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Music Through Math: Analyzing and Composing Scores Mathematically

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Music Through Math: A Set Definition of Notes

Katerina Hall

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University of Montana Conference on Undergraduate Research 2018

Approaching Both Fields from a New Angle

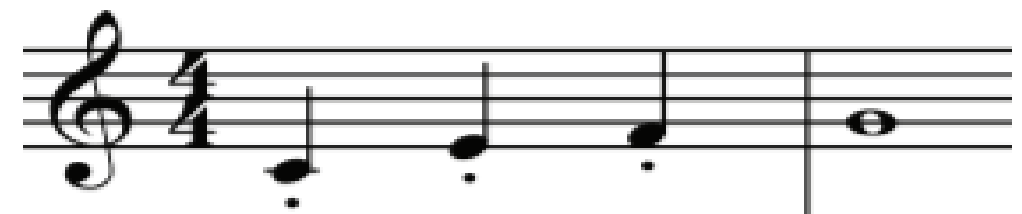
Start with the Music, look at the Math

- From simple nursery rhymes to complicated symphonies, all music can be analyzed with set theory.
- Each note corresponds to a number.
- We group these numbers based on the way the notes are grouped.
 - The first two measures of this song form the set: {0,7,9}.



Start with the Math, look at the Music

- Composers block stymies a great many would-be music writers.
- Overcome such blocks by picking a set and using the numbers to guide the notes.
- Say, we like the numbers 4, 7, 0, and 5.
 - Rearranging these we can produce this set: {0,4,5,7}. A pattern best known as "Oh when the saints..."



Composition Techniques With {0,4,7}

• Transposition: {4,e,8,4}

- Move all pitches in the set up or down by a specific interval



• Retrograde: {0,4,7,0}

- Reversing the order of the elements in a set



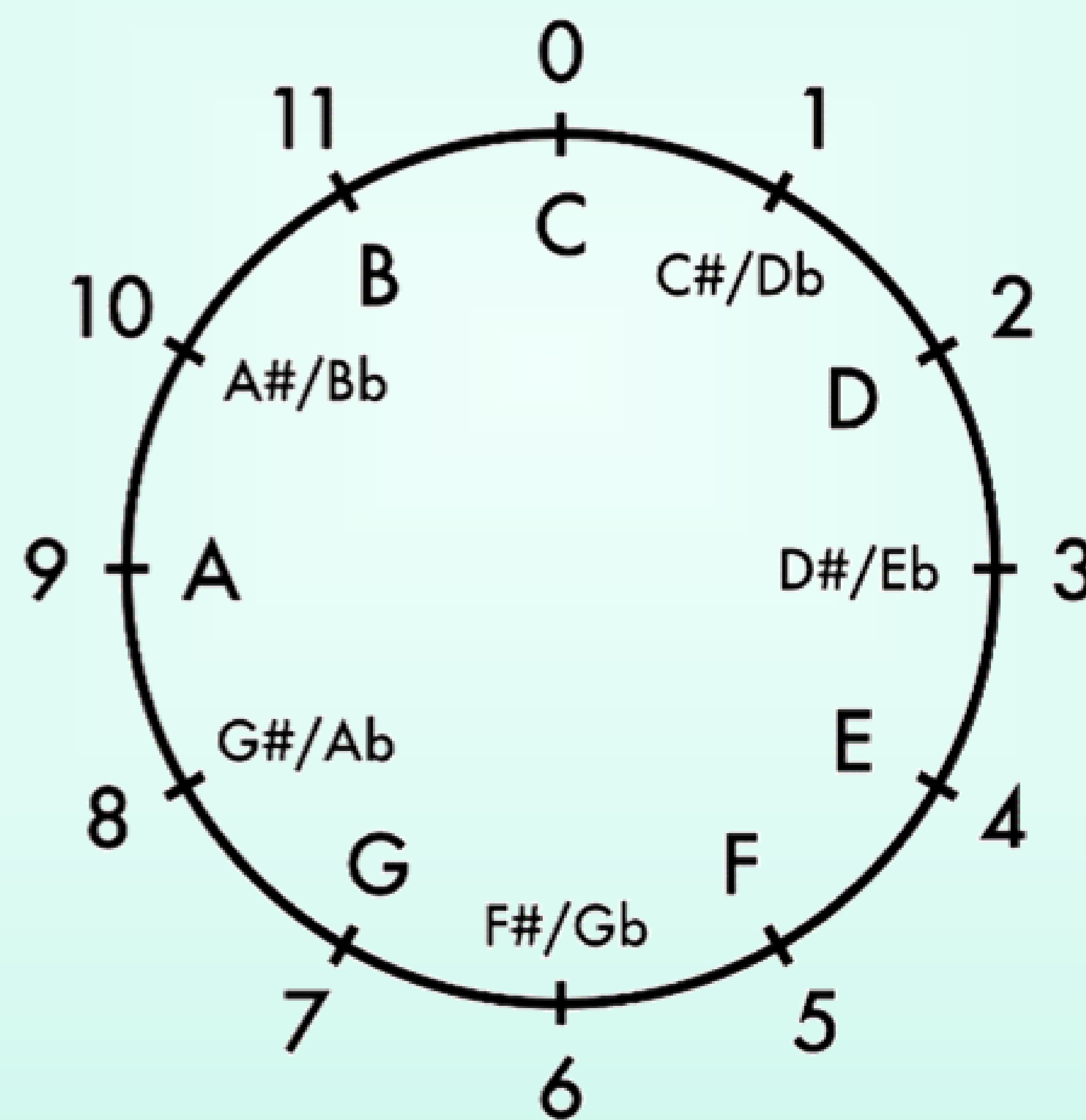
• Inversion: {0,5,8,0}

- A note n half-steps above C is flipped to become n half-steps below C



• Retrograde Inversion: {0,8,5,0}

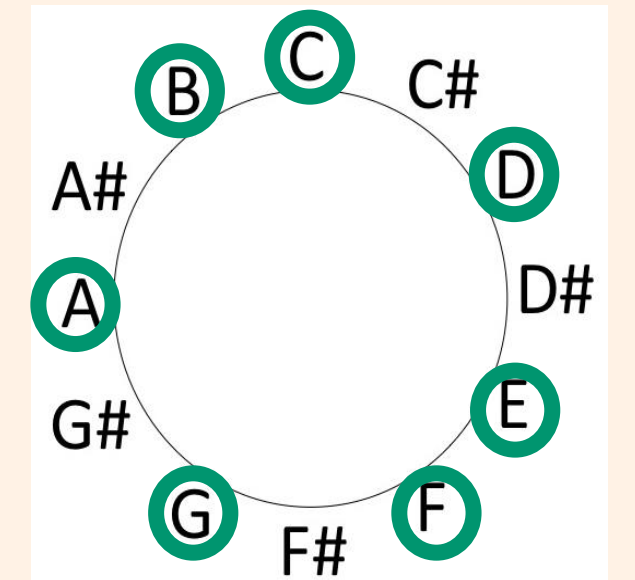
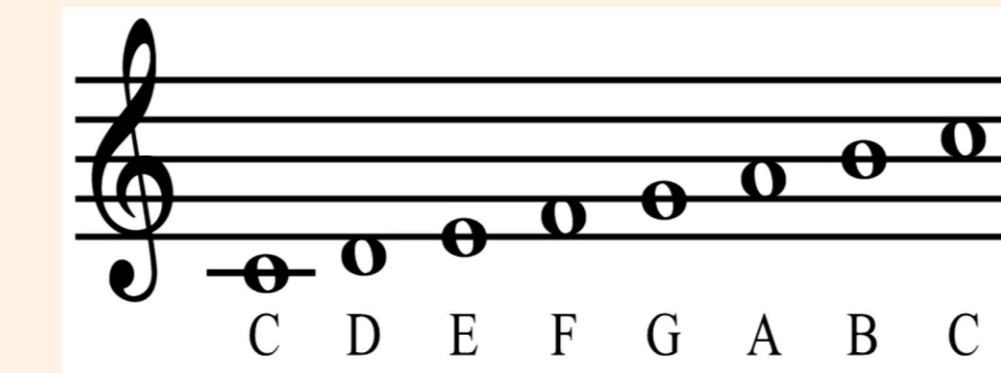
- First invert, then retrograde



Famous Sets

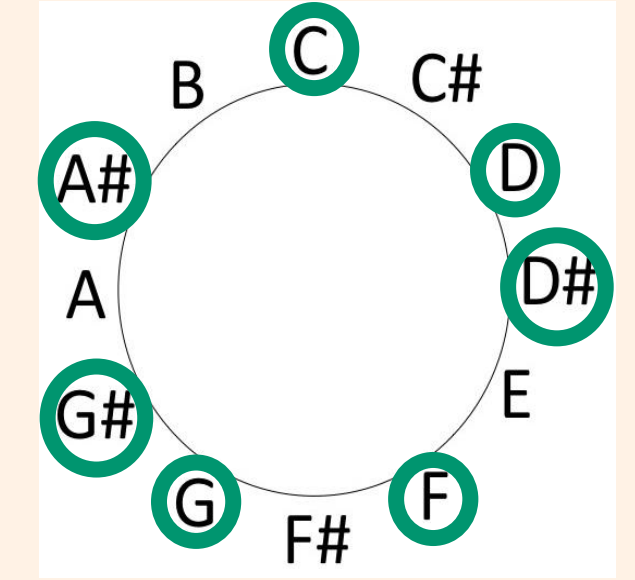
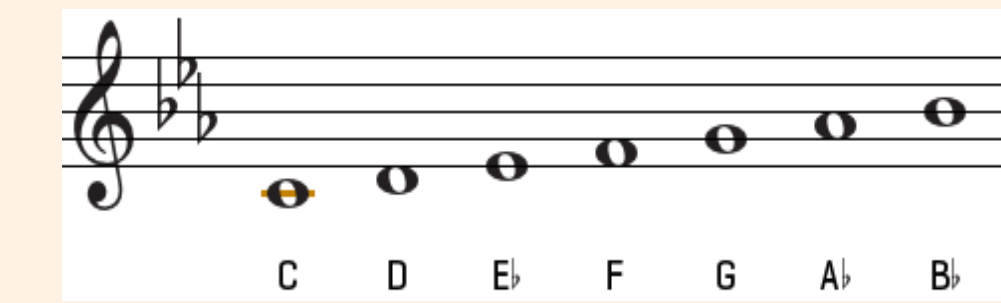
• Major Scale

- {0,2,4,5,7,9,e}
- Diatonic scale



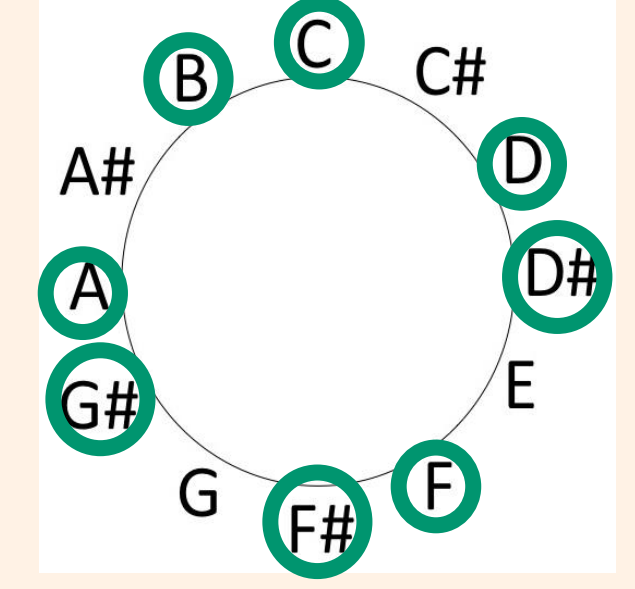
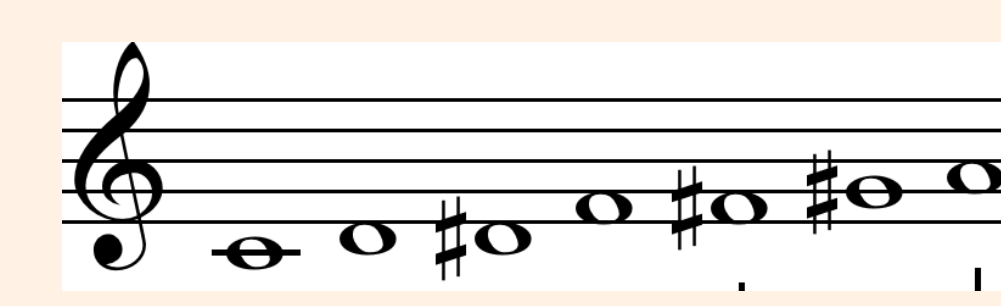
• Minor Scale

- {0,2,3,5,7,8,t}
- Three forms



• Octatonic Scale

- {0,1,3,4,6,7,9,t}
- Jazz chords



Key Definitions

- Pitch:** a note which we hear
- Pitch Class:** the name for a type of pitch regardless of octave displacement
 - The pitch class of C4 and C7 is simply C
 - There are 12 pitch classes in a standard octave, with 12 chromatic notes.
 - Two pitches which sound the same on a standard octave will have the same pitch class ($B\# = C$).
- Modular Congruence:** if two numbers b and c are such that $(b-c)$ is divisible by m , then, b and c are said to be "congruent modulo m " ($b = c \pmod m$).
- Pitch Class Representative:** the integers modulo 12 each represent a pitch class
 - This begins with pitch class $C=0$. All other pitch classes are numbered by counting up half-steps from pitch class C.
- Serialism:** Composition technique using numerical values to manipulate musical elements
- Pitch Class Set:** a list of pitch class representatives.

Second Viennese School

Chromatic - Expressionism
Atonality
Music with no tonal center



Arnold Schoenberg (1874–1951)

Other Post-Tonal Composers:
Claude Debussy
Béla Bartók
Leoš Janáček



Anton Webern (1883–1945)



Alban Berg (1885–1935)

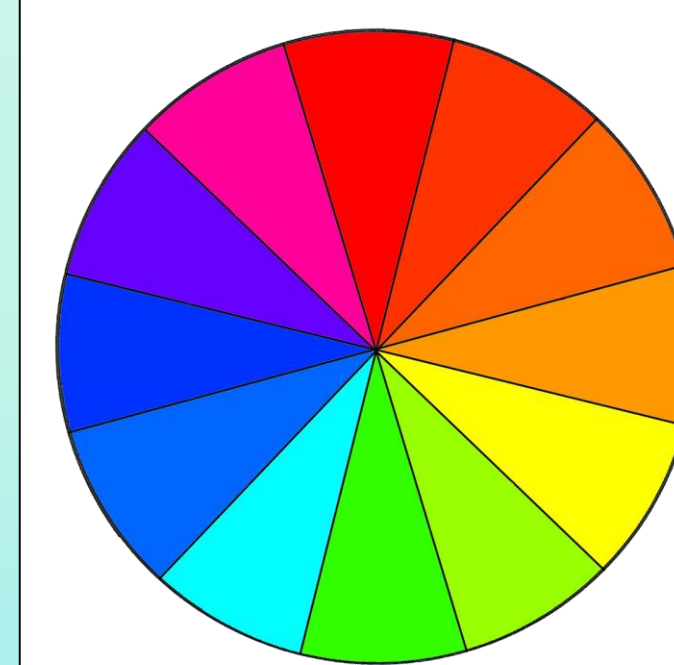
Twelve tone row:
All twelve pitch classes sound before any are repeated.

Katerina Set

- | | |
|---|---|
| K | e |
| A | 1 |
| T | 7 |
| E | 5 |
| R | 6 |
| I | t |
| N | 2 |
| A | 1 |
- {e,1,7,5,6,t,2,1}
 - A variety of names was tried first
 - It appears thus on a single staff.
 - Ten bars generated from this set appear below.



Chromatically Colorful Set

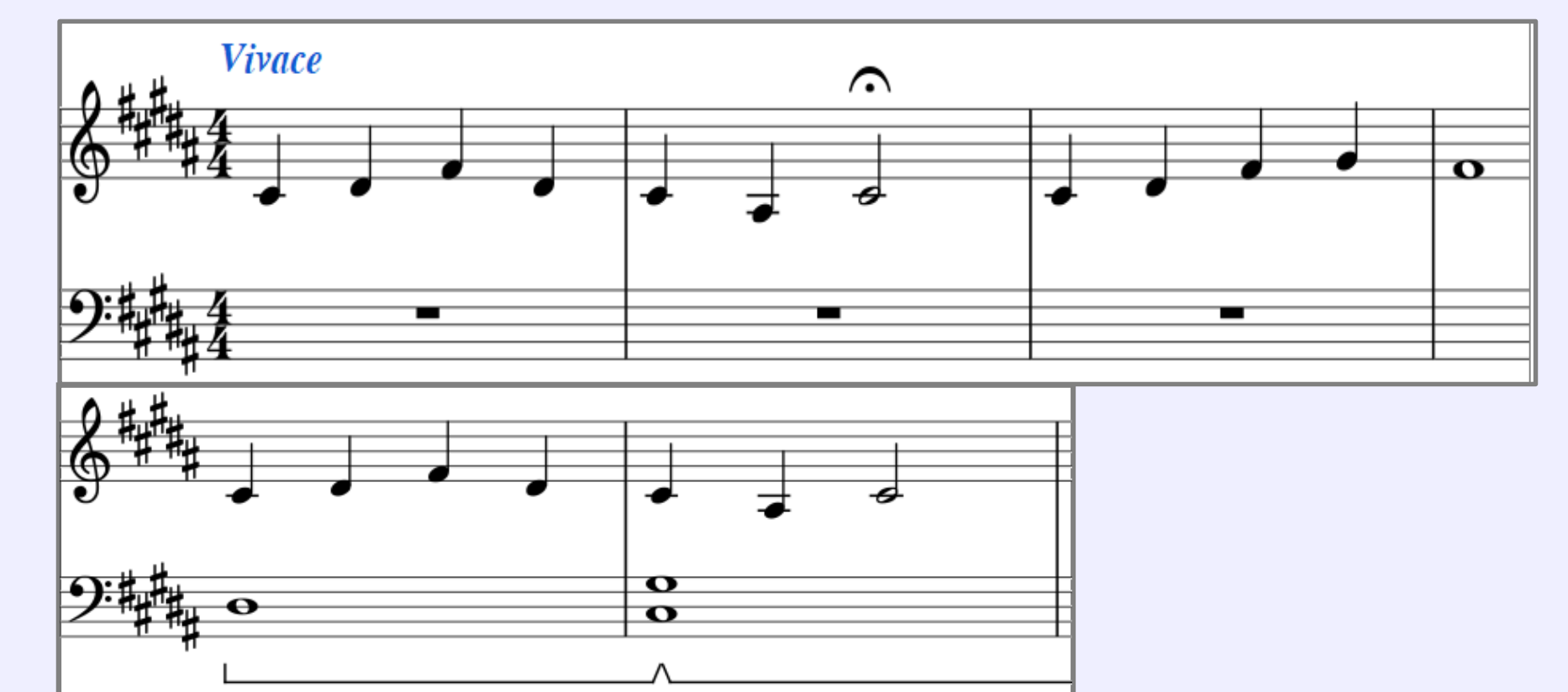


- Let Red=C=0
- Warm Set {0,1,2,3,4,5}
- Cool Set {6,7,8,9,t,e}
- Primary Set {0,4,9}
- Secondary Set {2,6,e}
- Cool is a transposition of Warm,
- Secondary is a transposition of Primary.

The End Set: "Piano Black"

• Pentatonic Scale on the black keys

- {6,8,t,1,3}



• You can write music by starting with numbers!

- Music composition accessible to non-musicians
- Math accessible to non-mathematicians
 - The modulo twelve system as an entry point to number theory.

Acknowledgments

- Anne Basinski – for encouraging me to find the overlap in my studies.
- Zachary Cooper – for insisting I learn about set theory composition and the wonderful possibilities it entails.
- Matthew Roscoe – for teaching me the mathematical theory behind what I wanted to do.
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