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Prizes of the French Academy of Sciences 2015 / Prix de l'Académie des sciences 2015

Foreword

The present issue of the *Comptes Rendus Physique* aims to provide the scientific reader with an opportunity to become acquainted with current scientific trends that have been distinguished by prizes of the French Academy of Sciences.

Leticia Cugliandolo has received the Irène-Joliot–Curie prize for 2015, citing her work on coarsening. What we mean by coarsening is shown schematically in Fig. 1. It occurs when atoms are randomly deposited on a plane surface, for instance by molecular beam epitaxy. Atoms form clusters that grow with the passage of time. The phenomenon takes place in three dimensions too, and is extremely important in the metallurgy of alloys. The number of atoms of each species is then fixed. This satisfies what is called *Kawasaki dynamics*. There are also cases, however, where clusters can grow or decay without any conservation rule. This defines *Glauber dynamics*; an example would be the case where there are two types of domains with different magnetizations. The geometry of Fig. 1, where clusters retain a compact form, is just one example, which has been chosen for its simplicity. In her article, Leticia Cugliandolo describes the geometric properties of various physical systems mimicked by several different models, some of which rely on a Hamiltonian, e.g., the Ising or the Potts model; other models have no Hamiltonian, e.g., the voter model, which simulates a collection of citizens whose opinions change according to those of the people they meet (Fig. 2). A success of the author is to have, in a special case, derived a precise form to what is generally just a "scaling hypothesis" (see formula 20 of her article).

Johann Troles and Laurent Brilland won the Peychès prize 2015 for their work on chalcogenide microstructured optical fibers for mid-IR applications. Most of the kilometers of optical fibers operating since about 30 years are used for long-distance communications, especially between different continents, and are made of silica glass. Optical fibers made of chalcogenide glasses are designed for other tasks, as the authors tell us. They have many applications in areas such as the environment, biology, medicine, industrial processes, defense, and astrophysics. Those fibers have been an innovation for their microstructured design, as well as the material. Their qualities are very different from those of the usual silica fibers. In silica fibers, the resolution of Maxwell's equations leads to a certain number of "guided" modes that propagate without loss along the fiber. There is always a guided mode, and sometimes there is only one, just as in a quantum well there may be a single bound state. These single-mode fibers are the only ones convenient for information transport over long distances. In chalcogenide micro-structured optical fibers, all modes suffer losses. The fiber is single-mode when one of the modes (the fundamental mode) has much lower losses than the other ones.

Jean-Jacques Greffet won the Servant prize. His article is a complete course on classical and modern optics. The modern part (which motivated the attribution of the prize) is devoted to near-field optics, that which takes into account the whole

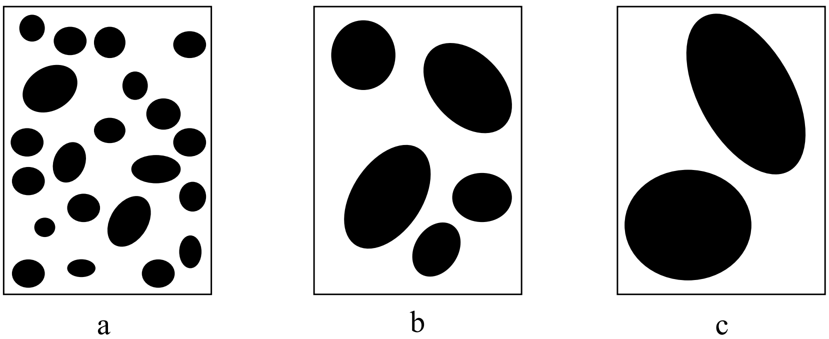

Fig. 1. A coarsening process. The black and white regions represent clusters of atoms of two different types. The length scales of the regions increase with the passage of time.

Fig. 1. Un processus de *coarsening*. Les zones blanches et noires représentent des amas d'atomes de deux espèces différentes. Les dimensions des amas deviennent de plus en plus grandes lorsque le temps s'écoule.

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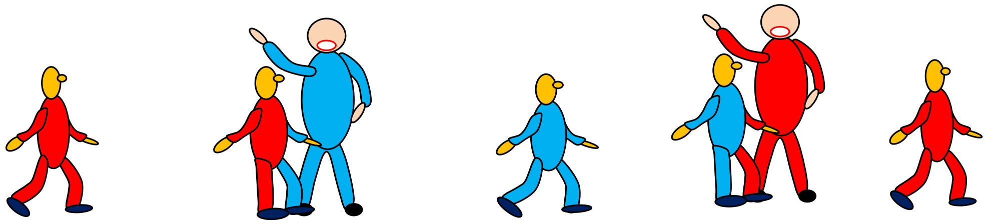

Fig. 2. The voter model. An initially red voter meets a persuasive blue voter and becomes blue until he meets a persuasive red voter.

Fig. 2. Schéma du modèle de l'électeur. L'électeur initialement rouge rencontre un beau parleur bleu et devient bleu jusqu'à ce qu'il rencontre un beau parleur rouge.

radiation of vibrating dipoles, including the parts in $1/r^2$ and $1/r^3$, not only the $1/r$ term. The classical part will be appealing for the non-expert, invited to refresh his knowledge of the historical article by which Kirchhoff, in 1860, introduced the concept of a black body (which absorbs all the light it receives) and proved that its luminance $f(T, \nu)$ is the same for all black bodies at a given temperature T and frequency ν. The determination of $f(T, \nu)$ was, according to Kirchhoff's prophecy, "a problem of the highest importance; and though difficulties stand in the way of our effecting this by experiment, there is nevertheless a well-grounded hope of ultimate success, since the form of this function is no doubt simple, as is the case with all functions hitherto discovered that do not depend on the properties of individual bodies." Forty years later, the function $f(T, \nu)$ was identified by Planck, and this was the foundation of quantum mechanics. While Kirchhoff's statements about the black body are undoubtedly correct, another part of his paper has been the object of controversies which are alluded to in Greffet's paper. Indeed, Kirchhoff claimed that "the ratio of the radiating and absorbing powers of all bodies at the same temperature is the same." This ratio would thus be equal to $f(T, \nu)$ for all bodies. Actually, there are exceptions. As Kirchhoff himself recognized, his theorem does not hold in an applied magnetic field. Neither does it hold for a nonlinear optical material. And if one reads the textbook on statistical physics of Landau and Lifshitz [2], one sees that these authors impose additional restrictions on the generality of Kirchhoff's law. An interesting point of view on this point will be found in Greffet's article.

Jean-Claude Garreau, who received the Leconte prize, explains in his article how the localization of an electron in a metal under the effect of disorder can be "simulated" by a single atom subject to periodic pulses. This analogy is based on a theory of Fishman, Grempel and Prange, which corresponds to Anderson's localization in one dimension. The situation of one spatial dimension is special since, as first pointed out by Mott and Twose in 1961, an arbitrarily weak disorder will localize (almost) all wave-functions. This analogy might be viewed as a fancy idea born from the imagination of a few theorists. However, in section 3.2, the reader becomes aware that this theory has been transformed into beautiful experiments performed in Lille in the last 15 years, which in fact motivated the attribution of the prize to Jean-Claude Garreau. Another surprise occurs in section 3.4, when one learns that the monoatomic simulator is not only able to simulate disorder in one dimension, but also in two or three dimensions (or more if desirable!). For this purpose, it is sufficient to have pulses that are no longer periodic, but superimpose two or three incommensurable periods. However, whatever the number of dimensions or periods, it may look surprising that a mathematical problem with disorder (which implies something like drawing lots) is equivalent to a deterministic quantum problem. Indeed, the author says in his abstract that this disorder is rather a "pseudo-disorder". In fact, it is an effect of quantum chaos. Incidentally, what is quantum chaos? In the first lines of the paper, it is defined as a system whose classical counterpart is chaotic. This definition, which somehow denies autonomy to quantum physics, has worried one of the referees. Perhaps our readers will have a better definition to propose. In any case, they will probably appreciate this article, which mixes well-known facts and new discoveries, not only those of the author and his group.

The winner of the Madeleine Lecoq prize for 2015 does not contribute to the present dossier. Actually she already described her work in a recent issue of our journal [3]. In her article, Cécile Grèzes described a new type of quantum device, which combines an ensemble of electronic spins with long coherence times, and a small-scale superconducting quantum processor. The goal is to store arbitrary qubit states over long times in orthogonal collective modes of the spin ensemble, and to retrieve them on demand.

Avant-propos

Ce numéro des *Comptes rendus Physique* veut offrir au lecteur scientifique cultivé l'occasion de faire connaissance avec les courants actuels dont les progrès récents ont été couronnés par un prix de l'Académie des sciences.

Leticia Cugliandolo a été désignée comme *femme scientifique de l'année* 2015 (c'est-à-dire lauréate du prix Irène Joliot–Curie) pour s'être notamment illustrée par ses travaux sur le *coarsening* (que l'on appelle quelquefois en français *mûrissement*). Ce qu'est le *coarsening*, la Fig. 1 en donne une idée. Il s'agit d'objets déposés au hasard sur une surface, par exemple des atomes par épitaxie par jets moléculaires. Ces atomes tendent à se grouper et à former des amas qui deviennent de plus en plus gros. Le phénomène existe aussi en trois dimensions et est très important pour la métallurgie des alliages. Le nombre d'atomes de chaque espèce est alors fixé ; c'est ce qu'on appelle la *dynamique de Kawasaki*. Mais il y a aussi des problèmes analogues où les amas peuvent grossir ou décroître sans aucune règle de conservation. C'est la *dynamique de*