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Citation Trend of Indian Physics and Astronomy Research during 2005-2020 through the Lens of Some New Indicators

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ABSTRACT

The indicator Citation Swing Factor (CSF) has recently been developed to quantitatively measure the diffusion process from h-core zone to h-core excess zone. This paper calculated CSF for Indian physics and astronomy research output appeared in selective Indian journals since 2005 to 2020. The theoretical values of CSF are also calculated on the basis of its fundamental equation and same was compared it with the respective observed values. The average error over entire time span is found 2.26 per cent indicating close proximity between theoretically expected and practically observed values. Besides, three other scientometric indicators are introduced here, viz. Time-Normalised Total Cited Ratio (TC), Time-Normalised Cited Uncited Ratio (CU) and Time-Normalised Total Uncited Ratio (TU). Of these four indicators, the variation of TC is highest (1.76), followed by TU (0.53), CU (0.37) and CSF(E) (0.09), as evident from the values of respective Coefficients of Variations. The numerical values of these indicators are found out for the same sample and the temporal variations along with their mutual interrelationships are determined by regression analysis. It is observed that the three indicators, TC, CU and TU are mutually interrelated through the following linear regression equations, i.e. $TC = -0.76 + 1.88*TU$ and $CU = -0.201 + 0.34*TU$.

Keywords: H-Index; Excess citation; e Index; R Index; Total citation; h-core citation; Citation diffusion; Citation swing factor; Cited to uncited ratio

1. INTRODUCTION

The term 'Citation' implies a connection between a part or whole of the cited document and a part or whole of the citing document, broadly known as source document[1]. A 'Reference' is the acknowledgement that one document gives to another and a 'Citation' is the acknowledgement that one document receives from another[2]. According to Garfield[3], there are many reasons behind the existence of citation. The citation analysis is the most popular technique used in scientometrics that helps in evaluating the quality of research publications, assessing the contribution of authors and standard of journals. Eugene Garfield[4-8] illustrated in several articles the potentialities of citation analysis in the evaluation of research faculty. According to Price[9], citation patterns in research articles indicate the research front in a particular subject domain. The citation is a recognition of intellectual works that is reckoned as principal rewards of science[10]. This paper has verified the observed values of a recently introduced indicator, viz. Citation Swing Factor, with its formula-based theoretically calculated values for a sample of Scopus-indexed 18357 Indian physics and astronomy research publications from 2005 to 2020, which received 91245 citations. Besides, this paper proposed three citation-based indicators, calculated their values for the same sample and determined the inter-relationship among them.

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2. LITERATURE REVIEW

Citation trend analysis includes the study of changing number of citations received by articles or journals over the years. Usually, the articles or journals of a particular discipline or subject are studied in this context. The citation trends of journals devoted to subjects like primatology[11], psychological medicine[12], forensic science[13] and behavioural psychology[14] were analysed. The citation trend analysis of physical therapy research output was done by Imai[15] et al. Morgan[16] investigated whether citation trends reflect epidemiologic patterns. Gazni[17] analysed journal self-citation trends and Ajibade & Stephen[18] analysed citation trends on E-government in South African countries. Giovanni[19], Biradar & Kumbar[20], Chi[21] and Singh[22] analysed citation trends on psychiatry, environmental science, political science and defense science respectively. The bibliometric indicators developed before 2k evaluated Journals on the basis of citation count and number of papers. The concept of author-level indicators and article-level indicators were developed after 2k. The introduction of h index by Hirsch[23] in 2005 was the milestone of modern or post-2k metrics. A scientist has h-index equal to H if the top H of his/her N publications from a ranked list have at least H citations

each[23]. Besides, there are numbers of indices developed so far known as h-type indices[24].

The citation trend of physics research output was observed by Alvarez, Vanz & Barbosa[25], where an analysis of Brazilian research on High Energy Physics from 1983 to 2013 was incorporated. Scientometric indicators for output, collaboration and impact studies were used to characterize the field. Tsay[26] carried out comparative study between scientometric data including number of source items, number of citations, impact factor, immediacy index, citing half-life and cited half-life, for crucial journals in physics, chemistry and engineering. Mugnaini, Packer & Meneghini[27] compared the average h-index of the members of the Brazilian Academy of Sciences with the members of the National Academy of Sciences (USA) for 10 different areas of science. Czerwon[28] analysed the dynamics of the subject domain, i.e. theoretical high energy physics based on six-year periods' (1979-1984) citations. This paper provided clues to understanding the growth of a new research domain from a core body of seminal literature. Mohan & Kumbar[29] carried out scientometric studies of the publications on stellar and galactic astrophysics research in India during the last 20 years.

Makhoba & Pouris[30] analysed Activity and Attractivity indices of South African research output and compared the same with BRICS nations in biotechnology, energy, astronomy and palaeontology from 2002 to 2012. Li *et al.*[31] carried out a bibliometric analysis of publications in the journal Symmetry from 2009 to 2019. Using bibliometric data generated through a model of citation dynamics, Medo & Cimini[32] compared several indicators for the scientific impact of individual researchers of physics. Andre[33] analysed 1.2 million research articles on LASER published since 1960 to present some bibliometric studies and found the h-index of 590. Moed & Raan[34] developed bibliometric indicators for researchers in physics and astrophysics on the basis of citation-per-publication ratio and researchers' individual perception. Flores, Raga & Roy[35] scientometrically evaluated articles published from 2010 to 2019 contributed by Mexican astronomers. Henneken & Kurtz[36] developed bibliometric indicators on the basis of number of citations, number of reads and number of downloads of the articles. Wildegaard[37] calculated 17 author-level indicators for 512 researchers in Astronomy, Environmental Science, Philosophy and Public Health. Havemann & Larsen[38] tested 16 bibliometric indicators with respect to their validity for the individual astrophysics researcher by estimating their power to predict later successful researchers.

3. RESEARCH GAP

The literature review shows enough works on citation trend analysis in different subject fields. A substantive number of analytical studies on author-level and institution-level bibliometric indicator development has also been observed. But, except one article[31], no work is found discussed on indicator analysis for the physics and astronomy journals. Also, only one work[29] is observed in Indian context dealing with indicator analysis in Indian astrophysics research domain. The absence of studies on journal-level bibliometric indicator analysis particularly in Indian context has created a research gap in this domain. It is historically justified that physics is the field where Indian contributions during both pre- and post-independence era have been really outstanding. It is borne out by the fact that one physicist from pre-independent India received the Noble Prize, and scientists like J.C. Bose, M.N. Saha, S.N. Bose, and K.S. Krishnan missed it narrowly. There are numbers of esteemed physics and astronomy journals started in colonial India and still continuing. It is thus imperative to carry out journal-level bibliometric indicator analysis in Indian physics and astronomy research domain. This paper has calculated and analytically interpreted four indicators (CSF, TC, CU & TU) for 15 core Indian physics and astronomy journals. The indicator CSF has recently been formulated[39] and other three indicators are introduced here.

4. NEW CITATION-BASED INDICATORS

4.1 Citation Swing Factor (CSF)

One of the major objectives of h-type indices were to normalise h-index by dividing the same by the number of publications or the age of citation (time normalisation). An author or journal just after receiving one citation enters in the domain of the cited vs. citing graph (Fig. 1) through the tail zone, which is the entry point for a cited item. The number of citations received may be increased in due course of time causing the said cited item gradually shifting from the tail zone towards h-core zone and eventually h-excess zone. This continuous movement of a cited item in the cited-citing graph (Fig. 1) with accretion of citation may be termed as diffusion of cited item. The two ratios, viz. Fold of Excess citation over Total citations (FET), denoted by e^2 and the Fold of h-core citation over Excess citations (FHE), denoted by θ^2 may be represented as, $\varepsilon^2 = E/T$ and $\theta^2 = H/E$, where *T, H* and *E* stand for Total Citation, h-Core Citation and Net Excess Citation respectively. The FET (ε^2) indicates the fractional excess citation or the strength of scattered citations. Whereas, the FHE (θ^2) indicates the fractional h-core citation or the strength of centralised citation. Being ratios of real numbers, θ and ε are continuous variables. As the excess citation or h-excess citation resides beyond the h-core square, it is interpreted as scattered citation. The h-core citation, on the other hand, is confined within the boundary of h-core square that is interpreted as centralised citation. On the basis of FET and FHE, another indicator is introduced, the name given to which is Citation Swing Factor (CSF), defined as $(d\theta/d\varepsilon)$ i.e., the differential coefficient of θ with respect to ε. The centralisation tendency of citation is always associated with its scattering, as the peripherals to the high-cited cores receive fewer citations by diffusion from the core domain. As a result, the high-cited items of the h-core, eventually exceeds the symmetric core zone to asymmetric h-excess zone. Also, some items from the low-cited or tail zone shift to the core zone. In this way, an incessant shifting process from tail to excess zone, via the core zone continues. This continuous shifting process of the cited-items from Tail zone to Excess zone via the Core zone portrays the diffusion of cited items. The indicator Citation Swing Factor (CSF) has been developed to measure this diffusion process quantitatively[39].

The observed or experimental value of CSF that is followed from the basic definition is represented as $(d\theta / d\varepsilon)$. Here both θ and ε are continuous variables. The differentiation of θ with respect to ε yielded the value $(-T^{3/2} / (E\sqrt{H}))$[39], where *T, H* and *E* indicate total citations, h-core citations and excess citations respectively. The indicator CSF thus points out the shift of h-core citations with respect to fold of excess citations to total citations, which in turn, figures the citation shift from h-core to h-excess zone.

$$CSF = (d\theta / d\varepsilon) = \left(-T^{\frac{3}{2}} / \left(E\sqrt{H} \right) \right) \quad (1)$$

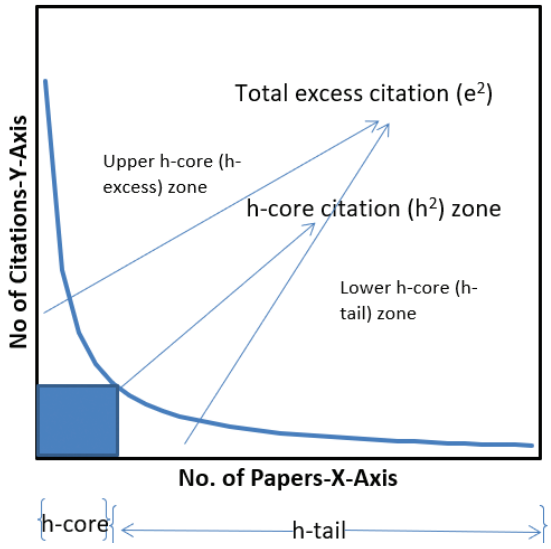

Figure 1. Three h-zones (excess, core and tail) in a cited vs. citing graph[39].

4.2 Time-Normalised Total Cited Ratio (TC)

Let '*n*' number of articles belonging to any subject 'S', were published in an arbitrary year 'y_1', of which '*k*' number of articles altogether received 'c' citations in any later year 'y_2' ($y_2 > y_1$). Hence, $(n - k)$ number of articles remained uncited in the year y_2. The Time-Normalised Total Cited Ratio, denoted by *TC* is defined as the ratio between total number of published articles (*n*) to the number of cited articles (*k*), divided by ($y_2 - y_1$). The difference between two years, ($y_2 - y_1$) may be regarded as the age of the publication.

$$TC = n / [k / (y_2 - y_1)] \quad (2)$$

The *TC* is a measure of the fold of total number of published articles with respect to the total number of cited articles. It figures out the relative abundance of total number of articles with respect to cited articles per unit age of the publication. This indicator implies whether a journal or author is a mass producer (can't attract citation) or an influential item (prone to citation).

4.3 Time-Normalised Cited Uncited Ratio

The Time-Normalised Cited Uncited Ratio (*CU*), denoted by *CU* is defined as the ratio between the number of cited articles (*k*) to the number of uncited articles $(n - k)$, divided by ($y_2 - y_1$). The *CU* is a measure of the fraction of cited articles with respect to total number of uncited articles. It figures out the relative strength of the cited articles with respect to the uncited articles per unit age of the publication. This indicator implies whether cited articles outnumber uncited articles in any subject. The variation of percentage of cited articles for different subjects may be studied by this indicator.

$$CU = k / [(n - k)(y_2 - y_1)] \quad (3)$$

4.4 Time-Normalised Total Uncited Ratio

The Time-Normalised Total Uncited Ratio (*TU*), denoted by *TU* is defined as the ratio between the number of total published articles (*n*) to the number of uncited articles $(n - k)$, divided by ($y_2 - y_1$). The *TU* is a measure of the fold of total published articles with respect to the number of uncited articles. It figures out the relative fraction of the uncited articles with respect to total number of published articles per unit age of the publication. This indicator implies the relative dominance of uncited articles in any subject domain.

$$TU = n / [(n - k)(y_2 - y_1)] \quad (4)$$

5. RESEARCH QUESTION

- Is the observed values of CSF (represented by $(d\theta / d\varepsilon)$ tally with the theoretical values of the same (represented by for Indian physics and astronomy research output from 2005 to 2020 as represented by Eq. (1)?
- How the values of the indicators *TC, CU* and *TU* for Indian physics and astronomy research output from 2005 to 2020 change with time or publication age?
- Is there any inter-relationship exists among these three indicators, i.e. *TC, CU* and *TU* ?

6. METHODOLOGY

The necessary data for calculating these four indicators have been collected from Scopus database. The search strategy followed in Scopus under 'Advanced Search' was, "SUBJAREA(PHYS) AND AFFILCOUNTRY (INDIA) AND (EXACTSRCTITLE(BULLETIN OF THE ASTRONOMICAL SOCIETY OF INDIA)). The time range was set since 2005 to 2020. The year 2005, marked by the discovery of Hirsch's h-index, bears special significance in the history of scientometrics. Zukerberg's Facebook was also born in this year. These features gradually started to influence the citation accumulation pattern in all disciplines, which intended us to consider the starting year as 2005.

The same 'Advanced Search' strategy as above has been repeated for other fourteen journals, viz. *Indian Journal of Biochemistry and Biophysics; Indian Journal of Physics; Indian Journal of Pure and Applied Physics; Indian Journal of Radio and Space Physics; Journal of Astrophysics and Astronomy; Journal of Medical Physics; Pramana - Journal of Physics*; *Defence Science Journal; Indian Journal of Engineering and Materials Sciences; Journal of Earth System Science; Journal of Scientific and Industrial Research; Journal of Vibrational Engineering and Technologies*; Proceedings of the Indian

National Science Academy and Proceedings of the National Academy of Sciences India Section A - Physical Sciences. The retrieved results from these fifteen searches were summed up at last, which figured 18357 articles in total, or 1147 articles per year on average. The total number of citations, h-core citations and excess citations figured 91245, 12361 and 78884 respectively. The yearwise breakup of the data is presented in Annexure I.

The values of the new indicators viz., *CSF*, *TC, CU* and *TU* are calculated for Indian physics and astronomy research output appeared in these fifteen journals since 2005 to 2020 (Annexure I (*CSF*) & Annexure II (*TC, CU* and *TU*)). The observed values of *CSF* are calculated on the basis of available data and the same have been compared with the respective theoretical values. Of the fifteen journals, eight journals belong to core domain of physics and astronomy, viz. *Bulletin of the Astronomical Society of India; Indian Journal of Biochemistry and Biophysics; Indian Journal of Physics; Indian Journal of Pure and Applied Physics; Indian Journal of Radio and Space Physics; Journal of Astrophysics and Astronomy; Journal of Medical Physics* and *Pramana - Journal of Physics*, while five journals belong to allied interdisciplinary areas of physics but publish articles on physics regularly, viz. *Defence Science Journal; Indian Journal of Engineering and Materials Sciences; Journal of Earth System Science; Journal of Scientific and Industrial Research* and *Journal of Vibrational Engineering and Technologies*. The last two journals, viz. *Proceedings of the Indian National Science Academy* and *Proceedings of the National Academy of Sciences India Section A - Physical Sciences* belong to entire natural science discipline but publish physics articles on regular basis. These two journals are very old and esteemed Indian science journals.

On the basis of yearly figures of h-core and h-excess citations, *FET* and *FHE* are calculated. The consecutive annual changes in the values of FHE and FET yielded $d\theta$ and $d\varepsilon$ respectively. The ratio of $d\theta$ to $d\varepsilon$ or $(d\theta / d\varepsilon)$ gives the observed value of *CSF*, which is compared with the theoretical value, i.e., $\left(-T^{\frac{3}{2}} / \left(E\sqrt{H}\right)\right)$ where T, H and E indicate total citations, h-core citations and net excess citations respectively. The total number of cited and uncited papers over the stipulated time span figured 12757 and 5600 respectively. The yearly figures of total, cited and uncited articles (Annexure I) yielded *TC, CU* and *TU* (Annexure II) since 2005 to 2020. The temporal variations of *CSF, TC, CU* and *TU* are observed. The correlation and regression analyses between *TC – CU, CU – TU* and *TC – TU* have been carried out to delineate their mutual interrelationships.

7. LIMITATIONS

This study has been executed on the basis of 18357 retrieved articles published in Indian physics and astronomy journals indexed in Scopus only. Hence, the articles published in non-Scopus Indian physics and astronomy journals, are automatically excluded from the scope of this study. This study analysed 91245 citations received by 12757 articles published from 2005 to 2020, while 5600 articles remained uncited till date. Thus, the number of articles, which are cited only came under the purview of this study that figured 12757 over a span of 16 years, indicating 797 cited articles per year on average.

In this study, the observed or experimental values of CSF have been tallied with its theoretical values in the domains of physics and astronomy. But the point to be noted here is that the CSF has its own limitations, as the total citations as well as h-core citations are manipulable through self-citation, re-citation or coercive citation. Hence it is important to develop modified CSF excluding the manipulated citations owing to biased and corrupted practices. The modified CSF supposed to portray the true picture of citation diffusion.

8. RESULTS AND ANALYSIS

The Scopus database indexed 18357 research articles on physics and astronomy during 2005 to 2020 appeared in fifteen journals, which received 91245 citations. The average number of citations per research publication over this period Fig. 5. The yearwise breakup of total citations (T), h-core citations (H) and net excess citations (E) are presented in Annexure I, to calculate FET and FHE. The changes between successive years' FET and FHE values are represented by dε and dθ respectively. The observed value of CSF, i.e. CSF(O) is calculated by dividing dθ by dε, which is represented by $(d\theta / d\varepsilon)$, and the expected or theoretical value of CSF, i.e. CSF(E) is given by Eqn. (1). It is found from Annexure I and Fig. 2, that the observed values are in close proximity with expected values with an average error of 2.26%, which asserts the validity of Eqn. (1) for Indian physics and astronomy research output during 2005 to 2020. The temporal variations of the magnitudes of CSF(O) [dotted line] and CSF(E) [solid line] are presented in Fig. 2, which shows the average, maximum and minimum values of CSF as 3.3, 3.8 and 2.9 respectively. The standard deviation of 15 observed and 15 expected values of CSF altogether is 0.278 or approximately 28%. The negative Kurtosis values of both CSF (Table 1) indicate their flat distribution with thin tail that accords near constancy of this indicator over the said time span. The coefficients of variation and standard deviations of CSF are fairly low, i.e. less than 0.1 and 1 respectively, which also signal its near constancy.

Out of 18357 publications, 12757 (≈70 %) articles received citation(s) while 5600 (≈30 %) articles remained uncited till date. The year wise breakup of total (n), cited (k), uncited $(n-k)$ publications and age of publications $(y_2 - y_1)$ are given in Annexure II, where y_2 indicates current year, i.e. 2021 and y_2 indicates publication years ranging from 2005 to 2020. The values of the indicators TC, CU and TU are calculated in accordance with the equations (2), (3) and (4) respectively and presented in Annexure II. The variations of TC, CU and TU with publication age are presented in Fig. 3. Of these four indicators, the variation of TC is highest (1.76), followed by TU (0.53), CU (0.37) and CSF(E) (0.09), as evident from the values of respective Coefficients of Variations (CV) (Table 1). The standard deviation is highest for TC (0.74), followed by TU (0.33), CSF (0.27) and CU (0.15) (Table 1). The graph for TC is highly skewed and possesses thick tail that is endorsed

Table 1. Statistical parameters of the indicators' values over the entire time span

Parameters / Indicators	Mean	Median	Range	Standard Deviation	Coefficient of Variation	Kurtosis
CSF(O)	3.26	3.29	0.74	0.27	0.08	-1.47
CSF(E)	3.25	3.24	0.90	0.3	0.09	-1.36
TC	0.42	0.15	2.98	0.74	1.76	12.25
CU	0.41	0.42	0.48	0.15	0.37	-0.99
TU	0.62	0.54	1.24	0.33	0.53	1.61

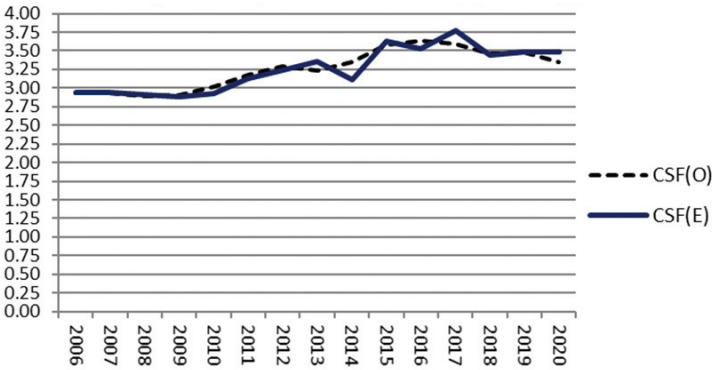

Figure 2. Temporal variation of CSF(O) and CSF(E).

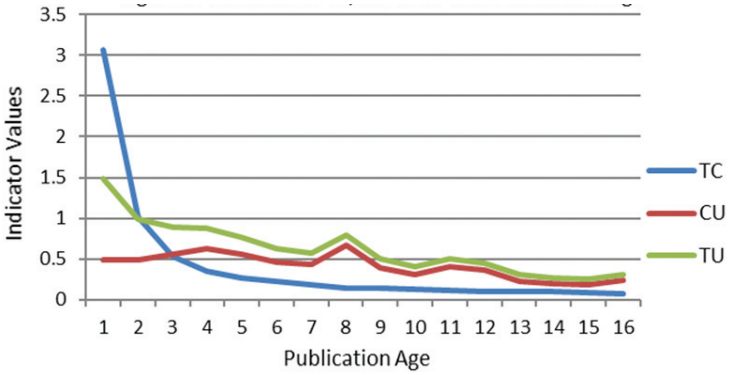

Figure 3. Variation of TC, CU & TU with Publication-Age.

by the high Kurtosis value of TC (Table 1). The variation of TC with publication age follows Harris Model as best fit graph with the equation, $TC = 1 / (a + by^c)$…….(5), where, $y = (y2 - y1)$ = Publication Age, a = (-5.789), b = 6.114 & c = 0.242. The graph for TU is little bit skewed and possesses thin tail that is endorsed by the low Kurtosis value of TU (Table 1). The variation of TU with publication age follows Rational Function as best fit graph with the equation, $TU = (a + by) / (1 + cy + dy^2)$.....(6), where, $y = (y_2 - y_1)$ = a = 7.55 * 10^{-13}, b = 4.346 * 10^{10}, c = 2.404 * 10^{10} and d = 7.068 * 10^{10}. Publication Age, a=7.55 * 10^{-13}, b = 4.346 * 10^{10}, c = 2.404 * 10^{10} and d = 7.068 * 10^{10}. The low kurtosis and standard deviations of TU indicate the poor variability or comparatively stronger constancy of TU. The graph of CU (Fig. 3) shows almost constant pattern that is also endorsed by its low coefficient of variation and standard deviation values. The negative Kurtosis values indicate its flat distribution with thin tail revealing constancy. The correlation Coefficient between TC and CU is found as 0.26, indicating weak positive correlation. The Correlation Coefficients between CU-TU and TC-TU are 0.74 and 0.84 respectively indicating strong positive correlations. The linear regression equations of CU on TU & of TC on TU are found out as:

$CU = -0.201 + 0.34 * TU$; [Coefficient of Determination (R^2) = 0.55; Standard Error = 0.11]….(7) and $TC = -0.76 + 1.88 * TU$; [Coefficient of Determination (R^2) = 0.70; Standard Error = 0.42)].....(8)

9. CONCLUSION

In this paper, the theoretical value of 'Citation Swing Factor' (CSF) is compared with its observed values that shows close proximity pointing out the appropriateness of the theory for the sample of this study. It needs to be tested for other samples from other subject domains. The CSF measures relative share of h-core citations with respect to net excess citations. Its variation indicates shift of h-core citations towards h-excess zone. The almost constancy of CSF values over 15 years indicates the steadiness of the diffusion process of h-core citations to h-excess zone. The majority of articles remained in h-core zone for long time span and shifted slowly to h-excess zone. The near constancy of CSF values over 15 years indicates rather slow but steady citation accumulation rate of Indian physics and astronomy articles.

The indicators TC, CU and TU are time normalised, i.e. the respective actual values are divided by the respective age of publications. This is done to minimise the bias arisen due to time dependence of citation accumulation process. The citation accumulation is accelerated with the increase in publications' age. The decreasing pattern of TC and TU with age proves that the number of cited articles increase with age of publication. The variation of TU however, is very trifle. The constancy of CU reveals that number of articles and number of cited articles both hike at an almost equal pace. The TU is linearly related with both CU and TC (equation (7) and (8)). The changing patterns of TC, CU and TU need to be studied for other subject domains also to analyse the growth pattern of cited articles with respect to total and uncited articles. These indicators include number of cited and uncited articles along with total number of articles. But, in any discipline quiet a large number of articles remain once cited or twice cited only. Hence, except 'cited' and 'uncited' articles, another category of articles may be introduced, i.e. 'poorly-cited' articles to modify the formalism of TC, CU and TU.

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Annexure I

Temporal variations of CSF since 2005 to 2020

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
T	6910	6157	6002	7224	7697	8428	7705	7471	7842	6814	4869	4318	3807	2499	1925	1577
H	1156	1024	1024	1296	1296	1156	961	841	1089	625	484	361	400	256	196	196
E	5754	5133	4978	5928	6401	7272	6744	6630	6753	6189	4385	3957	3407	2243	1729	1381
FET (ε)	0.91	0.91	0.91	0.91	0.91	0.93	0.94	0.94	0.93	0.95	0.95	0.96	0.95	0.95	0.95	0.94
FHE (θ)	0.45	0.45	0.45	0.47	0.45	0.40	0.38	0.36	0.40	0.32	0.33	0.30	0.34	0.34	0.34	0.38
dε		0.001	-0.002	-0.005	0.01	0.02	0.01	0.01	-0.01	0.03	-0.004	0.01	-0.01	0.001	0.0003	-0.012
dθ		-0.002	0.01	0.01	-0.02	-0.05	-0.02	-0.02	0.05	-0.08	0.01	-0.03	0.04	-0.005	-0.001	0.040
CSF (O)		-2.939	-2.930	-2.898	-2.903	-3.023	-3.181	-3.295	-3.229	-3.343	-3.577	-3.642	-3.600	-3.464	-3.485	-3.357
CSF (E)		-2.936	-2.941	-2.919	-2.877	-2.930	-3.129	-3.235	-3.359	-3.116	-3.635	-3.522	-3.774	-3.447	-3.481	-3.489
% Error		0.09	0.38	0.73	0.90	3.15	1.64	1.85	3.85	7.28	1.60	3.40	4.62	0.49	0.12	3.80

Annexure II

Temporal variations of TC, CU and TU since 2005 to 2020

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
n	947	935	903	1072	974	1041	1148	1144	1065	1319	1185	1224	1164	1120	1414	1702
k	754	685	660	803	791	852	866	894	897	993	870	903	831	702	700	556
n/k	1.26	1.36	1.37	1.33	1.23	1.22	1.33	1.28	1.19	1.33	1.36	1.36	1.40	1.60	2.02	3.06
(y_2-y_1)	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
TC	0.078	0.091	0.098	0.103	0.103	0.111	0.133	0.142	0.148	0.19	0.227	0.271	0.35	0.532	1.01	3.061
(n-k)	193	250	243	269	183	189	282	250	168	326	315	321	333	418	714	1146
k/(n-k)	3.91	2.74	2.72	2.99	4.32	4.51	3.07	3.58	5.34	3.05	2.76	2.81	2.50	1.68	0.98	0.49
CU	0.244	0.183	0.194	0.230	0.360	0.410	0.307	0.397	0.667	0.435	0.460	0.563	0.624	0.560	0.490	0.485
n/(n-k)	4.91	3.74	3.72	3.99	5.32	5.51	4.07	4.58	6.34	4.05	3.76	3.81	3.50	2.68	1.98	1.49
TU	0.307	0.249	0.265	0.307	0.444	0.501	0.407	0.508	0.792	0.578	0.627	0.763	0.874	0.893	0.990	1.485