

IN MEMORIAM: Professor RADU BALESCU

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Professor Radu Balescu passed away on June 1, 2006 in Rumania, a few days after his last student obtained his PhD at the University of Craiova. He was born in 1932 in Bucharest, Rumania, of a Belgian mother, and acquired Belgian nationality in 1959. He studied at the Université Libre de Bruxelles and was the assistant of Professor I Prigogine (Nobel laureate in 1977) from 1957 until 1961 when he became Assistant Professor. Until becoming Emeritus in 1997, he had been Ordinary Professor at the University of Brussels. He has lectured or has been visiting Professor all over Europe, in Kyoto, Austin and Mexico. Balescu made original contributions to plasma physics which led in 1963 to the publication of *Statistical Mechanics of Charged Particles*. This book contains a fairly complete statistical description of systems of charged particles. It is well known that the latter have a very peculiar behaviour as compared to neutral fluids. The reason is the long range of the Coulomb interactions, which introduces a strongly collective character. The usual methods of statistical mechanics, in particular of non-equilibrium states, lead to mathematical divergences in all expressions of the physical quantities. In 1960, Balescu derived a new kinetic equation by identifying an approximation scheme different from the usual Boltzmann or Landau schemes. The collective, many-body character of the collision processes in a plasma is thus explicitly accounted for, and the divergences disappear. It thus becomes possible to construct a consistent theory of transport processes in a fully ionized high-temperature plasma (unfortunately this necessarily highly non-linear kinetic equation is very difficult to solve). The consequences of this new kinetic equation, now called the Balescu–Lenard equation, are developed in this book, both for classical and quantum mechanical plasmas.

But Balescu remained very active in general statistical mechanics and published in 1975 *Equilibrium and Nonequilibrium Statistical Mechanics* (Wiley, 742 pp). This book is a comprehensive treatise of statistical mechanics. The main purpose was to achieve a presentation that would be as unified as possible. The new feature was a very wide coverage of non-equilibrium theory, which was not treated in standard textbooks of that time. It also introduced for the first time in a textbook some new concepts, such as the renormalization group theory of critical phenomena, which turned out to be very successful in forthcoming years. This book has been widely cited in the literature. Both this book and the previous one have been translated into Russian by leading Russian theorists.

The formulation of many-body dynamics in the framework of special relativity has been for a long time a difficult problem, and the previous answers were ambiguous. In a *Physica* paper of 1967, R Balescu and T Kotera, inspired by a very elegant work of Dirac, achieved a unification of classical (and later, quantum) Hamiltonian dynamics and special relativity. The key is the construction of the generators of the Poincaré group in terms

of canonical transformations. The result is a set of ten generalized Liouville equations acting on the phase space distribution function for a plasma and the electromagnetic field. These equations tell us how to describe time translation, spatial translation, rotation and Lorentz transformation in terms of canonical transformations which automatically ensure the relativistic covariance of the theory.

The Association “Euratom-Belgian State” was created in 1969. It is formed by the “Faculté des Sciences - Unité de Physique Statistique et Plasmas “ of the Université Libre de Bruxelles of which he was the Director until 1997, and of the Laboratory of Plasma Physics of the Ecole Royale Militaire-Koninklijke Militaire School; the union for fusion technology of the SCK-CEN joined the Association in 1975.

As a natural extension and application of the work on relativistic statistical mechanics of plasma-radiation interaction, he became interested in the programme of laser fusion and inertial confinement. He published several papers on anomalous transport in laser-created turbulent plasmas and on parametric instabilities. He served as a Euratom expert in this field and conducted several missions to laboratories devoted to laser fusion.

In 1988, Professor Balescu published a magnum opus, *Transport Processes in Plasmas* (North-Holland, 803 pp) Volume 1: Classical transport; Volume 2: Neoclassical transport. This set of two volumes presents a comprehensive review of the classical and the neoclassical theories of transport in plasmas, especially in the regime relevant to thermonuclear fusion. This is the first fully consistent presentation of the theory of neoclassical transport. It starts from first principles (Hamiltonian mechanics), going through kinetic theory, and ending in the explicit calculation of the transport coefficients and the discussion of the thermodynamic aspects of the transport. The second volume describes the non-trivial influence of the toroidal geometry (existing in magnetically confined plasmas) on the transport. The main aim here again was a unified presentation of the theory. It should be emphasized that these volumes encompass not only the work of many authors but that it is original in its conception and it includes many hundreds of pages of new consistent calculations and results. It is considered by many theorists as the current bible for plasma transport processes and has already been translated into Chinese.

These volumes do not include the so-called ‘anomalous transport’, a particularly important and very difficult topic and in 2005, he published a third volume

“Aspect of Anomalous Transport in Plasmas“. This problem is strongly connected to the study of turbulent phenomena in plasmas and Balescu and his co-authors have treated plasma turbulence by different methods. A Physical Review paper of 1995 is a typical example of such a study. It is shown there, on the basis of a simple, analytically solvable model of the motion of charged particles in a stochastic magnetic field, how dynamical and probabilistic concepts can be combined to form a theory of anomalous (or ‘strange’) transport. In particular, it is shown that the process can be described by a ‘continuous-time random walk’ (CTRW). It is then possible to use the well-developed methods of stochastic processes to study this type of turbulent plasma.

This survey of Professor Balescu’s work amply demonstrates the breadth and the depth of his contribution, not only to theoretical basic plasma and fusion physics, but also to statistical physics in general. It encompasses the conceptual roots of the disciplines and addresses the most challenging present-day problems. The excellence of his contributions were already recognized at a young age by the award of the De Donder Prize of the Académie Royale de Belgique in 1961 and by the very prestigious Prix Francqui in 1970.

He was a member or foreign member of several academies and in 1999 received the

von Engel Prize of the International Conference on Phenomena in Ionised Gases.

He was awarded the first Hannes Alfvén Prize of the Plasma Physics Division of the European Physical Society in 2000. This important Prize bears the name of the second Nobel laureate (after I. Langmuir) for work in the domain of the fourth state of matter.

Radu Balescu was also a humanist in the full sense of the word. Aside from French, he spoke Romanian and English and practiced several other languages. He had an extended knowledge of world literature. He loved music and enjoyed playing the piano. He was always generous with his time when discussing with his students, collaborators and visitors. He was very active in helping his Rumanian colleagues to integrate into the Western European scientific framework.

Radu Balescu enjoyed the pleasures of life and liked to spend evenings with colleagues and friends. He was a discreet and sensitive man who seldom discussed private matters but when he did, his eyes sparkled with pride and love when evoking his daughters and grand-daughters.

With the death of Radu Balescu, our country and the world loses a scientist of very great stature and his family and friends a warm and generous man.