

# STUDIES ON INDIAN MUSICAL SCALES

## *Part I. Computer Analysis on Venkatamakhi's Melakarta Scheme*

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### Introduction

Although both the North Indian and South Indian (Karnatak) classical music have had a common origin in the distant past<sup>1</sup> it is only in the last couple of centuries that a certain order has been brought into Karnatak Music in the matter of classification scheme mainly through the work of Venkatamakhi.<sup>2</sup> Thus the rationale of requiring that a *melakarta* should have all seven *svaras* and have *kramasampurna arohana* and *avarohana* has provided a firm basis for not only a good scheme of classification but also for a logical explanation of the *janaka-janya* system. No such comparable scheme appears to have gained acceptance for the current north Indian scales though some attempts at similar classification are available.<sup>3</sup>

Although the Venkatamakhi scheme is widely accepted in the South by no means can it be claimed to be perfect. Its chief virtue has been that it brought, for the first time, some order into what was otherwise chaos since none of the earlier schemes could be described to claim anything even remotely what has been achieved by the Venkatamakhi Scheme. On the other hand, one of the commonest criticisms that is directed against this scheme has been the *vivadi melas*, and also the inability of the scheme to cover in a natural way, several of the *ragas* which incorporate the reduced *panchama* such as, *Hamir-kalyan*, *Saranga*, etc., which have been known to be beautiful and well established *ragas*.

Accordingly there have been attempts to modify and or improve upon the Venkatamakhi Scheme. The scheme of 108 *melas*<sup>4</sup> involving *vikritha panchama* and another modified version<sup>5</sup> involving 84 *melas* partly overcome this difficulty. More comprehensive schemes involve relaxing the rule of a

*mela* to have the same set of *krama-sampurna svaras* in both *arohana* and *avarohana*. This leads to the possible 144 as well as 5184 *melas* discussed by Sambamurthy.<sup>4\*</sup>

Recently a systematic computer analysis of all the above aspects of scales has been undertaken in this laboratory. The main advantage of the computer is that it is capable of calculating thousand to million times faster than human beings and also the results can be readily quantified. In this first report we present the results of the analysis on the 72 *melakarta* scales of Venkatamakhi. Results of analysis on other aspects will be reported in later parts.

### Outline of the Method

Before we proceed to outline the results the following few remarks may be pertinent.<sup>6</sup> The cent values for *srutis* are used throughout. Being logarithmic, they have additive properties and are hence easy to handle. Again we use the term *sruti* to represent the continuum of tonal values. The units, of course can be different such as for example the frequency values or frequency ratios, the latter being essentially the same as the former except the starting note is normalised to have unit value. We use the term “*sruti interval*” specifically to denote the interval between two points in the *sruti* continuum. *Svaras* are terms associated with these points in the *sruti* continuum. It is thus clear that the conventional octave with *saptasvaras* actually has eight *sruti* points (including both the *shadjas*) while the *sruti* intervals are seven in number.

In the Venkatamakhi scheme sixteen of the conventional 22 *srutis* are used namely *Suddha Rishabha*, *Chatussruti Rishabha*, *Shatsruti Rishabha*, *Suddha Gandhara*, *Sadharana Gandhara*, *Antara Gandhara*, *Suddha Madyama*, *Pratimadhyama Panchama*, *Suddha Dhaivatha*, *Chatussruti Dhaivata*, *Shatsruti Dhaivata*, *Suddha Nishada*, *Kasiki Nishada* and *Kakali Nishada*. Consequently also the values of the *Suddha Gandhara*, *Suddha Rishabha* are stated to be equal to the *Chatussruti Rishabha* and *Chatussruti Dhaivata* respectively and the *Shatsruti Rishabha* and *Shatsruti Dhaivata* equal to *Sadharana Gandhara* and *Kasiki Nishadha* respectively. The values used for the twelve *srutis* are thus 0, 112, 204, 316, 386, 498, 588, 702, 814, 906, 1018, 1088 and 1200.

There seems to be, however, different opinions on the values of the notes of the *Suddha svaras*. The current convention in the south would appear to be based on taking the lowest of a particular variety as the *suddha svara* although a closer approximation to *lakshya* would appear to reduce these by one *sruti*<sup>7</sup> (excepting *ma*). In particular C.S. Iyer claims that the true value of the *suddha*

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\* A detailed study of possible number of *melas* was made by B.C. Deva and his *Psycho-Acoustics of Music and Speech* 1969, Chapter—Raga Rupa.

*ga* and *suddha ni* as handed down for renowned schools are nearer the *tristruti* values of 182 cents and 884 respectively. Reduction of values of the other *suddha* notes by one *sruti* does not appear to be fully warranted. Accordingly the calculation described below have been carried out with two sets of values one as already stated (hereafter referred to as Set I) and the other in which *suddha ga* and *suddha ni* are reduced from 204, 906 to 182 and 884 respectively (termed hereafter as Set II).

Table 1 summarises the data on the 72 *melas*. It gives the *sruti* values, *sruti* intervals between successive notes as well as a few other quantitative estimates to be discussed below. Table 2 gives the result of operation of modal shift and the same results are given in Table 3 in a slightly different form, which brings out the symmetry of the relations more elegantly. We shall now discuss these results in greater detail.

## Results and Discussion

### *Sruti Values and Sruti Intervals*

Besides the actual values of the *srutis* and their successive intervals we also give in Table 1 the value of the parameter  $\Delta$  defined as :

$$\Delta = (1 \Delta s_e 1) = (1 s_e - s_e 1)$$

where  $s_e$  stands for the *sruti* value in cents and (x) and x stand for mean values. It may be noted that since seven intervals are present in the span of an octave (=1200 cents) the mean value  $s_e = 171.4$  has been taken.<sup>8</sup>  $\Delta$  thus measures for each scale the mean deviation of the intervals from 171.4. The parameter  $\Delta$  may be seen to be a convenient measure of deviation from *samvadtva* or absence of it in a scale although the parameter itself is not based on *samvadtva* relation. Thus for instance the well known '*samvadi*' *melas* have systematically lower values of about 33 and 50 compared with *vivadi melas* which have relatively higher values about 60 and above. Table 4 classifies the 72 scales into four groups depending on the  $\Delta$  values. It is noticed that the *samvadi* *melas* fall mostly into groups I and II with  $\Delta$  values of about 30 and 51. Only a few of them fall in group III with  $\Delta$  values around 61. On the other hand the *vivadi melas* fall mostly into groups III and IV and with values around 61 and 86. Note particularly the very high values for eight of the scales containing the two notes responsible for *vivaditva* falling in group IV. Most of the scales with a single note responsible for *vivaditva* fall into group III.

In the light of the above discussion it is noteworthy that there are quite a few scales (group II) which perhaps are capable of being developed more fully and need attention like *Bhavapriya*, *Suryakantam*, *Suvarnangi*, *Namana-rayani*, *Ramapriya*, *Gamanasrama*, etc.

### *Modal Shift and Murchana Tables*

The modal shift operation is easy to perform especially with a computer.

It consists in starting with a particular scale say *Kanakangi* and shifting the origin (*shadja*) to each one of the subsequent notes, say *ri* to start with (i.e., equivalent to subtraction in the logarithmic scale of the *sruti* values of *ri* from each of the *sruti* values in the scale). This yields a new set which is compared with the standard set of 72 *melas* with known values. If the set coincides with any one of them it is accepted as giving rise to a *mela* through *murchana*.

In producing Table 2 by the method a correction of *sruti* value to a maximum of  $\pm 44$  cents was allowed for. Only coincidence which fulfil this condition are produced in Table 2. A given entry in the table corresponds to a scale shown on the left and a *svara* given on the top row. The number entered corresponds to the scale produced as a result of shifting the tonic of the scale shown on the left column to the particular *svara* against which the entry has been made. The 122 entries come under three broad classification. Those which need correction of only  $\pm 2$  cents, those which need correction of  $\pm 24$  cents those which need correction of  $\pm 44$  cents. The first group contains 14 in number and are marked by bold face. The second contain 78 and the last (in italics) contain 30. Calculation with Set II yielded practically the same results, viz., all the 122 *murchanas* relation as per Set II. However there were a few minor changes. Thus the first group of 14 relations with error  $\pm 2$  cents remained unaltered. However, the second group which had original list of 78 got reduced to 68 and these ten had increased mean error in the range of  $\pm 44$  cents and hence the last group now had 40 entries.

In Figure 1 the same results as given in Table 2 are given but are in a different form. This relates any two scales in the list of 72 by a square array of  $72 \times 72$ . The *svara* responsible for the *murchana* relation between the two is marked with appropriate symbol like *SRGMPDN*. The starting scale is given in the x-axis and the resulting scale in the y-axis. The following main features emerge from the study of these tables. Some of these are already discussed by others (see Sambamurthy<sup>4</sup> pp. 84-94).

(1) There are 56 *murchanakaraka melas* in all and 16 are sterile (*amurchanakaraka*). The 56 scales yield 122 positive relations. Of the 56 twenty yield only one each, 18 of them yield two each, twelve of them yield 3 each. There are six scales each of which generates five scales. These are the well known *melas* 8, 20, 22, 28, 29 and 65.

(2) Figure 1 brings out the symmetry properties nicely. Thus the entire square array has a 'mirror' symmetry about the diagonal joining of the points 1,1 & 72,72 provided we interpret<sup>9</sup> broadly the pairs such as R,N; G,D, & M,P as related by mirror equivalents. Thus every R, G, M in one half appears as N, D, P at the mirror equivalent site in the other half. The entire square array may be conveniently divided into four quadrants of the type *Purva-Purva* (*pp*), *Purva-Uttara* (*pu*) *Uttara-Purva* (*up*) and *Uttara-Uttara* (*uu*) quadrants. The 122 entries are distributed with maximum in *pp*-quadrant

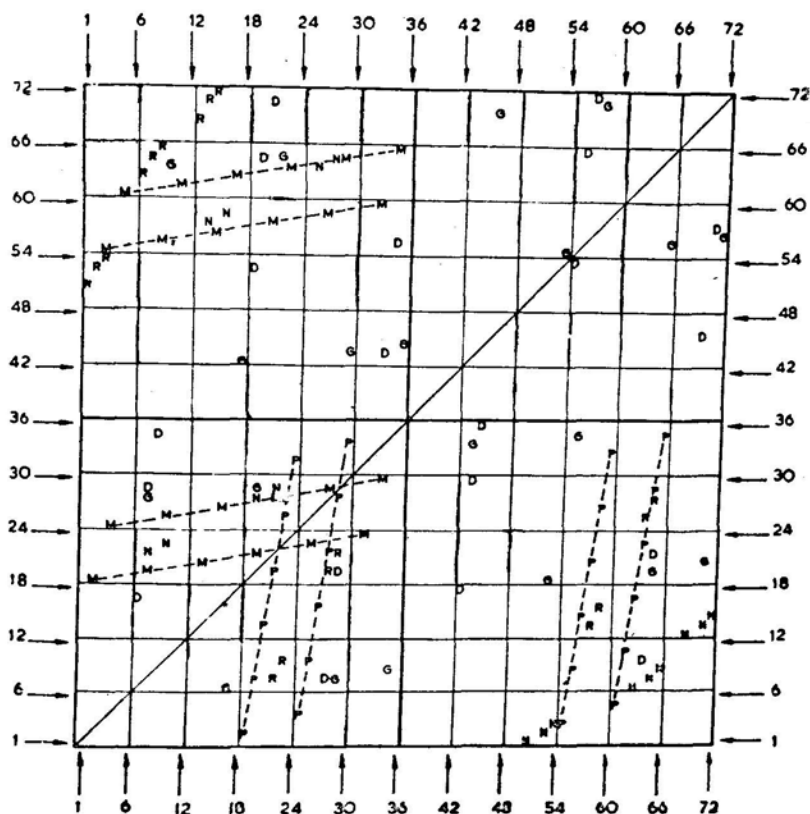


Fig. 1.

(42) up, pu quadrants coming next (35 each) and least number in uu quadrant (10).

(3) Because of the symmetry already pointed out, the number of M *murchanas* equals the number of P *murchanas* and similar results hold for the pairs RN and GD. The *samvadi* (M-P) *murchanas* are largest in number (48) with D-G coming next (40) and R-N least (34). In the *pp* quadrant *murchana* involve all *svaras* (R, G, M, P, D, N), and in (*pu*) (*up*) quadrants only four *svaras* are effective, namely R, G, M, D, N and R, G, P, D, N respectively, i.e., *svaras* P and M are sterile in *pu* and *up* quadrants. In the *uu* quadrant only two *svaras* are effective namely G D and the other three are sterile.

(4) Apart from these the symmetry relations within a quadrant may also be traced. For instance all the M, P *murchanas* fall systematically in a straight line (shown by broken line in Table 2). This feature is most prominent for the M, P *murchanas* and arises because the M involved are all *suddha madhyamas* and also the *panchama* is a fixed *svara*. Note that there are no *pratimadhyama murchanas* at all. The relations are only apparent for other categories such as

Table 1 Sruthi values and  $\Delta$  values in cyclic cents for 72-Melas of Venkatamakhi

Sl. No.	NAME	S	R	G	M	P	D	N	$\Delta$										
1.	KANAKANGI	0	112	204	498	702	814	906	80	37.	SALAGAM	0	112	204	588	702	814	906	83
2.	RATNANGI	0	112	204	498	702	814	1018	57	38.	JAL ARNAVAM	0	112	204	588	702	814	1018	73
3.	GANAMURTI	0	112	204	498	702	814	1088	54	39.	JALAVARALI	0	112	204	588	702	814	1088	90
4.	VANASPATI	0	112	204	498	702	906	1018	57	40.	NAVANEETAM	0	112	204	588	702	906	1018	73
5.	MANAVATI	0	112	204	498	702	906	1088	57	41.	PAVANI	0	112	204	588	702	906	1088	73
6.	TANARUPI	0	112	204	498	702	1018	1088	86	42.	RAGHUPRIYA	0	112	204	588	702	1018	1088	102
7.	SENAVATI	0	112	316	498	702	814	906	57	43.	GAVAMBHODHI	0	112	316	588	702	814	906	73
8.	HANUMATODI	0	112	316	498	702	814	1018	34	44.	BHAVAPRIYA	0	112	316	588	702	814	1018	50
9.	DHENUKA	0	112	316	498	702	814	1088	51	45.	SUBHAPANTUVALI	0	112	316	588	702	814	1088	67
10.	NATAKAPRIYA	0	112	316	498	702	906	1018	34	46.	SHADVIDHAMARGINI	0	112	316	588	702	906	1018	50
11.	KOKILAPRIYA	0	112	316	498	702	906	1088	34	47.	SUVARNANGI	0	112	316	588	702	906	1088	50
12.	RUPAVATI	0	112	316	498	702	1018	1088	63	48.	DIVYAMANI	0	112	316	588	702	1018	1088	79
13.	GAYAKAPRIYA	0	112	386	498	702	814	906	74	49.	DHAVALAMBARI	0	112	386	588	702	814	906	73
14.	VAKULABHARANAM	0	112	386	498	702	814	1018	51	50.	NAMANARAYANI	0	112	386	588	702	814	1018	50
15.	MAYAMALAVAGLAULA	0	112	386	498	702	814	1088	68	51.	KAMAVARDHANI	0	112	386	588	702	814	1088	67
16.	CHAKRAVAKAM	0	112	386	498	702	906	1018	51	52.	RAMAPRIYA	0	112	386	588	702	906	1018	50
17.	SURYAKANTAM	0	112	386	498	702	906	1088	51	53.	GAMANASRAMA	0	112	386	588	702	906	1088	50
18.	HATAKAMBARI	0	112	386	498	702	1018	1088	80	54.	VISVAMBARI	0	112	386	588	702	1018	1088	79
19.	JHANKARADHVANI	0	204	316	498	702	814	906	57	55.	SYAMALANGI	0	204	316	588	702	814	906	73
20.	NATHABHIRAVI	0	204	316	498	702	814	1018	34	56.	SHANMUGAPRIYA	0	204	316	588	702	814	1018	50
21.	KIRAVANI	0	204	316	498	702	814	1088	51	57.	SIMHENDRAMADYAMAM	0	204	316	588	702	814	1088	67
22.	KHARAHARAPRIYA	0	204	316	498	702	906	1018	34	58.	HEMAVATI	0	204	316	588	702	906	1018	50
23.	GAURIMANOARI	0	204	316	498	702	906	1088	34	59.	DHARMAVATI	0	204	316	588	702	906	1088	70
24.	VARUNAPRIYA	0	204	316	498	702	1018	1088	63	60.	NITIMATI	0	204	316	588	702	1018	1088	70
25.	MARARANJANI	0	204	386	498	702	814	906	57	61.	KANTAMANI	0	204	386	588	702	814	906	56
26.	CHARUKESI	0	204	386	498	702	814	1018	34	62.	RISHABHAPRIYA	0	204	386	588	702	814	1018	33
27.	SARASANGI	0	204	386	498	702	814	1088	51	63.	LATHANGI	0	204	386	588	702	814	1088	50
28.	HARIKAMBHOJI	0	204	386	498	702	906	1018	34	64.	VACHASPATI	0	204	386	588	702	906	1018	33
29.	SANKARABHARANA	0	204	386	498	702	906	1088	34	65.	MECHAKALYANI	0	204	386	588	702	906	1088	33
30.	NAGANANDINI	0	204	386	498	702	1018	1088	63	66.	CHITRAMBARI	0	204	386	588	702	1018	1088	62
31.	YAGAPRIYA	0	316	386	498	702	814	906	86	67.	SUCHARITRA	0	316	386	588	702	814	906	79
32.	RAGAVARDINI	0	316	386	498	702	814	1018	63	68.	JYOTISVARUPINI	0	316	386	588	702	814	1018	62
33.	GANGEYABHUSHANI	0	316	386	498	702	814	1088	80	69.	DHATUVARDHANI	0	316	386	588	702	814	1088	79
34.	VAGADHISVARI	0	316	386	498	702	906	1018	63	70.	NASIKABHUSHANI	0	316	386	588	702	906	1018	62
35.	SULINI	0	316	386	498	702	906	1088	63	71.	KOSALAM	0	316	386	588	702	906	1088	62
	CHITRA	0	316	386	498	702	1018	1088	92	72.	RASIKAPRIYA	0	316	386	588	702	1018	1088	91

Table 2 Murchanakaraka scales as per Venkatamakhi scheme

Sl. No.	NAME	R	G	M	P	D	N	Sl. No.	NAME	R	G	M	P	D	N
1.	KANAKANGI	51*	—	—	—	—	—	37.	SALAGAM	—	—	—	—	—	—
2.	RATNANGI	53*	—	19	—	—	—	38.	JALARNAVAM	—	—	—	—	—	—
3.	GANAMURTI	54	—	55	—	—	—	39.	JALAVARALI	—	—	—	—	—	—
4.	VANASPATI	—	—	25	—	—	—	40.	NAVANEETAM	—	—	—	—	—	—
5.	MANAVATI	—	—	61	—	—	—	41.	PAVANI	—	—	—	—	—	—
6.	TANARUPI	—	—	—	—	—	—	42.	RAGHUPRIYA	—	—	—	—	—	—
7.	SENAVATHI	63*	—	—	—	17*	—	43.	GAVAMBHODHI	—	—	—	—	—	—
8.	HANUMATODI	65	23	20	—	29	22	44.	BHAVAPRIYA	—	34	—	—	18	—
9.	DENUKA	66	—	56	—	35	—	45.	SUBHAPANTUVARALI	—	—	—	—	30	—
10.	NATAKAPRIYA	—	64	26	—	—	23	46.	SHADVIDHAMARGINI	—	70	—	—	36	—
11.	KOKILAPRIYA	—	—	62	—	—	—	47.	SUARNANGI	—	—	—	—	—	—
12.	RUPAVATHI	—	—	—	—	—	—	48.	DIVYAMANI	—	—	—	—	—	—
13.	GAYAKAPRIYA	69	—	—	—	—	—	49.	DHAVALAMBARI	—	—	—	—	—	—
14.	VAKULABHARANAM	71	—	21	—	—	58	50.	NAMANARAYANI	—	—	—	—	—	—
15.	MAYAMALAVAGAULA	72	—	57	—	—	—	51.	KAMAVARDHANI	—	—	—	—	—	—
16.	CHAKRAVAKAM	—	—	27	—	—	59	52.	RAMAPRIYA	—	—	—	—	—	—
17.	SURYAKANTAM	—	7*	63	—	—	—	53.	GAMANASRAMA	—	—	—	—	—	—
18.	HATAKAMBARI	—	43	—	—	—	—	54.	VISVAMBARI	—	55	—	—	—	—
19.	JHANKARADHAVNI	—	—	—	2	53*	—	55.	SYAMALANGI	—	—	—	3	54	—
20.	NATHABHIRAVI	—	29	22	8	65	28	56.	SHANMUGAPRIYA	—	35	—	9	66	—
21.	KIRAVANI	—	—	58	14	71	—	57.	SIMHENDRAMADYAMAM	—	—	—	15	72	—
22.	KHARAHARAPRIYA	8	65	28	20	—	29	58.	HEMAVATHI	14	71	—	21	—	—
23.	GAURIMANOCHARI	10	—	64	26	—	—	59.	DHARMAVATHI	16	—	—	27	—	—
24.	VARUNAPRIYA	—	—	—	32	—	—	60.	NITIMATI	—	—	—	33	—	—
25.	MARARANJANI	—	—	—	4	—	—	61.	KANTAMANI	—	—	—	5	—	—
26.	CHARUKESI	—	—	23	10	—	64	62.	RISHABHAPRIYA	—	—	—	11	—	—
27.	SARASANGI	—	—	59	16	—	—	63.	LATANGI	—	—	—	17	—	—
28.	HARIKAMBHOJI	20	—	29	22	8	65	64.	VACHASPATI	26	—	—	23	10	—
29.	SANKARABHARANAM	22	8	65	28	20	—	65.	MECHAKALYANI	28	20	—	29	22	—
30.	NAGANANDINI	—	44	—	34	—	—	66.	CHITRAMBARI	—	56	—	35	—	—
31.	YAGAPRIYA	—	—	—	—	—	—	67.	SUCHARITRA	—	—	—	—	—	—
32.	RAGAVARDINI	—	—	24	—	—	—	68.	JYOTISVARUPINI	—	—	—	—	—	—
33.	GANGEYABHUSHANI	—	—	60	—	—	—	69.	DHATUVARDHANI	—	—	—	—	—	—
34.	VAGADHISVARI	—	—	30	—	44	—	70.	NASIKABHUSHANI	—	—	—	—	—	13
35.	SULINI	—	9	66	—	56	—	71.	KOSALAM	—	21	—	—	46	—
36.	CHALANTA	—	45	—	—	—	—	72.	RASIKAPRIYA	—	57	—	—	58	14
														15	

Table: 3 The scales grouped on  $\Delta$  values

## GROUP I (34)

8, 34	62, 33
10, 34	64, 33
11, 34	65, 33
20, 34	
22, 34	
23, 34	
26, 34	
28, 34	
29, 34	

## GROUP III (61)

2	57	19	57
3	54	24	63
4	57	25	57
5	57	30	63
7	57	32	63
12	63	34	63
13	74	35	63
15	68		
38	73	55	73
40	73	57	67
41	73	61	56
43	73	66	62
45	67	68	62
49	73	70	62
51	67	71	62

## GROUP II (50)

9, 51	47, 50
14, 51	50, 50
16, 51	52, 50
17, 51	53, 50
21, 51	56, 50
27, 51	58, 50
44, 50	59, 50
46, 50	63, 50

## GROUP IV (86)

1	80	42	102
6	86	48	79
18	80	54	79
31	86	60	79
33	80	67	79
36	92	69	79
37	96	72	91
39	90		

R, N & G, D and this is because the *murchana* productive *gandharas* involved in the *murchana* table fall into two categories namely *sadharana gandhara* and *antara gandhara*. These two fall on separate lines (e.g., see *up* quadrant, the lines are not shown). The remarks apply to other varieties of *svaras* as well such as R, D and N.

(5) If the *pu* as well as *up* quadrants are marked with their own minor diagonals parallel to the major diagonal already drawn it may be noticed that the only point through which this minor *diagonal line* passes has the coordinates 65, 29 in *up* and 29, 65 in *pu* quadrants. This indicates that the M *murchana* of *Sankarabharana* produces its *pratimadhyama mela* 65 and inversely the P *murchana* of *Kalyani* produces the corresponding *suddhamadhyama mela* equivalent *Sankarabharana*. We have shown this more for illustrating the types of information that can be extracted. Similar diagonals of sub-quadrants can be drawn for more detailed analysis of relation between various *chakras*, etc., and will not be given here.

(6) Coming to the main diagonal itself it may be noted that it does not pass through any point with positive entry, i.e., there is no entry in the figure with x and y values equal (same scale in the x and y axes). If it had, it would have meant that the particular scale involved produces itself by *murchana*. This we know cannot happen with the present scheme of *melakarta* scale (excepting of course *s-murchana* which is a trivial case). The closest to expect is a pair of points occurring close to the diagonal. These are (28, 29, M *murchana*) and (29, 28, P *murchana*). There is also another pair 54, 55 G *murchana* and 55, 54 D *murchana*. Thus the M *murchana* of *Harikambodhi* produces 29 *Sankarabharanam* and symmetrically P *murchana* of *Sankarabharana* produces *Harikambodhi*. Similar but lesser relations could be deduced and are not detailed here.

(7) It may be mentioned that the types of linear relation within quadrants and their parallelism between quadrants enable further large number of deductions to be made. Some of these are: If the serial number of P *murchana* of a *purva mela* is a the serial number of the P *murchana* of its corresponding *uttara mela* is  $a + 1$ ; symmetrically also if the M *murchana* of a *purva mela* a yields b  $(a + 1)$ 's *uttara mela* M *murchana* yields  $b + 36$ , etc.

#### NOTES

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#### REFERENCES

1. Bharata's *Natya Sastra* assigned by some scholars to the period around 4th Century B.C. (while others ascribe to 2nd Century A.D.) is the earliest known work to discuss

- experiments on vina and srutis. Among the later works mention may be made of *Brhaddeśi* of Matanga (5th Century A.D. or 9th Century A.D.), *Sangeeta Saramritha* of Parsvadeva (11th Century A.D.), *Sangeeta Ratnakara* of Sarangadeva (1210-1247 A.D.), *Sangeeta Makaranda* of Narada (12th century A.D.), *Sangeeta Sara* of Vidya-ranya (1320-1380 A.D.), *Ragatarangini* of Lochana Kavi (1320-1380 A.D.), Ahobala's *Sangita Parijata* (1660 A.D.), *Svara Mela Kalanidhi* of Ramamatya (1550 A.D.), *Raga Vibodha* of Somanatha (1609 A.D.), *Sadraga Chandrodaya* of Pundarika Vittala (17th Century A.D.).
2. *Chaturdandi prakasika* (1660 A.D.) of Venkatamakhi had the germinal idea of classifying the musical scales under 72 melakarta scheme, although it developed into its full form in the hands of Govindacharya in *Sangraha Chudamani* (18th Century A.D.), with the current *Kanakangi-Ratnangi* nomenclature.
  3. A scheme somewhat similar to Venkatamakhi's has been developed by V.N. Bhatkhande in his *Shrimal-lakshya Sangitam* (1910) where the Hindustani ragas are classified under 10 thats.
  4. *South Indian Music*, Book V by P. Sambamurthy pp. 101-111. Indian Music Publishing House (1963). The actual number of *Suddha-Misra* varieties may be considerably less since some of the combinations may be impossible on technical grounds. See article by T. Satyagopal in the *Journal of Music Academy*, 45 (1974) 211.
  5. *Sangitachandrika* by Attoor Krishna Pisharoti Publishers Geeta Ltd., Trichur quoted by S. Venkatasubramonia Iyer, *Sangeet Natak* (1972) No. 23, 5.
  6. As pointed out by B.C. Deva (*Psychoacoustics of music and speech*, The Music Academy (1969), p. 124) the term *sruti* has been used in the Indian music literature with slightly different meanings depending on the context and also it lacks specially a clearcut definition. *Ekasruti* may thus mean 22, 70, 90 cents. Hence these clarifications on the notations used here.
  7. e.g. see p. 28 of "Venkatamakhi and the Raga System". by N.S. Ramachandran, *Sangeet Natak* (1973) issue 28 and also C.S. Iyer's *The Grammar of Karnatak Music*, p. 34 as well as *History of South Indian Music*, Ranga Ramanuja Iyyengar p. 184.
  8. While this mean value is taken over the entire range of octave it may be pointed out one may also think of another alternative namely the local mean of each svara over their zone. Thus the local mean values turn out to be (Ra) = 211, (Ga) = 302, (Ma) = 533, (Da) = 920, (Ni) = 997 for Set I. The only change for Set II is (Ga) = 295 and (Da) = 913. These are reasonably close to the values based on overall mean which yield values (Ra) = 171.4, (Ga) = 343, (Ma) = 514, (Da) = 857 and (Ni) = 1028.
  9. It is convenient to designate the seven svaras by general symbols S R G M P D N where the sub-classification such as Ra, Ri, Ru etc., are not required for discussion. The use of Ri, Ga, Ma etc., for such general connotation is likely to mislead since they are normally used to denote sub-varieties.