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June 2021

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Dabas, Bebi, "Publication productivity of women physicists in India: A Scientometrics study" (2021).

Library Philosophy and Practice (e-journal). 5624.

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Publication productivity of women physicists in India: A Scientometrics study

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ABSTRACT

The present study focused on the research publications of women faculty in the field of physics, Astrophysics, Astronomy and Atmospheric Science in India. To collect the data we have covered the women faculty of Central Universities, State Universities, IITs, NITs, IISER's, NISER's, research institutes, laboratories and some selected deemed universities. The first fact we found was that the number of women were very less as compare to male staff. To see the publication productivity of women authors we tried to analyze the year-wise productivity, authorship pattern, preferred journals, place and designation and the research papers received highest citations for the period of five years from 2011-2015. Year 2014 found to be the most productive year and in authorship pattern, women authors preferred to publish their research in collaboration. Highest number of research papers was published in Journal of Applied Physics.

Keywords: Women physicists, scientometrics, India, higher education, research

1. INTRODUCTION

The development of women has been at the forefront of policy making of Government of India for the last few decades. Despite the increasing number of women in higher education in science, women's participation at higher levels of science in tenured research positions has shown little increase [1]. Women constitute over one -third of the total science graduate and post-graduate degree holders, but comprise only 15-20% of the tenured faculty across research institutions and universities in India, (INSA Report) [2]. The present study is focused on identifying the role, number and journal research publications of

Indian female faculty/scientists in Physics, Astrophysics, Astronomy and Atmospheric Science during 2011-2015. While collecting the data of journal research papers, authors have attempted to see the different roles of women faculty in their respective institution. The women faculty is working on a variety of designations such as professors, associate professors, assistant professors, readers, lecturers, scientists, director and head of the institution. Apart from teaching and research, they are the member of many committees formed by their institutions, working on different projects also funded by various agencies as a principal/chief investigator.

2. REVIEW OF LITERATURE

In the recent past, several bibliometrics and scientometrics studies have been made to see the scientific productivity of women in science in different countries of the world. For instance Hildrun [3] analyzed the productivity and citedness of the staff of a German medical institute and found that male scientists are more prolific and cited more often than female scientists and also found that women in comparison to men have less scientific productivity and fewer in numbers in the institutes[3]. Bebi & Kumar [4] conducted a research on some select academic institutes in Delhi and found that male staff dominates in each institute because the number of female staff was found to be very few. But conversely a study by Leta and Lewison [5] on women in Brazilian science found that Brazilian men and women published similar number of papers, in terms of both quality and quantity. In another study Gupta and Sharma [6] explained several reasons for the lower productivity of the women scientists, some of them are caused by their roles in society and families like marriage, maternity and age.

Campion and Shrum [7] examined gender differences in science based on a survey of 293 scientists in Ghana, Kenya and the Indian state of Kerala and stated that there is gender inequality in the research systems of the developing countries. Nourmohammadi and Hodaei [8] investigated the contribution of Iranian women in science and technology. The study indicated a significant difference between the male and female scientific productivity. Results also showed that 99% of Iranian women research is done as joint publications. Another study by Sotudeh and Khoshian [9] revealed that in nano-science female perform equally to men in term of scientific publications. Ebadi and Schiffauerova [10] evaluated the scientific production as well as collaboration of Canadian researchers in the field of science and engineering and found that male researchers have published almost 5 times than females. Though, most of these studies are based on the comparison of women's scientific productivity with men's scientific productivity. Frietsch et al [11] analysed the production of women in science and technology of 14 countries and resulted that there is a positive and progressive growth in the scientific production of women. Lewison and Markusova [12] made a comparison between the proportion of females in 1985, 1995, and 2005, with a corresponding analysis of the major fields in which they worked, their propensity

to co-author papers internationally, and their citation records. They found as expected, that women had a higher presence in the biological sciences and a very low presence in engineering, mathematics, and physics. Their citation scores, on a fractionated basis, were lower than those for men in almost all fields and years. Isfandyari-Moghaddam et al. [13] findings indicated that there were several factors affecting the productivity of Iranian women and some of them were shortcomings in the existing laws, stereotypes and beliefs concerning women, family work, social and cultural contingencies, child care and low collaboration with male colleagues.

Numerous scientometrics and bibliometrics studies of Indian science have been published from last few years to see the contribution of female scientists. Goel [14] studied the publication productivity of Indian male and female researchers in psychology and found that the females were far behind than males in publishing research papers. Bal [15] examined 669 publications indexed by Pub Med during January 1994–April 2004 to study the scientific productivity of female biologists and found that women contributed 15 % of all publications. A study by Hasan et al. [16] found no significant difference in the contributions made by the male and female research scholars of CSIR. Garg and Kumar [17] conducted a study in life sciences and found significant difference in number and publications of male and female scientists. They also found that female works in small teams and with less international collaboration. Recently, Bebi & Kumar [18] analyzed the data of some selected central universities of India during 2011-2015 in the field of Physics and found that the number of women faculty is very less as compare to men colleagues. Another important finding of the study was that when these women faculty writing papers in collaboration, the number of male co-authors were more than the female co-authors.

3. METHODOLOGY

The present study aims to analyze the research output and role of women faculty in physical Science (Physics, Astrophysics, Astronomy and Atmospheric Science) in India during 2011-2015. To collect the basic data, authors prepared a list of all women scholars working at Central Universities, State Universities, selected deemed universities, IITs, NITs, IISER's, NISER's research institutes and laboratories in the field of Physics, Astrophysics, Astronomy and Atmospheric Sciences (Source: UGC and DST). To identify the name of women scholars, the official websites of selected institutions have been visited. Using the name of women scholars, authors first collected the data of their journal publications by downloading their Curriculum Vitae (CV) from each institution. To have a complete picture of the publications output of these women authors, other official sources like annual report and social networking sites like Google scholar public profile, research gate was also consulted. All the bibliographic details of journal publications were filled in Excel sheets and analyzed as per the objectives of the study. Each record of the data retrieved using various sources comprises a number of fields such as

author, number of authors, title, citation received (citations received by each paper as reflected by Google Scholar), year, place of women author in the publication and name of journal where the paper was published. Data for journals was enriched by impact factor and name of publishing country of journals.

4. LIMITATIONS OF THE STUDY

Though there are many higher education and research institutes in India, but this study is confined to those institutions which were established only till 2008 and had both Physics Department and women faculty. To make the list of institutions, mainly the website of UGC and DST was followed. Some institutes were randomly selected by putting Physics Institutes in India on Google, which are not found on both these websites.

5. OBJECTIVES

The study has the following objectives:

1. To know the various role and responsibilities of women physicists in their respective institutes;
2. To know the year-wise number of research publications;
3. To analyze the authorship pattern of articles;
4. To examine the distribution of output by publishing country of journals;
5. To prepare a list of most preferred journals by women faculty;
6. To see the place and designation of women authors in the jointly written research papers; and
7. To find out the most cited articles written by women faculty and citation pattern.

6. RESULTS AND DISCUSSION

This study is based on the analysis of 2890 research papers published by Indian women physicists during 2011-2015. A total of 99 institutes were selected for data collection including universities (central, state and deemed), IITs, NITs and Physics research institutes and laboratories, where physics department and women faculty both were found. In these 99 institutes total 2069 staff strength of physics were found. Of which only 340 were women faculties/scientists, who have published these 2890 research papers in collaboration with other male and female co-authors. The collected data revealed out a very poor percentage of women faculties/scientists, which shows a big gender gap in these Indian institutes covered under study.

6.1 Year-wise number of publications and their received citations

Publication productivity as measured by the number of research papers has been regarded as one of the main indicators of reputation of institutions/authors. The analysis of number of publications published by Indian women physical scientists yearly is shown in table 1. However this publication data is published by individual faculty/scientists. The data analyzed for the recent 5 years 2011-2015. Analysis shows that among all, year 2014 was most productive with 629 (21.77%) publications of the total 2890, followed by 2015 with 613 (21.23%) and 2013 with 590 (20.41%). The lowest numbers of papers were published in the year 2012 i.e. 517 (17.88%). But it is interesting to see that in all years the numbers of publications are more than 500.

Apart from the number of publications, the impact of the publications is also important. To do this, authors took the number of citations, the publications have received till the time of data collection (July, 2018). It can be seen in table 4 that the publications, published during 2011 received the highest number of citations i.e. 8959, followed by the year 2013 with 7495 number of citations.

Table 1: Year-wise number of publications

Sl. No.	Years	TNP	%	TNC	CPP
1	2011	541	18.7	8959	16.56
2	2012	517	17.8	6659	12.88
3	2013	590	20.4	7495	12.70
4	2014	629	21.7	5128	8.15
5	2015	613	21.2	3557	5.80
Total		2,890	100	31,798	11.1

*TNP= total number of papers, TNC= Total Numbers of citations, CPP= citations per paper

6.2 Authorship pattern of articles

The data collected on authorship pattern allowed us for an answer to the question- Do women publishes more articles as a single author or in collaboration? These types of analysis also help to know the team size, with which women authors work/collaborate. During analysis it was observed that 78 was the highest number of authors in an research paper where women authors collaborate. It can be seen from table 2 that 2890 were the total number of articles, published by authors in 5 years. These 2890 articles were written by 13,614 total authors, in which 4,728 were women authors and 8,886 were men authors. In other words it can be said that male authors were almost double in number than the female authors.

On the other hand, of a total 2890 articles analyzed in this study revealed that only 64 (0.48%) articles were written by single women authors and other 2774 (99.52%) articles in collaboration. Thus, the results are big indicator of collaborative research or team work rather than individual research. So, on the basis

of analysis it can be said that women scientists prefer to work in a team and in that team also prefer to work with male co-authors as the analysis showed that male co-authors were nearly double in number than the female authors.

Table 2: Authorship pattern of articles

Sl. No.	No. of Authors	TNP	%
1	Single	65	0.48
2	Two	625	9.18
3	Three	656	14.46
4	Four	551	16.19
5	Five	362	13.30
6	Six	198	8.73
7	Seven	143	7.35
8	Eight	63	3.70
9	Nine	49	3.24
10	Ten+	178	23.71
Total		2890	100

6.3 Distribution of output by publishing country of journals

Table 3 presents an analysis of distribution of output by publishing country of journals. This analysis will help to know that in which country the women scientists prefer to publish their work. Today we are seeing the access growth in published material, whether it is print or electronic. Almost all countries are publishing some kind of literature in the form of books, journals, e-journals etc. So in this situation we must know the country of publication in which maximum authors want to publish their research work.

Here, the analysis clearly indicates that United States of America (USA) is the first choice of Indian women scientists, for publishing their research work. It was found in the analysis that 40 countries were involved in publishing these 2890 articles, of which USA origin leading first with 887 (30.69%) papers and 13078 citations, followed by United Kingdom (UK) with 612 (21.18%) and Netherlands with 565 (19.55%) articles. India is on 4th place with publishing 325 (11.25%) articles. The rest countries were Germany, Singapore, and Switzerland etc.

Table 3: Distribution of output by publishing country of journals

Sl. No.	Countries	TNP	%	TNC
1	USA	887	30.69	13078
2	UK	612	21.18	7155

3	Netherlands	565	19.55	6649
4	India	325	11.25	775
5	Germany	200	6.92	2634
6	Singapore	72	2.49	408
7	Switzerland	46	1.59	141
8	France	22	0.76	206
9	Russia	17	0.59	55
10	Hungary	15	0.52	92
11	Japan	16	0.55	39
12	Egypt	10	0.35	131
13	China	10	0.35	22
14	Canada	10	0.35	39
15	Other	83	2.56%	374
Total		2890	100	31,798

6.4 Preferred Journals

A total of 797 journals have been chosen by authors to publish their 2890 articles during 2011-2015. Among them Journal of Applied Physics were the highly preferred journal, published 79 (2.73%) articles followed by Physical Review A and Physical Review D with 67 (2.32%) and 61 (2.11%) respectively. It is noteworthy here that all these three leading journals are published from USA. It is also important to mention here that in the listed and ranked 15 journals, 8 are published from USA. Two previous studies conducted by Bebi and Kumar (2017, 2018) also in support of this analysis that Journal of Applied Physics is the highly preferred journal by Indian women scientists because in those studies also, this journal occupied rank 1.

Table 4: Preferred journals

Sl. No.	Name of Journal	IF	Country	TNP	%	Rank
1	Journal of Applied Physics	2.176	USA	79	2.73	1
2	Physical Review A	2.925	USA	67	2.32	2
3	Physical Review D	4.394	USA	61	2.11	3
4	Journal of Alloys and Compounds	3.779	Netherlands	55	1.90	4

5	Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy	2.880	UK	51	1.76	5
6	Physical Review C	3.304	USA	49	1.70	6
7	Astronomy and Astrophysics	5.565	Germany	46	1.59	7
8	Monthly Notices of the Royal Astronomical Society	4.961	UK	45	1.56	8
9	Journal of High Energy Physics	5.541	Germany	44	1.52	9
10	Astrophysical Journal	5.551	USA	39	1.35	10
11	Applied Physics Letters	3.495	USA	37	1.28	11
12	Physics of Plasmas	1.941	USA	36	1.25	12
13	Physical Review E	1.941	USA	34	1.18	13
14	Applied Surface Science	4.439	Netherlands	30	1.04	14
15	Pramana	0.520	India	29	1.00	15

6.5 Place and designation of women authors in published research papers

Here, in the tables 5.1 and 5.2 an attempt has been made to know the place and designation of women scientists when writing research papers jointly or in a team. It is noteworthy to mention here that this study covered 99 Indian institutes of Physics in which 340 women faculty/scientists were found and these authors have published these 2890 articles along with other co-authors. The following analysis shows the place and designation of these 340 women authors only. The data shows that of these 2890 research papers, in 957 (22.2%) research papers, women authors had 2nd place when publishing work jointly.

Table 5.1: Place of women authors in the articles

Sl. No.	Place of Author	TNP	%
1	1 st	634	21.93
2	2 nd	957	33.11
3	3 rd	566	19.68
4	4 th	322	11.14
5	5 th	180	6.22
6	Other places	231	8.0
	Total	2890	100.00

Table 5.2 shows the designation of women authors in the research papers. Of the total 2890 articles women authors played a role of corresponding author in 1206 (41.7%) articles. Whereas, if we see their role as a first + corresponding author, in a very few papers i.e. 385 (13.32%) they were first + corresponding author or both. Based on the above analysis, it can be concluded that as a corresponding author female authors have written a good number of papers but the number of papers are very few in which they were first and corresponding author or both.

Table 5.2: Designation of women authors in the research papers

Sl. No.	Designation of Author	TNP	%
1	As corresponding	1206	41.86
2	As 1 st + corresponding	385	13.46

6.6 Five most cited papers co-authored by women scientists

When an article gets cited in another article, it means that this research work has some significance and good impact on human society and life. But it depends on how many times the particular article gets cited. The more times an article has been cited, means it is a good quality useful work of an author. Here we tried to investigate which paper were received highest number of citations over the period under study (data collected in September 2018). Table 6 presents a list 5 most cited papers written by Indian women scientists jointly. It can be seen from the table that a paper co-authored by R, Aditi Simha, from IIT, Madras received the highest number of citations 1119. It is remarkable to mention here that all the cited papers are written jointly in national and international collaboration.

Table 6: Five most cited papers co-authored by women scientists

Sl. No.	Details of Paper
1	<p>Title: Hydrodynamics of soft active matter</p> <p>Times cited: 1119</p> <p>Authors: M. C. Marchetti, J. F. Joanny, S. Ramaswamy, T. B. Liverpool, J. Prost, MadanRao, and R. AditiSimha*</p> <p>Author's Affiliation*: IIT, Madras</p> <p>Journal: Reviews of Modern Physics (2013)</p>
2	<p>Title: Scanning tunnelling microscopy and spectroscopy of ultra-flat graphene on hexagonalboron nitride</p>

	<p>Times cited: 871</p> <p>Authors:JiaminXue, Javier Sanchez-Yamagishi, Danny Bulmash, Philippe Jacquod, AparnaDeshpande*, K. Watanabe, T. Taniguchi, Pablo Jarillo-Herrero and Brian LeRoy</p> <p>Author's Affiliation*: IISER, Pune</p> <p>Journal: Nature Materials (2011)</p>
3	<p>Title: Dynamics of the Two Atoms Interacting with Quantized Two Modes Cavity Fields in the Ladder Configuration</p> <p>Times cited: 318</p> <p>Authors:Sudha Singh*, Amrita</p> <p>Author's Affiliation*: Ranchi University</p> <p>Journal: International Journal of Theoretical Physics (2013)</p>
4	<p>Title: An extremely luminous panchromatic outburst from the nucleus of a distant galaxy</p> <p>Times cited: 227</p> <p>Authors: A.J. Levan, N.R. Tanvir,S.B. Cenko et al. (Kuntal Mishra* 14th no. of Author)</p> <p>Author's Affiliation*: Aryabhata Res InstObservatSci</p> <p>Journal: Science, 2011, Vol. 333(6039): 199-202.</p>
5	<p>Title: Constraints on Fluid Dynamics from Equilibrium Partition Functions</p> <p>Times cited: 184</p> <p>Authors: Nabamita Banerjee*, Jyotirmoy Bhattacharya, Sayantani Bhattacharyya, Sachin Jain, Shiraz Minwalla, Tarun Sharma</p> <p>Author's Affiliation: IISER, Bhopal</p> <p>Journal: Journal of High Energy Physics, 2012.</p>

6.7 Frequency distribution of citations

Table 7 shows frequency distribution of citations. It indicates that 2890 papers received 31798 citations. Analysis of the citation data indicates that, of the 2890 published papers, 641 (22.18) papers did not receive any citation, and remaining 77.82% received one or more citations. The number of such papers who received more than 100 citations was 20.

Table 7: Frequency distribution of citations

No. of Citations	No. of Papers	Total Citations
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0	641	0
1	213	213
2	185	370
3	195	585
4	172	688
5	133	665
6	155	930
7	102	714
8	93	744
9	69	621
10	97	970
>10	835	25,298
Total	2890	31,798

7. CONCLUSION

In India, despite the increasing number of women in higher education, women's number on teaching and research positions are very less. Basically the present study is focused on the role, contribution and number of women scientists/faculty in higher education and research institutions in India in the field of Physics, Astrophysics and Astronomy. The results of the present study confirm that there is a gender gap in physics, astrophysics and astronomy in India. According to the results, after analyzing 2890 articles which were written by 13,614 total authors, of which 4,728 were women authors and 8,886 were men authors. In addition, it also aims to identify the number of women scientists/faculties in teaching and research institutes in India. It was a surprising fact came to know that a university like Banaras Hindu University there is no women faculty in Physics department despite a good number of men faculty i.e. 30. The results showed that women were the first author in less number of papers and also acted as a corresponding author less frequently. In more number of papers written jointly, men authors signed as corresponding author. The results also indicated that the papers received highest citations, women authors worked as a co-author in maximum number of papers not as first or corresponding author. It was also observed in the analysis that team size was small where women authors collaborate. So on the basis of this study it can be concluded that despite increasing number of enrollments in higher education, still women participation is lower. The number of working women in universities, research institutions found to be fewer as compare to male employees. There may be several reasons behind women's lower numbers and participation. Talking to some of faculties it was came to know that family; marriage; children are

some of the reasons responsible for lower participation of women. To keep this in mind there should be a need to encourage women to work and make policies for the betterment of women. In India, there are several policies have been made to encourage and support the women. Department of Science and Technology and UGC are running many schemes and fellowships for women to encourage and support them financially. But still on the basis of this study it is suggested that there is a need for more schemes, fellowships and research support system for women to encourage them so that they can step ahead and make their contribution better than the present scenario in India.

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