Chapter 1

Pavarotti: King of Second Formant Tuning

Most people with even a small interest in opera have heard of the late Luciano Pavarotti, often called the "King of the High C's." He gained this informal title by genuine achievement, which was followed by the fame that came from well-attended performances that reached still larger audiences through broadcasts and recordings. In truth it was not so much the high C's that made him famous. For one thing, C's alone cannot do that. There are many other tenors who can reliably produce a big *C5* (at 523 hertz, or cycles per second) who have failed to become famous. And although high notes were a prominent feature of Pavarotti's popular appearances, these seldom were C's. The marginally lower *B*-flat (466 hertz) appears far more frequently in tenor arias as a climactic note, offering ample opportunity to display power, beauty, and triumph in meeting the challenge of extended range. Clearly, the high note in an operatic aria is not simply an event like the pole vault, where the one who clears the greatest height can claim the title of king. Nonetheless, the athletic challenge of the high bar is an undeniable factor in the experience of opera, and Pavarotti, something of an athlete himself when young and slender, was adept at thrilling audiences with perfectly executed leaps to climactic heights.

"King of the High C's," however, is more than just another way of saying that Pavarotti was a great tenor. Though many a famous tenor has made a career without it, *C5* is generally recognized as the highest note to be expected of an operatic tenor. Pavarotti earned his “crown” primarily through the role of Tonio in Donizetti’s *La Figlia del Regimento*, where the pitch comes up nine times. Not only must the singer dispatch these notes with adequate power and beauty, he must convey as well an impression of freedom in their production. Palpable risk and effort are what make the *C5* exciting for the audience; nonetheless, the singer must conceal the physical limits of his pitch range behind a paradoxical sense of effortlessness.

The beauty, freedom, and even to a large extent the size of such notes are perceived subjectively, but the measurable pitch provides an objective frame of reference. A problematic aspect of any discussion of singing technique is the subjective nature of the terms generally used to describe what we perceive in a voice. Language has severe limitations for describing the quality of sound, whether the words are those of critics addressing the public or of singing teachers coaching their pupils. On the other hand, pitch and temporal features can be rendered quite precisely by musical notation, holding singers to objective standards that cannot be circumvented by singers' artful deceptions.

But the question before us is this: can objective measures capture the distinctiveness of Pavarotti's high notes, setting them apart from those of other tenors? In the course of this book, I hope to persuade you that the answer is affirmative.

In order to answer this question we will carefully examine the displays of **spectrum analysis**,* which show not only the pitch of the note that is heard, but also the whole series of overtones that are constituents of the sound, together with their relative strengths in measurable quantities. This display of spectral components defines a large part of the quality of a given sound, a property that, unlike pitch and duration, cannot be rendered by musical notation.

Let us go directly to a concrete example, the final *B4*-flat in the aria "Celeste Aida" From Verdi's *Aida* (Fig. 1.1). This challenging note is sounded before the orchestra enters just long enough to yield a power spectrum averaged over a few full cycles of vibrato. The averaging lumps together, as does the ear, all the minute changes in sound that occur as the voice modulates in vibrato at the rate of about six times per second. At the Groningen Voice Research Lab we have analyzed over 80 recordings of this particular *B4*-flat(1), and it is instructive to consider the contrast between Pavarotti's power spectra and those of his long-time rival for the claim to be the world's leading tenor, Placido Domingo.

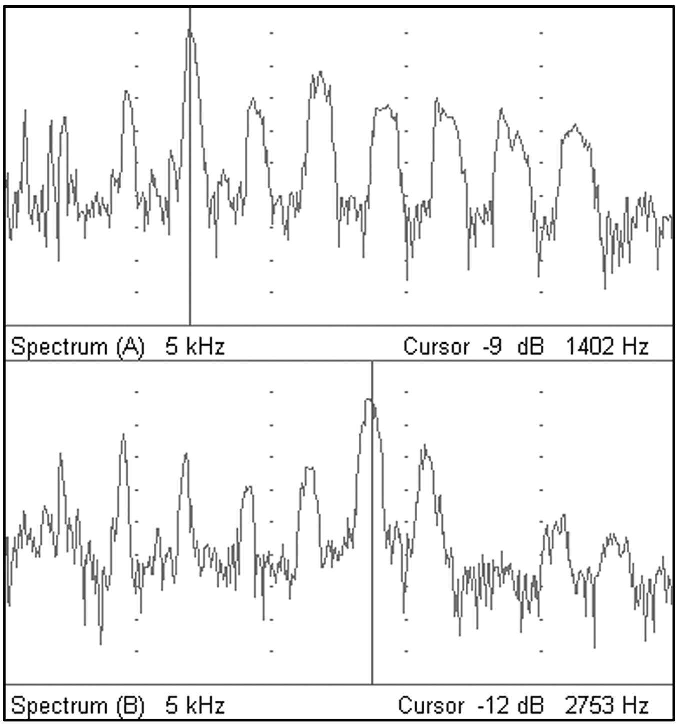

Fig. 1.1. **Power spectra** of *B4*-flat, final note of "Celeste Aida" from recordings of L. Pavarotti (above) and P. Domingo (below). The vowel sung is nominally [o] ("sol"). The spectra come from a moment where the orchestral sound is fading, and the clearly identifiable **harmonics** (there are 9 and 7, respectively, for Pavarotti and Domingo) are those of the singing voice. Each dot on the vertical axis represents 10 **decibels**, and the **dominant harmonics** (H3 and H6, respectively) exceed all others by more than 10 dB and thus carry the bulk of the sound. Frequency and intensity (decibel) measures of the harmonic at the cursor are displayed below the spectra.

* **Bold typeface** indicates the text is defined in the Glossary, which begins on page 110

Both recordings offer a solidly produced high note capable of arousing enthusiasm in audiences. The absolute intensity in decibels is not really an issue in studio recordings like these, since the balance with the orchestra can be adjusted at will, but both tenors have demonstrated in live performances that they are clearly capable of producing the large sound required for the heroic role of Radames, the character who sings the aria.

The spectral displays reveal some remarkable features. One is the extent to which the level of sound produced depends upon one or two frequency components. At this high pitch the number of harmonics available for resonation is limited. The two tenors have clear, selective **resonance strategies** that draw the largest part of their physical acoustic power from a single harmonic that is proximate to a **formant**, or resonance of the vocal tract. The other surprise is the contrast between the two strategies. Where Domingo relies on the resonance of the so-called **singer's formant** at about 2.8 kHz for the bulk of his sound, Pavarotti produces most of his with the third harmonic, just one octave lower at 1.4 kHz. Both these resonances are of course multiples of the pitch that sounds to the listener, at 466 Hz.

It can be convincingly shown that Pavarotti produces his dominant third harmonic by tuning to it the second formant of the vowel occurring there, on the word "sol." (Later, Chapter 4 is devoted to vowels and the formants/resonances that create them; for the moment we ask the reader to take this on faith.) One evidence of Pavarotti's exceptional skill in applying this strategy is the extent to which he deliberately distorts the second formant (of the vowel [o]) in order to match the third harmonic. He raises the formant at least 500 Hz, or more than 50%, from its speech value of about 900 Hz.

This high-pitch resonance strategy of tuning the second formant to the third or fourth harmonic is evident not only for a few choice "money notes," but it also appears in the form of **tracking** a harmonic's changing position as the sung pitch changes. A striking example of this is in the showy flourish on the first vowel of the text "e di pensier" that occurs at the end of the aria "La donna è mobile" from the opera *Rigoletto*. The vowel is first sustained on two pitches, *F4*-sharp and *A4*-sharp, before running through a rapid scale passage covering more than an octave (Fig.2). On the long *F4*-sharp the second formant rests on the fourth harmonic at about 1520 Hz, a value not far from that of F2 in speech(2). When the pitch moves up to *A4*-sharp, the fourth harmonic (which moves four times as far as the fundamental) is 350 Hz higher. Pavarotti nonetheless clearly follows it with the second formant. Since vowels are defined by the frequencies of the first two formants, it is not surprising that this move has a decided "brightening" effect on the quality of the vowel, which later "opens" as the pitch descends. The final sustained *B4* (here the money note) is also on the [e] vowel “pensier”, but at that pitch he tunes F2 to the *third* harmonic at 1520 Hz (Fig. 3), which is the same frequency as H4 was on the *F4*-sharp.

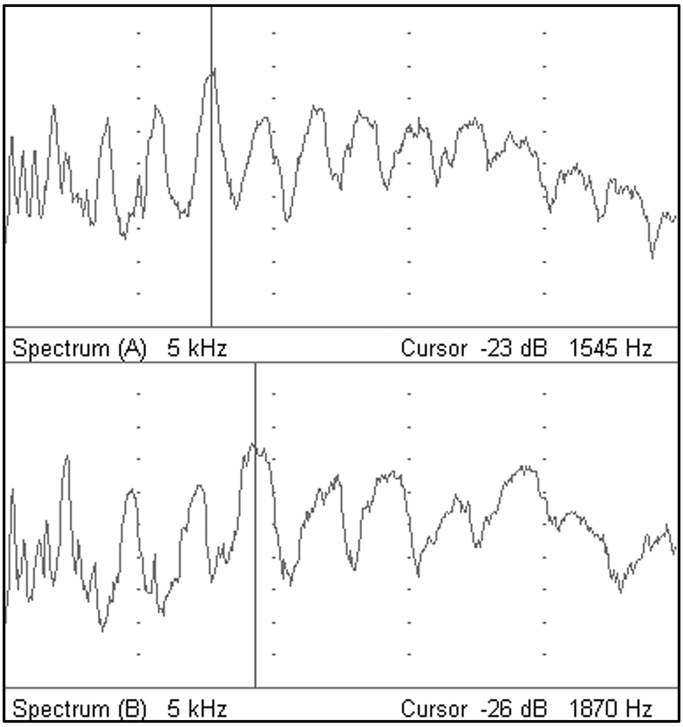

Fig. 1.2. Power spectra of sustained *F4*-sharp (above) and subsequent *A4*-sharp (below), both in a continuous phonation on the vowel [e] ("e di pensier"), from Pavarotti's recording of "La donna è mobile" from the opera *Rigoletto*. The *F4*-sharp is dominated by the fourth harmonic, boosted by the second formant. As the pitch moves up to *A4*-sharp, the singer follows H4 with F2, modifying the vowel in the direction of [i].

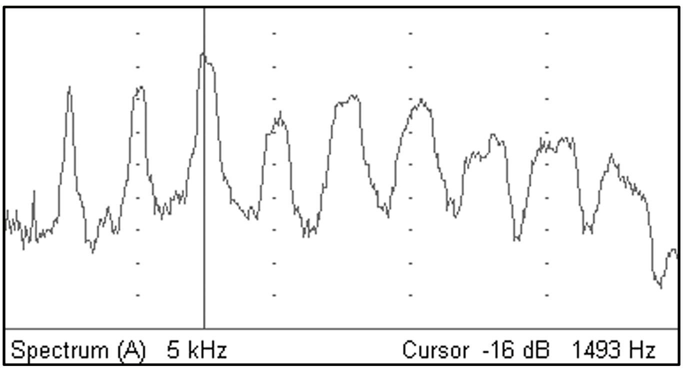

Fig. 1.3. Power spectrum of the final note of Pavarotti's "La donna è mobile," a *B4* on the vowel [e] ("pensier"). The second formant is the dominant resonance at the third harmonic, now at the same frequency as H4 was on *F4*-sharp in Fig. 1.2. Regarding the dominant F2/H3 combination, note the similarity with the *B4*-flat of Fig. 1.1, where the frequency of F2 is raised far above the speech value for the **back vowel** [o].

Some readers will have difficulty comprehending the preceding paragraphs, even after studying the figures. In fact, many readers may not be clear about the difference between a ***formant*** *and a* ***harmonic****. Such fundamental information will be presented systematically in the course of this book. The point here is to show that information having a crucial bearing on vocal technique and pedagogy is available as factual feedback—thus motivating the process of learning to recognize and interpret it.*

These two examples serve to illustrate a consistent strategy that is also evident in other recordings, including those with *C5,* “high C.” For those who are aware of the strategy, "king of second formant tuning" seems a more appropriate title for this master of **passaggio** and the **upper extension**.

While it is probable that neither Pavarotti nor his principal teachers were aware of F2 tuning as such, they clearly had, or developed, the expert hearing that led them to consistent application of the strategy. Modern technology has now made it possible to identify and measure the resonances of the vocal tract with nearly the same precision we have long applied to pitch. The expert ear is still the indispensable qualification of the serious teacher of singing; however, spectrum analysis, which is easily accomplished in the personal computer, can give factual feedback on our success, or lack thereof, in advantageously tuning the **vocal tract**.

So why, you may ask, hasn't this information, this opportunity for objective and reliable feedback, caught the attention of the majority of those who would emulate the careers of Pavarotti and other great opera singers? After all, the first detailed account of second formant tuning and its importance was published as long ago as 1994 in a scientific journal(3), followed in short order by advances in personal computing that could show spectrum analysis in **real time**. Well, for one thing, even within the limited domain of vocal technique, second formant tuning is only one of many factors that have been essential to Pavarotti's rise to the top. On the other hand, while it is also true that a successful career in opera requires more than singing in tune, that fact does not grant singers the license to ignore discrepancies in intonation on the claim that they are following their own subjective perception. Unlike out-of-tune singing, shortcomings in formant tuning *are* tolerated, so long as the sound otherwise fulfills requirements that can be more readily perceived by the unaided ear.

A more important obstacle to incorporating feedback from spectrum analysis into practical voice instruction has been the difficulty in relating it to ordinary perception. By contrast, we are quite well equipped to deal with pitch: even without the aid of instruments, a non-expert ear can discriminate pitch quite precisely. Identifying the dominant spectral components of a complex sound is a task of quite another order for the human ear, even if trivial for an appropriately programmed computer. We are accustomed to using instruments to extend our perception; however, it is natural to embrace more readily displays that enhance what our own senses perceive, such as those of a telescope or a satellite view of the earth, than to accept those that run counter to our own perceptions.

An instructive case in point is the way the displays of the original (light) spectrograph have been regarded historically. We perceive colors, which—like pitches in sound—are functions of wavelength and frequency. From such frequencies it is possible to identify chemical elements when ionized, and it is from this information that we derive the composition of remote heavenly bodies. The ability to obtain such information on the composition of materials understandably stirred the imaginations of some scientists and lay people when the spectrograph was invented, and at least one scientist of the time predicted that the spectroscope would become “the pocket companion of everyone amongst us."(4) That did not come to pass, but a similar prediction *has* been realized for television, which allows us to see what is not directly in front of our eyes. Seeing spectroscopically has a decidedly more limited appeal, and most of us are happy to leave it to the professionals. Similarly, the acoustic world that opens to the sound spectrograph will not ignite everyone’s imagination; however, specialists in the singing voice might discover it as an exciting new pedagogical tool. This book will encourage them to embrace the factual information so easily available in spectrum analysis, and apply it to the teaching of vocal technique.

Literature:

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