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INTERCOMMUNICATION AMONG PHYSICS RESEARCH GROUPS IN LATIN AMERICA

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Abstract—Communication patterns among Latin American research groups in solid state physics are analyzed using the journal articles they published during a five year span. The patterns found may be symptomatic of the stage of development of the countries involved.

We wish to describe certain communication patterns among research groups of physicists in solid state physics in Latin America. The findings may be of interest on three accounts. First, most studies of science communication have dealt with scientists in highly developed countries; here we provide some insight on communication patterns of scientists in developing countries—to our knowledge this is the first study of its kind applied to Latin America. Second, a major problem of science policy making is obtaining relevant information on which rational decision can be based; we suggest that findings of this and similar studies on science communication patterns can be used for science policy decisions, be that on an institutional, national or international level. Third, methodological problems plague the study of science communication and of relations among scientists—the particular methods of analysis applied here may be of interest to such studies in general.

Scientific communication has evolved into assuming properties of a complex ecological system involving many diverse elements and relations [1, 2]. Still the main and basic elements are scientific journals and articles contained therein. ZIMAN [3] and many others pointed out that the invention of the particular mechanism for the systematic publication of fragments of knowledge through journal articles may well have been the key event in the history of modern science. However, the study of scientific communication in a formal sense is of recent origin, prompted by a number of imbalances in the ecology of scientific communication. Relatively little is known on the patterns and dynamics of scientific communication, including journals; therefore many assumptions have to be made, and studies, such as this one, are bounded by serious limitations in existing knowledge.

The main assumption made in this study relates to journals. Since journals are so important, we choose to study communication patterns based on publication of articles in given journals. We assumed that scientists that publish articles in a given journal (or a given set of journals) are in a closer communication relationship than those that do not publish in that journal (or journals). We assumed, therefore, that the pattern formed by publication of articles in journals by given groups of scientists organized in institutions represents a pattern of communication among these groups; for instance, if two groups publish articles in the same journals, then we assume that they have a closer communication relationship than two groups that publish articles in different journals (or, in the extreme case, than groups that do not publish at all).

PHYSICS IN LATIN AMERICA

As in many other countries, physics in the countries of Latin America started as a supportive discipline to other sciences and to engineering. Its evolution into an independent subject organized and supported through independent institutions or departments is recent. For a long time research in physics was the isolated work of individuals. After the Second World War an increased number of physicists from Latin America were educated or obtained advanced training in Europe and the U.S.A. Upon their return to Latin America, they established physics research groups and institutions, graduate and postgraduate programs and, in effect, established physics in their respective countries as an independent field of activity and career.

Activity in solid state research in Latin America is also very recent. The first research groups were established at the close of the fifties, but of those existing today the largest number emerged in between 1966 and 1970. Some of the research groups are still in the formative stages. One of the results of the First Latin American Congress on Physics in 1968 in Mexico was the discovery by solid state physicists that a relatively large number of them exist in Latin America and that there was a need for regional coordination and cooperation among the already established and working research groups. The First and Second Latin America Symposia on Solid State Physics (Caracas 1969, Bariloche 1971) established communication among groups on a regional and continental basis.

However, even before these developments in solid state physics, Latin American physicists and governments recognized the advantages of regional (Continental) cooperation and communication for the development of physics. To that effect they established the Latin American Center for Physics (CLAF) in 1962 in Rio de Janeiro. CLAF established a program of regional cooperation among physics research groups. The basis of the program is the assumption that communication among groups is essential for the development of physics in the region and that recognition of potentials on a regional scale is the base for cooperative programs for further development.

In 1971 and 1973 CLAF published the first directories of the Latin American research groups in solid state physics[4]. The directories included productive research groups in Latin America and almost the total population of solid state physicists. These directories were compiled on the basis of questionnaires to some 2000 physicists and to some 90 institutes, educational institutions and scientific societies in 16 countries of Latin America. The questionnaires revealed a considerable number of research groups and publications leading to the analyses presented here.

DATA

As mentioned, we concentrated on the analysis of journal articles. The journal articles published during a five year span, 1967–1971, by Latin American physicists in solid state physics were identified from the questionnaires collected by CLAF in relation to the above mentioned directories. The identification of articles was supplemented by comprehensive bibliographic searching. In this way we obtained practically all the journal articles published by Latin American solid state physicists in that time period. The data consists of

606 journal articles from
76 journals, published by physicists working in
23 research groups (institutes) from
8 countries.

These represent research institutes working in solid state physics in Latin America at that time. Table 1 lists the 23 institutes showing the year of establishment and the number of journal articles produced by each group from 1967 until 1971. Also provided are shorthand labels for research groups used in later tables. The number of physicists working in solid state physics in each group is not included because of the relatively large variations from year to year. Two bibliometric analyses of the data were performed: one as suggested by Bradford's law and the other was an application of Goffman's indirect method.

BRADFORD LAW ANALYSIS

The best known bibliometric analysis is derived from a law formulated by S. C. Bradford[5]:

> "If scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus, where the number of periodicals in the nucleus and succeeding zones will be as $1:n:n^2:n^3\ldots$"

Table 1. Research groups in solid state physics in Latin America (Code taken from CLAF *Directory*[4])

Code	Scientific institution	Group established	No. of articles 1967–1971	In No. of journals
RA-1	Centro Atómico Bariloche Instituto de Física Dr. José A. Balseiro San Carlos de Bariloche—Argentina	1966	63	22
RA-2	Universidad Nacional de La Plata Facultad de Ciencias Exactas Departamento de Física La Plata—Argentina	1969	2	2
RA-3	Universidad Nacional de Cordoba Instituto de Matemática, Astronomia y Física Cordoba—Argentina	1969	5	5
BR-2	Instituto Militar de Engenharia Rio de Janeiro—Brasil	1971	1	1
BR-3	Universidade Federal de Minas Gerais Instituto de Pesquisas Radioativas Belo Horizonte—Brasil	1966	18	4
BR-4	Centro Brasileiro de Pesquisas Físicas Rio de Janeiro—Brasil	~ 1960	38	13
BR-6	Universidade de Brasília Departamento de Física Brasília—Brasil	1969	5	3
BR-7	Universidade Federal do Rio Grande do Sul Instituto de Física Porto Alegre—Brasil	1962	44	18
BR-8	Pontifícia Universidade Católica do Rio de Janeiro Departamento de Física Rio de Janeiro—Brasil	1966	36	13
BR-11	Universidade de São Paulo Instituto de Física e Química de São Carlos Departamento de Física e Ciências dos Materiais São Carlos—Brasil	1956	113	20
BR-12	Universidade de São Paulo Instituto de Física São Paulo—Brasil	1961	86	17
CH-1	Universidad de Chile Facultad de Ciencias Departamento de Física Santiago—Chile	1968	23	11
CH-2	Universid Técnica del Estado Escuela de Ingenieros Industriales Departamento de Física Santiago—Chile	1971	5	5
CH-3	Universidad de Concepción Instituto Central de Física Concepción—Chile	1968	4	4
CH-4	Universidad de Chile Facultad de Ciencias Físicas y Matemáticas Departamento de Física Santiago—Chile	1958	12	8
CH-5	Universidad Austral de Chile Instituto de Biofisica Valdivia—Chile	1967	4	4
CR-1	Universidad de Costa Rica Facultad de Ciencias y Letras Departamento de Física San José—Costa Rica	1967	5	3
MX-2	Universidad Nacional Autónoma de México Instituto de Física México—México	1960	60	16
MX-3	Instituto Politécnico Nacional Sección de Graduados de Física y Matematicas México—México	1967	18	7
PR-2	Universidad Nacional de Ingenieria Departamento Acadèmico de Física Lima—Peru	1967	6	5
RU-1	Universidad de la República Facultad de Ingeniería e Agrimensura Instituto de Física Montevideo—Uruguay	1968	7	3
VZ-1	Universidad de Los Andes Facultad de Ciencias Instituto de Física Merida—Venezuela	1968	1	1
VZ-2	Instituto Venezolano de Investigaciones Científicas Caracas—Venezuela	1966	50	20

A considerable amount of theoretical work has been done on the law, and numerous observations have been made on a variety of literature and related data. BROOKES[6] provided interpretations of the applications of the law and speculated on the underlying mechanism. From many observations on the adherence and non-adherence to the law, we can derive some conclusions on the state of an observed subject, literature collection or bibliography. Results of such analyses can be used for policy decisions e.g. on library acquisition.

Table 2 provides the distribution of the 606 articles among the 76 journals where they appeared listing the names of journals contributing 2 or more articles and especially emphasizing journals from Latin America. Of the 76 journals 71 (93%) journals from outside of Latin America published 387 (64%) articles, and 5 Latin American journals published 219 articles. The large

Table 2. Distribution of 606 articles published 1967–1971 by research groups in solid state physics in Latin America among the 76 journals where they appeared. Names of journals where 2 or more articles were published are given; there were 39 journals (all from outside of Latin America) which published one article each whose names are not listed. Starred Journals are published in Latin America. 71 journals which published 387 articles were from outside of Latin America and 5 journals from Latin America published 219 articles

No. of journals	Each of which published No. of articles	Journal title
1	153	**Ci e Cult.* (Brasil)
1	51	*Phys. Rev.*
2	50	*Bull. Amer. Phys. Soc.*
		**Rev. Mex. Fís.* (México)
1	38	*Phys. Lett.*
1	20	*J. Appl. Phys.*
1	19	*Phys. St. Sol.*
1	17	*Sol. St. Commun.*
1	16	*J. Phys. C—Proc. Phys. Soc.—Sol. St. Phys.*
1	14	*J. Phys. and Chem. Sol.*
1	13	*J. Chem. Phys.*
1	12	*Phys. Rev. Lett.*
1	11	**Acta Ci. Venez.* (Venezuela)
3	8	*J. Phys. E.—J. Sci. Instrum.*
		Rev. Sci. Instrum.
		Scripta Metall.
2	7	*Nuovo Cimento*
		Phil. Mag.
3	6	*Appl. Phys. Lett.*
		C.R. Acad. Sci. (France)
		Helv. Phys. Acta
2	5	*Chem. Phys. Lett.*
		Z. Metallk.
1	4	*Phys. Kondens. Mat.*
7	3	*Acta Metall.*
		J. Chrystal Growth
		J. Eletrochem. Soc.
		J. Mat. Sci.
		J. Phys. (France)
		**R. Bras. Fís.* (Brasil)
		Z. Angew. Phys.
6	2	**An. Acad. Bras. Ci.* (Brasil)
		Canad. J. Phys.
		IEEE Trans. Sonics and Ultrasonics
		Int. J. Quantum Chem.
		J. Nuclear Mat.
		Phys. Can.
39	1	(Names not listed)

(To be read as follows: There was 1 journal which published 153 articles, 1 journal published 51 articles, 2 journals published 50 articles each—(thus together publishing 100 articles), etc.... at the end there were 39 journals publishing one article each.)

number of journals outside Latin America indicates (a) that Latin American solid state physicists are members of the world scientific community utilizing the established, recognized and refereed means of communication (b) that domestic outlets are lacking, and (c) that Latin America physicists have definite preferences. Domestic journals operate on a national basis—with limited distribution. To assure a wider audience authors seek to publish in journals outside Latin America.

Top ranking of all journals is the Brazilian journal, *Ciencia e Cultura*, where members from seven research groups published. Second ranking is the well-known *Physical Review*. Third ranking is *Revista Mexicana de Fisica*; interestingly, this high rank is the result of a special issue devoted to the First Latin American Congress on Physics in 1968 which included papers from physicists from 9 Latin American countries. Most other high ranking journals are from the U.S.A.

The distribution of articles among journals does *not* conform to Bradford's law as can be seen in Table 3: the Bradford multiplier (n in the law) does not behave as expected and as observed in many other instances of physics literature (see Brookes). There is a wide divergence from the expected in the last zone. If the distribution is graphically represented as recommended by Bradford by plotting the cumulative number of articles against the logarithm of the cumulative number of journals, the divergence from the familiar Bradford hyperbolic curve becomes even more apparent: there is a tendency toward a linearity at the beginning of the curve (at what Brookes called the "Bradford nucleus") where the curve should not be linear at all, and there is a "collapse" from linearity ("Zipf linearity") at the end of the curve where the curve should be linear.

Table 3. Distribution of articles in journals according to Bradford Law. Since the Bradford multiplier is not approximately constant the distribution does not follow the law. (The Bradford multiplier is the ratio of number of journals in succeeding zone over number of journals in preceding zone)

Zone	No. of articles in the zone	Produced by No. of journals	Bradford multiplier
1	153	1	—
2	151	3	3.0
3	149	8	2.6
4	153	64	8.0

We suggest that this type of nonadherence to the Bradford law and distribution is a reflection of the relative stage of development of a subject, a country or a region. A highly developed subject (represented by a relatively complete bibliography, of course) will adhere to Bradford's law; a less developed subject will tend to deviate from the law by tending toward linearity with a "collapse" toward the end[7]. However, even highly developed subjects, but in the context of developing countries, will also tend to reflect the same deviation. This explanation is based on the plausible assumption that scientific literature of a country (or region) is a reflection of the stage of development of that country.

ANALYSIS ACCORDING TO THE INDIRECT METHOD

Theory

In an attempt at rectifying the most obvious deficiencies of the direct method for searching of a file of documents in an information retrieval system (where relevance of a document to a query is assessed independent of the relevance of other documents), Goffman[8] introduced an indirect method (where relevance of a document is assessed in relation to a class of other documents). Goffman's suggestion for the indirect method included a generalizable mathematical model of relations in communication and a general strategy for deriving associated classes of elements that are in communication. This theoretical construct allows for the application of the indirect method to aspects other than retrieval of documents.

Goffman defines a conditional probability (p_{ij}) that a document (x_j) is relevant to a query given that another document (x_i) is relevant to a query and conditional probability (p_{ji}) that a document

(x_i) is relevant to a query given that another document (x_j) is relevant. Goffman also defines a relation called communication (C) and proves that a document (x_i) communicates with a document (x_j) (i.e. x_iCx_j) only if the conditional probability (p_{ij}) is greater than an arbitrary critical probability (threshold). Such a relation is an order relation in that it is reflexive, transitive and asymmetric.

If a document (x_i) communicates with (x_j) and also the document (x_j) communicates with (x_i) (that is x_iCx_j and x_jCx_i), then the documents (x_i) and (x_j) are said to be in intercommunication (i.e. x_iIx_j). Intercommunication is an equivalence relation in that it is reflexive, transitive and symmetric.

Thus by setting a threshold a set of documents may be partitioned into equivalence classes, such that if a document is in a given class all members of the set of documents which are in intercommunication with that document are in that given class. Also, for a given threshold there may exist more than one class (disjoint subset) of documents, e.g. more than one set of documents may provide an answer to a question at a given threshold. The higher the threshold the more selective are the retrieved results. At higher thresholds there may be fewer classes with more than one member. Goffman's method suggests this strategy for obtaining answers:

(1) Define a specific procedure for computing the conditional probabilities and then compute the conditional probabilities that link any two documents in the collection.

(2) For all documents in the collection construct a matrix of these conditional probabilities.

(3) Select a threshold (e.g. an arbitrary high one) and from the matrix determine the classes of documents that intercommunicate above that threshold.

(4) Proceed by lowering the threshold and determining for every new threshold the intercommunication classes either till satisfied with the answer or till the variations in size and number of classes are exhausted.

Application

In this specific application of the indirect method we took research groups to be elements in intercommunication instead of documents. For the purpose of constructing a communication matrix of (and subsequently determining intercommunication classes between) research groups dealing with solid state physics in Latin America, we took that articles published in the same (common) journals indicate a degree of communication. The conditional probability (p_{ij}) that research group (x_i) communicates with group (x_j) was computed as follows:

$$p_{ij} = \frac{m(x_i \cap x_j)}{m(x_i)}$$

where $m(x_i \cap x_j)$ is the number of articles in journals common to research groups (x_i) and (x_j), while $m(x_i)$ is the total number of journal articles published by group (x_i). Conversely, conditional probability (p_{ji}) that research group (x_j) communicates with group (x_i) was taken as:

$$p_{ji} = \frac{m(x_i \cap x_j}{m(x_j)}$$

where $m(x_i \cap x_j)$ is as above and $m(x_j)$ is the total number of journal articles published by group (x_j).

For instance, group labeled RA-1 published 63 articles and group BR-4 published 38 articles. Of these 8 appeared in the same journals thus:

$$p(RA\text{-}1—BR\text{-}4) = \frac{8}{63} = 0.12,$$

and

$$p(BR\text{-}4—RA\text{-}1) = \frac{8}{38} = 0.21.$$

The probability of communication between RA-1 and BR-4 is 0.12 and the probability of communication in the other direction, from *BR*-4 to *RA*-1, is 0.21 (i.e. as mentioned, communication is an asymmetric relation). They intercommunicate at the threshold of 0.12 or probabilities below that (intercommunication is a symmetric relation).

Table 4 provides a matrix of the number of articles published in the same journals for every pair of research groups. For instance: groups *RA*-1 published 63 articles one of which appeared in the same journal as an article from group *RA*-2, three of which appeared in the same journals as articles from *RA*-3, etc.

Table 5 provides a matrix of the conditional probabilities of communication between every pair of research groups calculated from data in Table 4 using the above formulae. For instance: communication between *RA*-1 and *RA*-2 is 0.01 and between *RA*-2 and *RA*-1 is 0.50, between *RA*-1 and *RA*-3 is 0.04 and between *RA*-3 and *RA*-1 is 0.60, etc.

If the threshold for intercommunication is set at 0.60 or higher all the classes have only one member, that is, the threshold is too high to obtain any class that has at least two members; no two research groups intercommunicate at that probability. Setting the threshold to zero, all the groups converge into one intercommunication class. Since the first class with more than one member forms at 0.55, we decided arbitrarily to observe the formulation of intercommunication classes among the 23 research groups at thresholds (critical probabilities) of 0.50, 0.40, 0.30, 0.20 and 0.10.

Results

At the threshold of 0.50 the 23 research groups are partitioned into 21 disjoint intercommunication classes: 2 classes with 2 members each and 19 single member classes. The two classes with two members each are formed from Brazilian groups: in one class *BR*-4 and *BR*-8 intercommunicate and in the other *BR*-11 and *BR*-12. These groups were established between 1956 and 1966. Each of the groups produced more than 30 articles in the period surveyed. A great number of their papers appeared in the Brazilian journal *Ciencia e Cultura*, which is published by a national scientific society.

At the threshold of 0.40 17 intercommunication classes are formed:

1 class with 4 members (*CH*-2, *CR*-1, *RU*-1, *PR*-2)
1 class with 3 members (*BR*-3, *BR*-4, *BR*-8)
1 class with 2 members (*BR*-11, *BR*-12) and
14 classes with 1 member each.

The class with 4 members incorporates research groups from four Latin American countries. They were established recently, at the end of the sixties, and they produced a relatively small number of articles, none more than 8. However, all of them published articles in *Phys. Review* and some in *J. Phys. Chem. Sol.*, thus they formed an intercommunication class at this relatively high threshold. At the threshold of 0.30 11 intercommunication classes are formed:

1 class with 10 members (*RA*-1, *BR*-3, *BR*-4, *BR*-7, *BR*-8, *BR*-11, *BR*-12, *CH*-1, *MX*-3, *VZ*-2)
1 class with 4 members (*CH*-2, *CR*-1, *RU*-1, *PR*-2) and
9 classes with 1 member each.

The class with 10 members consolidated the previously formed classes of research groups from Brazil and added research groups from four other countries. All these groups were formed in the sixties; they contributed from 18 to 113 articles. The linking between the members of the group was provided by articles in *Bull. Amer. Phys. Soc.*, *Ciencia e Cultura*, *J. App. Phys.*, *Phys. Rev.* and *Phys. St. Sol.* It is evident that the existence of a strong journal in Brazil (*Ciencia e Cultura*) has provided a common outlet for publications for Brazilian research groups in solid state physics.

One large class of 19 members and 4 classes with one member each formed at the threshold of 0.20. The research groups that did not fall in the large class were: *BR*-2, *BR*-6, *CH*-4 and *VZ*-1.

Finally, at the low threshold of 0.10, 21 groups converged into one large class and only groups *BR*-2 and *VZ*-1 were left each to form a class of its own—each group produced only one article in the period surveyed.

Table 4. Number of articles from a research group that appeared in the same journals where each other research group published, i.e. $m(x_i \cap x_j)$. Numbers in parenthesis indicate number of articles published by the given research group

	RA-1	*RA*-2	*RA*-3	*BR*-2	*BR*-3	*BR*-4	*BR*-6	*BR*-7	*BR*-8	*BR*-11	*BR*-12	*CH*-1	*CH*-2	*CH*-3	*CH*-4	*CH*-5	*CR*-1	*MX*-2	*MX*-3	*PR*-2	*RU*-1	*VZ*-1	*VZ*-2
RA-1	(63)	1	3	0	2	8	0	24	15	34	18	17	1	2	5	0	4	15	11	5	7	1	24
RA-2	1	(2)	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1
RA-3	3	1	(5)	0	0	1	0	1	1	1	2	0	1	0	2	1	0	2	0	1	0	0	1
BR-2	0	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR-3	2	0	0	0	(18)	16	2	7	15	16	16	1	1	1	0	0	1	1	1	2	1	0	2
BR-4	8	1	1	0	16	(38)	2	12	20	20	25	7	1	1	2	0	3	6	3	2	3	0	7
BR-6	0	0	0	0	2	2	(5)	2	2	2	2	1	0	0	0	0	0	0	0	0	0	0	0
BR-7	24	0	1	0	7	12	2	(44)	15	29	15	16	3	2	5	1	5	7	8	1	4	1	17
BR-8	15	0	1	0	15	20	2	15	(36)	27	21	9	2	1	4	0	4	7	4	3	3	1	11
BR-11	34	0	1	0	16	20	2	29	27	(113)	63	17	2	2	4	0	5	8	10	5	6	1	20
BR-12	18	1	2	0	16	25	2	15	21	63	(86)	11	2	2	3	1	3	4	6	3	5	0	15
CH-1	17	0	0	0	1	7	1	16	9	17	11	(23)	3	2	2	0	5	3	7	1	4	0	15
CH-2	1	0	1	0	1	1	0	3	2	2	2	3	(5)	1	1	1	2	2	1	1	1	0	1
CH-3	2	0	0	0	1	1	0	2	1	2	2	2	1	(4)	0	0	1	1	2	1	1	0	2
CH-4	5	0	2	0	0	2	0	5	4	4	3	2	1	0	(12)	1	1	5	1	0	0	1	3
CH-5	0	0	1	0	0	0	0	1	0	0	1	0	1	0	1	(4)	0	1	0	0	0	0	0
CR-1	4	0	0	0	1	3	0	5	4	5	3	5	2	1	1	0	(5)	2	2	1	3	0	4
MX-2	15	1	2	0	1	6	0	7	7	8	4	3	2	1	5	1	2	(00)	5	2	3	1	12
MX-3	11	0	0	0	1	3	0	8	4	10	6	7	1	2	1	0	2	5	(18)	2	3	1	9
PR-2	5	0	1	0	2	2	0	1	3	5	3	1	1	1	0	0	1	2	2	(6)	3	0	3
RU-1	7	0	0	0	1	3	0	4	3	6	5	4	1	1	0	0	3	3	3	3	(7)	0	6
VZ-1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	(1)	1
VZ-2	24	1	1	0	2	7	0	17	11	20	18	15	1	2	3	0	4	12	9	3	6	1	(50)

Table 5. Matrix of conditional probabilities that a research group is in a communication relation with other groups, i.e.

$$p_{ij} = \frac{m(x_i \cap x_j)}{m(x_i)}; \qquad p_{ji} = \frac{m(x_i \cap x_j)}{m(x_j)}$$

	RA-1	*RA*-2	*RA*-3	*BR*-2	*BR*-3	*BR*-4	*BR*-6	*BR*-7	*BR*-8	*BR*-11	*BR*-12	*CH*-1	*CH*-2	*CH*-3	*CH*-4	*CH*-5	*CR*-1	*MX*-2	*MX*-3	*PR*-2	*RU*-1	*VZ*-1	*VZ*-2
RA-1	(1)	0.01	0.04	0	0.03	0.12	0	0.39	0.23	0.53	0.28	0.26	0.01	0.03	0.07	0	0.06	0.23	0.17	0.07	0.11	0.01	0.38
RA-2	0.50	(1)	0.50	0	0	0.50	0	0	0	0	0.50	0	0	0	0	0	0	0.50	0	0	0	0	0.50
RA-3	0.80	0.20	(1)	0	0	0.20	0	0.20	0.20	0.20	0.40	0	0.20	0	0.40	0.20	0	0.40	0	0.20	0	0	0.20
BR-2	0	0	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR-3	0.11	0	0	0	(1)	0.88	0.11	0.38	0.83	0.88	0.88	0.05	0.05	0.05	0	0	0.05	0.05	0.05	0.11	0.05	0	0.11
BR-4	0.21	0.02	0.02	0	0.42	(1)	0.05	0.31	0.52	0.52	0.65	0.18	0.02	0.22	0.05	0	0.07	0.15	0.07	0.05	0.07	0	0.18
BR-6	0	0	0	0	0.40	0.40	(1)	0.40	0.40	0.40	0.40	0.20	0	0	0	0	0	0	0	0	0	0	0
BR-7	0.45	0	0.02	0	0.15	0.27	0.04	(1)	0.34	0.65	0.34	0.36	0.06	0.04	0.11	0.02	0.11	0.15	0.18	0.02	0.09	0.02	0.38
BR-8	0.41	0	0.02	0	0.41	0.55	0.05	0.41	(1)	0.75	0.58	0.25	0.05	0.02	0.11	0	0.11	0.19	0.11	0.08	0.08	0.02	0.30
BR-11	0.30	0	0.00	0	0.14	0.17	0.01	0.25	0.23	(1)	0.55	0.15	0.01	0.01	0.03	0	0.04	0.07	0.08	0.04	0.05	0.00	0.17
BR-12	0.20	0.01	0.02	0	0.18	0.29	0.02	0.17	0.24	0.73	(1)	0.12	0.02	0.02	0.03	0.01	0.03	0.04	0.06	0.03	0.05	0	0.20
CH-1	0.73	0	0	0	0.04	0.30	0.04	0.69	0.39	0.73	0.47	(1)	0.13	0.08	0.08	0	0.21	0.13	0.30	0.04	0.17	0	0.05
CH-2	0.20	0	0.20	0	0.20	0.20	0	0.60	0.40	0.40	0.40	0.60	(1)	0.20	0.20	0.20	0.40	0.40	0.20	0.20	0.20	0	0.20
CH-3	0.30	0	0	0	0.25	0.25	0	0.50	0.25	0.50	0.50	0.50	0.25	(1)	0	0	0.25	0.25	0.50	0.25	0.25	0	0.50
CH-4	0.41	0	0.16	0	0	0.16	0	0.41	0.33	0.33	0.25	0.16	0.08	0	(1)	0.08	0.08	0.41	0.08	0	0	0.08	0.25
CH-5	0	0	0.25	0	0	0	0	0.25	0	0	0.25	0	0.25	0	0.25	(1)	0	0.25	0	0	0	0	0
CR-1	0.80	0	0	0	0.20	0.60	0	1.00	0.80	1.00	0.60	1.00	0.40	0.20	0.20	0	(1)	0.40	0.40	0.20	0.60	0	0.80
MX-2	0.25	0.01	0.03	0	0.01	0.10	0	0.11	0.11	0.13	0.06	0.05	0.03	0.01	0.08	0.01	0.03	(1)	0.08	0.03	0.05	0.01	0.20
MX-3	0.61	0	0	0	0.05	0.16	0	0.44	0.22	0.55	0.33	0.38	0.05	0.11	0.05	0	0.11	0.27	(1)	0.11	0.16	0.05	0.50
PR-2	0.83	0	0.16	0	0.33	0.33	0	0.16	0.50	0.83	0.50	0.16	0.16	0.16	0	0	0.16	0.33	0.33	(1)	0.50	0	0.50
RU-1	1.00	0	0	0	0.14	0.42	0.42	0.57	0.42	0.85	0.71	0.57	0.14	0.14	0	0	0.42	0.42	0.42	0.42	(1)	0	0.85
VZ-1	1.00	0	0	0	0	0	0	1.00	1.00	1.00	0	0	0	0	1.00	0	0	1.00	1.00	0	0	(1)	1.00
VZ-2	0.48	0.02	0.02	0	0.04	0.14	0	0.34	0.22	0.40	0.35	0.30	0.02	0.04	0.06	0	0.08	0.24	0.18	0.06	0.12	0.02	(1)

The formation of intercommunication classes at different thresholds can be graphically represented as well. The research groups could be laid around a circle arbitrarily in the order of their listing in Table 1, (as in Fig. 1) or in some other order. At each threshold lines are drawn between groups in the intercommunication. Graphic representation has an added information: it shows for each group in a class the number of intercommunication pairs it has, thus one can identify the "stronger" or "central" members of a class and study the "strength" of intercommunication patterns. As an example we present in Fig. 1, graphic representation of intercommunication classes at threshold of 0.20.

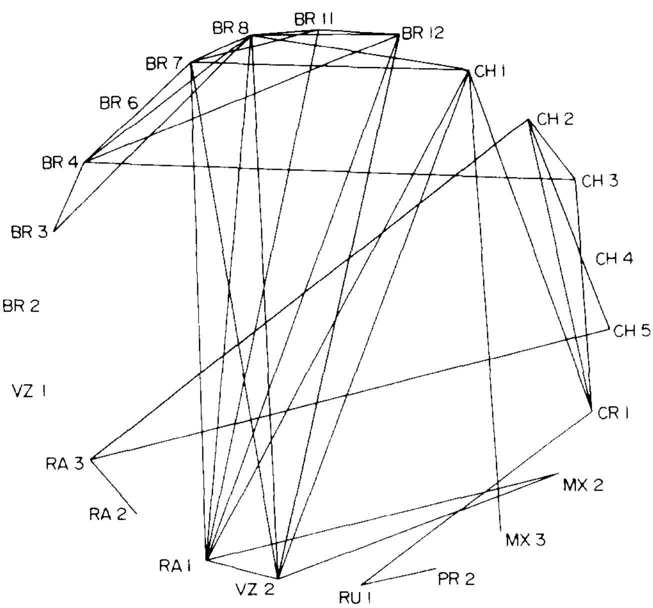

Fig. 1. Graphic representation of the intercommunication network of research groups in solid state physics in Latin America at threshold (probability) of 0.20.

SUMMARY CONCLUSIONS

Bradford-type analyses of the dispersion of articles among journals revealed a non-conformity with the Bradford law and distribution. That is, the distribution of articles written by 23 research groups in solid state physics from Latin America in the period 1967–1971 among journals lacked a strong core (Bradford nucleus) and had a tendency to a linear (Zipfian) distribution with a "collapse" at the end. Brookes suggests that one of the reasons for this particular type of non-conformity may be that the bibliography from which the distribution was constructed was incomplete or the time span of the bibliography was too short—he suggested at least a three year time-span for the bibliography. In this study the bibliography was complete and the time-span was five years, thus a different explanation should be offered. We suggest that the particular non-conformity of the literature dispersion from the expected arose because of the degree of development of the countries involved. Conformity with Bradford's law should be expected in highly developed subjects *and* highly developed countries. A lower stage of development of a subject or a country will cause nonconformity to the law of the type found here. A further investigation may find that this behavior is peculiar to similar epochs of development in all branches of science. It would be interesting to investigate the bibliographic behavior of another area of science in the same region or to investigate a subject area in Europe or the U.S.A. in the period of the late 19th or early 20th century, when conditions in the stage of development were similar. A broader implication is that bibliographic analyses can reveal something about a stage of a subject's or a country's development.

The indirect method-type of analysis of the intercommunication among the 23 research groups in solid state physics in Latin America revealed a relatively low degree of intercommunication. Only after the critical probability was lowered to 0.30 did half of the research groups intercommunicate with each other. Clearly, intercommunication based on journal articles is only one of the many facets of communication among research groups in a scientific discipline. Communication occurs in great many ways, it is affected by many factors and it could be studied in many ways. Thus the low level of intercommunication based on journal articles and studied by the indirect method may be because it represents only a relatively small reflection of the larger spectrum of communication of solid state physicists. It also may be due to the large number of specialized journals devoted to the field; thus the field itself does not exhibit intercommunication through journals to any larger extent than the figures we obtained. Or again we may be seeing a reflection on the development stage. It is hard to know the exact reasons because unlike the Bradford-type analyses, comparable figures do not exist for the indirect method-type of analyses, and similar studies using this method have not yet been done. Consequently, it may be of interest to observe intercommunication based on criteria other than journal articles (e.g. on the base of the topics of research) of the same groups, of similar groups in highly developed countries and regions, or encompassing different epochs. Comparisons between such different analyses using the same method may provide a deeper insight into communications in science.

The research groups in solid state physics in Latin America are spread over a large geographic area (about 2,595,000 km^2); the distances are very great producing relative isolation, the number of indigenous journals is low, and intercommunication seems low as well. All this points towards the necessity for, and the importance of, organizing communication on a regional basis. Research in science conducted in isolation *can not* be fruitful and useful, effective and efficient. We suggest that studies of the type presented here and the methodologies applied here have important applications in assisting science policy making. Information provided by this and similar studies can be used for planning, organizing, coordinating and integrating scientific activity. For those who deal with scientific communication, for information scientists and librarians, such studies and methods have implication for the services provided, for decisions on acquisition and dissemination and for the study of user information needs.

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