# HARISH-CHANDRA

1923-1983

THE INSTITUTE FOR ADVANCED STUDY

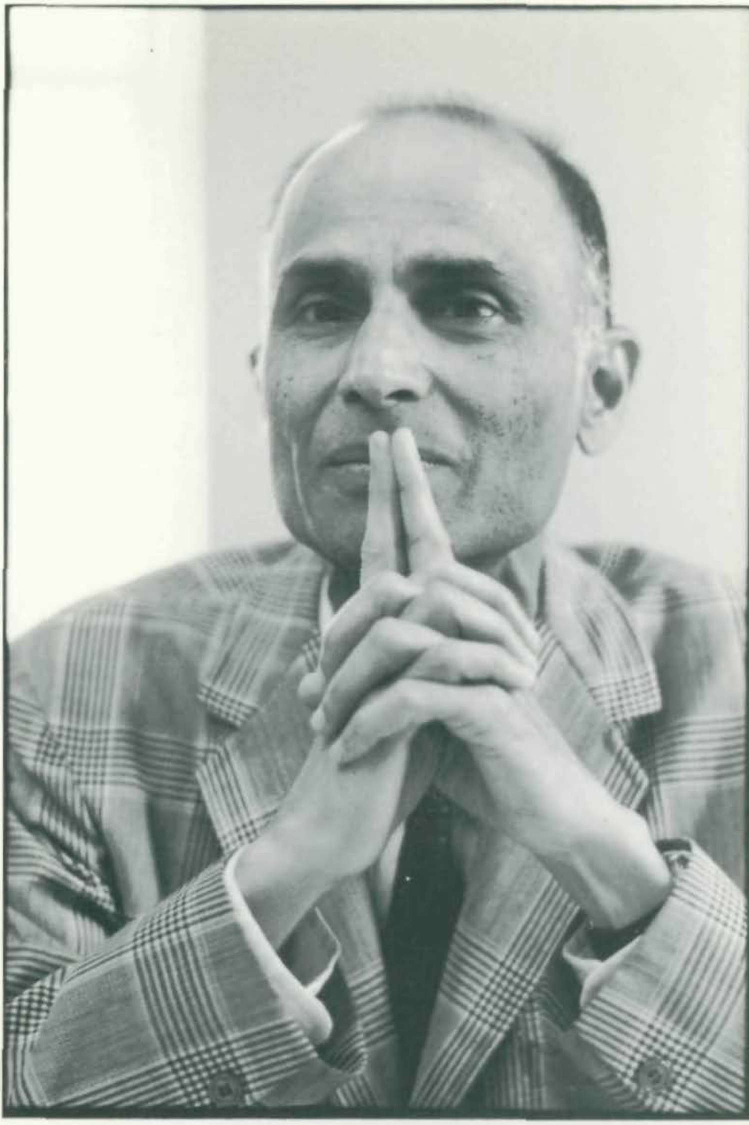

Photo by Herman Landshoff

# HARISH-CHANDRA: IN MEMORIAM

The conference on *Harmonic Analysis and the Representation Theory of Reductive Groups* that took place at The Institute for Advanced Study from April 23 to 27, 1984, was organized originally to celebrate the extraordinary mathematical achievements of Harish-Chandra and to mark the passage of his sixtieth year. We may take some comfort in the knowledge that, before his untimely death, he knew of our preparations both to honor his monumental contributions to mathematics and to pay our respects to an admired colleague. His decency, humanity and gentleness made his friendship all the more precious in a world increasingly inclined to be otherwise, and I treasure now, as others here must also, those good conversational walks that we shared across the Institute's lovely meadows or through its quiet woods.

The program in honor of Professor Harish-Chandra is given below. It is followed by the resolution which the Institute's Board of Trustees passed and recorded.

HARRY WOOLF
*Director*
*Institute for Advanced Study*

*Princeton*
*New Jersey, 1984*

*Conference on Harmonic Analysis and the Representation Theory of Reductive Groups*

April 23-27, 1984

Lectures will be held in the Library Annex

**Monday, April 23** MORNING SESSION

Moderator: D. Mostow

9:00 a.m. HARISH-CHANDRA AND HIS MATHEMATICAL WORK
V.S. Varadarajan, University of California, Los Angeles

11:00 a.m. GERBES AND SHIMURA VARIETIES
R.P. Langlands, Institute for Advanced Study

4:00 p.m. MEMORIAL GATHERING (THE CONTENTS OF THIS PAMPHLET)
Library Annex

**Tuesday, April 24** MORNING SESSION

Moderator: E. Kolchin

9:00 a.m. THE TRACE OF HECKE OPERATORS
J. Arthur, Institute for Advanced Study & University of Toronto

11:00 a.m. DISCRETE SERIES FOR SEMISIMPLE SYMMETRIC SPACES
T.Oshima, University of Tokyo

AFTERNOON SESSION

Moderator: R. Gangolli

2:00 p.m. A PALEY-WIENER THEOREM AND EXISTENCE OF AUTOMORPHIC FORMS OF LOW WEIGHT
L. Clozel, Institute for Advanced Study

4:00 p.m. ALGEBRAIC METHODS AND HARISH-CHANDRA MODULES
T. Enright, Harvard University & University of California, San Diego

**Wednesday, April 25** MORNING SESSION

Moderator: I. Segal

9:00 a.m. OPERATIONAL PROPERTIES OF THE RADON TRANSFORM
S. Helgason, Massachusetts Institute of Technology

11:00 a.m. HARISH-CHANDRA HOMOMORPHISMS FOR P-ADIC GROUPS
Roger Howe, Yale University

*No Wednesday Afternoon Session*

**Thursday, April 26** MORNING SESSION

*Moderator: C. Seshadri*

9:00 a.m. ON A RESULT OF WALDSPURGER
H. Jacquet, Columbia University

11:00 a.m. MATRIX PALEY-WIENER THEOREM FOR P-ADIC GROUPS
J. Bernstein, Harvard University

AFTERNOON SESSION

Moderator: R. Ranga Rao

2:00 p.m. REPRESENTATIONS OF SEMISIMPLE GROUPS OVER A LOCAL FIELD OF POSITIVE CHARACTERISTIC
D. Kazhdan, Harvard University

4:00 p.m. CHARACTER SHEAVES
G. Lusztig, Massachusetts Institute of Technology

**Friday, April 27** MORNING SESSION

Moderator: M.S. Narsimhan

9:00 a.m. LOCALIZATION OF HARISH-CHANDRA MODULES AND DERIVED FUNCTORS
W. Schmid, Harvard University

11:00 a.m. THE METHOD OF DESCENT AND UNIPOTENT REPRESENTATIONS
D. Vogan, Massachusetts Institute of Technology

# RESOLUTION
*By the Board of Trustees*

"The Board of Trustees here records its profound sense of loss in the death of Harish-Chandra, Professor in the School of Mathematics since 1963. Gentle in nature, generous of spirit, brilliant in his perceptions, he gave liberally of himself to all who knew him. His personal kindness, his absence of any vanity or anger, his sense of simplicity combined with his deep respect for the elegant complexities of his field, affected our whole community in mind and heart. We will miss his companionship and mourn his loss as friend and leader in the world of mathematical learning which he did so much to advance."

## MEMORIAL COMMENTS

*The comments by the four speakers are presented as recollections of Harish-Chandra and reflections upon his career, in the order in which they were given, and under each speaker's name.*

## V.S. Varadarajan
*University of California*
*Los Angeles, California*

It is now a little more than six months since Harish-Chandra passed away so suddenly. Our grief and pain are still very much with us. A vital part of the lives of the members of his family is gone while his friends and colleagues, especially from the younger generation, miss his inspiring presence. The Institute has lost a jewel, and India has lost one of her greatest sons. It is a privilege, although a very sad one, to be asked to say a few words in his memory on this occasion. I hope that my thoughts will find some resonance in you so that they may be of help in replacing our sense of loss with something more affirmative, perhaps a sense of fulfillment in having been associated with a truly remarkable, and one might say, even heroic life.

It was T.S. Eliot who said that after a great poet had lived certain things will have been said once and for all and cannot be repeated again. I feel that this is true of all great creative personalities, and so certainly true of Harish-Chandra. The originality and depth of his work will compel later generations to confer on him that luminous distinction reserved only for the most exalted figures of our science. I do not believe that any of us here will ever again come across someone quite like him. In the austere simplicity and uncompromising nature of his approach to life, in his preference for solitary and profound reflection, and in his awesome capacity to discern and persevere after distant goals, he resembled the legendary figures from his country's ancient past. And like them, he came to be quite detached about his achievements as well as his failures. This detachment was not a false modesty; like many great men Harish-Chandra was fully conscious of his gifts and what he could do with them. It was rather a deeper humility, whose origin lay in a conviction that science was a collective endeavour and that any single life is but a fragment in a larger fabric.

Harish-Chandra grew to manhood in the plains of Northern India. This region, fed by the great rivers Ganga and Yamuna, had always been a vital part of Indian life and consciousness. Several of our most famous ancient cities and kingdoms were located there and many of India's greatest men and women had emerged from its soil. In the years following Mahatma Gandhi's call for the British to quit India, the country shook off its stupor and there was a cultural and intellectual flowering in the entire nation. The rise of modern Indian science dates back to that era and inspiring figures like Ramanujan and Raman filled the horizon. Harish-Chandra grew to maturity in this milieu during the 1940s. His undergraduate studies were in the University of Allahabad, the modern city founded by the Moghuls in the sixteenth century near the ancient holy city of Prayag at the confluence of the rivers Ganga and Yamuna. His interest was at first in physics, and he came under the influence of K.S. Krishnan who was the professor of physics there at that time. Krishnan was a physicist of great distinction, at home in both theory and experiment, whose work on electromagnetic aspects of crystal physics had already won for him and his students international recognition. In his younger days Krishnan had collaborated with Raman in a series of experiments on the molecular scattering of light that had led to the discovery of the Raman effect in 1928. Cultured, gentle, with deep and wide interests, Krishnan had a real feeling for and understanding of the mathematical aspects of modern physics, and was the central figure in Harish-Chandra's early development. Harish-Chandra would later recall with genuine affection the influence that Krishnan, both as a man and as a scientist, had on him.

Harish-Chandra continued his studies in physics, first at the Indian Institute of Science in Bangalore in Southern India under H.J. Bhabha, and later, at Cambridge in England under P.A.M. Dirac. It was in Cambridge that he changed over from physics to mathematics. That was the time, before renormalization, when quantum electrodynamics was plagued by divergent integrals; and Harish-Chandra began to have serious doubts whether what he was doing had any link with physical reality, doubts that eventually drove him to seek comfort in the security of pure mathematics.

The influence of Dirac would stay with him forever. He would often openly and unreservedly give expression to the awe and reverence he had for Dirac. Although his work was not directly related to Dirac's, his life-long preoccupation with group representations began with Dirac's suggestion that he investigate the infinite dimensional representations of the Lorentz group. Between him and Dirac there was a subtle bond, an affinity of souls; like Dirac, Harish-Chandra would go his own way in science and nothing could deflect him.

This is not the occasion to go into detail about his scientific work. However, mathematics was such an overwhelming part of his life that it is also impossible not to say something about it. One of the major classical discoveries in the theory of group representations was the notion, due to Frobenius in the nineteenth century, of the character of a finite dimensional representation. In the 1920s Hermann Weyl had discovered a beautiful formula for the characters of finite dimensional representations of semi-simple groups. It was Harish-Chandra who significantly enlarged the scope of the concept of the character and discovered an infinite dimensional generalization of Weyl's formula that was equally beautiful. The theory of harmonic analysis on semi-simple groups that he erected based on his character theory is a wonderful generalization of classical harmonic analysis, and is destined to play, for reasons that I cannot go into here, a pivotal role in the great questions of analysis and arithmetic. He himself was unceasingly at work treating these questions until the end of his life. In his last years, when his energies began to diminish, it became evident that only his inner strength kept him going. The vast amount of unpublished work that he has left behind, much of it in the form of meticulously handwritten manuscripts, is a moving testimony to the essentially spiritual nature of his quest.

Except for a couple of visits of a few months' duration he never went back to India. He was somewhat unhappy about this for he felt that he could have done something valuable for Indian mathematics had he been able to make longer visits. He would often express his admiration for Takagi who went back to Japan and played an important role in the creation of the influential modern Japanese school in number theory. But with increasing uncertainties in his health, any return to India became out of the question; and his dreams were to remain just that. This circumstance often lent a sense of poignancy to this heart-felt concern for India, Indian science, and Indian scientists.

Although he was well aware of what was going on in mathematics he would often say that too much learning hindered his originality. This is, of course, an over-simplified description of his attitude toward the creative process and so, to give you a better feeling for his thinking, I shall read you a brief passage from a talk he gave, a few months before his death, on the occasion of the eightieth birthday celebration for Dirac: "I have often pondered over the roles of knowledge or experience on the one hand and imagination or intuition on the other, in the process of discovery. I believe that there is a certain fundamental conflict between the two; and knowledge, by advocating caution, tends to inhibit the flight of imagination. Therefore a certain naiveté, unburdened by conventional wisdom, can sometimes be a positive asset." He made these comments while discussing Dirac's discovery of the equations of motion of the electron; but they apply equally well to his own work and capture its spirit completely. He could even laugh at the fact that he was, in his opinion of course, not as well-informed as he should be; his favourite description of himself was as a man who had a deficiency of iron in his blood but for whom the only available remedy was to swallow a pound of nails every day.

His view of science was a noble one and there was no place for ego in it. There was no doubt in his mind that any one who had a chance to contribute to the flow of science should regard himself as a very fortunate person. He was critical of scientists, even great ones, who were unable to distinguish between the progress of science and the progress of their own work. Throughout his life his goal was to do as much as he could, for as long as he had the strength to work. This attitude allowed him to view the world around him with remarkable equanimity. It is my firm belief that he was, in the most demanding sense of that Sanskrit word, a *Sthithapragna*—one with a steady inner gaze, having conquered both disappointment and exultation.

Sigurdur Helgason
*Massachusetts Institute of Technology*
*Cambridge, Massachusetts*

Harish-Chandra's formal education and initial scientific papers were in the field of theoretical physics. With hindsight it seems that in his tastes and in his thinking he was always closer to mathematics; yet throughout his life he admired "the physicist's intuition" and although he himself claimed not to possess this "sixth sense" as he called it, one can argue that a physicist's background sometimes shows through in his papers. In any case it was an important turning point in his career when he came here to the Institute in the fall of 1947 and his scientific activity shifted to mathematics.

He turned to a systematic study of Lie groups, undoubtedly stimulated by the presence in Princeton of Hermann Weyl, Claude Chevalley and of his contemporary Dan Mostow. Considering his rather irregular mathematical background, he seems to have devoured the existing Lie group theory, tough as it was, at a ferocious rate; in April 1948 he submitted to the *Annals of Mathematics* a new algebraic proof of one of the major theorems in the subject, Ado's theorem.

Around 1950, armed with a complete command of Lie group theory, Harish-Chandra embarked on a project which was to occupy him for the rest of his life, namely "Infinite-dimensional representations of Semi-simple Lie Groups." In this undertaking, he steered a middle course between the significant examples studied by Bargmann, Gelfand and Naimark and the general theories for locally compact groups developed by Godement, Mackey, Segal and others. This was indeed a wise choice because here he could take full advantage of the rich structure theory of semi-simple Lie groups.

Developing theories for the so-called universal enveloping algebra and the analytic vectors which now have become standard tools in representation theory, Harish-Chandra isolated and solved one basic problem after another; the solutions have become the pillars in the foundation of the subject. He quickly found himself in new unexplored territory and everywhere he looked there were natural conceptually compelling problems to deal with. Looking backward and remembering the primitive state of the subject in 1950, one does not know what to admire most: the uncanny insight in finding the right chain of intermediary results to prove, or the consummate skill in carrying out the complex proofs. His magnum opus within representation theory, appropriately called "Harmonic Analysis on Semi-simple Lie groups," stretches from 1951 (when he considered the first special case) to 1976 when the general Plancherel formula was completed. The cumulative nature of this work of twenty-five years leads one to characterize it as monumental; yet even this does not do justice to the courage and pioneering efforts, conceptual and technical, which were needed to overcome the formidable obstacles along the way.

Since it would be inappropriate here to go into technical detail, I shall confine myself merely to mentioning some high points on this scenic road: the type I property of a semi-simple Lie group, the algebraic characterization of irreducibility, finiteness theorems for multiplicity, the character theory, the orbital integral theory, the discrete series, the spherical function theory, and the Plancherel formula.

The appearance of the four volumes of his collected papers, along with Varadarajan's inspired introduction, is a major publishing event. For many years to come, these volumes will be an indispensable source for experts and beginners alike; they also form a fitting monument to Harish-Chandra's wondrous achievements.

A good deal of this work was done during periods of persistent ill health. It could hardly have been completed without the brave support of his dear wife Lily, who with patience and courage during serious illnesses remained a mainstay in his life.

I first met Harish-Chandra in 1954 when he was invited to Princeton to give a lecture on representation theory to the physicists. While the subject was entirely foreign to me, the lecture made a lasting impression. In 1959 I happened to visit him and Lily in their apartment in Butler Hall near Columbia University. I had been reading recently his 1958 papers on spherical functions. I still remember a tiny desk in that apartment next to the kitchenette and found out in amazement that in this ungainly workspace he had actually written these long, magnificent papers. This tiny desk always symbolizes for me the ascetic discipline in his work habits.

Harish-Chandra was awarded the Cole prize in 1954 and the Ramanujan Medal of the Indian Science Academy in 1974. During the fifties and sixties the mathematical public watched in awe as dozens of major mathematical papers flowed from his pen; the subjects revealed a structure of surprising richness and beauty. As an example one may mention the remarkable and mysterious c-function which is attached to any semi-simple Lie group like an engraved jewel. It is not surprising that as these mysteries unfolded Harish-Chandra became completely captivated by the subject. He often expressed the view (which is of course shared by many mathematicians) that many of the most exalted mathematical results reveal themselves to us as if they were creations of a superior culture or even of a divine force. According to this view, the role of the mathematician is to uncover these creations like an archaeologist or to foresee them like a clairvoyant, rather than to invent them with his own mind.

With long hours of intense work, Harish-Chandra was an extremely prolific writer. He pursued his goals with firm determination, avoiding unnecessary distractions. Since each of his papers was for the most part based on his own previous work, the writing was easy for him. For quite a while the frequency of these long papers caused more admiration than assimilation by the mathematical public. Determined readers of his papers were, however, pleased to find them written with extreme clarity and care. A patient reader found no insurmountable obstacles because tedious details were given their due attention and not left to the reader to verify. This benefitted the subject of representation theory in two ways: workers in this field never hesitated using Harish-Chandra's results even if they had not worked through or even seen the proofs; secondly, his uncompromising and precise style became an example for others to follow. I believe this has contributed in no small way to the vigorous health which representation theory has enjoyed in recent years.

Here at the Institute he gave regular lectures on his work and he delighted in describing his current ideas to others. I remember a period in the mid-sixties when he was writing his major papers on the so-called discrete series. I had an adjoining office at the Institute. Often I could not help hearing through the wall that he was loudly singing at his desk. Sometimes on such occasions I would knock on his door on a small pretext and find him delighted at the interruption and eager to explain to me what he was doing, either on the blackboard or during a walk in the woods.

During the year 1960 persistent illness began to cast an ominous shadow over Harish-Chandra's life. He also realized that the long hours of intensive mathematical activity might be harmful. On the other hand, mathematical meditation had become such an integral part of his life that abstaining from it seemed unnatural and strenuous. Through expert medical treatment and Lily's devoted care a certain equilibrium developed. Thus the mid- and late sixties were a happy, relaxed and productive period. However, in 1969 he suffered a mild heart attack and from then on his heart condition was a cause of concern. Last year, it came to a serious crisis and he understood from medical information that the prospects of recovery were dim.

It cheered him greatly to see again many old friends assembled at a conference here at the Institute last October. Always the perfect gentleman, his spirits seemed to have lifted from the gloom of previous weeks. His warm handshake and radiant smile gave some of us a ray of hope; more likely it meant that he himself had come to terms with his bitter fate. Through his premature passing, mathematics and all of us have suffered a grievous loss; yet we can take comfort in memories of many years of warm and inspiring friendship.

# G. Daniel Mostow

*Yale University*
*New Haven, Connecticut*


The conference scheduled for this week has not turned out as its organizers first planned. And so we come together today, not to praise Harish for the accomplishments of his first sixty years, but to memorialize him. I can do that best by drawing upon my personal recollections.

Harish and I each arrived here at the Institute as new Ph.D's, he from Cambridge, England, I from Cambridge, Massachusetts. Actually, our friendship first developed at Fine Hall where we both attended Chevalley's lectures on the structure of semi-simple Lie algebras. We spent many leisurely hours together, conversing, strolling, even trying our hand at tennis.

I can describe the Harish of that period most accurately by quoting his own words. His first unforgettable remark occurred as we were walking back to the Institute after one of Chevalley's lectures. The lectures were consistently polished with all details neatly in place, but on that particular day, Chevalley got stuck. Those of you who are familiar with Chevalley's uncompromisingly rigorous style may be amused to hear how Chevalley coped: he crouched against the blackboard, drew a diagram which he covered with his body, stared at it, finally erased the figure, and announced, "My assertion is certainly correct, but I don't see at the moment how to prove it," and he deferred the point for the following lecture. On our way back to the Institute, Harish declared with genuine puzzlement, "How can one know a mathematical statement is true without knowing how to prove it?"

The remark tells much about the young Harish. For him, to know a theorem was to know how to prove it. As he proved one impressive structure theorem after another about Lie algebras, he would have a publication-ready manuscript with no details spared as soon as he declared that he had a proof.

An even more startling remark came as he was completing his second Princeton paper, which proves that the enveloping algebra of a Lie algebra has sufficiently many representations. We were on a post-Sunday-brunch walk when he mused, "You know, the best way to prove theorems is by induction." I was thunderstruck. I had alway thought and still do, that the best way to prove theorems is to get the right intuition about it. But so great was Harish's power to knock apart all the pieces of his mathematical problem, and so quick was he in reassembling the pieces in all feasible patterns of piling one upon another, that he ignored the difficulty most mathematicians have in sifting through the pieces to find the right pattern—probably because flashes of insight occupy so small a fraction of a mathematician's total work time.

Harish's mode of working was very strenuous, and he was not put off by hard work. In the mid-1950s on one of my visits to Columbia, he showed me the sheaf of notes he had made on C.L. Siegel's celebrated proof that the integral points of suitable $SL(n,\mathbf{R})$ orbits lie on a finite number of $SL(n,\mathbf{Z})$ orbits. He stated: "I had to rework the proof for my own benefit in ten successively different versions before I finally understood it." That was the proof that years later found its place in the famous joint paper with Borel on Arithmetic Groups.

Harish worked very intensely—seven days, or more accurately, seven nights a week in those days. He realized that he needed some periodic respite and would try to keep his mind completely free from mathematics for at least one summer month. He took up painting in the summers and was quite talented at it. In later years, though, he gave that up.

In point of fact, Harish had outstanding intuition and relied on it. When he began to study and to apply von Neumann's theory of disintegration of representations, the technical details sometimes outstripped the measure theory he had learned. He first studied measure theory after arrival at the Institute, i.e., after determining all the infinite dimensional unitary representations of the Lorentz group! To quote Harish, "When I'm in doubt about the measure theory, I consult Mautner; he's my lawyer."

At a later stage, when Harish ran into problems that called for methods from outside the area in which he was working, his very terminology reveals his confidence in his intuition. Still later he used the term "Lefschetz Principle" for the transfer of representation theorems for groups over complex numbers to groups over p-adic numbers in a sense that went far beyond the claim of the Lefschetz Principle of Algebraic Geometry. The term "cusp philosophy" which he coined suggests his confidence even more explicitly; and since cusp philosophy entails at its core an inductive procedure, the earlier remark about induction turned out to be on target after all.

What about the young Harish as a person? At age twenty, he started working with the physicist Bhabha in Bangalore as a research student. Two of their joint papers were sent to Dirac for publication in the Proceedings of the Royal Society. In 1945, Dirac accepted Harish as a research student in Cambridge. The long voyage from India to England was poignant for Harish. On the one hand he was thrilled at the prospect of working with Dirac; on the other, India was still trying to throw off the English yoke, and Harish's patriotism bred a bitter resentment towards the English. Aboard ship, as English passengers repeatedly tried to befriend him, Harish inwardly recoiled and kept his distance.

Once in Cambridge, that gem among cities, the many English virtues that he observed and admired led him to change his outlook. He came away loving Cambridge, and for many years afterwards fondly wore his college colors.

Harish was strikingly handsome. His remarkable looks were a topic of conversation even among men. Harish once or twice mentioned some foreign student acquaintances at Cambridge who were very successful with women, but that kind of social life was not for him. He much preferred the Puritanical mores of his homeland. And finally when he did return to India, to court and marry Lily, the wisdom of his preference became clear to all.

Harish greatly valued the live scientific atmosphere of this country's universities, but nonetheless he long cherished the idea of resettling in India. Ultimately, though, he gave up that idea with reluctance.

Back in 1947 he expressed his thoughts on Indian religion saying, as I recall, "I don't believe in God as a figure enthroned in a green chamber. But I have a profound respect for the philosophical aspirations of the Indian religion."

As his health began to falter in his final years, Harish fell back on the teachings of classical Indian philosophy about phased withdrawal from the life of action to the life of contemplation.

We know from the great pleasure he derived from seeing his friends at Borel's Sixtieth Jubilee last October how much he would have enjoyed his own Jubilee. He felt rewarded in seeing his theories thrive and bear so much fruit.

Each great work, in mathematics as in other forms of creativity, has its own uniqueness. But I believe it is accurate to say that no mathematician of our time has successfully completed so long and so arduous a climb, solo.

I am a descendant of a religious tradition quite different from that of Harish. Nevertheless, I, too, was stirred by the symbolism of Harish's ashes strewn at this Institute. For as long as group representation theory continues to spurt with remarkable vitality, his spirit will hover here. And that will continue for a long, long time.

Robert P. Langlands
*Institute for Advanced Study*
*Princeton, New Jersey*

I first met Harish-Chandra when I was an instructor at the University, in the fall of 1961, when he was visiting the Institute before taking up a position as professor in 1963. At that time the current literature seminar still was held every Wednesday in the old Fine Hall, and for me, in my youth, it was the central event of the week, with the best of mathematics and its brightest stars. Everyone attended, all of the Institute, or so it seems to me in retrospect, coming over to the University for that one afternoon, Harish-Chandra without fail, always on foot, and usually in the company of Armand Borel and André Weil.

I believe it was at the first meeting of the term—I had written to him earlier with questions and comments on his papers, but had not yet seen him—that he searched me out to give me, somewhat tardily, some reprints that I had requested. He was not yet forty, but already the man I remember. The carriage was erect and aristocratic. The magnificent features, which had, I am told, made of him and his young bride Lily the uncrowned prince and princess of the Amsterdam Congress in 1954, were austere and chiselled, the outward expression of an almost unbearable inner intensity. But the flashing smile and the sparkling laugh, often triumphant, occasionally mischievous, were more frequent then than they later became.

His greatest achievement, the construction of the discrete series, still lay before him, and I have always reckoned it my great good fortune to have met him before 1964, when he proved their existence, and to have been close to him at the time. The discrete series are the keystone of his own theory of harmonic analysis and, it seems to me, the clue to all later developments in representation theory, especially of the cohomological methods, which Harish himself never assimilated, and the source of its vigor, transforming it from a peripheral to a central mathematical domain.

This is not the place for a technical exposition. However, we can perhaps recall the beginnings of Harish-Chandra's mathematical career and of the subject with which he was identified and which was identified with him.

He took the M.Sc. degree in 1943 at the age of nineteen in Allahabad and, as was natural for an ambitious young man of a theoretical bent in India at the time, when Raman's fame and influence were strongly felt, he chose to study not mathematics but theoretical physics, moving to the Indian Institute of Science in Bangalore, where he met the very young girl who was later to become his wife and where he studied with H. J. Bhabha. Bhabha was perhaps too easy-going for Harish-Chandra's taste, but he did recognize the young man's promise and sent him off to study with Dirac, apparently as soon as wartime conditions permitted, for Harish was on board the ship bound for England before the war in the Pacific had ended.

During the time with Dirac, partly as a student in Cambridge and partly at this Institute, which Dirac visited in 1947/48, bringing him along as his assistant, Harish-Chandra abandoned physics and turned to mathematics. I suppose he followed his own inclinations, but I gather that Dirac did not conceal that he had a much higher regard for Harish's abilities as a mathematician than as a physicist. In no way did this diminish Harish's affection for Dirac. On the contrary, he was, and remained until the end, the only person for whom Harish expressed unreserved admiration. He credited Dirac, and perhaps a few other physicists of that generation, with a sixth sense or intuition, for him a spiritual quality, which he felt was denied himself and other mathematicians. We were, I am afraid, lesser beings.

In the last years in India and in England, Harish-Chandra was busy with relativistic field theory; his ideas have since found their way into some texts. Fields imply an infinite number of dimensions and relativistic entails the Lorentz group, a non-compact semi-simple group, and the focus of all Harish-Chandra's efforts, in spite of several attempts in his early years in America to break away, was to remain the theory of infinite-dimensional representations of semi-simple Lie groups.

Almost immediately upon his arrival in Princeton he began working at a ferocious pace, setting standards that the rest of us may emulate but never achieve. For us there is a welter of semi-simple groups: orthogonal groups, symplectic groups, unitary groups, exceptional groups; and in our frailty we are often forced to treat them separately. For him, or so it appeared because his methods were always completely general, there was a single group. This was one of the sources of beauty of the subject in his hands, and I once asked him how he achieved it. He replied, honestly I believe, that he could think no other way. It is certainly true that he was driven back upon the simplifying properties of special examples only in desperate need and always temporarily.

He very quickly set himself a goal, that of establishing a Plancherel formula for semi-simple groups, which at first glance seems idle, and one of those misguided attempts at generalization, in this case of Fourier analysis, to which mathematicians are so often tempted. I think Harish himself saw it a little that way, affirming repeatedly in the early years that he intended to finish up his work in group-representation theory and get on with something else, that it seemed wrong to him to spend most of his life on the subject.

Indeed, he turned to mathematics eager to conquer all that was best or most exciting at the time, taking courses on Lie algebras and class field theory from Chevalley and Artin at Princeton, and then moving on to Harvard to study algebraic geometry with Zariski. For those who knew him only later, it is astonishing and moving to hear him in a letter of 1949 to Irving Segal in which he describes his ideas for proving the Plancherel formula for complex groups stating that he knew too little analysis at the moment to do much with them, and then adding, "Besides there is algebraic geometry to be learnt"—the bar on the final "t" three-quarters of an inch long!

But Harish-Chandra's temperament did not allow him to disperse his energies. So, more and more taken up with semi-simple groups, which demanded complete concentration of his enormous abilities and whose features and significance only slowly revealed themselves, he never became an active geometer or arithmetician. Nonetheless, as we understand better each day, his work holds the key to some central and previously intractable problems in these domains. Harish knew this and, from the very beginning, greeted these developments with encouragements and, in my own case, great generosity. He struggled to master them, which for him meant turning the ideas over again and again until they caught and reflected the light of his own imagination, a long, sometimes almost impossible, task.

He was a man who kept no useless papers, apparently taking his manuscripts once published, turning them over, and using the backs for scrap. The rest, those still open, and there were several boxes full, he heaped on his desk, leaving only a small working space in the middle. Among them at his death were not only his own manuscripts in the course of preparation but also notes from Artin's lectures taken thirty-five years earlier, the papers of younger mathematicians with whose ideas he was preoccupied—there were several—and even notes from a current seminar which I had left in his pigeonhole two days earlier, on the Friday, as a gesture, little thinking he would look at them. But on the Saturday morning he came and sat down beside me before one of the lectures at the Borel conference, as he had not done for a long time, and inquired, "Do you really understand Arthur's work?" It had been the topic of the seminar. I replied, in what I thought was a self-deprecating fashion, that after all I had been studying it for six weeks. "Ah," he sighed, "I have been struggling with it for months."

Life at the Institute was not easy for Harish, but he felt that here was where he should be. He liked to lecture, and did so often, usually delivering courses on his own work, and more than one person has confided in me that it was at these lectures that he learned what it was to be a mathematician. However, Harish was in some ways a timid man and the rough-and-tumble and give-and-take which are also a part of life here did not appeal to him. Besides he always thought of himself as an outsider, perhaps because he came to mathematics late. He was a passionate admirer of two other great outsiders, Cézanne and Van Gogh, seeing himself in them. This I always felt, but I did not discover until after Harish's death that he himself had been an enthusiastic and talented painter in his youth.

It is difficult to communicate the grandeur of Harish-Chandra's achievements and I have not tried to do so. The theory he created still stands—if I may be excused a clumsy simile—like a Gothic cathedral, heavily buttressed below but, in spite of its great weight, light and soaring in its upper reaches, coming as close to heaven as mathematics can. Harish, who was of a spiritual, even religious, cast and who liked to express himself in metaphors, vivid and compelling, did see, I believe, mathematics as mediating between man and what one can only call God. Occasionally, on a stroll after a seminar, usually towards evening, he would express his feelings, his fine hands slightly upraised, his eyes intent on the distant sky; but he saw as his task not to bring men closer to God but God closer to men. For those who can understand his work and who accept that God has a mathematical side, he accomplished it.