Scientometric Analysis of Literature on Black Holes in J-Gate: The World Perspective

Parameshappa Kenchakaller
Research Scholar Dept. of P. G. Studies and Research in LIS Kuvempu University,
Jnana Sahyadri Shankaraghatta-577451
Karnataka, India,
E-Mail: parameshmlisc2009@gmail.com

B S Biradar
Professor Dept. of P. G. Studies and Research in LIS Kuvempu University,
Jnana Sahyadri Shankaraghatta-57745,
Karnataka, India,
E-mail: bsbiradar53@rediffmail.com

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Abstract: *The contemporary study inspects the research output literature on "Black Holes" data as retrieved from the J-Gate database during 2007-2021. The total of 38,481 publications analyzed through various scientometric techniques such as annual growth rate, most productive journal, most prolific authors, most cited papers from SJR ranking, geographical distribution, and most frequently occurring keywords of research productivity are all examined in this study. The study conceded only journal articles and a few theses the year-wise publications are to be increased year by year, and the annual growth rate is also to be increased but decreased in 2016. The most productive journal is Physical Review D, with 6042 publications (29.56%). The research outputs in the top 12 sub research areas range from 1240 to 23,887 publications. The highest number of papers published in America was by Fabian A. C. from Cambridge University. The paper Galactic Center, Massive Black Hole, and Nuclear Star Cluster by Reinhard Genzeland Frank Eisenhauer et al. have received 934 citations with 31.1 TCPY. It also identified the UK and USA as having contributed the most articles on black holes research, in this list, India was secured in 6th place, and the visualization purposes used VOSviewer software.*

Keywords: Scientometric Analysis, Black Holes, Research Output, J-Gate Database, Annual Growth Rate (AGR).

Introduction

The perceptions of scientometric and bibliometric analysis are similarly used and the most useful in the field of LIS (Library and Information Science) subject research. The major groups of science parameters for the aim level are determined by research productivity, publication impact, and other scientometric or bibliometric dimensions. Several broad bibliometric studies of the most relevant field sciences have been conducted over the last two decades. The word bibliometric was introduced by Alan Pritchard in 1969 and defined as "the application of mathematical and statistical methods to books and other media of

communication." Nalimove and Mulchenko (1969) introduced the word "scientometrics" to improve "the quantitative aspects of the research on the development of science in an information process". This makes it worthwhile to continue researching the quantifiable aspects of science and technology.

Concept of Black Hole

The black hole concept, Albert Einstein first predicted the existence of black holes in 1916, with his general theory of relativity. The term "black hole" was first coined many years later, in the 1960s, by American astronomer John Wheeler. Black holes are regions of space-time where the gravitational field is so strong that not even light can escape. The Nobel Prize in Physics will be awarded to three scientists in 2020 for their work on black hole research, and we have been chosen for this field. After getting the Nobel Prize for literature on black holes, the researcher was also very interested in and involved in this field (Bakkenes & Theo, 2010).

Review of Literature

Gajanan Khiste, et al. (2018): discussed the “Big Data” as reflected in the J-Gate database during from 2013–2017. The paper investigates the highest productive authors. The study is also aims to identify the most prolific authors, subject area, source type, etc., (Baldock & Colin, 2009). The result shows that there was total 8930 Articles on Big Data during the study period. The result shows that USA and UK are the most productive countries in the area of Big Data Analytics (Das & Anup, 2022). Sidlingappa M. Huded et al. (2019): From 2010 to 2019, this study examined "Data Mining" reveals from the J-Gate database. In the respective field, 6107 papers had been published. The result indicates that India and the USA published the most papers (Egghe & Leo, 2006). A maximum number of papers were published in the field of information science and systems. During the study period, Jason H. Moore of the University of Pennsylvania in America published the most papers. Rajeswari and K. Praveena (2019): analyzed the research productivity on "Digital Literacy" for 10 years from 2009 to 2018 and considered the J-Gate database (Garg& Priya, 2022). This study examines the journals source, year wise growth, geographical distribution, subject wise, RGR and Dt. In 2018, the maximum number of publications was 261 (16.30%). The arts and humanities contribute the most (849, or 53.03%). Satish Kumar (2020): examined a total of 20,311 research outputs on astronomy and astrophysics research in India collected from the WoS database between 1988 and 2021 (Kademani & B S, 2007). The research identifies India's publication pattern, CAGR, degree collaboration, and h-index, as well as research growth, types of documents, open access publications, most productive journals, country-wise collaborations, funding organizations, most highly contributing institutions, and most prolific authors. Mariyam Ashai et al. (2021): they employ bibliometric techniques in the study of astronomical objects, taking into account 93 records from the Scopus database (Kappi, et al., 2021). The study examines the most prolific authors, affiliations, geographical areas, and funding agencies. The research outputs selected as research papers, conference papers, researchers' reviews, etc. Finally, they used Gephi, Vosviewer and Science Scape software for the purpose of doing visualization work. Mallikarjun Kappi. et al. (2021): have shown that the study followed the research productivity with CPEPA status in universities during 2010-2019 as reflected in a total of 8952 records from the WoS database (Sahoo, et al., 2021). The total of three universities has been nominated such as Karnatak University, Dharwad, Bangalore University, Bangalore, and the University of Mysore, Mysore. This study examined journal articles, conference papers, and book chapters. The University of Mysore had the highest research productivity. This paper was chosen because multi-authored and highly cited papers account for the majority of publications (Said Sife& Edda, 2014). The

most prolific authors, ACPP, most frequently occurring keywords, and journals were identified. Finally, they used VOSviewer and Bibliometrix R-package software for the purpose of visualization (Table 1).

Table 1: Summary of the Study

Particulars	**Records**
Timespan	2007-2021
Journal Articles	38428
Thesis	53
Average publications from year	6.66
Document types	**Records**
Journal Articles	38428
Thesis	53
Total	**38481**

Objective of the study

- To identify the selected annual growth rate models;
- To identify the highly productive journals which are preferred by the scientists;
- To identify most productive authors in the field of black holes research;
- To study most impact of papers and their focus of research;
- To identify the country wise distribution of research and
- To identify the Most Occurred Keywords Analysis.

Methodology

The present study data was retrieved from the J-Gate database for 15 years of research publications, i.e., from 2007 to 2021 (Wang& Fakhar, 2022). The J-Gate database was introduced in 2001 by Informatics India Ltd. J-Gate is an e-resources gateway to the world's electronic journal literature. J-Gate provides unified access to a sufficient number of journal articles. The J-Gate policy has a simple, in built and easy to use interface, and also provides users complete control over search filters. By permitting users to access content from a wide variety of subjects as well as publishers on a single platform, J-Gate exponentially increases journal usage. It is reflected in the 38,481 publications on black holes research output collected on August 2022. A total of 38,481 publications were analyzed based on research data and used for scientometric techniques, i.e., document types, annual growth rate of publications, most productive journals, authors, subjects, countries, most occurred key words etc. The retrieved data were examined using Microsoft Excel, and for visualization purposes, the VOSviewer open-source tool was used.

Results and Discussion

Year wise growth of publications

The table 2 depicts the increase in research publications on black holes over a 15 years

period, from 2007 to 2021. A total of 38,481 research publications were published during the study period. The highest number of productivity publications, 4,222 (10.97%), were published in 2021, followed by 2020, i.e., 3,785 (9.84%). The number of publications in 2019 was 3,620 (9.41%), followed by 3,386 (8.80%) in 2018, and 2,668 (6.93%) in 2017. There were 2484 (6.46%) fewer publications in 2016, compared to 2015 (i.e., 2,489 (6.47%) publications) and 2014 (i.e., 2,316 (6.02%) publications). In 2013, there were 2,194 (5.70%) publications, and 2,075 (5.39%) documents were published in 2012. The years from 2007 to 2011 saw the total publications, with over 1,679 (4.36%) (Table 2).

Table 2: Year wise Growth of Publications

Year	Publications	Publications (%)	Cumulative Publications	Cumulative %
2007	1679	4.36	1679	0.64
2008	1850	4.81	3529	1.35
2009	1886	4.90	5415	2.08
2010	1901	4.94	7316	2.81
2011	1926	5.01	9242	3.55
2012	2075	5.39	11317	4.34
2013	2194	5.70	13511	5.19
2014	2316	6.02	15827	6.08
2015	2489	6.47	18316	7.03
2016	2484	6.46	20800	7.99
2017	2668	6.93	23468	9.01
2018	3386	8.80	26854	10.31
2019	3620	9.41	30472	11.70
2020	3785	9.84	34259	13.15
2021	4222	10.97	38481	14.77
Total	**38481**	**100**		

Annual Growth Rate (AGR)

The basic idea of publication growth, the number of research papers published for the study period from 2007 to 2021, is shown in table 3. The study totaled 38,481 published research productivity with an average of 6.53%. This table clearly shows that the year from 2007 to 2015 saw an increase in publication growth, but the year 2016 saw a decrease in publication growth. The maximum annual growth rate (AGR) is noted in 2018 at 26.91%, followed by 2021 at 11.55%. This AGR is measured using the equation provided by Kumar and Kaliya Perumal in 2015, which is described below as follows (Table 3 and Figure 1).

$$R = \frac{P1 - P0}{P0} \times 100$$

Where,
R = Publications annual growth rate (AGR) in%
P0 = Number publications in the base or previous year

P1 = Number of publications in the present year

Table 3: Annual Growth Rate (AGR)

Year	Publications	Growth Rate	AGR percentage (%)
2007	1679	0	0
2008	1850	171	10.18
2009	1886	36	1.95
2010	1901	15	0.8
2011	1926	25	1.32
2012	2075	149	7.74
2013	2194	119	5.73
2014	2316	122	5.56
2015	2489	179	7.47
2016	2484	-5	-0.2
2017	2668	184	7.41
2018	3386	718	26.91
2019	3620	234	6.91
2020	3785	165	4.56
2021	4222	437	11.55
Total	**38481**	**2549**	**97.89 Average=6.53**

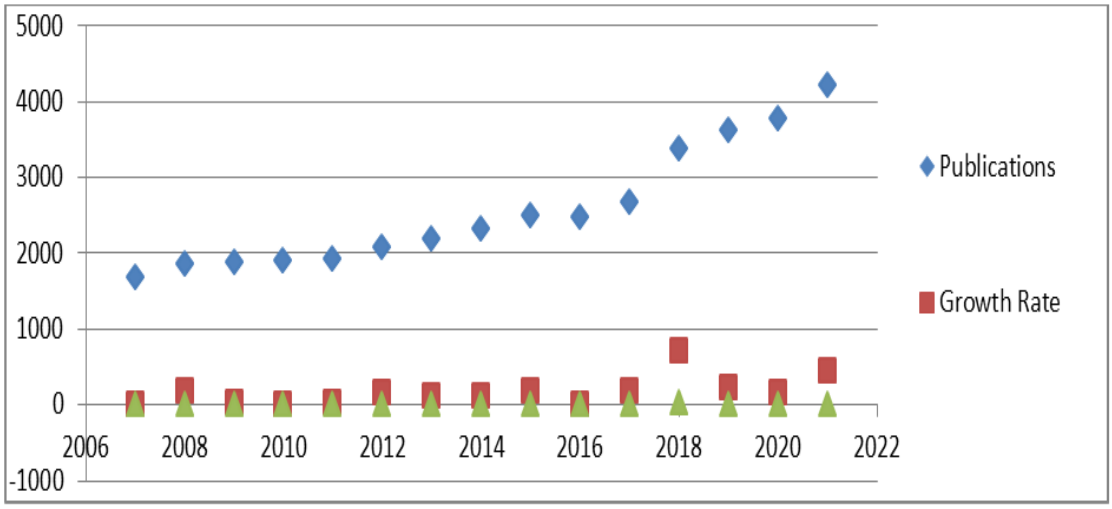

Figure-1: Annual growth Rate (AGR). ***Note:*** *Publications, Growth rate*

Most productive journals

The most productive journals on black holes research during the period of study are shown in table 4. Data analysis for the distribution of black holes research output. The most productive journal is Physical Review D, with 6,042 publications (29.56%) followed by the Journal of the Royal Astronomical Society, with 3,665 publications (17.93%), and the Astrophysical Journal, with 3,465 publications (16.95%). Followed by journal of high energy with 1564 publications (7.65%), followed by physical organic chemistry with 1111 papers (5.43%), and classical and quantum gravity 1097 papers (5.37%) The remaining five journals are among the top ten journals have contributed with below one thousand publications. Also identified in this study journal impact factors like Cite score, SNIP score and SJR 2021 score (Table 4).

Table: 4 Most Productive journals (Top 10)

Journal Name	Publications	Percentage (%)	Cite Score	SNIP Score	SJR-2021
Physical Review-D	6042	29.56	9.4	1.23	1.68
Royal Astronomical Society	3665	17.93	9.6	1.00	1.68
Astrophysical Journal	3465	16.95	9.5	1.1	1.9
Journal of High Energy	1564	7.65	10.4	1.25	0.9
Physical Organic Chemistry	1111	5.43	3.7	0.63	0.34
Classical and Quantum Gravity	1097	5.37	6.5	1.11	1.34
Astronomy and Astrophysics	963	4.71	2	0.67	0.40
Physics Letters B: Nuclear Physics and Particle Physics	947	4.63	2.8	0.51	1.75
Astrophysics Journal Letters	925	4.52	N/A	N/A	N/A
International Journal of Modern Physics-D	664	3.25	4.6	0.72	0.72

Most prolific authors and affiliation

Table 5 shows the top 20 most prolific authors in the black holes research area over the study period. The data contains 20 authors with 74 or more articles each. This table shows that Fabian A. C., of the University of Cambridge in England, is the most productive author, with 176 publications, followed by Vitor Cardoso, of the University of Amsterdam, with 132 articles, and Luis C. Hu, of the University of Antioquia, with 127 articles, in this order. It was also discovered that the authors Cosimo Bambi from EberhardKarls University of Tubingen with 118 papers and Abraham Loeb from Harvard University Astrom Dept. Cambridge, USA with 112 papers had the top 5th position. Followed by Emanuele Berti John Hopkins University, Maryland from USA with 110 papers, tracked by Eugen Radu Aveiro University, Portugal with 106 papers and Sahar Hod from Ruppin Academy Centre, Israel, with 103 papers. The remaining authors are more secured than those from 9th to 20th of the list and

have contributed below one hundred publications in the field of black holes research, respectively (Table 5).

Table 5: Most Prolific Authors (Top 20)

Author	Affiliation	Publications
Fabian A C	University of Cambridge, England	176
Vitor Cardoso	University of Amsterdam	132
Luis C Hu	University of Antioquia	127
Cosimo Bambi	Eberhard Karls University of Tubingen	118
Abraham Loeb	Harvard University Astrom Dept. Cambridge, USA	112
Emanuele Berti	John Hopkins University, Maryland USA	110
Eugen Radu	Aveiro University, Portugal	106
Sahar Hod	The Ruppin Academy Centre, Israel	103
Genny E Greene	Princeton University, USA	90
Ramesh Naryan	Harvard University Astrom Dept. Cambridge USA	90
J M Miller	University of Dalware, Newyork USA	84
Paolo Pani	Sapienza University Rom, Italy	83
Robert B Mann	University of Waterloo, Canada	83
Jiliang Jing	Hanan Normal University, China	80
Jutta Kanz	University of Oldenburg, Germany	77
Yun Soo Myung	Inje University, South korea	77
Mark A Scheel	Cornell University, Newyork USA	76
W N Brandt	Penn State University, USA	76
Enrico Barausse	Sissa, Italy	74
Marta Volonteri	National Centre for Scientific Research, French	74

Subject area of research

The whole publication in the black holes field has been divided into several sub-disciplines. Table 6 shows the top 12 subject areas in the field of black holes. The research outputs in the top 12 sub research areas range from 1,240 to 23,887 publications. The assessment of black holes research contribution indicates that 23,887 of the total documents are published in

Astrophysics, consequently Particles Physics fields 10682 documents and Astronomy 8,912 publications. The nuclear physics which was total of 5,287 papers, followed by applied physics 4472 papers, followed by mathematical physics 3017 papers and relativity with 3832 papers. The list shows remaining subjects are published in other sub research areas (Table 6).

Table 6: Subject Area of Research (Top 12)

Subject	Publications
Astrophysics	23887
Particle Physics	10682
Astronomy	8918
Nuclear physics	5287
Applied physics	4472
Mathematical Physics	3917
Relativity	3832
Plasma Physics	2148
Energy	2000
Optics and Opto Electronics	1765
Instrumentation	1758
Electronics	1683

Most cited papers (Top 10)

The table 7 represent the top 10 most cited research article of the black holes research output. This table indicates that highly cited papers determine the relevance of the SJR ranking in form of title, authors, countries, total citations, total citations per year, SJR ranking, and h-index, as reflected in the J-Gate database. All 10 papers have been published under different titles and have received more than 30 citations. The paper Galactic Center, Massive Black Hole, and Nuclear Star Cluster by Reinhard Genzeland Frank Eisenhauer et al. have received 934 citations with 31.1 TCPY, followed by Quasinormal modes of black holes: from astrophysics to strong theory by R A Konoplya and Alexander Zhidenko with 834 citations and 27.8 TCPY and Testing Black Hole Candidates with Electromagnetic Radiation by Cosimo Bambi with 216 citations and 7.2 TCPY. The entropy of hawking radiation by Ahmed Almheiri and Thomas Hartman (et al), from USA 213 citations, followed by origin of the heaviest elements: the rapid neutron capture process by John J Cowan and Christopher Sneden (et al) from USA with 183 citations, followed by Mimicking black event horizons in atomic and solid-state systems by Marcel Franz and Moshe Rozali from Canada, with 44 citations and TCPY 11. The list shows that the remaining papers are cited in other papers (Table 7).

Table 7: Most Cited Papers (Top 10)

Title of the Paper	Author	Country	TC	TCPY
The galstic center massive black hole and nuclear star cluster	Reinhard Genzel and Frank Eisenhauer et. al.	Germany	934	77.83
Quasinormal modes of black holes: from astrophysics to strong theory	Konoplya R A and Alexander Zhidenko	Germany	834	75.81
Testing black hole canditates with electromagnitic radiation	Cosimo Bambi	Germany	216	19.84
The entropy of Hawking Radiation	Ahmed Almheiri and Thomas Hartman et. al.	USA	213	213
Origin of the heaviest elements: the rapid neutron-capture process	John J Cowan and Christopher Sneden et. al.	USA	183	183
Mimicking black event horizons in atomic and solid-state systems	Marcel Franz and Moshe Rozali	Canada	44	22
Looking at cosmic near-infrared background radiation anisotropies	A Kashlinsky and R G Arendt et. al.	USA	44	11
Jerusalem lectures on black holes and quantum information	D Harlow	USA	34	5.66
Light rays, singularities, and all that	Edward Witten	USA	30	1
Large D limit of Einstein's equations	Roberto Emparan and Christopher P Herzog	Spain	30	15

TC= Total Citations, **TCPY**= Total Citations per Year

Most cited authors and co-authors

Figure 2 shows the most cited authors and co-authorship network papers with at least 30 citations. A minimum of 100 publications were chosen from 38,481 records for this visualization. The dimension of the rotations indicates the total citations received for each title and colors (Figure 2).

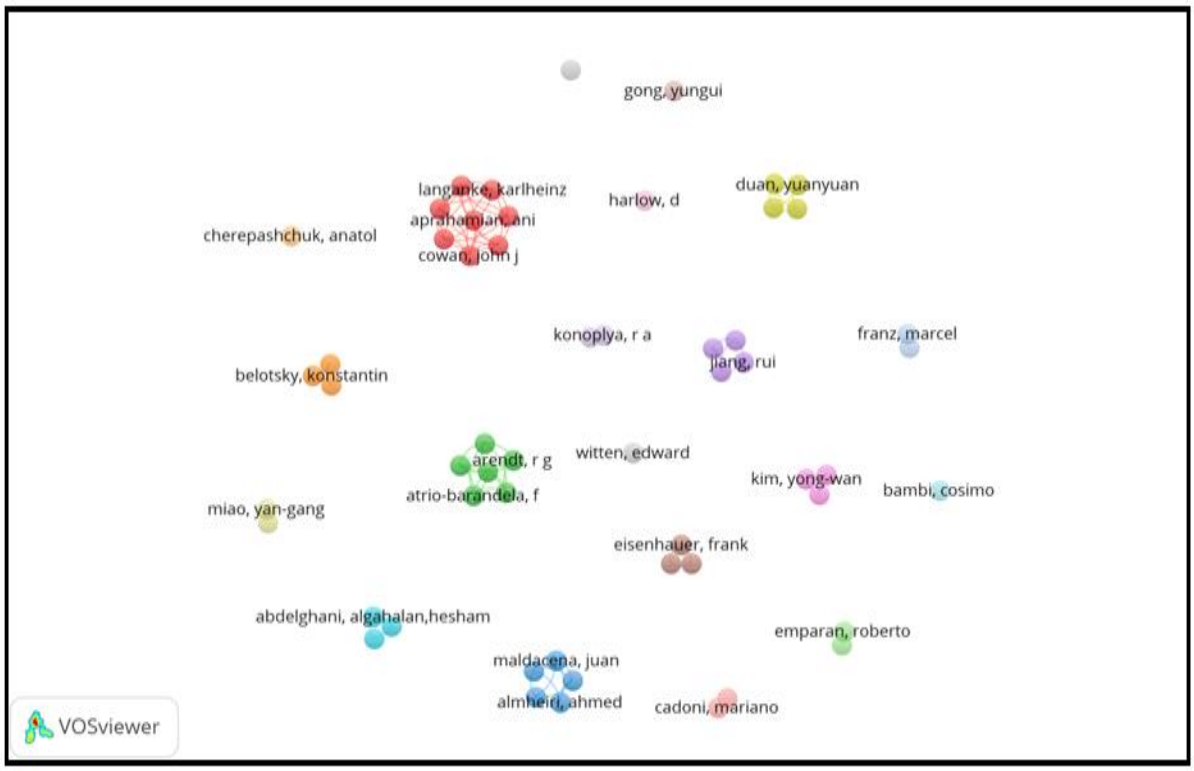

Figure-2: Most Cited Authors and Co-Authorship Papers Network Map

Geographical area wise distribution of publications

Table 8 shows the distribution of the top 10 most contributed countries in the field of black hole research output. It was exposed in this table, that the UK to Italy. The top ten nations contributed research literature during for the study period, with the United Kingdom taking first place with 14,099 publications, followed by the United State America with 10,679 publications. Germany is third place from the list with 5,053 papers, followed by Netherlands with 2,604 papers in 4th rank, followed by Singapore with 1,682 publications in 5th position and India is 6th position with 1,385 publications from the study period on black hole research literature. The remaining countries contributed more than 100 publications over the period of study (Table 8).

Table 8: Geographical Area Wise Distribution of Publications (Top 10)

Country	Publication	Rank
UK	14099	1
USA	10679	2
Germany	5053	3
Netherlands	2604	4
Singapore	1682	5
India	1385	6
France	1130	7
Switzerland	622	8
Canada	184	9
Italy	106	10

Most occurred keywords analysis

The keyword "co-occurrence" can successfully reflect the key research points on the subject of black holes and provide support for scientific research. To determine the relevance of the SJR ranking, we only considered 100 documents in the J-Gate database; the minimum number of occurrences of a keyword is five; we received a total of 100 keywords, and 17 meet the threshold from the study period. The number of keywords to be selected is 17 in Figure 3. The size of the node and the word in Figure 3 indicate the strength of the node. VOSviewer splits all keywords in publications into 5 clusters. The term "black holes" appears the most frequently in the research field, with a total of 21 occurrences. Other high-occurrence totals of 15 keywords include "Astrophysics," and "Quasars," with 10 keywords each, "Gravitational Waves," with 8 keywords, and "Astronomy," with 5 keywords. The strength of the link among two nodes refers to its occurrence. It can be used as a quantitative display of the link among two nodes (Figure 3).

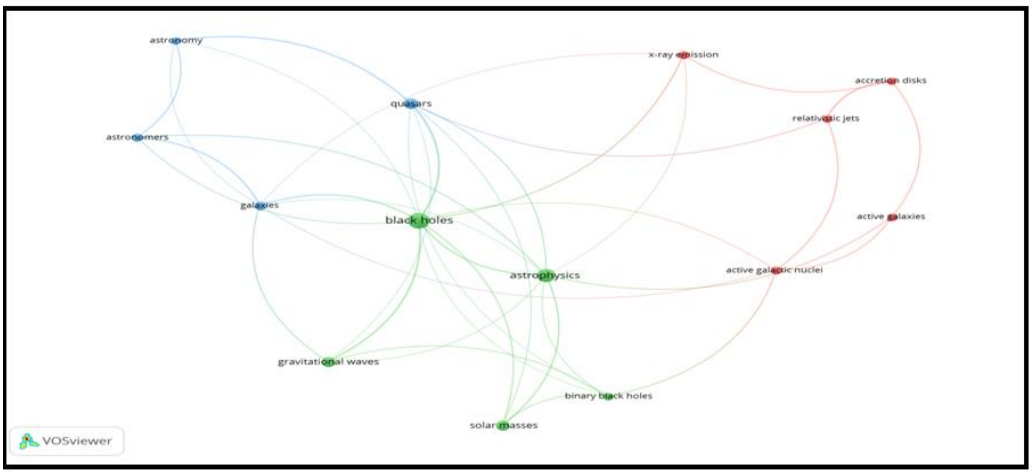

Figure-3: Most Occurred Keywords Network Map

Conclusion

This paper has assessed 38,481 publications on black holes research output, and their analyses in the J-Gate database from 2007 to 2021. There has been a growing trend of publications over the year, and the maximum number of documents is published in the list of articles. The highest productivity number, 4,222, was published in 2021. From 2007 to 2021, the annual growth rate increased from -5 to 718, with an average growth rate percentage of 6.53. The most productive journal is Physical Review D, with global level Fabian A C as the most productive author. The maximum number of publications in the subject area of research is astronomy, and the most cited paper is Galactic Center Massive Black Hole and Nuclear Star Cluster. The country wise distribution of publications shows the UK and USA in the 1st and 2nd ranks in that order. Germany has secured the 3rd rank by publications, and India has secured the 6th place on the list, with publications on black holes research literature. The keyword "Black holes" has the highest occurrence in the research field.

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