

**ANALYSING SPECTRAL COMPOSITION: BRIDGING SOUND  
MORPHOLOGY AND COMPOSITIONAL INTENT IN ELLEN  
JACOBS' *AND IN BETWEEN THERE IS* (2024)**

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Margot Meire

Student number: 02105544

Supervisor(s): Prof. Dr. Pieter-Jan Maes

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## ABSTRACT

The analysis of non-tonal, spectral acoustic compositions has long been challenged by an absence of structured frameworks that integrate both measurable spectral features and compositional intent. This thesis proposes a systematic approach to analyzing spectral compositions, focusing on Ellen Jacobs' *And In Between, There Is...* (2024), a case study in bridging spectromorphological features and creative intention. Through a segmented methodology combining score analysis, spectral visualization with Sonic Visualiser, and typification of spectral flux and time, this study demonstrates how spectral data can serve as structural markers without reliance on traditional tonal paradigms. Findings indicate that Jacobs organizes spectral movement through dynamic transformations of overtone relationships, supported by (extended) instrumental techniques and time-dependent energy fluctuations. By distributing spectral properties across the ensemble and integrating spectral flux as an active force, Jacobs constructs musical tension without conventional harmonic progressions, creating a layered and evolving sonic fabric. This research contributes to musicological discourse by offering an integrated model that balances objective spectral data and compositional intent, broadening analytical possibilities beyond perception-based frameworks. The proposed methodology can serve as a foundation for further analytical developments in contemporary spectral music, offering new perspectives for composers, analysts, and researchers engaged in studying non-tonal acoustic structures.

**Keywords:** Spectral Music, Spectromorphology, Acoustic Analysis, Compositional Intent

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The day has come on which I can proudly say: I did it. If you would have asked me what I wanted to be when I grow up as a kid, my solid answer would have been an astronaut. Let this thesis be an example that not everything in life goes as planned, yet all changes lead towards new paths one can discover. My path turned out to be musicology, and if you would have told me this 10 years ago, I would have looked very confused and thought that it meant a kind of doctor. However now, I would not change this for the world.

Over the past four years, I have grown into my passion in ways I could never imagine. The world of music as I knew it in 2021, when I started studying at Ghent University, is different than it is now. I have come to appreciate the creative insights composers use to construct mesmerizing pieces of audible beauty. As I am not blessed with qualitative eye sight, the ability to hear this allure does compensate.

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## GLOSSARY

| TERM              | DEFINITION                                                                                                                                                                                                                                                        |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Acousmatic sound  | A sound with no distinct sonic cause.                                                                                                                                                                                                                             |
| TARTYP            | Tableau Récapitulatif de la Typologie (Pierre Schaeffer, n.d.)                                                                                                                                                                                                    |
| Morphology        | The study of shapes and forms.                                                                                                                                                                                                                                    |
| Phenomenology     | The study of phenomena in how we perceive and understand them according to this subjective experience. (philosophy)                                                                                                                                               |
| Spectromorphology | How spectra change over time and how this affects their shape. (Denis Smalley, 108, 1997)                                                                                                                                                                         |
| Octavation        | The transposition by an octave, either up or down.                                                                                                                                                                                                                |
| Sound object      | The primary unit of sonic material in the light of <i>musique concrète</i> and electronic music. (Pierre Schaeffer, 1942). The sound object is not influenced by any sonic source creating it. Like an acousmatic sound.                                          |
| Note              | “the written symbol used to indicate duration and pitch of a sound by its shape and position on the staff” (‘note’, accessed on 12 May 2025, from <a href="https://www.merriam-webster.com/dictionary/note">https://www.merriam-webster.com/dictionary/note</a> ) |
| Tone              | A musical sound with respect to timbre and expression,                                                                                                                                                                                                            |
| Pitch             | The degree of highness and lowness of a tone. A single sound located in a broader harmonic spectrum. More specifically, this is about the sound perceived by humans.                                                                                              |
| Frequency         | The rate per second of a vibration constituting a wave, expressed in Hertz (Hz).                                                                                                                                                                                  |
| Overtones         | The harmonic partials of a fundamental frequency, which are frequencies themselves.                                                                                                                                                                               |
| Formants          | The strongest overtones in a harmonic spectrum.                                                                                                                                                                                                                   |
| Integer multiples | A whole number that can be evenly divided into another number.                                                                                                                                                                                                    |

|                                   |                                                                                                                                                                                |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cent deviation</b>             | The deviation between two units of measuring (cent) for the ratio between two frequencies.                                                                                     |
| <b>Sul I</b>                      | The string on the double bass referring to the G, with a frequency of $\approx 98$ Hz.                                                                                         |
| <b>Sul II</b>                     | The string on the double bass referring to the D, with a frequency of $\approx 73$ Hz                                                                                          |
| <b>Heterogeneous accumulation</b> | The dynamic layering of diverse spectral elements that gradually build over time, creating complex sonic textures through the interaction of contrasting frequency components. |
| <b>Median</b>                     | The middle value of a sorted ascending or descending range of values.                                                                                                          |
| <b>Root mean square (RMS)</b>     | The statistical average value of the amplitude over a period of time.                                                                                                          |

## INTRODUCTION

The 20<sup>th</sup> century has known a tendency toward a multitude of expressions in classical music. Some kept true to tonal frameworks, while others wondered what other materials could serve as a foundation of their creations. Spectral composers found their inspiration in the natural composition of sound, exploring how its molecules or overtones could serve as building blocks for musical creation. Instrumental timbres, along with their inherent variations, played a fundamental role in shaping the overall structure of the music. Gérard Grisey (1946-1998), a pioneer in spectralism, sought to reveal the inner world of sound in his works. By distancing himself entirely from tonal chord progressions and fixed pitch classes, he focused on the interplay between harmonic and inharmonic overtones to define musical structure. A spectrum is harmonic “when partials are integral multiples of the fundamental [frequency].”<sup>1</sup> These integer multiples remained essential building blocks for Grisey, serving as reference points for also structuring time in his music. More specifically, he based time on the duration of individual overtone frequencies within the natural spectrum, with lower frequencies lasting longer than higher ones. By respecting these divisions, he constructed time using spectral constellations, ensuring musical coherence rooted in the inner structure of sound rather than external tonal frameworks or cadential movements. To further develop this structure, Grisey combined multiple spectra derived from different tones, such as E2 in his piece *Partiels* (1975). This approach preserved continuity while introducing spectral variety, all drawn from one or more integer multiple overtone spectra.<sup>2</sup> It preserves a sense of naturality in the music, allowing it to emerge organically through sound while bridging the gap between objectively measurable spectral data and the composer’s creative intent. Although this intent is shaped by the spectral properties the composer engages with, the broader artistic vision remains equally significant, playing a crucial role in shaping the composition alongside its spectral and physical foundations.<sup>3</sup>

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<sup>1</sup> François Rose, “Introduction to the Pitch Organization of French Spectral Music”, *Perspectives of New Music* 34, no. 2 (1996): 9, <https://doi.org/10.2307/833469>.

<sup>2</sup> Gérard Grisey, “Tempus Ex Machina: A Composer’s Reflections on Musical Time”, *Contemporary Music Review* 2, no. 1 (1 January 1987): 259, <https://doi.org/10.1080/07494468708567060>.

<sup>3</sup> Margot Meire, “Overtones as a Structural Basis for Modern Compositions of the 20th Century: Gérard Grisey, Karlheinz Stockhausen and Eliane Radigue”, (bachelor’s dissertation, Ghent University, 2024), 23-27.

Beyond the 20<sup>th</sup> century, spectralist music has known contemporary variations, such as Annelies van Parys' *Meditations* (2005) or Eliane Radigue's *Occam Hexa II* (2015). Despite their deep foundation in instrumental acoustics and measurable frequency structures, the musicological analysis surrounding them remains somewhat rigid, with numerous studies focusing primarily on historical context and presenting them as a reaction against tonality, such as François Rose's 'Introduction to the Pitch Organization of French Spectral Music' (1996). While this is accurate, it often leads to the neglect of its measurable qualities in the analytical process. Spectral music challenges traditional analytical frameworks by prioritizing timbre, overtone relationships, and spectral evolution over key-based structures. While numerous scholars have contributed to understanding non-tonal composition, existing methodologies often fall short in capturing its structural intricacies.<sup>4</sup>

This thesis addresses the gap between objective spectral analysis and compositional intent by proposing an integrated framework that systematically examines spectral features while considering the creative decisions of the composer. The following **research question** is central to the investigation: *How can a combination of detailed music segmentation—using scores, Sonic Visualiser (VAMP) plugins, and sound-splitting software—alongside a global analysis of spectral features over time contribute to a structured approach to non-tonal spectral acoustic compositions?*

*In what way can insights into compositional intent, obtained through interviews with the composer, help in understanding the interactive and structural relationships within these compositions while also reducing the limitations of perception-driven models?*

The question comprises the proposed methodology which will be presented in Chapter 2, as well as the gap to be addressed in the literature review, Chapter 1.

The following **objectives** shape the direction in which the research is done. The first goal is to refine an analytical framework for non-tonal spectral compositions with a predominantly acoustic focus, drawing from a preliminary literature review. This framework will be based on the score and a selection of Sonic Visualiser plugins, specifically the VAMP type, to examine the spectral and timbral properties of the composition while taking instrumental techniques into consideration. The aim is to gain a comprehensive understanding of its overall structure analyzing spectral flux and time categories, mapping the course of spectral development throughout the piece.

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<sup>4</sup> Judy Lochhead, *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis* (Abingdon: Routledge, 2020), 46-68.

Additionally, this thesis highlights the importance of incorporating the composer, Ellen Jacobs (°1996), into the analytical process both before and after obtaining the results. The objective is to fully grasp the creative intentions behind the composition, linking qualitative insights to the objective data. This two-way approach allows the composer to first outline the narrative dimension of the piece before offering feedback on the analytical findings. In doing so, it fosters a dialogue that bridges objective analysis with subjective interpretation.

This thesis seeks to open avenues for analyzing spectral compositions through a structured and systematic perspective, further embedding their scientific and artistic relevance within the broader musicological discourse. The proposed method does not aim to serve as a definitive solution but rather as **a reorientation of existing analytical perspectives**, creating a more integrated approach that unites objectivity and subjectivity.

The **hypothesis** suggests that incorporating spectromorphological elements, both in the score and through selected VAMP Sonic Visualiser plugins, will enhance the structural understanding of the non-tonal spectral case study, providing a valuable reference point for future analyses. By categorizing the composition according to spectral flux and time, based on Lasse Thoresen and Andreas Hedman's research (2007), the study will determine the level of spectral flux by calculating the median value extracted from the Spectral Flux dataset. Time categories will then be derived from the Constant Q output, offering a clear depiction of how frequencies evolve throughout the piece.

The categorization of spectral flux and time are hypothesised to reflect the composer's intentions, where increased spectral flux will indicate heightened musical tension, timbral complexity, or dense orchestration, while decreased flux will suggest intentional clarity, stasis, or a more restrained sonic landscape. By aligning these spectral characteristics with insights from the interviews, the study will establish a meaningful connection between the composer's creative decisions and the underlying spectral behaviour of the composition.

Through a comprehensive literature review, this thesis seeks to identify previously proposed methods for analyzing both acoustic and electroacoustic non-tonal compositions. The focus lies on assessing the relevance of phenomenological and morphological spectral features or attributes within the broader context of music analysis. Key considerations include whether the emphasis is placed solely on perception or if measurable spectral features are also acknowledged, such as spectral slope and spectral flux. If the perceptual framework is adopted, what drives this choice?

Conversely, if it is not, what alternative approaches are proposed? These questions serve as guiding principles during the review of the literature.

This thesis examines studies that position listener perception as a central element, including Pierre Schaeffer's TARTYP framework, as analysed by Monika Lech (2017). It also explores more integrated approaches, such as Daniel Vélez's "Another Timbre: Toward a Critical Phenomenology of Sound" (2023) and Kaija Saariaho's "Timbre and Harmony: Interpolations of Timbral Structures" (1987). Additionally, two analyses of Saariaho's works—conducted by Grégoire Lorieux, a French composer affiliated with IRCAM (*Institut de Recherche et de Coordination Acoustique/Musique*), and Judy Lochhead—are included to further enrich the discussion on music analysis approaches.

On top of that, Tristan Murail's detailed look on spectra and their potential for music structure emergence in "Spectra and Sprites" (2005) is included to shape the argument of morphological rather than phenomenological importance. In the same light, Lasse Thoresen and Andreas Hedman's "Spectromorphological analysis of sound objects: an adaptation of Pierre Schaeffer's typomorphology" (2007), based on Denis Smalley's "Spectromorphology: Explaining Sound-Shapes" (1997) expands the elaboration on morphology in specific, and takes certain spectral features into consideration when examining larger patterns, or so-called *dynamic profiles* (Thoresen and Hedman, 2007).

Computationally driven approaches, such as that of Paul Lascabattes et al. in "Computational Analysis of Musical Structures Based on Morphological Filters" (2022), provide valuable insights into measurable sonic features, though they remain rooted in chordal progressions with a strong tonal foundation. Nevertheless, their method effectively demonstrates the importance of incorporating computational techniques into analytical frameworks.

Noticeable gaps found in the literature review of Chapter 1 are then analysed together with Judy Lochhead's *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis* (2020) and Robert S. Hatten's "A Speculative Hermeneutics for Music Analysis and Interpretation" (2021) to frame the problem definition later refuted by the proposed methodology for the analysis of non-tonal, spectral, acoustic compositions, applied to the case study presented in Chapter 3.

Chapter 2 "Proposed Methodology for the Analysis of Non-Tonal Spectral Acoustic Compositions" outlines an approach to analyzing spectral composition using *And In Between There Is ...* (2024) by Ellen Jacobs (°1996) as a case study. This chapter combines score analysis with an examination of the audio signal based on a recording of the piece

performed at the TRANSIT Festival in Leuven in 2024 by I SOLISTI and Spectra Ensemble.<sup>5</sup> The recording is analysed using a selection of Sonic Visualiser plugins. Additionally, the chapter incorporates two interviews. One was conducted prior to the analysis on November 21, 2024, and the other afterward on May 17, 2025. Through a series of pre-determined questions Ellen Jacobs was interviewed about her creative and narrative intentions behind *And In Between There Is ...* (2024) providing an additional analytical dimension that enriches the method and deepens the interpretation of the composition.

Chapter 3 presents the case study applying the proposed method to a contemporary spectral composition. Beginning with objective findings, the chapter culminates in an analytical discussion incorporating insights from both interviews. This discussion leads to a final structural interpretation of the piece addressing the research question and evaluating the hypothesis confirming or denying its validity. This will help determine whether a selection of sound morphologies and compositional intent are indeed bridgeable, thus answering the pre-mentioned research question.

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<sup>5</sup> Ellen Jacobs, *And In Between, There Is...*, Audio recording, 08:14, I SOLISTI and Spectra Ensemble (Leuven: TRANSIT Festival, 2024).

# CHAPTER 1: A LITERATURE REVIEW OF EXISTING ANALYTICAL METHODS CONCERNING NON-TONAL MUSIC COMPOSITIONS

## 1.1 Key Considerations in Non-Tonal Music Analysis: Exploring (Spectro)Morphologies, Phenomenologies, and Typological Approaches

### 1.1.1 Tristan Murail's Perspectives on Non-Tonal, Spectral Music

Tristan Murail has been a pioneer in reframing the analytical approach to non-tonal, spectral music. His works “Spectra and Sprites1” (2005) and “The Revolution of Complex Sounds” (2005), advance the notion that the inner properties of sound – its overtones and the duration of its spectral components – guide musical structure. He argues that “no correspondence exists between music perceived by the listener and that conceived by the composer”<sup>6</sup>. Rather, what matters are the acoustic interactions within the sound itself. If the composer would employ a more inherent approach, so he argues, the listener would better understand the sound as is. Overtones thus become a compositional priority. Murail’s technique of *additive synthesis* illustrates how a composer might gradually transform an instrument’s harmonic spectrum into noise by modifying the positions and amplitudes of partials. This process, often described through *timbral loops*, creates an evolving sonic landscape that replaces traditional tonal hierarchies. His approach emphasizes the morphologically measurable aspects of sound – its spectral evolution, synthesis parameters, and timbral modulation – thus providing a powerful alternative to pitch-centric models interpreting modulation through cadential motions and tonal rules.<sup>7</sup>

“The Revolution of Complex Sounds” (2005) expands these ideas, criticizing music theory’s shortcomings to develop adequate concepts for spectral (re)organization. Murail’s critique aligns with Judy Lochhead’s (2020) observations that

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<sup>6</sup> Tristan Murail, “Spectra and Sprites1”, *Contemporary Music Review* 24, no. 2–3 (1 April 2005): 138, <https://doi.org/10.1080/07494460500154806>.

<sup>7</sup> Murail, “Spectra and Sprites1”, 139-43.

scientific analytical approaches often neglect the sound's natural characteristics. In that sense, Murail internalised the viewpoint of composing, making sure that the inner qualities of sound were foregrounded over a shallow interpretation based on perception alone.<sup>8</sup>

The key elements outlined above are primarily morphological, serving to rationalize the sound's physical properties—a valuable contribution that provides analysts with concrete parameters like spectral evolution, additive synthesis, and timbral modulation to understand non-tonal, and especially spectral, structures. Yet Murail's framework extends beyond mere acoustics; in "Spectra and Sprites" (2005), he acknowledges perception as a critical lens, arguing that tonal systems artificially narrow listening experiences, and thus also analytical perception, whereas spectral materials invite active engagement. It offers analysts powerful tools; by placing interpretation in the sound's objective behaviour while remaining attentive to perceptual possibilities, Murail's approach reveals how spectral music **organizes time, tension, and form through its inherent sonorities**. However, his theory stops short of prescribing methods to systematically incorporate these insights, **leaving a gap between conceptual promise and analytical practice**. However, the connection between the inner sound properties and their desired perceptual constitution does point at a renewed way of shaping music and understanding it. Even so, his focus on the sound's parameters and features as a structural guide reshapes analysis—shifting the focus from pre-composed hierarchies to emergent sonic phenomena.<sup>9</sup> Incorporating texts from composers themselves in the literature review can offer interesting insights that lie on the split between compositional and analytical construct.

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<sup>8</sup> Tristan Murail, "The Revolution of Complex Sounds", *Contemporary Music Review* 24, no. 2–3 (1 April 2005): 123–30, <https://doi.org/10.1080/07494460500154780>.

<sup>9</sup> Murail, "Spectra and Sprites1", 137–47.

### 1.1.2 Pierre Schaeffer's *objets sonores*: insights from electroacoustic analysis

Building upon Murail's spectral theories that reveal how sound's internal structures can generate musical form, one finds complementary perspectives in Pierre Schaeffer's foundational work on sound objects. As examined by Monika Lech in "Pierre Schaeffer's Attempt to Create a Method of Electro-acoustic Music Analysis" (2017), Schaeffer's concept of the sound object represents a radical phenomenological reduction in which sound is divorced from its physical source and considered purely as an acoustic phenomenon. This approach, made possible through electroacoustic techniques like tape manipulation, fundamentally reorients musical analysis towards the intrinsic spectral and temporal characteristics of sound.<sup>10</sup>

Schaeffer's TARTYP (*Tableau récapitulatif de la typologie*, n.d.) classification provides a framework for analysing these sound objects through three primary dimensions: energy articulation, spectral mass and duration, however in a perceptual way.<sup>11</sup>

Lech's (2017) examination highlights the analytical process of identifying sound objects, beginning with the assessment of spectral mass – the continuum from pure sine tones to complex overtone clusters – and progressing to the evaluation of the *temporal grain*. She further argues that microtonal interactions in the sound object cause it to have friction, leaving an interesting phenomenological effect. Schaeffer himself referred to this as *phenomenological reduction*, as a way of interpreting the sound in an acousmatic manner, removed from its physical source. Once this sonic fingerprint is determined, Lech states that one should compare the sound objects with each other to understand the global musical structure, once again through subjective perception. The acknowledgement of the overall structure is interesting considering the contrast with the isolated, phenomenological reduction of Schaeffer.

His TARTYP is presented in Figure 1.<sup>12</sup>

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<sup>10</sup> Monika Lech, "Pierre Schaeffer's Attempt to Create a Method of Electro-Acoustic Music Analysis", *Kwartalnik Młodych Muzykologów*, no. 02 (33) (2017): 103.

<sup>11</sup> "The Concept of „Sound Object“(Objet Sonore) by Pierre Schaeffer", *Silent Listening*, 9 May 2008, accessed on 15 February 2025 from <https://silentlistening.wordpress.com/2008/05/09/the-concept-of-%e2%80%9esound-object-%e2%80%9c-objet-sonore-by-pierre-schaeffer/>

<sup>12</sup> Lech, "Pierre Schaeffer's Attempt to Create a Method of Electro-Acoustic Music Analysis", 114.

|                                       |                      | Durée démesurée<br>(macro-objets)<br>pas d'unité temporelle |                  | durée mesurée<br>unité temporelle |                                     |                                | Durée démesurée<br>(macro-objets)<br>pas d'unité temporelle |                         |
|---------------------------------------|----------------------|-------------------------------------------------------------|------------------|-----------------------------------|-------------------------------------|--------------------------------|-------------------------------------------------------------|-------------------------|
|                                       |                      | facture<br>imprévisible                                     | facture<br>nulle | durée réduite<br>micro-objets     |                                     |                                | facture<br>nulle                                            | facture<br>imprévisible |
| hauteur<br>masse<br>définie<br>fixe   | ÉCHANTILLONS<br>(En) | Hn                                                          | tenue<br>formée  | impulsion                         | itération<br>formée                 | Zn                             | ACCUMULATIONS<br>(An)                                       |                         |
|                                       |                      |                                                             | N                | N'                                | N''                                 |                                |                                                             |                         |
| hauteur<br>complexe                   | (Ex)                 | Hx                                                          | X                | X'                                | X''                                 | Zx                             | (Ax)                                                        |                         |
| masse<br>peu variable                 | (Ev)                 | Tx<br>Tn<br>trames<br>particulières                         | Y                | Y'                                | Y''                                 | Zy<br>pédales<br>particulières | (Ay)                                                        |                         |
| variation<br>de masse<br>imprévisible | unité<br>causale     |                                                             | W                | ?                                 | causes multiples<br>mais semblables |                                |                                                             |                         |
|                                       | E<br>cas général     | T<br>cas général                                            |                  |                                   | K<br>cas général                    | P<br>cas général               | L<br>cas général                                            |                         |
| sons tenus                            |                      |                                                             |                  | sons itératifs                    |                                     |                                |                                                             |                         |

Figure 1 Marcus Alessi, "Pierre Schaeffer's Typology of Sound Objects", n.d., accessed on 17 February 2025 from <https://www.marcusalessi.com/site/htmlarchives/Tartyp.html>.

Without going into specific details about this scheme, it does show that the sound object is defined thoroughly by many different features. On the left, for example, there are three boxes referring to the mass of the sound object, ranging from *hauteur masse définie fixe* to *variation de masse imprévisible*. In other words, Schaeffer indicates a range from a fix, 'natural' mass towards an 'unpredictable' mass, referring to the spectrum being able to shift in appearance. In that sense, it offers a hands-on scheme for categorising sound objects based on their phenomenological features. Temporal dimensions are also included, defining the shape of the sound object in time. Sound mass is mentioned too on the TARTYP, however rooted in the perceptual focus of the scheme. Its categories vary from *peu variable* to *variation de masse imprévisible*. Schaeffer did seem to consider sound features and their evolution in time, however considered also in the light of perception.<sup>13</sup>

Either way, practical limitations occur. The acousmatic approach's strength in phenomenological reduction can become a weakness when applied to complete musical structures, as it provides limited guidance for analysing developmental

<sup>13</sup> Ibid.

processes beyond individual sound objects. Even with the inclusion of perceptual sound mass development in time, mutual interactions are less considered.<sup>14</sup>

When compared with Murail's more compositionally oriented spectral theories, Schaeffer's system appears stronger at categorisation than at explaining musical continuity or large-scale form. Monika Lech, although arguing that the sonic footprint is largely determined by the comparison between sound objects, does not elaborate further on how this comparison could be conducted and what 'data' to look for. Nevertheless, the core insight of the sound object theory remains largely relevant for contemporary analysis due to the reoriented perspective on the sound itself compared to external tonal frames.<sup>15</sup> By focusing on the sound's intrinsic properties rather than external reference points, it provides an essential analytical lens for non-tonal, and accordingly spectral and electroacoustic music. Both 'genres' share common ground in acknowledging sonic features as a base.<sup>16</sup>

The challenge for contemporary analysts lies in integrating Schaeffer's phenomenological approach with more structurally sensitive approaches like Murail's, creating hybrid methodologies that can address both sound's immediate acoustic presence and its organisational logic across musical time. Even though perception can be of use in interpreting possible manifestations of sonic material outside the tonal convention, this approach in specific lacks a flexibility when it comes to the consideration of (1) concrete sonic features to look for and (2) their mutual interaction. This makes the scheme harder to use for gaining systematic and global understanding of the piece's structure. In a monophonic and isolated context, the TARTYP does seem to serve interesting perspectives. When it comes to multi-voiced structures, such as *And In Between, There Is...* (2024), this approach would fall short, since mutual interactions are a main catalyst of structure and possible pattern-formation.

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<sup>14</sup> Lech, "Pierre Schaeffer's Attempt to Create a Method of Electro-Acoustic Music Analysis", 120.

<sup>15</sup> Ibid.

<sup>16</sup> Murail, "Spectra and Sprites1", 137–47.

### 1.1.3 The concept of Iterability by Daniel Vélez (2023)

Pierre Schaeffer's sound object, as discussed by Monika Lech (2017), provides a valuable foundation for analysing non-tonal music by decoupling the isolated sound object of any external references, except for the perception of the listener. Daniel V. Vélez expands this in "Another Timbre: Towards a Critical Phenomenology of Sound" (2023) by rethinking the following sound object's dimensions through timbre, defined as a collage of acoustic characteristics: harmonicity (relations between partials and fundamental frequencies), temporality (transients and envelopes), and perceptual multidimensionality.<sup>17</sup>

Morphologically, Vélez's framework first examines harmonicity—whether partials conform to natural harmonic relationships or deviate into inharmonicity, and how they interact with the fundamental frequency. This relationship shapes the initial sound object. However, he does not provide measurement methods for these spectral relationships, such as what values contribute specifically to the measurements in question.

The following category, temporality, is broken down into transients (attack/decay) and spectral envelopes. Attack, defined as the amplitude's rise to peak level (visualised in Figure I in the Appendix B), and decay, its subsequent reduction (Figure II, see Appendix B), mark a sound's temporal boundaries, or in other words where it is in time. In between these temporal demarcations, Vélez marks the spectral envelope. Spectral envelopes show how sound energy is distributed across different frequencies and amplitudes. These analytical considerations illustrate the benefit of integrating objective data into theoretical models, relying on measurable elements.<sup>18</sup> Although the scope takes on a more morphological character compared to Schaeffer (Monika Lech, 2017), a further refinement of what spectral features to look for is not presented.

While Vélez' approach offers a valuable analytical starting point, he further argues that musical structure emerges through the composer's manipulation of (perceptual) multidimensionality—shaping perception and musical structure via spectral, temporal, and interactive compositional choices. For example, *iterability* (repetition/variation of sound objects) allows spectral properties to construct time, whether through proximity (invariance) or juxtaposition

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<sup>17</sup> Daniel V. Vélez, "Another Timbre: Toward a Critical Phenomenology of Sound", *The Oxford Handbook of the Phenomenology*, 20 November 2023, 2.

<sup>18</sup> Ibid.

(contrast).<sup>19</sup> This mirrors techniques in Eliane Radigue's work in which gradual timbral transformations direct listener attention towards inner sound properties, as well as Gérard Grisey's approach to musical time as a reflection of natural frequency durations in a spectrum.<sup>20</sup>

Phenomenologically, Vélez posits that sound objects are co-constituted by perception: composers guide listeners through emphasized properties, but reception remains inherently subjective. In that sense, the composer can never really be sure of how their compositions will eventually be perceived. His framework thus bridges physical sound properties (morphological) and phenomenological meaning, a connection that remained underexplored in case of Pierre Schaeffer's TARTYP (Monika Lech, 2017). Overall, Vélez's approach successfully illuminates the morphological features that aid in identifying sound objects and understanding their temporal positioning, though it falls short in addressing features like spectral flux to emphasize the spectrum's development over time. Notably, the inclusion of *iterability* proves valuable in examining the interactions between sound objects within a given space. In this regard, Vélez skillfully integrates considerations of both time and interaction among sound objects, emphasising their dual role in forming musical structure. However, the approach is limited by an absence of defined spectral features and a disconnect between its focus on perception and the compositional intentions underpinning broader structures due to the lack of morphological refinement.

#### *1.1.4 Analysing sound objects spectromorphological: Lasse Thoresen and Andreas Hedman (2007)*

Addressing the interactive limitations of Schaeffer's typology, Thoresen and Hedman created in their work "Spectromorphological analysis of sound objects: an adaptation of Pierre Schaeffer's typomorphology" (2007) a spectromorphological approach, inspired by Dennis Smalley's "Spectromorphology: explaining sound-shapes" (1997), which explicitly integrates dynamic evolution into the analysis of sound objects. Spectromorphology is "the perceived sonic footprint of a sound spectrum as it manifests in time."<sup>21</sup>

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<sup>19</sup> Ibid., 8.

<sup>20</sup> Margot Meire, "Overtones as a structural element in modern compositions of the 20th century: Gérard Grisey, Karlheinz Stockhausen and Eliane Radigue", (bachelor's dissertation, Ghent University, 2024).

<sup>21</sup> Yotam Mann, "Spectromorphology", 2017-2018, accessed on 18 February 2025, from <https://tambien.github.io/InteractiveMusic/module/spectromorphology>.

Their framework categorises sound objects into four types: a pitched, complex, dystonic or variable sound object. Especially the **variable sound object** captures transitional states that evolve over time. Three key elements emerge from this definition: perception, spectral features, and time.<sup>22</sup>

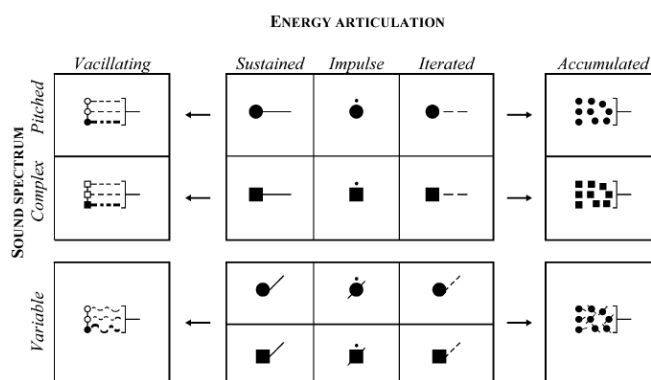


Figure 2. Typology – minimal representation.

**Figure 2** *Typology - minimal representation*, in Thoresen and Hedman, 'Spectromorphological Analysis of the Sound Object', 133.

Figure 2 shows their revised typology diagram. It visually organises these concepts, plotting sound types against energy articulation patterns. Unlike Schaeffer's phenomenological TARTYP, this framework emphasizes measurable spectral behaviours through symbolic representation: circles for pure and continuous sounds, squares for complex textures, and dots for layered sounds. The horizontal axis tracks energy continuity, distinguishing sustained from iterated articulation. This systematic approach reveals how spectral energy transforms temporally, establishing time as a fundamental analytical parameter and as dependent on spectral morphology.<sup>23</sup>

The authors develop this temporal analysis through four categories of time: gesture time (discrete sonic events that stand out as isolated events in time), ambient time (static, continuous textures), flutter time (rapid iterations merging into texture), and ripple time (transitional states in a periodic structure). These categories work in tandem with spectral analysis, examining three key characteristics: spectral width (pure tone to noise continuum), brightness (overtone

<sup>22</sup> Lasse Thoresen and Andreas Hedman, "Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology", *Organised Sound* 12, no. 2 (August 2007): 132, <https://doi.org/10.1017/S1355771807001793>.

<sup>23</sup> *Ibid.*, 133.

emphasis), and profile (energy distribution across frequencies). The dynamic profile completes the system by tracking amplitude envelopes, which are linked to larger patterns and the global structure of the piece. As such, Thoresen and Hedman link the internal evolution of a sound object to its broader temporal context, as shifts in intensity can emphasize dramatic contrasts or create smooth, evolving textures or even patterns.<sup>24</sup>

Besides that, the dynamic profiles are also phenomenologically relevant. Thus the morphological features serve a complementary perceptual goal. Sounds lacking dynamic profiles exist in homogeneous ambient time, creating static textures without perceptible onsets. Weak dynamic profiles maintain consistent onsets, emphasizing timbral qualities over energy changes. More structurally significant are impulse-like profiles, where sudden attacks create discrete sonic events with clear temporal positioning, and cyclic profiles that establish predictable rhythmic patterns through consistently repeated spectral features.<sup>25</sup> As this literature review has demonstrated thus far, the interplay between spectral features and time is a recurring theme, albeit interpreted slightly differently by each author.

The theory's most innovative contributions appear in the vacillating and accumulative profiles. Vacillating sounds exhibit instability either spectrally (through timbral fluctuation) or energetically (through amplitude variation), while accumulative profiles combine multiple dynamic types to create textural complexity. The authors particularly emphasize *heterogeneous accumulation*, where contrasting profiles interact to highlight temporal evolution – a core spectromorphological principle. Contrast is then used as a catalyst for increased tension.<sup>26</sup>

Additionally, Thoresen and Hedman (2007) extend their analysis to sound object boundaries. These boundaries, made up from onsets and endings, locate the sound object in time, making it more clear in a larger structural setting. Abrupt onsets with strong dynamic profiles create striking gestures that guide listeners in the absence of tonal centres, while smoother onsets that merge into sustained phases yield more ambiguous structures. This approach sheds new light on how tonal modulation could be replaced by the dynamic shaping of spectral materials over time.<sup>27</sup>

Figure 3 and 4 show respectively the onset and decay-embarkations of Thoresen and Hedman (2007).

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<sup>24</sup> Ibid., 134-37.

<sup>25</sup> Ibid., 137-38.

<sup>26</sup> Ibid.

<sup>27</sup> Ibid. 138-39.

- *Brusque onset*: e.g. a sound caused by a metal hammer stroke against metal; the attack transient is clearly and separately perceived.
- *Sharp onset*: e.g. a sound caused by a mallet or plectrum; the onset sound is closer to the character of the main body of the sound as opposed to the former case.
- *Marked onset*: normal (non legato) onset of a wind or string instrument.
- *Flat onset*: no particular marking of the onset as, for example, in legato playing.
- *Swelled onset*: a short crescendo/decrescendo.
- *Gradual onset*: the sound begins with a swell or a crescendo.
- *Without onset*: the onset cannot be heard – ‘*dal niente*’.

**Figure 3** Lasse Thoresen and Andreas Hedman, ‘Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer’s Typomorphology’, *Organised Sound* 12, no. 2 (August 2007): 138., <https://doi.org/10.1017/S1355771807001793>.

- *Abrupt ending*: sounds with an accentuated ending phase, containing elements alien to the main body of the sound; e.g. vibrating string dampened with metal rod.
- *Sharp ending*: sounds with an ending phase containing elements intrinsic to the main body of sound itself; e.g. harpsichord tone.
- *Marked ending*: sounds stopped suddenly, rather than rounded off.
- *Flat ending*: unmarked.
- *Soft ending*: the ending of the sustained sound is rounded off with a diminuendo.
- *Resonating ending*: a resonating sound is let free to resonate until it dies out; ‘*laissez vibrer*’.

**Figure 4** Lasse Thoresen and Andreas Hedman, ‘Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer’s Typomorphology’, *Organised Sound* 12, no. 2 (August 2007): 138., <https://doi.org/10.1017/S1355771807001793>.

Even though the re-evaluation of Pierre Schaeffer’s typomorphology is well constructed through the focus on energy evolutions and the morphological and temporal identification serving this interpretation, their method does not include compositional intent, or the narrative and creative ‘idea’ behind the structure. Yet it could serve as a useful blueprint for extracting spectral features in a time frame and using that to get an initial idea of the musical structure. Adding information of the intent could then form another layer allowing deeper analytical understanding. This leaves the question open for further refinement of the analysis method. However, compared to the previous examples, Thoresen and Hedman (2007) do seem to acknowledge the importance of collecting enough valid data of the sonic material instead of interpreting structure through entirely subjective, perceptual measures. This makes their article a useful base to build music analysis on for these spectral cases in specific.

### *1.1.5 Gradual transformations and the curves of tension: Kaija Saariaho's theoretical and practical views on timbre as a fundamental structure for non-tonal compositions*

While Kaija Saariaho's 1987 article "Timbre and Harmony: Interpolations of Timbral Structures" predates much contemporary literature, it remains relevant for examining timbre's structural role in non-tonal music. As both composer and theorist, Saariaho offers unique insights that complement later analytical approaches, like Tristan Murail (2005). In opposition to the previous literature, this part specifically focuses on the comparison between (1) the composer's ideas and intentions through Kaija Saariaho's text ("Timbre and Harmony", 1987) and (2) two examples of analytical approaches by Grégoire Lorieux, a French composer affiliated at the IRCAM (*Institut de Recherche et Coordination Acoustique/Musique*), and Judy Lochhead (2020). Although not analysing the same composition of Saariaho, their analytical perspectives could be interesting in seeing how researchers approach sonic material and compositional intent. Due to the availability of texts written by Kaija Saariaho herself, one could argue that the researchers took large portions of this information into account. On top of that, the interview conducted with Ellen Jacobs, the creator of the case study that will be discussed later, showed her inspiration from Kaija Saariaho, which is why she is included in the literature review.<sup>28</sup>

#### *1.1.5.1. Theoretical and compositional outlines of Kaija Saariaho*

Kaija Saariaho emphasizes timbre as the core compositional element, distinguishing it from Schaeffer's sound object. Unlike the sound object, which isolates sound from its source, timbre is tied to the instrument producing it. Yet the focuses are similar between Saariaho and Schaeffer, with both paying attention to the sound's level of purity. Purity ranges from pure tones to noise, while texture varies from grainy, often achieved through extended techniques, to smooth. Despite the limited technology available to Saariaho in 1987, she visualised overtone structures and translated timbral qualities into dynamic compositions. She used *curves of tension* to shape sound over time, focusing on gradual shifts in parameters like brightness, density and grain. In concrete terms, the structure is conveyed through the morphology of the sound and eventually through the *curves of tension*. Instead of developing themes through melody

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<sup>28</sup> Ellen Jacobs (composer), interviewed by Margot Meire (student at Ghent University), 21 November 2024.

or harmony, these shifts implement structure.<sup>29</sup> The interplay of harmonic and inharmonic elements drives her compositions, referring to the **sound's vitality** and **continuous state of transformation**. In harmonicity, the sound mimics a state of relaxation and stability. When there is inharmonicity, the sound underwent tension, referring to a state of instability. Whenever both stages would interact with each other, an "interpolation" would take place. Her approach also incorporates time as a structural element, aligning with spectralist methods that emphasize slow sonic evolution, also driven by the interpolations. This slowness was also connected to a perceptual time model, prioritising listeners' understanding of the music. Time functions as both a morphological and phenomenological element, shaping the structural development of timbre while also influencing its perception.<sup>30</sup>

#### 1.1.5.2 Grégoire Lorieux and his score-based analysis of *Amers* (1992)

Lorieux's study of *Amers* (1992) traces how timbre representations shape the work's aesthetics. His analysis begins with Saariaho's spectral examination of the foundational cello Eb1, where a resonance model analysis mapped frequency/amplitude relationships to identify dominant formants. He notes her use of resonance modelling to simulate how the cello's physical properties shape spectral content, allowing precise timbral reconstruction. Thanks to this resonance model, Saariaho was able to analyse places in a spectrum when it resonated the most, thus giving an idea of how the dynamic qualities are stratified. Lorieux underlines this in the following quote: "Un modèle de résonance est une représentation dynamique d'un son, celle de sa potentialité spectrale."<sup>31</sup> Saariaho paid a lot of attention to vitalising a sound. The mention of the resonance model of the base note is therefore useful in understanding this compositional idea of Saariaho. This technical work reinforces Saariaho's fundamental compositional approach: constructing an entire piece from the spectral evolution of a single pitch. In doing so, it realizes what Lorieux describes as the *founding utopia* of spectral music, namely the idea that a sound's full spectral representation can ensure structural coherence across both macro and micro levels.<sup>32</sup>

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<sup>29</sup> Kaija Saariaho, "Timbre and Harmony: Interpolations of Timbral Structures", *Contemporary Music Review* 2, no. 1 (1 January 1987): 104, <https://doi.org/10.1080/07494468708567055>.

<sup>30</sup> Ibid., 94-97.

<sup>31</sup> Grégoire Lorieux, "Analysis of *Amers* (1992) by Kaija Saariaho.", *IRCAM*, 2004, accessed 22 February 2025 from <https://brahms.ircam.fr/fr/analyses/amers/>.

<sup>32</sup> Ibid.

While Lorieux's analysis of *Amers* successfully traces the work's foundation in spectral transformations of a single pitch, it overlooks crucial morphological specifics that would deepen our understanding of Saariaho's methods.

Unlike Thoresen and Hedman's (2007) detailed spectromorphological framework with its precise dynamic profiles and spectral categorization, Lorieux treats timbral qualities as abstract concepts rather than measurable acoustic phenomena. The single use of the score and the lack of incorporation of computational measuring methods contributes significantly to the high level of abstraction. It could be enriched by integrating spectral visualizations and a deeper examination of interpolation techniques. These tools would clarify the transitions between harmonic and inharmonic elements, as well as the temporal and morphological dynamics underpinning Saariaho's timbral evolution.

However, acknowledging the technological tools and interpolation techniques Saariaho employed enhances Lorieux's analysis by linking her resonance model to a broader compositional vision. Her use of spectral tools, despite their limitations in 1987, allowed her to trace dynamic spectral transformations with precision.<sup>33</sup>

Furthermore, the analysis falls short in exploring extrapolation. It briefly mentions how spectral qualities move between instruments but overlooks the timing of these transformations and the physical processes behind them. Using spectromorphological tools (Thoresen and Hedman, 2007) could have clarified these aspects—for example, by tracking how the cello's sound spectrum changes when transferred to other instruments or how attack characteristics shift during timbral transitions. In other words, a lot of the noticeable features of Saariaho's compositions are lacking here, despite the acknowledgment of crucial constructive and intentional features of her composition, which could be non-beneficial for understanding her compositional scope and simultaneously her intentions.

#### 1.1.5.3 Judy Lochhead's theoretical views on non-tonal compositions and the importance of dynamic and interaction

Judy Lochhead's analysis of Saariaho's *Lonh* (1996) in *Reconceiving Structure in Contemporary Music* (2020) examines the work's spectral and structural elements using contemporary analytical methods. This perspective builds upon Saariaho's theoretical writings while demonstrating how modern approaches offer new insights into her compositional techniques. Including this analysis highlights the relationship between the composer's theoretical framework and current music-theoretical practices.<sup>34</sup>

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<sup>33</sup> Saariaho, "Timbre and Harmony", 104.

<sup>34</sup> Lochhead, *Reconceiving Structure in Contemporary Music*, 105-121.

The first useful addition to the interpretation of the composition is shaped by the visualisation of *timbral types*. Figure 5 shows the first list found in Lochhead's analysis of Saariaho. On the left, one can see five large categories of timbre (all underlined in red): vocal, electronic, nature and percussion, together with subcategories for expansion. On the right, Lochhead made abbreviations for each timbral type. These types seem to be mostly phenomenological, since no specific spectral qualities, such as envelope-structure or harmonicity/inharmonicity, are mentioned.

Figure 6 is particularly of interest since it shows a map of what timbral type occurs when. Interactions between timbres and their overlaps or frictions are visualised here. For example, in section I, there is a significant overlap between the choral mid-range (C-M) in the vocal timbre, and the birds-high (Brd) in the nature timbre. That means that both overtone-structures will merge or have friction at this time stamp. To fully determine the type of interaction, the analyst should have access to the spectral morphologies. From there, the interactions can be conceptualised as an extension of the *dynamic profiles* described by Thoresen and Hedman (2007).

However, Lochhead demonstrates advanced skill by creating a simple and clear map that can be placed alongside the composition, allowing listeners to phenomenologically identify different timbres and their interpolations or overlaps, and structure. According to the author, these interactive moments form what are known as *musical planes*, which consist of three key aspects: sonic luminance, formal flickering, and moments of intensity.

Sonic luminance, determining a sound's perceived brightness, emerges from the combined influence of pitch range and spectral features, where specific frequencies and morphological characteristics define this quality. Lochhead approaches this through an integrated morphological-phenomenological perspective while also analysing formal flickering—the recurring and evolving interactions of timbres that generate the expansion-contraction patterns central to Saariaho's compositional approach. These timbral transformations accumulate toward climactic moments of intensity that function as structural markers within the work.<sup>35</sup> Although she greatly acknowledges Saariaho's way of composing, the severe lack of morphological refinement does make the timbral map system less systematic, in the sense that her subjective perspective on them is elevated as analytically representative even though objective, measurable elements have been ruled out.

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<sup>35</sup> Saariaho, "Timbre and Harmony", 110-12.

Table 5.3 Electronics Part: Categories and Codes for Timbral Types.

| Categories of Timbral Types       |                           | Code |
|-----------------------------------|---------------------------|------|
| <u>Vocal</u>                      |                           | VOCL |
| Choral—high                       |                           | C-H  |
| Choral—mid-range                  |                           | C-M  |
| Murmuring Voices: male+female     |                           | Mur  |
| Spoken Voice                      |                           | Spkn |
| <u>Electronic</u>                 |                           | ELCT |
| High—electric sound               |                           | E-H  |
| Nasal—electronic sound, mid-range |                           | E-Na |
| Low—electronic sound              |                           | E-L  |
| <u>Nature</u>                     |                           | NATR |
| Birds—high                        |                           | Brd  |
| Wind/rain                         |                           | W/R  |
| <u>Percussion</u>                 |                           | PERC |
| Glockenspiel                      | High Glock                | Gl-H |
|                                   | Low Glock                 | Gl-L |
| Vib/Chimes                        | Windchime                 | WCh  |
|                                   | Vib/Chime—softer mallet   | VCS  |
|                                   | Vib/Chime—harder mallet   | VCH  |
|                                   | Bell—sustained            | BLL  |
| Cymbal                            | Cymbal—hit with metal     | CyM  |
|                                   | Cymbal—hit with wood      | CyW  |
|                                   | Cymbal—bowed              | CyB  |
| Gong                              | Gong—hit with wood        | GgW  |
|                                   | Gong—hit with soft mallet | GgS  |
| Drum                              | Bass Drum                 | BsD  |

Figure 5 Judy Lochhead, 'Electronics Part: Categories and Codes for Timbral Types', *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis*, 2020, 110.

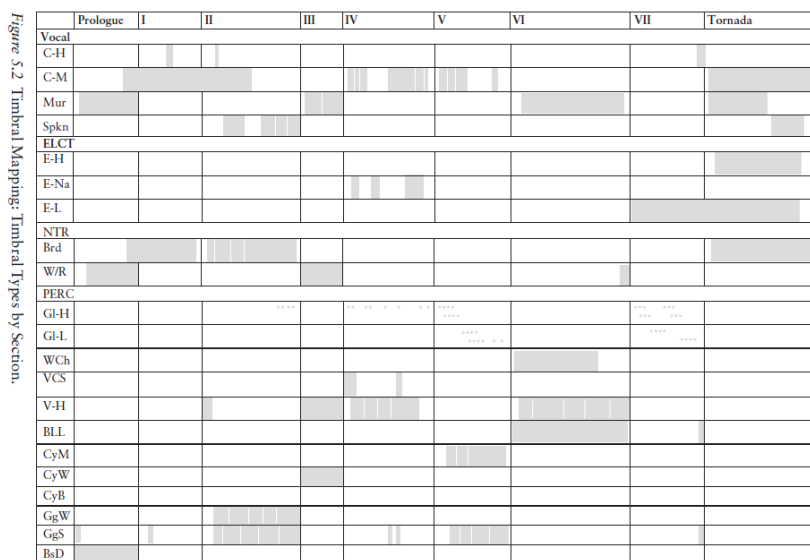


Figure 6 Lochhead, 'Timbral Mapping: Timbral Types by Section' in *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis*, 2020, 111.

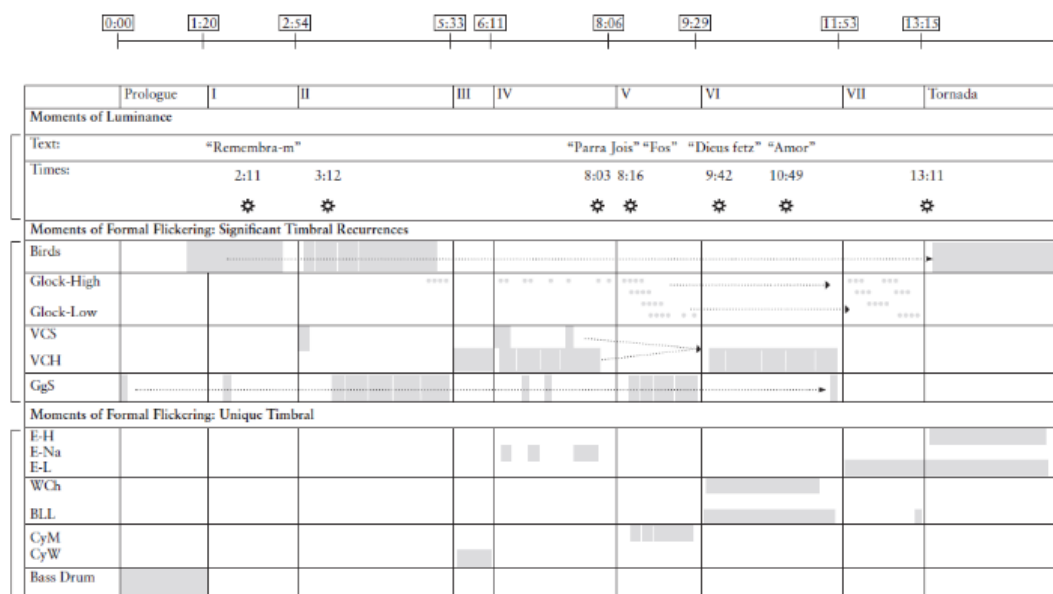


Figure 5.3 Radiance: Moments of Luminance and Moments of Formal Flickering in the Electronics Part.

Figure 7 Lochhead, 'Radiance: Moments of Luminance and Moments of Flickering in the Electronics Part.' in *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis*, 2020, 113.

Figure 7 above illustrates the recurrence and occurrence of various timbral types. The bird's timbre, for example, seems to occur at various time stamps during the composition. Below the recurrences, Lochhead portrays unique timbres, attributed to the bass drum, the E-H (high electric sound) and the BLL (bell-sustained). A scheme as such can be seen as an equivalent to a score, but instead of organising pitches according to external rules and 'logic', they are now structured conforming to (1) their perceptual (!) timbral qualities, (2) their development in time, i.e. how long certain partials last and how this influences energy and (3) their relationship with other timbres.<sup>36</sup> Her approach does hint at the acknowledgement of the importance of morphological features too, but a thorough systematic refinement remains absent. Therefore, this exclusion of spectromorphological attributes forms a large gap in Lochhead's analysis of *Lonh* (1996) by Kaija Saariaho.

<sup>36</sup> Lochhead, *Reconceiving Structure in Contemporary Music: New Tools in Music Theory and Analysis*, 113.

#### 1.1.5.4 Discussion

By examining two distinct analyses of Saariaho's compositions, *Amers* (1992) and *Lonh* (1996), it becomes clear that spectral compositions were not confined to a single interpretation. While each piece exhibits subtle and individual differences, Saariaho's own writings on timbre and harmony (1987) played a crucial role in shaping perspectives on her compositional approach. Both researchers identified valuable compositional and perceptual attributes worth studying to better understand the overall structure of the piece, yet certain gaps remained.

Grégoire Lorieux places a strong emphasis on score analysis. While this serves as a foundation for deeper understanding, integrating spectral visualizations could have provided a more precise measurement of timbral and sonic qualities. He also highlights the evolving timbral resonance shaped by various instrumental interactions, which can be compared to Saariaho's *curves of tension*. However, a clear spectral and temporal framework remains absent, as the analysis largely aligns with traditional score-based approaches. This approach is considered inadequate for capturing the intricate layering of spectral compositions, as they depend heavily on spectral features and their dynamic behaviour over time.

Lochhead's framework offers an innovative approach to structuring timbre through typological mapping, but it often oversimplifies morphological processes by prioritizing phenomenological perspectives, particularly those rooted in her own experience. While her analysis of *Lonh* (1996) aligns with Saariaho's technical intentions and provides valuable insight into the composition's underlying architecture, it also reflects certain hermeneutic shortcomings. Her reliance on subjective interpretation can obscure the deeper structural coherence of spectral compositions, making it difficult to fully articulate their spectral and temporal frameworks. Additionally, the timbral map she employs, while useful for systematic analysis, may flatten the multidimensionality of timbral evolution, limiting a more nuanced engagement with the intricate relationships between sound and form.

Despite the strong analytical approaches of both Lorieux and Lochhead, the composer's intentions and the sonic material receive too little attention, influencing the final interpretation of the musical structure in both pieces. While this section does not attempt to fully encapsulate the essence of Kaija Saariaho's oeuvre, it highlights how analysts approach non-tonal, spectral music from different perspectives—often allowing one-sided interpretations to obscure its structural depth.

### 1.1.6 Computational Analysis and the Benefits of Morphological Features

To conclude this part, the conference paper ‘Computational Analysis of Musical Structures Based on Morphological Filters’ (2022) by Paul Lascabettes et al. will be discussed.

It provides an innovative perspective on computational music analysis, utilizing morphological filters to explore structural relationships within symbolic music representations. By generalizing melodic contours to chord sequences and analyzing them through self-distance matrices, the approach uncovers patterns vital to understanding musical structures across scales, ranging from overarching sections to detailed segments. Central to this method is the application of the opening operation—a specific morphological filter that homogenizes and identifies regions within the matrices, useful for pattern recognition. Morphological filtering then provides a means to extract the underlying structure from complex data, for example an audio file. Here, the approach is applied to a self-distance matrix that encapsulates the chordal relationships within a musical piece. The process begins with an “erosion” operation, which removes small, insignificant details being like eliminating noise, thereby simplifying the matrix. This is subsequently followed by an expansion, which restores and emphasizes the dominant structures. Such an approach thus clarifies the overall structure of the music, effectively highlighting the fundamental patterns that define the piece. It offers a powerful alternative to traditional, perception-driven analysis.<sup>37</sup>By bridging spectral morphology with musicology, this methodology enhances analytical precision, focusing on measurable data rather than perceptual interpretation. Its ability to reveal deeper organizational principles provides a systematic framework that aligns with this thesis’ focus on spectral features, measurable with Sonic Visualiser, their temporal evolution and the minimisation of perceptual bias. However, the main input data are chordal relationships, which remains rooted in tonal music after all. One could instead look for spectral relationships, such as finding out to what fundamental a certain note connects. That way, the focus can be fully directed towards a musical base free from tonality. Either way, Lascabettes et al. (2022) presents a sophisticated technological approach to examining the underlying structure of a musical piece, aiming to identify patterns through objective analysis. While it leans toward tonal frameworks, its foundation remains valuable for prioritizing measurable features in broader musical contexts.

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<sup>37</sup> Paul Lascabettes et al., “Computational Analysis of Musical Structures Based on Morphological Filters”, in *Mathematics and Computation in Music*, ed. Mariana Montiel et al. (Cham: Springer International Publishing, 2022), 267–78, [https://doi.org/10.1007/978-3-031-07015-0\\_22](https://doi.org/10.1007/978-3-031-07015-0_22).

## 1.2 Perspectives on Intentionality and Polyphonic Timbre

As mentioned in the introduction of this chapter, analytical perspectives on non-tonal electroacoustic music will be explored here, despite the primary focus of the following case study being acoustic music. However, the composer of the case study, Ellen Jacobs, has created a remarkable piece titled *Inertia*, composed for quartet and tape. Thus, examining electroacoustic music analysis may provide valuable insights into understanding musical structures beyond tonal conventions. It heavily emphasizes the listener's perception, often shaping compositions around it. This approach evokes Pierre Schaeffer's concept of the sound object, which he articulated through the TARTYP—a framework for perceiving and categorizing sound based on its phenomenological attributes. His theoretical perspectives were profoundly shaped by electroacoustic music.<sup>38</sup> Furthermore, this section will equally address both morphological and intentional aspects of the analysis and its method, as these components define the scope of this research.

### 1.2.1 From sound object toward sound event: Simon Emmerson and Leigh Landy (2016)

To better understand the analytical considerations scholars apply to electroacoustic music, this part will discuss Simon Emmerson and Leigh Landy's (2016) "The Analysis of Electroacoustic Music: The Differing Needs of Its Genres and Categories", alongside "Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre" by Vinoo Alluri and Petri Toiviainen (2010). Although the chapters of this study are interconnected—each engaging with the concepts of the sound object and timbre in different ways—these texts introduce different perspectives on which aspects of non-tonal composition are considered analytically valuable and which are not.

Even though the part on Pierre Schaeffer's TARTYP (Monika Lech, 2017) was highly focused on phenomenologically identifying the acousmatic sound object, the other texts by Kaija Saariaho (1987), Judy Lochhead (2020), and Thoresen & Hedman (2007) extend beyond the isolated study of sound objects, incorporating considerations of interaction,

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<sup>38</sup> Lasse Thoresen and Andreas Hedman, "Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology", *Organised Sound* 12, no. 2 (August 2007): 129–41, <https://doi.org/10.1017/S1355771807001793>.

dynamic conceptualisation, and temporal structuring. The initial stratified analysis of the acousmatic sound object is criticized by Emmerson and Landy (2016), suggesting a more holistic approach.

The authors propose a broader analytical method that integrates structural, perceptual, and intentional dimensions of music, as outlined in the following questions:

- a) Who is the analysis for?
- b) Which works or genres are being studied?
- c) **What are the analytical intentions?** Musical structure, narrative discourse...?
- d) How do you want to present the results?
- e) **What sound materials are present, and what are their morphologies?**
- f) Do you want to convey reduced or contextual listening, and how does the sound material relate to that?
- g) What are the overall **structural relationships**?<sup>39</sup>

Although the intentional focus is not exclusively for compositional intentions, it does point at the consideration of a deeper layer for understanding the musical piece as is. This framework introduces a more holistic approach, balancing detailed sound identification with broader structural relationships. Notably, its focus on intentionality and narrative discourse marks a departure from earlier models, like Schaeffer's phenomenologically reduced acousmatic sound object, which was nonetheless a fundamental analytical tool for non-tonal music. Emmerson and Landy re-evaluated the conventional view by proposing the concept of the *sound event*. They first refer to spectromorphological elements characterising the sound object, i.e. the sound as isolated from the rest. After that, two main external forces are considered: compositional intent and audience perception. Emmerson and Landy suggest that both elements shape the interpretation of the sound event, deepening our understanding of its spectral evolution. The projection of compositional intentions onto the sound event lead towards a more integrated perspective. Insights from composer interviews, for example, could strengthen this interpretive approach.<sup>40</sup>

This perspective contrasts with the detached, scientific approach predominant from the 1950's onward, as described by Judy Lochhead (2020), although still showing signs of subjective hermeneutics.<sup>41</sup> In Emmerson and Landy's model,

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<sup>39</sup> Simon Emmerson and Leigh Landy, "The Analysis of Electroacoustic Music: The Differing Needs of Its Genres and Categories", in *Expanding the Horizon of Electroacoustic Music Analysis*, ed. Leigh Landy and Simon Emmerson (Cambridge: Cambridge University Press, 2016), 10-20, <https://doi.org/10.1017/CBO9781316339633.002>.

<sup>40</sup> Ibid.

<sup>41</sup> Judy Lochhead, *Reconceiving Structure in Contemporary Music*, 30.

however, intentionality is foregrounded as a means of overcoming perceptual limitations. This does not imply that the researcher's perspective is invalid; rather, it suggests that incorporating intentional and contextual factors can yield a more refined and systematic analytical process.<sup>42</sup>

Despite the interesting perspective of Emmerson and Landy (2016) on both internal and external influences on the sonic material, and consequently musical structure, it raises questions regarding how polyphonic environments are handled. An elaboration that considers these influences and simultaneously studies the interactions between different sound layers could enforce an even deeper understanding of the musical material at hand, especially since the spectralist approach to composition relies heavily on instrumental interactions, particularly in the use of overtones and their distribution across instrumental sections.<sup>43</sup> The structural relationships are mentioned in the questions, however not explained in detail in the article itself. Therefore, exploring methodologies that specifically account for the emergent characteristics of polyphonic textures could complement the sound event framework and lead to a more nuanced understanding of non-tonal, spectral music.

### 1.2.2 Outlines of polyphonic timbre analysis: Vinoo Alluri and Petri Toiviainen (2010)

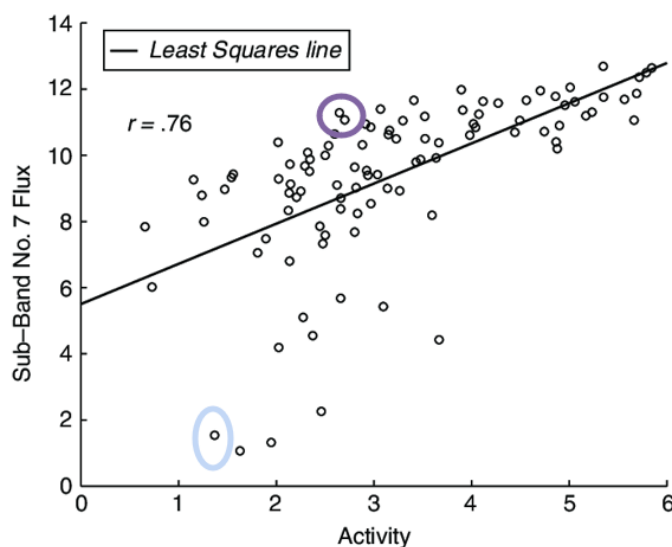


Figure 8 Vinoo Alluri and Petri Toiviainen, 'Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre', *Music Perception* 27, no. 3 (1 February 2010): 223–42, <https://doi.org/10.1525/mp.2010.27.3.223>.

<sup>42</sup> Ibid.

<sup>43</sup> Grisey, "Tempus Ex Machina", 239–245.

In this context, the work of Vinoo Alluri and Petri Toiviainen “Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre” (2010) offers valuable insights. Their research investigates the perceptual and acoustical attributes of polyphonic timbre, shedding light on how listeners cognitively process dense sonic textures. More specifically, they research the multidimensional features of timbre in the frame of timbre space. Within this space, they frame timbres that are perceptually similar.<sup>44</sup>

Figure 8 provides a visualisation of this timbre space. The y-axis indicates the level of spectral flux in the composition, expressed through temporal variations. This arrow illustrates how the spectral relationships change over time. The higher the y-level, the more dynamic variation there is. The x-axis shows the musical activity. Although never specified, such activity could be musical features, such as the addition of extended techniques related to performance. The overall idea is that the more dynamic there is, the more musical activity or ‘engagement’ as well. On the figure, the blue circle shows a timbre that has low spectral flux and does not convey a lot of musical activity. Perceptually, this is the least interesting case. Yet the purple circle reveals a whole different dimension, with more musical activity, more spectral flux and temporal variations. The r-coefficient is “[...] a number between -1 and 1 that measures the strength and direction of the relationship between two variables.”<sup>45</sup> When it has a positive value, suggesting that as activity increases, the spectral flux also increases, meaning that more active or complex stimuli are associated with greater spectral variations. On top of that, the closer the dots are to each other, the more perceptually similar the timbres are, yet again linked to their flux ‘types’. The morphological feature contributing to this similarity is, according to the authors, spectral centroid. This spectral centroid gives an indication of where the most spectral energy is located. The higher the value, the more energy there is in high frequencies, and vice versa. A higher value of spectral centroid indicates that the timbre will appear more sharp or bright compared to lower values. In many ways, it is like spectral slope.<sup>46</sup>

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<sup>44</sup> Vinoo Alluri and Petri Toiviainen, “Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre”, *Music Perception* 27, no. 3 (1 February 2010): 223–24, <https://doi.org/10.1525/mp.2010.27.3.223>.

<sup>45</sup> Shaun Turney, “Pearson Correlation Coefficient (r) | Guide & Examples”, *Scribbr*, 10 February 2024, accessed on 1 March 2025, from <https://www.scribbr.com/statistics/pearson-correlation-coefficient/>

<sup>46</sup> Alluri and Toiviainen, “Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre”, 223–24.

With the above in mind, one might ask why the analysis of polyphonic timbre is necessary. As outlined in the literature, non-tonal spectral composition relies on both spectromorphological identification of sound and an understanding of its perceptual impact on the listener. More specifically, composers and analysts have sought either to reveal the inner structures of sound to the audience or to provide a clear conceptual framework for perceptual features that aid further analysis. The combination of different timbres, a common feature of non-tonal spectral compositions, was notably employed by Eliane Radigue in *Occam Hexa II* (2016). She gradually layered multiple instrumental timbres to create instability, which, in phenomenological terms, became perceptible to the audience. This altered their musical perception, sharpening their awareness in contrast to the expectations shaped by tonal music and its conventional listening experiences.<sup>47</sup> Similar methods of layering were employed by Grisey as well, and too form a fundamental part of the case study presented here in *And In Between, There Is ...* (Ellen Jacobs, 2024). This makes the morphological focus presented here rather useful. It provides an analytical framework for identifying which overtone relationships influence the spectral flux value, especially linking it to particular musical activities taking place throughout. Temporal evolution is also highlighted by Alluri and Toiviainen, i.e. how the polyphonic timbre shifts in form. By tracking the spectral flux' peak, the researcher can identify where the composer likely wanted to direct attention to.<sup>48</sup> Their emphasis on spectral flux as a structural focal point is worth noting, as it links measurable spectral features to the overall composition while remaining compatible with a polyphonic context. However, while they recognize musical activity, they do not provide a detailed definition of its applicability to different instrumental layers within a composition. A more in-depth examination of how each instrumental layer shapes the larger spectral footprint could offer an even more precise understanding of the piece's construction and reveal how all layers contribute to the overall musical entity. Nevertheless, Alluri and Toiviainen (2010) have established a valuable framework for investigating non-tonal spectral compositions, highlighting how multiple instruments interact to shape the piece as a cohesive whole.

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<sup>47</sup> Meire, "Overtones as a structural basis for modern compositions of the 20th century", 43-44.

<sup>48</sup> Alluri and Toiviainen, "Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre", 235.

### 1.3 Conclusion for the literature review

This literature review explored diverse analytical approaches to non-tonal spectral and electroacoustic music, where the interplay between perceptual insights and morphological perspectives has been contested. Early frameworks, such as Pierre Schaeffer's TARTYP, provide a valuable starting point through a phenomenological reduction, isolating sound objects from their physical sources to reveal their perceptual manifestation, interpreted through electroacoustic compositions. Yet, as Schaeffer's scheme, explained by Monika Lech (2017), shows, a predominant reliance on perceptual categories often oversimplifies the complexity of musical structure, particularly in mapping polyphonic interactions and interpreting acoustic properties in relation to their foundation. In terms of understanding a composition for its timbral qualities and developments, this fell short.

Tristan Murail's (2005) spectral theories, focusing on *additive synthesis* and *timbral loops*, offer a morphologically oriented perspective. His approach introduces parameters such as spectral evolution and timbral modulation, both dependent on interactions between overtones. However, Murail's work remains largely theoretical and does not elaborate on how to systematically capture these spectral features over time. A similar gap in measurability appears in Daniel Vélez's (2023) article, which introduces the concept of iterability to bridge perception and morphology by placing the sound object in a more interactive temporal environment. However, in his case, structural narrative fell outside the research scope, overshadowed by a strong focus on temporal demarcations without a clear connection between spectral and temporal features.

Thoresen and Hedman's (2007) spectromorphological analysis, based on Denis Smalley (1997), significantly advances the discussion by integrating dynamic profiles and temporal categorizations, such as ambient, flutter, and ripple time, which concretely map the evolution of sound objects and connected time to sound. Their methodology lays the foundation for a data-driven approach but does not fully embrace the compositional idea behind musical structure, similar to Vélez' (2023) work. However, its limitations become more apparent in polyphonic timbre analyses, where the interaction between sound layers, as examined by Alluri and Toiviainen (2010), highlights the necessity of understanding spectral flux and musical activity beyond isolated events. Emmerson and Landy (2016) further emphasize this interactivity through the concept of the sound event, similarly subject to compositional intent as well.

Additionally, the comparative analysis of Kaija Saariaho's (1987) compositional techniques, demonstrated through her *curves of tension* and the nuanced interplay between harmonic and inharmonic elements, reveals that even sophisticated methodologies, such as those used by Grégoire Lorieux (2004) and Judy Lochhead (2020), are not systematic enough to merge measurable data with the subtleties of compositional intent. While detailed timbral maps and visualizations provide analytical anchors, they often fail to capture the evolving narrative embedded within spectral structures or offer a comprehensive view of the sonic foundation. In case of Lochhead specifically, the scheme relied on her own perception of the music material which she poured in a typology scheme. What she considers a 'bird-timbre' will not necessarily be interpreted the same by someone else. For Lorieux, his sole reliance on the score revealed many gaps in interpreting the spectral content residing in the composition which ultimately negated the understanding of the spectral structure.

Expanding on these perspectives, Paul Lascabettes et al.'s (2022) article introduced a computational approach that reinforced the significance of objective, measurement-based analysis, something which has been frequently advocated for throughout this literature review. By employing morphological filtering techniques, specifically its feature that reduces noise and accentuates dominant structures in matrices, the study uncovers underlying patterns shaping musical form. Although this method has primarily been applied to chord sequences rooted in tonal music, its technique presented a promising avenue for extending data-driven methods to non-tonal spectral analysis. It highlights the value of morphological features in analyzing sound contours and applying them to the overall structure of a musical piece. However, its emphasis on tonality, viewing structure primarily through a chordal lens, combined with the lack of narrative or intentional integration, limits its ability to fully capture the essence of spectral composition. If scaled back on rationality, with inclusion of intention, the approach could be more integrated.

## 1.4 Problem Definition

Robert S. Hatten (2021) and Judy Lochhead (2020) both contribute to defining the core problem of this thesis, highlighting the broader issues identified in the literature review. A struggle is the over-emphasis on rigid tonal frameworks when analysing spectral compositions that in essence do not align with this musical vision. Robert S. Hatten explained in his article “A Speculative Hermeneutics for Music Analysis and Interpretation” (2021) that music analysis could benefit from the combination of musical structure with expressive meaning intended by the composer. An example he sketches out is Robert Schumann’s hermeneutic analysis of Berlioz’s *Symphonie fantastique*, noting how Schumann oscillated between structural examination and expressive interpretation.<sup>49</sup>

Judy Lochhead (2020), on the other hand, critiques the overly hermeneutic and subjective interpretation done by individual researchers applied to contemporary, classic non-tonal music. She states that the lack of a transferable, objective analytical framework that considers compositional intent is missing, although it is necessary for the examination of specifically spectral compositions, in order to fully grasp which spectral properties and timbres contribute to the overall musical structure. She highlights the significance of analysis in shaping perspectives or narratives about such compositions, consequently their scientific value. Her specific critique on the overly subjective hermeneutic analytical views are expressed in a quote from Milton Babbitt included in her book: “[...] the limits of music reside ultimately in the perceptual capacities of the human preceptor.”<sup>50</sup> It suggests that what the researcher sees and only that accounts for the interpretation of the piece. This entails subjectivity under the guise of the ‘scientific discourse’, which can be associated with the “armchair scientists”.<sup>51</sup>

Music became deeply intertwined with scientific discourse, positioning analysis as a method for acquiring knowledge rather than engaging with artistic intent. However, due to the inherently subjective nature of this “armchair science”, she noted that many analysts simply imposed their own perspectives onto the musical material without considering its

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<sup>49</sup> Robert S Hatten, “A Speculative Hermeneutics for Music Analysis and Interpretation”, *The Musical Quarterly* 104, no. 1–2 (1 November 2021): 12–32, <https://doi.org/10.1093/musqtl/gdab006>.

<sup>50</sup> Milton Babbitt in Lochhead, *Reconceiving Structure in Contemporary Music*, 31.

<sup>51</sup> *Ibid.*, 31–35.

systematic implications, or using a systematic framework. As a result, a critical issue emerged: the absence of a clear, universally accepted definition of musical analysis for contemporary classical music, also applicable to the spectralist case. As Lochhead observes, English dictionaries lack a precise definition of musical analysis, as each researcher applies a unique interpretative framework to a musical work, leading to a broad and often ambiguous range of methodologies.<sup>52</sup> This ambiguity poses a particular challenge for spectral, non-tonal music. Without a systematic framework, compositions risk being analysed through tonal paradigms that fail to respect their unique musical construction. Additionally, the absence of an objective, transferable framework that accounts for compositional intent too makes it difficult to fully capture the structural and spectral characteristics of these types of compositions.

Both Robert S. Hatten (2021) and Judy Lochhead (2020) articulate this problem, which has surfaced in earlier literature and is central to this thesis. Hatten explored compositional and expressive intent within musical pieces, favouring a hybrid model that combined structural analysis with artistic considerations. However, Hatten's approach did not extend to the unique analytical demands of spectral compositions, particularly those shaped by sound morphologies and timbre. His definition of musical structure remained rooted in tonal frameworks and cadential movements, making it inapplicable to spectral compositions. Furthermore, his following statement shows inadequate content which can hardly be called a systematic framework:

Although the validity of speculative hermeneutic claims cannot be tested scientifically, there is nevertheless rigor in the exhaustive consideration of a wide range of evidence, and the satisfactory accounting for those questions posed by otherwise inexplicable variables, especially when they may be understood as coalescing into a coherent story, drama, or expressive trajectory.<sup>53</sup>

His conclusive statement, although pointing at an interesting analytical value which can stem from integrating compositional intent in the comprehensive mix, does claim that a scientific testing is difficult for speculative hermeneutics. In terms of spectral, non-tonal music compositions, this forms a problem as it largely relies on sound

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<sup>52</sup> Ibid, 46.

<sup>53</sup> Hatten, "A Speculative Hermeneutics for Music Analysis and Interpretation", 25.

morphologies and timbre, more specifically how these physical properties of a fundamental travel throughout the composition and interact with other sounds which is exactly what brings forward structure. Completely disregarding scientific validity for the sake of prioritising speculation and an “expressive trajectory” can hardly be viewed as a systematic analytical approach.

Lochhead (2020), on the other hand, recognized the scientific orientation of contemporary music analysis, particularly in spectralism, yet pointed out that orchestration and timbre were largely overlooked within the discourse: “Or in other words, timbre recedes from scholarly attention because of the particular ways it challenges existing concepts of musical structure.”<sup>54</sup> This quote highlights a scientific stance, or rather an opposing stance against other analytical focal points interesting for the spectral case, yet considered too challenging for the analytical process. Timbre and the orchestration of partials throughout the ensemble are essential elements of spectralist music. However, as Lochhead observes, these aspects are often neglected within the so-called “scientific discourse” that shapes music analysis, leading to a depletion of tonal ideas and structures onto inherently non-tonal material.

She emphasized that analysts, by framing their work as strictly scientific, often overlooked compositional intent as a reaction against 19th-century Romanticism. This omission results in an incomplete understanding of spectral compositions and highlights the need for a structured approach that connects spectromorphology with artistic intent. This thesis aims to bridge this gap by integrating measurable spectral features with compositional thought to preserve the unique structural logic of non-tonal music. The absence of a systematic methodology for analyzing spectral acoustic compositions limits deeper scientific inquiry and risks reducing musicological analysis to either strict data-driven approaches or subjective interpretations. Spectral features, such as spectral flux, overtone relationships, and broader sound morphologies, are essential in shaping non-tonal musical structure.<sup>55</sup>

Even though the literature review presented earlier demonstrated valuable efforts to analyse music outside the tonal framework, particularly within a spectral environment that prioritises sound morphology over tonal evolution, see Thoresen and Hedman (2007), Emmerson and Landy (2016) and Alluri and Toiviainen (2010), it lacked a concrete example of a method incorporating both aspects.

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<sup>54</sup> Lochhead, *Reconceiving Structure in Contemporary Music*, 53.

<sup>55</sup> *Ibid.*, 35-43.

Spectralist music demands an analytical approach that transcends traditional tonal frameworks, as its structural coherence is rooted not in tonal harmonic progressions but in timbral evolution, overtone relationships, and spectral transformations. Without a methodology designed to account for these elements, the full depth of spectral compositions remains inadequately explored. The inclusion of the compositional intent, then, could serve as an additional dimension of meaningfulness necessary to avoid an over-rationalisation of the sonic content and understand the piece for its creative and musical proficiency as well.

## CHAPTER 2: PROPOSED METHODOLOGY FOR THE ANALYSIS OF NON-TONAL, SPECTRAL, ACOUSTIC COMPOSITIONS

This proposed methodology serves as a reorientation of the previously discussed analytical approaches for examining non-tonal, spectral, and electroacoustic music, rather than a definitive solution to the identified gaps. While it acknowledges these gaps, it also draws inspiration from various perspectives, refining existing methods rather than presenting a fixed or exhaustive resolution.

The literature review and problem definition highlight several key gaps. Analytical frameworks that rely on perceptual bias, such as those proposed by Pierre Schaeffer (Lech, 2017) and Judy Lochhead (Lochhead, 2020), often lack systematic rigor. Additionally, compositional intent is frequently overlooked, and there is no clear definition of the spectral features that shape a composition's evolution over time, its polyphonic contexts, or the morphology of the sound itself. While various authors address these issues individually, an integrated approach remains absent, despite the clear foundations of spectralism outlined in the introduction. Although spectralist music lends itself to objective, measurable analysis, existing frameworks have yet to fully evolve to meet this potential.

In spectral music, sound morphology is central, as it reveals the unique sonic fingerprint that forms the foundation of a composition. Gérard Grisey (1946–1998) incorporated this principle by using the inner structure of sound, particularly the distribution of energy across all integer multiple partials, as a reference for shaping the overall temporal structure of his compositions. As outlined in the Introduction, this approach reinforces the connection between spectral properties and musical form, integrating timbral evolution into the broader compositional framework.<sup>56</sup> This emphasizes the crucial role of spectral and overtone relationships in interpreting musical structure within spectral music. To fully understand overtone interactions, Hermann von Helmholtz' book *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (1863) serves as a foundational reference. Helmholtz argued that when a fundamental pitch shifts across octaves, its harmonic structure maintains proportional integrity, ensuring the overtone

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<sup>56</sup> Grisey, "Tempus Ex Machina", 259.

ratios remain constant and preserving the characteristic timbre of the sound.<sup>57</sup> Building on Helmholtz's theory that harmonic structures maintain proportional integrity across octaves, spectralist composers take this principle further by actively shaping overtones throughout a composition. By merging Helmholtz's scientific foundation with their creative reinterpretation of harmonic spectra, they reveal how objective acoustical properties can seamlessly integrate with artistic intent. This approach transforms theoretical concepts into dynamic musical expressions, demonstrating how spectral principles not only preserve structural consistency but also enhance the expressive potential of sound.<sup>58</sup>

The steps outlined below present a structured approach to the issues mentioned in the literature review and problem definition, applied to *And In Between, There Is ...* (2024) by Ellen Jacobs (°1996). By systematically categorizing spectral flux and temporal structures, the methodology connects objective analysis with compositional intent, offering a deeper understanding of the dynamic evolution of sound.

## 2.1 : Data collection

The first step in the analytical methodology is to collect the data necessary to conduct the analysis in the first place. In this case, the data consists of two objective and two subjective elements: the score and audio recording, as well as two interviews conducted with the composer Ellen Jacobs, one before the analysis (21 November 2024) and one after (17 May 2025). The score and audio recording were provided by the composer herself.

Ellen Jacobs was selected after having taken 5 interviews from 5 different Belgian composers all writing non-tonal, spectral compositions. Jacobs was chosen due to the rich use of different acoustic instruments, as well as her profound way of handling sound and putting sound development on the foreground of her compositions. The piece *And In Between, There Is ...* (2024) was foregrounded by her as the most sound and spectral based, meaning that she deliberately used the sonic potential of the instruments to build the composition on, instead of relying on electronics.<sup>59</sup>

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<sup>57</sup> Hermann von Helmholtz, "Von der Schallempfindung im allgemeinen", in *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (Heidelberg: F. Vieweg und Sohn, 1863), 13-39.

<sup>58</sup> Rose, "Introduction to the Pitch Organization of French Spectral Music", 9-13.

<sup>59</sup> Ellen Jacobs (composer), interviewed by Margot Meire (student at Ghent University), 21 November 2024.

## 2.2: Data preparation

With the above mentioned material, the preparatory phase of the analysis can begin. Here, the compositionally-arranged segments in the score, indicated with the letters A-B-C-D-E, and the introduction, are taken as **the primary measures** for segmentation. This is another way of remaining faithful to the score's structure. The next step is to cut the audio recording according to these segments using Audacity, a free audio editing software.<sup>60</sup> If a score is not available, segments can be retrieved by applying the Queen Mary University Segmenter plugin in Sonic Visualiser. It detects structural changes in audio by analyzing features like timbre, pitch, and spectral content. It identifies points where the music shifts and automatically divides the piece into segments. These segments are then visualized, allowing users to refine the analysis for accuracy, even without a score.<sup>61</sup> This makes the plugin especially valuable when a score is unavailable, as it provides an alternative method for identifying structural divisions based on audio characteristics rather than predefined musical sections. However, when it comes to understanding compositional intent, it may be less effective than the segments provided here.

The separate audio files were segmented in Audacity, with the score placed alongside them to ensure alignment.

The succeeding step is to split the separate audio files per instrument/instrumental group. This is especially useful in dense and highly polyphonic sections., and allows for a more detailed spectromorphological analysis later on. It also helps fill the gap mentioned earlier of analytical methods not considering the possibility of spectra being present in multiples and interacting with each other, also being subordinate to deliberate placings of the composer. In order to implement instrumental isolation to paint a more accurate picture of the sounds present and their spectral footprint, Lalal.AI, an artificial intelligence-based application, is employed. Developed in Switzerland, this tool allows for an accessible way of splitting various instrumental sections in a polyphonic file, employing categories such as piano, winds, drums, strings, voice, and so on.<sup>62</sup>

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<sup>60</sup> "About Audacity", *Audacity*, n.d., accessed on 27 April 2025 from <https://www.audacityteam.org/faq/>.

<sup>61</sup> "Find and Download Plugins", *VAMP Plugins*, n.d., accessed on 20 December 2024 from <https://www.vamp-plugins.org/download.html>.

<sup>62</sup> "Lalal.AI", (Omnisale GmbH, September 2024), <https://www.lalal.ai/>.

While gaining a detailed understanding of sonic characteristics per instrumental section is valuable, it is crucial to remain critical of the tool's AI-based nature. Due to its inherent probabilistic functioning, the tool can occasionally struggle to make precise, clean separations in the initial sound file—for instance, cutting the double bass with the wind section. This is because the tool is trained on pre-implemented data, not always considering instrumental sounds that have been deliberately manipulated, such as the deliberate use of tape or extended techniques. However, the application provides a test sample before processing the entire audio file, enabling users to compare the output against the composition's available information. Nevertheless, challenges may arise when splitting compositions in which no instrument has a distinct presence, potentially due to significant sound manipulations. Depending on the specific segment, the effectiveness of splitting techniques can differ significantly. Therefore, it is suggested to remain cautious when using an AI-based sound splitter, since its accessibility can sometimes overshadow minor mistakes.

The variability among splits reflects the complexity of multi-voiced music, where overlapping frequency content and dynamic interactions naturally fluctuate. In sections with clear spectral boundaries, the tool provided near-perfect isolation, allowing for in-depth analysis of each instrument's unique contribution, especially in the case of the piano. In more complex sections, the less precise splits revealed the inherent interactivity between instruments, offering insights into how they blend and influence one another. Other sound splitting tools were reviewed, such as Sony's AI Sound separator. This tool in specific needs the programming of an API-code into Python, which requires advanced computational knowledge.<sup>63</sup> A brief visualisation on how to use the Lalal.AI tool is presented in Table II, Appendix D.

By employing a sound splitter, subtle sonic details become more apparent, facilitating a comprehensive understanding of the composition. Without this step, subtle nuances might go unnoticed, hindering the researcher's ability to fully grasp the global structure and interactions within the music and how possible spectral imbalances travel across the instruments. It serves as a tool for understanding orchestration elements that might be obscured in an unsplit file, reflecting the core pillars of spectralism: timbre and orchestration. Judy Lochhead highlighted these two elements as a way to move beyond the 'scientific' analytical framework often used by musicologists to examine contemporary music, including spectral music.<sup>64</sup>

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<sup>63</sup> "AI Sound Separation", *Sony*, 18 November 2020, accessed on 5 January 2025, from [https://www.sony.com/en/SonyInfo/technology/stories/entries/AI\\_Sound\\_Separation/](https://www.sony.com/en/SonyInfo/technology/stories/entries/AI_Sound_Separation/).

<sup>64</sup> Lochhead, *Reconceiving Structure in Contemporary Music*, 53.

## 2.3: Data Analysis

### 2.3.1: Score Analysis and Sonic Visualiser Plugins: Category 1 – Segmented

The score for *And In Between, There Is...* (2024) by Ellen Jacobs contains elaborate information on both the musical content and the performance of this content. The pitches of transposed instruments will be noted according to how they sound, not how they are written, since that is the data picked up by the plugins. For this part, it is important to pay attention to overtone series and their inherent logic, as that is also the focus for spectralists.

The score analysis is meant to construct a strong base analysis for the further interpretation of the Sonic Visualiser output. The score explains performance symbols guiding both musicians and researchers in playing and interpreting the work (see Appendix I). For example: a bisbigliando on the clarinet will have a different sonic effect compared to the same note without this technique. All such instrumental techniques have been clarified by Jacobs on these initial pages.<sup>65</sup>

Important to note in the light of the score analysis is that tonal structures, in relation to keys, intervals and chord progressions are fully ruled out. Instead, the spectral bases are sought, as they are revealed through the pre-analysis interview (21 November 2024), together with their integer multiples calculated through the following formula:

$F_n = n \cdot F_0$ .<sup>66</sup>  $F_0$  is the fundamental frequency in Hertz,  $n$  the position of the partial in the spectrum, and  $F_n$  the frequency of partial  $n$ .

As such, the score reveals not only instrumental techniques but also potential spectral interconnections through shared or differing fundamentals. In the pre-analysis interview, Ellen Jacobs identified the spectral bases as Sul I (G2, approximately 98 Hz) and Sul II (D2, approximately 73 Hz), both corresponding to strings on the double bass. Consequently, their integer multiples must be taken into account during the analysis.<sup>67</sup> The table of integer multiples is to be found in the Appendix C, Table I.<sup>68</sup>

The score analysis is then enriched by an initial selection of VAMP Plugins from Sonic Visualiser. First developed in 2006 at the Queen Mary University in London, this software is designed to make the analysis of an audio file detailed

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<sup>65</sup> Ellen Jacobs, *And In Between, There Is*, (Leuven: TRANSIT Festival, 2024).

<sup>66</sup> Jacobs (composer), interview, 21 November 2024.

<sup>67</sup> Ibid.

<sup>68</sup> Ron Vonk, "Contrabas Flageoletten", *Natuurkunde*, n.d., accessed on 12 December 2024, from <https://www.natuurkunde.nl/artikelen/509/contrabas-flageoletten>.

and accessible. On top of that, one can load VAMP plugins in here, allowing researchers to extract specific (spectral) features from the audio file. In this thesis, version 5.0.1 is used.<sup>69</sup> A list of VAMP Plugins can be found on their website.<sup>70</sup>

Table 2.1 shows the initial selection of plugins that can be used as an accompaniment for the score analysis. The sensitivity of the Aubio Pitch Detector to subtle pitch variations is crucial for spectral compositions, where harmonic structures evolve dynamically. It helps discern which frequency is the strongest among all. NNLS Chromagram, on the other hand, helps detect frequencies in the form of bins aligning with chromatic pitches. This simplifies the recognition of present frequencies in the composition that are potentially not present on the score, due to instrumental resonances for example. A combination of integrating the Aubio Pitch Detector, the NNLS Chromagram plugin, and the Spectrogram Layer in Sonic Visualiser, applied per segment and per split section via Lalal.AI, provides a robust framework for spectral analysis. This approach enables precise identification of spectral content and its distribution across time, offering clarity on where specific spectral elements manifest within the composition.<sup>71</sup>

The key objective here is to establish a meaningful connection between the score's contents and the outputs generated by the Sonic Visualiser plugins. While traditional score analysis provides structural and notational insights, it may overlook crucial spectral details that shape the composition's sonic identity. By integrating these plugins into the analytical process, previously unnoticed elements can be revealed, offering a more comprehensive understanding of the work and a connection between both materials (score and audio file).<sup>72</sup>

While these plugins enhance spectral analysis, it is important to acknowledge that they are not entirely foolproof. Occasionally, they may produce inconsistencies or misreadings due to inherent limitations in pitch detection and spectral visualization algorithms. However, when Aubio Pitch Detector fully aligns with the score, its role in the split analysis becomes less relevant, as the separation process inherently focuses on uncovering spectral details beyond what is

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<sup>69</sup> Chris Cannam, Christian Landone, and Mark Sandler, "Sonic Visualiser", version 5.0.1 (Queen Mary University London: Centre for Digital Music, 2024).

<sup>70</sup> "Find and Download Plugins", *VAMP Plugins*, n.d., accessed on 20 December 2024, from <https://www.vamp-plugins.org/download.html>.

<sup>71</sup> Ibid.

<sup>72</sup> Ellen Jacobs (composer), interview, 21 November 2024.

explicitly notated. In such cases, the plugin may offer little additional insight, as its function primarily serves to reinforce pitch tracking rather than reveal new spectral layers.<sup>73</sup>

**Table 2.1:** Selected plugins for the first layer of the analysis

| Plugin+ Settings and Developer                                                                                                                                                                                               | Function                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Aubio pitch detector: GPL, Paul Brossier</b><br>Min. fundamental frequency → 51,91 Hz<br>Max. fundamental frequency → 1975,53 Hz<br>Silence threshold → -90 dB<br>Audio frames per block → 1024<br>Window increment → 512 | Fundamental frequency estimation using the YIN algorithm; based on autocorrelation and difference function, no spectral transform (FFT) applied. |
| <b>NNLS Chromagram: GPL, Matthias Mauch</b><br>Scale → Linear;<br>Bins → Linear<br>Window size → 16384<br>Window increment → 2048                                                                                            | FFT-based magnitude spectrum projected onto pitch class templates using Non-Negative Least Squares; outputs 12-bin chroma vectors (bins).        |

The reason for choosing the above VAMP plugins is that they serve as practical tools for identifying which pitch is the strongest amidst the range of frequencies present. For example, the Aubio Pitch Detector provides a cleaner estimation of the dominant frequency compared to the Fundamental Frequency (wavelet method) plugin by Chris Cannam (2012).

That said, neither plugin is flawless. In passages dense with numerous powerful frequencies, both tools can struggle to isolate a single dominant pitch. This becomes particularly challenging when the composer intentionally introduces noise components or inharmonic elements, making it difficult for either plugin to determine the clear fundamental. Therefore, employing both these plugins alongside a careful score analysis, and utilising category 1 plugins as a cross-reference

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<sup>73</sup> “Find and Download Plugins”, *VAMP Plugins*, n.d., accessed on 20 December 2024, from <https://www.vamp-plugins.org/download.html>.

(ref. Table 2.1), ensures that each method helps compensate for the shortcomings of the other. Everything hinges on the musical context in which one finds oneself.

### 2.3.2: Second selection of Sonic Visualiser Plugins and analysis of the full segments

After the score analysis, along with the first category of selected Sonic Visualiser plugins, the second category can be utilised. These plugins are used to interpret broader energetic features within the (split) segments.

The selection made here consists of two plugins which are to be used per split segment, i.e. those split by Lalal.AI per instrumental category: Spectral Slope and RMS-Energy. The first one is a kind of quantification of the sound's brightness according to its spectral balance and consequently timbral transformations. With a window size and increment of 1024 (see Table 2.1), it is useful in visualising the steepness of the spectrum; a high, positive slope reveals that the spectral energy is concentrated in the high frequencies, indicating that the natural balance of the spectrum has been altered, whereas a rapidly decreasing or flat slope suggests that the fundamental frequency is dominant and the natural ratio between low and high frequencies is preserved.<sup>74</sup> Applying this to split segments helps identify how instruments influence timbral shifts and spectral tension. Linking it to the earlier score analysis and selected plugins, Aubio Pitch Detector and NNLS Chromagram, provides insight into orchestration and its connection to spectral slope output. For example, does a specific technique cause a steep slope, creating spectral imbalance? Does an instrument produce a flat slope, and how does it compare to other visualisations? Visualising the Spectral Slope plugin per split section enables a detailed comparison of timbral transformations, refining the analysis at a more granular level.

The **RMS-energy plugin**, using a 1-second window, efficiently tracks amplitude variations throughout the audio file, offering an essential perspective on the dynamic contours and overall energy changes within the performance. It is used on split sections of the segments to highlight subtle expressive nuances, showing how each instrument's energy shapes the overall sonic texture through amplitude variations. Furthermore, it can show which instruments in particular add to the overall structure by marking peaks of intensity. In spectral music, where timbral evolution and dynamic shaping are key compositional elements, the RMS-energy plugin helps to map intensity changes across time. By applying it to split

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<sup>74</sup> "Spectral Descriptors", *MATLAB Help Center*, n.d., accessed on 27 March 2025, from <https://nl.mathworks.com/help/audio/ug/spectral-descriptors.html#SpectralDescriptorsExample-9>.

sections, it reveals subtle expressive details within individual instruments, highlighting their specific contributions to the overall sonic structure. Together, these tools offer a comprehensive, complementary insight into the sonic evolution, each addressing a particular aspect of the spectral and temporal characteristics.<sup>75</sup>

When it comes to the segments in their entirety, two other plugins are foregrounded: the Spectral Flux and Constant Q. The **Spectral Flux plugin**, used with the same window size and increment and utilizing the L2 norm for enhanced sensitivity, measures the degree and speed of spectral change over time, making it particularly useful for identifying moments of spectral modulation, which can indicate shifts in timbre or playing techniques.<sup>76</sup> Unlike Spectral Slope, which assesses overall brightness by analyzing spectral tilt, Spectral Flux accentuates how frequency content shifts from one moment to the next. This makes it particularly effective for identifying transitions between stable harmonic regions and moments of spectral turbulence in a composition. Spectral Flux is able to reveal spectral motion throughout the segment, which can help understand its structural development. Rather than providing a static measurement, it emphasizes fluidity, helping to illustrate how the timbral material of the segment is actively shaped. It offers a real-time perspective on the dynamic interplay within a polyphonic segment.

Within the examination of the Spectral Flux, it is not only necessary to understand it in relation to the other plugins and the score analysis but also transform it into numerical data. Authors such as Alluri and Toiviainen (2010) argue that spectral flux is a key indicator of timbral change, capturing variations in spectral energy across time and playing a crucial role in the perception of musical dynamics and texture. They specifically emphasized it for polyphonic cases.<sup>77</sup> Following this similar logic, spectral flux is elevated as a numerical reference, whose dataset is extracted from Sonic Visualiser and its median is calculated. More detailed information will be presented in step 2.4.

Another step in the Spectral Flux analysis is to plot a bar chart showing median divisions per split section. For guidance on extracting the median value from a spectral flux dataset, see Table 2.4 under step 2.4. This helps assess how each instrument or section contributes to overall spectral flux transformations. Spectral orchestration actively shapes timbres

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<sup>75</sup> "Find and Download Plugins", *VAMP Plugins*, n.d., accessed on 27 March 2025, from <https://www.vamp-plugins.org/download.html>.

<sup>76</sup> "Spectral Descriptors", *MATLAB Help Center*, n.d., accessed on 27 March 2025 from <https://nl.mathworks.com/help/audio/ug/spectral-descriptors.html#SpectralDescriptorsExample-9>.

<sup>77</sup> Alluri and Toiviainen, "Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre", 223–42.

to mimic natural overtone behaviours, creating fluid transformations. By visualizing median spectral flux values per split section, the analysis can clarify how individual instruments influence the spectral motion of the composition. This reinforces a fundamental spectralist concept: sound is understood as a dynamic entity that evolves based on overtone relationships rather than fixed pitch structures.<sup>78</sup>

The last plugin being a part of the data analysis process for the full segments is the **Constant Q**. It operates on a logarithmic scale with linear bins and provides a detailed, time-resolved view of the frequencies present, effectively serving as a refined spectral envelope that shows exactly which frequencies emerge at any given moment. More specifically, it visualizes the time structure, showing when certain frequencies appear in isolation or interact with others. By mapping how frequencies enter, merge, and dissipate within a spectral composition, it offers a dynamic perspective on the temporal structure of sound.<sup>79</sup> In spectralist music, time is understood as a reflection of the natural balance of overtones within a base spectrum, where lower frequencies usually persist longer than higher ones.<sup>80</sup> Step 2.4 will elaborate on how this Constant Q output, together with the Spectral Flux Median, can be representative of the time structure of the segment, slowly but surely revealing its compositional structure to us. Table 2.2 lists the described plugins, their key Sonic Visualiser settings, and brief functions, sourced from the VAMP Plugins webpage, similar to Table 2.1.<sup>81</sup>

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<sup>78</sup> Rose, "Introduction to the Pitch Organization of French Spectral Music", 9-13.

<sup>79</sup> "Find and Download Plugins", *VAMP Plugins*, n.d., accessed on 27 March 2025, from <https://www.vamp-plugins.org/download.html>.

<sup>80</sup> Grisey, "Tempus Ex Machina", 259.

<sup>81</sup> "Find and Download Plugins".

**Table 2.2:** Selected plugins for the second layer of the analysis

| Plugin + Settings and Developer                                                                                                                                                                                                                             | Function                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Spectral slope: QM University of London, Chris Cannam and Jamie Bullock</b><br>window size → 1024;<br>window increment → 1024.                                                                                                                           | Computed from the log-magnitude FFT spectrum; linear regression estimates the tilt of spectral energy across frequency bins.                                                                                                 |
| <b>Spectral flux: BBC</b><br>window size → 1024;<br>window increment → 1024;<br>Plugin Parameters → Use L2 over L1 (more precise)                                                                                                                           | Frame-to-frame L2 norm difference of magnitude spectra from FFT; captures rapid spectral changes or onsets.                                                                                                                  |
| <b>Constant Q (log scale – linear bins): QM University of London</b><br>Min. frequency → 50 Hz<br>Max. frequency → 14700 Hz<br>Bins per octave → 36 bins<br>Overlap → 4<br>Linear interpolation<br>Audio frames per block → 1024<br>Window increment → 1024 | Time-frequency transform with geometrically spaced frequency bins; maintains constant Q-factor for improved pitch resolution, presented in a logarithmic scale.                                                              |
| <b>RMS-energy (use root): Chris Cannam and Jamie Bullock</b><br>Moving average window size → 1 sec.<br>Moving average percentile → 3<br>Dip threshold → 3<br>Low energy threshold → 1<br>Audio frames per block → 1024<br>Window increment → 1024           | Calculated as the square root of the mean squared amplitude over short time frames; reflects signal intensity in the time domain and is not based on FFT, but rather on the energetic course of the audio signal throughout. |

Despite Sonic Visualiser containing a large number of available plugins, selecting only a few plugins ensures a focused, efficient, and meaningful analysis tailored to the specific needs of spectral music. By prioritizing key aspects such as intensity, harmonic motion, timbral balance, and frequency evolution, the selection remains streamlined while still capturing the essential structural elements of spectral music. This approach allows for a well-rounded yet manageable analysis, ensuring that the data remains relevant and interpretable in the context of musical form and composition. This step characterizes each composition segment and its split sections using Lalal.AI, ensuring the final interpretation in step 2.4 is based on a thorough understanding of the composition's architecture.

## *2.4: Using Spectral Flux and Time as representatives of compositional intent*

### *2.4.1 Approaching Spectral Flux and Time through Sonic Visualiser and incorporating median values*

Categorising spectral flux and time represents a subtle yet essential step in the music analysis process outlined here. Drawing on the theory of Lasse Thoresen and Andreas Hedman (2007)—as discussed in the literature review—temporal categories reveal how the sonic material unfolds. This falls within the concept of **spectromorphology**. Time is regarded as a fundamental structural element in which the sound object exists. Their way of conceptualising time in function of the composition and spectromorphological development is useful to understand the flux in relation to the course of the segment/composition.<sup>82</sup>

By applying the **Spectral Flux plugin** in Sonic Visualiser to each segment (ref. Table 2.2), one can identify distinct flux types, gaining a detailed picture of the spectral changes. Table 2.3 represents both the Spectral Flux and Time categories used for the following case study. Spectral flux divisions are considered relative per segment. Absolute values are not present.

In order to decide whether the spectral flux is low, moderate or high, it is important to follow the following steps. The Spectral Flux plugin quantifies how the spectrum changes over the segment, generating numerical values in the form of a dataset. Table 2.4 presents the steps to be followed to achieve the values. A more detailed guide is provided in the

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<sup>82</sup> Thoresen and Hedman, "Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology", 129-135.

Appendix F. The reason why the median in particular is useful, is because of its reliable nature for measuring the typical behaviour of a certain spectral flux range. Calculating the mean, on the other hand, would not successfully convey a full picture of the behaviour, or in other words tell us to what extent the signal shows high values (peaks).<sup>83</sup> The Median Spectral Flux values can be plotted as a line graph, visually representing the overall trajectory of spectral change throughout the composition. This information is also included in Table 2.4.

These categorizations highlight how each segment integrates into the composition, creating a cohesive whole. In doing so, it illuminates how, over time, these elements create musical structure and perhaps even recurring patterns. This step underscores the flexible ways in which the composer arranges and modulates spectral flux and time throughout the composition. Whereas earlier steps identified the origin of each spectral flux type, with the use of the score and Sonic Visualiser plugins, this step labels and categorises them to facilitate deeper analysis.

This step also highlights the composer's deliberate manipulation of spectral flux and time, reinforcing the idea that these elements serve as primary tools for musical expression. Unlike conventional approaches that rely on thematic development or tonal resolution, the composition's logic is rooted in fluid transformations, where sound operates as a changing entity rather than a fixed construct. The ability to visualize and categorize these spectral movements makes it possible to dissect the mechanics of the composition with greater precision. It quite literally places the degree of spectral change, contextualised with the help of step 2.3, in a broader time frame.

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<sup>83</sup> Pritha Bhandari, "Centrummaten: Modus, mediaan en gemiddelde | Met voorbeelden", *Scribbr*, 21 October 2021, accessed on 4 May 2025 from <https://www.scribbr.nl/statistiek/centrummaten/>.

**Table 2.3:** Spectral Flux and Time Categories to be conceived from Step 2.3. Time categories are based on Thoresen, Lasse, and Andreas Hedman. 'Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology'. *Organised Sound* 12, no. 2 (August 2007): 129–41.

| Spectral flux category                                                                                                                                                                                                                | Time category                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Low flux:</b> Spectral flux shows minimal variation, indicating that most spectral content remains stable with little to no significant change over time.                                                                          | <b>Ambient Time:</b> A sustained and expansive sonic presence that lacks clear articulation, creating an atmospheric quality. Rather than being structured by discrete temporal events, Ambient Time unfolds gradually, often characterized blurred temporal boundaries. This quality allows sound to function as a backdrop, maintaining continuity while subtly evolving through minor spectral shifts. |
| <b>Moderate spectral flux</b> indicates noticeable shifts in spectral content, but these changes occur gradually rather than abruptly.                                                                                                | <b>Flutter Time:</b> refers to rapid micro-iterations of sound that merge into a fluid, shimmering texture, creating an impression of continuous motion. Unlike discrete repetitions, these fluctuations exhibit slight variations in pitch, intensity, or spectral content, resulting in a dynamic and evolving timbral quality.<br><br>Short iterations                                                 |
| <b>High spectral flux:</b> the spectral flux is characterised by a <u>sudden</u> increase or decrease in spectral energy, marking a hard line between both segments. Often, this category is the most apparent on a perceptual level. | <b>Ripple Time:</b> refers to a pattern of oscillating sonic events contributing to a dynamic and structured temporal framework. Ripple time acts more broadly compared to flutter time.<br><br>Long iterations                                                                                                                                                                                           |

**Table 2.4:** Step by step presentation of how to transform the Spectral Flux dataset from Sonic Visualiser in a median value.

| Step                        | Action                                                  | Details                                                |
|-----------------------------|---------------------------------------------------------|--------------------------------------------------------|
| <b>Apply plugin</b>         | Use Spectral Flux in Sonic Visualiser.                  | Select L2 over L1 norm for a more precise outcome.     |
| <b>Export data</b>          | File > Export Annotation Layer                          | Select the Spectral Flux Layer.                        |
| <b>Set parameters</b>       | Choose Column Separator “/”                             | Enable “Extract Audio Sample Frames”                   |
| <b>Save file</b>            | Export Current Selection                                | Save as a <b>.csv file</b>                             |
| <b>Open Microsoft Excel</b> | Data > Retrieve Data > From File<br>> From txt/csv file | Select the saved .csv file                             |
| <b>Configure import</b>     | Choose separating sign “/”                              | Click “Load” to import the dataset.                    |
| <b>Apply formula</b>        | Use =MEDIAN(range)                                      | Select the column containing the spectral flux dataset |
| <b>Plot line graph</b>      | Insert > Line Diagram                                   | Insert all achieved median values.                     |

When it comes to the time categorisations, the Constant Q plugin output is of importance. As mentioned in Table 2.2, Constant Q is capable of visualising the temporal course of frequencies. By employing Constant Q, the analysis moves beyond static frequency identification and into dynamic spectral behaviour, allowing time categorizations to be constructed based on observable frequency modulations. This is especially useful in spectral composition, where harmonic evolution does not follow conventional progressions but instead relies on continuous shifts in timbral and spectral content. Therefore, the plugin plays a crucial role in uncovering interactions between frequencies that contribute to the fluidity of spectral orchestration. Certain frequencies may appear in isolation, while others enter into complex relationships, influencing motion and transformation within the composition. Constant Q enables the segmentation of these interactions into identifiable time categories, facilitating a structured approach to analyzing spectral motion. Figure **III, IV and V** in Appendix E show examples of what Constant Q output to expect per time category, and its complementary nuances. Since these are only examples, it is essential to also refer to Table 2.3 for a more complete and accurate understanding.

### 2.4.2 Approaching compositional intent through a dual interview

After completing each analytical step, the interviews provide an essential qualitative layer to the process. The pre-analysis interview helps outline the composer's artistic vision, exploring the inspiration behind the piece and the strategies used to shape sound and sonic transformations. Additionally, it examines her approach to instrumental techniques and multi-voiced interactions, offering deeper insight into their role in the overall structural development of the composition. The pre-analysis interview helped shape the initial analytical scope by identifying the fundamental elements of the composition. Additionally, it refined the focus of this method, emphasizing the evolution of larger sound entities over time.

By integrating the spectral flux median line graph and time categorizations derived from Constant Q outputs, alongside insights from Thoresen and Hedman (2007), the second interview provides a critical qualitative dimension to the analysis. This questioning serves as a direct engagement with the composer which invites them to assess whether the analytical findings align with their intended narrative and structural choices. Their feedback either validates or challenges the data-driven conclusions, reinforcing the connection between quantitative spectral analysis and artistic intent. This step is essential in ensuring that spectral analysis does not exist in isolation but is actively linked to compositional thought. By bridging objective data with subjective interpretation, the process strengthens the relationship between measurable spectral transformations and the artistic vision guiding the piece. This approach not only refines the accuracy of the analysis but also underscores the broader significance of integrating computational methods within a musical framework that values both objective and expressive dimensions.

By actively linking spectral analysis to compositional thought, this step ensures that the analytical process does not remain confined to numerical interpretation but instead engages with the expressive and conceptual frameworks underlying the composition. The composer's insight validates or recontextualizes the findings, reinforcing the connection between measurable spectral transformations and artistic intent. This approach prevents spectral analysis from becoming a detached computational exercise and instead integrates it within a broader musical framework that respects both objective and interpretative dimensions.

In summary, Table 2.5 shows all analytical layers in a concise scheme.

**Table 2.5:** Concise overview of the analytical layers as explained in Chapter 2 “Proposed Methodology For The Analysis of Non-Tonal, Spectral, Acoustic Compositions”.

| Type of Analysis                                                                       | Tool / parameter                                                                             | Goal                                                                               |
|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Score-based analysis                                                                   | Manual, instrumental techniques and integer multiples Sul I and Sul II (Table I, Appendix ). | Harmonic and spectral overview, and spectral orchestration.                        |
| Audio signal – analysis<br>➔ Split segments (Lalal.AI)<br>➔ Entire segments (Audacity) | Sonic Visualiser Plugins (see Table 2.1 and 2.2)                                             | Spectral modulation, dynamics, energy and balance.                                 |
| Interpretative and intentional layer                                                   | Interviews (pre- and post-analysis)                                                          | Get a sense of intentionality <i>as is</i> and in relation to the analytical data. |

## CHAPTER 3: *AND IN BETWEEN, THERE IS* FROM ELLEN JACOBS (2024): A CASE STUDY

### The Composer: Ellen Jacobs

Before starting the analysis of *And In Between, There Is ...* (2024), a brief sketch of who the composer is will be discussed.

Ellen Jacobs, born in 1996, is a Belgian composer and flutist who obtained her master's degree in composition from KASK & Conservatorium School of Arts in Ghent, Belgium, in 2021. Her compositional style is rooted in sonic exploration and development, enriched by a strong sense of creative intuition. Through the integration of both acoustic and sometimes electronic sounds, Jacobs examines their spectral properties, treating them as fundamental compositional elements. Her master's project, *Inertia* (2021), investigated these intrinsic sonic characteristics by combining acoustic instruments with tape, drawing inspiration from the sounds she encountered during train journeys between Ghent and Antwerp. While electronics occasionally feature in her work, Jacobs also focuses extensively on purely acoustic instruments. This is evident in her compositions such as *Deadfold* (2022) and *And In Between, There Is ...* (2024), the subject of this thesis. In *Deadfold* (2022), acoustic sounds are altered through the manipulation of instruments using aluminium foil. In contrast, *And In Between, There Is ...* (2024) is centred entirely on instrumental acoustics and their capacity to evoke dream-like spaces, an approach influenced by Kaija Saariaho (1952–2023). As of today, she is working on recording ecological sound and building music around microscopic life beneath the Belgian soil.<sup>84</sup>

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<sup>84</sup> Benjamin Windelinckx, "JACOBS Ellen (1996)", *Matrix Centrum voor Nieuwe Muziek*, 2024, accessed on 20 October 2024, from <https://matrix-new-music.be/nl/publicaties/componistenfiches/jacobs-ellen/> ; Ellen Jacobs, "An Interview with Ellen Jacobs", interview by Margot Meire, 21 November 2024, audio, 25:40.

### 3.1 Segmented Score Analysis and Sonic Visualiser

#### 3.1.1 Introductory segment: bar 1 – 22

The focus in this segment lies on the following instruments: crotales, tam-tam, and later the double bass. Here, Lalal.AI was not yet used since the instruments play in large isolation, and were split together for the following segments.

In bar 1-3 (Figure 9), the crotales introduce a prelude (D4-Eb4-G4) leading into C5 and then an augmented triad (Eb4-G4-B4), circled in green. The term augmented triad is retained for the sake of clarity and ease, ensuring a familiar reference point without implying any additional harmonic or spectral significance. “L.v.” refers to *Laissez vibrer*. The fundamental detected by Aubio is B6 ( $\approx 1975$  Hz) for this triad, which will be discussed later. The addition of F4, also reappearing in bar 7 (see green arrow), initiates a link with the later double bass part.

The image shows a musical score for two percussion parts. Percussion 1 is marked with a tempo of 54 and a 4/4 time signature. It starts with a 'crotales' section marked 'mf' and 'L.v.'. In measures 1-3, it plays a prelude (D4-Eb4-G4) leading into C5 and then an augmented triad (Eb4-G4-B4), which is circled in green. The dynamics change to 'p' and then 'pp'. Percussion 2 is marked with a 'tam tam' section marked 'mp'. A green arrow points from the circled triad in Percussion 1 to the later double bass part.

**Figure 9** Ellen Jacobs, *And In Between, There Is ...* (Leuven: TRANSIT Festival, 2024), 1, 1-9, clarinet and trumpet.

At bar 10 (ref. Figure 10), the double bass enters, solidifying the harmonic base via its natural G2 (the frequency of the Sul I string,  $\approx 98$  Hz, see Table I, Appendix C). Its sound is to be transposed one octave lower than written. With its introduction in the segment comes the presentation of three higher harmonics: D6 – C6 – Eb6, respectively the 12<sup>th</sup>, 11<sup>th</sup> and 13<sup>th</sup> harmonic of Sul I (Table I Appendix). Their high nature could cause them to implement tension in the spectrum despite them being a part of it in the first place.

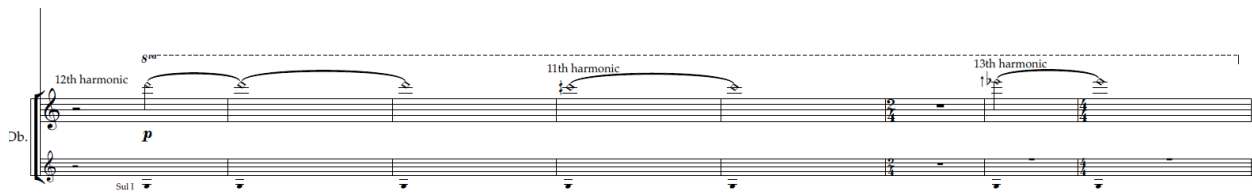


Figure 10 Ellen Jacobs, *And In Between, There Is ...*, (2024), 2, 10-17, double bass.

Prior to the onset of Segment A, the double bass plays a B3 accompanied by E4. B3 is a reference to the harmonics of the G2 spectrum (Table I Appendix), which strengthens its spectral connection. Inherent relationships between a fundamental and its integer multiple are transferable between octaves.<sup>85</sup> Thus far, E4 does not hold such a connection. O refers to a **flageolet**, a playing technique used on string instruments to mute the fundamental tone, here G2 of Sul I, and give the harmonics more space by touching the string lightly.<sup>86</sup> MSP then refers to *Molto Sul Ponticello*, a reference for the player to place the bow closer to the bridge, which normally results in a sharper, more ‘metallic’ sound.<sup>87</sup> The bisbigliando adds to the effect that Jacobs seems to implement, namely an introduction of the spectrum stemming from Sul I.

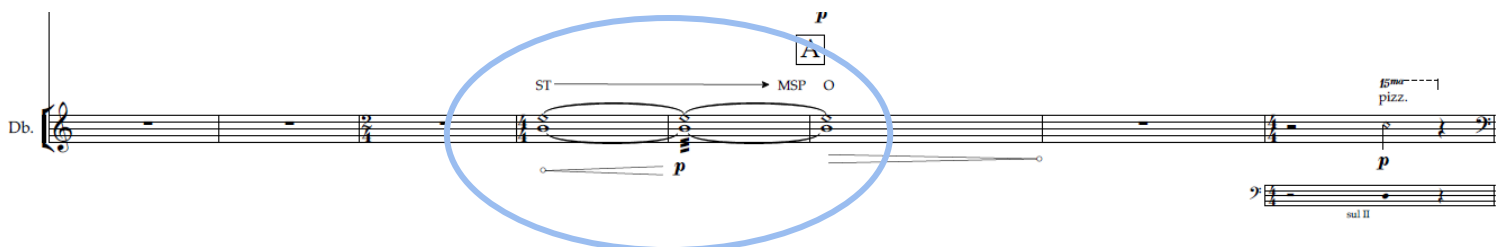


Figure 11 Ellen Jacobs, *And In Between, There Is ...*, (2024), 3, 18-25, double bass.

<sup>85</sup> Helmholtz, “Von der Schallempfindung im allgemeinen”, in *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*, 13-39.

<sup>86</sup> “ABC van muzikale begrippen”, *Concertgebouw Brugge*, 30 June 2020, accessed on 19 April 2025, from <https://www.concertgebouw.be/nl/abc-van-muzikale-begrippen>.

<sup>87</sup> “Sul Ponticello”, *Classical Voice San Francisco*, n.d., accessed on 19 April 2025, from <https://www.sfcv.org/learn/glossary/sul-ponticello>.

By employing the Aubio pitch detector, one may determine the fundamental frequencies throughout this segment. Nonetheless, since perfect alignment with the score was observed, this plugin is neither utilized further nor discussed in detail. For additional clarification, see Chapter 2, section 2.3.1. However, revisiting earlier bars, the spectral constellation in bar 3 remains noteworthy. Consisting of Eb4, G4, and B4, with a detected ‘fundamental’ of B6, this chord might serve as an early reference to the later G2 fundamental on the double bass. Could this triad have been intentionally placed to foreshadow the instability and spectral expansion introduced later in the piece?

Either way, the connection is clear: the spectral constellation acts as a prelude to the fundamental G2 on the Sul I double bass string (ref. Figure 10). Furthermore, the NNLS Chromagram provided no meaningful contribution to the analysis, as it failed to highlight any specific frequency bins. Without distinct spectral emphasis, its output lacked the necessary differentiation to offer new insights, rendering it redundant within the broader investigative framework.

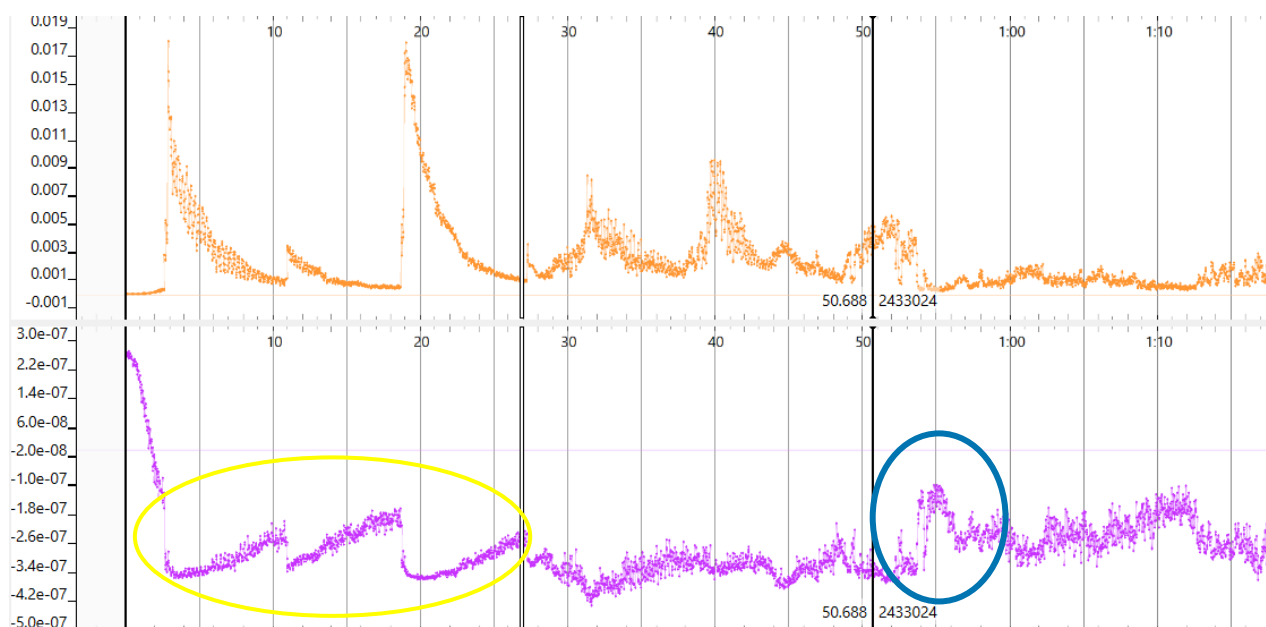


Figure 12 RMS-Energy (orange) and Spectral Slope (pink) for the introductory segment.

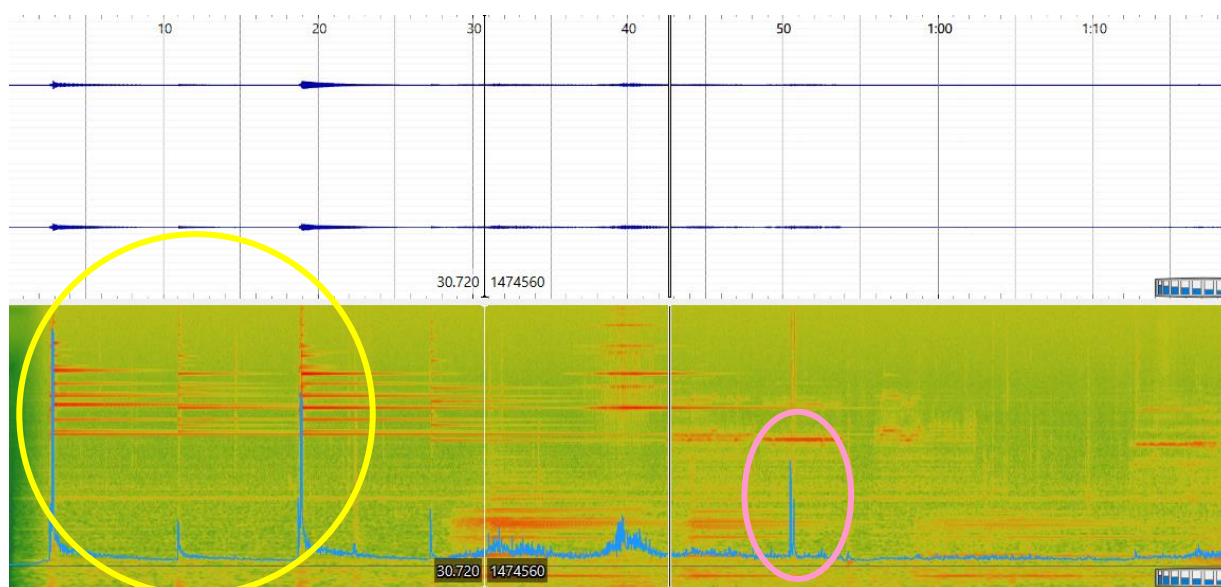
To capture the evolving sonic landscape of this segment, additional analyses were conducted using the constant Q, spectral slope, and spectral flux plugins.

In Figure 12 (circled in yellow), three spectral slope markers correspond to the first five bars of the composition (Figure 9). The middle slope is particularly striking, as it is the steepest. This aligns with the augmented triad in bar 3 (Eb4, G4, B4), which, as previously discussed, appears to foreshadow the later harmonics of the G2 string on the double bass.

This visualization further highlights the tension between these pitches and their tendency toward spectral imbalance and change, right of the bat. Compared to the surrounding slopes, this one is noticeably steeper and lacks the short ‘notch’ observed in the others. This notch may indicate a more gradual buildup of energy in the higher frequencies, whereas the triad’s slope stands out as abrupt and distinct. The blue circle highlights the spectral slope output for the double bass from bar 10 onward (Figure 10), likely a result of the particularly high nature of the instrument’s harmonics.

Regarding RMS energy, the largest peaks occur in bars 1 and 5 (Figure 9), coinciding with sustained notes played by the crotales. These emphasize C5 and B4, both appearing within the Sul I spectrum, with C5 notably serving as a prelude to bar 10. RMS energy quantifies the overall amplitude level, helping to identify moments of increased intensity within the composition.

Another useful plugin to use here is the **Constant Q**, used to detect the temporal evolution of the present frequencies in an audio signal, or in this case a composition. This is useful to see which frequencies appear strong, and which vanish in the presence of the strong ones. The **spectral flux** plugin provides a useful addition to this visualisation in terms of showing how the spectrum changes over time.



**Figure 13** Constant Q (green and orange) and spectral flux (blue) for the introductory segment (bar 1-22).

The blue lines on Figure 13 exhibit the spectral flux. Pronounced peaks appear around the 11<sup>th</sup> harmonic (bar 10) of C6 (see pink circle), implying a deliberate accentuation relative to the fundamental. The recurring cent deviations, common

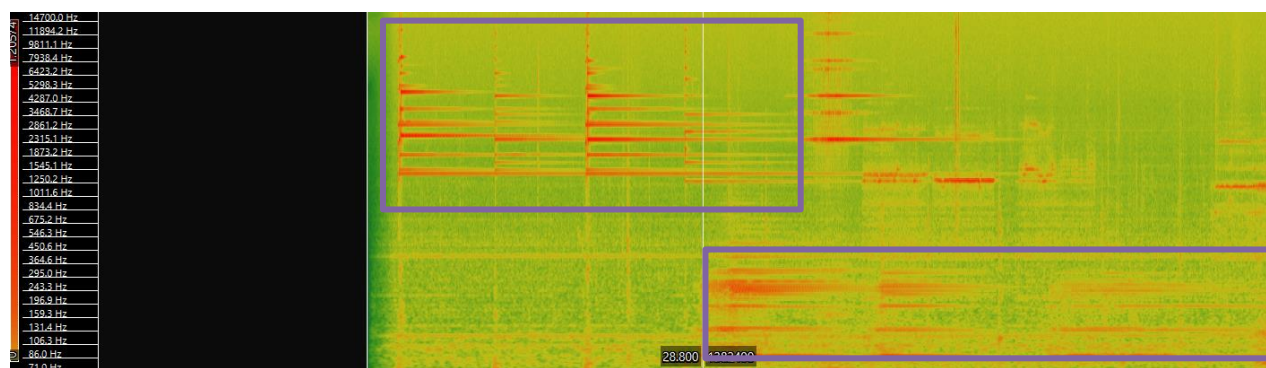
for higher overtones, further indicate that these higher harmonics do not adhere strictly to integer multiples of G2 but instead fluctuate, reinforcing the spectral ambiguity introduced by Jacobs from the very start of the composition. The traditional ‘stable’ role of the double bass in an ensemble is underpinned by its deliberate contribution to tension and spectral texture.

The prior peaks in flux (see yellow circle) are a reference to the *crotales*’ notes at the very beginning of the composition. Looking at the Constant Q, the fundamental seems to be less present compared to the overtones, with lines mainly appearing in higher registers. In terms of duration, all tones last almost exactly as long as each other. High overtones lasting for this amount of time and being so strongly emphasized does motivate the argument that Jacobs certainly sought structure outside of the tonal convention, more specifically by turning the sound inside out and putting overtones in the role of the fundamental.

When considering the two visualisations above together, the following observations can be made. The first and third peak are noticeably higher than the one in the middle. While the spectral slope of the middle sound, corresponding to the augmented triad, was steep, its spectral flux is lower. This can be attributed to its timing and dynamics. As noted in the score, this triad is played in *piano*, in contrast to the two surrounding notes, which are played in *mezzo forte*.

Furthermore, the notes in bars 1 and 5 both have a *glide* preceding the main note (ref. score Figure 11). These glides cement the note in the time frame by prolonging the onsets. So playing with time does seem to have significant effects on the eventual spectral flux, and simultaneously the spectral contours. The third high peak is located around the 11<sup>th</sup> harmonic of the SUL I string (ref. Figure 10). It reinforces the argument that the balance of the spectrum is deliberately disturbed. This implies that Jacobs not only manipulates the spectral composition, but also introduces structural tension by explicitly amplifying harmonics that would quickly fade in a natural setting. This creates a sonic instability in which traditional frequency relationships are turned upside down. Overtones are emphasized, fundamentals are more hidden.

The calculation of the Spectral Flux median is 0.277, giving it low spectral flux.



**Figure 14** Constant Q for the introductory segment

The Constant Q output for the Introductory Segment depicts clear flutter time, with periodic frequency bands appearing very lightly and short across the board. It forms a controlled, pulsating pattern. Periodic recurrences are marked in a purple box and are strengthened by the crotales marking clear onsets and allowing the sound to be prolonged by *laissez vibrer*.

### 3.1.2 Segment A : bar 23 - 48

#### 3.1.2.1 Clarinet and Trumpet

In contrast with the introductory segment, Segment A has been split by Lalal.AI, with the first section being the wind instruments. Since more instruments join from this section onward, using the sound splitter is proved useful.

The first tool used is the Aubio Pitch Detector, which revealed a dominant fundamental of A#4/ Bb4 at approximately 471 Hz, corresponding to the clarinet's initial note (Figure 15).<sup>88</sup> Due to its spectral connection to Sul II (ref. Table I) and the later introduction of Sul II on the double bass, this note in particular can be seen as a prelude to that.

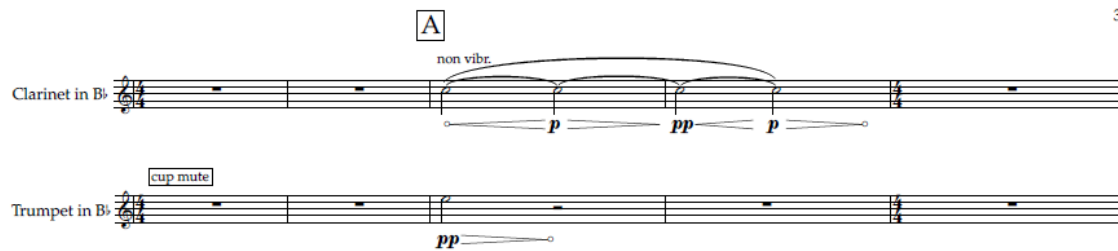


Figure 15 Ellen Jacobs, *And In Between, There Is ...* (2024), 3, 21-25, clarinet and trumpet.

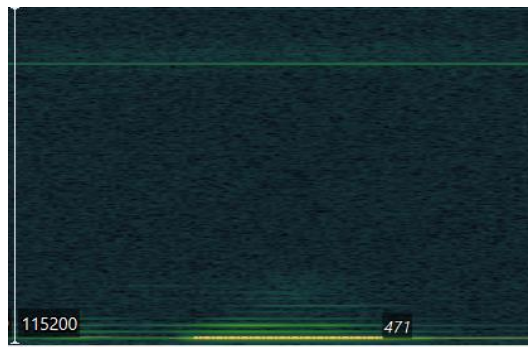


Figure 16 Spectrogram and Aubio for bar 21-25 wind section.

<sup>88</sup> "Wat is klankkleur?", *Preludium*, n.d., accessed 22 April 2025, from <https://www.preludium.nl/klankkleur#:~:text=Het%20geluid%20van%20een%20klarinet,de%20derde%20en%20vijfde%20boventoon.>

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Figure 17 shows musical notation for two instruments: Clarinet (Cl.) and Trumpet (Tpt.). The score spans from bar 26 to bar 32. The Clarinet part includes a box with the instruction: "Alternate irregularly between normal note and multiphonic. There must be no audible accents." Dynamics markings include *p*, *pp*, and *mp*. The Trumpet part features a sustained D4 note.

Figure 17 Ellen Jacobs, *And In Between, There Is ...*, (2024), 4, 26-32, clarinet and trumpet.

Thereafter, at bar 26, the clarinet plays both D4-F5 while the trumpet reinforces D4 until bar 38 – with a shift to C4-D5 (clarinet) and C4 (trumpet). D4 thus prominently appears for both instruments and in the primal part of Segment A. From bar 30, the clarinet plays a few notes with multiphonics (alternating bases of B3, C4, and D4 overlaid with G5, D5, and F5) disperse energy across several resonance modes. This results from the clarinet's unique ability to trigger alternative resonances that diverge from its typical odd harmonic series.<sup>89</sup> The further interaction between the trumpet and clarinet's multiphonics does evoke significant peaks in RMS-Energy (Figure 18), conceived by the deliberate emphasis on these multiphonics. Linking this info back to the overtone information tables in the Appendix (Table I) for Sul I and II, all bases refer back to Sul I, as well as the overlays. Therefore, it can be said that the clarinet is used here as a tool to portray Sul I's partials in a rich way. The presence of D4 and D5 can, however, also be related to the Sul II base presented by the double bass (Segment A, bar 25). Since the earlier observations by the Aubio Pitch Detector revealed prominence for Bb4, the narrative of Sul II's spectrum being the spectral anchor can shed new light on the interpretation of the multiphonics. They could serve as a reference to the Sul I partials of the introductory segment, although here the clarinet's ability to play these multiphonics is employed to convey initial spectral tension. RMS-energy should normally detect such a thing by showing a peak.<sup>90</sup> Lo and behold, this peak is visible (second peak indicated by the arrow).

The interference between the constant D4 (trumpet) and the clarinet's multiphonics creates a layered, rich texture through acoustic resonance and destructive interference, resembling the spectral interaction between both bases. The interference between the sustained D4 played by the trumpet and the clarinet's multiphonics creates a layered, evolving

<sup>89</sup> Gregory Oakes, "Clarinet Multiphonics", *Gregory Oakes*, 2011, accessed on 22 April 2025, from <https://www.gregoryoakes.com/multiphonics/>.

<sup>90</sup> "What is a True RMS Measurement?", *SensorLink*, 2023, accessed on 23 April 2025, from [https://sensorlink.com/articles/what-true-rms-measurement#:~:text=Root%20Mean%20Square%20\(RMS\)%20is,heat%20in%20the%20same%20load.](https://sensorlink.com/articles/what-true-rms-measurement#:~:text=Root%20Mean%20Square%20(RMS)%20is,heat%20in%20the%20same%20load.)

texture shaped by acoustic resonance and destructive interference. As the trumpet's stable pitch interacts with the clarinet's shifting harmonic spectrum, some frequencies are reinforced while others cancel out, producing dynamic spectral variations. This contrast enhances the timbral complexity, allowing the harmonic stability of the trumpet to merge with the spectral fluidity of the clarinet. The result is a rich sonic structure that mirrors the interplay between both instrumental bases, highlighting how resonance and interference shape the overall sound.

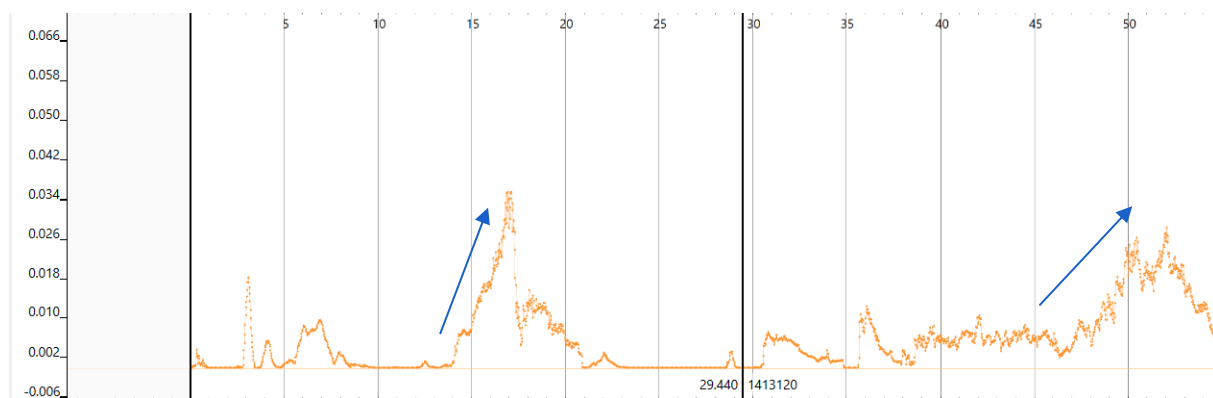


Figure 18 RMS energy for bar 21-32, wind section

By employing the RMS Energy Plugin, one is able to detect where the most amplitude resides. This can give an idea of which instrument or timbre takes the lead in a specific part. Two prominent peaks occur: the first corresponding to bar 26-27, the other to bar 30-32. Due to increased amplitude, these passages are marked in time as shaping the structure. F5 in bar 26 (Figure 17) is the 7<sup>th</sup> harmonic of Sul I, contrasting with D4, the 4<sup>th</sup> harmonic of Sul II.



Figure 19 Ellen Jacobs, *And In Between, There Is ...*, (2024), 5, 33-38, clarinet and trumpet.

Moving further in the score, around bar 33 (see Figure 19), the earlier stability is reestablished as the multiphonics disappear, and the steady D4 persists in the trumpet. At the same time, the subtle interference introduced by the clarinet lays the foundation for subsequent shifts in the spectrum. Although the clarinet predominantly plays at Eb4, its role remains understated due to the dynamics marked *pianissimo* – *mezzo piano* – *pianissimo*.

By bar 36, the clarinet sounds a progression—D4, Eb4, Bb4 (A#4)—accompanied by a vibrato. In the score's visual cues, the clarinet's notes are highlighted in yellow, whereas the trumpet's sustained D4 is depicted in blue. A lighter blue indicates a shift toward C5, which then proceeds to float between the two instruments (see Figure 20).

Spectrally, the clarinet's notes exhibit intriguing relationships. In a transposed context, Bb4 can be related to D2 (Sul II + trumpet note D4, in itself the 4<sup>th</sup>, ref. Table I) given that the 13<sup>th</sup> overtone of D2 is Bb5.<sup>91</sup> A similar logic appears in the article of Reginald Bain (2003) in which he claims that once the overtone series of one fundamental is memorised, it may be transposed to another fundamental while preserving similar mutual ratios among overtones. This applies to both weaker and stronger partials.<sup>92</sup>

In contrast, Eb4 does not lend itself to a similar explanation. Instead, it shares a spectral connection with G2, which coincides with the frequency of the Sul I string on the double bass. In the introductory segment, particularly between bars 10–17 (Figure 10), three overtones of Sul I are presented, with Eb6 emerging as its 13<sup>th</sup> harmonic. In this way, both the 13<sup>th</sup> harmonic of D2 on the clarinet, the 4<sup>th</sup> (D4) on the trumpet, and the harmonic components associated with G2 create spectral interactions in the score. Furthermore, the sudden introduction of C5 in the trumpet mirrors this relationship to G2, acting as a transposition of the 11<sup>th</sup> harmonic (C6). Could it be that the composer decided to introduce particularly high harmonics in the introduction to then spread them across instrumental sections and transpose them to benefit their perception and make them more apparent in the orchestral whole? The transposition could additionally be a method to project partials in different timbral environments, thus shedding a different light on them.

This assumption can be supported by the following part of the score (Figure 20) where the C5-note (dark blue) is 'floating' across both sections, below marked in dark blue. It can be interpreted as a prelude to C functioning later as a dual partial of both Sul I and II, emphasizing the *in between* space.<sup>93</sup> Yet at this part in the score, and as will be discussed later, the double bass has fully resided to Sul II.

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<sup>91</sup> Hermann von Helmholtz, "Von der Schallempfindung im allgemeinen", in *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (Heidelberg: F. Vieweg und Sohn, 1863), 13-39.

<sup>92</sup> Reginald Bain, *The Harmonic Series: A Path to Understanding Musical Intervals, Scales, Tuning and Timbre* (Columbia, SC: University of South Carolina School of Music, 2003): 4-5.

<sup>93</sup> Ellen Jacobs (composer), interviewed by Margot Meire (student at Ghent University), 21 November 2024.

Figure 20 shows a musical score for Clarinet (Cl.) and Trumpet (Tpt.) parts. The Clarinet part (top) features notes circled in light blue, with markings for 'high slow' and 'fast'. The Trumpet part (bottom) features notes circled in orange and purple, with markings for 'slow' and 'fast'. A blue arrow points from the Clarinet part to the Trumpet part. A text box at the bottom right indicates 'alternate very fast and irregularly between these notes, keep on repeating'.

Figure 20 Ellen Jacobs, *And In Between, There Is ...*, (2024), 6, 39-45, clarinet and trumpet

In the clarinet section, Bb4 (light blue) alternates with C5, while in the trumpet section, D4 (orange) appears alongside B3 and F#4 (marked in purple), being a split tone. A split tone on trumpet is a technique where the player adjusts their embouchure to simultaneously activate two adjacent notes from a natural overtone series. The lower the frequency, the less noise this split tone creates, which is applicable here.<sup>94</sup> Observing the spectral relationships of these notes, the split-tones are of particular interest. With F#4 being the transposition of B3's 3<sup>rd</sup> overtone, their relationship is natural. B3 then relates to G2, and F#4 in itself to D2. Therefore, the split-tones in itself present the spectral intertwining already suggested earlier. Such intertwining is expected to exhibit stronger spectral flux than a completely natural setting. Space is created for spectral interference or modulation.

When observing further, this interference proceeds between bar 39-45 and is supported by several bisbigliandi in both the clarinet and trumpet section. This technique is used to allow the note to have a more prominent vibration and thus 'texture' in the entirety. This supports the assumption that the composer aimed to expand the spectral space by not only deriving from the Sul-base of the double bass, but also adding instrumental techniques that make the notes produced more prominent and fitting within this supposed compositional narrative. Additionally, this fits within the meaning of the title: *And In Between, There Is ...*<sup>95</sup>

<sup>94</sup> Nathan Plante, "Split-Tones", *The Modern Trumpet*, 20 October 2020, accessed on 23 April 2025, from <https://themoderntrumpet.com/2020/10/20/split-tones/>.

<sup>95</sup> Jacobs (composer), interview, 21 November 2024.

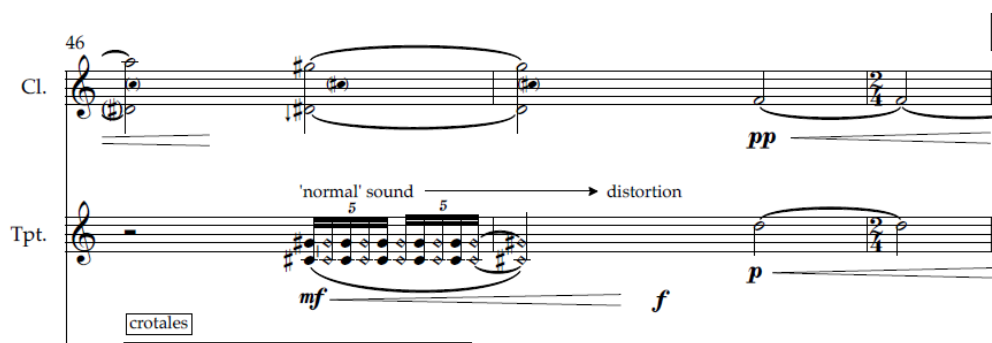


Figure 21 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 46-48, clarinet and trumpet.

For the last bars of Segment A, the clarinet plays C#4-(C5)-G5, followed by C#4-(C#5)-F#5, then ending with Eb4. Once again, a combination of Sul I and Sul II partials are at stake, increasingly building up tension to then reside to the pitch previously present for the crotales bar 1-3 and having a spectral relationship with Sul I (see 13<sup>th</sup> Eb6, Figure 10). For the trumpet, split tones remain, adding to increased distortion before residing to C5, the 7<sup>th</sup> partial for Sul II. Thus far for the wind section, the score analysis revealed a subtle introduction of Sul II partials as a prelude to the later introduction of Sul II in the double bass (see further). However over the course of the segment, traces of Sul I, exhibited in the previous segment, seem to have been implemented to distort the spectral balance. Instrumental techniques, such as multiphonics and split tones, added to this effect.

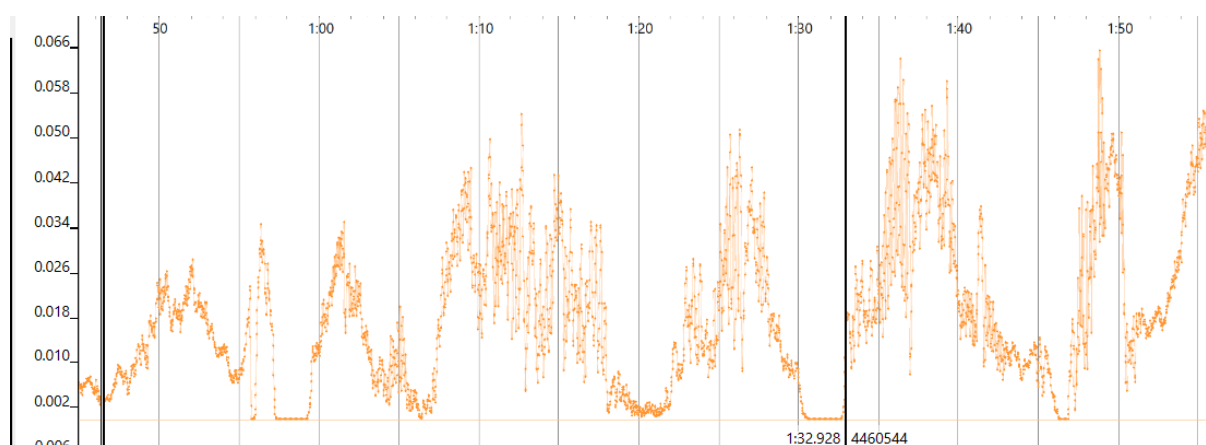


Figure 22 RMS-energy for bar 33-48, wind section, segment A

This increased tension is well visualised by the RMS-energy plugin. Showing profound peaks, this plugin reassures the score findings stating that deliberately combining partials from different fundamentals, together with (extended) instrumental techniques, causes the segment A for the wind section to have strong dynamic contours, shaping the music according to spectral tensions. These heightened energy levels reflect the spectral tensions inherent in the composition, demonstrating how harmonic interactions and timbral manipulations shape the musical phrasing. By layering distinct spectral components and emphasizing their interplay, the segment achieves strong dynamic contours that drive its expressive trajectory. Furthermore, the trumpet in particular marked strong presence and enforced this by largely staying true to Sul II.

When plotting the Aubio Pitch Detector for the entire wind section of Segment A, two other frequencies appear apart from 471 Hz: 263 Hz and 528 Hz, respectively connected to C4 and C5 (see yellow circles on Figure 23). This means that all fundamentals picked up by the Aubio Pitch Detector reside to D2 (Sul II), although directly or transposed. Despite the tension caused by the implementation of Sul I partials, Sul II partials anchor it all.

When reviewing the NNLS Chroma output (Figure 23), D4 (cream) emerges as a consistently dominant frequency—a clear reflection of its role in the trumpet section and its association with Sul II in the double bass. The Aubio output supports this observation. However, as stated earlier, other notes also assert themselves from time to time, here appearing as brief green boxes appearing and disappearing. This is the case for C (blue) and Bb (purple).

The interplay between the G2 base and D2 base becomes apparent here, highlighting that the composer did not limit the work to the overtones of the current Sul II, yet employed the latter as the most dominant anyway.

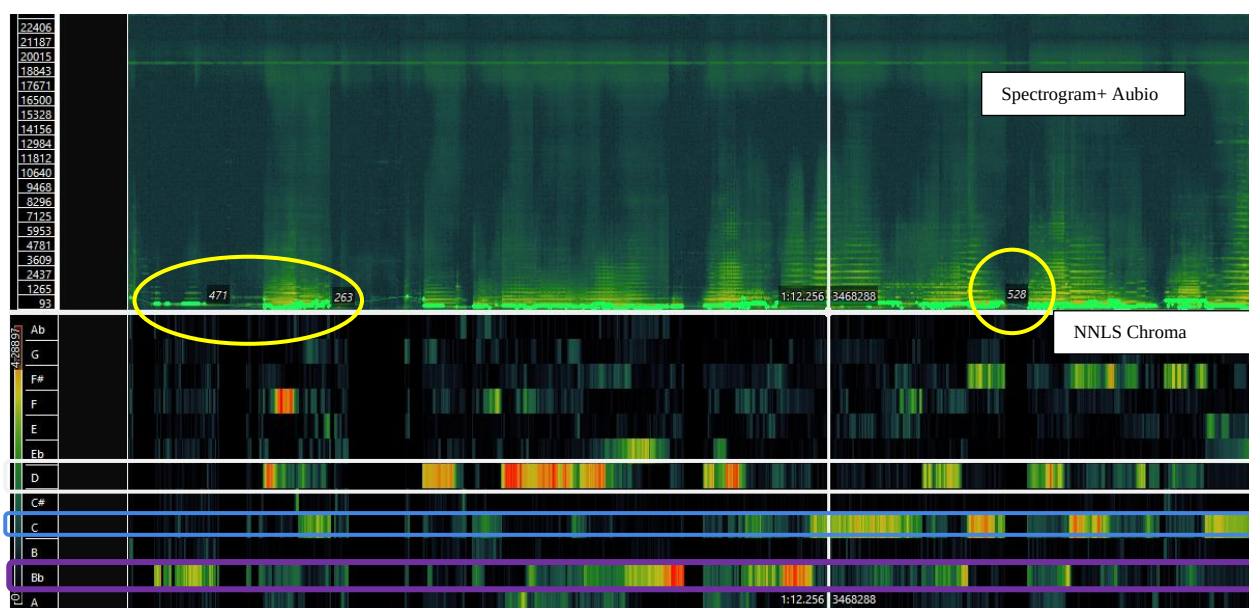


Figure 23 Spectrogram Layer, Aubio Pitch Detector, NNLS Chroma Plugin for Segment A, wind section

To get a further idea of the spectral manifestation of Segment A for the winds, the **spectral slope** is applied.

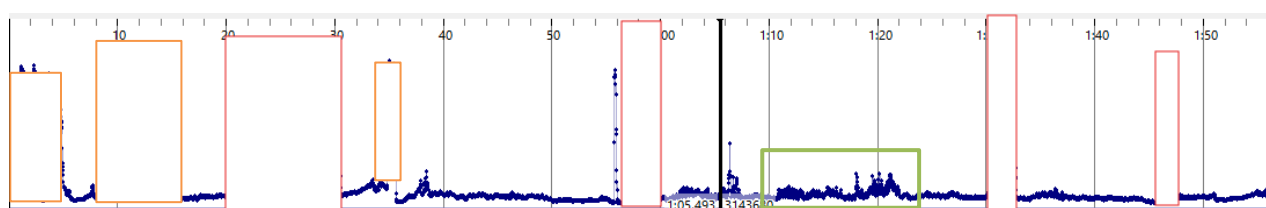


Figure 24 Spectral Slope for wind section, Segment A, silent parts hidden for visual coherence.

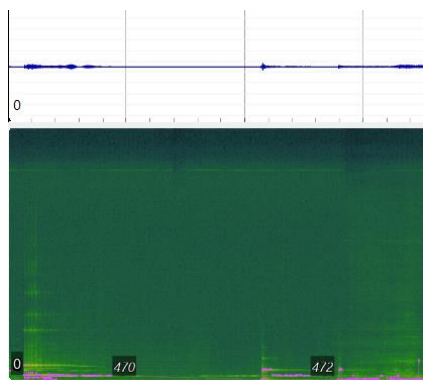
The white boxes hide parts of the spectral slope where there is silence. The higher the output of the spectral slope, the more energy there is in the higher frequencies which usually refers to an imbalance in a natural spectrum since most energy in a natural context resides in lower frequencies.

For the wind section of Segment A, no distinct peaks appear. This is simply because most notes reside in a lower register and are effectively transpositions of higher overtones from the base notes. Small increases are evident in bars 38–39 (marked in green for Figure 24), where the trumpet plays a C5 with added vibrato. At approximately 529 Hz, this higher frequency explains the observed increase in the slope. This output can be interpreted as the ratio between low and high frequencies remaining relatively stable, i.e. natural, which means that the natural energy courses of the overtones are maintained as well. This means that the wind section contains a coherent spectral base, with occasional peaks portraying

*local intensifications* of the spectral tension rather than abrupt disruptions. Rather than dismantling natural acoustic relationships, the composer reframes them across instrumental timbres and registers to generate spectral tension and structural articulation.

### 3.1.2.2 Percussion and Double Bass

Having first examined Segment A with a focus solely on the wind instruments (the Bb clarinet and Bb trumpet), we now shift our attention to the ensemble instruments: the vibraphone, xylophone, bass drum, and double bass. Using the **aubio pitch detector** (see Figure 26), the pitch of Bb4 ( $\approx 471$  Hz) turns out to be the most apparent, which is similar to the previous wind-case.



**Figure 25** Spectrogram layer, Aubio Pitch Detector for the percussion and double bass section, bar 23-25, segment A.

These pitches are represented by the vibraphone in the percussion section (see green square in figure 26). For almost the entire segment, this instrument continues to emphasize Bb4 and Bb3. Especially in the beginning of the section, this pitch is particularly strong since the other instruments either do not play, or contribute with Bb as well.

A

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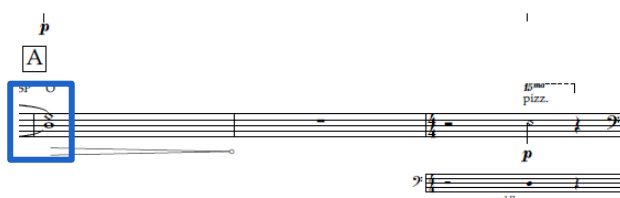
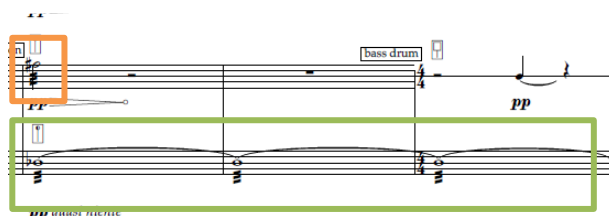


Figure 26 Ellen Jacobs, *And In Between, There Is ...*, (2024), 3, 23-25, percussion and double bass.

The xylophone plays a F#5 (orange), and in the double bass both B3 and E4 are present (dark blue). The strength of Bb4 can be clarified by its transposed relationship with D2's 13<sup>th</sup> harmonic Bb7 (Table I). Given it is played by the vibraphone, an instrument prone to strong vibration and rich spectral texture – further enhanced by the *bisbigliando* indication – contributes to its appearance in the aubio pitch detection. While the xylophone also resides to an overtone of D2 (10, F#5), as well as E4 (transposed from the 9<sup>th</sup> harmonic, Sul II) on the double bass, B3 holds connection to G2 through the 5<sup>th</sup> harmonic B4. In the initial state of Segment A, the double bass still leans on Sul I (G2).

Similar adaptations are observed here as in the wind section, where overtones of both Sul I and Sul II are spread across sections and even across the instrument's own performance. The dominance of Bb4 in the aubio pitch detector output can serve the argument that Sul II is the spectral anchor here. Transposing a partial downward, such as Bb5 → Bb4, it could gain more prominence in the ensemble.

Figure 27 Ellen Jacobs, *And In Between, There Is ...*, (2024), 4, 26-32, percussion and double bass.

Figure 27 exhibits bar 26-32. The double bass sounds D2-F3 (circled in pink), which later transforms into an alternation between C3-F3 (underlined in pink), accompanied by the indication “harmonic pressure”. With both C3 and F3 referring respectively to the 11<sup>th</sup> and 7<sup>th</sup> harmonic of **Sul I**, and **C also residing in Sul II’s spectrum**, the pressure seems to hold connection to the friction between Sul I and Sul II also mentioned in the split segment for the winds. Similar internal tension was found for the split tone on the trumpet, with B3 sounding with F#4 (Figure 20). This alternation then changes into Bb2-Eb3 (circled in yellow), respectively an overtone of D2 and G2. A similar explanation applies here. On this page, the double bass initially blends both spectral series, then shifts toward Sul I under harmonic pressure, and ultimately returns to a state of dynamic friction.

Even though bar 32, immediately following the previous interaction between Bb and D, states the dominance of Sul III (A1 string), D remains largely consistent in the double bass section up until bar 36. This also applies to the percussion, remaining true to Bb, playing both Bb3 and Bb4. Sul III could mean that all the notes should be interpreted according to the spectrum of A1. However, upon investigation of the score, most notes hold connection to Sul I or Sul II. In complex musical textures, the overlapping harmonic structures of various instruments often create an intertwined spectral landscape that deviates from theoretical expectations. Instead of a pure A1-based Sul III, the acoustic reality—

confirmed through spectral analysis—reveals that the dominant overtones correspond more closely to the series of G2 and D2. In combination with the information from the pre-analysis interview, stating that the piece was based on Sul I and II, this argument is strengthened.<sup>96</sup>

Figure 28 Ellen Jacobs, *And In Between, There Is ...*, (2024), 5, 33-38, percussion and double bass.

At this point in the score (Figure 28), with the exception of the double bass and initially the vibraphone, these spectral interactions are prominently present. The xylophone, and later on also the vibraphone, slide into the interactive sphere accordingly, while the double bass employs *circular bowing* as a technique to not only produce a pitch, but also bow hair noise.<sup>97</sup> This adds to the analytical narrative of implementing cross-spectral tension by playing Bb3-Eb4, both related to different fundamentals.

Based on the observations of the score so far, the composer seems to distribute overtones across various sections, each with its distinct timbre, while incorporating extended instrumental techniques, such as the circular bowing or additional vibration. This distribution leads to spectral modulation caused by non-coincident partials and simultaneously establishes connections among certain elements through a common fundamental frequency.

<sup>96</sup> Jacobs (composer), interview, 21 November 2024.

<sup>97</sup> "Circular Bowing", *The Modern Double Bass*, 2020, accessed on 19 April 2025, from <https://www.themoderndoublebass.org.uk/arco--circular.html>.

Figure 29 Ellen Jacobs, *And In Between, There Is ...*, (2024), 6, 39-45, percussion, and double bass.

Similar observations apply to Figure 29, where the friction appears even more pronounced, spanning all instruments for this section in the score. Most striking is the xylophone's so-called 'shimmer', being a cluster of Sul II overtones (see yellow circle). Preceding this shimmer, numerous pitches linked to D2 partials – either directly or transposed – are present in both the xylophone and vibraphone. However, the interplay of vibrato and *laissez vibrer* makes these dynamic and rich. The rapid succession of pitches, combined with the *forte* dynamic, intensifies the sense of **spectral expansion**, suggesting that the composer is exploring a broader sonic space, possibly even modulation. Furthermore, such emphasis on high pitches makes the increase in energy plausible since in 'normal' acoustic terms, high frequencies do not contain such accentuation.<sup>98</sup>

For the double bass section, the **circular bowing** is apparent. The blue circles (Figure 29) show C4-E4, both linked to **Sul II** and the pink circle Bb3-Eb4 with the latter holding connection to **Sul I**. The close frequency proximity between

<sup>98</sup> Annea Lockwood, "Special Section Introduction: Sound Explorations: Windows into the Physicality of Sound", *Leonardo Music Journal* 19 (2009): 44–45.



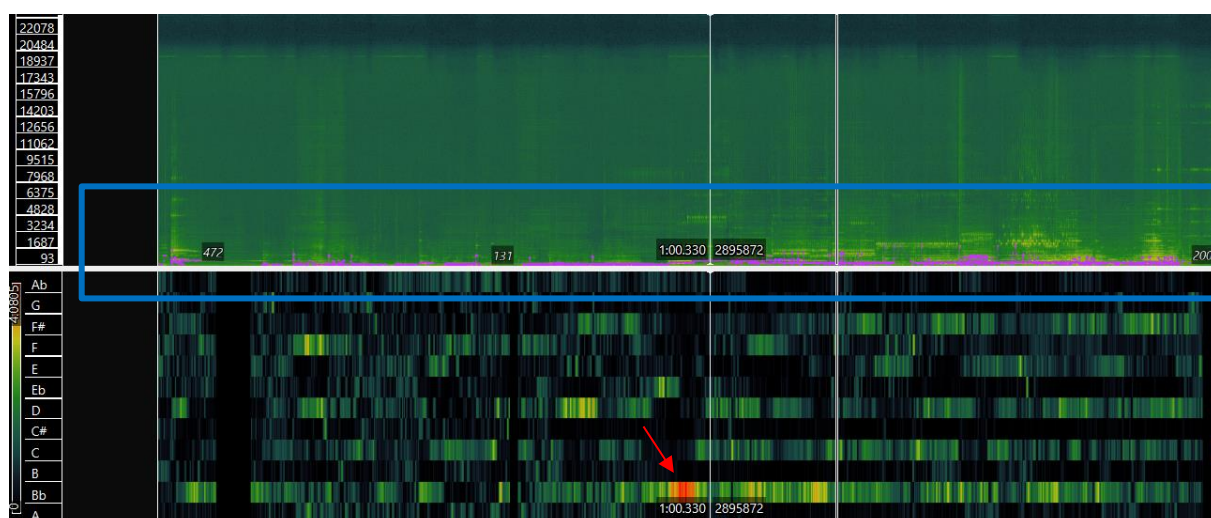
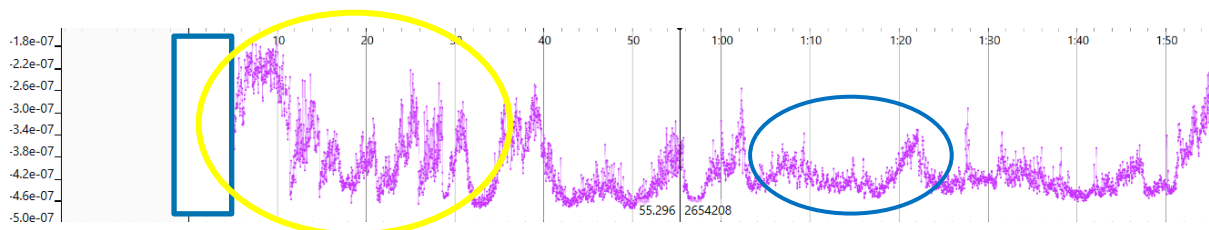


Figure 31 Spectrogram, Aubio and NNLS Chroma, full segment A, percussion and double bass.

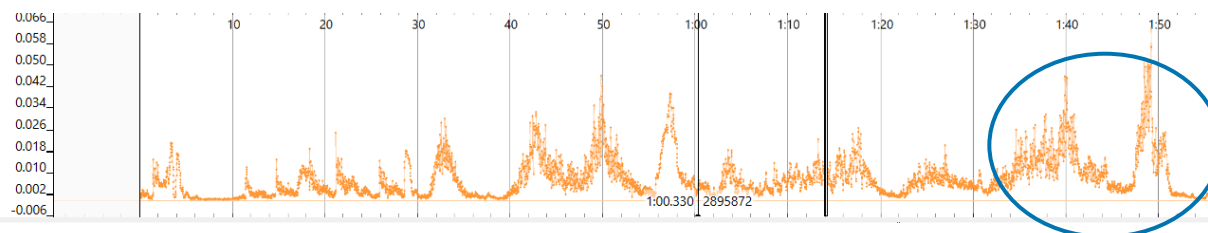
The Aubio Pitch Detector identifies three dominant frequencies (see blue mark): 472 Hz ( $\approx$ Bb4), 131 Hz ( $\approx$ C3), and 200 Hz ( $\approx$ G3). The earlier discussed subtle implementations of Sul I partials can be understood through this finding, as Bb4 maintains a connection to Sul II, C plays a dual role, and G3 functions as the second partial within the Sul I spectrum.

Although the NNLS Chroma plugin displays a large number of bins, it highlights one particularly significant point, which has an orange colour (see red arrow). This corresponds to **Bb4** (Sul II). However, the bin reveals that while Bb4 remains prominent throughout, it does gradually fade, reinforcing the narrative that Sul I progressively (re)claims its presence established earlier in the introductory segment through percussion and double bass as well. These outputs link the earlier score findings with objective data measured through Sonic Visualiser, demonstrating how intrinsic spectral properties evolve into structural and musical elements within the composition.



**Figure 32** Spectral slope percussion and double bass, segment A, silent parts hidden

Figure 32 exhibits steep spectral slopes, indicating a significant concentration of energy in the higher frequencies that directly reflects the instrumental techniques (i.e. circular bowing) and pitch distribution outlined in the score. The blue circle highlights the spectral shimmer in the xylophone (bars 43-44), where the playing technique and high-register partials push the spectral slope upward. Despite relying on a single spectral base, the orchestration amplifies the higher frequencies, creating an atypical spectral emphasis not commonly observed in natural acoustic settings.<sup>99</sup> Similarly, the initial steep peaks (marked in yellow) stem from harmonic pressure on the double bass (bars 26-31). The score confirms a strong focus on Sul I and Sul II partials, and this emphasis triggers spectral interference, manifesting as increased spectral slope values. Taken as a whole, the visual representation reveals a turbulent spectral balance, which logically aligns with the score's implementation of circular bowing and rich partial distribution across the ensemble, here percussion and double bass.



**Figure 33** RMS-Energy for percussion and double bass, segment A.

The RMS-Energy output reveals numerous peaks as well, which appear to be initiated by the instrumental passages highlighted in the above spectral slope. As these sections begin, noticeable rise in energy occurs, indicating their role as catalysts for further dynamic intensification. The highest peaks, marked near the end of the segment (see green circle), corresponds to the shimmer notes in the double bass (bars 45-48), which are traced back to the xylophone.

<sup>99</sup> Lockwood, "Special Section Introduction: Sound Explorations: Windows into the Physicality of Sound", 44-45.

This reinforces the earlier observation that the shimmer's spectral implications actively contribute to an evolving energy trajectory, shaping the music's contour.

### 3.1.2.3 Piano section



Figure 34 Ellen Jacobs, *And In Between, There Is ...*, (2024), 3, 21-25, piano.

For the piano, the first chords played are Bb2 (left hand) and C6 (right hand), sustained with a *laissez vibrer*. Spectrally, Bb2 is linked to Sul II, while C6, though associated with Sul II's 7<sup>th</sup> harmonic C5, also holds a spectral connection to Sul I as the 11<sup>th</sup> harmonic. This ties back to the introductory segment, where C6 appeared in the double bass as its 11<sup>th</sup> harmonic. By placing it in the piano section, with a timbre distinct from the double bass, C6 takes on a different colour while still representing the same spectral framework, though in a new light.



Figure 35 Ellen Jacobs, *And In Between, There Is ...*, (2024), 4, 26-32, piano.



Figure 36 Zoom in of bar 31, piano.



Figure 37 Zoom in bar 31-32, piano.

This chord is sustained until bar 27, where the piano shifts Bb2-Bb5 (circled in blue). Bb5, closely related to C6 in frequency, is firmly rooted in Sul II, with no direct connection to other spectral layers as C6 has. In bar 28, the chord transitions to F5-C6, both functioning as the 7<sup>th</sup> and 11<sup>th</sup> harmonics of Sul I. This suggests that, initially, the piano maintains its spectral bond with Sul I, diverging from the other instruments and marking distinct points in time. However, bar 27 introduces a temporary 'slip' into Sul II, potentially signalling the onset of spectral modulation—though in the opposite direction compared to the rest of the ensemble—highlighting the underlying instability.

Bar 29-30 introduce C2 and Bb1, including octave doublings, further reinforcing spectral ambiguity. C remains dual across spectra, while Bb remains a clear reference to Sul II. Bar 31 then presents a chord consisting of Eb5-F5-G5-B5 (circled in green)—a well-defined cluster of Sul I partials. In just a few bars, the piano navigates between two spectral spaces but leans more prominently toward Sul I. Furthermore the pitches D2-C2-Bb1 emerge, alternating consistently and maintaining a connection with the double bass's Sul II. Around bar 33 (Figure 38), this relationship is further reinforced through the introduction of F#2.



Figure 38 Ellen Jacobs, *And In Between, There Is ...*, (2024), 5, 33- 38, piano.



Figure 39 Zoom in bar 33 for piano.

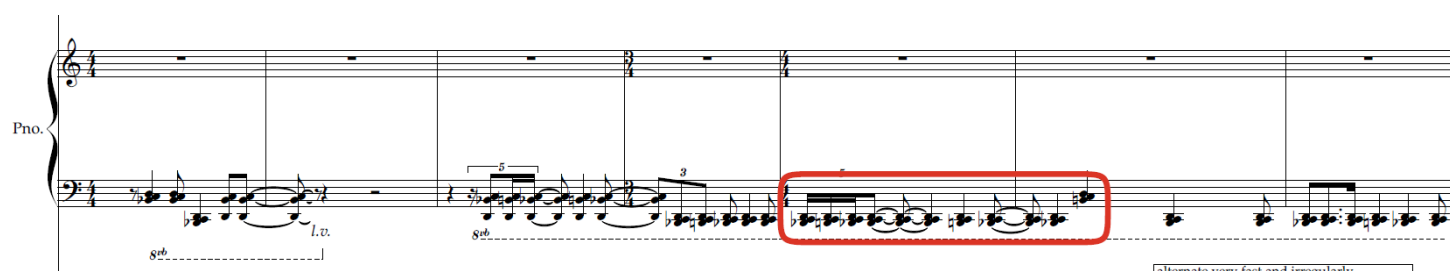


Figure 40 Ellen Jacobs, *And In Between, There Is ...*, (2024), 6, 39-45, piano.

The most significant passage, however, unfolds in bar 43 (marked in red on Figure 40). Here, the piano alternates B1 and Bb1 while continuously interacting with C2 and D2, marking a pronounced spectral modulation that coincides with the xylophone's spectral shimmer. Despite its low register, here even more emphasized by *8vb* + *laissez vibrer*, this subtle interplay actively contributes to the modulation, establishing a 'rumbling' foundation. In 'conventional' orchestrations, the bass section typically does not play a turbulent role, yet here, the composer deliberately ensures that spectral instability shines through even in the most understated tones. This alternation continues until the conclusion of Segment A, see Figure 41.

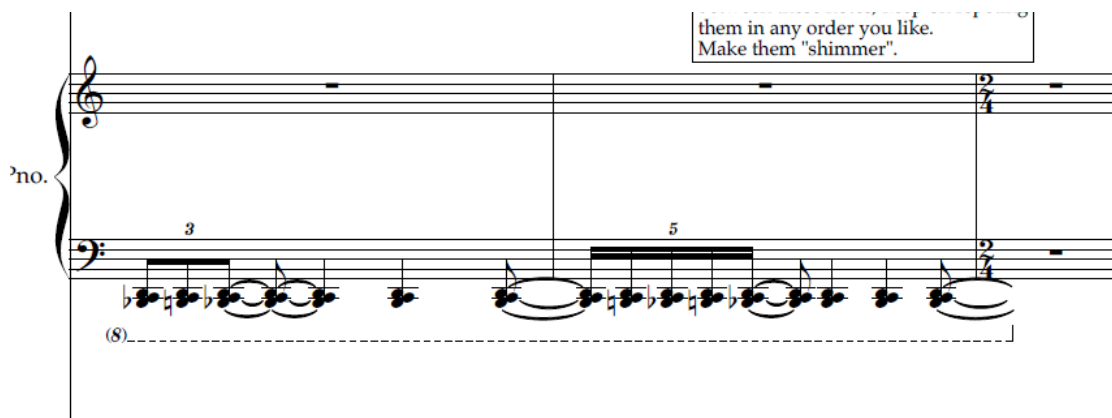


Figure 41 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 46-48, piano.

By first examining the Aubio Pitch Detector and NNLS Chroma plugin, one can determine what pitches in particular are strong, giving an idea of the prevailing spectrum. From the score alone, the piano section exhibited a spectral transition opposite to the percussion and double bass, namely with most pitches rooted in Sul I, yet a few Sul II slips

occurred. Especially near the end of the segment, the piano gradually adopts more and more Sul II partials, which then creates friction from the lower frequencies with the other instrumental sections.



Figure 42 Spectrogram, Aubio Pitch Detector and NNLS Chroma plugin for piano, Segment A

The Aubio Pitch Detector identified a wide range of frequencies, the first being 1047.3 Hz and marked in green ( $\approx$  C6), corresponding to the initial piano chords of Bb2-C6. The *laissez vibrer* of C6 likely contributed to its detection by Aubio. Even when the chord shifted to Bb2-Bb5, Aubio either registered no frequency or briefly detected C6, Sul I's 11<sup>th</sup> partial.

The strength of Sul I partials is confirmed, with the latter exhibiting 351/359 Hz ( $\approx$  F4, plus cent deviations). Meanwhile, the NNLS Chroma plugin subtly indicates Bb (marked in pink), supporting earlier assumptions that the spectrum begins transitioning toward Sul II from bars 29–30 onward (Figure 35). This Bb presence is short, followed by 199 Hz ( $\approx$  G3) in Aubio, which resonates from the apparent constellation in bar 31 (Eb5-F5-G5-B5). G3, being the second partial of Sul I, further reinforces the idea that Sul I remains dominant despite brief transitions into other spectral regions.

The yellow box highlights a section where Sul II plays a larger role than before, as Aubio detects 375 Hz ( $\approx$  F#4) and NNLS reveals bins for C, D, and E. Except for C, which is more structurally dual, Sul II briefly prevails from bar 32 onward. Even as Aubio subsequently detects 192 Hz ( $\approx$  G3), the F# bin remains in NNLS (see small yellow box).

Later, Aubio registers 78.4 Hz ( $\approx$  Eb2), while NNLS displays greater prominence in Sul II partials, with bins lighting up around E, D, and C (having dual connections). This further illustrates the spectral shifts occurring in the piano's 'rumbling' passages. The D bin stands out with particularly strong coloration, confirming its dominance.

While D is also dual—appearing in both Sul I and Sul II—the accompaniment of other pitches, such as E and Bb, directs attention more toward Sul II.

The growing prominence of Sul II is reinforced by the detection of 376 Hz ( $\approx$  F#4), Sul II's fifth partial (Table I). For the remainder of the piano section, NNLS shows no particularly strong bins, as none are distinctly coloured apart from D.

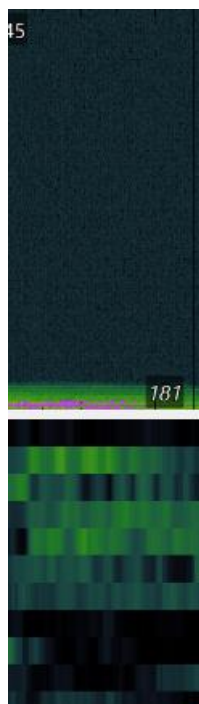


Figure 43 Zoom-in Aubio + NNLS piano 1:40-1:45, see Figure 42.

The above zoom-in displays the last dominant frequency, being 181 Hz ( $\approx$ F#3). Even though this pitch is not literally present anymore in the last bars for the piano, Segment A, it does serve the interpretation of Sul II claiming dominance, as this partial resonates so strongly that it has been picked up.

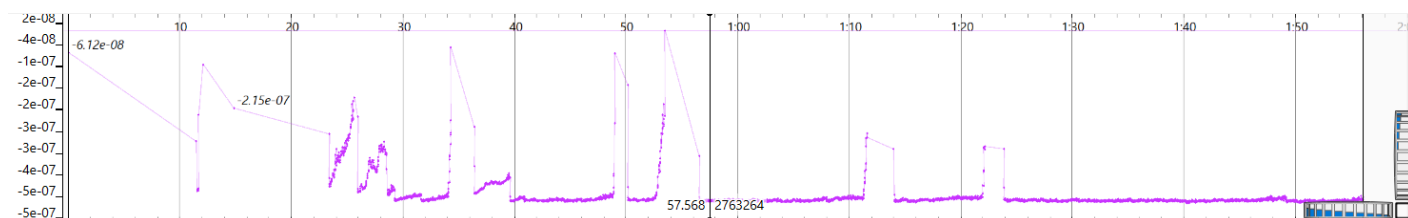


Figure 44 Spectral Slope Piano Section, Segment A.

The peaks observed in the Spectral Slope (Figure 44) do not correspond to audible section, but rather to silent passages. Since the spectral slope remains largely flat throughout the segment, several interpretations can be drawn. The piano's consistent use of low pitches ensures a smooth spectral distribution, preventing sharp peaks and contributing to a balanced spread of internal energy. Unlike RMS-energy, spectral slope stands apart from amplitude, focusing instead on the ratio of high to low frequencies.<sup>100</sup> Here, natural balance seems to be largely preserved.

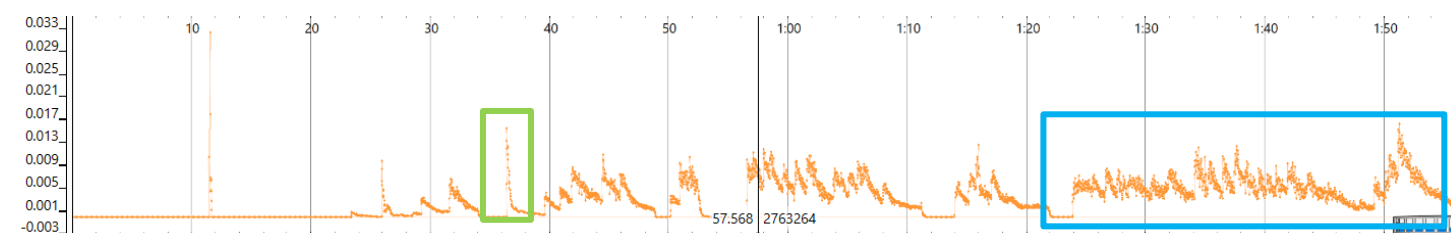


Figure 45 RMS-Energy for piano section, Segment A

The RMS-Energy output, in contrast, shows a gradual increase toward the end of the segment, reinforcing earlier assumptions, primarily drawn from the score, that the progressive introduction of Sul II partials drives spectral modulation in a direction opposite to the other instrumental sections (winds, percussion, and double bass). In the blue box, marking the final bars where the piano spans both Sul I and Sul II, RMS-energy rises as the piano establishes a rumbling foundation. This is likely a result of the alternation between partials of both spectral bases, effectively placing friction within a single instrumental section rather than across the ensemble. This shows detailed control over the sonic material on the composer's behalf.

At the beginning of the segment (green box), the previously noted Bb bin exhibits a slightly higher peak than its predecessor, reinforcing the modulation between Sul I and Sul II. Here, Sul II emerges as the primary driver of spectral tension (through Bb), subtly shifting the harmonic landscape before fully asserting itself in the later sections.

<sup>100</sup> "Spectral Descriptors", *MATLAB Help Center*, n.d., accessed on 27 March 2025, from <https://nl.mathworks.com/help/audio/ug/spectral-descriptors.html#SpectralDescriptorsExample-9>.

### 3.1.2.4 Global Analysis for Segment A

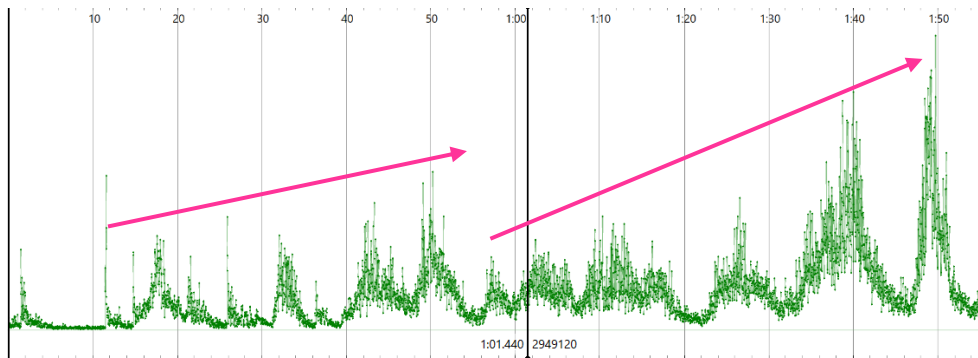
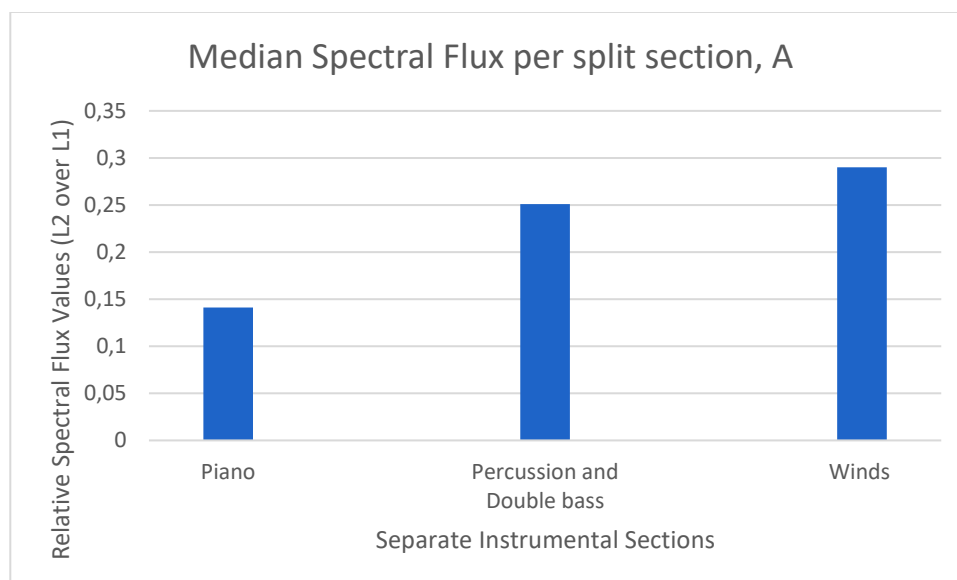


Figure 46 Spectral Flux output for the full Segment A

The Spectral Flux output above for Segment A further supports the observation of a progressive spectral modulation taking place due to the interplay between Sul I and Sul II partials. The spectrum is propelled toward change. The high number of peaks suggests that spectral changes are deliberate and intrinsic to the segment, rather than incidental. The build-up signalled by the first pink arrow indicates that although spectral interconnection is already present from the initial moments of Segment A, it is largely kept ‘moderate’, likely due to the piano’s role in first accentuating Sul I, floating from the introductory segment. The second pink arrow marks the propelled spectral flux increase, mainly ignited by the wind section marking profound presence. Figure 22 showed the RMS-energy output for the winds, which portrayed remarkable peaks throughout. These peaks also increased significantly toward the end, due to the trumpet’s use of split tones and a deliberate distortion containing two notes that corresponded to different partials, thus projecting the spectral interplay in one singular instrument (ref. Figure 20 and 21). All of these implementations have led toward a significant increase in spectral flux for Segment A near the end and leading up to Segment B.

Calculating the median spectral flux for Segment A (ref. Table 2.4) gives the value of 0.289, significantly higher than the introductory segment, confirming Segment A’s high spectral flux levels. The parts of spectral modulation marked on the Constant Q (see Figure 47), correspond to the passages marked with the pink arrow on the spectral flux output.

More and/or stronger frequencies from different spectra cause the sound to change and become more ‘dense’, if you will.



**Graph 1 Median Spectral Flux per Split Segment for A (relative values)**

The accompanying graph—labelled “Median Spectral Flux per Split Section, A”—visually reinforces this conclusion by comparing the relative contributions from different instrumental splits. Median Spectral Flux values have been calculated following Table 2.4, however for the split files instead of full file of Segment A.

In the graph, one can observe that splits corresponding to the percussion and double bass exhibit higher median values (around 0.25) compared to the piano (approximately 0.14). These differences support the analytical narrative: the percussion and double bass, with their emphasis on high partials and techniques such as circular bowing, help to increase spectral density and engender more pronounced peaks. These peaks correspond to the sections marked on the Constant Q display (noted by the pink arrow in the spectral flux output, Figure 46), where stronger or additional frequencies result in the evolving ‘density’ of the sound. The higher values for the winds underlines a compositional strategy: while the overall energetic contribution is distributed across various sections, the wind section plays a crucial role in sculpting the spectral landscape by introducing moments of heightened modulation. Their bursts of high spectral flux cause the sound to become denser and push the sonic material toward change, reinforcing the overall narrative of spectral tension and

transition within Segment A. Despite their spectral slope being relatively stable (ref. Figure 24), their share in spectral flux is notable and makes them the compositional protagonists for now.

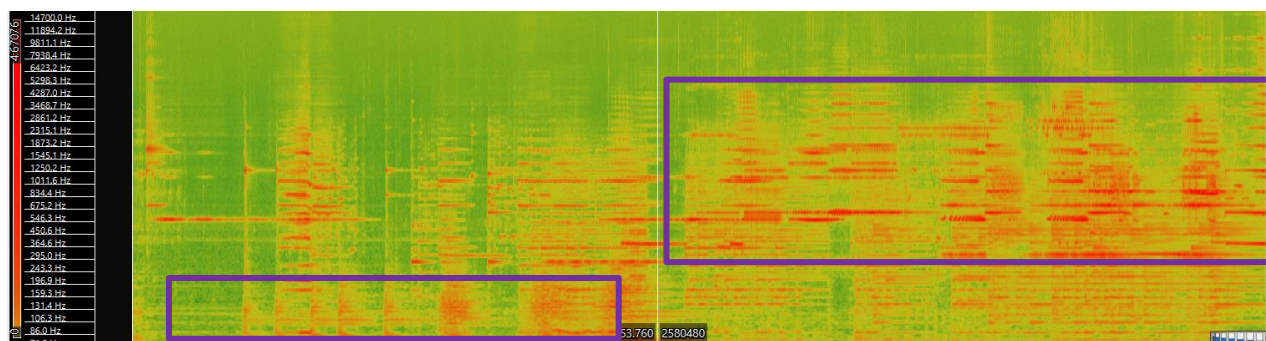


Figure 47 Constant Q output for the entire segment A, for settings ref. Table 2.2

The Constant Q plugin is used to visualize the temporal evolution of the spectrum, helping define structural categories essential for later dynamic profiling. One of Constant Q's strengths lies in its ability to represent periodic spectral variations as structured amplitude modulations over frequency bands (ref. Table 2.2). This makes it an ideal tool for capturing ripple time—a phenomenon observed in the segment's spectral progression.<sup>101</sup> As frequencies gradually intensify toward the end, with increasingly pronounced orange and red colorations in the upper registers, spectral modulation appears to unfold in a rhythmic manner, marked by two distinct periods of gradual spectral transformation (highlighted in purple). While the first purple box suggests flutter time with brief frequency iterations, the overall stacking of frequencies points to ripple time. The increasing density in the Constant Q toward the end reinforces how these layered frequencies drive temporal oscillations and spectral modulation.

<sup>101</sup> Thoresen and Hedman, "Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology", 129–41.

Looking at the overall structure of Segment A, a clear compositional strategy seems to emerge: spectral modulation unfolds through shifts between Sul I and Sul II partials, interwoven with instrumental techniques that reshape spectral interactions. The clarinet establishes spectral tension through multiphonics, adding layers of harmonic complexity that interact with the trumpet's sustained D4. This sets the foundation for spectral interference that is later echoed in the percussion and double bass section, where circular bowing amplifies friction between harmonics while adding bow hair noise. The xylophone's shimmering, consisting of Sul II partials, intensifies this effect, marking a spectral expansion that spreads across the ensemble in a dynamic/floating way. This connects back to the periodicity constituting the **ripple time** in dense frequency blocks (ref. Figure 47).

Meanwhile, the piano, initially tied to Sul I, exhibits a 'reverse' spectral modulation, gradually adopting Sul II partials. This juxtaposition between instruments showcases how Jacobs distributes spectral elements across timbral distinct sections, maintaining structural tension while ensuring harmonic relationships remain coherent. The NNLS Chroma plugin, RMS-Energy peaks, and Spectral Slope analysis collectively affirm this approach, illustrating how the composer deliberately balances spectral interference while allowing Sul II to progressively assert dominance. By blending these elements together with distinct instrumental techniques, Jacobs sculpts a dynamic spectral landscape, reinforcing musical tension through spectral contrasts. These findings, in combination with the high peaks in spectral flux and its high median value, serves the interpretation that the Segment A presents a vital spectral space.

### 3.1.3 Segment B (bar 49-64)

#### 3.1.3.1 Clarinet, Trumpet and Double Bass

Segment B is divided into three parts: (1) clarinet, trumpet, and double bass, (2) piano, and (3) percussion. Due to limitations in the Lalal.AI software, as mentioned in Chapter 2, the double bass slipped into the wind section. However, given that Segment B is the shortest in the composition, this issue does not compromise the analysis.

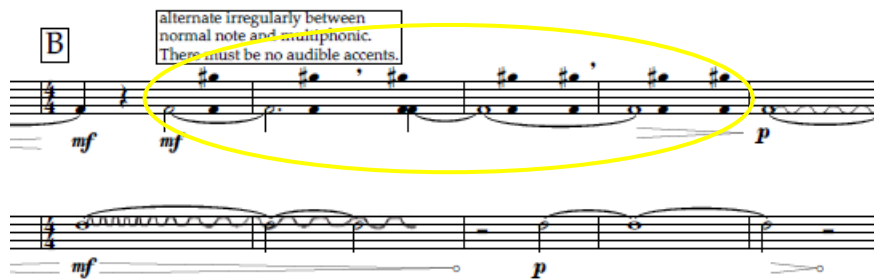


Figure 48 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 49-53, clarinet and trumpet.

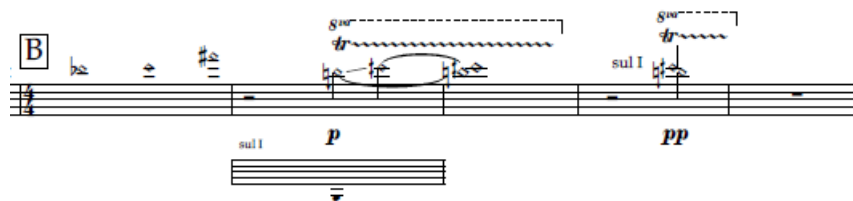


Figure 49 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 49-53, double bass.

Before starting the score analysis, it should be noted that the double bass resides back to Sul I in bar 50 (see Figure 49). The clarinet introduces multiphonics where Eb4 and F#5 stand out (see yellow circle, Figure 48), creating an alternative resonance that contrasts with the C5 on trumpet.<sup>102</sup> This contrast is essential: C5 plays a dual role between Sul I and Sul II, linking the 7<sup>th</sup> harmonic of Sul II with the 11<sup>th</sup> harmonic of Sul I (C6). This recurred in the previous segment as well. Similarly, F#5 emerges as the Sul II's 10<sup>th</sup> harmonic, and Eb4 continues to act as a catalyst for tension, referencing the Sul I spectrum and the 'augmented triad' from the crotales in the introductory segment (Figure 9).

<sup>102</sup> Gregory Oakes, "Clarinet Multiphonics", *Gregory Oakes*, 2011, accessed on 22 April 2025, from <https://www.gregoryoakes.com/multiphonics/>.

Meanwhile, the double bass reinforces this tension, presenting Bb4, C5, and F#5 in bar 49 (Figure 49)—pitches fully oriented toward Sul II, with only Eb4 and C5 providing partial connection to Sul I in bar 50. However, from bar 50 onward, the double bass settles into Sul I with accompanying tones B5 and C6 (Figure 49). Against the background of G2’s harmonic spectrum—where D4 ( $\approx 290.7$  Hz) is the third overtone—both F#5 and C5 exhibit a spectral connection to Sul II (Table I). This shared relationship of C5 in particular could serve as a bridge connecting them with the Sul I string of the double bass. A similar connection exists for B4 in the double bass part; B4 represents the fifth overtone of G2. Yet, the sustained vibrato in the double bass—and the use of the octavation sign—introduces a more tense harmonic effect, adding extra texture to the sound. By applying the octavation sign to B4 and C5 – thereby transposing them to B5 and C6 – the composer not only deepens the spectral connection between the double bass’ fundamental G2 and the clarinet and trumpet’s higher registers but also heightens the overall textural tension in the layered interplay.

8

Figure 50 Ellen Jacobs, *And In Between, There Is ...*, (2024), 8, 54-61, clarinet and trumpet.

Figure 51 Ellen Jacobs, *And In Between, There Is ...*, (2024), 8, 54-61, double bass.

The spectral interference that was dominant in Segment A remains, however more subtly. The clarinet’s multiphonics gradually dissolve into a sustained Eb4, re-emerging in bar 59 as well (Figure 50). The trumpet and double bass join at bar 55, where the trumpet’s muted B3 (with split-tone F#4) interacts with the double bass’ high harmonics of B5 and C6.

Sul I prevails, with the exception of the subtle tension implemented by F#4. By bar 58, the trumpet shifts to D4 (no vibrato). These choices indicate a spectral interplay that subtly realigns balance through Sul I's 12<sup>th</sup> and 13<sup>th</sup> harmonics (D6-Eb6), previously presented in the introductory segment and played by instruments other than the double bass.

At bars 57-58, spectral interference intensifies due to the double bass playing B5-C6 (Figure 51), and from bars 59-60, this interference expands further through F#4 (5<sup>th</sup> harmonic of Sul II) and B4 (5<sup>th</sup> harmonic of Sul I). Jacobs has implemented a spectral overtone parallel here between both fundamentals. By bar 61, the clarinet and trumpet align on B4 with bisbigliando, reinforcing the Sul I spectrum adopted from the double bass (Figure 50).

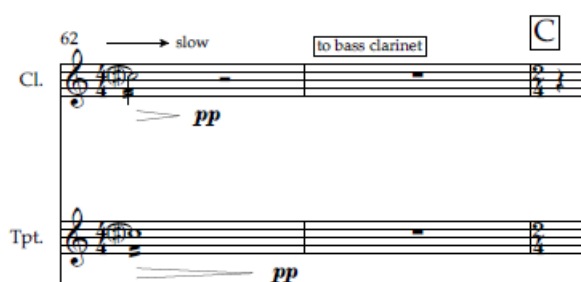


Figure 52 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 62-63, clarinet and trumpet.

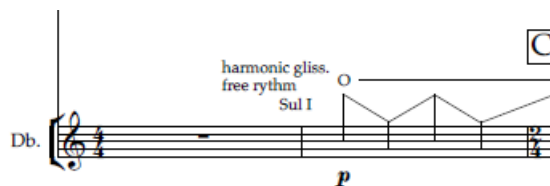


Figure 53 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 62-63, double bass.

Toward the segment's conclusion, the clarinet and trumpet sustain B4 (Figure 52) , while the double bass initiates harmonic glissando (Figure 53), a deliberate gesture signalling transition. Compared to Segment A, Segment B seems to be more 'restrained', yet spectral interference remains present. The trumpet's practice mute and split tones subtly alter the timbre, allowing spectral tension to persist on a tempered background level. This outlines the importance of deliberate choices when it comes to instrumental techniques and what their consequences can be.<sup>103</sup>

The Aubio Pitch Detector and NNLS Chroma plugin give the following outputs for the wind+double bass section (Segment B).

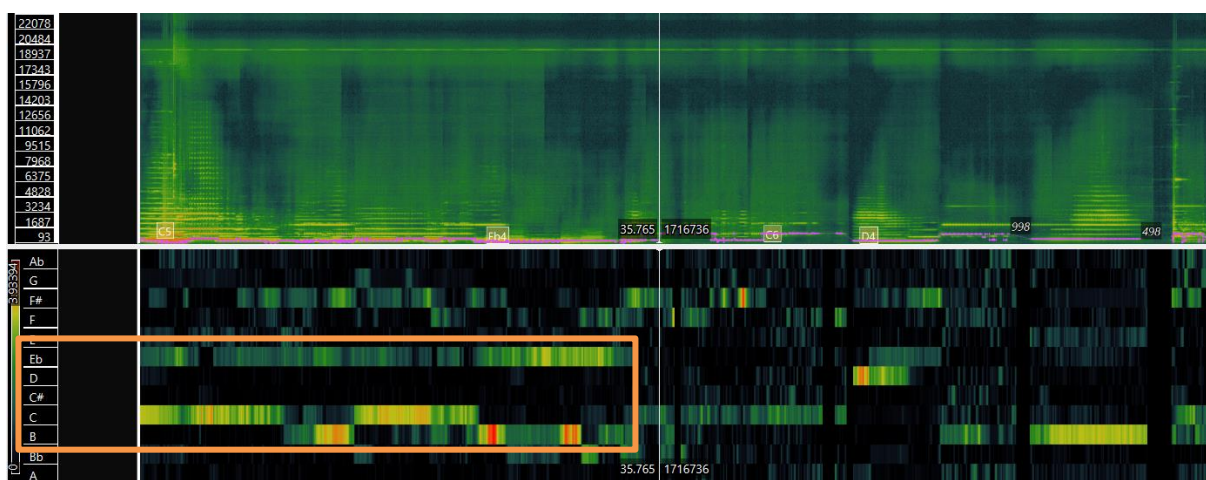


Figure 54 Spectrogram, Aubio Pitch Detector and NNLS Chroma plugin for Segment B, clarinet, trumpet and double bass.

Figure 54 shows the Aubio and NNLS output for the winds and double bass, Segment B. The trumpet's C5 emerges as the first strong pitch (see annotations on Aubio), followed by a gradual increase in the presence of B and Eb (as detected by NNLS, see orange box), with Aubio confirming Eb's appearance. These findings correspond to the clarinet's multiphonics and the trumpet's split tone, reinforcing their spectral interaction. Notably, while B is not detected by Aubio, NNLS confirms its presence, further supporting the idea that Sul I plays a dominant role in this section, though C5, being the 7<sup>th</sup> harmonic of Sul II, still holds significance.

The double bass frequently plays C6 with distinct vibrato, often paired with B5 (ref. Figure 51), which serves as a deliberate reference to Sul I (10<sup>th</sup> and 11<sup>th</sup> harmonics, Table I).

<sup>103</sup> Jacobs (composer), interview, 21 November 2024.

This Sul I dominance, first introduced in Segment A, becomes increasingly prominent toward the end of Segment B, a trend which is evident through the frequency readings of 998 Hz (B5) and 498 Hz (B4), corresponding to the 10<sup>th</sup> and 5<sup>th</sup> harmonics of Sul I. The vibrato applied to the double bass likely amplifies Sul I's presence further, a subtle yet effective emphasis that is reinforced by the winds playing B4 with *bisbigliando*, contributing to the broader spectral tension at play.

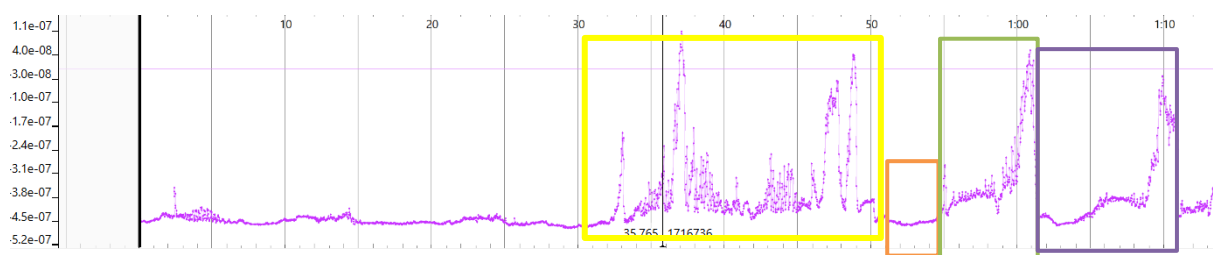


Figure 55 Spectral Slope for clarinet, trumpet and double bass, Segment B

The beginning of Segment B depicts a largely stable spectral slope, which usually points at a natural ratio between low and high frequencies in the spectrum, mostly labelled as ‘natural’.<sup>104</sup> However, as shown in the yellow box, the slope suddenly increases due to the double bass’ high harmonics (B5-C6, bars 55-58, Figure 51) and the trumpet’s split tones, causing an energy shift toward higher registers. This confirms that while these pitches remain harmonically justified in relation to Sul I, their particular emphasis disrupts spectral balance.

Yet, when the clarinet and trumpet introduce Eb4 and D4 (bars 58-59, orange box), the slope stabilizes again, likely due to the absence of vibrato and more centred harmonic grounding. But this stability is short-lived: the double bass’ spectral interference between bars 59-60 (green box) leads to another slope increase before the final B4 interaction (purple box) with the trumpet further amplifies spectral tension.

The spectral slope output reveals that while the wind and double bass section initially maintains a ‘stable’ frequency distribution, a spectral imbalance emerges toward the end of the segment. This imbalance stems from the application of instrumental techniques such as split tones and vibrato, as well as variations in timbre (illustrated in the purple box, where the trumpet joins).

Unlike the trumpet, the clarinet’s natural bore structure emphasizes odd harmonics over even ones, creating a distinct spectral profile. The trumpet, by contrast, does not align with this odd-even harmonic division, which influences the

<sup>104</sup> “Spectral Descriptors”, *MATLAB Help Center*, n.d., accessed on 27 March 2025, from <https://nl.mathworks.com/help/audio/ug/spectral-descriptors.html#SpectralDescriptorsExample-9>.

spectral slope. When the trumpet joins the clarinet while playing the same pitch, its broader harmonic spread disrupts the previously stable spectral distribution, causing the slope to rise.<sup>105</sup>

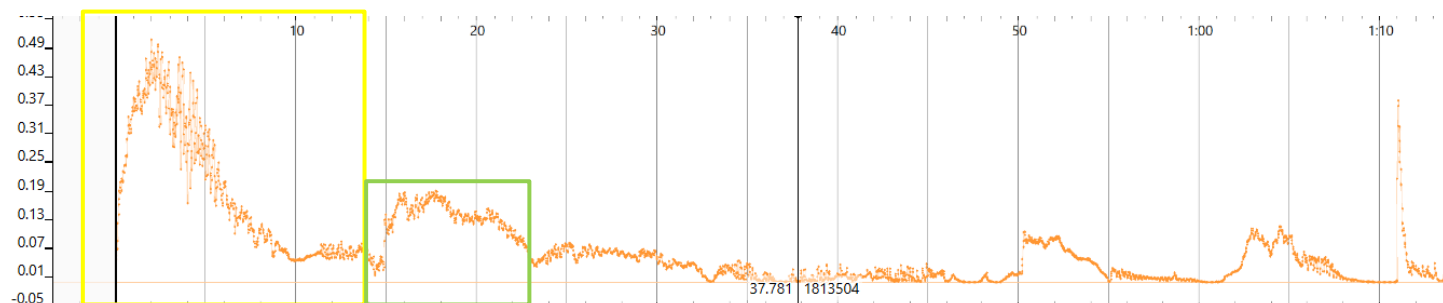


Figure 56 RMS-Energy output for winds and double bass, Segment B

The RMS-Energy output, when compared to the Spectral Slope, exhibits an inverse trend. The strongest energy peaks appear at the beginning of the segment, particularly during the interaction between the clarinet's multiphonics and the trumpet's C5 (yellow box). As vibrato is removed from the trumpet's C5, RMS-energy declines slightly but remains relatively high (green box). This suggests that even though spectral balance is maintained, the early phase of Segment B is still energetically strong, likely carrying over spectral modulation from Sul II's 7<sup>th</sup> harmonic C5, which was introduced at the end of Segment A.

By contrast, the flattest portion of the RMS-Energy curve coincides with the highest peaks in spectral slope. The double bass and trumpet contribute to spectral imbalance, yet their amplitude remains controlled (*pianissimo* and *decrescendo a niente*). This implies that Jacobs uses spectral imbalance as a background texture rather than a dominant feature, allowing subtle spectral interactions to shape the overall spectral space. Rather than enforcing a heavy, foregrounded presence, these elements contribute to a soft spectral shift. As a result, energy-wise, Segment B unfolds as a gradual background implementation of spectral tension, rather than a pronounced dramatic gesture.

<sup>105</sup> Oakes, "Clarinet Multiphonics".

Placing the Spectral Slope next to RMS-energy, it suggests that spectral imbalance is achieved more through timbral shifts rather than amplitude, reinforcing the idea that Jacobs prioritises spectral movement stemming from inherent features. The trumpet in particular showed this difference, as its harmonic spread disrupts the clarinet spectral ‘equilibrium’, raising the slope without necessarily increased loudness and amplitude.

### 3.1.3.2 Split segment for the piano

The following segment is a split part for the piano. Both the left and right hand will be studied simultaneously.



Figure 57 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 49-53, piano.

Bar 49-50 (Figure 57) show the shimmer that has been travelling across instruments since Segment A (see Figure 29). This shimmer being played by a large number of instruments, each with their own timbre, allows for a transformation which indicates the dynamic potential of Sul II’s partials. By placing them in a high register, the spectral balance is shifted which can cause the music to undergo a moment of transition solely from the nature of the tones. With bar 50 in the double bass reclaiming its Sul I string, the piano follows by implementing B1-B2 in the left hand, contrasted with Bb1-Bb2 in the right hand. Not only do both differ from each other in terms of spectral connection, but their frequencies lie in close proximity to each other, enforcing a microtonal interaction.

Bb1  $\approx$  58.27 Hz – B1  $\approx$  61.73 Hz

Bb2  $\approx$  116.54 Hz – B2  $\approx$  123.47 Hz

Even with the *pianissimo* and *quasi niente* indications, both reasons mentioned likely cause the piano to perform minor spectral tension, almost on a microscopic level, if you will.

The low nature of the frequencies does help restabilise the earlier spectral imbalance caused by the shimmer, which is why the tension here is labelled as more subtle compared to earlier. It seems as though the ‘rumbling foundation’ present at the end of Segment A has dabbled to the following Segment, although less chaotic.

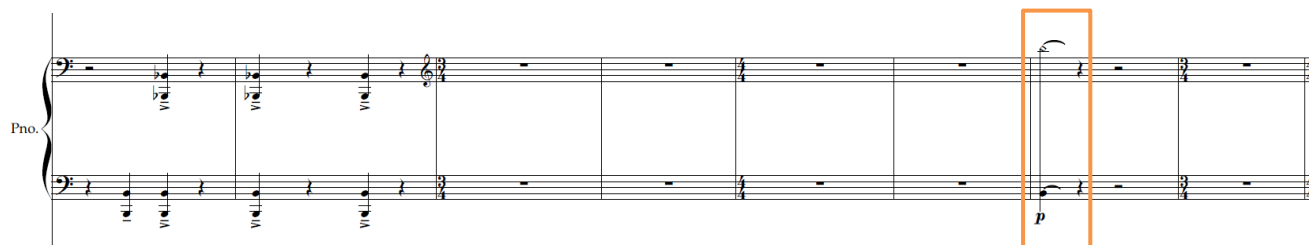


Figure 58 Ellen Jacobs, *And In Between, There Is ...*, (2024), 8, 54-61, piano.

These ‘microtonal’ chords are sustained, yet bar 60 shows a return to a higher register on the piano’s behalf, showing B2-B5 (orange box). The highest pitch conforms to Sul I’s 10<sup>th</sup> harmonic, with B2 adding extra foundation. This same harmonic appears in the double bass and winds as B4, the fifth of Sul I. On the piano’s behalf, this could be seen as a mark of temporary stability, since no additional vibrational additions are given, nor loud amplitudes.



Figure 59 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 62-63, piano.

However, bar 63 tells a different story. This chord contains of F#5 – G#5 – B5 – C#6. The pitches marked in blue reside in Sul II’s spectrum as the 10<sup>th</sup> and 11<sup>th</sup> harmonic. In that sense, the composer took partials of the similar position as in bar 10 (Figure 10), just from a different fundamental. She seems to almost literally ‘mirror’ both spectra to each other. The presence of B5 solidifies this assumption.

However, C#6 does not hold any connection to either Sul I or Sul II, yet it does float *in between* C6 and D6, both the 11<sup>th</sup> and 12<sup>th</sup> harmonic of Sul I.<sup>106</sup> Referring back to the title of the composition, *And In Between, There Is...* (2024), this microscopic handling of the sonic material does mark a point in time in which both spectra are mirrored. Is this perhaps a prelude to the harmonic glissando in the double bass, initiating Segment C? The answer is likely yes.

The following image (Figure 61) shows the Aubio Pitch Detector and the NNLS Chroma output for Segment B, Piano section.

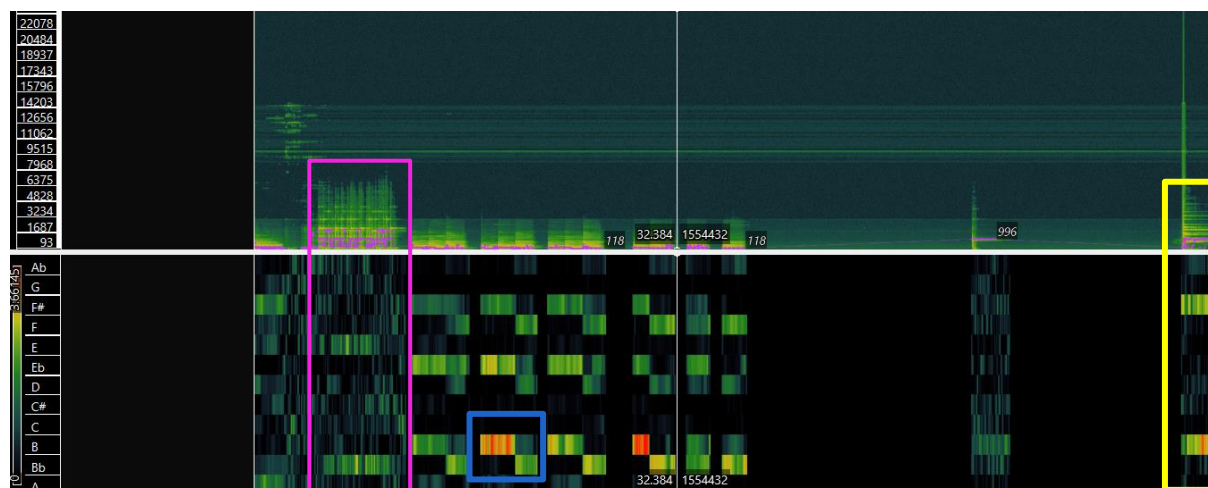


Figure 60 Spectrogram, Aubio Pitch Detector and NNLS Chroma plugin for Segment B, piano.

The piano's shimmer is marked in pink and makes it difficult for both plugins to detect one (or more) distinct pitches. Only when the separate chords come about in bar 51, both plugins provide more clarity. As for the Aubio, the frequency of 118 Hz is picked up, aligning with Bb2. This is likely caused by the fact that the chord of Bb1-Bb2 was played slightly louder compared to B1-B2 (*pianissimo* vs. *quasi niente*). Yet its prominence in Aubio is not fully foolproof, as is proved by the NNLS output. Here, B lights up yellow/orange, meaning that among all frequencies, this one too is prominently present (see blue box and Figure 61). At the same time, Eb lights up too, further confirming Sul I's presence. However the Bb1-Bb2 chord allows the frequencies to slip into Sul II's spectrum, which can be seen by both bins being in close proximity to each other. Figure 61 shows a zoom-in of such interacting bins to prove the particular way in which the composer managed to implement spectral interference on such a small scale.

<sup>106</sup> Jacobs (composer), interview, 21 November 2024.

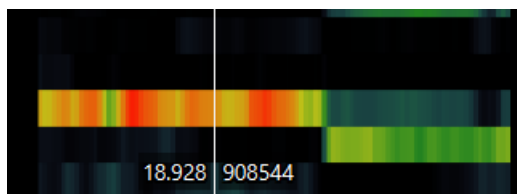


Figure 61 Zoom-in on NNLS Chroma, blue box Figure 60.

Without the NNLS output, such musical ‘microfibres’ would have not been observable. The following frequency output is 996 Hz (Figure 60), aligning with B5 and bar 60 on the score. Yet the very last visualisation corresponds to the last chord of the piano (bar 63). Figure 62 depicts its zoomed-in version.

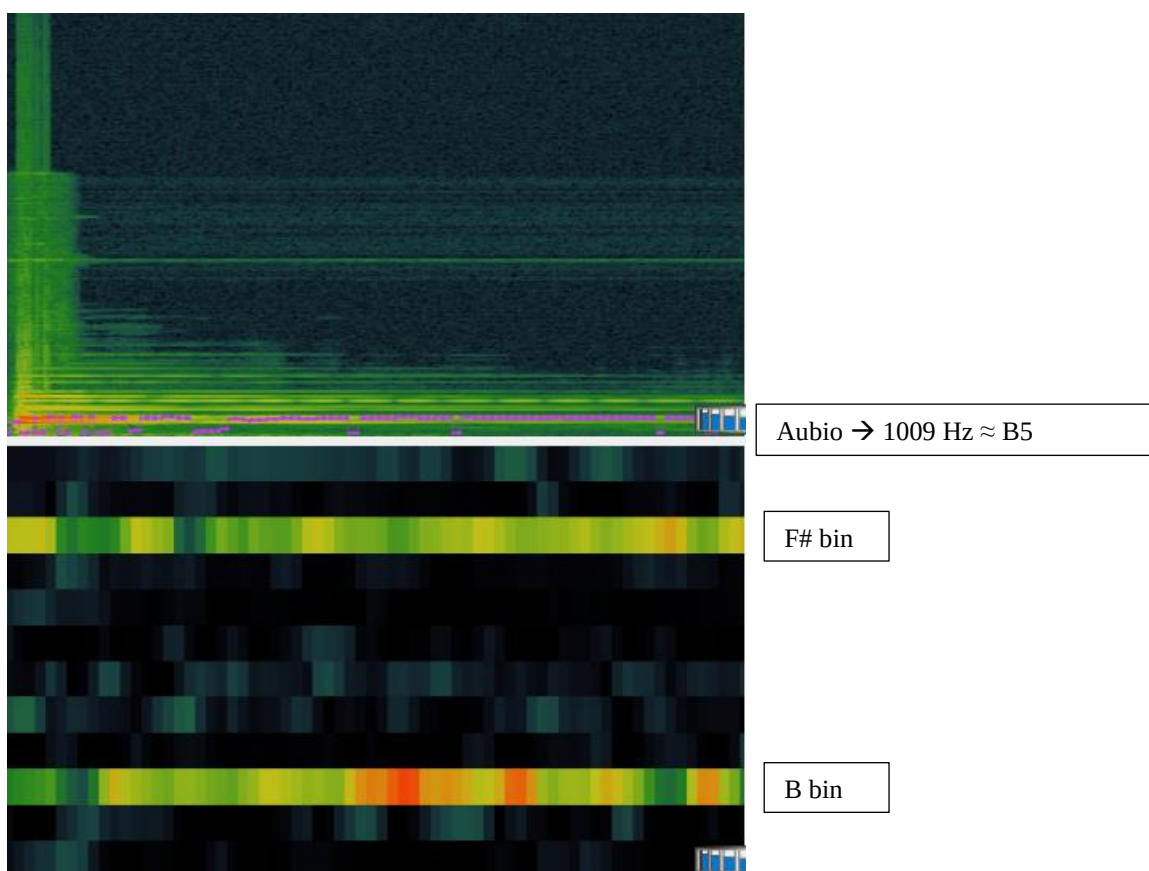


Figure 62 Zoom in on Spectrogram, Aubio and NNLS, yellow box Figure 60.

This zoom-in aligns with the yellow box on Figure 60. The bins lighting up for NNLS both correspond to F#5 and B5, coincidentally the 10<sup>th</sup> harmonics of respectively Sul II and Sul I. The earlier argument of the composer ‘mirroring’ both spectra with each other is therefore confirmed by this visual, mainly due to the prominent F# bin.

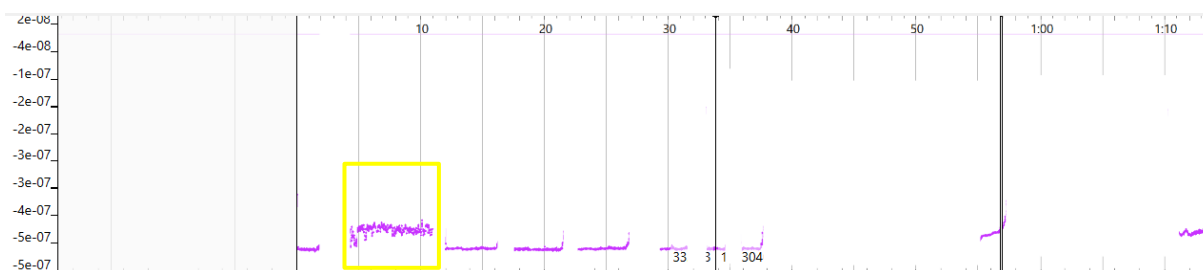


Figure 63 Spectral slope for piano segment B with silent parts hidden.

Upon initial observation of the spectral slope, it appears that it is mostly flat, pointing at the spectral balance being kept due to the low nature of the notes played on the piano, where its natural resonance was able to maintain. Slight turbulence is viewed for the shimmer on the piano (marked in yellow), but compared to the slope output for the winds and double bass, it appears way more stable, even for the end chord. A possible reason is that the winds and double bass, due to their expressive variability and techniques like bowing (circular bowing) and breathing control (split tones), introduce more fluctuations in spectral slope. This makes the piano a more stable anchor in ensemble settings, as evidenced by this output.

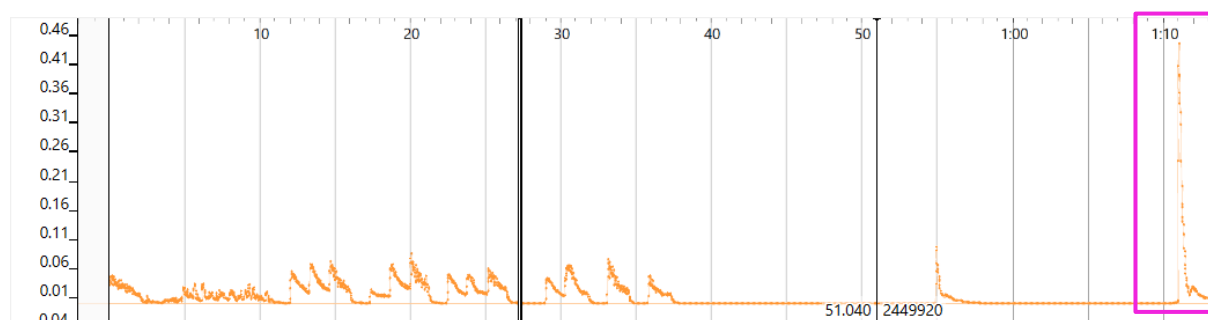


Figure 64 RMS-energy output for the piano section, segment B.

Subtle peaks in energy do occur for the split piano segment, which aligns with the low frequencies of the piano chords being played throughout most of the segment. These also create distinct marks in time, structuring musical time accordingly. The earlier assumption that the chord in bar 63 conveys a deliberate *in between* spectral tension is confirmed by the RMS-energy output as well (see pink box). Despite the levels being low, their contribution to the inner layers of the sonic fabric are not to be underestimated.

## 3.1.3.3 Percussion section



Figure 65 Ellen Jacobs, *And In Between, There Is ...*, (2024), 7, 49-53, percussion.

Although the percussion section in Segment B does not necessarily encompass a wide range of pitches, its role remains significant. The non-melodic instruments, in particular, introduce inharmonic frequencies that contribute to noise, thereby shaping the texture of the sound. The section opens with Eb5-F5 on the crotales (top) and C5 on the vibraphone (bottom), which later transitions into B4. The crotales then shift to the bass drum, generating inharmonic sounds that may also enrich the overall spectral balance.

Notably, all pitches can be traced back to Sul I, aligning with the double bass's fundamental presence in bar 50 (Figure 49). B4 serves as the 5<sup>th</sup> harmonic, while F5 corresponds to the 7<sup>th</sup> harmonic of G2 (Sul I, see Table I). Each of these pitches is accompanied by vibrations, reinforcing their prominence and texture while further solidifying the Sul I base.

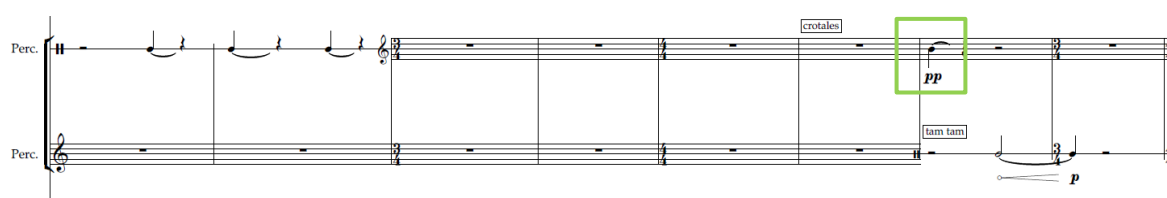


Figure 66 Ellen Jacobs, *And In Between, There Is ...*, (2024), 8, 54-61, percussion.

The percussion section plays a relatively minor role compared to the other instruments. Based solely on pitch content, a single brief B4 appears in the green box, but otherwise, there is no discernible pitch presence.

For now, the accents of the non-melodic percussion can be interpreted as temporal markers that establish structure, though they do not originate from within the harmonic framework since they lack pitch content.

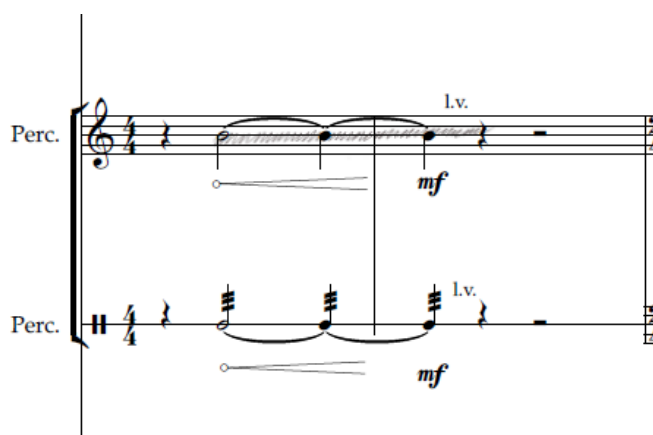


Figure 67 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 62-63, percussion.

However at the end of Segment B, the crotales (top) play a B4 with the metal stick, presumably used for creating a more prominent timbre. The bisbigliando for the tam-tam (bottom) further enriches texture, though pitch-less.

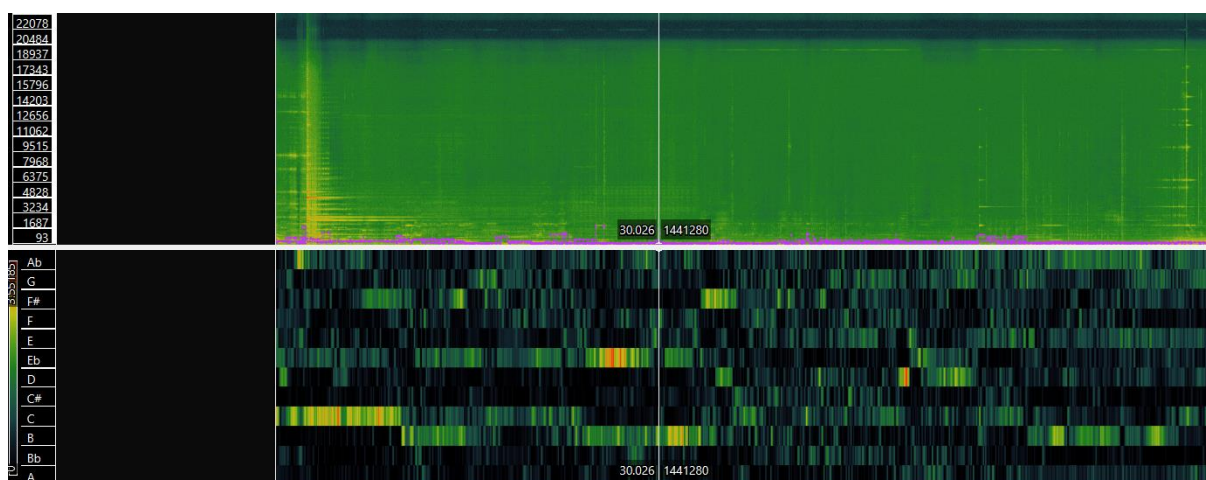


Figure 68 Spectrogram, Aubio and NNLS for Segment B, percussion

Figure 68 highlights the fundamental incompatibility of pitch-based detection methods when applied to non-melodic percussive sections, where harmonic tracking fails to yield meaningful results. Additionally, it underscores the risks associated with relying on Lalal.AI for sound separation, as spectral leakage introduces unwanted interference in downstream analyses such as NNLS. In this case, traces of the wind section remain interwoven within the percussive

material, however at a background level. Despite multiple filtration attempts aimed at isolating the percussion, the separation remained inadequate, preventing a fully reliable dataset for plugin-based spectral analysis. Given these limitations, continuing with plugin analysis for this section would compromise methodological accuracy, leading to potential distortions rather than meaningful insights. To uphold analytical integrity, plugins will not be applied to this dataset; instead, the study will focus on a broader spectral evaluation of the entire segment, ensuring a more stable and unbiased representation of the sound.

### 3.1.3.4 Global Analysis for Segment B

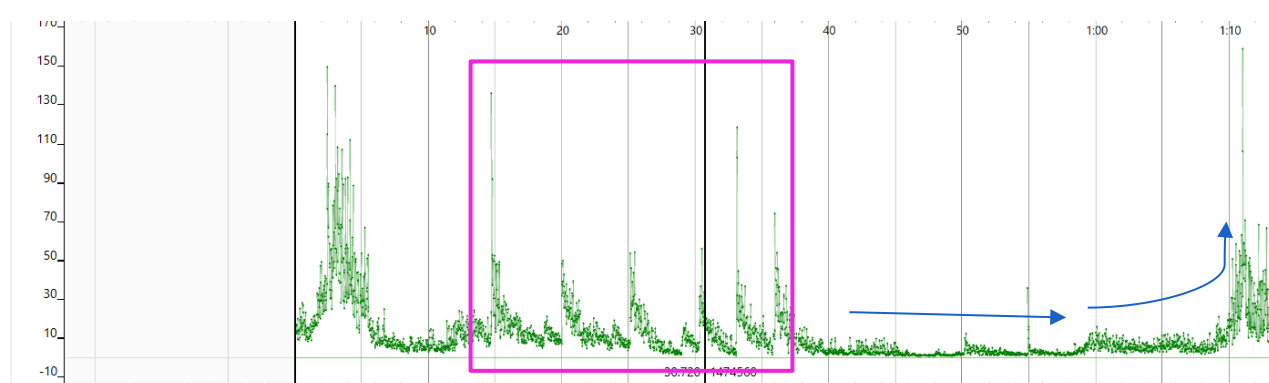
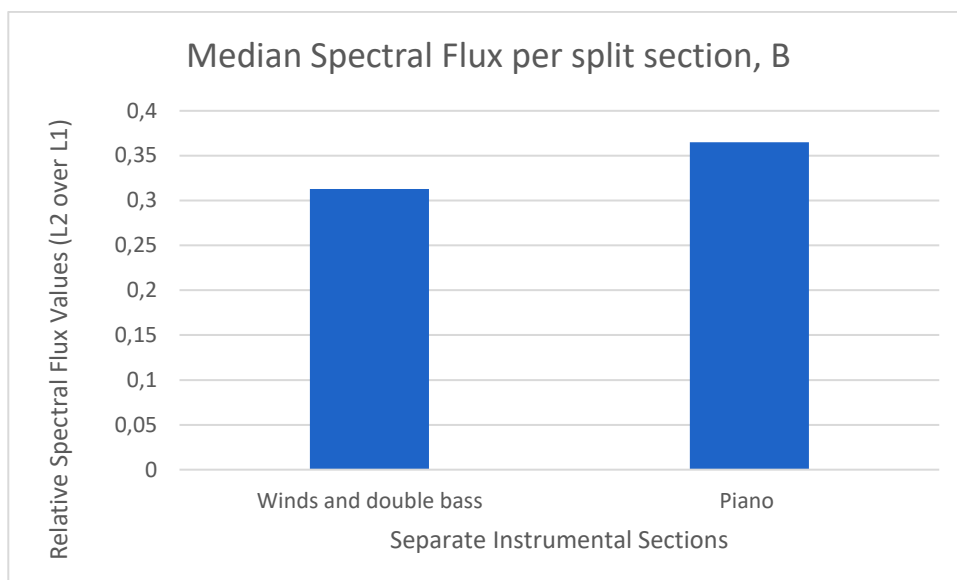


Figure 69 Spectral Flux output for Segment B.

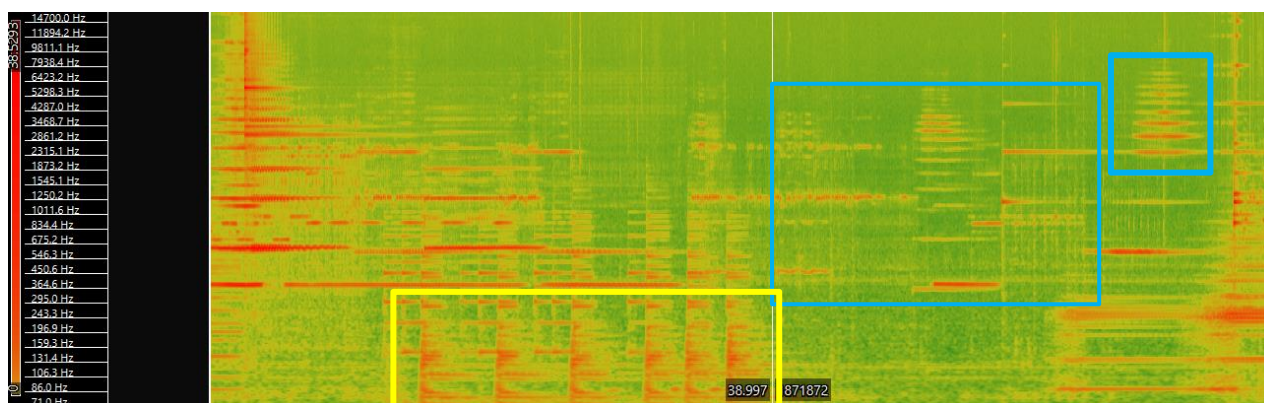
Upon visualising the spectral flux in Figure 69, it is evident that the line is not flat. The periodic fluctuations in the flux are attributed to the piano (pink box), and when it ceases to contribute to the ensemble, the flux stabilizes (blue flat arrow), becoming noticeably flatter. However, when the double bass introduces F#4 and the winds join with B4—alongside the addition of the crotales—the flux gradually expands again (blue ascending arrow). This shift signals the initiation of the harmonic glissando, led by the double bass, marking the transition from the end of Segment B into the beginning of Segment C. The flat, intermediate state of the Spectral Flux does show links with the more background-level changes occurring throughout the segment, compared to Segment A. Pulling this comparison through the median spectral flux value, the result is 0.258, lower than A and labelled here as moderate.

The separate contributions of the individual segments, with the exception of percussion as argued above, are visualised in the diagram chart below.



**Graph 2** Median Values for Spectral Flux per Section (except percussion) in B.

Because the piano shows a higher flux value than the winds and double bass, the initial shimmer that marks this section can be understood as playing a meaningful role in how the spectrum evolves over time. The final chord played by the piano, which includes a C#6, seems to introduce an intermediate space which is a subtle force that drives a transformation within the sonic texture. In contrast to Segment A, the piano now acts more clearly as a catalyst for spectral modulation, intentionally highlighting moments where primarily Sul I partials, and occasionally Sul II partials, extend the spectral field, though in a more measured and controlled way than before.



**Figure 70** Constant Q output for Segment B.

Looking at Figure 70, the significance of the piano is once again highlighted in the Constant Q output, marking recurring yet brief points in time (indicated in yellow). Compared to Segment A, where such iterations are more evenly distributed,

the frequencies here emerge as fleeting "flickerings" or residual traces of the piano's shimmer that appeared at the segment's onset. Examples of these are marked in blue. These subtle "flutters" of sonic material suggest that Segment B operates within flutter time, characterized by a moderate spectral flux. This contrasts with Segment A, which exhibits high flux and follows a ripple time structure. The overall sonic movement appears to be transitioning toward a state of relative "rest," especially when viewed in relation to the preceding segment. However, residual spectral interference persists, preventing the flux from fully settling into a low state and still keeping the music on a go.

In conclusion for Segment B, it unfolds with a deliberate sense of controlled energy. The clarinet and trumpet, through techniques like multiphonics and split tones, act with the double bass to reaffirm the prominence of Sul I, while subtle contributions from Sul II slip in. The piano's shimmering iterations serve as brief temporal markers. Segment A, on the other hand, showcased an active role of the ensemble, with the wind section employing multiphonics and continuous spectral tension, while percussion and the double bass contributed to dynamic peaks and complex overtone interactions. The latter in specific was more pronounced for Segment A. The spectral interplay retained a prominent sense of tension, driven largely by deliberate interference between Sul I and Sul II partials.

Segment B, however, leans toward a careful rebalancing. Although the clarinet and trumpet continue to employ modulatory techniques, their role is tempered by the double bass's reassertion of Sul I and the piano's role as a rhythmic and harmonic anchor. Even though the piano had a larger share in the spectral flux developments, the way in which it did it is more subtle. The resulting texture is one where spectral interference is present but more contained, providing a bridge that both contrasts with Segment A's energetic turbulence and smoothly guides the listener toward a new state in Segment C.



accordingly. The introduction of this research clarified the ways in which spectralists of the 20<sup>th</sup> century used a similar approach.<sup>107</sup>

Given that the trumpet's Eb5 is played with pronounced pulsation, it likely reflects the unstable nature of the 13<sup>th</sup> harmonic of G2 (conceptually Eb6, Table I). Its instability is further highlighted by (1) the octavation lowering the pitch and making it more profound, and (2) the pulsatile execution. Especially the latter can implement extra texture, metaphorically expanding the spectral space.

10

Figure 72 Ellen Jacobs, *And In Between, There Is ...*, (2024), 10, 70-77, bass clarinet and trumpet.

In bar 70, after a few bars of rest, the bass clarinet resumes with a sustained A4 (6<sup>th</sup> Sul II), followed by B4 (5<sup>th</sup> Sul I), also sustained. The trumpet simultaneously adds to the ensemble by playing a B4, followed by a C5 (7<sup>th</sup> Sul II) up until bar 74. Once again, as occurred multiple times throughout the score, C fulfils a dual role appearing for both Sul I (C6) as Sul II (C5). However, its lower position for Sul II marks a stronger prominence compared to the more fluctuating C6, in combination with the absence of vibrato. This ensures that both winds create a layer that alternates with the Sul I glissando on double bass. All depends on musical context.

From bar 74 onward, the trumpet resides to *halve valve split tones*, a technique where the player only partially presses the valve, which causes the harmonic spectrum to get adapted. In opposition to the ‘conventional’ split tones, the halve valve version is capable of producing an interval which is unconventional in ‘normal’ performance. Additionally, these cause the trumpet to get a more ‘vale’ sound, differing from its typical, sharp timbre.<sup>108</sup> In concrete terms, this would mean that certain overtones normally overshadowed by stronger formants are now emphasized, in combination with a tempered timbre.

<sup>107</sup> Rose, “Introduction to the Pitch Organization of French Spectral Music”, 30-39.

<sup>108</sup> Nathan Plante, “Halve-Valve”, *The Modern Trumpet*, 21 December 2020, accessed on 23 April 2025, from <https://themoderntrumpet.com/2020/10/20/split-tones/>.

In terms of compositional intent, this technique allows for the composer to choose which overtones come to the foreground, presumably those fitting within the overall compositional narrative. Here, the pitches are G4 (Sul I)-C5 (Sul II). Given the information on halve valve split tones, C5 can be attributed to Sul II due to its direct connection to this fundamental and the ‘scraping’ effect created by the unconventional pairing of differing fundamentals. The composer thus achieved a minor spectral tension in the trumpet, further contributing to the alternating layer. In combination with the earlier Sul I partials residing in both the bass clarinet and trumpet, these halve valve split tones can be interpreted as remnants of the earlier tension created between the two fundamentals.



Figure 73 Zoom-in on bar 74-75 trumpet halve valve split tones, see Figure 72.

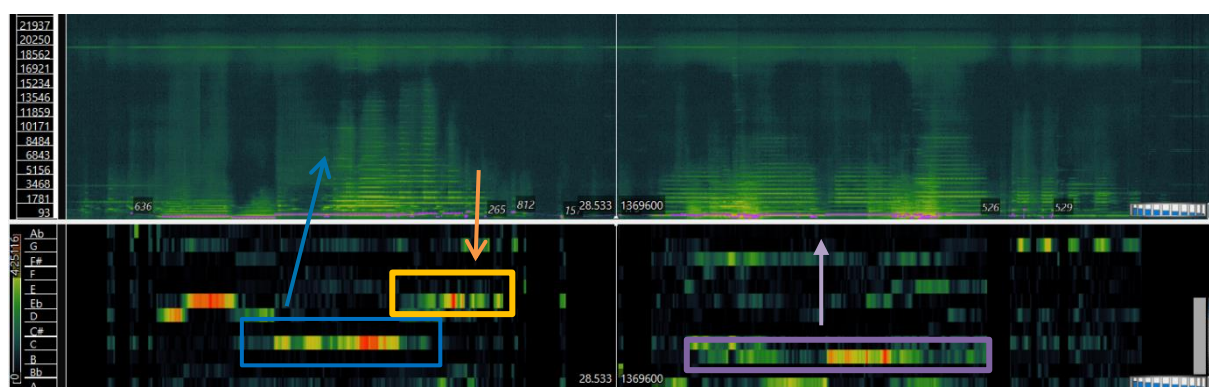


Figure 74 Spectrogram, Aubio Pitch Detector and NNLS Chroma output for the bass clarinet and trumpet, Segment C.

The wind section marks a clear presence of both Sul I and II residues across the segment. The first pitch to be detected is 636 Hz ( $\approx$  Eb5), created by the bass clarinet bar 65 (see Figure 71). The largest bin appearing for the NNLS Chroma output is C (see blue mark), played by the bass clarinet bar 65-66. The blue arrow marks the later ‘expansion’ seen in the spectrogram layer, which could have been prelude by this C5 holding connection to Sul II and melting into the trumpet’s Eb5, close to Sul II’s 9<sup>th</sup> partial E5 yet connecting to Sul I more through its 13<sup>th</sup> partial Eb6.

The pressuring effect added onto the trumpet, and the expanded spectrogram, all contribute to the narrative of the trumpet holding connection to Sul I and creating interference. The blue box and arrow highlight the blending of C5 into the broader spectrum, later influenced by the trumpet. The orange box and arrow indicate the Eb bin for NNLS.

At bar 70, the Aubio Pitch Detector registers 265 Hz ( $\approx$  C4) from the bass clarinet, lowering the spectrogram into a more contracted state. This persists until the trumpet reasserts itself with B4, the fifth of Sul I. The B bin for NNLS intensifies, and the spectrogram layer expands once more (see purple box and arrow). Recalling the end of Segment B for the winds, where a bisbigliando on B4 (clarinet and trumpet) subtly modulated the transition to the next segment, a similar spectral interplay emerges. Sul I partials drive further expansion of the spectrum, whereas Sul II residues temper it, creating a delicate and deliberate balance.

As the bass clarinet shifts from A4 to B4 (Figure 72), the trumpet concurrently plays B4 and C4, the latter playing a dual role and resurfacing in the halve valve split tone. This interaction causes the spectra to slide together in a minimized yet noticeable manner, manifesting within the trumpet's applied technique. Within the NNLS, additional bins illuminate as this nuanced interplay unfolds. Aubio detects 526 Hz ( $\approx$  C5) as the dominant pitch, initiating the fade-out in the final bars. The trumpet's sound scrapes against the interference between both spectra, concluding the passage with a minimal spectral shift.

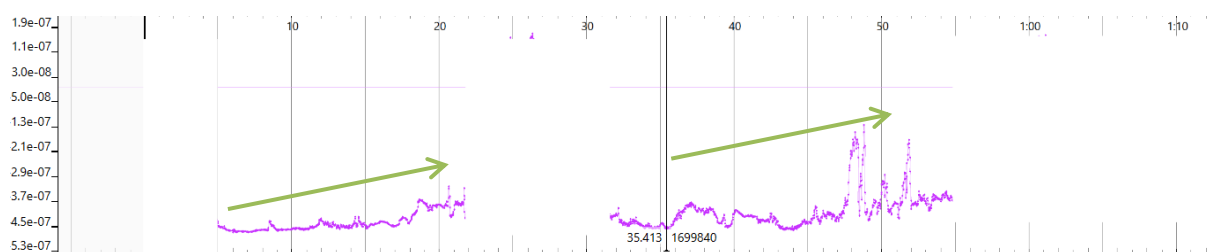


Figure 75 Spectral Slope output with silent parts hidden for the wind section segment C.

The spectral slope output exhibits subtle increases. However, the overall trend remains ascending rather than descending, as indicated by the green arrows tracing its movement. Each time the trumpet repeatedly plays the same note with deliberate techniques, the slope rises slightly, confirming a subtle spectral imbalance. The first is even a result of the melting of C5 (bass clarinet) into the trumpet's Eb5, shifting spectral focus on a microscopic level.

This effect is further reinforced by several factors: Eb5's connection to Sul I in contrast to most other pitch content, the pressuring technique and halve valve split tones, the appearance of corresponding bins, and the expansion of the spectrogram visualized above. Near the end, as both spectra seemingly slide into each other, the slope's increase becomes more pronounced. This underscores the significance of the halve valve split tone additions in conveying delicate spectral tension and modulation in the form of shifting balance.

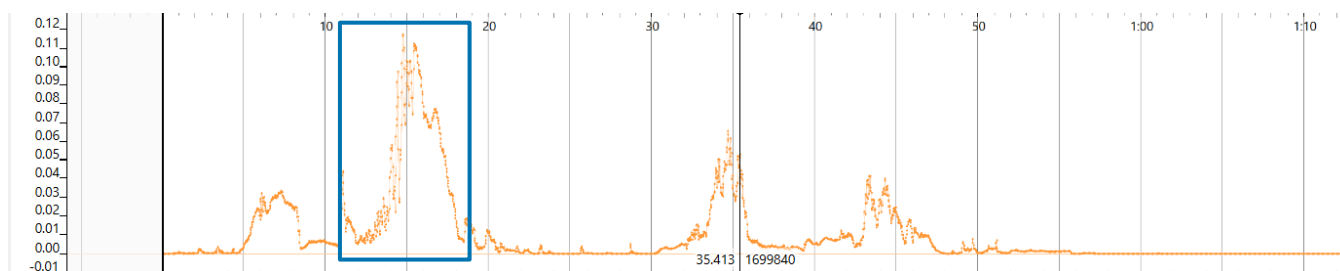


Figure 76 RMS-Energy for the wind section, Segment C.

Before describing this output, it needs to be clarified that from 0:75 seconds onward, the audio is silent, contributing to the flat RMS-energy.

The largest peak in energy, marked in blue, corresponds to the first subtle rise of the spectral slope above, as well as the expansion of the spectrogram exhibited Figure 74. This further underlines the significance of the trumpet's techniques in this section. However, the overall decay of RMS-energy goes in opposite directions of the spectral slope. It shows the importance of using multiple plugins to understand the dynamics residing in the composition, and in case of RMS-Energy how these contribute to a certain amplitude structure. This inverse proportional trend with the Spectral Slope reveals that the slight spectral imbalance caused by the winds recedes to a more background level, scraping the surface of the sound without overpowering it. The melting of C5 into Eb5 and the spectral focus shift provide additional insight into why RMS-energy moves inversely from Spectral Slope. The blending of spectral elements causes a delicate redistribution of energy, impacting overall amplitude structure. Additionally, the halve valve split tones play a crucial role: their unconventional technique introduces spectral tension that modulates balance, subtly influencing RMS-energy's decay.

### 3.1.4.2 Percussion and double bass

Upon first observation of the score for the percussion and double bass, one element in particular stands out, which is the free rhythm harmonic glissando in the double bass section, see Figure 77.

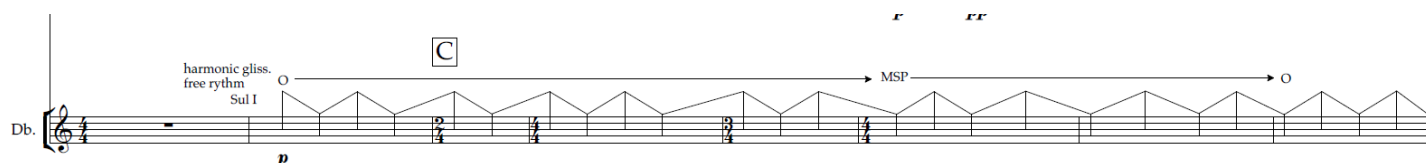


Figure 77 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 63-69, double bass.

Above the glissando, the letters “O → MSP → O” are portrayed, which is a reference to playing techniques. It was mentioned before that instrumental techniques are an effective way to achieve certain (spectral) musical goals. In this case, they can be interpreted as follows: O refers to a flageolet, a playing technique used on string instruments to mute the fundamental tone, here G2 or Sul I, and give the harmonics more space by touching the string lightly.<sup>109</sup> MSP stands for *Molto Sul Ponticello*, instructing the player to position the bow closer to the bridge, typically producing a sharper, more ‘metallic’ sound.<sup>110</sup> This harmonic glissando highlights overtones, allowing them to float in spectral space without being overshadowed by the fundamental tone, as in a natural setting. A similar effect occurred for the halve valve split tones in the wind section. The later sonic visualiser output can give more information on what harmonics specifically appear and how this affects the overall energy levels.

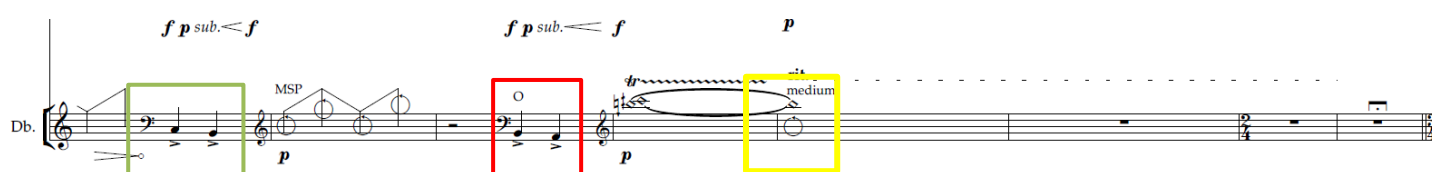


Figure 78 Ellen Jacobs, *And In Between, There Is ...*, (2024), 10, 70-77, double bass.

<sup>109</sup> “ABC van muzikale begrippen”, *Concertgebouw Brugge*, 30 June 2020, accessed on 19 April 2025, from <https://www.concertgebouw.be/nl/abc-van-muzikale-begrippen>.

<sup>110</sup> “Sul Ponticello”, *Classical Voice San Francisco*, n.d., accessed on 19 April 2025, from <https://www.sfcv.org/learn/glossary/sul-ponticello>.

In measure 70, the glissando is briefly interrupted by two prominent notes: C2 and B1 (see blue box). Recalling the earlier observation that the overtones of the G2 base are spread throughout the wind section, creating a strong spectral interrelationship, a similar logic applies here. While C2 and B1 are not directly linked to G2, their higher counterparts (C6 and B4) are, reinforcing spectral cohesion and creating a rich, layered texture within the orchestration. Similar higher pitches also emerged in the bass clarinet and trumpet.

Following these, a shorter harmonic glissando appears one measure later, now enhanced by the use of circular bowing. Circular bowing is a technique where the performer creates a circular motion with their right arm during the bow stroke, producing both pitch and bow hair noise. It is the most effective for lower notes.<sup>111</sup> Alongside MSP, this section explores overtones extensively in a higher register on an instrument not typically suited for such pitches. After the second break in the harmonic glissando, the double bass settles on two marked notes—B1 and A1 (see red box)—which reference a subtle spectral interplay with both pitches referring to respectively Sul I and Sul I and II. B is strongly emphasized, while A's ambiguous roots subtly weave tension into the microfibres of the sound.

Thereafter, the double bass shifts to a high register, playing B4 and C5 together. C5 connects indirectly to Sul I's 11<sup>th</sup> harmonic and directly to Sul II's 7<sup>th</sup>. In the ensemble, its vibrato mirrors the trumpet's halve valve split tone, sharing a turbulent quality but with greater intensity. This effect may reference the turbulence of Sul I's 11<sup>th</sup> partial C6, though the musical context suggests a Sul II manifestation, especially with the winds. It highlights the creative shaping of sonic material within a broader musical framework. In bar 74, the double bass concludes with B4 in circular bowing (see yellow box). While this technique is typically effective for lower notes, in this case it adds an intriguing noise element that might upset the overall sonic balance because of the way the bow hair is pressed against the string.<sup>112</sup> Note that this thesis does not delve into the details of instrumental acoustics or the finer points of these techniques.

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<sup>111</sup> "Circular Bowing".

<sup>112</sup> Ibid.

Overall, Jacobs uses the double bass in a nontraditional manner, introducing significant turbulence and spectral variation throughout the piece. Despite the ‘anchored’ tones C2 and B1 (bar 70), as well as B1 being prominently accentuated, the harmonic glissando in particular refers to a subtle spectral tension, keeping the sound moving and in a vital state. Relying on the ‘established’ spectral base does not automatically mean that all spectral content conveys a stable effect, as proved here.

The musical score for the percussion section of Ellen Jacobs' 'And In Between, There Is ...' (2024) is presented in two staves. The top staff, labeled 'crotales', begins with a melodic line on C5, marked 'p' (piano). It then transitions to a section marked 'mf' (mezzo-forte) and 'pp' (pianissimo). The bottom staff, labeled 'vibra', also begins with a melodic line on C5, marked 'p', and transitions to a section marked 'f' (forte) and 'l.v.' (laissez vibrer). The score is in 3/4 time and includes dynamic markings and articulation symbols.

Figure 79 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 64-69, percussion.

The percussion sections start Segment C with the crotales and vibraphone, both melodic instruments. They start off with a C5, for the crotales played with a ribbed metal stick at the edge of the instrument where it is used like a bow. The vibraphone employs a bisbigliando technique. Both instruments seem to enforce the C5 in the bass clarinet section, also using a bisbigliando. Let us recall what effect this pitch of the bass clarinet had. It corresponds to the 11<sup>th</sup> harmonic of G2 (C6) and the 7<sup>th</sup> of Sul II, further emphasized by the matching pitch in both percussion sections. The crotales then briefly switch to the bass drum for three measures. The idea that its turbulent character is spread out could be argued by the small mark l.v., which means *laissez vibrer*. Both instruments are prone to vibration, which is why they can be of use for enriching another note and their own.

Figure 80 Ellen Jacobs, *And In Between, There Is ...*, (2024), 10, 70-77, percussion.

However, things get particularly interesting in bar 70 for the vibraphone. Two notes are played simultaneously – F#4 and A4 – which blend into B4 and C5 (see pink box). The following measure shows the same. The crescendo towards the second F#4 – A4 could refer to the potential spectral importance of these notes, and their strong relationship with Sul II. Although A4 can be considered an overtone of D2 or, when transposed, of G2, it is the combination with F#4 that makes the D2 association stronger. Once again, musical context is important for the overall interpretation.

In bar 71 for the crotales, A5 and B5 (see orange box) are played together at a mezzo-piano dynamic; these notes represent the 9<sup>th</sup> and 10<sup>th</sup> harmonics of G2, respectively and for A too the 12<sup>th</sup> of Sul II, further underlining its ambiguous state. This bar also features a harmonic glissando on the double bass, using techniques like *Molto Sul Ponticello* and circular bowing. The metallic pitch from the *Molto Sul Ponticello* and the noise element introduced by circular bowing suggest that two different spectra are overlapping, thereby creating a subtle tension that invites further spectral investigation. This argument is enforced by the fact that the pitch content in itself relies on both fundamentals and they are paired in various ways to either confirm one base, or touch upon both.

In subsequent measures, the vibraphone plays A4–B4 and then C5–F#5 (yellow box), while the crotales sound B5–C6 simultaneously (blue box). The crotales clearly reference the 10<sup>th</sup> and 11<sup>th</sup> harmonics of G2. Meanwhile, A4, C5, and F#5 trace back to the D2 spectrum as its 10<sup>th</sup> harmonic, while A4, B4, and C5—regardless of octave—also function as overtones of G2. With A4 and C5 appearing in both groups, F#5 and B4 serve as spectral links to D2 and G2, respectively. While future spectral visualizations will determine the dominant spectrum, the score suggests that G2 likely takes the lead overall. This is supported by measure 73, where the double bass plays the same notes as the crotales, however one octave lower. Finally, the added vibrato and subsequent circular bowing indicate that the overall sound

undergoes a slight transformation, particularly because of F#4 and F#5 pushing the spectrum towards a state of change. What becomes apparent is the fact that the composer spreads partials from different origins all across the ensemble, colouring them with different timbres. The minor prelude in bar 74 even contains these differing partials (C5-F#5-A5-B5), perhaps even imitating the prelude performed in bar 4-5 (D4-Eb4-G4-B4) fully residing to Sul **I**, however Eb4 not being in order and referencing a higher register. Here, on the other hand, the collection is ‘questioned’ by B5, the only one **not** residing in Sul **II**. The idea is similar, but the fundamental is different. The double bass compromises to this (minor) fluctuation due to the slowed down vibrato and circular bowing (ref. Figure 78).

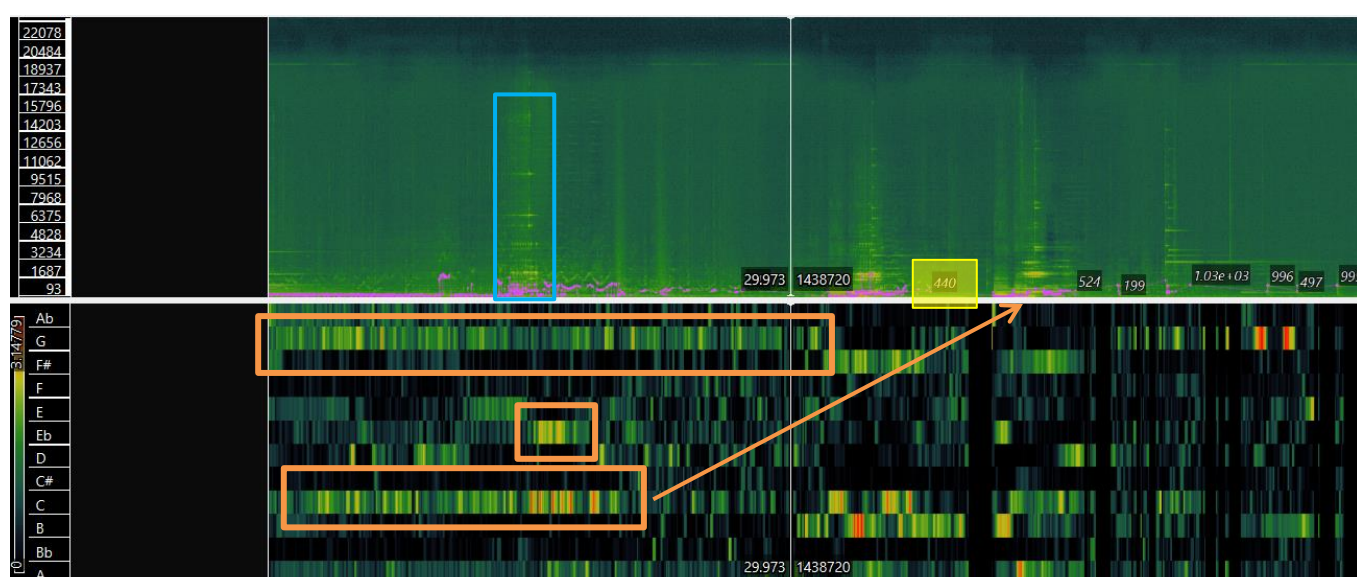


Figure 81 Spectrogram, Aubio Pitch Detector and NNLS Chroma plugin for the percussion + double bass section segment C.

The harmonic glissando on the double bass resists a singular dominant pitch due to its constant movement, yet both the Aubio Pitch Detector and NNLS Chroma plugin provide insight. Amid the glissando’s ‘chaos,’ NNLS Chroma organizes detectable pitches into clear bin pitches, with those in orange boxes marking the dialogue between percussion and double bass at that instance. The most apparent (from the bottom up) are C, Eb, and G which all correspond to Sul **I**, with C5 resurfacing in Aubio later (see orange arrow, 524 Hz). Examining the initial glissando, its spectrum subtly waves but avoids extreme heights, unlike the wind section. *Molto Sul Ponticello* introduces friction, creating a peak in the Spectrogram Layer (see blue box). Even without new partials, movement emerges from instrumental techniques, lending the double bass a rumbling quality, diverging from its conventional role of providing a stable underground. The detected 440 Hz ( $\approx$  A4), highlighted in yellow, aligns with percussion in bars 70–73 and its transposed version in the

double bass (bar 72), challenging Sul I further. NNLS identifies bins for both Sul's at this moment. Spectral slope and RMS-energy will reveal its broader energetic impact.

Ultimately, the plugin outputs highlight spectral duality; Aubio, aside from 440 Hz, aligns with Sul I partials and their transpositions, while NNLS mainly illuminates Sul II bins. This suggests Sul I's greater stability and dominance, yet its interaction with techniques like MSP, flageolet, and glissando absorbs the friction introduced by Sul II's residues.

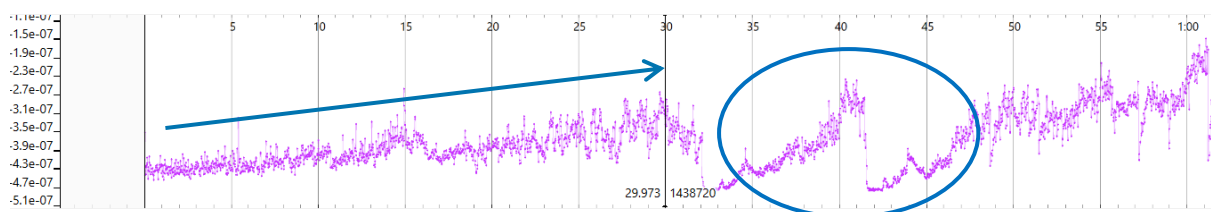


Figure 82 Spectral Slope output for percussion and double bass segment C.

Given the erratic nature of the slope shown on Figure 82 throughout almost the entire segment, one can assume that most of the spectral energy lies in the upper frequencies, suggesting significant spectral movement, in the sense that the spectral balance is distorted by more accentuation on those high frequencies in question.

Furthermore, the frequencies listed on Table I (Appendix) mostly consist of so-called “cent deviations”, meaning that the frequency of a higher overtone does not always match an exact integer multiple of the fundamental but rather fluctuates between neighbouring values.<sup>113</sup> When examining the harmonic glissando of the double bass, its effect comes to the forefront (see blue arrow). The spectral slope does not appear extremely steep; instead, it develops gently like a “pebble road” of harmonics. Two noticeably steeper segments, circled in blue (measures 70–73), correspond to the influence of the low anchor notes (in both percussion and double bass). This interaction introduces spectral elements such as F#4 and F#5, establishing subtle tensions and hints of spectral tension.

It appears that the double bass is probing the limits of the G2 spectrum, while the melodic percussion further accentuates particular overtones and introduces ‘inharmonic’ features, in the sense of them not corresponding to Sul I.

<sup>113</sup> “Tuning IX: Cent deviations”, *Carey Beebe Harpsichords*, 2011, accessed on 26 May 2025, from <https://www.hpschd.nu/index.html?nav/nav-4.html&t/welcome.html&https://www.hpschd.nu/tech/tun/cents.html>

In bar 74, as these peaks keep on increasing, the double bass and crotales produce B4 and B5 with significant vibrato (*laissez vibrer* and *vibrato ritenuto*), respectively. It is the high nature of the tones that causes the spectral balance to tilt, implementing spectral change and granularity.

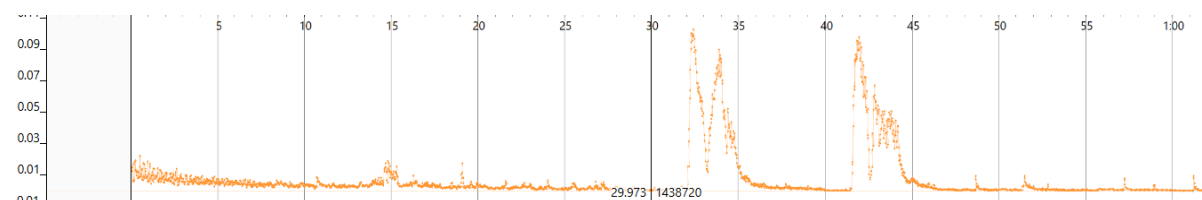


Figure 83 RMS-energy for percussion and double bass, segment C.

The RMS-energy shows two prominent peaks in a frame of relatively stable energy. These peaks are in specific correlated to bar 70 and 72. These are the moments where the double bass accentuates C2-B1 with F#4-A4 and B4-C5 in percussion (bar 70), followed by B1-A1 with percussion playing A4-B4 and C5-F#5. Partials have been mixed with each other and, on top of that, lay on a base of subtle spectral uncertainty as well. These peaks in energy mark moments in time where the friction is solidified and the glissando floating is (temporarily) stopped. However, more remarkable is the relatively stable RMS-foundation being laid out here. All of the spectral frictions and characteristics depicted earlier seem to perform on a background level more than the forefront, with two disruptions taking place. The sound looks to take a moment of recession, allowing the winds to punctuate the sonic fabric.

This output shows that causing spectral change does not have to be overly accentuated and foregrounded, but that it can equally nibble at the music's invisible underlayer thus causing tension from within. Even apart from the detailed pitch content, the overarching energetic trend of the sections shows creases on a flat energetic surface, proving the sound's vitality in a different energy level compared to previous examples.

Compared to the wind section, they offer a more defined, pulsating articulation of spectral tensions, while the percussion/double bass group continuously explores and expands these harmonic boundaries, while mostly remaining on a background level. This interplay not only enriches the overall texture but also underscores the intricate relationship between stability and dynamic fluctuation within the piece.

## 3.1.4.3 Split segment for the piano

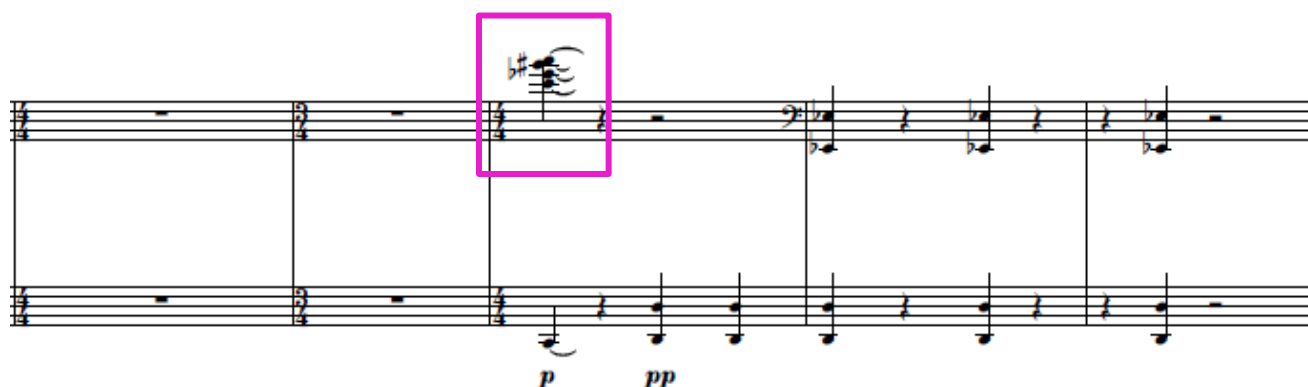


Figure 84 Ellen Jacobs, *And In Between, There Is ...*, (2024), 9, 65-69, piano.

On Figure 84, the right hand starts segment C (bar 67) by playing the chord (from bottom to top): **C6** – **Eb6** – **G#6** – **A6**, marked in pink. The left hand accompanies with C2. Considering the earlier information that the double bass plays an harmonic glissando on Sul I (G2), the chord can be interpreted as a collection of overtones relating to this fundamental, namely C6 as the 11<sup>th</sup>, Eb6 as the 13<sup>th</sup> and A6, with both C and A acting as ambiguous additions, yet here C6 is a direct link to Sul I. However G#6 currently seems the odd one out since it does not directly correspond to any harmonic in Sul I's spectrum. Looking back at the prominence of D2 and its spectrum as well, G#6 is the transposition of its 11<sup>th</sup> partial. In this context, the left-hand C2 acts to reinforce the dominant Sul I spectrum, while the introduction of G#6 creates a subtle spectral interference—a bridge that both contrasts with and enriches the overtone structure produced by the double bass. The deliberate inclusion of pitches outside the pure harmonic series serves to enhance the overall harmonic complexity and the dynamic spectral interplay within the composition.

However, upon further investigation of bar 67 in the left hand, the piano resides to D2-D3 maintained until bar 69, while the right hand plays Eb2-Eb3. Sul I seems to be present in the right hand, Sul II in the left hand. Due to the relatively stable timbral nature of the piano, these notes can however be interpreted as anchors for the Sul I-spectrum.<sup>114</sup>

<sup>114</sup> Neville H. Fletcher and Thomas D. Rossing, *The Physics of Musical Instruments*, (Springer Science & Business Media, 2012): 352-401.

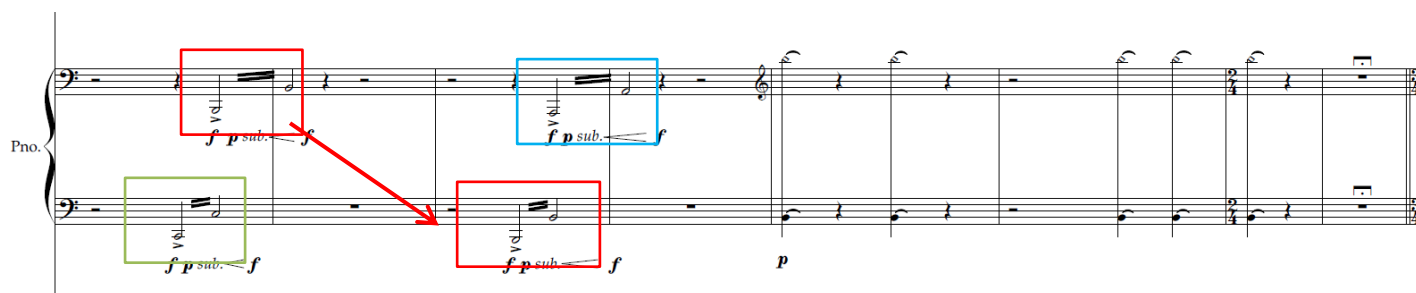


Figure 85 Ellen Jacobs, *And In Between, There Is ...*, (2024), 10, 70-77, piano.

From bar 70 onward, the piano continues to play strong pitches, with the dynamic marked forte – sub. piano – forte, emphasizing the prominence of the pitches. The left hand plays C2–C3 (green) while the right hand articulates B1–B2 (red). These considerably low pitches add to their overall strength. The transition between these pitches is performed through a bisbigliando, enriching the sonic texture. This turbulent character persists until bar 73. Spectrally, all pitches can be traced back to the Sul I-spectral base established by the double bass, which simultaneously plays a combination of these pitches: C2–B1 in bars 70–71 and B1–A1 in bars 72–73 (see red boxes and arrows). This section in the score is clearly marked, with C flowing into B, which then moves further in the left hand before ultimately resolving toward A (blue). All three pitches reside to Sul I ( $A_5 = 9$ ,  $B_5 = 10$  and  $C_6 = 11$ ).

In bar 74, the piano shifts to playing B2–B5 until the end of the segment, now in a soft piano dynamic. This quieter expression could hint at a return to a sense of naturality within the spectrum, following the subtle spectral interferences and inharmonic textures introduced by the double bass' circular bowing technique. Furthermore, it can be suggested that this aligns with the trumpet's halve valve split tones, simultaneously fading out the segment, however in that case, subtle friction remained. While this interpretation remains hypothetical, further analysis via spectral visualization could confirm or deny this hypothesis.

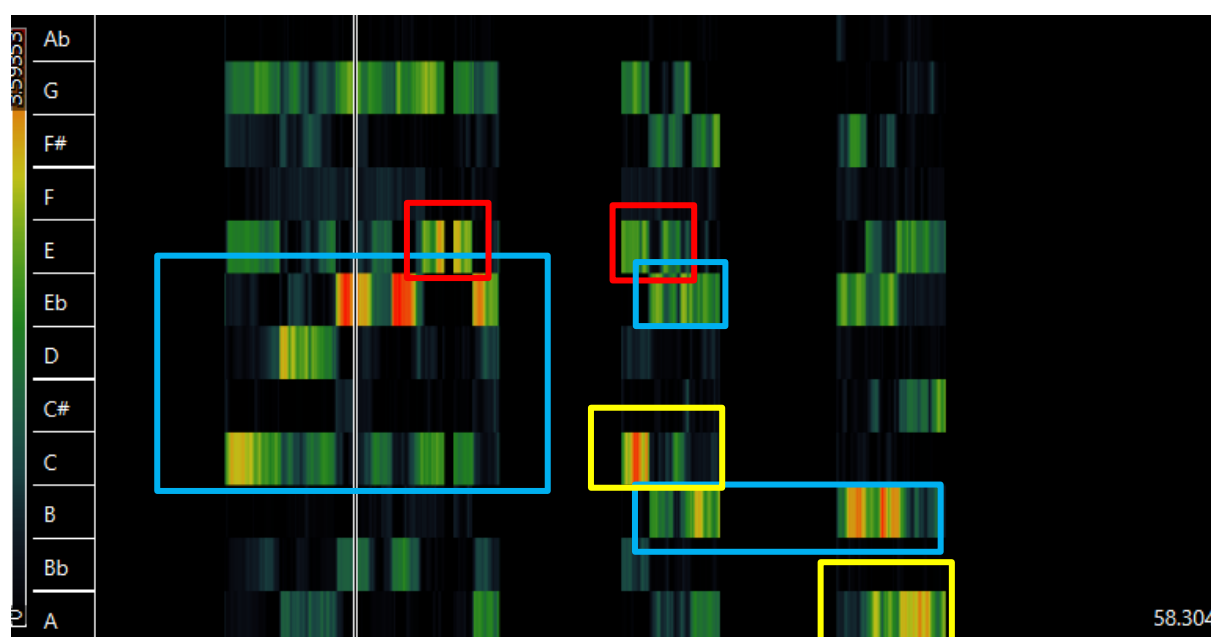


Figure 86 NNLS chroma plugin for the full piano segment C.

For the Sonic Visualiser analysis, the aubio pitch detector will not be utilised, as the fundamentals detected are already highly straightforward and logical due to their perfect alignment with the score. The piano plays little variation in pitches, making it more accessible to distinguish them by the score alone (ref. Chapter 2). However, in that case the NNLS Chromagram plugin is of interest considering its capability of visualising the present pitches through chromatic counterparts, making the overtones more visible due to the benefits of the visualisation format itself (ref. Table 2.1). Blue boxes are mainly Sul I partials, the red boxes Sul II, and yellow boxes indicate dual/ambiguous partials, referencing both.

The most vivid pitches are located at Eb, corresponding to the first opening chord of the piano for this segment. The other bins lighting up are D and C, with the latter also being part of the chord yet the former being present in the left hand (see blue box). Reconsidering the very first presentation of the 11<sup>th</sup>, 12<sup>th</sup> and 13<sup>th</sup> harmonic of Sul I (bars 10-17, Figure 10), the parallel with the bins lighting up here and additionally those present in the score can be drawn. This seems to solidify Sul I partials functioning as a stable anchor in the piano.

However the bin marked in red, linked to E, does spark interest. The plugin has picked up this pitch due to its longer sustain after the key was pressed on the piano. Considering that Eb2-Eb3 (right hand) is played at the same time as D2-

D3 (left hand), E can be traced back to the harmonic overtone series of D2, referring to the 9<sup>th</sup> partial E5 (Table I). This offers new insight into the earlier score interpretation, suggesting that D2-D3, particularly in bar 68 alongside Eb2-Eb3, is partially linked to the Sul I spectrum. Given the prominence of D2 compared to other partials, its subtle interactions with Sul I seem increasingly plausible. G#6 in the introductory chord further supports this argument. Meanwhile, the consistently apparent tones, marked in red, correspond to G5, reinforcing the idea that the Sul I spectrum maintains a strong presence despite subtle spectral interference from other overtones.

With C appearing stronger than before, and later B showing in blue, the role of the piano as anchoring Sul I further is apparent. However, a number of other bins are appearing as well, such as Eb, E, F# and G. Yet again, references to the Sul II spectrum remain, however very subtle (E and F#). If they were more dominant, than there was a higher chance of them showing by the Aubio Pitch Detector. However, as argued before, the fundamentals detected are already highly straightforward and logical due to their perfect alignment with the score. By maintaining a critical stance and employing other plugins for pitch detection, we have now come to discover the subtle presence of overtones linking to the D2-spectrum rather than the G2-spectrum. In terms of the resonance of the pitches present, such overtones can be seen as a natural extension of their being. However, when considering the earlier percussion splits, especially in the vibraphone, which reproduces similar pitches in bar 70-71 except for E3, it becomes apparent that the composer intentionally distributed the overtones of D2 across other instruments known for their vibrational qualities. This deliberate placement seems designed to introduce subtle tension while still preserving the overall spectral anchor of the piece. Similar subtlety occurred in the other sections as well, however in the piano's case it is more outspoken. Given the findings so far, spectral flux levels are expected to stay lower than in other segments due to the subtle, receding tension.

A (yellow) and B (blue) also appear later. With A being both a harmonic for Sul I and II, B appears only for Sul I. This selective harmonic distribution underscores the composer's intention to layer distinct spectral components. It occurs either across the ensemble or within one instrumental part, continuously shifting timbre and overtone manifestation. This section leans toward spectral blending, with dual pitches marked in yellow on the NNLS output serving as gateways to this effect.

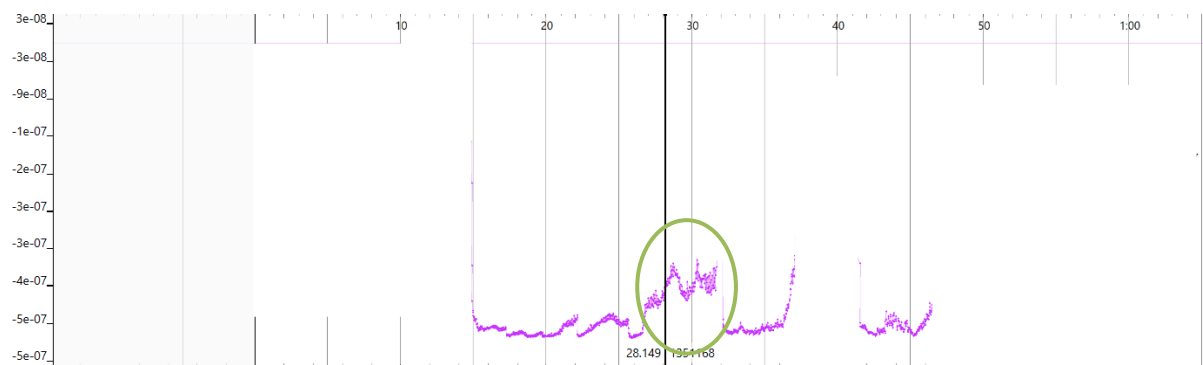


Figure 87 Spectral slope for piano, segment C, silent parts hidden.

Next, the Sonic Visualiser analysis of the Spectral Slope is used to explore the sonic and spectral behaviour of the piano. Based on the previous statement, motivated by *The Physics of Musical Instruments* written by Neville H. Fletcher and Thomas D. Rossing (2012), the piano contains a ‘stable’ timbre, meaning that its character is more soft instead or sharp, as was the case for the trumpet. This timbral fingerprint can influence the sounds produced by the instrument, making certain pitches more prevalent than others.<sup>115</sup>

Overall, the spectral slope climbs up subtly, meaning that there is in fact a shift in energy towards higher frequencies, although not abruptly. The larger spectral slope, circled in green, corresponds to the sustain of the notes in bars 70-73. These measurements suggest that the subtle variations in spectral energy distribution are more attributable to the instrument’s inherent resonance than to deliberate compositional manipulation. This argument is supported by chapter 5.2 “Acoustics of Timbre” in *Acoustics and Psychoacoustics*, written by David Howard and Jamie Angus (2013), stating that the so-called LTAS (Long Term Average Spectra) is a useful way of understanding the above spectral slope as dominated by the instrument’s inherent acoustic properties rather than by manipulations. The averaging inherent in LTAS essentially highlights the natural resonance of the instrument, supporting the view that the modest spectral variations observed are intrinsic.<sup>116</sup>

<sup>115</sup> Fletcher and Rossing, *The Physics of Musical Instruments*, 352-401.

<sup>116</sup> David Howard and Jamie Angus, “5.2: Acoustics of Timbre” in *Acoustics and Psychoacoustics*, 4th ed. (New York: Routledge, 2013), 233-34, <https://doi.org/10.4324/9780080961873>.

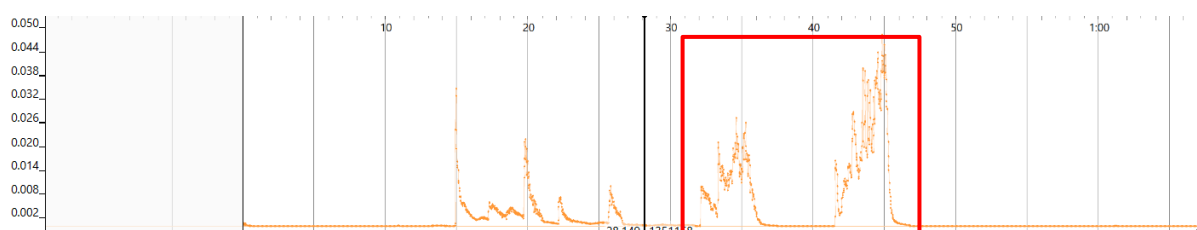


Figure 88 RMS-energy output for piano segment C.

The two prominent peaks circled in red on Figure 88 highlight bars 70-73. The increased amplitude detected here is attributed to the strong crescendo residing in the piano, with emphasis on B2 and later on A2. Notice that the second peak is larger than the first, highlighting the increased emphasis on A1-A2 as (1) a Sul II reference or (2) a solid reference to the higher 9<sup>th</sup> partial of Sul I. Considering the score information provided on this part, the Sul I reference prevails, bouncing partials between left and right hand, making them vital and move. This explains the larger peak, while the preceding smaller peaks mark deliberate moments through the piano's Eb3-Eb2 and D3-D2 chords (Figure 85), shaping the segment's structure in the output. In a way, it acts as a 'spectral metronome.'

#### 3.1.4.4 Conclusion for Segment C

Regarding spectral flux catalysts, the percussion and double bass section is suggested to have contributed the most, particularly due to the double bass' profound harmonic glissando. The piano, by contrast, is considered to have exhibited the least spectral changes, its largely steady chords, though occasionally shifting fundamentals, contributed more to spectral balancing rather than the turbulent storm observed in previous segments.

The trumpet and bass clarinet subtly engage with spectral tension—the trumpet's halve valve split tones introduce brief disturbances, while the bass clarinet maintains a steady sonic path. This reinforces the idea that winds exhibit less spectral flux compared to percussion and double bass.

Furthermore, the largest fluctuations in spectral slope were again attributed to percussion and double bass, while the winds demonstrated significantly less variation, though with higher RMS energy. This positioning suggests that the winds primarily occupy the foreground of the ensemble, scraping the surface of spectral interaction, whereas percussion and double bass manifest it more profoundly on a background level.

The piano, despite its underlying spectral interactions and blending, remains a steady anchor, exhibiting almost no spectral slope changes. The RMS further highlights two prominent peaks in time, corresponding to percussion and

double bass, reinforcing this anchoring effect. Ultimately, the interplay between spectral distribution and deliberate instrumental techniques differentiates the roles of the piano and percussion-plus-double bass in how they contribute to flux variations.

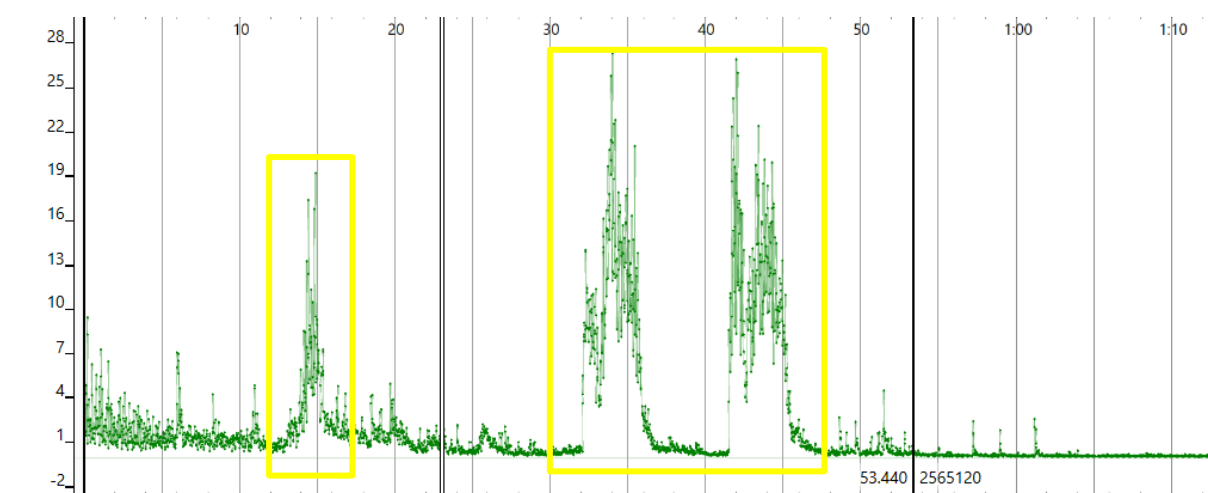


Figure 89 Spectral Flux for Segment C.

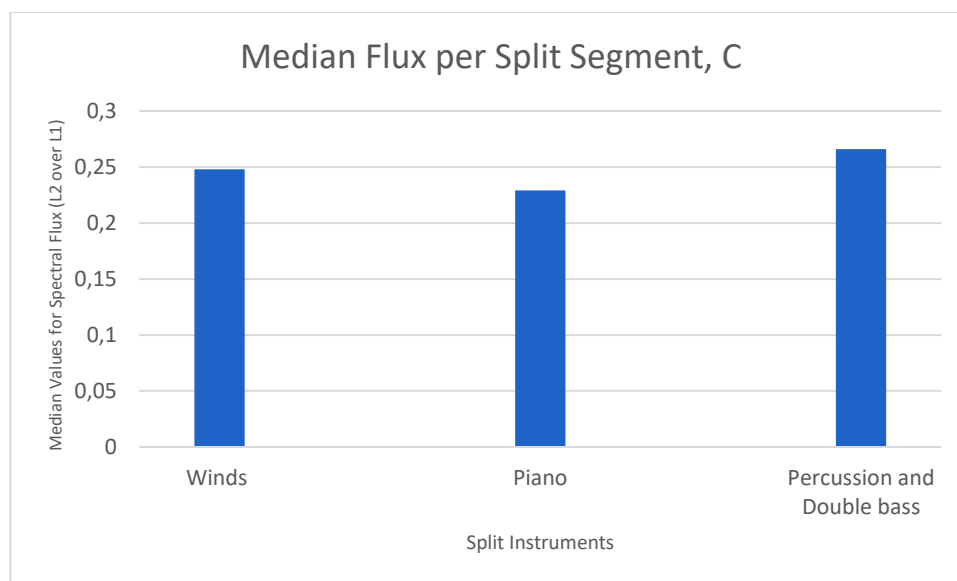
Figure 89 exhibits the spectral flux output for Segment C in its entirety. Changes in the spectrum do seem to occur, however less spread out and more concentrated. These concentrations are visible in the three large peaks, marked in yellow.

The first peak corresponds to bar 65-66, in which the bass clarinet plays a succession of pitches: D4-Eb4-D3-C5. The harmonics presented in bar 10-17 (Figure 10) by the double bass on Sul I seem to be transposed here and given yet another manifestation through the specific change from the clarinet to bass clarinet. Furthermore, due to the dual roles of almost all pitches except Eb4, spectral change looks to be induced and is confirmed by the first peak in question. It marks a deliberate point in time. The harmonic glissando's flux on the double bass playing alone for an instance exhibits a floating spectral flux, meaning that a controlled spectral movement where frequencies shift within a defined range takes place, maintaining an overall structural coherence while allowing for subtle variations in spectral energy. This aligns with the free rhythm harmonic glissando on Sul I for the double bass. Its instrumental techniques (O-MSP-O) further enhanced these subtle variations in question.

The two following peaks (second yellow box) are representing bar 71-72 and 73-74. The entire ensemble plays together here, with the piano and double bass in particular playing concrete accents which solidify the play. The percussion, in

the meantime, adds subtle Sul II partials to the mix and gives them texture through vibration/resonance. The wind section, on the other hand, sustains a C4 – B4 for the bass clarinet and a B4 for the trumpet. The turbulence caused in the last peak drizzles towards a significant decrease in flux, carried by the trumpet's halve valve split tones and the double bass' B4, its 5<sup>th</sup> partial, which appears in other instruments as well.

Below, the chart diagram shows the division in spectral flux across instruments, calculated through their individual medians (ref. Table 2.4).



**Graph 3** Median Flux per Split Segment C

The above chart diagram shows a clear division between the split segments in terms of spectral flux contributions. As suggested before, the piano contributes the least, due to its stable anchoring practices. The percussion and double bass, on the other hand, have the largest share in spectral flux output, which can be attributed to the double bass' free-rhythm harmonic glissando throughout the first half of the segment and its deliberate use of instrumental techniques to shape timbre, thus indicating spectral change. Although this section did not exhibit extreme values for RMS-energy, it effectively demonstrates spectral flux on a background level, implementing a moment of spectral stability within the composition without flattening out dynamics in any way. The winds, meanwhile, occupy an intermediate position among the spectral flux catalysts due to their mix of solidified pitches and deliberate instrumental techniques, particularly in the trumpet's pulsation and halve valve split tones.

When it comes to the full spectral flux for Segment C, its median (see Table 2.4) has a value of 0.216. This is the lowest spectral flux value achieved so far. The differing values throughout already indicate a vital sonic state in which the composition exists. Furthermore, the preceding analysis with the score and plugins hinted at spectral movement occurring on a background level, in contrast to previous segments, which were more foregrounded. The clearest example of this is the double bass' harmonic glissando. Speaking purely in terms of spectral connectivity, most pitches present could be traced back specifically to Sul I, though slight implementations of Sul II partials were observed as well. As Sul I's 5<sup>th</sup> partial B4 recurred multiple times throughout, the spectral anchoring—manifested in the piano, for example—demonstrates that spectral change does not take large leaps as previously observed.

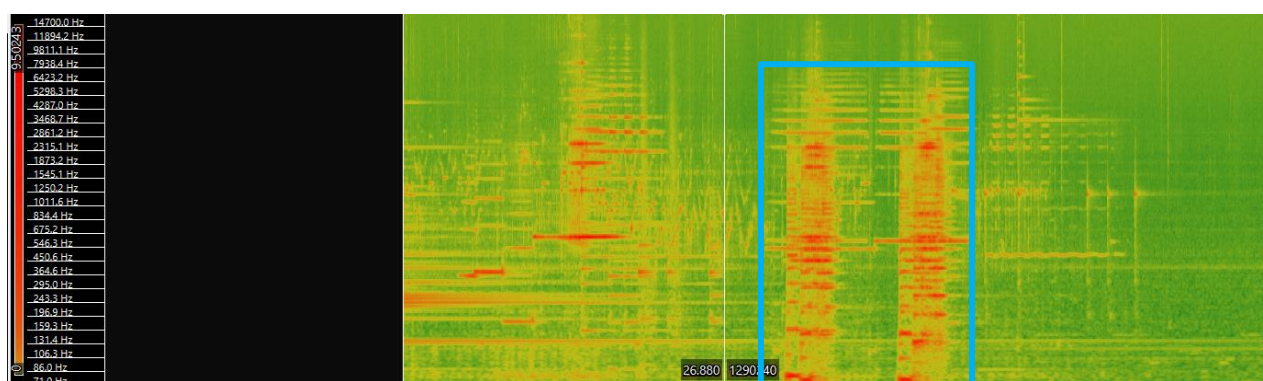


Figure 90 Constant Q output for Segment C.

As for the Constant Q output, the overall frequency count, particularly spectral density, is significantly lower compared to previous segments. The two most dense parts correspond to the two largest peaks (see blue box) in the spectral flux output, suggesting a pool of spread-out frequencies that culminate in these moments before rapidly decaying. This does not qualify as flutter time, which requires micro-fluctuations that continuously flutter through time and space, eventually producing subtle spectral modulation (Figure IV, Appendix E). Instead, the modulation here is decaying, interrupted by two distinct events. It is also not ambient time, which implies a continuous presence of sound with only microscopic variations (see Figure III, Appendix E). Despite having the lowest spectral flux recorded so far, the time structure leans toward ripple time, characterized by structured oscillations that maintain separation between sonic events, which is clearly visible.<sup>117</sup> The variability among time structure categories, as well as within them, suggests that they are highly

<sup>117</sup> Thoresen and Hedman, "Spectromorphological Analysis of Sound Objects", 129–41.

context-dependent and can manifest in various ways. In this case, the defining factor was the two breaks in the spectral flow (see Figure 89). In this case, however, the ripple time structure does not change into a dense modulation but ends with these deliberate breaks.

### 3.1.5 Segment D: bar 78 – 98

#### 3.1.5.1 Wind section

Here, the first section presented is the wind section, consisting of the bass clarinet in Bb and the trumpet in Bb.

Figure 91 Ellen Jacobs, *And In Between, There Is ...* (2024), 11, 78-85, bass clarinet and trumpet.

The segment is introduced by the trumpet playing a D5 (marked in yellow as well as its counterpart D4 on bass clarinet), accompanied by a significant amount of instrumental techniques. This creates a pulsating effect, reappearing in this composition plenty of times. Here, it can be seen as a further, more prominent manifestation of the earlier half valve split tone rounding up Segment C. By first implying *senza*, which is then followed by *wawa*, it indicates that there occurs a shift from a more ‘flat’ texture towards the pulsation just mentioned. A *wawa* in specific is linked to a mute on the trumpet creating this effect. It makes the instrument capable of producing a richer variety of overtones.<sup>118</sup>

Since the double bass, the main reference in much of the analysis, is rooted in Sul I, D5 may connect spectrally to it. However, at this moment, the double bass remains silent until bar 86, when it shifts to Sul II. Thus, the note could serve as a subtle prelude to its later Sul II presence. The trumpet’s D5 is projected onto the bass clarinet’s part from bar 81 onward but as D4, a harmonic of both Sul I and Sul II, allowing for dual interpretation. When the bass clarinet plays

<sup>118</sup> Nicolas Bejarano, “Complete Guide to Playing Mutes on a Trumpet”, *Brass Tonebase*, 3 May 2024, accessed on 24 April 2025, from <https://brass.tonebase.co/blog/complete-guide-to-playing-mutes-on-a-trumpet#:~:text=Like%20its%20baroque%20predecessors%2C%20the,the%20stem%20with%20the%20hand>

D4, the trumpet—using a similar technique—sounds Eb4 (see green box). Earlier, the octave Eb5 in Segment C was considered extra emphasized due to its attributed pulsation, particularly given the turbulent nature of its effective 13<sup>th</sup> partial, Eb6. While further spectral analysis is needed to determine if this creates spectral tension or modulation, this earlier finding helps interpret a similar occurrence here. The pulsation, however, is less pronounced.

Bar 85 features the bass clarinet sounding D4-C3 with a bisbigliando. D4, once again, allows for a dual interpretation, particularly in its role as a prelude to the later return of Sul II. An assumption now is that the spectral flux and possibly RMS Energy will exhibit some changes due to the dual character of D4 and similar role for C3 as well. The bisbigliando reinforces this assumption, expanding the turbulence of Sul I's high partials and its possible friction with Sul II. In bar 85, the trumpet sustains Eb4 with similar techniques.

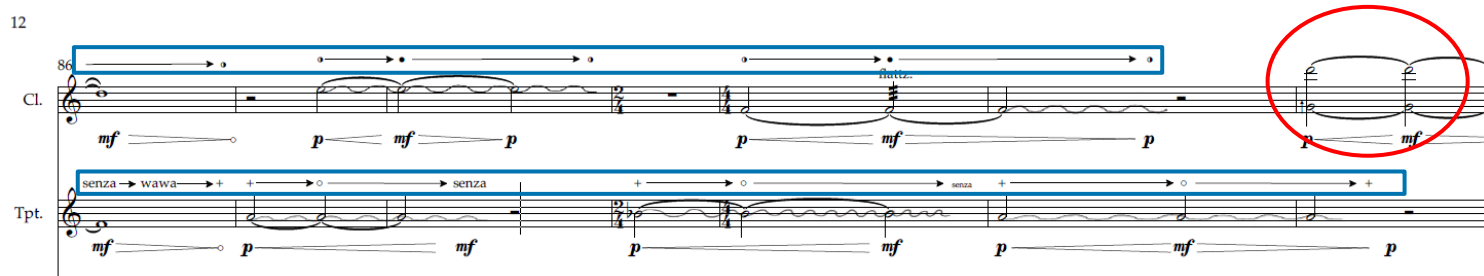


Figure 92 Ellen Jacobs, *And In Between, There Is ...* (2024), 12, 86-92, bass clarinet and trumpet.

More variation can be observed in Figure 92, displaying bar 86 – 92. At this point, the double bass has confirmed the transition to Sul II.

Yet the pitches present in both wind sections seem to mainly hold connection to the earlier Sul I. This assumption can be supported by the very beginning of the composition (Figure 9), namely the chord Eb4 – F4 – G4 – B4. All of these pitches refer back to Sul I (ref. Table I), taking into consideration the transferability of partials across octaves.<sup>119</sup>

In Figure 92, the bass clarinet plays C3 – D4 – Eb3 – F3/C5 (the latter circled in red), while the trumpet sounds Eb4 – G4 – G#4 – G4. Except for D4, C3/C5, and G#4, all connect to the initial chord, sharing a spectral base in Sul I, first introduced by the crotales (Fig. 9). D4 holds a dual role, while C3/C5 connect to Sul I's 11th partial (C6) and G#4 links

<sup>119</sup> Helmholtz, "Von der Schallempfindung im allgemeinen", in *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*, 13-39.

to Sul II (G#5 = 11th partial). Though tracing a pitch to a single fundamental is complex, references in the score, playing techniques, and pitch relationships across instruments help clarify their spectral connections.

Pulsating dynamics remain consistent, appearing in both the bass clarinet and trumpet (marked in blue). Most notes follow a crescendo-decrescendo structure, centring around mezzo forte, with the composer emphasizing these techniques deliberately. Given the dual and ambiguous spectral connection, further analysis using Sonic Visualiser—such as the NNLS Chroma plugin—could help identify which pitches stand out most. This will be examined later.

Residues of the Sul I base primarily reference higher, more turbulent overtones. Eb4 and C3/C5 correspond to the 13<sup>th</sup> and 11<sup>th</sup> harmonics, with C5 exhibiting ambiguity. The composer intentionally transposed them downward, adding texture through bisbigliandi and vibrato. Combined with Sul II integer multiples, this reinforces the sense of implied tension.

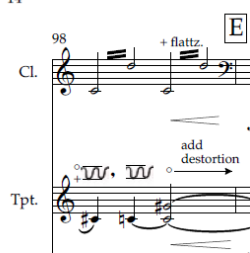
The image shows a musical score for two instruments: Bass Clarinet (Cl.) and Trumpet (Tpt.). The score spans measures 93 to 97. The Bass Clarinet part has a yellow box around measures 93-94, labeled 'bisch.', and a green box around measures 95-97, labeled 'wawa whitout stem'. The Trumpet part has a green box around measures 93-94, labeled 'wawa whitout stem'. Dynamics include p, pp, and cresc. poco a poco.

Figure 93 Ellen Jacobs, *And In Between, There Is ...* (2024), 13, 93-97, bass clarinet and trumpet.

The second half of Segment D for the winds, spanning measures 93-98 (Figure 93), begins with an F3-C5 chord, followed by a sustained Bb2 with pronounced vibrato (see yellow box). Bb2 then alternates with B2 through bisbigliando.

In bar 96, C3 alternates with B2 using bisbigliando, while bars 97 and 98 showcase Bb2 gliding to C4, followed by a quicker glide. The trumpet's B5 carries an exquisite vibrato (see green box), culminating in the second half of bar 93 with a quaver. In bars 95-97, the instrument alternates D4-Eb4 using wawa without stem, heightening the vibrating effect into a sharper, more pronounced quality.

14



**Figure 94** Ellen Jacobs, *And In Between, There Is ...* (2024), 14, 98, bass clarinet and trumpet.

The second half of bar 97 introduces B3-C4 for the bass clarinet, followed by complete distortion in bar 98 (see Figure 94) and the transition into Segment E, where the notes played are B3 – Bb3 – Bb3/F#4 for the trumpet.

Both instruments employ a range of techniques that highlight turbulent elements, with their spectra seeming to float and intertwine. At this point, Sul I and Sul II converge, with Sul II forming the foundation of the double bass, its designated partials (Bb2, D4, and F#4) reinforcing its presence. Yet, lingering overtones continue to reference Sul I, strengthening the idea that these two spectra remain closely intertwined.

Additionally, given the close proximity of pitches in this passage—such as Bb2 and B2, stemming from different fundamentals yet nearly identical in pitch—one could interpret Sul I’s overtones as forming a microtonal relationship with Sul II. The various instrumental techniques occurring simultaneously support this interpretation, as they convey friction, much like microtonal interactions. In a purely harmonic context, the residues of Sul I could be perceived as inharmonic, thus foreign to the base structure. However, given Sul I’s earlier dominance, its lingering presence allows for multiple interpretations. The composer deliberately layers overtones from different fundamentals, creating friction as they extend beyond their original spectra. This reminds one of the *curves of tension* by Kaija Saariaho (1952-2023), in which she fragments a single instrument into countless distinct timbres, crafting a dichotomous musical narrative. Through her deliberate layering of overtones from different fundamentals, she creates friction as they extend beyond their original spectra, approach which can also be recognised here.<sup>120</sup>

<sup>120</sup> Sheanna Wirasinghe, “Tension and the Cello: Kaija Saariaho’s *Petals*”, *Timbre and Orchestration*, 26 April 2023, accessed on 26 May 2025, from <https://timbreandorchestration.org/writings/amazing-moments-in-timbre/2023/4/26/tension-and-the-cello>.

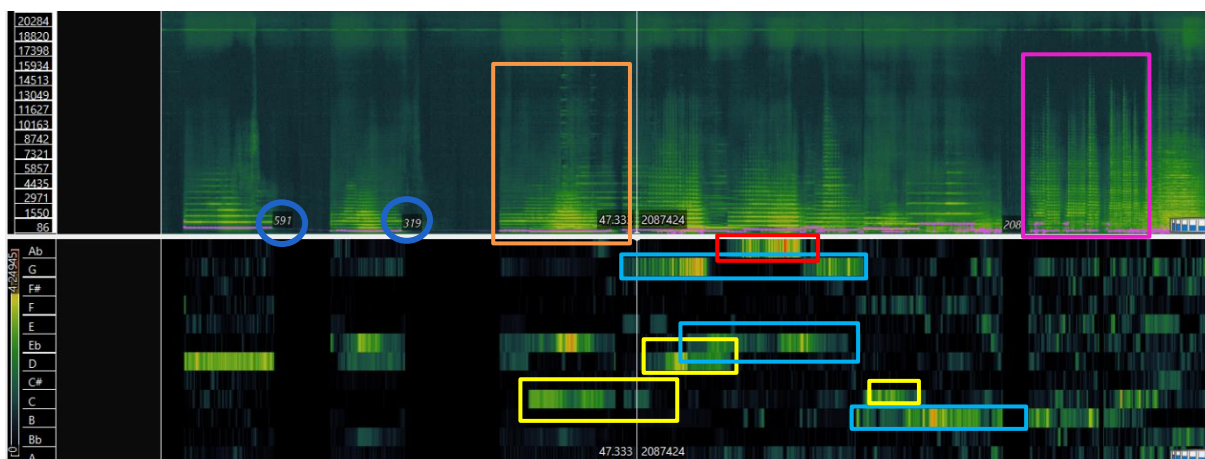


Figure 95 Spectrogram, Aubio Pitch Detector and NNLS Chroma for wind section segment D.

With the help of the Aubio Pitch detector, it appears that the notes produced by the trumpet overrule those of the bass clarinet. Figure 95 shows bars 78-82 yielding outputs of 591 Hz and 319 Hz (both circled in blue), corresponding to D5 and Eb4, respectively. When zooming in on the area marked in orange, the frequency of 319 Hz appears, aligning with Eb4, corresponding to bar 90 for the bass clarinet, however one octave higher.

A possible explanation for the overall predominance of the trumpet is its sharper timbre, resulting from its acoustics emphasizing all partials rather than just the odd ones, as is the case with the bass clarinet.<sup>121</sup> Additionally, the techniques indicated in the score play a crucial role. The alternation between *wawa* and *senza* requires the trumpet to perform a single note—such as the first D5—both with and without the mute. This rapid timbral shift introduces significant sonic variation, further reinforcing the trumpet’s dominance and leading.

The NNLS Chroma bins offer valuable insights as well. The first few bins can easily be linked to the aubio output and score information (see above), yet the ones following them do spark extra interest. All the bins marked in blue are full overtones of Sul I, with no spectral ambiguity taking place. The red bin means the same for Sul II. The yellow bins show dual pitches residing in both spectra. Sul I pitches dominate, but dual excerpts introduce a substantial range of additional frequencies, as seen in the spectrogram layer. When zoomed in, the Aubio pitch detector reveals no dominant pitch in the marked bins. This suggests the section’s multi-voiced nature is so strong that individual particles blend into a broad spectral space, creating spectral tension—evident in the multiplicity of bins within the NNLS Chromagram

<sup>121</sup>Oakes, “Clarinet Multiphonics”.

plugin. The zoom-in on Aubio for the pink-marked spectrogram layer reveals a predominance of 315 Hz ( $\approx$  Eb4) in bars 96-97 for the trumpet, accompanied by pronounced vibrato or a vacillating pitch movement. At this point, the NNLS Chroma plugin no longer detects strong bins.

The bins marked in blue, red and yellow contribute to the later increase in spectral density (pink box). They briefly anchor to the trumpet's Eb4 before losing stability, as partials from different fundamentals blend. The composer's unique instrumental techniques shape timbre and drive the modulation to its final stage.<sup>122</sup> Findings from the score, Aubio Pitch Detector and NNLS Chromagram confirm a shift toward greater density.

Examining energy-related plugins like RMS Energy and Spectral Slope can clarify whether this truly contributes to the broader context. Current findings already suggest its dominance and strong potential for increased energy.

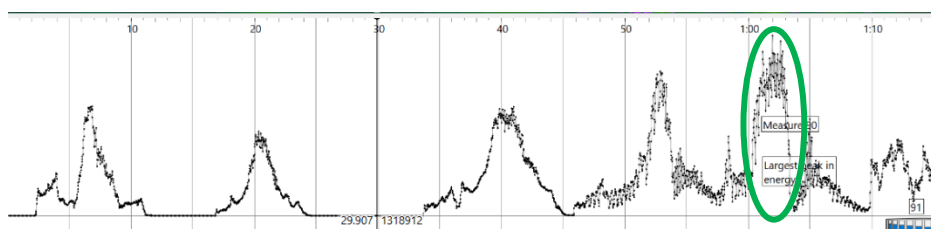


Figure 96 RMS Energy output for bar 78-92, wind section, Segment D

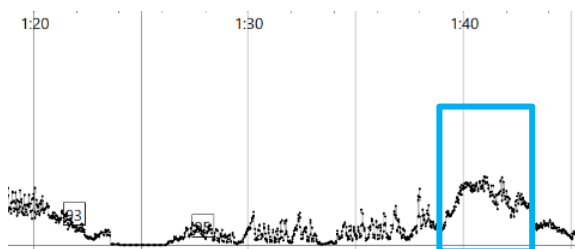


Figure 97 RMS-Energy output for bar 93-98, wind section, Segment D

The highest altitude of the peak occurs when the senza of the trumpet converges with the bisbigliando of the bass clarinet. This moment is marked as “Measure 90” on Figure 96 and circled in green.

<sup>122</sup> Wirasinghe, “Tension and the Cello: Kaija Saariaho’s *Petals*”.

When the trumpet's mute is briefly removed, its spectral energy reaches a higher level. Additionally, this coincides with the convergence of numerous NNLS bins, highlighted in blue, red, and yellow in Figure 95, where they interact and mix distinctly. Combined with the texture of the double bass and its varied spectral correlations, this reinforces the previously discussed narrative of heightened tension when partials of opposing fundamentals intersect.<sup>123</sup>

Beyond this peak, similar patterns emerge throughout the segment, progressively increasing in intensity over time. Leading up to this climactic moment, the wind section generates distinct energy peaks that serve as temporal markers. Despite the underlying turbulence, structural integrity is preserved on a spectral level. This organization arises from the rapid shifts in instrumental techniques, shaping the piece from within through the inherent sonic capabilities of the instruments.

However, towards the segment's conclusion the overall energy diminishes. Even as the wind section continues to employ deliberate instrumental techniques, such as *wawa without stem*, the presence of opposing partials decreases in terms of pitch content and spectral connectivity. Around bar 90, at the highest peak, Eb3 is juxtaposed with G#4, two pitches that lack shared spectral grounding. The most notable decline, however, is observed between bars 95 and 97 (Figure 97), where the bass clarinet and trumpet reference the 11<sup>th</sup>, 12<sup>th</sup>, and 13<sup>th</sup> harmonics initially introduced in bars 10 to 17 by the double bass (here: C3 – D4 – Eb4). At this point, they engage in an instrumental dialogue, accompanied by the Sul I reference, which temporarily seems to suppress the energy. Although the RMS is not entirely flat, it reaches lower peak values overall, emphasizing the significance of musical context.

The subsequent peak marks the conclusion of Segment D (marked in blue, Figure 97). It is characterized by pronounced distortion, partially due to the resurgence of Sul II partials, once again intertwined with deliberate instrumental techniques. For further analysis, we shall now incorporate the Spectral Slope plugin to determine where in the spectrum this energy is most concentrated.

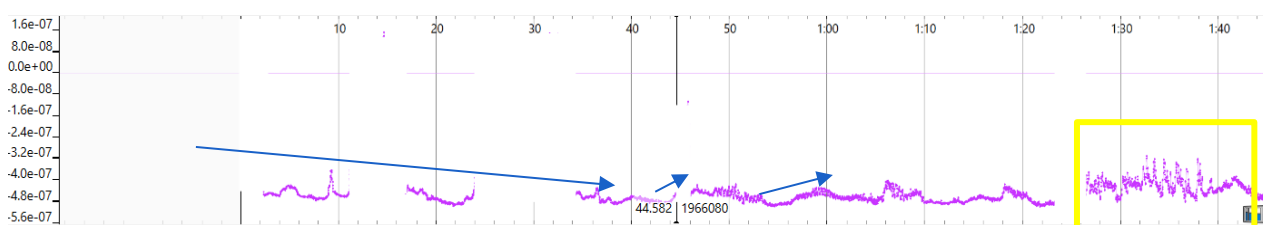


Figure 98 Spectral Slope output for the wind section Segment D, with parts hidden corresponding to moments of silence.

<sup>123</sup> Ibid.

Upon observation of the Spectral Slope output (Figure 98), the values seem to be relatively stable, with no distinct peaks appearing. However, that does not make the line flat, which means that energy does shift across registers, although subtly. For bar 78-82, the slope gradually declines, meaning that high frequencies in the spectrum do not last long (see descending arrow). However, when taking a closer look, the declines are followed by an increase (see first ascending blue arrow), which refers to the moment the trumpetist returns to the *wawa* (in alternation with *senza*). As explained earlier, this mute can activate a rich collection of overtones. The increase does however remain very subtle, but implements timbral differentiation appearing through the Spectral Slope output.

Less subtle are the fluctuating peaks at the end, marked in yellow. This is bar 97-98, which is indicated as having distortion due to the increased addition of Sul II partials, such as F#4 in the trumpet, accompanied by a short succession of differing instrumental techniques (*wawa* without stem → *wawa* + add distortion → *senza*, see Figure 93 and 94). Because the instrument's timbre shifts significantly within a short timeframe, the slope reveals that the spectral balance is disrupted, resulting in a continuous state of spectral instability. In other words, it visualizes a spectral modulation within the wind section, driven by a combination of varying spectral fundamentals and diverse instrumental techniques, utilizing the timbral possibilities of both. For example, allowing the bass clarinet, a typically low-pitched instrument, to play higher pitches inherently introduces instability.

## 3.1.5.2 Piano section



Figure 99 Ellen Jacobs, *And In Between, There Is ...*, (2024), 12, 86-92, piano.

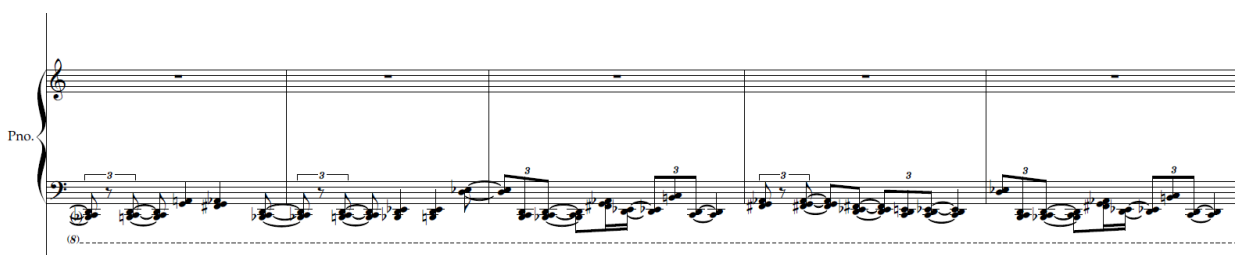


Figure 100 Ellen Jacobs, *And In Between, There Is ...*, (2024), 13, 93-97, piano

The piano enters Segment D with steady chords in bars 86 and 87 – specifically D3-D5 (see red box, Figure 99) and D3-F#5 (see yellow box, Figure 99) – which align with the reintroduction of Sul II in the double bass, suggesting that they present partials of Sul II (see Table I, Appendix C). Next, the piano plays low pitches, joined by the dynamic marking “crescendo poco a poco” which signals a gradual increase in volume, making the piano more prominent within the ensemble. Notably, some of these lower pitches echo earlier elements from Sul I – such as the Eb in bar 88 (circled in blue, Figure 99) – alternating with C, occupying a dual role.

However, the score itself makes it difficult to determine which pitches dominate, together with the perceptual experience of this section. This supports the thesis’ argument that analytical frameworks for non-tonal music, when based mainly on subjective perception, fall short in addressing the spectral and morphological nuances of the piece. One could qualitatively describe it as ‘chaotic’, yet this does not clarify why it appears that way, and what particular qualities contribute to this effect. The acknowledgement of sonic morphology offers an additional layer of insight and moves one toward a fuller understanding of the composition. It is possible that the compositional intent is subtly woven into the morphology of the piano section, overruling simple perceptual analysis.

In that sense, even though the score has brought a lot of information so far, this section will be approached slightly differently due to its ‘chaotic’ nature from bar 88 onward.

The first step is using the Aubio Pitch Detector and NNLS Chroma Plugin to get an idea of what pitch(es) prevail.

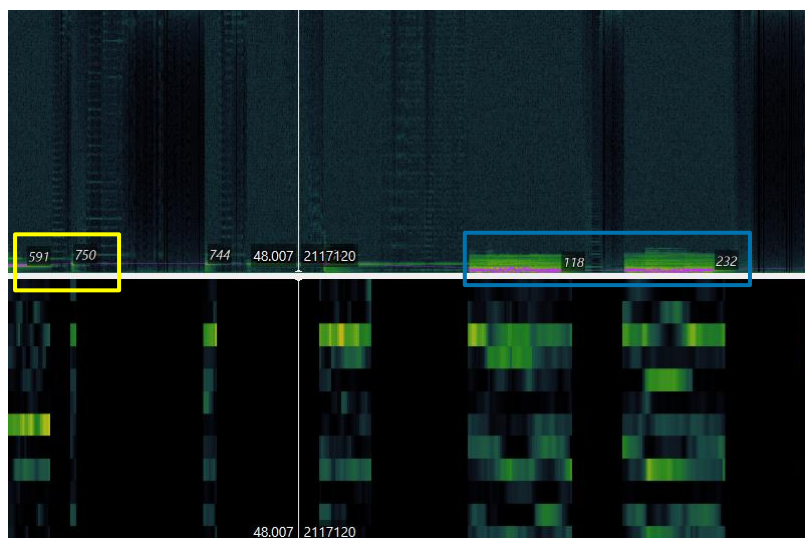


Figure 101 Spectrogram, Aubio, NNLS for bar 86-92 piano segment D.

In bars 86–87, the Aubio Pitch Detector output first registers D5 ( $\approx 591$  Hz) followed by F#5 ( $\approx 750$  Hz), both marked in yellow, matching the expectations set by the score. Moving on, bars 88–89 show a dominant frequency of 118 Hz ( $\approx \text{Bb}2$ ) and then 232 Hz ( $\text{Bb}3$ ). These pitches reinforce Sul II, corresponding to its 13<sup>th</sup> partial ( $\approx \text{Bb}5$ ), which remains prominent until bar 92. Thereafter (see Figure 102), the strongest frequencies are 104 Hz ( $\approx \text{G}\#2$ ) and 212 Hz ( $\approx \text{G}\#3$ ), followed by 421 Hz ( $\approx \text{G}\#4$ ) (all marked in yellow); next in line is G#5, the 10<sup>th</sup> partial of D2, further confirming the link to Sul II.

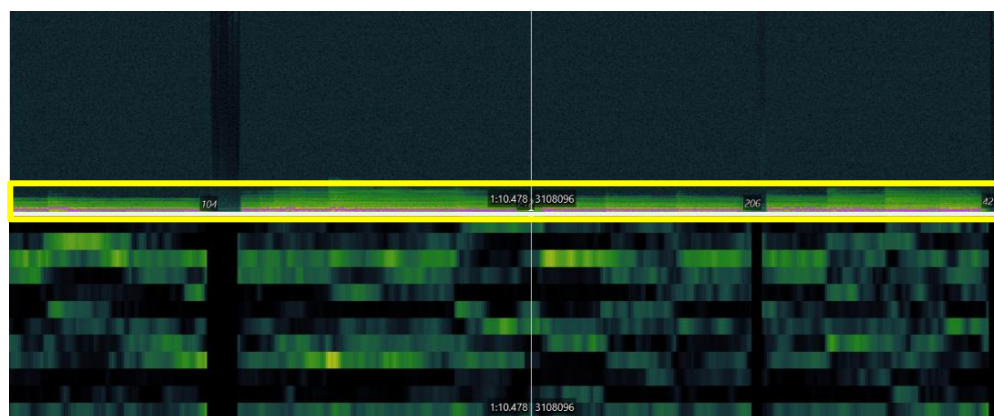


Figure 102 Aubio + NNLS for bar 93-97 piano segment D.

Figure 103 shows the Aubio output zoomed in showing the additional pitches discussed above as well. The **NNLS Chroma** plugin largely confirms to these observations, namely that there is not one pitch taking the clear lead. However, there is one place in particular where NNLS picks up a strong pitch, in particular A2 (see blue circle, Figure 103).

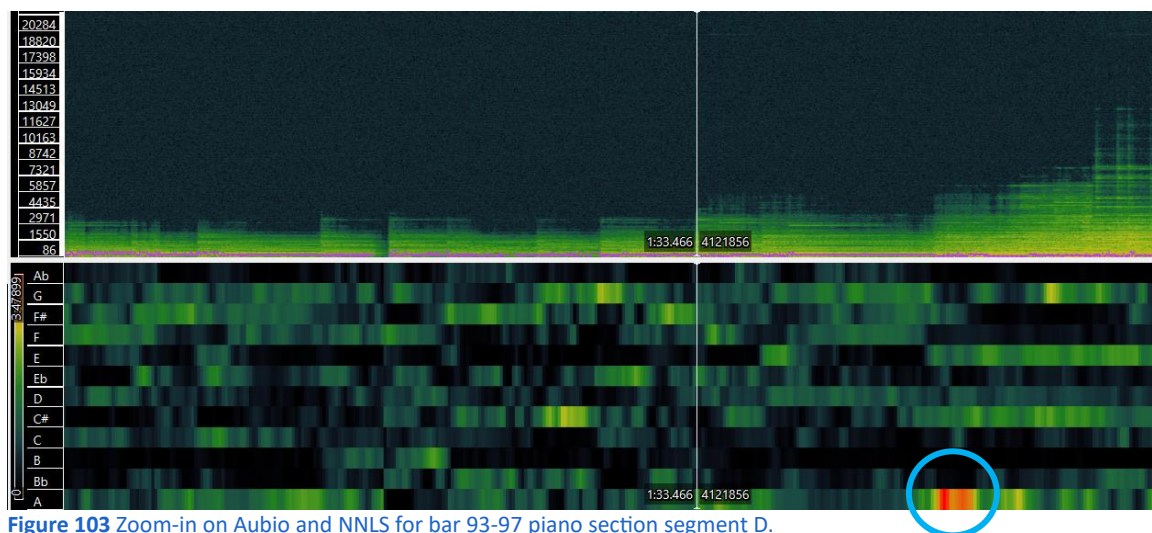


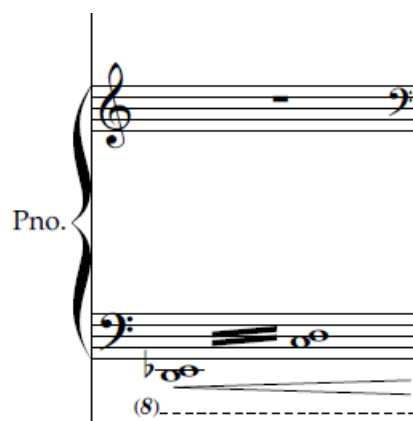
Figure 103 Zoom-in on Aubio and NNLS for bar 93-97 piano section segment D.

As with the previous pitches, this note connects to Sul II through its third partial, A3. Both the Aubio Pitch Detector and the NNLS Chroma Plugin confirm that Sul II is well established, with several of its partials appearing prominently. However, the score reveals that not only D2 partials are present. In certain bars, partials from both Sul I and Sul II can occur, however with modest variety at first. This variety begins to increase significantly from bar 90 (circled in blue on Figure 103), a point that also marks a significant RMS-energy peak measured for the wind section above. In that sense, the piano creates a propellor for spectral tension from the bottom-up like hot lava being pushed up from the Earth's core to eruption. A similar compositional technique can be found by Kaija Saariaho (1952-2023) who, by means of layering harmonic and inharmonic elements, created dynamic evolution in her compositions. Her intentions shone through in structural decisions relying on spectromorphology, although the latter term had not been introduced when Saariaho wrote 'Timbre and harmony: Interpolations of timbral structures' (1987).<sup>124</sup>

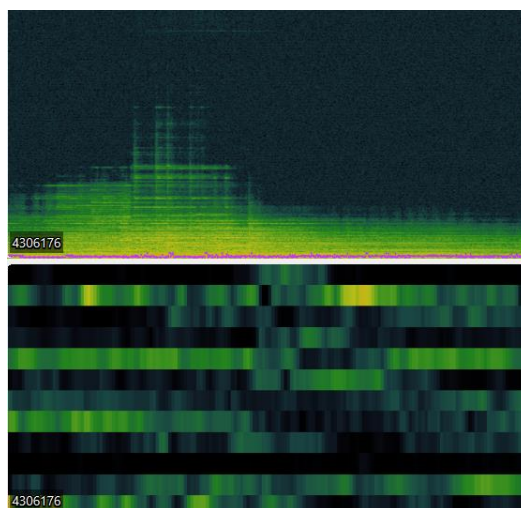
From that point on, both the score and Sonic Visualiser-output reveal that an increasing number of partials from a different spectrum – centred around G2 (Sul I) – are introduced into the piano section.

<sup>124</sup> Saariaho, "Timbre and Harmony: Interpolations of Timbral Structures", 93–133.

In the final bar of Segment D for the piano (Figure 104), a “glide” moves from D2-Eb2 to C3-D3, echoing Sul I’s higher partials, presented at bar 10-17 in the double bass section, introductory segment. This contrasts with the wind section portraying spectral distortion through instrumental techniques and differing partials. The particularly low register in which the piano plays adds to this rumbling effect. The Aubio Pitch Detector could, however, not define one dominant pitch here, adding to the overall narrative of turbulence (Figure 105).

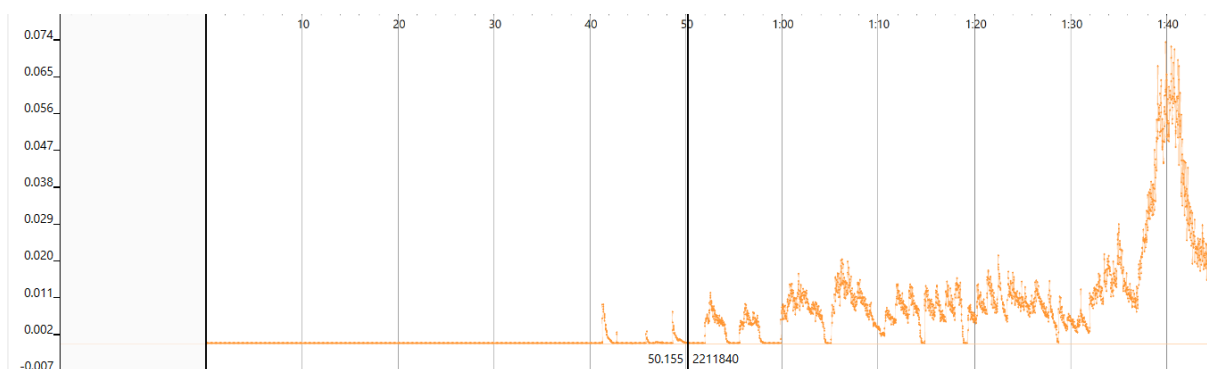


**Figure 104** Ellen Jacobs, *And In Between, There Is ...*, (2024), 14, 98, piano.



**Figure 105** Zoomed-in Spectrogram, Aubio Pitch Detector and NNLS Chroma plugin for bar 98, piano, segment D (Fig. 104).

To gain a deeper understanding of the piano’s spectral behaviour, the RMS-Energy, and Spectral Slope plugin are used.



**Figure 106** RMS-energy for piano section segment D.

The RMS-Energy (Figure 106) reveals a nearly continuous increase in energy that peaks near the end of the segment. While the initial evolution is subtle, the last peak is noteworthy. This aligns well with the score's direction of *crescendo poco a poco*, where the piano evolves from *pianissimo* to *fortissimo*, with the increasing amplitude supporting the dominance of low frequencies throughout. The earlier narrative of the piano, stating that it creates a rumbling underground for the rest of the ensemble to lie on, is applicable here. The moment where the piano creates the glide containing transpositions of the 11<sup>th</sup>, 12<sup>th</sup> and 13<sup>th</sup> partial of Sul I (bar 98, Figure 104), the peak increases significantly, marking a focal point in time in which modulation likely takes place.

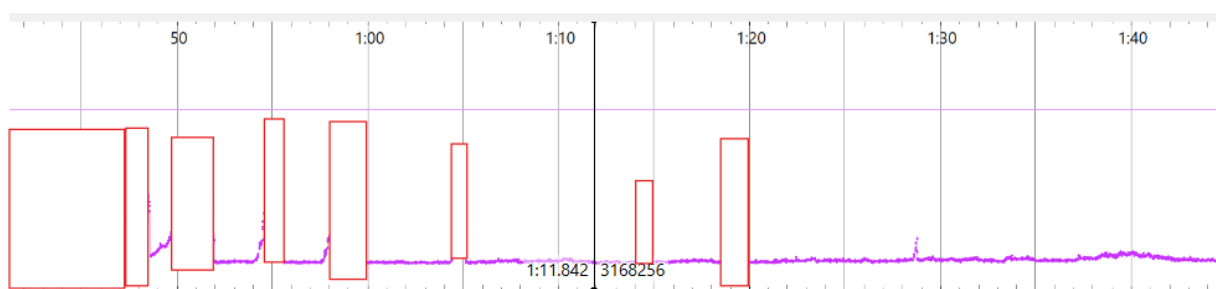


Figure 107 Spectral Slope output for piano section, segment D with silent parts hidden.

In contrast, the spectral slope output remains completely flat – after excluding moments of silence that might distort the overall visual, as was done with all Spectral Slope outputs. This flatness implies that, despite the evolving sonic content, the sound consistently maintains a rich spectrum of overtones, with a balanced relationship between high and low frequencies residing in the section.<sup>125</sup> Timbre wise, this means that the richness of the low notes on the piano is preserved and used as an amplifier of the ongoing increase in tension. It suggests that the piano, as seen in the RMS output, asserts itself in the foreground, using its spectral balance to shape a dynamic yet anchored foundation.

Taken together, these outputs offer a clear interpretation of the score: the double bass introduces Sul II in bar 86, and as the piano enters simultaneously, it reinforces this foundation by playing Sul II's partials. Later, however, Sul I's partials emerge, injecting rapid energy fluctuations (see RMS-energy output). The enduring richness of overtones, as indicated by the flat spectral slope, reinforces the idea that the composer intentionally reuses and evolves previously presented spectral material to push the music forward, as modulation does.

<sup>125</sup> "Spectral Descriptors".

### 3.1.5.3 Double bass and percussion

The final section of Segment D features percussion and double bass. While the primary focus of this research has been on the sonic and spectral aspects of the composition rather than its rhythmic implications, this section presents intriguing additions to the non-melodic percussion. Melodic elements appear in Segment D only from bar 86 onward, yet the tam-tam enters earlier, in bar 79, played with a coin (see red box, Figure 108). The metallic friction produced by this technique immediately introduces an inharmonic contour, anticipating the spectral interferences extensively discussed in relation to other sections (winds, piano).

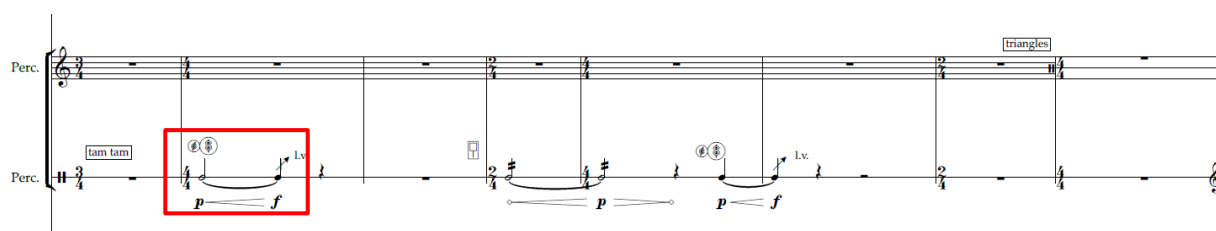


Figure 108 Ellen Jacobs, *And In Between, There Is ...*, (2024), 11, 78-85, percussion.

In order to be sure that this passage indeed conveys inharmonicity, one can have a look at the spectrogram layer. Rather than relying on precise numerical values, an important indicator is the absence of distinct spectral lines. When no clear lines are visible, it suggests that the overall spectrum at that moment is inharmonic, as the overtones do not follow integer multiples of the fundamental frequency. The following quote by Hideyuki Tachibana (2014) confirms that the spectrogram of percussive sounds, here the tam-tam, exhibit a smooth frequency spectrogram.<sup>126</sup>

[...] In formulating the methods, the authors basically assumed only the “anisotropic smoothness” of music spectrogram, which can be one of the minimalistic model that reflects the natures of these instruments. To be specific, the authors just assumed that harmonic instruments are smooth in time, **while the percussive instruments are smooth in frequency on a music spectrogram.**<sup>127</sup>

<sup>126</sup> Hideyuki Tachibana et al., “Harmonic/Percussive Sound Separation Based on Anisotropic Smoothness of Spectrograms”, *IEEE/ACM Transactions on Audio, Speech, and Language Processing* 22, no. 12 (December 2014): 2059–60, <https://doi.org/10.1109/TASLP.2014.2351131>.

<sup>127</sup> Ibid., 2059.

This underscores the value of using a sound splitter in multi-voiced contexts, as it enables visualisation of separate spectra for individual instruments, facilitating a deeper understanding of their contributions to the overall sonic architecture. Additionally, for this instrument, the use of category 1 plugins (see Table 2.1) is unnecessary due to its inherently inharmonic nature. At present, it appears to introduce a noise component associated with the spectral interference observed in other sections, likely contributing to a dynamic spectral flux.

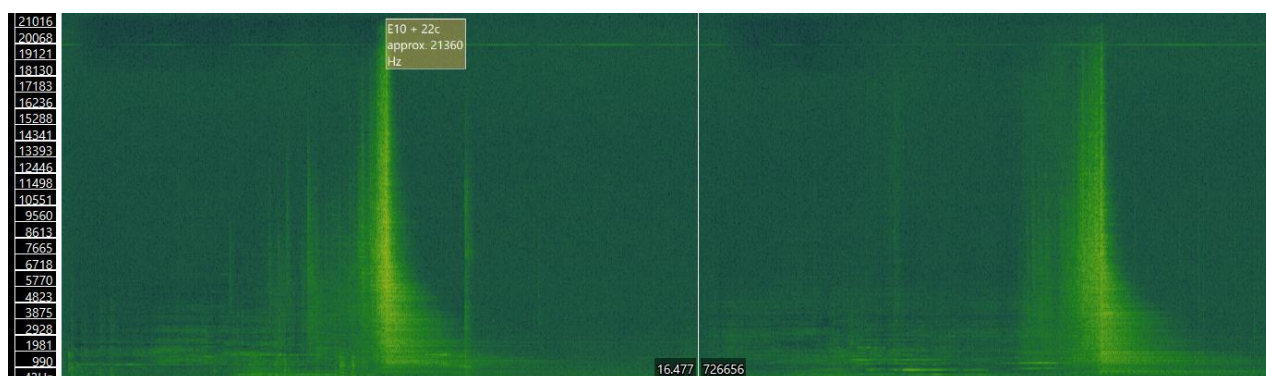


Figure 109 Spectrogram Layer in Sonic Visualiser for bar 78-83, tam-tam section.

Figure 109 above illustrates bars 78–83 of the tam-tam part in Segment D. On the far left, the frequency values are displayed. The manipulation of the tam-tam using a coin produces a broad spectrum of frequencies, as evident in the first annotated spectrum, which records a value of 21.360 Hz—with the consideration of cent deviations.

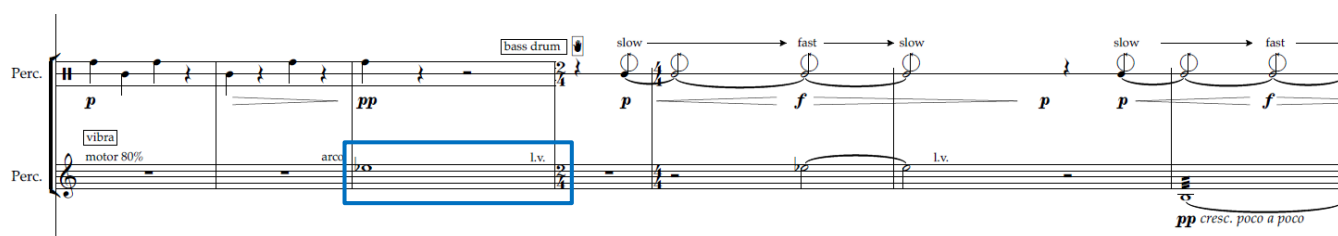


Figure 110 Ellen Jacobs, *And In Between, There Is ...*, (2024), 12, 86-92, percussion.

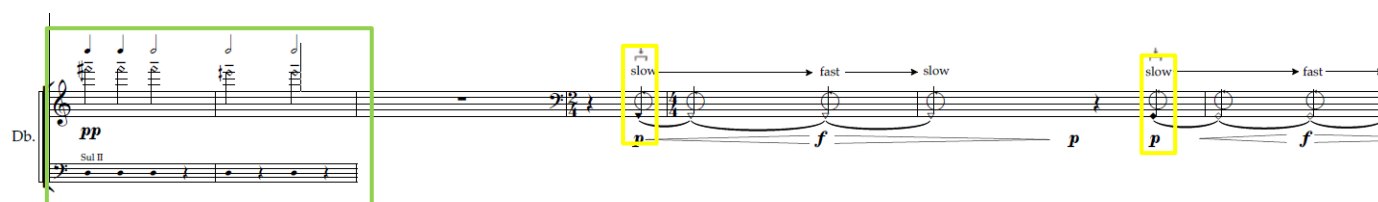


Figure 111 Ellen Jacobs, *And In Between, There Is ...*, (2024), 12, 86-92, double bass.

Looking at bar 86 (Figure 110) and further on the score, both the triangle, vibraphone and double bass enter Segment D as well. As for the double bass (Figure 111), it clearly depicted on Sul II, its harmonics F#5 and E5 are played, respectively its 9<sup>th</sup> and 10<sup>th</sup> harmonic (see green box). Referencing the performance notes, the shape of the notes for double bass refer to direct harmonics of the base Sul.<sup>128</sup>

In bar 89, the instrument employs two distinct techniques: circular bowing combined and extra pressure on the bridge to dampen the strings (see yellow boxes). By bar 93, the focus shifts to circular bowing paired with harmonic pressure while still applied at the bridge and the resulting pitch being G1. These complex techniques naturally lead to the introduction of additional noise components. Specifically, circular bowing produces bow hair noise layered over a definitive pitch. Although the low pitch of G1 prohibits a broad spectral expansion, it effectively destabilises the sonic foundation typically associated with the double bass.<sup>129</sup>

Observing the Table I in Appendix C, it further reveals that G does not share an overtone relationship with D2, suggesting subtle indications of Sul I—an interpretation that aligns with observations in other instrumental sections as well. In this context, the deliberate noise from circular bowing may reveal the emergence of a secondary spectrum that gradually modulates the sound. Moreover, playing on the bridge activates a distinct set of overtones, thereby enhancing the presence of G1. Future investigations with Sonic Visualiser plugins can provide additional insights into these phenomena.

In the percussion section (Figure 110), the vibraphone enters in bar 88 on an Eb5 (see blue box), which is replaced by a B3 in bar 92. The marking *laissez vibrer* instructs that the note should resonate, emphasizing the instrument's prominent role in the ensemble. Notably, the Eb5, like the G1, does not share a spectral relationship with Sul II; rather, it is a transposed form of Sul I's 13<sup>th</sup> overtone Eb6. This detail, combined with the sustained vibration, suggests that the resonance mimics the high-frequency character of Sul I's 13<sup>th</sup> overtone.

When the double bass resumes harmonic pressure on the same G1 pitch, the vibraphone shifts to a sustained B3, held through bar 97. This B3 exhibits a transposed spectral relationship with Sul I, as B4 is recognized as its 5<sup>th</sup> overtone. Accompanied by a gradual crescendo (“crescendo poco a poco”) and an additional vibrational marking, the overall spectrum appears to undergo further alterations.

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<sup>128</sup> Ellen Jacobs, *And In Between, There Is ...*, (Leuven: Transit Festival, 2024).

<sup>129</sup> “Circular Bowing”.

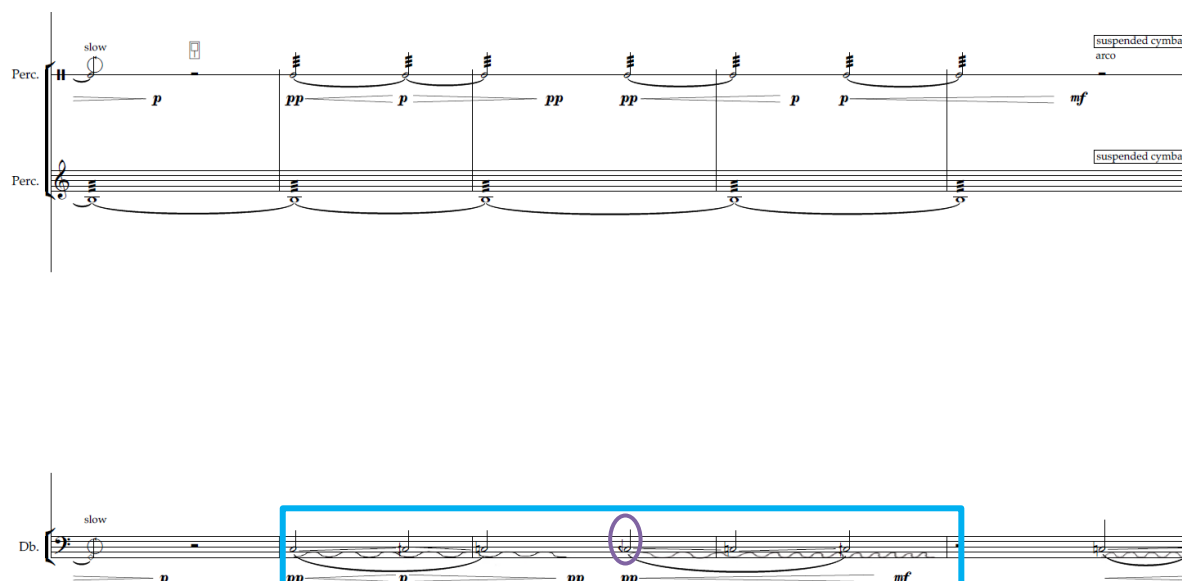


Figure 112 Ellen Jacobs, *And In Between, There Is ...*, (2024),13, 93-97, percussion and double bass.

Figure 112 shows the double bass primarily playing a C2, with brief shifts toward C#2 and Cb2 (B1), marked in a purple circle in the blue box. These semitonal shifts establish an unsteady fundament for the ensemble. Spectrally, C2 connects to both Sul I (with C6 as its 11<sup>th</sup> harmonic) and Sul II (with C5 as its 7<sup>th</sup> harmonic), and these subtle changes are sustained until the segment's end. Meanwhile, the vibraphone remains on B3, while the bass drum reinforces its vibrational character, thickening the sonic texture. All signs seem to point at a significantly stronger spectral tension emerging.

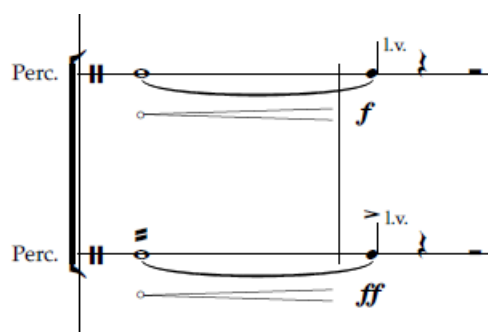


Figure 113 Ellen Jacobs, *And In Between, There Is ...*, (2024),14, 98, percussion.



Figure 114 Ellen Jacobs, *And In Between, There Is ...*, (2024),14, 98, double bass.

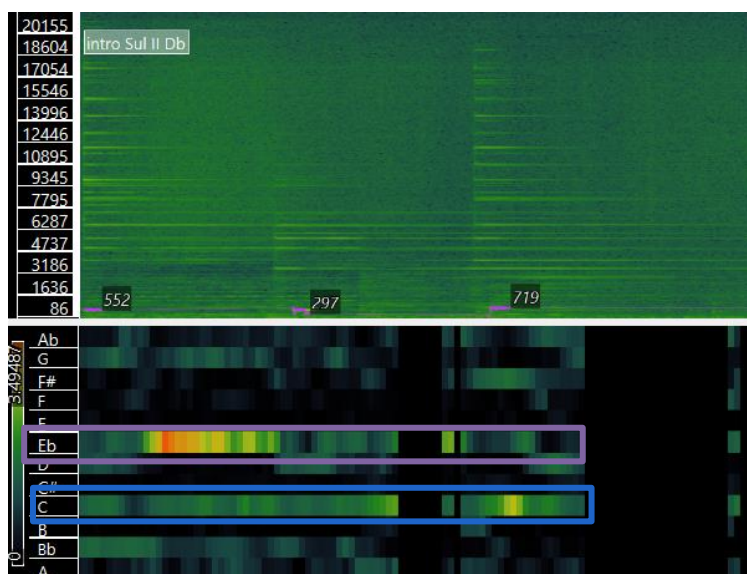


Figure 115 Spectrogram, Aubio and NNLS Chroma plugin output for bar 86-87.

On Figure 115, the Aubio Pitch Detector first identifies the fundamental D5 ( $\approx 552$  Hz), marking the introduction of Sul II on the double bass and reinforced by its F#5 and E5 partials, corresponding to the 9<sup>th</sup> and 10<sup>th</sup> partials of Sul II—confirming its presence. Shortly after, D4 ( $\approx 297$  Hz) is detected under similar conditions, followed by F#5 at 719 Hz. These findings solidify earlier assumptions that the double bass plays a crucial role in shaping Sul II's partials, as signalled in bar 86. Meanwhile, the preceding inharmonicity introduced by the percussion initiates a spectral counterforce, interacting dynamically with the double bass.

However, NNLS Chroma reveals a luminescent bin for Eb, a pitch exclusive to Sul I's spectrum (see purple box). This spectral imprint, induced by the percussion, concretises earlier assumptions that spectral tension emerges from the interplay between the double bass and percussion, which manifests through both differing partials and distinct instrumental techniques, as well as implied inharmonicity (see tam-tam with coin). Additionally, the 'dual' bin for C (marked in blue), referencing the double bass, enriches this tension further through microtonal shifts and dual fundamental affiliations, reinforcing the evolving spectral complexity.

However, further output (Figure 116) analysis reveals that after Eb, both plugins struggle to consistently detect a dominant pitch, likely due to the double bass' circular bowing and other instrumental techniques, causing fluctuations in the Aubio Pitch Detector. This necessitates greater reliance on the NNLS Chroma plugin, which consistently highlights B (yellow) and Eb (purple). In this instance, B assumes a strong Sul I connection, further enhancing spectral interplay.

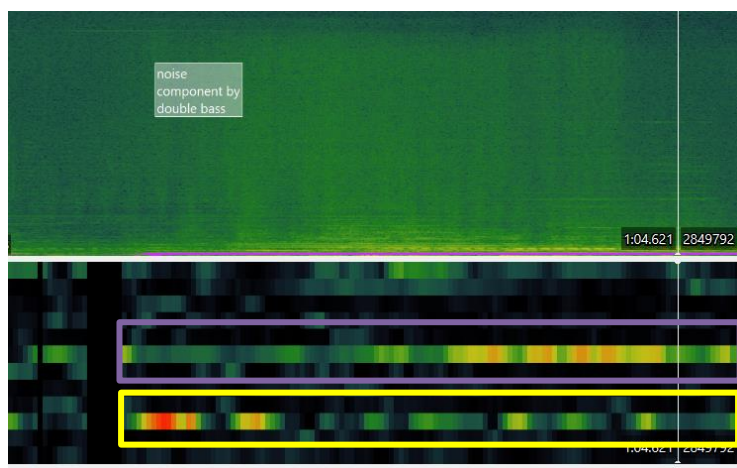


Figure 116 Spectrogram, Aubio, NNLS. Bar 89 – 92. Percussion and double bass.

Moreover, although the spectrogram presents some ambiguity, the inharmonic elements generated by the double bass and non-harmonic percussion actively shape the overarching narrative of turbulence and tension. Their spectral imprint adds layers of instability, reinforcing the interplay between harmonic and non-harmonic forces within the composition. The annotation in white shows the smooth spectrum as a result of inharmonicity, underlined by the article of Hideyuki Tachibana (2014).<sup>130</sup>

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<sup>130</sup> Tachibana et al., “Harmonic/Percussive Sound Separation Based on Anisotropic Smoothness of Spectrograms”, 2059-60.

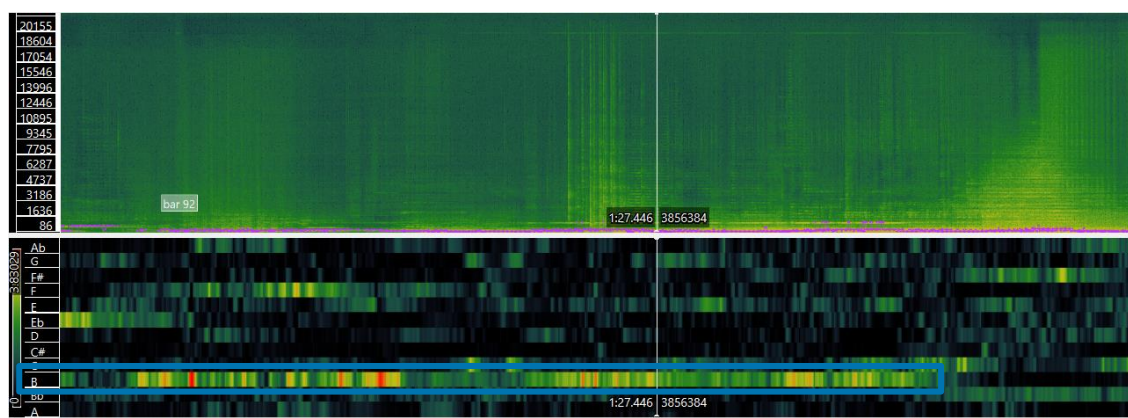


Figure 117 Spectrogram, Aubio, and NNLS Chroma plugin for bar 92-98

Figure 117 reveals that the Aubio Pitch Detector struggles to isolate a single dominant pitch, whereas the NNLS Chroma plugin distinctly highlights the prominence of B, marked in blue. This suggests that while B exerts a strong influence within the underlying sound texture, its presence does not manifest as a singularly defined pitch in Aubio's output. This reinforces the broader inharmonic narrative, emphasizing the spectral instability at play. Another reason for this particular outcome is that the double bass' glides from bar 94 onward, together with its profound vibration, suggest that Sul I partials—such as C and B—help drive the music forward. Although the plugins do not exactly detect these pitches, the score confirms their presence and the observed output, when considering the deliberate inharmonicity from noise components, feeds the narrative of two spectra interacting and conveying vitality in both the sound and overall composition.

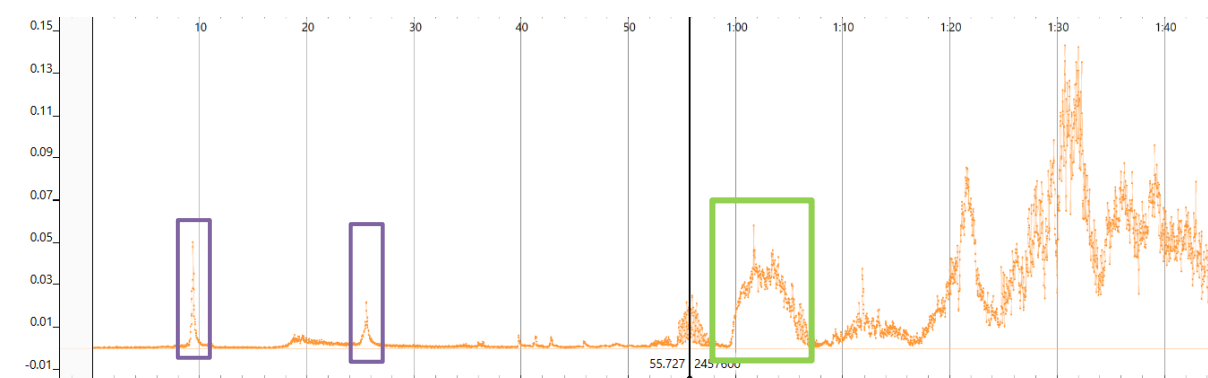


Figure 118 RMS-energy for percussion and double bass section, segment D.

Figure 118 displays the RMS-energy output for percussion and double bass in Segment D. Similar to the piano section, the energy progressively increases as the segment unfolds, driven by a series of spectral differentiations. However, a key distinction lies in the extensive use of instrumental techniques by both percussion and double bass, elaborated throughout the analysis. The initial manipulation of the tam-tam with a coin establishes distinct moments in time during the early phases of the segment (see purple boxes). As the section progresses, these minimal peaks visually develop into larger ones, reflecting a growing intensity. The peak around 1:00, highlighted in green, results from the double bass' damped strings in conjunction with circular bowing, introducing subtle noise components that create pressure on the sound. This accumulated tension acts as a catalyst, propelling the energy trajectory upward, clearly visible on the output. Although a traditional double bass, with its deep, warm timbre is expected to stabilize an ensemble, in this segment the double bass plays significantly low pitches (see Figure 112 and 114) while its distinct vibrato introduces an unstable underpinning. In doing so, it departs from its conventionally anchoring role. The interplay between percussion and double bass not only drives the segment's trajectory but also reinforces a broader narrative of instability and forward momentum. In this case, their pronounced amplitude trajectory, as visualized in Figure 118, highlights the prominence of this instability, bringing it to the foreground with striking intensity.

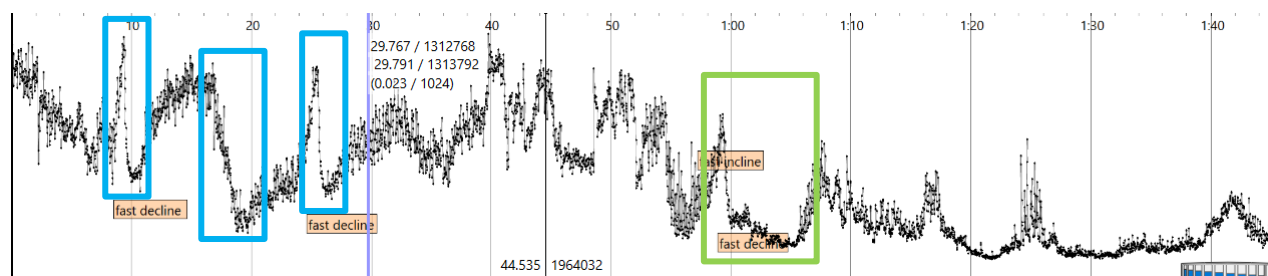


Figure 119 Spectral Slope output for Segment D, percussion and double bass section.

For the Spectral Slope, the most pronounced inclines and declines are distinctly marked. The first rapid declines correspond to the tam-tam's introduction around bar 79 (see blue boxes), where prominent noise components emerge. This sharp drop in spectral slope reflects the absence of resonant higher frequencies, either due to the inherently non-resonant nature of certain percussive instruments or the specific playing techniques employed. While the tam-tam is capable of producing sustained resonance under different conditions, the deliberate manipulation with a coin ensures a forceful attack, followed by a short sustain and rapid decay. As a result, the peaks are sharply articulated yet fleeting,

lacking the overtone complexity found in more harmonic sounds. This reinforces the narrative that the tam-tam serves as a prelude to the intensifying inharmonicity, disrupting the spectral balance and infusing dynamism throughout.

The second instance of a steep decline (see green box) is linked to the damped strings of the double bass. Damping prevents upper harmonics from fully resonating, disrupting the natural construction of the sound while introducing additional noise components.<sup>131</sup> This effect is clearly represented in the spectral slope's descent, reinforcing the significance of noise integration at this late stage of the composition. As the work nears its conclusion, these deliberate sonic alterations contribute to the spectral instability, solidifying the evolving modulation as the final section unfolds. It further demonstrates that the separate pitches found in the score are not merely fixed particles, but fluid entities shaped by the composer's manipulation of the 'natural' harmonic spectrum of both double bass strings. Beyond shifting the overtones, the deliberate use of instrumental techniques reshapes their very character, introducing variation and movement within an inherently non-tonal environment. Figure 119 illustrates how these manipulations influence the trajectory of spectral balance and imbalance in this case

#### 3.1.5.4 Global analysis for Segment D

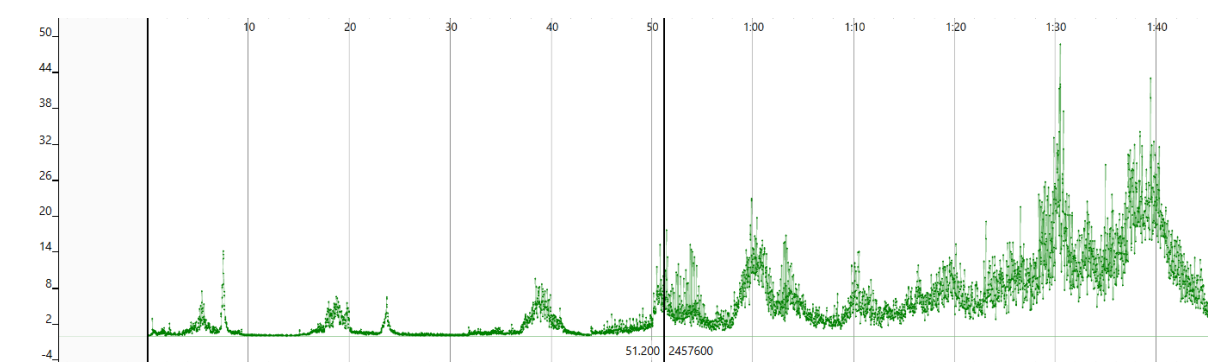


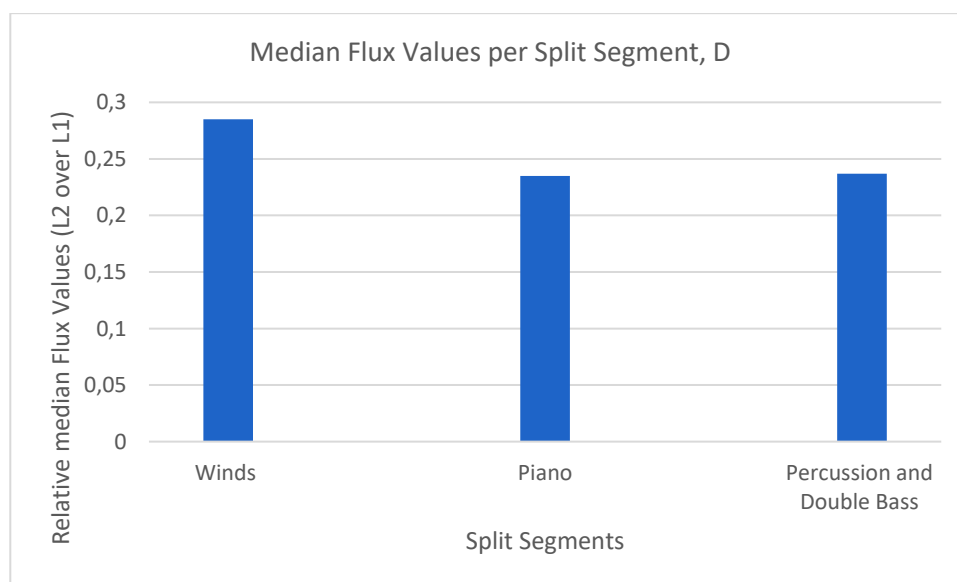
Figure 120 Spectral Flux output for Segment D.

The above picture shows the spectral flux output for Segment D. Mirroring the RMS-Energy outputs for majority of the split sections, this too exhibits an increasing trend. Specifically around 00:50, the increase seems to propel in a faster trend. From that moment onward (bar 86 and beyond), the piano, percussion, and double bass begin to align with the rest of the ensemble. Their significant roles in creating spectral tension, as explored in previous sections of the analysis, particularly through instrumental techniques, drive this spectral flux toward rapid transformation. At the start of the

<sup>131</sup> "Circular bowing".

segment, the tam-tam initiates the modulation, expanding the spectral space vertically (ref. Figure 109). A certain punctuality emerged from this, with the wind instruments striving for spectral blending. However, when the piano and double bass enter, this trend shifts. Sul II partials are introduced, alternating and juxtaposed with Sul I partials, a trend commonly recurring throughout *And In Between, There Is ...* (Ellen Jacobs, 2024). Techniques such as circular bowing and damped strings further propel spectral movement and inharmonicity, later adopted by the winds (e.g. wawa without stem). Overall, the piano remains the most stable, heightening its contrast with the other instruments. All of these elements have played a role in the rapidly increasing Spectral Flux plugin output. The Spectral Flux Median is calculated at 0.294 (ref. Table 2.4), the highest among all segments so far, marking Segment D as the most spectrally dynamic. Previous analytical discussions on Segment D have highlighted that, particularly in contrast to Segment C, the variability and plugin outputs reveal a significantly more turbulent environment. This indicates an expansion of spectral space, creating room for modulation to unfold. Despite approaching the composition's conclusion, the music remains dynamic and far from receding.

Below, a chart diagram visualizes the spectral flux distribution per split segment.



**Graph 4** Chart Diagram of the Median Spectral Flux values per split instrumental segment (D).

Observing Graph 4, the wind section holds the largest spectral flux share, followed by percussion and double bass, with the piano exhibiting the lowest value. However, the latter two remain closely aligned in their spectral flux contributions. The dominance of the winds stems from their frequent timbral shifts, particularly in the trumpet, where the addition or removal of a mute alters its sharpness, allowing the timbre to assert itself more prominently within the ensemble. By projecting specific pitch values onto these timbral variations, the composer can strategically amplify or suppress certain frequencies, shaping moments of spectral tension or relaxation. Similar handlings were used by for example Kaija Saariaho (1952-2023).<sup>132</sup> Coupled with the ‘unconventional’ approach to the bass clarinet, placing it in a higher register, the wind section solidifies its position as the leading contributor to spectral flux. Conversely, the piano retains the smallest share due to its previously discussed flat spectral slope (ref. Figure 107), which preserves the natural balance between low and high frequencies. This stability explains its minimal flux contribution. Meanwhile, the percussion and double bass introduce greater spectral variation, driven by inharmonic elements and alternative performance techniques, particularly the ‘unconventional’ treatment of the double bass, echoing the altered role of the bass clarinet.

Similar to Segment C, the piano again assumes the smallest spectral flux presence, reinforcing its potential function as a structural anchor despite periodic shifts into other spectra or its rumbling effect caused by rapidly succeeding pitches. Throughout the composition, the winds and the percussion-double bass section appear to alternate as the primary drivers of spectral flux, shaping the evolving spectral landscape.

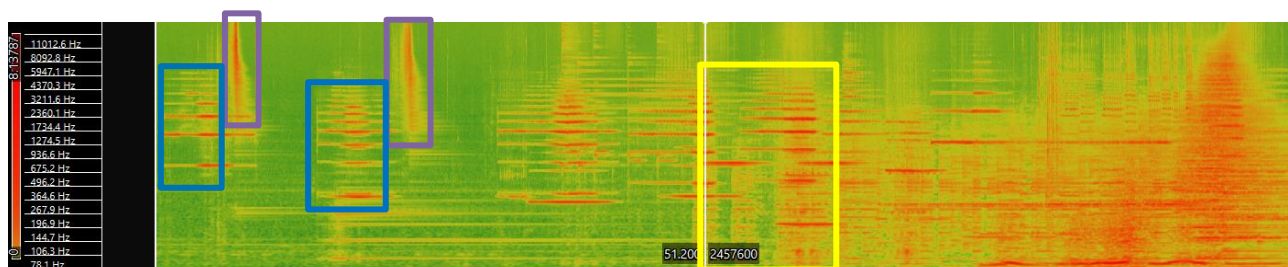


Figure 121 Constant Q output for Segment D.

The Constant Q output for Figure 121 illustrates the progression of present frequencies within Segment D. The ‘temporal markers’ previously discussed for the tam-tam at the beginning of the segment are clearly visible here and marked in purple. They represent vertical expansion, whereas the harmonic frequencies originating from the winds create

<sup>132</sup> Saariaho, “Timbre and Harmony: Interpolations of Timbral Structures”, 93–133.

horizontal expansion, although punctuated in time, and therefore not dense or extremely spread out (marked in blue). A similar trend continues until 00:50 (see yellow box), the moment mentioned earlier when the rest of the ensemble joins in and truly propels the spectral modulation (Figure 120). Towards the end, the spectrum appears extremely dense, further substantiating the argument of a rapidly developing spectral modulation. In this sense, the earlier temporal markers, both harmonic and inharmonic, have formed a larger pattern in time through which musical structure is created, without relying on tonal chord relationships, being influenced by key rules, or cadences serving as modulations.

Due to the repeating nature of the frequency patterns, and their eventual contribution to an even larger spectral expansion, the time structure is once again categorized as ripple time (Table 2.3). If it were ambient time, the majority of the Constant Q output would display a continuous shape, indicating that no changes would be perceived from the output (Figure III, Appendix E). Although minor variations might occur due to subtle sounds appearing sporadically, the overall structure would remain uninterrupted. In the case of flutter time, on the other hand, very small oscillations would appear, yet they would not portray a similarly constituted and strong ‘pattern’ as is more characteristic of ripple time.<sup>133</sup> Since this Constant Q output clearly depicts constituted patterns eventually evolving into a denser structure, the category of ripple time seems the most appropriate.

Having combined ripple time with different flux types throughout this analysis highlights the multidimensionality inherent in this composition, specifically in the way that frequency/pitch content does not only refer to specific spectral relationships, energy distributions, and potential imbalances, but equally to more ‘general’ structures that fundamentally shape the composition. As such, both the inner fibres and the finishing touches of the sonic fabric are interpreted and shaped through spectral features, both on an individual and an interactive level, completely disregarding tonality as a shaping hierarchy.

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<sup>133</sup> Thoresen and Hedman, “Spectromorphological analysis of sound objects”, 129-41.

### 3.1.6 Segment E: bar 99-107

The final segment of *And In Between, There Is...* (Ellen Jacobs, 2024), is Segment E. The wind section maintains the same instrumentation as the preceding segment: Bb bass clarinet and Bb trumpet.

Figure 122 Ellen Jacobs, *And In Between, There Is ...*, (2024), 14, 99-107, full ensemble.

The trumpet resumes its line from the end of Segment D with the Bb3-F#4 chord, both pitches referencing Sul II and marked in pink. In contrast, the bass clarinet sustains a profoundly vibrating C1, highlighted in green. This pitch recurs throughout the final segment, mirroring the Eb5 on the trumpet, a Sul I partial and marked in purple. Their sustained vibration and the bass clarinet's low register make them prominent in the ensemble, based purely on the score. In this sense, the wind section evokes the presence of Sul I and seems to specifically reference the Sul I overtones presented in

measures 10-17 at the composition's outset. However, the recurring dual role of C throughout the analysis should not be dismissed, as other instruments reveal numerous and/or strong manifestations of Sul II partials as well.

For instance, in the piano section (see orange box), the left hand plays the Bb1-F#2 chord (Sul II) and B1-C1-Eb2 (Sul I, with C functioning dually). Here, the piano literally embodies the spectral friction prevalent throughout the composition. This, combined with its strong fortissimo dynamic marking, further asserts its presence, causing the low frequencies to resonate under the pressure of spectral contradiction.

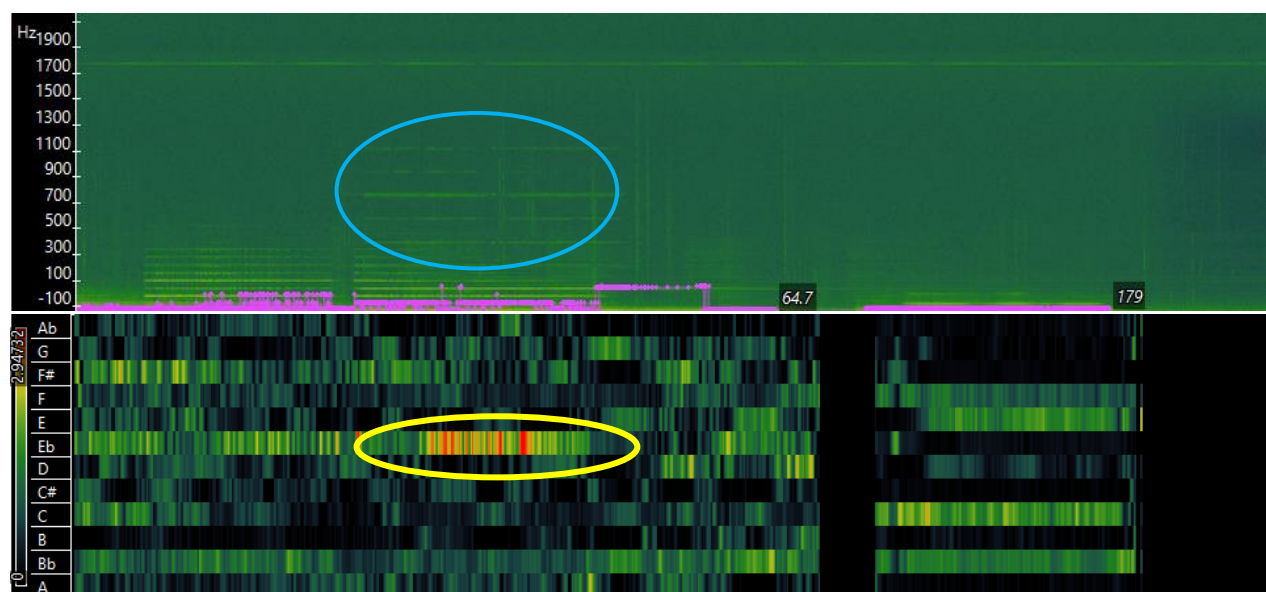
Thus far, the spectrum appears to have undergone a deliberate evolution throughout the composition, leading toward the eventual dominance of Sul II. The double bass, entering at the beginning of Segment E, plays a robust and low Bb1 in fortissimo with marked vibration (see yellow box), lending this pitch a significant texture that asserts dominance. In a way, the piano's left-hand chord can be seen as an amplification of Sul II partials and their transpositions, further securing its presence. The winds then form a spectral counterpoint to this deliberate bass, along with the piano's right hand, with the exception of the dually functioning C. The duality continues to be present.

Although the composition is nearing its end, consisting of only a few measures, one might expect the spectral tension and contradiction to subside, leading to a calm resolution. However, based solely on the score, the contradiction persists and is even amplified by the trumpet, which, while no longer using vibrato, employs the *wawa* mute to prolong the tension until the very end.

Nonetheless, the very last bar marks a significant shift. The bass clarinet plays the B2-E5 very quietly, see blue box. E5, the 9<sup>th</sup> Sul II partial, and B2, referencing the 5<sup>th</sup> Sul I partial, again and similarly to the piano, present this spectral friction within a single instrument. The high register of E5 makes it particularly prominent. This tremulous character connects to the Bb1 in the double bass, another Sul II reference. This brings the composition to a close where Sul I has effectively 'died out,' yielding to Sul II. The modulation has reached its final stage, not with full resolution, but as a consequence of the evolving intermediate spectral state. While the winds attempt to maintain a dual connection to Sul I, the bass clarinet and double bass ultimately form the concluding residue of Sul II. This contrasts with the introductory segment, where Sul I was introduced through the crotales and double bass. Its partials have resonated throughout the entire composition, now culminating in a confrontation with Sul II as a fluctuating end-state.

### 3.1.6.2 Global analysis of Segment E

The limitations of current audio separation techniques, as highlighted by Lalal.AI's inability to cleanly isolate instrumental sections containing the piano (and similarly for other instruments), subtly underscored the potential malfunctions discussed in Chapter 2: Proposed Methodology. This instance serves as a critical reminder of these constraints and suggests a valuable avenue for future research into the capabilities of AI-based sound splitters in complex multi-voiced textures. While a dedicated study of sound splitters falls outside this thesis's scope, this challenge reinforces the broader problem it addresses: the relative lack of systematic analysis applied to spectral-based, multi-voiced acoustic compositions. Even with its imperfections, utilizing Lalal.AI provided a basis for comparative analysis across different instrumental sections, allowing for the identification of broader spectral trends and potential interactions, which were then further scrutinized through score analysis and other methods. Therefore, this final section of Segment E integrates all plugins (Tables 2.1 and 2.2), applying them across the entire segment for the reasons previously outlined.



**Figure 123** Spectrogram, Aubio Pitch Detector and NNLS Chroma Plugin for Segment E, full.

Figure 123 shows two key numerical values were identified at 64.7 Hz and 179 Hz, corresponding to C2 and E3 (including cent deviations) and aligning with both Sul II pitches, however C being dual. Yet the yellow circle on the NNLS Chromagram output confirms a dominant pitch of Eb5, deliberately introduced by the trumpet.

Beyond this particular bin, no other frequencies are highlighted by a strong yellow/orange hue, indicating that many pitches coexist simultaneously. Additionally, a significant reduction in the number of bins and overtones near the

segment's end supports the narrative that the Sul II spectrum gradually overtakes and concludes the composition. Upon close examination, it is evident that when Eb5 dominates, the spectrogram shows a significant spectral peak. This is most likely due to its interaction with other Sul II partials, combined with Eb5's strong vibrational character and a subsequent "wawa" addition (see blue circle).

Finally, a brief moment of Bb dominance, observed at bar 103, is attributed to the combined playing of the crotales and double bass.

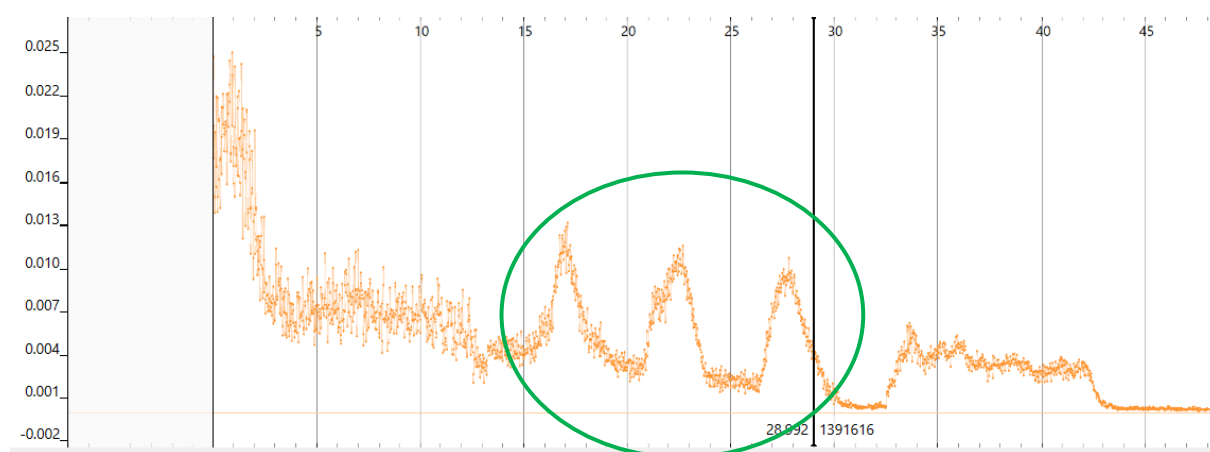


Figure 124 RMS-Energy for Segment E.

Regarding the RMS-energy output, the levels begin high and gradually decay, punctuated by deliberate peaks that correspond to moments of interaction between pitches with distinct spectral bases. The three most articulated peaks, circled in green, highlight the subtle interplay between the winds, percussion, and double bass. Each peak receives an additional boost when the bass clarinet reinforces C1 through its crescendo-decrescendo dynamic. The very low register of the bass clarinet, combined with the sharp timbre of the trumpet's Eb5, causes the energetic flow to be punctuated by these peaks. Moreover, the differing spectral bases may act as a creasing force throughout the segment, shaping its overall trajectory. This deliberate manipulation of energy levels serves as another layer in the compositional strategy, drawing attention to and even creating tension through the interaction of contrasting spectral elements. Notably, the segment's beginning appears more granular in terms of energy when compared to its conclusion.

This initial graininess results from the multiplicity of differing partials, creating tension through their inharmonicity and unfamiliar relationship to either Sul I's or Sul II's spectrum. It decays slowly as the composition ends with the bass clarinet playing E5-B2 and the double bass' Bb1. Bb1 and B1, positioned closely together, can produce beating, and

when combined with differing spectral bases, they create a nuanced sonic space that exists between stability and friction.<sup>134</sup>

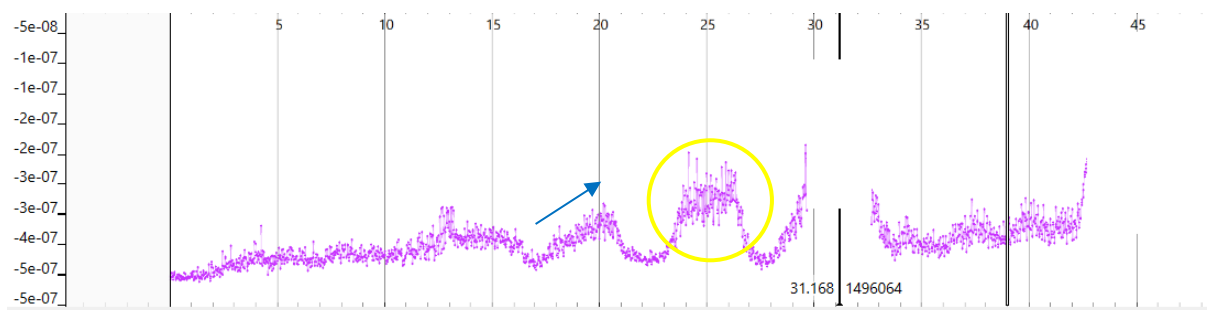


Figure 125 Spectral Slope for Segment E with silent parts hidden.

Overall, the Spectral Slope exhibits modest increases, with the most prominent one, circled in yellow, corresponding to bars 103–104, where the crotales play Bb4. Due to the additional *laissez vibrer* and the instrument’s metallic character, the resonant properties become more pronounced, allowing the pitch to resonate with a multitude of high partials. This prominence reveals that the Sul II reference is significantly more dominant, marking energy in higher partials and distorting the natural balance relative to the opposing spectrum, thus creating a steeper, positive spectral slope. Similarly, the preceding incline (see blue arrow) can be attributed to the trumpet’s deliberate vibrational emphasis on Eb5 in Segment E, interpreted under similar conditions. Near the end of the segment, the spectral slope remains slightly higher than at the beginning yet shows no clear inclines or declines, a phenomenon that could be linked to a brief bass clarinet solo (C1 in bar **105**), later followed by B2 (and E5) where the strength of the lower frequencies helps maintain a steadier slope.

<sup>134</sup> Julia Kursell, “Experiments on Tone Color in Music and Acoustics: Helmholtz, Schoenberg, and Klangfarbenmelodie”, *Osiris* 28, no. 1 (January 2013): 200–211, <https://doi.org/10.1086/671377>.

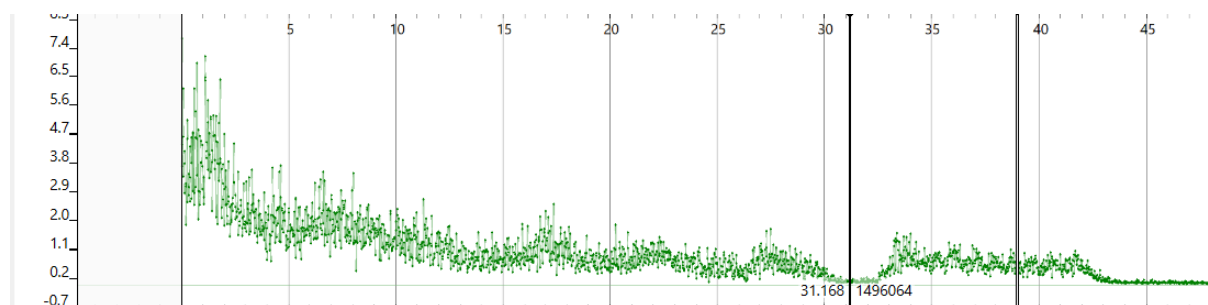


Figure 126 Spectral Flux for Segment E.

The connection between spectral flux and the size of the ensemble helps explain why we see that perhaps unexpected median flux value. Although the overall spectral flux tends to decrease, the median actually reaches its highest point in the composition at 0.38, indicating significant localised spectral activity. This makes sense because spectral flux does not necessarily require a large ensemble to be strong. In smaller groups or passages with fewer active instruments, individual spectral shifts become more prominent. There is less sonic masking, allowing the individual overtones to evolve more distinctly. The high median value suggests that despite the general downward trend, there are still focused moments of spectral movement occurring, likely due to dynamic interaction between a smaller number of instruments with highly contrasting timbres, or an altering of the timbre, as seen and discussed for the bass clarinet. Therefore, analyzing the numerical data and the median reveals that spectral flux can remain important even as the ensemble size decreases, emphasizing the role of timbral contrast and energy distribution over simply having a large number of instruments. Furthermore, the consistent emphasis on instrumental techniques throughout the composition reinforces the importance of subtle gestures in shaping spectral flux levels. It suggests that composers can convey spectral movement and modulation through nuanced approaches rather than solely relying on abrupt or bombastic changes. This does remind of Alluri and Toiviainen (2010) arguing that spectral flux and musical activity can be related to each other to understand structure in a non-tonal, spectral environment.<sup>135</sup>

While the segment might suggest resolution, the spectral flux data indicates otherwise. Linking this to the score reveals the subtle final dialogue between bass clarinet and double bass to be particularly intriguing. Despite the apparent dominance of Sul II partials over Sul I, the presence of B2 signifies a persistent underlying friction, creating beating with the double bass's Bb1 and contributing to the overall flux. Additionally, the piano's entry adds to the initial density

<sup>135</sup> Alluri and Toiviainen, "Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre", 223-242.

of Segment E, introducing granularity and spectral differentiation. Spectral flux remains a driving force in Segment E, reinforcing unresolved tension and shaping the composition's evolving harmonic and textural landscape, even at the end of the composition.

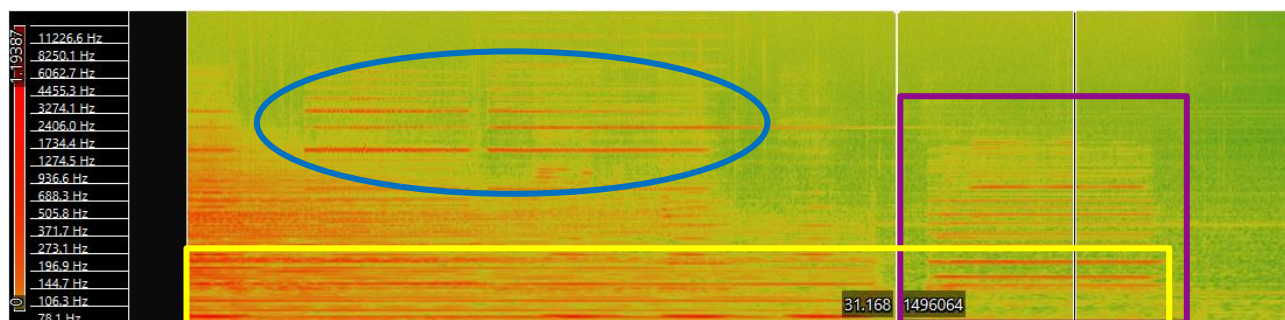


Figure 127 Constant Q output for Segment E.

Last but not least, the Constant Q reveals the temporal evolution of the present frequencies over the course of Segment E. The initial stages of the segment exhibit a very dense texture, previously attributed to the interplay of the ensemble, mainly propelled by the piano's mix of both Sul I and Sul II partials. The frequency lines above the dense sonic mass stem from the trumpet's Eb5 (circled in blue), distinctly rising above the rest. Meanwhile, the ensemble moves within a tightly packed spectrum, where individual differentiation becomes increasingly challenging. This dense mass eventually transforms into the bass clarinet / double bass' interplay, marked in purple. One can see that the lower frequency ranges, marked in yellow, sustain until the very end of the segment. This serves the following argument in the light of the time categorisation; the lower frequencies, mainly present in the bass clarinet and double bass serve as a kind of drone, serving a low underground on which the other sounds can lay. The other instruments, more particularly the trumpet and piano, then present complementary layers of differing partials creating the density and layering visualised. Therefore, the time structure is said to be ambient. This proves that high spectral flux can occur within extended durations as well. While the perceived change might be gradual, the continuous internal movement of numerous partials through modulation accumulates significant spectral difference over time. Once again, the multidimensional interplay of spectral flux and time is evident. Even as the ambient timeframe signals the composition's conclusion, the high flux value maintains a sense of ongoing sonic change, driven by the internal dynamics developed throughout. Later feedback from the composer could further refine this argument, but based on the output, it appears highly plausible.

## 3.2 Discussion of Analytical Results and their Connection to Compositional Intent

### 3.2.1 Conclusion for Segmented Analysis

Before delving into the findings with greater emphasis on the median values of spectral flux and the time categorisations as outlined in Lasse Thoresen and Andreas Hedman's article 'Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology' (2007), the above findings will be briefly summarised, combined with excerpts from the pre-analysis interview held with Ellen Jacobs on the 21<sup>st</sup> of November, 2024. Afterwards, her responses to the questions posed following the analysis, specifically on May 17, 2025, are linked to the overarching categories of spectral flux and time assigned to each segment of the composition. These questions directly address the correlation she perceives between the objective data presented in (1) the line graph displaying all median spectral flux values per segment and (2) the time categories based on Thoresen and Hedman (2007). Together, these measures not only illustrate the degree of spectral change throughout the composition but also reveal how these variations shape its progression and overall structure. Furthermore, they demonstrate that changes in the spectral fabric alone are sufficient to create structure, without requiring tonality to maintain coherence. By conducting both a pre-interview to gain insight into the overall intentions behind the piece and a feedback interview after the analysis, these intentions could be efficiently connected to the analytical data, ultimately serving as the final interpretation of this thesis.

#### 3.2.1.1 Spectral Foundations and Harmonic Structures

During the course of the analysis of *And In Between, There is* (2024) from Ellen Jacobs (°1996), the spectral foundations found through the score analysis and the additional use of VAMP Sonic Visualiser plugins revealed that the Sul I string of the double bass and its integer multiple overtones served as a strong foundation throughout, alternated by Sul II as the composition unravelled. The very first augmented triad residing in bar 3 of the composition, for example, revealed pitches that showed similarity with the integer multiples of Sul I in particular. After observing the alternation in the double bass itself between the Sul I and Sul II string, and interpreting the other pitches and instruments accordingly, these spectral foundations were very solid and clear. For example, when the NNLS Chromagram plugin was included in the analytical mix, other frequency-bins were revealed, either conforming to or differing from the information of both the score and Aubio Pitch Detector. In the overall course of the composition, the Sul I partials dominated, introducing spectral connections that reappear later in a sometimes-transformed way across various instrumental sections. Sul II,

then, progressively emerged, reinforcing spectral friction through fundamental shifts, instrumental techniques and spectral interactions that have shaped the sonic landscape.

When looking back at the beginning of the composition versus the ending, the shift between spectral bases becomes noticeable. Bar 3 features the chord Eb4-G4-B4, while the final bar (bar 107) presents E5-B2 for the bass clarinet and Bb1 for the double bass. When linked to the spectral integer multiples identified earlier, bar 3 aligns with Sul I, and bar 107 corresponds to Sul II, with B2 being an exception. Even from a simple observation of the composition's opening and closing moments, this spectral shifting is already evident. Establishing such correlations between spectral content is something Ellen Jacobs has described as a fundamental aspect of her compositions.

**[00:04:59] – Margot Meire**

Dus die boventonen vormen toch enigszins een vertrekpunt in de muziek?

**[00:05:02] – Ellen Jacobs**

Ja, wel een vertrekpunt sowieso. En voor mij zorgt het ervoor dat ik nog altijd een houvast heb. Want in de muziek die ik schrijf, dat is heel erg klankgebaseerd. Timbre is heel belangrijk en zo, maar... Toch graag wil ik natuurlijk dat je toonhoogtemateriaal een samenhang heeft. Ik ga weinig met een harmonisch verloop bezig zijn bijvoorbeeld, dan heb je wel iets van structuur nodig.<sup>136</sup>

This excerpt from the November interview suggests an underlying structural premise, the role of overtones as a guiding force in shaping the pitch content of the composition. The analytical findings thus far align with the composer's intentions, demonstrating a distinct approach. Unlike composers who allow sound to unfold freely within a space, she deliberately positions partial referencing pitches to establish a defined structure. The claim that this composition in specific is based on both Sul I and Sul II partials is not only a claim stemming from the earlier analytical findings, but also from the following quote from the interview.

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<sup>136</sup> Ellen Jacobs (composer), interviewed by Margot Meire (student at Ghent University), 21 November 2024.

**[00:03:38.170] – Ellen Jacobs**

Meestal vertrek ik vanuit één akkoord of toon en dan ga ik daarin eigenlijk kijken van oké, die noten zitten daarin, dan schrijf ik de boventoonreeks op van die noten en dan zoek ik eigenlijk, stel nu dat het met strijkers is bijvoorbeeld, naar de boventonen die dat daar in die reeks zitten, die daar uithalen en dan op zoek gaan naar andere manieren om die te spelen. Ik gebruik heel vaak boventonen dat de strijkers niet zo vaak gebruiken. Je kunt eigenlijk één harmonische op vier of vijf verschillende manieren spelen, meestal dan toch. En dan kan daar meer of minder **ruis** bij. Het hangt af van de manier waarop je speelt.<sup>137</sup>

This quote specifically highlights how a single tone can serve as the foundation for an entire composition. In *And In Between There Is* (2024), that foundation emerges from string instruments—here, the double bass—and, more precisely, from the overtone series of a tone that is typically not played on them, as she says so herself. The clearest example of this compositional, deliberate choice is the first introduction of Sul I’s overtones in the introductory segment, between bars 10 and 17. **The analysis pointed out the strikingly high nature of these overtones, which stands in contrast to the inherently low character of the double bass.**

Furthermore, within the broader framework of the composition, the double bass frequently plays at particularly high pitches; when it does not, the sound is manipulated through techniques such as circular bowing and bridge pressure. In some cases, a combination occurred, such as in bar 36 Segment A. Extended techniques, the focus of the following section, were confirmed by the composer to play a crucial role in transforming the overtones of the double bass string into essential structural elements of the composition—entirely independent of traditional tonality and key structures.<sup>138</sup> The quote also mentions the word *ruis*, translated as “noise.” More specifically, this refers to the instrumental techniques that will be discussed later. However, in terms of **spectral interconnectivity**, the noise component is already worth mentioning. Earlier analysis identified a significant presence of noise, both in the double bass and percussion sections. Its implementation added tension to the spectrum, a phenomenon that was particularly notable in Segment D and affected the median spectral flux calculation to be higher compared to the preceding segments. Incorporating these noise components serves as a means of generating tension.

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<sup>137</sup> Ibid.

<sup>138</sup> Ibid.

### 3.2.1.2 Instrumental Techniques and Spectral Modulation

Instrumental techniques played a fundamental role in shaping tension, instability, and spectral movement, influencing both spectral flux and the timbral qualities of the instruments involved. The most striking examples of this were found in the trumpet and double bass, both employing a wide array of techniques to either blend seamlessly into the ensemble or introduce contrasting textures. In particular, their manipulation of spectral flux dictated whether pitches emerged with prominence or subtlety, depending on the musical context. For the trumpet, the use of mutes altered the timbre significantly, with muted passages producing a darker, more subdued tone compared to the *senza* version. This gave the composer a nuanced tool for sculpting spectral complexity, allowing for a dynamic interplay between thickened and thinned sonic textures.

#### [00:05:48] Ellen Jacobs

[...] Van daaruit ga ik op zoek naar manieren waarop dat akkoord vanuit verschillende opzichten bekeken kan worden en zo een andere soort ‘glans’ kan krijgen. Dan helpt dat ook om die boventoonreeks te hebben en dan te zoeken naar hoe je het ensemble gaat vormgeven, dus hoe je het gaat ‘orkestreren’, waardoor het geheel ‘briljant’ zou klinken, bijvoorbeeld.<sup>139</sup>

The above November interview excerpt shows that on the one hand one overtone-series indeed shapes the entire orchestration of the piece. The word *glans* refers to ‘shimmer’, a type of timbre that occurred for the xylophone, piano and double bass, all after each other. With all instruments having a different timbre, the shimmer in itself took on multiple ‘identities’. The pitches that formed the shimmer were primarily Bb, C, and F#, shifting across registers depending on the instrument. In respective order, they corresponded to the 13<sup>th</sup>, 7<sup>th</sup>, and 10<sup>th</sup> harmonics of Sul II. As confirmed by the quote above, altering timbre through instrumental techniques or simply allowing the instrument to play higher is indeed regarded as a way to introduce differentiation and variety, all while remaining anchored in the same fundamental base.

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<sup>139</sup> Ibid.

The double bass transitioned to Sul II with circular bowing and occasional bridge pressure, refining timbral focus and subtly amplifying spectral flux. These techniques shaped both structural articulation and spectral modulation, producing a deep, rumbling presence that blended its partials with those of other instruments, intensifying modulation effects and shaping a fluid sonic landscape.

In contrast, the piano remained the most stable element, employing almost no instrumental techniques and contributing only minimally to spectral interferences. This, when viewed in relation to the bar chart depicting spectral flux distributions across split instruments, explains why the piano consistently had the shortest bar in most cases.

**[00:24:22] Ellen Jacobs**

Ik ben expres gegaan voor instrumenten die mij wat meer zouden uitdagen. Omdat ik weet, voor koperblazers heb ik nog nooit geschreven. Heel af en toe, in mijn oefeningen ofzo. Maar dan heb ik de trompet gekozen, omdat ik wist dat het een uitdaging zou zijn om dit te kunnen mengen met de anderen. En dan heb ik met de trompettist samen gezeten. Dus dat heb ik dan expres gedaan en daar zat een klarinet bij, piano, twee slagwerkers en contrabas. En dan heb ik geprobeerd om die instrumenten te gebruiken op een manier dat die niet meer hun authentieke, hun echte functie hebben.<sup>140</sup>

Beyond the double bass, the trumpet also played a crucial role in shaping *And In Between There Is...* (2024). What stands out most is the deliberate redefinition of each instrument's authentic function, fundamentally altering their timbre and sound production. This, in turn, influenced both spectral slope and spectral flux, most notably in Segment B, where the winds and double bass exhibited the steepest spectral slope values. While they were grouped together due to limitations in Lalal.AI's sound separation, having a degree of instrumental isolation was preferable to none.

For example, the correlation between instrumental techniques and the positively ascending (see Figure 55) spectral slope lay in the trumpet's use of split tones, paired with the double bass's higher register. These choices induced spectral imbalance, where lower frequencies were displaced by more prominent high-frequency energy, generating a heightened sense of tension. By stripping these instruments from their conventional playing techniques or expected timbral roles, their spectral parameters were actively reshaped, ultimately structuring the composition or, at the very least, defining

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<sup>140</sup> Ibid.

the sonic architecture of the segment itself. By manipulating resonance, overtone interactions, and spectral flux, she ensures that the inherent acoustic qualities, linking to sound morphology, of each instrument actively contribute to the evolving musical architecture. This approach allows for a nuanced interplay between sound materials, where structure emerges organically through spectral modulation rather than traditional formal constraints.

### 3.2.1.3 Spectral Flux Development and Structural Evolution

The most significant contributions to the objective analysis came from the application of VAMP plugins in Sonic Visualiser, which processed split segments per instrument via Lalal.AI. While the latter operates on a probabilistic model and occasionally introduced minor splitting inaccuracies, its overall output proved valuable in understanding each instrument's distinct role within the ensemble.

Returning to the initial problem statement of this thesis, Judy Lochhead's 2020 critique of the limited focus on orchestration and timbre within musical analysis, particularly for compositions that depart from tonality, highlighted an essential challenge. However, for this case, the deliberate implementation of spectral tension, relaxation and instrumental techniques was closely linked to the dispersion of partial referencing pitches from either Sul I or Sul II across the ensemble, alongside various timbral adaptations. By segmenting the analysis per instrumental section when feasible, spectral imbalances were detected through Spectral Slope while RMS Energy helped identify structural markers in time through pitch interactions. Without these tools, key structural implications risked being overlooked.

Examining the two primary plugins used for full segment analysis, Spectral Flux and Constant Q, reveals distinct findings. Each segment exhibited a unique flux-time combination, with Segment E displaying the highest flux levels, followed by D and A. As previously discussed, the timbral contrasts in Segment E emerged at a granular level, while inharmonic elements were particularly pronounced in Segment D, such as the use of a coin on the tam-tam, which created punctual noise like accents that contributed to the deliberate structuring of the composition's progression. These interventions underscore the relevance of spectral flux as a fundamental tool for analyzing structural developments in non-tonal spectral compositions, as well as spectral detection in general. While pitch tracking via the score, Aubio Pitch Detector and NNLS Chromagram helped to map spectral distribution, highlighting where Sul I or Sul II partials were present and which exhibited greater prominence, the real structural insights came from spectral flux and Constant Q, which demonstrated how these spectral elements actively shaped the compositional framework, making the sound vital.

This aspect likely holds the closest connection to the composer's intentions, a topic present in the hypothesis of this research.

What stood out most was not just the differences between spectral flux median values per segment but the way Sul I and Sul II alternations transformed pitch interactions into spectral narratives rather than tonal chord progressions. As outlined in the proposed methodology in Chapter 2, chord relationships were deliberately omitted, as the key concern was not mutual harmonic structures but the spectral foundation of partials and how orchestration and instrumental techniques shaped their interactions.

Furthermore, references to the initial presentation of the 11<sup>th</sup>, 12<sup>th</sup>, and 13<sup>th</sup> partials of Sul I (bars 10–17), along with the augmented triad in bar 3, proved more insightful in understanding how partials were distributed across the ensemble and throughout the composition as a whole. While NNLS Chromagram helped identify pitches absent from the Aubio Pitch Detector and Spectrogram Layer, the interview later revealed that sound took precedence over strict chordal relationships, reinforcing the spectral nature of the compositional framework.<sup>141</sup>

Ultimately, the analytical process illuminated a strongly spectromorphological approach, wherein the focus was placed on the evolution of sound over time—hence the fusion of flux with time dimensions. The literature review established that situating the sound object within a temporal context enhanced structural recognition, even in the absence of tonality and external key structures.<sup>142</sup> Moreover, research suggested that in multi-voiced environments, spectral flux combined with performance elements, here interpreted as instrumental techniques, could effectively outline the trajectory of sound in time, serving as a representation of structure.<sup>143</sup> Unlike earlier studies in the literature review that frequently linked spectral phenomena to perception (see Chapter 1), this analysis anchored its findings in objective spectral measures, both numerical and visual. These objective markers then provided a bridge to the later incorporation of (1) the pre-analysis interview with Ellen Jacobs (21 November 2024) and (2) an interview on 17 May 2025. By prioritizing compositional intentions within a systematic, measurable framework, the research ensures that these intentions are represented meaningfully—on the condition that an interview is available to contextualize the findings. In this case, that condition is securely met, reinforcing the validity of the approach.

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<sup>141</sup> Jacobs, interview, 21 November 2024.

<sup>142</sup> Thoresen and Hedman, "Spectromorphological Analysis of Sound Objects", 134-37.

<sup>143</sup> Alluri and Toiviainen, "Exploring Perceptual and Acoustical Correlates of Polyphonic Timbre", 223-24.

### 3.2.1.4 Time Structure Variations and Spectral ‘Space’

The most recurrent time structure throughout the composition, based on Thoresen and Hedman (134–37, 2007), was ripple time, which organized spectral oscillations and punctuated moments of modulation. The brief occurrences of flutter time in the introductory segment and Segment B and ambient time in Segment E underscore the multidimensionality within the piece and, more importantly, confirm that flux and time combinations are not fixed. If they were, an external structural force in a way similar to tonality would be imposed onto the findings, ultimately overlooking the internal spectral connections that shape the music’s architecture.

Here, structure is derived from intrinsic sonic features such as the Sul I or II base and the particular orchestrations built upon them, as argued in the previous parts and supported by quotes from the interview.<sup>144</sup> Another finding was that time was deeply intertwined with spectral space. In Segment D, this relationship was particularly pronounced, as the evolving frequencies in time directly shaped the expansion of spectral space. Rather than functioning as an external parameter imposed on the composition, time itself became an active force, structuring the way sound unfolds. This further underscores the correlation between spectral flux and time, where specific changes in the spectrum, captured through spectral flux measurements, determine how frequencies are distributed across time, ultimately forming the composition’s time structure. Gérard Grisey employed similar structural approaches, explicitly emphasizing the role of overtones as a catalyst for shaping time structures, which he referred to as the ‘skeleton of time’.<sup>145</sup> Yet, due to the variability among flux and time combinations, this interaction remains dynamic rather than rigid.

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<sup>144</sup> Jacobs (composer), interview, 21 November 2024.

<sup>145</sup> Grisey, “Tempus Ex Machina”, 239-41.

### 3.2.2 Global Analysis of *And In Between There Is* (2024)

#### 3.2.2.1 Spectral Flux and Time per segment overview and discussion

**Table 3.1** Spectral Flux Type, Median Spectral Flux Value and Time Category per Segment for the composition.

| Score Segment | Spectral Flux Type + Median Value | Time category type |
|---------------|-----------------------------------|--------------------|
| Intro         | Low spectral flux: 0.227          | Flutter time       |
| A             | High spectral flux: 0.289         | Ripple time        |
| B             | Moderate spectral flux: 0.258     | Flutter time       |
| C             | Low spectral flux: 0.216          | Ripple time        |
| D             | High spectral flux: 0.294         | Ripple time        |
| E             | High spectral flux: 0.380         | Ambient time       |

Table 3.1 shows a concise overview of the different median spectral flux values and time categories found per segment for *And In Between, There Is* (2024). The numerical values will be discussed afterwards, as well as the feedback of the composer received on 17 May 2025 on the analytical data.

One of the first observations that can be made is that ripple time reappears the most. This suggests that the composition is inherently built on organised spectral oscillations, observed through the Constant Q plugin output. The persistence of ripple time under both low and high spectral flux conditions demonstrates how spectral movement is distributed across the piece and is subordinate to the composition's multidimensionality.

Furthermore, when it comes to the spectral flux values themselves, the highest are present at D and E, which mark dual moments in the composition's trajectory. For D, the combination with ripple time causes a kind of intensification of spectral instability. For E, the combination with ambient time implements a spectral complexity that is more sustained rather than punctuated. This causes a sense of climax instead of interruption which makes sense in the context of the piece ending. The high spectral flux level for E is a topic of later discussion.

With Segment C having the lowest spectral flux value, it serves a moment of structural rest contrasting with A and D who both also have ripple time yet a significantly higher flux. For C, the ripple time construct contains no major transformations for the spectral content yet implements structure anyways on a more background level. In case of the

variations with a higher spectral flux, the spectral movement has a larger role in shaping tension. Therefore, Segment C functions as a controlled transitional space between more dynamic segments. If spectral flux were uniform across the board, structure would be more difficult to achieve, as juxtaposition and contrasts play a key role in shaping composition. Ultimately, the table provides structure to the detailed analysis in Chapter 3, as the discussed details support this condensed categorisation. The remarkable interplays between the spectral flux and time give a sense of how the piece evolves and if any possible patterns arise. In this case, the combination of “high spectral flux” and “ripple time” is the most recurring, existing two times for Segment A and Segment D. Even though the numerical values tell that the spectral flux is not exactly the same, the combinations do give the sense that they form points in the composition holding a significant amount of spectral flux and being somewhat correlated to each other. Referring to the chart diagrams used per segment to outline the spectral flux divisions among instruments, segments A and D displayed the most similarities. The piano contributed the smallest share, while the winds had the largest, with percussion and double bass falling in between. This reinforces the argument that both segments exhibit similarities, though not identical, and form a discernible pattern. The table, in this regard, is useful in identifying these recurring ‘patterns’.

A comparable observation applies to the introductory segment and segment C, both characterized by a low spectral flux ripple time combination. In contrast, segments B and E stand out due to their unique configurations. In the introductory segment and segment C, spectral flux remained minimal, yet structural integrity persisted. This stability stemmed from the presence of a few recurring structures or entities detected by the Constant Q and linked to score findings and data from other plugins during section 3.1.

At present, the most significant aspects are spectral flux and time, as analysed through Constant Q, which offers a broader perspective on the piece.

Ellen Jacobs was asked what correlation she herself saw between the obtained results and the outline and title of the composition. Her answer was that the time categorisations resembled her ideas and intentions for the piece perfectly, with the following quote supporting this:

[...] Het wisselen tussen "ripple time" en "flutter time" (dit zie ik als wisselen tussen het bos en de kamer binnen) mondt uiteindelijk uit in "ambient time" op het einde, waar er een soort van tussenwereld gecreëerd wordt tussen het bos en de huiskamer. De "ambient time" sluit mooi aan bij wat ik ogen had met de zogenaamde "tussenruimte" van "And in between, there is..."<sup>146</sup>

In the November interview, she mentioned that the composition was based on the style of Kaija Saariaho (1952-2023), for which she composed *And In Between, There Is ...* (2024) as a reference to the *dreamspaces* and *curves of tension* widely known in her oeuvre.

Wat ik nu heb gedaan voor mijn laatste werk is dat ik dat op een heel intuïtieve manier heb aangepakt. De opdracht was om gebaseerd op het werk van Kaija Saariaho, een stuk te schrijven. Ik had daar dan zes instrumenten voor en ik wist van, oké, ik wil iets doen, want ik had ook gelezen dat zij ook heel hard bezig is met *dreamspaces* en dat inspireerde mij om daarmee iets te doen. Dus ik dacht van, oké, hoe klinkt een ruimte gewoon ergens binnen, versus in een bos. Dus ik ben dan met een cymbaal, echt, naar het bos gegaan en daar heb ik mijn stuk opgenomen. En dan heb ik dat ook thuis gedaan, zodat ik die twee met elkaar kon vergelijken. Ik heb wel niet geanalyseerd met een programma ofzo. Gewoon echt puur, wat geeft dat voor mij? En bijvoorbeeld in het bos zat daar veel meer laagte in dan thuis. Dus dan heb ik die twee eigenlijk gemengd. Dus daarom ook de titel *And In Between There Is*, omdat dat tussen de twee werelden zit eigenlijk, een ruimte dat ik gecreëerd heb. Voorlopig is dat echt heel intuïtief, maar ik schrijf wel heel veel op.<sup>147</sup>

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<sup>146</sup> Ellen Jacobs (composer), interviewed by Margot Meire (student at Ghent University), 17 May 2025.

<sup>147</sup> Jacobs (composer), interview, 21 November 2024.

As discussed in Chapter 1 of the literature review, Saariaho shaped the larger structure of her works through spectral and timbral parameters. Her use of inharmonicity, characterized by differing spectral bases and noise components, heightened tension and created focal points, while balanced harmonics maintained stability. This contrast was further reinforced by extended techniques that modulated timbre and graininess, contributing to either tension or stability.<sup>148</sup> These structural lines correspond to the time categories identified through the Constant Q plugin. Aligning flux values with them reveals a broader and more coherent structure within the composition. In this way, the time structures function as an overarching framework that unifies the sonic and spectral material, offering a more global perspective on the composition's structure.

As previously mentioned, spectral flux is represented by numerical values, which are discussed in detail later. Chapter 2, Proposed Methodology, explains how these values were obtained. To visualize their progression over time, a line graph was plotted in Microsoft Excel and is presented below. This graph was subsequently shared with Ellen Jacobs on May 17, 2025.

The question centred on the correlation between the line graph and the narrative dimension of her work. She noted that the graph aligns precisely with the structure she envisioned while composing, accurately highlighting the most important focal point near the end, specifically in segments D and E. Since her process was largely intuitive, she values the median spectral flux graph as a representation of her compositional intent, reflecting the spectral changes she aimed to implement throughout the piece.<sup>149</sup> Connecting this to previous mentions of Kaija Saariaho (1952–2023), the visualized line graph can be compared to the concept of *dreamspaces* and *curves of tension*. Between the introductory segment and segment B, segment A marks a peak in spectral flux before gradually decreasing toward segment C. This illustrates the *curves of tension*, as the sound and its spectral properties, examined in section 3.1, undergo various transformations shaping this pattern. Examining the table and the parallels between the introductory segment and segment C, as well as segment A and segment D, the graph reinforces these findings through their similar positions. Segments B and E emerge as dual moments that further clarify the structure, while segment C appears as a turning point toward a continuously increasing spectral flux. With the largest focal points emerging for the ending part of the composition, this graph resembles the intended structure accurately.<sup>150</sup>

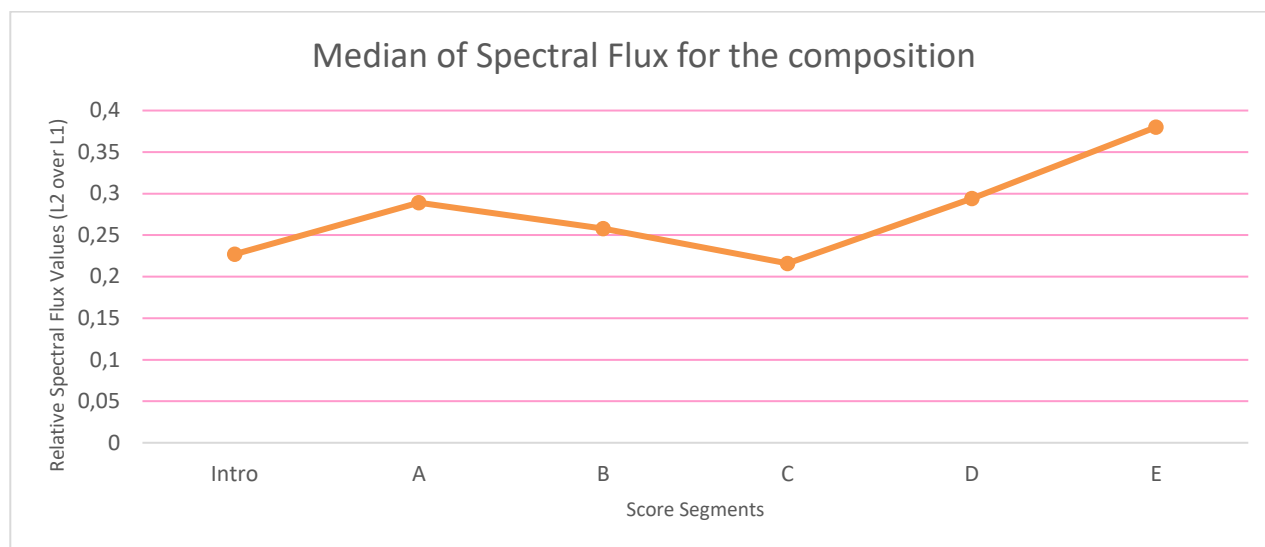
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<sup>148</sup> Saariaho, "Timbre and harmony: Interpolations of timbral structures", 94-97.

<sup>149</sup> Jacobs (composer), interview, 17 May 2025.

<sup>150</sup> Ibid.

Together with the composer's insights before and after the analysis presented in this thesis, the sound morphology, through plugins and score analysis, effectively bridges with her intended artistic vision.



**Graph 5** The evolution of the Spectral Flux median throughout the composition, calculated per individual segment. X-axis: score segments, Y-axis: relative spectral flux median values per segment for L2 over L1.

Jacobs was also asked whether she considered spectral flux a valid and objective measure of musical structure. She answered as follows: “Zeker! Het is fijn om te zien dat de onderliggende structuur ook zeer duidelijk hoorbaar is en zich vertaalt in de grafiek. Het belangrijkste moment zit in dit werk op het einde en dat geeft de grafiek ook zeer duidelijk weer.”<sup>151</sup>

According to her, the flux and time categorisations are valuable and useful ways of understanding the overall course of the composition and, additionally, the differences among the segments. It shows that each segment was carefully curated to both fit in the entirety yet inject enough contrast too for the variety to emerge and shape it. Furthermore, the graph can even be linked to the initial sketch made by Jacobs for *And In Between, There Is ...* (2024).

<sup>151</sup> Jacobs (composer), interview, 17 May 2025.

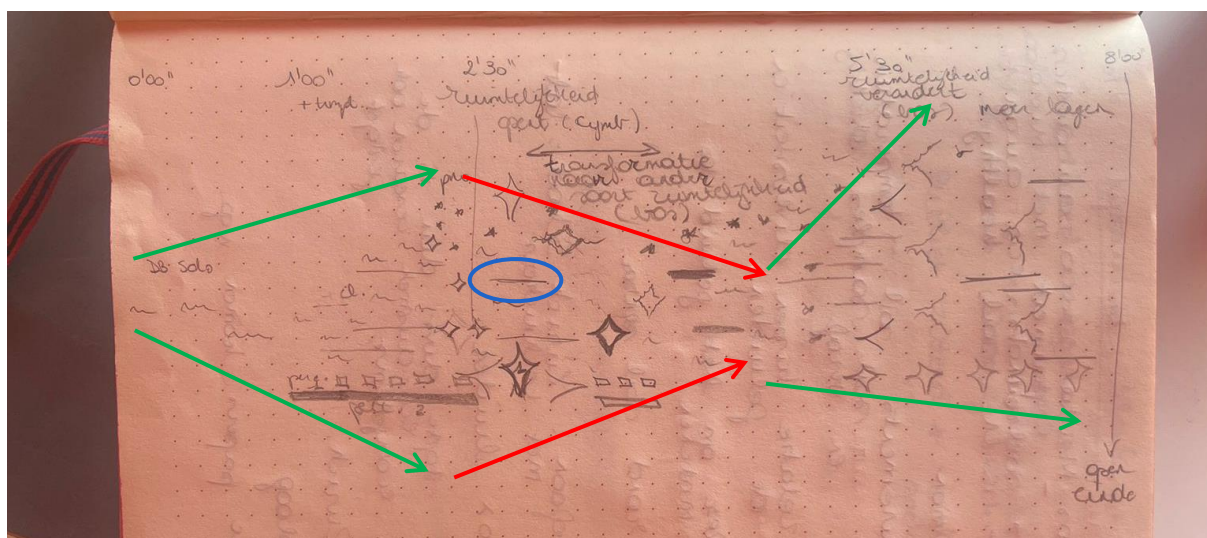


Figure 128 Photograph from Ellen Jacobs, *Initiële schets van And In Between, There Is*, 20 June 2024.

Figure 128, taken by Ellen Jacobs (2024), shows her initial sketch for *And In Between, There Is ...* (2024). The green annotation represents the transformation between the introductory segment and Segment A, which also undergoes a significant flux change. This expansion connects directly to the line graph, which was plotted based on the median spectral flux values per segment (see Graph 5).

The horizontal lines (see example circled in blue) in the sketch depict the sonic layers Jacobs envisioned. The green arrows illustrate the increase in layers from the introduction to Segment A, followed by a slight decrease. The stars symbolize the shimmer moving from the xylophone to the double bass and then to the piano, initiated at the end of Segment A and proceeded throughout Segment B. The number of sonic layers also drops noticeably in Segment C, aligning with the line graph, which shows the lowest spectral flux value of all. As the transformation progresses, the sonic layers multiply again, building toward the end of the composition through Segment D and E. The red arrows indicate the decrease, while the following green arrow marks the increase once more. At the end of the sketch, Jacobs included the phrase “ruimtelijkheid verandert (bos), meer lagen,” which translates to “spatiality changes (forest), more layers.” This reinforces her intent to expand the sonic layers and spectral friction to enhance spatiality, creating a shifting sonic fabric through varying partials and instrumental techniques. The words “open einde” or “open end” further clarify why the median spectral flux line graph also reflects an open end.

Since spectral flux does not decrease, the composition avoids stagnation. Instead, the open end aligns with the highest median spectral flux value (E), and in combination with the ambient time category, results in a blurred transformation.

By incorporating her initial compositional sketch alongside the median spectral flux line graph, and with both taking on a remarkably similar form, the connection between intuitive creativity and objective, numerical data is clearly established.

The last question asked to Ellen Jacobs after presenting her the analytical results was the following: On a scale of 1 to 5, how would you rate these analytical insights in terms of a deep, scientific understanding of the case study and acoustic, non-tonal, spectral music in the broader sense? In other words, how would you rate the relationship between objective data and your own creative intent? When she gave it a 4, her motivation was the following: “Ik ben zeer positief verrast door de parallellen die getrokken zijn met mijn eigen intenties voor dit werk en de wetenschappelijke analyse. Het is mooi om te zien dat de vorm van mijn werk ook wetenschappelijk op dezelfde manier wordt weergegeven als ik zelf in gedachten had.”<sup>152</sup> Building on the composer’s feedback, one could argue that the alignment between objective data and her artistic intentions forms a cohesive and multidimensional representation of the composition, capturing both its structural framework and narrative depth.

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<sup>152</sup> Jacobs (composer), interview, 17 May 2025.

## CONCLUSION

This thesis was built around the following research question: *How can a combination of detailed music segmentation—using scores, Sonic Visualiser (VAMP) plugins, and sound-splitting software—alongside a global analysis of spectral features over time contribute to a structured approach to non-tonal spectral acoustic compositions? In what way can insights into compositional intent, obtained through interviews with the composer, help in understanding the interactive and structural relationships within these compositions while also reducing the limitations of perception-driven models?*

The hypothesis was as follows: By incorporating spectromorphological elements, both in the score and through selected VAMP Sonic Visualiser plugins, will enhance the structural understanding of the non-tonal spectral case study, providing a valuable reference point for future analyses. By categorizing the composition according to spectral flux and time, based on Lasse Thoresen and Andreas Hedman's research (2007), the study will determine the level of spectral flux by calculating the median value extracted from the Spectral Flux dataset. Time categories will then be derived from the Constant Q output, offering a clear depiction of how frequencies evolve throughout the piece.

The categorization of spectral flux and time will reflect the composer's intentions, where increased spectral flux will indicate heightened musical tension, timbral complexity, or dense orchestration, while decreased flux will suggest intentional clarity, stasis, or a more restrained sonic landscape. By aligning these spectral characteristics with insights from the interviews, the study will establish a meaningful connection between the composer's creative decisions and the underlying spectral behaviour of the composition.

The literature review explored various analytical approaches to non-tonal music, including electroacoustic perspectives, which share common ground with spectral compositions. Pierre Schaeffer's TARTYP, a framework that conceptualizes the sound object perceptually, raised important questions about its applicability to broader musical structures divorced from tonality and instead rooted in spectral, measurable features. While some methods placed excessive emphasis on perception (ref. Judy Lochead, 2020), others prioritized spectral features at the cost of compositional narrative (ref. Lascabettes et al.). The challenge of integrating objective, measurable spectral data with compositional intent has been largely overlooked in contemporary music analysis of non-tonal spectral compositions. A deeper understanding of both these foundations and the creative intent behind them contributes to a more holistic analytical approach.

A transferable method can enhance musicological insight without diminishing creative expression through overly rationalized analysis. This thesis proposed a method structured around three core pillars: (1) score analysis, emphasizing orchestration rather than harmonic progressions or tonal conventions, (2) a curated selection of VAMP Sonic Visualiser plugins, including Aubio Pitch Detector, NNLS Chromagram, Spectral Slope, RMS Energy, Spectral Flux, and Constant Q, chosen to maintain analytical balance, and (3) composer interviews, conducted both before the analysis to establish creative intentions and after to assess whether the results aligned with the original artistic vision, thus taking steps toward a co-creative analytical approach. However, the latter was not an explicit research objective.

By integrating these three pillars, this thesis sought to answer the research question and confirm the hypothesis. The combination of a segmented analysis with Spectral Flux and Constant Q, alongside two interviews with the composer, did provide a global understanding of the musical structure and interactive relationships within its multi-voiced framework. The strong alignment between the median spectral flux line graph, the post-analysis interview, and the composition's initial sketch suggests that this method is effective for analyzing non-tonal spectral acoustic compositions.

Perception-driven models, which rely heavily on subjective interpretation while neglecting measurable spectromorphological features, were alternated by this approach. The method relied on objective data, consistently verified by VAMP Sonic Visualiser plugins when applicable, and was further enhanced by the integration of Lalal.AI, a sound splitting tool that provided deeper insight into the contribution of individual instruments within each segment. Its limitations were considered yet posed no major problems for the quality of the analysis. Prioritizing orchestration and timbre alongside objective data reduced reliance on perception driven models while offering a more comprehensive understanding of the composition. A segmented analysis proves to be an effective method for examining these compositions and getting a detailed understanding of the components making up the musical piece.

The alignment between the median spectral flux line graph and the post-analysis composer interview helped shape the final picture of the composition, demonstrating the value of spectral flux as a bridge between objective data and artistic intent. This also confirms the concepts proposed by Alluri and Toiviainen (2010) in elevating spectral flux to be an analytical representative. Furthermore, the integration of time categories introduced by Thoresen and Hedman (2007) proved valuable for interpreting larger structures, unified with the Constant Q plugin output. It specifically reinforced

earlier spectral findings through the score and plugins. The composer later provided positive feedback on these categories, noting a strong correlation between them and her idea of *sound transformation within an imaginative spectral space*, whether referencing her room or the forest or *in between*.

In short, this thesis demonstrated that combining segmented spectral analysis with objective data driven methodologies and compositional intent provides a structured framework for analyzing non-tonal acoustic spectral compositions. By employing measurable spectral features such as spectral flux and time structures through Constant Q alongside a dual interview approach, this study successfully addressed the limitations of perception-driven models while enhancing musicological insight into spectral composition.

Beyond Spectral Flux and Constant Q, additional analytical tools played a crucial role in refining the methodology. The Aubio Pitch Detector and NNLS Chromagram facilitated precise *pitch tracking, uncovering spectral foundations within Sul I and Sul II along with their intricate overtone relationships*. Meanwhile, Spectral Slope identified balance shifts across registers and RMS Energy helped mark *structural moments through amplitude variations*. Together, these techniques enriched the analysis, ensuring a multidimensional perspective on spectral movement and structural coherence. Despite some limitations outlined in Chapter 2 regarding the sound splitter and Sonic Visualiser plugins, the analysis still offers a cohesive perspective on *both its structural foundation and narrative depth*.

Integrating these spectral measurements within the framework of the score and plugin-based analysis positioned Spectral Flux and Constant Q as **key** analytical tools. The connection between initial compositional intent outlined in the pre-analysis interview and the insights gained from the post-analysis discussion reinforced the research question, objective and hypothesis. This interplay created a dynamic interpretative space where the composition was understood in terms of its structural depth without relying on subjective analytical perception or tonal frameworks.

*And In Between There Is ...* (2024) by Ellen Jacobs provided a compelling case study for this proposed method, illustrating the significance of *in between* states not just between room and forest but also *between objective spectral features and compositional intent*. The strong alignment between analytical findings and Jacobs' artistic vision underscores the value of systematic measurable approaches to music analysis that are distanced from subjective, perception-based interpretations. By demonstrating that spectral movement alone is capable of constructing musical form, this research reinforces the possibility of analyzing objective data without neglecting compositional identity.

Future research could build upon this thesis by incorporating electroacoustic case studies, expanding the scope beyond acoustic instrumental timbres to explore their interplay with adaptations such as tape and live electronics. Works like Ellen Jacobs' *Inertia* (2021) and Maarten Buyl's compositions offer compelling opportunities for further examination, providing deeper insight into analytical possibilities within spectral music. This approach could also refine the co-creative analytical process between musicologists and composers, fostering a dynamic methodology that evolves through multiple feedback sessions. By continuously adapting and refining the process, the end product would not only enhance scientific and musicological understanding, as seen in this study, but also generate creative insights beneficial to composers themselves. The dual interview approach was a minimal step into a similar direction. Including the creator of the composition in the analysis even more intensely can potentially foster greater insight into the sonic architecture of the music and its relation to the objective measured data.

Alongside this expansion, investigating how AI can support spectral analysis without compromising compositional intent presents another valuable avenue. Machine learning models capable of tracking spectral flux and time structures more dynamically could greatly improve analysis methodologies. However, current machine learning techniques, such as Naïve Bayes and Recurrent Neural Networks, face limitations when applied to multi-voiced structures and long-term spectral dependencies. Future work could focus on refining AI tools to better capture spectral relationships and microtonal interactions, drawing from foundational research such as Jing Liang's "Harmonizing Minds and Machines: Survey on the Transformative Power of Machine Learning in Music" (2023). This research provides a useful starting point for advancing AI-oriented methods in spectral music analysis.<sup>153</sup> An integration like this could potentially compensate for occasional errors in the Lalal.AI sound splitter and Sonic Visualiser VAMP plugins, creating a more robust analytical environment where every sonic particle can be examined with greater precision, relying on machine learning's abilities to detect patterns and their sources.

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<sup>153</sup> Jing Liang, "Harmonizing Minds and Machines: Survey on Transformative Power of Machine Learning in Music", *Frontiers in Neurorobotics* 17 (10 November 2023), <https://doi.org/10.3389/fnbot.2023.1267561>.

Another promising direction would be the integration of audience perception experiments into the proposed methodology. These studies could complement computational analysis, offering insights into whether listeners naturally recognize spectral shifts and their role in musical structure. Understanding perceptual reception could not only validate analytical findings but also highlight the creative possibilities that emerge from spectral composition. By integrating empirical listener responses with systematic spectral analysis, future research could bridge theoretical insights with practical engagement, enhancing both musicological discourse and artistic innovation. Experiments could take on the form of interactive installations that probe participants' bodily experience of a selection of contemporary, Belgian compositions in the same aesthetic line as the case study presented in this thesis.

At last, a deep study into sound splitting software and its implications for analysis can be useful. Here, Lalal.AI served valuable data yet also performed minor inconveniences. Expanding this research to compare different instrument splitting models would help identify their strengths and weaknesses in extracting isolated sound sources from ensemble recordings. Some tools may struggle to differentiate overlapping frequencies, particularly in spectral music where harmonic interdependencies play a crucial role. Others may perform better at distinguishing extended techniques, such as circular bowing in the double bass or split tones in brass instruments. Understanding how these algorithms preserve or distort spectral integrity is essential for improving their application in spectral musicology.

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## APPENDIX A: DUTCH SUMMARY OF THE THESIS

De analyse van niet-tonale, klassieke en spectrale composities is lange tijd beïnvloed en uitgedaagd door dominante tonale paradigma's en structuren. Hierdoor zijn fundamentele structurele elementen, zoals de verspreiding van boventonen binnen een compositie, grotendeels op de achtergrond geraakt. Bovendien toont de geschiedenis van dergelijke analyses een tendens waarbij onderzoekers hun persoonlijke perceptie boven objectieve, empirische gegevens stelden. Judy Lochhead (2020) wijst op dit probleem en stelt dat het gangbare wetenschappelijke discours binnen de analyse vaak de overhand kreeg ten koste van het respect voor spectrale bouwstenen, zoals boventoon-orkestratie en timbre.

Deze dominante analytische benadering heeft geleid tot een verstarring van methoden, waardoor een systematisch kader zich slechts langzaam heeft kunnen ontwikkelen. Daarnaast werd de intentionele en creatieve dimensie van dergelijke composities overschaduwd door een al te ver doorgedreven rationalisatie, ondanks het ontbreken van een gestructureerd analytisch model. Het is daarom van essentieel belang een brug te slaan tussen de objectieve klankgegevens en de subjectieve, creatieve laag die de componist heeft gevormd. Zo kan een analytisch kader recht doen aan zowel de materiële als de artistieke aspecten van spectrale composities.

Deze masterproef stelt een heroriëntatie voor van bestaande analysemethoden, waarbij rekening wordt gehouden met geluidsmorfologie, haar structurele en interactieve eigenschappen, en de narratieve dimensie die door de componist is geïmplementeerd. De casestudy waarop deze benadering zal worden toegepast, is *And In Between, There Is ...* (2024) van Ellen Jacobs, een Belgische componiste voor wie klankbeleving centraal staat. Door middel van een gesegmenteerde methodologie die partituuranalyse, spectrale visualisatie met Sonic Visualiser en typering van spectrale flux en tijd combineert, laat deze studie zien hoe spectrale gegevens kunnen dienen als structurele markers zonder te vertrouwen op traditionele tonale paradigma's. De bevindingen geven aan dat Jacobs spectrale beweging organiseert door dynamische transformaties van boventoonrelaties, ondersteund door (uitgebreide) instrumentale technieken en tijdsafhankelijke energieflectuaties.

Door spectrale eigenschappen over het ensemble te verdelen en spectrale flux als een actieve kracht te integreren, bouwt Jacobs muzikale spanning op zonder conventionele harmonische progressies, waardoor een gelaagd en evoluerend sonisch weefsel ontstaat. Dit onderzoek draagt bij aan het musicologische discours door een geïntegreerd model aan te

bieden dat objectieve spectrale gegevens en compositorische intentie in evenwicht brengt, waardoor de analytische mogelijkheden verder gaan dan op hermeneutische, perceptie-gebaseerde kaders.

Deze masterproef maakt overigens gebruik van een geluidssplitter, Lalal.AI, om de lagen van de compositie uit elkaar te rafelen en te begrijpen hoe elk instrument of elke instrumentengroep bijdraagt aan het geheel. Op die manier wordt ook het polyfonische karakter van de compositie in acht genomen, een gegeven dat zich amper toonde in het literatuuronderzoek naar analysemethoden voor niet-tonale, spectrale muziek.

## APPENDIX B: ATTACK-DECAY VISUALISATIONS

A standardised image of the attack and decay of a sound signal, visualised in the classic Waveform output.

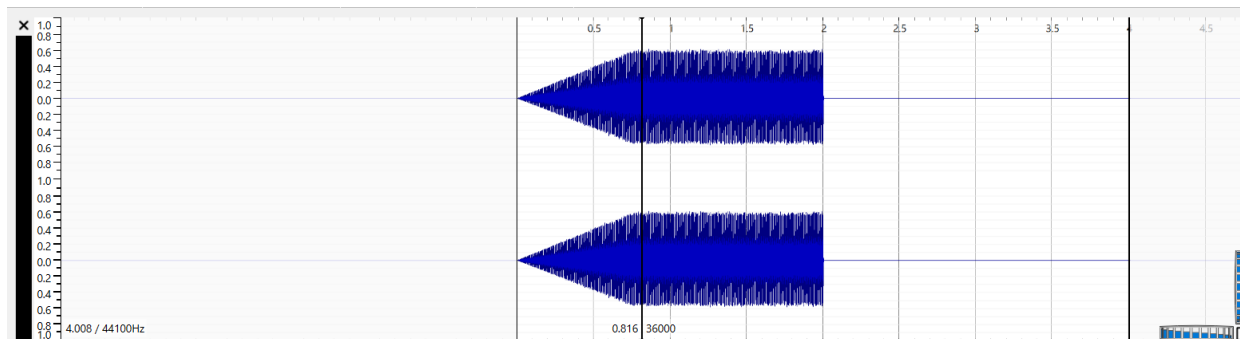


Figure I Attack visualisation on Sonic Visualizer

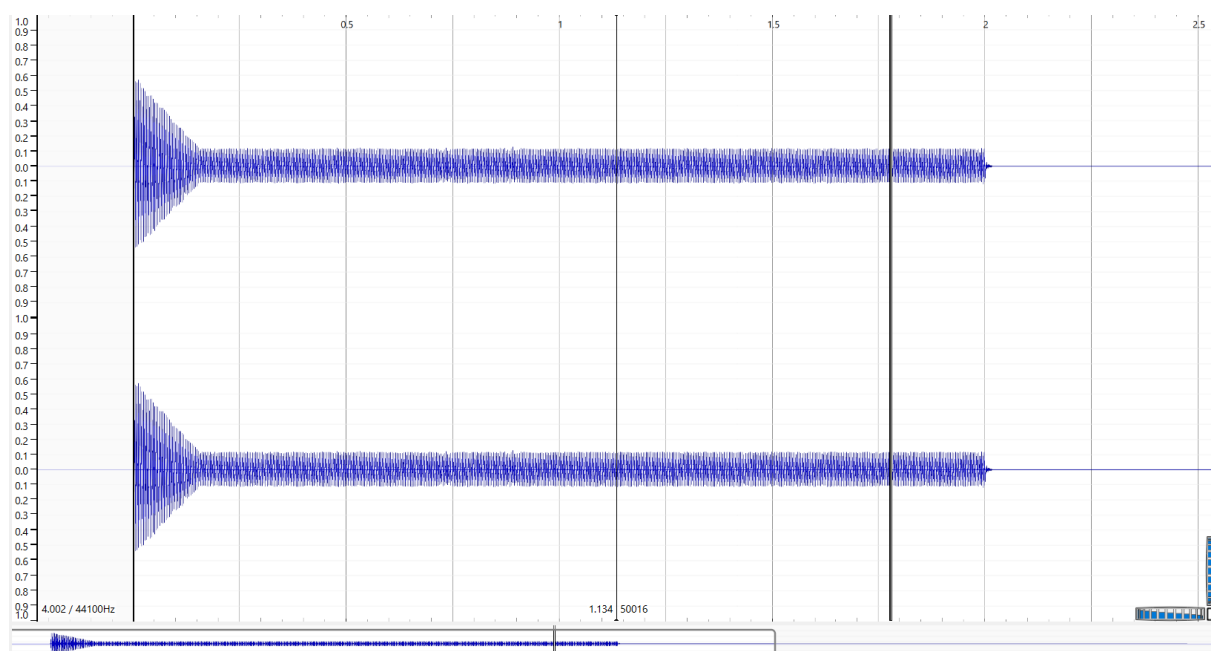


Figure II Decay visualisation on Sonic Visualizer

## APPENDIX C: INTEGER MULTIPLES

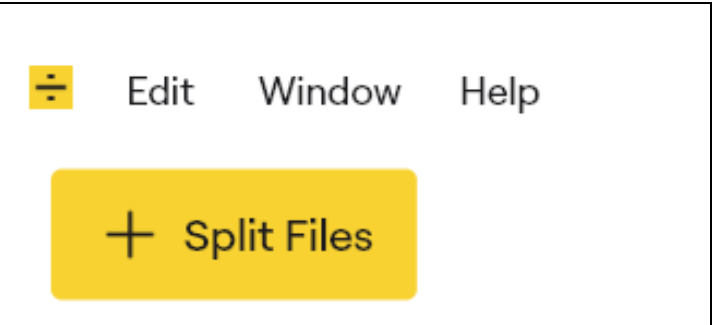
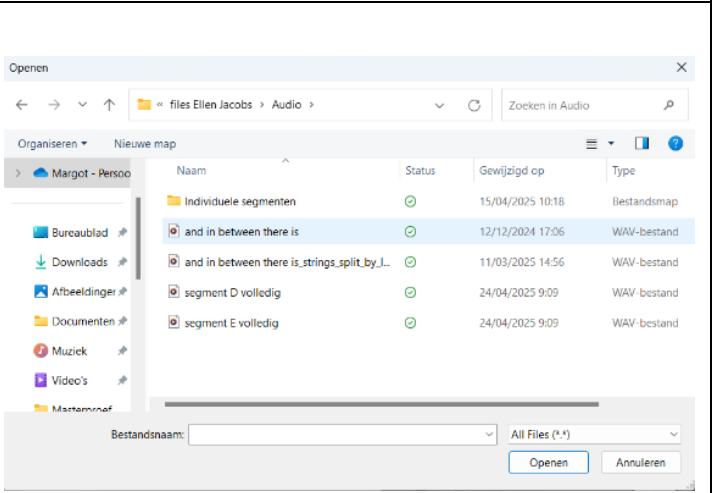
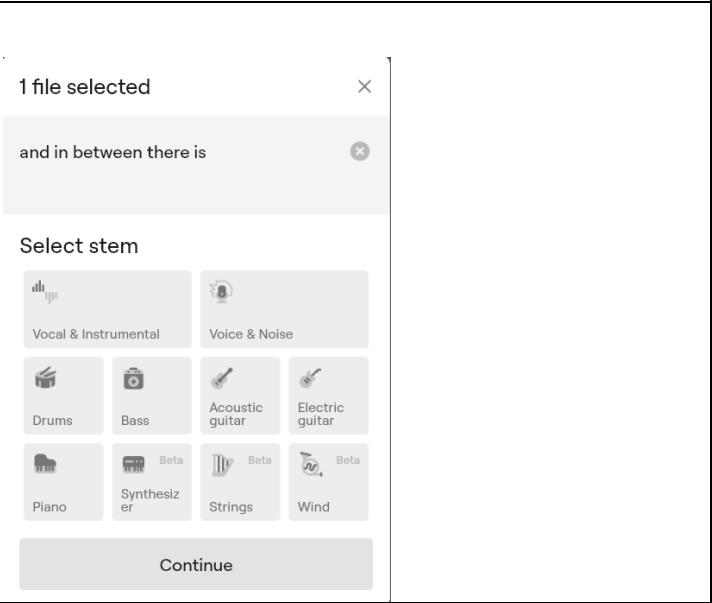
The integer multiples of respectively Sul I and Sul II are calculated through the formula  $F_n = n \cdot F_0$  and double checked

**Table I** Integer Multiples of respectively Sul I and Sul II on the double bass, calculated through the formula  $F_n = n \cdot F_0$  and retrieved from Ron Vonk, “Contrabas flageoletten”, n.d., accessed on 12 December 2024, from <https://www.natuurkunde.nl/artikelen/509/contrabas-flageoletten>.

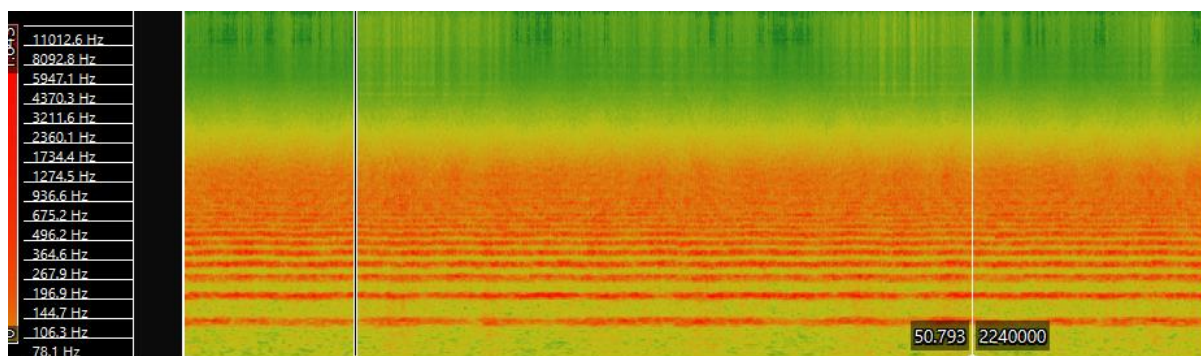
| G2 (Sul I) $\approx 98$ Hz | D2 (Sul II) $\approx 73$ Hz |
|----------------------------|-----------------------------|
| G3 $\approx 196$ Hz (2)    | D3 $\approx 146$ Hz (2)     |
| D4 $\approx 294$ Hz (3)    | A3 $\approx 220$ Hz (3)     |
| G4 $\approx 392$ Hz (4)    | D4 $\approx 293$ Hz (4)     |
| B4 $\approx 490$ Hz (5)    | F#4 $\approx 366$ Hz (5)    |
| D5 $\approx 588$ Hz (6)    | A4 $\approx 440$ Hz (6)     |
| F5 $\approx 686$ Hz (7)    | C5 $\approx 513$ Hz (7)     |
| G5 $\approx 784$ Hz (8)    | D5 $\approx 586$ Hz (8)     |
| A5 $\approx 882$ Hz (9)    | E5 $\approx 660$ Hz (9)     |
| B5 $\approx 980$ Hz (10)   | F#5 $\approx 730$ Hz (10)   |
| C6 $\approx 1078$ Hz (11)  | G#5 $\approx 807$ Hz (11)   |
| D6 $\approx 1176$ Hz (12)  | A5 $\approx 876$ Hz (12)    |
| Eb6 $\approx 1274$ Hz (13) | Bb5 $\approx 949$ Hz (13)   |

APPENDIX D: MANUAL LALAL.AI

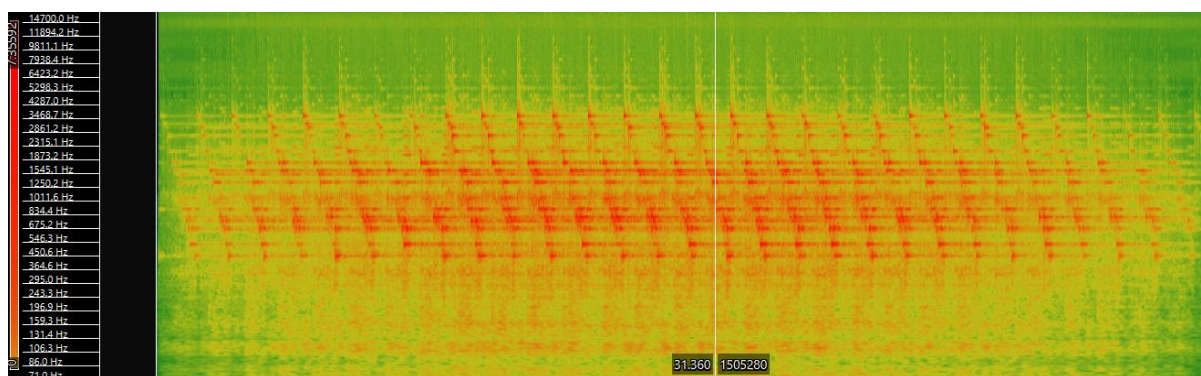
Table II Manual on how to split an audio file in Lalal.AI .

|                                                                                                                                                                                       |                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <p>Open Lalal.AI in the browser or via the application on desktop and search for the “+ split files” button.</p>                                                                      |    |
| <p>Search for the audio file you want to split and select.</p>                                                                                                                        |   |
| <p>Select the instrument / instrumental group you wish to split by simply clicking the appropriate icon.</p> <p>Lalal.AI will start the sample for tehe split file automatically.</p> |  |

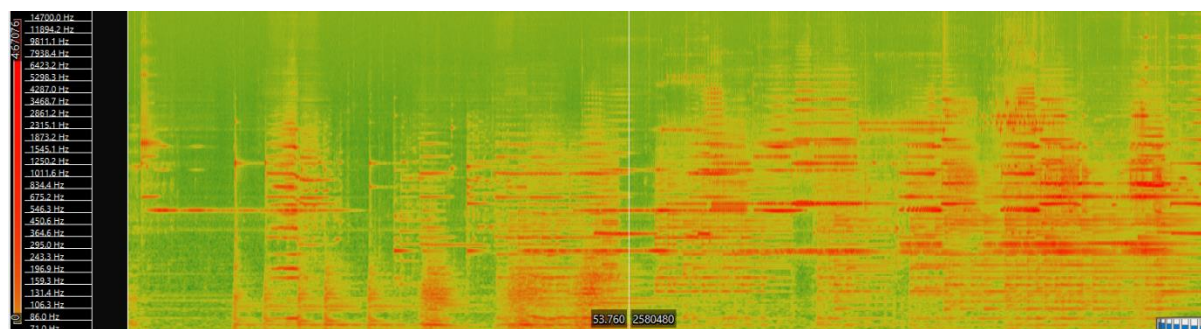
## APPENDIX E: EXAMPLES OF TIME CATEGORIES (AMBIENT, FLUTTER, RIPPLE) IN SONIC VISUALISER (CONSTANT Q)



**Figure III** An example of Ambient Time in Sonic Visualiser Constant Q, from 'ambient6.ogg', 16 September 2011, accessed on 10 April 2025 from [https://freesound.org/people/\\_mysterious\\_/sounds/128364/](https://freesound.org/people/_mysterious_/sounds/128364/).



**Figure IV** An example of Flutter Time in Sonic Visualiser Constant Q, from Gregor Quendel, 'Cinematic Piano Shimmer Soundscape', 1 March 2025, accessed on 10 April 2025, from <https://freesound.org/people/GregorQuendel/sounds/790564/>



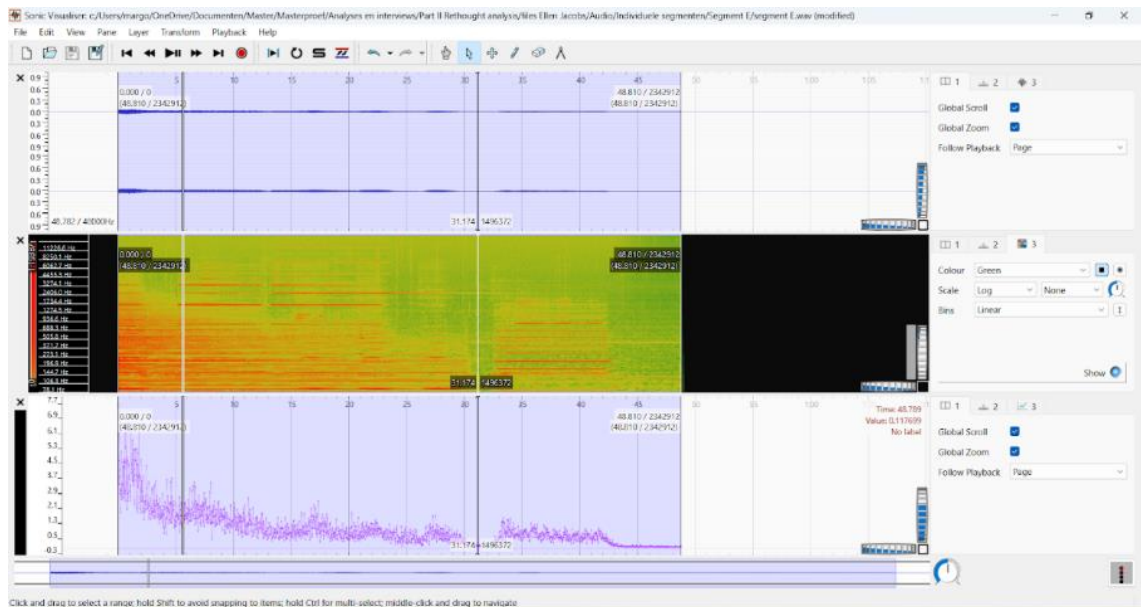
**Figure V** An example of Ripple Time in Sonic Visualiser Constant Q, from Ellen Jacobs, *And In Between, There Is ...*, (Leuven: TRANSIT Festival, 2024), 3-7, 23-48, full Segment A.

Figures III, IV, and V are not the only examples of ambient, flutter, and ripple time, but serve as reference points for categorizing time based on Constant Q output.

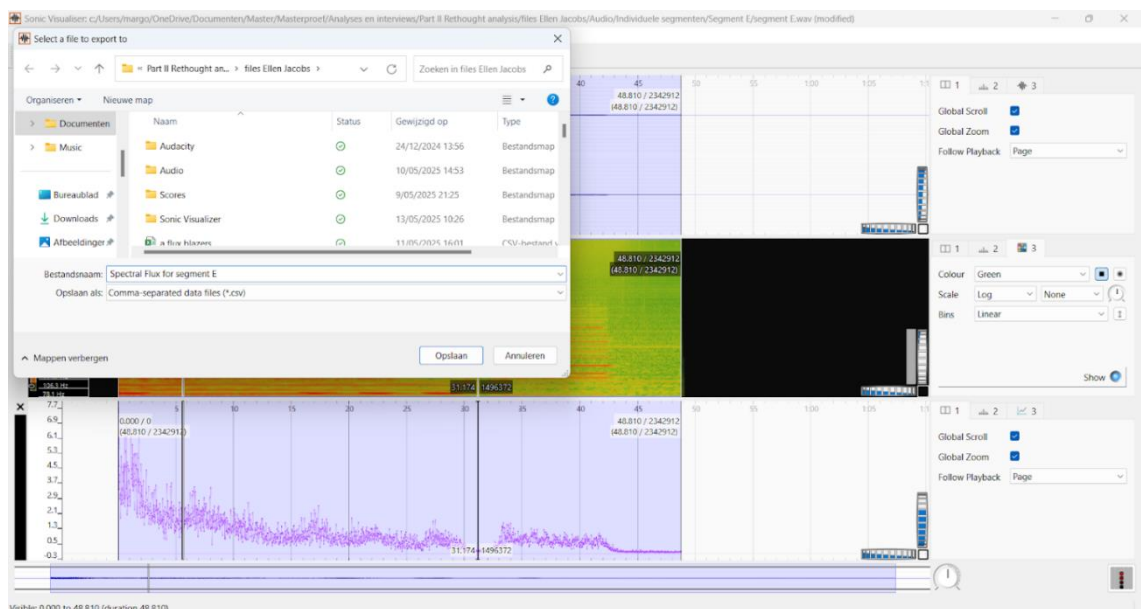
Ambient time is characterized by mostly flat, smeared-out lines with minimal variation or sharp transitions. Flutter time, by contrast, features small "shimmers" of frequencies appearing throughout, creating brief and subtle interruptions as the music progresses—referred to in Table 2.3 as "short iterations." Ripple time differs in that it involves larger oscillations rather than delicate shimmers. As noted in Table 2.3 as "long iterations," its frequencies are more widely spread, resulting in broader spectral modulations.

## APPENDIX F: MANUAL FOR TRANSFORMING SPECTRAL FLUX (SONIC VISUALISER) DATASET INTO A MEDIAN VALUE (MICROSOFT EXCEL)

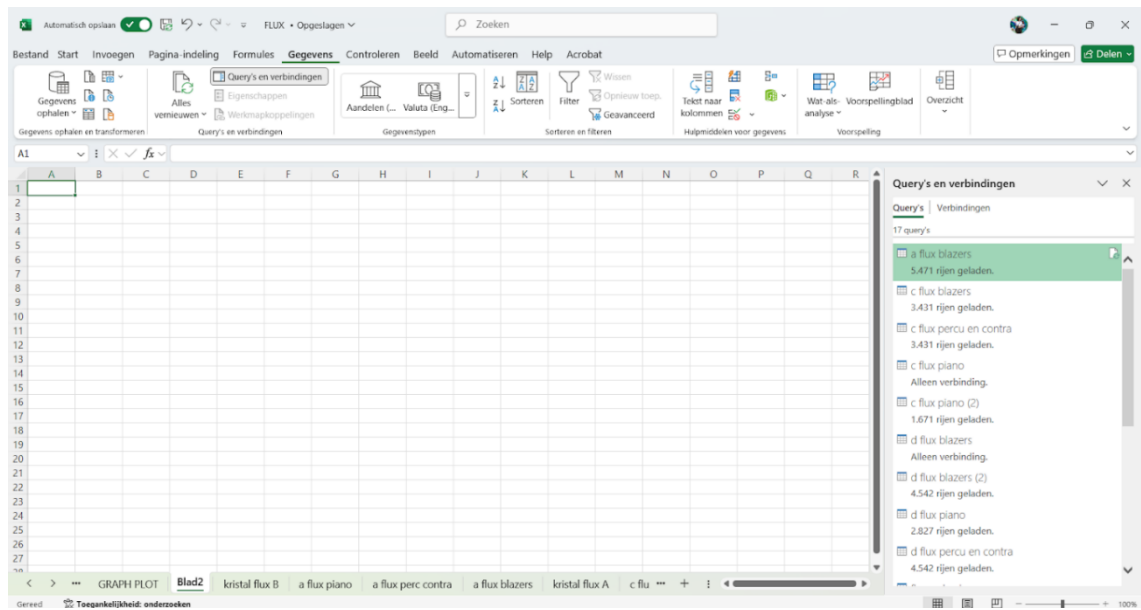
1. Plot the Spectral Flux Layer and select it.



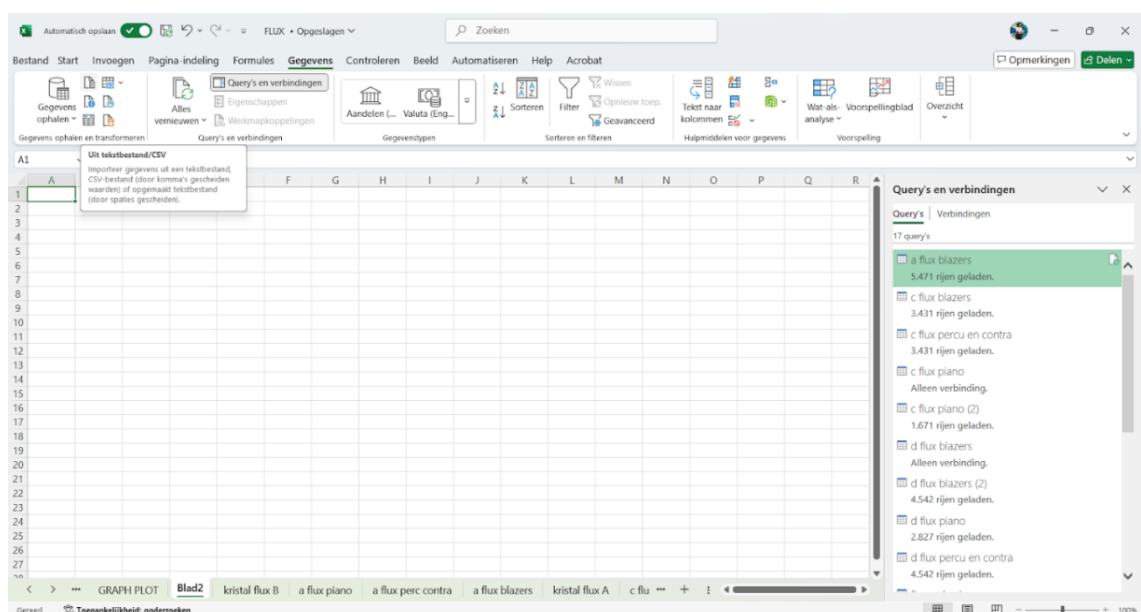
2. Give the annotation layer name and save it to your computer in a csv. file.



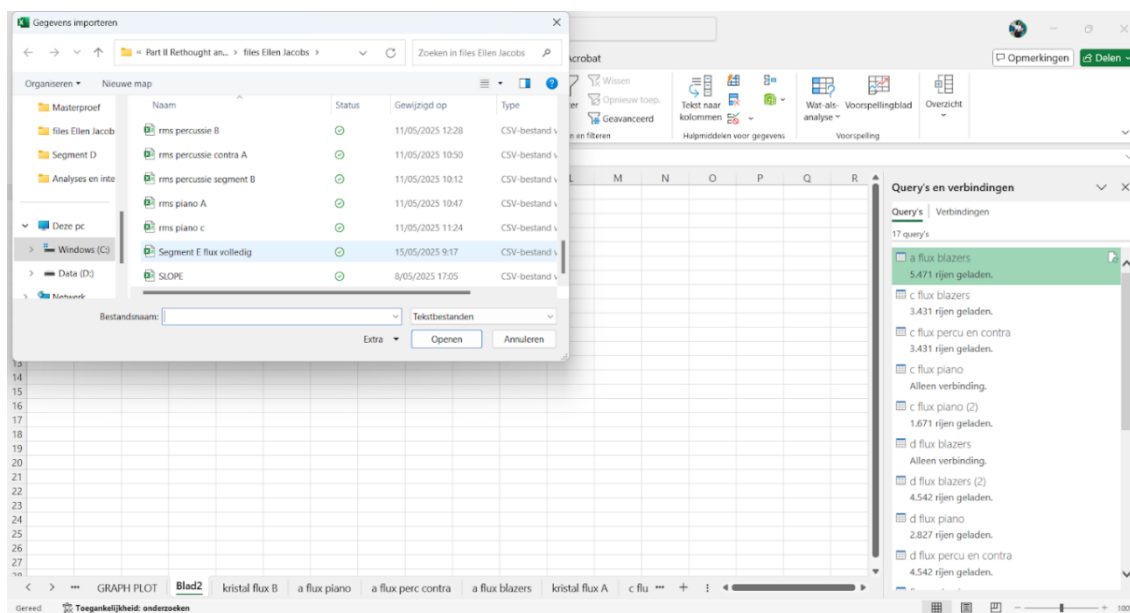
3. Open Microsoft Excel and select “Gegevens” (Data) > “Gegevens ophalen” (Import Data)



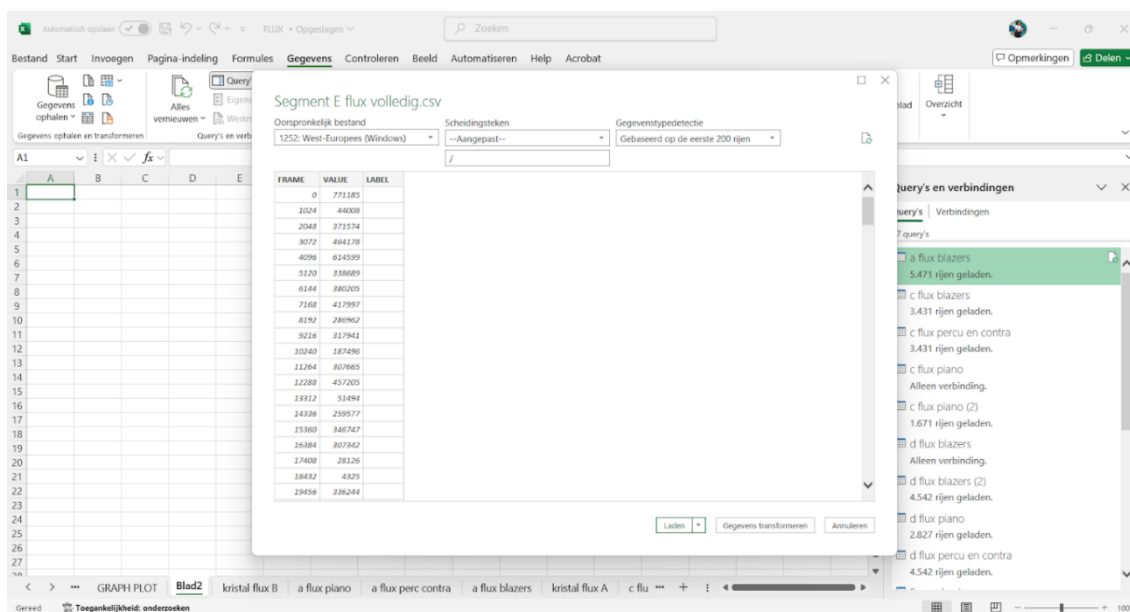
4. Select “Uit tekstbestand/CSV” (from txt. file/CSV)



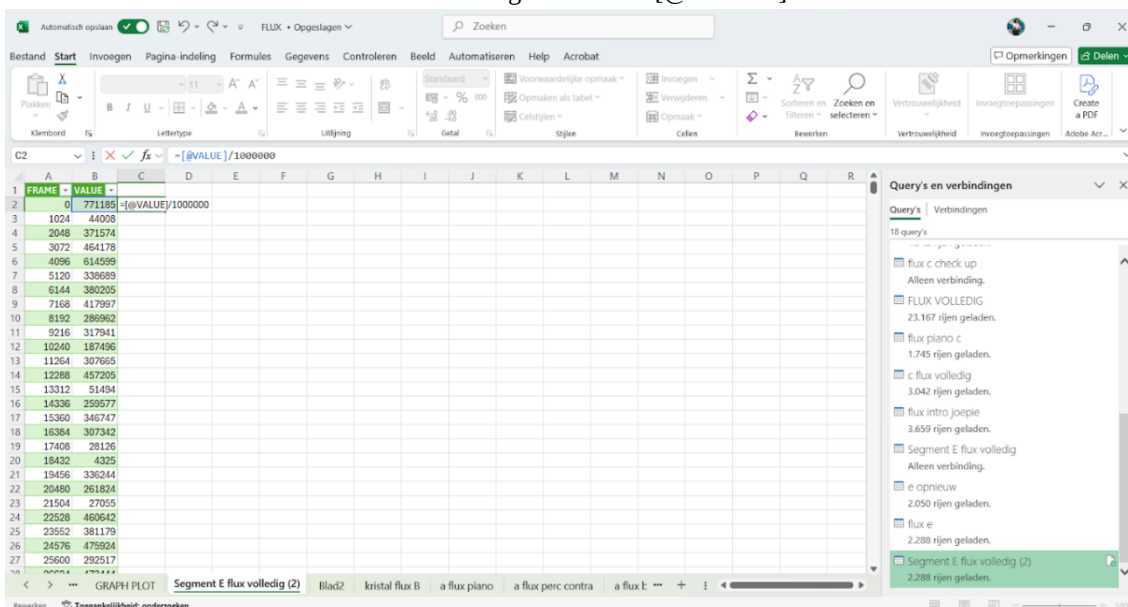
5. Open the file containing the annotation layer previously retrieved from Sonic Visualiser.



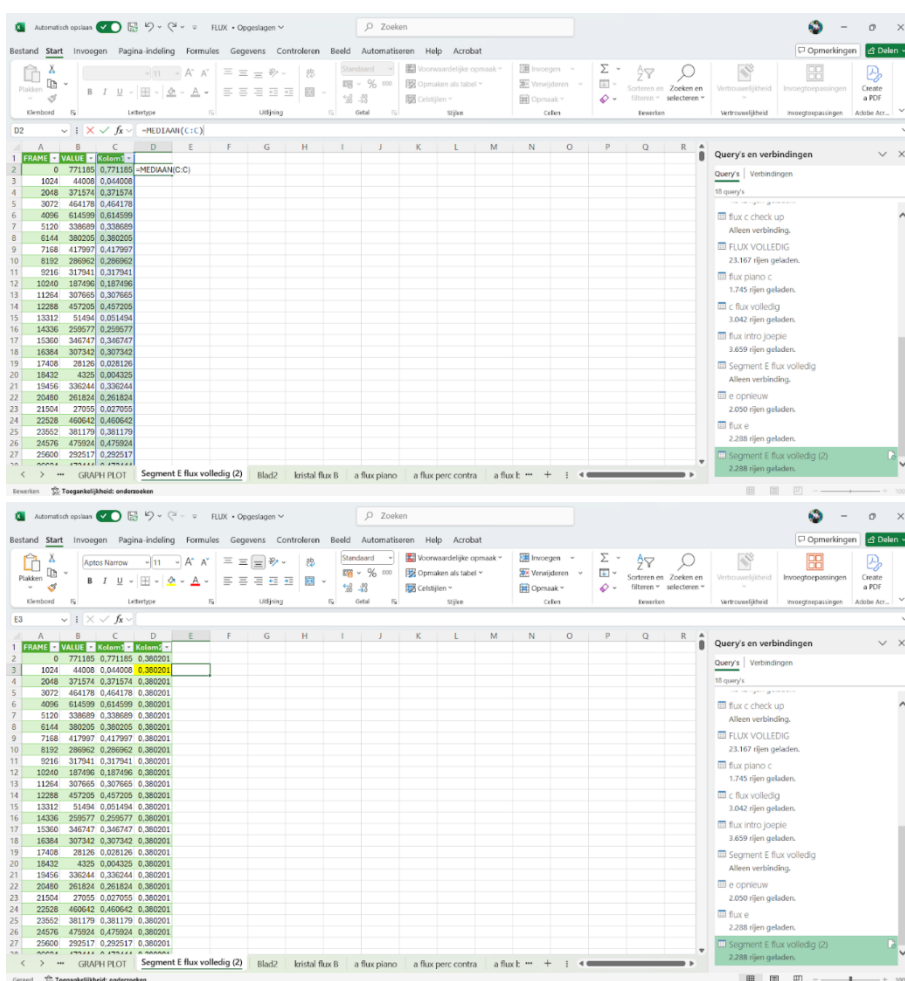
6. Choose for the “scheidingsteken” (separation sign) a “/” and press load.



7. Select a value in Column B and insert the following formula :  $=[@VALUE]/1000000$



8. Select Column C containing the Spectral Flux dataset. Insert the formula  $=\text{MIDIAAN}(C:C)$ .



## APPENDIX G: PRE-ANALYSIS INTERVIEW, 21 NOVEMBER 2024.

Jacobs (composer), Ellen. Interviewed by Margot Meire (student at Ghent University), 21 November 2024. Format: audio recording and transcription.

**[00:00:01.630] – Margot Meire**

Eerst en vooral, en het is misschien een cliché vraag, maar hoe start je het compositieproces? Wat is zeg maar de bron waarmee je aan de slag gaat?

**[00:01:06.480] – Ellen Jacobs**

Dat is altijd een beetje verschillend. Maar vaak start het wel van iets niet-muzikaal, dus vanuit een idee of een concept of een verhaal. Bijvoorbeeld voor *Inertia* heb ik treinopnames gemaakt, maar dat was eigenlijk gewoon puur vanuit... Ik pendelde van Antwerpen naar Gent. Toen ik nog in Gent studeerde. En dat was vanuit... Ja, het geluid dat daar, als je in de trein zit, aanwezig is. Dus dan heb ik dat gewoon eigenlijk opgenomen en ben ik van daaruit vertrokken. En dan heb ik eerst mijn tape gemaakt en daarna pas de instrumenten erbovenop gezet, en vanuit die klanken dat ik gevonden heb, de instrumenten daar zo goed mogelijk bij laten matchen. Dus dat vind ik een heel toffe manier om te werken, omdat dat mij ook inspireert om dan op zoek te gaan naar andere soorten klanken op de instrumenten zelf. Dus dat zou ik ook nog veel meer willen doen. Maar soms is het ook gewoon puur akoestisch en dan vertrek ik vanuit... Ja, dat is meestal een concept echt. En wat ik dan ook doe is eerst al een soort van verloop maken van mijn werk. Dus ik weet dan welk materiaal ik wil gebruiken. Dat schrijf ik dan ook meestal een lijstje echt op van oké, die technieken vind ik interessant op dat instrument. Ik probeer altijd zo'n beetje de grenzen op te zoeken. En dan maak je dus dat tijdsverloop, wat zelf ook afhankelijk is van dat concept.

**[00:02:48.620] – Margot Meire**

Ja, tuurlijk. En bij die instrumenten zijn dat dan *extended techniques*?

**[00:02:52.600] – Ellen Jacobs**

Ja, vaak wel. Maar ik zoek soms ook wel gewoon met de muzikanten zelf, als ik daar de mogelijkheid toe heb. Dan zeg ik van, ik heb dit in mijn hoofd bijvoorbeeld gehad op een instrument, want natuurlijk is het ook heel specifiek altijd. Dat is per instrument anders. En dan ook nog eens specifiek welk instrument dat ze spelen, welk merk enz. Dus dat vind

ik ook wel belangrijk om in dat proces mee te kunnen nemen. Dat ik dan even met hen kan samenzitten. Want dat lukt ook niet elke keer.

**[00:03:25.980] – Margot Meire**

Nee, dat snap ik. En bij dat akoestische ga je dan soms ook aan de slag met echt boventonen?

**[00:03:31.800] – Ellen Jacobs**

Ja, heel vaak.

**[00:03:32.840] – Margot Meire**

En knutsel je daar dan mee? Ga je boventonen weghalen of toevoegen? Hoe ga je daar specifiek mee om?

**[00:03:38.170] – Ellen Jacobs**

Meestal vertrek ik vanuit één akkoord en dan ga ik in dat akkoord eigenlijk kijken van oké, die noten zitten daarin, dan schrijf ik de boventoonreeks op van die noten en dan zoek ik eigenlijk, stel nu dat het met strijkers is bijvoorbeeld, naar de boventonen die dat daar in die reeks zitten, die daar uithalen en dan op zoek gaan naar andere manieren om die te spelen. Ik gebruik heel vaak boventonen dat de strijkers niet zo vaak gebruiken. Je kunt eigenlijk één harmoniek op vier of vijf verschillende manieren spelen, meestal dan toch. En dan kan daar meer of minder ruis bij. Het hangt af van de manier waarop je speelt. Op die manier gebruik ik eigenlijk het spectrum om te kijken van oké, die noten zitten daar in, welke boventonen zijn er mogelijk en zodanig te selecteren dat de gehele structuur wel nog klopt.

**[00:04:59.070] – Margot Meire**

Dus die boventonen vormen toch enigszins een vertrekpunt in de muziek?

**[00:05:02.250] – Ellen Jacobs**

Ja, wel een vertrekpunt sowieso. En voor mij zorgt het ervoor dat ik nog altijd een houvast heb. Want in de muziek die ik schrijf, dat is heel erg klankgebaseerd. Timbre is heel belangrijk en zo, maar... Toch graag wil ik natuurlijk dat je toonhoogtemateriaal een samenhang heeft. Ik ga weinig met een harmonisch verloop bezig zijn bijvoorbeeld, dan heb je wel iets van structuur nodig.

**[00:05:27.590] – Margot Meire**

Dat is zo. En dan dat timbre aspect is ook iets wat me heel erg interesseert. Is dat echt iets dat dan het hele verloop van jouw stuk bepaalt? Want je zegt al, ik gebruik geen harmonisch geluid. Is dan wel het timbre een centrale focus?

**[00:05:48.990] – Ellen Jacobs**

Ja, eigenlijk wel. Dus wat ik vaak doe, dat heb ik bijvoorbeeld gedaan bij *Deadfold*, Daar heb ik echt wel bepaald van oké, ik wil dat het eerst heel briljant klinkt en dat het overgaat naar iets dat meer dof klinkt. Van daaruit ga ik op zoek naar manieren waarop dat akkoord vanuit verschillende opzichten bekeken kan worden en zo een andere soort ‘glans’ kan krijgen. Dan helpt dat ook om die boventoonreeks te hebben en dan te zoeken naar hoe je het ensemble gaat vormgeven, dus hoe je het gaat ‘orkestreren’, waardoor het geheel ‘briljant’ zou klinken, bijvoorbeeld. Dus dan zoek ik ook naar, hoe kan ik bijvoorbeeld een basklarinet heel hoog laten spelen, zodat je ook hier het timbre op een heel andere manier kunt benaderen.

**[00:06:44.360] – Margot Meire**

En zorgt dat timbre dan ook voor de dynamiek in jouw werken?

**[00:06:50.250] – Ellen Jacobs**

Ja, dat zal er wel mee te maken hebben, maar de dynamiek hangt vooral af van het verloop dat ik op voorhand heb vastgelegd.

[...]

**[00:07:54.520] – Margot Meire**

Dus als ik het goed begriip implementeer je het wel om het verloop wat ‘soepeler’ te maken?

**[00:07:58.410] – Ellen Jacobs**

Ja, klopt.

**[00:08:08.620] – Margot Meire**

Oké, super. En heb je dan zelf ook het gevoel dat als je die tonale regels eigenlijk toch meer achterwege laat, waardoor je eerder naar de natuurlijkheid van de klank gaat en uiteindelijk haar natuurlijkheid blootlegt?

**[00:08:22.790] – Ellen Jacobs**

Ja, zeker. En dat is voor mij... Ik vind dat... Dat is ook iets dat ik nog moeilijk vind soms om te kunnen overbrengen aan de muzikant zelf. Je merkt namelijk van, ze voelen dat ook, dat gaat meer om klank en over hoe een klank intern beweegt. Dat kan soms heel minutieus en heel fragiel zijn. Het is dus een uitdaging om dit goed te kunnen uitvoeren, want technisch is het stuk misschien minder complex, maar omdat het over deze kleine details gaat, kan het toch moeilijk zijn voor de muzikant. De toon moet namelijk intern bewegen. Dus dat, ja... Dat zoek ik soms zelf nog van, oké, ik moet eigenlijk altijd goed kunnen samen zitten met de muzikanten op voorhand, voordat de eerste echt repetitie is voor een

première ofzo, want anders dan... Dan snappen ze... Allee, niet dat ze het niet echt snappen, maar dan heb je het misschien niet direct door.

**[00:09:33.430] – Margot Meire**

Omdat ze vaak klassiek geschoold zijn, waarschijnlijk.

**[00:09:36.390] – Ellen Jacobs**

Ja, ja.

**[00:09:37.190] – Margot Meire**

Dat vind je dan toch wel een drempel soms.

**[00:09:40.110] – Ellen Jacobs**

Soms wel, ja. Ik ben daar zelf nog in aan het zoeken van hoe ik dat het beste kan overbrengen en hoe dat het duidelijkste overkomt. En dat ligt ook in notatie natuurlijk. Als je een partituur van mij ziet, dan kan daar soms precies heel weinig op staan. Maar eigenlijk gebeurt daar heel veel in. Dus ja, daar ben ik nu wel echt heel hard mee aan het zoeken. Want als ik nu met mijn meest

recente werk, dat nu op Transit geweest is, voelde ik dat van, oké, ik ben nu nog meer naar de essentie aan het gaan van wat ik wil doen, maar dat zorgt er ook voor dat mijn partituur nog veel meer wordt uitgedund, zeg maar.

**[00:10:33.610] – Margot Meire**

Maar dus je werkt wel met scores als ik het goed begrijp.

**[00:10:38.800] – Ellen Jacobs**

Ja, dat wel, ja.

**[00:10:39.720] – Margot Meire**

Oké, ook waarschijnlijk omdat je met instrumentatie werkt.

**[00:10:42.160] – Ellen Jacobs**

Ja, ja. Dus ja, natuurlijk, als je vanuit *Inertia*, bijvoorbeeld met de tape, heb ik wel een click-track gemaakt, zodat de partituur die ik schreef er goed op kon gesynchroniseerd zijn. Maar ik denk, het is nog altijd wel het makkelijkste om met scoren te werken. Omdat ik toch ook wel... Ik kan ook wel vrijheid geven aan mijn muzikant, ik heb daar niet zoveel problemen mee. Maar het verloop is heel belangrijk. Het tijdsverloop, dat is heel belangrijk in mijn muziek. Dus als ik geen score maak, dan valt dat weg.

**[00:11:21.510] – Margot Meire**

Ja, nee, snap ik. Heeft jouw omgang met boventonen en timbre dan ook een invloed op die temporele dimensie? Hoe zie je dat eigenlijk vervlochten met elkaar? Dat is misschien een moeilijke vraag, maar het lijkt me wel interessant om over na te denken.

**[00:11:44.340] – Ellen Jacobs**

Ja, ik denk... Allee, dat is sowieso... Dat is zeker vervlochten met elkaar, omdat dat... Stel dat mijn verloop zou zijn van een 'dunne' naar een meer donkere klank gaan, dan is die donkere klank het hoogtepunt. Dan zijn de boventonen die ik ga uitkiezen en meer in de verf wil zetten door het instrumenteren, heel belangrijk en in functie van wat er in de tijd gebeurt. Dus in die zin loopt dat samen.

**[00:12:32.320] – Margot Meire**

Dus je maakt ook gebruik van tape, bij *Inertia* bijvoorbeeld. Maak je ook nog gebruik van andere technologische middelen? Of zeg je van, als ik het doe, is het enkel tape?

**[00:12:46.470] – Ellen Jacobs**

Ik heb dat nog niet gedaan. Maar het zou kunnen dat ik dat wel nog ga doen. Maar nu ben ik heel veel met *field recording* bezig. Ik heb daar een beurs voor gekregen om onhoorbare geluiden te kunnen opnemen. Dus onder de grond, onder water. Ook in de lucht dus, ja, op de elektromagnetische geluiden, die dingen. Dat is nu voor mij de focus, om te zoeken naar geluiden die me opnieuw kunnen inspireren om van daaruit te componeren en methoden uit te breiden. Dus ik denk dat dat dan weer zal resulteren in werken waarbij ik een tape ga maken en van daaruit vertrekken. Maar ik sluit het ook niet uit om ooit live electronics te gebruiken, maar dat is momenteel nog niet gebeurd.

**[00:14:03.980] – Margot Meire**

En als je dat doet, die *field recordings*, ga je dan ook, dat is misschien nu een moeilijke vraag ofzo, maar ga je dan van daaruit een akoestiek binnen die opgenomen geluiden gaan zoeken? Of wacht je eerst tot je geïnstrumenteerd hebt en dan ga je verder op die instrumentale geluiden? Hoe gaat dat precies in z'n werk?

**[00:14:23.300] – Ellen Jacobs**

Ik probeer eigenlijk een soort van... Dus ik verzamel die geluiden en dan probeer ik daar wel al een ruimte in te creëren met die geluiden die ik heb gevonden.

**[00:14:40.660] – Margot Meire**

Oké. En dan van daaruit ga je gaan denken van welke instrument zet ik daar op? Hoe ga ik die laten spelen?

**[00:14:47.540] – Ellen Jacobs**

Dat is eigenlijk gewoon een extra laag, die instrumenten. Dus dat is voor mij echt één.

**[00:14:52.420] – Margot Meire**

Ja, oké. Ik snap het. Oké, super. Dat is ook nog een interessante vraag, want vorig jaar bij mijn bachelorproef heb ik vooral de heel bekende spectrale composities onderzocht om mezelf zo wat in te werken. Maar daarbij zeiden ze eigenlijk altijd, zeker bij de Franse school, we werken eigenlijk continu, we werken niet doelgericht in onze composities. Ze hebben dus geen concreet begin noch einde. Doe jij dat ook? Of zeg je van, ik steek er wel een duidelijke richting in?

**[00:15:26.670] – Ellen Jacobs**

Ja, dat doe ik wel. Dat is eigenlijk één van de belangrijkste dingen voor mij, namelijk dat de vorm heel goed zit en duidelijk is.

**[00:15:44.050] – Margot Meire**

Dat vind ik interessant, want vaak in literatuur merk je dat spectraliteit en akoestische composities heel strak worden gedefinieerd.

**[00:15:52.540] – Ellen Jacobs**

Ja.

**[00:15:59.330] – Margot Meire**

Als je die akoestiek zelf gaat bekijken, welke methode gebruik je daarvoor? Schrijf je dat op, hanteer je wiskundige methodes of?

**[00:16:12.520] – Ellen Jacobs**

Ik schrijf dat eigenlijk op. Wat ik nu heb gedaan voor mijn laatste werk is dat ik dat op een heel intuïtieve manier heb aangepakt. De opdracht was om gebaseerd op het werk van Kaija Saariaho, een stuk te schrijven. Ik had daar dan zes instrumenten voor en ik wist van, oké, ik wil iets doen, want ik had ook gelezen dat zij ook heel hard bezig is met *dreamspaces* en dat inspireerde mij om daarmee iets te doen. Dus ik dacht van, oké, hoe klinkt een ruimte gewoon ergens binnen, versus in een bos. Dus ik ben dan met een cymbaal, echt, naar het bos gegaan en daar heb ik mijn stuk opgenomen. En dan heb ik dat ook thuis gedaan, zodat ik die twee met elkaar kon vergelijken. Ik heb wel niet geanalyseerd met een programma ofzo. Gewoon echt puur, wat geeft dat voor mij? En bijvoorbeeld in het bos zat daar

veel meer laagte in dan thuis. Dus dan heb ik die twee eigenlijk gemengd. Dus daarom ook de titel *And In Between There Is*, omdat dat tussen de twee werelden zit eigenlijk, een ruimte dat ik gecreëerd heb. Voorlopig is dat echt heel intuïtief, maar ik schrijf wel heel veel op. Dus ik heb altijd mijn boekje, en ik schrijf dan op wat dat voor mij is. En aan de hand van die woorden die er dan uitkomen, probeer ik het daaraan te linken.

**[00:17:42.650] – Margot Meire**

Dus zou je dan zeggen dat je dan meer vanuit het perceptuele gaat werken, van wat jij zelf ervaart?

**[00:17:49.020] – Ellen Jacobs**

Eigenlijk wel, ja.

**[00:17:50.700] – Margot Meire**

Dat is ook een mooie methode wel. Wat zou in een ideale wereld voor jou het mooiste effect zijn dat je composities kunnen overbrengen aan een publiek dat eigenlijk niet per se thuis is in dat soort composities?

**[00:18:14.440] – Ellen Jacobs**

Ik vind, als ik ze heb kunnen boeien met iets, of het gevoel heb kunnen geven van oké, ze voelen daar misschien iets bij of zo. Of ze voelen dat ze daar een beetje worden ingezogen. En dan kun je misschien achteraf niet per se zeggen van... Wat deed dat nu exact met mij? Maar vaak krijg ik wel dat ze er wel van genoten hebben. Of dat ze... Dat het wel iets duidelijk is of zo. Daarom is die vorm ook zo belangrijk. Omdat je dat dan kunt... Ja, dan is dat één geheel. En dan is er één indruk, hoop ik, dat dat kan weergeven. Maar welke indruk, dat laat ik aan het publiek zelf. Maar ik heb zo één keer wel echt een mooi compliment gekregen van iemand dat daar echt niks van kende en dat waren vier werken van nieuwe muziek. En die zei van, ja, dat van jou vond ik het meest authentieke. Terwijl in dat van mij eigenlijk het meest externe techniek zat in het, en dus zagezegd het moeilijkste zou kunnen zijn om naar te luisteren. Maar ik wil dat het authentiek overkomt. Toen dacht ik ook echt van, oh ja, dat is, ik wil echt wel dat het authentiek overkomt en dat het kan bij mij is. Dus daarom zit mijn... Allee, daarom is het ook belangrijk dat die perceptie van mij daar ook in zit.

**[00:19:37.470] – Margot Meire**

Oh, dat vind ik heel mooi. Eigenlijk... Deze antwoord had ik niet verwacht. Want vaak, en dat is ook zo'n beetje waarnaar ik op zoek wil gaan in mijn thesis, vaak wordt dat soort componeren heel droog, technisch, met de computer aangepakt, heel wetenschappelijk. En ik vind dat je daar weer zo afstand creëert tussen je muziek en je publiek.

**[00:20:13.190] – Ellen Jacobs**

Zeker.

**[00:20:13.770] – Margot Meire**

En omdat jij dan eigenlijk vanuit je eigen gevoel gaat en je eigen intuïtie, ga je denk ik ook sneller een breder publiek kunnen aanspreken? Ja, de rijkdom van de klank. Zonder dat zou dat heel rigide zijn, denk ik.

**[00:20:30.120] – Ellen Jacobs**

Ja, ja, ja. En ik vind het wel een uitdaging om zo intuïtief te werken. Nu heb ik het expres ook nog meer gedaan. Omdat ik weet dat Saariaho dat ook deed. Maar dat is wel eng.

**[00:20:54.070] – Margot Meire**

Ergens sta je wel in het onbekende, maar ik denk dat daar nooit echt een slechte uitkomst bij kan zijn. Je hebt je eigen gevoel en je hebt je ook al enige ervaring opgebouwd. Ik denk dat dat ook wel groeit ofzo.

**[00:21:06.700] – Ellen Jacobs**

Ja, dat groeit zeker.

**[00:21:07.720] – Margot Meire**

Ik vind het al zeker mooi dat je op die manier te werk gaat. Ja. En dan toch mooie resultaten hebben.

**[00:21:14.990] – Ellen Jacobs**

Merci.

**[00:21:15.790] – Margot Meire**

Is er één bepaalde compositie van jou waarbij je denkt, daar ben ik echt zo het meest op die klank echt diep ingegaan?

**[00:21:29.240] – Ellen Jacobs**

Ik zou zeggen *Inertia*, Als nu het werk *And In Between There is*, dat ik nu net heb gecomponeerd, die twee denk ik. Maar bij *Inertia* was het echt, dat is ook het stuk waar ik het langste aan heb gewerkt. Omdat ik dat echt zo hard wou dat die instrumenten... dezelfde klankkwaliteit konden brengen als wat er in de tape zat. En dat was niet eenvoudig.

**[00:21:57.470] – Margot Meire**

Nee, dat lijkt mij heel complex.

**[00:21:59.450] – Ellen Jacobs**

Ja. Dus dat is zoeken, zoeken, zoeken.

**[00:22:01.650] – Margot Meire**

Ja, tuurlijk.

**[00:22:02.230] – Ellen Jacobs**

En heel veel versies zijn er geweest.

**[00:22:05.580] – Margot Meire**

En componeer je dan op piano enkel?

**[00:22:08.040] – Ellen Jacobs**

Eigenlijk amper. Vooral in mijn hoofd. Want ik begin een klein beetje aan de piano voor het startakkoord te vinden, maar dat heb ik nu niet gedaan bij *Inertia*, want dan ben ik vertrokken van tape. Dus daar heb ik dan heel veel naar geluisterd. En ook tot in de details helemaal hoog gezet, omdat het eigenlijk een heel traag verloop is maar de klank wel constant verandert. Je hoort dit wel niet. Van daaruit ben ik gewoon de instrumenten daarop gaan zetten. Wat daarbij wel belangrijk was, is de elektrische gitaar. Die heeft daar heel veel in bijgedragen. Ik heb het dan wel een keer met twee gitaristen nog kunnen bekijken wat ook wel goed is, want dan kun je zien van qua notatie, van hoe is dat het duidelijkst voor jullie alle twee. Dan weet je oké, dan zal het voor de meeste spelers wel duidelijk zijn.

Maar het is heel specifiek welke snaren ze moeten gebruiken ook enz., want op een bepaald moment, dat hoor je niet in de opname, maar valt de tape weg en is dat alleen de gitaar die overneemt. Dus dat was heel belangrijk, dat ik die klank kon reproduceren, dat in die gitaar zat, en dat die op een bepaald moment het volledig overnam in de tape/loop.

**[00:23:47.600] – Margot Meire**

En dat was jouw eerste compositie, *Inertia*?

**[00:23:52.350] – Ellen Jacobs**

Nee, dat was eigenlijk voor mijn masterproef geschreven. Ik ben daar een jaar ofzo mee bezig geweest.

**[00:24:04.230] – Spreker 1**

Toch wel heel mooi dat je dat op een jaar hebt kunnen realiseren.

**[00:24:09.200] – Margot Meire**

Ja, ja, ja.

**[00:24:10.380] – Margot Meire**

En bij die keuze voor instrumentatie... Allee, hoe breed ga je daarin? Heb je echt al heel gekke instrumenten daarvoor gekozen?

**[00:24:22.310] – Ellen Jacobs**

Ja, nu was dat echt eigenlijk puur... Voor *Inertia* was dat puur praktisch omdat er een masterclass kwam van een ensemble en dat was eigenlijk de aanzet om dat werk te beginnen schrijven en dat was dan die bezetting. Dus daar komt de bezetting vandaan. Maar dan bijvoorbeeld nu voor mijn laatste werk mocht ik dan zes instrumenten kiezen uit een grotere bezetting. Ik ben expres gegaan voor instrumenten die mij wat meer zouden uitdagen. Omdat ik weet, voor koperblazers heb ik nog nooit geschreven. Heel af en toe, in mijn oefeningen ofzo. Maar dan heb ik de trompet gekozen, omdat ik wist dat het een uitdaging zou zijn om dit te kunnen mengen met de anderen. En dan heb ik met de trompettist samen gezeten. Dus dat heb ik dan expres gedaan en daar zat een klarinet bij, piano, twee slagwerkers en contrabas. En dan heb ik geprobeerd om die instrumenten te gebruiken op een manier dat die niet meer hun authentieke, hun echte functie hebben.

**[00:25:40.190] – Margot Meire**

Dus niet altijd de contrabas de baslijn geven etc.

**[00:25:43.870] – Ellen Jacobs**

Als ik kan kiezen, dan daag ik mezelf wel graag uit. Ik weet dan namelijk van, oké, nu heb ik de tijd om daar dieper op in te gaan op hoe kan een trompet zich bewegen in mijn muziek.

**[00:26:06.860] – Margot Meire**

En een trompet lijkt me wel een behoorlijke uitdaging.

**[00:26:18.090] – Ellen Jacobs**

Ja, ja, ja. Die heeft het echt moeilijk gehad.

**[00:26:21.650] – Margot Meire**

Ik vind het wel boeiend dat je jezelf probeert uit te dagen door geen conventionele instrumenten te kiezen, die vaak wel worden gebruikt bij akoestische muziek. Contrabas wordt denk ik wel nog veel gebruikt, omdat hij een hele brede range heeft en veel resoneert. Zo'n trompet resoneert ook wel, maar het is toch anders hè.

**[00:26:43.420] – Ellen Jacobs**

Ja, maar het gevaar is dat hij eigenlijk niet mengt met de rest. Daarom heeft hij dus de hele tijd met dempers gespeeld.

## APPENDIX H: POST-ANALYSIS INQUIRY 17 MAY 2025

Jacobs (composer), Ellen. Interviewed by Margot Meire (student at Ghent University), 17 May 2025. Format: Questioning via Microsoft Forms.

### Resultaten weergeven

Respondent

1 Anoniem

57:32

Tijd voor invullen

1

Naam \*

Ellen Jacobs

2

De bevroagde verklaart dat de antwoorden gebruikt mogen worden als data voor de conclusie van de masterproef met bovenvermelde titel, samen met het interview afgenomen op **21 November 2024 te Antwerpen** en de overige bevindingen, te vinden in **Chapter 3: Analysis of *And In Between, There Is ...* (2024) ; A Case Study \***

☒ Ja☐ Nee

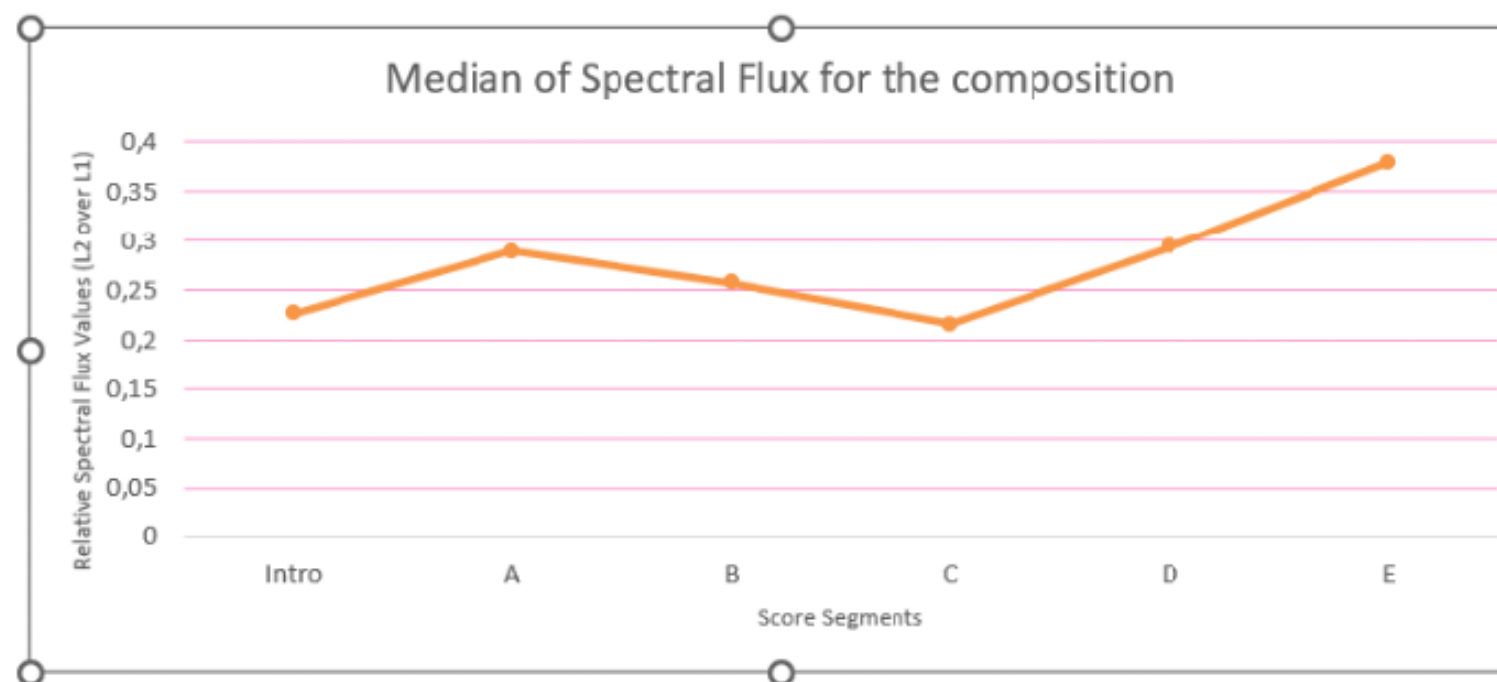
3

De afbeelding toont een grafiek gebaseerd op de **mediaanberekeningen** van de spectrale flux (de mate waarin het spectrum verandert) per segment uit de partituur (intro, A, B, C enz.). Deze grafiek is bedoeld als analytische, structurele vingerafdruk van de compositie.

- De mediaan meet het midden van een datareeks en geeft trends in deze reeks weer. Daarom is het accurater dan het gemiddelde.

De vraag is: Hoe zie je deze structuur verband houden met je eigen intenties bij het stuk? Meer bepaald: zie je deze lijngrafiek een link hebben met de narratieve dimensie van de compositie?

\*\* Het antwoord mag zo kort of lang zijn als je zelf wilt. \*



**Graph 5** The evolution of the Spectral Flux median throughout the composition, calculated per individual segment. X-axis: score segments, Y-axis: relative spectral flux median values per segment for L2 over L1.

Ik vind het zeer interessant om dit te zien. Deze grafiek is eigenlijk exact wat ik vormelijk voor ogen had bij het schrijven van dit werk. De intensiteit stijgt vooral naar het einde toe, zoals deze grafiek ook aangeeft. Ik ben blij om te zien dat dit zich ook in de spectrale flux vertaalt omdat ik vooral vanuit mijn eigen systeem en deels intuïtief te werk ben gegaan.

4

Denk je dat deze "spectrale flux" een nuttige manier is om de structuur in jouw compositie te herkennen? Helpen de pieken en dalen in de spectrale flux om de verschillende delen, secties of belangrijke momenten in jouw compositie te onderscheiden? \*

Zeker! Het is fijn om te zien dat de onderliggende structuur ook zeer duidelijk hoorbaar is en zich vertaalt in de grafiek. Het belangrijkste moment zit in dit werk op het einde en dat geeft de grafiek ook zeer duidelijk weer.

5

Zie je een directe link tussen deze objectieve metingen van het geluid en mogelijke nieuwe muzikale ideeën, texturen, of ontwikkelingen die je in toekomstige composities zou kunnen verkennen? Zo ja, hoe? \*

Ja, het zou een hulpmiddel kunnen zijn om mijn geluidswereld nog meer te verdiepen. Door gebruik van deze software zou ik de spectrale elementen eventueel nóg effectiever kunnen inzetten. Dit zowel vormelijk als gevoelsmatig.

Welk verband zie je tussen de beoogde resultaten en de titel van de compositie?

De afbeelding toont de categorieën per segment gevonden in de analyse. Hieronder een oplijsting van de beoogde categorieën, gebaseerd op Thoresen, Lasse, and Andreas Hedman. 'Spectromorphological Analysis of Sound Objects: An Adaptation of Pierre Schaeffer's Typomorphology'. *Organised Sound* 12, no. 2 (August 2007): 129–41. <https://doi.org/10.1017/S1355771807001793>.

\*\* Deze categorieën zijn ruim geïnterpreteerd en in relatie tot de spectrale flux.

**Ambient Time:** A sustained and expansive sonic presence that lacks clear articulation, creating an atmospheric quality. Rather than being structured by discrete temporal events, Ambient Time unfolds gradually, often characterized blurred temporal boundaries. This quality allows sound to function as a backdrop, maintaining continuity while subtly evolving through minor spectral shifts. **Flutter Time:** refers to rapid micro-iterations of sound that merge into a fluid, shimmering texture, creating an impression of continuous motion. Unlike discrete repetitions, these fluctuations exhibit slight variations in pitch, intensity, or spectral content, resulting in a dynamic and evolving timbral quality. → Short iterations **Ripple Time:** refers to a pattern of oscillating sonic events contributing to a dynamic and structured temporal framework. Ripple time acts more broadly compared to flutter time. → Long iterations \*

**Table 3.1** Spectral Flux Type, Median Spectral Flux Value and Time Category per Segment for the composition.

| Score Segment | Spectral Flux Type + Median Value | Time category type |
|---------------|-----------------------------------|--------------------|
| Intro         | Low spectral flux: 0.227          | Flutter time       |
| A             | High spectral flux: 0.289         | Ripple time        |
| B             | Moderate spectral flux: 0.258     | Flutter time       |
| C             | Low spectral flux: 0.216          | Ripple time        |

|   |                           |              |
|---|---------------------------|--------------|
| D | High spectral flux: 0.294 | Ripple time  |
| E | High spectral flux: 0.380 | Ambient time |

Voor zover ik de categorieën kan begrijpen heb ik wel de indruk dat ze mijn intenties met dit werk ook weergeven. Het wisselen tussen "ripple time" en "flutter time" (dit zie ik als wisselen tussen het bos en de kamer binnen) mondt uiteindelijk uit in "ambient time" op het einde, waar er een soort van tussenwereld gecreëerd wordt tussen het bos en de huiskamer. De "ambient time" sluit mooi aan bij wat ik ogen had met de zogenaamde "tussenruimte" van "And in between, there is..."

7

Op een schaal van 1 tot 5, hoe zou je deze analytische inzichten beoordelen met het oog op een diepgaande, wetenschappelijke kennis over de case study en akoestische, niet-tonale, spectrale muziek in de bredere zin? M.a.w. hoe beoordeel je de verhouding tussen objectieve data en jouw eigen creatieve intentie? \*

1 2 3 4 5

8

Verklaar je gegeven cijfer. \*

Ik ben zeer positief verrast door de parallellen die getrokken zijn met mijn eigen intenties voor dit werk en de wetenschappelijke analyse. Het is mooi om te zien dat de vorm van mijn werk ook wetenschappelijk om dezelfde manier wordt weergegeven als ik zelf in gedachten had. Ik ben benieuwd om het hele onderzoek te lezen!

APPENDIX I: SCORE OF *AND IN BETWEEN, THERE IS* (ELLEN JACOBS, 2024)

and in between, there is...

Ellen Jacobs

2024

Commissioned by Transit Festival  
Written for I SOLISTI & Spectra Ensemble

Clarinet in Bb and Bass Clarinet in Bb

Trumpet in Bb

2 Percussionists

Piano

Double Bass

## Performance notes

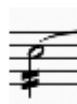
### Clarinet in Bb and Bass Clarinet in Bb



Alternate irregularly between normal note and multiphonic.  
There must be no audible accents.



Vibrato: The speed of the vibrato must follow the drawing.



bisbigliando

Multiphonics: the fingerings of the multiphonics are indicated in the part itself.

Trumpet in Bb

Vibrato: The speed of the vibrato must follow the drawing.



bisbigliando



split tone



normal split tone



halve valve split tone

**Percussion****Percussion 1**

- Cortales 2 octaves
- Xylophone
- Bass drum
- 3 triangles
- Suspended cymbal (medium)

**Percussion 2**

- Vibraphone
- tamtam
- suspended cymbal (medium)



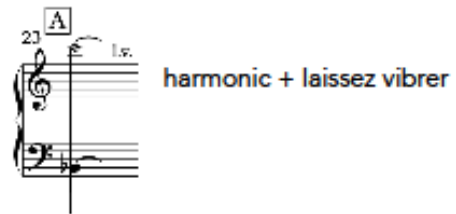
with coin

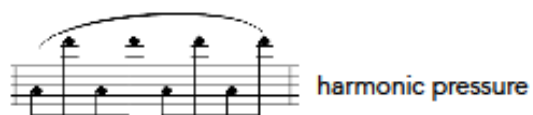
vibr. motor 0% —————> 30% Indication for the motor of the vibraphone.



use ribbed metal stick at the edge of the crotales, like a bow.



**Piano****Double Bass**



harmonic pressure



Vibrato: The speed of the vibrato must follow the drawing.



Circular bowing. The speed of the bowing is indicated above the staff.



Alternate very fast and irregularly between these harmonics, keep on repeating them in any order you like. Make them "shimmer".



Harmonic glissando, as high as possible.



on the bridge



damped strings + circular bowing



harmonic pressure + circular bowing



and in between, there is...

♩ = 54

Ellen Jacobs

Percussion 1

crotales

mf

p

mf

pp

Percussion 2

tam tam

mp

The musical score is written for two percussion parts. Percussion 1, labeled 'crotales', is written on a single staff with a treble clef. It features a melodic line with notes and rests, with dynamics markings of *mf*, *p*, *mf*, and *pp*. Above the staff, there are three 'L.v.' markings. Percussion 2, labeled 'tam tam', is written on a single staff with a bass clef. It features a sustained sound, indicated by a long horizontal line with a 'mp' dynamic marking. The tempo is indicated as '♩ = 54' at the top left. The composer's name, 'Ellen Jacobs', is at the top right.

2

10

Perc.

L.v.

*mf* *pp*

Perc.

*pp*

*quasi niente*

Db.

12th harmonic

*p*

11th harmonic

13th harmonic

Sol 1

3

**A**

Clarinet in B $\flat$  *non vibr.*

Trumpet in B $\flat$  *cup mute*

Perc. 18 *xylophone* *bass drum*

Perc. *Lv.* *vibraphone* *pp quasi niente*

Piano *Lv.*

Db. *ST* *MSP* *O* *pizz.* *ad II*

4

26

Cl.

Alternate irregularly between normal note and multiphonic. There must be no audible accents.

*pp* *mp*

Tpt.

*p* *p* *mp*

Perc.

*p* *p*

Perc.

motor on vibr. motor 0% 1.v. 30%

*pp* *mp* *mp* *pp*

Pno.

1.v. 1.v. 1.v. 1.v.

*pp* *p*

quasi niente *p*

Db.

harmonic pressure

*p* *p* *p* *mp*

Sul III normal pressure

33

Cl.

*pp* *mp* *pp* *pp* *p sub.* *p* *mf* *p*

Tpt.

*pp* *mp* *pp* *pp* *mf* *pp* *mf*

Perc.

*p* *pp* *50%* *mf* *mf*

*xylofoon*

Perc.

*mf* *mf*

Fno.

*p*

Db.

*mp* *pp* *fast* *slow* *mf* *p*

alternate very fast and irregularly between these harmonics, keep on repeating them in any order you like. Make them "shimmer".

46

Cl.

pp mf mf p

alternately irregularly between normal note and multiphonic. There must be no audible accents.

Tpt.

'normal' sound → distortion

mf f p mf p

Perc.

crotales

use ribbed metal stick at the edge like a bow

quasi niente pp mf quasi niente

Perc.

arco f mf 80% 50%

Pno.

alternately very fast and irregularly between these notes, keep on repeating them in any order you like. Make them "shimmer".

pp

quasi niente

Db.

B

sul I P PP

8

54

Cl.

pp

bisb. fast

pp

mp

Tpt.

practice mute

mp

p

p

pp

no vibrato

pp

bisb. very slow

p

Perc.

crotales

pp

tam tam

p

Pno.

p

Db.

idem

p

pp

62  $\rightarrow$  slow

Cl.  $\rightarrow$  *pp*  $\rightarrow$  *p*  $\rightarrow$  *f*

to bass clarinet

C

bisb. fast

Ord.

Tpt.  $\rightarrow$  *pp*  $\rightarrow$  *p*

Perc. Lv.  $\rightarrow$  *mf*  $\rightarrow$  *mf*  $\rightarrow$  *pp*

crotales

bass drum

Perc. Lv.  $\rightarrow$  *mf*  $\rightarrow$  *p*  $\rightarrow$  *f*

vibra

Pno.  $\rightarrow$  *mf*  $\rightarrow$  *p*  $\rightarrow$  *pp*

Db.  $\rightarrow$  *p*  $\rightarrow$  *MSF*

harmonic gliss.  
free rhythm  
Sul I

C

Detailed description: This musical score page contains six staves. The Clarinet (Cl.) staff starts at measure 62 with a piano (*pp*) dynamic, followed by a crescendo to *p* and then *f*. It includes a 'to bass clarinet' instruction and a 'bisb. fast' marking. The Trumpet (Tpt.) staff has a *pp* dynamic followed by *p*. The Percussion (Perc.) section consists of two staves: the upper staff features 'Lv.' (low voice) with *mf* and *pp* dynamics, and 'crotales' and 'bass drum' markings; the lower staff features 'Lv.' with *mf*, *p*, and *f* dynamics, and a 'vibra' marking. The Piano (Pno.) staff has an *mf* dynamic followed by *p* and *pp*. The Double Bass (Db.) staff features a 'harmonic gliss. free rhythm Sul I' marking, a *p* dynamic, and a 'MSF' (Musical Structure Form) section indicated by a line with arrows. A 'C' time signature change is marked at the beginning of the Db. staff.

10

70

Cl. *no vibr.* *pp* *rit.*

Tpt. *no vibr.* *pp* *pp* *rit.*

Perc. *crotales* *mp* *mp* *p* *Lv.*

Perc. *pp* *f* *pp* *pp* *f* *pp*

Pno. *f p sub. < f* *f p sub. < f* *p*

Db. *MSP* *p* *p* *rit. medium*

Detailed description: This musical score page contains five staves for measures 70 through 74. The instruments are Clarinet (Cl.), Trumpet (Tpt.), Percussion (Perc.), Piano (Pno.), and Double Bass (Db.). The Clarinet and Trumpet parts feature melodic lines with 'no vibr.' markings and dynamic markings of *pp*. The Percussion part includes 'crotales' and 'Lv.' markings with dynamics *mp* and *p*. The Piano part has a complex texture with dynamics *f p sub. < f* and *p*. The Double Bass part includes 'MSP' and 'rit. medium' markings with a dynamic of *p*. The score is written in 4/4 time and includes various musical notations such as slurs, ties, and dynamic markings.

**D**  
78 A Tempo ♩ = 54 11

Cl. *p* *pp*

Tpt. *p*

Perc. triangles

Perc. tam tam *p* *f* *p* *f* lv.

Pno.

Db. A Tempo ♩ = 54

12

86

Cl.

*mf* *p* *mf* *p* *p* *mf* *p* *p* *mf*

Tpt.

*mf* *p* *mf* *p* *mf* *p* *mf* *p*

Perc.

*p* *pp* *p* *f* *p* *f*

vibra

motor 80%

arco

1.v.

1.v.

*pp* *cresc. poco a poco*

Pno.

*p* *pp* *cresc. poco a poco* *sf*

Db.

*PP* *p* *f* *p* *f*

slow

fast

slow

slow

fast

93

Cl.

*p* *pp* *p* *pp* *p* *cresc. poco a poco* *bisb.* *bisb.*

Tpt.

*pp* *p* *cresc. poco a poco* *wawa without stem*

Perc.

*slow* *p* *pp* *p* *pp* *p* *pp* *p* *mf* *suspended cymbal arco*

Perc.

*suspended cymbal*

Pno.

*slow* *p* *pp* *p* *pp* *pp* *mf*

Db.

*slow* *p* *pp* *p* *pp* *pp* *mf*

14

98

Cl. *+ flaut.* **E** *senza vibr.* *quasi niente*

Tpt. *add distortion* *senza* *senza vibr.* *senza* *wawa +*

Perc. *crotales* *arco* *L.v.* *p*

Perc. *L.v.* *ff*

Pno.

Db. **E** *senza vibr.* *harmonic pressure* *pp* *senza vibr.* *quasi niente*

*ff* *pp* *ff* *pp*

*quasi niente*