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Research Output of Indian Women Scientists in the field of Physics and Astronomy: A Scientometrics study

Bebi Dabas
bebi.mywork@gmail.com

Shailendra Kumar
shail3@yahoo.com

Research Output of Indian Women Scientists in the field of Physics and Astronomy: A Scientometrics study

Bebi[1*], Shailendra Kumar[1]

[1]Department of Library and Information Science, University of Delhi, Delhi, India

*** Corresponding Author**

Dr. Bebi,
Post-Doctoral Fellow
Department of Library and Information Science,
University of Delhi, Delhi
India − 110007
E-mail: bebi.mywork@gmail.com

Abstract

The research output of the women scientists of the selected Indian research institutes in the field of physics and astronomy is analyzed for a period of 2011 to 2015. It is observed that the strength of women scientists (12.35 %) are less in compare to men scientists (87.65%), as only 73 women scientists out of total 583 staff. These women scientists have published total number of 713 research articles, and the current study reveals the contribution of each scientist individually. The highest numbers of papers (144) were published by National Physical Laboratory but Indian Institute of Astrophysics got the highest number of citations for fewer publications (2018 for 129 articles). The majority of these articles were published in collaboration with other institutes of national and international level. To understand the collaboration between these and other institute the collaboration coefficient is calculated (CC) and found that these institute have average CC ~0 .7480. On the basis of analysis of 713 publications of women scientists, the Journal of Astronomy and Astrophysics is assigned as rank one because maximum articles were published in this journal, and in term of most productive authors, Aditi Sen De from Harish Chandra Research Institute with maximum 38 publications is allocated as rank one among all women scientists. Additionally, this study also presents detailed information on the corresponding and first authorship of all these papers.

Keywords: Women scientists, Indian, Physics, Astronomy, h-index, i10-index

1. Introduction

Indian women scientists are actively working in field of science for well over a century. Since from the independence (1947), the numbers of women enrolment in graduate, post-graduate and PhD level have increased significantly, but still less in the field of science, especially in rural area, though, the sufficient efforts are made to increase the facilities for their education. It is rarely seen that laboratory, Department of science (government of India), and Universities are either headed or govern by a woman scientist. In the past several policies have been made in order to improve the situation of women in science and therefore, there is a need to measure the success of these policies, and still government is in the process to make many policies concerning women education and research to encourage them. One of the measures is to analyze the presence of women in academic and research institutions and their scientific productivity resulting from research. In the present era it is essential to understand the strength

and contributions of woman scientist, especially in field of sciences, which may be helpful for the policy makers to decide that how much improvement is required for the education of women. The aim of the present work is to determine that in the current scenario (2011 to 2015) whether the number and scientific productivity of women scientists is equal to their male counterparts or not.

A number of gender based studies have been conducted in the past to see the contributions of women in science and technology. Lemoine (1992 a); Prpic (2002); Abramo et al. (2009); Lariviere et al. (2011); Pudovkin et al. (2012); Nourmohammadi & Hodaei (2014); Tao et al (2017); Cislak, Formanowicz & Saguy (2018). Lemoine (1992 a) studied the productivity of male and female scientists in Venezuela using Lotka's law mainly considering the gender of the authors, type of journals in which they publish their articles. This study showed a significant difference between male and female scientists and found that women are less productive than men. Prpic (2002) conducted a study on gender and productivity differentials in science for Croatia. This study showed that publication productivity of female scientists is less than their male counterpart and pointed out that reason of less research productivity is due to lack of their position in the social organization of science and international collaborations. In another study, Abramo et al. (2009) measured the contribution of star scientists in the Italy and revealed out women research productivity and strength are less with respect to their male scientists. Likewise another study by Lariviere et al. (2011), on the basis of gender classification, focused for the research funding, publication output, and their scientific impact in the University of Quebec (Canada) and found the similar results that women are less research productive in compare to men, and their achieved citations were also fewer. Later Pudovkin et al. (2012) conducted the similar study in DRFZ (Deutschen Rheuma-Forschungs-Zentrums) Germany by analyzing 313 papers of research staff from 2004-08 (5 years), and supported to the study of Lariviere et al. (2011). Therefore, these past studies indicating the same situation of women scientist in Venezuela, Italy, Canada, and Germany. Nourmohammadi & Hodaei (2014) investigated the contributions of Iranian women in science and technology during 2000-2010 and observed that 99% of women research has published paper as joint author publications. In another recent study by Tao et al (2017) focused on the similarities and differences in the U.S. and China for gender differences in publication productivity among academic scientists and engineers, and observed that women are less research productive than their male peers in both the countries. In most

recent study, Cislak, Formanowicz & Saguy (2018) conducted a research on gender bias in the field of social science and suggested further studies are required for the gender inequality in different filed. The output of all cited studies suggesting that the gender base research output of scientific community may be different in different countries, however, most of them indicating than research output of women scientists are less in compare to that of women. As a developing country the situation in India may be different from developed countries and need to be investigated using recent data.

Some of previous studies focused on contribution of Indian women scientist in the field of sciences Garg & Kumar (2014); Upadhye et al (2014) Bebi & Kumar (2017), Bebi & Kumar 2018). Garg & Kumar (2014) presented a study for the contribution of women scientists in the field of life science for a period of 2 years only (2008-2009) in India. They observed that women scientist exclusively contribution is 3.4 % in the research publication; however, this contribution rose to 46.91 % in joint publication with male scientists. This study also found that women scientists work in small teams and have very less international collaboration in papers. However, In an another study by Upadhye et al (2014)[5] focused on women scientist's journal publication productivity in Bhabha Atomic Research Centre, India for the period of 2006-2010. But this study concentrates on the collaboration of women scientist at national and international level, and does not present a picture on gender base publication. Another study was conducted by Bebi and Kumar (2017) to understand the contributions of women faculties/scientists for research productivity in the select institutions of Delhi, India. This study focused on the 802 publications in the discipline of physics for 5 years from 2011-2015 and observed the similar results as in above cited studies that women scientists are less in research productivity and numbers in compare to their male colleagues. The study also pointed out that in the join publications women authors found as a co-author in maximum publications. Consecutively Bebi & Kumar (2018) measured the research output of women faculties in Central Universities, India for the same year and same field and found similar results. Furthermore studies are required in this field using the recent data to understand the current scenario for the contribution women scientists.

The current study focuses on the strength and contribution of women scientists in the field of physics and astronomy of various Institutes in India during last five years (2011-2015). This study presents a detail study on gender distribution of faculty in various institutes, the institute

with highest publications, and the women scientist contributions as with highest publication and citations. Analyses of this study present a broader picture on the contribution of the women scientist contribution like field of interest areas/specializations, research articles which are written by women scientists as first and corresponding author, most favorable journals for publications, and their collaborations at national and international level.

2. Methodology

The data of the women faculty in physics and astronomy of special institutes/laboratories in India was collected from the various sources, such as: Curriculum Vitae (CV) downloaded from the institutes websites, Annual reports, Google scholar, Research gate and Web of Science for 2011-2015. The data was collected in the months of November, December (2017) and January (2018). The study covers the faculty members of Physics and Astronomy only. The authors have used different sources to collect the data because all publications have not been covered by any single source. The results of the present study are based on the availability of data only. During collecting the data it was found that some authors written papers in collaboration (i.e. ALICE & STAR collaboration) in which number of authors were found very high (sometime more than 600 & 700), so these kind of papers are excluding from the study because it is a difficult task to identify the female authors among them and more especially in case of foreign names.The authors prepared a list of scientists of Physics of all special institutes in India and separated them by gender. All the bibliographic details of journal publications were filled in Excel sheets and analyzed as per the requirements of the study.

3. Results and Discussion

3.1 Distribution of faculty by gender

In order to gain an accurate number of female scientists it is essential first to identify the male and female separately. Table 1 show the data of women as well as total staff strength for twelve academic and research institutes in the field of Physics and Astronomy which were selected for the study. The institutes are arranged alphabetically. It can be seen that a total of 583 scientists were found, of which only 73 are women scientists. The highest number of women faculty was found in National Physical Laboratory (15), nearly followed by Space Physics Laboratory (14). Among all, Bose Institute performed poorly with just one

female faculty out of total 16 members in the Physics department. The table clearly depicts that the number of female scientists is very less than the male scientists.

Table 1: Distribution of faculty by gender

Sr. No.	Name of Institute	Estd.	Total Faculties	Female Scientists/ faculties
1	ARIES*	1954	20	2
2	Bose Institute	1917	16	1
3	Harish Chandra Research Institute	1975	20	3
4	Indian Institute of Astrophysics	1786	43	9
5	Indian Institute of Science	1909	40	3
6	Institute of Physics	1874	26	2
7	National Physical Laboratory	1947	145	15
8	Physical Research Laboratory	1947	46	2
9	Raman Research Institute	1948	32	7
10	Saha Institute of Nuclear Physics	1949	67	10
11	Space Physics Laboratory	1963	53	14
12	Tata Institute of Fundamental Research	1945	75	5
Total			**583**	**73**

ARIES*= Aryabhatta Research Institute of Observational Sciences

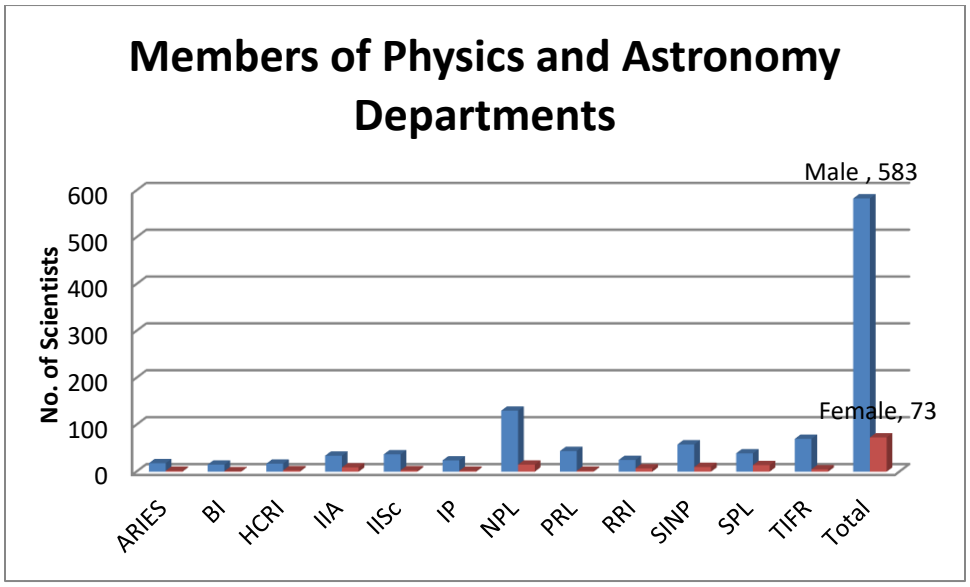

Figure 1: Members of Physics and Astronomy Departments

3.2 Institute and year wise research publications

To revealed out the contribution of women scientist their research outputs are analyzed and shown in Table 2. Table 2 represents year-wise publications of women scientists for the period 2011 to 2015. The data shows that highest numbers of publications are from National Physical Laboratory (144), followed by Indian Institute of Astrophysics (129) and Space Physics Laboratory (107). The lowest research publications are from Bose Institute (5). If we see the year-wise growth of research publications that was highest in 2013 (162), in which highest productive institute was found Indian Institute of Astrophysics with 38 publications and in all 5 years also it the highest number of publications from this institute. The second highest productive year is 2015 with 157 publications, in which highest productive institute was found National Physical Laboratory with 41 publications. The next following years are 2014 with 138 publications and 2012 with 132 publications. The least productive year is 2011 with 124 publications, in which highest number of publications are from Indian Institute of Astrophysics (27).

Table 2: Institute and year wise research publications

Sr. No.	Name of Institute	Years					Total	%
		2011	2012	2013	2014	2015		
1	ARIES	4	4	2	5	4	19	2.7
2	Bose Institute	0	3	0	0	2	5	0.7
3	Harish Chandra Research Institute	9	11	19	11	10	60	8.5
4	Indian Institute of Astrophysics	**27**	25	**38**	16	23	129	18
5	Indian Institute of Science	9	1	11	14	8	43	6.0
6	Institute of Physics	10	5	9	5	7	36	5.0
7	National Physical Laboratory	22	23	22	**36**	**41**	**144**	20.2
8	Physical Research Laboratory	2	3	6	5	4	20	2.8
9	Raman Research Institute	8	12	16	12	15	63	8.9
10	Saha Institute of Nuclear Physics	9	12	17	13	16	67	9.3
11	Space Physics Laboratory	23	**26**	19	17	22	107	15.0
12	TIFR	1	7	3	4	5	20	2.8
Total		**124**	**132**	**162**	**138**	**157**	**713**	**100**

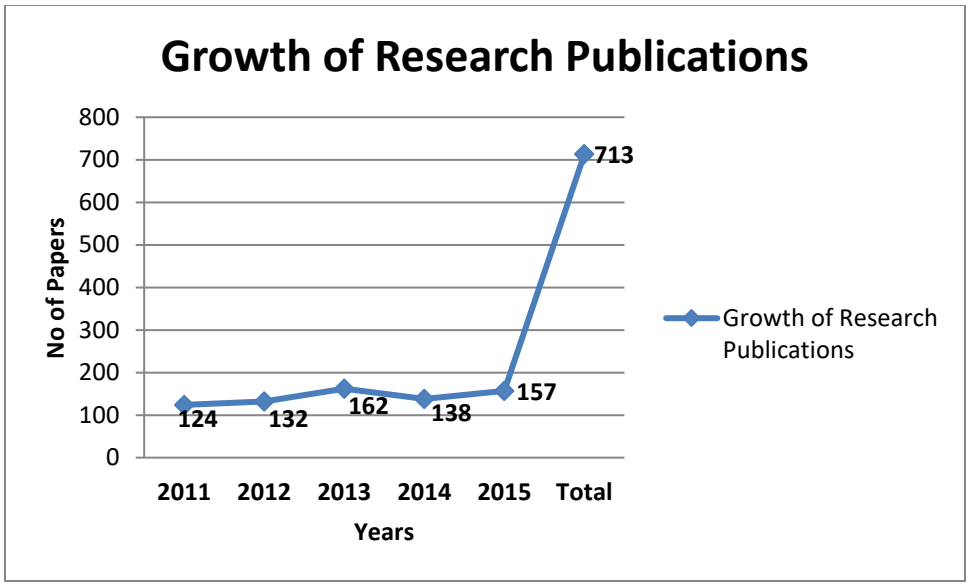

Figure 2: Growth of Research Publications

3.3 Citations received by Institutes

Citations are important to determine the quality and usage of scholarly work. A high number of citations are a good indicator that the author/institute is credible. In term of that, table 3 shows the research output of institutes and their received citations. It presents the most productive institute with citations, h-index and i10-index. It is interesting to be said that in spite of producing maximum number (144) publications, National Physical laboratory received 1556 citations, on the other hand, the Indian Institute of Astrophysics ranks second in publications (129) but at the top in receiving citations (2081). Further in the subsequent section, table 9 shows the highest citations received by individual women scientists. The data collection for the present study was completed in the month of January (2018), so citations may be vary in future from this data. The impact of output has been examined by using the following indicators:

Citation per paper: The average number of *citations per paper* is calculated by dividing the total number of *citations*by the total number of *papers.* This is a very useful metric to assess the average impact for a journal or author or an institution.

h-Index: The *h index* was *proposed* by J.E. Hirsch in 2005. The index is based on a list of publications ranked in descending order by the number of citations these publications received. The value of h is equal to the number of papers (N) in the list that have N or more citations.

i10-index: Introduced by Google scholar in 2011. *i10- index* refers to the number of paper with at least10 or more citations.

Table 3: Citations received by Institutes

Sl. No.	Institutes	Total Papers	Total Citations	CPP*	h-index	I10-index
1	ARIES	19	610	32	10	9
2	Bose Institute	5	13	2.6	0	0
3	Harish Chandra Research Institute	60	716	12	16	28
4	Indian Institute of Astrophysics	129	2081	16	25	61
5	Indian Institute of Science	43	403	9	12	14
6	Institute of Physics	36	489	13	13	15
7	National Physical Laboratory	144	1556	11	20	51
8	Physical Research Laboratory	20	493	24	11	14
9	Raman Research Institute	63	778	12	17	27
10	Saha Institute of Nuclear Physics	67	544	8	12	20
11	Space Physics Laboratory	107	760	7	15	23
12	TIFR	20	326	16	12	12
	Total	**713**	**8769**	**12**	**42**	**274**

***CPP=**Citations per paper

3.4 Authorship Pattern

Authorship pattern in the research papers is another indicator to understand the nature of collaboration, whether scientists work as a single author or in a team. The distribution of women scientist authors in their respective articles are shown in table 4. It could be noted that multi authored papers (which included 3, 4 and 5 authored papers) are maximum with 346 (48.5%) of the total 713. Second highest is mega authored papers (which included more than 5 authored papers) with 264 (37%). Two authored papers are 86 (12.1%0) of the total 713 papers. Single authored papers are least i.e. 17 (2.4%) out of 713 or it can be said that out of 713 research papers only 17 papers are purely written by women authors and rest are written in collaboration.

If we see institution-wise authorship pattern, out of 12, in six institutions (ARIES, IP, NPL, PRL, SINP,TIFR) single authored papers has not been found and in three institutions (ARIES, IP, TIFR) two authored papers has not been found. So it can be inferred from the analysis that authors believe in collaborative research and they write much research papers in collaboration. During the analysis it was also observed that these 713 research papers were written by 4957

total authors jointly, among them 1220 were female authors and 3736 were male authors. It was also a major finding that in comparison to male authors, the number of female authors was very less.

Table 4: Authorship Pattern

Sl. No.	Name of Institute	Authorship Pattern				Total Papers
		Single Authored	Two Authored	Multi-Authored (3-5)	Mega-Authored (>5)	
1	ARIES	-	-	5	14	19
2	BI	2	2	1	-	5
3	HCRI	1	12	42	5	60
4	IIA	6	20	49	54	129
5	IISc	2	9	23	9	43
6	IP	-	-	19	17	36
7	NPL	-	6	89	49	144
8	PRL	-	1	16	3	20
9	RRI	5	20	28	10	63
10	SINP	-	6	30	31	67
11	SPL	1	10	44	52	107
12	TIFR	-	-	-	20	20
Total		**17**	**86**	**346**	**264**	**713**
%		**2.4**	**12.1**	**48.5**	**37.0**	**100**

Collaborative Coefficient: This measure examines the strength of co-authorship. Different authors have suggested different measures for measuring the strength of collaboration. Lawani suggested Collaborative Index (CI), while Subramanyam suggested Degree of Collaboration (DC). Ajiferuke pointed out the inadequacy in these two measures and suggested Collaborative Coefficient (CC), which incorporates some of the merits of these two measures. This measure is based on fractional productivity defined by Price and Beaver[13]and is given by the formula given below:

$$CC = 1 - \frac{\sum_{j=1}^{k}(1/j)F_j}{N}$$

Here F_j denotes the number of j authored research papers, N denotes total number of research papers published and k is the greatest number of authors per paper. According to Ajiferuke, CC tends to zero as single authored papers dominate and to 1-1/j as j-authored papers dominate. This implies that higher the value of CC, higher the probability of multi authored papers.

To determine the CC of journal articles numbers of authors are calculated shown in table 4 during the period of 2011-2015.

CC= 0.7480

The value of CC indicates here that multi-authorship is dominating. Hence, it can be said that authors preferred to work in collaboration more than individual. Authors have calculated the CC of individual institutes also and found the same result that woman scientists worked in collaboration more as compare to individual publication.

3.5 Place and Designation of women authors

As the current study is analyzing research productivity of women scientists, so it is important to see their position in publications, especially when writing papers jointly. To do so, authors have identified their place and designation in publications, whether they are first, corresponding or both is shown in table 5. The analysis is based on the research publications of 73 women scientists covered under study from 12 institutes During the analysis it was came to know that out of 713, there were 17 papers which were solely written by women authors, so in those papers they were played a role of both first + corresponding author. There were few papers in the study in which author role was not shown especially in case of corresponding author. The table shows overall analysis of the place and designation of women authors in the covered research publications. It can be seen that out of 713 papers, in 148 papers women scientists signed as first author, in 234 papers they have signed as corresponding author and in 121 papers they have signed as a first + corresponding author. During analysis it was observed that male authors acted as a first and corresponding author in maximum number of papers. So, on the basis of analysis it can be concluded that women authors signed as corresponding author in more papers, as compare to first and both (first and corresponding).

Table 5: Place and Designation of women authors

Sl. No.	Name of Institute	Place of Women Author			Total Papers
		As 1st Author	As Corresponding Author	As 1st+ Corresponding Author	
1	ARIES	5	3	3	19
2	Bose Institute	4	5	4	5
3	HCRI	10	14	9	60
4	IIA	27	31	21	129
5	IISc	5	8	2	43
6	IP	1	8	1	36
7	NPL	37	72	31	144
8	PRL	1	1	1	20
9	RRI	10	33	8	63
10	SINP	13	19	10	67
11	SPL	31	38	29	107
12	TIFR	4	2	2	20
Total		**148**	**234**	**121**	**713**

3.6 Most productive women authors

As described in the methodology also the authors have tried to collect the highest data of every woman scientist covered in the study from various sources to make the analysis fair but actual publications may be differ because all publications have not been covered by any single source. On the basis of collected data only table 6 provide a rank list of 10 most productive women authors. Data reveals that Aditi Sen De from HCRI topped the list with 38 research publications and ranked first, followed by G C Anupama from Indian Institute of Astrophysics with 30 publications. Janaki S Mylavarapu, from SINP ranked third with 29 publications.

Table 6: Most productive women authors

Sl. No.	Author	Designation	Affiliation	No. of Publications	%	Rank
1	Aditi Sen De	Associate Professor	Harish Chandra Research Institute	38	5.3	1
2	G. C. Anupama	Professor	Indian Institute of	30	4.2	2

			Astrophysics			
3	Janaki S Mylavarapu	Professor	Saha Institute of Nuclear Physics	29	4.0	3
4	Ranjana Mehrotra	Chief Scientist	National Physical Laboratory	27	3.8	4
5	ShikhaVerma	Professor	Institute of Physics	27	3.8	4
6	Geetha Ramkumar	Scientist SG	Space Physics Laboratory	26	3.7	5
7	Suja Elizabeth	Chief Research Scientist	Indian Institute of Science	24	3.4	6
8	M. Sampoorna	Reader	Indian Institute of Astrophysics	23	3.2	7
9	A. Subramaniam	Scientist	Indian Institute of Astrophysics	22	3.0	8
10	Nita Dilawar	Principal Scientist	National Physical Laboratory	21	2.9	9

3.7 Research Interest Areas of Women Scientists

There are many sub disciplines in physics and astronomy. Women scientists are working almost in every area but it is interesting to see which the areas of majority, where women scientists concentrate more. The research interest areas of women scientists are analyzed and shown in Table 7. It can be seen from table 7 that out of 73 women scientists, 10 women scientists are working in the area of astrophysics and astronomy. The second highest research interest area is condensed matter physics (6) followed by high energy physics and atmospheric physics (4) respectively. The other areas were space physics, nuclear physics, plasma physics etc.

Table 7: Research Interest Areas of Women Scientists

Sl. No.	Research Interest Areas	No. of Women Scientists	%
1	Astrophysics &Astronomy	10	
2	Condensed Matter Physics	6	
3	High Energy Physics	4	

4	Atmospheric Physics	4	
5	Space Physics	3	
6	Other areas	46	
	Total	**73**	

3.8 Most Preferred Journals

Impact factor of a research journal is a very important parameter to analysis the quality of journal and research. Authors want to publish their quality research in a good impact factor international journal related to their fields. Table 8 represents a ranked list of 10 journals where women scientists preferred to publish their research papers and interesting to see that all are international with good impact factor. A total of 221 journals were found to publish these 713 articles, of which *Astronomy and Astrophysics* ranked first with 45 publications, nearly followed by *Monthly Notices of the Royal Astronomical Society* with 43 publications. While looking at Indian Scenario, it was observed that *MAPAN-Journal of Metrology Society of India* ranked at number 11 with 10 publications. During analysis it was came to know that a total of 20 countries was involved in publishing these 713 publications, of which only 59 publications are from Indian Journals and rest 654 were from foreign journals, in which USA was leading with publishing 268 publications followed by UK with 165 publications.

Table 8: Most Preferred Journals

Sl. No.	Name of Journal	IF (2016)	Country	No. of Articles	%	Rank
1	Astronomy and Astrophysics	5.014	Germany	45	6.31	1
2	Monthly Notices of the Royal Astronomical Society	4.961	UK	43	6.03	2
3	Astrophysical Journal	5.533	USA	38	5.33	3
4	Physical Review A	2.925	USA	26	3.65	4
5	Journal of Atmospheric and Solar-Terrestrial Physics	1.326	UK	20	2.81	5
6	Physical Review D	4.568	USA	17	2.38	6
7	Journal of Applied Physics	2.068	USA	17	2.38	6

8	Journal of High Energy Physics	6.83	Germany	17	2.38	6
9	Physics of Plasmas	2.115	USA	16	2.24	7
10	Physical Review C	3.82	USA	14	1.96	8

3.9 Highly Cited Research Papers of Women Scientists

As described in above section 3.3 (table 3) that citations give the credibility to an author how his/her work is qualitatively good and useful. Different from table 3, table 9 presents highly cited research papers of women scientists. The analysis shows that all the 10 papers listed in the table were written in collaboration. It is noteworthy here that no women author is first author in these highly cited papers. The place of the author is provided in the table. The maximum number of citations (227) received by a paper co-authored by Kuntal Mishra, Scientist in ARIES. During the analysis it was came to know that this paper was written by a total of 63 authors, of which Kuntal Misha was at 14th no of author among all. Among these 10 leading papers, 5 are from Indian Institute of Astrophysics, written by Sivarani T. in domestic and international collaboration.

Table 9: Highly Cited Research Papers of Women Scientists

Sl. No.	Paper Details	Author Affiliation	No of Citations
1	A.J. Levan, N.R. Tanvir,S.B. Cenko et al. (**Kuntal Mishra** 14th no. of Author) Science, 2011, Vol. 333(6039): 199-202.	ARIES	227
2	Jason P. Smolinski[1], Young Sun Lee, Timothy C. Beers et al. (**Sivarani, T.**9th no. of Author) The Astronomical Journal, 2011, Vol. 141 (89): 1-29.	Indian Institute of Astrophysics	125
3	S. Srivastava, K. Jain, V.N. Singh et al. (**Nita Dilawar** 6th no. of Author) Nanotechnology, 2012, Vol. 23 (20): 1-7.	NPL	124
4	Young Sun Lee, Timothy C. Beers, Carlos Allende Prieto (**Sivarani, T**. 9th no. of Author)	Indian Institute of Astrophysics	122

	The Astronomical Journal, 2011, Vol. 141 (3): 1-18.		
5	N. R. Tanvir[1], A. J. Levan[2], A. S. Fruchter et al. (**Kuntal Mishra**19th no. of Author**)** The Astrophysical Journal, 2012, Vol. 754 (1): 1-13.	ARIES	107
6	D. Carollo, T.C. Beers, J Bovy et al. (**Sivarani, T.** 4th no. of Author) The Astrophysical Journal, 2011, Vol. 744 (2): 1-22.	Indian Institute of Astrophysics	104
7	T.C. Beers, D. Carollo, Z Ivezic et al (**Sivarani, T.**11th no. of Author) The Astrophysical Journal, 2012, Vol. 746 (1): 1-23.	Indian Institute of Astrophysics	99
8	S.K. Srivastava, D. Kumar, **Vandana**et al. Solar Energy Materials and Solar Cells, 2012, Vol. 100: 33-38.	NPL	90
9	**4.** Ghosh, T Thakore, **SandhyaChoubey** Journal of High Energy Physics, 2013, Vol. 1304: 1-28. W. Aoki, T.C. Beers, Y.S. Lee et al. (**Sivarani T.**11th no. of Author) The Astronomical Journal, 2013, Vol. 145 (13): 1-22. P.S.B. Dev, S Goswami, **ManimalaMitra**et al. Physical Review D, 2013, Vol. 88 (9): 1-9.	HCRI Indian Institute of Astrophysics PRL	87
10	P.S.B. Dev,**S. Goswami**, ManimalaMitraet al. Physical Review D, 2013, 88 ((9): 1-6.	PRL	86

3.10 Institutional Collaboration

Collaboration in research is very necessary whether at national or international level. Collaboration brings all members together, where they can discuss or communicate their ideas and can find out more results/solutions for the research as compare to single author. Table 10 lists the 11 institutions of India which had maximum collaboration with domestic level and

international level. In this analysis authors have tried to know with which institution these institutes had maximum collaboration at domestic and international level. It can be seen from the table that ARIES had maximum collaboration with Indian Institute of Astrophysics at domestic level and with Space Telescope Science Institute at international level. Among all institutes Indian Institute of Astrophysics had the highest number of papers with domestic collaboration (19) and international collaboration (11). During analysis it was observed that USA, Sweden, Japan, Germany, Switzerland and South Korea had higher share of internationally collaborated papers.

Table 10: Institutional Collaboration

Sl. No.	Name of Institute	Maximum Collaboration With	
		Domestic Collaboration	**International Collaboration**
1	ARIES	Indian Institute of Astrophysics (5)	Space Telescope Science Institute, USA (7)
2	Harish Chandra Research Institute	JNU & University of Delhi (6 each)	Albanova University, Sweden (4)
3	Indian Institute of Astrophysics	TIFR (19)	ETH Zurich, Switzerland (11)
4	Indian Institute of Science	TIFR (4)	Max Planck Institute for Chemical Physics of Solids, Germany (5)
5	Institute of Physics	IITs (7)	Gran Sasso Science Institute, Italy (5)
6	Raman Research Institute	IIT, IISc (5 each)	University of Waterloo, Canada (6)
7	Saha Institute of Nuclear Physics	IITs (7)	GSI Helmholtz Centre for Heavy Ion Research, Germany (6)
8	TIFR	Indian Institute of Astrophysics& SINP (3each)	Chalmers University of Technology, Sweden (7)
9	Space Physics Laboratory	ISRO (13)	University of Bern, Switzerland (7)
10	National Physical Laboratory	Academy of Scientific and Innovative Research (6)	Yonsei University, South Korea (1)

11	Physical Research Laboratory	HCRI (3)	Yonsei University, South Korea (2)

*The number in parentheses shows the number of papers

Conclusion

The research productivity gap between male and female authors is evident from 1980's to till date, that men on an average publish more papers than women and present study is also pointing out similar situation in the present era. On the basis of analysis of data during 2011-2015, it can be concluded that the number of women scientists are very less in compare to men scientists. Only 73 women scientists are found among 583 total staff strength of physics and astronomy departments. These 73 women scientists contributed to the total of 713 journals articles for the period of 5 years. During the calculation of total numbers of authors, it is found that these 713 research papers are written by 4957 authors jointly, among them 1220 are female authors and 3736 are male authors. But reason for less numbers in authorship is due to their less strength. CC indicates that women scientists preferred to conduct their research in collaboration, not as individual. The analysis based on the citations received by the institutes revealed that highest citations are received by Indian Institute of Astrophysics (2081). Another significant finding is that women authors signed as corresponding author in more papers, as compare to first and both (first and corresponding). National Physical laboratory contributed highest number of publications (144) among all institutes, but if we see the individual contribution of women scientists, the data revealed that Aditi Sen De (HCRI) topped the rank list with 38 publications. Out of 221 journals, journal of *Astronomy and Astrophysics* ranked first as maximum paper 45 ware published in this Journal. Institutional collaboration shows that these institutes are have collaboration with research and academic institutions working in the same research fields.

The current study concludes that gender-balance will not be achieved as long as the fraction of women staff is smaller than the men staff. To help the policy makers further studies are required and for that gender- related data must be collected, examined, and analyzed to give the clear picture of male and female portions and also try to find out the problems why there is big gender- discrimination in the research and teaching institutions.

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Dr. Bebi obtained her BLIS, MLIS, MPhil (LIS) and PhD (LIS) from, DLIS, University of Delhi, Delhi. She also obtained MA (Political Science) from University of Delhi. Presently, she is a Post-Doctoral Fellow (UGC- Dr. S. Radharkrishnan Post Doctoral Fellowship in Humanities and Social Sciences) in the Department of Library and Information Science, University of Delhi, Delhi. Her area of expertise includes Electronic Resources, Bibliometrics and Scientometrics.

Dr. Shailendra Kumar has done his Ph.D. in Library and Information Science, he got his Master degree in LIS and B.Sc. from University of Delhi. He is presently working as Associate Professor in DLIS, University of Delhi. He served also IGNOU, CSIR and INSA at Delhi. He has to his credit more than 75 publications and five books. He has delivered more than 130 invited lectures at various universities and conferences. His interest areas are Library and Information Management Softwares, E-Learning and Scientometrics.