CHAPTER – V

FINDINGS, SUGGESTIONS AND CONCLUSION

5.1. Introduction

The present study ‘Scientometric Dimensions of Radio Astronomy Research: A Study Based on Science Citation Index’ has been undertaken to access and analyze the status of Indian and Chinese Radio Astronomy literature in comparison with other major countries of the world, the study includes Growth pattern of Radio Astronomy literature; Authorship collaboration and Author productivity; Productivity of Institutions; and productivity of Journals in the field of radio astronomy.

5.2. Major Findings

The important findings of the research study are carried out through ‘Scientometric dimensions of radio astronomy research: a study based on Science Citation Index’ are summarized as below:

Growth of Publications

➢ It is observed that the output of world publications has steadily increased from 11,509 (5.88%) publications in the year 1999 to 17,163 (8.767%) in the year 2012, for Indian publications steadily increased from 298 (4.357%) publications in year 1999 to 814 (11.9%) publications in the year 2012 and Chinese publications increased from 320 (2.92%) publications in the year 1999 to 1429 (13.05%) publications in year 2012 respectively.
Indian publications are placed in 4th among the Asian countries with 6,840 publications. China stands at 3rd position with 10,950 publications. Japan ranks first among Asian countries with 15,627 publications.

The relative growth rate of world publications decreases gradually from 0.683 to 0.092 correspondingly the doubling time \((D_t)\) increases from 1.015 to 7.553 during study period (1999–2012).

The relative growth rate for Indian output decreases gradually from 0.702 to 0.127 except in the year 2006 (0.188), correspondingly the doubling time increases from 0.988 to 5.469.

The relative growth rate for Chinese output also decreases gradually from 0.805 to 0.140, correspondingly the doubling time increases from 0.860 to 4.956.

The mean relative growth rate and doubling time in the field of radio astronomy for world publication is 0.248 & 4.526, for Indian publications 0.241 & 3.781 and for Chinese publications 0.272 & 3.350 respectively,

Growth of publications reveals inverse proportion between value of relative growth rate and doubling time for World, Indian and Chinese publications.

The activity index steadily increased from 74.11 to 135.74 during the year 1999-2012 for Indian publications and for Chinese publications activity index is also increased from 49.71 to 148.86. The Average Activity Index for Indian publications is 97.86 and 96.54 for Chinese publications.

The research effort by both Indian and Chinese scientists in the field of Radio Astronomy is lower than the world’s average.
For the Indian publications, Exponential growth model fits well with 93.2%. Exponential growth model fit best appropriate model for Chinese radio astronomy publication data (98.3%), whereas, for World’s radio astronomy publications data exponential and linear growth model fits well (96.7%).

**Authorship and Collaboration**

- For Indian publication, there is a gradual decrease in single authored publications from 20.81% (62 publications) to 7.49% (61 publications) and increase in multi authored publications from 79.19% (236) to 92.51% (753), with an average of 11.36% single authored and 88.64% of multi authored publications.

- For Chinese publications, there is a slight variation in single authored publications that is 10% to 10.7% in the year 1999-2002 and again decreasing to 5.46% in the year 2012. For multi authored publications slightly increasing from 90% to 94.5% with an average 7.7% for single and 92.3% for multi authored publications.

- The authorship trend is towards multi-authored publications in Indian publications. Two authored publications rank first with 1813 (26.51%) publications, followed by Three authored publications rank 2nd with 1562 (22.84%), Four authored publications rank 3rd with 931 (13.61%) and Single authored publications rank 4th with 777 (11.36%) publications.

- The authorship trend is towards multi-authored publications in Chinese publications. Three authored publications rank first with 2518 (23%) publications, followed by Two authored publications rank 2nd with 2295
(20.96%), Four authored publications rank 3\textsuperscript{rd} with 1676 (15.31%), Five authored publications rank 4\textsuperscript{th} with 1045 (9.54%) and Single authored publications rank 5\textsuperscript{th} with 843 (7.7%) publications.

\begin{itemize}
  \item It is interesting to note that the publications with more than thousand authors, it is mainly due to the research going by group collaborations in the field of astronomy such as BELLE Collaboration, LIGO Scientific Collaboration, BaBar collaboration, VIRGO collaboration etc.
  \item The average number of authors per publication (collaborative index) has increased from 7.89 to 58.14 for Indian publications and 7.29 to 76.25 for Chinese publications in the year 1999-2012, indicating the trend towards multi-authorship publications.
  \item The Degree of Collaboration (DC) increased gradually from 0.792 to 0.925 in the study period with average 0.886 for Indian contributions and for Chinese contributions the degree of collaboration is observed slight deviation in the study period from 0.90 to 0.945 with an average 0.923, again indicating trend towards multi-authorship publications.
  \item Collaboration Coefficient has increased from 0.508 to 0.668, indicating that research among the Indian scientists is fairly collaborative with an average collaborative coefficient of 0.615. Collaborative coefficient has increased from 0.61 to 0.71 in the study period 1999-2012, indicating that research among the Chinese scientists is fairly collaborative with an average collaborative coefficient of 0.662.
\end{itemize}
It can be inferred that the Chinese scientists contributed more in collaborative research than the Indian scientists.

A total of 19,833 authors have contributed 6840 publications over a period of 14 years (1999-2012). It is observed that S. Banerjee has contributed maximum number of publications among all the Indian scientists with 152 publications (having h-index 29) followed by Chakrabarti, SK. ranks 2nd with 110 publications (having h-index 16). Desai, S. rank 3rd with 98 publications (having h-index 35) respectively, are the major contributors in India in the field of Radio Astronomy.

A total of 23,043 authors contributed 10950 publications over a period of 14 years (1999-2012). It is observed that Zhang J has contributed maximum number of publications among all the Chinese scientists, that is 278 publications with h-index 39, followed by Liu Y ranks 2nd has contributed 273 publications with h-index 34, Zhang L ranks 3rd has contributed 230 publications with h-index 36 respectively, are the major contributors in China in the field of Radio Astronomy.

**Productivity of Institutions**

Tata Institute of Fundamental Research (TIFR), Mumbai contributed highest publications of 1210 (17.69 %), followed by the Inter University Centre for Astronomy Astrophysics (IUCAA), Pune ranks 2nd with 824 (12.04 %), the Indian Institute of Astrophysics (IIAP), Bengaluru ranks 3rd with 774 (11.31 %).
Among the Indian Universities, the Panjab University ranks first which contributed 223 (3.26 %), followed by Jadavpur the University which ranks 2\textsuperscript{nd} with 212 publications, the University of Delhi which ranks 3\textsuperscript{rd} with 148 (2.164 %) are the major contributing institutes in India in the field of Radio Astronomy.

According h-index, IUCAA ranks first with highest h-index 67, followed by TIFR ranks 2\textsuperscript{nd} with 58 h-index, IIAP ranks 3\textsuperscript{rd} with 39 h-index.

TIFR ranks first in order contributing 17.65% of PaI, followed by IUCAA 12.05% of PaI, IIAP with 11.31% of PaI in total research output. The other institutes got less than ten percent of PaI. This variation may be due to less output during the study period in radio astronomy field.

TIFR received 24,923 citations for the 1,210 publications with 20.60 average citations per publication (ACP), followed by IUCAA received 21,480 citations for 824 publications with 26.07 ACP, IIAP received 9,081 citations for 774 publications with 11.73 average citations per publication.

The Indian institutions are collaborated more with USA (58.9\%) based institutions compared to countries. The Max Planck Society, Germany ranks first among foreign intuitions with 381 (5.57\%) collaborative publications, followed by Atomic Energy Alternative Energies Commission CEA, France ranks 2\textsuperscript{nd} with 242 (3.53\%) collaborative publications, the University System of Maryland, USA ranks 3\textsuperscript{rd} with 221(3.231\%) collaborative publications respectively.
The Chinese Academy of Sciences contributed the highest publications of 6,494 (59.31 %), followed by the Peking University ranks 2nd with 1,235 (11.28 %), and the Nanjing University ranks 3rd with 915 (8.36%) publications.

Among the Chinese Universities, the Peking University ranks first which contributed 1235 (11.28 %), followed by the Nanjing University which ranks 2nd with 915 (8.36%), the University of Science Technology China which ranks 3rd with 868 (7.93%) publications.

According to the h-index, the Chinese Academy of Sciences ranks first with highest h-index 111, Peking University which ranks 2nd with 60 h-index, the University of Science Technology China which ranks 3rd with 53 h-index.

The Chinese Academy of Sciences received 1,14,477 citations for the 6,494 publications with 17.63 average citations per publication (ACP), followed by Peking University received 21,697 citations for 1,235 publications with 17.57 ACP, the Nanjing University received 13,813 citations for 915 publications with 15.10 average citations per publication.

The Chinese Academy of Sciences ranks first in order contributing 59.31% of PaI, followed by the Peking University which rank 2nd 11.28% of PaI, the Nanjing University which ranks 3rd with 8.36% of PaI in total research output. The other institutes got less than eight per cent of PaI. It can be inferred that the only few institutions are contributing number publications in the field of Radio Astronomy research.

It is observed that the USA tops the list contributing 44.712% (87,532 publications) of the total output. Germany ranked 2nd with 15.99% (31,320)
publications and England ranked 3rd with 14.1% (27,438) publications. China and India, among major contributing countries occupy 10th and 13th positions with respect to number of publications in the field of Radio Astronomy.

- Among the thirty eight Asian countries, Japan tops the list as it alone accounts for about 26.6% (15,627) of Asian output, Russia ranks 2nd contributing 23.8% (13,981) publications during the study period.
- China which was in 10th place in overall world publications, occupies 3rd position in the Asian continent, contributing 18.643% (10,950) of the total output.
- India which was in the 13th place in overall world publications, occupies 4th position by contributing 11.646% (6,840) publications.
- South Korea stands 5th with 6.55% (3847) publications; Israel stands 6th with 4.99% (2935) publications. Rest of the all the Asian countries contribute less than 1 per cent of publications. The top most four major Asian countries contribute maximum output of 80% with other 38 Asian countries contributing remaining 20% of the total output in the Asian continent.

**International Collaboration**

- The USA ranks first with the highest collaboration share i.e 25.07% & 26.778% share with India and China respectively, followed by Germany with 11.69 % and 14.1 % share, England with 8.51 % and 9.12 % and Japan with 7.66% and 7.34 % share with India and China respectively.
India is collaborated with China with 5.34% (369) collaborative publications and China is collaborated with India with 3.4% collaborative publications respectively.

**Productivity of Journals**

- The most preferred journals by the Indian scientists are Physical Review D ranks first with 1,588 (23.22 %), Monthly Notices of the Royal Astronomical Society ranks 2\(^{nd}\) with 828 (12.11 %) publications, Astronomy and Astrophysics ranks 3\(^{rd}\) with 651 (9.518%) publications. The most preferred journals by the Chinese scientists are Physical Review D with 2,227 (17.03 %) publications, The Astrophysical Journal ranks 2\(^{nd}\) with 1,865 (17.03 %) publications, the Monthly Notices of the Royal Astronomical Society ranks 3\(^{rd}\) with 975 (8.9%) publications.


- The Annual Review of Astronomy and Astrophysics stands first with 97 average citations per publication, followed by Astronomy & Astrophysics Supplement Series received total 774 for 29 publications with an average of 26.69 citations per publication, the Astrophysical Journal Supplement Series received a total of 1608 for 67 publications with an average 24 citations per publication, Physical Review D received a total citations of 41,590 for 2,225 publications with an average of 18.68 citations per publication, Classical and Quantum Gravity received a total of 2896 citations for 155 publications with
an average 18.68 citations per publication, Monthly Notices of the Royal Astronomical Society received 17911 citations for 975 publications with an average of 18.37 citations per publication in the field of radio astronomy which are preferred by the Chinese scientists.

- For the Indian publications, the maximum number of publications (2358) published in the journals are having an impact factor in between 4.052 to 4.864, followed by 1216 publications published in the journals which have an impact factor of 1 to 1.725. Two publications are published in a journal which is having an impact factor of 24.037, 28 publications are published in a journal which is has an impact factor of 14.137 and one publication each have an impact factor of 13.312 and 10.188 as per the impact factor JCR 2013 published by Thomson Reuters.

- For the Chinese publications, the maximum number of publications (3444) published in the journals have an impact factor in between 4.052 to 4.864, followed by 1865 publications published in a journal which have an impact factor of 6.28. 1501 publications are published in the journals which have an impact factor of 1.066 to 1.955. One publication is published in a journal which has an impact factor of 24.037; 67 publications are published in a journal which have an impact factor of 14.137 and one publication each have an impact factor of 13.312, 11.833 and 10.188.

- It can be inferred that both the Indian and Chinese scientists have chosen the well reputed high quality journals for the communication of their research output.
The rank distribution of number of publications does not fit to the Bradford’s distribution.

5.3. Suggestions

The following suggestions have been made based on the major findings of the study:

1. Indian and Chinese Scientists have to be more collaborative with the advanced and developed countries and for that, policies have to be made by government/ institutions for the collaborative research with the top most foreign institutions.

2. The scientist depends heavily on the journals published abroad and more particularly those journals that are published in the USA. It is, therefore, necessary to encourage the scientists in India to use more journals published in India and also contribute original research publications to the Indian journals and thereby their impact factor is raised and also India becomes a prominent country in publishing the quality journals with higher impact factor, and further the Indian journals seek international market.

3. The modernization of Radio Telescopes with the incorporation of new technologies would lead further research activities. Establishing research institutes and encouraging scientists to take up the research or projects on priority with the collaboration with other research institutes and Universities.
4. Adequate manpower and infrastructure facilities may be developed in the research institutions as well as in Universities so that more researches are undertaken in these areas.

5. The Universities and research institutions are to be provided with more financial assistance in the form of research grants to increase the quality of research.

5.4. Further Areas of Research

Further Research in the area of Radio Astronomy can be extended to the following facets.

- Institutional Research Productivity in the field of Radio Astronomy at national and International level can be conducted.
- Country wise collaboration studies can be extended.
- Priority areas of research in the field of Astronomy in different countries can be carried out.
- Collaboration and Communication of Individual Scientists can be carried out.
- Study on Obsolescence of literature in the field of Radio Astronomy will be of very much use to the librarians and managers of information centers.
5.5. Conclusion

The human being is always fascinated by the stars, making astronomy one of the first sciences to develop. As technology has improved, moving from the naked eye to the advanced radio telescopes, so has the ability to see further into the universe. Achieving this level of detail requires an unparalleled collaboration between telescopes around the world, often in real-time. In fact, the most detailed picture of the universe is obtained by combining the signals from many radio telescopes scattered across the face of the earth. This technique, called the Very Long Baseline Interferometry (VLBI) can achieve resolutions one thousand times better than that of the Hubble Space Telescope. In this view the Indian and Chinese Scientists have more collaboration with the advanced developed countries.

The scientometric studies help in the analysis of research and development trends in identifying the areas that are most active and those which are becoming important and identifying the influences and cross fertilizations. The studies are also useful to the policy makers who are deciding the priority areas in certain domains. The bibliometric laws are very useful in understanding the communication pattern, information transfer, use which in term have several implication for libraries and information centers, especially in the research and development institutions. The empirical testing of the law of Bibliometrics is another contribution of this study, which has an implication for further understanding of the theory of Bradford’s law of scattering. The ranking of journals is a new criterion for the selection of science journals.
This study gives a bird’s eye view of the extent of research activities and research productivity in radio astronomy literature. The main objective of the study reveal the status of radio astronomy research in the Chinese and Indian context, its strong and weaker areas of research, quantity and quality of research output, dynamics of research across institutes and geographic regions.

The study provides the qualitative and quantitative analysis of the progress of the Indian and Chinese radio astronomy literature as reflected by its publications output reported in the Science Citation Index database. Such a study may prove to be of use to the Indian science policy makers and managers to have an insight of the radio astronomy situation in the country. The applications of science indicators are useful for both the descriptive as well as analytical purposes. Findings of the study have tremendous value for applications. They are useful to students, teachers, research scholars and scientists for their overall academic purposes; research as well as development of tacit and explicit knowledge. It is also useful for library and information science professionals for their collection development in their library.