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EPS Grand Challenges

Physics for Society in the Horizon 2050

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EPS Grand Challenges

Physics for Society in the Horizon 2050

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Preface

Over the last decades, the European Physical Society (EPS) has raised concerns on some of the main problems humankind faced up to now and examined the role of physics to address them. But what are the urgent societal challenges in the future and what holds the world's physics agenda to solve them? One objective of the *EPS Grand Challenges project* is indeed to explore our ability in imagining and shaping the development of physics at the Horizon 2050.

The scientific committee of this *Grand Challenges* publication chaired by Carlos Hidalgo, includes the following chapter coordinators: Ralph Assmann, Felicia Barbato, Christian Beck, Kees van der Beek, Giulio Cerullo, Luisa Cifarelli, Luc van Dyck, Felix Ritort, Christophe Rossel, Mairi Sakellariadou, Bart van Tiggelen, Claudia-Elisabeth Wulz. They played the leading role in the development of the project that addresses two pillars: *Physics as global human enterprise for understanding nature* and *Physics developments to tackle major issues affecting the lives of citizens*. The essays, written by more than 70 leading scientists, outline the in-depth analysis of the strong links between basic research, its applications and their impact on a sustainable society. The interplay of natural sciences with social and human sciences is also discussed together with the role of open science, education, ethics, and responsible citizens in an interdisciplinarity environment.

The scientific committee would like to express its gratitude to the Editorial Board members¹ for their contribution in defining the structure and the topical content of this project. The constant support of the successive EPS Presidents (Luc Bergé, Petra Rudolf, Rüdiger Voss, Christophe Rossel), the EPS Secretaries General (Anne C Pawsey, David Lee) and the EPS secretariat during the whole process is deeply acknowledged. Finally, the excellent work of the editorial team of *Europhysics News* [EPN] in preparing the special issue on the *EPS Grand Challenges* [1] is also well recognised.

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Ralph Assmann



Ralph Assmann has obtained his doctorate in physics from the Ludwig-Maximilians-University in Munich. His PhD research was performed at the Max Planck Institute for Physics in Munich and at CERN in the ALEPH experiment on the mass of the Z boson, spin polarized particle beams and precise energy calibration. He then spent almost four years as research associate and staff at Stanford University and SLAC, where he worked on operation, modelling and design of colliders. For the next 15 years he worked at CERN in leading roles on the LEP and LHC colliders. He was LHC machine coordinator in run I of the LHC operation, during which the Higgs boson was discovered in 2012. From 2012 to 2023 he worked as Leading Scientist for Accelerator R&D at DESY, where he researched new, compact accelerators. He was awarded an ERC synergy grant in 2014. Over 10 years, until 2024, Dr Assmann has been the proposer and founding coordinator of the EuPRAXIA ESFRI project, a 569 M€ project on building the world-wide first user facility based on plasma-based accelerators, today supported by more than 50 institutes. He has been the Chair of the Accelerator Group in the European Physical Society from 2020–2023, the leader of several large Helmholtz and European funding grants and the coordinator of the European Network for Novel Accelerators. Presently, Dr Assmann is the Head of Accelerator Operation and Development at GSI in Germany, responsible for GSI's heavy ion beams and the future beam commissioning of the FAIR accelerators.

Felicia Barbato



Felicia Barbato is proposer and principal investigator of the project Crystal Eye: a wide sight to the Universe looking for the electromagnetic counterpart of gravitational waves, a satellite detector for gamma ray astronomy. Thanks to her interest in cosmic rays physics and space experiment she recently joined the HERD and DAMPE collaborations. She is now detector responsible for the Zirè payload of the NUSES space mission.

Her missions as researcher are innovation and education. With these aims in 2015 she joined the Physics and Optics Naples Young Students, a group of students and young researchers dedicated to the diffusion of the scientific culture, and became member of the European Physical Society (EPS) joining the Young Minds Project, giving many contributions for the diffusion of astroparticle physics and technology. This passion for the diffusion of the scientific culture together with the passion for technology, led her to be part of the management board of the EPS Technology and Innovation Group for some years.

Christian Beck

Christian Beck is a Professor at Queen Mary University of London, UK. He is Head of the Dynamical Systems and Statistical Physics Group and a Fellow of the Alan Turing Institute (the UK's national institute for data science and artificial intelligence). Currently he is the Chairman of the EPS Statistical and Nonlinear Physics Division.

Christian Beck got his PhD in Theoretical Physics at RWTH Aachen in Germany and spent some time as a postdoc in Warwick, Copenhagen, Budapest, and Maryland before joining the University of London. He has more than 150 journal publications and is the author of two books. His research interests are in the general area of statistical physics, dynamical systems, data-driven analysis and stochastic modelling of complex systems. Together with E G D Cohen from Rockefeller University, New York, he has developed so-called superstatistical techniques, which have become a well-known method to understand heterogeneous systems in non-equilibrium statistical physics. More recently he has also dealt with the physics of sustainable energy systems, frequency fluctuations in power grid networks, spatio-temporal patterns of air pollution concentrations and other environmental problems where methods from statistical physics can be applied.

Giulio Cerullo

Giulio Cerullo is a Full Professor with the Physics Department, where he leads the Ultrafast Optical Spectroscopy laboratory. He is a Fellow of the Optical Society of America, the European Physical Society, the Accademia dei Lincei and past Chair of the Quantum Electronics and Optics Division of the European Physical Society. He has participated in numerous European projects, including two that received ERC grants. He has co-founded three spin-offs, among which CRI and NIREOS. He is on the Editorial Advisory

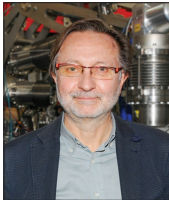
Board of the journals *Optica*, *Laser & Photonics Reviews*, *Scientific Reports* and *Journal of Raman Spectroscopy*. He has been General Chair of the conferences CLEO/Europe 2017, Ultrafast Phenomena 2018 and International Conference on Raman Spectroscopy 2022.

Luisa Cifarelli

Luisa Cifarelli was until 2022 Full Professor of Experimental Physics at the University of Bologna (Italy) where she is now Emeritus. Her research interests have mostly been in very high energy subnuclear physics in major European laboratories such as CERN, Geneva (Switzerland) and DESY, Hamburg (Germany). She has been a member of the CERN Council, of the INFN Board of Directors (Italy), of the Scientific Council of CNRS (France) and of JINR (Russia). She has been President of the Italian

national research institute Centro Fermi, of the European Physical Society (EPS) and of the Italian Physical Society (SIF). She has been Chair of the Forum on International Physics of the American Physical Society (APS), a member of the APS Committee on International Scientific Affairs and she is now APS International Councillor. She is member of the ALICE Collaboration at the CERN LHC and of the Scientific Advisory Committee of DIPC (Spain). She is a member of the Academia Europaea and of the Accademia delle Scienze dell'Istituto di Bologna. She has been a member of the Governing Board of the Bologna Academy and is currently a member of its Scientific Committee. She is the founder and director of the Joint EPS-SIF International School on Energy, which is held in Varenna (Italy) on a biennial basis.

Carlos Hidalgo



Carlos Hidalgo received his PhD degree from Madrid Complutense University with his work on structural defects in solids and positron annihilation spectroscopy. His next area of research was related to plasma turbulence, transport and plasma diagnostics at CIEMAT where he is currently leading the Spanish National Fusion Laboratory.

Carlos has worked in different international laboratories, initially as a PhD student [Technical University of Denmark, Nuclear Research Centre of Grenoble, Technical University of Helsinki] and later as visiting scientist [Fusion Centre at the University of Austin (US), Oak Ridge National Laboratory (US), Joint European Torus (UK), Max Planck Institute (Germany), National Institute Fusion Studies (Japan), Southwestern Institute of Physics (SWIP, China)].

He has led different research teams in the framework of the International Fusion Programme and participated in European and International Advisory Committees on Fusion Science and Technology. He has chaired the Division of Plasma Physics and the Forum on Physics and Society of the European Physical Society.

Felix Ritort



Felix Ritort is full professor in condensed matter physics. He got his PhD in statistical physics in 1991 under the supervision of G Parisi and M Rubi. Until 2002 he made contributions to the field of disordered and nonequilibrium physics. Afterward, he started an experimental career in single-molecule biophysics to investigate energy processes at the molecular level. Ritort's group is recognized worldwide as a leader in applying the finest methods to extract quantitative information about thermodynamics and kinetics of

molecular interactions. He has been awarded several prizes including the ICREA Academia Award 2008, 2013, 2018 and the Bruker Prize 2013 from Spanish Biophysical Society. He chairs the Division of Physics for Life Sciences of the European Physical Society.

His scientific research is highly multidisciplinary at the frontiers of physics, chemistry and biology. His lab is referenced worldwide on merging theory and experiments to investigate the thermodynamics and nonequilibrium behavior of small systems using single-molecule methods. Dr Ritort applies the finest concepts and tools from statistical physics to extract valuable information about a wide range of molecular processes: from the energetics of nucleic acids and proteins to the intermolecular binding kinetics in proteins, peptides and other macromolecular structures. A recurring theme in his research is the understanding of how molecular systems embedded in noisy thermal environments outperform the efficiency of macroscopic systems: being small has advantages that nature has exploited. Recently he has directed his interest to the study of energy and information and the search for principles that govern the emergent complexity of evolutionary ensembles in the molecular and cellular world.

Christophe Rossel



Christophe Rossel is a condensed matter physicist with education and academic professional experience in Switzerland (University of Neuchâtel and Geneva) and in the United States (Temple University, Philadelphia and University of California, San Diego). In 1987 he joined the IBM Research-Zurich Laboratory pursuing a scientific career focused on the physics of superconductors and later on nanoscience and the integration of advanced functional materials for semiconductor technology. As a member of various panels and president of the Swiss (SPS, 2008–12) and European Physical Societies (EPS, 2015–17) he has engaged in science policy issues, representing the community of physicists. A fellow of the EPS and of the Institute of Physics (IOP, UK) he was a member of the Open Science Policy Platform (OSPP, 2016–20) in Brussels and has been an executive board member of the Swiss Academy of Sciences (SCNAT) since 2018. He also chairs the EPS technology and Innovation group (TIG) as well as the working group on Physics and Industry of the International Union of Pure and Applied physics (IUPAP). He is emeritus senior researcher still affiliated with IBM.

Mairi Sakellariadou



Mairi Sakellariadou is a professor of Theoretical Physics at King's College London (University of London). She has studied Mathematics at the National and Kapodistrian University of Athens, Astrophysics at the University of Cambridge and obtained her Doctor of Philosophy in Physics at Tufts University (USA). She has worked at the Universities of Brussels, Tours, Pierre and Marie Curie (Sorbonne University), Zürich, Geneva and the theory division of CERN. She was also professor of General Relativity at the National and Kapodistrian University of Athens. She is a member of the LIGO Scientific Collaboration (LSC), the LISA Consortium, the Einstein Telescope Consortium, as well as the MoEDAL

experiment at LHC (CERN). She chairs the Gravitational Physics Division (GPD) of the European Physical Society (EPS), and is a member of the Executive Committee of EPS and Editor-in-Chief of the International journal ‘General Relativity and Gravitation’ (Springer Nature). Her research covers various aspects of theoretical physics, early universe cosmology, classical and quantum gravity, particle physics, noncommutative geometry, as well as astrophysics. She has co-authored more than 300 papers published in international specialised journals and has given hundreds of invited talks in international conferences.

Kees van Der Beek



A condensed matter physicist and citizen of the world formerly working for the Centre National de la Recherche Scientifique (CNRS) in Palaiseau, **Kees van der Beek** is now Vice President for Research at the Institut Polytechnique de Paris and Vice-Provost for Research at Ecole polytechnique in Palaiseau, near Paris in France. His scientific interests cover superconductivity and its mechanisms, the ensemble of quantized flux vortices in type II superconductors, the physics of elastic manifolds in a random potential and other soft matter systems and more generally materials science. He has worked on irradiation damage on materials, and used large-scale equipment such as particle accelerators and synchrotrons. More recently, he has been interested in magnetic systems and in semiconductor physics, mainly in the light of topological insulators.

Before moving to France, he completed his secondary education in Singapore as well as in the Netherlands. He obtained his PhD from Leiden university in the Netherlands, graduating on the exotic properties of the vortex lattice in the then recently discovered cuprate high-temperature superconductors, after which he held post-doctoral fellowships at Argonne National Laboratory in the United States and at EPFL in Switzerland. He continued work on superconductivity at the Laboratory of Irradiated Solids of the Ecole polytechnique in France, of which he later became the head. Kees has had a long-term engagement in the French and European Physical Societies, and had the pleasure of successively chairing the condensed matter divisions of both. He was the head of the Physics of Light and matter department of the Paris Saclay University south of Paris, and one of the architects of the new Graduate School of Physics at Paris-Saclay. He is currently scientific delegate at the National Institute of Physics at CNRS.

Luc van Dyck



Luc van Dyck holds a degree in biochemical engineering and a PhD in the life sciences. After twelve years of research in Belgium and Germany, he moved to the private sector where he managed public-private collaborations and public funding in the research department of a global animal health company. From 2001 to 2011 he worked at the European Molecular Biology Laboratory (EMBL), where he served as executive coordinator of a platform of scientific organizations and learned societies, the Initiative for

Science in Europe (ISE), involved in policy and advocacy at the European level. ISE is widely recognized for having been instrumental in the creation of the European Research Council (ERC). As a free-lance consultant, he worked for various organizations such as the OECD/Global Science Forum, EuroScience, the European Physical Society (EPS) and the AXA Research Fund. He now serves as Senior Advisor for Policy and Partnership Relations at the research infrastructure Euro-Argo ERIC.

Bart Van Tiggelen



Bart van Tiggelen got his master's degree in astronomy at the Leyden University and his PhD degree in physics and astrophysics at the University of Amsterdam. After some postdocs he settled in at Grenoble as a full research professor with CNRS and studied the propagation of all kinds of waves (seismic waves, acoustic and elastic waves, electromagnetic and matter waves) and is presently interested in magneto-optics and QED. He has been the scientific coordinator of many interdisciplinary programs in France, especially on the interface of physics and mathematics or biology. He is an engaged member of the French Physical Society and was the former Editor-in-Chief of EPL. Today he defends the new challenges in Open Science, especially towards younger generations.

Claudia-Elisabeth Wulz



Claudia-Elisabeth Wulz studied Technical Physics at TU Vienna, where she obtained her PhD 'sub auspiciis', a special form of graduation under the auspices of the Federal President, who awards this highest possible distinction for academic achievements for a doctoral degree in Austria. During her studies she took up research at CERN, the world's largest laboratory for particle physics in Geneva. First as a summer student, and later also as a fellow, she worked in the group of Carlo Rubbia at the UA1 experiment, where she took part in the discovery of the W and Z bosons. As a member of the Institute of High Energy Physics of the Austrian Academy of Sciences she then became a founding member of the CMS experiment, one of the two large multi-purpose detectors at the Large Hadron Collider where the Higgs boson was discovered in 2012. She has held several leading roles, including the Chair of the CMS Collaboration Board, the highest decision-making body of the experiment. She was a member of the High-Energy and Particle Physics Board of the European Physical Society. She is also a member of the Board of Trustees, the Scientific Advisory Board, at Carinthia University of Applied Sciences and an adjunct professor at TU Vienna, lecturing on particle and astro-particle physics.

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