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Research Article

Scientometric Assessment of Indian Scientists' Contribution to Selected Physical Review Journals during 2004-2018

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ABSTRACT
The present study reveals Indian authorship trend and their contribution in five selected highly cited journals of American Physical Society (APS) as reflected in the Web of Science (WoS) database. During 2004-2018, India placed 11th rank having 4.6% contribution and Indian scientists published total 9,823 research articles including 50.98% international collaboration. The *Physical Review* D (PRD) journal published majority of Indian authored articles which also get larger citations impact and developed European countries like USA, Germany and France were the leading collaborating countries. Maximum articles received citations in the range of ≥1 - <10 and only 194 articles attracted at least 100 or more citations. It is also found that the Indian scientists involved in high energy physics produced significant research articles under international collaborative experimental groups like ALICE, ATLAS, STAR etc to share cost, infrastructure and capabilities. The study will be helpful for policy makers and scientists in identifying Indian researchers' publication pattern in the selected APS journals of repute.

Keywords: Scientometrics, Contribution, Scientists, Physics, American Physical Society, Physical Review Journals, India.

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INTRODUCTION

Since Independence, India's Higher Education system has witnessed a paradigm shift and has became the third largest higher education system in the world, after the US and China.[1] India's large science and technology (S&T) infrastructure comprises 920 UGC affiliated Universities and 95 Institution of National Importance, many R&D laboratories, centers, Govt. departments as well as private institutions.[2] Due to the significant growth of S&T infrastructure and S&T investments in the country, a huge number of research findings are coming out and publishing in different national as well as international journals of repute. However, the Indian scientists prefer to publish their scientific results in foreign journals rather than national level journals due to absence of sufficient good quality journals and also for wider recognition and credibility.[3,4]

Founded in 1899, the *American Physical Society* (APS) is a professional body that serves the international physics community with internationally known and highly cited peer-reviewed research journals.[5] Therefore, the present study is an effort to identify the Indian authorship contribution and trend in the selected APS journals by seeking answer to the following research questions.

i. What are the Indian scientists' contributions to reputed APS journals?

ii. What patterns of collaboration trend are evidenced among the scientists and their scholarly impacts?

iii. What are the primary collaborating countries and participated institutions?

iv. What are the emphasized and focus research areas among the scientists?

Literature Review

The literature review summarizes and highlights the related papers on present research scenario of S&T in India as well as in the discipline of physics or sub-branch areas.

Hiremath, Gourikeremath, Hadagali and Kumbar[6] assessed India's publication growth in S&T during 1989-2014 and reported that India's publication trend corresponds to the world's average. The Bhabha Atomic Research Centre (BARC), Mumbai played dominant role followed by the Indian Institute of Science (IISc), Bengaluru. Garg, Dutt and Kumar[7] evaluated the papers of Indian scientists for the

year 1997 as covered in the Science Citation Index (SCI) and reported that physical sciences, chemical sciences and medical sciences produced about 57% of the total output. In another study, Basu and Aggarwal[8] evaluated the impact of international collaboration on institutional performance in India and showed that the Tata Institute of Fundamental Research (TIFR), Mumbai had a very high productivity, collaboration and IF.Gupta and Dhawan[9] stated that India ranks 12th place in science and technology (S&T) research having 2.04% global publications share during 1996–2006. Further, Physical sciences subject dominates the S&T research domain in India. In another study, Gupta and Dhawan[10] pointed out that condensed matter physics is the most popular sub-field in Physics research in India and found that *Physical Review B* has been considered as the most productive journal. Dhawan[11] also investigated the trend of physics research in India and China during 1990 and 1995 and reported that China is ahead of India and ranked 7th in the world while India placed 10th position.

Raina, Gupta and Kandhari[12] made an attempt to identity the evolutionary trend of collaboration in India in four sub-disciplines of physics during 1800-1950 and also discovered the collaboration profiles of four renowned physicists. In the history of Indian physics, the decade of 1920-30 constitutes the main landmark period and witnessed a quantum leap in publications. In another paper, Raina and Gupta[13] assessed the process of the institutionalization of research in physics in India during 1900-1950 in terms of author productivity, sub-discipline wise productivity, collaboration, globalization and country wise distribution of publications.

Bhattacharya, Singh and Sudhakar[14] in their macro level analytical study, evaluated the changes in research priorities in major fields of Physics of thirty three countries during two different time periods - 1990 and 1995. The study showed that South Korea has shown a remarkable increase in rank while India lost its position from 8th to 10th place. Khanna, Singh, Tewari and Saini[15] analyzed the publications output of the Guru Nanak Dev University (GNDU), Amritsar in physics and astronomy during the period 2006-15 and pointed out that among leading 25 Indian Universities, the University of Delhi shared majority of the publications followed by Panjab University whereas GNDU ranked 23rd position with 652 publications.

Sudhier[16] examined 352 scholarly publications appended in the Physics doctoral thesis of researchers of Indian Institute of Science (IISc) and the University of Kerala (KU) during 2004-2008 on several aspects like publication productivity, authorship trend, ranked journals, communication channels etc and pointed out that the Physicists prefer to publish research findings in American Physical Society (APS) journals. Rajan, Swaminathan and Vaidhyasubramaniam[17] pointed out that the research productivity from Indian institutions has been steadily increasing in last few years and materials science, physics and astronomy were the strong subject areas with maximum quality output.

It is evident from the above review that Indian scientists contribute a significant proportion of publications share at the Global level and physical science is the top priority area of research in India. In this context, the present endeavor explores the Indian physicists' contribution to global level reputed journals of American Physical Society.

Objectives of the Study

The present study examines the Indian researchers' contribution in five selected American Physical Society (APS) journals during 2004 – 2018 using scientometric methods. It especially looks at the key trends based on authorship pattern, collaboration activity, partnering countries, participated institutions and citation impact.

Data source, limitations and methodology

The present scientometric study covers only Indian authored/ co-authored articles published in the Physical Review journals for last 15 years spanning from the period of 2004 to 2018. The *Physical Review* journals[5] are published by the American Physical Society (APS) and it has the collection of 15 leading international peer-reviewed research journals. But, the present study considers only five oldest research journals (Table 1) of APS. However, the *Reviews of Modern Physics* (1929-) publishes review based articles and *Physical Review Letters* (1958-) publishes shorter articles of broader interest. Hence, these two oldest journals have been excluded from the study.

The '*Physical Review*' journals first published in 1893 and later in 1970, the journal splits into several sub-journals titled Physical Review A, B, C and D to focus particular field of physics. Later on, in 1993 a fifth journal titled '*Physical Review E*' was introduced.[18]

For this purpose, the *Web of Science* (WoS) - core collection database of the Clarivate Analytics has been consulted during the last week of October, 2019and following advanced query strings have been applied.Publication Name: (Physical Review E OR Physical Review D OR Physical Review C OR Physical Review B OR Physical Review A)

Refined by: Document Types: (Article) AND Countries/ Regions: (India)

Indexes= SCI-Expanded, SSCI, A&HCI, Timespan= 2004-2018

The search has retrieved total 9,920 records comprising of article (9,823), editorial materials (20), correction (13), retracted publication (1), review (49) and letter (15). Out of

the total publications, only journal articles (9,823) have been selected and shortlisted for the study. Later, the data have also been analysed to get desired output as specified in the objectives of the study. Tables and figures have been used to interpret the data. In addition, for measuring citation impact, different indices like *h*-index[20] and *A*-index[21] have been applied.

RESULTS

The following sub-sections categorize and demonstrate 9,823 research articles on various aspects like chronological break-up, source journal, collaboration trend, authorship, collaborating country, institution and citation pattern.

Country wise distribution of articles

Table 2 shows the leading 15 countries' contribution in 5 selected APS journals. Out of total 2,13,903 journal articles during the time span 2004 to 2018, *USA* published majority of 70,800 articles which occupy 33.01% followed by *Germany* having 37,854 articles (17.7%) and *Peoples R. China* having 24,525 articles (11.46%). However, *India* secured 11th place with 9,823 articles which share 4.6%.

Triennial period wise distribution of articles

Further insights can be drawn by examining the details from Table 3 which shows the triennial period wise distribution of articles and corresponding collaboration output. The Indian scientists contributed total 9,823 articles to five source journals during 2004 to 2018. Of these, 4,815 articles (49.02%) were produced from national collaborations while international collaborations occurred in 5,008 articles (50.98%). Highest number of 2,659 articles (27.07%) outputted during the year 2016-18 followed by the preceding year, 2013-15 having 2241 articles (22.81%). It is observed from Figure 1 that an increasing trend has been seen in total contributions, national collaborations as well as international collaborations.

Journal wise distribution of articles and scholarly impact

Table 4 depicts the data pertaining to journal wise distribution of articles and corresponding citation impact. Out of 5 APS journals, *Physical Review D* (PRD) published maximum of 2,960 articles (30.13%) with highest average citations of 21.74 per paper, *h*-index of 97 and 311 articles get at least 50 or more citations. This is followed by *Physical Review B* (PRB) journal having 2,366 articles (24.08%) and *Physical Review E* (PRE) journal having 1,766 articles (18%). Moreover, the articles published in the *Physical Review B* (PRB) journal received maximum *A*-index of 157.13 and highest number of 100 articles of Physical *Review E* (PRE) journal was uncited. Conversely, total 9,823 articles received 18.38 average citations per paper, *h*-index of 123, *A*-index of 213.3, uncited articles of 385 and 738 articles received at least 50 or more citations.

Collaboration wise distribution of articles

Collaboration wise output of articles and corresponding citation impact has been revealed in the Table 5. Out of total 9,823 articles, majority of the articles, i.e. 5,008 produced from international collaboration while 4,815 articles (49.02%) produced from national collaboration. Maximum international collaboration i.e. 59.09% occurred in the sub-field of '*particles, fields, gravitation and cosmology*' (PRD journal) followed by '*condensed matter and materials physics*' (PRB journal). Similarly, highest numbers of national collaborative output were evidenced in the '*statistical, nonlinear, biological and soft matter*

Table 1: List of selected Physical Review journals.

Sl. No.	Journals	Starting year	JCR, 2019*
1.	Physical Review A (PRA): atomic, molecular and optical physics and quantum information	1970	2.777
2.	Physical Review B (PRB): condensed matter and materials physics	1970	3.575
3.	Physical Review C (PRC): nuclear physics	1970	2.988
4.	Physical Review D (PRD): particles, fields, gravitation and cosmology	1970	4.833
5.	Physical Review E (PRE): statistical, nonlinear, biological and soft matter physics	1993	2.296

*2019 Journal Citation Reports (Clarivate Analytics, 2020)[19]

Table 2: Distribution of articles by country during 2004-2018.

Sl. No.	Country/ region	No of Articles (N=2,13,903)	%articles
1.	USA	70,800	33.01
2.	Germany	37,854	17.7
3.	Peoples R. China	24,525	11.46
4.	Japan	22,742	10.63
5.	France	22,014	10.3
6.	England	17,342	8.11
7.	Italy	15,454	7.22
8.	Russia	14,069	6.57
9.	Spain	12,952	6.05
10.	Canada	10,646	4.98
11.	**India**	9,823	4.6
12.	Switzerland	8,278	3.87
13.	Brazil	8,154	3.81
14.	Poland	6,954	3.25
15.	South Korea	6,155	2.877

physics' (PRE journal) area. On the contrary, international collaboration gained wider citation impact having 22.44 average citations per paper, h-index of 114 and 155 articles received at least 100 or more citations. On the other hand, national collaboration output gained lower citation impact and only 43 articles attracted at least 100 or more citations.

Authorship distribution

Authorship pattern in research articles of different journals have been illustrated in the Table 6. Out of total 9,823 articles, majority of 2336 articles (23.8%) were produced by three-authored, followed by two-authored with 2299 articles (23.40%) and four-authored with 1426 articles (14.52%). It is significant to note that more than 10 authored produced 1565 articles which occupied 15.93% share. Figure 2 sketches the authorship distribution in different journals and showed that the *Physical Review C* (PRC) and *Physical Review D* (PRD) journals published maximum articles which were produced by more than 10 authored. The *Physical Review E* (PRE) and *Physical Review A* (PRA) disseminated maximum 2 and 3 authorship articles. However, maximum collaboration occurred under the international collaborative efforts like ALICE, Belle, BESIII, BaBar, CMS, PHENIX, STAR etc and Indian scientists produced significant number of research output collaborating with these experimental consortia groups.

Country wise collaboration output and scholarly impact

Table 7 reports contribution of leading 15 collaborating countries and corresponding scholarly impact. During 2004-2018, the Indian scientists collaborated with the scientists of total 103 countries to produce 5,008 articles. Of these, *USA* produced lion's share of 2,324 articles having maximum *h*-index of 105 and highest 113 articles received at least 100 or more citations. This is followed by *Germany* with 1,816 articles and *France* with 1,210 articles. Furthermore, the 616 collaborating articles with *Brazil* received wider citation impact of highest number of 38.69 average citations per paper. Additionally, leading partnering countries collaboration linkages have been mapped in the figure 3 by using VOSviewer software tool.

Focus area wise contribution of leading collaborating countries

Table 8 highlights the leading 10 collaborated countries' contribution in the five focus areas of the source journals during 2004- 2018. The five Physical Review journals focus particular field of physics. In all the five sub-fields of Physics, the *USA* and *Germany* lead among the collaborating countries and placed 1st and 2nd rank respectively. Apart from these, collaboration with the *France* scientists were also strong during the period and secured 3rd rank in three sub-areas i.e. '*condensed matter and materials physics*', '*nuclear physics*' and '*statistical, non-*

Table 3: Triennial period wise break-up of articles during 2004-2018.

Year	APS Journals					Number of articles	%articles	NCP	ICP
	PRA	PRB	PRC	PRD	PRE				
2004-2006	145	463	190	299	216	1313	13.36	660	653
2007-2009	198	459	233	430	275	1595	16.24	853	742
2010-2012	240	456	316	630	373	2015	20.51	955	1060
2013-2015	**333**	349	362	744	453	2241	22.81	1066	1175
2016-2018	311	639	403	857	449	2659	27.07	1281	1378
Total=	1,227	2,366	1,504	2,960	1,766	9,823	100	4,815	5,008

NCP=National Collaborative Papers; ICP=International Collaborative Papers

Table 4: Distribution of articles and citations by journal.

Journal	Number of articles	%articles	ACPP	h-index	A-index	AC_{50}	Uncited articles
Physical Review A	1,227	12.5	12.73	47	78.36	43	50
Physical Review B	2,366	24.08	20.3	82	157.13	193	81
Physical Review C	1,504	15.31	20.34	73	141.08	135	62
Physical Review D	2,960	30.13	21.74	97	156.16	311	92
Physical Review E	1,766	18	12.41	51	76.21	56	100
Total	9,823	100	18.38	123	213.3	738	385

ACPP= Average citations per paper; AC50= Number of articles received at least 50 or more citations

linear, biological and soft matter physics'. Alternatively, *Canada* ranked 3rd position in the sub-area of '*atomic, molecular, optical physics and quantum information*' while *Russia* secured the 3rd place in '*particles, fields, gravitation and cosmology*' sub-area.

Most productive institutions

Table 9 explores most prolific institutions and scholarly impact of the corresponding publications. The *Tata Institute of Fundamental Research*, Mumbai contributed maximum of 1358 articles in the five source journals during 2004-2018. This is followed by the *United States Department of Energy DOE* having 1089 articles and the *Centre National De La Recherche Scientifique CNRS* having 923 articles. However, collaborating publications i.e. 758 of the *University of California, U.S.* gained highest citation impact of 37.56 average citations per paper. Alternatively, the *United States Department of Energy DOE* received maximum *h*-index of 88 and also maximum 70 its publications received at least 100 or more citations. It is observed from the table that out of top 10 most productive institutions, 5 institutions were from foreign countries.

Citation pattern

Table 10 evaluates citation pattern of the articles published in selected APS journals. Citations have been grouped under 7 categories. Majority of 4,508 articles (45.9%) attracted citations in the range of ≥1 - <10 followed by 2274 articles (23.15%) in the range of ≥10 - <20. It is seen from the table that only 4 articles received at least 500 or more citations and 3.92% articles remain uncited. Further, distribution of articles according to citations have been sketched in the Figure 4.

Findings

The findings of the study are summarized below

During 15 years time period from 2004 to 2018, the *USA* shared maximum contributions (33.01%) while *India* ranked 11th position with 4.6% of total articles. The Indian scientists published total 9,823 articles (50.98%) in five source journals of APS and rising trend have been seen in terms of total contributions, national collaborations as well as international collaborations. The *Physical Review D* (PRD) journal shared majority of 2,960 articles (30.13%) with wider average citations of 21.74 per paper. In total, 9823 articles received

Table 5: Collaboration wise break-up of articles and citation impact.

Collaboration Types	APS Journals					Number of articles	ACPP	h-index	AC100
	PRA	PRB	PRC	PRD	PRE				
National Collaboration	724 (59%)	996 (42.1%)	746 (49.6%)	1211 (40.91%)	1138 (64.44%)	4,815 (49.02%)	14.16	78	43
International Collaboration	503 (41%)	1370 (57.90%)	758 (50.4%)	1749 (59.09%)	628 (35.56%)	5,008 (50.98%)	22.44	114	155
Total	1,227	2,366	1,504	2,960	1,766	9,823	18.38	123	198

ACPP= Average citations per paper; AC_{100} = Number of articles received at least 100 or more citations

Table 6: Authorship pattern.

Authorship	APS Journals					Total	%	Cum. %
	PRA	PRB	PRC	PRD	PRE			
1	73	63	69	200	130	535	5.44	5.44
2	344	421	212	720	602	2299	23.40	28.84
3	334	543	260	644	555	2336	23.8	52.64
4	231	389	151	370	285	1426	14.52	67.16
5	109	251	84	117	110	671	6.83	73.99
6	71	161	31	44	41	348	3.54	77.53
7	23	135	28	13	20	219	2.23	79.76
8	19	123	32	10	08	192	1.95	81.71
9	10	92	18	05	10	135	1.37	83.08
10	3	51	36	5	2	97	0.98	84.06
>>10	10	137	583	832	03	1565	15.93	100
Total	1227	2366	1504	2960	1766	9823	100	

Table 7: Country wise distribution of quality indices.

Sl. No.	Country/ Region	Articles	ACPP	h-index	AC_{100}
1.	USA	**2324**	27.14	**105**	**113**
2.	Germany	1816	28.92	98	96
3.	France	1210	30.14	86	69
4.	Russia	1110	34.71	95	86
5.	Peoples R. China	1015	33.35	86	70
6.	England	946	31.21	83	63
7.	Japan	908	32.88	84	65
8.	Italy	866	26.41	73	41
9.	South Korea	833	32.83	80	54
10.	Spain	772	30.98	75	51
11.	Poland	701	33.29	74	49
12.	Czech Republic	645	34.82	74	48
13.	Brazil	616	**38.69**	75	49
14.	Switzerland	615	31.76	70	41
15.	Taiwan	560	33.58	69	39

ACPP= Average citations per paper; AC_{100} = Number of articles received at least 100 or more citations

Table 8: Journal and focus area wise contribution of leading collaborated countries.

Sl. No.	Journal	Focus Areas	Leading 10 collaborating countries
1.	PRA (N= 1227)	atomic, molecular and optical physics and quantum information	USA (153); Germany (82); Canada (46); Japan (46); France (38); England (36); Peoples R. China (30); Italy (27); Poland (26); Australia (22)
2.	PRB (N= 2366)	condensed matter and materials physics	USA (450); Germany (392); France (233); Japan (161); England (142); Italy (101); Switzerland (77); Sweden (56); Peoples R. China (54); Spain (53)
3.	PRC (N= 1504)	nuclear physics	USA (440); Germany (328); France (294); Peoples R. China (239); Russia (239); Poland (204); Brazil (195); South Korea (190); Czech Republic (189); Japan (171)
4.	PRD (N= 2960)	particles, fields, gravitation and cosmology	USA (1105); Germany (856); Russia (797); Peoples R. China (669); South Korea (588); Spain (574); England (570); France (567); Italy (558); Japan (489)
5.	PRE (N= 1766)	statistical, nonlinear, biological and soft matter physics	USA (176); Germany (158); France (78); Italy (46); England (41); Japan (41); Peoples R. China (23); Canada (22); Israel (20); Russia (19); Spain (19)

18.38 average citations per paper, 123 *h*-index, 213.3 *A*-index and 385 uncited articles.

Moreover, international collaborative publications occupied 50.98% share having 5008 articles that also attracted larger citations impact compared to national collaborative output. Three-authored contributed majority of 23.8% share of total contributions and more than 10 authored accounted15.93% of total articles. Out of total 103 collaborating countries, *USA* ranked the leading position followed by *Germany* and *France*. However, collaborating articles with *Brazil* gained wider citation impact. The collaboration effort with the *USA* and *Germany* dominated in all the five focus areas whereas *France* also produced significant collaboration output and secured 3rd rank in three sub-areas of physics.

The *Tata Institute of Fundamental Research* shared highest number of 1,358 articles followed by the *United States Department of Energy DOE.* Conversely, collaborating publications of the *University of California, U.S.* gained highest average citations per paper. Highest share of 45.9% articles get citations in the range of ≥1 – <10 and 3.92% articles remain uncited.

Table 9: Most prolific institutions.

Sl. No.	Institution	Articles	ACPP	*h*-index	AC_{100}
1.	Tata Institute of Fundamental Research, Mumbai, India	**1358**	23.12	74	45
2.	United States Department of Energy DOE, US	1089	33.48	**88**	**70**
3.	Centre National De La Recherche ScientifiqueCNRS, France	923	30.2	80	56
4.	Bhabha Atomic Research Centre, Mumbai, India	835	23.81	63	27
5.	Saha Institute of Nuclear Physics, Kolkata, India	815	18.90	58	19
6.	Indian Institute of Sciences, Bangalore, India	769	19.17	54	17
7.	National Research Centre Kurchatov Institute, Russia	768	36.51	81	59
8.	University of California, U.S.	758	**37.56**	80	56
9.	University of Paris-Saclay, France	757	32.39	74	45
10.	Panjab University, Chandigarh, India	735	31.42	73	44

ACPP= Average citations per paper; AC_{100} = Number of articles received at least 100 or more citations

Table 10: Distribution of citation pattern.

Citation Range	PRA	PRB	PRC	PRD	PRE	Total	%articles
≥ 500	0	2	1	1	0	04	0.04
≥100 - <500	6	53	39	89	7	194	1.97
≥50 - <100	37	138	95	221	49	540	5.5
≥20 - <50	177	500	289	672	280	1918	19.52
≥10 - <20	288	598	332	674	382	2274	23.15
≥1 - <10	669	994	686	1211	948	**4508**	**45.9**
Uncited	50	81	62	92	100	385	3.92
Total	1227	2366	1504	2960	1766	9823	100

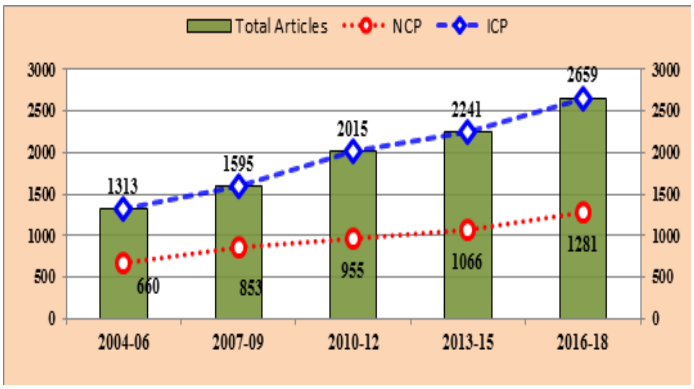

Figure 1: Trend of articles publication and collaboration.

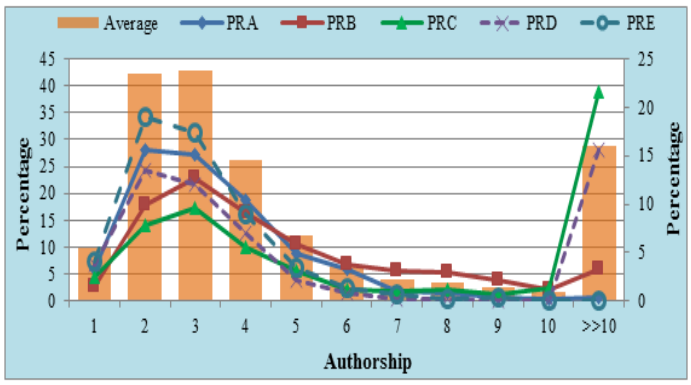

Figure 2: Authorship distribution of in different APS journals.

DISCUSSION AND CONCLUSION

In last 15 years, the Indian scientists contribute significant number of articles in reputed journals of APS and the trend has been increasing year by year. Further, highest number of research articles published on the sub-areas of '*particles, fields, gravitation and cosmology*' followed by '*condensed matter and materials physics*'. In physics discipline, international collaboration trend slightly dominates over national collaborative effort and the trend is getting momentum. It is evident from the study that India is one of the leading countries in terms of contribution in high impact source journals of APS. It may also be argued that the Indian scientists are producing quality scientific output and have gained excellence in physical sciences research. Further, the collaboration phenomenon in research output is balanced and has showed strong inter-institutional collaboration network at the national level along with apparent international collaboration linkage.

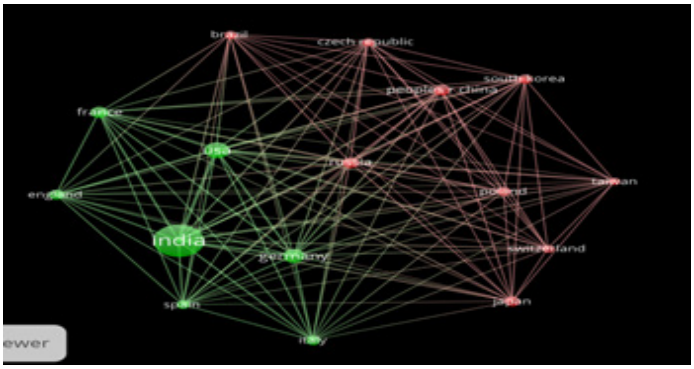

Figure 3: Network mapping of 15 most collaborating countries.

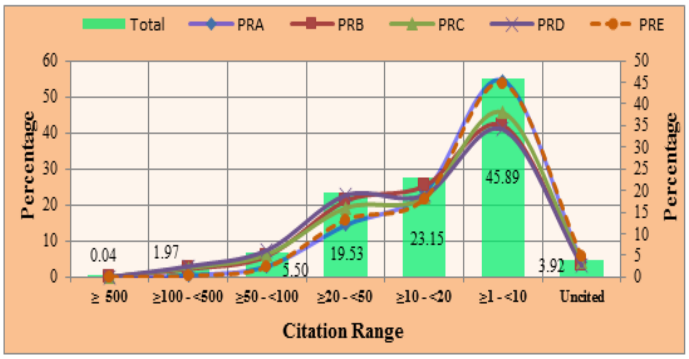

Figure 4: Citation range wise distribution of journal articles

In this contest, it is worth noting that the international experimental consortia are now playing an imperative role in India's high-energy physics research. The Indian scientists are now producing significant share of internationally collaborative papers under the international experimental research groups like ALICE,[22] Belle,[23] BaBar,[24] CMS[25] etc. that facilitate particle collider as a primary scientific research instruments.[26] The collider is the world's most complex technology that accelerates particles to very high kinetic energies and let them collide from opposite directions in the center of the detector.[26] This technology needs massive fund for development and maintenance of the infrastructure and also demands expertise from different professional communities like engineers, technicians, physicists.The scientists from membership institutions in different countries across the world team up and collaborate for research purposes in high-energy experiments. Through this initiative, the institutional scientists may participate in the global level scientific research projects for sharing fund, infrastructure and expertise.[27] Additionally, this joint venture also helps in enhancing scientific capability and country's knowledge base. Hope, these finding will encourage India's higher education as well as research institutions in identifying where we stand in outstanding research journals publication picture in comparison with others.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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