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Passeport pour les deux infinis: an educational project in French

Nicolas Arnaud[a,*], Sébastien Descotes-Genon[b], Sophie Kerhoas-Cavata[c], Jacques Paul[c], Jean-Luc Robert-Esil[d], Perrine Royole-Degieux[e]

[a]*LAL, Univ Paris-Sud, CNRS/IN2P3 (UMR 8607), Orsay, France*
[b]*Laboratoire de Physique Théorique, CNRS/Univ. Paris-Sud (UMR 8627), 91405 Orsay Cedex, France*
[c]*CEA, Irfu, SPP, Centre de Saclay, F-91191 Gif-sur-Yvette, France*
[d]*APC, Université Paris, Diderot-Paris 7, CNRS/IN2P3, CEA, Observatoire de Paris, 10, rue A. Domon & L. Duquet, Paris, France*
[e]*CNRS/IN2P3, 3 rue Michel-Ange, 75016 Paris, France*

Abstract

Passeport pour les deux infinis (”Passport for the two infinities”, in short Pass2i) is a French educational project aiming at promoting the physics of the infinitely small (particle physics) and of the infinitely big (cosmology & astrophysics) to high-school teachers and students. It is managed since 2009 by a small team of outreach experts (physicists and engineers) from the CNRS and the CEA. The Pass2i cornerstone is a reversible book – where each side explores one of the two infinities – and which is given for free to science high school teachers who request it, thanks to the support of French funding agencies. The Pass2i non-profit association wants to be a bridge between science and education: training sessions are organized for teachers, educational resources created and made available for download on the Pass2i website `http:///www.passeport2i.fr`, and a quarterly e-letter published.

Keywords:
Education, Infinitely large, Infinitely small, Outreach, Reversible book

1. The educational project

The French ”Passeport pour les deux infinis” (”Passport to the two infinites”, in short Pass2i) project started in early 2009 with a threefold goal. First, Raising the public awareness of current basic science; then, showing the growing connections between particle physics and cosmology; finally, providing science and education a forum of fruitful exchanges. The project was developed by scientists (physicists and engineers from CNRS and CEA) in association with science teachers. Indeed, high-school teachers (and their students) are the main target audience for Pass2i since the beginning of the project, while secondary targets are the higher education and the general public. The idea was to provide teachers with a self-contained set of resources – in French – which they could use to introduce the notions of ”modern science” (particle physics, astrophysics and cosmology) which are at the frontier of the high-school science curriculum. Physics teachers have various education background, ranging from chemistry to mathematics. Therefore, they are not always comfortable with physics areas they did not learn, or which look far from the core of the curriculum. Yet, many of them are eager to know more about these topics which struck a cord in all audiences. They are also looking for ideas for some new, more applied, courses which were recently added to the curriculum and which focus on the scientific approach. The stepping stone of the project is an outreach book also called ”Passeport pour les deux infinis”. Targeting audiences with a high-school level in science, it gives the reader a scientifically-valid introduction of the physics of the ”infinitely small” and of the ”infinitely large”. These two fields of basic science are indeed more and more tightly connected, with com-

*Corresponding author
Email address: `narnaud@lal.in2p3.fr` (Nicolas Arnaud)

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Figure 1: Institutes and funding agencies which support the project "Passeport pour les deux infinis".

mon topics (matter-antimatter asymmetry in the Universe, search for new particles which could be components of the dark matter, study of high-energy particle collisions recreating conditions which existed shortly after the Big-bang, etc.), often tackled by research teams gathered in the same laboratories. Describing these topics in the same book was a obvious choice: while the distance scales are widely apart, the scales of energy involved are close. The early ages of the Universe and violent astrophysical phenomena involve energies of magnitude similar to those probed in particle physics. These connections lead to the name of the project and to the design of the book: reversible, with each half exploring one field. Thanks to an agreement between French funding agencies – the CEA and its IRFU department, the CNRS, the P2IO Laboratory of Excellence, the Paris-Diderot university and the Paris-Meudon observatory: see Fig. 1 – and the famous science editor Dunod, the book, almost 200 pages-long, was published using four-color process and sold in bookshops for a modest price (15 euros). In return, a few thousands copies of the "Passeport" were bought by the association and are being given for free to teachers who register on our website: `http:///www.passeport2i.fr`. They also receive a quarterly electronic newsletter to distribute outreach and educational information – within Pass2i and outside of it: Pass2i is one of the many education and outreach projects currently ongoing in France. In addition, events are organized for teachers: training sessions in institutes, virtual web conferences, etc. These are more than simple courses: using various resources among which the "Passeport" book, participants are encouraged to prepare educational sheets which can then used to teach a given topic. These documents are made available for free on the Pass2i website so that other teachers can download them, adapt them for their own purpose and spread them over.

2. The book

The book "Passeport pour les deux infinis" is based on contributions from more than sixty experts coming from the French scientific community – the CNRS, the CEA and the Universities. Their articles were then

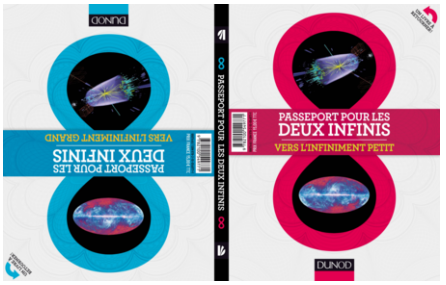

Figure 3: Cover of the second edition of reversible book "Passeport pour les deux infinis" (2013).

edited by a steering committee of six editors-in-chief to give the book its unity and to make sure all foreseen topics were properly covered. Both paths are organized in the same way: all chapters are two-page long and include at least one picture or one educational plot. The first chapters present the theoretical concepts of the science field and are followed by several other ones, describing the actual experiments which explore it. While the first part is common in outreach books, the second one is rarely present. But it matches the initial goal to bridge the gap between textbook science and today's research. This is the main reason why a second edition of the book was published in September 2013, three years after the first one: it includes the discovery of the Brout-Englert-Higgs boson at the LHC and the first cosmological results of the Planck satellite. The two parts of the "Passeport" end with a glossary to help the reader understand scientific or technical terms. The book being reversible, the two parts meet on a scale of distances which ranges from 10^{-18} m (the smallest length currently probed by particle physics experiments) to 10^{26} m (the size of the visible Universe). Figure 2 shows a typical chapter of the book: the rich iconography and the detailed captions help understand the text. The structure in short chapters enables a non-linear reading, inviting the readers to hop on and off following their interests. Figure 3 shows the covers of the second edition (published in 2013) of the book. In addition to the 4,500 copies of the "Passeport" bought thanks to the financial support to the project and which are being given to the teachers (about 3,000 have been distributed so far), more than

UNE PARTICULE, C'EST GROS COMMENT ?

La physique de l'infiniment petit cherche à observer des détails toujours plus fins de la structure de la matière. À chaque étape sont apparus de nouveaux objets, que les physiciens se sont empressés d'étudier !

Participants au 5e congrès Solvay en 1927

Ce congrès, baptisé du nom de son mécène l'industriel belge Ernest Solvay, avait pour thème « électrons et photons ». C'est là que la mécanique quantique – très différente de la physique dite « classique » – a été acceptée par la communauté des scientifiques. Signe particulier de cette conférence : 17 des 29 participants avaient obtenu ou allaient obtenir un prix Nobel ! Parmi eux on peut citer Niels Bohr (B), Marie Curie (C), Paul Dirac (D), Albert Einstein (E), Werner Heisenberg (H), Max Planck (P) ou encore Erwin Schrödinger (S).

Les physiciens passent leur temps à raisonner en termes d'ordre de grandeur : quelle est la vitesse typique d'une voiture ? La taille habituelle d'un grain de sable ? La distance entre deux planètes du système solaire ?

En effet, pour modéliser un phénomène, il faut savoir identifier les éléments pertinents et les décrire en utilisant les outils appropriés, tout en négligeant ce qui est trop petit, trop gros, trop lent ou trop rapide. Ainsi, pour étudier la course d'une voiture sur un circuit automobile, inutile de s'intéresser à la rotation de la Terre autour du Soleil (les échelles de distance et de temps sont bien trop grandes) ou au mouvement des grains de poussière dans la boîte à gants (les mêmes échelles sont bien trop petites). Et ce n'est pas la peine de recourir à la mécanique quantique ou à la relativité générale pour déterminer si la voiture sortira de la route au prochain virage !

Pour comprendre les distances associées à l'infiniment petit, commençons par nous, les êtres humains. Notre taille typique est de l'ordre du mètre – eh oui, voilà comment les physiciens nous considèrent, que nous mesurions un mètre soixante ou deux mètres... Chacune de nos cellules est un million de fois plus petite, et avec un grossissement cent fois supérieur (un cent-millionième de mètre), vous pouvez distinguer l'ADN qui est au cœur de leurs noyaux.

Fleur Pollen Molécule Atome Noyau Quarks et gluons

centimètre micromètre nanomètre femtomètre

10^{-2} 10^{-6} 10^{-8} 10^{-10} 10^{-15}

Taille (en mètres)

Grossissez encore dix fois, et vous atteignez le milliardième de mètre : c'est la distance entre deux atomes d'une molécule. Les atomes eux-mêmes sont dix fois plus petits. Ils sont constitués d'électrons et d'un noyau atomique de taille dix mille fois plus modeste (cent millièmes de milliardième de mètre), constitués de protons et de neutrons eux-mêmes dix fois plus petits. On arrive alors au millionième de millionième de millimètre.

Plongeons encore plus profondément dans la matière. Les neutrons et les protons sont constitués de quarks dont on ne connaît pas la taille (au moins mille fois plus petite que celle des protons). On ignore également celle des électrons. Jusqu'à présent, les expériences semblent indiquer que les quarks et les électrons sont ponctuels et donc élémentaires... Le sont-ils vraiment, ou la résolution de nos expériences est-elle encore trop faible pour mettre en évidence leur structure ? Personne ne le sait.

À chaque niveau de détails sa discipline scientifique : physique des matériaux, chimie, physique atomique, physique nucléaire, physique des particules... Toutes ces échelles de distance ont une contrepartie en termes d'énergie. Car plus on veut sonder la matière sur de courtes distances, plus il faut fournir d'énergie aux projectiles employés, et plus les accélérateurs nécessaires sont de taille importante. Voilà qui explique pourquoi les physiciens des particules, dans leur course à l'infiniment petit, se sont aussi lancés dans des expériences toujours plus grandes – jusqu'au LHC, dont les détecteurs ont la taille d'immeubles de plusieurs étages.

D'une fleur aux quarks : vers l'infiniment petit

À chaque échelle de longueur correspondent de nouveaux détails qui apportent des informations supplémentaires sur la structure de la matière. En-deçà du nanomètre, les figures sont des représentations et non pas des photos réelles. La physique de l'infiniment petit explore un large domaine qui part de l'angström (un dixième de milliardième de mètre, la taille caractéristique d'un atome) et s'arrête actuellement au niveau du milliardième de milliardième de mètre. Les échelles plus petites se dérobent encore à l'expérience et leur contenu éventuel est un mystère.

Figure 2: Example of a chapter from the "Passeport pour les deux infinis" book: "how big a particle is?".

7,000 copies have been sold in bookstores and 1,500 bought by the CERN. This shows that the book has been well-received by French teachers and by the general audience. Although it focuses primarily on experiments in which the French scientific community is involved, we think that translating it to another language (and in particular English) is feasible if a small team of motivated people can be formed. What we are currently lacking of are the financial resources needed to perform a first draft translation, to find a foreign editor and to set the ground for a new contract with the Dunod editor.

3. Conclusions

"Passeport pour les deux infinis" (e-mail contact: contact@passeport2i.fr) is an innovative educational and outreach project promoting particle physics, astrophysics and cosmology to science high-school teachers in France. The collaboration with the science editor Dunod allowed us to produce a high-quality reversible book, which is still the main entry point for teachers in the project four years after its first release. This would not have been possible without the support of several institutes and agencies which provided us the financial resources needed to make the project come true. The royalties of the book are entirely reinvested by the association and are mainly used to fund the shipping of book copies and to print leaflets describing the project.

Finding the right balance between a non-profit project like Pass2i and a private editor is not easy. The experience gained while collaborating with Dunod is available for sharing with the whole education & outreach community. What is sure is that whether printed contents or digital resources are produced, their quality must be professional to ease their circulation within the target audience. And this kind of expertise is not commonly present in laboratories. Outsourcing the production of outreach material is thus a natural solution – but an expensive one. Alternatives should be sought for. The Pass2i project is now a reference for French high-school teachers willing to learn more about the "physics of the two infinities". The main challenge ahead is to keep it alive in the long term with limited resources (both in terms of manpower and money), in particular when we run short of free copies of the book. This requires strengthening the range of education and outreach projects developed in parallel by the French scientific community, so that anyone interested in knowing more about these fields can find the best material suited for its needs. Translating the book to other languages remain a mid-term goal for the project.

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