Physical Research Laboratory (PRL), founded in 1947 by Dr. Vikram A. Sarabhai, is a premier scientific institution under the Department of Space, Government of India. The laboratory started with its focus on research areas of Astronomy and Cosmic Rays. In course of time, several new disciplines were added to its research theme. The current research activities of PRL are truly of multi-disciplinary nature at the cutting edge of science. These include Astronomy and Astrophysics, Space and Atmospheric Sciences, Solar Physics, Geosciences, Planetary Science, Atomic, Molecular & Optical Physics, Theoretical Physics & Cosmology.

PRL currently has four campuses: the main campus at Navrangpura, Ahmedabad, with several world-class experimental and computing facilities; many leading laboratories in Thaltej campus, Ahmedabad; Optical and Infrared Observatory at Mount Abu, and Udaipur Solar Observatory at Udaipur.

The research work done at PRL has been recognized by peers at both national and international levels. This is also reflected in International and national awards and honours received by PRL scientists over the years.

The laboratory has a very strong human resource development component with doctoral (Ph.D.), post-doctoral & visiting scientist programmes, summer internship programme for B.Sc./M.Sc. students and college teachers, project training for graduate and post graduate students in science, engineering and computer applications. PRL also conducts biennial PG Course in Space & Atmospheric Science since 1998 for the Center for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) established in Dehradun which is affiliated to the United Nations.

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Physical Research Laboratory

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Main Campus
Ahmedabad

Mt. Abu
Observatory

Thaltej Campus
Ahmedabad

Udaipur Solar
Observatory

Astronomy and Astrophysics

The sight of a dark night with millions of twinkling stars is fascinating and intriguing to human beings since time immemorial. Stars form in large molecular clouds that exist in space. With time, stars evolve and when their fuel, mainly hydrogen, is exhausted they become cooler, redder and bloat up in size, reaching a stage called super-giant. Some of them throw away their outer shell, forming spectacular planetary nebulae while others end their lives with a violent explosion, shining brilliantly, called supernovae. Remnants of stars turn into white dwarf, neutron stars and black holes and vanish from sight but make their mysterious presence felt through strong gravity.

Electromagnetic radiation, from gamma-ray to radio, plays the role of a messenger telling us about these astronomical sources and events happening in the universe. Scientists at PRL are engaged in seeking answers to a host of questions on many exotic astronomical sources and events by analyzing radiation emanated by them. It requires light collecting telescopes, sophisticated instruments and basic techniques to decode messages coming from sources millions and billions of light years away.

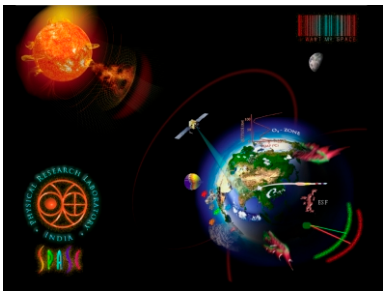
The 1.2 mt. optical and IR telescope at Gurushikhar, Mt. Abu is one of the major facilities used by the PRL astronomers. The main scientific programmes pursued are: hunt for extra-solar planetary systems, studies of various astronomical objects, like the comets, star-forming regions, star clusters, novae, supernovae, variable stars, cool stars, X-ray binaries, pulsars, active galactic nuclei and gamma ray bursts (GRBs). The scientists have been using multi-wavelength observational data covering X-rays, to ultraviolet, optical, infrared, and radio wavelengths to carry out fore-front research studies of astronomical objects. These data are obtained using various techniques, like photometry, spectroscopy, polarimetry, etc. with the help of several existing ground - and spaced-based national and international telescope facilities. They also utilize High Performance Computing facility of PRL to explain various observational signatures. The observation capabilities at Mt. Abu are going to be enhanced with the 2.5 Mtr. telescope and its back-end instrumentation.

Solar Physics

The Sun is our nearest star, and an interesting cosmic object that helps in understanding stars and the astronomical universe. The close proximity of the Sun reveals fine details of its outer visible surface at widely ranging spatial and temporal scales; not possible to achieve for other distant stars. It is a giant physical laboratory in which energy is generated by nuclear fusion; controlled reproduction of which is still not achieved on the Earth.

As the Sun heats the ground, thermal air turbulence develops in the surrounding atmosphere, blurring the visibility of fine features on the solar surface. Therefore, a good solar observing site should be located in a suitable place to reduce this effect. With this objective, a unique solar observatory was established on a small island in the middle of Lake Fatehsagar, Udaipur, in September 1975. The large body of water surrounding the observing site improves the 'seeing', and being in Rajasthan has the additional advantage of a large number of cloudless days needed for continuous observation of the Sun. Investigations of the Sun at Udaipur Solar Observetory (USO) revolve around the central theme of solar magnetic and velocity fields, solar activity, solar eruptive processes and high resolution solar observations. Basic physical phenomena of the birth and development of active regions, and flare mechanism are also being studied. The data obtained at USO are available to scientists working on related fields, and various national and international organizations. The scientists take part in several international collaborative programmes. In October 1995, USO joined the international project, GONG - Global Oscillation Network Group, to study several fundamental problems of solar interior. One of its kind, Multi-Application Solar Telescope (MAST), of 50 cm aperture with sophisticated back-end instruments was commissioned in 2015 for measurement of solar magnetic fields and imaging the solar surface and its atmosphere. The groups along with colleagues of various scientific institutes of India are now working on the first dedicated space-based solar mission, ADITYA-L1, for the study of the Sun from Langrangian-L1 point. A new solar radio observing facility (e-CALLISTO) is also now commissioned.

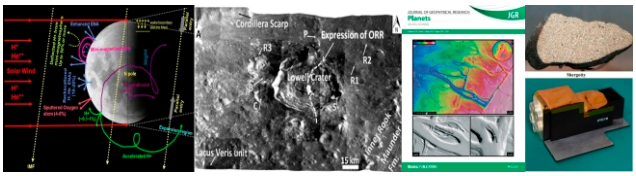
Space and Atmospheric Sciences



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 working in the Space and Atmospheric Sciences 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. Atmospheric research has been one of the major scientific activities of PRL since its inception in 1947. During these past decades these studies progressed leaps and bounds mainly due to initiation of new and contemporary research programmes of global impact accompanied with new technological advancements, and contribution of the scientists in major leadership roles in both national and international fora.

The broad questions currently being pursued include: How do the concentrations of key atmospheric constituents such as trace gases, ozone, clouds 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? How are the atmospheric regions coupled vertically and horizontally (across latitudes)? These questions are addressed through a multi-pronged approach, by conducting in situ studies using rocket and balloon - borne instruments, remote sensing at optical and radio wavelenghths, as well as by analytical modelling. PRL scientists are leading the effort on the ISRO's Aeronomy satellite mission by contributing several payloads and payloads for satellite investigations of solar wind interactions with Venusian and Martian ionospheres. Further while continuing its effort in probing the atmosphere and the space environment around planets and other solar system objects the group has plans to make space-based observations of trace gases and atmospheric parameters.

Planetary Sciences



The study of the atmospheres, surfaces and interiors of solar system objects, and the processes that govern them constitutes planetary science research at PRL. This is achieved through theoretical models (computer simulations), laboratory studies of meteorites and samples from planetary bodies, remote sensing analysis, and spacecraft based observations through planetary missions. Initiated with Chandrayaan-1, and the associated landmark discovery of water on the Moon, design and development of instruments for planetary missions (payloads) has now become one of the prime activities. Recently, PRL has developed and delivered payloads for Chandrayaan-2 mission. Observations from these instruments will provide insights into the elemental composition of lunar rocks and soil and lunar thermal behaviour. In addition, several other important instruments are being developed for upcoming planetary missions of ISRO, to address several outstanding issues related to planetary science. Facilities to simulate planetary environments are available in PRL and larger ones will be developed. Laboratory studies of planetary samples and meteorites are carried out at state-of-the art experimental facilities established in the division such as NGMS, MC-ICPMS, LA-ICPMS, Nano SIMS, EPMA and XRF. Petrological, morphological, chemical composition and isotopic studies of samples are used to characterize past and contemporary processes in the solar system. Important scientific questions are addressed related to early solar system, planetary surface science, impacts processes and planetary evolution.

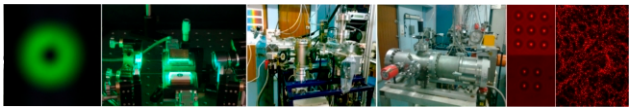
Data from remote sensing of planetary bodies is used to study surface topography and morphology, surface composition being determined through imaging spectroscopy and surface age through crater chronology. The objective is to understand geological processes, like impact cratering, volcanism, tectonism, and space weathering. Theoretical models are developed to understand physical and chemical processes of ionospheres and atmospheres of planets and comets. These models are used to study the effects of dust storms, meteors, solar flares and CMEs on the Martian ionosphere. Climate change on Mars is also being studied using general circulation model and long-term satellite data. The work related to interplanetary dust and astrochemistry is also being carries out.

Geosciences

The research activities in the Geosciences are focused on understanding the origin and evolution of the planet Earth and its various components, with special emphasis on time scales and processes. Frontline research areas in geosciences are encompassing the five broad themes viz: (1) Solid Earth Studies; (2) Aquatic and Terrestrial Biogeochemistry; (3) Paleo climate; (4) Isotope Hydrology; and (5) Aerosol Chemistry. The research methodologies employed to pursue the research in Geosciences include field observations and laboratory measurements of abundances of elements and isotopes, both stable and radioactive, and thermal & optical luminescence properties of materials using modern analytical tools and state-of-the-art instruments. Most of the Geoscience research requires extensive field work for field observations and collection of required samples from various geological and environmental reservoirs and repositories (geological formations, cave deposits, tree rings, coral reefs, terrestrial and oceanic sediments, seawater, groundwater, river water, estuaries, rain, snow, atmospheric moisture and aerosol). The spatial domain of research in Geosciences spans from deep crustal to atmospheric processes and the time domain ranges from geological processes operating on timescale of millions of years to atmospheric processes varying on sub-hourly time scales. The inferences drawn are based on evidences ranges from visual observations of large scale geomorphological, structural and geological features in the field to precise measurements of isotopic and chemical composition in laboratory using various modern instruments.

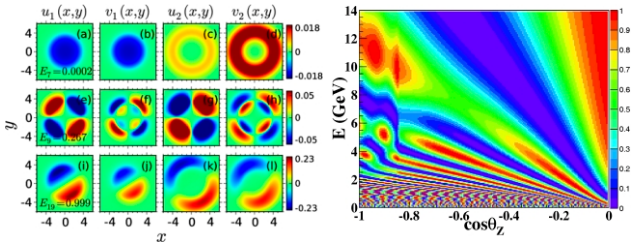
Atomic, Molecular and Optical Physics

Atomic, Molecular & Optical Physics research activities are going on in different domains that encompasses Earth sciences, planetary sciences, classical and quantum optics, atomic and molecular physics and physics beyond standard model. In a sense it is a microcosm of PRL.



Being interdisciplinary by nature, it covers a wide range of topics starting from foundations of quantum mechanics to astrochemistry. Along with classical and quantum properties of light, scientists investigate atoms, molecules, molecular clusters or condensed matter systems using vast range of electromagnetic spectrum and other sources like high energy electrons and charged ions for basic as well as applied research. However, all the theoretical and experimental activities in this area can be categorised under the themes: (i) Atomic and Molecular Physics, (ii) Optical Physics, (iii) Luminescence Physics and Applications and (iv) Astrochemistry. To support the cutting-edge research in these areas, the PRL has state of the art laboratories for quantum science and technology, photonics, luminescence dating, low temperature astrochemistry, laser induced breakdown spectroscopy and attosecond physics.

Theoretical Physics



The activities in the area of theoretical physics span a wide range from sub-atomic particles to phenomena at the cosmological scales. The primary focus is to understand the very microscopic laws governing different physical phenomena. In particular the focus is to delve into study of fundamental particles and their interactions, properties at extreme conditions, the physics of the very early universe and addressing cosmological questions, high temperature superconductivity and cold atoms.

The elementary particles interact via interactions or forces that are described by the standard model of particle physics. Although extremely successful, there are strong reasons to believe for the existence of new particles or forces beyond the standard model. To name a few, neutrino oscillations unambiguously implying non-zero mass of neutrinos, matter anti-matter asymmetry observed around us and concrete evidences of dark matter and dark energy, both together constituting about 95% of the energy budget of the universe. These call for going beyond the standard model of particle physics and suggesting ways to look for these new particles and forces, be it at terrestrial experiments, like particle colliders and accelerators or astrophysical and or cosmological

observations. On a more macroscopic scale, the focus is to explain the very bizarre properties shown by the high temperature superconductors, in particular the anomalous properties observed in unconventional superconductors. Advent of laser technology has paved the way to study individual atoms or a small bunch of them in a controlled way. This allows to study deep questions about quatum phase transitions, which are analogous to liquid to vapour transition in case of water.

All of these require analytic calculations, supplemented with state of the art numerical computations, simulations and analysis of data from various experiments, all of which are carried out in house at PRL.

PRL is a unique centre of excellence where research on such a wide range of themes ranging from interior of the Earth, Solar system, Stars, Galaxies to Universe are pursued under one roof.

Facilities at PRL

Computer Centre

PRL Computer Centre is equipped with Vikram-100 High Performance Computer Cluster which supports scientists, researchers and research scholars at PRL who require high performance computing.

PRL has 1Gbps Internet connectivity through National Knowledge Network (NKN) Optical Fiber Cable (OFC), and 1Gbps through BSNL OFC.

Library

Library plays a crucial role in facilitating research in the laboratory by making available latest books, journals, e-journals in the respective areas. RFID and Wi-Fi enabled PRL Library subscribes to full-text databases, like AGU Digital Library, PROLA, GSA Archive, Nature archive (access from 1987) and Science Archive. IEEE Digital Library, SPIE Digital Library and AIAA Journals are made available through Antariksh Gyan – ISRO Libraries Consortium.

Recently, Library has started to carry out similarity check using the ithenticate software. The PRL Library maintains an institutional repository which consists of journal articles published by the PRL authors from 1990 to present and is also linked through the Library homepage. All the PRL theses from 1952 onwards are now available electronically. All the PRL Technical Notes since 1977 have been digitized and are available for users. The E-books can be accessed through the library homepage.

Workshop

PRL Workshop is a state-of-the-art mechanical workshop that provides extensive support to scientists and engineers. The workshop is used to design, develop and fabricate suitable components, devices, attachments, adaptors or the entire instruments to support the research work. The workshop has a wide range of machines, from conventional ones to High-tech CNC. Over the years newer instruments are added and also the facilities are developed at other campuses of PRL.

National and International Acclaim

PRL alumni have played a key role in the development of institutions and programmes in India and abroad. The Indian Space Research Organization (ISRO) was nucleated in PRL and two of the past ISRO Chairmen, Prof. U.R. Rao and Prof. K. Kasturirangan are distinguished alumni of PRL. The Institute of Plasma Research (IPR) was nucleated by the erstwhile Plasma Physics Programme (PPP) group at PRL.

Numerous books on contemporary topics have been authored and edited by PRL scientists.

Distinguished Professorships

PRL hosts prestigious Vikram Sarabhai Professorship and K. R. Ramanathan Professorship, under which eminent scientists are invited for lectures, popular talks and academic stays for extended durations. Several Nobel Laureates have graced these professorships. PRL also hosts visiting positions under various national and international exchange programmes.

Doctoral and Post-doctoral Programmes

PRL has contributed significantly to the scientific manpower development in the country through Doctoral (Ph.D.) and Post-Doctoral programmes. PRL attracts highly motivated students to pursue doctoral research in several branches of Theoretical Physics, Space and Atmospheric Sciences, Astronomy, Astrophysics and Solar Physics, Atomic, Molecular & Optical Physics, Planetary Sciences, and Geosciences. Students are trained through rigorous course work followed by a research programme leading to a Ph.D degree. The Post-Doctoral programme at PRL also attracts young researchers to work on research themes of complementary interests.

The fellowships at PRL compare with the best in the country. Details of these programmes are available on the PRL website. It can also be obtained from the Head, Academic Services, PRL.

Capacity Building Programmes

UN course on Space Sciences

Under the auspices of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) affiliated to the United Nations, PRL has been organizing Post-Graduate Course in Space & Atmospheric Science every alternate year since 1998. Participants from the Asia-Pacific region have been attending this course.

RESPOND programme

On behalf of ISRO, PRL administers the RESPOND programme (Sponsored Research) in Space Sciences. The main objective of the RESPOND programme is to establish strong links with academic institutions in the country to carry out research and developmental projects, which are of relevance to Space Sciences. RESPOND provides funding to academia in India for conducting research and development activities particularly in the fields of Astronomy and Astrophysics, Astrochemistry, Cosmology, the Physics of Earth's atmosphere, ionosphere magnetosphere, Planetary and Interplanetary Space Physics, Solar Physics, Space Weather and Space Plasma Physics. Through the RESPOND projects, it is expected to derive useful outputs of such R&D to support ISRO programmes. It is also aimed to enhance academic base, generate human resources and infrastructure at academic institutes to support the space programme of India. In order to facilitate the faculty of universities and Institutes to prepare suitable proposals of relevance to space programme, a detailed list of R&D areas/sub areas/topics have been evolved as per major programmes of ISRO, by the various centres of ISRO and published at https://www.isro.gov.in/research-and-academia-interface.

Programmes for Students and Teachers

A summer internship programme for students and college and university teachers is organized to provide them with hands-on experience in research methodologies in various disciplines.

This programme is organized during May-July every year and is meant for BSc (final)/MSc First year students in Physics, Chemistry, and Geosciences. The programme for teachers is meant for those involved in teaching Physics and Geosciences at graduate and post- graduate levels and having interest in pursuing research.

Project Training Programmes

PRL offers project training for Science and Engineering students. In addition, trainees are also taken in the Computer Centre, Workshop, Library, and Engineering Services and at Mt. Abu and

Udaipur observatories. Additional information on academic and training programmes and relevant application forms, are available on PRL website.

Interactions with Society

PRL values its interaction with society and organizes science exhibitions and Open Houses periodically to inform society about its programmes, contributions and the excitement of pursuing science. Outreach events and popular talks are arranged from time to time on topical events of cutting edge research.

PRL celebrates the National Science Day by holding a series of programmes that include a science quiz and lectures for high school students and teachers. PRL scientists also visits schools and colleges, Universities in different cities and organize Open House Science Exhibitions from time to time. Celebration of World Space Week with a special emphasis on encouraging students from rural background are another salient features of PRL's outreach programme.

> Developmental tasks continually require decision-making based not on administrative procedures and precedents, nor even on economic models by themselves, but on the appreciation of hard realities related to science and technology in the context of our social environment.
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> August 1967 **- Dr. Vikram A. Sarabhai**