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Citation Behaviour of Physics and Astronomy Researchers in the Western Himalayan Region

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ABSTRACT

The study aims to examine the citation behaviour of Physics and Astronomy researchers from Indian central universities in the Western Himalayan region. By employing Bibliometrix and Biblioshiny packages in R Studio, an analysis of 13,065 cited sources was conducted using data from the Scopus database over a ten-year span (2012-2021). The findings highlight a preference for influential journal articles and reviews, with an inclination towards articles authored by two or three individuals. These findings offer valuable insights for stakeholders including researchers, policymakers, and funders, to enhance research impact in the region. The study also draws attention to 'undefined' tags in bibliographic data and calls for refinement in defining metadata to enhance bibliographic data quality and reliability.

Keywords: Citation behaviour; Citation analysis; Central universities; Western Himalayan region; Physics and Astronomy

1. INTRODUCTION

The Western Himalayan region (WHR) of India is a distinctive geographic and cultural region that is distinguished by its untamed terrain, harsh weather patterns and abundant biodiversity[1]. The area is well known for its distinctive geography, which features high-altitude deserts, alpine meadows, and dense woods that are home to various wildlife species[2]. Numerous universities that play a significant role in advancing research and education in a range of disciplines are located in the WHR region, which includes Himachal Pradesh, Jammu, Kashmir, and Uttarakhand[3].

The Government of India established 12 new Central Universities (CUs) in 2009-10; during this time, some state institutions were also elevated to the rank of CUs. There are four important CUs (Central University of Himachal Pradesh, Central University of Jammu, Central University of Kashmir and Hemwati Nandan Bahuguna Garhwal University) in the WHR of India. The present study's geographical scope is confined to these newly created CUs under the Central Universities Act 2009 in WHR. These universities offer numerous bachelors, master, and doctoral degree programs. Moreover, these universities conduct research in many fields such as physics, geology, environmental studies, and climate change. Physics & Astronomy research at these universities have contributed significantly to the development of knowledge in this field.

The goal of citation behaviour analysis is to provide information about the sources that have been used, so that other researchers can easily find and use those sources in their own work[4]. Additionally, citation behaviour helps to establish the credibility of the author and their work by demonstrating that they have conducted thorough research and are knowledgeable about the existing literature in their field. Smith[4] opined that analysis of cited references can also be used to verify or test a specific hypothesis about information use. It can also be used to compare user behaviour today with user behaviour several years ago, understanding that citations do not strictly parallel use. Knowing how citation behaviour affects knowledge dissemination and intellectual structure is crucial as it is a source of academic dynamism. A key component of behaviour related to scientific research is citation behaviour. Citation behaviour can be understood as the conscious dissemination of knowledge since citation behaviour is related to authors' selection of references according to their knowledge motives[5].

The easiest way to track citation behaviour is citation data, which also helps assess the impact of Science. Citation analysis is a well-known method for evaluating the significance and effect of research across a range of disciplines[6]. To comprehend the relationship between citations and cited papers and to spot trends and patterns

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in citation behaviour, it requires analysing the references cited in research publications. Citation analysis has drawn more attention recently in the context of evaluating the research landscape in developing countries like India. According to Reitz[7], *"citation analysis is a bibliometric technique in which works cited in publications are examined to determine patterns of scholarly communication."* The present study aims to analyse researchers' 'citation behaviour'. The researcher has adopted the bibliometric method and citation analysis parameters to examine the referencing or citing behaviour of the Physics and Astronomy researchers in WHR of India. The research will focus on how scholars cite literature in their work; knowing how they cite and other features of citation behaviour can assist higher authorities develop best practices and making informed decisions regarding university research policy.

2. LITERATURE REVIEW

Many scholars have employed various techniques and resources to assess the analysis of citation behaviour. Bornmann and Daniel[8] present a thorough evaluation of previous research on the function of citation behaviour and frequency in determining scientific influence. We also note the many tools and resources that researchers have used to study citation patterns. Citation analysis has become a valuable research tool for librarians, information professionals, and scholars in many fields. Tavernaro and Salisbury[9] and Atkinson & Thornton[10] highlighted the benefits of using citation analysis to study scholarly communication processes and library management of collections.

To examine the citation behaviour of faculties and researchers of various universities, numbers of studies have been conducted. Kodandarama and Chandrashekara[11-12] evaluated the references cited by the researchers of University of Mysore and University of Karnataka while Kimball[13], *et al.* evaluated references cited by Atmospheric Science faculty at Texas A&M University. These studies reveal the important information about regional citation patterns, including the types and numbers of sources cited, their accuracy, and variations in citation patterns over time. Citation behaviour has been studied in many populations, including faculty, researchers, and undergraduate students. The citation behaviour of undergraduate students was investigated in the 2006 study by Carlson[14], in the same year Clarke and Oppenheim[15] investigated the reference behaviour of students in the Department of Information Science at Loughborough University.

A study by Bhat and Sampath Kumar[16] focuses on web citations in academic electronic journals. A study by Hakak and Ali[17] provided a citation analysis of journal articles published in Annals of Library and Information Science from 2010 to 2019, while Singson[18], *et al.* attempted to investigate the citation behaviour of teachers in Pondicherry University. These studies shed light on the citation habits of different demographic groups. A number of studies have examined how citation behaviour affects information flow and the structure of the intellectual. According to a study by Yang and Liu[5], the way people cite sources have a significant impact on "knowledge diffusion and intellectual structure". To examine the citation practices of researchers, Cui[19], *et al.* analysed multivariate data from multiple sources. They found that researchers tended to cite highly influential works and were influenced by their social networks. Citation studies yield a variety of outcomes. Given that it identifies distinctive behavioural components in the data retrieved, it is an effective tool for better understanding scientific communication processes.

The most evident reflection of a researcher's citation behaviours is in the references they furnish in their research articles[20]. An in-depth evaluation of the referred sources is also known as citation analysis. Liang and Rousseau[21] considered references cited as a critical parameter to analyse the impact of research than the citations received. They also opined that cited references should be used in citation analysis instead of received citations.

3. OBJECTIVES OF THE STUDY

In this study, the citation behaviour of scientists at CUs in the WHR of India. Researchers' citation behaviour can be understood was investigated by analysing the cited references of their publications. Additionally, it may be able to propose or recommend necessary actions to institutions and higher authorities. A data visualisation method based on R was used to identify trends and patterns in the citation behaviour of these researchers in order to achieve these objectives. We aim to obtain comprehensive information on the referencing behaviour of physics and astronomy researchers in the WHR. This information can be used to develop programs that expand the scope and relevance of research in the field. It can also increase knowledge of citation patterns and analyses. In this context, the following are the objectives of the current study:

- To determine the predominant document types cited by researchers in the field and examine the impact of 'undefined' document types in cited references.
- To assess the reliance on peer-reviewed articles as the primary source of information among physics and astronomy researchers in the WHR.
- To analyse the author's keywords and trending topics in the sources cited by the researchers.

4. METHODOLOGY

This study employed bibliometric analysis to examine the references cited in scientific publications published in scopus-indexed journals by the physics and astronomy researchers.

4.1 Data Collection

Data for this study were obtained from the Scopus[22] database; a comprehensive bibliographic database widely used in academic research. The application process

involved querying a database using affiliation codes for universities in the WHR of India. The data collection spanned ten years, from 2012 to 2021, to provide a comprehensive overview of the citation landscape over a period of time. The search was limited to articles and reviews as document types, which ensured a focus on research results. A total of 13,065 cited sources were retrieved.

4.2 Data Analysis

Bibliometric analysis was performed using R Studio with Bibliometrix and Biblioshiny packages to analyze the retrieved data. These packages provide powerful bibliometric analysis capabilities.[23] Records retrieved from each university were extracted in to the BibTex file format, which facilitated data organisation and analysis. The BibTex file was the source of bibliometric analysis. This allowed the extraction of relevant information from the references, such as the year of publication, authors, journal titles, and other bibliographic details. Various bibliometric indicators and visualisation techniques were applied to the retrieved information. These analyses included citation counts, co-citation networks, bibliographic linking, and other measures to identify key authors, journals, and research topics in Physics and Astronomy in the WHR.

5. DATA ANALYSIS AND INTERPRETATION

5.1 Document Types Cited by the Researchers

Analysing the types of documents cited by researchers in Table 1 provides valuable insights into their reference practices and preferences. The primary document type researchers cite across all CUs in the WHR is '*articles'*. The high percentages of article references, ranging from 69.56 % to 81.91 %, indicate a strong reliance on peer-reviewed journal articles as the main source of information and research. This finding aligns with the established practice of citing scholarly articles as primary evidence for academic research in Physics and Astronomy. In contrast, other document formats including books, book chapters, and conference papers are represented in references cited by academics at a somewhat lower rate. The percentages for other document formats range from 0.21 % to 2.92 %, showing that article-based sources are often preferred by researchers in the subject. Although books and conference papers are useful for sharing research results, the Physics and Astronomy community tends to rely more on articles.

It is important to acknowledge the existence of 'undefined' or 'not available' document types in the cited references. These document types represent cases where a specific citation classification or metadata is missing or not available (NA) in the citation database. The percentage of 'undefined' document types varies from 9.40 % to 20.37 %, indicating that some references cited by researchers lack proper categorisation or document type information are incomplete. The inclusion of 'unspecified' or 'undefined' or 'not-available' document types highlights the need for accurate documentation and reference categorisation to ensure clarity and consistency in future research. To increase bibliographic information accuracy and consistency, researchers and database providers should strive for comprehensive and standardized classification practices.

5.2 Analysis of Top Ten Journals

Table 2 shows the ten most cited journals with relevant information such as number of cited articles, country of origin, publisher, h-index, SJR, quartile and CiteScore. The data highlights the importance of several impactful journals that have gained considerable attention in the research community. For instance, *Physical Review Letters*, published by the American Physical Society in the United States, emerged as the most frequently cited journal, with 333 articles citing it. This journal boasts a 647 h-index, indicating its extensive impact on the

Table 1. Types of documents cited by the physics & astronomy researchers

S. No.	Document type	CUHP	%	CUJ	%	CUK	%	HNBGU	%	Total	%
1	Article	3918	79.67	2894	77.52	575	81.91	2582	69.56	9969	76.30
2	Book	14	0.28	10	0.27	3	0.43	11	0.30	38	0.29
3	Book chapter	4	0.08	9	0.24	5	0.71	10	0.27	28	0.21
4	Conference paper	68	1.38	179	4.80	14	1.99	121	3.26	382	2.92
5	Editorial	3	0.06	5	0.13	0	0.00	4	0.11	12	0.09
6	Erratum	6	0.12	0	0.00	0	0.00	0	0.00	6	0.05
7	Letter	7	0.14	6	0.16	2	0.28	10	0.27	25	0.19
8	Note	4	0.08	4	0.11	0	0.00	4	0.11	12	0.09
9	Retracted	2	0.04	1	0.03	0	0.00	0	0.00	3	0.02
10	Review	287	5.84	262	7.02	35	4.99	206	5.55	790	6.05
11	Short survey	4	0.08	4	0.11	2	0.28	8	0.22	18	0.14
12	Undefined	601	12.22	359	9.62	66	9.40	756	20.37	1782	13.64
Total		**4918**	**100**	**3733**	**100**	**702**	**100**	**3712**	**100**	**13065**	**100**

Table 2. Top ten journals cited by the physics & astronomy researchers

S. No.	Sources	No. of articles cited	Country	Publisher	h- index	SJR	Quartile	Cite score
1	Physical Review Letters	333	United States	American Physical Society	647	3.25	Q1	16.8
2	Physical Review C - Nuclear Physics	234	United States	American Physical Society	221	1.32	Q1	6
3	Physical Review D - Particles, Fields, Gravitation and Cosmology	207	United States	American Physical Society	363	1.68	Q1	8.3
4	Astrophysical Journal	181	United States	American Astronomical Society	445	1.9	Q1	9.5
5	Applied Physics Letters	177	United States	American Institute of Physics	452	1.03	Q1	6.6
6	Physical Review B - Condensed Matter and Materials Physics	170	United States	American Physical Society	460	1.54	Q1	6.9
7	Journal of Applied Physics	154	United States	American Institute of Physics	331	0.67	Q2	4.7
8	Monthly Notices of the Royal Astronomical society	146	United Kingdom	Oxford University Press	340	1.68	Q1	9.6
9	ACS Applied Materials and Interfaces	118	United States	American Chemical Society	255	2.14	Q1	14.4
10	Physical Review B	114	United States	American Physical Society	460	1.54	Q1	6.9

field. Additionally, it ranks in the first quartile based on SJR and demonstrates an impressive CiteScore of 16.8. Furthermore, "*Physical Review C - Nuclear Physics"* and *Physical Review D- Particles, Fields, Gravitation, and Cosmology,* both publications of the American Physical Society, hold significant influence within the field, as evidenced by their respective h-index of 221 and 363. These journals also exhibit strong performance in terms of SJR, Quartile, and CiteScore, solidifying their standing as reputable outlets for Physics & Astronomy research.

Moreover, analysis highlights the contributions of journals such as the *Astrophysical Journal, Applied Physics Letters*, and *Journal of Applied Physics*. These journals have consistently received citations in our dataset. These journals, published by reputable organisations in the United States, exhibit respectable h-indexes. Their quartile rankings indicate their positions as noteworthy sources of scholarly publications. Additionally, it is worth noting the inclusion of *Monthly Notices of The Royal Astronomical Society*, a journal published by Oxford University Press in the United Kingdom. This journal has garnered significant attention within the field, with 146 articles citing it. It's h-index of 340 and first-quartile ranking reinforce its influence in Astronomy research. The presence of journals from different countries, such as the United States and the United Kingdom, indicates the global nature of Physics and Astronomy research. Researchers draw from diverse sources, considering publications from various countries for their scholarly work. Overall, Table 2 highlights the key journals Physics and Astronomy researchers refer for research projects. These journals represent the core literature in the field and serve as reputable sources of information and scientific advancement. Researchers can refer to these publications to access high-impact research, and these journals play a pivotal role in shaping scholarly discourse within our field of study.

5.3 Authorship & Collaboration Patterns

Table 3 presents the information on authorship patterns distribution across different types of documents. The data indicate a strong collaboration culture among Physics & Astronomy researchers. The majority of publications cited involve multiple authors, ranging from 17.97 % to 36.36 % for two-author publications and from 17.81 % to 22.66 % for three-author publications. This highlights the importance of teamwork and interdisciplinary research in the field. As the number of authors increases, the percentage of publications declines. Single-author publications range from 8.79 % to 34.85 %, indicating a lower frequency compared to collaborative works.

5.4 Top 50 Keywords

Figure 1 show a visual representation of the most frequently mentioned author keywords in the sources cited by Physics and Astronomy researchers. The word cloud represents the relative frequency of each keyword, with larger fonts indicating higher frequency. Among the top

Table 3. Authorship patterns in the sources cited by the physics & astronomy researchers

Authorship pattern	Article	%	Book & chapters	%	Conference papers	Reviews	%	Others	%
1	876	8.79	23	34.85	37	101	12.78	648	34.88
2	1791	17.97	24	36.36	57	170	21.52	434	23.36
3	1775	17.81	7	10.61	79	179	22.66	291	15.66
4	1485	14.90	6	9.09	67	127	16.08	146	7.86
5	1113	11.16	2	3.03	47	76	9.62	85	4.57
6	807	8.10	1	1.52	29	46	5.82	48	2.58
7	603	6.05	0	0.00	16	31	3.92	31	1.67
8	414	4.15	1	1.52	12	15	1.90	18	0.97
9	251	2.52	0	0.00	6	16	2.03	9	0.48
10	178	1.79	0	0.00	0	5	0.63	6	0.32
More than 10	675	6.77	1	1.52	32	24	3.04	11	0.59
NA	1	0.01	1	1.52	0	0	0.00	131	7.05
Total	**9969**	**100**	**66**	**100**	**382**	**790**	**100**	**1858**	**100**

50 author keywords, "graphene" stands out as the most cited keyword with a frequency of 227. This indicates significant attention and interest in this versatile material in the Physics and Astronomy community. The keyword "galaxies: active" follows closely with a frequency of 182, emphasising that research focuses on the study of active galaxies and their properties. Other important author keywords are "nanofluid" (140), "quasars: general" (124), and "graphene oxide" (119). It illustrates the importance and popularity of these topics in physical and astronomical research.

Keywords related to materials and their properties are also shown in the figure. For example, "adsorption" has a frequency of 102, representing the study of surface interactions. In contrast, "nanoparticles" (68) and "nanocomposite" (50) refer to nanoscale materials and their applications. Keywords such as "gas sensor" (69), "supercapacitor" (62), and "metal-organic frameworks" (52) indicate interest in applied research and technological development in the field. The finding provides a valuable overview of keywords cited by physicists and astronomers. It reflects current research trends and focuses areas. The visualisation is an invaluable reference for scientists and researchers seeking to understand fundamental topics and research directions in Physics and Astronomy.

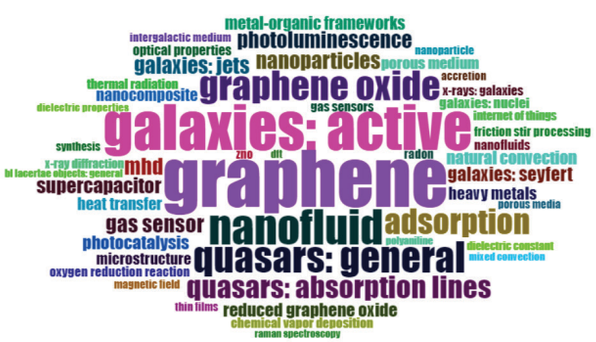

Figure 1. Word cloud of top 50 author keywords.

5.5 Most Productive Authors Cited by Researchers

Table 4 lists the top 10 most productive authors cited by Physics and Astronomy researchers of the WHR. The table ranks the authors based on their h-index. It includes their total citations (TC) and the number of publications (NP) cited by researchers. With an h-index of 66 (NP-86; TC- 15515), Sheikholeslami M ranks first in the list which indicates a strong impact.Wang Y follows closely in second place with an h-index of 61 and an impressive total citation count of 51,793 from 109 publications. Wang X ranks third with an h-index of 57 and a total citation count of 32,584 from 85 publications. Zhang H and Li X occupy the fourth and fifth positions, respectively, with high h-index values of 56 and 55. Zhang H has garnered 35,985 citations from 74 publications, while Li X has amassed 58,682 citations from 71 publications. The remaining authors, including Zhang J, Liu Y, Kumar R, Li Y, and Li Z, have also made notable contributions to the field. They have h-index values ranging from 52 to 55. Their total citation counts vary from 10,110 to 28,625, reflecting their impact and influence within the Physics and Astronomy community. Overall, the top 10 authors cited by Physics and Astronomy researchers demonstrate their productivity, influence, and recognition within the field. Their contributions have advanced knowledge and understanding in these disciplines. Researchers widely cite their work, highlighting their significant impact on the scientific community.

5.6 Top 10 Affiliations Cited by Researchers

The University of California stands out as the most frequently cited affiliation, indicating its strong influence and contribution to research in these disciplines. It is followed by The University of Tokyo, Tsinghua University, Pennsylvania State University, and the Indian Institute of Technology. The presence of prestigious institutions such as the Massachusetts Institute of Technology, the University of Tennessee, Peking University, Stanford

Table 4. Top 10 most productive authors

S. No.	Authors	h-index	TC	NP
1	Sheikholeslami M	66	15515	86
2	Wang Y	61	51793	109
3	Wang X	57	32584	85
4	Zhang H	56	35985	74
5	Li X	55	58682	71
6	Zhang J	55	28625	92
7	Liu Y	54	23745	75
8	Kumar R	53	11272	145
9	Li Y	52	21235	100
10	Li Z	51	10110	74

Table 5. Top 10 affiliations

S. No.	Affiliation	Articles cited
1	University of California	456
2	University of Tokyo	181
3	Tsinghua University	132
4	Pennsylvania State University	130
5	Indian Institute of Technology	122
6	Massachusetts Institute Of Technology	119
7	University of Tennessee	114
8	Peking University	110
9	Stanford University	109
10	Tohoku University	107

University, and Tohoku University on the top 10 list reflects their impact and recognition within the Physics and Astronomy research community. These top institutions functions as centre for research and innovation that attract talented researchers and foster an environment conducive to pioneering research. The international distribution of highly cited institutions in these areas reflects the collaborative nature of research in these fields. As a result, it emphasises the importance of international cooperation and team work in Physics and Astronomy.

6. DISCUSSION

The results of this study provide valuable information about the various aspects of citation behaviour of Physics and Astronomy researchers in the WHR of India. The analysis of the types of documents cited by researchers demonstrates a significant dependence on journal articles. This result aligns with the accepted practice of using scientific papers as the primary source of support for academic work in these areas. A large percentage of references are included in the reviews, demonstrating their significance in synthesising and summarising existing knowledge. Analysis of highly cited journals reveals influential and reputable sources of Physics and Astronomy research. Journals published by the American Physical Society such as Physical Review Letters, Physical Review C - Nuclear Physics, and Physical Review D-Particles, Fields, Gravitation, and Cosmology exhibit vital impact and recognition within the field. The presence of journals from different countries highlights the global nature of Physics and Astronomy research. It also emphasises diverse sources.

An analysis of authorship and collaboration patterns shows that Physics and Astronomy researchers tend to cite articles with a moderate number of authors, especially those with two or three authors. Collaboration appears to be more common in articles and review articles, while books and chapters are cited less often. These findings illuminate field dynamics and highlight the importance of joint research between Physics and Astronomy. An analysis of the most popular keywords mentioned by researchers shows the most influential research areas and interests in Physics and Astronomy. “Graphene” is becoming the most cited keyword, reflecting significant attention and interest in this versatile material. Other significant keywords include “galaxies: active”, “nanofluid”, and “quasars: general”, indicating the importance and popularity of these subjects in the field. The study’s visualisation reveals emerging research interests and emphasises the interdisciplinary nature of Physics and Astronomy research.

7. CONCLUSIONS

This study used Bibliometrix and Biblioshiny packages of R Studio to analyse the citation behaviour of Physics and Astronomy researchers from the four central universities in the WHR. The analysis revealed interesting and important insights about these researchers’ citation behaviour and scholarly practices. The findings of the study have profound implications for researchers, policymakers, and funders. Understanding trends in citation behaviour or practices can help with knowledge transfer and impact assessment. This result can influence collaboration, funding allocation, and research priorities.

This study contributes to the existing literature on science communication in Physics and Astronomy. Overall, this research contributes to our knowledge of citation practices and methods used in Physics and Astronomy research at the central universities in the western Himalayas. The results underline the significance of encouraging global partnerships, opening up access to significant research, and promoting multidisciplinary research initiatives. The factors that influence citation behaviour deserve further investigation in the future.

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His contributions to this study are to provide overall guidance and direction at every step involved in the process of collecting and analysing the data, as well as drafting the paper.