Studia UBB Digitalia, Volume 62 (LXII) 2017, December, Issue 2, 95-154

Published Online: 2017-12-30

DOI:10.24193/subbdigitalia.2017.2.06

A short history of computer use at Faculty of Physics – University of Bucharest

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Abstract: For physicists computing is a main activity. Starting from devising an experiment to problem solving with computer, from using mathematical tables to other aids to computation, physics has grown its strength by using each step the numerical computation. So, computing for researches as well as education was used and steadily improved by us, starting from first minicomputers to the last generation of computers and algorithms. In this presentation we will follow, in short, the evolution of computing, hard and soft, in physics at our faculty. We selected here the main field of interests that was connected with problems showing: programmed solutions, simulations and modeling, computer application and software during the time. Such a time recollection is interesting and surprises me as how diverse and far such activity was done. Examples will be from computation in tradition physics, to biology, chemistry, astronomy, medicine to data processing and visualization, data management, to create our own educational software and so on. The fields as nonlinear dynamics, complexity, chaos and fractals, as well as fluid dynamics, atomic, molecular or nuclear physics, earth or stellar physics, connected to improvement of the experiments and devices via artificial intelligence are some of our topics which will be exemplified here.

Keywords: Computational physics; data processing; data visualization; history of computers.

1. A short History

Science being organically bounded to numerical and quantitative results was always related to computation. For science and in particular physics (Analytical and Rational Mechanics, Astronomy) is obvious that methods and procedures to simplify the huge amount of computation was the main field that used the machines that could solve their problems. So, from the early abacus, we used currently a mechanical calculator or slide ruler or mathematical tables and the computation was enlisted on a worksheet.

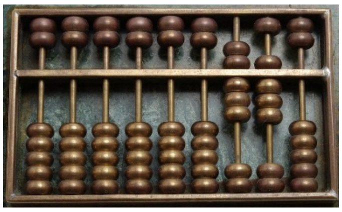
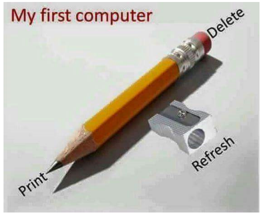


Figure 1. Abacus

B. Pascal on a stamp



My old “computer”

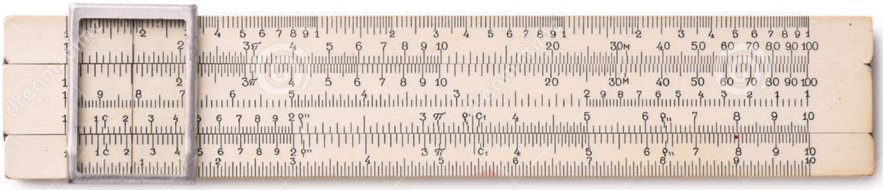


Figure 2. Slide ruler

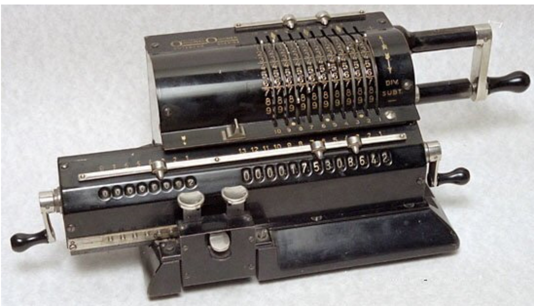
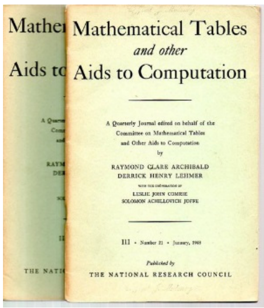
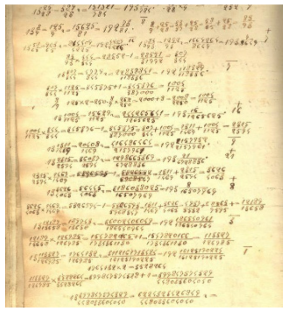


Figure 3.[1] Mechanical calculator



Tables for computations

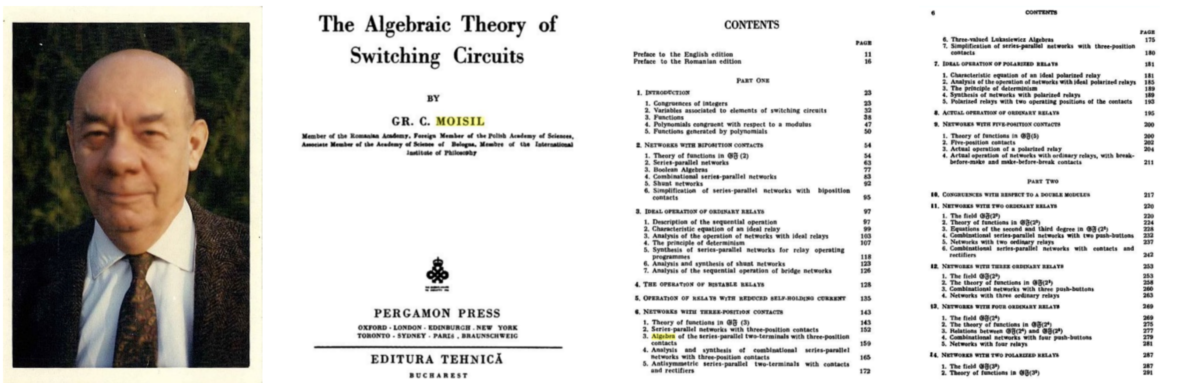


Worksheet, an endless calculations

After WW2 quick and important changes were made in the technology of computers and computing. A brief list is the following: 1961 – replacement of vacuum tube from old electronic computers with transistors and use the magnetic core memory; 1963 – ASCII – American Standard Code for information interchange; 1964 – CDC-6600, supercomputer designed by Seymour Cray and 1966 Hewlett Packard – general purpose computer HP-2115.

[1] http://www.vintagecalculators.com/html/desktop_calculator_photo_library.html

In Romania, during the first half of the fifties decade, Acad. Grigore C. Moisil, as a true pioneer, visualized the future of computers in society [1 - 5], [9]. Even then, he realized the importance of mathematical logic and theory of automata for designing computers. In 1959, inspired by the International Congress of Romanian Mathematicians held in Bucharest (in 1956), Acad. Grigore C. Moisil (1906-1973), Professor of Algebra at the Faculty of Mathematics and Physics, founded, for the first time in the country, the Specialization of Computing Machines in the Department of Mathematics of the faculty [5, 7]. At the beginning, the curriculum was mostly theoretical but in time the staff used the experience of the Institute of Atomic Physics (IFA - Bucharest), which had built-up the first computing machines CIFA. A progress was achieved by the end of 1964, when the Center received the digital CIFA-3 computer, produced in the mentioned IFA. In 1968 the Romanian Government bought an IBM Computer which was assigned to three owners: CCUB (e.g. Minister of Education), Government Commission of Informatics (e.g. the high body for supervising Computer Science in the Country) and Minister of Agriculture. In 1969 Professor Gr. Moisil founded in the Faculty of Mathematics the Chair of Informatics, the first one in the country (Figure 4). In 1970, the staff of the Center consisted of 16 programmers and analysts and 6 technicians or junior operators and programmers [6, 7, and 8].



The Algebraic Theory of Switching Circuits

BY

GR. C. MOISIL

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Figure 4. Prof. Grigore G. Moisil (1906 – 1973) and his seminal book for Romanian computer scientists

Prof. Grigore C. Moisil was the real founder of the basis for computer use, namely the mathematical techniques for programming and problem solving. Computing Center of the University of Bucharest (CCUB), was an important step in the history of computer science in Romania.

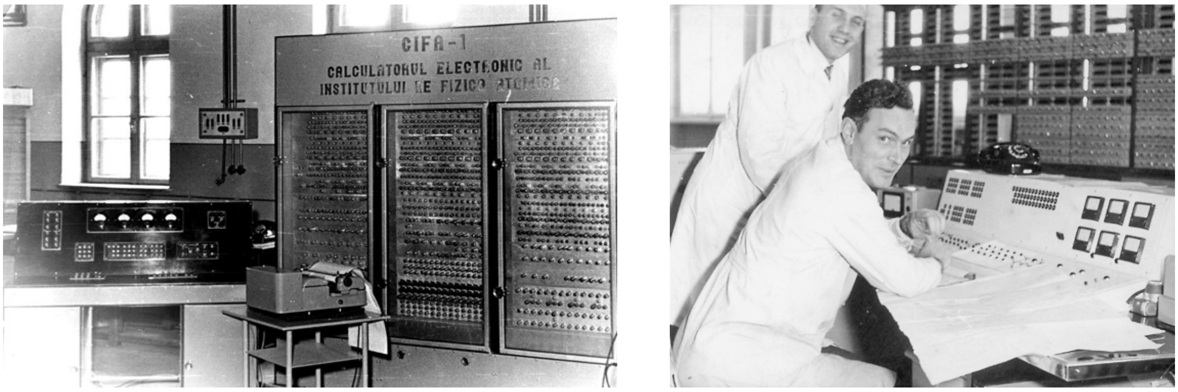


Figure 5. The first Romanian electronic computer – IFA – CIFA1 and
his main designer Victor Toma

Meantime for us as researchers and professors was available the new hand-held programmable calculator, which made us able to learn programming and also to solve many difficult scientific problems, of course at its capabilities. In order: Hewlett Packard *HP-35 – 1*972 the first hand-held scientific calculator; Hewlett-Packard *HP-65* – 1974 the first hand-held programmable calculator, Texas Instruments *TI30* - 1977 was a popular low-cost scientific calculator, Texas Instruments *TI 58* - 1977 was also a scientific programmable calculator. The last one has a replaceable program memory module that allows calculator to be customized. These calculators enabled us to use spreadsheets in our computing activity in physics laboratory and for student activities which was a great step for learning computations (Figure 6).

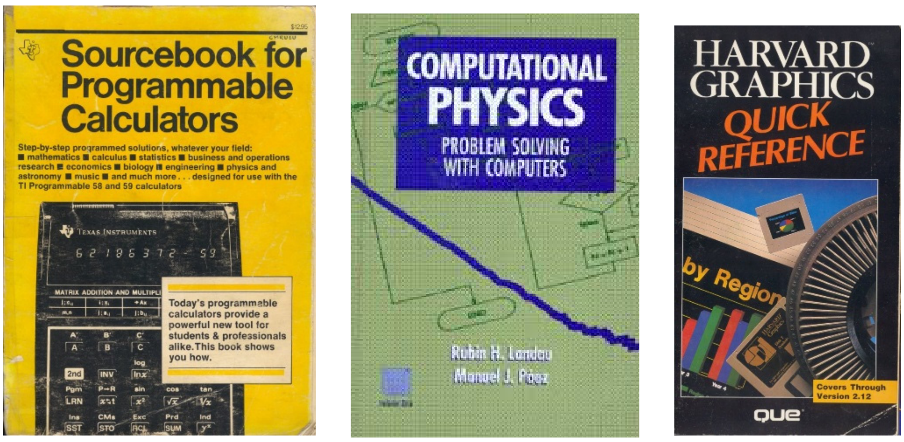


Figure 6. Some of the books we used for physics computing

In Romania at 1984 some 80.000 people were working in IT industry and universities (Felix computer) – IBM compatible.

A great step was made when the personal home computer was released in the United Kingdom in 1982 by Sinclair Research. It became quickly the main device for computing and working in physics (Figure 7).

Figure 7. The Sinclair home computer and his programming book in BASIC

Quickly a Romanian analog was released: namely CoBra, and after that a new version HC, in several models: 85 and 88 (Figure 8).

Figure 8. The CoBra and HC88 Romanian made home computer

All of the home computers needed TV or a video monitor screen terminal. The programs were stored on magnetic tapes, read and write by cassette recorder. We managed to create interfaces (hard and soft) to connect home computers to IBM matrix printer, so it was much easier to handle the data or to produce primitive graphics.

It was quickly adopted for teaching and teachers, as well as students. Even researchers used their capabilities. That was indeed a great step forward for disseminating electronic computers, learning programming and using them at home, in schools and also for games (Figure 9).

In the universities, learning programming was not bounded to the Faculty of Mathematics, but quickly spread in all science and technical faculties like physics, chemistry (Figure 10a and 10b). Departments of computing, electronics and computers, were established also in principal technical universities from Romania.

From my point of view one of most important aspects were the development of the skill for data management, data reduction and error analysis, data presentation and optimization using special computer codes (usually home made), random-process simulations and measurements, modeling and optimization of analytical data analysis, and so on.

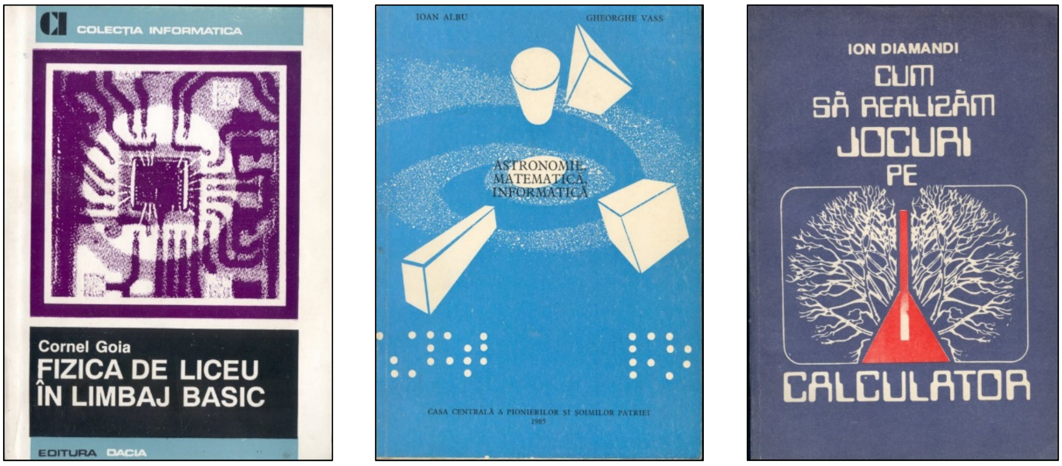


Figure 9. These are some of the popular books for computing used in that period

Figure 10a. The building of Faculty of Mathematics and the new Faculty of Physics

Figure 10b The front of the Faculty of Physics, the new building from Bucureşti-Măgurele campus

Corresponding textbooks and other materials flooded in libraries (Figure 11).

Using computers and computing libraries, we learned by understanding the computer technology and also by programming. A lot of papers, books and periodical helped us to make our own programs for workout the scientific problems.

One of the most used and best fundamental books was the *Numerical Recipes* (Figure 12).

Other books (a selection) are presented in Figure 13.

In the following parts we will present a short summery of fields we use computer and computing methods: in physics, chemistry, biology, natural sciences, and also in art, and other humanistic researches (Figure 14).

Figure 11. Several of the books used for scientific numerical data manipulation

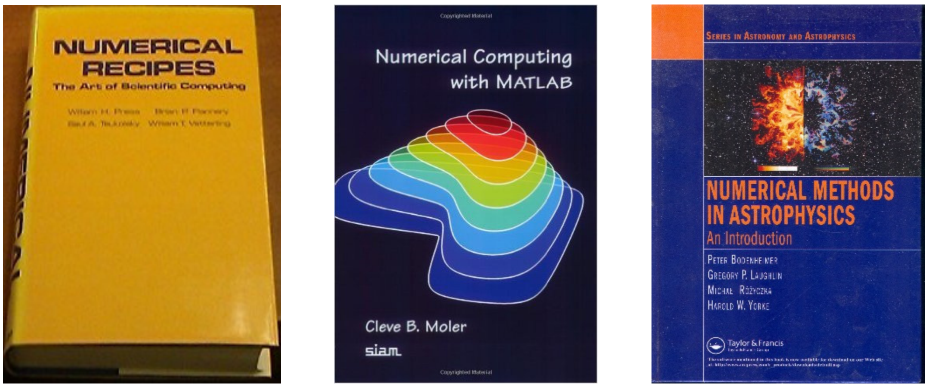


Figure 12. Books for numerical computing used by scientists and students at the Physics Faculty of Bucharest University

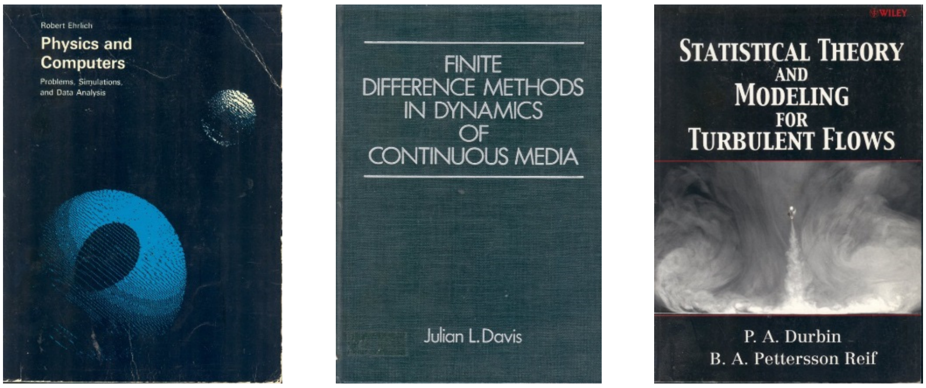


Figure 13. Books for numerical computing in physics, and for far more complex computations related to continuous media simulation and for plasma physics

The last quoted fields were closely related to the development of studies in nonlinear dynamic theories, complexity, chaos and fractals.

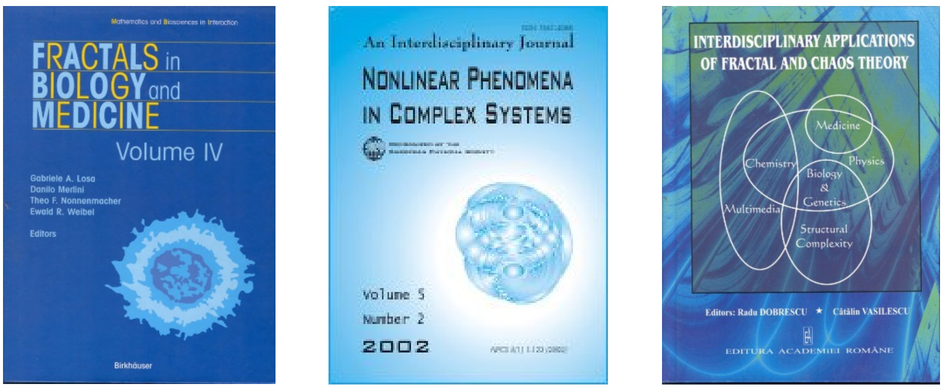


Figure 14. Complexity, chaos and fractals books that were intimately related to our researches and to computer facilities

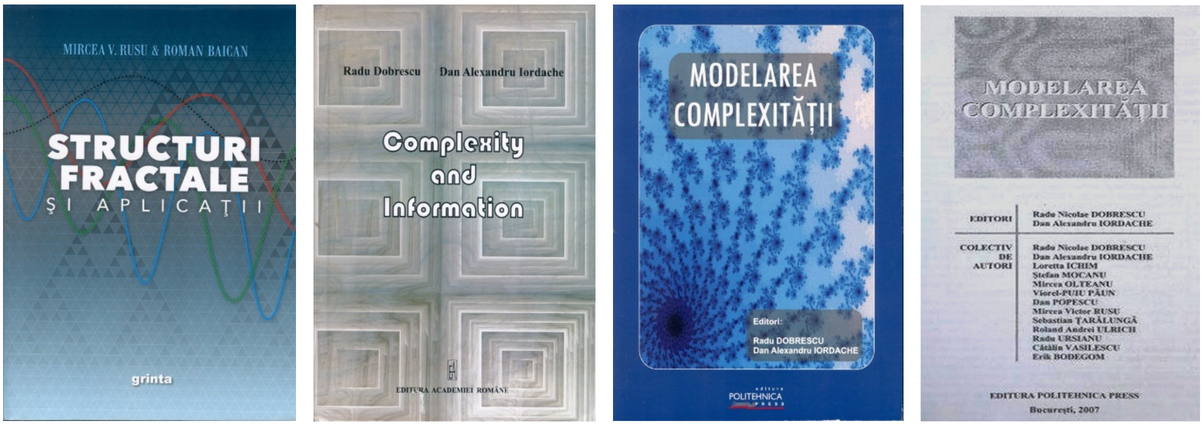


Figure 15. Some of our contributions and researches in fractal and complexity theory

Meantime we enriched our knowledge's and hence we extended our activities applying virtual instrumentations and started to develop our directions of researches using artificial intelligence methods and codes, like cellular automata, neural networks (Figure 16).

Figure 16. Books on virtual instrumentations and artificial intelligence methods and codes, like cellular automata, neural networks written in Romanian

All the mentioned books and others are listed at the end of our paper in ***References***.

2. Fields covered at our faculty that extensively used computers and codes

2.1 Spectroscopy. *Different fields of spectroscopy: Nuclear Magnetic Resonance (NMR), Electron Paramagnetic Resonance (EPR), Visible and Infrared Spectroscopy (VIS, IR), Mössbauer Spectroscopy (MS).*

Magnetic resonance spectroscopy

NMR spectroscopy was used for studies of molecules that contain hydrogen (protons). For that we built our own Magnetic Resonance Spectrometer, first of autodyne type [51] and after Bloch magnetic induction techniques (Relaxation Effects in Nuclear Magnetic Resonance Absorption). It has to be mentioned that our device was among the first built in Romania at that time.

A combination of experimental and computing methods was used in order to obtain the first reliable NMR signals. Early computing devices were used for electronics (autodyne) and for magnetic field distribution in the region of the coil and sample (figures 17 and 18).

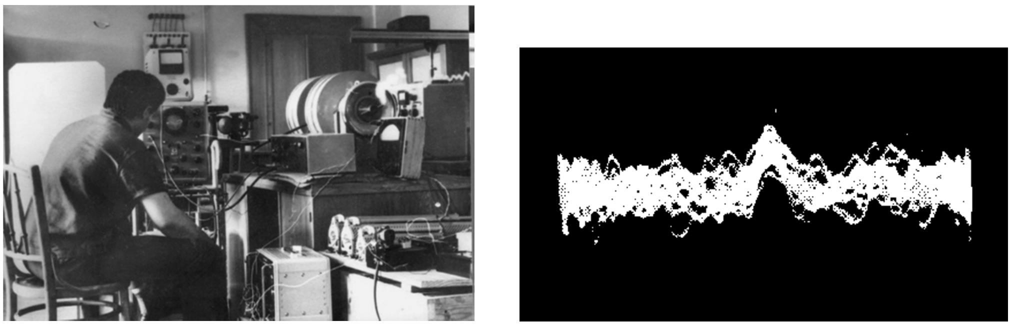


Figure 17. Student using for diploma thesis our NMR spectrometer (1963) searching for the signal on a scope

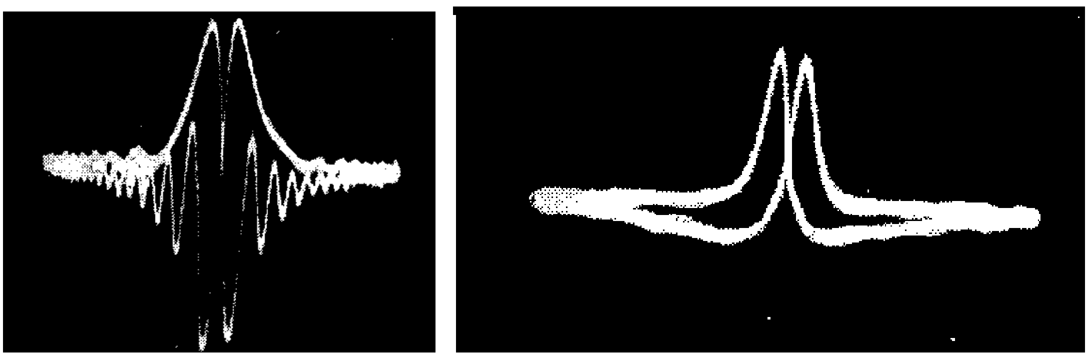


Figure 18. Photos of the NMR signal in homogenous magnetic filed

NMR studies at low magnetic field need Helmholtz coils. Magnetic field distribution in center of coils was computed using basic formulas from figure and after were made corrections for the finite volume of the sample using series expansion (Figure 19) and corrections after measurements for calibration.

If the NMR studies need mainly computing capacities, EPR spectroscopy need difficult computations for spectra interpretation.

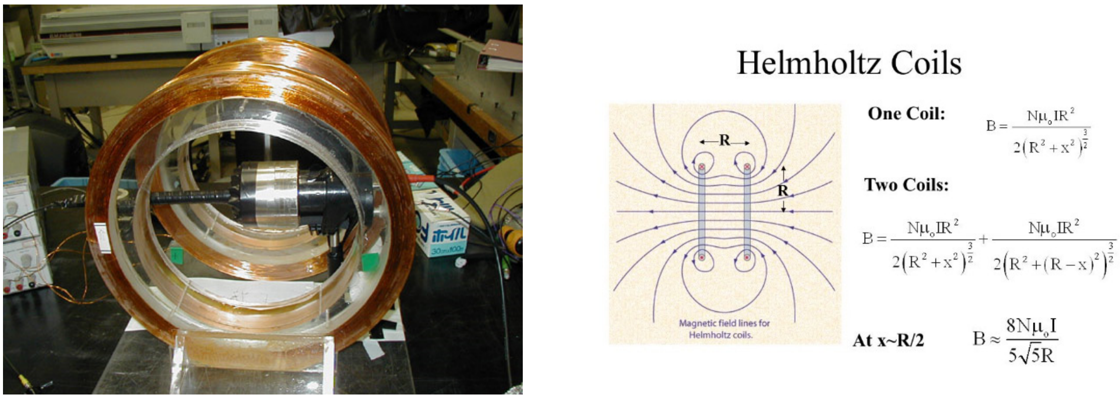


Figure 19. Helmholtz coils and design formulas in first approximation

Usually primary computations are done by spectrometer's electronics, but an additional computation has to be performed using computers special codes. Noise reduction, signal to noise improvement, spectra interpretation and simulations need farther specific computations, which are difficult to be done. The researchers have to be skilled to make their own codes or to rely to the existing one. We did such codes because of lack of money and also we want to have program codes suited for the experimental condition we work [52], [54].

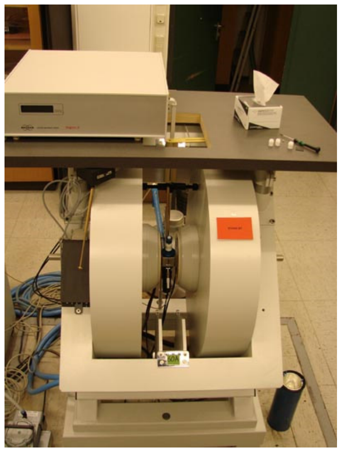


Figure 20. The JEOL EPR spectrometer used at our laboratory

Mössbauer spectroscopy (MS)

MS was an intensive period of work between 1964 and 1974. We built the spectrometer using available (scrap) components and made quite reliable system of measure [55] (Figure 21). We included an automatic change of the speed needed for exploring the desired range of Doppler shift energy variation of gamma rays (actually 14.4 keV – Fe-57 isotope) using an electromechanically switching system relays used in telephony (Figure 22). On the other hand we used the same switching system relays for data acquisition of gamma ray flux in order to improve the signal to noise ratio using the techniques of accumulation of data for each channel corresponding to a given gamma ray energy [56, 57, and 58]. For that time this idea of noise reduction due to repetitive spectra acquisition was completely new and innovative way of obtaining accurate spectra. It was also the first of this type made in Romania. We obtained the high scientific award of Ministry of Education and Researches for Mössbauer device and the following researches done. We used these capabilities for many Mössbauer Effect Applications in Chemistry [59, 60, and 61].

With this spectrometer we were able to study magnetic materials, namely Magnetite with spinel structures F_3O_4. We obtained valuable data on magnetic structure of the crystal, the way of the distribution of the impurities in the crystalline lattice, their influence on the magnetic properties of the material, the atomic structure nearby the iron atoms (local order or disorder), and the way of phase transition between ordered and disordered structure, which lead us to a new approaches of these transitions and led us to conclusion that in some cases the structure is not ordered, nor disordered but acquire a fractal local distribution. Among the problems we studied were the Iron valence spectra in doped Magnetite [62, 65, and 67], spin and charge densities in Ti-dopped Magnetite [63], the hyperfine interactions in Doped Magnetite [64]. In order to analyse and for data reduction we worked out a computer code for quantitative analysis of Iron compounds using Mössbauer Spectroscopy [66].

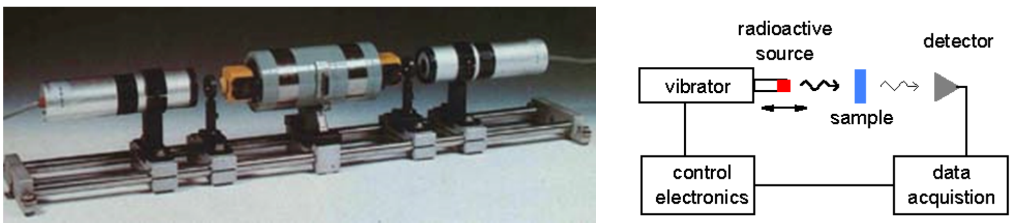


Figure 21. The radioactive source, electromagnetic drive to control the speed, the sample holder and the photomultiplier as a detector in a complete MS with a block schematic

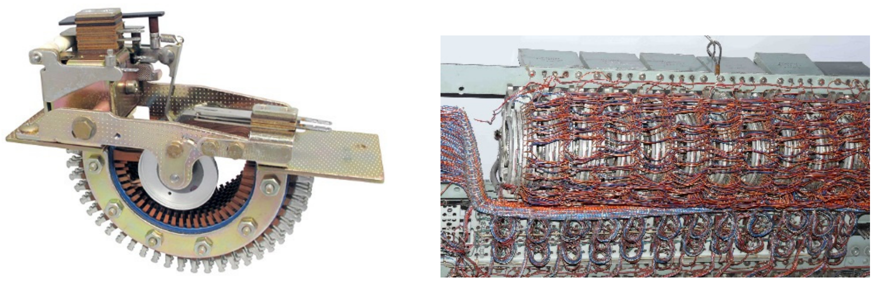


Figure 22. Electromechanically switching system relays that govern the speed and also the channel of data accumulation

A typical spectrum recorded and analyzed is given in Figure 23.

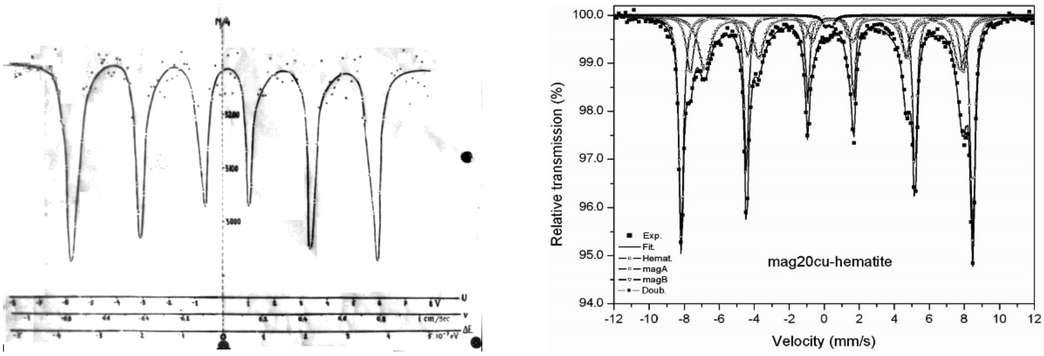


Figure 23. Our first Mössbauer spectrum of pure Magnetite and a complex spectrum of mixture of Magnetite (Fe_3O_4) and Hematite (Fe_2O_3)

Each type of sub-lattice from the oxide has his 6-line Zeeman spectrum. If there are several sub-lattices the spectra is a convolution of all sub-lattices contribution. To understand the crystalline structure and their atomic arrangement it has to be de-convoluted. This task can't be done without specific dedicated software we managed to do. The task is hard and optimization for a minimum χ-square deconvolution is cumbersome and time spending activity. Usually for a good deconvolution are necessary several days of work. We used the IBM's machine from Atomic Physics Institute with the help of Dr. Mircea Morariu from the Mössbauer group led by Dr. Dănilă Barb. The complexity of the spectra was impossible to solve directly so we needed to choose and enter the initial values of the parameters that define the whole spectra using a less performing computer (SINCLAIR). If we have six sub-lattices with 6 lines each we need to define 6 x 6 = 36 lines and if we assume the shape of a line is Gaussian (defined by 3 parameters) we have to find optimized, 36 x 6 = 216 parameters. It was a very long task for each deconvolution, so each sample took at list a couple of month to optimize. Usually a set of samples for one compound took some 6 month of work. But we created a basis for deconvoluting all kind of complex spectra whose complexity arise form superimposing several simpler spectra.

It is clear that without good, high memory, and high speed computers, such a task could not be finished.

Infrared (IR) spectrometry

In our department of Atomic and Nuclear Physics, the activity concerned studies of atoms, molecules and substances in different environments and under different conditions. One of the main experimental studies was done recording and interpreting the IR spectra of some samples, at different temperatures. We used an IR spectrophotometer

Unicam SP1100, an analog device that records the spectra on paper. We had to analyze and interpret spectra on paper that was not so easy and precise. So we considered that is possible to improve the quality of interpretations if we make a modification of spectrophotometer in order to obtain the digital (numerical) file of the spectra. For that we made a digital to analog converter scheme that can be seen on Figure 24. We used an 8080 processor as core of the computing system and made all hard equipment and the soft necessary to accomplish the task [68]. In Figure 25 we present two spectra recorded by modified spectrometer and presented on a computer monitor. We considered that all these improvements necessary in order to be able to better understand the results. We studied the I.R. spectra of amorphous $Mo_x(a\text{-}Ge)_{1-x}$ thin films [69, and 71], and problems arised when surface we study presents roughness and hence the optical constants deduced had to be corrected [70].

Figure 24. Unicam SP1100 Infrared Spectrophotometer with analog to digital conversion and 8080 processor as core of the computing system

Many of the results that we will present in the following sections were done using this upgraded spectrophotometer.

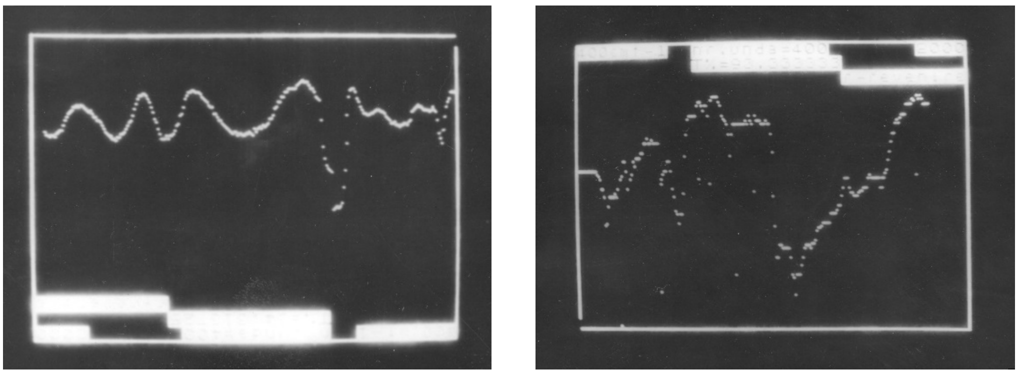


Figure 25. Two examples of IR spectra recorded using the upgraded spectrophotometer (photos from the monitor screen)

Dinosaur Eggs from Haţeg Basin

As an example of interesting studies that were done are the Dinosaur eggs studies found in Haţeg basin from Romania. We carried out measurements on serial sections through dinosaur eggshells (Figure 26) and used IR spectrometry (transparences and reflectance) in order to capture as many as possible valuable data on the composition, structure and formation. Extensive and multitask studies were done. We measured physical, geometrical – allometric properties, optical (Visible and IR – transmission and reflectance), electron microscopy, thermodynamic analysis. We studied also dielectric properties, and carried out chemical analysis, and correlate all findings with paleontological, stratigraphical and geological data of the place where these eggs were found. We compared the data with the today's eggs of chicken and these gave us the possibility of inferring biological aspects on the Dinosaur biology, environment they lived, and other unknown characteristics. We were able to create a scenario of their life using the physics of the eggshell [72, 73, and 74].

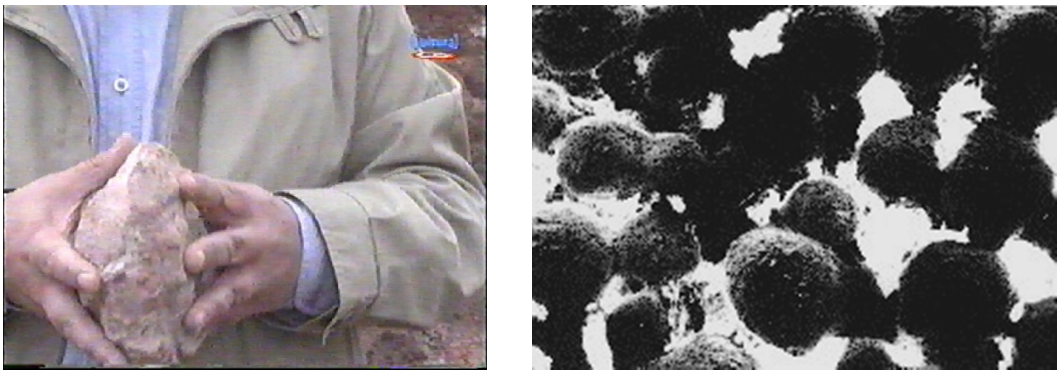


Figure 26. A freshly discovered dinosaur egg fragment and a longitudinal section through eggshell, first layer – optical microscopy

The pore structure of these eggshells exhibits peculiar hierarchical self-similarity, from millimeter scale to nanoscale. At optical scale, the eggshell is built up by packing bundles of calcite carrots, well aligned with their axis perpendicular to the eggshell surface, with "gaps" (macro pores) in between. Each calcite carrot is about 0.5 mm in diameter and has the length equal to the eggshell thickness. Scanning electron microscopy (SEM) reveals that these carrots are in turn micro porous spongy calcite structure, with ~μm average pore diameter. The structure on an even smaller scale is studied by transmission electron microscopy (TEM) on thin sections prepared by ion milling, using methods from material science, revealing yet another layer of complexity (Figure 27). The observed features led us to the conclusion that calcite crystallization leading to the carrot morphology is controlled from the nano- to micro-scale by the structure of the collagen net developed in the eggshell cell.

A surprising conclusion resulted from our study: the pore distribution is not a Gaussian but a power low that is typical for some self-similar structures. In this way we found that the biological survival of the eggs was much enhanced, despite the variability of the early harsh environment. This conclusion resulted from measurements and computations made using our image analysis codes and fractal dimension codes we made for that. In Figure 27 are presented results for one of the serial cuts slide from eggshell, and the fractal analysis code for determining the fractal dimension of the distribution. We found that this fractal distribution can be found even at micro scale, revealed by TEM scanning.

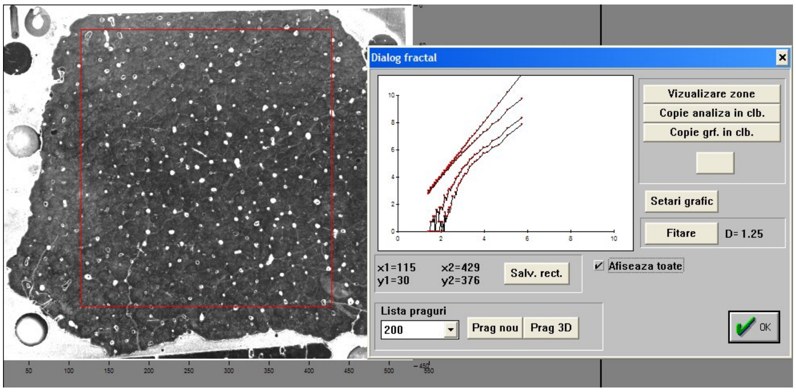


Figure 27. Example of fractal dimension computation using box counting method applied directly to the image

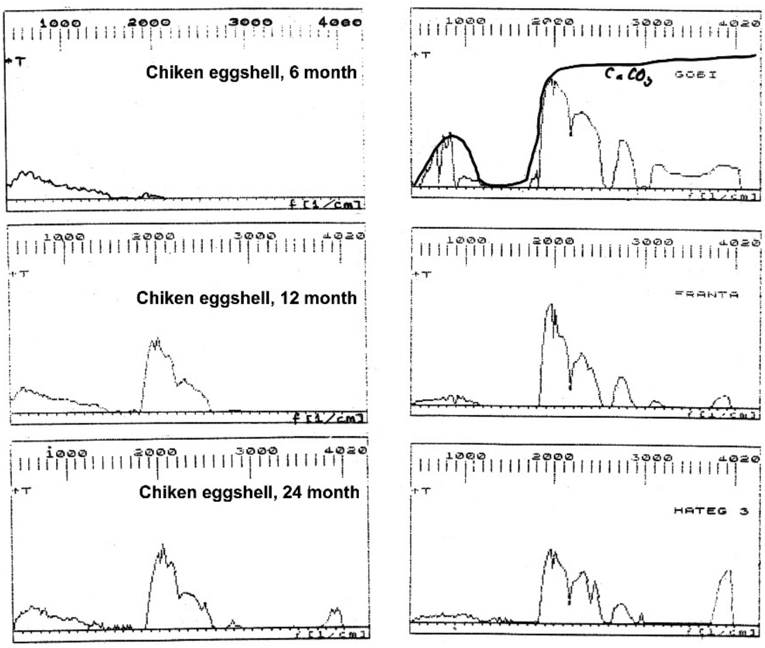


Figure 28. The IR transmittance spectra of the chicken eggshells and dinosaur eggshells

Another interesting result comes from IR transparency of the bulk shell of the egg. Comparing the chicken eggs IR transparency spectra with that of the dinosaur eggshell we found a nice evidence of the evolution in time of the calcite structure of the columnar structure (Figure 28). The main features of the eggshell could be recognized even there are millions of years as time leg. In the transparency spectra there is a gap around 1500 cm^{-1} that is preserved in both types of eggshells. If we compute the temperature of the thermal radiation corresponding to that range of opacity we found a value near 40^0 C which suggests that the eggshell is not transparent for this range of radiation. The direct conclusion is that the eggshell acts as an "accumulator" of inner heat energy in order to maintain constant temperature inside the eggs. So, the eggs could be hatched in great reliable condition despite the variation in environment condition. Hence the hatching has a nigh rate of survival yield.

3. Computing in nonlinear dynamics, fractals and chaos

One of the main fields we extensively used was the study of nonlinear dynamical systems, fractals and chaos. At that point we can quote the Sir Isaac Newton, from *Philosophie Naturalis Principia Mathematica:*

> *"It is the glory of geometry that from so few principles, fetched from without, it is able to accomplish so much."*

Indeed the fractals, chaos and nonlinear dynamics are inherent related to computing. The fractals were discovered by Benoit Mandelbrot in the time he worked at IBM Research Center (1982). Fractals, being "exactly the same at every scale or nearly the same at different scales" as defined by Benoit B. Mandelbrot, are complicated, yet fascinating patterns that are important in aesthetics, mathematics and science and engineering.

By using non-spatial dimensions, mathematicians and scientists have explored spaces beyond traditional 3-dimensions. Examples include 4-dimensional 'cubes' called tesseracts. Understanding of these structures can offer insights into real world problems such as optimizing a network's path to follow the shortest distance. Physicists and mathematicians, routinely formulate even higher dimensions, known as ordered states, to manipulate complicated equations that would be much harder to work with at a lower dimension. It is not uncommon for atomic physicists to work with a dimensional space in the teens in order to keep track of all possible states of particles found at the subatomic level.

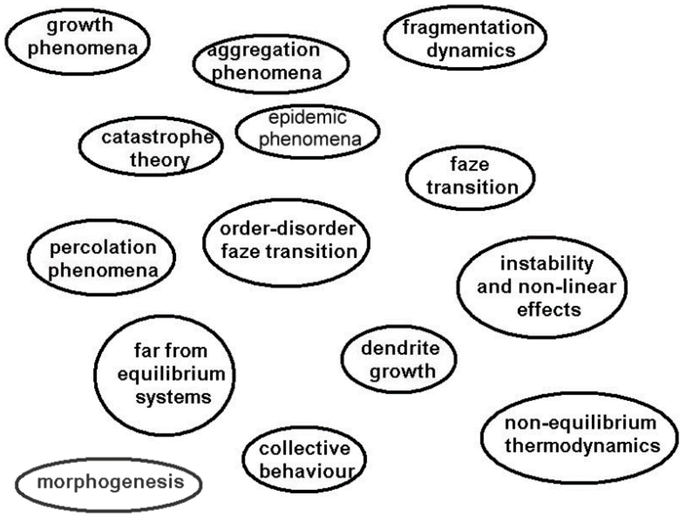


Figure 29. Different fields that were unified into a new general theory, *Theory of Complexity*

The aim this field is to understand the patterns and shapes found in nature: galaxies, clouds, snowflakes, ocean waves, coastlines, leaves, forests, patterns on skin and on butterflies, shapes and forms of crystals and molecules and macromolecules (e.g., synthetic polymers and proteins), shapes of biological cells and viruses. Mandelbrot (1982) developed and introduced a new kind of geometry, *fractal geometry* (different from Euclidean geometry) [72]. It was shown that many naturally occurring structures that are usually described as irregular, random, or chaotic actually have shapes that can be measured and categorized. Many shapes and patterns found in everyday life can be described on the basis of somewhat simpler geometrical considerations. In fact, fractal geometry can be considered a new way of looking at nature.

We started from 80's to use complexity theory, and more specific nonlinear dynamics, to understand many unsolved problems for atomic and nuclear physics, astrophysics, biology and medicine, and finally extended these studies to larger fields such psychology, social behavior, and other humanistic fields. In the following we will make a short description of these studies. All of them used extensively computers and computing for modeling and simulation of the phenomena [40], [73, 74, and 75].

Fractals and chaos

Because fractal theory and chaos gave us a powerful mathematical and computational tool, a lot of earlier researches were reconsidered and other were started once we put in work this tool. [76 to 92]. According to Benoit Mandelbrot, the father of modern fractals, a fractal is, "a set with self-similar geometry and fractional dimensions.

We started to workout the mathematical theory of fractal geometry; we produced several computer codes for computing parameters (fractality, fractal dimension, randomness, statistical distribution, noise, multi-fractality and so on) related to fractal analysis of the signal, image and data. In the above cited references you can find some of the most important of our researches. Being a vast area it is not intended here to make even a short description of them, but we can mention some of these problems. For example the first problems were related to define and measure the fractal dimension of the data. Our data came sometimes as time series or noisy data from a specific mathematical space, or image analysis, or sounds and so on. It was necessary to check for self-similarity of the data and the volume of sample we analyse. One of the difficult problems encountered was related to method of measuring the fractal dimension, knowing that primary data have to be transformed mathematical. This transformation has to be reliable not to smear-out the fractal characteristics. For example, any kind of noise reduction procedure or smoothing of the image or time series could destroy the fractal characteristics of the signal (data). Hence, the usual codes for numerical data processing are not usable for that task. We produced our codes for all kind of statistical analysis and fractal analysis that have to be used in such cases. On the other hand, there exist commercial codes for fractal analysis but unfortunately in some cases these are no reliable. Careful code production for fractal and nonlinear system analysis is compulsory for serious fractal analysis. We did that on time span of almost 10 years. A review of these codes and methods is described in [92]. Another interesting aspect is that in our department, teaching fractals and nonlinear dynamics as regular courses begins around 1985 and many generations of students finished these lectures. Some of them use fractal analysis in their researches activities in their field.

It is obvious that we made steps forward new computing strategies that include cellular automata (CA) algorithms, neural network (NN) based codes, statistical and mathematical algorithms on much more complex analysis, like Kolmogorov entropy, and other strategies for finding peculiar fractal or nonlinear aspects of the problems. In the same categories are methods of solving nonlinear differential equations, or using finite difference methods for exploring solutions of problems in the field of continuous media like: fluid dynamics, plasmas, jets, thermal propagation or electromagnetic propagation through non-homogenous materials and media. Topics are for example: self-organizing networks for extracting jet features; recurrent NN for real-time matrix inversion, deconvolution of complex spectra of different natures, fuzzy systems, ecological problems, atmospheric physics (Earth and planets, including stellar atmospheres), cancer and epidemic diseases, land erosion and forest preservation, tectonics and earthquake early warning, understanding the brain activity and learning processes and other mathematical models to simulate a learning/problem-solving activity of the brain. A lot other models are dedicated to ultrasound tomography imaging of defects using NN; modeling of robot motion using NN; photogrammetric target processing using artificial NN; use of NN for an expert system in nuclear medicine image analysis.

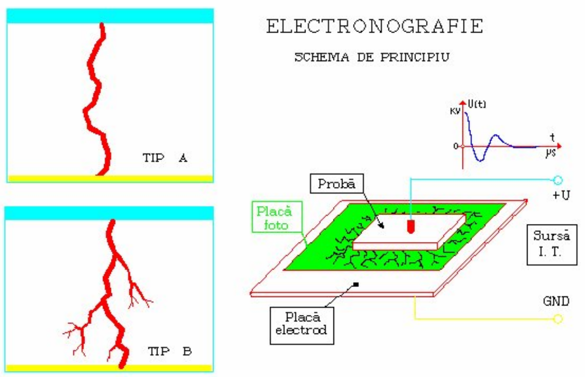
Figure 30. Lightening images. The irregular path is characteristics and difficult to understand

A special attention and work we done on understanding atmospheric discharges – bolt of lightning, lightning, sparks, dielectric breakdown, branching electric discharges that sometimes appear on the surface or in the interior of insulating materials (Lichtenberg and Kirlian discharges).

Related to these are other collective phenomena, which are inherent non-linear. Among them are corona discharges, digital imaging techniques that record light produced by photons emitted during corona discharge electrical breakdown or arcing often seen as a bluish (or other color) glow in the air adjacent to pointed metal conductors carrying high voltages, and emits light by the same property as a gas discharge lamp.

New researches suggests that a) lightning are triggered by cosmic ray shower, b) lightning produce electromagnetic waves in upper atmosphere that create correlated lightings over the entire Earth that shoes power low time distribution, c) lightning create a specific electromagnetic noise that could perturb communications, d) lightning are sometimes associated to specific geometrical form like ball lightening, e) unusual type of lightning could be found in the upper atmosphere, over the clouds and are directed upward and not downward (elf and sprites). It is now well known that the intricate, tortuous, path of the lightning is a typical non-linear phenomenon produced by quickly changing in electric field distribution over a large region of space. Understanding of these features are of theoretical as well as practical interest. In the following we will present short description of our researches.

All of these phenomena are similar to other phenomena apparently un-connected, but today we can understand their behavior, trough self-similar properties and also under the law of universality specific for complex phenomena. An interesting example is the St. Elmo’s fire (light), a weather phenomenon in which luminous plasma is created by a coronal discharge from a sharp object in a strong electric field in the atmosphere (such as those generated by thunderstorms or created by a volcanic eruption). Equivalent is the function of the Geiger-Müller tube used in nuclear physics to detect charged particles coming from radioactive substances.



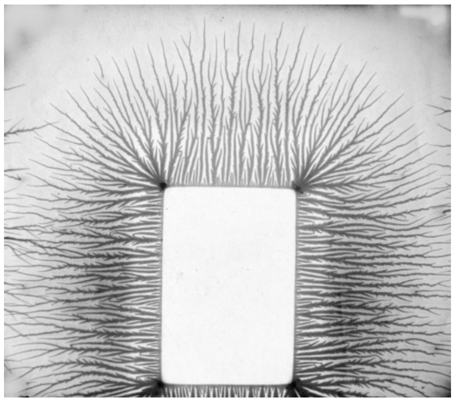


Figure 31. Device for studying surface electric discharge (electromyography)
Figure 32. Image of the branching structure of the surface electric discharge captured on a photographic film

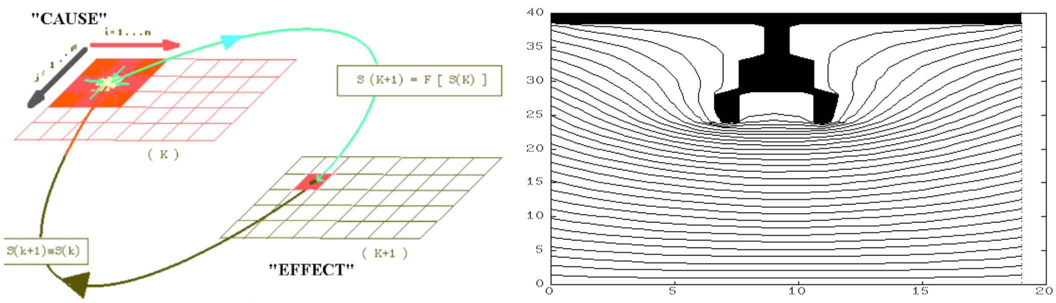


Figure 33. Algorithm for simulation lightning strimer, using cellular automata code

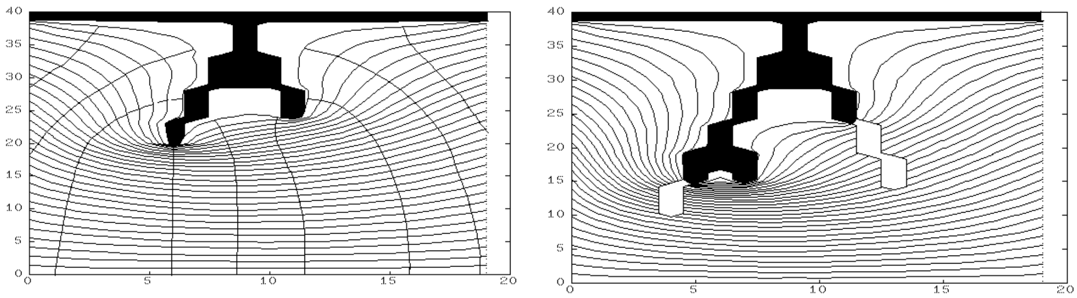


Figure 34. Step by step results of the simulation: propagation of the strimer (cellular automata)

It is amazing that that kind of phenomena we can find in liquid flow, liquid mixing phenomena, turbulence, diffusion phenomena starting from chromatography, electro deposition, and the transport phenomena governed by Brownian motion.

Turbulent flow, or turbulence, is found to have two important and interrelated properties. It is chaotic and it can transport, stir, and mix its constituents with great effectiveness.

By chaotic, we mean that it is characterized by irregular temporal and spatial dynamics that are unstably related to its initial and boundary conditions.

Connected phenomena, by their universality law, can be seen in particle deposition of thin films technology, or in sedimentation, or columnar growth of crystals, that could be well described by Diffusion-Limited Aggregation (DLA), a kinetic critical phenomenon.

DLA is a statistical growth process that progresses much like Eden growth, but the addition of sites occurs with the highest probability where the gradient of a substance that is diffusing toward the existing cluster is greatest. The sites with the highest gradients tend to occur at the sharpest and outermost points of the cluster, thus leading to the unstable and rapid growth of these points. Dendrite structures results that have been suggested as a promising model of growth for many natural processes. Unlike cellular automata and Eden growth, DLA is considered a global model as opposed to a local model. Whereas the probability of growth depends on the local gradient, the gradient itself is determined by the patterns of diffusion around the entire cluster that arise from the shape of the cluster as a whole. Growth therefore exhibits long-range correlation, an important characteristic in a structure that may approximate global optimization for transport of metabolic materials. The fractal dimension of a DLA cluster as a whole is known to be about 1.71 in a plane.

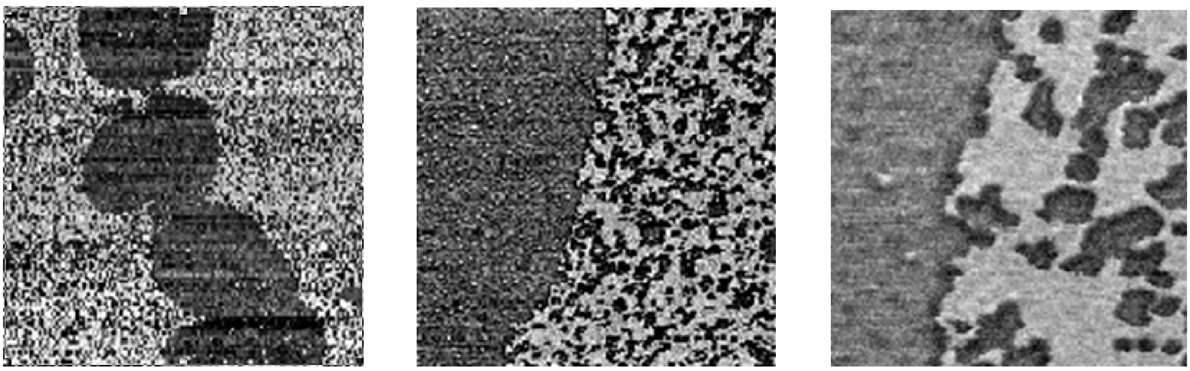


Figure 35. Experimental technique of adhesion AFM for dimyristoylphosphatidylethanolamine (DMPE) film, made by Langmuir-Blodgett (LB) technique, at a surface pressure for which coexist both liquid expanded (LE) and liquid-condensed (LC) phases

Careful analysis of images and computation of the free energy of the molecule layer on the liquid could (Figure 35) be understood that shows fractal geometry of the border separation between phases.

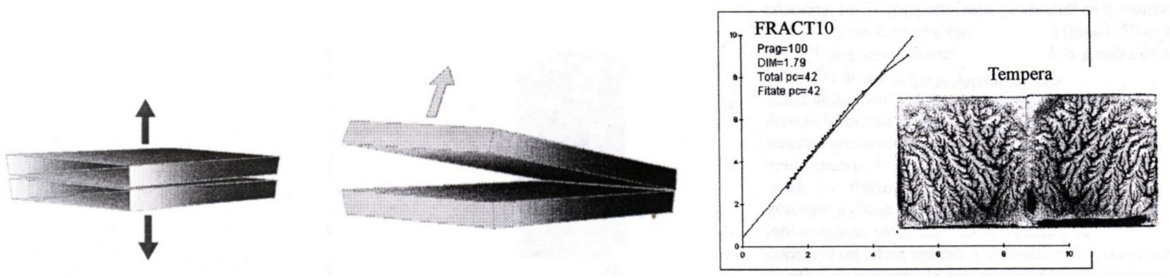


Figure 36. Detachment experiments and fractal analysis of the branching pattern using one of our codes for fractal dimension computation

These kinds of researches could be interesting as a special type of modern art, but in essence is related to the molecular interactions between liquids of different viscosity (oil, water color, tempera, glues, etc.) with a substrate. All of them exhibit fractal structure with different but specific fractal dimension. An interesting application was our study of the fractal dimension of the cracks developed in old paintings. There are notable (statistical) differences between the systems of cracks for a drying paint with quick drying time compared with the long time of drying. Application could be found in identification of forgeries, and also for approximate dating of old paintings [186]. Also we can benefit from these experiences in our home made painting activities of our house.

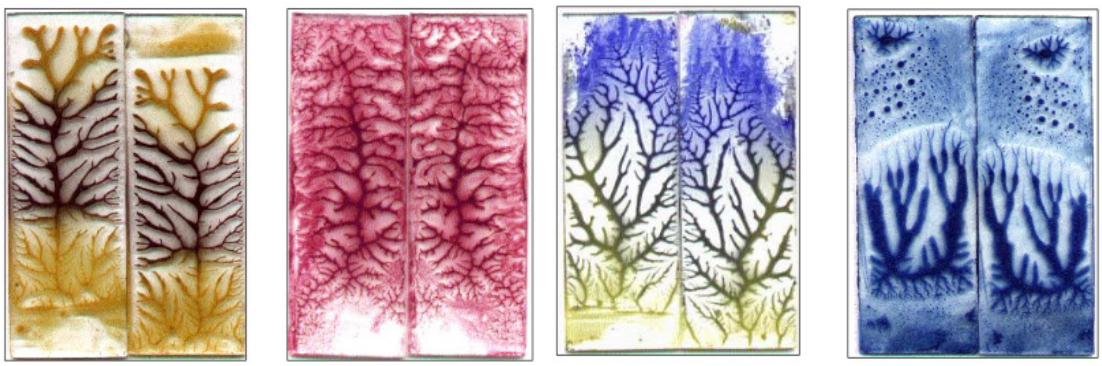


Figure 37. Lifting-Hele-Shaw-Cells; water-paint and oil paint (our experiments)

In figure we show our experiences using adhesion physics, limb formation and branching. All the physical effects are related to the intermolecular interactions between paint and substrate (glass plate), Figure 36 and Figure 37. The images are representative for universality phenomena that include all kind of complex systems, starting form paint, rivers branching, dune formation and erosion, clouds, the climate on planets, plants and trees, limb formation and so on.

Without being directly connected to the above phenomena we studied charged particle movement in electric or magnetic (or both) fields that occurs in Solar wind and give rise to the famous auroras (polar lights, northern lights, aurora borealis) a natural light display in the Earth's sky, predominantly seen in the high-latitude regions. Auroras are produced when the magnetosphere is sufficiently disturbed by the solar wind that the trajectories of charged particles in both solar wind and magnetospheres' plasma, mainly in the form of electrons and protons, incoming into the upper atmosphere due to Earth's magnetic field, where their energy is lost. The resulting ionization and excitation of atmospheric atoms and molecules emits light of varying colors and complexity. The Solar wind interaction with magnetic field of Earth during Solar activity effects planetary magnetospheres. The heliophysics is closely tied to the study of space weather and the phenomena that affect it, and consequently to climatology.

Going in upper atmosphere we can found other phenomena, that were and remained our interests: in the cosmic ray flux of particles with origins outside the Earth environment, namely from deep space, active galaxies, neutron stars, black holes end so on. The cosmic ray flux produces avalanche by multiple collision with the atmosphere constituents and can be observed on the Earth surface like a background radiation. In order to model the movement of charged particles from deep space, to our Galaxy, to our atmosphere, we have to model the process by stochastic models for particle transport (sometimes by Monte Carlo simulation).

At the end of this lengthy list of phenomena witch were studies by us in the last 30 years, we carefully analyse the limits of fractal analysis and models, because becoming a "universal panacea" to study unconventional and the non-linear phenomena, very easily it could be used as universal conclusions, un unwanted habit in the scientific research.

Who is interested in the above list of thematic and fields we studied, can found particular examples in the references.

A large area of interests was the computational electrodynamics or electromagnetic modeling of the interaction of electromagnetic fields with physical objects and the environment. Typically this involves computations for different approximations of the Maxwell's equations and is used to calculate antenna performance, electromagnetic compatibility, radar cross section and electromagnetic wave propagation in free space or in between a specific environment. Great deals in that computation could be to account for the scattering or absorption of radiation by small particles from atmosphere. This could be of interests also for astrophysics where we have to understand the propagation of electromagnetic wave (including light) in stellar or planetary atmosphere.

Not far from these topics are the electromagnetic propagation in non-homogenous media (natural environment) or in region with buildings, constructions, wires, metallic objects, usually man made artifacts (cables, metallic towers, antennas, airplanes, cars, ships, submarines). The last example of interest is in all kind of Radar applications, steals devices.

From these categories we studied extensively propagation in natural environment of the electromagnetic waves (for telecommunication needs, especially cell phones), and fractal applications in designing antennas with various characteristics impossible to achieve on conventional design.

The propagation was studied trying to find a better model of propagation though landscape (which is fractal in essence) in order to maximize the transmitted power with minimum number of antennas. We found that the fractal model is a much better model over the classical one.

For all kind of mobile vehicle the most important is to have a better gain of receiving the signals from emitters (Phone, TV, radio, information, GPS, radar and so on). The main problems are that all these kind of application work in different frequency bands and the antennas have to be small. This is a major problem for antennas, which mast be designed to work in a broad band of frequencies (from MHz to GHz or even THz). We found after years of study that fractal geometry could give a better solution with reasonable good results using one or maximum two small antennas. All the details could be found in references form [93] to [126]. The work was covered by a patent from Adam Opel from Germany. We also succeeded to design small, patch antenna based on fractal design for wireless sensors (RFID). http://en.wikipedia.org/wiki/Computational_electromagnetics

The most difficult problem that arises was to solve the Maxwell's equations for different conditions. Usualy that is done using the *finite element* method (FEM) in order to find approximate solution of *partial differential equations* (PDE) and/or integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an equivalent ordinary differential equation, which is then solved using standard techniques such as finite differences. Finite element programs with Websites: could be ANSYS/Emag, COMSOL AC/DC Module COMSOL RF Module, COSMOS/M, EZNEC Antenna Software.

Another method is the *method of moments* (MOM) or *boundary element method* (BEM). Both are numerical computational method of solving linear partial differential equations which have been formulated as integral equations (i.e. in *boundary integral* form). It can be applied in many areas of engineering and science including fluid mechanics, acoustics, electromagnetics, fracture mechanics, and plasticity. Because it requires calculating only boundary values, rather than values throughout the space defined by a partial differential equation, it is significantly more efficient in terms of computational resources for problems where there is a small surface/volume ratio. Conceptually, it works by constructing a “mesh” over the modeled surface. However, for many problems boundary element methods are significantly less efficient than volume-discretization methods (*Finite element method, Finite difference method, Finite volume method*). Boundary element formulations typically give rise to fully populated matrices. This means that the storage requirements and computational time will tend to grow according to the square of the problem size. By contrast, finite element matrices are typically banded (elements are only locally connected) and the storage requirements for the system matrices typically grow quite linearly with the problem size. Compression techniques (*e.g.* multipole expansions or adaptive cross approximation /hierarchical matrices) can be used to ameliorate these problems, though at the cost of added complexity and with a success-rate that depends heavily on the nature of the problem being solved and the geometry involved.

Sometimes we used differential equation solvers such thet *Finite-difference time-domain* (FDTD) is a popular computational electrodynamics modeling technique. It is considered easy to understand and easy to implement in software. Since it is a time-domain method, solutions can cover a wide frequency range with a single simulation run. This method belongs in the general class of grid-based differential time-domain numerical modeling methods. Maxwell’s equations, in partial differential form, are modified to central-difference equations, discretized, and implemented in software. The equations are solved in a leapfrog manner: the electric field is solved at a given instant in time, then the magnetic field is solved at the next instant in time, and the process is repeated over and over again. Current FDTD modeling applications range from near-DC (ultralow-frequency geophysics involving the entire Earth-ionosphere waveguide) through microwaves (radar signature technology, antennas, wireless communications devices, digital interconnects, biomedical imaging/treatment) to visible light (photonic crystals, nanoplasmonics, solitons, and biophotonics). Approximately 30 commercial and university-developed FDTD software suites are available for use. For example *ScatLab* - electromagnetic scattering simulations mainly based on classical Mie theory solution and *Sonnet Lite* -a free MoM code http://www.sonnetsoftware.com/products/lite/download.asp

Other software we use was FEKO from EM Software & Systems and HFSS from Ansoft.

The results, as a Minkowski fractal antenna computed and produced using the above soft wares is presented in Figure 38.

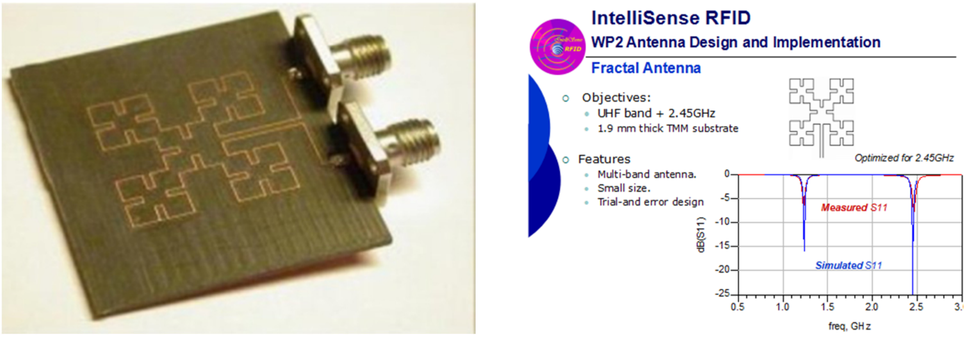


Figure 38. One of the fractal antenna designs as an interface for a Smart RFID [ ]

Another very interesting application of fractal geometry was energy harvester design inspired from fractal geometry. Energy harvesting is a process by which energy is derived from external sources – ambient energy. It could be solar power, thermal energy, wind energy, salinity gradient, kinetic energy, and one of the earliest applications of ambient power collected from ambient electromagnetic radiation was the crystal radio.

The harvested energy can power small autonomous sensors such as those developed using MEMS (Micro-Electro-Mechanical-System) accelerometers.

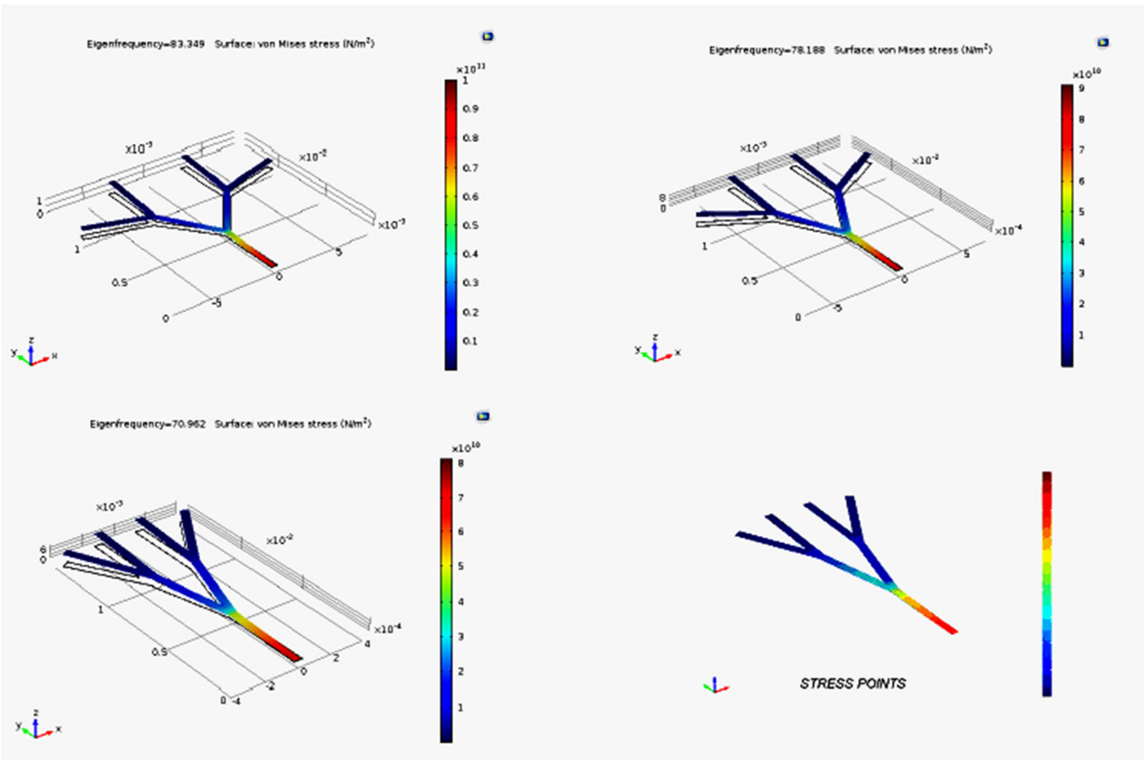


Figure 39. Fractal based cantilever design for energy harvester device

It was our idea to use fractal based cantilever configuration as vibration part of the energy harvester. It could in principle increase the number of piezoelements that could add their voltage so it increase the output voltage, can reduce the resonance frequency of the cantilever to meat the low frequency spectrum of the heart beat and also to reduce the physical dimension of the device.

In order to improve the voltage for broadband piezoelectric energy harvesting. Unfortunately for our case we can't use this idea because our harvester has to be used near the human hart in order to power the cardiac simulator. Images from our fractal, cantilever geometries used as cantilevers could be seen in Figure 39.

Molecular Physics and Physical chemistry

A large area of problems that have to be solved was in the field of atomic, molecular and physical chemistry.

These problems could be roughly divided in two main branches: solving Schrödinger equations for atoms and molecules and modeling interaction of atoms, molecules with surfaces. All of these problems belong to so called quantum physics of many particle systems.

The mathematical and physical problems are enormous. The mathematical treatment is extremely laborious and cumbersome. The only way of solving the problems is to find simplified models (physical approximation and mathematical simplification) because the equation was impossible to solve directly even with the best computers we have today.

So it is a kind of "game" to find ideas, and to "feel" the approximation you can do using your experience. It's difficult to discuss extensively these problems and so I live for reader to have the pleasure to run through references from [127] to [142].

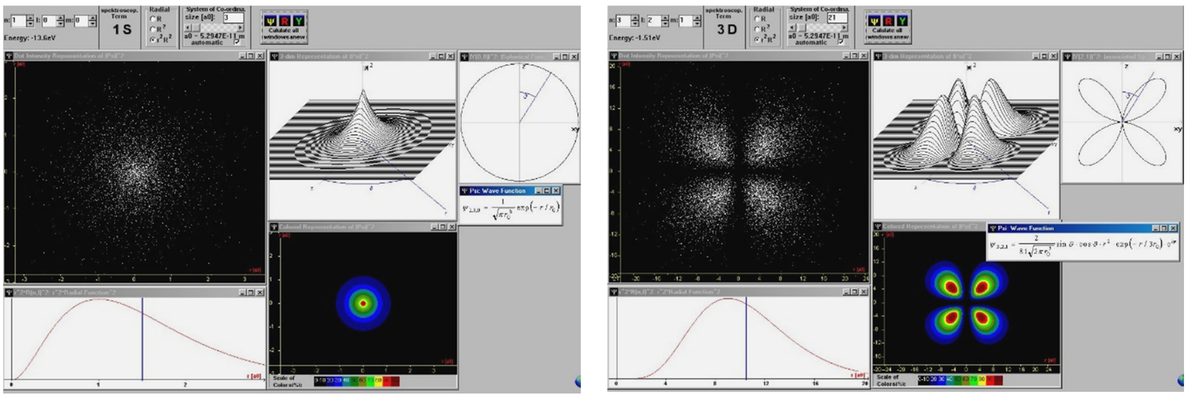


Figure 40. Visualization of the electron wave function and related parameters of an atom

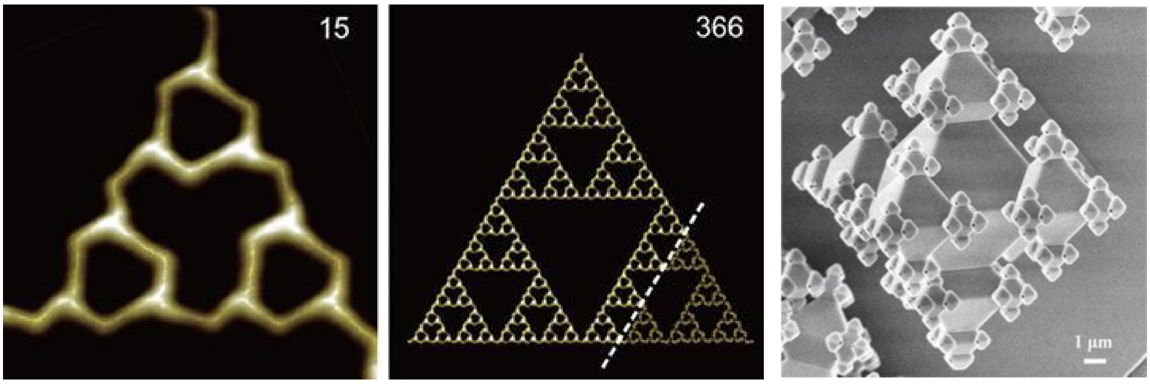


Figure 41. Molecule arranged as fractal structures
and atoms in Sierpinski deposition on solid substrate
https://www.chemistryworld.com/news/fractal-first-as-molecules-form-sierpinski-triangles-/8408.article

Astronomy and astrophysics

This is another extremely large and exciting field of computer applications. It implies not only mathematical difficulty in solving the equations but also to find physical data. But also we have to use the evidence for many possible scenarios of "what are there in space". Combination of observations, data, physical unknown environment, and so many unknown local conditions are overwhelming. But still little by little, our understanding about the comets, planets, stars, galaxies, nebula, black holes, and other "cosmic fauna" was increasing. Having also in mind that we want, as mankind, to conquer the space, these models and computational solutions, or scenarios, become more and more important.

The astronomy has a peculiar situations, in great majority of cases you can't obtain direct data or to examine or experiments something in cosmos. So the only powerful "device" we have is modeling simulations and making scenarios. The computers are crucial for that endower. We started to work in astronomy and astrophysics using computers mainly after 1989. Till now we gained a great deal of experience and we had a large group of students, now PhD in astrophysics that created a large team of researchers. This can be seen after the notable results in all domains of astronomy, astrophysics and even in astronautics.

Some of the topics we studied were physics of the Sun (active Sun, physical phenomena visible on the Sun's surface – granulation, flares, sunspots, magnetic field, Nucleosynthesis, and solar jets). In the same line were the instabilities in star evolution, and the study of binary stars, eclipsing stars and their light curve. Also we studied planetary physics, phenomena in high atmosphere; Sprites and Elfs fractal structure of continental crust; geodynamic activities, image analysis of planetary surfaces (Europa surface - finite element modeling the surface), and fractal dimension of the rough surface (Eros asteroid, Figure 42).

Another problem was the origin of the cosmic rays and the modulation of extragalactic Cosmic Rays by a galactic magnetic wind.

Difficult problems arise when we try to understand and model features observed of distant objects. One example was put by studying galaxies with active nuclei in center (AGN). They exhibit two visible features, a disc of accretion from a nearby galaxy, and two powerful jets of particles produced by AGN.

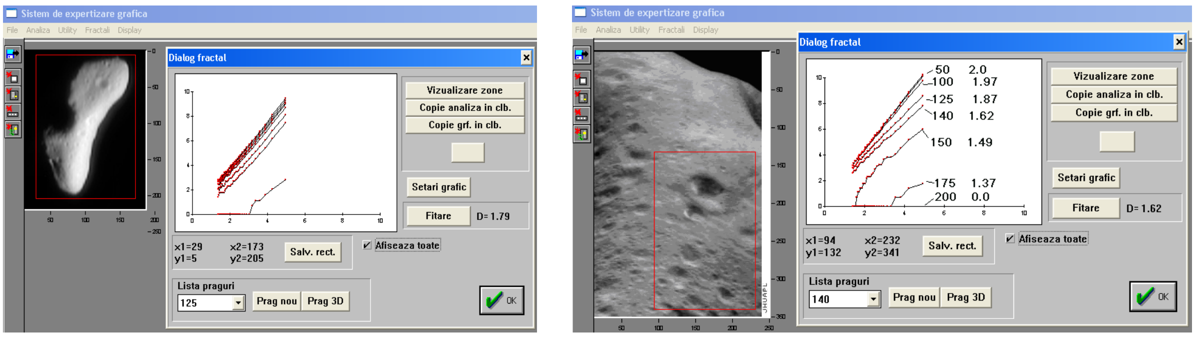


Figure 42. Eros surface analyzed using NEAR spacecraft close encounter (2000 February 10)

Having very good data form radio telescopes we made careful analysis of the jets and made some suppositions about the physics of the jets, in order to create an enough plausible model of the jet.

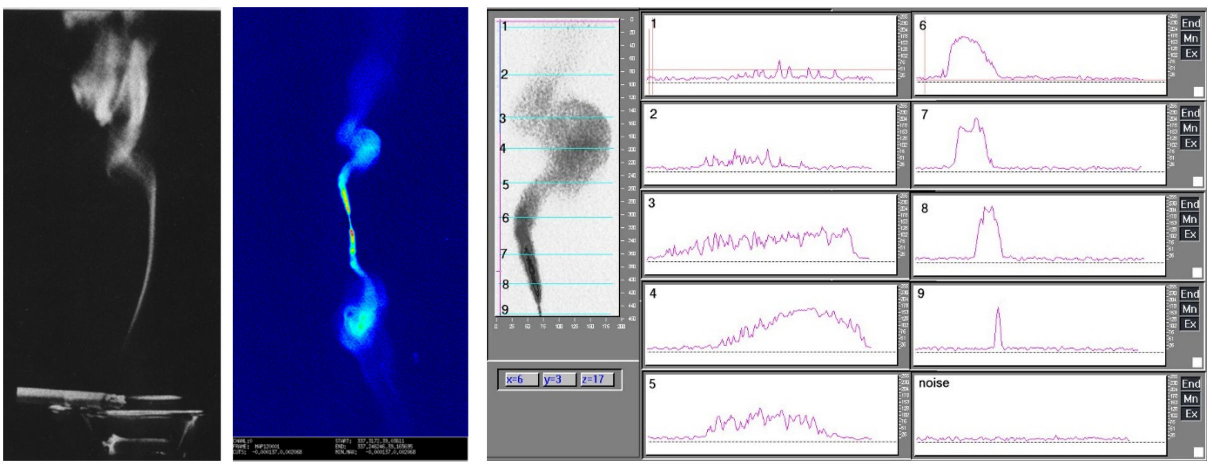


Figure 43. Universality of the turbulence in flow, smoke and jet form 3C449 galaxy. Example of image analysis of the upper jet of 3C449 AGN

As was expected a great number of nonlinear phenomena drive the mechanisms form these objects and a careful fractal analysis of the data and images seems to be in accordance with our scenario. Once again fractal analyses give fruitful result to incorporate in models.

As in the last section we can't describe here and discuse extensively all the problems we examined and in which we have notable results. I leave for reader to have the pleasure to run through references from [143] to [176] to find the spectrum of our activities. Once again, it is necessary to recognize that without computers was not possible to cover all the topics.

Different other computer applications

- Biology and medicine

Recent studies have shown that fractal geometry can be useful for describing the pathological architecture of tumors and, perhaps more surprisingly, for yielding insights into the mechanisms of tumor growth and angiogenesis that complement those obtained by modern molecular methods.

Tumor vasculature has long been known to be more chaotic in appearance than normal vasculature (Figure 44). Now that angiogenesis has been identified as a critical event in tumor progression and as a potential target for treatment, there is an increasing need to understand the origins and consequences of the abnormal vascular architectures found in tumors. Fractals show promise as useful measures of these complex structures.

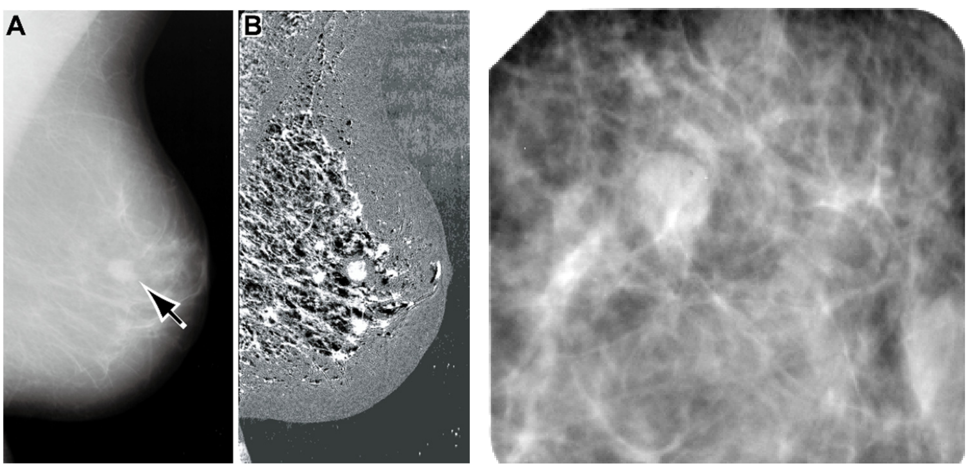


Figure 44. Medical image processing – breast radiography suitable for image analysis

The observed fractal dimensions of the tumor vasculature as a whole and of the minimum path closely correspond to those produced by a statistical growth process known as invasion percolation. Recent studies have shown that invasion percolation can be used both to describe the irregular vascular architecture in tumors and to elucidate some of the mechanisms that regulate the numbers of vessels and the patterns of their interconnections (Figure 45).

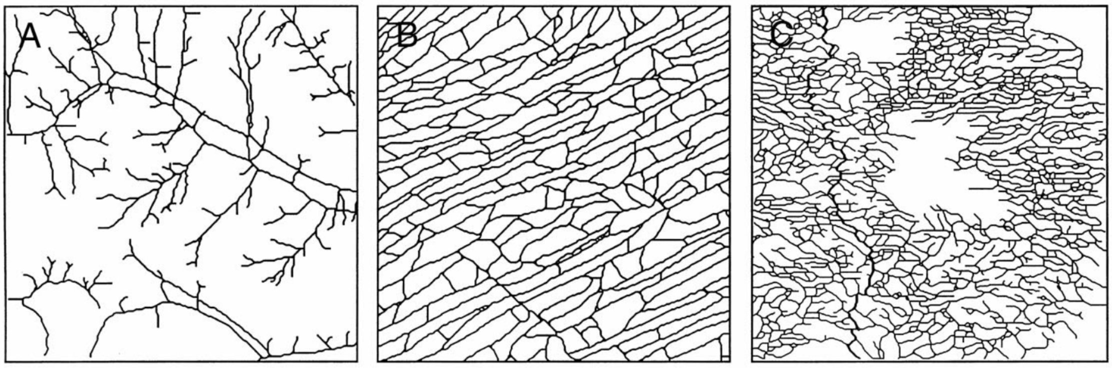


Figure 45. Skeletonized images of vascular networks (*A*, normal arteries and veins. *B*, normal subcutaneous capillaries. *C*, tumor vasculature). The path of minimum length is highlighted on the tumor vasculature to illustrate the tortuosity of these vessels [180a]

Because we were involved in a series of studies related to the possible radiation contamination of the population during a hazardous releasing of radioactive materials we completed a study that was finalized and described in “Bio-mathematical Models for Radon Daughters Inhalation”. The ModeLung© software was produced as an application to the data from Cernobil (Russia) disaster [181].

The spread of fractal models that describe different human behaviors are steadily increasing. Some of these studies, added here as examples are: Fractal structure of mental and social processes: the hypothesis of affect logic, *A multifractal dynamical model of human gait, Shape analysis applied to automatic recognition of tumor cells, Cytoskeleton as a Fractal Percolation Cluster: some Biological Remarks, Computer-aided estimate and modeling of the geometrical complexity of the corneal stroma, Cognition Network Technology: object orientation and fractal topology in biomedical image analysis. Method and applications.* [186], [187], [188].

- Computer in education

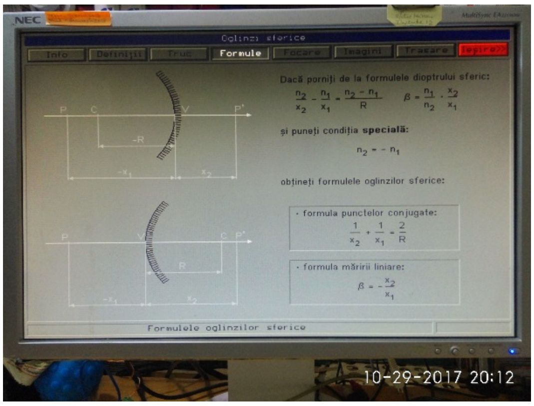
This was an essential part of our activities as professors at the physics faculty. The computer literacy is considered crucial for the future. Romanian students have won many prestigious prizes at different international Olympiads for Mathematics, Physics, Astronomy and Astrophysics, Chemistry and of course Informatics. I think there is no better description than Daniela Rus[2] sad:

> *I was born in Romania to a computer scientist and a physicist, which definitely gave me the science bug early. I was a big fan of Jules Verne and especially liked* ***20,000 Leagues Under the Sea****. I also watched reruns of Lost in Space and loved the computer prodigy Will Robinson and his B9 robot.*
>
> *My father encouraged me to learn to program in high school and taught me Boolean algebra. From there, I knew I wanted to study computer science in college, and then at Cornell for graduate school. When my PhD adviser John Hopcroft talked about how the grand vision for computer science was to be able to use these equations and algorithms to get physical machines to do all of these things that humans cannot or do not want to do, I decided that robotics was the path for me.*
>
> *My work is in part driven by my belief that everyone should know how to solve problems using computing. For years, people have talked about increasing accessibility to computers, with the goal of eventually having one laptop per child. But I have found that children are even "more" drawn to robots than computers, and so I believe robots, more than anything else, can help children learn about geometry, physics, programming and many other things. Technological literacy is as important as reading writing and mathematics, because it is all around us. We want to get children interested and excited in robotics from a young age, so that they can be tomorrow's innovators. In a nutshell, we need to introduce computational thinking as a mandatory subject in all the grades, starting with kindergarten. Developing these abilities is not merely "learning to code," but what you might call "coding to learn*."
>
> (www.CSAIL.MIT.EDU/PERSON/DANIELA-RUS)

As I sad we had plenty of activity and results in the education. Our students benefit from computer assisted education in many fields, especially in physics. Our year log program of In service teacher training was a continuation of learning to program in high school. Also we diversify our activities in this field organizing regular summer schools on internet learning (Romanian Internet Learning Workshops – RILW, in collaboration with Dr. Mihai Jalobeanu from Cluj-Napoca) organized with SOCRATES – ERASMUS European funds, we won many years. It is possible to see our students activities if you take a glance on the references, in which almost 50% of them were done with our students form the faculty.

---

[2] Director of MIT's Largest Research Lab on Computer Science and Artificial Intelligence. For more than 50 years, CSAIL's research has pushed the boundaries of computing and played a vital role in the digital revolution, from the first time-sharing systems and the first computer password to public key encryption and the free-software movement



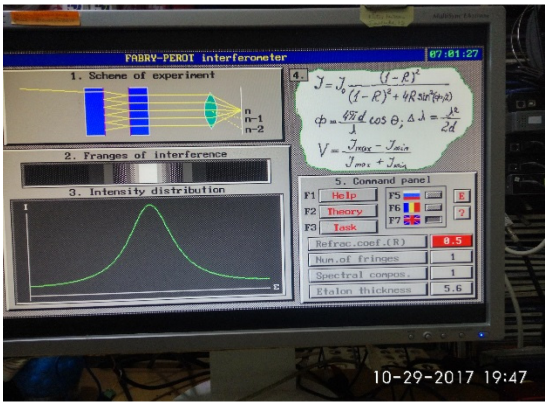


Figure 46. Example of computer codes for Physics [213]

Also we organized at the Casa Corpului Didactic (CCD – Teacher house) from Bucharest, lectures and activities for creating computer codes for physics. In this way also the teachers from schools were involved in creating their own codes for specific thematic, to help teaching.

It is difficult to mention all that products but I can mention the collaboration with Prof. Stefan Grigorescu from Bucharest and Dr. Roza Dubrăveanu from Chăşinău (Republic of Moldavia), Figure 46.

One of the most efficient didactic activities was our collaboration with Bonn University in which at least 20 students did their MSc diploma. Because it was in the field of astrophysics their activities were creating and using specific software. These activities were done alternatively at the Max Planck Institute of Radioastronomy (Bonn) Figure 47 and 48, and at the Faculty of Physics, University of Bucharest Figure 49.

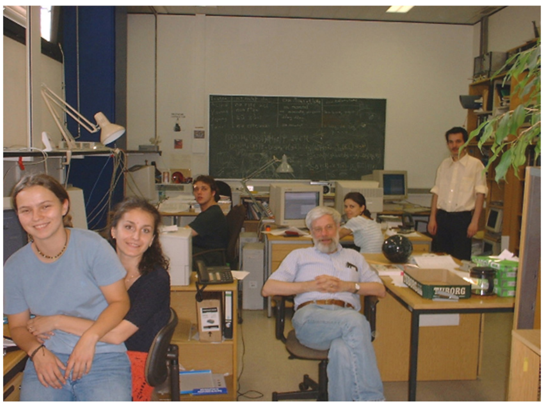


Figure 47. Our students at Bonn University, Max Planck Institute of Radioastronomy 2003. The Romanian student's lab with Prof. Peter Biermann, head of the department

Figure 48. The group of Romanian students in visit at the larges Radiotelescope from Europe, at Efelsberg, Germany

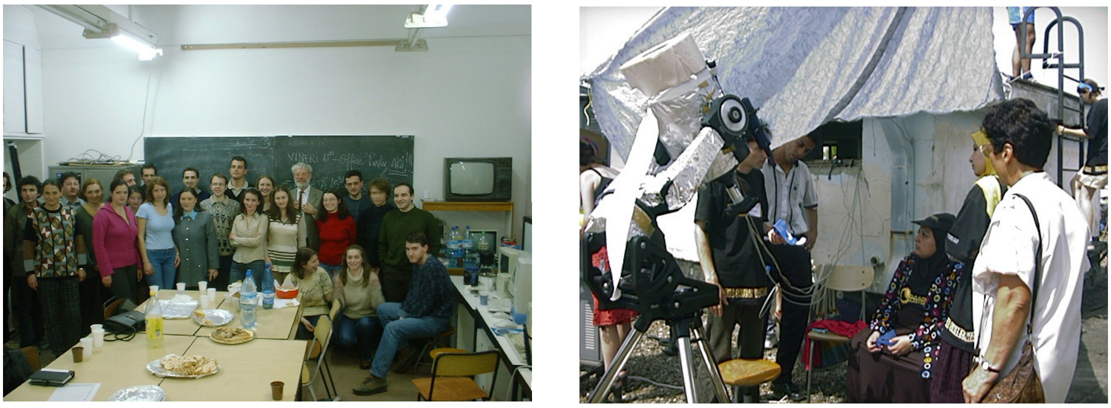


Figure 49. Students from Bucharest and Cluj, in Astrophysics laboratory from the Bucharest Physics Faculty with invited lectures from Germany, Prof. P. Biermann, and from France Dr. M. Birlan in the joint activity under Socrates/Erasmus European Program

A remarkable moment was in 1999 when the one of the place to observe and study of solar eclipse was Bucharest. We organized International School for Young Astronomers (ISYA-24, 1999) at our faculty and over 50 students and 20 professors from all over the world attended the event. In Figure 50 students on the roof of Physics Faculty, Bucharest, during the 1999 solar eclipse, that attended International School for Young Astronomers (ISYA-24, 1999)

Figures 50. Images of student activities and discussions at Bucharest during the 1999 solar eclipse, with Prof. Jay Pasacoff (U.S.A.) and Dr. Donat Wentzel (Univ. of Maryland, U.S.A.)

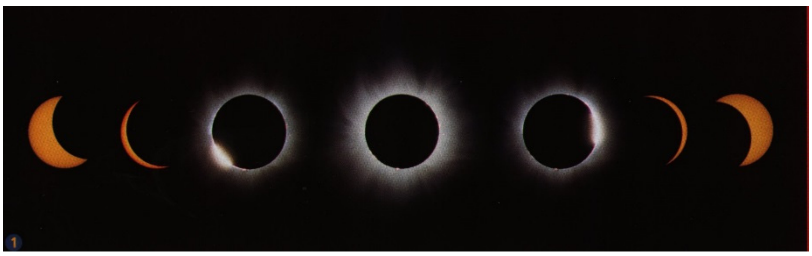


Figure 51. Sequences of the solar eclipse from 1999 at the Faculty of Physics made by students

As the result of our more than 15 years of collaborating with German Universities, we succeeded to obtain a powerful computer that was located at our Faculty (Figure 52).

Figure 52. Upgrading computing facilities at the Faculty of Physics at Bucharest University ALICE supercomputer from Wuppertal University, Germany

In order to improve students and specialist from different fields of activities (scientific of coarse) we organized with the help of an European program (Socrates/ Erasmus) a series of five seminars (Intensive activities), each year one, in collaboration with more than ten universities from Europe (England, Germany, Italy, France, Iceland) namely Romanian Internet learning Workshop (RILW). That was held in different towns from Transylvania. Organizer was Bucharest University and Dr. Mihai Jalobeanu from Cluj-Napoca. [221]

- Archeology and anthropology

The past fifty years have seen a rapid increase in fractal research in fields such as geology, anthropology, archaeology, and mathematics (Brown, 2007). The implications of fractals and their occurrence in nature and human culture continue to intrigue scientists and mathematicians, but much research remains.

- Archeological study of ancient artifacts – The Hystria statue

Pieces of a statue (an archaic Syrian Phoenician style) were uncovered in the sacred zone of Histria and dates about 6th century BC (Figure 53). The two pieces of the statuette were found in different location, having also in common the same constitutive material. We found that is not made by clay but nearly pure melilite. This suggests the casting material had a special provenance, providing some insight regarding the type of parent rock. We made also analysis of the materials and the inclusions and found that the two pieces being to one statue that was found. In order to reconstruct the original, the fragments were analyzed by a nondestructive method (image analysis using digital X-ray images). To be sure we computed the absorption coefficient at X-ray of two energies, 55 keV and 70 keV.

Figure 53a. Archeological artifact found in Dobrogea, Romania

The absorption coefficient for the two pieces was computed and shows the same values in both pieces (Figure 53b). Variation from the middle part corresponds to the junction of the two parts. So, we concluded that surely the two pieces belong to the same statue.

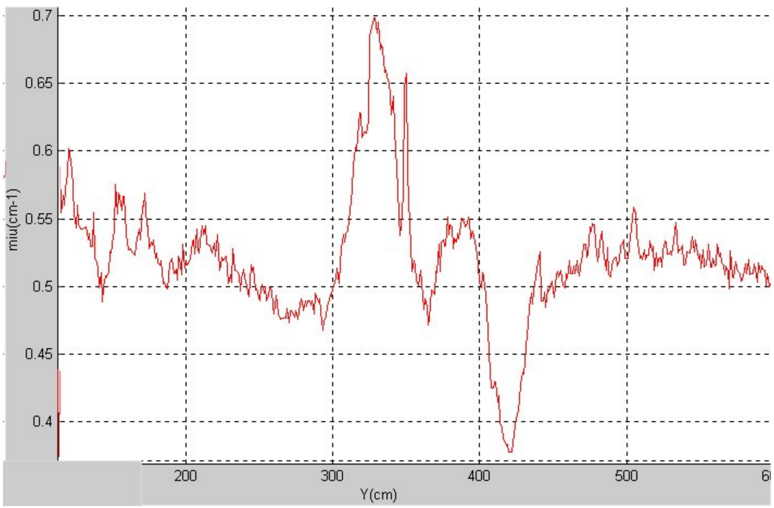


Figure 53b. The computed absorption coefficient for the two pieces

- History and cultural heritage; fractal structure of human settlements

The idea that a city could be “smart” was a science fiction that was pictured in the popular media. The performance of the computer codes dedicated for architecture and city planning, the prospect that a city might become smart, sentient even, is fast becoming the new reality. The convergence of information and communication technologies is producing urban environments that are quite different from anything that we have experienced hitherto. Cities are becoming smart not only in terms of the way we can automate routine functions serving individual persons, buildings, traffic systems but in ways that enable us to monitor, understand, analyse and plan the city to improve the efficiency, equity and quality of life for its citizens in real time. This is changing the way we are able to plan across multiple time scales, raising the prospect that cities can be made smarter in the long term by continuous reflection in the short term [188].

Smart cities are often pictured as constellations of instruments across many scales that are connected through multiple networks which provide continuous data regarding the movements of people and materials in terms of the flow of decisions about the physical and social form of the city. Cities however can only be smart if there are intelligence functions that are able to integrate and synthesize this data to some purpose, ways of improving the efficiency, equity, sustainability and quality of life in cities. We define in such a way so called “metabolic and organic city”.

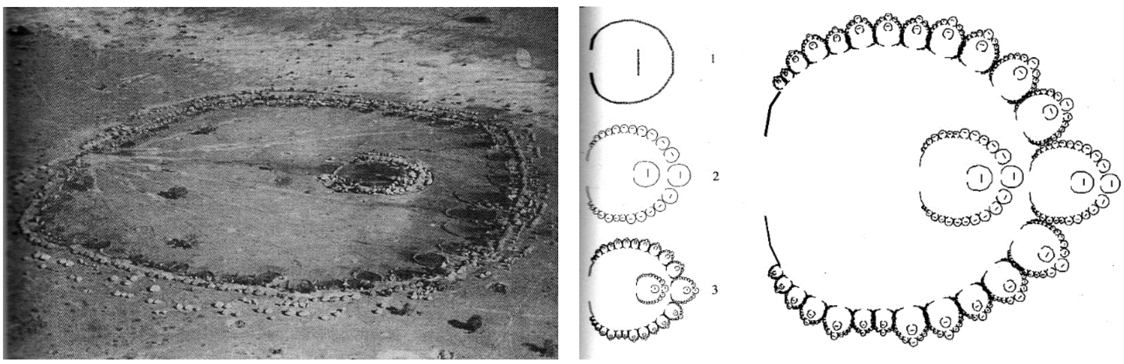
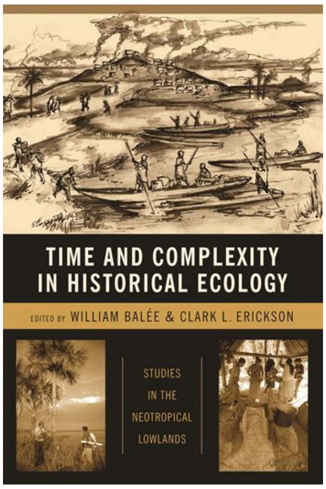


Figure 54. African settlements as example of spontaneous fractal “thinking” of a small village

Structural stability of the metabolism of cities as a process of morphogenesis will create adaptive cities that could fulfill various local demands in shortest time, and could easily adapt to changes and new demands. Interesting is that we can find self-similar, fractal geometry, in the development of some cities from the past till today’s organization. (London, Paris). Also we can found in some settlements (Figure 54) from Africa, a self-similar way of distribution of the huts [204], [205].

It seems to us that social systems spontaneously found such optimal arrangements. It could be that anthropology could benefit from the ideas of spontaneous self-similar systems not only for settlements but also for social activities, social interactions, and even beliefs that enable to develop a Theological Anthropology. Also a need for revisiting the Micro—Macro distinction in social theories emerge.

An exhaustive work on this topic was done with the Institute of Architecture from Bucharest, department of urbanism and city planning [188]. It was correlated as a problem of urban anthropology and change. Valuable results come from it that re-thinking the future city plans.



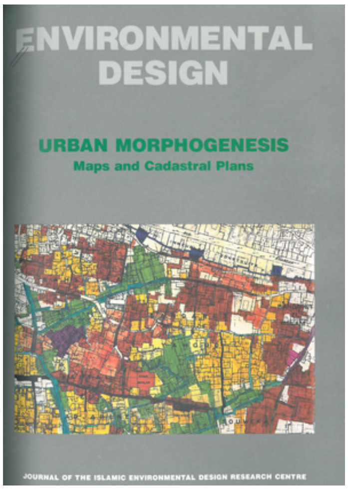


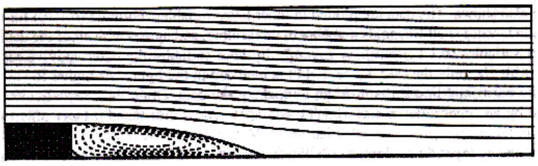
Figure 55. Two books that emphasizes how complexity theory enter in the filed of urban morphogenesis

- Music

We were asked to study the physics of the natural trumpets. The trumpet is, called the natural trumpet and is part of a class of blowing instruments spread in the Carpathians, Poland (*trembita*), the Balkans, Sweden (*näverlur / neverlur*), Norway (*Raklur, langlur*) and Finland (*touhitorvi*). Today, on the territory of Romania, instruments belonging to the natural trumpet category are found in Oas, Maramures, Bucovina and Apuseni mountains. The sound of the natural trumpet is present a ritual one - the funeral, and a ceremonial one - the measurement of the milk (sâmbra), event related to the pastoral life. About 25 years ago, the trumpet signals marked the beginning and the end of the day, from sunrise to the end of milking. They conveyed a hierarchy of the order of completion of the work.

Figure 56. A galvanized sheet trumpet and a opper one, in use

The phenomena we were asked to study was the way the sound could be modulated and haw different pitches could be produced knowing the natural trumpets have ho holes to do that. It is known that the way of blowing the air and mouse attached to the mouthpiece also the tongue of the singer can do that variation but how? The trumpet signal has identity connotations. The local people of the area are able to recognize exactly the one who launches the signal. What makes one signal different from another, at first glance, seems to keep the melodic profile of the signal. But if we try to identify ways of recognizing the signals, the situation proves to be more complicated. Stabilization of the sound emission is achieved by wetting the instrument before use in view of temperature equalization throughout its length. This makes it so important for the sound produced?



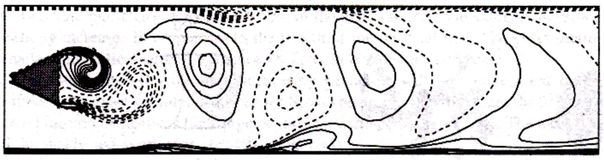


Figure 57. Simulation of the air flow and the turbulence (vortex) that is produced at the sudden changes of the flow geometry (lower part of the image, dotted lines)

Figure 58. Doppler measurements of the air flow around on obstacle. The vortex formation is evident

The simple physics of the wave propagation into the pipe, the length of the pipe that gives the standing wave conditions could not account well with the facts. We studied, and still we are in work to show that the main "secrets" lie in the turbulence that is produced at the entrance of the air. We are now trying to work out the Kolmogorov turbulence theory in order to account for these peculiar phenomena.[3] An interesting idea could be to find if there are any relations of this natural trumpet with that used by Celts.

More on the diversity of ideas that arise in the recent times could be found in [189 to 203]

- Art and Fashion

Because fractal geometry and hence analysis could be used to quantize the irregular shapes or apparent chaotically shaped found in nature or in some artifacts, we analyzed images of old paintings crack pattern. A fractal analysis shows that original old paintings present cracks texture that is different from the artificial "aging" paintings. Sometimes paintings could be categorized as original one, but after the fractal image analysis they could be found as fake [186]. Drying paintings and structure of the cracks are specific in each case.

Fractal arts and design turns to be unusual application of fractals and computers in modern design. For example some type of the hairstyle (Figure 59) could show self-similar geometrical structure that sometimes could be considered as very original one.

Figure 59. Hire stiles that show self-similar structure

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With a group of colleagues (some of them high school physics teachers) we design models for young ladies dress. Because the imprinting models on textile can be easily made by computer assisted manufacturing techniques, we made specific fractal software patterns.

It was finished and gave us the chance to produce such textile and fractal model imprinted (Figure 60).

A general conclusion is that almost all the human activities are results of competition between order and disorder. Fractal geometry and chaos theory could account for that.

Figure 60. Rebecca and Guinevere in fractal design dress and imprinted fractal motifs

At the end we can make some comments of how computers, IT, artificial intelligence and the broad band in scientific achievements have changed our civilization and way of thinking.

The complex systems research focuses on generic properties. The concepts and methods are largely inspired from the physics of disordered systems, but the basic ideas have also been expressed in mathematics as structural stability [73], in the physics of phase transitions as classes of universality [75]. The existence of generic properties, is a sensible explanation for the fact that although biological or social systems are difficult to entirely specify and exist under many variants, they are still able to maintain global functional and recognizable properties. The following definition of complex system is minimal and applies to most systems we might be interested in. Complex systems are composed of many different interacting elements that exhibit non-linear interactions. They form a network composed of the elements and their interactions have many entangled loops. The definition obviously applies to the brain and its neurons, the immune system and its molecular and cellular components, a society made of human agents and so on.

In fact the scientific interest in complex systems is not only motivated by the mathematical challenge they represent, nor by the fact that we constantly face them in our everyday environment. The real challenge to our intelligence is their functional organization: in the brain, assemblies of neurons think, the immune system is able to build an immune response to external pathogens; societies have evolved institutions enabling them to respond to their environmental challenges.

Furthermore this functional organization is both adaptive still robust. Complex systems can vary in composition; sometimes the chemical and even cellular composition of a given complex system such as an organ of a living system, e.g. the liver of a mammal, varies, but we consider it as the same system, with identical global properties. And maintaining this identity is much more than maintaining the invariance of some average over the properties of the constituents [223].

The native, spontaneous, human sense of self-similar patterns could be best represented by a famous XVIIIth century painting of Hokusai (Figure 61).

Figure 61. “The Great Wave”, Japanese painter Katsushiks Hokusai (XVIII-th century)

Conclusion

Computers and information technologies helped us to reach a new way of viewing the world. All sciences, all human activities benefit today from these facilities. And the future will show us facets of these achievements that started in the modern form in the last 100 years.

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