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FIVE DECADES OF RESEARCH ON "GALAXY" IN INDIA: A QUANTITATIVE STUDY

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ABSTRACT: *The present study investigate the characteristics of the literature and growth of Galaxy research in India during 1960-2014, based on Web of Science (WoS) database and make quantitative and assessment of research impact by way of analysing various features of research output by using the scientometric techniques through bibliometric indicator. A total of 1199 literature were published on Galaxy, which received total 22030 citations. The average number of publications per year was 27.88 and the average number of citations per publication was 18.37. The publications peaked in the year 2013 with 120 publications and the highest number of citations 2877 was in 2009. This study analyzes the research studies based on year of publication, journal, international collaboration, spatial distribution and keyword occurrence frequency. The results of this work reveal that the publication on the Galaxy have grown high at a slow rate over the past 54 years and the curve fits the polynomial curve with* $R^2 = 0.9576$.

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Publications on Galaxy appeared in 51 journals of which most active journal was "Monthly Notices of the Royal Astronomical Society" published by Oxford University Press on behalf of the Royal Astronomical Society originating from United Kingdom and 345(28.774%) of the total 1199 publications. A total of 5617 authors contributed on Galaxy research. The most active author was Chengalur, JN produced maximum no. of publications 63 of total publications. 1035 institutions contributed of which Tata Institute of Fundamental Research; Mumbai is the most productive institution. For globalization of Galaxy Research in India, the results show there were 56 Countries/territories which participated in Galaxy research. USA produced maximum publications 421 that is 35.113 % of total publication with higher citations (11613). A Keyword analysis reveals that Formation, Evolution, Structure, Dynamics and Disk are the most used keywords.

KEYWORDS- Galaxy, Scientometric, Bibliometrics, INDIA

1. INTRODUCTION

Galaxies can be understood as large collections of stars in the universe. In a galaxy, billions of stars are bound together by the inter gravitational forces. Our Sun is also a part of the Milky Way galaxy. Galaxies are of different sizes: dwarf galaxies, average galaxies, and massive galaxies. The simplest galaxy classification system, invented by Edwin P. Hubble, classifies galaxies as either spiral, elliptical, or irregular in shape. The Milky Way is an

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average spiral galaxy with two satellite galaxies orbiting it. Studying galaxies falls into the realm of cosmology, the study of the evolution of the universe on the largest scale. By looking at the distribution of galaxies in space, Edwin P. Hubble discovered that the universe is expanding. Hubble found that all galaxies in all directions are receding from us, and the ones farther away are receding the fastest (Observatorio ARVAL, 2001)

In India, the Galactic Astronomy is a rapidly growing area, it has evolved manifolds. With new galaxies being discovered this area holds promising results in near future. Therefore an analytical investigation is required to assess the growth made in this area of research so far in Indian context.

2. DATABASE AND SCOPE

To assess the trend of research publication on Galaxy Science and locate and collect the literature, Web of Science (WoS) was used. The Search Strategy used to conduct Web of Science (WoS) search is as mentioned below:

TS= "Galaxy" OR "structure" = (Search Term) ; Where TS is a topic search that retrieves occurrences of the search term in the article title, abstract, keywords within a time span of 1960-2014, were used to locate publications that contained these words in publications' titles, abstracts, and keyword lists. This process was followed for another series

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of search terms given by (Kennicutt et. al., 2001). These were used to locate publications that contained the words in publications' titles, abstracts, and keyword lists.

3. RESULTS AND ANALYSIS

There were 1199 articles that met the selection criteria which appeared in the WoS database during 1960-2014 and these were analyzed. The specific characteristics of the publications such as no. of publications, the no. authors involved in the production of these publication, institutions, journals etc were taken into consideration.

3.1 Publication characteristics of Indian Galaxy Science Research during 1960-2014.

The total 1199 articles of Indian scientists during 1960-2014 were abstracted from WoS related to Galaxy Science publication. From Table 1 and 2, the output of 1199 paper received a total of 22030 citations during the said period with an average of about 18.37 citations per paper. The average number of publications per year is 27.88 and Compound Annual Growth rate (CAGR) is 9.56%

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Table 1: Bibliographic Record of Galaxy research in India during study period

Bibliometric indicators `	No.
Total Article found:	1199
Total No. of Countries contribution	56
Total No. of Author's contribution	5617
Total No. of Institution's contribution	1035
Total No. of Journal appeared	51
Total No. of Keywords (raw) appeared	4748

Source: WoS

Table 2: Citation Metrics of Galaxy research in India

Citation-based indicators	No.
Total Article found:	1199
Sum of the Times Cited	22030
Sum of Times Cited without self-citations	20246
Citing Articles	15517
Citing Articles without self-citations	14824
Average Citations per Item	18.37
h-index	61

Source: WoS

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3.2. PUBLICATION PATTERN

Publication Pattern of Galaxy research from 1960 to 2014 is presented in figure 1. The highest (120) numbers of publications was in 2013.It is important to mention here that initial publication observed in the year 1972. A 103 time's increase was observed over the study period, (from 1 in 1972 to 106 in 2014). The average number of publications published per year was 27.88

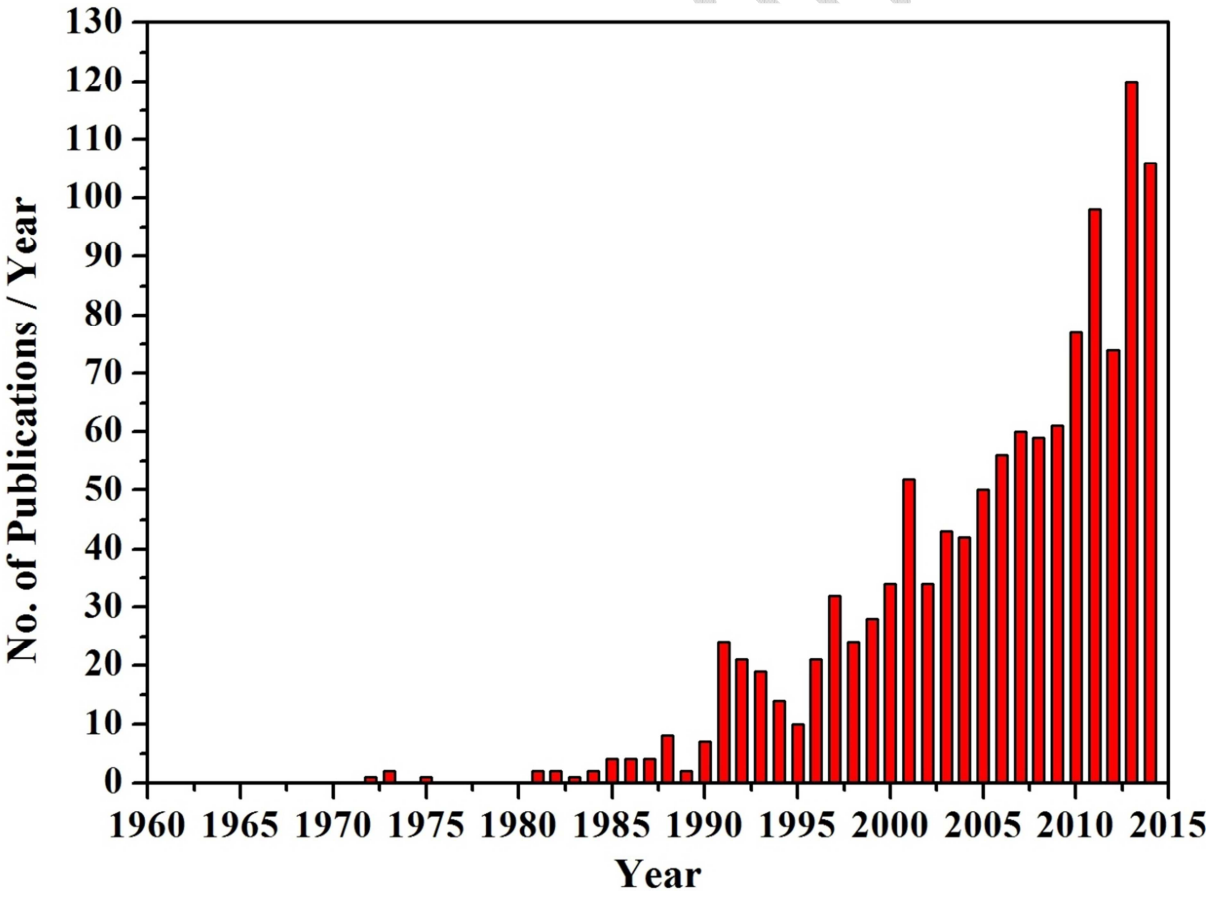

Figure 2: Publications pattern of Galaxy research in India during 1960-2014

3.3. Growth Pattern

The cumulative progression was represented by a 4th degree power law distribution during 1960-2014 giving an idea of the polynomial growth rate (Figure 2). The fit produced a high regression coefficient (Table 3) of determination to the collected data (R^2 = 0.957). The polynomial best fit as shown in table 3 for Galaxy research was found to be: $y = 0.0001x^4 - 0.9007x^3 + 2687.6x^2 - 4E+06x + 2E+09$, where y is the cumulative number of publications and x is the number of years since 1960.

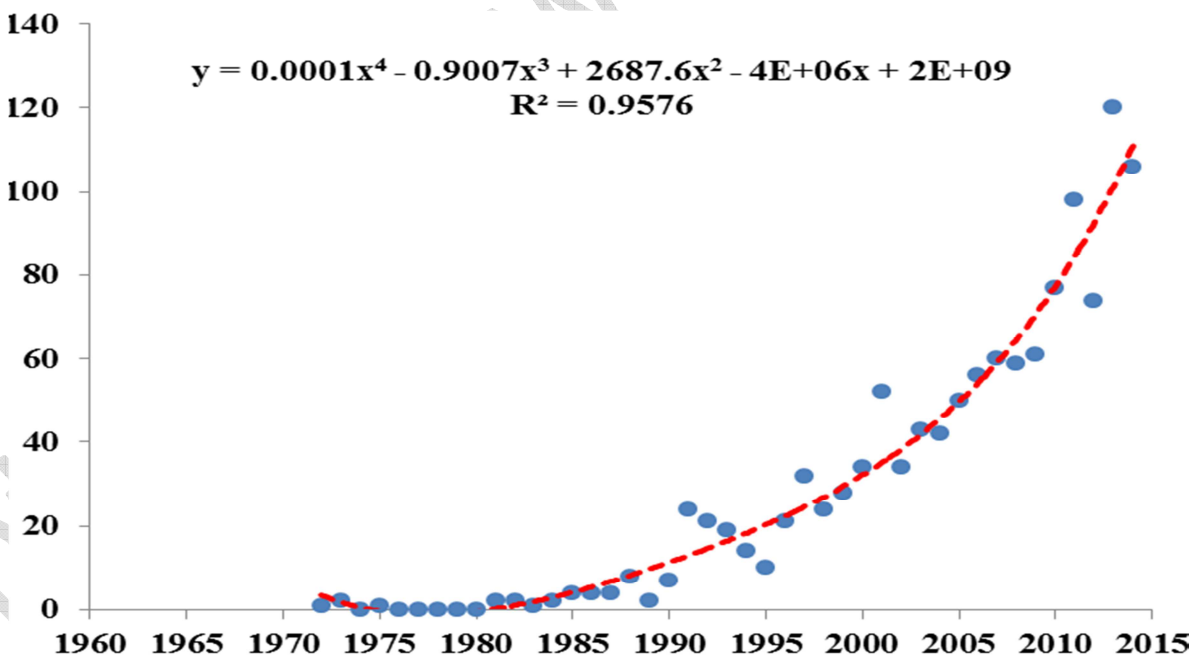

Fig 2: Growth pattern of Galaxy research in India during 1960-2014.Orange dot describe the distribution of publication (observed value) and blue dashed line describe the correlation of distribution of publication where regression coefficient R^2 = 0.957

Table 3: Different Regression Type with Regression coefficient

Regression Type	**Equation**	**Regression (R^2)**
Linear	$y = 2.2839x - 4523.9$	$R^2 = 0.804$
Logarithmic	$y = 4546.3\ln(x) - 34512$	$R^2 = 0.802$
Polynomial	$y = 0.0001x^4 - 0.9007x^3 + 2687.6x^2 - 4E+06x + 2E+09$	$R^2 = 0.957$

The growth of literature shown in figure 2 can be divided into 2 parts, in 1st part (1960-1971) there is no literature published by Indian scientist as (India) is an affiliation country found in Web of Science (WoS). In 2nd part (1972-2014), follows polynomial growth rate which indicate that the number of papers concerning Galaxy research were growing at a high but slow growth rate

3.4. Citation pattern

Fig 3 and 4 represents the year wise growth of citations received by Indian author and total no. of citations per year and no. of publications per year during 1960-2014 on Galaxy research. The total 1914 articles of Indian scientists during 1960-2014 were abstracted from WoS related to Galaxy research publication which received a total of 22030 citations with 18.37 average citations.

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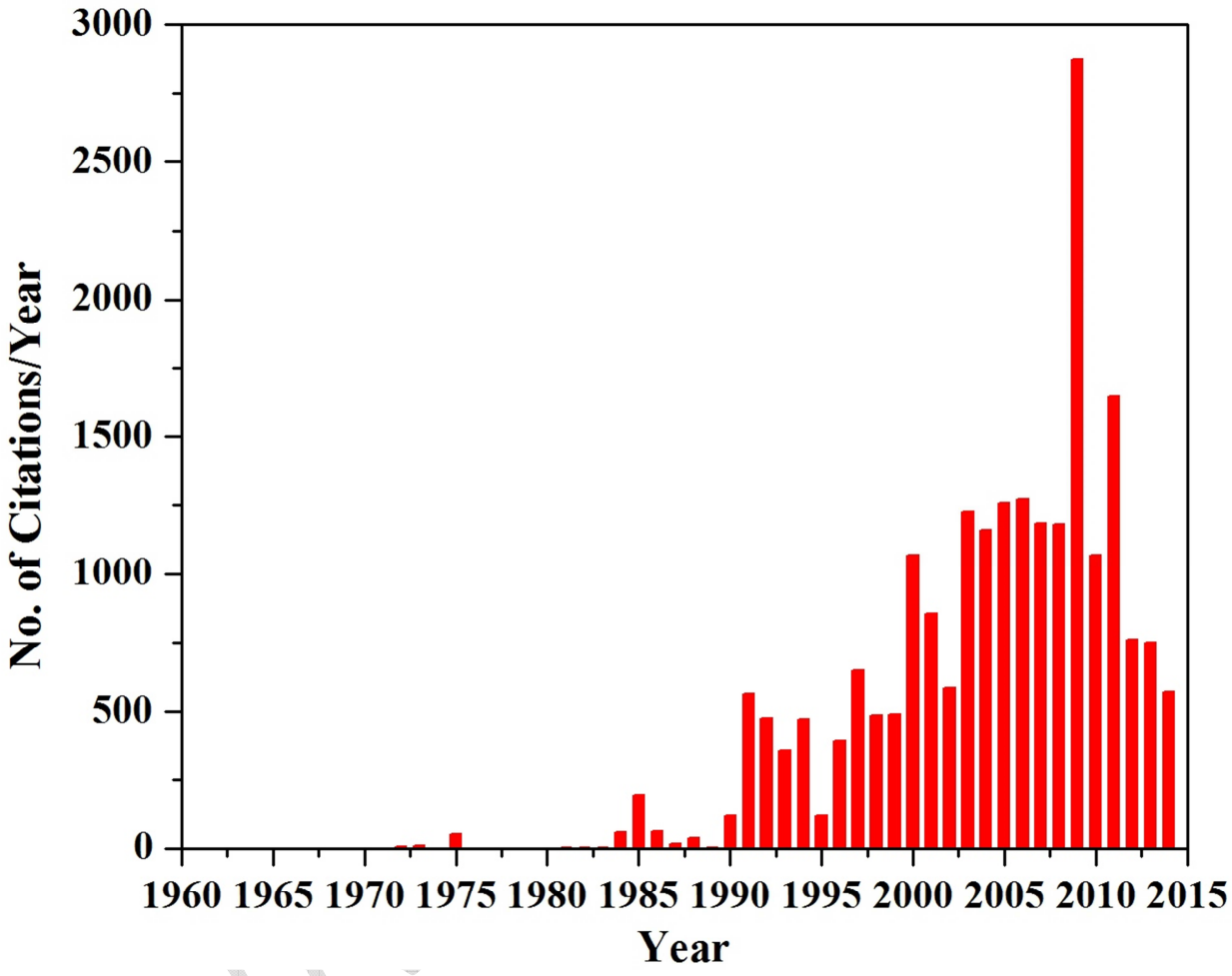

Figure 3: Citation Pattern of Galaxy research in India during 1960-2014

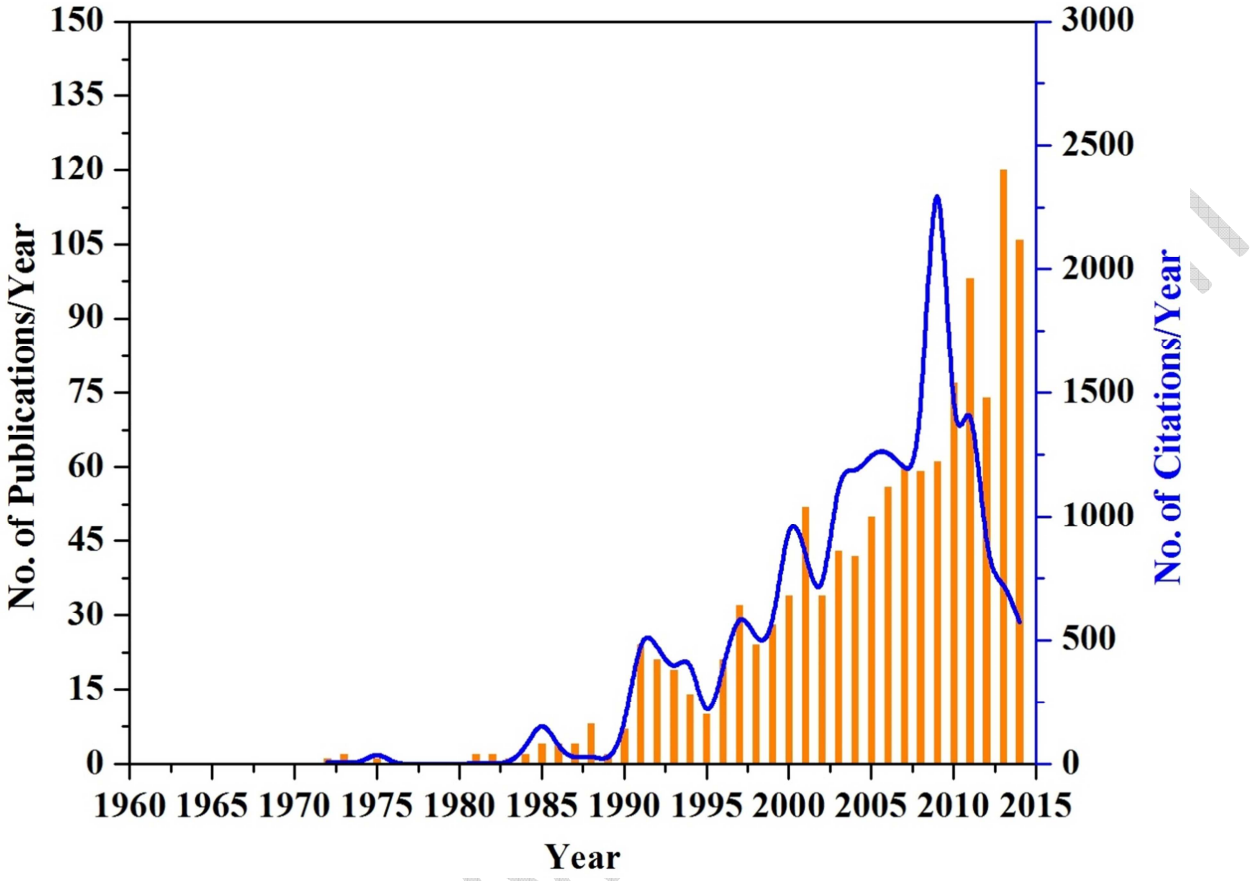

Fig 4: Citation pattern of Galaxy research in India during 1960-2014: total citation/year Vs no. of publications/year. Blue line (right Y axis) indicates the citations pattern against red line (left Y axis) describe the publication pattern

The pattern of citation received during the said year is very fluctuating. In the starting year 1972, the total number of citation received 5 with an average citation 5.The minimum citation received in the year 1982 is two (2) with average citation 1 and the maximum citation received in the year 2009 is 2877 with average citation 16.83. It is important to note here that after the year 2009 publication increases but citation decreases.

3.5 INSTITUTION:

3.5.1. Top 20 Institutions and their research impact

The contribution of different institutions was estimated by affiliated institution of at least one author. A total of 1199 articles on Galaxy research appeared from 1035 institutions. Out of 1035 institution, 405 institutions appeared one time and 136 institutions appeared two time.

Table 4 shows the top 20 productive institutions during the last 54 years, 1960-2014.Out of these top 20 institutions, 7 institutions are Indian institution. Tata Institute of Fundamental Research which contributed highest publication had published 329 (27.440%) paper followed by Inter University Centre for Astronomy Astrophysics 245, Indian Institute of Astrophysics 190 and Raman Research Institute 161.

while the other 13 are foreign institutions. Among these 7 are belong to USA namely National Aeronautics Space Administration (NASA), University of California System, California Institute of Technology, National Radio Astronomy Observatory,Harvard University, United States Department of Energy and Smithsonian Institution; 2 are belong to France namely Centre National De La Recherche Scientifique and Observatoire De Paris, France; 2 are belong to Germany namely Max Planck Society and European Southern

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Observatory, Germany; 1for Russian Academy of Sciences, Russia and 1 University of Cambridge, UK.

Table 4: Top 20 Institutions and their research impact

Institution	Region	TP (%)	TC	AgCPA	h-index
Tata Institute of Fundamental Research	India	329(27.440)	6720	20.43	36
Inter University Centre for Astronomy Astrophysics	India	245(20.434)	5703	23.28	41
Indian Institute of Astrophysics	India	190(15.847)	2857	15.04	25
Raman Research Institute	India	161(13.428)	420	15.03	26
Centre National De La Recherche Scientifique	France	155(12.927)	4892	31.56	40
Max Planck Society	Germany	121(10.092)	5317	43.94	35
Observatoire De Paris	France	97(8.090)	3347	34.51	36
Indian Institute of Science Iisc Banglore	India	81(6.756)	1716	21.19	21
National Aeronautics Space Administration (NASA)	USA	80(6.672)	4851	60.64	32
European Southern Observatory	Germany	78(6.505)	4540	58.21	32
University of California System	USA	76(6.339)	4562	60.03	29
California Institute of Technology	USA	76(6.339)	3972	52.26	26
National Radio Astronomy Observatory	USA	65(5.421)	1397	16.63	20
University of Cambridge	UK	64(5.338)	4241	66.27	30
National Centre for Radio Astrophysics	India	62(5.171)	1397	16.63	20
Harvard University	USA	57(4.754)	1409	24.72	18
University of Pune	India	53(4.420)	766	14.45	16
Russian Academy of Sciences	Russia	53(4.420)	1167	22.02	22
United States Department of Energy	USA	52(4.337)	4276	82.23	26
Smithsonian Institution	USA	51(4.254)	976	19.14	18

TP= Total no. of Galaxy related articles published by an institution; **TC** = Total no. of citation received; **AgCPA**= Average no. of citations per article; h-**index**=defined by the no. of h papers among an institution's no. of publications that have at least h citations each. Source: WoS

Table 4 reveals the impact of research in terms of quality of papers. The AgCPA (the average no. of citation per article) indicates the average impact of articles published by a institution and the h-index (defined as the no. of h papers among a institution's no. of

publications that have at least h citation each) are used to identify which institution has the largest no. of high quality articles in the Galaxy research. It is seen from the above table that Galaxy research related articles authored in foreign institution (United States Department of Energy) have the highest average impact (AgCPA=82.23) followed by University of Cambridge average impact (AgCPA=66.27).Among Indian institution, Inter University Centre for Astronomy Astrophysics highest average impact (AgCPA=23.28) in AgCPA index.

3.6 JOURNAL:

3.6.1 Top 20 Journals and their research impact

Galaxy research papers appeared in 51 journals. Papers have appeared in highest no. in the journal "Monthly Notices of the Royal Astronomical Society" published by Oxford University Press on behalf of the Royal Astronomical Society originating from United Kingdom.

Table 5 shows the top 20 productive journals. These 20 out of the 51 journals had published 1166 of the total 1199 articles. The "Monthly Notices of the Royal Astronomical Society" ranked first with 345(28.774%);"Astronomy and Astrophysics 250 (20.851%)" "Astrophysical Journal 231(19.266 %) ","Astrophysics and Space Science 62(5.171 %)"

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and "Journal of Astrophysics and Astronomy 53(4.420%)"; ranked at 2nd, 3rd, 4th, and 5th, respectively.

Table 5: Top 20 Journals and their research impact

Journal	TP(%)	TC	AgCPA	Journal Metrics (2013) SJR	IPP	SNIP	Country
Monthly Notices of the Royal Astronomical Society	345(28.774)	5258	15.24	2.760	4.639	1.325	UK
Astronomy Astrophysics	250 (20.851)	5645	22.58	1.471	1.932	0.612	France
Astrophysical Journal	231(19.266)	4537	19.64	3.159	4.348	1.145	UK
Astrophysics and Space Science	62(5.171)	284	4.58	1.081	1.748	1.056	Netherland
Journal of Astrophysics and Astronomy	53(4.420)	236	4.45	0.477	0.541	0.224	India
Astronomical Journal	42(3.503)	931	22.17	2.795	3.282	1.092	UK
Physical Review D	34(2.836)	1123	33.03	1.899	3.192	1.136	USA
Astrophysical Journal Letters	25(2.085)	189	7.56	3.914	4.852	1.487	UK
Journal of Cosmology and Astroparticle Physics	19(1.585)	127	6.68	0.615	2.374	0.465	UK
New Astronomy	18(1.501)	129	7.17	1.074	1.332	0.726	Netherland
IAU Symposia	16(1.334)	3	0.19	-	-	-	Puerto Rico
Bulletin of the Astronomical Society of India	15(1.251)	35	2.33	1.091	1.068	0.516	India
Astrophysical Journal Supplement Series	2(1.001)	2464	205.33	6.857	9.687	3.125	USA
Research in Astronomy and Astrophysics	8(0.667)	22	2.75	0.953	1.331	0.768	UK
International Journal of Modern Physics D	7(0.584)	41	5.86	0.733	1.021	0.540	Singapore
Publications of the Astronomical Society of Japan	6(0.500)	50	8.33	1.521	1.626	0.750	Japan
Classical and Quantum Gravity	6(0.500)	185	30.83	1.476	2.192	0.966	UK
Astronomy Astrophysics Supplement Series	6(0.50)	63	10.50	-	-	-	France
Astronomische Nachrichten	6(0.500)	10	1.67	0.775	1.042	0.576	Germany
Publications of the Astronomical Society of the Pacific	5(0.417)	132	26.40	2.990	3.147	1.266	USA

TP= Total no. of Galaxy related articles published by a Journal (followed by the percentage of Galaxy related articles in the journal of a total Galaxy related articles); **TC** = Total no. of citation received ; **AgCPA**= Average no. of citations that Galaxy related articles in a journal received ; **h-index**= no. of h papers among a journal's no. of publications that have at least h citations each. **SJR** = SCImago Journal Rank is weighted by the prestige of a journal. Subject field, quality and reputation of the journal have a direct effect on the value of a citation. SJR also normalizes for differences in citation behavior between subject fields; **IPP** = Impact per Publication (IPP) measures the ratio of citations per article published in the journal; **SNIP** = Source Normalized Impact per Paper measures contextual citation impact by weighting citations based on the total number of citations in a subject field. Source: WoS and SCOPUS

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Table 5 shows the citation impact on top 20 journals. The AgCPA (Average no. of citations that Galaxy related articles in a journal received and the h-index (defined by the no. of h papers among a journal's no. of publications that have at least h citations each) are used to identify which journals have the largest no. of high quality articles in the Galaxy research. It is seen from the above table that the journal "Astrophysical Journal Supplement Series" published by IOP Publishing for the American Astronomical Society in USA has the highest average impact (AgCPA=205.33) although the journal "Monthly Notices of The Royal Astronomical Society" has the highest no. of publication but ranked 7th in the AgCPA index.

3.7 AUTHOR

3.7.1. Top 20 most Prolific Authors and impact of their research output

A total of 1199 articles included the author addresses. Articles on Galaxy research have been contributed by 5617 authors. Top 20 productive authors were ranked based on the no. of total articles. Chengalur, JN produced maximum no. of publications 63 i.e. 5.254 % of total publications with ranked first followed by Saikia, DJ ; Srianand, R; Jog, CJ ; Dwarakanath, KS ; ranked at 2nd , 3rd , 4th and 5th respectively. Table 6 showed the top 20 productive authors during the last 54 years, 1960-2014.

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Table 6: **Top 20 most Prolific Authors and impact of their research output**

Author	TP(%)	TC	TC woSC	CI	CIwoSC	AgCPA	h-index
Chengalur JN	63(5.254)	1036	900	667	617	16.44	20
Saikia DJ	57(4.754)	790	704	575	541	13.86	17
Srianand R	49(4.087)	1490	1349	792	753	30.41	23
Jog CJ	43(3.586)	1093	967	777	742	25.42	17
Dwarakanath KS	34(2.836)	311	300	289	281	9.15	9
Petitjean P	31(2.585)	1703	1600	1041	1016	54.94	22
Sagar R	30(2.502)	519	500	466	453	17.30	13
Mitra S	27(2.252)	755	671	436	421	27.96	15
Bharadwaj S	27(2.252)	443	388	316	296	16.41	13
Anantharamaiah KR	27(2.252)	446	400	338	320	16.52	13
Begum A	25(2.085)	485	419	323	302	19.40	14
Singh KP	24(2.002)	162	150	142	132	6.75	8
Nath BB	23(1.918)	305	272	247	235	13.26	11
Mazzotta P	23(1.918)	581	495	277	261	25.26	14
Kanekar N	23(1.918)	435	394	283	267	18.91	13
Ensslin TA	23(1.918)	719	636	401	387	31.26	14
Subramaniam A	22(1.835)	259	252	247	240	11.77	10
Ledoux C	22(1.835)	1172	1071	515	494	53.27	18
Goss WM	22(1.835)	418	384	340	327	19.00	12
Ganesh S	22(1.835)	431	376	287	270	19.59	13

TP(%): Total no. of Galaxy related articles published by a author (followed by percentage of Galaxy related articles by a author of the total Galaxy related article) **TC:** Total no. of citation**; TC woSc:** Sum of Times Cited without self-citations**; CI:** Citing Articles **; CIwoSC:** Citing Articles without self-citations**; AgCPA:** Average Citations per Article**; h-index :** no. of h papers among a author's no. of publications that have at least h citations each. Source: WoS

Table 6 reveals the impact of research in terms of quality of papers. The AgCPA (the average no. of citation per article) indicates the average impact of articles published by a

institution and the h-index used to identify which author has the largest no. of high quality articles in the Galaxy research. It is seen from the above table 4 that Galaxy research related articles authored by Petitjean, P have the highest average impact (AgCPA=54.94) followed by Ledoux, C (AgCPA=53.27) although Chengalur, JN ranked 13th in the AgCPA index.

3.8. TOP 20 CITED PUBLICATION IN GALAXY RESEARCH IN INDIA DURING 1960-2014

Table 7 Top 20 most Prolific papers and impact of their research output

S.N	Bibliography	TC	AgC
1	Alexander, L. V., Zhang, X., Peterson, T. C., Caesar, J., Gleason, B., Tank, A., … Vazquez-Aguirre, J. L. (2006). Global observed changes in daily climate extremes of temperature and precipitation. Journal of Geophysical Research-Atmospheres, 111(D5), D05109. http://doi.org/10.1029/2005JD006290	732	73.20
2	SIKKA, D., & GADGIL, S. (1980). On the Maximum Cloud Zone And The Itcz Over Indian Longitudes During The Southwest Monsoon. Monthly Weather Review, 108(11), 1840–1853. http://doi.org/10.1175/1520-0493(1980)108<1840:OTMCZA>2.0.CO;2	412	11.44
3	Parthasarathy, B., Munot, A., & Kothawale, D. (1994). All-India Monthly And Seasonal Rainfall Series - 1871-1993. Theoretical and Applied Climatology, 49(4), 217–224. http://doi.org/10.1007/BF00867461	277	12.59
4	Krishnamurti, T. N., Kishtawal, C. M., Zhang, Z., LaRow, T., Bachiochi, D., Williford, E., … Surendran, S. (2000). Multimodel ensemble forecasts for weather and seasonal climate. Journal of Climate, 13(23), 4196–4216. http://doi.org/10.1175/1520-0442(2000)013<4196:MEFFWA>2.0.CO;2	270	16.88
5	Dentener, F., Drevet, J., Lamarque, J. F., Bey, I., Eickhout, B., Fiore, A. M., … Wild, O. (2006). Nitrogen and sulfur deposition on regional and global scales: A multimodel evaluation. Global Biogeochemical Cycles, 20(4), GB4003.	234	23.40

	http://doi.org/10.1029/2005GB002672		
6	Mooley, D., & Parthasarathy, B. (1984). Fluctuations In All-India Summer Monsoon Rainfall During 1871-1978. Climatic Change, 6(3), 287–301. http://doi.org/10.1007/BF00142477	216	6.75
7	Rao, P., Jain, A., Kishore, P., Balamuralidhar, P., Damle, S., & Viswanathan, G. (1995). Indian MST Radar .1. System Description And Sample Vector Wind Measurements In St Mode. Radio Science, 30(4), 1125–1138. http://doi.org/10.1029/95RS00787	204	9.71
8	Goswami, B. N., & Mohan, R. S. A. (2001). Intraseasonal oscillations and interannual variability of the Indian summer monsoon. Journal of Climate, 14(6), 1180–1198. http://doi.org/10.1175/1520-0442(2001)014<1180:IOAIVO>2.0.CO;2	199	13.27
9	Singh, R. P., Dey, S., Tripathi, S. N., Tare, V., & Holben, B. (2004). Variability of aerosol parameters over Kanpur, northern India. Journal of Geophysical Research-Atmospheres, 109(D23), D23206. http://doi.org/10.1029/2004JD004966	188	15.67
10	Chattopadhyay, N., & Hulme, M. (1997). Evaporation and potential evapotranspiration in India under conditions of recent and future climate change. Agricultural and Forest Meteorology, 87(1), 55–73. http://doi.org/10.1016/S0168-1923(97)00006-3	171	9.00
11	Dey, S., Tripathi, S. N., Singh, R. P., & Holben, B. N. (2004). Influence of dust storms on the aerosol optical properties over the Indo-Gangetic basin. Journal of Geophysical Research-Atmospheres, 109(D20), D20211. http://doi.org/10.1029/2004JD004924	156	13.00
12	Reddy, M. S., & Venkataraman, C. (2002). Inventory of aerosol and sulphur dioxide emissions from India: I - Fossil fuel combustion. Atmospheric Environment, 36(4), 677–697. http://doi.org/10.1016/S1352-2310(01)00463-0	156	11.14
13	Reddy, M. S., & Venkataraman, C. (2002). Inventory of aerosol and sulphur dioxide emissions from India. Part II - biomass combustion. Atmospheric Environment, 36(4), 699–712. http://doi.org/10.1016/S1352-2310(01)00464-2	145	10.36
14	Khattri, S. D., & Singh, M. K. (2000). Colour removal from synthetic dye wastewater using a bioadsorbent. Water Air and Soil Pollution, 120(3-4), 283–	135	8.44

	294. http://doi.org/10.1023/A:1005207803041		
15	Kulkarni, P., & Venkataraman, C. (2000). Atmospheric polycyclic aromatic hydrocarbons in Mumbai, India. Atmospheric Environment, 34(17), 2785–2790. http://doi.org/10.1016/S1352-2310(99)00312-X	127	7.94
16	PARTHASARATHY, B., KUMAR, K., & KOTHAWALE, D. (1992). INDIAN-SUMMER MONSOON RAINFALL INDEXES - 1871-1990. Meteorological Magazine, 121(1441), 174–186.	125	5.21
17	Bhat, G. S., Gadgil, S., Kumar, P. V. H., Kalsi, S. R., Madhusoodanan, P., Murty, V. S. N., … Vinayachandran, P. N. (2001). BOBMEX: The Bay of Bengal Monsoon Experiment. Bulletin of the American Meteorological Society, 82(10), 2217–2243. http://doi.org/10.1175/1520-0477(2001)082<2217:BTBOBM>2.3.CO;2	122	8.13
18	BHALME, H., & MOOLEY, D. (1980). LARGE-SCALE DROUGHTS-FLOODS AND MONSOON CIRCULATION. Monthly Weather Review, 108(8), 1197–1211. http://doi.org/10.1175/1520-0493(1980)108<1197:LSDAMC>2.0.CO;2	120	3.33
19	Goswami, B. N. (1998). Interannual variations of Indian summer monsoon in a GCM: External conditions versus internal feedbacks. Journal of Climate, 11(4), 501–522. http://doi.org/10.1175/1520-0442(1998)011<0501:IVOISM>2.0.CO;2	111	6.17
20	Lal, S., Naja, M., & Subbaraya, B. H. (2000). Seasonal variations in surface ozone and its precursors over an urban site in India. Atmospheric Environment, 34(17), 2713–2724. http://doi.org/10.1016/S1352-2310(99)00510-5	108	6.75

Citation Style: APA (6th edition); **TC**: Total Citations; **AgC:** Average Citations

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3.9 GLOBALIZATION OF GALAXY RESEARCH IN INDIA

3.9.1 Spatial Distribution of Publications

Based on the author attributions, we can map the world-wide geographic distribution of Galaxy research publication. As shown in fig-5, the major spatial clusters of research institutes located in Asia, followed by Europe, Africa, South America and North America. Several minor clusters distributed in other parts of the world.

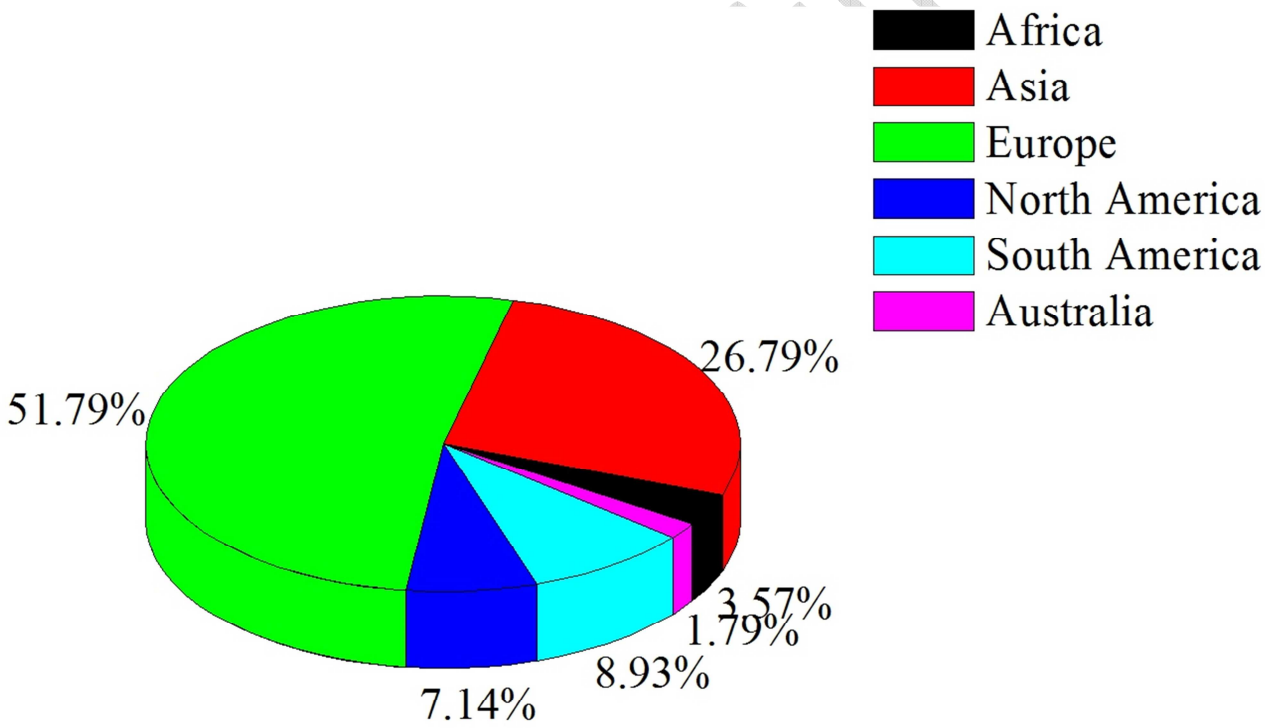

Figure 5: Geographic distribution of Galaxy research publication

1199 articles which included author address, source country and research institute. There were 56 collaborating Countries/territories except India which participated in Indian institution in Galaxy research. Out of 56 Countries/territories there are seven countries with which the collaboration is high, over 100 publications: United States, France, Germany, UK, Italy , Australia and Netherland and five countries with medium-high collaboration, over 50 publications: Chile , Spain, Canada, Russia and Japan and there are 8 countries with little collaboration over 25 publications and rest of 13 Counting just 1–2 collaborations, 10 with just 3–10 and 13 with just 11-25.

3.9.2. Top 20 Countries International Collaborations and impact of their research output

Top 20 countries / territories were ranked based on the no. of total articles, along with the citations, percentage of internationally collaboration publications (Table-8). Out of these 20 countries / territories, The USA produced maximum publication 421 that is 35.113% of total publication with higher citations (11613).The AgCPA (the average no. of citation per article) indicates the average impact of articles published by a country and the h-index (define as the no. of h papers among a country's no. of publications that have at least h citation each) are used to identify which country has the largest no. of high quality articles in the Galaxy research. It is seen from the below table 8 that Galaxy research related articles authored in South Africa (Africa) have the highest average impact (AgCPA=80.53) followed by Poland

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(Europe) AgCPA=70.55 although USA ranked 17th in the AgCPA index. Data regarding international research collaboration shows that it become more prevalent during study period and fruits of cooperation contributed to the overall scientific output in various countries and in the broad field of Galaxy research.

Table 8: Countries working collaboratively with Indian institutions on Galaxy research during period 1960-2014.

Countries	Continent	TP(%)	TC	AgCPA	h-index
USA	North America	421(35.113)	11613	27.58	49
France	Europe	192(16.013)	6040	31.46	44
Germany	Europe	188(15.680)	6990	37.18	41
England	Europe	168(14.012)	6546	38.96	38
Italy	Europe	123(10.259)	3804	30.93	36
Australia	Australia	106(8.841)	4404	41.55	26
Netherlands	Europe	101(8.424)	4319	42.76	33
Chile	South America	89(7.423)	4585	51.52	32
Spain	Europe	88(7.339)	4663	52.99	31
Canada	North America	75(6.255)	4200	56.00	27
Russia	Europe	68(5.671)	1699	24.99	25
Japan	Asia	58(4.837)	3984	68.69	24
Denmark	Europe	47(3.920)	1356	28.85	21
Poland	Europe	40(3.336)	2822	70.55	19

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Taiwan	Asia	38(3.169)	1043	27.45	15
South Africa	Africa	36(3.003)	2899	80.53	19
Wales	Europe	34(2.836)	1239	36.44	20
Switzerland	Europe	33(2.752)	2750	83.33	17
Brazil	South America	31(2.585)	889	28.68	12
Sweden	Europe	30(2.502)	866	28.87	19

TP= Total no. of Galaxy related articles published by a country (followed by the percentage of Galaxy related articles in the country of a total Galaxy related articles); **TC** = Total no. of citation received; **AgCPA**= Average no. of citations; **h-index**= no. of h papers among a country's no. of publications that have at least h citations each. Source: WoS

3.10 Analysis of keywords

Keyword analysis in research paper is very interesting in order to follow and identify the trends in the science and engineering branch (Montoya et. al., 2014). As a result of our work a total of 4748 different keywords, from 1960 to 2014 in the Galaxy have been identified. The no. of analysed publications during the study period was 1199.

To obtain accurate results, we pre-processed the keywords by merging the singular and plural forms of the same terminology, and those keywords with the same meaning while using different expressions.A total 4276 unique Keywords are obtained. Among these unique keywords 1881 (43.98 %) appear once or twice at the most, we can deduce that this can be a sign of lack of research continuity or of a wide range of research focus. Table 7 shows the most used keywords during the considered period.

3.10.1 TOP 20 KEYWORDS

The top 20 most frequently used keywords for the study period are listed in Table 9. The five most frequently used keywords were ‘‘Formation’’, ‘‘Evolution’’, ‘‘Structure’’, “Dynamics” and “Disk”

Table 9: **Top 20 most frequently used keywords for the study period**

Keywords	**Total**	**%**
Abundances	96	2.24
Associations	30	0.70
Bulge	29	0.67
Center	43	1.00
Disk	141	3.29
Dynamics	151	3.53
Evolution	266	6.22
Formation	251	5.86
Fundamental parameters	33	0.77
Globular clusters	16	0.37
Halo	127	2.97
Kinematics	136	3.18
Nucleus	17	0.39
Open clusters	35	0.81

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Stellar content	27	0.63
Structure	233	5.44

NO: Number of time occurrences; Source: WoS

3.10.2 QUICK RISING THEMES

The Compound Annual Growth Rate (CAGR) was used to identify the top most frequently used keywords and to select quick rising themes of Galaxy research, which could be indicators of future research directions. The Compound Annual Growth Rate (CAGR) of top 20 keywords were separately calculated based on the following formula (Compound annual growth rate, (n.d))

$$\mathrm{CAGR}(t_0, t_n) = (V(t_n)/V(t_0))^{\frac{1}{tn-t_0}} - 1$$

$V(t_0)$: Initial observed value, $V(t_n)$: last observed value, $t_n - t_0$: number of years.

The CAGR provides smoothed growth rates free from the annual fluctuations of keywords occurrences during the study period. Table 10 lists the top 20 keywords according to the CAGR and sorted them by their rank. The ranks in Table 10 show that ‘‘Halo’’, ‘‘Dynamics’’ and “Abundances” are three leading hot issues that continue to attract broad attention. ‘‘Dynamics’’ (CAGR, 11.80%) kept its dominance in terms of total quantity and annual growth rate.

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Table 10 Top 20 Quick rising themes for the study period

Keywords	V(t0)	V(tn)	t0	tn	CAGR(%)
Abundances	1	11	1991	2014	10.99
Associations	1	2	1997	2014	4.16
Bulge	2	2	1999	2014	0.00
Center	1	1	1991	2014	0.00
Disk	2	14	1991	2014	8.83
Dynamics	1	13	1991	2014	11.80
Evolution	4	22	1991	2014	7.69
Formation	3	30	1991	2014	10.53
Fundamental parameters	1	4	1992	2014	6.50
Globular clusters	1	1	1993	2014	0.00
Halo	1	17	1991	2014	13.11
Kinematics	2	10	1992	2014	7.59
Nucleus	1	2	1993	2013	3.36
Open clusters	1	3	1991	2014	4.89
Stellar content	1	3	1991	2014	4.89
Structure	3	23	1991	2014	9.26

t0 : the Initial (first) year (The Year in which no. of keywords occurrence first time) ; **tn**: the last year (No. of keywords occurrence); **V(t0)**: Initial observed value (no. of keywords occurrence); **V(tn)**: last observed value (no. of keywords occurrence); **CAGR(%):** Compound Annual Growth Rate (CAGR); **Source: WoS**

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4. CONCLUSION:

Results of this study relating to the scientometric analysis of the research on the Galaxy research during 1960-2014 provided helpful insights into the research on the Galaxy research in many fronts including the patterns of publication outputs, journals, geographic and institutional contributions, and the keyword frequencies. In total 1199 article published during the investigation period. The following conclusions have been drawn from this study:

(1) Galaxy research related research has significantly increased in the last 54 years. The amount of Galaxy research related publication outputs rose at an average annual growth rate of % over the past five decades.The growth curve fit 4th degree polynomial with the R^2 = 0.964. This growth has been slow rate and significantly high though not exponential in nature. It is concluded that the growth is on a rise and will surely increase further.

The results also provided valuable information on the citations made to the Galaxy research papers. Total Number of Citations, Average Citations per Item, and H-index. There were 22030 total citations with 18.37 average citations to 1199 papers on the Galaxy research from this study. The research field has had a significant impact on the general literature with H-index of 61, a rough measure of its impact.

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(2) A total of 51 journals had published 1199 articles on Galaxy. The most active journal was "Monthly Notices of the Royal Astronomical Society" published by Oxford University Press on behalf of the Royal Astronomical Society originating from United Kingdom which published 345(28.774%) of the total 1199 article, followed by "Astronomy and Astrophysics 250 (20.851%)" and "Astrophysical Journal 231(19.266 %). The results also provided valuable information on the citations received by journal. the journal "Astrophysical Journal Supplement Series" published by IOP Publishing for the American Astronomical Society in USA has the highest average impact (AvgCPA=205.33) although the journal "Monthly Notices of The Royal Astronomical Society" has the highest no. of publication but ranked 7th in the AgvCPA index.

(3) A total of 1199 Articles on Galaxy appeared from 1035 institutions. Tata Institute of Fundamental Research which contributed highest publication had published 329 (27.440%) paper followed by Inter University Centre for Astronomy Astrophysics 245, Indian Institute of Astrophysics 190 and Raman Research Institute 161.It has been found that Galaxy related articles authored in foreign organization (United States Department of Energy) have the highest average impact (AgCPA=82.23) followed by University of Cambridge average impact (AgCPA=66.27).Among Indian institution, Inter University Centre for Astronomy Astrophysics highest average impact (AgCPA=23.28) in AgCPA index.

(4) A total of 5617 authors contributed on Galaxy research. The most active author was Chengalur, JN produced maximum no. of publications 63 of total publications 1199 with ranked first followed by Saikia, DJ ; Srianand, R. It is important to note that Galaxy related articles authored by Petitjean, P have the highest average impact (AgCPA=54.94) followed by Ledoux, C (AgCPA=53.27) although Chengalur, JN ranked 13th in the AgCPA index.

(5) For globalization of Galaxy Research in India, 56 Countries/territories participated in Galaxy research. USA produced maximum publications 421 followed by France (192) and Germany (188). South Africa (Africa) have the highest average impact (AgCPA=80.53) followed by Poland (Europe) AgCPA=70.55 although USA ranked 17th in the AgCPA index.

(6) The keyword analysis of the studied publications revealed the hot direction and quick rising themes of Galaxy research. ''Formation'', ''Evolution'', ''Structure'', "Dynamics" and "Disk" were the hottest issues of Galaxy research. There are 20 top quick rising themes which calculated by CAGR. ''Halo'','' Dynamics'' and "Abundances" are three leading hot issues that continue to attract broad attention.

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