Eur. Phys. J. A (2017) **53**: 214
DOI 10.1140/epja/i2017-12403-6

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Theoretical Physics

Daniel Gogny*

J.-F. Berger[1], J.-P. Blaizot[2], D. Bouche[1], P. Chaix[2], J.-P. Delaroche[1], M. Dupuis[1,a], M. Girod[1], J. Gogny[3], B. Grammaticos[4], D. Iracane[2], J. Lachkar[2], F. Mariotte[5], N. Pillet[1], and N. Van Giai[6]

[1] CEA, DAM, DIF, F-91297 Arpajon, France
[2] CEA, Saclay, Gif-sur-Yvette, France
[3] Livermore, USA
[4] CNRS, IMNC, F-91406 Orsay, France
[5] CEA, Fontenay-aux-Roses, France
[6] Institut de Physique Nucléaire, CNRS-IN2P3 and Université Paris-Sud, F-91405 Orsay, France

Received: 27 September 2017

Communicated by N. Alamanos

Abstract. In this article, the scientific life of D. Gogny is recounted by several collaborators. His strong involvement in researches related to various fields of physics (such as nuclear, atomic and plasma physics as well as electromagnetism) appears clearly, as well as the progresses made in the understanding of fundamental physics.

1 Introduction

This article bears witness to Daniel Gogny's life as a physicist. It reviews the scientific progress and developments Daniel made with his former colleagues, more recent coworkers, as well as three generations of PhD students. Daniel changed our understanding of the atomic nucleus when he introduced, in the early 70s, a finite range nuclear effective interaction. The Gogny force still serves today as a benchmark for the latest developments in nuclear theory. Daniel spent most of his career at the Commissariat à l'Energie Atomique (CEA) in the Military Application Direction (DAM). He has deeply contributed to its national and international scientific standing and has left his mark on a large community, especially in training several generations of physicists. His contribution to the scientific research performed at the CEA was not limited to nuclear physics. He also ingeniously tackled problems related to the radar electromagnetic signature, and to atomic and plasma physics. Even now, Daniel's work plays a crucial role in improving nuclear data accuracy. Daniel retired from the CEA in 2004 but continued to mentor doctoral students and work with his collaborators both in the CEA-DAM and at the Lawrence Livermore National Laboratory (LLNL) in the USA, for the next 11 years. He contributed to build strong links between the DAM physics community and US National Laboratories around challenging problems in various fields of physics, and especially through the role he played in the establishment of the DAM-NNSA agreement.

The way Daniel conducted his research was profoundly rooted in his philosophy of life, as explained by one of his children, Jordan Gogny, during the first Gogny conference held in December 2015:

"My father had a view of life informed by his love of problem-solving. When first faced with trouble, it is almost impossible to say what exactly is at issue. Where to begin is almost as much of a dilemma, as is the problem itself, and usually the nature of your predicament is neither as grand nor as obvious as one might hope or else the solution would be simple and the fix clear. Instead, it ends up being one of many seemingly trivial details; a subtle complication prone to oversight. Identifying the source of the issue is a rare gift that few have been as blessed with as my father, and it is a talent that drove him to discover things we could only have dreamt of before.

And finally I think it was this fascination with perplexity, this draw to mystery more than anything else, that attracted him to mathematics as a means by which to unveil the enigmatic essence of existence and defined his spirit. Here, he approached his interests using a method he was very much convinced of (and not bad at) yet did not feel restricted to. You would be very surprised just how much he knew of subjects far outside his professional preview; things like history, culture, politics, music and philosophy.

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* Contribution to the Topical Issue "Finite range effective interactions and associated many-body methods - A tribute to Daniel Gogny" edited by Nicolas Alamanos, Marc Dupuis, Nathalie Pillet.

[a] e-mail: `marc.dupuis@cea.fr`

But since it is not convenient to study everything all at once within the span of one lifetime, better to pick one and do well where you excel. This particular pragmatism came from an attitude of his wanting to see the whole of but one aspect of reality first, if nothing else, because he believed in depth before breadth: once captured by a question posed —usually in science— he would focus intensely on the specifics and it was only until he understood fully the minutia that he would proceed to perform his great work, and not a moment before. He would insist on reviewing the introductory material over and over again until crystal clear and pressed his peers to restate the general idea in simplest terms. He asked not so much for the answers themselves, but to be sure of what he already knows and to survey his colleagues for agreement, to see if they too have the same understanding. After all, it's very confusing to communicate with others concerning the same text when everyone speaks and thinks of it differently. More importantly, by doing this, he was addressing the question "what are the basics?", the atomic facts, if you will, which, while elementary are also essential, for whatever is basic is likewise fundamental, and whatever that may prove to be is necessarily the case, extending abstractly to any and all possible relations and their manifestations, meaning if you are right in one regard, it stands to reason the principle adopted will apply universally (one hopes) thereby enabling you to deduce the whole —therein lies the integral truth.

Besides his area of expertise —fission— my father would often drift into tertiary topics of particular intrigue to him, namely numbers theory of relativity and specifically time dilation, magnetism and string theory, just to name a few.

The pursuit of knowledge at the deepest level of understanding, getting at the bottom of the underlying veracity of reality, knew no end for him. Once transfixed by a new notion, there could be no peace of mind from then until the moment of insight arrived. If you could see him passing up and down the halls of our home, roaming the gardens restlessly, scouring the fragile pages of ailing texts for answers unknown, you would think him quite mad, and indeed he was able to drive himself very much insane if it would bring him closer to some transcendent truth. My father was always a skeptic. He would often say to me "doubt is the most important thing", yet you have to start somewhere in science, usually with a theory entirely your own, and that requires a modicum of faith and boundless imagination. He had no fear of making the strongest claim: If the implications of the thesis were of consequence, he would argue for it forcefully and incessantly.

It is not enough that one simply does something in science out of obligation, but because one truly believes in what they are doing. My father's hero, Marie Curie, is maybe the model disciple, giving her life in an effort to bring to light something new and extraordinary and today, radiation, a radical idea for its time, is as common a notion as the recipe for apple pie. The revelation of radiation and ideas like it expand our collective consciousness, even when we are oblivious of its influence, well beyond our initial condition and elevates us all above our mortal coil.

With all the progress we've made, all we've learned and accomplished, it's easy to feel confident and be proud, but what, I ask, does it mean? How ought we reflect on ideas that come of it? Having internalized all we've gained, in what state do we find ourselves in? That is the questions my father posed with his work and I hope all of you will demand with yours."

2 Daniel Gogny's scientific life

How did the passion between Daniel and physics begin? Daniel told the story of how he became a theoretical nuclear physicist this way. He said he was walking in the streets of Paris and ran into an old friend, who said "Hey there, what are you doing?" Daniel replied, "not much, why?" The friend said, "Well, I'm going down to sign up at the University to become a physicist, why don't you come along with me?" Daniel said, "O.K. Why not, I've nothing better to do right now". That is how it began.

His years at the University led him to cross paths with Louis De Broglie, Professor of Theoretical Physics at the *Faculté des Sciences de Paris*, from whom he had the privilege to learn theoretical relativistic physics and quantum mechanics, even during the weekends at the Master's house.

2.1 Contributions in nuclear physics

Daniel was hired by the CEA-DAM in late 1962 on the recommendation of Louis de Broglie. L. Dagens, who was head of the applied mathematics section and who was deeply involved in the French nuclear military program, entrusted him with the elaboration of microscopic methods dedicated to the study of nuclear structure. At the end of the 60s, as the CEA-DAM's computing facilities were under embargo, Daniel was seconded until 1973, at the "Institut de Physique Nucléaire" (IPN) in Orsay in the laboratory of Professor Maurice Jean.

Before the end of the 1960s, only the bare nucleon nucleon-nucleon (NN) interaction, designed to reproduce all known bound and scattering properties of two-nucleon systems, had been developed. The presence of a hard core complicated direct calculations in finite nuclei. Besides, solving exactly the many-body problem for a large number of particles was, and still is, impossible except in very light nuclei. The idea of introducing a mean-field approximation, which allows reducing the many-body problem to many one-body problems, with eventual corrections to this mean-field, was very appealing. In collaboration with P. Pires and R. de Tourreil, Daniel was already involved in the design of a soft-core NN interaction (labeled GPT) suitable for nuclear Hartree-Fock calculations and perturbation corrections [1,2].

At the same time, in building 100 of IPN, the introduction of Skyrme phenomenological effective NN interactions offered new possibilities with very promising mean-field results. More precisely, it allowed for the first time to reproduce both radii and binding energies in spherical nuclei. After the laborious and rather disappointing second order calculations of the G-matrix based on the GPT interaction performed along with M. Maire [2], Daniel convinced himself that the only possible "way out" was the "phenomenological effective force" allowing for mean-field calculations of Hartree-Fock type. Such calculations were becoming accessible to the new generations of computers. Daniel, who was always on the lookout for new methods, decided to develop his own phenomenological NN interaction.

Daniel wanted his force to treat on the same footing the mean-field and the pairing correlations in the framework of the Hartree-Fock-Bogoliubov (HFB) theory. He also wanted to go beyond the mean-field. For those purposes, a finite range was necessary. The Skyrme forces which already existed were of zero range. Thus, he created an interaction with a finite range in its central term. In that case, however, calculations were very time consuming, and considering the still very modest power of computers in the late 1960s, some people told him that it was not "feasible". This was probably one more reason that motivated Daniel to create the D1 force! He devised a separable expansion [3] for calculating matrix elements of two-body finite-range local interactions with harmonic oscillator wave functions (on which HFB quasi-particle states are expanded). This separable expansion made the calculations tractable within a reasonable amount of time. Then Daniel started to write both the fitting procedure code and his spherical HFB code for finite nuclei.

He ingeniously used physics insights previously harvested from studies based on the GPT interaction to design an elaborate fitting procedure guided by both nuclear matter and properties of finite nuclei. Most of the calculations necessary to determine the coefficients of the D1 effective interaction (D1 stands for Daniel 1) were conducted on weekends, when computers were more accessible. Finally the D1 parameterization was settled in the late 60s. The first HFB results obtained for spherical nuclei with this force were presented at the Munich conference in 1973 [4]. Results as well as the D1 force parameters were first published in its proceedings (see fig. 1 and ref. [4]). The famous Trieste paper [5] details the fitting procedure, the HFB method and the associated numerical techniques. A more general paper discussing many observables deduced from the HFB code calculations was published much later, in 1980 [6].

In 1973, leaving Orsay to go back to the CEA laboratory located in Bruyères-le-Châtel, Daniel started to form a new theoretical nuclear structure team. He first convinced M. Girod and J. Dechargé from the CEA Limeil lab to join him at Bruyères-Le-Châtel. At the Daniel Gogny Jubilee in 2006 [7], M. Girod spoke of his encounter with Daniel:

"*One day, arrived a researcher. He seemed full of life, having with difficulty contained passion and what he tried to communicate with us. He came from the IPN of Orsay, the laboratory of Professor Jean, Marcel Vénéroni, Dominique Vautherin, and he had made a new force. This fellow was Gogny... This force was his child*".

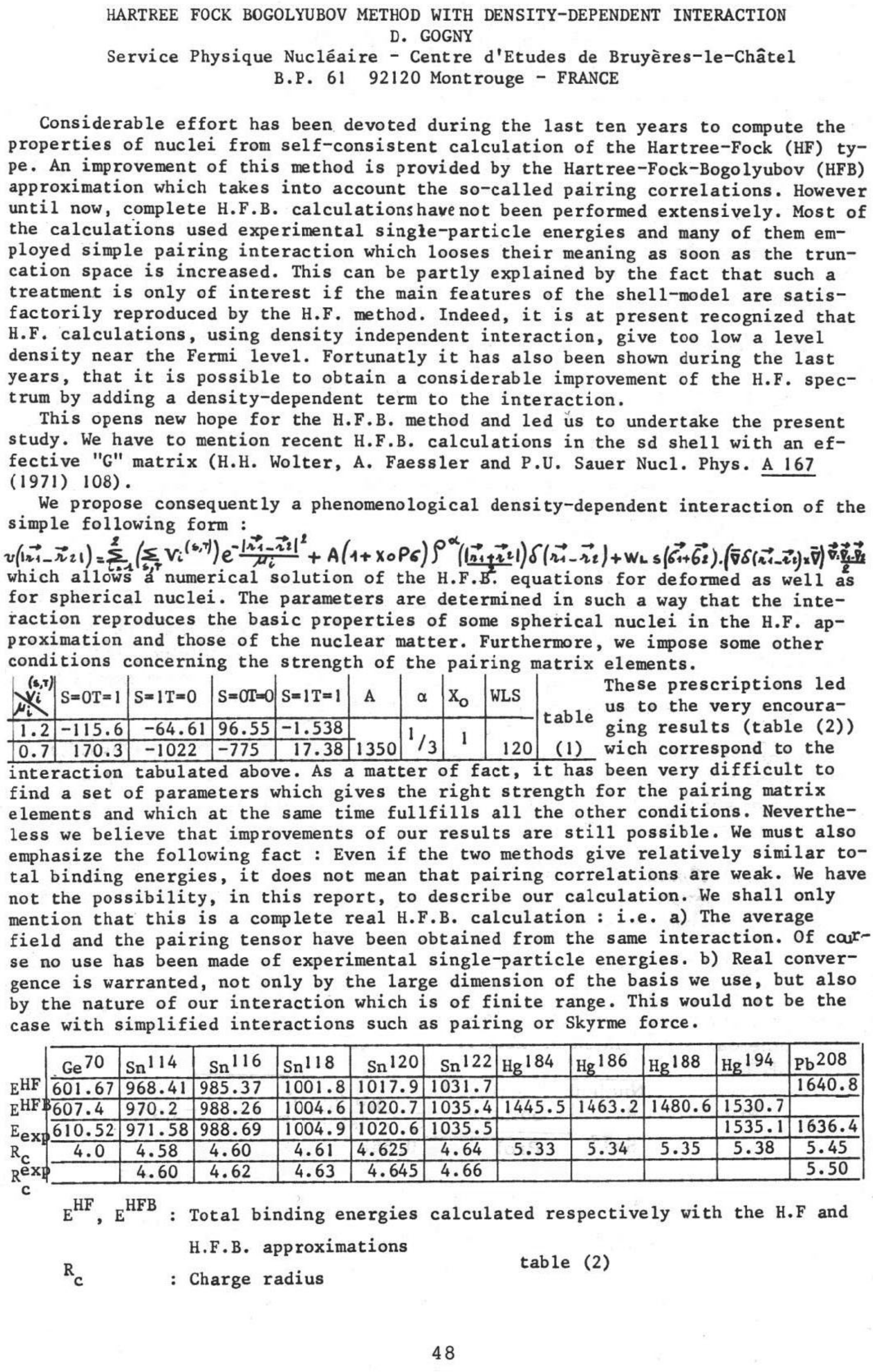
With this new D1 force, the "Hartree-Fock machine" imagined by Jacques Dechargé (see fig. 2) could start working; both persons can perfectly be identified... In 1975, M. Girod and J. Dechargé, under the stimulation of Daniel, developed the axially symmetric HFB code [8]. The challenge was to decrease as much as possible computing time with the "unconfessed" purpose of making the code as fast as, and even faster than that of the Skyrme force practitioners. Long months were necessary to optimize the code and to correct many programming errors: phase errors, errors of factor π or $2\ \pi$ or $\pi/2$ or $\sqrt{\pi}$, array overflows, etc. On the IBM 360-91 of Saclay, which in 1975 was one of the fastest computers in the world, one could not exceed 512Ko of memory to have a result during the day, 800Ko for night runs, 1000Ko for the weekend. This is where the method of separation of variables [3] was especially critical, as well as the genius of the programmers... They eventually came down to 10 s per iteration, with up to 10 harmonic oscillator shells. They had reached their objective. But Daniel and his collaborators were still worried: was the D1 force correctly going to describe deformed nuclei like the Samarium isotopes?

The first peer-reviewed article, published with the D1 force, reported axially symmetric potential energy surfaces obtained at the HF approximation for ^{148,150,152,154}Sm isotopes [9]. The conclusion of this first study was that the D1 interaction was reliable for studying nuclear deformations.

From 1976 on, the CEA Bruyères-le-Châtel group focused on beyond mean-field developments based on the generator-coordinate method. They calculated the charge density with a collective wave function whose generator coordinate was the quadrupole axial moment [10]. Daniel considered it important to keep a strong connection with experiments and one of the finest collaborations symbolizing this was the one he conducted for more than ten years with B. Frois and his team at Saclay. There, a new electron linear accelerator (ALS) and a remarkable set of detectors offered the opportunity to determine nuclear densities at the 1% level in the center of nuclei. High energy elastic electron scattering was going to shed light on the limits of mean-field theory by probing the nuclear interior. The Bruyères-le-Châtel theory group and the Saclay experimental group started an extraordinary fruitful collaboration that had a worldwide impact [11,12].

At the same time, intense efforts were also dedicated to Random Phase Approximation (RPA) calculations which gave a harvest of good results. J.-P. Blaizot, B. Grammaticos and Daniel calculated the monopole resonances within RPA with various forces and provided, for the first time, an estimate of the nuclear incompressibility modulus, $K_\infty = 210 \pm 30\,\text{MeV}$ [13,14]. The properties of the Gogny interaction were particularly well suited for the RPA formalism, as J.P. Blaizot stated:

"*In trying to implement the Random Phase Approximation to study collective excitations of nuclei, I met with difficulties related to the zero range nature of the Skyrme force that I was then using. These difficulties could naturally be resolved by using the finite range force that Daniel was then developing ...*" [15].



HARTREE FOCK BOGOLYUBOV METHOD WITH DENSITY-DEPENDENT INTERACTION

D. GOGNY
Service Physique Nucléaire - Centre d'Etudes de Bruyères-le-Châtel
B.P. 61 92120 Montrouge - FRANCE

Considerable effort has been devoted during the last ten years to compute the properties of nuclei from self-consistent calculation of the Hartree-Fock (HF) type. An improvement of this method is provided by the Hartree-Fock-Bogolyubov (HFB) approximation which takes into account the so-called pairing correlations. However until now, complete H.F.B. calculations have not been performed extensively. Most of the calculations used experimental single-particle energies and many of them employed simple pairing interaction which looses their meaning as soon as the truncation space is increased. This can be partly explained by the fact that such a treatment is only of interest if the main features of the shell-model are satisfactorily reproduced by the H.F. method. Indeed, it is at present recognized that H.F. calculations, using density independent interaction, give too low a level density near the Fermi level. Fortunatly it has also been shown during the last years, that it is possible to obtain a considerable improvement of the H.F. spectrum by adding a density-dependent term to the interaction.

This opens new hope for the H.F.B. method and led us to undertake the present study. We have to mention recent H.F.B. calculations in the sd shell with an effective "G" matrix (H.H. Wolter, A. Faessler and P.U. Sauer Nucl. Phys. A 167 (1971) 108).

We propose consequently a phenomenological density-dependent interaction of the simple following form :

$$v(|\vec{r}_1-\vec{r}_2|)=\sum_{i=1}^{2}\Big(\sum_{S,T} V_i^{(S,T)}\Big)e^{-\frac{|\vec{r}_1-\vec{r}_2|^2}{\mu_i}}+A(1+x_oP_\sigma)\,\rho^{\alpha}\Big(\frac{|\vec{r}_1+\vec{r}_2|}{2}\Big)\delta(\vec{r}_1-\vec{r}_2)+W_{LS}(\vec{\sigma}_1+\vec{\sigma}_2)\cdot\big(\vec{\nabla}\delta(\vec{r}_1-\vec{r}_2)\times\vec{\nabla}\big)\quad \vec{\nabla}=\frac{\vec{\nabla}_1-\vec{\nabla}_2}{2}$$

which allows a numerical solution of the H.F.B. equations for deformed as well as for spherical nuclei. The parameters are determined in such a way that the interaction reproduces the basic properties of some spherical nuclei in the H.F. approximation and those of the nuclear matter. Furthermore, we impose some other conditions concerning the strength of the pairing matrix elements.

$V_i^{(S,T)}$ \ μ_i	S=0T=1	S=1T=0	S=0T=0	S=1T=1	A	α	X_o	WLS
1.2	-115.6	-64.61	96.55	-1.538	1350	$^1/_3$	1	120
0.7	170.3	-1022	-775	17.38				

table (1)

These prescriptions led us to the very encouraging results (table (2)) wich correspond to the interaction tabulated above. As a matter of fact, it has been very difficult to find a set of parameters which gives the right strength for the pairing matrix elements and which at the same time fullfills all the other conditions. Nevertheless we believe that improvements of our results are still possible. We must also emphasize the following fact : Even if the two methods give relatively similar total binding energies, it does not mean that pairing correlations are weak. We have not the possibility, in this report, to describe our calculation. We shall only mention that this is a complete real H.F.B. calculation : i.e. a) The average field and the pairing tensor have been obtained from the same interaction. Of course no use has been made of experimental single-particle energies. b) Real convergence is warranted, not only by the large dimension of the basis we use, but also by the nature of our interaction which is of finite range. This would not be the case with simplified interactions such as pairing or Skyrme force.

	Ge^{70}	Sn^{114}	Sn^{116}	Sn^{118}	Sn^{120}	Sn^{122}	Hg^{184}	Hg^{186}	Hg^{188}	Hg^{194}	Pb^{208}
E^{HF}	601.67	968.41	985.37	1001.8	1017.9	1031.7					1640.8
E^{HFB}	607.4	970.2	988.26	1004.6	1020.7	1035.4	1445.5	1463.2	1480.6	1530.7	
E_{exp}	610.52	971.58	988.69	1004.9	1020.6	1035.5				1535.1	1636.4
R_c	4.0	4.58	4.60	4.61	4.625	4.64	5.33	5.34	5.35	5.38	5.45
R_c^{exp}		4.60	4.62	4.63	4.645	4.66					5.50

E^{HF}, E^{HFB} : Total binding energies calculated respectively with the H.F and H.F.B. approximations

R_c : Charge radius

table (2)

Fig. 1. Proceedings of the Munich conference, 1973 [4].

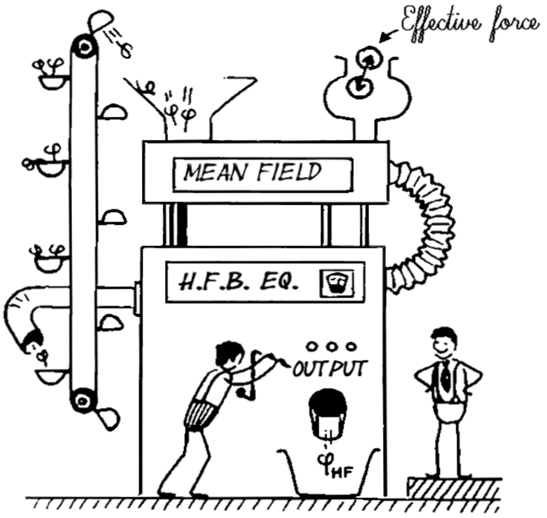


Fig. 2. Comic representation of the Hartree-Fock method, by J. Dechargé.

Then, in 1977 Daniel performed with R. Padjen a study of the collective modes in nuclear matter, through the calculation of the Landau parameters and the forward scattering amplitude sum rule [16]. Along with J. Dechargé, B. Grammaticos and L. Sips, the RPA response function for a broad momentum transfer range was characterized [17,18].

The work on RPA was the opportunity to extend the collaboration with B. Frois on the problem of transition densities for various collective states of ^{208}Pb as new experimental data were obtained at the ALS [19,20].

By the end of the 70s, a triaxial HFB code with the Gogny force was implemented by M. Girod and B. Grammaticos [21,22]. The first triaxial maps from this approach were published in 1978. Thanks to the collaboration with K. Kumar [23], using a five dimensional Bohr Hamiltonian code, it was possible to predict the charge and transition densities of the deformed ^{152}Sm nucleus including triaxial effects. This work indicated that the pairing correlations obtained with the D1 force were too strong. As a consequence, the calculated rotational and vibrational spectra were spread too far apart. This was one of the motivations to re-examine the parameters of the D1 force, which led to the well-known D1S parametrization [24].

However, the main reason for the advent of the D1S parametrization came from elsewhere, going back to the mid-70s. At that time, one of the most challenging problems in nuclear physics, namely the microscopic description of fission, was obviously on Daniel's mind. The collaboration between J.-F. Berger, the new Bruyères-le-Châtel team member, M. Girod and Daniel led to their first work on fission. They achieved a description of the fission of actinides from constrained HFB calculations with the D1 force using a two center axial harmonic oscillator basis. In 1981, these advances were recognized in a report to the "Académie des Sciences" in Paris [25], presented by R. Dautray (see fig. 3).

These fission studies revealed that the nuclear surface coefficient a_{s} was too strong, leading to an unrealistic (too high) second fission barrier. The D1 parameters were therefore refined in order to better reproduce the fission barriers (see fig. 4) and to reduce the intensity of pairing correlations. Thus, D1 turned into D1S (S for surface) [24], which has been, and still is, commonly used.

To go beyond the static description of fission, Daniel started working with Q. Haider, who provided the ground for the dynamic approach [26]. These developments have spawned new research directions for the next generation of physicists!

In the late 80s, the nuclear isomerism phenomenon became a vivid research topic. With his collaborators from Bruyères-le-Châtel and LLNL, Daniel studied more particularly shape isomers in even-even non-fissile [27] as well as fissile [28] nuclei.

The wealth of nuclear structure properties predicted using the Gogny force with mean-field and beyond mean-field approaches had opened up doors to improve the modeling of nuclear reactions. For Daniel, this part of the story began in 1978, when André Michaudon pressured him to discuss at the Harwell Conference on "Neutron Physics and Nuclear Data" [29] the contribution of self-consistent microscopic calculations in the process of nuclear data evaluation. However, the audience was not very keen on theory and anticipating a mixed reception of his remarks, Daniel concluded his presentation claiming that it is not always possible to use theory in the field of nuclear data evaluations. Nevertheless, the will of Daniel to increase the share of microscopic ingredients in reaction models was soon realized. In the early 1980s, the microscopic description of nucleon-nucleus scattering was undertaken within the Brueckner-Hartree-Fock theory, using the results of calculations in nuclear matter by Jeukenne, Lejeune and Mahaux [30], and the radial matter densities calculated with the D1 force [6,17]. The developed models contributed to the interpretation of measurements of fast neutron scattering by nuclei such as ^{208}Pb [31], in the rare earth region, and for actinides [32,33]. This work was later applied to the study of proton and neutron scattering on a large number of spherical and deformed nuclei [34,35]. From 2002 on, Daniel oversaw developments that started from the Melbourne G-matrix [36], solutions of the Brueckner-Bethe-Goldstone equations, and a description of target states obtained from the RPA model with the D1S force, leading to a microscopic, parameter free, description of medium energy nucleon elastic and inelastic scattering [37,38].

In addition, starting in the late 90s, work on microscopic level densities [39,40] has enabled the DAM to play a leading role in the evaluation of nuclear data useful for civil and defense nuclear applications. In parallel, fundamental studies have benefited from the progress of theory in the interpretation of experimental work on the multipolar giant resonances conducted at Saclay, such as the determination of the response functions of nuclei to excitations by α particles of intermediate energies by Bonin [41], a member of H. Faraggi team.

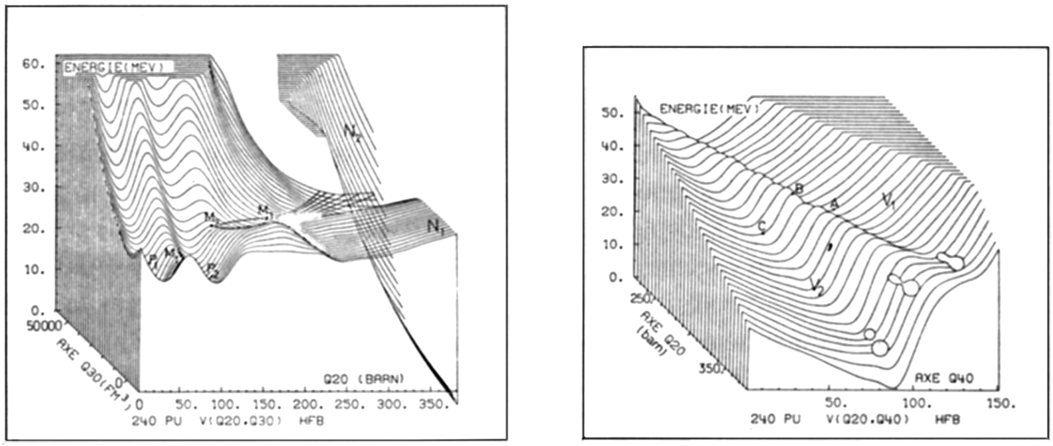


Fig. 3. Potential energy surfaces of ^{240}Pu in the collective variables Q_{20} and Q_{30} (left) and variables Q_{20} and Q_{40} (right). The figures have been extracted from ref. [25].

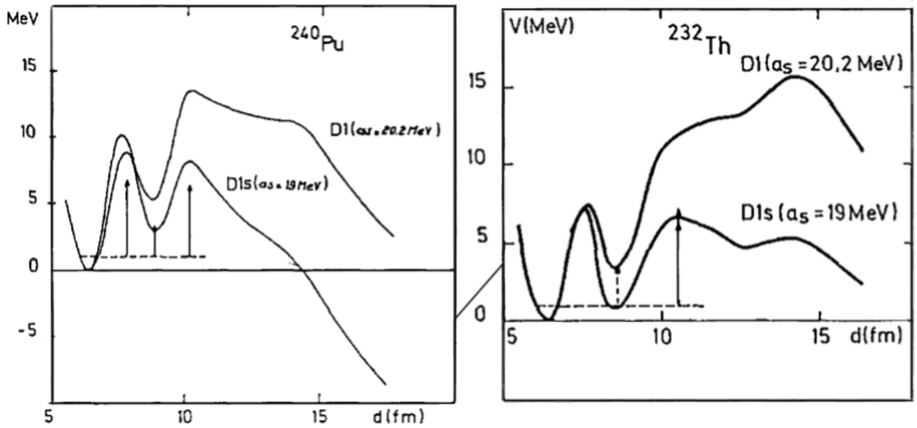


Fig. 4. Axial potential energy curves for ^{240}Pu (left) and ^{232}Th (right), calculated with the D1 and D1S parameterizations [24].

Beyond his interest in low energy nuclear physics, Daniel's involvement in Iracane's doctoral thesis [42] was an opportunity to study the properties of the non-perturbing QCD vacuum and its excitations, using a Hamiltonian formulation (not fashionable at that time) and a Hartree-Fock-Bogoliubov approach. One goal was to establish a link between the realistic nucleon-nucleon interaction and the interaction stemming from quarks and gluons degrees of freedom. Unfortunately, this work was never published.

Daniel was also actively involved in bringing together French and American research laboratories. In 1998, he was entrusted by J. Bouchard, the Director of CEA-DAM, with the mission to explore the scientific cooperation opportunities in the unclassified fields between the DAM, LLNL and the Los Alamos National Laboratory. An agreement between the national security administration of the department of Energy (DOE-NNSA) and CEA-DAM was formally signed. The founding conference of this DAM-NNSA cooperation was organized by Daniel and J. Lachkar for the DAM part.

In 2002, Daniel became a part-time consultant at the Lawrence Livermore National Laboratory.

During this time, he was able to continue, much to his satisfaction, a profitable trade with the great figures of the laboratory as M. S. Weiss and A. K. Kerman. However, Daniel did not break relations with his former team and continued his scientific assistance in proof-reading articles, joining collaborations within the DAM/NNSA agreements, and in the supervision of PhD theses, especially that of Dupuis [43] on the microscopic description of the pre-equilibrium reactions from 2002 to 2006, and that of Bernard [44,45] on the description of intrinsic excitations in the fission process from 2008 to 2011.

In 2005, Daniel initiated a project with J. Vary (Iowa State University) and Andrey Shirokov (Moscow State University) to investigate the properties of nuclear and neutron matter properties with the soft non-local interaction JISP16. From a theoretical and numerical analysis, he showed that JISP16 saturates nuclear matter in the Hartree-Fock approximation, which came initially as a surprise to him. A more detailed investigation, including the analysis of higher order effects, was then performed leading to a Physical Review publication in 2014 [46].

During his years at LLNL Daniel devoted the bulk of his research time to expanding the microscopic theory of fission he had developed with J.-F. Berger in the 1980s. He continued his work with J.-F. Berger and H. Goutte from Bruyères-le-Châtel on the fission dynamics [47]. Over the span of the past 10 years, his main activity was to oversee with W. Younes a full program on fission that shed much needed light on some of the hardest questions in fission theory, in particular a quantum-mechanical definition of scission, the use of generator coordinates suited to the fission problem, the consistent treatment of the center of mass correction before and after scission, and a microscopic prescription to estimate the pre-scission energy [48–50]. These efforts not only produced a more fundamental understanding of fission, but also extremely realistic results concerning fragment masses, kinetic, and excitation energies within the same theoretical framework. The Bruyères-le-Châtel and LLNL fission teams then developed together a theoretical model to include the coupling between single-particle and collective degrees of freedom involved throughout the fission process [44,45].

His talents as a valuable scientific contributor, his team spirit and his willingness to take on challenging problems led Daniel to address new topics in physics without, however, giving up his chosen field of nuclear physics.

2.2 Contributions in other fields of Physics

In 1984, Daniel was commissioned by the Scientific Director of the DAM to propose a microscopic description of the excitation and ionization states of plasma ions in order to deduce the photon-atom interaction and to evaluate, with the participation of Dechargé [51,52], the opacity coefficients of materials. Moreover, a collaboration with M.S. Weiss from LLNL led to the study of nuclear transitions induced by an optical laser coupled to atomic electrons [53]. These early studies led him to focus on nuclear excitations in plasmas by photon absorption, electron scattering and electron capture (NEET mechanism) in the 90s. The initial motivation was to look for shape isomers in order to achieve energy storage for laser or μ-laser applications. The isomers topic led the nuclear physics group of CEA-DAM to evaluate by theory the gyromagnetic, magnetic and quadrupole moments of different isomeric states in parallel with the experimental work undertaken at GANIL facilities.

In 1986, a program was started at Bruyères-le-Châtel in order to understand the physics and acquire the expertise in the technology related to power Free Electron Laser. Daniel took part in the study of the photon emission in saturated regime done by Iracane [54] and Chaix and in the interpretation of the measurements performed on the linear electron accelerator facility ELSA built at Bruyères-le-Châtel.

Meanwhile, Daniel was appointed in 1986 head of the DAM project on "surface équivalente radar" and made a significant contribution to the French research on radar stealth. He undertook, with various members of the Service, describing the diffraction of electromagnetic waves by an ionized gas. The scientific and technical feasibility of the project was demonstrated and proved the skills and the dynamism of its Project Manager. In 1988, Daniel joined the CEA-DAM located in the Bordeaux area (CESTA) as Director of Research upon a request of its director, M. Launois. However, as mentioned in the previous section, he continued to regularly visit the Paris region where he continued in parallel to be involved in nuclear physics works, remaining in close touch with his former team in Bruyères-le-Châtel and with J. Lachkar.

As part of the involvement of Daniel in stealth technology and physics, ionization in rare gas mixtures was experimentally studied at Bruyères-le-Châtel between 1987 and 1992. Daniel started a work with P. Guimbal in order to understand the phenomenon. They performed the first calculations to deduce what could be suitable parameters for the plasmas. Several experiments were set up in that short time using different ionization methods which gave a better understanding of the underlying physics and provided key numerical figures from an engineering point of view. But applications eventually seemed too uncertain and the program came to an end.

In the 90s, attention became focused on chiral media due to potential applications such as radar cross-section (RCS) management. One of the key problems in the design of artificial chiral composites for RCS applications was the constitutive parameters modeling.

Upon his arrival at CEA/CESTA Daniel began calculating the microwave response of various materials, in particular of chiral compounds. With F. Mariotte, Daniel developed an analytical model which allowed them to calculate the constitutive parameters of artificial chiral composites [55–59].

All those studies, directed by Daniel, permitted to establish very fruitful collaborations with the electrical Engineering Department of the University of Pennsylvania (headed by Nader Engheta), the Electrical and Computer Engineering Department of the University of Arizona at Tucson (Richard Ziolkowskia) and the Technical University of Saint-Petersburg (Sergei Tretyakov).

With Fedor I. Fedorov of the Belorussian Academy of Science, Daniel chaired the scientific committee of the "3rd International Workshop on Chiral, Bi-isotropic and anisotropic Bi-Media, Chiral'94" in Périgueux in May 1994, co-organized by JP. Parneix of the Bordeaux I University and F. Mariotte. Daniel also contacted R. Mittra, head of the Electromagnetic Laboratory of the University of Illinois, thereby starting a very successful collaboration on diffraction modeling. This collaboration produced articles in the best Electromagnetics journal (IEEE Radio Science). It also led to the American version "Asymptotic Methods in Electromagnetism" from the book of D. Bouche, F. Molinet and R. Mittra "Asymptotic Methods in Electromagnetism." His wife, Patricia, translated the book, with the assistance of Daniel.

In 1995, Daniel joined the Bruyères-le-Châtel Physics Department (DPTA) at the request of its head J. Lachkar.

As Scientific Director, Daniel was associated with the entire Department's work. Daniel continued his leadership role in the nuclear physics work with the supervision of theses and the exploration of novel theoretical approaches. For instance, one of the less well-known contributions of Daniel to nuclear physics is the theoretical study of Nuclear Excitation by Electron Transition (NEET) which is usually considered the most efficient nuclear excitation process in plasmas. Daniel's work on the microscopic NEET probability led the way to the development of a macroscopic model to predict a NEET rate under given thermodynamic conditions in a plasma [60]. At the present time, research on this subject is still very active [61].

3 Academic recognitions and beyond

The research work undertaken in determining the D1 force and the demonstration that this approach has a remarkable predictive power drew the interest of the international scientific community, and resulted in the award to Daniel of the French Physical Society Joliot-Curie Prize in 1986. In 1999, Daniel was awarded the "biennal Lazare Carnot" scientific prize from the French Academy of Science acknowledging the decisive and sustainable progress nuclear physics made thanks to his work, as well as his important contribution to the French radar stealth program.

On May 30-31, 2006, the CEA organized the Jubilé Daniel Gogny, recognizing the body of his work (spanning over more than 40 years) and contributions to scientific advancement in France. The meeting brought together more than fifty of Daniel's former co-workers and students from American laboratories, as well as Japanese, Spanish, Italian, German, and Romanian institutions.

From December 8 to 11, 2015, the memory of Daniel was honored by an international conference held in CEA-DAM, the First Gogny Conference, which gathered more than 80 participants, family, friends and former colleagues. The success of this conference showed the commitment of the community to continue his work and make decisive progress in understanding the atomic nucleus for both the needs of applications and the advancement of knowledge. The second Gogny conference is already scheduled and is now being organized by the "Universidad Autónoma de Madrid" for the end of 2017.

Daniel committed himself fully when it came to answer a question and solve a theoretical problem. "I will not sleep until I find a way to the solution," were his words. Daniel had a clear and deep vision of physics problems and he never hesitated, and even enjoyed, "getting his hands dirty". Daniel valiantly wrote hundreds of pages of demonstrations for his students and collaborators. His writings, which always bore his frank and teasing humor, provide clarifications and detailed formalism that tackled the problems submitted to him. Beyond his immense scientific merits, it is his qualities of modesty and human warmth as well as his profound respect for others that his collaborators and friends will remember.

Two of the authors (MD and NP) thank W. Younes for his careful reading of the present article and for his valuable advice.

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