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ACTO DE INVESTIDURA COMO DOCTOR *HONORIS CAUSA* DE LA UNIVERSIDAD DE SEVILLA DEL PROFESOR DR. PETER HÄNGGI

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argo

del Profes

Manuel Morillo Buzón

Catedrático de Física Teórica

de la Universidad de Sevilla

Señor Rector Magnífico de la Universidad de Sevilla
Señores Vicerrectores, decanos y miembros del Claustro universitario
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Es para mí un gran honor apadrinar la investidura como Doctor *Honoris Causa* del Profesor Peter Hänggi. Antes de comentar brevemente sus numerosos éxitos como científico, permítanme que apunte algunos detalles de su biografía.

El Profesor Hänggi nació el 29 de noviembre de 1950 en Bärschwil, una pequeña población suiza.

Cursó sus estudios de enseñanza primaria y secundaria en Breitenbach, donde ya despertó la atención de sus maestros por su especial talento para la Física, la Química y la Matemática. Posteriormente, en el Kirschgarten Gymnasium de la ciudad de Basilea, acaba el bachillerato. Tras obtener la *Matura,* ingresa en la Universidad de Basilea, donde estudia Física con intención de especializarse en Física Teórica (a pesar del consejo de sus profesores que decían que la Física Teórica era muy difícil). No obstante, Peter hace caso omiso del consejo y obtiene el título de *Bachelor of Science* en 1972 y *Master of Science* en 1974 en Física Teórica. En 1977 obtiene el título de Doctor con una tesis sobre las simetrías de los procesos estocásticos y la teoría de la respuesta en estos procesos.

Tras doctorarse continúa su formación posdoctoral en la Universidad de Urbana-Champaign de Illinois (EE.UU.), donde colabora con el Prof. Hans Frauenfelder. A continuación regresa a Europa, a la Universidad de Stuttgart, y tras una estancia de un año en el grupo del Prof. Hermann Haken, vuelve a América, a la Universidad de California en San Diego donde colabora con el Prof. Kurt Shuler. En el otoño de 1980 acepta una plaza de profesor en el Polytechnic Institute de Nueva York. A finales de 1985, se traslada a la Universidad de Augsburgo en Alemania como Catedrático, donde con mucho entusiasmo y sólo dos colaboradores, Peter Jung y Waldemar Hontscha, pone los cimientos de lo que hoy es ciertamente uno de los centros de referencia a nivel mundial de la Física Estadística y de la Materia Condensada. El *Institut für Physik* de Augsburgo es un centro de atracción de numerosos investigadores de diferentes países, con gran influencia en diversas áreas de investigación de la Física.

El Prof. Hänggi ha llevado a cabo una ingente actividad profesional como investigador y como educador. En esta segunda faceta, baste con indicar que en su Cátedra de Augsburgo se han defendido 8 Tesis de Habilitación, así como 26 Tesis Doctorales.

Su labor investigadora es excepcional. A fecha de febrero de 2010, cuenta con más de 580 publicaciones que han recibido más de 22.000 citas. Cifras ciertamente impresionantes, más aún si se tiene en cuenta la diversidad de temas que el Prof. Hänggi ha explorado. En estos días en que se observa un alto grado de especialización en sectores cada vez más estrechos del conocimiento, el *curriculum* científico del Dr. Hänggi es ejemplar por su variedad. Así, por citar sólo algunas de sus áreas de investigación, ha trabajado en: Mecánica Estadística, Procesos Estocásticos, Motores Brownianos, Sistemas Cuánticos Disipativos, Hidrodinámica y Microfluidos, Información y Computación Cuántica, Teoría de las Procesos Activados, Termodinámica Relativista, etcétera.

Quiero resaltar de entre sus publicaciones los artículos de revisión que han surgido de la escuela de Augsburgo, publicados en revistas de tanto prestigio como *Review of Modern Physics*, *Physics Reports*, *Advances in Chemical Physics*, *Advances in Physics*, *Lecture Notes in Physics*, etc.

Estos artículos son de una gran utilidad a la comunidad científica.

El trabajo científico del Prof. Hänggi le ha hecho merecedor de más de treinta premios y distinciones. Así, es Fellow of the American Physical Society, Member of the Board of the German Physical Society, Fellow of the Japanese Society for the Promotion of Science at the Institute for Fundamental Chemistry in Kyoto, Fellow of the Institute of Physics of the United Kingdom, miembro electo de la Statistical and Nonlinear Physics Division of the European Physical Society (EPS) y de la Max-Planck-Society. En 1995, recibió la Cátedra Nicolás Cabrera de la Universidad Autónoma de Madrid. Es, desde 2003, miembro de la más antigua y prestigiosa academia alemana, la Academia Leopoldina fundada en 1652. Ha sido investido Doctor *Honoris Causa* por varias Instituciones: la Universidad de Silesia en Katowice (Polonia), la Universidad de Camerino en Italia, la Universidad de Barcelona, la Academia Nacional de Ciencias de Ucrania, la Universidad Estatal de

Tatar en Kazan (Rusia) y la Universidad Humboldt de Berlín en Alemania.

El Prof. Hänggi es un gran animador de la ciencia europea. Ha organizado multitud de reuniones, conferencias, talleres, etc., promoviendo el contacto y la colaboración entre numerosos investigadores europeos y de fuera de Europa, facilitando asimismo el contacto entre los jóvenes investigadores y los de más madurez científica. Esta labor de discusión, propagación y divulgación de las ideas y proyectos científicos ha sido complementada con su participación en los Consejos Editoriales de una veintena de revistas del máximo prestigio.

Las contribuciones científicas del Prof. Hänggi son muy variadas. De entre ellas, quisiera señalar algunas. Sus investigaciones acerca de los procesos reactivos en sistemas dinámicos disipativos culminaron en la fórmula para la velocidad de reacción *de Grote-Hynes-Hänggi-Mojtabai*. Posteriormente, propuso una solución a un problema que venía de lejos: el llamado *Kramers turnover problem*. A destacar también son sus investigaciones en procesos cuánticos donde el efecto túnel viene modulado por fenómenos disipativos. Más recientemente sus estudios se han dirigido al control de los procesos activados y al estudio de sistemas con barreras fluctuantes de gran relevancia en procesos químicos y biológicos.

Peter Hänggi descubrió el fenómeno de destrucción del efecto túnel coherente mediante la aplicación de campos externos de intensidades y frecuencias adecuadas. Para ello hizo uso de un esquema matemático denominado teoría de Floquet. Creo que no exagero si digo que, con estos estudios, Hänggi y sus colaboradores pusieron además, al día, esta útil herramienta matemática bastante olvidada por muchos físicos. Estas ideas han abierto la puerta a otros investigadores que han usado estos procedimientos para el control y la manipulación de procesos en sistemas nanoscópicos, e incluso están teniendo aplicaciones en los procesos de información cuántica.

El fenómeno de resonancia estocástica, como ejemplo del papel constructivo del ruido en los fenómenos naturales que involucran sistemas no lineales sometidos a fuerzas externas dependientes del tiempo, ha sido objeto de numerosas publicaciones por parte de Prof. Hänggi y colaboradores. Uno de sus trabajos más citados, publicado en 1998 en *Reviews of Modern Physics*, constituye una pequeña monografía sobre el tema. La aplicación de los fenómenos de resonancia estocástica a diversos problemas de neurobiología y medicina es hoy día un asunto de gran interés. De hecho, el Prof. Hänggi tiene una patente relacionada con los aspectos prácticos del fenómeno. Relacionada con la resonancia estocástica, pero distinta de ella, es la sincronización inducida por ruido. Nuestro grupo en Sevilla ha tenido la gran suerte de poder colaborar con el Prof. Hänggi en estos temas de investigación durante los últimos diez años. Fruto de esta colaboración ha sido, entre otros resultados, la extensión a los regímenes cuánticos con efecto túnel de la teoría de la sincronización inducida por ruido, o la extensión de la resonancia estocástica a regímenes no-lineales, donde son posibles ganancias en la relación señal-ruido superiores a la unidad.

Otro ejemplo del papel constructivo del ruido lo constituyen los *ratchets*, a cuyo estudio el grupo de Augsburgo ha contribuido de manera decisiva. En particular, en 1994 Peter Hänggi propuso el importante concepto de *motor browniano* para designar dispositivos que usan el ruido térmico para el transporte a través de estructuras asimétricas con el objetivo de generar un movimiento dirigido. Estas ideas forman la base de una patente de Peter Hänggi para dispositivos de separación de células sanas e infectadas.

En los últimos años, el Prof. Hänggi ha realizado estudios, en los que han colaborado miembros de nuestro grupo, acerca de la extensión a regímenes relativistas del movimiento browniano y de la Termodinámica.

Quisiera por último señalar la intensa vinculación del Prof. Hänggi con diversas actividades científicas de nuestra Institución, así como la inestimable ayuda y colaboración que presta a miembros de nuestra Universidad. Un ejemplo de ello es el papel fundamental como parte del Comité

Organizador del Congreso Internacional: *New Horizons in Stochastic Complexity* celebrado en la Universidad de Sevilla en septiembre de 2004. Su experiencia, ánimo y capacidad de trabajo, fueron determinantes para el éxito de la empresa. Es también de agradecer la ayuda para recibir en su grupo en Augsburgo a jóvenes investigadores que hoy, afortunadamente, son Profesores Titulares en nuestra Universidad.

Discurso de investidura del Doctor *Honoris Causa* Peter Hänggi

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It is indeed a distinguished pleasure to be here and to receive this great honour of a Doctor *Honoris Causa* from the Universidad de Sevilla. This honour is extremely special for me and incredibly gratifying. This University was founded as early as in 1505. With 505 years passed since, it is therefore much, much older than my home University in Augsburg. I understand that the motto this fine University lives by is based on the four qualities: "Equality, Liberty, Justice and Pluralism"; an impressive motto indeed. I am also so happy to be in a city which has been home for many famous natives for example for the baroque painters Diego Velázquez and Murillo, the explorer Juan Díaz de Solís and Antonio de Ulloa, poets such as Gustavo Adolfo Bécquer (in Sevilla my favorite hotel just carries his name) and the Nobel Laureate Vicente Aleixandre and many other writers and scientists. And just on the side: Which University worldwide can say that one of their main buildings is a most beautiful "*Old Tobacco Factory*" –with the latter serving as the setting for the very famous opera "Carmen" by Bizet? It goes without saying that I am therefore very grateful and simply like to say "thanks to all of you".

In particular, I like to express my deep respect and thanks to all those fine scientists and world-known colleagues working in the *Facultad de Física* who worked hard in order to make this honour happen for me. Although I have my personal doubts, I nevertheless hope that I am sufficiently worthy to accept this distinguished honour from an institution that has produced many fine and distinguished university graduates.

Turning next to some science: It is that omnipresent jittery motion of small, micro-scaled objects, being caused by the uncorrelated, completely irregular collisions with the particles that make up a thermal environment, labelled in science as **Brownian motion**, which played a prominent role throughout my scientific life. In my opinion, this field lies at the heart of two prime scientific disciplines; namely (i) the field of Thermodynamics together with its dynamical features brought about with Statistical Physics, and (ii) the world of Quantum Mechanics. The development of the phenomenon of Brownian motion, which is based on the molecular-kinetic theory of heat, provides a prominent link between the microscopic dynamics and the resulting macroscopic phenomena. Such processes are best known as diffusion and fluctuation phenomena. It is even fair to say that most areas in physics, if not all, have become influenced and have markedly been advanced over the last hundred years or so via many seminal investigations and their related theoretical descriptions and devised methods that have been employed in elucidating this important phenomenon. A historic first success of Brownian motion was the result mentioned above that it provides a link between macroscopic transport quantities and the microscopic world of atoms and molecules: Upon testing of the pioneering theories put forward by distinguished scientists such as Albert Einstein and Marian von Smoluchowski several gifted experimentalists, such as e.g. Jean Perrin, succeeded in determining the masses of molecules and atoms and the related natural constants such as the Loschmidt-Avogadro number. The latter knowingly yields the number of molecules/atoms that are contained in the corresponding molar weight. Notably, these efforts helped to clarify the issue whether matter must be considered to be continuous or being made up of discrete units. With the experiments strongly supporting the atomistic hypothesis of matter the remaining "Continuists", in particular Ernst Mach, who is known for his cynical remarks like "…and have we seen it (i.e. the molecules/atoms)?", had no choice left but to concede.

Building up on the acknowledged state of the art of Brownian motion theory my most prominent research contributions up to now are in statistical physics and in the physics of condensed matter. Among those are (i) my acknowledged contributions to the theory of reaction rates for systems that exhibit a *memory dynamics* and (ii) my way of implementing the *periodic-orbit theory*, as known in chaos theory for conservative systems, into dissipative quantum systems operating at finite temperatures –covering absolute zero up to room temperatures. Moreover (iii), about twenty years ago, I discovered a phenomenon nowadays known under the label of ***C**oherent **D**estruction of (Quantum)-**T**unneling*; in short "**CDT**". This topic wins increasing importance for applications on the molecular and nano-scale. Typical examples are the *control* of decoherence and the population transfer occurring in molecular systems and its use for optimized quantum transport in a variety of quantum information processing nanoscale devices.

Over the last 20 years or so, the name “Hänggi” has unmistakably become connected with the pioneering works which I originally performed in collaboration with my gifted collaborators in Augsburg and elsewhere. These constitute (iv) the phenomenon of *Stochastic Resonance* (SR) and (v) the creation of the new discipline of *Brownian motors*, a term which I coined in 1995. It is also these fields of Stochastic Resonance, Brownian motors and related other fields where I most successfully profited from collaborative research with several fine colleagues from the Physics Faculty here: In particular, I like to mention Manuel Morillo, Jesús Casado-Pascual, Azucena Álvarez-Chillida, David Cubero, Claus Denk and, as well, your Dean of the Facultad de Física, José Gómez-Ordóñez.

What is Stochastic Resonance and Brownian motors all about? These two topics make use of a most remarkable idea which changed our perception of the omnipresent “noise” that surrounds us.

More precisely, the effect of Stochastic Resonance amounts to the fact that an appropriate small dose of noise can, rather surprisingly, strongly *boost weak signals* or any weak information rather than hamper it. This is why this phenomenon has found widespread applications in various contexts of Physics, Chemistry, Material Sciences and, above all, also for the Life Sciences, up to its striking clinical applications in Medicine. The Stochastic Resonance work done with colleagues from here refers to a practical application; addressing the issue of maximizing "signal gain" between the output and the input.

Related in spirit, but physically different, is the theme of Brownian motors. These are stochastic "micro-/nano-machines" that allow for noise-assisted, directed transport of particles (or more generally, for a directed transport of any information *per se*) in systems away from thermal equilibrium, that exhibit either an intrinsic or a dynamically induced breaking of symmetry. The main working principle is that *thermal Brownian motion* when assisted by a source of non-equilibrium perturbation *is able to perform work against an external load*. With these systems therefore operating outside the regime of thermal equilibrium the restrictions imposed by the second law of thermodynamics do not apply; put differently, these novel machines do not present perpetual mobiles of the second kind. In Augsburg we have advanced these phenomena not only within the classical regime, but as well put forward both, theory and new applications, for the nonlinear, dissipative and time-dependent quantum regime. This task did pose a most demanding theoretical challenge. With such Brownian motors at hand, one is able to devise a diversity of novel technological gadgets, such as Brownian diodes and/or transistors, Brownian pumps and yet other cleverly devised separation devices that put the ubiquitous Brownian motion to a constructive use in nano-sciences and life sciences. A most recent success story is our blueprint study of the world's smallest quantum machine: a two-atom motor fuelled by a time-varying magnetic field.

The topic of Brownian motion has likewise inspired many of us to deploy a consistent treatment of phenomena far from thermal equilibrium –a regime that is indispensably connected with life to exist. This theme of Brownian motion theory even extends to applications in Cosmology, Astrophysics and High Energy Physics, such as for example, for the description of false vacuum decay and the inflationary universe. This topic of stochastic physics has verifiably impacted on cross-disciplinary fields, such as the above mentioned applications of stochastic phenomena which are of essential and constructive influence for action and function in the Life Sciences. This Brownian motion theme even extends to *a priori* seemingly distant disciplines such as *Social Sciences* (statistical behaviour of networks) and *economics*, with activities known under the label of "Econophysics". This given listing encompasses areas where several researchers at and from this very Universidad de Sevilla have enriched repeatedly our scientific knowledge for mankind with guiding contributions.

As I mentioned at the beginning, I started doing physics at the University of Basel, Switzerland, in Nuclear Physics and High Energy Physics. One of my papers I am quite proud of is the first paper in my publication list: muon decay in orbit in 1974. Using weak interaction theory and full relativistic Dirac theory, I calculated therein the electron emission spectra of bound muon decay by accurately accounting for effects such as the finite nuclear size and the vacuum polarization. Those timely calculations impacted experimental efforts, such as the search for neutral currents in various laboratories around the world. I remember this work well, not only since it was my first piece of scientific work, but even more so, because of the tedious programming that I mastered at that time with archival means such as primitive Fortran language, machine language and punch cards, etc. The University at that time had no computer facilities but I was allowed to perform my calculations on an industry computer located at a well known, large-sized chemical industry in Basel, where I could use their Univac-machine for 5 hours from midnight to 05:00 in early morning! It meant good practice for me. I learned a lot in writing optimal codes aimed at using minimal calculation time; a feature which seems superfluous nowadays with our fast computer equipment.

I learned a lot of Thermodynamics and Quantum Mechanics in those days, but still do not know enough even up to the present days. These topics continue to fascinate me. As some of you may remember, the structure of the famous Schrödinger equation, i.e. the fundamental equation that determines the physics occurring on a microscopic level, possesses a time evolution, being governed by a diffusion equation, or a Fokker-Planck-dynamics that is with a potential, which evolves in imaginary time. It is thus the *paths of Brownian motion* that ultimately determine quantum dynamics (Feynman path integrals).

It is also no secret that the famous set of the three Laws of thermodynamics, in particular the "Second Law", also entails deep consequences for the structure of quantum mechanics. This "Second Law", which in essence determines the *direction* in which all thermal processes proceed, has recently undergone seminal refinements. Its validity has even been questioned in the context of the trendy field of nanoscience –the science of the very small. This occurred within the timely research activities that involve the issue of *nonlinear fluctuation theorems*. The latter relate non-equilibrium measurements to thermal equilibrium quantities –an amazing connection indeed. Here again I profited from my acquaintance with this fine University in achieving a true first –the discovery together with Professor Morillo of a nonlinear fluctuation theorem that relates suitably conceived *nonequilibrium work with thermal entropy*.

Finally I am proud to mention recent work done in close collaboration with two young colleagues here, namely Prof. David Cubero and Prof. Jesús Casado-Pascual. Our obtained results made worldwide headline News in the year 2007: A longstanding issue in physics that dates back to considerations by such giants in science as Max

Planck and Albert Einstein deals with the conundrum of what is the temperature of a fast moving body in relation for its value when at rest. By use of relativistic molecular dynamic simulations we succeeded in establishing the correct form of the *relativistic velocity distribution*. The latter has been debated controversially over many decades. Moreover, we devised a consistent concept of relativistic temperature and devised a *relativistic thermometer*. This joint work presents in fact the seed for the burgeoning activity of Relativistic Brownian motion and did provide a new insight for Relativistic Thermodynamics in conceiving in Augsburg the new field of *Relativistic Photographic Thermodynamics*. A hallmark of the latter is that it uses only facts and data which you can "look back" upon.

Next, let me also comment on some more personal relations with this fine University. I think that by now I co-authored ~ **13** scientific joint works with the colleagues here in the Physics Department. After having made acquaintance with

Professor Morillo in early 1984 at a memorable conference in Santander, and later again also at the famous Sitges meetings, it took some time before we actually engaged in joint scientific objectives. The specific scientific collaboration started with a DAAD-funded visit to my work group by Prof. Jesús Casado-Pascual in spring 2001. The collaboration then truly blossomed when both work teams obtained mutual funding twice via the German Academic Exchange Program (DAAD) "Acciones Integradas Hispano-Alemanas". Our collaboration culminated with the organization by Prof. Dr. Manuel Morillo, Prof. Dr. Azucena Álvarez-Chillida and myself of the International Conference entitled "***New Horizons in Stochastic Complexity***". It took place in the beautiful Pabellón de México in the very heart of Sevilla from September 15-17 in 2004. With me travelling around the world frequently I still collect up to these days very praising words about our meeting from participants. Additionally, they all remember well the architectural beauties of the city and, not surprisingly, all compliment on the excellent Sevilla food and the "Manzanilla".

My prime scientific motto has always been: “Let us do intriguing science”. In this context, I am particularly pleased to obtain this distinguished honour from the Universidad de Sevilla. I truly enjoyed, and continue to do so, doing science with several colleagues and students from this highly reputable University. I hope that I will be able to strengthen even further the existing ties and to seek new scientific enterprise and challenges with many of you here.

The road towards identifying those scientific discoveries will not always be smooth; ever encountering complications will present hurdles that need to be mastered and overcome. It is such challenges that make future tasks so exciting and interesting. I consequently share with you the confident belief that science will continue to blossom and enrich wisdom to mankind from which we and future generations shall profit. Let this distinct award of a Doctor *Honoris Causa* mark the beginning for even more intense scientific and social initiatives between our two Universities in Sevilla and in Augsburg.

In this spirit of undertaking such new challenges I like to say **THANKS** and can only refer to the Logo of this city, namely the celebrated "**No8Do**" –NO-MADEJA-DO. Last but not least, I also owe deep and sincere thanks to my dear wife Gerlinde and my son Alexander who both suffer from my all too frequent absence from home, but nevertheless keep supporting me and bear with me. Coming to my close I must thank you all for listening and enduring me during this presentation.

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