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# Jacques Raynal

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**Abstract.** We recall Jacques Raynal's career, his main bibliographical data and achievements, summarizing his topics of interest and works. We also give some biographical and personal data. We have collected a few words about him from friends and colleagues, in addition to those given by the authors of the articles published in this EPJA issue in memory of the Emperor of the ECIS code.

**PACS.** 21.10.Gv Coupled channel analysis – 24.10.Ht Optical models (nuclear reactions)

## 1 His background and career path

Jacques Raynal was born on August $10^{th}$, 1934; he left us on April $10^{th}$, 2020. He belonged to the "*Centre d'Études Nucléaires de Saclay*", CEN (later named "*Commissariat à l'Énergie atomique*", CEA). Jacques was a physicist affiliated at the Division of Theoretical Physics, the **SPhT**, "*Service de Physique Théorique, Laboratoire de l'institut de Physique Fondamentale du CEA Saclay*". He started his research career in Nuclear Physics with his PhD (done at the SPhT) on: *The use of polarized deuterons beams and the determination of the optical model parameters* [1]. He elaborated his first versions of reaction codes using Optical Model Potentials (OMP) in the years 1970-1980. The first version of his ECIS code was presented in his famous 1981 publication [2]. But the original reference should be found in his ICTP IAEA workshop lecture in 1971 [3] [1].

Jacques Raynal performed his studies at l'École Polytechnique ("X"). He belonged to the 1953 class. In Fig. 1, one can see his photography in those years (from [4]). One of his classmate, Ch-M. Marle, recalled the early years of Jacques (in the article he wrote in memory of Jacques in the Polytechnique School review [5]): *"Sa vocation était déjà très affirmée : il désirait faire de la recherche scientifique*[2]".

In the second year of the X School, he had already spent a training period of internship in the SPhT. After the School, he joined the SPhT department where he spent his entire career, until his official retirement in 1994.

During his retirement period, he was affiliated to CEA DAM DIF[3] as a scientific advisor (he presented himself as: *"consultant", see below in the ECIS96 part, in Sec. 3.2*). At that time, he was also participating to the works for the Nuclear Energy Agency (NEA). The articles he published later on appeared with his home personal address. In the NEA notes on the Web site [6], his codes (DWBA07, ECIS12) are mentioned with "name and establishment of author" as: *Jacques Raynal 4, rue du Bief 91380 Chilly Mazarin*. This was his last affiliation, at his home personal institute where he continously worked on Nuclear Reactions.

### 1.1 References to Raynal's early formal works in nuclear physics and reaction theory

Following first works in physics [7] during his training period, he performed a series of early studies on specific formalism aspects of the nuclear reactions:

- Helicity formalism for nuclear reactions [8];
- Spin-orbit interaction in inelastic Nucleon Scattering [9];
- First developments on the CC codes for OMP calculations of nuclear reactions, that he explained during the lectures he gave at Trieste in 1971 [3];
- Parameters of the OMP in Ref. [10]
- First developments on what would become the ECIS code: J. Raynal, Notes on ECIS-79 (May 25, 1982).

### 1.2 Raynal's work on 3-body approach in the years 1969-1971 with Janos Revai

The Raynal-Revai (RR) coefficients were introduced in the article published in 1970 [11] :

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[1] As noticed by R. Capote, *"Jacques himself often proudly used for the ECIS reference his 1971 lecture."*

[2] *"His vocation was already very clear: he wanted to do scientific research."*

[3] CEA Direction des Applications Militaires, Direction Île de France.




**Fig. 1.** *Photography in the Polytechnique school album, in 1953 [4].*

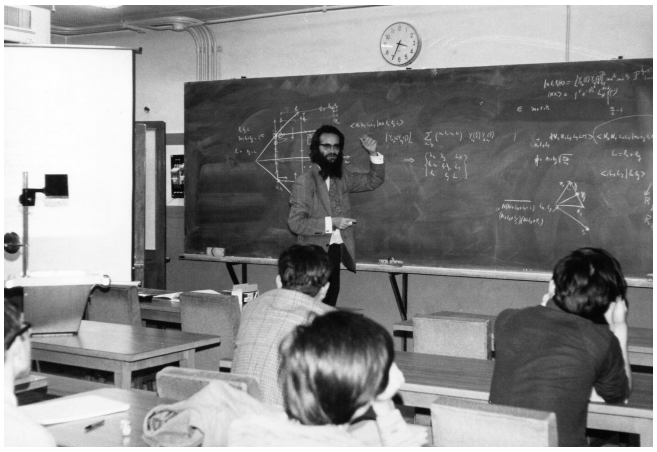


**Fig. 2.** *Jacques giving a lecture.*

"*The transformation from one set of Jacobi co-ordinates to another for hyperspherical functions is closely related to the Talmi-Moshinsky transformation for two particles in an oscillator well. The corresponding coefficients are calculated analytically.*"
In those years, they were a significant "fait d'armes" - feat of arms, tour-de-force, that he mentioned later in the notes he wrote for the $50^{th}$ anniversary booklet of the 1953-graduated class [12]:
"*Cher ami, 11.11.02*
*(. . . ) Un ami autrichien, H. Von Geramb me racontait que les professeurs Clebsch et Gordan de Göttingen avaient été surpris quand des collègues leur avaient annoncé que leurs noms avaient été donnés à des coefficients par les participants d'une conférence dont ils revenaient. Je lui dis que cela était arrivé à moi aussi : Janos Revai, revenant d'une conférence à Dubna en 1970, m'annonça qu'on avait décidé de nommer ce que nous avions publié "les coefficients de Raynal-Revai.*"
"*Dear friend, 11.11.02*
*(. . . ) An Austrian friend, H. Von Geramb, told me that Professors Clebsch and Gordan from Göttingen were surprised when colleagues told them that their names had been given to coefficients by the participants of a conference from which they were returning. I told him that this had happened to me too: Janos Revai, returning from a conference in Dubna in 1970, told me that they had decided to call what we had published " Raynal-Revai 's coefficients.*"

## 2 References

### 2.1 Nuclear reaction codes

Jacques Raynal explained the numerical algorithms developed for the ECIS code, "*Equations Couplées en Itérations Séquentielles*"", "*Coupled Equations in Sequential Iterations*" in his review article [2] quoted in every paper using the ECIS code. The next versions were ECIS86 [13], elaborated to include the treatment of vibration excitation modes and ECIS94 [14], to improve the computing time of the Coulomb scattering problems. New versions of the code were elaborated to solve physical problems submitted by his colleagues, nuclear physicists working in the experimental analysis [15] or in field of the nuclear data evaluation [16]. Jacques Raynal also developed other codes to perform calculations with optical model potentials in the Distorted Wave Born Approximation (DWBA): there was the DWBA91 code used for the analysis of nucleon-nucleus scattering, followed by new versions in 2005 [17] and 2007 [18], in particular to improve the computing operations for specific problems of elastic and inelastic scattering with nucleon-nucleon potentials.

### 2.2 Reactions, inelastic processes, break-up, deformation effects

Following the elaboration of reaction codes, Jacques directly participated to the OMP analysis of data results on elastic scattering [19], OMP nuclear collective modes [20], proton-nucleus inelastic scattering [21–23], inelastic scattering processes [24, 25], deformation effects [26] and break-up modes [27].

### 2.3 Statistical model and CC for fission cross sections

In the 90's, as an output of his works on CC calculations, Jacques Raynal had exchanges with the physicists evaluating the nuclear fission data, at the Bucharest university. He explained to them how to run the CC calculations for the nuclear reactions on actinides, and he learned from them about the treatment of the fission channels, with the statistical model including the level densities. He made developments of the ECIS code directly for the need of the nuclear data evaluation of the fission channels, as recalled by A. Tudora in Sec. 4.3. The works presented in Refs. [28, 29] explicitly mentioned the private communications with Jacques. The direct calculations were made using the CC method and the ECIS94-95 code [14].



**Fig. 3.** *Jacques with Roberto Capote in Havana, Cuba. (Family album).*

### 2.4 Dirac formalism

To analyze the nucleon-nucleus scattering at high energies (several hundreds of MeV), in particular for inelastic scattering with polarized protons, Jacques Raynal developed codes including the Dirac relativistic formalism in coupled-channel (CC) calculations. The OMP parameters were carefully checked in this formalism [30,31,34] and the applications of the Dirac and Schrödinger formalisms were compared on several experimental results of proton scattering on stable targets, like $^{16}$O, $^{24}$Mg and $^{26}$Mg [33] $^{40}$Ca [34], *sd* shell nuclei [35]. During a conference held at Cuba in 1997, Jacques presented his results on the microscopic description of elastic and inelastic nucleon scattering investigated using the Dirac and Schrödinger formalisms [36].
He had passionate debates on nuclear reaction problems with colleagues during evening sessions (Fig. 3).

## 3 1996-2019 Jacques Raynal's activities during his retirement period

### 3.1 New versions of ECIS

In 1996, just before his retirement, J. Raynal has developed the new version of the code, ECIS96. Then he elaborated ECIS97, when he became *"Consultant at the Service de Physique Nucléaire, Centre d'Etudes de Bruyères-le-Châtel"*, as indicated in the proceedings on ECIS 1996 [37]. Here are some paragraphs extracted from the notes on ECIS96: *"Abstract. Some improvements in ECIS88 like the use of expansion of the potentials in term of Bessel functions lead to ECIS94 and to write the Notes on ECIS94 before I had to retire on the 1/9/1994. However, on the suggestion of Arjan Koning, the code was modified to deal with continuum for compound nucleus calculations. This point, existing in ABAREX was not in ANLECIS. Now, ECIS95 should do the same kind of computation as ABAREX, but in the Coupled Channel formalism. Further work has been done this year by introducing energy dependent potentials defined by Mahaux' dispersion relations. This required more changes than the previous step and gives ECIS96. Some other additions should be done for experiments with exotic beams. Such beams are usually produced by extraction at 0 degrees after a reaction, which produces tensor polarisations very large for exotic nuclei with high spins. There are tensor polarisation effects on the total scattering cross-sections and on the total cross-section, even if they are generally too small to be measured."*
*And : "I want to thank the Service de Physique Nucléaire of the Centre d'Etudes de Bruyères-le-Châtel" and the "Service de Physique Théorique" of the Centre d'Etudes de Saclay" which gave me the possibility to continue my activities."*

### 3.2 Legacy, Nuclear reaction codes including ECIS

For complete structure-reaction calculations, further developments were carried out to include ECIS into both EMPIRE [38,39] and TALYS [40] nuclear reaction modelling systems. ECIS96 was used for the EMPIRE implementation [39]. ECIS06 and ECIS-12 [41] were used for TALYS1.2, the *"Nuclear Model Code System for Analysis and Prediction of Nuclear Reactions and Generation of Nuclear Data*" [42]:
*It completely integrated optical model and CC calculations by ECIS-06 - incorporation of recent optical model parameterizations for many nuclei, both phenomenological (optionally including dispersion relations) and microscopically. There is no new formal report for ECIS06, but there is a "how to use" feature integrated into the program.* The latest version ECIS-12 [41] is registered in the NEA and ORNL code libraries. It is described as a complete code for calculations with CC, Statistical Model, Schrödinger and Dirac Equation, Dispersion Relation. As mentioned on the NEA page [41], *"The ECIS code has been developed over a period of more the fifteen years, and several earlier versions exist. The statistical model part is based on ANLECIS, developed by P. Moldauer.*"

### 3.3 Discussions on spin-orbit terms

In one of his last papers, J. Raynal explained his view about operating spin-orbit transition interactions [43]. In the 2003-2004 period, there was also an active debate about spin-orbit interactions in ArXiV papers, between J. Raynal [44] on the one hand, and K. Amos and collaborators [45], on the other hand.

### 3.4 Legacy, inspirating works

Between 1996 and 2005, Jacques Raynal contributed to several works on the microscopic analysis of the nucleon-nucleus scattering with colleagues, Amos (see [46]) and von Geramb [47], Capote and Quesada [48]. The OMP analysis for proton-scattering and CC calculations done by Jacques have inspired the studies described in the articles of this EPJA topical issue, in which the applications of either the algorithms or ideas developed by Jacques, or the applications of his ECIS or DWBA codes are presented:




**Fig. 4.** *Photos of the IAEA building in September 2006, taken by Jacques during his stay in Vienna.*

- Studies of (p,n) reactions [49];
- Theory works for partial waves in nuclear scattering [50];
- Calculated nuclear data generated for reaction evaluation, using OMP and CC equations [16];
- Calculations of Wigner $3j$ coefficients [51];
- Non-locality in OMPs for nucleon-nucleus scattering [52];
- CC analysis of the elastic scattering with exotic nuclei within OMP approach [53];
- Applications to proton-nucleus inelastic scattering [54];
- Developments of Raynal's DWBA code [55] and beyond ECIS and DWBA [56];
- Theory for low energy neutron incident reactions [57] and nucleon-induced inelastic scattering [58];
- CC analysis of elastic and inelastic scattering for the studies of giant resonance excitations; calculations of the sub-Coulomb fusion cross sections [15];
- CC effects in nucleus-nucleus inelastic scattering [59] and in heavy ion reactions [60].

*Jacques had a passion for nuclear reaction theory. He had also a passion for photography. He took pictures during his various travels, for instance at Cuba (taking B/W shots of La Habana town scenes). He used to photograph the places where he met colleagues: in Vienna, he took the famous sites and some views of the IAEA building (Fig. 4). He was also a passionate bicycle traveler and he liked to climb mountains (see App. B).*

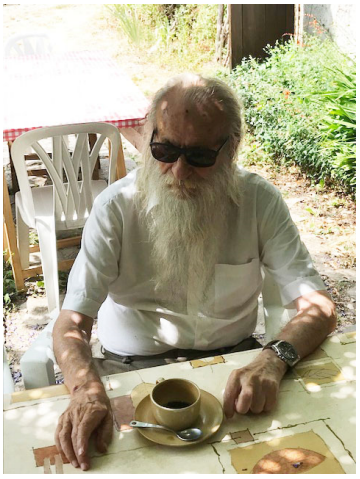


**Fig. 5.** "*Jacques in July 2019, in Cevennes region.*" (*From [4], photo taken by his classmate Yvon Batide*).

## 4 Words about Jacques Raynal

### 4.1 Message from Roberto Capote

(*Roberto.CapoteNoy@iaea.org*) - *April 2021.*
*NAPC Nuclear Data Section, IAEA, Vienna, Austria.*

"*I have one comment (. . . ) The really big question to our readers is "How we can teach the people to be like Jacques?". I know we cannot teach passion and commitment, but still this is probably one of the most relevant questions we are faced with.*"

### 4.2 Message from János Révai

(*revai.janos@wigner.hu*) - *September 2020.*
*Wigner Research Center for Physics, Budapest, Hungary.*

"Dear Dr. Alamanos,
I came across your paper about Jacques Raynal. (...) It was a pleasure for me to read your warm remembrances about him. He was certainly not a person with whom it was easy to establish close contacts. Your sentence with "What do you want me to do?" especially struck me, since I have so often heard his famous "Qu'est-ce que vous voulez que je fasse?". I have spent two years in Saclay (1969-1971), probably still before you. We shared the same office and worked together. You didn't mention in your paper our main result, which made his name probably even more recognized, than his favorite ECIS and calculations of inelastic nuclear reactions. I am talking about the Raynal-Revai (RR) coefficients, which were introduced in: *Transformation coefficients in hyperspherical approach to the three-body problem, Nuovo Cim. A68 (1970) 612* which are widely used and cited ever since.
Even our families were in contact, we both had two daughters of about the same age. We even visited his parents' house in Millau. Unfortunately, after I left Saclay our collaboration



**Fig. 6.** *Jacques in uniform in Paris streets, student at the Ecole Polytechnique, in 1953.(Family album).*

gradually died out, although he visited me in Budapest and Dubna.
It was so good to learn, that my old friend "le barbu" is not completely forgotten."

### 4.3 Message from Anabella Tudora

(*anabella.tudora@fizica.unibuc.ro*) - *February 2021.*
*University of Bucharest, Nuclear Physics Dept., Romania.*
*(The original letter in French is in Appendix A.)*

" I met Mr. Raynal at the beginning of the 90's: Mr. Enrico Sartori had informed Mr. Raynal that a small group from the University of Bucharest was using ECIS on a PC-286 computer. This group of professor Vladuca (who passed away in 2006) consisted of 3 persons: G. Vladuca, me and Mihaela Sin. It was a first time to run ECIS on such a small computer. So, Mr. Raynal wanted to meet those who had done it. I had realized the ECIS version for the small PC-286 (the first PCs at that time), by segmenting the code into several modules (which successively entered the PC's RAM during the computation, following the logic scheme of the code). It was then that our friendship began. I remember that the following year Mr. Raynal invited me in Saclay. Then we talked for the first time about his work in progress concerning the part of ECIS dedicated to the compound nucleus mechanism (by statistical model). He wanted to use the transmission coefficients of the output channels $T_{n'l'j',nlj}$ for each $J^\pi$ directly into the statistical model. At that time, this was called the coupled treatment of the two reaction mechanisms, the direct interaction and the compound nucleus. While all other codes (e.g. GNASH, our STATIS code etc.) used the classical decoupled treatment of the two mechanisms, i.e. by using the transmission coefficients of the particle channels provided by ECIS (or other codes of direct interaction) which were interpolated to the excitation energies. Professor Vladuca being a great specialist in statistical model (he was my teacher) we could advise Mr. Raynal on the statistical model, the level densities (especially for the compound nucleus along its fission path) etc., while he advised us on the coupled channel method employed in the treatment of the direct interaction mechanism for the neutron induced reactions of actinides.
During his first visit to Bucharest, Mr. Raynal has developed a special version of ECIS for our group starting from the one made for the PC-286, he realized a specific output for the transmission coefficients going directly into our STATIS code, as well as other output matrices, diagonalizations, etc.. I can say that he had made this version for me, since in our group I was responsible for the direct interaction treatment. I still have this version and it works very well, even today (obviously without segmentation and adapted to the new Windows compilers). This version is unique and I consider it as better than other versions included in different reaction codes. Because it was made by Mr. Raynal, himself, especially to be used in the reaction codes for actinides, which include the treatment of the fission channel in the frame of a refined modeling with subbarrier effects (developed by Professor Vladuca).
I also remember an invited lecture given by Mr. Raynal at the Institute of Nuclear Physics and Engineering (IFIN-HH) in Bucharest-Magurele during one of his visits to our Faculty of Physics (in 95 or 96), this lecture being addressed to the theoreticians and mathematicians of the institute.
Mr. and Mrs. Raynal came several times in Romania, staying in Bucharest and in the Moldavia region. I remember a funny story. During one of their visits, I invited them to an excursion to visit several monasteries in the area around Bucharest. We were in the courtyard of one of the monasteries and we were waiting (together with other tourists) for the monk who was the guide of the museum. Suddenly a woman (tourist) approaches Mr. Raynal and asks him (in Romanian) why he doesn't open the museum of the abbey and start the guided tour because the tourists were waiting for him. Obviously, he did not understand what this tourist wanted of him. I realized that, because of his big beard, the tourist had mistaken him with a monk. So I intervened and explained to her that he is not a monk, he is a tourist like all of us. But I did not translate to Mr. Raynal the discussion concerning the confusion with a monk. A few years later, I told him all this and he had a lot of fun, and so did Mrs. Raynal and their daughters.
But the dearest memories are the visits and trips made with Mr. and Mrs. Raynal (and sometimes also with their family) in France (almost everywhere around Paris and in the South "le Midi" etc.). I can't find the words to express all my feelings for them. I always keep Mr. Raynal in my soul. I continue the friendship with Mrs. Raynal."

### 4.4 Remembering Jacques Raynal, message from Enrico Sartori

(*esartori@noos.fr*) *May, 14$^{th}$ 2020.*
*IAEA, 1973-1984. OECD/ Nuclear Energy Agency, till 2009* [4]

"The sad news reached us that Jacques Raynal passed away. We lose with him one of the finest applied mathematicians specialised in particular in nuclear theories. Once you have met him, you will certainly not forget him. He worked for many years at the theoretical physics service of the CEA; his office was in the open access area at Orme-les-Merisiers, part of the Saclay Centre.
I have met him for the first time when in 1983 we had organised an International Nuclear Coupled-Channel Model Code Intercomparison exercise with the aim of verifying whether the different codes used around the world would provide the same solution to the same nuclear physics problem. Our big surprise was that his code had capabilities the others did not have: it was an order of magnitude faster and capable on the same computer make and unlike the other codes, to take care of a large number of couplings. His code, called ECIS would also carry out best fits on experimental data in order to extract nuclear model parameters. It provided not only the expectation values but the full covariance matrices, which were badly needed for expanding the information in evaluated nuclear data files with the purpose of estimating the uncertainties inherent to modelling. An unusual feature of this code, compared to others, is the choice of solving a problem either with the Schrödinger or the Dirac equation".
"His youth was difficult, he had to flee during the Second World War when the Wehrmacht moved close to his village. After the war, when he returned, his house, the full village had been razed to the ground, so with his mother and brother they had to find a new place where to live.
He was what in France they call an "X", he had studied in the most prestigious École Polytechnique. Only the brightest could attend those schools. I had the impression that he did not have a boss; because he was so bright, he could research whatever he found original, interesting and new.
It took me some time to get really acquainted with him, as his way of thinking would follow several paths at the same time. With time I got used to it and so we had interesting discussions at lunchtime, about mathematics, science, and life. His was fond of adventures: when younger he would bicycle from Paris to Istanbul through the Balkans and back, on return partly with a boat from Greece to Italy.

One day he showed me a thick article that he had submitted for publication. Full sixty pages! I looked inside: it was full of mathematical formulæ. I asked him *"And they published it?". "Yes, they did!" "What is it about?" "It is about hexagonal groups". "And what is it useful for?" "I really don't know". "Why did you write it then?" "Because nobody before me made this investigation"*. Two years later he told me: *"I have received a letter about my hexagonal group paper today, someone is asking a few questions". "OK, what does he need it for?". "He is studying hexagonal viruses"*. Curiosity is the basis of scientific research; the benefits emerge later. This characterised in particular Jacques Raynal. Among his activities was teaching at the Workshops on Applied Nuclear Theory and Nuclear Model Calculations for Nuclear Technology Applications, held at the International Centre of Theoretical Physics, Miramare, Trieste. There he was teaching the theory and use of two of his codes:

- DWBA/DWBB, elastic scattering with nucleon-nucleon potential and distorted wave Born approximation for inelastic scattering;
- ECIS, coupled channel, statistical model, Schrödinger and Dirac equation, dispersion relation.

His ECIS model is so unique and effective that it was included in other nuclear model codes handling a wider range of problems. Jacques Raynal's code ECIS has become indeed famous and is used in all countries; maybe not in all, but on all continents except Antarctica (Fig. 7). These codes are only one aspect of his work; I have restricted this description to the part I am familiar with."

*"May he rest in peace."*

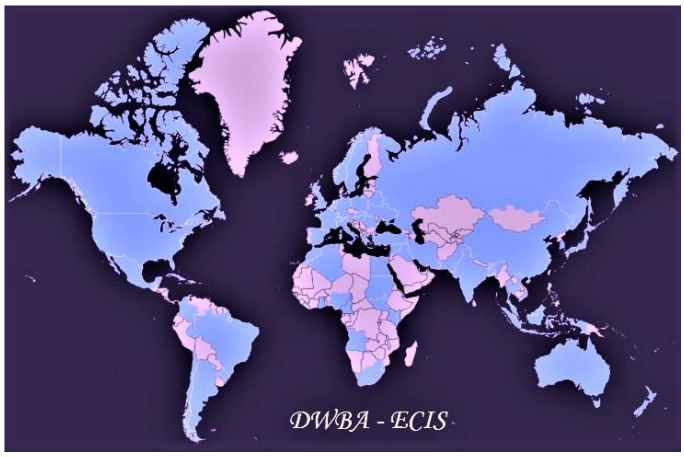



**Fig. 7.** *ECIS world map in 2020: in blue the countries where Jacques Raynal's codes are used.*

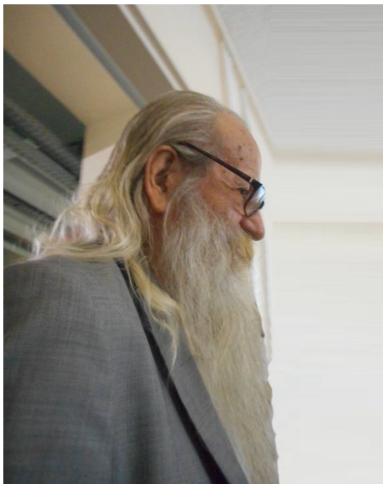


**Fig. 8.** *Jacques Raynal, 2016.*

[4] *Head of Computer Program Service and Reactor Physics in 1985-2009. Interacting with Jacques Raynal, in particular during the dissemination phase of the ECIS and DWBA98 codes in the NEA databank.*

*Acknowledgments* We thank Mrs Claude Raynal for sharing her memories about Jacques and for providing us with photographs from her family albums.

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*Guest Editors*

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## Appendix A

*Lettre originale complète (français) d'A. Tudora. 2021.*

" J'ai connu monsieur Jacques Raynal au début des années 90 : monsieur Enrico Sartori avait informé M. Raynal qu'un petit groupe de l'Université de Bucarest utilisait ECIS sur un ordinateur PC-286. Ce groupe du professeur Vladuca (décédé entre temps, en 2006) comptait trois personnes : Gheorghita Vlăducă, moi et Mihaela Sin. Faire fonctionner ECIS sur un si petit ordinateur : c'était une première. Alors M. Raynal a voulu rencontrer ceux qui avaient réussi cela. J'avais fait cette version d'ECIS pour les petits ordinateurs PC-286 (les premiers PC à l'époque), en réalisant une segmentation du code en plusieurs modules (qui entraient successivement dans la mémoire vive du PC pendant le déroulement du calcul, suivant le schéma logique du code).

C'est alors que notre amitié a commencé. Je me rappelle que monsieur Raynal m'a invitée l'année suivante à Saclay. Alors nous avons parlé pour la première fois de son travail en cours concernant la partie d'ECIS dédiée au noyau composé (par le modèle statistique). Il voulait utiliser les coefficients de transmission des voies de sortie ($T_{n'l'j',nlj}$ à chaque $J^\pi$) directement dans le modèle statistique. A l'époque, on nommait cela le traitement couplé des deux mécanismes, l'interaction directe et le noyau composé. Tandis que tous les autres codes (par exemple GNASH, notre code STATIS etc.) utilisaient le traitement classique découplé des deux mécanismes, c'est-à-dire en utilisant les coefficients de transmission pour les voies de particules fournis par ECIS (ou d'autres codes d'interaction directe) qu'on interpolait aux énergies d'excitation. Comme le professeur Vladuca était un grand spécialiste en modèle statistique (il fut mon maître), nous avons pu conseiller M. Raynal sur le modèle statistique, les densités de niveaux (surtout pour la voie de fission) etc., tandis que lui nous a conseillés sur le traitement de l'interaction directe par les voies couplées de réactions sur les actinides.

Au cours de sa première visite à Bucarest, M. Raynal a élaboré une version spéciale d'ECIS pour notre groupe : en partant de la version faite pour le petit PC-286, il a produit une sortie spécifique pour les coefficients de transmission allant directement dans notre code STATIS, ainsi que d'autres sorties pour les matrices, les diagonalisations etc.). Je peux dire qu'il avait fait cette version pour moi, puisque dans notre petit groupe j'étais responsable du traitement de l'interaction directe. Je garde encore cette version d'ECIS. Elle fonctionne très bien, même maintenant (évidemment sans segmentation et adaptée aux nouveaux compilateurs pour Windows). Elle est unique et je la considère meilleure que d'autres versions. Car elle avait été faite par M. Raynal, lui-même, pour être utilisée dans les codes de réactions sur les actinides, y compris les voies de fission traitées par un modèle complexe, avec des effets sous-barrière, développé par le professeur Vladuca.

Je me rappelle aussi une leçon invitée donnée par M. Raynal à l'Institut de Physique et Ingénierie Nucléaire (IFIN-HH) de Bucarest-Magurele au cours d'une de ses visites à notre Faculté de Physique (en '95 ou '96). C'était une leçon destinée surtout aux théoriciens et mathématiciens de l'institut.

M. et Mme Raynal sont venus plusieurs fois en Roumanie, en passant des séjours à Bucarest dans la région de la Moldavie. Lors d'une visite (en novembre '95 si je me rappelle bien), ils ont voulu aller à Constanta (une ville-port au bord de la mer Noire) même si le temps de novembre était assez mauvais pour une telle excursion. Sur la route de retour de Constanta, il pleuvait et il y avait un vent très fort, un arbre est tombé sur leur voiture en cassant le pare-brise, pas d'autres dégâts. A l'époque, il n'y avait qu'un seul représentant Peugeot à Pitesti, à 120 km de Bucarest. C'est là qu'ils sont allés le lendemain (en voiture sans pare-brise), accompagnés par ma collègue Mihaela Sin, pour faire la réparation[5].

Je me rappelle aussi une histoire amusante. Au cours d'une de leurs visites, j'ai invité M. et Mme Raynal dans une excursion pour visiter plusieurs monastères dans la région autour de Bucarest. On était dans la cour d'un des monastères et on attendait (avec d'autres touristes) le moine qui était le guide du musée. Tout-à-coup, une femme (touriste) s'approche de M. Raynal et lui demande (en roumain) pourquoi il n'ouvre pas le musée de l'abbaye et ne commence pas la visite guidée car les touristes l'attendent. Evidemment, il ne comprenait pas ce que cette touriste voulait de lui. Je me suis rendu compte qu'à cause de sa grande barbe, la touriste l'avait confondu avec un moine. Alors je suis intervenue en lui expliquant qu'il n'est pas le moine guide, mais un touriste comme nous tous. Je n'ai pas traduit à M. Raynal la discussion concernant la confusion. Quelques années plus tard, je lui ai raconté tout cela, il s'en est beaucoup amusé, Mme Raynal et ses filles aussi.

Mais les plus chers souvenirs sont les visites et les voyages faits avec M. et Mme Raynal (parfois aussi avec leurs filles et leurs familles) en France (à Paris, presque partout autour de Paris et dans le Midi etc.). J'ai passé une semaine dans la maison ancienne des grands-parents de M. Raynal, à Nissergues (un village historique très spécial). M. et Mme Raynal m'ont fait connaître le Midi, me faisant presque tout visiter dans la région, Cirque de Navacelle, Pont du Gard, Avignon, Carcassonne, le canal du Midi, la Camargue, les Aigues Mortes, etc. Au cours de mes périodes de travail au CEA-DAM de Bruyères-le-Châtel (et à l'IPN Orsay), quand j'habitais en Ile-de-France, ils ont été presque comme mes parents, chaque week-end j'étais invitée chez eux, en rencontrant leurs filles, leurs maris et enfants et le frère de M. Raynal (décédé en 2015). Je suis restée amie avec leur fille cadette Catherine. Même quand j'habitais à Aix-en-Provence (en travaillant au CEA de Cadarache), M. et Mme Raynal venaient me voir et m'emmenaient chez eux à Nissergues.

Je ne trouve pas les mots pour exprimer tous mes sentiments pour eux. Je garde toujours monsieur Raynal dans mon âme. Je continue l'amitié avec Mme Raynal. Claude Raynal m'a envoyé des photos de jeunesse de M. Raynal (notamment la photo de 1953 en uniforme, étudiant à l'Ecole Polytechnique)."

[5] *During one of the visits (in November '95 if I remember correctly), they wanted to go to Constanta (port town of the Black Sea) even though the weather in November was rather bad for such an excursion. On the way back from Constanta, it was raining and there was a very strong wind, a tree fell on their car breaking the windshield, no other damage. At that time there was only one Peugeot representative in Pitesti, at 120 km from Bucharest. That's where they went the next day (in a car without a windshield), accompanied by my colleague Mihaela Sin, to make the repair.*



**Fig. 9.** *(Top) Jacques with his friend, climbing Mont Blanc in 1958. (Bottom) Jacques in 1954. (Family album).*

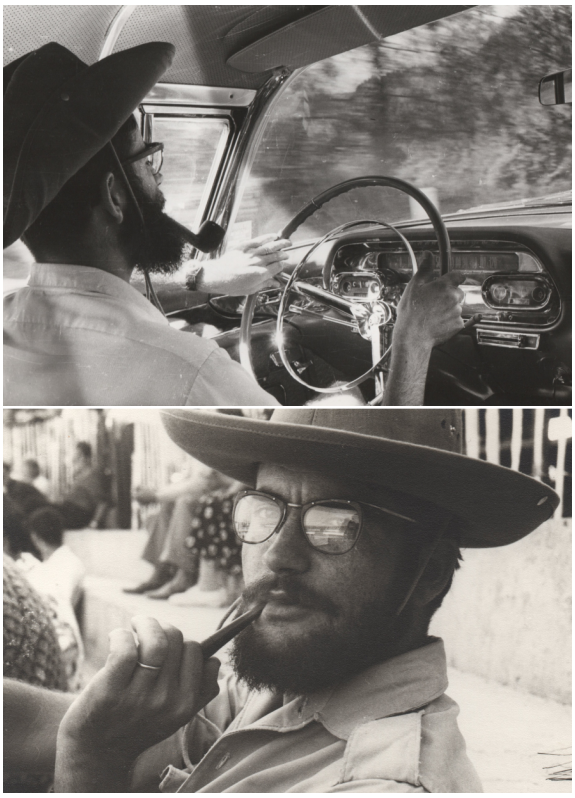


**Fig. 10.** *Jacques driving (a Cadillac) in September 1962. (Family album).*



**Fig. 11.** *Jacques with his brother Jean-Claude, at his home at Chilly-Mazarin. (Family album).*

## Appendix B. Family's records.

"Le 3 août 1958, Jacques était au sommet du Mont Blanc. Il participait à une école d'été aux Houches, et avec un copain unijambiste, ils ont décidé de faire l'ascension. Cela resta célèbre, parce qu'ils *étaient montés à deux avec trois pieds.*
Bien des années plus tard, il monta au sommet du Mont Fuji, avec un ami américain. Il avait loué une voiture pour arriver au pied de la montagne, son permis japonais étant encore valide. Mais... ils ont fait une erreur de 90 degrés pour redescendre, et ils se sont perdus. Heureusement, l'armée japonaise était là en manœuvres, et les a ramenés au parking où se trouvait la voiture, après avoir fait rouvrir la route à péage, fermée la nuit."
"On August 3, 1958, Jacques was on the summit of Mont Blanc. He was taking part in a summer school in Les Houches, and with a one-legged friend, they decided to make the ascent. And it remained famous, because they *had gone up with two with three feet.*
Many years later, he climbed Mount Fuji with an American friend. He rented a car to get to the bottom of the mountain, his Japanese license was still valid. But...they made a mistake of 90 degrees to go down, and they got lost, the Japanese army was there on maneuvers, and brought them back to the car park where their car was, after opening the toll road, which was closed at night."

In the 50s-60s, Jacques climbed mountains (Fig. 9). In the seventies, Jacques was paving the way for the development of the nuclear reaction codes.
Between his travels and conferences (Fig. 10), Jacques exchanged about his physics works and about fundamental questions on Physics with his brother Jean-Claude Raynal (Fig. 11), who was also a theorist, working in the field of high energy hadronic physics. One day, they wondered what the spin of God could be.