PHYSICAL RESEARCH LABORATORY

(From April 1977 to March 1978)

INTRODUCTION :

Astronomy and Astrophysics have been, among many other scientific disciplines, the fields of major interest to the Physical Research Laboratory (PRL) Ahmedabad. Research activities in this field and related studies are being carried out by various groups at PRL, namely, Infrared Astronomy, Geo-cosmophysics, Solar and Planetary Physics, Laboratory Plasma and Astrophysics and Theoretical Physics.

Research Programmes and Results Obtained in 1977-78:

1. INFRARED ASTRONOMY

(a) Photometry :

An improved model of the photometer was fabricated during last year, which permitted detector operation at solid CO_2 temperature. Using this photometer, over 100 stellar objects have now been studied, with the help of telescopes at U.P. State Observatory at Naini Tal and IIA Observatory at Kavalur, in J(1.25 micron), H (1.65 micron) and K (2.2 micron) bands.

(b) High resolution spectroscopy :

IR group has undertaken fabrication of high resolution Fourier Transform Spectrometer. A full scale carpentry model has been made for conceptual help during fabrication.

2. GEOCOSMOPHYSICS :

(a) Luna—24 Samples :

Six soils from Mare Crisium sampled by LUNA-24 deep drill core have been studied for particle tracks, microcraters, and stable and radio-active isotopes. These samples were obtained from the Soviet Academy of Sciences through the Indian National Science Academy. Major results of these studies are the following :

(i) The particle track records can be understood in terms of two stage evolutionary history of this drill core soil column :

(a) a rapid deposition of the lower zone of the drill core column with little or no predepositional irradiation followed by (b) either a deposition of preradiated material or a very slow deposition of immature material over the entire upper zone of this regolith column.

(ii) One of the most interesting results obtained was the low value of cosmogenic ^{21}Ne concentration which places an upper limit of about 150 million year (m.y.) for the deposition time scale of the first 80 cm of this drill column.

(iii) Morphological studies have revealed several spherules rich in potassium.

(iv) It is found that even in an extremely pure lunar soil sample, about 60% of the crystals get exposed on the lunar surface with zero shielding condition for time periods greater than 10^4 years.

(b) Solar flare records in lunar and meteorite Samples :

Solar flare heavy nuclei composition has been obtained using specially selected lunar and meteorite samples that have received solar flare irradiation at about 1 m.y. and greater than 4 billion year (b.y.) before present respectively.

(c) Low-energy protons and alpha-particles in 2-4 AU space :

Analysis of particle track and noble gas isotope data in the meteorite St. Severin indicates anomalous nuclear-spallation effects in samples within 1 cm depth of the preatmospheric surface. The observations are suggestive of the presence of a low energy component in the St. Severin orbit and are not consistent with the low energy particles being of solar origin.

(d) Studies of the Dhajala meteorite :

Work on estimation of the orbit of Dhajala meteorite has been completed. The results give an evidence of minimal modulation of galactic cosmic rays (GCR) at high heliolatitudes (15°S) during solar minima of 1975 ; about 35% higher GCR fluxes have been encountered there during 1975-76 compared to those at the solar equatorial belt.

3. SOLAR RADIO ASTRONOMY :

Main emphasis of the solar radio astronomy programme during 1977-78 has been to understand and derive plasma parameters around two solar radii above the photosphere of the Sun by utilizing the observational data of the high resolution decametric spectroscope at 35 MHz. Some of the important results are :

(a) The burst component of decametric noise storm falls mainly into two categories : (i) decametric type III bursts and (ii) short duration ($\leqslant$1 sec) bursts showing fine structure in frequency and time, designated as "BF" bursts. Our analysis of the "BF" type bursts has shown fine structure in scale sizes (less than 10^3 km) within the larger scale electron density irregularities of $\sim 10^3$ —10^4 km around two solar radii from the photosphere.

(b) A model for decametric storm bursts to explain the observed features during 1974-77 is suggested.

(c) Noise storms with maximum "BF" bursts were associated with proton events, which can be considered as an additional criterion for the prediction of proton flares.

4. LABORATORY PLASMA AND ASTROPHYSICS :

(a) Experimental Plasma Physics :

During 1977-78, the studies on basic processes in low desnsity, low temperature plasmas were continued through the following experimentas :

1. Collisionless plasma instabilities;
2. Nonlinear wave propagation;
3. Single particle and plasma confinement in non-adiabatic magnetic traps;
4. Plasma-neutral gas interaction.

A major new programme on collective processes and plasma heating during the interaction of a relativistic electron beam and a dense mirror confined plasma has been initiated. Some of the important achievements are

(i) Magnetized collisionless plasma experimental system :

For partial simulation of many space plasma phenomena, it is desirable to have a highly ionized magnetized plasma system where the collisional mean free paths are larger than the plasma dimensions. Plasma densities of $10^{11}cm^{-3}$ at a few times 10^{-5} torr has been achieved.

(ii) Plasma-neutral gas experiment :

The critical velocity phenomenon predicted by Alfven to occur when the kinetic energy of a streaming plasma exceeds the ionization potential of a neutral gas cloud with which the plasma interacts in the presence of a transverse magnetic field has been experimentally observed.

(iii) Solitary wave behaviour in strongly inhomogeneous plasma :

The experiments on ion acoustic soliton propagation in plasma density gradients have been extended to gradient scale sizes comparable with the solitary wave width. Under such strongly nonadiabatic conditions, the soliton undergoes a partial reflection at the inhomogeneous region.

(iv) Mirror magnetic field system for REB-plasma interaction experiments :

A pulsed 1:2 ratio mirror magnetic field system for REB-plasma interaction experiments has been designed, fabricated and tested. The desired field configuration was achieved by an interactive procedure. The magnetic field measurements confirm the design for a current of 2kA; the field at the centre is 3kG.

(b) Laboratory Astrophysics :

(i) Photoelectron spectroscopy :

A high resolution photoelectron spectrometer has been built to study the ionization/excitation potentials, vibrational level spacing and transition probabilities of different electronic stages of a molecular ion. The characteristic parameters of the photolectron spectrometer are being studied now by recording the photoelectron spectrum of argon at 584 Å.

(ii) Photoabsorption cross-sections for atomized gases :

The design aspects for atomic oxygen photo-cross-section experiment are being worked out. Efforts have been made to do some exercise to produce and measure the concentration of atomic oxygen using NO_2 titration technique. In addition to atomic oxygen, O_2 (ground state), O_2 ($^1\Delta_g$) and O_2 ($^1\Sigma$) species have been observed in the afterglow produced by the microwave discharge of O_2. Efforts are being made to separate chemically a few of the species mentioned above.

5. THEORETICAL ASTROPHYSICS :

(a) Stream-functions in the asteroidal belt :

Based on the theory developed to account, in a self-consistent manner, the formation of Kirkwood gaps, an attempt was made to obtain a stream function to characterize the mean velocity. It has been shown that a stream function exists only in the stationary case and that in the time dependent problem, a stream function as well as a potential function exist even though this problem is two dimensional.

(b) A theory of the formation of planets and satellites :

A theory of nonlinear resonant interactions between the solar wind and the gas disc is proposed in which solar wind excites surface waves on either side of the disc and this in turn generates body waves which mutually interfere generating the "Jet Streams". These jet streams condense to form the planets. This mechanism can also explain the rings around Uranus as well as the inclination of the spin axis of the planets to their ecliptic.

(c) Astrophysical Plasmas :

(i) Accretion induced overstability of density waves in a self-gravitating disc :

A two-component differentially rotating disc of self-gravitating particles is considered in the hydrodynamical frame work. This system is shown to sustain two pairs of density waves, corresponding to the familiar Jeans modes and an acoustic type of mode (similar to ion-acoustic modes in plasmas). Due to mass and momentum transfer from the gaseous to the stellar component (an accretion process), the acoustic modes suffer a strong damping, whereas the Jeans modes which were oscillatoryf now become overstable provided the thermal velocity oe the star is larger than that of gaseous component. Thr waves with frequencies near the corotation have a rathe, large growth rate. This amplification can explain the maintenance of spiral structure and a "selective" amplification could even determine the wave-frequency (or pattern velocity).

(ii) Interaction of intense radiation with a plasma in the early universe :

A model problem of interaction of high intensity electromagnetic radiation with plasma is studied. An analysis is carried out to see the existence of any instability which would give rise to a bunching of matter and hence the separation from radiation. The effect of the radiation is taken through the ponderomotive force, the radiation itself being represented by a wave kinetic equation for the photon number density. This problem is relevant for the question of the formation of galaxies in the early universe.

(iii) Dynamics of slightly ionized gravitating plasmas :

At a certain stage, during the evolution of the universe, after the decoupling of matter from the radiation and after the matter has cooled, a significant fraction of the matter will be in the form of neutral gas. A small fraction of the matter will, however, still remain in the plasma stage. The Jeans frequency and the ion plasma frequency may then be comparable and the system would exhibit new modes and new characteristics of instabilities. The stability properties of such systems are being investigated from the point of view of studying the dynamics of galaxies in their early stage.

(iv) Relativistic Langmuir solitons :

Nonlinear Schrödinger equation, describing the nonlinear Langmuir waves in a relativistic Vlasov plasma in a strong magnetic field, is derived. In the relativistic limit, this equation gives envelope solitons which are discussed from a point of view of their applications to pulsars.

(v) Charged particle motion in an electromagnetic field on Kerr background geometry :

The trajectories of charged particles in an electromagnetic field superimposed on the Kerr background have been studied. The electromagnetic fields considered are of two types : a dipole magnetic field with an associated quadrupole electric field, and a uniform magnetic field. The most interesting aspect of the study is the illustration of the effect of inertial frame dragging due to the relation of the central star, which appears through the existence of nongyrating bound orbits at and inside the ergo-surface.

6. SOME FUTURE PROGRAMMES

(a) Infrared astronomy :

One meter telescope for infrared astronomy :

A major programme in the IR area for the next 3 years will be the setting up of one meter aperture telescope at Gurushikhar, Mount Abu. The fabrication of the primary and the secondary mirrors will be carried out at the IIA, Bangalore, under supervision of Dr. Vainu Bappu. The BARC has agreed to fabricate the mechanical drive and control system for the telescope. Designing of the electronic controls is in progress at the PRL.

(b) Geocosmophysics :

Studies of the Dhajala meteorite :

Two programmes are currently in progress with a view to (i) estimate the neutron production profile with depth in meteorities, and (ii) establish the depth profiles of ^{53}Mn.

Spacelab experimental package :

An experimental package to study the charge state of low energy (5-50 MeV/amu) ions in solar and galactic cosmic rays has been accepted by the NASA to be flown in the first Space Shuttle in 1980. This experiment is jointly proposed by the physical Research Laboratory and the Tata Institute of Fundamental Research. Event-time analysis and charge state determination will be achieved by programmed rotation of the detector stack and momentum filter action of the geomagnetic field, respectively.

The initial model of the package has already been designed and simulation of the various subsystems is in progress.

"ALLSCAN" Camera network for meteorite photography :

The "ALLSCAN" camera network has been initiated to photograph the night sky over Gujarat and Rajasthan to detect meteors, fireballs and meteorites in flight. The network will consist of a series of cameras suitably spaced with a timing mechanism so that the trajectories of the fireballs etc. can be accurately determined by triangulation. Such a network is planned for the first time in this part of the world and will help in the determination of the preatmospheric orbits of these objects and in the recovery of the meteorites.

(c) Solar and Planetary Physics :

Interplanetary Scientillations (IPS) :

Three station IPS observatory :

This project, funded by the Department of Science and Technology, was undertaken in May 1977. Since then, designs of various subsystems, such as antenna array Butler matrix, receiver, data acquisition system, etc., have been finalized. Work on the installation of a large antenna array at 103 MHz (area about 5000 m^2) has started at Thaltej IPS field site near Ahmedabad. It is expected that the first IPS station at Thaltej would be completed by October 1978.

Surat and Rajkot will be other two IPS stations, where South Gujarat and Saurashtra Universities have each allotted to the PRL two acres of their campus land for the purpose of installing the IPS stations. Using the three IPS stations, at a distance of about 200 km from one another, daily average solar wind velocity can be estimated. Aslo, study will be made of interplanetary shocks and blast waves, corotating streams, etc. It is expected that all the three IPS stations will be operational by the middle of 1979.

Solar radio astronomy :

High sensitivity, high resolution radio spectroscopy of the Sun at 136—140 MHz will be carried out with the help of high gain steerable antenna array built earlier for SOLRAD-satellite telemetry. 2.8 GHz radiometer and wide-band meter wavelength radio spectroscope will be operated as solar flare patrol. Plans are being made to extend solar radiometric work to millimeter wavelengths in collaboration with the Space Applications Centre (ISRO), Ahmedabad. At present, feasibility of deploying microwave and millimeter wave radiometers in the path of totality of the solar eclipse of February 1980, is being considered for the study of lower chromosphere. Collaboration with Vedhshala Udaipur Solar Observatory on the high spatial and temporal resolution optical studies of the Sun will be continued.

(d) Laboratory Plasma and Astrophysics :

Experimental Plasma Physics :

Relativistic electron beam generator :

In order to obtain high power levels (10^{10} W) for an REB diode, the energy needs to be compressed to about 50 nano sec. The parameters for an energy compression facility, formed of a water-dielectric transmission line and an associated switching system have been designed. These components are being fabricated presently. The system is expected to be put into operation shortly.

In the meanwhile, the design data for a higher rated (1 MV, 5000 J) Marx-generator are being worked out.

Developments in the high temperature plasma diagnostics

The relativistic electron beam interaction with the plasma is expected to produce a dense (10^{14} cm^{-3}) hot (0.1 - 1.0 keV) magnetized plasma. Non-perturbing diagnostics under development include X-ray spectrometer and microwave radiometer. The design for both instruments has been completed and components are under procurement.

Laboratory Astrophysics :

A new VUV light source :

A new type of pulsed VUV source has been designed and fabricated in the laboratory and is being tested for absolute intensity at various emission lines produced by multipliionized atoms. In a conventional pulsed source, the condensor is discharged using a mechanical switch or thyratron, whereas in the present case, current switching action is achieved by applying a strong magnetic field perpendicular to the source. In this technique, there seems to be no limitation on the current which can be passed through the source except that set by cooling of the source.

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14. Pratap R.,
The Asteroidal belt and Kirkwood gaps—a statistical study, *Pramana*, **8**, 438 (1977).

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(*a*) Third International "Kiev" Conference on Plasma Theory held at Trieste, Italy in April, 1977.

1. Buti B.,
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2. Varma R. K.,
   On Alfven critical velocity for plasma neutral gas interaction.

(*b*) L. D. de Feiter Memorial Symposium on STIP held at Tel Aviv, Israel in June, 1977 :

1. Bhatnagar A., Ballabh G. M., Jain R., Rao S. S., Bhonsle, R. V., and Sawant H. S.,
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2. Bhonsle R. V., Sawant H. S., Degaonkar S. S. and Alurkar S. K.,
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3. Sawant G. S., Bhonsle R. V., Degaonkar S. S. and Alurkar S. K.,
   Estimation of exciter length of type IIIb bursts near two solar radii derived from microscopic solar decametric spectral features.

(*c*) 40 th Meteoritical Society Meeting held at London in July 1977 :

1. Doshi N., Goswami J. N., Lal D., Rao M. N. and Venkatesan T. R.,
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2. Goswami J. N. and McDougall J. D.,
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(*d*) IUPAP Conference on Statistical Physics held at Technion, Haifa, Israel in Aug. 1977 :

1. Pratap R.,
   Strong turbulence in an electron gas.

(*e*) Luna: 24 Conference held at Houston in December, 1977 :

1. Bhandari N., Padia J. T., Potdar M. B. and Shah V. G.,
   Radio-activity and morphology of Luna-24 samples.

2. Goswami J. N. and Lal D.,
   Particle tracks and micro-craters in Luna-24 drill core samples.

(*f*) Seminar on Protostars and Planets held at Arizona, Tucson in January, 1978 :

1. Pratap R.,
   Density waves in planetary system formation.

(*g*) Ninth Lunar Science Conference held at Houston in March, 1978 :

1. Gopalan K., Goswami J. N., Rao M. N. and Venkatesan T. R.,
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   (Supervised by Professor U. R. Rao)

2. Goswami J. N.,
   "Nuclear tracks in extraterrestrial silicate grains," (Supervised by Professor D. Lal)

3. Sawant H. S.,
   "Studies in solar-terrestrial physics,"
   (Supervised by Professor R. V. Bhonsle).

R. V. Bhonsle