J. Evol. Equ. 17 (2017), 1–15

1424-3199/17/010001-15, *published online* March 16, 2017
DOI 10.1007/s00028-017-0387-1

Journal of Evolution Equations

Preface

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Jan Prüss, May 2016

This special issue of JEE is dedicated to Jan Prüss on the occasion of his 65th birthday and his retirement. It consists entirely of original research papers which reflect Jan's broad scientific interests. As a matter of fact, many of the contributing authors had, and continue to have, an extensive collaboration with Jan.

Jan Prüss was born in Heiligenhafen on January 13, 1951. After his studies in mathematics and physics at the University of Kiel (1969–1976) he moved to the University of Paderborn, where he completed his Ph.D. thesis in 1979 under the supervision of K. Deimling. Working as an assistant professor (Hochschulassistent) in Paderborn (1981–1987), enriched by two longer stays in the USA (in Carbondale, Illinois and Blacksburg, Virginia), he obtained his habilitation in mathematics in 1984. Between 1988 and 1992 he held a Heisenberg fellowship awarded by the German Research Foundation (DFG). During this period he was visiting professor at the Technical University Delft, the University of Zurich, and the University of Graz for one semester each. In 1993, he was substitute professor for analysis at the University of Oldenburg and later received an offer for the chair in analysis at the University of Weimar. After one year in Weimar, he was appointed professor for applied analysis at the Martin Luther University Halle-Wittenberg, where he remained until his retirement in March of 2016. During his career he held several other positions as visiting professor, among them at the University of Franche-Comté in Besançon, Hiroshima University, Helsinki University of Technology, and Vanderbilt University, Nashville.

Among Jan's main areas of interest are the theory of evolution equations, operator semigroups, maximal regularity, Volterra equations, quasilinear parabolic problems as well as moving boundary and interface problems. Besides his numerous important contributions toward a deeper understanding of the qualitative properties of general (abstract) evolutionary problems, his publication record also reflects Jan's strong interest in applying the abstract results to a wide range of mathematical models arising in physics, biology, chemistry, and technology.

During the first two decades of his scientific career, a great deal of Jan's research focused on the study of abstract Volterra equations and their applications. At that time, this was a rapidly developing area of research, which was to a large extent motivated by problems from mathematical physics such as viscoelasticity, heat conduction in materials with memory and electrodynamics with memory. Both Jan's Ph.D. thesis, entitled *Semilineare Integrodifferentialgleichungen*, and his habilitation thesis, entitled *Lineare Volterra-Gleichungen in Banach-Räumen*, deal with the theory of abstract Volterra equations, with the latter forming the basis of the highly cited monograph [B1], which appeared in 1993 and has been the standard reference in this field since then. Recently, the second edition of this foundational and groundbreaking book has appeared in the Modern Birkhäuser Classics series.

The book [B1] provides a comprehensive account of the modern linear theory of Volterra equations, which generalizes the theory of C_0-semigroups to a large extent. Here Jan often uses properties of the *vector-valued Laplace transform* as a key tool. Many of the results in [B1] are original research contributions due to Jan. For example, the concept of parabolicity and the notion of k-regular kernels, which are of central importance with regard to maximal L_p-regularity [24,37,48], were introduced in [22]. Another important contribution is the application of the *subordination principle*—which had been known for completely positive measures—to vector-valued Volterra equations [16,18,20]. In this context, the results in [23] on the representation of Bernstein functions are fundamental. A significant part of [B1] is devoted to the treatment of *nonscalar* Volterra equations in a general setting (see also [11,14]), which covers most of the linear equations from viscoelasticity. Jan also obtained deep results on the integrability of resolvents and its connection to stability properties of Volterra equations [B1], [16,17,20,29,31]. Around the nineties, Jan had a very fruitful collaboration with Ph. Clément, which led to very nice results, e.g., on maximal regularity for parabolic Volterra equations and its applications to nonlinear problems [23,25,41,48]. Further important results concerning the asymptotic behavior of linear and nonlinear evolutionary integral equations are contained in [26,44,47,51,94]. The currently growing interest in nonlocal PDE including time fractional problems shows that Volterra equations are still a topical subject.

Parallel to his work on Volterra equations, Jan studied general semilinear evolution equations in his first papers [1–4]. Already here one can see the broad scope of his mathematical thinking. In [2], for instance, he conducted an in-depth study of time periodic solutions, combining tools from nonlinear analysis (see also [5,12]), dynamical systems, and evolution equations.

These results were also the starting point for his investigation of semilinear age-structured population equations in [6,8,9] which focused on the existence of equilibrium and persistent solutions and their stability properties. In these papers, positivity and the spectral theory of C_0–semigroups, but also Volterra equations, played an important role. Mathematical biology reappeared several times in Jan's work [33,35,87] and in particular in his important papers [67,71] with G. Webb and others about the longterm behavior of prion models. Moreover, he commonly treated biological systems in his teaching in ODE and dynamical systems, as witnessed in the introductory book *Mathematical Models in Biology* [B3] (in German).

Jan continued to work on the qualitative behavior of semilinear problems, see for instance [68,70,73,119], and on operator semigroup and spectral theory [10,19,49,72, 84,114]. Undoubtedly, the most prominent of Jan's publications in semigroup theory is the highly cited paper [10] which has become a standard reference in the stability analysis of viscoelastic materials and other wave-type problems.

The concept of maximal L_p-regularity for abstract evolution equations was introduced by G. Da Prato and P. Grisvard already in 1975. The discovery of the maximal L_p-regularity result by G. Dore and A. Venni in 1987 induced many new developments in the fields of harmonic analysis, PDE, operator theory, and geometry of Banach spaces. Jan was one of the first researchers to understand the full scope of this concept for parabolic evolution equations. Together with H. Sohr he introduced the class BIP of operators admitting *bounded imaginary powers* [21], and the subsequent paper [27] on elliptic operators satisfying this property initiated many further developments in this field. In particular, Jan showed in [39] that all generators of semigroups satisfying a heat-kernel or Poisson bound have the property of maximal L_p-regularity, even in the rather abstract setting of homogeneous spaces. A first result concerning the boundedness of the *H^∞-calculus* of elliptic operators was presented by Jan in [42] and, together with S. Monniaux [38], he obtained the first maximal regularity results for noncommuting operators.

After L. Weis proved in 2001 the characterization theorem of maximal L_p-regularity in terms of the $\mathcal{R}$-boundedness property of the resolvent, Jan was again one of the first researchers who was able to combine this concept with the theory of parabolic boundary value problems subject to *general boundary conditions*. In particular, the definition of an *$\mathcal{R}$-sectorial operator* goes back to Jan and Ph. Clément [48]. A systematic approach to boundary value problems of the above form, operator-valued Fourier multipliers, and $\mathcal{R}$-bounded sets of operators, representing the state of the art, was then given in [B2]. In his survey article [55], the so-called *Bari Lecture Notes*, Jan very clearly indicated the importance as well as the potential of the maximal L_p-regularity approach to nonlinear and, in particular, quasilinear evolution equations.

The definition of an *$\mathcal{R}$-bounded H^∞-calculus* appeared first in the article [50]. Concerning the Stokes equation in fluid dynamics, Jan [50] was again the first in proving that the negative of the Laplacian, as well as of the *Stokes operator*, admit $\mathcal{R}$-bounded H^∞-functional calculi on L_p and solenoidal L_p-spaces, respectively. Later on, this turned out to be very important, e.g., in his studies of liquid crystals [116,124,128]. His regularity result [81] on *non-Newtonian fluids* is still a benchmark in the field. Jan also proved in [107] the maximal L_p-regularity of solutions of the Stokes equation subject to energy preserving boundary conditions, which play a very important role, e.g., in engineering applications.

Jan applied the method of maximal regularity, in collaboration with the Italian school around G. Metafune, D. Pallara and A. Rhandi, to Ornstein-Uhlenbeck operators [56] and to operators with singular coefficients [64,66,75,78,88,131].

His deep understanding of the maximal L_p-regularity property for parabolic evolution equations allowed him to also find very beautiful and elegant proofs of *vector-valued Fourier multiplier theorems of Mikhlin type*, which are now presented in [B5] in all their beauty.

In the second part of [B2], Jan was the first researcher to give an explicit description of the solution operators for vector-valued parabolic boundary value problems with general boundary conditions. This was significantly extended to the existence of a bounded H^∞-calculus in [62] and to the case of inhomogeneous boundary data in [80]. In particular, the notion of maximal L_p-regularity was generalized to spaces of type L_p in time and L_q in space, where it was again Jan to realize that now Triebel-Lizorkin spaces appear on the boundary.

Jan's deep understanding of parabolic boundary value problems was the basis for major extensions to more general boundary conditions, in particular dynamic boundary conditions. He obtained deep results on the Cahn-Hilliard equation [68,70,73,94] and on the Stefan problem [58,79,85,104,109,113,115]. In [86], boundary conditions of relaxation type were introduced for the first time, building a general framework for a large class of nonstandard boundary value problems, including free boundary value problems and diffusion on the boundary.

Jan made fundamental and long-lasting contributions to the study of quasilinear parabolic evolution equations and their applications. In [24,55,74,82,90,97,105,112], the basic issues of existence, uniqueness, and regularity of solutions and their geometric properties are investigated. The approach taken makes systematic use of the theory of L_p-maximal regularity. A hallmark of this theory, which itself is rooted in deep results of vector-valued harmonic analysis, is the ensuing ability to employ basic results of nonlinear analysis, such as the inverse function theorem and the implicit function theorem, in order to establish further properties of solutions. The short paper [63], where maximal L_p-regularity in the presence of time weights is investigated, turned out to be of great importance for the study of quasilinear parabolic equations [97,112,127], as it allows to encode and treat the well-known smoothing property that is typical for parabolic equations. In [90], Jan considered the situation where the set $\mathcal{E}$ of equilibria of a quasilinear parabolic equation forms a finite-dimensional C^1-manifold. This situation occurs frequently in problems with underlying symmetry properties, that is, in problems that are invariant under the action of a group. In case that the equilibria are *normally stable*, Jan established a *generalized principle of linearized stability*. The difficulty in obtaining this result is caused by the fact that solutions starting out close to a normally stable equilibrium $e_* \in \mathcal{E}$ will not necessarily converge to e_*, but rather to another nearby equilibrium on $\mathcal{E}$ whose location is a priori unknown. This result turned out to have wide applications. Over the last 15 years, Jan has devoted his mathematical interests to the study of moving boundary problems in fluid flows and phase transitions [58,65,79,85,95,96,98–100,103,104,106,108,111,113, 115,118,120,122,123,129]. While processes with moving surfaces are omnipresent in nature, it turns out that their mathematical analysis poses great challenges. The recent monograph [B5] introduces and develops a comprehensive approach for the mathematical analysis of a wide array of problems involving moving interfaces. The approach includes an in-depth study of abstract quasilinear parabolic evolution equations, elliptic and parabolic boundary value problems, transmission problems, one- and two-phase Stokes problems, and the equations of incompressible viscous one- and two-phase fluid flows. This monograph is expected to become a highly cited reference in the field.

Besides his deep and broad mathematical research, Jan also made significant contributions in the field of chemical engineering. This line of research started in 1985 and led to a fruitful interdisciplinary cooperation with the Institute of Technical Chemistry at the University of Paderborn, lasting over a period of two decades. Driven by the desire to gain a deeper understanding of continuously operated flow-based chemical processes, Jan developed and analyzed mathematical models for reactive mixing processes in two-phase flow reactors [E1,E2,E3,E4,E6,E18,E23]. Based on continuum physical balances, Jan obtained scale-reduced descriptions, showing a very good sense for the required complexity to capture all relevant phenomena, typically resulting in PDE-systems in one or two space dimensions with transport modeled via convection, diffusion, and dispersion. Building on the models for two-phase flows, one main area of research was on mass transfer across fluid interfaces, in particular reactive transfer of gas in gas–liquid systems [E11,E13,E15,E16,E21,E23,E24,E26] and the transfer of volatile compounds from polymer [E19,E22,E25]. Jan also studied particulate systems [E27,E30,E32], where he brought in his expertise on population balance modeling from mathematical biology. From 1999 on, when computational fluid dynamics had reached a level of maturity which allowed for significant insights into flow-based processes via detailed numerical simulations, Jan gave his support to pave the way for carefully employing this technique to obtain a deeper understanding of specific two-phase processes [E31,E33,E36,E37,E38,E39,E40]. In this work with chemical engineers, Jan proved to be a generous and patient teacher. His legacy also consists in initiating a style of scientific communication which is based on extensively using the black board and mathematical formulas, a practice quite unique for an institute of chemical engineering. Of course, Jan also looked at these models from the mathematical analysts' point of view and, some time later, often came back to study their properties concerning existence of unique solutions and their qualitative behavior. In this way, the cooperation with engineers was also mathematically very fruitful, motivating Jan's above mentioned theoretical research, e.g., on two-phase flows with moving deformable interfaces, multicomponent fluid systems, and non-Newtonian flows.

Jan has been a dedicated teacher. His courses were deeply inspired by his manifold research interests. In his teaching, he gave an excellent and comprehensive introduction to modern analysis, masterly choosing the material. His lectures were crystal-clear and he always highlighted the mathematical structure behind the results. But maybe their most prominent feature was the multitude of examples and applications which motivated and illustrated the theory. His books *Mathematical Models in Biology* and *Ordinary Differential Equations and Dynamical Systems* [B3,B4] (in German) demonstrate his commitment as a teacher.

All the editors of this special issue had the privilege of collaborating with Jan. His unfaltering dedication to mathematics, his deep and encyclopedic knowledge of many branches of analysis, his ease to rapidly grasp new material, his generosity of sharing ideas, and his contagious sense of optimism left a lasting impression on us. We would like to express our deep gratitude to Jan for all of this.

Finally, we would like to thank W. Arendt and M. Pierre, the managing editors of *Journal of Evolution Equations*, for their valuable help and continuous support in publishing this special issue.

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