Chapter 5

Research Trends at PRL

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RESEARCH TRENDS AT PRL

The ever increasing size and specialized nature of research today, makes it difficult for a small group of experts to evaluate fully, the complex landscape of research. The limited availability of funds has made it almost mandatory to measure the research outputs in all the subject fields. Since lot of money is being invested in this endeavour, most of the policy makers in the governments are asking for research output in quantitative terms.

As the science and technology research is becoming an increasingly international pursuit, more and more people are undertaking the quantitative studies to measure science. Such studies point to useful indicators of research such as scientific productivity, thrust areas of research and preferences for publication modes. Tracking citations and understanding their trends in context is a key to evaluate the impact and influence of research. To discern the research trends at PRL, the researcher has studied two components of research output – research publications of PRL scientists and bibliographies of theses of PRL doctoral students.

Elements of Research

According to Lancaster (1991) for assessing the research productivity of an organization and its impact, four major elements are important. These are the inputs, the process, the outputs and the outcomes of research. Lancaster opines that the inputs are the most tangible and hence measurable. The primary input is financial resource which is used to purchase the secondary resource like the human resource and the facilities (laboratories, buildings, libraries, etc.) that make the research possible. Factors affecting the quality of research process include the size of the research group, its composition, the leadership

provided, the institutional climate and the degree of collaboration. Various personal and behavioral characteristics of researchers also affect the research process. Efficiency of the research group can be measured in terms of completion of projects on time and within budget. The research output is the result achieved through the research process. The results become relevant only when they are made known to individuals or organizations that can apply them. This is done by publishing the results in reports, scholarly journals and papers presented at conferences. Cost effectiveness criteria would include the number of research publications produced per person employed. The research outcome is generally considered to be the benefit to the organization or society at large.

The present study is confined to the measurement of research output of PRL only. It has not touched upon other aspects of research – input, process and outcome - as it would be beyond its scope.

The present chapter covers the division wise break-up of the research output, research trends visible during the period of study, identifies the topics of research which attracted more number of papers than the others and most prolific scientists of PRL during 1997-2006.

Division wise break up of research output of PRL scientists

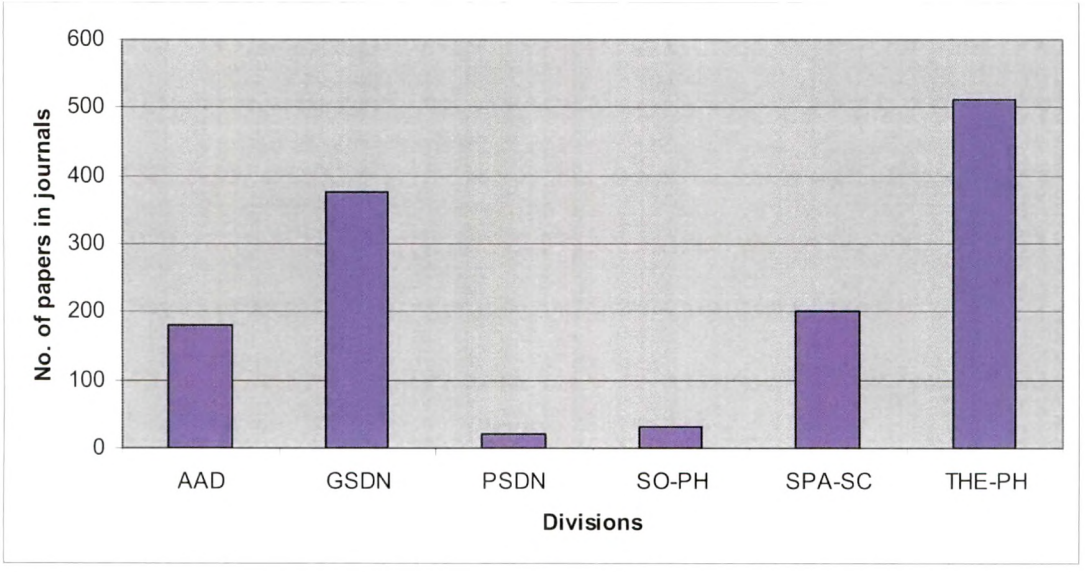
According to research carried out in six broad subjects, there are six divisions in PRL. As mentioned in chapter 3, these are Astronomy and Astrophysics (AAD), Geosciences (GSDN), Planetary Sciences (PSDN), Space and Atmospheric Sciences (SPA-SC), Theoretical Physics (THE-PH) and Solar Physics (SO-PH). Earlier SO-PH was part of Astronomy Division. PSDN, which was formed by merging PLANEX and SOXS projects was part of GSDN. The researcher thought it appropriate to find out the division wise break up of productivity of PRL scientists. Tables and figures 2.1 to 2.6 give the division wise research output of PRL scientists – papers published in journals, papers published in conference proceedings and number of invited talks delivered.

Table 2.1 and Figure 2.1 give an indication of the division wise publication output in journals from 1997-2006. The data for SO-PH and PSDN is from 2002. Amongst all divisions, productivity of Theoretical Physics - THE-PH (38.77%) and Geosciences - GSDN (28.45%) divisions is more than other divisions during 1997-2006.

Table 2.1: Division wise break up of Papers Published in Journals during 1997-2006

Division	No. of Publications
AAD	180
GSDN	375
PSDN	20
SO-PH	32
SPA-SC	200
THE-PH	511
Total	1318

Fig 2.1: Division wise break up of Papers Published in Journals during 1997-2006



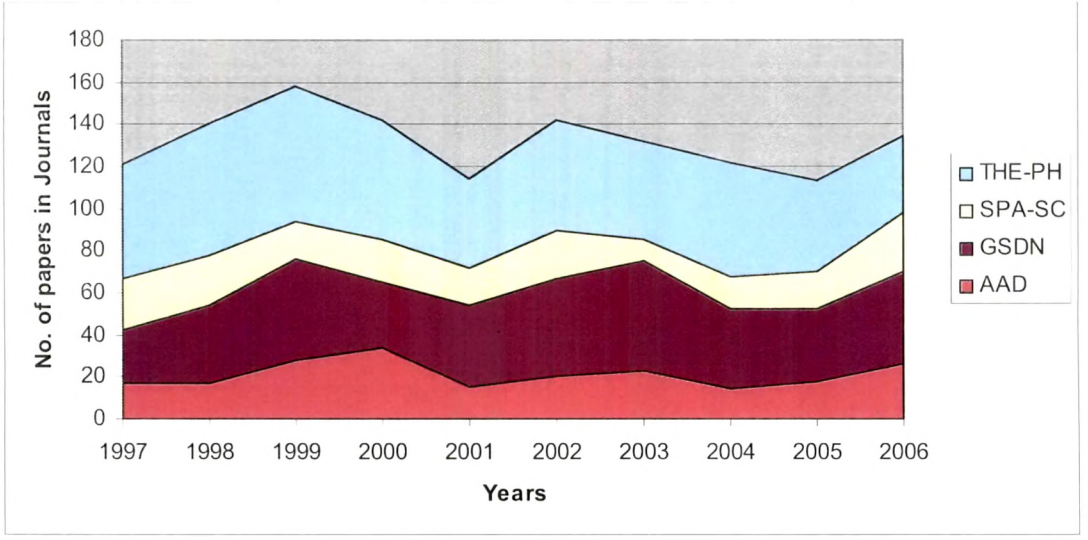
Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.2 and Figure 2.2 give the research output pattern of four major divisions from 1997 through 2006. For broader picture, Solar Physics is included in Astronomy Division and PSDN is included in Geosciences division. AAD produced maximum (34) number of papers in the year 2000, Geosciences Division (GSDN) produced maximum number of papers (52) in 2003, Space Sciences Division (SPA-SC) produced maximum (28) papers in 2006 and Theoretical Physics Division (THE-PH) produced maximum (64) papers in 1999.

Table 2.2 : Year wise pattern of Papers in Journals from 1997-2006

YEAR	AAD	GSDN	SPA-SC	THE-PH
1997	17	25	25	54
1998	17	37	24	62
1999	28	48	18	64
2000	34	31	20	57
2001	15	39	18	42
2002	20	47	23	52
2003	23	52	10	47
2004	14	38	16	54
2005	18	34	18	43
2006	26	44	28	36
Total	212	395	200	511

Fig 2.2 : Year wise pattern of Papers in Journals from 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

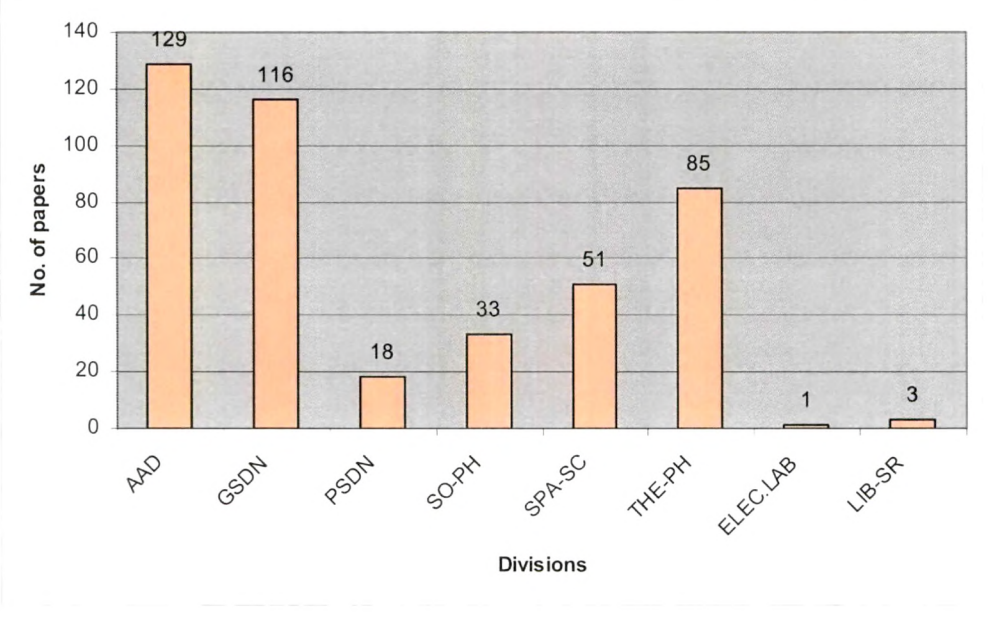
The figure above shows that over the years, productivity of SPA-SC has remained more or less same while it has improved for AAD and almost doubled for GSDN. Most likely reason for this seems to be that more number of faculty joined PRL in Geosciences division during this period. THE-PH has seen a decrease in its research output in journals especially from 2004 onwards.

Table 2.3 and Figure 2.3 below give the division wise break up of papers published in conference proceedings. Out of 436 papers in conference proceedings, maximum of 129 papers (29.59%) are published by Astronomy division followed by GSDN with 116 papers (26.61%) and THE-PH with 85 papers (19.50%). Space Science Division published only 51 papers (11.70 %) in conference proceedings during the 10 year study period. Amongst the Facilities of the institute, 3 papers were published by Library & Information Services and one paper by Electronics Lab. There is no paper from Computer Centre and Workshop published in the conference proceedings during the period 1997-2006.

Table 2.3 : Division wise break up of Papers in Conference Proceedings during 1997-2006

Division	Papers	%
AAD	129	29.59
GSDN	116	26.61
PSDN	18	4.13
SO-PH	33	7.57
SPA-SC	51	11.70
THE-PH	85	19.50
ELEC.LAB	1	0.23
LIB-SR	3	0.69
Total	436	100.00

Fig 2.3 : Division wise break up of Papers in Conference Proceedings during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.4 and Figure 2.4 below give the year wise pattern of research output in conference proceedings in four major divisions of PRL (by bringing SO-PH under the fold of Astronomy and PSDN under the fold of GSDN as these were formed in the middle of the study period) . The table shows that Geosciences and Theoretical Physics division saw a decrease in number of papers published in conference proceedings, while Space Science division saw an increase in number of papers in conference proceedings from 1997 to 2006. There is an increase in Astronomy division's contribution in conference proceedings till 2005 with a sharp dip in 2006.

Table 2.4: Year wise pattern of Papers in Conference Proceedings from 1997-2006

YEAR	AAD	GSDN	SPA-SC	THE-PH
1997	9	15	0	15
1998	17	13	15	15
1999	13	11	2	11
2000	11	3	7	9
2001	14	4	6	1
2002	37	24	15	8
2003	20	17	2	6
2004	4	21	0	9
2005	29	15	0	6
2006	8	11	4	5
Total	162	134	51	85

Fig 2.4 : Year wise pattern of Papers in Conference Proceedings from 1997-2006

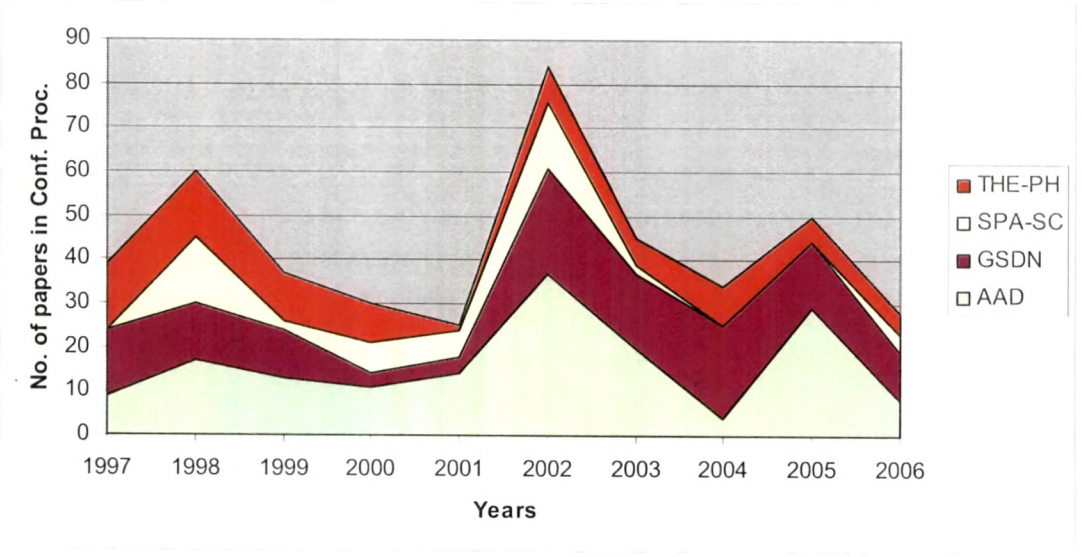
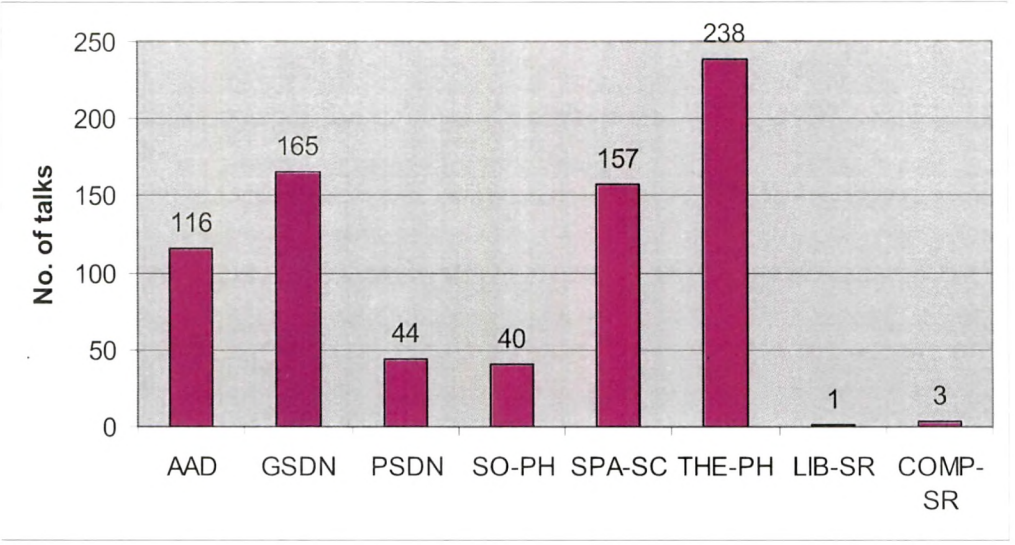


Table 2.5 and Figure 2.5 give the division wise break up of number of invited talks delivered by the scientists of PRL during 1997-2006. Out of the total of 764, THE-PH and GSDN top the list with 238 and 165 invited talks delivered respectively.

Table 2.5 : Division wise break up of Invited Talks delivered during 1997-2006

Division	No. of Invited Talks	%
AAD	116	15.18
GSDN	165	21.60
PSDN	44	5.76
SO-PH	40	5.24
SPA-SC	157	20.55
THE-PH	238	31.15
LIB-SR	1	0.13
COMP-SR	3	0.39
TOTAL	764	100

Fig 2.5 : Division wise break up of Invited Talks delivered during 1997-2006



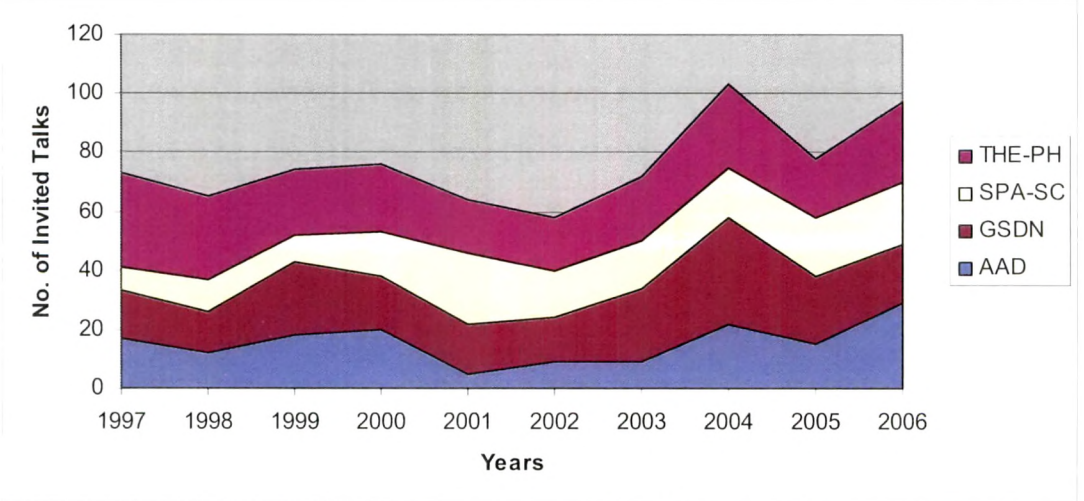
Note : AAD – Astronomy, GSDN – Geosciences, PSDN – Planetary Sciences, SO-PH – Solar Physics, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Table 2.6 and Figure 2.6 give the year wise pattern of number of invited talks delivered by PRL scientists of four major divisions from 1997 to 2006. Here again the data of SO-PH is included in Astronomy and that of PSDN is included in GSDN. The table shows that number of invited talks over the years have decreased for Theoretical Physics division, increased for Astronomy and Space Science divisions and increased marginally for Geosciences division.

Table 2.6 : Year wise pattern of Invited Talks delivered during 1997-2006

Division	AAD	GSDN	SPA-SC	THE-PH
1997	17	16	8	32
1998	12	14	11	28
1999	18	25	9	22
2000	20	18	15	23
2001	5	17	24	18
2002	9	15	16	18
2003	9	25	16	22
2004	22	36	17	28
2005	15	23	20	20
2006	29	20	21	27
Total	156	209	157	238

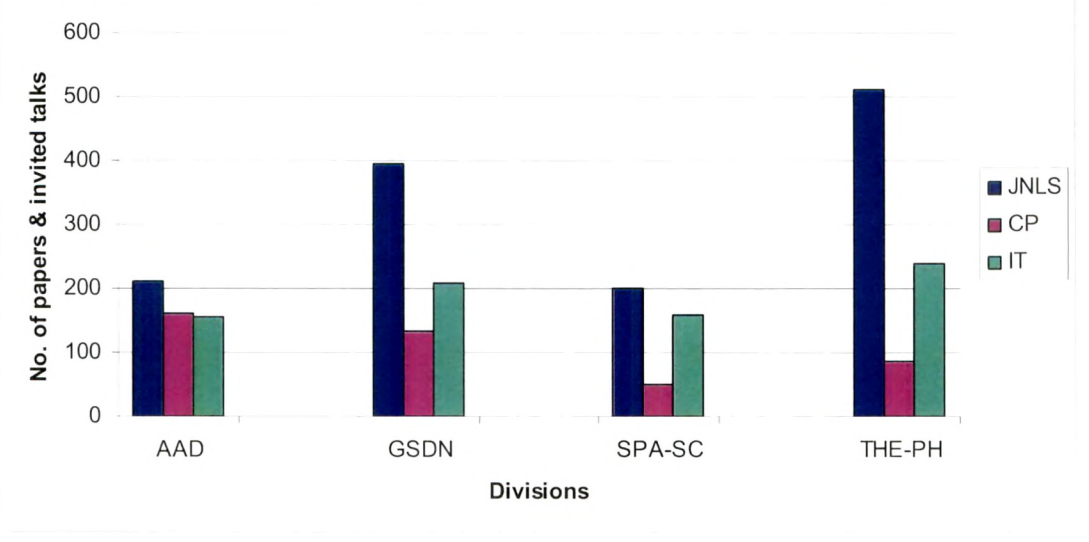
Fig 2.6 : Year wise pattern of Invited Talks delivered during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Thus the division wise break up of all the research output components (papers published in journals, papers in conference proceedings and invited talks) reveals that Theoretical division is most productive in terms of papers published in journals (511) and invited talks delivered (238). Geosciences division comes second in all the three categories of the research output with 375 papers in journals, 134 papers in conference proceedings and 209 invited talks delivered. Astronomy division produced maximum number of papers in conference proceedings (162) but delivered least number of invited talks (156). SPA-SC produced least number of papers in journals (200) and in conference proceedings (51). Graphical representation of the consolidated research output of four major divisions is given in Figure 2.7 below.

Fig 2.7 : Division wise consolidated research output of PRL during 1997-2006



Note : AAD – Astronomy, GSDN – Geosciences, SPA-SC – Space & Atmospheric Sciences, THE-PH – Theoretical Physics

Active Research Topics

After the broad division wise break up, it would be logical to take a look at the more specific subject headings under which the research was undertaken. The sample for identifying the research trends is papers published in journals (1318). The subject headings were arrived at by doing content analysis of the articles published in journals in each year and giving 2-3 keywords relevant to the main subject. Then each article was alotted a PACS number. As mentioned in chapter 3, PACS is Physics and Astronomy Classification Scheme, devised by American Institute of Physics. This data was merged for all the years and sorted in descending order in order to determine the number of articles published in each micro topic. Thus a PACS number of 96.3 indicates the micro topic - Moon, where in 96 referes to the Solar System which is a topic under broad subject heading of 90 - *Geophysics, Astronomy and Astrophysics*. Then the number of articles published in all the micro topics under a topic were added up. These were further merged to arrive at a broad subject area. Tables 2.7 to 2.20 give the number of papers published in journals under different subject headings.

Table 2.7 gives the number of articles published in journals (1318) under 10 broad subject areas out of which first eight are under the Theoretical Physics, ninth is interdisciplinary and tenth includes Geoscience, Space Science and Astronomy. This is because the PACS covers the theoretical physics most extensively as it was the first field of physics for which PACS was developed. Gradually Astronomy, Geosciences and Space Science subjects were added by AIP for classification and retrieval of articles in these fields.

Table 2.7 : Number of papers under broad subjects of PACS

PACS No.	Broad Subjects	No. of Papers	%
0	***General Physics***	**136**	10.32
10	***Physics of Elementary Particles And Fields***	**118**	8.95
20	***Nuclear Physics***	**32**	2.43
30	***Atomic And Molecular Physics***	**31**	2.35
40	***Electromagnetism, Optics, Classical Mechanics***	**143**	10.85
50	***Physics of Gases, Plasmas, Electric Discharges***	**43**	3.26
60-70	***Condensed Matter***	**12**	0.91
80	***Interdisciplinary Physics And Related Areas***	**57**	4.32
90	***Geophysics, Astronomy And Astrophysics***	**746**	56.60
	Total	**1318**	100.00

The table above shows that PACS Number 90 (Geophysics, Astronomy and Astrophysics) accounts for more than half of the total share of articles published in journals. Theoretical Physics subject field has been dealt with maximum depth (0-70) by PACS, as this scheme was devised to organise articles in Theoretical Physics. Out of the seven broad PACS subject headings in Theoretical Physics, ***Electromagnetism, Optics and Classical Mechanics*** attracted 143 (10.85%) papers, followed by ***General Physics*** with 136 (10.32 %) papers and ***Physics of Elementary Particles And Fields*** with 118 papers (8.95%).

Tables 2.8-2.16 gives the detailed picture of number of papers on various topics under each broad subject mentioned in Table 2.7.

Under the broad subject of ***General Physics***, 136 papers were published during 1997-2006 by PRL scientists. Out of these 136 papers, the top three topics which attracted maximum number of papers are *Quantum mechanics, field theories and special relativity* (66) followed by *Statistical physics, thermodynamics and nonlinear dynamics* (48) .

Table 2.8 : Number of papers under ***General Physics.***

PACS No.	Topics	No. of Papers
0	***General Physics***	**136**
1	*Communication, education, history and philosophy*	0
2	*Mathematical methods in physics*	3
3	*Quantum mechanics, field theories and special relativity*	66
4	*General relativity and gravitation*	13
5	*Statistical physics, thermodynamics, nonlinear dynamics*	48
6	*Metrology, measurements and laboratory procedures*	0
7	*Instruments, apparatus and components*	6

Table 2.9 gives the number of papers in different topics under ***Physics of Elementary Particles and Fields.*** In this group, the topic *Properties of Specific Particles* attracted the maximum number of papers (56) out of 118 papers published.

Table 2.9 : Number of papers under ***Physics of Elementary Particles and Fields***

PACS No.	Topics	No. of Paper
10	***Physics of Elementary Particles and Fields***	**118**
11	*General theory of fields and particles*	22
12	*Specific theories and interaction models*	22
13	*Specific reactions and phenomenology*	18
14	*Properties of specific particles*	56

Table 2.10 below shows that a total of thirty two papers were published in the broad subject of ***Nuclear Physics*** under which *Nuclear Structure* attracted 17 of papers in the ten year period of 1997-2006.

Table 2.10 : Number of papers under ***Nuclear Physics***

PACS No.	Topics	No. of Papers
20	***Nuclear Physics***	**32**
21	*Nuclear structure*	17
23	*Radioactive decay and in-beam spectroscopy*	1
24	*Nuclear reactions : general*	7
26	*Nuclear astrophysics*	3
28	*Nuclear engineering and nuclear power studies*	2
29	*Experimental methods and instrumentation*	2

Table 2.11 shows that ***Atomic and Molecular Physics*** attracted a total of 31 papers during 1997-2006 out of which 15 were published under the topic *Atomic Properties and interactions with photons* and 10 were published under *Atomic and molecular collision processes.*

Table 2.11 : Number of papers under ***Atomic and Molecular Physics***

PACS No.	Topics	No. of Papers
30	***Atomic and Molecular Physics***	**31**
31	*Electronic structure of atoms and molecules*	3
32	*Atomic properties and interactions with photons*	15
33	*Molecular properties and interactions with photons*	2
34	*Atomic and molecular collision processes*	10
37	*Mechanical control of atoms, molecules and ions*	1

Table 2.12 shows that 143 papers were published on the topic ***Electromagnetism, Optics, Acoustics and Fluid Dynamics,*** out of which 134 were published on *Optics*. No papers were published on *Acoustics* and *Heat Transfer*.

Table 2.12 : Number of papers under ***Electromagnetism, Optics, Acoustics and Fluid Dynamics***

PACS No.	Topics	No. of Papers
40	***Electromagnetism, Optics, Acoustics & Fluid Dynamics***	**143**
41	*Electromagnetism, electron and ion optics*	8
42	*Optics*	134
43	*Acoustics*	0
44	*Heat Transfer*	0
47	*Fluid Dynamics*	1

Table 2.13 below shows that ***Physics of Gases & Plasmas*** attracted 43 papers during 1997-2006. It is interesting to note that the topic *Physics of Gases* did not attract a single paper during the study period.

Table 2.13 : Number of papers under ***Physics of Gases and Plasmas***

PACS NO.	Topics	No of Papers
50	***Physics of Gases and Plasmas***	**43**
51	*Physics of Gases*	0
52	*Physics of Plasmas and Electric Discharge*	43

Table 2.14 below shows that the broad subject of ***Condensed Matter*** attracted only 12 papers in the ten year period, clearly indicating that it is not an active area of research for PRL.

Table 2.14 : Number of papers under ***Condensed Matter***

PACS No.	Topics	No of Papers
60-70	***Condensed Matter***	**12**
61	*Structure of solids and liquids, crystallography*	2
62	*Mechanical and acoustical properties of condensed matter*	0
64	*Equations of state, phase equilibria and phase transitions*	2
65	*Thermal properties of condensed matter*	0
71	*Electronic structure of bulk materials*	1
74	*Superconductivity*	0
77	*Dielectrics, piezoelectrics and ferroelectrics*	1
78	*Optical properties, condensed matter*	6

Table 2.15 below shows that under the broad subject of ***Interdisciplinary Physics*** 57 papers were published during the 10 year period of 1997-2006 out of which 37 were published in *Physical Chemistry and* Chemical *Physics.*

Table 2.15 : Number of papers under ***Interdisciplinary Physics***

PACS No.	Topics	No. of Papers
80	***Interdisciplinary Physics***	**57**
81	*Materials science*	1
82	*Physical chemistry and chemical physics*	37
83	*Rheology*	0
84	*Electronics, radiowave and microwave technology*	4
85	*Electronic and magnetic devices*	10
87	*Biological and medical physics*	2
89	*Other areas of applied and interdisciplinary physic*	3

Since PACS has grouped ***Geophysics, Astronomy and Atmospheric Sciences*** under one broad subject, the researcher thought it appropritate to give the break up of micro topics as indicated by the specific PACS number under each topic. Table 2.16 gives the break up

of topics under the broad subject group of ***Geophysics, Astronomy and Atmospheric Sciences.***

Table 2.16 : Number of papers under ***Geophysics, Astronomy and Astrophysics***

PACS No.	Topics	No. of Papers
90	***Geophysics, Astronomy And Astrophysics***	**746**
91	*Solid Earth Physics*	127
92	*Hydrospheric and Atmospheric Geophysics*	236
93	*Geophysical Observations, Instrumentation*	13
94	*Physics of The Ionosphere And Magnetosphere*	58
95	*Fundamental Astronomy And Astrophysics*	36
96	*Solar System, Planetology*	170
97	*Stars*	67
98	*Stellar Systems, Interstellar Medium, Universe*	39

As seen from the table above, *Hydrospherics and Atmospheric Geophysics* attracted the maximum number of papers (236) followed by *Solar System, Planetology* (170) and *Solid Earth Physics* (127) respectively.

Further classification of these topics into micro topics gives a clearer picture about thrust areas of research under this broad subject. As for example, Table 2.17 below shows that out of 127 papers on the topic of ***Solid Earth Physics,*** 45 papers were published in the micro topic of *Geochronology* and 30 papers were published in micro topic of *Properties of Rocks and Minerals* .

Table 2.17 : Number of papers under ***Solid Earth Physics***

PACS No.	Micro Topics	No. of Papers
91	***Solid Earth Physics***	**127**
91.1	*Geodesy and Gravity*	1
91.25	*Geomagnetism and Paleomagnetism*	1
91.3	*Seisomology*	2
91.35	*Earth's Interior Structure and Properties*	7
91.4	*Volcanology*	3
91.45	*Tectonophysics*	7
91.5	*Structural geology*	18
91.6	*Properties Rocks And Minerals*	30
91.65	*Mineralogy and Petrology*	3
91.67	*Geochemistry*	8
91.7	*Information Related to Geologic Time*	2
91.8	*Geochronology*	45

Similarly Tables 2.18-2.24 give the break up of micro topics under the topics falling under the broad subject heading of Geophysics, Astronomy and Atmospheric Sciences (90). And Table 2.25 gives the overall picture of thrust areas of research carried out in PRL.

Table 2.18 below shows that the topic of ***Hydrospheric and Atmospheric Geophysics*** attracted 236 papers, out of which 114 papers were published on *Atmosphere Dynamics and Meteorology* and 70 papers were published on *Hydrology and Glaciology.*

Table 2.18 : Number of papers in under ***Hydrospheric and Atmospheric Geophysics***

PACS No.	Micro Topics	No. of Papers
92	***Hydrospheric And Atmospheric Geophysics***	**236**
92.05	*General aspects of oceanography*	1
92.1	*Physical oceanography*	3
92.2	*Chemical and biological oceanography*	26
92.3	*Paleoceanography*	4
92.4	*Hydrology and glaciology*	70
92.6	*Atmosphere dynamics and meteorology*	114
92.7	*Global climate change*	18

Table 2.19 below gives the information that 13 papers were published under ***Geophysical Observations, Instrumentation*** out of which 9 were in *Techniques and Instruments for Geophysical Research.*

Table 2.19 : Number of papers under ***Geophysical Observations, Instrumentation***

PACS No.	Micro Topics	No of Papers
93	***Geophysical Observations, Instrumentation***	**13**
93.3	*Information related to geographical regions*	4
93.85	*Instruments and techniques for geophysical research*	9

Table 2.20 below gives the break up of the micro topics under the topic ***Ionosphere and Magnetosphere*** and shows that maximum number of papers (49) were published on *Physics of the Ionosphere* in the 10 year study period which goes on to show that almost 5 papers were published every year on this topic indicating that it was an active research area.

Table 2.20 : Number of papers under ***Ionosphere and Magnetosphere***

PACS No.	Micro Topics	No. of Papers
94	***Ionosphere And Magnetosphere***	**58**
94.05	*Space plasma physics*	4
94.2	*Physics of the ionosphere*	49
94.3	*Physics of the magnetosphere*	5

Table 2.21 gives the break up of active research micro topics under the topic Fundamentsl Astronomy and Astrophysics. Under this topic, maximum number of papers (25) were on Astronomical Instrumentation during 1997-2006.

Table 2.21 : Number of papers under ***Fundamental Astronomy and Astrophysics***

PACS No.	Micro Topics	No. of Papers
95	***Fundamental Astronomy And Astrophysics***	**36**
95.1	*Fundamental astronomy*	7
95.3	*Fundamental aspects of astrophysics*	2
95.55	*Astronomical and space research instrumentation*	25
95.85	*Astronomical observations*	2

Under the topic of ***Solar System and Planetology***, maximum papers were published in *Solar Physics* (82) followed by *Solar system objects, Meteorites* (63). It is interesting to note that first article in the micro topic of 'Moon' was published in 2002 indicating that research on Chandrayan I which was launched in October 2008 had begun way back in 2002.

Table 2.22 : Number of papers under ***Solar System, Planetology***

PACS No.	Micro Topics	No. of Papers
96	***Solar System, Planetology***	**170**
96.12	*Planetology of solid surface planets*	1
96.15	*Planetology of fluid planets*	1
96.2	*Moon*	5
96.25	*Planetology of comets and small bodies*	12
96.3	*Solar system objects, meteorites*	63
96.5	*Interplanetary physics*	6
96.6	*Solar physics*	82

Table 2.23 below shows that ***Stars*** attracted 67 papers out of which *Variable and Peculiar Stars* attracted 19 papers followed by 17 papers on the miro topic of *Normal Stars*.

Table 2.23 : Number of papers under ***Stars***

PACS No.	Micro Topics	No. of Papers
97	***Stars***	**67**
97.1	*Stellar characteristics and properties*	16
97.2	*Normal stars*	17
97.3	*Variable and peculiar stars*	19
97.6	*Stellar evolution (including black holes)*	9
97.8	*Binary and multiple stars*	6

Table 2.24 below gives data that under the topic of ***Stellar systems, Interstellar Medium and Universe***, 39 papers were published, out of which 14 papers were published in *Cosmology* and 12 papers in *Quasars and Active Galaxies.*

Table 2.24 : Number of papers under ***Stellar Systems, Interstellar Medium and Universe***

PACS No.	Micro Topics	No. of Papers
98	***Stellar Systems, Interstellar Medium, Universe***	**39**
98.2	*Stellar clusters and associations*	1
98.35	*Characteristics and properties of milky way galaxy*	3
98.38	*Interstellar medium and nebulae in milky way*	2
98.54	*Quasars, active or peculiar galaxies, objects and systems*	12
98.58	*Interstellar medium and nebulae in external galaxies*	3
98.62	*Characteristics and properties of external galaxies objects*	2
98.7	*Unidentified sources of radiation outside the solar system*	2
98.8	*Cosmology*	14

To identify the micro topics which attracted most number of publications, a list was prepared by arranging all micro topics (thrust areas) in an descending order of number of publications. Table 2.25 shows the list of most active research areas (micro topics) on which papers were published during 1997-2006.

The table below reveals that during the study period of 1997-2006, in Astronomy, most active research topics were *Solar Physics (*82 papers), *Variable and Peculiar Stars* (19 papers) and *Normal Stars* (17 papers).

Thrust areas of research in Geosciences and Planetary Sciences are *Hydrology and Glaciology (70 papers), Solar System Objects, Meteorites (*63 papers) and *Geochronology (*45 papers).

Table 2.25 : Most active research topics during 1997-2006

PACS No.	Micro Topics	No. of Papers
92.6	Atmosphere dynamics & meteorology	114
96.6	Solar physics	82
42.5	Quantum optics	80
92.4	Hydrology and glaciology	70
96.3	Solar system objects, Meteorites	63
94.2	Physics of the ionosphere	49
91.8	Geochronology	45
14.6	Leptons	44
3.65	Quantum mechanics	41
82.33	Reactions in various media	36
91.6	Physical properties of rocks and minerals	30
5.45	Nonlinear dynamics and chaos	28
92.2	Chemical and biological oceanography	26
95.55	Astronomical, Space research instrumentatio	25
52.27	Basic studies of specific kinds of plasmas	21
97.3	Variable and peculiar stars	19
11.3	Symmetry and conservation laws	18
91.5	Structural geology	18
92.7	Global climate change	18
42.25	Wave optics	17
97.2	Normal stars	17

The thrust areas in Space Sciences are *Atmospheric Dynamics and Meterology (114 papers)* followed by Physics of *Ionosphere (49 papers).*

Quantum Optics (80 papers), *Leptons* (44 papers) and *Quantum Mechanics* (41 papers) were the most active topics of research in Theoretical Physics.

The researcher hopes that this information will be useful to the institute's decision makers for future research planning.

Productivity of Scientists

Research output of scientists is affected by many factors such as age, education, status, the subject field and funds available for research. Stephan & Levin (1993) showed that there is evidence that, generally scientists produce less output as they age. They also concluded that age – publishing profiles differ across the subject fields. In physical sciences, peak output is generally produced by the young scientists. The result obtained in one of the studies carried out by Jacobs (2001) showed that there is a significant difference between the numbers of papers published by the scientists with doctorates as compared to those without PhDs. There is also a relationship between the importance of the scientist and the number of papers he/she has published during his/her life. According to Price (1986) prestige seems to be one of the driving forces that encourages scientists to publish profusely. That is why promotion remains the driving force behind faculty research and publication, as this upgrades the faculty members in status and pay. Pelz & Andrews (1966) showed that teaching and administrative positions taken up as advancement in career facilitate publishing.

Tables 2.26-2.29 give the list of most prolific scientists in terms of papers in journals, papers in conference proceedings and invited talks delivered.

Table 2.26 gives the list of top most prolific researchers who have published more than 20 papers in journals during the years 1996-2007. Prof. G. S. Agarwal, Director PRL from 1996 to 2005 tops this list with 137 papers, followed by Prof. A. K. Singhvi with 61 papers and Prof Utpal Sarkar with 54 papers published in journals.

Table 2.26 : Most prolific researchers - for papers published in journals

Division	Author	No. of papers
THE-PH	Agarwal G S.	137
GSDN	Singhvi A. K.	61
THE-PH	Sarkar U	54
GSDN	Ramesh R.	50
GSDN	Bhandari N	46
GSDN	Bhattacharya S. K.	42
THE-PH	Kota V. K. B.	42
SPA-SC	Chandra H.	33
THE-PH	Panigrahi P. K.	33
AAD	Ashok N. M.	31
THE-PH	Rao N. N.	31
THE-PH	Rindani S. D.	31
THE-PH	Joshipura A. S.	30
SPA-SC	Lal S.	30
GSDN	Sarin M. M.	30
SPA-SC	Jayaraman A.	29
GSDN	Gupta S. K.	27
PSDN	Murty S. V. S.	27
THE-PH	Mohanty S.	26
GSDN	Somayajulu B. L. K.	26
AAD	Ganesh S.	25
PSDN	Goswami J. N.	25
AAD	Vats H. O.	23
THE-PH	Prasanna A. R.	22
SPA-SC	Acharya Y. B.	21
GSDN	Krishnaswami S.	21
GSDN	Ray J. S.	21

Table 2.27 gives the indication of most prolific researchers to publish more than 10 papers in conference proceedings. Out of these eight are from Astronomy division, five from SO-PH, three each from THE-PH and GSDN, two from SPA-SC and one from PSDN.

Table 2.27 : Most prolific researchers – for papers in conference proceedings

Division	Author	No. of papers
GSDN	Gupta S. K.	25
AAD	Ashok N. M.	21
AAD	Ganesh S.	21
AAD	Baliyan K. S.	20
GSDN	Ramesh R.	20
PSDN	Murty S. V. S.	19
AAD	Vats H. O.	19
AAD	Anandarao B. G.	18
AAD	Joshi U. C.	18
SO-PH	Tripathy S. C.	18
AAD	Banerjee D. P. K.	17
SPA-SC	Jayaraman A.	16
SO-PH	Ambastha A.	14
SPA-SC	Chandra H.	14
THE-PH	Kota V. K. B.	14
THE-PH	Dave H.	13
THE-PH	Agarwal G. S.	12
SO-PH	Bhatnagar A.	12
AAD	Chandrasekar T.	11
SO-PH	Jain K.	11
SO-PH	Jain R.	11
GSDN	Somayajulu B. L K.	11

Thus maximum number of papers in conference proceedings are contributed by Prof S K Gupta (25), Prof N M Ashok (21) and Dr S Ganesh (21).

Table 2.28 gives the names of scientists with more than 10 invited talks to their credit.

Table 2.28 : Most prolific researchers – for Invited talks delivered

Division	Researcher	No. of Invited Talks
THE-PH	Agarwal G. S.	64
SPA-SC	Jayaraman A	46
SPA-SC	Lal S	39
GSDN	Singhvi A K	35
GSDN	Ramesh R	31
SO-PH	Ambastha A	23
PSDN	Goswami J N	22
GSDN	Sarin M M	21
THE-PH	Kota V. K. B.	20
THE-PH	Dave H	19
AAD	Joshi U. C.	19
THE-PH	Rao N. N	16
AAD	Anandarao B. G.	15
AAD	Baliyan K. S.	15
THE-PH	Panigrahi P K	15
SPA-SC	Chandra H	14
SPA-SC	Sekar R	14
GSDN	Bhandari N.	13
PSDN	Murty S. V. S.	13
SO-PH	Srivastava N	13
SO-PH	Jain R.	12
SO-PH	Venkatakrishnan P	12
THE-PH	Amritkar R. E.	11
AAD	Janardhan P	11
THE-PH	Sarkar U	11
AAD	Vats H O	11

Out of these top researchers, seven are from THE-PH, five are from AAD, four each from GSDN, SO-PH and SPA-SC, and two from PSDN.

Table 2.28 above shows that Prof G S Agarwal from THE-PH division has delivered maximum (64) invited talks during the period 1997-2006 followed by Prof Jayaraman from SPA-SC division with 46 invited talks. Prof Agarwal is also the most prolific researcher with 137 papers published in journals to his credit. This finding confirms De Solla Price's remark in his book 'Little Science Big Science' (1969), that 'productivity breeds productivity'.

However, if we consolidate all three kinds of research output considered in this study, following list emerges of top scientists of PRL with more than 30 papers and invited talks put together. Prof. G. S. Agarwal tops the list with 213 papers plus talks, followed by Prof. R. Ramesh with 101 items and Prof. A. K. Singhvi with 96 items to their credit during the period of study.

It is interesting to note that in addition to being such prolific researchers, many of the scientists listed below held adminsitrative positions too. Prof. G. S. Agarwal was the Director of PRL from 1995-2005, Prof Krishnaswami was the Director from 2005-06 and Prof J N Goswami is the Director from 2006. Prof S K Bhattacharya was the Dean during 2004-07 and Prof A K Singhvi was the dean during 2007-10. Besides these, most of the other scientists also held the position of chairman of their respective division during different years of the study period.

Table 2.29 : Most prolific researchers during 1997-2006 with more than 30 papers in journals, conference proceedings and invited talks

Division	Name	No of Papers
THE-PH	Agarwal G S.	213
GSDN	Ramesh R	101
GSDN	Singhvi A K	96
SPA-SC	Jayaraman A	91
SPA-SC	Lal S	79
THE-PH	Kota V. K. B.	76
GSDN	Bhandari N	69
THE-PH	Sarkar U	65
SPA-SC	Chandra H	61
GSDN	Murty S. V. S.	59
AAD	Vats H O	53
AAD	Ashok N. M.	52
GSDN	Gupta S. K.	52
GSDN	Sarin M M	51
THE-PH	Panigrahi P K	48
GSDN	Goswami J N	47
THE-PH	Rao N. N	47
AAD	Ganesh S.	46
GSDN	Bhattacharya S. K.	42
THE-PH	Rindani S D	41
SO-PH	Ambastha A	37
AAD	Joshi U. C.	37
GSDN	Somayajulu B. L K.	37
AAD	Baliyan K. S.	35
AAD	Anandarao B. G.	33
THE-PH	Dave H	32
SPA-SC	Acharya Y. B.	31

Lotka's Law of Scientific Productivity

Having collected the data of research output of PRL scientists, the researcher thought it worth while to check out whether productivity of PRL scientists conforms to the Lotka's Law of Scientific Productivity.

Alfred J Lotka (1926) studied author productivity patterns and developed one of the main laws in bibliometrics. He observed that in a given area of science there are a lot of authors who publish only once, while a small group of prolific authors contribute a large number of publications. This premise is the basis of Lotka's Law also commonly known as the 'inverse square law' for author productivity. This law uses the number of authors contributing one paper as the base number and goes on to predict the number of authors contributing 2, 3, 4, 5, papers and so on using the formula

$$y_x = c * 1/x^2$$

Where y_x is the number of authors contributing x papers and c is the number of authors contributing one paper.

One condition to arrive at a list of prolific authors is to take a time frame such that authors have opportunity to publish more than once. Generally a ten year period is considered to be reasonable. As the period of the present study is also 10 years, the researcher thought it appropriate to look into this aspect of a bibliometric study too. The sample of 1318 articles published in journals was used to see whether the sample follows the Lotka's Law. These 1318 articles have been contributed by 622 authors out of which 333 authors have contributed a single paper in journals during 1997-2006. Using the Lotka's law of productivity, authors contributing two papers would be

$$Y_2 = 333 * 1/2^2$$

$$= 333/4$$

$$= 83$$

In the present study sample there are 75 authors contributing two papers during the 10 year period of study. Similarly, according to Lotka's law there would be 37 authors contributing 3 papers. Actually there are 28 authors contributing 3 papers. Till this point, the present study can be considered to conform to the Lotka's Law. However, for authors contributing 4 papers the actual figure and those derived from the law are too far apart – according to the Lotka's law there should be 21 authors contributing 4 papers while actually there are 40 authors contributing 4 papers. But 5 paper data (15) nearly matches with the Lotka figure of 13 authors contributing 5 papers, number of authors contributing 6 papers is 9 according to Lotka's Law, while actually in the study sample it is 19 authors contributing 6 papers.

Table 2.30 : Non-conformation of Lotka's Law

No. of Papers	Authors (actual)	Authors (Lotka)
1	333	333
2	75	83
3	28	37
4	40	21
5	15	13
6	19	9
7	20	7
8	9	5
9	7	4
10	5	3

The data in the above table indicates that the present study conforms to the Lotka's Law of scientific productivity only partially (up to 3 papers). This could be due to the fact that in the present study, each collaborative author get the count of one paper instead of giving credit to only the first author or giving proportionate credit according to the number of collaborative authors. A few earlier studies (Gupta, 1987) and (Nwagwu, 2006) also found that Lotka's Law did not hold true in their studies.

Summary of results

- The division wise break up of all the research output components (papers published in journals, papers in conference proceedings and invited talks) reveals that Theoretical division is most productive in terms of papers published in journals (511) and invited talks delivered (238). Geosciences division comes second in all the three categories of the research output with 375 papers in journals, 134 papers in conference proceedings and 209 invited talks delivered. Astronomy division produced maximum number of papers in conference proceedings (162) but delivered least number of invited talks (156). SPA-SC produced least number of papers in journals (200) and in conference proceedings (51).
- The content analysis of the articles published in journals and the use of PACS to alott keywords helped to identify the thrust areas of research carried out in PRL. Thrust areas in Astronomy are *Solar Physics* (82 papers), *Variable and Peculiar Stars* (19 papers) and *Normal Stars* (17 papers). Thrust areas of research in Geosciences and Planetary Sciences are *Hydrology and Glaciology (70 papers), Solar System Objects, Meteorites* (63 papers) and *Geochronology* (45 papers). In Space Sciences, maximum number of papers (114) were published on *Atmospheric Dynamics and Meterology* followed by *Ionosphere* (49 papers) and in Theoretical Physics maximum number of papers were published on *Quantum Optics* (80 papers), *Leptons* (44 papers) and *Quantum Mechanics* (41 papers). The researcher hopes that this information will be useful to the institute's decision makers for future research planning.
- The broad subject of ***Condensed Matter*** attracted only 12 papers in the ten year period clearly indicating that it is not an active area of research for PRL. No research was done on the topics *Acoustics, Heat Transfer, Physics of Gases* and *Rheology*.
- The sample of this study does not completely follow the Lotka's Law of scientific productivity.

- ❖ It is interesting to note that many of the prolific researchers held senior adminsitrative positions too. This confirms the earlier studies carried out by Pelz and Andrews (1976) and Price (1986) that motivation to publish comes from recognition and prestige.

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