

Half a million Gregorian chants

On a computational playground

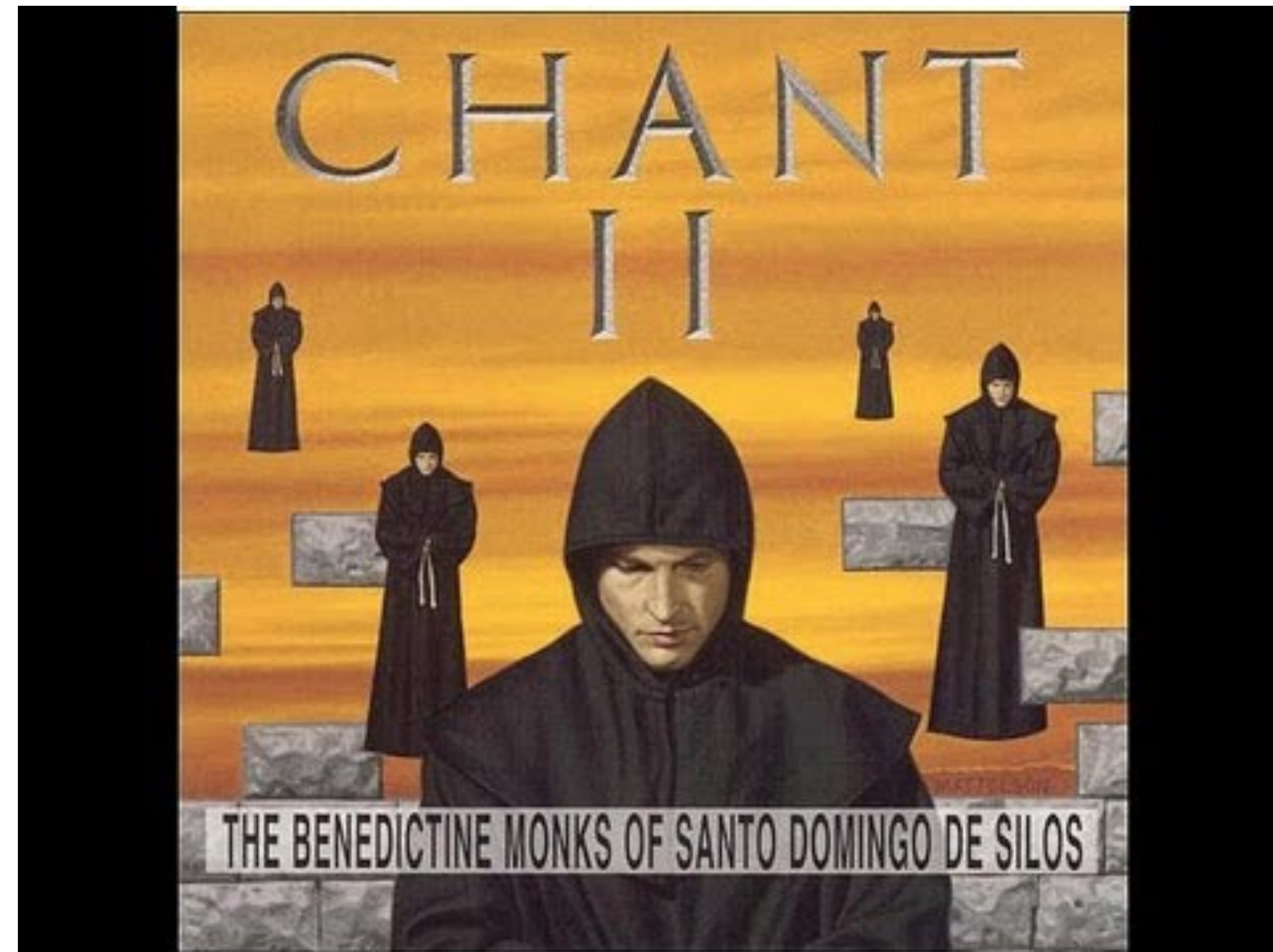
Jan Hajič jr, ÚFAL MFF UK/MÚA CAS, 2023-06-15

Research opportunities!



What is Gregorian Chant?

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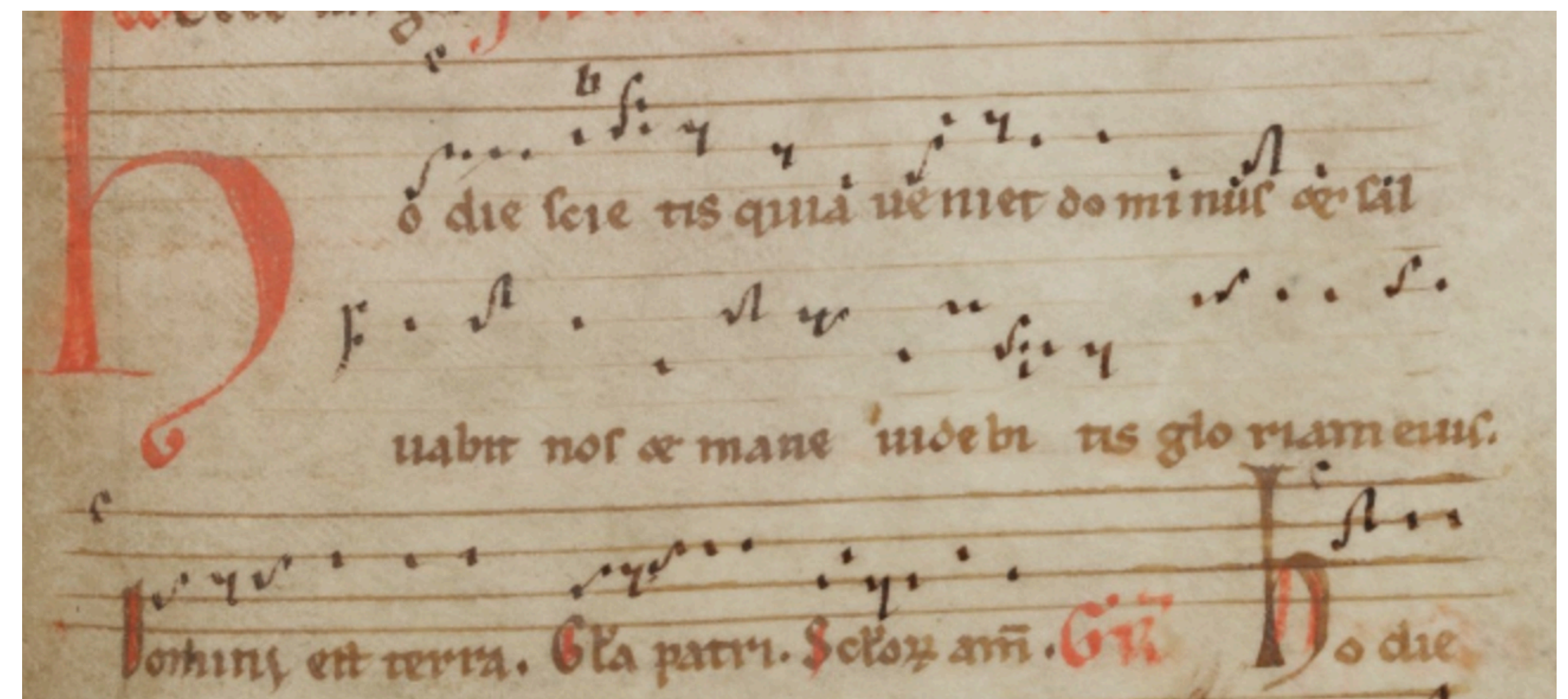
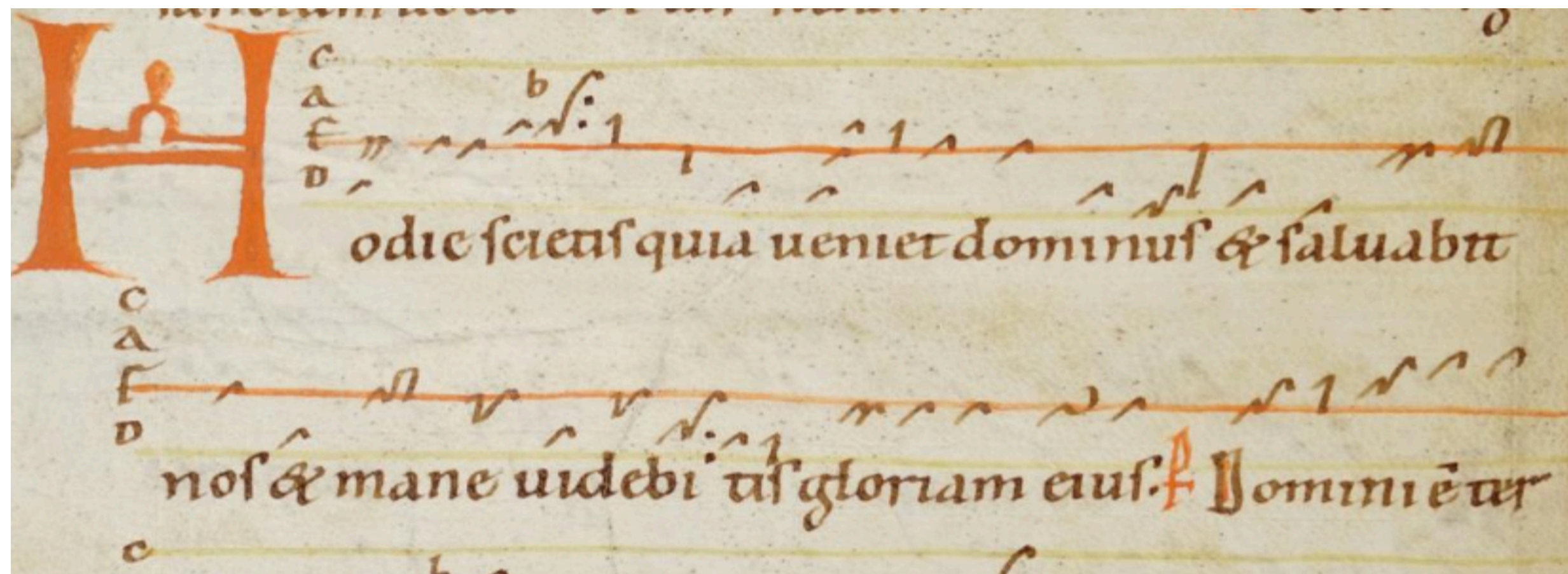
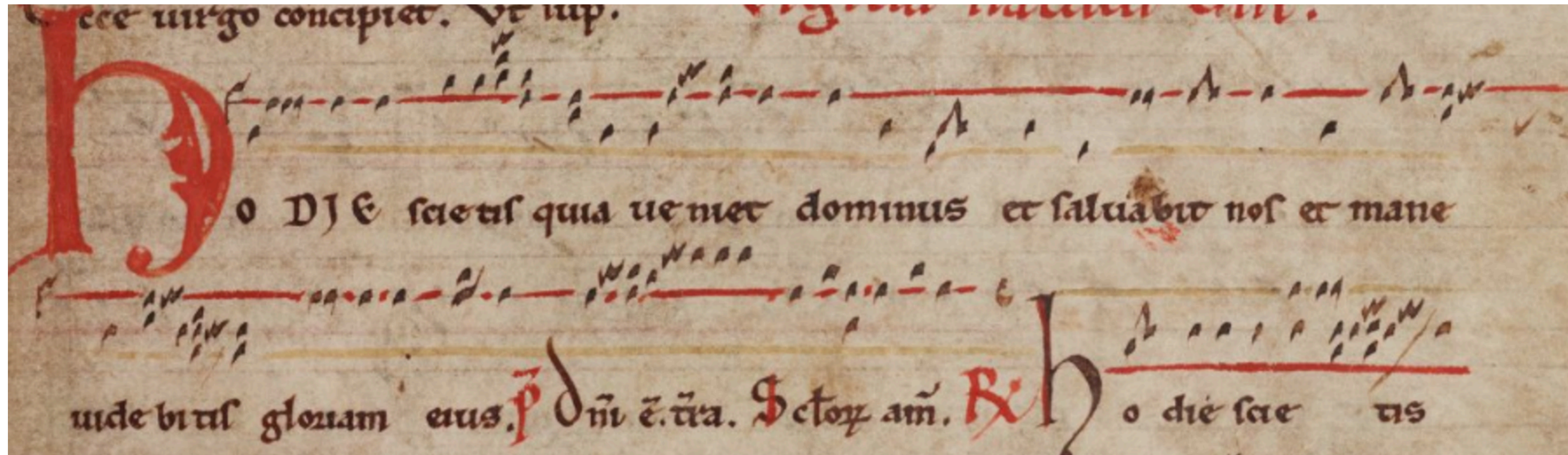


<https://www.youtube.com/watch?v=-mWBF3W-ORU>

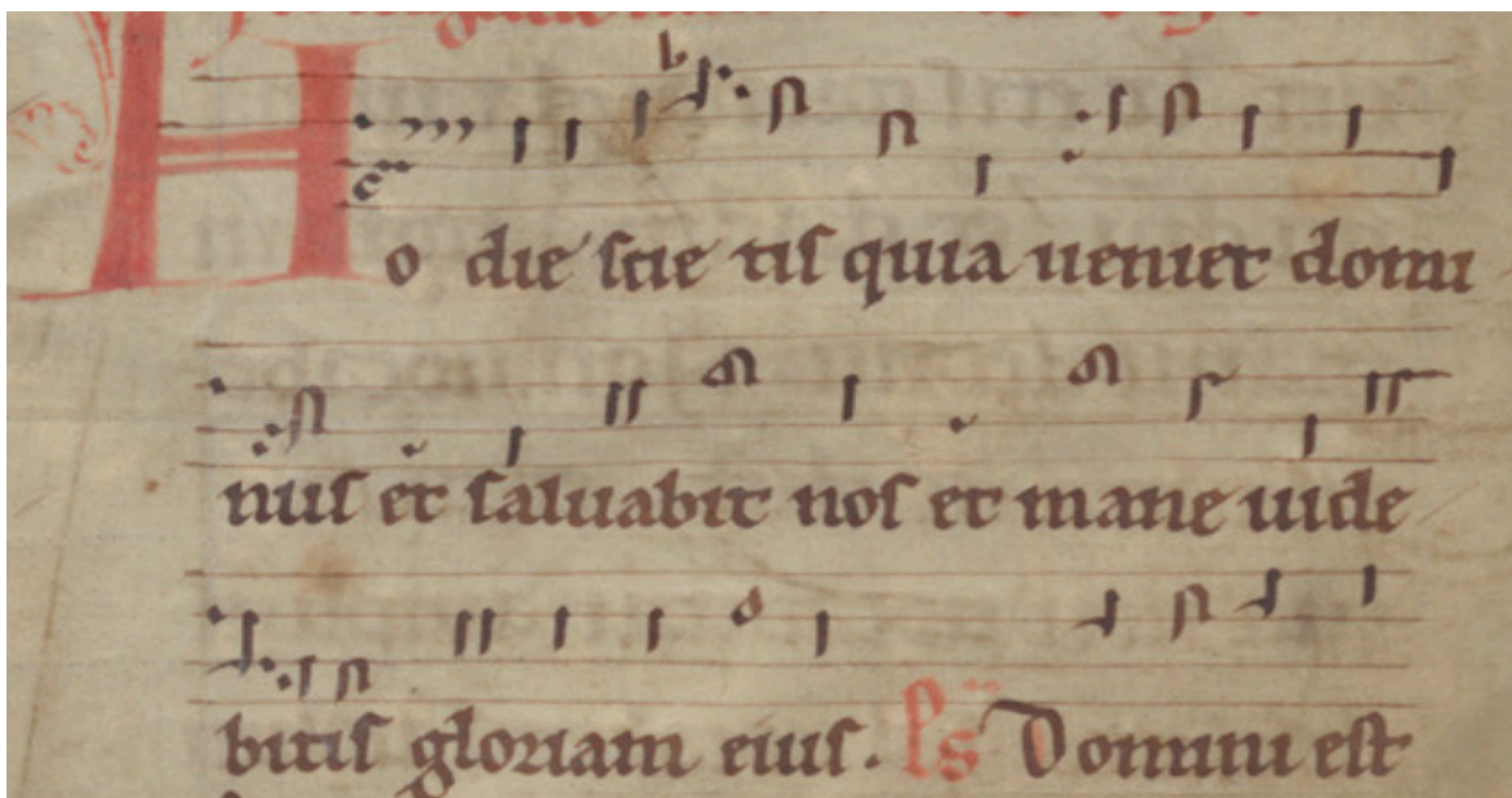
What music is this?

- **Vocal monody.** A single melody sung on a given Latin text.
- **Liturgical.** Performance itself is an act of worship, a ritual. Always in a sacred context. (Leaving aside concert performances...)
 - The act of **singing** a text in a certain way is what marks the text as sacred.
 - **Text is primary.**
- **Oral tradition.** Sung primarily from memory.

What music is this?



What music is this?



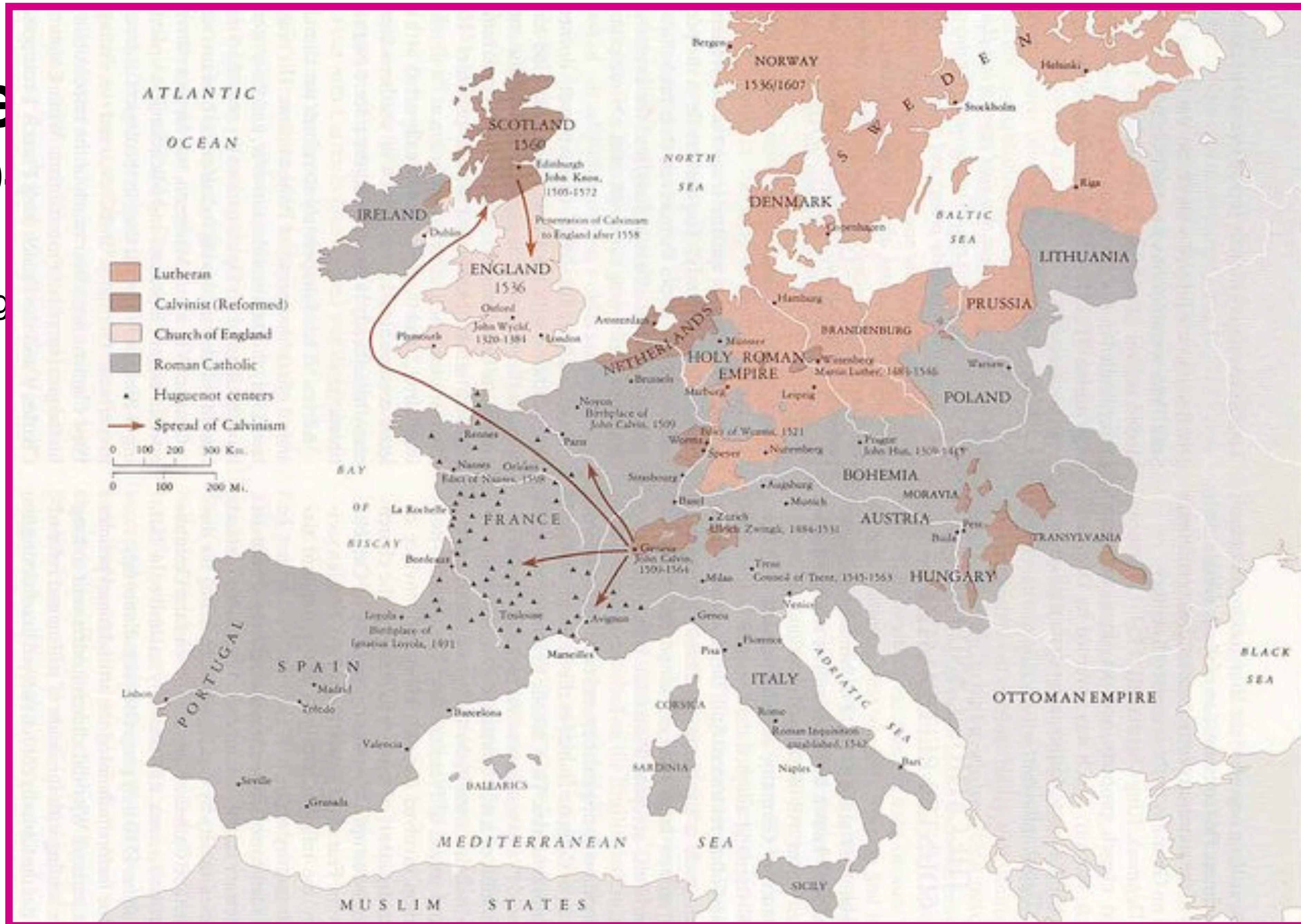
Gregorian Chant

1500+ years of music in 45 minutes

- Liturgical music of the (Roman) (Catholic) Church, 600(?)—2023(?)

Great 1500

- Liturg



Gregorian Chant

1500+ years of music in 45 minutes

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- Monody (just a single melody)
 - No rhythmic values recorded, pitches (C, D, E, ...) only after ± 1050
- Melodies organized according to mode

“Musical” aspects

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“Musical” aspects

- Principles of repertoire organisation
 - Type of liturgy and position within a service selects genre
 - Position within the “liturgical year” selects specific text and melody
- Sources correspond to this organization: “liturgical books” for types of service, temporal order

**Repertoire: description,
transmission, reception**

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- **Primarily an oral, memory-based tradition**

**Repertoire: description,
transmission, reception**

Gregorian Repertoire

Chant in Liturgy

- Roman Catholic liturgies (services) are very strictly defined **rituals**
- Each liturgy has prescribed steps (which follow from the meaning of the ritual):
 - What **actions** must be performed (e.g.: “Now the priest goes to the left side of the altar.” “Now the altar boy rings a bell.” “Now the congregation stands and the priest reads the gospel.”)
 - What **texts** must be said (e.g.: introductory formulae, prayers for the day, reading from the Gospel, a series of blessings throughout...)
 - **How** these words are to be said: spoken aloud by the priest (or the congregation), spoken silently by the priest, **or sung** (by the priest, the congregation, or the *schola*)
- **Gregorian chant is the primary way of singing** those texts which ought to be sung.
 - Conversely, chant should be sung at the times and in the ways in which liturgy prescribes it.

Types of liturgy

- **Mass**

- Central form of Christian/Catholic worship, eucharistic sacrament
- Usually public, with the laity (i.a. participating in the sacrament)
- If you have been to church: this is the typical liturgy there.
(Architecture of churches is subordinated to how mass is performed.)

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(Architecture of churches is subordinated to how mass is performed.)

- **Divine Office**

- Compulsory prayers for clergy — priests, monks.
- No laity participation (can watch if Office takes place in an accessible location)
- Rule of St. Benedict: 7x a day, roughly 3 hours apart outside of night

Chant genres in liturgy

Mass

Office

Liturgy

Chant genres in liturgy

Mass

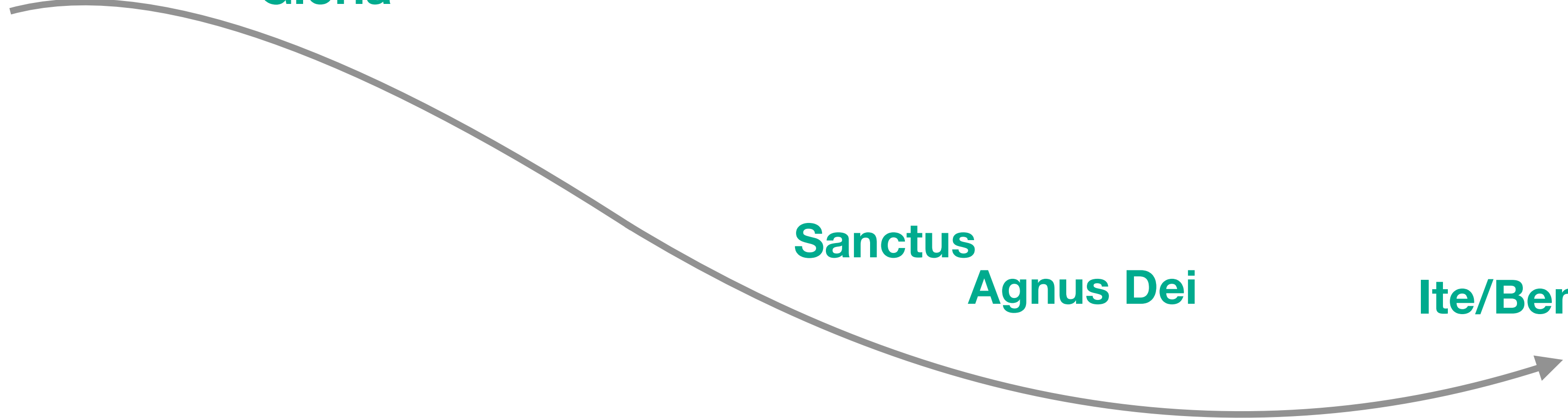
Kyrie Gloria

Sanctus
Agnus Dei

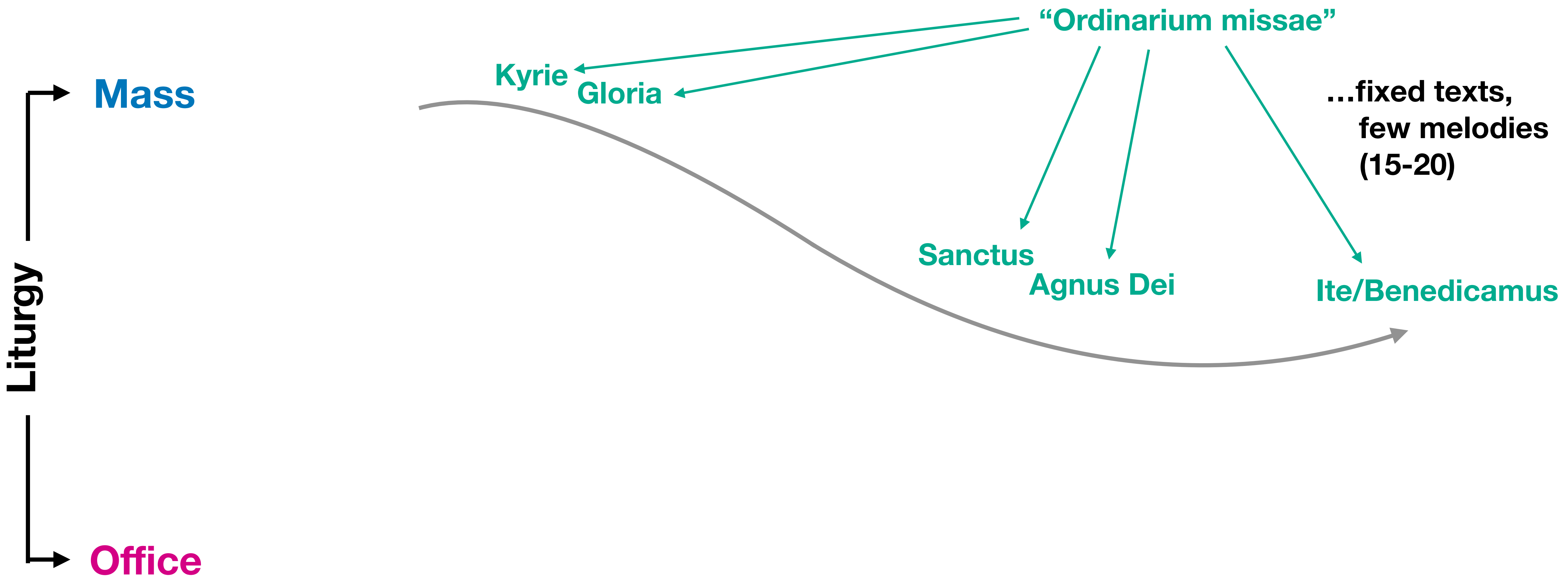
Ite/Benedicamus

Office

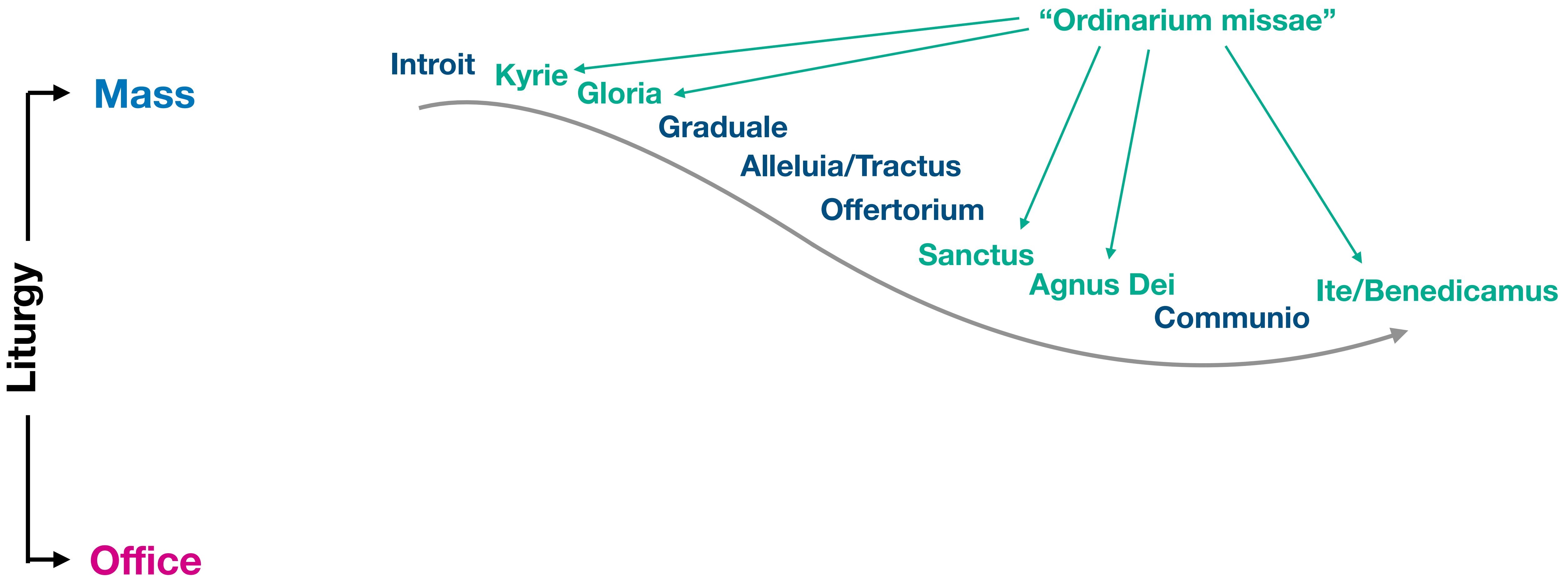
Liturgy



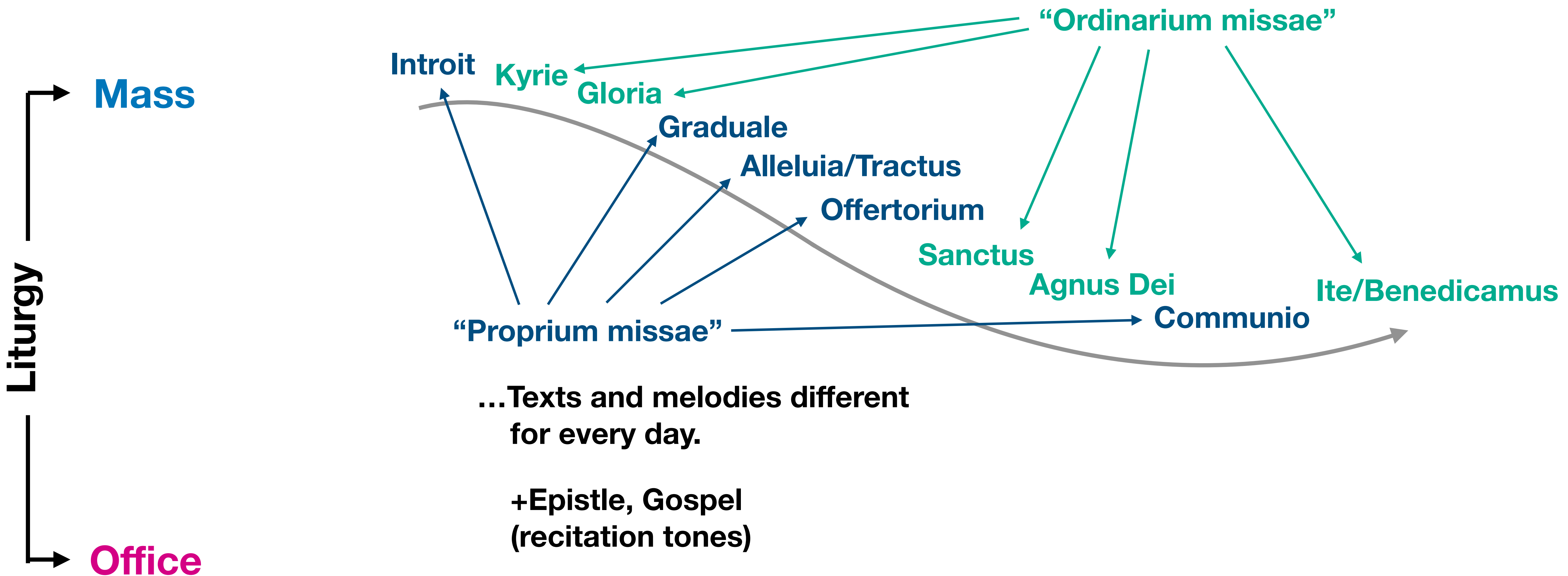
Chant genres in liturgy



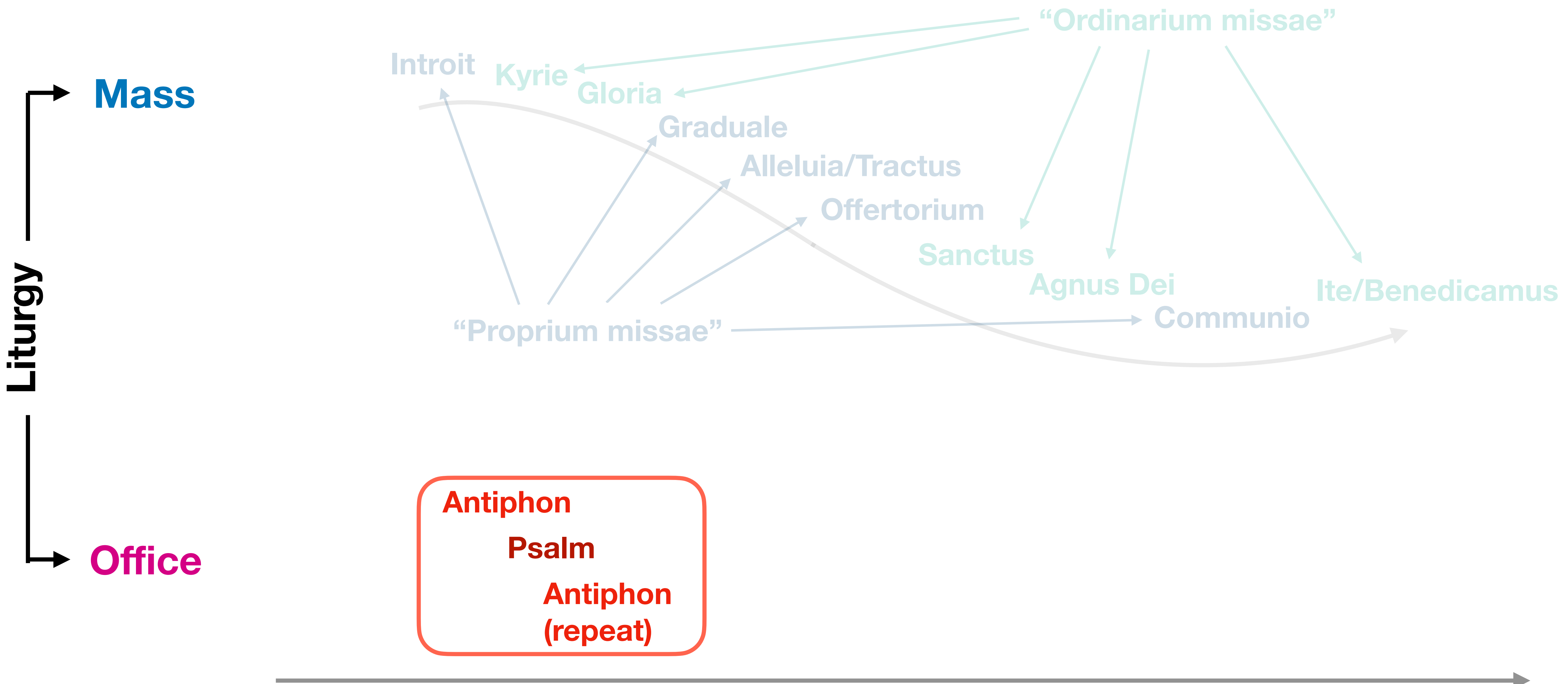
Chant genres in liturgy



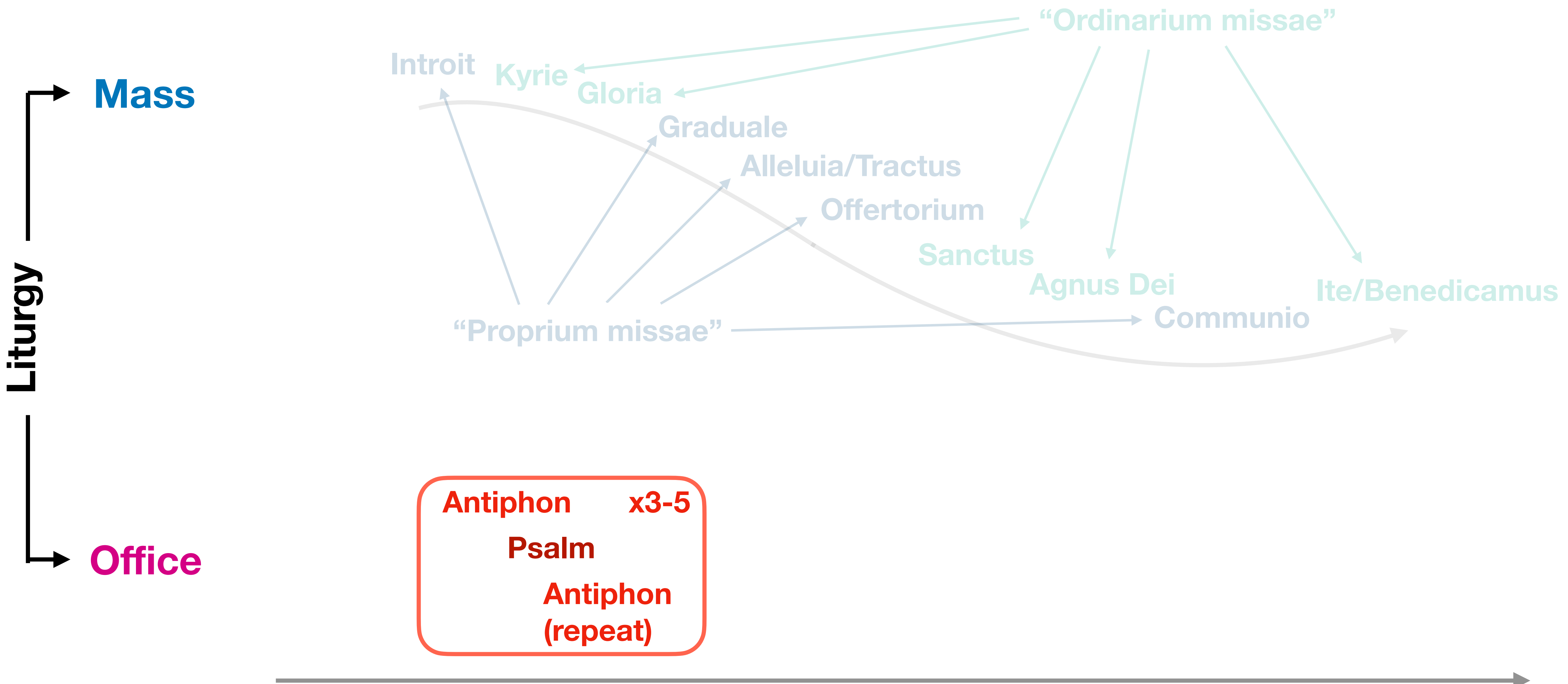
Chant genres in liturgy



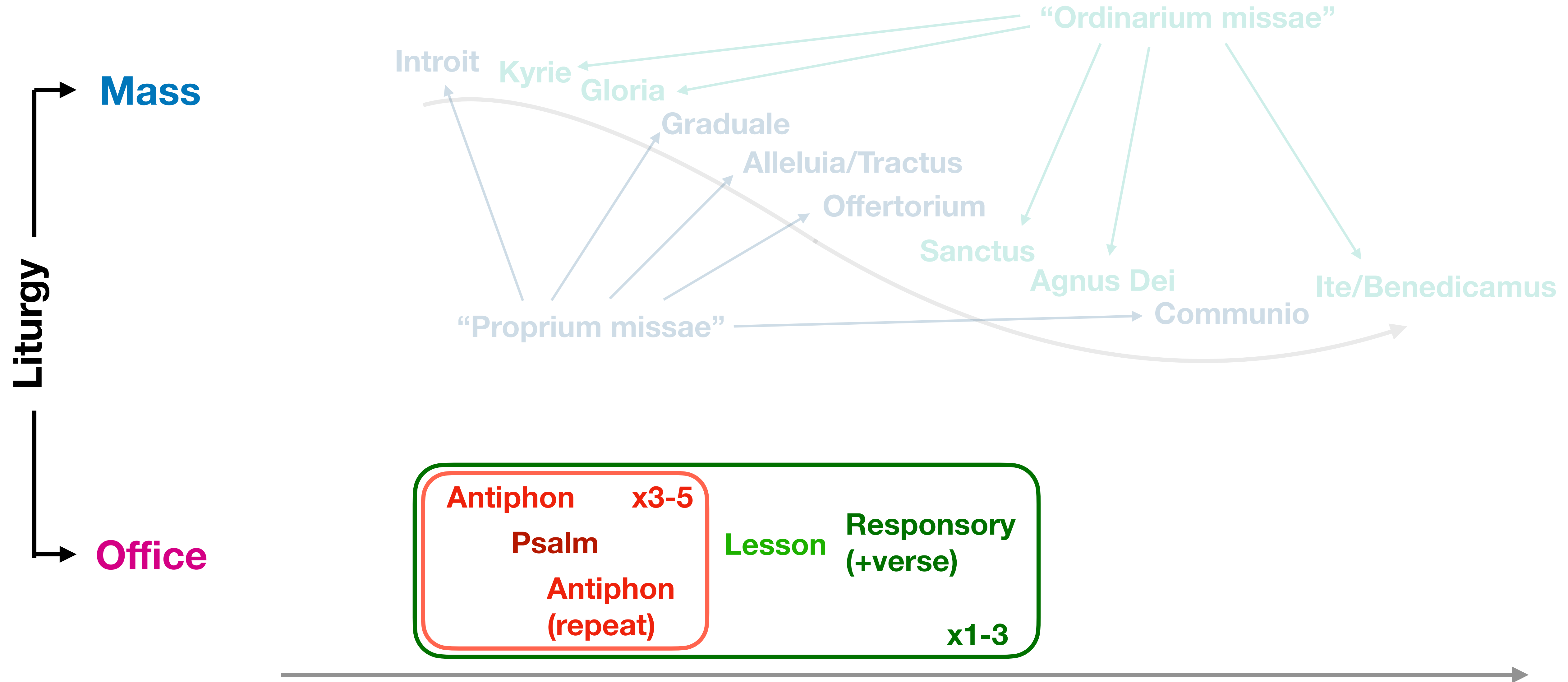
Chant genres in liturgy



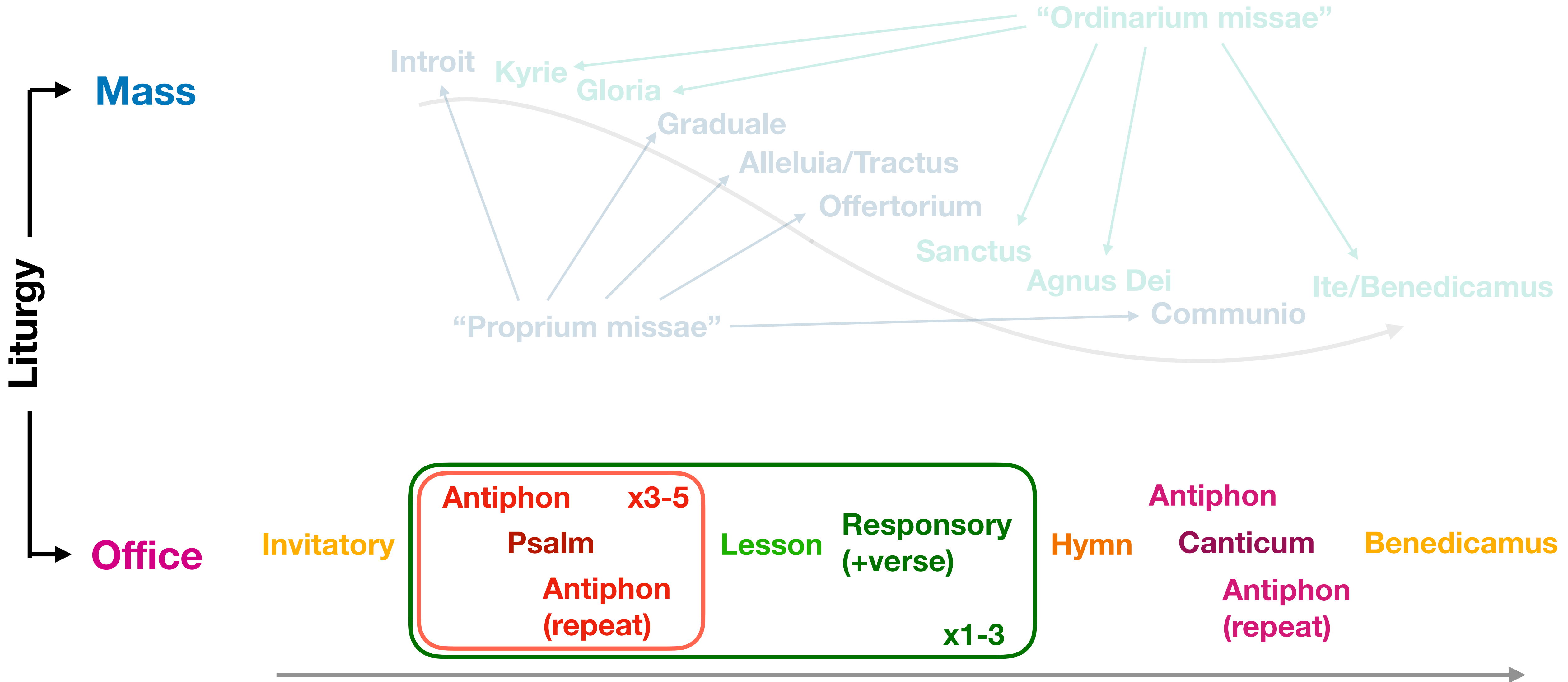
Chant genres in liturgy



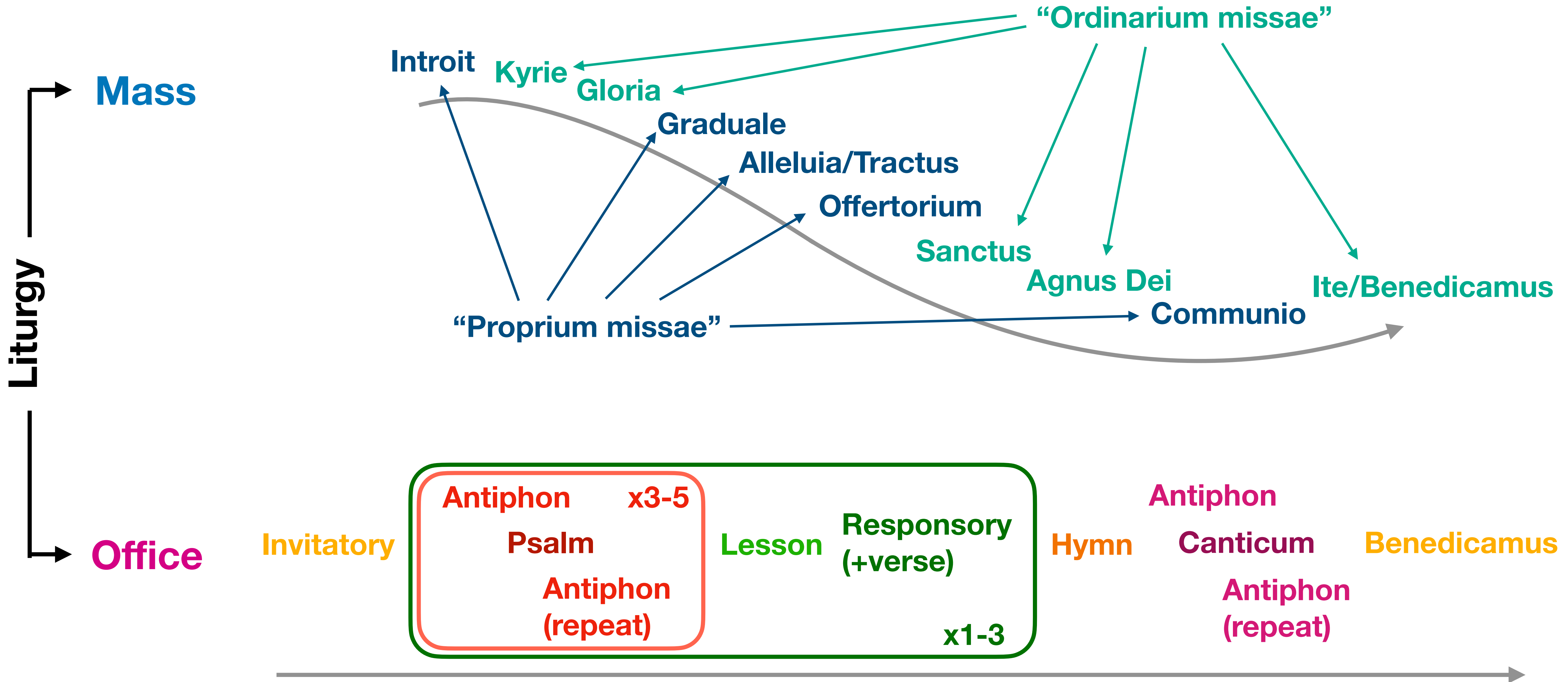
Chant genres in liturgy



Chant genres in liturgy



Chant genres in liturgy



Sources of chant: Liturgical books

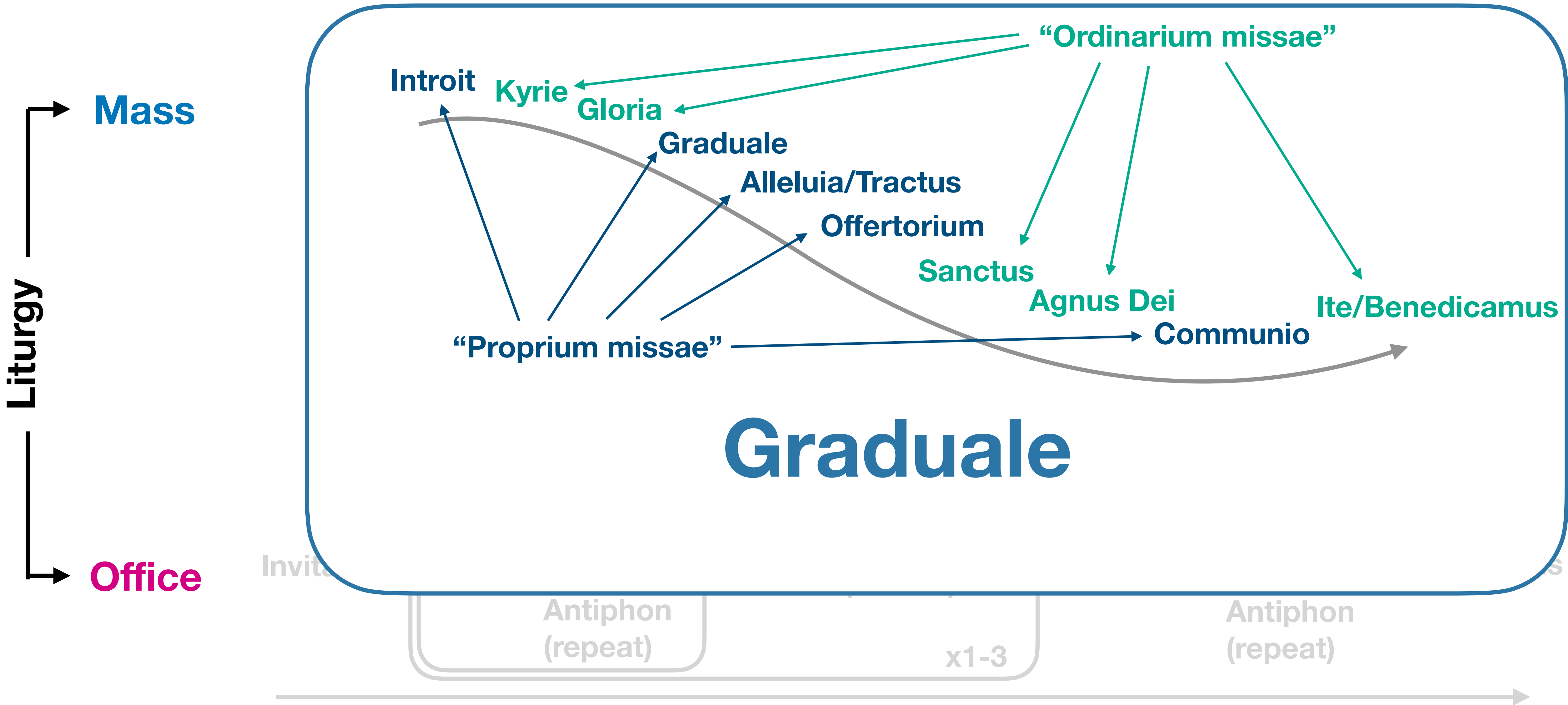
Mass

Liturgy

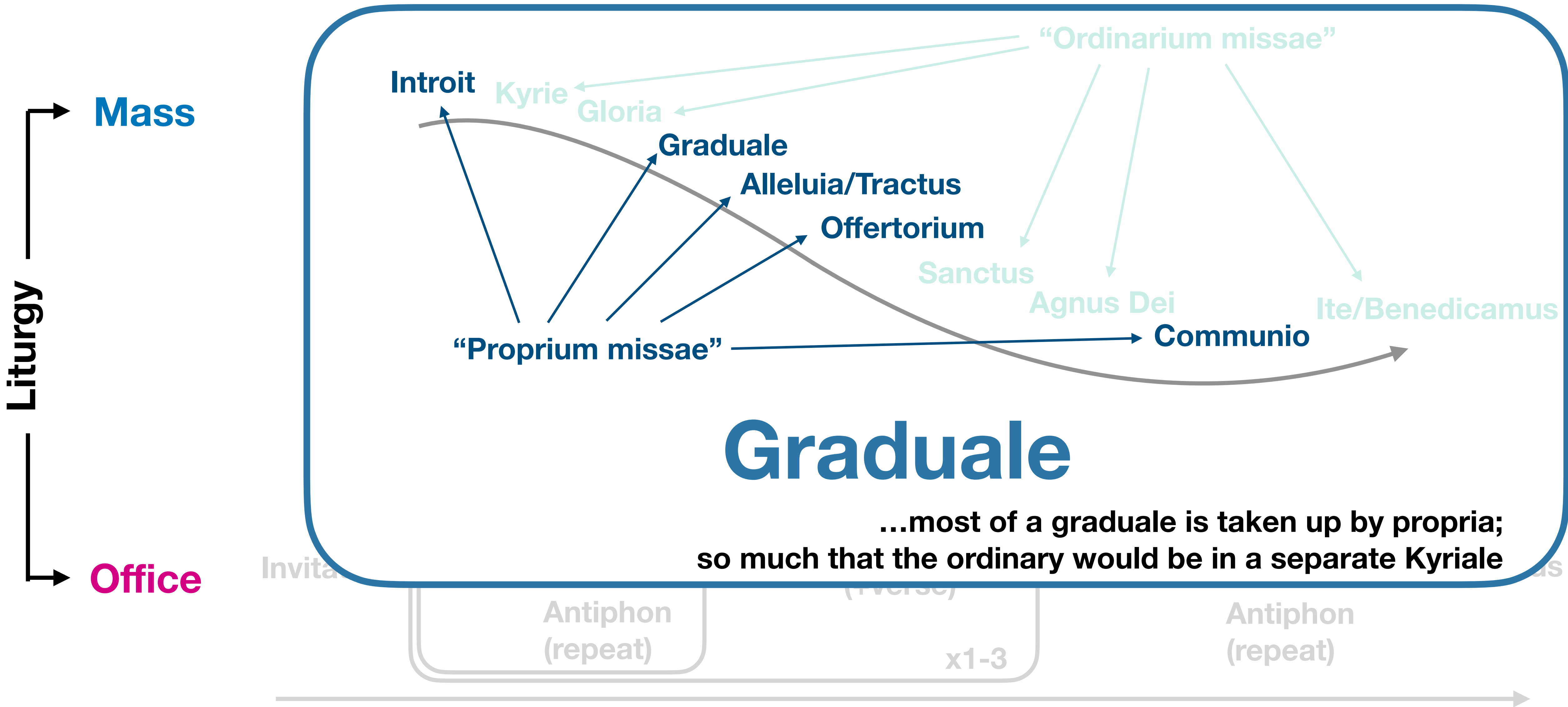
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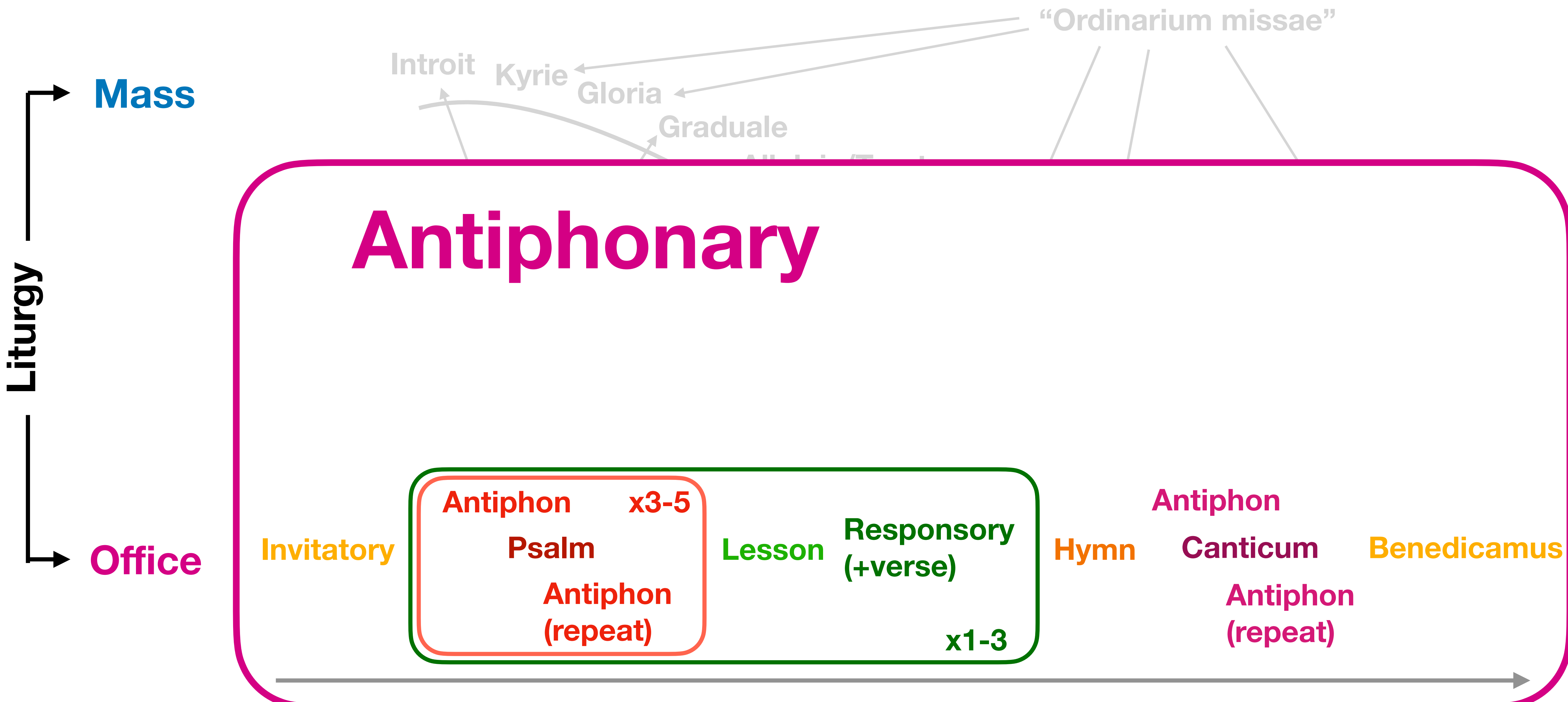
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Liturgy

Mass

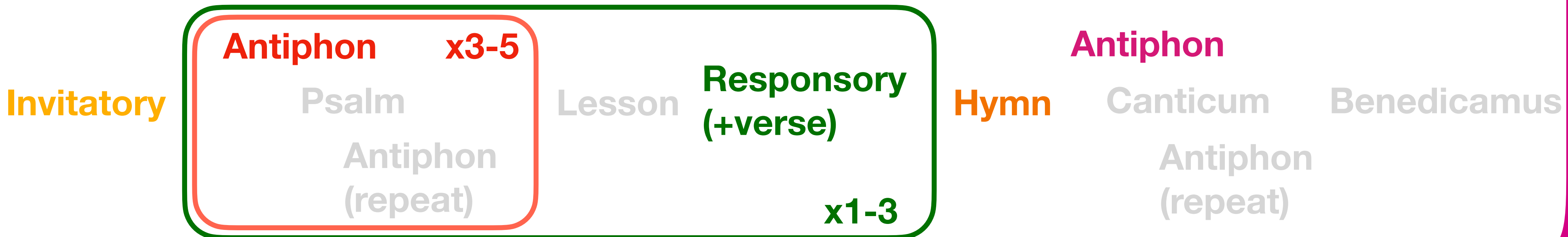
Office

Introit Kyrie Gloria Graduale

“Ordinarium missae”

Antiphonary

...mostly antiphons and responsories.
 Psalms & cantica known by heart (and if need be, in a psalter).
 Hymns can be in a hymnary.
 Mixed sources exist! (Esp. in Bohemia: “Graduals” of the Hussites/Utraquists)



Organization of liturgical books

- A Gradual or Antiphonary contains usually more than 1000 melodies.
- No `ctrl+f` in 1150... how to find what you need?
- Solution: write down chants **in the order in which you need them.**
 - Start where you left off last time!
 - Needs only a bookmark.
 - Gradual stays on the organ loft (schola sings during mass)
 - Antiphonaries stay in the “choir” (clergy sings)

Liturgical year

- **Advent** — Christmas — **Ordinary time** — **Lent** — Easter — **Ordinary time**
- **Feasts:** Christmas, Epiphany, Easter, Pentecost, All Saints, Corpus Christi, Trinity...
- Many **Marian** feasts, individual **Martyrs**, other saints, ...
 - Sundays & weekdays numbered by to their relationship to major feasts
“16th Sunday after Trinity”
“Wednesday after 16th Sunday after Trinity”
- **Every liturgy of every day in the year has a prescribed set of chants!**
- Thus is defined the order in which you need the individual chants,
and therefore the **order in which they are written** into liturgical books

Gregorian Melodies

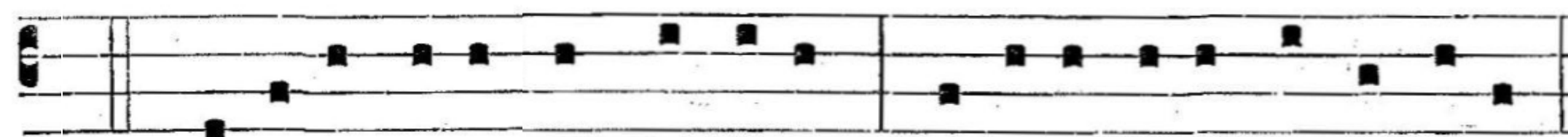
Chant melodies

How can we describe them?

- Predates nearly all of European music theory!
- Concepts that apply:
 - **Complexity** (mostly: melismaticity — how many notes per syllable?)
 - **Form** (=are there repeated parts? How do they repeat?)
 - **Modality** (=contemporaneous theory, but also not just theory)
- Modern attempts at new theories of chant melody not too successful so far.
 - Semiotics, centonization, memory-based coalescence, ...?

Chant melodies: complexity

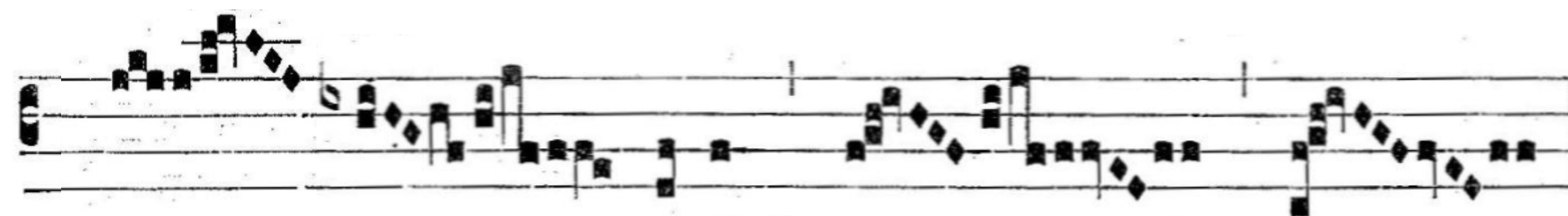
From syllabic to melismatic



Ps. Laudá-te Dómi-num de cae-lis : * laudá-te e-um in excélsis.



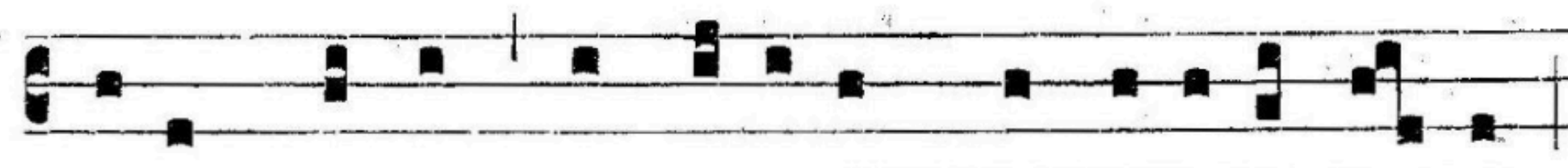
exal-tá- tum est nomen e- ius so-lí- us :



pá- tu- it. *

Comm.

5.
V



ENIT Sponsus; * et Vírgines, quae pa-rátae e- rant,

Grad.

3.
S



PECI- OSUS * for- ma



prae fí- li- is hó- mi- num, dif-fú-

Chant melodies: form

- Straightforward forms: from beginning to end, no repetitions
- Forms with a “verse” in the middle
 - Psalm verses in 2 parts:
initiation — recitation — middle — recitation — ending

Psalm



1. Do - mi - ne probasti me et	cogno - vi-sti me:	tu cognovisti sessionem meam et resurrecti - onem meam.
2. Intellexisti cogitationes	me-as de lon - ge:	semitam meam et funiculum meum in - vesti - ga-sti.
[verses 3-23 omitted]		
Glo - ri - a	Pa-tri et Fi-li-o,	et Spi - - - - - ri-tu-i Sancto.
Si - cut erat in principio, et	nunc et sem - per,	et in saecula saecu - - - - - lorum. Amen.

Chant melodies: form

- Straightforward forms: from beginning to end, no repetitions
- Forms with a “verse” in the middle
 - Psalm verses in 2 parts:
initiation — recitation — middle — recitation — ending
- “Respond” principle, like a refrain
- Strophic forms: hymns, sequences, ...

Chant melodies: modality

Where problems start.

- Modality as a **music-theoretical principle** from ancient Greece
 - Transmitted from Boethius, Martianus Capella, late antiquity sources
 - 8 modes: dorian, hypodorian, phrygian, hypophrygian, lydian, hypolydian, mixolydian, hypomixolydian
 - Determined by the **final** (dorian/phrygian/lydian/mixolydian) and **range** (going significantly under the final => “hypo-” mode)

“d”

“e”

Dorian

Hypodorian

Phrygian

Hypophrygian

Lydian

Hypolydian

Mixolydian

Hypermixolydian

“f”

“g”

↓ = final of plainchant mode

					ω	φ	υ	π	μα	η		Γ	β		χ	ι	μα	η	Γ	
					Ν	Ϛ	Ϛ	Ϛ	π	υ	ο		Ϛ		λ	ι	π	υ	τ	Ν
	Δ				ε	υ	ι	π	ο	κ	η	Ϛ			λ	ο	κ	η		
	†				Ν	υ	τ	ο	κ	ω	ο				λ	υ	κ	ι	τ	
		ζ			τ	β		φ	Ϛ	ρ	μ		ι	θ			μ			
					†	Γ	Λ	Ϛ	ο	π			ρ	υ						
					~	ζ	Ϛ	ω	φ	υ	π	μ	η	η		λ	α	ζ	μ	
					ε	†	†	Ν	Ϛ	π	ο	π	υ	λ		Γ	η	υ	α	
	ι				~	†	Δ	ω	†	τ	π	ο	κ	κ	τ	η	λ	Γ	β	
					π	ε	ω	†	†	ζ	ο	μ	λ		η	λ	η	τ	β	
					ρ		ω	υ	ζ	τ	β	φ	Ϛ	ρ	υ	μ	π	ι	υ	
					η	π	Ϛ	†	Γ	Λ	Ϛ	Ϛ		ο	κ	ζ	υ	ι	υ	
	ω				ρ	ω	~	ζ	ε	ω	φ	υ		π		μ	ι	θ		
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
	ω				ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
					ω	η	η	ε	†	Λ	Ϛ	υ		π	ο	π	μ	ι	θ	
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- ...but Gregorian chant is not a particularly ancient Greek tradition!

Chant melodies: modality

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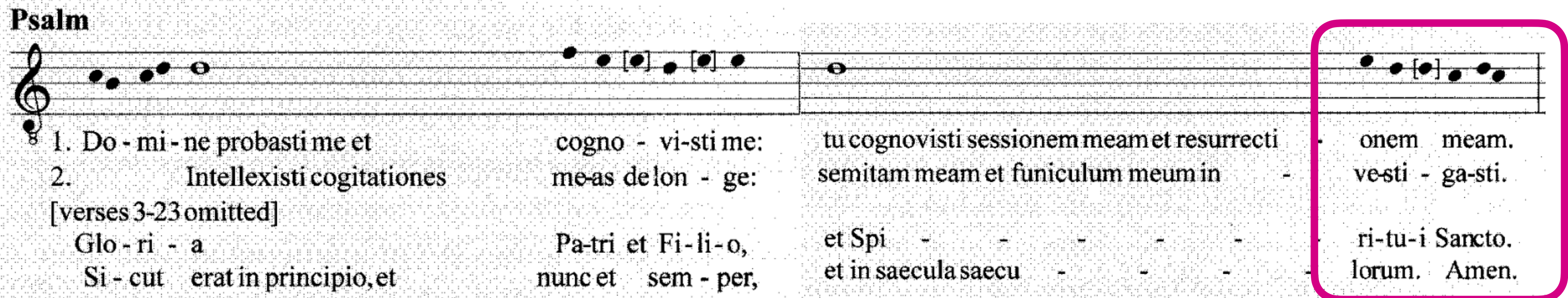
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- Chant sources of type “**Tonary**”
 - Antiphons grouped not by liturgical year, but by **mode** and **differentia**

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Psalm

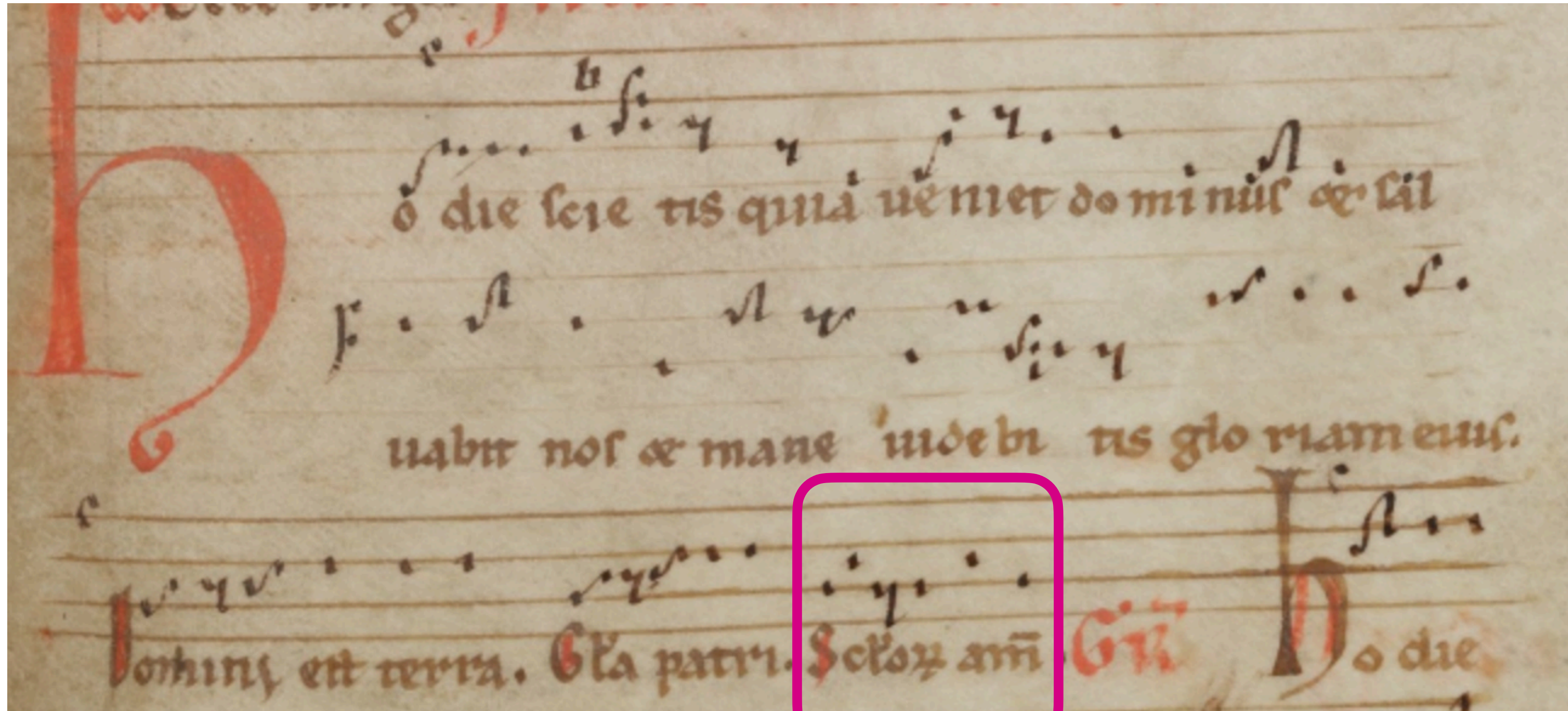


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2. Intellexisti cogitationes meas de lon - ge: semitam meam et funiculum meum in vesti - ga - sti.
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“saeculorum Amen”

Chant melodies: modality

Where problems start.



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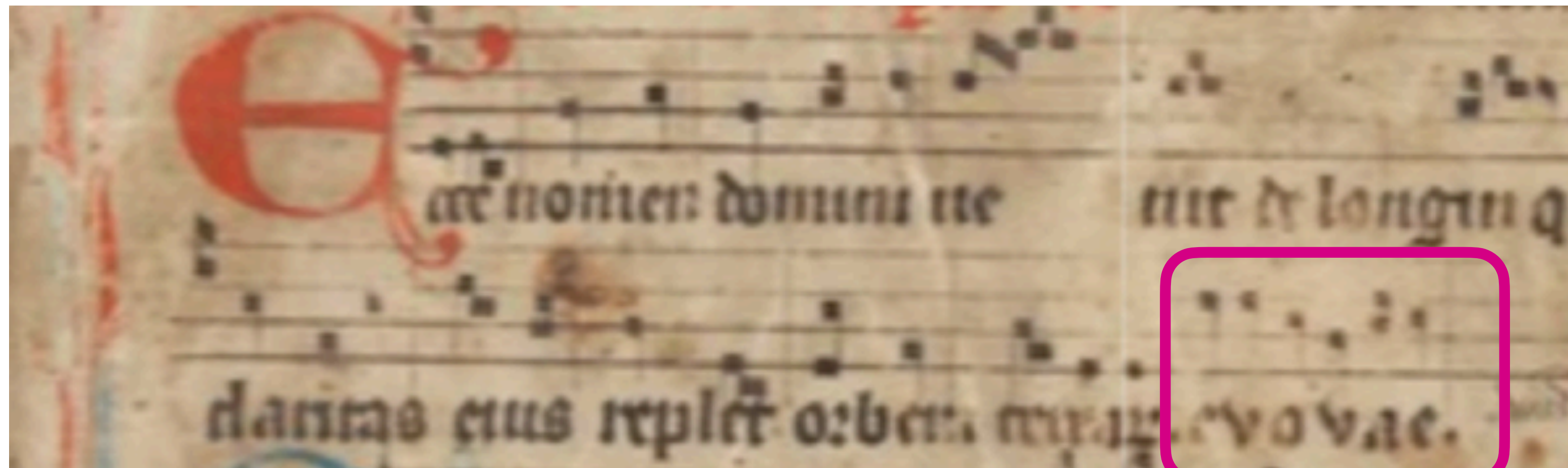
and **differentia**

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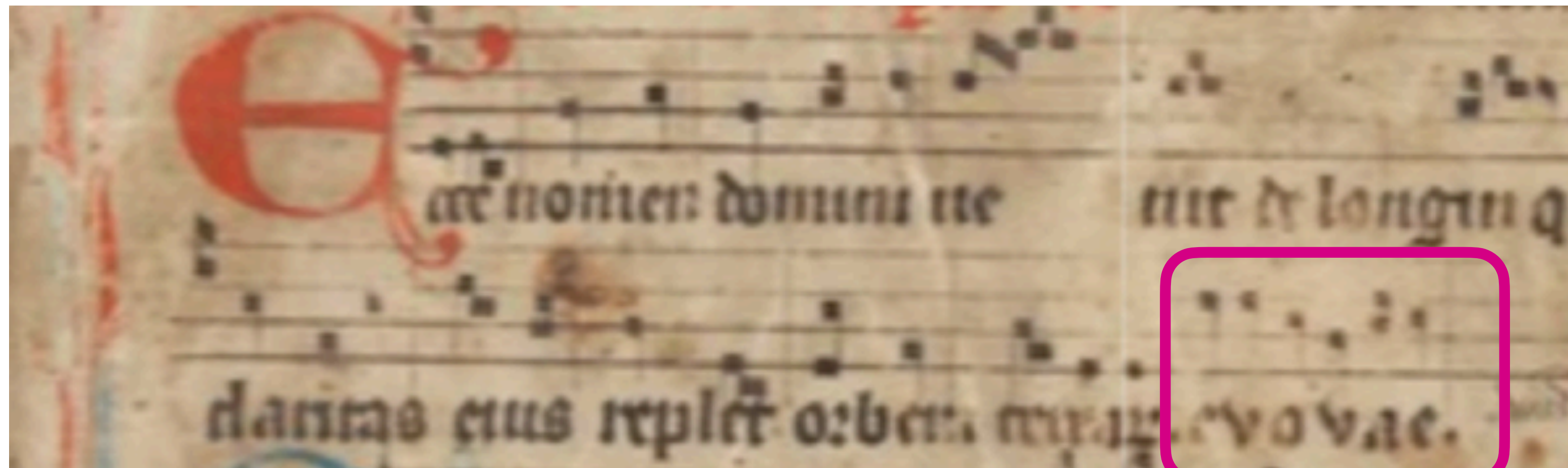
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e - u - o - u - a - e

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“saeculorum Amen”
e - u - o - u - a - e

Antiphon

Psalm

Antiphon
(repeat)

Available psalm tones

1 ending on or or or

2

3 * * * ending on or or * or b

4 E or a ending on or or or or

5 or

6

7 ending on or or or

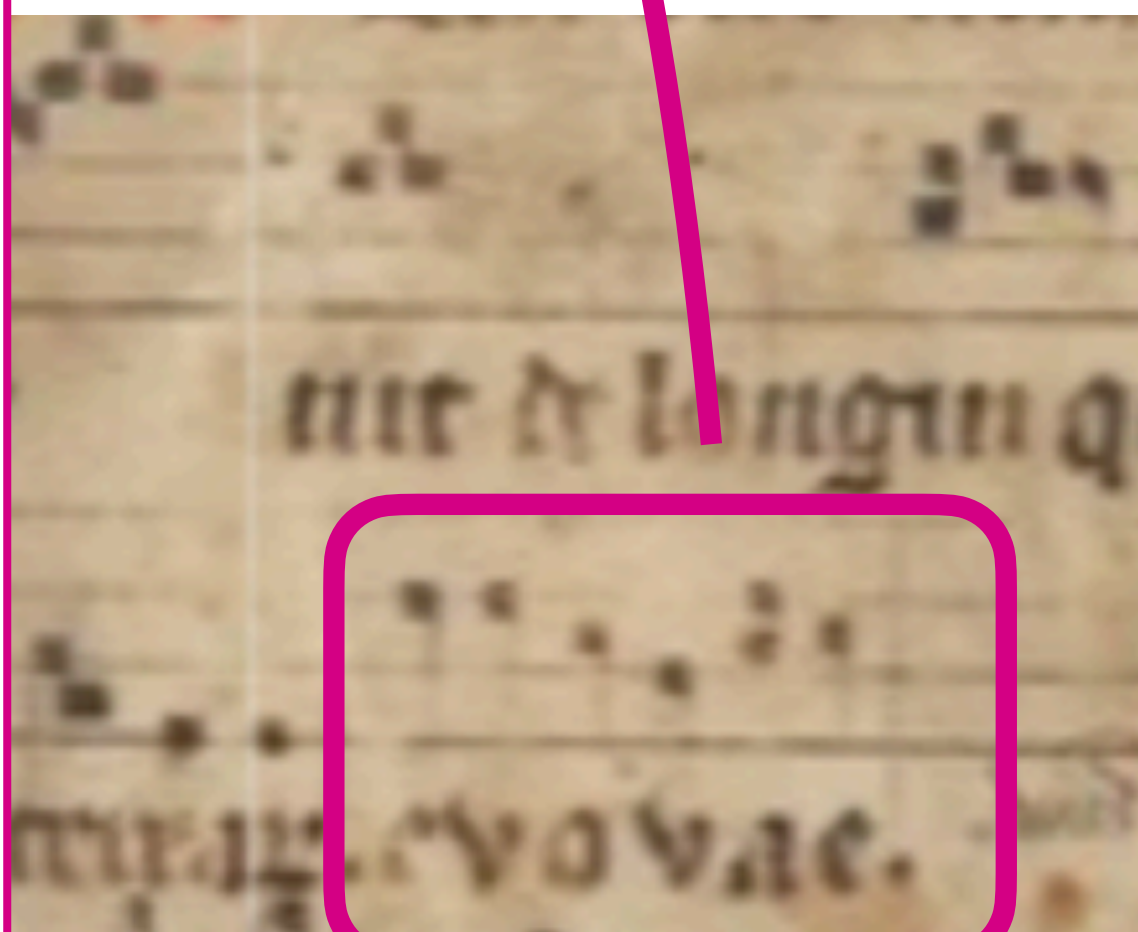
8 either or

tonus peregrinus

modality

Key for organizing repertoire (in memory)

Organizational year, but by mode and differentia



“saeculorum Amen”
e - u - o - u - a - e

Antiphon
Psalm
Antiphon
(repeat)

Available psalm tones

1 ending on or or or

3 * * * ending on or or * or b

4 E or a ending on or or or or

5 ending on or

6 ending on or or or

7 ending on or or or

8 either or

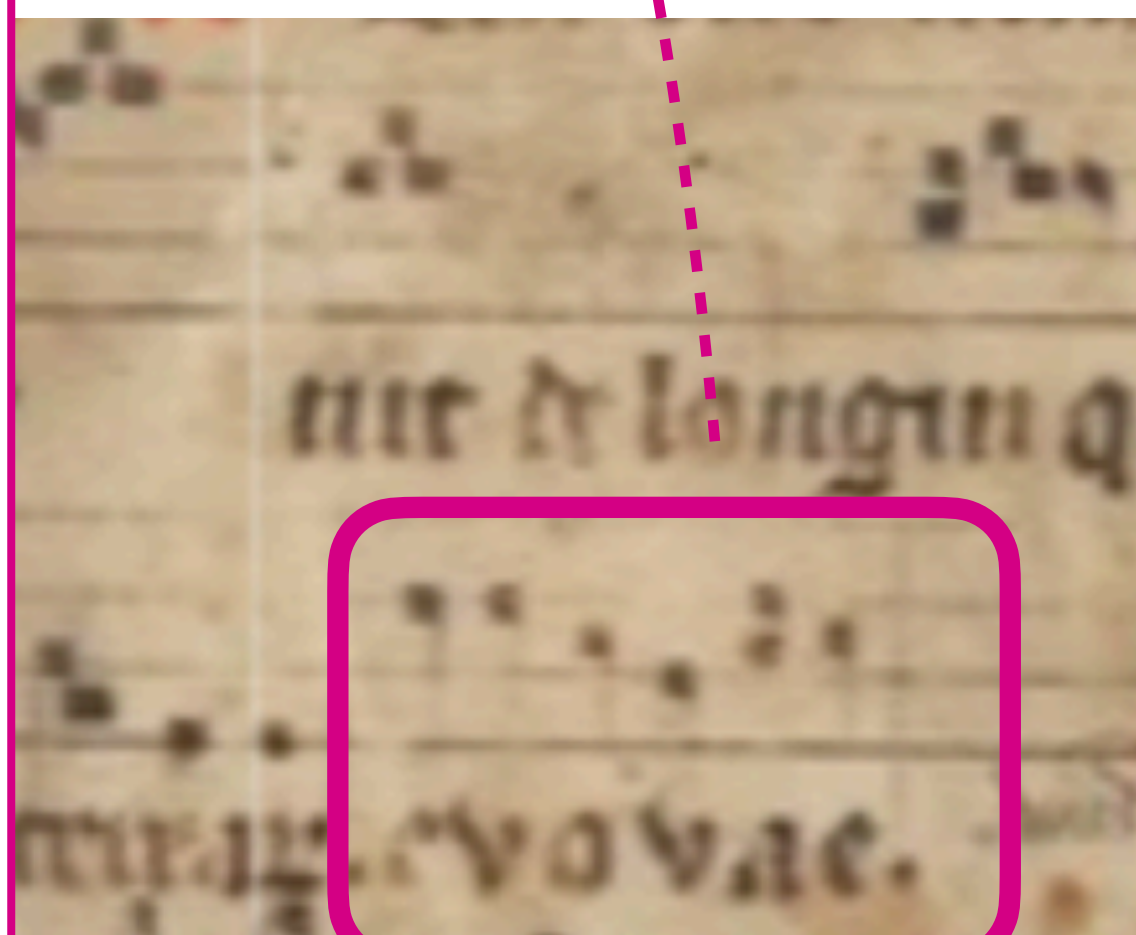
tonus peregrinus

Modality

Psalm tone selected according to differentia

Key for organizing repertoire (in memory)

Organized by liturgical year, but by mode and differentia



“saeculorum Amen”
e - u - o - u - a - e

Antiphon
Psalm
Antiphon
(repeat)

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“ex”:
mode “e”,
differentia “x”

Chant

Where prof

- Modality as
- Chant sour
- Antiphon

DE TONO PRIMO ΛΥ
 THENTICIS PROTUS

ΜΟΝΑΝΘΕΛΗΕ
 Cta Sctōrū Amen

Gaudete in dō
 E tēn m̄ seden un̄ tālū Atus
 S tātū eīd om̄nū Rēdime nū
 E x̄ sur̄ gē quāre ob l̄ gō aut̄ m̄
 DIFFERENTIAE GXA
 S̄CULORŪ ΛOMĒH

Gaudemus om̄nē in dō
 S̄ uscep̄ im̄s deus m̄ sectam
 R orate cæli desuper
 J̄ ndina domine

SUPERIOR DIFFERENTIA
 M̄ isereris om̄nū m̄ct
 L̄ ex dom̄nū in̄prehensib

“De tono primo authenticus protus”
 = Mode 1 (authenticus protus = dorian)

ity

ganizing repertoire

ear, but by mode and differentia



Code “ex”:
 mode “e”,
 differentia “x”

Chant r

Where pro

• Modality as

• Chant sour

• Antiphon

DE TONO PRIMO ΛΥ
THENTICIS PROTUS

ΙΩΑΝΝΗΝΟΣ ΕΛΛΗ
Cta Sctōrū Amen

Gāudeat in dō
E tēn mīserēdīcōnīā
S tātuī eīd omīnū Rēdīmēnū
E x sūr gē quāre ob lēgō autē m

DIFFERENTIAE GRA
SCTŪRŪ AMEN

Gāudeamus omnes in dō
S ūscerpimus deus mīserīcōrdīā
R orate cæli desuper
I nclīnā dōmīne

SUPERIOR DIFFERENTIA
Mīsereris omnīū mīserīcōrdīā
L ex dōmīnī īnterprehensīb

“De tono primo authenticus protus”
= Mode 1 (authenticus protus = dorian)

ity

One differentia as a heading
& its section of associated antiphons

Cta Sctōrū Amen

ear, but by mode and differentia

da Nullus est
an ungi nem

Code “ex”:
mode “e”,
differentia “x”

Chant r

Where pro

• Modality as

• Chant sour

• Antiphon

DE TONO PRIMO ΛΥ
 THENTICIS PROTUS

ΙΩΑΝΝΗΝΟΣ ΕΛΛΗ
 Cta Sctōrū Amen

Gāudeatē inclīnō
 E tē mīserēdētīa dīī Stūs
 S tātuī eīd omīnūs Rēdīmētū
 E x sūr gē quāre ob lēgō autē m
 Sīb

DIFFERENTIAE GXA
 SFCULORU AMEN

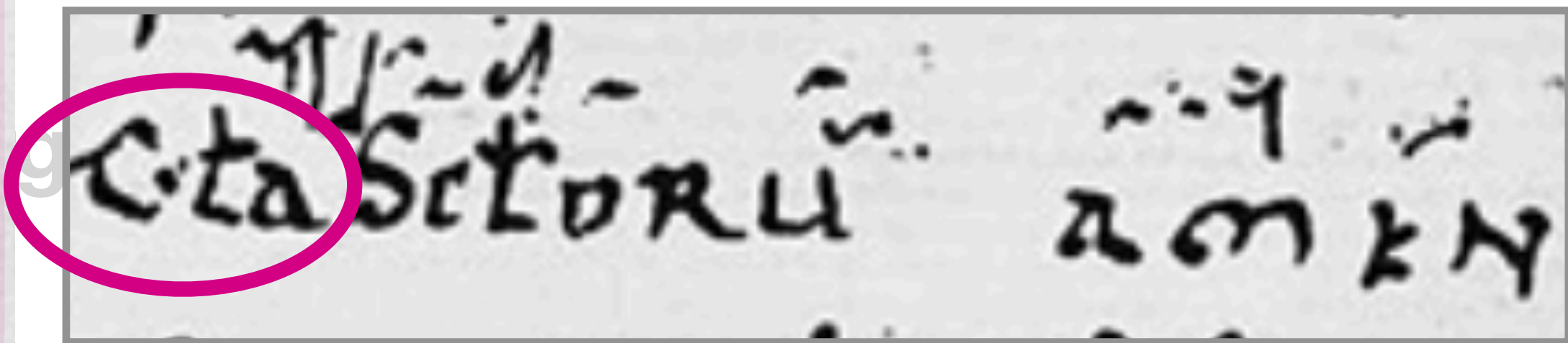
Gāudeamus omnes inclīnō
 S ūscerpimūs deus mīserētām
 R orate cāelīdesupēr
 J nclīnā dō mīne

SUPERIOR DIFFERENTIA
 Mīsererīs om nīūm et
 Lī ex dōmīnīūm rēpētētīb

“De tono primo authenticus protus”
= Mode 1 (authenticus protus = dorian)

ity

One differentia as a heading
& its section of associated antiphons



The associated differentia code

ear, but by mode and differentia



Code “ex”:
mode “e”,
differentia “x”

Chant

Where pro

• Modality as

• Chant sou

• Antiphon

DE TONO PRIMO ΛΥ
 THENTICIS PROTUS

ΓΛΑ ΣΚΛΟΡΥ ΑΜΕΝ

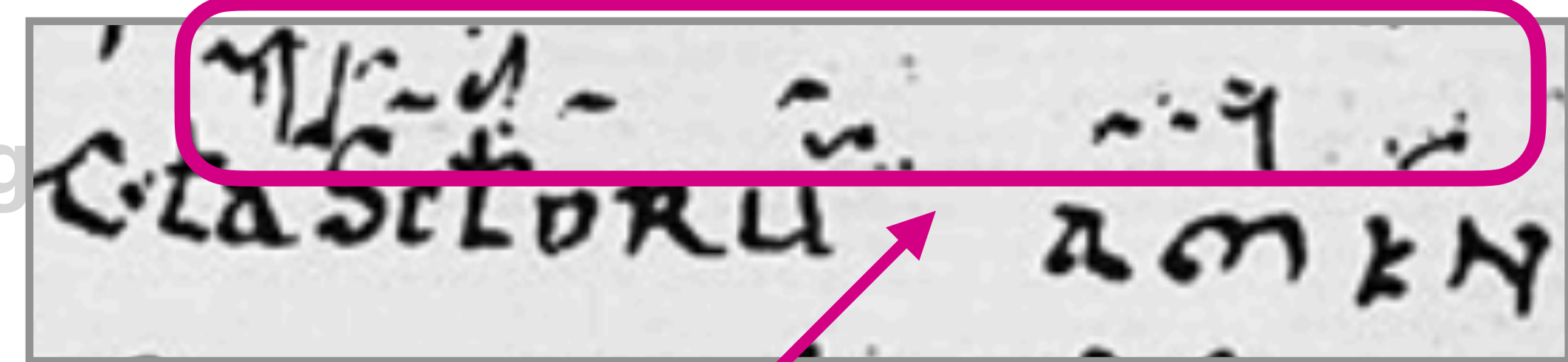
Ο ἀυδέτε ἰνδῆο
 Ε ἰ ἐν ἡσθελεν ἰνδῆο ἄυ
 Σ τὰυτε εἰδ ὀμῖνυς ἡεδῖμενε
 Ε ἡσῦρ γε ἡῦαρε ὀβ ἡγο ἄυτῖν
 ΔΙΨΕΡΗΤΙΑΕ ΓΧΑ
 ΣΚΛΟΡΥ ΑΜΕΝ

Ο ἀυδέτε ἰνδῆο
 Σ ἡσθελεν ἰνδῆο ἄυ
 Ρ ὀρατε ἡελῖδε ἡσθελεν
 ἡνδῖνα δὸμῖνε

SUPERIOR DIΨΕΡΗ
 ΤΙΑ ἡσθελεν ἰνδῆο ἄυ
 ἡε δὸμῖνυ ἡνδῖνε

“De tono primo authenticus protus”
= Mode 1 (authenticus protus = dorian)

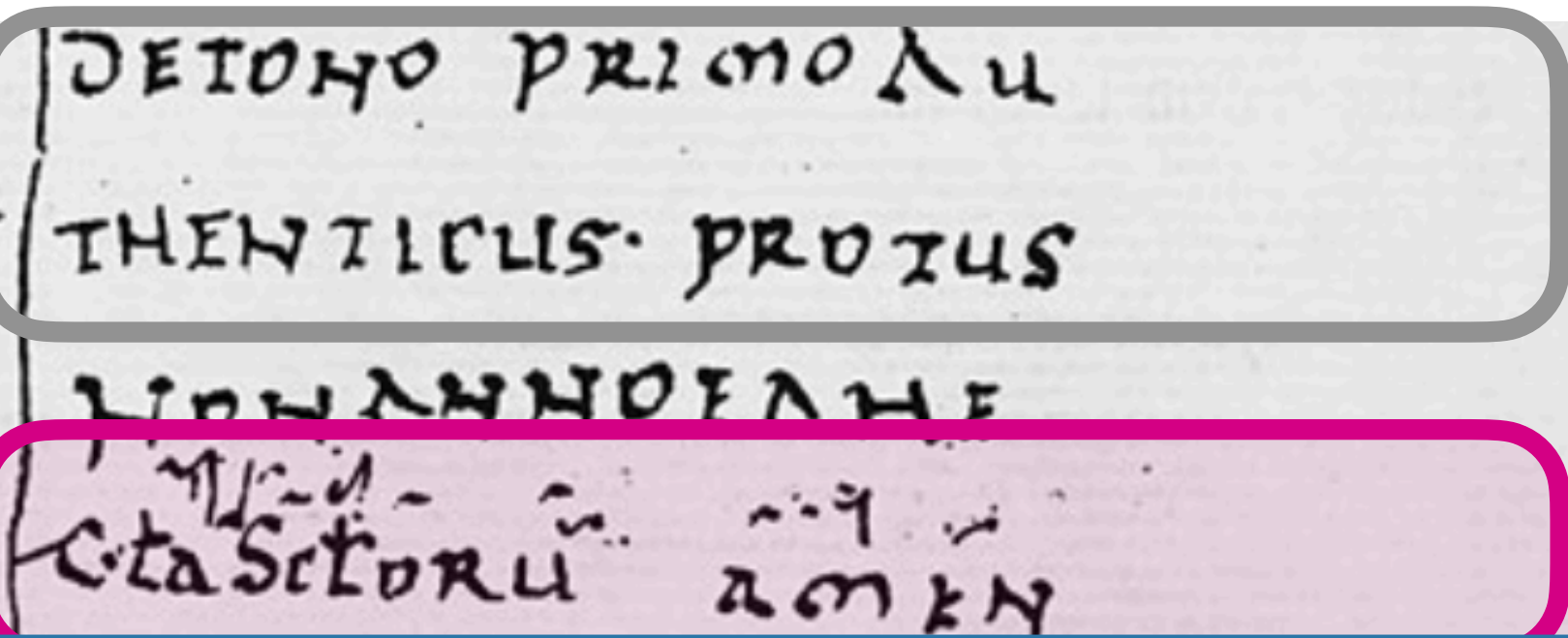
One differentia as a heading
& its section of associated antiphons



Neumes.
These marks encode the melody
(not exact pitches) of the differentia.



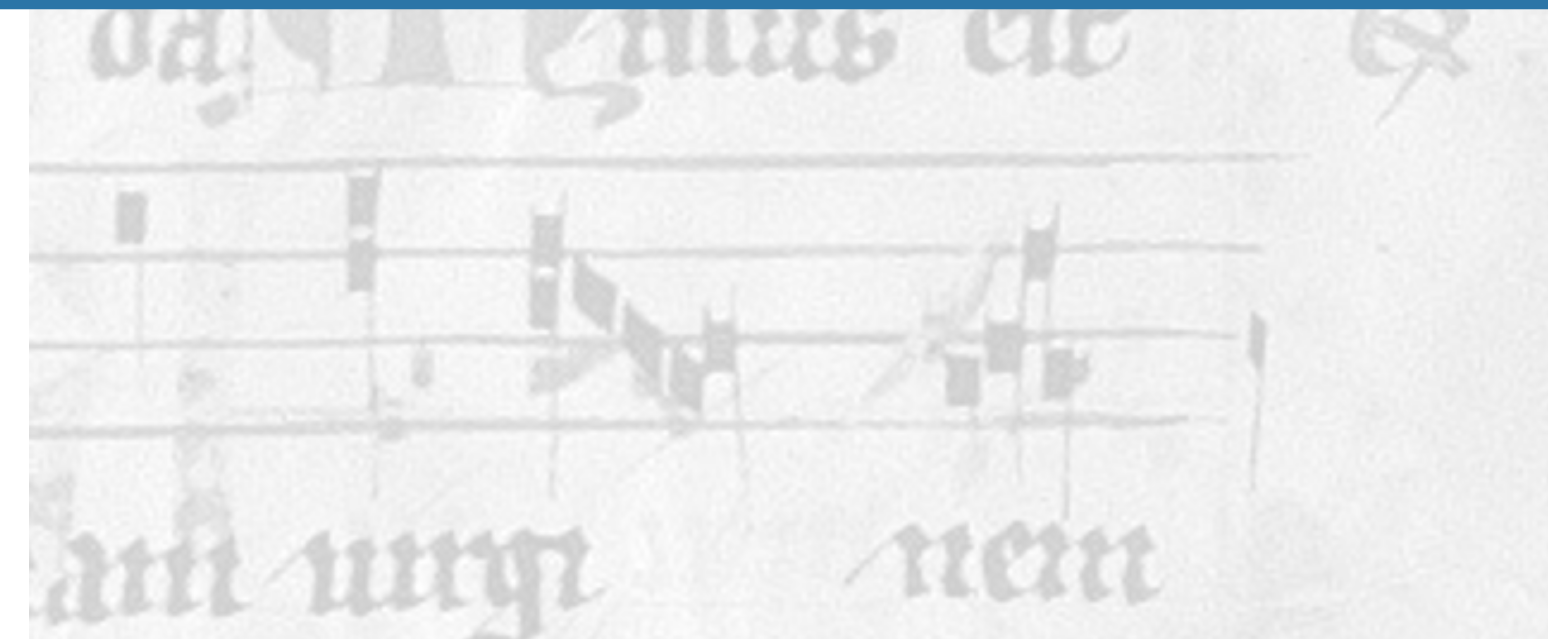
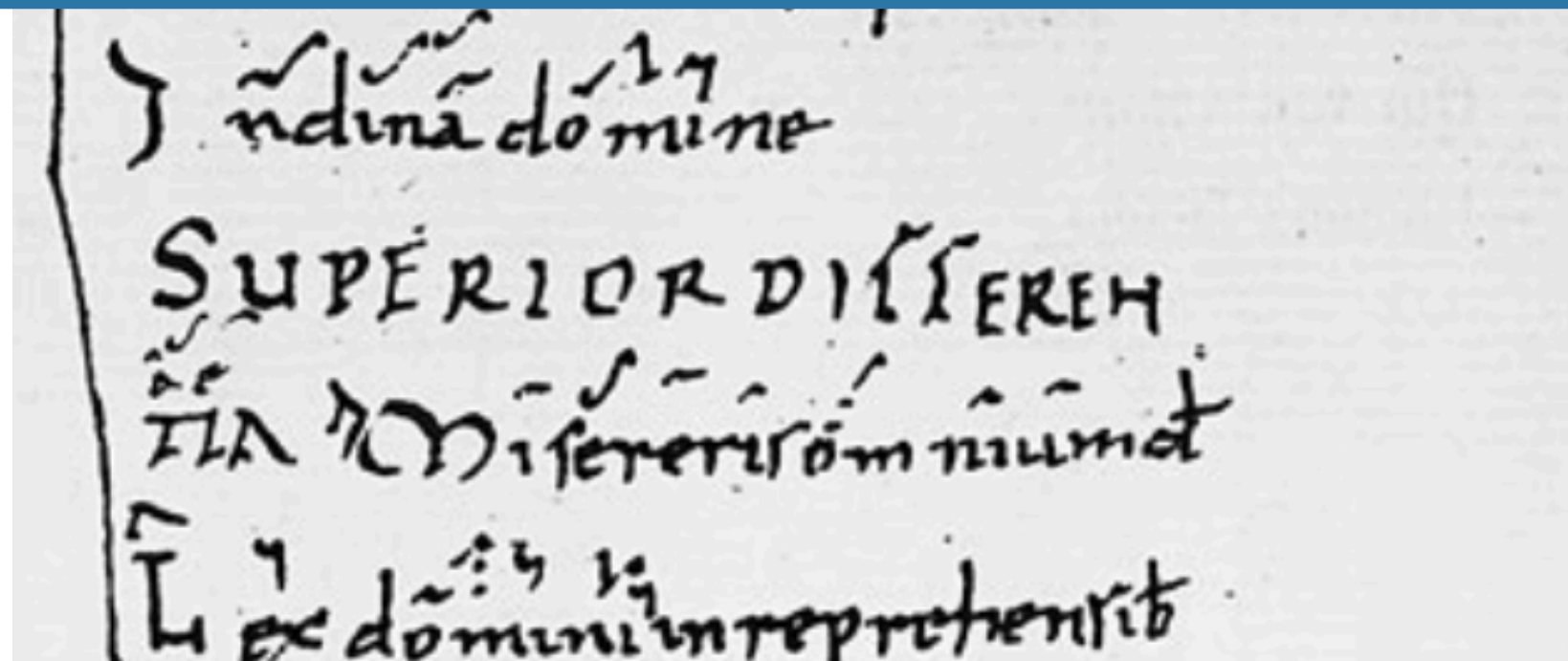
Code “ex”:
mode “e”,
differentia “x”



“De tono primo authenticus protus”
= Mode 1 (authentus protus = dorian)

One differentia as a heading

Chant is an oral tradition based on memory.



x”

Chant melodies: modality

Where problems start.

- Modality as a **practical** principle for **organizing repertoire** **in memory**.
- Chant sources of type “**Tonary**”
 - Antiphons grouped not by liturgical year, but by **mode** and **differentia**
 - Each antiphon in tonary is a representative of a **group of similar melodies**

Chant melodies: modality

Where problems start.

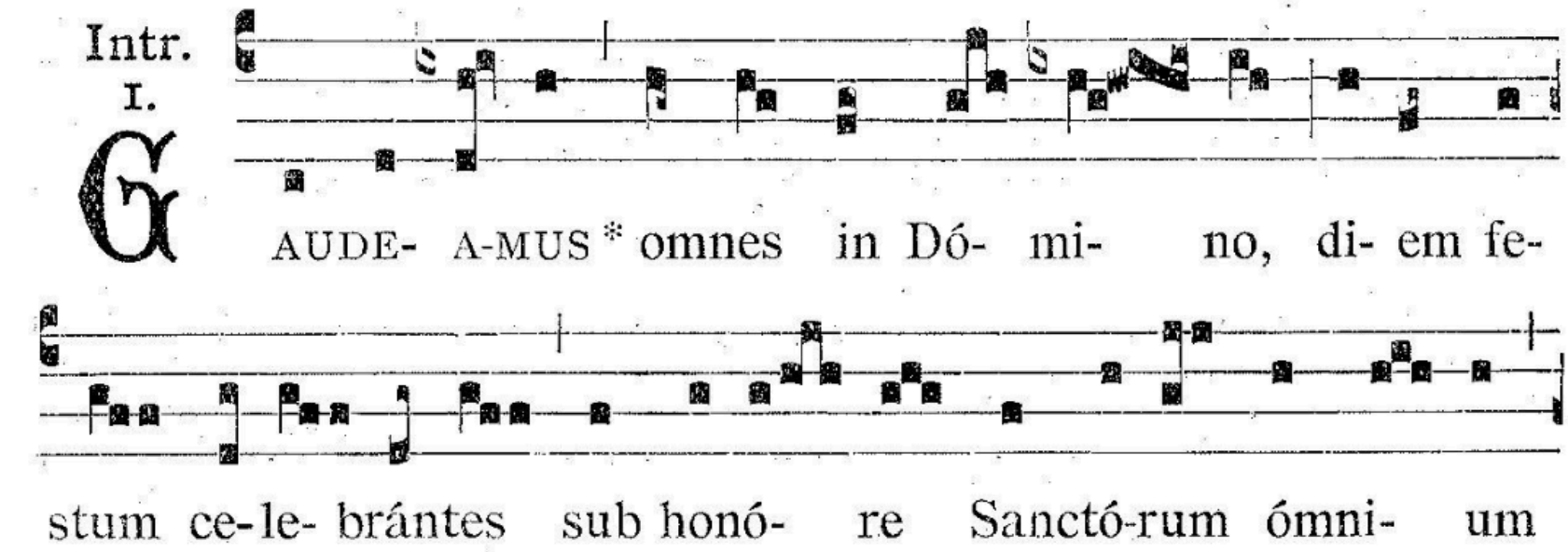
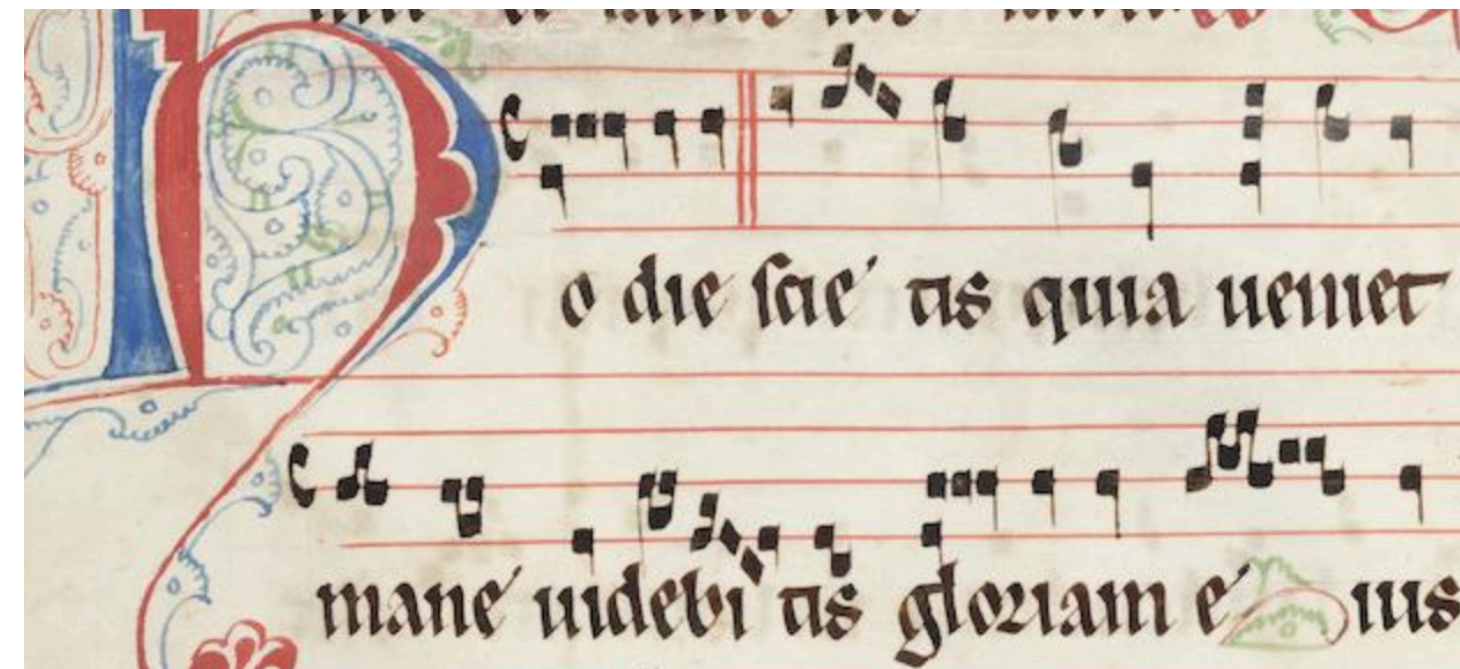
- Modality as a **practical** principle for **organizing repertoire** **in memory**.
- Chant sources of type “**Tonary**”
 - Antiphons grouped not by liturgical year, but by **mode** and **differentia**
 - Each antiphon in tonary is a representative of a **group of similar melodies**
- ...But tonaries still contain **eight modes**, like Greek theory! (And the final notes work!)
 - Not clear why this should be the case.
 - Greek heritage in chant? Byzantine “oktoechos”...

Chant melodies: modality

Where problems start.

- Competing ideas of modality: the **theoretical concept** (Greece, Boethius) vs. the **practical concept** (“Cantus tradition” as recorded by tonaries).
- This took some 200-400 years to reconcile: **Guido of Arezzo!** (±1050)
 - Note: staff notation (also Guido of Arezzo) motivated by the need to learn exact pitches without a teacher present (recall: **memory tradition!**)
- Later, once there was a theory good enough to gain broad acceptance, chant melodies were **edited to fit to the modes of theory better.**
 - Most prominently: **Cistercians** (monastic order, “white monks”, ±1200)

History of Gregorian chant



Gregory I.
redaction (?)

Staff
notation

Solesmes
reform



Carolingian
expansion

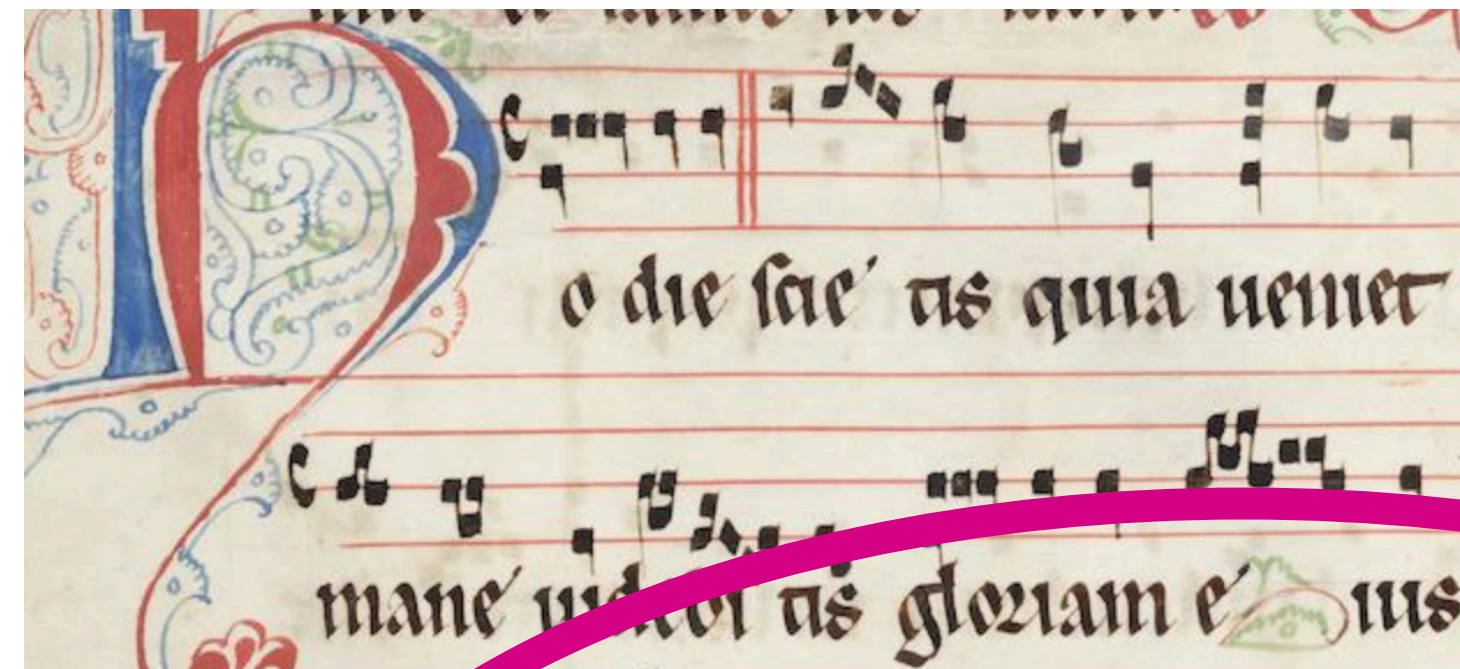
Cistercian
reform

Council of Trent:
"Editio Medicea"

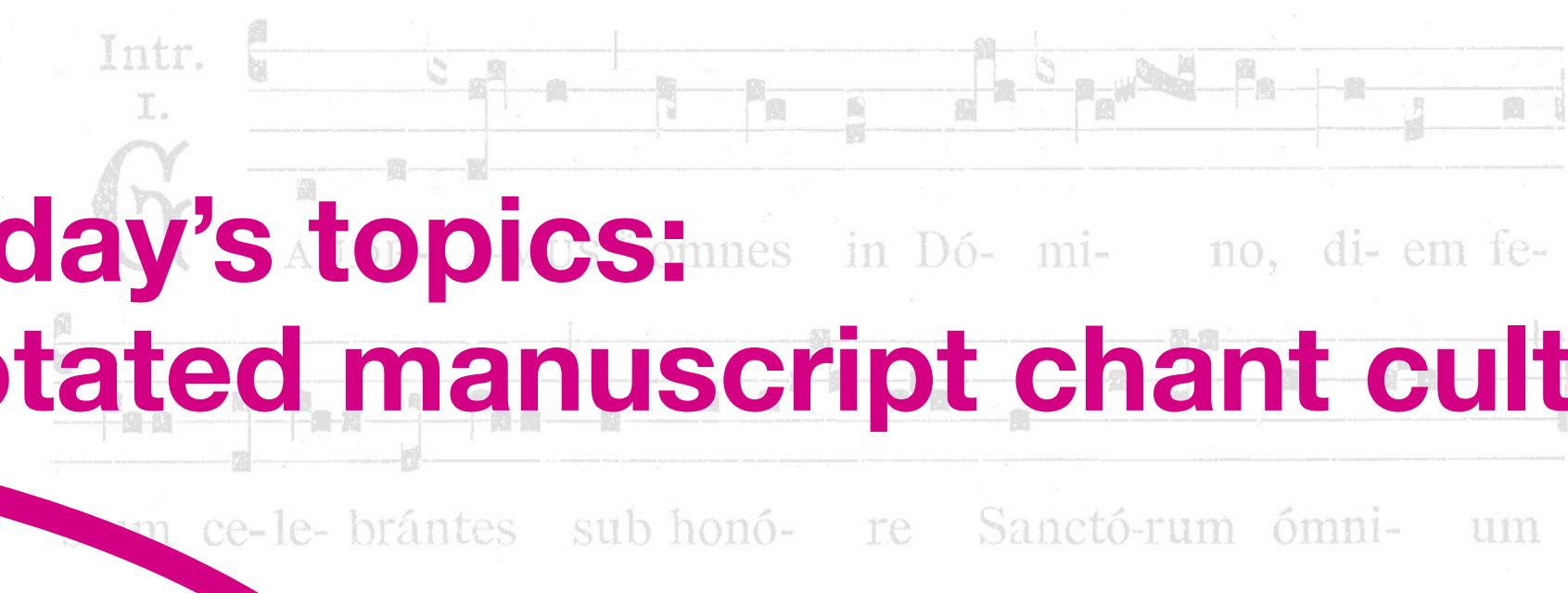
Vatican II
liturgical reform



History of Gregorian chant



Today's topics:
Notated manuscript chant culture



Gregory I.
redaction (?)

Staff
notation

Solesmes
reform

600?

800

1050

1200

1600

1900

1980

Carolingian
expansion

Cistercian
reform

Council of Trent:
"Editio Medicea"

Vatican II
liturgical reform



Notated manuscript chant culture

- **Exact pitch sequences known** for chant melodies from written sources
- **Manuscript transmission** means standardization is costly, difficult, and hard to verify
- The combination of these two factors means there is **measurable diversity**
 - ...even within a rigidly-defined tradition,
 - ...even with strong institutional incentives towards conservation.
 - Diversity attested to by the Council of Trent (mid-16th century) acting to standardize Roman chant tradition (...again)
- **Diversity makes chant research interesting!**

Medieval chant diversity

- **Temporal, geographical, “institutional”**. 500 years, large and densely populated area.
 - ...Such a broad tradition with directly comparable artefacts is an outlier.
- How did Gregorian **melodies** develop?
 - Were there geographically defined “melodic dialects”, or was development roughly equal across all of Latin Europe?
 - We need better analytical theories of chant melody. We don’t know what phenomena to track.
- How did Gregorian **repertoire** develop?
 - What transmission networks were important? (Not trivial — i.a. French-Bohemian connection.)
 - What level of commonality was there?

Digital Chant Scholarship

Digital Humanities “Axis”

Digitization

Digital editions

Databases

Quantitative
research

„More“

Simulating acoustics of destroyed spaces
„Periphery“: Listening habits, performance science...

Digital „access“

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Digital Humanities “Axis”

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Distant Reading (F. Moretti)

SCALE

Digital „access“

Digital „research“

Digital Humanities “Axis”

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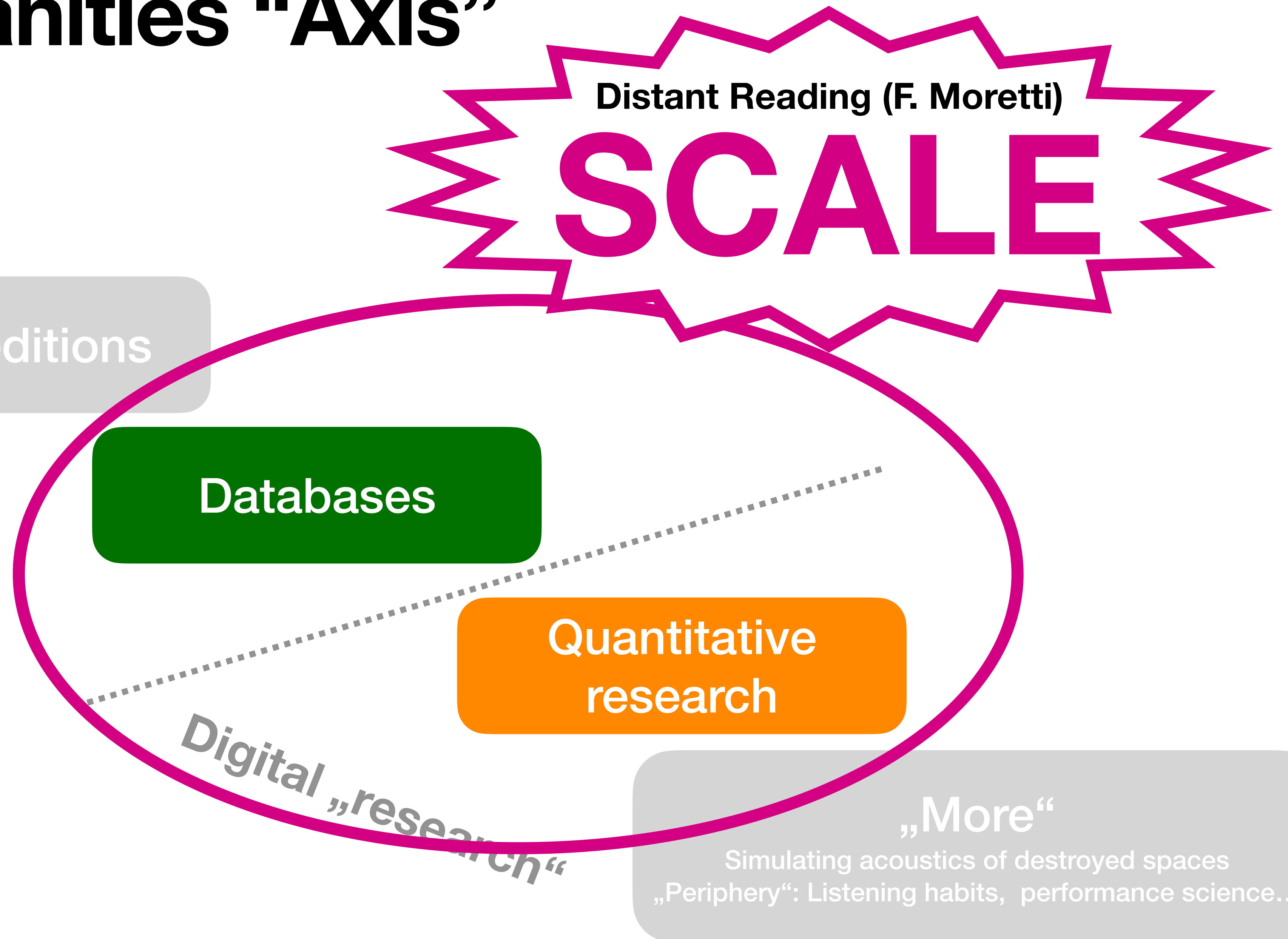
Digital „research“

„More“

Simulating acoustics of destroyed spaces
„Periphery“: Listening habits, performance science...

Distant Reading (F. Moretti)

SCALE



Cantus Database

Cantus Database

cantus.uwaterloo.ca

- Development since the late 80s
- Catalogue of chants in sources
 - **489 549** chants
- Key idea: **Cantus ID**
 - Primarily a textual “edition”
- “**Volpiano**” for melodies
 - Low % of melodies transcribed ($\pm 60\ 000$, incl. fragments)



HOME
Home page

ABOUT
Information

SOURCES
List of inventories

CHANTS
Search

FEASTS
List of feasts

TERMS
Genres & Fields

RESOURCES
Docs, Instructions, Tools

Cantus: A Database for Latin Ecclesiastical Chant - Inventories of Chant Sources

Cantus is a database of the Latin chants found in manuscripts and early printed books, primarily from medieval Europe. This searchable digital archive holds inventories of **antiphoners** and **breviaries** -- the main sources for the music sung in the Latin liturgical Office -- as well as **graduals** and other sources for music of the Mass.

New phases of the project include adding chant melodies to existing records and indexing other types of chant manuscripts, including processionals, pontificals, and sources that contain sequences.

Cantus Database is a part of the Cantus Index network of manuscript databases.

For our full catalogue of chants as well as access to the integrated network of partner chant databases, see **Cantus Index** ([Catalogue of Chant Texts and Melodies](#)).

Use the Cantus Database if you are:

- looking for the complete contents of an indexed source;
- investigating a particular manuscript or liturgical centre (monastery or cathedral);
- seeking quick access to the online archives that hold digital images for many of the sources indexed by Cantus;
- searching for a chant by text;
- searching for a chant by melody - use the **Melody Search Tool**;
- wondering which chants were sung on a particular Saint's day or any other liturgical day throughout the year;
- searching for concordances of a chant;
- analysing the usages of particular chants in sources from across medieval Europe and beyond;
- creating a new inventory.

Use the Cantus Index if you:

- would like to confirm the full text and Classical Latin spelling of any of the indexed chants;
- want to broaden your search for a chant to sources beyond the Cantus Database.

Access to the Cantus Database and Cantus Index is **free**, in accordance with the aims of the International Musicological Society's Study Group **Cantus Planus** which include the exchange of data in electronic form.

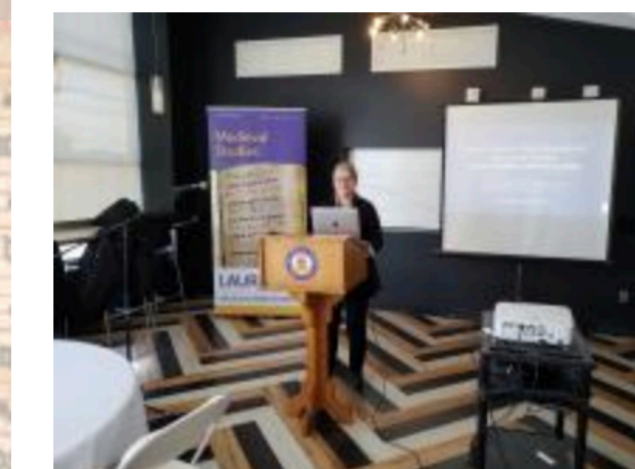
Jump to source

- Browse sources -

What's new

Wed, 03/15/2023 - 20:31

Cantus at Laurier's Medieval Day



Mon, 03/13/2023 - 09:58

The story of the Riesencodex heist, live on UK TV (GB News)!

Click [here](https://youtu.be/qCTZXbSfBgk?t=5851) (<https://youtu.be/qCTZXbSfBgk?t=5851>) to watch Michael Portillo's interview with Dr. Jennifer Bain about the amazing journey of the Riesencodex in post-World-War-II Europe.

Wed, 03/01/2023 - 22:23

Web Exhibit: Vertical Lines in Barnard MS 1

Check out this multi-page web exhibit by Gareth Cordery, a student of Susan Boynton at Columbia University: <http://liturgicalmanuscripts.sandbox.library.columbia.edu/barnardbarlines/>. Close-up photos and explanations of the varied scribal uses of vertical lines in the manuscript *New York, Columbia University - Barnard College Library, MS 1* are accompanied by an extensive bibliography and comparative statistical analysis. The glossary of terms and links to other web resources are certain to be helpful for students, too!

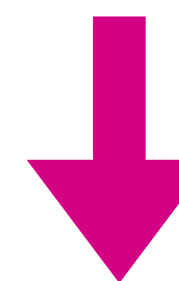
Barnard MS1 is indexed in the Cantus Database: <https://cantusdatabase.org/source/683940>.

Tue, 08/09/2022 - 22:26

Cantus IDs

Organizing repertoire by text & genre.

Cantus ID: 003511



Text incipit

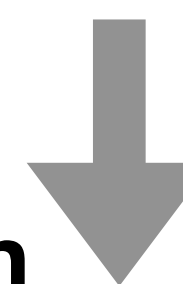
Genre

CH-Fco Ms. 2	024r	Judaea et Jerusalem*	Vigilia Nat. Domini	P	A		003511	*	✓		Image
CH-SGs 388	050	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CH-SGs 390	042	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CDN-Hsmu M2149.L4	030r	O Juda et Jerusalem nolite	Vigilia Nat. Domini	L	A		003511	8	✓	♪	Image
CZ-Pst DE I 7	013r	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8			
CZ-Pu VI.E.4c	067v	Judaea et Jerusalem*	Dom. 4 Adventus	L	A	1	003511				
CZ-Pu VI.E.4c	071v	Judaea et Jerusalem nolite	Vigilia Nat. Domini	L	A	1	003511				
D-B Mus. 40047	017r	Judaea et Jerusalem nolite timere	Nativitas Domini	V	A	1	003511	8			Image
D-KA Aug. LX	015v	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓	♪	Image

Chant records

489 549 of these.

Cantus ID: 003511

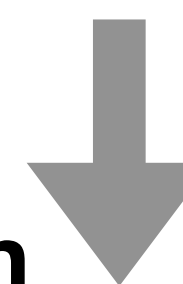


Source (siglum)	Folio	Text incipit	Feast	Office	Genre	Position	Mode	Text?	Melody?	Digitized?	
CH-Fco Ms. 2	024r	Judaea et Jerusalem*	Vigilia Nat. Domini	P	A		003511	*	✓		Image
CH-SGs 388	050	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CH-SGs 390	042	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CDN-Hsmu M2149.L4	030r	O Juda et Jerusalem nolite	Vigilia Nat. Domini	L	A		003511	8	✓	♪	Image
CZ-Pst DE I 7	013r	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8			
CZ-Pu VI.E.4c	067v	Judaea et Jerusalem*	Dom. 4 Adventus	L	A	1	003511				
CZ-Pu VI.E.4c	071v	Judaea et Jerusalem nolite	Vigilia Nat. Domini	L	A	1	003511				
D-B Mus. 40047	017r	Judaea et Jerusalem nolite timere	Nativitas Domini	V	A	1	003511	8			Image
D-KA Aug. LX	015v	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓	♪	Image

Chant records

Chronology and provenance?

Cantus ID: 003511



Source (siglum)	Folio	Text incipit	Feast	Office	Genre	Position	Mode	Text?	Melody?	Digitized?	
CH-Fco Ms. 2	024r	Judaea et Jerusalem*	Vigilia Nat. Domini	P	A		003511	*	✓		Image
CH-SGs 388	050	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
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D-KA Aug. LX	015v	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓	♪	Image

Source record

<https://cantus.uwaterloo.ca/source/123612>

CANTUS Database
D-KA Aug. LX

Provenance: **Zwiefalten**

Date **12th century** | 1100s+

Cursus: **Monastic**

Inventoried by:

- **Charles Downey**
Catholic University of America
- **Joseph Metzinger**
Catholic University of America
- **Keith Glaeske**
Catholic University of America
- **Lila Collamore**
Catholic University of America
- **Richard Rice**
Catholic University of America

Proofreader/s :

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Provenance

Century

Environment
(roughly)

Source record

<https://cantus.uwaterloo.ca/source/123612>

Source descriptions!

Karlsruhe, Badische Landesbibliothek - Musikabteilung, Aug. LX

Signum:

D-KA Aug. LX

Summary:

Late twelfth-century antiphoner of which the musical notation was almost completely rewritten in the 13th/14th century. Originated in Zwiefalten; was taken from there to the abbey of Reichenau early in the 16th century. Four-line staff, with red F-line and yellow C-line; seven different notations. Monastic cursus. 276 folios.

Liturgical occasions:

Ff. 001b-116v: Winter Temporale and Sanctorale. 1b, Advent; 3r, Nicholas; 7v, Lucy; 14v, Great "O" Antiphons; 16v, Nativity; 21v, Stephen; 24r, John the Evangelist; 26r, Holy Innocents; 29v, Epiphany; 34v, Ferial Office; 38v, Fabian and Sebastian; 41r, Agnes; 43r, Conversion of Paul; 43v, Immaculate

Conception; 46r, Purification of the V
Annunciation of Mary; 58v, Septuag
Wednesday; 64v, Lent; 77r, Passion
Friday; 89v, Holy Saturday; 91v, East
material. This section has been inde
106v, Finding of the Cross; 109r, Ale
117r-237r: Summer Sanctorale. 117r
123r, Paul; 125v, Peter in Chains; 12
Assumption of Mary; 139v, Beheadin
Day; 144r, Maurice; 145r, Michael; 14
Martin; 160v, Brice; 160v, Othmar; 16
Saints; 181v, Dedication of a Church
193r, Summer Histories; 207r, Antiph
Invitatory Tones; 219v, Office for the
Common of Mary; 234r, Benedict; 23
a010r, Januarius, Faustus, and Marti
Mark, Evangelist; a031v, Corpus Chr
a035r, Finding of Stephen's relics; a0
Mary.

Description:

Karlsruhe Aug. LX presents several challenges to the researcher. It is written in six different hands and seven notational styles spanning five centuries. A brief overview is provided below:

- 1: late 12th-century Carolingian minuscule
 - 2: an early 13th-century hand on ff. 261r-262v
 - 3: a mid-13th-century Gothic minuscule (ff. 225v-230r--the added Offices of Elizabeth of Hungary and Catherine of Alexandria)
 - 4: a mid-15th-century hand (the added material on ff. 104r-144)
 - 5: 15th-century Gothic minuscule (ff. 133v-240v)
 - 6: 15th-century Humanist hand (140v)
- Karl Hain describes the characteristics of each hand in his *Ein musikalischer Palimpsest*, pp. 21-9; his discussion of the different notations, describing exactly where they are used in the manuscript, can be found on pp. 30-69. The seven types of notations he describes are the following:
- 1: a 12th-century South-German notation with red F-line and yellow C-line similar to the one found in Graz 807 (ff. 82v and 225v-227v)
 - 2: German notation with red F-line and yellow C-line similar to the one found in GB-Lbl-B. Add. 24680 and B-Br-2034 (ff. 219v-221r)
 - 3: German notation on four-line staff (223r)
 - 4: German notation (ff. 22r, 129v, 223v-224v, 231r, 233v)
 - 5: Hufnagel notation on four-line staff, found anywhere when not otherwise specified
 - 6: a 15th-century notation on five-line staff, found in the interpolated material (ff. 1r [211]-30v [270])
 - 7: Square notation on red four-line staff (ff. 191r-193r)

Chants are often written in a haphazard manner: for example, the ending of the antiphon "O clavis David et sceptrum" (14v) is written four lines above where it is begun. This is especially prevalent among verses to responsories (e.g., see ff. 44v, 45r, 65v, 68v, 76r, 170r, 204r, 212v). An extreme example of this is the verse "Averte oculos meos ne videant," which is begun on 103v but is

Provenance

Century

Environment
(roughly)

CANTUS Database

D-KA Aug. LX

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Date **12th century** | 1100s+

Cursus: **Monastic**

Inventoried by:

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Source record

<https://cantus.uwaterloo.ca/source/123612>

Source descriptions!

Karlsruhe, Badische Landesbibliothek - Musikabteilung, Aug. LX

Siglum:

D-KA Aug. LX

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Provenance

Century

Environment
(roughly)

Many people involved,
ongoing development

CANTUS Database

D-KA Aug. LX

Provenance: **Zwiefalten**

Date **12th century** | 1100s+

Cursus: **Monastic**

Inventoried by:

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Catholic University of America
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Catholic University of America
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Melody encoding: Volpiano

<https://cantus.uwaterloo.ca/chant/270435>

O Juda et Jerusalem nolite

Source:

Halifax (Canada), St. Mary's University - Patrick Power Library, M2149.L4 1554

Folio: Sequence:

030r 5

Feast:	Office/Mass:	Genre:	Cantus ID:	Mode:	Differentia:
Vigilia Nat. Domini	L	A	003511	8	G1

Differentia database:



118a

Addendum:

050

Manuscript Reading Full Text (standardized spelling):

O Juda et Jerusalem nolite timere cras egrediemini et dominus erit vobiscum alleluia

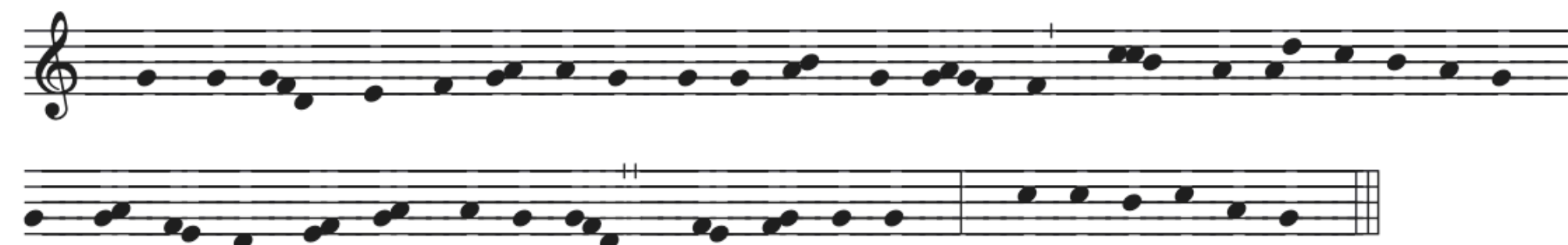
Manuscript Reading Full Text (MS spelling):

O iuda et iherusalem nolite timere cras egrediemini et dominus erit vobiscum alleluya | ~Miserere

Range:



Volpiano:



Melody encoding: Volpiano

<https://cantus.uwaterloo.ca/chant/270435>

O Juda et Jerusalem nolite

Source:

Halifax (Canada), St. Mary's University - Patrick Power Library, M2149.L4 1554

Folio: Sequence:

030r 5

Feast:	Office/Mass:	Genre:	Cantus ID:	Mode:	Differentia:
Vigilia Nat. Domini	L	A	003511	8	G1

Differentia database:

 118a

Addendum:

050

Manuscript Reading Full Text (standardized spelling):

O Juda et Jerusalem nolite timere cras egrediemini et dominus erit vobiscum alleluia

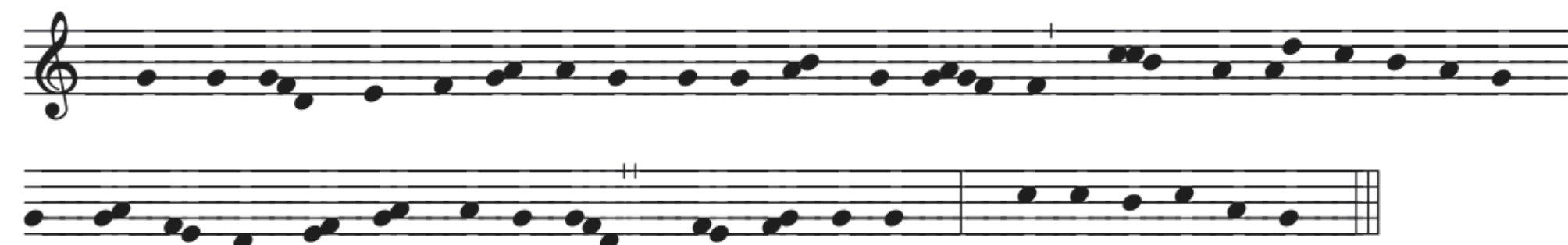
Manuscript Reading Full Text (MS spelling):

O iuda et iherusalem nolite timere cras egrediemini et dominus erit vobiscum alleluya | ~Miserere

Range:



Volpiano:



Melody encoding: Volpiano

<https://cantus.uwaterloo.ca/chant/270435>

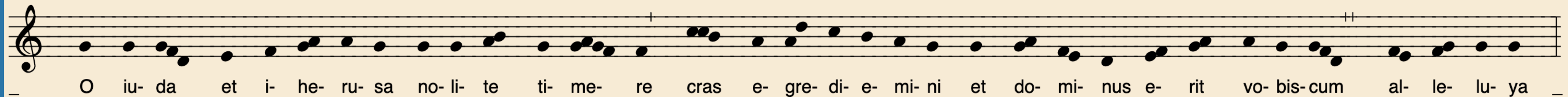
O Juda et Jerusalem nolite

Volpiano is a font!

Source:

Halifax (Canada)

Folio: Sequ
030r 5



O iu- da et i- he- ru- sa no- li- te ti- me- re cras e- gre- di- e- mi- ni et do- mi- nus e- rit vo- bis- cum al- le- lu- ya

Feast:

Vigilia Nat. Dom

Volpiano

1---g---g--gfd---e---f--gh--h--g---g--g--hj---g--ghgf--f7---kkj---h--hl--k--j--h--g---g---gh--fe--d---ef--gh---h--g--gfd77---fe--fg--g--g---3

Differentia data

Text
(syllabized)

O iu-da et i-he-ru-sa-lem no-li-te ti-me-re cras e-gre-di-e-mi-ni et do-mi-nus e-rit vo-bis-cum al-le-lu-ya

Manuscript Reading Full Text (standardized spelling):

O Juda et Jerusalem nolite timere cras egrediemini et dominus erit vobiscum alleluia

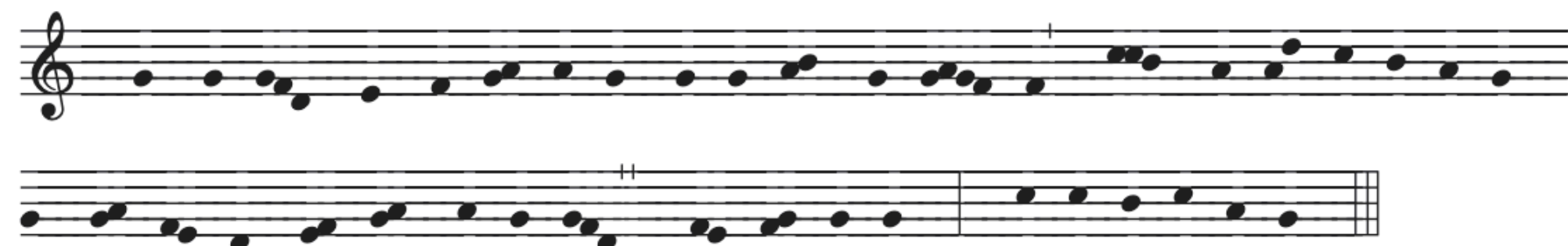
Manuscript Reading Full Text (MS spelling):

O iuda et iherusalem nolite timere cras egrediemini et dominus erit vobiscum alleluia | ~Miserere

Range:



Volpiano:



<https://hajicj.github.io/volpiano-editor/>

Melody encoding: Volpiano

<https://cantus.uwaterloo.ca/chant/270435>

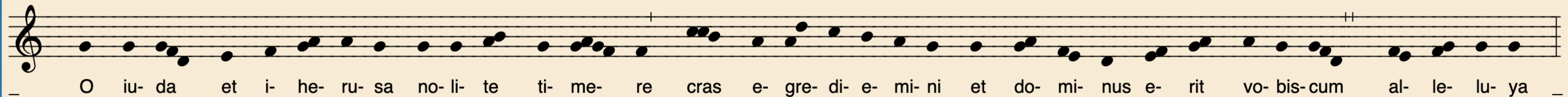
O Juda et Jerusalem nolite

Volpiano is a font!

Source:

Halifax (Canada)

Folio: Sequen
030r 5



O iu- da et i- he- ru- sa no- li- te ti- me- re cras e- gre- di- e- mi- ni et do- mi- nus e- rit vo- bis- cum al- le- lu- ya

Feast:

Vigilia Nat. Dom

Volpiano

1---g---g--gfd---e---f--gh--h--g---g--g--hj---g--ghgf--f7---kkj---h--hl--k--j--h--g---g---gh--fe--d---ef--gh---h--g--gfd77---fe--fg--g--g---3



Text
(syllabized)

O iu-da et i-he-ru-sa-lem no-li-te ti-me-re cras e-gre-di-e-mi-ni et do-mi-nus e-rit vo-bis-cum al-le-lu-ya

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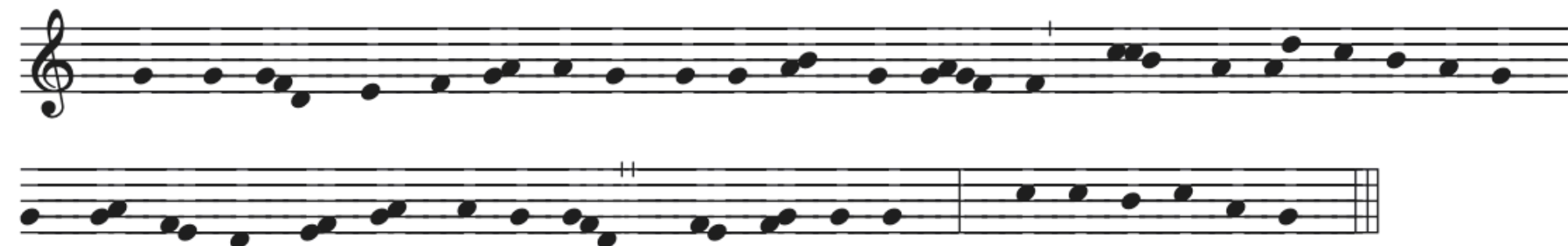
Manuscript Reading Full Text (MS spelling):

O iuda et iherusalem nolite timere cras egrediemini et dominus erit vobiscum alleluia | ~Miserere

Range:



Volpiano:



<https://hajicj.github.io/volpiano-editor/>

Volpiano is de facto also an *encoding standard*. E.g.:

End of line in Ms.: “7”

Must have G-clef at start separated by word separator “—“

If notation is missing, mark segment using “{ }”

Cantus Index

Cantus Index

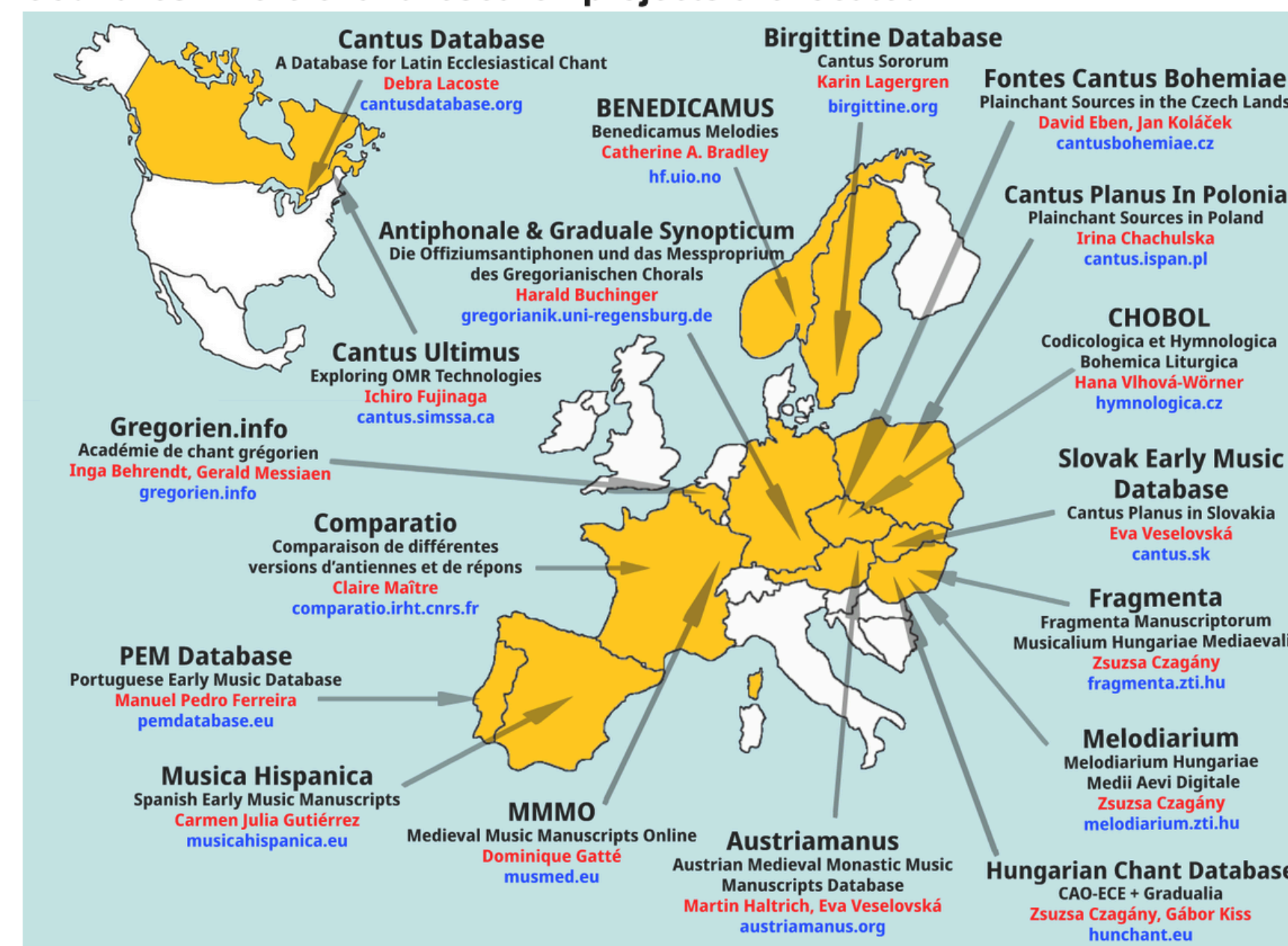
<https://cantusindex.org/>

- Cantus DB is great. Let's have more!
- 18 databases since 2012
- 876 530 chant records total
- Greater geographical diversity

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
CD	368500	26927	13008	25060	211	16273	18203	6293	4308	12732	10661	6029	2896	3094	514,195
	365034	26272	12853	22157	210	16039	17773	6156	4043	11767	9685	5935	2759	3043	503,726
PEM	-	646	4909	6809	84	687	3187	2668	1111	147	1188	1572	14504	3974	41,486
		518	4502	6276	0	673	2740	2617	929	119	905	1363	14047	2373	37,062
FCB	-	-	-	6074	2457	8895	2787	-	-	-	2057	4851	4618	1851	33,590
				6065	2457	8895	2421				2056	4829	4580	1794	33,097
HCD	-	-	228109	448	855	-	24354	-	-	-	-	-	-	-	253,766
			1760	414	0		10419								12,593
CPL	-	-	-	6337	2195	3989	7112	-	1954	1241	2637	2945	3248	801	32,459
				6307	2184	3974	5749		1927	1191	2626	2944	3223	782	30,907
SEMM	-	-	-	-	-	104	205	709	4432	24521	19570	8418	11206	7416	76,581
						103	196	705	4332	23225	18633	8247	11061	7213	73,715

Cantus Index: Catalogue of Chant Texts and Melodies

Countries where chant-research projects are located:



Cantus Index is a catalogue of chant texts and melodies for the liturgical Office and Mass. Through the use of unique "Cantus ID numbers," multiple online medieval music databases have been networked together in order that chant texts and melodies can be searched on this Cantus Index website and matches in all of the partner databases will be returned.

Online projects integrated in the Cantus Index Network:

- 2012: **Cantus Database** (Debra Lacoste, University of Waterloo, Canada)
- 2012: **Portuguese Early Music Database** (Manuel Pedro Ferreira, Lisboa, Portugal)
- 2012: **Slovak Early Music Database** (Eva Veselovská, Bratislava, Slovakia)
- 2012: **Hungarian Chant Database** (Zsuzsa Czagány, Gábor Kiss, Budapest, Hungary)
- 2013: **Fontes Cantus Bohemiae** (Jan Koláček, David Eben, Praha, Czech Republic)
- 2013: **Cantus Planus in Polonia** (Irina Chachulska, Polish Academy of Sciences)
- 2014: **Cantus Ultimus** (Ichiro Fujinaga, McGill University, Montréal, Canada)




Fulltext search Cantus ID

Genre
 - Any -

Recently added chants

- Et qui non diligit fratrem suum quem
AV - 002231e | Added by **Franco Ackermans**
1 day 5 hours ago
- Domine audivi auditionem tuam et timui
Ca - a07606 | Added by **Dominique Crochu**
1 day 11 hours ago
- Deus quis similis erit tibi ne taceas
GrV - g00641b | Added by **Pablo F. Cantalapiedra**
1 day 12 hours ago

Recently added melodies

- 
BD - mBAR107 | Added by **Nicholas David Yardley Ball**
1 month 3 weeks ago
- 
BD - mBAR106 | Added by **Nicholas David Yardley Ball**
1 month 3 weeks ago
- 
BD - mBAR105 | Added by **Nicholas David Yardley Ball**
1 month 3 weeks ago

Recent comments

- Scio quem quaeritis non est 1 day 7 hours ago

Database \neq Dataset

Database != Dataset

Digitization

Digital editions

Databases

Dataset: a “view” of a database for the purposes of further (empirical) research.

Quantitative research

„More“

Simulating acoustics of destroyed spaces
„Periphery“: Listening habits, performance science...



Database to dataset

- Databases typically built over a long time
- Despite best effort to standardize, there will be some drift in how data is collected (e.g.: melody transcription guidelines)
 - Quantitative methods have higher (near-absolute) data consistency requirements => requires some cleaning
- They will likely not be a representative sample of the entire phenomenon of which they store instances — huge domain, not so many scholars
 - Datasets have to be carefully built **for a given research purpose**

Chant Datasets

- **CantusCorpus v0.2**
 - From 2020 (Bas Cornelissen, Willem Zuidema, John Ashley Burgoyne: *Natural units for mode classification in plainchant*. ISMIR 2020), chants with melodies from the Cantus Database
 - <https://github.com/bacor/cantuscorpus>
- **Christmas dataset**
 - Tiny, compared to CantusCorpus (only ± 120 chants)
 - **Targeted:** Christmas Eve vespers (**antiphons** + **responsory**) from late medieval Bohemical sources,
 - Plus all corresponding melodies from Cantus Index
- There are others (e.g. **GregoBase** database and corpus)

Quantitative research

on the nature of chant modality, and on melodic evolution

Caution to self

- Designing an experiment that really answers a research question is tricky
 - The method is **NOT** the valuable part, it is just a way towards a result
 - In NLP/ML and other “problem solving” fields, the method **is** the result...
- Feel free to point out anything you think I overlooked!



Modality

“d”

“e”

Dorian

Hypodorian

Phrygian

Hypophrygian

Lydian

Hypolydian

Mixolydian

Hypermixolydian

“f”

“g”

↓ = final of plainchant mode

Modality from a computational perspective

- Recall: “theoretical” modality (Boethius & Greeks...) vs. “practical” (tonaries)

ΔΕΙΤΟΝ ΠΡΩΤΟΝ
 ΤΗΝΤΙΚΛΙΣ ΠΡΟΤΟΣ
 ΜΟΝΑΧΟΙΣ
 ΟΥΑΝΟΡΟΥ ΑΜΕΝ
 Ο αὐδὲν ἰνδῶ
 Ε τὸν σφῶδερὸν τῶν αὐτῶν
 Σ τὰ τὸν εἰς ὀμνὸν ἰνδῶ
 Ε ἔξω γὰρ ἰνδῶ ὁβ ἰνδῶ
 ΔΙΦΕΡΕΝΤΙΑΣ ΟΥΑ
 ΣΦΟΥΡΟΥ ΑΜΕΝ
 Ο αὐδῶν ὀμνὸν ἰνδῶ
 Σ ἰνδῶν ἰνδῶν ἰνδῶ
 Ρ ὀμνὸν ἰνδῶ ἰνδῶ
 Ι ἰνδῶ ἰνδῶ
 ΣΥΠΕΡΙΟΡ ΔΙΦΕΡΕΝ
 ΤΙΑ ΜΙΣΕΡΕΝ ΟΜΝΙΜΟΝ
 Ι ἰνδῶ ἰνδῶ ἰνδῶ

Modality from a computational perspective

- Recall: **“theoretical”** modality (Boethius & Greeks...) vs. **“practical”** (tonaries)
 - Music-theoretical predictions of modes not always accurate, when compared to how the given melody is classified in tonaries/sources
 - Same antiphon sometimes in different modes in different tonaries!
- Observed: melodic “formulas” shared across multiple different chants (Frere, 1901; Helsen, 2008)

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- Theories such as **centonization** (Ferretti, 1921; Wagner, 1934; Levy, 1970).
 - Chant melodies in fact built from such re-usable “blocks”
 - Modes are “dictionaries” of these blocks

Modality from a computer

- Recall: “**theoretical**” modality (Boethius & Greeks...) v
 - Music-theoretical predictions of modes not always
 - melody is classified in tonaries/sources
 - Same antiphon sometimes in different modes in diff
- Observed: melodic “formulas” shared across multiple
- Theories such as **centonization** (Ferretti, 1921; Wagner, 1934; Levy, 1970).
 - Chant melodies in fact built from such re-usable “blocks”
 - Modes are “dictionaries” of these blocks

Ex. 2 (continued)

The image shows a musical score for Gregorian chant with letter notation above the notes. The letters represent pitch classes: C, B, G, H'' (two ledger lines above), D, J (one ledger line above), E', B', and G. The score is divided into several systems, each with a line number in parentheses: (b), (6), (7), (8), (9a), and (9b). Blue boxes highlight specific melodic blocks: a G note in system (b), a G-D-J block in system (7), a G-H''-D block in system (8), and a G-H''-D block in system (9b). A circled 'N' is placed above the G notes in systems (b), (7), and (9b). A circled '*' is placed above the H'' note in system (b). A circled 'N' is placed above the G note in system (8). The lyrics are: (b) Qui in Chri - sto ba - pti - - za - ti e - stis (end); (6) Chri - stum in - du - i - stis Al - le - lu - - ia; (7) Glo - ri - a pa - tri et fi - li - o et spi - ri - tu - i san - cto (7) Christum etc.; (8) Si - cut e - rat in prin - ci - pi - o et nunc et sem - per; (9a) et in se - cu - la se - cu - lo - rum a - men (7) Christum etc.

Levy, Kenneth. The Italian Neophytes' Chant. *Journal of the American Musicological Society*, Vol. 23, No. 2 (Summer, 1970), pp. 181-227

Modality from a computer

- Recall: “**theoretical**” modality (Boethius & Greeks...) v
 - Music-theoretical predictions of modes not always
 - melody is classified in tonaries/sources
 - Same antiphon sometimes in different modes in different sources
- Observed: melodic “formulas” shared across multiple sources
- Theories such as **centonization** (Ferretti, 1921; Wagner, 1934; Levy, 1970).
 - Chant melodies in fact built from such re-usable “blocks”
 - Modes are “dictionaries” of these blocks
- Centonization **criticized**, mainly for its mis-interpretation & **analytical imprecision** (Treitler, 1975; Hiley, 1993)

Ex. 2 (continued)

(b) Qui in Chri - sto ba - pti - - za - ti e - stis (end)

(6) Chri - stum in - du - i - stis Al - le - lu - - ia

(7) Chri - stum in - du - i - stis Al - le - lu - - ia

(8) Glo - ri - a pa - tri et fi - li - o et spi - ri - tu - i san - cto (7) Christum etc.

(9a) Si - cut e - rat in prin - ci - pi - o et nunc et sem - per

(9b) et in se - cu - la se - cu - lo - rum a - men (7) Christum etc.

Levy, Kenneth. The Italian Neophytes' Chant. *Journal of the American Musicological Society*, Vol. 23, No. 2 (Summer, 1970), pp. 181-227

Modality from a computational perspective

Maybe there is something here
to be discovered at scale!

- Recall: **“theoretical”** modality (Boethius & Greeks...) vs.
 - Music-theoretical predictions of modes not always accurate, when only the given melody is classified in tonaries/sources
 - Same antiphon sometimes in different modes in different tonaries!
- **Observed: melodic “formulas”** shared across multiple different chants (Frere, 1901; Helsen, 2008)
- Theories such as **centonization** (Ferretti, 1921; Wagner, 1934; Levy, 1970):
 - Chant melodies in fact built from such re-usable “blocks”
 - Modes are “dictionaries” of these blocks
- Centonization **criticized**, mainly for its mis-interpretation & **analytical imprecision** (Treitler, 1975; Hiley, 1993)

Modality from a computational perspective



Maybe there is something here
to be discovered at scale!

- Can modes be characterized as “dictionaries” of melodic units?

Modality from a computational perspective



Maybe there is something here
to be discovered at scale!

- **Can modes be characterized as “dictionaries” of melodic units?**
- Basic idea: if modality can be characterized by some feature, we should be able to **classify melodies into modes** based on this feature!
 - Cornelissen et al., 2020: up to **95 %** of antiphons from CantusCorpus v0.2 classified correctly based on Volpiano **n-gram features** (The experiment, however, has issues...)
- How to answer yes/no? What is the threshold?
 - ...idea: this is the **“practical”** (empirical) view of modality, so let’s compare to the **“theoretical”**!

Modality from a computational perspective

- Experiment design:
 1. First, classify antiphons into modes using the “music-theoretical” approach (final, initial + range). This is the baseline.
 2. Select some “modally characteristic” melodic units,
 3. Classify antiphons into modes using the “empirical/dictionaries” approach,
 4. See if this “empirical” approach has **at least the same accuracy** as the “theoretical”.

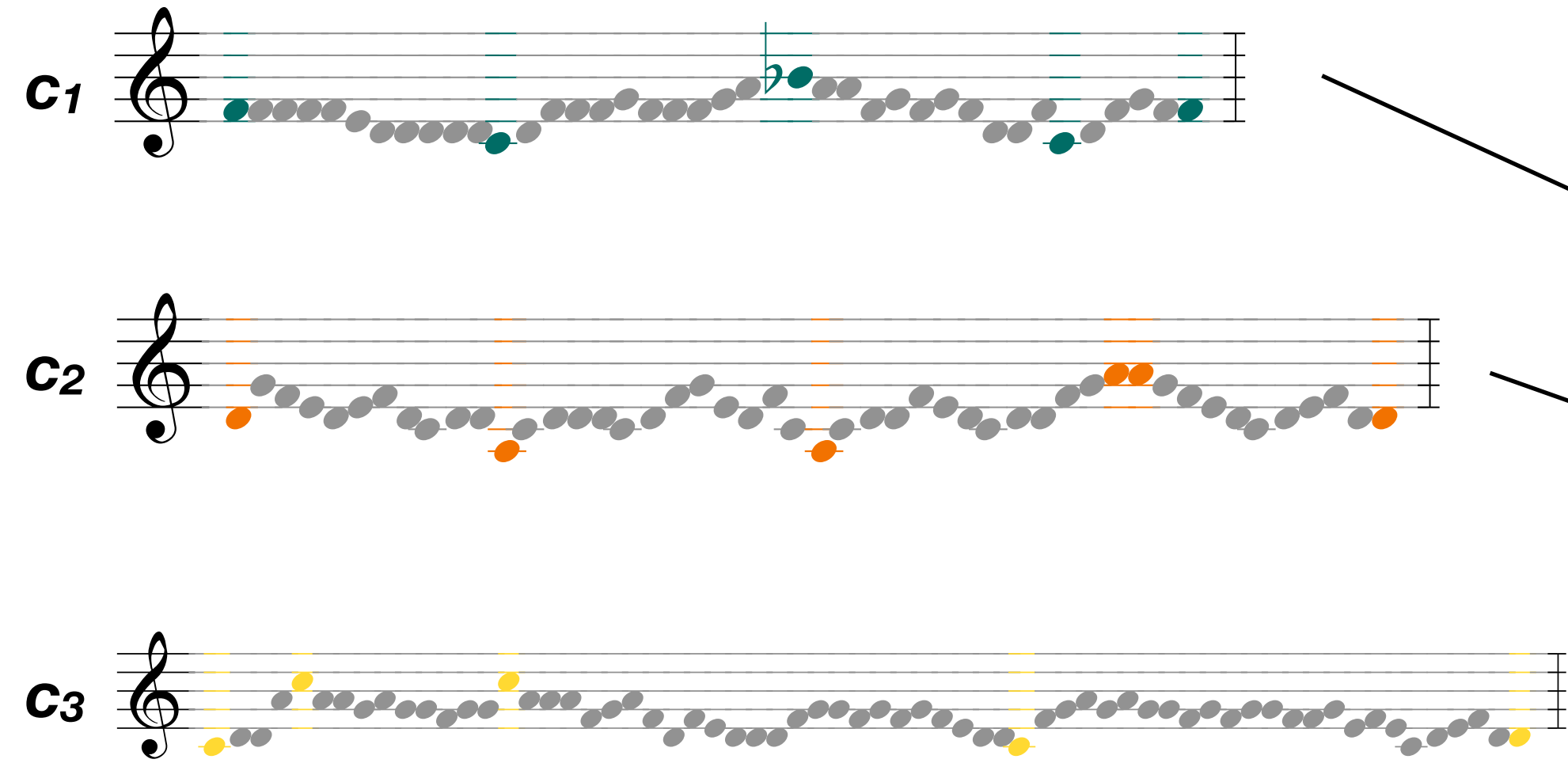
Step 1. “Music-Theoretical” Classification

Antiphon melodies C_{Test}

Extracted features

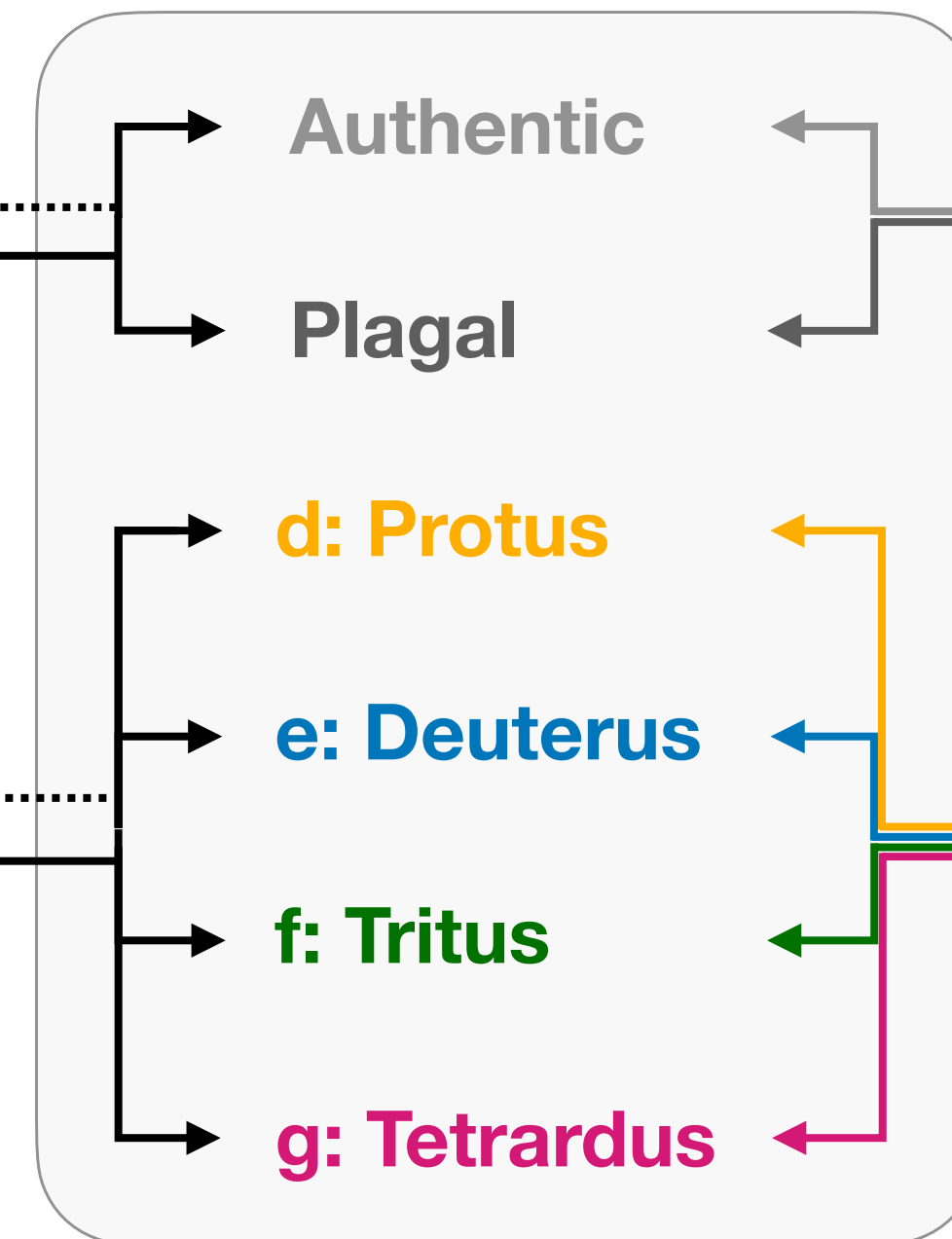
Last note
First note
Lower range from final
Upper range from final

Results



	Last note	First note	Lower range from final	Upper range from final
C_1	f	f	-3	3
C_2	d	d	-3	4
C_3	d	c	-1	6

Classification method:
rules defined by
music theory



	$m_i = \dots$
C_1	6
C_2	2
C_3	1

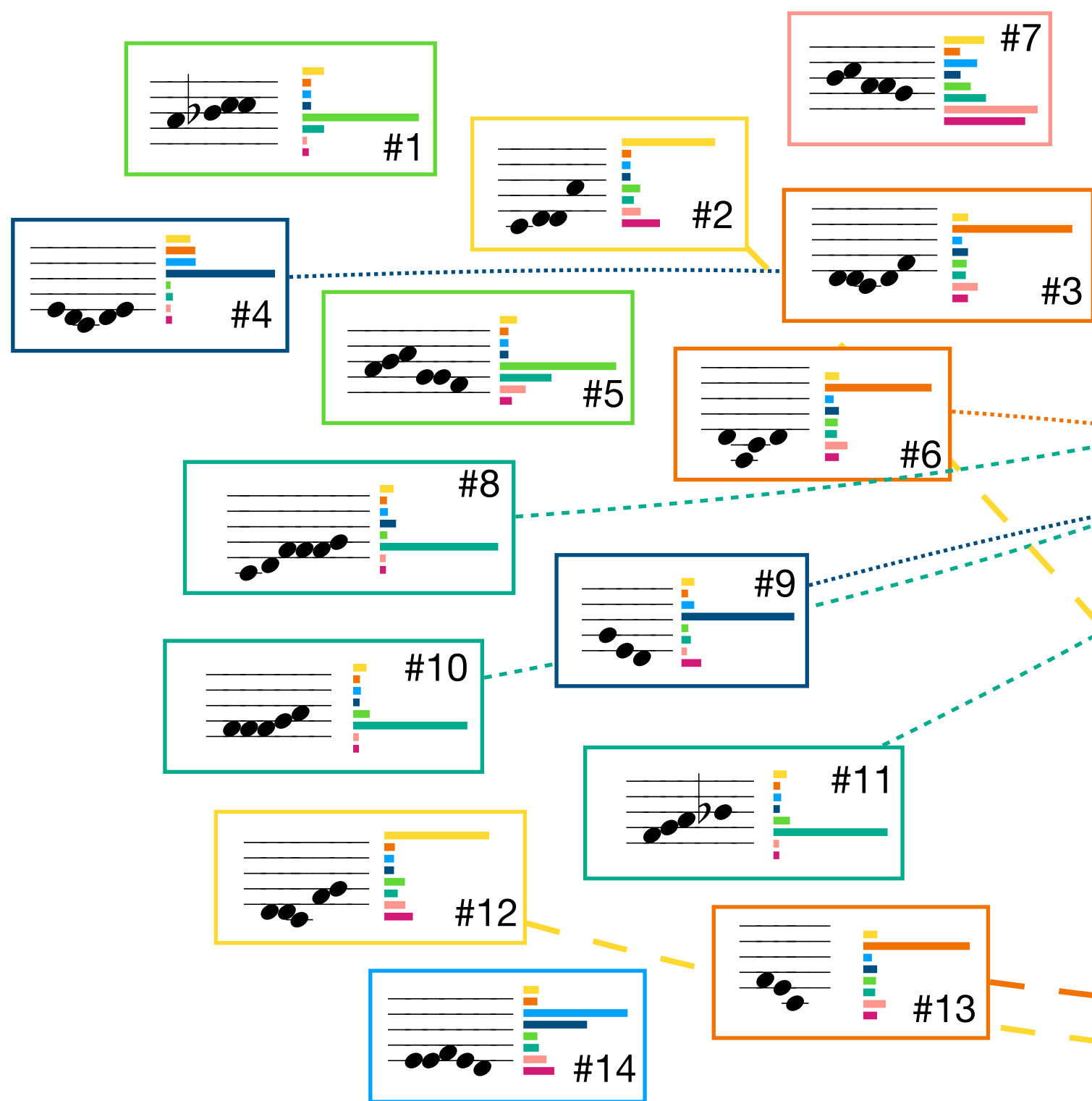
Part 1: feature extraction (final, initial, range)

Part 2: classification

Step 2 & 3. “Empirical” Classification

Precomputed (step 2) | Classification runtime (step 3)

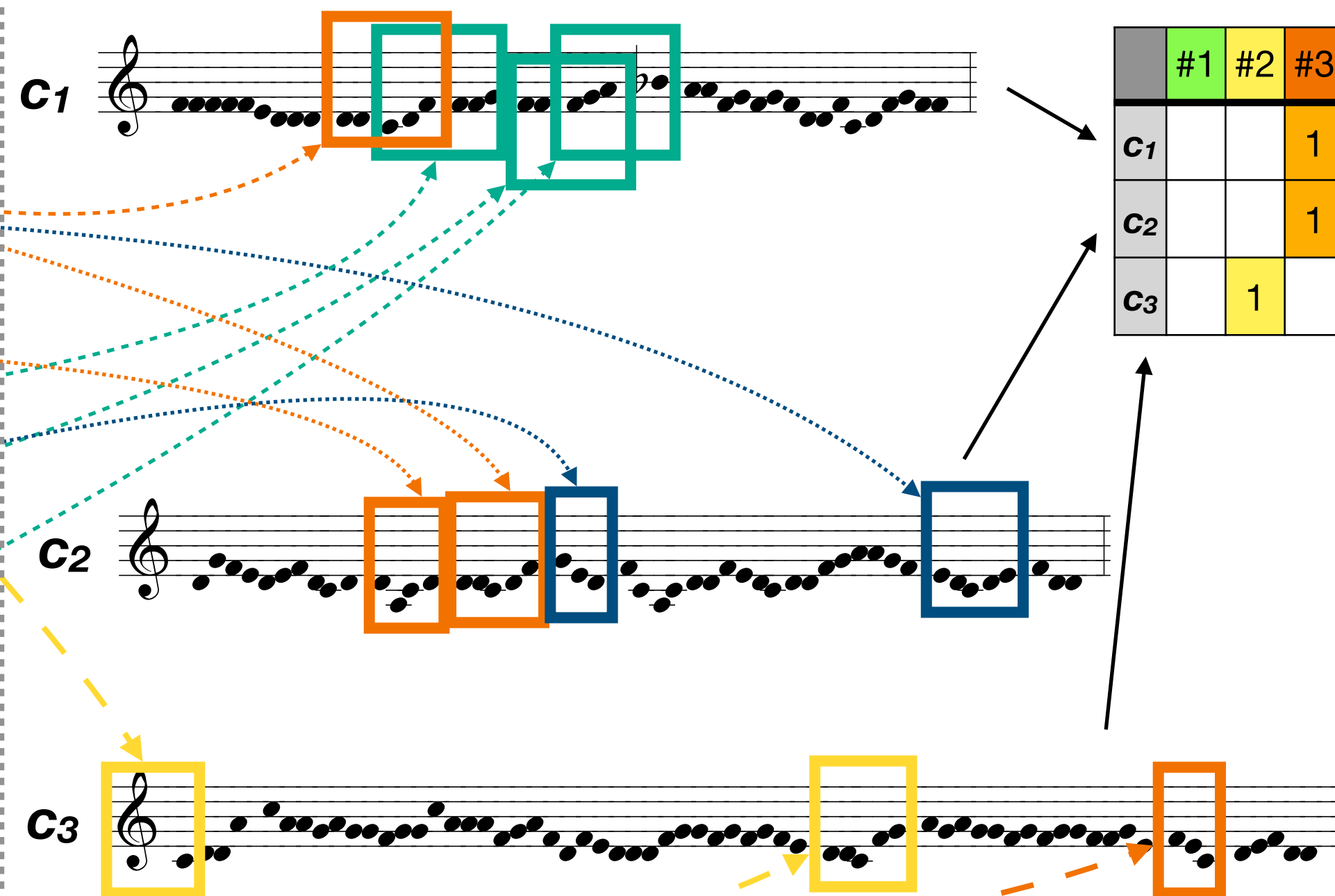
Set of characteristic melodic units



Part 0: Selecting melodic units that are characteristic for a mode

(Thresholds: prec. 0.5, rec. 0.025)

Antiphon melodies C_{Test}



Part 1: feature extraction (occurrences of characteristic mel. units)

Extracted features:
Table of melodic unit counts

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14
C ₁			1					1		1	1			
C ₂			1	1		1			1					
C ₃		1										1	1	

Results

	$m_i = \dots$
C ₁	6
C ₂	4
C ₃	1

Classification:
Log-Linear models

Part 2: classification

Step 4. Compare accuracy (f-score)

Results:
“Empirical” metoda

	$n^T_i = \dots$
C₁	6
C₂	4
C₃	1

Real modes
(from Cantus DB)

	$m_i = \dots$
C₁	6
C₂	2
C₃	1

Results:
“Theoretical” method

	$n^V_i = \dots$
C₁	6
C₂	2
C₃	1

Empirical method f-score

= 0.66

Theoretical method f-score

= 1.00

If this were the case, we would conclude that modality likely **cannot be** characterized by dictionaries of characteristic units.



Modality from a computational perspective

- Experiment design:
 1. First, classify antiphons into modes using the “music-theoretical” approach (final, initial + range). This is the baseline.
 2. Select some “modally characteristic” melodic units,
 3. Classify antiphons into modes using the “empirical/dictionaries” approach,
 4. See if this “empirical” approach has **at least the same accuracy** as the “theoretical”.
- Dataset: broadest possible — **CantusCorpus v0.2**
 - **Antiphons**, balanced subset to avoid mode biases: $500 \times 8 = 4000$ **melodies** total.
 - Data cleaning: remove non-note characters, liquescents, differentiae (!)

Results

- **“Theoretical”** method score: ranging from **0.78 to 0.87** (default settings vs. optimized rules melody range thresholds in different modes)
- **“Empirical”** method score: **0.83**
 - But: if dataset is not balanced (using all 13085 available antiphons): **0.91**

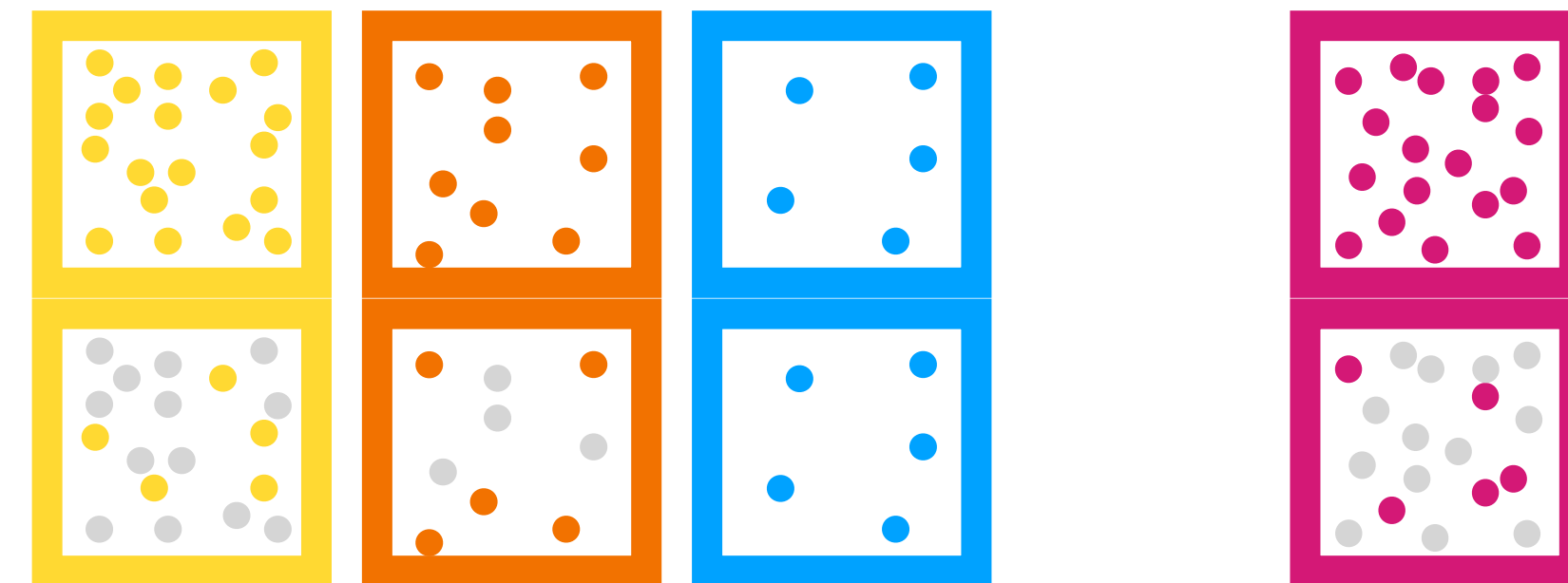
Observations

- Theoretical method: mistakes (nearly) only authentic vs. plagal. **Finals work.**
- Experiments on responsories: similar results (**0.83 vs. 0.85**)
 - Melodic units **do not generalize** between genres (scores: 0.65). (Expected.)
- **Stripping differentiae** has a large impact on the classification result. (Expected.)
 - Cornelissen et al. (2020) didn't... and their 0.95 accuracy drops to 0.90 if differentiae are stripped, and their main observation (words are a better segmentation than 4-grams) does not hold.

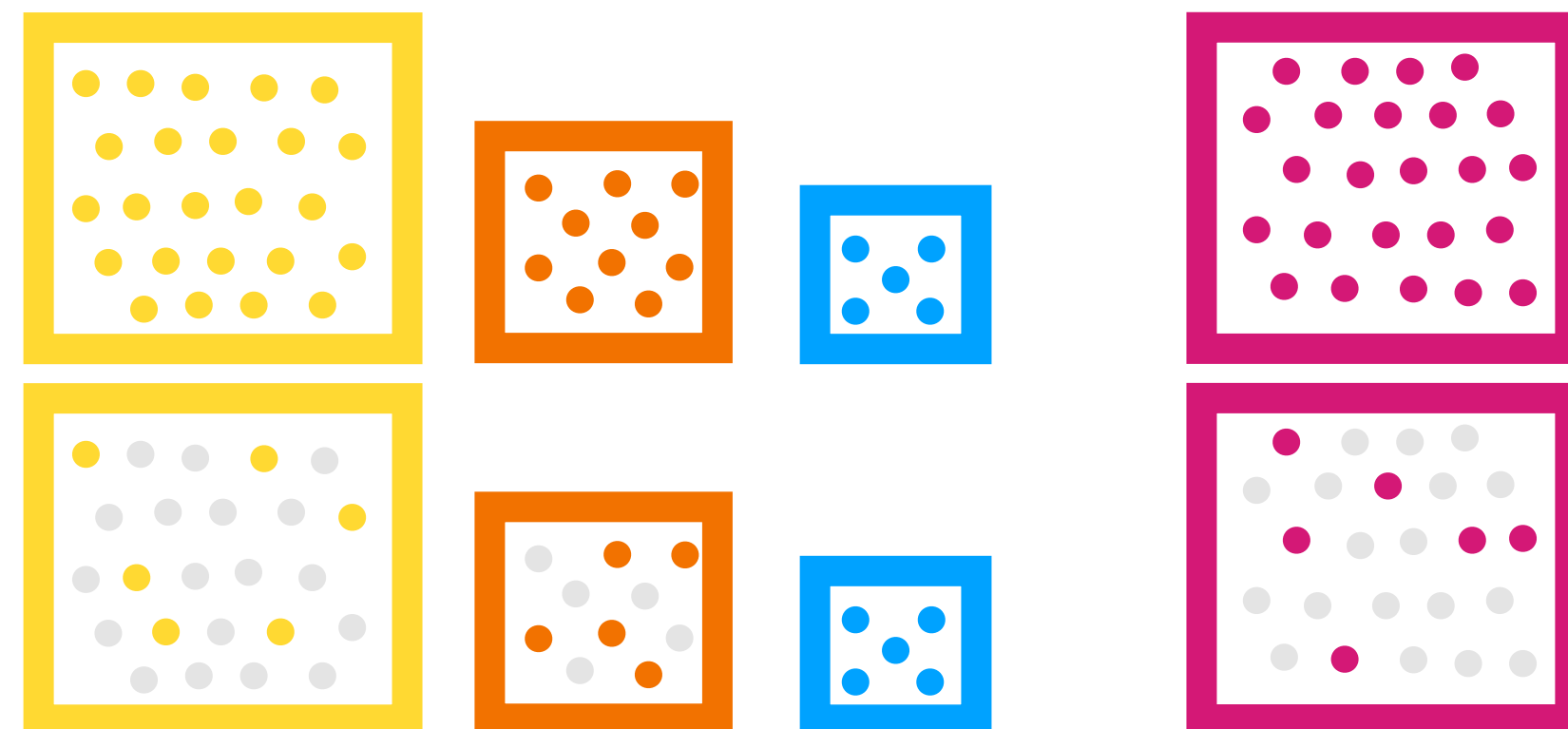
Observations

- Unbalanced dataset: the “density” of melodies in modes is roughly constant. Modes with more melodies likely contain greater melodic variability overall.

Case 1.
All modes have similar intra-class variance,
some are more densely sampled.
...balancing compensates this advantage.



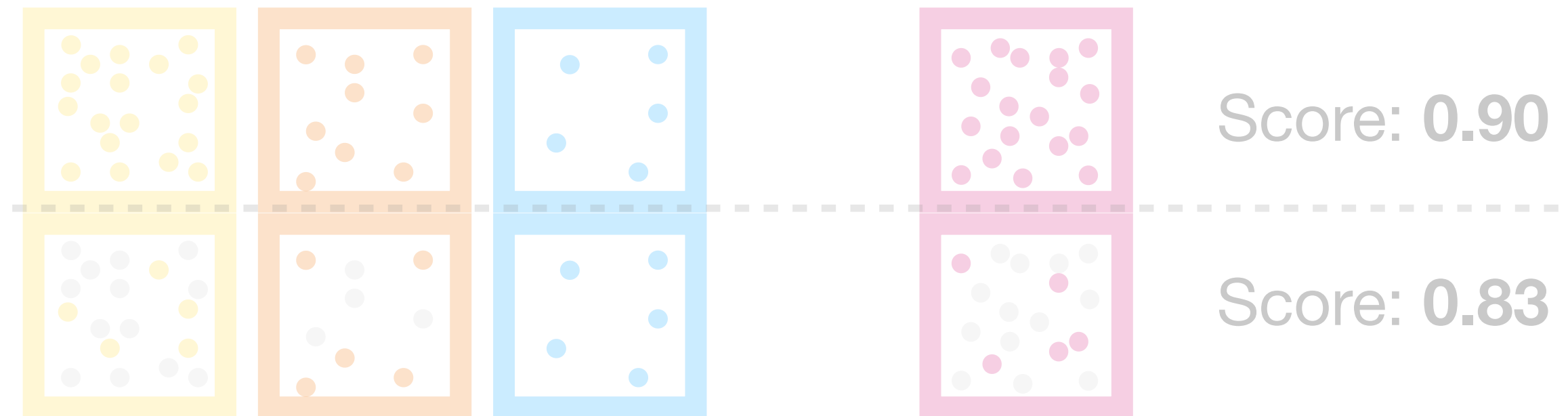
Case 2.
All modes have similar “density” of melodies,
modes with more melodies have more variance.
...balancing makes larger modes sparse.



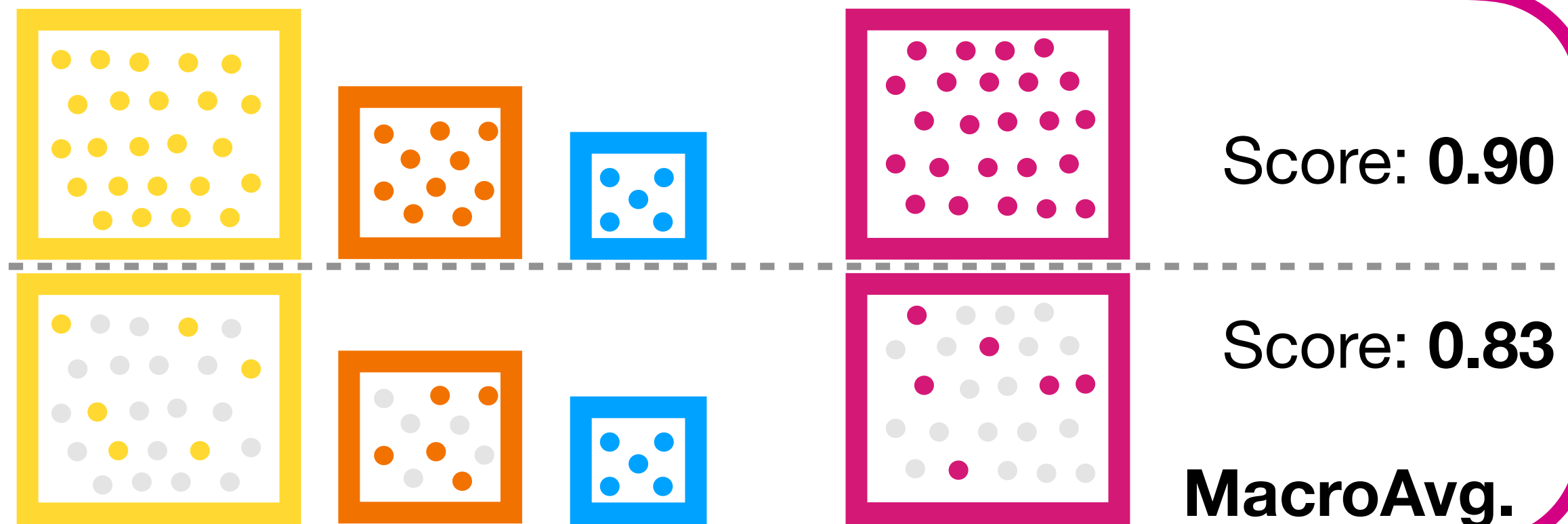
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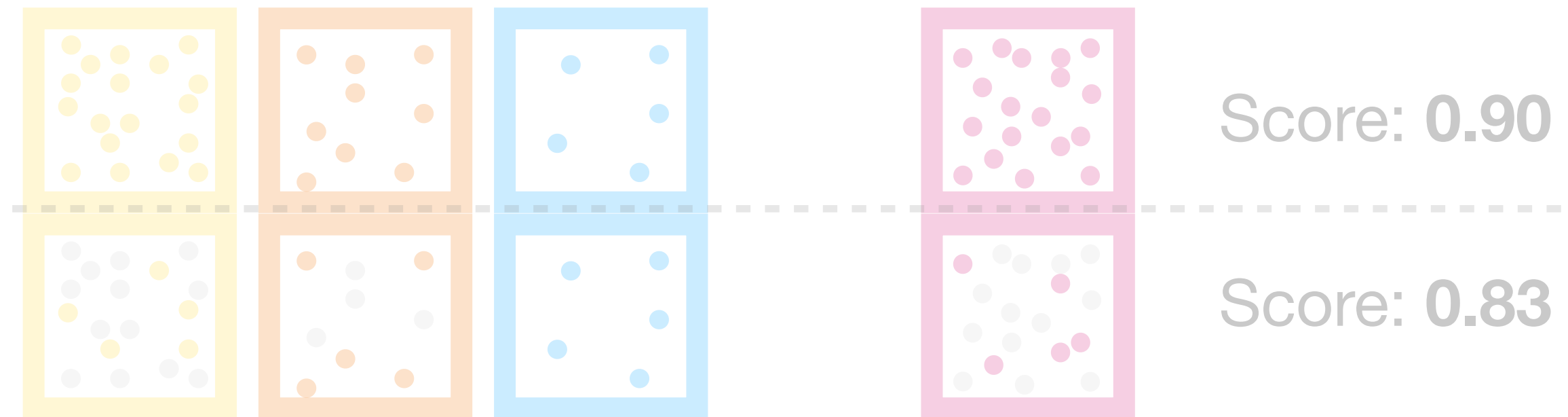
MacroAvg.

Observations

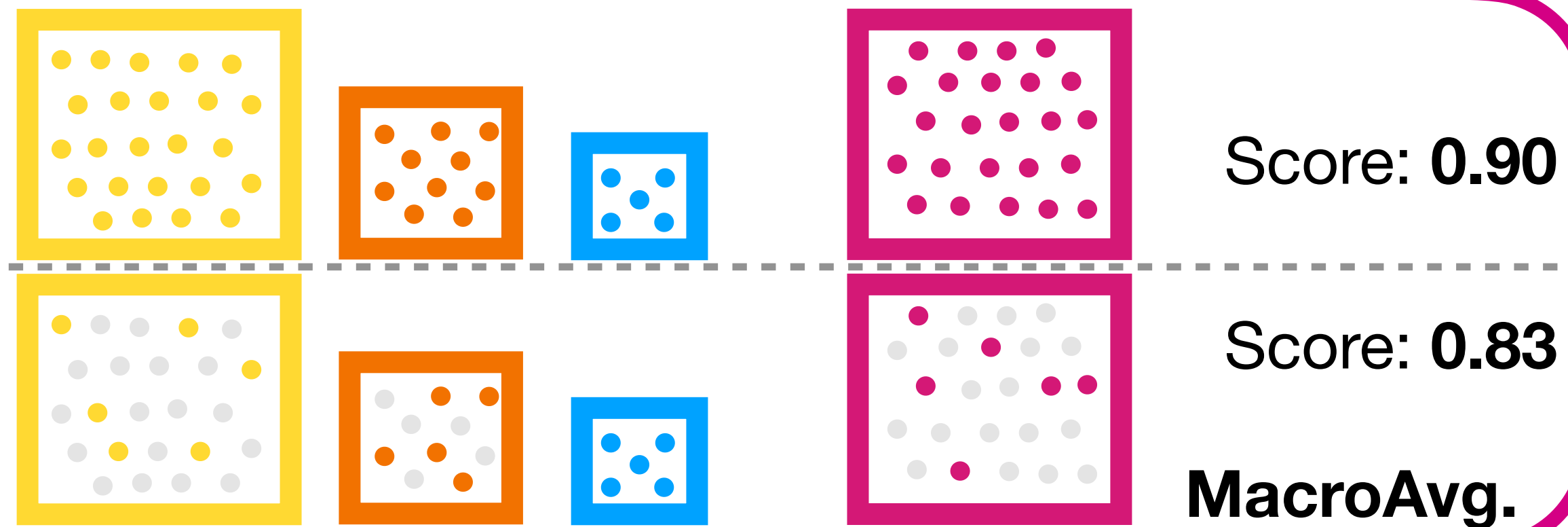
Makes good sense if we remember the memorized structure of repertoire evidenced by tonaries!

- Unbalanced dataset: the “density” of melodies. Modes with more melodies likely contain greater variance overall.

Case 1.
All modes have similar intra-class variance, some are more densely sampled.
...balancing compensates this advantage.



Case 2.
All modes have similar “density” of melodies, modes with more melodies have more variance.
...balancing makes larger modes sparse.



Insights?

- “Dictionary” view of modality might be a good way of looking at modes.
- Did we put centonization back in the game?
 - Not yet: we have merely looked at individual characteristic units from which one cannot build the entire melodies.
- More experiments: statistical **segmentation!**
 - Powerful unsupervised learning methods
 - Cornelissen et al.: segment accuracy up to 0.91 (after stripping differentiae), Vojtěch Lanz’s (ongoing) thesis at MFF UK: over 0.95!
- Leads to a **new question**: What is the “density” of melodies in modes? How to measure it?

Melodic evolution

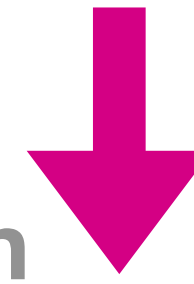
Melodic diversity

- Recall: **Temporal, geographical, “institutional” diversity of chant.**
 - 500 years, large and densely populated area.
- How did Gregorian **melodies** develop?
 - Were there geographically defined “melodic dialects”, or was development roughly equal across all of Latin Europe?
 - We need better analytical theories of chant melody. We don’t know what phenomena to track.

Melodic diversity

Multiple melodies & their metadata for the same Cantus ID available.

Cantus ID: 003511



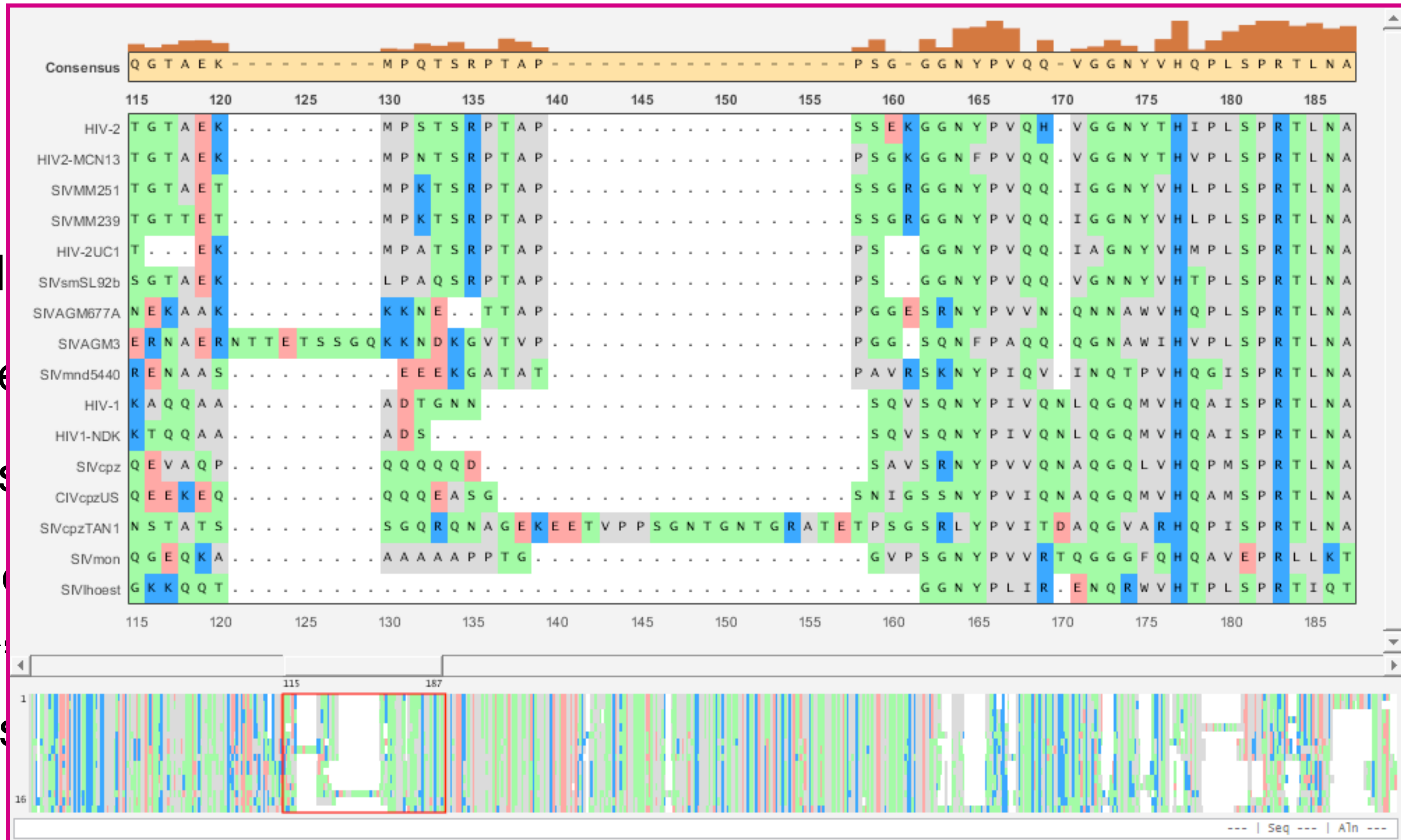
Source (siglum)	Folio	Text incipit	Feast	Office	Genre	Position	Mode	Text?	Melody?	Digitized?	
CH-Fco Ms. 2	024r	Judaea et Jerusalem*	Vigilia Nat. Domini	P	A		003511	*	✓		Image
CH-SGs 388	050	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CH-SGs 390	042	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓		Image
CDN-Hsmu M2149.L4	030r	O Juda et Jerusalem nolite	Vigilia Nat. Domini	L	A		003511	8	✓	♪	Image
CZ-Pst DE I 7	013r	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8			
CZ-Pu VI.E.4c	067v	Judaea et Jerusalem*	Dom. 4 Adventus	L	A	1	003511				
CZ-Pu VI.E.4c	071v	Judaea et Jerusalem nolite	Vigilia Nat. Domini	L	A	1	003511				
D-B Mus. 40047	017r	Judaea et Jerusalem nolite timere	Nativitas Domini	V	A	1	003511	8			Image
D-KA Aug. LX	015v	Judaea et Jerusalem nolite timere	Vigilia Nat. Domini	L	A	1	003511	8	✓	♪	Image

Measuring melodic diversity

- Melodies are represented simply as **strings** (Volpiano encoding)!
- **String edit distance: Levenshtein** (It's a standard algorithm available in every language...)
 - More generally: Needleman-Wunsch algorithm
- A field has implemented these at scale: **bioinformatics!** (Proteins are strings, too.)
 - **Multiple Sequence Alignment** algorithms, originally meant for thousands of DNA, RNA or protein sequences
 - Chant is really easy for them...

Measuring melodic diversity

- Melodies
- **String ed**
- More ge
- A field has
- **Multiple**
of DNA
- Chant is



nds

Measuring melodic diversity

The screenshot displays the ChantLab web application interface. At the top, a navigation bar includes a home icon, 'Chant list', 'Manage data', 'Manage alignments', 'Dashboard', 'Settings', and 'Help'. A search bar on the right is labeled 'Search incipit'. Below the navigation bar, there are several control panels. On the left, 'Display options' includes checkboxes for 'Show headers', 'Show text', 'Show colors', and 'Show conservation'. The 'Display mode' section shows 'Volpiano' selected over 'Raw', with '11 sequences' listed below. In the center, there are buttons for 'Save', 'Download FASTA', 'Download JSON', 'Distance Matrix', 'Chant Network', 'Manuscript Network', and 'Reduce to Contrafacts'. On the right, a 'Data sources' panel lists 'CantusCorpus v0.2', 'Graduals', 'asummo', '003511-enriched', 'netvor', and 'netvor-0.2' (which is checked). A 'Save' button is also present in this panel. The main area shows four musical staves, each with a title and a close button (X). The titles are: '0: A-Wn 1799**, 017r, M', '1: D-KNd 1161, 017v, M', '2: CDN-Hsmu M2149.L4, 032r, M', and '3: F-Pn lat. 15181, 140v, B'. Each staff contains a musical score with colored vertical bars (orange, purple, blue, green, yellow) overlaid on the notes, representing melodic diversity. The lyrics are written below the notes.

ChantLab (<http://chantlab.mua.cas.cz>) – you can try it out!

Chant list Manage data Manage alignments Dashboard Settings Help

Search incipit

Display options: Show headers, Show text, Show colors, Show conservation

Display mode: Volpiano Raw

10 sequences

Save Download FASTA Download JSON Download Newick

Distance Matrix Chant Network Manuscript Network

Reduce to Contrafacts Phylogenetic Tree

Distance matrix

	Judaea et	Judaea et	Judaea et	Judaea et	Judaea et	Judaea et	Judaea et	Judaea et	Judaea et
Judaea et	0.00	0.21	0.18	0.33	0.51	0.75	0.75	0.76	0.75
Judaea et	0.21	0.00	0.27	0.41	0.61	0.71	0.70	0.73	0.72
Judaea et	0.18	0.27	0.00	0.27	0.50	0.76	0.75	0.76	0.76
Judaea et	0.33	0.41	0.27	0.00	0.47	0.80	0.78	0.78	0.79
Judaea et	0.51	0.61	0.50	0.47	0.00	0.84	0.83	0.82	0.81
Judaea et	0.75	0.71	0.76	0.80	0.84	0.00	0.18	0.24	0.26

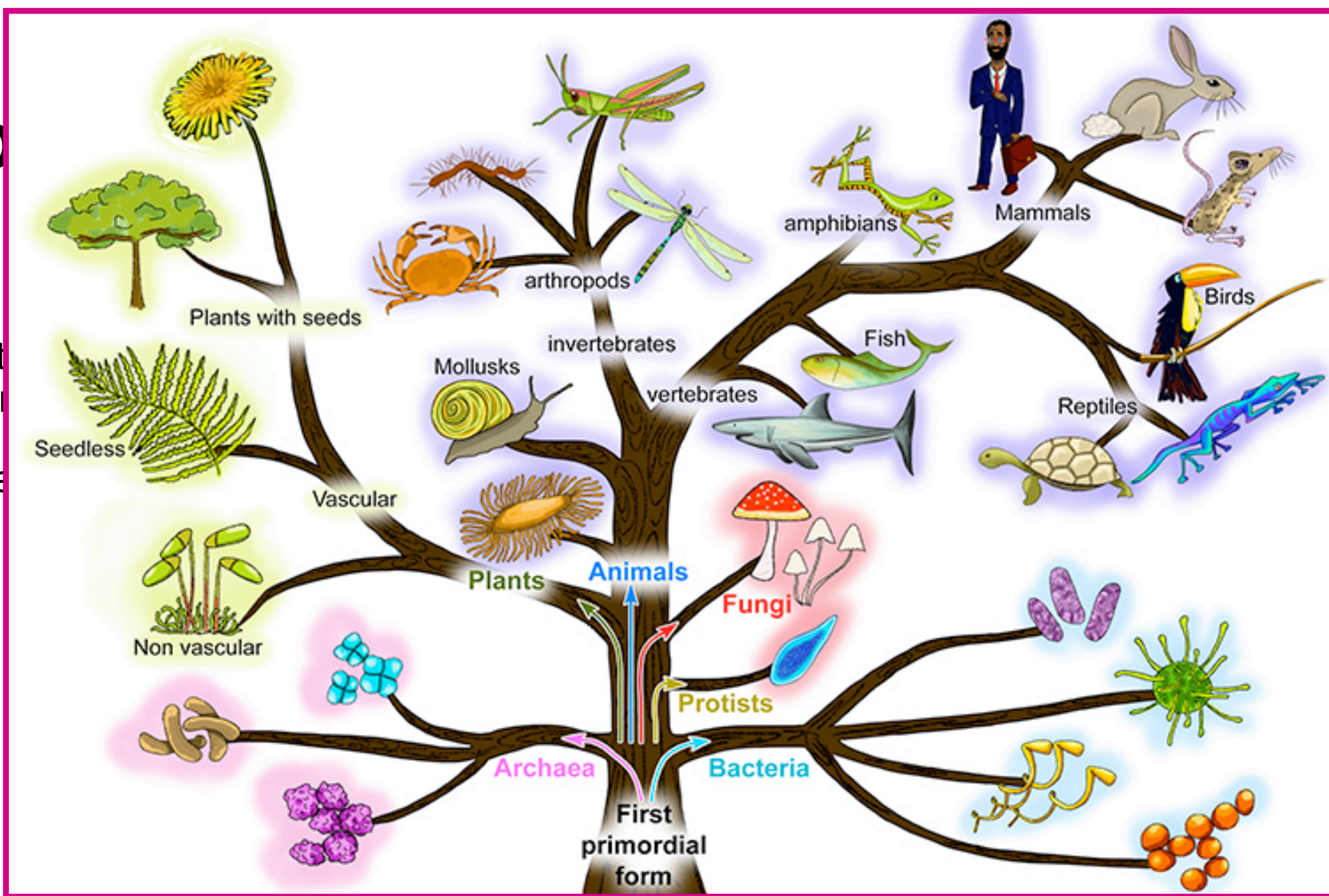
Distances for each pair of melodies!

Melody evolution

- The distance matrix is a good visualization to support thinking about chant melodies, but we can do more.
- Next step that bioinformaticians would do: build a **phylogenetic tree**

Melo

- The dist can do
- Next ste



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Melody evolution

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 - Leaves of the tree: **sources** (=century, provenance, etc.)
 - Topology and branch lengths in the tree: how melodies evolved in time & place!

Melody evolution

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- Next step that bioinformaticians would do: build a **phylogenetic tree**
 - Leaves of the tree: **sources** (=century, provenance, etc.)
 - Topology and branch lengths in the tree: how melodies evolved in time & place!
- Can this bring **meaningful** results for chant melodies?
 - Concerns like: non-tree structure of cultural vs. biological evolution (lateral transfer)
 - Must be tested experimentally!

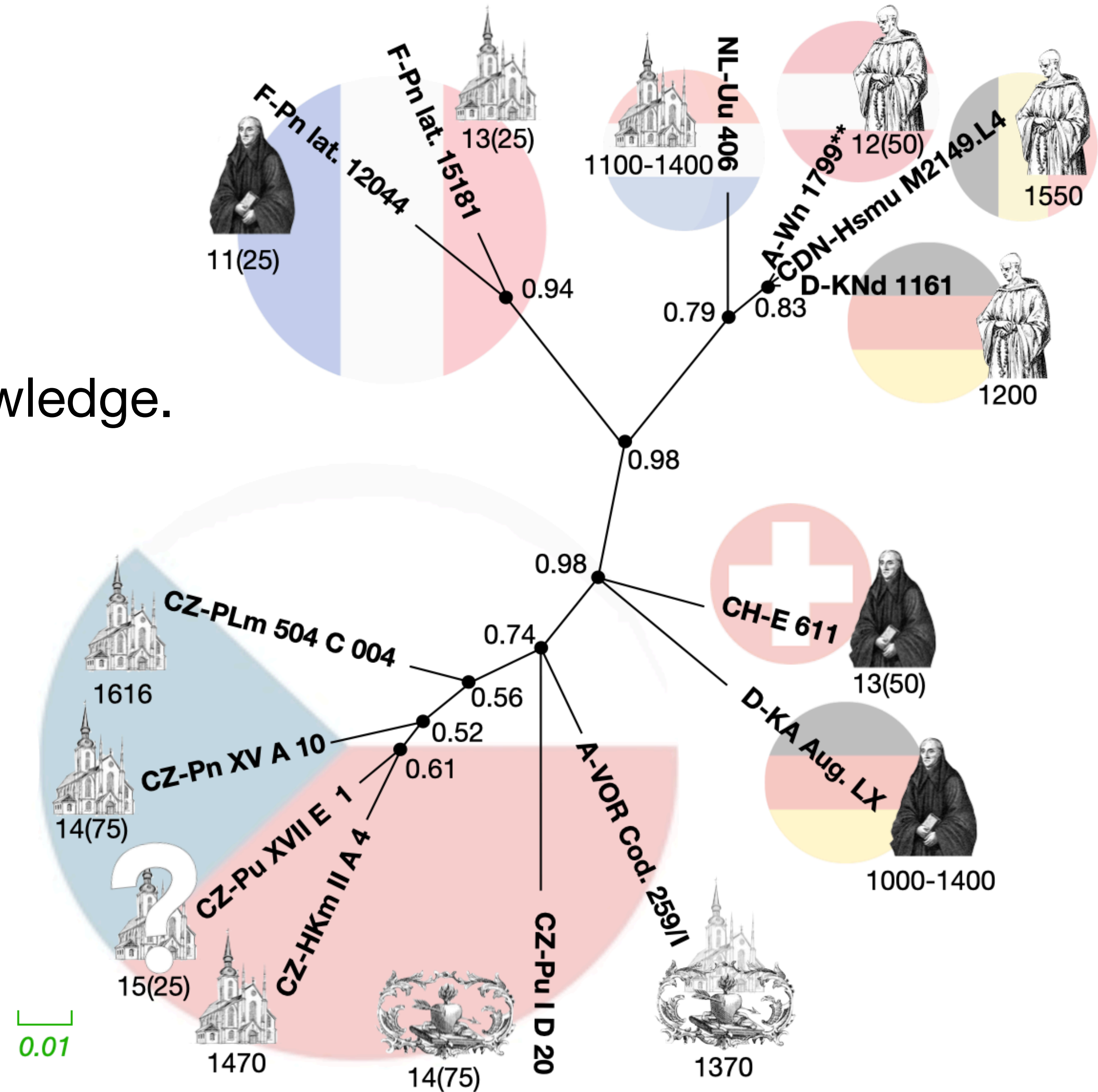
Melody evolution: phylogenetic trees

- Leaves of the tree: **sources** (=century, provenance, etc.), topology and branch lengths in the tree: how melodies evolved in time & place!
- For testing, requires **sources** that can be aligned: they all must contain a set of the **same melodies**
 - In bioinformatics, not an issue: genes mostly shared among related species
 - In chant scholarship: we have mostly melodies of antiphons, but **office sources do not share much repertoire...**
- Fortunately: **Christmas** dataset!
 - Christmas Eve vespers, 120 melodies from ± 20 sources. Selected 5 antiphons and 1 responsory.

Christmas Vespers

A first phylogeny thereof

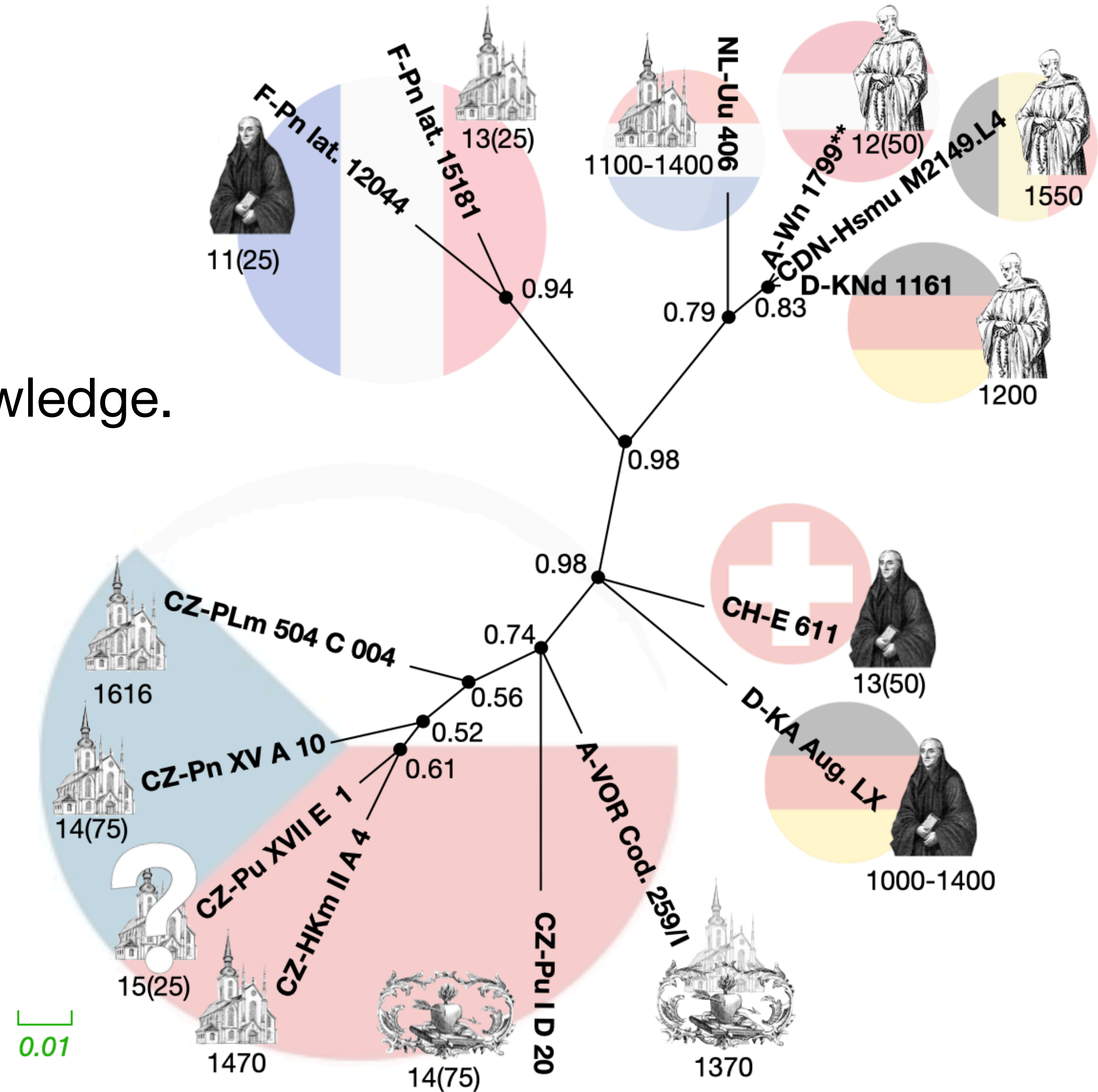
- Validation against musicological knowledge.



Christmas Vespers

A first phylogeny thereof

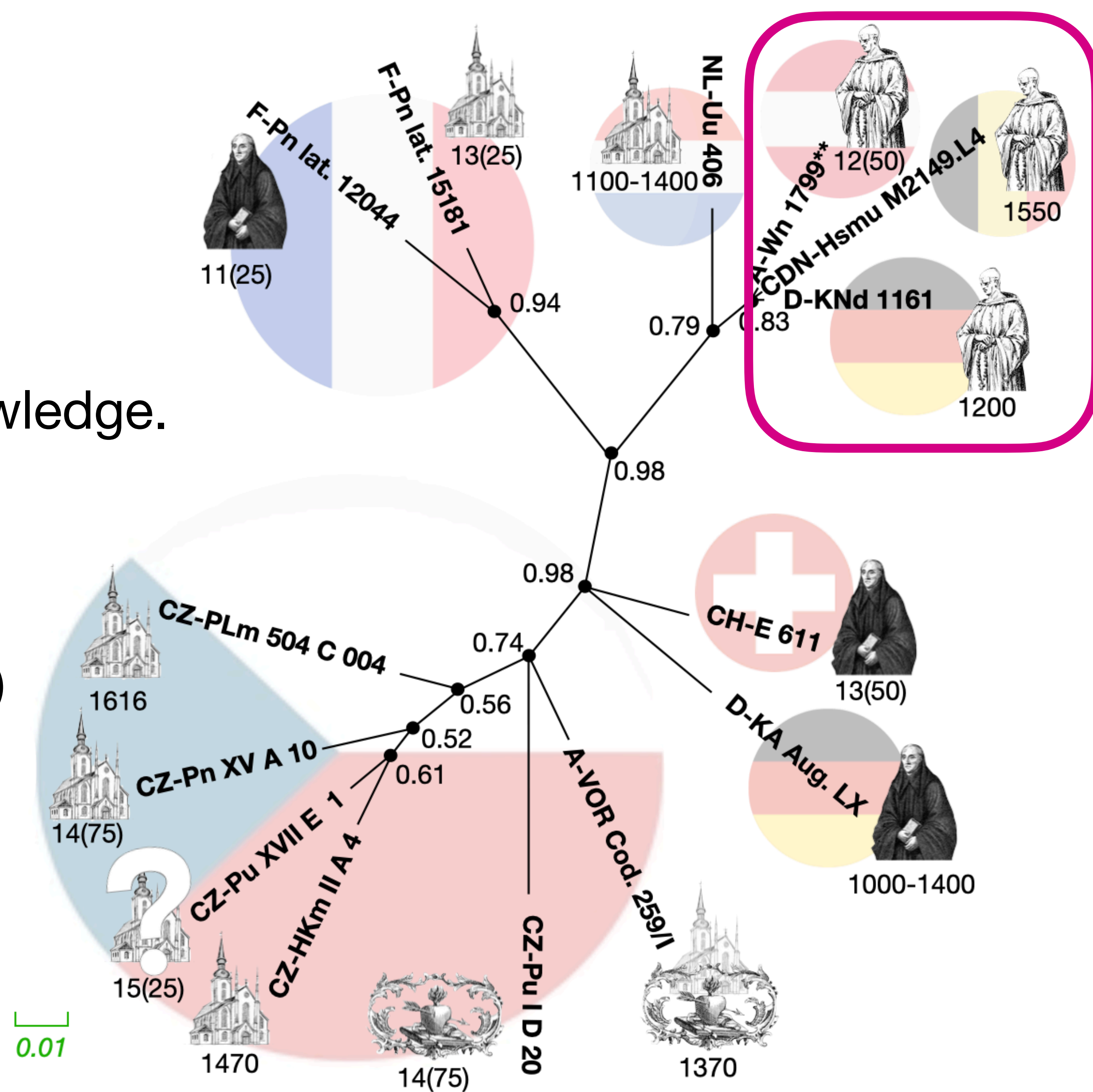
- Validation against musicological knowledge.
- Conforms to expectations?



Christmas Vespers

A first phylogeny thereof

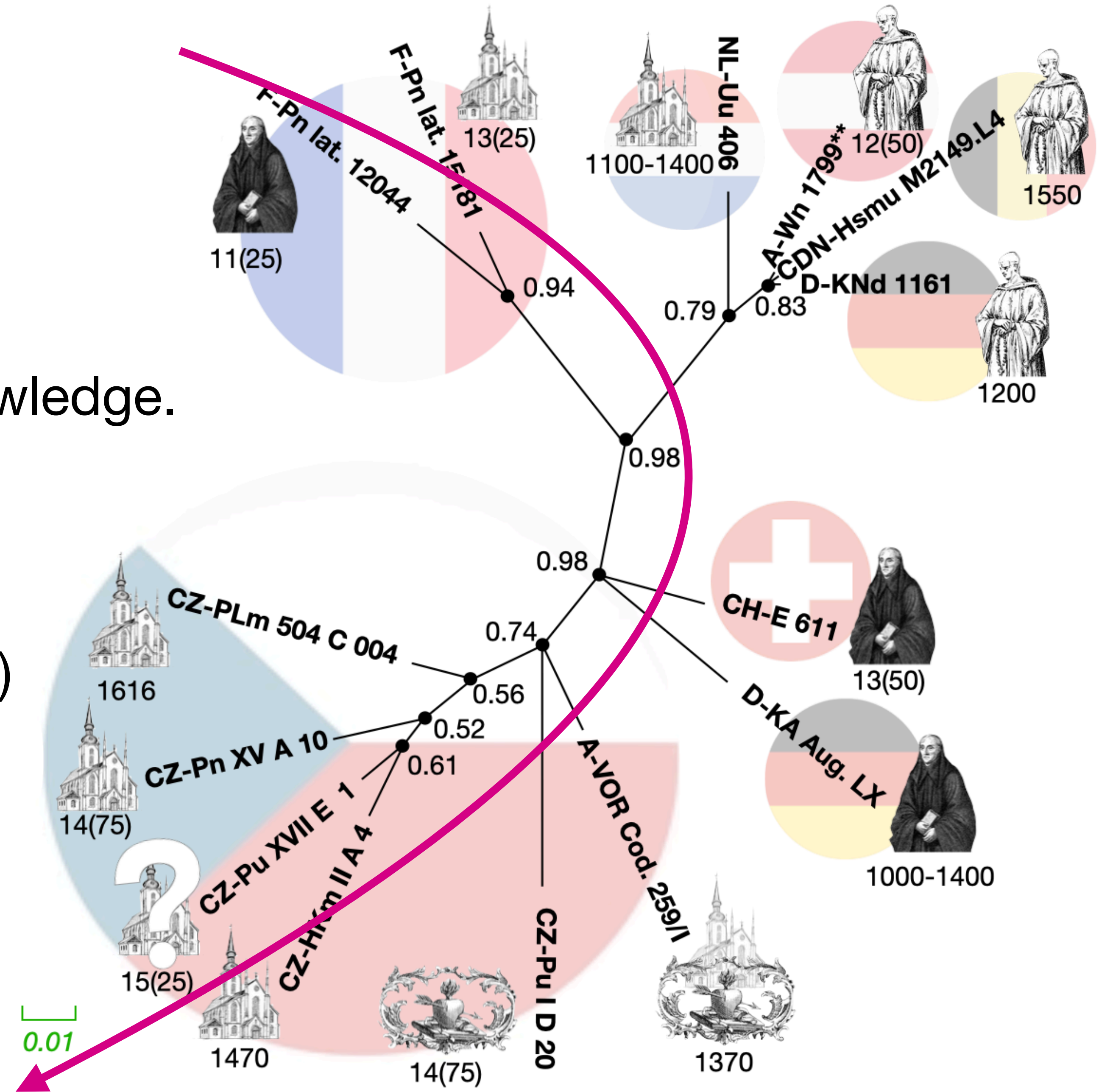
- Validation against musicological knowledge.
- Conforms to expectations?
- Cistercian group (recall: history — Cistercian reform)



Christmas Vespers

A first phylogeny thereof

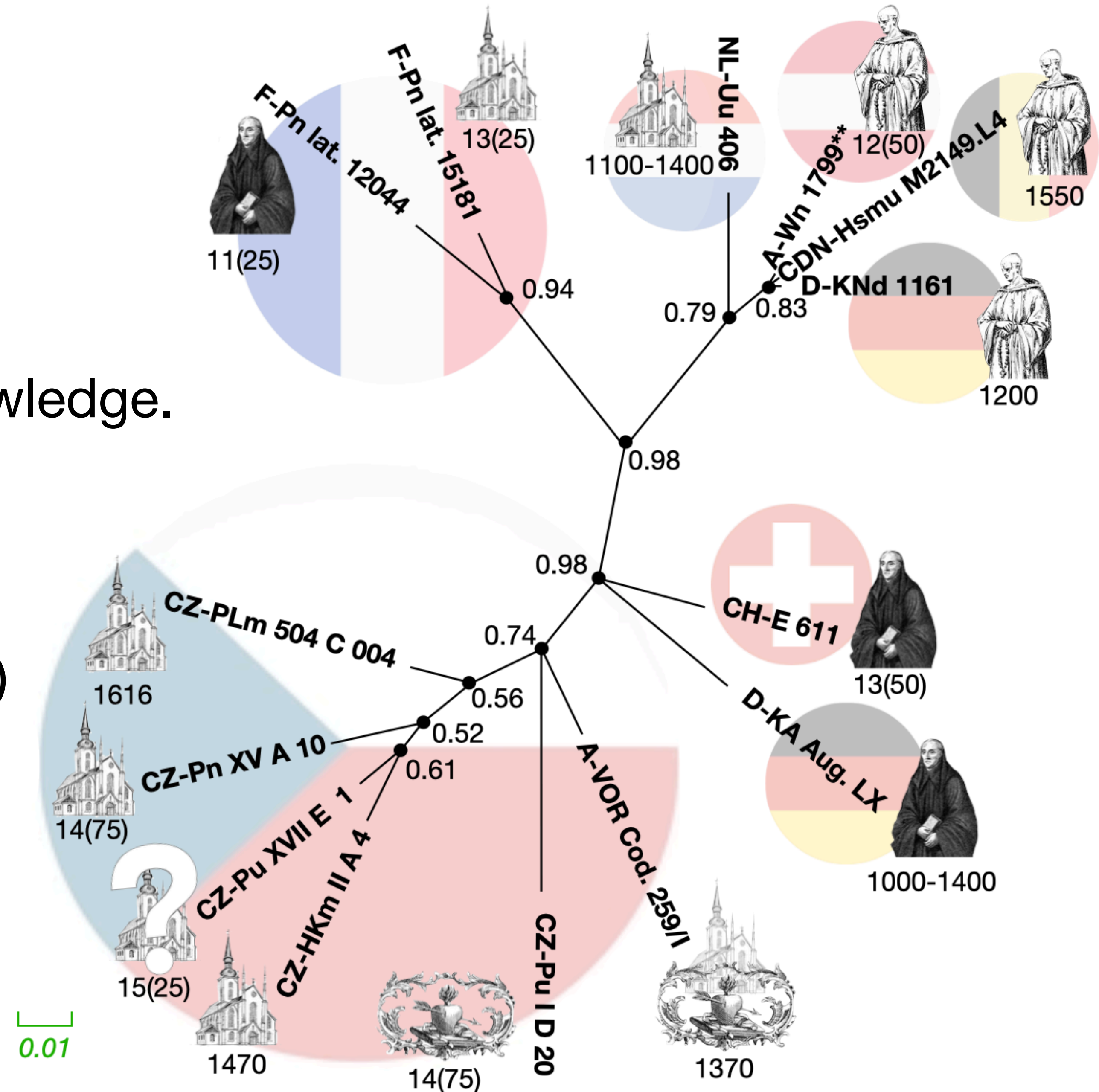
- Validation against musicological knowledge.
- Conforms to expectations?
 - Cistercian group (recall: history — Cistercian reform)
 - Geographical gradient



Christmas Vespers

A first phylogeny thereof

- Validation against musicological knowledge.
- Conforms to expectations?
 - Cistercian group (recall: history — Cistercian reform)
 - Geographical gradient
 - Benedictine & Augustinian topologies
- ...overall: **yes?** (Manuscript under review.)



**Repertoire:
structure/transmission**

Recalling an issue with phylogenetic trees...

- Leaves
 - Topo
 - For too
 - In biom
 - In chant scholarship: have many melodies of antiphons, but **office sources do not share much repertoire!**
 - Fortunately: **Christmas** dataset!
 - Christmas Eve vespers, 120 melodies from ± 20 sources. Selected 5 antiphons and 1 responsory.
- Out of more than 100 000 antiphons with images in the Cantus Database, impossible to find 30 that would all occur in a diverse set of sources.
- Wasn't chant repertoire supposed to be standardized?
- melodies (must be alignable)
- long related species
- name & place!

Recalling an issue with phylogenetic trees...

- Leaves of the tree: **sources** (=century, provenance, etc.)
- Topology and branch lengths in the tree: how melodies evolved in time & place!
- For testing, requires **sources** that all contain a set of the **same melodies** (must be alignable)
 - In bioinformatics, not an issue: genes mostly shared among related species
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 - Christmas Eve vespers, 120 melodies
Selected 5 antiphons and 1 response

Repertoire may be more diverse than **melodies** & easier to model...

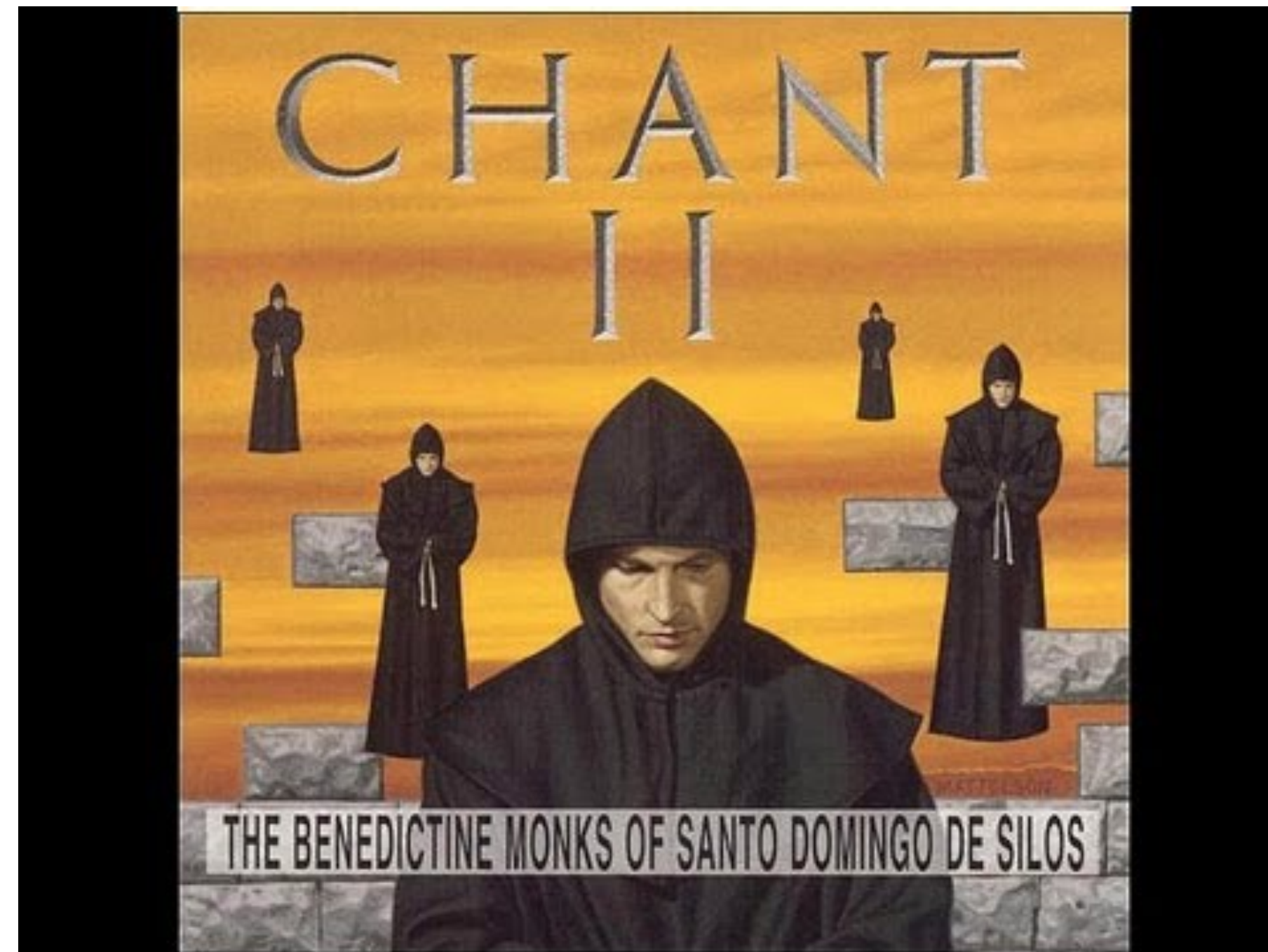
Measure repertoire diversity first?
Correlate with melodic diversity?

Research opportunities!

...thanks to Cantus DB & Cantus Index



Thank you!



<https://www.youtube.com/watch?v=-mWBF3W-ORU>

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