

Plainchant Analyser for MEI Neumes: A Tool for Understanding Chant Transmission

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Introduction

In this paper, we present the **Plainchant Analyser for MEI Neumes (Plainchant Analyser, or PAM)**,¹ a prototype web application designed to assist musicologists in the search and analysis of historical chants encoded in the Music Encoding Initiative (MEI) Neumes format ([Roland et al., 2014](#)).

Plainchant was transmitted orally for centuries, with its compositional principles grounded in formulaic structures that reused melodic segments across varying texts. From the eleventh century onwards, transmission gradually shifted from orality to writing. The plainchant repertory – comprising thousands of melodies sung over many centuries and across various regions – was preserved in a wide range of notational styles. Regarded as sacred, this body of texts and melodies was generally not subject to significant voluntary alteration. The stability of plainchant enables tracing melodic material across time and space. Due to the repertory’s vastness and the complexity of notations, scholars have typically focused on small subsets, rarely engaging in large-scale comparative analysis. PAM addresses these limitations by using computational methods to find and analyse melodies across different scripts within a broader comparative framework.

PAM enables analysis of plainchant melodies found in manuscripts (books and fragments) in the archives of Braga and Guimarães (Portugal), written between the twelfth and the seventeenth centuries.² PAM currently comprises approximately fifty melodies across over one hundred sources, with half of the repertoire written in Aquitanian neumes and the other half in square notation, all encoded in MEI Neumes. Each notational style conveys different levels of complexity and types of musical information.³ Designed for scalability, PAM can be expanded to include more melodies and notational styles, including Eastern neumes and modern staff notation. This paper shows the current status of the PAM and outlines its functionalities.

¹ The tool is available online: <https://echoes-from-the-past.github.io/PAM/>. PAM is part of the research project “Echoes from the Past: Unveiling a Lost Soundscape with Digital Analysis” (2022.01957.PTDC) <https://doi.org/10.54499/2022.01957.PTDC>.

² The melodies were first encoded with GABC, then transformed into MEI files ([Thomae et al., 2024](#)).

³ Aquitanian neumes were written around a line whose meaning could change according to the mode of the chant, but information on the location of the semitone was not always provided ([De Luca, 2020](#)). Iberian square notation was written on a staff with four or five lines and it always provided clear information on the pitches ([Ferreira, 1995, pp. 58–60](#)).

1 Search filters & analysis functionalities

PAM offers numerous search filters and analysis tools, enabling users to sort through the corpus and highlight various features of chants in the search result table (Figure 1). Search options include filtering by metadata, text, finalis, melodic pattern (sequence of pitches), and contour (sequence of melodic intervals), as presented in Sections 1.1 and 1.2. Users can further refine their search results by ornamental neumes and notation type (Section 1.3).

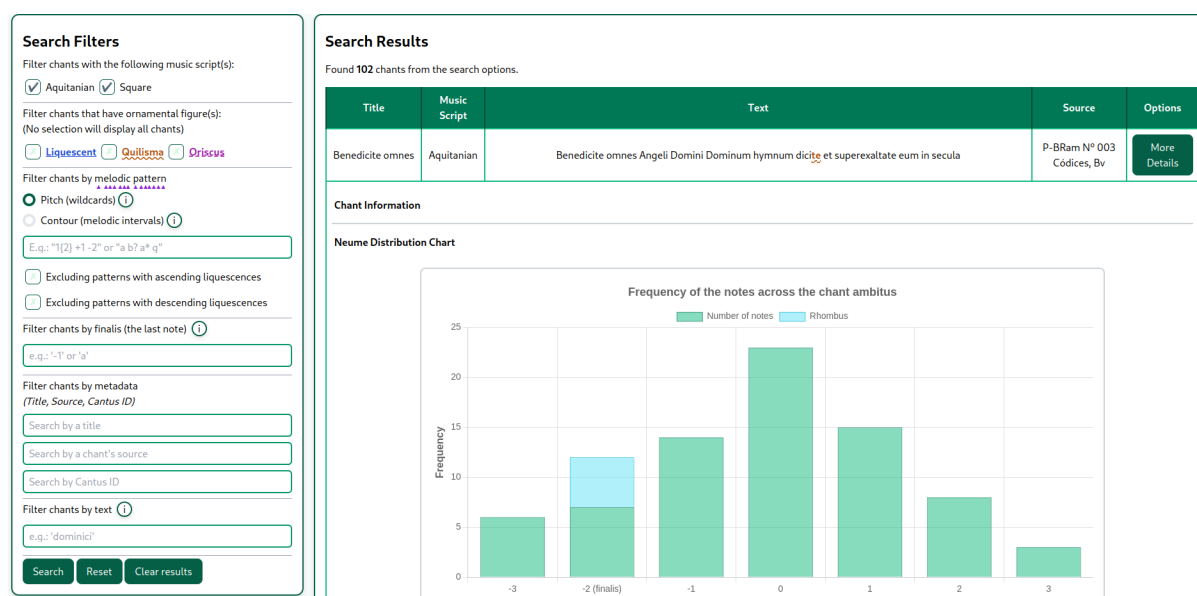


Figure 1: Graphical user interface (GUI) of the Plainchant Analyser.

1.1 Metadata & text search

Users can search the corpus by entering a chant's metadata (Figure 2):

- **Title:** Typically derived from the first two or three words of the chant (Figure 3).
- **Source:** Identified by its siglum in the *Portuguese Early Music (PEM)* database,⁴ which combines the RISM⁵ sigla with the manuscript shelfmark.⁶ (Figure 4)
- **Cantus ID:** A unique identifier assigned to chants within the Cantus Index cataloguing system, linking multiple online early music databases⁷ and allowing users to retrieve all versions of a chant for analysis and comparison. (Figure 3)

⁴ <https://pemdatabase.eu/>

⁵ <https://rism.info/>

⁶ For example, *P-BRam N° 003 Códices* refers to a fragment housed in the *Arquivo Municipal of Braga*, identified by the shelfmark "N° 003 Códices" (see <https://pemdatabase.eu/source/82438>).

⁷ <https://cantusindex.org/>

Filter chants by metadata
(Title, Source, Cantus ID)

Search by a title

Search by a chant's source

Search by Cantus ID

Filter chants by text ⓘ

e.g.: 'dominici'

Search Reset Clear results

Figure 2: Input fields for filtering chants by metadata and text.

Search Results				
Found 3 chants from the search options.				
Title	Music Script	Text	Source	Options
O lux	Square	O lux et decus hispaniae sanctissime Jacobe qui inter apostolos primatum tenes primus eorum martyrio laureatus o singulare praesidium qui meruisti videre redemptorem nostrum adhuc mortalem in deitatem transformatum exaudi preces servorum tuorum et intercede pro nostra salute omnium que populorum aleluia	P-BRs Ms. 028, 18r	More Details
O lux	Square	O lux et decus hispaniae sanctissime Jacobe qui inter apostolos primatum tenes primus eorum martyrio laureatus o singulare praesidium qui meruisti videre redemptorem nostrum adhuc mortalem in deitatem transformatum exaudi preces servorum tuorum et intercede pro nostra salute omnium que populorum aleluia	P-BRs Ms. 028, 105v	More Details
O lux	Square	O lux et decus hispaniae sanctissime Jacobe qui inter apostolos primatum tenes primus eorum martyrio laureatus o singulare praesidium qui meruisti videre redemptorem nostrum adhuc mortalem in deitatem transformatum exaudi preces servorum tuorum et intercede pro nostra salute omnium que populorum aleluia	P-BRs Ms. 034, 278	More Details

Figure 3: Search results when searching for the title “O Lux” or Cantus ID “a00193”.

Title	Music Script	Text	Source
Benedicite omnes	Square	Benedicite omnes angeli domini dominum hymnum dicite et superexaltate eum in secula	P-BRs Ms. 034, 330
De fructu operum	Square	De fructu operum tuorum domine faciabitur terra ut educat panem de terra et vinum laetificet cor hominis ut exhilaret faciem in oleo et panis cor hominis confirmet	P-BRs Ms. 034, 123
Dicit dominus	Square	Dicit dominus implete hydrias aqua et ferte architricino dum gustasset architriclinus aquam vinum factum dicit sponsus servasti vinum bonum usque adhuc hoc signum fecit Jesus primum coram discipulis suis	P-BRs Ms. 034, 027
Ecce virgo	Square	Ecce Virgo concipiet et pariet Filium et vocabitur nomen ejus hemanuel	P-BRs Ms. 034, 012
Jerusalem surge	Square	Iherusalem surge et sta in excelso et vide jucunditatem quae veniet tibi a Deo tuo	P-BRs Ms. 034, 006

Figure 4: Different chants from manuscript “P-BRs Ms. 034”.

The “Search by text” functionality is useful to analyse a text segment that appears in multiple chants, enabling users to discover and assess any differences between the chants, such as their original sources, music script, and the text-music correlation (Figure 5).

Search Results				
Found 3 chants from the search options.				
Title	Music Script	Text	Source	Options
Mitte manum	Aquitanian	Mitte manum tuam et cognosce loca clavorum alleluia et noli esse incredulus sed fidelis alleluia	P-BRad Pastas 028, Bv	More Details
Mitte manum	Aquitanian	Mitte manum tuam et cognosce loca clavorum alleluia et noli esse incredulus sed fidelis alleluia	P-BRad Pastas 176, r	More Details
Mitte manum	Square	Mitte manum tuam et cognosce loca clavorum alleluia et nolii esse incredulus sed fidelis alleluia	P-BRs Ms. 034, 066	More Details

Figure 5: Result table when searching for the text “clavorum alleluia”.

1.2 Melodic pattern search

1.2.1 Pitch/Location pattern with wildcards

Users can input a sequence of notes in a textbox. In square notation, notes are represented by letters; while in Aquitanian script, they are represented by numerical values based on their relative position with respect to the line, as this neumatic script only indicates the interval size between two notes, but not their exact pitches. The line is at location 0; notes above it are represented by positive integers, whereas notes below it by negative integers. Matching melodic patterns are highlighted with purple triangular markings on the corresponding syllables in the “Text” column of the table (Figure 6). In Section 2, users can view a modern rendition of the chant, where the matching notes are highlighted in purple (Figure 20).

Found 3 chants from the search options.

Title	Music Script	Text
Factus est repente	Square	Factus est repente de caelo sonus adven ientis spiritus vehementis ubi erant sedentes alleluia et repleti sunt omnes spiritu sancto loquentes magnalia dei alleluia alleluia
Tunc invocabis	Square	Tunc invocabis et dominus exaudiet clamabis et dicet ecce adsum
In sanctitate serviamus	Square	In sanctitate serviamus domino et libera bit nos ab inimicis nostris

Figure 6: Result table with triangular markings highlighting the syllables where the melodic pattern was found.

The melodic pattern search supports the use of **wildcards**, offering users flexibility and aiding the analysis of fragmentary, poorly preserved, or sometimes partially unreadable sources. Wildcards help detect and compare minor melodic variations, contributing to a deeper understanding of chant transmission. Following the conventional Regular Expression standard,⁸ the wildcards are:

- **Dot**: an arbitrary note.
- **Question mark** (quantifier): an optional note (zero or one occurrences).
- **Asterisk** (quantifier): repetition of a note (zero or more occurrences).
- **Curly brackets** (quantifier): specify the number of occurrences as a specific number or a range.

Users can click on the “i” information button to view the tooltip for syntax help and examples (Figure 7).

Wildcard tooltip

The following rules applies to both **square music script's pitches** (A/a to G/g, *case insensitive*) and **Aquitania script's relative location to the line** (e.g., -1, 0, +2, +3). Note that blank space between characters and the plus sign "+" for positive integers are *optional*.

The wildcards follow the conventional *regular expression* standard.

- Use a dot **.** to search for one arbitrary note. For example:
 - **d . a** will look for the following sequences of notes: **d f a**, **d a a**, **d c a**, etc.
- Use a question mark **?** *after a note or a dot* to search for an optional note. For example:
 - **f d? a** will look for the following sequences of notes: **f d a**, or **f a**.
 - **-2 .? +1** will look for the following sequences of notes: **-2 +1**, **-2 +1 +1**, **-2 0 +1**, or **-2 -3 +1**, etc.
- Use an asterisk ***** *after a note* to search for any number of repetition of that note (0 or more occurrences). For example:
 - **f d* a** will look for the following sequences of notes: **f a**, or **f d a**, **f d d a**, **f d d d a**, etc.
 - **f .* a** will look for the sequences starting with **f** and ending with **a**, with any number of notes in between.
- Use curly brackets and numerical value(s) *after a note* to search for a specific number or range of repetitions for that note. For example:
 - Syntax: **c{2}**, **a{2,4}**, **+2{1,5}**, or **.{3}**
 - **+2 +1{2} -1** would search for all occurrences of **+2 +1 +1 -1**
 - **f c{1, 5} a** would search for all occurrences of **f**, followed by **1 to 5 c**, and ending with **a**.
 - **-1 .{2,4} +3** would search for all occurrences of **-1**, followed by **2 to 4 arbitrary notes**, and ending with **+3**.

Close

Figure 7: Tooltip for the wildcard search feature.

1.2.2 Contour search

The contour search, or search by melodic intervals, retrieves chants that share the same up/down/unison movements. This method accounts for transposition, a phenomenon that otherwise the only pitch search could not detect. Users can perform a contour search in two ways:

- By entering a **sequence of integer values** (e.g., +1 -2 0 to search for a melody that moves up one step, then down two steps, and then stays the same).

⁸ A quick guide to Regular Expression can be found here: <https://www.rexegg.com/regex-quickstart.php>.

- Using a **sequence of letters**, with “u” representing “up”, “d” for “down”, and “s” for “same”.

1.3 Filter by chant features

Users can filter chants by their music script or by the presence of ornamental figures, such as liquescence, quilisma, and oriscus (Figure 8). Although the exact musical meaning of these shapes remains uncertain, they are important for understanding vocal performance and scribal practices. Syllables containing ornamental neumes are highlighted on the “Text” column of the search result table as follows (Figure 9):

- **Liquescence**: solid blue underline.
- **Quilisma**: wavy orange underline.
- **Oriscus**: dashed violet underline.

The use of different colours and underlines styles is intended to improve accessibility, particularly for users with colour vision deficiency.⁹

Filter chants with the following music script(s):

☒ Aquitanian ☒ Square

Filter chants that have ornamental figure(s):

(No selection will display all chants)

☒ Liquescence ☐ Quilisma ☐ Oriscus

Figure 8: Music script and ornamental figures filters.

Title	Music Script	Text	Source	Options
Tu mandasti	Aquitanian	Tu <u>mandasti</u> <u>mandata</u> tua custodire nimis utinam dirigantur vie <u>me</u> e ad custodi <u>en</u> das justification <u>es</u> tuas	P-Brad Pastas 009, 035r	More Details
Chant Information				
Neume Distribution Chart				
Modern Rendition				
Tu mandasti Tu man das ti man da ta tu a cus to di re ni mis u ti nam di ri gan tur vi e me e ad cus to di en das jus ti fi ca ti o nes tu as				

Figure 9: Example of a chant containing all types of ornamental figures.

⁹ Recommended terminology by the *National Center on Disability and Journalism* <https://ncdj.org/style-guide/>.

1.4 Melisma highlighting

Users can search for melismatic syllables by setting the minimum number of notes a syllable must have (Figures 10, 11).

Other options

☒ Enable melisma highlighting

Melisma(s) with at least notes in a syllable

Figure 10: Melisma highlighting option.

Ecce virgo	Aquitanian	Ecce vir go concipiet et pariet filium et vocabitur nomen ejus hemanuel	P-BRad Pastas 023, Av	More Details
Ecce virgo	Aquitanian	Ecce vir go concipiet et pariet filium et vocabitur nomen ejus hemanuel	P-BRad Pastas 011, 007r	More Details

Chant Information

Neume Distribution Chart

Modern Rendition

Ecce virgo

Ec ce vir go con ci pi et et **pa** ri et fi **li** um et vo ca bi tur no men ej us he

ma nu el

Figure 11: Melisma highlighting in **green** of syllables with at least 6 notes.

2 Analysis toolset

The analysis toolset offers detailed information about the chant, supported by a bar graph to assist in mode identification (Figures 12 and 13). It presents note frequency (itches in square notation or relative locations in Aquitanian notation), ambitus (melodic range), and finalis (final note). For Aquitanian chants, it also indicates the presence of rhombus-shaped neumes, which may signal a semitone and aid mode analysis.

Benedicite omnes	Aquitanian	Benedicite omnes Angeli Domini Dominum hymnum dicite et superexaltate eum in secula	P-BRam N° 003 Códices, Bv	More Details
Chant Information Title: Benedicite omnes Source: P-BRam N° 003 Códices, Bv Cantus ID: g00398 PEM Database URL: https://pemdatabase.eu/gallery-item/13126 Music Script: Aquitanian Possible Mode(s): 3 Mode Analysis: - The finalis is located 2 steps below the line (position -2). - The rhomboidal punctum can be found exclusively two steps above the line (+2) or two steps below the line (-2). Possible mode(s) include mode 3. The pitch of the line is 'G'. For more information, see Mode Detection for Aquitanian Script (github.com) MEI File: 001_C01_benedicite-omnes_pem82441_aquit_AQUIT.mei (GitHub)				
Neume Distribution Chart				
Modern Rendition				

Figure 12: Analytical information of the chant “Benedicite omnes”.

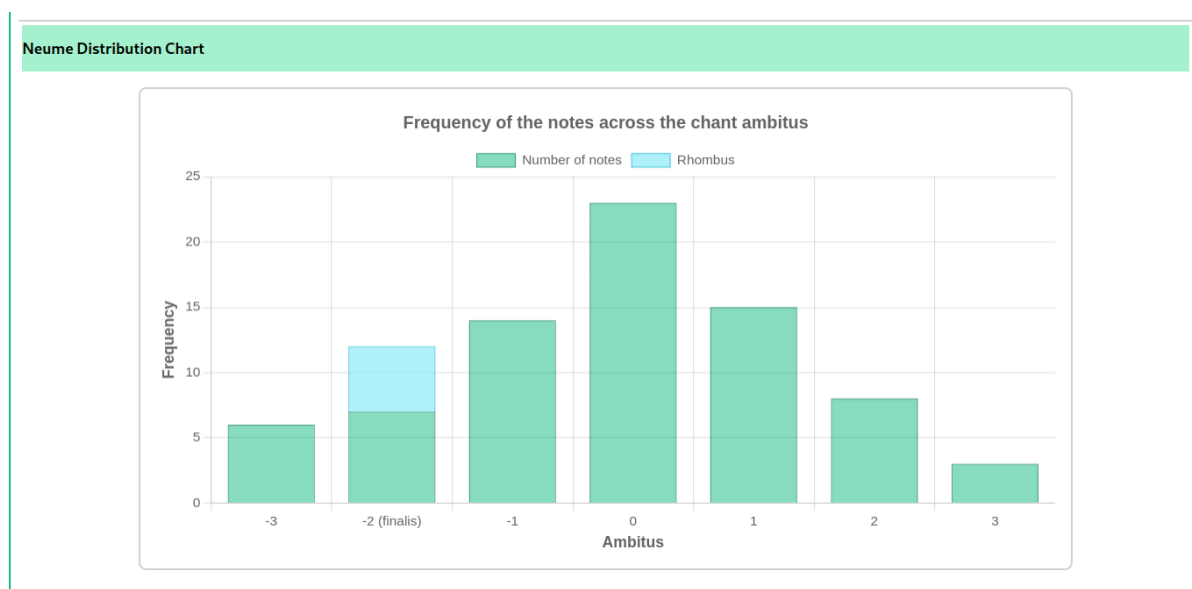


Figure 13: Neume Distribution Chart of the chant “Benedicite omnes” as found in the fragment P-BRam, N° 003 Códices, written in Aquitanian neumes.

3 In-text melody and chant visualisation

3.1 Pitch/Location with each syllable

PAM allows users to view the notes’ pitch or location along with the syllables (Figures 14, 15). Moreover, for chants in Aquitanian neumes with detectable mode, users can select to see the pitch values instead of Aquitanian locations (Figure 16).

☐ Show pitch/location with each syllable

☐ Show Aquitanian in pitch value (only available for chants with detected mode)

☒ Enable modern rendition of chants (Verovio)

Figure 14: Options to enable pitch/location with each syllable, Aquitanian location in pitch value, and modern rendition of chants.

Martinus Abrahe	Aquitanian	Martinus Abrahe sinu letus excipitur martinus hic pauper et modicus coelum dives in greditur hymnis coelestibus honoratur Mar(-2)ti(-21-1-1-2)nus(-2) A(-210)bra(12)he(2) si(23)nu(2) le(23)tus(2) ex(20)ci(12)pi(32)tur(2) mar(3244)ti(5)nus(32) hic(2) pau(323)per(1) et(1) mo(0-111)di(-2-1-2)cus(-2) coe(-2)lum(-10) di(0-10)ves(-1-2) in (-1)gre(12)di(1332201)tur(10) hym(2)nis(324) coe(2)le(212)sti(1-1)bus(-1-2) ho(-3)no(-110121-121-121-1101-11-2)ra(-2-1-2)tur(-2)
Martinus Abrahe	Square	Martinus Abrahe sinu letus excipitur Martinus hic pauper et modicus caelum dives in greditur hymnis coelestibus honoratur Mar(g)ti(gcaag)nus(g) A(gcb)bra(cd)he(d) si(de)nu(d) le(de)tus(d) ex(db)ci(cd)pi(e)tur(d) Mar(d)ti(edefg)nus(e) hic(d) pau(ede)per(c) et(aa) mo(cb)di(ag)cus(g) cae(g)lum(ab) di(bab)ves(ag) in (a)gre(cd)di(ceddbc)tur(cb) hym(d)nis(edefg) coe(e)le(ede)sti(dc)bus(cb) ho(ac) no (cdcadcacbcacg)ra(gag)tur(g)

Figure 15: Pitches and locations shown with each syllable.

De fructu operum	Aquitanian	De fructu operum tuorum Domine satiabitur terra ut educas panem de terra et vinum laetificet cor hominis ut exhilaret faciem in oleo et panis cor hominis confirmet De(f) fru(ga)ctu(a) o(a)pe(a)rum(a) tu(g)o(a)rum(g) Do(g)mi(f)ne(fe) sa(f)ti(ag)a(a)bi(g)tur(f) ter(fgag)ra(gf) ut(f) e(f)du(ga)cas(f) pa(g)nem(f) de(e) ter(fg)ra(f) et(f) vi(fgab)num(a) lae(a)ti(caaga)fi(g)cet(efg) cor(fe) ho(d) mi (def)nis(ed) ut(fga) e(a)xhi(cab)la(fgf)ret(ggf) fa(fg)ci(f)em(f) in(fd) o(ef)le(dedcd)o(dc) et (f) pa(efg)nis(agabg) cor(fe) ho(f)mi(ba)nis(gafe) con(f)fir(e)met(f)
De fructu operum	Square	De fructu operum tuorum domine faciabitur terra ut educat panem de terra et vinum laetificet cor hominis ut exhilaret faciem in oleo et panis cor hominis con firmet De(f) fru(ga)ctu(a) o(a)pe(a)rum(a) tu(g)o(a)rum(g) do(g)mi(f)ne(fe) fa(f)ci(ag)a(a)bi(g) tur (f) ter(fgaga)ra(gf) ut(f) e(f)du(ga)cat(f) pa(g)nem(f) de(e) ter(ff)ra(f) et(f) vi(fgbab)num(a) lae(a)ti(caaga)fi(f)cet(egga) cor(fe) ho(d)mi(defede)nis(ed) ut(fga) ex(a)hi(caa)la(gagfg)ret(gf) fa(fg)ci(f)em(f) in(fd) o(ef)le(dedcd)o(dc) et (f) pa(efg)nis(agaba) cor(fe) ho(f)mi(ga)nis(abgf) con (e)fir(ee)met(f)

Figure 16: Aquitanian location in pitch value, in comparison with the square notation version of the same chant.

The result of the melodic and contour search—whose corresponding syllables are marked in the chant’s text with triangular symbols (as described in Section 1.2)—can also be highlighted in purple by selecting the “Show pitch/location with each syllable” checkbox (Figure 17).

Ecce virgo	Square	Ecce Virgo concipiet et pariet Filium et vocabitur nomen ejus hemanuel Ec(d)ce(cfe) Vir(fg)go(d) con(de)ci(ga)pi(ge)et(fefd) et(de) pa(gaccca)ri(ga)et(a) Fi(a)li(abca)um(a) et(a) vo(cc)ca(ag)bi(bab)tur(gaba) no(fe)men(f) e(gaba)jus(ag) he(fgeed)ma(dfga)nu(fed)el(d)
Manducaverunt	Square	Manducaverunt et saturati sunt nimis et desiderium eorum attulit eis dominus non sunt fraudati a desiderio suo Man(de)du(c)ca(d)ve(fg)runt(afgaag) et(ga) sa(g)tu(fe)ra(fa)ti(g) sunt(f) ni(g)mis(d) et(d) de(fe)si(f)de(ga)ri(g)um(g) e(g)o(fe)f)rum(dec) at(fg)tu(f)lit(f) e(f)is(fgabgabag) do(f)mi(fgagfg)nus(gf) non(a) sunt(g) frau(f)da(gg)ti(d) a(deffed) de(c)si(d)de(fg)ri(g)o(gafgfe) su(defef)o(ed)
Mercennarius	Square	Mercennarius est cujus non sunt oves propriae videt lupum venientem et dimittit oves et fugit et lupus rapit et dispergit oves alleluia Mer(g)cen(g)na(c)ri(a)us(gaba) est(bcb) cu(b)jus(c) non(d) sunt(e) o(d)ves(c) pro(b)pri(cd)ae(d) vi(b)det(d) lu(c)pum(b) ve(a)ni(b)en(ga)tem(g) et(g) di(a)mit(c)tit(b) o(gabg)ves(a) et(g) fu(efg)git(g) et(ga) lu(c)pus(b) ra(gabg)pit(ag) et(f) di(g)sper(a)git(b) o(g)ves(f) al(g)le(gf)lu(e)ia(e)

Figure 17: Highlighted notes from melodic pattern search with its corresponding syllables.

3.2 Modern visualisation

A modern rendition of the chants is available through the Verovio engraver library ([Pugin et al., 2014](#)), as shown in Figures 18 and 19 for chants in Aquitanian and square notation, respectively. It can also highlight the melodic pattern search results, displaying the matching notes in purple and melismatic syllables in green text (Figure 20).

Dicit dominus

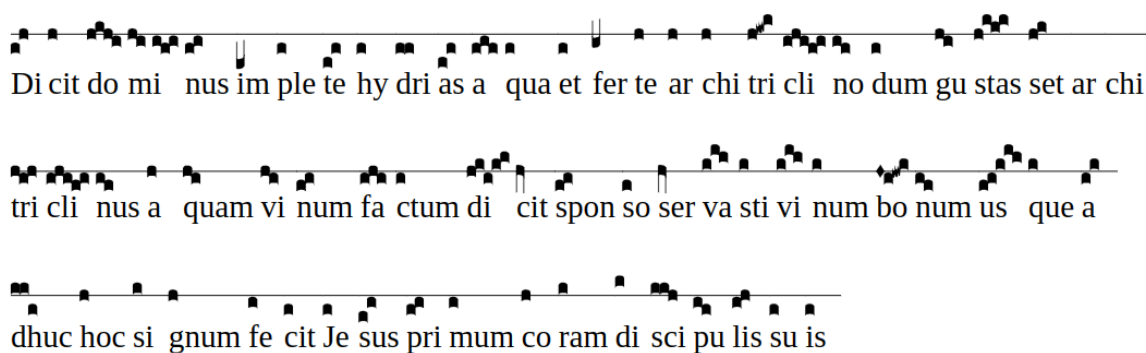


Figure 18: Modern rendition of the chant “Dicit dominus” in Aquitanian neumes.

De fructu operum



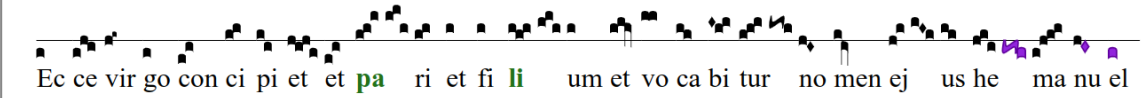
De fru ctu o pe rum tu o rum do mi ne fa ci a bi tur ter ra ut e du cat pa nem de ter

ra et vi num lae ti fi cet cor ho mi nis ut ex hi la ret fa ci em in o le o et pa

nis cor ho mi nis con fir met

Figure 19: Modern rendition of the chant “De fructu operum” in square notation.

Ecce virgo



Ec ce vir go con ci pi et et **pa** ri et fi **li** um et vo ca bi tur no men ej us he ma nu el

Figure 20: Melisma text and notes highlighting. In **green**: Syllables that bear a melisma of 6 notes or more. In **purple**: melodic pattern “-1 -2”.

Conclusion

PAM offers a range of search and analysis options for exploring features and melodic patterns across a large corpus of chants in Aquitanian and square notations. This innovative and forward-looking tool assists musicologists to conduct sophisticated analysis and comparisons, supporting a more detailed and nuanced understanding of plainchant transmission over the centuries.

Acknowledgements

This paper was written under the project “Echoes from the Past: Unveiling a Lost Soundscape with Digital Analysis” (2022.01957.PTDC).

Collaborative work on the analysis of chant notations is continuing as part of the Digital Analysis of Chant Transmission project (<https://dact-chant.ca>), directed by Jennifer Bain and supported in part by the Social Sciences and Humanities Research Council of Canada (895-2023-1002).

Elsa De Luca’s work is funded by national funds through the FCT – Fundação para a Ciência e a Tecnologia, I.P., under the Norma Transitória – DL 57/2016/CP1453/CT0085.

Antoine Phan’s work is funded by (1) the Research Initiation Grant ("Bolsa de Iniciação à Investigação"), provided by the FCT – Fundação para a Ciência e a Tecnologia (2022.01957.PTDC); and (2) by the LinkedMusic project.

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