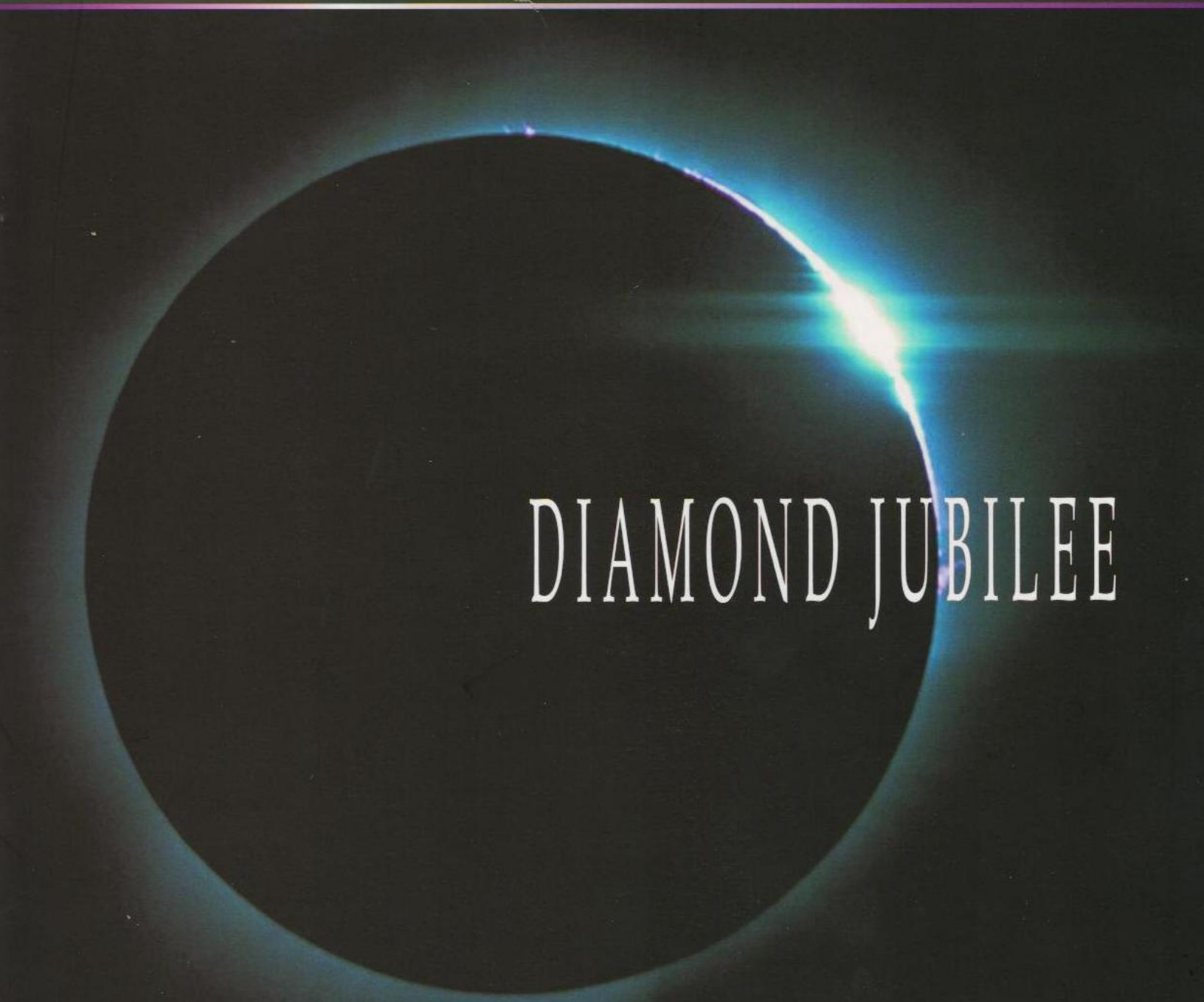
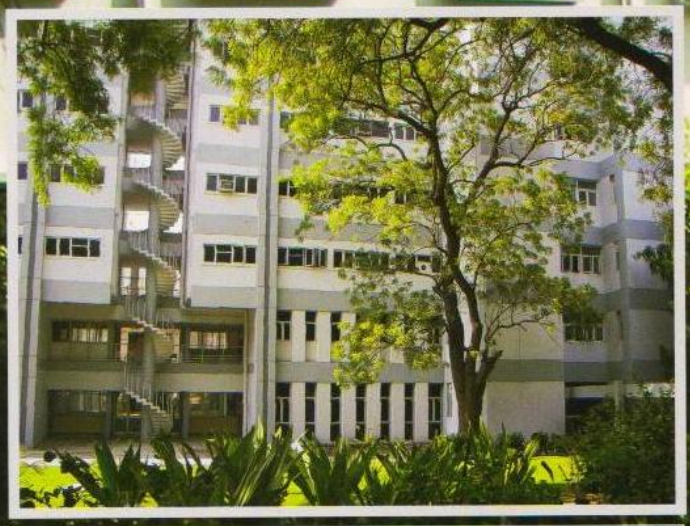
PHYSICAL RESEARCH LABORATORY



DIAMOND JUBILEE

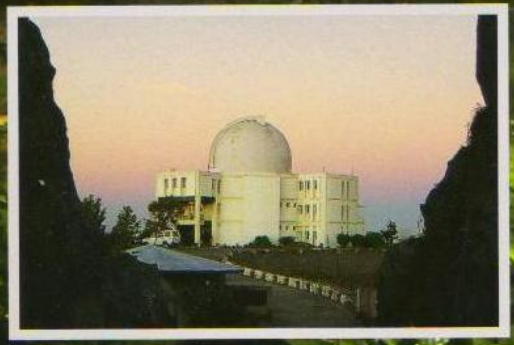
2006-07



PRL MAIN CAMPUS, AHMEDABAD

Theoretical Physics
Space & Atmospheric Sciences
Planetary & Geosciences

Library
Computer Center
Support Facilities
Ramanathan Auditorium
Central Administration

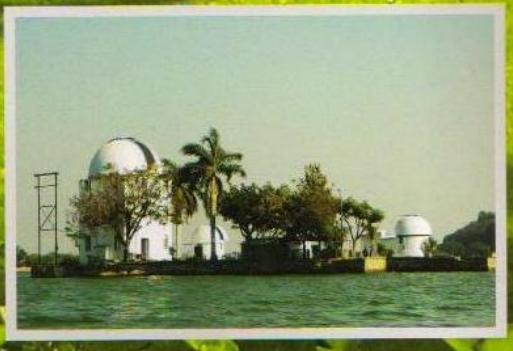


INFRARED OBSERVATORY, MT. ABU

1.2 m Infrared Telescope
Aluminising Plant

THALTEJ CAMPUS, THALTEJ, AHMEDABAD

Astronomy & Astrophysics
PLANEX Program



SOLAR OBSERVATORY, UDAIPUR

Solar Physics

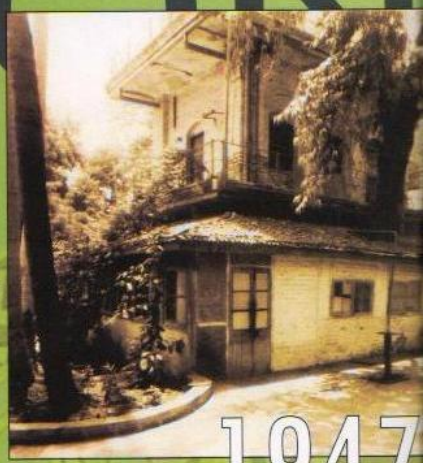
The Physical Research Laboratory, PRL, regarded as the cradle of Space Sciences in the country, was founded by Dr. Vikram A. Sarabhai on 11 November, 1947. The Laboratory was established to carry out research in Cosmic Rays and Atmospheric Sciences, the areas of specialization of Dr. Sarabhai, the Founder, and Prof. K.R. Ramanathan, its first Director. During the past six decades, PRL has grown into a front-ranking research institution of the country through its pioneering contributions on a breadth of scientific programs in the areas of Space & Atmospheric Sciences, Astronomy & Astrophysics, Planetary & Geosciences and Theoretical Physics. A recent addition to this broad spectrum of research areas is Planetary Sciences and Exploration.

The scientific growth of PRL also resulted in its expansion, starting with a few rooms at the residence of Dr. Sarabhai's family "Retreat" in 1947, to four large campuses at present—the main and a satellite campus at Ahmedabad, one at Udaipur hosting the Solar Observatory and the fourth, the Infrared Observatory at Mt. Abu. The main campus houses the Theoretical Physics, Space & Atmospheric Sciences and Planetary & Geosciences Divisions, main library, computer center, support facilities and the Ramanathan Auditorium. The scientific activities and facilities of PRL are supported by an able administration also based at the main campus. The Astronomy & Astrophysics Division and the PLANEX program are at the satellite campus at Thaltej.

Scientists and scientific activities of the Laboratory have received critical national and international acclaim which has carved a niche for PRL among the global scientific community. PRL also has the distinction of being the nucleation center for the Indian Space Research Organization and the Institute for Plasma Research, Gandhinagar. In addition, PRL has been continually nurturing young talent through its doctoral and other training programs, thus contributing significantly to the development of highly skilled scientific and technical manpower needs of the country. Many scientists of PRL, over time, have taken up leadership roles to guide the country's science and technology initiatives, particularly in the field of space application and exploration.

Over the last sixty years, PRL has been fulfilling its mandate to promote "fundamental research in Physics, Astrophysics, Geophysics and other allied subjects" and has been expanding its research canvas to new and exciting frontier areas. These, in turn, are generating new scientific questions and technological challenges which are being addressed by PRL scientists through novel approaches. This brochure provides a glimpse of science at PRL and its continuing efforts to be at the forefront of fundamental research.

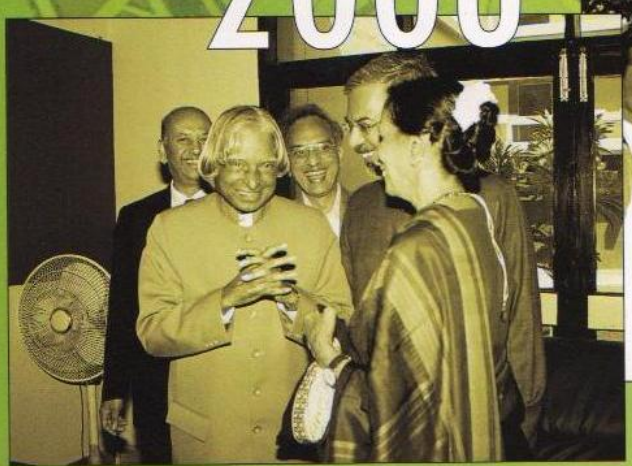
MILESTONES



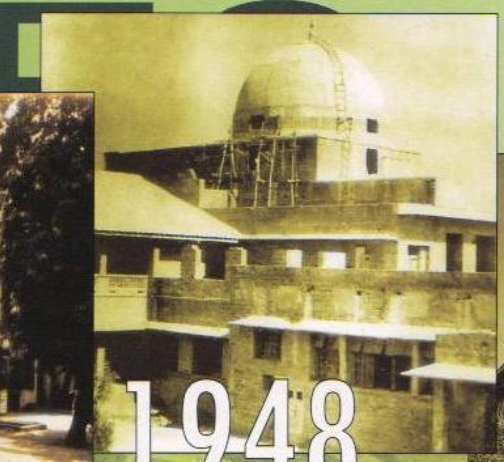
1947

- 1947, 11th November: PRL founded at "Retreat"; Initiated Cosmic Ray Studies
- 1948: Moved to M. G. Science Institute; began Atmospheric Sciences Program
- 1949: Initiated Theoretical Physics; Radio Physics & Electronics Programs
- 1950: Formed First Council of Management
- 1951: Established Ozone Station at Hill View, Mount Abu
- 1953: Set up Ionospheric Research Station
- 1954: Prime Minister Jawaharlal Nehru inaugurated the first building of PRL
- 1955: Set up the Gulmarg Research Station for Cosmic Rays Studies
- 1963: PRL signed Quadri-partite Agreement
- 1968: Formed Plasma Physics Group
- 1973: Established Geocosmophysics Group
- 1973: Celebrated Silver Jubilee Year
- 1975: Seeded Infrared Astronomy and Interplanetary Scintillation Groups
- 1981: Amalgamated Udaipur Solar Observatory with PRL
- 1987: Established the Thaltej Campus
- 1987: PRL received the Vikram Sarabhai Award from the Gujarat Government
- 1994: 1.2m telescope at Mt. Abu made operational
- 1995: Formed Laser Physics & Quantum Optics Group
- 1996-97: Celebrated Golden Jubilee Year
- 2001: Initiated the Planetary Sciences and Exploration (PLANEX) Program
- 2001: Celebrated Silver Jubilee Year of Udaipur Solar Observatory
- 2006-07: Celebrated Diamond Jubilee Year

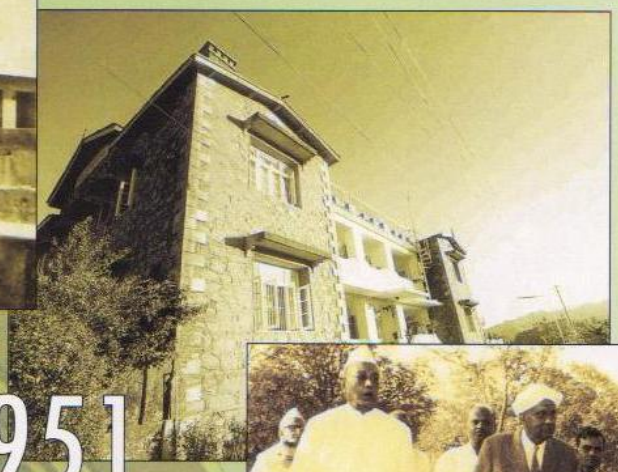
2006



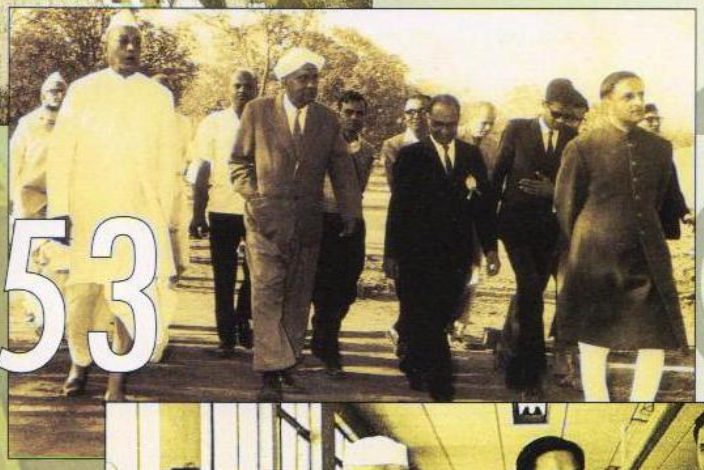
MILESTONES



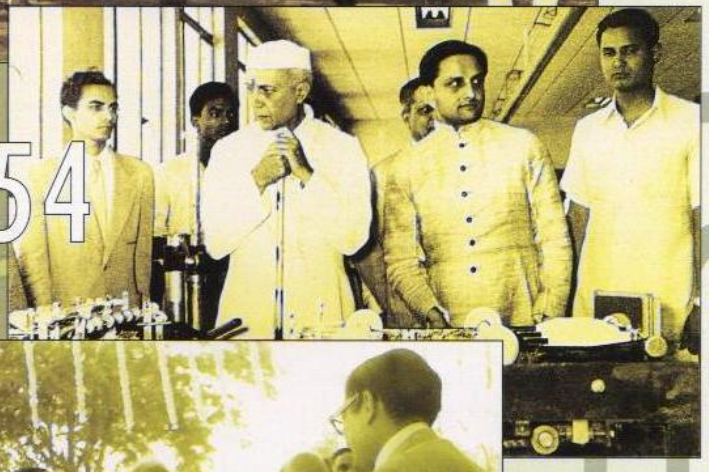
1948



1951



1953

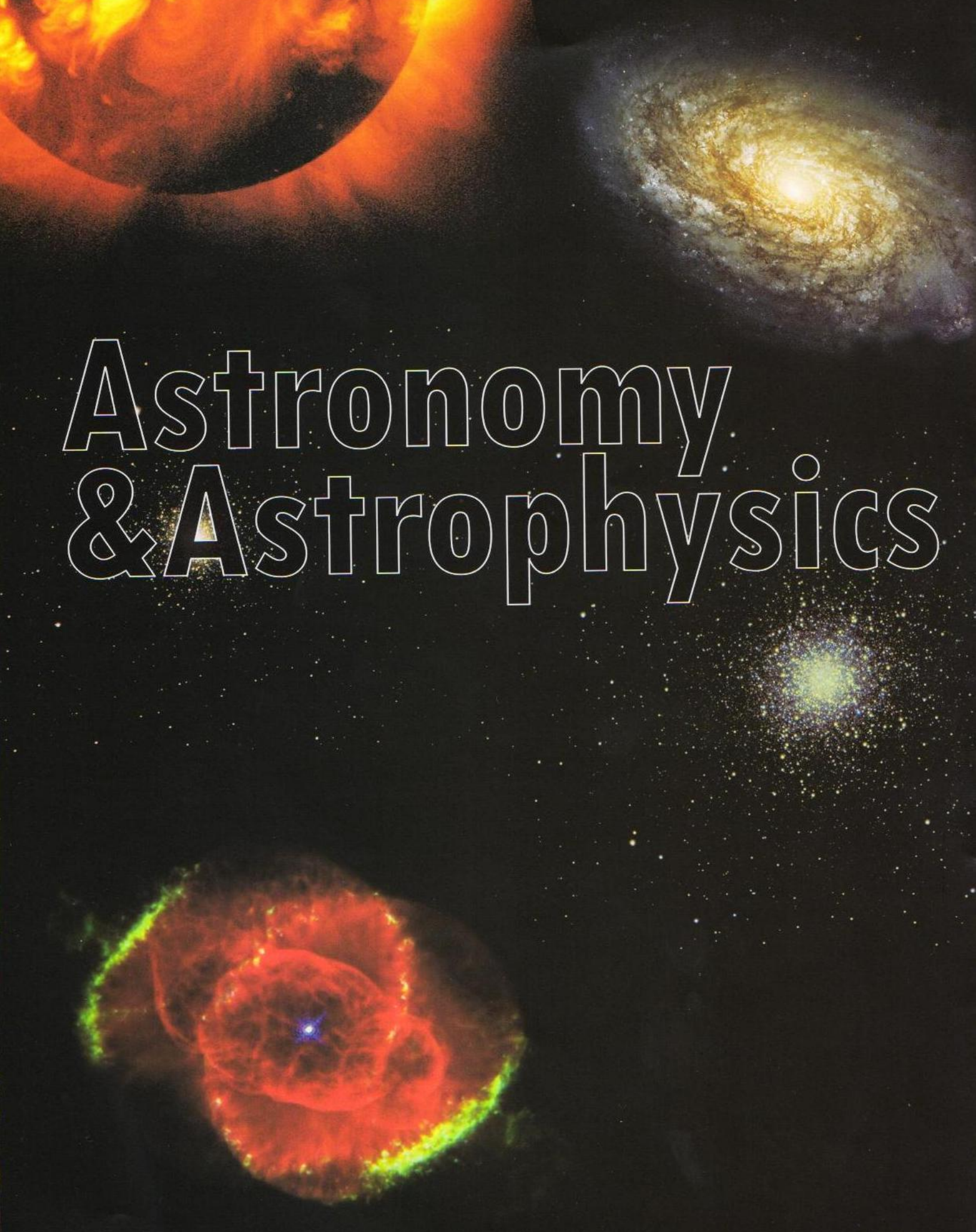


1954

1973

1997

1987


Astronomy
&Astrophysics

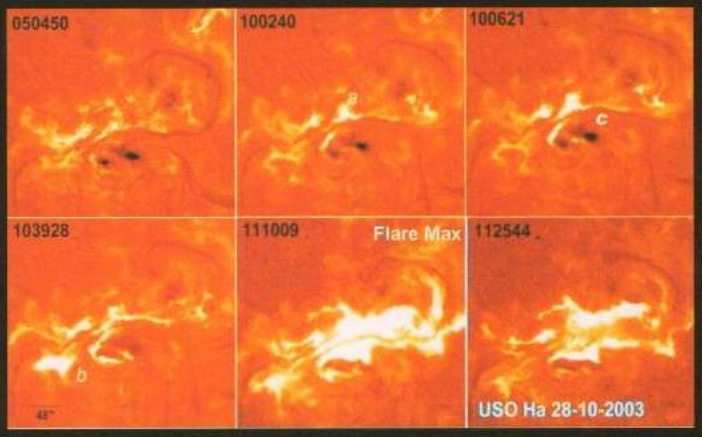
The Sun during the day and starlit sky during the night have fascinated mankind since the dawn of civilization. The Sun continues to draw the attention of astronomers as some of its attributes such as its internal structure, the solar activity cycle, origin of solar flares and their influence on interplanetary space remain to be fully characterized. Similarly, there are many aspects of stellar evolution that need to be explored and understood. The research activities of the Astronomy and Astrophysics Division cover a wide spectrum of topics to address questions that include: What are the details of the processes regulating the generation, storage and release of energy from the Sun during its active and passive periods? What are the effects of these processes on interplanetary space and on the Earth? How do stars form in dense interstellar molecular clouds? How do they interact with the surrounding medium? How do they finally evolve to exotic objects such as the white dwarf, planetary nebulae, novae & supernovae and end their lives? How do active galactic nuclei generate large amount of energy in a small volume? Observations of the Sun and other exotic stellar objects in our own galaxy, the "Milky Way", and in far away galaxies provide clues to these questions. Scientists of the Division are carrying out such observations using the indigenously built Infrared Telescope at Mt. Abu while the studies of the Sun are conducted from the Udaipur Solar Observatory and also from dedicated space-borne instruments on Indian satellites.

What are the details of the processes regulating the generation, storage and release of energy from the Sun? How do stars form in dense interstellar molecular clouds? How do they evolve to white dwarf, planetary nebulae, novae & supernovae?

The origin and evolution of energetic transient phenomena occurring on the Sun and its outer layers, provide valuable information on generation, storage and release of energy from it. High spatial resolution observations of magnetic velocity fields in flare sites by PRL scientists have clearly demonstrated the role of magnetic shears in the storage and release of energy during solar flares. More recently, studies on solar flare produced X-rays are also being made using a dedicated Solar X-ray Spectrometer (SOXS) flown on-board an Indian geostationary satellite. Results from this experiment, especially from hitherto unobserved spectral emissions from iron and nickel, have shed new light on solar flare phenomenon and temperature profile in the solar corona. Dr. R. Jain, associated with the SOXS project, observes, "Our X-ray results have provided new openings to probe the outer atmosphere of the Sun during flares."

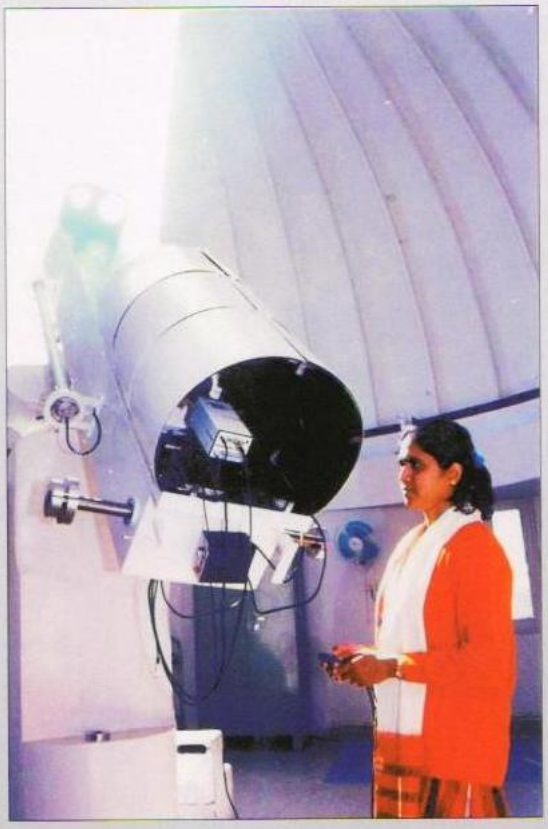
The discovery that the Sun is oscillating with different characteristic time scales has opened a new window to study its interior through what is now known as Helio-seismology, similar to the concept of studying interior of the Earth through seismic observations. An international Global Oscillation Network Group (GONG) has been monitoring solar oscillations round the clock at six centers across the globe, the Udaipur Solar Observatory being one of them. The results obtained though broadly confirm the standard solar model, they have raised new questions regarding the internal structure of the Sun.

The effect of solar energetic particles and radiations in the interplanetary space and on the Earth, termed as Space Weather, is an active area of research in global communication and space exploration. Scientists of the Division are pursuing studies of space weather through investigations of solar wind,



the continuous flow of low energy solar particles, and of sporadic energy release from the Sun during active periods, using facilities at PRL and elsewhere and also by analyzing spacecraft data. These studies have given new insights into the processes of mass ejection from solar corona and morphology of the energetic solar flares.

Galactic and extragalactic astronomy is another thrust area of research of the Astronomy and Astrophysics Division. Nova outburst, an important celestial phenomenon, results from accretion of matter on a white dwarf from a companion star that predominantly contributes hydrogen-rich material. Scientists of the Division are credited with the first observation of a rare Helium Nova, where spectroscopic observations showed that the material added was predominantly helium and not hydrogen. Studies of eruptive stars provide new information on ejected nascent stellar material and its subsequent evolution in the surrounding medium. Observations of one such eruptive variable showed the presence of hydrous cool molecular material in its surrounding. This provides new inputs to model astrochemistry in cooler stellar neighborhood. Spectroscopic studies on another eruptive variable seemed to indicate that it is young and surrounded by a circumstellar disk of gas, dust and ice. Although models have been proposed to explain these stellar eruptions, a proper understanding of such outbursts and the unexpected presence of cool circumstellar material is still awaited. Prof. N. M. Ashok and Dr. D. P. K. Banerjee, engaged in these programs comment, "these results are very new and exciting and have drawn the attention of astronomers around the globe resulting in joint international ventures to study these phenomena further."



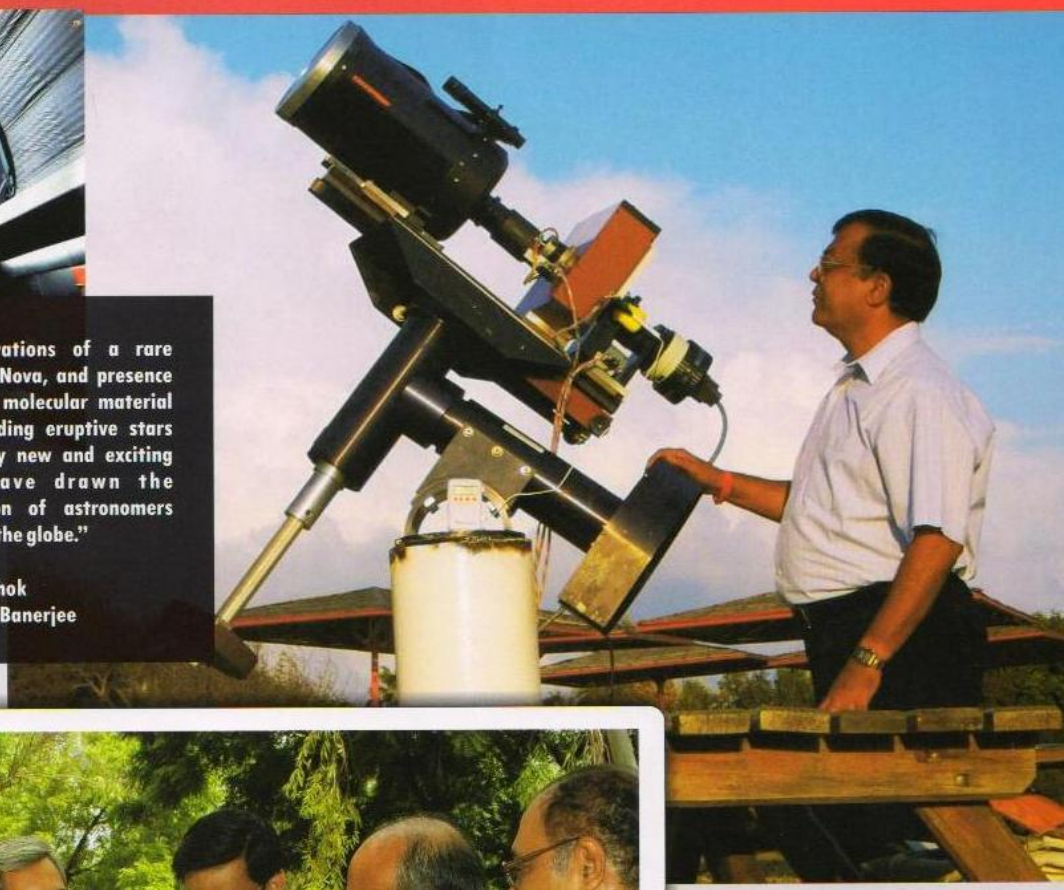
The process of star formation generally takes place in dense nebular region of interstellar space under the influence of gravitational field, and may proceed through different pathways. Observations carried out by the Division members on the Lagoon nebula suggest the possible slowing down of star formation rate, while in the dark cloud L1340, massive star formation seems to occur through accretion rather than coalescence, as has been generally accepted. Circumstellar dust, in the form of shell and other structures, has been detected around both massive stars and cool carbon-rich stars. These observations help to understand the processes leading to the formation of grains from condensation of gas in a circumstellar environment.

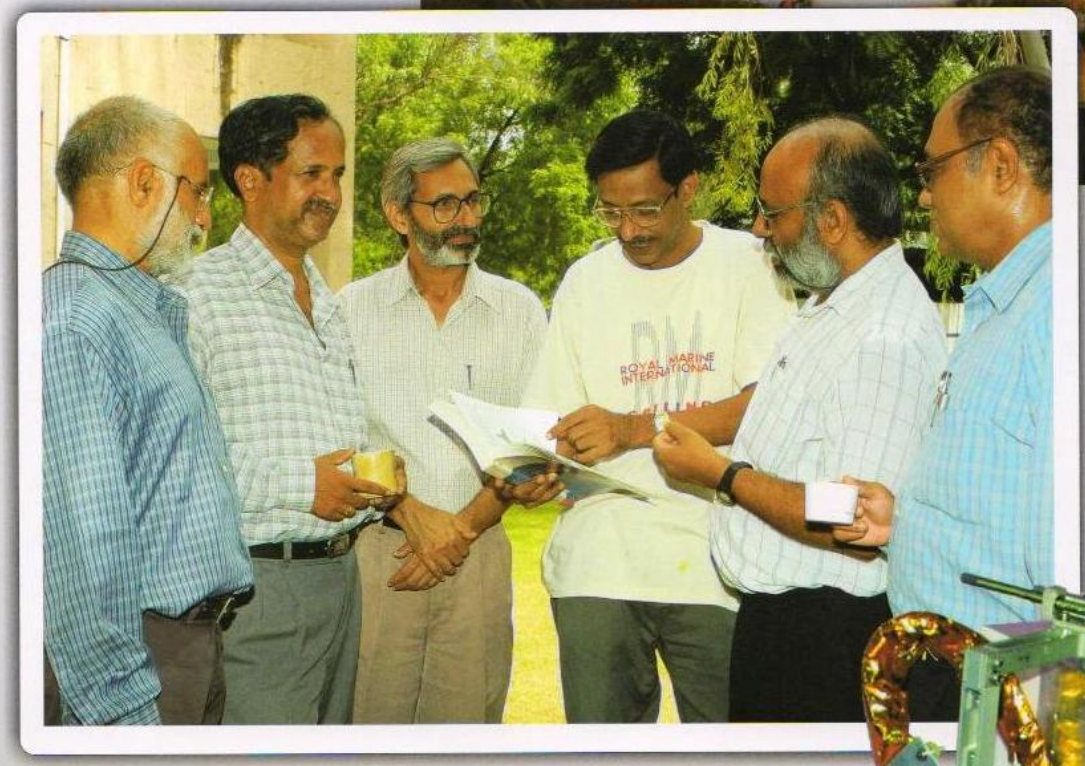
The source of the tremendous energy generated in the inner regions of Active Galactic Nuclei (AGN), that have extremely large magnetic field and extended jet structures, continues to attract attention of the astronomical community. Scientists of the Division are engaged in studies of AGN variability in polarized light emitted by them to characterize conditions prevailing in their most energetic inner regions.

The Astronomy and Astrophysics Division will continue to explore the various processes occurring in the Sun with a "Multi Application Solar Telescope (MAST)" to be established soon at Udaipur. Prof. P. Venkatakrishnan, leader of the MAST project observes, "MAST" will provide new opportunities and challenges to Indian Solar Physicists." In stellar astronomy the emphasis will be to further enhance our understanding of stellar evolution and to search for extra-solar planets using new and state of the art optical and infrared imagers and spectrometers.

"Observations of a rare Helium Nova, and presence of cool molecular material surrounding eruptive stars are very new and exciting and have drawn the attention of astronomers around the globe."

N.M. Ashok
& D.P.K. Banerjee



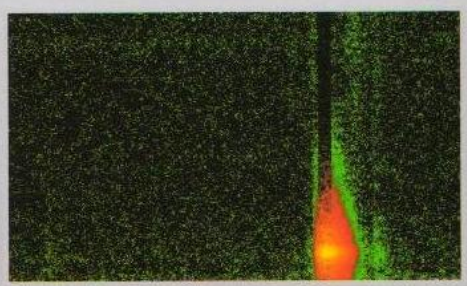


"Multi Application Solar Telescope (MAST) will provide new opportunities and challenges to Indian Solar Physicists."

P. Venkatakrishnan

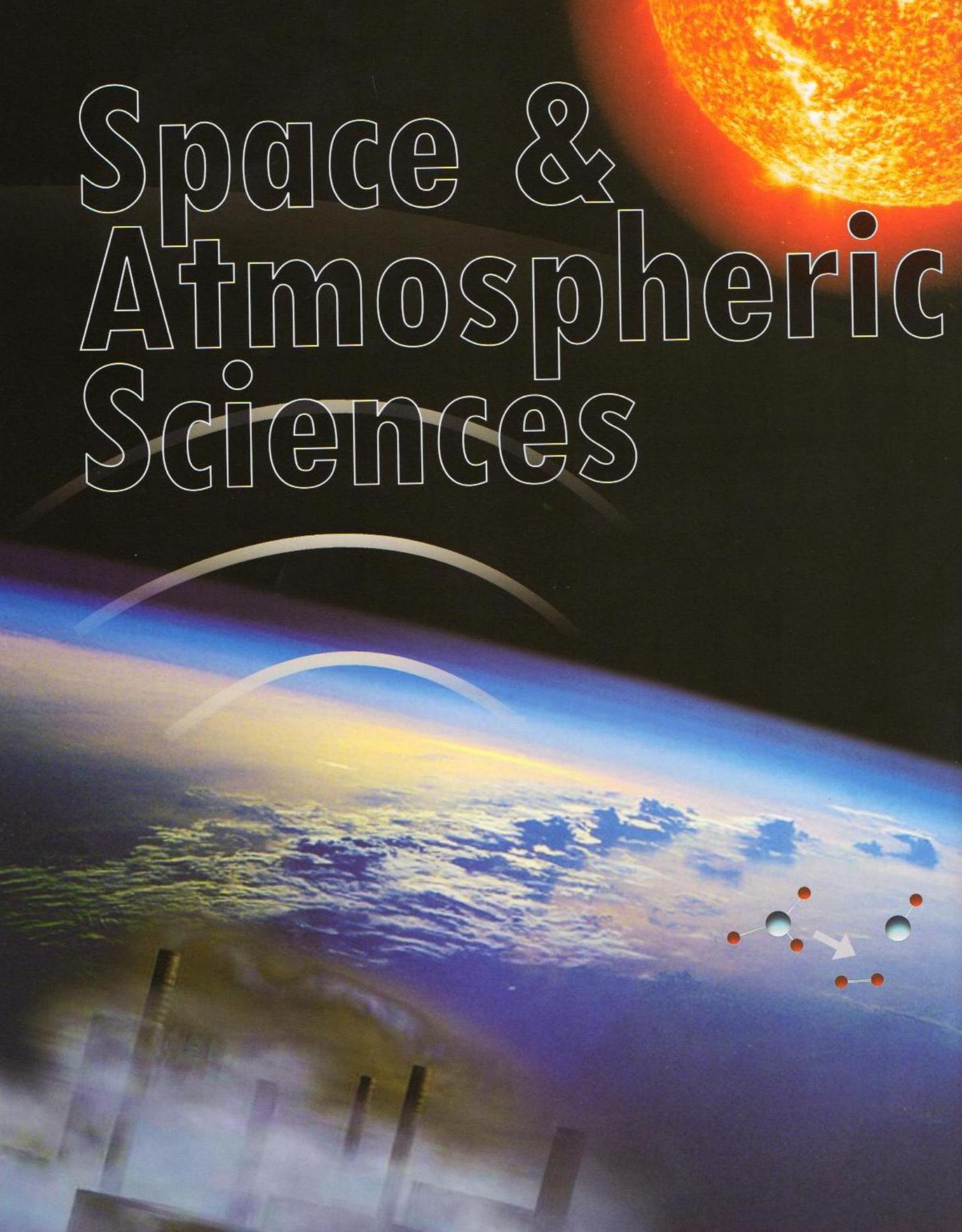
"Our X-ray results, using a dedicated Solar X-ray Spectrometer (SOXS) flown on-board an Indian geostationary satellite, have provided new openings to probe the outer atmosphere of the Sun during flares."

R. Jain



SOXS Count Flux Spectrogram

Space & Atmospheric Sciences

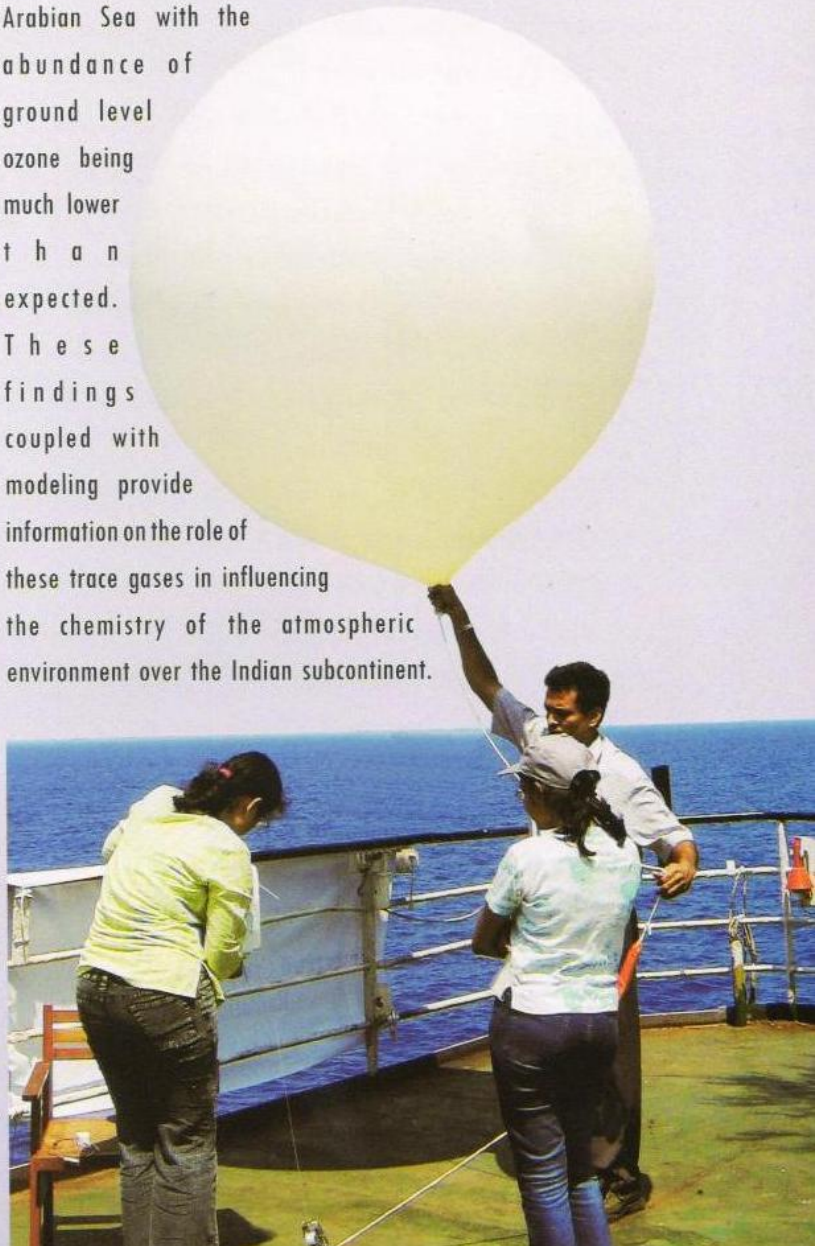


The presence of air and water on the Earth makes it a unique planet in our Solar System. These two reservoirs have played a major role on the evolution and sustenance of life on the Earth. Both the atmosphere and the oceans are in a state of perpetual motion and their composition is in a state of continuous change due to natural and anthropogenic causes. The scientists of the Space and Atmospheric Sciences Division are engaged in studies to obtain in-depth understanding of processes and feedbacks that have relevance to complex phenomena occurring in the atmosphere and to global change. The broad questions being pursued include: How do the concentrations of key atmospheric constituents such as trace gases, ozone, and aerosols change with time and space, especially over and around the Indian sub-continent? What are their effects on energy budget of the atmosphere? How does the space environment influence the earth-atmosphere system? These questions are addressed through a multi-pronged approach, by conducting *in situ* studies using rocket and balloon borne instruments, remote sensing by optical and radio probes as well as by analytical modeling.

How do the concentrations of key atmospheric constituents, trace gases, ozone, and aerosols, change with time and space? How does the space environment influence the earth-atmosphere system?

The earth's atmosphere is broadly divided into four regions. The uppermost layer is the thermosphere followed by the mesosphere, stratosphere and troposphere. Solar radiation interacts with the constituents of the various layers of the atmosphere. These interactions in the thermosphere and mesosphere generate the ionosphere abundant in plasma. The ionosphere is subdivided into three layers, the uppermost one is known as the F region. The physical processes occurring in the ionosphere are influenced by charged particles, whose motion is governed by earth's magnetic field. The special configuration of the magnetic and electric fields gives rise to complex phenomena in the ionosphere, one of them being the Equatorial Spread-F (ESF) which is important from both academic and practical perspectives. Scientific investigations on electron density distributions and air-glow emissions carried out by the Division using rocket-borne and ground-based instruments and numerical simulation, have led to fundamental understanding of the ESF phenomenon and its possible precursors that may enable prediction of its occurrence.

A major effort of the Division during the last decade was to understand the behavior of ozone and trace gases such as Chloro-Fluoro-Carbons (CFCs) in the stratosphere and the troposphere in terms of chemistry and dynamics of these regions. Studies of transport and transformation of ozone and related chemical species from the Indian subcontinent to the surrounding marine regions have also been pursued. The results of these studies suggest that in winter the Bay of Bengal is more polluted than the Arabian Sea with the abundance of ground level ozone being much lower than expected. These findings coupled with modeling provide information on the role of these trace gases in influencing the chemistry of the atmospheric environment over the Indian subcontinent.



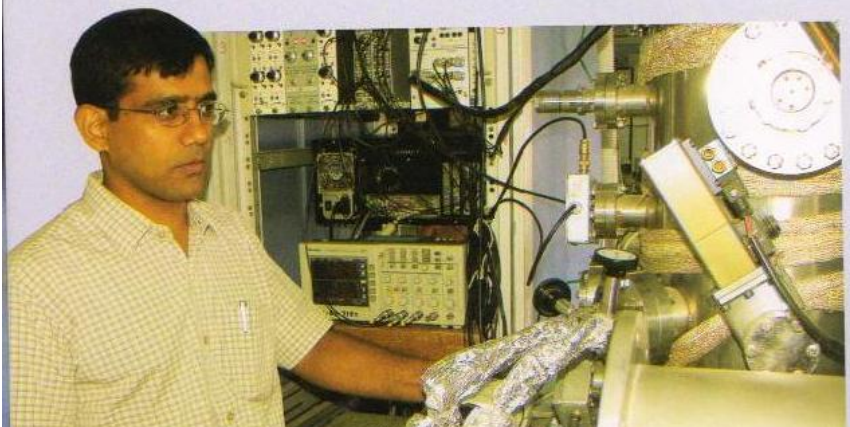
Prof. Shyam Lal observed, "These results have important implications to atmospheric chemistry and global change studies."

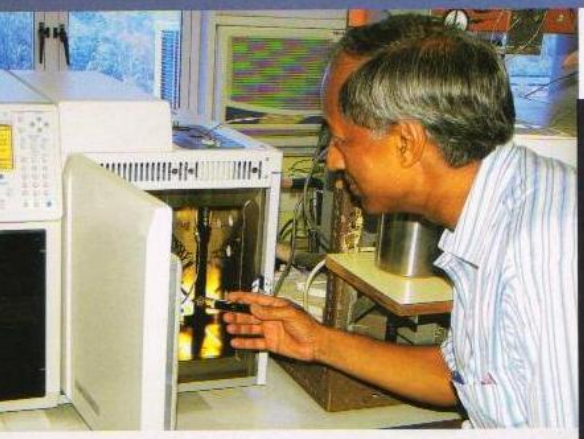
Aerosols play an important role in atmospheric radiation budget which has thermal and climatic implications. Extensive studies are being carried out by the Division on atmospheric aerosols in terms of their size, composition, distribution and radiative properties through a variety of approaches. A major contribution of the Division is estimation of the aerosol radiative forcing over the Indian subcontinent and the surrounding marine regions both through direct observations, as part of the Indian Ocean Experiment and field campaigns of the ISRO Geosphere Biosphere Program, and analytical modeling. Current research activities are focused on apportionment of the absorbing and scattering, and natural and man-made aerosols to the total aerosol radiative forcing to assess their relative importance to climate change. Prof. A. Jayaraman, while reviewing these findings commented, "Quantifying the contribution of aerosols to overall radiation budget of the atmosphere is crucial for climate related studies, particularly to enhance predictive capabilities."

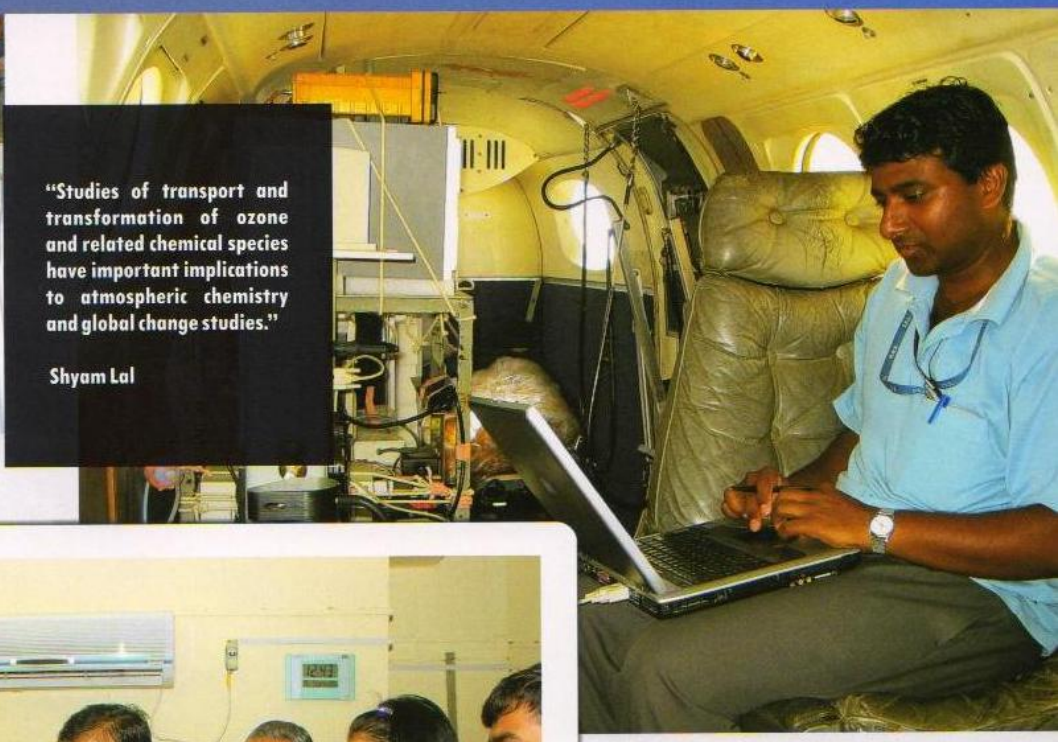
Interaction of photons with molecules in the atmosphere is of interest to atmospheric and space scientists. Laboratory studies of such interactions using SO_2, CS_2 and CCl_4 are being conducted by the Division to complement the field-based observations. The results demonstrate that dependence of the photo-absorption cross section on temperature differs among these molecules. For example, studies of NO_2 showed that interactions of molecules in excited state can lead to anomalous radiative lifetime. Studies on dissociative ionization of molecules are also being carried out through a novel approach by analyzing the momenta of fragment ions using an ion-momentum spectrometer built in-house. Investigations on an allied topic, namely the effect of photon induced or other kinetic processes on the oxygen isotope composition of atmospheric ozone and carbon dioxide have revealed the occurrence of non-mass dependent isotopic fractionation. These results are important to understand atmospheric chemistry at molecular level in the stratosphere.

In addition to our own planet, scientists of the Division are also carrying out modeling studies of the space environment around Mars and comets based on spacecraft data from the Martian and cometary atmospheres. These studies bring out the importance of solar X-rays on the electron density distribution in Martian atmosphere.

The Division while continuing its effort in probing the atmosphere and the space environment around planets and other solar system objects, has ambitious plans to make space based observations of trace gases and aerosols. The future thrust of the Division will be to integrate ground-based, space-borne and *in situ* measurements of these two key components along with numerical models to quantitatively evaluate their impact on regional and global climate. Satellite-based experiments to investigate large-scale spatial structures in ionosphere and space weather impact on it, and studies of clusters in gaseous environments will also form part of future research of the Division.

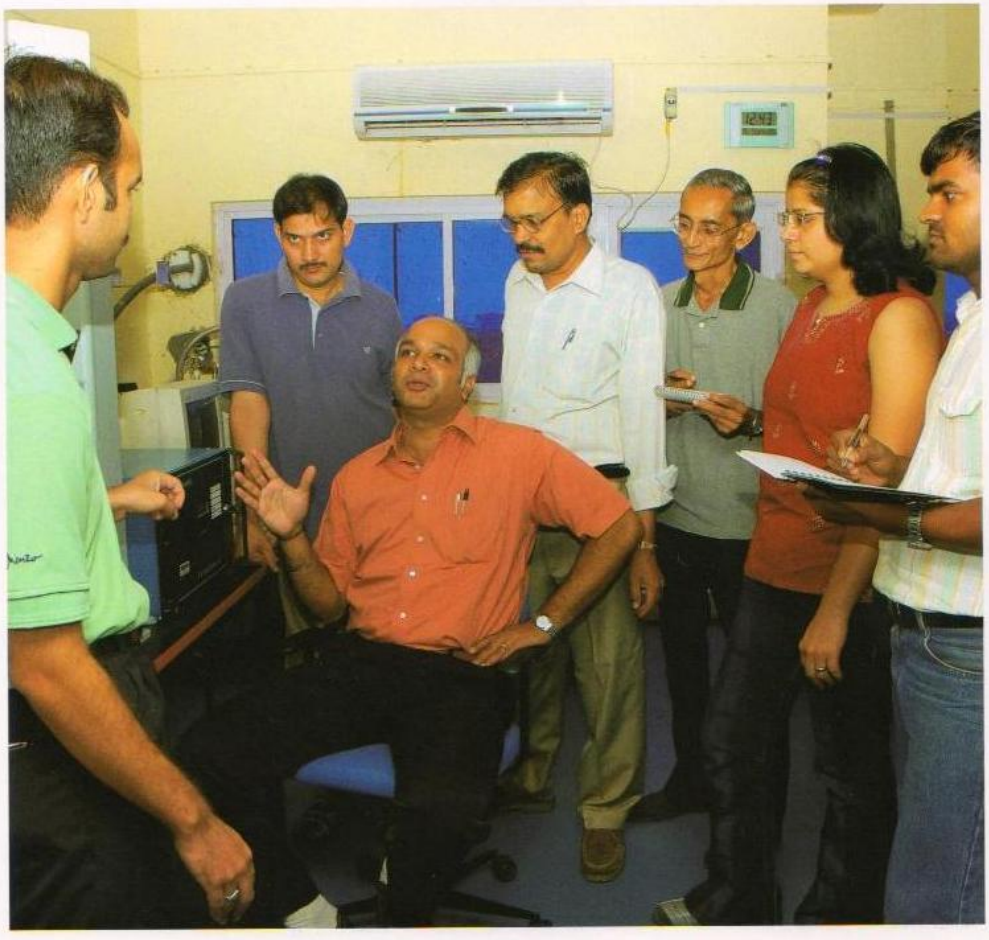






"Studies of transport and transformation of ozone and related chemical species have important implications to atmospheric chemistry and global change studies."

Shyam Lal

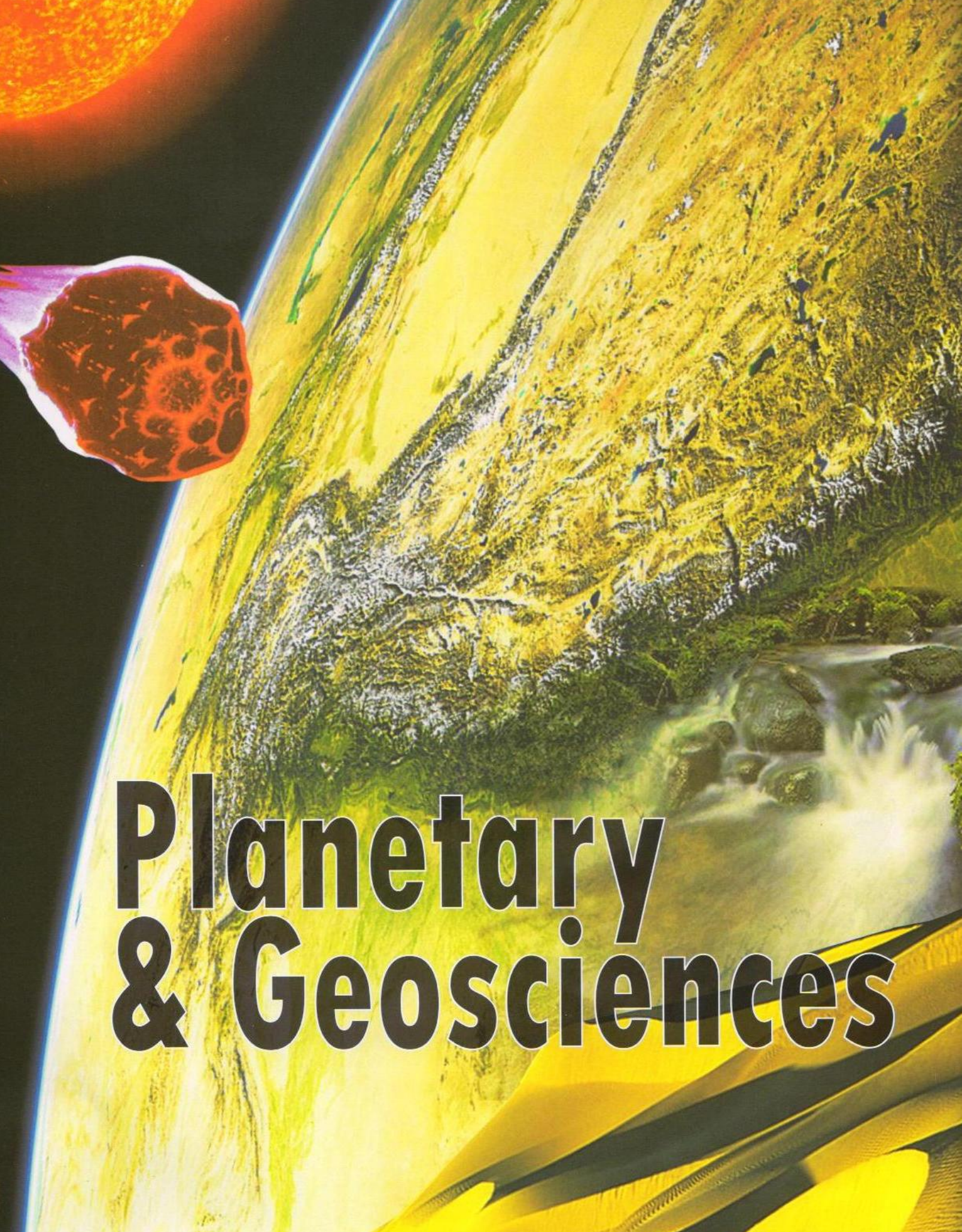


"Quantifying the contribution of aerosols to overall radiation budget of the atmosphere is crucial for climate related studies, particularly to enhance predictive capabilities."

A. Jayaraman

"I am very much excited about the instruments we make at PRL to study the upper atmosphere. I am very happy to be a part of the ionospheric group, which is one of the first groups of PRL."

Uma Kota


Planetary
& Geosciences

The Solar System, with the Sun at its center, is our 'stellar' home in the cosmos. Studies on the origin and evolution of the solar system, with emphasis on our planet Earth are the primary research objectives of the Planetary and Geosciences Division. Scientists of the Division address several overarching questions on these topics, by examining the chemical, isotopic and luminescence records contained in various terrestrial and extraterrestrial samples. The questions include: When and how did the solar system form? How have the various solar system objects evolved through time? What are the processes that determined their evolution? How do these processes vary in time and space?

When and how did the solar system form? How have the Sun, Earth and other solar system objects evolved through time? What are the processes that determined their evolution? How do these processes vary in time and space?

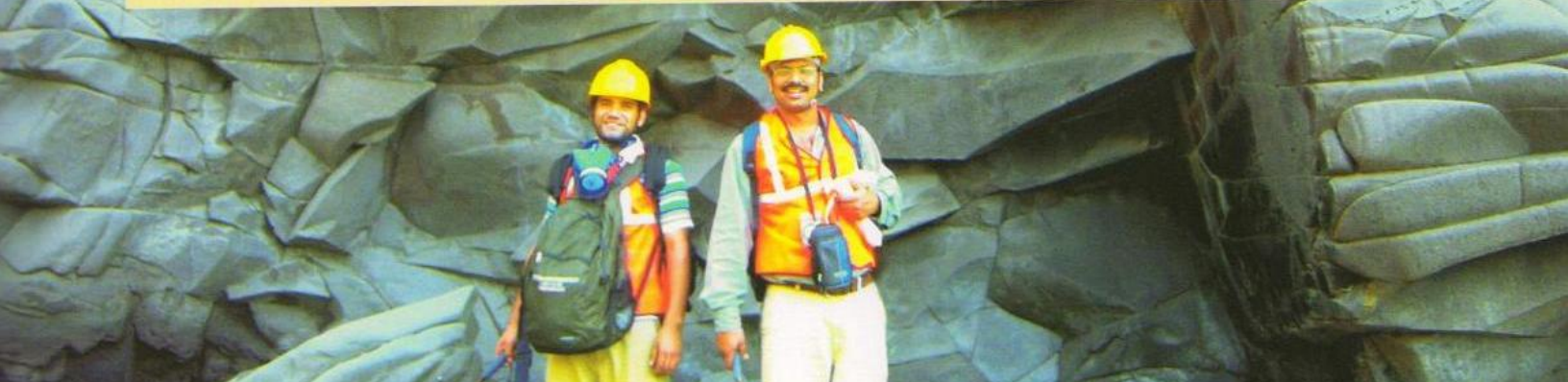
Information on the origin and early stages of evolution of the solar system is stored in some of the minerals formed during its inception. These minerals are extremely rare and are present only in some select groups of primitive meteorites. Isotopic records obtained from these minerals suggest that the death of a massive star triggered the collapse of an interstellar gas and dust cloud that led to the formation of the solar system. Similar studies on another meteorite that fell in the Piplia Kalan village of Rajasthan State, India, provided an unequivocal explanation to one of the long standing issues in solar system studies, namely, identification of the heat source for melting of asteroids during the very early stages of the solar system evolution. The results firmly established that the radioactive decay of Al-26 was the heat source responsible for this melting. These seminal studies led Prof. J. N. Goswami to remark, "these results, that are first of their kind, have drawn the attention of the global planetary scientific community."

Meteorites also contain records of ancient planetary atmospheres and chemical composition of source materials which accreted to form planets. Noble gas and nitrogen isotope studies of meteorites that are fragments of Mars, led to the characterization of ancient Martian atmosphere, and inferences on the chemical composition of the source materials for the Earth and Mars.

Research in Geosciences covers a wide range of topics, with focus on understanding the evolution of various internal (mantle, lithosphere) and external (atmosphere, hydrosphere, biosphere) reservoirs of the Earth, their interactions with each other, and their impact on climate, biogeochemical cycles, and land forms. This is achieved through studies of various materials and processes occurring on the Indian subcontinent, its adjacent seas, and by establishing their global tele-connections.

For example, geochemical and isotopic studies of a unique mantle derived carbon-bearing rock, called carbonatites, confirmed the existence of a long time scale (million year) carbon cycle in the Earth, and tracked the source of these unusual magmas to deep-seated mantle plumes.

The interactions among the surficial reservoirs of the Earth and the processes occurring within and among them influence climate on different time scales. On long time scales, in the range of millions of years the coupling between tectonics and chemical weathering is a key regulator of the atmospheric CO_2 content, and



hence of global climate. Studies on chemical and isotopic composition of rivers draining the Himalaya and the Deccan Plateau have brought out the importance of enhanced silicate weathering in these regions on the atmospheric CO_2 budget, and its contribution to the chemical and isotopic evolution of the oceans.

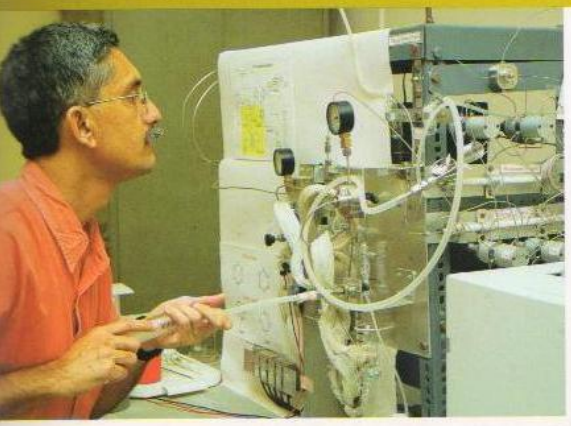
Ocean processes, such as air-sea CO_2 exchange, biological productivity, export of carbon from surface to deep layers and water circulation regulate the biogeochemistry of carbon and climate on short time scales (tens to thousands of years). Studies by the Division show that the Arabian Sea is an important source of CO_2 to the atmosphere whereas the Bay of Bengal is a net sink, bringing out the significance of such regions on the fate of anthropogenic CO_2. Recent studies of atmospheric aerosols, an important climate agent, show that chemistry at micro-scale can affect their composition and characteristics. This in turn can have important bearing on their role on the radiation budget of the atmosphere and hence on regional climate. Prof. M. M. Sarin, prompted by these results observes, "the characterization of aerosol chemistry at nano to micro-scales and their variability in time and space is essential to evaluate their influence on regional climate."

Another component of climate research at PRL is on past climates, particularly deciphering the signatures of past monsoon variability over various spatial and temporal scales, from ocean and continental records such as sea sediments, speleothems, and desert deposits. Several interesting findings have resulted from these studies conducted by the Division. For example, a recent multi-proxy investigation of sediment cores from the eastern Arabian Sea brought out the key role of solar variability on the South-West Monsoon intensity on centennial time scales. Prof. R. Ramesh, engaged in this field of research opines, "Our future high resolution studies of paleomonsoon will provide a more critical assessment of this coupling and its implications to Global Change."

The evolution of land forms also depends on climate. Deserts are an important land form on the surface of the Earth, the Thar Desert of Rajasthan, India being one of them. The chronology of sand profiles and other desert deposits from the Thar was determined based on luminescence method developed at PRL. These results have unequivocally established the antiquity of the Thar Desert to be at least 200,000 years, laying to rest the idea that it is a man-made desert. Further, these investigations have also revealed that the Thar has undergone phases of waxing and waning during its evolution. According to Prof. A. K. Singhvi, "luminescence dating of desert deposits has opened a completely new window to investigate the evolution of deserts and their relation to climate change."

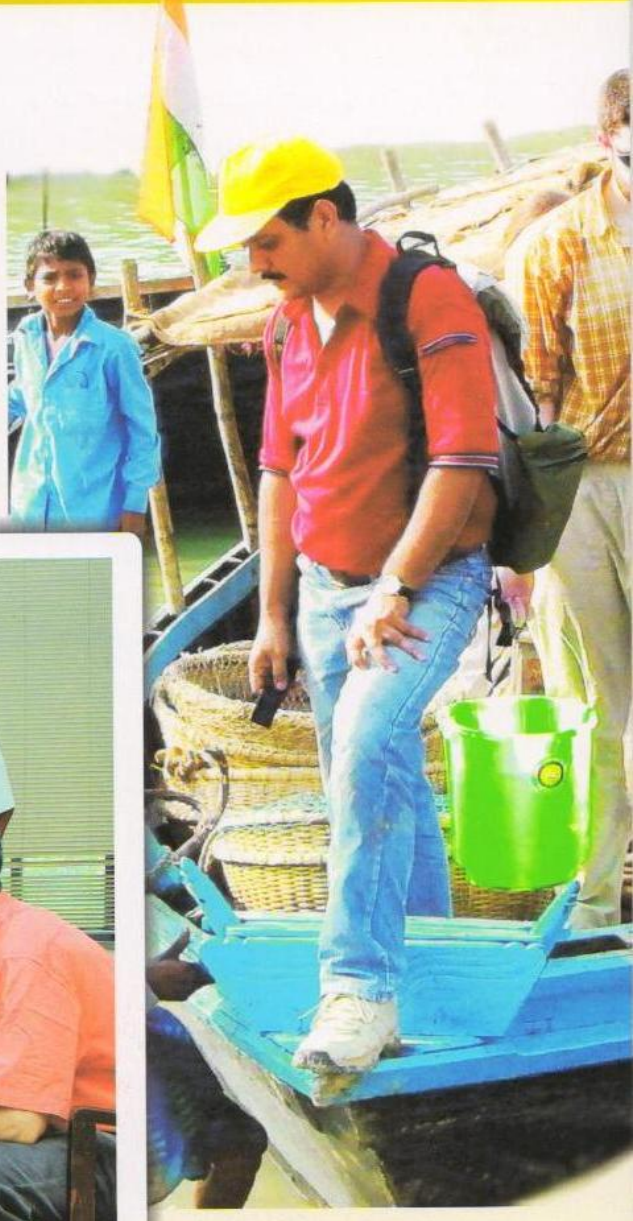
Hydrology is another area of research being pursued by the Division, one of the topics of study being the source of high fluoride concentration in ground waters, a subject that has direct societal relevance. Studies of aquifers of North Gujarat suggest that the high fluoride content in their ground waters owes its origin to enhanced aridity during the last glacial maximum.

Looking ahead, the Planetary and Geosciences Division will pursue research on the evolution of solar system objects through studies of new astromaterials, such as cometary and interstellar dust in addition to samples from the moon, meteorites and Mars using state of the art techniques. The focus in Geosciences will be on studies of crust-mantle cycling, water-rock interactions, ocean-atmosphere chemistry, high resolution paleoclimate reconstruction and global evolution of dry lands.



"Our future high resolution studies of paleomonsoon will provide a more critical assessment of this coupling (Solar variability and South-West Monsoon) and its implications to Global Change."

R. Ramesh



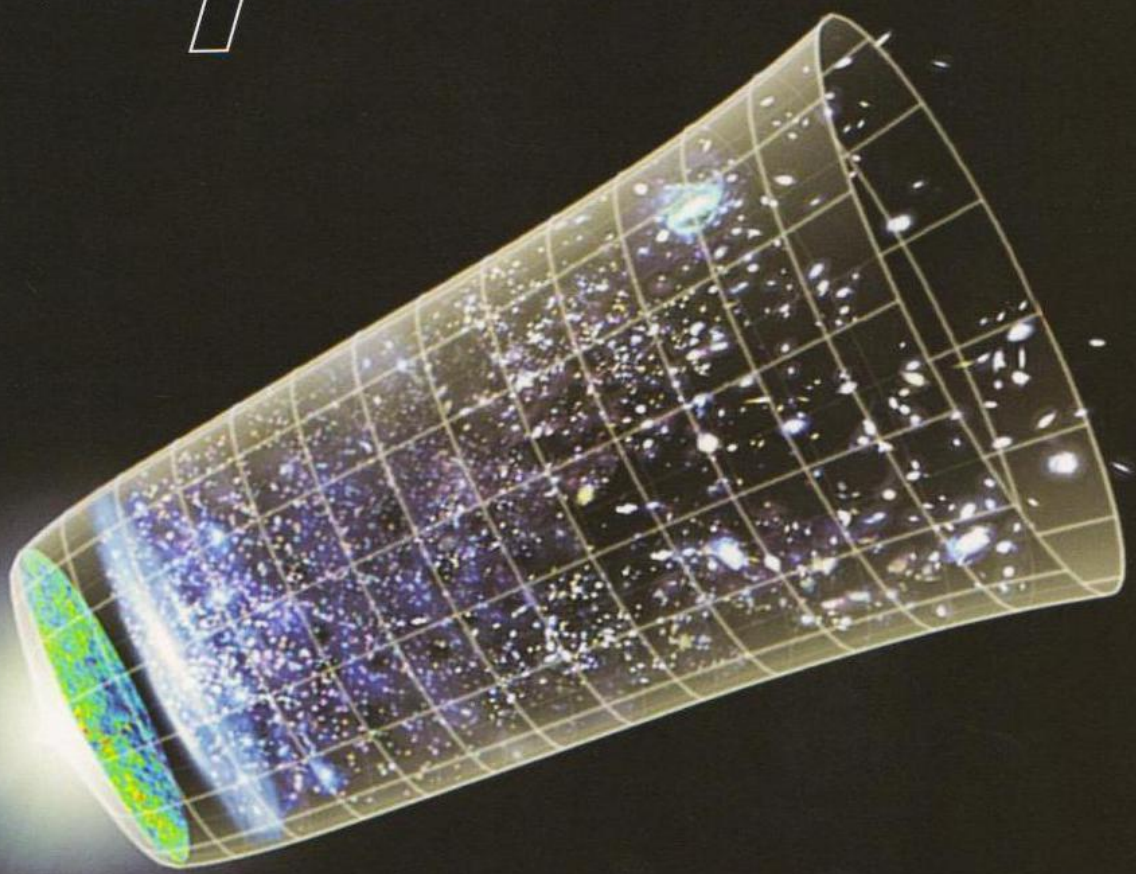
"These results, (establishment of Al-26 decay as the heat source for melting asteroids during early solar system evolution) that are first of their kind, have drawn the attention of the global planetary scientific community."

J. N. Goswami

"The thing that excites me most in PRL is that the whole environment for doing research is very good here. Also, the facilities available to the student are state of the art."

Vineet Goswami

Theoretical Physics



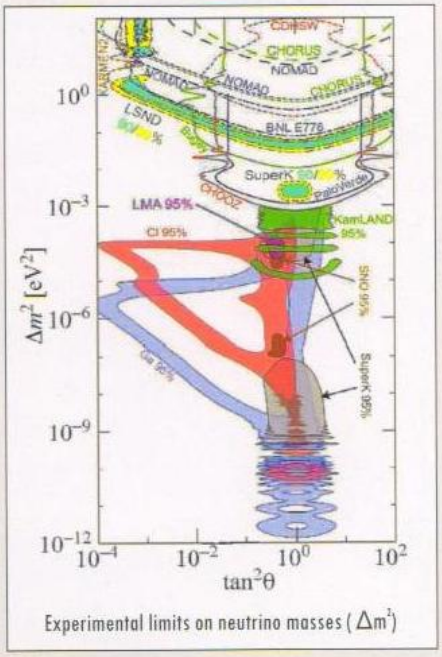
The broad objective of research programs of the Theoretical Physics Division is to understand the physical principles governing behavior of fundamental particles at microscopic level and relate them to the macroscopic world around us. The goal is to investigate fundamental issues such as; How matter and light behave and interact in the microscopic world? How do they relate to the macroscopic world? How did the universe evolve during its very early epoch? To achieve this goal, the Division is engaged in a wide spectrum of activities, that include high-energy physics, astro-particle physics, cosmology, atomic and nuclear physics, non-linear dynamics, quantum optics and quantum information.

The interactions of the fundamental particles in nature are governed by forces called the strong and electroweak forces. These interactions are well described by the sound theoretical framework, known as the standard model (SM) of basic forces. Ideas that go beyond this model have been suggested to explain some unresolved puzzles in the SM. PRL scientists have proposed novel ideas in this direction and have contributed to the study of existing frameworks such as supersymmetry.

How matter and light behave and interact in the microscopic world? How do they relate to the macroscopic world? How did the universe evolve during its very early epoch?

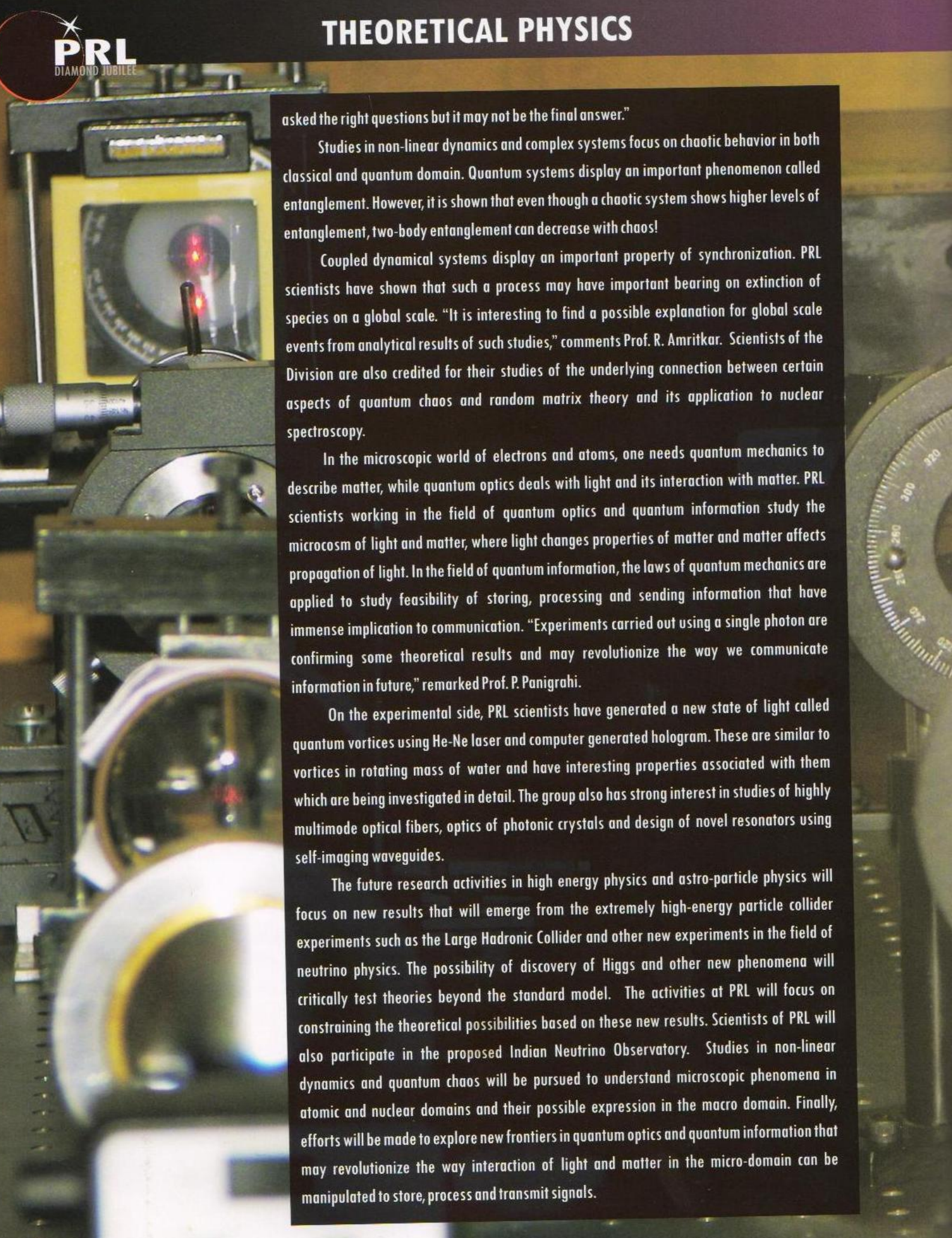
Neutrinos are fundamental particles that are generated during fusion reactions in the Sun and other stars and also during energetic particle interactions in the earth's atmosphere. These particles fill the universe almost entirely. A major breakthrough in particle physics during the last decade is the discovery that different types of neutrinos, assumed to be massless and chargeless, can switch from one type to another. This finding implies that neutrinos must have small but finite mass, contrary to the prediction of the standard model. The topic of neutrino mass and its implications is a major area of research worldwide. PRL scientists have made significant contributions in this area through novel ideas that explain the results obtained from solar and atmospheric neutrino experiments. Their predictions await confirmation from forthcoming experiments using new experimental facilities being set up to explore ultra-high energy interactions.

Research in astro-particle physics and cosmology is on events and processes that have occurred in the early universe, including the question of matter-antimatter asymmetry. Neutrino physics plays a key role in explaining the long standing puzzle of why our universe appears to be dominated by baryons (protons and neutrons) and not by anti-particles. The theories of neutrino masses invoke heavy neutral particles. It is proposed that the very decay of these heavy particles result in the predominance of matter over anti-matter through a complex mechanism called "leptogenesis". PRL scientists have suggested interesting modifications to leptogenesis scenario. In Prof. Utpal Sarkar's opinion, "Research in neutrino physics and leptogenesis carried out at PRL has paved way for similar research elsewhere."



Experimental limits on neutrino masses (Δm^2)

Our universe is filled with photons of 2.7 degree Kelvin temperature. Their measurements in different directions reveal the presence of a small but finite anisotropy in this temperature. These features of the cosmic microwave background (CMBR) are explained by postulating inflation of the early expanding universe. There are, however, some discrepancies between the basic theory of inflation and CMBR observations. PRL scientists have contributed to resolve these discrepancies by modifying the basic inflation theory. According to Dr. S. Mohanty, "Inflation theory has



asked the right questions but it may not be the final answer."

Studies in non-linear dynamics and complex systems focus on chaotic behavior in both classical and quantum domain. Quantum systems display an important phenomenon called entanglement. However, it is shown that even though a chaotic system shows higher levels of entanglement, two-body entanglement can decrease with chaos!

Coupled dynamical systems display an important property of synchronization. PRL scientists have shown that such a process may have important bearing on extinction of species on a global scale. "It is interesting to find a possible explanation for global scale events from analytical results of such studies," comments Prof. R. Amritkar. Scientists of the Division are also credited for their studies of the underlying connection between certain aspects of quantum chaos and random matrix theory and its application to nuclear spectroscopy.

In the microscopic world of electrons and atoms, one needs quantum mechanics to describe matter, while quantum optics deals with light and its interaction with matter. PRL scientists working in the field of quantum optics and quantum information study the microcosm of light and matter, where light changes properties of matter and matter affects propagation of light. In the field of quantum information, the laws of quantum mechanics are applied to study feasibility of storing, processing and sending information that have immense implication to communication. "Experiments carried out using a single photon are confirming some theoretical results and may revolutionize the way we communicate information in future," remarked Prof. P. Panigrahi.

On the experimental side, PRL scientists have generated a new state of light called quantum vortices using He-Ne laser and computer generated hologram. These are similar to vortices in rotating mass of water and have interesting properties associated with them which are being investigated in detail. The group also has strong interest in studies of highly multimode optical fibers, optics of photonic crystals and design of novel resonators using self-imaging waveguides.

The future research activities in high energy physics and astro-particle physics will focus on new results that will emerge from the extremely high-energy particle collider experiments such as the Large Hadronic Collider and other new experiments in the field of neutrino physics. The possibility of discovery of Higgs and other new phenomena will critically test theories beyond the standard model. The activities at PRL will focus on constraining the theoretical possibilities based on these new results. Scientists of PRL will also participate in the proposed Indian Neutrino Observatory. Studies in non-linear dynamics and quantum chaos will be pursued to understand microscopic phenomena in atomic and nuclear domains and their possible expression in the macro domain. Finally, efforts will be made to explore new frontiers in quantum optics and quantum information that may revolutionize the way interaction of light and matter in the micro-domain can be manipulated to store, process and transmit signals.

"Research in neutrino physics and leptogenesis carried out at PRL has paved way for similar research elsewhere."

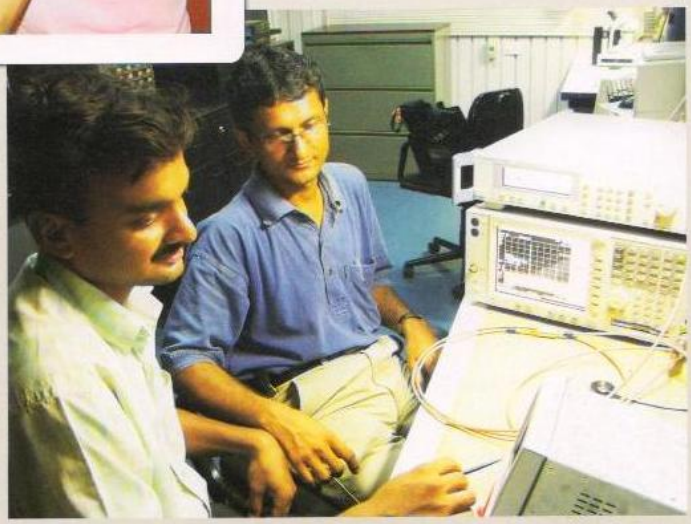
Utpal Sarkar

"Experiments carried out using a single photon are confirming some theoretical results and may revolutionize the way we communicate information in future."

P. Panigrahi

"I am working in quantum optics lab. Working with lasers gives the feeling that how fascinating light is!! In PRL I have full freedom of research and I can impose or discuss any new ideas with our group."

Ashok Kumar



CHANDRAYAAN-1

Planets and stars have been fascinating man since time immemorial. His quest about these heavenly objects took a giant leap in 1969, when Apollo 11 astronauts set foot on the Moon and opened gates for Planetary Exploration. Samples returned from the moon by the Apollo and Luna missions provided PRL scientists an excellent opportunity to participate in Lunar research and make significant contributions in studies of intensities of energetic particles from the Sun and other galactic sources reaching the lunar surface over the past millions of years. Coincidently, 1969 also marked an important event in the history of Space Research in India, the establishment of the Indian Space Research Organization (ISRO). The rapid growth of ISRO during the ensuing decades, particularly self sufficiency in satellite and launch vehicle technologies and the experience of PRL scientists in Lunar Research paved way to plan and put together a mission to the moon, Chandrayaan-1. More broadly, these developments led to establishment of a national program on Planetary Sciences and Exploration (PLANEX) with PRL as the nodal agency.

The primary objective of PLANEX program is to encourage and enhance research in Planetary Sciences in the country by generating interest on the subject among research students and scientists, by giving them support and facilities to pursue their research interests and by providing them opportunities to participate in planetary research.

Since the last five years, the PLANEX group at PRL is fulfilling this goal through various approaches. As a result, at present there are about twenty groups across the country pursuing research in planetary sciences. Further, students, teachers and young scientists are educated in planetary sciences through annual workshops and by providing them opportunity to work on planetary science programs at PRL.

A national facility for studying extra-terrestrial materials is set up at PRL as a part of the PLANEX program. Several instruments such as, Electron-probe Micro-analyzer, X-ray Fluorescence Spectrometer and Inductively Coupled Plasma Mass Spectrometer (ICP-MS) are available in this facility for use by PLANEX scientists from PRL and elsewhere.

A major effort of the PRL - PLANEX group during the last couple of years was on the design and development of one of the instruments to be flown on-board the Chandrayaan-1 spacecraft. This pay load, the High Energy X-ray Spectrometer (HEX) will investigate the continuous migration of Radon, a volatile and radioactive noble gas from the visible and hotter lunar surface towards its permanently shadowed and cold polar region. This study has significant implication to the movement of other volatiles such as water molecules on lunar surface and hence for the possible presence of water on the lunar polar regions. The tests on the engineering model of HEX, built in collaboration with ISRO Satellite Centre (ISAC), Bangalore, have been successful and the flight model is under fabrication.

Major plans for the expansion of PLANEX activities are underway. These include development of detailed science and implementation plans for future missions, in particular for Chandrayaan-2, and other planetary missions. Further, as part of the PLANEX program, a dedicated center will be established at PRL for analysis of scientific data from Chandrayaan-1 mission.

GEOPHYSICAL RESEARCH LETTERS, VOL.26 NO.12, PAGES 1669-1672, JUNE 15, 1999

First simultaneous *in situ* measurement of electron density and electric field fluctuations during spread F in the Indian zone

H. S. S. Sinha, Shikha Raizada and R. N. Misra
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

PERGAMON

Seasonal variations in surface ozone and its precursors over an urban site in India

ATMOSPHERIC ENVIRONMENT

Shyam Lal[1], Manish Naja, B. H. Subbaraya
[1]Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

Luminescence dating of loess-palaeosol sequences and coversands: methodological aspects and palaeoclimatic implications

EARTH SCIENCES REVIEWS

A. K. Singhvi[1], A. Bluszcz, M. D. Bateman, M. Someshwar Rao
[1]Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

ELSEVIER

Groundwater $\delta^{18}O$ and δD from central Indian Peninsula: influence of the Arabian Sea and the Bay of Bengal branches of the summer monsoon

Journal of Hydrology

S.K. Gupta, R.D. Deshpande, S.K. Bhattacharya, R.A. Jani
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

ELSEVIER

EMBEDDED RANDOM MATRIX ENSEMBLES FOR COMPLEXITY AND CHAOS IN FINITE INTERACTING PARTICLE SYSTEMS

Physical Reports

V. K. B. Kota
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

^{26}Al in Eucrite Piplia Kalan: Plausible Heat Source and Formation Chronology

SCIENCE

G. Srinivasan, J. N. Goswami, and N. Bhandari
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 23, 2181, doi: 10.1029/2003gl01800. 2003

Relationship between CME velocity and active region magnetic energy

P. Venkatakrishnan, B. Ravindra Udaipur Solar Observatory, Physical Research Laboratory, Rajasthan, India

Detection of knots and jets in IRAS 06061+2151

Astronomy & Astrophysics

B.G. Anandrao[1], A. Chakraborty, D.K. Ojha, and L. Testi
[1]Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

PHYSICAL REVIEW LETTERS

Enhanced Polarization of the Cosmic Microwave Background Radiation from Thermal Gravitational Waves

Kaushik Bhattacharya, Subhendra Mohanty, and Akhilesh Nautiyal
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

PII S0016-7037(99)00201-X

Pergamon

Re-Os isotope systematics in black shales from the Lesser Himalaya: Their chronology and role in the $^{187}Os/^{188}Os$ evolution of seawater

Geochimica et Cosmochimica Acta, Vol. 63, No. 16, PP. 2381-2392, 1999

Sunil K. Singh, J.R. Trivedi, and S. Krishnaswami
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L19712, doi, 10.1029/2005GL024070, 2005

Early deglacial (~19—17 ka) strengthening of the northeast monsoon

Manish Tiwari*, R. Ramesh*, B.L.K. Somayajulu*, A.J.T. Jull, and G.S. Burr
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

Vacuum solutions of neutrino anomalies through a softly broken U (1) symmetry

THE EUROPEAN PHYSICAL JOURNAL C

A.S. Joshipura, S.D. Rindani
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

A&A 409, 1007,-1015 (2003)
DOI: 10.1051/004-6361:20031160

The enigmatic outburst of V445 Puppis - A possible helium nova?

Astronomy & Astrophysics

N. M.Ashok and D. P. K. Banerjee
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS A: MATHEMATICS AND GENERAL

Entanglement by linear SU (2) transformations: generation and evolution of quantum vortex states

G.S. Agarwal and J Banerji[1]
[1]Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

PHYSICAL REVIEW A 74, 022708 (2006)

Triply charged carbon dioxide molecular ion: Formation and fragmentation

R. K. Singh, G. S. Lodha, Vandana Sharma[1], I.A. Prajapati[2], K.P. Subramaniam[3] and B. Bapat[4]
[1,2,3,4]Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D202214, doi: 10.1029/2006JD007142, 2006

Aerosol radative forcing during clear, hazy, and foggy conditions over a continental polluted loc ation in north India

S. Ramachandran, R. Rengarajan, A Jayaraman, M. M. Sarin, and Sanat K. Das
Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India

SCIENTIFIC PUBLICATIONS

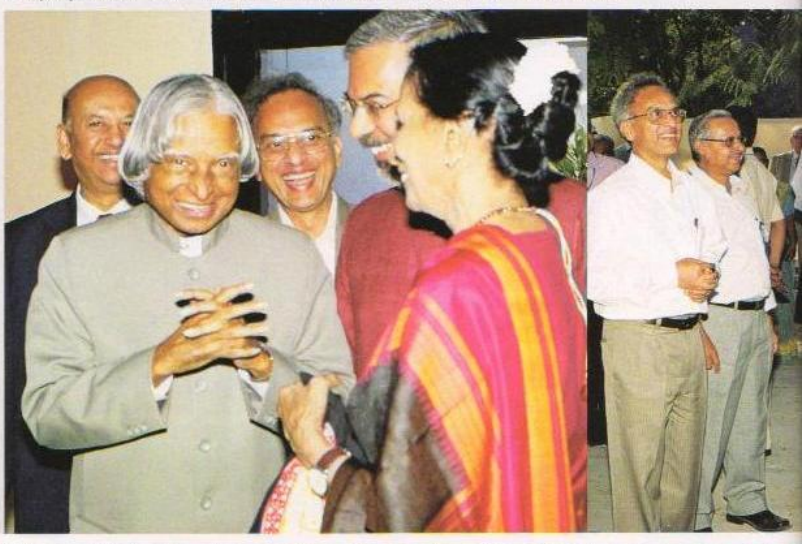
DIAMOND JUBILEE CELEBRATIONS OF PRL

The Physical Research Laboratory is celebrating its Diamond Jubilee to mark its sixtieth anniversary. The celebrations were inaugurated by His Excellency the President of India, Dr. A. P. J. Abdul Kalam on 11 November, 2006. The function was also graced by a number of dignitaries, past and present staff members of PRL, invitees from research and educational institutions and friends of PRL.

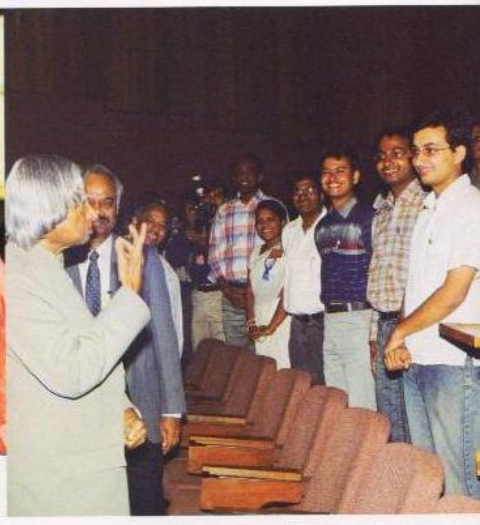
The dignitaries spoke about the key role of PRL and its research in regional, national and international context. Dr. G. Madhavan Nair, Chairman, ISRO, highlighted the involvement of PRL in the upcoming Chandrayaan-1 mission and future space and planetary missions. Prof. U. R. Rao, Chairman, PRL Council of Management, provided a crisp summary of research at PRL and the challenges facing it to retain its unique position in fundamental research globally. Shri Narendra Modi, Chief Minister, Gujarat, presented the ongoing wholesome development of the state and the role PRL scientists could play in this venture. H. E. the Governor of Gujarat, Shri Nawal Kishore Sharma, emphasized the need for more interaction between scientists and society.

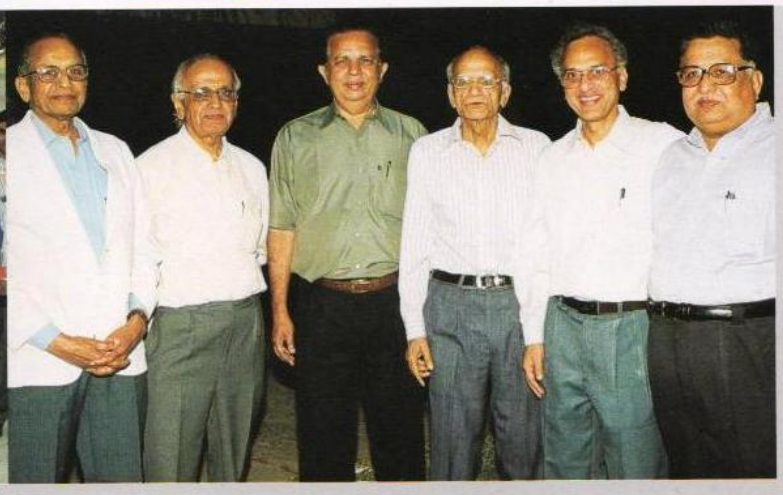
The President, in his talk, while recounting his close association with PRL during the sixties remarked, "PRL is indeed the cradle of Space Science, Space Technology and Space Applications and above all is creating leaders in Science and Technology over the years. It continues to effortlessly combine front-line basic research, technological development and projects like Chandrayaan-1 that operates in a mission mode; I would like to wish PRL and its members all the best."

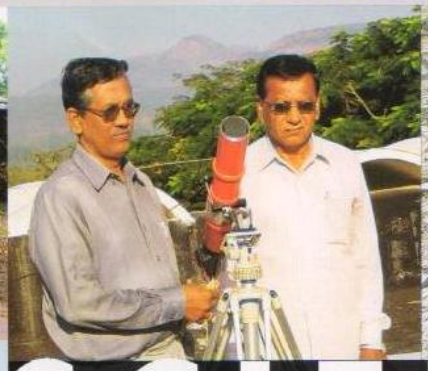
The curtain raiser to the Diamond Jubilee celebrations was a symposium on, "Recent Excitements in Science and Future



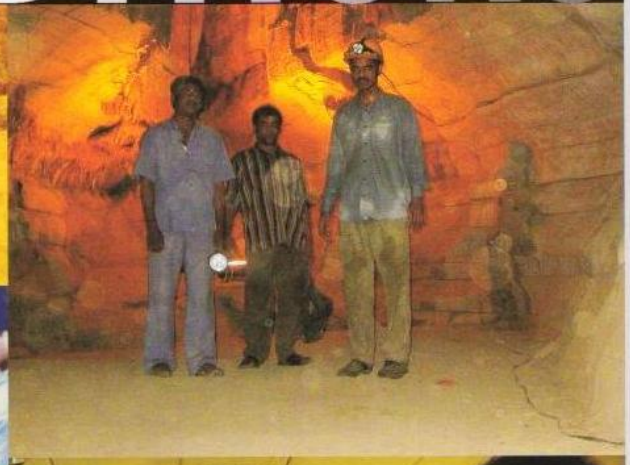
Perspectives," organized by the PRL Alumni Association. Prof. J. E. Blamont, a close associate and well wisher of PRL delivered the keynote address. The inaugural function was followed by a three day "Open- House" exhibition on PRL. The celebrations continued throughout the year. During this period, PRL also hosted a number of scientific conferences and public lectures.



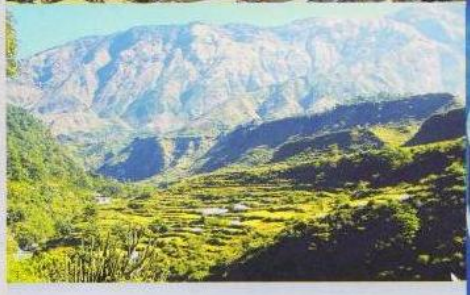
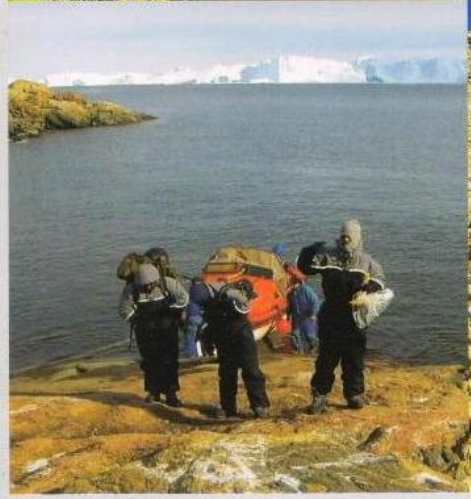
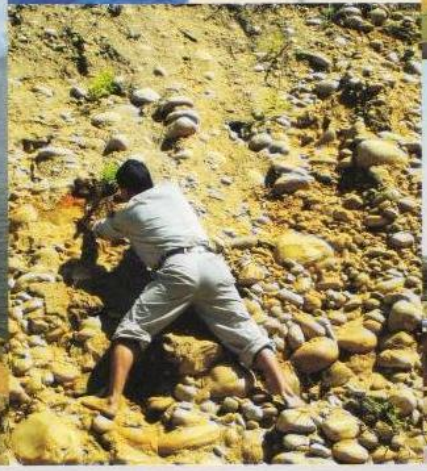


SCIENTIFIC EXPEDITIONS




PRL FAMILY

PHYSICAL RESEARCH LABORATORY
NAVRANGPURA, AHMEDABAD-380 009, INDIA

Editorial Co-ordinator: S. Krishnaswami
Published by: Physical Research Laboratory, Ahmedabad
Design: Mastermind (079-23244491)
Printed by: Print Vision