

# **Scales, Chords, and Cadences: Practical Music Theory for MIR Researchers**

Chords

# Main Topics

- ▶ **Chord Basics**
- ▶ **Chord Labels**
- ▶ **Evaluation for Automatic Chord Recognition**
- ▶ **Higher-Level Organization of Harmonic Material**

# Terminology

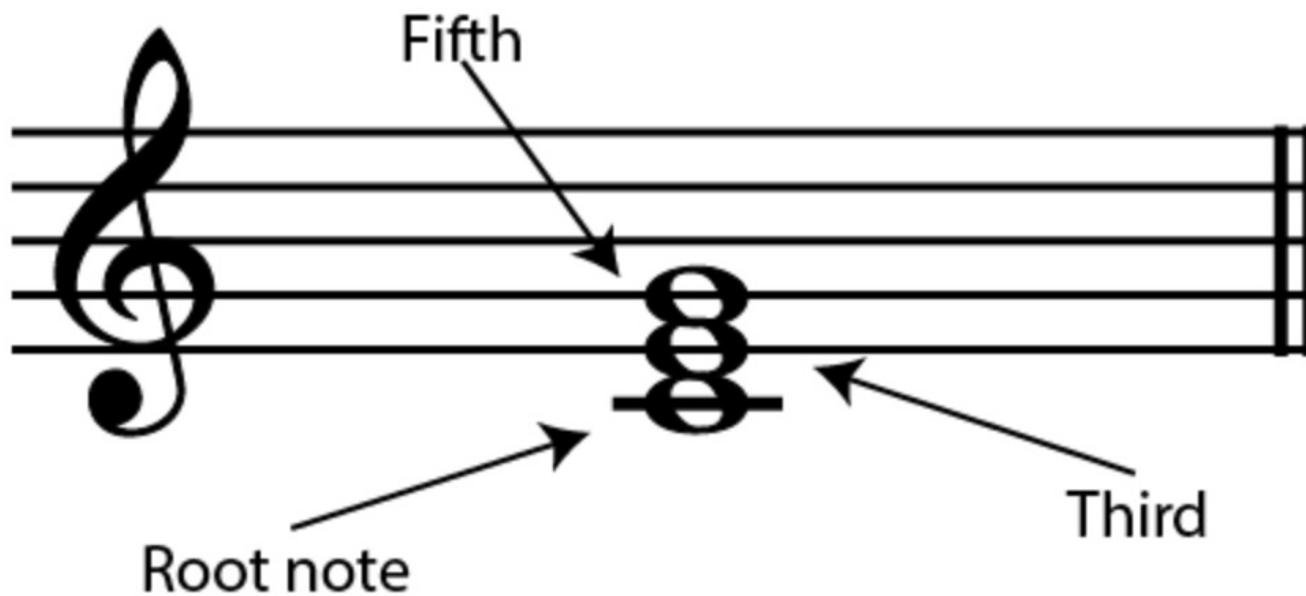
- ▶ **Root**
- ▶ **Scale degree**
- ▶ **Chord tones**
- ▶ **Non-chord tones**
- ▶ **Quality**
  - **Major, Minor, Augmented, Diminished**
- ▶ **Triads**
- ▶ **Seventh chords**
- ▶ **Added Notes/Extensions**

# **Chord Basics**

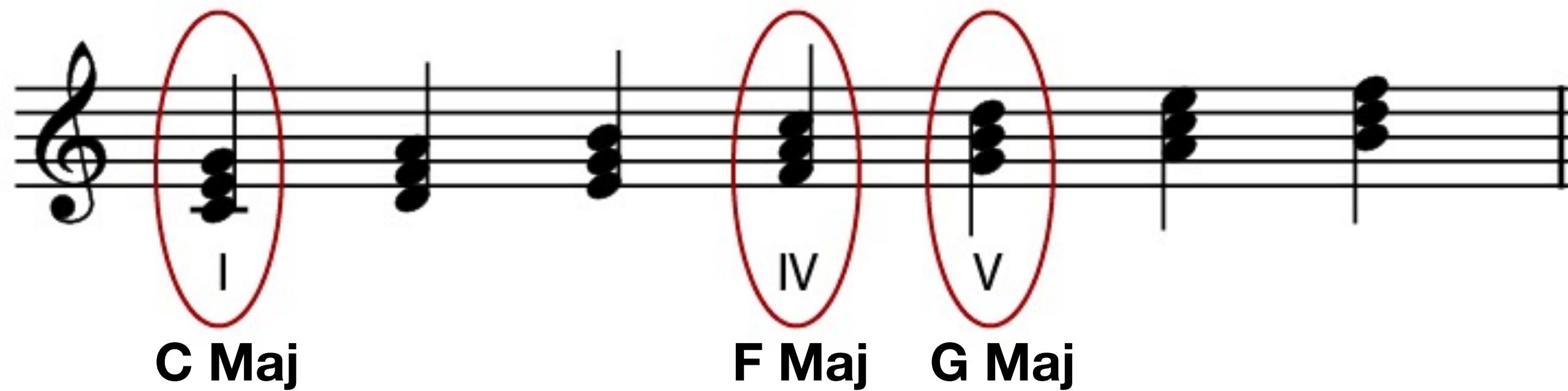
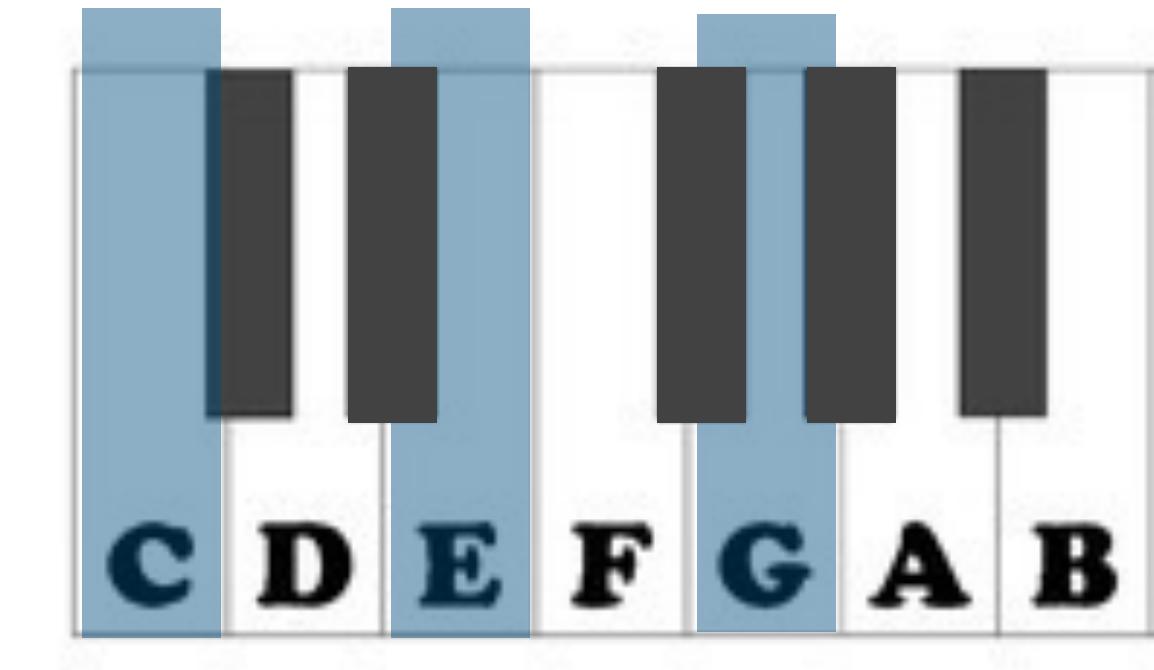
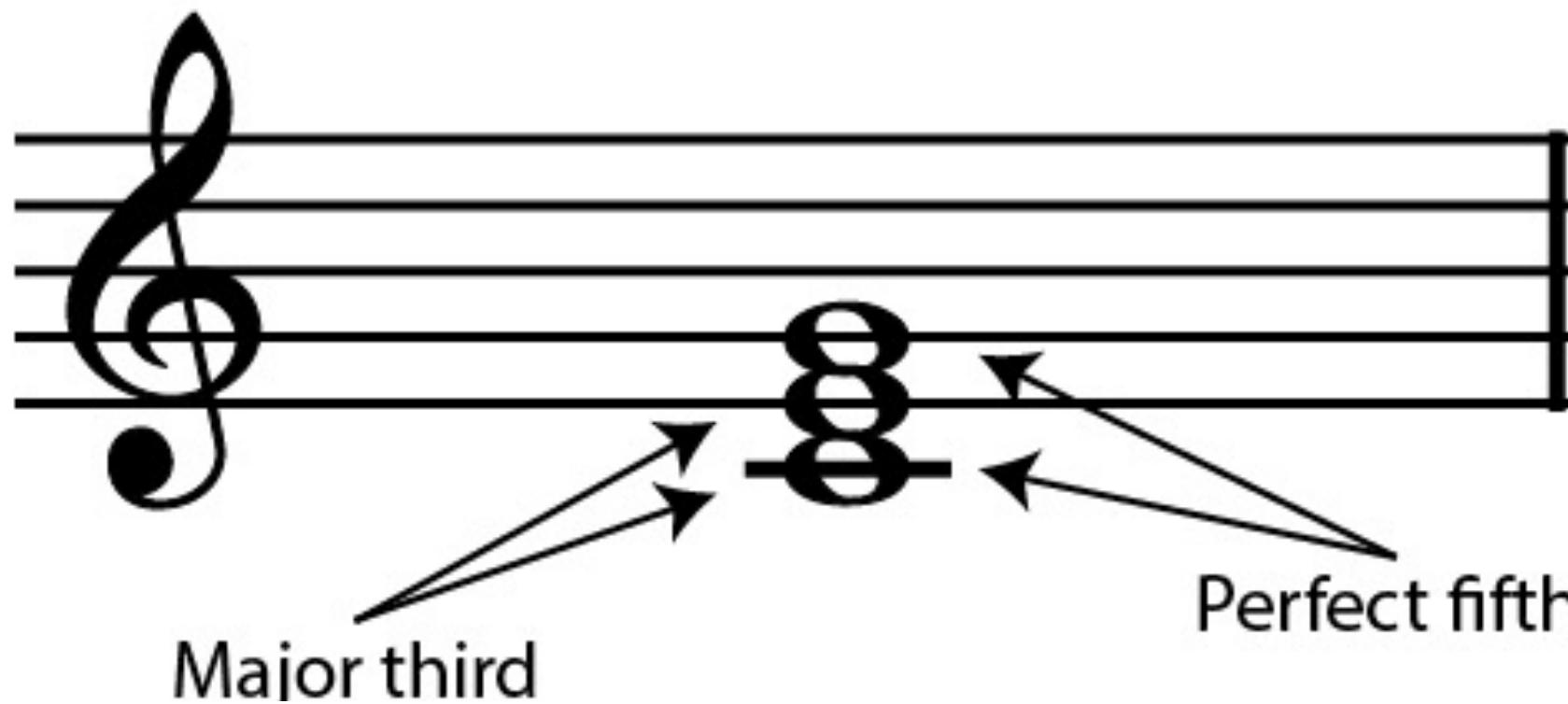
# Chords



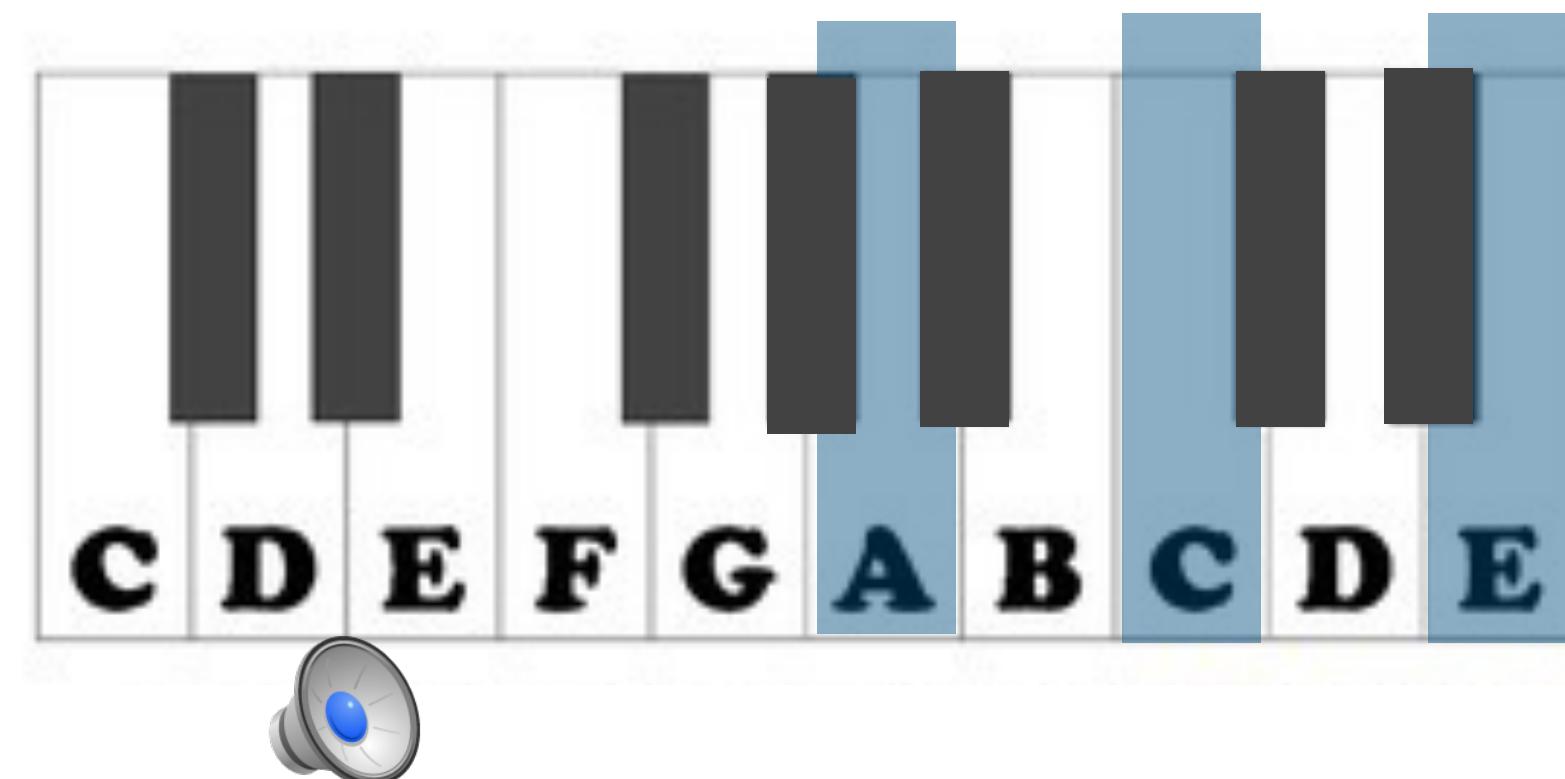
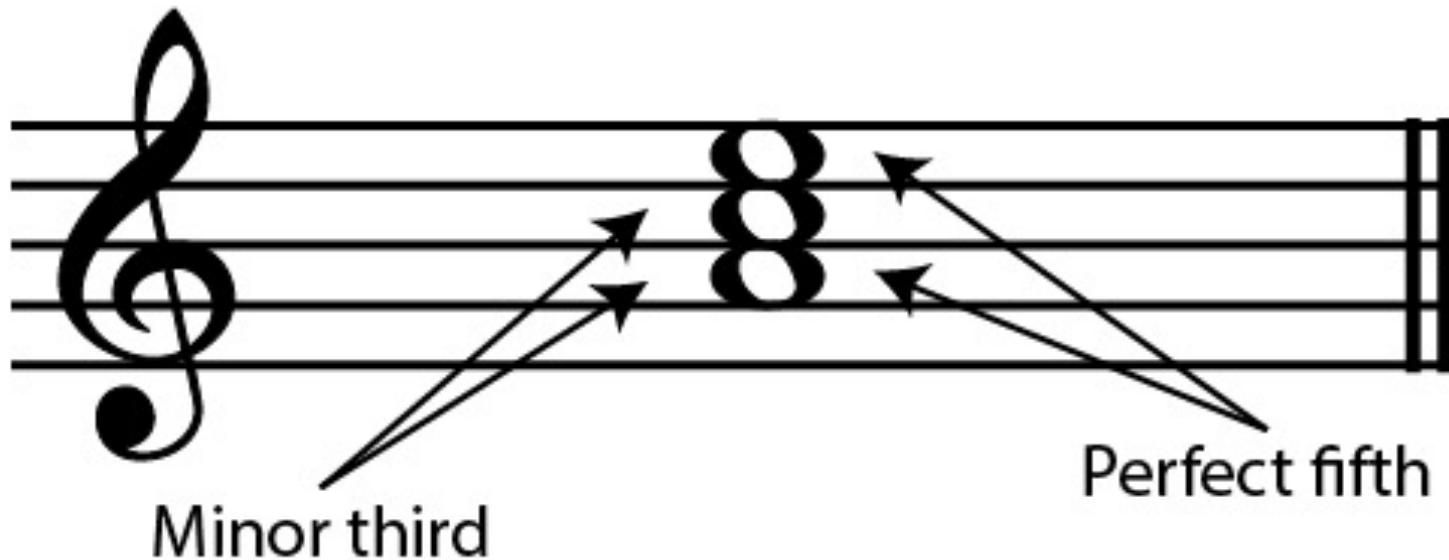
I	ii	iii	IV	V	vi	vii <sup>o</sup>
Cmaj	Dmin	Emin	Fmaj	Gmaj	Amin	Bdim



# Quality: Major Triads

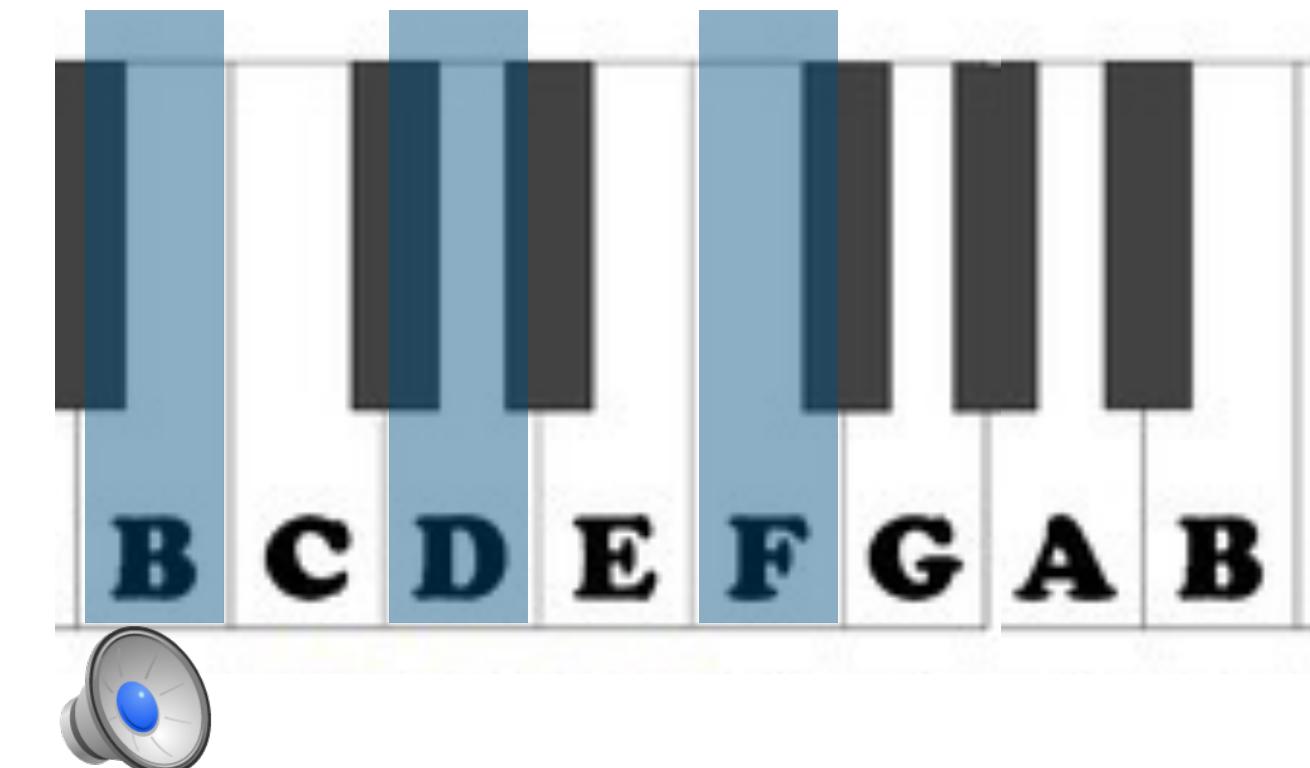
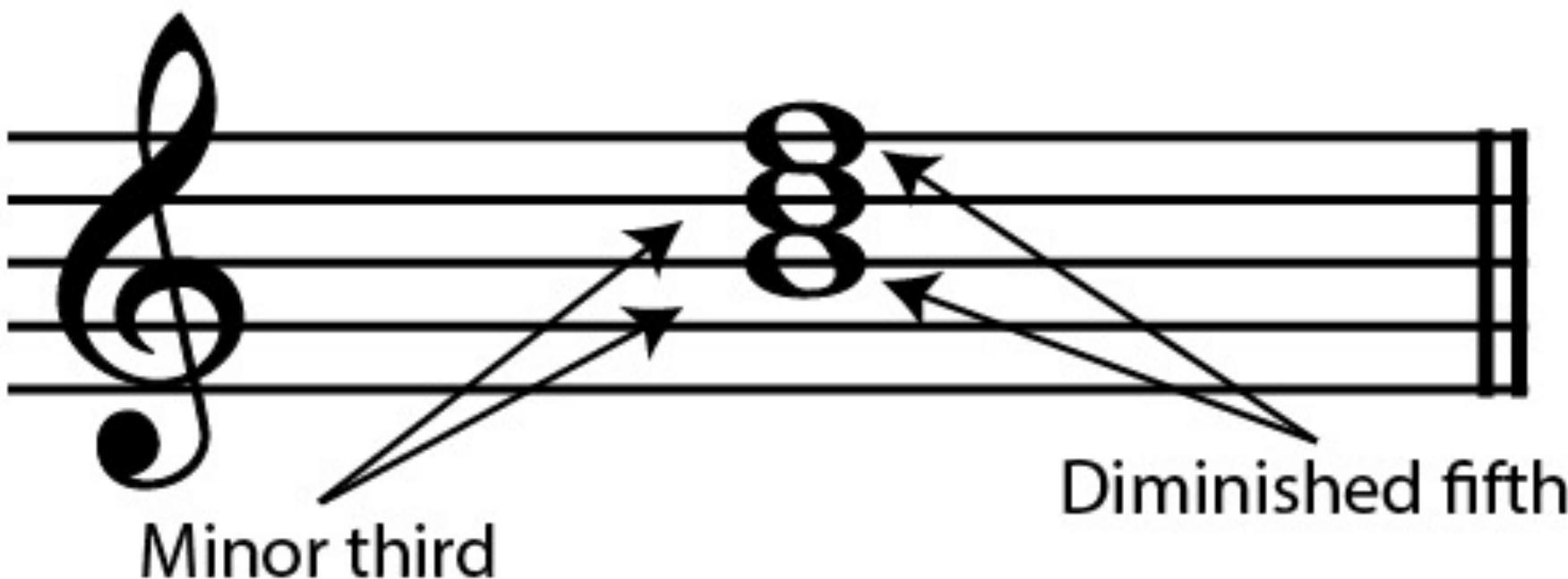


# Quality: Minor Triads



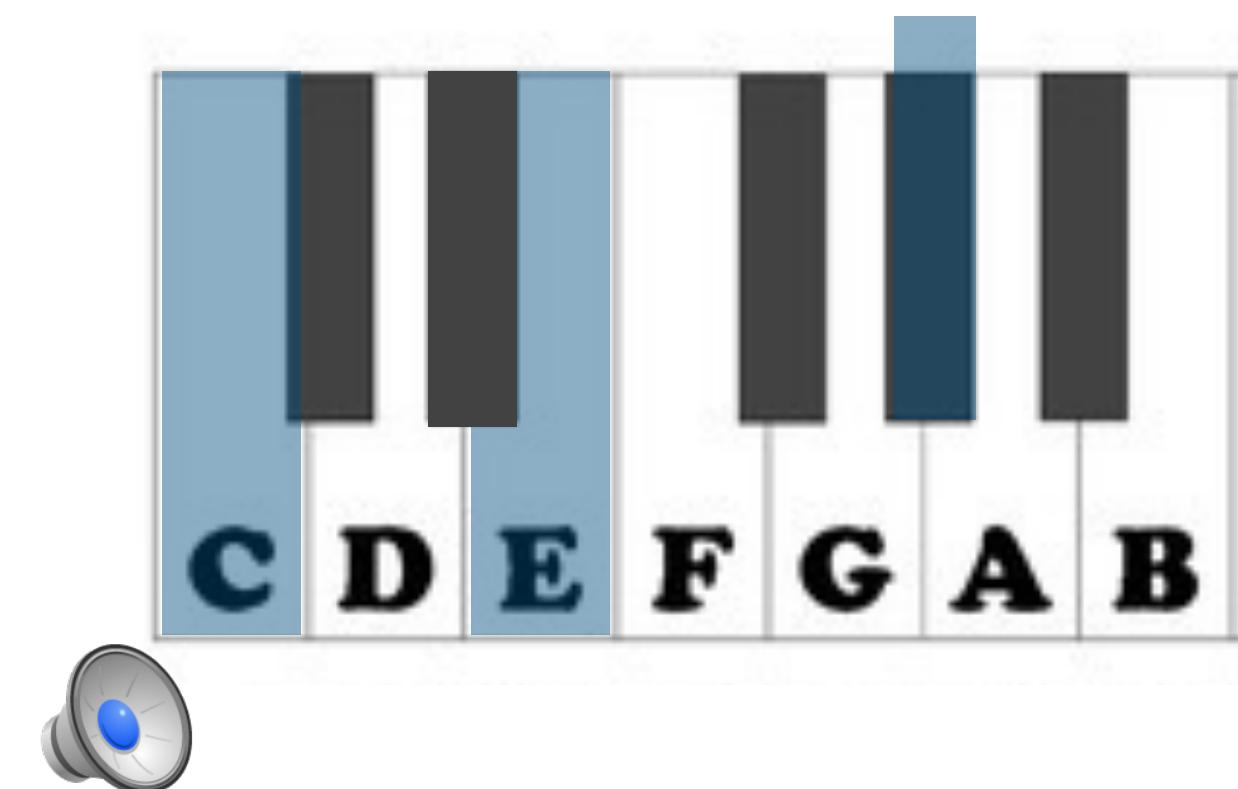
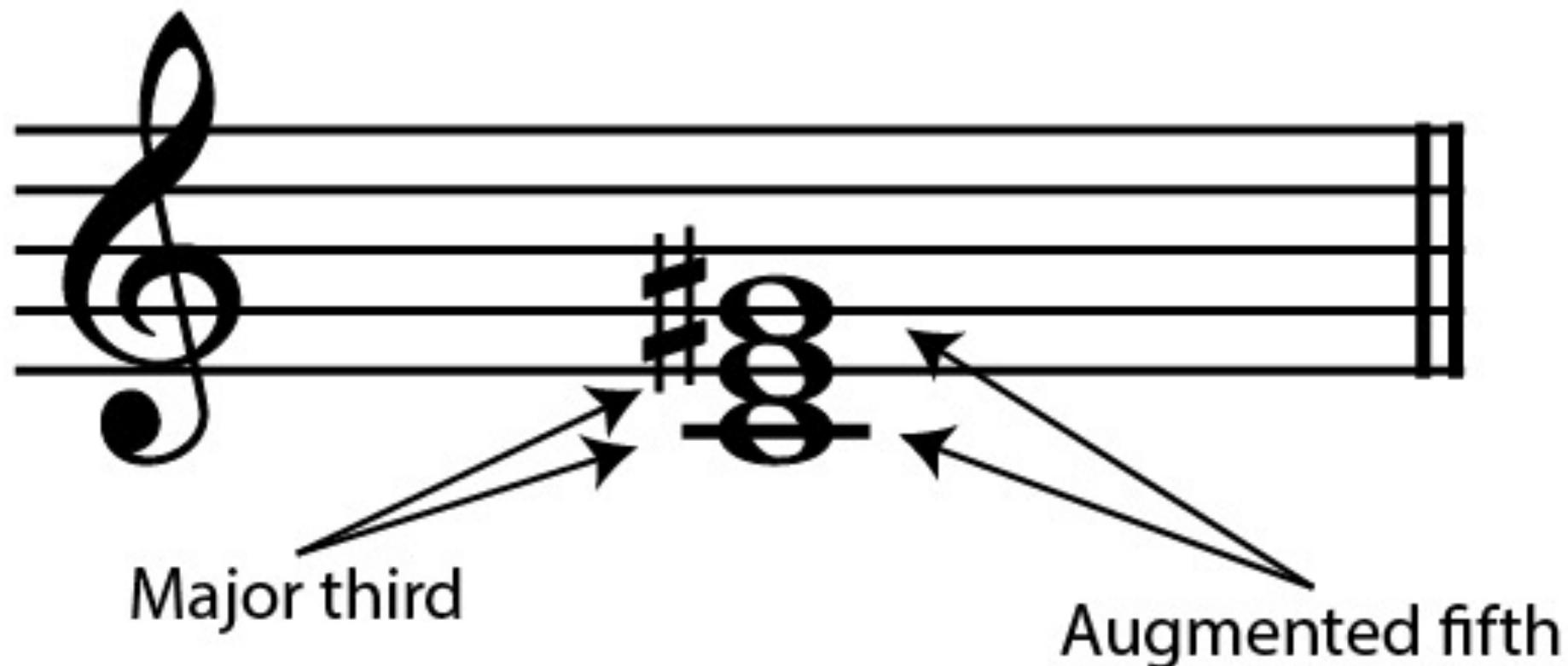
A musical staff with a treble clef. It shows three chords: d min (two black notes), e min (three black notes), and a min (three black notes). Red ovals highlight the second and third chords. Below the staff, Roman numerals indicate the chord functions: II, III, and VI. Below these, lowercase Roman numerals identify the chords as d min, e min, and a min respectively.

# Quality: Diminished Triads



b dim

# Quality: Augmented Triads



A musical staff with a treble clef. The notes C, E, and G are shown. The note E is circled in red, and below it is the Roman numeral III<sup>+</sup>. The label "Caug" is at the bottom.

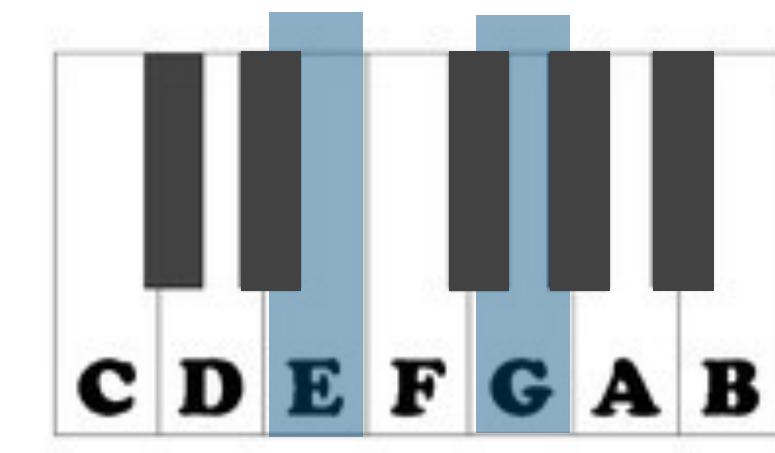
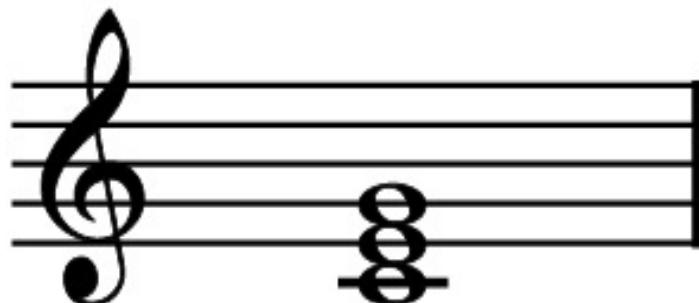
III<sup>+</sup>

Caug

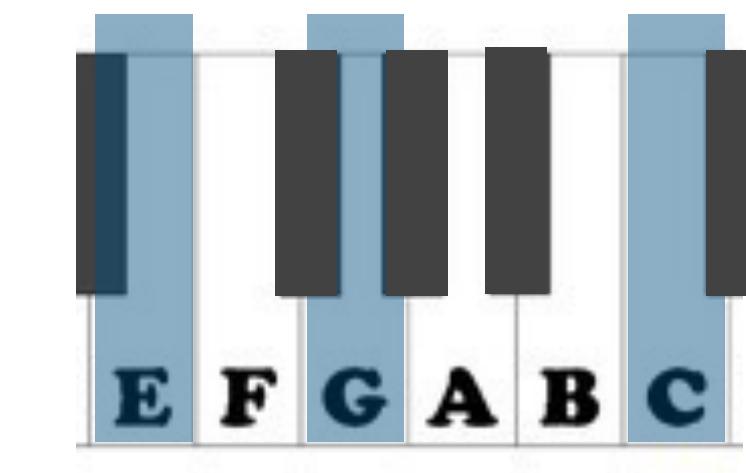
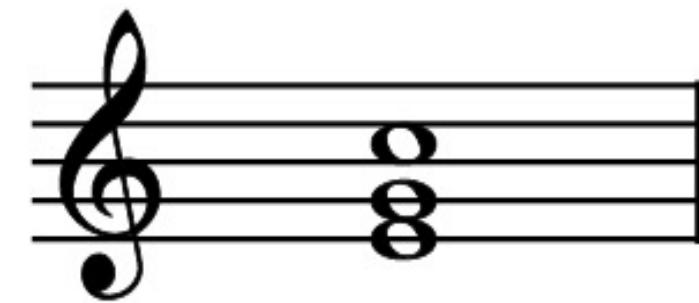
# Triadic Inversions



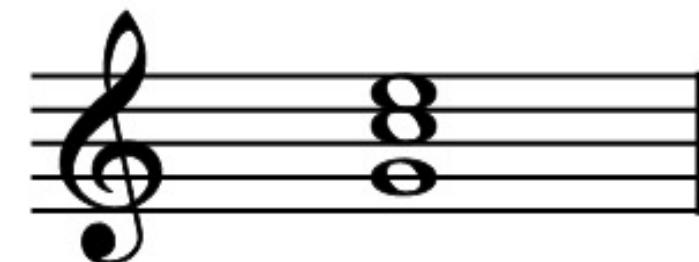
**Root position**



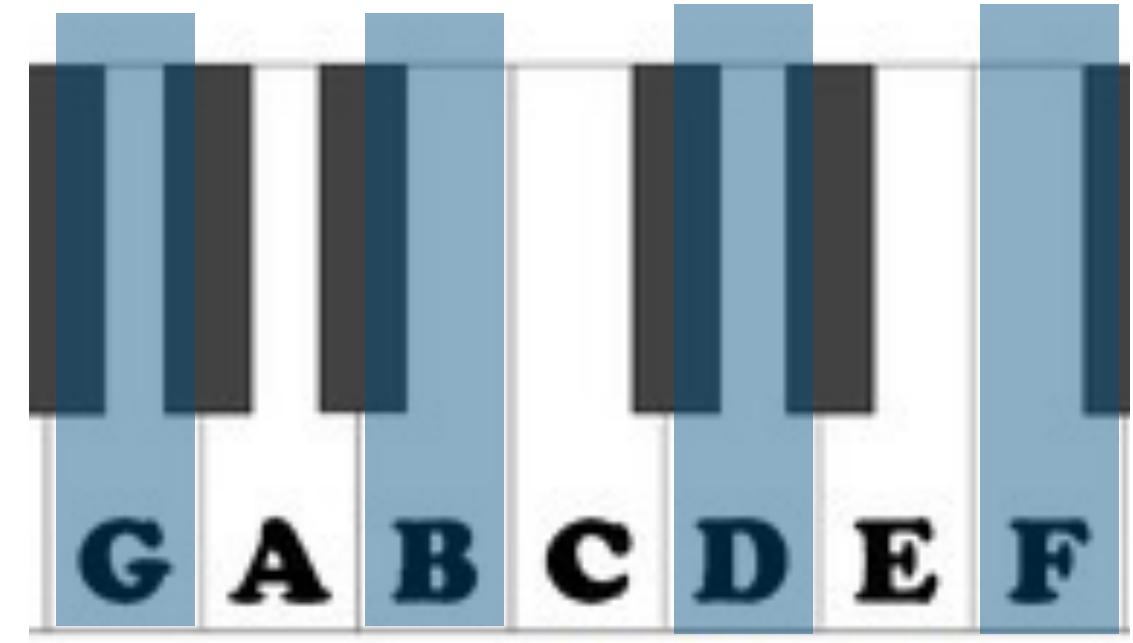
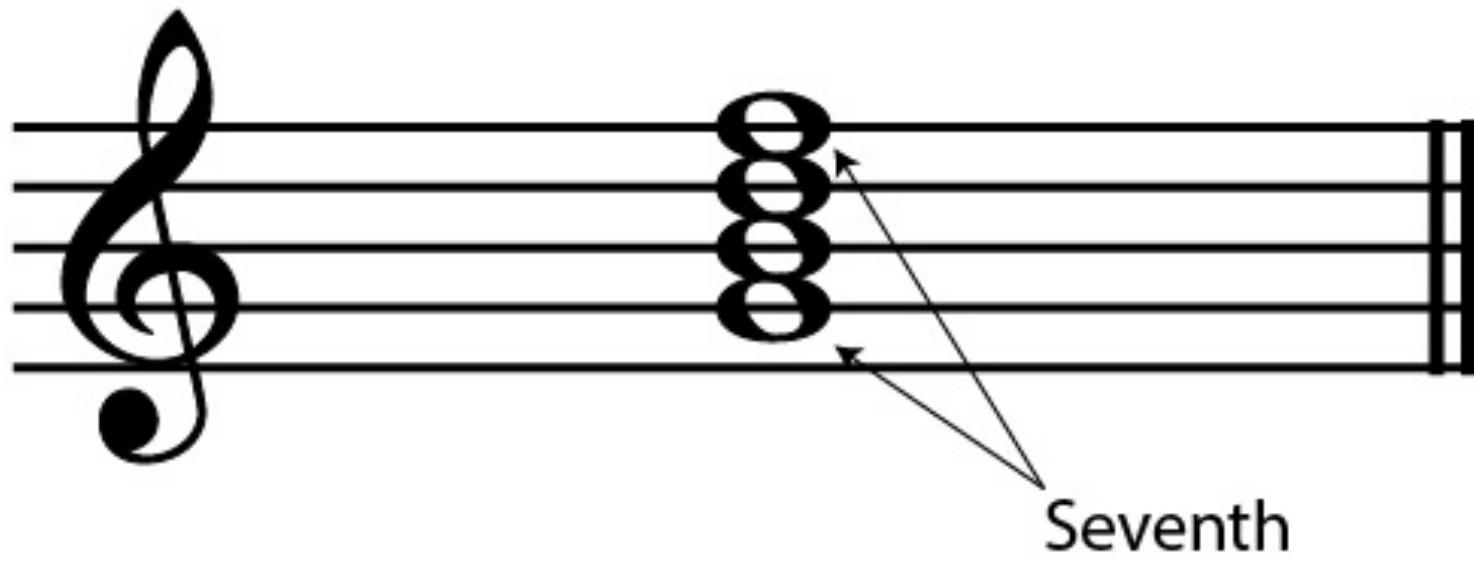
**First Inversions**



**Second Inversions**



# Seventh Chords



## Dominant Seventh Chords

A musical staff with a treble clef. Above the staff, the label "G7" is shown. Below the staff, two arrows point to the notes of a G7 chord: one arrow points to the top note of a stack of three black circles (labeled "Major triad"), and another arrow points to the bottom note of the same stack (labeled "Minor seventh"). The staff itself shows a sequence of eighth notes.

G<sup>7</sup>

Major triad    Minor seventh

G<sup>7</sup>

v<sup>7</sup>

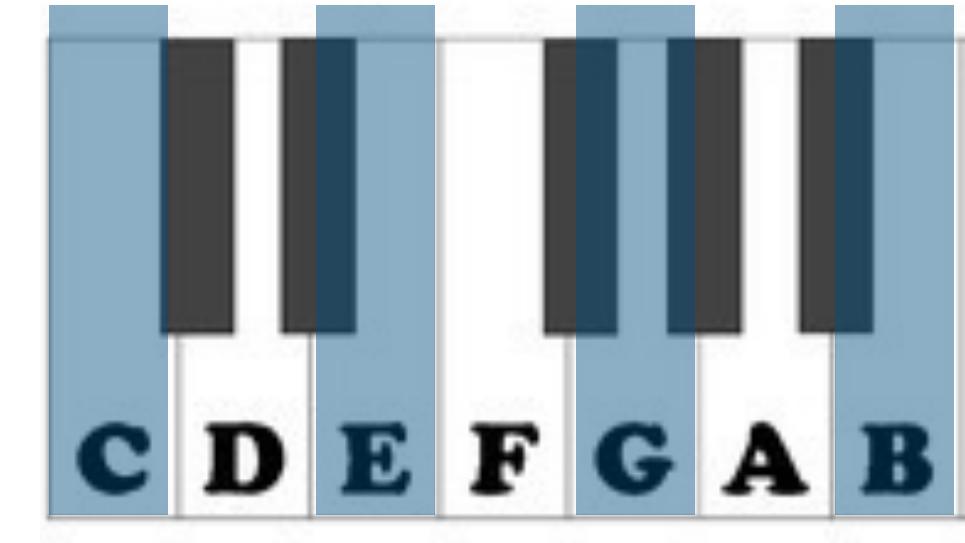
# Seventh Chords

## Major Seventh Chord

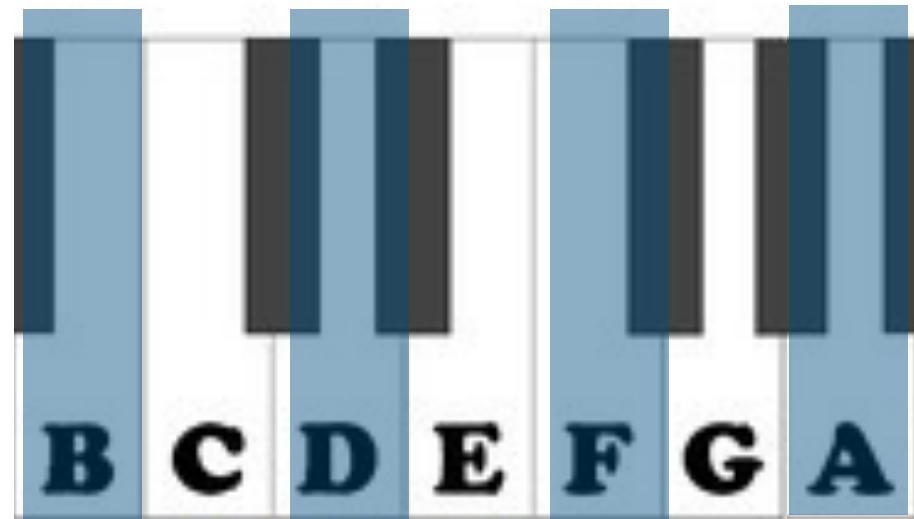
A musical staff in G clef shows three chords: CMaj<sup>7</sup>, CMaj<sup>7</sup>, and FMaj<sup>7</sup>. The first CMaj<sup>7</sup> chord is analyzed with arrows pointing from the root (C) and the seventh (B) to the label "Major triad" and "Major seventh" respectively. The second CMaj<sup>7</sup> chord is labeled I<sup>7</sup>. The FMaj<sup>7</sup> chord is labeled IV<sup>7</sup>.

## Minor Seventh Chord

A musical staff in G clef shows three chords: Dm<sup>7</sup>, Em<sup>7</sup>, and Am<sup>7</sup>. The first Dm<sup>7</sup> chord is analyzed with arrows pointing from the root (D) and the seventh (B) to the label "Minor triad" and "Minor seventh" respectively. The second Dm<sup>7</sup> chord is labeled ii<sup>7</sup>. The Em<sup>7</sup> chord is labeled iii<sup>7</sup>. The Am<sup>7</sup> chord is labeled vi<sup>7</sup>.



# Seventh Chords



## Half-diminished Seventh Chord

Bm<sup>7(b5)</sup>

Diminished triad    Minor seventh

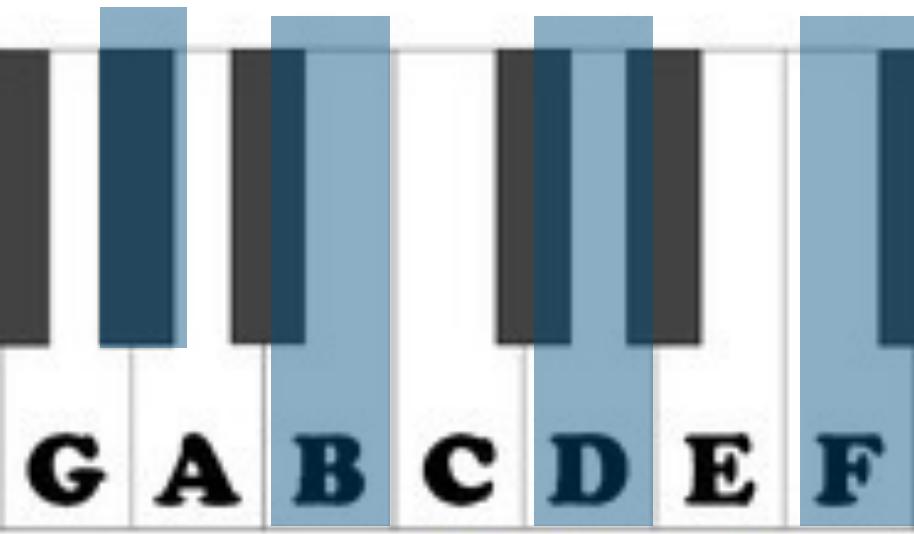
vii<sup>°</sup>

## Diminished Seventh Chord

G<sup>#</sup>dim<sup>7</sup>

Diminished triad    Diminished seventh

vii<sup>°</sup>



# Seventh Chords - Summary

Chord	Triad type	Seventh interval	Chord symbol		
Dominant seventh	Major	Minor seventh	C <sup>7</sup>		
Major seventh	Major	Major seventh	CMaj <sup>7</sup>	CMa <sup>7</sup>	C <sup>Δ</sup>
Minor seventh	Minor	Minor seventh	Cm <sup>7</sup>	C <sup>-7</sup>	Cmin <sup>7</sup>
Half-diminished seventh	Diminished	Minor seventh	Cm7 <sup>(b5)</sup>	C <sup>ø</sup>	
Diminished seventh	Diminished	Diminished seventh	Cdim7	C <sup>ø7</sup>	



**G<sup>7</sup>**

Major triad    Minor seventh



**CMaj<sup>7</sup>**

Major triad    Major seventh



**Dm<sup>7</sup>**

Minor triad    Minor seventh

**Bm7(b5)**

Diminished triad    Minor seventh

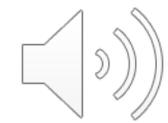
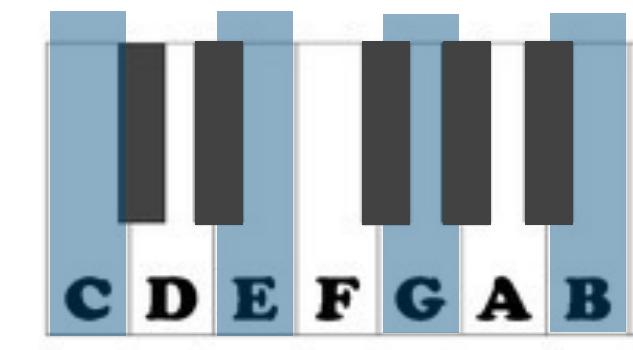
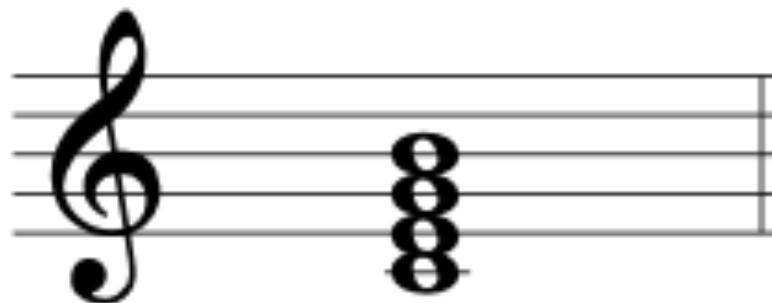


**G#dim<sup>7</sup>**

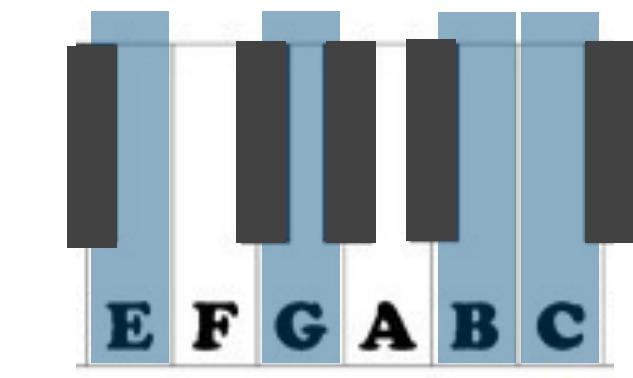
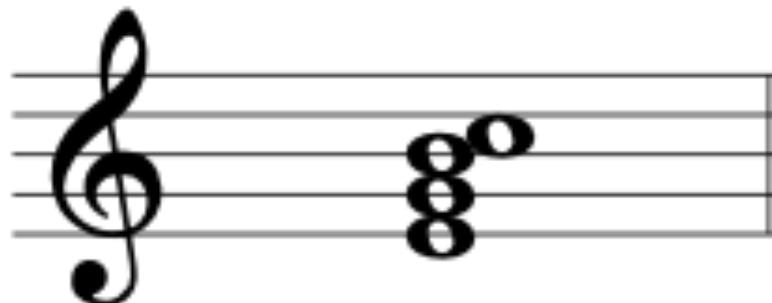
Diminished triad    Diminished seventh

# Seventh Inversions

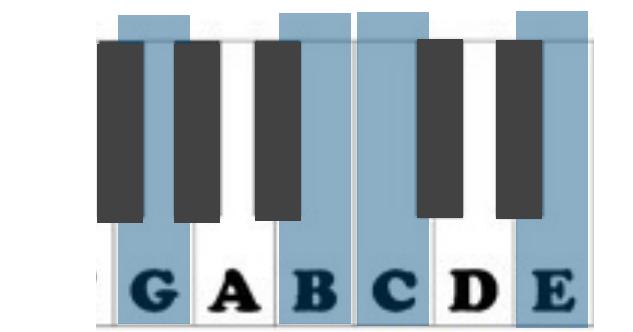
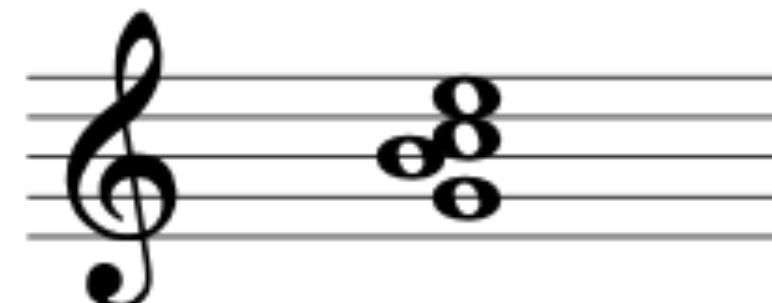
**Root position**



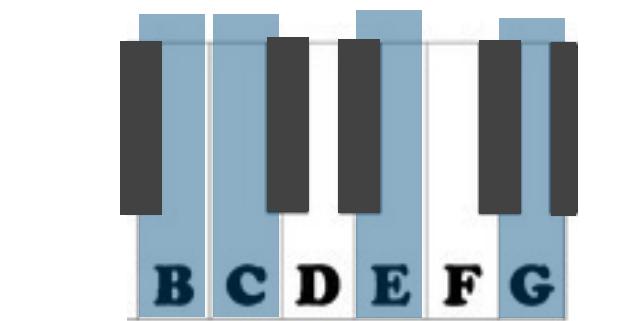
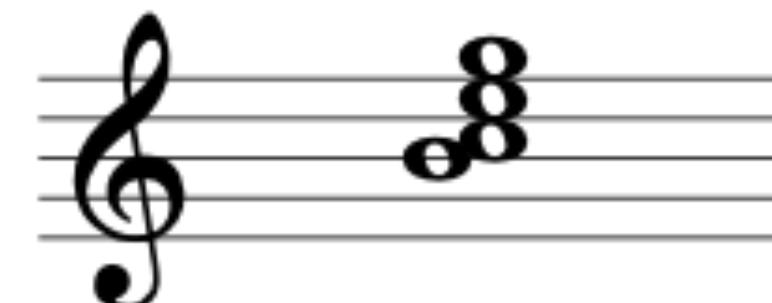
**First Inversion**



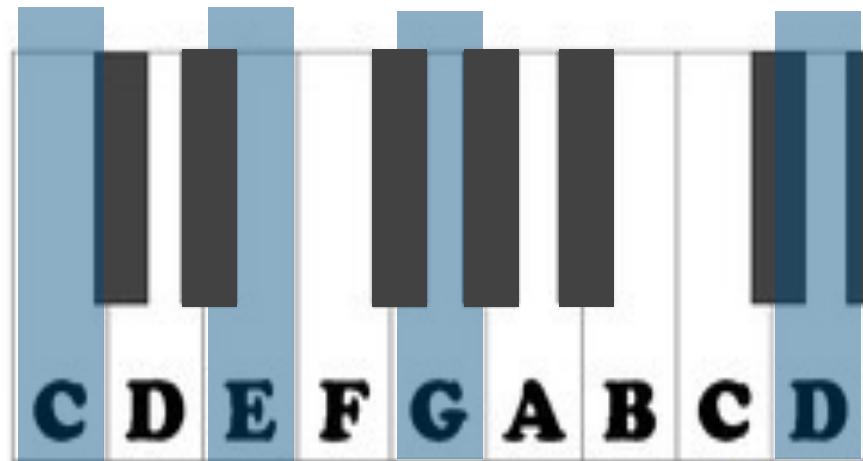
**Second Inversion**



**Third Inversion**

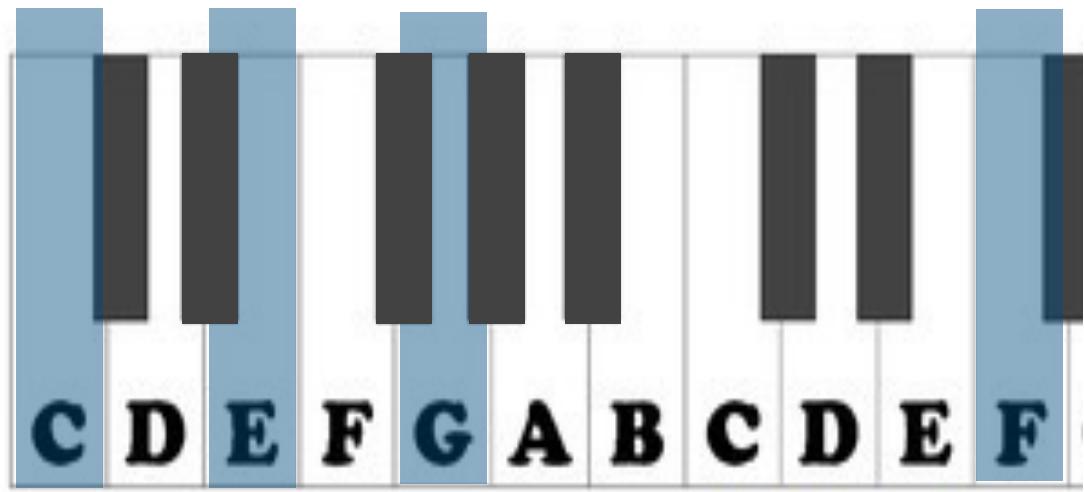
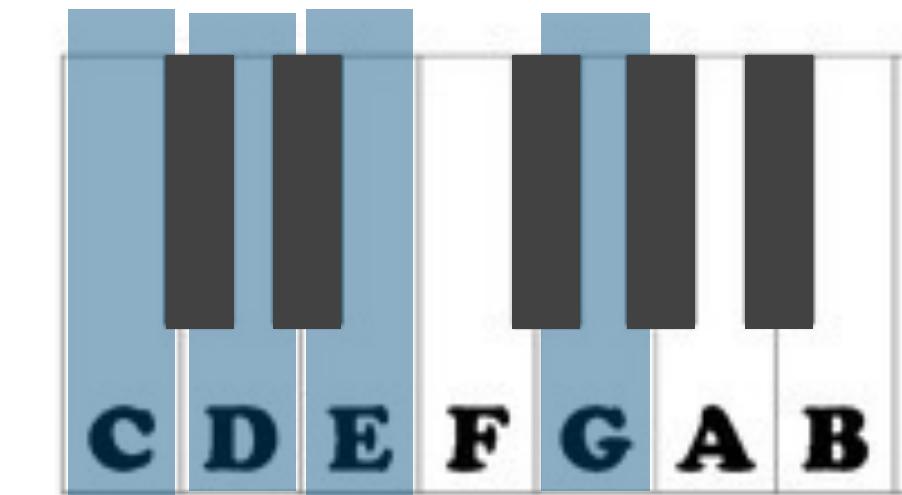


# Other Added Notes/Extensions



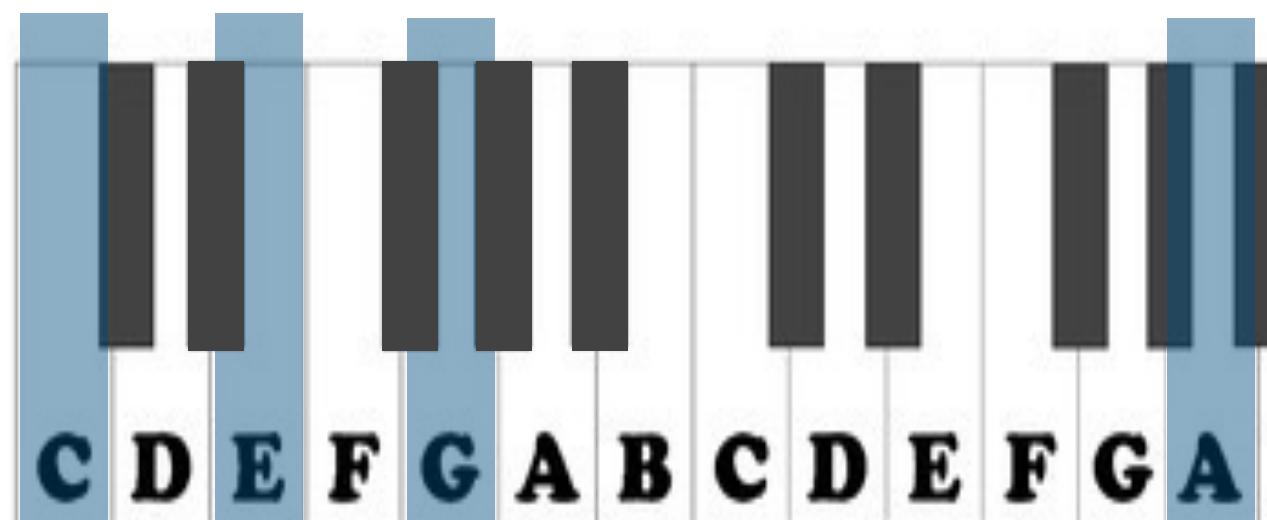
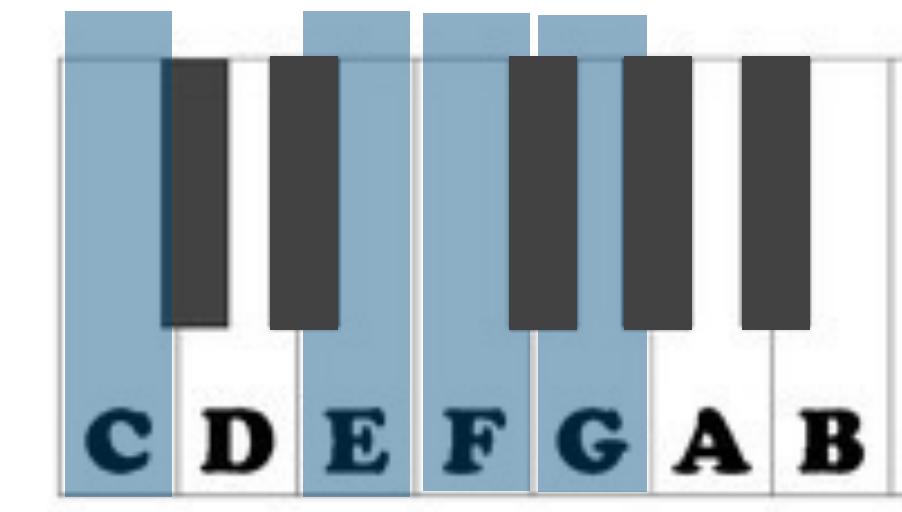
add9

Musical notation for an add9 chord. It consists of a treble clef followed by two eighth notes on the second and third lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



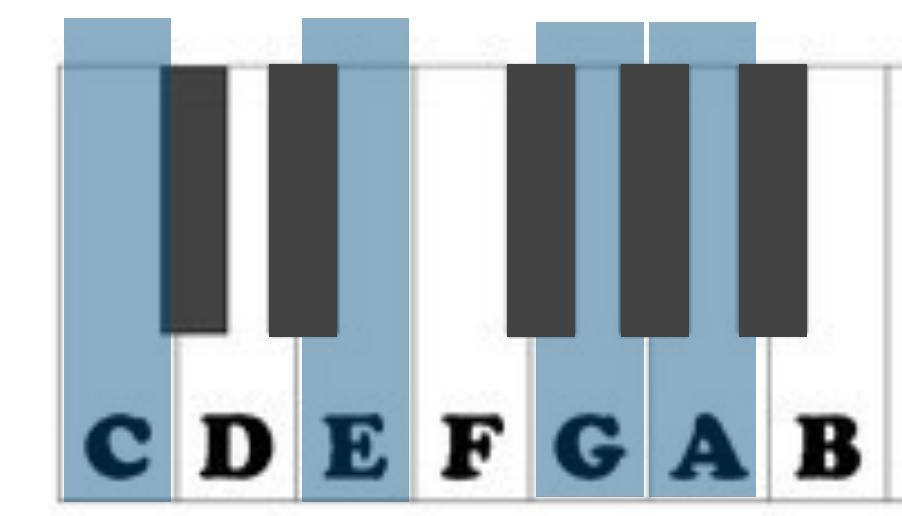
add11

Musical notation for an add11 chord. It consists of a treble clef followed by three eighth notes on the second, third, and fourth lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



add13

Musical notation for an add13 chord. It consists of a treble clef followed by four eighth notes on the second, third, fourth, and fifth lines of the staff. Two small speaker icons are positioned below the staff, one on each side of the notes.



# **Chord Labels**

# What Information Different Labels Contain

- ▶ **Roman numerals**

- Scale degree + quality (major, minor, diminished, etc.)
- Indicate if any notes are added (7, 9, etc.)
- *Explicitly linked to key*

I  
in C major

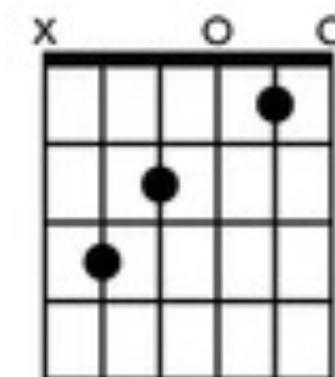
- ▶ **Chord Symbols**

- Root + quality (major, minor, diminished, etc.)
- Indicate if any notes are added (7, 9, etc.)
- *Independent of key*

C  
or  
**Cmaj**

- ▶ **Tabulature**

- Denotes fingering on guitar fretboard
- *Independent of root and key*



# Information Different Labels Contain



## 9 Variationen über ein Minuett von Duport

Mozart

The image shows a musical score for '9 Variationen über ein Minuett von Duport' by Mozart. The score consists of four measures of music for two staves. The top staff is in G major (two sharps) and the bottom staff is in D major (one sharp). The time signature is common time (indicated by '4'). The first measure starts with a forte dynamic (F) and contains a single note. The second measure starts with a piano dynamic (P.) and contains a sequence of eighth notes. The third measure starts with a forte dynamic (F) and contains a sequence of eighth notes. The fourth measure starts with a piano dynamic (P.) and contains a sequence of eighth notes. Below the music, there are labels: 'D:' followed by a Roman numeral 'I' under the first measure, 'Dmaj' under the second measure, 'V7' under the third measure, and 'A7' under the fourth measure. Each label is accompanied by a small speaker icon.

Chords can be expressed vertically, horizontally,  
or a combination of the both

# Information Different Labels Contain

## 9 Variationen über ein Minuett von Duport

Mozart

**Non-chord tones**

D:      I                  I                  V<sup>7</sup>                  I

Dmaj      Dmaj      A<sup>7</sup>      Dmaj

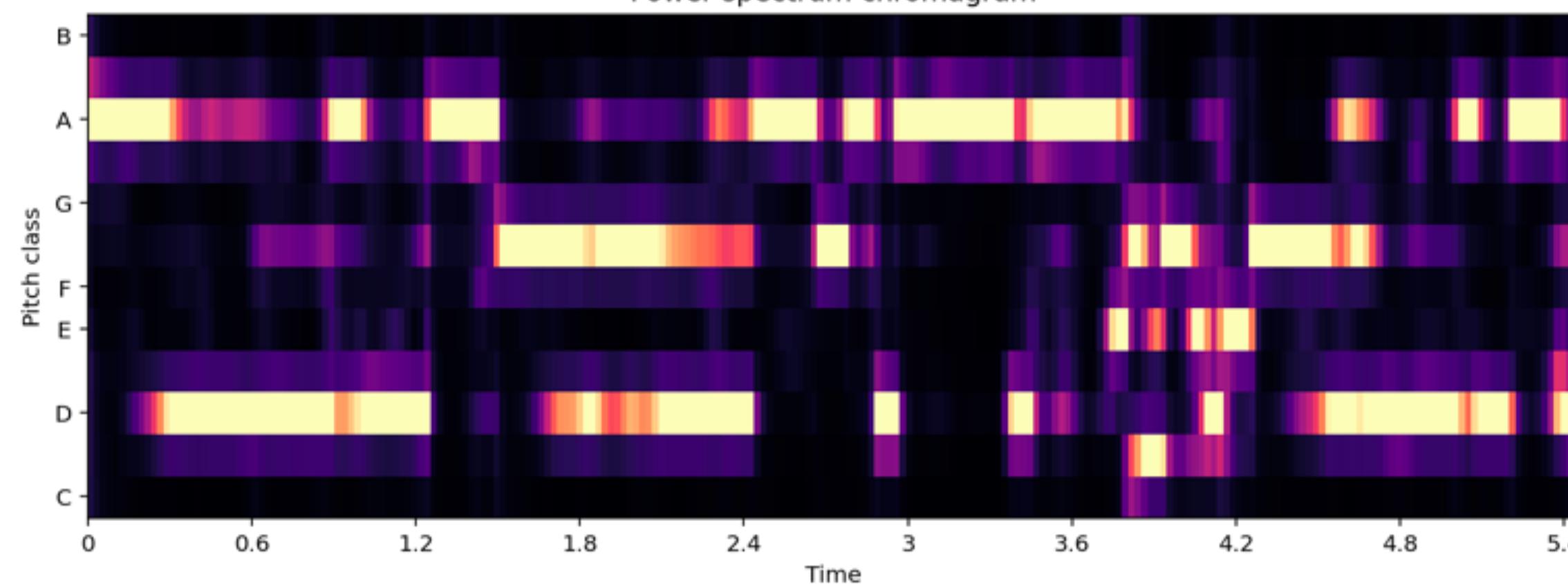
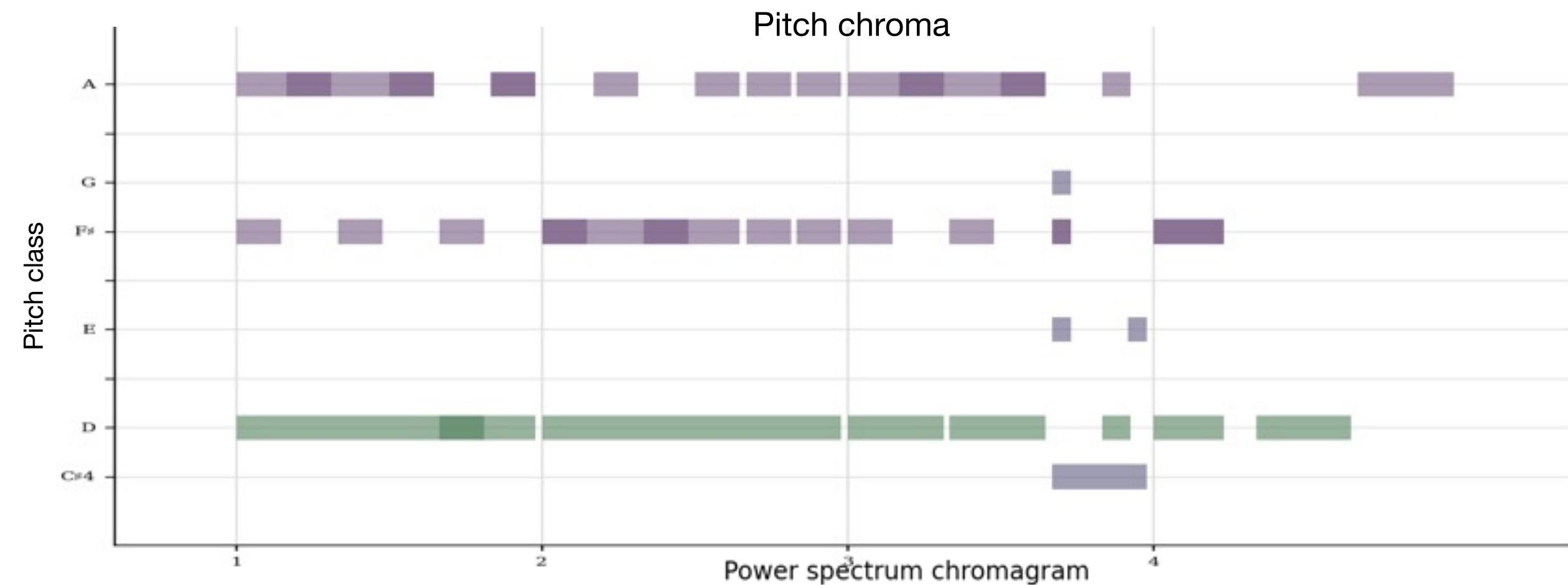
# Information Different Labels Contain

## 9 Variationen über ein Minuett von Duport

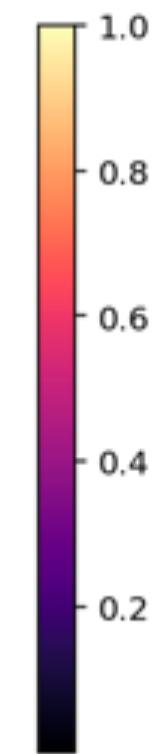
Mozart

**Non-chord tone**

D:	I	I	I <sup>64</sup>	V <sup>7</sup>	I
	I	I	V <sup>7</sup>	I	
<b>Dmaj</b>	<b>Dmaj</b>	<b>A<sup>7</sup></b>		<b>Dmaj</b>	



D: I      I      V<sup>7</sup>      I  
 Dmaj      Dmaj      A<sup>7</sup>      Dmaj



# Pitch Class Content in Chords

## Variations on 'Es war einmal ein alter Mann', WoO 66

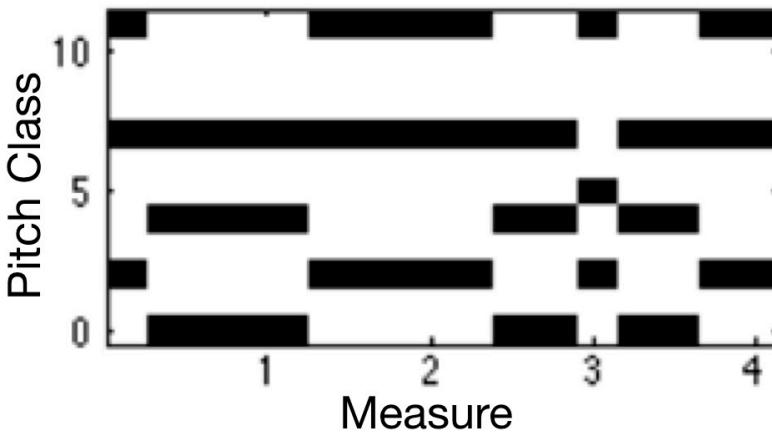
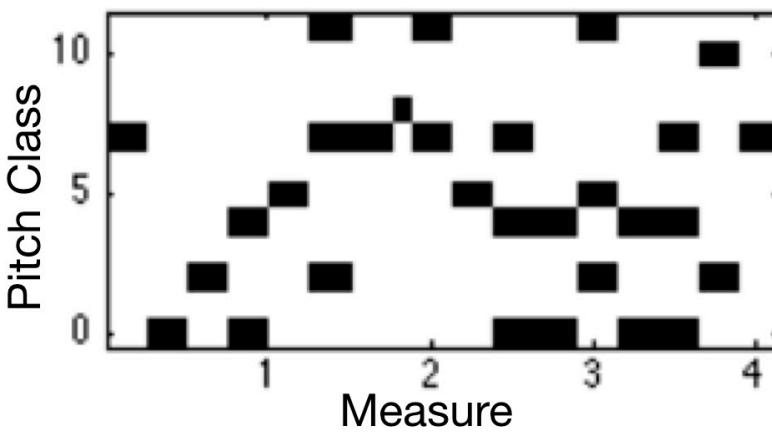
Theme

T

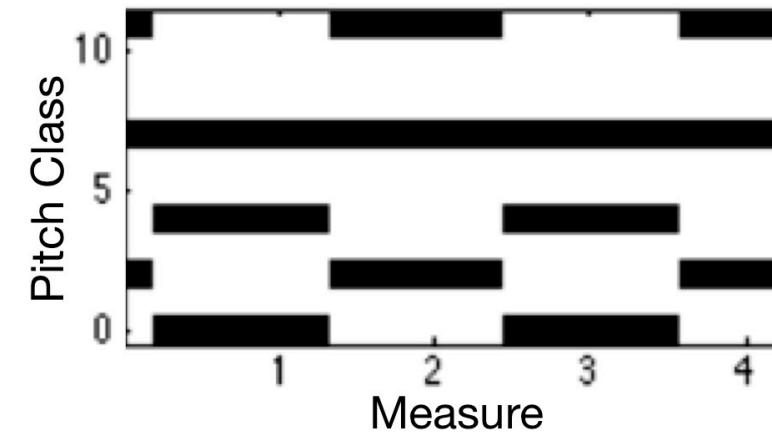
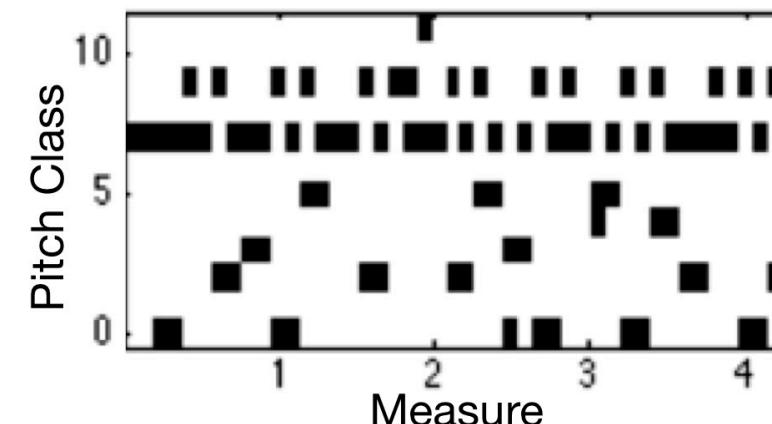
V I V6 I I6 viio6 I V64 V

D

Theme (Symbolic)



Variation (Symbolic)



Variation

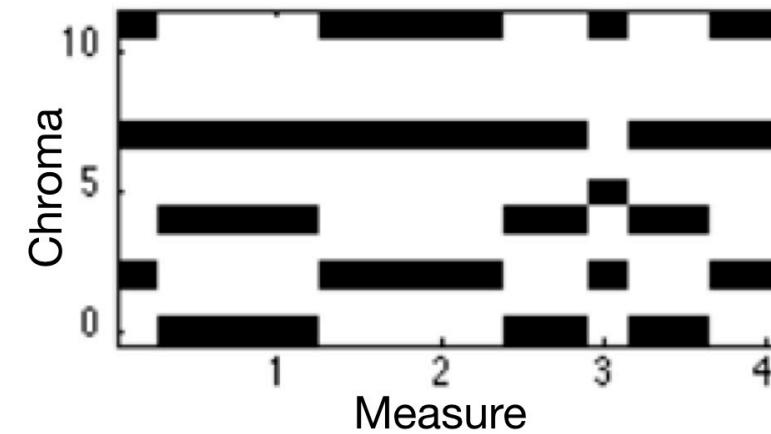
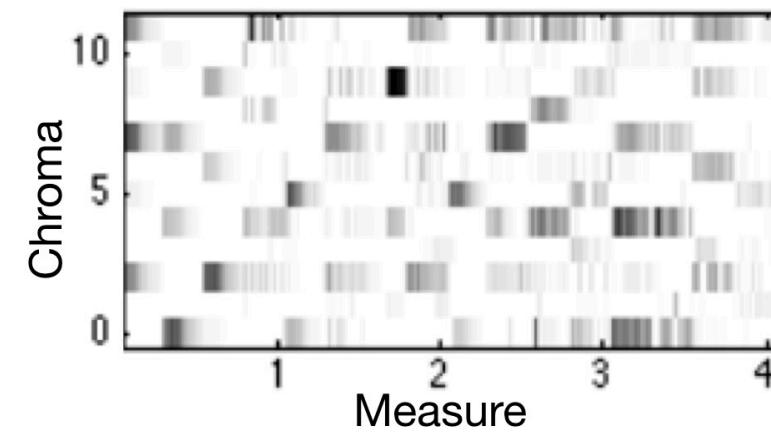
Beethoven

T

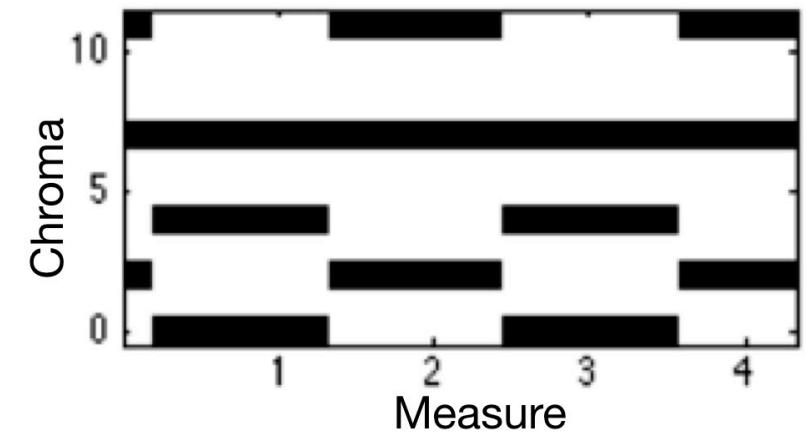
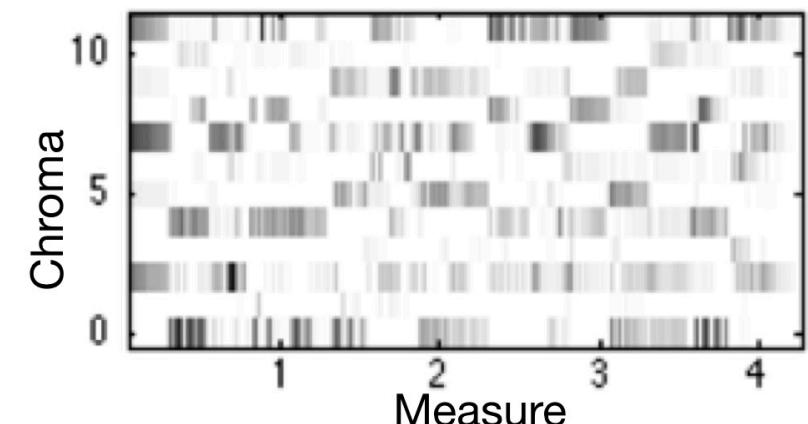
V I V I V I V

D

Theme (Audio)



Variation (Audio)



# **Corpora**

# Some Corpora

	Name	Label Type	(i)	(ii)	(iii)
(i)	Kostka-Payne	Chord tones		<pre> Key 0 18333 3 1 Key 17499 26666 1 0 Key 24999 37499 0 0 Key 35833 46666 3 1 Chord 0 416 3 Chord 416 833 8 Chord 833 1666 3 Chord 1666 2499 4 Chord 2499 3333 3 Chord 3333 4166 8 Chord 4166 4999 3 </pre>	<pre> !!!OTL: Embraceable You !!!COM: Gershwin, George !!!ODT: 1928 **jazz *&gt;[A,B,A2,C] *&gt;A *M4/4 *G: 1G:maj7 = 1B-o7 = 1A:min7 </pre>
(ii)	iRealB	Chord symbols		<pre> % RWC-MDB-C-2001 No.2 % Mozart: Symphony No.40 in g minor, 1st Movement @K=g @M=2/2 % key=g-minor, meter=2/2 % bars 1- (theme I) g:   : i   i   i   i   ii-7'''   ii-7'''   V7'   V7   i   !V9'''   i'   !V9'''   i'   {v: ii-7   !V-9''   I! 1/2!V9'''' 1/2!V9''''/I   I 1/2!V9'''' 1/2!V9''''   I 1/2!V9'''' 1/2!V9''''   I !V9''''/I I !V9''''/I   I} V3!7''   i V'   i   i   iv7'   iv7={III: ii7   V7   V7   </pre>	
(iii)	Beatles	Chord symbols			
(iv)	Real World Computing (RWC)	Roman numerals		<pre> # title: I Don't mind # artist: James Brown # metre: 6/8 # tonic: C </pre>	
(v)	Billboard	Chord symbols		<pre> 0.0 silence 7.3469387e-2 A, intro,   A:min   A:min   C:maj   C:maj   8.714013605   A:min   A:min   C:maj   C:maj   15.611995464   A:min   A:min   C:maj   C:maj   22.346394557 B, verse,   A:min   A:min   C:maj   C:maj   29.219433106   A:min   A:min   C:maj   C:maj   36.279501133   F:maj   F:maj   D:maj   D:maj   43.053922902   G:maj   G:maj   C:maj   C:maj   </pre>	

# Some Datasets

	Name	Label Type
(i)	Theme and Variations with Roman Numeral Encoding (TAVERN)	Roman numerals
(ii)	(ABC)	Chord symbols
(iii)	(BPH-FS)	Chord symbols

(i) !!!COM: Mozart  
 !!!OTL: 12 Variations on "Ah Vous dirais-je, Maman"  
 !!!Variation: Theme a  
 \*\*function \*\*harm \*\*kern \*\*kern  
 \* \* \*clefF4 \*clefG2  
 \* \* \*k[] \*k[]  
 \*M4/4 \*M4/4 \*M2/4 \*M2/4  
 \*C: \*C: \*C: \*C:  
 =1 =1 =1 =1  
 4T 4I 4C 4cc  
 4T 4I 4c 4cc  
 =2 =2 =2 =2  
 4T 4Ib 4e 4gg  
 4T 4Ib 4c 4gg  
 =3 =3 =3 =3  
 4T 4IV 4f 4aa  
 4T 4IV 4c 4aa  
 =4 =4 =4 =4  
 4T 4Ib 4e 4gg  
 4T 4Ib 4c 4gg  
 =5 =5 =5 =5  
 4T 4ii 4d 4ff  
 4T 4viio 4B 4ff  
 =6 =6 =6 =6  
 4T 4I 4c 4ee  
 4T 4vi 4A 4ee  
 =7 =7 =7 =7  
 4P 4iib 4F 4dd  
 4D 4V 4G (8.ddL  
 . . . 16eeJk  
 =8 =8 =8 =8  
 2T 2I 2C 2cc)  
 \*- \*- \*- \*-

(ii) -1 8 f 1 m 0 i  
 8 16 f 5 D7 1 V65  
 16 20 f 1 m 0 i  
 20 24 f 5 D7 2 V43  
 24 26 f 1 m 1 i6  
 26 28 f 2 d 1 ii-6  
 28 31 f 5 D7 0 V  
 31 40 A- 3 m 0 iii

(iii)

chord	measure	beat	totbeat	timesig	op	no	mov	length	global_key	local_key	numeral	figbass	changes	phraseend
.Eb.I	1	1	1	2/4	127	12	1	2.5	Eb	I	I			FALSE
V43	2	1.5	3.5	2/4	127	12	1	1.5	Eb	I	V	43		FALSE
I	3	1	5	2/4	127	12	1	2.5	Eb	I	I			FALSE
V2	4	1.5	7.5	2/4	127	12	1	1.5	Eb	I	V	2		FALSE
I6	5	1	9	2/4	127	12	1	1	Eb	I	I	6		FALSE
vi	5	2	10	2/4	127	12	1	1	Eb	I	vi			FALSE
IV\\\\\\	6	1	11	2/4	127	12	1	2	Eb	I	IV			TRUE
IV	7	1	13	3/4	127	12	1	1	Eb	I	IV			FALSE
ii6	7	2	14	3/4	127	12	1	1	Eb	I	ii	6		FALSE
V2	7	3	15	3/4	127	12	1	1	Eb	I	V	2		FALSE
I6	8	1	16	3/4	127	12	1	2	Eb	I	I	6		FALSE
vi64	8	3	18	3/4	127	12	1	1	Eb	I	vi	64		FALSE
ii7	9	1	19	3/4	127	12	1	2	Eb	I	ii	7		FALSE
V43	9	3	21	3/4	127	12	1	1	Eb	I	V	43		FALSE
I6(7)	10	1	22	3/4	127	12	1	1	Eb	I	I	6	7	FALSE

# **Higher-Level Organization of Harmonic Material**

# Some Standard Pop Music Chord Progressions

**Blues**

C - F - G  
I - IV - V



A musical staff in G clef and common time. It shows three chords: C major (G, B, D), F major (F, A, C), and G major (G, B, D). The bass line consists of open circles on the first and third strings.

**Axis**

C - G - a - F  
I - V - vi - IV



A musical staff in G clef and common time. It shows four chords: C major (G, B, D), G major (G, B, D), A minor (A, C, E), and F major (F, A, C). The bass line consists of open circles on the first and third strings.

50's  
Doo wop

C - a - F - G  
I - vi - IV - V



A musical staff in G clef and common time. It shows four chords: C major (G, B, D), A minor (A, C, E), F major (F, A, C), and G major (G, B, D). The bass line consists of open circles on the first and third strings.

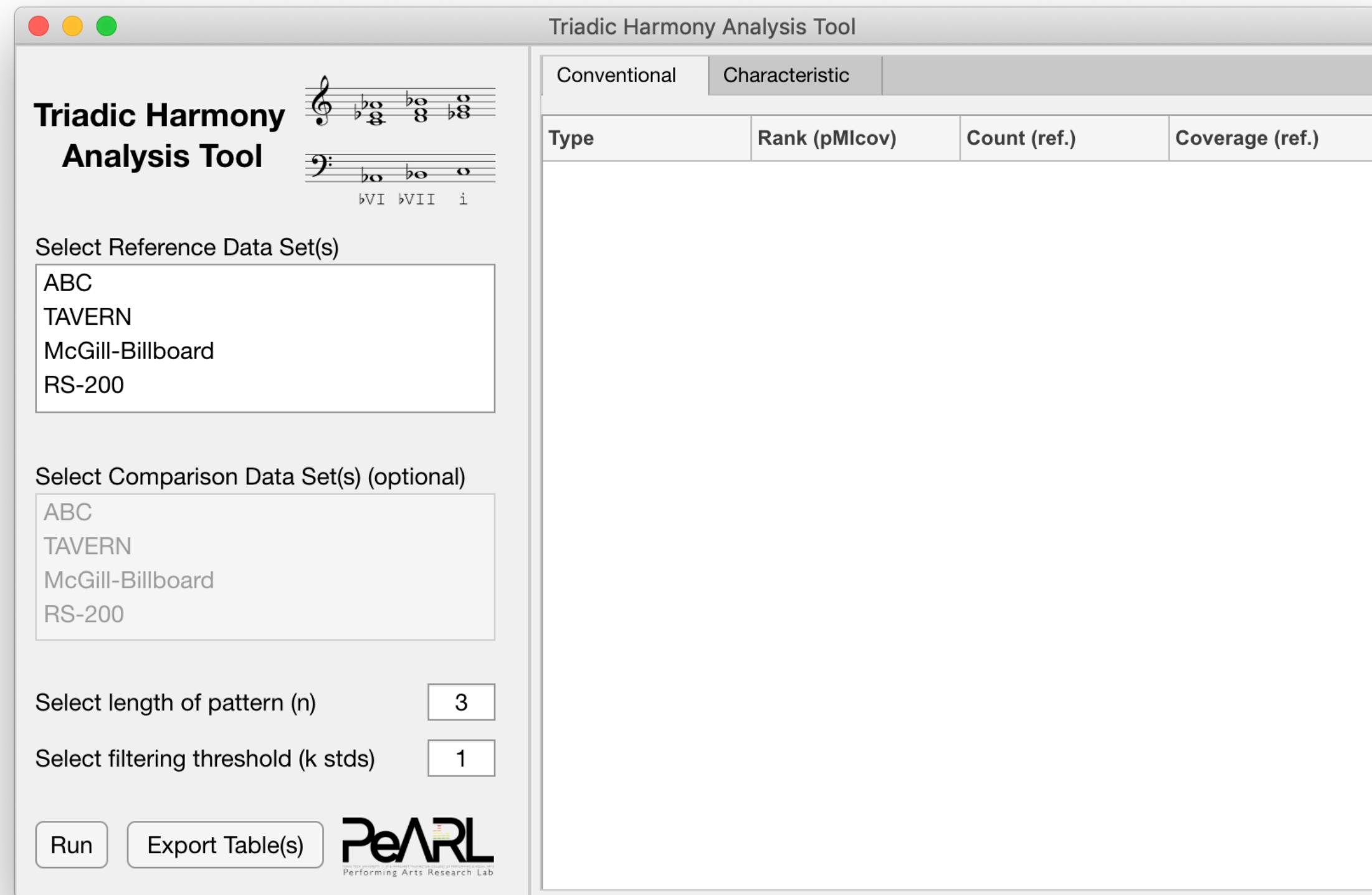


4 Chords  
(2011)



# Chord Progressions in Corpora

Sears and Forrest (2001)



# Function

- ▶ **Casual: Certain chords tend to lead to other chords**
  - V-I can give a sense of closure in certain musical styles
    - will get into more details about this later
- ▶ **Formal: Hierarchical model to capture how chords work together to build phrases**
  - Tonic (I) – Pre-dominant (ii or IV) – Dominant (V)

# TAVERN (gettavern.org)

## 12 VARIATIONEN über „Ah vous dirais-je, Maman“

Mozarts Werke.

für das Pianoforte  
von

Serie 21. № 6.

**W. A. M O Z A R T.**

Köch. Verz. № 265.

### TEMA.



# TAVERN (gettavern.org)



# TAVERN (gettavern.org)

Quiz: Matching a variation to a theme

A musical staff in G clef, 3/4 time, and A-flat key signature. The top line consists of eighth notes, and the bottom line consists of sixteenth notes. Several notes are circled in yellow. Below the staff, labels indicate note patterns: 'I/T' under the first measure, 'V7/D' under the second measure, and 'I/D' under the third measure. A large orange box encloses the last two measures.

I/T      V<sup>7</sup>/D      I/D

I/T



Three variations of musical staves, each with a different note pattern and a different key signature. The first variation (G clef, 6/8 time) has labels 'I/T', 'V<sup>65</sup>/T', 'V<sup>7</sup>/T', and 'I/T'. The second variation (G clef, 2/4 time) has labels 'I/T', 'V<sup>7</sup>/D', and 'I/T'. The third variation (G clef, 2/4 time) has labels 'V<sup>7</sup>/D', 'I/D', 'V<sup>7</sup>/D', and 'I/T'. The note patterns in these staves correspond to the circled notes in the staff at the top.

I/T      V<sup>65</sup>/T      V<sup>7</sup>/T      I/T

V<sup>7</sup>/D

I/T      V<sup>7</sup>/D      I/D

V<sup>7</sup>/D      I/T

# Evaluation of Automatic Chord Estimation Algorithms

# MIREX Evaluation Metrics

- 1. Chord root note only**
- 2. Major and minor: N, maj, min**
- 3. Seventh chords: N, maj, min, maj7, min7, 7**
- 4. Major and minor with inversions: N, maj, min, maj/3, min/b3, maj/5, min/5**
- 5. Seventh chords with inversions: N, maj, min, maj7, min7, 7, maj/3, min/b3, maj7/3, min7/b3, 7/3, maj/5, min/5, maj7/5, min7/5, 7/5, maj7/7, min7/b7, 7/b7**

**Labels not independent due to  
overlapping content between labels**

# BEYOND CHORD VOCABULARIES: EXPLOITING PITCH-RELATIONSHIPS IN A CHORD ESTIMATION METRIC

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note name	C	C#	D	D#	E	F	F#	G	G#	A	A#	B
pitch class	0	1	2	3	4	5	6	7	8	9	10	11
C (I)	o	-	-	-	o	-	-	o	-	-	-	-
d (ii)	-	-	o	-	-	o	-	-	-	o	-	-
e (iii)	-	-	-	-	o	-	-	o	-	-	-	o
F (IV)	o	-	-	-	-	o	-	-	-	o	-	-
G(V)	-	-	o	-	-	-	-	o	-	-	-	o
a (vi)	o	-	-	-	o	-	-	-	-	o	-	-
b <sup>o</sup> (vii <sup>o</sup> )	-	-	o	-	-	o	-	-	-	-	-	o

Let  $C$  be the number of predicted notes  $\hat{y}$  in the ground truth correctly identified  $y$

$$C = |y \cap \hat{y}| \quad (1)$$

Let  $I$  be the number of insertions (extra predicted notes) in the estimated chord that are not present in the ground truth.

$$I = |\hat{y} \setminus y| \quad (2)$$

Let  $A$  be the accuracy measurement for each chord estimate, calculated from  $C$  and  $I$  scaled between 0 and 1.

$$A = \frac{C - I + |y|}{2|y|} \quad (3)$$

# Main Takeaways

- ▶ **Chord Labels**
  - **Different types of chord labels (roman numerals, pop chord labels, tablature) contain different types of information with respect to key and chord root**
  - **Chord labels represent which notes or chroma are chord tones versus non-chord tones**
- ▶ **Higher-Level Organization of Harmonic Material**
  - **Chords do not occur in isolation**
- ▶ **Evaluation for Automatic Chord Recognition**
  - **Chord labels are not independent of one another**