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RESEARCH TRENDS IN GLOBAL OUTPUT OF COSMIC RAYS: A SCIENTOMETRIC ANALYSIS

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Abstract

This paper attempts to highlight the publication status and growth of global cosmic rays research output of Web of Science during 2004-2013. A total of 20395 publications were published on cosmic rays during this period. The average number of publications per year is 2039.5 and the highest number of publications 2565 was published in 2009. The scientometric parameters studied in this paper include forms of publications, annual growth rate, relative growth rate and doubling time of publications, authorship pattern, identification of most prolific authors, country wise distribution of publications, identification of highly productive institutions, language wise distribution of publications and highly preferred source titles for publications.

Keywords: *Cosmic rays, Scientometrics, Annual growth rate, Author productivity, Co author index and collaboration coefficient*

1. Introduction

The term "cosmic rays" usually refers to galactic cosmic rays, which originate in sources outside the solar system. However, this term has also come to include other classes of energetic particles in space, including nuclei and electrons accelerated in association with energetic events on the Sun and particles accelerated in interplanetary space. These rays actually play a vital role

in our daily life as they are also responsible for continuous production of a number of unsuitable isotopes in the Earth's atmosphere. But continuous research found out that there are inadequate evidences for a controversial theory that attempts to link cosmic rays and global warming. Thus, these studies are concluded that these rays are non responsible for global warming. The continuous research on this subject produced many number of publications. But it seems no attempt has been made to focus on the productivity pattern of this subject so far. Therefore, the present study has been made in order to identify the growth pattern of the publications in the field of cosmic rays so as to understand the magnitudes of the research as indexed in web of science database.

Scientometrics is one of the sciences that measure the scientific productivity of a discipline, individuals or the institution. It is one of the most reliable and scientific way to track science and technology research and publication activities. During the last few years scientometric analysis has been increasingly used to evaluate the research performance of researchers, institutions and a country and the growth of various disciplines of science and technology. The analysis has also been used to evaluate the research output of many researchers around the world. The Scientometric is also facilitating to understand the magnitude of the growth of particular subjects, especially the trends and pattern in growth, contribution of a particular author or institutions, the collaboration pattern and relative growth rate.

2. Need for the study

The review of literature revealed that there is no scientometirc study has been carried out so far in the field of cosmic rays. As such, this maiden study made on attempt to focus on the productivity patterns of the subject understudy as well as most prolific authors and most productivity institutions so as to focus their efforts to the world.

3. Objectives for the Study

The following objectives are framed for this study

- To identify the forms of publications that are published under the field of study over a period of last decade
- To illustrate the growth patterns of the cosmic literature by the ways of measuring Annual Growth Rate, Relative Growth Rate and Doubling Time of publications.
- To focus on the authorship patterns of research output of the discipline

- To identify Relative citation impact and top ranking highly productive countries
- To identify the most preferred journal titles for the publication of the cosmic rays researcher
- To identify Language-wise distribution of cosmic rays research output

4. Methodology

The Web of Science database was used for retrieving data on cosmic rays during 2004-2013, using search terms namely 'cosmic rays' in 'topic filed'. A total of 20395 publications were downloaded with no. of bibliographical data, the data were transferred to spread sheet application and analyzed the data as per objectives of the study.

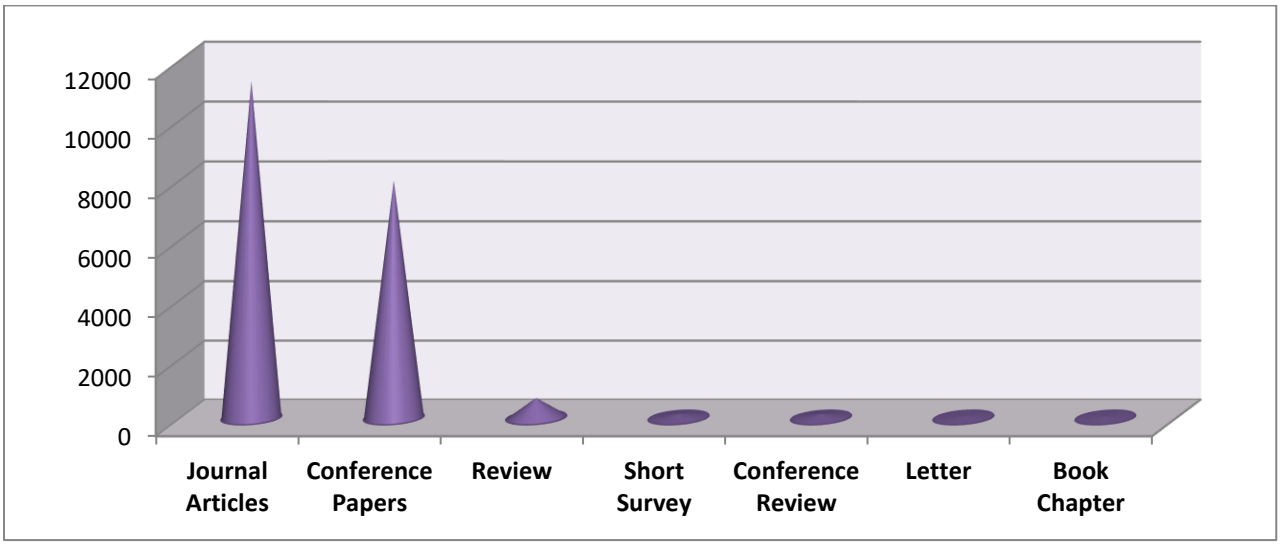
5. Data analysis and interpretations

5.1 Forms of publications

Table 1 Forms of publications

S. No.	Forms of publications	No. of publications	Percentage
1	Journal Articles	11321	55.51
2	Conference Papers	7996	39.21
3	Review	679	3.33
4	Short Survey	146	0.72
5	Conference Review	137	0.67
6	Letter	66	0.32
7	Book Chapter	50	0.24
Total		**20395**	**100.00**

Figure 1 Form of Publications



The table 1 and figure no 1 reveal that the major source of publications covered by web of science database on cosmic rays research are Journal articles with 11,321 publications (55.51%) followed by conference papers with 7,996 publications (39.21%). Review ranks the third position with 679 publications (3.33%) and remaining forms of publications are less than one percentage as seen in the table. The results indicate that the research outputs on the subject of the period covered by the study are mostly published in the form of journal articles.

5.2 Annual Growth Rate (AGR) of the Publications

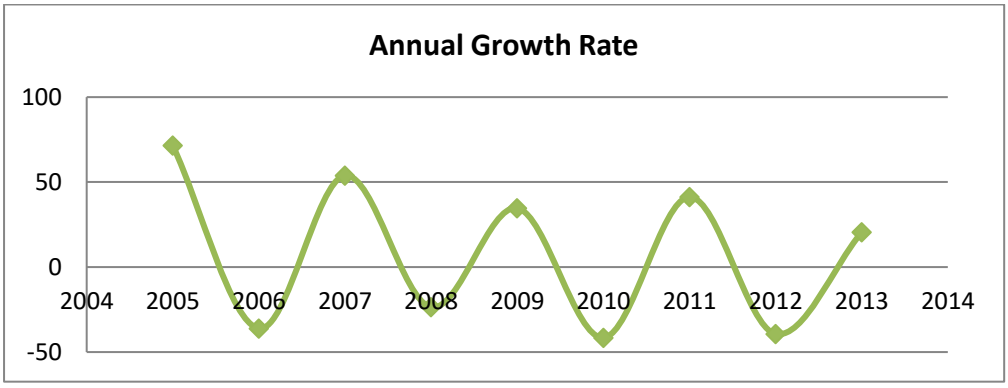
Table 2 provides the AGR of the number of documents for period starting from 2004 to 2013. Thus, the AGR is calculated with the formula:

$$AGR = \frac{\text{End Value - First Value}}{\text{First Value}} \times 100$$

Table 2 Annual Growth Rates of Publications

Year	No. of Publications	Annual Growth Rate (AGR)
2004	1479	-
2005	2536	71.47
2006	1621	-36.08
2007	2494	53.86
2008	1905	-23.62
2009	2565	34.65
2010	1812	-41.56
2011	2559	41.23
2012	1553	-39.31
2013	1871	20.48

Figure 2 Annual Growth Rates of Publications



The Table 2 and figure no-2 reveal that during the period of 2004 to 2013, a total of 20,395 publications were published on cosmic rays research. The highest number of publications is 2,565 published in 2009. The lowest publications of 1,479 are published in 2004. The average number of publications published per year was 2039.5. The Table 2 also shows that the Annual Growth Rate of the total publications calculated year wise. It is seen in the table that there are fluctuations in the growth rate in the study period especially, it has decreased -36.08 in 2006 and it was increased to 53.86 in 2007. Since then, there is fluctuation in year after year as illustrated in figure no - 2. The reason for the fluctuation is that there is no constant growth of publications in every year.

5.3 Relative Growth Rate (RGR) and Doubling Time

The Relative Growth Rate (RGR) is the increase in number of articles or pages per unit of time. The mean relative growth rate (R) over the specific period of interval can be calculated from the following equation.

Relative Growth Rate (RGR) formula:

$1 - 2R = \text{Log } W_2 - \text{Log } W_1 / T_2 - T_1$

Whereas

1-2 R- mean relative growth rate over the specific period of interval

$\text{Log}_e W_1$ - log of initial number of articles

$\text{Log}_e W_2$ - log of final number of articles after a specific period of interval

$T_2 - T_1$- the unit difference between the initial time and the final time

The year can be taken here as the unit of time.

Doubling Time (DT) = 0.693/R

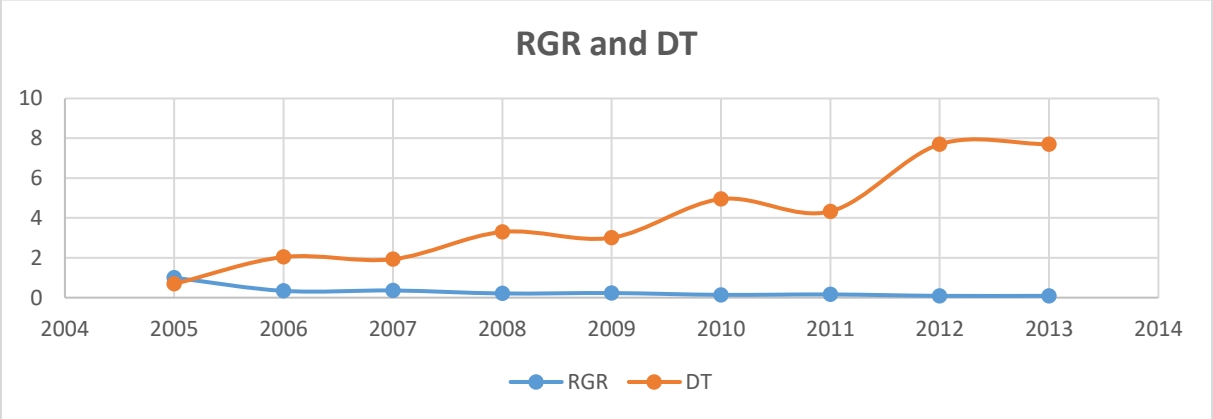
Table 3 Relative Growth Rate (RGR) and Doubling Time (DT) of publications

Year	No. of Publications	Cumulative Total	W1	W2	RGR	DT
2004	1479	1479		7.30	-	
2005	2536	4015	7.30	8.30	1.00	0.69
2006	1621	5636	8.30	8.64	0.34	2.04
2007	2494	8130	8.64	9.00	0.36	1.93
2008	1905	10035	9.00	9.21	0.21	3.3
2009	2565	12600	9.21	9.44	0.23	3.01
2010	1812	14412	9.44	9.58	0.14	4.95
2011	2559	16971	9.58	9.74	0.16	4.33
2012	1553	18524	9.74	9.83	0.09	7.7
2013	1871	20395	9.83	9.92	0.09	7.7

The year wise RGR is found to be in the range of 1 to 0.09. Year wise calculation of RGR reveals that it has decreased from 2004 to 2006 and thereafter the trend is seen fluctuating (figure 3). The highest value corresponds to 2005, whereas the lowest value for the years 2012 and 2013. The Doubling Time too has a trend similar to that of RGR. It ranges from 0.69 to 7.7

(figure 3). A year wise increase is seen during the first two year period of the study, the DT has shown a year wise increase from 0.69 to 2.04 and thereafter it is fluctuating.

Figure 3 Relative Growth Rate for research output



5.4 Authorship patterns of publications

Table 4 Authorship pattern of publications

Block	Year	Single	CAI	Two	CAI	Multi	CAI	Mega	CAI	Total	CC
1	2004	141	147	397	124	537	109	404	71	1479	0.58
	2005	194	118	432	79	797	94	1113	114	2536	0.62
	2006	97	92	439	126	606	112	479	76	1621	0.61
	2007	130	80	514	96	812	98	1038	108	2494	0.64
	2008	89	22	382	93	589	93	845	115	1905	0.64
Total		**651**		**2164**		**3341**		**3879**		**10035**	**0.62**
2	2009	151	110	393	92	704	102	1317	101	2565	0.65
	2010	106	110	403	134	432	88	871	94	1812	0.63
	2011	76	56	258	61	678	90	1547	118	2559	0.68
	2012	106	128	259	100	407	97	781	99	1553	0.63
	2013	114	114	412	132	573	114	772	81	1871	0.64
Total		**553**		**1725**		**2794**		**5288**		**10360**	**0.65**

CAI: Co -Authorship Index, CC–Collaboration Coefficient

The authorship pattern was analyzed to determine the percentage of single and multiple authors. From the table 4, it is observed that out of 20395 publications, maximum of 9167 (44.95%) publications have been contributed by mega authors, followed by multi authors with 6135 (30.08%) publications, two authors with 3889 (19.07%) publications. Only 1204 (5.90%) publications have been contributed by single authors. It indicates that the multi authored works are more than that of single authored contributions in the field of cosmic rays.

For calculating the co-authorship index and collaboration coefficient for authors, countries have been replaced by block. For this study, the authors have been classified into two blocks, vz Single, Two, Multi and Mega authors and the results of Co-authorship index and collaboration coefficient have been presented in the Table 4. It reveals that the result of co authorship index is observed that the value of CAI for increasing and decreasing trend in the two block year periods. This implies that the collaborative pattern in cosmic research is mainly characterized by co-authored papers not by single authored papers.

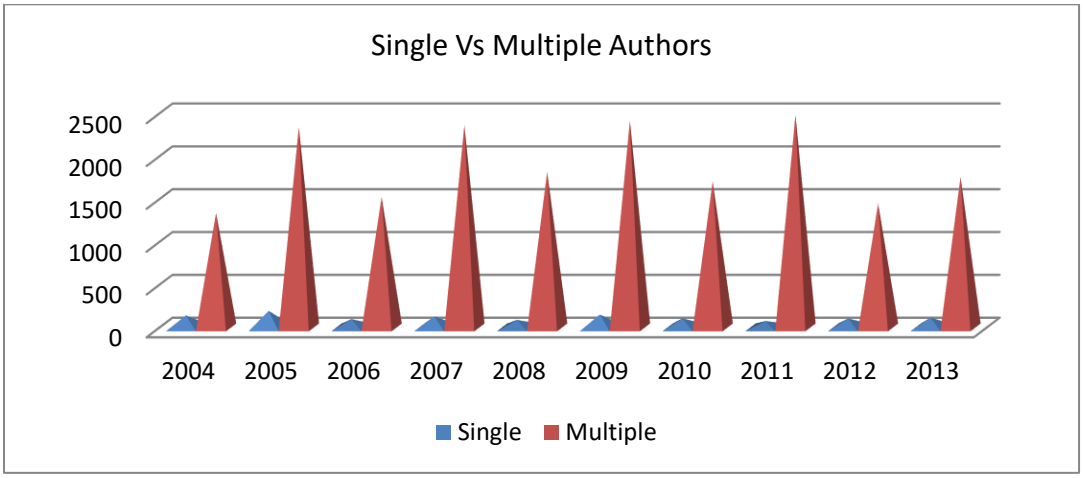
The average value of CC for the output is 0.64. The highest value of CC is 0.68 in 2011 and lowest 0.58 in 2004. However, the value of CC is showing increasing as well as decreasing trend in the two blocks year periods.

5.5 Authorship trend analysis

Table 5 Authorship trend analysis

Single Authors			Multiple Authors		Quantum of Research Output	Degree of Collaboration
Year	**Quantum of Output**	**Percentage**	**Quantum of Output**	**Percentage**		
2004	141	0.69	1338	6.56	1479	0.90
2005	194	0.95	2342	11.48	2536	0.92
2006	97	0.47	1524	7.47	1621	0.94
2007	130	0.64	2364	11.59	2494	0.95
2008	89	0.44	1816	8.90	1905	0.95
2009	151	0.74	2414	11.84	2565	0.94
2010	106	0.52	1706	8.3**6**	1812	0.94
2011	76	0.37	2483	12.1**7**	2559	0.97
2012	106	0.52	1447	7.09	1553	0.93
2013	114	0.56	1757	8.61	1871	0.94
Total	**1204**	**5.90**	**19191**	**94.10**	**20395**	**0.94**

Figure 4 - Authorship Trend Analysis



The Table 5 and figure no-4 present single and multiple authors productivity pattern on yearly basis. A careful examination of the table reveals that the productivity patterns on the cosmic rays are much contributed by multiple authors than the single author since 2004 to 2013. Thus, from this analysis it can be interpreted that basically the cosmic rays research is much dominated by team research. And collaborative research is a phenomenal one.

The Degree of Collaboration of publications of the cosmic rays literature is 0.94. This brings out clearly the prevalence of team research in this field. Out of the total publications 94.10% of contributions were collaborated with multi authorship and 5.90% of contributions were collaboration with single authors.

5.6 Identification of most prolific authors

Table 6 Identification of Most Prolific Authors

Rank	Author	Institutes	No. of publications	Percentage
1	Engel, R	Karlsruhe Institute of Technology, Germany	283	1.39
2	Kampert, K H	Bergische Universität Wuppertal, Germany	265	1.30
3	Roth, M	Karlsruhe Institute of Technology, KIT, Germany	264	1.29
4	Haungs, A	Karlsruhe Institute of Technology, KIT, Germany	253	1.24

5	Horandel, J R	Radboud University Nijmegen, Netherlands	234	1.15
6	Heck, D	Karlsruhe Institute of Technology, KIT, Germany	231	1.13
7	Mathes, H J	Karlsruhe Institute of Technology, KIT, Germany	210	1.03
8	Daumiller, K	Karlsruhe Institute of Technology, KIT, Germany	208	1.02
9	Schieler, H	Karlsruhe Institute of Technology, KIT, Germany	202	1.00
10	Oehlschlager, J	Karlsruhe Institute of Technology, KIT, Germany	202	1.00

Table 6 presents the rank list the authors who have contributed more than 200 articles and more than that who are taken into account to avoid a long list. Most of the authors are from Germany, hence, it can be interpreted that the cosmic rays research has been dominated by the Germany researchers.

It reveals that Engel, R, Karlsruhe Institute of Technology, Germany is the most productive author contributing 283 articles followed by Kampert, K H, Bergische Universität Wuppertal, and Germany with 265 articles and Roth, M, Karlsruhe Institute of Technology, Germany with 264 articles respectively.

5.7 High Productive Institutions

Table 7 High Productive Institutions

Ranks	Institutions	Country	No. of Publications
1	Istituto Nazionale Di Fisica Nucleare, Frascati	Italy	1337
2	University of Tokyo	Japan	869
3	NASA Goddard Space Flight Center	USA	754
4	University of Maryland	USA	616
5	Pn Lebedev Physics Institute, Russian Academy of Sciences	Russia	575
6	Skobeltsyn Institute of Nuclear Physics of Moscow State University	Russia	516
7	California Institute of Technology	USA	489
8	European Organization for Nuclear Research	Switcherland	477
9	University of Chicago	USA	471
10	Universita degli Studi di Roma Tor Vergata	Italy	447

Table 7 shows the institutes that have contributed 400 or more publications on cosmic rays research during 2004-2013. Findings revealed that Istituto Nazionale Di Fisica Nucleare, Frascati, Italy with 1337 publications is the most productive institution in the field of cosmic rays research followed by University of Tokyo, Japan with 869 publications, NASA Goddard Space Flight Center, USA with 754 publications and University of Maryland, USA with 616 publications.

5.8 Highly Productive Countries

Table 8 Highly Productive Countries

Ranks	Country	Total Publications (%)	Ranks	Country	Total Publications (%)
1	USA	8205 (40.23%)	11	Poland	899 (4.41%)
2	Germany	4163(20.41%)	12	Netherlands	845 (4.14%)
3	Italy	3745(18.36%)	13	India	822 (4.03%)
4	Russia	3201(15.70%)	14	Canada	650 (3.19%)
5	Japan	2431 (11.92%)	15	Brazil	625 (3.06%)
6	France	2270 (11.13%)	16	Mexico	557 (2.73%)
7	England	1935 (9.49%)	17	Sweden	531 (2.60%)
8	China	1318 (6.46%)	18	Australia	504 (2.47%)
9	Switcherland	1165 (5.71%)	19	South Korea	464 (2.28%)
10	Spain	1132 (5.55%)	20	Finland	349 (1.71%)

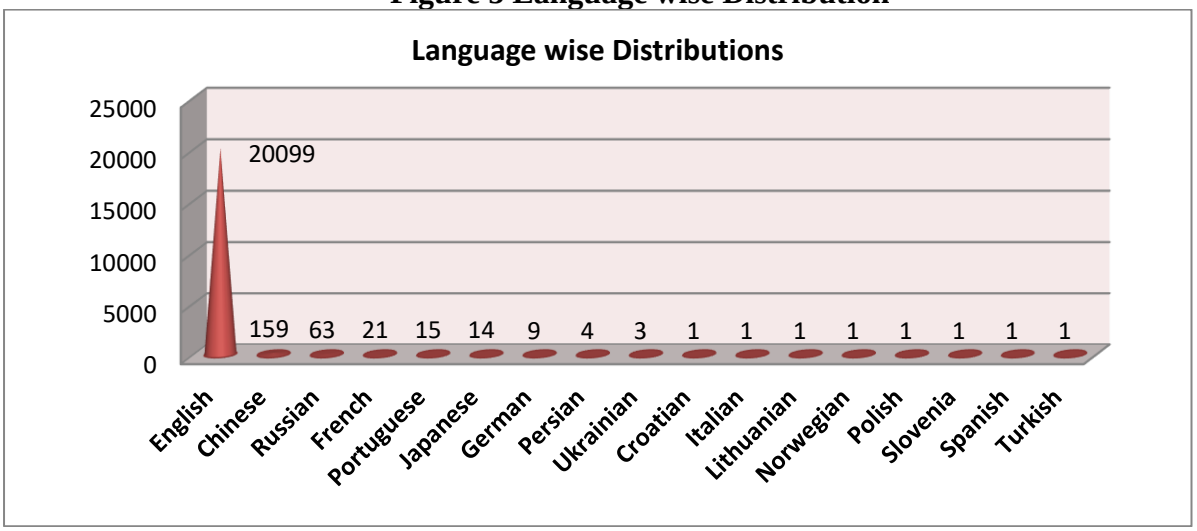
There were 116 countries involved in the research in cosmic rays, however, USA topped the list with highest share (40.23%) of publications. Germany ranked second with 20.41% share of publications followed by Italy 18.36% share of publications, Russia with 15.70% share of publications, Japan with 11.92% share of publications, France with 11.13% share of publications, England with 9.49% share of publications, China with 6.46% share of publications and the remaining countries are publishing less than 6% of the research output in this study period. The publication share of highly productive countries (≥300 publications) on cosmic rays is given in Table 8.

5.9 Language wise Distributions

The study reveals that the maximum number of publications have been published in English language with 20099 publications (98.5%), followed by Chinese language with 159

publications (0.78%), Russian language ranks third position with 63 publications (0.31%). And the remaining languages such as French, Portuguese, Japanese and other languages are constituted in negligible percentage. The English language superiority was found in every year in total productivity of the discipline.

Figure 5 Language wise Distribution



5.10 Most Preferred Source Titles

The conference publications and scientific journals are most important medium of communication in scientific field. To determine the most productive journals and conference publications in this field preferred sources of the cosmic researchers for their publications.

Table 9 Source Title of Publications

Rank	Source Title	Country	No. of Publications	Impact Factor
1	Astrophysical Journal	UK	1614	5.99
2	Astronomy and Astrophysics	France	1270	4.48
3	Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment	Netherlands	1062	1.32
4	Proceedings of the 30th International Cosmic Ray Conference Icrc 2007	Mexico	982	-
5	Proceedings of the 32nd International Cosmic Ray Conference Icrc 2011	China	945	-
6	Proceedings of the 29th International	India	943	-

	Cosmic Ray Conference Icrc 2005			
7	Aip Conference Proceedings	USA	871	-
8	Nuclear Physics B Proceedings Supplements	Netherlands	730	3.95
9	Advances in Space Research	England	725	1.36
10	Astroparticle Physics	Netherlands	633	4.45

The scientific literature on cosmic rays is spread over 2138 different source journals and conference publications. The rank list of top 10 source titles with impact factor is listed in the Table 9. It reveals that Astrophysical Journal, UK tops the list with the highest number of publications 1614 (7.91%) and the impact factor is 5.99, followed by this, Astronomy and Astrophysics, France with a share of 1270 (6.23%) publications and the impact factor is 4.48. Nuclear Instruments and Methods in Physics Research Section. Accelerators Spectrometers Detectors and Associated Equipment occupy the third position with 1062 (5.21%) publications and the impact factor is 1.32. The fourth highest source title is Proceedings of the 30th International Cosmic Ray Conference ICRC 2007, Mexico with 982 (4.81%) publications.

6. Summaries and Conclusion

Cosmic rays play a very predominant role in archaeology, climate change, computes, global warming, solar weather and space travel etc. A lot of research is being carried out all over the world in this field. A total of 20395 publications were published on cosmic rays during 2004-2013 as indexed in the database under study. The single most prevalent form of publications is the Journal articles of 55.51% out of the of the total literature published. The highest number of publications 2,565 (12.58%) were published in 2009. The average number of publications published per year was 2039.5. The value of Co Authorship Index has both increasing and decreasing trend in the two blocks year periods. The highest value of Collaboration Coefficient is 0.68 in 2011 and the average value of Collaboration Coefficient for cosmic rays is 0.64. Out of the total publications 94.10% of contributions were collaborated with multi authorship and 5.90% of contributions were collaboration with single authors.

The Degree of Collaboration of the cosmic rays is 0.94. Engel, R, Karlsruhe Institute of Technology, Germany is the most productive author contributing 283 articles followed by

Kampert, K H, Bergische Universität Wuppertal, and Germany with 265 articles. Most of the authors from Germany, hence, it found that the cosmic rays research has been dominated by Germany researchers. Istituto Nazionale Di Fisica Nucleare, Frascati, Italy topped the list with 1337 publications followed by University of Tokyo, Japan with 869 publications and NASA Goddard Space Flight Center, USA with 754 publications. The USA topped the list with 40.23% share of publications. Germany ranked second with 20.41% share of publications followed by Italy with 18.36% share of publications and Russia with 15.70% share of publications. Astrophysical Journal, UK gets top rank in terms of number of publications and impact factor. However, the contribution of the Indian research towards this research is negligible.

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