Laudatio aus Anlass der Verleihung des Förderungspreises 2020

Dear Professor Kaltenbacher, dear Julian, dear Colleagues,

it is a great pleasure to present the scientific achievements of my outstanding young colleague, Julian Fischer, on the occasion of receiving the Förderungspreis of the Austrian Mathematical Society in 2020.

Julian completed his PhD in 2013 in Erlangen with Professor Günther Grün and after a few postdoc years in Zürich and Max Planck Institute in Leipzig, he became the youngest tenure track assistant professor at IST Austria at the age of 27. This year he received an ERC Starting Grant, the most prestigious and competitive research grant in Europe.

Julian is an extraordinary talent working in partial differential equations (PDEs). Within a few years after his PhD he has become an international leader in the analysis of PDEs arising in continuum mechanics. He has solved three major open problems that have been attempted in vain by many senior top mathematicians. More remarkably, these breakthroughs mark quite different areas of partial differential equations, underlining his remarkable breadth and technical mastery. Let me briefly comment on these three particular instances of his works but let me stress that his contributions are by no means limited to these three areas of PDE theory; they were chosen to represent the breadth and versatility of his works.

The first topic is the *thin film equation* where Julian made a remarkable discovery in his PhD thesis which he finished within just two years. It is a highly nonlinear fourth order PDE with free boundary, describing the evolution of the height of a viscous thin liquid film on a flat surface. Imagine a droplet of coffee falling on the table; the key question is its expansion as time goes on, i.e. the motion of the boundary of the support of the droplet. Many groups of top authors have analyzed the qualitative behavior of solutions of the thin film equation, nevertheless, the central problem remained completely open: no rigorous lower bounds on the propagation of the free boundary were known. The obvious observation from everyday life, that a droplet extends, lacked any proof! In solving this conundrum, Julian built around a rare accomplishment: he discovered a new monotone quantity for the thin film equation. He proved that a carefully chosen weighted moment of the droplet with a power law decaying weight cannot decrease too quickly. This enabled him for the first time to derive estimates *from below* on the propagation of the free boundary. Monotone quantities for non-linear PDEs are always game-changers but finding them is a tremendously difficult enterprise, in particular for well-studied equations like the thin film equation. Well-deserved, this idea has led to several single-author publications in top journals.

After joining the MPI Leipzig as a postdoc in Felix Otto's group, Julian quickly established himself as a key player in the field of *stochastic homogenization.* The goal of this area is to describe the large scale behavior of elliptic and parabolic equations with random coefficients via simpler effective equations. While the basic idea is simple and ubiquitously used in the physics literature, its rigorous mathematical verification is notoriously hard. This field requires a mastery not only in PDE's but also in probability theory. While the linear theory has been relatively well understood over several decades by the works of Kozlov, Papanicolaou, Varadhan, Avellanada, Lin in the 1970's-80's and more recently by Otto, Armstrong and Gloria, the quantitative analysis of the nonlinear equations have remained an almost uncharted territory until very recently when Fischer, with S. Neukamm[1] proved optimal homogenization rates for random *nonlinear* elliptic PDEs, achieving the same rates of convergence as Gloria and Otto in the linear elliptic case.

Fischer, however, brought yet another aspect into the homogenization game: the *very practical goal to compute* the homogenized effective coefficients from observed real life data. In a recent single-authored article[2], Fischer analyzed a scheme for the numerical computation suggested by a group around the outstanding applied mathematician Le Bris[3]. This scheme basically asserted that it is advantageous to perform the computation of effective properties not on a random material sample, but to pre-select a material sample that reproduces certain statistical properties of the medium exceptionally well. The mainstream opinion in stochastic homogenization was that this method would anyway introduce uncontrollable errors and a mathematical justification is hopeless. Fischer proved the mainstream opinion wrong, providing *"a spectacular theoretical foundation"* (quoted from Mourrat et al[4]) for the method by Le Bris and coworkers.

For the third direction, just recently, Julian – together with his first PhD student Sebastian Hensel and two collaborators – achieved a breakthrough in the analysis of *mean curvature flow*[5]. This is a fundamental equation describing, among others, the evolution of interfaces along the gradient flow minimizing the surface area: it was shown that the weak (bounded variation) solution to planar multiphase mean curvature flow is unique prior to the first topological change. *Fischer's result marks a rare progress on uniqueness properties of weak solution concepts for mean curvature flow since the seminal works of Chen–Giga–Goto and Evans–Spruck on viscosity solutions in 1991.* Since 1991 no progress in the case of multiple phases could be made at all and hence the attention of the community slowly turned to strong solution concepts[6]. Julian's result has revived a research

[1] J. Fischer, S. Neukamm, arXiv:1908.02273

[2] J. Fischer, Arch. Ration. Mech. Anal., 234 (2019), 635-726

[3] C. Le Bris, F. Legoll, W. Minvielle, Monte Carlo Methods Appl. 22 (2016), 25-54; see also X. Blanc, C. Le Bris, F. Legoll, Philos. Trans. A 374 (2016), 20150168

[4] A. Hannukainen, J.-C. Mourrat, H. Stoppels, arXiv:1905.06751

[5] J. Fischer, S. Hensel, T. Laux, T. Simon, arXiv:2003.05478

[6] see for example L. Bronsard, F. Reitich, Arch. Rational Mech. Anal. 124 (1993), 355–379, C. Mantegazza, M. Novaga, V. Tortorelli, Ann. Sc. Norm. Super. Pisa. 3 (2004), 235–324, T. Ilmanen, A. Neves, F. Schulze, J. Differential Geom. 111 (2019), 39–89, C. Mantegazza, M. Novaga, A. Pluda, F. Schulze, arXiv:1611.08254

area where almost everybody else has basically given up!

Julian's productivity is outstanding both in quality and quantity. Including preprints, he has written 30 articles, most of them in leading journals. His trajectory is clearly upwards: just last year he submitted eight articles. It is not only the sheer number of publications that stands out, but also the amount of scientific material produced: Four of his recent works exceed 80 pages in length! This high productivity notwithstanding, his real strength is the true innovations in his research.

I would like to congratulate Julian, an extraordinary young mathematician with stellar accomplishments and lots of further potential, to the well deserved Prize!

(László Erdős)