

The Marvels of the Human Voice: Poem-Melody-Vocal Performance

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Abstract

This paper examines and compares vocal performances. It also follows the path of poem to melody to singing, and their interrelations. Results are demonstrated in examples in which comparison is made between performances of the same melody by two or more artists in: “Au Cimetière” by Berlioz, “Der Tod und das Mädchen” by Schubert, the Aria “In Questa Reggia” (Turandot) by Puccini, and the ariette “Ah quel dîner” (La Périochole) by Offenbach.

Introduction

This work, presented at a study day on music performance at the Buchman-Mehta Music Academy in Tel-Aviv (February 28, 2005), is concerned with singing and interpretation, studied from the analysis of Fast Fourier Transform (FFT) spectrograms of recordings of singers' voices. This is a direct analysis of the sound source, in the form of acoustic waves (signals) emitted from the singer's mouth. Musical (and other) information is extracted and deciphered, and the encoded messages are interpreted. This analysis is objective and independent of the listener (see remarks in Appendix B). The path leading from a poem through its setting to music by a composer and finally to its realization by a performing artist is also followed

and discussed. Excerpts from: (1) Berlioz Melodie: “Au Cimetière” (No. 5 in the song cycle: “Les Nuits d’Ete”), (2) Schubert Lied: “Der Tod und das Mädchen”, (3) Puccini aria: “In Questa Reggia”, from Act II, scene II of Turandot, and (4) Offenbach ariette “Ah quel dîner” from La Périochole, each performed by two or more artists, are compared and analyzed. Results illustrate the various nuances in the interpretation by the various artists.

Berlioz Melodie: “Au Cimetière”

The poem “Au Cimetière” by Theophile Gautier, from the song cycle “Les Nuits d’Été”, set to music by Berlioz, is a song of melancholy, sadness and loneliness.

First stanza (here divided into two parts):

<u>Connaissez-vous</u> la blanche tombe	Sur l’if, une pâle colombe,
<u>Où flotte avec</u> un son plaintif	Triste et seule, au soleil couchante,
<u>L’ombre d’un if?</u>	<u>Chante son chant.</u>

Each stanza in the poem consists of two parts, each built of two structural units, consisting of two long phrases, with 9, and 8 syllables, respectively, followed by a short one of 4 syllables. This structure is adhered to in Berlioz’s Melodie (score, Figure 1). Berlioz wrote a melody with a very low ambitus, illustrated by the first stanza, spanning the range B flat – D – A, in the first part, and B flat – D flat – A flat in its second part. This is in accord with the atmosphere of a cemetery (exterior), and melancholy (inner feelings). A further feature is a unit of four repeated notes, such as in the opening of each line in the first stanza, first part (corresponding to the underlined

syllables in the text). It is repeated at the end of the stanza, modified by a downward leap. For English translations of this and the following texts, see Appendix A.

Au Cimetiere

Hector Berlioz

Crespin N r-R N r''-R R R R sr-R R''
 von Otter R'' N''-N' N'' K''-R' R''-R' R' N''-N' N''-R' R'

Con_ nais_ sez vous la blan_ che tom_ be,

Cr N'' sr' R' R R R-r sr-R r' R'
 6 vO N'' r''-r' r''-r' R''-R' R''-R R''-R t'-R-d'- N'r' R''-R'

Ou flotte a_ vec un son plain _ tif

Cr W N N N-r N R r-R-r N k-R
 12 vO N'' N'' N''-R' N''-R' N''-N' N''-R' R''-R' R' k'-R

L'ombre d'un if? Sur l'if u_ - - - ne pa_

Cr r N N-R R'' N sr R r R r kR N r-R''
 18 vO r''-r' N'' N''-N'-N'' R'' N' sr''-r' k''-R' R' R' r' R' sr' R'-R''

_ le co_ lom_ be Triste et seu_ le au so_ leil cou_ chant,

Cr R R N' r'-R'
 24 vO R'' R'' R'' C'

Chan_ te son chant

Figure 1. Score of the first stanza (low voice version). The symbols above the notes will be explained in the following text.

Figure 2 presents the spectrogram of the unit of four repeated notes (the note B) opening the stanza (Connaissez-vous), sung by Regine Crespin (top) and Anne Sofie von Otter (bottom).

Figure 3 presents the four-note unit (repeated A) in “L’ombre d’un if”.

The added symbols used in the score (Figure 1) and in the spectrograms are a part of an extended notation and tone families classification scheme (Rapoport, 1996, 2004) to which the reader is referred for more detailed and complete presentation. The part needed in this study is explained here in a simplified manner: The FFT spectrograms (such as in Figs. 2, 3 and the others) represent the sound spectrum in a frequency-time diagram, with time as the horizontal axis and frequency as the vertical axis. The spectrogram “freezes” sound in time, and converts it into a picture, to be subject to observation and analysis. In the spectrogram, a tone is shown as a series of parallel lines along the horizontal time axis, corresponding to the fundamental and the series of overtones (harmonics). The sound intensity of any component of the overtone series is shown as its relative blackness in the diagram. The top part of the figure shows intensity vs. time of the sound waves. In the diagram, a tone of constant, non-varying frequency (like a piano tone) appears as a straight line, parallel to the time axis, and is denoted N. Vibrato is manifested as a sinusoidal modulation of frequency, a wiggly appearance in the spectrograms. Tones with vibrato are denoted as R-family tones. There are several varieties of tones, denoted according to their vibrato amplitude (or extent): large (R-tone), small (r), and very small (sr). Artists produce still a further variety of tones made of combination of N-family and R-family tones: a tone might start as an N tone, turning into an R tone, thus

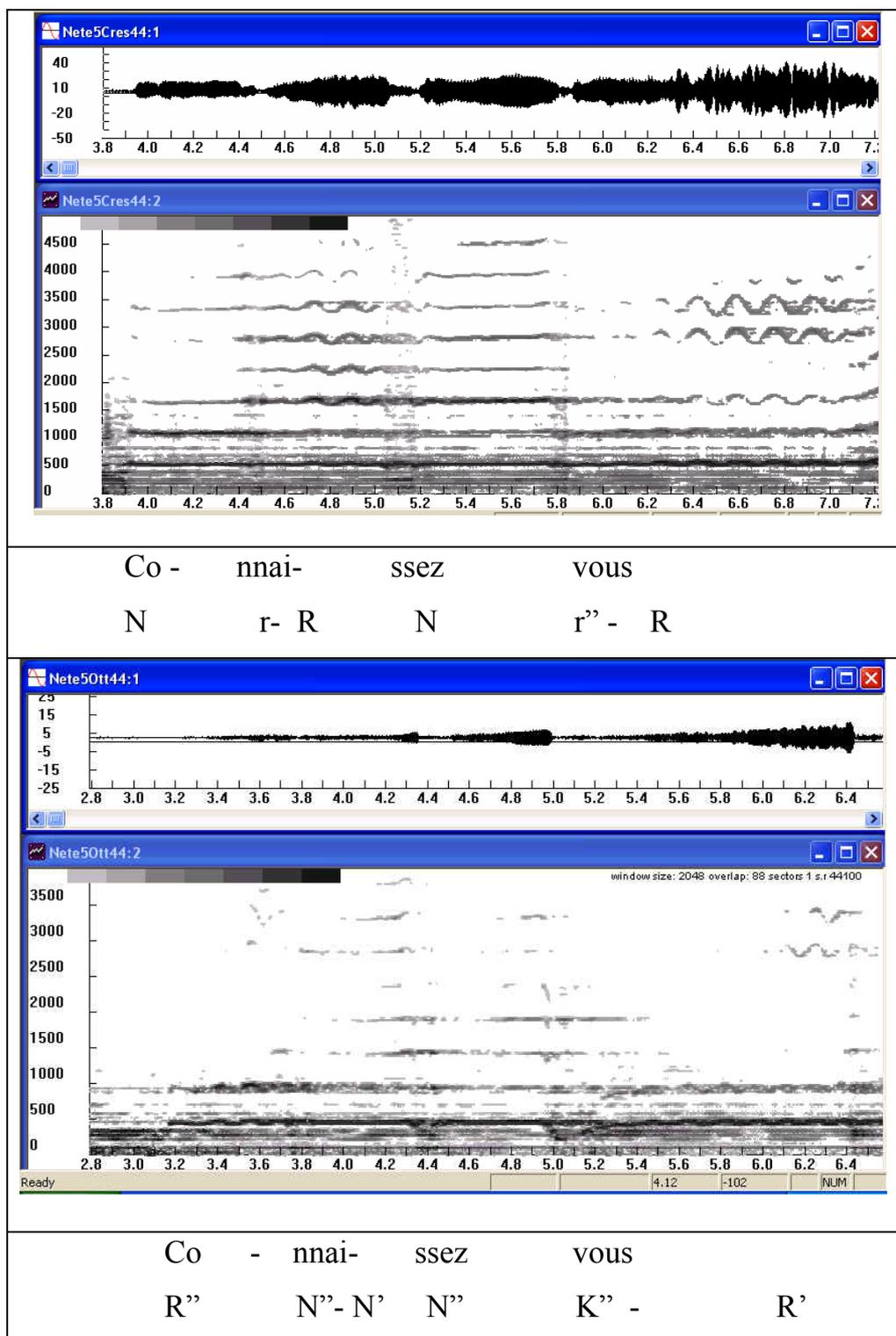


Figure 2: The phrase: Connaissez-vous. Top: Crespin, bottom: von Otter.

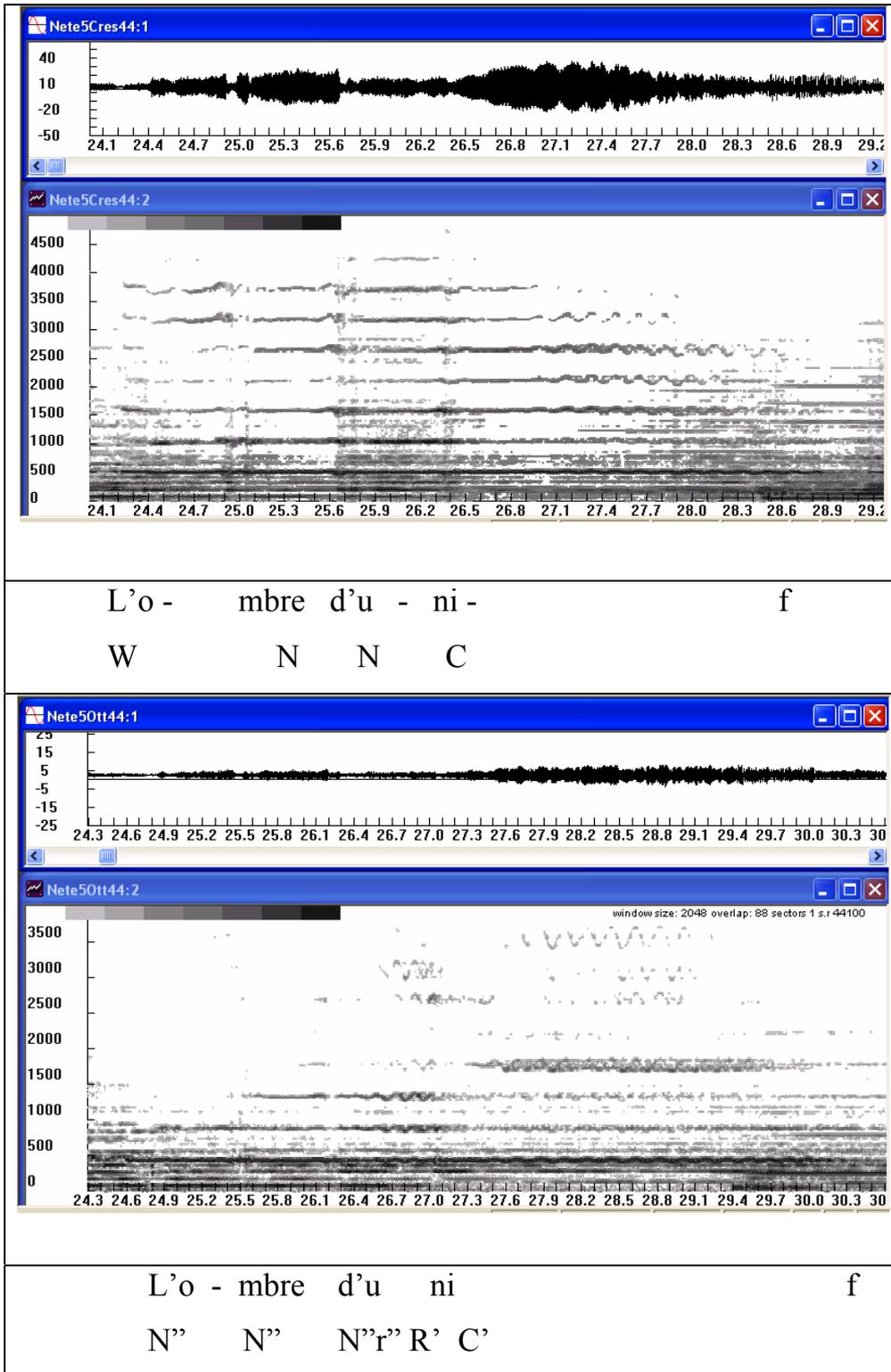


Figure 3. The phrase “L’ombre d’un if”. Top: Crespin; Bottom: von Otter.

denoted N-R (or NR). In a more gradual manner, a tone denoted N-r-R starts as N tone and develops vibrato in two stages of increasing vibrato amplitude. Such N-r-R and N-R tones belong to the C family (Rapoport, 1996). Furthermore, tones such as R-r, and r-R-r, sr-r, sr-r-R are self explanatory. This reflects the richness of tones and nuances produced by singers to express emotions and mood in singing (Rapoport, 1996). Still along the overtone spectrum there is also room for richness of nuances: We divide the frequency domain into two parts: (1) frequency lower than 2000Hz – range of vowel formants. (2) frequencies above 2000Hz, especially the range 2500-4000Hz (male singers), and 3000-5000Hz (female singers). This range is called the singer's formant (Sundberg, 1987). For the tone types discussed above, the full harmonic spectrum is present in full intensity: vowel formants + singer's formant. Tones denoted N', R' r' etc. represent tones with low intensity singer's formant. Tones denoted N'', R'', r'', etc. represent tones of very low, or zero-intensity singer's formant. All these are variants and nuances of timbre qualities. This completes the repertoire of tone types present in the singing of Crespin and von Otter in "Au Cimetière", first stanza.

Comparison of the two performances demonstrates the different approaches of the two artists. Crespin sings in full voice with fully developed overtones. The nuances and emotional inflexions are characterized by the artistic use of a wide variety of vibrato forms, including tones without vibrato (N-tones) alternating with tones with one or another varieties of vibrato: of very small, small, and large amplitude (sr, r and R-tones, respectively), and tones such as r-R, r-R-r, N-r, N-R.

Von Otter's singing is more delicate, as befits the melancholic atmosphere of the song: she plays mostly with the intensity of the overtones:

tones with only the low overtones (N^{''}, sr^{''}, r^{''}, and R^{''}-tones), low-intensity excitation of the high overtones (N['], sr['], r['], and R[']-tones). Tones with full intensity overtones (N and the sr, r, and R varieties) are much less frequent. All these are aspects of timbre, used as means of expression. Thus, Crespin uses the varieties of vibrato that affect the tone timbre (in the spectrograms it is the temporal aspects of timbre, Rapoport, 2004). Von Otter uses the overtone intensity as the parameter of voice quality and expression (vertical, or frequency spectrum aspects in the spectrogram). The sequence of N and R tones (Crespin), or the equivalent sequence of rise and fall in the intensity of overtones (von Otter) along the melodic line indicates the momentary tension – release (or excitement – relaxation) progression. Thus R indicates tension relative to N, and R^{''} (also relative to r).

This is clearly demonstrated in Figure 4, showing somewhat longer phrases. One might observe that in the top part of Figure 4, the number of N and r tones or parts of tone relative to the number of R tone parts is larger than in the bottom part, indicating increased tension in the latter.

One might observe that the information concerning vocal performance presented in Figs.2-4 is summarized in the notation in Fig.1, where one can follow the various tone nuances along the melodic line, the patterns of tension-relaxation, and the relation: text-melody-performance, down to the level of the relation of a particular tone type to specific word and specific musical note.

In the same way, Fig.6-7 (further below) are summarized in Fig.5, and Figs. 9-11 are summarized in Fig.8.

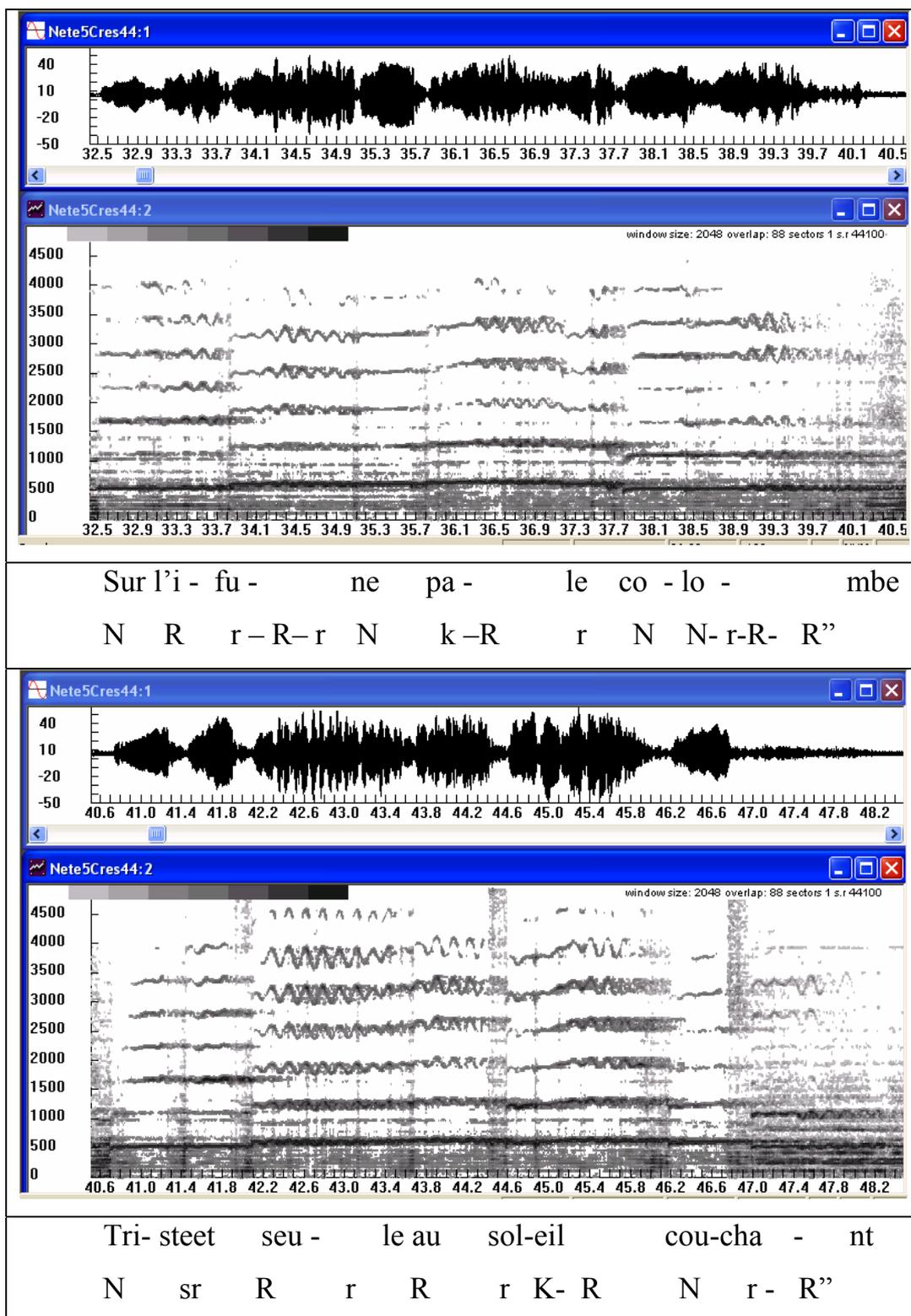


Figure 4. The second part of the first stanza (Crespin singing)

Schubert Lied: “Tod und das Mädchen”

The poem, by Claudius, is a struggle between a young girl who attempts to chase away Death, and Death, pretending to be a friend, who tries to entice her.

For the Death part, Schubert wrote a sequence of three one-note melodic segments: on D (first and second phrase), on F (third phrase), and again, on D (fourth phrase). A small rise to E and then F, then a descent to C and A terminate the second phrase. Similarly, a dip to A, rising back to D terminate the fourth phrase. These (seemingly monotonous) one-note phrases depict the atmosphere of the part.

The score of the phrase of the Death part (one-note melody) “Gib deine Hand, du schön und zart Gebild” is presented in Figure 5. Here DFD-DG refers to Dietrich Fischer-Dieskau, and Fsb to Brigitte Fassbaender.

Schubert: Tod und Maedchen (Der Tod) Franz Schubert

DFD-DG	KR	::	Kr	rR	K	r''	KR	r'	Ksr	R	rR
Ferrier	R		K	R	K	K	K		K	K	K
Fsb	kR		sr-R-r	sr	r-R	r'-r	sr-R-r		K	sw	sw-R-r''

Gib dei_ ne Hand, du schoen und zart Ge_ bild! bin

Figure 5. The phrase: “Gib deine Hand, du schön und zart Gebild”.

FFT spectrograms of this phrase, divided into two sub-phrases, are shown in Figure 6.

As can be observed in Kathleen Ferrier’s singing, a different type of tones is observed. Such tones start much below the nominal target frequency, and rise towards it in a convex arc. At the steady state full vibrato

develops. These tones are denoted K-tones. (KR or K-R are also used to demonstrate the two-stage nature of such tones). These are dark deep tones expressing grief and death, as befitting the part sung by personified Tod in the Lied. Indeed, in Ferrier's spectrogram most tones are K tones. Outstanding is the K tone on the word "deine" whose dark timbre might very easily be distinguished on listening. Fassbaender, in contrast, takes the role of Der Tod as the enticer. Her singing consists of various expressive sr, r, and R varieties.

In the second sub-phrase (Figure 7), again, all the tones in Kathleen Ferrier's singing are K tones. They differ in small nuances. Fassbaender's singing, again, comprises various types of R-family tones, with fine control of vibrato, ranging from sw (irregular vibrato at very small amplitude) to r, changing to R on the words "schön" and "Gebild"). Yet grief is expressed in the K tone on the word "zart".

The flexibility and fine control of the expressive qualities of vibrato are again demonstrated in Fassbaender's singing, as can be seen in Figure 6. Small amplitude and large amplitude vibrato alternate; a noteworthy example: the word "deine", the two vowels of whose diphthong are distinguished by changing the vibrato amplitude, leading to a tone labeled: "sr-R-r (and sr on the word's end syllable), with emphasis on the i of the diphthong ei. Similarly, an sr-R-r tone on the word "schön" in the second sub-phrase is again noteworthy. Fischer-Dieskau's singing, recorded with Gerald Moore (DG) some 27 years after Ferrier's is very similar to the latter in tone type and interpretation, as is obvious from the notation in Figure 5.

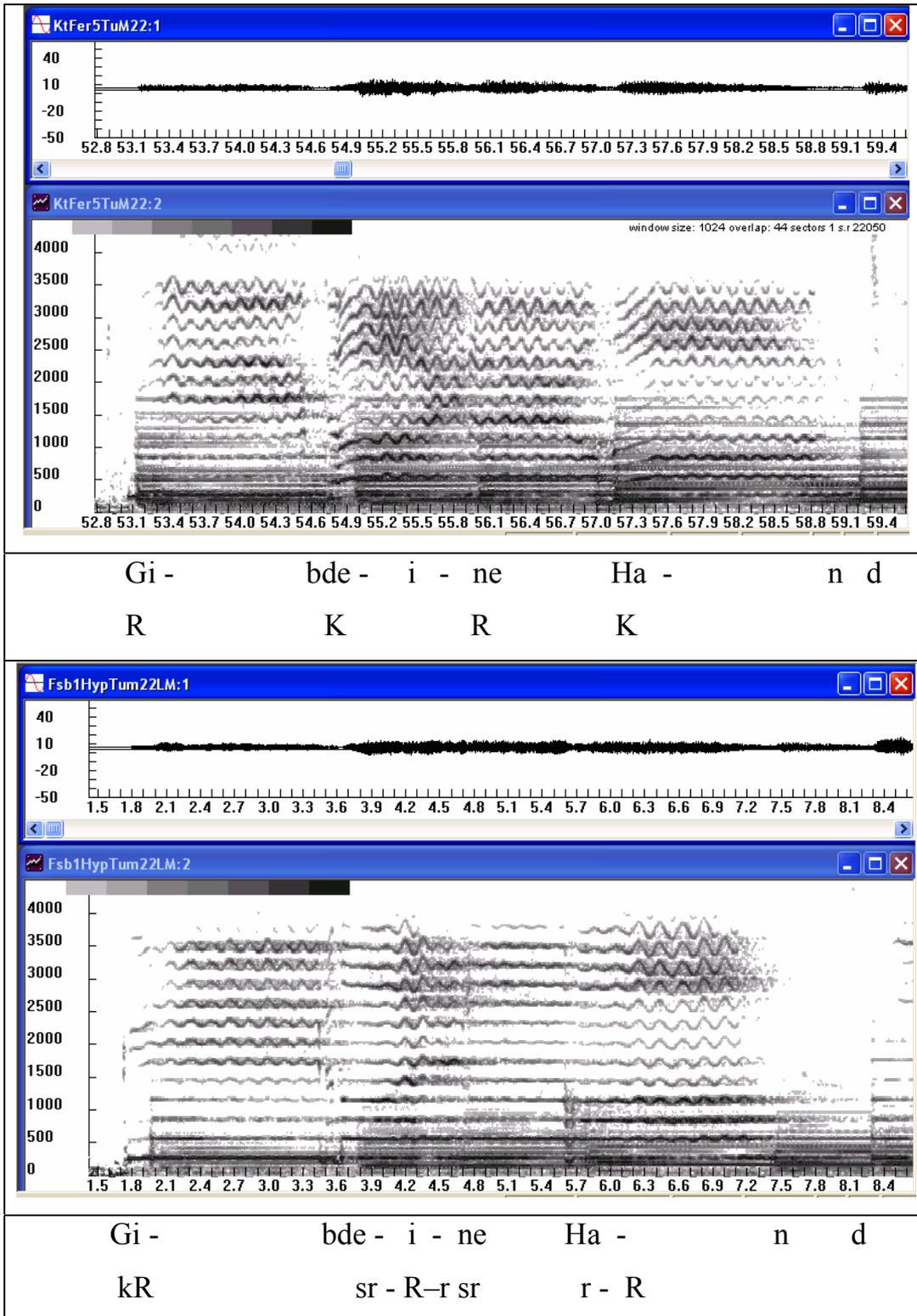


Figure 6. Death and the Maiden. Top: Ferrier; Bottom: Fassbaender

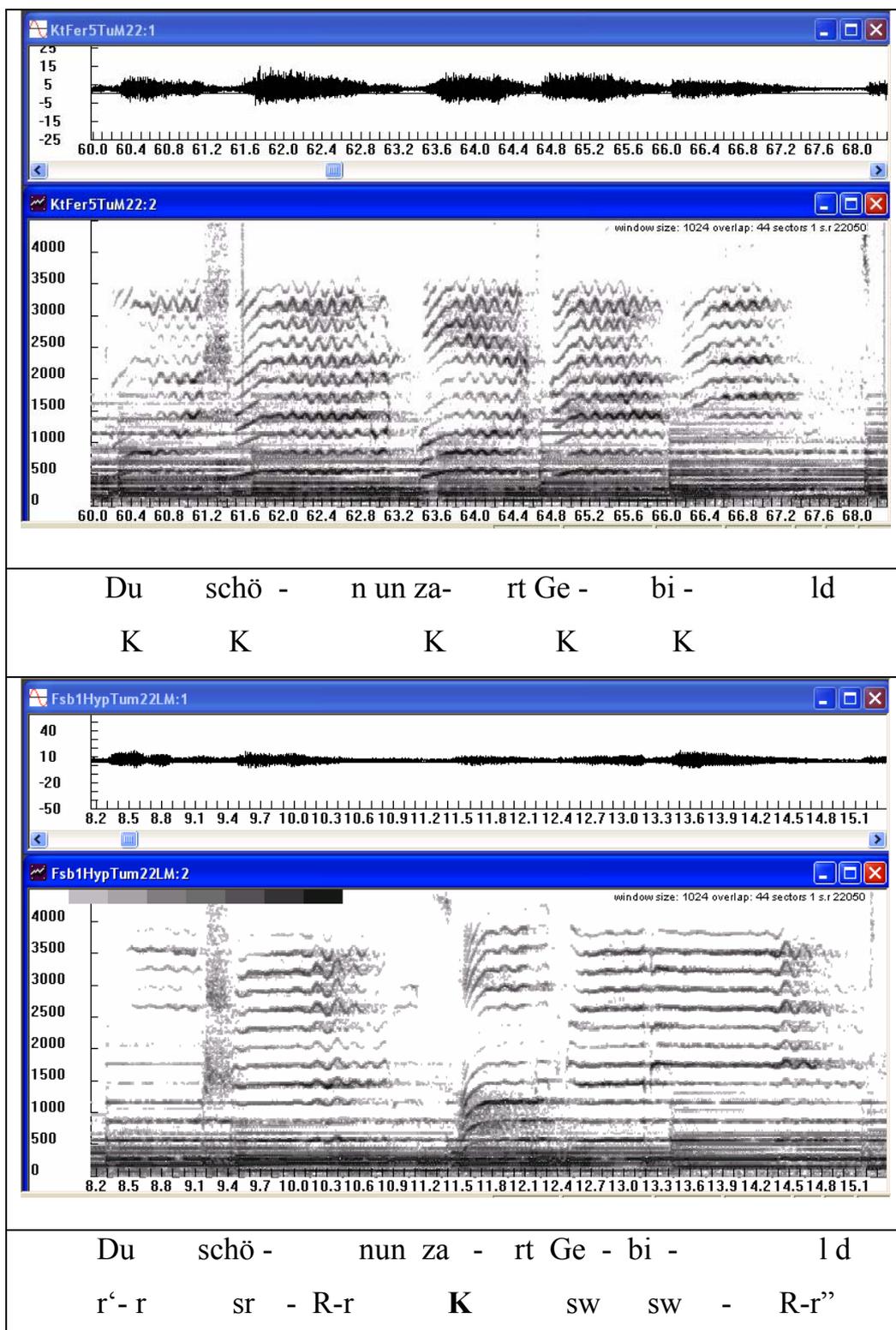


Figure 7. Death & Maiden. Top: Ferrier; Bottom: Fassbaender

The first stanza is centered around the “desperate cry”: the first line starts with a segment of six tones on the same note D, descending gradually to A. It serves as an introduction to the second line, where a leap of a third to the word “grido” and a second leap of a fourth to the word “disperato” emphasize the significance of these two crucial words. The climax is reached at the third line: “E quel grido...”, whose melodic contour contains two leaps: by a fourth, with *sforzando*, on the words: “quel” (grido), and “traverso”, again emphasizing their importance. In contrast to the legato and smooth melodic contours in the first two lines (with two leaps in the latter), the contour of the third line spans a larger ambitus, with two large jumps, and many notes are marked *sforzando*. The fourth line constitutes a relaxation after the build-up of tension in the previous three lines, returning to a smooth melodic contour.

Vocal FFT spectrograms of performances by Joan Sutherland and by Maria Callas, presented in Figures 9 (first 5 tones of line1), and 10 (line 3), demonstrate the different approaches of Sutherland and Callas. Sutherland, indeed, regards the first line as an introduction, as indicated by the R tones. Note that the duration of the tones is expressed in the number of vibrato periods contained in it. Thus, r3 and R6 denote tones with three and six vibrato periods, respectively. The duration of one vibrato period is approximately 160ms (i.e., six periods per second). Callas, on the other hand, sets the atmosphere of fury right from the beginning, producing Z-tones. Such tones, as seen especially in Figure 10 (bottom), are tones that start well below the nominal target frequency, and rise abruptly to the target, steady-state frequency. This abrupt rise or jump is characteristic of tones occurring in art songs and arias expressing rage and utmost tension. Z tones also drop abruptly at the tone’s end, the last vibrato period being particularly short.

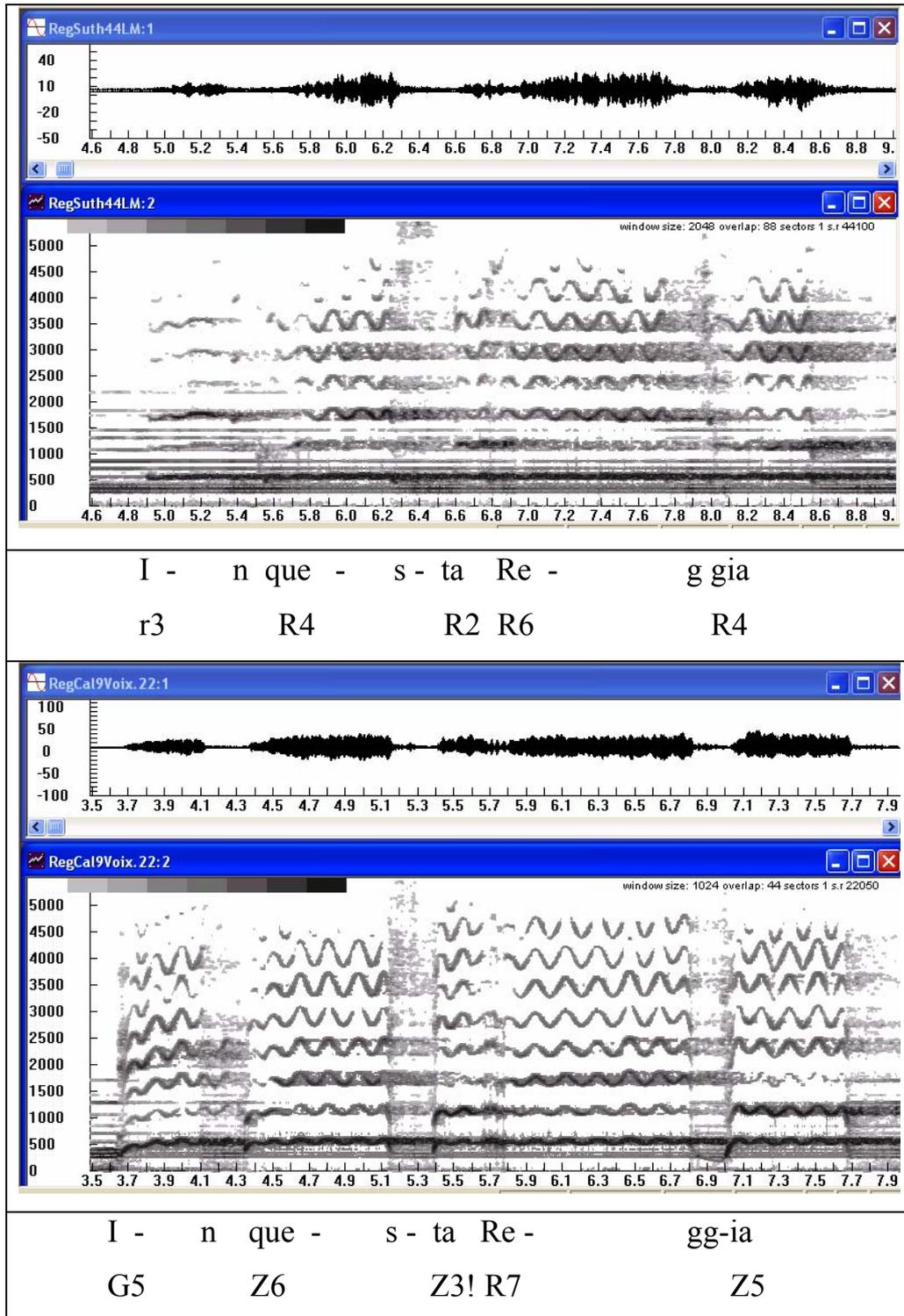


Figure 9. Turandot: In questa Reggia, opening 5 tones. Top: Sutherland; Bottom: Callas

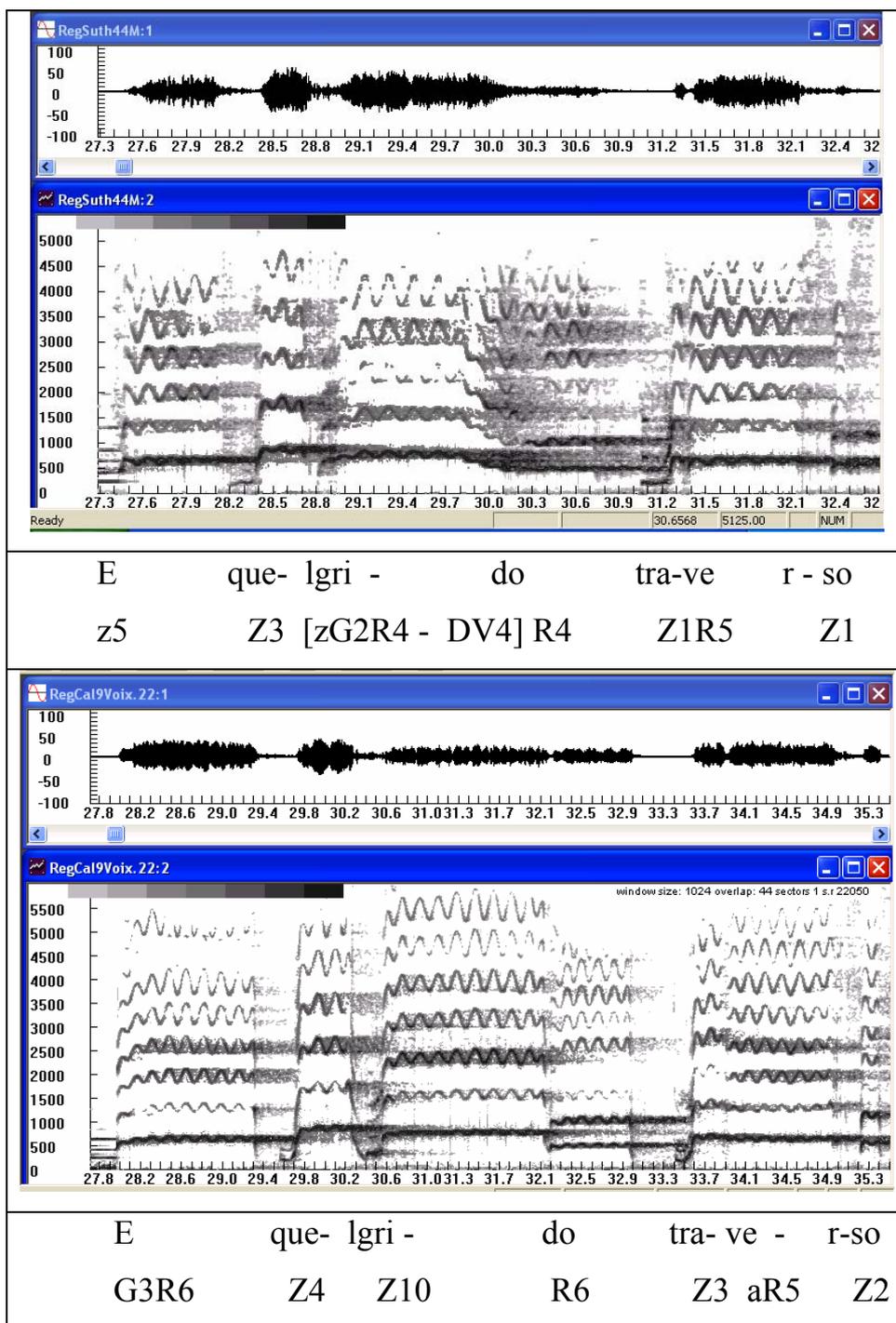


Figure 10. Turandot: In Questa Reggia, third line, first stanza. Top: Sutherland; Bottom: Callas

Again, the numbers following the Z symbols signify the number of vibrato periods. Another type of a tone (such as the opening tone in Callas's singing) is a K-tone with vibrato superposed on the convex rise. It is denoted by G.

Referring again to the score (Figure 8), the pattern of Z and R tones corresponding to tension-relaxation, respectively, is also evident. In Sutherland's singing, tension rises gradually from line 1 to the climax in line 3, as indicated by the pattern of Z and R-tones, finally relaxing completely in line 4 (variety of R nuances). Within the phrases, the excitement is at the first two bars of the line, relaxing at the third and fourth bars. In Callas's singing, there is tension in the first two bars of lines 1 and 2, expanding to the first three bars in the third line, where a climax is reached, relaxing in the fourth bar, leading to fully relaxed fourth line.

On the micro scale, a few features are noteworthy: On the first appearance of the word "grido" (2nd bar, 2nd line) Sutherland produces her first Z tone, whereas Callas, who already produced them on the 1st line, produces the more ornamental, artistic, G-tone. On the word's 2nd appearance (3rd line) Callas produces Z tones on both syllable, whereas Sutherland produces a rather elaborate, more complex artistic tone, marked: [zG2R4-DV4], starting with a jump z (smaller than a Z), getting rounded to a G tone with 2 vibrato periods, reaching a steady state of a four vibrato periods R tone, followed by a portamento descent (D) with four vibrato periods (V4). The square brackets, here and elsewhere, denote that the enclosed within is produced with legato.

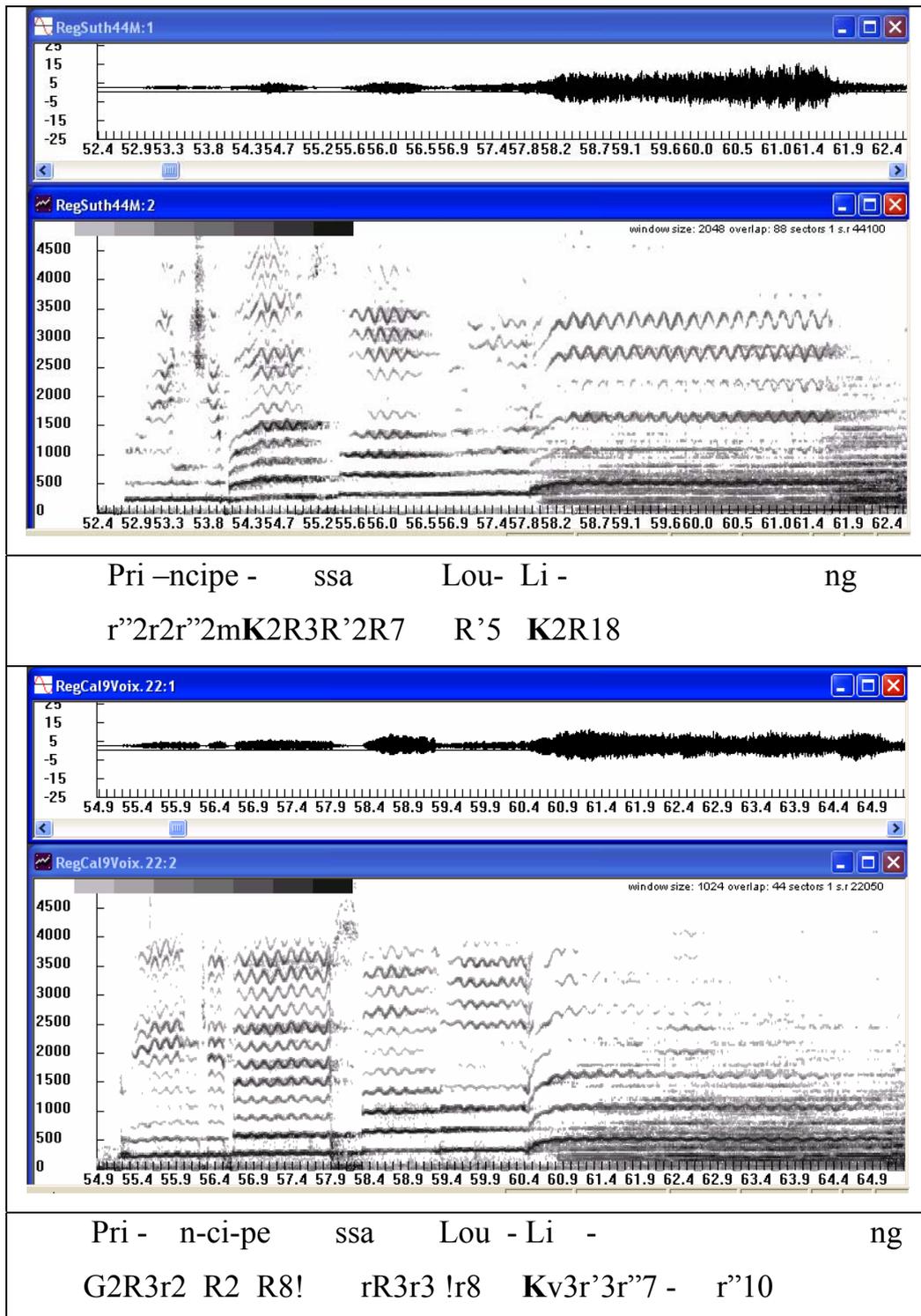


Figure 11. Turandot: the phrase “Principessa Lou Ling”. Top: Sutherland, Bottom: Callas

Sutherland	r"2r2	r2	K2R3r'2	R7	R'5	K2R18
Callas	G2R3r2	R2	R8!	r1R3r3	!r8	K3r3r'7-r"10

Prin_ ci_ pes_ sa Lou Ling

Figure 12. The phrase “Principessa Lou Ling”.

The final relaxation in the fourth line leads to the next stanza, full of tenderness and yearning, starting: “Principessa Lou Ling...”, which Puccini begins with a gradually rising concave melodic phrase, expressing yearning, affection, and nostalgic grief (Figure 12), also expressed in the R and K tones in the spectrograms of Figure 11.

The climax of the aria is reached at the phrase: “io vendico su voi... quella purezza, quel grido e quella morte”, where Puccini writes significant leaps of a sixth on the word grido, and sixth and seventh on the word morte (score Figure 13), specially stressed in Z tones in Callas’s singing. Sutherland produces other varieties of artistic nuances, noted in Figure 13. These are XHV tones. XH, CH, and ch tones are arch-like tones (Rapoport, 2004) that in the spectrogram appear as a tone with a convex rounded frequency increase to a climax, terminating in a rounded convex frequency descent. The V indicates vibrato superposed on the arch, with the indicated number of vibrato periods. XH, CH and ch denote the frequency range spanned along the frequency axis, being large, medium, and small, respectively.

Sutherland !R3 R3! R3 R3 R3 R8 R3 R4 R2R"2 R4 R3
 Callas(V) G2R2 R3r2 R4 Z5! zR4 Z10 CHV4 R4 GR2r"2 rR4! rR3r

io ven - di - co su voi - - su voi quel - la pu -

S R6! R3 R3! XHV9 !R3 [XHV9 R3] Z1R8D4 R7 R3
 C(V) rR8 rR3 Rt3 Z8 Z3 Z8 Z3! Z1Z8r2 Z6 Z4

3 rez - za, quel gri - do e quel - la mor - te! Quel

S Z1Z17RD7 R8 G8 Z1R7 CH11RD4 R5! ch11 R6
 C(V) ZG2R21RD5 Z8 Z4 Z6 Z14Rd5 Z4 Z7! Z6

5 gri - do e - que - e la mor - te

Figure 13. The phrase: "io vendico su voi....quella purezza, quel grido e quella morte".

A Short Excerpt from Offenbach's Operetta *La Périchole*

In a lighter, comical vein, a short melodic phrase from the ariette "Ah quel dîner je viens de faire" in Offenbach's operetta *La Périchole*, as sung by Regine Crespin and Frederica von Stade is presented in the spectrograms of Figure 14.

La Périchole tells about the dinner she had: "What a meal I've just had, and what extraordinary wine. I've had so much, I do believe that now I'm a little drunk ..."

The reader can by now perceive the variety of the tones in the spectrograms. In Crespin's singing, noteworthy are the tones corresponding to the word "dîner", two tones with gradual, rather steeply rising frequency for both syllables, expressing sarcastic admiration for the extraordinary dinner.

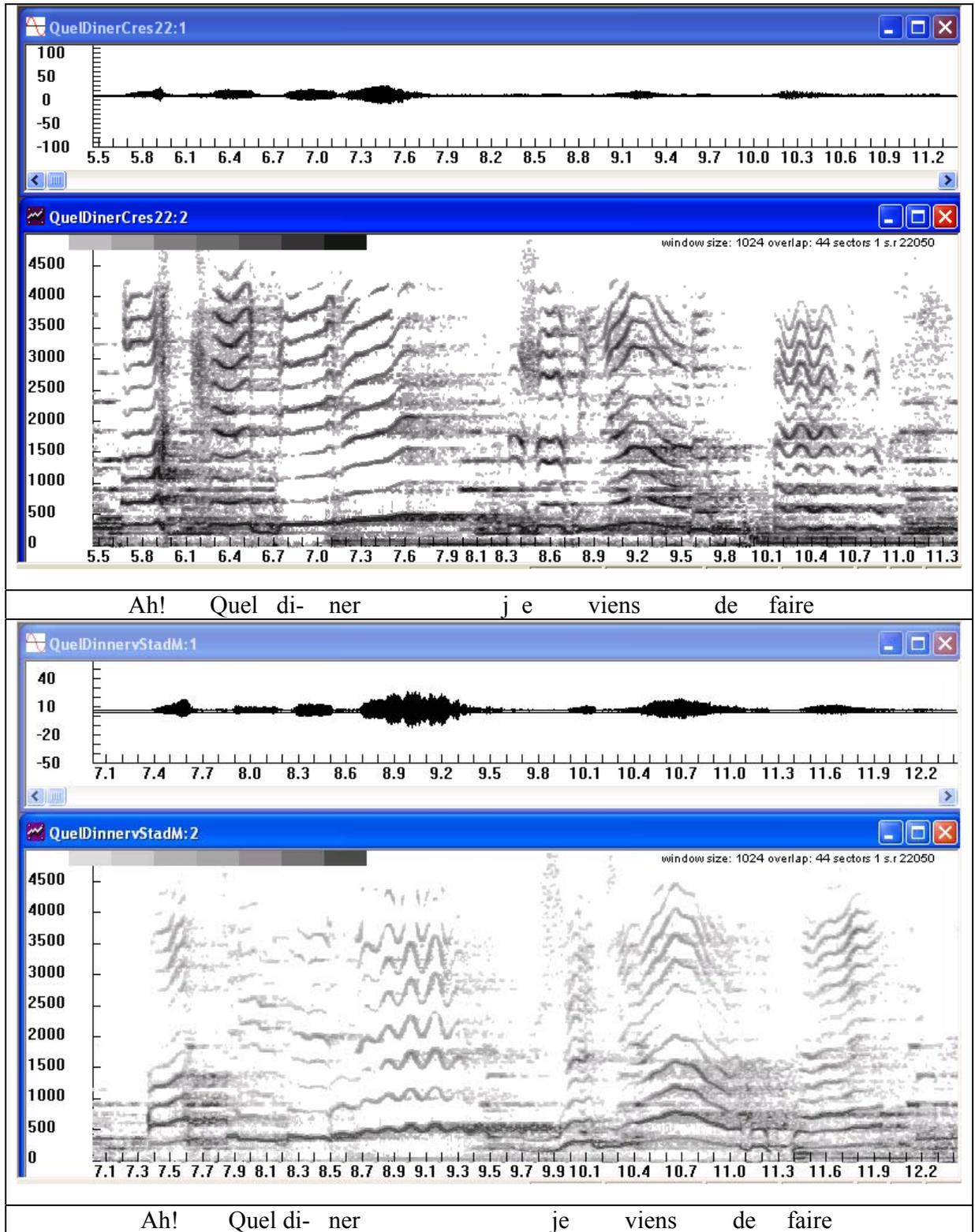


Figure 14. La Périchole: Ah! quel dîner. Top: Crespin, Bottom: von Stade.

The corresponding tones in von Stade’s singing start with decreasing frequency and small vibrato on the syllables: “quel dî-“ followed by mildly rising frequency on “-ner”, with vibrato. The most unusual shape of the tone on the word “viens” for both artists expresses exclamation: I had such a dinner! (All the tones in the spectrogram can be described according to Rapoport (2004), but here is not the place to introduce more symbols.) However, Crespin relaxes at the end to an R tone for the word “faire”, whereas von Stade exaggerates it with a tone of increasing frequency with vibrato, similar to that of “dîner”.



As can be seen from comparison with the score, indeed there is an ascending sequence F sharp–G, and a jump to C for the segment “quel dîner”, and thus the rising pitch in the corresponding tones in Crespin’s singing is in accord with Offenbach’s intentions. The first descent and then the rise in von Stade’s singing corresponds to the transition from the sigh “Ah!” to “quel dîner”, thus putting the emphasis on Ah! and not on quel dîner. Crespin’s relaxation at the end of the phrase is, again in accord with Offenbach, a descending sequence on “viens de faire” whereas von Stade’s ascending pitch is again exaggerated, not in accord with Offenbach. To my taste von Stade’s singing sounds excessive with mannerism, bordering on the vulgar, as compared to Crespin’s chic and coquettish manner.

Discussion

Nuances are important in the art of singing. Here a large variety of nuances, classified into different classes or families, were demonstrated in four melodies corresponding to four different moods and emotions, from melancholy and sadness (Berlioz), death (Schubert), or enticement (Schubert, in Fassbaender's interpretation), rage and revenge (Puccini) to light-heartedness (Offenbach). These nuances form a vocabulary of expressive singing in Lieder and opera arias.

In Berlioz's "Au Cimetière" Crespín uses the varieties of vibrato, that affect the timbre (in the spectrograms it is the temporal aspects of timbre, Rapoport, 2004). Von Otter uses the overtone intensity as the parameter of voice quality and expression (vertical, or frequency spectrum aspects in the spectrogram). In *Der Tod und das Mädchen* both Ferrier and Fischer-Dieskau produce K tones that start below the target frequency, rising to it in a convex arch, imparting some additional depth and darkness to the tones, thus painting the atmosphere of the Lied. In *Turandot* "In questa reggia" Z tones paint the crucial words "grido disperato" and others, depicting an atmosphere of rage and vengeance. Still a different set of tone forms appears in the ariette from Offenbach's *La Périchole*, befitting the comic atmosphere.

It is worth mentioning that in a recent paper Lerdahl (2001) proposed a process or recipe by which a poem could be set to melody. It is based on a hierarchical phonological analysis of the text, assigning the appropriate phonological stress on the various syllables, leading to corresponding musical grouping, meter, and tone duration, and eventually leading to a melodic contour. Recently and independently, Wagner (2005) used similar procedures

to analyze songs by the Israeli popular song composer Sasha Argov, with emphasis on the meter and rhythm of Argov's melodies and their relations to the texts, thus illustrating Argov's musical creativity and inventiveness. In a recent investigation of Schönberg's Sprechmelodien in "Pierrot Lunaire" (German texts by Hartleben), Rapoport, (2004, and 2006) made direct comparisons between FFT spectrograms of German speech intonation of the poems as read aloud by two persons, and the corresponding Sprechmelodien. He demonstrated that the musical rhythm was determined by the syllabic structure of the German text, and the Sprechmelodien's melodic contours were patterned after the intonation patterns of the spoken text. In the present study, interest is in the relation text – mood (and emotion) – melodic contour, and particular words of special importance. The melodic contour reflected the mood in the text: low ambitus, with same-note segments (Au Cimetière), one-note melody (Death), and contour comprising jumps on significant words: grido, morte (Turandot).

These are interpreted by the performing artists utilizing the numerous vocal nuances demonstrated here.

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Appendix A: Sources

Berlioz: Les Nuits d'Été:

Regine Crespin: Decca 440416 (recorded 1963)

Anne Sofie von Otter: *Berlioz: Les Nuits d'Été*. DG445 823 (recorded 1988)

Schubert: Der Tod und das Mädchen

Kathleen Ferrier: Decca 433476 1949 (Edinburgh Festival)

Brigitte Fassbaender: Hyperion CDJ 33011 (recorded 1990)

Dietrich Fischer-Dieskau: DG 415188 (recorded 1969-70)

Puccini: Turandot

Maria Callas: *Puccini & Bellini Opera Arias*. EMI CDC7 47966 (recorded 1954)

Maria Callas: *La Voix du Siècle*. EMI 7495022 (stated as recorded 1958)

Joan Sutherland: *Puccini: Turandot*. Decca 414 274 (recorded 1972)

Offenbach: La Périchole

Regine Crespin: *Grandi Voci*. Decca 440416 (recorded 1970-71)

Frederica von Stade: *Metropolitan Opera Gala*. DG 449177 (recorded 1996)

The full texts with their English translations can be found in the companion booklets of these CD's.

**Appendix B: Background Material, The Path: Sound Spectrogram –
Deciphering - Interpretation**

The vocal analysis presented in this study does not depend on a particular group of subjects filling a prepared questionnaire which is then analyzed statistically. It analyses directly the sound waves emerging from the singer's mouth. The various stages in the development of the present method of analysis, leading from observations made on the spectrograms to their interpretation and relation of the various vocal nuances to emotions, is described in detail in Rapoport (1996, 1997, and mostly in 1996a), to which the reader is referred for background material, and briefly outlined here:

The starting point – the vocal FFT spectrograms – belongs to the realms of physics and acoustics. The method was developed in the following steps:

- (1) Observation of the FFT spectrogram at the level of a single tone (or single syllable) led to the discovery of a large number of vocal nuances, and to the conclusion that even a single tone is a composite entity that can be decomposed into smaller, and simpler elements (e.g. vibrato).

- (2) These elements were further identified, and it was found that a small number of elements is sufficient to describe all the vocal nuances observed. Thus, a large variety of vocal tones are formed by the various ways that these elements can be organized in time (temporal structures)
- (3) Classification and grouping of the vocal nuances into six families: N, C, R, (T,K), S, Z families, according to their similarity, and elements they share in common. In the present work only elements from the N, C, R, K, and Z families were demonstrated.
- (4) Development of a special notation by assigning definite symbols to each of the elements.
- (5) Classification of the tone families in a hierarchical scheme according to structural considerations based on the type and number of the elements composing the tone.
- (6) Establishing a relaxation-tension hierarchy in the classification scheme from first principles (Rapoport, cited above). The two hierarchies were found to coincide. This led to the hierarchy, in the order from neutral, calm to excited: $N < C < R < (T,K) < S < Z$.
- (7) Association of vocal nuances and emotions. This was done by correlating the families of vocal tones and nuances in the sung vocal spectrograms with the emotional context in the texts of a large number of opera arias and art songs. This is also demonstrated in the present work, where N and R tones correspond to the atmosphere of sadness, loneliness and melancholy in “Au Cimetière”; K tones correspond to death and grief in Kathleen Ferrier’s and Dietrich Fischer-Dieskau’s singing in *Tod und das Mädchen*; Z tones correspond to the words “Un grido disperato” and others, expressing rage and vengeance in Callas’s and Sutherland’s singing in “In questa reggia”.

(8) Marking the symbols of each nuance, according to the notation, above the corresponding note in the score, leads to a “performance score” that allows observation of tension-relaxation patterns along the melodic line, relation of particular vocal nuances to important words in the text, comparison of performances of two or more artists, etc.

All these are deductions from the spectrograms done in a scientific, objective way. The various steps in the development of the analysis can be re-examined, reconsidered, modified, replaced, or improved if questioned. One might raise questions regarding objectivity in assessment, or expressing merit or preference for one performance relative to another in expressing the emotion or moods in the song or aria. However, if any was made here it was based on the vocal nuances in the performance, rather than on subjective personal taste preference.

Additional Musical Aspects

This work’s main purpose is analysis and comparison of vocal performances, and their relation to the text which was the source of inspiration to the composer.

The relation of vocal nuances to emotions and moods in the text and the emphasis of key words in the text were demonstrated. Of course the composer is also artistically sensitive to these factors, and has a variety of dimensions to express them in the music. This work concentrated on the melody, only one of these dimensions, and does not consider other dimensions: harmonic, contrapuntal, timbral-orchestrational, etc. It leads to the interesting question as to what extent is the singer influenced by the text, by the

melody, or by the other dimensions. This stimulating point certainly deserves further research. However, the author's experience shows the predominance of the influence of the text and its emotional context, especially in opera, where acting is involved.