Appendix:

Some Scientific aspects of Indian Music;

Music is as much a science as it is an art. But, by and large the scientists, the musicologists and the musicians are still unacquainted with their common roots. In March 1970, Sangeet Natak Academy, New Delhi convened a seminar on Science and Music. Scientists, Historians and Musicians sat at a common table and exchanged ideas and everyone learnt that he was not isolated but had many things in common with everyone else. As a result of this Seminar, many eyes have been opened and many slumbering minds awakened.

Many problems were raised and discussed. It was felt that the attempts at deep studies of smaller areas of musicology could follow this generalized preliminary meetings of minds. The Academy therefore arranged a small symposium of Musical Scales and also a workshop on Psychological responses to Raagas in February 1973.

The symposium concentrated on the problems of musical scales. Shri K K Sharma of Calcutta has been studying the Mathematical and Philosophical implications of Moorchanas. **The subject matter of the present work has been taken from that study.**

To appreciate the reverse/inverse relationship in various Raagas let us first try to understand the science and art of Indian Music, Moorchana Chakras, Swara Gramas, etc. a Musicometrical view of Indian music as understood by Sri K.K.Sharma. (Musical scales, report of Symposium, Feb 1973, Sangeet Natak Academy, New Delhi).

A Musicometrical view of Indian music with particular reference to Moorchana Chakras:

That music is a referential art and that musical compositions create and reflect psychic moods and emotions through some mysterious process of mutative symbolizations has been an age long and universal belief. But the truth of this belief could not be subjected to any systematic verification. If some day the musical experience come to be technological verifiable, the study of how and what of music – a chain of physical stimuli generated by sound waves evoking a chain of psychic responses in terms of moods and emotions – is bound to assume a highly scientific importance for a systematic probe into the manifold possibilities of what music can contribute to mental health of man in his musical moments.

Musicometry: That branch of musicology which seeks to study musicality as a function of numbers and to interpret the temporal phenomena of music in terms of spatial concepts of numerically constituted tonal locations and movements in musical space, some of the basic tenets of the academic side of Indian Classical Music which probably used to be formerly known as Marga Sangeet are being studied.

Moorchana Chakra s

A melodically valid structure of 7 Swaras constitutes what is called Musicometrically a Moorchana chakra. The function of such a chakra is to generate 7 different melodic modes by shifting the tonic note i.e Shadja from one Swara to another. Since the earliest times, it has been noted in Indian Musicological systems that the tonal peculiarity of Moorchana lies in the fact that, firstly all the modes generated by it have equal melodic validly and secondly, that all of them vary vitally from one another in their emotive ethos while retaining an essential similarity in their melodic fabric.

The objective criteria of the melodic validity of the tonal structure as enumerated by Narada, Bharata, Sangdeva etc. in terms of ten qualities i.e Dasagunayuktam throw particularly no light in the nature of the structure itself. The later designation, since the time of Matanga, of any such structure as a raaga, meaning, that which pleases-ranjayati-iti-raagah, has hardly been able to improve the situation. **The nature of a tonal structure, therefore, possessing melodic validly must be studied Musicometrically in the light of basic tendency of Indian music to blend dissonance and consonance and array & disarray, together in a melodic whole creating waves after ways of melodic tension and relaxation and making the later prevail upon the former at the end of the musical experience.** Such a blending of pairs of opposites can be done best only when the following conditions in the construction of a tonal structure are fulfilled.

Conditions for tonal structures:

1. **Predominance of ultimate Consonance over initial dissonance being the first requirement of music**. For ensuring this for every Swara in the Moorchana chakra there should be some other Swara or Swaras in it being to that one relation of 2:3, 3:4, 4:5, 5:8, 3:5 or 5:6 these relations expressing the six high consonances.

2. The minimum numbers of Swaras being mutual relations of 2:3 or 3:4 in a raaga of 7 Swaras must be 4, the possible maximum being no more than 5 under conditions mentioned below.

3. **Predominance of inner array over outer disarray being the second requirement of Indian music**. For that all Swaras in the Moorchana chakras must be located within the prescribed limits of minimum and maximum distance from one another, all such distance being measurable in precise terms.

Note: The rules applying to limits of minimum and maximum distance as laid down below have been framed mainly to ensure that the middle point of the octave √2 remains unchangeable point of demarcation between the Fourth and Fifth Swara of any Raaga. This law of immutability of √2 as the demarcating point between the two tetra chords, the Purvanga and Utaranga of a raaga means, in practical terms that neither its Fourth should ever be higher than 45/32 nor its Fifth note should ever be lower than 64/45 in relation to Shadja which is taken to be 1. It may be mentioned here in passing that later development in Indian music permitting sometimes a slight dominance of disarray over array in melody, appear to have led to a minor relaxation in this rule by letting the middle point of octave to be over reached or under reached by the fourth or fifth note of a raaga by adding or subtracting small shrutyantara 2048/2025 to 45/32 or 64/45 as the case may be.

4. The minimum and maximum distance between any two contiguous Swaras of Moorchana chakra must not be less than 16/15 and more than 75/64. In permissible Moorchana chakra the minimum and maximum permissible distance between any two contiguous Swaras however are 135/128 and 32/27 respectively.

5. The minimum and maximum distance between any Swara of a Moorchana chakra and its third Swara must not be less than 256/225 and 675/512 respectively. In permissible Moorchana chakra the minimum and maximum distance are 9/8 and 4/3 respectively.

6. The minimum and maximum distances between any Swaras of Moorchana chakra and its fourth one must not be less than 32/25 & 45/32 respectively.

7. The middle point of the octave should not be crossed over by the Fourth or Fifth Swara of a Raaga either way, their distance limits from the tonic note being 45/32 & 64/45 respectively.

In permissible Moorchana chakras the middle point of the octave may be crossed by fourth or fifth Swara either way but the permitted crossing must not exceed by Shruti ratios – 64/45 & 45/32 respectively.

The symmetrical and asymmetrical Moorchana chakras:

When the Moorchana chakra is constituted with all its Swaras located in conformity with the above rules, a melodically well integrated consonance and dissonance and array & disarray emerges from it generating a set of 7 different Raagas when the pattern is symmetrical and that of 14 different Raagas when it is asymmetrical.

Note: A Moorchana chakra is a melodic pattern to generate a set of 7 Raagas by shifting the tonic from one note to another whether the shifting operates from left to right or from right to left. Now when both the sets of the Raagas so generated are identical, the Moorchana chakra is said to be symmetrical and when they are different it is said as asymmetrical.

The principles of the above moorchana chakra have been used to define transposed Raagas.

The Indian Melody:

The primeval Indian System of melody had an elaborate logical structure based on certain principles, can be conclusively proved from the great importance given to tonal purity and precision in chanting of Vedic hymns.

It is also an indisputable fact that Vedic hymns have always been held in highest esteem for their deep spiritual meanings, and that they have inspired Indian philosophy, literature and art as nothing else has done. The uncommon insistence laid on their tonal accuracy can only be explained by accepting that melodic phrases were as important as verbal phrases in the disclosures of those meanings and for the dawn of inspirations that were supposed to follow them.

In the post Vedic period , though there was a loss of emphasis given to sensuous appeal but , the spiritual preference was never ignored. To cater for both the spiritualist and sensualists alike the melody was pursued as Margi Sangeet, the music of search and was developed in to an organization of sound to make melody a precise and powerful vehicle of expressions and symbolizations of variety of ideas and emotions. It appears that the secret of the technique Margi Sangeet was based on certain facts of dynamic orderliness inheriting the phenomena of melody by virtue of which patterns of such orderliness got transferred into images of beauty and currents of dynamism turned in to waves of emotions enveloping man's heart and soul. This dynamic orderliness was perhaps the very seed of Indian melody as it exists till date in various forms. **This system of melody, as is evident from all that remains of it**

today, was structurally a balanced combination of rigidity of artistic norms and flexibility of artistic freedom, having its base in an artistic balancing of various pairs of opposites like consonance and dissonance, symmetry and asymmetry, definiteness and infiniteness. It was this balancing from top to bottom which cumulatively infused meaningfulness in to melody.

It remains a mystery as yet as to how the two fold meaningfulness of music, absolute & referential revealing peculiarities of melodic structure on the one hand and trends of emotional and ideational expressions and symbolisms on the other hand could emerge from integral process of measured balancing of musical contents. Similarly how mathematical proportions could generate phenomena of psychological judgment and understanding shall ever remain subject of discovery to the human intelligence. **But it is difficult for a logical mind to deny the fact that the world of music is a fabric of numbers and melody a sound manifestation of ordered dynamism, the source of which lies in numeric relations.** Therefore, to understand the structural logic and basic principles of this system it is essential to find out as to how numeral relations entered in their making.

The literature of Indian Musicology from the Shiksha Granthas down to Natya Shastra (200 BC – 200 AD) and Sangeet Ratnakar (1210-1247 AD) have explained the musical ideas and terms more from psychological angle than mathematical angle apart from mixing Physics & Metaphysics. Because of this, the subjective approach to realities has been a dominant trend in Indian Musicology rather than the objective approach. A typical example of this practice may be cited from Bharta's initial definition of Swaras (notes) as Vadi (sonant), Samvadi (consonant), Anuvadi (assonant) and Vivadi (dissonant). All the above four qualities of Swaras have subjective rather than objective nomenclature indicating how they are perceived psychologically without any reference to how they may be conceived mathematically. **A certain pitch of sound become a Swara only when it stands a certain mathematical relation vis-à-vis the tonic note and when this relationship is of an accepted category from the point of view of its shrutisthan (microtonal location) in the scale**. To define the Swara psychologically is to describe its musical effect while to define it mathematically it is to indicate its cause. **In the field of music art, it may be necessary to know the tonal effect of a note but in the field of music science it is necessary to know its tonal cause.** The situation hardly improves by Bharata's famous employment of the process of chatussarana for finding twenty two

shrutis of the musical scale on two separate Veenas having the same order of tuning. This process is not only a little torturous but presumes both Veenas to have been tuned in the same scale designated by him as Sadja-Grama. The only objective description of the scale is the fact the series of its seven Swaras arranged by intervals of 3,2,4,4,3,2 & 4 shrutis respectively. Now since the Shruti has nowhere been defined by him or any of his predecessors as a unit of tonal measurements and since the Indian musical scale is certainly not of one of equal temperament the Sadja Grama remains undefined and objectively vague for all scientific purposes. Similar is the case with Madhyama-Grama, in which its fifth Swara i.e Panchama is lower than that of Sadja-Grama by just one pramana shruti, the latter term also being objectively vague. Modern musicologists have tried to find out the mathematical value of pramana shruti equated it with Pythogorean comma which is equal to 81/80. They have also tried to find out the mathematical values of other shrutis referred by Bharata. The medieval musicologists have also tried to explain that judgment and realization of tonal values is possible only by the sense of consonance. But this is hardly a valid explanation because inferences drawn by subjective faculties about objective phenomena may have an artistic value but not a scientific validity. Though it is true that tonal qualities are not acoustical but mental phenomena and as such they depend for their definition upon the psychological laws governing human perception and upon the learned response patterns. But since both the perceptions and learned response patterns are subject to fluctuations from time to time and to variations from individual to individual, musicology has to use mathematical terms verifiable by physical means while defining musical ideas and terms in order to make its definitions more precise, clear and open to rational understanding.

In modern times the melody has been defined by Helmholtz as "Horizontal resolution of harmony". He has further described it as " succession of single tones of varying pitches", making a design in pitch and rhythm to produce a satisfying musical effect in which motive, phrase and period are formed by combination in proper relationship of movements and sound. In some other analysis the melody has been defined as, "sequence of tones, when it is apprehended in terms of unified and single response which arises from the tones themselves, but is contributed by the act of the listener. The expressive intent of melody differs from that of words in the way that the function of words is to express the concept of actuality, "while the function of melody is to express the structural

scheme of actuality. **Words generate concepts which may or may not stimulate feelings. Melody on the other hand generates feeling which may or may not generate concepts. The expressive character of melody makes a tune, "a sentence" that makes a sense. It also gives it the semblance of an idea by virtue of which a unique response of thought and mood is awakened in the listener.** This character of melody is possible only as a result of tonal dynamism. As Edmund Gurney puts it, each tone in a melody contains an inherent yearning to move on to some other tone, yielding a form, a unity to which all the parts in their respective places are closely connected. Describing the tonal movement Max Schoen says, **"Each tone commands what tone shall follow it, each interval commands another interval to succeed it, the whole movement pulling to one and only one close.**

Further the Greek Word 'tonos' means tension. Melody being a sequence of dynamically interrelated tones has tension as its basic material and speaks primarily the language of tension. The totality of this tension is the psychological reflection of the image of the integral order of the tonal movement, structure, variety and unity in melody and ultimately melody itself. **In a way a melody is thereby a tensional complex in which mutually related tones are stringed in a single file giving each one of them a certain degree of importance which determines the frequency of the appearance of each Swaras in the total scheme of tonal movement.**

According to victor Zuckerkande the movement proceeds on two planes simultaneously. In the background, the succession of main stations and in the foreground the detours by which the station is linked to the station. The function of former is to provide the melody with a skeleton and the function of the later is to supply it with flesh and blood. "Beauty, individuality, distinction do not reside in the skeleton but in that which the skeleton support. The ear must instinctly be aware of the corresponding background-foreground relation of the melody. Since the beauty, the interest and in fact the very meaning of melody every time lies precisely in the relation between flesh and blood of musical foreground and the supporting skeleton of background, a melody can be enjoyed only when this relationship between these two is understood. This relationship is ultimately connected with that of balance. A dissonance being formless tonal 'no' and a consonance disembodied a tonal aye in a melody; therefore a melodic elaboration becomes an exercise in balancing the aye and noes of tonality. This balance in melody is achieved through tonal order because **order is the heaven's first law in art as in nature and tonal order is the first and**

last mathematical order, because tone is the only mediating factor between music and mathematics. **A melody is therefore a tonal structure in which aesthetic unity in complexity is achieved by sub-ordination of all its tonal elements to the basic and dominating ground ratio of the tonic**. This is why the tonic has been called as Shadja in Indian musical terminology which means that it is both the progeny and the progenitor of the other six notes of the diatonic scale, the initial cause as well as the ultimate effect of its musical meaning.

The problem of balance between symmetry and asymmetry like that of balance between consonance and dissonance has led in the west as well in India the question of numerical constituents of tonal material because a tone is only a psychological phenomenon of the physical reality of a pitch which is caused by certain frequency of vibration in the air which is a purely mathematical term. According to Theodore Lipps, "each interval resolves towards that tone which has a vibration rate of some power of 2, 3 & 5." Only tones having frequencies of some power of 2, 3 & 5 have been supported by James Jeans who says that two tones sound well together when the ratio of their frequencies can be expressed by the use of small numbers and smaller the number the better is the consonance and the farther we go from small numbers the farther we go into the realm of dissonance or discord. This fact was known to Pythagoras, some 2500 years ago, he was the first to ask the questions as to why consonance is associated with the ratio of small numbers. So far no satisfactory answer to this question has been found though a lot of attempts have been made to answer it. But this question takes us into deep thoughts of why and how of the relations between Music and Mathematics in to which perhaps no one is competent to go. In this connection the famous statement of Plato can be quoted which says, "God forever geometrizes and also that of Galileo which says", Nature's great book is written in mathematical language".

Turning to James Jean's who says that a scientific study of action of universe has suggested a conclusion that the universe appears to have been designed by a pure mathematician. To this he adds, "In one sense it may be argued that everything is mathematical. The simplest form of mathematics is arithmetic; the science of numbers and these permeates the whole of life.

What is true of physical universe should be true of musical world also. If the former is a mathematical idea assuming tangible forms and qualities under the rule of numbers, the later i.e. the musical world should also behave in a similar manner. The

Indian concept of divine origin of music is probably a mythologically expressed recognition of this very truth. Let us use this recognition to mathematically understand the Indian Music. For that let certain basic principles regarding the tonal dynamics of melody which has been formulated to explain the tonal movements in mathematical terms be studied. Till these principles are proved to be correct on the basis of essential principles of melody, let them be treated as tentative starting points rather than as established end results of fact finding process.

The basic theorems are given below:

1. The graphic symbolization of octave structure of the pitch series is accomplished by equiangular spiral line ascending or descending continually and returning after every turn to points above or below those passed before. In the process the radius of the spiral gets exactly doubled or halved as it moves away from or towards the centre of the spiral after having described an angle of 360^0 and the equation of the spiral being $\underline{r} = 2$.

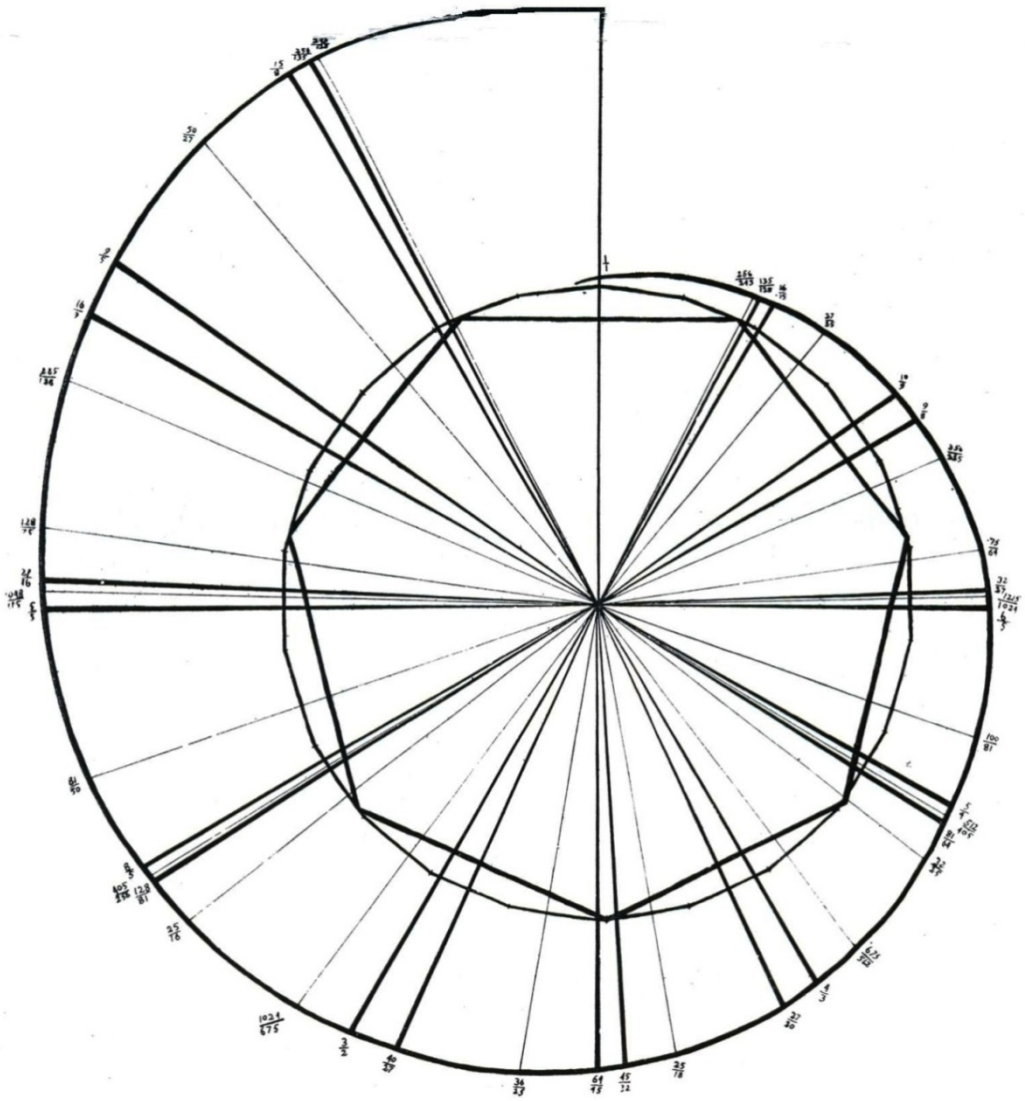

Fig. 1. The equiangular spiral of the pitch series of the Octave.

2. Octave structure of the pitch series from any given pitch to is next unison, that i.e. from any given frequency to its double or half, if divided in its circular form in to seven equal sectors, shall indicate seven Swara Grama's (tonal zones). In this tonal division the tonic i.e the adhar swara (shadja) shall be permanently located in the exact middle of the first zone and each one of the remaining six Swaras of any diatonic mode shall be located somewhere in each of the remaining six zones subject to laws of consonance and dissonance, with the provision that in certain eventualities brought about by laws of symmetry and asymmetry, any two neighbouring notes may be located in the same zone, any of its adjacent zones being left entirely vacant, provided that the middle of the octave shall not be crossed one way or another whether by

fourth or fifth of the note and further that if it has to be crossed at all, a distance travelled either way shall remain below 81/80.

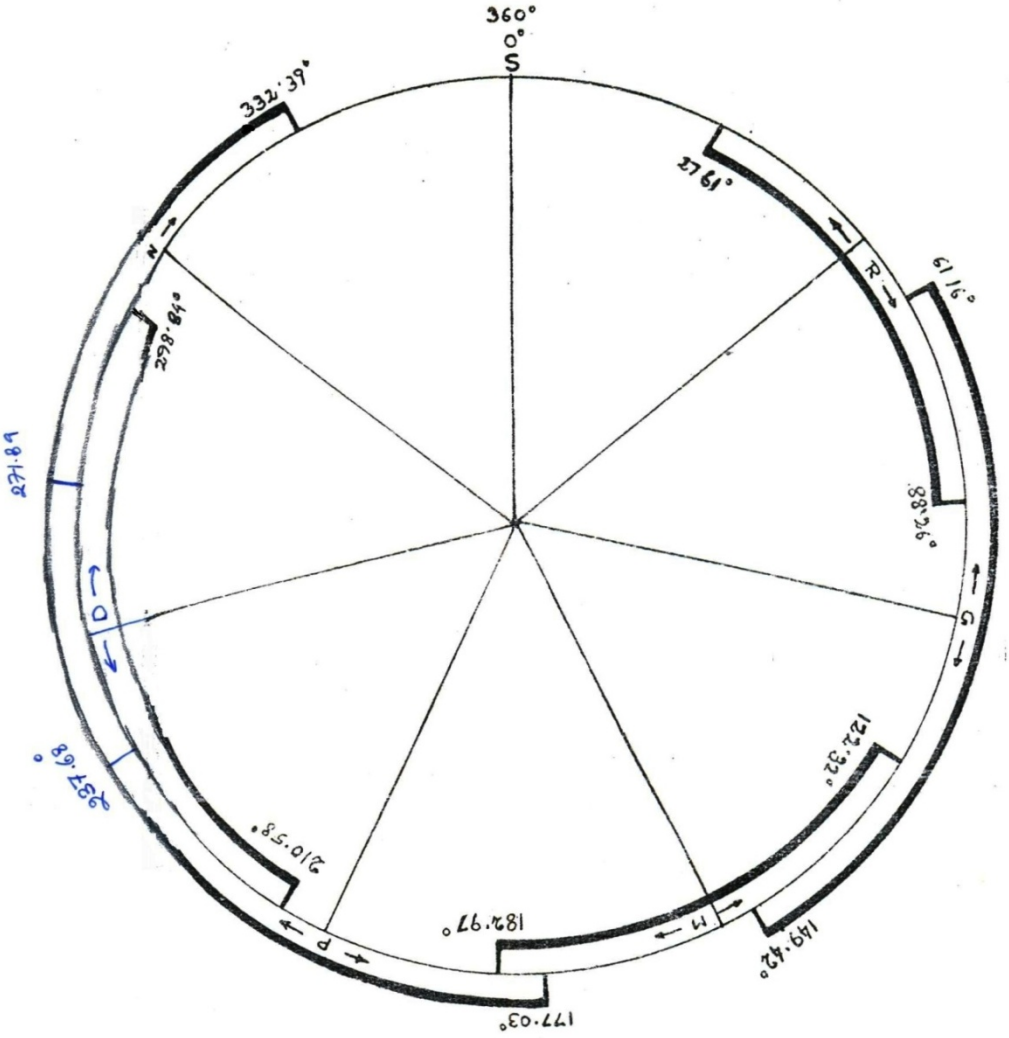

Fig. 2. The seven tonal zones (Svara grama-s)

3. The octave structure of pitch series, if divided in to twenty-two equal parts, shall indicate twenty-two Shruti-Gramas (microtonal – zones). In this zonal division the tonic shall be located at the meeting point of first and the twenty-second zones and no two adjacent Swaras of any melody shall be at a mutual distance of less than one and more than six Shruti-Gramas as demanded by laws of symmetry & asymmetry.

4. The spiral line representing the octave structure of the pitch series consists of infinite points of tonal locations of which only such points are capable of producing melodic Swaras which are expressible in terms of integers

constituted by prime numbers 2, 3 & 5 or their multiples, the smaller integers being capable of producing more consonants and bigger on producing more dissonant tonal relations.

Notes (a) Consonance & dissonance are relative terms being two sides of the same coin, the tonal tension and the diminishing order of one is the developing order for the other, But since the incidence of consonance is finite and that of dissonance is infinite, the former has its natural limitations while the later has to be limited artistically at some point by a system of melody. The Indian system of melody seems to have limited the admissibility of integers by generating tonal relations in its scale at 2187/2048 an integer creating a tonal relation described by Pythagoras as the howling of the devil.

b) There are known to be two different methods of forming musical scales; **the divisive and the cyclic**. The former, as in the West admits a large number of prime numbers as constituents of its tone making integers. The later as in China and Japan keeps down the number to only two prime numbers 2 & 3. However, the **Indian scale is both divisive and cyclic.** The inclusion of prime number 5 in this scale and exclusion of all others like 11, 13 & 17 and so on is indicative of its dual fact. By doing so, Indian scale provides an ideal field for balancing pairs of opposite, like symmetry and asymmetry, consonance and dissonance, definiteness and infinity.

5. The diatonic melodic mode comes into existence only when each one of its seven Swara is connected with some other Swara by relations of consonance, either by the ratio of 3:2 or 5:4 or 6:5. Among these relations the number of first ratio (3:2) cannot be more than five and should not be less than four, the number of other two i.e. 5:4 and 6:5 depending upon how much of a tonal consonant or dissonant content of the mode is desired.

6. A melodic Mode being constituted not by any of its Swaras (notes) individually but by the composite pattern of all its note-intervals in their totality. It is born wherever, that is at the beginning of whichever interval its tonic may happen to be located, with the added fact that each one of such locations produces a different mode with a different ethos and **what is true of a pattern is true of the reverse of it.** (it is this philosophy which has been the basic inspiration of the present study)

Note (a) Since the central term of reference for all the notes of a mode is its tonic , the later unfailingly creates the mode inherent in the pattern, where so ever it may be located in the octave spiral. This also means that the location of the tonic is not an absolute but a relative concept in Indian music and that the ensuring **modes are algebraic rather than arithmetic phenomena**.

b) The fact that shifting of one tonic from one note interval to another produces altogether different mode is one of the central facts of the melodic system, called Moorchana in Indian Musicology, which mean brightening up by turn of each one of many aspects of melodic content contained in any note pattern. Since multiplicity of aspects in a note pattern is possible mathematically only when note intervals are of unequal lengths, the chromatic scale of all twelve notes, which has an unchanging character with uniform note intervals, is totally unsuited for Indian Music. Only the presence of asymmetry in symmetry can bring out individuality in a community. Indian music believes in creating only such tonal communities as are composed of individualities distinguishable from one another and it permits the community to speak only through one individual at a time.

c) The reverse of a Swara pattern is also a Swara pattern, because the same laws of consonance-dissonance and symmetry–asymmetry relations enter in to the composition of both. This gives birth to tonal individualities in a tonal community, which are not only different from one another but also the reverses of one –another. This balance between freedom & law of tonal co-existence is the soul of Indian Music, which must express itself in elaboration of all its norms and their deviants.

7. The tonic has one fixed character but the other six Swaras have many changing ones. Each mode should, therefore be formulated and known in terms of characters of all its Swaras taken as a whole.

The above theorems may be followed by several others for a more precise and coherent understanding of Indian System of melody. Though tonal language is too precise to be translated in to words and music is least tangible of all arts, still the facts stands that **music is ordered motion and the disciplines dynamism of music, generates a complex emotions through tonal motions and goes to the roots of our being and takes shapes in the inner gestures which embody our deepest and most ultimate response.** However, the knowledge of co-relation between musical form

and emotional experience has yet to pass through lots of objective experimentation in order to attain the dignity of science.

In view of the above scientific definitions, elaborations of Melodic patterns, as used in Indian music and are called Raagas, it has been thought as to whether such principles can be applied on them and applying the above scientific principle on the existing popular Raagas of both the Hindustani and Carnatic system it has been studied as to whether by reversing the swaras patterns of such Raagas we get some other melodic patterns ,which are either resembling some of the other the existing popular raagas , in that case to be called as inversely related Raagas or as to whether such reverse patterns also are melodic in nature qualifying the prerequisite of being the full- fledged raagas , having their own individuality and character. Similar possibility has been seen by transposing the swaras of the existing raagas and seeing as to whether such transposed patterns also resemble with some of the other existing popular Raagas, in that case to be called as transposed Raagas or as whether such transposed patterns also are melodic in nature qualifying the prerequisite of being the full-fledged Raagas.

The twenty-two Srutis