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Mapping review networks: Exploring research community roles and contributions

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In this paper we investigate the position of a review network within a research specialty; the network of scholars who write reviews of their colleagues' work. This is one of the voluntary activities that researchers perform as a prerequisite for the functioning of the invisible college. We compare this network to other networks within the specialty, and this allows us to distinguish various roles: *stars*, *influentials*, *members*, *reviewers* and *juniors*. As scholars are characterized by different role-configurations, the invisible college becomes stratified. We discuss the implications for the development of a referee factor and review factor, norms for refereeing and reviewing, and the development of systems-based research evaluations.

Introduction

Scientific communication systems engage scientists in formal research-related activities, informal activities, and volunteer-based activities [GARVEY & GRIFFITH, 1968; GRIFFITH, 1990]. Scientometric evaluations focus predominantly on the formal aspects of scientific communication; measurable outputs such as journal impact factors [GLÄNZEL & MOED, 2002] and citation networks [SMALL, 2005; WHITE, 2001]. Informal activities are elusive and less frequently studied, but research shows that the written acknowledgement in science "has become an institutionalized element of the scholarly communication process" ([CRONIN, 2001, P. 427]; see also, [CRONIN, 1995; DAVIS & CRONIN, 1993]) and in some co-authorship studies there has been an emphasis on underlying processes of informal collaboration [LAUDEL, 2001; MELIN & PERSSON, 1996; NEWMAN, 2004]. Volunteer activities may be defined in terms of the services that scientists undertake to support a scientific communication system – i.e., to ensure that contributions are good for the system as a whole as well as the career of the individual scientist. Such activities include refereeing papers for publication, organising conferences, chairing award/grant committees, and writing reviews of newly published books and papers.

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Research concerning scientific communication systems usually focuses on highly cited and co-cited papers in a research field, and scholars who are research stars; however, voluntary support work is also essential. Without voluntary support work, certain communities, for instance, invisible colleges, might not function effectively. An invisible college is a communication system comprised of approximately 80 to 100 scientists who are part of the social "in-group" of a subject specialty [CRANE, 1972; PRICE, 1986]. Invisible colleges normally grow when scientists from subject specialties share similar interests, interact with one another at select conferences, and communicate new knowledge both formally and informally. Over time, the social network of the invisible college can become more "visible" due to the published output of its scholars [WHITE & AL., 2004; ZUCCALA, 2006].

In this paper we present research results based on an explorative study of review work. Our focus is the scientist from an invisible college network who writes an editorial summary (review) of a colleague's research paper or monograph. The chosen specialty is an area in mathematics known as Singularity Theory. When a new paper is published in Singularity Theory, a mathematician may refer to it in his own work, but prior to this, he may also be asked by a Mathematical Reviews editor to write a formal review. The function of the review is to give colleagues in the specialty (or broader field) a brief idea of its significance so that they can decide whether or not to read or even cite the original work. To be asked to review a particular paper means that a mathematician has acquired the respect of his peers, and has the reputation of being careful, reliable and knowledgeable in the specialized area to which the paper belongs (D. Trotman, personal communication, November 3, 2006). Given the importance that is placed on reviewing in mathematics, our research objective is to investigate who the reviewers are in Singularity Theory research, and what their role is vis-à-vis other types of roles within the invisible college.

Bibliometric methods

Dialog MathSci maintains a record of review contributions; hence 85 prominent Singularity Theorists were selected from this database to construct a review network. MathSci covers international publication data from 1940 to the present. In addition to journal articles, "roughly 10,000 monographs, conference proceedings, theses and technical reports are reviewed annually" (MathSci Bluesheet). Review work in mathematics is formal, but does not need to be extensive: a few lines to 600 words are written to explain main results in a paper. The AMS guide states that a review can sometimes be evaluative; however "negative critical remarks [are expected to be] objective, precise, documented and expressed in good taste." If the reviewer thinks that

the item "duplicates earlier work, [he/she] must cite specific references" and if the reviewer also thinks "that the item is in error, the errors should be described precisely" [MATHEMATICAL REVIEWS DATABASE, 2006].

Our data were collected using both the Dialog MathSci and the Dialog SciSearch citation index. Table 2 in the Appendix demonstrates how the data were categorized before they were used for separate mapping procedures. First, we mapped the Singularities specialty based on the author co-citation analysis procedure outlined in [WHITE & GRIFFITH, 1981], using Cosine as the similarity measure [AHLGREN & AL., 2003; LEYDESDORFF, 2005]. Co-citation counts for the 3570 author pairs [i.e., 85(85-1)/2=3570 pairs] were retrieved from SciSearch for the period 1974 to 2006.

Figure 1 shows the final SPSS-11 multidimensional scaling and cluster routine. With the SPSS cluster procedure three Singularity Theory sub-fields have been identified, including the authors attributed to these fields (A-Real and Complex Analytic Geometry; B-Topology of Complex Algebraic Singularities; C-Singularities of Differentiable Maps). SciSearch was used again to retrieve directed citation counts between the 85 Singularity Theorists, and to create a NetDraw [BORGATTI, 2002] map of their citation network (see Figure 3). The authors at the centre of the spring-embedded network are those who have received the most citations.

With MathSci we retrieved a total publication count for each of the Singularity Theorist, then used the Dialog RANK command to produce a ranked list of mathematicians who have written signed reviews for the author. Figure 2 shows the number of publications for MARIA A. S. RUAS and a ranked list of mathematicians who have reviewed her work. The names highlighted in this list are members of her invisible college (also appearing on Figure 1). With the reviewer and reviewed author data extracted from MathSci, we also created a NetDraw map (principle components layout) to illustrate the key contributors to this invisible college's directed review network (see Figure 4). Reviewers have a distinct role in a research community as cognitive supporters. Again, our objective is to determine who the main reviewers are in Singularities research, and how they relate to other roles within the invisible college.

For our first analysis, we have ranked (ascending) each author in terms of their publication output and compared it to their individual review contributions. Figure 5 shows that reviews tend to be less frequent than publications, yet some authors have reviewed as much as they have published (e.g., HOUSTON, FUKUI, TROTMAN); while others have actually published less, and contributed more to their scholarly communication system as reviewers (e.g., STEVENS, CHILLINGWORTH, GIBLIN). With the ranked reviewer data, we then examined how many reviews have been written by authors 'inside' the Singularity Theory specialty and how many have been written by 'outsiders' from neighbouring subjects (see Figure 6). This particular specialty is open to external reviewing: 86% of this community's published articles have been reviewed by authors from other specialties.

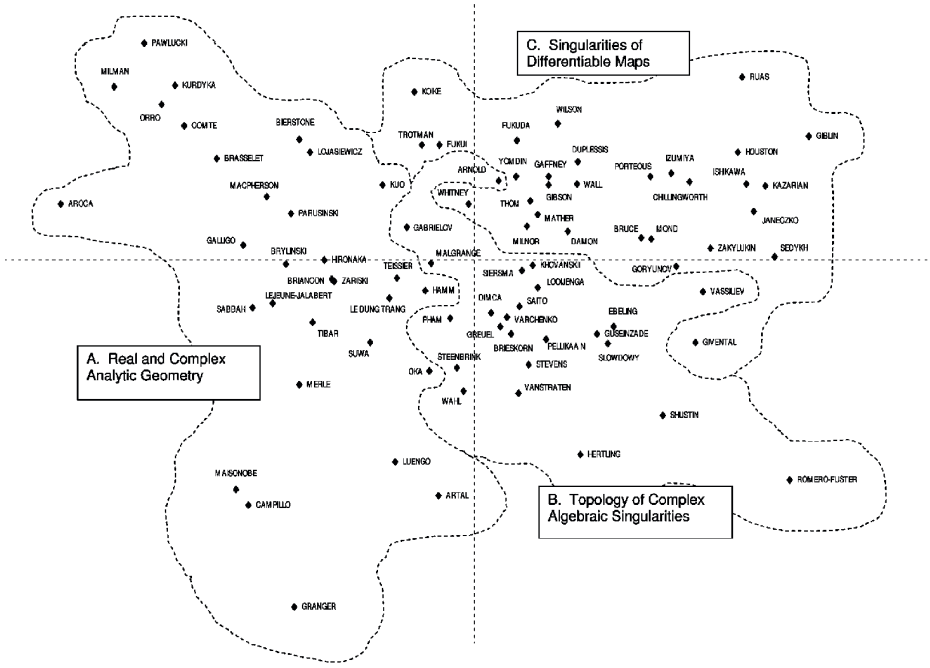

Figure 1. Co-citation map of 85 Singularity Theory authors (1974–2006), and research subfields (SciSearch)

RUAS, MARIA A.S.? = 33 publications (First publication in 1986)

[Reviewers]

RANK No.	Items	Term
1	4	ANDRICA, DORIN
2	3	OUTERELO DOMINGUEZ, ENRIQUE
3	3	WILSON, LESLIE CHARLES
4	2	LI, YANG CHENG
5	2	TIBAR, MIHAI
6	1	BEEM, J. K.
7	1	CHILLINGWORTH, D. R. J.
8	1	FUKUI, TOSHIZUMI
9	1	GOMOZOV, EUGENI P.
10	1	HURLEY, DONAL
11	1	IBANEZ, SANTIAGO
12	1	JANECZKO, STANISLAW
13	1	JIANG, GUANGFENG
14	1	LEVINE, J. P.
15	1	NUNO-BALLESTEROS, JUAN J.
16	1	WEINER, JOEL L.

Figure 2. Number of publications for MARIA A. S. RUAS and ranked reviewers (MathSci)

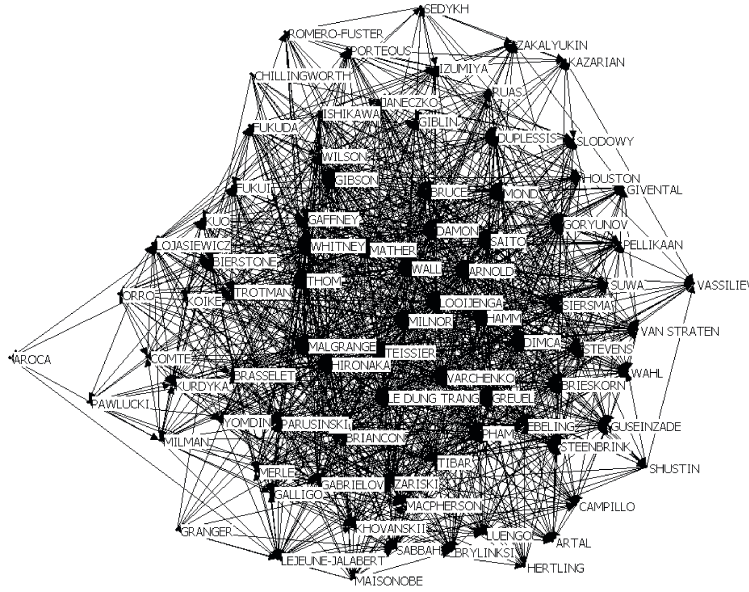

Figure 3. Directed citation network for 85 authors in Singularity Theory (1974–2006; SciSearch)

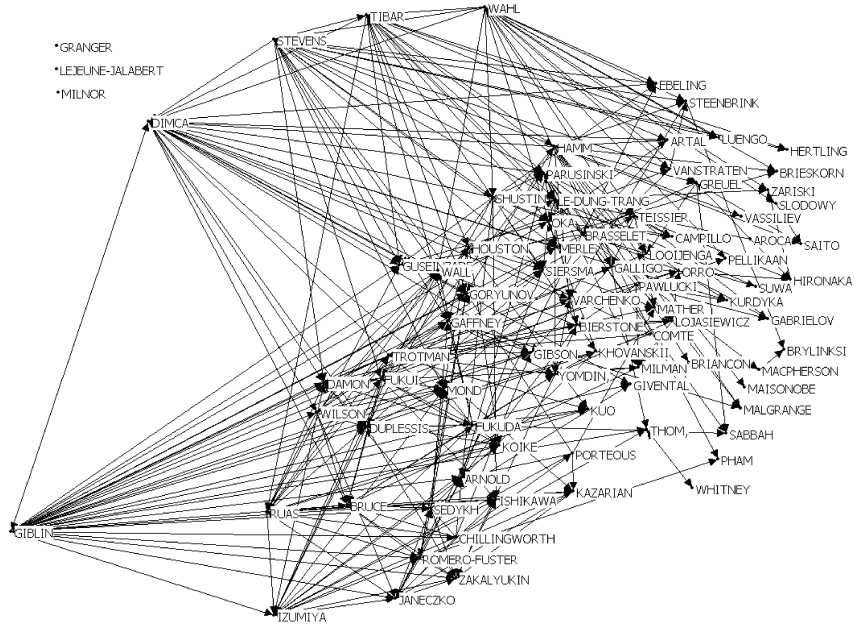

Figure 4. Directed review network for 85 authors in Singularity Theory (1970–2006; MathSci)

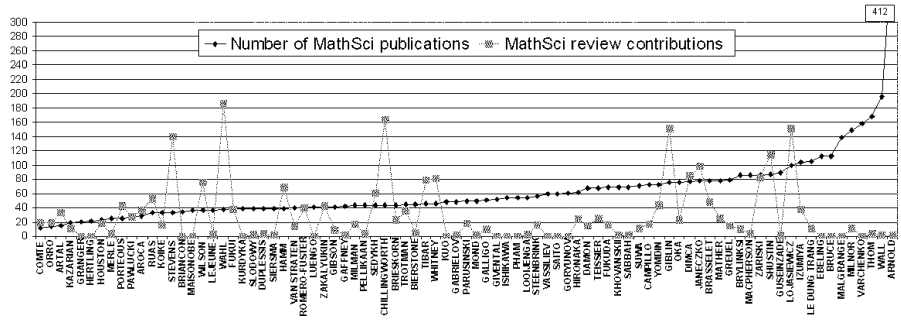

Figure 5. Publication counts for Singularity Theory authors compared to review contributions. Authors ranked by publication count (MathSci)

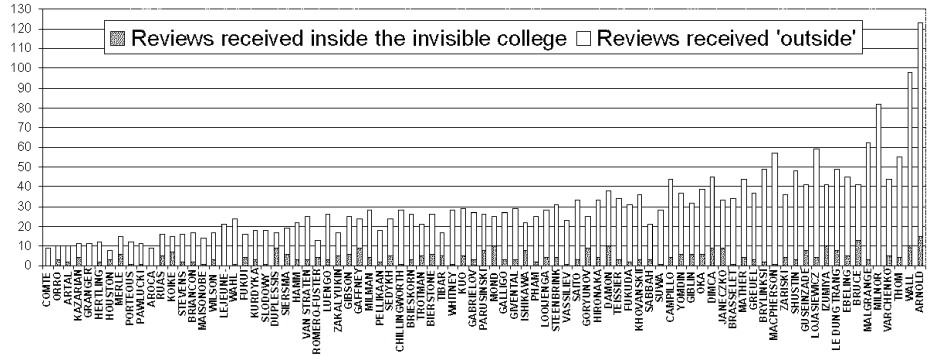

Figure 6. Reviews received by authors within Singularity Theory versus outside reviewers. Authors ranked by number of reviews received (MathSci)

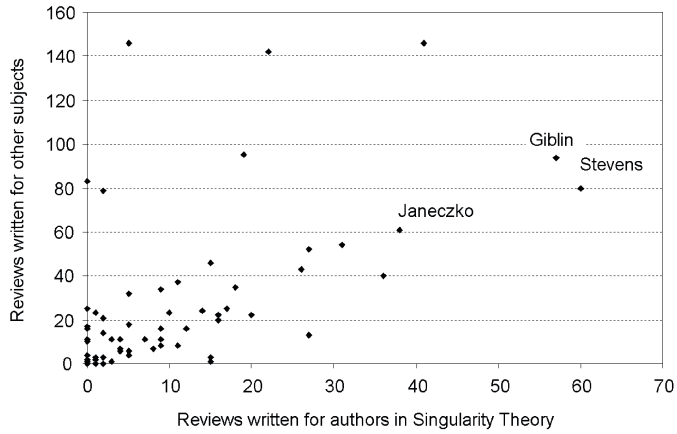

Figure 7. Reviews written for authors in Singularity Theory compared to reviews written for other subjects (MathSci)

We also measured the relationship between the reviews that the Singularity Theorists have written for colleagues within the invisible college to the reviews written for colleagues 'outside' the specialty and found a positive correlation (r=0.620). The scatterplot shown in Figure 7 shows that authors who review papers within the Singularity Theory specialty (e.g., GIBLIN; STEVENS; JANECZKO) also tend to contribute frequently to the mathematics review system in general.

To determine if the Singularity Theorists who review papers are also likely to cite one other (Figures 3 and 4), we used the QAP (Quadradic Assignment Procedure) matrix correlation function in UCINET [BORGATTI & AL., 2002]. A QAP compares the observed correlation with the average correlation of 2500 random permutations. Since the average was zero, with a standard error of 0.015, the observed Pearson correlation value of 0.147 was significant (<0.00). In other words, a positive correlation exists between writing a review of an particular person's work and citing the same person.

Findings

Our bibliometric findings indicate that mathematicians will undertake review work at different stages in their career: junior researchers will write reviews (e.g., COMTE; ORRO) as well as seniors, with stronger publication profiles (e.g., GIBLIN; DIMCA). Figure 5 also shows that there is a small group of well-published mathematicians who have *not* engaged in this type of support work (e.g., LOOIJENGA, PHAM, GORYUNOV), including an elite group of influential mathematicians clustered at the top of the publication rank (e.g., ARNOLD, WALL, MILNOR). Can we explain this review output-versus-publication output imbalance? Yes, but there are perhaps more contributing factors than just one.

Here we cannot account for the personal motivations of a mathematician; hence, those who have been ambitious and/or eager to devote most of their time to research could have refused to write reviews or could have passed the work on to another colleague. Also, if a mathematician has been academically strong – i.e., an influential and recognized leader – he/she might not have had time to write reviews. Influential researchers are typically busy with other roles, such as mentoring Ph.D. students, chairing committees, organising special seminars/workshops, lecturing and travelling to conferences. Junior researchers may have more time for volunteer work, hence those who agree to write reviews could be interested in generating some exposure or demonstrating to the seniors where their abilities and interests lie. Some of the mathematicians may have never been invited to write a review due to a particular language barrier (e.g. Russian members of the invisible college have probably only reviewed work produced in Russian journals). Senior mathematicians who have written reviews might have enjoyed the process, or felt that it was a good way to keep in touch

with new research results. Certain seniors may have also developed a reputation as being very efficient review writers.

Review work in mathematics is not subject-specific or subject-centred. The review system tends to function in a way that is similar to the citation system: a mathematician may cite a relevant paper of interest, just as he or she might review a paper of interest, regardless of the specialty area to which the paper belongs. Specialty areas in mathematics generally grow because there is a core set of research problems for mathematicians to solve, but cross-over interests with other subjects (i.e., permeable boundaries) are expected and allow mathematicians to build important connections. SINGH [1998] reinforces this notion eloquently: "the value of mathematical bridges is enormous. They enable communities of mathematicians who have been living on separate islands…to explore each other's creations" (p. 191).

Our QAP matrix analysis of the review network and citation network points to another logical outcome: mathematicians who review each other's papers also tend to cite each other. If a mathematician becomes familiar with a piece of work and has the appropriate knowledge background to make evaluative or critical remarks, it makes sense that he might use that work to build upon new ideas in his/her own research. The opposite case also makes sense: a researcher who regularly cites the work of a particular colleague (international or not) is also likely to be asked by a mathematics editor to write a review of his/her colleague's publications.

Roles in Singularity Theory

With the bibliometric data that we have collected, our selected authors in Singularities research may be described and compared to each other on the basis of contribution roles. Each role is derived from the co-publication, co-citation, citation, and review data used to create Figures 1, 3 and 4. The roles also stem from our observations of the mathematicians' nodal positions on the three figures. Below, we list five types of contribution roles. Although each role is described separately, they are not necessarily mutually exclusive. Multiple roles, or role configurations (including roles not identified here) can make up an author's complete contribution profile. For instance, we have identified THOM as a *star*, but he has also been *influential* to many early members of the Singularity Theory community. Likewise, GIBLIN is a *member* of the Singularity community, but we know that he has also been a frequent *reviewer*.

1) *Stars:* mathematicians who are central to the specialty area, i.e., highly co-cited with other specialty members and cited frequently by researchers in all of mathematics. Stars have a significant reputation in mathematics as a whole, including the capacity to become award winners. Mathematicians who fit this role include HIRONAKA, MILNOR, THOM, MATHER.

2) *Influentials:* mathematicians who are well-published and highly cited or co-cited. Their work is influential to the specialty area's development, thus they are central to the invisible college's intellectual structure. Mathematicians who fit this role include ARNOLD, ZARISKI, WALL, WHITNEY, BRIESKORN.

3) *Members:* mathematicians with moderate-to-strong publication records who are cited by their specialty colleagues. Members often collaborate with other specialty members; thus their position is slightly more peripheral than stars and influentials. Still, they are major contributors to the invisible college network. Mathematicians who fit this role include BIERSTONE, MILMAN, PARUSINSKI, GUSEINZADE, VAN STRATEN, TIBAR, KURDYKA.

4) *Reviewers:* mathematicians who are members of the specialty research area, but participate often in cognitive support work – in this case, the writing of editorial reviews. Their publication output may or may not be strong, but the amount of work that they do as reviewers is significant. Mathematicians who fit this role include JANECZKO, WAHL, GIBLIN, STEVENS, CHILLINGWORTH.

5) *Juniors:* mathematicians who are students, postdoctoral fellows or relatively new members of the specialty and focused on developing their research profile. Since their publication output is not as strong as other members, they tend to be slightly peripheral in the co-citation network. Mathematicians who fit this role include COMTE, ORRO, KAZARIAN, ARTAL.

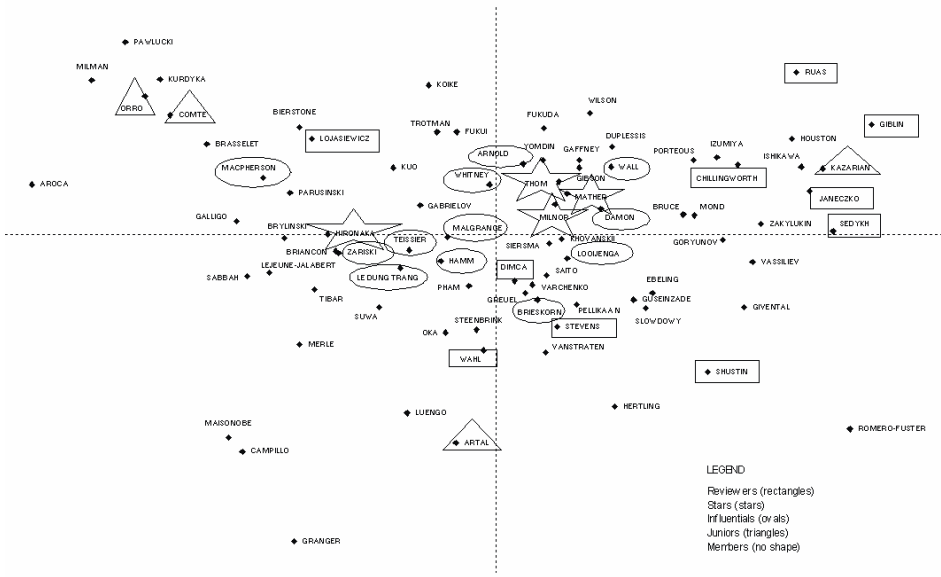

Figure 8. Roles within Singularity Theory research

Figure 8 presents a mapping of the five contribution roles and how they fit within Singularity Theory's basic co-citation (intellectual) structure. Each author on the map is labeled according to his/her last known and most predominant role. The extent to which these roles enable this invisible college to function requires further in-depth study concerning the behaviors of the Singularity Theorists and their degree of investment in role-related activities.

Research implications

This study of the Singularity Theory community possesses interesting research implications concerning support work in science and the degree to which it should be accounted for in performance evaluations. Recently attention has been given to referee work in science (note: a voluntary activity that is similar to reviewing) and the introduction of a new impact measure termed the 'referee factor' [ROUSSEAU, 2006]. WILSON & LANCASTER [2006] suggest that a mathematically defined 'referee factor' "could be built in to standard assessments of performance, acting as an incentive for people to [referee] manuscripts" (p. 812). Both authors are concerned that some scientists do not referee enough papers for publication, however referee work is generally anonymous, so it is not easy to monitor.

Here we show that cognitive support work within the science system is a role-based activity; thus it may be unrealistic to state the following: "for the system to be fair, all scientist should be refereeing two to three times as many articles as they submit" [WILSON & LANCASTER, 2006]. A role-based system implies that a scientist's informal, formal, and volunteer-related contributions are closely tied to the type of role he/she possesses within a research community and may not change unless his/her overall profile (role configuration) changes. For example, in order for a research *star* or *influential* to referee two to three times as many articles as he or she produces, this scientist might need to minimize work associated with other areas of contribution – i.e., organizing international meetings, mentoring Ph.D. students; traveling to give special seminars, etc.

And finally, if our distinction between roles makes sense, then perhaps more thought needs to be given to role-based evaluations in different parts of the science system. General statements about the number of reviews a scientist must write, or papers he/she must referee relative to his or her publication output are not useful if they neglect the importance of roles. We know, for instance, that a football team needs a variety of players to perform different functions on the field (e.g., goalkeeper; strikers; midfielders; defenders), and that *all players* cannot *at the same time* play the position of striker (at most two). We use this metaphor because it shows us that research specialties tend to operate according to the same principle. Different roles have to be performed by scientists at different times throughout the development of a specialty/invisible college, and all roles must be in balance to ensure that the community is functioning

successfully. If a researcher is evaluated only on one dimension we fail to recognize the impact he or she is having while playing other critical roles. Role-based assessments can tell us whether or not critical roles are being carried and where changes might be introduced to create improvements.

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Appendix

Alphabetical list of Singularity Theory authors (n = 85) and data categories

AUTHOR	Year of 1st publication	Number of MathSci publications	Average cocitation rate with other invisible college members	Citations received by indivisible college members	MathSci review contributions	Review contributions to Invisible College	External review contributions	Reviews received inside the invisible college	Reviews received 'outside' the invisible college
ARNOLD	1957	412	68	503	1	0	1	15	108
AROCA	1971	29	2	11	37	5	32	0	9
ARTAL	1991	15	3	16	33	10	23	2	8
BIERSTONE	1973	45	14	85	5	2	3	6	20
BRASSELET	1973	78	4	26	48	11	37	1	33
BRIANCON	1973	34	14	105	0	0	0	2	15
BRIESKORN	1964	44	25	134	23	2	21	3	23
BRUCE	1979	112	19	183	0	0	0	13	28
BRYLINKSI	1975	86	7	49	10	0	10	2	47
CAMPILLO	1978	72	2	15	17	0	17	4	40
CHILLINGWORTH	1967	44	2	0	164	22	142	1	27
COMTE	1996	11	1	5	19	11	8	0	9
DAMON	1973	68	18	120	15	8	7	10	28
DIMCA	1976	77	12	60	85	31	54	9	36
DUPLESSIS	1975	39	9	73	4	3	1	9	8
EBELING	1962	112	6	34	0	0	0	5	40
FUKUDA	1966	69	5	43	16	15	1	2	29
FUKUI	1985	39	3	30	38	16	22	4	12
GABRIELOV	1968	48	10	66	1	0	1	3	24
GAFFNEY	1976	42	11	84	1	1	0	9	15
GALLIGO	1973	50	5	34	10	4	6	3	24
GIBLIN	1968	76	2	16	151	57	94	6	26
GIBSON	1969	41	15	120	9	5	4	6	19
GIVENTAL	1980	52	5	38	0	0	0	3	26
GORYUNOV	1978	61	7	56	0	0	0	9	16
GRANGER	1967	21	0	2	0	0	0	0	11
GREUEL	1975	79	17	118	15	4	11	3	34
GUSEINZADE	1966	89	5	37	1	0	1	8	33
HAMM	1971	39	16	118	69	26	43	3	19
HERTLING	1993	22	1	3	0	0	0	2	10
HIRONAKA	1957	62	30	198	24	1	23	4	29
HOUSTON	1997	23	2	5	18	15	3	3	5
ISHIKAWA	1983	54	1	6	0	0	0	8	14
IZUMIYA	1978	104	4	20	38	14	24	10	31
JANECZKO	1982	78	3	14	99	38	61	9	24
KAZARIAN	1993	20	2	9	11	4	7	4	7
KHOVANSKII	1978	69	7	40	1	1	0	3	33
KOIKE	1979	33	2	20	16	0	16	7	8
KUO	1965	48	9	64	0	0	0	5	24
KURDYKA	1984	39	4	26	0	0	0	3	15
LE DUNG TRANG	1970	105	25	167	11	5	6	8	41
LEJEUNE-JALABERT	1971	37	6	47	2	0	2	0	21
LOJASIEWICZ	1950	100	15	82	151	5	146	4	55
LOOUENGA	1971	54	24	235	2	0	2	4	24
LUENGO	1981	41	2	14	0	0	0	3	23
MACPHERSON	1967	86	7	37	4	1	3	1	56
MAISONOBE	1979	37	1	8	0	0	0	1	13
MALGRANGE	1963	139	22	145	0	0	0	3	59
MATHER	1965	78	37	301	25	0	25	4	40
MERLE	1973	25	4	14	3	1	2	6	9
MILMAN	1976	43	1	12	17	9	8	4	24
MILNOR	1950	149	63	273	11	0	11	0	82
MOND	1978	49	9	77	1	0	1	10	15
OKA	1972	76	8	44	23	5	18	6	33
ORRO	1983	14	1	9	20	9	11	3	7
PARUSINSKI	1985	49	7	48	18	7	11	8	18
PAWLUCKI	1984	26	3	24	28	12	16	1	10
PELLIKAAN	1988	43	3	11	4	0	4	2	16
PHAM	1963	54	13	83	0	0	0	2	23
PORTEOUS	1960	25	5	63	42	17	25	1	11
ROMERO-FUSTER	1983	41	0	9	40	27	13	4	9
RUAS	1986	33	1	1	53	18	35	5	11
SABBAH	1978	69	8	41	1	0	1	3	18
SAITO	1971	59	19	126	0	0	0	3	30
SEDYKH	1981	44	2	5	61	15	46	5	19
SHUSTIN	1980	87	2	11	114	19	95	3	45
SIERSMA	1973	39	14	92	1	1	0	6	13
SLODOWY	1978	39	5	25	2	2	0	1	17
STEENBRINK	1975	56	13	91	16	2	14	4	27
STEVENS	1984	33	4	21	140	60	80	2	14
SUWA	1969	71	2	8	11	0	11	1	27
TEISSIER	1970	68	26	201	25	9	16	3	31
THOM	1949	168	34	175	3	1	2	4	51
TIBAR	1984	46	4	18	79	27	52	5	12
TROTMAN	1976	45	5	33	36	16	20	5	16
VAN STRATEN	1985	40	3	17	14	3	11	3	22
VARCHENKO	1975	158	19	117	0	0	0	5	39
VASSILIEV	1990	59	4	19	0	0	0	1	22
WAHL	1974	38	10	65	187	41	146	1	23
WALL	1955	196	34	247	1	1	0	10	88
WHITNEY	1940	46	27	163	81	2	79	1	27
WILSON	1976	37	4	23	76	36	40	3	14
YOMDIN	1973	72	3	13	43	9	34	6	31
ZAKALYUKIN	1983	41	6	69	42	20	22	5	12
ZARISKI	1940	86	24	163	83	0	83	4	32