Evaluative Report of Harish-Chandra Research Institute

1. Name of the CI

Harish-Chandra Research Institute (HRI), Allahabad.

2. Year of establishment

The Institute was founded as the **Mehta Research Institute** in 1965, with an endowment from the B.S. Mehta Trust, Calcutta. Till October 10, 2000, the Institute was known as Mehta Research Institute of Mathematics and Mathematical Physics (MRI) after which it was renamed as Harish-Chandra Research Institute (HRI) after the internationally acclaimed mathematician, late Prof. Harish-Chandra.

3. Is the CI part of the university

Yes

4. Names of programmes offered

HRI offers Integrated Ph.D. and Ph.D. in Physical Sciences and Mathematics. Please see Appendix 1 of the "profile."

5. Interdisciplinary programmes

None.

6. Courses in collaboration with other universities, industries, foreign institutions, etc.

Doctoral Students can work under joint supervision of two guides, where one guide is from one of the collaborating institutions with whom HBNI has a formal MOU. In addition, students can also attend credit courses offered at collaborating institutions.

7. Details of programmes discontinued, if any, with reasons

NIL

8. Examination System

Semester system

9. Participation of the department in the courses offered by other departments

Faculty/students of HRI sometimes participate in teaching/coursework

in other departments (CIs) of HBNI.

10. **Number of teaching posts sanctioned, filled and actual (Professors/Associate Professors/Asst. Professors/others)**

Please see para 24 of the Profile.

11. **Faculty profile with name, qualification, designation, area of specialization, experience and research under guidance**

Please see Appendix 1

12. **List of senior Visiting Fellows, adjunct faculty, emeritus professors**

Please see para 26 of the 'Profile'.

13. **Percentage of classes taken by temporary faculty – programme-wise information :**

NIL

14. **Programme-wise Student Teacher Ratio :**

3:2 for lectures. For doctoral students norm of maximum 8 students per faculty is strictly followed.

15. **Number of academic support staff (technical) and administrative staff: sanctioned, filled and actual**

Please see para 24 of the 'Profile'.

16. **Research thrust areas as recognized by major funding agencies**

All the major areas of theoretical physics and mathematics. For theoretical physics these include string theory, high energy phenomenology, condensed matter physics, quantum information and computation, and astrophysics. Several of these groups make use of high performance computing. For mathematics the areas are number theory, geometry and topology, analysis, and algebra.

Funding in all these areas of R&D activities is provided by the Department of Atomic Energy.

For more details, please see para 3.1 of the 'Criteria-wise Inputs'.

17. **Number of faculty with ongoing projects from a) national b) international funding agencies and c) Total grants received. Give**

the names of the funding agencies, project title and grants received project-wise.

Full funding is received from the Department of Atomic Energy and all the faculties are involved in one or more projects. Details of ongoing projects and grants for HRI put together are given in Appendix 2.

18. Inter-institutional collaborative projects and associated grants received

Please see Appendix 2.

19. Projects funded by DST-FIST; UGC-SAP/CAS, DPE; DBT, ICSSR, AICTE, etc.; total grants received.

More than 95% of our funds come from the DAE. There are a few small projects supported by the DST, CSIR, etc.

20. Research facility / centre with

- **state recognition**
- **national recognition**
- **international recognition**

HRI is a theory institute so there are no laboratories in the usual sense. However, there are several state of the art facilities. These include the high performance computing (HPC) centre, the regional centre for accelerator based particle physics (RECAPP), and a computing facility for research on neutrino physics.

21. Special research laboratories sponsored by / created by industry or corporate bodies

The facilities at HRI are funded entirely by the Government of India through the DAE. Some of the work, e.g, on nanomaterials or quantum computation, has long term implications in technology development.

22. Publications:

Please see para 3.3 of the 'Criteria-wise inputs'.
Average Citation per publication: 7.03
Average Impact Factor per publication for HRI (AIF): 3.77
h-index for HRI is 26.

23. Details of patents

We are a theoretical research institute and do not have experimental/research laboratories and so no patents.

24. Areas of consultancy and income generated

Not applicable. Please see para 3.4 of the 'Criteria-wise Inputs'.

25. Faculty selected nationally/ internationally to visit other laboratories/ institutions/ industries in India and abroad

Visits within India are very large. For visits abroad, please see Appendix 4.

26. Faculty serving in

a) National committees b) International committees c) Editorial Boards d) any other (please specify)

Please see Appendix 3 of the 'Criteria-wise Inputs.

27. Faculty recharging strategies (UGC, ASC, Refresher / orientation programs, workshops, training programs and similar programs).

HRI inspires and supports its faculty to participate in and organise national and international workshops and conferences, visit universities abroad for short term research assignments, to participate in collaborative projects with universities in India and abroad. All these steps help to recharge the faculty members and motivate them.

28. Student projects :

- **percentage of students who have done in-house projects: 100%**

(100 % of our students, both post BSc and post MSc do some project work during the coursework phase, before formally taking up research.)

- **percentage of students doing projects in collaboration with other universities/ industry/ institute:** 0%**.**

All our post BSc students, who join the integrated Ph.D., spend two summers at other DAE institutions to do experimental projects.

29. Awards / recognitions received at the national and international level by

- **Faculty**
- **Doctoral / post doctoral fellows**
- **Students**

Please see Appendix 1 of the 'Criteria-wise Inputs'.

30. Seminars/ Conferences/ Workshops organized and the source of funding (national/ international) with details of outstanding participants, if any.

Please see Appendix 5.

31. Code of ethics for research followed by HRI

We adhere to the general principles enunciated by HBNI in the criteria wise inputs in the NAAC submission. As practising scientists we also take guidance from the ethical guidelines and procedures suggested by the Indian Academy of Sciences:
http://www.ias.ac.in/academy/sci_val/scival-report.pdf

32. Student profile programme-wise

Please see para 15 and para 28 of the 'Profile.'

33. Diversity of students

Please see Para 2.1 of the 'Criteria-wise Inputs'.

34. How many students have cleared Civil Services and Defense Services examinations, NET, SET, GATE and other competitive examinations? Give details category-wise.

Our students continue in research, beyond their Ph.D, and do not opt for civil services or defence work. Most of them qualify the UGC-CSIR NET examination during their Ph.D. tenure, since it provides an added qualification when applying for faculty positions later.

35. Student progression

All students joining HRI for doctoral work go for post-doctoral research.

36. Diversity of staff

Please see para 2.4.3 of the 'Criteria-wise Inputs.'

37. Number of faculty who were awarded M.Phil., Ph.D., D.Sc. and D.Litt. during the assessment period

Nil

38. Present details of infrastructural facilities with regard to

a) Library: Please see para 4.2 of the 'Criteria-wise Inputs'. The library has adequate physical facilities such as reading-rooms, reprography, internet and is stocked with number of journals, books

(21155) and other library resources (i.e. CDs/ cassettes, etc.). In addition the Department of Atomic Energy (DAE) has set up a consortium to subscribe 2405 journals through Science Direct and these are available to HRI. 84 electronic journals are available on desktop in the campus.

b) Extensive internet facilities are available to staff and students.

c) Total number of class rooms: 6 Lecture Halls with ICT facility are also available. ICT available consists of the hardware, software, networks and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images) as well as related services.

d) Students' laboratories No (HRI is a theory institute)

e) Research laboratories Yes (High performance computing facility)

39. List of doctoral, post-doctoral students and Research Associates

Please see Appendix 6.

40. Number of post graduate students getting financial assistance from the university.

Rs. 16,000/- per month for the first 2 years in the research phase.
Rs. 18,000/- per month for the next three years in the research phase.

41. Was any need assessment exercise undertaken before the development of new programme(s)? If so, highlight the methodology.

The Ph.D. program has been running since the beginning of HRI. The integrated Ph.D. program was started about a decade back since it was felt that many of the students trained in the university system needed significant coursework to move to the research phase, and also project work to make the appropriate choice of research area. Having a program with post B.Sc. entrants would ensure that they could do advanced courses during their M.Sc. phase, and also get acquainted with the research at HRI via short projects. This integrated Ph.D. program has been remarkably successful, and now accounts for 70% of the entrants to HRI.

Please also see para 1.1.2 of the 'Criteria-wise Inputs.

42. Does HRI obtain feedback from

a. faculty on curriculum as well as teaching-learning-evaluation? If yes, how does HRIT utilize the feedback?

b. students on staff, curriculum and teaching-learning-evaluation and how does HRI utilize the feedback?

c. alumni and employers on the programmes offered and how does HRI utilize the feedback?

The graduate committee obtains feedback from faculty and students on a regular basis. The students provide a written feedback at the end of each semester, in addition interactions in the middle of the semester. The feedback is passed on to the concerned faculty members and discussed in the graduate committee. Based on these we continuously update our teaching strategy, and have also undertaken a couple of major restructuring of the coursework.

43. List the distinguished alumni of the CI (maximum 10)

The list below includes those, who received a Ph.D. based on the work done at HRI, but prior to the setting up of HBNI.

Sl. No	Name
1.	Sourav Roy, Faculty at IACS, Kolkata
2.	Pradeep Mohanty, Faculty at SINP Kolkata
3.	Partha Mukhopadhyaya, Faculty at IMSc. Chennai
4.	Mrinal Kanti Das, Faculty at ISI Kolkata
5.	Anirban Mukhopadhyaya, Faculty at IMSc. Chennai
6.	Partha Konar, Faculty at PRL Ahmedabad
7.	Sanoli Gun, Faculty at IMSc. Chennai
8.	Sanjeev Kumar, Faculty at IISER Mohali
9.	Purusottam Rath, Faculty at CMI Chennai
10.	Soumya Das, Faculty at IISc. Bangalore, won Young Scientist Award

44. Give details of student enrichment programmes (special lectures/ workshops/ seminars) involving external experts.

HRI regularly hosts international experts to give seminars in their field of specializations. Several interaction meetings/workshops have been organized at HRI during last five years.

45. List the teaching methods adopted by the faculty for different programmes.

Besides class room teaching, the students do assignments and short projects pertaining to the course material. They are often required to give seminars at the end of the course, and these form a part of the overall evaluation. Beyond class hours students are free to contact teachers, or course tutors, anytime that they need. Beyond the basic first

semester courses, most courses involve some degree of understanding of research level material.

46. How does HRI ensure that programme objectives are constantly met and learning outcomes are monitored?

For course students the course feedback and the examination performance provides an indicator. At the end of the coursework phase the `comprehensive exam' (OGCE) serves as a test for the preparedness of the student to undertake research. In the research phase the annual evaluation, based on a seminar attended by the doctoral committee, keeps a check on performance.

47. Highlight the participation of students and faculty in extension activities.

Beyond their research activity HRI faculty and students participate in outreach activities at several levels. These include various schools conducted for external students ranging from the Ph.D. level down to high school students. Notable among these is the summer program run by the mathematics department. We also hold talent search examinations for students from schools in Allahabad (to encourage them to take up a career in science). There are several science lectures held in the vernacular as part of the Rajbhasha program.

48. Give details of "beyond syllabus scholarly activities".

HRI is a research institution, and the `syllabus' based learning forms only a small part of our activity. The faculty and Ph.D. students are continuously engaged in research, and the quality of their work is reflected in the publication record of the institute. The students and faculty give lectures very frequently in various national and international fora. There are conferences, schools, and discussion meetings running at HRI throughout the year, and many distinguished scientists from India and abroad participate in these. This allows the HRI students to interact with the leading scholars in their discipline.

49. State whether the programme/ CI is accredited/ graded by other agencies? If yes, give details.

Yes, by UGC

50. Briefly highlight the contributions of HRI in generating new knowledge, basic or applied.

HRI focuses on theoretical physics and mathematics. We discuss the contributions of HRI faculty to scientific knowledge separately in these two areas.

(a) Physics:

Research in Physics at HRI is carried out in the fields on string theory, high energy phenomenology, condensed matter physics, quantum information and computing, and astrophysics. The outstanding contribution of Prof. Ashoke Sen of HRI to fundamental physics is well known. In addition to this, there are several major results that have emerged from HRI in the last few years. We touch on some of these below.

(i) String theory:

A large number of internationally recognized works on formal aspects of quantum gravity and quantum field theory and the interplay of formal developments with the real life world of cosmology, particle physics and condensed matter physics has come out of HRI in the past year. A particular development on the formal front makes very specific predictions about the leading correction term to the area law of black hole entropy. This correction has to be reproduced by any admissible theory of quantum gravity and thus acts as a filter for limiting the class of viable theories. Other examples of formal developments that have originated in HRI are techniques to simplify calculation of scattering amplitudes in gauge theories, higher derivative corrections to string theory and a fresh look at gauge gravity duality through the stochastic quantization procedure.

A development that has been initiated and carried forward in HRI is a duality between a class of two dimensional quantum field theories and generalized gravitational theories. What is unique here is that this duality involves non supersymmetric realistic theories and thus opens the door to bringing condensed matter physics within the ambit of such duality. An application to strange metals in one dimension sets the stage for future developments. Application of formal string theory to practical issues in cosmology and hydrodynamics constitute an equally vital part of HRI contributions.

(ii) High energy phenomenology:

In July 2012, it was announced that the large hadron collider (LHC) has seen signature of the Higgs boson. In the first publication from India after the announcement, HRI scientists, in an internationally acclaimed work, carried out a multichannel global analysis of all data from ATLAS, CMS and the Tevatron experiment to see how much scope exists for deviation from the standard model scenario. The conclusion is that there are enough avenues to explore, an example being the

couplings of the observed scalar with up and down fermions. It is also worth mentioning that one of the most important works pertaining to LHC physics which discusses higher order corrections in the total cross section for Higgs boson production in hadron-hadron collisions has also come from HRI.

(iii) Condensed matter physics:

One of the more striking pieces of condensed matter research in the recent past has involved HRI theorists. This is the discovery of magnetic superatoms. A cluster of atoms that mimics the properties of single atoms is termed a superatom. Non magnetic superatoms have been known for a while and they are useful for designing materials whose electronic properties can be tuned. Discovery of these magnetic superatoms has paved the way for designing materials whose electrical as well as magnetic properties can be tuned. Another condensed matter contribution involves the development of a real space method for visualising interacting quantum systems. This makes use of advanced computational methods and has already yielded insight on longstanding problems in superconductivity and frustrated magnets. Finally, there have been major results on the tunneling probe and junctions between low dimensional quantum liquids.

(iv) Quantum information:

One of the most fundamental properties of quantum entanglement is the concept of monogamy. This is a requirement in quantum cryptography and HRI scientists have recently established an important result in this area.

Quantum information devices almost always operate on quantum many body system substrates. In understanding the flow of classical and quantum information in quantum many body systems scientists of HRI have been playing a pioneering role. The recent work on quantum information aspects of non equilibrium many body systems and resonating valence bond systems is an important contribution. The HRI-IISc collaboration in theory and experiments related to quantum information has been particularly fruitful. The most striking result has to do with the `no hiding' theorem which asserts that the information missing from one system must be residing somewhere else in the universe. The missing information cannot be hidden in the correlation between the system and its environment. The very first experimental verification of this theorem involved HRI theorists and IISc experimentalists.

(v) Astrophysics:

There have been major results on the evidence of black holes by studying the flow of accreting matter around a star.

(b) Mathematics:

The mathematics group at HRI carries out research in several areas. In algebra, work is done on algebraic groups and related structures, the theory of groups and group rings, representation theory, and infinite-dimensional Lie algebras. Work in analysis is in the field of harmonic analysis of Lie groups. Activity in geometry includes discontinuous groups and Riemann surfaces, algebraic topology, variational problems on manifolds, Chow groups of rational surfaces, and moduli of vector bundles. The number theory group works on algebraic, analytic and combinatorial number theory, automorphic forms and cryptography. The following paragraph highlights the recent contributions of the HRI mathematics faculty.

On the international research level the mathematics group founded several disciplines of mathematics as in vector bundles, Serre's problem on projective modules, principal G-bundles, Frobenius splittings, Waring's problem, etc.

Over the last couple of years the focus has been on issues in number theory e.g. exploring zero sum problems in additive combinatorics and related extremal problems, convolution sum identities, identities of Ramanujan Tau functions etc. as also harmonic analysis, differential geometry and representation theory. Some very recent contributions are the verification of Schanuel's conjecture (which is important in transcendental number theory) for uncountably many n-tuples, asymptotic classification of harmonic manifolds in three dimensions, interpolation of two real analytic curves, partial proof of a conjecture of Bocherer on a property of Jacobi forms of weight 2, monochromatic solutions of Diophantine equations and certain classifications of finite groups of prime order. Hardy-Sobolev inequality for the magnetic laplacian and quantization of vortices is also being studied.

Doctorates from the mathematics group are now faculty members at various IIT's, IISER's, ISI's, and major universities. Group members are involved in the Madhava competitions at the school level, the Intel talent search committees, and in the programs of the Indian Academies to train students. There is a vibrant Visiting Student's Program every summer and some of the INMO finalists visit HRI. The active participation of the mathematics group in these outreach efforts has rejuvenated mathematics learning at college and university levels. This has led to the generation of a pool of manpower trained in current topics in mathematics who are not only trained to start a research career but are also able to contribute significantly in different areas of science and engineering.

51. Detail five major Strengths, Weaknesses, Opportunities and Challenges (SWOC) of HRI.

Strengths

1. The faculty of HRI are world recognised authorities in their respective areas.

2. The quality of doctoral students is very good due to the rigorous selection process in place and also because HRI is considered the top research destination by prospective students.

3. The research training, involving classroom lectures and projects, is of high standard.

4. The infrastructural facilities, including computing resource, internet access, library, power backup, and housing are excellent.

5. The faculty and students get to interact with world renowned scientists via conferences and schools held at HRI, and also via travel to other national and international institutions.

Weaknesses

1. The number of faculty, and so the number of students that we can absorb, is small. This partly limits our impact.

2. The absence of experimental labs can limit the perspective of young physics students.

3. Since Allahabad is not considered a major metropolitan centre, attracting/retaining faculty whose spouses also need employment has been a problem.

4. A residential campus far from the city sometimes poses problems in terms of medical support, schools, etc.

5. Getting qualified support staff, and the stability of public services like electricity, telephones, etc., can be a problem.

Opportunities

1. The generous support from the Government through the DAE, allows us to maintain HRI as a world class facility.

2. The faculty and students get to interact with the leading scientists via mutual visits.

3. Faculty members and students can venture into interdisciplinary areas if they so wish.

4. The faculty and students can gain national and international recognition through their research.

5. The faculty have an opportunity to interact with young students, in the high school and B.Sc. stage, and inspire them to take up a research career.

Challenges

1. Maintaining a leadership position despite the small size, and the fluctuations that arise due to faculty movement.

2. Maintaining a high reliability infrastructure despite the disadvantage of our location.

3. Adhering to all the governmental guidelines while retaining the flexibility and competitiveness that characterise the best institutions worldwide.

4. Increase the student intake and our scientific output without any compromise on quality.

5. Diversify into emerging areas of physics and mathematics, while functioning within the current constraints.

52. Future plans of HRI.

The plans, broadly, are of two types:

(i) We wish to start a standalone M.Sc. program, in both physics and mathematics, without the students necessarily pursuing Ph.D. at HRI. This will be the first effort in our part of the country where research faculty will be directly involved in a teaching program. This will involve some growth in infrastructure as well as an increase in the faculty strength by at least 10.

(ii) We wish to diversify, over the next 10 years if possible, into areas like soft matter physics, non-equilibrium systems, emerging areas of astrophysics, and several areas of mathematics that are underrepresented at HRI.

List of appendices (to be made available to the assessment team during their visit)

1. HRI: Appendix 1: Faculty profile referred to at para 11.
2. HRI: Appendix 2: Ongoing projects referred to at para 17.
3. HRI: Appendix 3: Not attached.
4. HRI: Appendix 4: Visits Faculties to international Laboratories/

Institutes abroad during the period 2009 – 2013 referred to at para 25.

5. HRI: Appendix 5: Seminar/ Meetings/ Conferences/ Colloquia referred to at para 30.
6. HRI: Appendix 6: List of doctoral students referred to at para 39.