

PROJECT COMPLETION REPORT

**Analysis of Sound Spectrum of Mantras and their
Relation with Geometric Patterns of Yantras**

SUBMITTED BY

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PROJECT COMPLETION REPORT

One soft copy of the Project Completion Report should be submitted on email. The Report should consist of Part A - Summary Report and Part B - Comprehensive Report. The report should be on the Standard Format provided.

1. Project Title: Analysis of Sound Spectrum of Mantras and their Relation with Geometric Patterns of Yantras

2. Duration of Project: From 02/04/2022 To 31/12/2024

3. Focus Area: Chemical Engineering

4. Principal Investigator

Name: Anurag Tripathi

Organisation/Institution: Indian Institute of Technology Kanpur

5. Co-Principal Investigators

Name: Nachiketa Tiwari

Organisation/Institution: Indian Institute of Technology Kanpur

6. Collaborating Organisations

Organisation	Team Members	Activities/Tasks assigned
NIL	NIL	NIL

Part A - Summary Report

1. Project Objectives

Objective as per the approved Project	Fully Achieved /Partially Achieved (indicate shortfall)	Reason for Partial Achievement
To perform a detailed analysis of the sound spectrum of few select Mantras. Specific attention will be given to the Mantras whose deities which have some specific Yantra associated with them. The dominant Fourier frequencies corresponding to each Mantra will be obtained by spectrum analysis of the recorder sound waves.	Fully Achieved	
To use the identified frequencies to vibrate thin metal plates and investigate the effect of these individual frequencies on the plate vibration and pattern formation of the granular materials on these vibrating plates.	Fully achieved	
To investigate the effect of different combinations of the dominant Fourier frequencies obtained from the sound spectrum of Beej Mantras on the vibration and pattern formation.	Fully achieved	
To compare the patterns obtained from these dominant frequencies of the Mantras with the geometric patterns of corresponding Yantras and explore any relation/connection between the two.	Fully achieved	

2. Deliverables

Deliverables as per the approved Project	Fully/Partially/Not Achieved	Reason for Partial/ Non Achievement
1. Interaction with Vedic Scholars and collection of samples of recited Mantras	Fully achieved	
2. Conducting experiments to generate basic Chladni patterns using simple harmonic vibrations on thin plates of different shapes	Partially achieved	Only square shape plates were used. This is to enable comparison across different voices for the same plate.
3. Analysis of the sound spectrum of few select Beej Mantras and Identification of the dominant frequencies from Fourier analysis of the sound spectrum.	Fully achieved	
4. Experimental study of pattern formation on vibrated beds using	Fully achieved	

individual and combined effect of the dominant frequencies		
5. Image analysis of the patterns and comparative study of the geometric patterns of Yantras	Partially achieved	Patterns obtained were of good quality for direct visual comparison. Did not require any computational analysis to identify the patterns formed.
6. Analysis of the results and report writing	Fully achieved	

3. Specific Benefits/Outcome

(Please give details)

- Patent, if any : NIL
- Product/Process developed/ technology transferred : NIL
- List of Publications arising from the Project : NIL
- Linkages developed : With Vedic/Sanskrit Scholars in Dehradun, Prayag and Brahmavart for further collaboration

4. Manpower trained

- No. of Students based on the project: Two (Part time)
- No. of Master's Thesis/Reports: Zero
- Position and Number of Other Technical Staff Trained: One

5. Methodology (Minimum 250 Words):

Interactions with the Vedic Sanskrit scholars was undertaken for proper recitation of the selected *Mantras*. The chanting of the scholars were recorded and analysed to identify the ranges of frequencies over which the investigations need to be done. The collected voice samples were used for identification of the dominant Fourier frequency ranges.

Experimental setup to perform the vibrations of thin metal plates using simple harmonic vibrations was used in the first step. Using an existing setup in IITK, we successfully reproduced the well-known Chladni patterns at different frequencies. From the analysis of the collected audio samples, it was observed that using first the few dominant frequencies obtained from Fourier analysis was not sufficient to reproduce the audio signal accurately.

The existing experimental setup, used for obtaining Chladni pattern, which relied on using the amplitude and frequency as the input for vibration was found unsuitable for this analysis. To overcome this, an in-house setup was designed that permitted a complex audio signal to be directly given to the plate. This setup was used for vibrating the plate with the audio signal of different Mantras. Three different types of Chants were finally considered for experimentation. The first type considered included long, complex non-repeating chants or Sukta. The second type of chant involved a specific Mantra repeating over and over again. For this case, we used Gayatri Mantra chantings by Pt. Shriram Sharma Acharya ji, founder of All World Gayatri Parivar. The third type of Mantras considered were of smaller lengths and typically had beginning with Pranavakshar and ending with Namah. The Beej mantra of the specific deity and his name with appropriate Sanskrit suffix formed the central part of the mantra. Specifically, chants for Ganapati, Durga Devi, Shiva, Narayana, Rudra, Vishnu and Hanumana was explored. These Mantras were repeated over multiple cycles. The patterns formed by using the recorded audio signals were checked for repeatability and reproducibility.

•Salient Research Achievements:

A new setup was designed to permit direct input of complex audio signals. This allowed us to avoid the approximation of the chant by using only a few frequencies that could be used by the readymade setup available in market.

•New Observations (minimum 200 words):

1. For very low amplifications of the chanting, no motion of the sand on the vibrating plate was observed. With increase in amplification (using an external amplifier), the sand particles on the plate start to slowly move and rearrange. For very high volumes, the chanting becomes significantly distorted. In addition, the inertia of the sand and its uneven distribution on the plate starts to affect the vibrations of the plate.
2. Fourier Analysis of the recorded chants from different scholar revealed that the frequency ranges for most of the recorded voice samples lie in between approximately 100 Hz to 1500 Hz. Frequencies below 100 Hz and above 2000 Hz have very little FFT amplitude. While ignoring these frequencies did lead somewhat change of the audio, its essence was well retained by using only frequencies within this range.
3. A correct reconstruction of the chant requires using a significantly large number of the frequencies. Using only few dominant Fourier frequencies was NOT sufficient to reproduce the essential features of the audio.
4. All types of chants gave rise to nearly steady pattern after some initial time. After this initial time, the patterns seem to evolve very slowly and could be considered nearly steady. Such nearly steady patterns were observed for various Deity namaskar Mantras as well. These patterns included straight lines, circular arcs, circles, and triangles. Many of the patterns formed could be related to the Chladni patterns obtained by vibrating the plate sinusoidally at different frequencies.
5. The same chant, when recited by different scholars, produced different pattern. Hence it appears that the pattern formed does depend on the person who is reciting the chant. Some chants, on the other hand, did show nearly similar looking patterns despite being recited by different scholars. Thus a complex dependency of the pattern on the chant itself as well as the speaker is observed.
6. However, a common pattern that seems to emerge from multiple situations is the pattern with a circle in the center and four arcs around the corners. Most of the other patterns may be considered a diffused variant of the same pattern. This pattern corresponds to the Chladni pattern observed at the frequency of around 360 Hz for the aluminum plate used in these experiments.
7. Given the dependency of the chant on the person's voice, no apparent relation of the patterns formed could be found from the geometric patterns of the Yantras of the corresponding Deities.

•Innovations (Give bulleted list):

1. Designed an In-house thin plate vibration setup using a loud-speaker and amplifier to permit direct input of complex audio signals.
2. Successfully generated Chladni patterns with a much cheaper setup.
3. Obtained reproducible patterns for chanting using for a given Scholar's voice.

6. Indication of scope for future work (Maximum 300 Words):

A large amount of data has been generated during the current project. Various interesting patterns have been observed for the sand on vibrating plate by using different chants. In future, we wish to explore the effect of the vibration of the chants on a thin film of liquid. A vibration setup capable of vibrating small amounts of liquid has also been fabricated in this regard and will be explored in future.

7. Procurement/Usage of Equipment:

Sr.	Name of Equipment	Make/ Model	Cost (Rs.)	Date of Purchase & Installation	Remarks
1	Audio Speaker (1500W)	Purchased from local market	12,000	Oct. 2022	Part of equip 1: Chladni setup with vibration sources. Broke-down during experiments for high volumes.
2	Audio Speaker (1800W)	Purchased from local market	20,000	Oct. 2022	Part of equip 1: Chladni setup with vibration sources
3	Transistor with amplifier and speaker	JVD brand purchased from local market	6,700	Oct. 2022	Part of equip 2: Sound recorder and amplifier
4	WIRELESS GO II SINGLE-CHANNEL WIRELESS MICROPHONE SYSTEM	RODE (Amazon)	21,989	30 th Dec. 2022	Part of equip 2: Sound recorder and amplifier
5.	Sound Proof Box	Fabricated by local vendor	14,000	Oct. 2022	Part of equip 1: Chladni setup with vibration sources
6	Desktop	HP Desktop with Intel core i7 10700	97,393	13th Nov. 2023	Part of equip 3: Desktop and Laptop
7	Laptop	HP Intel Core i5 Laptop	73,667	20 th Nov. 2023	Part of equip 3: Desktop and Laptop
8	Liquid Vibration Setup	Fabricated by local vendor	24,890	Oct. 2023	Part of equip 1: Chladni setup with vibration sources
9	Powder Vibration Setup	Fabricated by local vendor	24,160	Oct. 2023	Part of equip 1: Chladni setup with vibration sources
10	Wireless Projector	Benq GS50	73,202	Mar. 2024	Part of equip 1: Chladni setup with vibration sources
11	Hard disk sata 2TB	Purchased from local vendor	6,744	16 th Dec 2024	Part of equip 3: Desktop and Laptop.

Part B –Comprehensive Report

(The Comprehensive Report should be precise in detail and self-contained)

1. Project Title Analysis of Sound Spectrum of Mantras and their Relation with Geometric Patterns of Yantras

2. Literature Review

Geometric patterns on thin metal plates were observed by Ernst Chladni long back in 1787 [1]. These patterns, referred to as ‘Chladni patterns’, have been repeatedly observed by researchers by vibrating the metal plates harmonically at certain frequencies [2]. Some researchers have even suggested controlling the motion of multiple objects on a Chladni plate [3]. However, it is not clear whether any consistent geometric patterns can be observed by using more complex real life audio signals on the vibrated plates. Specifically, utilisation of audio sound of few selected Mantras from the Indian tradition and their effect on the pattern formation on thin solid plates has not been investigated. Some commonly used geometrical patterns in Yantras are listed in [4]. These geometrical patterns include Shiva and Shakti triangles, round and pointed petal lotus consisting of circles and arcs. However, whether such geometric patterns of Yantra for a particular Deity have any connection with the frequencies of the Namaskar Mantra associated with the Deity has not been investigated before to the best of our knowledge.

3. Methodology adopted for Development of the Product/Process in the Research Project

(State briefly in 800 words)

Interactions with the Vedic Sanskrit scholars was undertaken for proper recitation of the selected *Mantras*. The chanting of the scholars were recorded and analysed to identify the ranges of frequencies over which the investigations need to be done. The collected voice samples were used for identification of the dominant Fourier frequency ranges. Experimental setup to perform the vibrations of thin metal plates using simple harmonic vibrations was used in the first step. Using an existing setup in IITK, we successfully reproduced the well-known Chladni patterns at different frequencies.

From the analysis of the collected audio samples, it was observed that using first the few dominant frequencies obtained from Fourier analysis was not sufficient to reproduce the audio signal accurately. In fact, a large number of frequencies were needed to correctly reproduce the audio signal of a single syllable. Further, despite using multiple frequencies, the reproduction of the audio was found to be of accuracy. The existing experimental setup, used for obtaining Chladni pattern, which relied on using the amplitude and frequency as the input for vibration was found unsuitable for this analysis.

To overcome this, an in-house setup was designed that permitted a complex audio signal to be directly given to the plate. This setup was used for vibrating the plate with the audio signal of different Mantras. Three different types of Chants were finally considered for experimentation. The first type considered included long, complex non-repeating chants or Sukta. Specifically, Sri Rudram Namakam chant from Yajurveda, recited by Vedic Scholar K. Suresh and his team (available on youtube) was used for the first type. The second type of chant involved a specific Mantra repeating over and over again. For this case, we used Gayatri Mantra chantings by Pt. Shriram Sharma Acharya ji, founder of All World Gayatri Parivar. The chant was fed to the vibration setup and repeated over and over again to see if any pattern emerges from the vibrations of the Gayatri Mantra. In both these cases, a steady pattern was formed after few minutes.

The third type of Mantras considered were of smaller lengths and typically had beginning with Pranavakshar and ending with Namah. The Beej mantra of the specific deity and his name with appropriate Sanskrit suffix formed the central part of the mantra. Specifically, chants for Ganapati, Durga Devi, Shiva, Narayana, Rudra, Vishnu and Hanumana was explored. In addition, we also used the Nama japa of Shri Ram. These Mantras were repeated over multiple cycles. A range of different amplification volume levels were considered for each of these chants and each experiment was repeated minimum two or three times. These third type of Mantras were recorded in the voice of different Sanskrit scholars and the patterns emerged were compared with each other. In addition, the patterns for the Durga yantra, Ganesh Yantra and Rudra Yantra were compared with corresponding patterns obtained from the namaskar chants for these Deities.

4. Description of the any Product/Process developed during the project

An in-house experimental setup permitting direct input of complex audio signals to vibrate thin plates for exploring patterns formation due to such complex signals was designed and built.

5. Outputs & Outcomes:

a. Technology Development

- Technology developed at Lab scale/pilot scale/commercial scale: Lab Scale development of inhouse vibrating setup for direct input of complex audio-signals for vibration of thin plates
- Technology demonstration in field setup - No
- Technology Transfer to industry: No
- Buyers/End users of product: None
- Affordability: NA

b. Knowledge Creation

- Patent filings: None
- Participation in conference/ training workshops attended: None

c. Knowledge Dissemination

- Describe the strategies used to disseminate the research findings and knowledge. • Examples of dissemination methods:
 - i. Conference presentations: None
 - ii. Workshops and training sessions: NA
 - iii. Online resources (websites, open access repositories): In preparation
 - iv. List of Courses developed: NA
 - v. Social media/other media outreach: NA

d . Publications

Type of Publications	Number of Publications	List of Publications	Authors & Co-Authors	Theme of the publication	References
Research Papers	0				
Books	0				

Articles	0				
Poster presentations	0				
Journals published through IKS center / Project	0				
Magazines	0				

e. Describe How the project resulted in integration of IKS and Contemporary knowledge

The project utilised the contemporary knowledge from the domain of mechanical engineering dealing with pattern formation on thin plates during their vibration with that of Deity Namaskaram chant audios recorded from Sanskrit Scholars. It revealed interesting pattern formation due to these chants. The reason behind these pattern formation is yet to be deciphered and will be explored in future.

f. Knowledge Repository

NA

g. Capacity building

- Officers/faculty: Great exposure for the PI about various Sanskrit scholars teaching and research work
- Temporary manpower recruited/trained: Two part time students and one full time staff was trained

h. Results & Analysis with figures

Chladni patterns were successfully reproduced using a simple harmonic vibrator available at IITK. As mentioned in literature, the patterns were observed only for select few frequencies. Simple sinusoidal vibration using a modal vertical shaker to a thin metal plate give rise to pattern formation only at a few specific frequencies. These patterns correspond to Chladni patterns for a vibrated square plate. Few such patterns obtained for a square aluminium plate are shown below in Fig. 1.

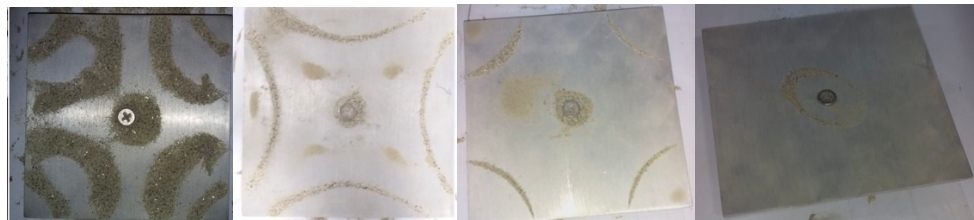


Fig. 1: Patterns obtained on an aluminum plate (10cm x 10cm) at different frequencies using a Modal shaker.

Fast Fourier Transform (FFT) analysis of the audio signal of few often-used syllables (see Fig. 2) as well recorded chants from different scholars (see Fig. 3) were done. The relevant frequencies were found to lie within the range of 100Hz-2000Hz. Frequencies above and below this range had amplitudes much smaller than the dominant ones. Hence we conclude that frequencies larger than 2000 Hz may not play important role in the chants and the overall analysis. While ignoring these frequencies did lead somewhat change of the audio, its essence was well retained by using only frequencies with in this range. However, within this limited range itself, many frequencies have amplitudes that are not negligible compared to the few (around 6 to 10) dominant ones.

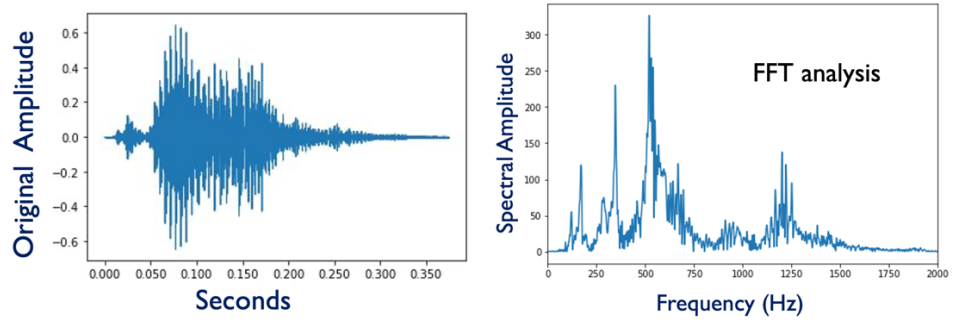


Fig. 2: Original audio signal (left) and FFT (right) of syllable 'ka' uttered by a volunteer.

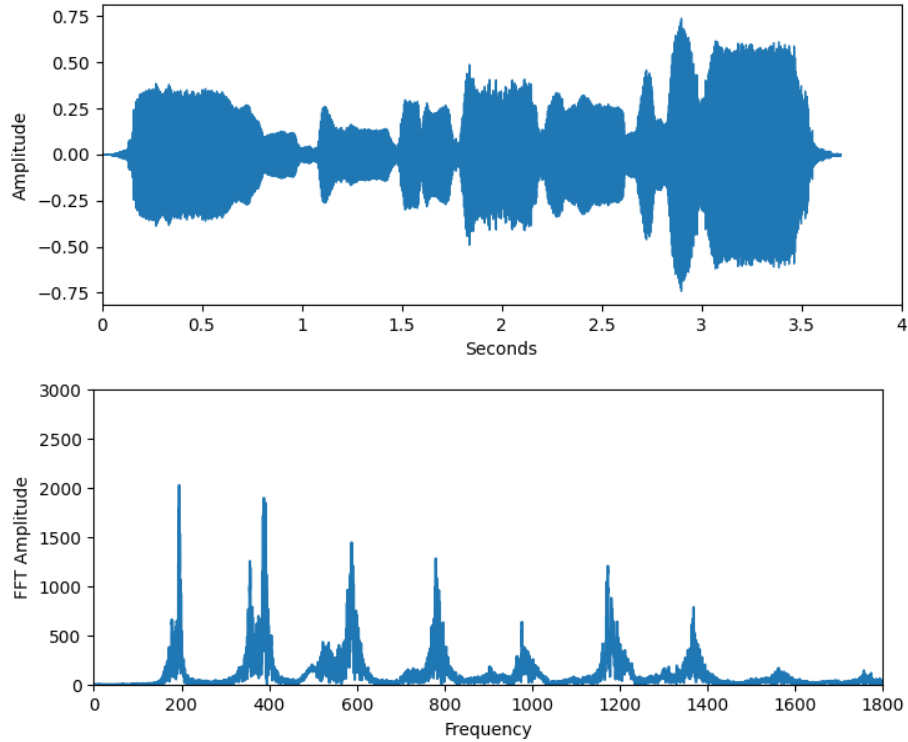


Fig. 3: Original Audio signal (top) and FFT (bottom) of Durga Devi Namaskar Chant recited by an Acharya of Shukla-Yajurved Madhyami Shakha.

A correct reconstruction of the chant requires using a significantly large number of the frequencies. Using only few dominant Fourier frequencies was NOT sufficient to reproduce the essential features of the audio. Due to this limitation, the idea of using the only a first few dominant frequencies could not be used as it lead to huge loss of information from the audio signal. In order to facilitate input of the complex audio without any distortion for vibrating the plates, an inhouse setup (shown in Fig. 4) was designed by attaching a thin aluminium plate to a speaker. The new designed setup was able to successfully reproduce the Chladni patterns for different frequencies as shown in figure 4.

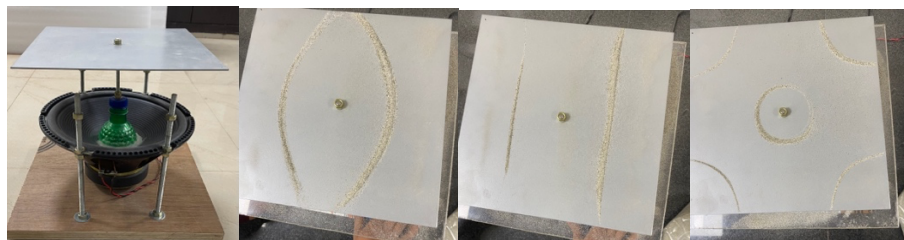


Fig. 4: Patterns obtained on an aluminum plate (25cm x 25cm) at different frequencies using inhouse vibration setup (shown in the left).

This setup was used for vibrating the aluminium plate with the audio signal recorded from different scholars. These recorded audios were then directly used as input to vibrate the thin aluminium plate at different amplifications by using an amplifier. As expected, for very low amplifications of the recorded chanting, no motion of the sand on the vibrating plate was observed. With increase in amplification (using an external amplifier), the sand particles on the plate start to slowly move and rearrange. For very high volumes, the chanting becomes significantly distorted. In addition, the inertia of the sand and its uneven distribution on the plate starts to affect the vibrations of the plate.

Three different types of Chants were considered for experimentation. The first type considered included long, complex non-repeating chants or Sukta. Specifically, Sri Rudram Namakam chant from Yajurveda, recited by Vedic Scholar K. Suresh and his team (available on youtube) was used for the first type and a steady patterns was observed after around 3 minutes which seemed to evolve very slowly after that. Fig. 5 shows the snapshot Complex chant of First type i.e., of Namakam gave rise to a nearly steady pattern after around 3 minutes which then seems to evolve very slowly. Time snapshots obtained for this chant are shown below in fig. 5.

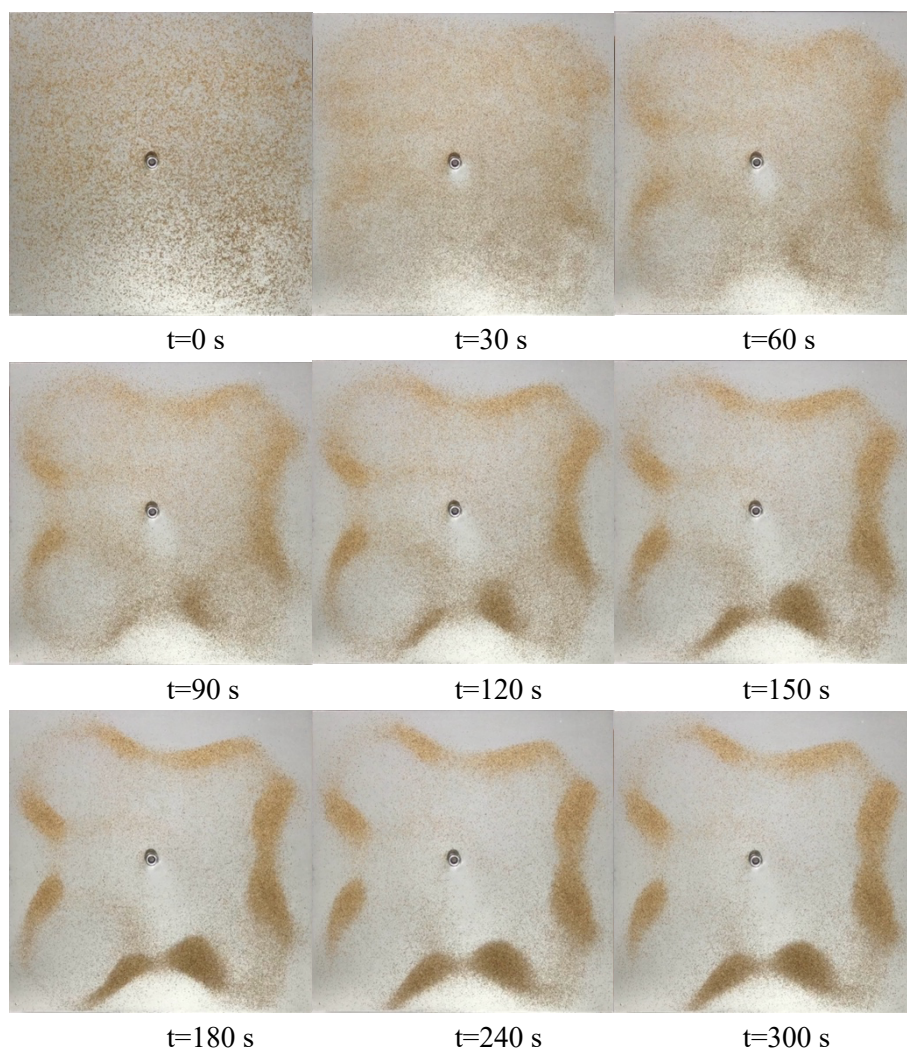


Fig. 5: Patterns obtained on an aluminum plate by Sri-Rudram Namakam Chant from Yajurveda.

Second type included a Complex chant such as that of *Gayatri mantra* which was repeated over multiple times to see if it leads to any pattern formation. This chant also gave rise to a nearly steady pattern after some initial time which then seems to evolve very slowly. The initial and final time snapshots obtained for this chant are shown below.

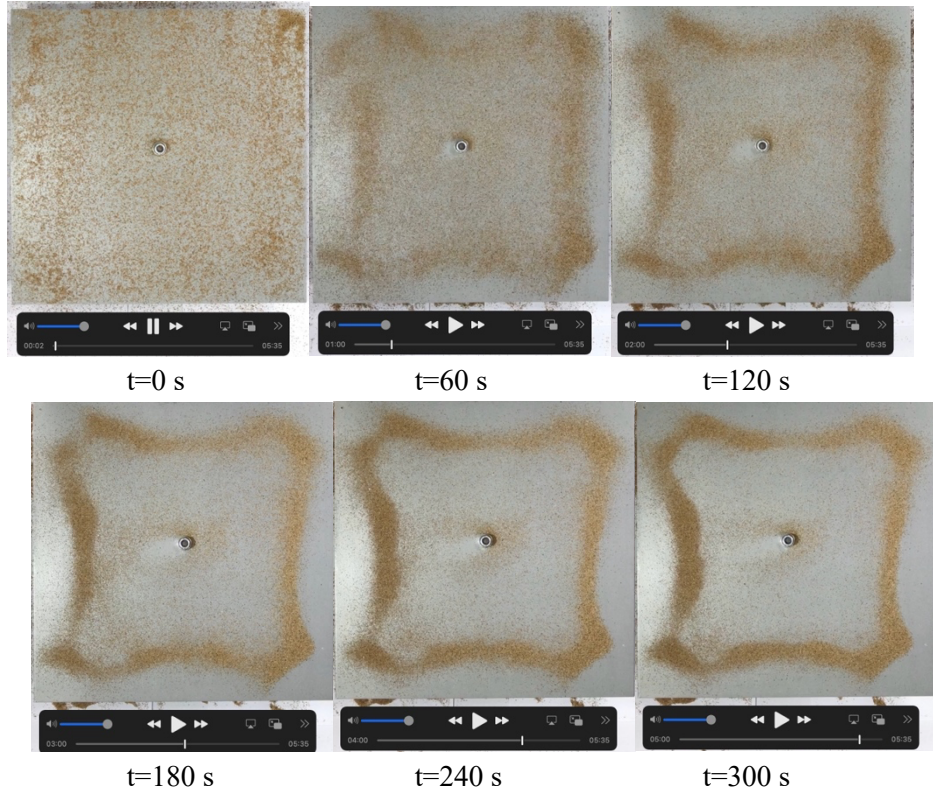


Fig. 6: Patterns obtained on an aluminum plate by *Gayatri Mantra*.

The third type of chants involved Deity specific *mantra*. For the sake of brevity, only the final patterns obtained by these chants are given below for each case. In all the cases, the initial condition was randomly sprinkled sand on the plate as shown for $t=0$ case in figures 5 and 6. These chants were obtained from YouTube videos without any background music.

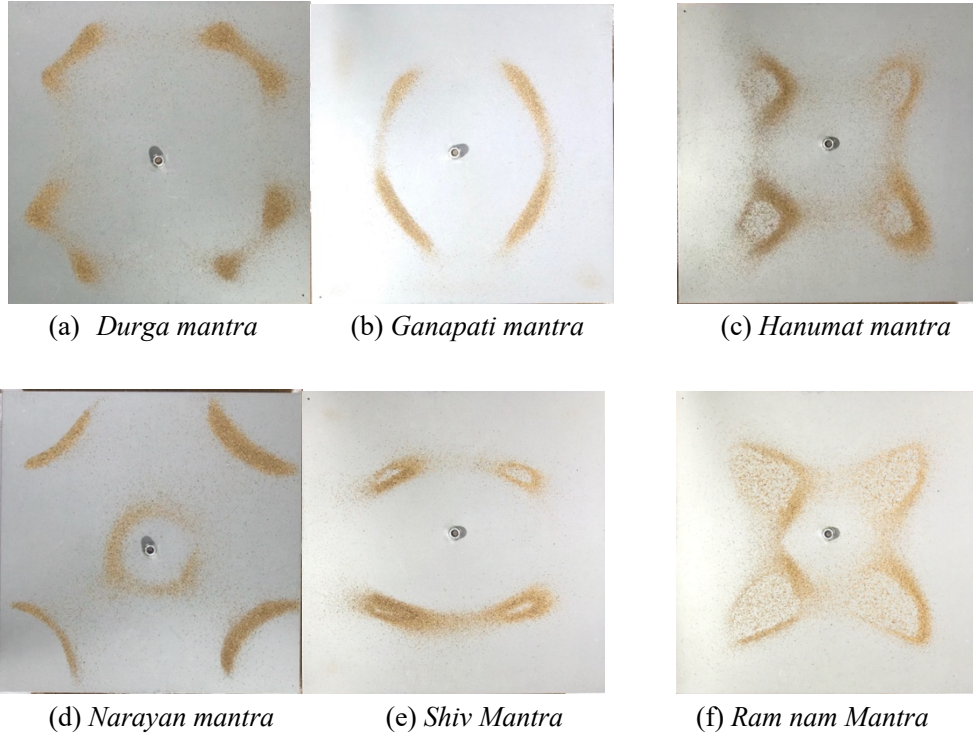


Fig 7: Patterns formed due to the chanting of Deity specific *mantra*. Note that the patterns formed are sensitive to the person chanting and the same pattern may or may not be observed when some other voice is used for the same Mantra.

These Deity specific chants were then again recited by Sanskrit scholars who were contacted by our team. The scholars from different places were contacted for this. Specifically, we have collected chants of some specific Mantras from Vedic Sanskrit Scholars from Gaziabad, Devprayag,

Brahmavart and Prayagraj. It was ensured that the same Mantra was chanted by at least two scholars to facilitate the comparison of the patterns obtained by using their respective chants. A detailed analysis of the same audio obtained from different scholars was done and the patterns formed on the plate due to their recitation were compared. An example of the same is shown in the figure below. The Hanumat Mantra (*Om Ham Hanumate Namah*) was chanted by three different scholars. The audio signal for the same is shown in first column of figure. The FFT analysis of the chants show that the dominant frequencies for the three scholars are not same. However, the pattern formed from the three audio signals does seem to resemble significantly with each other. Interestingly, the audio signal from the Youtube Hanumat mantra chanting showed a different pattern. Further, the patterns observed below somewhat resemble to the Narayana Mantra (showing a circle and four arcs). These patterns appear to be a diffused form of the Chladni pattern obtained from Sinusoidal vibration of the plate near 360 Hz as shown in figure 4 (right). While a peak close to 360 Hz is observable in all the cases, the peaks at other frequencies are also observable which in some cases have larger amplitude than the peak corresponding to 360 Hz.

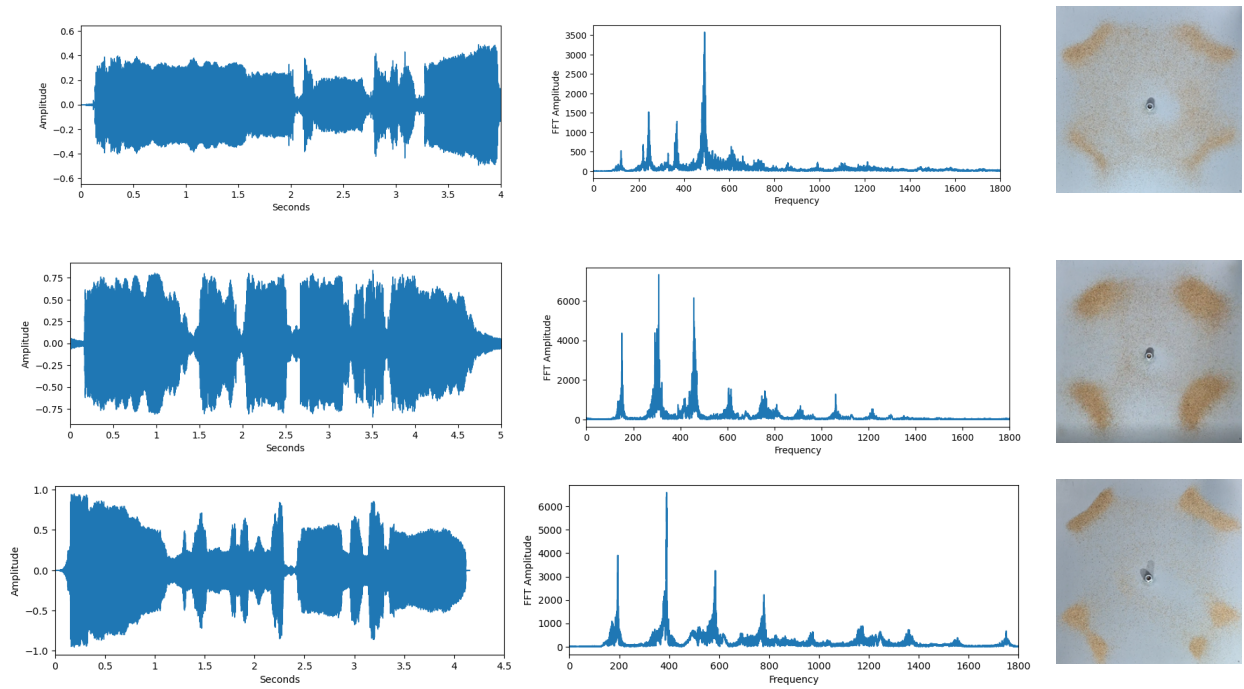


Fig 8: Audio signal (Left column), Fourier frequency decomposition (middle column) and the final pattern formed (right column) due to the chanting of Deity specific *mantra* (*Hanumat Mantra*) by three different scholars.

A more careful comparison by using the same Mantra chant using different scholar revealed that the patterns were also sensitive to the voice of the scholar and not just to the chant itself. The patterns obtained for the same scholar's voice across different Mantra chants is reported in figure 9 for a given scholar in each row. Three different rows correspond to chants from three different scholars. Each column corresponds to a particular Mantra. The first four columns correspond to Namaskar chants for lord Ganapati, lord Hanuman, Lord Shiva, Devi Durga. The last column corresponds to Mahamrityunjay mantra. While there is some common signature for each column, the similarity across each row is also evident. In some cases, the patterns for different mantras seem to correspond more closely to each other than that for the same Mantra. For example, the patterns for last two columns of first row correspond more closely to the first two columns of the last row despite the difference in the mantra being chanted and the person chanting the mantra as well. These results indicate a complex interplay of the chanted Mantra as well as the role of the person chanting the Mantra. However, a common pattern that seems to emerge from multiple situations is the pattern with a circle in the center and four arcs around the corners. Most of the other patterns may be considered a diffused variant of the same pattern. This pattern corresponds to the Chladni pattern observed at the

frequency of around 360 Hz for the aluminum plate used in these experiments. More detailed analysis of the obtained results is needed to identify the cause for the same.

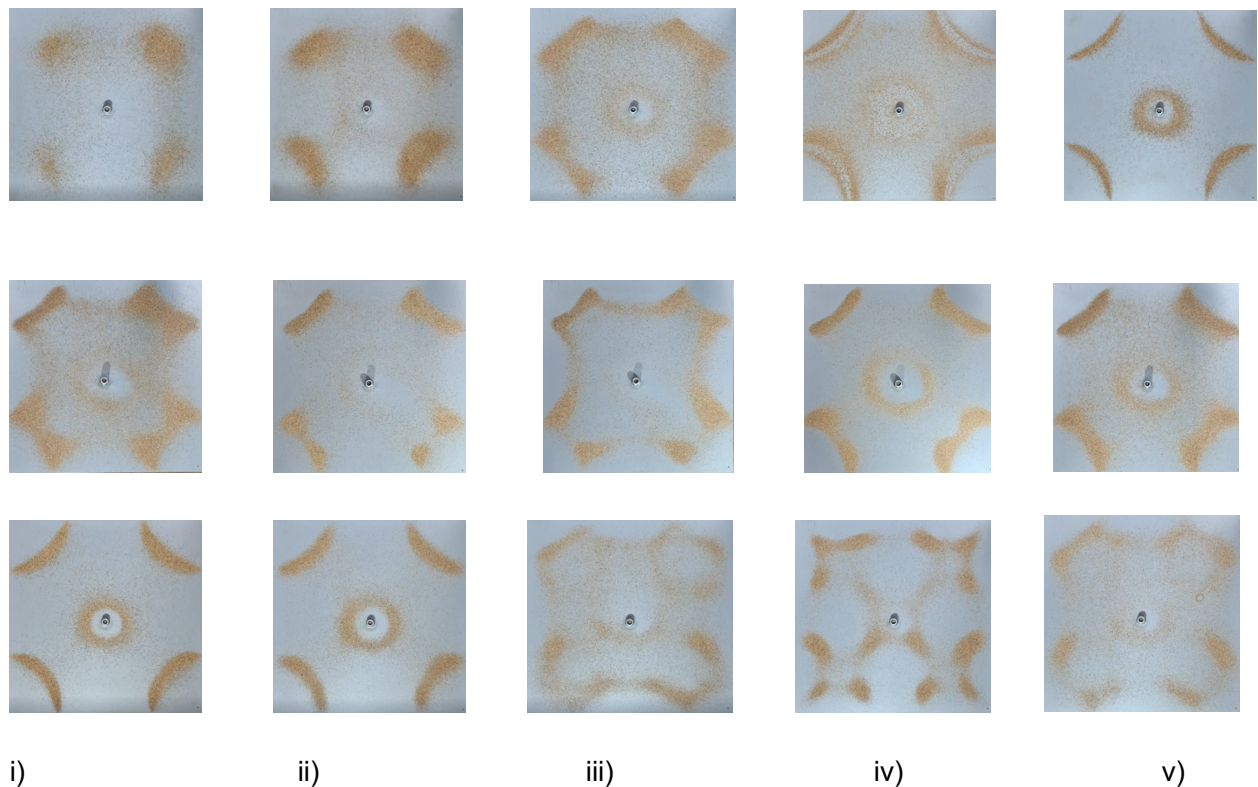


Fig. 9: Patterns obtained from the chanting of Vedic Sanskrit Scholar from Gaziabad (top row) and Devprayag (middle row) and Prayagraj (bottom row) after repeated plate vibrations using the complete audio signal. First to last column denote the patterns formed due to the Deity Mantra for i) Lord Ganapati, ii) Lord Hanumana, iii) Lord Shiva, iv) Devi Durga and that obtained from v) MahaMrityunjaya mantra.

i. Achievements/ highlights of the project

An in-house experimental setup permitting direct input of complex audio signals to vibrate thin plates for exploring patterns formation due to such complex signals was designed and built.

Various interesting patterns are observed for different chants which seem to depend on the chant as well as on the voice of the scholar. A common pattern that seems to emerge from multiple situations is the pattern with a circle in the center and four arcs around the corners. This pattern corresponds to the Chladni pattern observed at the frequency of around 360 Hz for the aluminum plate used in these experiments.

j. References

- [1] Chladni, E.F.F. Entdeckungen über Die Theorie des Klanges; Leipzig, Germany, 1787. Excerpts translated by R.B. Lindsay, *in* Acoustics: Historical and Philosophical Development, PA, 1973.
- [2] Kovacic, I.; Kanovic, Z. Chladni Plate in Anechoic Chamber: Symmetry in Vibrational and Acoustic Response. *Symmetry* **2023**, *15*, 1748. <https://doi.org/10.3390/sym15091748>.
- [3] Zhou, Q., Sariola, V., Latifi, K. *et al.* Controlling the motion of multiple objects on a Chladni plate. *Nat Commun* **7**, 12764 (2016). <https://doi.org/10.1038/ncomms12764>
- [4] K. Ramasubramanian, "Yantras or Mystic Diagrams: A Wide Area for Study in Ancient and Medieval Indian Mathematics", *in* Gaṇitānanda, Selected Works of Radha Charan Gupta on History of Mathematics, Springer (2019), 227-262.

k. Appendices

- NA

l. Project Outcomes Contribution to (Bullet points. No more than 250 words in each category)

- Dṛṣṭi: Results obtained in the project establish that utilization of modern scientific and engineering tools for exploring traditional knowledge reveals new insights and opens up avenues for new research problems.
- Jñāna: New information and observations about pattern formation on thin vibrated plates due to complex audio inputs instead of simple harmonic input.
- Laukika-prayojana: The methodology and the experimental setup built in this project opens-up the possibility of exploring the effect of complex audio signals having a combination of multiple frequencies on the vibration behaviour of thin plates.

Name of PI

Anurag Tripathi



Signature

Name of Co-PI

Nachiketa Tiwari

Signature

Head of the Institution

Dean R&D

Signature