



# **Bibliometrics in the History and Philosophy of Science**

**European Summer School for Scientometrics**

**Vienna, September 12-16, 2011**

**Werner Marx**

**Information Service**

**Chemical Physical Technical Section  
of the Max Planck Society**

## Why History of Science?

“Philosophy of science is as useful to scientists as ornithology is to birds.”

Richard Feynman (1918-1988, Nobel Prize in Physics 1965)

“To know nothing about them [our scientific ancestors] is, to me, as limiting in one’s self-regard as not knowing one’s actual parents.”

Gerald Holton (1922-, science historian at Harvard University, grew up in Vienna, 1938: emigration to the USA)

## Why historical Bibliometrics?

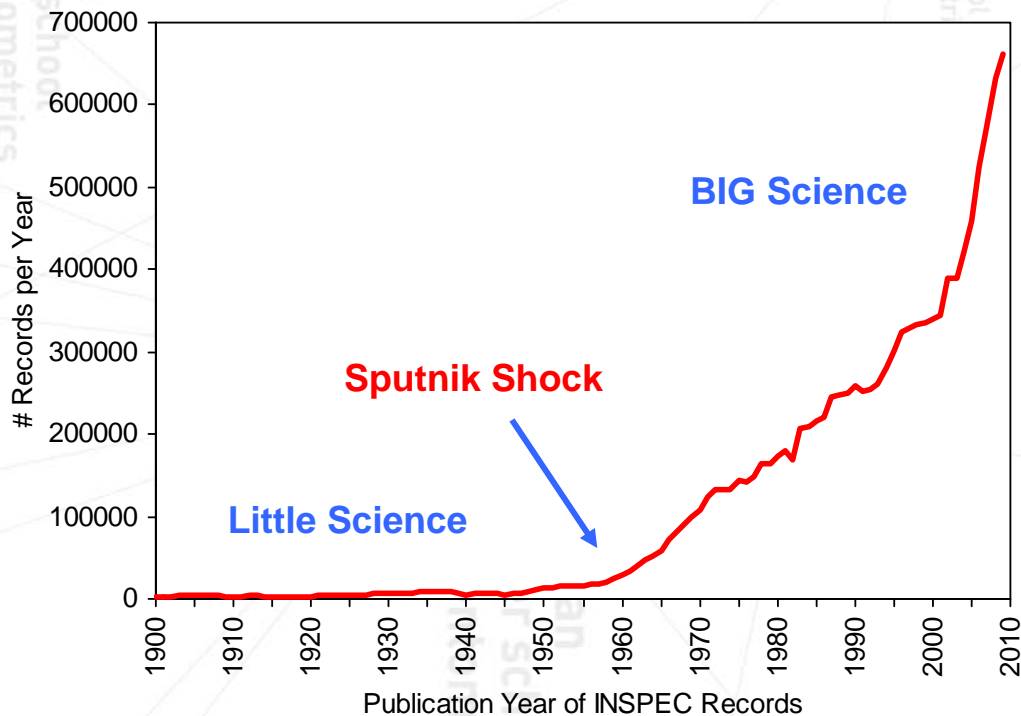
- less clashes as compared to research evaluation of living people
- providing quantitative data: the reception of early seminal works, the history of scientific journals, books, conference series ...
- the emergence and time-evolution of research fields and topics ...
- the impact of pioneers: time-adjusted h-index of Planck, Einstein ...
- refreshing discussions: the Kuhnian philosophy of science ...

## The Data Sources

- Web of Science (in particular CoS)  
articles: 1900-, citations:1900-
- Scopus (Elsevier)  
articles: 1823-, citations:1996-
- Chemical Abstracts Service (CAS) literature file  
articles: 1900-, citations: 1996-
- INSPEC database for Physics, Electronics & Computing  
articles: 1897-, citations: announced for 2011
- Physical Review Online Archive (PROLA)  
articles & citations: 1893- (PR to PR citations only)
- SAO/NASA Astrophysics Data System (ADS)  
articles: 1823-, citations: 1980- (patchy)
- Google Scholar: unclear boundary conditions

## Little Science vs BIG Science

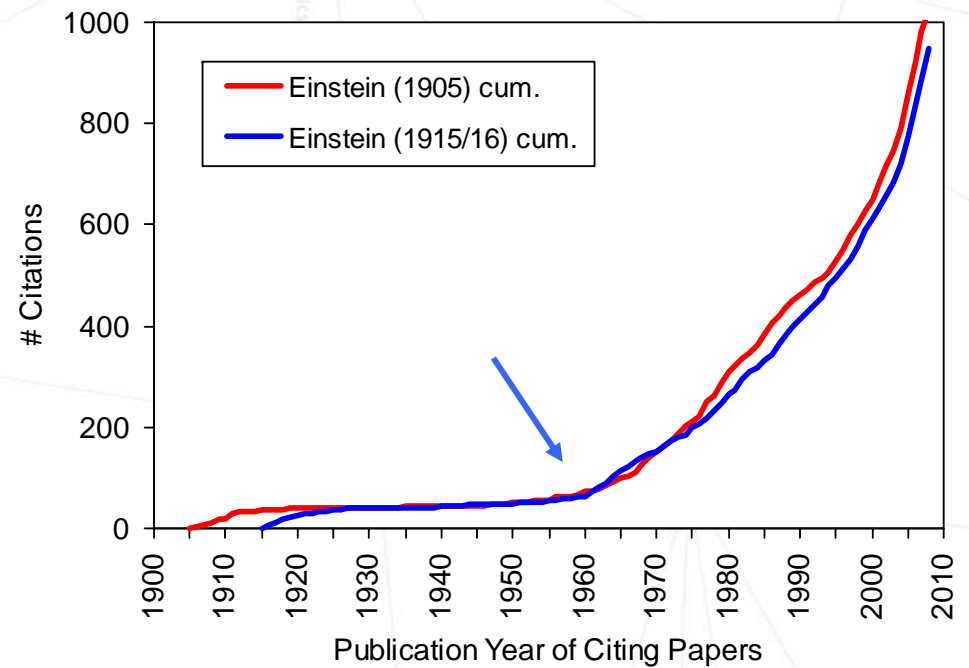
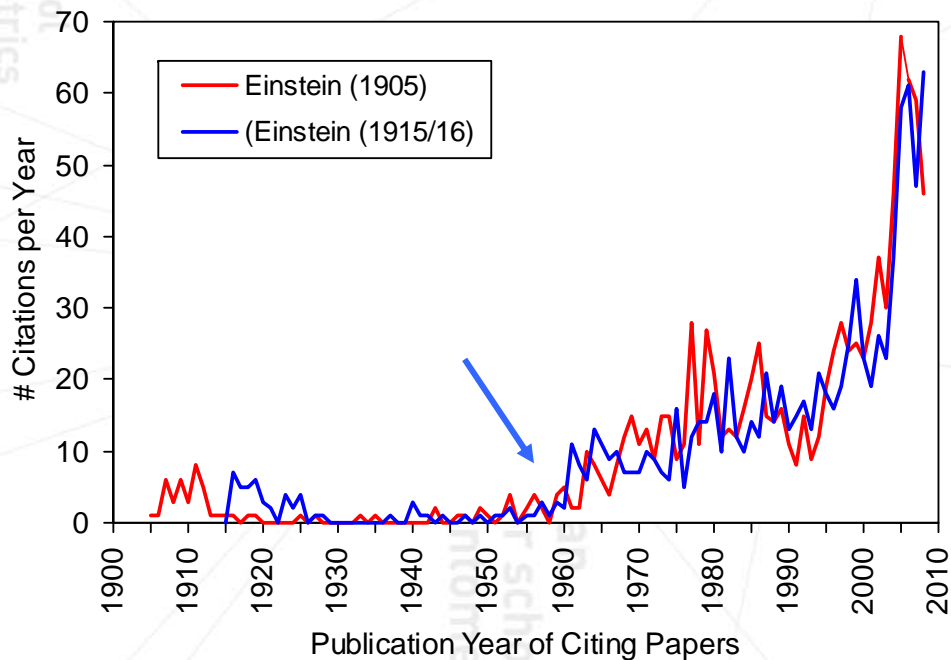
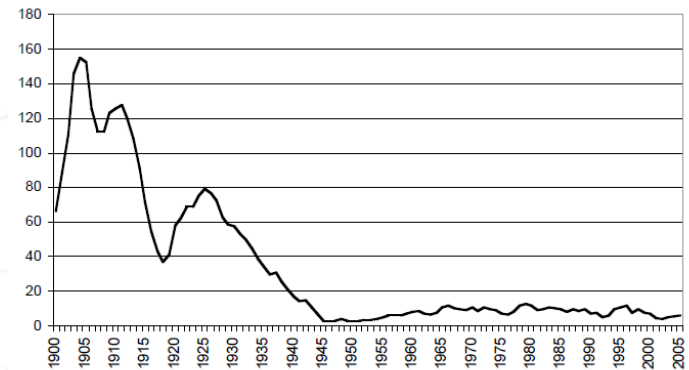
Time Evolution of INSPEC Records (1900-2010)



- 1900-1950: 2500-10,000 records / year  
1950-2010: 10,000-700,000 records / year
- 1900-1950 is only about 2 % of the total physics literature 1900-2010
- distinct bend around 1960: Sputnik Shock
- we may define historical papers: papers published prior to 1950 / 1960
- we may assume different publication and citation habits / cultures

## The BIG Science Boost

**Annalen der Physik 1900-1904**  
Simon Pratt, Thomson Reuters





## The Tools: Advertising 1889 and today



THE KODAK CAMERA.

**“You press the button, -  
- - - we do the rest.”**

The only camera that anybody can use without instructions. Send for the Primer, free.

The Kodak is for sale by all Photo stock dealers.

**The Eastman Dry Plate and Film Co.,**

Price \$25.00—Loaded for 100 Pictures. ROCHESTER, N. Y.

A full line Eastman's goods always in stock at LOEBER BROS., 111 Nassau Street, New York.

- tidy interfaces pretend easy access, clean data and easy searching
- however, the reality is quite different, in general
- and in particular for historical papers!

## WoS Search Modes

### General Search: Publications

Source  
Journals

~~Other  
Journals~~

~~Books~~

~~Conference  
Proceedings~~

Not covered by the SCI  
But covered by the CPCIs

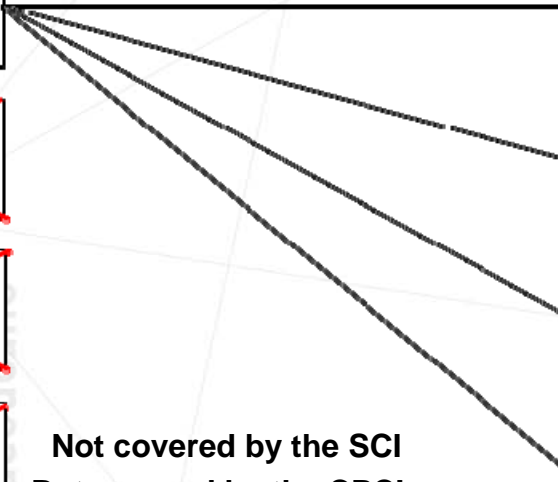
### Cited Reference Search: Citations

Source  
Journals

Other  
Journals

Books

Conference  
Proceedings







## Cited Reference Searching

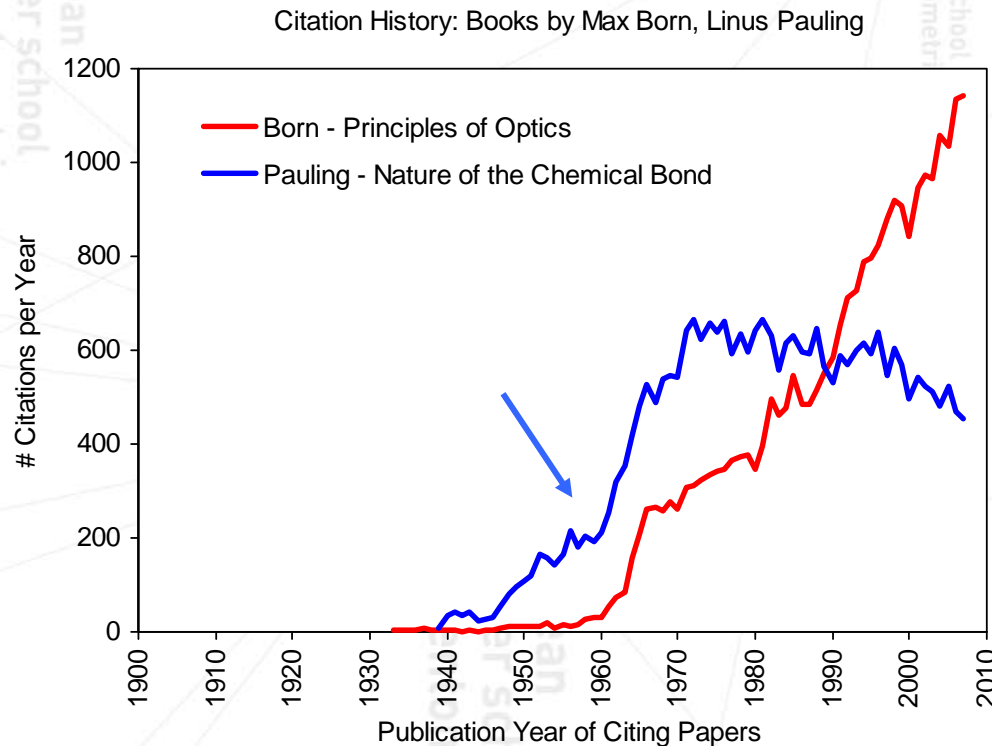
Cited Author	Cited Work [SHOW EXPANDED TITLES]	Year	Volume	Page	Article ID	Citing Articles **	View Record
PLANCK M	ANN PHYS	1900	1	736		1	
PLANCK M	ANN PHYS	1900	1	737		1	
PLANCK M	ANN PHYS LPZ	1900		729		1	
PLANCK M	ANN PHYS-BERLIN	1900	3	764		2	<a href="#">View Record</a>
PLANCK M	ANN PHYS-BERLIN	1900	1	69		86	<a href="#">View Record</a>
PLANCK M	ANN PHYS-BERLIN	1900	1	719		27	<a href="#">View Record</a>
PLANCK M	QUANTUM CONCEPT	1900				1	
PLANCK M	UEBER VERBESSERUNG W	1900		202		1	
PLANCK M	VERH D PHYS GES	1900	2			1	
PLANCK M	VERH DT PHYS GES	1900	2	237		154	
PLANCK M	VERH DTSCH PHYS GES	1900	2	202		92	
PLANCK M	VERH DTSCH PHYS GES	1900	2	203		2	
PLANCK M	VERH DTSCH PHYS GES	1900	2	238		1	
PLANCK M	VERH DTSCH PHYS GES	1900	2	239		3	
PLANCK M	VERH PHYS GES	1900				1	
PLANCK M	VERHANDL DTSCH PHYS	1900	2	2		1	

Blue: AP papers linked  
with WoS source  
records

Red: DPG papers not  
published in WoS  
source journals

Black: No source items  
and/or citation errors

## Book Citations



Book citations are important because:

- books comprise seminal papers worked up and integrated into the scientific knowledge
- many books are highly cited: the two books presented here received about 30,000 citations

however, book citations are limited to those from journals

again, the citation history shows the bend around 1960

## Limited Journal Coverage

### Philosophical Magazine

1900: vol. 50 not covered

1903: vol. 6 not covered

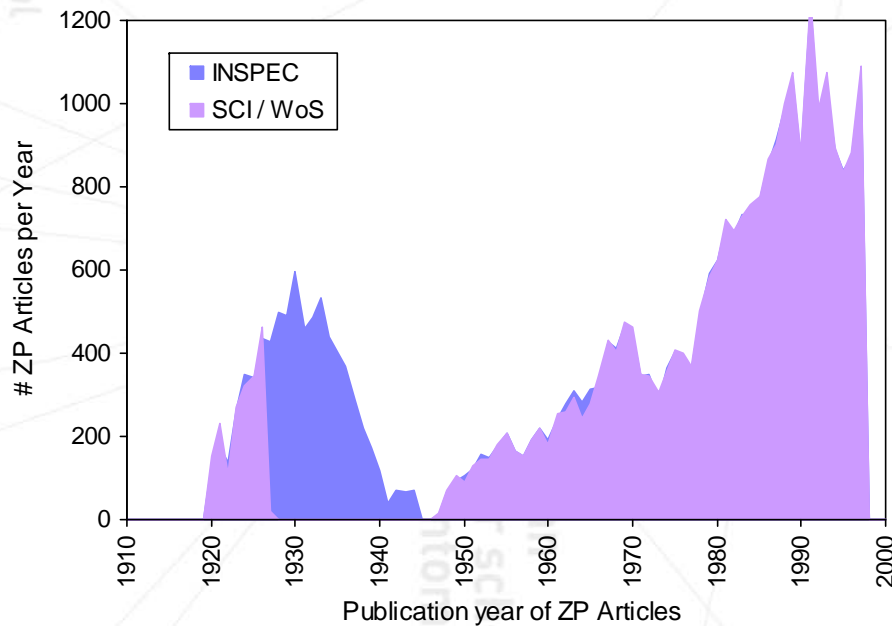
1904: vol. 7 not covered

1911: vol. 21 not covered

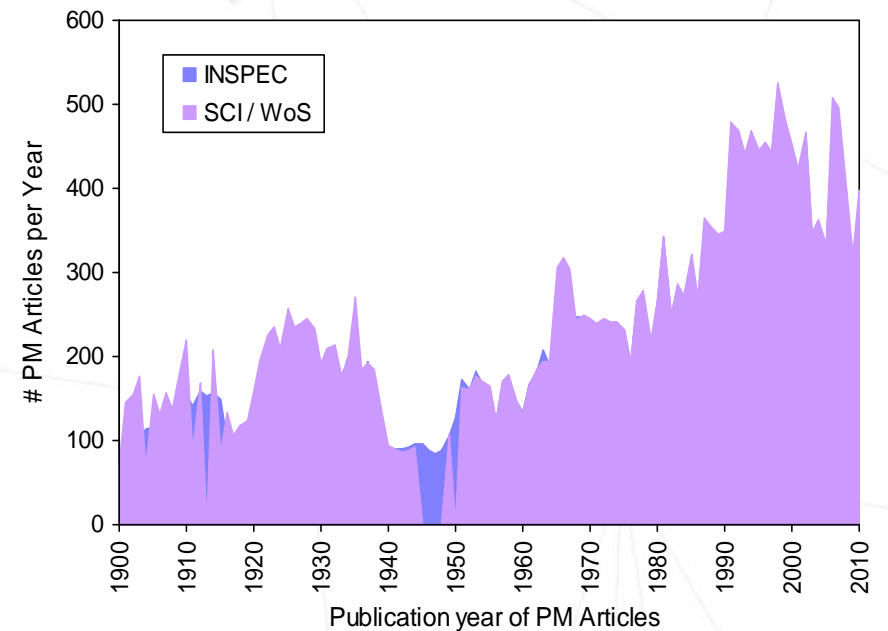
1915: vol. 29 not covered

1913, 1945-1948, and 1950: all  
volumes not covered

Output Time-Evolution: Zeitschrift für Physik



Output Time-Evolution: Philosophical Magazine



## Special Issue: Russian Journals

M. Cardona, W. Marx  
Vitaly L. Ginzburg: A bibliometric study  
In: Vitaly L. Ginzburg  
On superconductivity and superfluidity –  
A scientific autobiography  
Springer, Berlin Heidelberg (2009)

### Note added in Proof:

After finishing this manuscript, A. Wittlin pointed out to us the possible reason why **the complete 1950 issues of the ZhETF are missing** in the Western literature databases... In those witch hunting days, Soviet publications, including scientific journals, were either formally or informally banned. Anderson suggests that **issues arriving to the USA may have been dumped straight into the harbors ...**

### Letter from Ginzburg:

There were some difficulties with publication of the articles in English for the scientist from the USSR in the period from 1947 till 1958. The very good journal **Journal of Physics of the USSR** has been closed, probably, in 1947... Probably (in spirit of our Soviet life) the already published **English language journal was destroyed** or it was destroyed even in proofs ... (14-03-2007)

## Database Errors

- original language assigned incorrectly:  
Angewandte Chemie, Zeitschrift für Metallkunde ...
- alternating coverage of the original and translated version:  
Russian Journal of Experimental and Theoretical Physics ...
- mapping errors (missing links between cited reference and records):  
Philosophical Magazine (E. Rutherford, Phil. Mag., May 1911)  
=> citation matching fails, citations are not counted under Times Cited
- translation errors:  
Original title of a paper by Max Born (1914): Über die Methode der Eigenschwingungen in der Theorie der spezifischen Wärmen  
WoS: Method of natural oscillations in the specific conduction theory  
INSPEC: Natural vibrations and specific heats

W. Marx

Special features of historical papers from the  
viewpoint of bibliometrics

Journal of the American Society for Information  
Science and Technology (2011)

## Complex Author and Journal Names

- C. von Linne, C. von Linneus, C. von Linnaeus, C. Linne ...
- Lord Kelvin alias W. Thomson, Lord Rayleigh alias J.W. Strutt ...
- 1900-1944, 1998-2011: M. von Laue, 1945-1997: M. vonLaue (author)
- 1900-1997: inconsistent, 1998-2011: M. vonLaue (reference author)

J Phys, N J Phys(ik) - (1790-1800)  
Ann Phys(ik) - (1790-1899)  
Ann Phys(ik) Chem(ie) - (1790-1899)  
Annalen - (1790-1899)  
Gilb(erts) Ann Phys(ik) - (1790-1899)  
Pogg(endorffs Ann Phys(ik) - (1790-1899)  
Pogg(endorffs Ann Phys(ik) Chem(ie) - (1790-1899)  
Wied(emanns Ann Phys(ik) - (1790-1899)  
Wied(emanns Ann Phys(ik) Chem(ie) - (1790-1899)  
Ann Phys(ik) - (1900-)  
Ann Phys(ik) Berlin - (1900-)  
Ann Phys(ik) Leipzig - (1900-)



“Just like genetic information, citations can accumulate heritable mutations” (C.G. Specht, 2010, F1000)

## Citation Errors: Incorrect References

Paper	# citations (correct + incorrect)	# incorrect citations	% incorrect citations
W. Kohn & L.J. Sham (1965)	19234	668	3.47
O. K. Andersen (1975)	4562	89	1.95
G. Mie (1908)	4836	297	6.14
R. Kohlrausch (1854)	467	73	15.63
J. Lindhard (1954)	1945	362	18.61
G. Wassermann (1933)	216	177	81.94



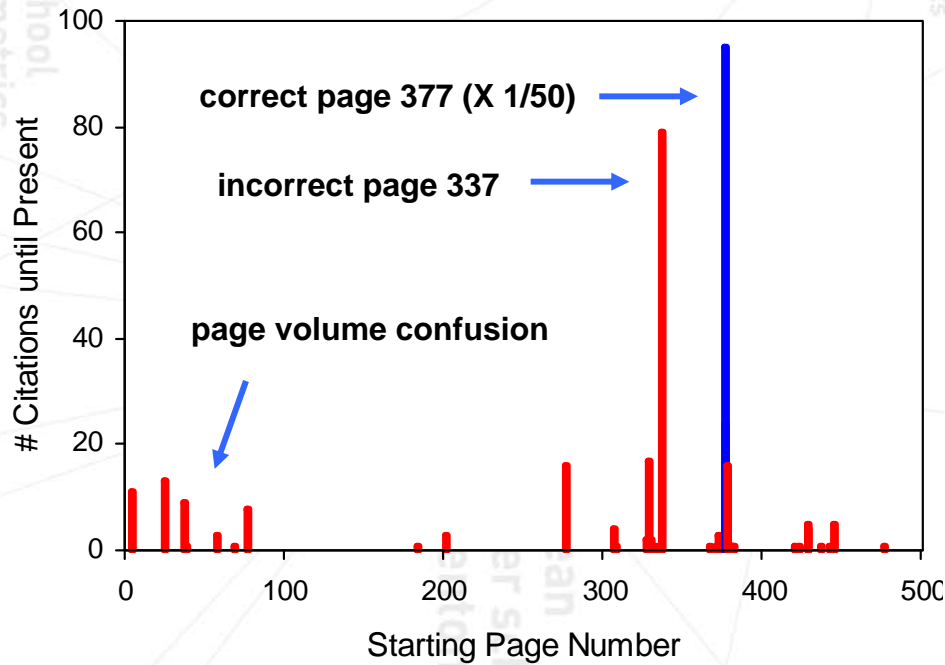
W. Marx

Special features of historical papers from the viewpoint of bibliometrics

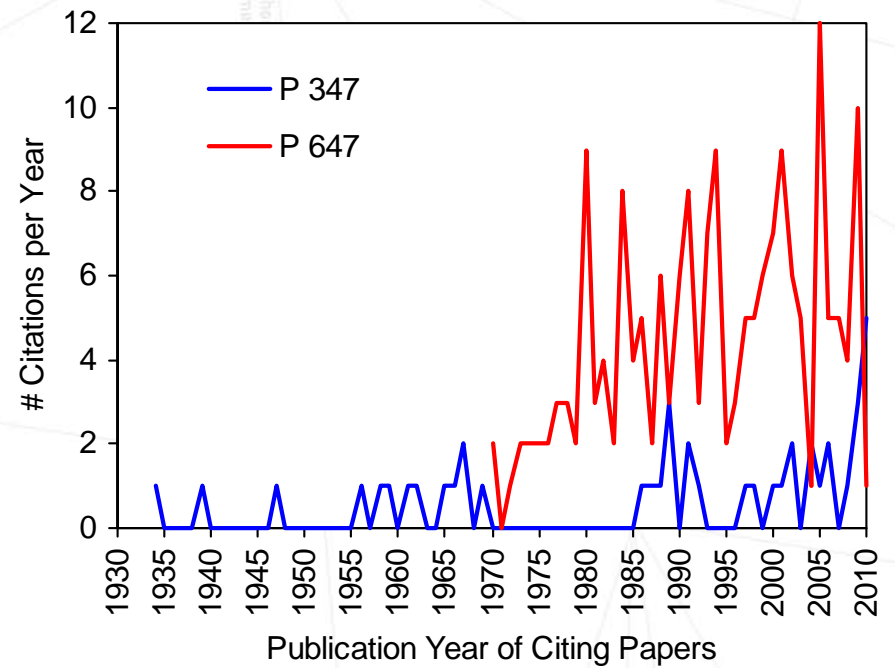
Journal of the American Society for Information Science and Technology (2011)

## Incorrect Starting Pages

Mie Paper



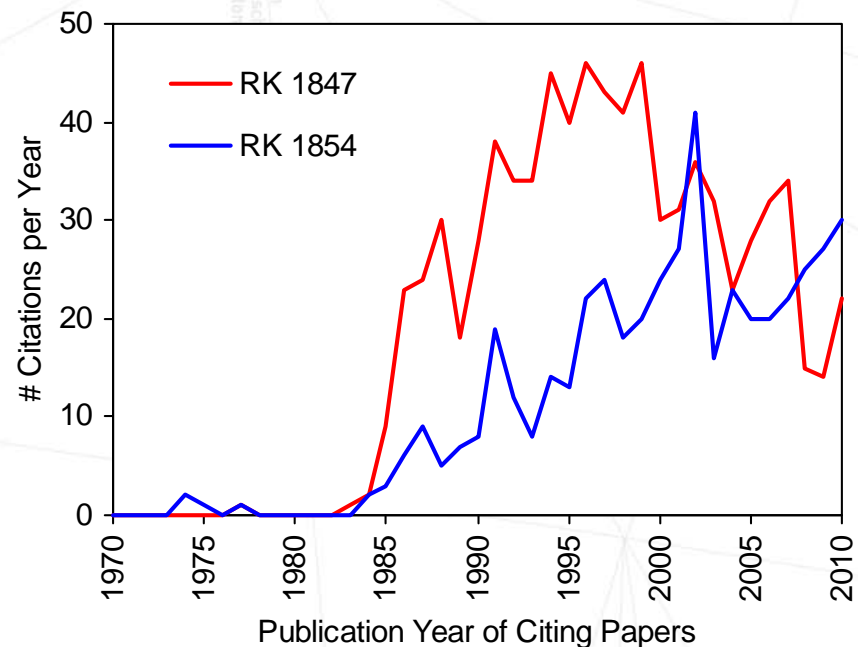
Wassermann Paper



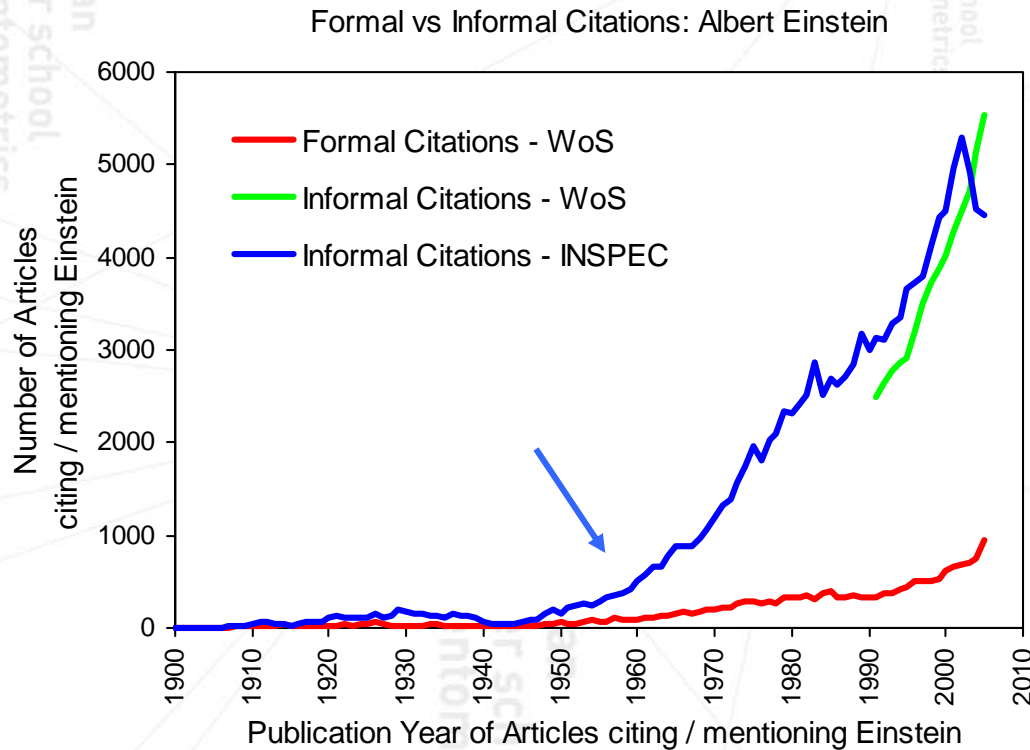
## Additional Sources of Errors

- confusion of starting pages:  
 R. Kohlrausch (1854) page 56 (part I)  
 vs page 179 (part II)
- confusion of related papers:  
 Kohlrausch 1847 vs Kohlrausch 1854
- confusion of authors:  
 student vs teacher, discoverer vs  
 re-discoverer
- possibly more sources of errors?

Kohlrausch Papers 1847 vs 1854



## Informal Citations and Obliteration



“Obliteration—perhaps even more than an astronomical citation rate—is one of the highest compliments the community of scientists can pay to the author.... It would mean that his contribution was so basic, so vital, and so well-known that scientists everywhere simply take it for granted. He would have been obliterated into immortality.”

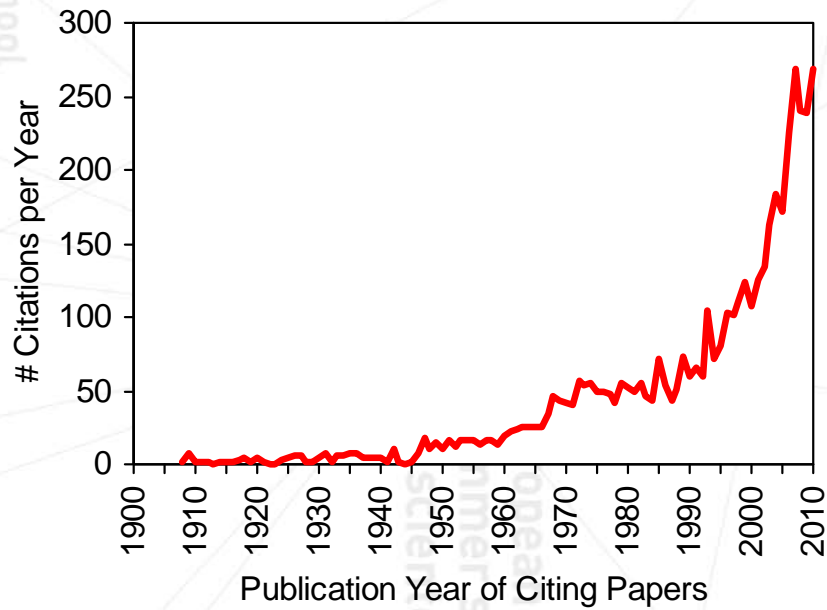
Eugene Garfield, Essay 1975

**Mie paper: 4700 citations**

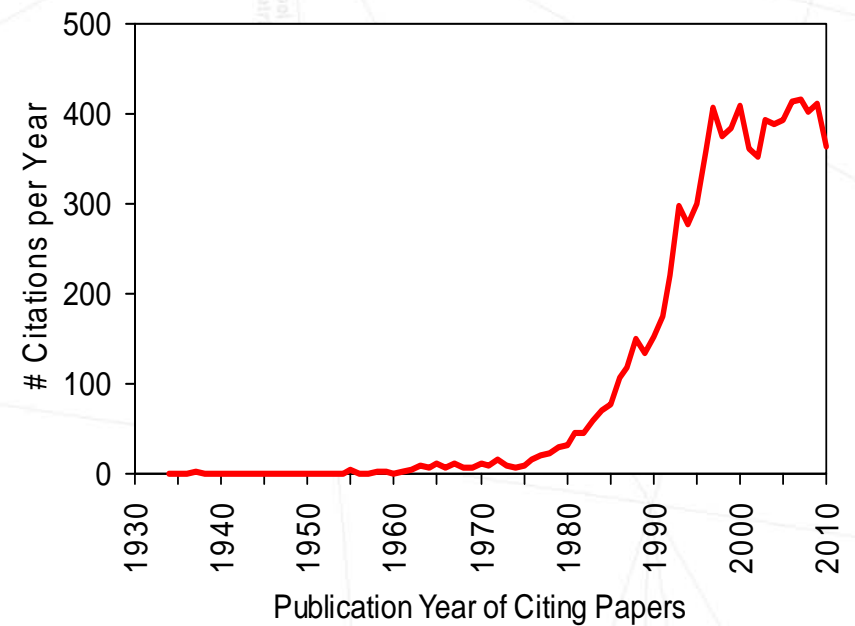
**M&P paper: 8400 citations**

## Sleeping Beauties / Hidden Pearls

G. MIE: ANN PHYS V25 P377 (1908)



C. MÖLLER & M.S. PLESSET:  
PHYS REV V46 P 618 (1934)

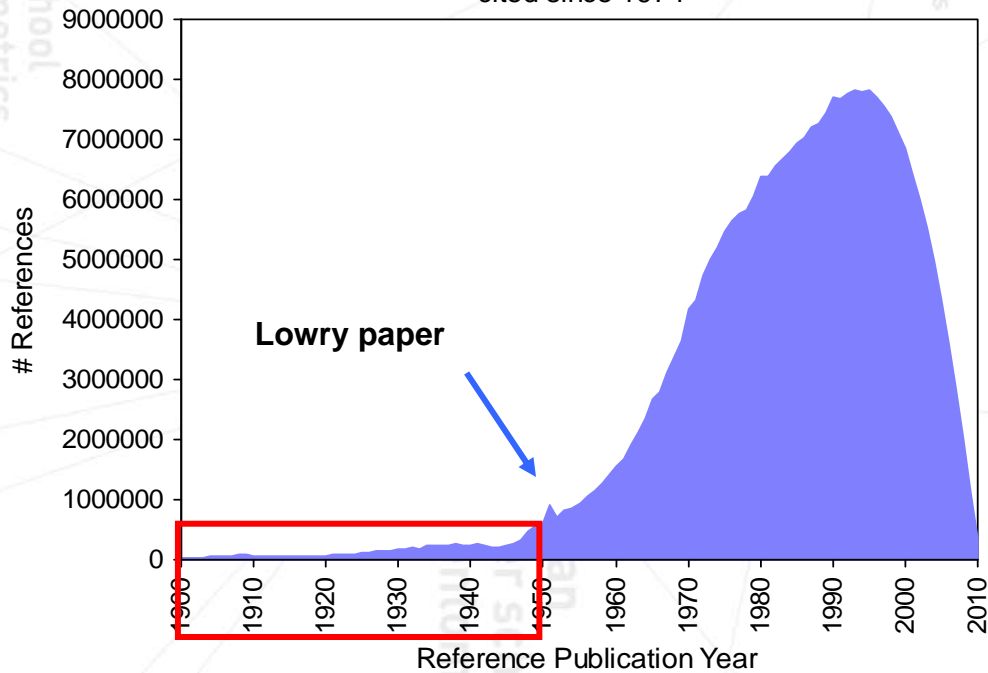


O. H. Lowry, N. J. Rosebrough, A. L. Farr, and R. J. Randall  
Protein Measurement with the Folin Phenol Reagent  
J. Biol. Chem. 193, 265–275 (1951)

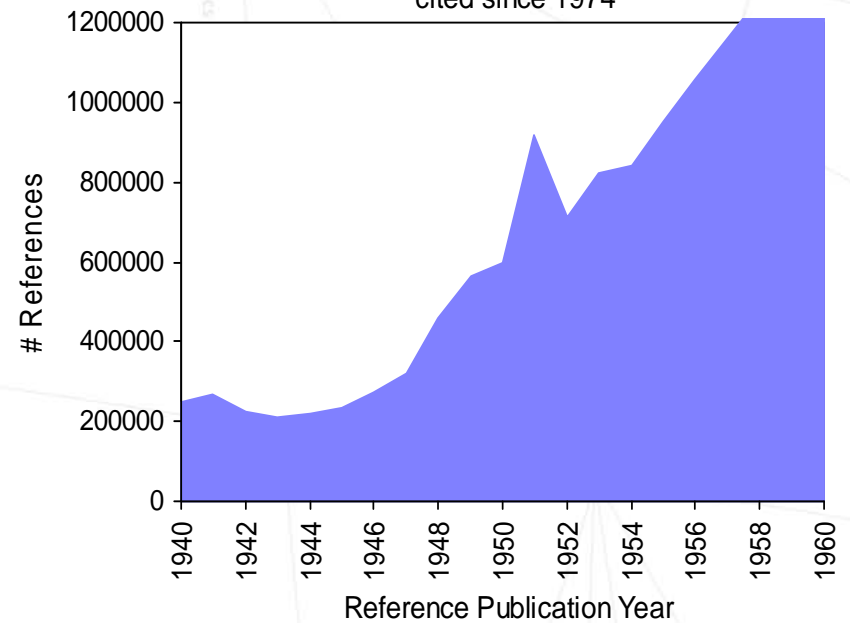
**Lowry paper: ~ 300 000 citations!**

## Reference Spectroscopy

Reference Publication Years 1900-2010  
cited since 1974



Reference Publication Years 1940-1960  
cited since 1974

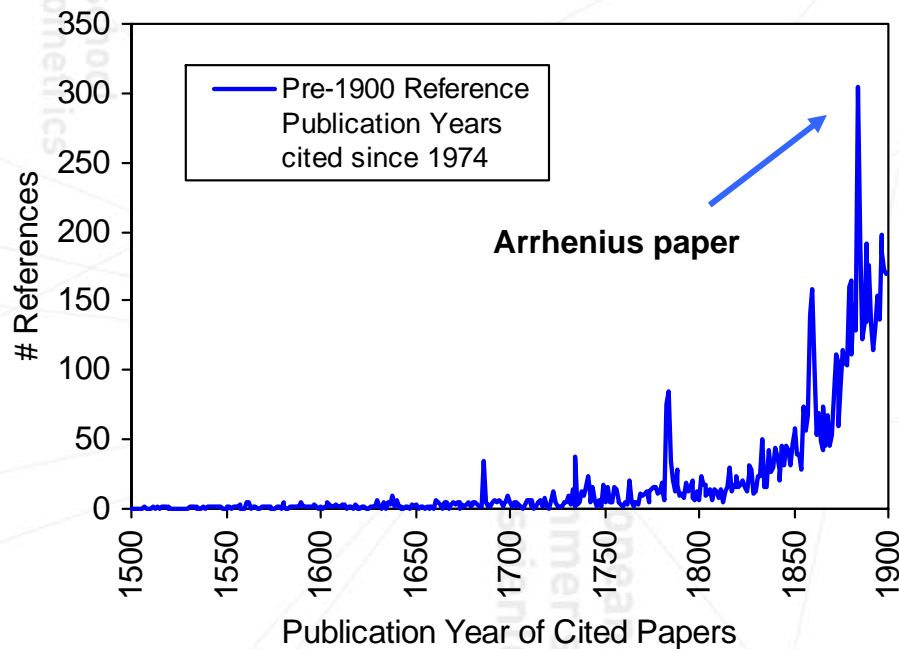


M. Walker & W. Marx

Which old papers have been cited most in Meteorology?

Royal Meteorological Society Newsletter 3, 11-13 (2010)

## Reference Spectroscopy



E. Halley: An historical account of the trade winds, and monsoons, observable in the seas between and near the tropicks, with an attempt to assign the phisical cause of the said winds.

Philosophical Transactions 16:153-168 (1686).

doi:10.1098/rstl.1686.0026

J. Jurin: Invitatio ad observations meteorologicas communi consilio instituendas a Jacobo Jurin M.D Soc. Reg. Secr et Colleg. Med: Lond: Socio.

Philosophical Transactions 379: 422-427 (1723).

J.J.D. DeMairan: Traité physique et historique de l'aurore boréale imprimerie royale (1733).

G. Hadley: Concerning the cause of the general trade-winds.

Philosophical Transactions 39: 58-62 (1735).

doi:10.1098/rstl.1735.0014

J.J. Hemmer, and C. König: Weather observations from Mannheim, Germany, in: *Emphemerides Societatis Meteorologicae Palatinae, Observationes Anni 1783*, edited by J. Hemmer and C. König, pp. 1- 77, Fr. Scwan, Mannheim, Germany (1783).

B. Franklin: Meteorological imaginations and conjectures.

Manchester Literary and Philosophical Society Memoirs and Proceedings 2, 122 (1784).

H.F. Blanford: On the connection of the Himalayan snowfall and seasons of drought in India. *Proceedings of the Royal Society of London* 37: 3-22 (1884).

S. Arrhenius: On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine* 41: 237-276 (1896).

W. Marx, L. Bornmann, M. Cardona

Reference standards and reference multipliers for the comparison of the citation impact of papers published in different time periods

Journal of the American Society for Information Science and Technology

61 (10) 2061-2069 (2010)

## Time-Adjustment – Reference Multipliers

journal title	citing papers per paper: 2000-2009 / 1900-1909
<i>Astrophysical Journal</i>	79.12
<i>Physical Review</i>	39.45
<i>Philosophical Magazine</i>	30.87
Physics (total)	15.15



## Time-Adjustment – STR Paper by Einstein

basis for reference multiplier	reference multiplier	calculation	time-adjusted citation count
actual cites from 1905 to 1915	0		37
Physics (total)	15	$15 \times 37$	555
<i>Physical Review</i>	40	$40 \times 37$	1480
<i>Astrophysical Journal</i>	80	$80 \times 37$	2960

## Time-Adjustment – Three Pioneers in Physics

scientist	reference multiplier	time-adjusted h-index
Max Planck	0 / 15 / 40	13 / 53/ 68 / 92*
Albert Einstein	0 / 15 / 40	50 / 120 / 139
Ernest Rutherford	0 / 15 / 40	20 / 91 / 93

\* pre-1900 papers included

W. Marx, L. Bornmann

How accurately does Thomas Kuhn's model of paradigm change describe the transition from a static to a dynamic universe in cosmology?

A historical reconstruction and citation analysis  
Scientometrics 84 (2) 441-464 (2010)

## The Kuhnian Philosophy of Science

According to Kuhn, science takes place in a cyclic pattern:

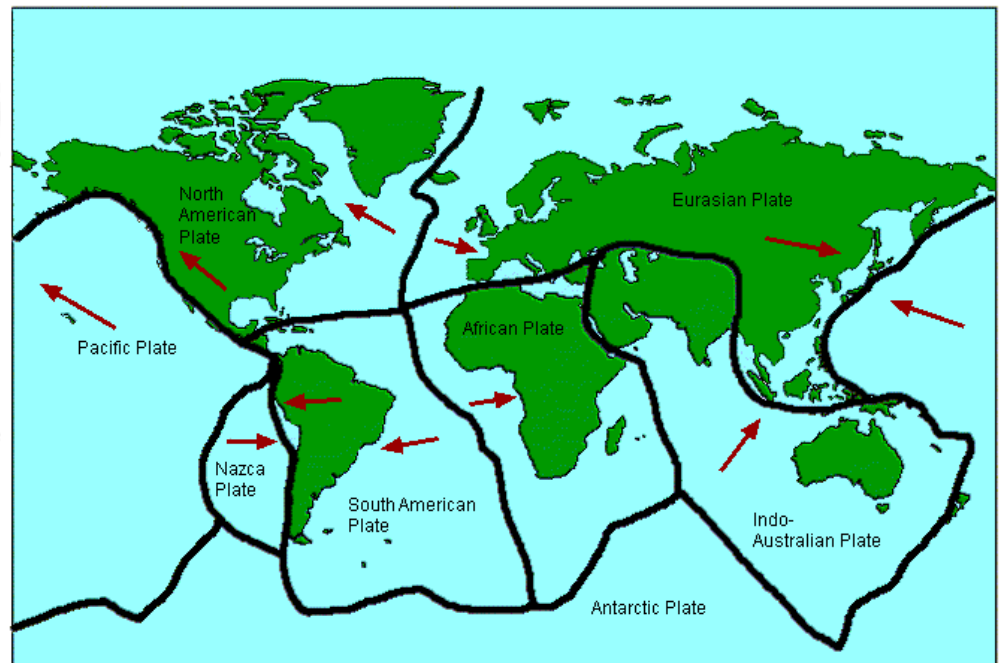
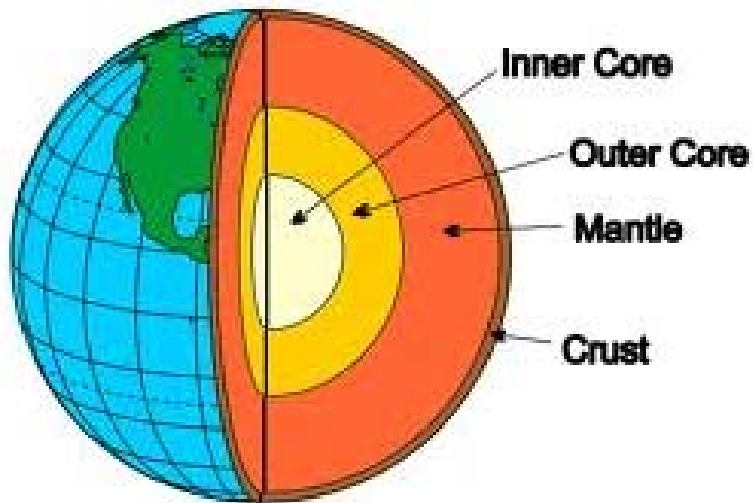
- normal science based on paradigmas (explanatory models, methods)
- extraordinary science: scientific revolutions (model crisis and paradigma shift)

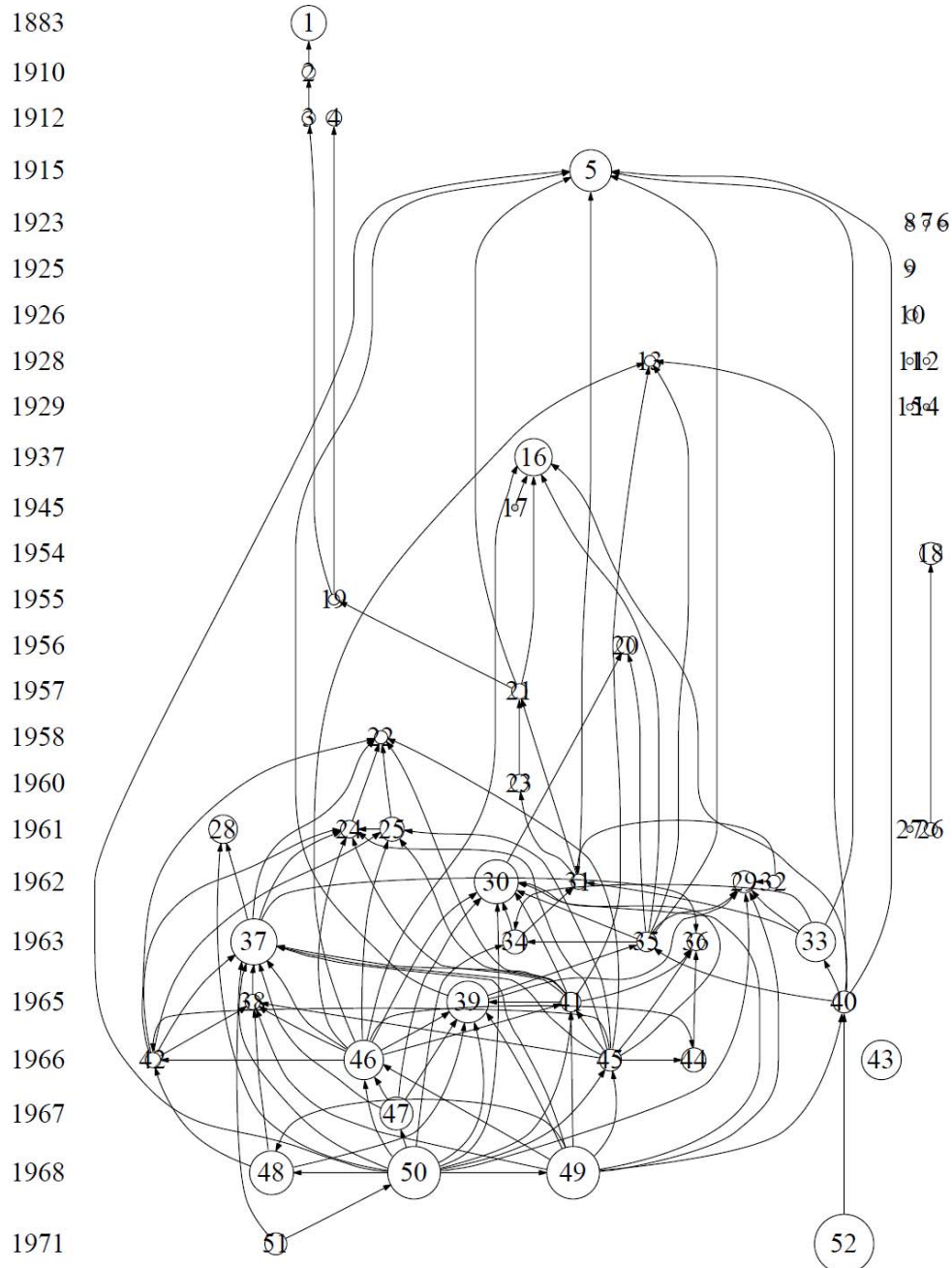
Kuhn: science is driven by problem solutions, not by a fixed goal (absolute truth)  
Scientific progress is similar to biological evolution

However:

- discussion remained on a philosophical level, no mechanism for big science
- we need: in-depth analysis of breakthroughs, combined with bibliometric data

## A Case Study: The Emergence of Plate Tectonics



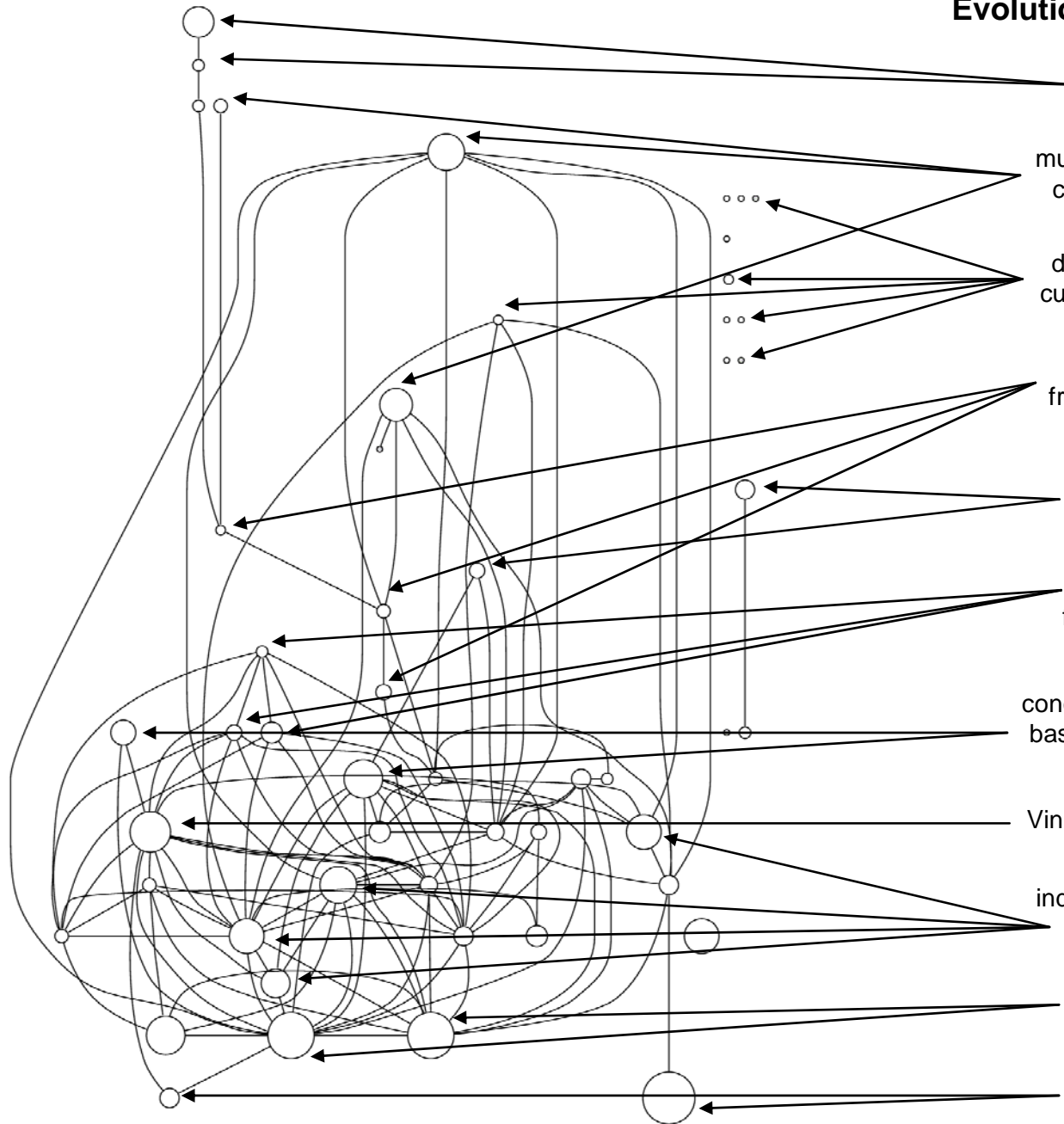


#	Key-Paper	LCS	GCS
1.	SUESS E, 1883, DAS ANTLITZ DER ERDE	1	404
2.	TAYLOR FB, 1910, BULLLL GEOL SOC AM, V21, P179	1	62
3.	WEGENER A, 1912, GEOL RUNDSCHAU, V3, P276	1	62
4.	WEGENER A, 1912, PETERM GEOGRAPH MITT, V58, P185/253/305	1	89
5.	WEGENER A, 1915, DIE ENTSTEHUNG DER KONTINENTE	7	575
6.	JOLY J, 1923, NATURE, V111, P603	0	0
7.	JOLY J, 1923, PHILOS MAG, V45, P1167	0	8
8.	JOLY J, 1923, PHILOS MAG, V46, P170	0	1
9.	AMPFERER O, 1925, NATURWISS, V13, P669	0	6
10.	DALY RA, 1926, OUR MOBILE EARTH	0	36
11.	HOLMES A, 1928, GEOL MAG, V65, P236	0	4
12.	HOLMES A, 1928, NATURE, V122, P431	0	4
13.	HOLMES A, 1928, T GEOL SOC GLASGOW, V18, P559	4	36
14.	DUTOIT AL, 1929, AM J SCI, V17, P179	0	0
15.	HOLMES A, 1929, MIN MAG, V40, P205/286/340	0	11
16.	DUTOIT AL, 1937, OUR WANDERING CONTINENTS	5	467
17.	DUTOIT AL, 1945, AMER J SCI, V243, P404	0	0
18.	BULLARD E, 1954, PROC R SOC LONDON SER A-MATH, V222, P408	1	150
19.	RUNCORN SK, 1955, ADVAN PHYS, V4, P244	1	43
20.	BULLARD EC, 1956, ADV GEOPHYS, V3, P153	2	95
21.	CREER KM, 1957, PHILOS TRANS R SOC SER-A, V250, P144	2	85
22.	MASON RG, 1958, GEOPHYS J ROY ASTRON SOC, V1, P320	6	64
23.	COLLINSON DW, 1960, GEOL SOC AMER BULL, V71, P915	1	102
24.	MASON RG, 1961, GEOL SOC AMER BULL, V72, P1259	6	106
25.	RAFF AD, 1961, GEOL SOC AMER BULL, V72, P1267	4	179
26.	BULLARD EC, 1961, GEOPHYS J ROYAL ASTR SOC, V4, P282	0	57
27.	GASKELL TF, 1961, GEOPHYS J ROY ASTRON SOC, V5, P80	0	0

Nodes: 52, Links: 113  
 GCS, top 100; Min: 0, Max: 1112 (GCS scaled)  
<http://garfield.library.upenn.edu/algorithmichistoriographyhistcite.html>.

# Evolution of Plate Tectonics

1883  
1910  
1912  
1915  
1923  
1925  
1926  
1928  
1929  
1937  
1945  
1954  
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1961  
1962  
1963  
1965  
1966  
1967  
1968  
1971



forerunners

multiple evidence without convincing mechanism

discussion of convection currents in mantle material

ambiguous evidence from paleomagnetic data

further evidence from heat flow data

further evidence from magnetic stripes

concept of sea floor spreading based on convection currents

Vine Matthews Hypothesis

independent confirmation and break-through

final confirmation and establishment

ongoing research



W. Marx, L. Bornmann

How accurately does Thomas Kuhn's model of paradigm change describe the transition from a static to a dynamic universe in cosmology?

A historical reconstruction and citation analysis  
Scientometrics 84 (2) 441-464 (2010)

## Conclusions from Case Studies

- citation network extending throughout more than a century
- the concept did not emerge suddenly out of the blue
- forerunners, various approaches, different strands
- no continuous development but several decisive steps
- a final breakthrough but no real Kuhnian revolution
- the need for an explaining mechanism adapted to big science and the possibility of verification

=> „Perhaps it is time to reformulate Kuhn's theory of revolutionary change in science in more continuous terms ...“

(Henry Small, JASIST V54 P394 (2003))



## Pliny Quotation

“I have placed at the beginning of my books the names of my sources. I’ve done it because I believe that it is a pleasurable endeavor that shows honorable humility. It vouchsafes profound respect to those who have prepared the way to my own achievements.”

Pliny the Elder, Roman scholar & scientist  
(23 AD - 79 AD)

