On the Applicability of the Ancient Śruti Scheme to the Current Fixed-Tonic, Variable-Interval Mēla System

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Introduction:

The 2-vīṇā experiment\textsuperscript{1} of Bharata in his opus the Nāṭyaśāstra demonstrates the relative proportions of the seven svara-s in terms of śruti-s to be 4-3-2-4-3-2 for Sa-Ri-Ga-Ma-Pa-Dha-Ni in the ṣadja-grāma. The relative proportions in the madhyama-grāma were shown to be 4-3-2-4-3-4-2. The total in either grāma was 22 śruti-s. The theory of 22 śruti-s in the ancient Indian music was thus established. The 2-vīṇā experiment of Bharata formed the basis for the theory of 22 śruti-s.

Subsequent lakṣṇakāra-s have reiterated the theory of 22 śruti-s. But they have rearranged the svara-s among the 22 śruti-s. And because they started with 22 śruti-s and rearranged the svara-s cyclically, they always obtained 22 śruti-s.

Modern musicologists freely adapted the western concepts of intonation and acoustics to the Indian music theory. Despite such radical adaptations, they continued to base their theories on the concept of the 2-vīṇā experiment of Bharata, which formed as it were the basis for the entire literature pertaining to the theory of 22 śruti-s. In addition to the nomenclature for the 22 śruti-s, they worked out precise mathematical values for all the 22 śruti-s in terms of ratios with respect to the tonic Sa. They even based the current rāga system on these 22 śruti-s by placing them among the various rāga-s.

In the ancient mūrchanā system, different scales were obtained by shifting the tonic (ādhāra-svara) while the intervals of the seven svara-s were fixed. Gradually Indian music has undergone a paradigm shift in adopting the mēla system. The current mēla system is a fixed-tonic, variable-interval, twelve-svara system. Here, the different scales are generated simply by changing the interval, for example, from śuddha ṛṣabha to catuḥ śruti ṛṣabha, with a fixed ādhāra-ṣadja.

This paper provides a conceptual analysis on the applicability of the ancient theory of 22 śruti-s to the current mēla system with the 2-vīṇā experiment of Bharata as the basis. It gives a very brief sketch of the extant literature to present the necessary background, followed by the core analysis. The paper also briefly touches upon the factors germane to the pitching of the svara-s.
Past Studies:

Sir William Jones (in 1793) and Captain Augustus Willard (in 1834) were among the first modern scholars to write on the octave divisions in Indian music (Jairazbhoy 2008: 349). Subsequent scholars have given the theory of 22 śruti-s a mathematical treatment. Most of them freely adapted alien western concepts of tuning to the śruti system and liberally applied the principles of acoustics to Indian music. The attempt was to show the continuity of the ancient śruti system and to justify equivalence with Just intonation, conveniently ignoring the important fact that the consonance of the major third (Ga), which is essential for the Just intonation, was not considered as consonance in the Nāṭyaśāstra. In fact, Ga was considered as an anuvādi interval and therefore could not have been equal to 5/4 (Komaragiri 2005: 63). But both Indian and western scholars were taken in by such submissions. In quantifying 22 distinct pitches, these scholars incorrectly equated śruti-s with svara-s. Never did Bharata and the other ancient lakṣṇakāra-s say that śruti-s and svara-s were the same. The different steps in the 2-viṇā experiment between two svara-s were not usable as distinct svara-s. Śruti-s were not singable entities (Ramanathan N 1996: 4). The concept of śruti had no existence in performance (ibid: 1).

The classification of the jāti-s or later, of the rāga-s was never based on the śruti-s (Komaragiri 2005: 66). Levy had shown that the practice of rāga music for the past 500 years or so has been based on tempered 12-tone systems (ibid: 92). Prominent post-Saṅgītaratnākara lakṣṇakāra-s have described rāga-s in terms of 12 svara-s and not in terms of śruti-s. But by the time of Veṅkaṭamakhī, the idea of equating śruti-s with svara-s and locating them in rāga-s had taken root (ibid: 66). This had a damaging influence on subsequent theories.

The Gāyan Samāja was established in Poona in the 1850s to deliberate upon the quantification of the śruti system for the Hindustāni music. Later in the late 1920s, the Madras Music Academy pioneered a similar movement for the Karnāṭaka music (Ramanathan N 1993: 35–36). Scholars have written extensively on the validity and quantification of the 22 śruti-s and even placed them among the various rāga-s in vogue. The word ‘modern’ in this paper refers to the period from the late eighteenth century to the current times. Prominent scholars such as K. B. Deval, Ernest Clements, S. M. Tagore, Fox Strangways, Pingle, Abraham Panditthar, B. C. Deva, Alain Daniélou, C. S. Ayyar, H. V. Modak, G. H. Ranade, F. Framjee, S. Ramanathan, P. Sambamurthy and several others have derived precise values for the 22 śruti-s from the natural harmonic series. Table A-1 in Appendix A gives the typical values. Notable exceptions were N. Jairazbhoy, N. Ramanathan, H. Powers, Ratanjankar and a few others. These scholars have rejected the quantification of the 22 śruti-s and attributing such theories to Bharata.

Jairazbhoy, Stone, Mark Levy et al were among the first modern scholars to have approached this subject through empirical pitch analysis several decades ago. They showed that the theoretical values and the
actual measured pitch values were at variance and that there is significant variation in the performance. Thus they questioned the continued usage of the theory of 22 śruti-s in the current-day practice of music. Their focus was primarily the Hindustāni music. This paper however presents a systemic analysis based on the idea first proposed by Komaragiri (2005).

The 2-Vīṇā Experiment with Changing Intervals:

Bharata applied the 2-vīṇā experiment to the fixed-interval, variable-tonic grāma system, with the following conditions:

1. The seven svara-s were organized with three different interval sizes; Sa, Ma and Pa were the largest, Ri and Dha were the next in size and, Ga and Ni were the smallest intervals. These intervals may be designated as A, B and C respectively so that A > B > C. The mathematical sign “>” means ‘greater than.’ The fourth interval was the first reduction in the 2-vīṇā experiment with pañcama of the madhyama-grāma as the reference.
2. The svara Ma was at the center of the saptaka and the saptaka was symmetrical about Ma in the ṣaḍja-grāma.

In the ṣaḍja-grāma, the condition A > B > C was fixed. In this configuration, while performing the 2-vīṇā experiment, Ga & Ni merged with their lower svara-s in the second sāraṇā (step) resulting in two śruti-s each, totaling 4 śruti-s. Likewise, Ri & Dha merged with their lower svara-s in the third sāraṇā resulting in three śruti-s each, totaling 6 śruti-s. Finally, Sa, Ma and Pa merged with their lower svara-s in the fourth sāraṇā resulting in four śruti-s each, totaling 12 śruti-s. The total number of śruti-s from all the sāraṇā-s was 22. Thus the 2-vīṇā experiment with the above configuration resulted in 22 śruti-s (Also see the explanatory note # 1). This śruti scheme worked flawlessly within the grāma system.

But when the 2-vīṇā experiment is applied to the current fixed-tonic, variable-interval mēla system, the resulting number of śruti-s is not consistently 22 as the condition A > B > C is violated. This of course applies to the modern rāga system. The following hypothetical intervallic relationships and the resulting number of śruti-s the 2-vīṇā experiment will yield, illustrate this concept further:

A > B > C:  22 śruti-s
A > C > B:  22 śruti-s
B > A > C:  21 śruti-s
B > C > A:  20 śruti-s
C > A > B:  21 śruti-s
C > B > A:  20 śruti-s
This simple exercise of changing the intervallic relations opens up possibilities hitherto unexplored. And such exploration is indeed realistic as the intervals do change in the current mēla system.

The above concept may be illustrated further with actual values. For example, the following svara-s can form a saptaka. Refer to Table A-1 in Appendix A.

\[
\begin{align*}
Ri &= 32/27 \text{ or } 6/5 \text{ (ṣaṭ śruti ṛṣabha)} \\
Ga &= 5/4 \text{ or } 81/64 \\
Ma &= 4/3 \\
Pa &= 3/2 \\
Dha &= 16/9 \text{ or } 9/5 \text{ (ṣaṭ śruti dhaivata)} \\
Ni &= 15/8 \text{ or } 243/128
\end{align*}
\]

The following possibilities exist. Ga at 5/4 can merge with Ri at 32/27. This amounts to 92 cents. Ga at 5/4 can merge with Ri at 6/5. This amounts to 70 cents. Ga at 81/64 can merge with Ri at 32/27. This amounts to 112 cents. Ga at 81/64 can also merge with Ri at 6/5. This amounts to 92 cents. Therefore there are three possible reduction factors (intervals) for Ga to merge with Ri and they are 70 cents, 92 cents and 112 cents (arranged in the ascending order). Likewise, there are three reduction factors for Ni to merge with Dha.

Similarly, there are two possible reduction factors for Sa to merge with Ni and Ma to merge with Ga; they are 90 cents and 112 cents. Continuing, Pa has only one possible reduction factor to merge with Ma and that is 204 cents.

Finally, Ri and Dha have two possible reduction factors to merge with Sa and Pa respectively; they are 294 cents and 316 cents. See the explanatory note # 5 for the cent value calculations. All the cent values are rounded off.

Out of the several possible saptaka arrangements, consider the following arrangement by selecting the first intervals consistently (i.e. 32/27, 5/4, 4/3, 3/2, 16/9 & 15/8):

\[
\begin{align*}
Ga &\text{ & } Ni \\
Sa &\text{ & } Ma
\end{align*}
\]

Ga & Ni have 92 cents, Sa & Ma have 112 cents, Pa has 204 cents and Ri & Dha have 294 cents, totaling 1200 cents (octave). In this example, there are four different interval sizes.

With these four interval sizes, the 2-vīṇā experiment yields the following number of śruti-s:
Sāraṇā-1: 0 svara-s times 1 = 0 śruti-s
Sāraṇā-2: 2 svara-s times 2 = 4 śruti-s
Sāraṇā-3: 2 svara-s times 3 = 6 śruti-s
Sāraṇā-4: 1 svara-s times 4 = 4 śruti-s
Sāraṇā-5: 2 svara-s times 5 = 10 śruti-s

The total number of śruti-s is 24 and not 22. If the first sāraṇā is not counted, the total number of śruti-s would be only 17. This shows that the 2-vīṇā experiment with changing intervals does not always yield 22 śruti-s. For unequal intervals, as the interval size varies, the 2-vīṇā experiment yields different number of śruti-s for different intervallic configurations (svara arrangements), and for equal intervals or for intervals as mere positions, due to the cyclic process, the 2-vīṇā experiment always yields the same number of śruti-s with which the experiment started, proving nothing in the process (Komaragiri 2005: Tables 2.1 to 2.19, 24–44).

The revelation of this simple truth is made possible because the analysis started with svara-s, as was done in the 2-vīṇā experiment and not with śruti-s and therefore does not presuppose 22 śruti-s. The entire experiment was based on the matching of the known svara-s.

If one considers svara-s as so many śruti-s away from other svara-s within the cyclic frame of 22 śruti-s, this truth will never be revealed because reducing the number of śruti-s of one svara will automatically increase the number of śruti-s of the other svara, totaling 22 always (Komaragiri 2005: 49–51). Post-thirteenth century lakṣṇakāra-s have differed with each other in their placement of śuddha-vikṛta svara-s within the 22-śruti schematic, leading to absurd inconsistencies if one were to assign pitch values to these positions (ibid: 52). This was precisely the mistake committed by these lakṣṇakāra-s, misleading the modern scholars. It is clear therefore that the ancient concept of śruti could not be extended to the current mēla system.

In the variable-interval mēla system, the number of śruti-s will vary depending upon the relative interval sizes as shown above. This is inevitable because in the ancient grāma system, an N-śruti-ed interval (svara) did not contain N 1-śruti intervals.

Bharata illustrated the relative proportion of the svara-s with the help of the 2-vīṇā experiment. This was of course valid for the fixed-interval grāma system. The concept of śruti operated within the context of the grāma system. The number 22 was incidental to the 2-vīṇā experiment with the specific svara arrangement pertaining to the ṣaḍja-grāma, satisfying the condition A > B > C (Komaragiri 2005: 53–54).

The primary purpose of the measure (pramāṇa⁶) of śruti was to differentiate the two grāma-s; the difference being in the measure of the pañcama. Abhinavagupta said grāma vibhāgārthamēva...
śrutikīrtanam (Ramanathan N 1996: 1). That is, śruti was said to have been used primarily to differentiate the two grāma-s. In the mēla system, with the dissolution of the grāma-s, the operation and usage of the word śruti is no longer valid in its original intent.

Other Factors:

In real life, the actual pitch production and perception is quite complex although the whole process happens seamlessly. The intricacy and the non-linearity in hearing combined with the complex neuro-physiological and psycho-physical cognition processes necessitate a flexible intonation that stretches beyond simple ratios. The empirical pitch analysis (Komaragiri 2005) clearly shows characteristic pitch profiles (svara movements) with significant variability in the intonation.

During the ancient times, the human ear was certainly the sole judge for determining the intervals. In fact, Abhinavagupta states that augmenting or diminishing a sound should be perceivable by the ear (śrōtragrāhyasya) (Ramanathan N 1996: 2).

Conclusion:

In the past, several scholars such as Jairazbhoy et al have shown the fallacy in the quantification of the 22 śruti-s by conducting empirical pitch measurements in the Hindustāni idiom. This paper looks afresh for the first time at the issue and clearly shows that the ancient theory of 22 śruti-s illustrated by Bharata through the 2-vīṇā experiment in the Nāṭyaśāstra is systemically not applicable to the current fixed-tonic, variable-interval mēla system.

Explanatory Notes [for the superscripted numerals]:

1. The 2-vīṇā experiment of Bharata demonstrates the relative proportions between the 7 svara-s in terms of śruti-s, as 4-3-2-4-3-2 for Sa-Ri-Ga-Ma-Pa-Dha-Ni in the ṣaḍja-grāma. That is, Sa was 4 śruti-s from (lower) Ni, Ri was 3 śruti-s from Sa and so on. The proportion between the svara-s in madhyama-grāma was 4-3-2-4-3-4-2. The experiment was as follows. Two vīṇā-s were tuned identically to the svara-saptaka of the ṣaḍja-grāma. The first vīṇā was kept unchanged throughout the experiment. The strings of the second vīṇā were lowered in tension, successively in four steps as follows. Step 1: the string tension was lowered in such a way that the pañcama of ṣaḍja-grāma matched with the pañcama of the madhyama-grāma. Bharata called this interval as śruti. By lowering the pañcama by a śruti, the second vīṇā represented the madhyama-grāma [4-3-2-4-3-4-2]. And by similarly lowering the tension in the rest of the strings [svara-s], the second vīṇā was tuned once again to the ṣaḍja-grāma, but it was a śruti lower. Step 2: by lowering the tension in the strings again in the same way, Ga and Ni of the second vīṇā matched with Ri and Dha of the
first vīṇā, which was kept unchanged. Because of this svara-matching in the 2nd step, Ga and Ni were said to have 2 śruti-s each. Proceeding in the same manner, in Step 3: Ri and Dha of the second vīṇā matched up with Sa and Pa of the first vīṇā. Therefore, Ri and Dha were said to have 3 śruti-s each. And finally, in Step 4: Sa, Ma and Pa of the second vīṇā matched up with Ni, Ga and Ma of the first vīṇā, and thus Sa, Ma and Pa had 4 śruti-s each. Thus the total number of all the śruti-s was 22 (Abhinavagupta 1964: 20). It is pertinent to note here that the entire premise of the experiment was matching of the known svara-s and not śruti-s.


4. Prominent post-Sarhīṭaratnākara lakṣṇakāra-s such as Puṇḍarīka Viṭṭhala (Sadrāgacandrōdaya), Lōcana (Rāgatararīginī), Ahōbala (Sarīgītapāṛijātā), Śrīnīvāsa (Rāgattativibōdha), Ḥṛdaya Nārāyaṇa (Hṛdayaprałaṣā), Sōmanātha (Rāgavibōdha) and Veṅkaṭamakhī (Caturdaṇḍīprakāśikā) have described rāga-s in terms of 12 semitones and not in terms of śruti-s.

5. Cent is a unit of octave measurement. It divides each semitone into 100 equal parts and the octave into 1200 equal parts. This was introduced by Englishman, J. Ellis in the 19th century in the context of equal temperament. One cent, \( C = 2^{\frac{1}{1200}} \) and therefore \( N \) cents = \( 2^{\frac{N}{1200}} \). So to find the number of cents, \( N \), in any frequency ratio, \( R \), the formula to use is \( 3986 * \log R \), i.e., \( C = \frac{1200}{\log 2} \times \log R \), to the base 10. For example, cents of Pa = \( 3986 * \log (3/2) \approx 702 \) cents. Working with cents enables multiplication to be converted into addition. Table A-1 in Appendix A gives the cent values of various musical intervals. As a further illustration, the distance (interval) between say, 5/4 and 32/27 can be calculated in cents as \( 3986 * \log \left(\frac{5}{4} / \frac{32}{27}\right) \approx 92 \) cents.

6. Pramāṇa means a measure. In the 2-vīṇā experiment (see the note # 1 above) the first reduction was to match the pañcama of the ṣaḍja-grāma with the pañcama of the madhyama-grāma. Bharata called this pramāṇa (measure) as śruti (tat pramāṇam śrutih). This is unambiguous in the edition brought out in 1964 by the Oriental Institute, Baroda (page 20). Bharata did not coin the word pramāṇa śruti. But some scholars have interpreted this as pramāṇa śruti citing the kāśi edition of the Nāṭyaśāstra (page 318). Later scholars like Ācārya Bṛhaspati and Prof. Sambamurthy have extended this further by formulating the different types of pramāṇa śruti-s such as pramāṇa, nyūna and pūrṇa or, pramāṇa, upa-mahāti and mahāti etc. Such a mention of three varieties of 1 śruti intervals is certainly not there in the Nāṭyaśāstra.
Appendix A:

Table A-1: Commonly Accepted 22 Śruti Values:

These 22 śruti ratios are collated from various authors and are commonly accepted [sometimes, two more prati madhyama values at 729/512 & 40/27 are also given]. These values were also endorsed by the scholars at the Music Academy conference in 1929 (Komaragiri 2005: Appendix C, Page 1 of 5). About 250 different values were worked out for the 22 śruti-s by the various authors (Sathyanarayana 1970: 70).

<table>
<thead>
<tr>
<th>Kaṃṭhaka Svara</th>
<th>Modern Values</th>
<th>Cents [Rounded Off]</th>
</tr>
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<tr>
<td>śuddha ṛṣabha-1</td>
<td>256/243</td>
<td>90</td>
</tr>
<tr>
<td>śuddha ṛṣabha-2</td>
<td>16/15</td>
<td>112</td>
</tr>
<tr>
<td>catuḥ śruti ṛṣabha-1</td>
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<td>182</td>
</tr>
<tr>
<td>catuḥ śruti ṛṣabha-2</td>
<td>9/8</td>
<td>204</td>
</tr>
<tr>
<td>sādhāraṇa gāndhāra-1</td>
<td>32/27</td>
<td>294</td>
</tr>
<tr>
<td>sādhāraṇa gāndhāra-2</td>
<td>6/5</td>
<td>316</td>
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<td>antara gāndhāra-1</td>
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<tr>
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</tr>
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</tr>
<tr>
<td>śuddha madhyama-2</td>
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<td>520</td>
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<td>prati madhyama-1</td>
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<td>590</td>
</tr>
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<td>prati madhyama-2</td>
<td>64/45</td>
<td>610</td>
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<td>Paṇicama</td>
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<td>128/81</td>
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<td>1110</td>
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<td>1200</td>
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References:


