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[1] of Bharata in his opus the *Nāṭyaśāstra* demonstrates the relative proportions of the seven *svara*-s in terms of *śruti*-s to be 4-3-2-4-4-3-2 for *Sa-Ri-Ga-Ma-Pa-Dha-Ni* in the *ṣaḍja-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-ṣaḍja*.

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[2]) and Captain Augustus Willard (in 1834[3]) 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 *anuvādī* 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-*vīṇā* 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[4] 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 *Karṇāṭaka* 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 Pandithar, 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.

Ri = 32/27 or 6/5 (*ṣaṭ śruti ṛṣabha*)
Ga = 5/4 or 81/64
Ma = 4/3
Pa = 3/2
Dha = 16/9 or 9/5 (*ṣaṭ śruti dhaivata*)
Ni = 15/8 or 243/128

The following possibilities exist. *Ga* at 5/4 can merge with *Ri* at 32/27. This amounts to 92 cents[5]. *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):

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 (*pramāṇa*[6]) 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 4-3-2-4-4-3-2 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.

2. **Sir William Jones** published "On the Musical Modes of the Hindoos" in 1793.
3. **Captain Augustus Willard** published "A Treatise on the Music of Hindoostan" in 1834.
4. **Prominent post-*Saṅgītaratnākara lakṣṇakāra*-s** such as Puṇḍarīka Viṭṭhala (*Sadrāgacandrōdaya*), Lōcana (*Rāgataraṅgiṇi*), Ahōbala (*Saṅgītapārijāta*), Śrīnivāsa (*Rāgatattvavibōdha*), Hṛdaya Nārāyaṇa (*Hṛdayaprakāśa*), 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 = $2^{1/1200} = \sqrt[1200]{2}$ and therefore N cents = $2^{N/1200}$. So to find the number of cents, N, in any frequency ratio, R, the formula to use is 3986 * Log R i.e., C = (1200/Log 2) * Log R, to the base 10. For example, cents of *Pa* = 3986 * Log (3/2) ≈ 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 [(5/4) / (32/27)] ≈ 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 pramāṇaṃ śrutiḥ*). 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 *kāśī* 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-mahatī* and *mahatī* 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).

Karṇāṭaka Svara	Modern Values	Cents [Rounded Off]
śuddha ṛṣabha-1	256/243	90
śuddha ṛṣabha-2	16/15	112
catuḥ śruti ṛṣabha-1	10/9	182
catuḥ śruti ṛṣabha-2	9/8	204
sādhāraṇa gāndhāra-1	32/27	294
sādhāraṇa gāndhāra-2	6/5	316
antara gāndhāra-1	5/4	386
antara gāndhāra-2	81/64	408
śuddha madhyama-1	4/3	498
śuddha madhyama-2	27/20	520
prati madhyama-1	45/32	590
prati madhyama-2	64/45	610
Pañcama	3/2	702
śuddha dhaivata-1	128/81	792
śuddha dhaivata-2	8/5	814
catuḥ śruti dhaivata-1	5/3	884
catuḥ śruti dhaivata-2	27/16	906
Kaiśika niṣāda-1	16/9	996
kaiśika niṣāda-2	9/5	1018
kākalī niṣāda-1	15/8	1088
kākalī niṣāda-2	243/128	1110
tāra ṣaḍja	2/1	1200

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