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Scientometric Portrait of Nobel Laureate Rainer Weiss

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Abstract: The paper presents qualitative aspects of the research communications of Nobel Laureate Rainer Weiss based on 224 journal articles published during the publication phase of 1957-2017. This study has explored different scientometric indicator such as the chronological distribution of articles, prominent collaborators, authorship pattern, the journal-wise scattering of articles, keyword analysis, study of different metrics and top cited articles under different headings and presented the analysis.

Keywords: Scientometric analysis, publications productivity, Nobel Laureate, Rainer Weiss, h-index.

Introduction:

Rainer Weiss is a German-born American physicist who was awarded the Nobel Prize for Physics for the year 2017 along with Kip S. Thorne and Barry C. Barish *"for decisive contributions to the LIGO detector and the observation of gravitational waves".* Weiss was born in Berlin to Fredrick Weiss (Neurologist) and Gertude Loesner (Actress) on 29th September 1932. He completed graduation in 1955 and Ph.D. in 1962 from Massachusetts Institute of Technology. The topic of his Ph.D. was "*Stark Effect and Hyperfine Structure of Hydrogen Fluoride*". From 1960 to 2001, he held various positions in Tufts University, Princeton University and Massachusetts Institute of Technology. From 2001 to till date is Professor of Physics Emeritus at Massachusetts Institute of Technology.

He is also the recipient of host of awards:
1968: MIT Baker Award for Excellence in Teaching
1983: NASA Achievement Award (Monolithic Bolometers)
1990: NASA/GSFC Group Achievement Award (COBE)
1991: NASA Exceptional Scientific Achievement Medal (COBE)
1991: NASA Group Achievement Medal (COBE)
1994: National Space Club Science Award (COBE)

1998: American Academy of Arts and Sciences, Fellow

2000: John Simon Guggenheim Memorial Foundation Fellowship

2000: National Academy of Sciences, Member

2003 Medaille de l'ADION Observatoire de Nice

2006: Gruber Prize in Cosmology (as part of COBE team)

2007: American Physical Society Einstein Prize

2016: Special Breakthrough Prize in Fundamental Physics (LIGO)

2016: Gruber Prize in Cosmology (LIGO)

2016: Shaw Prize in Astronomy (LIGO)

2016: Kavli Prize in Astrophysics (LIGO)

2016: Harvey Prize in Science and Technology (LIGO)

2017: Willis E. Lamb Award for Laser Science and Quantum Optics (LIGO)

2017: Princess of Asturias Award for Technical and Scientific Research (LIGO)

2017: Nobel Prize in Physics (jointly with Kip Thorne and Barry Barish)

Rainer Weiss has contributed 224 research articles in different journals, 17 conference papers, 2 book chapters, 2 technical reports, 1 paper yCatalogue and an IAU circular. His major projects include *Atomic Clock development*, *Balloon program to measure Cosmic Background Radiation*, *Science Working Group Chairman*, *COBE satellite program* and *Laser Interferometer Gravitational-Wave Observatory (LIGO)*

Objectives of the Study:

The objectives of the present study are

- To explore qualitative aspects of the research communications of Nobel Laureate Rainer Weiss
- To study chronological distribution of articles
- To study authorship pattern
- To study co-contributor analysis
- To study different metrics such as h-, g- and i10 indices
- To study citation analysis of articles
- To study journal-wise contribution of articles
- To analyse NASA Scientific and Technical Information (STI) keywords in the articles
- To study highly cited articles

Methodology:

Rainer Weiss has authored research articles, conference papers, and books chapters. Only research articles published in journals is considered for the present study. The data required for the study such as complete bibliographical details of each article is retrieved from SAO/NASA Astrophysical Data System (ADS). The bibliographical details of each article are segregated in different MS-Excel sheets as per objectives of the study. Full productivity credit was applied; that is authors were given full credit for every article in which their name appeared. The title of each article is carefully analysed to record keywords, subjects, journals, co-authors etc.

Analysis and Interpretation:

Chronological Distribution of Articles:

The chronological distribution of articles published in journals is presented in Table-1. It is clear from Table-1 that Rainer Weiss published his first journal article ("*Magnetic moments and hyperfine-structure anomalies of* Cs^{133}, Cs^{134}, Cs^{135} *and* $Cs^{13''7}$) at the age of 24 years and 4 Months in the January 1957 issue of the Physical Review journal. From 1957 to 2017, he has published 224 articles in different and reputed journals apart from conference papers, reports, and book chapters. Out of his 60 years of publication period from 1957 to 2017, he has published 124 (55.36%) journal articles in the last ten years from 2008 to 2017. The average articles published per year from 1957 to 2017 is 3.73.

Table-1: Publications Per Year

Year	Articles Published
1957-1967	7
1968-1977	25
1978-1987	5
1988-1997	30
1998-2007	33
2008-2017	124
	224

Prominent Collaborators:

Table-2 presents the list of prominent authors who collaborated with Rainer Weiss in his 224 journal articles. Fritschel, P is the most prominent collaborator who contributed 146 journal articles with Rainer Weiss followed by Gustafson, R with 144 journal articles and Giaime, J, Raab, F and Zucker, M with 143 journal articles. Ten authors collaborated in 142 journal articles followed by 36 authors collaborating in 141 journal articles.

Table-2: Prominent Collaborators

Author	No. of Articles
Fritschel, P	146
Gustafson, R	144
Giaime, J	143
Raab, F	143
Zucker, M	143
10 Authors	142
36 Authors	141

Authorship Pattern:

Table-3 depicts the detailed authorship pattern of Rainer Weiss's 224 journal articles. It is observed that only 26 articles (11.61%) are single authored and 198 articles (88.39%) are co-authored with different authors. An in-depth analysis of authorship pattern reveals that out of 198 co-authored journal articles, 57 (28.80%) articles have co-authors ranging between 2 to 39 followed by 128 (64.64%) articles having co-authors ranging between 200 to 998. Another 13 (6.56%) journal articles have co-authors ranging from 1000 to 1571. The two articles titled "Supplement: Localization and broadband Follow-Up of the gravitational-wave transient GW150914" and "Localization and broadband Follow-Up of the gravitational-wave transient GW150914" published in 2016 in the special issue (Focus on Astrophysical Implications of the First LIGO Detection GW150914) in the journals The Astrophysical Journal Supplement Series and The Astrophysical Journal Letters respectively was authored by 1571 authors including Rainer Weiss. It is also observed that the 198 co-authored articles had total authorship of 82341 authors (by applying full productivity count).

Table-3: Authorship Pattern

Number of Authors	No. of Articles
Single	26
2	14
3	3
4	2
5	4
6	1
8	1
9	2
10	5
11	1
13	3
14	2
15	1
18	5
19	1
20	2
21	2
22	1
23	1
27	1
28	4
39	1
203	1
204	1
256	1
304	1
308	1
369	1
374	4
375	1
403	1
404	3
411	1
427	1
428	3
431	1
443	3
444	1
446	4
448	1
454	1
455	1
456	1
465	1
477	1
478	1
479	1
501	2
502	1
503	2
504	3
505	1
506	1
527	2
540	1
545	1
571	1
585	1
656	1
660	1
668	3
681	1
701	1
712	2
715	1
722	1
723	1
724	1
750	1
770	1
792	1
794	2
795	1
796	1
797	2
801	1
802	1
805	1
810	1
815	1
818	1
849	2

850	1
852	1
853	1
869	1
872	1
876	2
877	1
878	1
888	1
889	1
897	1
893	2
896	1
902	1
907	1
921	1
924	1
937	1
945	1
955	1
958	2
959	1
960	2
961	1
962	1

965	1
966	1
967	2
969	1
970	1
975	1
979	2
982	2
988	1
990	1
991	1
997	1
998	1
1000	1
1002	1
1006	2
1013	1
1043	1
1046	1
1051	1
1184	1
1389	1
1414	1
1571	2
	224

Channels of communication:

The 224 articles published in different journals are presented in Table-4. It is noted that the 224 scientific publications are scattered in 36 journals of different publishers from 6 different countries. Rainer Weiss has contributed maximum 72 (32.14%) articles in the journal *Physical Review D* during 1973 to 2017 which have received 3884 citations. In *The Astrophysical Journal*, 28 (12.5%) articles and in *Physical Review Letters*, 23 articles (10.27%) are recorded. It is also observed that 173 (77.23%) of articles are published in only six journals. He has contributed only once to 18 journals. The 13 articles published in the journal *The Astrophysical Journal Letters* have received a total of 4555 citations. He has been associated for 50 years with the journal *Physical Review Letters* (which has Impact Factor of 8.462) for publishing 23 articles which have received 3958 citations. Among the highest impact factor journals, he has contributed 2 articles in *Nature* which has an impact factor of 40.137.

Table-4: Journal-Wise Scattering of Articles

Sl. No.	Journal	No. of Articles	%	Period of Journal Usage			Citations received	Impact Factor	Publisher	Country of Publisher
				FPY	LPY	Span				
1	Physical Review D	72	32.14	1973	2017	45	3884	4.568	American Physical Society	United States
2	The Astrophysical Journal	28	12.50	1979	2017	39	3796	5.533	IOP Publishing	United Kingdom
3	Physical Review Letters	23	10.27	1968	2017	50	3958	8.462	American Physical Society	United States
4	American Journal of Physics	19	8.48	1967	1971	5	2	1.069	American Association of Physics Teachers	United States
5	Classical and Quantum Gravity	18	8.04	2004	2017	14	1600	3.119	Institute of Physics Publishing	United Kingdom
6	The Astrophysical Journal Letters	13	5.80	1983	2016	34	4555	5.522	Institute of Physics Publishing	United Kingdom
7	Advances in Space Research	4	1.77	1991	2015	25	20	1.401	Elsevier Ltd.	United Kingdom
8	The Astrophysical Journal Supplement Series	4	1.77	2012	2016	5	132	8.955	IOP Publishing	United Kingdom
9	Applied Optics	4	1.77	1984	1992	9	90	1.65	Optical Society of America	United States
10	Physical Review	3	1.40	1957	1967	11	72	NA	American Physical Society	United States
11	Physics Today	3	1.40	1999	2014	15	132	4.188	American Institute of Physics	United States
12	Review of Scientific Instruments	3	1.40	1961	2001	41	72	1.515	American Institute of Physics	United States

13	Astronomy & Astrophysics	2	0.90	2012	2012	1	144	5.014	EDP Sciences	France
14	Journal of Geophysical Research	2	0.90	1965	1996	32	44	3.454	Wiley-Blackwell	United States
15	Nuclear Inst. and Methods in Physics Research	2	0.90	2004	2010	7	343	1.362	Elsevier BV	The Netherlands
16	Nature	2	0.90	1991	2009	19	234	40.137	Nature Publishing Group	United Kingdom
17	Optics Letters	2	0.90	2002	2004	3	41	3.416	Optical Society of America	United States
18	Physical Review X	2	0.90	2016	2016	1	272	12.789	American Physical Society	United States
19	Annual Review of Astronomy and Astrophysics	1	0.45	1980	1980	1	90	30.733	Annual Reviews, Inc.	United States
20	The Journal of the Acoustical Society of America	1	0.45	1989	1989	1	0	1.587	Acoustical Society of America	United States
21	Annalen der Physik	1	0.45	2017	2017	1	8	3.039	Wiley - VCH Verlag GmbH & Co. KG	Germany
22	Earth and Planetary Science Letters	1	0.45	1971	1971	1	0	4.409	Elsevier BV	The Netherlands
23	Journal of Cosmology and Astroparticle Physics	1	0.45	2013	2013	1	39	4.734	Institute of Physics	United Kingdom
24	Journal of Vacuum Science Technology	1	0.45	2000	2000	1	3	1.573	American Institute of Physics	United States
25	Living Reviews in Relativity	1	0.45	2016	2016	1	341	29.3	Springer	Germany
26	New Journal of Physics	1	0.45	2009	2009	1	64	3.786	Institute of Physics Publishing	United Kingdom
27	Nature Photonics	1	0.45	2013	2013	1	194	37.859	Nature Publishing Group	United Kingdom

28	Proceedings of the National Academy of Science	1	0.45	1993	1993	1	2	0.425	National Academy of Sciences	United States
29	Physics Letters	1	0.45	1962	1962	1	7	NA	Elsevier BV	The Netherlands
30	Physics Letters A	1	0.45	1996	1996	1	111	1.772	Elsevier BV	The Netherlands
31	Physical Review A	1	0.45	2017	2017	1	0	2.925	American Physical Society	United States
32	Physica Scripta	1	0.45	1980	1980	1	0	1.28	Royal Swedish Academy of Sciences	Sweden
33	Reports on Progress in Physics	1	0.45	2009	2009	1	718	14.311	Institute of Physics Publishing	United Kingdom
34	Reviews of Modern Physics	1	0.45	1999	1999	1	12	36.917	American Physical Society	United States
35	Science	1	0.45	1992	1992	1	1449	37.205	American Association for the Advancement of Science	United States
36	Technology Review	1	0.45	1975	1975	1	0	NA	Massachusetts Institute of Technology	United States

FPY=First Paper Published Year; LPY=Last Paper Published Year

Keyword Analysis:

The NASA's STI keywords are carefully noted and presented in Table-5. For all 446 keywords with 110 unique keywords were found appended to 224 journal articles. The top five keywords are presented in Table-5. Further analysis reveals that “Methods data analysis” appeared in 49 articles followed by “Gravitational waves” in 30 articles and “Space vehicle” in 19 articles. The other high-frequency keywords are “Astrophysics”, “Stars luminosity function; mass function”, “Astronomy microwave” and “Cosmology cosmic microwave background”

Table-5: Keyword Analysis

Keywords	Total
Methods data analysis	49
Gravitational waves	30
Space vehicles	19
Astrophysics	17
Stars luminosity function; mass function	17
Astronomy microwave	16
Cosmology cosmic microwave background	16

Study of Different Metrics:

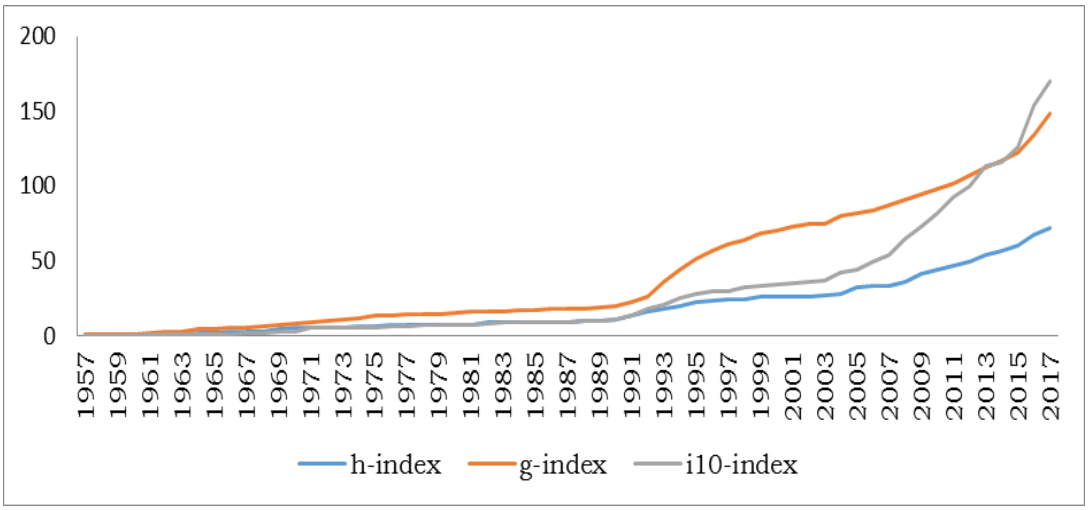
The different metrics such as citations, h-, g- and i10-indexes are calculated and presented in Table-6. The overall analysis reveals that Rainer Weiss’s 224 journal articles have received 22487 citations including 1388 self-citations. The average citations per paper is 100.40. The h-, g- and i10-indices for 2017 are 72, 148 and 170 respectively. The i100-index is 51.

Table-6: Study of Different Metrics

Year	Articles Published	Referred citations to referred papers	Non referred citations to referred papers	Total Citations	h-index	g-index	i10-index
1957	1	1	0	1	1	1	0
1958	-	4	0	4	1	1	0
1959	-	1	0	1	1	1	0
1960	-	-			1	1	0
1961	1	4	0	4	1	2	1
1962	1	2	0	2	1	3	1
1963	1	3	0	3	2	3	1

1964	-	4	1	5	2	4	1
1965	1	2	0	2	2	4	1
1966	-	5	0	5	3	5	1
1967	2	8	0	8	3	5	2
1968	1	7	0	7	3	6	2
1969	7	13	0	13	4	7	3
1970	8	18	0	18	5	8	3
1971	5	23	2	25	5	9	5
1972	-	18	1	19	5	10	5
1973	2	22	0	22	5	11	5
1974	1	18	5	23	6	12	5
1975	1	14	0	14	6	13	5
1976	-	16	0	16	7	13	6
1977	-	8	1	9	7	14	6
1978	-	8	0	8	7	14	7
1979	1	10	0	10	7	14	7
1980	2	13	2	15	7	15	7
1981	-	22	1	23	7	16	7
1982	-	8	0	8	9	16	8
1983	1	17	0	17	9	16	9
1984	1	21	0	21	9	17	9
1985	-	8	0	8	9	17	9
1986	-	21	0	21	9	18	9
1987	-	13	2	15	9	18	9
1988	1	11	2	13	10	18	10
1989	1	10	0	10	10	19	10
1990	2	30	1	31	11	20	11
1991	7	98	2	100	13	22	13
1992	9	211	15	226	16	26	18
1993	3	501	98	599	18	36	21
1994	5	627	31	658	20	44	25
1995	-	581	64	645	22	51	28
1996	2	538	93	631	23	57	30
1997	-	388	87	475	24	61	30
1998	1	354	65	419	24	64	32
1999	2	381	120	501	26	68	33
2000	3	337	46	383	26	70	34
2001	1	244	105	349	26	73	35
2002	1	295	45	340	26	75	36
2003	-	257	65	322	27	75	37
2004	7	318	42	360	28	80	42
2005	8	348	53	401	32	82	44

2006	3	321	80	401	33	84	49
2007	7	337	70	407	33	87	54
2008	10	532	162	694	36	91	65
2009	13	582	71	653	41	94	73
2010	8	668	120	788	44	98	82
2011	6	767	83	850	47	102	93
2012	11	738	286	1024	49	107	100
2013	7	986	113	1099	54	112	113
2014	14	1118	152	1270	57	117	116
2015	7	1097	190	1287	60	122	126
2016	29	2708	511	3219	67	134	154
2017	19	2645	1340	3985	72	148	170
	224			**22487**			



Highly Cited Articles:

The list of highly cited articles of Rainer Weiss is presented in Table-7. The list of articles with more than 700 citations is provided with full bibliographic details. The citations were retrieved from SAO/NASA Astrophysical Data System up to 26th October 2017. The article "Structure in the COBE differential microwave radiometer first-year maps" published in Astrophysical Journal – Letters in 1992 has received the highest number of 2347 citations. It is also observed that 51 articles have received more than 100 citations. His top 15 articles have received 12045 citations which is little over half of the total citations received by his 224 articles.

Table-7: Highly Cited Articles

Author(s)	Title	Source Vol, Issue	Year	Citations As Per ADS
Smoot, G. F et. al.	Structure in the COBE differential microwave radiometer first-year maps	Astrophysical Journal - Letters, Vol. 396, Issue. 1, p. L1-L5	Sept.1, 1992	2347
Abbott, B. P et. al.	Observation of Gravitational Waves from a Binary Black Hole Merger	Physical Review Letters, Vol. 116, Issue 6, id.061102	Feb.2016	1928
Abramovici, A et. al.	LIGO - The Laser Interferometer Gravitational-Wave Observatory	Science, Vol. 256, Issue 5055, p. 325-333	Apr.17, 1992	1450
Abadie, J et. al.	Topical Review: Predictions for the rates of compact binary coalescences observable by ground-based gravitational-wave detectors	Classical and Quantum Gravity, Vol. 27, Issue 17, id. 173001	Sept.2010	780
Abbott, B. P et. al.	LIGO: the Laser Interferometer Gravitational-Wave Observatory	Reports on Progress in Physics, Vol. 72, Issue 7, id. 076901	Jul.2009	718
Abbott, B. P et. al.	GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence	Physical Review Letters, Vol. 116, Issue 24, id.241103	Jun.2016	714

Conclusion:

The 224 articles of Rainer Weiss published in different journals are analysed with respect to qualitative aspects of the research communication. Weiss published first journal article in the year 1957 at the age of 24 years. The period from 2008-2017 has been most productive with 124 (55.36%) articles published in journals. The average articles published per year from 1957-2017 is 3.73. among the prominent collaborators, Fritschel, P is a co-author for 146 articles followed by Gustafson, R for 144 articles. The authorship pattern revealed that he has published 26 single-authored articles followed by 14 two-authored articles. By applying full productivity credit, it is observed that 198 co-authored articles had total authorship of 82341 authors. He has published 72 articles in the journal Physical Review D followed by 28 articles in The Astrophysical Journal. The NASA's STI keyword analysis showed that 110 unique keywords are appended to 224 articles. The keyword "Methods data analysis" appeared in 49 articles followed by "Gravitational waves" in 30 articles. His 224 journal articles have received 22487 citations with 100.40 citations per article. Among the highly cited articles, his top 15 cited articles have received 12045 (53.56%) of total citations.

The scientometric portrait of Rainer Weiss revealed the amount of research carried out and the contributions made to the growth of research field. He primarily concentrated on cosmic microwave background and gravitational radiation phenomena. He worked on the LIGO detector and the observation of gravitational waves for almost 50 years. A life that is so much dedicated, passionate and perseverance to achieve and succeed has resulted in the discovery of gravitational waves on 14th September 2015. Rightly and deservingly, a Nobel Prize in Physics for the year 2017 is awarded to Rainer Weiss. His life, work, and contributions to the scientific community around the world is worth emulating. He is and should be the role model and an inspiration to generations to come.

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