Research Article OPEN ACCESS

Volume-9 | Issue-4 | Oct-Dec-2023|

VEETHIKA-An International Interdisciplinary Research Journal

E-ISSN: **2454-342x**

Double Blind Peer Reviewed Journal

URL: https://veethika.qtanalytics.in

Mapping of Indian Astrophysics Research: A Scientometric Analysis of Research Output During 2013-2022

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Received: 18th October, 2023 ***Accepted:*** 26th October, 2023, ***Published***: 02nd November, 2023

ABSTRACT: The study has been conducted to analyze the research output of Astrophysics literature for a period of ten years i.e., from 2013- 2022 as reflected in the database of Web of Science. The year wise productivity, authorship pattern, most trending research topics, citation impact of most productive journals etc. are evaluated. The most productive year is 2022 with 596 publications (14.62%) and the least productive year is 2013 with 243 publications (5.96%). It has gained 105771 citations for the total of 4078 publications. Multi- authorship or more than ten authored contributions (863 publications, 21.16%) are found highest followed by three and two authorships with 755 publications (18.51%) and 700 publications (17.17%) respectively. The highest impactful journal is found as Astronomy and Astrophysics publish by EDP Sciences having the maximum value of h-index (71), g- index (210), m-index (6.45), also the maximum Citations (48023). The study also reveals that the cosmological observations based on Planck measurements is one of the most trending research topics in the present era in Astrophysics. The most prolific author's keywords found are galaxies: active, cosmology: observations and methods: data analysis with total link strength of 626, 389 and 350 respectively.

KEYWORDS: Scientometrics, Research productivity, Astrophysics, Authorship Pattern, Co-occurrence, Bibliographic Coupling, Citation Impact, India

1. INTRODUCTION

Astrophysics is the branch of Astronomy, the oldest scientific discipline of mankind which better helps understanding the subject of Physics at extreme scales. The main motive of Astrophysics is to understand the working principle of the universe, exploring its origination and evolution and also searching for the possibility of life hood in other different planets of the universe. It employs different concepts, methods, principles of Physics and Chemistry in order to comprehend the lifespan, death, birth and nature of galaxies, planets, nebulae, different celestial bodies of space. Scientometric study is the mathematical and statistical analysis to evaluate a research literature. It basically deals with quantifying and analyzing science & technology related aspects evaluating overall research performance of an author, journal, organization or institution, database etc. It is utilized to identify different indicators such as productivity, publication pattern, authorship pattern and collaborative research, author affiliation, citations and nature of the subject area over the timespan considered. The scientometric analysis is a technique for providing new insight into the research area of study which eventually helps in formulating policy making for deriving long term economic and social benefits. The study, therefore has been undertaken to understand the present scenario of Indian Astrophysics research performance as seen through Web of Science (WoS) database. **(Leydesdorff and Milojevis 322-327)**

DOI: https://doi.org/10.48001/veethika.2023.09.04.001

2. REVIEW OF LITERATURE

A lot of scientometric studies have been carried out so far in the evaluation of scientific literature in different subject fields. A sufficient range of publications have been reviewed for the present study.

Kenchakaller and Biradar has conducted a scientometric study on 3818 Indian publications of Black Holes reflected from WoS database. A timespan of 15 years (2008-2022) is taken into consideration. The study reveals that 97.59% articles contribute to literature among all the document types. Ajith Parameshwaran as the most productive author from the Bangalore International Center for theoretical science is found to publish 119 papers (32,405 citations, 61 h-index). Similarly, the most productive journal is Physical Review contributing 604 publications and receiving 16,068 citations. The keyword "Black Holes" occurs most frequently with 435 number of occurrences. India has got 8th position out of the 80 countries involve in the total output to the world's literature. Astronomy and Astrophysics is the related research area contributing 2423 publications with 47.45% sharing. (1- 6)

Mohan and Kumbar have applied different scientometric techniques to evaluate research performance in Steller and Galactic Astrophysics for a twenty years period. An exponential growth of the literature has been observed in the given period. In the ranked list of institutional contributors, TIFR, Mumbai has got top position contributing 26.03 percent of total output, whereas R. Srianand has topped in the ranking of authors contributing 143 papers. The study indicates a vast amount of collaborative research and India is found mostly to collaborate with USA. The most preferred journal has contributed a percentage of 32.95 to the total publications. A significant impact can be observed in the value of h-index i.e., 115. The highest altmetric score is received as 2411. (82-103)

Satish has assessed research outcome of Astronomy and Astrophysics by using various scientometric tools and techniques. A total of 20,311 data are retrieved from WoS for the time length 1988-2017. A 5% of yearly growth of Astronomy and Astrophysics publications has been observed on average. Physical Review 'D' is found as the most productive journal whereas TIFR, Mumbai and Banerjee S. of TIFR are the most prolific institute and author respectively. Research collaboration is preferred by the authors in this field. The study concludes that although the research in Astronomy and Astrophysics are growing but in a steady way, emphasis is needed for quality research to publish in high impact journals. (1-20)

A gradual growth in the productivity is found when **Vinay et al.** has made an attempt to quantify 2723 publications on Astrobiology. Analyzing the collected data on Web of Science published up to 2021 reveals the most productive journal as Astrobiology followed by Astrophysical Journal. Similarly, Charles S. Cockell is found as the most prolific author whereas Manasvi Lingam as the most promising author of recent years. The study concludes with the fact that journals and the authors' area of interest are observed to be the key factors which determine the longer relationship between them. (15- 24)

A bibliometric study has been conducted by **Zhang et al.** to analyze 13386 publications of the journal 'European Journal of Medicinal Chemistry' (EJMC) from 1987 to 2022. A yearly increase in the productivity has been observed in the study. Using VOSviewer software, the network visualization of co- occurrence of keywords reveals gradual shift in the theme of EJMC from phenotypic drug discovery to target-based drug discovery. The near future research themes of this journal are directed towards tumor multidrug resistance, dual inhibitors and oxidative stress. (1- 14)

Scholarly communications of antimicrobial resistance (AMR) have been evaluated by **Ablakimova et al.** for the time period 2013-2023 considering data from Web of Science Core Collection. A notable increase in the publication productivity in antimicrobial resistance is observed indicating a growing awareness of this field. Research collaboration is prevalent in this area. The study reveals the most prolific journal as 'Medicine', countries as USA and China, commonly encountered microorganisms as Klebsiella pneumoniae and Acinetobacter baumanii. Germany shows a strong tendency towards collaborative research. The analysis has given insights for collaborative efforts, guiding for upcoming research priorities and improve treatment solution for the infectious diseases. (1- 15)

3. OBJECTIVES

i. To analyze the Annual publication and citation trend of Astrophysics literature in India

ii. To calculate the Relative Growth Rate (RGR) and Doubling Time (Dt) of the research data.

iii. To identify top 20 highly cited articles in the field of Astrophysics on basis of Global Citation

DOI: https://doi.org/10.48001/veethika.2023.09.04.001

iv. To identify the pattern of Authorship of the publication of Astrophysics Literature

v. To assesses the citation impact of top 20 most prolific source titles

vi. To analyze the network of Bibliographic Coupling in terms of sources and co-occurrence of keywords in terms of Authors' keywords

4. METHODOLOGY

The study has been conducted by considering Clarivate Analytics' scientific and indexing database Web of Science. Applying the keyword 'Astrophysics' in the search field with filtration of Country as India and Period of ten years from 2013-2022. After using the refining criteria, a total of 4078 scholarly publications have been retrieved from the database involving 247 publication titles, 6972 authors and 5359 keywords. The various publications have been scattered in 3959 Articles (97.082%), 81 Review Articles (1.986%), 47 Proceeding Papers (1.153%), 24 Corrections (0.059%), 9 Editorial Materials (0.221%), 3 Letters (0.074%) and rest are Book Chapters, Book Reviews, Data Papers, Early Access, Retractions (0.025%) having single contribution each. The obtained data has been analyzed through different aspects of Scientometrics to meet the objectives. Data has been exported in text file and analyzed with MS Excel, VOSviewer and Biblioshiny of R software for data visualization.

5. DATA ANALYSIS AND INTERPRETATIONS

5.1 Frequency Distribution of Publications and Citations

The year-wise productivity of Astrophysics research output analysis reveals an increasing trend in the growth of the literature. The year 2022 is found as the most productive year with 596 publications (14.62%) and 2013 as the least productive year with 243 publications (5.96%). Exceptions are also observed in the years 2018 and 2020 which shows a slight little fall in the productivity. Noticeably, the first half of the period (2013-2017) contributes 1668 publications with 40.9% share to the total Indian output whereas more than half (59.09%) of the publications have been shared during the last half of the period (2018-2022) with 2410 scholarly communications.

The Astrophysics literature for the study period has gained 105771 citations for the total 4078 publications. Every publication has got citations. The maximum citation has received in the year 2015 for 354 publications comprises of 22353 citations whereas the minimum citation of 1577 has received in the year 2022. The reason for low citation in 2022 may be because it generally takes a period of time to get citations. The citation per paper is also highest in 2015 (63.14) and lowest in 2022 (2.67). On an average, the citation per year is calculated as 10577.1 and mean citation per publication is counted as 28.42.

Table 5.1: Annual Publication and Citation trend

S.N.	Year	Total Publications	% of 4078	Cumulative Publications	Total Citations	% of 105771	Citation per Paper
1	2013	243	5.96	243	5705	5.39	23.48
2	2014	301	7.38	544	12348	11.67	40.75
3	2015	355	8.71	899	22353	21.13	63.14
4	2016	376	9.22	1275	7353	6.95	19.45
5	2017	393	9.64	1668	17890	16.91	45.41
6	2018	377	9.24	2045	15851	14.99	42.05
7	2019	473	11.6	2518	9487	8.97	20.1
8	2020	461	11.3	2979	5474	5.18	11.77
9	2021	503	12.33	3482	7733	7.31	15.4
10	2022	596	14.62	4078	1577	1.49	2.67
Total		***4078***	***100***		***105771***	***100***	***284.23***

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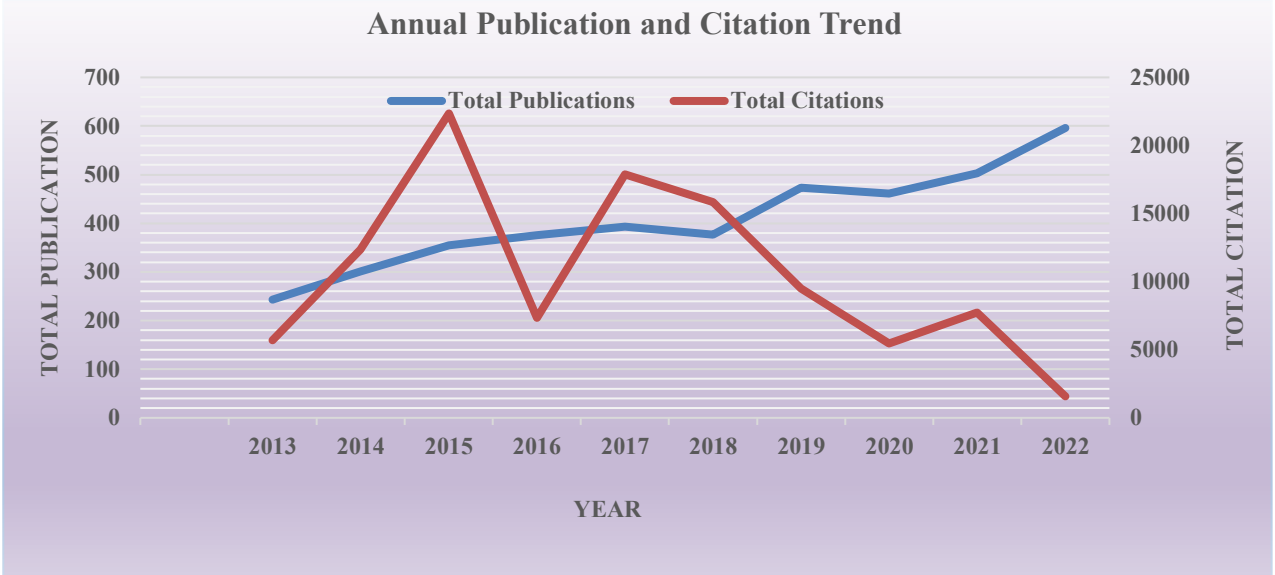

Fig. 5.1) Year wise distribution of publications and citations.

The primary y- axis denotes Total Publications and the secondary y- axis denotes Total Citations. Publication shows an increasing trend and citations a fluctuating trend.

5.2 Relative Growth Rate (RGR) and Doubling Time (Dt) of the literature

The relative growth rate (RGR) is the increase in the number of publications per unit of time. Mathematically, the RGR in a particular span of time R(a) can be calculated as:

$$R(a)=\frac{W2-W1}{T2-T1}$$

Where, W1 and W2 are log w1 and log w2, Natural Log of initial and final Publications

T 2 – T1, the unit difference between the initial and final time

R(a) = per unit of publications per unit of time (one year is considered as the unit of time)

The value of the difference between log of initial and final publication would be ln 2= 0.693

Doubling time (Dt) is defined as the time required for publications to become double of the existing amount. (Baskaran 160-169)

$$\text{Doubling time (Dt)} = \frac{0.693}{RGR}$$

There exists a direct equivalence between the two indicators Doubling time (Dt) and Relative growth rate (RGR), here also, RGR decreases from 0.806 to 0.158 and doubling time increases from 0.860 to 4.438, throughout the years from 2013 to 2022. The year 2013 shows the highest value of Relative Growth Rate (RGR) (0.806) and lowest value of Doubling Time (Dt) (0.860) whereas in contrast, the lowest RGR (0.156) and highest value of Dt (4.442) has been observed in the year 2021. Noticeably, whatever the increment or decrement, the changes have occurred in a minimal amount.

Table 5.2: Relative growth rate (RGR) and doubling time (Dt) of publications

S.N.	Year	Total Publications	Cumulative	(W1)	(W2)	(RGR)	(Dt)
1	2013	243	243		5.493		
2	2014	301	544	5.493	6.299	0.806	0.860
3	2015	355	899	6.299	6.801	0.502	1.380
4	2016	376	1275	6.801	7.151	0.349	1.983
5	2017	393	1668	7.151	7.419	0.269	2.579
6	2018	377	2045	7.419	7.623	0.204	3.401
7	2019	473	2518	7.623	7.831	0.208	3.331
8	2020	461	2979	7.831	7.999	0.168	4.122
9	2021	503	3482	7.999	8.155	0.156	4.442
10	2022	596	4078	8.155	8.313	0.158	4.386
	Total	***4078***			***Mean***	***0.313***	***2.943***

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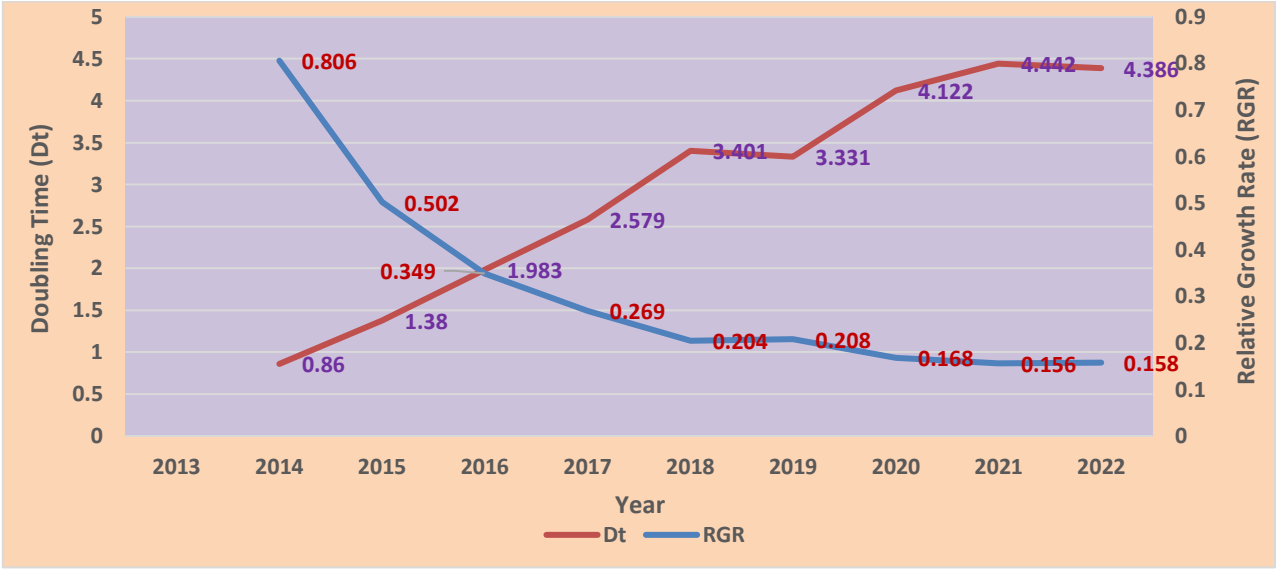

Fig 5.2: Doubling time (Dt) and Relative Growth Rate (RGR) of Publications. Both are showing an inverse relation of publication in which x-axis denotes year, primary y-axis indicates Doubling time (Dt) and the secondary y-axis RGR.

5.3) Top 20 Highly Cited Articles in The Field of Astrophysics

Table 5.3 enlists top 20 most Global cited documents which calculates number of citations received from documents contained in the entire database of Web of Science. Article entitled "Planck 2013 results. XVI. Cosmological parameters" published in 2014 in the journal Astronomy & Astrophysics by Ade et al. has gained the highest global citation 8187. The paper mainly presents "the first cosmological results based on Planck measurements of the cosmic microwave background (CMB) temperature and lensing-potential power spectra" **(Ade et al.)**. The cosmological observations based on Planck measurements is one of the most trending research topics in the present era in Astrophysics which could be proved from the list of 20 highly cited articles that 11 articles out of top 20 is based on the Planck results. This series of Planck results articles has been published in the journal "Astronomy and Astrophysics". Articles on observation of Gravitational waves, gamma rays from binary neutron star have also gained popularity. Normalized Total Citation as extracted from the Biblioshiny package of R Software can be seen maximum (158.36) for the article 'Planck 2018 results: VI. Cosmological parameters' which are calculated by actual count of citing documents to expected citation rate for documents with same type, year and subject coverage.

Table 5.3) Top 20 Highly Cited Articles in the area of Astrophysics (On the basis of Global Citation)

Rank	Paper	Year	Author	Total Citations (TC)	TC per Year	Normalized TC	Source Title
1	Planck 2013 Results. XVI. Cosmological Parameters.	2014	Ade et al.	8187	909.67	127.67	Astronomy & Astrophysics
2	Planck 2015 Results. XIII. Cosmological Parameters.	2016	Ade et al.	5474	782.00	116.82	Astronomy & Astrophysics
3	Astropy: A community Python package for astronomy.	2013	Robitaille et al.	5305	530.50	123.29	Astronomy & Astrophysics
4	GW170811; Observation of gravitational waves from a Binary Neutron star Inspiral.	2017	Abbott et al.	4287	714.50	97.81	Physical Review Letters
5	Planck 2018 results: VI. Cosmological parameters.	2020	Aghanim et al.	2802	934.00	158.36	Astronomy & Astrophysics

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6	Gravitational waves and gamma-rays from a Binary Neutron star merger: GW170817 and GRB 170817A.	2017	Abbott et al.	1809	301.50	41.27	Astrophysical Journal Letters
7	Planck 2013 Results XXII Constraints on Inflation.	2014	Ade et al.	1505	167.22	23.47	Astronomy & Astrophysics
8	The Astropy project: Building an open-science project and status of the five v2.0 core package.	2018	Price – Whelan et al.	1313	262.60	60.92	Astronomical Journal
9	Gravitational waves and gamma-rays from a binary neutron star merger: GW170817 and GRB 170817 A.	2017	Abbott et al.	1236	206.00	28.20	Astrophysical Journal Letters
10	Planck 2013 Results. I. Overview of products and Scientific Results.	2014	Ade et al.	1126	125.11	17.56	Astronomy & Astrophysics
11	The Murchinson widefield array: the square kilometre array Precursor at low radio frequencies.	2013	Tingay et al.	790	79.00	18.36	Publications of the Astronomical Society of Australia
12	Planck 2013 Results XXIV. Constraints on primordial non- Gaussianity.	2014	Ade et al.	629	69.89	9.81	Astronomy & Astrophysics
13	Planck 2015 Results XX. Constraints on Inflation.	2016	Ade et al.	616	88.00	13.15	Astronomy & Astrophysics
14	Dark energy survey year 1 Results: cosmological constraints from galaxy clustering and weak lensing.	2018	Abbott et al.	599	119.80	27.79	Physical Review d
15	The second fermi large area telescope catalog of gamma- ray pulsars.	2013	Abdo et al.	572	57.20	13.29	Astrophysical Journal Supplement Series
16	Planck 2018 results: X. Constraints on inflation.	2020	Akrami et al.	555	185.00	31.37	Astronomy & Astrophysics
17	Astrophysical Implications of the binary black hole merger GW150914.	2017	Abbott et al.	547	91.17	12.48	Astrophysical Journal Letters
18	Planck 2015 Results XI. CMB Power Spectra, Likelihoods, and Robustness of Parameters.	2016	Aghanim et al.	534	76.29	11.40	Astronomy & Astrophysics
19	Planck 2015 Results I, Overview of Products and Scientific Results.	2016	Adam et al.	508	72.57	10.84	Astronomy & Astrophysics
20	Planck 2013 Results XV. CMB Power Spectra and Likelihood.	2014	Ade et al.	490	54.44	7.64	Astronomy & Astrophysics

5.4 Authorship Pattern of Publications of Astrophysics Literature

From table 5.4, the highest number of contributions (863 publications, 21.16%) have been reported by multi authored publications (more than ten authors). A total of 755 publications contributing 18.51% to the total output by three authors is reported in the second rank followed by two authors with 700 publications (17.17%) and four authors with 565 (13.85%) publications. Single authors contribute only 5.2% publications. This increasing trend of multi authorship indicates the growing interest in research collaboration with medium-large team.

Table 5.4: Authorship Pattern of Publications of Astrophysics Literature

Sl. No	Pattern	Total Publication	Percentage	Total Authors	Percentage	Rank
1	Single Author	212	5.20	212	1.04	***VII***
2	Two Authors	700	17.17	1400	6.85	***III***
3	Three Authors	755	18.51	2265	11.08	***II***
4	Four Authors	565	13.85	2260	11.05	***IV***
5	Five Authors	341	8.36	1705	8.34	***V***

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6	Six Authors	232	5.69	1392	6.81	***VI***
7	Seven Authors	162	3.97	1134	5.55	***VIII***
8	Eight Authors	105	2.57	840	4.11	***IX***
9	Nine Authors	89	2.18	801	3.92	***X***
10	Ten Authors	54	1.32	540	2.64	***XI***
11	More than ten	863	21.16	89227	38.62	***I***
	Total	***4078***		***101776***		

Fig. 5.3: Authorship Pattern of Publications in Astrophysics. Multi-authored (more than ten authored) contributions are found highest followed by three and two authored contributions.

5.5) Impact Measures of Journals: Total Citation, h-index, g-index, m-index and Impact Factor (IF)

Table 5.5 and Fig 5.4 represents various citation indices of the top 20 most preferred sources. H-index, G-index, M-index and Total Citations are obtained from Biblioshiny app of R Package, Impact Factors (IFs) are collected from the websites of the respective journals. The journal Astronomy and Astrophysics publish by EDP Sciences for European Southern Observatory which contributes 15.03% to the total output has attained the Highest h-index (71), g-index (210), m-index (6.45), also the maximum Citations (48023). Astrophysical Journal Supplement Series as publish by American Astronomical Society is found as the highest Impact Factor journal (IF=9.2). Contrary to that, the journal Astrophysics publish by Springer, United Stated has received the lowest value of all the indices i.e H-index (3), G-index (6), M-index (0.33), TC (59) and IF (0.673).

Table 5.5: Citation indices/impact of top 20 most prolific sources of Astrophysics research output

Sl. No.	Sources	Publication	% value	Country/ Origin	Publisher	h-index	g -index	m-index	Total citation	IF	Rank
1	Astrophysics and Space science	815	19.99	Netherlands	Springer Netherlands	37	47	3.36	8116	1.83	1
2	Monthly Notices of The Royal Astronomical Society	673	16.50	UK	Oxford University Press	45	74	4.09	11168	5.287	2
3	**Astronomy & Astrophysics**	**613**	**15.03**	**France**	**EDP Sciences**	**71**	**210**	**6.45**	**48023**	**5.802**	**3**
4	Astrophysical Journal	347	8.51	UK	American Astronomical Society	46	64	4.18	7369	5.874	4
5	Journal of Astrophysics and Astronomy	299	7.33	India	Springer India	13	24	1.18	1193	1.27	5
6	Research in Astronomy and Astrophysics	151	3.70	UK	IOP Publishing	14	20	1.27	743	1.469	6

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7	Physical Review D	107	2.62	United States	Americal Physical Society	29	55	2.64	3278	5.296	7
8	Astrophysical Journal Letters	68	1.67	UK	American Astronomical Society	28	67	2.8	6103	7.413	8
9	European Physical Journal C	53	1.30	Germany	Springer New York	22	36	2	1415	4.59	9
10	Astronomical Journal	45	1.10	UK	IOP Publishing	16	43	1.45	2314	6.263	10
11	Journal Of Cosmology and Astroparticle Physics	41	1.01	UK/Italy	IOP Publishing/SISSA	16	31	2	1023	7.28	11
12	Astrophysical Journal Supplement Series	33	0.81	UK	American Astronomical Society	16	32	1.45	1792	9.2	12
13	New Astronomy	30	0.74	Netherlands	Elsevier	7	13	0.64	193	1.325	13
14	Modern Physics Letters A	25	0.61	Singapore	World Scientific	7	10	1	135	1.594	14
15	Astrophysics	24	0.59	United States	Springer	3	6	0.33	59	0.673	15
16	International Journal of Modern Physics D	23	0.56	Singapore	World Scientific	9	15	0.9	246	2.547	16
17	Publications of the Astronomical Society of Australia	23	0.56	England	Cambridge University Press	14	22	1.4	1832	5.571	16
18	Physical Review C	22	0.54	United States	American Physical Society	10	15	0.91	257	3.09	17
19	Annals Of Physics	20	0.49	Netherlands	Elsevier	8	13	0.89	194	2.73	18
20	International Journal of Theoretical Physics	20	0.49	United States	Springer New York	6	16	0.55	257	1.708	18
21	General Relativity and Gravitation	18	0.44	United States	Springer New York	7	11	0.64	146	2.84	19
22	Solar Physics	16	0.39	Netherlands	Springer Netherlands	7	13	0.64	175	2.961	20

* H-index for a journal is defined as the number of papers with citation no ≥ H. E.g. If an author has 3 publications each with at least 3 citations, then its h-index will be 3.
* g- index is the unique largest number such that the top g articles receive together at least g^2 citations.
* M- index is measured by considering H-index i.e., H/N, where N is the number of years from its 1st publication.
* Impact Factor (IF) of a journal is calculated for a given period as the average number of citations received per publication during the two preceding years.

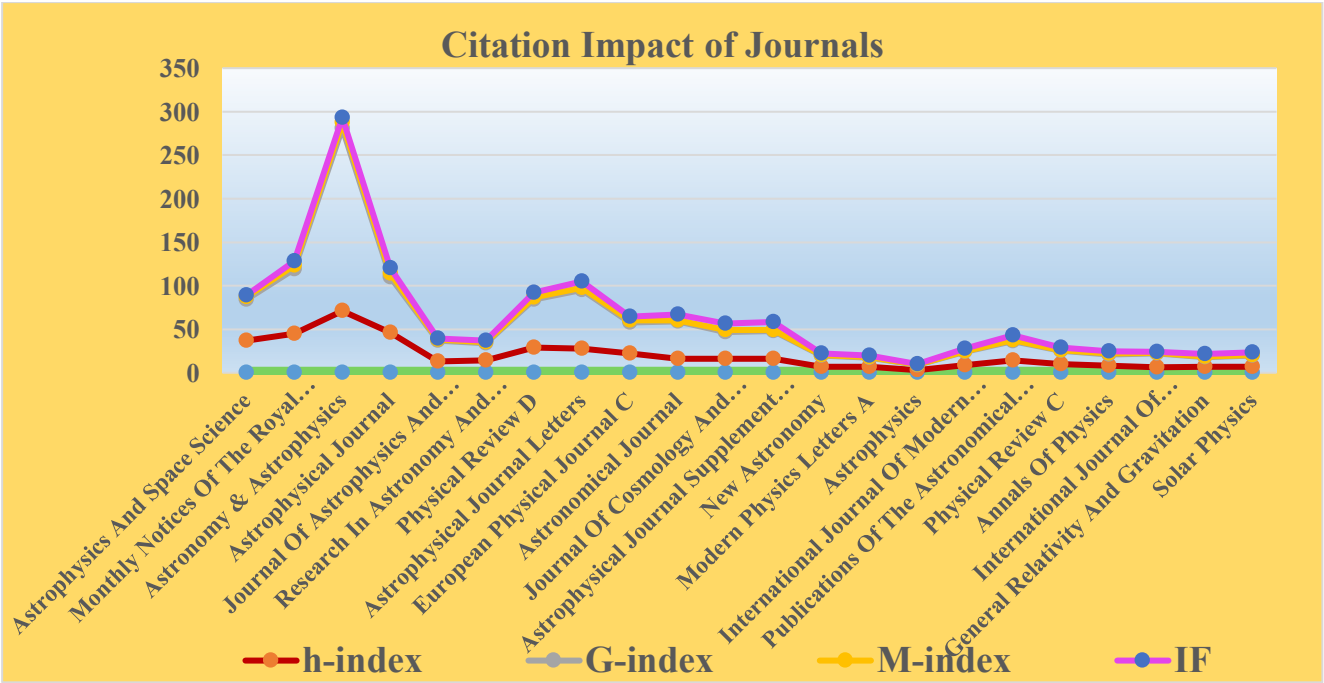

Fig 5.4: Citation Indices/Impact of top 20 most prolific Sources of Astrophysics Research Output

5.6) Network Analysis of Bibliographic Coupling of Sources (Weight by Citation)

Bibliographic Coupling between two items (Sources) indicate the link between them that both items cite the same document. Fig. 5.5 shows bibliographic coupling of authors that cite the same sources. The coloured

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circles represent different sources that are co-linked with different circles, the size of each circle represents the citation score of the sources. Out of total 6 clusters, the largest cluster with red colour consists of 23 sources with 1034 links followed by Cluster 2 in green colour and Cluster 3 in sky blue with 17 and 10 number of sources; 773 and 288 number of total links respectively.

The highly cited Journal (46051 citations) Astronomy and Astrophysics belongs to Cluster 2 co-linked with 53 other sources making total link strength 216885. This journal is highly co-related with Monthly Notices of the Royal Astronomical Society of the same cluster 2 forming total link strength 80904.

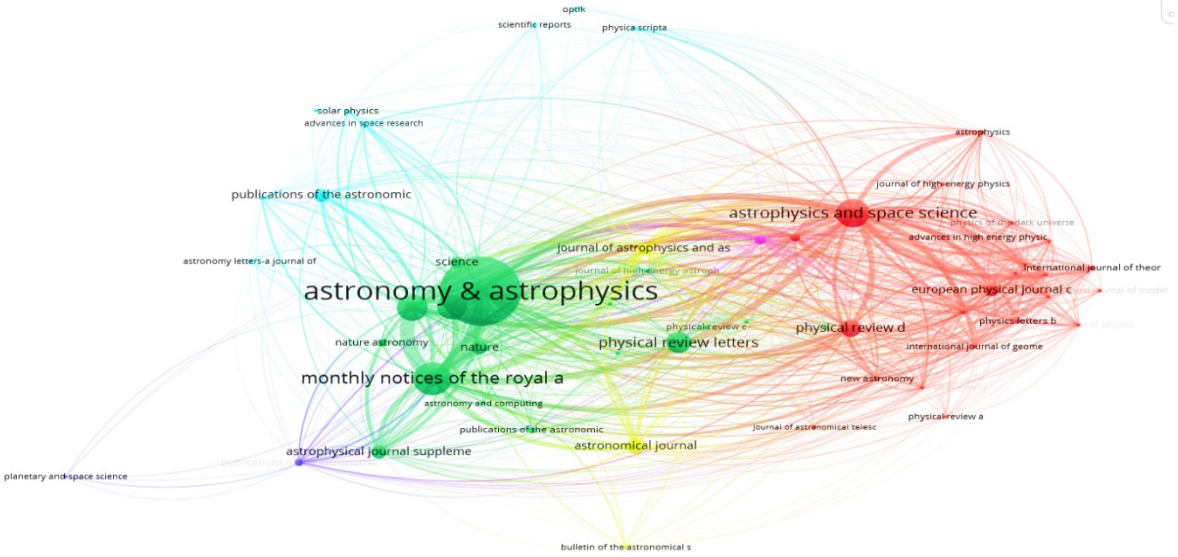

Fig 5.5: Bibliographic Coupling of Sources with weight on basis of Citation Score. Out of 246 sources, 56 sources form the largest set of connected networks with 6 clusters and 2346 total links.

Table 5.6: Cluster table for Bibliographic Coupling of Sources

Sl. No	Cluster	Colour	No of Sources	Total Link
1	Cluster 1	Red	**23** (Astrophysics and Space Science, Journal of Cosmology and Astro particle Physics, Physical Review D etc.)	1034
2	Cluster 2	Green	**17** (Astronomy and Astrophysics, Monthly Notices of the Royal Astronomical Society, Astrophysical Journal Supplement Series etc.)	773
3	Cluster 3	Sky Blue	**10** (Physica Scripta, Optik, Solar Physics etc.)	288
4	Cluster 4	Yellow	**3** (Bulletin of Astronomical Society of India, Journal of Astrophysics and Astronomy etc.)	142
5	Cluster 5	Dark Blue	**2** (Planetary and Space Science, Publications of the Astronomical Society of Japan)	57
6	Cluster 6	Pink	**1** (Journal of Alloys and Compunds)	52

5.7) Network Analysis of Co-occurrence of Keywords in terms of Author's Keywords (Weight by Documents)

VOSviewer has been used to unveil the dominant research areas or the research trends in the field of Astrophysics that have emerged in the period of study. Out of total 5359 authors keywords, 172 keywords consisting of 7 clusters are identified that met the threshold. The most prolific keywords found in these clusters are galaxies: active, cosmology: observations and methods: data analysis holding total link strength of 626, 389 and 350 respectively. From table 5.8 it is clear that the top 10 prominent keywords are in cluster 2 and cluster 3. The largest cluster being cluster 1 in red colour consists of 33 keywords followed by green and blue coloured cluster with 29 keywords each.

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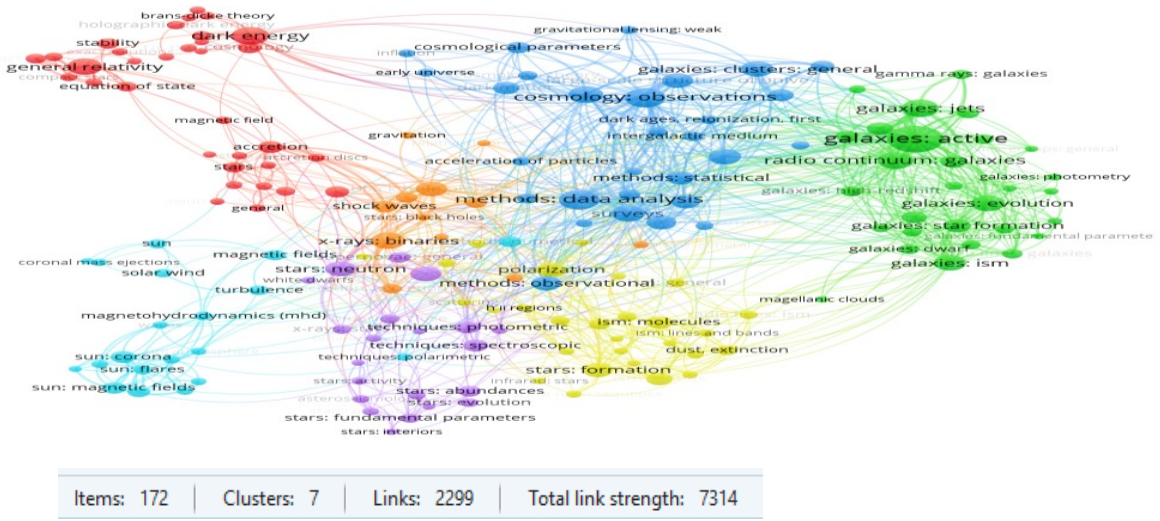

Fig 5.6) Co-occurrences of Author's Keyword (Network Visualization). The network consists of 172 keywords that co-occur with 2299 different keywords producing total link strength 7314.

Table 5.8) Top 10 most prolific keyword in terms of Total Link Strength

Rank	Keyword	Cluster	Occurrences	Total Link Strength
1	Galaxies: active	Cluster 2	251	626
2	Cosmology: observations	Cluster 3	137	389
3	Methods: data analysis	Cluster 3	136	350
4	Galaxies: jets	Cluster 2	111	314
5	Radio continuum: galaxies	Cluster 2	109	303
6	Cosmic background radiation	Cluster 3	96	264
7	Galaxies: evolution	Cluster 2	91	260
8	large-scale structure of universe	Cluster 3	81	237
9	Galaxies: ism	Cluster 2	86	233
10	Surveys	Cluster 3	88	225

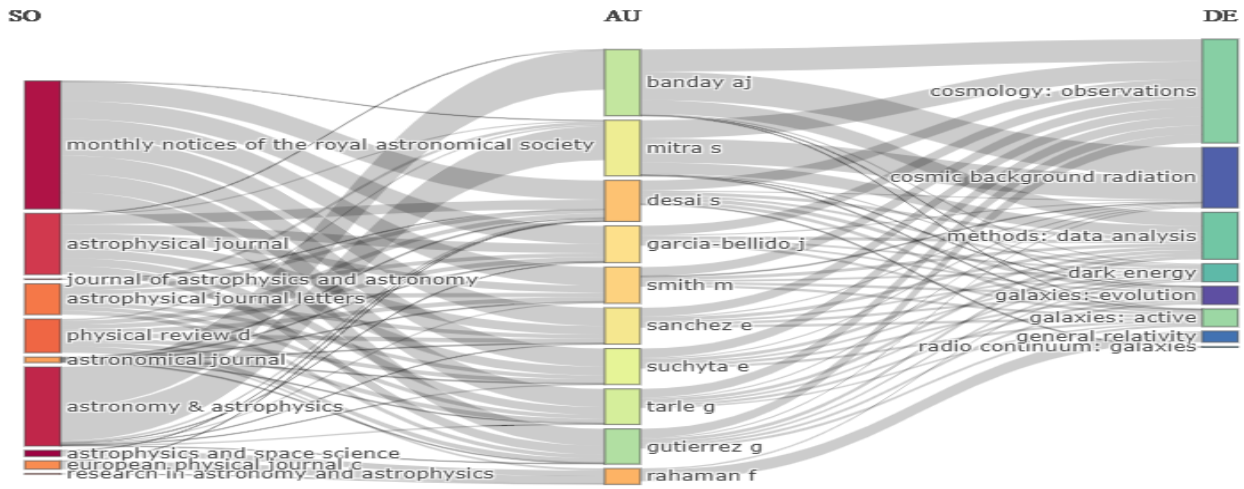

Fig 5.7: Three- field plot (Sankey diagram) showing the relationship among top 10 of the three metrics viz., Author (middle)-Source (Left)-Keyword (Right).

DOI: https://doi.org/10.48001/veethika.2023.09.04.001

The preponderance of the following keywords in the clusters are identified as follows:

Cluster 1: The system (red) is connected to Accretion, Dark Energy, General Relativity, Magnetic Field, Stars, X-Rays etc.

Cluster 2: The system (Green) is connected to Galaxies: Active, Galaxies: Jets, Galaxies: Evolution, Galaxies: Star formation, Galaxies: Dwarf, Radio Continuum: Galaxies etc.

Cluster 3: The system (Blue) is connected to Cosmology: Observations, Galaxies: Clusters: General, Methods: Data Analysis, Methods: Statistical, Cosmological parameters etc.

Cluster 4: The system (Perrot Green) is connected to Cosmic Rays; Dust, Extinction; Stars: Formation; Ism: Molecules; Infrared: Stars; Polarization etc.

Cluster 5: The system (Purple) is connected to Stars: Neutron, Star: Abundances, Stars: Fundamental Parameters, Technique: Photometric, Technique: Spectroscopic etc.

Cluster 6: The system (Sky Blue) is connected to Sun, Sun: Corona, Sun: Flares, Sun: Magnetic Fields, Magnetohydrodynamic, Solar Wind, Turbulence etc.

Cluster 7: The system (Orange) is connected to Accretion, Accretion Disk; Gravitation; X-Rays: Binaries; Hydrodynamics; Stars: Black Holes etc.

5.8 Sankey Diagram: Three-field Plot connecting three metrics together

Three- field plot has been used to investigate the connections between the three metrices Source- Author-Keyword. The most connected author in the network AJ Banday is found to have 168 publications making relation with both top 10 sources and authors. Astronomy and Astrophysics is the most preferred journal in which AJ Banday prefer to publish his articles contributing 101 publications. He has research interest in Cosmic background radiation (72 publications), Cosmology: Observations (56 publications) and Methods: Data analysis (35 publications) etc. The top 10 authors mostly prefer to publish their Research in the journal Monthly Notices of the Royal Astronomical Society. (324 Publications). Cosmology: Observation is the most influenced research area in which the top 10 authors together contribute with 263 publications.

6. FINDINGS

- The most productive year is 2022 with 596 publications (14.62%) and the least productive year is 2013 with 243 publications (5.96%). More than half (59.09%) of the publications have been shared during the last half of the period (2018-2022) with 2410 scholarly communications.
- The Astrophysics literature for the study period has gained 105771 citations for the total of 4078 publications. The maximum citation (22353) has received in the year 2015 for 355 publications whereas the minimum citation of 1577 has received in the year 2022.
- Inverse relation can be established between the indicators Relative Growth Rate (RGR) and Doubling Time (Dt) where RGR decreases from 0.806 to 0.158 and Dt increases from 0.860 to 4.438 throughout the years from 2012 to 2021.
- The cosmological observations based on Planck measurements is one of the most trending research topics in the present era in Astrophysics that could be proved from the list of 20 highly Global Cited articles that 11 articles out of top 20 is based on the Planck results. This series of Planck results articles have been published in the journal 'Astronomy and Astrophysics'.
- Multi- authorship or more than ten authored contributions (863 publications, 21.16%) are found highest followed by three and two authorships with 755 publications (18.51%) and 700 publications (17.17%) respectively.
- The journal Astronomy and Astrophysics publish by EDP Sciences for European Southern Observatory which contributes 15.03% to the total output has attained the highest h-index (71), g-index (210), m-index (6.45), also the maximum Citations (48023). Astrophysical Journal Supplement Series as publish by American Astronomical Society is found as the highest Impact Factor journal (IF=9.2).
- The network of bibliographic coupling of sources shows that the highest cited Journal (46051 citations) Astronomy and Astrophysics belongs to Cluster 2 co-linked with 53 other sources. This journal is highly co-related with Monthly Notices of the Royal Astronomical Society of the same cluster 2 forming total link strength 80904.
- The most prolific author's keywords found are galaxies: active, cosmology: observations and methods: data analysis with total link strength of 626, 389 and 350 respectively.
- From the three-field plot of Source- Author-Keyword, it is evident that the most connected author AJ Banday prefer to publish his articles in

DOI: https://doi.org/10.48001/veethika.2023.09.04.001

the journal Astronomy and Astrophysics. The top 10 authors mostly prefer to publish their Research in the journal Monthly Notices of the Royal Astronomical Society (324 Publications).

CONCLUSION

A scientometric research in the field of Astrophysics is carried out in order to evaluate the productivity, authorship pattern, most trending research topics, citation impact of most productive journals etc. An increasing trend in the productivity can be observed as it can be seen that more than half (59.09%) of the publications have been shared during the last half of the period (2018-2022) with 2410 scholarly communications. The cosmological observations based on Planck measurements is one of the most trending research topics in Astrophysics which is also evident from the list of 20 highly cited articles that 11 articles out of top 20 is based on the Planck results. An increasing trend of multi authorship indicates the growing interest in research collaboration in this field. The highest cited journal Astronomy and Astrophysics publish by EDP Sciences is highlighted for having the maximum H-index (71), G-index (210), M-index (6.45), also the maximum Citations (48023). This journal can also be seen to make highest bibliographic coupling (with 53 other sources), highly co-related with the journal Monthly Notices of the Royal Astronomical Society forming total link strength 80904. This is also the most preferred journal of the most connected author AJ Banday in the network of three metrices' connections i.e., Source- Author- Keyword. Overall, we can conclude that although research in Astrophysics in India is prominent enough but it has scope for more and better research in the near future.

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