

SLOBODAN SIMIĆ: AN APPRECIATION

DRAGOŠ CVETKOVIĆ

Mathematical Institute (SANU)
Serbian Academy of Sciences and Arts
Kneza Mihaila 36
11000 Beograd, Serbia
e-mail: ecvetkod@etf.rs

AND

PETER ROWLINSON

Mathematics and Statistics Group
Division of Computing Science and Mathematics
Scotland FK9 4LA, United Kingdom
e-mail: p.rowlinson@stirling.ac.uk

In the memory of Slobodan Simić

Abstract

Slobodan Simić¹ had many interests and many friends. Doubtless each of his 66 co-authors² has a story to tell, but here we can offer only our own personal perspectives.

Keywords: Slobodan Simić.

2010 Mathematics Subject Classification: 01A70.

1. A DISTINGUISHED RECORD

DC writes: In 2017, I published my “Autobiographical notes” [4], which concentrated primarily on my scientific work. According to the Index of Names, Slobodan Simić is the person most frequently mentioned there. Following chronological records in the book, I present several steps in the scientific career of Slobodan Simić, who was my master’s and doctoral student.

¹Slobodan Simić untimely died on May 16, 2019.

²as listed in MathSciNet, February 8, 2019.

1970, summer term

In the academic year 1969/70 I delivered a non-obligatory course in Graph Theory for students at the Faculty of Electrical Engineering, University of Belgrade. Some 20 – 30 students attended the course and six of them successfully passed the examination, among them Slobodan Simić and Laslo Kraus. Both of them became my collaborators in scientific work.

1971, April 25

I nominated students Slobodan Simić and Laslo Kraus for a student award³ for 1971 for their first steps in scientific work. They received this award a little later, as recorded in an official document on June 4.

1973, June 25 – July 1

Together with Slobodan Simić and Ivan Gutman, I took part in the work of the International Colloquium on Infinite and Finite Sets in Keszthely on Balaton Lake in Hungary. The conference was devoted to the famous Hungarian mathematician Paul Erdős on the occasion of his 60th birthday. Slobodan was driving us in a Ford car belonging to his father, a University Professor. We went through Croatia to pick up Ivan Gutman in Zagreb.

1974, June 24–30

The Fifth Balkan Mathematical Congress took place in Belgrade. Among the participants from abroad were Paul Erdős and Horst Sachs. Simić and I were showing Belgrade to Erdős and Sachs. Professor Erdős had forgotten his case (the only property that he had, as he pointed out) at the airport. Consequently we drove to the airport and retrieved the case. We took the guests to mount Avala, near Belgrade, and also to Vršac Hill in Vršac.

1974, over the year

Slobodan and I took part in the scientific project “Automated Design”. The project leader was Branko Raković, Professor of Electronics.

1977, April 10–16

Together with Slobodan Simić and accompanied by my wife Zorica, I took part in the International Colloquium for Graph Theory and Applications in Oberhof, in the former German Democratic Republic. The colloquium was held in honour of Professor Horst Sachs on the occasion of his 50th birthday. We drove there by way of Budapest, Vienna, Prague and Dresden and back via Nürnberg and Linz.

³The award was established by editors of a series of books “Topics in Mathematics (Mathematical Library)”, published by the Department of Mathematics.

1977, May 5

S. Simić submitted to the Faculty of Electrical Engineering a proposal for the subject of a doctoral thesis. The proposal was accepted on June 21. On July 20 I informed Professor J.J. Seidel (in The Netherlands) about this thesis in progress.

1977, August 2

I proposed to the Japanese mathematician J. Akiyama that S. Simić, J. Akiyama and K. Kaneko publish a joint paper [1] since they had all come independently to the same results. All three colleagues agreed. This case was later described by F. Harary in his article on independent discoveries in graph theory [23]:

“Here are two more draw stories both involving the Japanese graph theorist, Jin Akiyama. By way of background, I met in person both Dragoš Cvetković and his doctoral student S. Simić on arrival at Belgrade airport in 1974. At about the same time, Akiyama and his student K. Kaneko were also deriving graph equations for line graphs and n -th power graphs. Friendly correspondence between Tokyo and Belgrade led to a triply joint paper which is to appear in 1980.⁴”

1977, October 26–28

A visit to Graz and Leoben in Austria together with S. Simić and my wife Zorica.

1977, November 5

I wrote a positive report on the paper [1] mentioned above.

1979, June 24–26

The American mathematician F. Harary delivered a few lectures on graph theory in Ljubljana, Slovenia. Slobodan and I flew there to take part. Immediately before this trip Slobodan married Vesna.

1980, April – June

During my scientific trip to USA and Canada I discussed with J. Akiyama the possibility of writing a joint scientific monograph on graph equations, in which G. Exo (USA) and S. Simić would take part. This project was never realized.

1980, November 22

A meeting of the Belgrade — Ljubljana Graph Theory Group was held in Belgrade. There were three participants from Ljubljana (T. Pisanski, V. Batagelj and B. Mohar) and five from Serbia, among them S. Simić. This meeting was later declared to be the first Yugoslav Symposium on Graph Theory.

⁴In fact, the paper had already appeared in 1978.

1982, October 25

Slobodan and I submitted to the Mathematical Institute, Belgrade, the manuscript of our joint book “Combinatorics — Classical and Modern” [20].

1984, March 6

The paper [25] with only two authors (Radosavljević and Simić) was already in print, when a paper by M. Syslo and J. Topp with the same result was submitted to a domestic journal. At my suggestion, all interested parties agreed that the names of our Polish colleagues should be added to the list of authors. Such an unbelievable case of independent discoveries had already occurred with S. Simić (see year 1977 above).

1986, April 15

Being at the University of Stirling, Scotland, for the whole 1985/86 academic year, I was writing letters of recommendation for S. Simić for several universities in the USA.

1990, May 2–4

Together with Slobodan, I took part in the third Meeting of the European Group for Combinatorial Optimization in Barcelona. We were accompanied by members of our families (Slobodan’s son, wife and her sister and my wife). We were staying in Lloret del Mar in the neighborhood of Barcelona.

1991, March 9

I celebrated my 50th birthday together with some friends. Slobodan was not able to come since he had some problems with the police, who were present that day throughout Belgrade because of large demonstrations.

1991, October

After the tragic death of my wife Zorica in June this year, several memorial meetings with family and friends took place. One such meeting was attended by Slobodan and his wife Vesna.

1994, July 17 – August 2

I visited Stirling, together with Slobodan and our wives. The purpose of the trip was the work on a scientific monograph, jointly with our Scottish colleague Peter Rowlinson, on eigenspaces of graphs [10].

1995, April 14–16

Together with Slobodan, I took part in the conference “Algebra, Logic, Discrete Mathematics” in Niš, Serbia. We gave one invited talk on graphs with small second largest eigenvalue [21]: both took part in the presentation. There were over 100 participants, some 20 of them from abroad.

1996, January 31

Peter Rowlinson submitted to the publishing house (Cambridge University Press) the manuscript of our new book [10]. We were working on the book for the last few years. These days we signed the contract for the book and completed the publisher's questionnaire concerning the marketing of the book.

1996, March 15

Professor S. Bogdanović informed me and Slobodan that a new edition of our book "Discrete Mathematics" [22] had just been published in Niš.

1996, March 26

We presented our forthcoming book "Eigenspaces of Graphs" [10] at the Seminar for Graph Theory in Novi Sad, Serbia.

1996, April 18

Slobodan and I met with a group of colleagues from the Technological Faculty, Belgrade, who were interested in discrete mathematics.

1996, May 5

A public promotion of our book "Discrete Mathematics" [22] took place in Niš with the participation of the authors.

1997, May 13

Presentation of the scientific monograph "Eigenspaces of Graphs" [10] in the Serbian Academy of Sciences and Arts. The speakers were Academicians Ivan Gutman and Aleksandar Ivić, Slobodan Simić and myself.

1997, December 2

Peter Rowlinson told us that the funding bodies in Great Britain had approved plans for a joint scientific project next year, including a one month stay by Slobodan and me at the University of Stirling.

1998, July 8

Slobodan and I, together with our wives Vesna and Nevenka, arrived at Stirling University, Scotland. We spent one month in Stirling working together with Peter Rowlinson on star partitions of graphs and other subjects.⁵ As a result we subsequently published four papers [8, 11, 12, 13].

1999, January 9

I invited a few colleagues from the Department of Mathematics at the Faculty of Electrical Engineering, including Slobodan, to my house for informal talks on the situation at the Faculty. At that moment I was the Head of the Department and the situation at the Faculty was very unpleasant because of the policy of the Government towards universities.

⁵Several records in the book concerning Slobodan and related to our work this July are omitted here.

1999, March 25

A short meeting with Slobodan at the Faculty during the aggression of the NATO Alliance on Serbia.⁶ Almost nobody was at the Faculty. All were upset.

1999, August 9

Motivated by results on a special class of graphs (graphs with least eigenvalue -2) obtained by Slobodan, Peter and me (with computational support from M. Lepović), I proposed to Slobodan and Peter writing a joint book on the subject.

2001, first few months

Slobodan, Peter and I were working very hard on our book with the working title “Graphs with Least Eigenvalue -2 ” [16]. There were several versions of the manuscript: purple, green, blue, orange and pink, according to the colour of the paper on which they were printed.

2001, July 1–6

I presented (jointly with Slobodan and Peter) paper “The maximal exceptional graphs with largest degree less than 28” [14] at the 18th British Combinatorial Conference held at the University of Sussex in Brighton.

2001, July 14–28

Slobodan and I were the guests at the University of Stirling. Together with Peter we continued our work on the monograph [16].

2001, November 22

Promotion of the monograph [24] by M. Petrović and Z. Radosavljević at the University of Kragujevac, Serbia. The speakers were S. Simić and me.

2001, December 16

Correspondence with Professor U.R.S. Murty concerning refereeing papers for the journal *J. Combinatorial Theory, Series B*. Although the starting point was quite different, I drew his attention to my paper [9] (coauthors M. Lepović, P. Rowlinson and S. Simić) submitted to the journal two years ago but still without referee reports. Very soon two positive reports were received, and the paper was published in 2002.

2002, May 10

A meeting in the Mathematical Institute, Belgrade, devoted to my 50th published book. Vera Kovačević-Vučević and Slobodan Simić were speaking about my books.

2002, August 11–15

I presented the paper [15], coauthored by P. Rowlinson and S. Simić, at the conference “Geometric and Algebraic Combinatorics” in Oisterwijk, The Netherlands.

⁶See https://en.wikipedia.org/wiki/NATO_bombing_of_Yugoslavia.

2002, December 2

I sent to Slobodan an e-mail from Australia concerning my stay there. In particular, I reported that some colleagues from Australia had used our results (joint with M. Doob) on eigenvectors of the eigenvalue -2 in generalized line graphs [6].

2003, May 29 – June 8

Peter Rowlinson with his wife Carolyn were on a visit to Belgrade. Slobodan, Peter and I were just finishing our book [16]. Peter visited several places: Kragujevac, Sremska Mitrovica and Kotor (Montenegro), where he was the guest of Slobodan Simić.

2003, August

Slobodan, Peter and I submitted the manuscript of our book [16] to the publisher (Cambridge University Press).

2003, November 20

A meeting of the Department of Mathematics. Simić was the Head of the Department and, because of several problems affecting his health, he tried several times to resign his post but that was not accepted by the Dean (of the Faculty of Electrical Engineering).

2004, February

Proof reading of our book [16]. We were in touch with an Indian company which was responsible for the final form of the \LaTeX files of the book.

2005, February 19

Academician Aleksandar Ivić and Professor Žarko Mija]lović nominated our book [16] for the Award of the City of Belgrade. The nomination related only to Slobodan and me since the award was confined to citizens of Serbia.

2005, March 15

The list of nominated books for the Award has been published in the daily press (Večernje novosti). Our book was listed among 9 books from the area of natural and technical sciences.

2005, March 24

Together with Slobodan I submitted to the jury for the Award some additional information on the book. However, our book did not receive the Award.

2005, July 10–24

Slobodan and I were in Great Britain. In the first week we were at the 20th British Combinatorial Conference in Durham. The next week we spent at the University of Stirling, where we continued together with P. Rowlinson and F.K. Bell our earlier investigations on star complements of graphs. The UK's Engineering and Physical Sciences Research Council [EPSRC] supported our stay, together with the University of Stirling.

2006, March 23

P. Rowlinson sent us three very favourable reports from the EPSRC on the outcomes of our project the previous year.

2006, September 5

A one day conference “Spectra of Graphs and Applications”, SGA2006, on the occasion of 40 years of my scientific work and 65th birthday. Many participants from abroad and from Serbia, among them Slobodan Simić and Peter Rowlinson.

2007, May

I acquired a working room from the Serbian Academy of Sciences and Arts [SASA] in the building across from the main building of SASA. The room was within the Mathematical Institute. Since the room was big enough, I shared it with my collaborators Slobodan Simić and Tatjana Davidović.

2007, December

A book describing the work of our scientific project [7] has been published. Among other topics a biography and bibliography of Slobodan Simić was included.

2009, October

The scientific monograph “An Introduction to the Theory of Graph Spectra” [18] has been published.

2010, May 23

A call for proposals of scientific projects has been issued by the Serbian Ministry of Science. Slobodan Simić became leader of our project since I was in retirement.

2011, January

I became deputy project leader. However, Slobodan passed to me all duties of a project leader.

2011, November 15

A special issue of the scientific journal *Linear Algebra and Its Applications* devoted to my 70th birthday has been published. Slobodan Simić was one of the guest editors for this issue.

2013, October 11

The Award of SASA for Mathematics for 2013 has been granted to a group of five Research Professors from Mathematical Institute, among them Slobodan Simić.

2014, April 3

A lecture in SASA by two of five colleagues who had received an Award of SASA, namely Slobodan Simić and Nenad Mladenović.

2016, May 18–20

International scientific conference “Spectra of Graphs and Applications”, SGA2016, on the occasion of my 75th birthday. Slobodan was absent because of illness.⁷

2. RECOLLECTIONS

PR adds: I do not keep a permanent diary, but I have strong recollections of collaboration with Slobodan over three decades. In particular, I recall his embrace of star complements [11], his work on the signless Laplacian [17], and his introduction of an edge-colouring technique in a new proof that generalized line graphs are characterized by 31 forbidden subgraphs [15]. Of course, he has contributed to many other areas of algebraic graph theory, and beyond. He has made several visits to Stirling, not always with DC, but more often than not with his wife Vesna. On return visits to Belgrade with my wife, they have always made us very welcome. We have discussed mathematics in many locations, from a dungeon in Glendevon (Scotland) to a beach near Ulcinj (Montenegro). The latter was reached by road from Kotor, where we stayed in his late mother’s picturesque house and were presented with the first fig of the season. After a drive of 80 kilometres we transferred to a large black Mercedes: the ominous overtones of this vehicle faded as a rough track gave way to the shoreline and a small restaurant. Here we enjoyed a sumptuous open-air supper, cooked on an open fire, with views to nearby Albania.

Slobodan has engaged with mathematicians in several countries: in Stirling he developed a close relationship with my late colleague Francis Bell [3], and in Messina (Sicily) with Enzo Li Marzi [2], who invited us as speakers to a memorable conference in Messina in March 2002. On 24 July 2001, Slobodan, Francis Bell and their wives enjoyed a visit to St Andrews (Scotland), a day which turned out to be Slobodan’s birthday. Unfortunately, the untimely death of Francis Bell in 2006 curtailed a fruitful and growing collaboration with Slobodan, whose friendship was much valued by Francis. But the mathematics continues, and those of us in the scattered community of spectral graph theorists look forward to yet more contributions from this versatile mathematician.

3. THREE BOOKS

Three monographs written jointly by DC, PR and Slobodan Simić were mentioned in Section 1: *Eigenspaces of Graphs* [10], *Spectral Generalizations of Line Graphs*:

⁷In addition, Slobodan Simić is mentioned in some appendices in the book [4] but this is not included here.

on *Graphs with Least Eigenvalue -2* [16] and *An Introduction to the Theory of Graph Spectra* [18]. We give a short commentary on these books, highlighting the enthusiastic engagement of Slobodan in their preparation. Each of the books was completed before a publisher was sought, and we were fortunate in that our first choice of Cambridge University Press [CUP] was realized. We are grateful to Roger Astley of CUP for his help in bringing our projects to fruition.

The first book was proposed by DC in view of new results on graph angles (DC) and star partitions (PR). It soon became clear that the book would be enhanced by incorporating some of Slobodan's results, in particular his algorithm for constructing a star partition and his theorems on the largest and second largest eigenvalue of a graph. Fortunately, Slobodan agreed to become the third author and the book was published in 1997 as volume 66 in the series *Encyclopedia of Mathematics and its Applications*. It was well received: "This outstanding book ..." [R. Merris, *Image* (International Linear Algebra Society) 21 (1998) 6–7], "... highly recommended ..." [R.J. Wilson, *Proc. Edinburgh Math. Soc.* 42 (1999) 658].

Meanwhile, star complements (introduced independently by Mark Ellingham and PR in 1993) had come to the fore as a means of investigating the relation between graph structure and a single eigenvalue. By 1999, we had realized that they could be used to determine the maximal exceptional graphs;⁸ more precisely, they brought a solution within the scope of the computers available at the time. (As mentioned briefly in Section 1, the programming was undertaken in 1999 by Mirko Lepović in Kragujevac: he worked in very difficult circumstances because NATO targeted Kragujevac with graphite bombs which caused repeated disruption to the electricity supply.) The identification of the 573 maximal exceptional graphs was the catalyst for a second book. There we included Slobodan's more recent results on graphs with a small second largest eigenvalue and an outline of his proof confirming the polynomial reconstruction conjecture for graphs with least eigenvalue -2 . The book was published in 2004 and received favourable reviews: "... this book will be the standard guide" [P.J. Cameron, *Bull. London Math. Soc.* 37 (2005) 479–480], "... deserves a place on the bookshelf ..." [M. Doob, *Mathematical Reviews* MR2120511 (2005m:05003)]. In 2015 we published as a supplement to this book the paper [19], in which we surveyed progress in the area over the previous decade.

By the time our second book was completed, the monograph [5] was out of print, and so we decided that a third book would be useful. The first edition of [5], published in 1980, was an essentially comprehensive treatise on graph spectra, but the subsequent exponential growth in the number of papers in spectral graph theory precluded a fully comparable treatment. We decided on a self-contained

⁸An exceptional graph is a connected graph, other than a generalized line graph, whose eigenvalues lie in $[-2, \infty)$.

introductory text aimed at graduate students, with a selection of classical and modern topics. Building on previous experience, each author wrote three chapters, and these were then supplemented and re-written by the other two authors. As usual, it was a pleasure to work with Slobodan, and we saw our third book published in 2009: “an excellent resource for researchers” [J.T. Soccoman, *Mathematical Association of America*, Review 16 August 2010], “the one and only ‘bible’ of the field — no other text comes close in quality or completeness”, [Amazon customer review, 15 June 2013]. It is clear that Slobodan should have taken pride in his achievements.

REFERENCES

- [1] J. Akiyama, K. Kaneko and S.K. Simić, *Graph equations for line and n -th power graphs*, Publ. Inst. Math. (Beograd) **23(37)** (1978) 5–8.
- [2] F.K. Bell, E.M. Li Marzi and S.K. Simić, *Some new results on graphs with least eigenvalue not less than -2* , Rend. Sem. Mat. Messina Ser. II **9(25)** (2003) 11–30.
- [3] F.K. Bell and S.K. Simić, *On graphs whose star complement for -2 is a path or a cycle*, Linear Algebra Appl. **377** (2004) 249–265.
doi:10.1016/j.laa.2003.08.016
- [4] D. Cvetković, *Autobiographical Notes*, V. Kovačević-Vujčić (Ed.), (Akademska misao, Beograd, 2017), in Serbian.
- [5] D. Cvetković, M. Doob and H. Sachs, *Spectra of Graphs*, 3rd Edition (Johann Ambrosius Barth, Heidelberg, 1995).
- [6] D. Cvetković, M. Doob and S.K. Simić, *Generalized line graphs*, J. Graph Theory **5** (1981) 385–399.
doi:10.1002/jgt.3190050408
- [7] D. Cvetković, I. Gutman and V. Kovačević-Vujčić (Eds.), *Graphs, Optimization, Chemistry: Reports on the Work of a Scientific Project* (Akademska misao, Beograd, 2007), in Serbian.
- [8] D. Cvetković, M. Lepović, P. Rowlinson and S.K. Simić, *A database of star complements of graphs*, Univ. Beograd, Publ. Elektrotehn. Fak., Ser. Mat **9** (1998) 103–112.
- [9] D. Cvetković, M. Lepović, P. Rowlinson and S.K. Simić, *The maximal exceptional graphs*, J. Combin. Theory Ser. B **86** (2002) 347–363.
doi:10.1006/jctb.2002.2132
- [10] D. Cvetković, P. Rowlinson and S.K. Simić, *Eigenspaces of Graphs* (Cambridge University Press, Cambridge, 1997).
doi:10.1017/CBO9781139086547
- [11] D. Cvetković, P. Rowlinson and S.K. Simić, *Graphs with least eigenvalue -2 : the star complement technique*, J. Algebraic Combin. **14** (2001) 5–16.
doi:10.1023/A:1011209801191

- [12] D. Cvetković, P. Rowlinson and S.K. Simić, *Some additions to the theory of star partitions of graphs*, Discuss. Math. Graph Theory **19** (1999) 119–134.
doi:10.7151/dmgt.1089
- [13] D. Cvetković, P. Rowlinson and S.K. Simić, *Some characterizations of graphs by star complements*, Linear Algebra Appl. **301** (1999) 81–87.
doi:10.1016/S0024-3795(99)00179-2
- [14] D. Cvetković, P. Rowlinson and S.K. Simić, *The maximal exceptional graphs with largest degree less than 28*, Bull. Acad. Serbe Sci. Arts, Cl. Sci. Math. Natur. Sci. Math. **122** (2001) 115–131.
- [15] D. Cvetković, P. Rowlinson and S.K. Simić, *Graphs with least eigenvalue -2 : a new proof of the 31 forbidden subgraphs theorem*, Des. Codes Cryptogr. **34** (2005) 229–240.
doi:10.1007/s10623-004-4856-5
- [16] D. Cvetković, P. Rowlinson and S.K. Simić, *Spectral Generalizations of Line Graphs: on Graphs with Least Eigenvalue -2* (Cambridge University Press, Cambridge, 2004).
doi:10.1017/CBO9780511751752
- [17] D. Cvetković, P. Rowlinson and S.K. Simić, *Signless Laplacians of finite graphs*, Linear Algebra Appl. **423** (2007) 155–171.
doi:10.1016/j.laa.2007.01.009
- [18] D. Cvetković, P. Rowlinson and S.K. Simić, *An Introduction to the Theory of Graph Spectra* (Cambridge University Press, Cambridge, 2009).
doi:10.1017/CBO9780511801518
- [19] D. Cvetković, P. Rowlinson and S.K. Simić, *Graphs with least eigenvalue at least -2 : ten years on*, Linear Algebra Appl. **484** (2015) 504–539.
doi:10.1016/j.laa.2015.06.012
- [20] D. Cvetković and S.K. Simić, *Combinatorics—Classical and Modern*, Naučna knjiga (Beograd, 1984), in Serbian.
- [21] D. Cvetković and S.K. Simić, *The second largest eigenvalue of a graph—a survey*, Int. Conf. on Algebra, Logic & Discrete Math., Niš, April 14–16, 1995, Bogdanović, Ćirić and Ž. Perović (Eds.), (FILOMAT (Niš) **9**, 1995) 449–472.
- [22] D. Cvetković and S.K. Simić, *Discrete Mathematics, Mathematics for Computer Science, Improved and Extended Edition* (Prosveta, Niš, 1996), in Serbian.
- [23] F. Harary, *Independent discoveries in graph theory*, Annals of the New York Academy of Sciences **328** (1979) 1–4.
doi:10.1111/j.1749-6632.1979.tb17761.x
- [24] M. Petrović and Z. Radosavljević, *Spectrally Constrained Graphs* (Faculty of Science, Kragujevac, 2001).
- [25] Z. Radosavljević, S.K. Simić, M. Sysło and J. Topp, *A note on generalized line graphs*, Publ. Inst. Math. (Beograd) **34(48)** (1983) 193–198.

Received 11 January 2019

Revised 12 February 2019

Accepted 12 February 2019