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Raga: Conceptual and Experimental Approaches

Abstract: Difficulties in the acoustic analysis of extra-European musics often stem from categorisations of phenomena that do not account for the explicit (or implicit) models upon which the creation and perception of musical structures are based. This paper defines the concept of melodic model, elaborated and modified over nine centuries in India to account for a particular melodic phenomenon: the rāga. In the second part, tools and methods are presented for characterising rāga intonation, as well as for achieving their automatic transcription and classification.

Keywords: Musical Acoustics - Ethnomusicology - Musical scales - Transcription - Melody - Raga

Abstract: Difficulties in analysing extra-European musics are often bound to categorisations of phenomena that do not take into account explicit (or implicit) models on which the creation and perception of musical structures are based. This paper defines the concept of melodic model, a concept elaborated and transformed for nine centuries in India to underlie a particular melodic phenomenon: rāga. In the second part, tools and methods are presented relating to rāga intonation and their automatic transcription and classification.

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Difficulties in analysing an extra-European musical system often stem from a categorisation of phenomena that betrays an ethnocentric approach: believing, for example, that one can describe separately intonation, ornamentation and melodic phrasing[2]. In this article we present work that has led us to study the perception of melodic constructions under various aspects that are unified under the term rāga, the fundamental principle of melody in India for approximately eleven centuries.

In the first part, we present the evolution of the concept of rāga, focusing particularly on changes that have occurred in recent decades.

Important theoretical and historical works on music undertaken in India over the preceding two centuries are at the origin of modern ethnomusicology. It would be inappropriate to ignore the contributions of Jones, Willard, Tagore, Mahillon, etc.[3] The experimental approach that we present in the second part is therefore new only in the tools made available to us by technology.

Models of melodic construction have been elaborated at different periods by music theorists of India; some are complementary, others incompatible. One can say that the execution of a rāga is the putting into action of these various models and the resolution of their contradictions. During experimentation, one must therefore take into account the fact that there necessarily exists a gap between theory and practice, in other words, that one must attempt to "discern what a musician does from what he seeks to do, and from what he declares he does"[4].

In such a brief presentation it is difficult to take sufficient distance from controversies of the north/south or Hindu/Muslim type which are one of the reasons for the diversity of musical genres in India. The ideas we present here reflect positions common to numerous Hindu and Muslim musicians who perform dhrupad or khayāl, the two 'classical' musical genres still practised today in northern India. For more historical details, the reader may usefully refer to Neuman[5] or Van der Meer & Bor[6].

FIRST PART: ORIGIN AND FORMALISATION OF RAGA

1. Foundations of the melodic system

By melodic model we mean a set of procedures which permit establishing (1) a division of tonal space into micro-intervals, (2) a finite set of modes, or permutations of these micro-intervals, (3) a finite or infinite set of melodic classes, or sequences of notes, and (4) predictions about the importance and respective roles of notes in these melodic classes. The most ancient melodic model to which musicians of India refer is that of Sanskrit treatises of the pre-mediaeval period, particularly the Dattilam[7] and the Nāṭyaśāstra[8]. The latter would have been written at a date difficult to determine, probably between the 2nd century BC and the 5th century AD. There exist multiple commentaries on the Nāṭyaśāstra and on the theory of musical scales formulated by Bharata, its presumed author[9]. But it is especially in the 18th century that the 'discovery' of this theory by the famous orientalist Sir William Jones[10] provokes a renewed interest that will continue until the 20th century.

It is interesting to translate the axioms of this theory into 'extra-Asiatic' musical terms[11]... Bharata poses the problem of tuning cordophones (vīṇās). Suppose for example that we wish to tune a harp to the 'natural' scale. Bharata uses, to quantify intervals, an entity that he calls 'śruti'[12] but of which he does not define the exact nature: frequency ratios, procedure for realising an interval, etc. Let us admit like him that a 'reasonable' division of the octave into micro-intervals is realisable with 22 śrutis. Until proof to the contrary, one must agree that the śruti is not necessarily a unit of measurement (of constant size). According to Bharata, the distribution of intervals in the fundamental scale Ma-grāma would be as follows:

Ni	Sa	Re	Ga	Ma	Pa	Dha	Ni
do	ré	mi	fa	sol	la	si	do
4	3	2	4	3	4	2	

The correspondence of Indian notes: Sa, Re, Ga... with ré, mi, fa... indicates that the Ma-grāma is a sort of mode of D. The śrutis serve in fact to identify simply the consonance relations (saṃvādī): 9 śrutis for a fourth and 13 for a fifth. Under these conditions, the scale defined above would possess the same consonances as that of Zarlino: do-sol, mi-si, fa-do, sol-ré, la-mi and of course the fourths obtained by inversion. Putting into equations an experiment described by Bharata (experiment of the two vīṇās[13]) permits concluding that the intervals are indeed ordered according to their 'measurement' in śrutis: 2 for the major semitone, 3 for the minor tone, 4 for the major tone, 5 for the Pythagorean minor third, 6 for the harmonic minor third, 7 for the harmonic major third and 8 for the Pythagorean major third. The dissonant interval ré-la, which measures 12 śrutis, is the famous modal fifth or wolf fifth.

The comparison between the Ma-grāma and Zarlino's scale stops there, for the system possesses a degree of indeterminacy: one can indeed identify two chains of fifths: fa-do-sol-ré and la-mi-si, but to place the second in relation to the first, one must know, for example, the value of the interval do-mi. Now this interval is classified by Bharata as 'assonant' (anuvādī). We have shown[14] that instead of removing the indeterminacy by imposing the frequency ratio of the harmonic major third (5/4) (Ptolemaic tuning), one can play with other parameters which permit, amongst other things, tempering the thirds, fifths or octaves.

Bharata does not seek, like piano tuners, to resolve by temperament the problem of the modal fifth (12 śrutis), and proposes to us instead a second fundamental scale, the Sa-grāma, identical to the Ma-grāma except that the Pa is one śruti higher (pramāṇa śruti, or syntonic comma), which gives after transposition:

Ni	Sa	Re	Ga	Ma	Pa	Dha	Ni
do	ré	mi	fa	sol	la	si	do
4	3	2	4	4	3	2	

The modal fifth of 12 śrutis is now carried over to the interval la-mi. A system of modes is obtained by taking any plagal transposition (mūrcchanā) of these two fundamental scales. One chooses one or the other in order to position the modal fifth at will. On each mūrcchanā one can now enumerate interesting sequences of notes called melodic classes (jāti). The jātis are therefore archetypes of melodies in which one must see, not only sequences of notes, but above all sequences of intervals. The identification of melodic intervals with the aid of śrutis prodigiously simplifies the exact prediction of consonances and dissonances by avoiding all calculation on whole-number fractions: although the śruti is not a unit of measurement, comparisons of intervals between two notes are reduced to evaluating their size in śrutis.

Bharata's fundamental scales can undergo two alterations which are equivalent, in Zarlino's scale, to sharpening (raising by 2 śrutis) the fa or (and) the do: antara Ga and kākalī Ni. It is easy to observe, like Dattila, that Sa-grāma is the plagal transposition of Ma-grāma by sharpening the fa and taking sol as the starting note[15]. (Conversely, Ma-grāma is deduced from Sa-grāma by sharpening fa and do and starting from ré). By repeating twice the first process, one obtains two new scales, sādhārita and kaiśika, which exhaust all possible sequences of 2, 3, or 4 śrutis contained in heptatonic scales formed from two cycles of fifths offset by a major third. Bharata's model is therefore equivalent to all plagal transpositions of four fundamental scales. None of these scales contains an interval of one śruti. If one wishes to remedy this, one can formalise an extension of the model by repeating three times the alteration/transposition process starting from kaiśika. (The fourth time one would fall back on Sa-grāma.) One then arrives at 7 fundamental scales. Two other extensions, which we shall not describe here, permit introducing the intervals of 5 and 6 śrutis (minor thirds) which intervene in chromatic heptatonic modes (see below, deśī rāgas).

The most general solutions of the system of equations translating Bharata's axioms establish three distinct values of the śruti: the syntonic comma, the minor semitone and the Pythagorean limma[16]. The latter is the only one that intervenes as an interval between two notes in chromatic modes. Numerous authors have nevertheless affirmed that the ancient theory was only operational if the śrutis had equal dimensions. A partisan of this thesis, Bose[17] envisages various systems of equal micro-intervals: 22, 27, ... 53. He rejects the 22-interval scale in which he cannot distinguish the minor semitone from the syntonic comma. Observing moreover, like Helmholtz, that the partition into 53 equal intervals (anuśrutis) produces intervals of harmonic minor third, harmonic major third and fifth very close to the whole-number fractions 6/5, 5/4 and 3/2, he reconstructs a melodic model on this scale[18].

2. Genesis of rāgas

The grāma-mūrcchanā-jāti system certainly remained for a long time, in the north as in the south, the theoretical basis of Indian music — even if we cannot know what the music consisted of at that period. The concept of rāga appeared well after the Nāṭyaśāstra, since this term was defined, in the sense in which we use it today, around the 9th-10th century in the Bṛhaddeśī of Mataṅga: "a type of sound composition, formed by melodic movements, which has the effect of colouring the hearts of men."[19] The Saṅgītaratnākāra of Śāraṅgadeva, in the 13th century, describes 264 jātis (melodic classes) of which 58 are specifically named as rāgas[20].

A large number of rāgas were originally popular airs that the ancients collected and classified according to their tonal structure. Certain 'new' rāgas (the deśī rāgas: Toḍī, Bhairava, etc.) use chromatic heptatonic modes (containing a minor third adjacent to a semitone, for example do-ré♭-mi-fa...). The corresponding scales, as we have seen, are not deducible from Bharata's two grāmas, consequently an extension of the theory would have been imposed at the time. The theorists preferred to formulate a more direct way of obtaining all chromatic modes: it suffices to preserve two notes in consonance relation (for example do and sol), and to define for the remaining five two positions: normal and altered. The altered positions are for example ré♭, mi♭, fa♯, la♭ and si♭. One thus arrives at what we call a modal system based on a semitonic scale. This system is known under the name of mela, a term which would have appeared for the first time in 1160 in the Rāga Taraṅgiṇī of Locana Pandita[21]. However, a century later, Śāraṅgadeva does not mention this theory and keeps to Bharata's formulation.

3. Tonic and modal system

Popular airs being often sung with the accompaniment of a drone (tuntune, ektār), rāgas are naturally centred on a tonic. To sing or perform these rāgas on an instrument, particularly a lute, one tends to place the tonic always at the same pitch. The modes are then no longer obtained by transposition, as on a harp, but by alteration. These alterations should in principle respect the micro-intervals of the grāmas. But Bose observes[22] that the theorists of southern India, who today use the system of 72 melas popularised by Venkatamakhi (end of 17th century), are content in fact to propose names like sādhāraṇa Ga, kaiśika Ni, etc., without defining the intervals. Paradoxically, all recognise the existence of śrutis and therefore claim to follow the purest tradition.

The marked preference, after the 7th century, for fretted cordophones (lute then stick zither: rudra vīṇā in the north and sarasvatī vīṇā in the south) only confirms this change[23]. Indeed, if one arranges the frets so as to produce one of Bharata's fundamental scales, the lowest note (Sa) will be treated as a tonic, a notion which is absent from ancient theory. On the other hand, only the Sa-grāma is usable because it does not contain a note in modal fifth relation with the tonic. The 'natural' scale, in southern India, is therefore the Sa-grāma (our mode of D), whilst in the north one adopts the Ni-mūrcchanā of the Ma-grāma, or, which amounts to the same thing, Zarlino's scale. Consequently, śuddha Ga (Ga natural) designates for example E♭ in the south, and E in the north. There is no reason a priori to qualify as 'natural' the Sa-mūrcchanā of the Sa-grāma or the Ni-mūrcchanā of the Ma-grāma. However, the adoption of a single natural scale obscures the raison d'être of the two grāmas, very important according to the Nāṭyaśāstra since the Sa-grāma/Ma-grāma distinction is found in the jātis[24].

The idea of plagal transposition is therefore losing ground since the disappearance of harps, a phenomenon which begins around the 8th century. At the time of Ahobala[25], mūrcchanā no longer designates a plagal transposition, but an ascending and descending scale. Śruti, in the south, designates indifferently a micro-interval, an enharmonic position, and the drone...

The system of 72 melas has the merit of being easy to implement, because of low theoretical level, and as a side effect the invention of new 'rāgas' based on scales unacceptable according to śāstric tradition: in the mode of a rāga, it is indeed necessary that each note be part of at least one fifth. The scales in which one finds the largest number of rāgas from northern India are moreover those which possess the maximum number of consonances.

4. Rāga-rāgiṇī system

Musical terminology has also evolved considerably in northern India, which suggests that important changes took place after the 10th century, whilst a certain confusion reigned regarding the interpretation of new musical ideas in the light of ancient texts. Musicians, who conform above all to oral tradition, are not interested in a systematisation of rāgas based on their tonal structure, but prefer to describe in figurative form their specific attributes: from the 11th century, Nārada classifies rāgas as male and female in the Saṅgītamakaranda[26]. In the 15th century, the Mānkutūhala, a text now lost but translated into Persian and commented on by Faqirullah, the author of Rag Darpan[27], describes the engendering of new rāgas (putras) by the association of two parent rāgas (rāga-rāgiṇī). This process naturally leads to new classifications (rāgamālā) in which each of the six fundamental, pentatonic rāgas has five heptatonic wives, the rāgiṇīs, and eight sons (putras). There exist numerous versions of rāgamālā illustrated from the 16th century by miniaturist painters[28].

5. Rāga lakṣaṇas: static characteristics

The attributes (lakṣaṇas) which permit characterising rāgas are firstly the tonal structure (mode, scale, consonances, etc.), vādī, the most brilliant note, graha, the most frequent note at the beginning of a phrase, nyāsa, the note on which one rests at the end of a phrase, etc. These notions were defined in the jātis of the Nāṭyaśāstra, in relation to the principal sentiments (rasas). The aesthetic theory of rasa is at the centre of philosophy and art in India[29]. Musicians also possess 'statistical' knowledge about rāgas: bahutva and alpatva, respectively the most frequent and rarest notes. All these attributes (except bahutva/alpatva) are much more difficult to determine when dealing with real rāgas rather than jātis. "Vādī and saṃvādī should be understood in relation to musical phrases and elaboration. Each development makes a particular note 'sound' or 'shine'... Therefore a rāga normally contains numerous vādīs and saṃvādīs."[30] For similar reasons, it is doubtful that one can formulate a simple correspondence between notes, melodic phrases and sentiments (rasas).

6. Sequential and dynamic characteristics of rāga

For want of an explicit formalism, musicians of northern India refer above all, for the definition of rāgas, to the repertoire of sung compositions. Each composition summarises the static and sequential characteristics: important phrases, graha, nyāsa, vādī, etc., but it also contains information of psychological order: the poetic theme of the text must harmonise with the rāga, and vice versa. Jahangir Khan, the uncle of Alladiya Khan, was reputed to know no fewer than '25,000 compositions'[31]! However, "the individuality [of a rāga] is not that of fixed airs found in poetic songs and folk songs of all countries. It is of such a nature that it offers artists a vast field for demonstrating their talent by introducing variations."[32] Another way of characterising a rāga, which we qualify as 'dynamic' because productive, is therefore to state rules of melodic progression. These rules are generally formalised very summarily but they are acquired intuitively with long experience of improvisation; one of the essential points being to respect certain proportions in time as well as in tonal space.

Developing a rāga is a bit like drawing a face from memory: the mental image must be preserved throughout the execution. A schematic way of representing both the melodic and aesthetic aspects of a rāga is to perform a calana[33]. This is a short piece which summarises its characteristic movements (with appropriate treatments: ornamentation, etc.) whilst evoking its specific atmosphere[34]. An abusive simplification (but very widespread today) consists in reducing the calana to an ascending (āroha) and descending (avarōha) scale devoid of any intrinsic character.

One of the most unusual aspects of northern Indian music is the theory of the time of performance of rāgas: each rāga is associated with a period of the day during which it produces its optimal psychological effect. Certain rāgas are also seasonal. This principle is scrupulously observed by musicians (and by those responsible for radio programming). Concerts are organised in the morning to permit artists to perform Toḍī, Bhairavi, Jaunpuri, etc. There exists in fact a well-shared consensus on performance times, established conventionally from observations on the circadian cycle.

7. Classification of rāgas: theoretical approach

Since rāgas were, originally, a categorisation of compositions (often drawn from folklore), it is legitimate to use their discriminant characteristics (lakṣaṇas) to deduce a classification. Intuitive classifications are used by musicians to transmit to their disciples the essentials of musical knowledge.

The discriminant factor of numerous rāgas is their melodic phrasing (aṅga), a notion which accords much importance to the treatment of notes. Groups of rāgas can therefore be identified thanks to these morphological resemblances[35]. However, even if the rāga aṅga permits bringing together related rāgas despite their different tonal structures (for example Toḍī and Bilāskhanī Toḍī), it does not permit categorising all rāgas[36]. In a rational classification one must therefore take account of multiple characteristics which can be grouped into two categories:

Time-independent characteristics

1. Tonal structure: mode, consonances and micro-intervals
2. Relative frequencies of occurrence of notes (extension of the concepts of bahutva and alpatva)

Time-dependent characteristics

1. The most frequent notes at the beginning (graha) or end (nyāsa) of phrases
2. The note most used on the strong beat (vādī)
3. Short melodic motifs (alaṅkāra)
4. Characteristic phrases (tāna)

To these aspects must be added historical considerations. Tradition indeed considers the rāga as an irreducible melodic entity. This conception has the advantage of accounting for melodic species in terms of evolution: rāgas, like plant or animal species, are born and die. If new rāgas are formed by hybridisation or by analogical inference[37] most fail and do not survive their inventor, others become autonomous species[38]. A classification taking account of historical criteria can be reduced to the cross-section of a phylogenetic tree[39].

8. Modern conceptions[40]

In northern India, the return towards an axiological conception begins at the end of the 19th century, in an attempt to rehabilitate classical music often assimilated to practices judged decadent by a middle class little cultivated but already turned towards the West. An in-depth study of this phenomenon is found in Van der Meer[41]. Certain fundamental changes are induced by new forms of performance which are popularised by great musicians and fixed by the first recordings. Faiyaz Khan, for example, the greatest singer who was recorded at the beginning of the century, always begins with insistence on the note 'Sa' because he considers that the rāga must develop from the tonic. "This implies the completion of a long process in which the various systems of central notes have been simplified so that today it is difficult to imagine what could have been the function and meaning of concepts like graha, aṃśa, nyāsa and vādī."[42]

However, the most significant event of this century has been the adoption of the classification of V.N. Bhatkhande (1860-1936). This musicologist (a lawyer by profession) played a considerable role in the rehabilitation and popularisation of classical music of northern India, publishing in six volumes (from 1917 to 1936) a collection of melodies which today constitutes the manual par excellence of modern music schools. Although Bhatkhande's work is today widely appreciated, his attempt at systematisation of rāgas was vigorously criticised by great musicians and theorists of the time: Omkarnath Thakur, D.C. Vedi, K.C. Brihaspati.

Bhatkhande classifies rāgas into ten thātas or modes, a simplified version of the 72 melas of southern India: six diatonic modes (mode of C or thāta bilāval, mode of D or thāta kāfī, etc.) and four chromatic modes (toḍī, pūrvī, mārvā, bhairava), each mode being named after the best-known rāga which borrows its scale. The irreversible effect of this reduction is illustrated by this example cited by Van der Meer[43]:

"Even in the recent period we come across rāgas which were very important fifty years ago, but now seem on the verge of obscurity. The rāga Pūrvī for instance is quoted by D.C. Vedi as a very basic rāga, which seems in accordance with Bhatkhande's idea to call a thāta after that rāga. At present however Pūrvī is seldom heard, whereas its derivative Pūriyādhanāśrī is far more common. A reason may be that the performance of Pūrvī is very demanding as it uses a sequence of five chromatic notes: g m ṛ p d [mi fa fa♯ sol la♭] in complicated patterns. Moreover there are three other rāgas with the same scale: Basanta, Paraja and Lalitagaurī. The difficulty has probably manifested itself when Basanta joined this group, because up to about fifty years ago Basanta not only differed vastly in its tonal patterns but also used the śuddha dha [la natural] instead of komala dha [la♭]. Lalitagaurī was (and is) a rare variety. Nowadays Basanta and Paraja being almost identical, most artists sing them in a mixed form: Parajabasanta. Given the fact that the scale of a rāga has become more and more important, it seems increasingly more difficult for two or more rāgas with the same scale to survive. So, the scale type of Pūrvī lives on in Basanta and the melodic pattern in Pūriyādhanāśrī."

Because it is less discriminating, the modern conception leaves the field open (particularly for instrumentalists, who dominate the scene today) to the invention of 'new rāgas' based on unprecedented combinations of note sequences, or unusual mixtures of known rāgas. These innovations which the public relishes often retain no specific character and would therefore be condemned to disappear if they were not made permanent by recordings.

There exist in fact few or no works in European languages on the music of northern India, today, which are not a pale remake or an extension of Bhatkhande's theory: Kaufmann[44], Jairazbhoy[45], Moutal[46], to cite only three. The latter, who hails Bhatkhande as "one of the greatest Theorists of Music of all Time"[47] (the capitals are the author's), does not hesitate to write[48] that "Indian Musicians of the past performed only about ten Rāgas during their lifetime..." and concludes that "the standardisation that has begun is an entirely positive and welcome phenomenon." Thanks to this standardisation, in reality, as Van der Meer observes[49], numerous music teachers follow the notations of printed works of which they conscientiously reproduce the errors! Others content themselves with imitating commercial recordings of fashionable artists... This social phenomenon has been analysed, in the domain of tabla, by Kippen[50].

The theories of Bhatkhande and his successors seek above all to make a clean slate of speculations on micro-intervals drawn from multiple interpretations of ancient theory: Jairazbhoy and Stone[51] arrive, on the basis of experimental measurements, at denouncing the chaotic character of the phenomenon: "... any intonation within certain limits (perhaps within 25 or 30 cents on either side of the tempered intonation) can be acceptable." At the practical level, Jairazbhoy proposes a system of 32 heptatonic modes (thātas) formed from two unalterable notes (Sa and Pa) and five notes which have two possible alterations on the semitonic scale.

9. 'Neo-classical' conceptions

Van der Meer[52] has shown that Jairazbhoy's 32 thātas could be described by plagal transposition (mūrcchanā), which permits additionally specifying the nature of intervals and locating dissonances. The scales generated by plagal transposition possess several thātas in common, and in such a system only knowledge of micro-intervals can remove ambiguity about the tonal structure of a rāga. Since the melodic structure of rāgas is, to a large extent, a function of micro-intervals[53], one conceives that śrutis permit theoretically differentiating rāgas which apparently share the same thāta: Multānī/Toḍī, Bilāskhanī Toḍī/Bhairavī, etc. Moreover, the melodic structure of a rāga results partly from the resolution of internal dissonances of its scale: thus, omitted (varja), oscillating (āndolit), oblique (vakra) or rare (alpatva) notes are often notes directly implicated in a dissonance[54].

Framjee[55] and Bose[56] have attempted to formulate a theory of rāga inspired by the ancient model, confounding rāga and scale, and arriving at normative conclusions about micro-intervals. For his part, Daniélou[57] defends an ideal conception of intervals based on the supposed psychological properties of the integers 2, 3, and 5 which intervene in frequency ratios. Like Bose — whose conclusions he does not share — he does not hesitate to tax as incorrect the modern interpretation of rāgas when it does not correspond to his theoretical predictions. Arnold goes so far as to formulate a procedure for calculating the time of performance of a rāga, based on a speculative interpretation of the grāma-mūrcchanā-jāti system, since revised in the light of the work cited here[58].

10. Order and chaos

The problem with attempts at systematisation of rāgas is that one tends to reduce them to a mode plus some rules of improvisation, which favours a combinatorial approach to the detriment of their specific atmosphere (rāga rūpa). B.C. Deva is the first author to have proposed studying the rāga as a Markovian process[59]. He defines an 'entropy' function which is a measure of information, or at least the capacity of the rāga to generate motifs (if not meanings). If all note sequences are licit, then entropy is maximal because the system is entirely chaotic. Conversely, if in certain sequences the system becomes deterministic (maximum redundancy, or minimum information) then entropy is nullified. Deva's study, although it is limited, for technical reasons, to discrete notations (compositions), tends to show that melodies based on a combinatorial model (the South Indian melakartā system) have an entropy superior to those which bring into play tonal hierarchies and explicit rules of melodic progression. The modern conception of rāga would therefore lead, according to Deva, to more 'chaotic' music, whilst the classical vision was certainly more constraining but permitted at the same time differentiating a more considerable number of rāgas. The relaxation of constraints therefore paradoxically leads to the disappearance of great rāgas (e.g.: Pūrvī) at the same time as the creation of new entities that the ustāds of the beginning of the century would have hesitated to qualify as 'rāgas'. To summarise the point of view (very much in the minority today) of purists, the modern vision does not limit itself to the exploration of new possibilities, but also betrays a profound qualitative change in musical conceptions. This dilemma between order and chaos is perhaps in fact at the heart of the debate on creativity in learned 'ethnic' musics.

Footnotes

[1] Group Representation and Treatment of Knowledge, National Centre for Scientific Research, 31 Ch. Joseph Aiguier, Marseille.

[2] Arnold, Bor & Van der Meer 1985.

[3] Bor 1988.

[4] Daniélou, personal communication.

[5] Neuman 1980.

[6] Van der Meer 1982.

[7] Lath 1978.

[8] Ghosh 1961.

[9] Bel 1988.

[10] Jones 1784.

[11] Term inspired by Klarenz Barlow and Peter F. Müller, who created an amusing programme: Ausserindische Musik, for German radio.

[12] This word is feminine but we use it in the masculine like most francophone authors

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PART TWO: EXPERIMENTAL TOOLS

11. Study of Rāga Intonation

The first experimental work on rāga intonation was conducted by Clements and Deval[60], who measured the lengths of vibrating strings under the direction of the famous singer Abdul Karim Khan. Their identification of the 22 śrutis as a pentadic harmony system was even voted as the best solution to the śruti problem by the All India Music Conference in 1929 in Madras[61]. Nevertheless, this interpretation was severely criticised by V.N. Bhatkhande, and even Abdul Karim Khan, towards the end of his life, came to disapprove of it. In the 1940s, Daniélou undertook measurements of microintervals using a tunable harmonium to verify his theoretical predictions. Much later, in 1980, he presented at UNESCO House in Paris an electronic organ with fixed tuning that precisely generates the 52 degrees of his scale. Whilst Deva, Jairazbhoy and Stone measured intervals from oscillogram films, Levy[62] sought to locate particular points of melodic lines using a strobotuner.

The author's first contributions date from 1979 with the creation of a Shruti harmonium, a polyphonic electronic organ equipped with a digital tuning system that allows programming of musical scales with resolution better than the cent (hundredth of a semitone)[63]. Experiments quickly showed that, in the melodic complexity of rāga, the tonal skeleton is often more conceptual than real: there is contradiction, as might be expected, between the positions imposed by the attraction of the drone (the tānpūrā) and the theoretical necessity of using 'just' melodic intervals. Moreover, the experimental procedure often leads to an impasse when it comes to defining 'ideal' notes without considering their treatment or melodic context. Finally, musicians do not necessarily apply the same evaluation criteria in concert, demonstration, and in a laboratory.

[60] Clements 1912
[61] Arnold 1980 pp.5-6
[62] Levy 1982
[63] Arnold & Bel 1983

In order to analyse the most subtle nuances of melodic phrasing in a real musical context, the author created in 1980-81 an improved melograph, the Melodic Movement Analyser (MMA)[64]. The MMA was subsequently completed by a fundamental extractor, built by the author, which functions in real time[65]. These machines allow inexpensive digital storage on magnetic tape of pitch/intensity measurements with one-cent resolution at a rate of 50 (or more) measurements per second.

The MMA is primarily used to transcribe music in the form of melograms. Figure 1 shows a phrase from rāga Jayajayavantī performed by Asad Ali Khan on the rudra-vīṇā (the peaks correspond to attacks), and Figure 2 highlights a microtonal intonation phenomenon in rāga Darbārī Kanaḍā (by the same performer): the tonic Sa, normally the most 'stable' note of the scale, is played slightly higher (2 cents then 8 cents) to initiate an ascending movement. A similar treatment of Re is described in Arnold[66]. This phenomenon is far from chaotic, an idea we have contested in a controversy with N.A. Jairazbhoy regarding Levy's work[67]. But it is not reducible to Bhatkhande's hypothesis either, according to which the intonation of a note would be in simple relation to its context (ascending or descending).

Fig.1: rāga Jayajayavantī
Fig.2: rāga Darbārī Kanaḍā

The MMA allows a 'microscopic' study of intonation: one can move an index along the melodic line and obtain a precise reading of the tonal position every 1/50 second. One can also create small histograms giving an average and standard deviation over a short duration. One can finally 'step back' and create a tonal distribution histogram of a piece of unlimited duration. Figure 3 is such a histogram of rāga Sindhūrā sung for 6 minutes by Mrs Bhupender Seetal. This

[64] This project, undertaken by International Society for Traditional Arts Research (ISTAR, New Delhi) received support in India from the Ford Foundation and the National Centre for the Performing Arts (NCPA) of Bombay.
[65] Bel 1985a
[66] Arnold 1985
[67] Jairazbhoy 1985, Arnold, Bor & Van der Meer 1985

tonagram is nothing other than the statistical scale of the rāga, an idea suggested to us by the study of a Vietnamese song[68].

Fig.3: tonagram of rāga Sindhūrā sung by Mrs Bhupender Seetal

We note the relative importance of the notes do (10%), re (8.5%), sol (9%) and the secondary role of mib (4%) and si (3%) which are strongly connected to re and do respectively. mib, fa, la, sib are not notes on which one can 'sit', consequently the corresponding peaks are less marked than those of do, re and sol. To extract the tonal skeleton of this rāga, one must try to eliminate melodic connections and note treatments: attacks, portamenti, etc.

For this, the melodic line is analysed through three windows, which gives the selective tonagram of Figure 4.

The first window, of typical duration 0.1 second, eliminates curve segments that are too irregular. The second window, of duration 0.4 second, eliminates segments that fall outside a rectangle 80 cents high, and averages the measurements at the centre of each validated rectangle. The successive averages are sent to the third window, of duration 0.2 second, which eliminates segments whose slope exceeds a threshold.

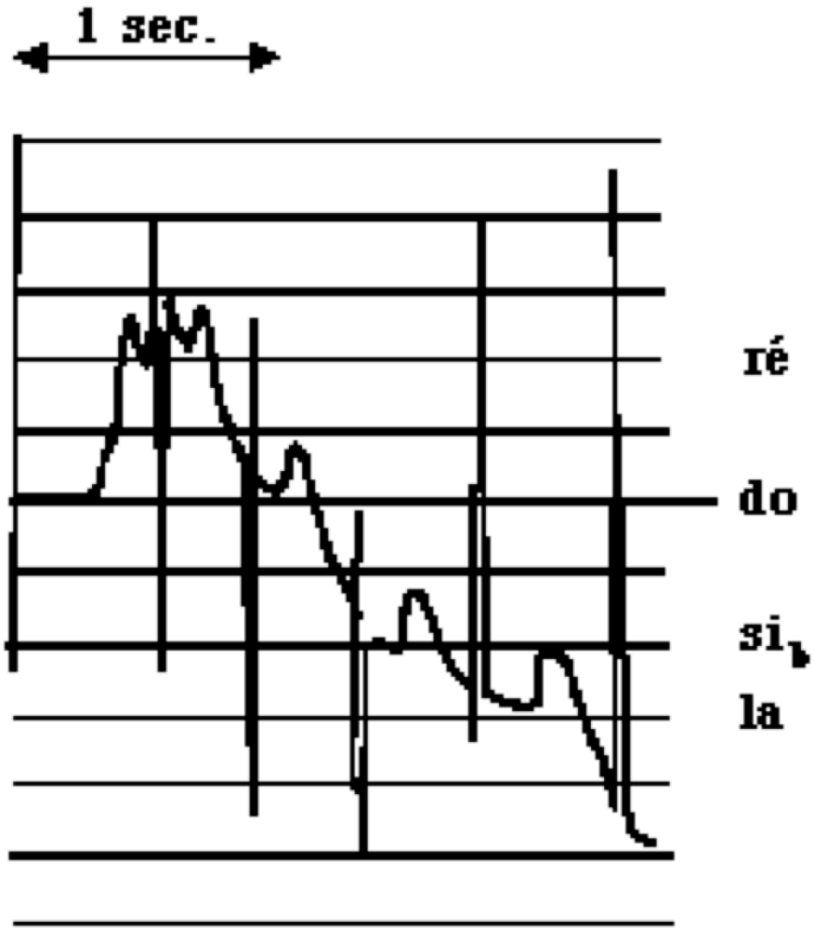


Fig.1 : *rāga Jayajayavantī*

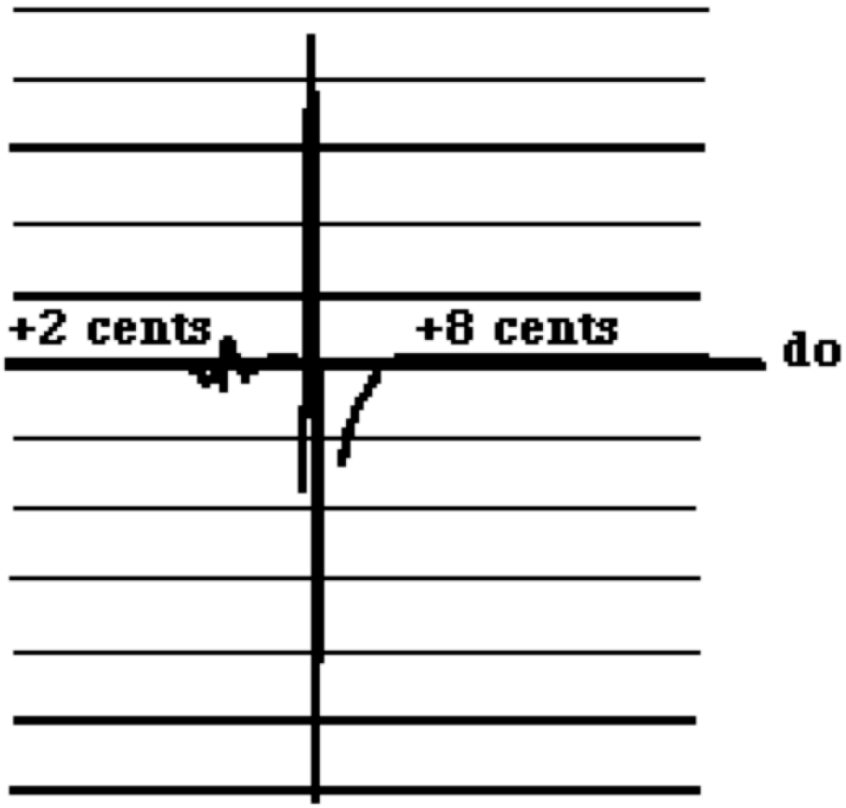


Fig.2 : *rāga Darbārī Kanaḍā*

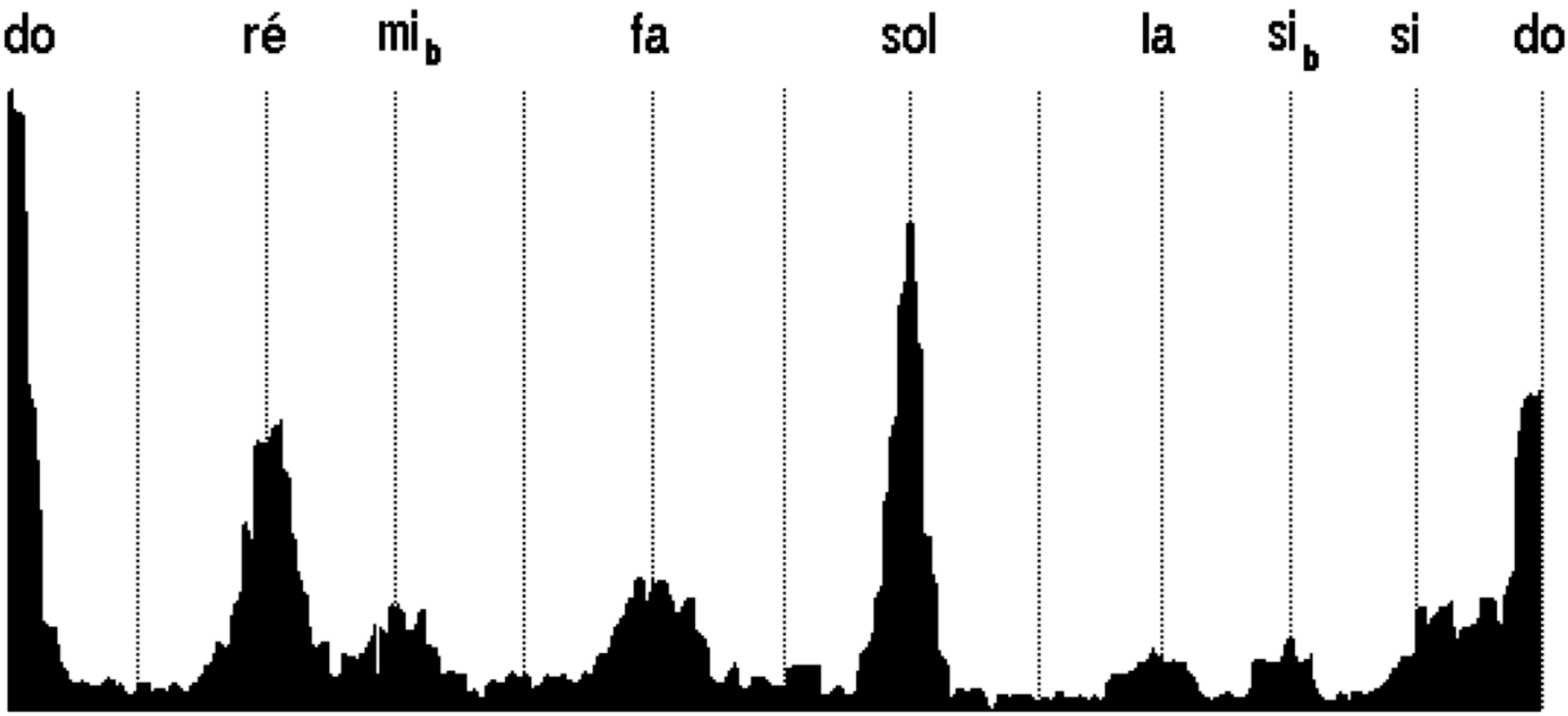


Fig.3 : tonagramme de *rāga Sindhūrā* chanté par Mme Bhupender Seetal

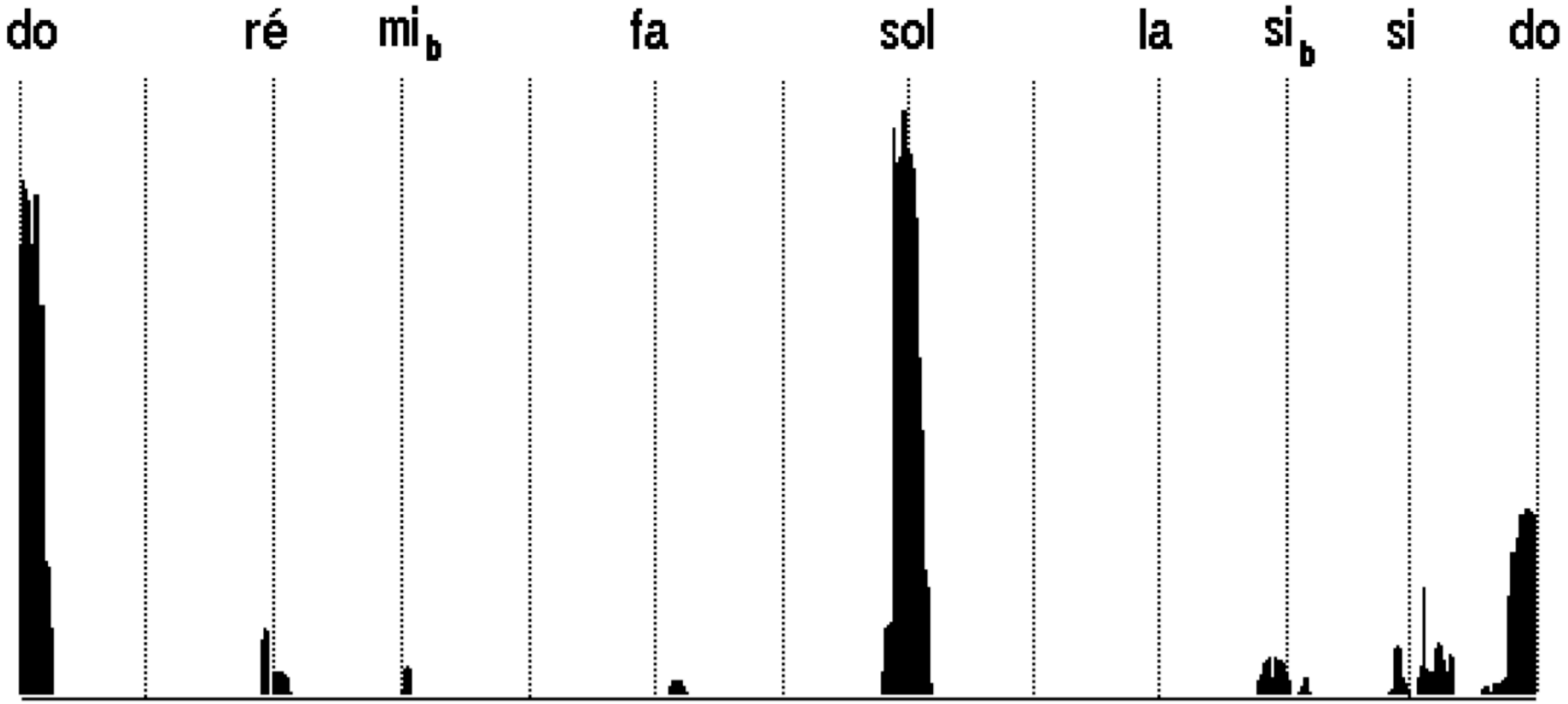


Fig.4 : tonagramme sélectif, *rāga Sindhūrā*

Fig.4: selective tonagram, rāga Sindhūrā

In a sense, the second window erases vibrato and the third selects the plateaus that characterise sustained notes, in total 9% of measurements for this example. The window parameters are adjusted according to the recordings. On the selective tonagram, we note the almost total disappearance of fa (0.3%) but a fairly clear characterisation of the positions of re, mib and sol. Nothing can be concluded about the other notes, however, as the tonagram was calculated without particular precaution: one must first carefully analyse the melograms and select interesting fragments taking into account different octaves and treatments

[68] Leipp 1977 p.182

particular: Z.M. Dagar, for example, often plays a 'medium' Sa which is about 4 cents lower than the drone's tonic.

12. Example of Measurement Interpretation

We give an overview of the comparative study concerning a very popular rāga: Toḍī, whose mode is do, reb, mib, fa#, sol, lab, si. (do here designates the tonic Sa.) Using the statistical methods described above, we have determined the following tonal positions:

Name	reb	mib	fa#	sol	lab	(lab)	sib
Mallikarjun Mansur chant	88	293	625	701	794	1095	?
Z.M. Dagar rudra vīṇā	93	293	600	702	785		1108
Faiyaz Khan chant	90	294	606	702	?	(810)	1104
Bismillah Khan shahnāī	99	303	617	705	?	(805)	1116
Kishori Amonkar chant	96	288	594	702	792	(810)	1110
Asad Ali Khan (1) rudra vīṇā	99	290	593	702	795	(802)	1105
Asad Ali Khan (2) shruti harmonium	100	294	606	702	794		1108
Bor-Van der Meer shruti harmonium	96	294	606	702	792	(804)	1110

The last two series of measurements are shruti harmonium tuning experiments by Asad Ali Khan and by Bor & Van der Meer. For lab we have distinguished two measurements: that of the lower octave (mandra saptak) governed by the phrase lab-si-do-reb-mib, and that of the middle octave (in brackets), where lab must individualise itself with a 'brilliant colour'. In this simplified example we shall not consider standard deviations.

First Interpretation

If one does not consider the (equivalent) concepts of consonance or tuning procedure (grāma), one considers, like (implicitly) Jairazbhoy and Levy, that all notes exist only through their relation to the tonic. One can therefore interpret the averages and standard deviations of tonal positions:

note	average	standard deviation
reb	95	4
mib	294	4
fa#	606	10
sol	702	1
lab	792	3
(lab)	(806)	(3)
si	1107	6

The greatest dispersion falls on fa#, very difficult to locate as it is barely suggested in melodic movements. The averages indicate marked tendencies of 'deviation' compared to the tempered scale: 100, 300, 600, 700, 800, 1100: reb, mib and lab somewhat 'low', and fa# and si somewhat 'high'. One must consider the attraction of the tonic (do) and the dominant (sol) of the drone (tānpūrā). One can estimate that si, reb, fa# and lab are defined in relation to these two centres using semitones of 93, 95, 96, 90 (96) cents.

Second Interpretation

For the sake of simplification, we shall use in the rest of this exposition only the measurements of lab in the lower octave. Does there exist a scale derived from Bharata's theory that could account for the measured intervals? The extension of Bharata's model that would generate Toḍī's mode amounts to 144 chromatic scales formed by two cycles of fifths offset by a major third whose dimension depends on the comma[69]. The measurement (in cents) of this third is (408-c), where c is the value of the comma in cents. At the extremities, the cycles extend mutually by two modal fifths measuring respectively (702-c) and (678+c). For each interpretation of Toḍī, one seeks the scale and comma value that best predict the intervals. We shall discuss here only the average values. The tuning schemes closest to the measurements (least squares criterion on intervals) are as follows:

Cycles de quintes	écart interv.	écart pos.	comma	numéro
si fa# **réb lab mib + + do sol**	3	1	6	(1)
réb lab mib + + do **sol + + + si fa#**	4	2	18	(2)
do sol + + + si fa# **réb lab mib**	4	2	5	(3)
mib + + do sol + + + si fa# **réb lab**	4	2	5	(4)

The second column indicates the average deviation (in cents) on intervals, the third that on positions relative to the tonic, and the following column the optimal comma value. One must keep in mind that this interpretation represents a harp tuning situation in the absence of the drone, and therefore cannot account for actual experimental conditions. It has the advantage of pointing towards a simple and complete abstract model. Solution (1) is the best provided one knows how to tune the Pythagorean minor third do-mib (3 successive descending fifths) and especially the third sol-si which equals 408-6 = 402 cents... Procedure (2) is a tour de force: starting from si, one tunes mib with a third of 408-18 = 390 cents, then fa#, lab, reb by fifths. The procedure becomes complicated when one must tune do from mib, as previously, then sol from si by four descending fifths (or a Pythagorean third), unless one is capable of spontaneously producing a modal third of 678+18 = 696 cents between do and sol! The only difficulties with procedure (3) are the thirds of 408-5 = 403 cents and the Pythagorean third sol-si as previously. As for solution (4), it is a variant of (3) in which one prefers to tune mib from do. Besides its relative simplicity, another reason to prefer solution (3) is that it produces a scale

[69] Bel 1985b

possessing the maximum number of internal consonances: see the rectangle do-sol-mib-lab-do.

Third Interpretation[70]

One now places oneself in the presence of the tānpūrā: do and sol are then fixed and necessarily consonant (do-sol = 702 cents), which eliminates procedures (1) and (2). It is not easy to follow procedure (3) because of the thirds lab-do and mib-sol. These intervals appear little in melodic movements and are difficult to evaluate. The reasoned solution is therefore to tune si first: the four successive fifths actually produce a Pythagorean limma (90 cents) which is easy to tune directly. One then tunes fa# at the fifth of si, mib a harmonic major third above si, and lab then reb by two descending fifths from mib. The scheme is therefore as follows:

			réb	lab	mib	
do	**sol**	**+**	**+**	**+**	**si**	**fa#**

in which si-mib is a true harmonic third of 386 cents (ratio 5/4). Under these conditions, fa#-reb is a modal fifth of 680 cents. How do musicians accommodate such an interval? Let us return to the tuning procedure above, and the values of the measured average intervals:

	do-sol	do-si	si-fa#	si-mib	la_b-mi_b	$ré_b$-la_b	fa#-$ré_b$
théorie	**702**	**90**	**702**	**386**	**702**	**702**	**680**
mesure	**702**	**93**	**699**	**387**	**702**	**697**	**689**

One sees that the proposed procedure is pertinent, but that musicians actually temper the fifths of the chain si-fa#-reb-lab in order to distribute the comma of the modal fifth.

In conclusion, we have already introduced, in addition to that of 'tonic', three concepts foreign to Bharata's theory: the harmonic major third as a consonant interval, the limma between a note and the tonic or dominant, and finally temperament which allows masking of modal fifths.

It would remain to interpret individual deviations from the model. Why for example is Bismillah Khan's mib noticeably higher than that of other musicians? The answer lies at the level of the inharmonicity of the shahnāī[71].

One conceives that the study of rāga intonation rests on the comparison of theoretical models possessing one or several degrees of freedom, allowing musicians to achieve acceptable compromises. For each rāga, the analysis should be completed by a tuning experiment with the musicians who provided the data.

The study we have undertaken[72] covers thirty hours of samples drawn from the most famous recordings, particularly in the domain of khayāl singing. To this must be added about a hundred rāga calanas sung and several hours

[70] Van der Meer, personal communication
[71] Bel 1985a
[72] in 1984 at the NCPA laboratory in Bombay

of demonstrations commented upon by the rudra vīṇā player Asad Ali Khan. We estimate despite this that this material is incomplete as it would be necessary, for each rāga, to have multiple interpretations by the same musician whilst taking into account stylistic differences (dhrupad/khayāl for example).

13. Notation and Automatic Transcription

Musical notation, even if it is regarded with condescension or even contempt by most musicians, is increasingly felt as an indispensable tool by teachers trained outside the traditional cocoon. Southern musicians have used it for two centuries, but for northern ones it is difficult to define a middle ground between the descriptive notations of ethnomusicologists and the skeletal notation (sargam) popularised by Bhatkhande. The system we have developed, by carefully comparing manual notation with the complete representation given by the MMA, is an extension of Bhatkhande's, to which we have added the representation of the principal note treatments[73]. Figure 5 presents a fragment of calana from rāga Āśā transcribed on the MMA melograph, notated on Western staff and in extended sargam (bottom line). One will note the very characteristic attack of notes in the ascending movement re-fa-sol:

Fig. 5: rāga Āśā, calana composed by D.C. Vedi (fragment)

It is possible to use the three windows that serve for filtering tonagrams to characterise note treatments, and thus achieve symbolic transcription of rāgas in extended sargam[74]. Automatic transcription is in our view the only one that can satisfy the enormous need for rāga documentation. The most recent version of the transcription software gives an error rate (compared to the best manual notations) of less than 3%. Part of the errors comes from the impossibility of fixing, independently of rāgas, thresholds for characterising phenomena: what is perceived as a mīṇḍ (portamento) in one rāga can be interpreted as an ordinary connection in another. What is interesting is that most of the

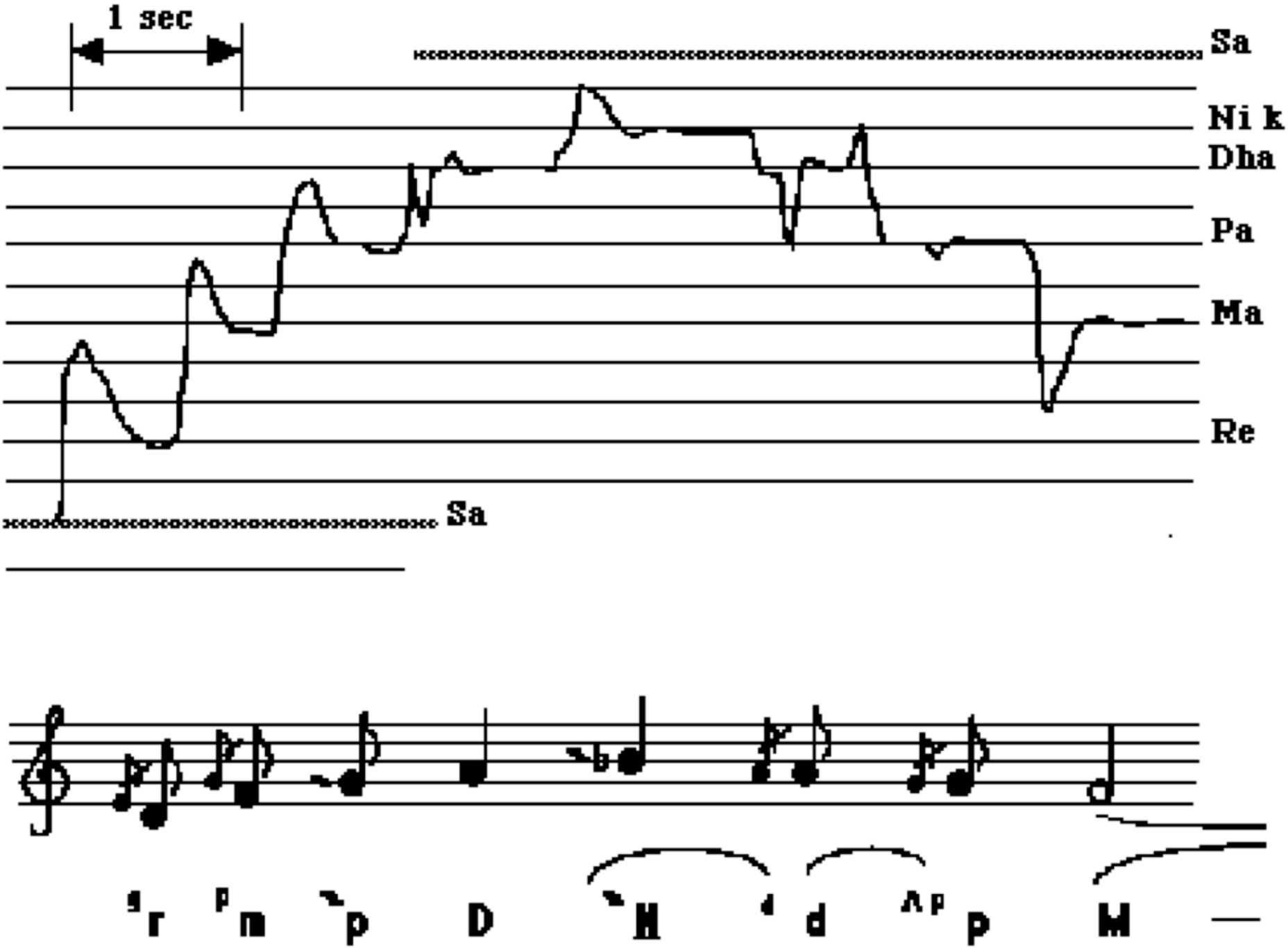


Fig. 5 : *rāga Āśa*, *calana* composé par D.C. Vedi (fragment)

[73] Bor, Arnold & Mott 1985

[74] Van der Meer & Bel 1986

recurring errors highlight presupposition phenomena: certain treatments are systematically noted (perceived?) even if they do not appear in automatic transcription. Others are ignored from the second occurrence. The gap between descriptive and prescriptive notations is consequently the best revealer of the influence of a mental image (for example, the entity 'rāga X') on the perception and interpretation of a sound reality.

Automatic transcription allows reduction of the sound continuum to a chain of symbols carrying discrete information: note names and principal melodic connections. These symbol chains can then be subjected to statistical treatment which gives, for each rāga, the distribution of phrase-beginning notes (graha), etc., as well as the most characteristic phrases (tānas)[75].

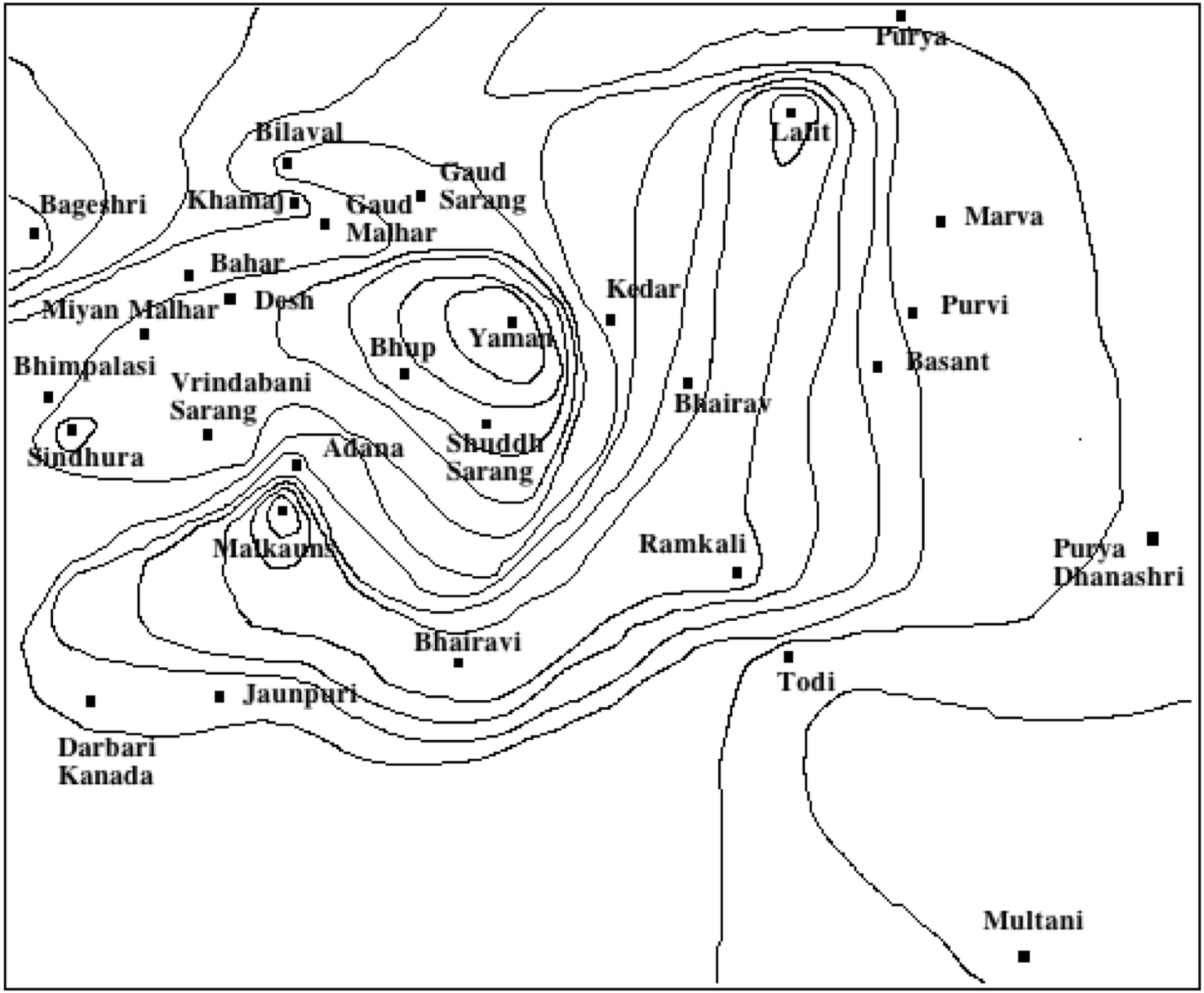
14. Automatic Classification of Rāgas

A classification method based on time-independent criteria has been experimented with by Van der Meer in collaboration with the author. Given two non-selective tonagrams, one evaluates a dissimilarity (or a distance) which is a function of Boolean attributes (presence/absence of a note) and an integral calculated on the two histograms. The integral takes into account possible offset of origins: two rāgas similar up to a transposition will therefore have a small dissimilarity. The coefficients that determine the relative importance of criteria have been adjusted experimentally. According to the viewpoint adopted, different representations are possible: in a metric space (classical/ multidimensional scaling), or on trees. Figure 6 represents a two-dimensional projection of the configuration of 30 rāgas in a 29-dimensional Euclidean space (classical scaling). The tonagrams were drawn from recordings of calanas whose average duration is of the order of two minutes. This result is interesting insofar as it shows, on one hand, that the information contained in tonagrams allows very pertinent groupings of rāgas, and on the other hand that the calanas used are sufficiently informative to discriminate rāgas even when limiting oneself to time-independent characteristics. Furthermore, we have observed that this type of classification highlighted well the resemblances and divergences of interpretation of the same rāga. Current work concerns taking into account time-dependent characteristics, operating from transcriptions.

15. Conclusion

An essential distinction of learned 'ethnic' musics (compared to folklore) is the interaction between practice and theory. A scientific approach implies observation of musical phenomena using increasingly sophisticated tools, whilst drawing from concepts conveyed by written and oral traditions. This methodology requires interdisciplinary collaboration and a long period of contact with the greatest expert musicians, directly involved in model development and results evaluation. Musical data processing techniques must respect the plurality, ambiguity and

[75] Van der Meer & Bel 1986


Purya
Lalit
Bilaval
Gaud Sarang
Bageshri
Khamaj
Gaud Malhar
Marva
Bahar
Kedar
Miyan Malhar
Desh
Purvi
Bhup
Yaman
Basant
Bhimpalasi
Vrindabani Sarang
Bhairav
Shuddh Sarang
Sindhura
Adana
Malkauns
Ramkali
Purya Dhanashri
Bhairavi
Todi
Jaunpuri
Darbari Kanada
Multani

incompleteness of interpretations. Musicologists like Jones, Willard, Tagore and Fétis, who had begun by studying Indian music for long years, showed a more scientific spirit than the presumed founders, at the end of the 19th century, of ethnomusicology[76].

Concerning rāgas, our objective is to enable the greatest number of music students, in India as elsewhere, to understand the principles of melodic organisation that characterise this musical system of considerable richness. For this we plan to publish a collection of the most important rāgas, essentially a compilation of melodic transcriptions (calanas) completed by data on essential characteristics (lakṣaṇas), historical aspects and their interpretations by the greatest musicians. The work will be completed by a series of recordings and educational software. A compilation was begun by ISTAR in New Delhi, within the framework of a documentation project directed by D.C. Vedi, but it has become possible today on a larger scale as new tools for data capture and processing have been developed for this purpose.

On the theoretical level, the study of a learned extra-European music allows importing numerous concepts foreign to classical musicology: melody classification, improvisation schemes, microtonal intonation and interval theories. Described abstractly, these concepts are transposable to other sound universes and can open the way to experimentation with new musical structures.

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[76] Bor 1988

[77] Thanks to Françoise Delvoye and Wim van der Meer for their numerous suggestions and corrections.