

Proceedings of the INTERNATIONAL  
CONGRESS OF MATHEMATICIANS  
1986

VOLUME 1

August 3–11, 1986  
Berkeley, California, USA



PROCEEDINGS OF THE  
INTERNATIONAL CONGRESS OF  
MATHEMATICIANS

AUGUST 3–11, 1986





# INTERNATIONAL CONGRESS OF MATHEMATICIANS

Berkeley, California

August 3-11, 1986

EDITED BY

ANDREW M. GLEASON

## Library of Congress-in-Publication Data

International Congress of Mathematicians (1986: Berkeley, Calif.)

Proceedings of the International Congress of Mathematicians, 1986: August 3-11, 1986, Berkeley, California, USA.

Includes index.

1. Mathematics--Congresses. I. American Mathematical Society. II. Title.

QA1.I82 1986 510 87-24109

ISBN 0-8218-0110-4

The 1986 International Congress of Mathematicians was supported in part by Grant INT-8417900 from the National Science Foundation including contributions from the Department of the Air Force, Air Force Office of Scientific Research, and the Department of Energy, Office of Energy Research. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the Department of the Air Force, or the Department of Energy.

This work relates to Department of Navy Grant N00014-85-G-0145 issued by the Office of Naval Research. The United States Government has a royalty-free license throughout the world in all copyrightable material contained herein.

The 1986 International Congress of Mathematicians was supported in part by Grant DAAG29-85-G-0091 from the Department of the Army. The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

Photo credits: William G. Chinn, Benedict H. Gross, Hikosaburo Komatsu, Jill P. Mesirov, and Klaus Peters.

Copyright © 1987 by the American Mathematical Society.

Printed in the United States of America.

All rights reserved except those granted to the United States Government.

The paper used in this book is acid-free and falls within the guidelines established to insure permanence and durability. ∞

## PREFACE

The *Proceedings* of the International Congress of Mathematicians, 1986, are printed in two volumes.

Volume 1 contains the official record of the Congress held at Berkeley from August 3 to August 11, 1986, the list of Ordinary Members, the reports on the work of the Fields Medalists and the Nevanlinna Prize Winner, the Plenary addresses, and the addresses in sections 1–8. Volume 2 contains the addresses in sections 9–19.

The Short Communications made by members at the Congress are not included in the *Proceedings*, but the names of the communicators and the titles of their papers will be found by section in the scientific program. Summaries of these contributions, if received in time, were printed in *Abstracts*, issued to members during the Congress.

Berkeley, 1986

## PAST CONGRESSES

1897 Zurich	1950 Cambridge, U.S.A.
1900 Paris	1954 Amsterdam
1904 Heidelberg	1958 Edinburgh
1908 Rome	1962 Stockholm
1912 Cambridge, U.K.	1966 Moscow
1920 Strasbourg	1970 Nice
1924 Toronto	1974 Vancouver
1928 Bologna	1978 Helsinki
1932 Zurich	1982 Warsaw (held in 1983)
1936 Oslo	



**Ahlfors: 1936 Fields Medalist,  
Honorary President of the Congress**

## PAST FIELDS MEDALISTS AND NEVANLINNA PRIZE WINNERS

### Recipients of Fields Medals

1936 Lars Ahlfors	1970 Alan Baker
Jesse Douglas	Heisuke Hironaka
1950 Atle Selberg	Sergei Novikov
Laurent Schwartz	John Thompson
1954 Kunihiko Kodaira	1974 Enrico Bombieri
Jean-Pierre Serre	David Mumford
1958 Klaus Roth	1978 Pierre Deligne
René Thom	Charles Fefferman
1962 Lars Hörmander	Gregori Margulis
John Milnor	Daniel Quillen
1966 Michael Atiyah	1982 Alain Connes
Paul J. Cohen	William Thurston
Alexander Grothendieck	Shing-Tung Yau
Stephen Smale	

### Nevanlinna Prize Winner

1982 Robert Tarjan



**Lehto, Moser, Mesirov**



## ORGANIZATION OF THE CONGRESS

The National Academy of Sciences of the United States, through the U.S. National Committee for Mathematics, invited the International Mathematical Union to hold the 1986 International Congress of Mathematicians in the United States at the University of California, Berkeley. The invitation was accepted by the International Mathematical Union at the Warsaw Congress in August, 1983. Final action was taken a few days later when the Warsaw Congress at its Closing Ceremonies accepted the invitation to Berkeley, which was presented by Professor Jack K. Hale on behalf of the mathematical community of the United States of America.

The Academy, in turn, asked the American Mathematical Society to handle the organizational aspects of the Congress. The Society organized the Congress as a nonprofit corporation, ICM-86, and Jill P. Mesirov was appointed Executive Director. ICM-86 used the services of the American Mathematical Society's Meetings Department headed by H. Hope Daly, who served as Congress Manager.

The scientific program was organized by a Program Committee appointed by the International Mathematical Union. Its members were Enrico Bombieri, Lennart Carleson, Friedrich E. P. Hirzebruch (Chairman), David Mumford, Louis Nirenberg, Michael O. Rabin, J. A. Rozanov, David P. Ruelle, and I. M. Singer. The committee divided the program of the Congress into 19 sections and appointed a panel to nominate speakers in each section. The committee also approved the inclusion of sessions for ten-minute Short Communications in the Congress. In October of 1985 the Program Committee selected 16 mathematicians to give Plenary Addresses and 148 to give lectures in sections. Invitations were issued over the following weeks. Of the 164 invited, 14 plenary and 132 section speakers were present at the Congress.

The Fields Medals Committee, consisting of P. Deligne, J. Glimm, L. Hörmander, K. Ito, J. Milnor, J. Moser (Chairman), S. Novikov, and C. S. Seshadri arrived at its decisions in early 1986. The Nevanlinna Prize Committee, whose members were S. Cook, L. D. Faddeev (Chairman), and S. Winograd, also completed its work early that year.

The Board of Directors of ICM-86 appointed a Steering Committee, chaired by Andrew M. Gleason of Harvard University, to oversee the arrangements. There were several subcommittees of the Steering Committee. The Local Arrangements Committee was chaired by John W. Addison Jr. of the University of California, Berkeley; the Scheduling and Abstracts Committee consisted of Kenneth A. Ross of the University of Oregon and Hugo Rossi of the University of Utah; the Committee on Special Funds was chaired by Richard D. Anderson, Louisiana State University; and the Public Information Committee was chaired by Yousef Alavi of Western Michigan University.

Late in 1984, preliminary announcements of the Congress were sent out to all countries where some mathematical organization could be located, requesting information on the number of copies of the First Announcement they required. The First Announcement, prepared in English, French, German, and Russian,

was sent to these mathematical organizations in early 1985. The Second Announcement contained detailed information about the Congress, instructions about submitting abstracts for Short Communications, and the preregistration and housing form. It was sent to over 8,000 individuals starting in December of 1985. The Third Announcement, which contained a preliminary version of the scientific program, was distributed with the acknowledgment of preregistration between March and June of 1986. In all, 3,586 Ordinary Members, 340 Accompanying Members, and 69 Child Members registered for the Congress. Of these 721 Ordinary Members, 24 Accompanying Members, and 7 Child Members registered on site.

The Congress had several sources of revenue. A subvention was received early on from the International Mathematical Union. Grants were later received from the Air Force Office of Scientific Research, Army Research Office, Office of Energy Research, Office of Naval Research, National Science Foundation, Alfred P. Sloan Foundation, and the Vaughn Foundation Fund. Through the efforts of the staff and the Committee on Special Funds, donations in the form of cash, goods, and services were received from a number of both public and private individuals and corporations. It is especially interesting to note that nearly 9,000 members of the American Mathematical Society made contributions to the Congress totaling over \$30,000. Registration fees were \$125 for Ordinary Members registered before May 15, 1986, and \$163 thereafter; \$60 and \$78 for Accompanying Members; and \$30 for Child Members.

The International Mathematical Union gave travel grants to 32 young mathematicians from developing countries or from countries with currency difficulties. The Congress waived their registration fees, and, thanks to funds received from the Sloan Foundation and GTE Laboratories Incorporated, was able to give them room and board in the residence halls.

All sessions of the Congress took place on the campus of the University of California, Berkeley. The Opening Ceremonies were held in the Greek Theater. All other plenary sessions were held in Zellerbach Auditorium. These sessions were simultaneously broadcast over closed circuit television to several large lecture halls. Video tapes of the plenary lectures were shown in the evenings. The lectures in the sections were given at a number of locations on the campus.

In addition to the invited lectures, about 700 ten-minute Short Communications were given and a large number of informal seminars were arranged by participating mathematicians. Abstracts of the Short Communications were published in a book distributed to all Ordinary Members. An educational materials exhibition consisting of 40 booths representing 26 exhibiting firms was open throughout the Congress.

The Steering Committee arranged various social events. The Chancellor of the University of California, Berkeley hosted an outdoor reception in the Faculty Glade on the first evening of the Congress, Sunday, August 3. A western-style barbecue and rodeo was held Thursday evening, August 7, in the Cow Palace in San Francisco, where 2,800 members attended. A jazz concert was presented on Saturday, August 9, and a classical concert on Sunday, August 10. Each of these concerts was attended by approximately 1,500 participants.

## THE CONGRESS AND ITS COMMITTEE STRUCTURE

### BOARD OF DIRECTORS

- Steve Armentrout, Pennsylvania State University  
Frederick W. Gehring, University of Michigan  
Chairman: Ronald L. Graham, Mathematical Sciences Research Center,  
AT&T Bell Laboratories  
Secretary: Jill P. Mesirov, Thinking Machines Corporation  
George D. Mostow, Yale University (Member, IMU Executive  
Committee)  
Treasurer: Franklin P. Peterson, Massachusetts Institute of Technology

### STEERING COMMITTEE

- John W. Addison, Jr., University of California, Berkeley  
Yousef Alavi, Western Michigan University  
Peter J. Bickel, University of California, Berkeley  
Hirsh G. Cohen, Research Division, IBM  
H. Hope Daly, American Mathematical Society  
Solomon Feferman, Stanford University  
Chairman: Andrew M. Gleason, Harvard University  
Leon A. Henkin, University of California, Berkeley  
Shirley A. Hill, University of Missouri  
Richard M. Karp, University of California, Berkeley  
Linda Keen, Lehman College, CUNY  
Jill P. Mesirov, Thinking Machines Corporation  
Henry O. Pollak, Mathematical Communication & Computer  
Sciences Research Laboratory, Bell Communications  
Research Laboratory  
Kenneth A. Ross, University of Oregon  
Hugo Rossi, University of Utah  
Shmuel Winograd, IBM

### OTHER COMMITTEES

#### LOCAL ARRANGEMENTS COMMITTEE

- Chairman: John W. Addison, Jr., University of California, Berkeley  
Mary Ann Addison  
Henry L. Alder, University of California, Davis  
Lenore Blum, Mills College  
William G. Chinn, San Francisco, California  
Ginette Henkin  
Irving Kaplansky, Mathematical Sciences Research Institute,  
Berkeley



**Hirzebruch, Alavi, Atiyah**

## THE CONGRESS AND ITS COMMITTEE STRUCTURE

Robion C. Kirby, University of California, Berkeley  
Eugene L. Lawler, University of California, Berkeley  
Calvin C. Moore, University of California, Berkeley  
Robert Osserman, Stanford University  
P. Emery Thomas, University of California, Berkeley  
Anthony J. Tromba, University of California, Santa Cruz

### COMMITTEE ON SPECIAL FUNDS

#### Committee Members:

Chairman: Gerald L. Alexanderson, University of Santa Clara  
Richard D. Anderson, Louisiana State University  
Morton L. Curtis, Rice University  
Susan J. Friedlander, University of Illinois, Chicago  
David Gale, University of California, Berkeley  
Andrew M. Gleason, Harvard University, (ex-officio)  
Daniel Gorenstein, Rutgers University, New Brunswick  
Jill P. Mesirov, Thinking Machines Corporation  
(ex-officio)

Executive Secretary: K. Brooks Reid, Louisiana State University  
Alice T. Schafer, Wellesley College and Simmons College  
Albert R. Stralka, University of California, Riverside

#### Advisory Board:

George E. Brown, Jr., Member of the United States  
Congress, 36th District, California  
Edward E. David, Jr., President, Exxon Research and  
Engineering Company  
Gerard Debreu, Professor of Economics and Mathe-  
matics, Nobel Laureate in Economics, University of  
California, Berkeley  
Marvin L. Goldberger, President, California Institute  
of Technology  
Ira Michael Heyman, Chancellor, University of  
California, Berkeley  
Brockway McMillan, Vice-President, Military Systems,  
Bell Laboratories, retired; former Under Secretary,  
U.S. Air Force  
I. M. Singer, John D. MacArthur Professor of Mathe-  
matics, Massachusetts Institute of Technology  
James M. Vaughn, Jr., Chairman, Vaughn Foundation  
Fund

### PUBLIC INFORMATION COMMITTEE

Director of Publicity: Donald J. Albers, Menlo College  
Yousef Alavi, Western Michigan University  
Advisor: Gerald L. Alexanderson, University of Santa Clara  
William G. Chinn, San Francisco, California  
Jane M. Day, San Jose State University

## THE CONGRESS AND ITS COMMITTEE STRUCTURE

Advisor: Ronald L. Graham, Mathematical Sciences Research  
Center, AT&T Bell Laboratories  
Peter J. Hilton, SUNY at Binghamton  
Lester H. Lange, San Jose State University  
Jean J. Pedersen, University of Santa Clara

## ADMINISTRATIVE STAFF

Executive Director: Jill P. Mesirov, Thinking Machines Corporation  
Congress Manager: H. Hope Daly, American Mathematical Society  
Business Manager: Lee Ann Lima



## LIST OF DONORS

### GRAND BENEFACTORS

Department of the Air Force, Air Force Office of Scientific Research  
The Board of Trustees of the American Mathematical Society  
The Membership of the American Mathematical Society  
Department of the Army, Army Research Office  
Department of Energy, Office of Energy Research  
Department of the Navy, Office of Naval Research  
National Science Foundation  
Alfred P. Sloan Foundation  
University of California, Berkeley  
James M. Vaughn, Jr., Vaughn Foundation Fund

### BENEFACTOR

International Mathematical Union

### PATRONS

AT&T Foundation  
Exxon Research and Engineering Company  
GTE Laboratories Incorporated  
General Motors Corporation  
Grumman Corporation  
John Hancock Mutual Life Insurance Company  
International Business Machines Corporation

### SPONSORS

Amoco Foundation, Inc.  
Honeywell Inc.  
Joint Policy Board for Mathematics  
Mathematical Association of America  
James H. Simons

### DONORS

Deloitte Haskins & Sells  
HERMANN publishers in arts and sciences  
Hughes Aircraft Company  
Pergamon Press  
Raytheon Company  
Springer-Verlag  
Texaco Philanthropic Foundation Inc.  
Western Michigan University

CONTRIBUTORS

American Microsystems, Inc.  
Anonymous Contributor  
Associated Microfilm Management Services, Inc.  
Battelle Memorial Institute  
Leonard E. Baum  
Chevron Research Company  
Chrysler Corporation  
Computer Sciences Corporation  
Cornnuts, Inc.  
Institute for Defense Analyses, Communications Research Division  
Lockheed Corporation  
Louisiana State University  
Mother's Cookies  
The MITRE Corporation  
Society for Industrial and Applied Mathematics  
University of Illinois at Chicago

FRIENDS

Richard D. Anderson  
Anonymous in Appreciation of Hope Daly and Staff  
Applied Technology  
Association for Women in Mathematics  
Bowerman Brothers, Inc.  
Cooley, Incorporated  
Data Tech's, Inc.  
DES Offset, Inc.  
Harvard University, Department of Mathematics  
Hasbro, Inc.  
Industrial Electric Company  
Lyons & Morrison Paper Co.  
Massachusetts Institute of Technology, Department of Mathematics  
Mathematical Reviews  
Modern Press, Inc.  
E.P. Miles, Jr.  
Polaroid Foundation, Inc.  
Precision Business Forms, Ltd.  
Rourke-Eno Paper Company, Inc.  
Andrew Shahinian  
Simmons College  
Thinking Machines Corporation  
University of Santa Clara  
Wellesley College  
Wesleyan University

OTHERS

Kailash K. Anand

Truman A. Botts

Dreyer's Grand Ice Cream

East Bay Municipal Utility District (California)

Freeman Furniture, Inc.

Michael Integlia, Jr.

Bill Israel, Conference Marketing Coordinator,

Jolly Giant Conference Center, Humboldt State University

Murray S. Klampkin and Andrew C-F Liu, University of Alberta

Massachusetts Envelope Company

Port of Oakland (California)

RIS Paper Company, Inc.

Edward F. Schmeichel

Joseph R. Tassone

United Paper Stock Company