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Visualizing the Intellectual Structure of Iranian Physicists in Scisearch during 1990-2009: An Author Co-Citation Analysis (ACA)

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Abstract

The purpose of this paper was to study and map the intellectual structure of Iranian physicists using author co-citation technique during 1990-2009. The results of the study showed that Iranian physicists have produced 6290 documents indexed in *Science Citation Index* (SciSearch) during the studied period. Publication counts have grown at an approximate rate of 24/70 % per year. Setare M.R. with 121 documents was the most productive Iranian author in this study. Applied Physics, with1564 documents was the most interesting subject area for the Iranian physicists. We identified 42 Iranian and international physicists who were highly co-cited in 6290 documents during the studied period. Using principal components analysis, 8 subject factors were extracted. The subject areas of factors were in: "Physics, Particles & Fields", "Astronomy & Astrophysics", "Physics, Mathematical", "Physics, Multidisciplinary", "Physics, Nuclear", "Cosmology", "Physics, Atomic, Molecular & Chemical", and "Physics, Fluids & Plasmas". The PFNet map of the intellectual structure of Iranian physicists in SciSearch during 1990-2009 showed a central subject area in "Physics, Particles & Field" with Witten E. as its focal author. The other clusters were rooted in this essential cluster.

Keywords: Information Visualization (IV), Intellectual structure, Co-Citation, Physics scientific outputs, Iran.

Introduction

Citation counts of scientific outputs are one of the main and important factors for evaluating countries, authors, universities and institutes. Citation databases like SCI offer standard Scientometric tools via citations. Visualization of the intellectual structure (or Mapping of Science) is a subfield of scientometrics that uses the methods like citation and co-citation analysis for mapping and visualizing information.

Co-citation analysis is one of the bibliometric techniques that can be used to "map" the topical relatedness of clusters of authors, journals or articles. In other words, the intellectual structure of a research field can be visualized using this technique. It involves counting documents from a chosen field – paired or co-cited documents that appear frequently in the bibliographic reference lists of citing documents. Co-citation studies compile co-citation

counts in a matrix form and scale them statistically to capture "a snapshot at a distinct point in time of what is actually a changing and evolving structure of knowledge" (Small, 1993).

A science map is two- or three-dimensional representation of a science field, a 'landscape of science', in which the items in the map refer to themes and topics in the mapped field, such as cities on a geographical map. In these maps the items are positioned in relation to each other in such a way that the ones which are cognitively related to each other are positioned in each other's vicinity, whilst the ones that are not or hardly related are distant from each other. In general, all mapping and visualization techniques structure large amounts of data by clustering documents, authors or other elements that used to build a map (Noyons, 2004).

Different Studies show the rapid growth of scientific research outputs in Iran (ScienceWatche, 2003; Wilson & Osareh, 2003; Moin, Mahmoudi, Rezaei, 2007). Also on the one hand, some studies show that in the national level Physics ranks 2nd among the basic sciences in terms of output in SCI (Mehrdad, Heydari, Sarbolouki & Etemad, 2004) and on the other hand, Physics has been one of the standard fields in publication, citation and co-authorship comparisons of nations, national groups and major regions for the last two decades (Uzun, 1996).

Review of Literature

The background of the research showed that many bibliometric studies are done on Physics. About a century ago, Alfred Lotka (1926) published his findings on the frequency distribution of scientific productivity in Physics and Chemistry.

Vlachy (1982), studied trends in Czechoslovak Physics research-manpower, publication output, and citation response.

He also (1984) studied publication output of European Physics. For this purpose, Vlachy processed "Physics Abstracts" from printed volumes of 1970-1983 and sorted them by subfields, affiliation and authorship. The study results suggested that Europe represented 32% of the world Physics information output. Its major activity was Condensed Matter 26.5%, Geo- and Astrosciences 12.0%, Phenomenology 10.3%, Nuclear 10.0%, Atomic and Molecular 7.9%, Material Science 6.2%, Particles 5.6%, Bio- and Medical Physics 5.5%, etc.

Uzun (1996) studied Physics publications in Middle Eastern countries (Egypt, Iran, Iraq, Jordan, Saudi Arabia, Syria, and Turkey) through a total number of 2368 papers, from mentioned countries published in the international journals during 1990-1994. He showed the national contributions, main subjects of activity, journal preferences of authors, and co-authorship patterns.

Vogel (1997) examined a number of papers, cumulative impact factor, average impact factor, international co-authorship, and most visited journals and main Chilean institutions with 598 papers on Physics published during 1987 and 1994 with at least one author presenting Chilean affiliation. He found that Physics scientific publications were growing in

Chile, and international collaboration played an important role in them. The articles spread in 165 different journals, while most of them were published in a few journals with high impact factor.

Kim (2001) examined research performance of Korean physicists, comparing Korean-authored papers versus internationally co-authored papers, indexed in SCI, 1994-1998. Totally, 4,665 papers published by the researchers affiliated with the Physics departments or Physics-associated laboratories at Korean universities and indexed by SCI were analyzed. Kim results showed that Korean-authored papers tended to be published in Korean, Japanese, and UK journals, while internationally co-authored papers were more likely to appear in German, Dutch, and Swiss journals. Among the 18 authorship countries (on the basis of first author), 93 internationally co-authored papers were from U.S.

Karamustafaoğlu (2007) studied the citation rates and characteristics of 466 Turkish Physics publications that appeared in the research journals listed in the Science Citation Index (SCI) for the period 1983-2003. His study found that the papers appeared in a set of 96 journals, and approximately half of the total output was included in only 13 titles of them; 6 or 7 of which were journals of high impact. There has been a substantial shift of Turkish papers from European journals to American journals over the last decade. This change is an example for a developing country to integrate with the world scientific society. Turkish publications were mainly about Astrosciences, Condensed Matter Physics and Mathematical Physics.

Nattar (2009) studied 829 articles published in the 60 issues of 5 volumes of the *Indian Journal of physics* during the years 2004-2008 to observe the authorship pattern, geographical distribution of contributions and the number of pages used in each volume. Results indicated that the highest numbers of papers had been written through collaboration by authors. The scientific contributions in this journal from India were slightly more than those from the other countries. The growth and popularity of this journal showed an upward trend.

In addition, there are some other studies examining the current status and research trends in Iranian science:

Mehrdad, Heidari, Sarbolouki & Etemad (2004) studied basic sciences in the Islamic Republic of Iran (Chemistry, Physics, Mathematics, Biosciences and Geosciences) during years 1975–2002. They noted that Iran's science is still thriving.

Osareh and McCain (2008) studied the structure of Iranian Chemistry research using author co-citation technique. They identified 43 Iranian and international chemists who were highly cited in 7,682 Iranian Chemistry publications indexed in Science Citation Index during 1990 to 2006. The publication counts have grown at an approximate rate of 26% per year from a low 26 articles in 1990 to 1677 in 2006. A principal components analysis identified seven clusters that include "Synthesis of Carbonyl Compounds", "Solvent-free Synthesis of Organic Compounds", "Oxidation of Organic Compounds", "Physical Organic Chemistry",

"Ionophores", "Crown Ethers" and "Analytical Chemistry". They also map the intellectual structure of Iranian Chemistry research, using author co-citation and applying PFNet software.

Soheili, Osareh & khademi (2011) studied intellectual structure of Iranian Biologist outputs in Science Citation Index (SciSearch) during 1990-2008. Their results showed Iranian biologists have produced 2121 documents during the studied period. Co-citation map of their study showed 8 clusters. Iranian authors were on the edge of clusters and had not formed any clusters.

However, the review of literatures showed that Iranian physics outputs has not been studied using bibliometric analysis solely. Iranian Physics scientific outputs ranked as the second biggest discipline in Thomson ISI database after Chemistry. Therefore, we decided to study the intellectual structure of Iranian physicists in SciSearch file via Dialog database.

Aims and objectives

The purpose of this article is to study and map the intellectual structure of Iranian physicists' scientific outputs indexed in SciSearch during 1990-2009 using co-citation analysis.

Research Methodology

Author Selection

For selecting co-cited authors the SciSearch file (file 34) on the DIALOG was used. S SC=Physics*[1] command was used to identify documents in Physics in this database. Then the Geographical Location Search Strategy (SGL=Iran)[2] was used to provide the set of documents of Iranian scientists (Specifying Iran as at least one author's address), and the command of Publication Year Span (SPY=1990:2009)[3] was executed to select all Iranian Physics documents in DIALOG during the studied period.

The Rank command was used to identify the most cited authors in 6290 Iranian Physics publications. Finally the top 50 authors were selected. The details of these authors are shown in Table 1. In this table Iranian authors are shown in bold face.

Table 1

Authors Highly Cited in Physics Documents with an Iranian Author's Address

RANK	Name	Citation counts	RANK	Name	Citation counts
1	WITTEN E.	268	26	PADMANABHAN T.	84
2	FRISCH M.J.	152	27	STROMINGER A.	84
3	NOJIRI S.	152	28	POLCHINSKI J.	81
4	HAWKING S.W.	139	29	**ARKANIHAMED N.**	80

RANK	Name	Citation counts	RANK	Name	Citation counts
5	SEIBERG. N.	138	30	**CHAICHIAN M.**	80
6	HE J.H.	131	31	CALDWELL R.R.	79
7	LANDAU L.D.	129	32	LI M.	75
8	MALDACENA. J.	124	33	GROSS D.J.	74
9	**SETARE M.R.**	122	34	**ALISHAHIHA M.**	73
10	GIBBONS G.W.	120	35	ELNASCHIE M.S.	73
11	PERDEW J.P.	119	36	**ABBASBANDY S.**	72
12	CAI RG.	118	37	GUBSER S.S.	72
13	PERLMUTTER S.	118	38	CAPOZZIELLO S.	71
14	DOUGLAS M.R.	115	39	CALLAN C.G.	70
15	WEINBERG. S.	109	40	LIAO S.J.	69
16	RIESS A.G.	107	41	SAHNI V.	69
17	**JAFARIZADEH M.A.**	104	42	CVETIC M.	68
18	CARROLL S.M.	99	43	COOPER F.	65
19	SEN A.	93	44	BIRRELL N.D.	64
20	**ALIMOHAMMADI M.**	91	45	**DEHGHANI M.H.**	64
21	ELIZALDE E.	90	46	FREUND H.P.	64
22	SPERGEL D.N.	87	47	SCHRODINGER E.	64
23	AHARONY O.	86	48	WAZWAZ A.M.	64
24	CONNES A.	86	49	**KHORRAMI M.**	63
25	RANDALL L.	86	50	LI H.	62

Data Gathering

We retrieved the author co-citation counts for these initial top 50 authors using DIALOG analysis and then put citing-cited authors in a co-citation matrix and retained all authors with a mean of five or more author co-citations over the time period. Therefore, a threshold was set to eliminate "outlier" authors with less than 5 co-citations. This reduced the number of authors in the analysis to 42.

Data analysis

One of the multivariate techniques is factor analysis, a data reduction technique that yields factors and the factor loadings of the authors for each of those factors. Authors who work in the specialized areas tend to build on each others' ideas, and are likely to be co-cited by other researchers in the field (McCain, 1990).

A Principal Components Analysis with Varimax rotation was employed to extract the key factors based on their correlations. Factors with eigenvalues over 1 were selected. Only authors with loadings ±0.4 were included in the factors. We also used PathFinder network

analysis to map the intellectual structure based on the strongest inter-author raw co-citation counts.

Results and discussion

The results of the study show that Iranian physicists in the SciSearch (File 34) on DIALOG have 6290 documents during the studied period (1990-2009).

As shown in Table 1, Setare M. R. with 121 items ranked the first as the most productive author and Shokri B. and khorami M. followed respectively. The details of the ten top productive Iranian authors in the field of Physics are given in Table 2.

Table 2

The Most Productive Iranian Physics Researchers

RANK	authors' names	documents
1	SETARE M.R.	121
2	SHOKRI B.	84
3	KHORRAMI M.	78
4	JAFARIZADEH M.A.	76
5	KARIMIPOUR V.	62
6	GOLESTANIAN R.	59
7	NOZARI K.	59
8	TABAR MR R.	59
9	AKHAVAN M.	58
10	ALIMOHAMMADI M.	54

The 6147 documents out of 6290 are articles and others include 53 reviews, 28 editorial materials, 26 corrections, 24 letters, 11 notes, and one is biographical record.

The publication counts have grown at an approximate rate of 24.70 % per year from a low number of 16 documents in 1990 to 1324 documents published in 2009. Figure 1 illustrates the growth of the Iranian-authored Physics documents during 1990 to 2009. As was expected, the growth of Iranian scientific publications on Physics based on publication years is rapid.

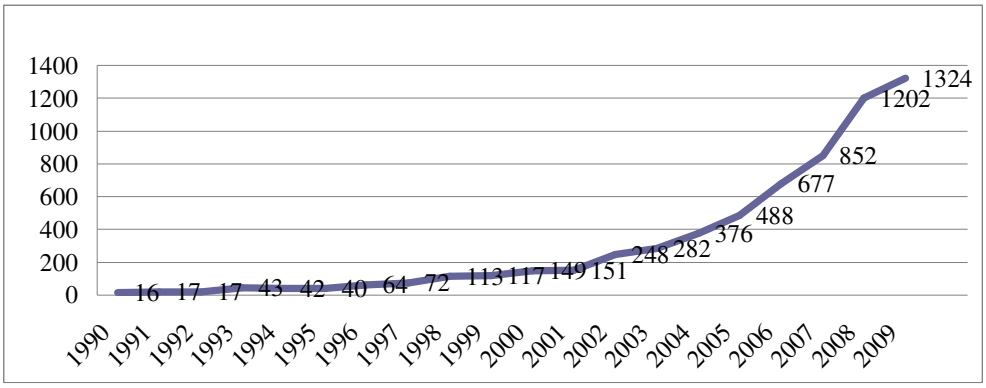

Figure 1. Growth of Iranian physics documents in SciSearch

As Osareh & McCain (2008) pointed out, studies of Iranian scientific research using SciSearch will naturally yield an incomplete picture because Iran's scientific language is Farsi (Persian), while Thomson Scientific databases focus on English language publications. Therefore, Iranian research productivity in Physics could even be higher if Iranian scientific publications in Farsi were included along with the English-language Iranian publications indexed in SciSearch during 1990-2009.

Results show 6288 documents (99.96%) are in English, one item in Chinese and one item in Russian.

Table 3 shows the subject categories of the 6290 documents. As can be seen "Physics, Applied" with 1564 documents ranked first and "Physics, Multidisciplinary" & "Physics, Condensed Matter" followed it respectively. It should be noted that in subject classification of documents we allocate more than one subject to some of them. Therefore, the number of subjects almost increases than the number of documents (6290).

Table 3
The Ten Top Subject Categories of Iranian Physics Documents (1990-2009)

RANK	Terms	Documents
1	Physics, Applied	1564
2	Physics, Multidisciplinary	1290
3	Physics, Condensed Matter	1272
4	Physics, Mathematical	1032
5	Physics, Particles & Fields	782
6	Physics, Atomic, Molecular & Chemical	673
7	Chemistry, Physical	591
8	Physics, Nuclear	579
9	Materials Science, Multidisciplinary	555
10	Physics, Fluids & Plasmas	489

Factor analysis

The analysis of the data using the principal component analysis showed 8 factors with a total percent of variance 73.42. The results are shown in Table 4; Iranian physicists are in bold face.

Factor 1 includes 24 authors with a range of Pearson Coefficient Correlation from 0.448 to 0.945 having 33.730 percent of the variance. Main research topic was on Physics, Particles & Fields. The most of the authors in this factor are international physicists with only two Iranians (Alishahiha M. & Arkanihamed N.).

Factor 2, in Astronomy & Astrophysics, totally contains international authors without any Iranian physicists, but Setare M.R. & Alimohammadi M. participate in this factor via secondary loading. The sum of variance for this factor was 12.129%.

Factor 3, in Physics, Mathematical subject area, includes four authors that most of them loaded via high loading (0.898, 0.896, and 0.821). Two authors of these are Iranian (Chaichian M. & Ardalan F.). This factor covered 8.544 % of all variance.

Factor 4, in Physics, Multidisciplinary, includes five exclusively international authors and no Iranians participate even via a secondary or tertiary loading in this factor. Birrell N.D. participated in another Factor (Factor 5) with a high loading, also Weinberg S. participated in Factor 1& 2. This Factor has 7.267 % of variance.

Factor 5, in Physics, Nuclear, contains Iranian and international authors. This factor includes six authors among which Setare M.R. and Dehghani M.H. are Iranian physicists who also participated in Factor 2 and Factor 1 respectively.

Factor 6, Cosmology, includes only two authors (Carroll S.M. & Riess A.G.); both of them loaded via high loading (0.871&0.786). Riess A.G. also participated in factor 2 (Astronomy & Astrophysics) via secondary loading. This factor has 4.859% of variance.

Factor 7, in Physics, Atomic, Molecular & Chemical includes two authors; Alimohammadi M. (Iranian) and Derrida B. (International). Alimohammadi M. also participated in Factor 2 (Astronomy & Astrophysics). Any other author (whether Iranian or international) does not participate even via secondary or tertiary loadings in this factor. This factor has 3.875 % of variance.

Factor 8, in Physics, Fluids & Plasmas, includes only one author (Schutz G.M.) loaded in this factor with high loading (0.876). This factor has minimum percent of variance (2.803).

Table 4

Factor Analysis of 42 Authors Highly Co-Cited

Names	Components							
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
	Particles & Fields	Astronomy & Astrophysics	Mathematical	Multidisciplinary	Nuclear	Cosmology	Atomic, Molecular & Chemical	Fluids & Plasmas
Cvetic M.	0.945							
Balasubramanian V.	0.933							
Aharony O.	0.931							
Gubser SS.	0.900							
Strominger A.	0.899							
Polchinski J.	0.896							
Alishahiha M.	**0.875**							
Maldacena J.	0.868							
Callan CG	0.856							
LI M.	0.834							
Seiberg N.	0.825							
Sen A.	0.817							
Gross D.J.	0.815							
Douglas M.R.	0.757		0.483					
Gibbons G.W.	0.687				0.485			
Witten E.	0.650							
Hawking S.W.	0.642							
Crandall L.	0.482							
Arkanihamed N.	**0.459**							
Perlmutter S.		0.883						
Spergel D.N.		0.868						
Padmanabhan T.		0.812						
Nojiri S.		0.760						
Elizalde E.		0.697			0.524			
Weinberg S.	0.475	0.533		0.476				
Chaichian M.			**0.898**					
Ardalan F.			**0.896**					
Connes A.	0.448		0.821					
Schrodinger E.				0.848				
Landau L.D.				0.789				
Cooper F.	0.561			0.653				
Birrell N.D.				0.550	0.699			
Setare M.R.		**0.620**			**0.642**			
Cai RG.	0.598				0.619			
Dehghani M.H.	**0.517**				**0.581**			
Carroll S.M.						0.871		
Riess A.G.		0.419				0.786		
Derrida B.							0.882	
Alimohammadi M.		**0.442**					**0.716**	
Schutz G.M.								0.876
% of Variance	33.730	12.129	8.544	7.267	6.928	4.859	3.875	2.803

Pathfinder analysis

Pathfinder analysis generates a network structure in which the path between two nodes (i.e., authors) is a geodesic that does not violate the condition of triangular inequality (Schvaneveldt, 1990). Data was analyzed using PFNet software. This software reduced data to 6 clusters. Figure 2 shows the network diagram (called PFNet). None of the Iranians is counted as the center of the sub networks.

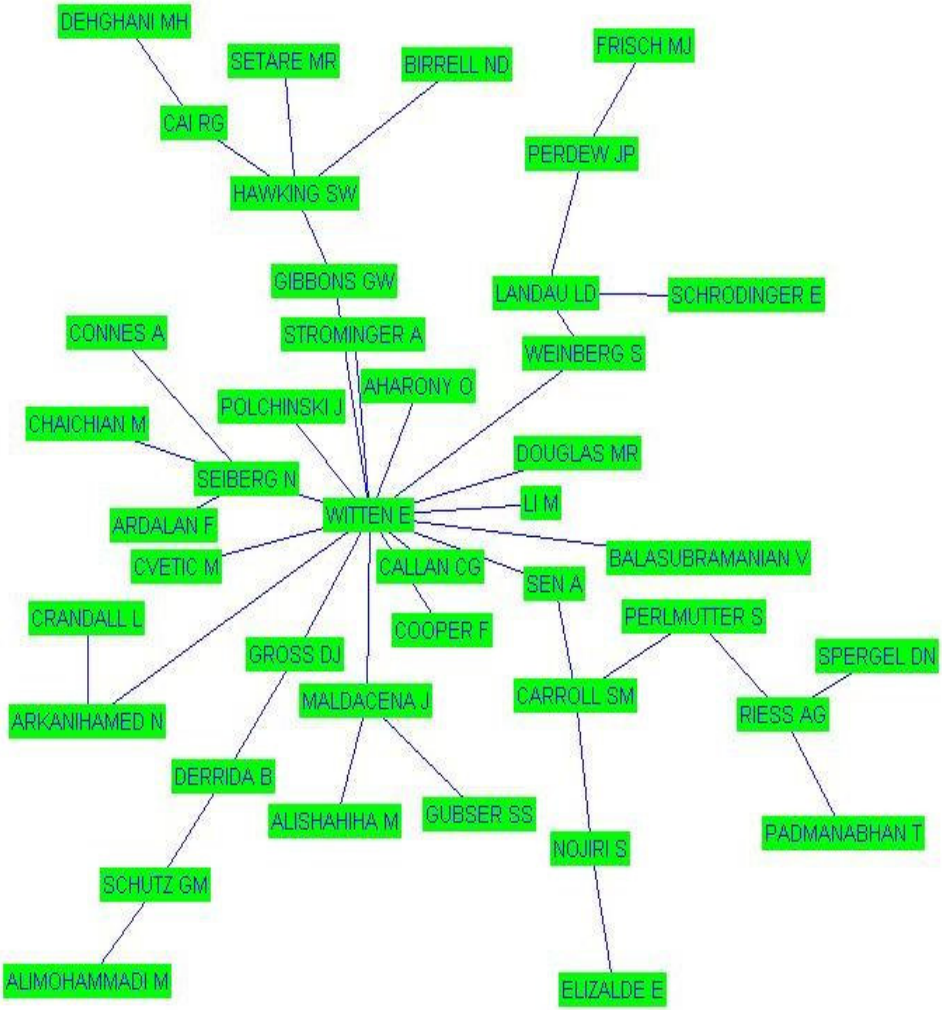

Figure 2. PFNet map of co-citation counts for highly cited authors in Iranian physics documents, 1990-2009

For better understanding of this map, in Figure 3, instead of authors, we assigned subject areas of them to the map, Iranian authors are shown in bold shape. Figure 3 can show clearly the subject areas of the map. In Figure 3, one central cluster- Physics, Particles & Fields- formed by Witeen E. in the center and other clusters connected with this. Two Iranian authors (Alishahiha M. & Arkanihamed N.) participated in this cluster.

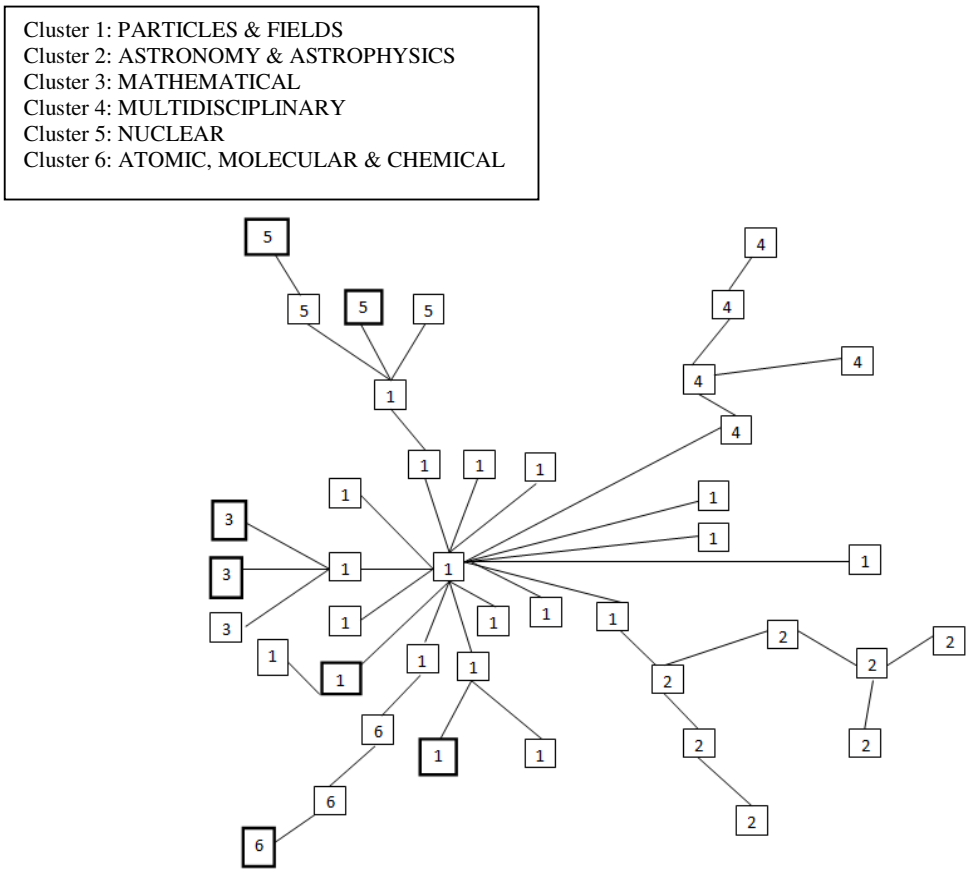

Figure 3. Intellectual structure map for highly cited authors in Iranian physics documents during 1990-2009

Second cluster is in Astronomy & Astrophysics. This cluster is connected by Sen A. to Physics, Particles & Fields.

The third cluster is in Physics, Mathematical. Seiberg N. connected this subject area to Physicsp, Particles & Fields. Chaichian M. and Ardalan F**.** are Iranian authors in this cluster.

The Fourth cluster is in Physics, Multidisciplinary. Weinberg S. connected this subject area to Physics, Particles & Fields.

The Fifth cluster is in Nuclear. This cluster is connected by Hawking S.W. to physics, particles & fields. Two Iranian authors - Setare M.R. & Dehghani M.H. - participated in this cluster.

The Sixth cluster is in Atomic, Molecular & Chemical. Derrida B. connected this cluster to Physicsp, Particles & Fields. Alimohammadi M. - Iranian author- is on the end of this cluster.

Conclusion

Iranian physicists have produced 6290 documents indexed in Science Citation Index during 1990 to 2009 with a growth at an approximate rate of 24/70 % per year. All these

documents were extracted from DIALOG for this study. Almost all of the documents were in English, while the national language of Iran is Farsi. Therefore, a small sum of Iranian research productivity in Physics has been covered in this study (6290 documents). Factor analysis of the data, yielded 8 factors in "Particles & Fields", "Astronomy & Astrophysics", "Physics, Mathematical", "Physics, Multidisciplinary", "Physics, Nucler", "Physics, Cosmology" ,"Physics, Atomic, Molecular & Chemical" and "Physics, Fluids & Plasmas". In factor analysis "Particles & Fields" have the most percent of variance (33/70) and most number of authors (24) by first rotation and also most other authors via second or third rotation participated in this factor. Therefore, this factor is the main and the most important topic in this study. Also the most Iranian authors have participated in this factor. PathFinder network also showed that intellectual structure of Iranian physicists includes one cluster -Physics, Particles & Fields- in center that formed by Witten E. Thus, similar to factor analysis, the map also showed that Particles & Fields is the main cluster. Other clusters in – "Astronomy & Astrophysics", "Physics, Mathematical", "Multidisciplinary Physics", "Physics, Nuclear", "Physics, Atomic, Molecular & Chemical" were rooted in this cluster. Alishahiha M. & Arkanihamed N**.** (in Physics, Particles & Fields), Chaichian M. & Ardalan F. (in Physics, Mathematical) and Setare M.R. & Dehghani M.H. (in Physics, Nuclear) are Iranian authors in the PFNet map of the intellectual structure of Iranian physicists.

Regarding this map, none of the Iranians located as a focal author in this network and almost all Iranian authors are on the edge of the clusters. Since we did not observe any study in Iranian Physics scientific output, we compared this map with other scientific maps in Basic Sciences. Comparing the results of this study with other research studies, it is clear that Iranian physicists have played a less active role comparing with Iranian Chemists in Osareh and McCain (2008) map in which Iranian chemists formed at least two clusters. However, the role of Iranian authors in Biology (Soheili, Osareh, Khademi, 2011) is closer to Physicists in our study.

End notes:

1. select subject Category = Physics*
2. select geographical location = Iran
3. select publication year during 1990 to 2009

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