Bibliometric analysis of document flow on academic social networks in Web of Science

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Abstract

Analysis of a document array on academic social networks (ASNs) in Web of Science for the period from 2005 to 2020 was carried out with use of analytical services data of the WoS and CiteSpace (the program for visualization of patterns and trends in scientific literature). The following parameters of the array were analyzed: publication dynamics; document types structure; countries, organizations and authors leading in the number of publications; thematic categories to which documents of the array are assigned; publications (journals, monographs) in which the documents of the array are published; most cited publications. An increase in the number of publications on the ASNs in WoS was established since 2005. The largest number of ASNs studies is conducted in the USA (University of Pittsburgh), UK (Wolverhampton University, Manchester University), China, Spain (University of Granada), Germany (Max Planck Society for Scientific Research), Canada, India and the Netherlands (Leiden University). The ASNs were studied in the main thematic areas: Computer Science, Computer Science and Librarianship, Mechanical Engineering, Engineering and Technology. Four out of the first ten highly cited publications, are devoted to altmetrics. Using the CiteSpace, it was shown that when ASNs started rise, their organizational structure was beeing studed. Later, altmetrics used in the ASNs became the main subjects of ASNs research. The keywords occurrence revealed that the most frequent terms are “altmetrics”, “impact”, “citation”. As part of the document flow, also identified publications in which the ASNs are used as a source of bibliographic data for systematic or meta-analysis (in medicine predominantly), or as a platform for experimental data discussion.

Introduction

Since the development in 2005 of Web 2.0 technologies (O’Reilly 2005) and such Web 2.0 applications as text messengers, wikis, social networks, scientists, like other categories of Internet users, have become engaged in global (Facebook, Twitter, YouTube, Flickr, MySpace) and professional (LinkedIn) social networks (Boyd and Ellison 2007).

Global social networks are used by scientists both for scientific (search for scientific literature or scientific collaboration) and educational purposes (Jordan 2014). Social networks that meet the scientists’ needs in information exchange, cooperation and self-organization named academic social networks. Social networks aimed specifically at academics appeared very quickly (Nentwich et al. 2012; Ortega 2016). Boyd and Ellison noted: “The definitive components of Web 2.0 applications to be an online social network are four: a place to establish a personal profile, a list of connections with other users, the ability to monitor the activities of those who appear on the list, and the ability to establish new connections” (Boyd and Ellison 2007). In accordance with this definition, academic social networks are the well-known CiteULike, Mendeley, Academia.edu, ResearchGate, Connotea, Zotero. A data repository MyExperiment positions itself as an ASN also (Guler et al. 2016).

Global social networks are under active scientific investigation. The document array in the WoS database on this issue reaches 100,000 documents[1]. The document flow in the WoS on the problem of ASNs is

more modest, it nowadays does not exceed 1500. The analysis of this document array is of interest to clarify the question of who and for what reason is showing scientific interest and other sorts of one in a new phenomenon of scientific communication - academic social networks. Bibliometric analysis was chosen to study the document flow.

Bibliometrics is a collection of methods that can be used to quantitatively and structurally analyze scientific literature. Currently, polythematic scientometric databases like Scopus and WoS are often used as a source of scientific document array. On the platforms of the databases are developed commercial scientometric analytical systems (SciVal, InCite), which make it possible to characterize multidimensionally the investigated document arrays based on bibliographic and other data on publications and authors of these publications. Also on the platforms, analytical services that provide a number of parameters allowing to assess the performance of the research field for free (SciVal, InCite are licensed separately) have been developed. We researched publications on the ASNs topic in WoS.

Another bibliometric focus is science mapping. By means of science, mapping analysis based on bibliographic networks the extraction of knowledge from the intellectual, social or conceptual structure of a research field can be done. Several science mapping software tools were developed (Cobo et al. 2011). In this work for mapping of the research field ASNs a program for patterns and trends visualization in scientific literature CiteSpace (Chen 2004, 2006, 2017; Chen et al. 2010; Chen and Song 2019).

[1] A request in WoS (July 2020) has retrieved about 100,000 documents, where the phrase "social network *" was found in the titles, authours's keywords and other controled terms.

Materials And Methods

Materials. The search for documents on the ASNs in the WoS database was carried out at the request formulated as follows: TS =("social scientific network *" or "academic social network *" or "social research network *" or "scholar * social network *" or "academic social site * "OR" social media for academics "or Mendeley or CiteULike or" Academia.edu "or ResearchGate or" Research Gate "or MyExperiment or" Scientific Social Community "or Connotea OR Zotero). Initially, the request included the names of the projects "Next Nature Network", REIsearch, Scispace, Scientbook, Epernicus, SciSpace. But when analyzing the sample, it was noticed that when they were excluded, the sample size did not change at all. That is, there are no publications on them in WoS. TS - WoS code that provides search in bibliographic record fields: title; essay; author's keywords; keywords plus WoS, upon request. The truncation character asterisk (*) represents any group of characters, including no character (for example, network * matches networks and networks). Terms that are phrases are enclosed in quotation marks ("social scientific network *"). In addition to the phrases "social scientific network *", "academic social network *", "social research network *", the query lists the names of the main scientific social networks.

There were found 1216 documents for the period from 2005 to 2020 (May 2020). The search was carried out on all WoS citation indexes available at SPSL SB RAS for the license (Science Citation Index Expanded (SCI-EXPANDED) -1975-present; Social Sciences Citation Index (SSCI) -1975-present; Arts &

Humanities Citation Index (A & HCI) -1975-present; Conference Proceedings Citation Index-Science (CPCI-S) -1990-present; Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH) -1990-present present; Book Citation Index-Science (BKCI-S) -2005-present; Book Citation Index-Social Sciences & Humanities (BKCI-SSH) -2005-present; Emerging Sources Citation Index (ESCI) - -2015-present) across all retrospective arrays including 2020.

When searching, we faced the problem of separating publications: in some, academic social networks were mentioned as a source of bibliographic information for simple review, systematic review, metanalysis, in others - as a place to store data, in still others - as a place to discuss certain professional issues. We were interested in publications where academic social networks were the object of scientific research. We tried to exclude such a document by using the not operator and listing addresses (for example, "not TS = (https://data.mendeley.com OR" Mendeley Data "OR" https://www.researchgate.net "OR myexperiment.org), but this did not help us. When browsing the selection with exceptions using the NOT operator, we continued to find publications of the above nature, for example, publications where the ResearchGate network was simply listed as a source of bibliographic information. For this reason, we analyzed the entire document flow.

Methods

WoS. Analytical services of the WoS database were used to obtain information about the investigated document array by the following parameters: dynamics of publications by year; type-specific structure of an array of documents; leading authors in terms of the number of publications; leading organizations in terms of the number of publications; thematic categories to which the documents of the array are assigned, the distribution of publications by country; editions (magazines, monographs) in which the documents of the array are published; the most frequently cited publications.

CiteSpace. The CiteSpace, program for visualizing patterns and trends in scientific literature, used to analyze the co-citation of documents, co-occurrence of keywords in documents, and names of institutions.

Documents co-citation analysis is one of the ways to determine the relationship between various publications in a certain field of research: if two publications are cited in the third jointly, then with a high degree of probability they belong to the same research area (Small 1973). Clustering of the document citation network and automatic tagging of clusters with the author's keywords, additional WoS keywords of citing articles or terms from the titles of citing articles or terms from abstracts using the CiteSpace program allow you to identify research trends in the analyzed document array.

Collaboration networks are plotted in CiteSpace on the analysis of the co-occurrence in the document of the original array (1216 documents from WoS, in our case) of the scientific institution' names (institutions collaboration) or authors' names (authors collaboration).

The analysis of the co-occurrence of keywords in the titles of articles, abstracts, among the author's keywords and Keywords Plus WoS of the original documentary array on the ASNs topic in CiteSpace allow us to identify their frequency distribution and thematic clusters in which they are grouped. Clustering the network of co-occurred keywords and labeling them with terms from the titles of articles in which they occur together allow us to identify the topics of the investigated document array.

The results of the analysis of co-citation of documents, co-occurrence, institution names (author names), keywords are presented in the form of pictures of the corresponding networks and clusters, in which the corresponding analyzed parameters (references, authors, organizations, keywords) are grouped.

Results And Discussion

Document types and publication languages

According to analytical services WoS, the bulk of documents are scientific articles in journals (54.4% of documents), in conference proceedings (23.8% of publications) and reviews (18.2%) (Table 1). About 95% of the documents found in WoS are published in English, which is logical for the international scientometric base.

Table 1 Document types scientific social networks documents array from WoS

Document types	Number of in WoS
Article	661
Proceedings Paper	290
Review	222
Data Paper	55
Editorial Material	29
Early Access	28
Book Chapter	21
Letter	8
Meeting Abstract	7
Book Review	5
News Item	4
Database Review	3
Software Review	2

The dynamics of publications

The number of publications on ASNs in WoS for the period has been growing since 2005, which indicates a significant increase in the interest of scientists in ASNs (Fig. 1). The appearance of documents on the issues under study since 2005 is quite logical, since the concept of "Web 2.0" to denote services (platforms, projects) filling with information materials that users of these networks are engaged in was introduced by Tim O'Reilly (American publisher of the O'Reilly publishing house) ... He introduced it officially with an article titled "What Is Web 2.0" in 2005. (O'Reilly 2005).

Funding of the ASN researches

ASNs researches were funded by 581 organizations. It is important to take into account that 834 records about publications (68.6% of 1216) do not contain data on funding organizations. It follows from that only about 30% of the researches have been completed with the help of grant financial support. The most frequently mentioned funding organizations are shown in the table 9.

In the row of funding organizations are: National Natural Science Foundation of China; European Commission (Belgium - Luxembourg) (14 publications); National Council for Scientific and Technological Development (Brazil) (12 publications); Coordination Agency for the Improvement of Personnel in Higher Education CAPES (Brazil) (11 publications); Foundations for Basic Research for Central Universities (China) (10 publications); National Science Foundation (USA) (10 publications) (Table 2).

Table 2 Funding Organizations for the ASN Researches

Funding organizations	Country	Number of publications were the organization is mentioned
National Natural Science Foundation of China (NSFC)	China	53
European Commission (EC)	European Union	14
National Council for scientific and technological development CNPQ	Brazil	12
Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior CAPES	Brazil	11
Fundamental Research Funds for the Central Universities	China	10
National Science Foundation (NSF)	USA	10

The source structure of the document array on scientific social networks

The documents of the array on the ASN were published in more than 600 editions, which indicates the scattering of information. The most productive journals are Scientometrics (68 entries), Data in brief (54 entries), Journal of the association for information science and technology (27 entries), Journal of informetrics, and Lecture notes in computer science "(25 entries each)," Proceedings of the International conference on scientometrics and informetrics "(22 entries) (Table 3).

The journals, in which papers on ASNs are published, have been assigned 171 categories according to the WoS thematic classifier. The most significant categories, in which the percentage of the total number of records in the sample exceeds 10%, are: *Informatics and librarianship* (350 documents - 28.8%), *Informatics and information systems* (196 documents - 16.1%), *Interdisciplinary research in the field of computer technology* (158 documents - 12.9%) (Table 4).

Table 3 The sources of the ASNs publication

Journal	Publications
Scientometrics	72
Data in brief	58
Journal of the association for information science and technology	27
Journal of informetrics	25
Profesional de la informacion	16
Online information review	16
Journal of ethnopharmacology	13
Plos one	12
Learned publishing	10
Aslib Journal of Information Management	9

Table 4 WoS categories assigned to ASNs publications

Web of Science categories	Publications
Information science library science	350
Computer science information systems	196
Computer science interdisciplinary applications	158
Computer science theory methods	100
Multidisciplinary sciences	84
Engineering electrical electronic	70
Computer science artificial intelligence	62
Education educational research	55
Pharmacology pharmacy	39
Computer science software engineering	38
Management	28
Social sciences interdisciplinary	28
Communication	27
Surgery	24
Chemistry medicinal	20

Scientific meetings

Less than a fourth (24%) of the ASNs publications are presented in the proceedings of 222 conferences. The main of ones are:

- «14th International society of scientometrics and informetrics conference ISSI» (8 documents);

- «21st International conference on science and technology indicators STI peripheries frontiers and beyond» (8 documents);

- «15th International conference of the international society for scientometrics and informetrics ISSI» and «17th International conference of the international society for scientometrics and informetrics ISSI» (7 documents);

- «IEEE ACM International conference on advances in social networks analysis and mining ASONAM» and «Internoise ASME 2012 Noise control and acoustics division conference» (5 documents).

Countries and organizations leading in ASNs research, structure of collaboration of organizations

Scientific social networks are researched in 105 countries, with the largest amount of research being conducted in the USA (17.5%), China (11.6%), Great Britain (10.9%), Spain (8.6%), Germany (6, 3%), Canada (5.7%), India (5%) (Table 5).

ASNs publications are affiliated with more than 1482 organizations. The main institutions deal with the issues are: University of Wolverhampton (UK) (44 documents), Leiden University (Netherlands) (20 documents), University of Manchester (UK) (18 documents), University of Pittsburgh (USA) (16 documents), University of Wuhan (China) (15 entries), Max Planck Society for Scientific Research (Institute for Solid State Research) (Germany) (13 documents), University of Granada (Spain) (13 documents), University of British Columbia (Canada) (12 entries), Malay University (Malaysia) (11 records), as well as the Russian Academy of Sciences (Russia), South China Pedagogical University (China) and the University of Southampton (UK) - 10 publications per organisation (Table 6).

Table 5 Countries conducting researches on ASNs

Country	Publications	Country	Publications
USA	213	Iran	35
peoples R China	141	Pakistan	29
United Kingdom	133	Poland	28
Spain	105	France	27
Germany	77	South Africa	27
Canada	70	Austria	24
India	62	Finland	22
Italy	60	Malaysia	22
Netherlands	54	Switzerland	21
Australia	48	South Korea	18
Brazil	46	Belgium	17
Russia	45	Saudi Arabia	16

Table 6 Leading scientific institutions by the number of publications on ASNs

Organizations	Country	Publications
University of Wolverhampton	UK	44
Leiden university	Netherlands	20
Manchester university	UK	18
University of Pittsburgh	USA	16
Wuhan university	China	15
Max Planck Society (Division Science & Innovation Studies)	Germany	13
Max Planck Institution of Solid State Research	Germany	13
University of Granada	Spain	13
University of British Columbia	Canada	12
University of Malaya	Malaysia	11
Russian Academy of Science	Russia	10
South China normal university	China	10
University of Southampton	UK	10

Leading Authors in Academic Social Networks Research

In the resulting sample of publications, 2238 authors were identified who study ASNs. The largest number of publications belongs to such researchers as: Thelwall M. (44), Bornmann L. (16), Haunschild R. (13), Costas R., Tang Y. (11), Kousha K. (10) (Table 7).

Table 7 Leading authors by the number of publications on scientific social networks

Authors	Organizations	Publications
Thelwall, Mike	University of Wolverhampton, Wolverhampton, United Kingdom	44
Bornmann, Lutz	Administrative Headquarters of the Max Planck Society, Munich, Germany;	16
Haunschild, Robin	Max Planck Institute for Solid State Research, Stuttgart, Germany	13
Costas, Rodrigo	Leiden University, Leiden, Netherlands	11
Tang, Yong	South China Normal University, Guangzhou, China	11
Kousha, Kayvan	University of Wolverhampton, Wolverhampton, United Kingdom	10
Abramov, Valery M.	Russian State Hydrometeorological University, Saint Petersburg, Russia	9
Ortega, Jose-Luis	Consejo Superior de Investigaciones Cientificas (CSIC)	9
Zahedi, Zohreh	Leiden University, Leiden, Netherlands	9
De Roure, David	University of Oxford, Oxford, United Kingdom; University of Southampton, Southampton, United Kingdom	8
Haustein, Stefanie	Université du Québec à Montréal, Montreal, Canada; University of Ottawa, Ottawa, Canada	8
Goble, Carole Anne	University of Manchester, Manchester, United Kingdom	7
Gogoberidze, George G.	Russian State Hydrometeorological University, Saint Petersburg, Russia	7
He, Daqing	University of Pittsburgh, Pittsburgh, PA,USA	7
Herman, Eti	University of Haifa, Haifa, Israel	7
Nicholas, David	Tomsk State University, Tomsk, Russia; CIBER Res Ltd, Berks, United Kingdom	7
Shiri R	Finnish Institute of Occupational Health, Finland	7

Most frequently cited publications on the topic of "academic social networks"

The ten most frequently cited articles (Table 8) on the ASN were published from 2009 to 2015. in such publications as "Nucleic acids research", "Scientometrics", "Proceedings of the national academy of sciences of the United States of America", "Journal of Informetrics", "Journal of the association for

information science and technology". On average, such articles are cited 11 to 38 times per year. The total number of citations varies from 105 to 305.

The total number of citations of publications in the collection in July 2020 is 5813, the average number of citations of the document is 6.8, and the Hirsch index is 35.

Among the most frequently cited publications is the work of Wolstencroft K. et al. 2013 (Wolstencroft et al. 2013) performed at the School of Computer Science, University of Manchester. The article by Wolstencroft K. et al., 2013 is devoted to the Taverna platform, which hosts tools for processing biological research data. This article appeared as part of the scientific social media workflow due to the fact that the repository for the working materials of these studies is the NCC myExperiment. A frequently cited article by Goble C.A. is dedicated to the same network. et al. (Goble et al. 2010).

Noteworthy is the fact that out of dozens of highly cited publications, six are devoted to academic reputation on-line and altmetrics. (Bornmann 2014; Haustein et al. 2014; Li et al. 2012; Mohammadi and Thelwall 2014; Thelwall and Kousha 2015; Zahedi et al. 2014) (Table 8, highlighted in blue). Altmetrics are new methods of scientometrics that evaluate the results of research activities not based on the number of citations of publications in scientific journals (academic weight, scholarly impact - highlighted in blue in Table 8), but by their presence, mention and use on the Internet and traditional media (social weight, social impact - highlighted in blue in Table 8). In the ASN, such altmetrics are actively included. In a scientist's profile, his activity on alternative metrics can be assessed at ResearchGate, Mendeley. In articles (Li X., Thelwall M., Giustini D., 2012) (Li et al. 2012) and (Thelwall M., Kousha K., 2015) (Thelwall and Kousha 2015), the possibilities of social networks for assessing academic influence (scholarly impact measurement) are analyzed.

Two articles from the list of actively cited (Thelwall and Kousha, 2014; 2015) are devoted to scientific social networks ResearchGate and Academia.edu, respectively (Thelwall and Kousha 2014, 2015), and the article by Mohammadi E, Thelwall M., 2014 discusses the peculiarities of the altmetric "Mendeley readership" for the social sciences and humanities, in ASN Mendeley, respectively.

Among the most frequently cited articles is the article by Ahmed A, Xing EP, 2009 (Ahmed and Xing 2009), which develops a machine learning method for modeling the behavior of dynamic networks of various nature (gene networks, the network of interaction of US Senators). An academic social network is considered as one of the networks. Semantic transformations of concepts (authors' keywords) of scientific articles are modeled.

Thus, the top 10 highly cited articles indicate that scientific social networks are of interest to the scientific community as tools for assessing academic activity on the Internet, as objects for analyzing their structure, as repositories for placing scientific data, as objects for developing algorithms for analyzing scientific social networks. (computer modeling of processes, including).

Table 8 Top 10 Most Cited Web of Science Publications on Social Scientific Networks

Article	Year of publication	Number of citations
Wolstencroft K, Haines R, Fellows D, Williams A, Withers D, Owen S, Soiland-Reyes S, Dunlop I, Nenadic A, Fisher P, Bhagat J, Belhajjame K, Bacall F, Hardisty A, Nieva de la Hidalga A, Balcazar Vargas MP, Sufi S, Goble C (2013) The Taverna workflow suite: designing and executing workflows of Web Services on the desktop, web or in the cloud. Nucleic Acids Research 41:W557–W561 . doi: 10.1093/nar/gkt328 (Wolstencroft et al. 2013)	2013	305
Zahedi Z, Costas R, Wouters P (2014) How well developed are altmetrics? A cross-disciplinary analysis of the presence of 'alternative metrics' in scientific publications. Scientometrics 101:1491–1513 . doi: 10.1007/s11192-014-1264-0 (Zahedi et al. 2014)	2014	165
Bornmann L (2014) Do altmetrics point to the broader impact of research? An overview of benefits and disadvantages of altmetrics. Journal of Informetrics 8:895–903 . doi: 10.1016/j.joi.2014.09.005 (Bornmann 2014)	2014	149
Li X, Thelwall M, Giustini D (2012) Validating online reference managers for scholarly impact measurement. Scientometrics 91:461–471 . doi: 10.1007/s11192-011-0580-x (Li et al. 2012)	2012	146
Goble CA, Bhagat J, Aleksejevs S, Cruickshank D, Michaelides D, Newman D, Borkum M, Bechhofer S, Roos M, Li P, De Roure D (2010) myExperiment: a repository and social network for the sharing of bioinformatics workflows. Nucleic Acids Research 38:W677–W682 . doi: 10.1093/nar/gkq429 (Goble et al. 2010)	2010	135
Ahmed A, Xing EP (2009) Recovering time-varying networks of dependencies in social and biological studies. Proceedings of the National Academy of Sciences 106:11878–11883 . doi: 10.1073/pnas.0901910106 (Ahmed and Xing 2009)	2009	135
Haustein S, Peters I, Bar-Ilan J, Priem J, Shema H, Terliesner J (2014) Coverage and adoption of altmetrics sources in the bibliometric community. Scientometrics 101:1145–1163 . doi: 10.1007/s11192-013-1221-3 (Haustein et al. 2014)	2014	124
Mohammadi E, Thelwall M (2014) Mendeley readership altmetrics for the social sciences and humanities: Research evaluation and knowledge flows. Journal of the Association for Information Science and Technology 65:1627–1638 . doi: 10.1002/asi.23071 (Mohammadi and Thelwall 2014)	2014	121
Thelwall M, Kousha K (2015) ResearchGate: Disseminating, communicating, and measuring Scholarship? Journal of the Association for Information Science and Technology 66:876–889 . doi: 10.1002/asi.23236 (Thelwall and Kousha 2015)	2015	116
Thelwall M, Kousha K (2014) Academia.edu: Social network or Academic Network? Journal of the Association for Information Science and Technology 65:721–731 . doi: 10.1002/asi.23038 (Thelwall and Kousha 2014)	2014	105

Thematic focus of research on academic social networks

In total, the studies in which the ASNs are featured are classified in 118 thematic areas. The most quantitatively filled directions are reflected in Table 9.

Table 9 Distribution of publications on ASN according WoS Subject Areas

Research Areas	Publications
Computer Science	411
Information Science Library Science	350
Engineering	105
Science Technology Other Topics	88
Education Educational Research	63
Pharmacology Pharmacy	42
Business Economics	35
Social Sciences Other Topics	32
Communication	27
Surgery	24
Neurosciences Neurology	23
General internal medicine	22
Chemistry	19
Public environmental Occupational health	19
Plant sciences	18
Psychology	18
Telecommunications	18
Dentistry oral surgery medicine	17
Integrative complementary medicine	17
Physics	16

Scientific social networks have been investigated in the following main thematic areas: informatics - 411 documents (33.8%), informatics and librarianship - 350 documents (28.8%), mechanical engineering and technology - 105 documents (8.6%), science and technology - 88 documents (7.2%), education - 63 documents (5.2%). The presence in the sample of articles related to thematic sections of the medical direction is due to the fact that social scientific networks (ResearchGate, Mendeley) are used by physicians and biologists to select literature for a review, systematic review, meta-analysis (Agrawal et al. 2020; Bajwa et al. 2017; Simmons et al. 2020; Weldegebreal and Worku 2019). The analyzed array of 1216 documents includes about 140 publications containing terms (review and “systematic literature search” or “systematic review*” or meta-analysis) in the title, abstract or indexed terms, referred to the areas of Pharmacology Pharmacy Public, Surgery, Neurosciences Neurology, General internal medicine, Environmental Occupational Health, Medicine General Internal, Clinical Neurology, Dentistry Oral Surgery Medicine, etc., in the overwhelming majority of cases, medical, research areas.

Mapping the ASNs document array based on the document co-citation analysis

The document co-citation network (Fig. 3) in CiteSpace is characterized by the number of nodes and links of citation. Each node in the document co-citation network is a separate reference in the ASN document array in WoS. 662 nodes were identified, networked by 2943 co-citation links. The color of the link is determined by the year the document was first co-cited. The size of a node is determined by the number of co-citations of a given document. Table 10 presents the first 11 most frequently cited articles. In Figure 2, they are indicated by the name of the first author and the year of publication of the first 11 (out of 666) documents with high co-citation values (Table 11).

Table 10 References ranked by the number of citations in the ASN document co-citation network (highlighted in Fig. 3)

Reference co-citation	Year of publication	Reference	Article title	Cluster
106	2013	(Thelwall et al. 2013)	Do altmetrics work? Twitter and ten other social web services	2
91	2012	(Li et al. 2012)	Validating online reference managers for scholarly impact measurement	2
88	2014	(Van Noorden 2014)	Online collaboration: scientists and the social network	1
74	2015	(Costas et al. 2015)	Do “altmetrics” correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective	0
73	2015	(Thelwall and Kousha 2015)	ResearchGate: disseminating, communicating, and measuring scholarship?	1
72	2014	(Thelwall and Kousha 2014)	Academia.edu: social network or academic network?	1
71	2014	(Mohammadi and Thelwall 2014)	Mendeley readership altmetrics for the social sciences and humanities: research evaluation and knowledge flows	0
71	2014	(Zahedi et al. 2014)	How well developed are altmetrics? A cross-disciplinary analysis of the presence of ‘alternative metrics’ in scientific publications	0
64	2014	(Haustein et al. 2014)	Coverage and adoption of altmetrics sources in the bibliometric community	0
63	2010	(J. Priem et al. 2010)	Altmetrics: A manifesto	2
58	2011	(Eysenbach 2011)	Can tweets predict citations? Metrics of social impact based on Twitter and correlation with traditional metrics of scientific impact.	2

Table 11 Clusters of the document co-citation network for the document array on ASN

Cluster ID	Cluster size	Cluster silhouette	Mean year of publication	LLR (*log-likelihood ratio* tests)	Cluster issue interpretation; references to citing articles, from the titles, abstracts, keywords of which labels for clusters are selected
5	25	0.972	2005	***Professional indexing*** (15.67, 1.0E-4); tagging practice (15.67, 1.0E-4); academic social network (0.1, 1.0);	There are significant differences in indexing (bookmarking in CiteULike) by article authors, social network users who bookmark pages with the article, and professional indexing by information workers (librarians-organizers) (Kipp 2011);
3	43	0.977	2007	***Community recommendation*** (51.49, 1.0E-4); exploring social tagging (51.49, 1.0E-4); social tag (42.81, 1.0E-4);	Exploring social tagging for personalized community recommendations (Ke and Chen 2012; Kim and El Saddik 2013)
28	3	1	2007	***Full-text article*** (13.94, 0.001); different subject field (13.94, 0.001); Google Scholar (6.04, 0.05);	ResearchGate was the top single website providing full-text files (10.5 % of full-text articles) for Google Scholar (Jamali and Nabavi 2015)
14	7	0.989	2010	***Cold-start problem*** (14.62, 0.001); effective recommender algorithm (14.62, 0.001); academic social network (3.69, 0.1);	An Effective Recommender Algorithm for Cold-Start Problem in Academic Social Networks (Rohani et al. 2014)
2	85	0.88	2011	***Social science*** (91.39, 1.0E-4); altmetrics source (68.44, 1.0E-4); bibliometric community (68.44, 1.0E-4); humanities research (64.45, 1.0E-4);	Mendeley reader data could be a useful supplementary measure to remedy some limitations of citation analysis across the social sciences and humanities (Mohammadi and Thelwall 2014).
0	102	0.813	2014	***Case study*** (83.95, 1.0E-4); **altmetrics** data provider (80.86, 1.0E-4); meta-	Case studies and meta-analysis reviews of altmetrics data providers (particularly Mendeley, CiteULike and others) .(Bornmann 2015; J.-L. Ortega 2020)

				analysis review (80.86, 1.0E-4);	
4	41	0.915	2014	***Mendeley reader*** (178.49, 1.0E-4); early citation (85.72, 1.0E-4); citation count (68.31, 1.0E-4); multidisciplinary comparison (68.31, 1.0E-4);	Series of studies of ASN/bibliographic manager Mendeley (metrics "Mendeley reader", structures of the scientific community Mendeley, etc.) and some other ASN (ResearchGate) (Thelwall 2017; Thelwall and Kousha 2017).
1	100	0.934	2015	***Academic social network*** (126.49, 1.0E-4); research universities (101.34, 1.0E-4); academic social networking site (96.81, 1.0E-4);	User, disciplinary structure of ASN, other aspects of functioning, comparative analysis of ASNs (Bhardwaj 2017)

DCA revealed 112 clusters 8 of which are visually presented on the Fig. 4, 5. For automatic marking of clusters (Figs. 3 and 4), terms from the titles of citing documents (citers) were selected by the CiteSpace program and ranked on the bases of the algorithm of the algorithm using LLR (log-likelihood ratio test) (Chen et al. 2010). In Fig. 4, 5 clusters are labeled with the same term, in tab. 12 - three or four (CiteSpace identifies 100 terms, ranked in descending order of value of the applied algorithm (LLR)).

Table 12 Articles in the document co-citation network with betweenness centrality value exceeding 0.1.

Co-citation	Betweenness centrality	Publication year	Article
4	0.19	2005	Hammond T, 2005 (Hammond et al. 2005)
27	0.16	2010	Priem J, 2010 (Jason Priem and Hemminger 2010)
2	0.15	2005	Lund B, 2005 (Lund et al. 2005)
19	0.10	2006	Golder SA, 2006. (Golder and Huberman 2006)

The oldest are clusters 5, 3 and 28. The average year of publication of the cited document in them is 2005 and 2007. The documents (links) of these clusters 5 and 3 are the intellectual basis of the research directions "professional indexing" and "social tagging", "Community recommendation".

At the initial stages of the formation of scientific social networks, the problem of content systematization was solved (cluster 5). Social network developers have followed a path that has already been tested in the creation of document repositories and digital libraries: labeling content with descriptors (descriptive terms), also called keywords or tags. You can navigate, filter or search by tags. In the case of a repository and a digital library, tagging was carried out by the creators of the resource (repository, digital library) using the data provided by the author of the document, and in the case of social networks, the content indexing function was provided to users and took the form of social tagging (collaborative tagging), which is also called Volksonomy (folksonomy = folk taxonomy) (Hotho et al. 2006; Rawashdeh et al. 2013). In the article, which is the main citer of the cluser (citing 10 out of 25 publications of the cluster), scientists perform a comparative analysis of thematic indexing of scientific articles using the social tagging method (CiteULike) and the professional indexing method (PubMed).

In article (Kipp 2011) , which is the main citer of the cluser (citing 10 out of 25 publications of the cluster), scientists perform a comparative analysis of thematic indexing of scientific articles by the social tagging method (CiteULike) and the professional indexing method (PubMed).

Later (cluster 3, 2007) the problem of organizing services by recommending content to users based on social tags, collaborative tagging *(Community recommendation**s***), appears.

Cluster article Golder S.A., Huberman B.A. (2006) (Golder and Huberman 2006), which is highlighted in the network as the key one (BC = 0.10) (Table 13) (Table 13), as an example are given the ASN / bibliography management systems (bibliographic managers) CiteULike[2] and Connotea[3], in which social tagging of links to scientific publications was applied.

The next in chronological order is cluster 28, which highlights the analysis of full text sources in the Google Scholar search engine as a separate topic. Of the individual sites, ASN ResearchGate is the most productive source of full text in this system (Rohani et al. 2014).

Cluster 14 (average year of publication of cluster documents - 2010) denotes research on the problem of developing recommendation systems for ASNs. Recommender systems are programs that are designed to predict which objects (movies, music, books, news, websites) will be of interest to the user, given certain information about his profile. When creating recommendation systems, the “cold-start problem” comes first. The "cold start problem" is a problem solved in the development of recommender systems in social networks. The problem is what the ASN should offer to a new user of the network and to whom to offer new content (Rohani et al. 2014).

Further, in terms of chronology and localization in the network, there are clusters (2, 0 and 4) with various aspects of studying the altmetrics “Social science”, “Case study”, “Mendeley reader” (Table 11). It is no coincidence that among the cited articles on the "path to these clusters" is the publication "Manifaesta Altmetria". In 2010, a group of four experts (Jason Priem (University of North Carolina-Chapel Hill), Dario Taraborelli (Wikimedia Foundation), Paul Groth (University of Amsterdam), Cameron Neylon (Science and

Technology Facilities Council)) made a proposal using alternative metrics (alt-metrics, altmetrics) [4]. The essence of their proposals is expressed in the Altmetry Manifesto (J. Priem et al. 2010).

Almost the most numerous cluster 1 symbolizes the research front that studies various aspects of ASN: user composition, disciplinary structure of networks, comparative ASN research (Table 11).

The fact that alternative metrics of the ASN and the assessment of scientific impact on their basis are actively studied in the scientific literature is confirmed by our research using the CiteSpace program for the co-occurrence of keywords in titles, abstracts, indexed terms of articles from the array of documents on the ASN. The terms most frequently encountered in this array are "altmetrics", "impact", "citation" (Table 13).

Table 13 CiteSpace keywords co-occurrence analysis in the document array on ASNs

Co-occurrence frequency	Year of publication of the article with the first mention of the term	Keyword
151	2013	altmetrics
124	2012	impact
96	2008	citation
93	2012	social media
87	2013	Mendeley
76	2014	ResearchGate
59	2012	science
56	2010	academic social network
54	2011	bibliometrics
49	2014	metrics
45	2009	social network
43	2012	web
42	2015	indicator
40	2012	journal
38	2014	Twitter
38	2014	Google Scholar
37	2008	citation analysis
36	2008	information
31	2008	open access
30	2016	media
28	2016	article
25	2015	Scopus
25	2010	network
23	2007	CiteUlike
21	2013	academiaedu
21	2015	publication
21	2015	model

Примечание: Приведено 27 из 484 ключевых слов, порог включения в табл. – встречаемость не менее 20.

Table 14 Keywords co-occurrence network clusters

Cluster ID	Cluster size	Cluster silhouette	Mean year of publication	LLR (*log-likelihood ratio* tests)
4	42	0.841	2011	scientific workflow (16.18, 1.0E-4); bioinformatics (10.75, 0.005); semantic web (7.07, 0.01); training planning (5.49, 0.05);
3	45	0.884	2011	descriptor (11.93, 0.001); title keyword (11.93, 0.001); tagging (11.93, 0.001); CiteULike (11.43, 0.001);
1	86	0.77	2014	altmetrics (13.64, 0.001); citation analysis (12.43, 0.001); webometrics (10.14, 0.005); citation counts (7.6, 0.01);
0	89	0.69	2014	ResearchGate (15.86, 1.0E-4); academic social network (11.12, 0.001); social media (9.72, 0.005); social networking sites (6.68, 0.01); f1000 (5.54, 0.05);
11	4	0.976	2015	back (10.53, 0.005); physical fitness (10.53, 0.005); pelvis (10.53, 0.005); hamstring stretching (10.53, 0.005);
5	32	0.809	2016	Zotero (20.02, 1.0E-4); innovation (14.97, 0.001); author-based metrics (9.96, 0.005); feminist research (9.96, 0.005);
6	29	0.928	2017	anticancer (16.83, 1.0E-4); anti-inflammatory (16.83, 1.0E-4); antioxidant (11.18, 0.001); phytochemistry (7.49, 0.01);
2	68	0.817	2017	systematic review (10.05, 0.005); obesity (10.05, 0.005); meta-analysis (6.69, 0.01); prevalence (6.69, 0.01);
29	2	0.994	2018	clinical decision support system (?, 1.0); usage statistics (?, 1.0); academic librarians (?, 1.0); accuracy (?, 1.0);
13	3	0.997	2019	intraocular pressure (11.03, 0.001); physical activity (11.03, 0.001); glaucoma (11.03, 0.001); exercise (8.27, 0.005);

The results of cluster analysis of the network of co-occurrence of keywords were interesting (Fig. 5). In this case, thematic areas were revealed that were not found in DCA. These directions are not connected with the direct study of the ASNs, but with their use as a source of bibliography for performing a review, systematic review or meta-analysis (KWco-occurrence, clusters 11, 2, 29, 13). All of them are related to the analysis of medical literature. Cluster 4, which identifies the Scientific workflows + Bioinformatics topic, should be referred to the same series. Taverna Workflow Management System (http://www.taverna.org.uk) is a bioinformatics tool for managing workflows and experiments. Two articles on this platform are among the frequently cited articles (Wolstencroft et al. 2013). This tool came into our field of vision for the reason that it is compatible with the repository of workflows (workflows repositories) myExperiments, which positions itself as a scientific social network social network.

All these clusters, reviled using co-word analysis, are not identified using document citation analysis, since they are not united by a common research problem and, therefore, a common intellectual base in the form of a set of cited publications, but the use of social networks as a source of literature or a repository of workflows (workflows).

It should be noted that the research topics of such authors as Abramov, Valery M. and Gogoberidze, George G. (Russian State Hydrometeorological University, Saint Petersburg, Russia) are not explicitly reflected in the research fronts identified by CiteSpace. Moreover, both authors are included in the list of authors with a large number of publications in the studied array of documents (Table 7). The studies of these scientists are classified in WoS as Geosciences Multidisciplinary; Water Resources; Computer Science Interdisciplinary Applications, etc. The works of these scientists were included in our array for the reason that abstracts of all publications of these authors contain a link (https://www.researchgate.net/profile/Valery_Abramov2/) to V. Abramov's profile in Researchgate. “The platform gave excellent opportunities to preliminary discussion and data exchange in the frame of these researches”, writes V. Abramov. Thus, in this study, these works form the research front of cluster 0 (Table 14).

[2] In February 2019, CiteULike announced that it would be ceasing operations as of March 30, 2019).

[3] Connotea discontinued service on March 12, 2013)

[4] Altmetrics is a discipline whose subject is the creation and research of new metrics (alternative metrics) for evaluating a scientific product (articles, books, presentations, statements and discussions on the topic of scientific research, computer programs, etc.) within the virtual space (the number discussions on social networks, downloads and views in scientific repositories and bibliographic managers, etc.).

Conclusions

Academic social networks are a new type of scientific communication that is implemented in the electronic environment. Following the formation of global social networks based on Web 2.0 technologies, specialized academic social networks were developed to meet the needs of scientists. As a

phenomenon of social communication, global social and scientific social networks are the object of study of scientists. A large number of scientific works are devoted to the study of global social networks. For example, in Web of Science, only in response to the query TS = (Twitter OR Facebook), we found 34,150 documents (as of January 21, 2020). The scientific document array for the ASNs topic is more modest in size. In this work, a multidimensional scientometric study of the document array presented in the WoS is carried out. Countries, organizations, scientists which are investigating or using the modern form of communication between scientists - academic social networks, are identified. It is shown that research on ASNs began to be conducted in 2005. Leaders in research on ASNs are scientists from Great Britain, Germany, USA, Spain. At present, the main issues discussed in connection with the ASNs are alternative metrics designed to reflect the activity of scientists on-line, developed for a number of networks. This is evidenced by the fact that among the most frequently cited documents according to the WoS database, there are many articles devoted to this topic. Using the program for visualizing patterns and trends in scientific literature CiteSpace, a network of citation of documents for an array according to the ASNs was built, the clustering of which made it possible to identify the main areas of research from 2005 to 2019. social tagging and professional indexing, the problem of "cold access" was solved. Subsequently, in some ASNs (Mendeley) systems for assessing scientific activity in the web environment (altmetrics) were developed. In addition, the organization of various ASNs, the behavior of their members, etc. are studied. However, altmetrics in ASNs are the main research trend. In addition, in this study, the CiteSpace program was used to identify the nature of collaboration between organizations in the study of ASNs.

It should be noted that, in our sample from WoS, along with articles that directly analyze ASNs, there are articles in which ASNs are referred to as scientific data repositories (Mendeley, myExperiment). Among them, there are articles with high citation rates (Goble et al. 2010; Wolstencroft et al. 2013). All this indicates that the document flow we are analyzing reflects not only the fact that ASNs are the object of scientific research, but also the fact that ASNs have entered directly into the life of scientists.

Academic social networks continue to evolve. For example, there are messages about the termination of activities of some of them (CiteULike, Connotea). Time will show what the further ways of transforming scientific social networks will be. As well as the developing phenomenon of scientific communication, ASNs require further research.

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Declarations

Declaration of Competing Interest

The authors have no conflicts to disclose.

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Figures

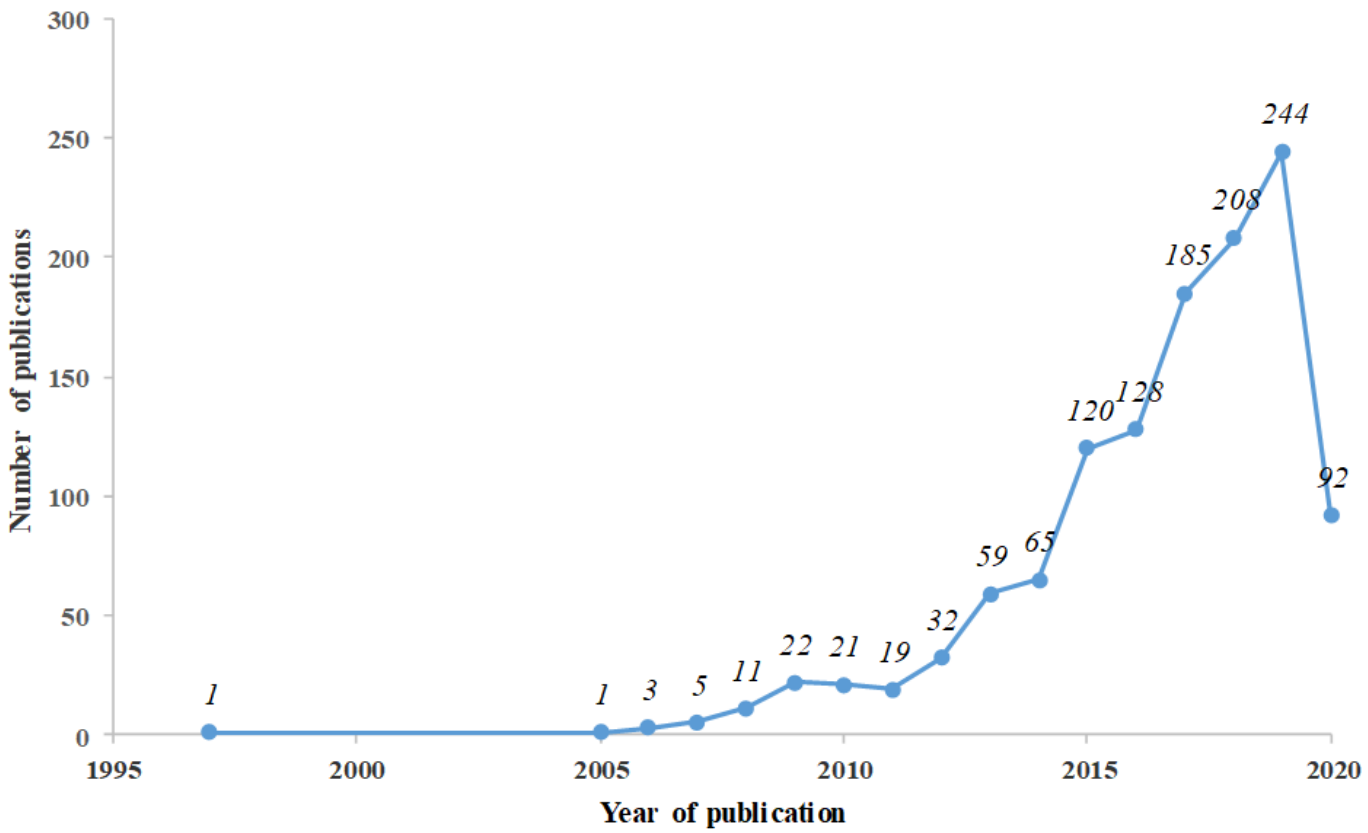

Figure 1

The dynamics of publications of the information array on the ASN in the WoS database. The year 2020 is not indicative, as the ASNs document array for this year was not full because the last downloading of information about one took place in May 2020.

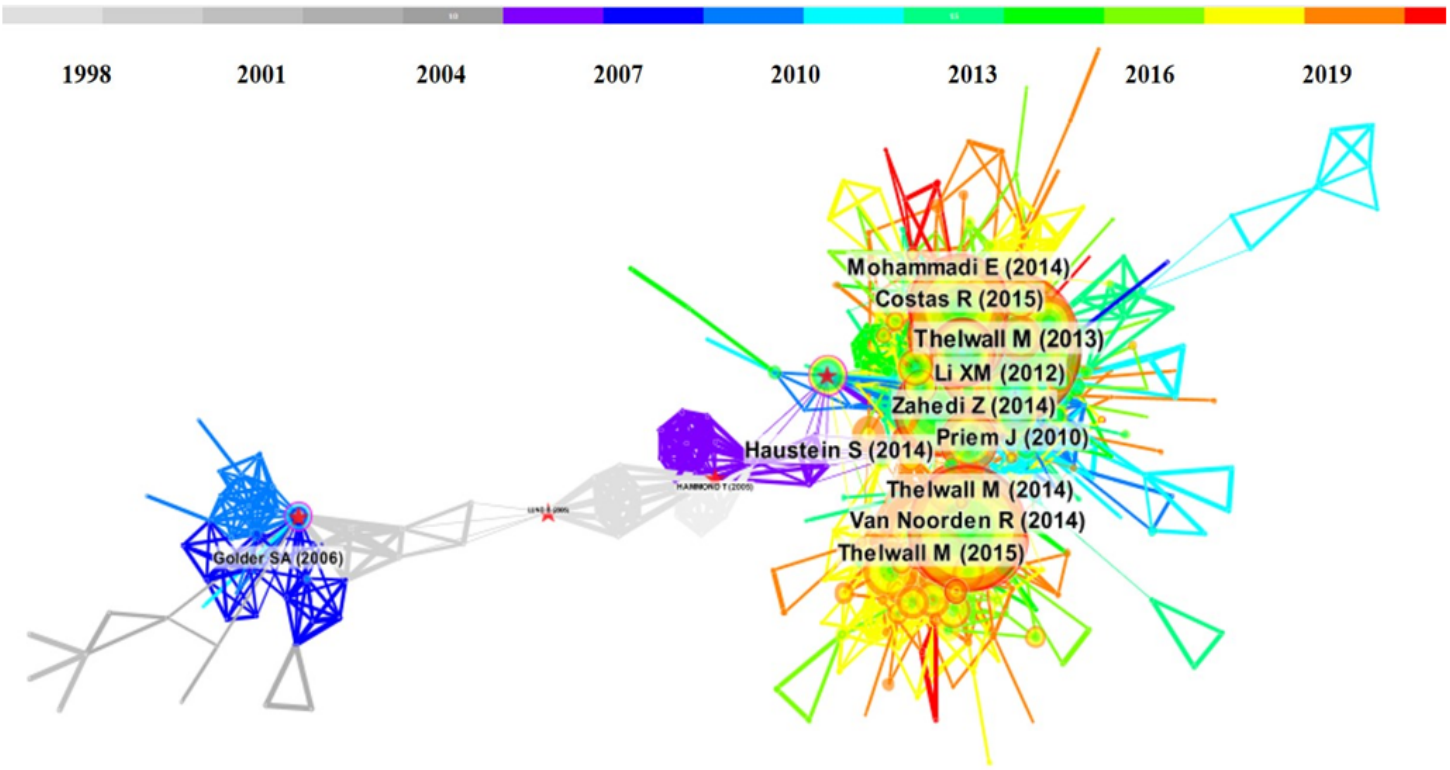

Figure 2

Documents co-citation network for the ASN documents array. Built on the basis of 36626 valid references of 1216 publications. Retrospective from 2005 to 2020. The 666 nodes were identified, linked by 2870 co-citations. When building networks in CiteSpace, a different color palette can be selected to represent the citation year. We have chosen a palette starting with a shade of gray (2005), turning into a rainbow spectrum (until 2020).

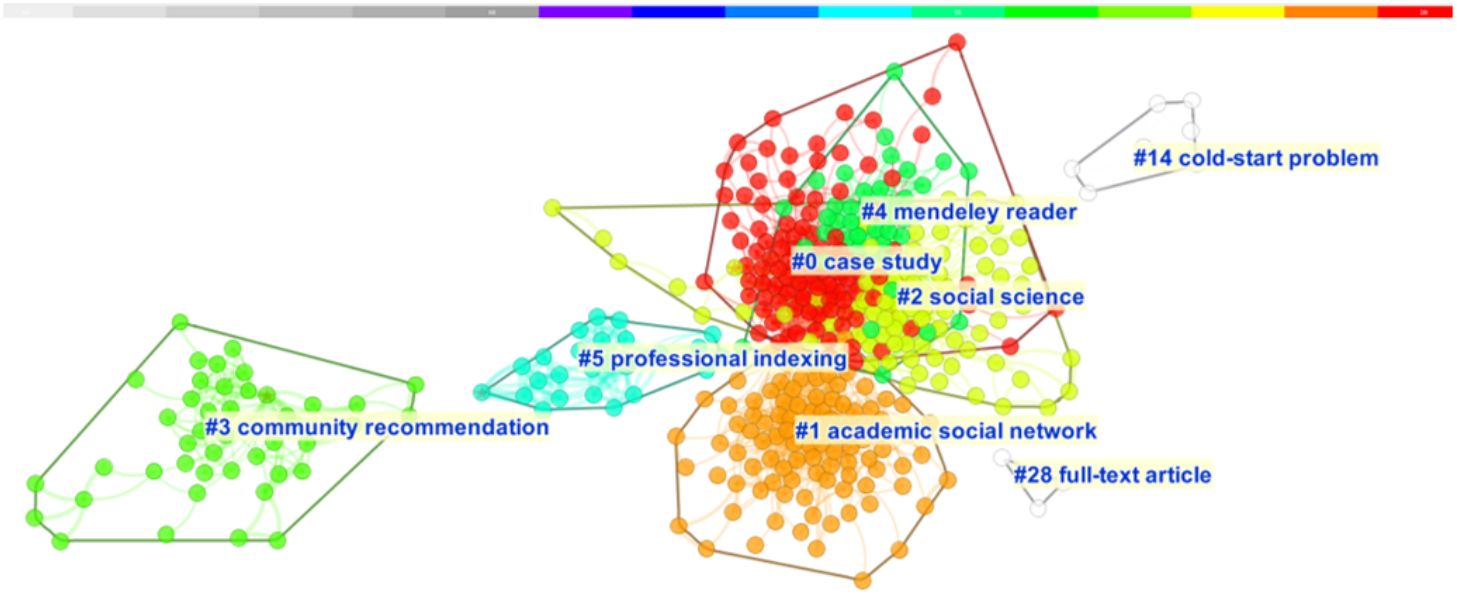

Figure 3

Clusters document co-citation network for the document array on ASNs.

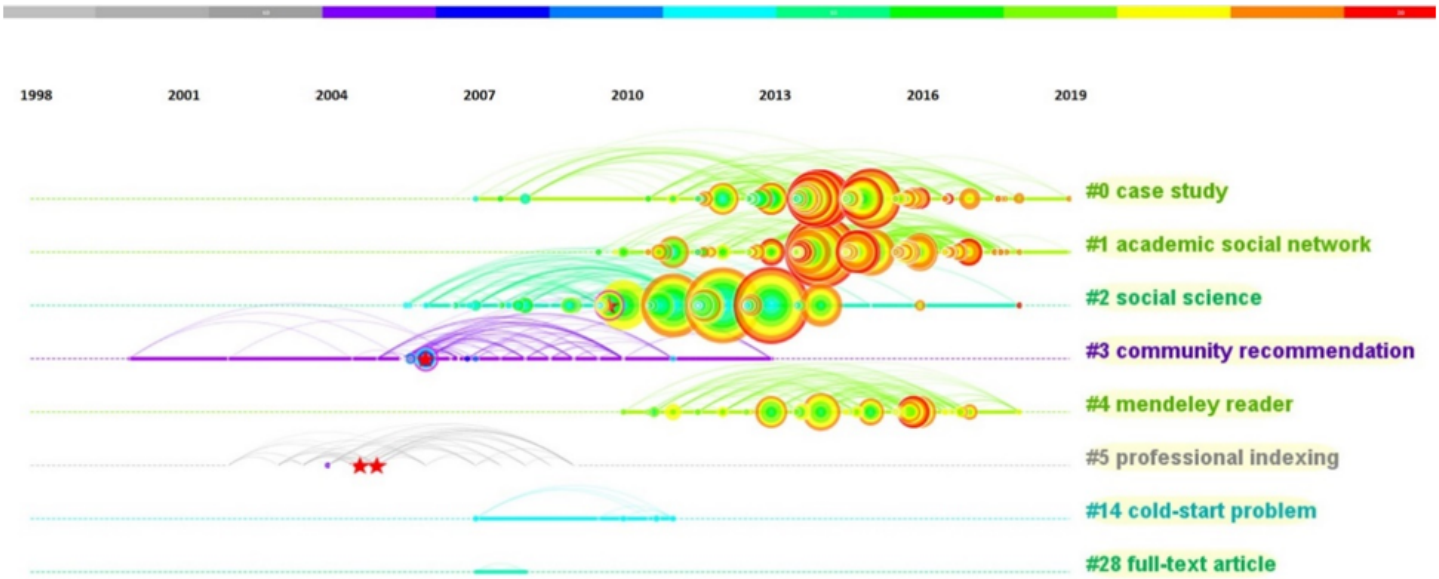

Figure 4

Timeline view of clusters of documents co-citation network for the document array on ASNs

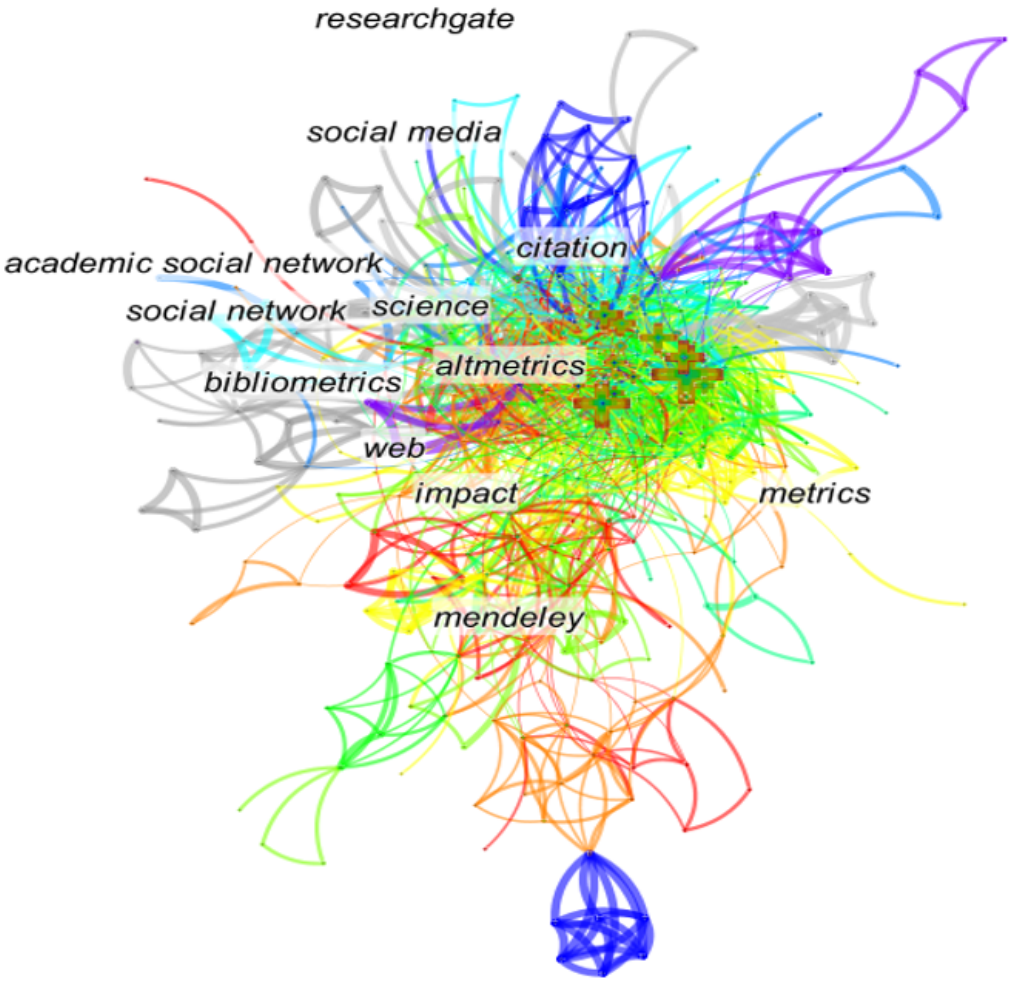

Figure 5

CiteSpace keywords co-occurrence analysis in the document array on ASNs

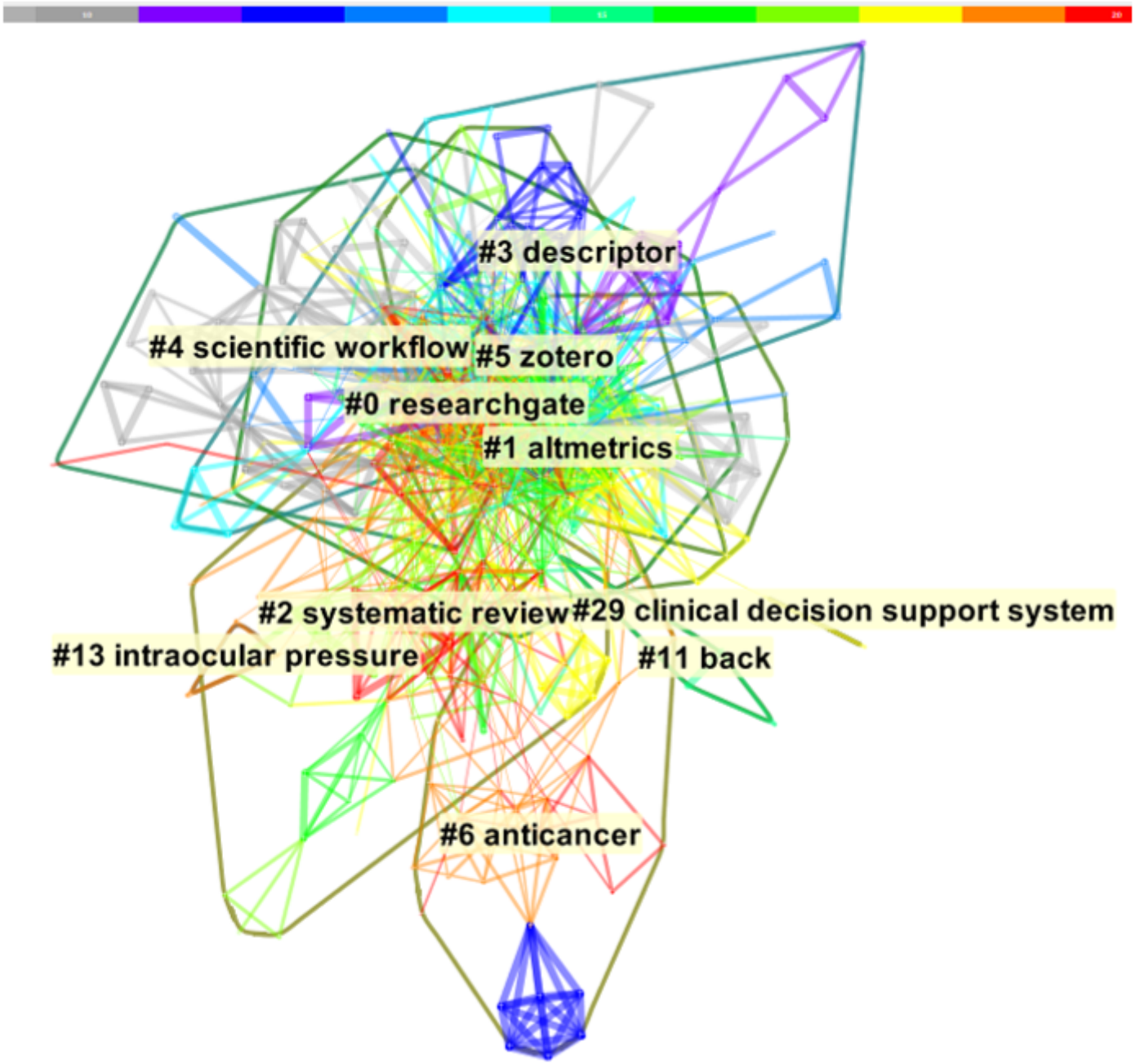

Figure 6

Keywords co-occurrence network clusters. Plotted in CiteSpace.