

# Singularities

Volume 40 - Part 1

PROCEEDINGS OF  
SYMPOSIA IN  
PURE MATHEMATICS

AMERICAN MATHEMATICAL SOCIETY

# **SINGULARITIES**

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IN PURE MATHEMATICS  
Volume 40, Part 1**

# **SINGULARITIES**

**AMERICAN MATHEMATICAL SOCIETY  
PROVIDENCE, RHODE ISLAND**

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## PREFACE

The American Mathematical Society held its twenty-ninth Summer Research Institute at Humboldt State University in Arcata, California, from July 20 to August 7, 1981.

The basic aim of the institute was to survey the various branches of Singularity Theory and to discuss recent progress and open problems. Some of the major topics were resolution and deformation of singularities in the algebraic and analytic categories; smoothing theory and mixed Hodge structures; equisingularity, the study of polar varieties and Whitney stratifications; Milnor fibration, monodromy and intersection pairing; analytic results, including the Gauss-Manin connection and relations with differential systems; metric properties and curvature; connections with knot theory and link theory; equivariant results and automorphic forms; unfoldings, adjacency, classification of singularities and modality; stability of singularities; Newton diagrams; Morse theory and intersection homology; and applications to physics and other sciences.

### PRINCIPAL LECTURES

*Canonical desingularization.* SHREERAM ABHYANKAR, Purdue University

*Milnor lattices and Dynkin diagrams.* EGBERT BRIESKORN, University of Bonn, West Germany

*Differentiable maps with small critical set.* PHILIP CHURCH, Syracuse University

*Topological triviality in versal unfoldings.* JAMES DAMON, University of North Carolina

*The low dimensional topology of singularities.* ALAN DURFEE, Smith College

*Rational curves with cusps.* DAVID EISENBUD, Brandeis University

*A-tangent spaces, classification and differential geometry.* TERENCE GAFFNEY, Northeastern University

*Steady-state bifurcation theory.* MARTIN GOLUBITSKY, Arizona State University

*Resolution games.* HEISUKE HIRONAKA, Harvard University

*The topology of real algebraic sets.* HENRY KING, University of Maryland

*Metric study of the neighborhood of a singularity.* REMI LANGEVIN, University of Paris, France

*Smoothing components of singularities.* EDUARD LOOIJENGA, Catholic University, Nijmegen, Netherlands

*Intersection homology.* ROBERT MacPHERSON, Brown University

*Distance function from a submanifold of Euclidean space.* JOHN MATHER, Princeton University

*Geometry of quasi-homogeneous surface singularities.* WALTER NEUMANN, University of Maryland

*On the stability of the Newton boundary.* MUTSUO OKA, Tokyo Institute of Technology, Japan

*Complements of hyperplanes.* PETER ORLIK, University of Wisconsin, Madison

*Vanishing homologies and the  $n$ -variable saddle method.* FRÉDÉRIC PHAM, Nice University, France

*Birational factorization of three-folds and singularities.* HENRY PINKHAM, Columbia University

*Periods of integrals over vanishing cycles.* KYOJI SAITO, Kyoto University, Japan

*Smoothings of isolated singularities and mixed Hodge structures.* JOSEPH STEENBRINK, University of Leiden, Netherlands

*Polar varieties and Whitney stratifications.* BERNARD TEISSIER, Ecole Polytechnique, Paris, France

*Topological description of Whitney stratifications.* LÊ DŨNG TRÁNG, University of Paris, France

*The structure of quasi-homogeneous singularities.* PHILIP WAGREICH, University of Illinois at Chicago Circle

*Classification of unimodal singularities of complete intersections.* CHARLES T. WALL, University of Liverpool, England

## SEMINAR SERIES

The names of the seminar speakers are listed in the order in which they appeared on the program.

### (1) Organized by Philip Church and Martin Golubitsky:

*When are germs finitely determined in general?*, by Andrew du Plessis

*Extension problems and related themes in differential analysis*, by Gerald W. Schwarz

*Poincaré-Hopf type theorems for maps to  $\mathbf{R}^2$* , by Daniel S. Chess

*Calculating the Poincaré dual to  $S_{(j)}^{1,1,1,1}$* , by Terence J. Gaffney

*Unfoldings of analytic foliation singularities*, by Tatsuo Suwa

*Composite differential functions*, by Edward Bierstone

*Caustics by reflexion*, by Peter Giblin

*The bending of a thin triangular beam*, by Timothy Poston

*Topological classification of smooth mappings*, by Andrew du Plessis

*Intrinsic derivatives*, by Ian Porteous



- Singular theory of submanifolds of Euclidean space*, by Ian Porteous  
*Counting singularities*, by James W. Bruce  
*An application of singularity theory to a nonlinear partial differential equation*, by Philip T. Church  
*Equivalence of generic mappings*, by Leslie C. Wilson  
*Some results on finite determinacy and stability not requiring explicit use of smoothness*, by Yosef Yomdin  
*Newton filtrations, monomial algebras and nonisolated and equivariant singularities*, by James Damon  
*Contact germs of the plane*, by Chris Gibson  
*Topological type in families of germs*, by Henry C. King  
*Topology of polarization fields in crystal acoustics*, by Per Holm  
*Deformations of zero-dimensional complete intersections after M. Granger, T. Gaffney*, by Anthony Iarrobino  
*Hilbert scheme as flat  $n$ -fold locus of a family of mapping germs*, by André Galligo  
*Criteria for  $C^0$ -sufficiency of jets of maps*, by David Trotman  
*On topological types of polynomial map germs*, by Isao Nakai  
*A duality theorem of foliations*, by Franz W. Kamber  
*Counting tritangent planes of space curves*, by Clint McCrory  
*Bifurcation with symmetry*, by Martin Golubitsky  
*Bifurcation involving the hexagonal lattice*, by Ernesto Buzano  
*On Faa' de Bruno's formula and intrinsic derivatives*, by Felice Ronga  
*Maps from  $(n + 1)$ -manifold to  $n$ -manifold*, by James G. Timourian  
*Is singularity theory useful?*, by A. John Coleman  
*Stratifications via co-rank one projections*, by Robert Hardt  
*Lifting 3-manifolds out of the plane*, by Harold Levine  
*The Euler numbers of singularity sets*, by Barry Hill-Tout  
*Topology of tame polynomial hypersurfaces*, by Allen Broughton  
*An algorithm of construction of the semi-universal deformation of an isolated singularity*, by Herwig Hauser  
*Multiple points, chaining, and the Fulton Hansen connectedness theorem*, by Terence Gaffney

**(2) Organized by Alan Durfee and Lê Dũng Tráng**

- Introduction to the theory of  $D$ -modules (differential systems)*, by Zoghman Mebkhout  
*Report on  $b$ -functions (Bernstein-Sato polynomials)*, by Tamaki Yano  
*Relations between polar invariants and  $b$ -functions*, by Benjamin Lichtin  
*Mixed Hodge structures*, by Fouad Elzein  
*Global monodromy and structure of elliptic Lefschetz fibrations*, by Richard Mandelbaum  
*Lefschetz theorems on affine algebraic varieties*, by Helmut Hamm  
*Differential forms in  $\pi_1$* , by Toshitake Kohno

*On the topology of smoothable singularities*, by Gert-Martin Greuel  
*Harmonic PL-forms*, by Gerald L. Gordon  
*Computation of some projective invariants*, by Audun Holme  
*Regular stratification of subanalytic sets*, by David Trotman  
*Vanishing cycles and Thom stratification*, by Claude Sabbah  
*Asymptotic mixed Hodge structures*, by Joseph Steenbrink  
*Mixed Hodge structure on the Milnor fiber*, by John Scherk  
*Log complexes of currents and Hodge structure*, by James King  
*Exponents and geometric genus*, by Morihiko Saito  
*Transversality theorems for polar varieties*, by Jean-Pierre Henry  
*Another view of critical point theory*, by István Fáry  
*Polarized mixed Hodge structure and monodromy*, by Eduardo Cattani  
*Questions on the proof of the hard Lefschetz theorem*, by Klaus Lamotke  
*Morse theory on the intersection homology*, by Mark Goresky  
*Structure of critical sets of complete intersection*, by Yosef Yomdin  
*An integral formula for the Milnor number*, by Gary Kennedy  
*The topology of the nondegenerate Newton boundary*, by Mutsuo Oka  
*Saturations of plane curves*, by Antonio Campillo  
*Vanishing folds in  $\mu$ -constant families*, by Donal O'Shea  
*On the equisingularity of quasi-ordinary surfaces*, by Ignacio Luengo  
*On the topology of Deligne's weight filtration*, by Clint McCrory  
*Coverings of quasi-homogeneous surface singularities*, by Walter Neumann  
*Critical spaces and stratified mappings*, by Andrew du Plessis  
 *$L_2$  cohomology and intersection homology of locally symmetric varieties*, by Steve Zucker  
*Kinematic theory of the linking number*, by Remi Langevin  
*The tangent space and exponential map of an isolated singularity*, by David Stone  
*Primitive elements in Lie algebras and Schubert singularities*, by Donald King

**(3) Organized by Peter Orlik and Philip Wagreich**

*Derivations and deformations of quasi-homogeneous singularities*, by Jonathan Wahl  
*Milnor fibers and Alexander polynomials for plane curves*, by Richard Randell  
*Quasi-ordinary singularities of surfaces in  $\mathbb{C}^3$* , by Joseph Lipman  
*Simultaneous resolution of some families of isolated surface singularities*, by Henry Laufer  
*Regular singularities*, by Stephen S. T. Yau  
*Analog of  $p$ -cyclic quotient singularities in characteristic  $p$* , by Peter Russell  
*Isolated line singularities*, by Dirk Siersma  
*Newton clouds and isolated singularities*, by Marc Giusti  
*Schubert's enumerative geometry of triangles*, by Robert Speiser  
*Ample divisors on 3-folds*, by Andrew Sommese  
*Alexander invariants of the complement of a plane singularity curve*, by Anatoly Libgober

- Finding the non-degenerate quadratic singularities*, by Norman J. Goldstein  
*On the monodromy groups of singularities*, by Norman J. Goldstein  
*Surfaces of general type with positive signature*, by Richard Mandelbaum  
*Normally flat deformation of rational and minimal elliptic singularities*, by Ulrich Karras  
*Differential invariance of multiplicity*, by Yih-Nan Gau  
*Homology of projective varieties with good  $\mathbf{C}^*$ -action*, by James Carrell  
*Topological classification of surfaces with  $\mathbf{C}^*$ -action in  $P^3$* , by Gottfried Barthel  
*On complex surfaces with small cohomology*, by Ludger Kaup  
*Estimation of the Łojasiewicz exponent and Newton polygon*, by Benjamin Lichtin  
*On the geometry of canonical singularities and Newton polygons*, by Jonathan Fine  
*Weyl groups and Cremona transformations*, by Igor Dolgachev  
*Liaison and deformation of singularities*, by Ragnar-Olaf Buchweitz  
*Projected resolution of rational singularities*, by Oswald Riemenschneider  
*Resolution of certain Gorenstein singularities*, by Kurt Behnke  
*Singularities of period maps and weak Torelli theorems*, by Roy Smith  
*Intersection homology of nilpotent orbits*, by Robert MacPherson  
*Logarithmic differential forms and arrangements of hyperplanes*, by Hiroaki Terao  
*The Gysin map of homogeneous spaces*, by Ersan Akyildiz  
*On the  $K(\pi, 1)$  problem for isolated singularities of complete intersections*, by Horst Knörrer  
 *$\mathbf{C}^*$  equivariance of the semi-universal deformation of a  $\mathbf{C}^*$ -equivariant sheaf*, by Fernando Puerta  
*On singularities on degenerate Del Pezzo surfaces of degree 1, 2*, by Tohsuke Urabe  
*Geometric genus for isolated singularities of quartic surfaces*, by Isao Naruki  
*Rational double points and group representations*, by Gerard Gonzalez-Sprinberg  
*Purely elliptic singularities of dimension  $> 2$* , by Kimio Watanabe  
*Special polars and curves with one place at infinity*, by Robert Ephraim  
*Nets of curves in  $\mathbf{P}^2$* , by Michel Merle  
*Singularities of the tangent developable*, by Ragni Piene  
*Nonsingular (sic) complete intersections*, by John Wood  
*On global extensions of Dynkin diagrams*, by Lawrence Brenton  
*On the Jacobian problem*, by John Randall

Evening seminars were also arranged informally, and included talks by the following speakers:

- Introduction to Enriques surfaces in characteristic area and characteristic  $p$* , by William Lang  
*Enriques surfaces of special type and curves of low genus*, by François Cossec

*Resolution games (continuation of hour lecture)*, by Heisuke Hironaka  
*Iterated torus links*, by Walter Neumann  
*Projective degenerations of Enriques surfaces*, by Jayant Shah  
*D-modules amplified*, by Lê Dũng Tráng  
*Intersection homology; examples and background*, by Mark Goresky  
*Desingularization*, by Henry Laufer  
*Equisingularity*, by Bernard Teissier  
*Resolutions*, by Shreeram Abhyankar  
*Differential systems*, by Lê Dũng Tráng  
*Arnold classification*, by Alan Durfee  
*Coxeter groups*, by A. John Coleman  
*Unfolding, stable mapping germs*, by Charles T. Wall  
*Mixed Hodge structure*, by Joseph Steenbrink

These volumes contain the proceedings of the Summer Institute. The revised texts of all but one of the principal lectures and almost all the seminar talks are included. There are some papers of purely expository nature and some containing mostly original research, while the majority fall somewhere between the two. We hope that the uninitiated will find a sufficient number of introductory articles, and that the experts will consider the proceedings a good summary of the state of the art and will find interesting new results and challenging problems in it. The participants served as referees and we all owe each other thanks for the thorough and painstaking work. The organizers invited a few Soviet mathematicians from the active and important school of V. I. Arnold. Unfortunately, none could come. We are therefore particularly pleased to include a translation of Arnold's article on open questions with the author's comments and with updated references.

The beautiful surroundings at Arcata contributed to the success of the Institute.

Peter Orlik  
Madison, Wisconsin  
June 15, 1982

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