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Modes, polyphony, computing

A multilevel approach

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Abstract

Modality is one of the less well-understood--and therefore undervalued--aspects of polyphony. Despite more than half a century of research into the 'modes of polyphony', many questions about their nature, evolution and meaning lack definitive answers. However, there is a very substantial body of relevant primary sources dating from the fifteenth to the eighteenth century (and even beyond), so many indeed that the question arises whether the systematic application of computational methods can shed light on some of these issues. To set the scene, I will briefly discuss modality as detailed in Sebastian z Felsztyna's *Opusculum musice* (1517), followed by an overview of the main contested aspects of modality. The main part of my talk will then be about computational approaches to various kinds of relevant data, organised into several levels.

The first level deals with the sources. The Polymode database that I created to collect these now describes nearly 1000 textual and musical sources. Many of these sources contain modal cycles, sets of compositions that systematically go through all modes (whether 8, 12, or maybe another number). Data about these cycles form the second layer of my approach: the approximately 750 cycles in Polymode allow various aspects of the history of polyphonic modality to be visualised. The third level is that of the compositions in the cycles, as well as those named in the textual sources. This is very much a work in progress, but such data will enable us to find patterns in, for example, finals, scales, and transpositions of the modes. Scores, and by extension encodings, form the fourth level. Numerous aspects of modality can be uncovered by a systematic analysis of those compositions. So far analysis of cadences, for example, has mostly been done by hand: to do so computationally, on a large scale, would be quite helpful for our understanding. The final level is that of musical audio. It is unrealistic to expect that enough encodings will be available for this type of research any time soon. But the quality of polyphonic audio transcription is improving fast. This raises the question of what audio analysis could contribute to our understanding of modality. This too is a work in progress, but the first results are quite encouraging.

The greatest challenge of digital musicology is, in my opinion, translating computational results to musical insights. In my closing words, I will reflect on my attempts to do so for polyphonic modality. Hopefully, something can be learnt from these that can be generalised to the application of computational methods to other open issues in musicological research.

Once upon a time…

Baldus and his friends made the world an unsafe place

- Teofilo Folengo, *Baldus* (1517 and later editions)



https://www.digitale-sammlungen.de/en/view/bsb10190234

Between killings…

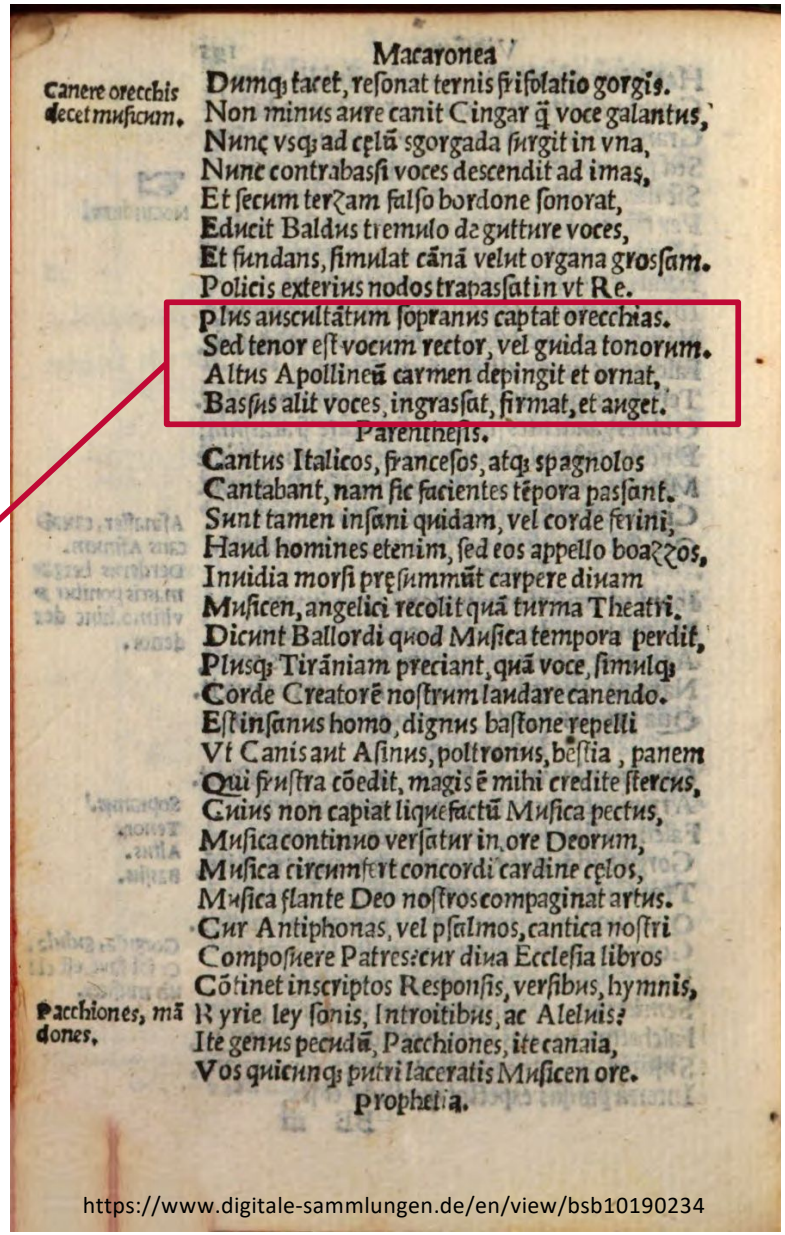
Baldus and his gang also like to sing

- described in detail, with appropriate terminology

> The soprano is the most captivating to the listeners' ears, but the tenor is the rector of the voices and *the guide of the tones*. The alto colors and ornaments the Apollonian song. The bass nourishes, fortifies and augments the other voices (tr. Mullaney 2007, adapted to 1521 ed.)

note the matter-of-fact mention of the 'tenor principle'

- the tone [mode] of a polyphonic piece is that of its tenor


Macaronea

Canere orecchis decet muſicam.

Dumq; tacet, reſonat ternis fritolatio gorgis.
Non minus aure canit Cingar q̃ voce galantus,
Nunc vsq; ad cęlũ sgorgada ſurgit in vna,
Nunc contrabaſsi voces descendit ad imas,
Et ſecum terzam falſo bordone ſonorat,
Educit Baldus tremulo de gutture voces,
Et fundans, fimulat cãnã velut organa groſſam.
Policis exterius nodos trapaſſat in vt Re.
plus auscultãtum ſopranus captat orecchias.
Sed tenor eſt vocum rector, vel guida tonorum.
Altus Apollineũ carmen depingit et ornat,
Baſſus alit voces, ingraſſat, firmat, et anget.

Parenthesis.

Cantus Italicos, franceſos, atq; spagnolos
Cantabant, nam fic facientes tẽpora paſſant.
Sunt tamen inſani quidam, vel corde ferini,
Haud homines etenim, ſed eos appello boaz̃os,
Inuidia morſi pręſummũt carpere diuam
Muſicen, angelici recolit quã turma Theatri.
Dicunt Ballordi quod Muſica tempora perdit,
Plusq; Tirãniam preciant, quã voce, ſimulq;
Corde Creatorẽ noſtrum laudare canendo.
Eſt inſanus homo, dignus baſtone repelli
Vt Canis aut Aſinus, poltronus, bẽſtia, panem
Qui fruſtra cõedit, magis ẽ mihi credite ſtercus,
Cuius non capiat liquefactũ Muſica pectus,
Muſica continuo verſatur in ore Deorum,
Muſica circumfert concordi cardine cęlos,
Muſica flante Deo noſtros compaginat artus.
Cur Antiphonas, vel pſalmos, cantica noſtri
Compoſuere Patres: cur diua Eccleſia libros
Cõtinet inscriptos Responſis, verſibus, hymnis,
Pacchiones, mã dones. Kyrie ley ſonis, Introitibus, ac Aleluis?
Ite genus pecudũ, Pacchiones, ite canaia,
Vos quicunq; putri laceratis Muſicen ore.

Prophetia.

https://www.digitale-sammlungen.de/en/view/bsb10190234

A little surprise

actually, this source belongs to the earliest layer of evidence for polyphonic modality

- vast amount of evidence dating from c. 1525 until well into the 17th century

challenges widespread narrative of a simple transition from modality to tonality during the Renaissance

- 8 modes are scales of medieval planchant, bad fit with polyphony
- replaced by Aeolian and Ionian, effectively minor and major scale, by Glarean (1547)
- case closed

unlocking that vast amount of evidence is the core of my talk

first we need some background in the modes

A closer look at the modes

Sebastian z Felsztyna, *Opusculum musice compilatum noviter* (Kraków 1517)

- plainchant for beginners
- ~50% about the modes



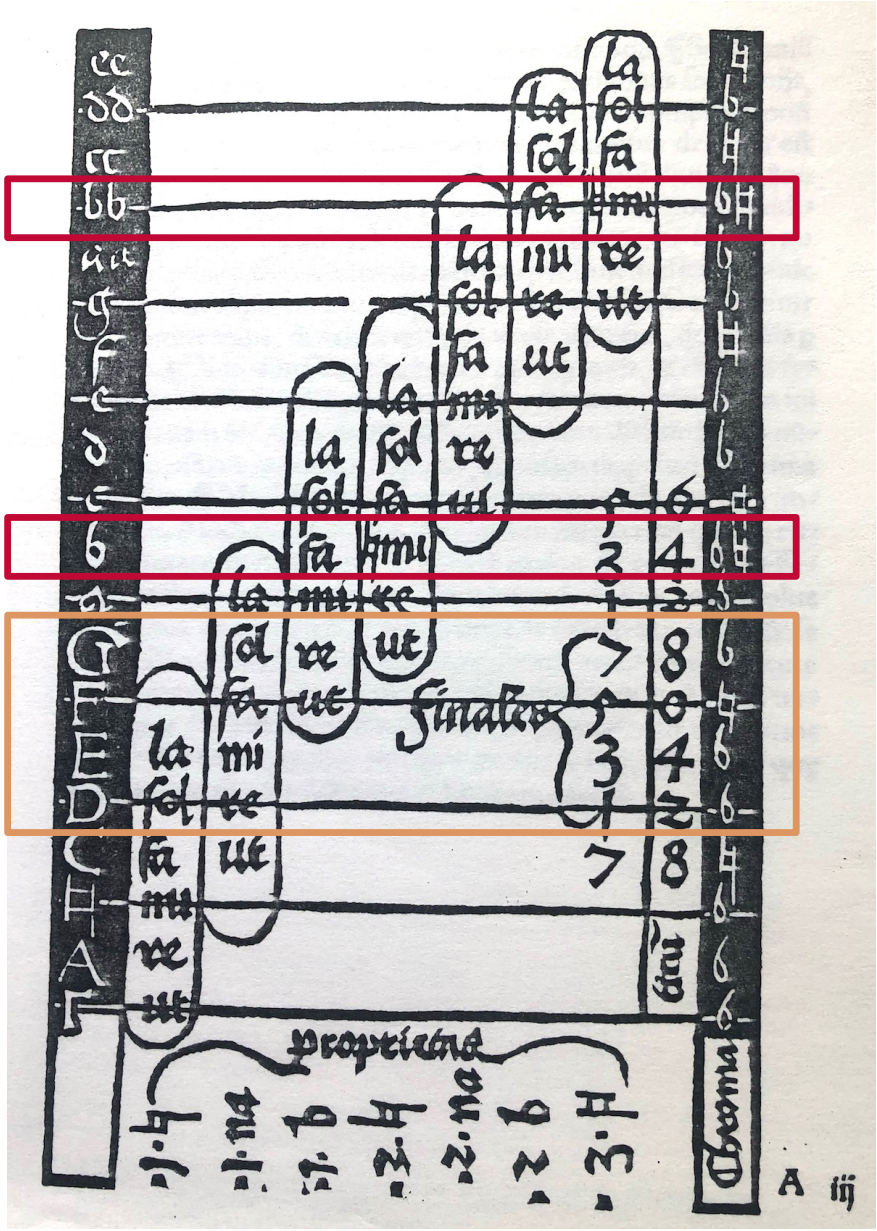
facsimile: Kraków 1978

First, the scale

there is just one scale

- here depicted as a ladder
- 7 hexachords defining the intervals
- allowing for both B-natural and B-flat (red boxes)
- modal finals (D, E, F, G) are notes on the scale (orange box)

modes better understood as constellations within a single scale with a flexible pitch B



facsimile: Kraków 1978

Repercussion

characteristic interval in the melody (in blue)

- large in *authentic* modes 1, 3, 5, 7
- small in *plagal* modes 2, 4, 6, 8

modes with the same final are differentiated by *range* or *ambitus*

- authentic = high; plagal = low



facsimile: Kraków 1978

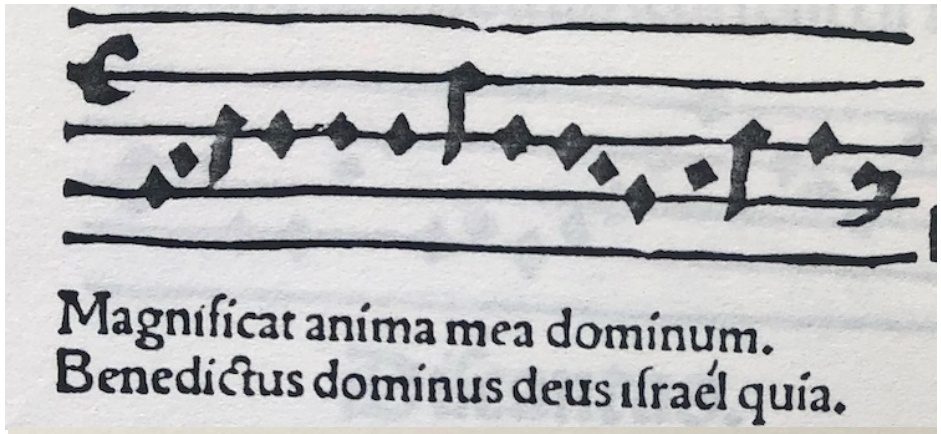
Examples

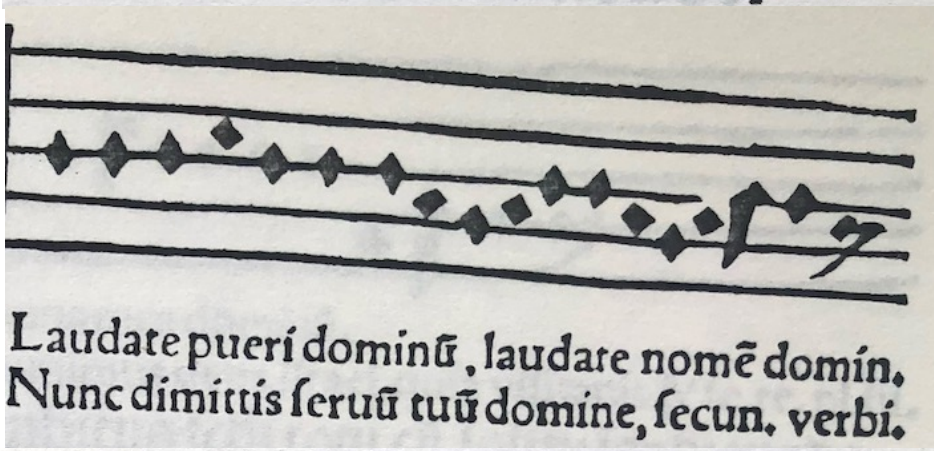
one set of examples illustrate psalm / canticle recitation

- these employ melodic patterns (often called called *psalm tones*) that are associated with the modes
- recitation is mostly on the repercussion top note

most psalm tones have multiple endings *(differentiae),* often not on the modal final

- the following antiphon will take care of this







tone 1 examples

facsimile: Kraków 1978

Examples

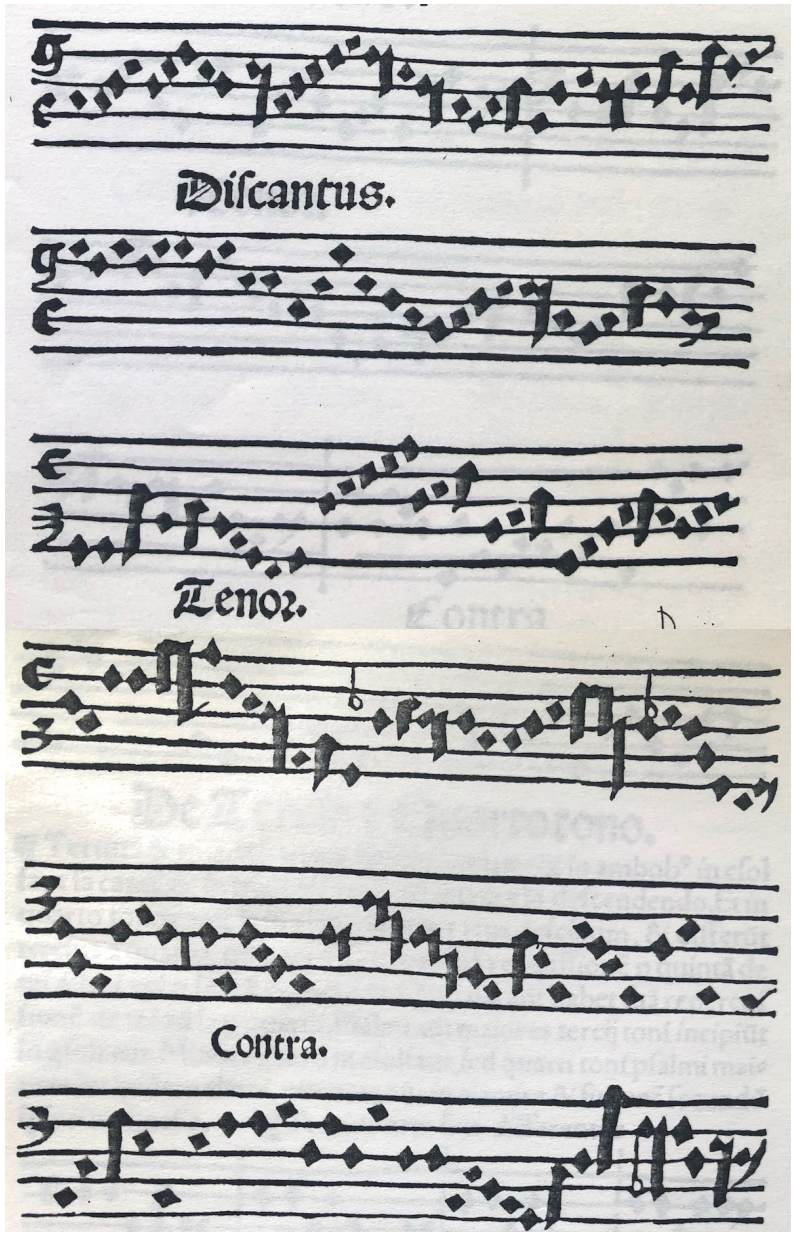
there is also one 3-voice example for each mode

- casually, no further explanation
- example shown here is mode 1

important milestone nevertheless

- the 8 examples form a (polyphonic) *modal cycle*
- first complete modal cycle in a music treatise
- oldest datable modal cycle that is not psalm (Magnificat) tone-based

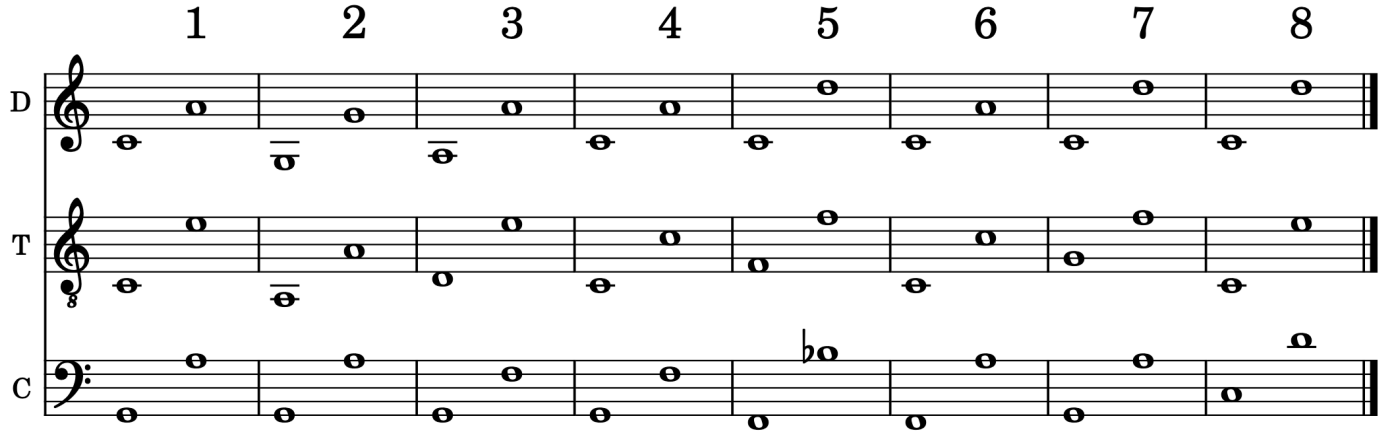
modal cycles have an special place in my research (Wiering 2001, Wiering & Visscher 2025)



facsimile: Kraków 1978

Quick analysis of the polyphonic examples

- examples all end on the modal final
- clear evidence of repercussion in tenor melodies
- voice ranges are interesting



- range of tenor matches with mode
- other voices show no clear evidence of modal characteristics
- again, polyphony seems an extension of monophony

What have we learned from Sebastian?

monophony

- 8 modes, labelled 1-8
- 4 finals, D, E, F, G
- each final serves an authentic (high) and a plagal (low) mode
- characteristic melodic interval: repercussion

polyphony

- modes casually applied to polyphony, as an extension
- tenor principle
- modal cycle

what is mode in polyphony?

The Modes of Classical Vocal Polyphony

Berhard Meier's *Die Tonarten der klassischen Vokalpolyphonie, nach den Quellen dargestellt* (1974) proposes a synthesis based on later source evidence (c. 1540-1600)

1. the modes are pre-compositional entities in polyphony
2. 4 authentic-polyphonic and 4 plagal-polyphonic modes
3. each mode allows for specific cadence tones
4. melodic invention often shaped by the main intervals

deviation of modal norms can be explained as text expression

- shows deep insight in the expressivity of the music
- but also potentially a way of explaining away all evidence against this synthesis

Polyphonic mode 5

final F, one flat
- tenor is in mode 5 (red)
- shared with quinto and canto
- alto and basso are in the complementary mode 6 (blue)

overall range is high
- note the high cleffing (orange)



the *tonal type* provides a quick indication of the piece's mode
- signature – clef(s) – final
- ♭ – g2 c2 c3 c3 f3 – f3

Polyphonic mode 6

final F, one flat

- tenor is in mode 6 (blue)
- shared with quinto and canto
- alto and basso are in the complementary mode 5 (red)

overall range is low

- note the low cleffing (orange)



tonal type: ♭ – c1 c3 c4 c4 f4 – f2

Listen to the difference

Hilliard ensemble

- same performance pitch
- note how the tonal space unfolds in each piece

mode 5



Palestrina's *Le vergini* (1581) is another modal cycle

- 8 pieces setting stanzas 1-8
- no music for 9-11
- no mention of mode in the source

mode 6



Debated issues in polyphonic modality (some of them)

in the past

- number of modes (8, 12, …)
- how to deal with finals A, B and C
- transposition and (key) signatures
- proper and improper cadences

- terminology
- definition and derivation of mode
- relation to psalmody
- relation to Greek modes
- symbolic meaning
- modal affect

in modern research

- role of modes in composition
- authentic-plagal distinction
- historical development of modality
- relationship to tonality
- reality of mode (Powers 1992)

big issues, requiring big evidence to resolve
fortunately there is such evidence

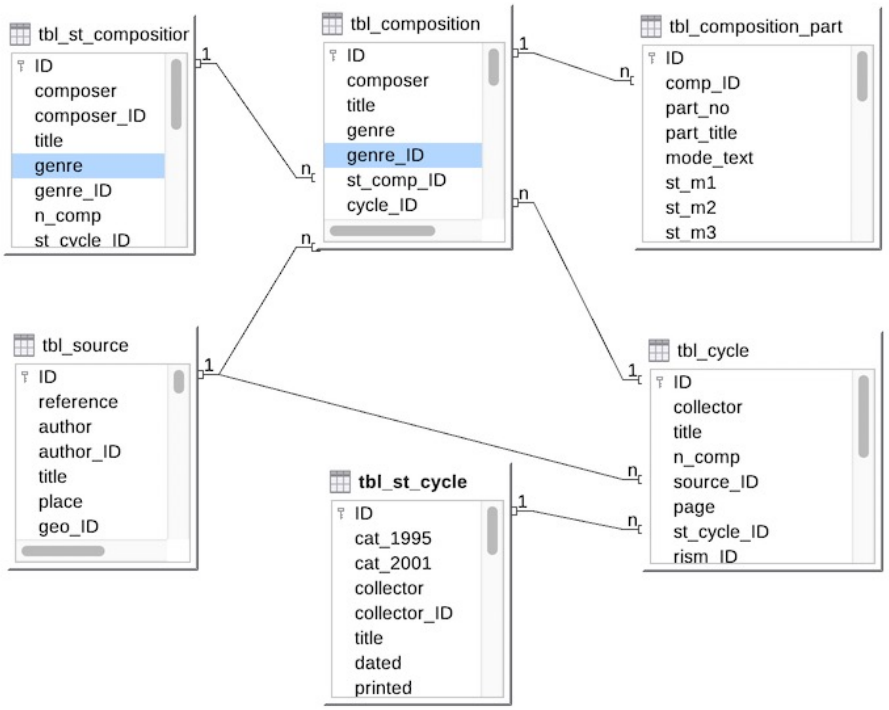
Outline: turning the evidence into data

1. introduction to polyphonic modality
2. overview of the evidence
3. investigate what insight can be gained using computational approaches
4. briefly reflect on the experiences

five levels

1. sources
2. modal cycles
3. content of the cycles
4. notated compositions
5. audio recordings

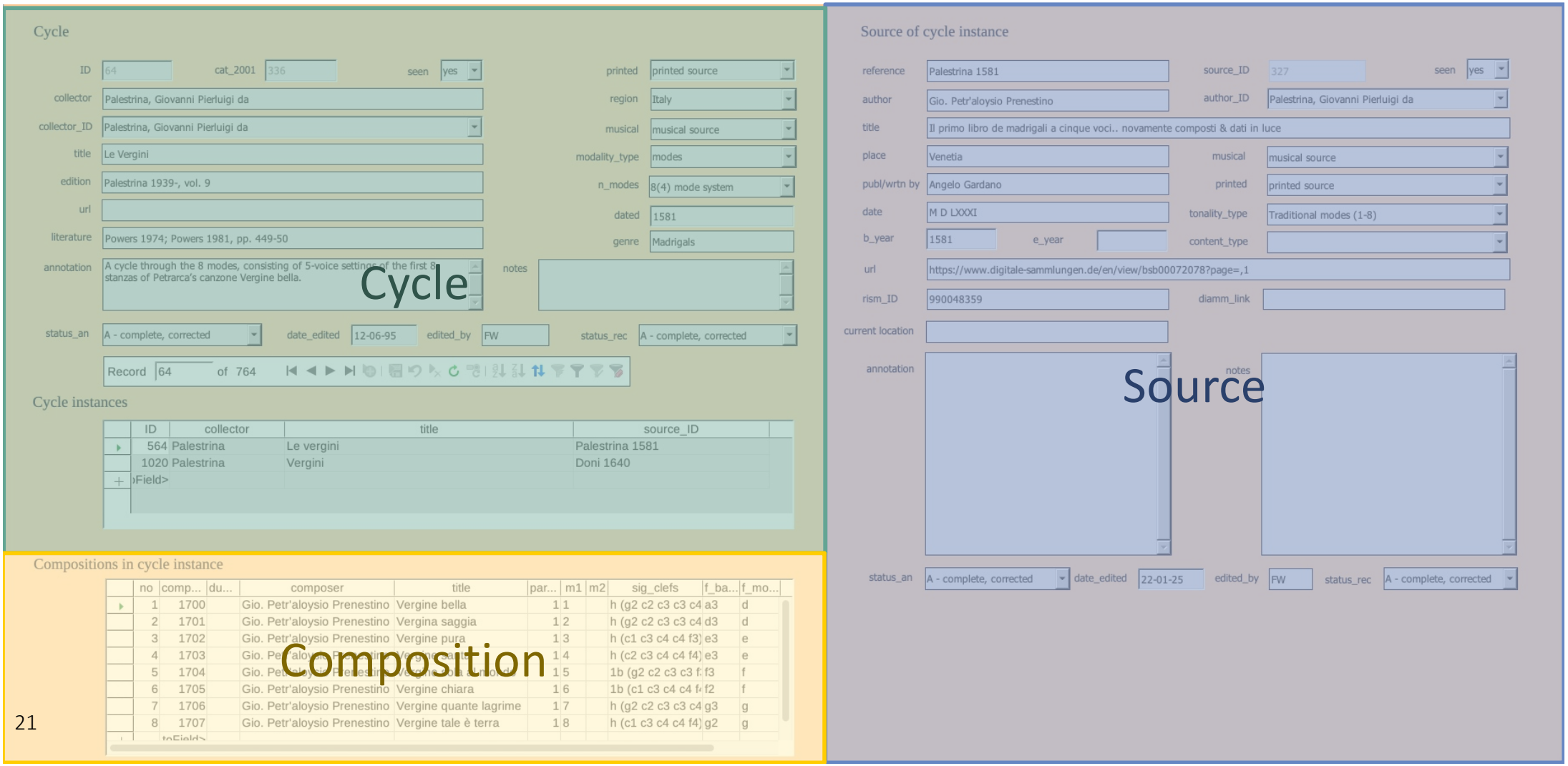
Polymode



Polymode ER diagram (simplified)

modal cycle data: https://www.projects.science.uu.nl/ics-cantostream/polymode.php

Polymode view (one of many)



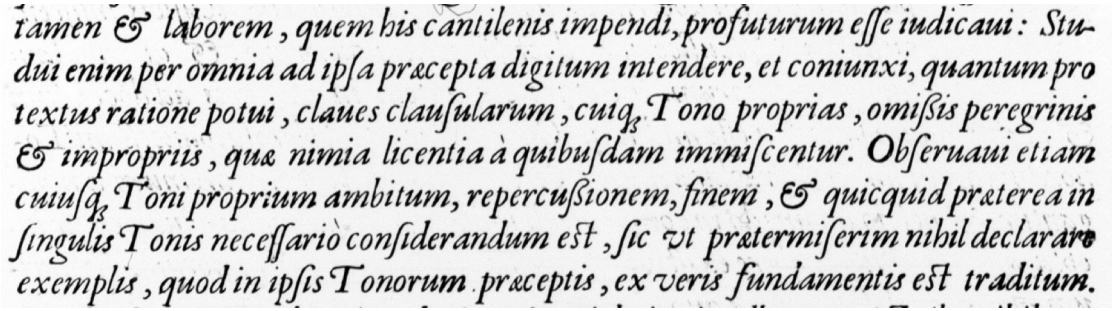
Level 1: Sources

main types of sources

- music prints and manuscripts
  - compositions assigned to a mode
  - modal cycles
- music treatises
  - often with music examples
  - and/or lists of compositions
- mixed sources
  - explanations of the music

other

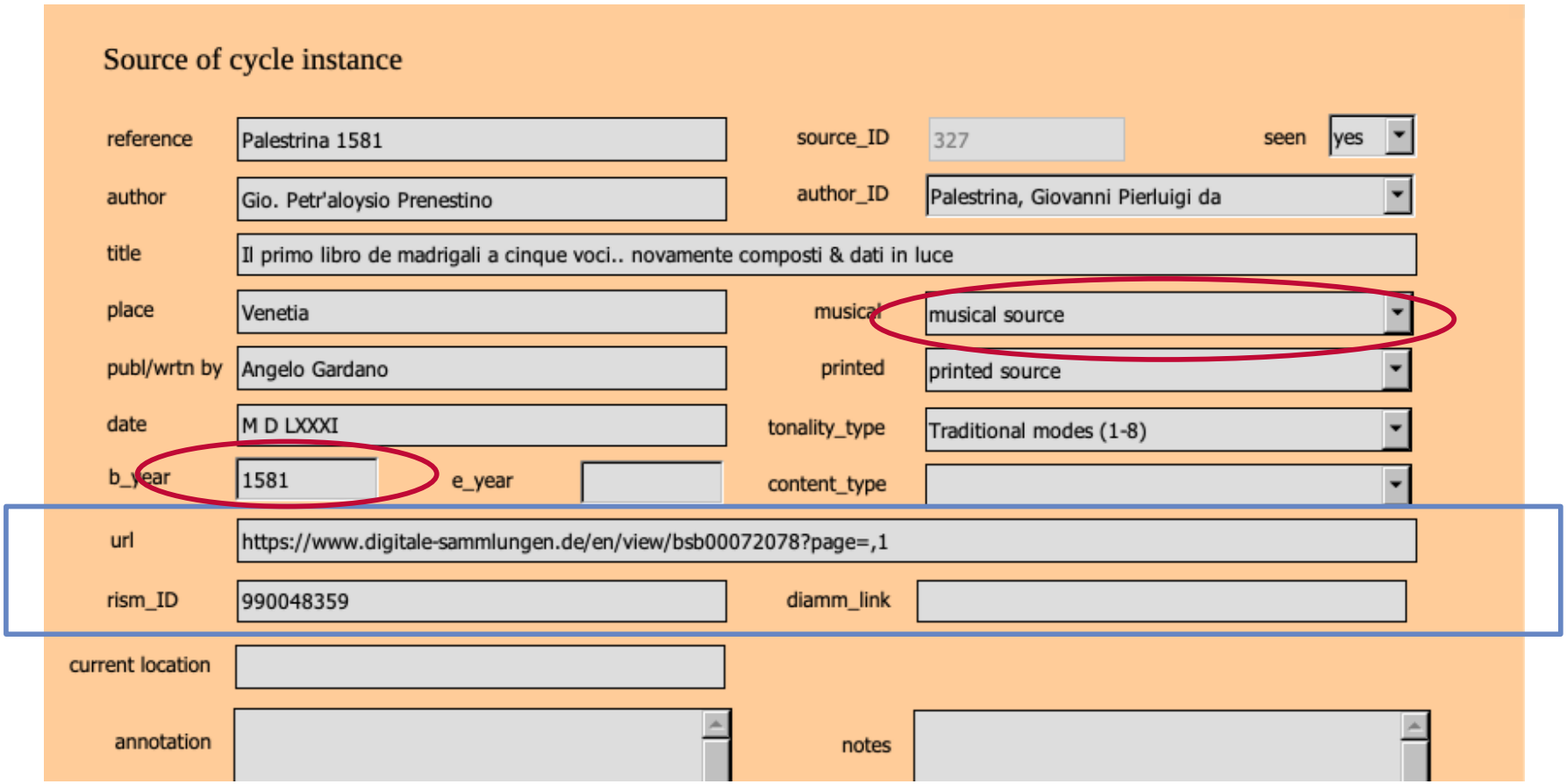
- archival documents, letters, poems…
- pictures
- musical instruments


tamen & laborem, quem his cantilenis impendi, profuturum esse iudicaui: Studui enim per omnia ad ipsa præcepta digitum intendere, et coniunxi, quantum pro textus ratione potui, claues clausularum, cuiq; Tono proprias, omissis peregrinis & impropriis, quæ nimia licentia à quibusdam immiscentur. Obseruaui etiam cuiusq; Toni proprium ambitum, repercussionem, finem, & quicquid præterea in singulis Tonis necessariò considerandum est, sic vt prætermiserim nihil declarare exemplis, quod in ipsis Tonorum præceptis, ex veris fundamentis est traditum.

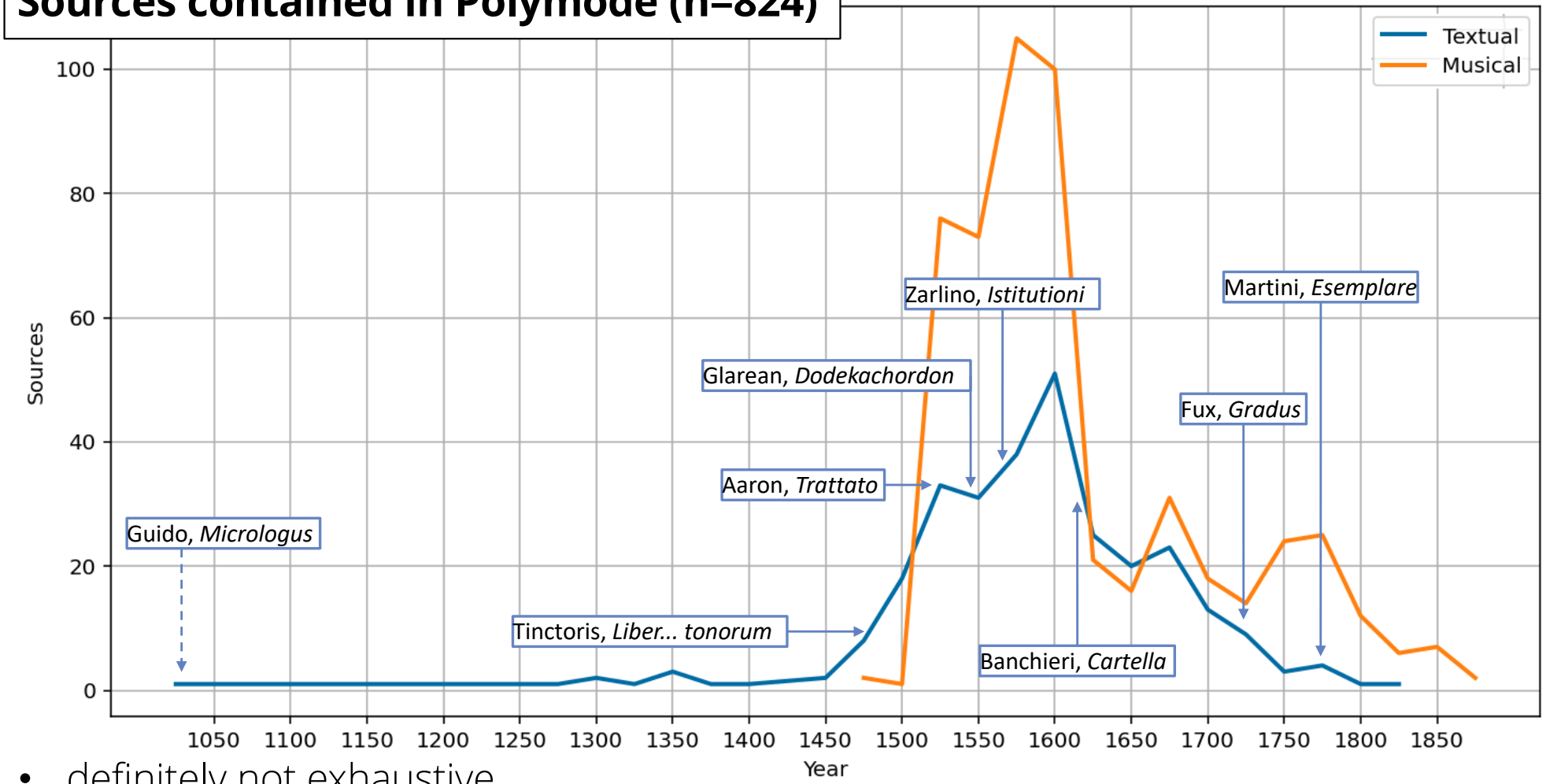
AI translation (emphasis added):
For I have endeavored throughout to adhere strictly to the rules themselves; and—as far as the nature of the text allowed—I have combined the characteristic cadences proper to each tone, while omitting the foreign and improper ones that some introduce through excessive license. I have also observed the specific range, repercussion, and final note of each tone—along with whatever else requires consideration in the individual tones—ensuring that I have illustrated with examples every point taught regarding the rules of the tones based on true principles.

mixed source: Eucharius Hoffmann's *XXIIII Cantiones* (1577)

Source data in Polymode



Sources contained in Polymode (n=824)



- definitely not exhaustive
- note amount of sources dated 1525 and later

Querying treatises using RAG and LLM

Historical Music Theory Query System created by Richard Freedman and his team: https://theory.crimproject.org/

- digitised treatises from TML, TMI and TME

example prompt

- what are the most popular definitions of mode (excluding the rhythmic modes and mode as a synonym for interval)

response (abbreviated)

1. Mode as an ordering/species of the diapason (a pitch-ordering or species of interval—defined by final, ambitus, and position of semitones). [...]
2. Mode as a melodic/practical category: a modulation or cantilena-shape (ambitus + finals + clausulae, cadences and typical terminations. [...]

like in Sebastian

suggestive results; require rigorous evaluation

Level 2: modal cycles

A modal cycle is a set of compositions that systematically goes through all modes. It must exist or have existed in music notation

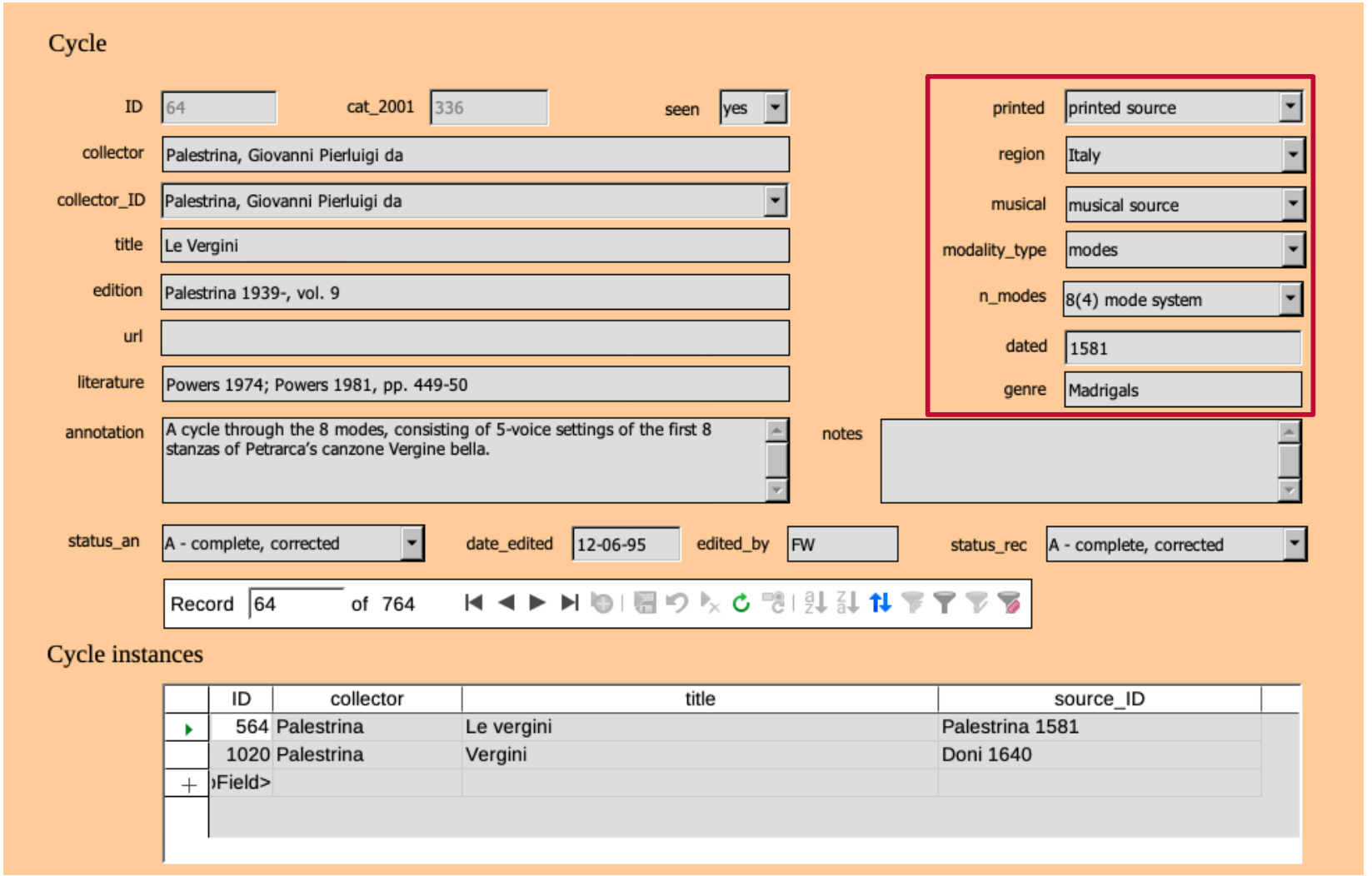
- modal ordering is often not made explicit (e.g. Palestrina's *Vergine*)
- if modal ordering appears to be intended, cycles may be incomplete, disordered, or interleaved with other pieces

collected how?

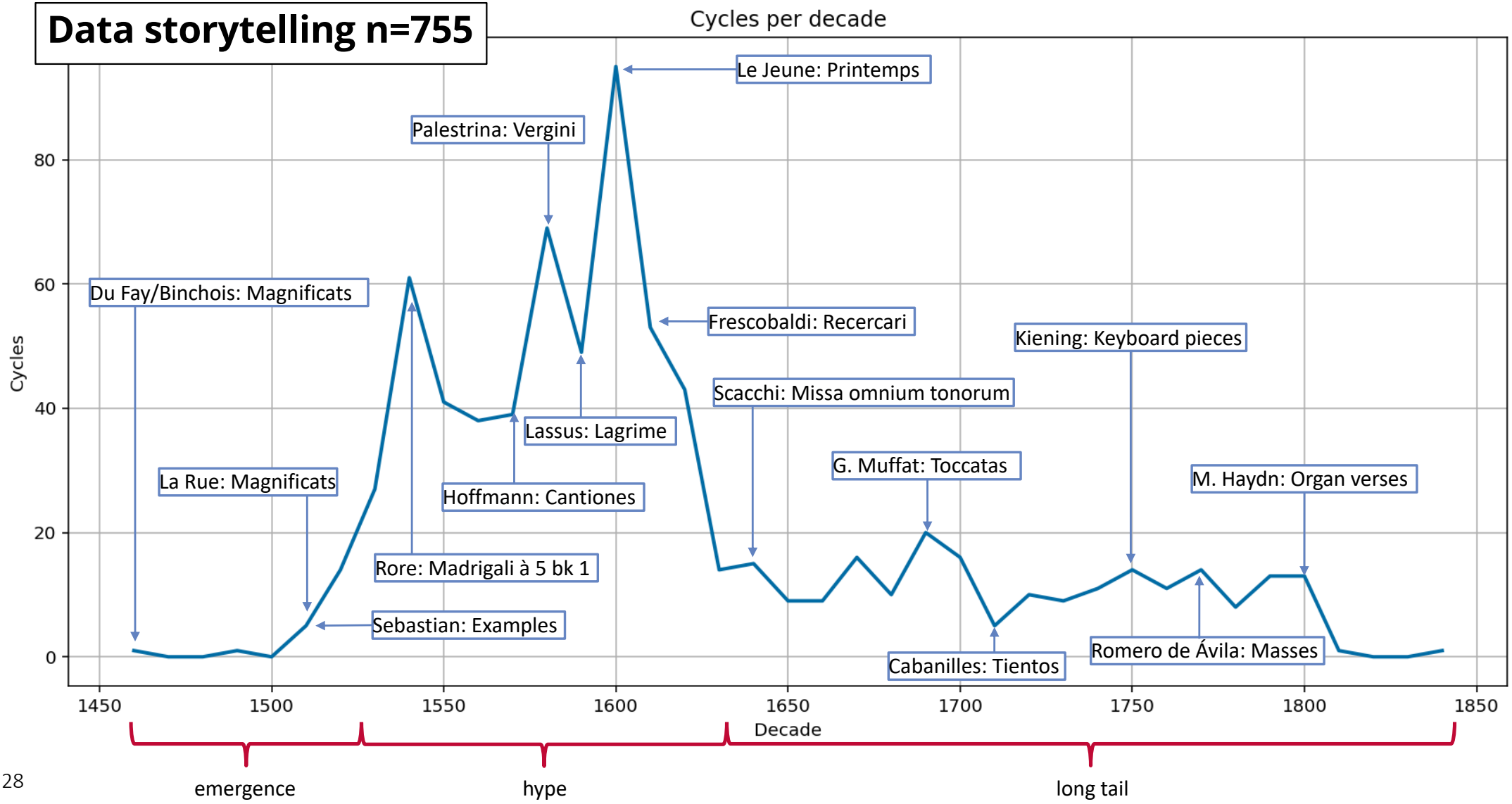
- literature and library research (first 474, others)
- 176 extracted from RISM data (https://rism.digital/exports/index.html) using Python script
- many from other online catalogues

robust evidence for the practical reality of the polyphonic modes

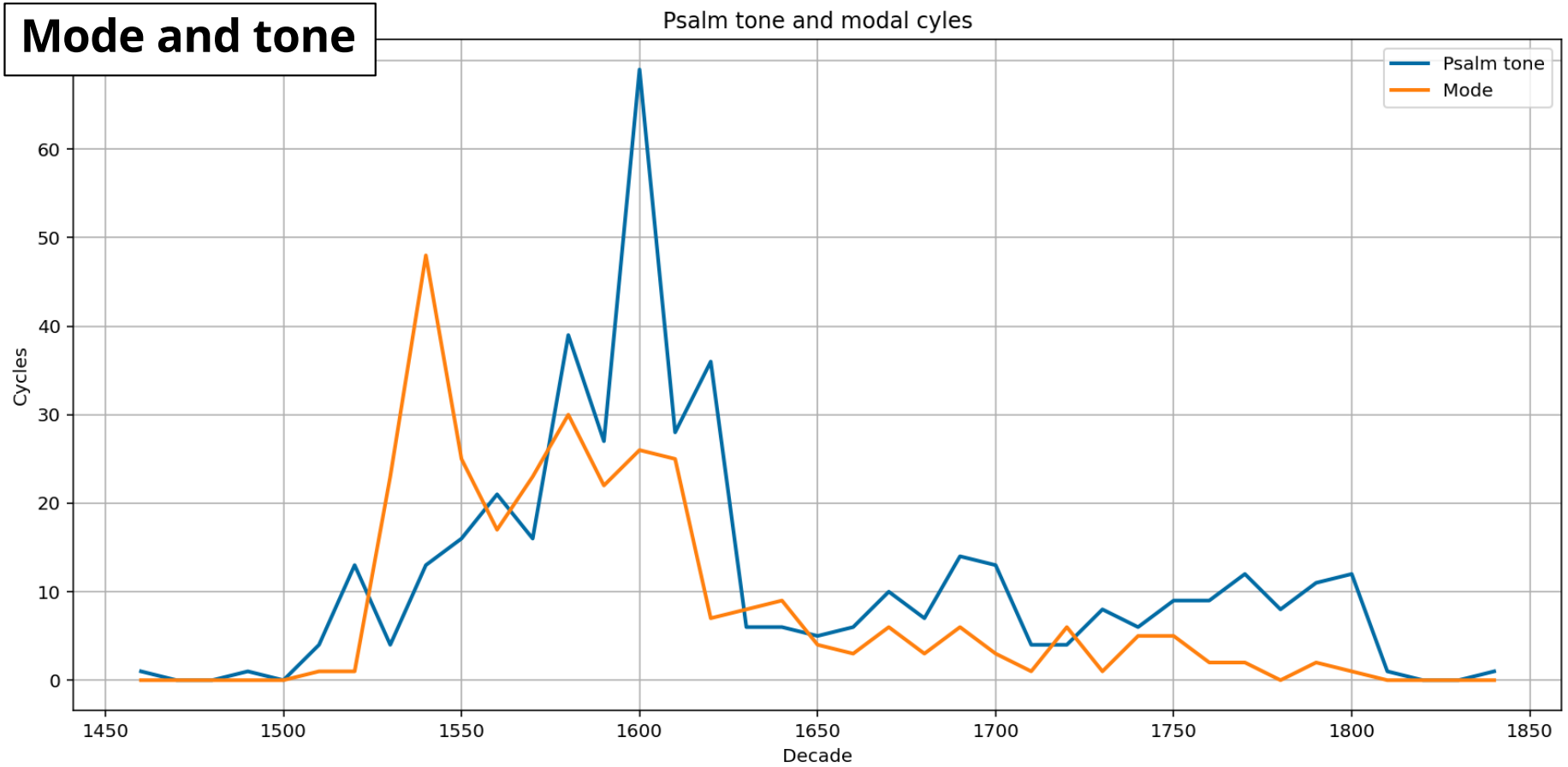
Cycle data


Cycle
ID
64
cat_2001
336
seen
yes
collector
Palestrina, Giovanni Pierluigi da
collector_ID
Palestrina, Giovanni Pierluigi da
title
Le Vergini
edition
Palestrina 1939-, vol. 9
url
literature
Powers 1974; Powers 1981, pp. 449-50
annotation
A cycle through the 8 modes, consisting of 5-voice settings of the first 8 stanzas of Petrarca's canzone Vergine bella.
notes
printed
printed source
region
Italy
musical
musical source
modality_type
modes
n_modes
8(4) mode system
dated
1581
genre
Madrigals
status_an
A - complete, corrected
date_edited
12-06-95
edited_by
FW
status_rec
A - complete, corrected
Record
64
of 764
Cycle instances
ID
collector
title
source_ID
564
Palestrina
Le vergini
Palestrina 1581
1020
Palestrina
Vergini
Doni 1640
Field>

Data storytelling n=755



Mode and tone



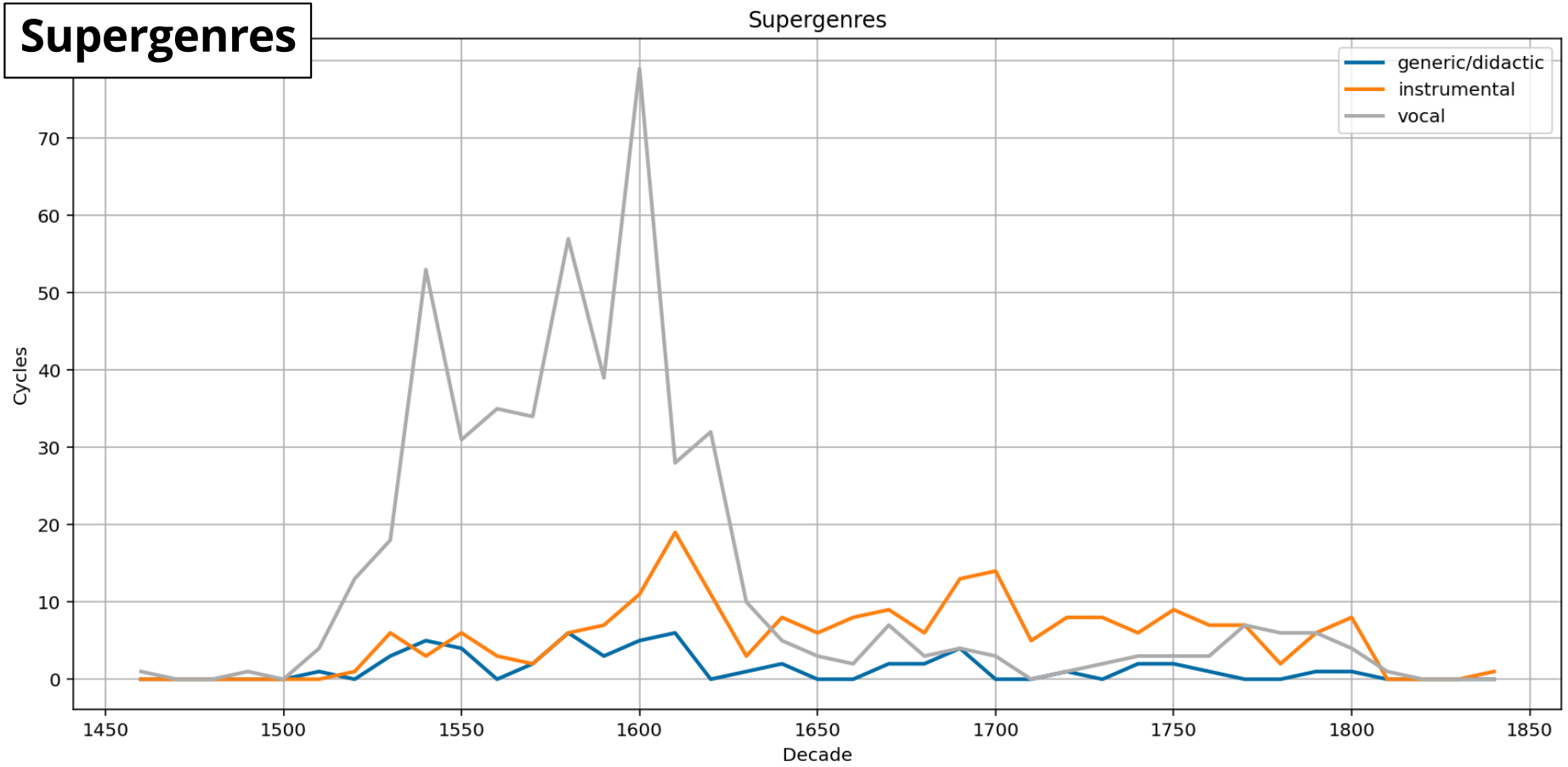
- psalm tone = melodic pattern
- mode = abstraction

get entangled in polyphony

8 'psalm tone keys' or 'church tones' from c. 1590 (Dodds 2023)

- tones distinguished by *transposition* mainly
- e.g. tone 1 = d-♮ ; 2 = g-♭

Supergenres



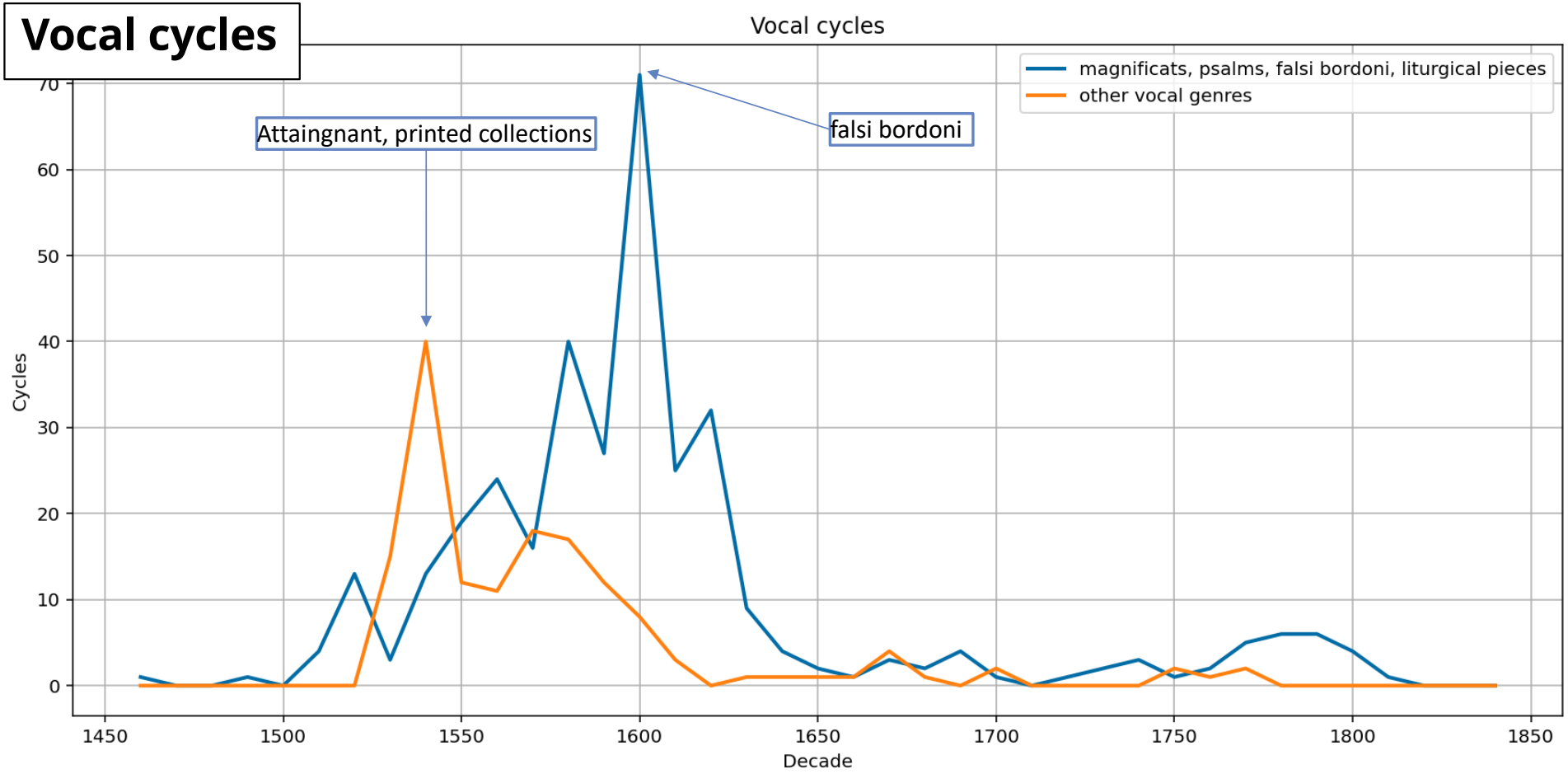
before 1630

- most cycles are vocal
- fewer didactic and instrumental cycles

after 1630

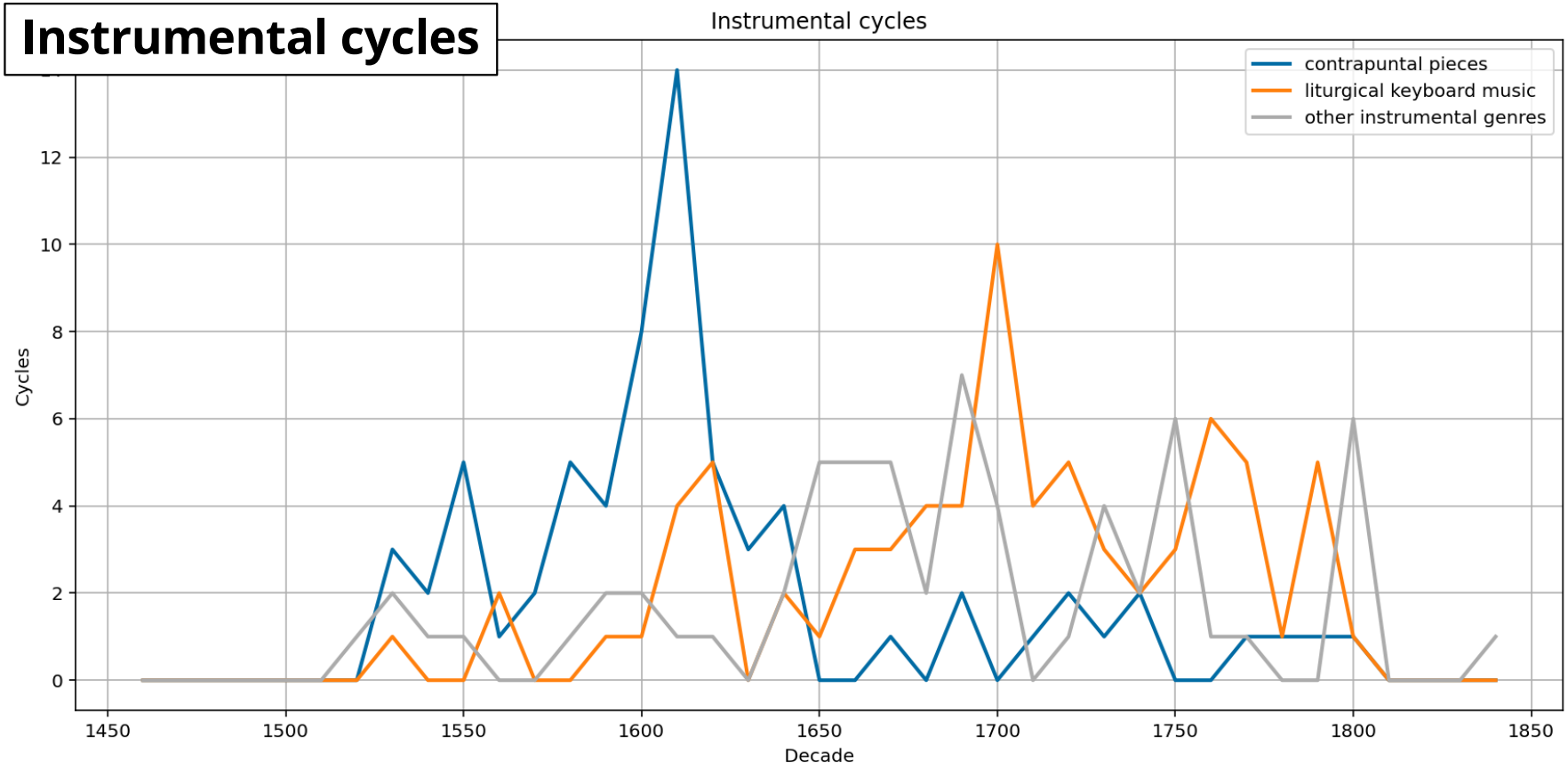
- instrumental cycles prevail (hardly a long tail)
- didactic cycles almost disappear

Vocal cycles



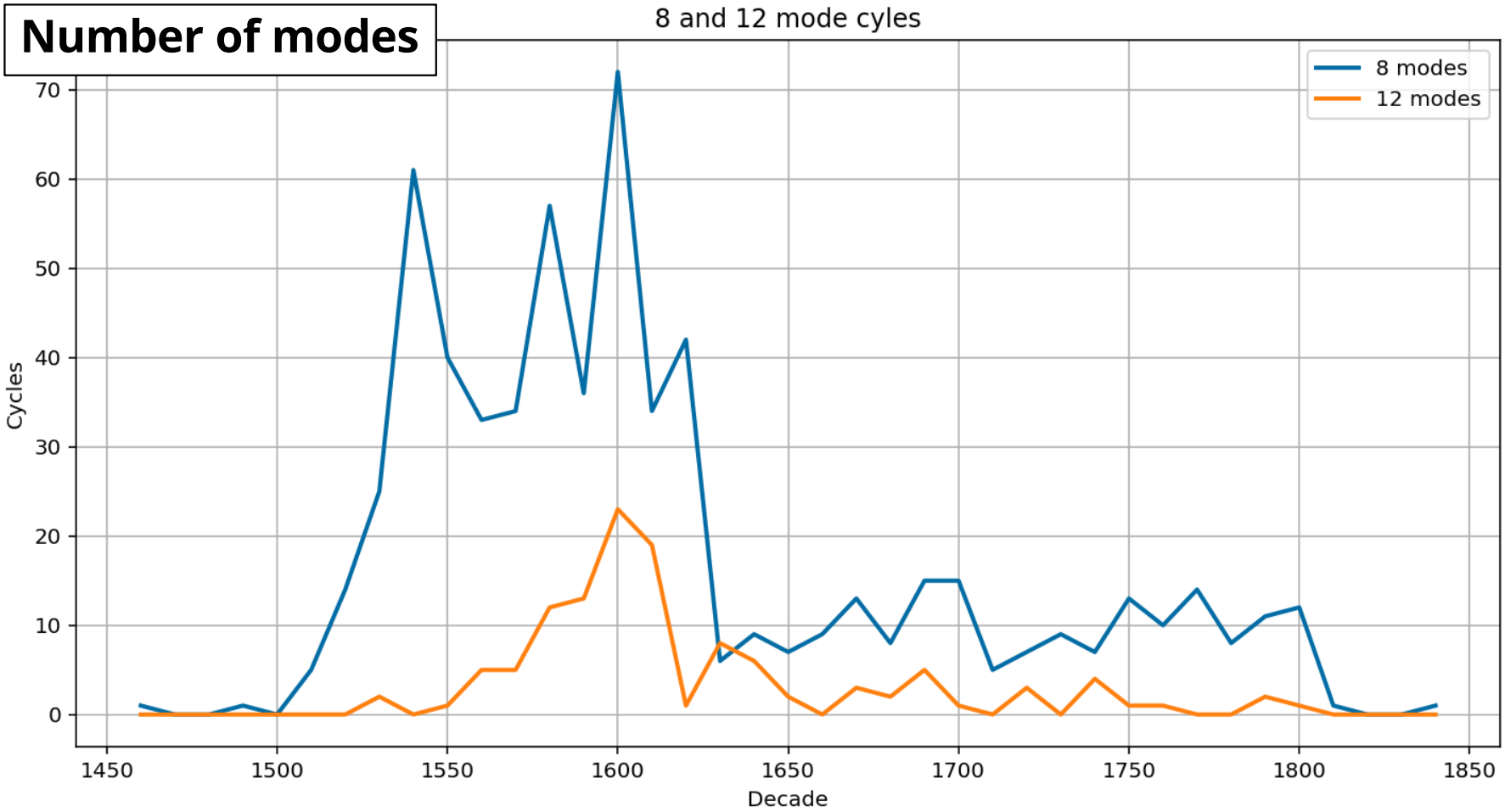
- mass, motet, chanson and madrigal cycles mostly restricted to ‘hype’ period
- longer lifespan for psalm/magnificat tone related genres

Instrumental cycles



- substantial amounts of ricercars, fantasias, tientos etc. until 1640
- liturgical keyboard cycles are a late phenomenon
- same is true for ‘other’ cycles such as dances, sonatas, preludes, toccatas
- from ‘theory-informed’ to ‘pragmatic’ use of modes?

Number of modes



- composing in 12 modes short-lived phenomenon during hype phase
- here too a shift to ‘pragmatic’ modality?

Some insights

based on just this data (not looking yet at the notes) we can already get a more nuanced view of polyphonic modality

- main period of interest 1540-1640
- genre differences indicating different contexts of use and motivations

theory-informed

- didactic cycles (e.g. in treatises)
- cycles demonstrating mastery (e.g. ricercars, madrigals)

pragmatic (with a longer lifespan)

- sets covering all liturgical needs (e.g. magnificats)
- convenient way of ordering a collection (e.g. Attaingnant, Kiening)

Level 3: content of the cycles

Compositions in cycle instance

	no	comp...	du...	composer	title	pa...	m1	m2	sig_clefs	f_ba...
	1	1700		Gio. Petr'aloysio Prenestino	Vergine bella	1	1		h (g2 c2 c3 c3 c4)	a3
	2	1701		Gio. Petr'aloysio Prenestino	Vergina saggia	1	2		h (g2 c2 c3 c3 c4)	d3
	3	1702		Gio. Petr'aloysio Prenestino	Vergine pura	1	3		h (c1 c3 c4 c4 f3)	e3
	4	1703		Gio. Petr'aloysio Prenestino	Vergine santa	1	4		h (c2 c3 c4 c4 f4)	e3
	5	1704		Gio. Petr'aloysio Prenestino	Vergine sola al mondo	1	5		1b (g2 c2 c3 c3 f3)	f3
	6	1705		Gio. Petr'aloysio Prenestino	Vergine chiara	1	6		1b (c1 c3 c4 c4 f4)	f2
▶	7	1706		Gio. Petr'aloysio Prenestino	Vergine quante lagrime	1	7		h (g2 c2 c3 c3 c4)	g3
	8	1707		Gio. Petr'aloysio Prenestino	Vergine tale è terra	1	8		h (c1 c3 c4 c4 f4)	g2
		<toField>								

collect metadata and basic features of the compositions

- in progress, only preliminary results so far

spot relationships and unusual patterns

- as here in modes 1 and 2 (see e.g. Powers 1981, Coluzzi 2026)

Cycle size

- most cycles contain 1 piece per mode
- or 2 pieces per mode
- really long cycles often consist of liturgical organ pieces
- even longer cycles exist!

Number of pieces	Cycle count
8	99
12	51
9	17
16	12
10	9
24	8
4	6
22	6
6	5
14	5
7	4
11	4
19	4
13	3
17	3
21	3
5	2
15	2
18	2
20	2
25	2

Number of pieces	Cycle count
26	2
31	2
32	2
40	2
100	2
23	1
27	1
28	1
30	1
34	1
35	1
36	1
37	1
39	1
47	1
55	1
56	1
57	1
63	1
64	1
87	1
120	1

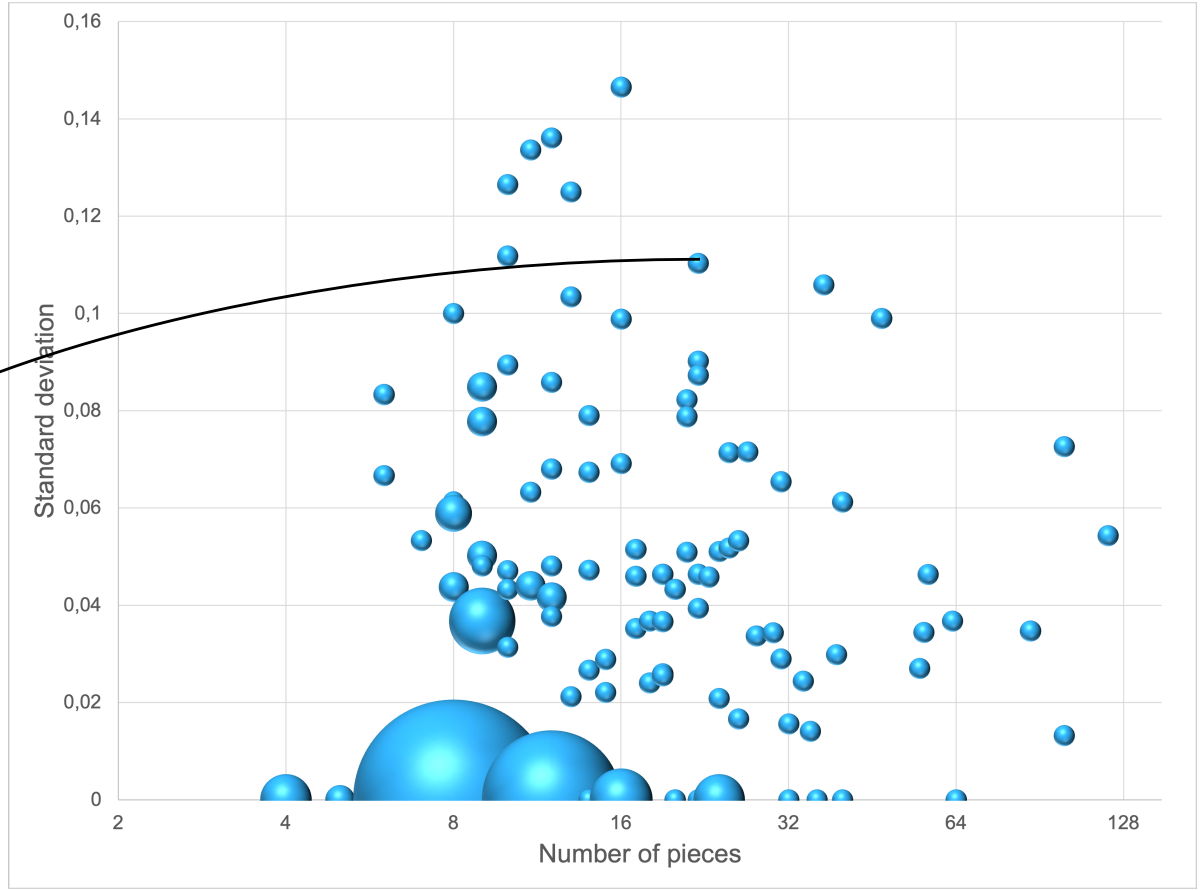
G.B. Degli Antonii, Versetti per tutti li tuoni (1687)

Cycle composition

are all modes equally represented?

- normalised standard deviation over count of pieces per mode
- high SD correlates with *a posteriori* modal ordering
- e.g. Gallus Dressler, *Cantiones à 5* (1570), SD = 0.106

Mode	Piece count
1	12
2	2
3, 4	6
5	3
6	10
7	1
8	3



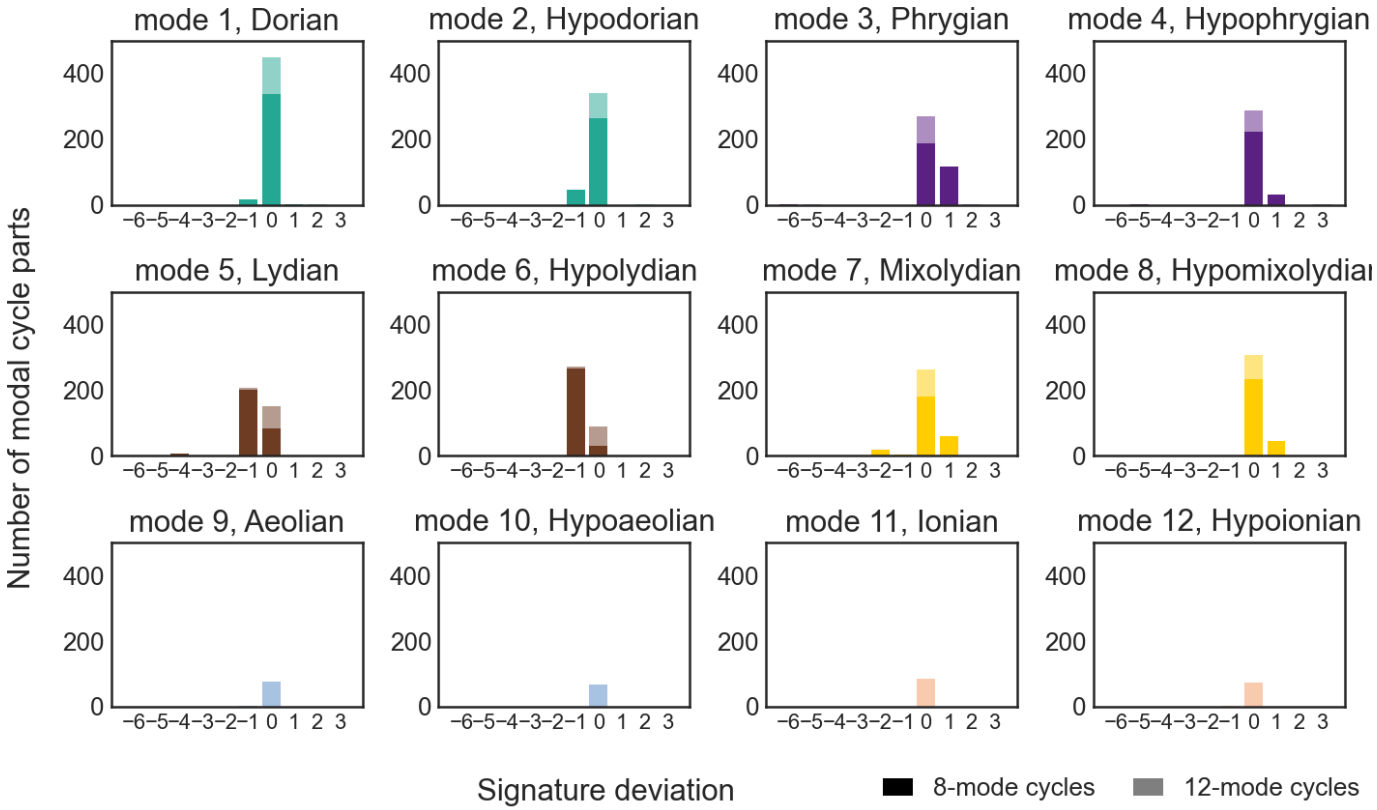
How often does a piece get a ‘wrong’ signature?

analysis by Mirjam Visscher scoring

- 0: as expected
- *-n:* ‘flat’ deviation
- *+n:* ‘sharp’ deviation

Lydian modes have largest deviation

- especially mode 6
- ‘real’ mode 6 mainly in 12-mode cycles



Level 4: notated compositions

music encoding has been practiced since 1960s

- initially, many incompatible formats
- converged to restricted number of formats (and communities), with a varying amount of interoperability

encodings are collected in online corpora mainly, each with their own focus

- typical size 100s-1000s pieces
- largest resources consist of digital editions by citizen scientists (often with accessible encodings)

Overview of 20 corpora containing early music (item counts December 2025)

Dataset name	url	content	number of items before 1700	main format	nature
Goldberg Corpus	https://www.goldbergstiftung.org/en/	15th and early 16th century music	3600	CMME	citizen science
Computerized Mensural Music Editing	http://www.cmme.org/ ; https://github.com/tdumitrescu/cmme-music	15-16th c. polyphony, with works by Josquin, Berchem and others	c. 260	CMME	scholarly
Polish Digital Scores	https://polishscores.org/	Polish music, 16th-20th century	1740	Humdrum	scholarly
Josquin Research project	https://josquin.stanford.edu/	Works by Josquin and contemporaries	902	Humdrum	scholarly
Tasso in Music	https://www.tassomusic.org/	Musical settings of Tasso's poems, with works by Monteverdi, Marenzio, Wert, Cifra, others	778	Humdrum	scholarly
KernScores	http://kern.ccarh.org/	Western composers, 14-20th century, with works by Frescobaldi, Monteverdi, Corelli and others	c. 350	Humdrum	mix
Tomás Luis de Victoria	https://www.uma.es/victoria/index.html	Spanish music from Morales onward, including works by Guerrero, Victoria, Ceballos, Vasquez	c. 1000	Lilypond	citizen science
Citations: The Renaissance Imitation Mass	https://crimproject.org/	16th c. imitation masses and their models	c. 300	MEI	scholarly
Gesualdo online	https://ricercar.gesualdo-online.cesr.univ-tours.fr/	Complete works of Gesualdo	222	MEI	scholarly
Measuring polyphony	https://measuringpolyphony.org/ ; https://github.com/MeasuringPolyphony/mp-music-files	14th century motets	61	MEI	scholarly
Electronic Linked Annotated Unified Tablature Edition	https://e-laute.info/	Lute music from the German-speaking areas, mainly in German lute tablature	60, growing	MEI	scholarly
ELVIS database	https://github.com/ELVIS-Project	Contains multiple subcollections, some also existing as separate corpora. Includes compositions printed in Glarean's Dodekachordon works by Palestrina, Victoria and others	c. 1000	multiple formats	scholarly
Neuma	http://neuma.huma-num.fr/	Contains multiple subcollections, with works by Josquin, Ockeghem, Dufay, Frescobaldi and others	c. 600	multiple formats	scholarly
Choral Public Domain Library	https://www.cpdl.org/wiki/	Choral music of any age	c. 30000	MusicXML and others	citizen science
Electronic Medieval Music Score Archive Project	https://github.com/cuthbertLab/emmsap	14th century music	3600	MusicXML	scholarly
Archive of Iberian Polyphony	https://iberianpolyphony.fcsh.unl.pt/	Iberian polyphony from the Renaissance	130	MusicXML	scholarly
The 1520s Project	https://1520s-project.org/about/	1520s polyphony, with works by Willaert, Senfl, Verdelot and others	491	MusicXML, Sibelius	scholarly
Lost Voices	http://digitalduchemin.org/	16th c. French chansons	c. 350	Sibelius	scholarly
John Robinson/Lute Society editions	https://github.com/TimCrawford/jhr_repo	Lute music from Renaissance and Baroque	c. 8000	TAB	citizen science
Electronic Corpus of Lute Music	https://ecolm.org	Lute music from Renaissance and Baroque	1619	TabCode	scholarly

sorted by main encoding format

Encoded modal cycles

resource	cycles
Josquin Research project	La Rue, Magnificat (4 pieces)
ELVIS	Glarean, Dodekachordon
Lost voices	Du Chemin, chansons books 1, 4-8 are ordered by modal pair
The 1520s Project	Rore, Madrigali à 5 bk 1
Tomás Luis de Victoria	Magnificat cycles by Ceballos, Guerrero, Morales, and Victoria
CPDL	42 complete cycles

CPDL seems a very useful resource

- contains individual pieces from other cycles as well
- MusicXML encodings are frequently corrupted (?converted from Lilypond?)

in general

- vocal cycles only, many Magnificat cycles
- almost no 12-mode cycles
- not yet a representative sample

Encoding Hoffmann

very interesting 12-mode source

- big: 24 pieces for 4-6 voices, 12 in natural and 12 in flat system
- compare to Hoffmann's own theory

unfortunately the music isn't that exciting

- encoding in MuseScore was quite tedious
- almost gave up after first 12


XXIIII. CANTIONES,
QVATVOR, QVINQVE, ET SEX
VOCVM,
ACCOMMODATÆ AD XII. TONOS, QVI
veteribus & præstantißimis Muſicis in vſu fuerunt, & à recentioribus
quoq; quibuſdam approbati ſunt, & vſurpati:
Authore
EVCHARIO HOFMANNO, FRANCO,
Scholæ Stralſundenſis Cantore.
Tenor
VVITEBERGÆ Iob. Schwertel excudebat, Anno M. D. LXXVII.

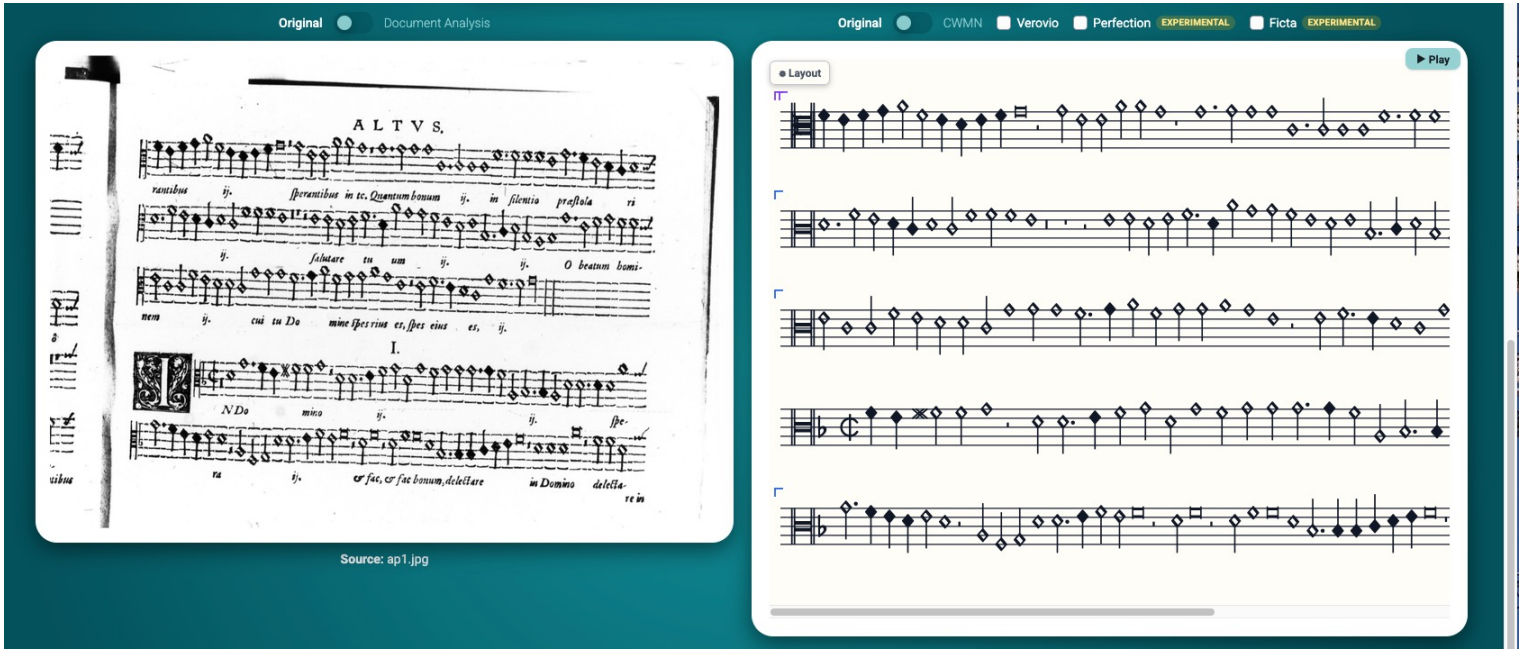
OMR to the rescue



I used David Cheong's Mensural Optical Music Recognition, https://omr-webapp-1046295414238.us-central1.run.app/ on the remaining 12 pieces

- scans separate pages of notation, multi-step interactive process
- decent performance even on mediocre scans
- anecdotally, sped up the data entry and first correction by at least 50%

MuRET



MuRET Lite: https://muret.iuii.ua.es/lite/

- scans separate pages, automatic process
- not tested extensively (yet), but substantial speedup is highly likely

current OMR tools are definitely robust enough for mensural music encoding

Next step: analysing cadences

cadences are an important feature of the modes, and of Renaissance polyphony in general

2-voice framework (a)

- preparation → dissonance → imperfect → perfect consonance

extension to 3, 4 and more voices (b)

- apparent V-I harmonic progression is a secondary feature
- cadences manipulated in all sorts of ways
- clausula patterns may appear *in all voices*

simplification for quantitative research (c)

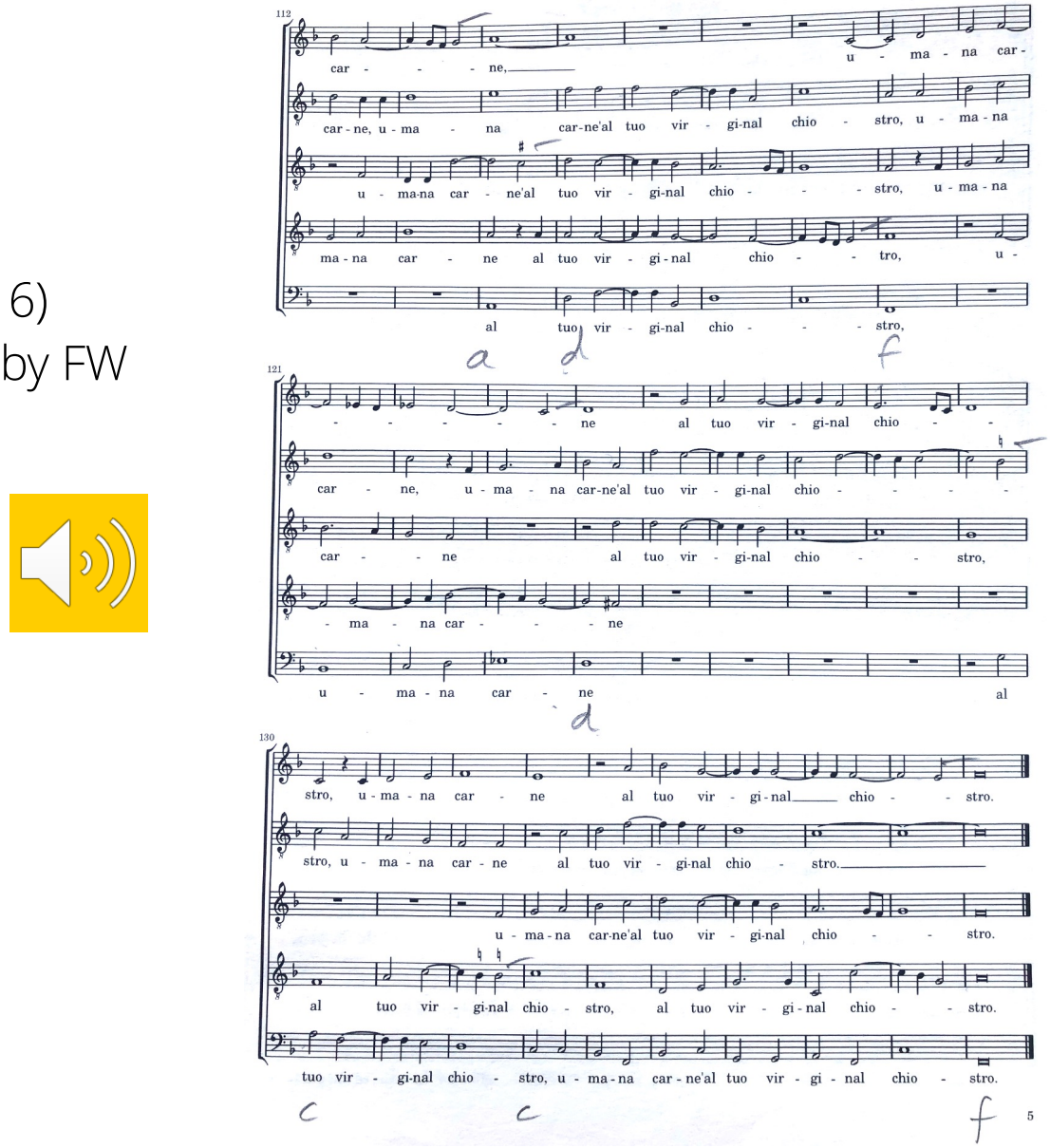
- clausula cantizans + dissonance, closing on strong beat



Example annotated score

Palestrina, Vergine chiara (mode 6)

- manual cadence annotations by FW



Palestrina's cadences

manual annotation by FW

cadence tool from *CRIM intervals*
- very detailed analysis
- only used the cadence tones

compared to manual annotations
- red boxes contain the same info

evaluation (complete cycle)
- precision: 0.949
- recall: 0.915
- F1: 0.932

quite impressive performance!

cadence mode	a	b	c	d	e	f	g	total
1	10		2	4	4	5	1	26
2	8			5	1		3	17
3	5		6		1		4	16
4	6		6		4		2	18
5			13	1		5	1	20
6	1		2	3		5		11
7	2			8	1		5	16
8	2		4	3	1	1	7	18

CadType	LeadingTones	CVFs	Low	RelLow	Tone	RelTone	Measure	Beat	Sounding
Clausula Vera	1	QCT	F2	P1	F	P8	24.0	3.0	4.0
Authentic	1	CTB	F2	P1	F	P8	34.0	1.0	5.0
Clausula Vera	1	CT	F2	P1	F	P8	44.0	1.0	4.0
Abandoned Authentic	-1	cx	C4	P12			61.0	1.0	3.0
Phrygian Clausula Vera	1	CT	D3	M6	D	M6	84.0	1.0	4.0
Phrygian Clausula Vera	1	CT	A2	M3	A	M3	114.0	1.0	5.0
Authentic	1	tCB	D3	M6	D	M6	115.0	1.0	5.0
Authentic	1	TCB	F2	P1	F	P8	119.0	1.0	5.0
Phrygian Clausula Vera	1	CT	D3	M6	D	M6	124.0	1.0	4.0
Clausula Vera	1	TCx	F3	P8	C	P5	130.0	1.0	4.0
Clausula Vera	1	CT	C3	P5	C	P5	133.0	1.0	4.0
Evaded Clausula Vera	-1	Tc	A2	M3			137.0	1.0	5.0
Authentic	1	CTB	F2	P1	F	P8	139.0	1.0	5.0

https://intervals-streamlit.crimproject.org/

CRIM intervals also available as Python library

Hoffmann's cadences (natural system)

Hoffmann lists modal cadences in his *Doctrina de tonis* (1582)

- shown here as squares (simplified)
- cadences in *Cantiones* (1577, nos 1-12) identified with CRIM tools

cadence / mode	a	b	c	d	e	f	g	g-sharp
1	7			11	1	4		
2	9			12		3	1	
3	13	2	5		13		2	1
4	7		8	2	7			
5	3		4			5		
6	3		9			7		
7	1	1	5	6			11	
8			4	2			9	
9	10		3	3				
10	5		6		2			
11			13	1			5	
12			9		4	1	2	

- reasonable agreement, with a few suprises going in both directions
- similar outcomes for flat system

Hoffmann's cadences (molle system)

Cantiones (1577, nos 13-24)

cadence	a	b-flat	c	d	e	f	g
mode							
1		2		4			7
2		2		6			8
3	4		3	10	4	2	
4	5	1	5	7		3	
5		6	1	6		5	
6		9		4		5	
7			3			5	4
8			7			5	5
9	4		2	12		3	1
10	3			6		3	
11			5			9	
12	4		10			11	3

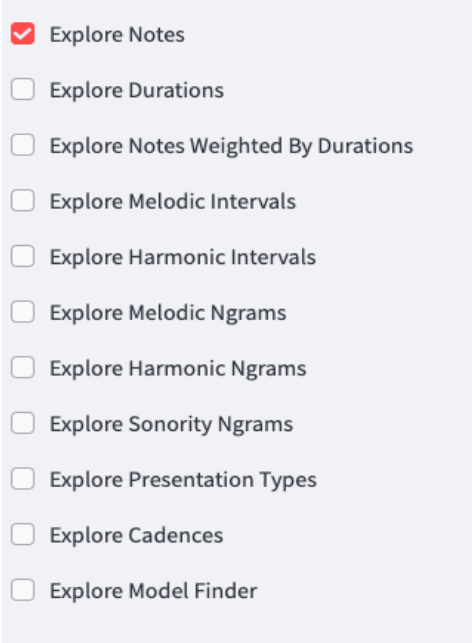
- again, reasonable match between theory and music
- CRIM tools seem to be doing a decent job
- promising for corpus analysis (given enough encodings…)

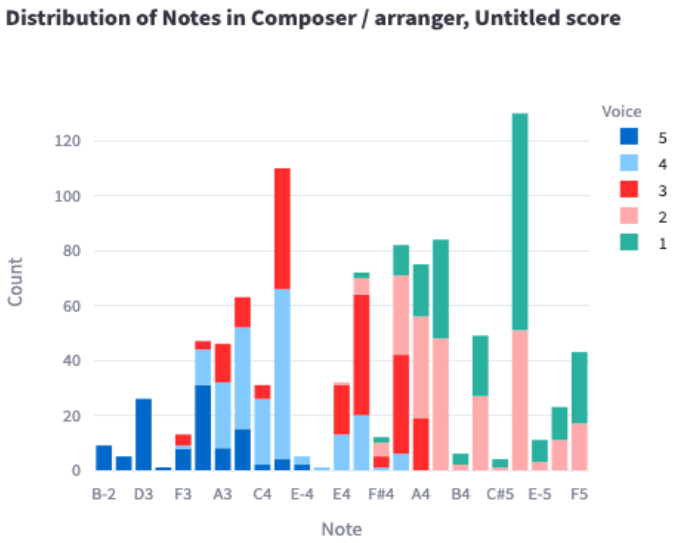
Symbolic wishes and possibilities

- CRIM tools
- several other symbolic tools sets

wishlist

- voice profiles and ranges
- melodic patterns
- dissonance, counterpoint
- sonorities, chords
- relationships between pieces
- beginnings and endings





Hoffmann, In Domino spera (mode 4, flat system, final a)

availability of encodings remains a major limitation

- for ideas on how to remedy this see CORSICA report (Bergwall et al. 2025)

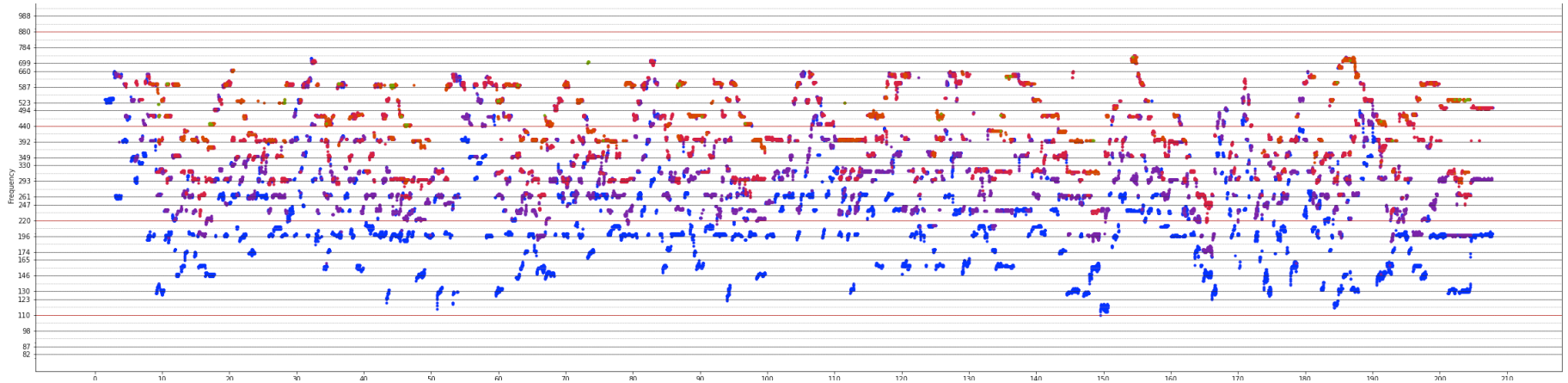
Level 5: audio recordings

the number of audio recordings is *much higher* than the number of encodings

- much technical progress in audio music analysis

recent multiple F0 extraction methods perform very well

- deep learning method developed by Cuesta et al. (2020) gives best results
- example: Palestrina, *Vergine bella*, performed by Hilliard ensemble
- note: shows pitch observations: no notes, no voices



Corpus analysis with pitch class profiles (pcps)

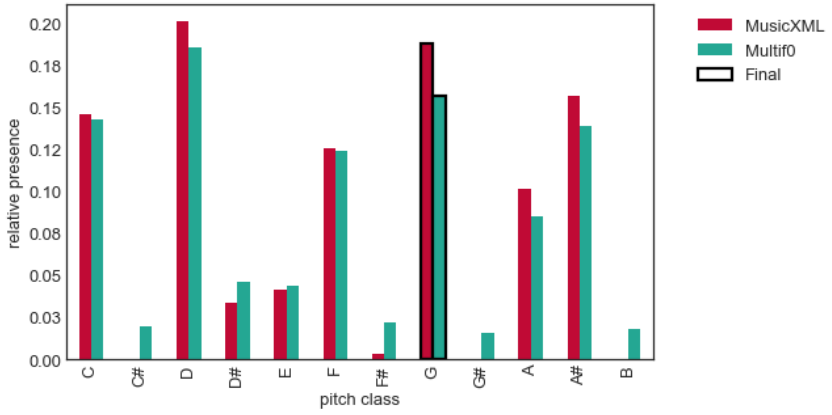
pcps are histograms showing the presence of each pitch class in a composition

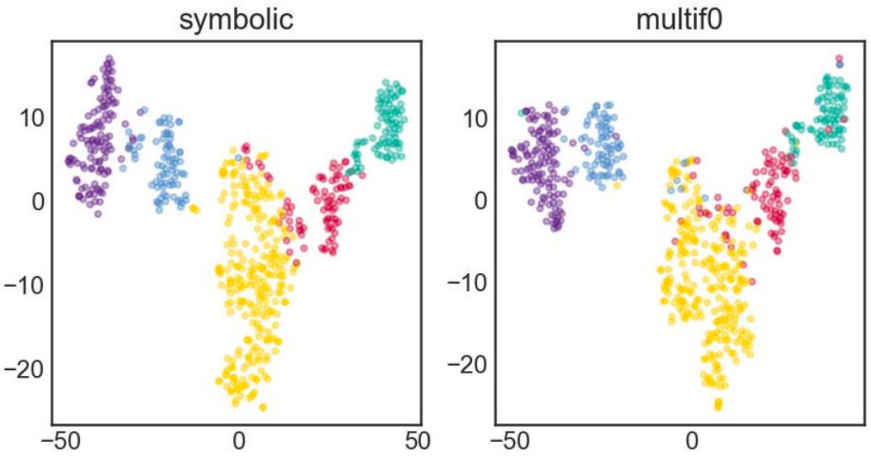
audio pcps closely resemble symbolic pcps

- systematic comparison on Josquin research Project (Visscher & Wiering 2025)

unsupervised clustering

- symbolic and audio clusters very similar!
- modal pairs clearly visible
- Lydian not a separate cluster





encodings: 611 pieces from Josquin Research Project, https://www.josqu.in/
audio: https://open.spotify.com/playlist/2QyBpYbo1W5fZhjrIx1uew?si=ef55e1ae74294179
extractions: https://zenodo.org/records/15352071

Creating an audio corpus

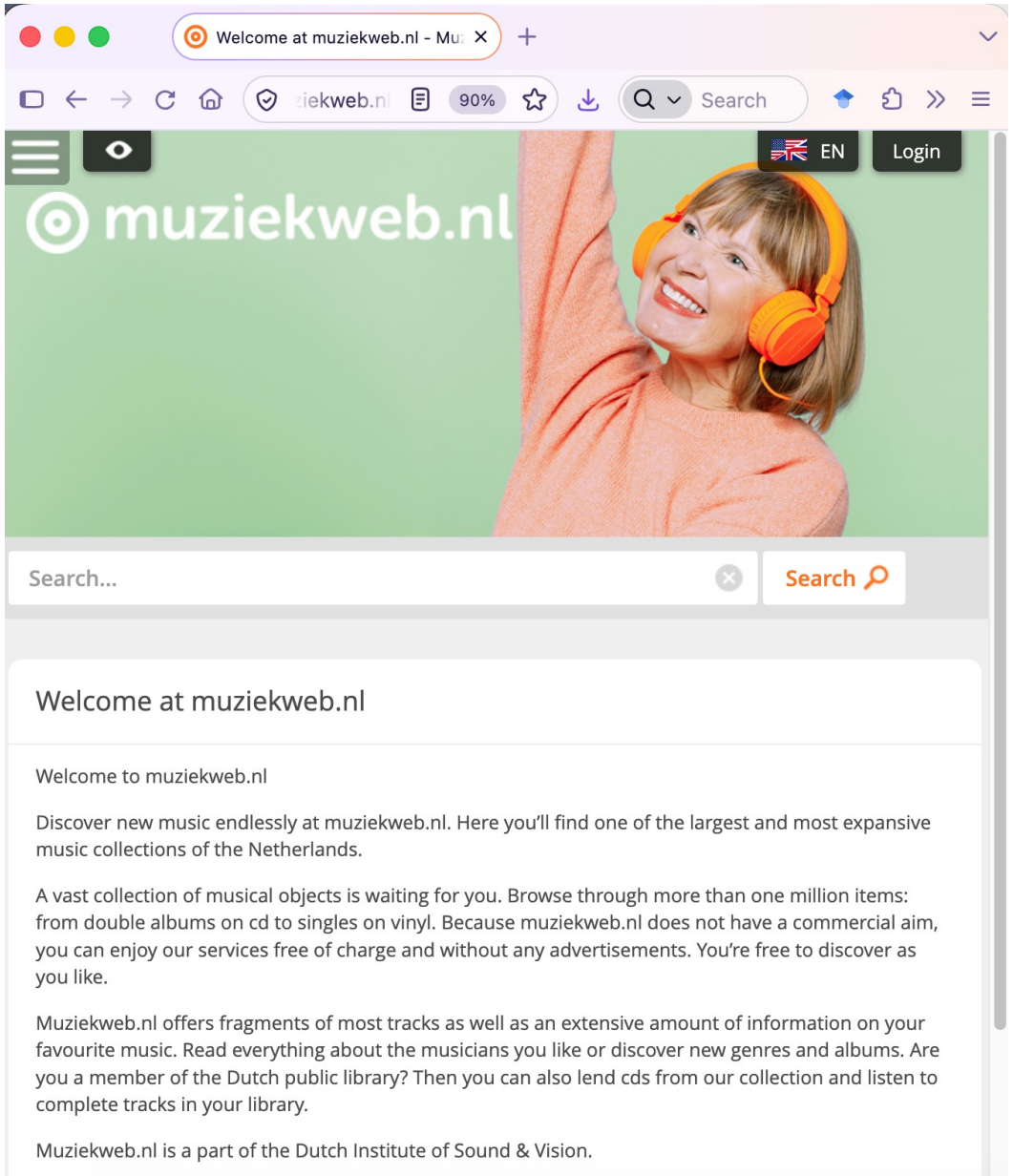
special agreement with Muziekweb.nl

- 8,699 compositions, represented by 12,140 audio tracks
- composed between 1450 and 1750
- balanced for quarter centuries
- representative for countries

MultiF0 extractions

- pitch class profiles
- therefore no authentic/plagal distinction

source: PhD thesis Mirjam Visscher (2027)

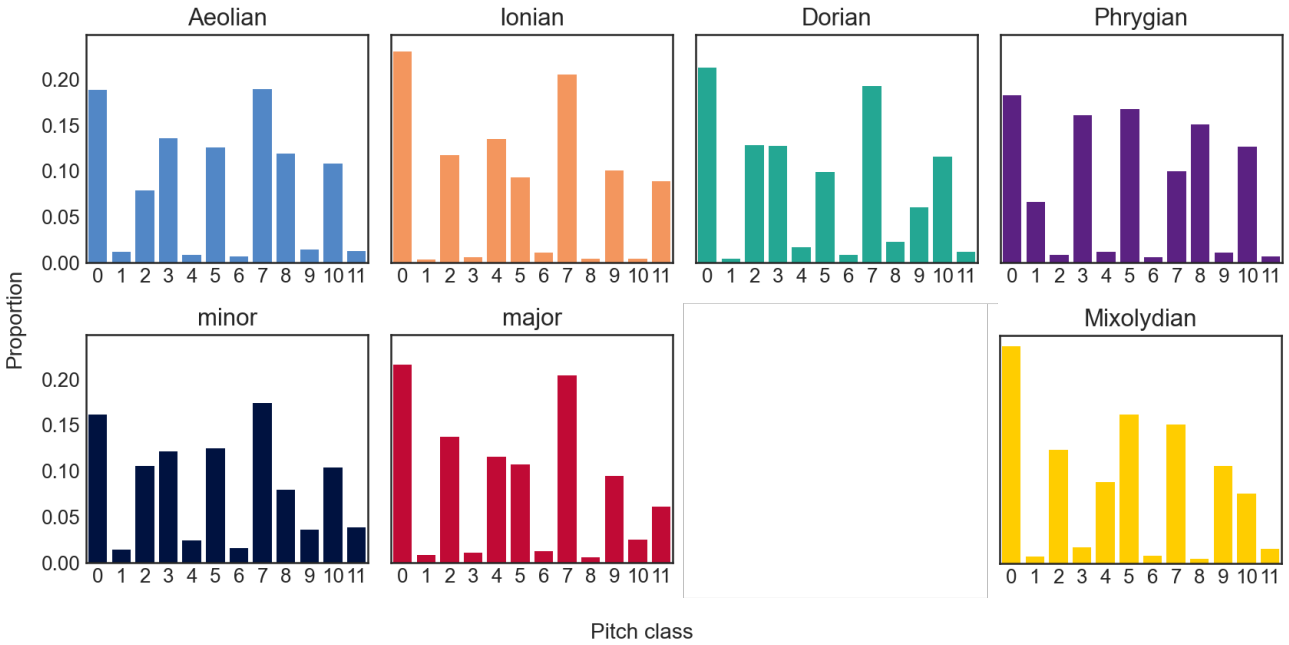


Study the evolution of modality and tonality

2 sets of reference pitch class profiles, aligned to the final
- 5 modal pairs (c. 1500)
- 2 (tonal) keys (c. 1700)

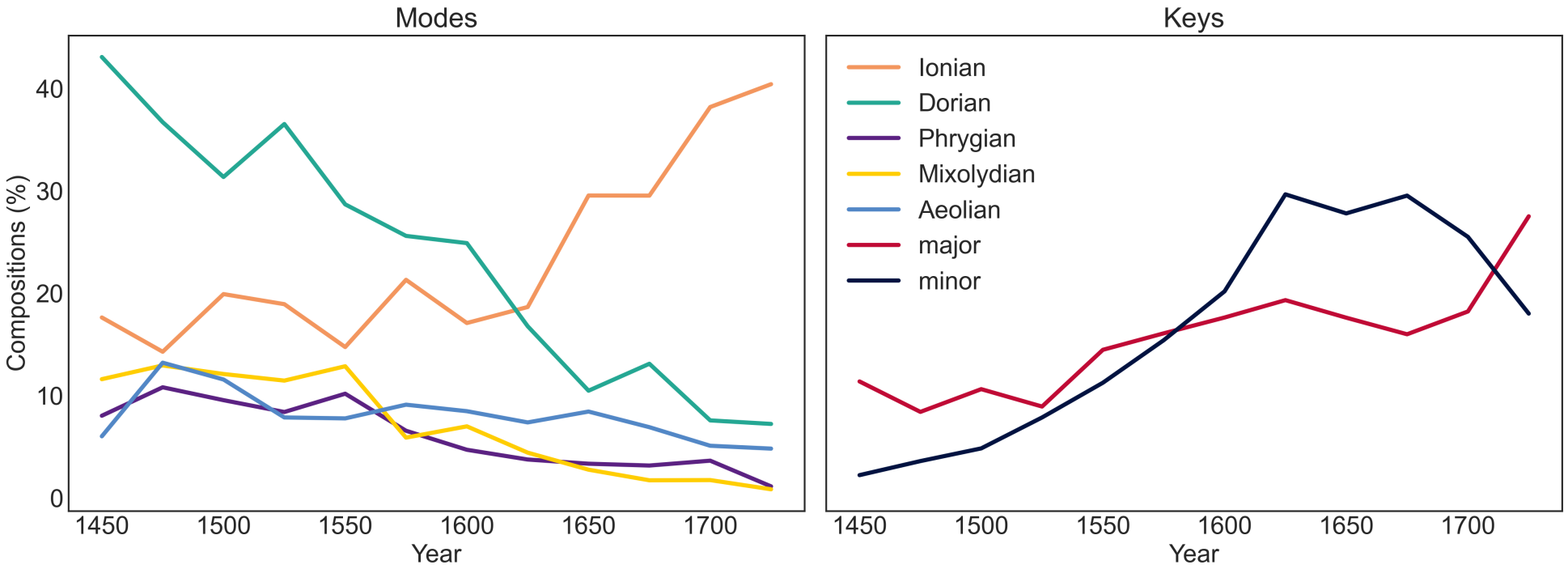
analyse data from two perspectives, beginning and end
- how strong is the presence of the profiles in the data

closest profile → label



Visscher, Wiering and Van Kranenburg (2026)

Development over three centuries



- modal pairs, show a downward trend, Ionian excepted
- keys show an upward trend
- should interpreted as tendencies in the corpus, not as observations at composition level

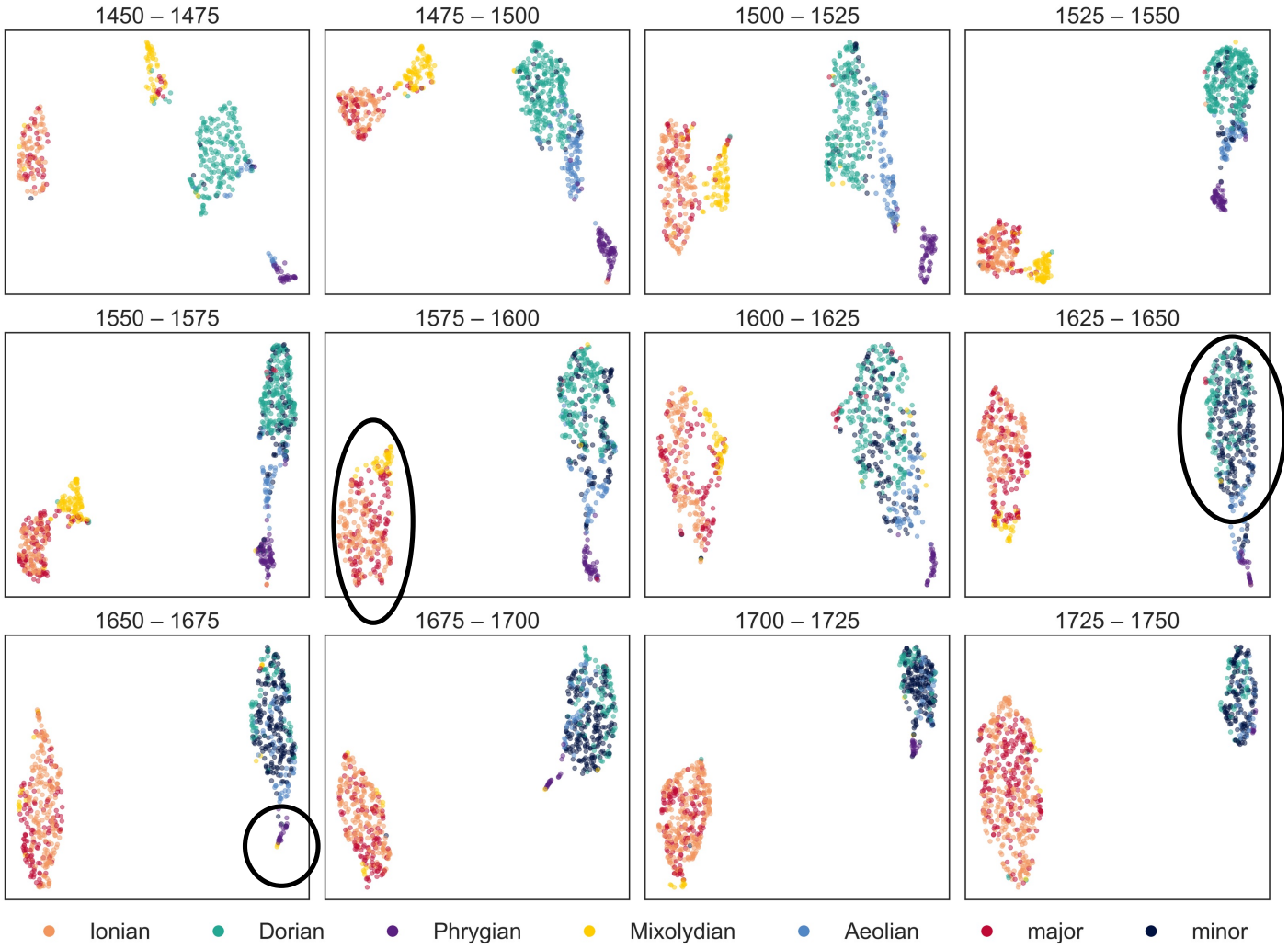
Clustering (supervised) per quarter century

main tendencies

- Mixolydian merges gradually with Ionian/major
- Dorian/Aeolian becomes increasingly minor
- Phrygian gradually disappears

some caveats

- not about modal cycles
- just pitch class feature
- other features might paint a different picture



What is mode in polyphony, and how does computing help?

studying the data at scale does bring us closer to some answers

- defuses the ‘reality’ question (Powers) – mode was definitely a cultural reality
- undermines the ‘universal’ stance (Meier) – there is just too much variety and contradiction
- leaves us in the middle: a flexible theoretical system with an amazing practical and creative potential

only some relevant aspects of modality have been studied here

- scale, final, range and cadence are relatively easy to model
- melody is more difficult, not to mention affects, meanings and contextual factors

unreflective application of computational methods may emphasise the similarities between modality and tonality

- ‘otherness’ of the modes is more difficult and maybe more important to understand

Some generalisable experiences

just by collecting and ordering data one can already create a nuanced overview of a substantial research theme

music-historical data this isn't really 'big' data

- accumulation of lots of hand-crafted small data encapsulating enormous amounts of expertise

this necessitates a constant alternation of close and distant reading approaches

- dialogue between qualitative and quantitative methodologies

dataset design and creation is often undervalued in comparison to other kinds of academic output, and this should change

Generalising a little further

access to usable encodings is a very serious bottleneck
- develop collaboration with citizen scientists

audio corpus analysis has become a mature methodology
- complements symbolic analysis

at all levels, interesting tools are available for part of the work
- programming one's own tools remains necessary

variety in data is helpful for addressing a wide range of aspects of the topic
- but raises considerable interoperability issues

Conclusion for digital musicology

it is important to tackle substantial research themes like polyphonic modality both as a *driver* and as a *validation environment* for computational and digital musicology approaches

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- Muziekweb (audio data)
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- Richard Freedman and Alex Morgan (CRIM Intervals)



thank you for your attention

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