The Antiphysical Review

Founded and Edited by M. Apostol **4** (1997)

ISSN 1453-4436

Ten "crazy" problems of physical research

M. Apostol
Department of Theoretical Physics,
Institute of Atomic Physics,
Magurele-Bucharest MG-6,
POBox MG-35, Romania
e-mail: apoma@theor1.ifa.ro

1 Theory of the social conflicts (theory of war)

A collection of civilizations may be described originally (at the initial moment of time) by a certain peaked distribution; this is called the "Adam" initial condition. A freely and peacefully developing civilization undergoes a progressive evolution, whereby the "Adam" initial distribution becomes a well-known gaussian. This tells us that under such a development a free and peaceful civilization increases in size proportionally with the evolution time, and produces springoffs, both larger and smaller in size, over a certain range, proportional with the square root of the evolution time.

All the above are more or less expected for a free evolution. However, the actual conditions in our realistic world are such that we encounter "vicious civilizations", i.e. civilizations which engage in warfare whenever they meet each other. What would be the result of the evolution in such a world dominated by "wars"? Will all these civilizations perish, vanish, will they be shatterred in smaller and smaller "worlds"? Will be there any survivor, after such a global, or local, warfare? These questions are tried to be answered by such a theory of social conflicts, or a theory of war.

It has recently been noticed that the physical mechanisms which govern certain chemical reaction and diffusion processes (like coagulation, aggregation, aglutination, coarsening, etc) have natural counterparts in social phenomena. For instance, the competition between cultures has led to a rich historical record in which certain civilizations are dominant for long time periods only for suddenly disappear. Why?

The answers to these questions can be obtained by formulating quantitatively the evolutionary processes, and by treating these formulations with the well-established methods of theoretical physics. These models can be viewed as attempts to get measurable information about various social processes, such as the competion of biological species, extinction and persistence of civilizations, egalitarian competition between civilizations of equal sizes, the ultimate domination of superpowers, and many other aspects of social history.

2 Movements on the stock markets (theory of the financial markets)

The price fluctuations on the financial markets have always been attended with great interest, for obvious reasons.

For "liquid" markets, *i.e.* organized markets where transactions are frequent and the number of actors is large, statistical models have been used in analyzing the temporal changes of the assets prices. There has been concluded, by rather simplifying models, that the variations in prices might be distributed normally, *i.e.* following the well-known gaussian distribution. These markets are, typically, foreign exchange markets, organized futures markets and stock index markets, markets for large stocks, etc. Actually, the analysis of the time variation of the prices on such markets, where the prices are sampled many times a minute, and temporal series with various time-steps are used, revealed large deviations from a gaussian, exactly there where the situation is the most interesting for the financial speculation, namely on the tail of the distribution; the actual distribution has a heavier tail than the gaussian distribution. This is a very interesting phenomenon, in view of the fact that the gaussian distribution corresponds to a natural, uncorrelated phenomenon, and these deviations are of utmost practical significance.

Various other distributions have been proposed for the financial markets, and concepts like self-similarity (at least over short periods of time), scaling, "efficient market hypothesis" (*i.e.* lack of correlations), and the "turbulence" of the financial markets have been invoked to get a deeper characterization and understanding of the financial phenomenon.

This phenomenon is typical for complex systems with many degrees of freedom, where many internal and external factors interact at each instant in order to fix the transaction price. Public policy, interest rates and economic conditions undoubtedly influence market behaviour. However, the precise nature of their influence is not well known and, given the complex nature of the pricing mechanism, simple deterministic models are unable to reproduce the properties observed in financial time series. The statistical methods of theoretical physics are considered to be the most adequate and efficient tool in dealing with such a problem.

3 Breaking and protecting the quantum codes of communication (quantum cryptography)

Human desire to communicate secretly is at least as old as writing itself, and goes back to the beginnings of our civilization. Encoded communication is used in military, diplomacy, banking, computing, etc.

Classical cryptography is based on key encrypting and decrypting algorithms. However, the secret communication always uses a communication channel, and this one is vulnerable to passive eavesdropers (as, for instance, public announcements in mass-media), *i.e.* any key distribution can always be monitored without the legitimate users being aware that any eavesdropping has taken place. A long enough passive monitoring can always lead, at least in principle, to a code breaking, since the problem amounts to factoring large integers. New methods of fast integers factoring, and highly-performing computers render the classical code security more and more vulnerable. Recently, attention has been focused on quantum encoding, based on quantum entanglement, a well-known feature of quantum mechanics, with the hope of ensuring an unbreakable secret communication.

In quantum cryptography there are two legitimate users, "Alice" and "Bob", who employ a quantum-mechanical wavefunction. Since this wavefunction is entangled it does not contain any information, so an eavesdroper, "Eve", has nothing to find out; moreover, any measurement performed by Eve tells the two legitimate users that the communication channel is monitored. The information between Alice and Bob "comes into being" only after these users perform measurements. This way, the two legitimate users establish their quantum code, and thereafter communicate publicly.

The quantum encoding described above is, however, idealised, because it neglects noise. The main problem in quantum encoding is how to distinguish between an eavesdroper and an innocent noise.

Quantum entanglement seems to be a physical resource which allows us to perform qualitatively new types of data processing. In addition to its role in data security there are many others fascinating applications, like quantum teleportation, for instance.

4 Quantum computers

Quantum computers can compute faster because they accept as the input not a single number, but a coherent superposition of many different numbers and subsequently perform a computation (*i.e.* a sequence of unitary operations) on all of these numbers, simultaneously. This can be viewed as a massive parallel computation, but instead of having many processors working in parallel we have only one quantum processor performing a computation that affects all numbers in a superposition, *i.e.* all components of the input state vector.

Obviously, the quantum computing concept originates in quantum mechanics, the main foundation of modern physics.

Quantum computers employ qubits, *i.e.* physical systems that can be prepared in any superposition of two orthogonal states. A register of quantum computing is made of many qubits, that may be viewed as binary registers. Each qubit is able to perform a Hadamard transform, *i.e.* a map of each original orthogonal states to two equally weighted superpositions of these states. The exponential speed-up of quantum computers takes place at the very beginning of their computation, therefore, which makes the quantum computing a very attractive alternative to the classical computing.

All this looks, of course, too good to be true, so where is the catch? Unfortunately, no quantum measurement can extract all the exponentially-large information from a quantum computation. These measuremnents can only extract probabilistic results, which, nevertheless, could be quite useful. In general, quantum measurements can only give global information about the results of the computation. Recent research have laid foundation for the new field of quantum computation, and quantum algorithms have been steadily improved; for example, it is already known a very efficient algorithm for quantum factoring, which, at least in theory, leads us directly to quantum cryptanalysis.

5 Evolution of an ecological species in an environment with constraints (lamb's problem with a wolves' pack)

Consider a particle ensemble which consists of a diffusing prey and a certain number of indepedent, diffusing predators. The prey is absorbed, or dies, whenever it is touched by any of the predators. One may obviously call the prey as consisting of lambs, and the predators may be viewed as a lion pride, or wolves' pack. We are interested in the probability for a lamb surviving until certain (long) time when it is besieged by the predatory lions, or wolves. While this appear to be a simple problem, there are many unknown aspects of the long-time behaviour, which are certainly relevant for the ecological equilibrium of the biological species.

The resolution of the many unclear aspects of this problem has fundamental ramifications for diffusive processes in the presence of complex absorbing boundaries, and also has practical implications, as this type of capture appears in a variety of applications, such as diffusion-controlled chemical kinetics, wetting, melting, etc.

The problem has also many interesting, and perhaps unexpected results. It is known, for instance, that in a three-dimensional space the capture process is unsuccessful, *i.e.* there is a finite probability that the lamb survives indefinitely; on a plane the capture process is successful, *i.e.* the lambs die with probability one, but the average lifetime of the lambs is infinite, due to the diffusiveness of the predators.. In one dimension, *i.e.* on a line, diffusing lions are more efficient in their predation, and the problem arises of the most efficient survival strategy of the besieged species.

These are only a few aspects of a complex, fascinating problem, addressing issues of a large interest, and tractable with the means of the theoretical physics.

6 Theory of the political coalitions

Mathematical tools and physical concepts might be a promising way to describe social collective phenomena, such as strike process, political organizations, group decision making, social impact, outbreak of cooperation, power genesis in groups, stock market, etc.

Suppose that we have a certain number of countries, that might align themselves in two competing coalitions. Any pair of countries has a certain mutual propensity, of cooperation, conflict, or mutual ignorance; each country actor has a certain size, and may belong to either one of the two coalitions. A certain distance may be defined between any pair of countries, showing the degree of mutual alignment. The question arises whether stable coalitions might be developed within such a scenario, and this problem is a certain modified version of a well-known problem in statistical physics, namely that of the Ising model in various contexts.

It can be shown that two competing world coalitions yield one unique stable distribution of actors, while, on the opposite, a unique world leadership allows the emergence of unstable relationships. Neutral, frustrated, and risky actors can be included in discussion. The cold war organisation after world war II can be shown to be rather stable. The emergence of a fragmentation process from eastern group disappearance can also be proved, as well as the continuing western group stability. One may obtain some hints about possible policies to stabilize world nation relationships, as for example, integrating former eastern countries within Nato in order to oppose current fragmentation process.

The case of China, as an extremely huge country built up from several very large states requires a particular attention; Cuba staying almost alone in a singular "coalition" is a chalenge to such an approach; local-field effects like helping Ukraina to allign by a slight economical aid are to be considered; a given country could become hostile to some former allies, still staying in the same coalition (German recognition of Croatia against the will of other European partners as France and England); risky actors, like Romania having its own foreign policy in former Warsaw pact, deserves another special attention, etc

7 Theory of the meandering rivers

Data analysis shows that there is a nearly constant ratio of radius of curvature to meander length and of radius of curvature to meander width. Why?

Meandering rivers are ubiquitous in nature and can be found all over the world. It is a signature of their intellectual chalenge that they have captured the imagination of scientists during the time:
A. Einstein, *Die Ursache der Meandebildung der Flusslaufe und des sogenannten Baerschen Gesetzes,* Die Naturwissenschaften, **2** 223 (1926).

The meandering river on an alluvial plane can be viewed as being characterized by a non-linear dynamics of the river channel migration, while describing the terrain inhomogeneity by noise. The motion of the river channel in this scenario is unstable, and it can be shown that by inclusion of the formation of ox-bow lakes the system may be stabilized. The evolution predicted within such a meander river model comprises instabilities, bifurcations, abandoned channels, etc; the latter become silted up and over thousands of years these silted channels become compressed to form shale beds between which oil is often found.

These questions can be addresssed within the classical fluid mechanics, including non-linearities and stochasticity. The resulting intricate topology leads to challenging problems in differential and algebraic geometry, stability, chaotical behaviour, etc. Deltas, branchings, floods, silting are relevant items for hydrographical basins, and, in general, for environmental issues.

8 Global effects of the rough geometries

Suppose that we have two linear segments intersecting each other under a certain angle; suppose that they are elastic media, and a wave is excited at the end of one branch. What is that propagating elastic wave at the other ends of this branching system? What the wave propagation would be like for an intricate, disordered network of many branches? At each branching point we have reflection, a sudden change of direction (is that a diffraction?), a transmission, etc. What are the global quantities in terms of which we may characterize the wave propagation in such a texture?

Suppose that we have a very rough surface, upon which light is beamed; what the light reflection will look like in this case? What if the surface roughness has a certain geometrical structure, like, for instance, a certain fractal? Will there be extinctions, interference, quasi-regular diffraction, as on a planar grating?

Internal stress in a brittle material results in slipping the contact surfaces and developing cracks which propagate along multi-branching patterns. What is the simplest model of fracture, and what are the major parameters which control the building-up of the cracks and their propagation.

Travelling wave phenomena in reaction-diffusion systems often involve sharp interfaces, or fronts, separating different reaction states. What is the relation between the normal front velocity and its curvature? How does a flame propagate in various closed geometries? How does the inner front structure change in time? A purely geometric theory will assume that this structure is invariable in time; but this rules out major changes like spontaneous nucleation along the front, spiral waves, spot replication and spiral turbulence, etc., observed experimentally.

In what sense the asymptotic solutions are free solutions, and how much of the short scales information is still contained in them?

9 Theory of competition

A number of biological species in a simple ecosystem undergo selection, reproduction, mutations, competition, etc. Each species can be defined by its genome, and the output of the evolution may be described in terms of the probability to have a certain genome over the entire biological population. Selection is represented by the concept of fitness landscape, *i.e.* a function of the genotype that represents the average number of survivals per unit of time, and condenses the effects of reproductive efficiency, survival and foraging strategies, predation and parasitism, etc. Mutations takes a certain species into each of its neigbouring species. Each of these evolution processes takes place with a certain rate, and a master equation can be written down for the genome probability. This equation is highly nonlinear, and its solutions are largely unknown.

What are the conditions under which a certain species will survive in such a fitness landscape with competition? What is the role of the competition in this survival? Will there survive the best adapted ones, or the most numerous ones that are the least adapted? What is the connection between the genotype and the fenotype in such an evolutionary process? What is the relatioship between the predictions of such a model and the experimental data acquired from studies on bacterial and viral populations? Most theoretical studies are performed for the time being in a linear genotypic space, but the real spaces of evolution are hyperspaces. What will be the role of spatial dimensions on such models of biological evolution with competition?

Usually, the evolutionary distributions get flatten during long times, so one of the most important problem is whether a given biological species will indeed survive, and how, why, under realistic ecological conditions. What are the theoretical elements able to preserve a peaked distribution of eco-species over a long, very long time? Is the human genome entirely subjected to the physical laws of nature, in which case it would be liable to perish in time, or it is not?

10 Theory of the group decisions (theory of democracy)

A group is, of course, composed of individuals, and, as such, it is a highly complex system with many degrees of freedom. Consequently, one may expect a very complicate behavior for a social group. However, the individuals compete within a group, so that many of the individual tendencies get mutually extincted; one may have, therefore, a much simpler behaviour for a group, under certain conditions, than for a collection of independent individuals. What are the features of this collective behaviour, and how do they come out from the tremendous interplay of the individual degrees of freedom? What is the universality and what are the irrelevant variables for a social group? This is a typical question in the theory of the critical phenomena.

As regards the group decision making one has to be interested in "polarization" and getting a compromise within a group, under individual conflicts and external social constraints (social "pressure"); *i.e.*, the very basis of democracy. Balanced and unbalanced represenattions, leaders and minority roles, etc can all be taken into account in such a theoretical approach.

An individual choice may be represented by a two-valued variable ("yes" or "no", for example), and interaction between individual variables are introduced, such as to have a conflict, an agreement ("positive" conflict), neutrality, frustration, etc. This is easily recognized as the main ingredient of an Ising model, well-known, and studied, in statistical physics. Homogeneous subgroups with no constraints always polarize along "extremist" decisions, for instance, and this can be obtained from such a study; the direction of these "extremist" choices is, however, arbitrary, such that each "extremist" view is equiprobable. The exchange among the members of a group favours alignment along the same issue, but unfavours the compromise; external social pressure is extremely efficient on selecting an option; etc.

One of the main challenges to such a model of social behaviour is to include the non-rational behaviour, which is a real basic feature. It might be accounted for by means of a concept analogous to temperature.