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May 2018

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Kumar, Satish, "Bibliometric mapping of Research Productivity of TIFR Mumbai as seen through the mirror of Web of Science" (2018). *Library Philosophy and Practice (e-journal)*. 1819.
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Bibliometric mapping of Research Productivity of TIFR Mumbai as seen through the mirror of Web of Science

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Abstract:

The paper reveals the research productivity of the scientist of Tata Institute of Fundamental Research (TIFR), Mumbai, India during the year 2001-2015. The study is an analysis of total productivity of TIFR with comparing its Astronomical research productivity during the year 2001-2015. Web of Science (WoS) database was used for the bibliographic data retrieval. Bibliographic data were analyzed by using bibliometric tools and techniques. The research is conducted with a purpose to know the total research productivity of TIFR as well as Astronomical productivity over the period of 15 years (2001-2015), the literature growth, document types, the citations received, source journals, collaborating institutions & countries and research funding agencies. Findings also indicate the publication pattern, CAGR, degree of collaboration, H-Index as well as the nature of the research activities carried out.

Keywords: *Bibliometric, Scientometrics, Research productivity, Citation analysis, Research evaluation, Authorship Pattern.*

1. Introduction:

The application of bibliometric methods is very popular and adequate in the natural sciences to evaluate the quantitative productivity of an individual, a subject, an institution as well as a country. The bibliometric methods for monitoring research performance in science explicitly consider the heterogeneity of publication and citation behaviors in the discipline. Bibliometric methods are used in studies of properties and behavior of recorded knowledge, for analysis of the structures of scientific and research areas, and for evaluation of research activity and administration of scientific information¹. Bibliometric methods are used to explore the impact of a research field, a set of researchers, or a particular article. Bibliometrics became prominent because of the need to manage the vast funds that were going into the science and technology sectors, especially into research and development

activities². Citation analysis is being used as a tool for evaluating the research contributions of the scientific community. It is used for counting of citations of particular research institute or scientists. Citation analysis is a method that interlinks a document with another on a specific subject that opens the door of measuring the science with different point of view to judge the science. Citation analysis indicates the performance measure that shows influential scientists and important works were cited more often than others³.

2. Review of Literature:

A good number of bibliometric studies have been carried out by different researchers on various subject fields. During the last few years, a number of scientometric studies have been progressively used to evaluate research performance of countries, institutions and nations as a whole. Bibliometric seem to have provided the best available groundwork for measuring the outputs of an individual researchers as well as an institution in view of the fact that there is good correlation between the fame of a scientists and their research publications. Karpagam⁴ carried out scientometric analysis to evaluate nano-biotechnology research during 2003-2012 and studied the growth, global publications share and citation impact, share of international collaborative papers and contributions of major collaborative partner countries. Patra, Bhattacharya and Verma¹ analyzed the growth pattern, core journals and authors' contribution in the field of bibliometric using data from Library and Information Science Abstract (LISA) and found that the growth of literature does not show any definite pattern. Mishra & Sarangi⁵ conducted bibliometrics studies of IITs & NITs during 2012-14 and ranked these technology institutes as per the citations received for their research papers and faculty h-index. Tanaka and Ho⁶ conducted a scientometric study to evaluate the global scientific output of desalination research to assess the characteristics of the research tendencies and research performances based on bibliographical data retrieved from WoS for the period 1991-2008. Gopikuttan and Awasthy⁷ measured research productivity of Kerala University and results of the study indicate that Chemistry, Physics, Astronomy & Astrophysics are the prime areas of research. The maximum numbers of international collaborations are with scientists from USA. Jeevan and Gupta⁸ have analyzed the contribution and impact of Indian Institute of Technology, Kharagpur and suggested a methodology for studying the quantitative profile of a research institution, with a view to get

idea about the performance and impact of research produced in each department, and the comparison of the impact of research in various departments.

All above mentioned studies analyzed the author productivity, citation analysis authorship pattern, areas of specialization, most prolific authors, and list of preferred journals for publishing. Majority of the bibliometric studies have used quantitative methods for measuring the research productivity.

3. The Institute - TIFR: Profile

Tata Institute of Fundamental Research is an autonomous National Research Centre of the Government of India, under the umbrella of the Department of Atomic Energy (DAE) and a deemed University awarding degrees for master's and doctoral programs. The Institute was established in 1945 with the assistance from the Sir Dorabji Tata Trust under the vision of Great Scientist Dr Homi J. Bhabha. TIFR conducts research primarily in the natural sciences, mathematics, biological sciences, and theoretical computer science. It is considered to be one among India's excellent research centre. TIFR main campus is located in Mumbai, with centers at Pune, Bangalore and Hyderabad. In the 1950s, TIFR gained fame in the research field of cosmic ray physics, with the setting up of research facilities in Ooty and in the Kolar gold mines. In 1970, TIFR started research in field of radio astronomy with the setting up of the Ooty Radio Telescope (ORT). Encouraged by the success of ORT, Prof. Govind Swarup convinced J. R. D. Tata to help in setting up the Giant Metrewave Radio Telescope (GMRT) near Pune, India; the centre is named National Centre for Radio Astronomy (NCRA). TIFR is pioneer and one of the leading research institutes in India.

4. Objectives

Following are the objectives of the study:

- To examine the research output of TIFR during 2001–2015.
- To compare and analyze the total publication of TIFR with its publication in the field of Astronomy & Astrophysics.
- To analyze the year wise distribution of research publications.
- To find out the ranking of prolific contributors
- To study the year wise authorship pattern of research outputs.

- To study the subject coverage of research publications.
- To know the collaborating institutions as well as countries.
- To find out the prolific source journals of publications.
- To know the degree of collaboration.

5. Statement of the Problem

The problems involved in the present research can be represented through the following questions:

- What is the productivity level of the TIFR faculties in respect of referred research publications in different areas of their research?
- What is the productivity of TIFR scientist in the field of Astronomy & Astrophysics and its comparison with gross publication?
- What is the trend of research with regard to the sources, authorship pattern, frequency of publication, areas of research, collaborating institutions and countries, funding agencies etc?

6. Scope and Limitations

- The Scope of the present study is to evaluate the research productivity of TIFR, Mumbai.
- The study is limited up to the analysis of the referred research publication of TIFR, Mumbai published during 2001-2015.

7. Data and Methodology

Bibliographical database Science Citation Index-Expanded (SCI-E), a product of Clarivate Analytics (previously, Thomas Reuters) was used for the present study. Data were extracted from Advance search using the keywords “OG= (Tata Institute of Fundamental Research OR TIFR)” for the period of 2001-2015. Total 10, 491 data were retrieved. Downloaded data was transferred to MS Excel. Again, Further Data were refined with the subject domain “Astronomy & Astrophysics”, 2252 research publication was retrieved for the same period under the subject ‘Astronomy & Astrophysics’, the data was transferred for analysis in MS-Excel. Bibexcel and Pajek softwares were also used for data analysis and visualization.

8. Data Analysis and Interpretation

8.1 Year wise distribution and growth of publications

Year	TIFR Gross Publication (%)	CAGR*	Total citation received	Average citation per paper	Citing Articles	H-Index
2001	498 (4.75)	-	11476	23.04	10426	55
2002	536 (5.12)	7.63 %	14568	27.18	13149	49
2003	461 (4.39)	-13.99%	21557	46.76	19964	53
2004	541 (5.16)	17.35 %	14956	27.65	13596	62
2005	603 (5.75)	11.46 %	12320	20.43	11123	57
2006	573 (5.46)	-4.98 %	15750	27.49	13961	51
2007	633 (6.03)	10.47 %	12382	19.56	10942	45
2008	672 (6.40)	10.47 %	17696	26.33	15349	53
2009	745 (7.10)	10.86 %	14249	19.13	12971	49
2010	749 (7.13)	0.54 %	18413	24.58	15816	52
2011	794 (7.57)	6.01 %	12043	15.17	10073	50
2012	910 (8.67)	14.61 %	16371	17.99	13846	48
2013	903 (8.61)	-0.77 %	11923	13.2	10357	44
2014	925 (8.82)	2.44 %	12817	13.81	10805	41
2015	948 (9.04)	2.49 %	6752	7.11	5448	33
Total	10491 (100%)	4.97 %	213273	21.96	187826	146

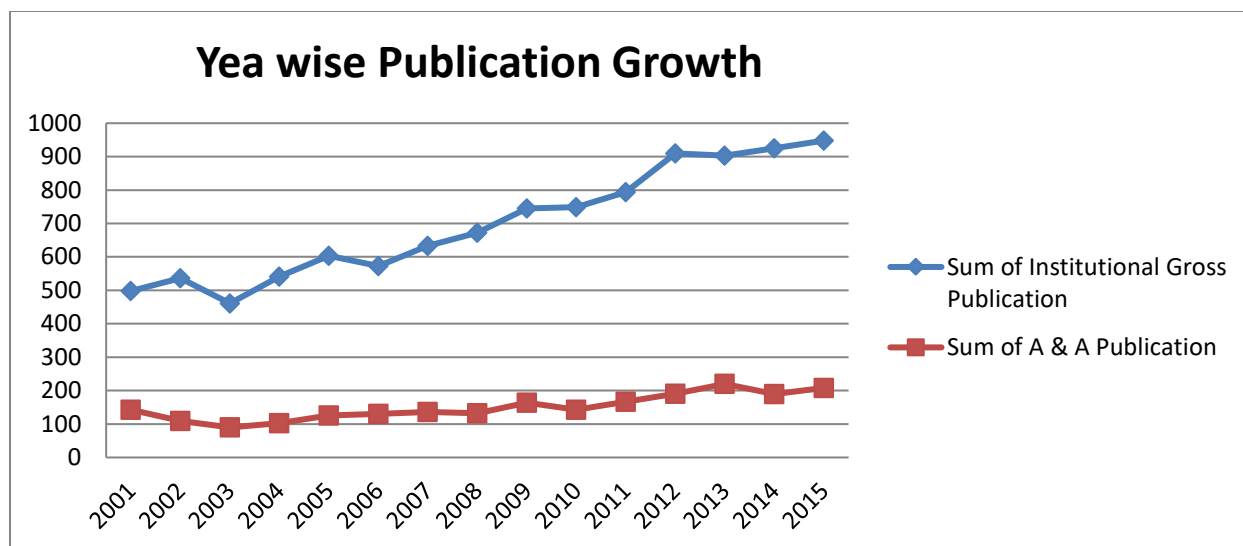
Table-01 (I)

*CAGR= Compound Annual Growth Rate

Year	TIFR's A & A Publication (%)	Percentage of TIFR gross Publication	CAGR* (A&A)	Total citation received	Average citation per paper	Citing Articles	H-Index
2001	143 (6.35)	28.71 %	-	2968	20.76	2642	33
2002	109 (4.84)	20.33 %	-23.78 %	5472	50.2	4961	27
2003	90 (4.00)	19.52 %	-17.43 %	4579	50.88	3961	26
2004	103 (4.57)	19.04 %	14.44 %	3009	29.21	2746	32
2005	126 (5.60)	20.89 %	22.33 %	3026	24.02	2678	29
2006	130 (5.77)	22.69 %	03.17 %	2574	19.8	2359	29
2007	136 (6.04)	21.48 %	04. 62 %	2388	17.56	2075	28
2008	132 (5.86)	19.64 %	-02.94 %	7358	55.74	6872	30
2009	164 (7.28)	22.01 %	24.24 %	5228	31.88	4889	28
2010	143 (6.35)	19.09 %	-12.80 %	3445	24.09	2716	34
2011	167 (7.41)	21.03 %	16.78 %	3527	21.12	2901	33
2012	191 (8.48)	21.00 %	14.37 %	8438	44.18	7306	34
2013	220 (9.78)	24.36 %	15.18 %	3847	17.49	3319	31
2014	190 (8.44)	20.54 %	13.64 %	2958	15.57	2425	29
2015	208 (9.24)	21.94 %	09.47 %	2921	14.04	2364	25
Total	2252 (100%)	21.47 %	05.45 %	61738	27.41	54216	82

Table-01(II)

*CAGR= Compound Annual Growth Rate



Graph-01

It can be observed from the above table that TIFR, Mumbai has published 10,491 research publications over the period of 15 years during 2001-15. Out of 10,491 papers, the Institute has published 2252 research papers in the field of Astronomy and Astrophysics (A&A) which is 21.47 % of the institutional gross publication. The Institute research output has increased year by year except 2003, 2006 and 2013. A & A research publication has also increased except 2002, 2003, 2008 and 2010. Compound Annual Growth Rate (CAGR) has been calculated with the **Formula: CAGR= (Ending Value / Beginning Value)^{1/n-1} -1** and found that 4.47 % was the average CAGR for the institutional gross publication and 5.45 % for the publication of A&A in the study period. TIFR gross publication has received 213273 citations and citing articles are 187826. TIFR's A & A articles have received 61738 citations and have cited 54216 that show TIFR scientist's work is more recognized than they have cited the previous works. TIFR gross publication and A & A subject publication average citation per paper is 21.96 and 27.48 respectively that indicates that TIFR's A & A research has been given more scientific importance than its other research field. TIFR gross publication H-Index is 146 whereas A & A publications H-index is 82.

8.2 Document Type

It can be seen from the table and graph 02 that TIFR published 8,942(85.23 %) articles in journals, 1,425(13.58 %) articles in Conference Proceeding, 208(1.98 %) as Reviews, 139(1.32 %) as Editorial, 258 (2.46 %) as meeting abstracts and rest of the publication in different scholarly sources. It is very interesting to know from the table 02 (given below) that TIFR's A&A publication trend in various documents is almost same as institutional trend. TIFR researchers prefer to publish their research articles in journals.

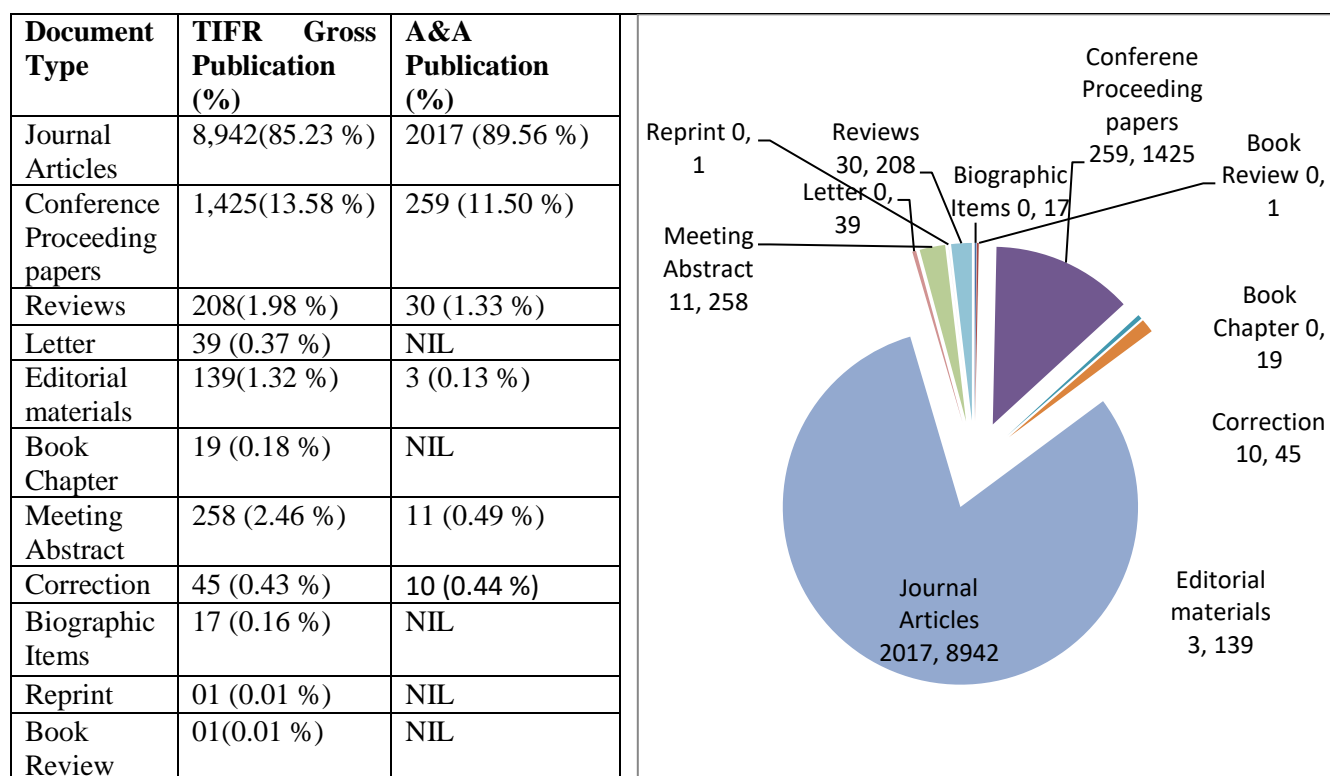


Table-2, Graph-02

8.3 Open Access

Access Type	TIFR Gross Publication (%)	A&A Publication (%)
Open Access journal Publication	717 (6.83 %)	51 (2.26 %)
Subscription/paid access Publication	9,774 (93.17 %)	2,201 (97.74 %)

Table-03

TIFR published 93.17 % of its total publication during 2001-15 in the subscription based access journals and 6.83 % only in open access journals where as in the field of A&A TIFR scientist published only 2.26 % articles in open access and 97.74 % in paid journals. It shows that TIFR scientists are less attracted towards the open access journals for publishing their research work.

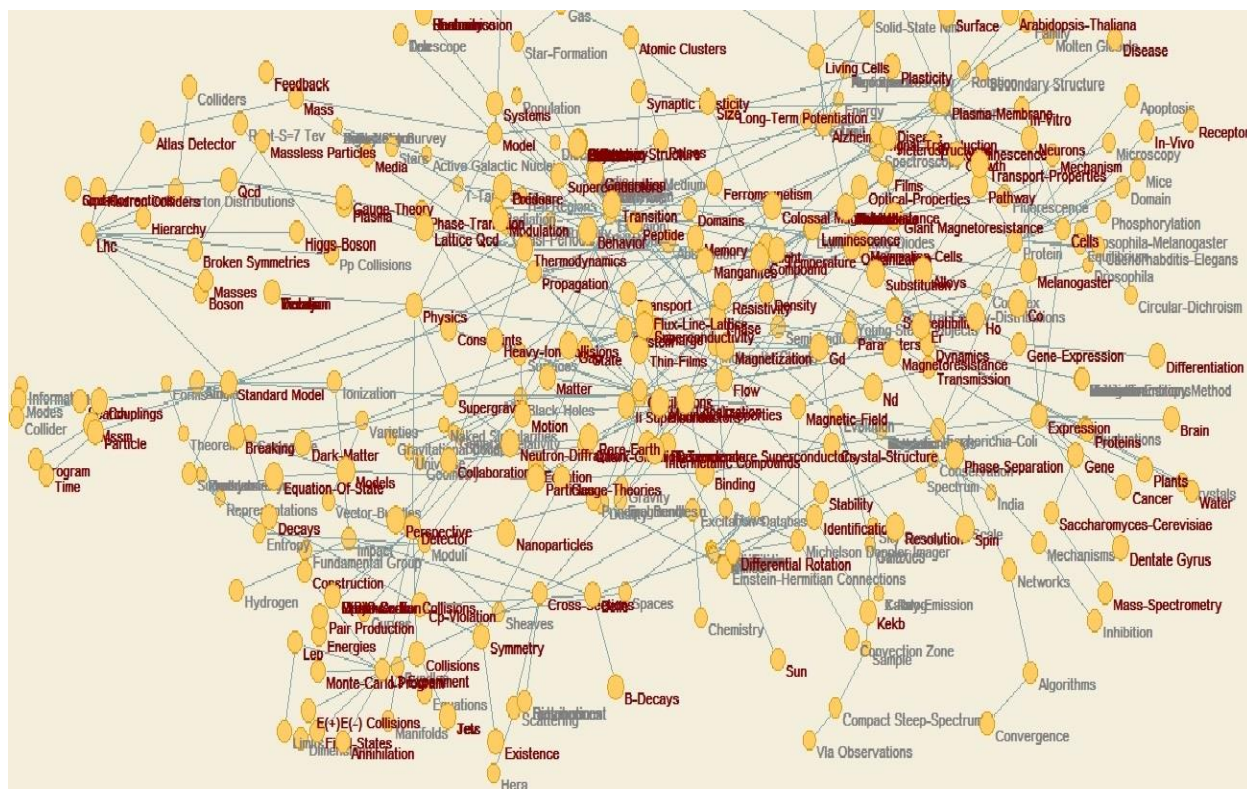
8.4 Subject wise coverage

TIFR Gross Publication		TIFR A&A Publication	
Subject	Publication (%)	Subject	Publication (%)
Physics	4772 (45.48 %)	Astronomy and Astrophysics	2252 (100%)
Astronomy and Astrophysics (A&A)	2252 (21.46 %)	Physics	1092 (48.49 %)
Mathematics	1274 (12.14%)	Meteorology Atmospheric sciences	51 (2.26 %)
Biochemistry -Molecular Biology	731 (6.96 %)	Geology	45 (1.99 %)

Chemistry	587	(5.59 %)	Engineering	21	(0.93 %)
Materials science	465	(4.43 %)	Instrumentation	20	(0.89 %)
Engineering	367	(3.49 %)	Geochemistry Geophysics	8	(0.35 %)
Computer science	296	(2.82 %)	Remote sensing	5	(0.22 %)
Optics	296	(2.82 %)	Telecommunications	5	(0.22 %)
Biophysics	273	(2.60 %)	Optics	3	(0.13 %)
Neurosciences	242	(2.30 %)	Other topics	2	(0.09 %)

Table-04

It is quite clear from the above table that TIFR main focus area of research is Physics (45.48 %), Astronomy & Astrophysics (21.46 %), Mathematics (12.14%), followed by Life sciences, chemistry, engineering and computer sciences. Apart from its core area of research, scientists are also engaged in the sub-domain of research and/or doing interdisciplinary research. Astronomy & Astrophysics is the second highest research interest field at TIFR and have 2252 (21.46 %) publication out of its total publication i.e. 10491. Astronomy & Astrophysics research is further categorized under different subjects such as Physics, Meteorology, Geology, Engineering, Instrumentation, Optics etc. due to its interdisciplinary sub- domain nature. The key word clustering graph is given below that also shows the area of importance and how research terms are interrelated that denotes the overlapping of research interest.

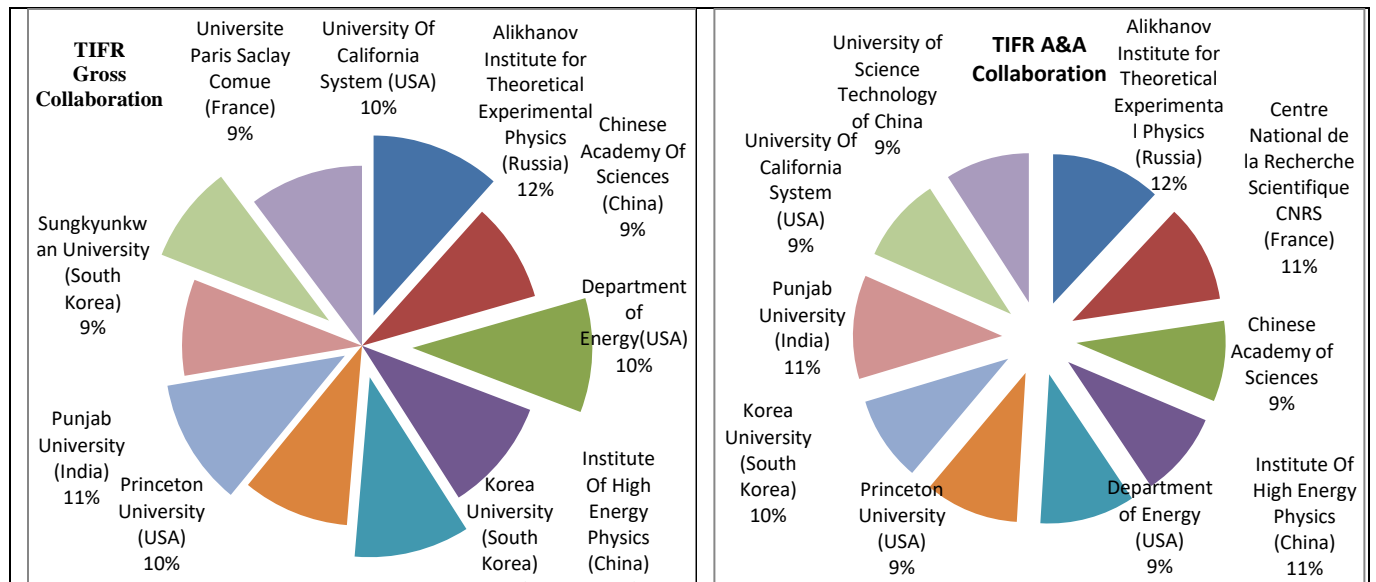


Graph-03- Key words clustering Graph

8.5 Top 10 collaborating Institutions

TIFR Gross Collaboration		TIFR A&A Collaboration	
Institution	Publication (%)	Institution	Publication (%)
Alikhanov Institute for Theoretical Experimental Physics(Russia)	1167 (11.14)	Alikhanov Institute for Theoretical Experimental Physics(Russia)	604 (26.82)
Punjab University(India)	1145 (10.91)	Punjab University(India)	568 (25.22)
Korea University (South Korea)	1041 (9.92)	Centre National de la Recherche Scientifique CNRS (France)	539 (23.93)
Department of Energy(USA)	1030 (9.82)	Institute Of High Energy Physics (China)	521 (23.13)
University Of California System (USA)	1029 (9.81)	Korea University (South Korea)	515 (22.87)
Institute Of High Energy Physics (China)	1022 (9.74)	University Of California System (USA)	469 (20.83)
Princeton University(USA)	963 (9.18)	Department of Energy(USA)	468 (20.78)
Chinese Academy Of Sciences(China)	896 (8.54)	Princeton University(USA)	466 (20.69)
Universite Paris Saclay Comue (France)	882 (8.41)	University of Science Technology of China	461 (20.47)
Sungkyunkwan University (South Korea)	868 (8.27)	Chinese Academy of Sciences	442 (19.62)

Table-05



Graph-04

TIFR is doing collaborative research in its area of research with prominent institutions of the world. TIFR's top collaborating institutes are from Russia, USA, South Korea, France and China. Out of ten collaborating institutions three are from USA, two are from South Korea and China. Only one institution is from India and France. It can also be observed from the table 05 & Graph-04 that Collaborating Institutions in the field of A&A are too from the same countries like TIFR gross collaboration.

8.6 Top 10 collaborating Country

TIFR Gross Collaboration		TIFR A&A Collaboration	
Country	Publication (%)	Country	Publication (%)
USA	2944 (28.01 %)	USA	1190 (52.84 %)
Germany	1772 (16.89 %)	Germany	787 (34.95 %)
France	1409 (13.43 %)	Russia	681 (30.85 %)
China	1344 (12.81 %)	China	662 (29.40 %)
Russia	1336 (12.74 %)	South Korea	646 (28.69 %)
South Korea	1260 (12.01 %)	France	601 (26.69 %)
England	1241 (11.83 %)	England	513 (22.78 %)
Switzerland	1038 (09.89 %)	Switzerland	492 (21.85 %)
Taiwan	885 (08.44 %)	Taiwan	460 (20.43 %)
Italy	868 (08.27 %)	Spain	448 (19.89 %)

Table-06

TIFR had highest collaboration with USA followed by Germany, Russia, China, South Korea, England, Switzerland, Taiwan and Italy during the period 2001-15. TIFR's A&A research collaboration had too with the same countries in same ranking like its gross collaboration but Italy has been replaced by Spain in top ten. TIFR almost one-third gross publication and more than half A & A publication are with USA collaboration.

8.7 Top 10 Publishing Journals

TIFR Gross Publishing Journals						
Journal	Publication (%)	Impact Factor of the journal**	Total citation received	Average citation per paper	Citing Articles	H-Index
Physical Review D	619 (05.90 %)	4.568	20,836	33.66	15,126	62
Physical Review Letters	484 (04.61 %)	8.462	21,631	44.69	14,593	78
Physics Letters B	357 (03.40 %)	4.807	19,513	54.66	15,187	54
Journal of High Energy Physics	311 (02.96 %)	6.063	8,390	26.98	5,412	47

MNRAS*	279 (02.66 %)	4.961	4,547	16.3	3,248	35
Physical Review B	265 (03.40 %)	3.836	5,601	21.14	4,520	37
Astrophysical Journal	232 (02.21 %)	5.533	5,303	22.86	4,290	36
Astronomy & Astrophysics	184 (01.75 %)	5.014	3,526	19.16	2,683	31
Current Science	170 (01.62 %)	0.843	724	4.26	685	15
Journal of Applied Physics	156 (01.49 %)	2.068	1,735	11.12	1,617	21
Total	3,057(29.14 %)	4.615	91,806	25.48	67,361	42

Table-07(I)

*Monthly Notices of the Royal Astronomical Society **JCR-IF-2017

TIFR A&A Publishing Journals						
Journal	Publication (%)	Impact Factor of the journal**	Total citation received	Average citation per paper	Citing Articles	H-Index
Physical Review D	619 (27.49 %)	4.568	20,836	33.66	15,126	62
Physics Letters B	357 (15.85 %)	4.807	19,513	54.66	15,187	54
MNRAS*	279 (12.39 %)	4.961	4,547	16.3	3,248	35
Astrophysical Journal	232 (10.30 %)	5.533	5,303	22.86	4,290	36
Astronomy & Astrophysics	184 (08.17 %)	5.014	3,526	19.16	2,683	31
Journal of Astrophysics and Astronomy	42 (01.86 %)	0.394	231	5.5	224	8
Astrophysical Journal Letters	39 (01.73 %)	5.522	669	17.15	602	17
Advances in Space Research	31 (01.38 %)	1.401	167	5.39	163	7
Classical and Quantum Gravity	30 (01.33 %)	3.119	832	27.73	750	14
International Journal of Modern PhysicsD	29 (01.29 %)	2.476	181	6.24	160	6
Total	1,849 (82.10%)	3.779	55,805	20.86	42,433	27

Table-07(II)

TIFR has published highest 619 research papers in ‘Physical Review D’ journal which is also highest in A & A publications. ‘Physics Letters B’ has published 357 research papers which is second highest publishing journal in A & A and third in TIFR gross publishing journal. Out of

top ten TIFR gross publishing journals, five journals are top five most publishing journals of A & A. It seems that all TIFR publication in ‘Physical Review D’, ‘Physics Letters B’, MNRAS, Astrophysical Journal and Astronomy & Astrophysics journal are from A & A subject only. TIFR top 10 publishing journal covers 29.14 % of total publications in which 1671 (15.93 %) research articles are from the A & A subject research. TIFR’s top 10 A & A research publishing journals covers 82.10 % of total A & A publications.

8.8 Top 10 Funding Agency for Project based Research

TIFR Gross Project based Research		TIFR A&A Project based Research	
Funding Agency	Publication (%)	Funding Agency	Publication (%)
DST INDIA	497 (4.74 %)	DST INDIA	245 (10.88 %)
SFI IRELAND	423 (4.03 %)	SFI IRELAND	215 (9.55 %)
COLCIENCIAS COLOMBIA	407 (3.88 %)	COLCIENCIAS COLOMBIA & NSF USA	214 (9.50 %)
CONACYT MEXICO	388 (3.70 %)	CONACYT MEXICO	205 (9.10 %)
CNRS IN2P3 FRANCE	376 (3.58 %)	CNRS IN2P3 FRANCE	196 (8.70 %)
DFG GERMANY	369 (3.52 %)	DFG GERMANY	194 (8.62 %)
NSF USA	362 (3.45 %)	RFBR RUSSIA	191 (8.48 %)
RFBR RUSSIA	337 (3.21 %)	DOE USA & STFC UK	164 (7.28 %)
STFC UNITED KINGDOM	334 (3.18 %)	FAPESP BRAZIL	155 (6.88 %)
FAPESP BRAZIL	310 (2.96 %)	CNPQ BRAZIL	144 (6.39 %)
Total	3803 (36.25 %)	Total	1923 (85.39 %)

Table-08

TIFR received maximum fund for project based research from Department of Science & Technology, Government of India for its gross publication as well as for the A & A research publications. TIFR top 10 project based funding agencies are from developed western countries of the world. TIFR produce 3803 (36.25 %) of its total research as well as 1923 (85.39%) of research articles in the field of A & A through project funded research. It is remarkable to observe that more than 85 % of A & A research publications are by project funded research.

8.9 Top 10 Highly productive Authors

Top 10 Highly productive Authors in TIFR gross research publications during 2001-15.

S. N.	Author	No. of Publications	Percentage	Total citation received	Average citation per paper	Citing Articles	H-Index
1.	Banerjee, S	901	8.59 %	42637	47.48	24372	77
2.	Kumar, A	807	7.69 %	27980	34.84	14035	67
3.	Tully, C	774	7.38 %	29940	38.68	14735	72

4.	Hebbeker, T	764	7.28 %	29381	38.46	14350	71
5.	Gavrilov, V	735	7.01 %	28184	38.35	13717	70
6.	Ruchti, R	734	6.99 %	28059	38.23	13707	69
7.	Narain, M	733	6.98 %	47232	64.44	29853	72
8.	Bhatnagar, V	732	6.97 %	28029	38.29	13706	69
9.	Gershtein, Y	729	6.95 %	28065	38.5	13682	70
10.	Johnson, M	728	6.94 %	27958	38.4	13682	69

Table-9(I)

Top 10 highly productive Authors in TIFR A & A research publications during 2001-15.

S. N.	Author	No. of Publications	Percentage	Total citation received	Average citation per paper	Citing Articles	H-Index
1.	Banerjee, S	427	18.96 %	16668	39.04	10584	54
2.	Tully, C	380	16.87 %	15406	40.54	9716	52
3.	Hebbeker, T	378	16.78 %	15363	40.64	9703	52
4.	Narain, M	336	14.92 %	21642	64.41	15957	50
5.	Johnson, M	335	14.87 %	14354	42.85	9014	50
6.	Choi, S; Cutts, D; Ellison, J; Gavrilov, V & Heintz, U	334	14.83 %	14360	42.99	8993	50
7.	Bean, A; Bhatnagar, V; Elvira, VD & Lipton, R	333	14.78 %	14344	43.08	8987	50
8.	Barberis, E; Varelas, N & Wayne, M	332	14.74 %	14334	43.17	8986	50
9.	Gerber, CE; Gershtein, Y; Hirosky, R & Snow, GR	331	14.69 %	14287	43.03	8984	49
10.	Kumar, A	330	14.65 %	14446	43.78	9149	50

Table-9(II)

Table-09 (I) shows TIFR gross publicational productivity. Scientist Banerjee, S was the most productive author during the year 2001-2015. Banerjee, S has published 901 (8.59%) articles. He has received 42637 citations with an average of 47.48 citations. His citing articles were 24372. His H-Index is 77. Kumar, A is on the second rank of most productive authors list. He has published 807 articles with H-Index 67 but he has lowest H-Index in top 10 authors. Tully, C has published 774 papers but got more citation than Kumar, A. and have H-Index 72. Hebbeker, T has also published 768 articles but have H-Index of 71. Gavrilov, V has published 735 articles but have H-Index of 70. In the list of top 10 most productive authors, H-Index is in the range of 67 to 77 and publication range is about 6.94 % to 8.59 %. Most of the author received average citation around 38 except Banerjee, S and Narain, M. Narain, M received highest average citation. Here, it is clear than citation is the key point in addition to the publication to get the proper recognition in the field of research. Citation defines a research work of a scientist and

their value in the field of research. It is very optimistic to see that TIFR publications contributors received good citations in their research publications.

Table-09 (II) shows TIFR's A & A publication productivity. Banerjee, S is too the most productive author in the field of A & A research like its gross productivity. He has published 427 articles in A & A and has H-Index 54. Top 5 authors of A & A publications are from top 10 most productive gross publication list which shows that A & A scientist are the most productive scientist in TIFR. A & A most of the scientists have H-Index 50 and top 10 scientist H-Index range is between 49 and 54. Some scientist in the rank 6, 7, 8 and 9 have same publication, citations and H-Index that show these scientist are working as group of scientist. The Co-citation analysis graph is given below which visualize the citation-pattern.



Graph-05- Co-Citation analysis graph

8.10 Year wise Authorship Pattern

8.10.1 Year wise Authorship Pattern in TIFR gross Publications

Year	One Author	Two Author	Three Author	More than Three Author	Total
2001	80	127	74	217	498 (4.75 %)
2002	83	112	87	254	536 (5.12 %)
2003	73	104	78	206	461 (4.39 %)
2004	60	105	87	289	541 (5.16 %)
2005	66	103	95	339	603 (5.75 %)

2006	73	116	94	290	573 (5.46 %)
2007	49	117	112	355	633 (6.03 %)
2008	61	137	124	350	672 (6.40 %)
2009	88	145	117	395	745 (7.10 %)
2010	76	140	132	401	749 (7.13 %)
2011	80	144	125	445	794 (7.57 %)
2012	72	160	136	542	910 (8.67 %)
2013	73	135	135	560	903 (8.61 %)
2014	51	155	135	584	925 (8.82 %)
2015	61	165	131	591	948 (9.04 %)
Total	1046 (9.97%)	1965(18.73%)	1662(15.84%)	5818 (55.46%)	10491 (100%)

Table-10(I)

8.10.2 Year wise Authorship Pattern in A & A Publications

Year	One Author	Two Author	Three Author	More than Three Author	Total
2001	22	34	17	70	143 (6.35 %)
2002	13	23	22	51	109 (4.84 %)
2003	08	16	11	55	90 (4.00 %)
2004	04	20	16	63	103 (4.57 %)
2005	13	12	16	85	126 (5.60 %)
2006	15	21	17	77	130 (5.77 %)
2007	07	16	20	93	136 (6.04 %)
2008	11	17	25	79	132 (5.86 %)
2009	09	20	26	109	164 (7.28 %)
2010	14	14	17	98	143 (6.35 %)
2011	10	28	23	106	167 (7.41 %)
2012	08	31	19	133	191 (8.48 %)
2013	12	25	23	160	220 (9.78 %)
2014	05	28	15	142	190 (8.44 %)
2015	02	17	22	167	208 (9.24 %)
Total	153 (6.80%)	322 (14.30%)	289 (12.83%)	1488 (66.07%)	2252 (100%)

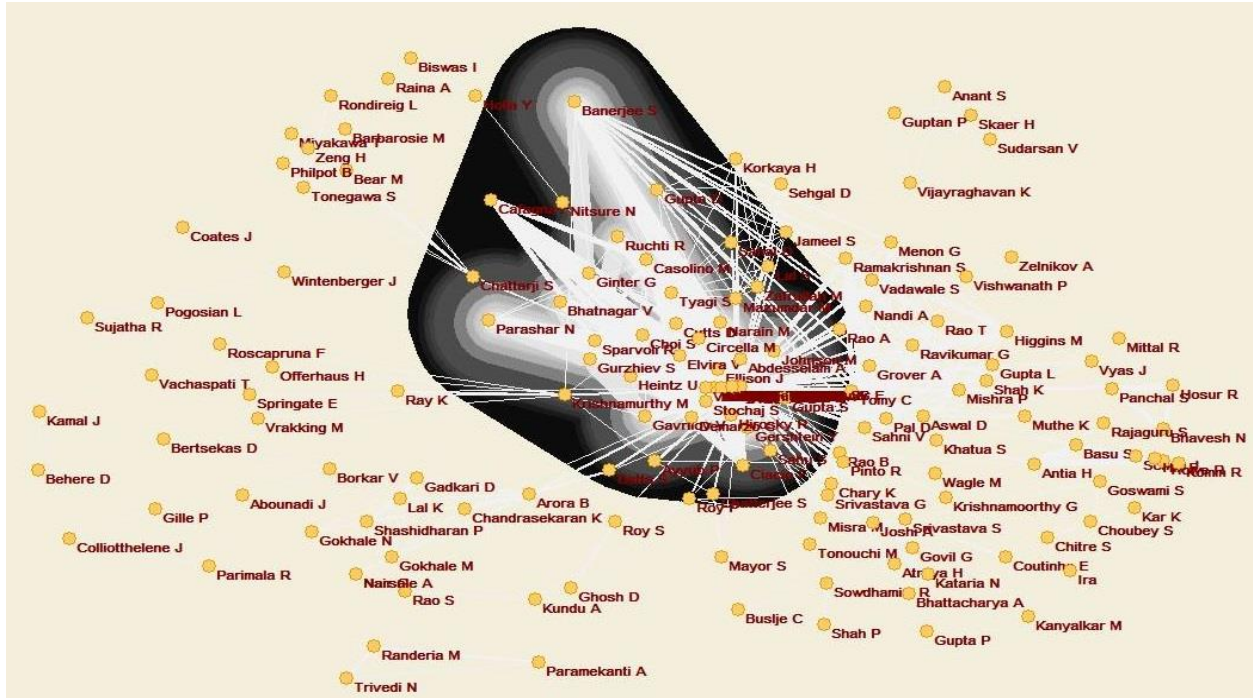
Table-10(II)

From Table-10(I), It can be observed that TIFR gross publication during 2001-2015 was 10491 out of that, 1046 (9.97%) publications are single authored, 1965 (18.73%) are two authored, 1662(15.84%) are three authored and 5818(55.46%) research articles are published by more than three authors.

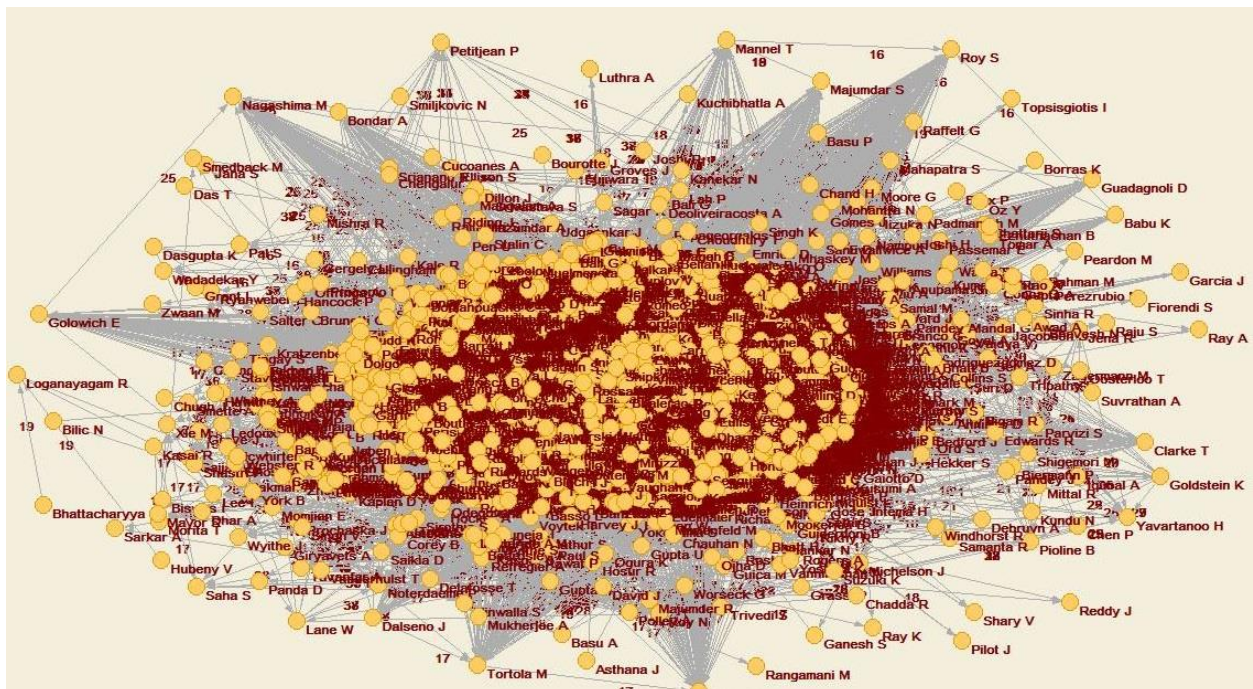
From Table-10(II), TIFR has published 153(6.80%) research papers in single authorship, 322(14.30%) papers in two authorship, 289(12.83%) papers in three authorship and remaining 1488(66.07%) of the A & A research publications are in more than three authorship.

The trends show that multi-authorship research or collaborative research work are more focused at TIFR. The single authorship is very less. The Scientists are more involved in collaborative

research than individual research. Graph-06 is also visualizing is the collaborative pattern and can be seen that top most productive authors in nucleolus of collaboration. The Bibliographic coupling graph is shown as graph-07 which is visualizing the bond of relation among the research work.



Groph-06-Co-Authorship occurrence graph



Groph-07- Bibliographic coupling graph

Degree of Collaboration

In order to determine the strength of Collaboration (DC), the following formula given by Subramanyam K.⁹ has been applied-

$$DC = N_m / N_m + N_s$$

(Where, DC = Degree of Collaboration, N_m = Number of Multiple Authored Papers and N_s = Number of Single Authored Papers)

So,

- (i) **The Degree of Collaboration (DC) for TIFR Gross Publication=**
9445/9445+1046=0.900
- (ii) **The Degree of Collaboration (DC) for TIFR A & A Publications=**
2099/2099+153=0.932

The degree of collaboration during 2001-2015 in TIFR's gross publication and A & A subject publications are 0.900 & 0.932 respectively. It indicates that there is very high level of collaboration in research publications at TIFR.

FINDINGS

As a result of systematic analysis and interpretation of the data obtained for the present study from WoS, the following specific points were observed about the study of Research productivity of TIFR.

- ❖ TIFR has published 10491 research papers over a period of 15 years during 2001-15. The year 2015 was the most productive year with 948(9.04%) papers in institutional gross publication and 2013 in A & A publications with 220(24.36%) articles. It is also observed that TIFR is increasing its productivity year by year.
- ❖ According to the type of publications by TIFR, the more numbers of articles are published in journals. TIFR has published 8,942(85.23 %) articles in journals out of that 2017 (89.56 %) research articles of total Astronomy & Astrophysics publication are in journals.
- ❖ TIFR published 93.17 % of its total publication during 2001-15 in the subscription based journals that shows TIFR scientists are less attracted towards the open access journals for publishing their research work.
- ❖ The Institute main area of research is Physics and Astronomy & Astrophysics. Institute has produce 4772 (45.48 %) research articles in Physics followed by 2252 (21.46 %) in Astronomy & Astrophysics.
- ❖ TIFR's faculties are utmost collaborating with USA. Out of 10 collaborating countries 07 are from well developed leading western countries and 03 countries are from Asia; and those are too leading researcher's countries among Asian countries.
- ❖ Alikhanov Institute for Theoretical Experimental Physics (Russia) is the top collaborating Institutions with contribution of 1167 (11.14 %) research articles. TIFR is collaborating with high performing institutions from western developed countries and

from India, only Punjab University is under the top ten collaborating institutions which is also renowned for high quality of research.

- ❖ TIFR is publishing its research papers in high impact factor journals. The journal 'Physical Review D' is the most preferred journal by the faculties of TIFR and having highest number 619 (05.90 %) of total publications which are all from A & A subject. The Average impact factor of its top 10 journal publications is 4.615 with H-Index 42.
- ❖ Project funded research are also high in numbers, 36.25 % for gross publications and 85.39 % in the field of A & A. Out of top 10 project funding agencies 9 are from western developed countries.
- ❖ Banerjee, S was the most productive researcher and has published 901 (8.59 %) articles in its gross publication and 427 (18.96 %) articles in A & A. Top 10 most productive authors have contributed 7637 (72.78 %) articles in its gross publications during 2001-15.
- ❖ The contributions of multi-authored publications have the highest number of articles i.e. 9445(90 %) in TIFR's gross publications and 2099 (93.21 %) in A & A that shows collaborative research has been preferred in comparison to individual research.

Conclusion

This work explores the factors of efficiency of scientists of TIFR in research, both in terms of the number of articles, the worth of the publication and trend of research. TIFR has doubled its per year publication during 2001-15. The picture that emerges the causes of research output is multifarious. There are many factors that contribute to the research productivity. Research group size or access to available resources is just one which may not be very important. Research performance must take into account the personal (individual), motivational and structural (working environmental) factors, and the interaction among peers. However, it can be seen from the above quantitative analysis and its finding that TIFR scientist are working enthusiastically to increase the number of research articles, their publication in high impact factor journals, collaborating with leading institutions of the world to maintain as well as upgrade the legacy of the institution in its domain of research.

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