.8 | 0.333 | 74.6 | 24.2 | 32.5 | 23.0 | 315 | 0.3 | 1.7 | 0.0 | 0.0 | 0.0 |
| 15/12/04 | 11.7 | 4.29 | 10.6 | 0.317 | 73.9 | 24.7 | 33.4 | 23.2 | 316 | 11.3 | 0.4 | 0.0 | 0.0 | 0.0 |
| 16/12/04 | 17.7 | 4.17 | 10.2 | 0.318 | 76.1 | 24.4 | 32.1 | 23.3 | 288 | 15.7 | 1.8 | 0.2 | 0.0 | 0.0 |
| 17/12/04 | 5.0 | 4.24 | 10.5 | 0.318 | 75.1 | 24.9 | 33.1 | 23.0 | 296 | 3.2 | 1.5 | 0.2 | 0.0 | 0.0 |
| 18/12/04 | 4.3 | 4.40 | 10.9 | 0.329 | 74.9 | 24.8 | 33.1 | 22.9 | 328 | 1.8 | 2.2 | 0.3 | 0.0 | 0.0 |
| 19/12/04 | 2.1 | 3.86 | 9.8 | 0.288 | 74.7 | 25.5 | 34.2 | 22.7 | 221 | 0.6 | 1.4 | 0.1 | 0.0 | 0.0 |
| 20/12/04 | 2.0 | 3.65 | 9.0 | 0.275 | 75.3 | 24.7 | 32.7 | 22.7 | 210 | 0.7 | 1.3 | 0.0 | 0.0 | 0.0 |
| 21/12/04 | 2.9 | 3.91 | 9.6 | 0.294 | 75.3 | 24.7 | 32.8 | 22.9 | 241 | 0.9 | 1.9 | 0.0 | 0.0 | 0.0 |
| 22/12/04 | 3.4 | 3.94 | 9.8 | 0.294 | 74.6 | 24.8 | 33.3 | 22.9 | 281 | 1.4 | 1.9 | 0.1 | 0.0 | 0.0 |
| 23/12/04 | 2.9 | 3.55 | 9.1 | 0.266 | 75.1 | 25.5 | 34.0 | 22.9 | 225 | | | | | |
| 24/12/04 | 3.7 | 4.20 | 10.3 | 0.308 | 73.4 | 24.5 | 33.4 | 23.4 | 249 | 1.5 | 2.0 | 0.2 | 0.0 | 0.0 |
| 25/12/04 | 3.2 | 4.02 | 9.9 | 0.302 | 75.2 | 24.8 | 32.9 | 23.7 | 282 | 2.0 | 1.1 | 0.1 | 0.0 | 0.0 |
| 26/12/04 | 2.5 | 3.70 | 9.5 | 0.286 | 75.6 | 25.8 | 33.3 | 22.6 | 190 | 1.9 | 0.6 | 0.0 | 0.0 | 0.0 |
| 27/12/04 | 1.8 | 3.83 | 9.6 | 0.292 | 76.1 | 25.0 | 32.9 | 22.3 | 145 | 1.4 | 0.4 | 0.0 | 0.0 | 0.0 |
| 28/12/04 | 0.8 | 3.47 | 8.7 | 0.263 | 75.9 | 25.0 | 33.0 | 21.9 | 119 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 |
| 30/12/04 | 0.7 | 3.17 | 8.1 | 0.255 | 80.5 | 25.6 | 31.8 | 21.9 | 83 | 0.3 | 0.4 | 0.0 | 0.0 | 0.0 |
| 31/12/04 | 0.3 | 3.39 | 9.0 | 0.264 | 78.0 | 26.5 | 33.9 | 18.9 | 51 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| 01/01/05 | 0.3 | 3.45 | 9.0 | 0.279 | 81.1 | 26.2 | 32.3 | 19.2 | 32 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| 01/01/05 | 0.3 | 3.62 | 9.5 | 0.284 | 78.6 | 26.3 | 33.5 | 19.0 | 25 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |

Wellcome Trust Radio 4 Aldeburgh Music Smithsonian Institute UCL Neuroscience

Surrey: Microbiology, Mathematics, Medicine, Programming, Sleep Research Rutherford Centre

Times Higher Education British Library Frank Moer Institute TedX Groningen Nordezoon Festival

# CHEMISTRY

# MATHE RINI

# ROSM SORI

Milton Mermikides (University of Surrey)

Debra J. Skene (University of Surrey)

Renata Rhia (University of Edinburgh)

Vlad Vyazovskiy & Nanyi Cui (Oxford University)

Yurubi Rosales Suarez/ Professor Paul Krause  (University of Surrey)

Anna Tanczos

University of Surrey

Research & Innovation Support

The Royal Society

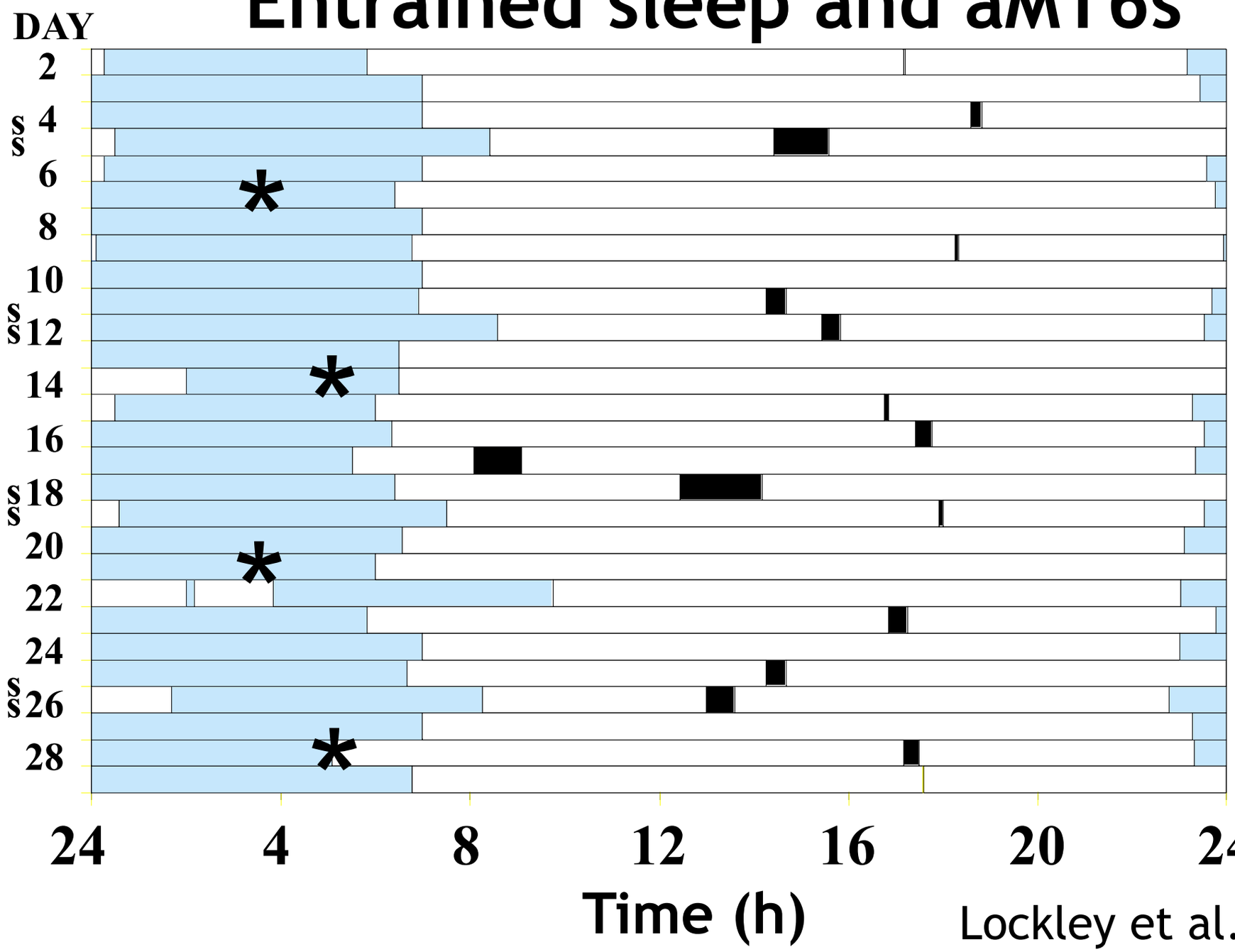
# SOUND ASLEEP

# MAKING SLEEP VISIBLE TO THE BLIND

Debra J. Skene (University of Surrey)

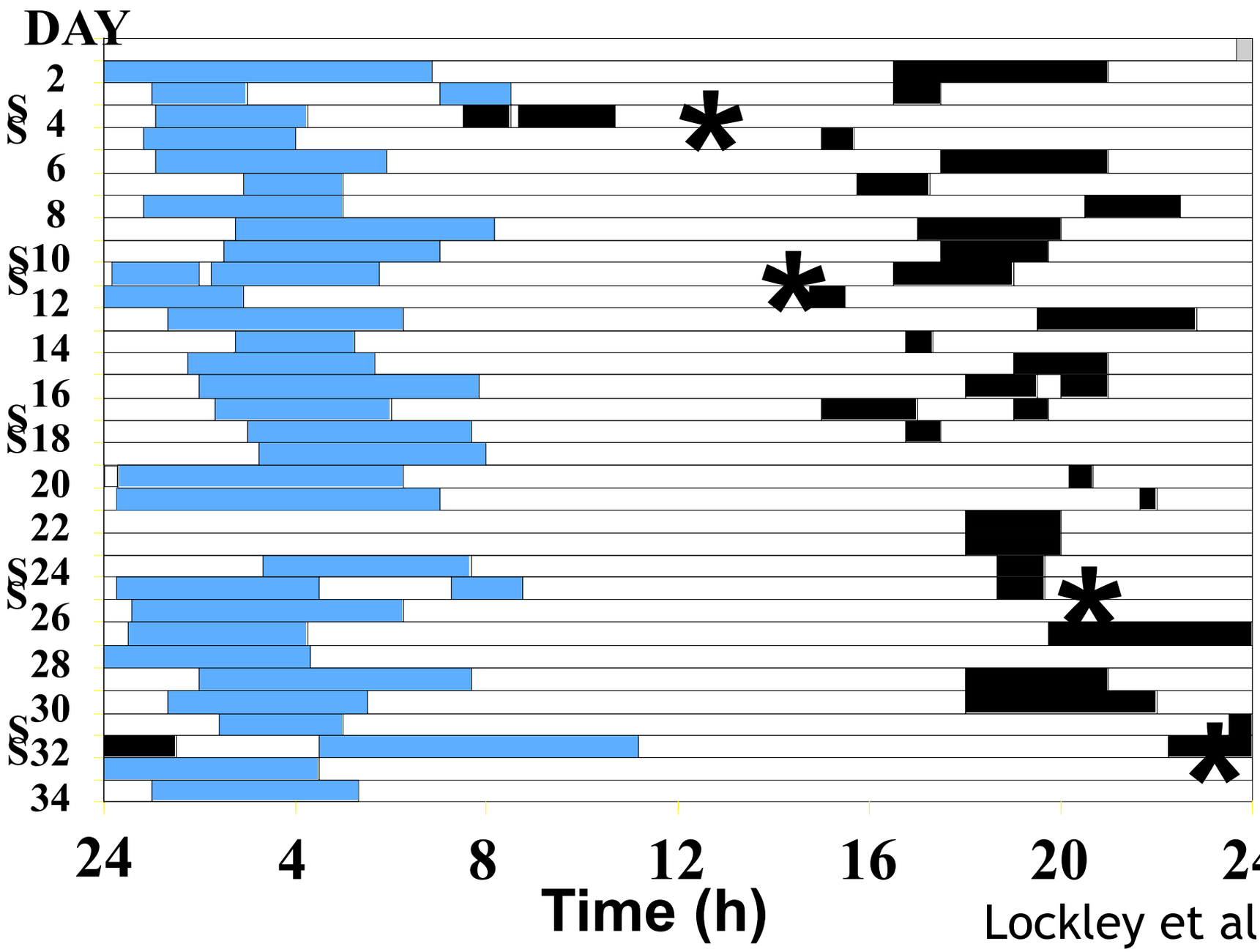
Milton Mermikides (University of Surrey)

# Entrained sleep and aMT6s




Lockley et al., 1997

# Abnormal circadian phase - poor sleep- daytime nap



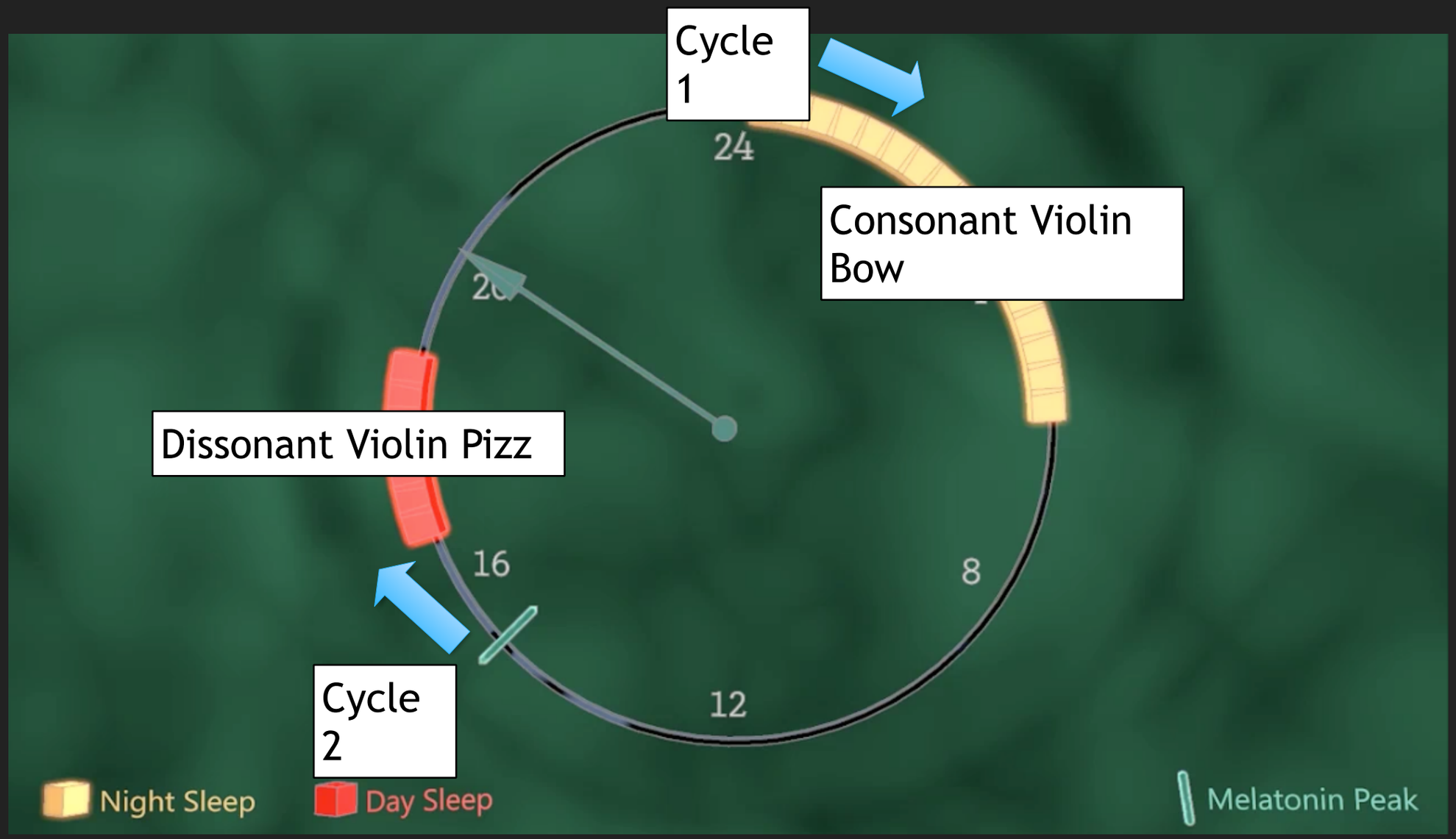

Lockley et al., 1997

# MUSICAL ANALOGIES

**24-Beat Cycle** (Shona Mbira)

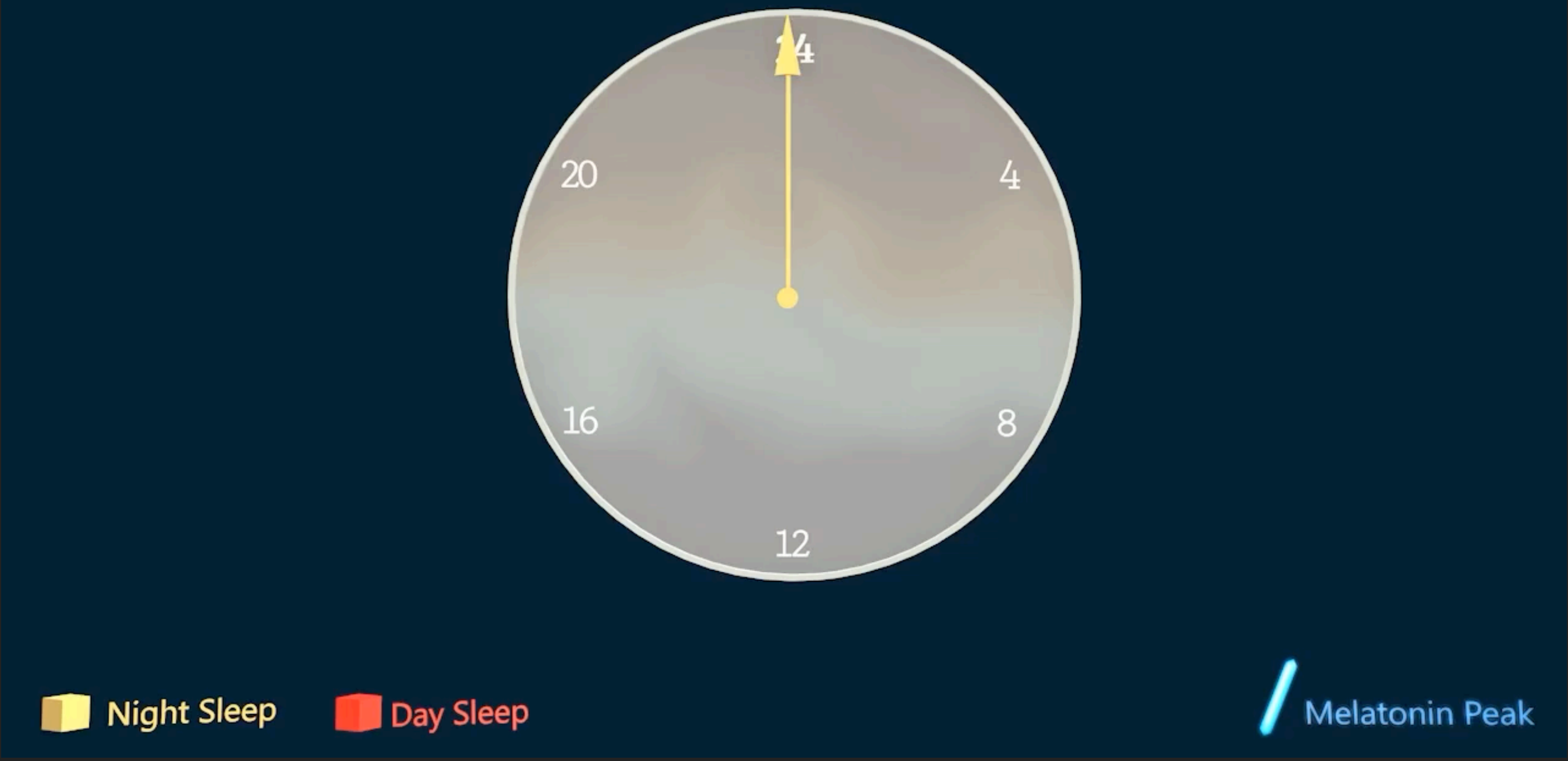
**Displacement/Phase** (West Africa, Steve Reich)

**Diatonic/non-diatonic** to represent comfort


Cycle 1
Consonant Violin Bow
Dissonant Violin Pizz
Cycle 2
24
16
8
12
Night Sleep
Day Sleep
Melatonin Peak

S12

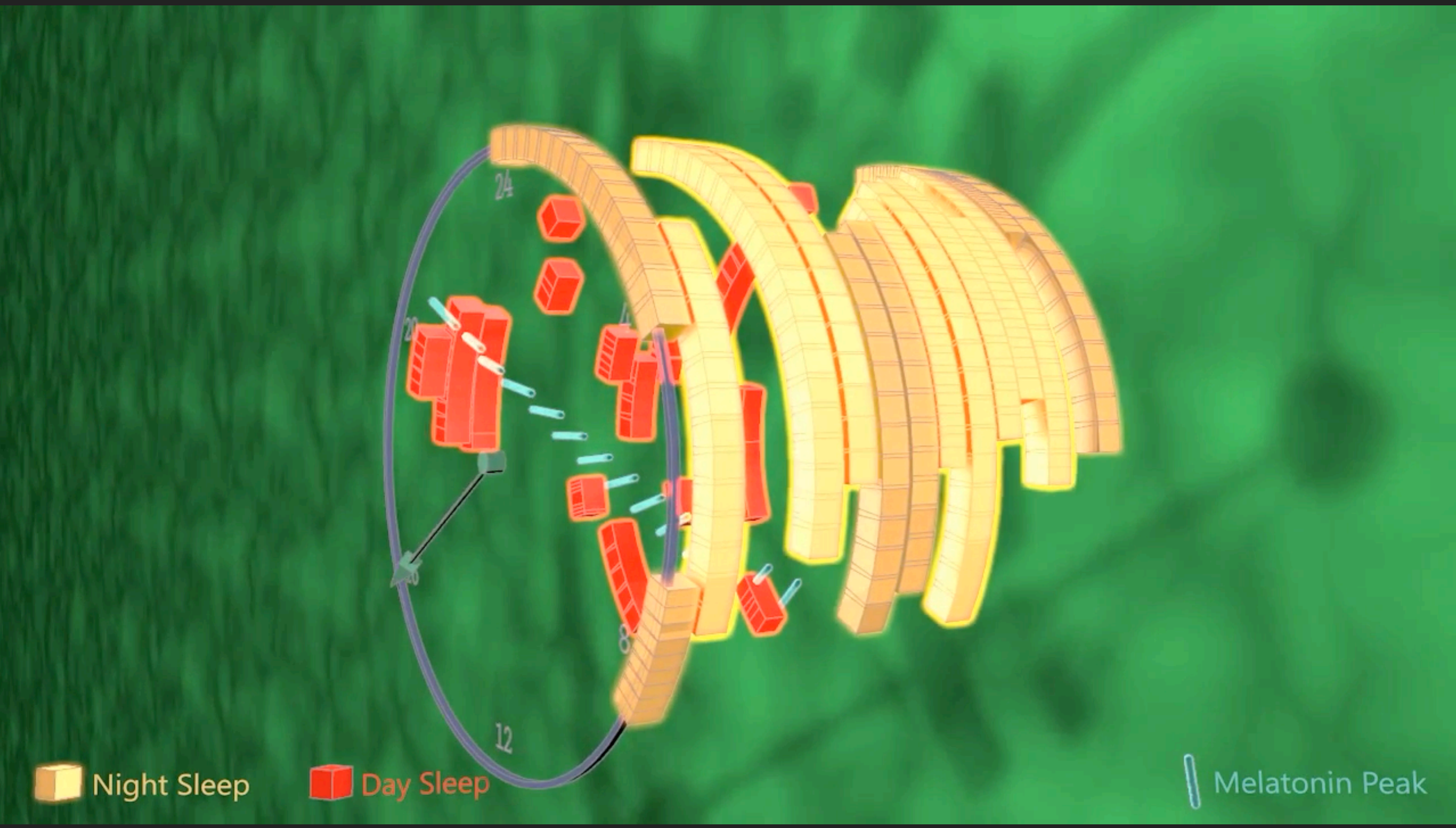
# ENTRAINED SLEEP


0
4
8
12
16
20
Night Sleep
Day Sleep
Melatonin Peak

S23

# NON 24 H SLEEP/WAKE DISORDER

0
4
20
4
16
8
12
Night Sleep
Day Sleep
Melatonin Peak

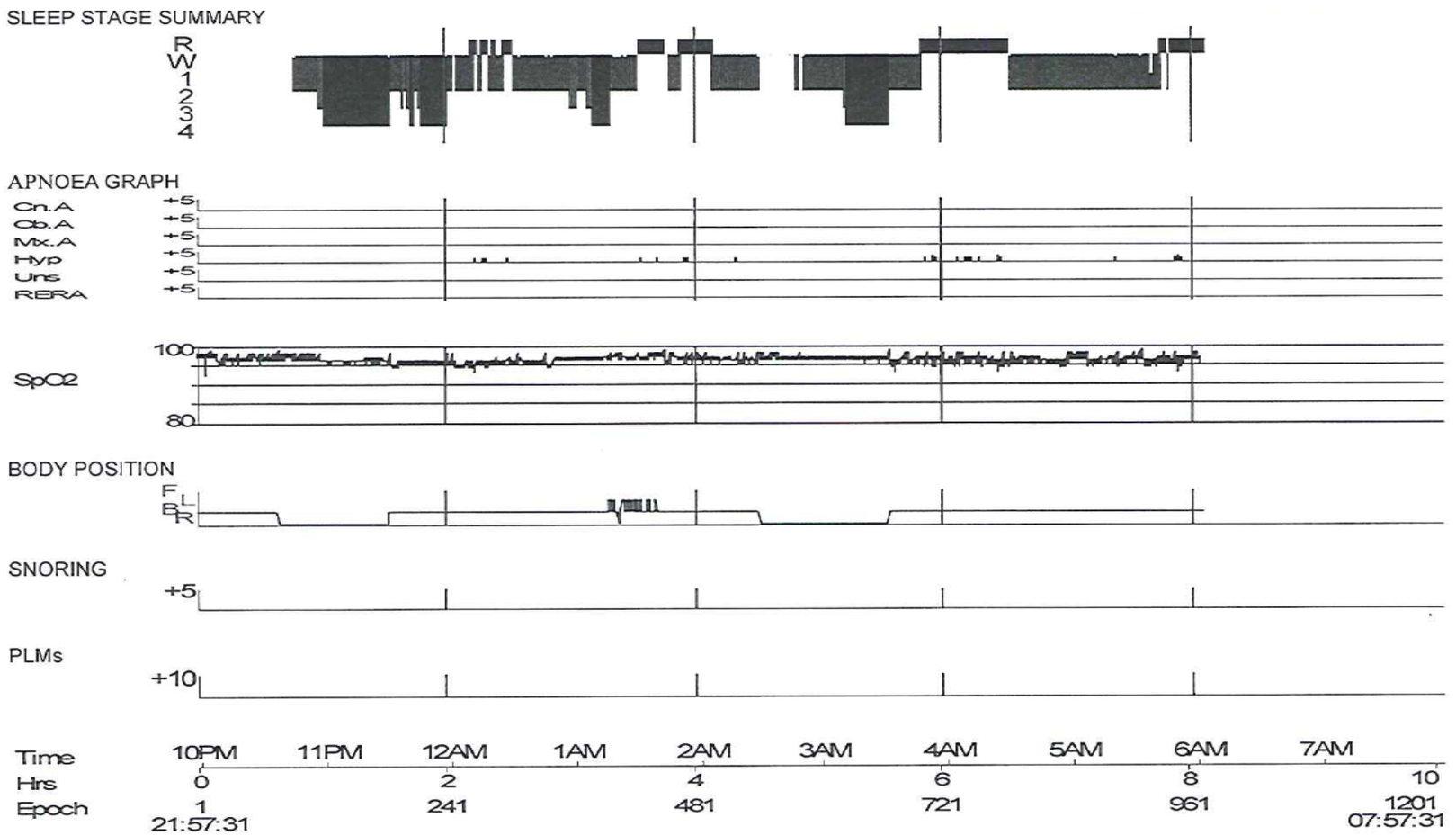

24
20
8
12
Night Sleep
Day Sleep
Melatonin Peak

# *PSG NOCTURNE:*

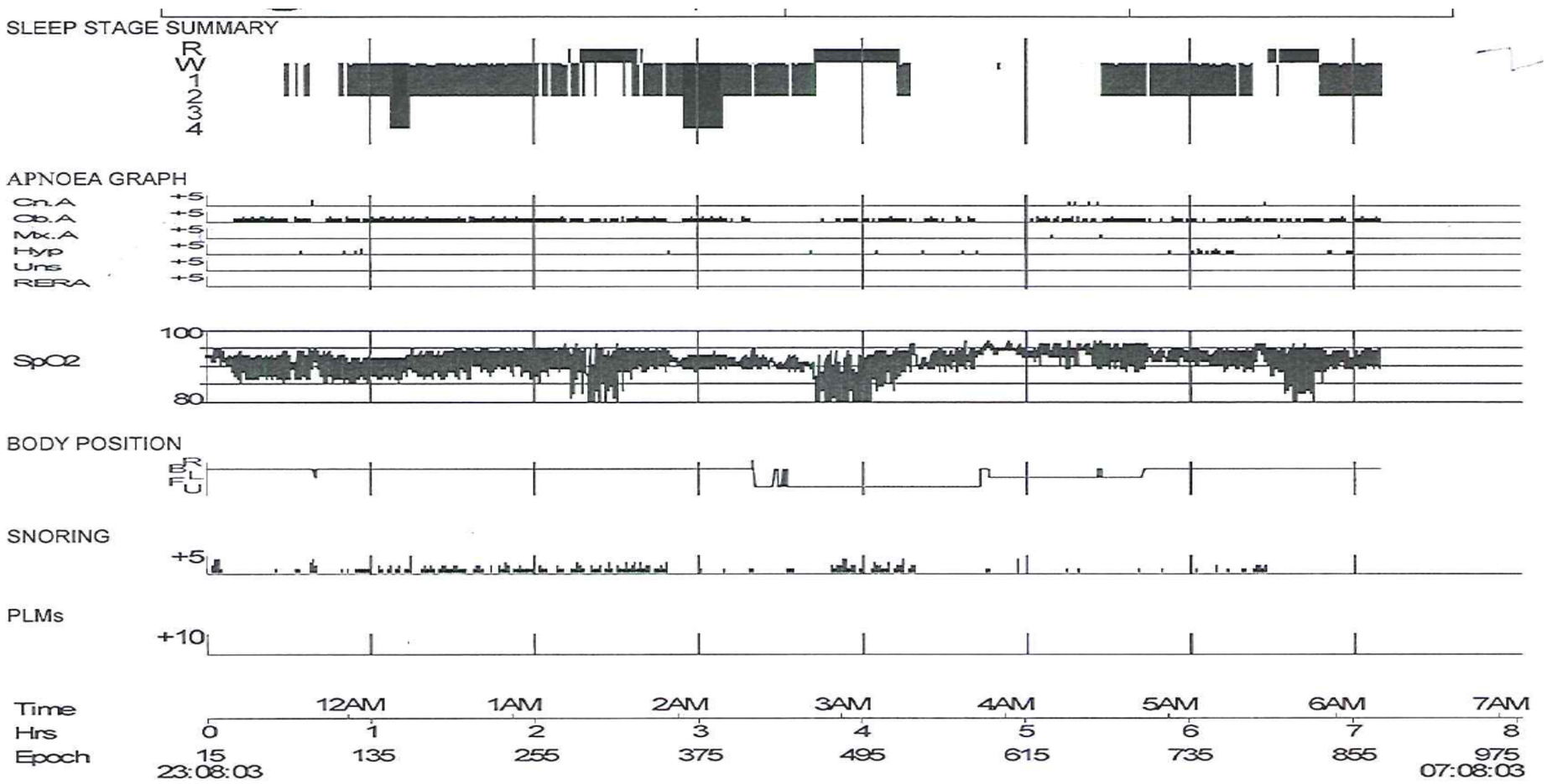
# CONVERTING PSG DATA INTO MULTI-LAYERED COMPOSITIONS.

Renata L Riha  (University of Edinburgh)

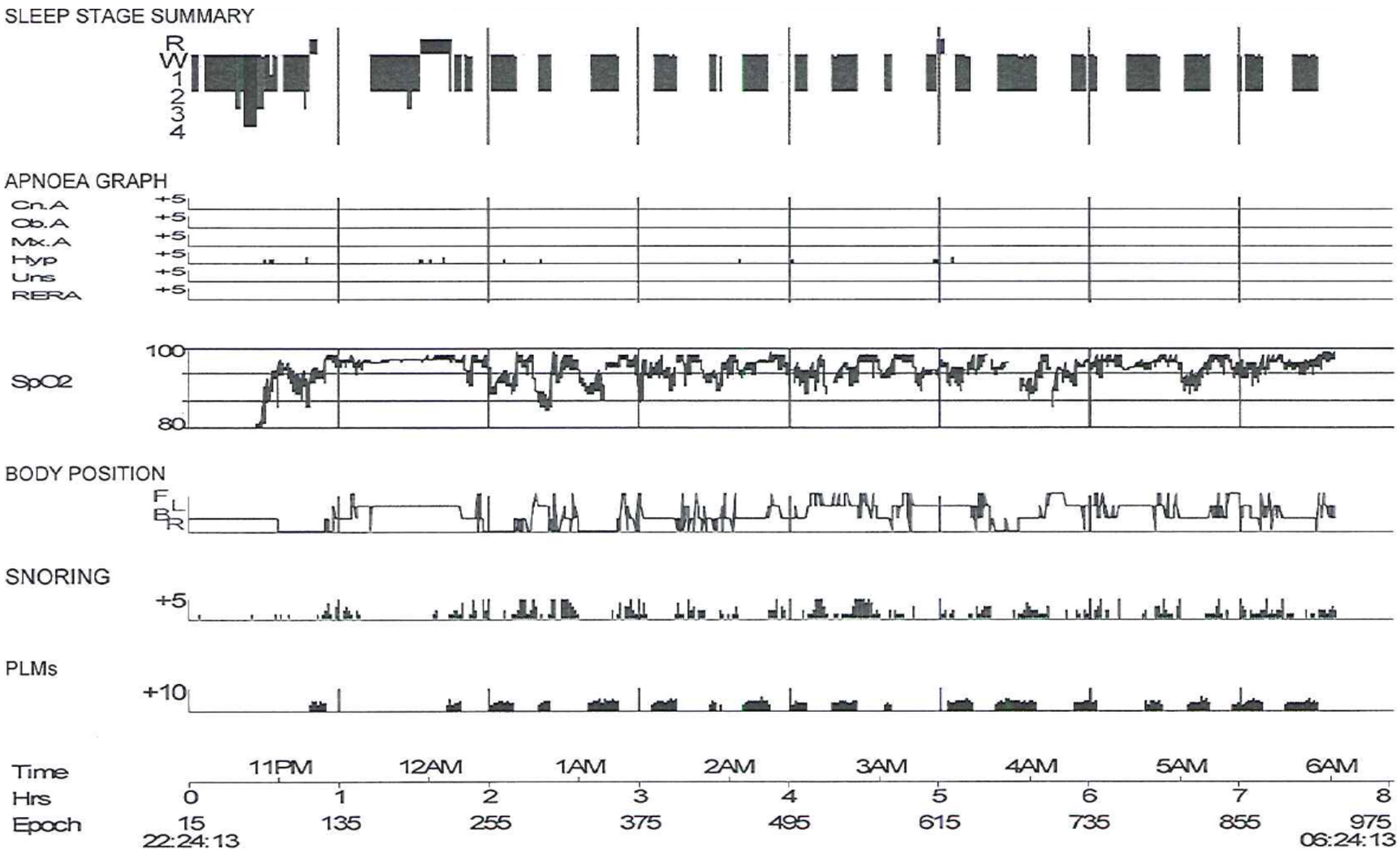
# NORMAL PSG


SLEEP STAGE SUMMARY
R
W
1
2
3
4
APNOEA GRAPH
Cn.A
Ob.A
Mx.A
Hyp
Uns
RERA
+5
SpO2
100
80
BODY POSITION
F
L
R
SNORING
+5
PLMs
+10
Time
Hrs
Epoch
10PM
11PM
12AM
1AM
2AM
3AM
4AM
5AM
6AM
7AM
0
2
4
6
8
10
1
241
481
721
961
1201
21:57:31
07:57:31

# SEVERE SLEEP APNOEA



# RESTLESS LEG SYNDROME



# PSG AS SCORE

1. Grande Cymbale Chinoise
Grosse Caisse (très grave)

2. Gong
Tam-tam clair
Tam-tam grave

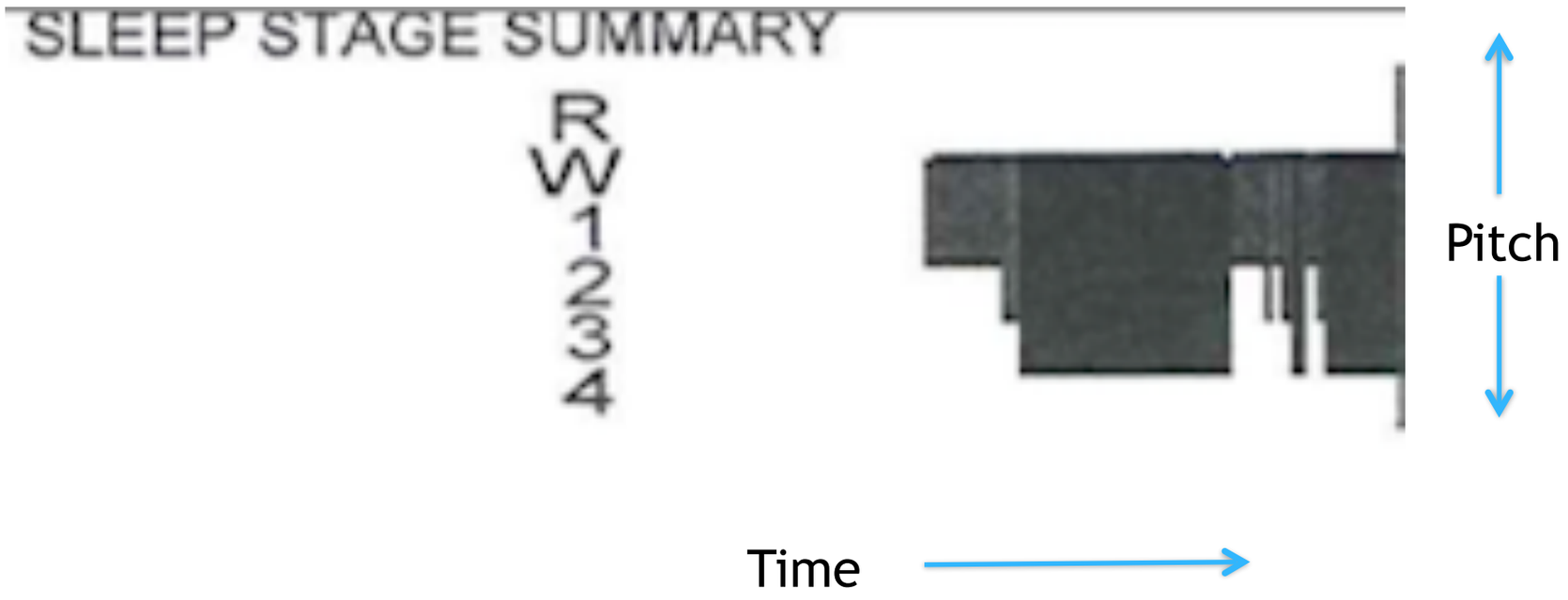
3. 2 Bongos — clair, grave
Caisse Roulante
2 Grosses Caisses — moyenne, grave

4. Tambour militaire
Caisse roulante

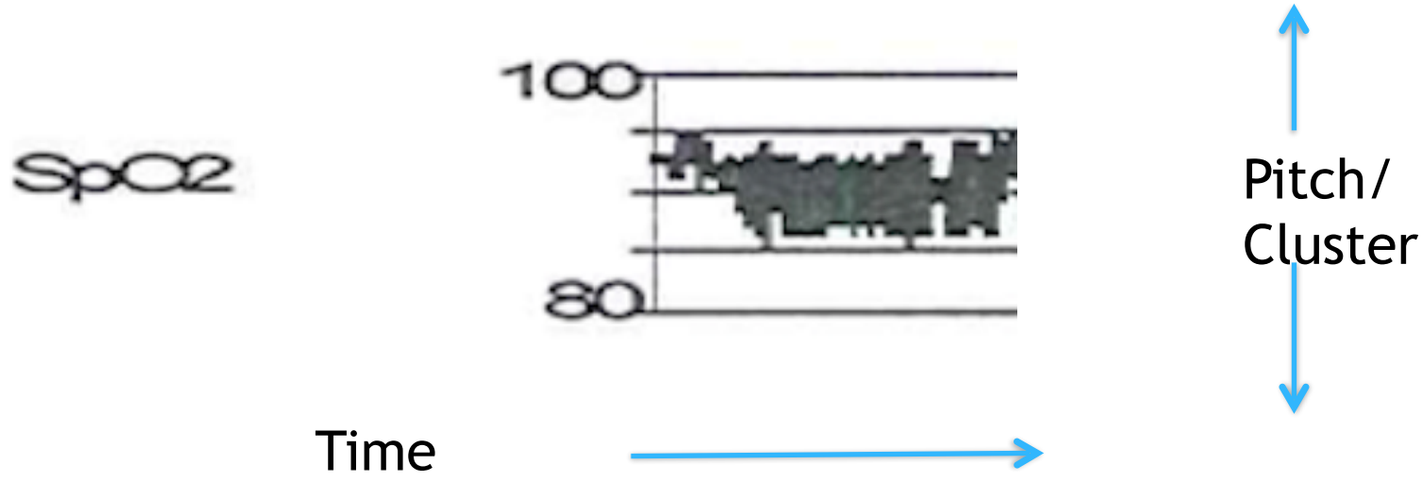
5. Sirène claire
Tambour à corde

6. Sirène grave
Flouet
Glissando

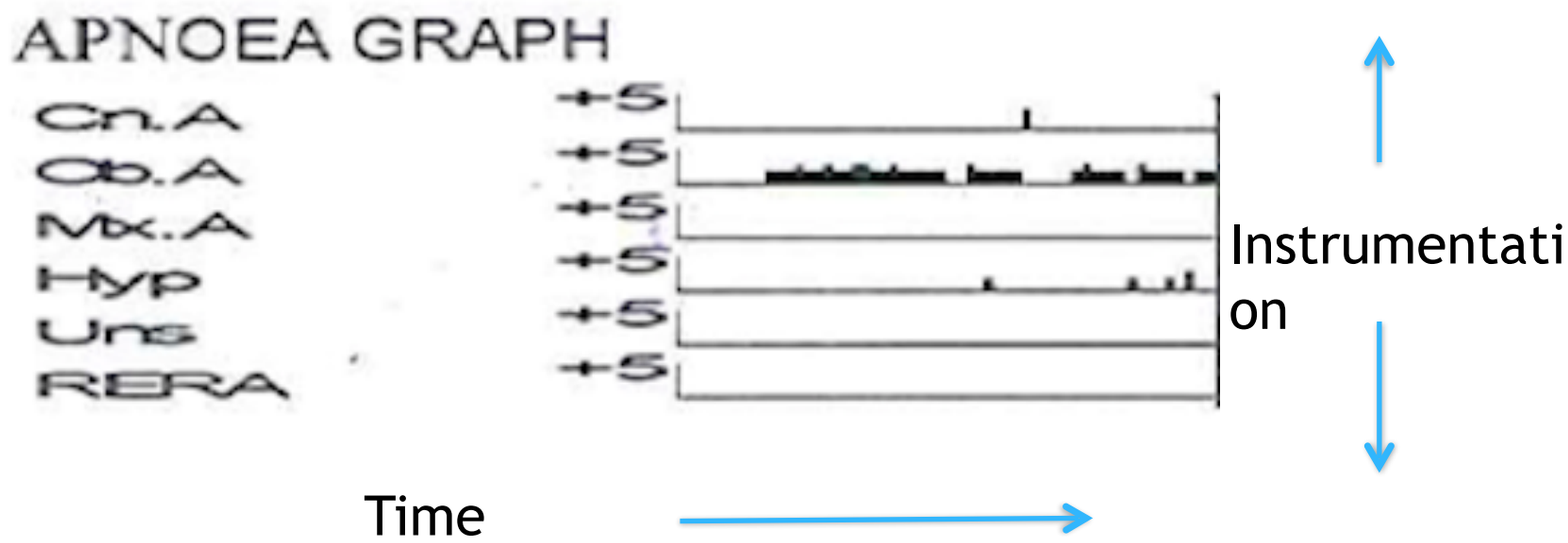
# SLEEP FLUTE MELODY



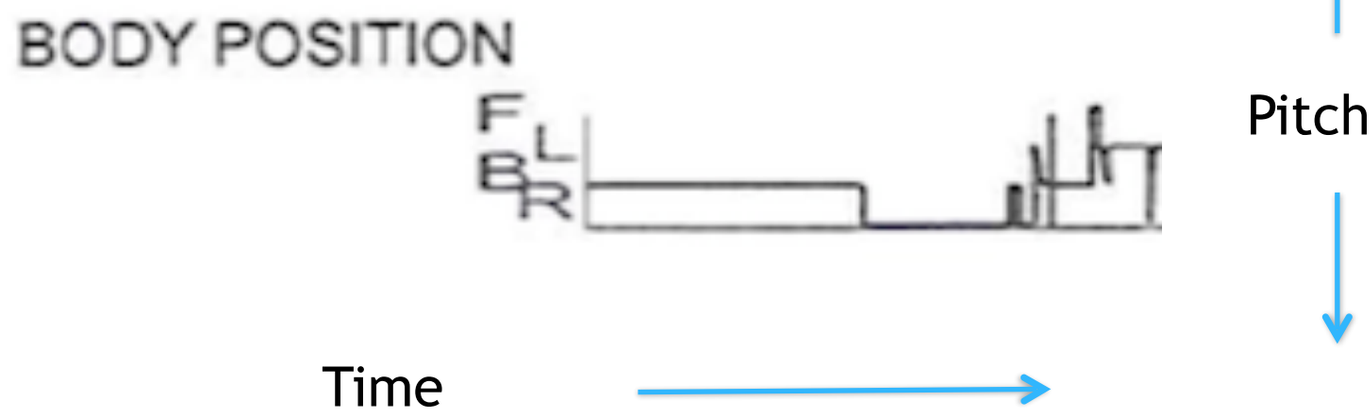
# SPO2 TEXTURE/HARMONY



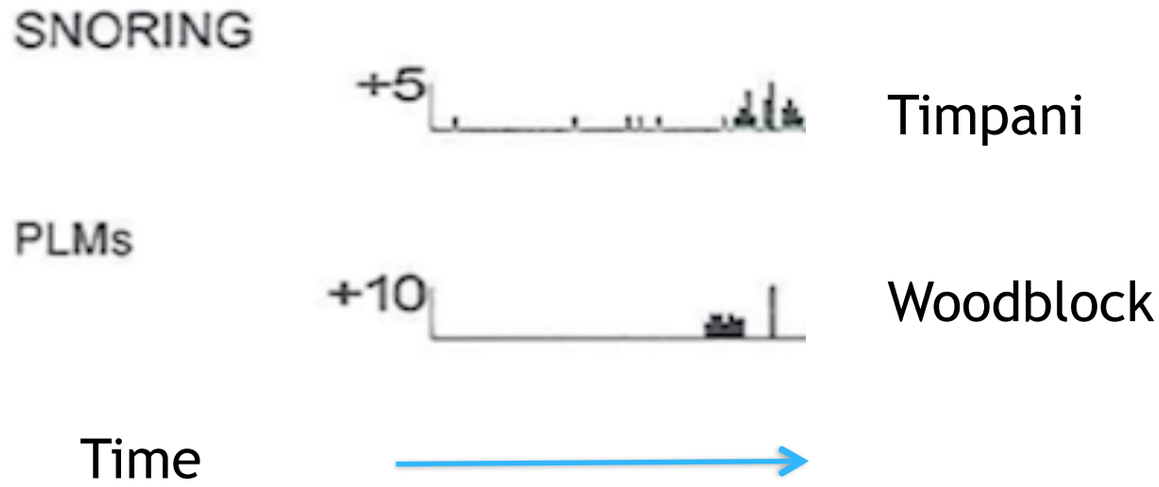
# APNOEA PERCUSSION/PIZZICATO



# BODY POSITION BASS-LINE



# SNORING AND PLM TIMPANI/WOODBLOCK



S9

# NORMAL SLEEP

S11

# APNOEA

S21

# RESTLESS LEG SYNDROME

# THE INNER SOUND OF SLEEP

## TRANSLATING EEG DATA TO THE AUDIO SPECTRUM

Vladyslav Vyazovskiy (University of Oxford)

Milton Mermikides (University of Surrey)

# WAVES

Pitch Domain

| | |
|---|---|
| Gamma | 32-100Hz |
| Beta | 14-60Hz |
| Alpha | 8-12Hz to 30-50Hz |
| Theta | 4-8Hz |
| Delta | 0.5-3Hz |

# WAVES

Gamma 32-100Hz

Beta 14-60Hz

Alpha 8-12Hz to 30-50Hz

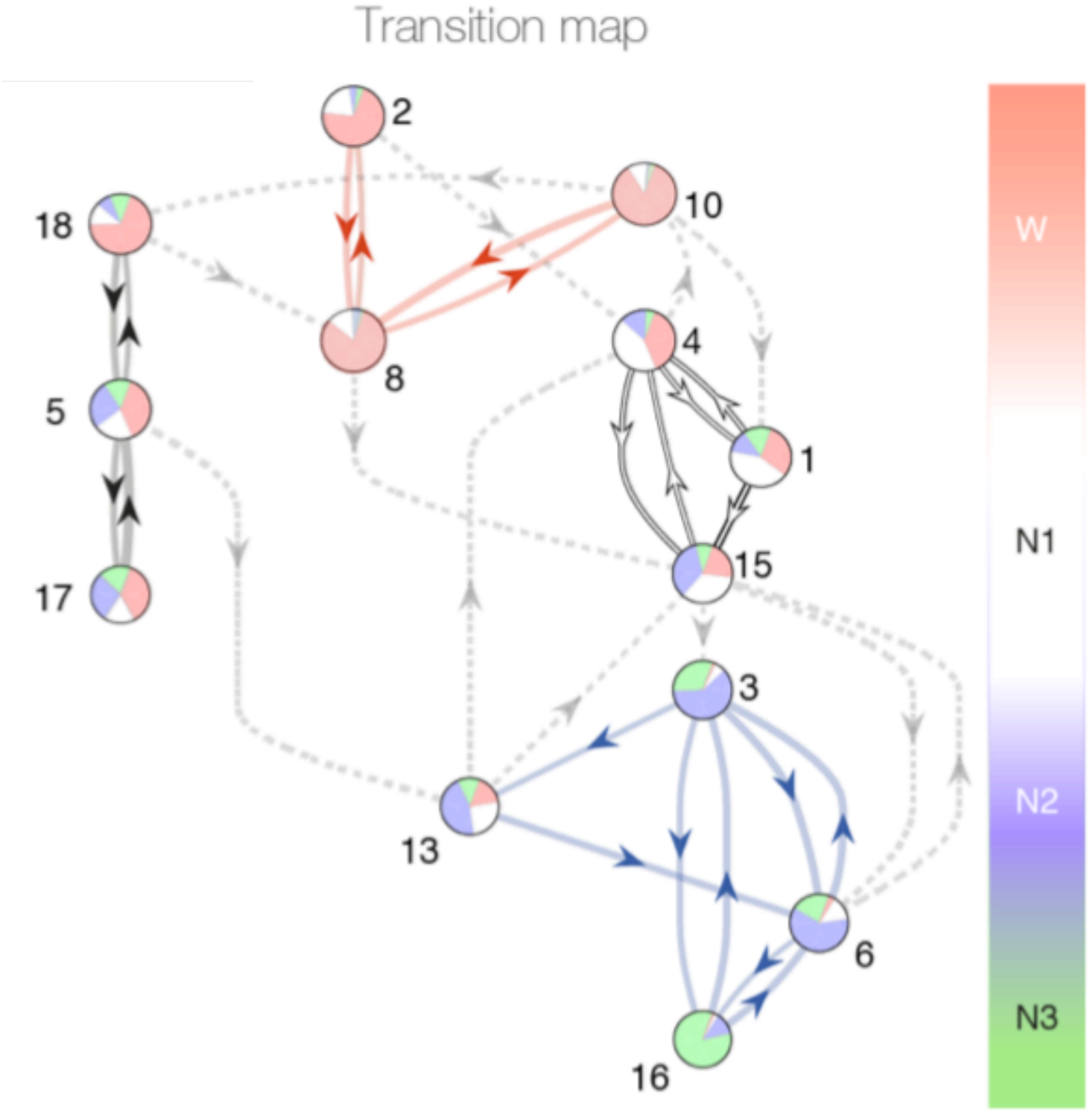
Theta 4-8Hz

Delta 0.5-3Hz

Rhythmic Domain

[Morten
HMM]

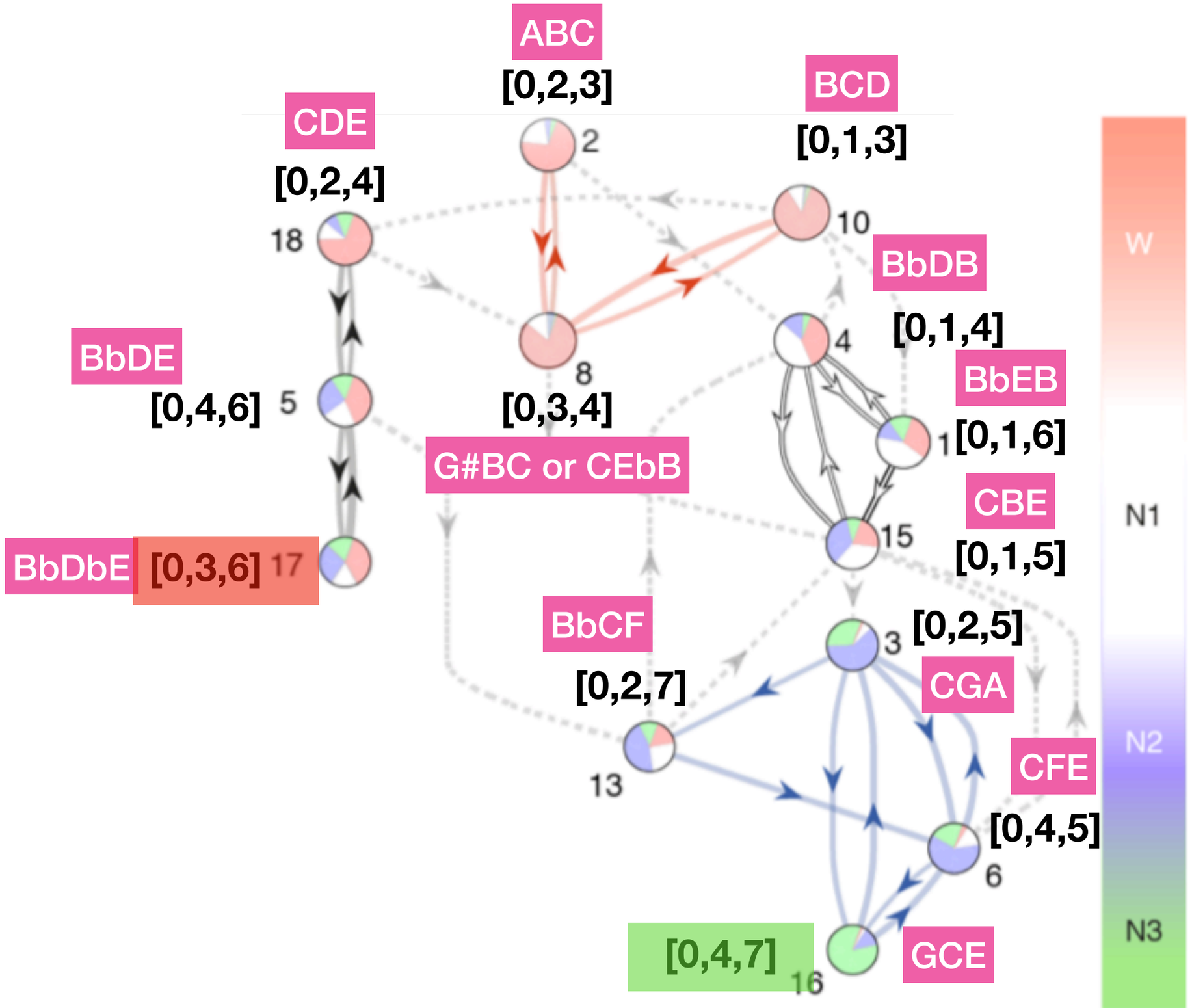
# Network as Consonance/Dissonance Vectors


Transition map
2
10
18
8
4
5
1
15
17
3
13
6
16
W
N1
N2
N3

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 3-1 | | | | | | | | | |
| 3-2a | | | | | | | | | |
| 3-2b | | | | | | | | | |
| 3-3a | | | | | | | | | |
| 3-3b | | | | | | | | | |
| 3-4a | | | | | | | | | |
| 3-4b | | | | | | | | | |
| 3-5a | | | | | | | | | |
| 3-5b | | | | | | | | | |
| 3-6 | | | | | | | | | |
| 3-7a | | | | | | | | | |
| 3-7b | | | | | | | | | |
| 3-8a | | | | | | | | | |
| 3-8b | | | | | | | | | |
| 3-9 | | | | | | | | | |
| 3-10 | | | | | | | | | |
| 3-11a | | | | | | | | | |
| 3-11b | | | | | | | | | |
| 3-12 | | | | | | | | | |

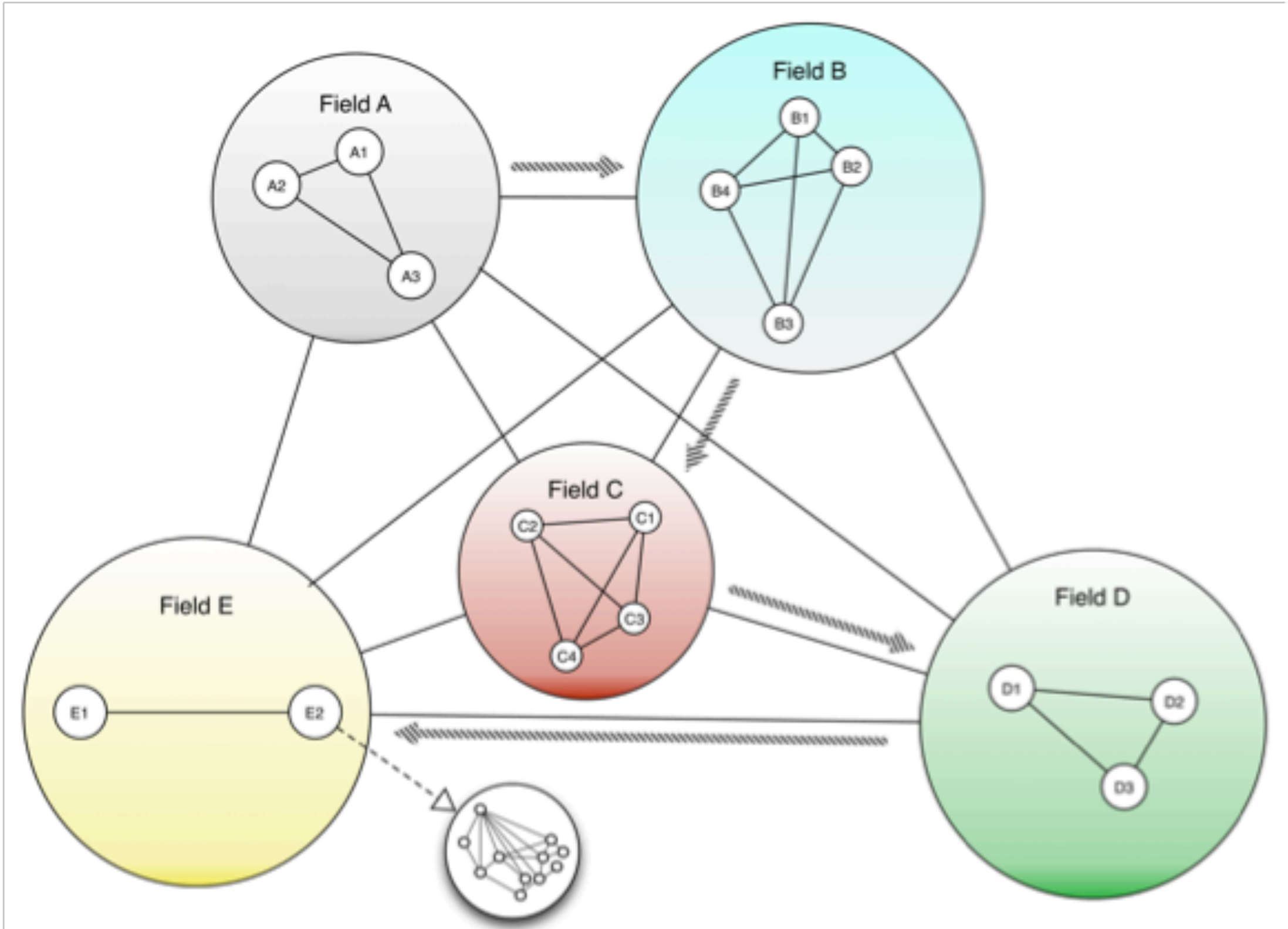
| | | | | |
|---|---|---|---|---|
| **1** | **3-1** | `[0,1,2]` | `<2,1,0,0,0,0>` | Cluster |
| **2** | **3-2A** | `[0,1,3]` | `<1,1,1,0,0,0>` | Soft Cluster A (Phrygian) |
| 3 | 3-2B | `[0,2,3]` | | Soft Cluster B (Aeolian) |
| **4** | **3-3A** | `[0,1,4]` | `<1,0,1,1,0,0>` | Hijaz A |
| 5 | 3-3B | `[0,3,4]` | | Hijaz B: Twilight |
| **6** | **3-4A** | `[0,1,5]` | `<1,0,0,1,1,0>` | Desert |
| 7 | 3-4B | `[0,4,5]` | | Sun |
| **8** | **3-5A** | `[0,1,6]` | `<1,0,0,0,1,1>` | Viennese A |
| 9 | 3-5B | `[0,5,6]` | | Viennese B |
| **10** | **3-6** | `[0,2,4]` | `<0,2,0,1,0,0>` | Whole Tone Cluster |
| **11** | **3-7A** | `[0,2,5]` | `<0,1,1,0,1,0>` | Blues trichord A (Soul) |
| 12 | 3-7B | `[0,3,5]` | | Blues trichord B (Trane) |
| **13** | **3-8A** | `[0,2,6]` | `<0,1,0,1,0,1>` | Italian 6th A |
| 14 | 3-8B | `[0,4,6]` | | Lydian |
| **15** | **3-9** | `[0,2,7]` | `<0,1,0,0,2,0>` | Sus chord |
| **16** | **3-10** | `[0,3,6]` | `<0,0,2,0,0,1>` | dim. chord |
| **17** | **3-11A** | `[0,3,7]` | `<0,0,1,1,1,0>` | minor chord |
| 18 | 3-11B | `[0,4,7]` | | major chord |
| **19** | **3-12** | `[0,4,8]` | `<0,0,0,3,0,0>` | Aug. chord |

# Trichord Interval Vectors




## Trichord category and Interval Components

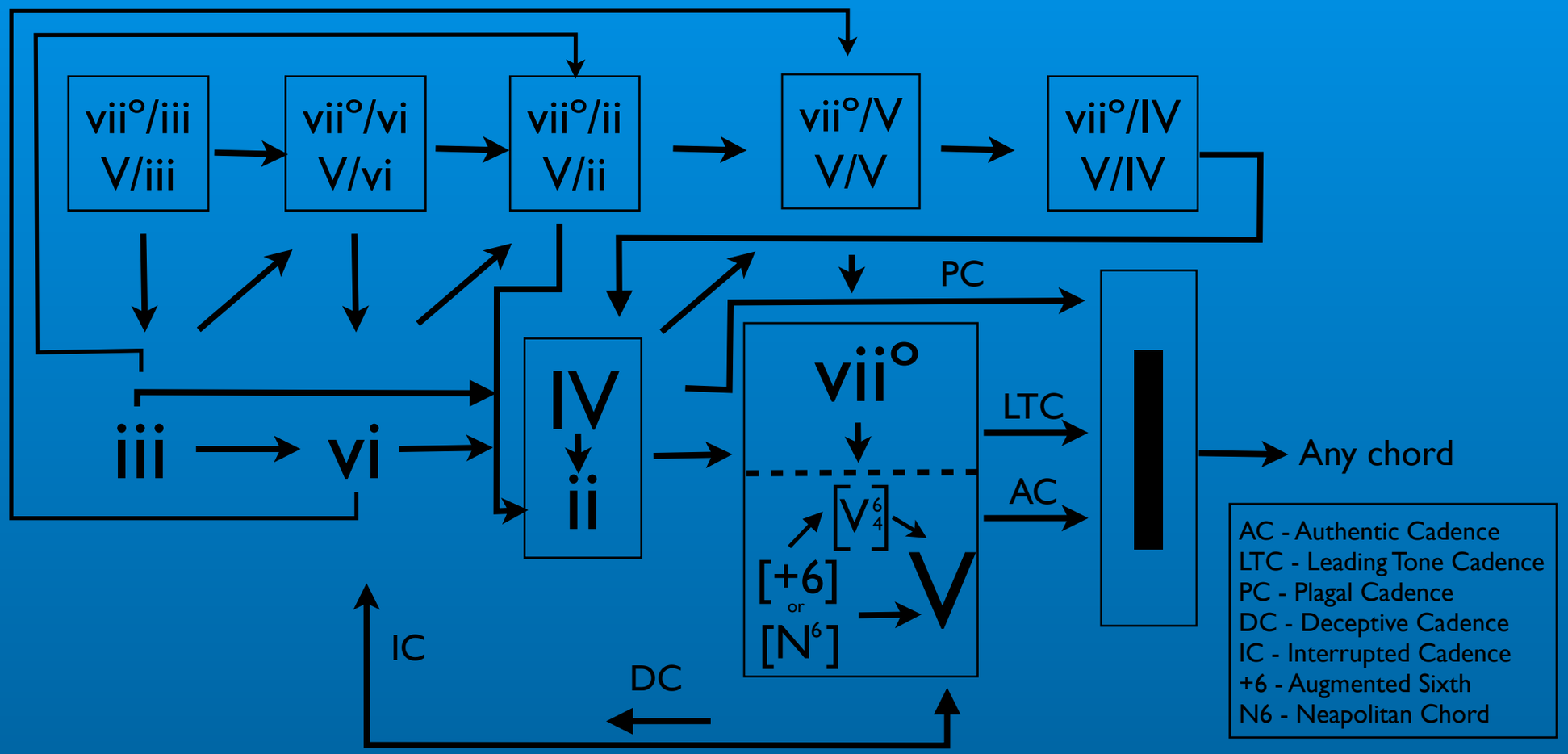
# Network as Musical Proximity




# Multi-level hierarchical units

# Network as Harmonic Function

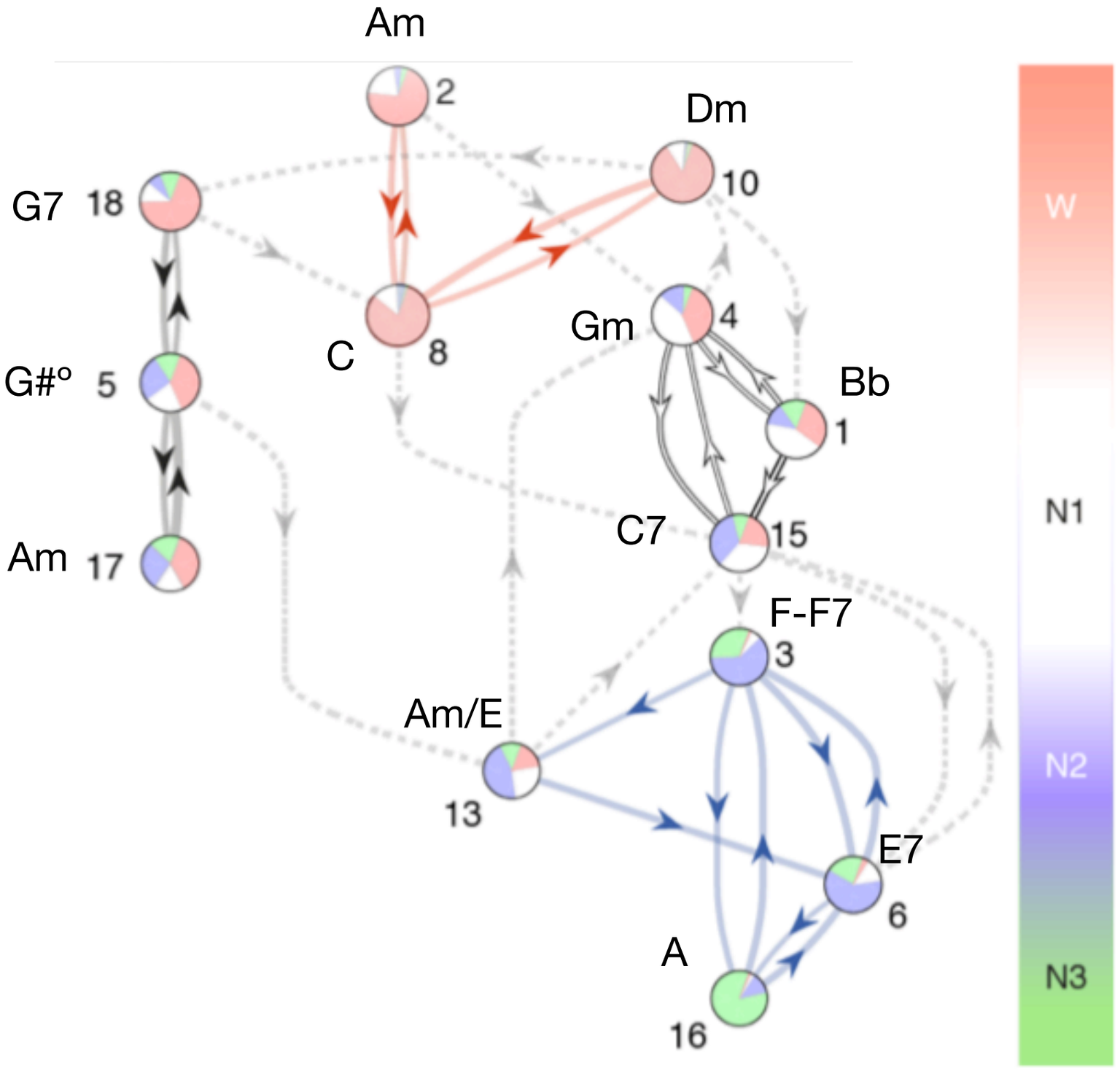
# Tonal Harmony Flow Chart...
# for Common Progressions in a Major Key




These triads (particularly V & vii°)may be freely extended to 7th chords

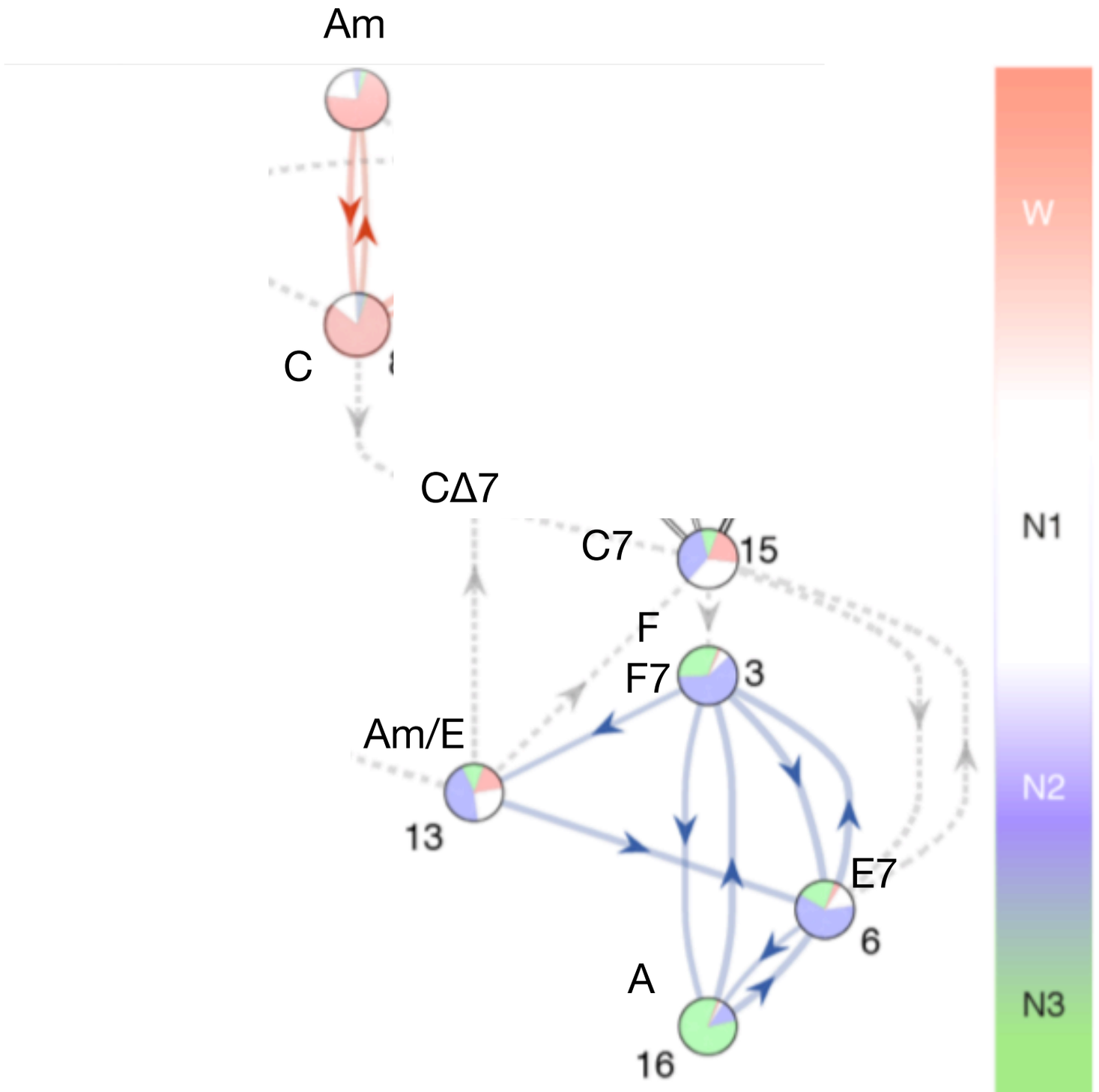
@miltonline

# Tonal Devices



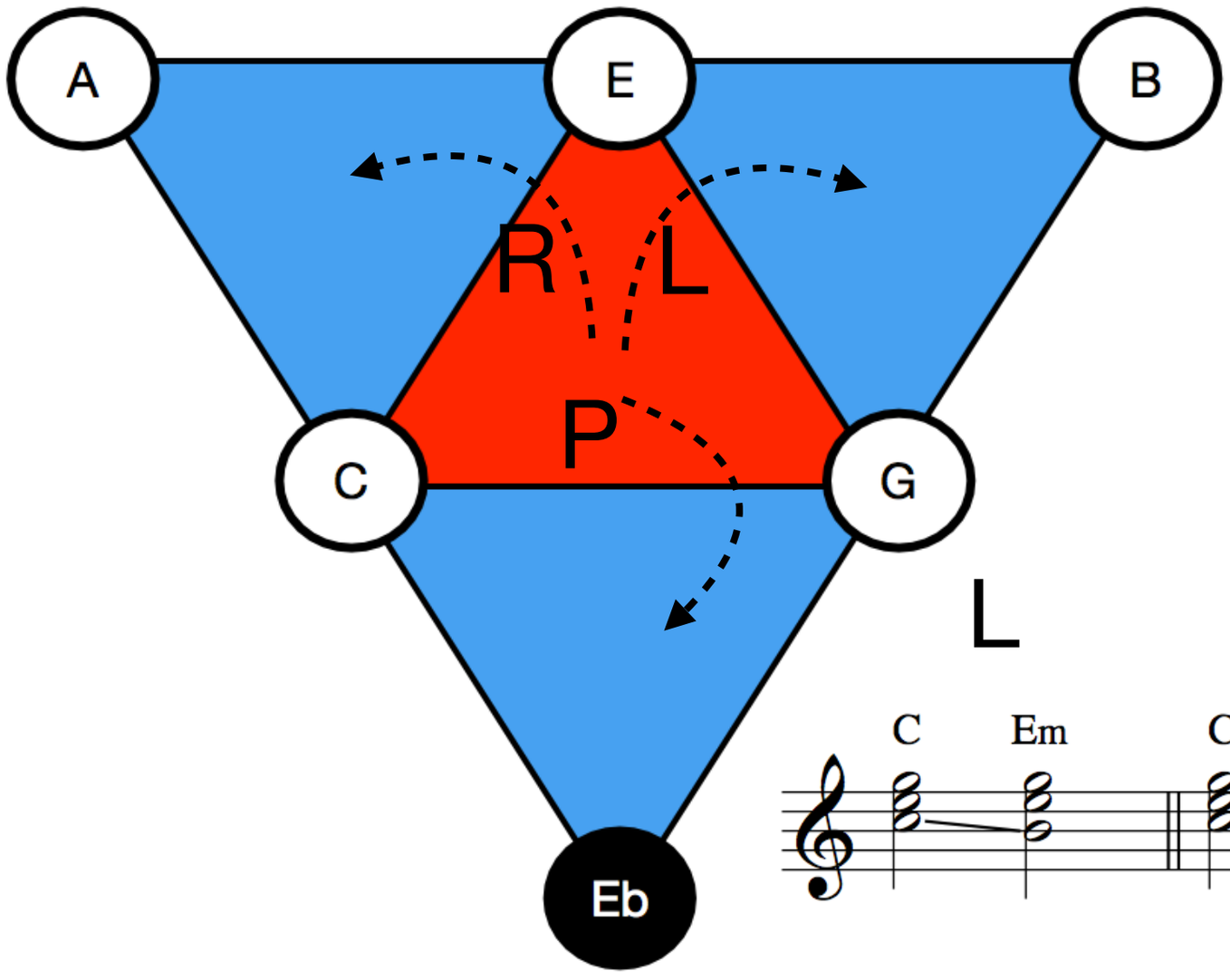

## Harmonic Tonal Devices: key areas/directionality

# Tonal Devices

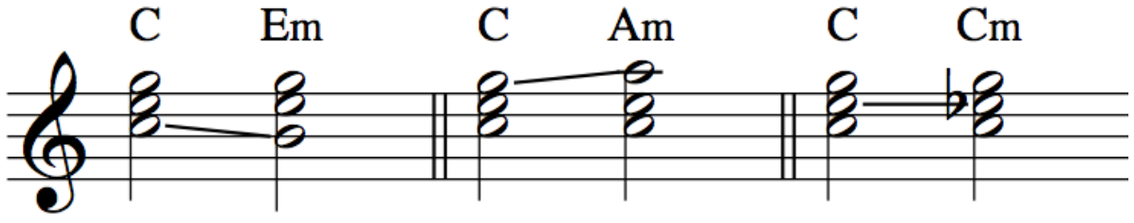



## Harmonic Tonal Devices: key areas/directionality

# Network as Harmonic Transformation




L R P



R

L

S

Eb Bb F C

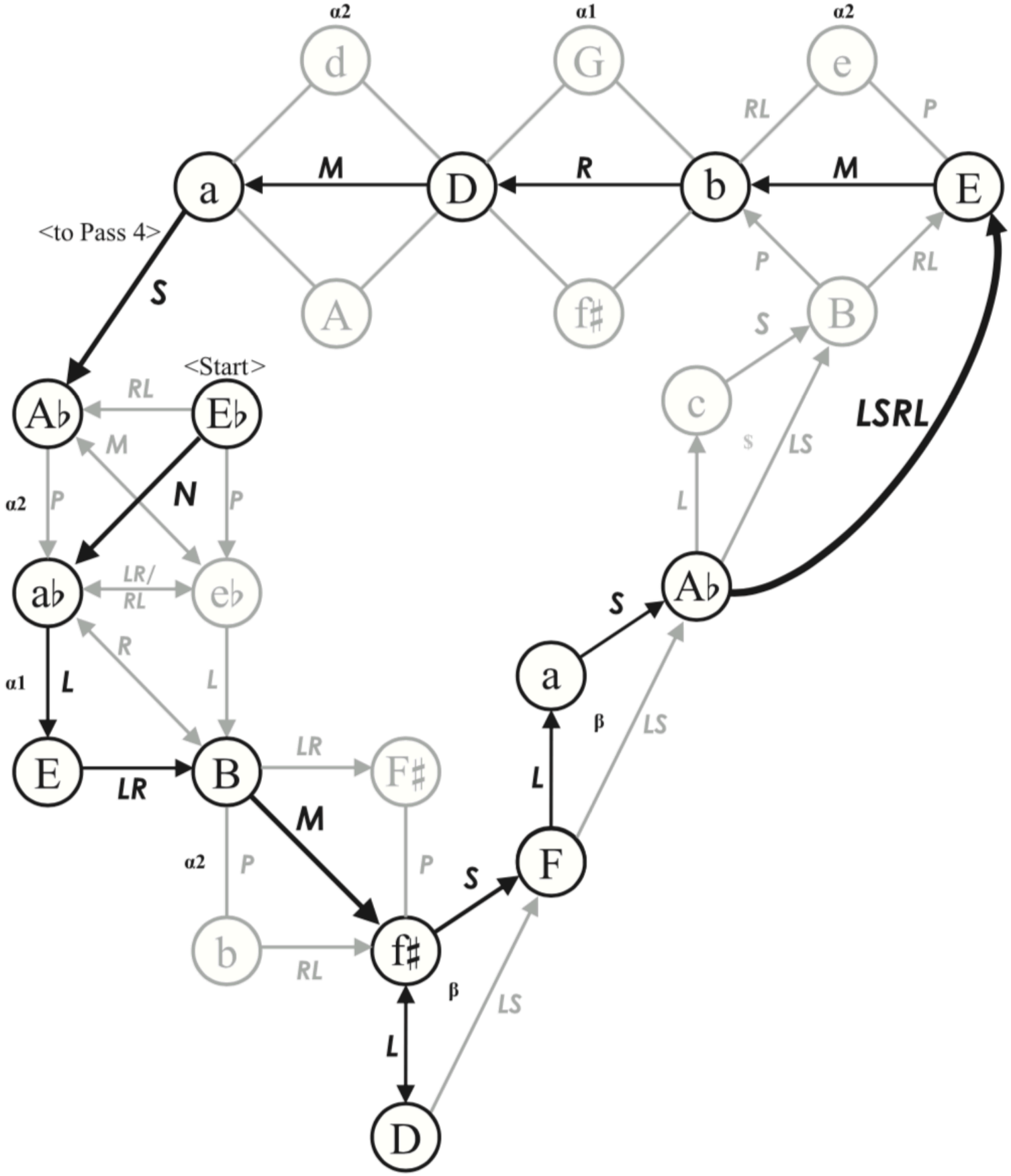
B F# C# G# D#

G D A E B

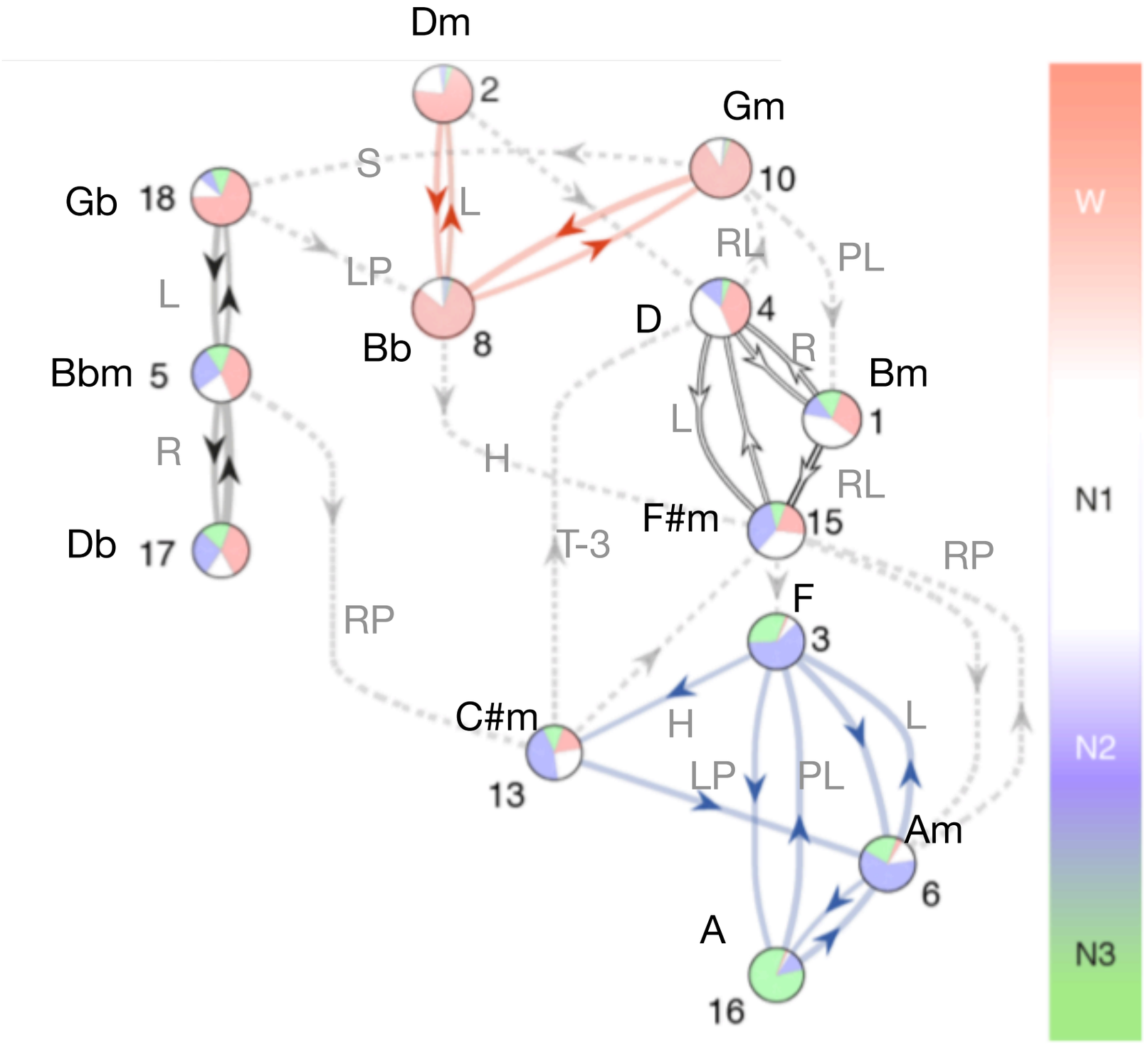
Eb Bb F C G D

B Gb Db Ab Eb Bb

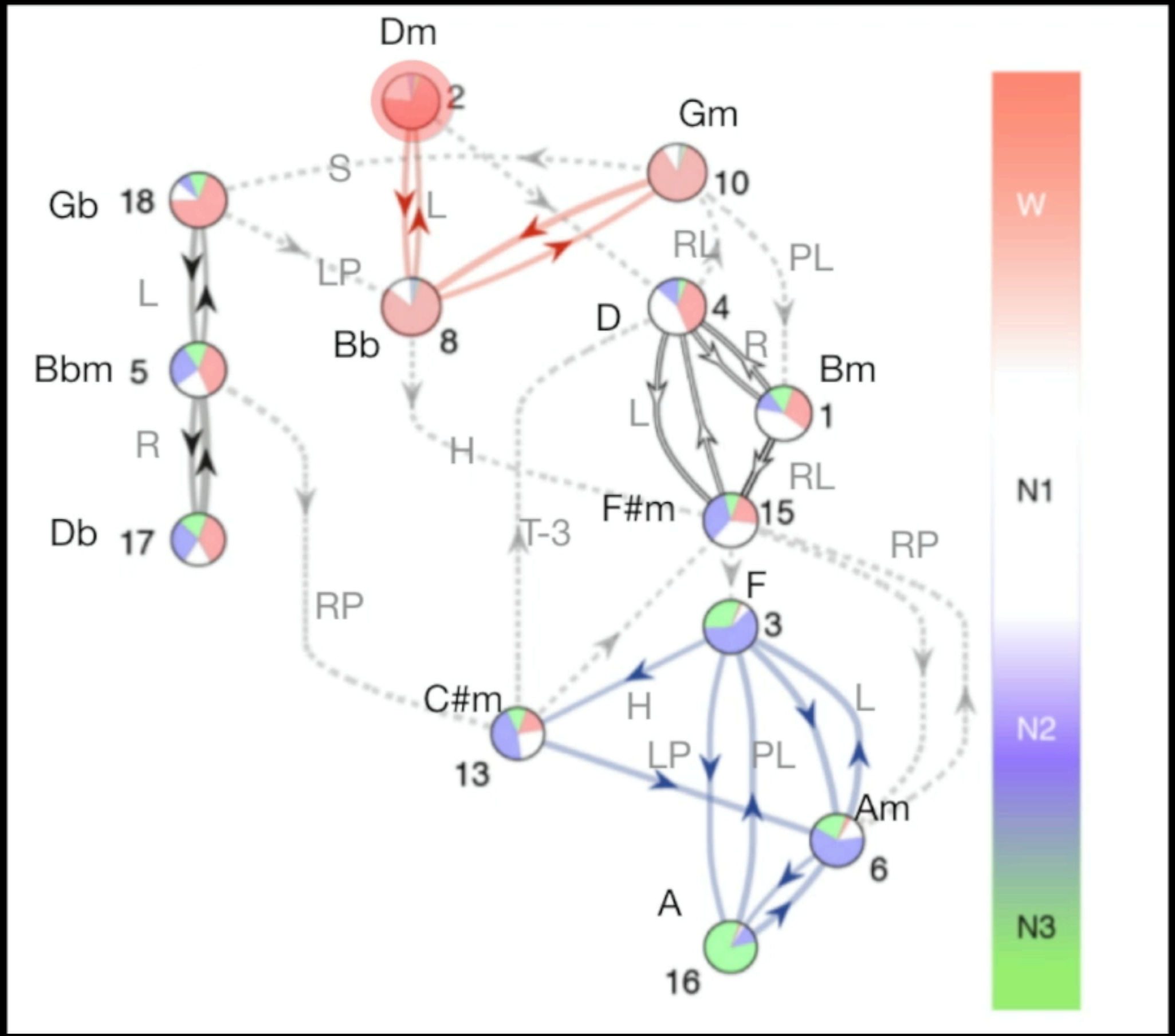
D A E B F# C#


α2
α1
α2
d
G
e
RL
P
a
M
D
R
b
M
E
<to Pass 4>
S
P
RL
A
f♯
S
B
<Start>
c
LSRL
RL
A♭
E♭
M
s
LS
α2
P
N
P
L
ab
LR/
RL
eb
S
A♭
R
α1
L
L
a
β
LS
E
LR
B
LR
F♯
L
M
α2
P
P
S
F
b
RL
f♯
β
LS
L
D

# Neo-Riemannian Transformational Network




**Pathways denote**
**Number of common tones/intervallic proximity**


Dm
2
Gm
10
Gb
18
S
L
LP
L
Bb
8
RL
PL
D
4
R
Bm
1
Bbm
5
R
H
L
RL
F#m
15
Db
17
T-3
RP
RP
F
3
C#m
13
H
L
LP
PL
Am
6
A
16
W
N1
N2
N3

# CODA

# Thanks