

SCIENTOMETRIC ANALYSIS OF LITERATURE ON BLACK HOLES

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Abstract: The study presents a quantitative assessment of research literature on black holes using scientometric methods. A total of 37,776 publications were retrieved from the Web of Science indexing database over a decade, from 2012 to 2021. Scientometric analysis entails the quantitative examination of research publications. The study investigates various scientometric analysis techniques, including document types, year-wise growth of literature on black holes, Performance Efficiency Index (PEI), Relative Citation Impact (RCI), Relative Growth Rate (RGR), doubling time (Dt), most prolific authors, geographical distribution, and keyword occurrences. The maximum number of document types in the form of research articles was 36,018 (95.347%). The maximum number of papers (5,153) was published in 2021. The PEI and RCI decreased, while the Relative Growth Rate (RGR) declined, and the Doubling Time (Dt) increased during the study period. The USA is the highest contributor globally in black hole research publications. Fabian, A. C., is the most prolific author in the black holes research field in the study period. The most occurring keyword is 'Black Holes' from the study period. MS Excel was used to evaluate the gathered data, and VOSviewer software was used for data visualization purposes.

Keywords: Black holes, Scientometric analysis, Relative growth rate (RGR), Doubling time (Dt), PEI & RCI, Web of Science, VOSviewer.

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1. INTRODUCTION

Scientific productivity is frequently measured in terms of research productivity subsequently, the data on the number of publications by the researchers, organizations, and journals can easily be collected and are also generally quite consistent. As a result, the expansion of publications in the fields of economics, management sciences, operational research, mathematics, and statistics has helped to document and implement suitable quantitative measuring methods for evaluating the efficacy and efficiency of researchers. It has controlled to the emergence of concepts like Librametrics, Bibliometrics, Informetrics, Scientometrics, and Webometrics or cybermetrics (Chellappandi, 2018; Arun, 2020).

Scientometrics is a bibliometrics subfield that concerns calculating and analyzing scientific productivity. The co citation evaluation is one of the most valuable quantitative techniques in scientific investigations to plan a way and change aspects of scientific research, (Bram, 1991). Nalimov and Mulchenko originally used the term "scientometric" in 1969. The quantitative aspects of measuring science research literature have grown in popularity and are used to describe the study of science: growth, structure, interrelationships, and productivity.

As the name implies, scientometrics is primarily concerned with the study of novel facets of scientific and technological research output (Hjørland, 1995).

1.1 BLACK HOLES CONCEPT

The idea of black holes in 1916, when Albert Einstein's universal theory of relativity was the first to exploit the presence of black holes. A few decades later, in 1960, American astronomer John Wheeler was the first to propose the black hole model. Black holes have such a tremendous gravitational pull that even light cannot escape from them. It appears to be inevitable that black holes will form as a result of gravitational matter collapse (Tiwari, 1978).

2. REVIEW OF LITERATURE

(Sudhier, 2010) analyzed journals cited by physics scientists at the Indian Institute of Science (IISc) in Bangalore to evaluate the pertinence of Bradford's Law of Scattering, which involved 690 publications covering 11,319 bibliographies composed by 79 PhD theses from 2004 to 2008. Prepared for a ranked journals list and Physical Review B with 9.53% citation, followed by Physical Review A with 7.69%. and the Astrophysical Journal with 5.47% of received citations in the researchers' preferred journals. (Zheng, 2011) investigated the highly-cited articles in physics data and collected 15,44,205 articles from the Web of Science database during 1979–2008. A notable fact is that the 5 highly productive Japanese researchers are not matched by the 5 highly productive institutions, which are all located in the USA The University of Tokyo is one of the top 11 universities, and the only single-author publications in the top 19 are written by Americans. The highly cited papers are scattered across 25 categories of subject. The physics papers, multidisciplinary in nature, are the most cited, with 424 articles, and are the number one category in total articles, followed by physics. (Bala, 2014) critically analyze 316 scholarly communications published in the Indian Journal of Biochemistry & Biophysics. NISCAIR publishes the peer-reviewed open-access monthly journal. The number of articles, the kinds of publications cited, the most cited sources or journals, etc., were the main topics of the study. 18 (5.7%) single-

author publications were examined in the study, whereas 162 (51.3%) articles had multiple authors. India's journal publications are marginally more numerous than those of the other nations. (Santha, 2016) analyzed the world perspective on Atomic Physics data retrieved from the WoS database from 2004 to 2013. The database includes 29402 atomic physics research productivity. With a maximum of 6099 documents and an average number of papers per year (APPY) of 2940.2, scientific research publications reached their peak in 2008. Between 2005 and 2012, the Compound Annual Growth Rate (CAGR) publications value dropped from 0.58 to 0.33. The Collaboration coefficient on research articles in atomic physics has an average value of 0.63. According to the study, over 5% of papers have been traced by a single author, but 94.40% of papers have multi-authorship publishing.

(Sangam, 2019) conducted a scientometric analysis using data taken from the WoS database in 2001–2016 literature on global warming and climate change. Growth trend, authorship pattern, collaborative index, collaborative coefficient, degree of collaboration, form division, most preferred authors, and productivity by country were among the many characteristics that were examined in this study.

Single- authored contributions decreased as multi-authored contributions increased and the number of publications frequently increased year over year. There has been an increase in both the level of multi-author collaboration and collaborative efficiency. The doubling time for climate change between 2001 and 2016 is 0.98 and 4.36, respectively, and the relative growth rate of climate change publication production is increasing. (Kappi, 2020) have conducted a bibliometric study on Optics research outputs in India during 2015-2019. The information, which included 5318 publications in total, was taken from the SCOPUS indexing database. The research output of various research institutions in India, as well as the research literature landscape in international journals, was also evaluated in the article. (Vijaya, 2021) investigated the Scientometric analysis of astronomy research performance from 2010 to 2019. The WoS indexing database yielded 6905 research publications in total. The highest with 861 (12.47%) papers published in 2018, and the

Table 1: Document types - wise distribution of publications

Sl. No.	Document Types	TP	Percentage	TC	ACPP	h-index
1.	Article	36018	95.347	1234093	34.263	837
2.	Review Articles	837	2.216	103842	124.064	145
3.	Proceedings Papers	309	0.818	4833	15.641	28
4.	Editorial Materials	272	0.72	1725	6.341	18
5.	News Items	170	0.45	62	0.364	4
6.	Letters	64	0.169	314	4.906	6
7.	Book Reviews	53	0.14	1	0.018	1
8.	Book Chapters	52	0.137	23565	453.173	38
9.	Data Papers	1	0.003	5	5	1
Total		37,776	100	13,68,440	36.225	

researcher’s degree of collaboration ranges from 0.66 to 0.78 in the field of astronomy from the study period. The maximum value of Annual Growth Rate (AGR) is 0.14 in 2011, with 582 publications. The mean value of the degree of collaboration with 0.71. The most prolific author, Katz, U from the USA, published 38 papers and highest Average Citations Per Paper (ACPP) and h-index. The most contributed country is the USA with 2554 (36.99%) articles related to the output of astronomical research throughout the study period.

3.OBJECTIVES OF THE STUDY

The main objectives of the study are to find out:

- i. To examine the selected document types of literature on Black Holes;
- ii. To identify the year-wise growth and productivity, including PEI and RCI indices;
- iii. To examine the relative growth rate (RGR) and doubling time (Dt) of the literature on Black Holes;
- iv. To identify the most prolific authors and
- v. To identify the top 10 countries in Black Holes research productivity.

4.METHODOLOGY

Over the course of the ten-year study period, from 2012 to 2021, the necessary data were gathered from the Web of Science database. Originally created by the Institute for Scientific Information (ISI), the subscription-based online scientific citation indexing service Web of Science (previously Web of Knowledge) provides a comprehensive citation search. articles related

to the output of astronomical research throughout the study period. It is currently maintained by Clarivate Analytics, formerly Thomson Reuters’ Intellectual Property and Science Business (Keshava, 2020). It can be reflected in the 37,776 publications collected on 8th April 2022 on black holes research literature. All the publications were analyzed based on research data, i.e., document types, year-wise growth of publications, PEI, RCI, relative growth rate (RGR) and doubling time (Dt), most productive authors, countries, and keyword occurrences. The study reflected data were measured by MS Excel and VOSviewer software.

5.DATA ANALYSIS AND INTERPRETATIONS

5.1 Document types-wise distribution of publications

Table 1 shows that the highest number of document types, in the form of an article, was 36,018 (95.347%), with 12,34,093 citations received and 837 h-index. Followed by the review articles with 837 (2.216%) publications with 145 h-index instead of 1,03,842 citations. Proceedings papers with 309 (0.818%) records secured with 3rd position, but only 52 publications in the form of book chapters received a good number of citations with 23,565, and the highest ACPP with 453.173. Followed by Editorial Materials with 272 (0.72%) records, News Items with 170 (0.45%), letters with 64 (0.169%), book reviews with 53 (0.14%), and data papers 1 (0.003%) record respectively.

Table 2: Year-wise growth of publications

Year	Publications	Percentage	Total Citations	PEI	RCI
2012	2781	7.36	126142	1.252	1.252
2013	2915	7.72	125168	1.185	1.185
2014	3139	8.31	151467	1.332	1.332
2015	3320	8.79	134855	1.121	1.121
2016	3637	9.63	161935	1.229	1.229
2017	3797	10.05	150287	1.092	1.092
2018	4102	10.86	138364	0.931	0.931
2019	4250	11.25	137257	0.891	0.891
2020	4682	12.39	135522	0.799	0.799
2021	5153	13.64	107443	0.575	0.575
Total	37776	100	1368440	1	1

PEI= Performance Efficiency Index, RCI=Relative Citation Impact

Table 3: Publications’ relative growth rate (RGR) and doubling time (Dt)

Year	Publications	CP	W1	W2	RGR	Mean RGR	Dt	Mean Dt
2012	2781	2781	0	7.93	0	0.260	0	2.761
2013	2915	5696	7.93	8.647	0.717		0.966	
2014	3139	8835	8.647	9.086	0.439		1.578	
2015	3320	12155	9.086	9.405	0.319		2.172	
2016	3637	15792	9.405	9.667	0.262		2.645	
2017	3797	19589	9.667	9.882	0.215		3.223	
2018	4102	23691	9.882	10.072	0.190		3.647	
2019	4250	27941	10.072	10.237	0.165		4.200	
2020	4682	32623	10.237	10.392	0.155		4.470	
2021	5153	37776	10.392	10.539	0.147		4.714	
Total	37776							

5.2 Year-wise growth of publications

Table 2 represents the growth of publications on black holes research productivity over 10 years from 2012 to 2021. During the study period, 37,776 documents were published in total. The greatest quantity of publications, 5,153 (13.64%), was published in 2021, followed by 2020, i.e., 4,682 (12.36%). In the year 2019, there were 4250 (11.25%) publications, followed by 2018, i.e., 4102 (10.86%) publications, followed by 2017, i.e., 3797 (10.05%). In the year 2016, there were 3637 (9.63%) followed by 2015, i.e., 3320 (8.79%) publications followed by 2014 i.e. 3139 (8.31%) in the year 2013, there were 2915 (7.72%) publications and 2781 (7.36%) documents are published in the year 2012.

The highest number of 1,61,935 citations received in 2016, and a total of 13,68,440 citations received

from the study period. Both the Performance efficiency index and the Relative citation impact are to have equal value from the respective study.

5.2.1 Performance Efficiency Index (PEI)

The performance efficient index in metric studies is calculated to assess the efficiency and research publications of each productivity. Where,

$$PEI = \frac{\text{TotalPublications}/\text{Publeationspresntyear}}{\text{TotalCitations}/\text{Citationspresentyear}}$$

5.3 Relative Citation Impact (RCI)

The relative citation impact value of various research explored and its position in the order of proof are later discussed. Hence, using this study, minimal information about the relative citation impact. The RCI is measured by the end of the previous year, then the current year of

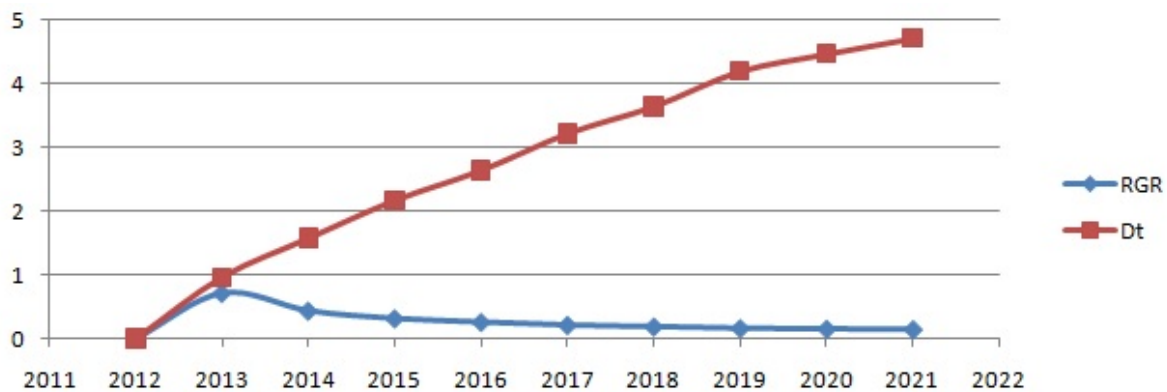


Figure 1: Relative Growth Rate and Doubling Time

Table 4: Most productive authors (Top 20)

S. No.	Name	Affiliation	Publications	%	TC	h-index
1	Fabian A C	University of Cambridge, England	301	9.017	15016	59
2	Stern D	NASA JPL, USA	246	7.37	12677	57
3	Ho L C	Kavli Institution of Astronomy & Astrophysics, China	210	6.29	10381	48
4	Walton D J	University of Hertfordshire, England	195	5.84	8796	48
5	Brandt W N	PCSHE, US	182	5.44	8117	48
6	Miller J M	University of Michigan, USA	169	5.07	7675	45
7	Harrison F A	California Institute of Technology USA	164	4.91	9364	48
8	Wang Y	Georgia State University, US	158	4.74	8446	46
9	Zhang L	Hong Kong Polytechnic University, Hong Kong	157	4.7	6358	37
10	Chen Y	University of Utah, USA	156	4.68	5119	36
11	Bambi C	Eberhard Karls University of Tübingen	154	4.61	3436	34
12	Vignali C	INAF Italy	152	4.55	2266	26
13	Stuchlik Z	Silesian University, Opava	144	4.32	4457	38
14	Gandhi P	University of Southampton, England	142	4.25	3220	32
15	Cardoso V	University of Amsterdam	139	4.17	7248	48
16	Greene J E	Princeton University, USA	136	4.074	6895	48
17	Loeb A	Smithsonian Institution, USA	136	4.075	4186	36
18	Miller Jones JCA	Curtin University, Australia	134	4.02	3276	35
19	Oshaughnessy R	Rochester Institute of Technology, USA	132	3.95	32603	62
20	Mann R B	University of Waterloo, Canada	131	3.93	5589	36

Israel and the Netherlands.

Table 5: Geographical distribution of publications (Top 20)

S. No.	Country	Publications	%
1	USA	13206	20.66
2	China	6531	10.21
3	England	5542	8.67
4	Germany	5403	8.45
5	Italy	4283	6.7
6	France	3078	4.81
7	Japan	2942	4.6
8	India	2825	4.42
9	Canada	2689	4.22
10	Spain	2681	4.19
11	Netherlands	2325	3.63
12	Chile	1780	2.78
13	Russia	1753	2.74
14	Australia	1696	2.65
15	Brazil	1451	2.27
16	South Korea	1232	1.92
17	Iran	1206	1.89
18	Switzerland	1196	1.88
19	Poland	1080	1.69
20	Israel	1030	1.62

5.8 Most occurred keywords network map

Figure 4 shows the keywords occurrences network map visualized by the VOSviewer software from all the selected publications from the study period. The most used keyword is 'black holes' with 4,572, and the total link strength is 22,452. The remaining most used keywords are thermodynamics, having radiation, entropy, etc.

6. CONCLUSION

37,776 publications on black hole literature that were indexed in the Web of Science database between 2012 and 2021 were evaluated for this study. There is an increasing trend of publications from the year-wise, and the list of articles contains the most published documents. The highest number of documents, 5,153, was published in 2021. The PEI and RCI values are equal as per the scientometric method in this study. The relative growth rate decreased from 0.717 to 0.147 from 2013 to 2021, and in 2021, the doubling time was 4.714, up from 0.966 in 2013. Globally, Fabian,

A. C. is the most prolific writer, followed by Stern, D., and Ho, L.C. in the 2nd and 3rd position in that order. It is also found that the authors Walton, D J and Brandt, W.N. secured the top 4th and 5th ranked productivity, respectively, in black hole literature. The United States and China rank first and second, respectively, according to the geographic distribution of publications. India came in at number eight with 2,825 publications on black hole literature, while England came in third with 5,542 articles. This demonstrates the active participation of Indian institutions and scientists in black hole research.

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