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MAPPING OF LITERATURE ON BOSE – EINSTEIN CONDENSATION

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ABSTRACT

This paper attempts to highlight quantitatively the growth and development of research work in this field on Bose-Einstein Condensation (BEC) in terms of publication output as per Science Citation Index (1982-2005). During 1982–2005 a total of 5258 papers were published by scientists in this field. The average number of publications per year were 219. The highest number of papers (814) were published in 2004. There were 77 countries involved in the research in BEC. USA is the top producing country with 1632 publications (31%) followed by Germany with 620 publications (11.79%). Authorship and collaboration trend was towards multi-authored papers. Intensive collaboration was found during 1996-2005. One paper "Astrophysical Journal 543 (1), (2000), L39-L42" had 56 collaborators. There were 1635 international collaborative papers. Bilateral collaboration accounted for 24 percent of total collaborative papers. National Institute of Standards & Technology (USA) topped the list with 179 publications followed by University of Colorado (USA) with 160 publications. The most prolific authors were W. Ketterle (USA) with 93 publications; K. Burnett (England) and M. Lewenstein (England) with 68 publications each; and S. Stringari with 57 publications. The most preferred journals by the scientists were Physical Review-A with 1504 papers; Physical Review Letters with 824 papers; Journal of Physics-B with 205 papers; Physical Review- B with 178 papers; Physics Letters-A with157 papers; Physical Review–E with 122 papers; and Journal of Low Temperature Physics with 102 papers. The high frequency keywords were Bose-Einstein Condensation (2012), Gases (1928), Atoms (860), and Dynamics (493).

Keywords: Bose-Einstein Condensation; Growth of literature; Scientometrics; Bibliometrics; Mapping of literature.

INTRODUCTION

In 1924 the Indian physicist Satyendranath Bose made important theoretical calculations regarding light particles. He sent his results to Einstein who extended the theory to a certain type of atom. Einstein predicted that if a gas of such atoms were cooled to a very low temperature all the atoms would suddenly gather in the

lowest possible energy state. The process is similar to when drops of liquid are formed from a gas, hence the term condensation. Seventy-two years were to pass in achieving this extreme state of matter in 1995 as Cornell and Wieman produced a pure condensate of about 2000 rubidium atoms at 20 nK (nanokelvin), i.e. 0.000 000 02 degrees above absolute zero. Ketterle performed corresponding experiments with sodium atoms independently of the work of Cornell and Wieman. The condensates he managed to produce contained more atoms and could therefore be used to investigate the phenomenon further. Using two separate Bose–Einstein Condensates which were allowed to expand into one another, he obtained very clear interference patterns, i.e. the type of pattern that forms on the surface of water when two stones are thrown in at the same time. This experiment showed that the condensate contained entirely co-ordinated atoms. Ketterle also produced a stream of small "BEC drops" which fell under the force of gravity. This can be considered as a primitive "laser beam" using matter instead of light. One of the latest developments is a BEC on microelectronics chip (Pandey, 2003; Koganuramath et al., 2004).

The Royal Swedish Academy of Sciences awarded Nobel Prize in Physics for the year 2001 jointly to Wolfgang Ketterle, MIT-Harvard Centre for Ultracold Atoms (CUA), Eric A. Cornell of JILA and the National Institute of Standards and Technology, and Carl E. Wieman of JILA and the University of Colorado at Boulder for their achievement on Bose-Einstein Condensation.

Evaluation is one of the key components of any research and development activity. One well-known productivity indicator is the number of publications produced by the scientists, institutions and countries. Studies like this will provide some insight into the complex dynamics of research activity and enable the scientists, policy makers and science administrators to provide adequate facilities and proper guidance.

Research publications are clearly one of the quantitative measures for the basic research activity in a country. It must be added, however, that what excites the common man, as well as the scientific community, are the peaks of scientific and technological achievement, not just the statistics on publications. There are also other kinds of research and technology development-mission oriented, industry-oriented, country-specific, etc., progress in these cannot be obviously measured by counting only the number of publications (Chidambaram, 2005). Many scientometric studies have appeared in the literature to focus on the performance of science in various domains (Schubert and Braun, 1990; Braun and Schubert, 1991; Garg and Sharma, 1991; Sen and Shailendra, 1992; Kademani et al., 2006).

OBJECTIVES

The main objective of the study is to present the growth of literature on Bose-Einstein Condensation and make the quantitative assessment of status of the research by way of analyzing the following features of research output:

- To find out year-wise growth of publications,
- To find out geographical distribution of research output,
- To find out authorship and collaboration pattern in the publications,
- To find out the extent of international collaboration,
- To find out the most prolific authors in the field,
- To find out organization-wise distribution of publications,
- To find out the channels of communications used by the scientists,
- To verify Bradford distribution of papers and sources,
- To find out language-wise distribution of publications, and
- To find out the high frequency keywords appeared in the Key Words Plus field in the Science Citation Index.

MATERIALS AND METHODS

Data was collected from the *Science Citation Index*-On disc (CD-ROM) (1982-2005) published by the Institute for Scientific Information, Philadelphia. Science Citation Index (SCI) is one of the very comprehensive databases covering all aspects of science and it covers about 4000 journals with high impact factors. The records on the subject 'Bose-Einstein Condensation' were downloaded for the years 1982-2005 by using the keyword "Bose Einstein Condens* " in the 'Basic Index' field. A total of 5258 records retrieved were downloaded and analysed as per objectives of the study.

RESULTS AND DISCUSSION

Year-wise growth of publications on 'Bose-Einstein Condensation'

During 1982-2005 a total of 5258 publications were published on 'Bose-Einstein Condensation' by researchers in various countries. The average number of publications produced per year were 219.08. The highest number of publications (814) were produced in 2004. Table 1 and Figure 1 present the year-wise growth and collaboration rate, and the production productivity rate in the field of 'Bose-Einstein Condensation'. It can be clearly visualized from the figure that growth of the literature was very slow during 1982-1995 and it peaked during 1996-2005, indicating that research on 'Bose-Einstein Condensation' received a major boost during this period. The main reasons for the growth of literature after 1995 was the result of major breakthroughs in achieving BEC by C. E. Wieman and E. A.

Cornell's group with a dilute sample of magnetically trapped ^{87}Rb atoms (Anderson et al., 1995), Wolfgang Ketterle's group succeeded in producing BEC using ^{23}Na atoms (Davis et al., 1995) and R. G. Hulet's Group produced a condensate using ^{7}Li with attractive interactions (Bradley et al., 1995). Many researchers have started conducting research in this field because of the many potential applications of BEC in various fields.

Table1: Year-Wise Publication Productivity and Collaboration Rate on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Year	Single authored Publications	Multi-authored Publications	Total Number of Publications	Collaboration Rate
1982	1	2	3	0.67
1983	2	4	6	0.67
1984	2	7	9	0.78
1985	4	3	7	0.43
1986	3	3	6	0.5
1987	1	7	8	0.88
1988	1	1	2	0.5
1989	4	1	5	0.2
1990	1	10	11	0.91
1991	9	12	21	0.57
1992	12	19	31	0.61
1993	7	21	28	0.75
1994	13	29	42	0.69
1995	12	33	45	0.73
1996	36	126	162	0.78
1997	36	179	215	0.83
1998	62	260	322	0.81
1999	49	300	349	0.86
2000	83	401	484	0.83
2001	81	468	549	0.85
2002	125	529	654	0.81
2003	101	623	724	0.86
2004	124	690	814	0.85
2005	97	664	761	0.87
Total	866	4392	5258	0.83

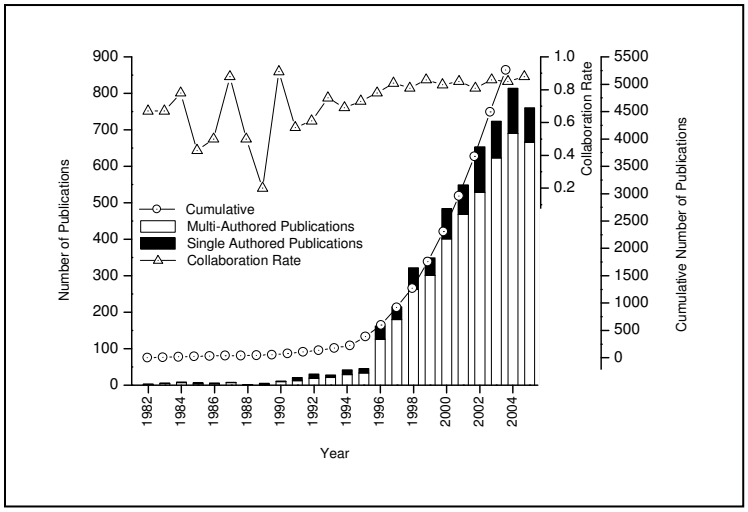

Figure 1: Publication Productivity Growth on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Geographical Distribution of Research Output

There were as many as 77 countries carrying out research in the field of Bose-Einstein Condensation and produced 7331 publications. Table 2 provides a ranked list of countries contributing to this field, the number of publications of each country and the their share in percentages. USA is the top producing country with 1632 publications (22.26%) of the total output, followed by Germany with 620 publications (8.46%), Italy with 524 publications (7.15%), Peoples-R-China with 438 publications (5.97%), France with 432 publications (5.89%) and England with 385 publications (5.25%). Figure 2 provides the year-wise growth of the top five countries.

Table 2: Country-Wise distribution of publications on 'Bose-Einstein Condensation' as per *SCI* during 1982-2005

Sl. No.	Country	Publications	Percentage
1	USA	1632	22.26
2	Germany	620	8.46
3	Italy	524	7.15
4	Peoples-R-China	438	5.97
5	France	432	5.89

Sl. No.	Country	Publications	Percentage
41	Moldova	11	0.15
42	North-Ireland	11	0.15
43	Slovenia	11	0.15
44	USSR	11	0.15
45	Colombia	10	0.14

Table 2, continued

6	England	385	5.25	46	Armenia	9	0.12
7	Japan	357	4.87	47	Singapore	8	0.11
8	Russia	347	4.73	48	Bulgaria	6	0.08
9	Brazil	198	2.70	49	Chile	6	0.08
10	Netherlands	192	2.62	50	Vietnam	6	0.08
11	Australia	175	2.39	51	Croatia	5	0.07
12	Israel	165	2.25	52	Jordan	5	0.07
13	Spain	150	2.05	53	Lithuania	5	0.07
14	Poland	146	1.99	54	Egypt	4	0.05
15	Austria	121	1.65	55	Iran	4	0.05
16	Canada	109	1.49	56	Morocco	4	0.05
17	New-Zealand	103	1.40	57	Wales	4	0.05
18	Denmark	93	1.27	58	Czech-Republic	3	0.04
19	Finland	91	1.24	59	Pakistan	3	0.04
20	Sweden	89	1.21	60	Thailand	3	0.04
21	Scotland	76	1.04	61	U-Arab-Emirates	3	0.04
22	India	75	1.02	62	UKSSR	3	0.04
23	Belgium	72	0.98	63	Byelarus	2	0.03
24	Switzerland	59	0.80	64	Cyprus	2	0.03
25	Greece	50	0.68	65	Estonia	2	0.03
26	Mexico	50	0.68	66	Fed-Rep-Ger	2	0.03
27	Taiwan	38	0.52	67	Latvia	2	0.03
28	Romania	35	0.48	68	Rep-of-Georgia	2	0.03
29	South-Korea	35	0.48	69	Saudi-Arabia	2	0.03
30	Ukraine	33	0.45	70	Yugoslavia	2	0.03
31	Portugal	32	0.44	71	Azerbaijan	1	0.01
32	Hungary	31	0.42	72	Costa-Rica	1	0.01
33	Turkey	30	0.41	73	Indonesia	1	0.01
34	Ireland	27	0.37	74	Malaysia	1	0.01
35	Uzbekistan	25	0.34	75	Tunisia	1	0.01
36	Norway	19	0.26	76	Uruguay	1	0.01
37	Argentina	15	0.20	77	Venezuela	1	0.01
38	Cuba	12	0.16	78	<Anon>	69	0.94
39	South-Africa	12	0.16	Total		7331	100
40	Hong-Kong	11	0.15	<Anon> - Publications without country affiliation			

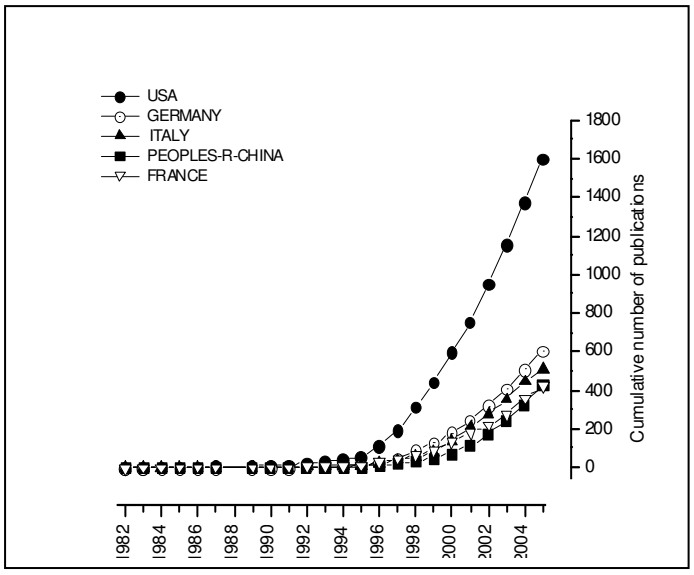

Figure 2: Year-Wise Distribution of Publications of Top Five Highly Productive Countries on Bose-Einstein Condensation

Authorship and Collaboration Pattern

Year-wise authorship and collaboration trend on Bose-Einstein Condensation is given in Table 3. Authorship trend is towards multi-authored papers. Two authored papers accounted for 30.47 percent followed by three authored papers with 23.93 percent, and single authored papers with 16.47 percent. It can be seen from Table 3 and Figure 1 that the collaboration trend is more intensified during 1996-2005 as 4240 (80.63%) collaborative papers were produced. Forty-four papers had more than 10 collaborators. The paper "*Astrophysical Journal* 543 (1), (2000), L39-L42" had the highest number of 56 collaborators. The highest collaboration rate 0.91 was found in 1990. Research is becoming more and more collaborative in recent years when compared to earlier years as all the governments are giving a lot of impetus to multi-institutional research and development activities (Kademani et al., 2005).

Table 3: Authorship and Collaboration Trend on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Year	Number of papers under various Authorships																	Total Pub.
	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	20	56	
1982	1	1	1															3
1983	2	2	2															6
1984	2	4	3															9
1985	4		2		1													7
1986	3	1	2															6
1987	1	4	3															8
1988	1		1															2
1989	4	1																5
1990	1	5	5															11
1991	9	4	7	1														21
1992	12	8	9	2														31
1993	7	11	5	3	2													28
1994	13	12	6	7		2		2										42
1995	12	14	10	6	2		1											45
1996	36	53	39	16	10	3	4				1							162
1997	36	76	52	22	14	11	2	2										215
1998	62	104	74	33	22	14	8	3	1	1								322
1999	49	128	69	40	21	17	13	6	1	2	2	1						349
2000	83	142	118	63	35	21	8	3	5	1	1	1	1	1			1	484
2001	81	173	129	83	35	16	12	6	8	1	4					1		549
2002	125	201	147	87	56	15	12	5	3	2					1			654
2003	101	224	173	85	62	33	23	12	4	4	1		2					724
2004	124	213	205	124	68	30	23	10	7	5	4	1						814
2005	97	221	196	106	61	35	19	11	10	3		2						761
Total	866	1602	1258	678	389	197	125	60	39	19	13	5	3	1	1	1	1	5258
%	16.47	30.47	23.93	12.89	7.40	3.75	2.38	1.14	0.74	0.36	0.25	0.10	0.06	0.02	0.02	0.02	0.02	100.00

International Collaboration

In recent years, many countries have realized the importance of collaborative research to tackle many scientific problems, resulting higher in more international collaboration activities. Table 4 presents the international collaboration pattern on 'Bose-Einstein Condensation'. There were 1635 international collaborative papers. Bilateral collaboration accounted for 24.00 percent of total collaborative papers followed by trilateral collaborative papers with 6.03 percent. There were 69 papers with no country affiliation.

Table 4: International Collaboration Pattern of Publications on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Year	Number of Countries						Total Number of Publications
	<ANON>	1	2	3	4	5	
1982		3					3
1983		5	1				6
1984		8	1				9
1985		6	1				7
1986		4	1	1			6
1987		6	2				8
1988		2					2
1989		5					5
1990		7	4				11
1991	1	17	3				21
1992		23	8				31
1993		19	9				28
1994		30	12				42
1995	3	28	12	1	1		45
1996	4	103	45	9	1		162
1997	5	143	57	7	3		215
1998	10	232	64	14	2		322
1999	6	243	84	15	1		349
2000	5	318	123	30	6	2	484
2001	6	401	109	25	6	2	549
2002	10	455	154	31	3	1	654
2003	4	465	190	58	7		724
2004	7	534	191	71	9	2	814
2005	8	497	191	55	8	2	761
Total	69	3554	1262	317	47	9	5258
Percentage	1.31	67.59	24.00	6.03	0.89	0.17	100.00

<ANON> - Publications without country affiliation

Most Prolific Authors

The most prolific author was W. Ketterle (USA) who was awarded Nobel Prize for Physics in 2001 for his contributions and had the highest number (93) of publications. This is followed by K. Burnett (England) and M. Lewenstein (England) with 68 publications each; S. Stringari (Italy) with 57 publications; P. Meystre (USA) and P. Zoller (Austria) with 54 publications each; and P.S. Julienne (USA) with 50 publications. Table 5 presents the most prolific authors who have contributed 25 or more papers.

Table 5: Most Productive Authors (those who have ≥ 25 publications to their credit) in 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Sr. No.	Author	Country	No. of Publications	Rank	Sr. No.	Author	Country	No. of Publications	Rank
1.	Ketterle-W*	USA	93	1	28.	Pu-H	USA	32	18
2.	Burnett-K	England	68	2	29.	Smerzi-A	Italy	32	18
3.	Lewenstein-M	England	68	2	30.	Castin-Y	France	31	19
4.	Stringari-S	Italy	57	3	31.	Rzazewski-K	Poland	31	19
5.	Meystre-P	USA	54	4	32.	Tiesinga-E	USA	30	20
6.	Zoller-P	Austria	54	4	33.	Williams-CJ	USA	30	20
7.	Julienne-PS	USA	50	5	34.	Alexandrov-AS	England	29	21
8.	Cornell-EA*	USA	49	6	35.	Bigelow-NP	USA	29	21
9.	You-L	Peoples-R-China	48	7	36.	Inouye-S	USA	29	21
10.	Kevrekidis-PG	USA	46	8	37.	Phillips-WD	USA	29	21
11.	Malomed-BA	Israel	45	9	38.	Aspect-A	France	28	22
12.	Tosi-MP	Italy	45	9	39.	Dalibard-J	France	28	22
13.	Clark-CW	USA	43	10	40.	Fort-C	Italy	28	22
14.	Stoof-HTC	Netherlands	43	10	41.	Grimm-R	Austria	28	22
15.	Adhikari-SK	Brazil	42	11	42.	Minguzzi-A	Italy	28	22
16.	Cirac-JI	Germany	42	11	43.	Tsubota-M	Japan	28	22
17.	Inguscio-M	Italy	42	11	44.	Ruostekoski-J	England	27	23
18.	Santos-L	Germany	40	12	45.	Walls-DF	New-Zealand	27	23
19.	Shlyapnikov-GV	Russia	39	13	46.	Arimondo-E	Italy	26	24
20.	Ueda-M	Japan	38	14	47.	Chiofalo-ML	Italy	26	24
21.	Wieman-CE*	USA	37	15	48.	Abdullaev-FK	Uzbekistan	25	25
22.	Frantzeskakis-DJ	Greece	35	16	49.	Bishop-AR	USA	25	25
23.	Zhang-WP	Australia	35	16	50.	Chikkatur-AP	USA	25	25
24.	Javanainen-J	USA	34	17	51.	Hulet-RG	USA	25	25
25.	Hansch-TW	Germany	32	18	52.	Kivshar-YS	Australia	25	25
26.	PerezGarcia-VM	Spain	32	18	53.	Reatto-L	Italy	25	25
27.	Pritchard-DE	USA	32	18					Truncated

∗ - Nobel Prize Winners in Physics for 2001.

Organisation-Wise Distribution of Publications

There were 1412 organisations involved in research activity on Bose-Einstein Condensation. Table 6 shows the organizations that have contributed 52 or more publications during 1982-2005. National Institute of Standards & Technology (USA) topped the list with 179 publications followed by University of Colorado (USA) with 160 publications; University of Oxford (England) with 137 publications; MIT (USA) with 134 publications; Ecole-Normale-Super (France) with 120

publications, University of Trent (Italy) with 118 publications; and Chinese Academy of Sciences- Peoples-Republic (China) with 108 publications.

Table 6: Distribution of Institutes as per Number of Publications on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Sl. No.	Institute	Country	Publications
1	NATL-INST-STAND-&-TECHNOL	USA	179
2	UNIV-COLORADO	USA	160
3	UNIV-OXFORD	ENGLAND	137
4	MIT	USA	134
5	ECOLE-NORMALE-SUPER	FRANCE	120
6	UNIV-TRENT	ITALY	118
7	CHINESE-ACAD-SCI	PEOPLES-R-CHINA	108
8	INNSBRUCK-UNIV	AUSTRIA	103
9	INFM	ITALY	100
10	RUSSIAN-ACAD-SCI	RUSSIA	98
11	UNIV-HANNOVER	GERMANY	97
12	LOS-ALAMOS-NATL-LAB	USA	85
13	UNIV-CONNECTICUT	USA	81
14	UNIV-ARIZONA	USA	79
15	UNIV-TOKYO	JAPAN	76
16	MAX-PLANCK-INST-QUANTUM-OPT	GERMANY	74
17	IST-NAZL-FIS-MAT	ITALY	73
18	UNIV-ILLINOIS	USA	73
19	HARVARD-SMITHSONIAN-CTR-ASTROPHYS	USA	71
20	UNIV-ESTADUAL-PAULISTA	BRAZIL	71
21	UNIV-FLORENCE	ITALY	70
22	AUSTRALIAN-NATL-UNIV	AUSTRALIA	69
23	SCUOLA-NORMALE-SUPER-PISA	ITALY	69
24	HARVARD-UNIV	USA	66
25	POLISH-ACAD-SCI	POLAND	66
26	TEL-AVIV-UNIV	ISRAEL	65
27	UNIV-PARIS-06	FRANCE	64
28	UNIV-MILAN	ITALY	63
29	UNIV-MUNICH	GERMANY	61

Table 6, continued

30	UNIV-MASSACHUSETTS	USA	59
31	TOKYO-INST-TECHNOL	JAPAN	57
32	UNIV-SAO-PAULO	BRAZIL	57
33	UNIV-QUEENSLAND	AUSTRALIA	55
34	UNIV-UTRECHT	NETHERLANDS	54
35	GEORGIA-INST-TECHNOL	USA	53
36	CNRS	FRANCE	52
37	STANFORD-UNIV	USA	52

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Preference of Channels of Communication by Scientists

Scientists communicated their publications through variety of communications channels. Table 7 depicts that 94.35% of the literature was published in journal articles followed by Reviews (2.80%) and Editorial Materials (1.03%).

Table 7: Distribution of Literature on 'Bose-Einstein Condensation' in Various Channels of Communication

Channels of communication	Number of papers	Percentage
Articles	4961	94.35
Reviews	147	2.80
Editorial-Materials	56	1.07
Letters	41	0.78
Corrections	25	0.48
Notes	13	0.25
News-Items	9	0.17
Meeting-Abstracts	3	0.06
Biographical-Item	1	0.02
Book-Review	1	0.02
Reprint	1	0.02
Total	5258	100.00

Preference of Journals for Communication by Scientist*s*

The distribution of papers were spread over 234 journals. The leading journals preferred by the scientists were *Physical Review-A* with 1504 papers; *Physical Review Letters* with 824 papers; *Journal of Physics-B* with 205 papers*; Physical Review-B* with 178 papers; *Physics Letters-A* with157 papers; *Physical Review-E* with 122 papers; *and Journal of Low Temperature Physics* with 102 papers. Table 8 and Figure 3 provide the journal-wise scattering of publications. Dutta and Sen (2005) have investigated rank versus number of articles distribution pattern of a journal system from the view point of Bose-Einstein Statistics assuming a subject equivalent to a phase space, a specific or micro-subject as equivalent phase cell and corresponding journals as the Bose-Einstein particles.

Table 8: Journals Preferred by Scientists for Publishing Articles on 'Bose-Einstein Condensation'as per *SCI* during 1982-2005

Journal Title	Impact Factor 2004	Country	Number of Publications
Physical Review A	2.902	USA	1504
Physical Review Letters	7.218	USA	824
Journal of Physics B	1.761	England	205
Physical Review B	3.075	USA	178
Physics Letters A	1.454	Netherlands	157
Physical Review E	2.352	USA	122
Journal of Low Temperature Physics	0.859	Netherlands	102
European Physical Journal D	1.692	USA	93
Physica B	0.679	Netherlands	74
Europhysics Letters	2.12	France	73
International Journal of Modern Physics B	0.361	Singapore	72
Journal of Optics B-Quantum And Semiclassical Optics	1.746	USA	72
Journal of Physics A-Mathematical and General	1.504	England	68
Journal of The Physical Society of Japan	1.577	Japan	68
Communications in Theoretical Physics	0.871	PeoplesRChina	62
Nature	32.182	England	59
Chinese Physics Letters	1.176	PeoplesRChina	50
Optics Communications	1.581	Netherlands	50
Physical Review D	5.156	USA	50
Science	31.853	USA	47
Physica A	1.369	Netherlands	45
Solid State Communications	1.523	England	41
Modern Physics Letters B	0.421	Singapore	40

Table 8, continued

Journal of Chemical Physics	3.105	England	39
Physica C	1.072	Netherlands	39
Journal of Modern Optics	1.148	England	37
Applied Physics B-Lasers and Optics	2.215	USA	36
Journal of Physics - Condensed Matter	2.049	Russia	34
JETP Letters	1.455	Japan	30
Journal of Statistical Physics	1.747	USA	29
Physica Status Solidi B	0.982	Germany	26
Physics Reports-Review Section of Physics Letters	14.742	Netherlands	23
European Physical Journal B	1.426	USA	22
Physica Scripta	0.661	Sweden	22
Comptes Rendus de L Academie des Sciences Serie IV	-	France	20
Journal of Research of the Nat Inst of Stand and Tech	1.123	England	20
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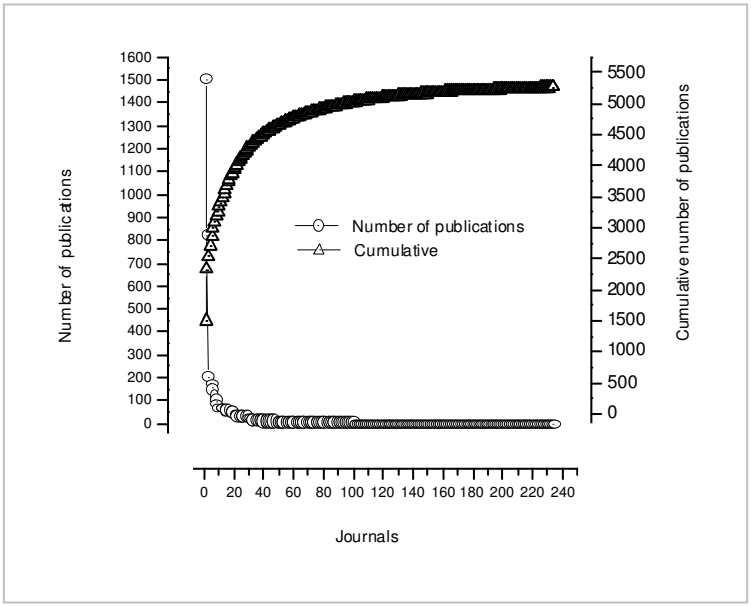

Figure-3: Bradford-Zipf Bibliograph of Distribution of Journals on 'Bose-Einstein Condensation' as per *SCI* (1982-2005)

Language-Wise Distribution of Publications

English has topped the list with 5215 (99.18%) publications; followed by Russian with 22 (0.42%) publications; Chinese with 12 (0.23%) publications; French with 8 (0.15%) and Spanish with 1 (0.02%) publications. Scientists have contributed predominantly in English.

Distribution of Keywords

Keywords are one of the best scientometric indicators to understand and grasp instantaneously the thought content of the papers and to find out the growth of the subject field. By analysing the keywords appeared either on the title or assigned by the indexer or the author himself will help in knowing in which direction the knowledge grows. The high frequency keywords will enable us to understand what are all the aspects of Bose-Einstein Condensation have been studied. The keywords appeared in the Key Words Plus field in SCI were analysed for the purpose. The high frequency keywords were Bose-Einstein Condensation (2012), Gases (1928), Atoms (860), Dynamics (493), States (428), Traps (315), Collective Excitations (298), Systems (273), Collisions (266), and Scattering (265). Table 9 gives a list of high frequency keywords appeared more than 40 times.

Table 9: Keywords with ≥ 40 Frequencies Appeared in the 'Bose-Einstein Condensation' Research Publications in the Keyword Plus Field as per *SCI* 1982-2005

Keyword	Frequency	Keyword	Frequency
BOSE EINSTEIN CONDENSATION	2012	VAPOR	78
GASES	1928	PROPAGATION	76
ATOMS	860	COHERENCE	75
DYNAMICS	493	PHASE TRANSITIONS	74
STATES	428	COLD ATOMS	72
TRAPS	315	MAGNETIC FIELDS	71
COLLECTIVE EXCITATIONS	298	COLD	68
SYSTEMS	273	OSCILLATIONS	68
COLLISIONS	266	PHOTOASSOCIATION	67
SCATTERING	265	CONDENSATIONS	66
GROUND STATE	245	CESIUM	64
VORTICES	232	CU2O	62
TRANSITIONS	214	LI 6	62
INTERFERENCE	198	PARTICLES	62
PHASE	194	DECAY	61
SUPERFLUID	188	INSULATOR	61
SOLITONS	176	BEAMS	60

Table 9, continued

EINSTEIN CONDENSATION	173	INSTABILITIES	59
LIGHT	172	ENTANGLEMENT	58
TEMPERATURE	171	LITHIUM	58
FIELDS	169	ATOM LASERS	57
NEUTRAL ATOMS	169	MAGNETOOPTICAL TRAP	56
EXCITATIONS	167	ATOMIC GASES	55
MOLECULES	162	SPECTRA	52
MODELS	160	HELIUM	50
NONLINEAR SCHRODINGER EQUATIONS	152	HARMONIC TRAPS	49
FESHBACH RESONANCES	149	TRAPPED NEUTRAL ATOMS	49
STABILITY	143	GUIDING NEUTRAL ATOMS	48
SODIUM ATOMS	122	SYMMETRY BREAKING	48
MAGNETIC TRAP	121	2 DIMENSIONS	46
BOSONS	118	CROSSOVER	46
VORTEX	118	SCHRODINGER EQUATIONS	46
COLLAPSES	117	MODES	45
OUTPUT COUPLER	116	TRANSPORT	45
LASER	115	GROSS PITAEVSKII EQUATION	44
WAVES	115	QUANTUM PHASE	44
ARRAYS	110	BCS SUPERCONDUCTIVITY	43
SCATTERING LENGTHS	107	DENSITY	43
ATTRACTIVE INTERACTIONS	106	OPTICS	43
OPTICAL LATTICES	106	PHASE COHERENT AMPLIFICATION	43
SPECTROSCOPY	100	MOTIONS	41
EQUATIONS	98	QUANTUM	41
DARK SOLITONS	97	RELATIVE PHASE	40
FLUCTUATIONS	94	ULTRACOLD ATOMS	40

truncated

CONCLUSION

The phenomenon of Bose-Einstein Condensation was predicted by the eminent Indian Physicist, Satyendranath Bose in 1924 and the subsequent papers by Einstein could not result in any major research activity in this field until it was experimentally established by the Weiman and Ketterle groups in 1995. Bose-Einstein Condensation provides physicists with a new way of studying quantum effects on a large scale, similar to the threshold effects observed in superconductivity. The rapid pace of developments in atomic BEC during the last few years has taken the scientific community by surprise and the challenges ahead are many. Growth of literature has peaked during 1996-2005 indicating the major

impetus received to pursue research in this field. Collaboration trend is towards multi-authored papers. Many group collaborative research efforts were seen. USA is the major producer of scientific output with 1632 papers to its credit in this field followed by Germany with 620 papers. Bilateral international collaboration accounted for 24.00%. A maximum of five-country collaboration was found. More than 94% of the publications were published in the journals with high impact factors is suggestive of the publication behaviour of scientists who preferred to publish their papers in highly reputed journals. Citation analysis of these papers may give interesting insights into the dynamics of this field.

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