Département de Physique
École normale supérieure

Normale Physics Review

Fights Bohr-dom

9th of March 2021

Édito N_7: La newsletter physicienne pour Normaliens confinés

*C'est avec grand plaisir que j'ai accepté d'écrire quelques mots pour l'éditorial de ce septième numéro de la déjà célèbre Normale Physics Review. C'est pour moi l'occasion de saluer cette superbe initiative et de remercier tous ceux qui y contribuent, de près ou de loin. En cette période si compliquée pour la vie collective, il est réconfortant de voir que les plus jeunes d'entre nous se mobilisent pour la renforcer et pour remettre le partage au centre de nos préoccupations. Cette fois-ci, Laurette Tuckermann a pris la plume pour nous partager sa vision de notre discipline. La NPR vous transportera également à La Havane pour découvrir son université sous la houlette de Carlos Ernesto Lopetegui. C'est chaque fois un bonheur d'ouvrir la NPR, je ne peux que tous vous inciter à y apporter votre contribution. Longue vie à la NPR ! (**Jean-Marc Berroir**)*

[Announcements]

The NPR is happy to present you its new website. We hope it will make it easier for you to read our content! It may not be perfect, we are still working on it. Here is the link : `normalephysicsreview.netlify.app`

Our team is still open to new redactors! Feel free to contact us at any time if you want to help us to improve our project. It is a good opportunity to broaden your experience in the Physics department. Contact **Esteban Foucher** if you are in $\varphi 20$ or **Guillaume de Rochefort** if you are in $\varphi 19$ or anyone else in the editorial board (see our emails at the end of the issue).

[Physicists' life]

One word about ... Physics Faculty of the University of Havana

In the highest point of the city, with a direct view to the Caribbean Sea, you can find one of the most impressive and iconic places in Cuba : the University of Havana. With 290 years of prolific history, it is the most prestigious educational institution of the country encompassing 16 faculties and more than 14000 students from all over the nation, as well as an important number of internationals. In the top of the hill, a privileged place has been reserved since the 1950's for the Physics Faculty (known by all of us as FF-UH by its spanish name : *Facultad de Física de La Universidad de La Habana*) .
With a very small number of collegiate and professors, opposite to the common tendency in the University, it is a very particular faculty. No more than 15 students in average graduate every year. Yet, this difference renders the environment almost familiar, and the education very personalized. The interchange between different generations of students is remarkable, as it is the relation with the professors. And that is something I really enjoyed during my time there, sometimes you could get to forget the limit in between professors and students, who could get involved in very intense discussions about any kind of topics, from science to politics, to economics to sports (I will certainly remember the basketball matches between professors and students).

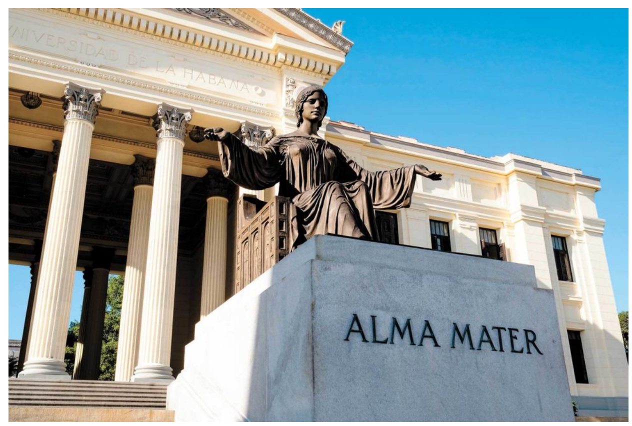

Figure 1 – *One of the University of Havana's most iconic symbol, the Alma Mater statue in the top of the hill*

A longer undergrad ... why?
There is a remarkable difference with respect to European approach based on the Bologna program, that is worth mentioning : Bachelor in Cuba, and in particular the Physics' one, comprises a 5 year formation. The first three years are mostly

oriented to a general formation in the tools of Mathematics for Physics, and in General Physics (including a large Experimental formation), with a gradual introduction to Theoretical Physics, that represents most of the curriculum in the last years of studies, along with some humanity subjects like Philosophy and Political Economics. But a common point during the whole formation is the research oriented formation and the continuous immersion of students in real research projects. This is the key feature that is highly defended by the advocates of the 5 year program formation who fear that a reduction would end up sacrificing it. In particular, since the end of the second year you have to get involved in one of the Research Groups of the Faculty, dedicating one day every week (at least), to research. Something that I absolutely appreciated is that once you enter one of these groups you are treated as an equal, being invited to participate of all seminars and events as the rest of the members, getting the feeling of what it is like to be a graduate student, and what real research is about.

Scientific Journeys : Every year, during one week, usually in the month of May, a big movement occurs around the biggest event organised by the students of the Faculty : The Scientific Forum. Every student is encouraged to present his results from the whole year of research in one of several panels and the most relevant results are recognised. With 37 editions so far, it keeps a long tradition of good level of presentations and has never ceased to keep students in the highest expectation. It is an incredible week and a big party of knowledge and interchange, as not only the student presentations are hold but also, conferences from invited researchers in topics of science or society.

The research at FF-UH : The landscape of research in the faculty is quite diverse. It includes a Center for Complex Systems and Satistical Physics, A Laboratory of Photo-voltaic research, a laboratory of structural analysis, a laboratory of Semiconductor nano-structures and a group of Theory of Nano-Structures. Also, a large collaboration with an Astrophysics group in the Institute for Cybernetics, Mathematics and Physics of La Havana (ICIMAF), renders the latter one of the most actively growing research topics in the school. This extraordinary diversity makes of the Physics Faculty of the University of Havana a reference center for research in Latin-America, and constitutes a remarkable achievement in a developing country. In this sense, a large dose of creativity, hard work and sense of duty have kept those groups in constant growth. It is notable in particular the amazing job that people who do experimental physics make in achieving the most interesting results with undeniable limitations arising from several years of economic constraints. I remember with a particular enthusiasm one paper that appeared in the Revista Cubana de Fisica in 2019 where they present a highly creative experience on simulating experiments on granular media in gravities different of that of the earth, at a cost of less than 500 euros ! ! ! (See Rev.Cub.Fis. 36,46 (2019)).
And is in this spirit that I want to finish my (I hope not too long), article about my previous university, with a reference to what I consider were the biggest gifts (apart from a very rigorous formation on Physics and Maths), from my professors there : a constant call for creativity, for efficiency and sense of duty, not only with science, but also with society !

Figure 2 – *University of Havana : Physics Department*

Carlos Ernesto Lopetegui

Undergraduate Intership : Optical vortex at home ?

The prospecting for my intership started early : I was sending application from end of January- beginning of February. Mainly because I'm the kind of person who sinks into the ocean of stress if he is a bit in a hurry and I wanted to take the time in order to found an intership which suits to me. Following some recommendations of teachers from my *Classe préparatoire*, I was scrolling pages of research groups of the CNRS center in Bordeaux. And some words stopped me : "acoustic vortices", "optical vortices" : I was really puzzled imagining a maelström of accoustic waves. Then, I decided to contact the team leader of the *Singular optic group*, E.Brasselet to discuss about this notion. After a few exchanges he proposed me to work with them on this topic, the precise subject needed to be precised later, with respect to their actual researches.

Well, weather was good, sun was shining, I fund my intership and we were in March. And lockdown. Because of sanitary restrictions, the lab didn't accept interns working on site -quite embarrassing for an experimental work. We were around mid of May. Fortunately for me, my supervisor proposed me something original. He wanted me to try to produce, observe and study optical vortex, at home, without all the material you can get in a lab. Of course, the purpose of the study should be modest, far from what we originally consider, but the challenge was real and very exciting ! Deal, I will spend July to do singular optics on a shoestring in my bed room.

Optical vortex

First, let's explicit what we called an *optical vortex* or a *phase singularity*. Let's consider a scalar optical field writing on its complex form $E(\mathbf{r})$:

$$E(\mathbf{r}) = A(\mathbf{r})\exp(i\psi(\mathbf{r})) \tag{1}$$

When the amplitude factor A vanished, the phase is ill-defined because every values of ψ are convenient. This zeros (isolated) are called *phase singularity*. They correspond to the intersection points of null lines for the real and imaginary part of the field. Why is it called a vortex ? Simply because if you compute the phase on a line surrounding only one of this points, you see that every values between $]-\pi, \pi]$ are continuously reached : the phase *flows* around the point. We can defined the phase circulation as :

$$\frac{1}{2\pi}\oint_{\Gamma} \nabla_{\mathbf{r}}\,\psi\,dl \tag{2}$$

The phase circulation is non-zero when we surround a phase singularity and then takes integer values. The integer enables to characterized the singularity and it's called *topological charge*.[1] Briefly, optical vortex can appear when at least 3 planar waves are interfering (because you need isolated zero points) and can be detect be interferometry. When you take two incident waves, with direction inclined with a angle θ, you expect fringes. The interfringe scaled as $\propto \frac{1}{\sin\theta}$. Now, in presence of singular point, the fringes bifurcated and the number of branches is equal to the topogical charge $+1$ (see Figure 3).

How to do this at home ?

In my case, we choose to produce as planar waves as possible. There is a simple trick to do that. Take a translucent paper and send a beam on it. Project the figure on a wall. You should see a granular stain. This figure is called a *speckle field* and is the result of interferences between a large number of coherent beams propagating in random directions. I had to try to detect optical vortex in this speckle. The only thing I buy to construct my home-made interferometer was a basic pointer for presentation. I prospect broken mirrors, polarizer sheet from a game console, binoculars, lens from an old microscope, camera... and Legos ! Using Lego, I was able to construct the structure of a fashion Mac-Zendher interferometer. I stick mirrors on Lego walls who can rotates, Laser was

1. One can see that there is obviously a strong connection with the lectures *Topological Physics*. Here we'll discuss experimental features. I won't spend time to explain how to characterize your mug coffee with a shoestring.

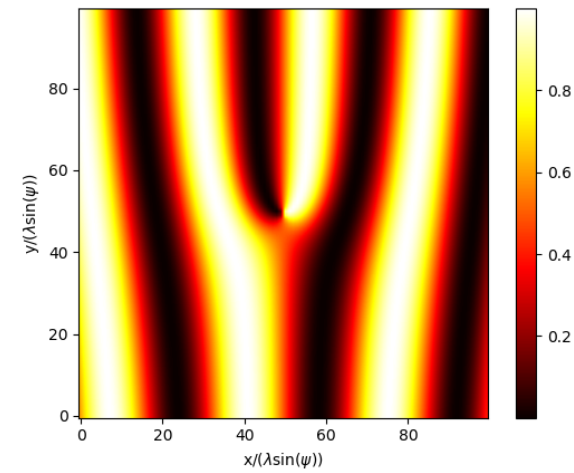

Figure 3 – *Interfringes in presence of a singular point (coordinates* (50, 50)*). The bifurcated fork has two branches, indicating a topological charge of* $+1$.

caught in a wood structure and I use the LCD screen of the camera directly to record images (see Figure 4). Challenge completed, I finally observed this singular forks, as displayed on the mystery photo (Figure 5) !

Despite of the overall situation, this intership was funny and a good way to end a curious online semester. What a pleasure to finally work on *touchable* objects ! We regularly discussed by e-mail with my supervisor during July to share advancements, problems and ideas and it was exciting to discuss together on how to construct a Mc-Gyver interferometer.

I'd rather you to take enough time to search your intership. Scroll the pages of the groups, read some publications. Above all, discuss (in the time they can offer to you) with the researchers. One question you should ask it's how much time they can give to you and/or how many people could mentor you in the lab. It's crucial for this first intership where we all unfortunately lack of autonomy.

L.Brivady

Sir, I have a question

Vous êtes khôlleur ou tout simplement curieux ? Peut-être trouverez-vous dans les questions suivantes un problème ouvert intéressant. Vous observez un phénomène étrange ? Arrêtez de regarder The Lupin et envoyez-nous une question (adresses mail en fin de review) !

I : Is the use of a logarithmic scale in audiometry relevant for describing the relation between the intensity of the

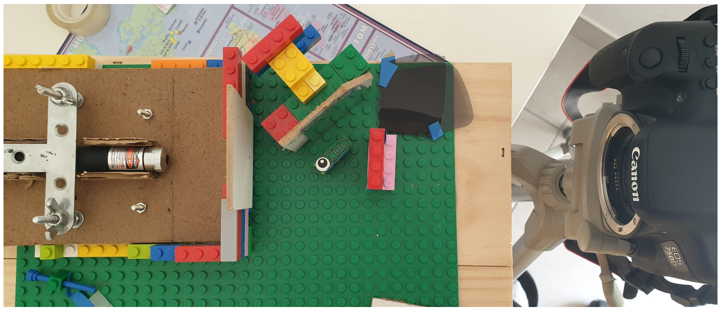

Figure 4 – *The home-made interferometer. From left to right : the laser source caught in a lego structure. The metallic piece maintains the pointor on. The separator lame, taken from a toy microscope. On the top, the mirror. Then the polarizer sheet, used to adapt the intensity of the probe beam. On the bottom, the diffusive sheet. On the right, the camera whitout the objective. I used relative small (1/300s) exposure time to suppress parasite vibration but ensuring that the luminosity is sufficient. The interferometer is located on a bicycle innertube to limit vibrations.*

sound and the stimulus ? ;

II : Open a tap above a plane surface. You might observe that there is a disk were there the level of water is smaller. How its radius scales depending on different parameters ? ;

III : A vibrating structure has prefered frequencies, called "modal frequencies". What the magnitude order of the modal for a bridge ? For the structure of your choice ? ;

IV : [Special 2024 O.G] Should a pole vault use a longer pole to beat the world record of Armand Duplantis (6.18 meters -indoor) ? ;

V : [Special biathlon] After the sprint part, you reach the shooting range. Because it was hard, your heart beats at 190bpm. The target is 25m away. You point the center of the target. What's the deviation of the bullet if you shot during a beat ? ;

VI : How much water drop off as spring morning dew on the grass ? ;

VII : How long does it take to dig a tunnel of diameter 2 meters at 10 meters depth ? Assess the time needed to construct the Channel tunnel. Is a similar calculus valid for the construction time of a building of 10m high ? ;

VIII : What is the frequency of your voice ? ;

IX : How many leaves are there on a three ? Is there a relation with its high ? ;

X : How many ears has a mouse ? ;

Thanks to **G.Rochefort, L.Brivady**

About the previous questions...

Question VIII of N_5 :

Could we imaging replacing the power supplies in our everyday life by human powered sources of energy ? Is charging while pedalling cellphones a durable and reasonable solution to the upcoming challenges ? This questions are aroused by the following previous question in the NPR : *How many mechanical work could you reasonably deliver in one day ? To supply your daily energy consumption, how many workers would you need ?*. Indeed, to decide whether or not humans can self-power their phones, we need to assess their production capacity.

Some recalls. First, I need to recall some equivalency between units. Physicists commonly quantify energy in joules J (or eV if we're interested by atoms). Nevertheless, nutritionists cherish the calorie unit C (with a capital C). And your electricity bill gives your consumption in kilo-watt per hour kWh. We have : $4.14\ kJ = 1\ C$, $1\ kWh = 3.6\ MJ$. To give some order of magnitude : the heating value of oil is around $38\ MJ/L$. Then 1 Liter of oil delivers around $10\ kW/h$ of energy. The yield of a motor is 40 percents. Finally, 1 Liter in a car produces $4\ kWh$ of mechanical work. A standard lamp consumption is about $0.1\ kWh$ and for a basic radiator it's $1\ kWh$. And what's about us ? Every day, we eat 2000C in average, i.e $2.3\ kWh$. So one can see that our metabolism baseline is $0.1\ kWh$. Energetically, we are equivalents to bulbs.

Guinea pig in its wheel. We saw that when we're inactive, emit as much heat as a bulb. This is not glorious. Now imaging that your job is to produce as much work as possible every day, on a stationary bike. You're pedalling 8 hours per day. During this time, I'll assume that the average power produced is around $125\ W$ (for a trained cyclist, this correspond to the power delivered in an fully endurance effort, which can be supported during many hours). So you'd develop $1\ kWh$ per day of mechanical work (every day !). To encourage you to pedal, we will assume that there is no loss in the energy chain.

One can see that for the modest cost of 1.5€, your car deliver $4\ kWh$ of mechanical work. Which correspond to 4 peoples pedalling a full day for you paid 0.4€ per day.

Then, in a world where power plant would be replaced by human powered plant, we all would be slavers, having 4 slaves pedalling for us to commute.

We can go further. What's our daily energy consumption ? Taking that one use his car $20km$ per day ($\sim 14\ kWh$), 10 electrical devices turned on 10h per day ($\sim 10 * 2\ kWh \sim 20\ kWh$), a radiator turned on 10 hours ($10\ kWh$), we can assess it at $44\ kWh$ per day. In other words, one need 44 slaves to supply his consumption...

Discussion The previous calculations are taken from the work of Jean-Marc Jancovici (see references). M Jancovici uses simple consideration of order of magnitudes to explain clearly the current environmental issue we are facing. Indeed, one of the major crisis we would deal with is the end of fossils fuels because they still represent the major part of the sources of energy consumed. And it's a smokescreen to think that we could keep the same standard of living with just adding some muscular sources of energy with respect to the rough calculus below.
Another one to finish : A tractor delivers a power of 150 horsepower, namely 100 kW. The farmer uses it around 4 hours per day and consequently needs 800 kWh every day. The exploitation would need 8.000 people to replace the tractor where one is enough currently ! There is 400k farmers for 65 millions of french today. Tomorrow, 320 millions farmers would be needed...

References

Jean-Marc Jancovici, *Combien suis-je un esclavagiste? (Web)*

Discussion

Math or Physics ?

How many times have you asked or been asked, "Which do you prefer, math or physics ?" You may have formulated an answer to this : probably "physics", since you are reading the Normale Physics Review. But what does this really mean ? It is obvious that math and physics are closely related. Is there a clear-cut distinction between the two ? If so, what is it ? And how can mathematics and physics be defined ? A common starting point is : Mathematics consists of posing and proving theorems. Physics consists of discovering new fundamental laws and testing them. Sociologically, neither is anywhere close to being true. The overwhelming majority of people called physicists never discover new fundamental laws, even those who publish many papers and receive awards. And many people called mathematicians do not prove theorems.

In studying electromagnetism or quantum mechanics or advanced classical mechanics, a great deal of what we learn is differential equations such as the Poisson or Schrodinger equations and techniques and special functions for solving them. Is this math or physics ? Most will probably agree that this is math, or perhaps mathematical methods for physics, but this was not clear in my mind for a long time. Basically, this is the mathematics/physics that was developed in the 19th century, before the two diverged.

Mathematics has marched triumphantly across the landscape of the natural sciences, inventing and applying seemingly strange objects like complex numbers and quaternions. The alchemists were unable to explain the chemical elements, but the periodic table was finally ordered by the spherical harmonics. Biology is next on the agenda. In his famous article *The unreasonable effectiveness of mathematics in the natural sciences* [*Communications on Pure and Applied Mathematics* 13, 1, 1960], physicist Eugene Wigner states "The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve." Mathematician and philosopher Bertrand Russell believed that this was due to the nature of humans : "*physics is mathematical ... because ... it is only its mathematical properties that we can discover*" [*An Outline of Philosophy*, 1927]. Physicist Max Tegmark, on the other hand, believed that this was due to the nature of physics : "*the physical world is a mathematical structure, and we are simply uncovering this bit by bit.*" [*Found. Phys.* 38, 101, 2008]. Another question about human nature : Is mathematics invented or discovered ?

In the Great Hall of Ecole Polytechnique (sorry !) there is a stone tablet on which are engraved the names of the great professors of yore (a romantic expression for the past, often used semi-ironically, like "*d'antan*" or "*jadis*" in French) : Ampere, Arago, Cauchy, Liouville, Hermite, Hadamard, Lagrange, Fourier, Poisson, Ampere, Mathieu, Navier, Painlevé, Poincaré. None of the above are designated as professors of physics. Instead, they are professors of mathematics or of mechanics. *Mechanics* ? Where does that fit into our classification ? Mechanics is the physics that precedes the early 20th century revolutions of quantum mechanics and relativity. There seems little reason to distinguish it logically from physics ; clearly, if anything, mechanics is a particular and large branch of physics. In the last few decades, physics journals and departments have exploded with new types of mechanics problems : the behavior of granular media, new kinds of elastic shells. This brings up a new question (which we will not address) : what is the difference, if any, between physics and engineering ? Is it in the object of study ? Clearly not, from the example of mechanics above. Is it in the degree of applicability ? But don't physicists also aspire to be useful ? Is it in the degree of generality ? What about the construction of a new type of telescope or laser ?

Nowadays, *Physical Review* contains articles on stock pricing, recessions, traffic jams, income inequality, the ranking of sports teams. One hears new terms such as *econophysics* and *sociophysics*. In what sense are these physics ? Certainly not, if physics is defined to be an object of study. Perhaps, if physics is defined as a collection of methods, or a way of thinking. Is that what physics is ? Mightn't we say just as easily – and perhaps more appropriately – that this research uses a collection of mathematical methods that are usually used or that originated in physics ? Or is the rule that when people who call themselves physicists start to study something else, they call it a kind of physics ? Perhaps the definition is sociological or tautological : physics is what is done by people who call themselves physicists, who work in physics departments and publish in what are called physics journals.

My own field is fluid dynamics, in which a (the ?) major problem is turbulence. Fluid motion is described by equations derived by Navier in France in 1822 and Stokes in England in 1844. (Note that even when there were so few scientific journals and articles, scientists did not read them.) The Navier-Stokes equations are perfectly adequate descriptions of the flow of incompressible Newtonian fluids and computers are perfectly capable of solving them to increasingly high Reynolds numbers each year, reproducing the phenomenology of turbulence seen in the laboratory. What then is "the problem of turbulence" ? I will propose an analogy. Outside of the relativistic and quantum-mechanical domains, Newton's laws are perfectly good descriptions of the motion of particles. If we know the positions and velocities of a million or more particles at some time, along with the forces acting on them and the shape and nature of the domain, we can enter all of this into a computer and Newton's laws will give the positions and velocities of the particles at a later time. Yet, this procedure seems rather short on elegance, generality, or insight.

This is where statistical mechanics enters. Boltzmann did not discover any new force or law ; what he did was to situate the problem on a higher level, defining macroscopic variables that condense the Newtonian description into a much more useful one. This is quite different from the revolutions of quantum mechanics or relativity, which addressed incorrect results produced by the previously accepted Newtonian laws of physics. I propose that the "problem of turbulence" is similar, that while the Navier-Stokes equations are not wrong, the description they provide is at too low a level to be useful despite their accuracy. We seek a formalism that will not invalidate or correct the Navier-Stokes equations, but will sit on top of them to provide the macroscopic predictions that we seek. Basically, we will have the "answer" to the turbulence problem once we know what the question is.

Returning to statistical mechanics, what is it ? Is it physics, as you have been taught ? Or might it actually be math ? I can propose a different distinction between physics and math. The laws of gravitation or electromagnetism could logically be other than they are. But mathematics proceeds by pure logical reasoning and could not be other than it is. By this definition, much of statistical mechanics would be math ; it is derived by pure thought. An important development from the last quarter of the 20th century is what is sometimes called the chaos revolution, developed by researchers such as May, Lorenz, Feigenbaum and Swinney in the U.S. and Coullet, Tresser, Pomeau, Manneville, Libchaber, Berge, Dubois, Fauve in France (yes, France, and even ENS, played a crucial role in the chaos revolution !) These researchers discovered that small changes in initial conditions could grow exponentially, leading to completely different endpoints. Of course, this is true of any system in which there is exponential growth, but they showed that this could also be true of systems in which the trajectories occupy a bounded subspace, called strange attractors. This led to completely rethinking ideas in several fields, such as meteorology. You have probably heard of the butterfly effect, by which a butterfly flapping its wings in Brazil might lead to the formation of a distant tornado. The separation of trajectories (outcomes) implies that another digit of accuracy in initial meteorological conditions (i.e. a 10-fold reduction in uncertainty) leads to only an additional day (for example) of accurate prediction. In 1969, MIT meteorologist Edward Lorenz, proposed that the time horizon for weather prediction was limited to two weeks ; 50 years later, atmospheric scientists reiterated this estimate [E. Lorenz, Tellus 21, 289, 1969 ; F. Zhang et al. J. Atmos. Sci. 76, 1077, 2019]. Hamiltonian chaos has come to play an important role in plasma physics, which in turn describes prospective nuclear fusion reactors such as the ITER tokamak at Cadarache in Provence. Chaos theory, more properly called dynamical systems theory, concerns the qualitative behavior of differential equations, and builds on the field developed in the 1880s by Henri Poincaré. (The Institut Henri Poincaré is a block away from ENS, on rue Pierre et Marie Curie). [*Dynamical systems theory is the right way to understand the behavior of nonlinear differential or difference equations, just as linear algebra is the right way to understand the behavior of systems of linear equations. Linear algebra is viewed as math and, moreover, a fundamental and necessary part of every quantitative person's education. Yet dynamical systems theory, in contrast, is viewed as a somewhat specialized topic.*] Is chaos theory math or physics ?

To address this question, let us focus just on physics (or physicists) for the moment. The physicist Victor Weisskopf (1908-2002) divided physics into "***intensive***" and "***extensive***". **Intensive physics** is the formulation of new fundamental laws, as in high energy physics. **Extensive physics** is the explanation of phenomena in terms of known fundamental laws, as in condensed matter physics and plasma physics. Philip Anderson (1923-2020), who won the Nobel Prize in physics in 1977 for his work in magnetic and disordered systems, had strong opinions about this. He rejected the classification of extensive physics as less worthy than intensive physics, giving the word "emergence" to the complexity that connects the different levels. Presenting a hierarchy of elementary particle physics, many-body physics, chemistry, molecular biology, cell biology, ... going all the way up to physiology, psychology, social sciences, Anderson states : "*At each level of complexity entirely new properties appear and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. But this hierarchy does not imply that science X is just applied Y. At each stage entirely new laws, concepts and generalizations are necessary, requiring inspiration and creativity to just as great a degree as in the previous one.*" [P.W. Anderson, Science 177, 393, 1972]. Both statistical mechanics and chaos theory would seem to be examples of the "emergence" or "complexity" described by Anderson.

I have asked a great many questions but proposed very few answers. To the extent that I have a conclusion, it is this. Between the time of Aristotle and the mid 19th century, the discipline that attempted to catalogue and explain the wonders of the world was called natural philosophy ; the subdivisions of physics, chemistry and biology date from the mid 19th century. But today, it should not be necessary to decide whether what you are doing is called math or physics or pure or applied physics or chemistry or engineering. Call yourself a natural philosopher and a seeker of truth. (**Laurette Tuckerman**)

Mystery photo

The previous photo - N_6

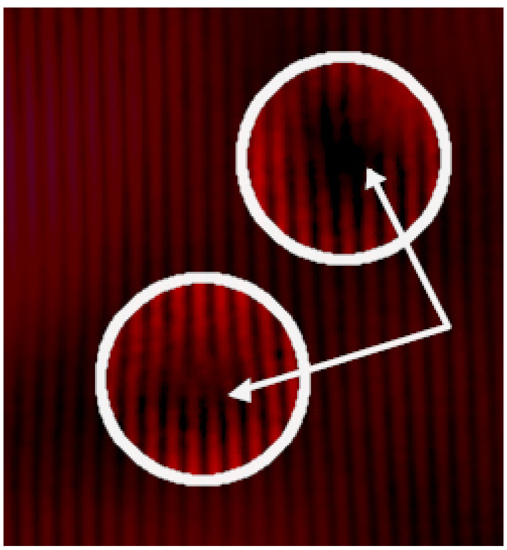

Figure 5 – *NPR6*

This is a selected part of the images I captured during my intership with my set-up. (Numerical zoom x5). On the background one can see regular interfringes. The two inlighted are singular fringes locating two vortex of opposite charges. The upper one separates into two branches, so the topological number is $+1$. The other is two branches joining into one, so the topological number is -1. Obviously, one can imagine another convention (looking from up to down) so the charges would be inverted. (**L.Brivadi**)

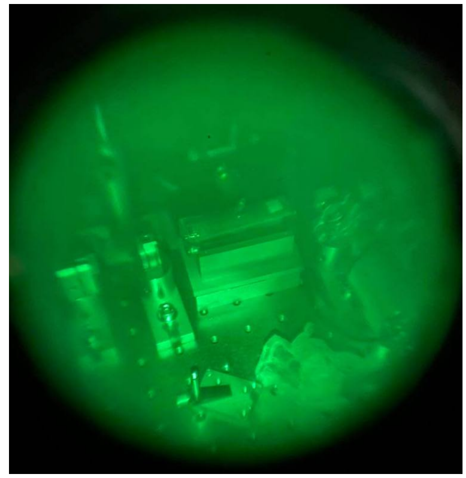

Figure 6 – *Merci à* ***G. de Rochefort*** *pour sa photo ! Arriverez-vous à trouver de quoi il s'agit ?*

[Acknowledgements]

We thank our contributors for their fantastic articles and questions. We also thank everyone who send us their feedback and encouragements. And thank you dear reader !

We need you !

If you would like to contribute or support us, don't hesitate to contact us :

— **Esteban Foucher** φ20 : esteban.foucher@ens.fr

— **Rodrigue Orageux** φ20 : rodrigue.orageux@ens.fr

— **Basile Dhote** φ19 : basile.dhote@ens.fr

— **Ludovic Brivady** φ19 : ludovic.brivady@ens.fr

— **Guillaume de Rochefort** φ19 : guillaume.de.rochefort@ens.fr

(The Editorial Board)